

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n      "Default Dataset": "/path/to/your/dataset"\n}'
```

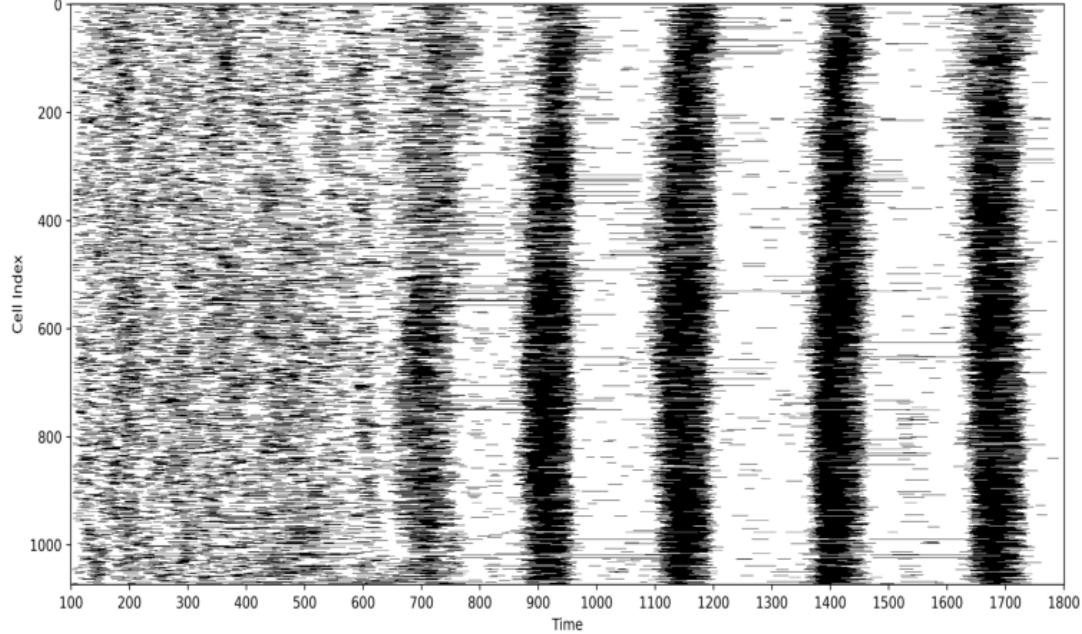
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

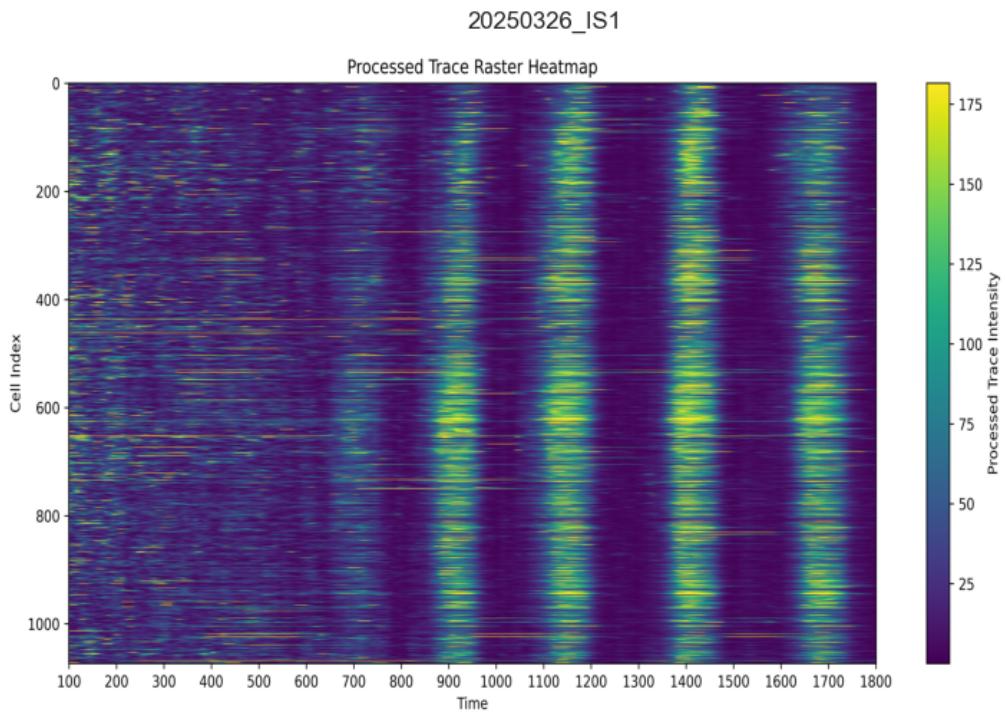
Binary Activity Raster Plot

20250326\_IS1

Binarized Activity Raster Plot



## Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 11955

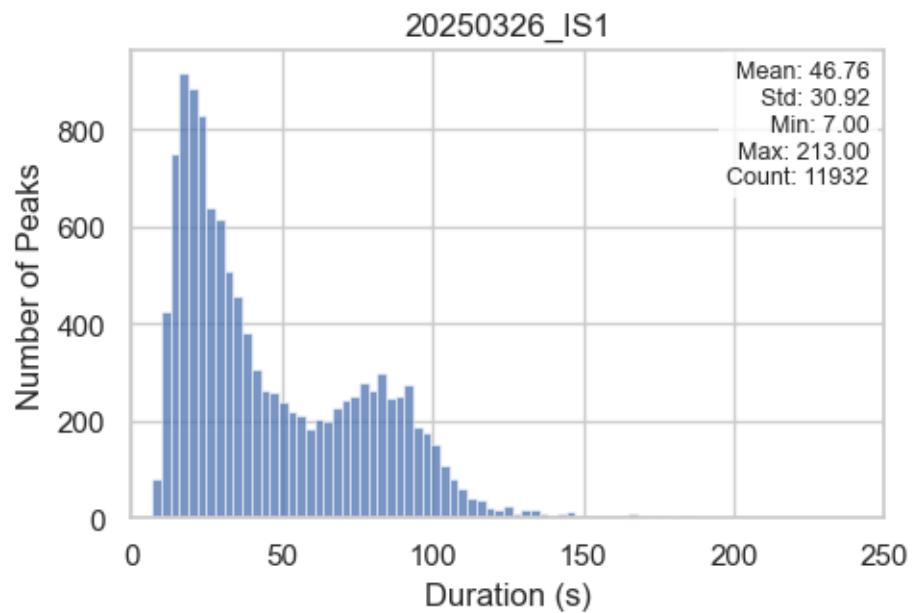
Total number of cells: 1074

### 1.1.3 Peaks statistics

```
[2025-08-08 14:45:19] [INFO] calcium: Removed 23 outliers from dataset  
'20250326_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:45:19] [INFO] calcium: Lower bound: -55.5, Upper bound: 225.0
```

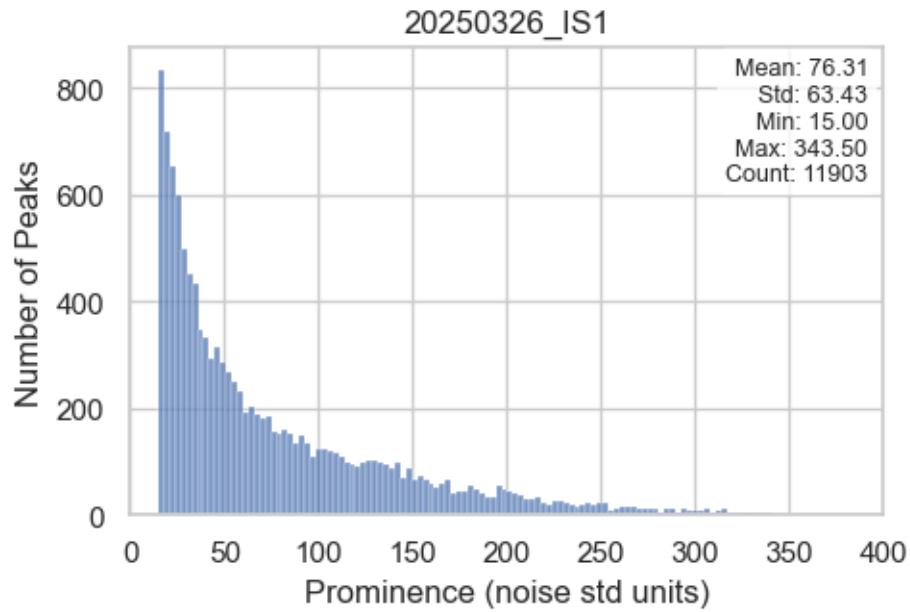
## Distribution of Peak Durations



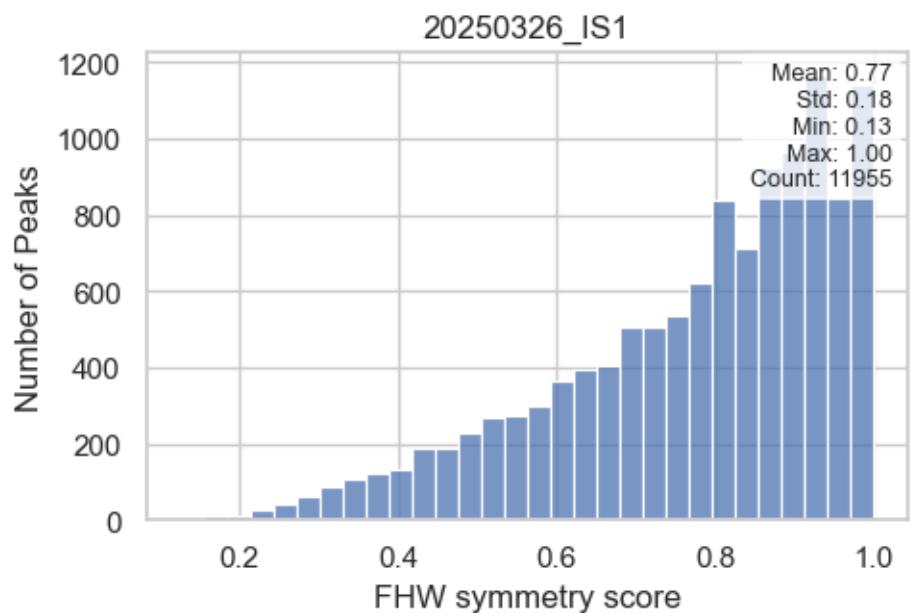
```
[2025-08-08 14:45:19] [INFO] calcium: Removed 52 outliers from dataset '20250326_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:45:19] [INFO] calcium: Lower bound: -91.17500000000001, Upper bound: 345.8
```

## Distribution of Peak Prominences

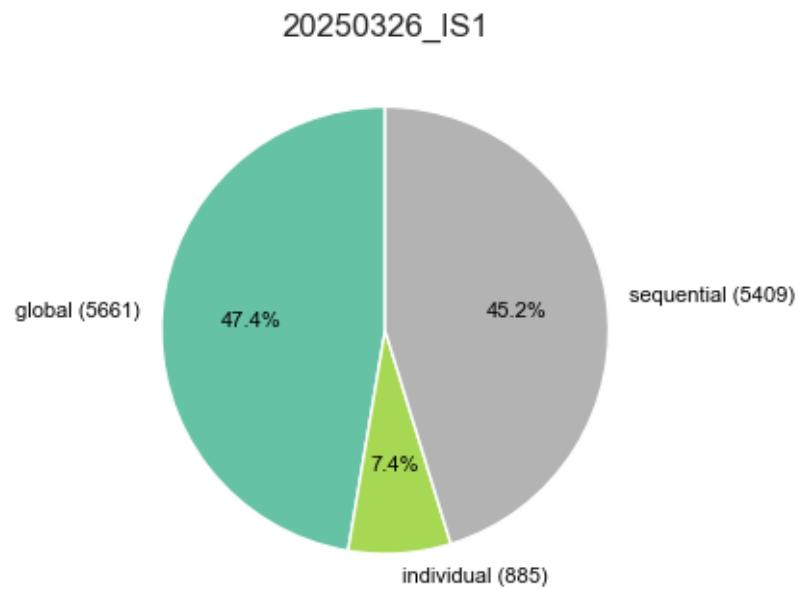


## Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

Distribution of Peaks by Event types

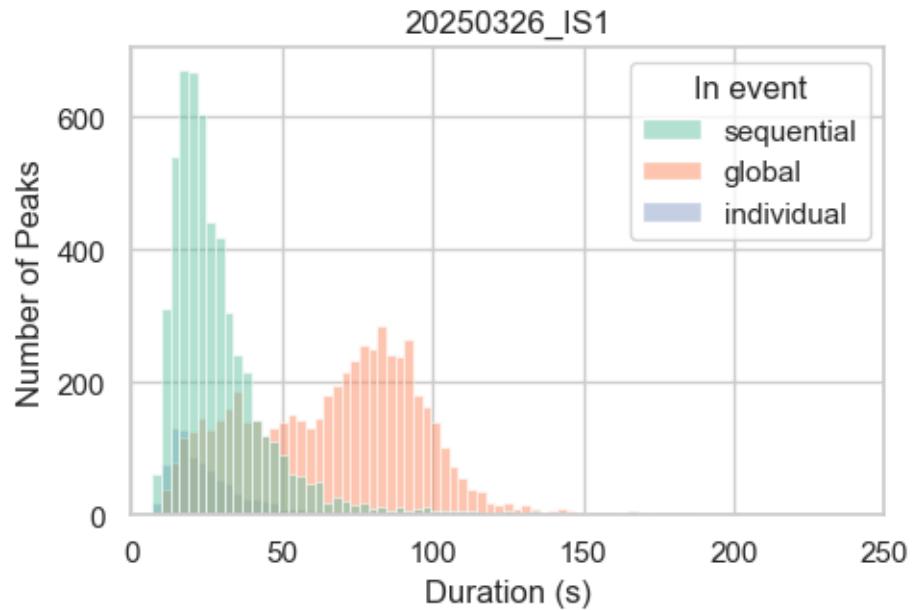


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:45:20] [INFO] calcium: Removed 23 outliers from dataset  
'20250326_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:45:20] [INFO] calcium: Lower bound: -55.5, Upper bound: 225.0
```

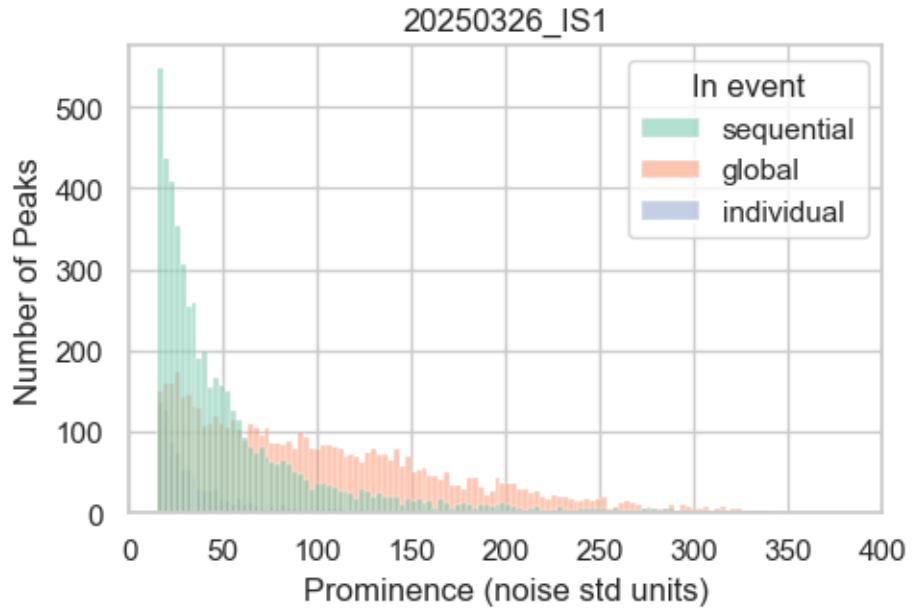
## Distribution of Peak Durations by Group



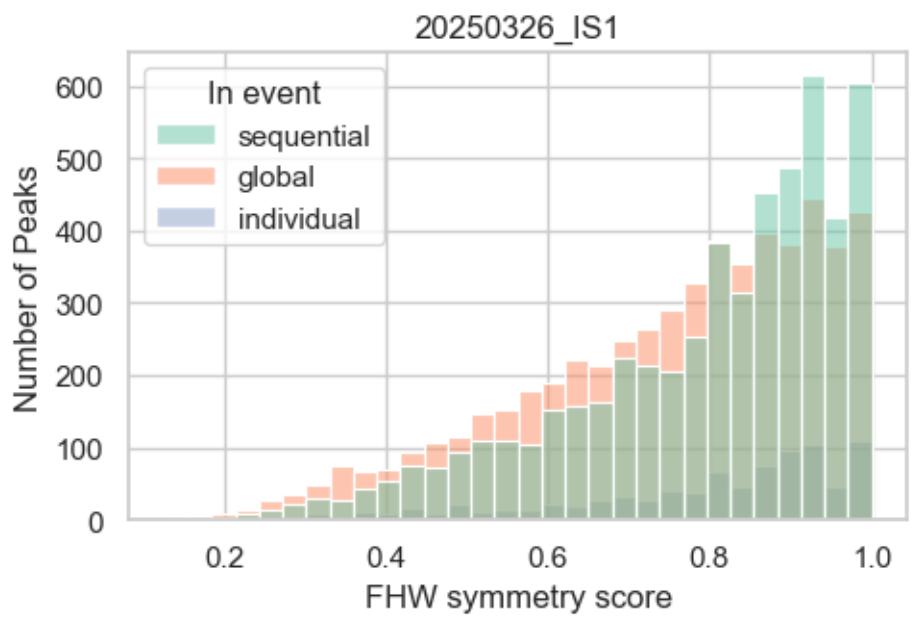
[2025-08-08 14:45:20] [INFO] calcium: Removed 52 outliers from dataset '20250326\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 14:45:20] [INFO] calcium: Lower bound: -91.2, Upper bound: 345.8

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group

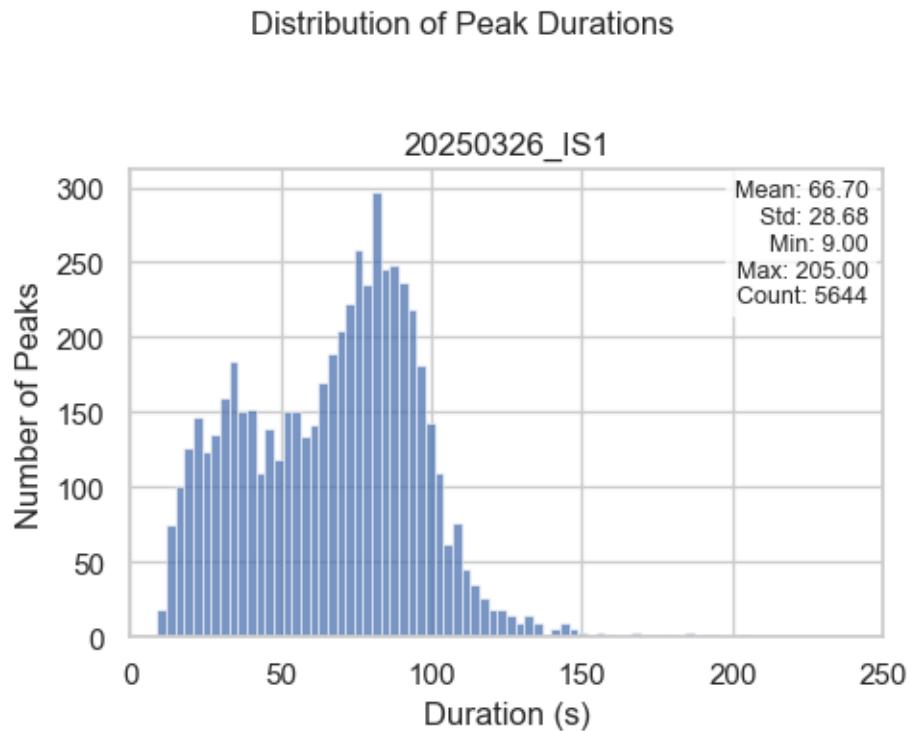


## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:45:21] [INFO] calcium: Removed 17 outliers from dataset  
'20250326_IS1' for column 'Duration (s)'
```

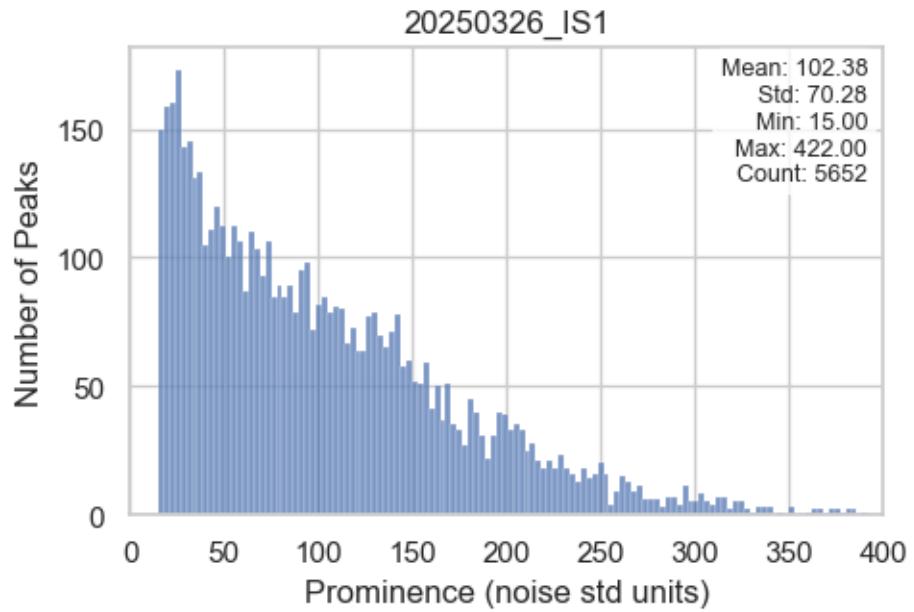
```
[2025-08-08 14:45:21] [INFO] calcium: Lower bound: -24.5, Upper bound: 223.0
```



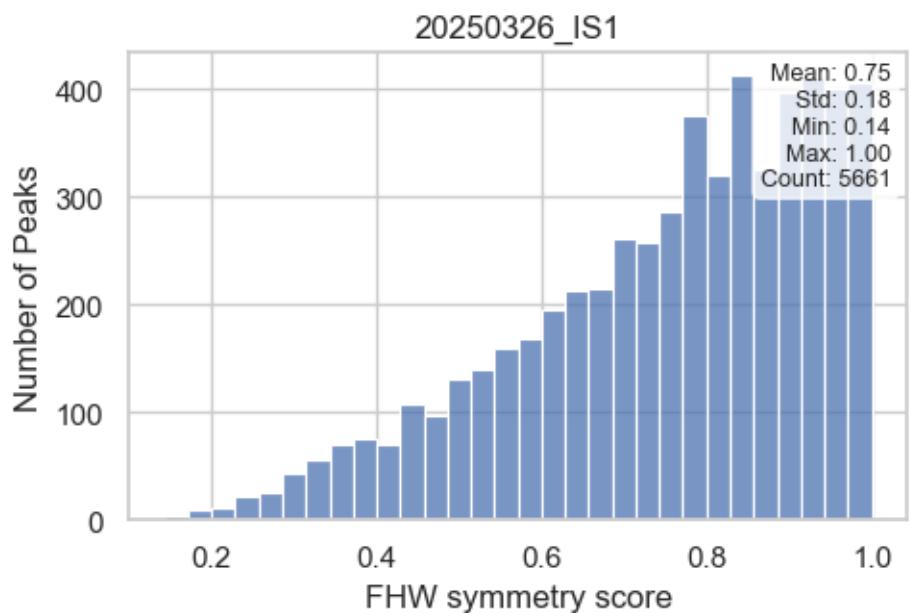
```
[2025-08-08 14:45:21] [INFO] calcium: Removed 9 outliers from dataset  
'20250326_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:45:21] [INFO] calcium: Lower bound: -101.45000000000002, Upper  
bound: 435.90000000000003
```

## Distribution of Peak Prominences



## Distribution of Peak Symmetry Scores

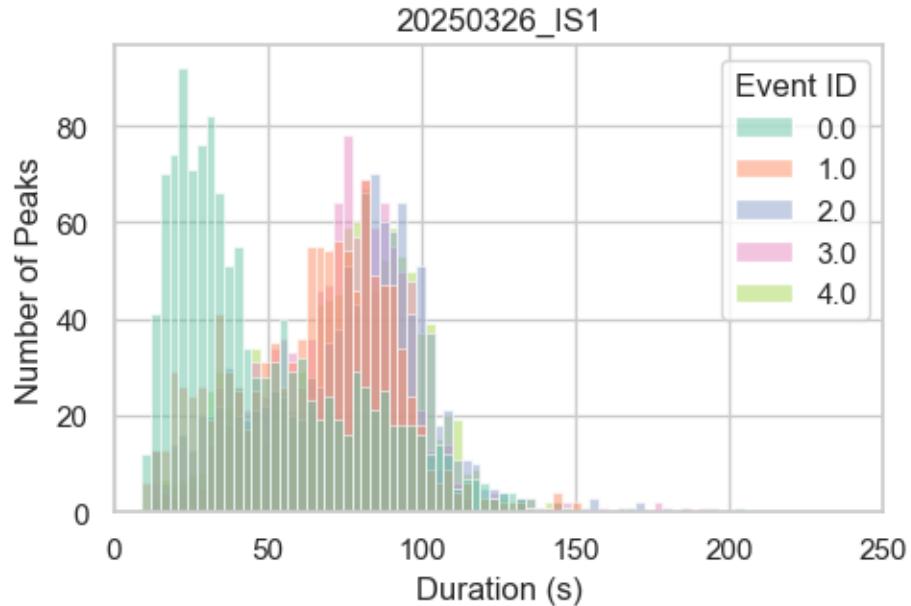


### 1.2.2 Peak statistics in global event per event ID

[2025-08-08 14:45:21] [INFO] calcium: Removed 17 outliers from dataset '20250326\_IS1' for column 'Duration (s)'

[2025-08-08 14:45:21] [INFO] calcium: Lower bound: -24.5, Upper bound: 223.0

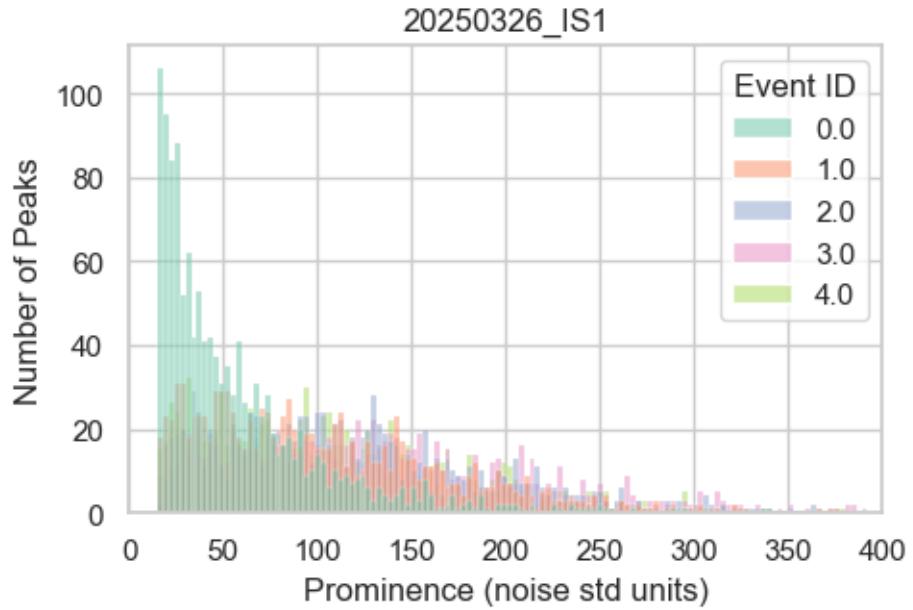
Distribution of Peak Durations by Group



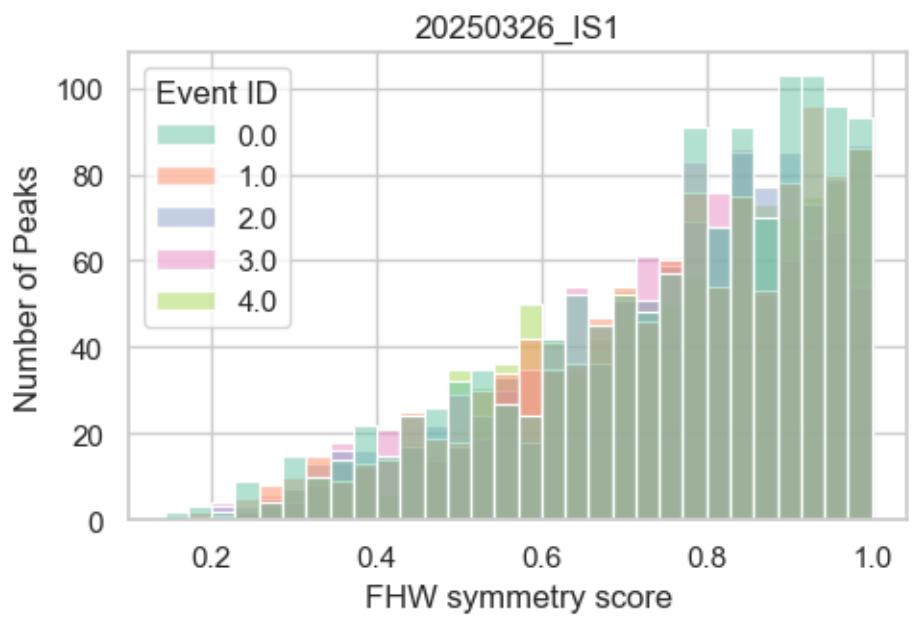
[2025-08-08 14:45:22] [INFO] calcium: Removed 9 outliers from dataset '20250326\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 14:45:22] [INFO] calcium: Lower bound: -101.5, Upper bound: 435.9

### Distribution of Peak Prominences by Group



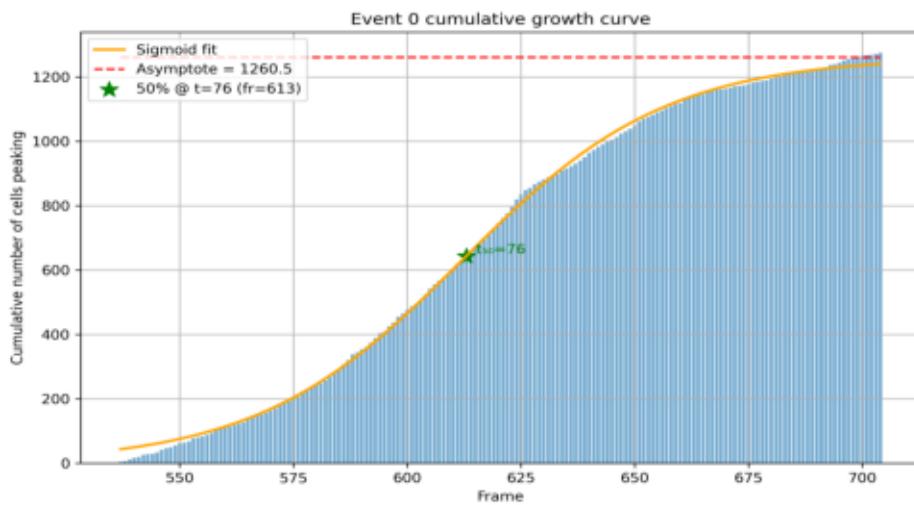
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

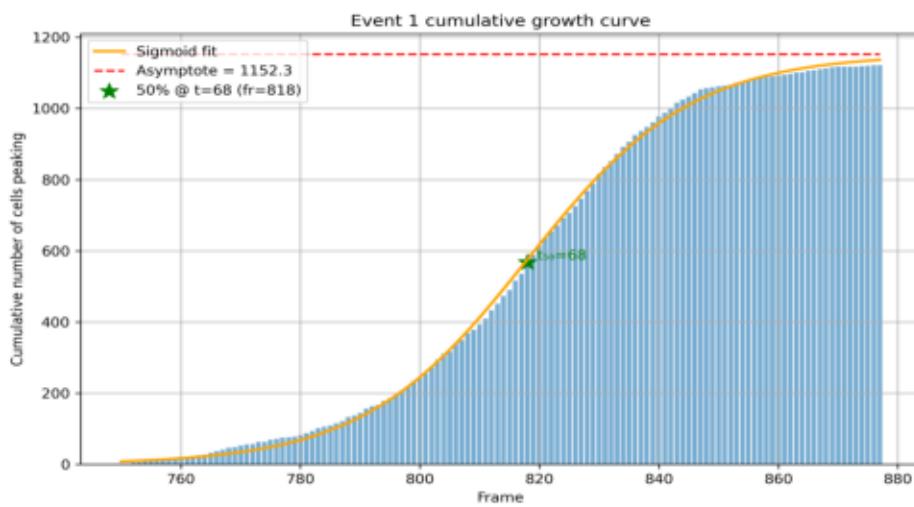
Event Activity Overlay (Event ID: 0)

20250326\_IS1



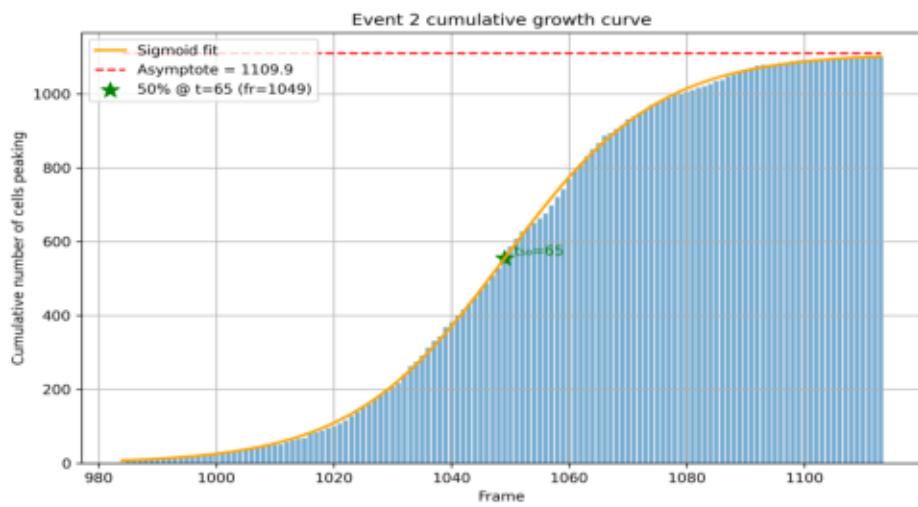
Event Activity Overlay (Event ID: 1)

20250326\_IS1



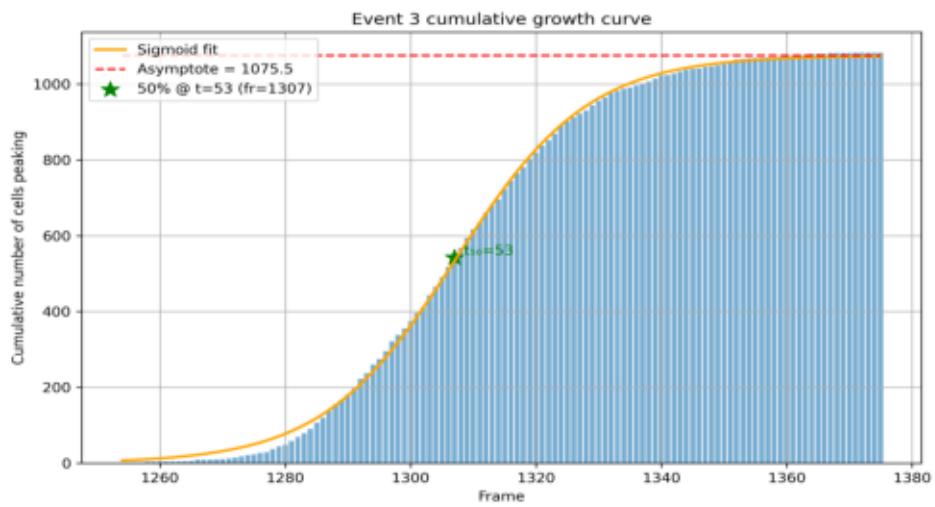
## Event Activity Overlay (Event ID: 2)

20250326\_IS1



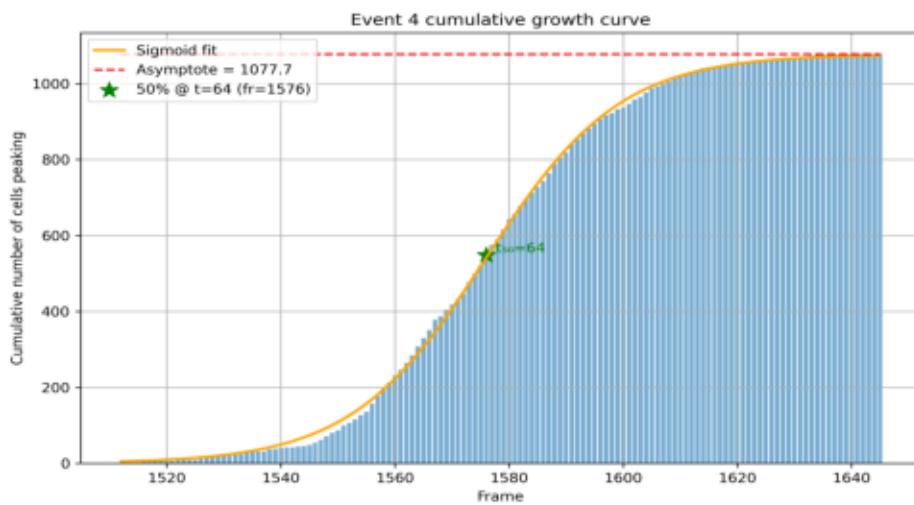
## Event Activity Overlay (Event ID: 3)

20250326\_IS1



## Event Activity Overlay (Event ID: 4)

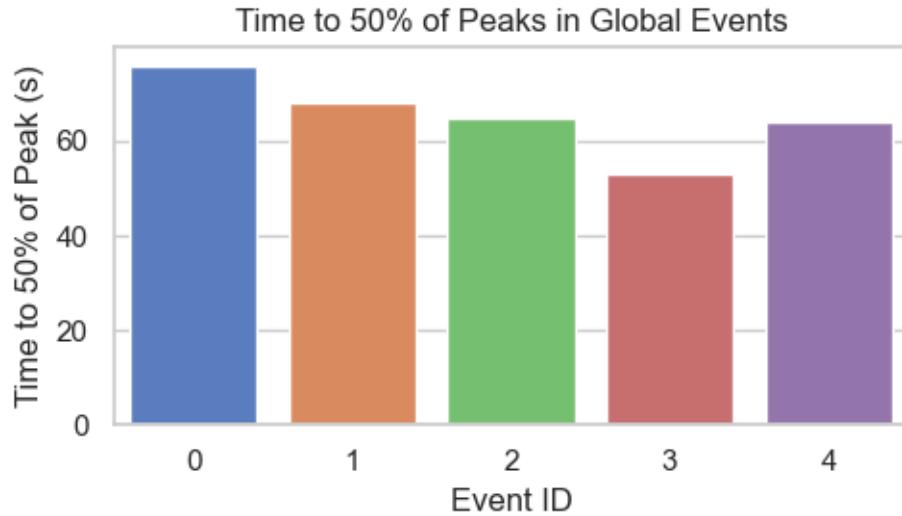
20250326\_IS1



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analyses\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.
```

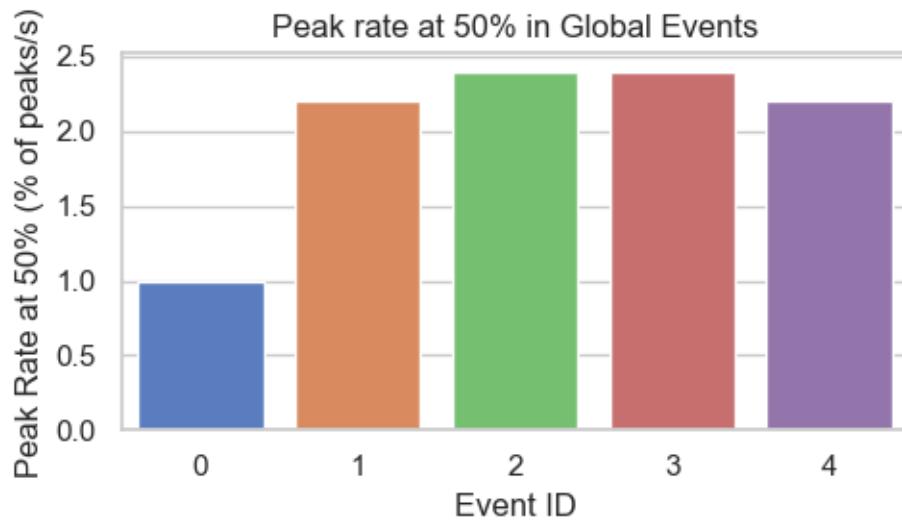
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column, dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys
is\visualizers.py:297: FutureWarning:
```

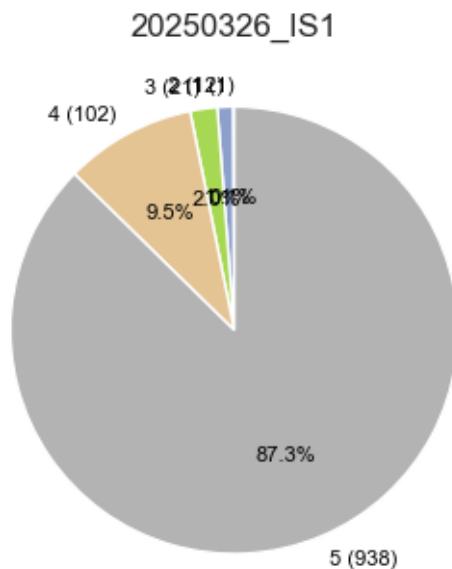
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,
dodge=False, palette=palette, legend=False)
```



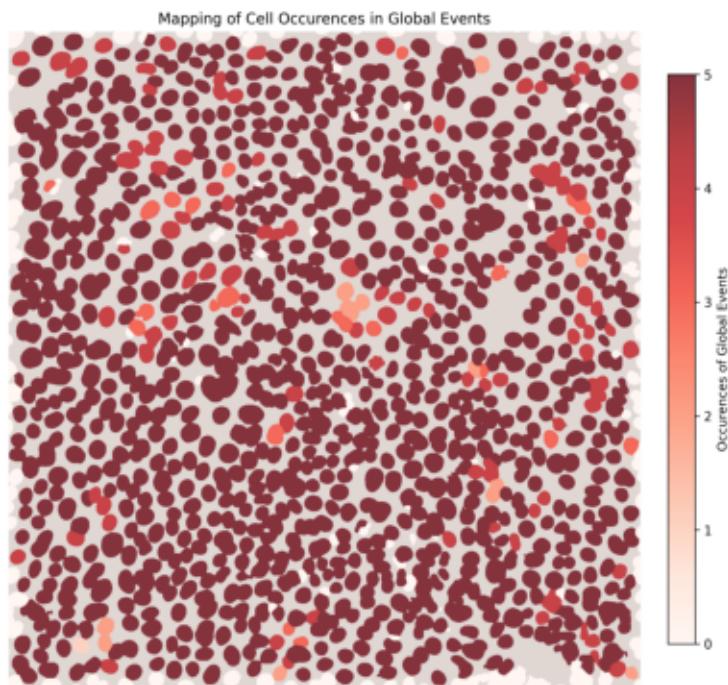
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

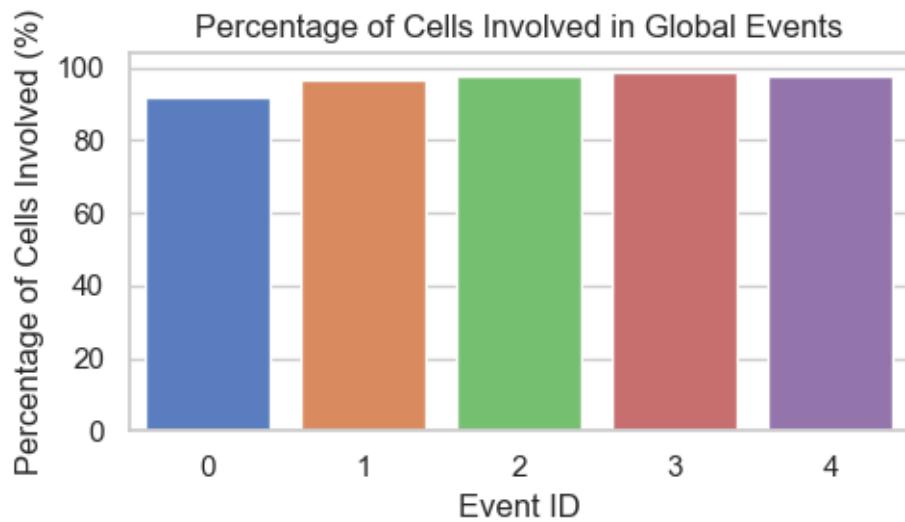
20250326\_IS1



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [210.0, 227.0, 260.0, 267.0]

Estimated periodicity: 0.911

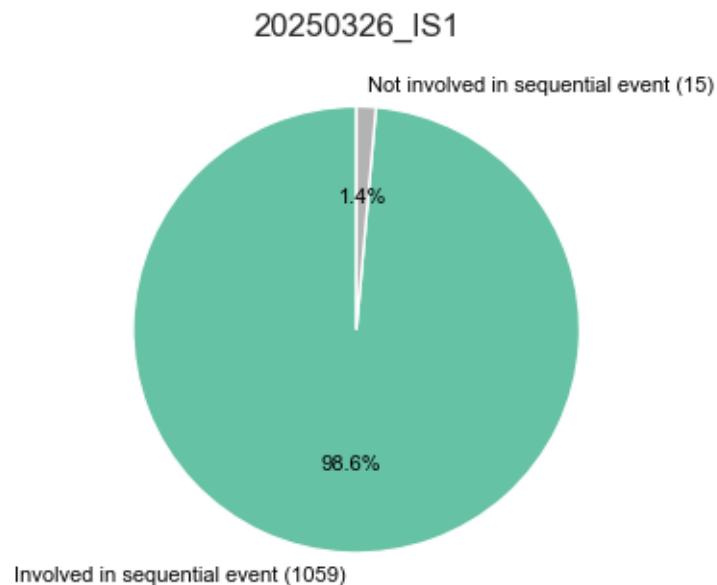
The global events exhibit a regular periodic pattern.

Estimated frequency (1/mean interval): 0.004 Hz

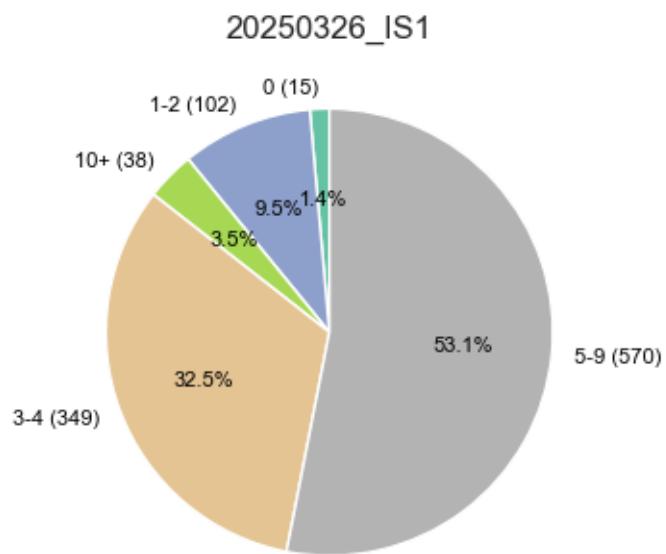
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

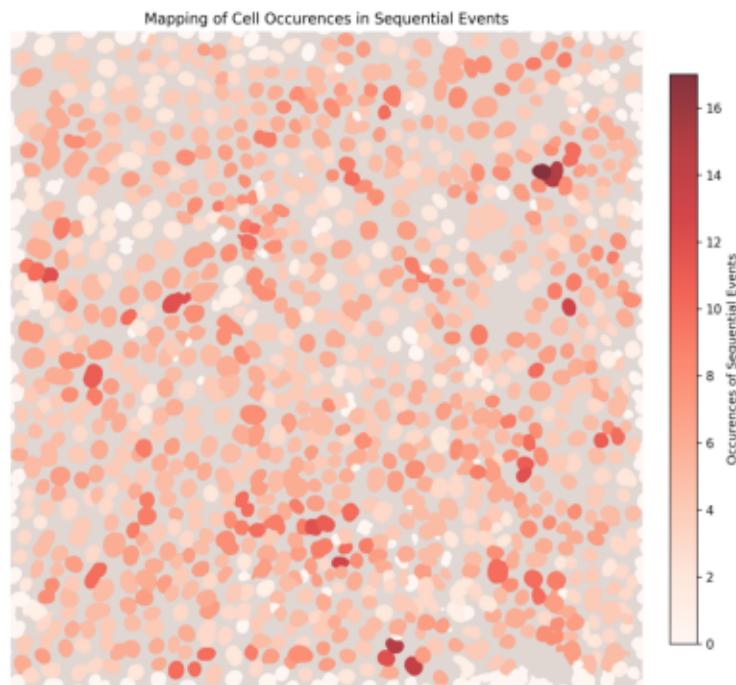


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250326\_IS1

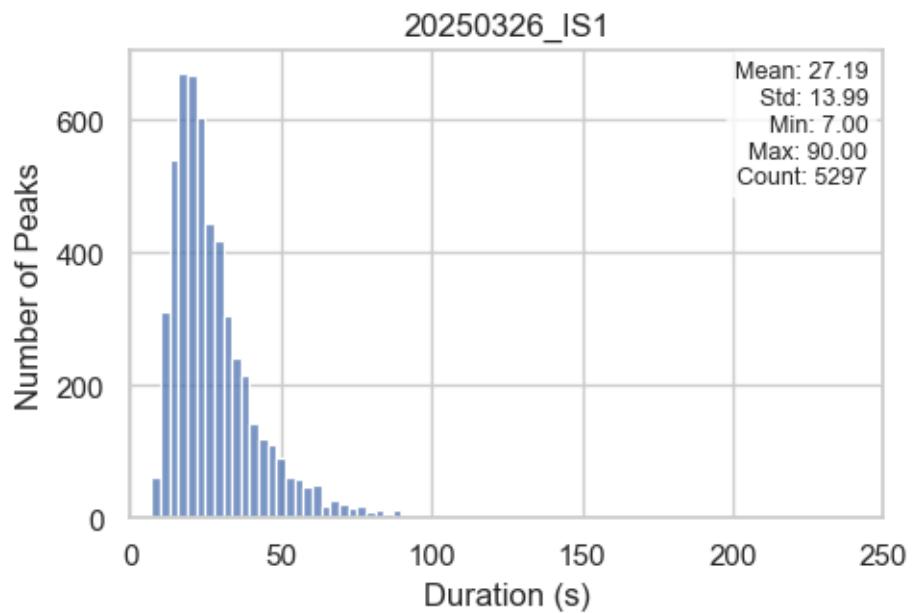


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:45:28] [INFO] calcium: Removed 112 outliers from dataset  
'20250326_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:45:28] [INFO] calcium: Lower bound: -6.0, Upper bound: 90.0
```

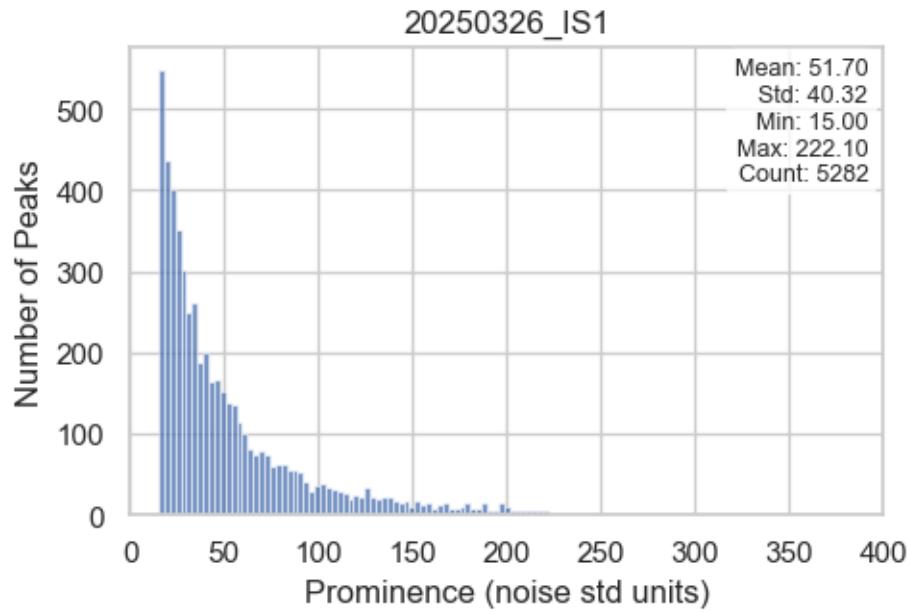
## Distribution of Peak Durations



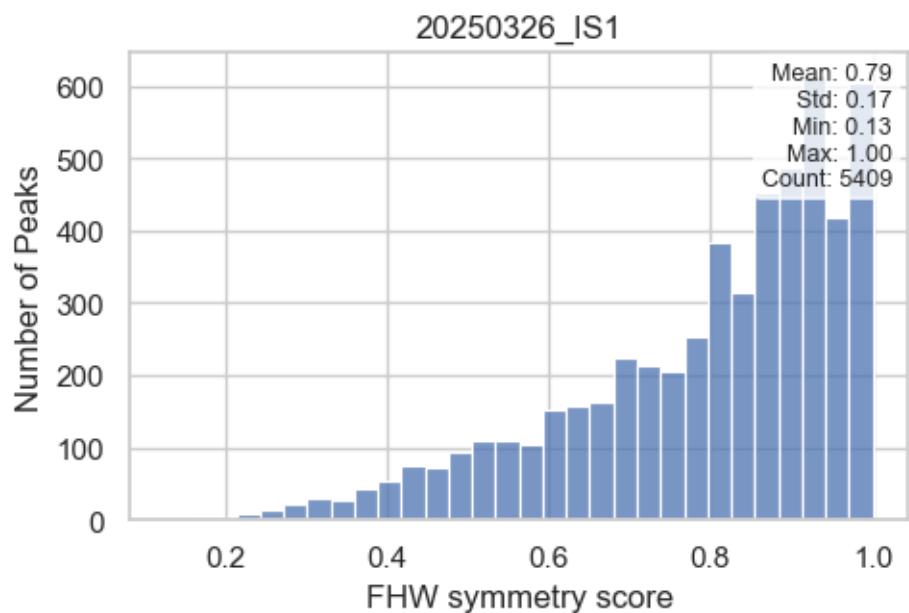
```
[2025-08-08 14:45:28] [INFO] calcium: Removed 127 outliers from dataset '20250326_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:45:28] [INFO] calcium: Lower bound: -43.14999999999984, Upper bound: 223.8499999999997
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

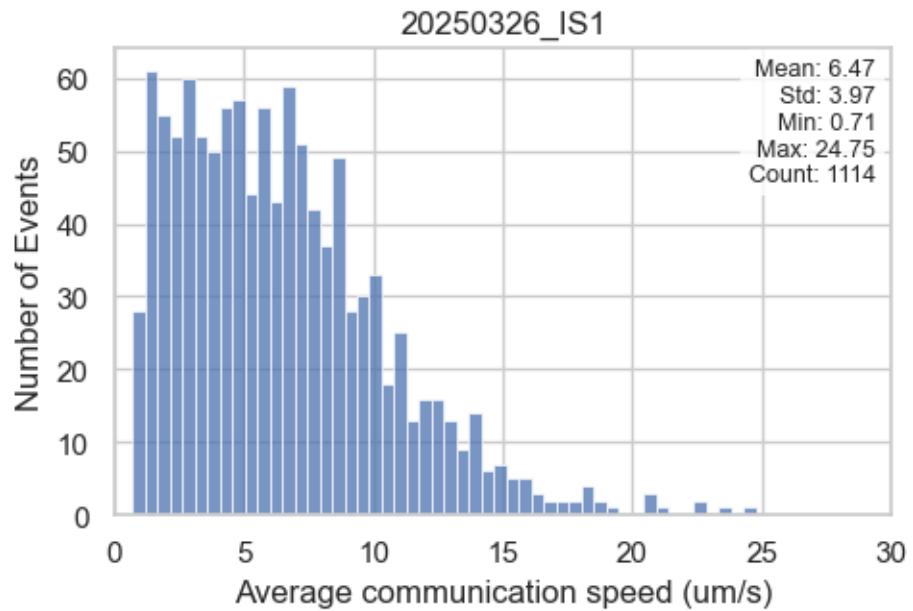


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:45:29] [INFO] calcium: Removed 2 outliers from dataset '20250326\_IS1' for column 'Average communication speed (um/s)'

[2025-08-08 14:45:29] [INFO] calcium: Lower bound: -4.670000000000001, Upper bound: 24.810000000000002

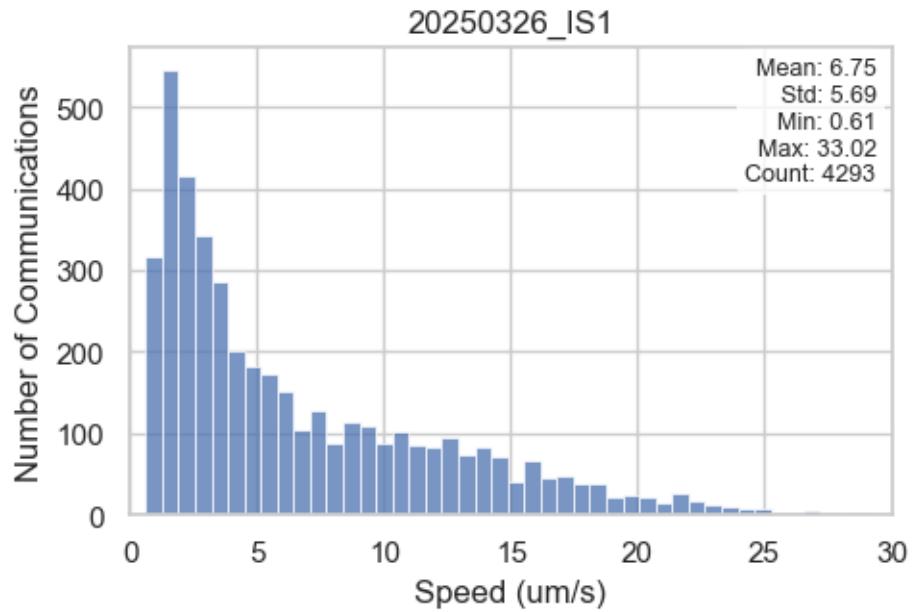
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:45:29] [INFO] calcium: Removed 0 outliers from dataset '20250326\_IS1' for column 'Speed (um/s)'

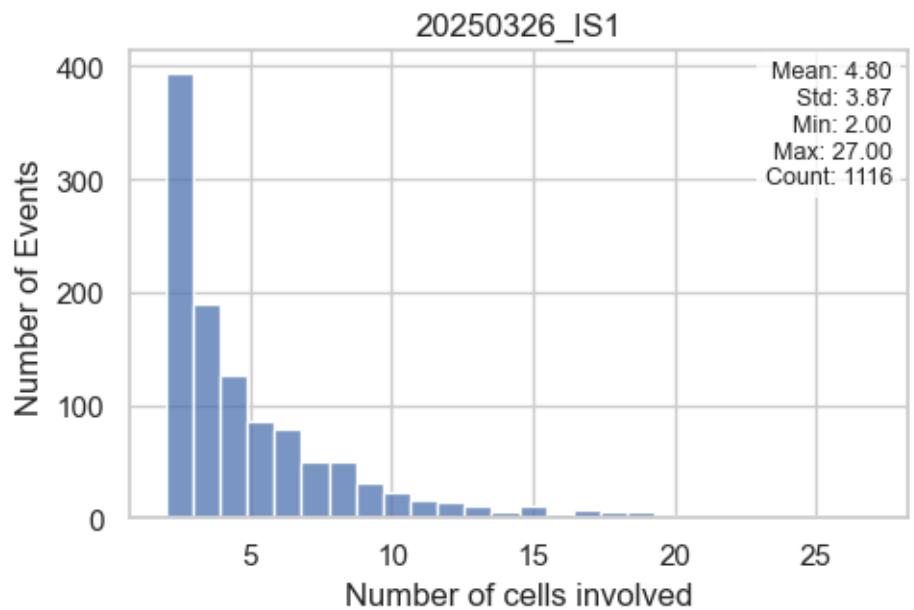
[2025-08-08 14:45:29] [INFO] calcium: Lower bound: -9.71999999999997, Upper bound: 34.05999999999995

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

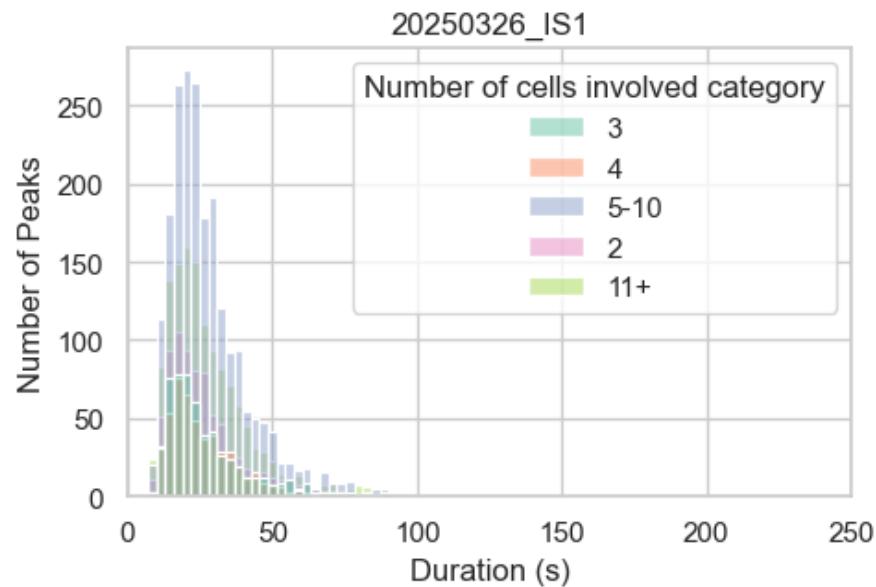


### 1.3.5 Influence of cell count per event on statistics

[2025-08-08 14:45:29] [INFO] calcium: Removed 112 outliers from dataset '20250326\_IS1' for column 'Duration (s)'

[2025-08-08 14:45:29] [INFO] calcium: Lower bound: -6.0, Upper bound: 90.0

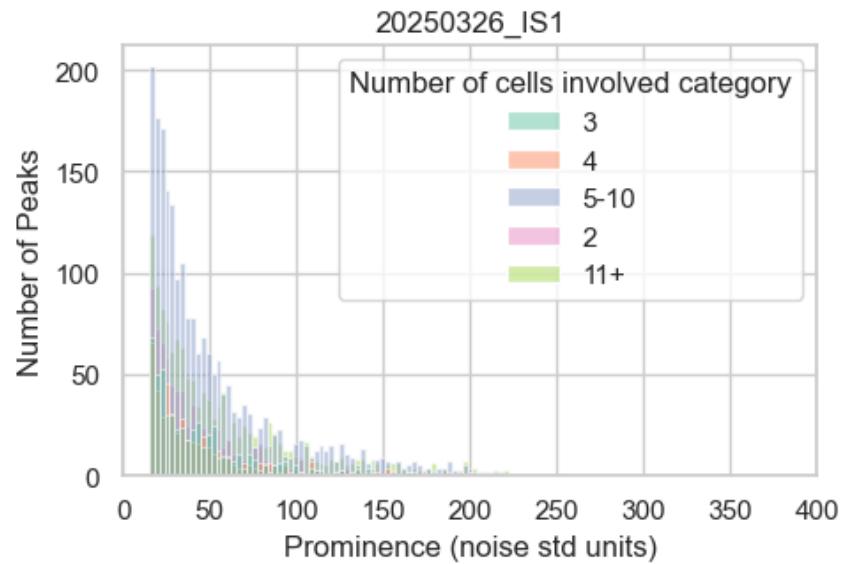
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



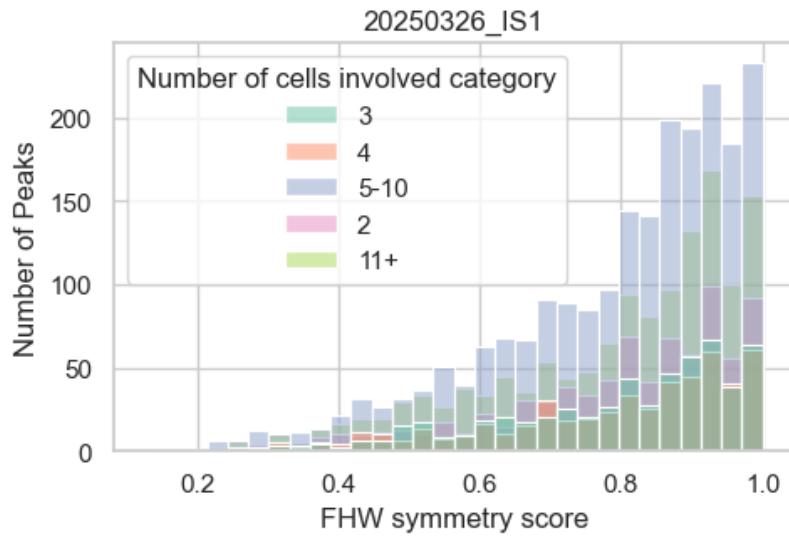
[2025-08-08 14:45:29] [INFO] calcium: Removed 127 outliers from dataset '20250326\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 14:45:29] [INFO] calcium: Lower bound: -43.1, Upper bound: 223.8

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



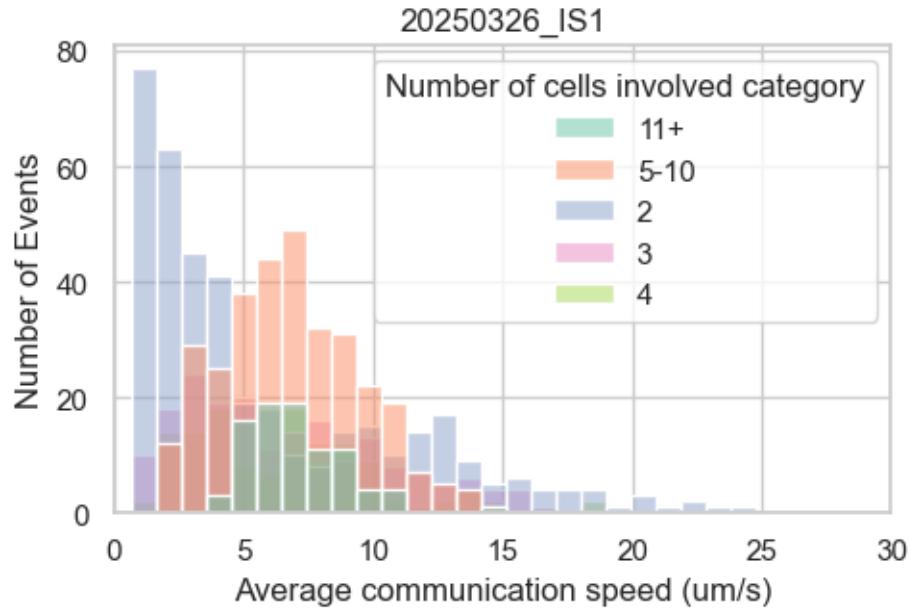
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 14:45:30] [INFO] calcium: Removed 2 outliers from dataset
'20250326_IS1' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 14:45:30] [INFO] calcium: Lower bound: -4.7, Upper bound: 24.8
```

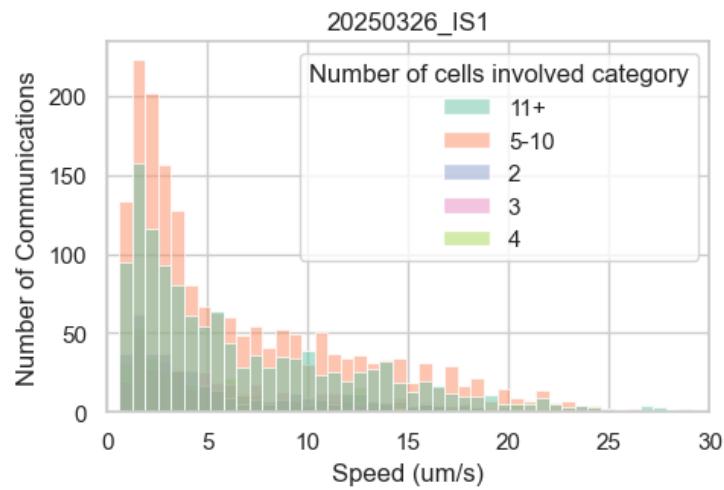
## Distribution of Average Communication Speeds by Number of Cells Involved



```
[2025-08-08 14:45:30] [INFO] calcium: Removed 0 outliers from dataset  
'20250326_IS1' for column 'Speed (um/s)'
```

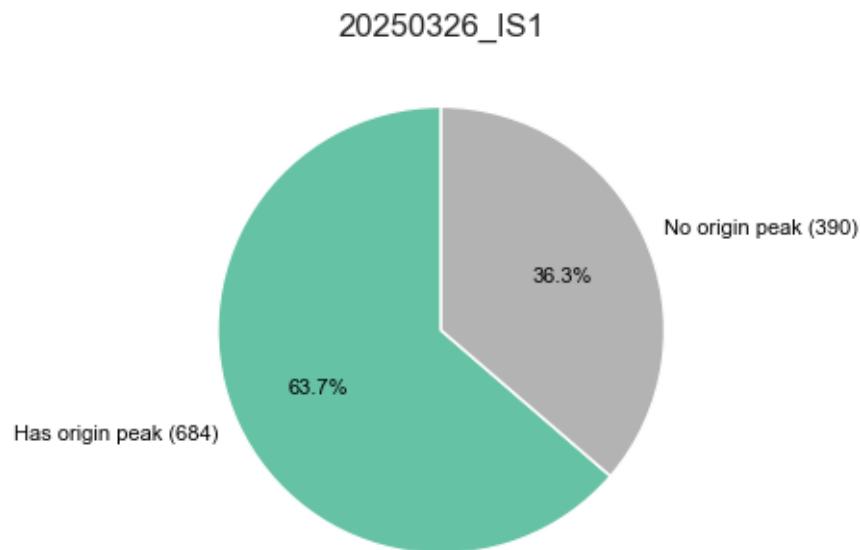
```
[2025-08-08 14:45:30] [INFO] calcium: Lower bound: -9.7, Upper bound: 34.1
```

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

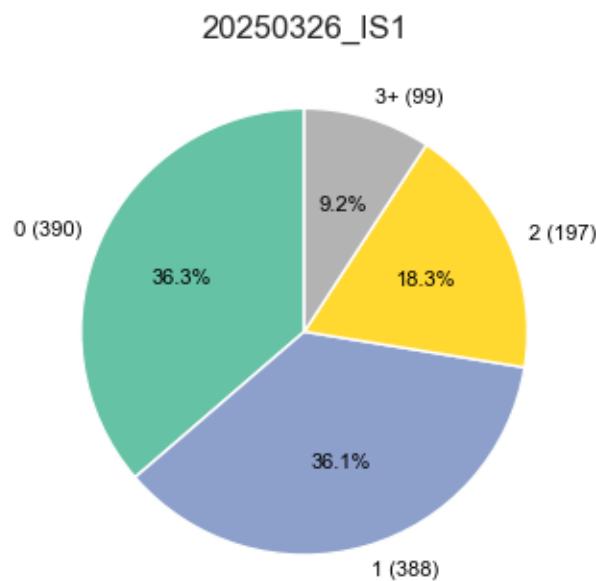


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

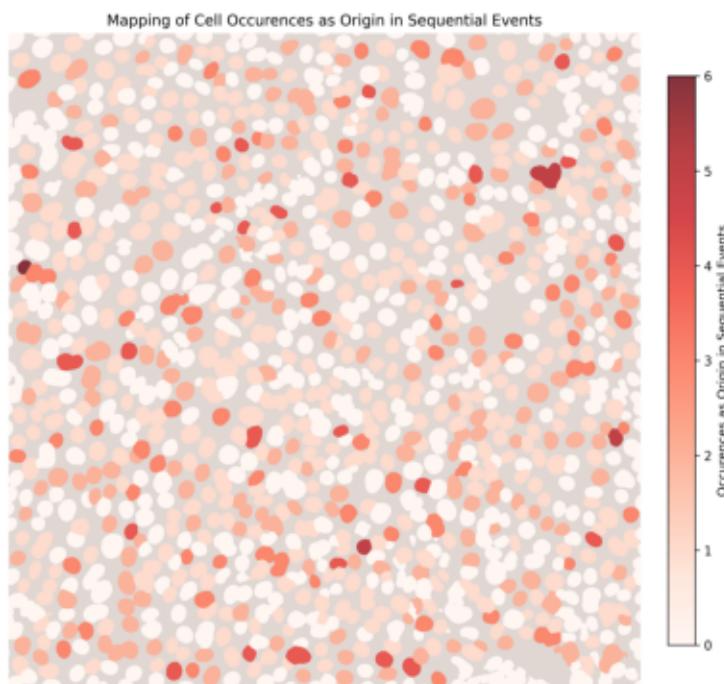


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

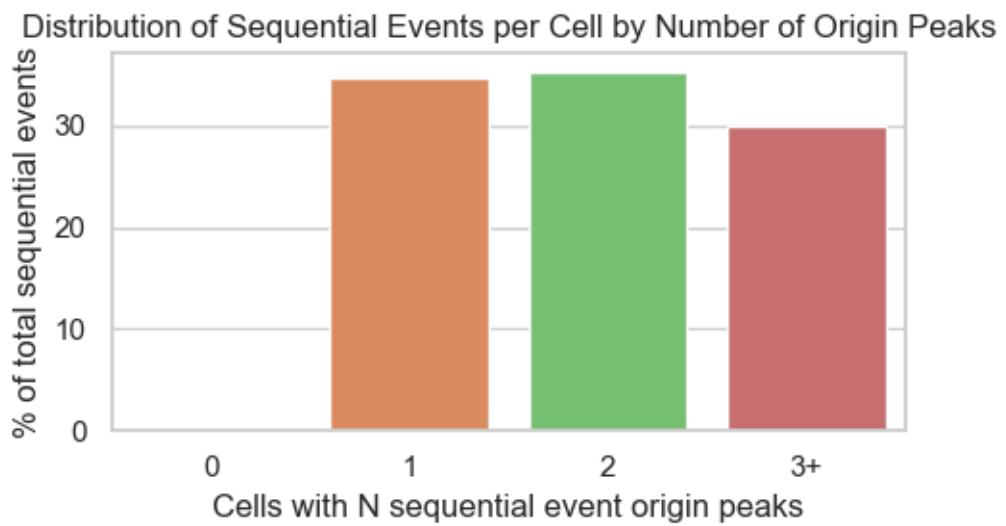
20250326\_IS1



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

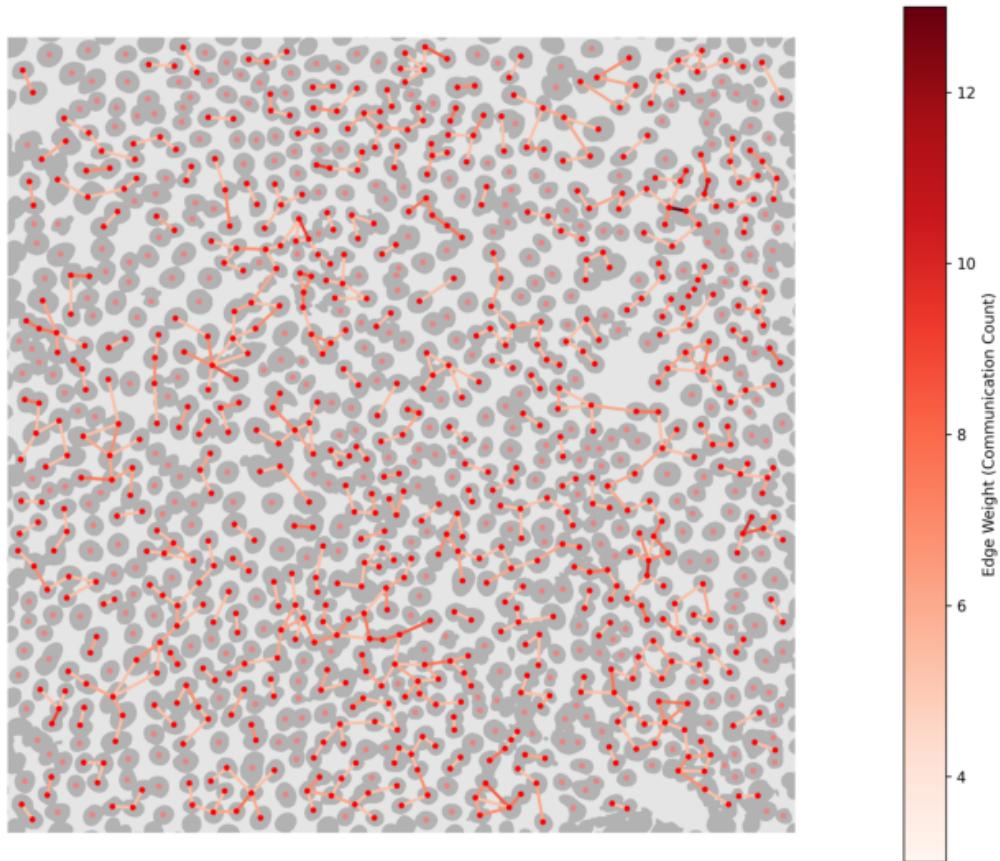


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250326\_IS1

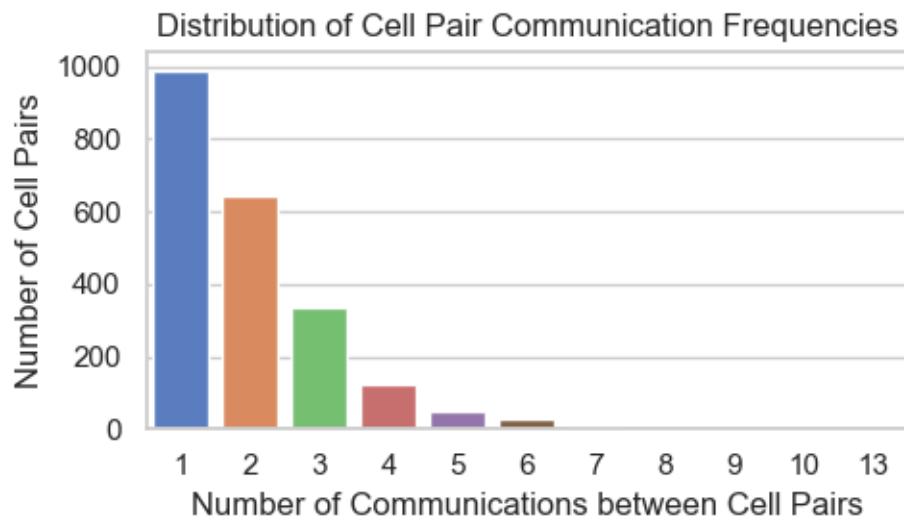
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

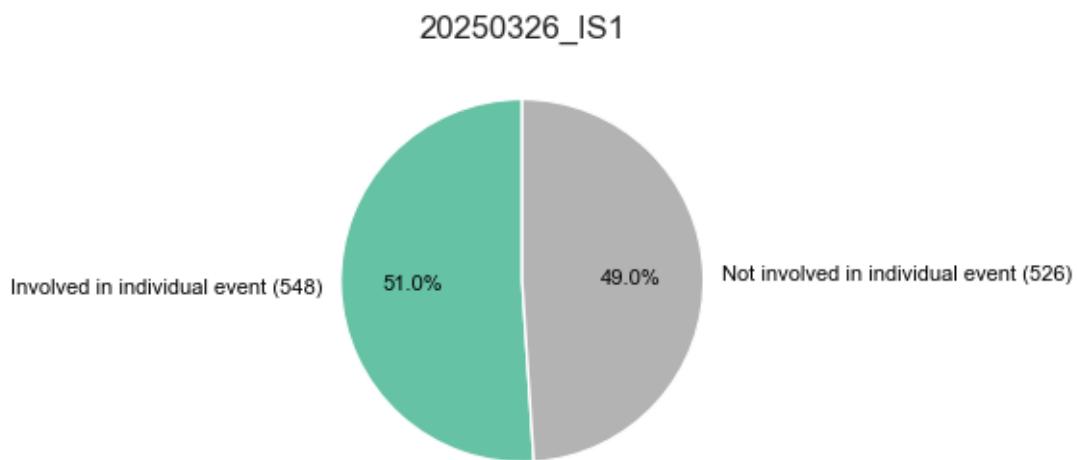
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



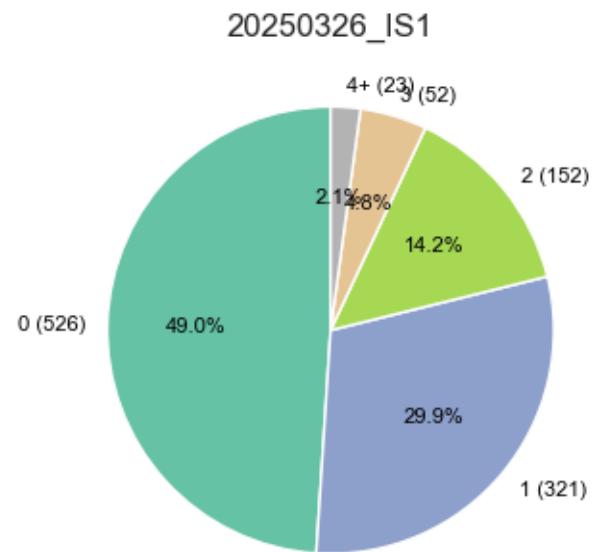
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

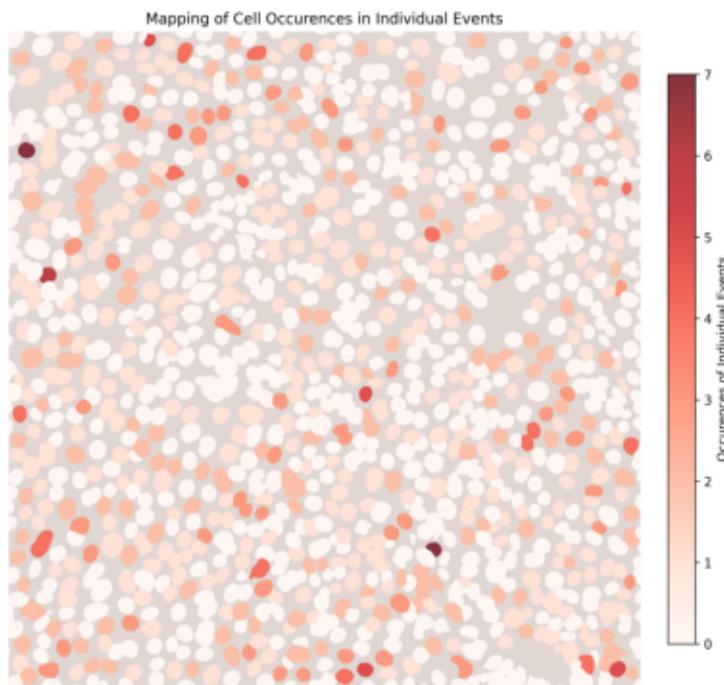


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250326\_IS1

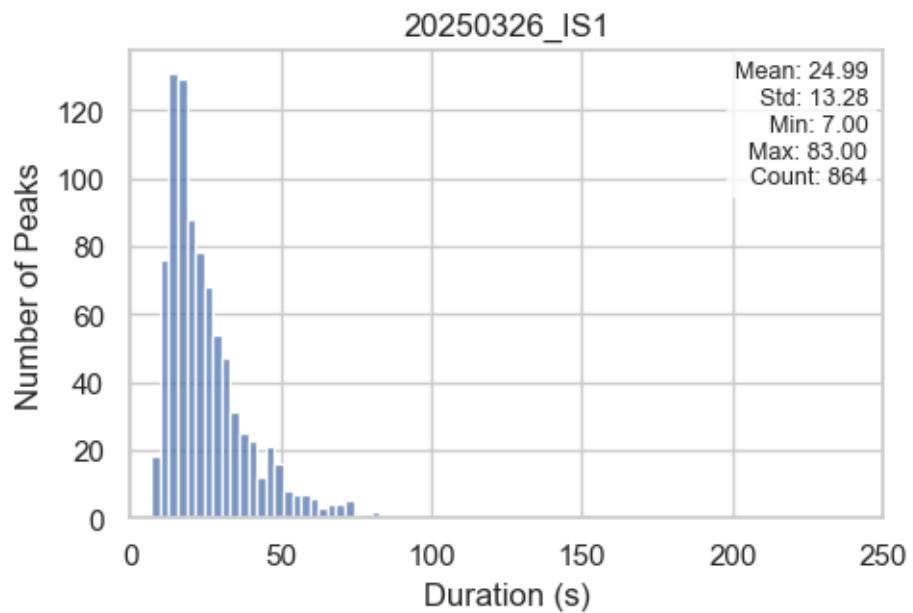


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:45:34] [INFO] calcium: Removed 21 outliers from dataset  
'20250326_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:45:34] [INFO] calcium: Lower bound: -10.5, Upper bound: 83.0
```

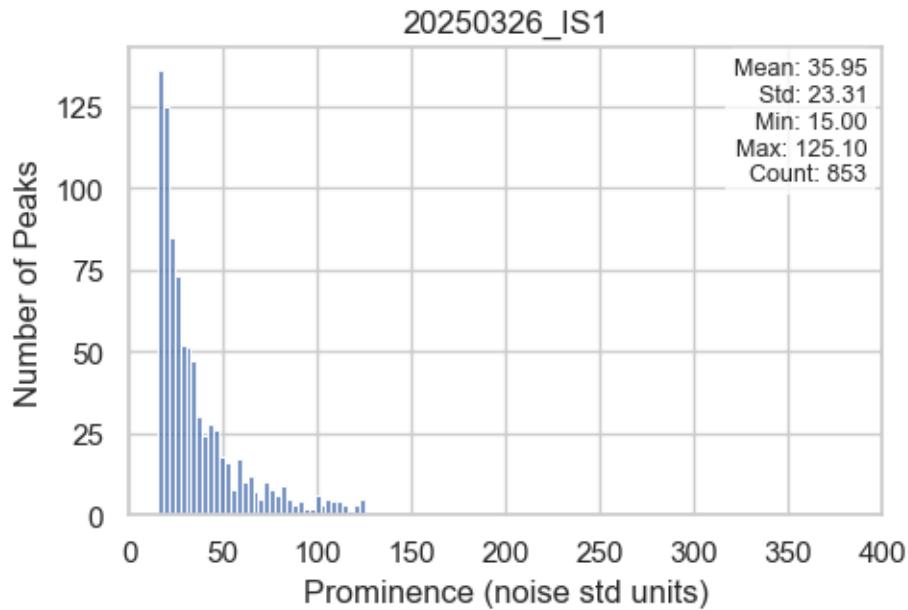
## Distribution of Peak Durations



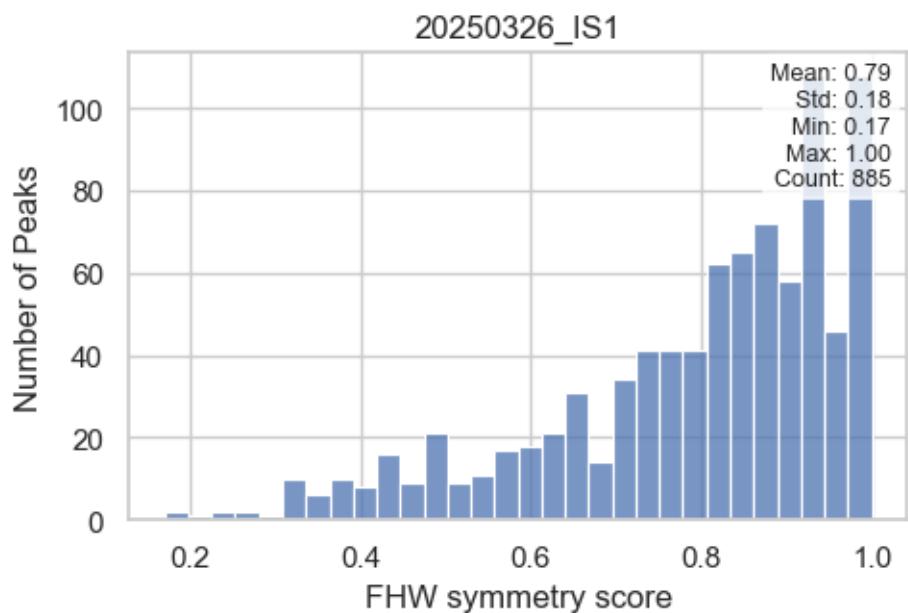
```
[2025-08-08 14:45:34] [INFO] calcium: Removed 32 outliers from dataset '20250326_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:45:34] [INFO] calcium: Lower bound: -19.550000000000004, Upper bound: 125.1000000000001
```

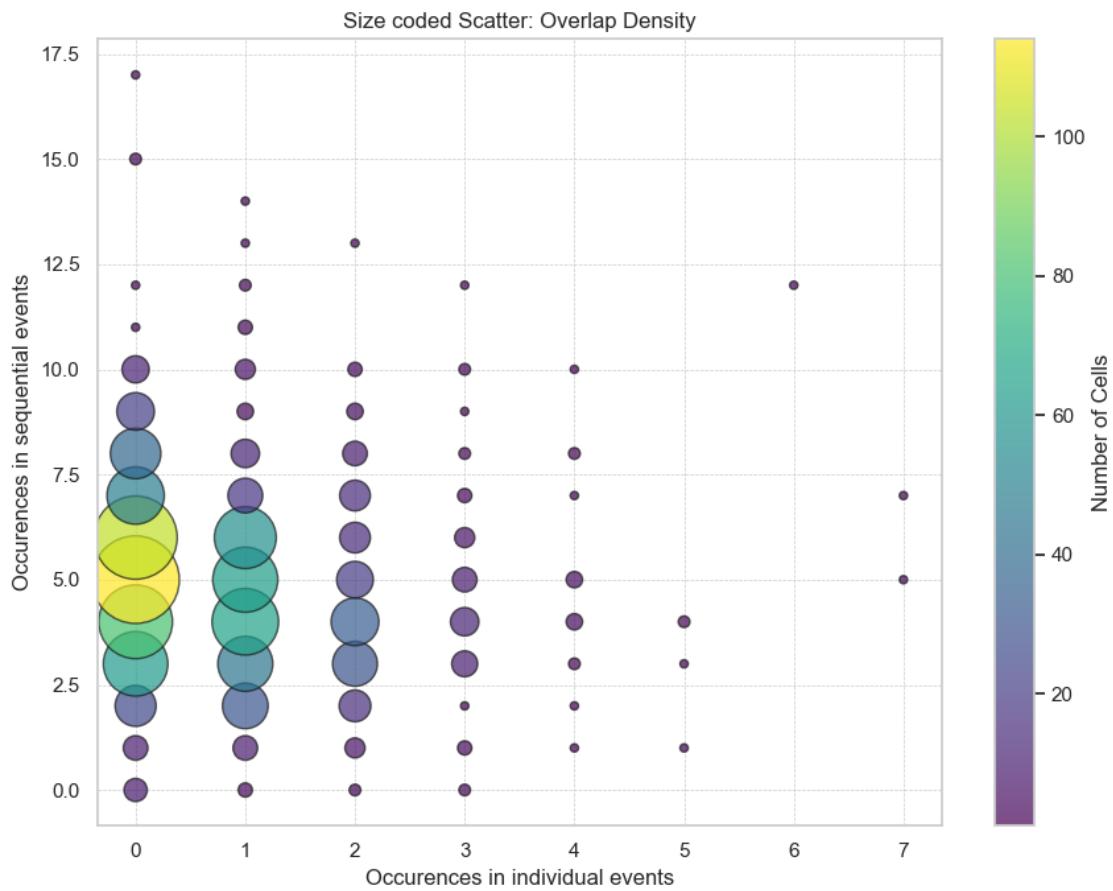
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

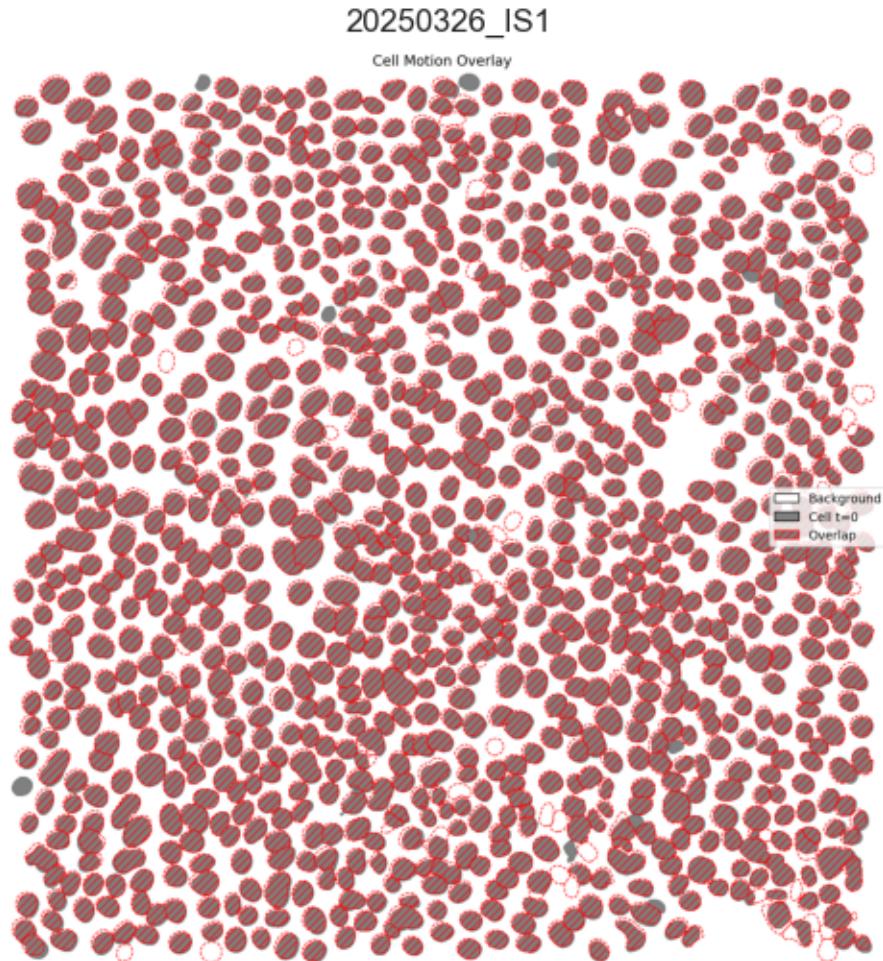


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 1057
- Hoechst image taken at t=1801: 1054
- Number of cells difference: absolute 3, relative 0.28%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1118572
- Pixels segmented as cell at t=1801: 1144633
- Overlapping pixels between t=0 and t=1801: 985731 (87.11% of total)
- Pixels exclusive to t=0: 132841 (11.88% of total)
- Pixels exclusive to t=1801: 158902 (13.88% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n      "Default Dataset": "/path/to/your/dataset"\n}'
```

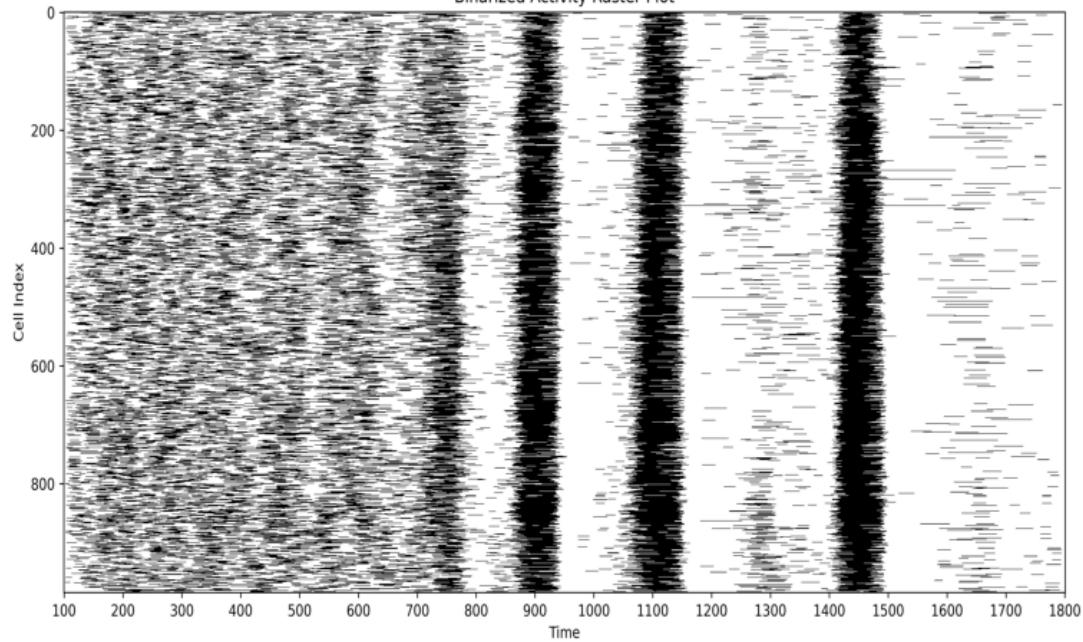
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

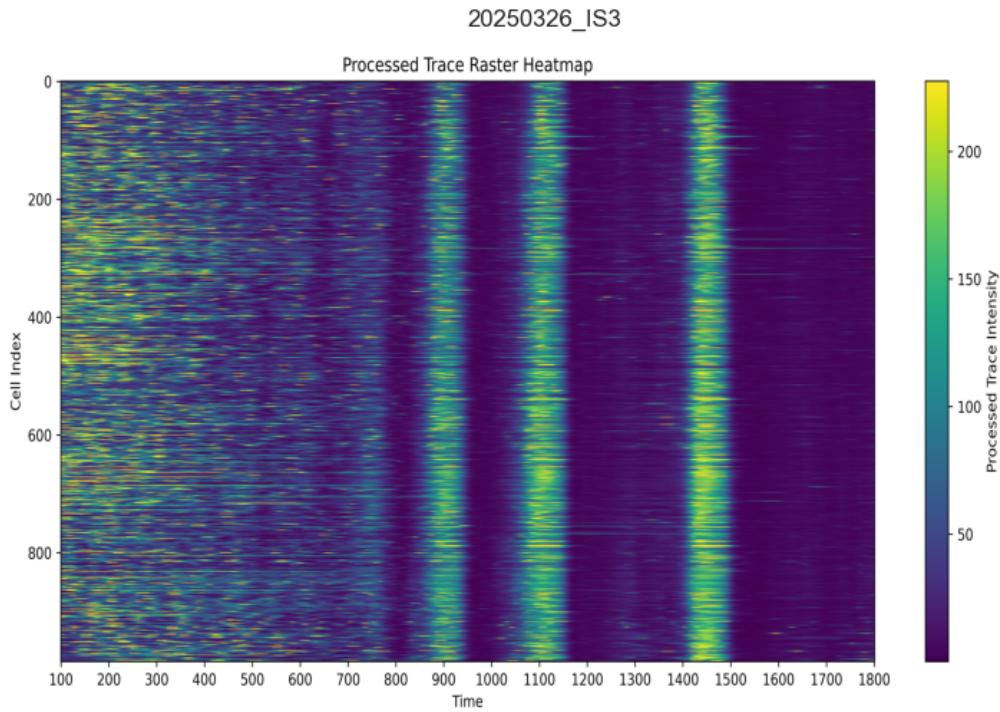
Binary Activity Raster Plot

20250326\_IS3

Binarized Activity Raster Plot



## Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 12215

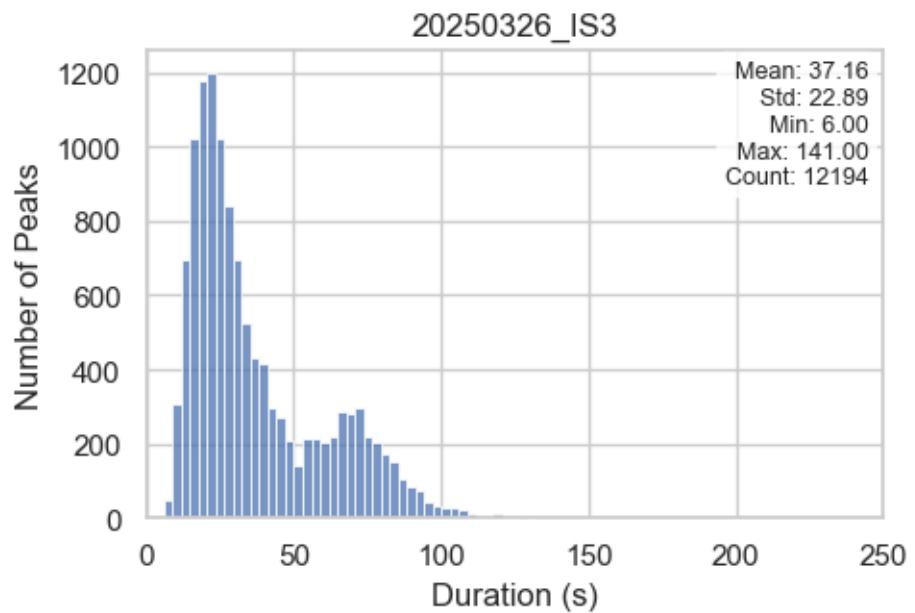
Total number of cells: 985

### 1.1.3 Peaks statistics

```
[2025-08-08 14:46:30] [INFO] calcium: Removed 21 outliers from dataset  
'20250326_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:46:30] [INFO] calcium: Lower bound: -26.5, Upper bound: 144.0
```

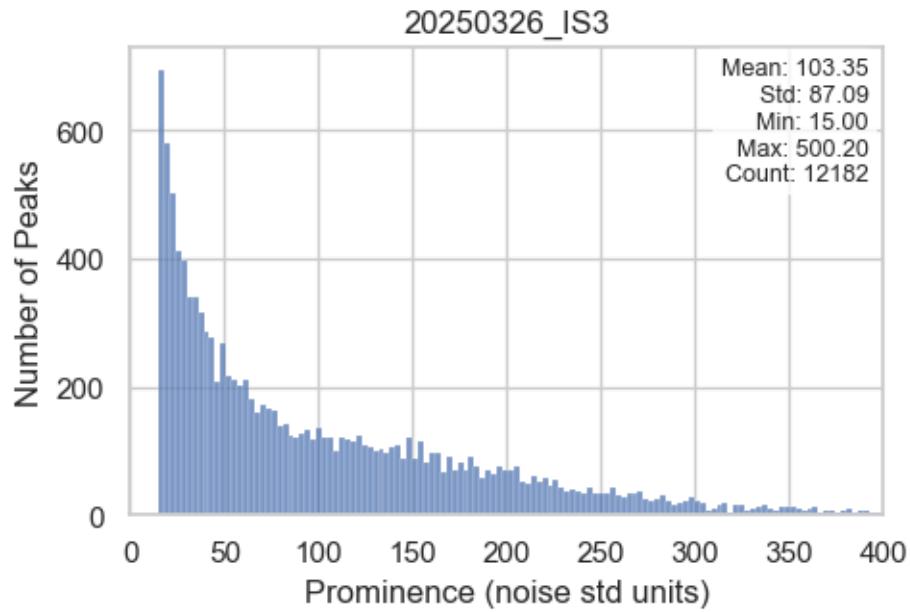
## Distribution of Peak Durations



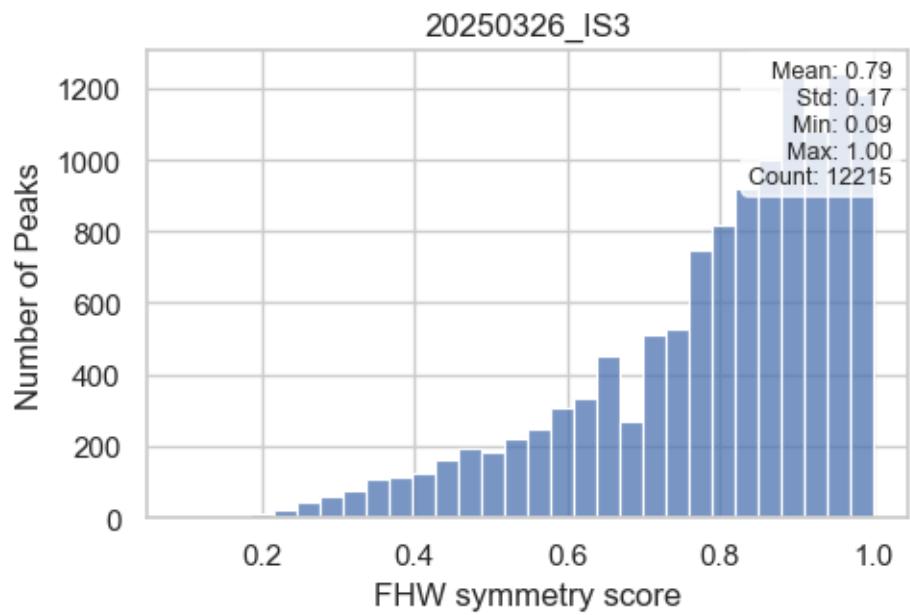
```
[2025-08-08 14:46:30] [INFO] calcium: Removed 33 outliers from dataset '20250326_IS3' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:46:30] [INFO] calcium: Lower bound: -142.39999999999998, Upper bound: 504.4
```

### Distribution of Peak Prominences

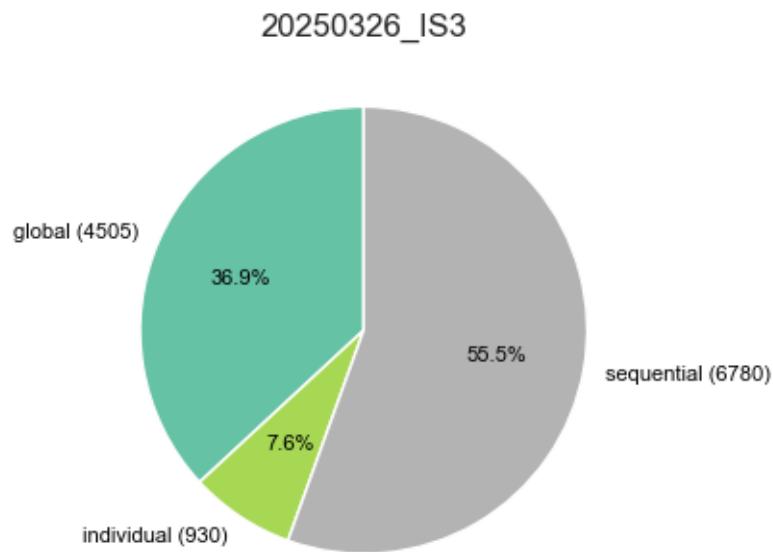


### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

Distribution of Peaks by Event types

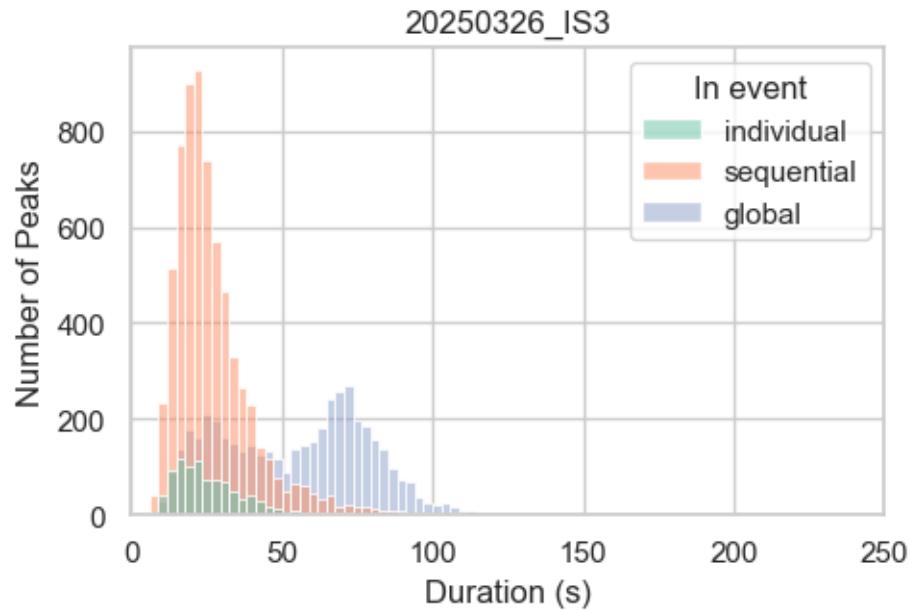


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:46:30] [INFO] calcium: Removed 21 outliers from dataset  
'20250326_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:46:30] [INFO] calcium: Lower bound: -26.5, Upper bound: 144.0
```

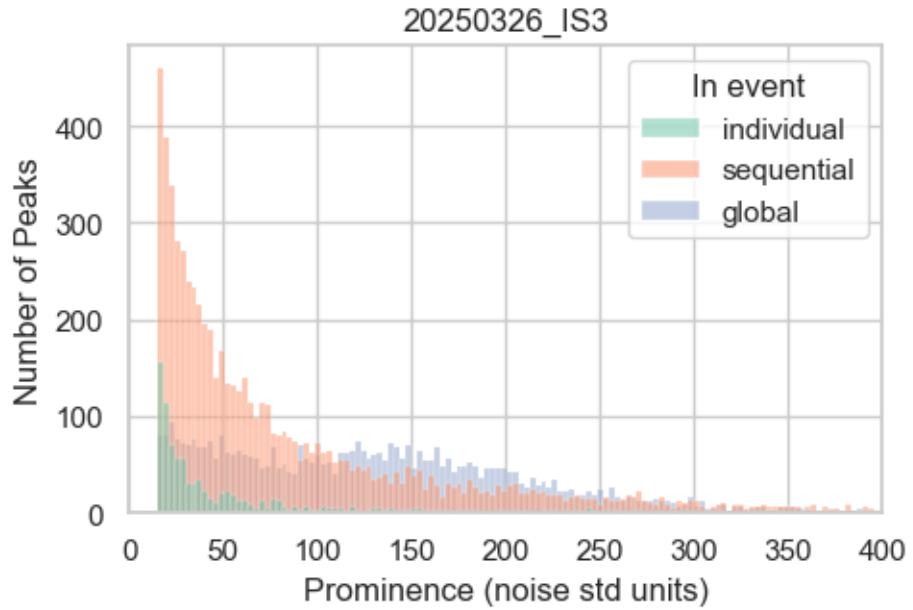
## Distribution of Peak Durations by Group



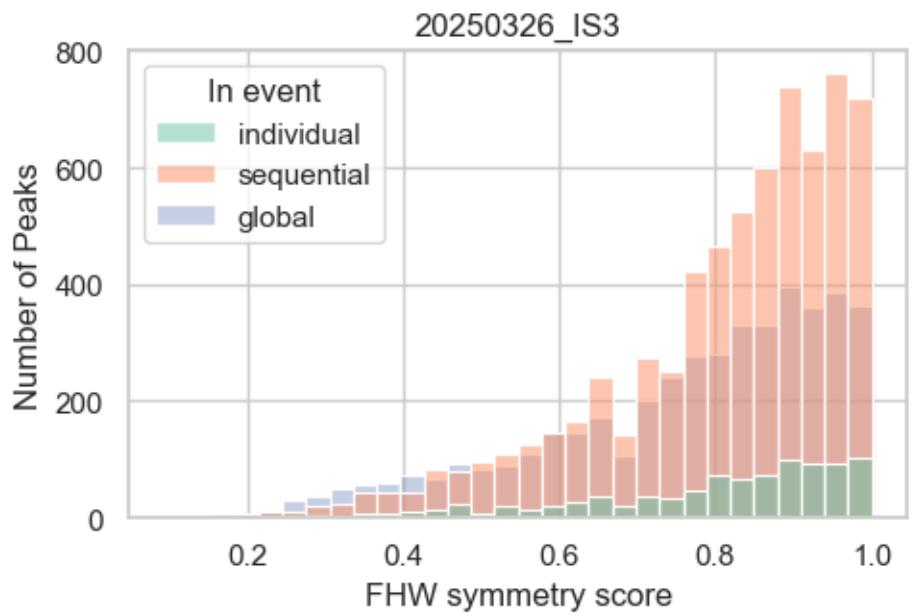
```
[2025-08-08 14:46:30] [INFO] calcium: Removed 33 outliers from dataset  
'20250326_IS3' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:46:30] [INFO] calcium: Lower bound: -142.4, Upper bound: 504.4
```

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



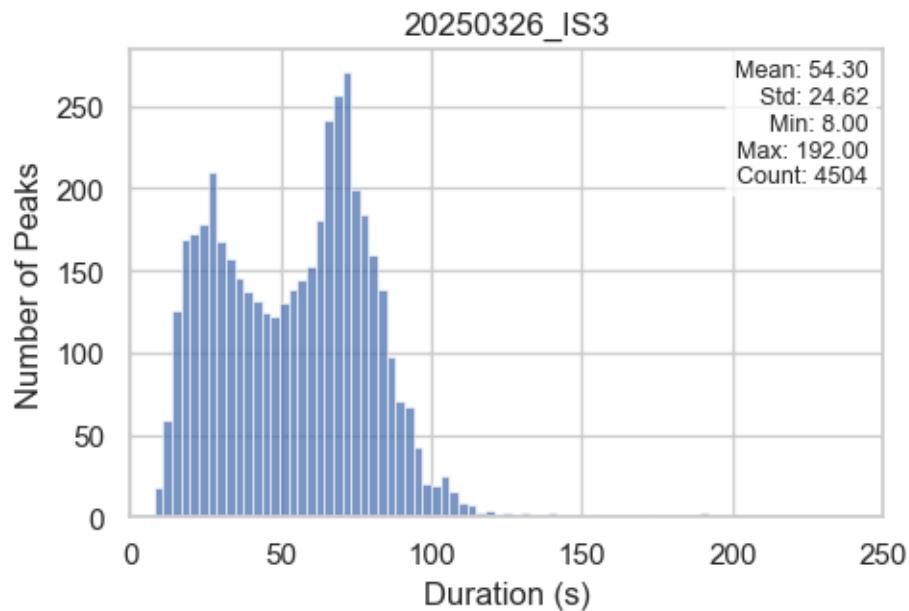
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:46:31] [INFO] calcium: Removed 1 outliers from dataset  
'20250326_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:46:31] [INFO] calcium: Lower bound: -29.5, Upper bound: 196.0
```

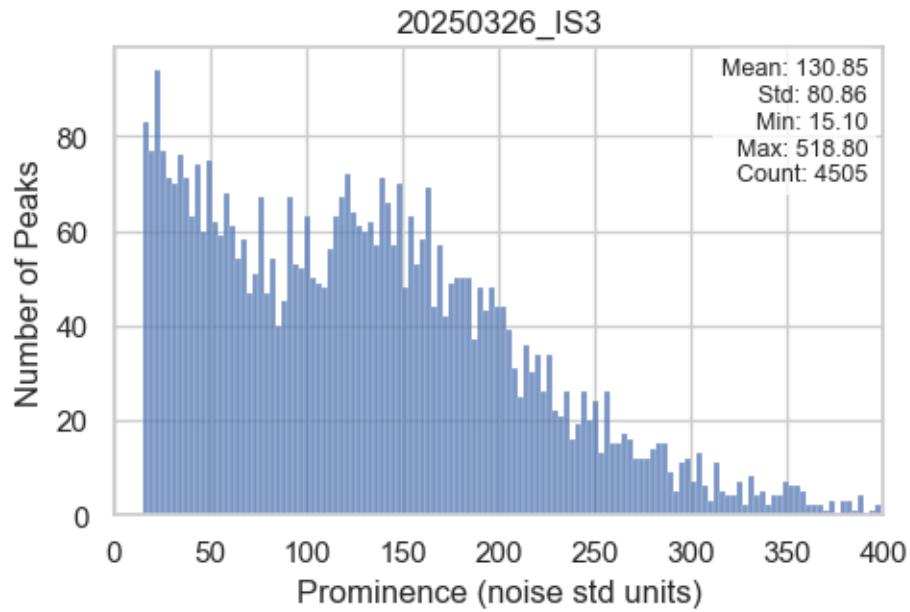
Distribution of Peak Durations



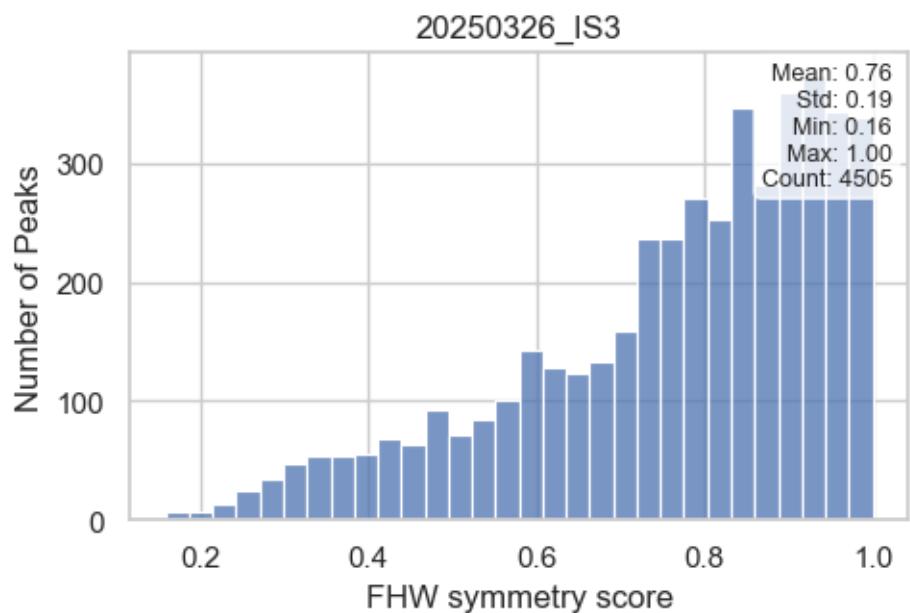
```
[2025-08-08 14:46:31] [INFO] calcium: Removed 0 outliers from dataset  
'20250326_IS3' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:46:31] [INFO] calcium: Lower bound: -117.7999999999997, Upper  
bound: 542.199999999999
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

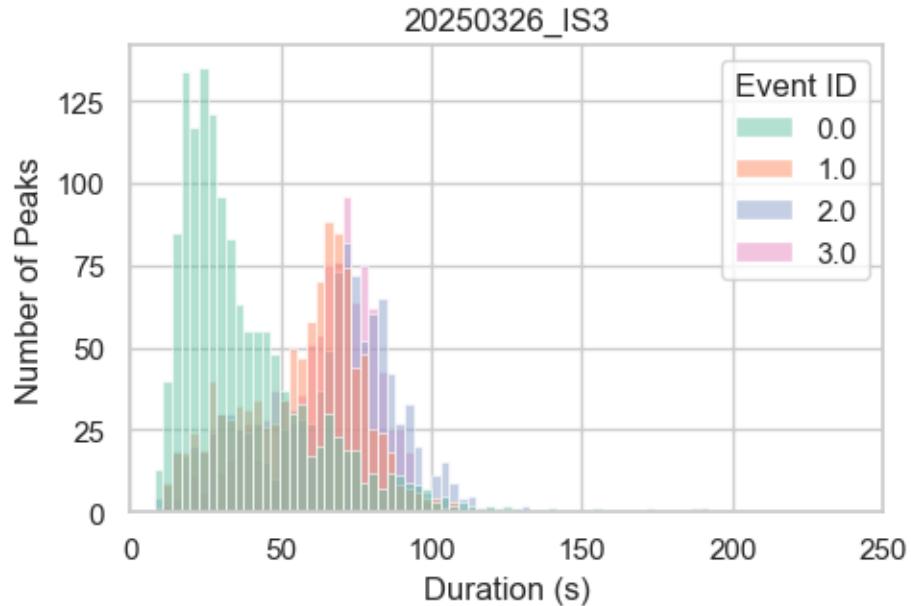


### 1.2.2 Peak statistics in global event per event ID

[2025-08-08 14:46:32] [INFO] calcium: Removed 1 outliers from dataset '20250326\_IS3' for column 'Duration (s)'

[2025-08-08 14:46:32] [INFO] calcium: Lower bound: -29.5, Upper bound: 196.0

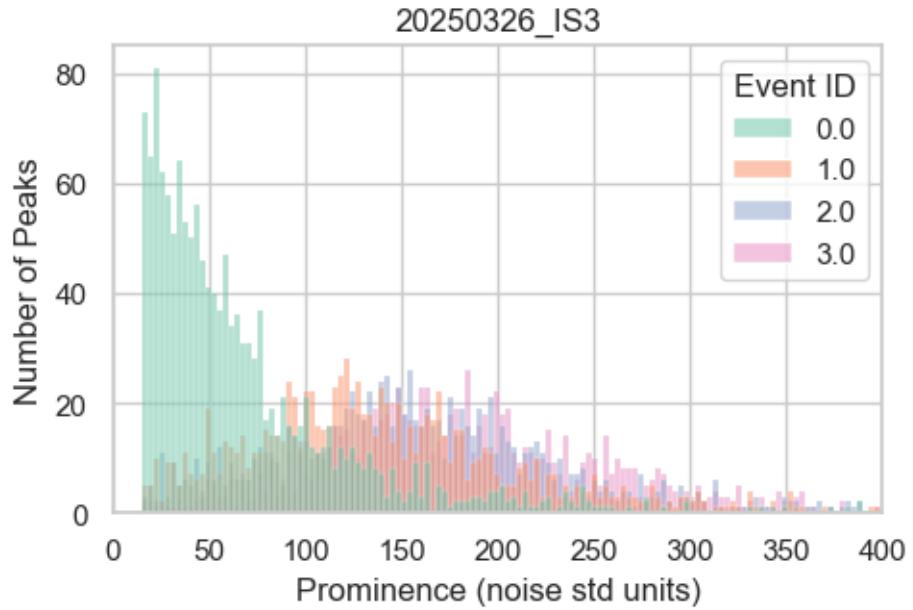
Distribution of Peak Durations by Group



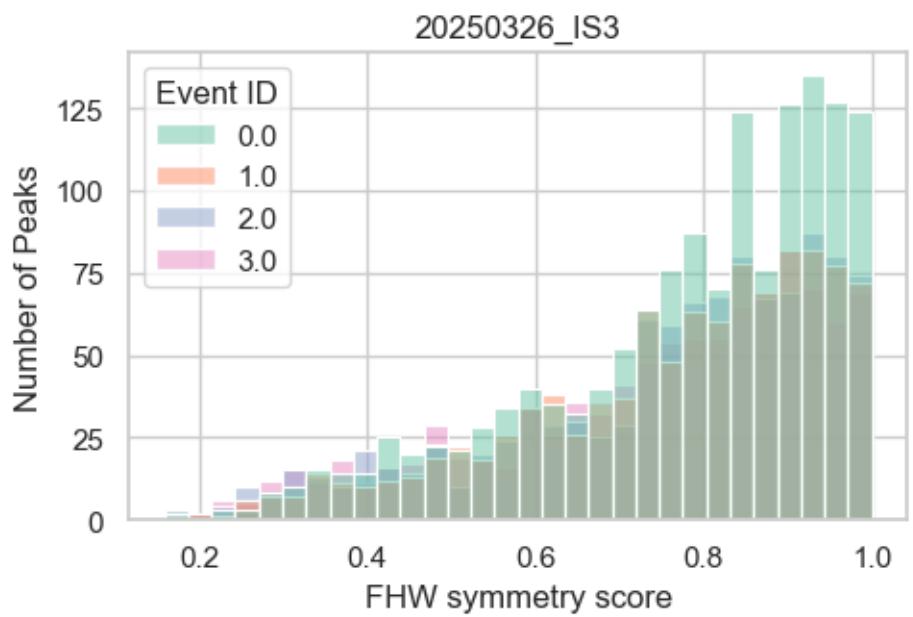
[2025-08-08 14:46:32] [INFO] calcium: Removed 0 outliers from dataset '20250326\_IS3' for column 'Prominence (noise std units)'

[2025-08-08 14:46:32] [INFO] calcium: Lower bound: -117.8, Upper bound: 542.2

### Distribution of Peak Prominences by Group



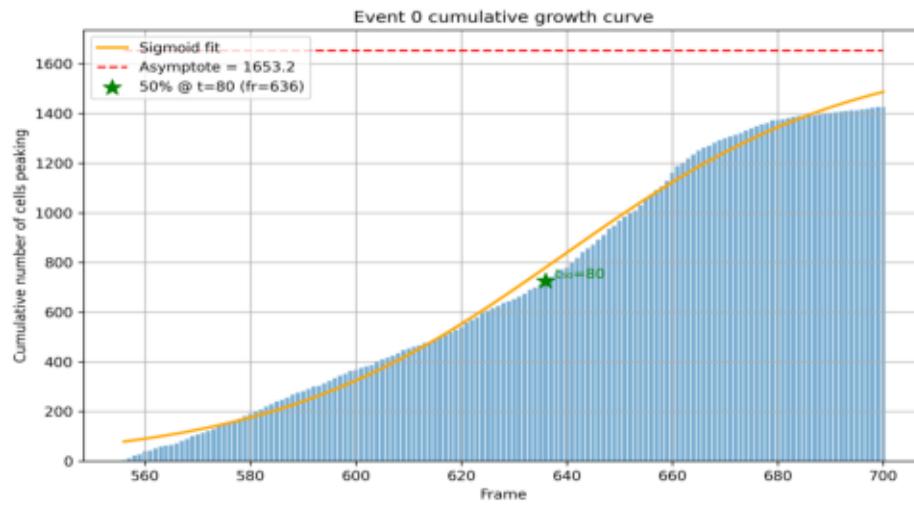
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

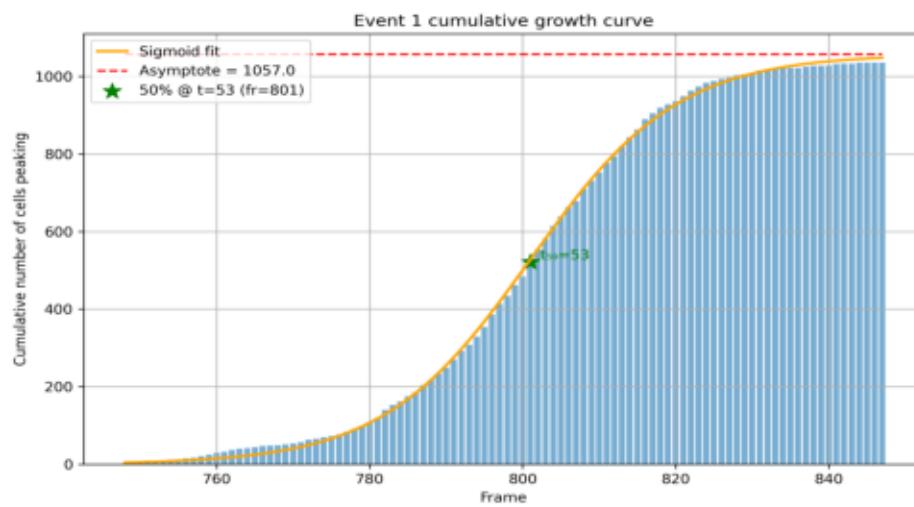
Event Activity Overlay (Event ID: 0)

20250326\_IS3



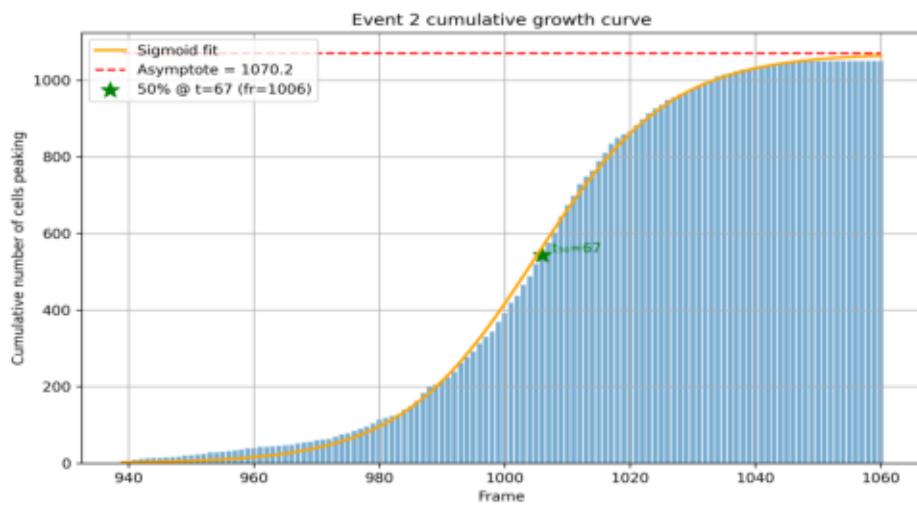
Event Activity Overlay (Event ID: 1)

20250326\_IS3



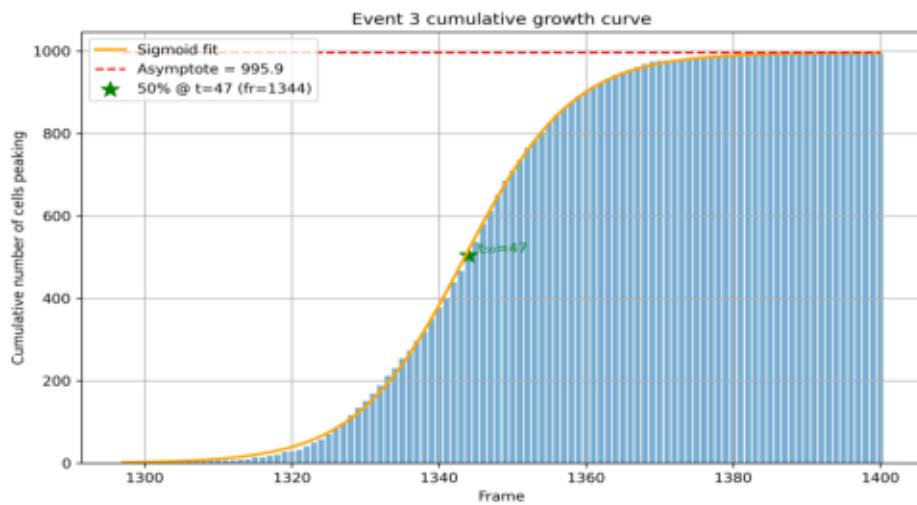
## Event Activity Overlay (Event ID: 2)

20250326\_IS3



## Event Activity Overlay (Event ID: 3)

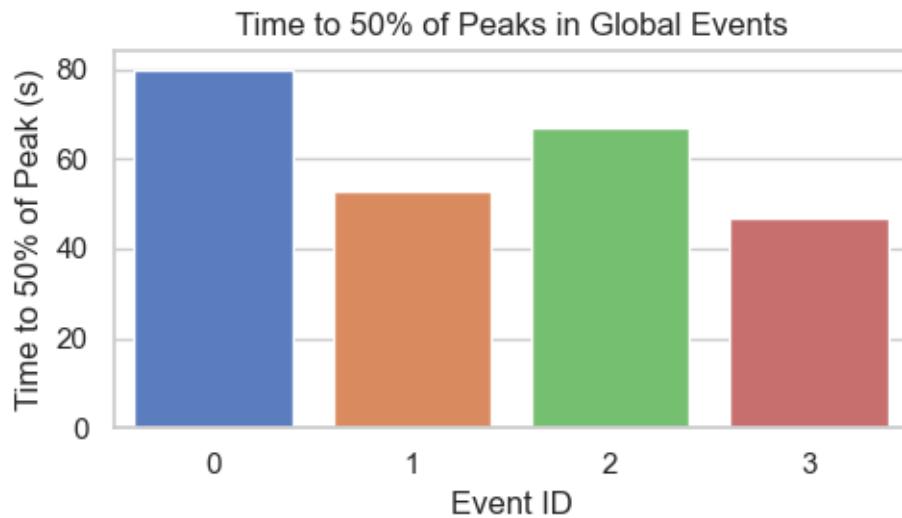
20250326\_IS3



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

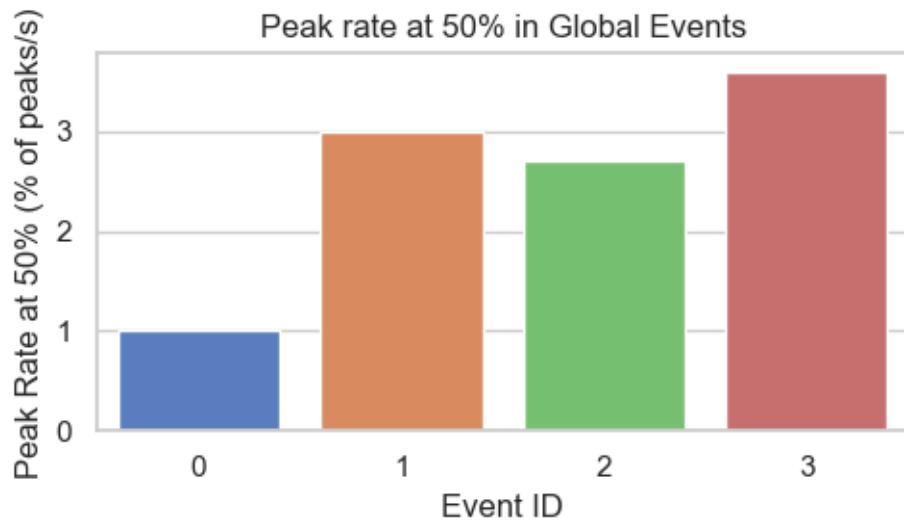
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

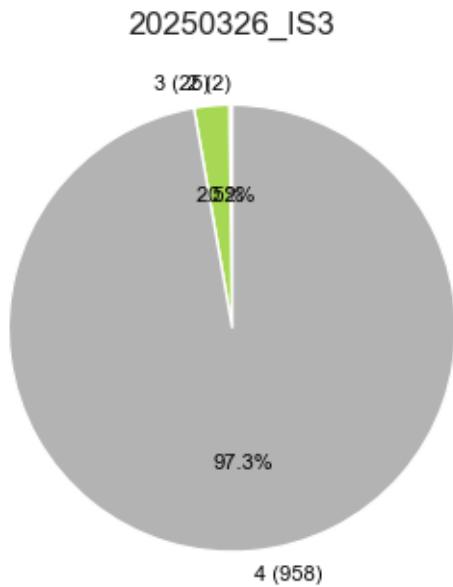
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



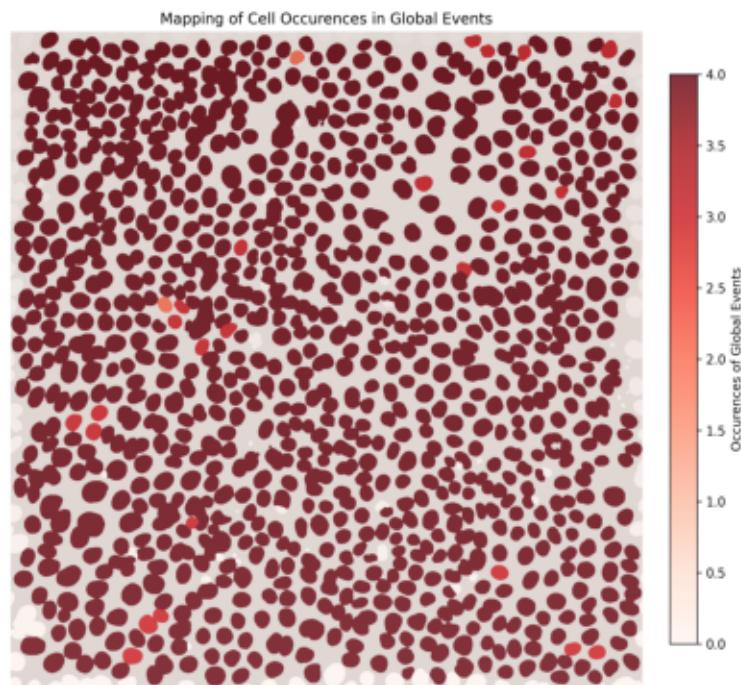
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

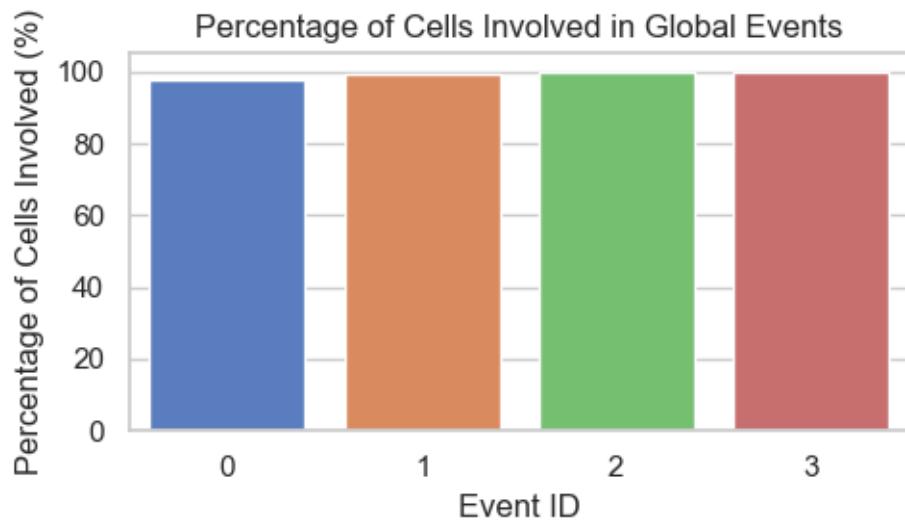
20250326\_IS3



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



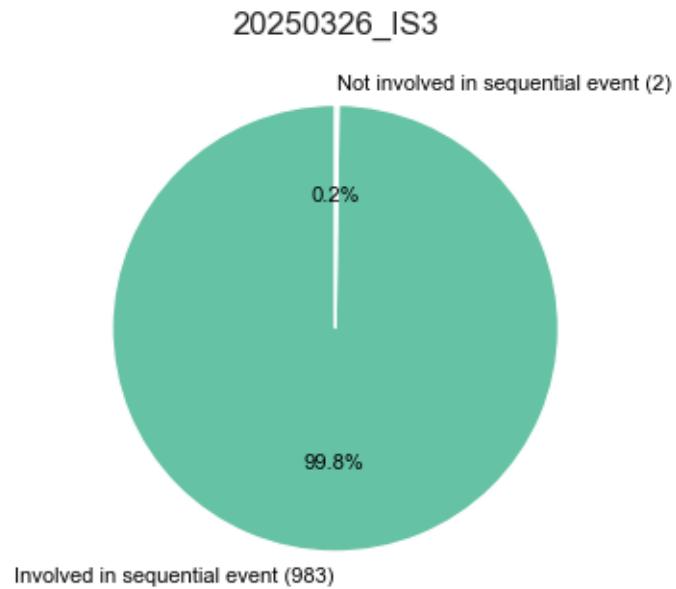
### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [149.0, 205.0, 343.0]  
Estimated periodicity: 0.740

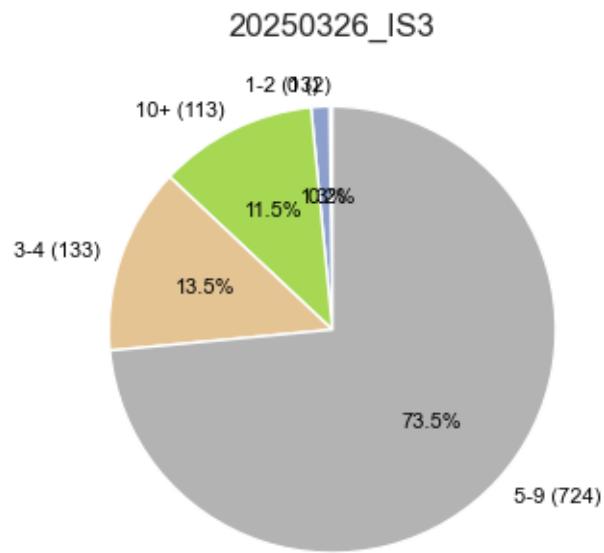
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequential events

Distribution of Cells Involved in Sequential Events

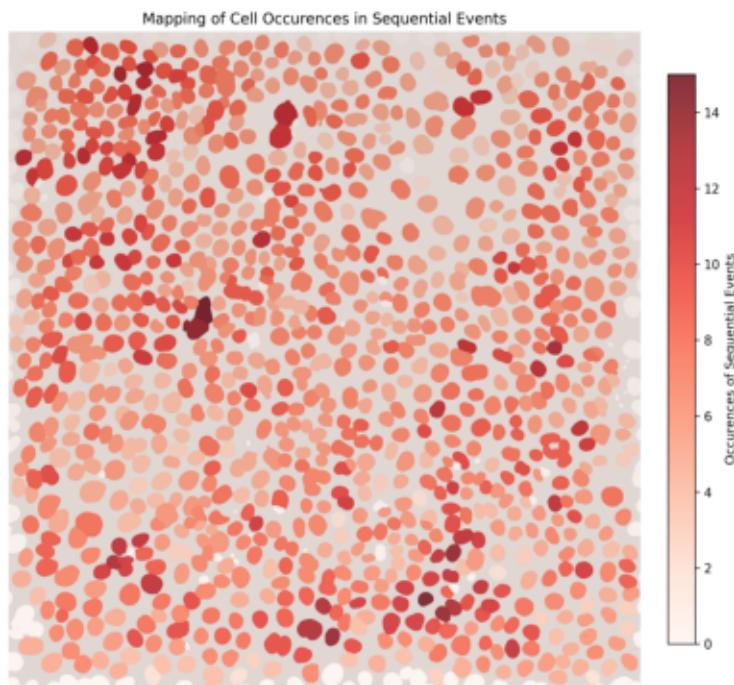


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250326\_IS3

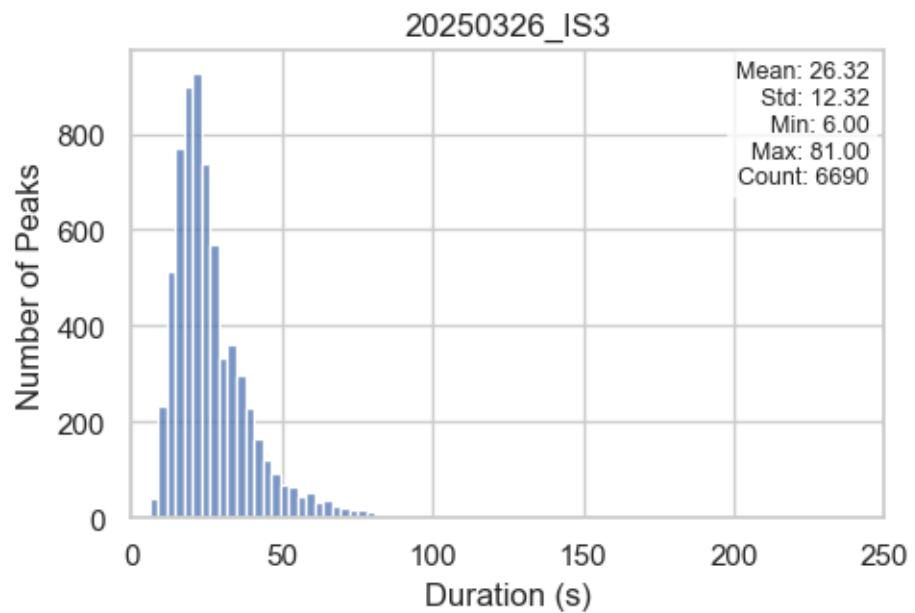


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:46:38] [INFO] calcium: Removed 90 outliers from dataset  
'20250326_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:46:38] [INFO] calcium: Lower bound: -3.0, Upper bound: 81.0
```

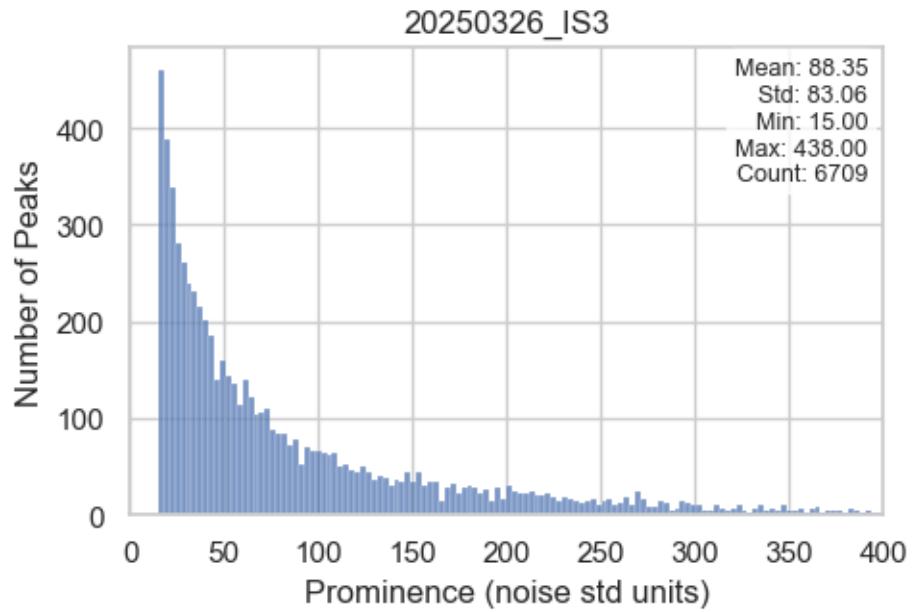
## Distribution of Peak Durations



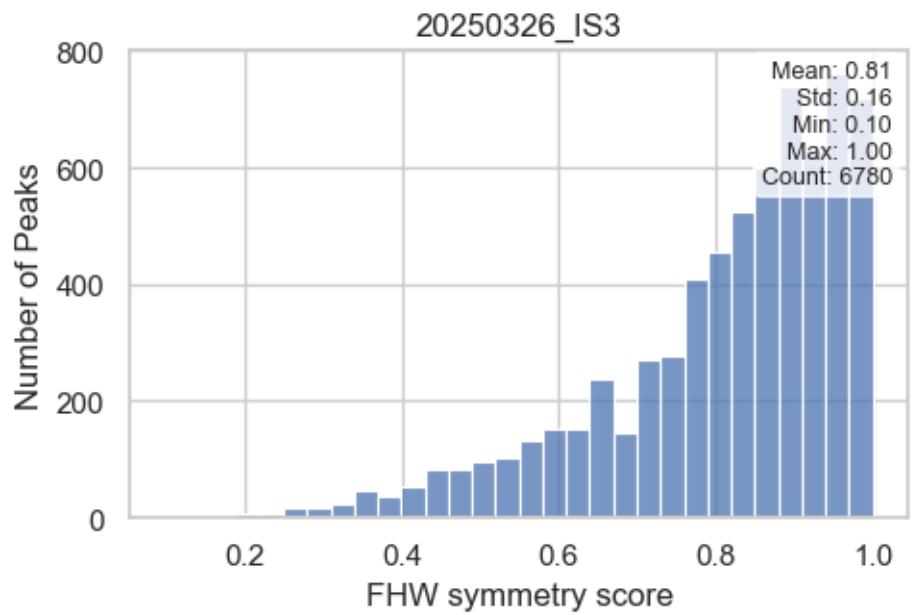
```
[2025-08-08 14:46:38] [INFO] calcium: Removed 71 outliers from dataset '20250326_IS3' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:46:38] [INFO] calcium: Lower bound: -106.91250000000002, Upper bound: 438.63750000000005
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

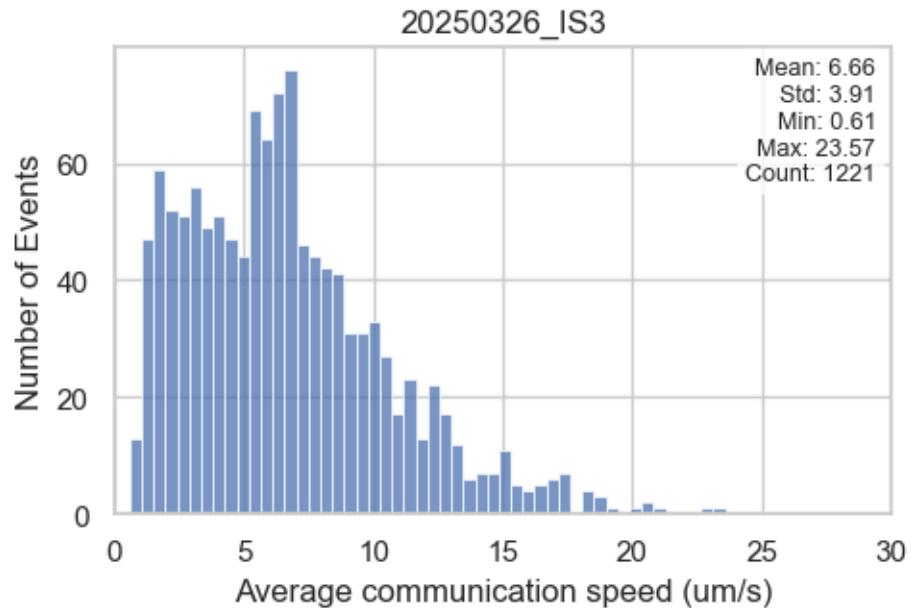


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:46:38] [INFO] calcium: Removed 2 outliers from dataset '20250326\_IS3' for column 'Average communication speed (um/s)'

[2025-08-08 14:46:38] [INFO] calcium: Lower bound: -4.18, Upper bound: 24.31

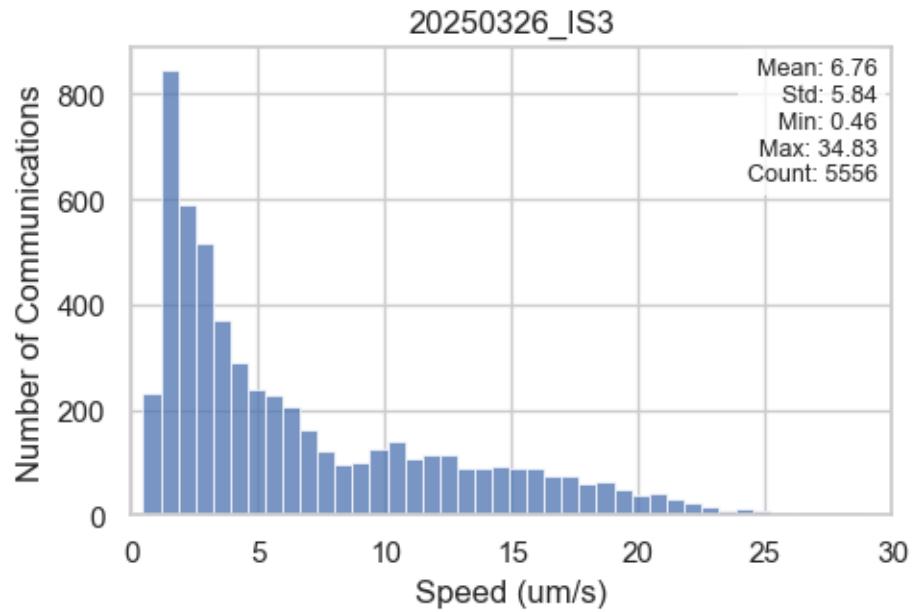
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:46:38] [INFO] calcium: Removed 1 outliers from dataset '20250326\_IS3' for column 'Speed (um/s)'

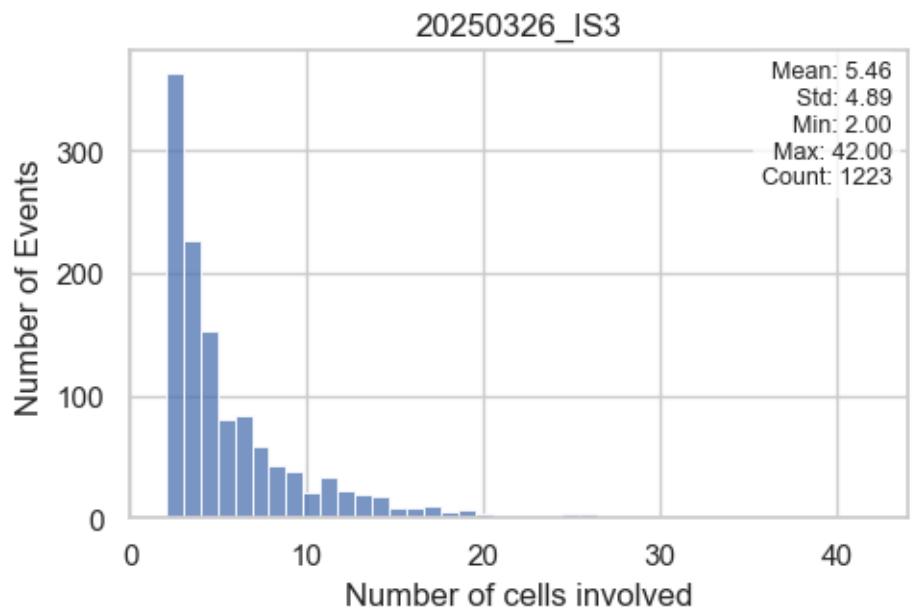
[2025-08-08 14:46:38] [INFO] calcium: Lower bound: -10.09499999999999, Upper bound: 34.83999999999996

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

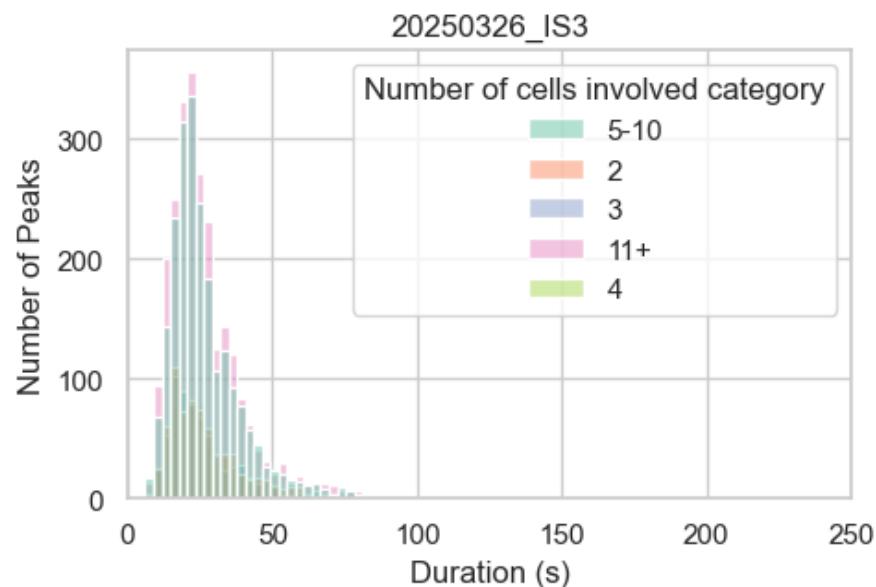


### 1.3.5 Influence of cell count per event on statistics

[2025-08-08 14:46:39] [INFO] calcium: Removed 90 outliers from dataset '20250326\_IS3' for column 'Duration (s)'

[2025-08-08 14:46:39] [INFO] calcium: Lower bound: -3.0, Upper bound: 81.0

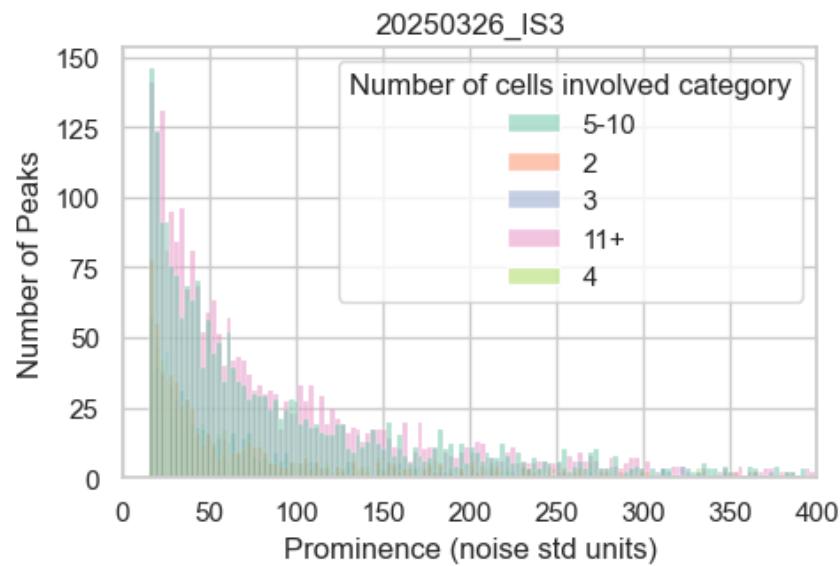
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



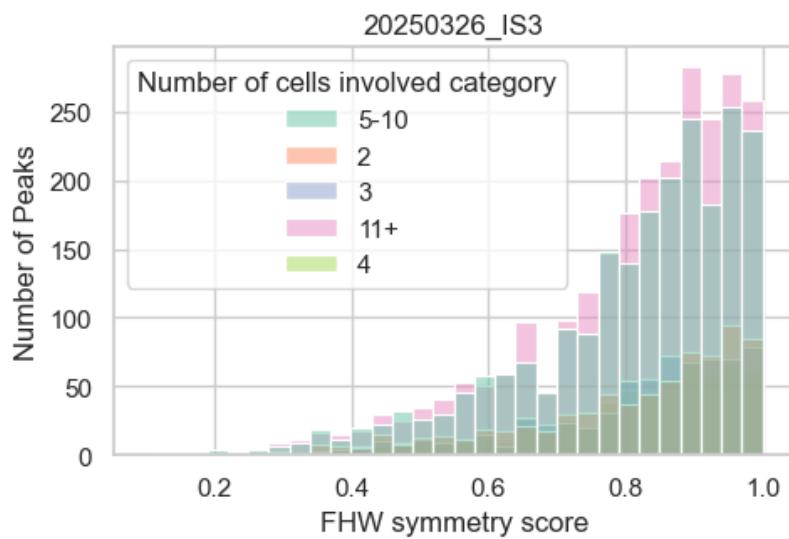
[2025-08-08 14:46:39] [INFO] calcium: Removed 71 outliers from dataset '20250326\_IS3' for column 'Prominence (noise std units)'

[2025-08-08 14:46:39] [INFO] calcium: Lower bound: -106.9, Upper bound: 438.6

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



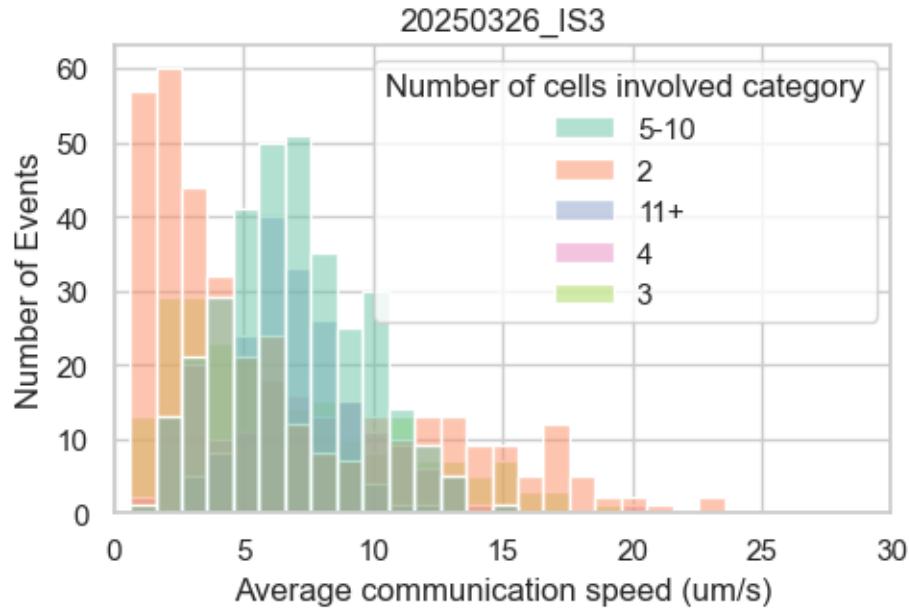
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



[2025-08-08 14:46:40] [INFO] calcium: Removed 2 outliers from dataset '20250326\_IS3' for column 'Average communication speed (um/s)'

[2025-08-08 14:46:40] [INFO] calcium: Lower bound: -4.2, Upper bound: 24.3

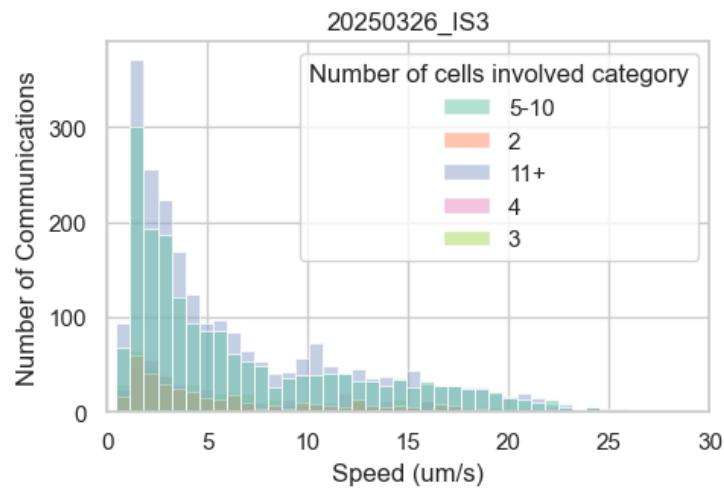
## Distribution of Average Communication Speeds by Number of Cells Involved



[2025-08-08 14:46:40] [INFO] calcium: Removed 1 outliers from dataset '20250326\_IS3' for column 'Speed (um/s)'

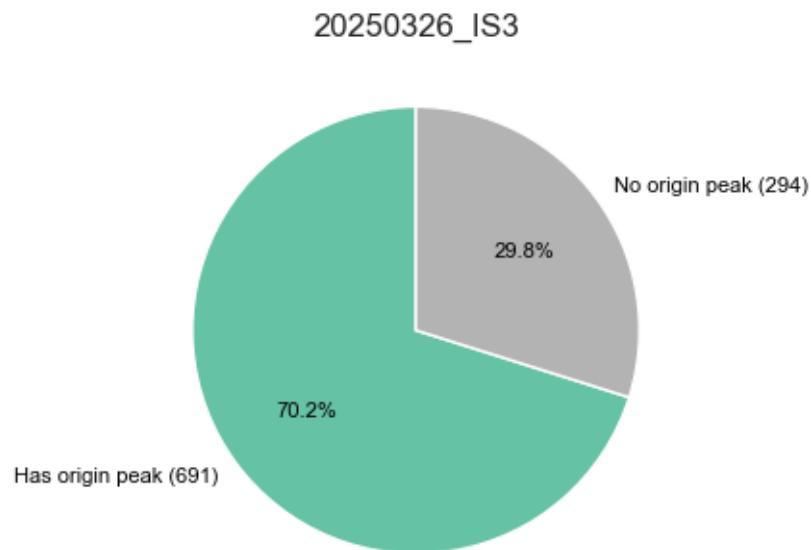
[2025-08-08 14:46:40] [INFO] calcium: Lower bound: -10.1, Upper bound: 34.8

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

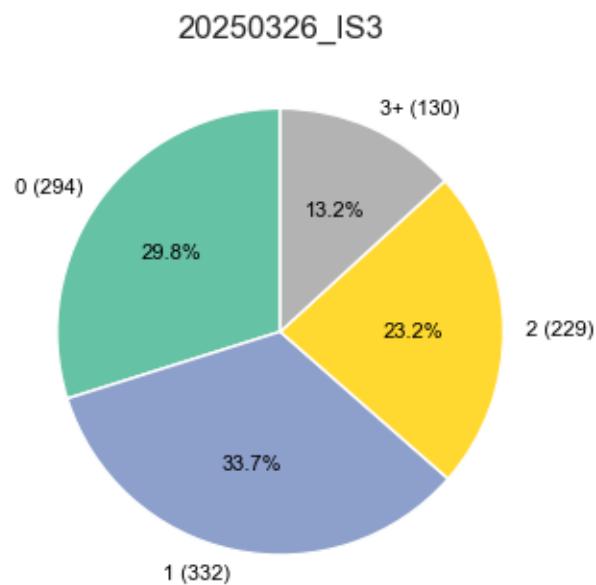


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

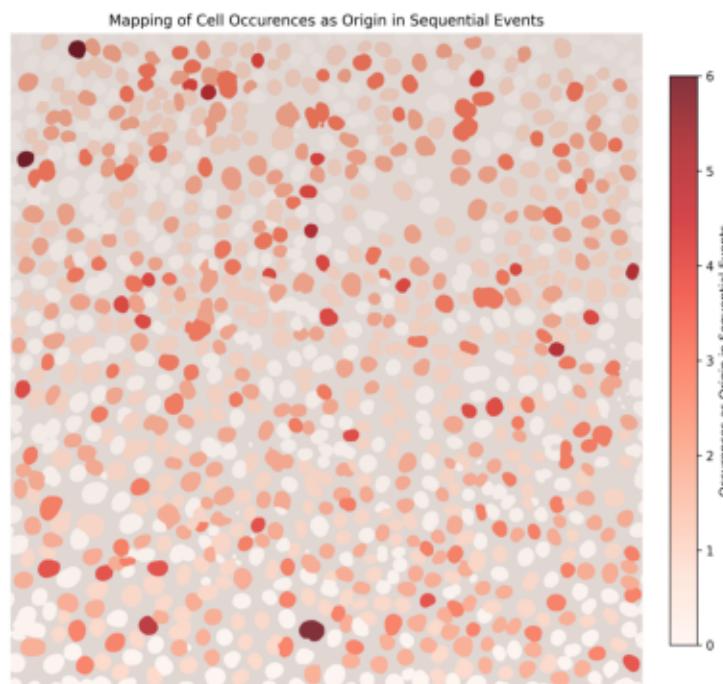


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

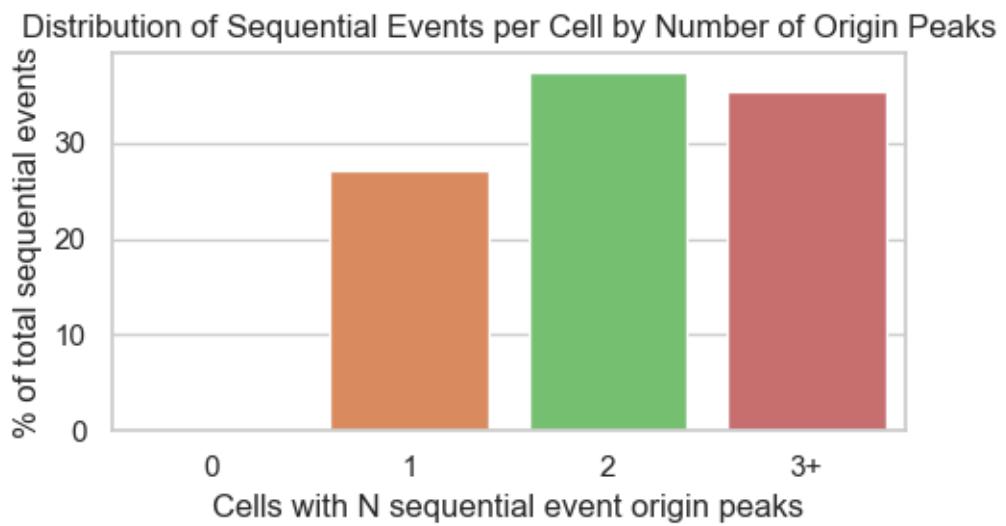
20250326\_IS3



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

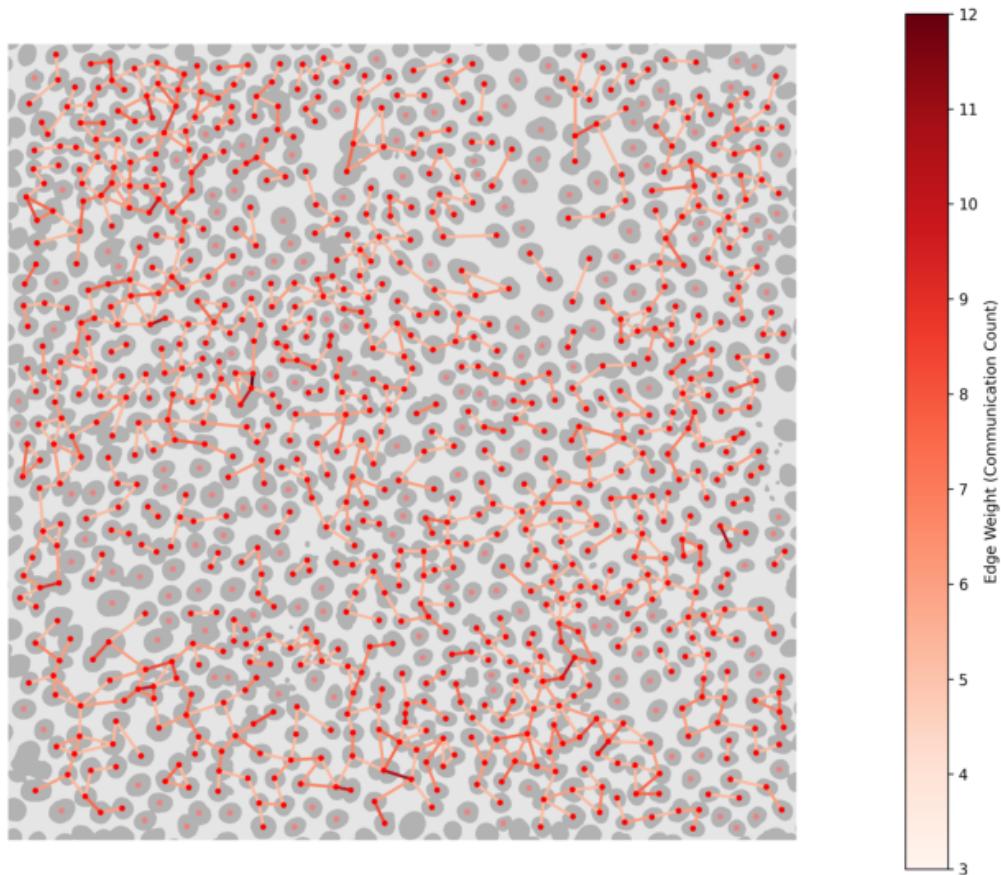


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250326\_IS3

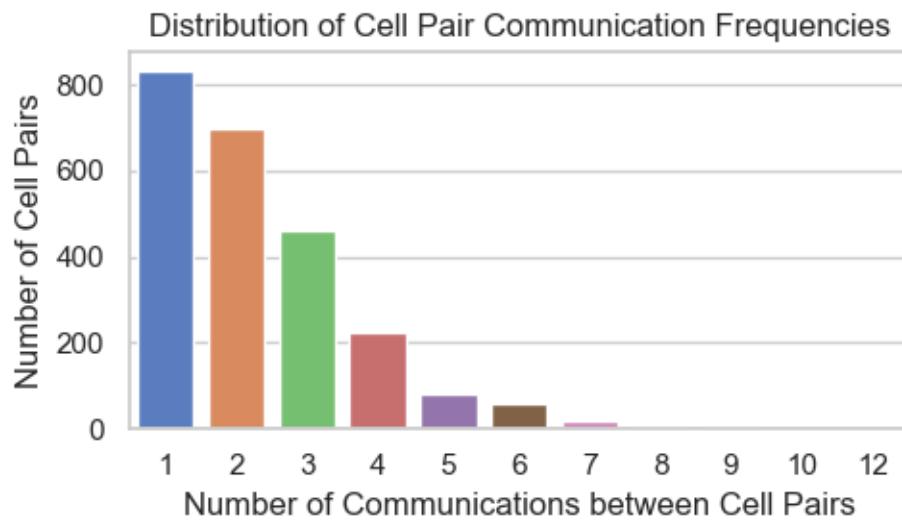
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

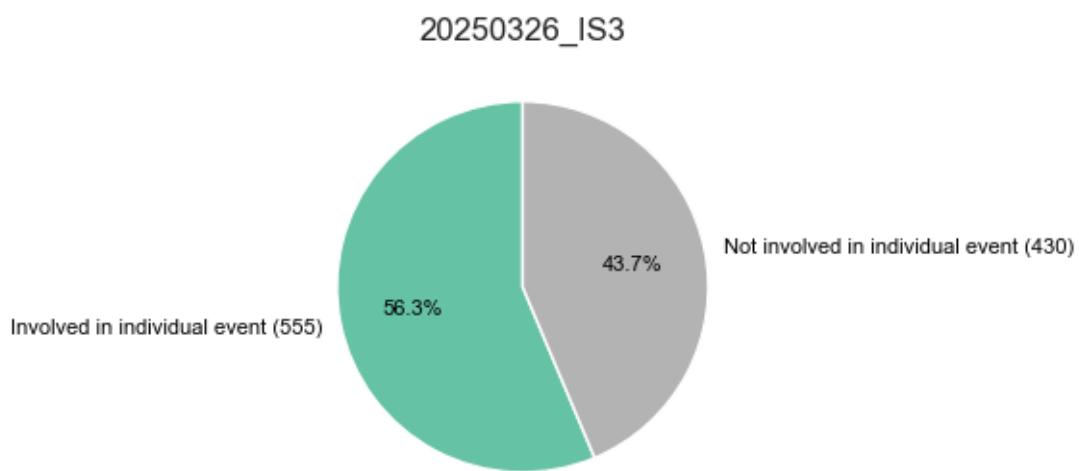
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



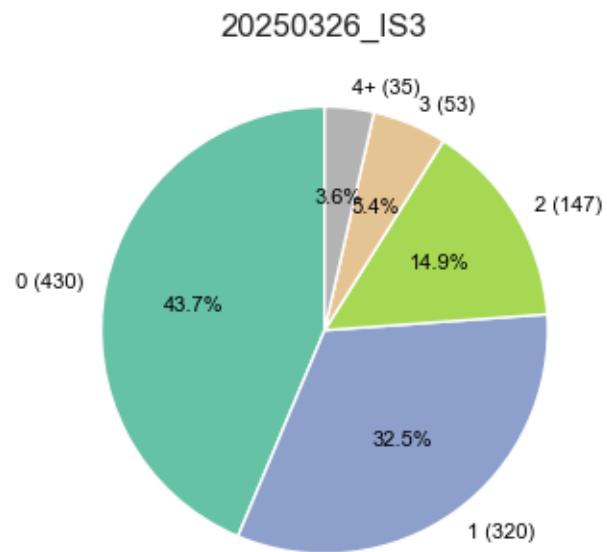
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

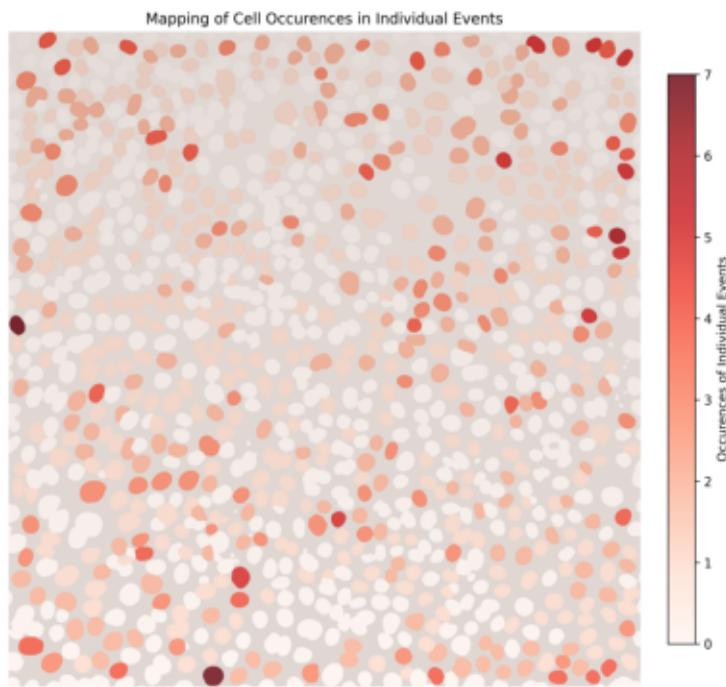


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250326\_IS3

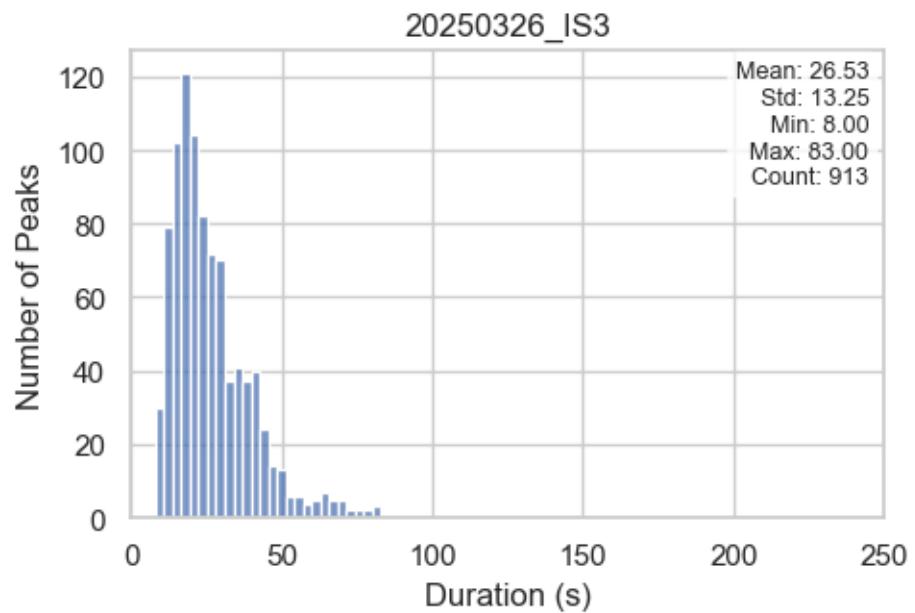


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:46:44] [INFO] calcium: Removed 17 outliers from dataset  
'20250326_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:46:44] [INFO] calcium: Lower bound: -8.125, Upper bound: 84.0
```

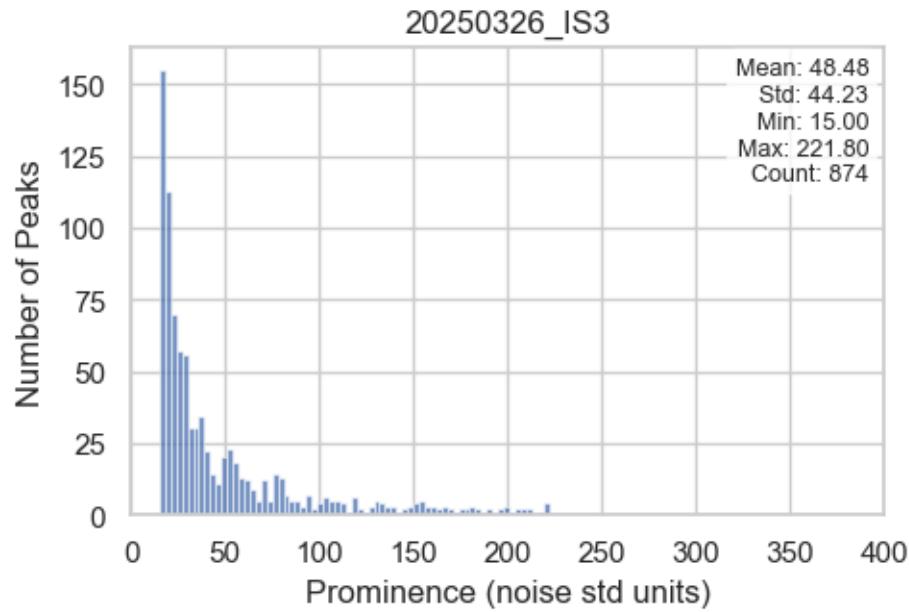
## Distribution of Peak Durations



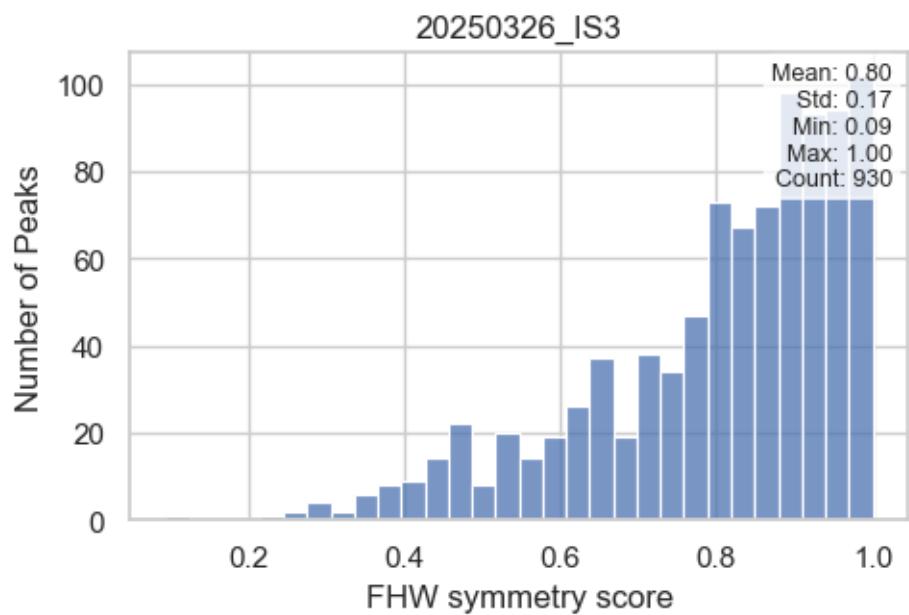
```
[2025-08-08 14:46:44] [INFO] calcium: Removed 56 outliers from dataset '20250326_IS3' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:46:44] [INFO] calcium: Lower bound: -55.94999999999996, Upper bound: 222.625
```

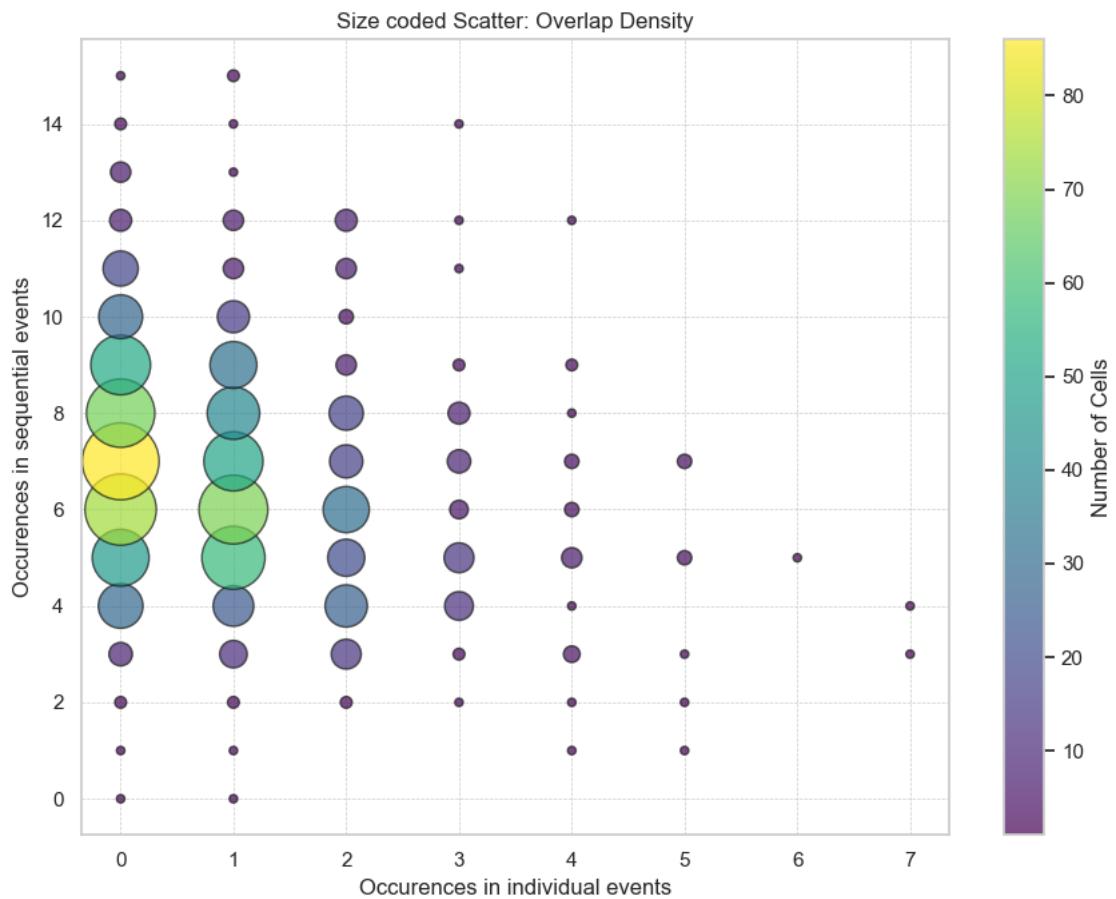
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

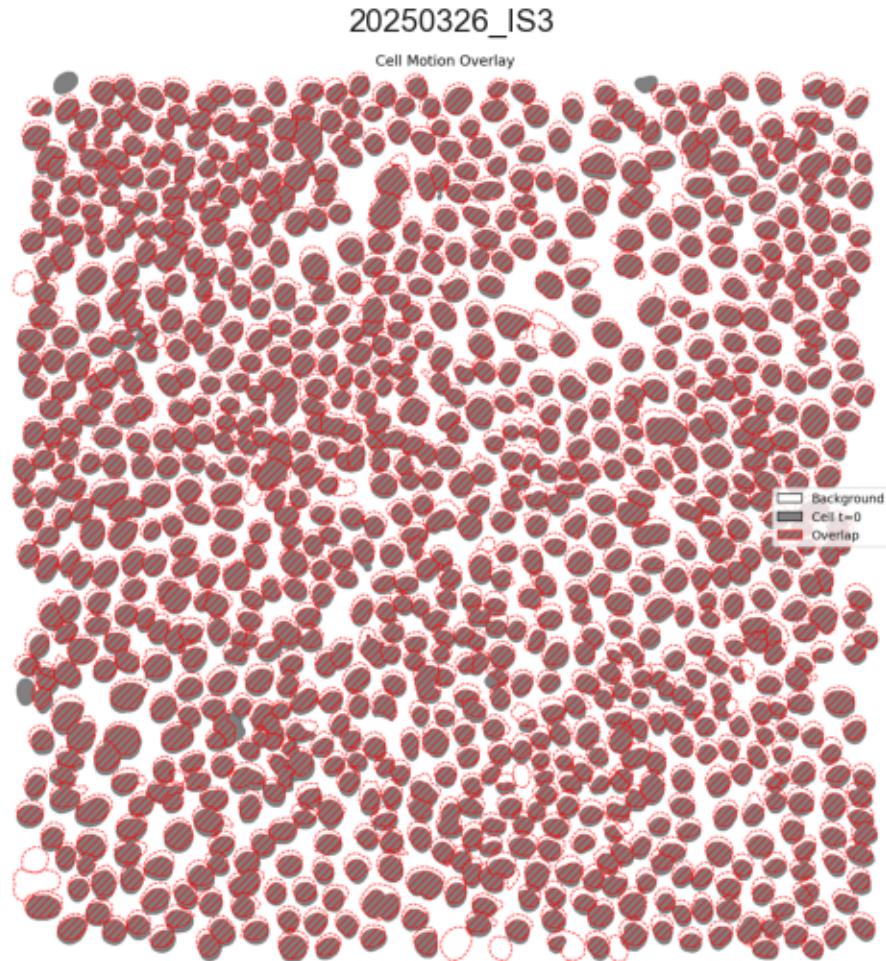


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 985
- Hoechst image taken at t=1801: 999
- Number of cells difference: absolute 14, relative 1.41%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1166809
- Pixels segmented as cell at t=1801: 1288137
- Overlapping pixels between t=0 and t=1801: 937179 (76.35% of total)
- Pixels exclusive to t=0: 229630 (19.68% of total)
- Pixels exclusive to t=1801: 350958 (27.25% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n    "Default Dataset": "/path/to/your/dataset"\n}'
```

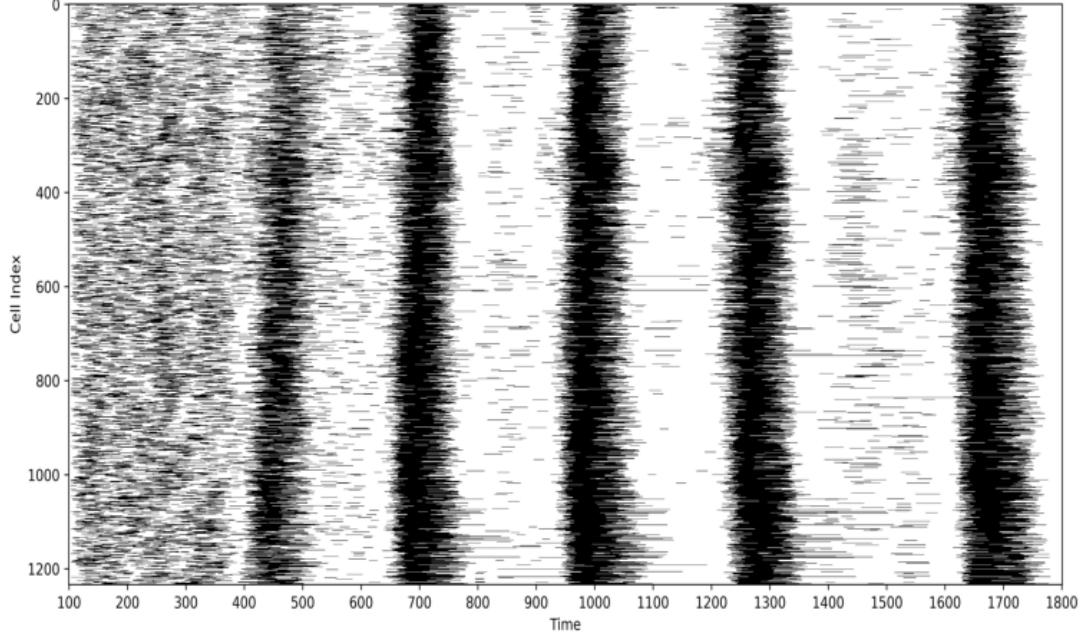
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

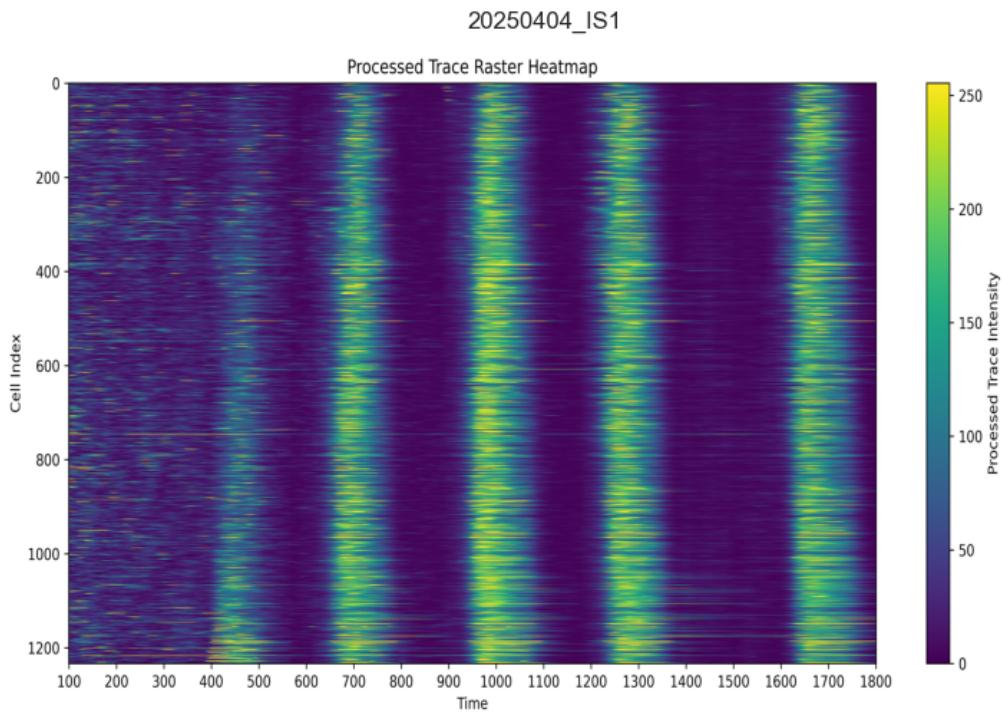
Binary Activity Raster Plot

20250404\_IS1

Binarized Activity Raster Plot



## Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 11644

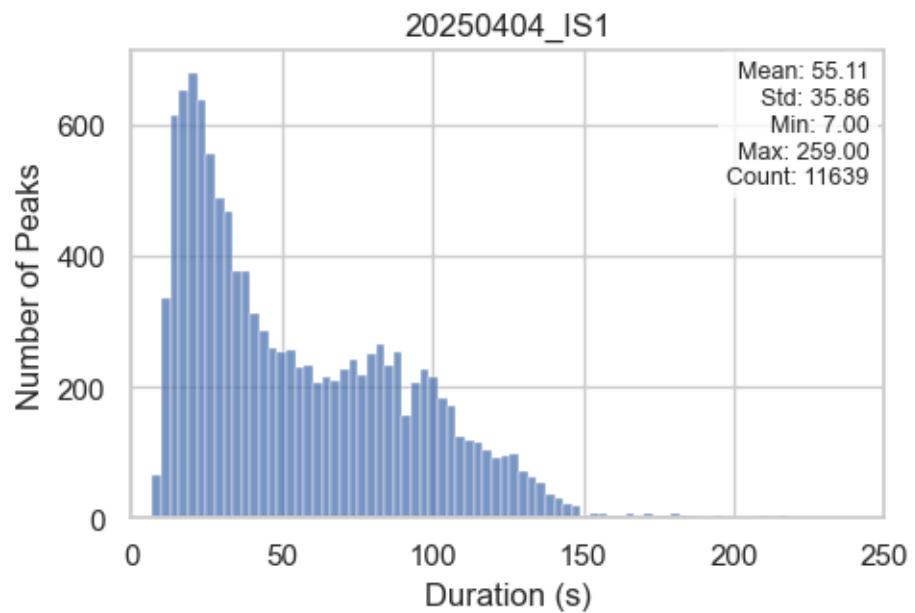
Total number of cells: 1234

### 1.1.3 Peaks statistics

```
[2025-08-08 14:47:36] [INFO] calcium: Removed 5 outliers from dataset  
'20250404_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:47:36] [INFO] calcium: Lower bound: -64.5, Upper bound: 260.0
```

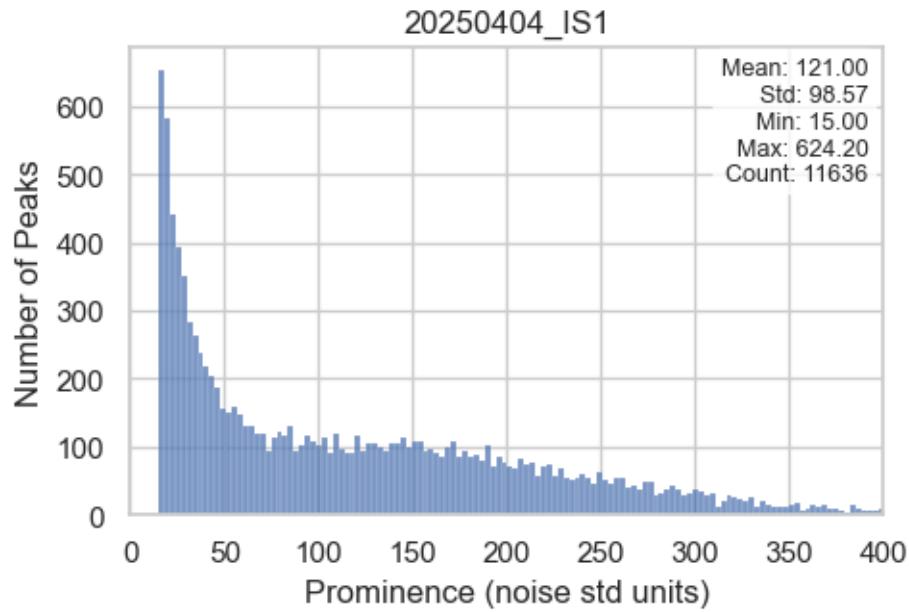
## Distribution of Peak Durations



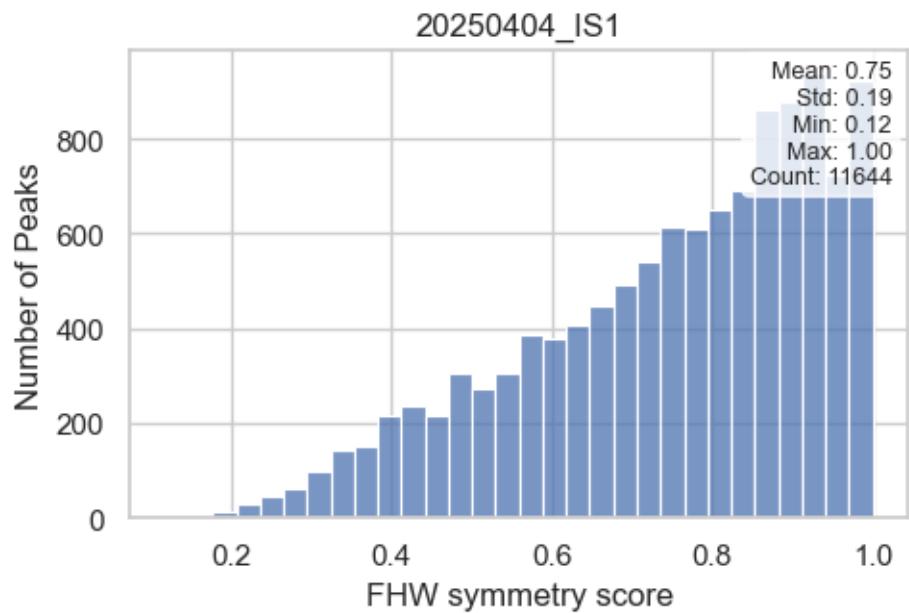
[2025-08-08 14:47:36] [INFO] calcium: Removed 8 outliers from dataset '20250404\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 14:47:36] [INFO] calcium: Lower bound: -185.95, Upper bound: 625.3

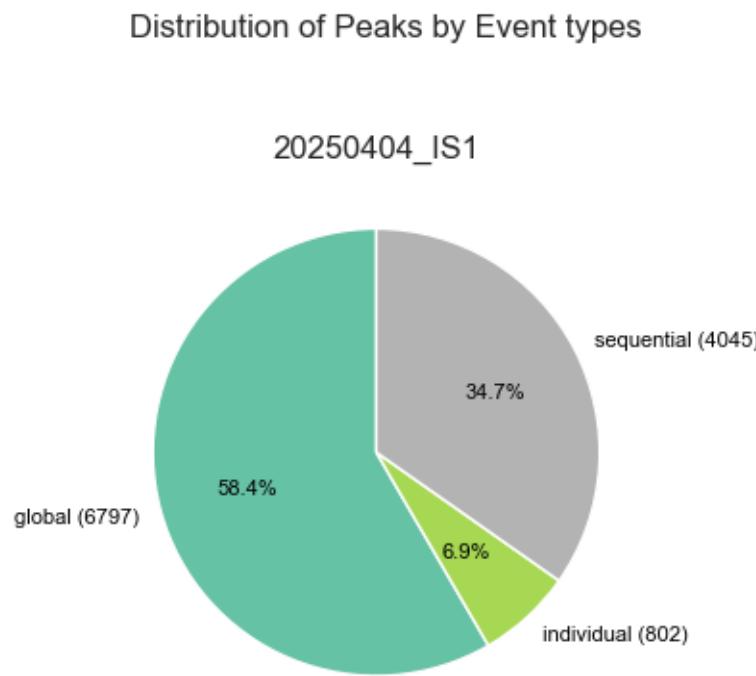
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

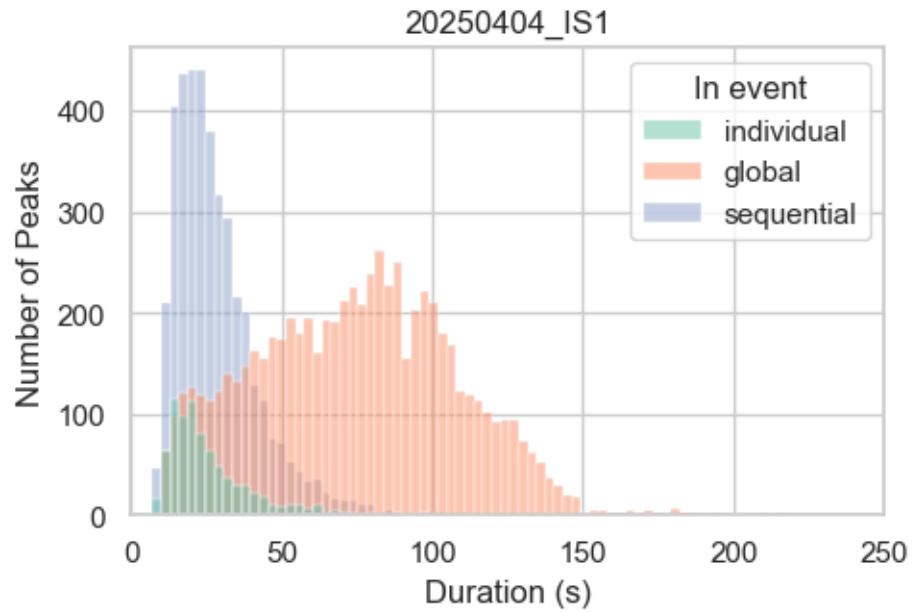


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:47:36] [INFO] calcium: Removed 5 outliers from dataset  
'20250404_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:47:36] [INFO] calcium: Lower bound: -64.5, Upper bound: 260.0
```

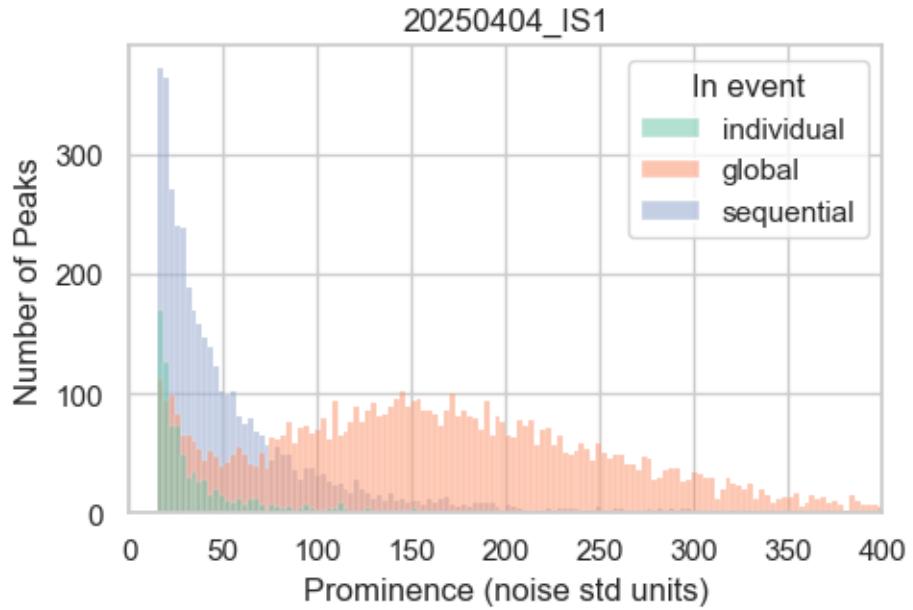
## Distribution of Peak Durations by Group



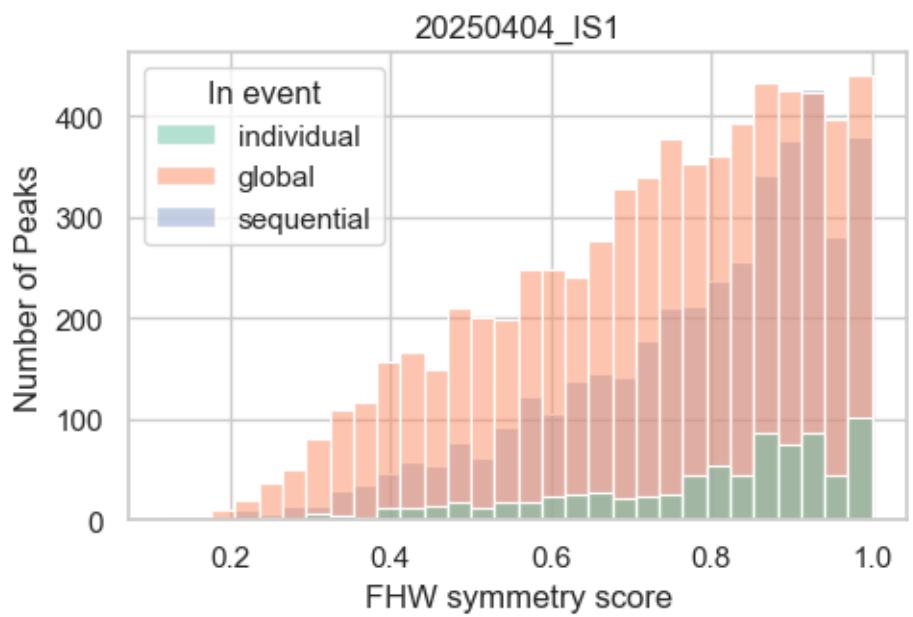
[2025-08-08 14:47:36] [INFO] calcium: Removed 8 outliers from dataset '20250404\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 14:47:37] [INFO] calcium: Lower bound: -185.9, Upper bound: 625.3

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



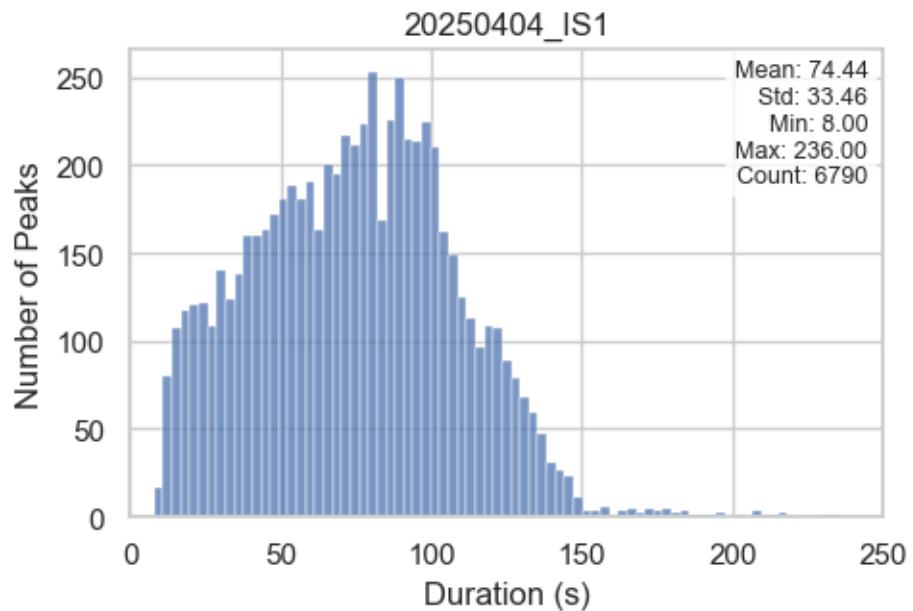
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:47:37] [INFO] calcium: Removed 7 outliers from dataset  
'20250404_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:47:37] [INFO] calcium: Lower bound: -24.5, Upper bound: 245.0
```

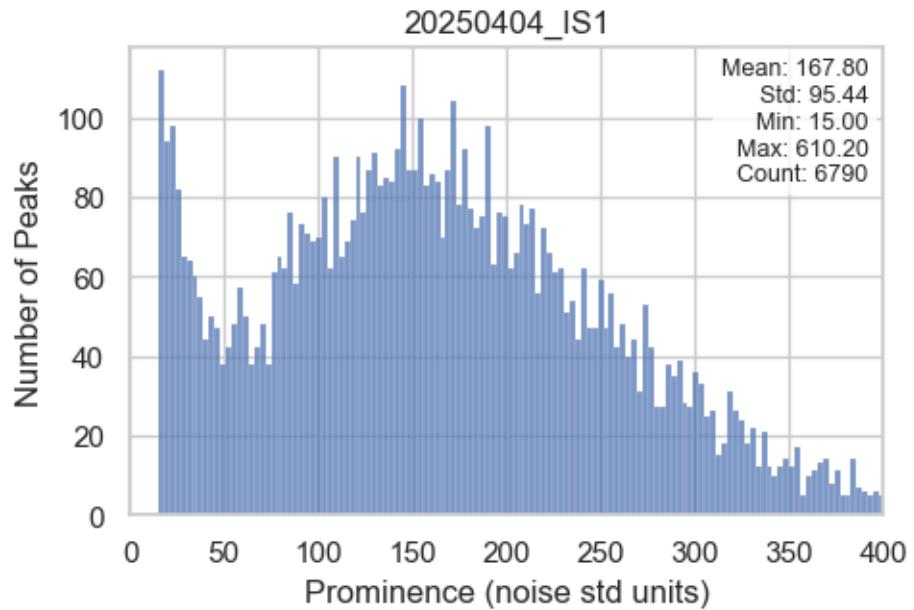
Distribution of Peak Durations



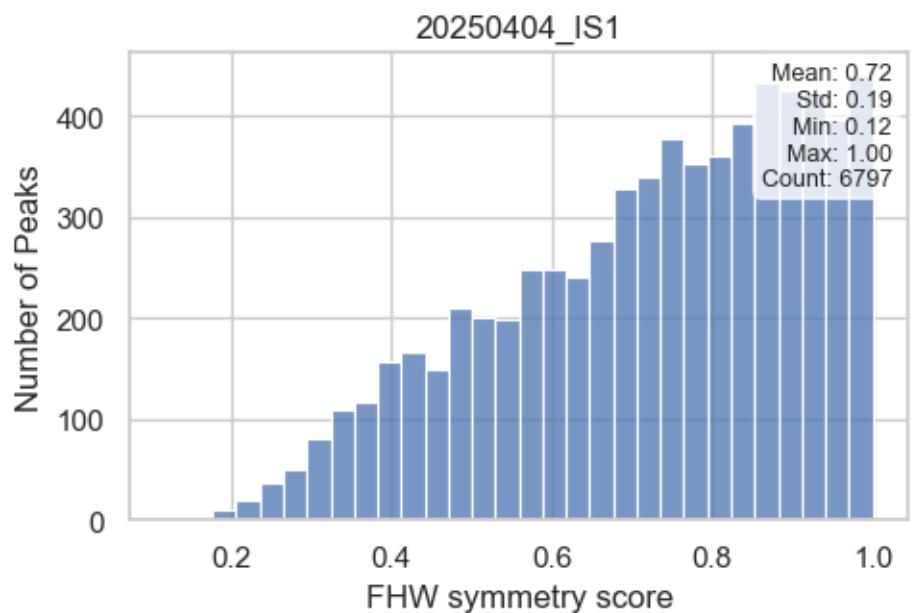
```
[2025-08-08 14:47:37] [INFO] calcium: Removed 7 outliers from dataset  
'20250404_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:47:37] [INFO] calcium: Lower bound: -93.8999999999998, Upper  
bound: 611.199999999999
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

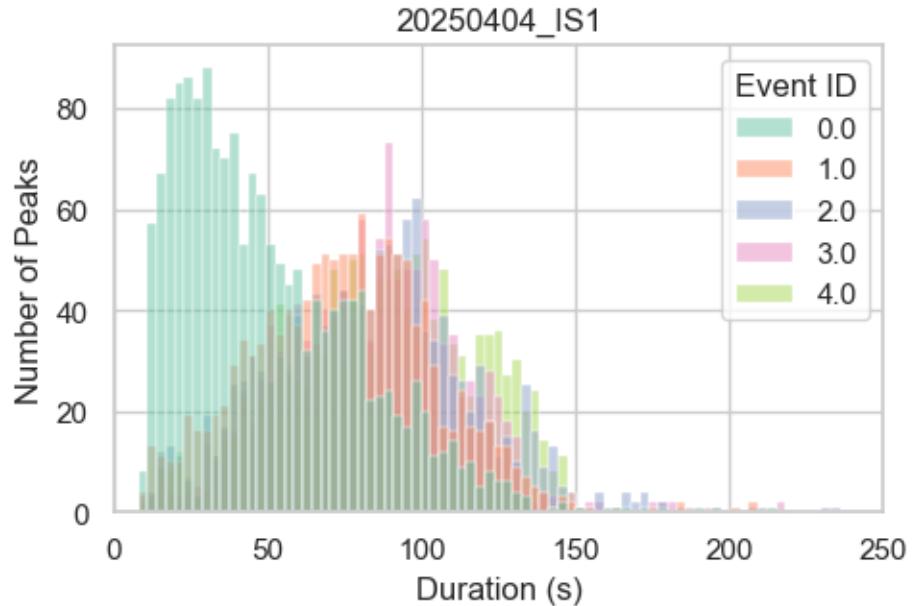


### 1.2.2 Peak statistics in global event per event ID

[2025-08-08 14:47:38] [INFO] calcium: Removed 7 outliers from dataset '20250404\_IS1' for column 'Duration (s)'

[2025-08-08 14:47:38] [INFO] calcium: Lower bound: -24.5, Upper bound: 245.0

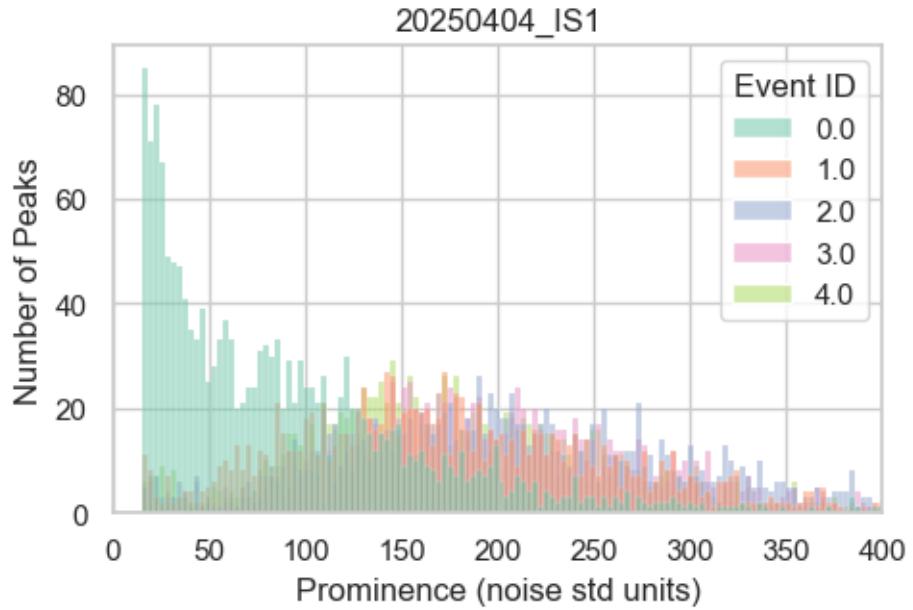
Distribution of Peak Durations by Group



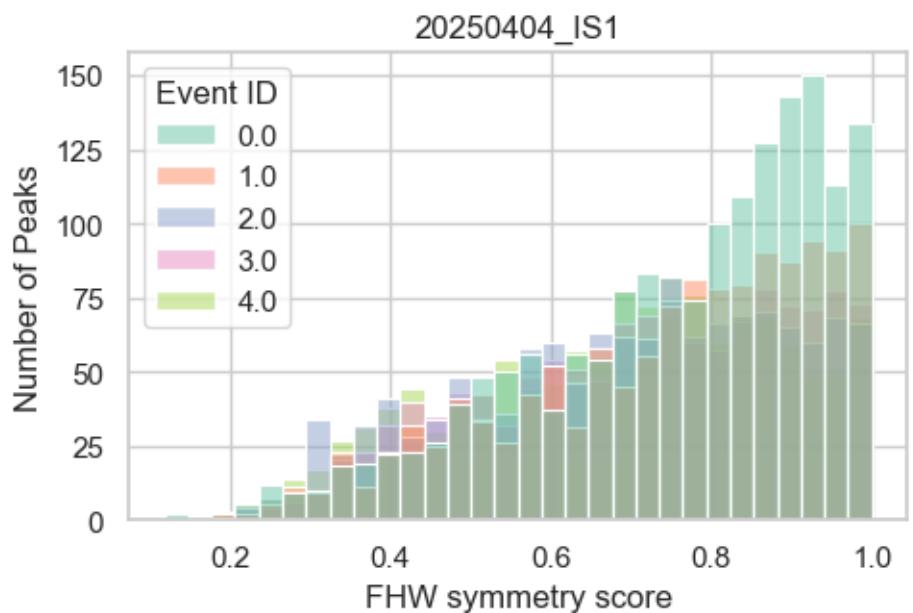
[2025-08-08 14:47:38] [INFO] calcium: Removed 7 outliers from dataset '20250404\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 14:47:38] [INFO] calcium: Lower bound: -93.9, Upper bound: 611.2

### Distribution of Peak Prominences by Group



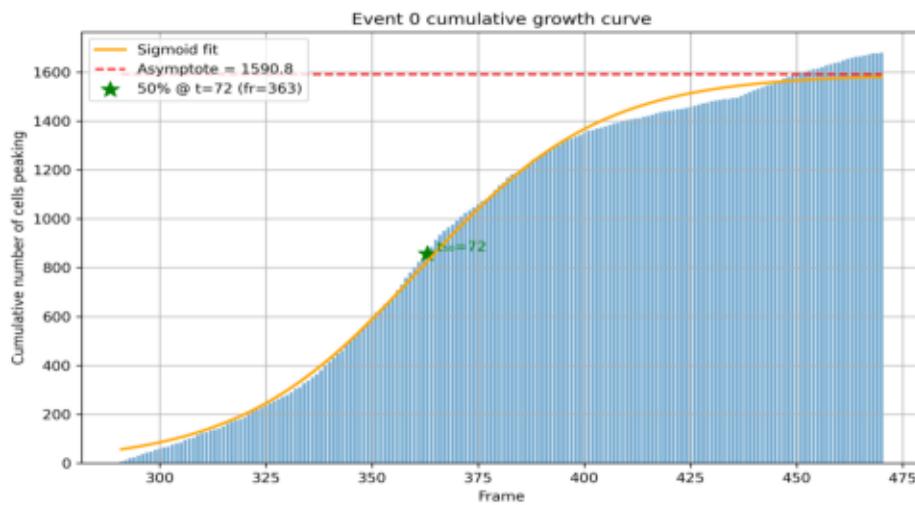
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

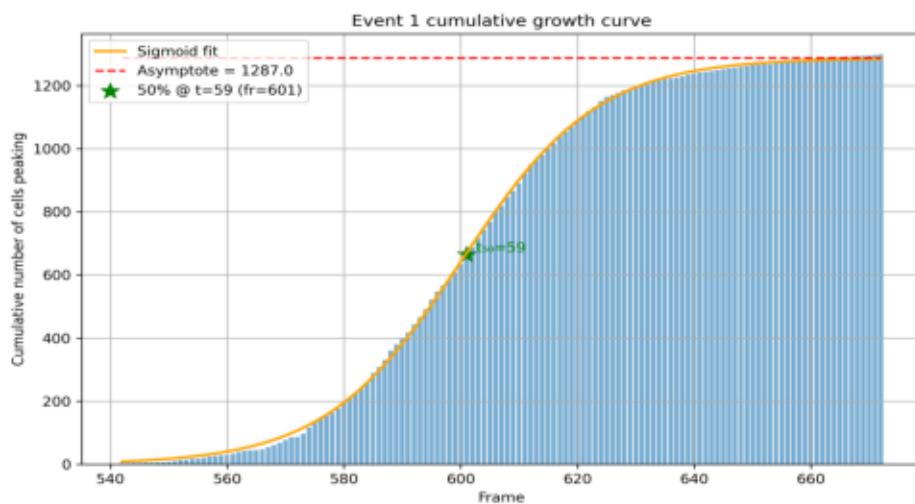
Event Activity Overlay (Event ID: 0)

20250404\_IS1



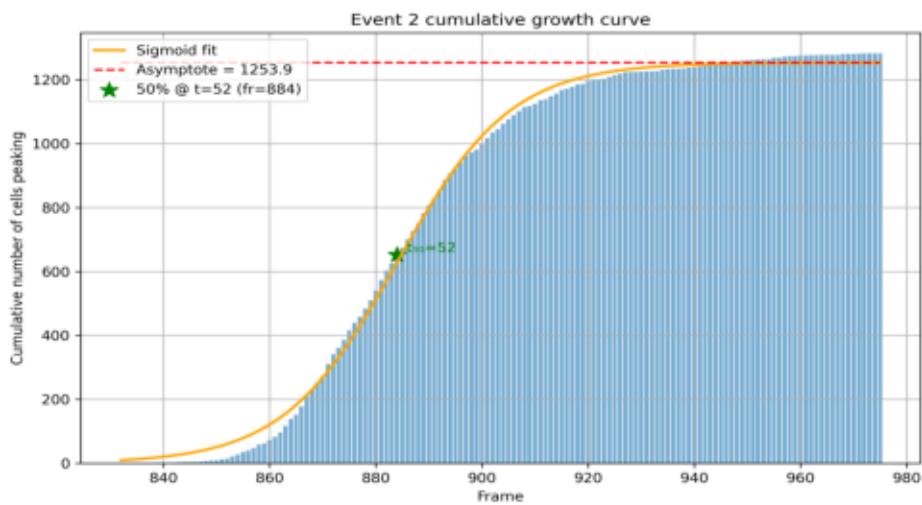
Event Activity Overlay (Event ID: 1)

20250404\_IS1



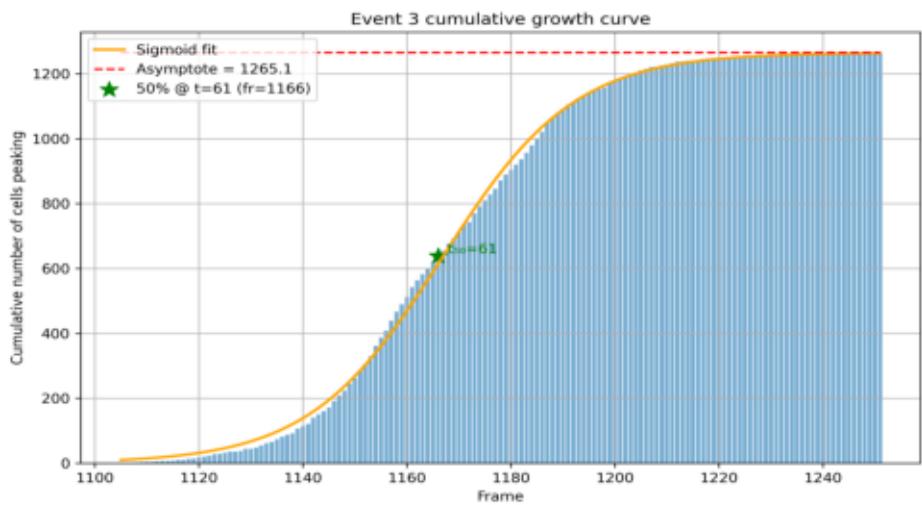
### Event Activity Overlay (Event ID: 2)

20250404\_IS1



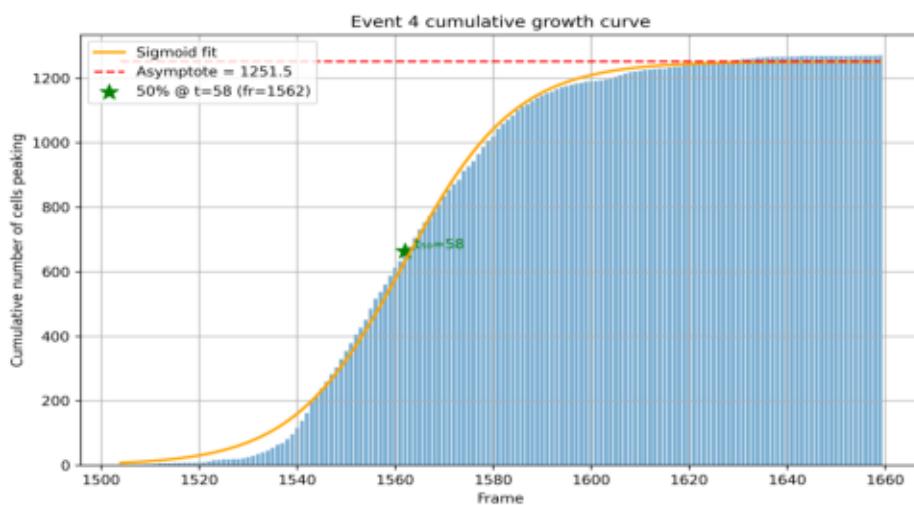
### Event Activity Overlay (Event ID: 3)

20250404\_IS1



## Event Activity Overlay (Event ID: 4)

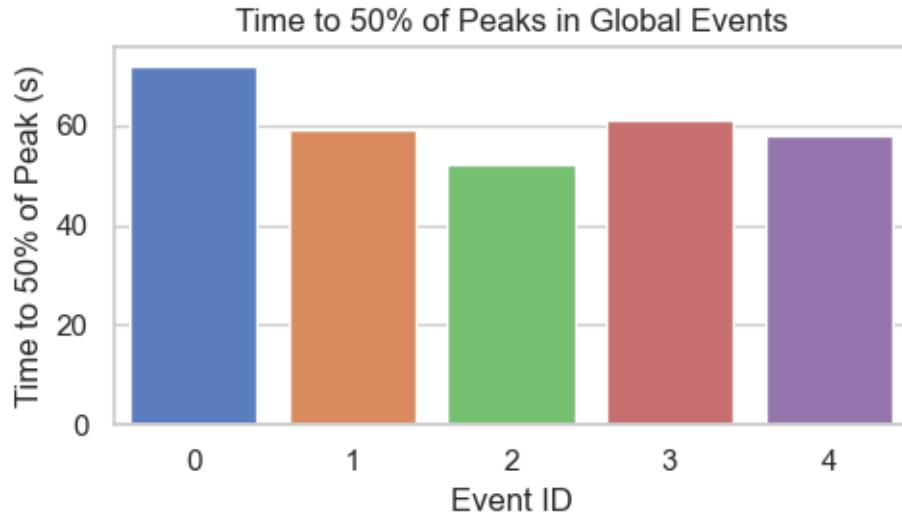
20250404\_IS1



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

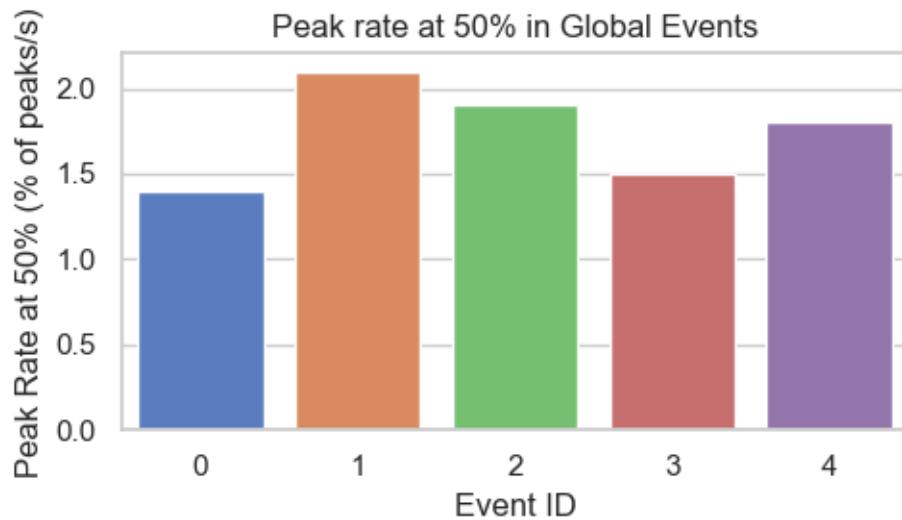
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys
is\visualizers.py:297: FutureWarning:
```

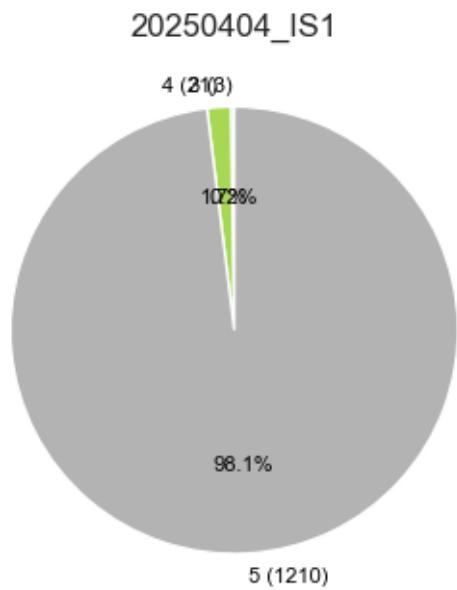
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,
dodge=False, palette=palette, legend=False)
```



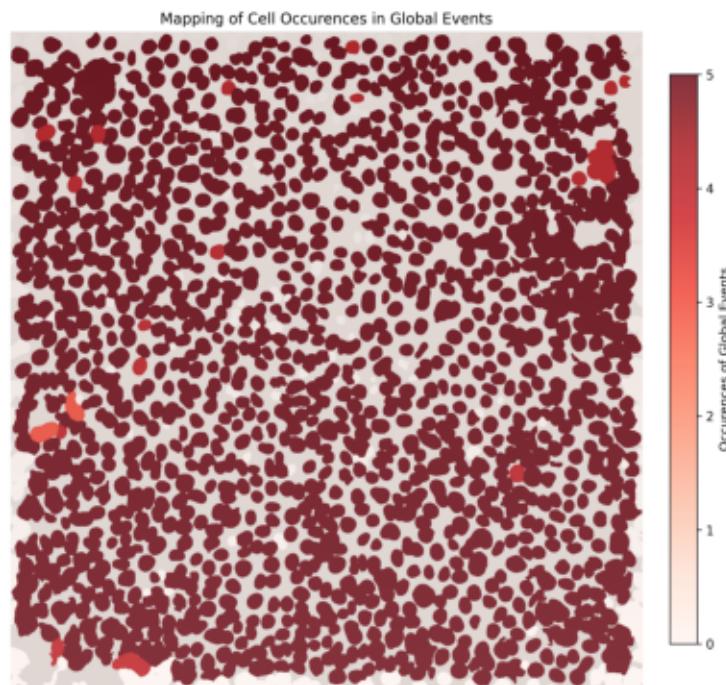
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

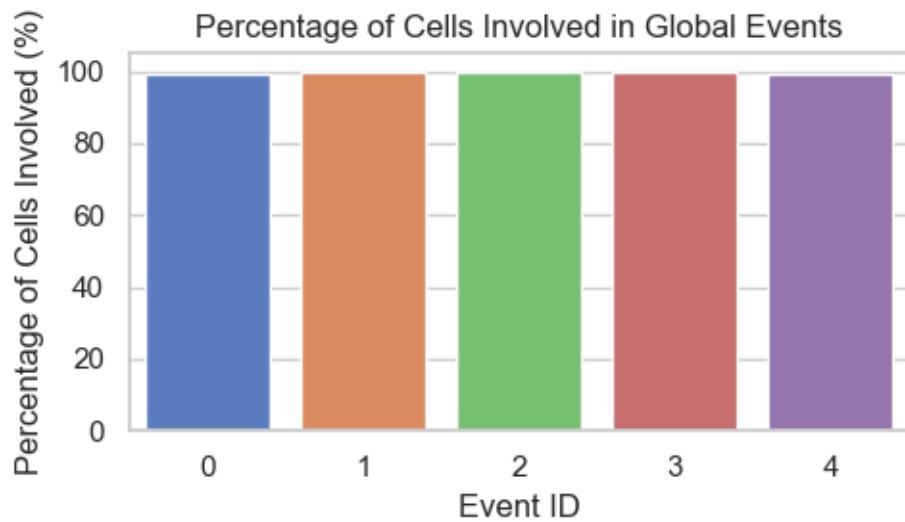
20250404\_IS1



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [241.0, 286.0, 281.0, 396.0]

Estimated periodicity: 0.839

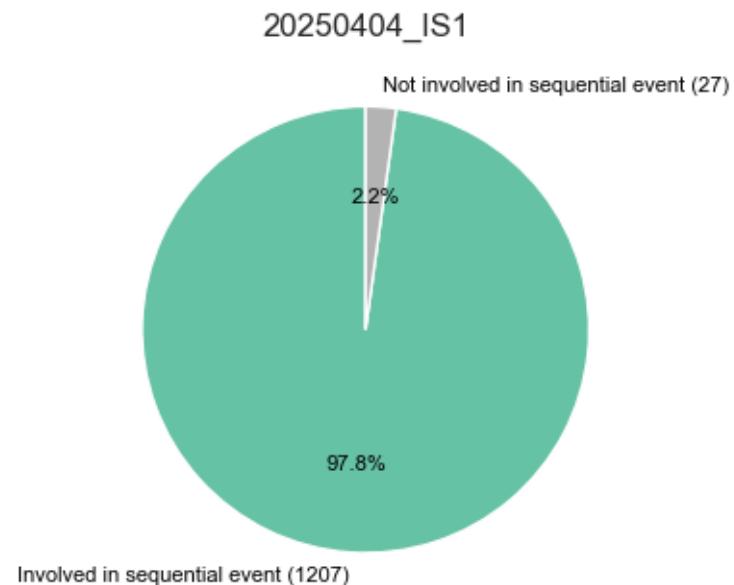
The global events exhibit a regular periodic pattern.

Estimated frequency (1/mean interval): 0.003 Hz

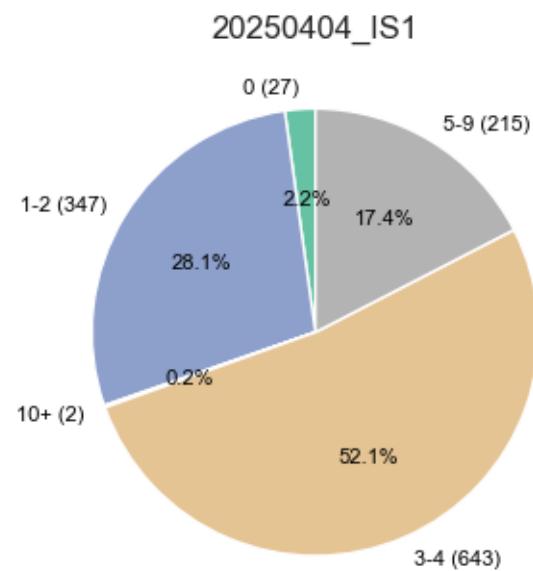
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

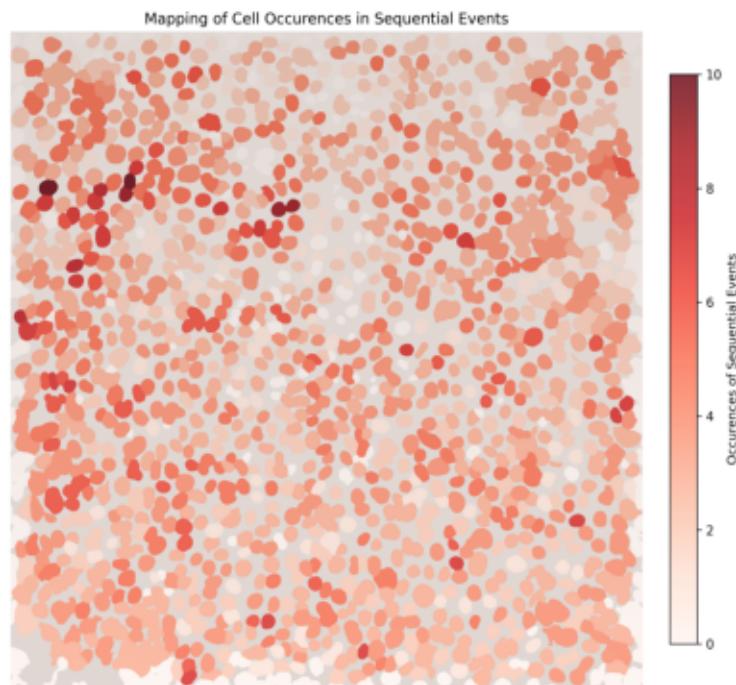


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250404\_IS1

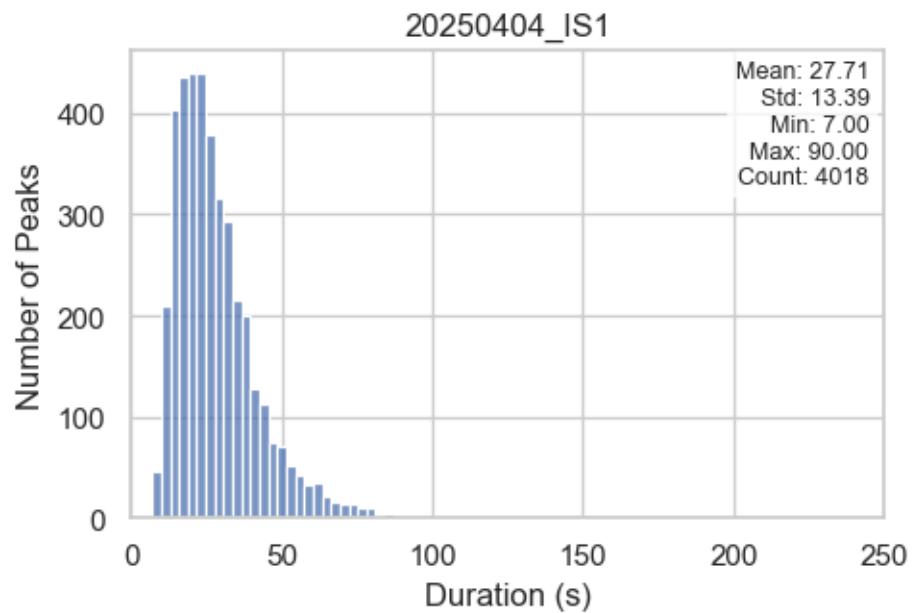


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:47:45] [INFO] calcium: Removed 27 outliers from dataset  
'20250404_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:47:45] [INFO] calcium: Lower bound: -6.0, Upper bound: 90.0
```

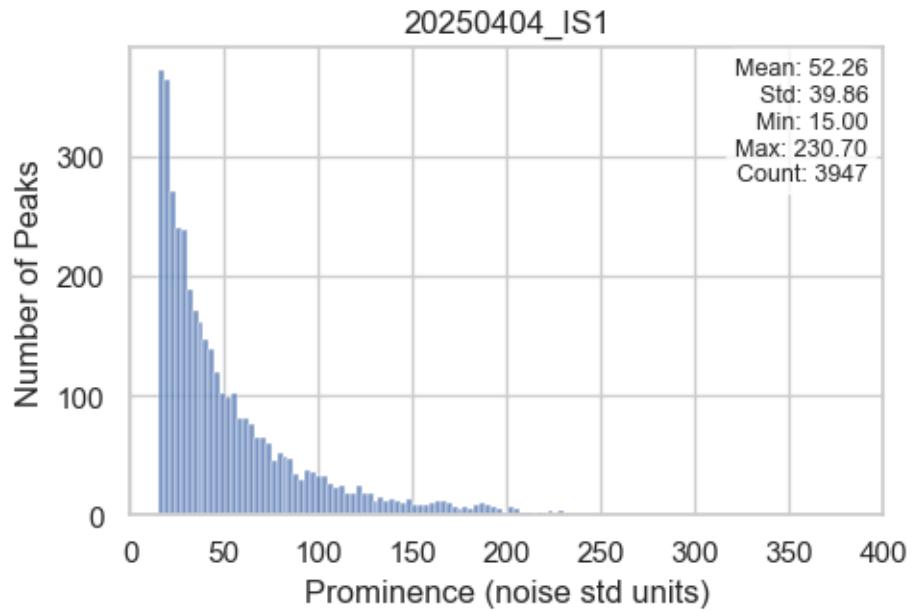
## Distribution of Peak Durations



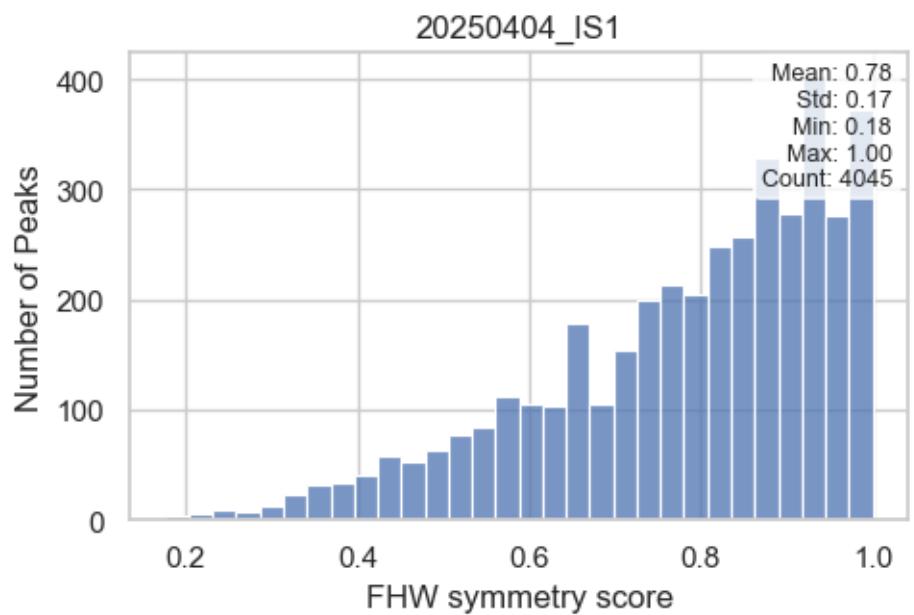
```
[2025-08-08 14:47:45] [INFO] calcium: Removed 98 outliers from dataset '20250404_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:47:45] [INFO] calcium: Lower bound: -45.0, Upper bound: 231.0
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

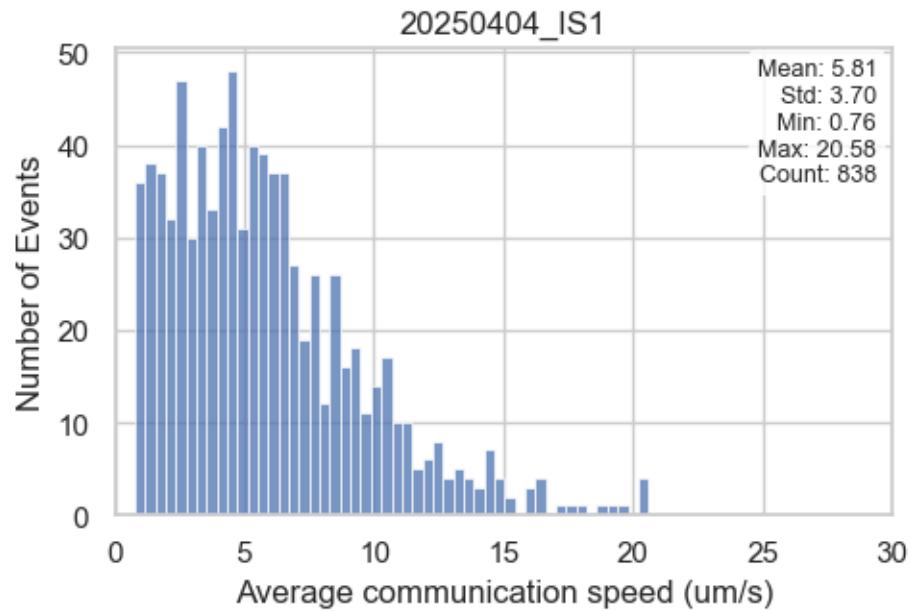


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:47:45] [INFO] calcium: Removed 1 outliers from dataset '20250404\_IS1' for column 'Average communication speed (um/s)'

[2025-08-08 14:47:45] [INFO] calcium: Lower bound: -3.9775000000000005, Upper bound: 21.845

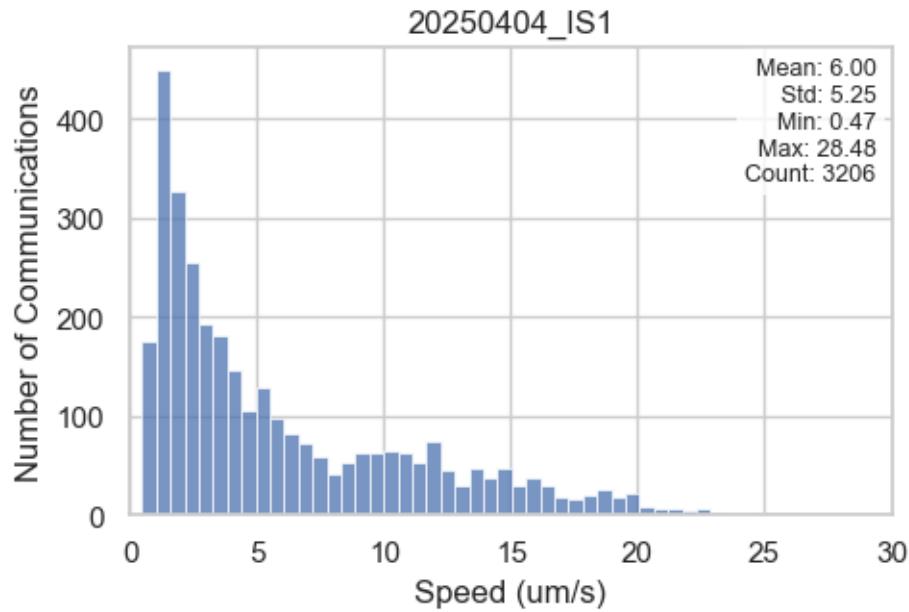
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:47:45] [INFO] calcium: Removed 0 outliers from dataset '20250404\_IS1' for column 'Speed (um/s)'

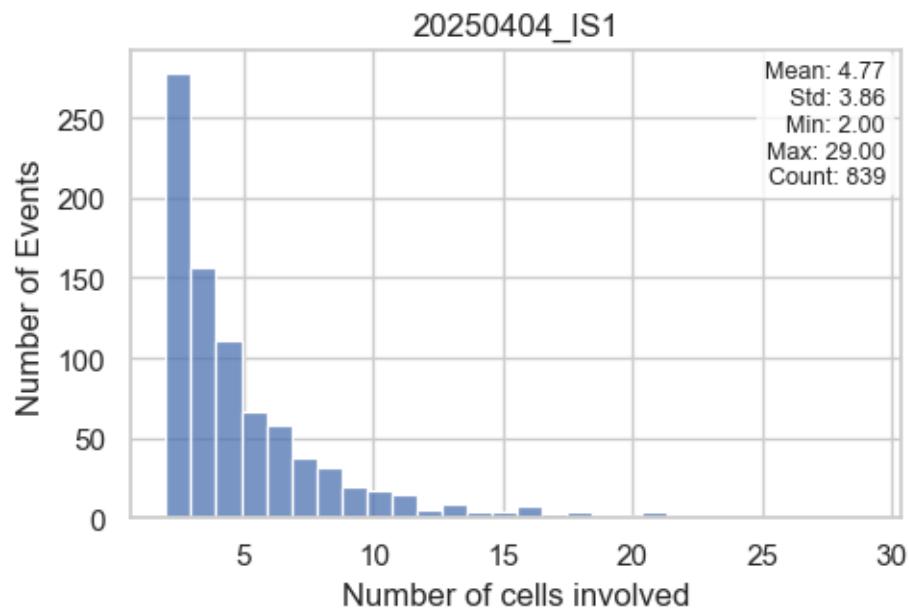
[2025-08-08 14:47:45] [INFO] calcium: Lower bound: -9.257499999999999, Upper bound: 31.5525

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

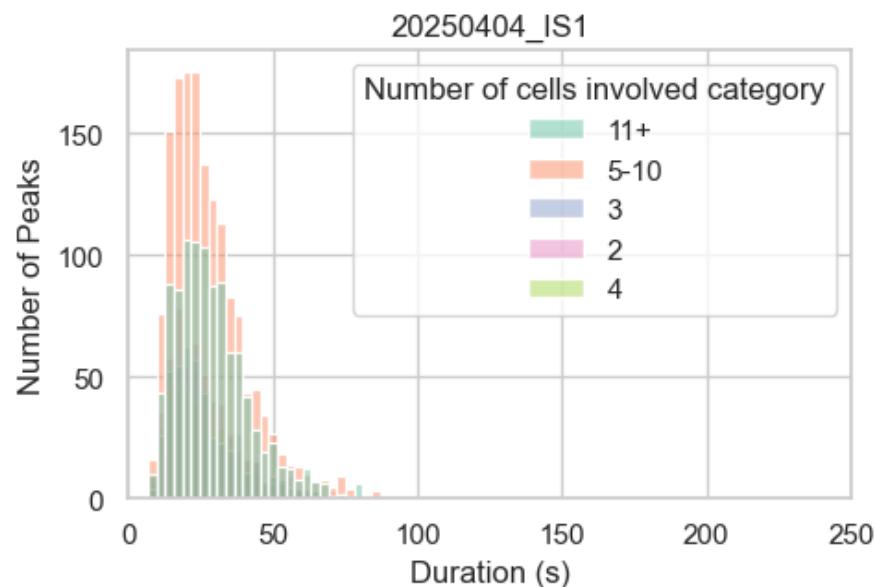


### 1.3.5 Influence of cell count per event on statistics

```
[2025-08-08 14:47:46] [INFO] calcium: Removed 27 outliers from dataset  
'20250404_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:47:46] [INFO] calcium: Lower bound: -6.0, Upper bound: 90.0
```

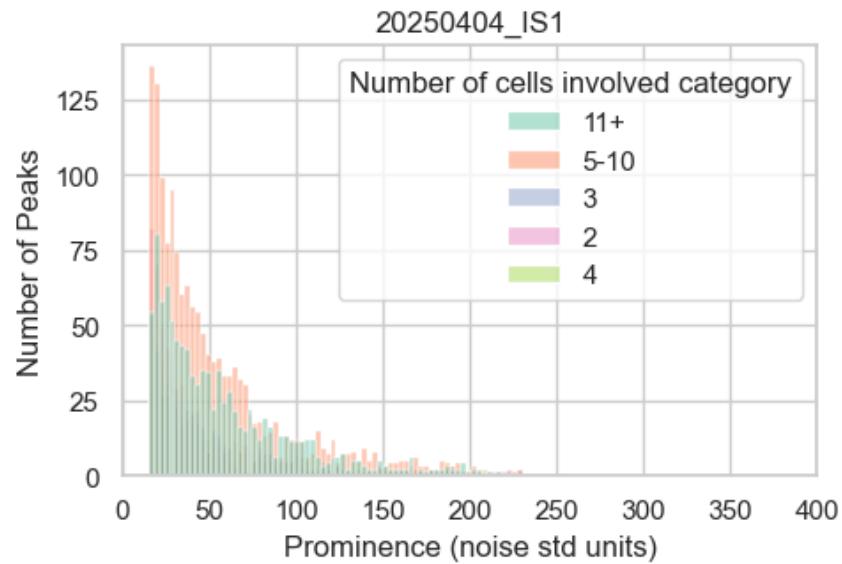
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



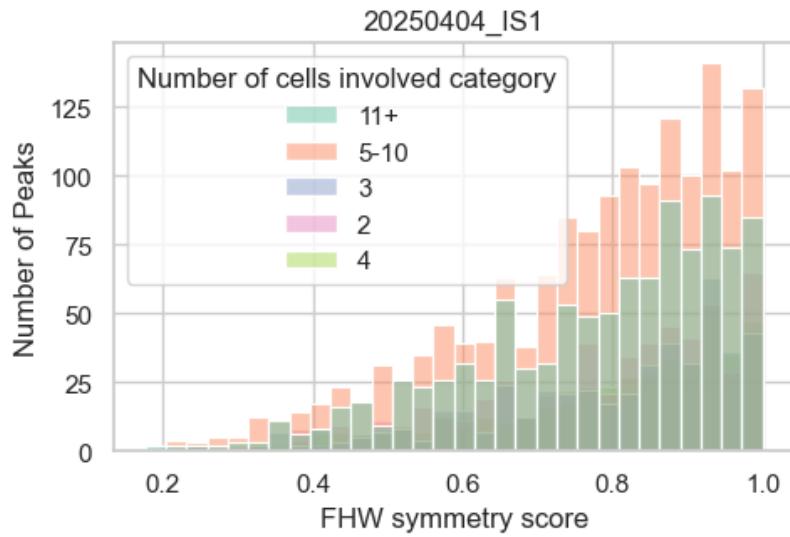
```
[2025-08-08 14:47:46] [INFO] calcium: Removed 98 outliers from dataset  
'20250404_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:47:46] [INFO] calcium: Lower bound: -45.0, Upper bound: 231.0
```

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



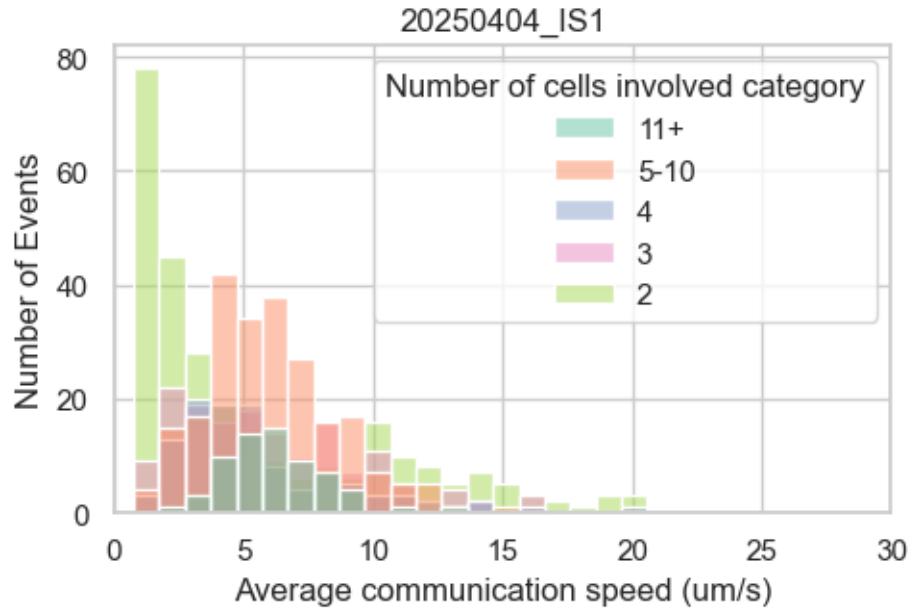
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 14:47:47] [INFO] calcium: Removed 1 outliers from dataset  
'20250404_IS1' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 14:47:47] [INFO] calcium: Lower bound: -4.0, Upper bound: 21.8
```

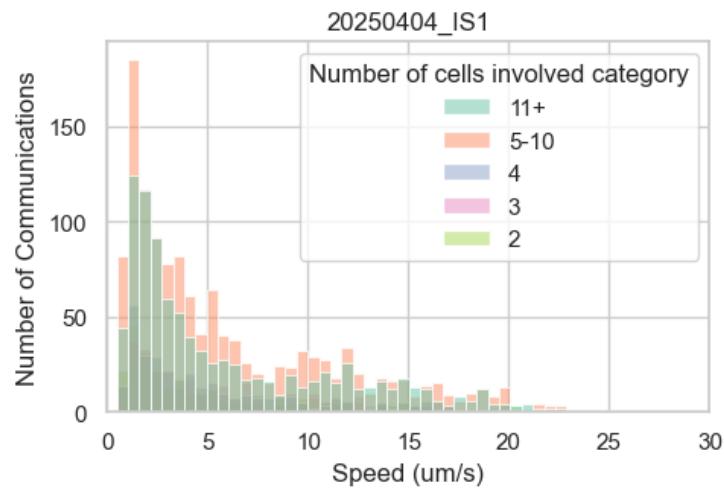
## Distribution of Average Communication Speeds by Number of Cells Involved



[2025-08-08 14:47:47] [INFO] calcium: Removed 0 outliers from dataset '20250404\_IS1' for column 'Speed (um/s)'

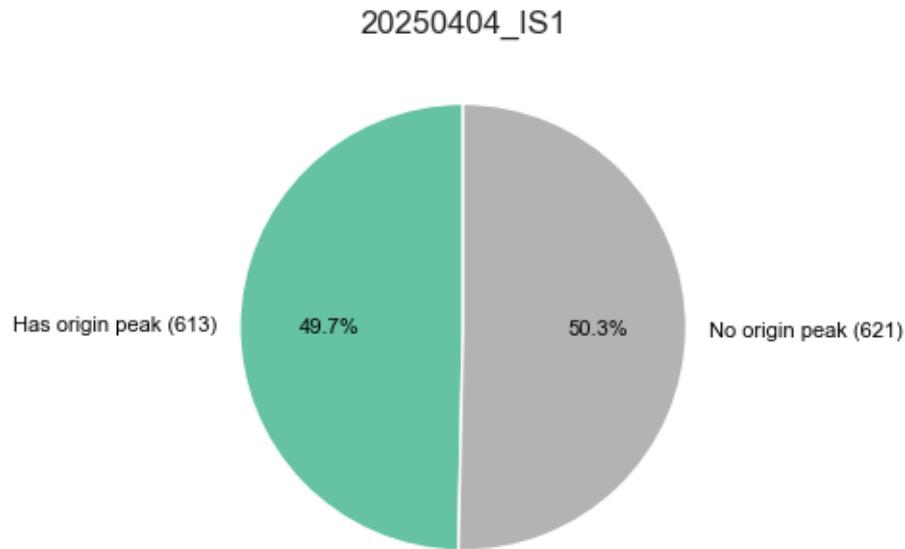
[2025-08-08 14:47:47] [INFO] calcium: Lower bound: -9.3, Upper bound: 31.6

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

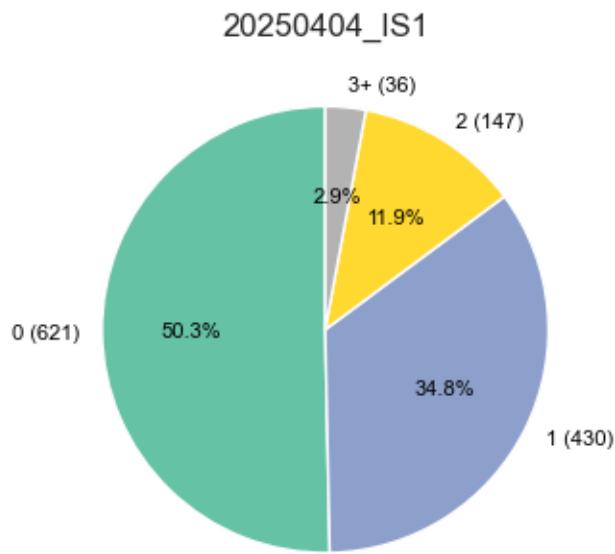


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

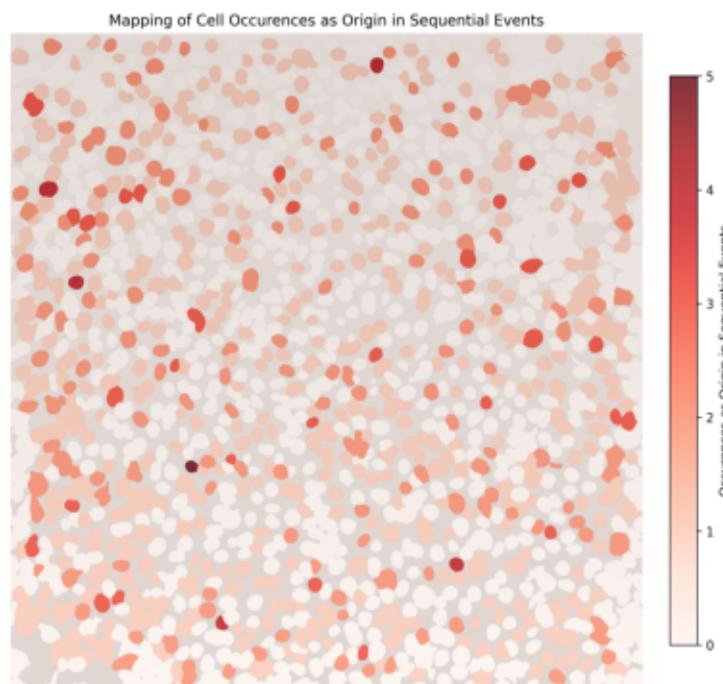


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

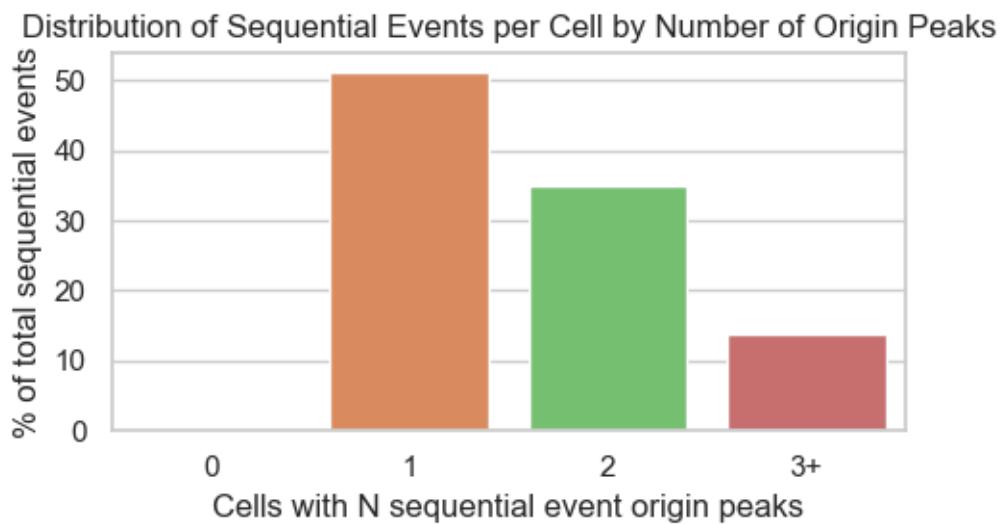
20250404\_IS1



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

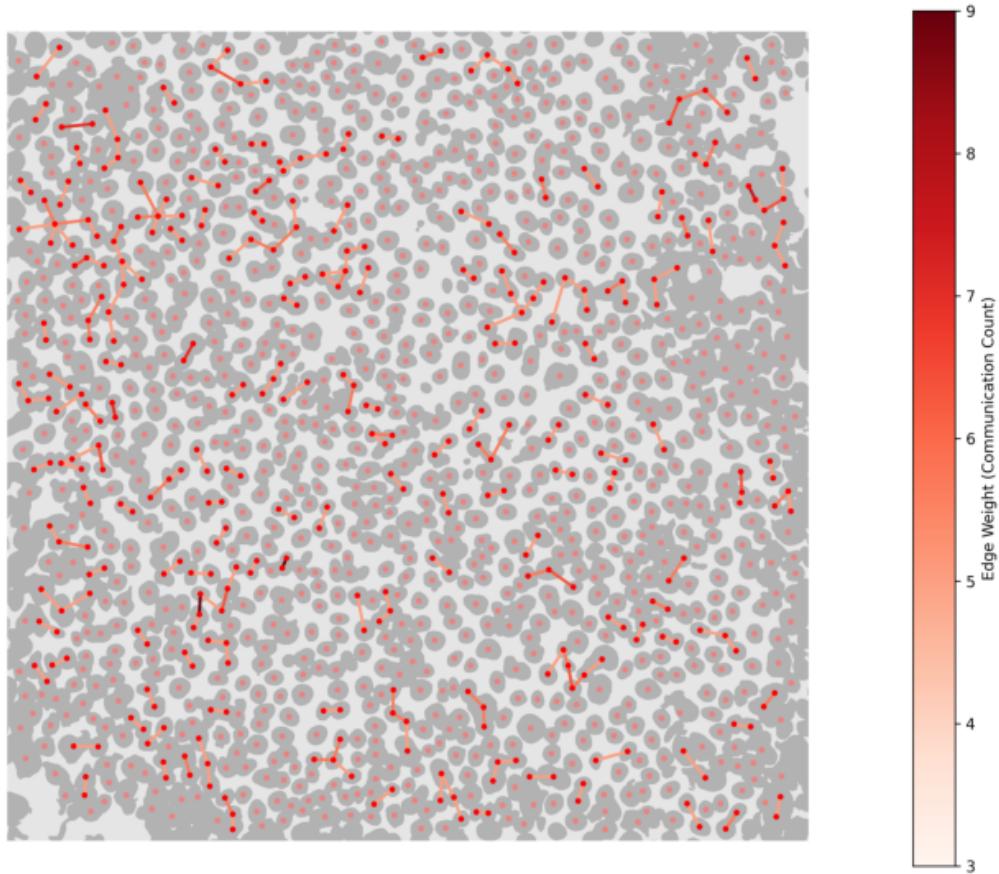


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250404\_IS1

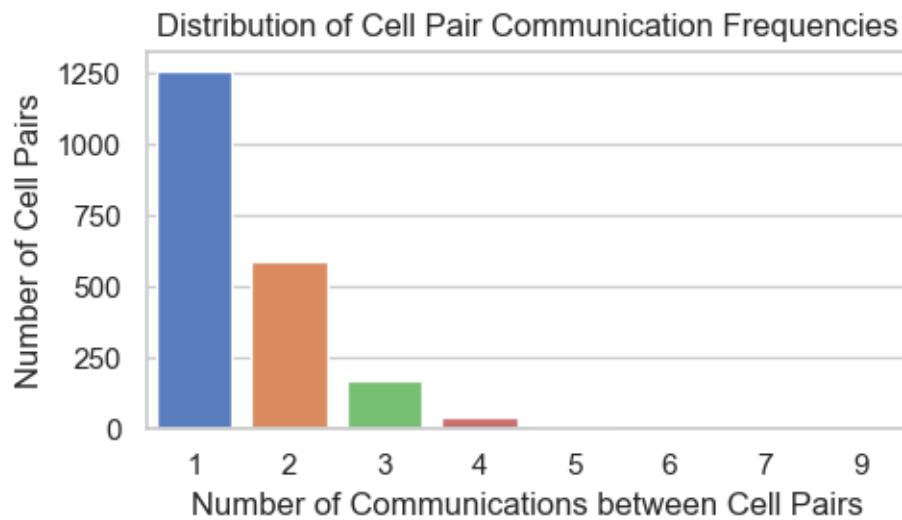
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

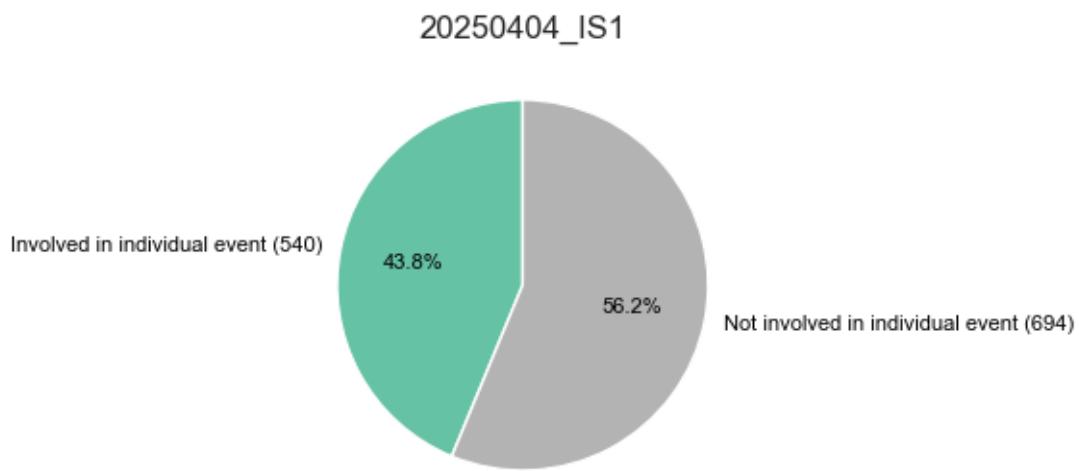
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



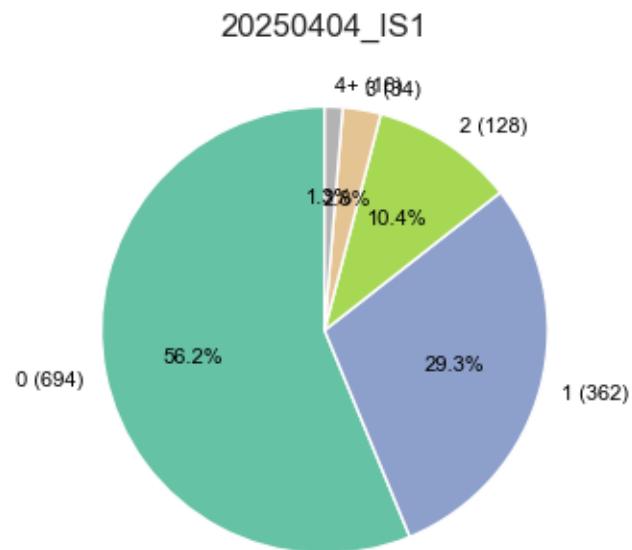
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

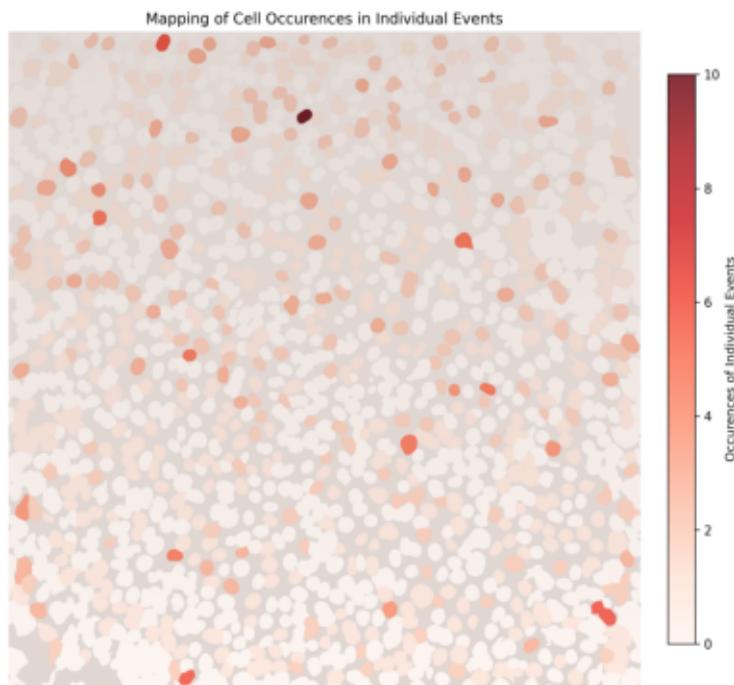


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250404\_IS1

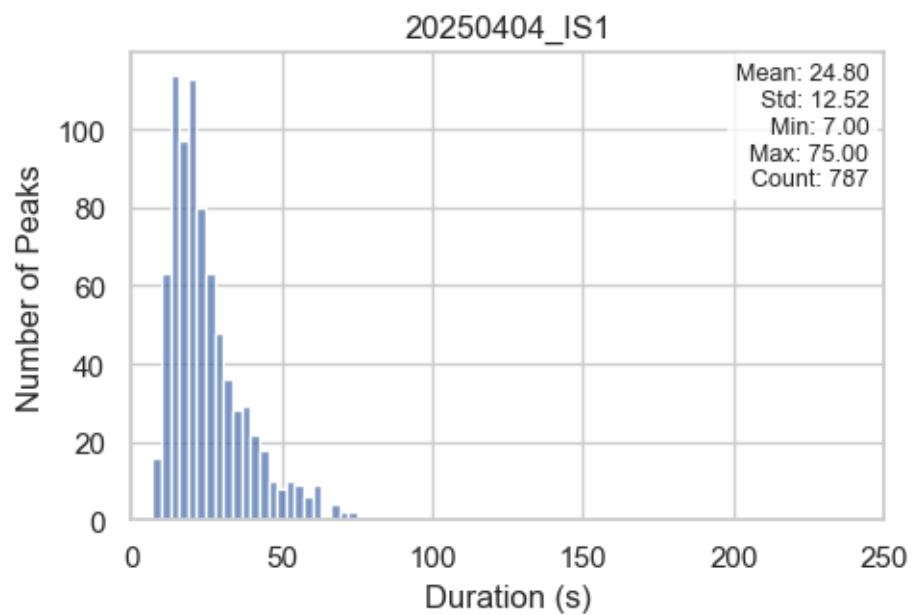


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:47:51] [INFO] calcium: Removed 15 outliers from dataset  
'20250404_IS1' for column 'Duration (s)'
```

```
[2025-08-08 14:47:51] [INFO] calcium: Lower bound: -6.5, Upper bound: 76.0
```

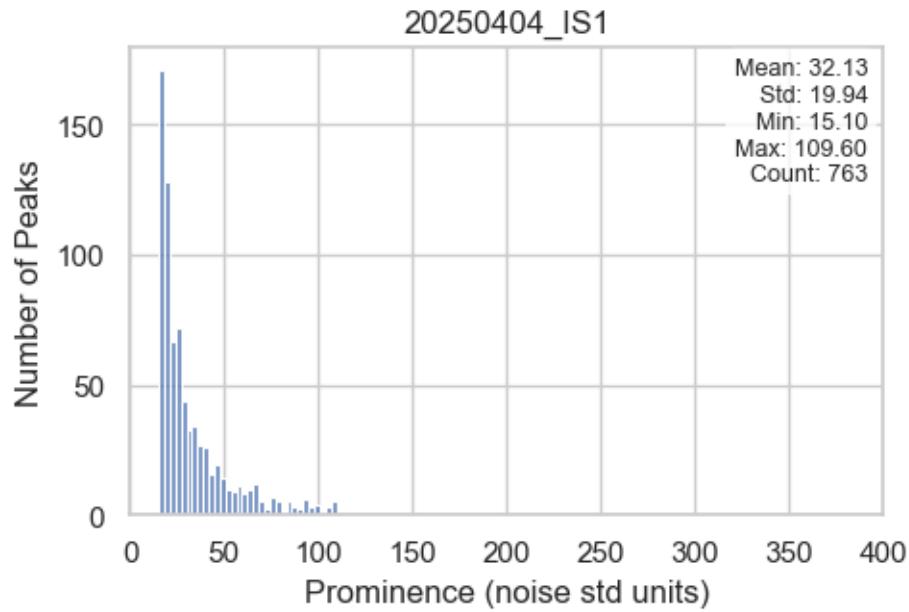
## Distribution of Peak Durations



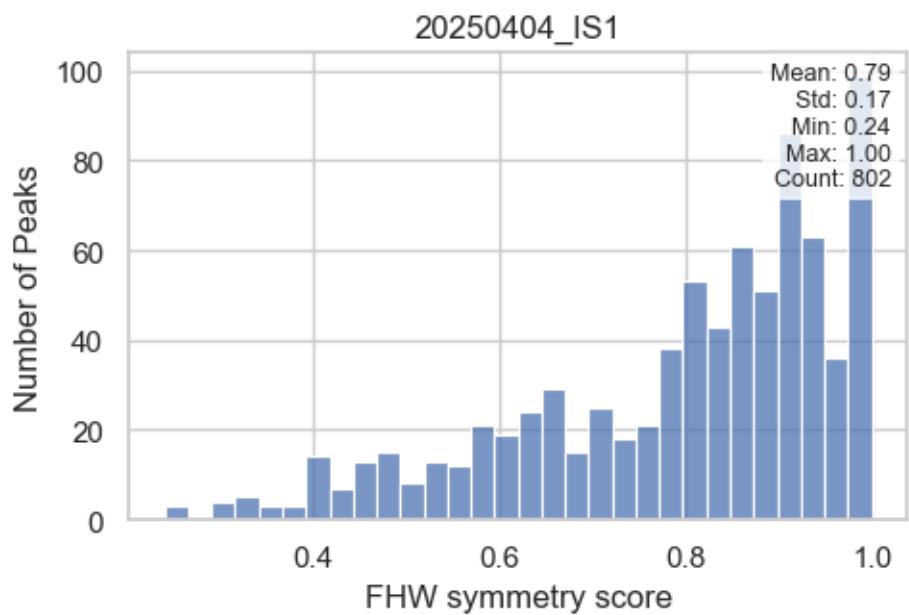
```
[2025-08-08 14:47:51] [INFO] calcium: Removed 39 outliers from dataset '20250404_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:47:51] [INFO] calcium: Lower bound: -15.650000000000002, Upper bound: 110.3000000000001
```

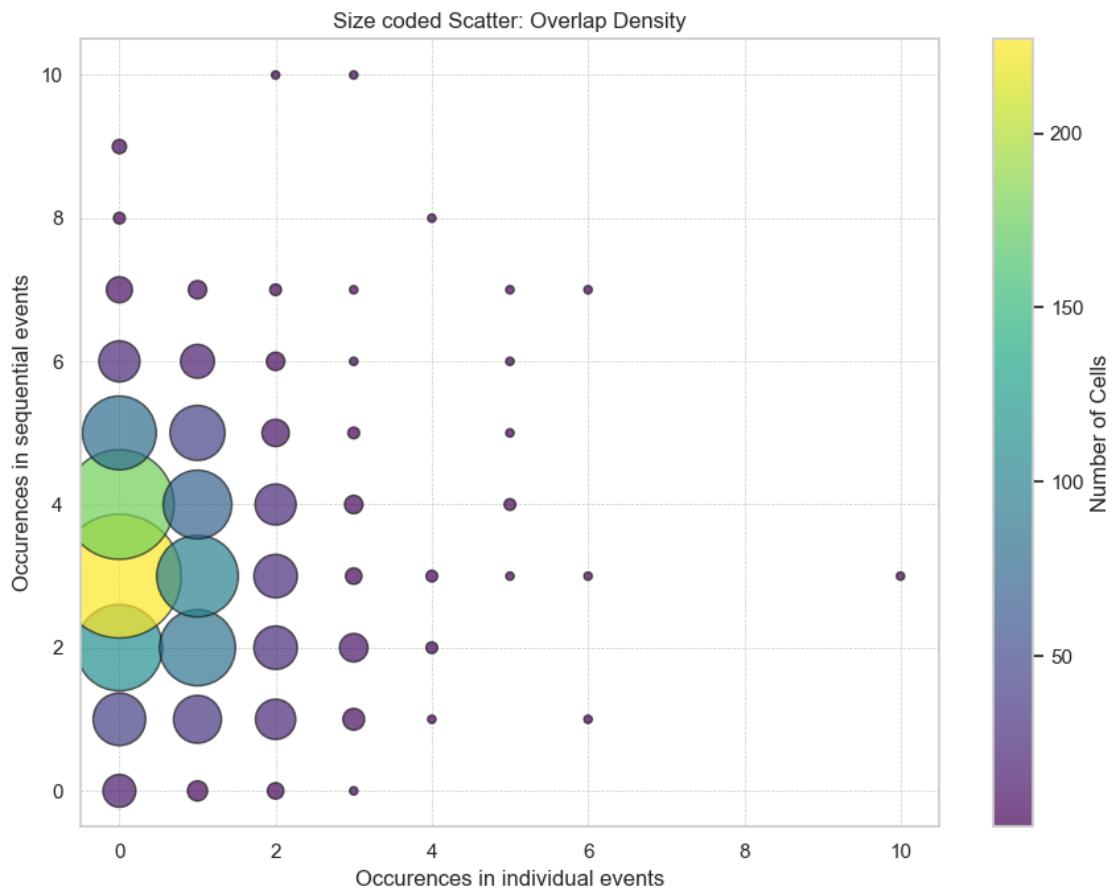
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

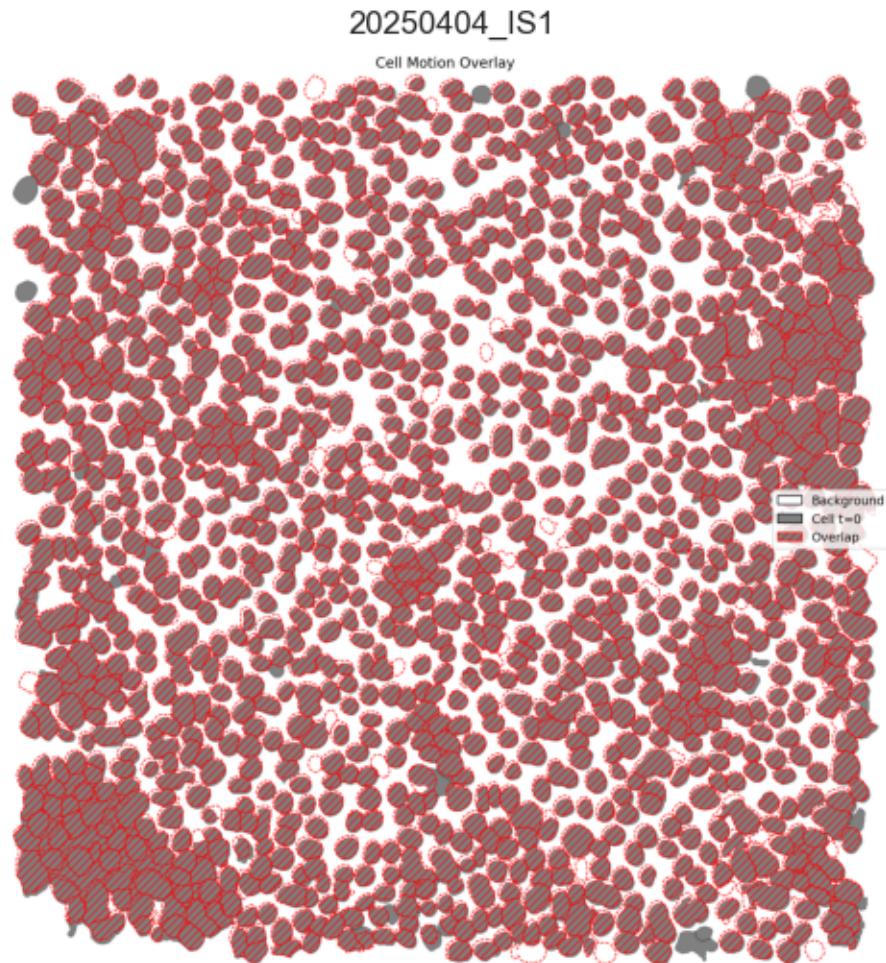


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 1234
- Hoechst image taken at t=1801: 1238
- Number of cells difference: absolute 4, relative 0.32%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1369674
- Pixels segmented as cell at t=1801: 1414102
- Overlapping pixels between t=0 and t=1801: 1219514 (87.62% of total)
- Pixels exclusive to t=0: 150160 (10.96% of total)
- Pixels exclusive to t=1801: 194588 (13.76% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n      "Default Dataset": "/path/to/your/dataset"\n}'
```

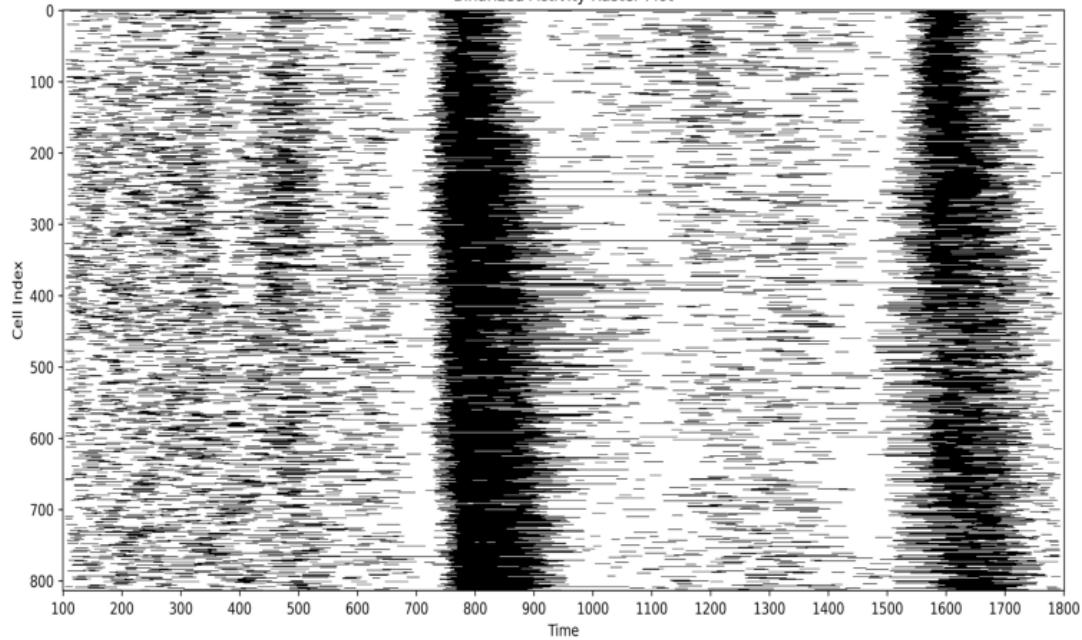
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

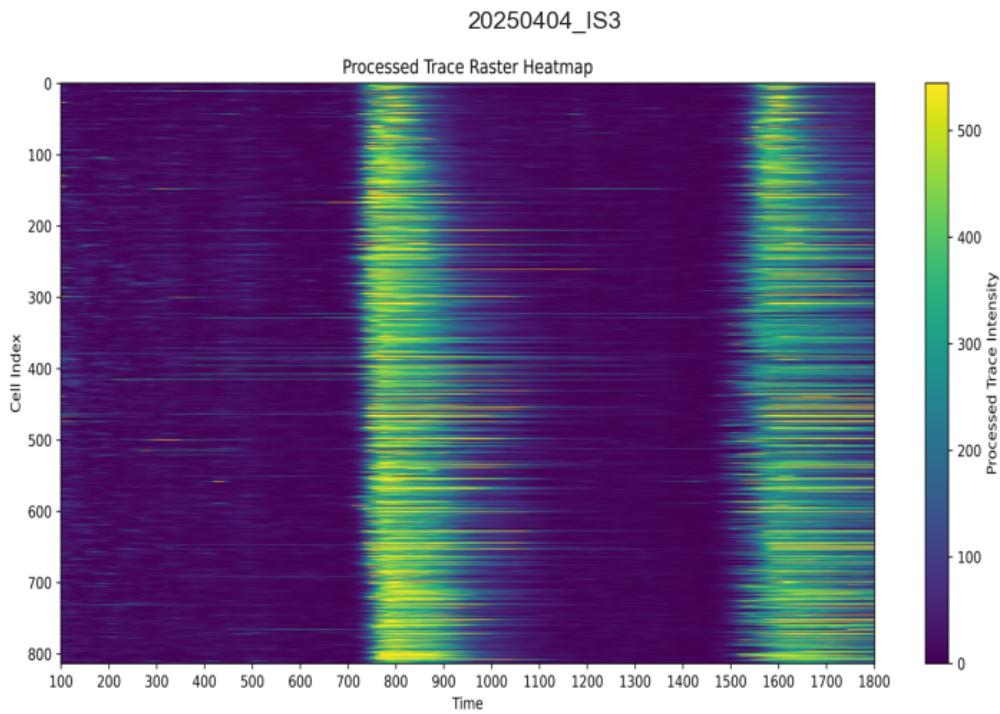
Binary Activity Raster Plot

20250404\_IS3

Binarized Activity Raster Plot



Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 6049

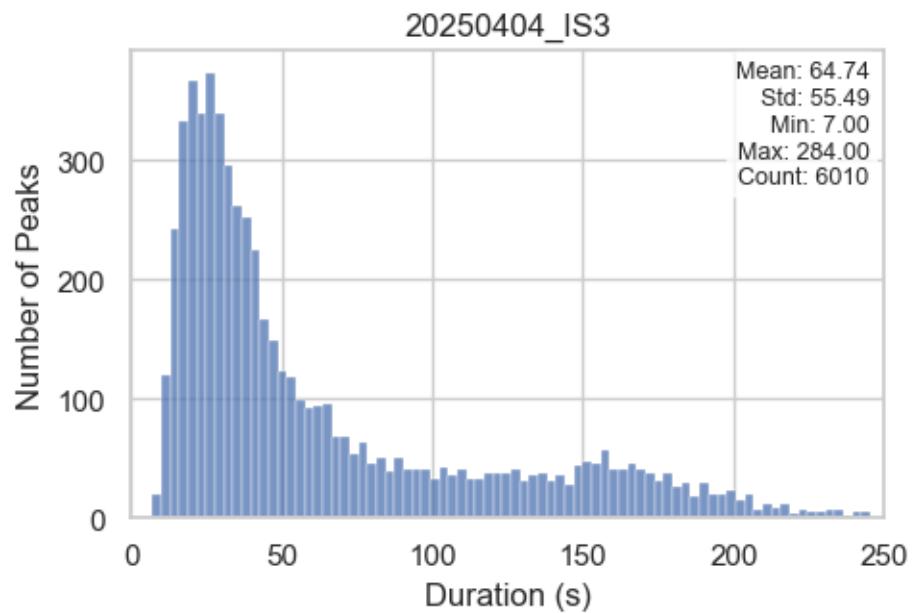
Total number of cells: 814

### 1.1.3 Peaks statistics

```
[2025-08-08 14:48:46] [INFO] calcium: Removed 39 outliers from dataset  
'20250404_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:48:46] [INFO] calcium: Lower bound: -72.5, Upper bound: 285.0
```

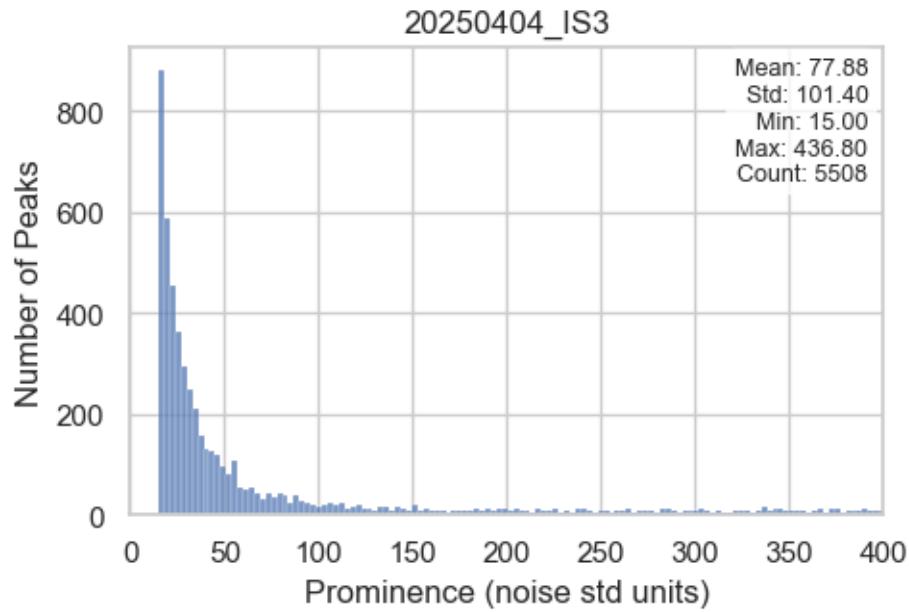
## Distribution of Peak Durations



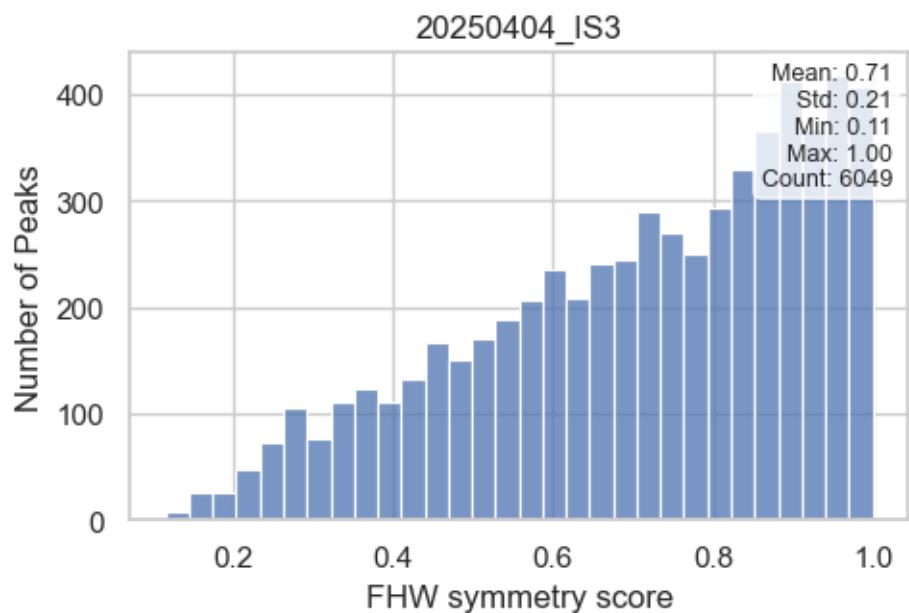
[2025-08-08 14:48:46] [INFO] calcium: Removed 541 outliers from dataset '20250404\_IS3' for column 'Prominence (noise std units)'

[2025-08-08 14:48:46] [INFO] calcium: Lower bound: -134.8, Upper bound: 437.2

## Distribution of Peak Prominences

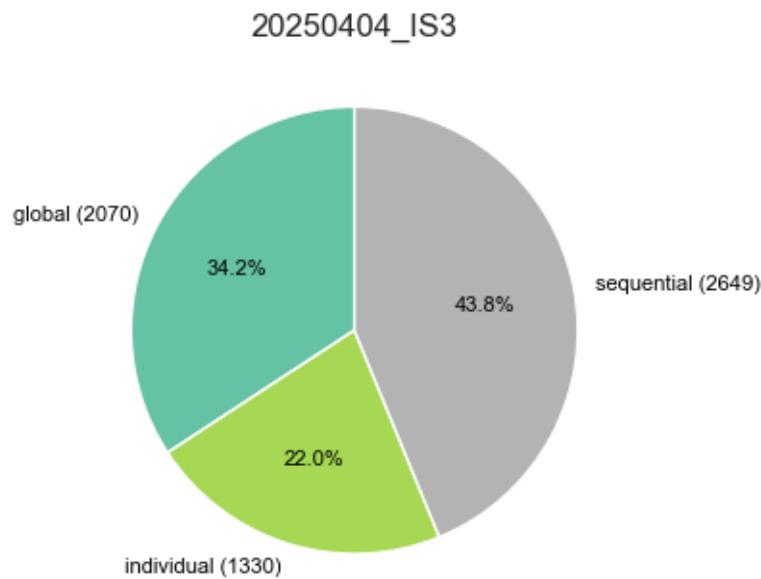


## Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

Distribution of Peaks by Event types

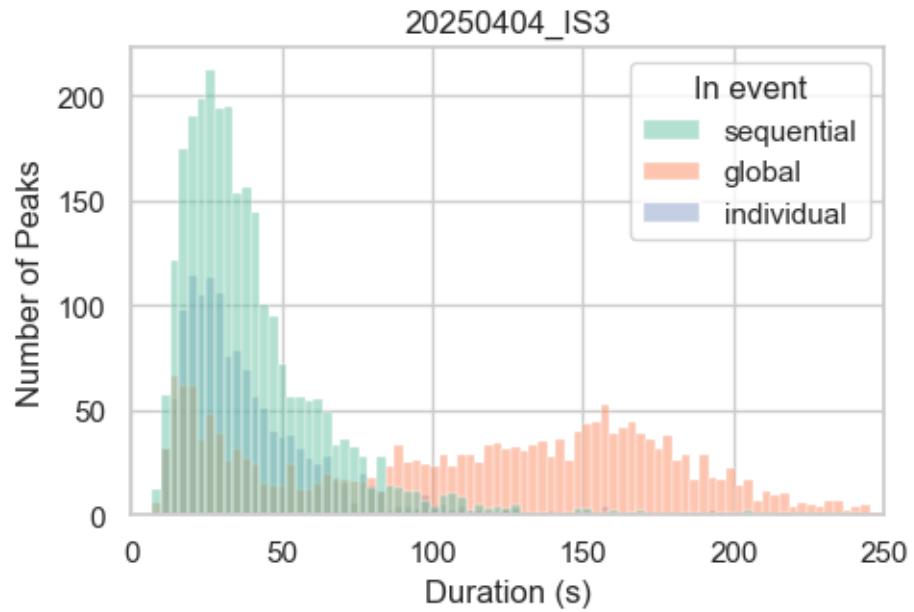


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:48:46] [INFO] calcium: Removed 39 outliers from dataset  
'20250404_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:48:46] [INFO] calcium: Lower bound: -72.5, Upper bound: 285.0
```

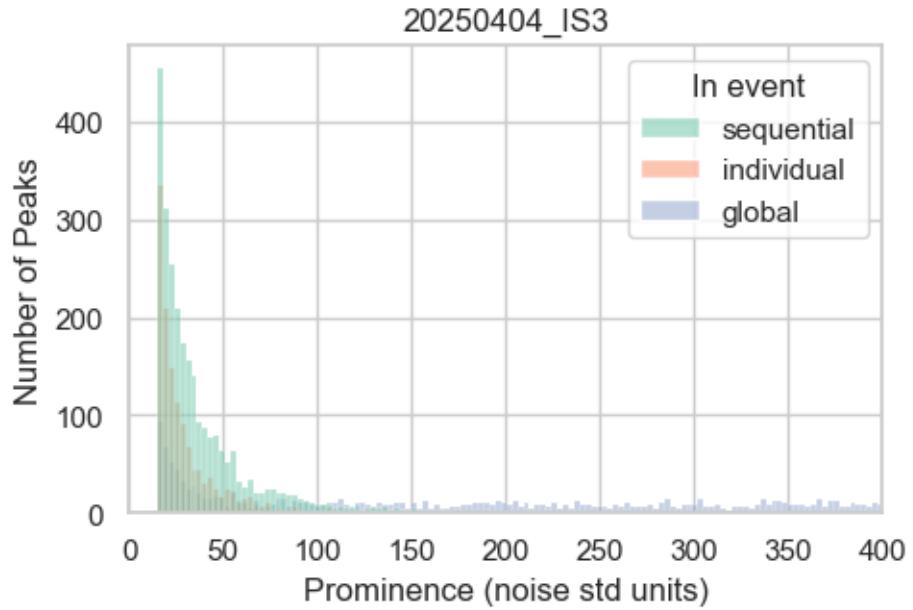
## Distribution of Peak Durations by Group



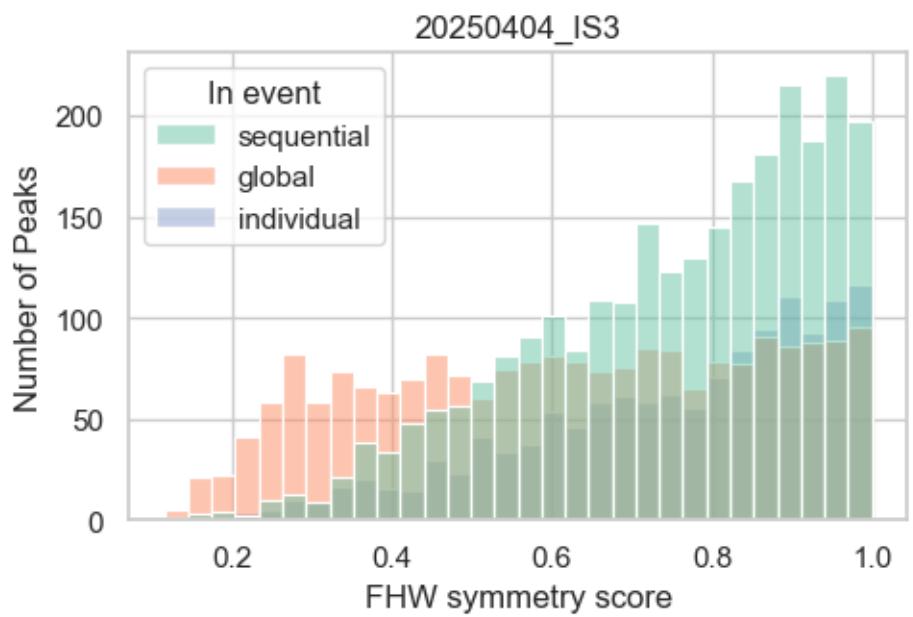
[2025-08-08 14:48:47] [INFO] calcium: Removed 541 outliers from dataset '20250404\_IS3' for column 'Prominence (noise std units)'

[2025-08-08 14:48:47] [INFO] calcium: Lower bound: -134.8, Upper bound: 437.2

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



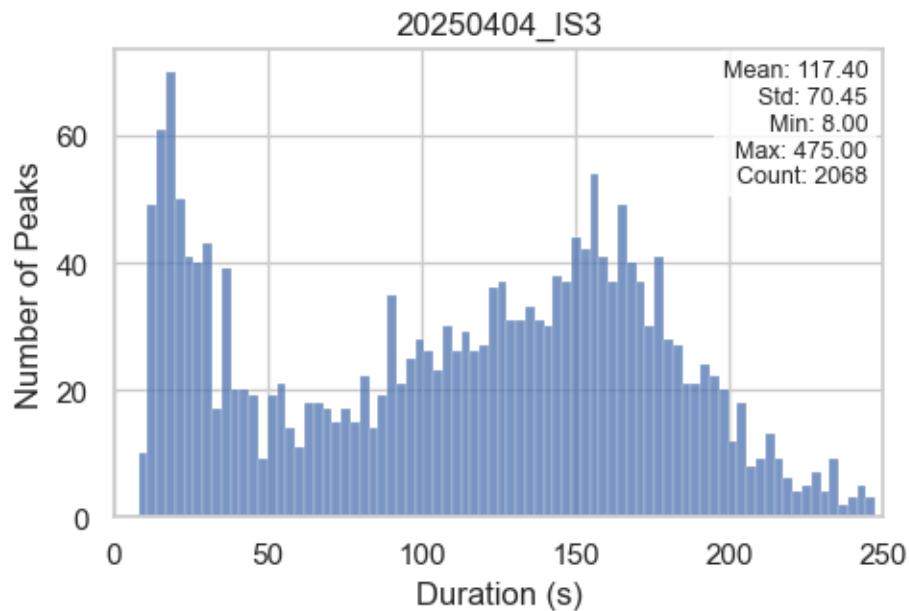
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:48:47] [INFO] calcium: Removed 2 outliers from dataset  
'20250404_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:48:47] [INFO] calcium: Lower bound: -112.5, Upper bound: 498.0
```

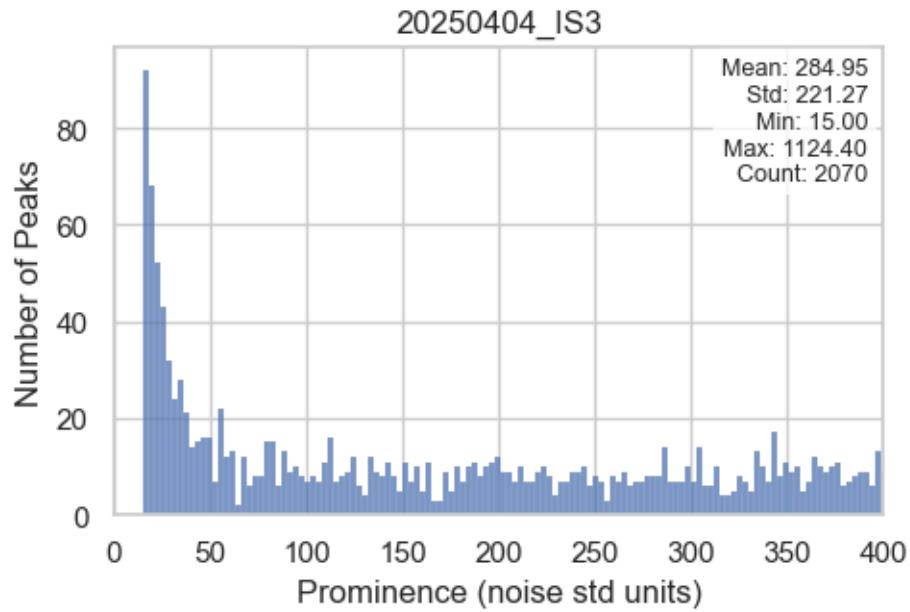
Distribution of Peak Durations



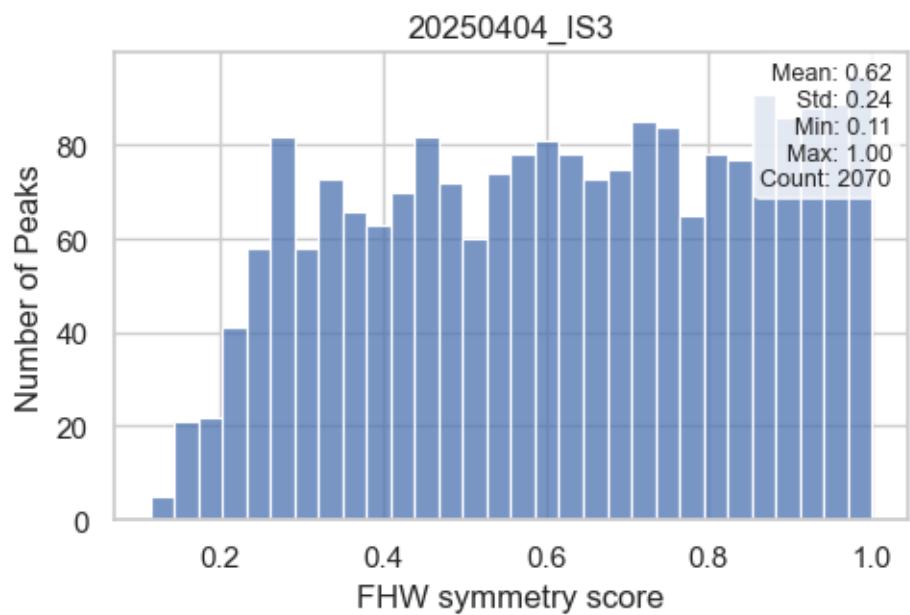
```
[2025-08-08 14:48:47] [INFO] calcium: Removed 0 outliers from dataset  
'20250404_IS3' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:48:47] [INFO] calcium: Lower bound: -467.9750000000001, Upper  
bound: 1540.6250000000002
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

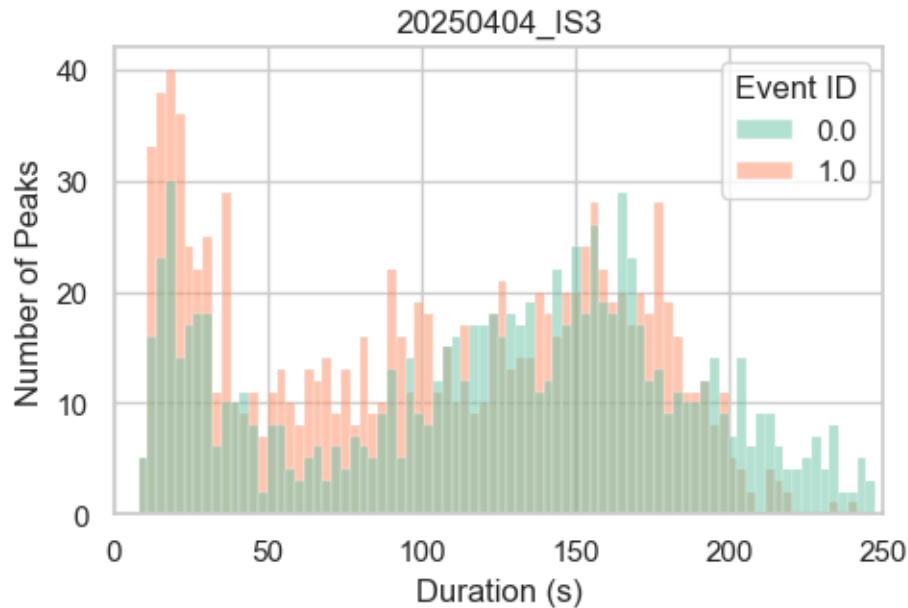


### 1.2.2 Peak statistics in global event per event ID

[2025-08-08 14:48:48] [INFO] calcium: Removed 2 outliers from dataset '20250404\_IS3' for column 'Duration (s)'

[2025-08-08 14:48:48] [INFO] calcium: Lower bound: -112.5, Upper bound: 498.0

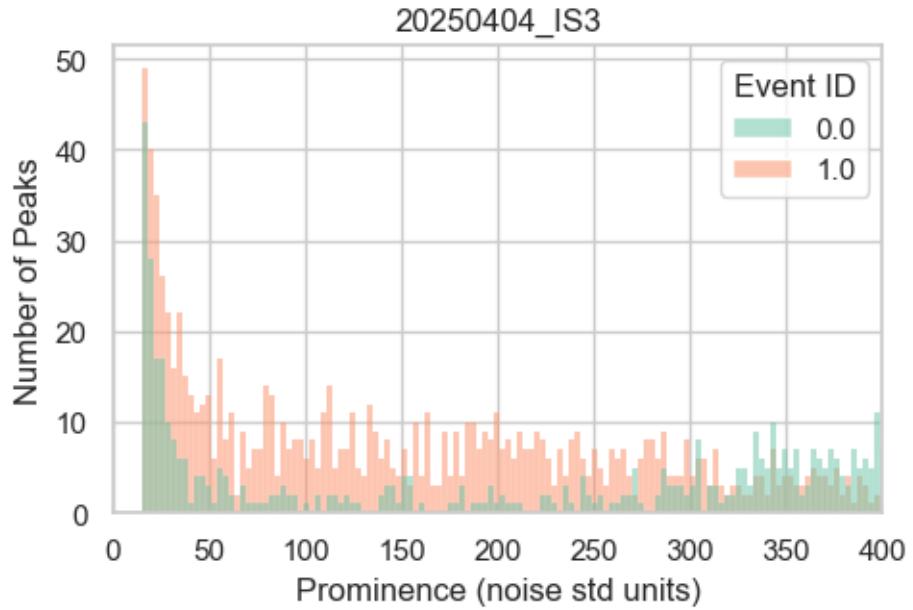
Distribution of Peak Durations by Group



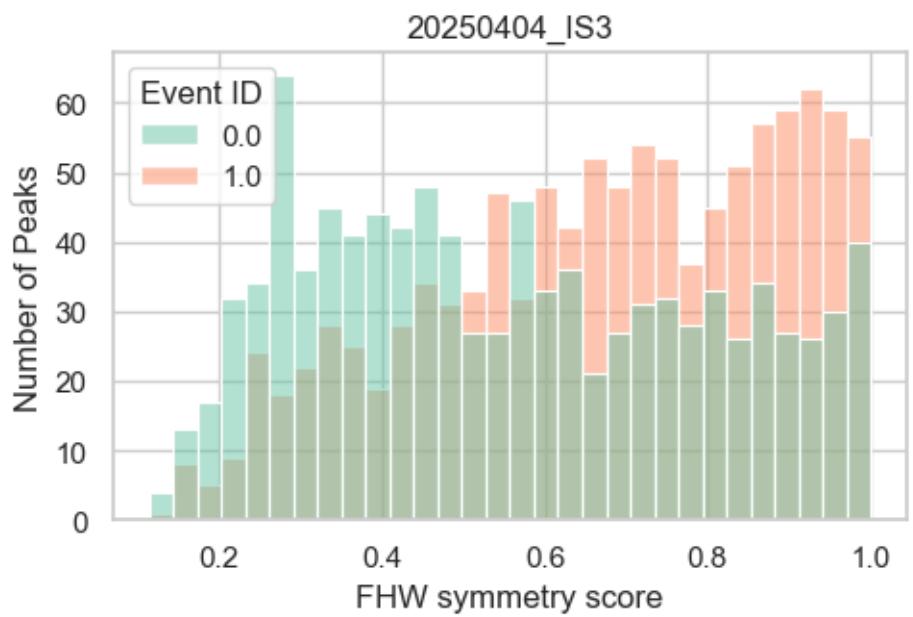
[2025-08-08 14:48:48] [INFO] calcium: Removed 0 outliers from dataset '20250404\_IS3' for column 'Prominence (noise std units)'

[2025-08-08 14:48:48] [INFO] calcium: Lower bound: -468.0, Upper bound: 1540.6

Distribution of Peak Prominences by Group



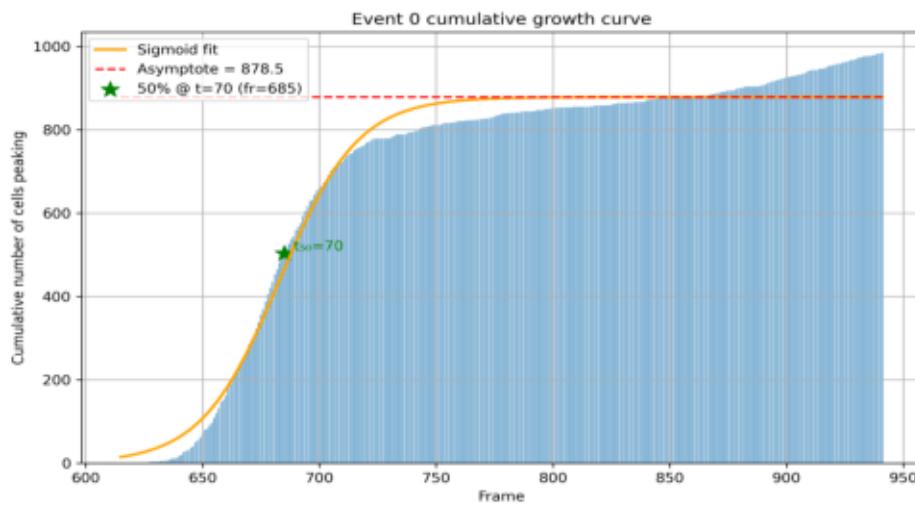
Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

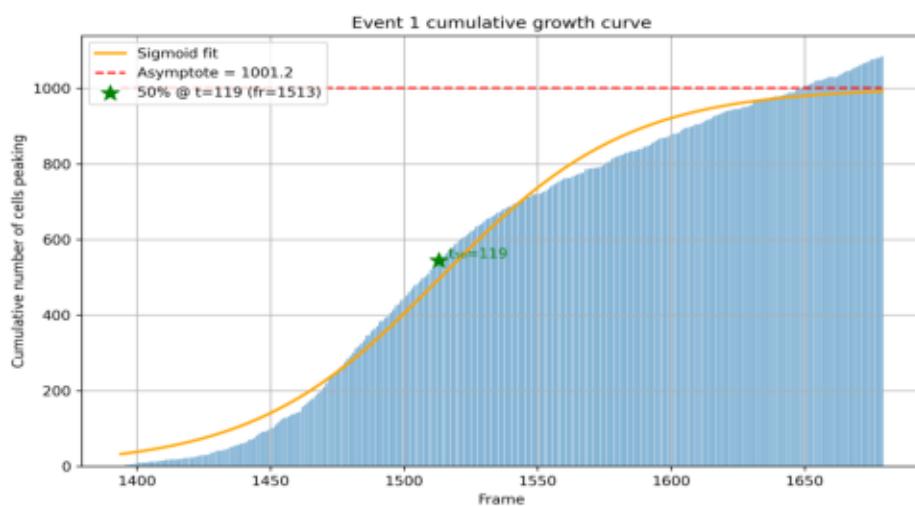
Event Activity Overlay (Event ID: 0)

20250404\_IS3



Event Activity Overlay (Event ID: 1)

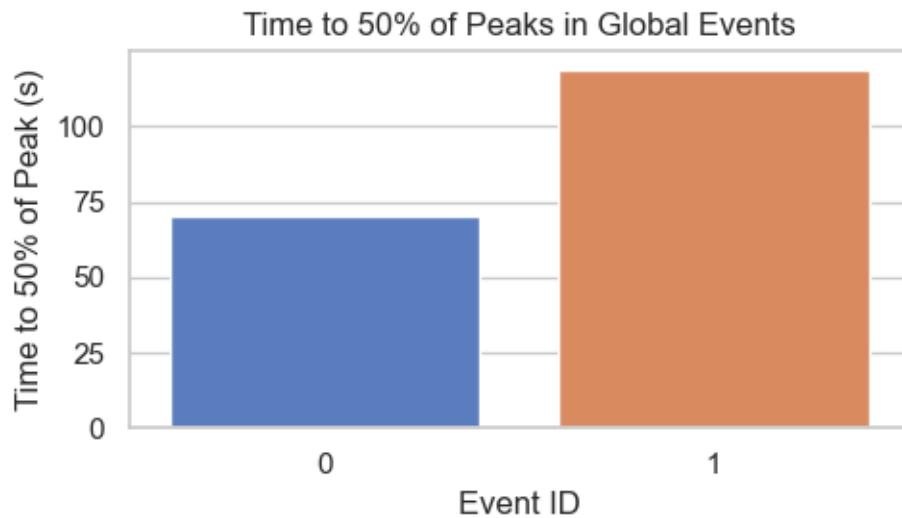
20250404\_IS3



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

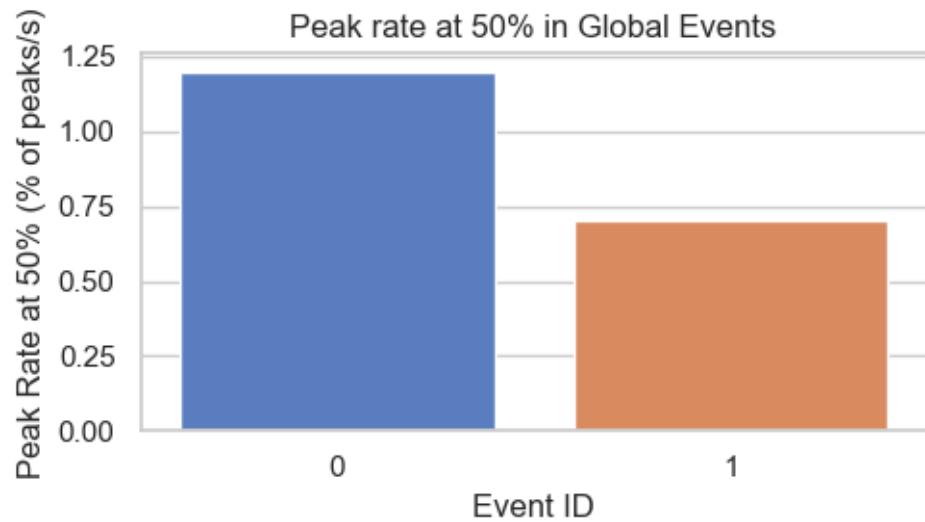
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

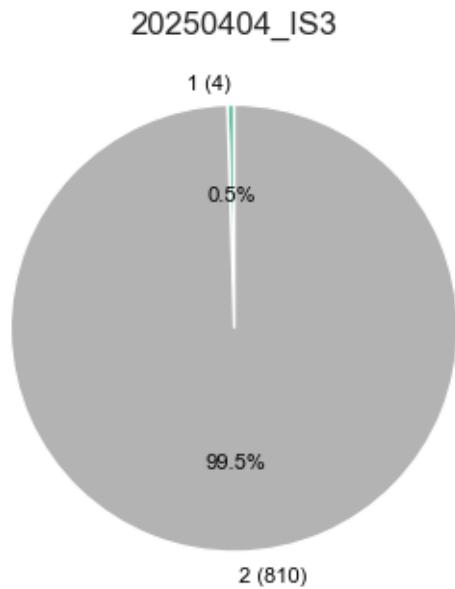
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



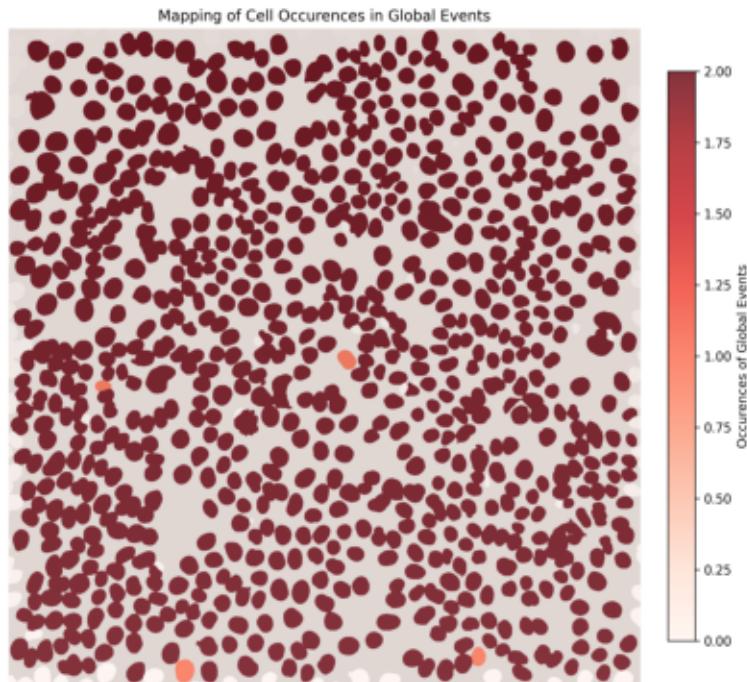
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

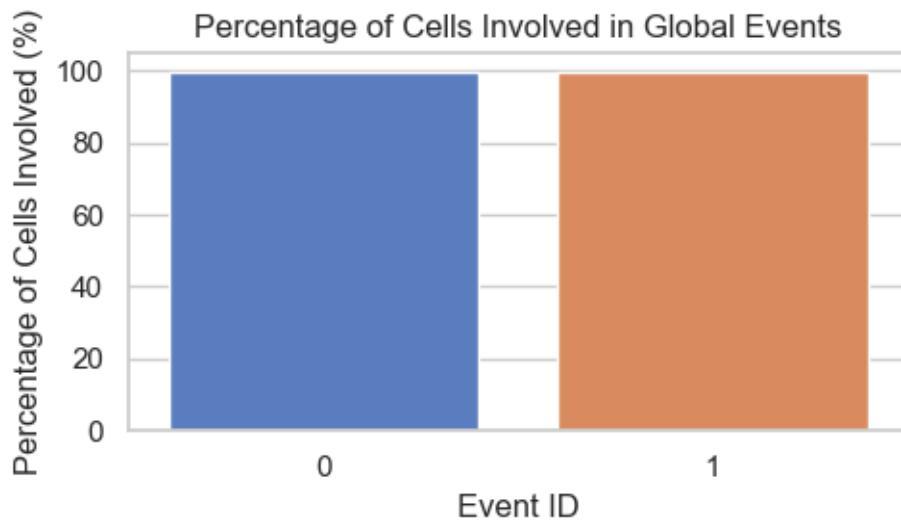
20250404\_IS3



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



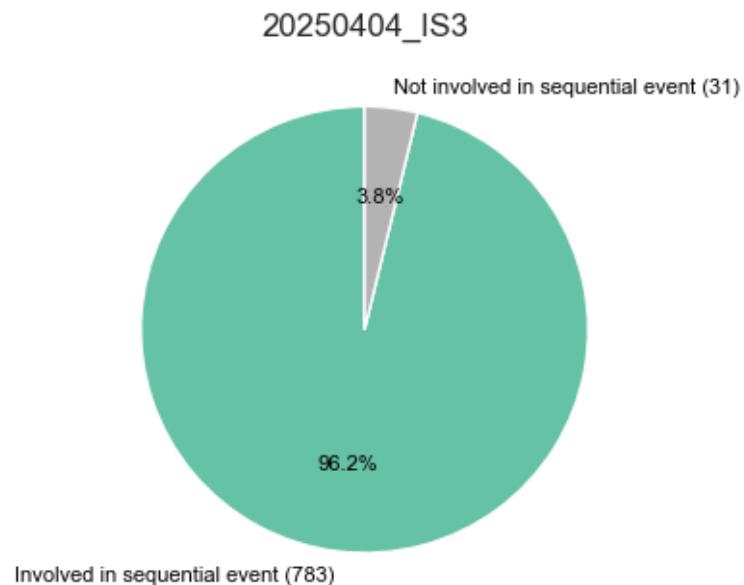
### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [831.0]

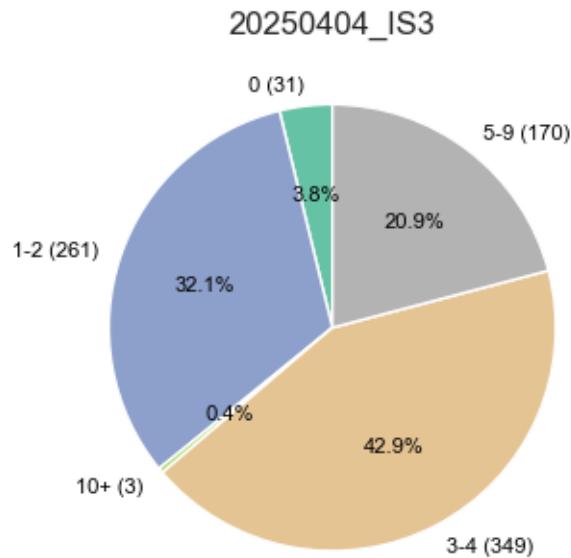
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

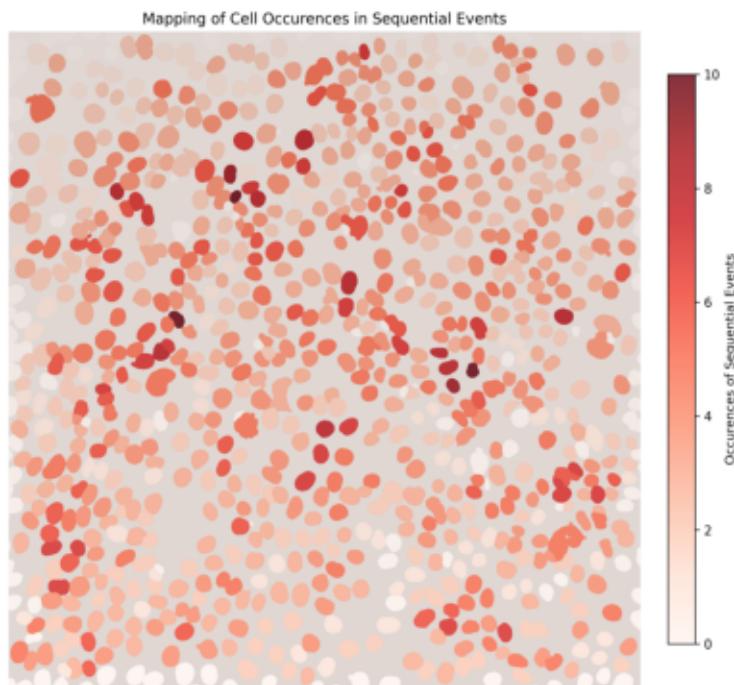


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250404\_IS3

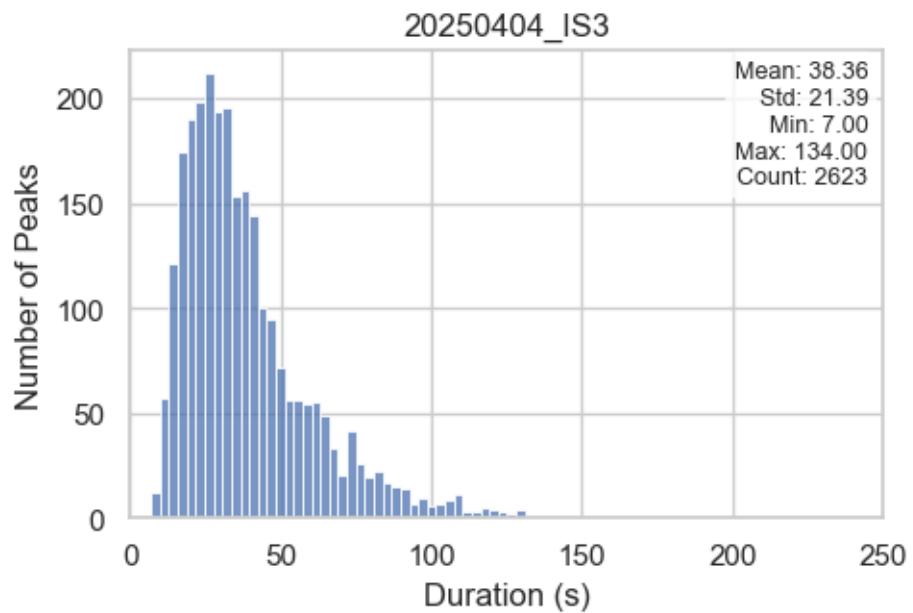


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:48:53] [INFO] calcium: Removed 26 outliers from dataset  
'20250404_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:48:53] [INFO] calcium: Lower bound: -14.5, Upper bound: 135.5
```

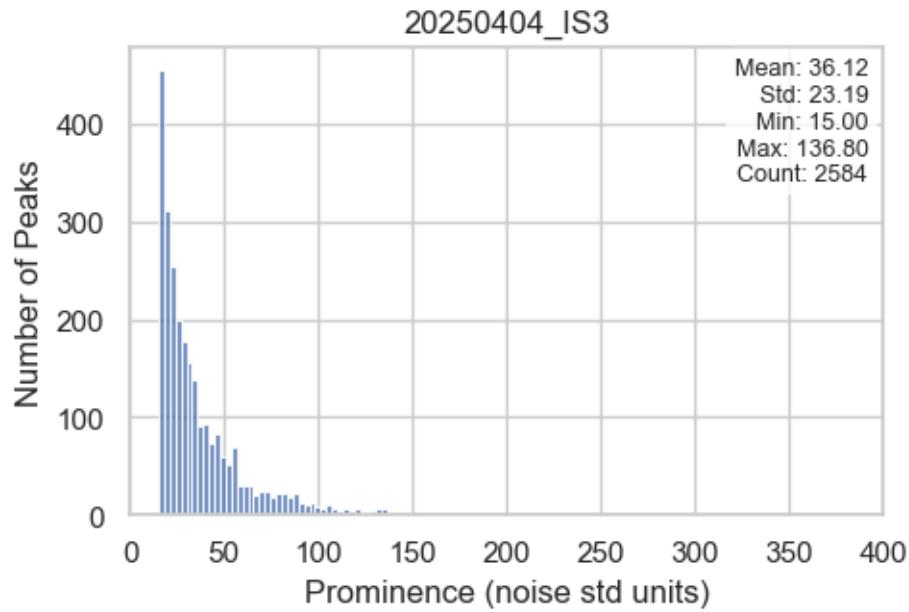
## Distribution of Peak Durations



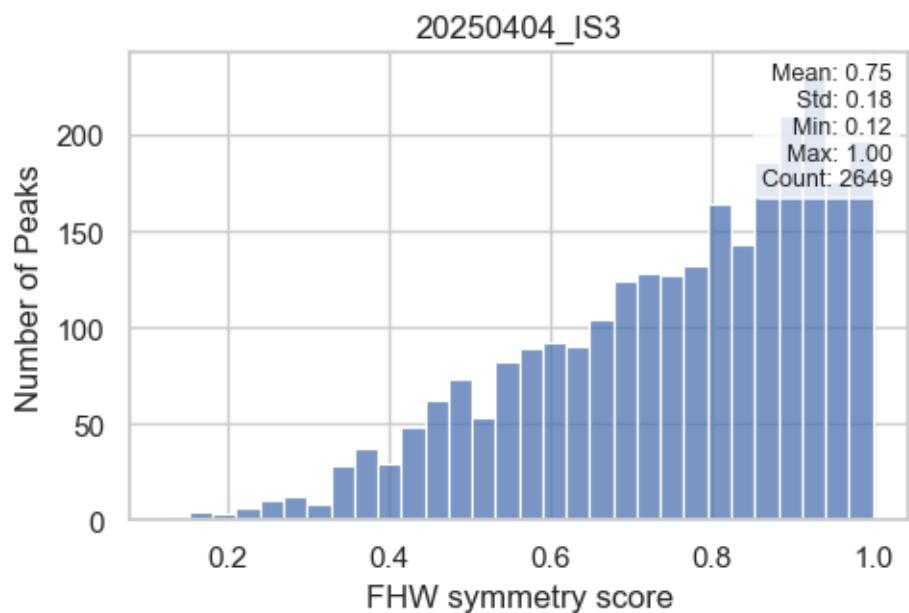
```
[2025-08-08 14:48:53] [INFO] calcium: Removed 65 outliers from dataset '20250404_IS3' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:48:53] [INFO] calcium: Lower bound: -19.250000000000007, Upper bound: 137.35000000000002
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

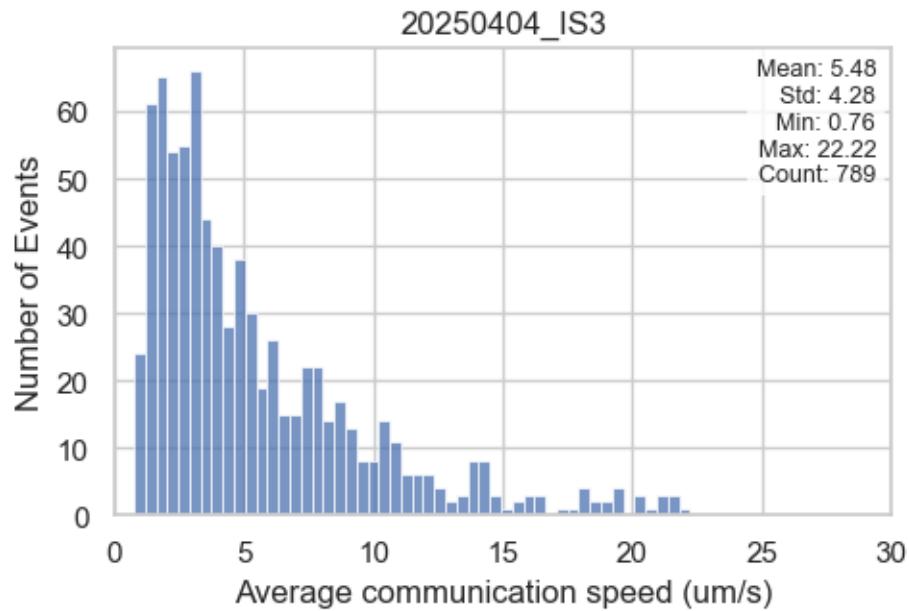


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:48:53] [INFO] calcium: Removed 10 outliers from dataset '20250404\_IS3' for column 'Average communication speed (um/s)'

[2025-08-08 14:48:53] [INFO] calcium: Lower bound: -5.317499999999999, Upper bound: 23.089999999999996

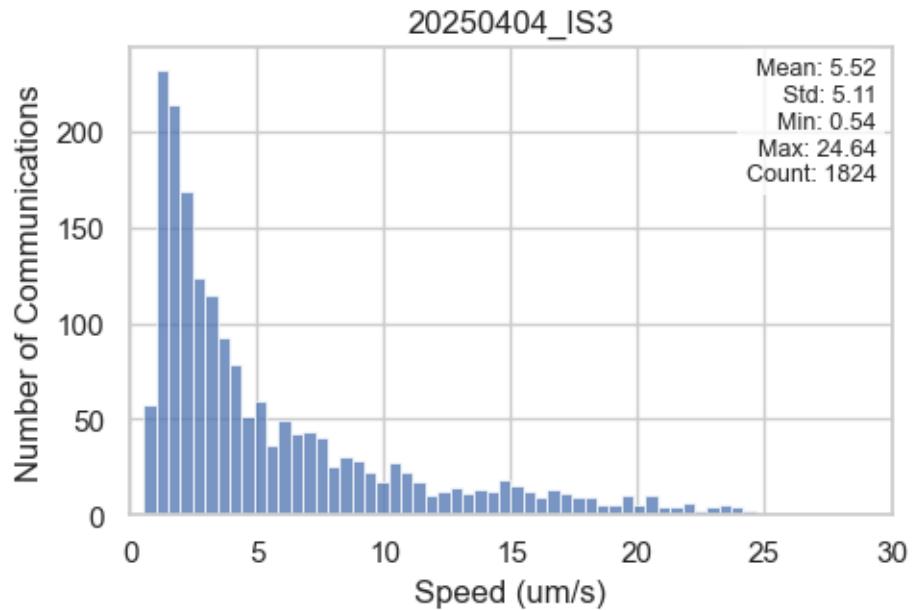
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:48:53] [INFO] calcium: Removed 26 outliers from dataset '20250404\_IS3' for column 'Speed (um/s)'

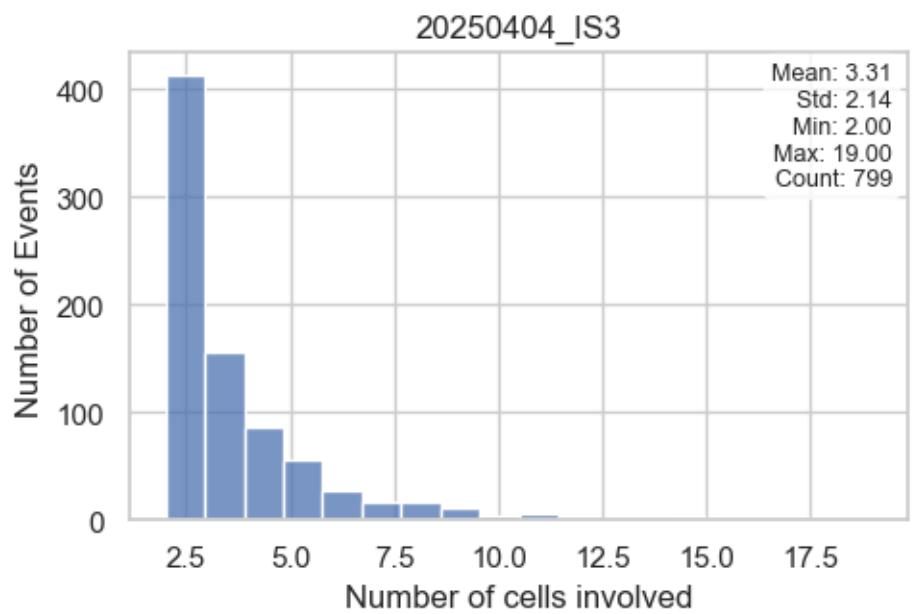
[2025-08-08 14:48:53] [INFO] calcium: Lower bound: -6.690000000000002, Upper bound: 24.770000000000003

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

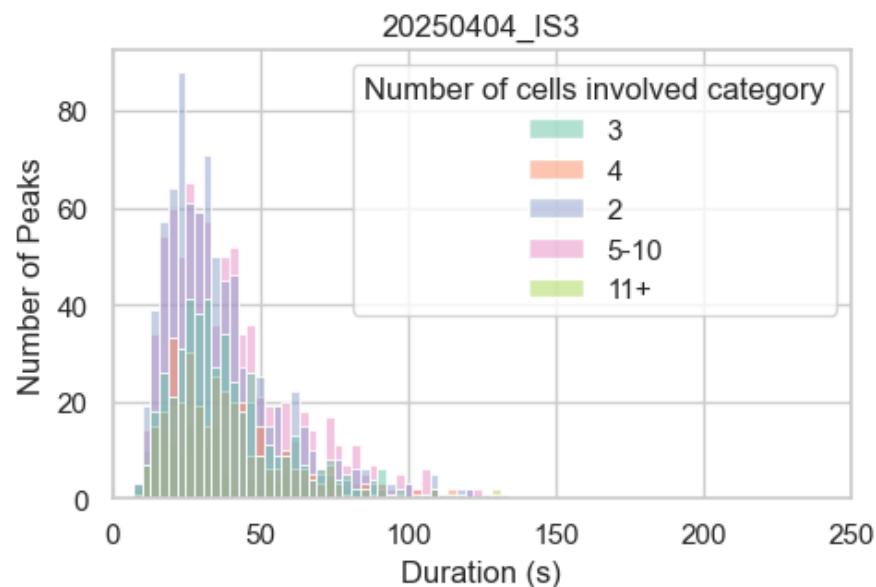


### 1.3.5 Influence of cell count per event on statistics

[2025-08-08 14:48:54] [INFO] calcium: Removed 26 outliers from dataset '20250404\_IS3' for column 'Duration (s)'

[2025-08-08 14:48:54] [INFO] calcium: Lower bound: -14.5, Upper bound: 135.5

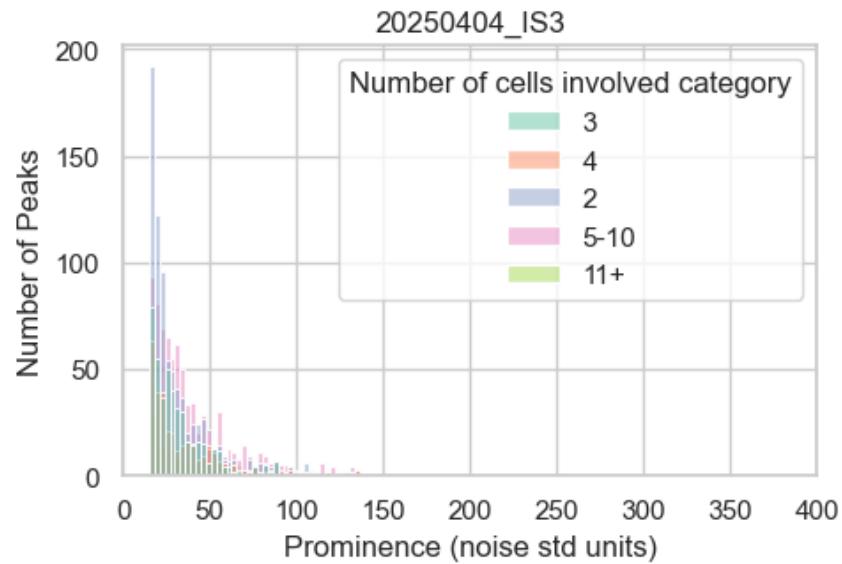
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



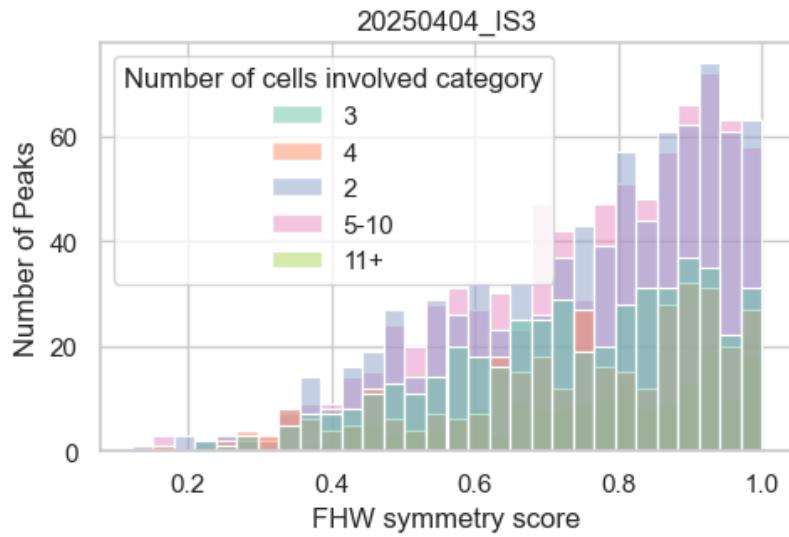
[2025-08-08 14:48:54] [INFO] calcium: Removed 65 outliers from dataset '20250404\_IS3' for column 'Prominence (noise std units)'

[2025-08-08 14:48:54] [INFO] calcium: Lower bound: -19.3, Upper bound: 137.4

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



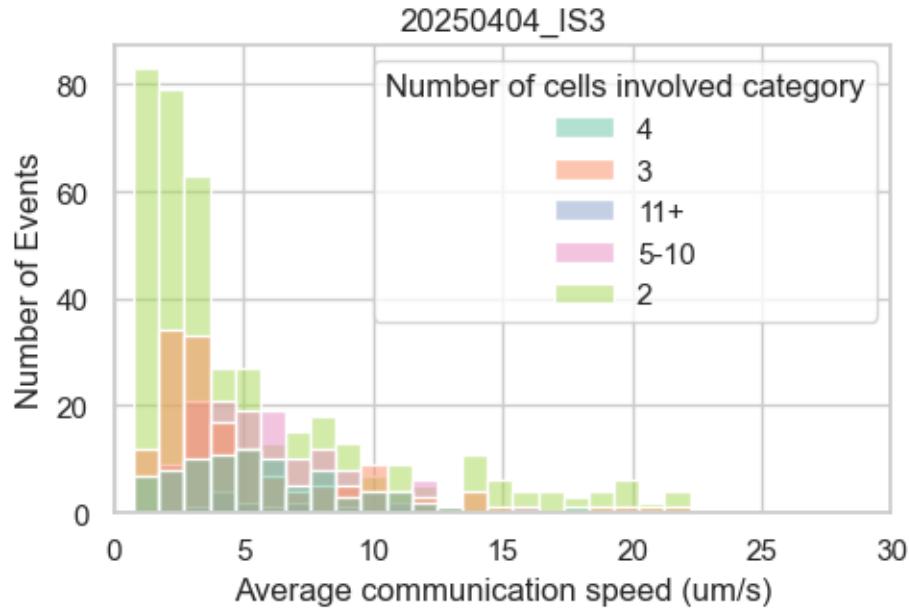
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 14:48:54] [INFO] calcium: Removed 10 outliers from dataset
'20250404_IS3' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 14:48:54] [INFO] calcium: Lower bound: -5.3, Upper bound: 23.1
```

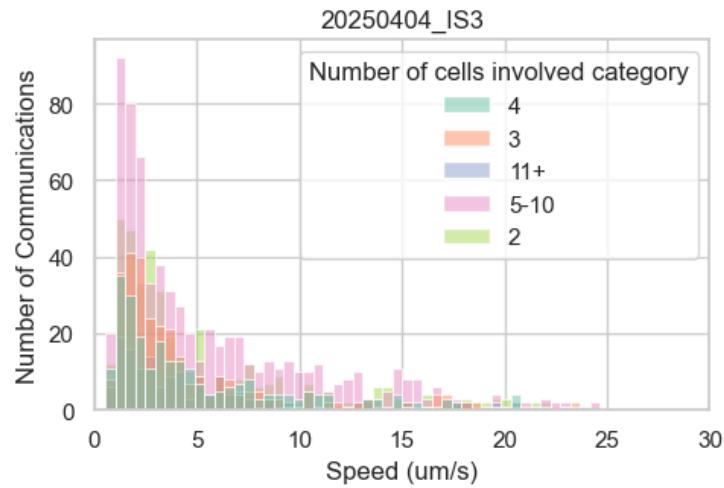
## Distribution of Average Communication Speeds by Number of Cells Involved



[2025-08-08 14:48:55] [INFO] calcium: Removed 26 outliers from dataset '20250404\_IS3' for column 'Speed (um/s)'

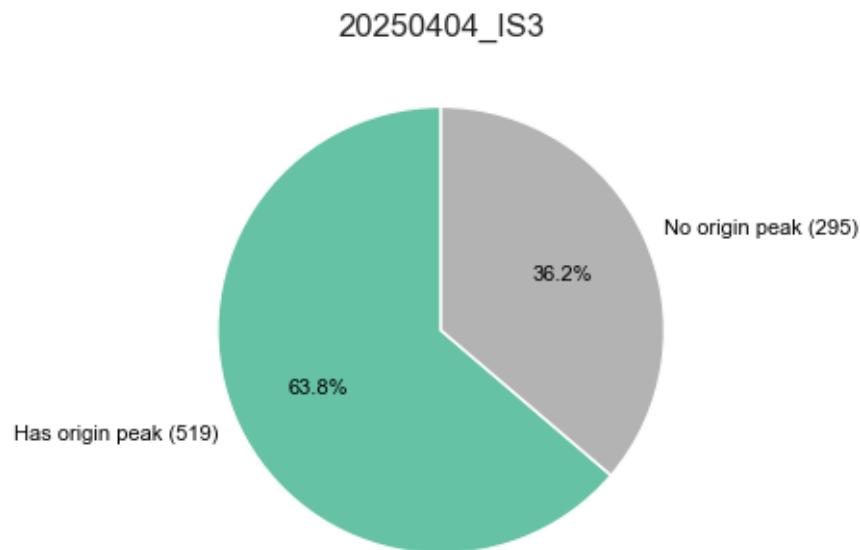
[2025-08-08 14:48:55] [INFO] calcium: Lower bound: -6.7, Upper bound: 24.8

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

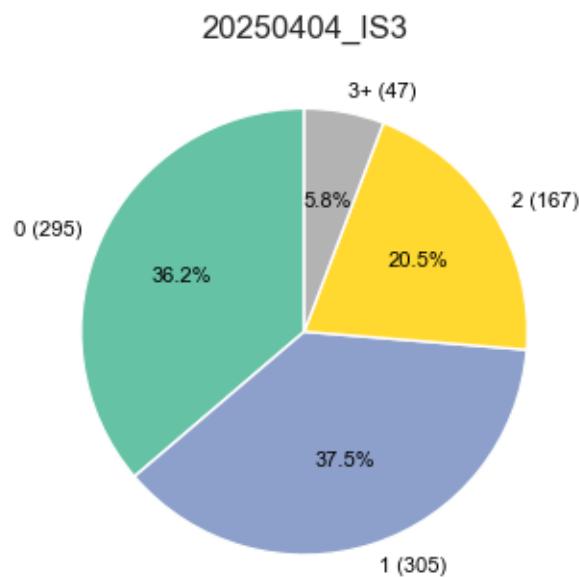


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

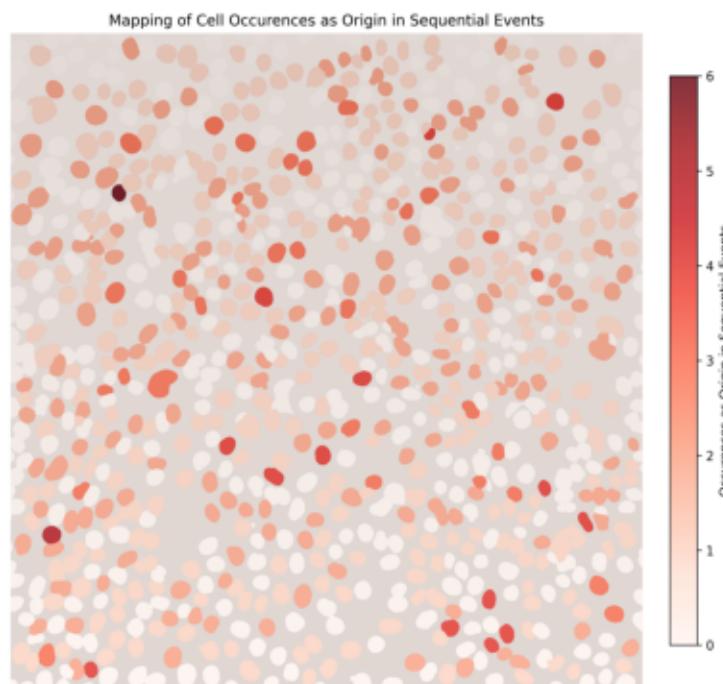


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

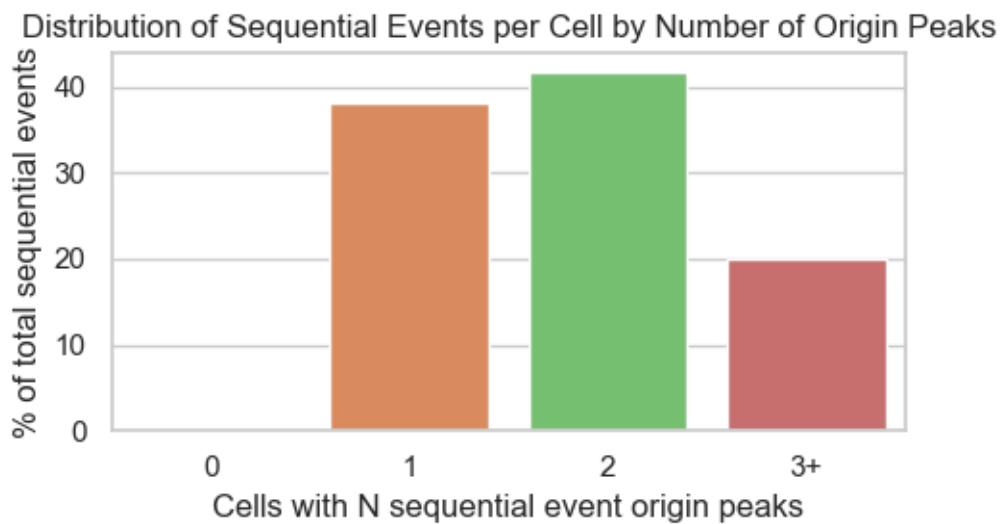
20250404\_IS3



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

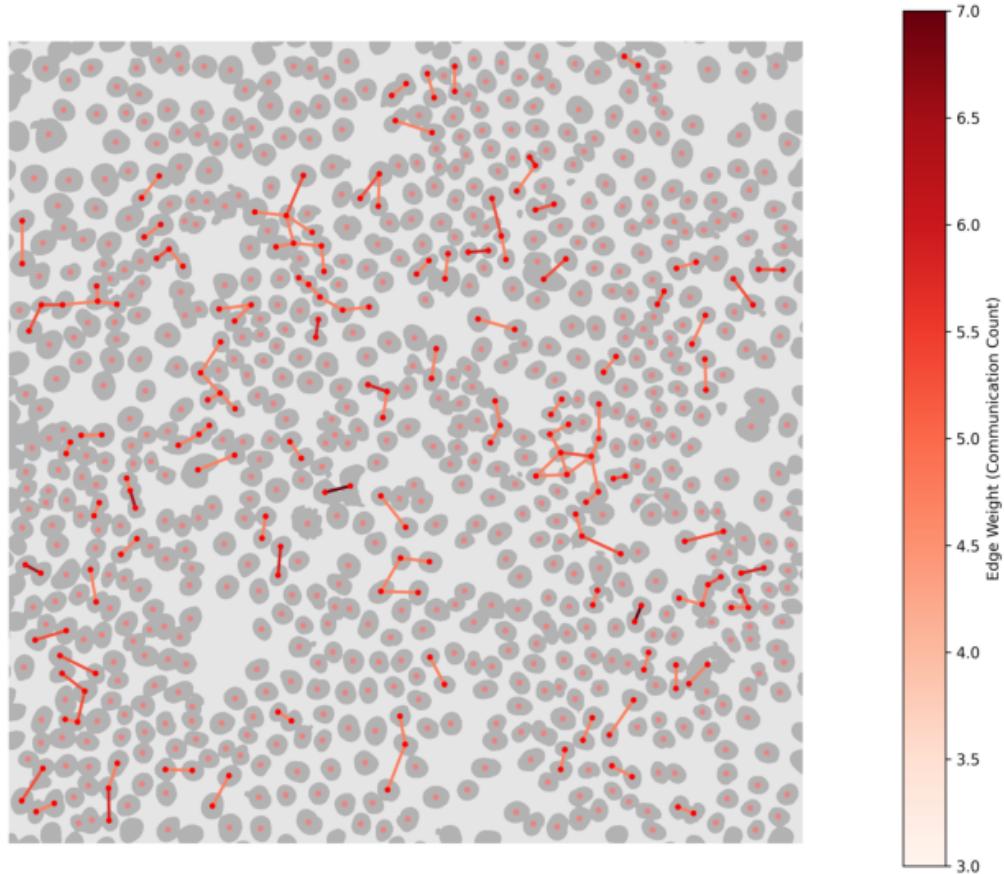


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250404\_IS3

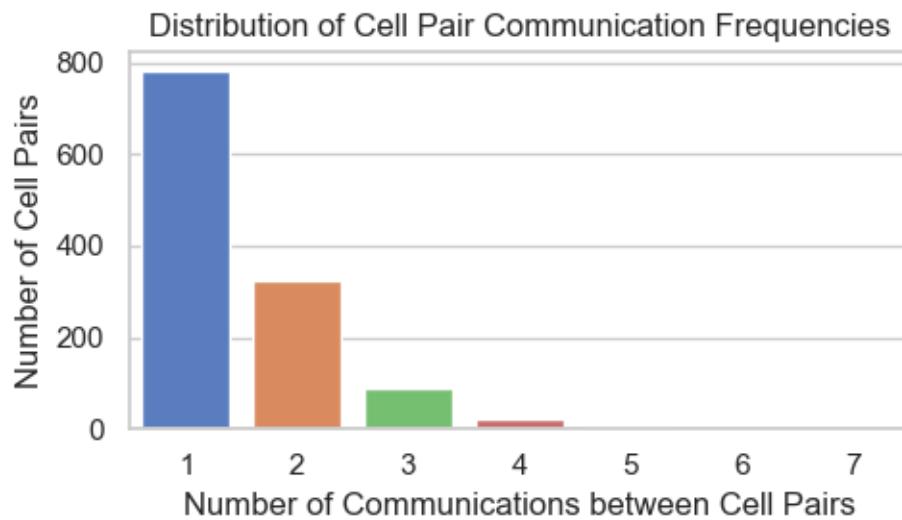
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

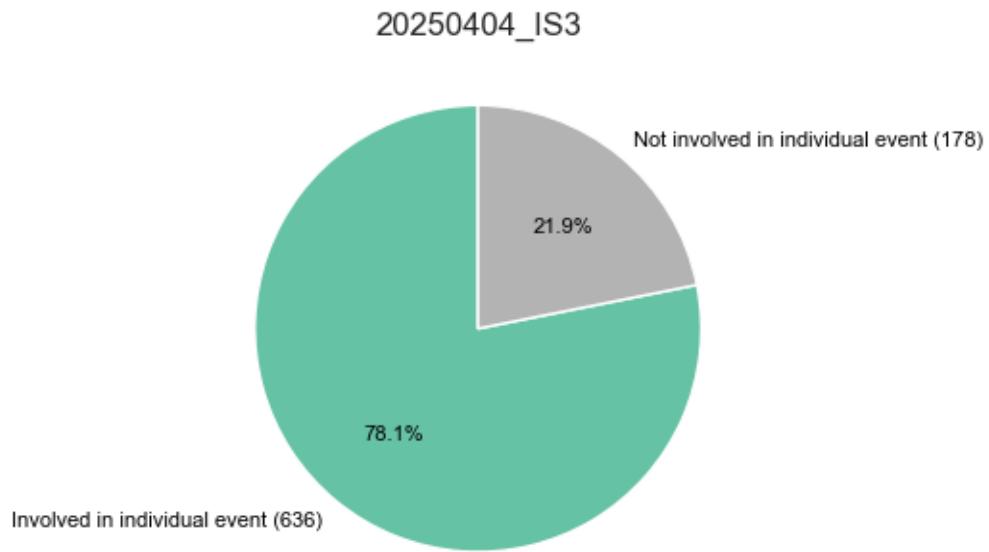
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



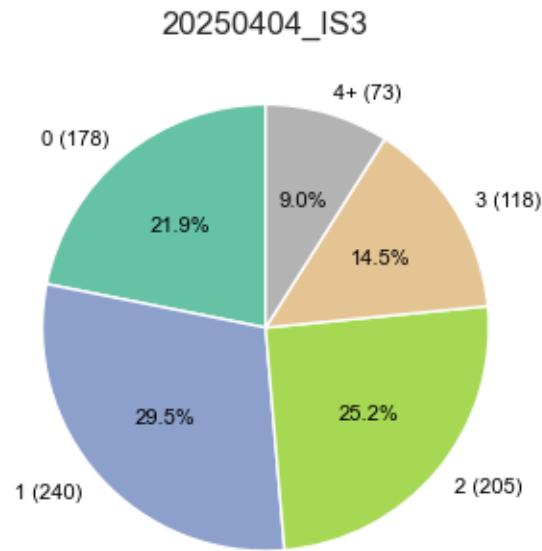
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

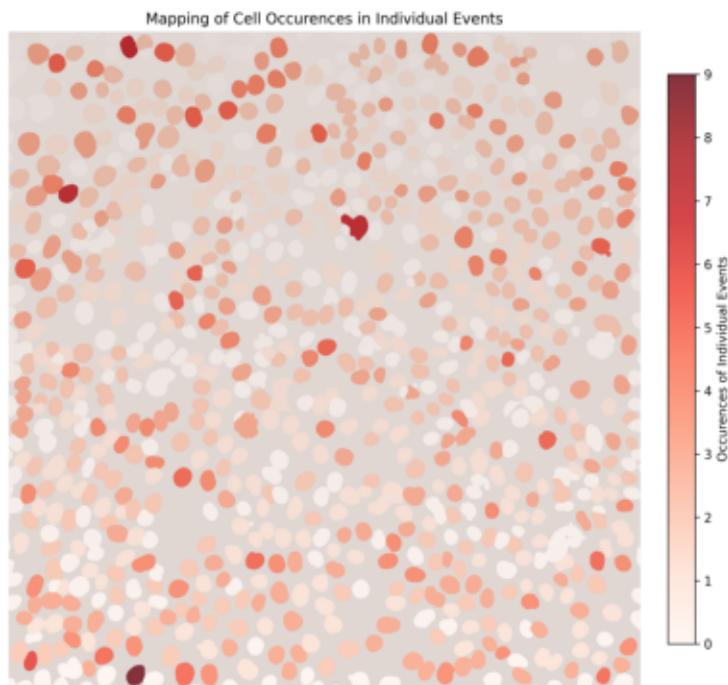


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250404\_IS3

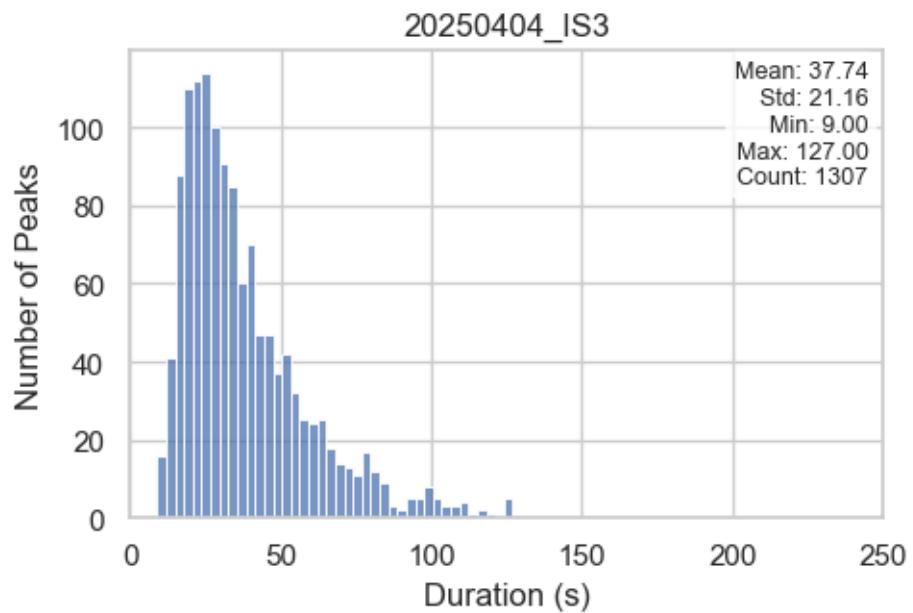


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:48:58] [INFO] calcium: Removed 23 outliers from dataset  
'20250404_IS3' for column 'Duration (s)'
```

```
[2025-08-08 14:48:58] [INFO] calcium: Lower bound: -16.0, Upper bound: 127.0
```

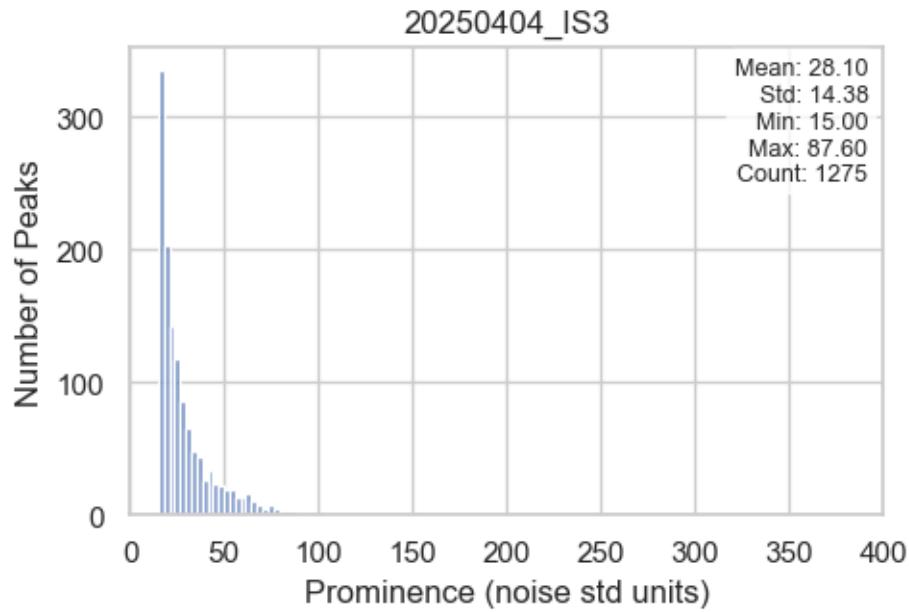
## Distribution of Peak Durations



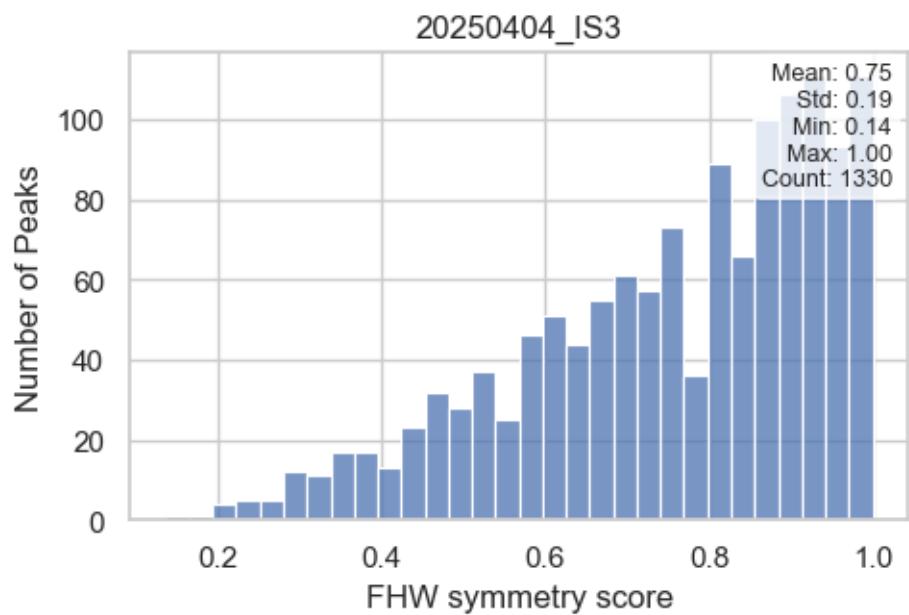
[2025-08-08 14:48:59] [INFO] calcium: Removed 55 outliers from dataset '20250404\_IS3' for column 'Prominence (noise std units)'

[2025-08-08 14:48:59] [INFO] calcium: Lower bound: -8.312500000000004, Upper bound: 87.80000000000001

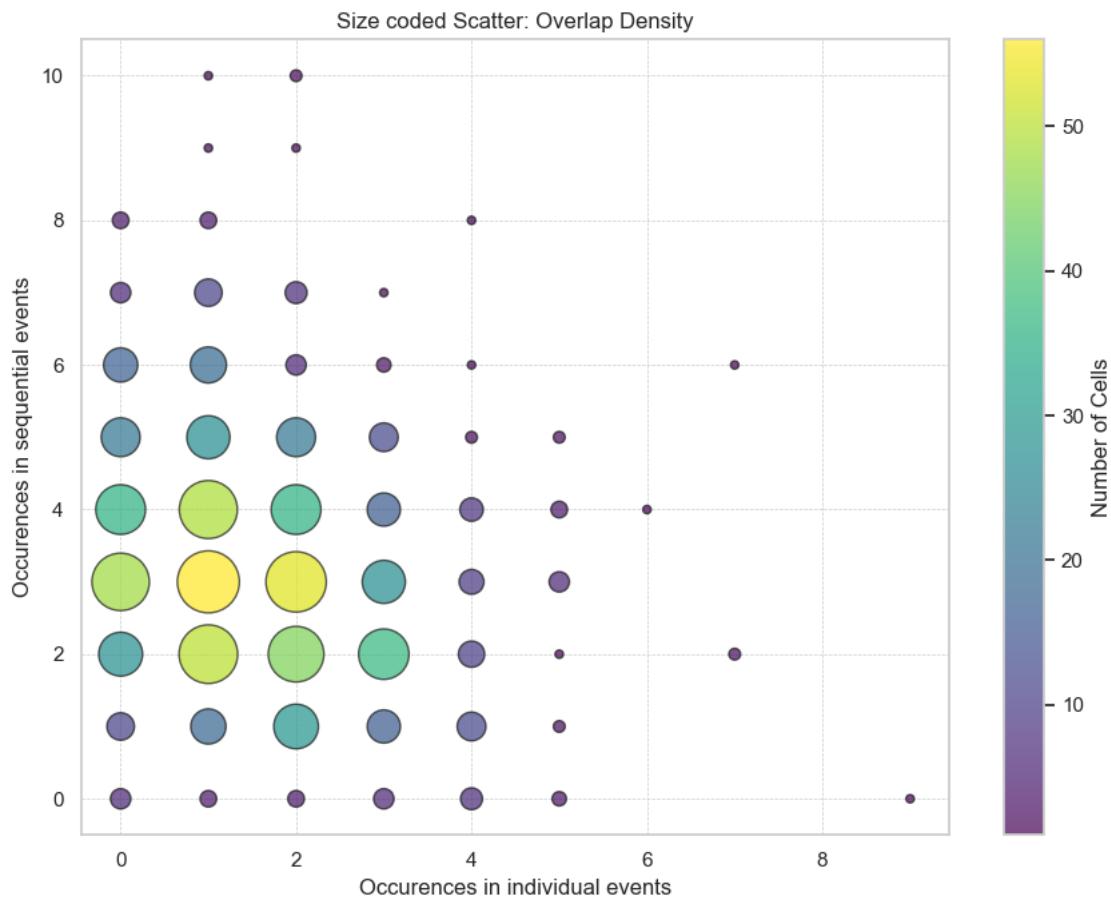
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

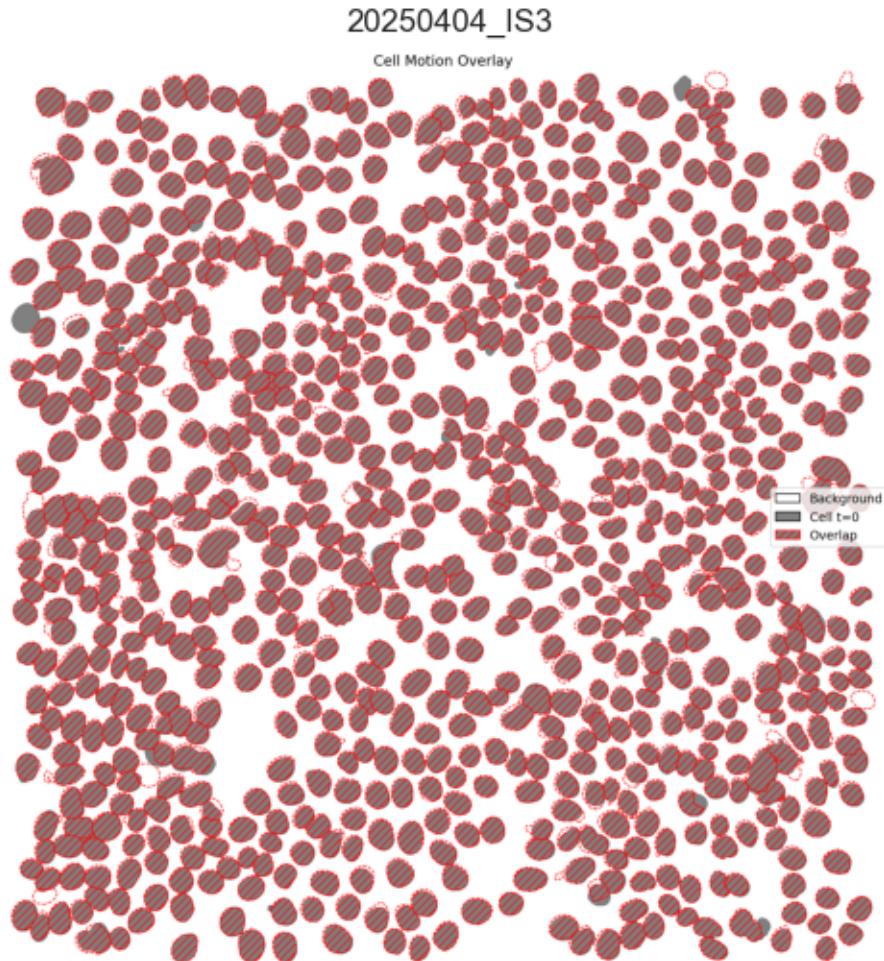


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 814
- Hoechst image taken at t=1801: 812
- Number of cells difference: absolute 2, relative 0.25%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1056876
- Pixels segmented as cell at t=1801: 1081782
- Overlapping pixels between t=0 and t=1801: 988607 (92.45% of total)
- Pixels exclusive to t=0: 68269 (6.46% of total)
- Pixels exclusive to t=1801: 93175 (8.61% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n      "Default Dataset": "/path/to/your/dataset"\n}'
```

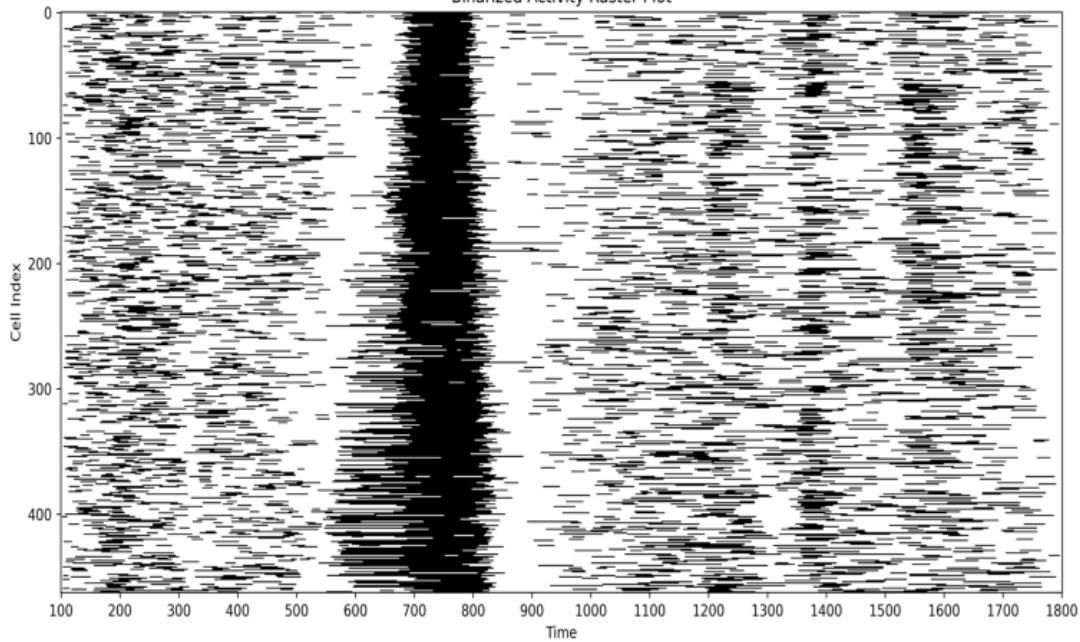
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

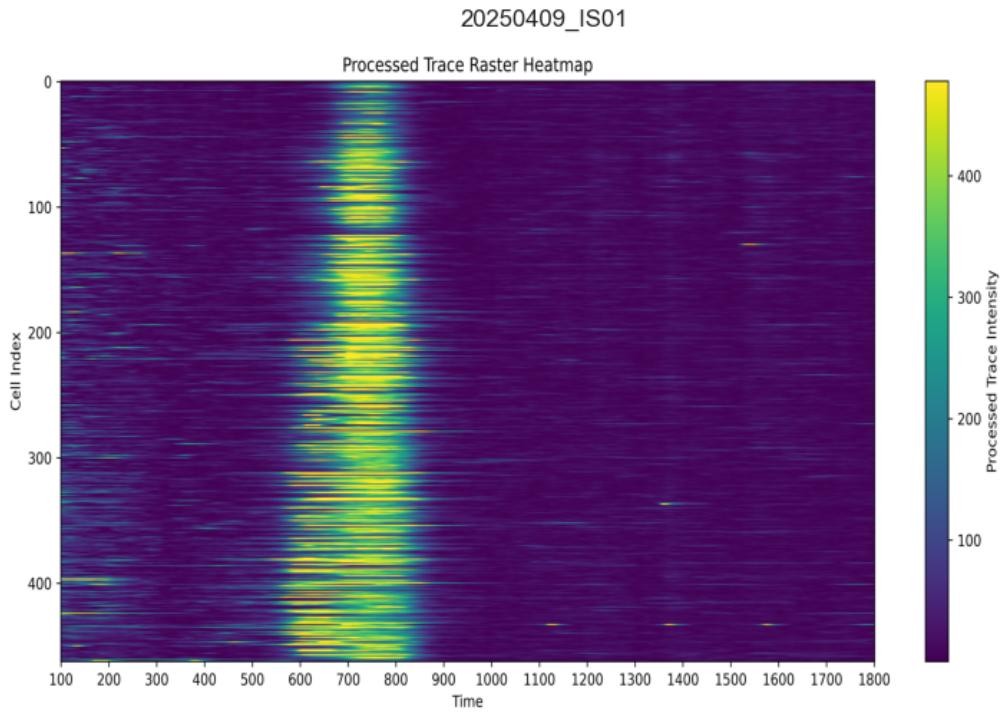
Binary Activity Raster Plot

20250409\_IS01

Binarized Activity Raster Plot



Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 3649

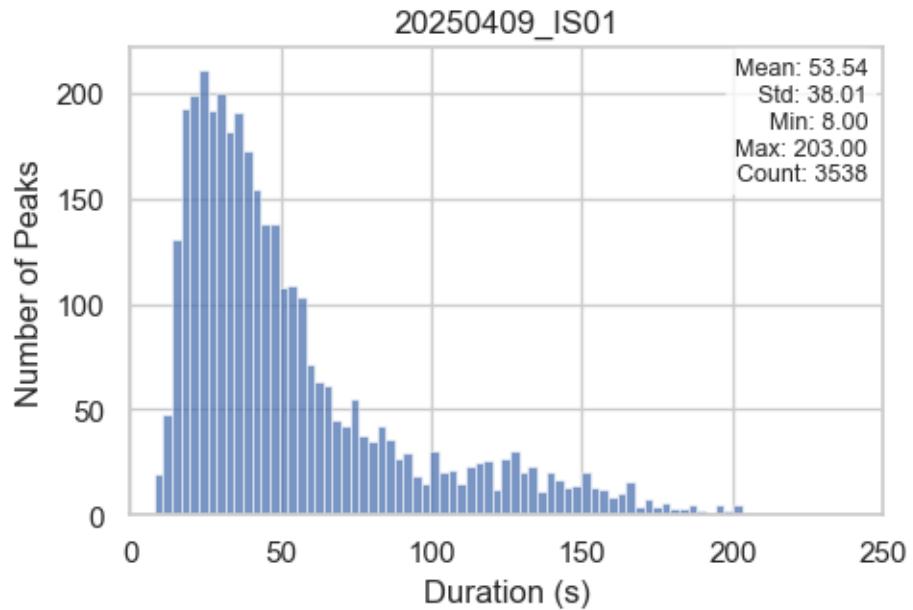
Total number of cells: 463

### 1.1.3 Peaks statistics

```
[2025-08-08 14:50:26] [INFO] calcium: Removed 111 outliers from dataset  
'20250409_IS01' for column 'Duration (s)'
```

```
[2025-08-08 14:50:26] [INFO] calcium: Lower bound: -39.0, Upper bound: 203.0
```

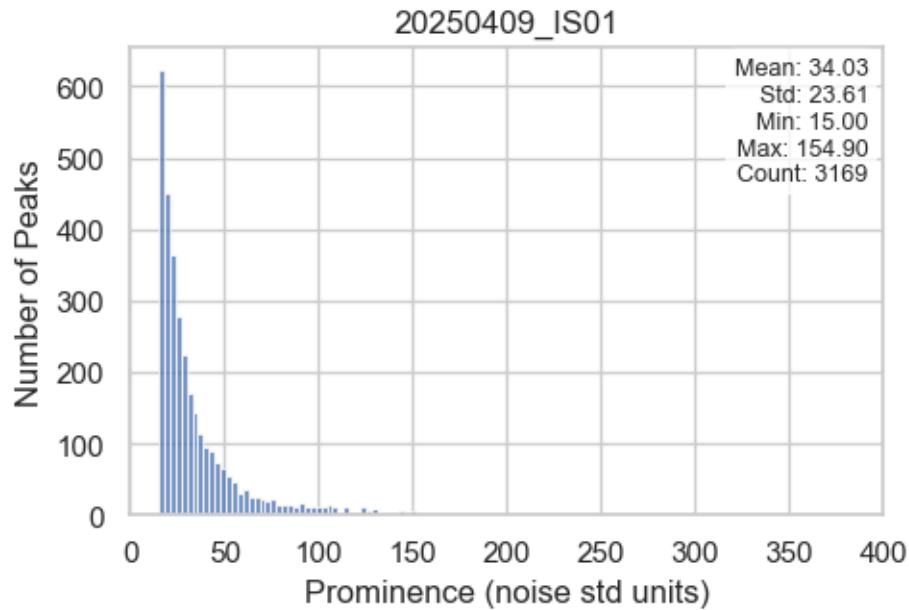
## Distribution of Peak Durations



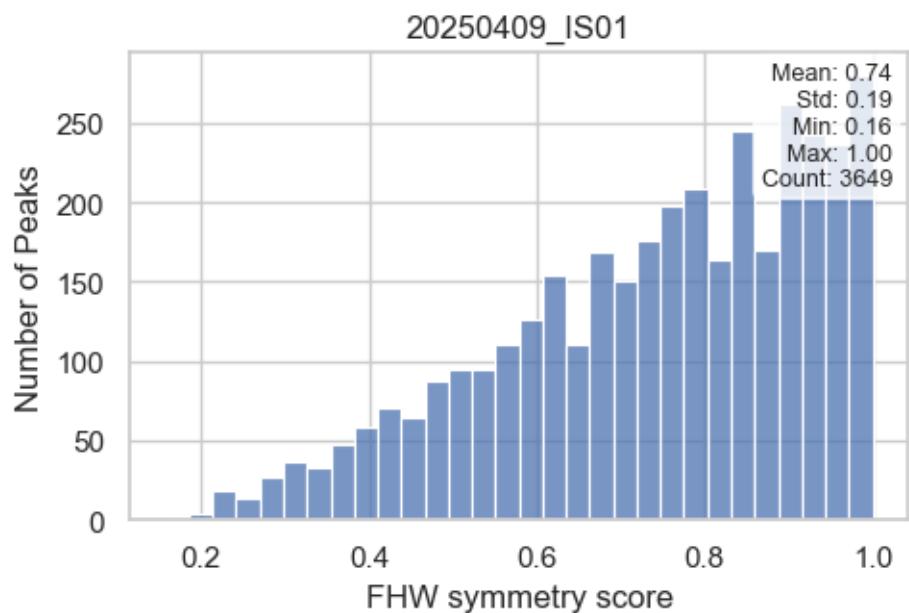
[2025-08-08 14:50:26] [INFO] calcium: Removed 480 outliers from dataset '20250409\_IS01' for column 'Prominence (noise std units)'

[2025-08-08 14:50:26] [INFO] calcium: Lower bound: -30.89999999999995, Upper bound: 155.0

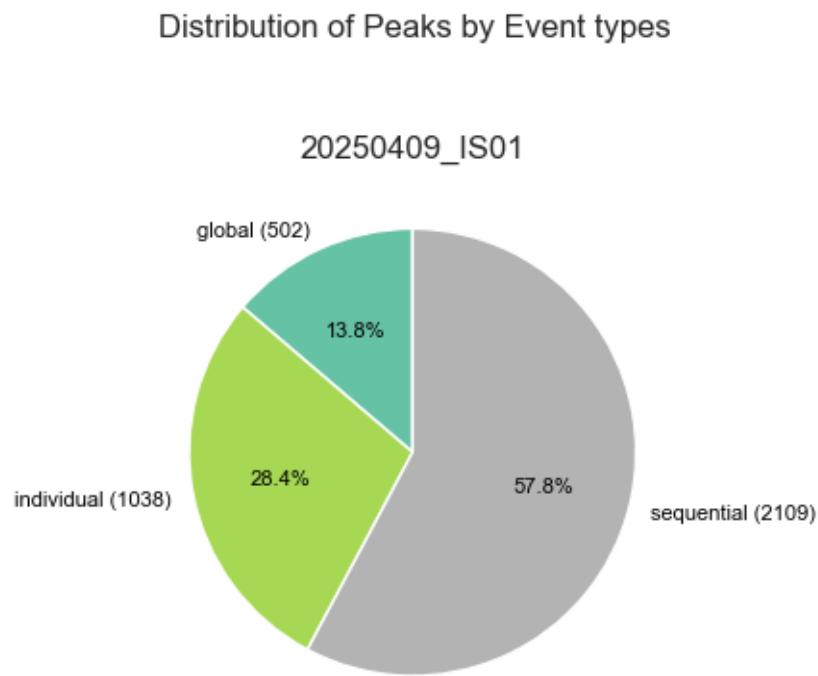
## Distribution of Peak Prominences



## Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

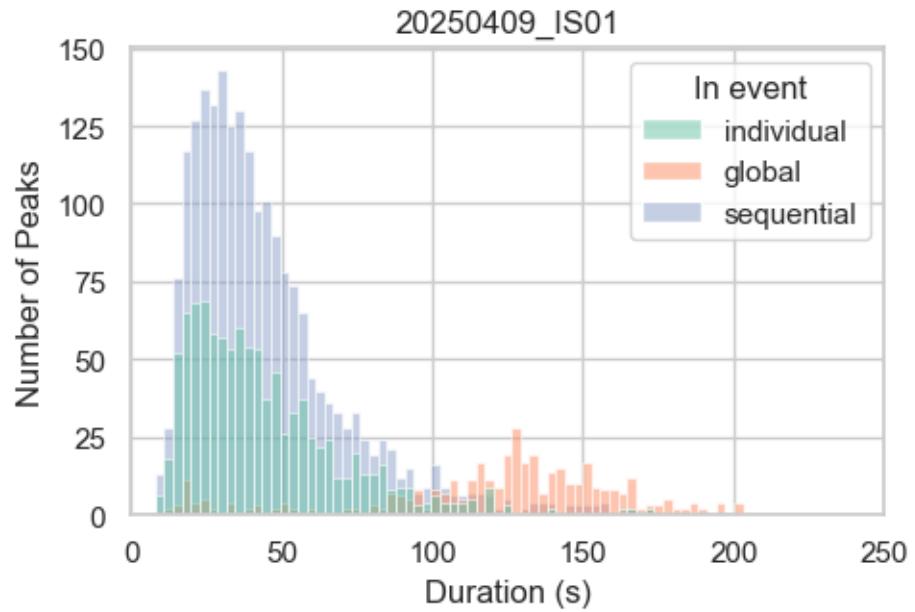


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:50:26] [INFO] calcium: Removed 111 outliers from dataset  
'20250409_IS01' for column 'Duration (s)'
```

```
[2025-08-08 14:50:26] [INFO] calcium: Lower bound: -39.0, Upper bound: 203.0
```

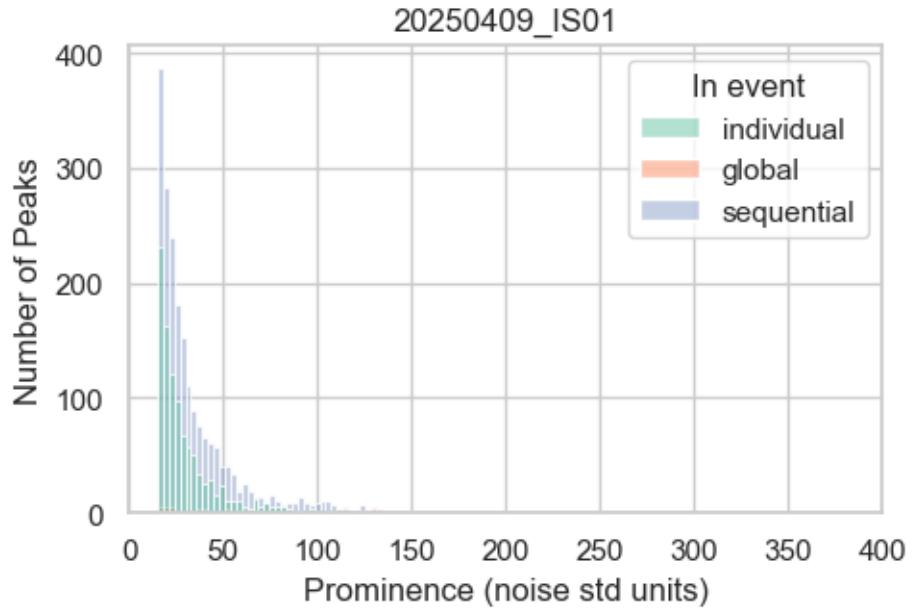
## Distribution of Peak Durations by Group



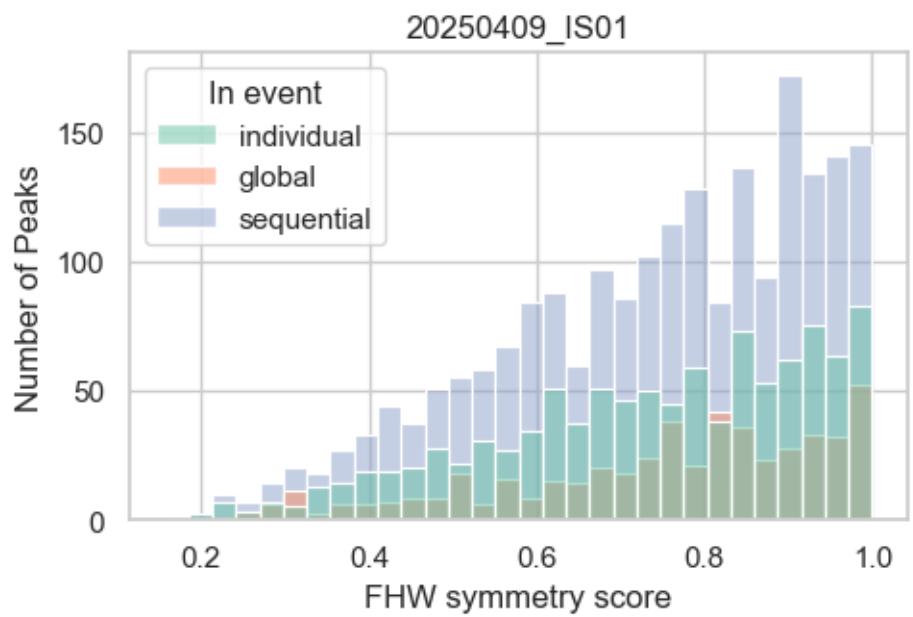
```
[2025-08-08 14:50:27] [INFO] calcium: Removed 480 outliers from dataset  
'20250409_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:50:27] [INFO] calcium: Lower bound: -30.9, Upper bound: 155.0
```

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



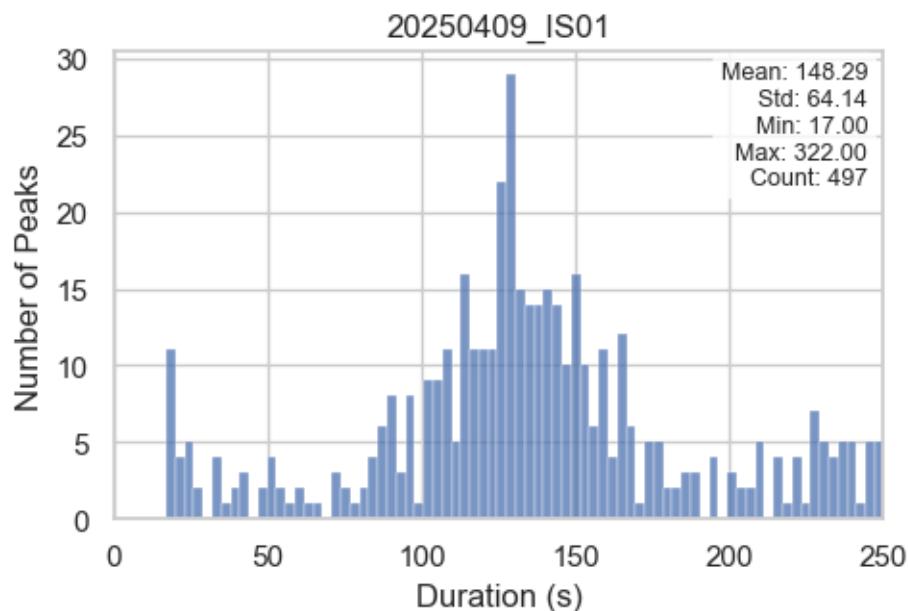
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:50:27] [INFO] calcium: Removed 5 outliers from dataset  
'20250409_IS01' for column 'Duration (s)'
```

```
[2025-08-08 14:50:27] [INFO] calcium: Lower bound: 17.0, Upper bound: 369.0
```

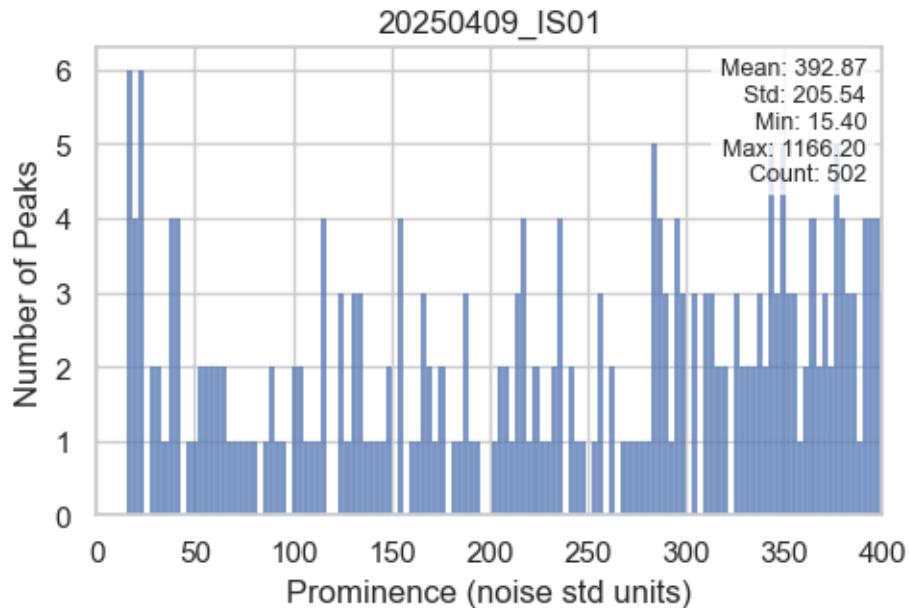
Distribution of Peak Durations



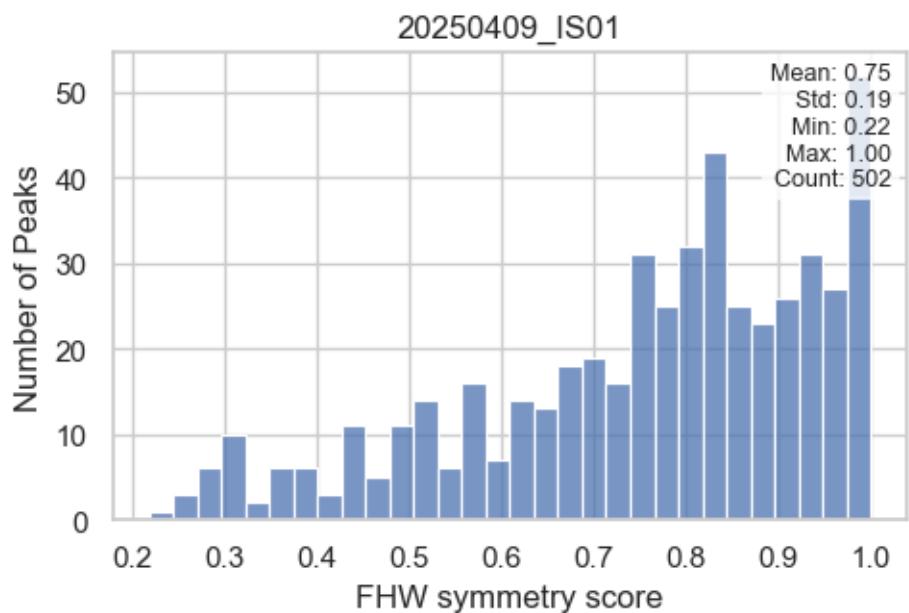
```
[2025-08-08 14:50:27] [INFO] calcium: Removed 0 outliers from dataset  
'20250409_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:50:27] [INFO] calcium: Lower bound: -168.6750000000001, Upper  
bound: 1350.9750000000004
```

## Distribution of Peak Prominences



## Distribution of Peak Symmetry Scores

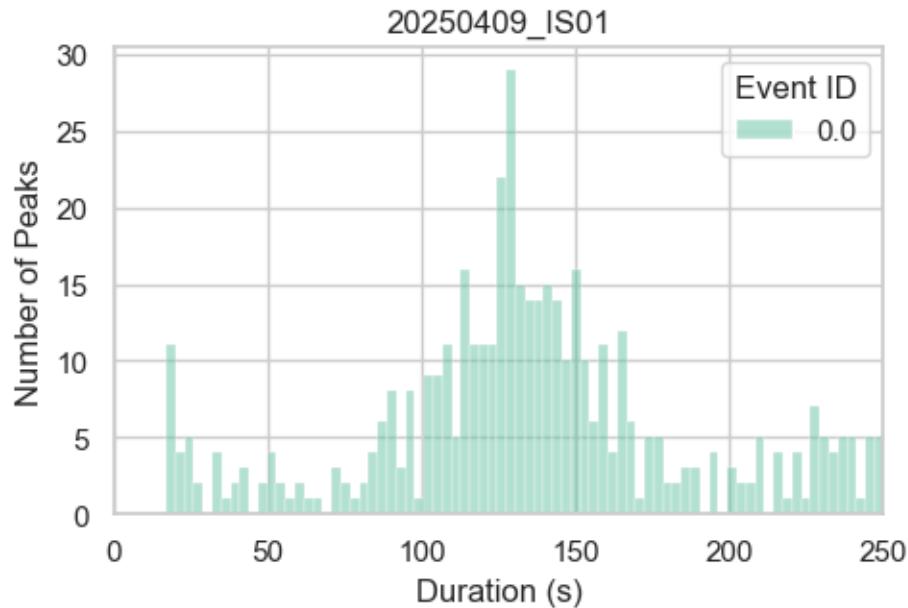


### 1.2.2 Peak statistics in global event per event ID

```
[2025-08-08 14:50:28] [INFO] calcium: Removed 5 outliers from dataset  
'20250409_IS01' for column 'Duration (s)'
```

```
[2025-08-08 14:50:28] [INFO] calcium: Lower bound: 17.0, Upper bound: 369.0
```

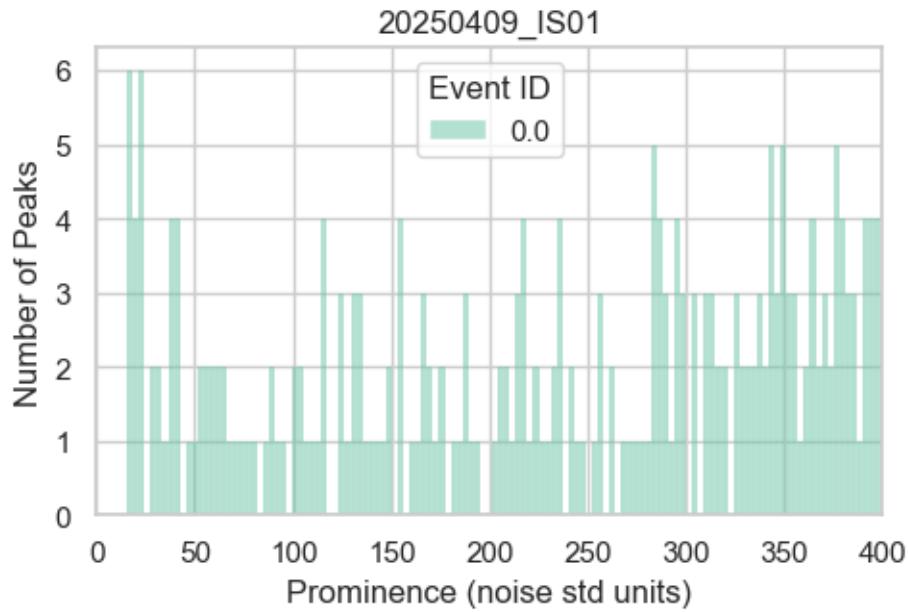
Distribution of Peak Durations by Group



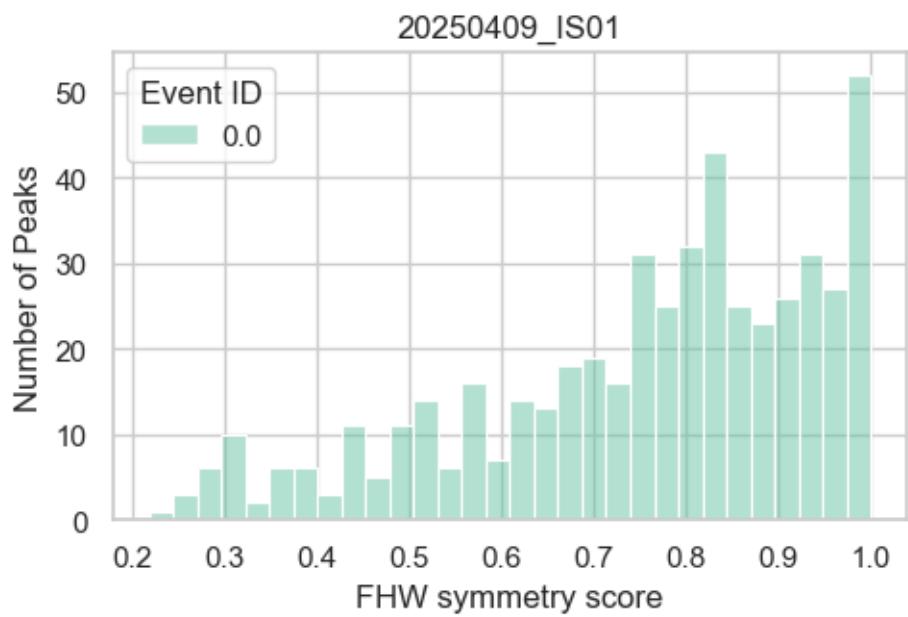
```
[2025-08-08 14:50:28] [INFO] calcium: Removed 0 outliers from dataset  
'20250409_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:50:28] [INFO] calcium: Lower bound: -168.7, Upper bound: 1351.0
```

### Distribution of Peak Prominences by Group



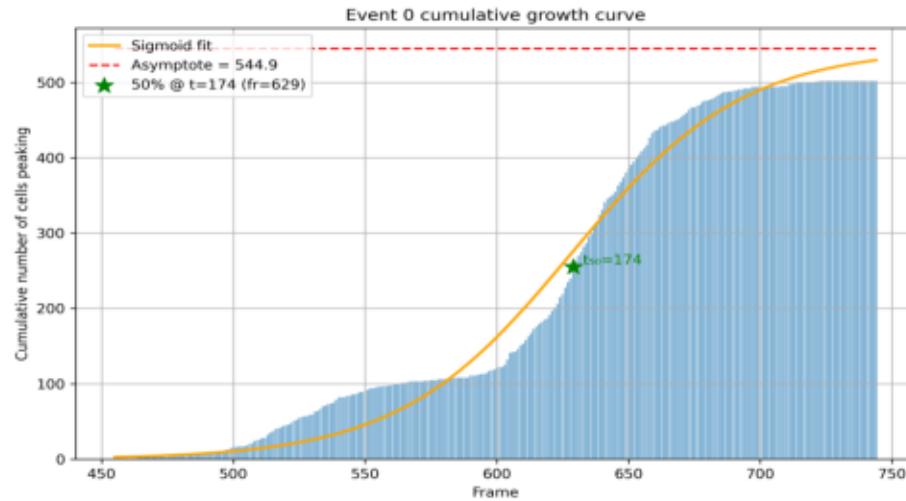
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

Event Activity Overlay (Event ID: 0)

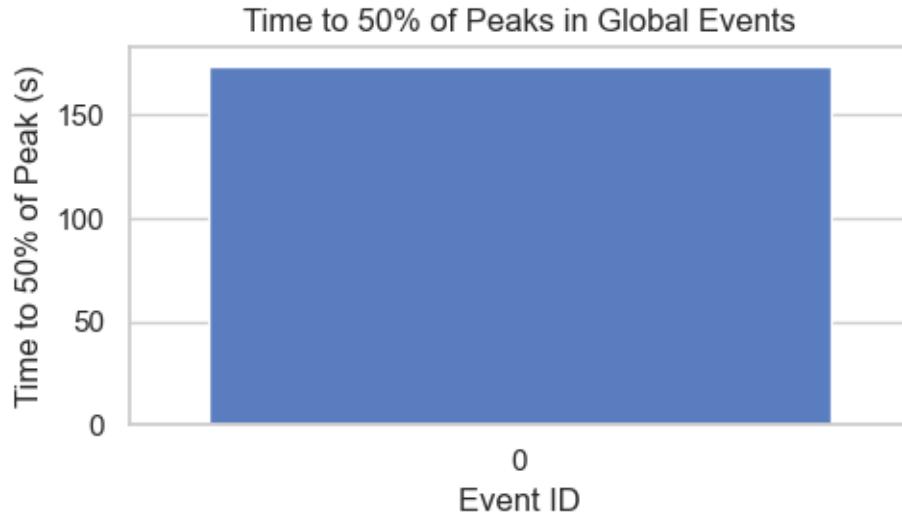
20250409\_IS01



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

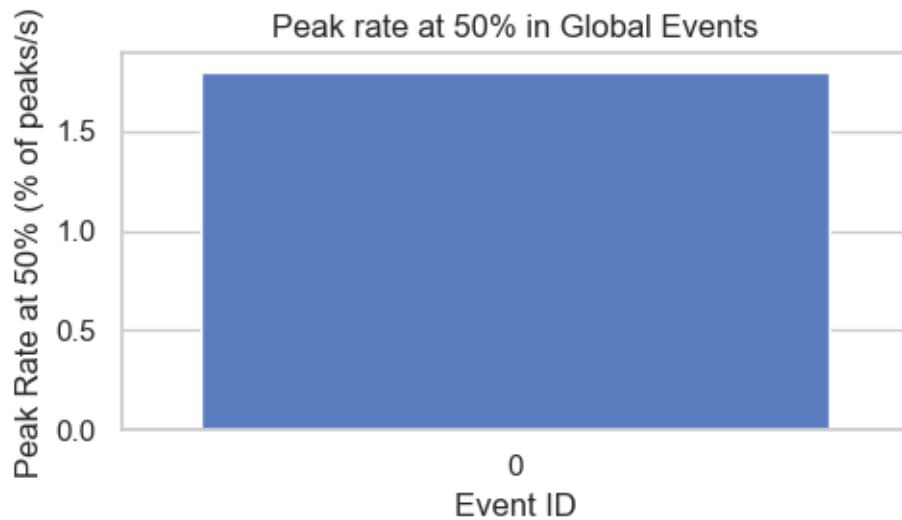
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys
is\visualizers.py:297: FutureWarning:
```

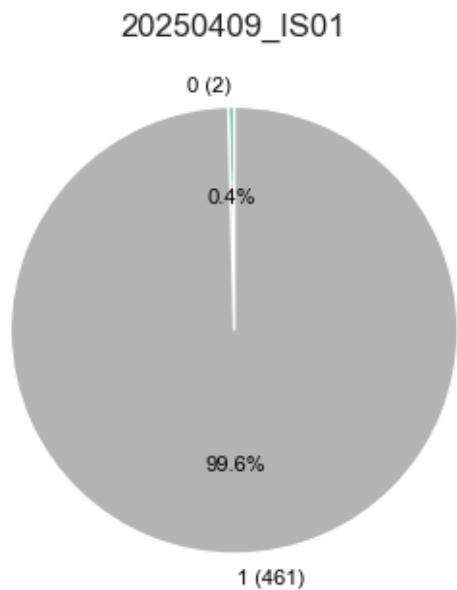
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,
dodge=False, palette=palette, legend=False)
```



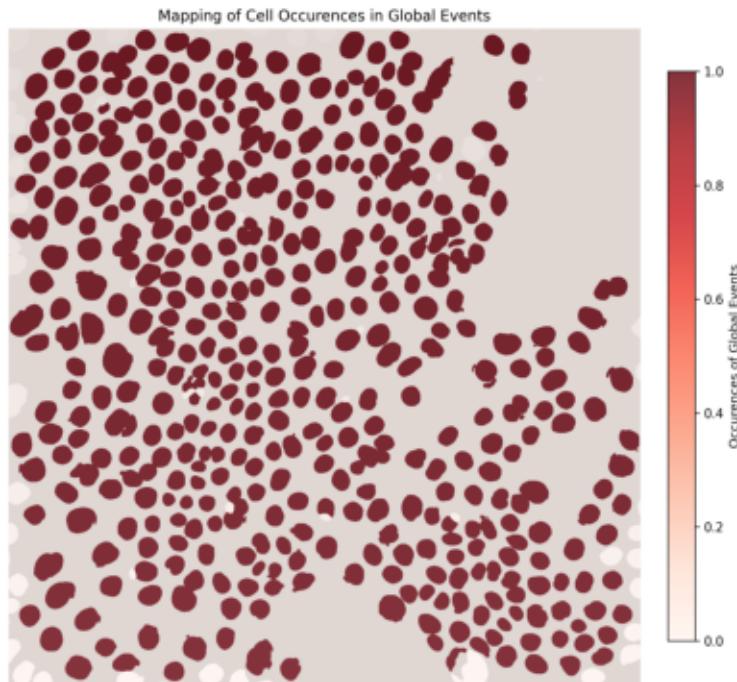
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

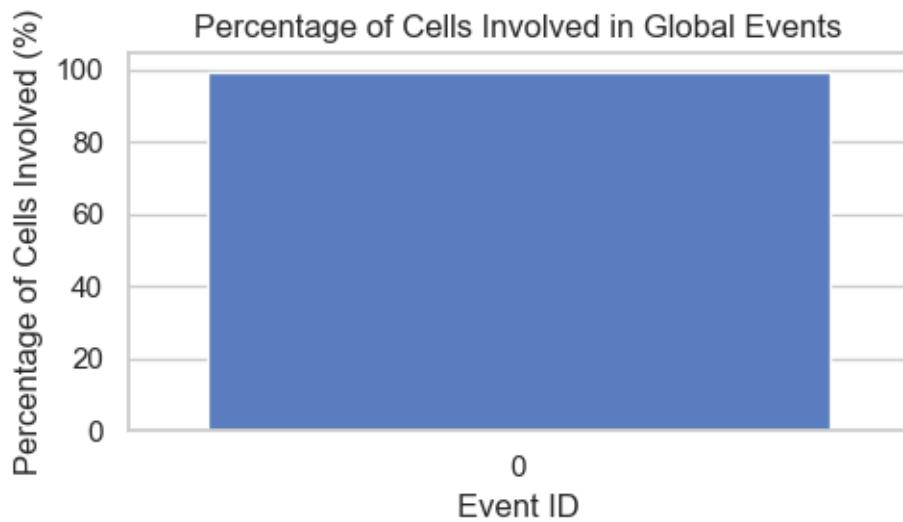
20250409\_IS01



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



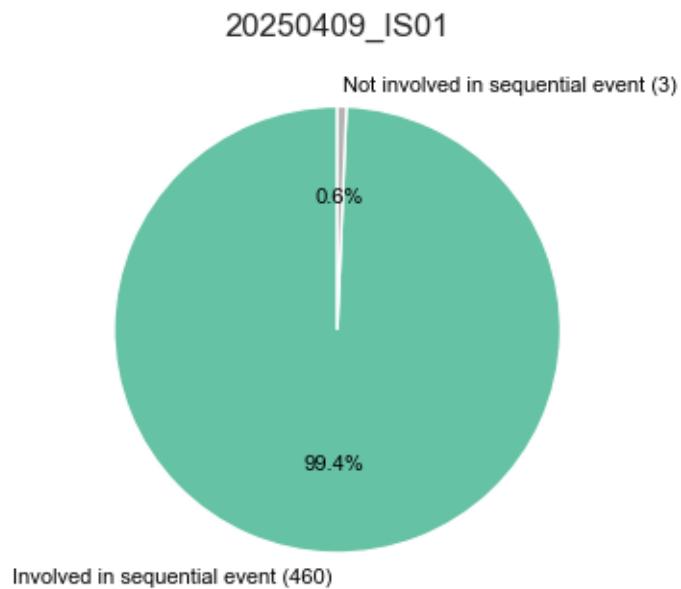
### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: []

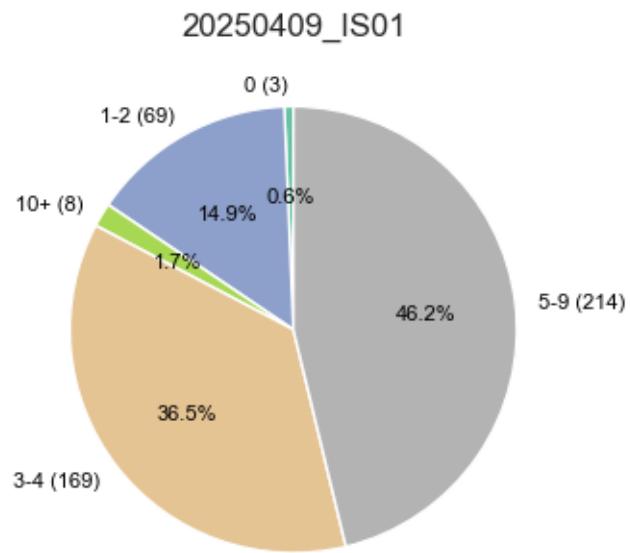
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequential events

Distribution of Cells Involved in Sequential Events

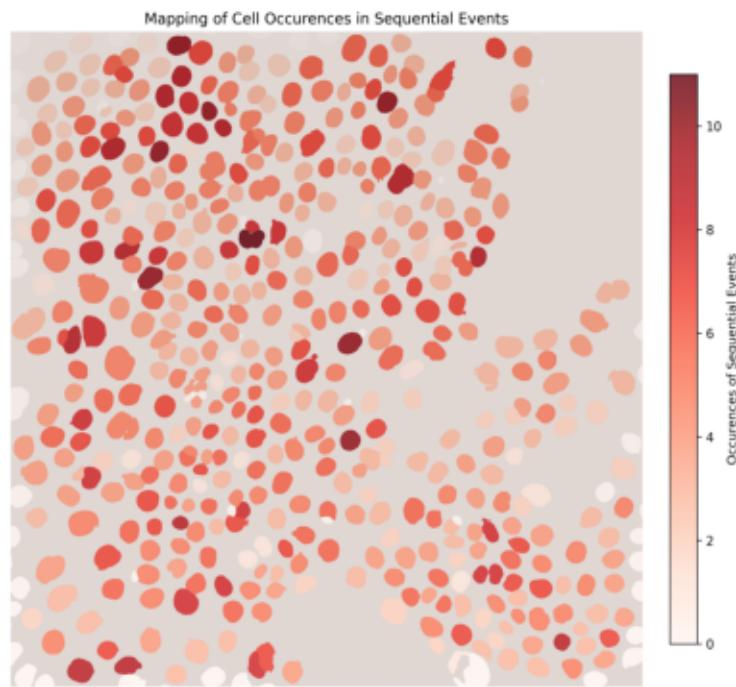


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250409\_IS01

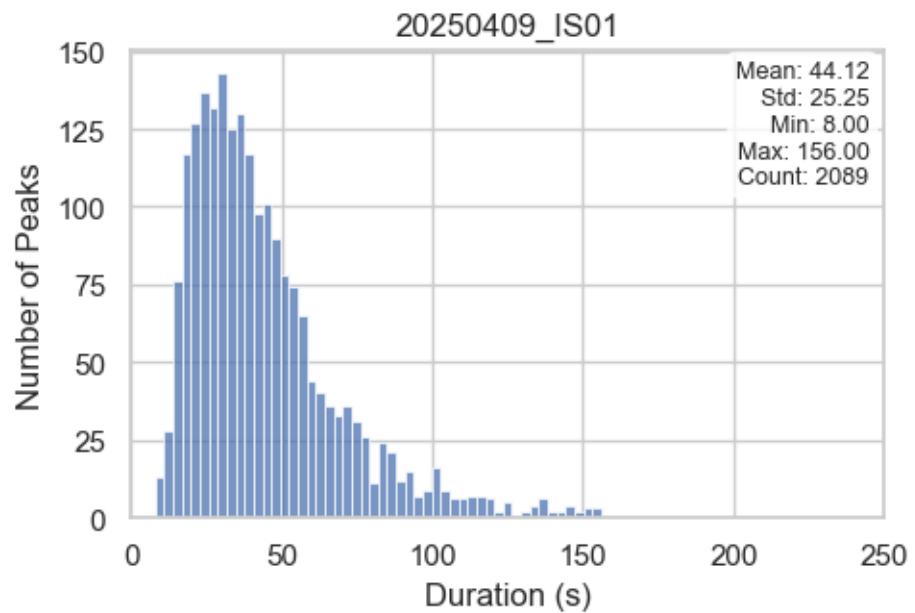


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:50:31] [INFO] calcium: Removed 20 outliers from dataset  
'20250409_IS01' for column 'Duration (s)'
```

```
[2025-08-08 14:50:31] [INFO] calcium: Lower bound: -17.5, Upper bound: 156.5
```

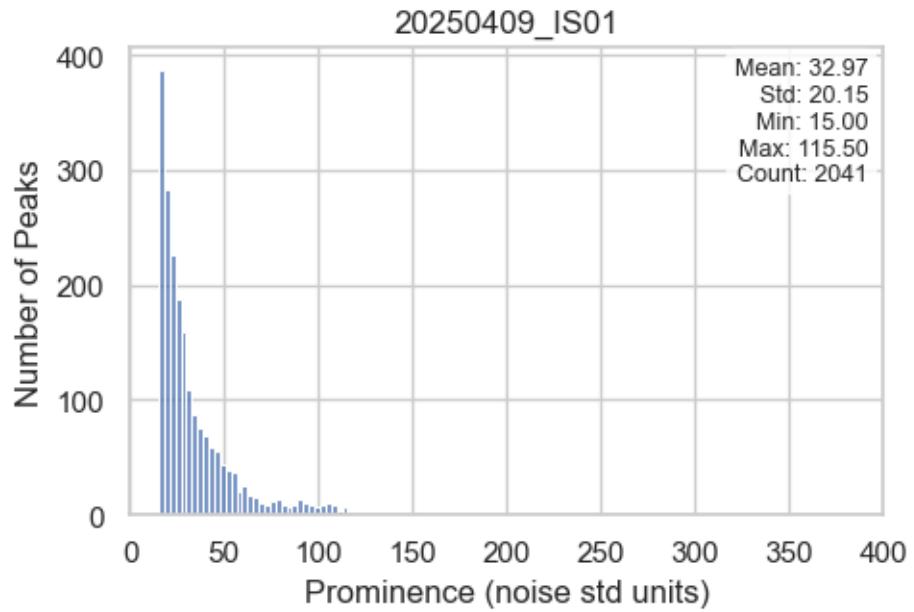
## Distribution of Peak Durations



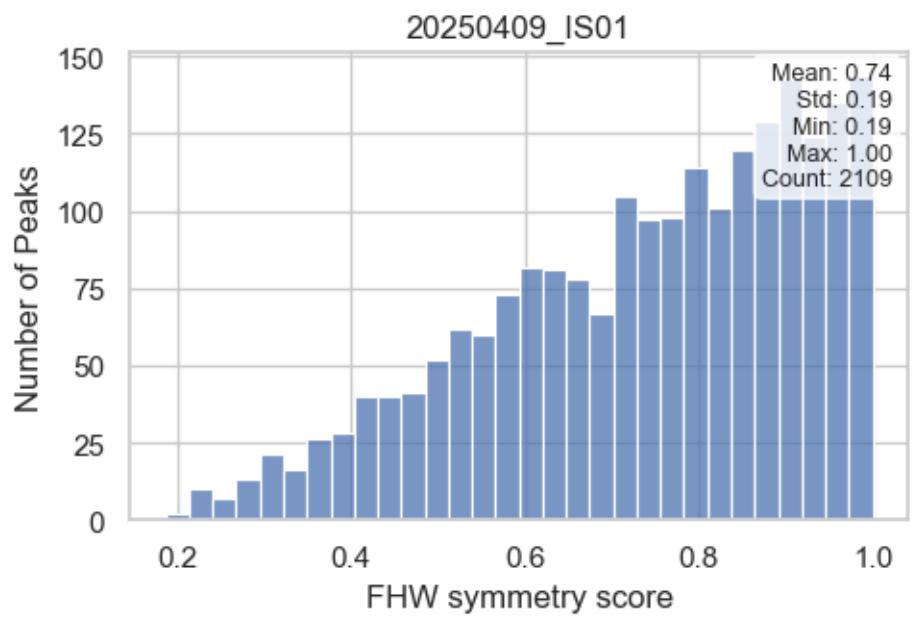
```
[2025-08-08 14:50:32] [INFO] calcium: Removed 68 outliers from dataset '20250409_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:50:32] [INFO] calcium: Lower bound: -13.750000000000007, Upper bound: 118.85000000000001
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

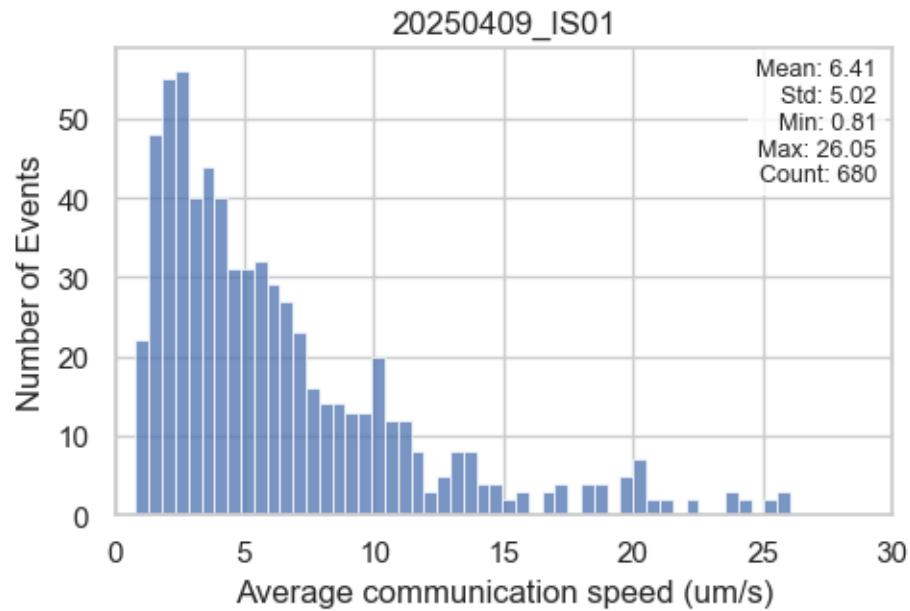


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:50:32] [INFO] calcium: Removed 8 outliers from dataset '20250409\_IS01' for column 'Average communication speed (um/s)'

[2025-08-08 14:50:32] [INFO] calcium: Lower bound: -6.074999999999998, Upper bound: 26.42999999999996

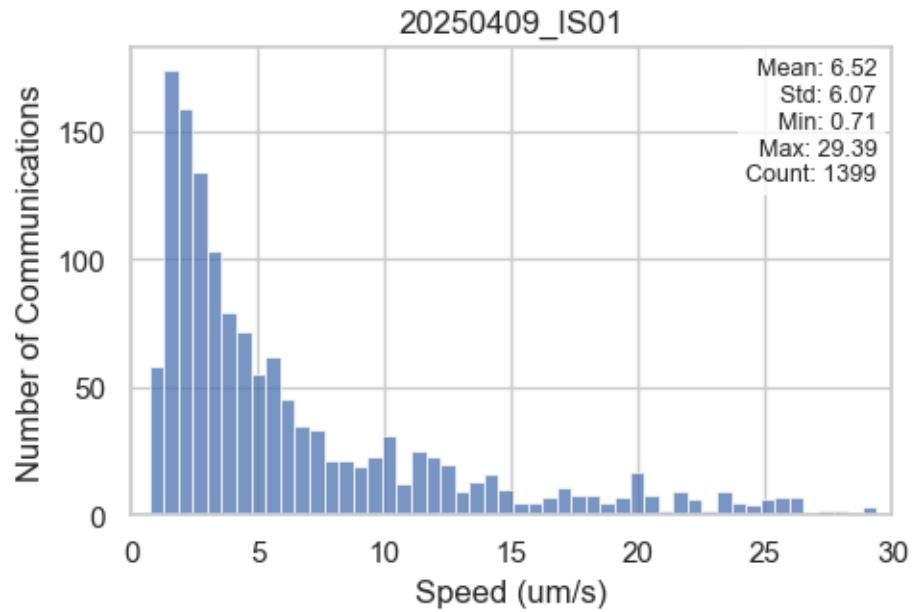
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:50:32] [INFO] calcium: Removed 22 outliers from dataset '20250409\_IS01' for column 'Speed (um/s)'

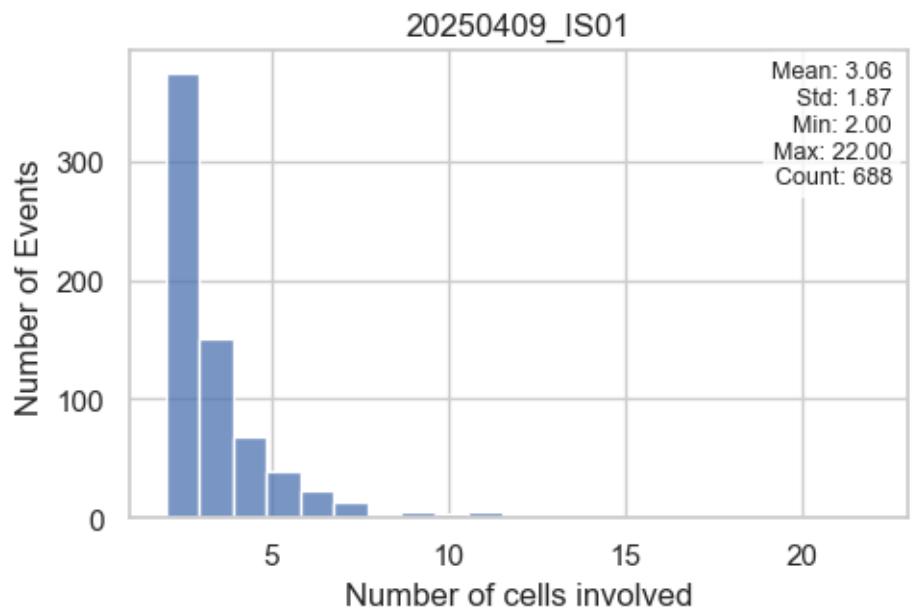
[2025-08-08 14:50:32] [INFO] calcium: Lower bound: -7.945000000000001, Upper bound: 29.620000000000005

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

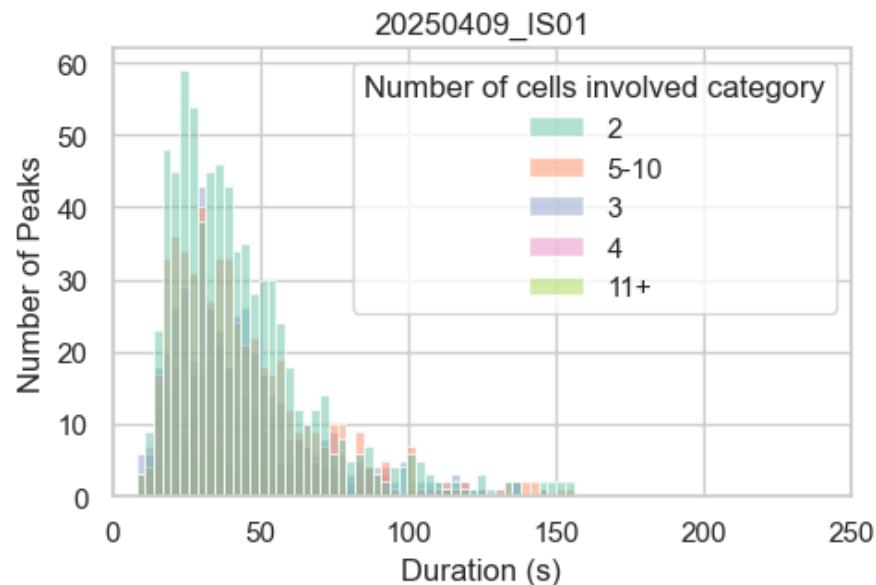


### 1.3.5 Influence of cell count per event on statistics

[2025-08-08 14:50:33] [INFO] calcium: Removed 20 outliers from dataset '20250409\_IS01' for column 'Duration (s)'

[2025-08-08 14:50:33] [INFO] calcium: Lower bound: -17.5, Upper bound: 156.5

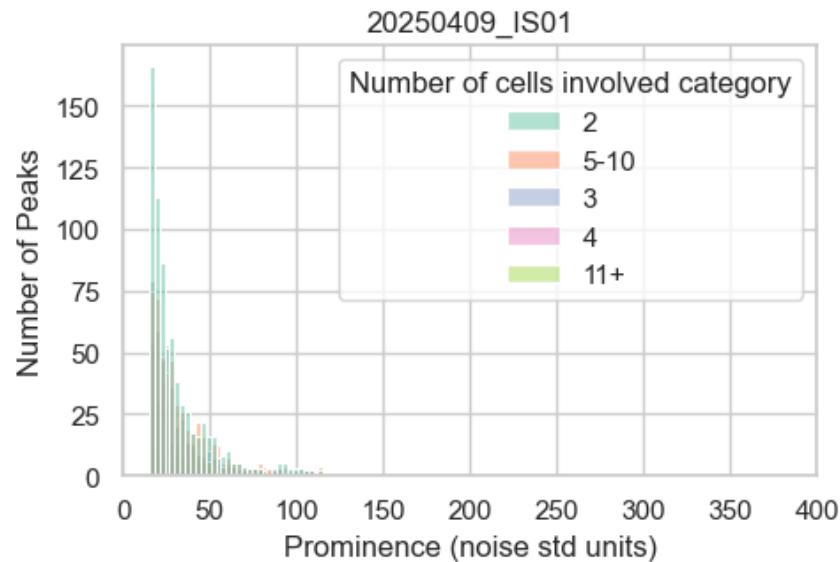
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



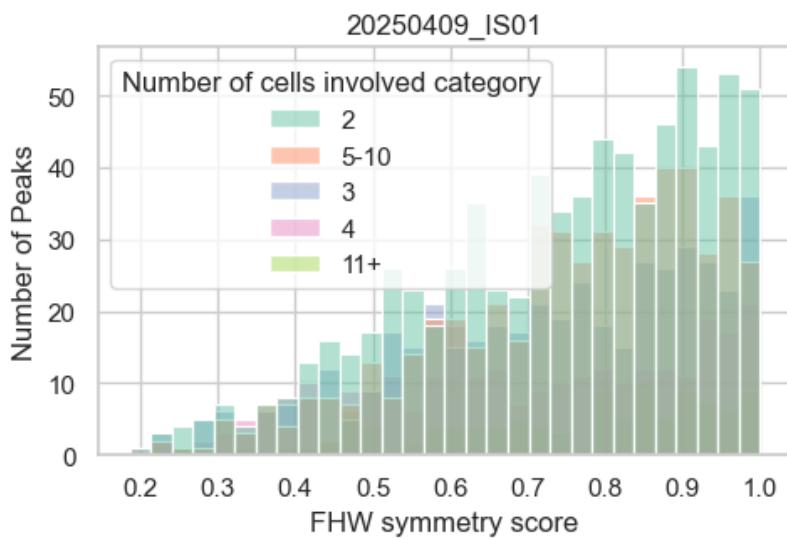
[2025-08-08 14:50:33] [INFO] calcium: Removed 68 outliers from dataset '20250409\_IS01' for column 'Prominence (noise std units)'

[2025-08-08 14:50:33] [INFO] calcium: Lower bound: -13.8, Upper bound: 118.9

## Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



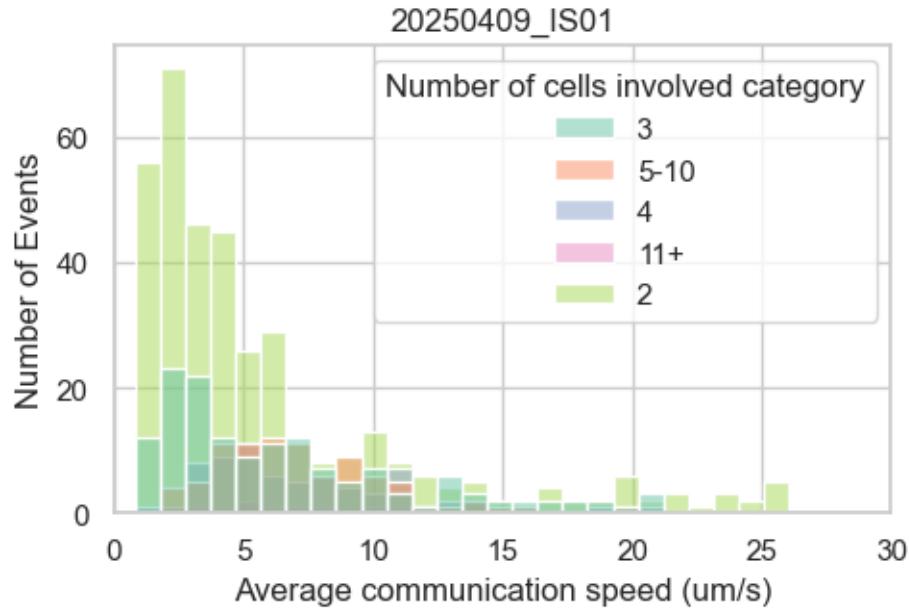
## Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



[2025-08-08 14:50:33] [INFO] calcium: Removed 8 outliers from dataset '20250409\_IS01' for column 'Average communication speed (um/s)'

[2025-08-08 14:50:33] [INFO] calcium: Lower bound: -6.1, Upper bound: 26.4

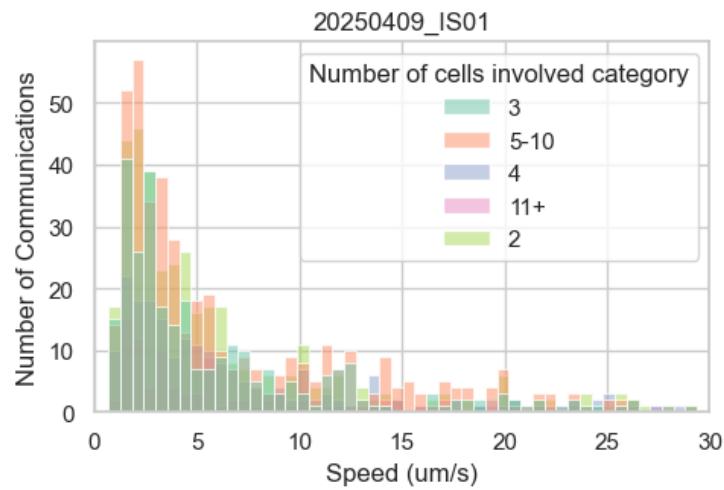
## Distribution of Average Communication Speeds by Number of Cells Involved



[2025-08-08 14:50:34] [INFO] calcium: Removed 22 outliers from dataset '20250409\_IS01' for column 'Speed (um/s)'

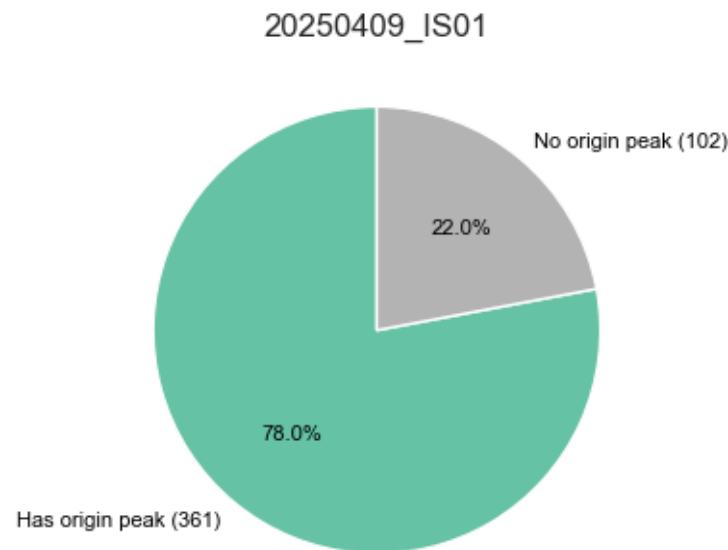
[2025-08-08 14:50:34] [INFO] calcium: Lower bound: -7.9, Upper bound: 29.6

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

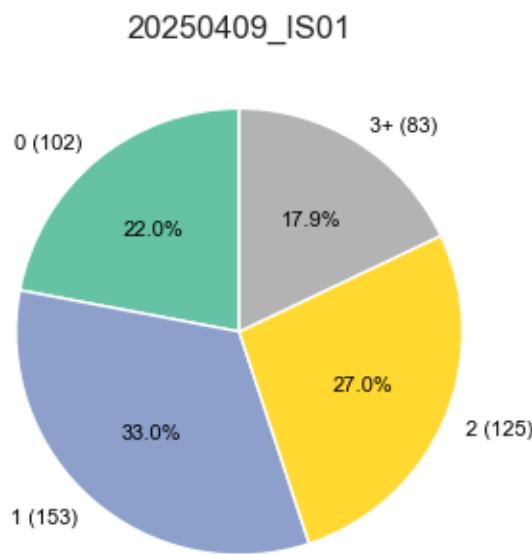


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

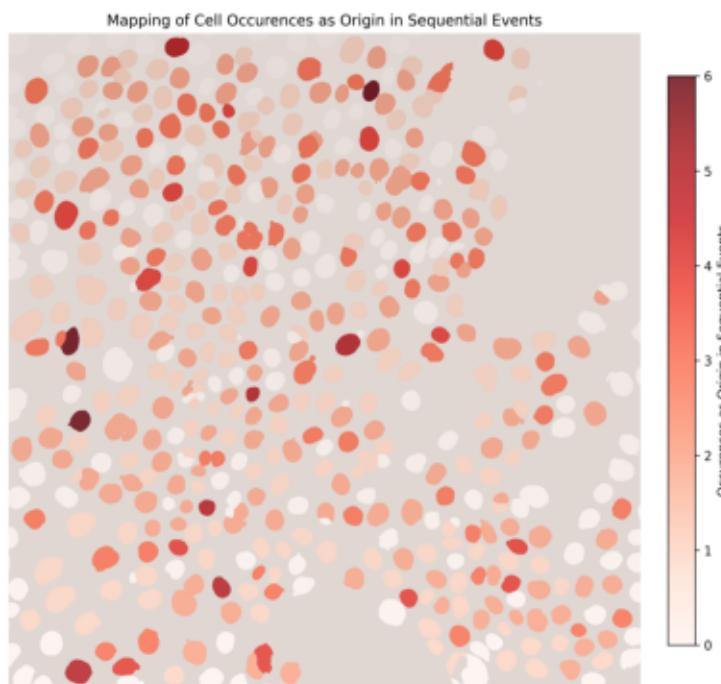


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

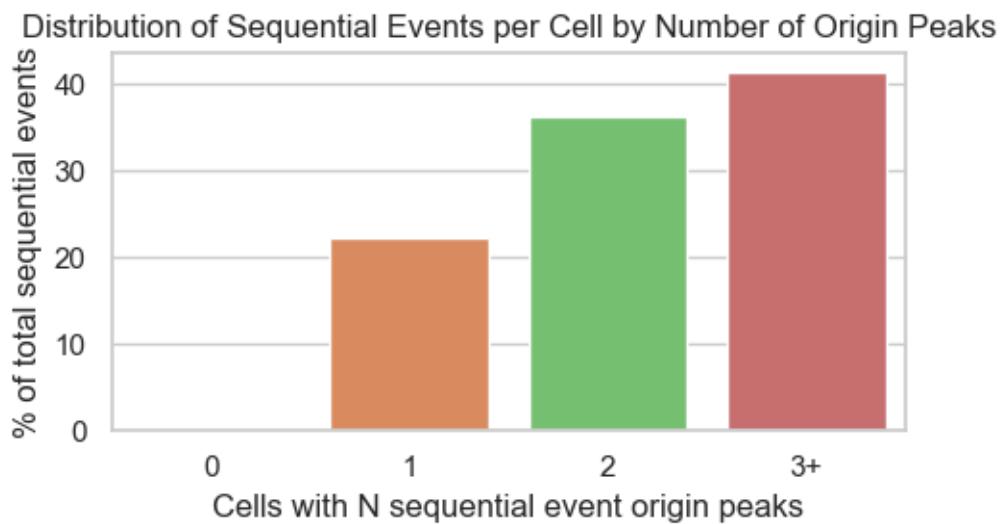
20250409\_IS01



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

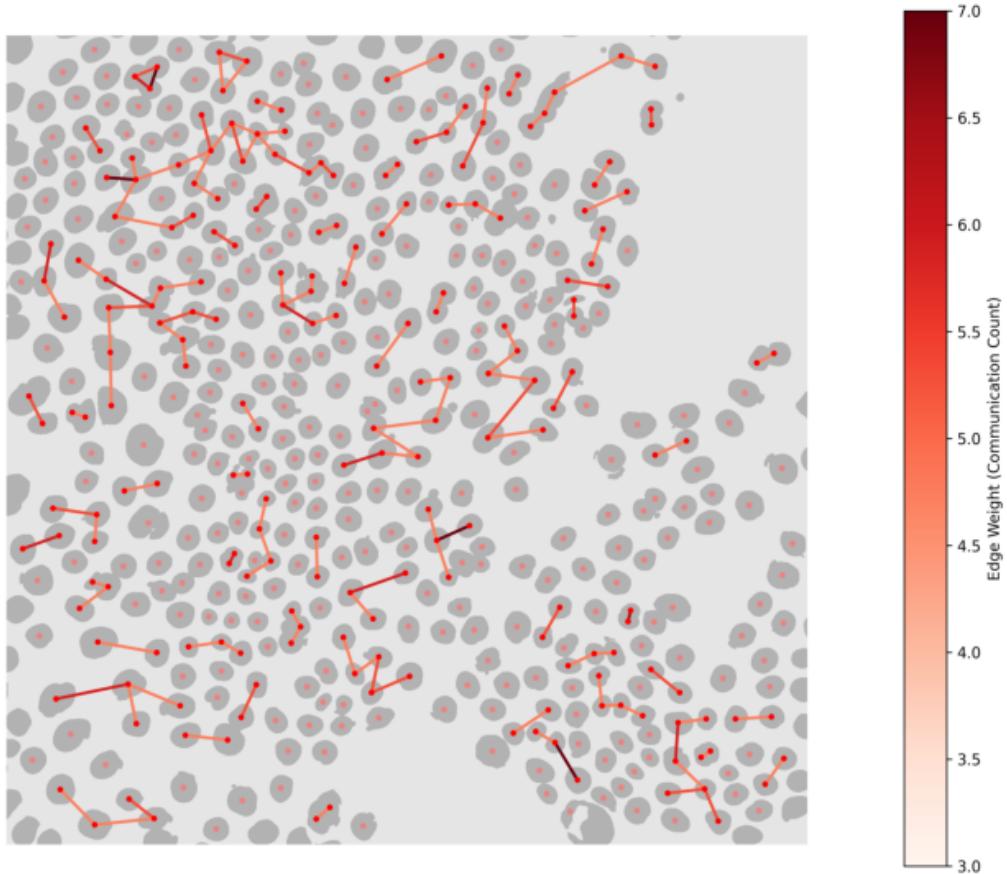


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250409\_IS01

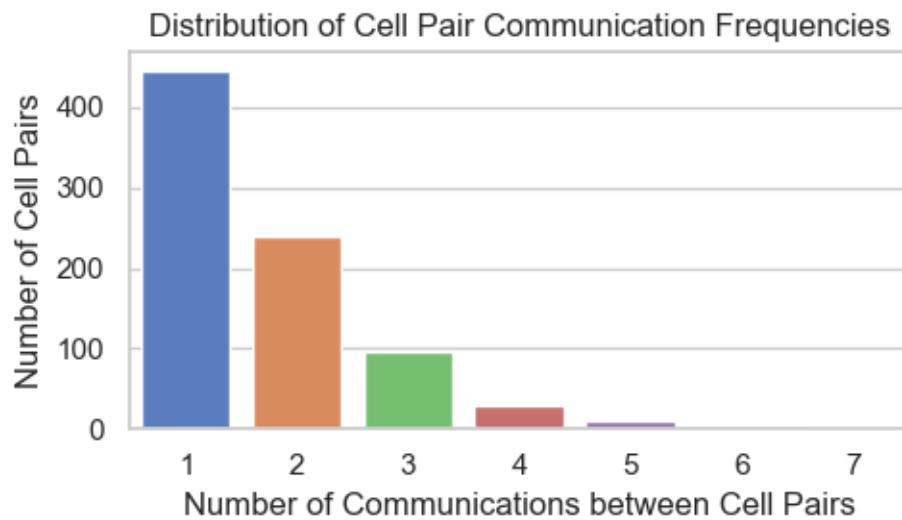
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

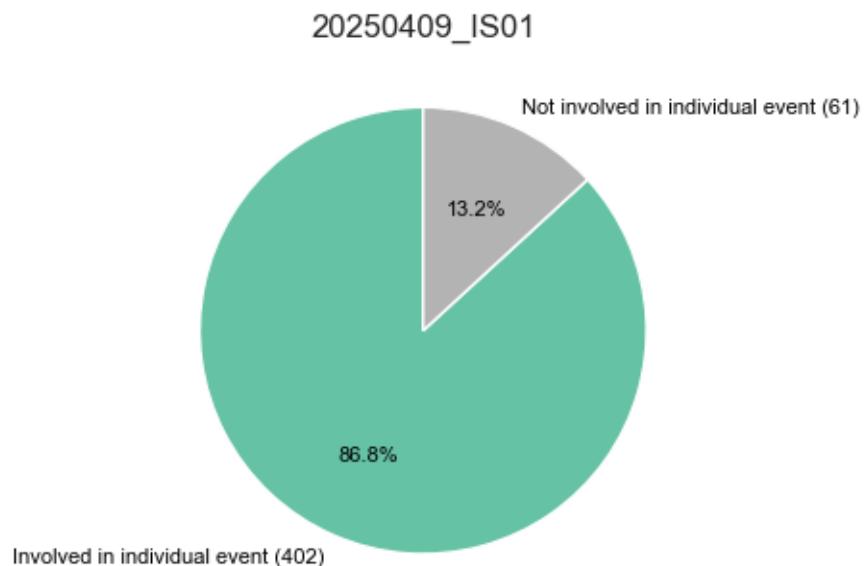
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



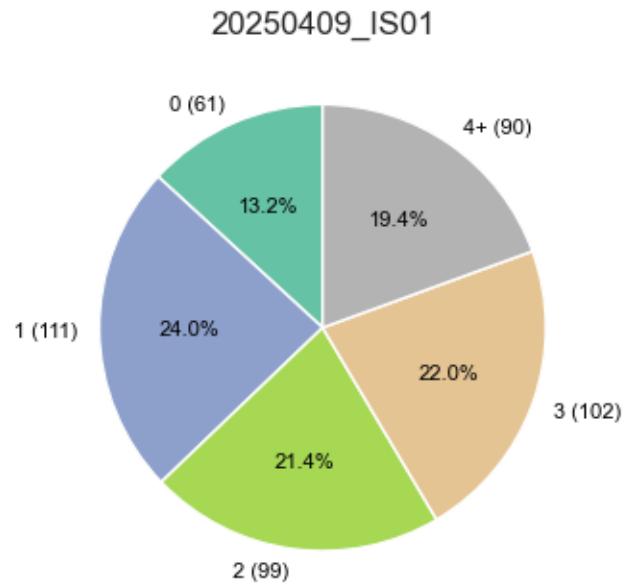
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

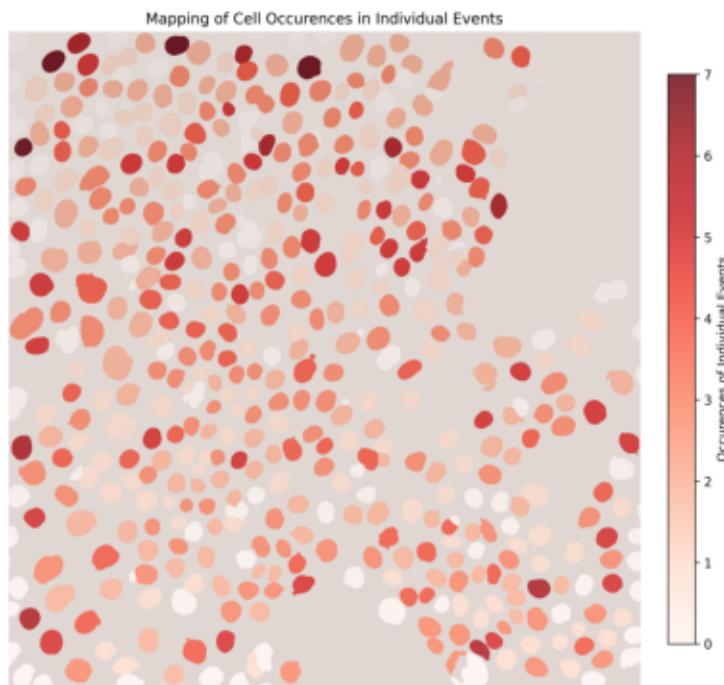


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250409\_IS01

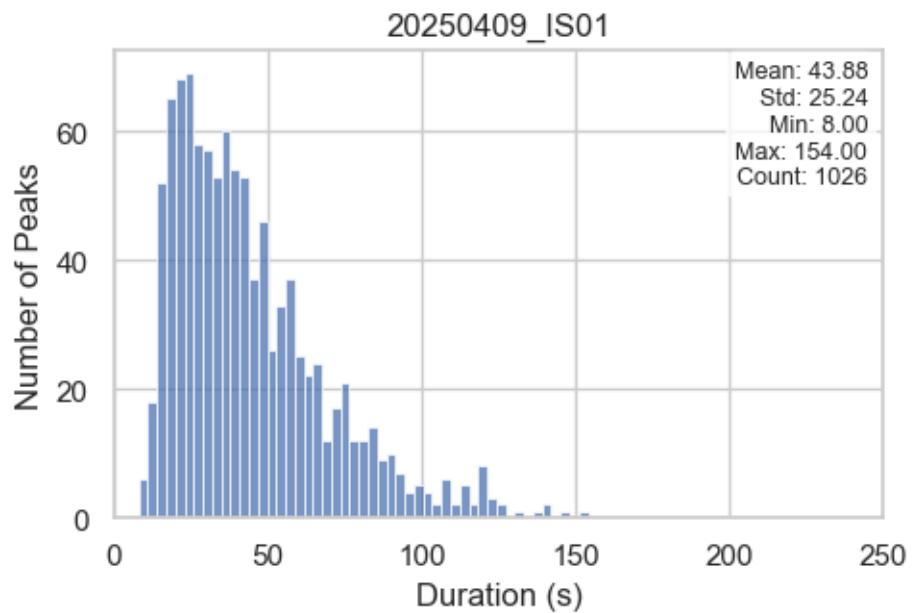


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:50:37] [INFO] calcium: Removed 12 outliers from dataset  
'20250409_IS01' for column 'Duration (s)'
```

```
[2025-08-08 14:50:37] [INFO] calcium: Lower bound: -24.125, Upper bound: 156.0
```

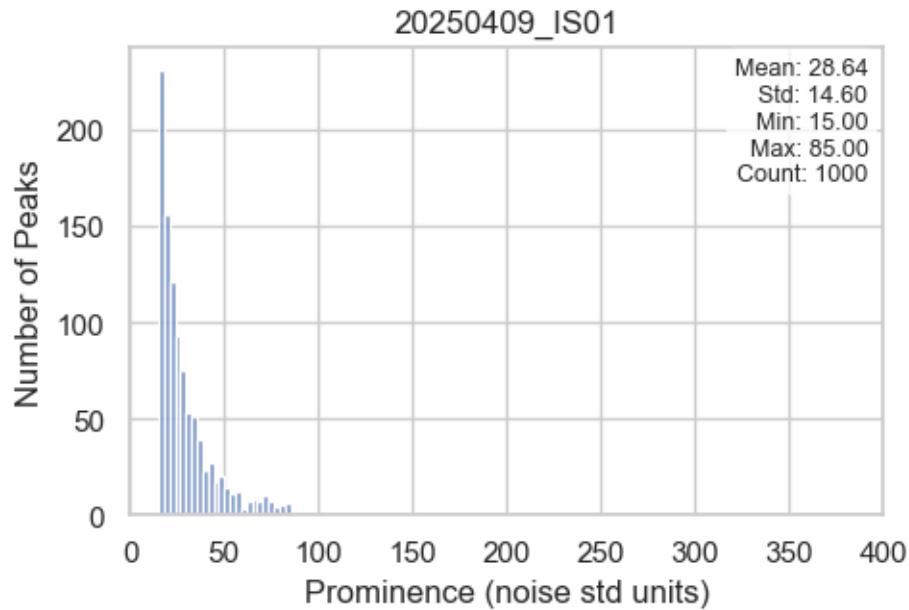
## Distribution of Peak Durations



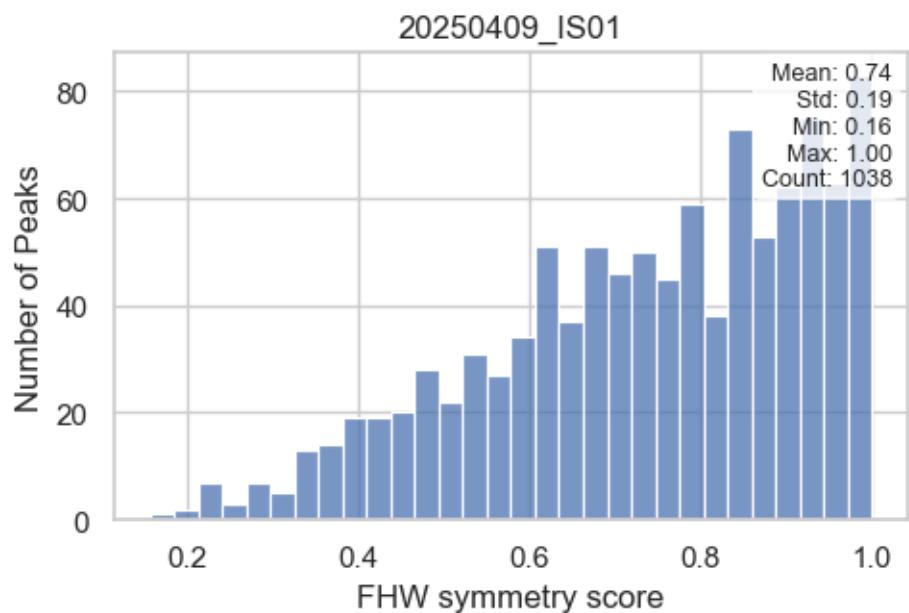
```
[2025-08-08 14:50:37] [INFO] calcium: Removed 38 outliers from dataset  
'20250409_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:50:37] [INFO] calcium: Lower bound: -7.162499999999998, Upper  
bound: 86.19999999999999
```

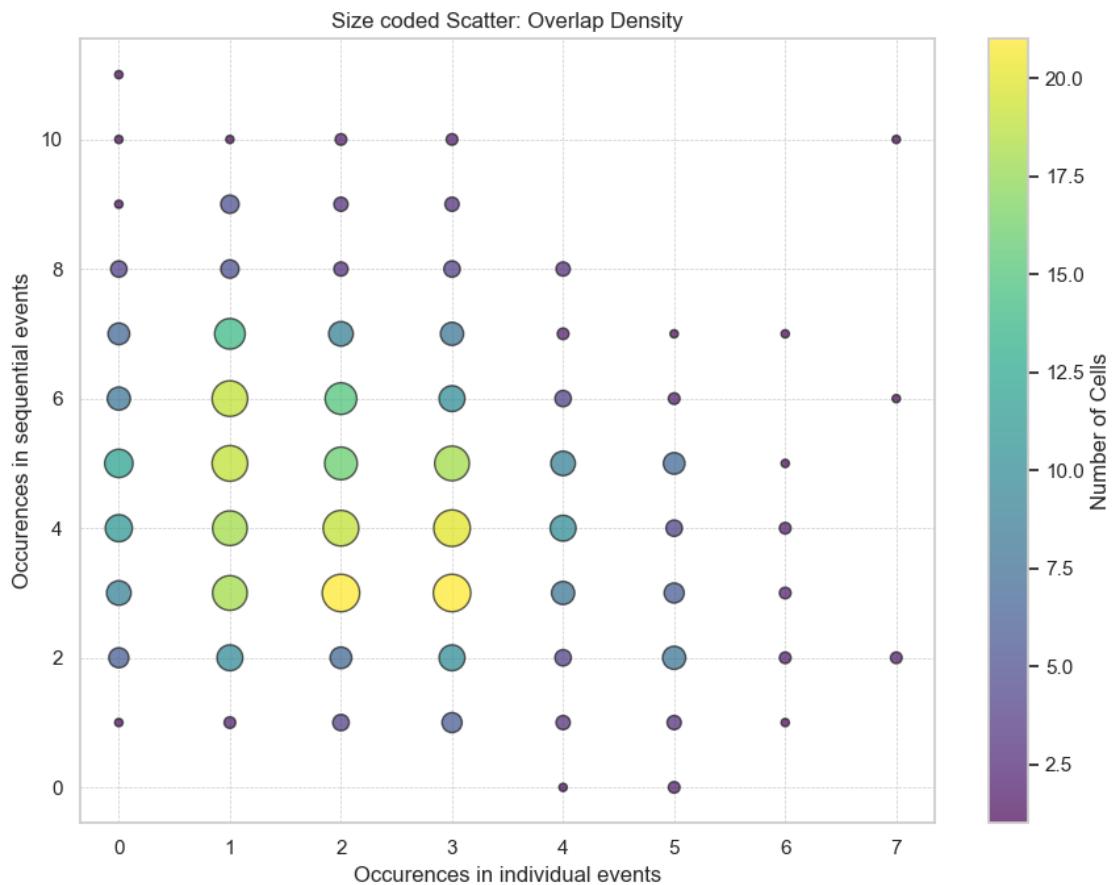
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

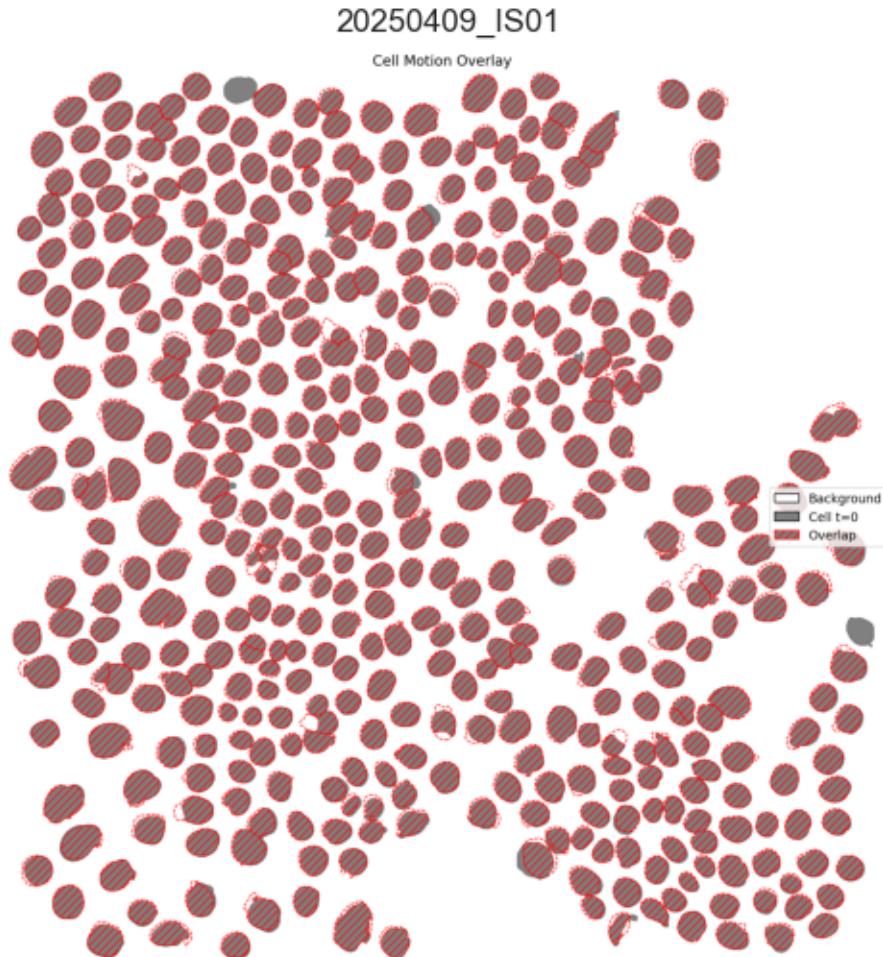


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 463
- Hoechst image taken at t=1801: 454
- Number of cells difference: absolute 9, relative 1.96%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 799186
- Pixels segmented as cell at t=1801: 781380
- Overlapping pixels between t=0 and t=1801: 723667 (91.57% of total)
- Pixels exclusive to t=0: 75519 (9.45% of total)
- Pixels exclusive to t=1801: 57713 (7.39% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n    "Default Dataset": "/path/to/your/dataset"\n}'
```

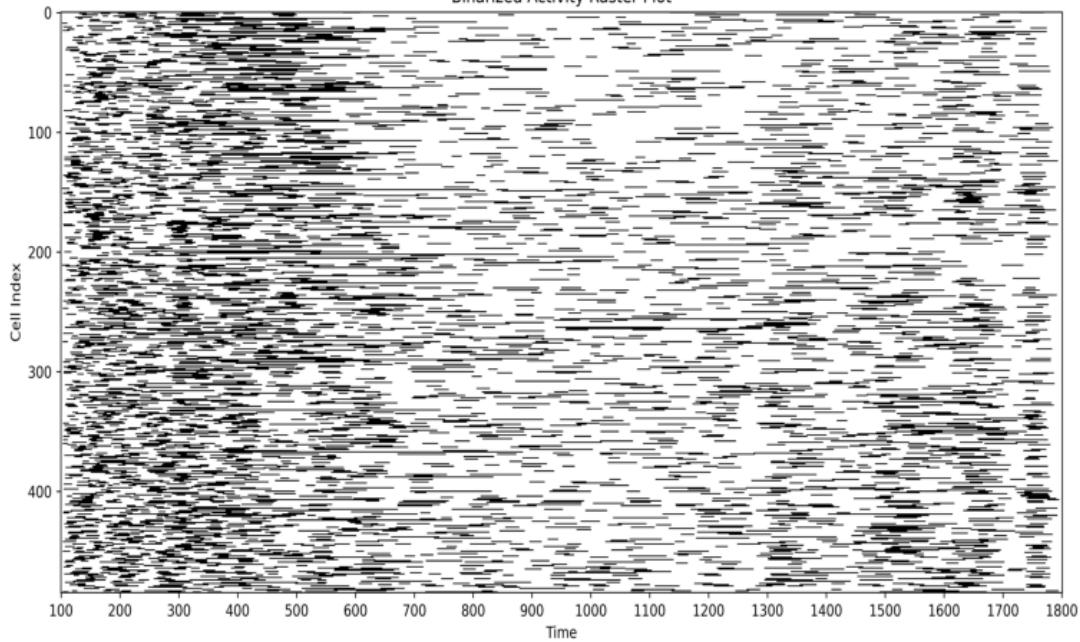
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

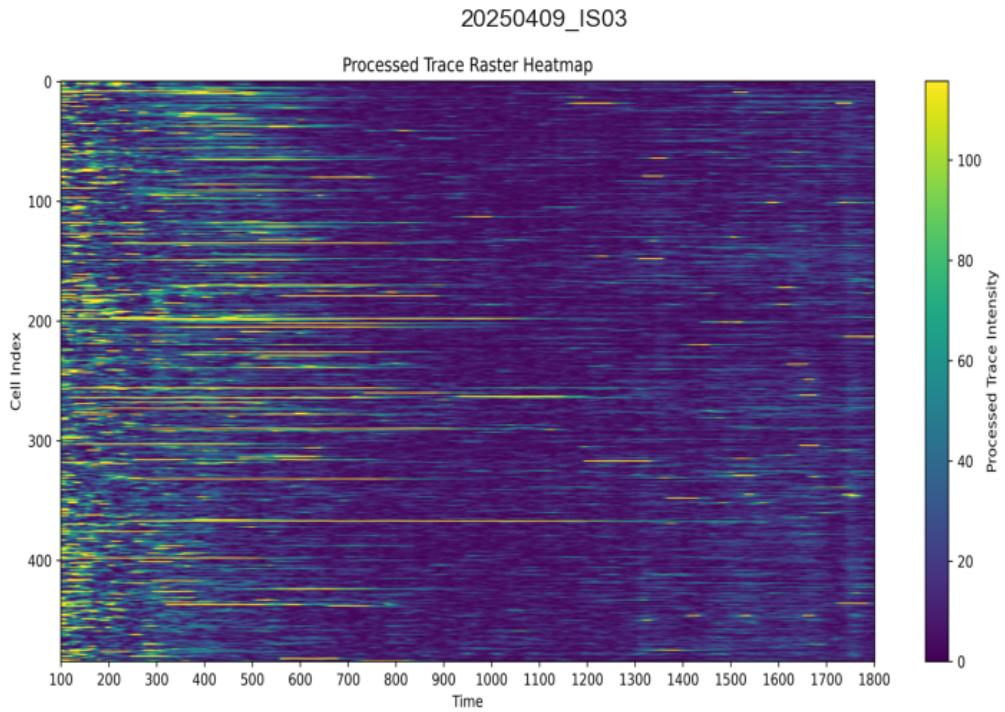
Binary Activity Raster Plot

20250409\_IS03

Binarized Activity Raster Plot



## Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 4264

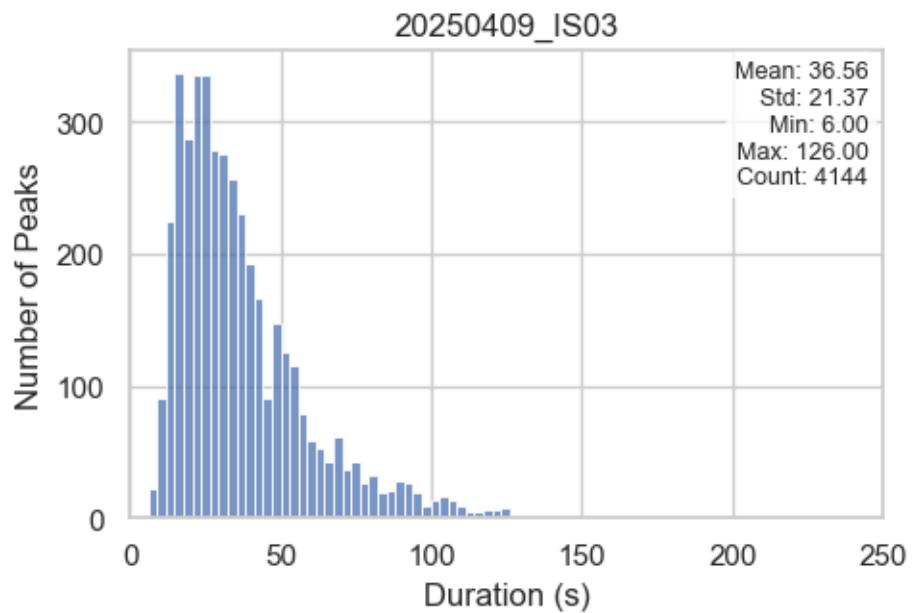
Total number of cells: 485

### 1.1.3 Peaks statistics

```
[2025-08-08 14:51:29] [INFO] calcium: Removed 120 outliers from dataset  
'20250409_IS03' for column 'Duration (s)'
```

```
[2025-08-08 14:51:29] [INFO] calcium: Lower bound: -17.0, Upper bound: 126.0
```

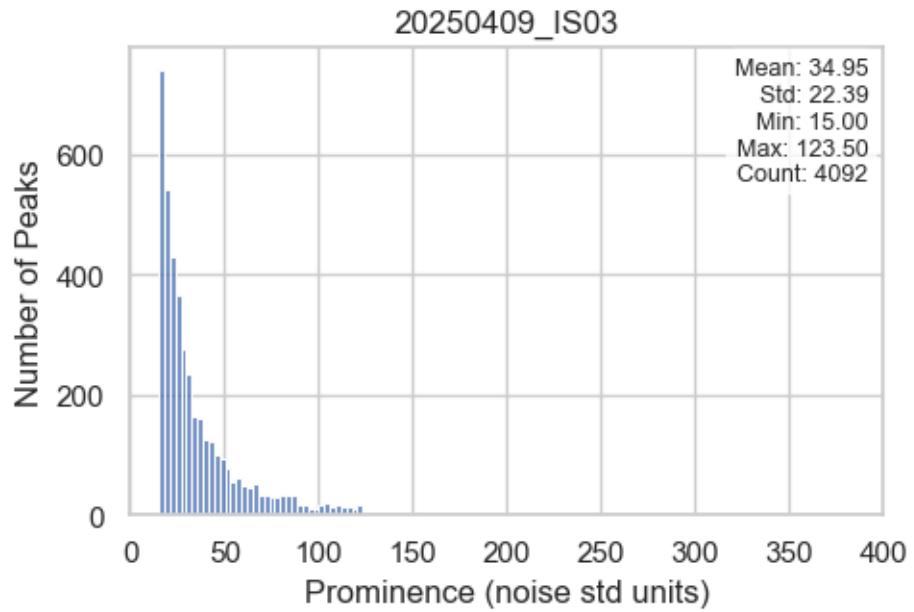
## Distribution of Peak Durations



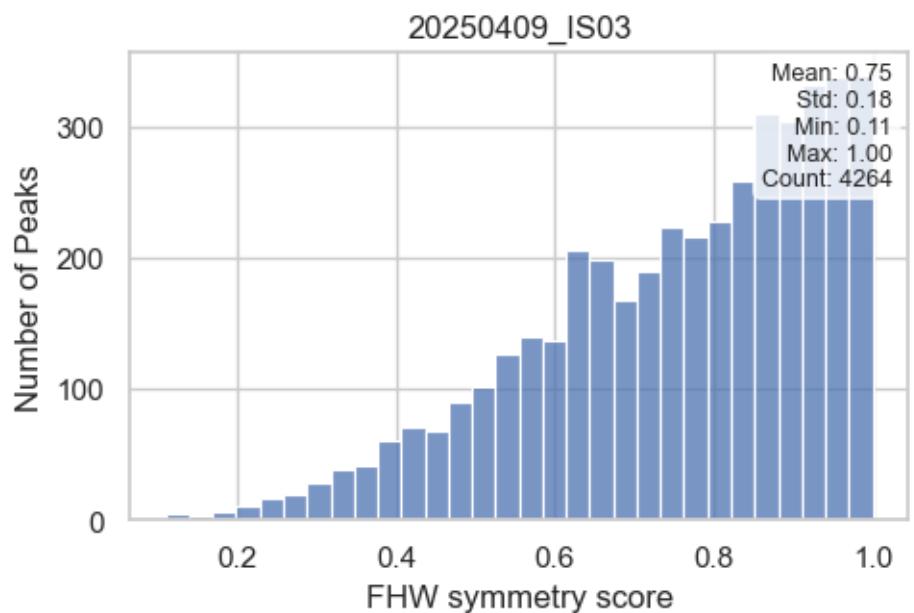
```
[2025-08-08 14:51:29] [INFO] calcium: Removed 172 outliers from dataset  
'20250409_IS03' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:51:29] [INFO] calcium: Lower bound: -19.437499999999993, Upper  
bound: 123.6999999999999
```

### Distribution of Peak Prominences

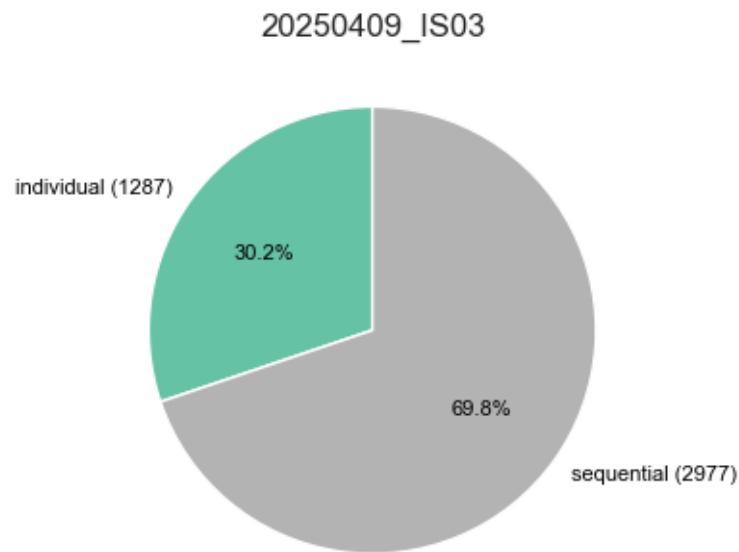


### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

Distribution of Peaks by Event types

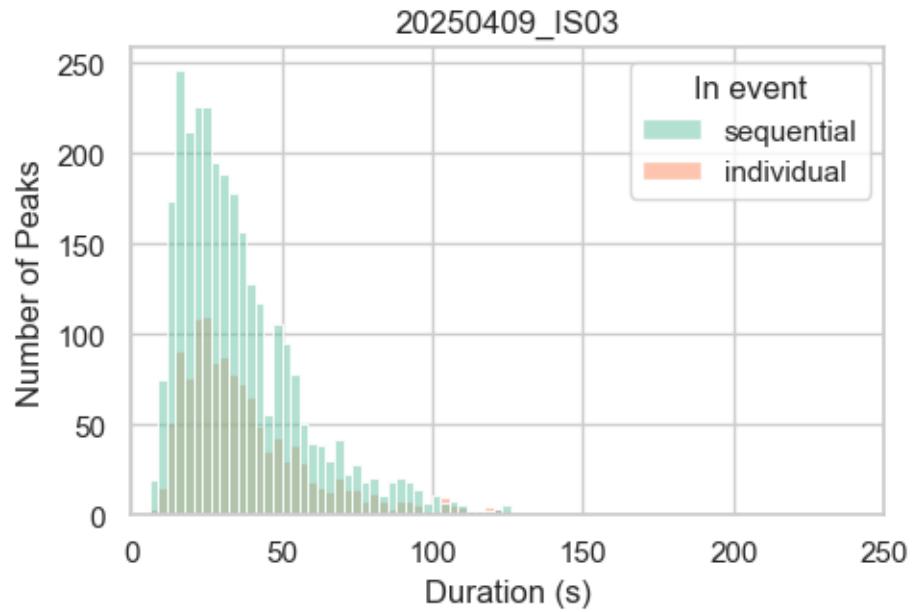


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:51:29] [INFO] calcium: Removed 120 outliers from dataset  
'20250409_IS03' for column 'Duration (s)'
```

```
[2025-08-08 14:51:29] [INFO] calcium: Lower bound: -17.0, Upper bound: 126.0
```

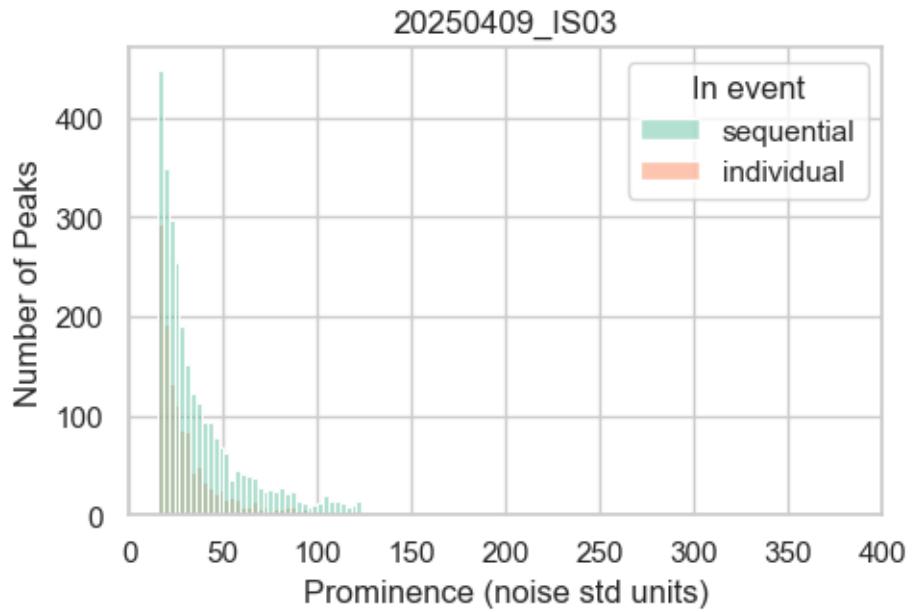
## Distribution of Peak Durations by Group



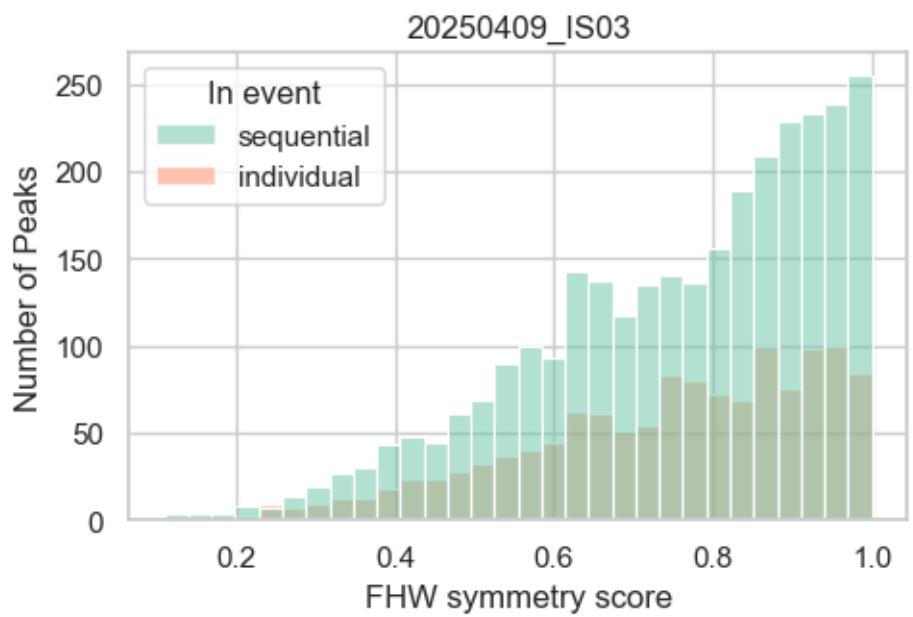
[2025-08-08 14:51:29] [INFO] calcium: Removed 172 outliers from dataset '20250409\_IS03' for column 'Prominence (noise std units)'

[2025-08-08 14:51:29] [INFO] calcium: Lower bound: -19.4, Upper bound: 123.7

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:51:30] [WARNING] calcium: No data to plot for column 'Duration (s)'
```

```
[2025-08-08 14:51:30] [WARNING] calcium: No data to plot for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:51:30] [WARNING] calcium: No data to plot for column 'FWH symmetry score'
```

### 1.2.2 Peak statistics in global event per event ID

```
[2025-08-08 14:51:30] [WARNING] calcium: No data to plot for column 'Duration (s)'
```

```
[2025-08-08 14:51:30] [WARNING] calcium: No data to plot for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:51:30] [WARNING] calcium: No data to plot for column 'FWH symmetry score'
```

### 1.2.3 Kinetics of global events

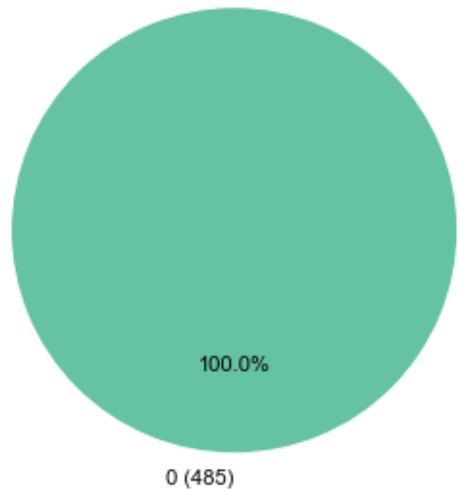
```
[2025-08-08 14:51:30] [WARNING] calcium: No data to plot for column 'Time to 50% (s)'
```

```
[2025-08-08 14:51:30] [WARNING] calcium: No data to plot for column 'Normalized peak rate at 50% (% of peaks/s)'
```

#### 1.2.4 Cells occurrences in global events

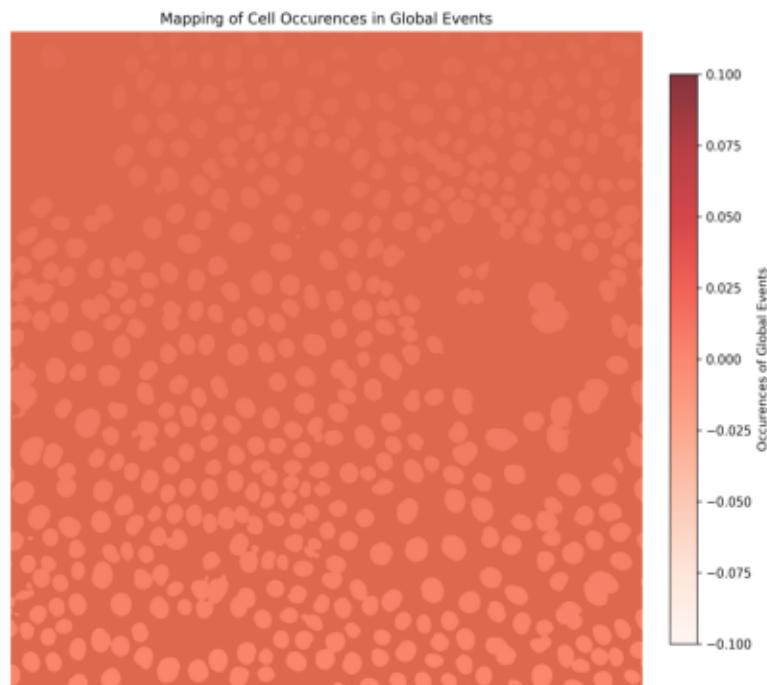
Distribution of Unique Global Events per Cell

20250409\_IS03



## Cell Mapping with Occurences in Global Events Overlay

20250409\_IS03



[2025-08-08 14:51:31] [WARNING] calcium: No data to plot for column '% of cells involved'

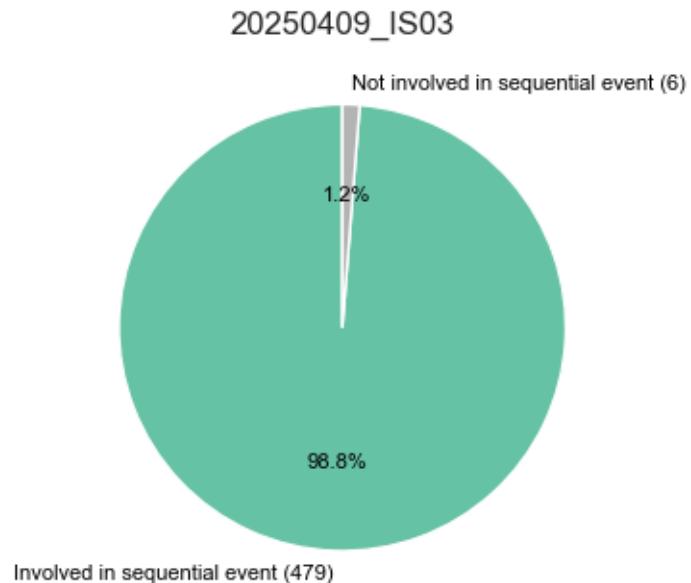
### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: []

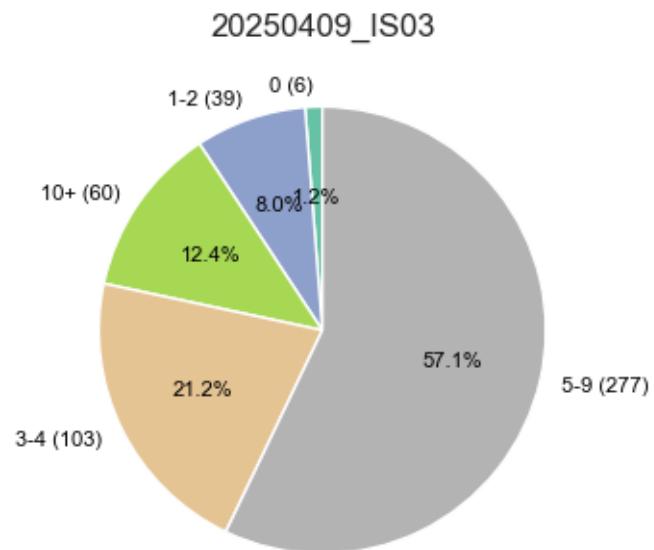
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequential events

Distribution of Cells Involved in Sequential Events

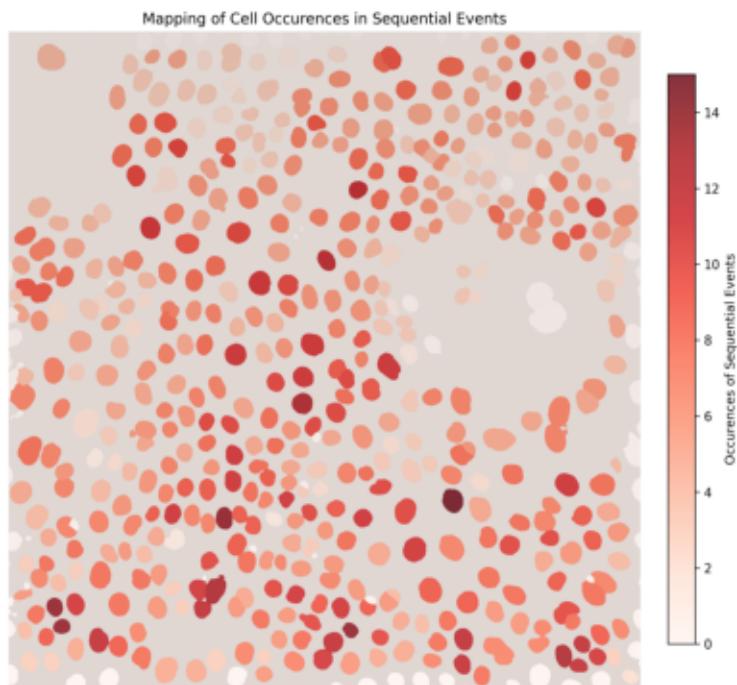


### Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250409\_IS03

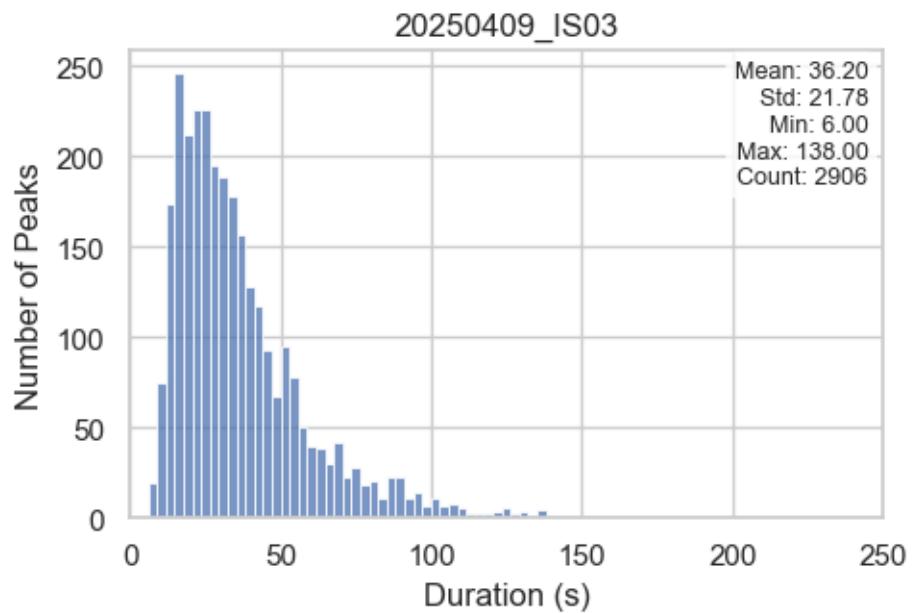


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:51:32] [INFO] calcium: Removed 71 outliers from dataset  
'20250409_IS03' for column 'Duration (s)'
```

```
[2025-08-08 14:51:32] [INFO] calcium: Lower bound: -18.0, Upper bound: 138.0
```

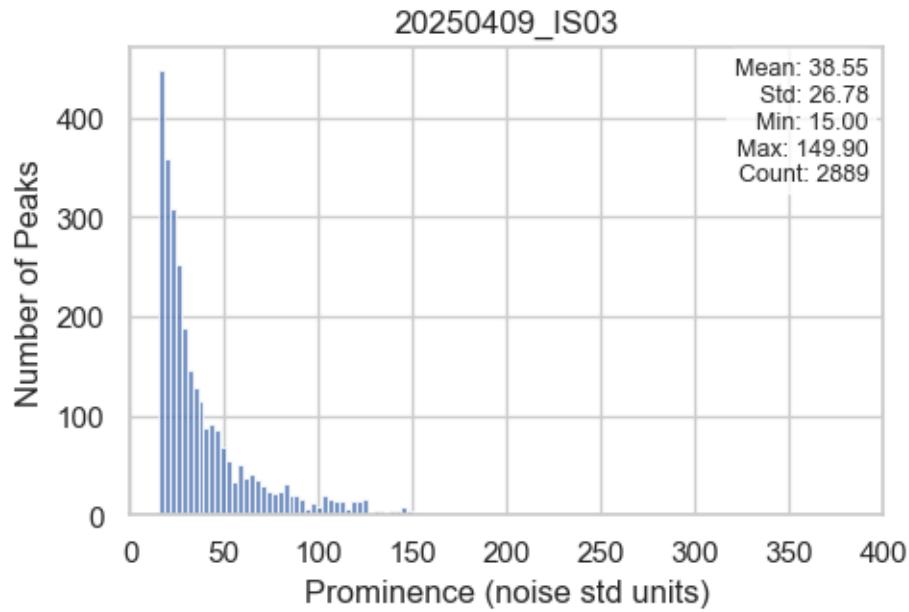
## Distribution of Peak Durations



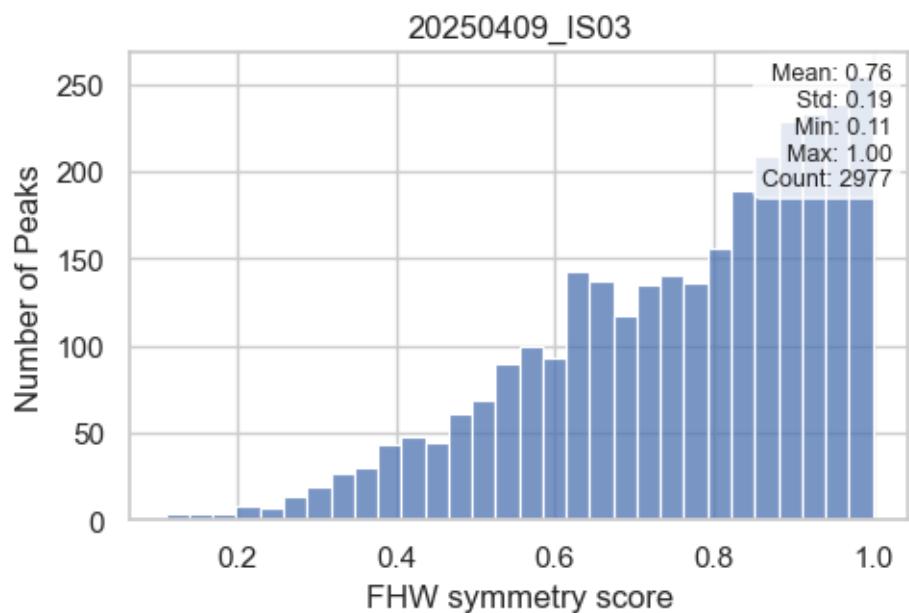
```
[2025-08-08 14:51:32] [INFO] calcium: Removed 88 outliers from dataset '20250409_IS03' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:51:32] [INFO] calcium: Lower bound: -22.800000000000004, Upper bound: 150.0
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

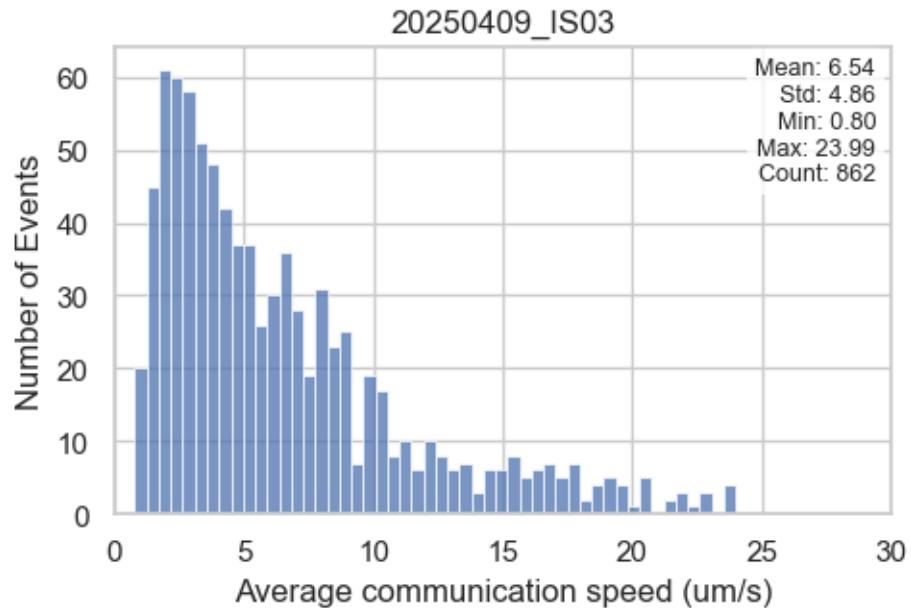


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:51:33] [INFO] calcium: Removed 13 outliers from dataset '20250409\_IS03' for column 'Average communication speed (um/s)'

[2025-08-08 14:51:33] [INFO] calcium: Lower bound: -5.8425, Upper bound: 26.305

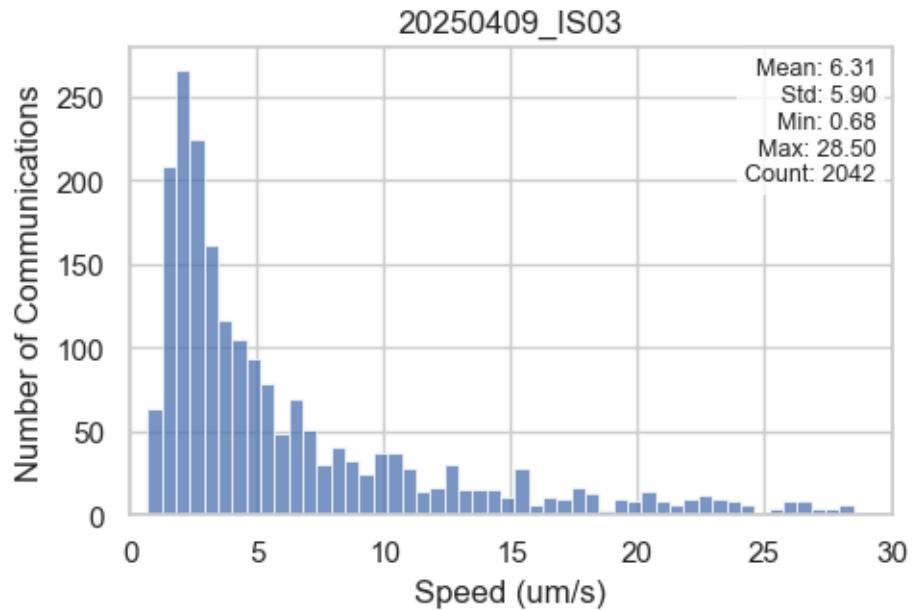
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:51:33] [INFO] calcium: Removed 60 outliers from dataset '20250409\_IS03' for column 'Speed (um/s)'

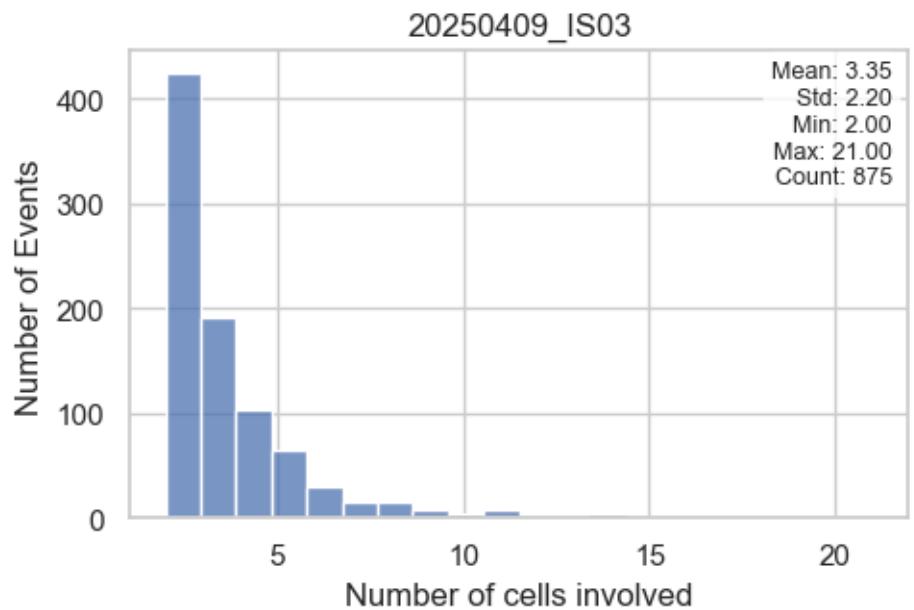
[2025-08-08 14:51:33] [INFO] calcium: Lower bound: -7.52375, Upper bound: 28.54249999999997

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

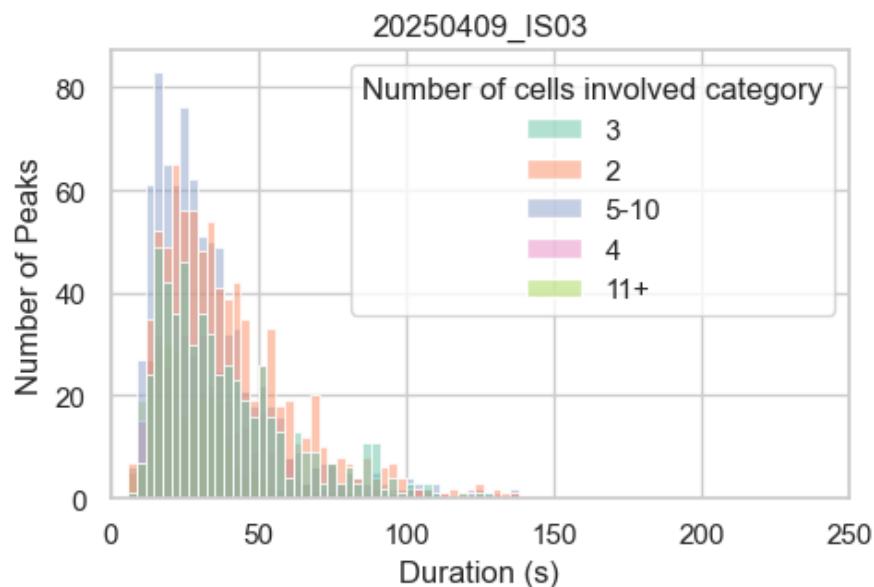


### 1.3.5 Influence of cell count per event on statistics

```
[2025-08-08 14:51:33] [INFO] calcium: Removed 71 outliers from dataset  
'20250409_IS03' for column 'Duration (s)'
```

```
[2025-08-08 14:51:33] [INFO] calcium: Lower bound: -18.0, Upper bound: 138.0
```

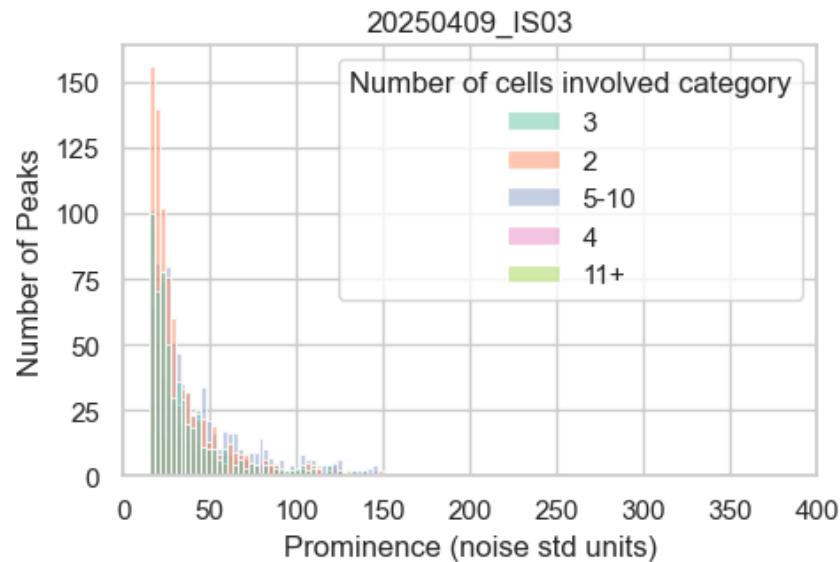
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



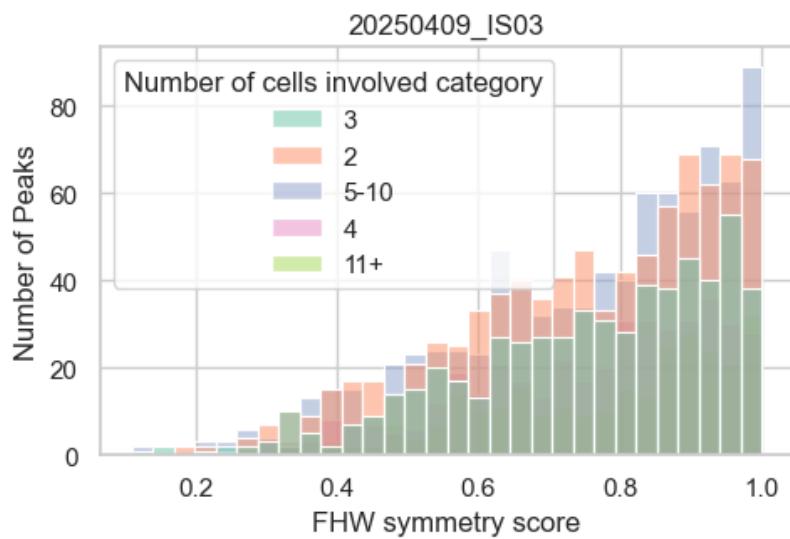
```
[2025-08-08 14:51:33] [INFO] calcium: Removed 88 outliers from dataset  
'20250409_IS03' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:51:33] [INFO] calcium: Lower bound: -22.8, Upper bound: 150.0
```

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



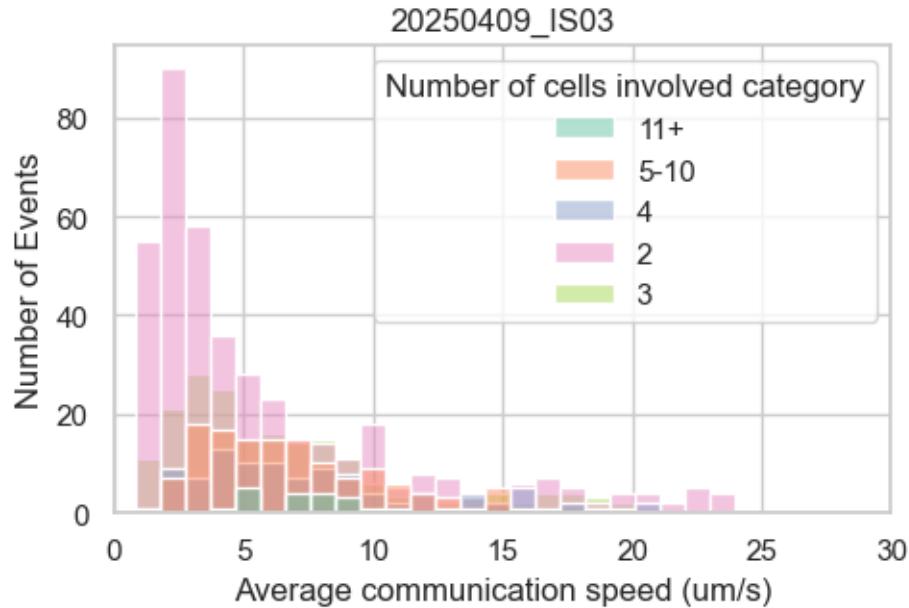
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



[2025-08-08 14:51:34] [INFO] calcium: Removed 13 outliers from dataset '20250409\_IS03' for column 'Average communication speed (um/s)'

[2025-08-08 14:51:34] [INFO] calcium: Lower bound: -5.8, Upper bound: 26.3

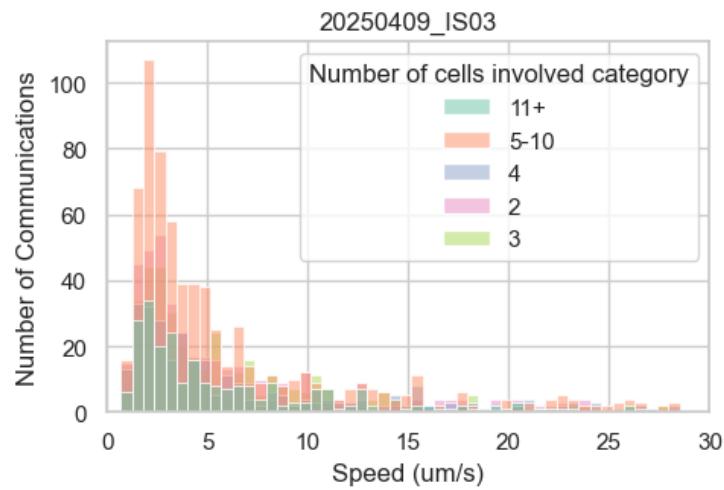
## Distribution of Average Communication Speeds by Number of Cells Involved



[2025-08-08 14:51:34] [INFO] calcium: Removed 60 outliers from dataset '20250409\_IS03' for column 'Speed (um/s)'

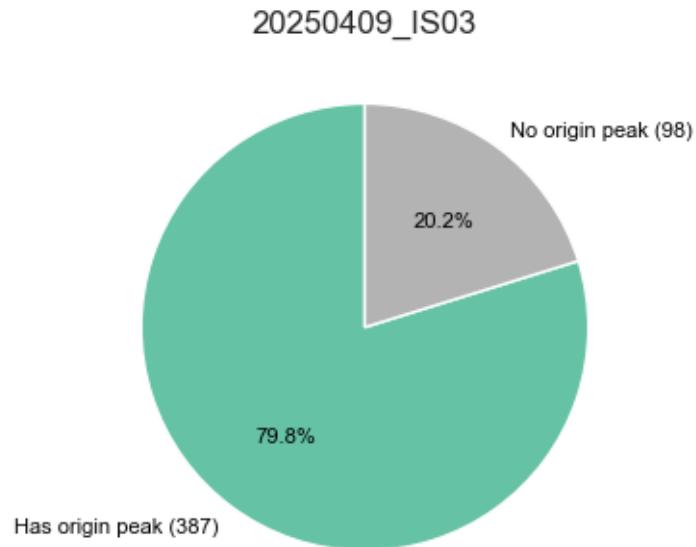
[2025-08-08 14:51:34] [INFO] calcium: Lower bound: -7.5, Upper bound: 28.5

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

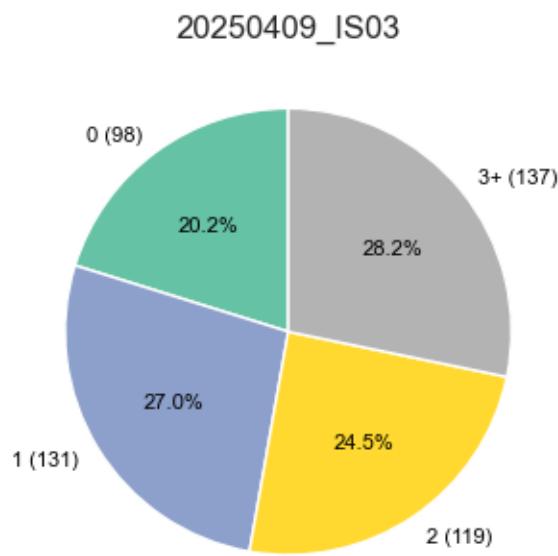


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

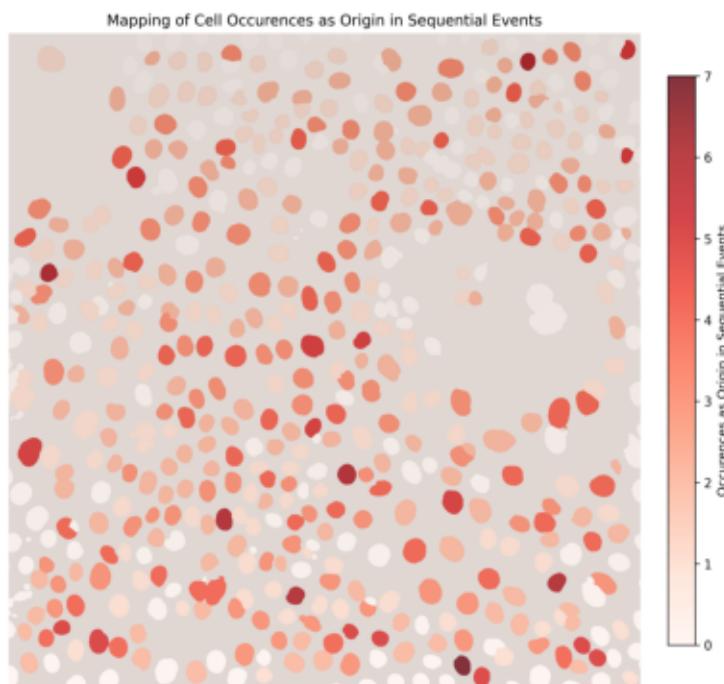


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

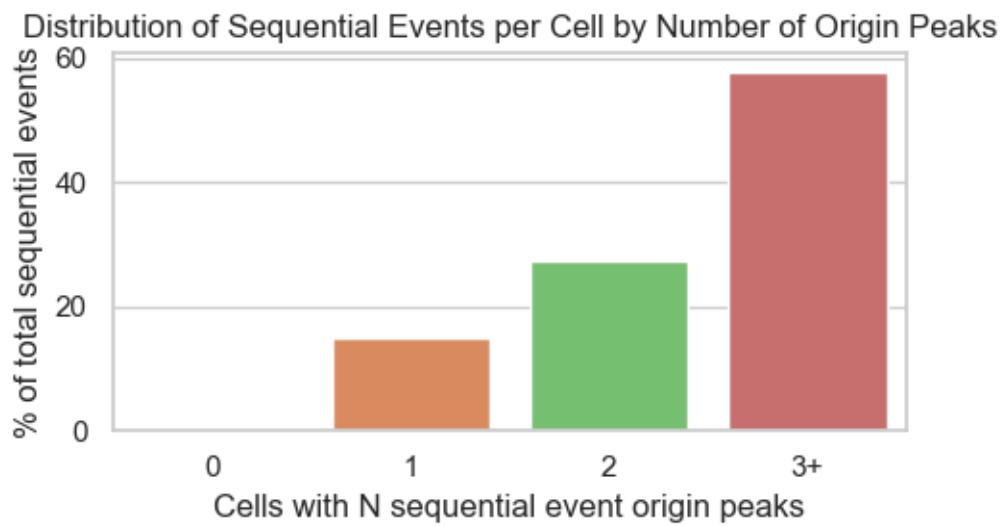
20250409\_IS03



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

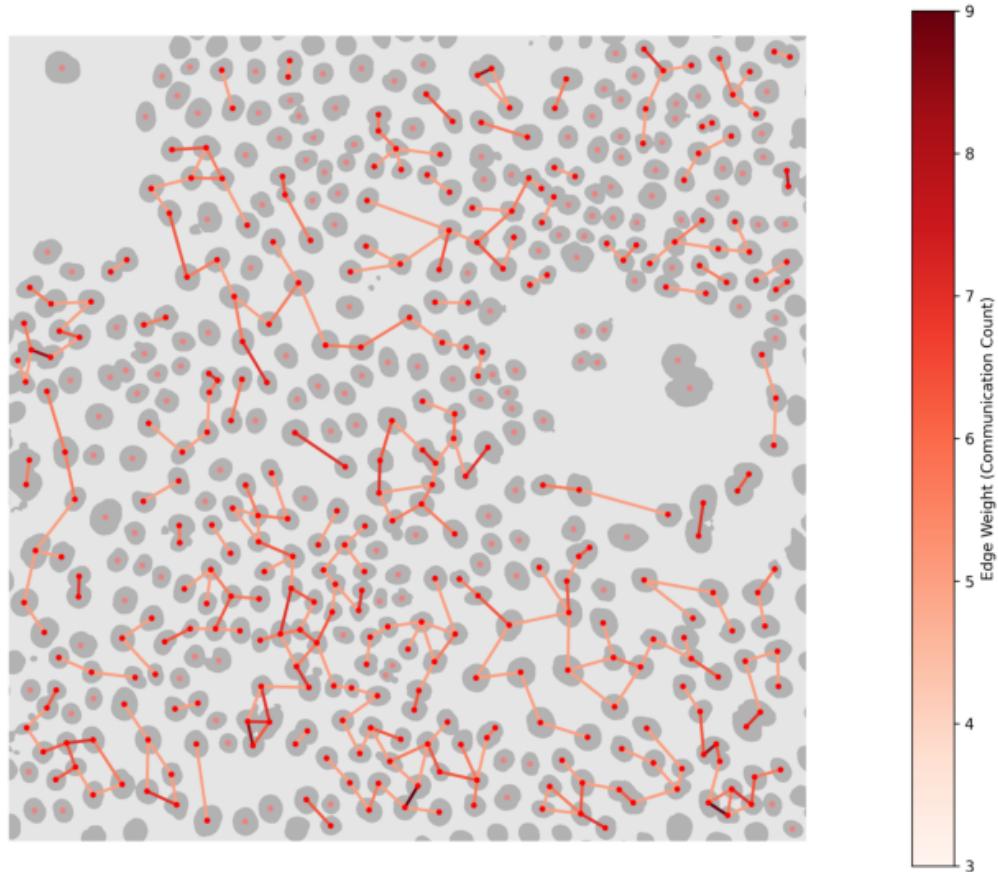


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250409\_IS03

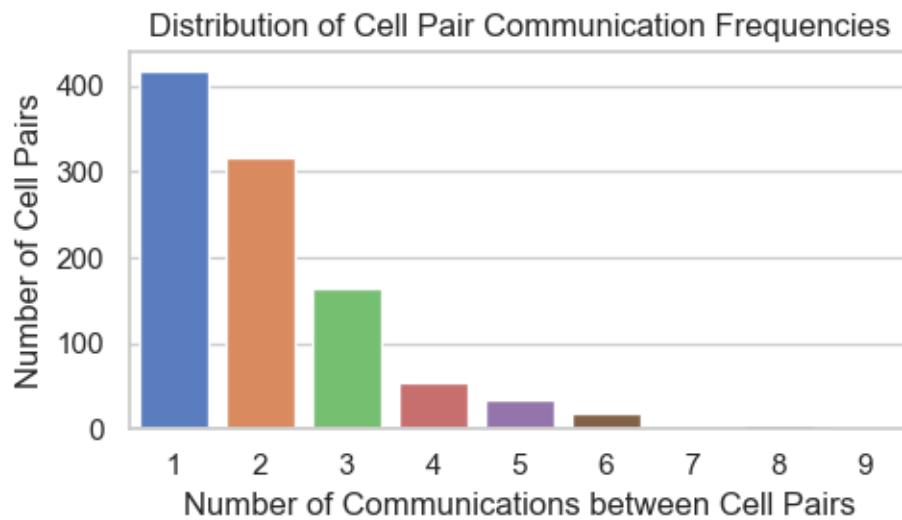
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

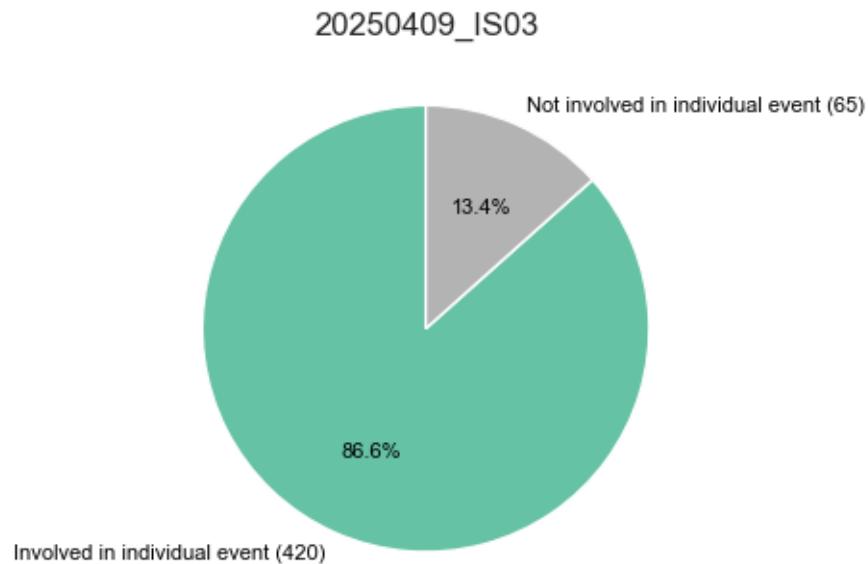
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



## 1.4 INDIVIDUAL EVENTS

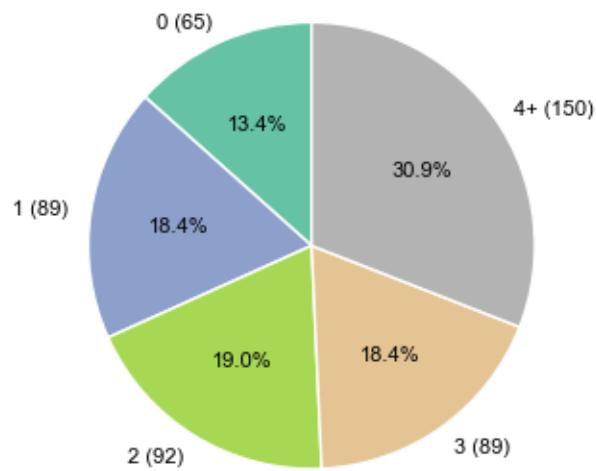
### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events



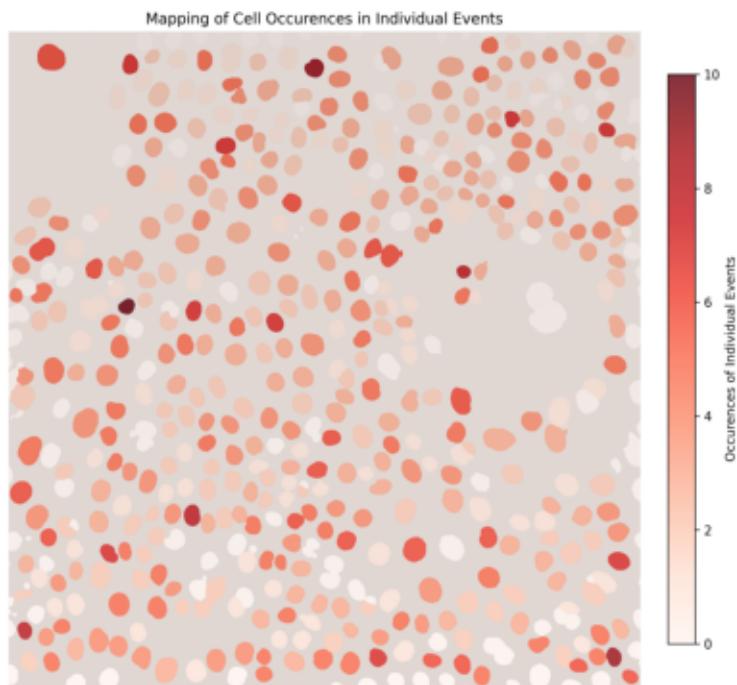
### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)

20250409\_IS03



## Cell Mapping with Occurrences in Individual Events Overlay

20250409\_IS03

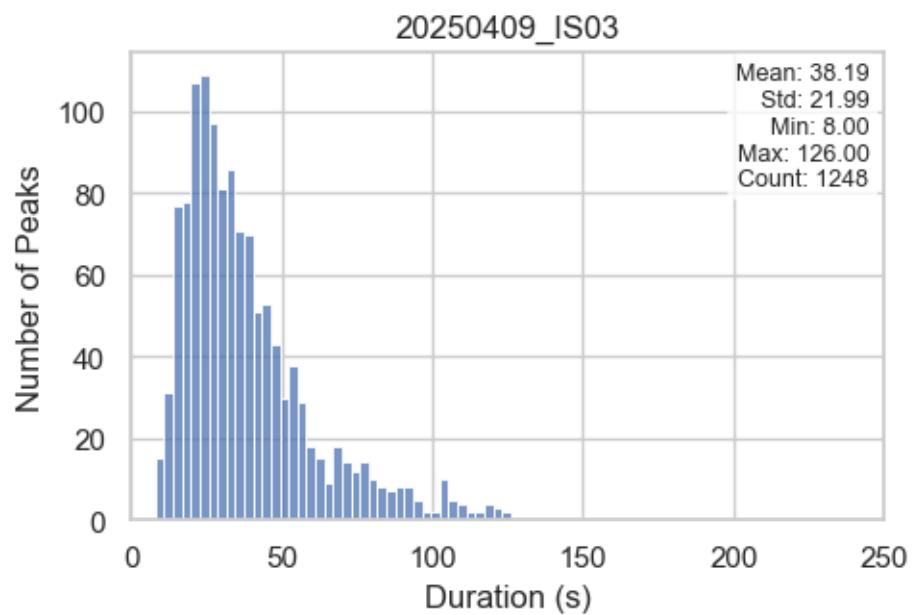


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:51:38] [INFO] calcium: Removed 39 outliers from dataset  
'20250409_IS03' for column 'Duration (s)'
```

```
[2025-08-08 14:51:38] [INFO] calcium: Lower bound: -16.0, Upper bound: 127.0
```

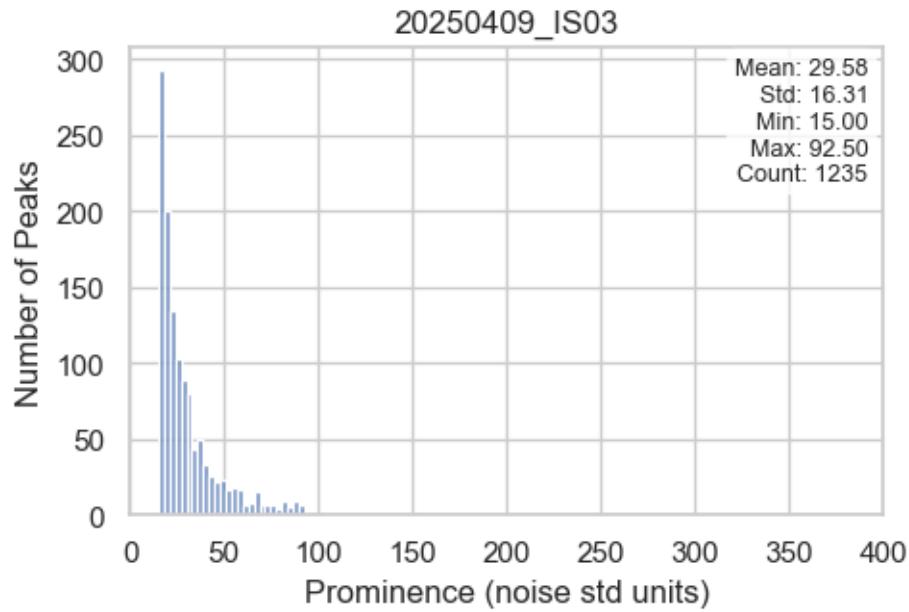
## Distribution of Peak Durations



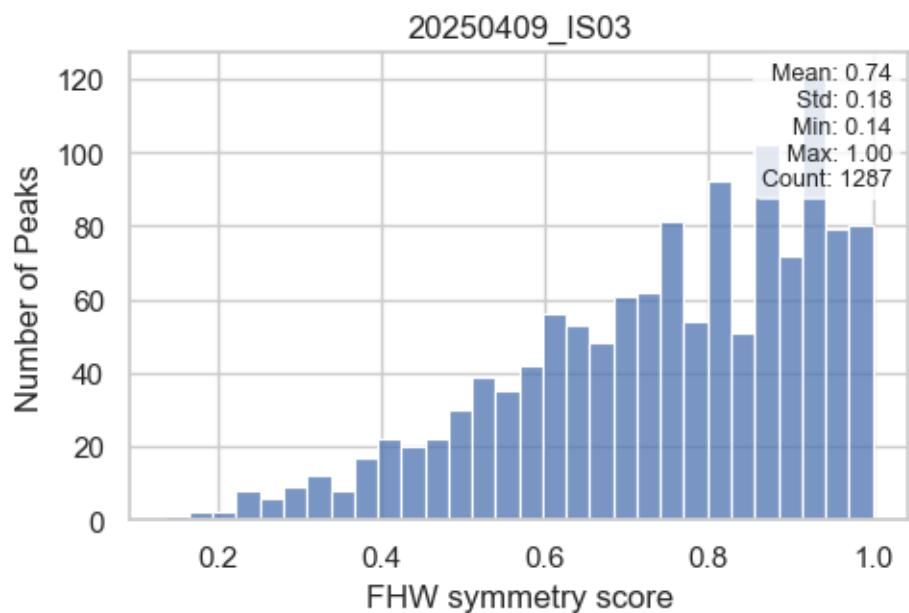
[2025-08-08 14:51:39] [INFO] calcium: Removed 52 outliers from dataset '20250409\_IS03' for column 'Prominence (noise std units)'

[2025-08-08 14:51:39] [INFO] calcium: Lower bound: -9.575, Upper bound: 93.0

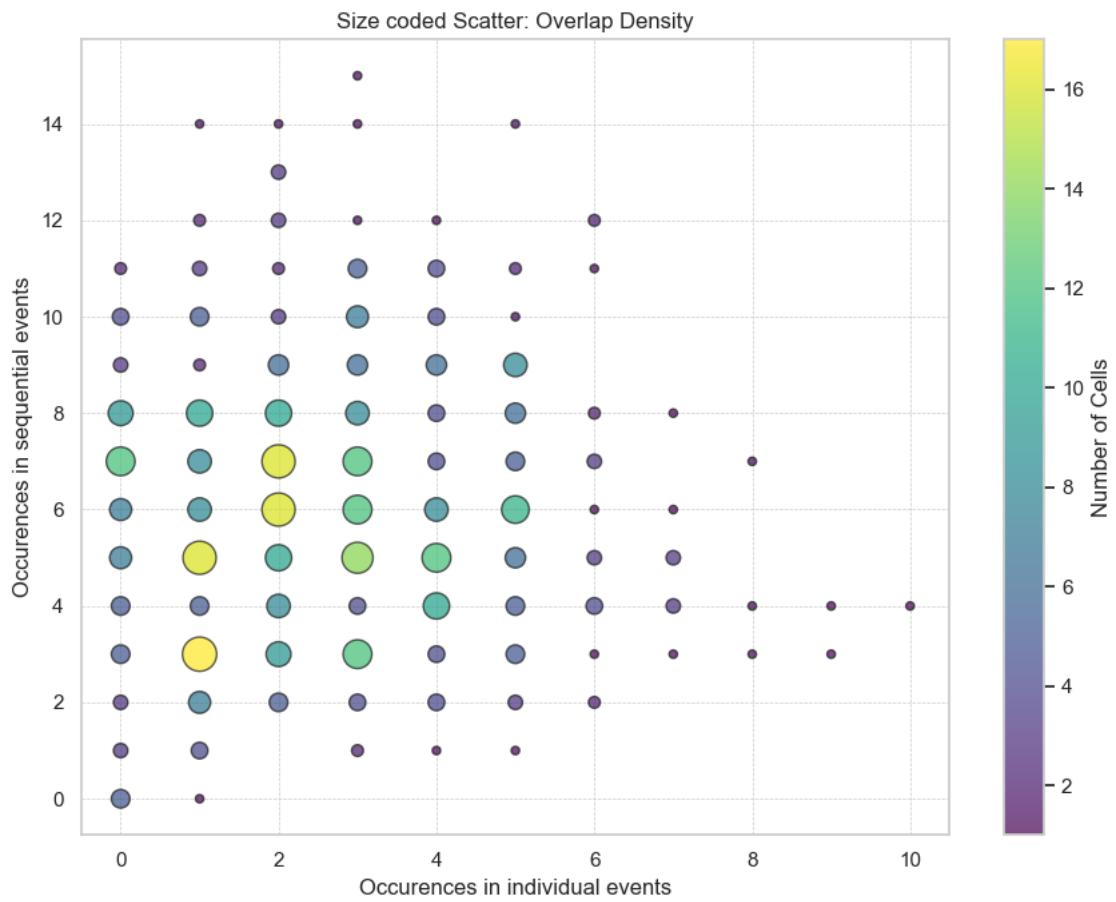
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

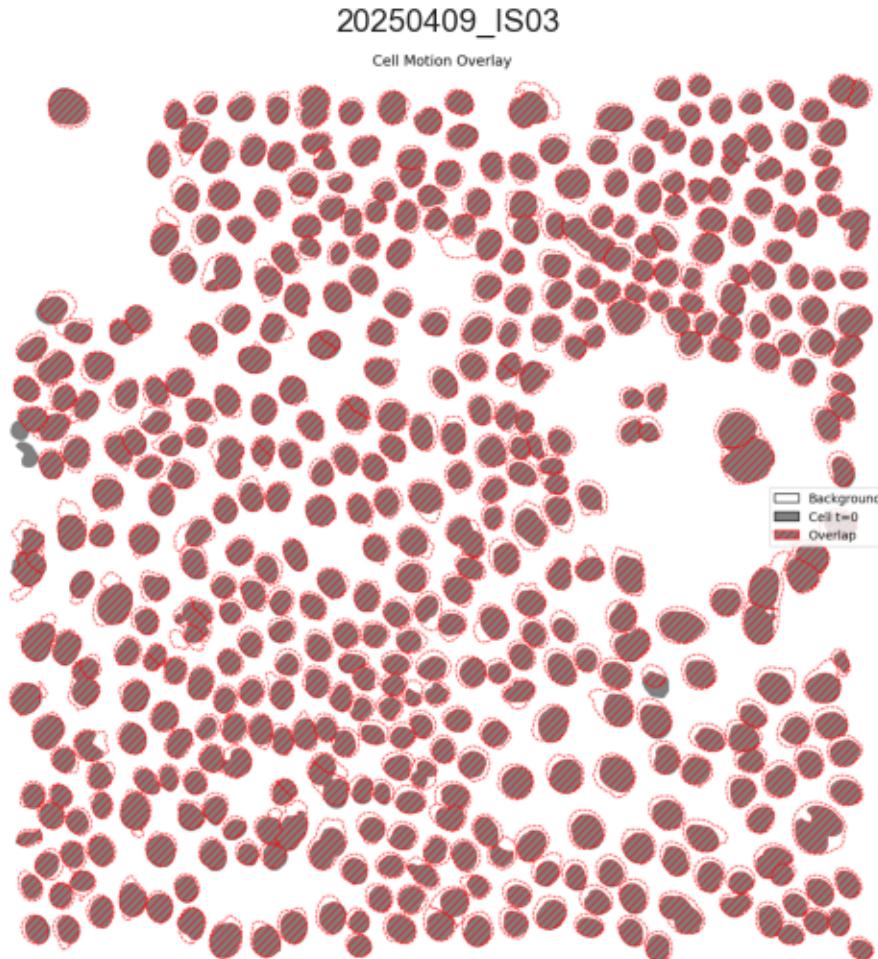


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 485
- Hoechst image taken at t=1801: 479
- Number of cells difference: absolute 6, relative 1.24%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 753273
- Pixels segmented as cell at t=1801: 957052
- Overlapping pixels between t=0 and t=1801: 734853 (85.93% of total)
- Pixels exclusive to t=0: 18420 (2.44% of total)
- Pixels exclusive to t=1801: 222199 (23.22% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n    "Default Dataset": "/path/to/your/dataset"\n}'
```

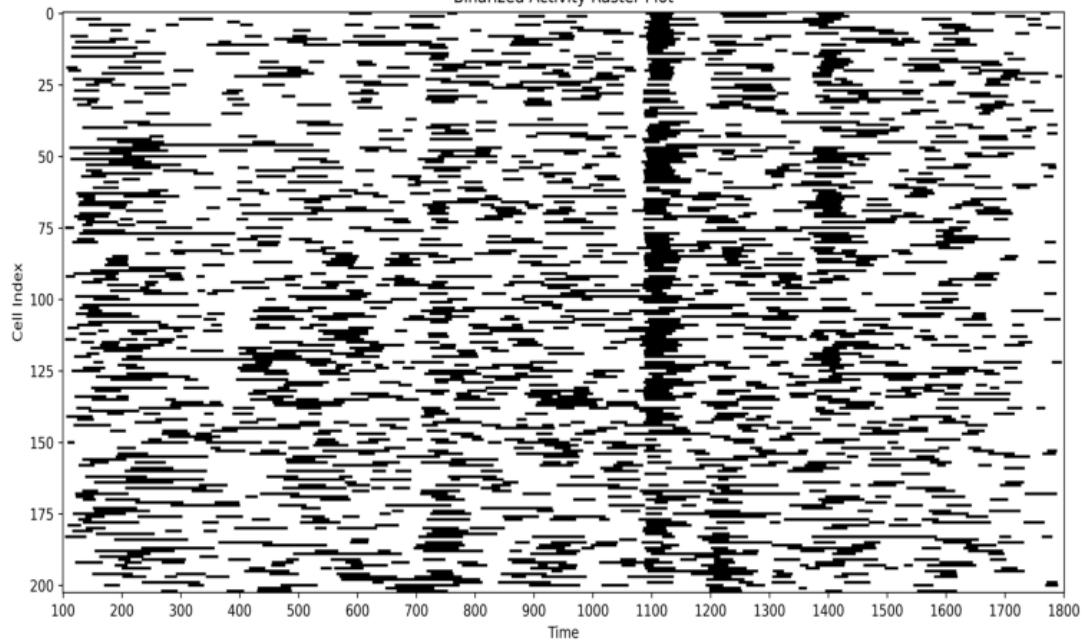
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

Binary Activity Raster Plot

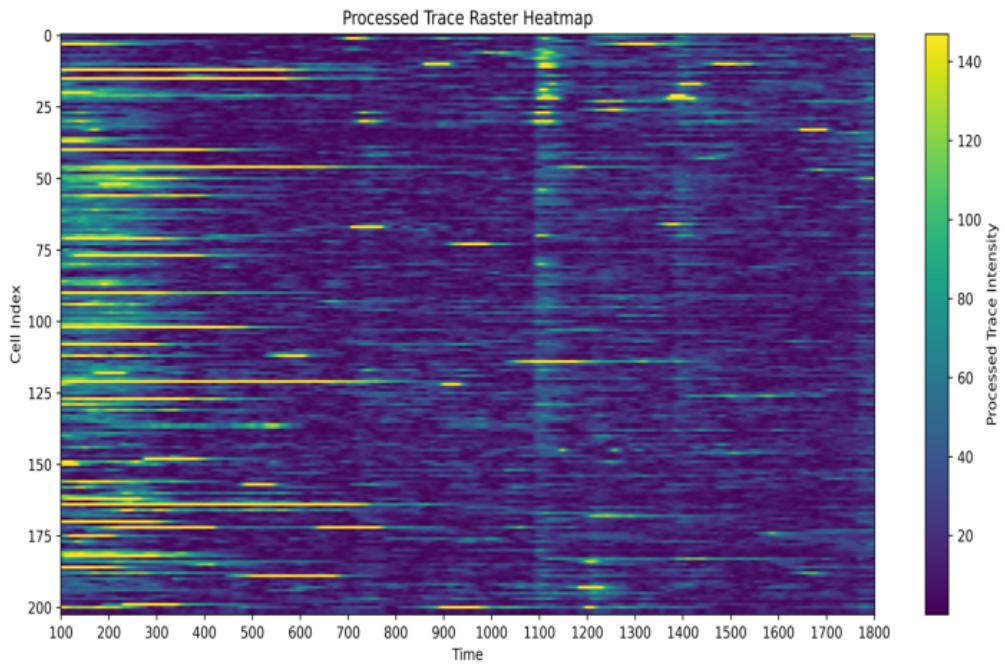
20250409\_IS05

Binarized Activity Raster Plot



Heatmap Activity Raster Plot

20250409\_IS05



### 1.1.2 Peaks population

Total number of peaks: 1806

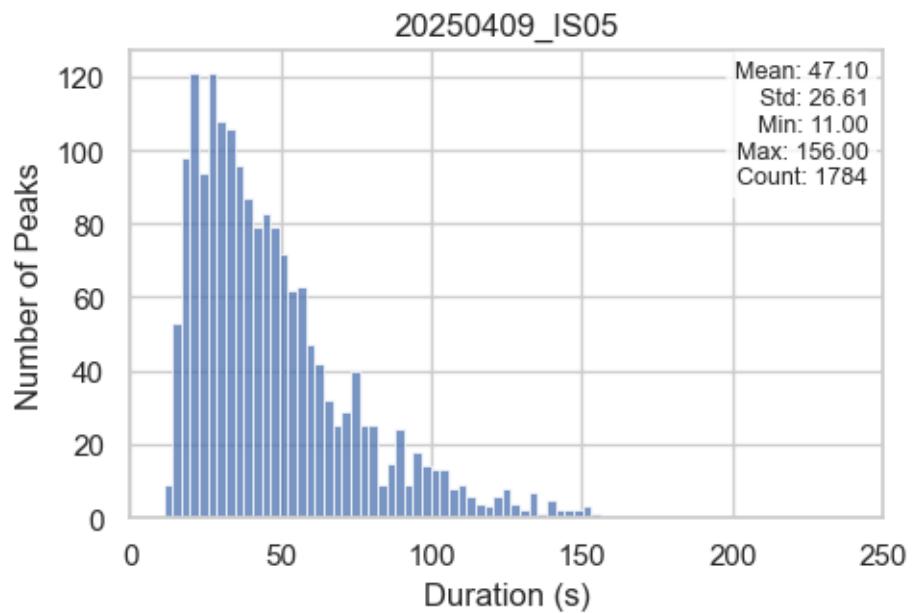
Total number of cells: 203

### 1.1.3 Peaks statistics

```
[2025-08-08 14:52:29] [INFO] calcium: Removed 22 outliers from dataset  
'20250409_IS05' for column 'Duration (s)'
```

```
[2025-08-08 14:52:29] [INFO] calcium: Lower bound: -20.0, Upper bound: 156.0
```

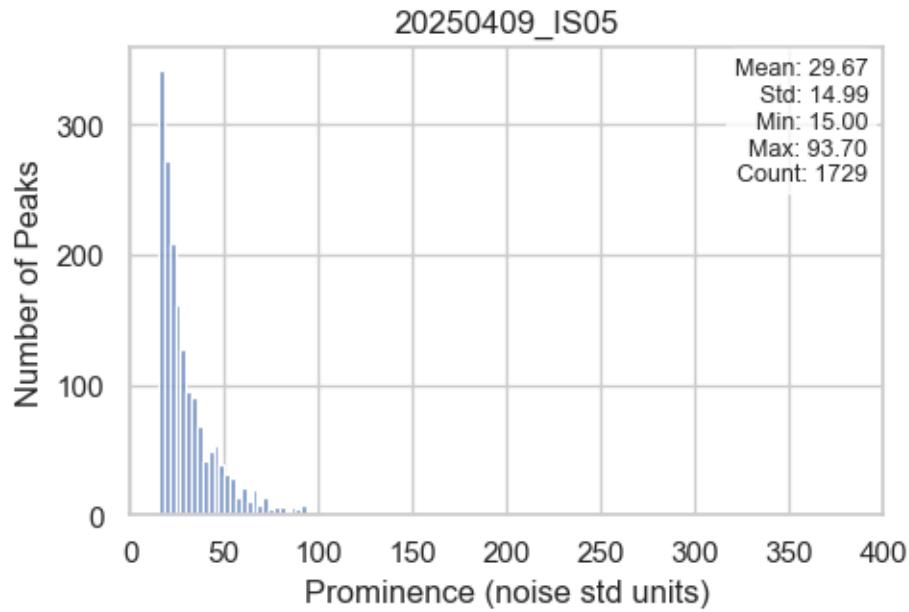
## Distribution of Peak Durations



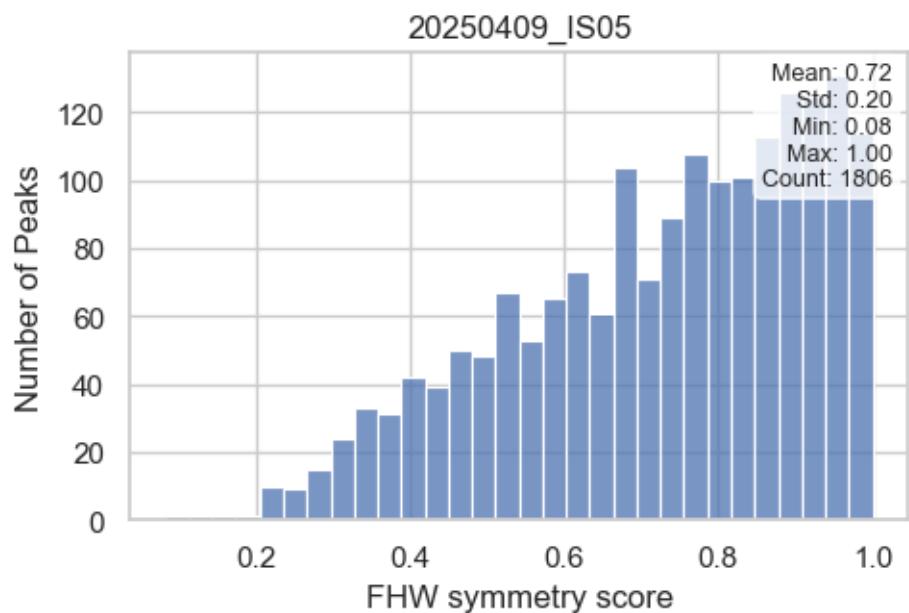
```
[2025-08-08 14:52:30] [INFO] calcium: Removed 77 outliers from dataset  
'20250409_IS05' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:52:30] [INFO] calcium: Lower bound: -9.199999999999996, Upper  
bound: 94.19999999999999
```

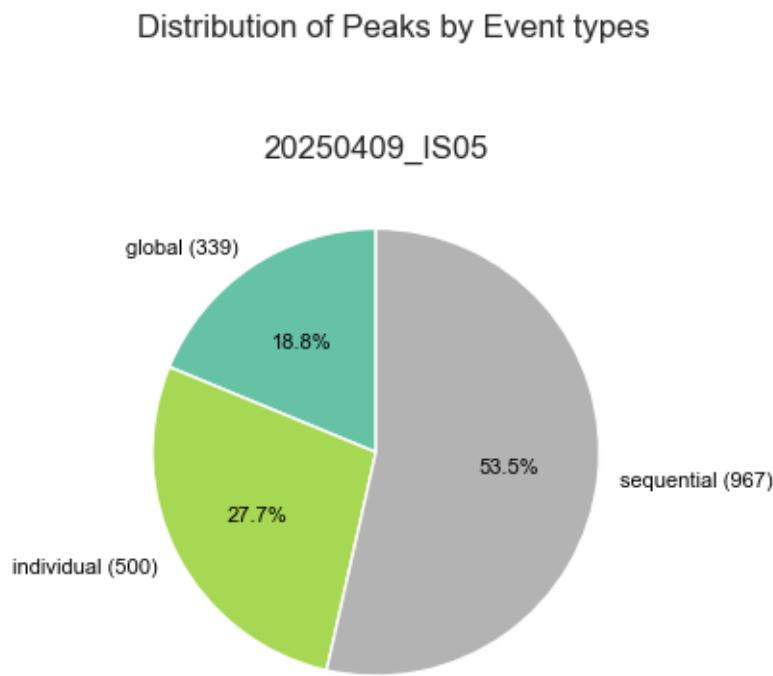
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

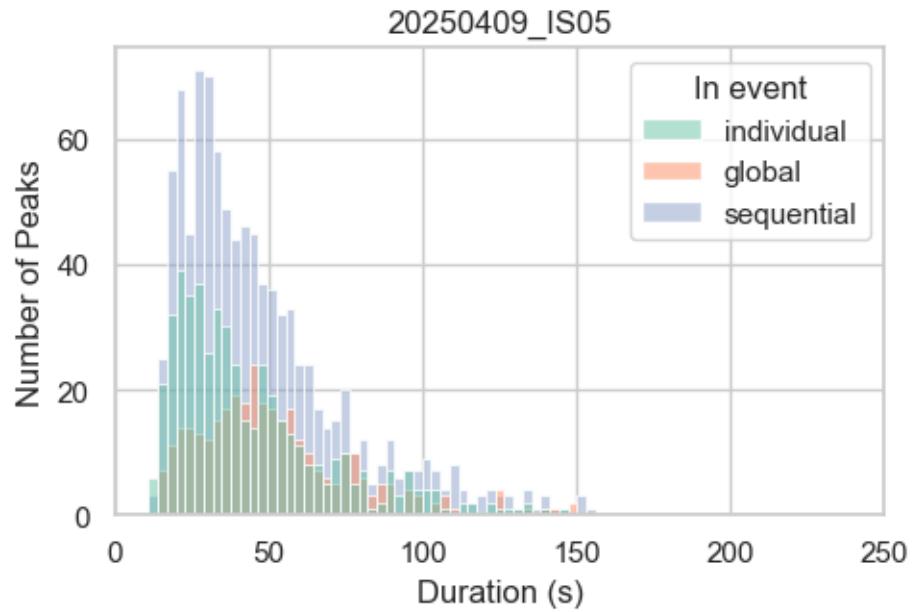


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:52:30] [INFO] calcium: Removed 22 outliers from dataset  
'20250409_IS05' for column 'Duration (s)'
```

```
[2025-08-08 14:52:30] [INFO] calcium: Lower bound: -20.0, Upper bound: 156.0
```

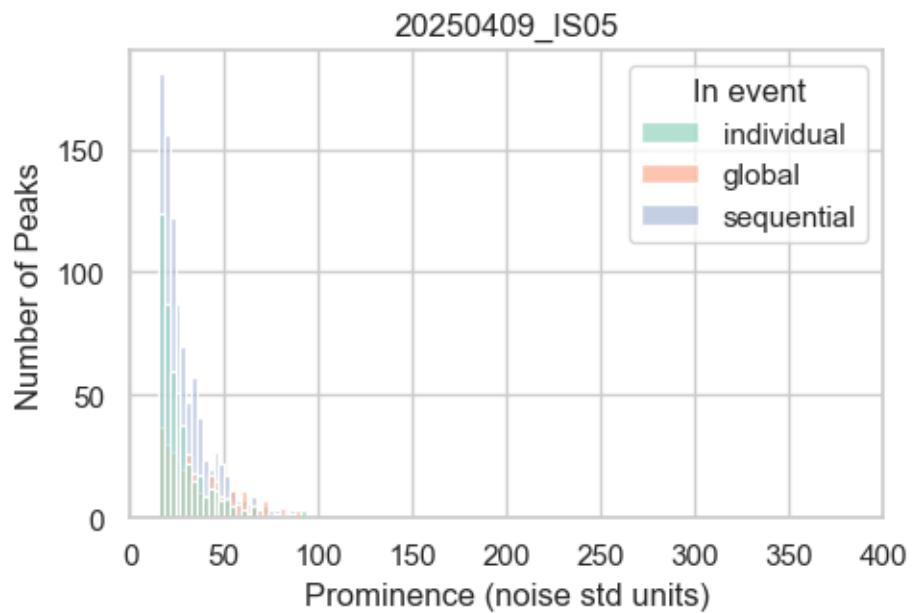
## Distribution of Peak Durations by Group



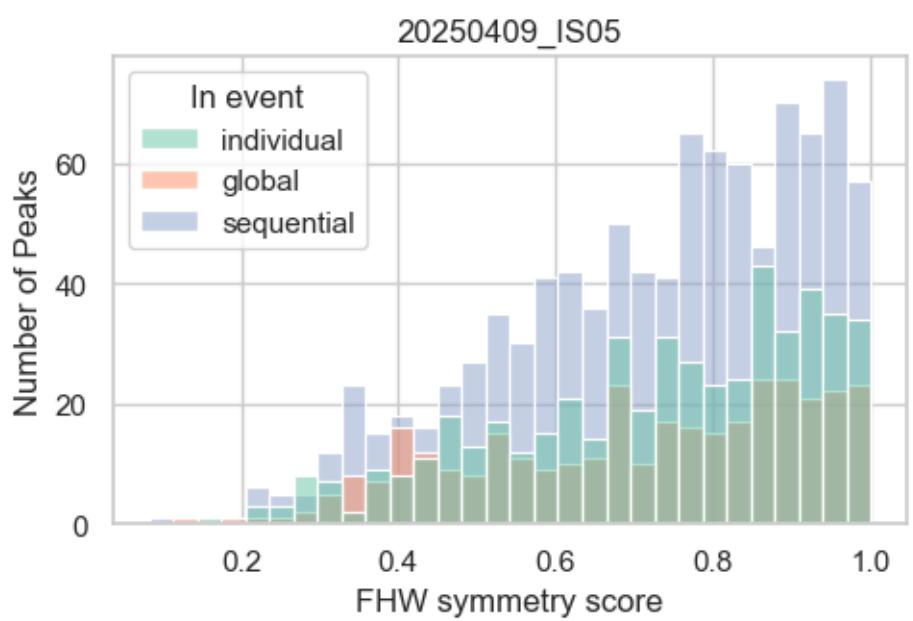
[2025-08-08 14:52:30] [INFO] calcium: Removed 77 outliers from dataset '20250409\_IS05' for column 'Prominence (noise std units)'

[2025-08-08 14:52:30] [INFO] calcium: Lower bound: -9.2, Upper bound: 94.2

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



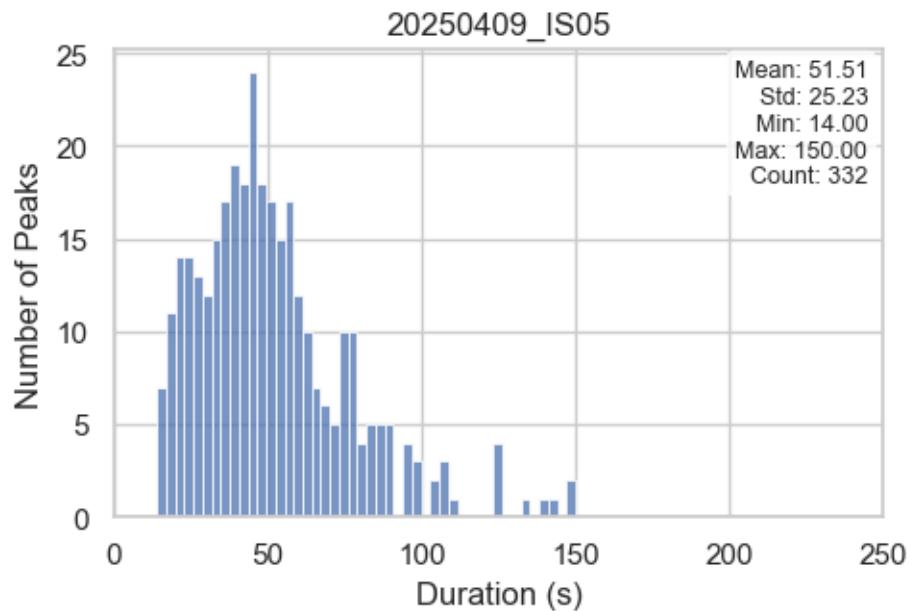
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:52:31] [INFO] calcium: Removed 7 outliers from dataset  
'20250409_IS05' for column 'Duration (s)'
```

```
[2025-08-08 14:52:31] [INFO] calcium: Lower bound: -12.5, Upper bound: 158.0
```

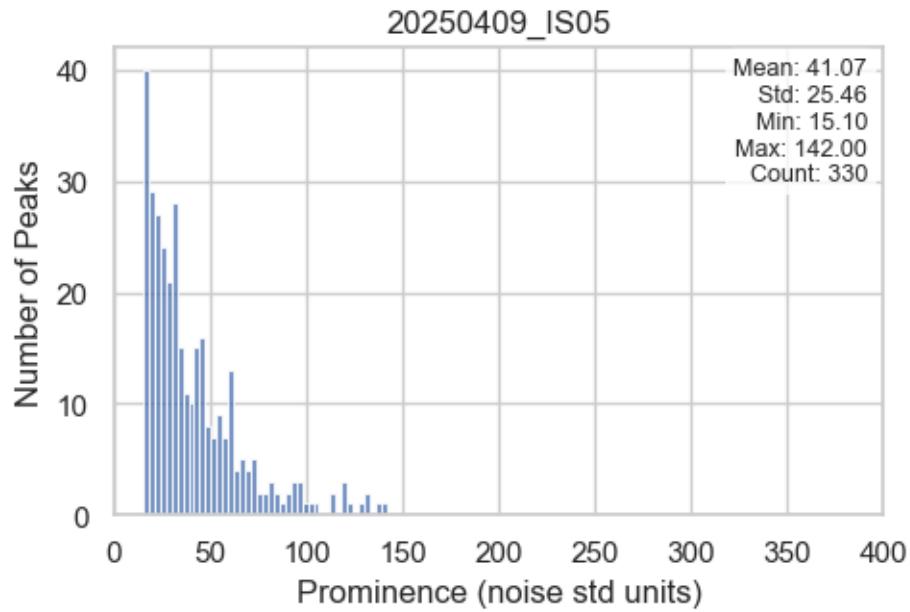
Distribution of Peak Durations



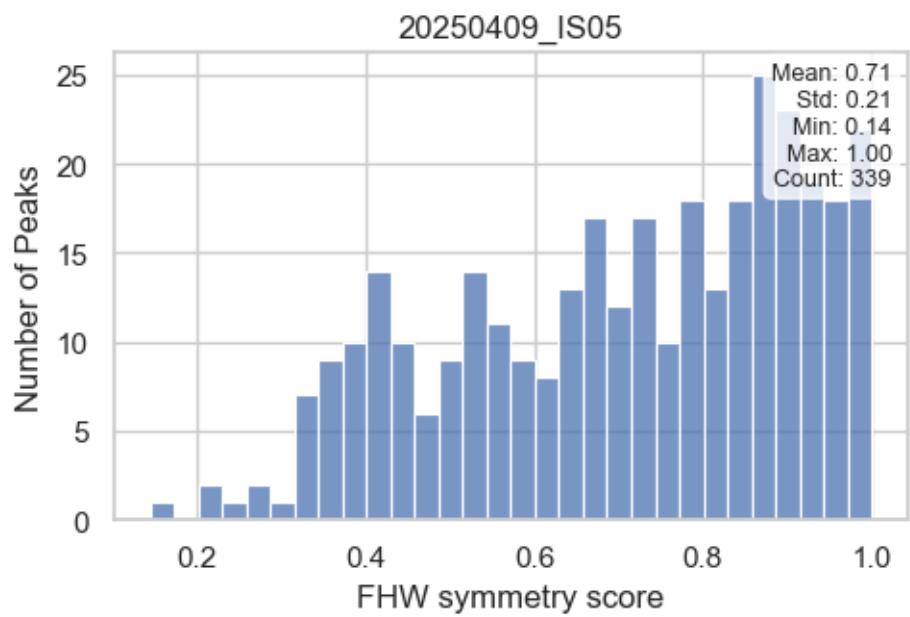
```
[2025-08-08 14:52:31] [INFO] calcium: Removed 9 outliers from dataset  
'20250409_IS05' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:52:31] [INFO] calcium: Lower bound: -25.47499999999998, Upper  
bound: 150.25
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

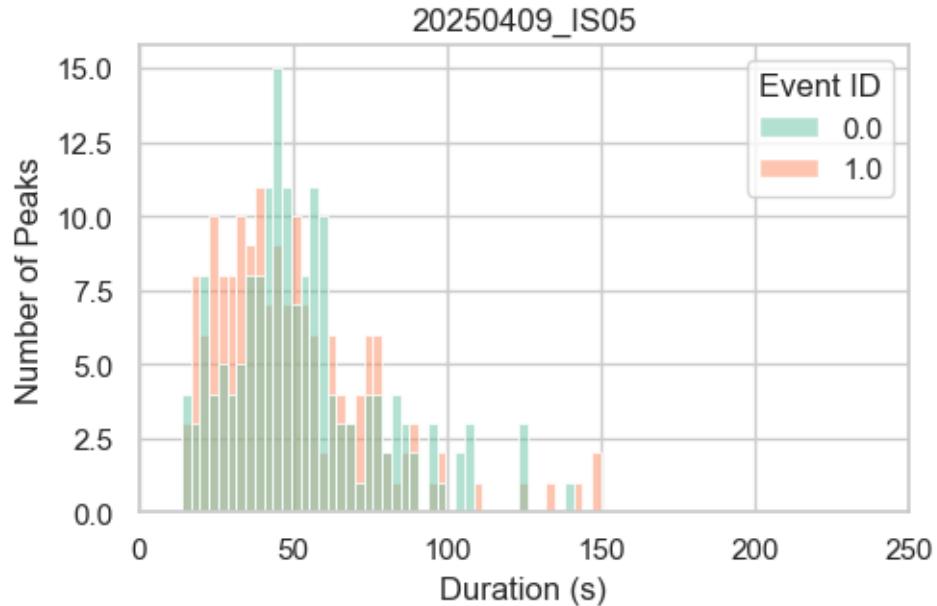


### 1.2.2 Peak statistics in global event per event ID

```
[2025-08-08 14:52:31] [INFO] calcium: Removed 7 outliers from dataset  
'20250409_IS05' for column 'Duration (s)'
```

```
[2025-08-08 14:52:31] [INFO] calcium: Lower bound: -12.5, Upper bound: 158.0
```

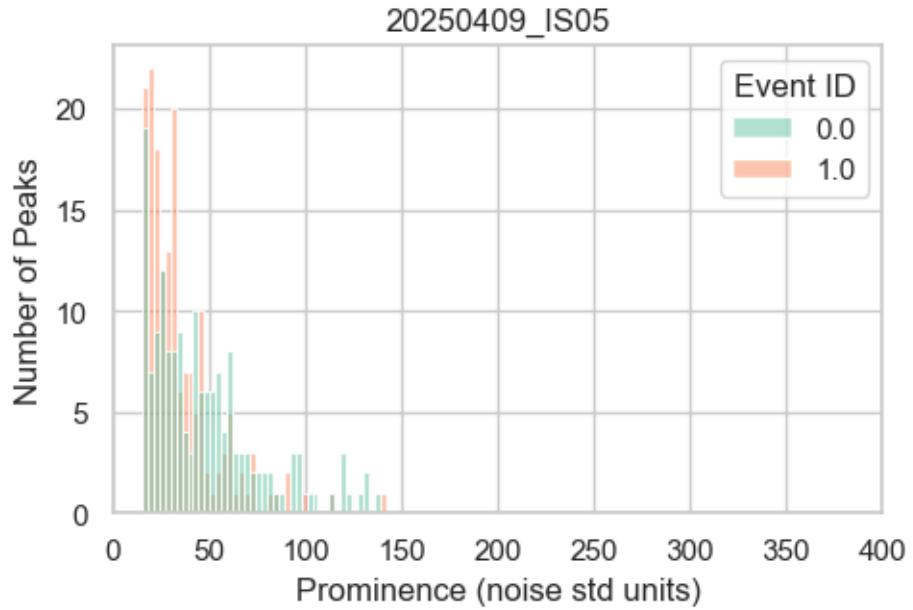
Distribution of Peak Durations by Group



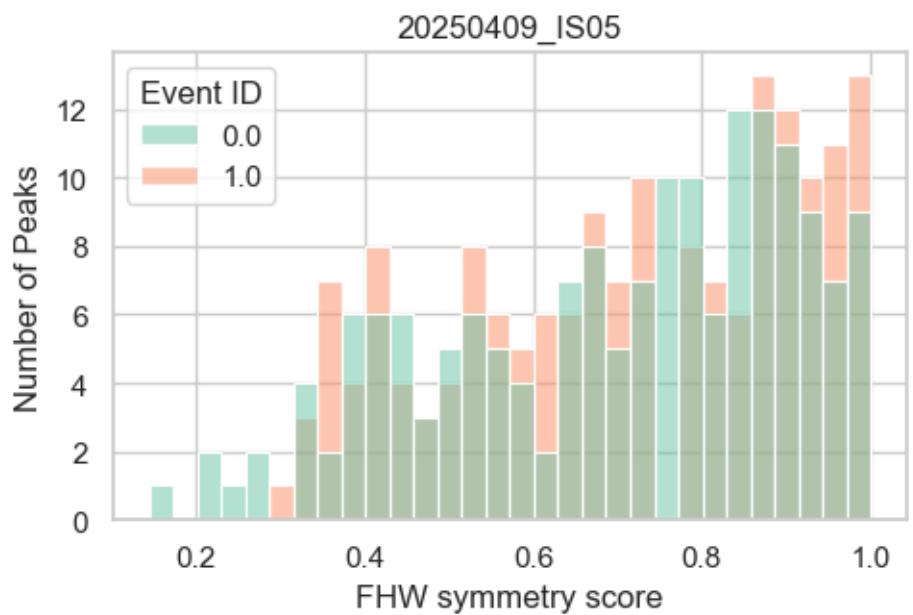
```
[2025-08-08 14:52:31] [INFO] calcium: Removed 9 outliers from dataset  
'20250409_IS05' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:52:31] [INFO] calcium: Lower bound: -25.5, Upper bound: 150.2
```

### Distribution of Peak Prominences by Group



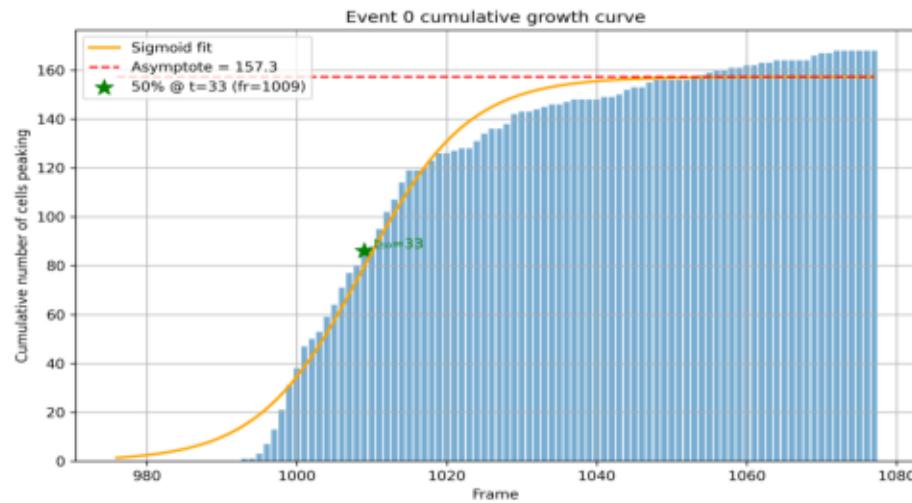
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

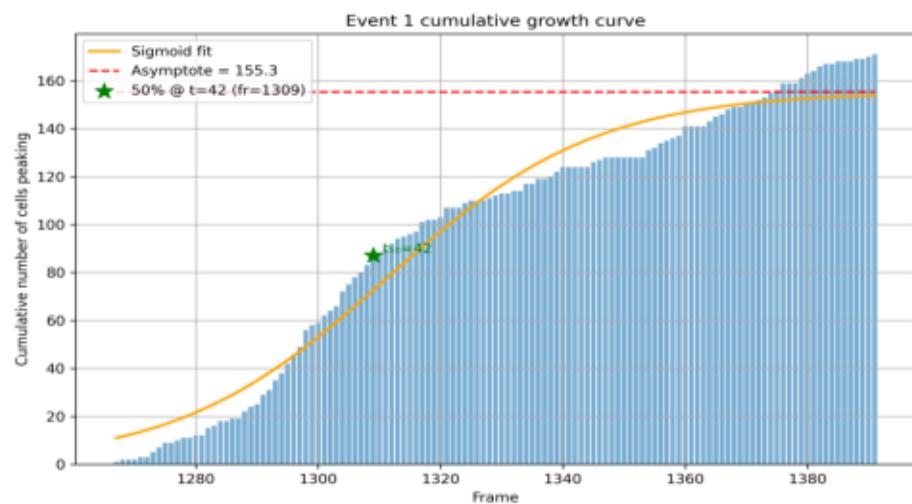
Event Activity Overlay (Event ID: 0)

20250409\_IS05



Event Activity Overlay (Event ID: 1)

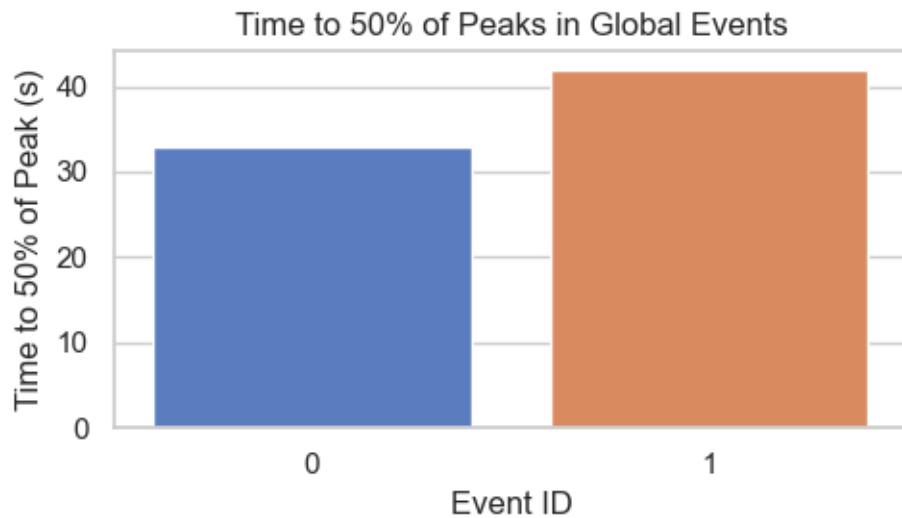
20250409\_IS05



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

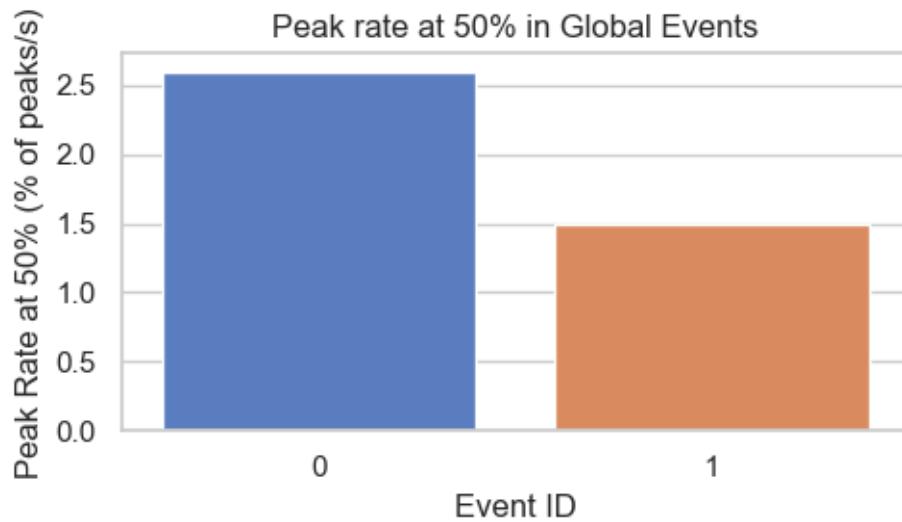
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

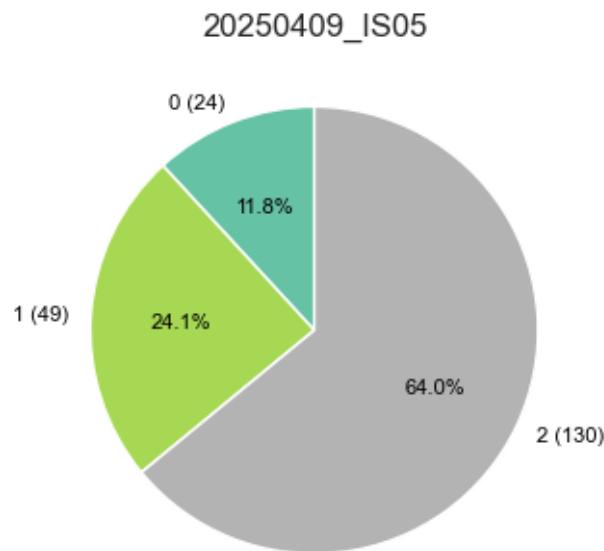
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



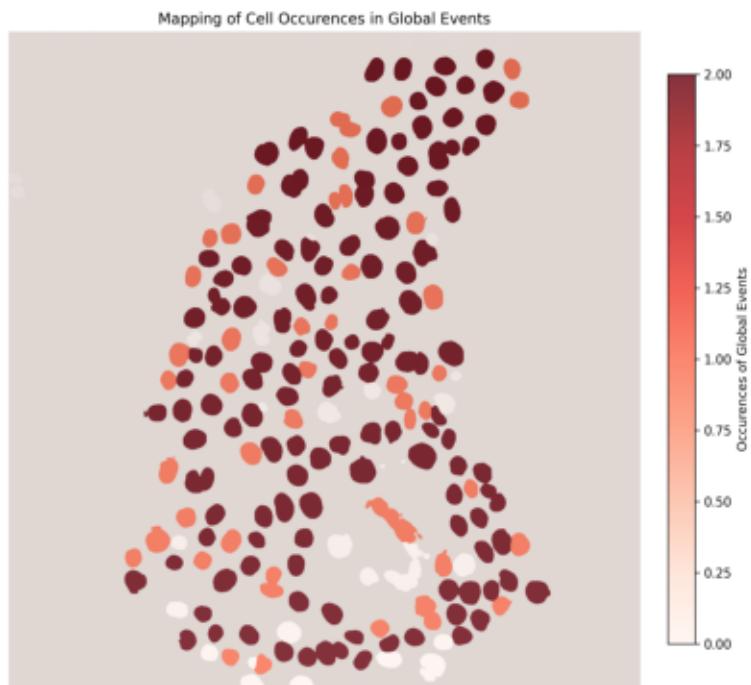
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

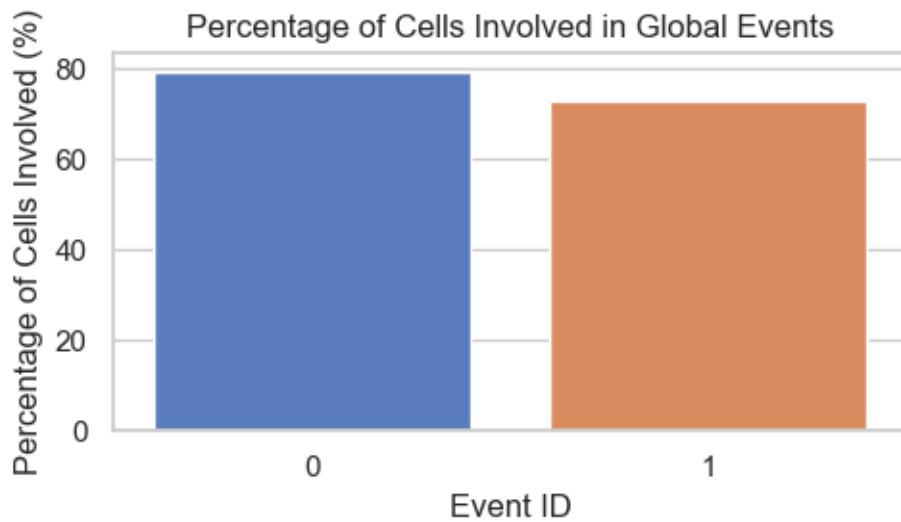
20250409\_IS05



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



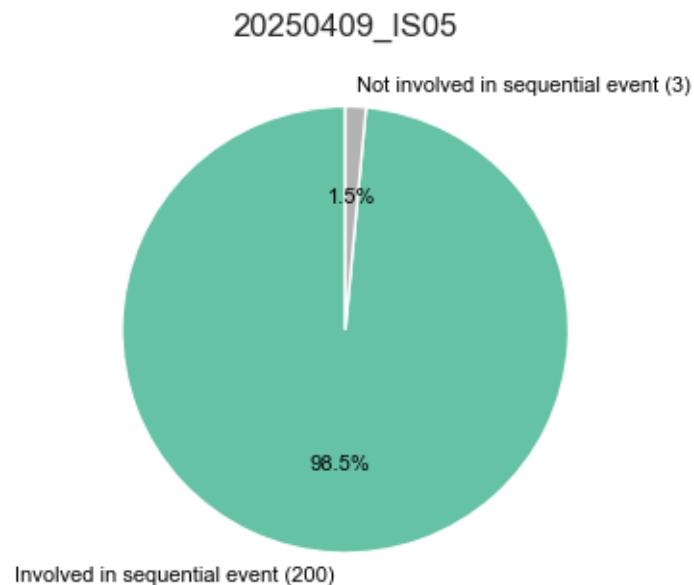
### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [292.0]

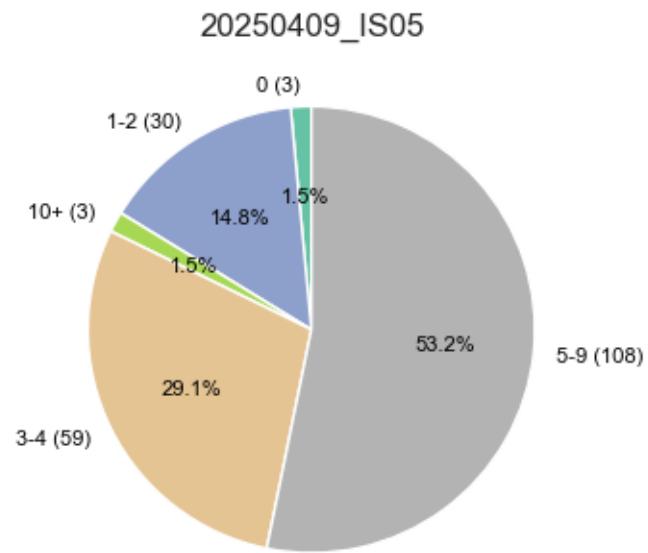
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

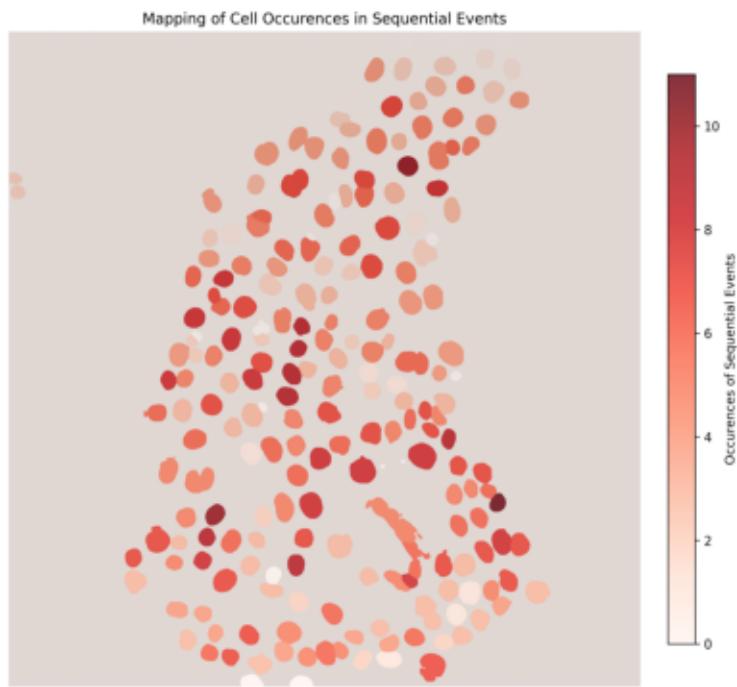


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250409\_IS05

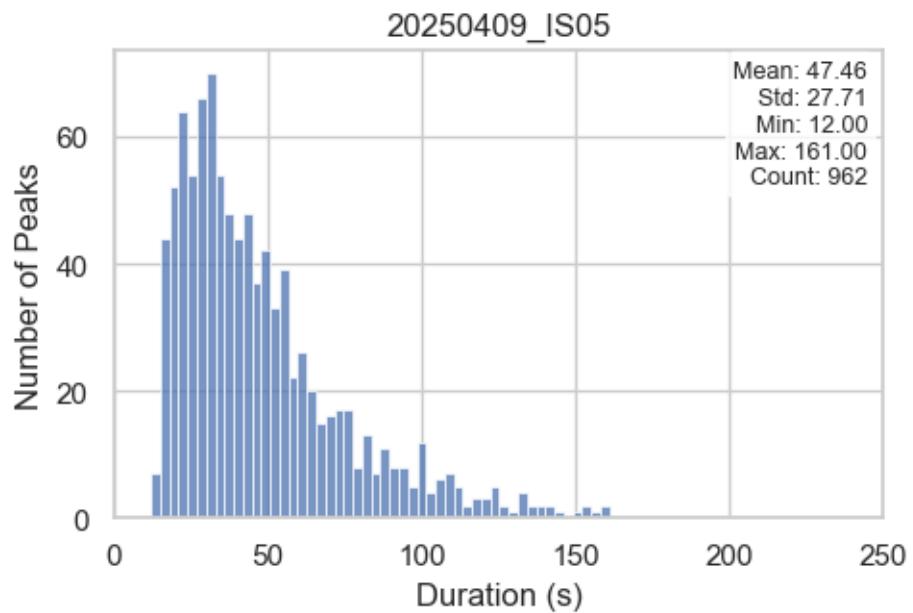


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:52:36] [INFO] calcium: Removed 5 outliers from dataset  
'20250409_IS05' for column 'Duration (s)'
```

```
[2025-08-08 14:52:36] [INFO] calcium: Lower bound: -20.0, Upper bound: 172.0
```

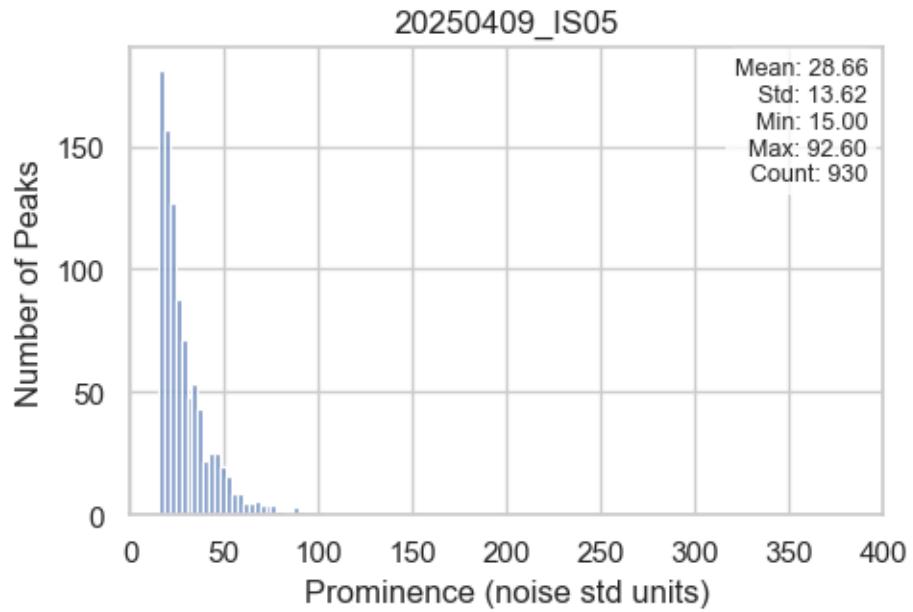
## Distribution of Peak Durations



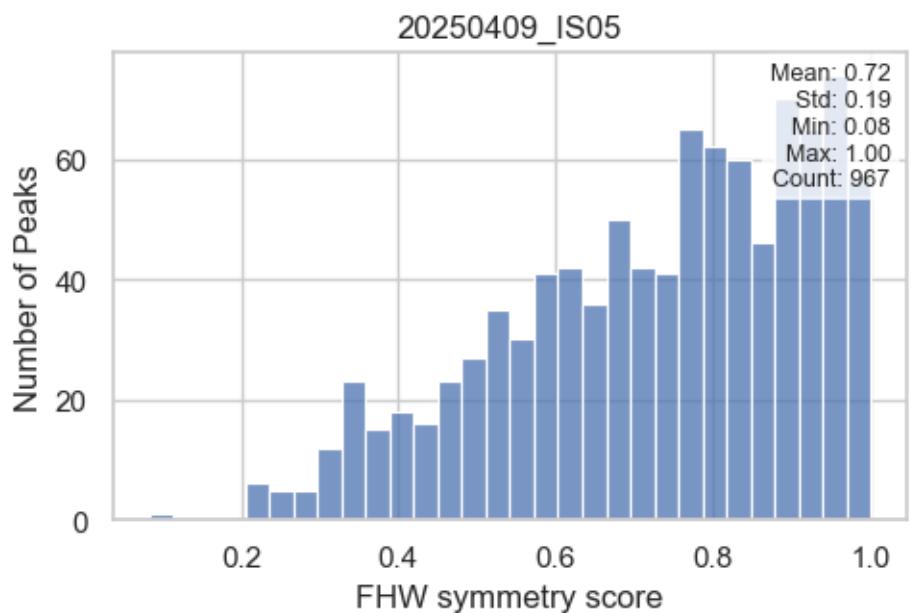
```
[2025-08-08 14:52:36] [INFO] calcium: Removed 37 outliers from dataset '20250409_IS05' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:52:36] [INFO] calcium: Lower bound: -6.02499999999988, Upper bound: 94.47499999999997
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

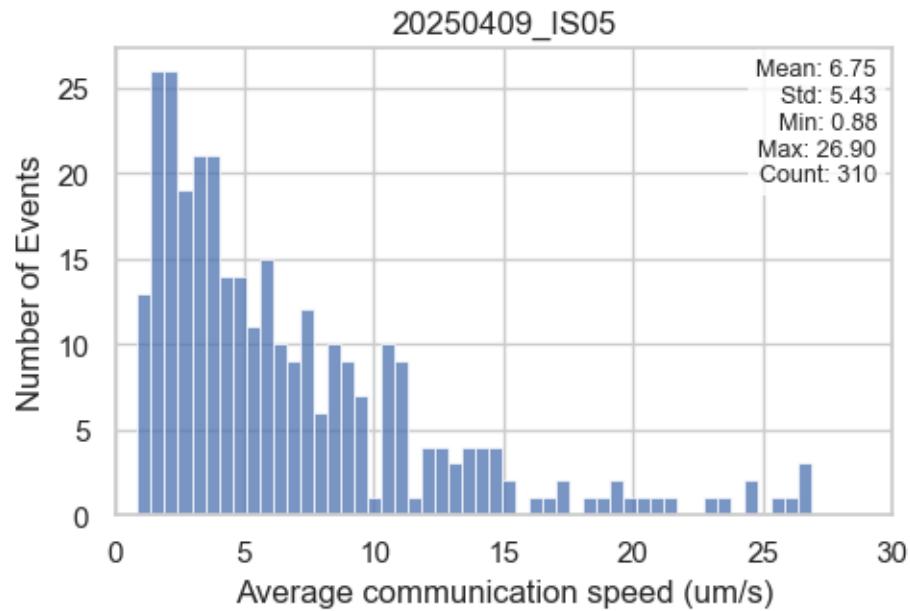


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:52:36] [INFO] calcium: Removed 7 outliers from dataset '20250409\_IS05' for column 'Average communication speed (um/s)'

[2025-08-08 14:52:36] [INFO] calcium: Lower bound: -6.609999999999999, Upper bound: 28.25999999999998

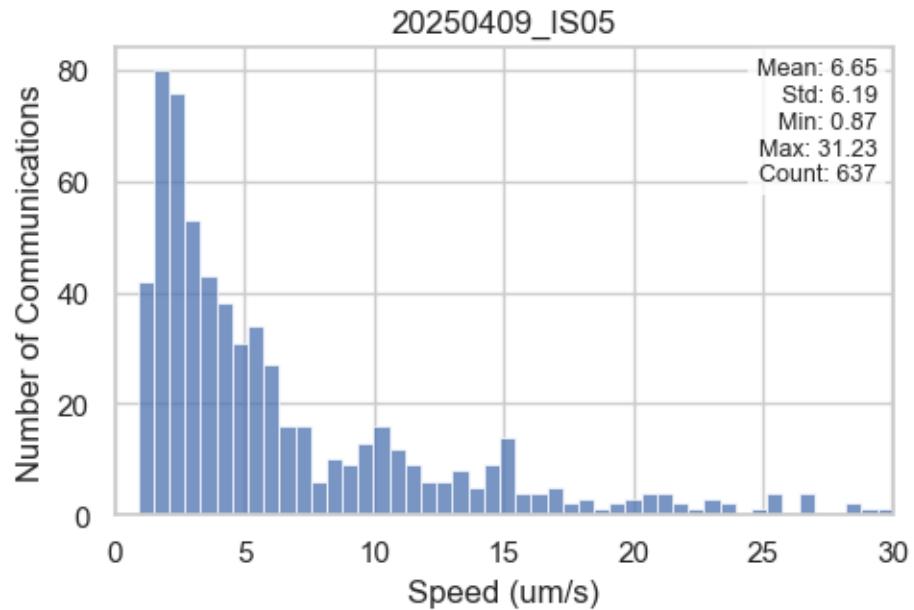
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:52:36] [INFO] calcium: Removed 13 outliers from dataset '20250409\_IS05' for column 'Speed (um/s)'

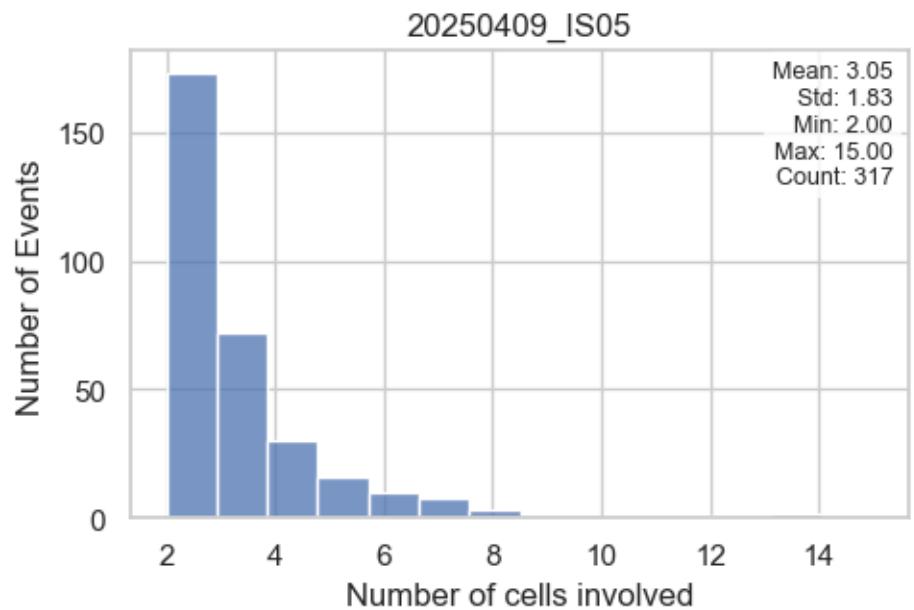
[2025-08-08 14:52:36] [INFO] calcium: Lower bound: -8.493749999999999, Upper bound: 31.3125

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

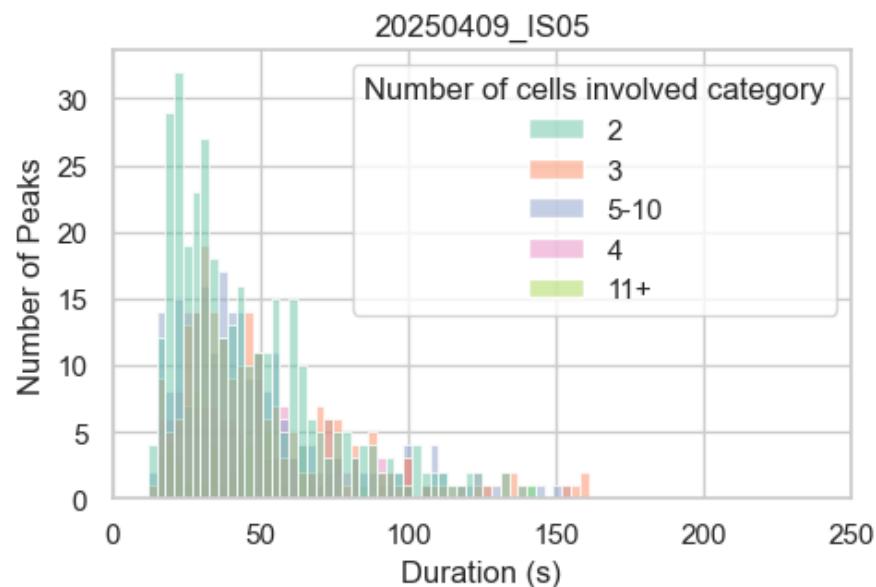


### 1.3.5 Influence of cell count per event on statistics

[2025-08-08 14:52:37] [INFO] calcium: Removed 5 outliers from dataset '20250409\_IS05' for column 'Duration (s)'

[2025-08-08 14:52:37] [INFO] calcium: Lower bound: -20.0, Upper bound: 172.0

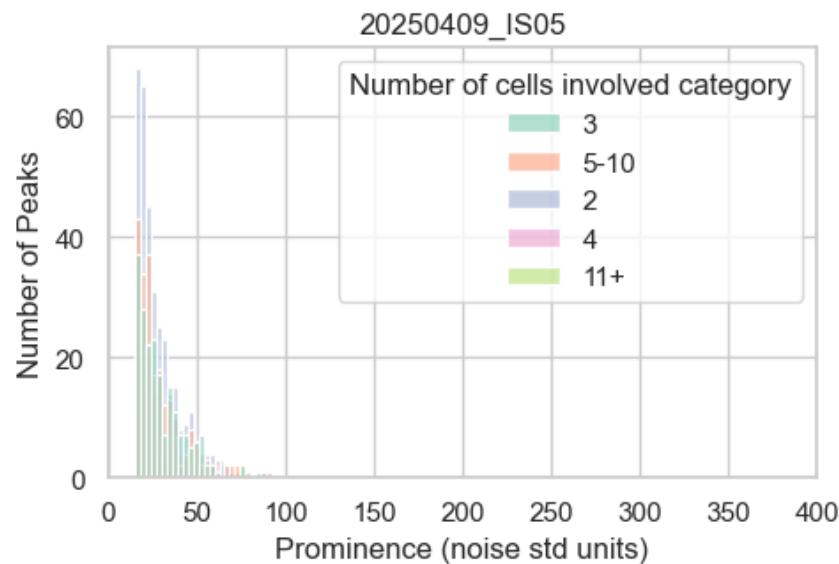
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



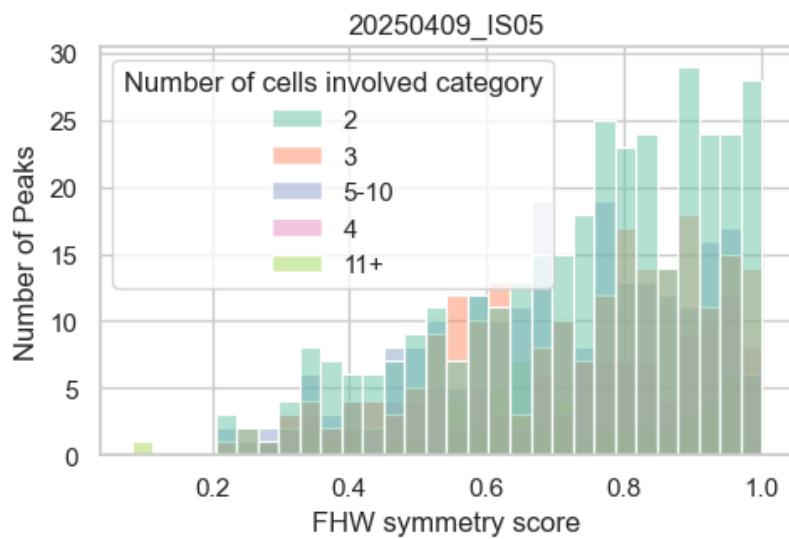
[2025-08-08 14:52:37] [INFO] calcium: Removed 37 outliers from dataset '20250409\_IS05' for column 'Prominence (noise std units)'

[2025-08-08 14:52:37] [INFO] calcium: Lower bound: -6.0, Upper bound: 94.5

## Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



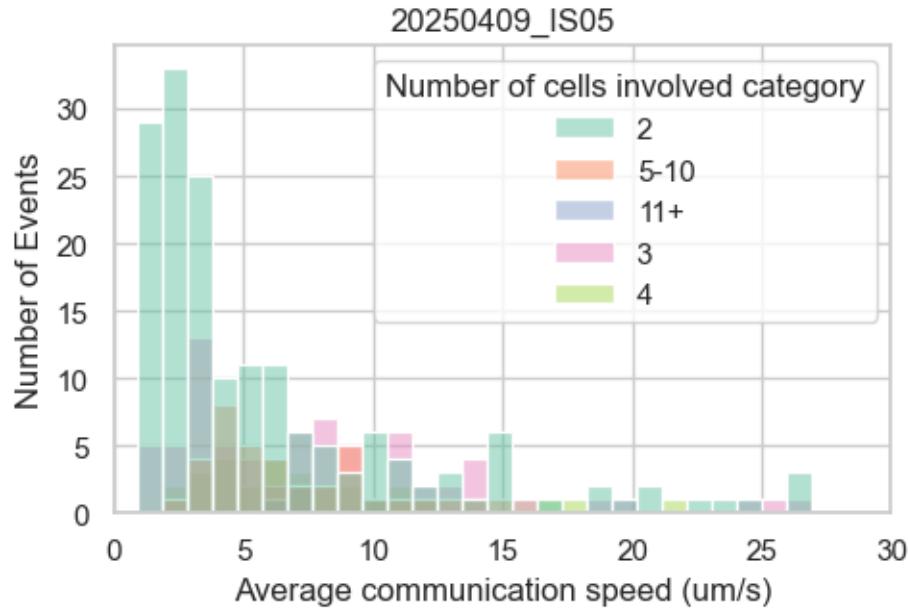
## Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 14:52:38] [INFO] calcium: Removed 7 outliers from dataset  
'20250409_IS05' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 14:52:38] [INFO] calcium: Lower bound: -6.6, Upper bound: 28.3
```

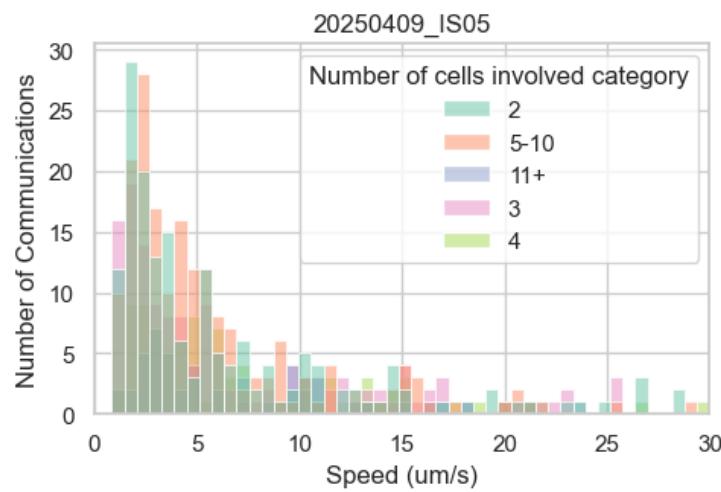
## Distribution of Average Communication Speeds by Number of Cells Involved



[2025-08-08 14:52:38] [INFO] calcium: Removed 13 outliers from dataset '20250409\_IS05' for column 'Speed (um/s)'

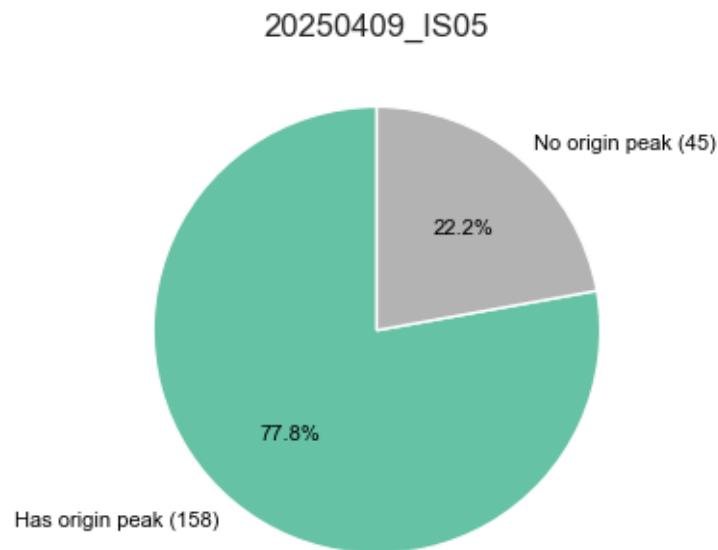
[2025-08-08 14:52:38] [INFO] calcium: Lower bound: -8.5, Upper bound: 31.3

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

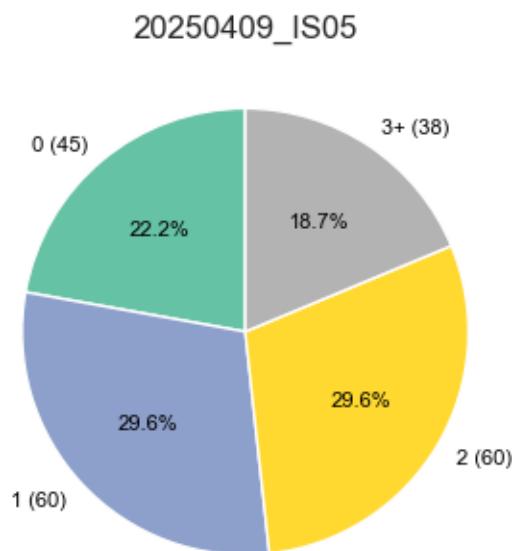


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

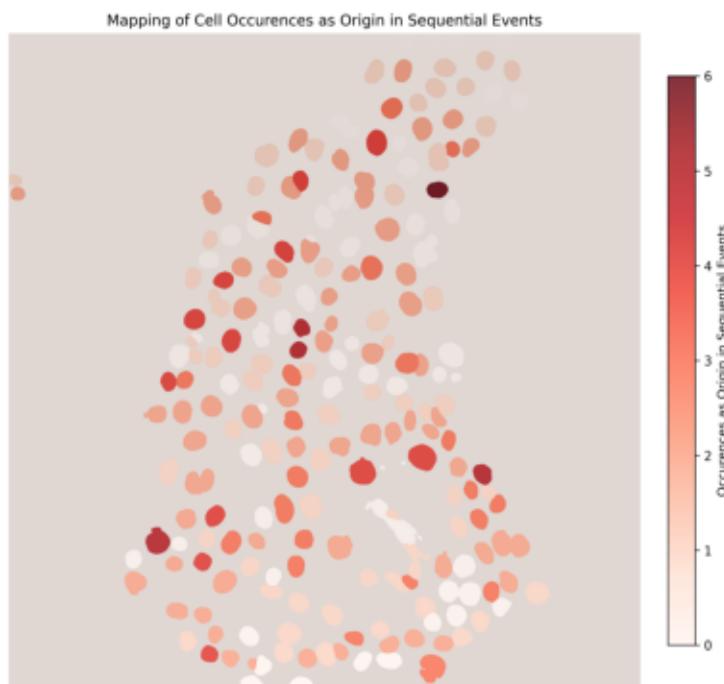


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

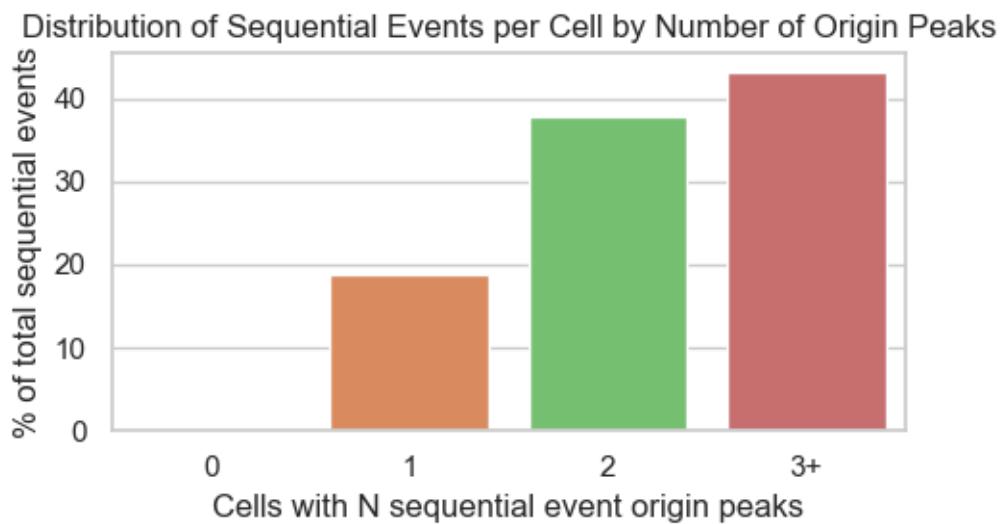
20250409\_IS05



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

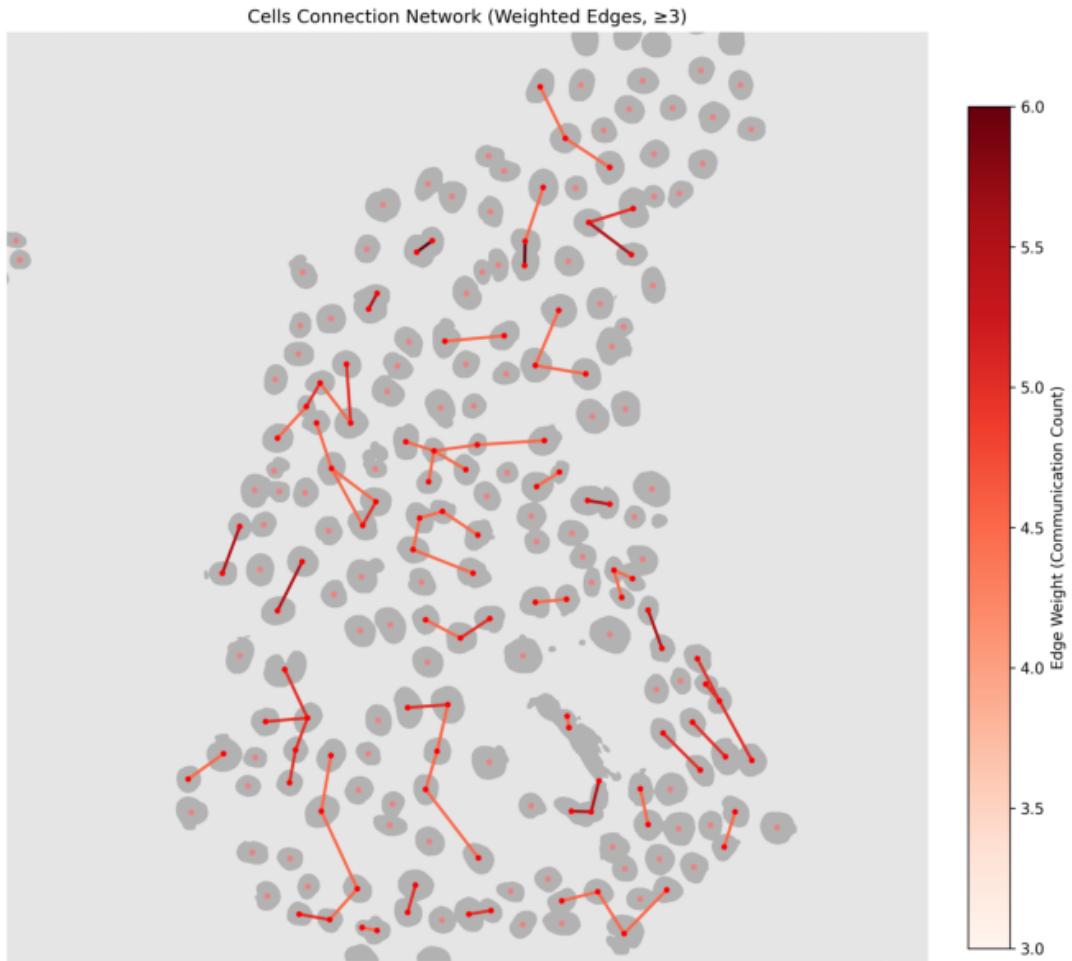
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.3.7 Connection network between cells

Cell Connection Network Graph

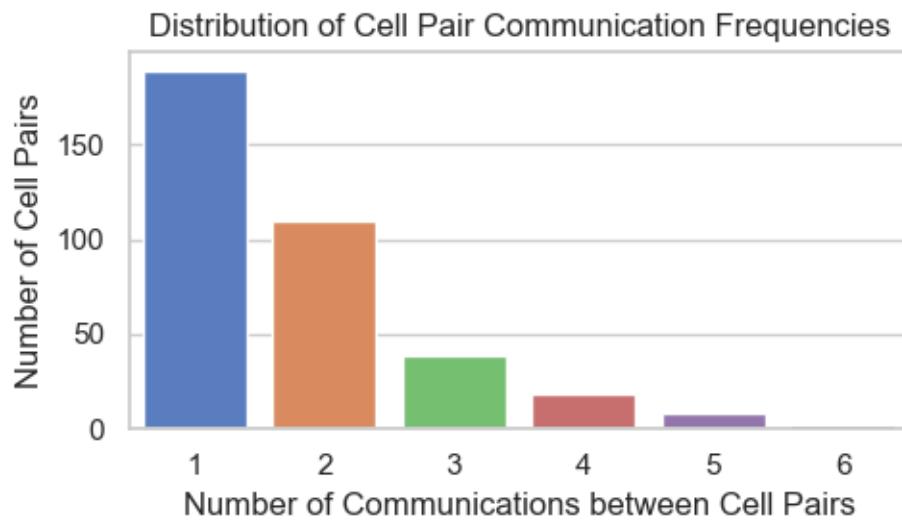
20250409\_IS05



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

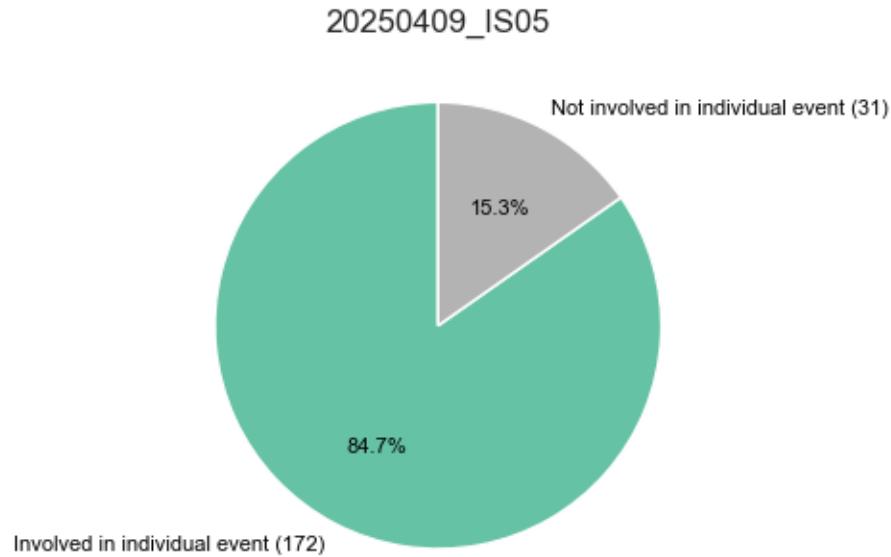
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



## 1.4 INDIVIDUAL EVENTS

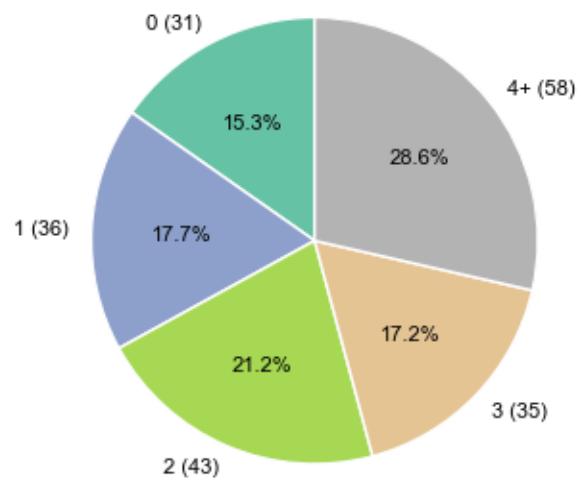
### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events



### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)

20250409\_IS05



## Cell Mapping with Occurrences in Individual Events Overlay

20250409\_IS05

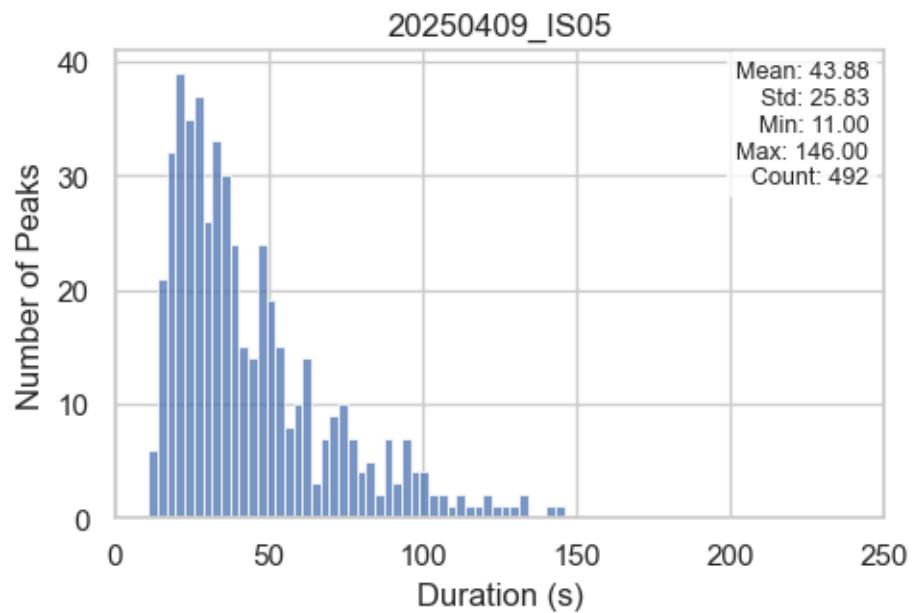


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:52:42] [INFO] calcium: Removed 8 outliers from dataset  
'20250409_IS05' for column 'Duration (s)'
```

```
[2025-08-08 14:52:42] [INFO] calcium: Lower bound: -25.5, Upper bound: 156.0
```

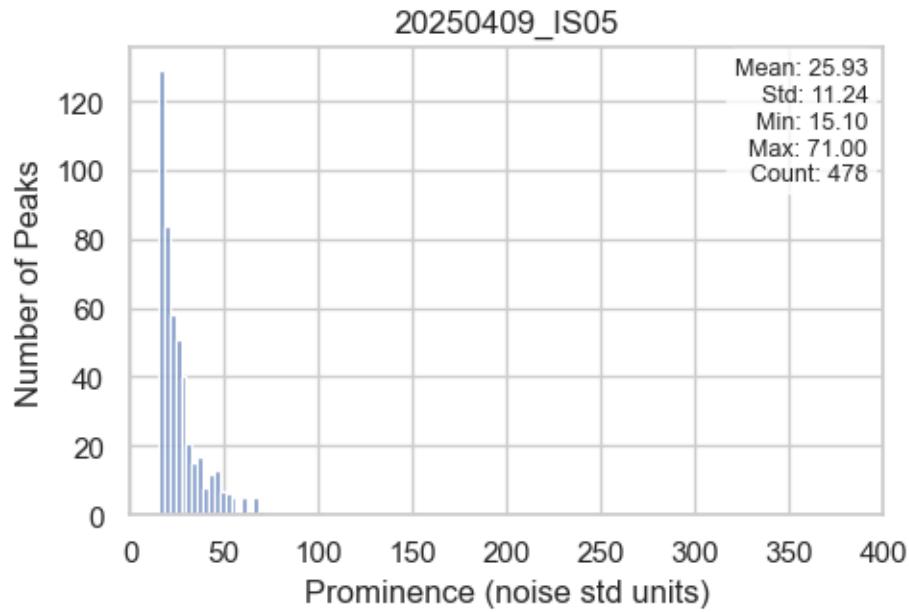
## Distribution of Peak Durations



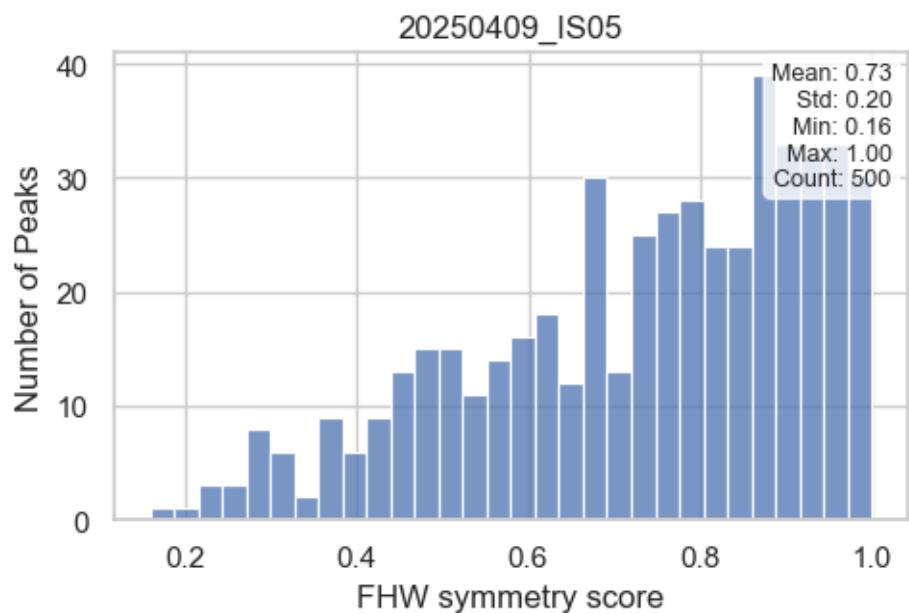
```
[2025-08-08 14:52:42] [INFO] calcium: Removed 22 outliers from dataset '20250409_IS05' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:52:42] [INFO] calcium: Lower bound: -2.8874999999999957, Upper bound: 73.69999999999999
```

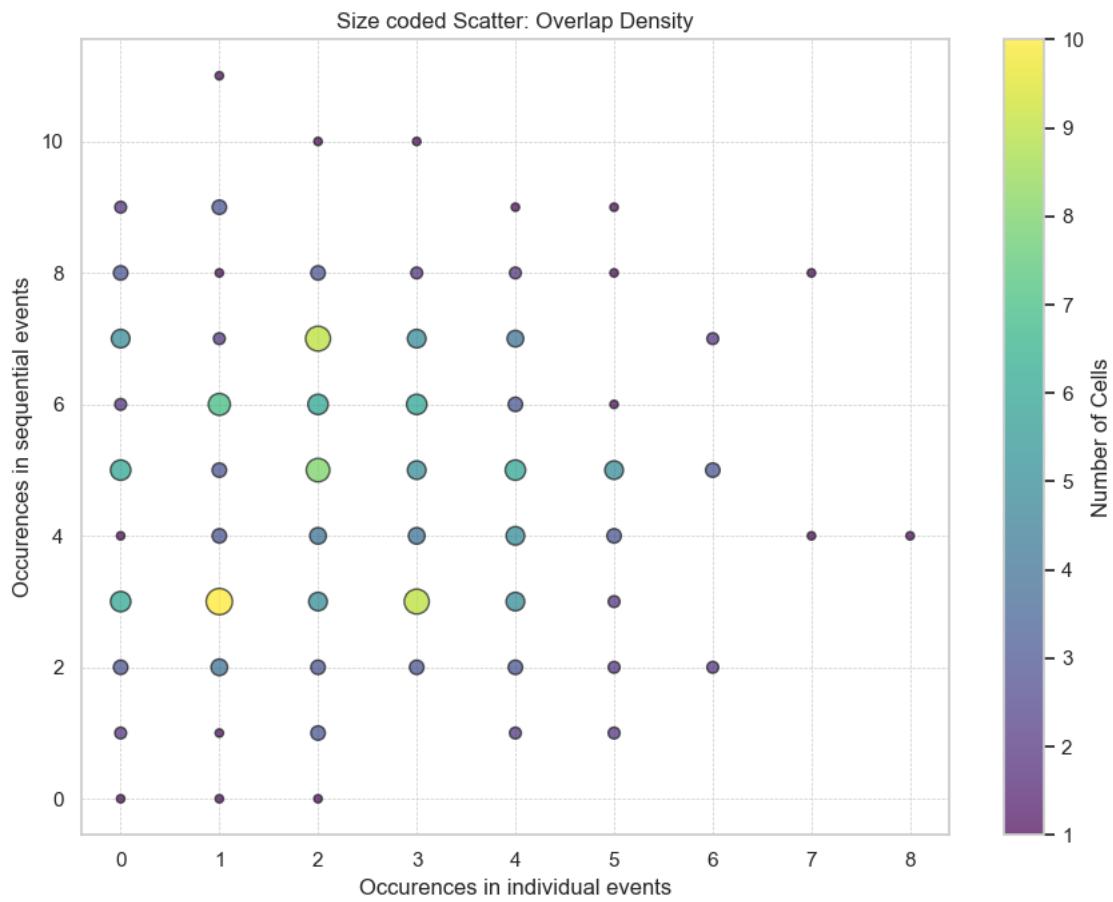
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores



### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n    "Default Dataset": "/path/to/your/dataset"\n}'
```

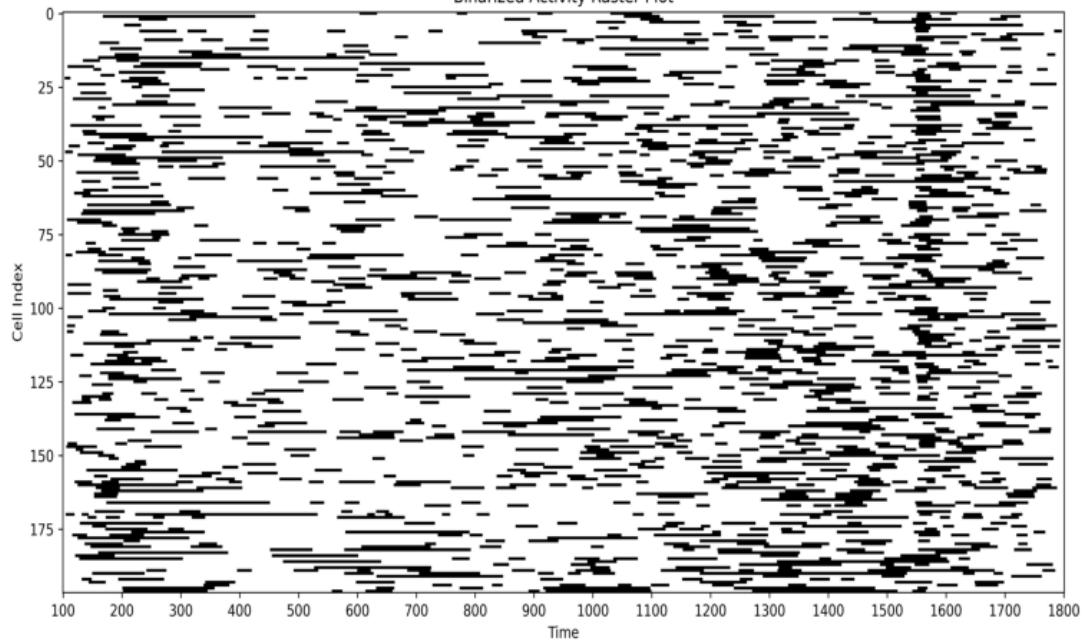
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

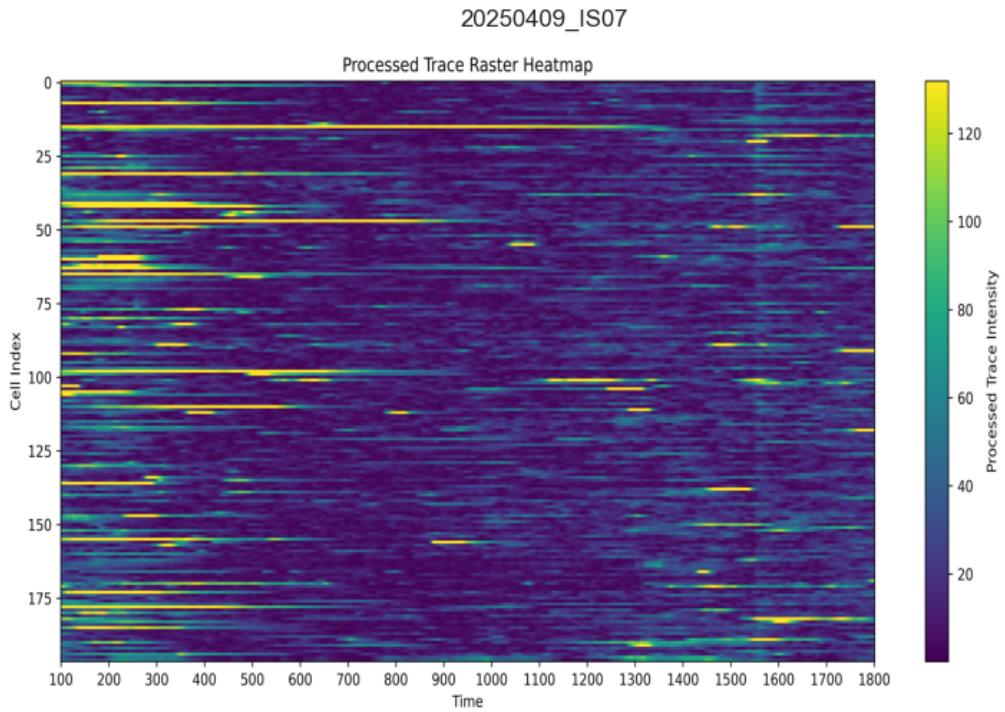
Binary Activity Raster Plot

20250409\_IS07

Binarized Activity Raster Plot



## Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 1391

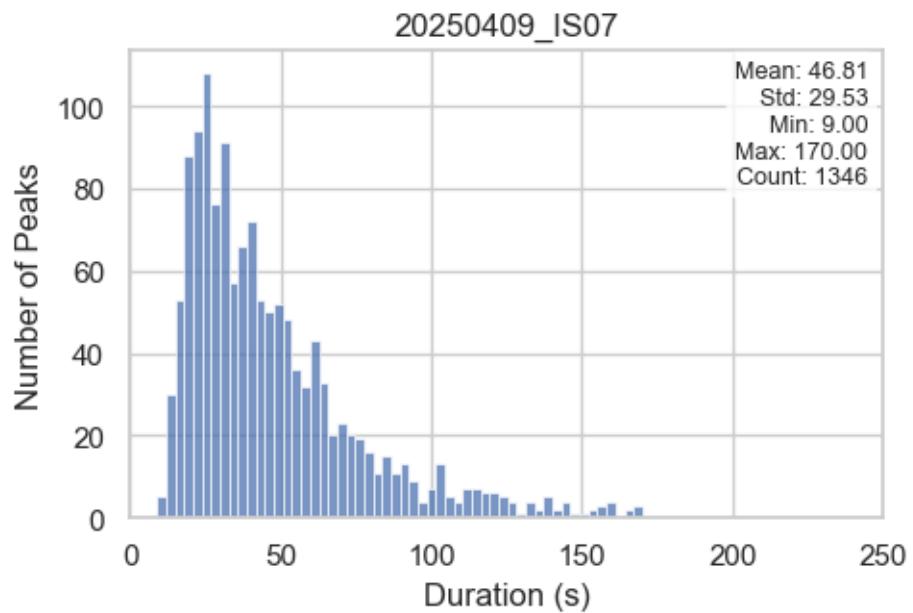
Total number of cells: 197

### 1.1.3 Peaks statistics

```
[2025-08-08 14:53:37] [INFO] calcium: Removed 45 outliers from dataset  
'20250409_IS07' for column 'Duration (s)'
```

```
[2025-08-08 14:53:37] [INFO] calcium: Lower bound: -28.0, Upper bound: 170.0
```

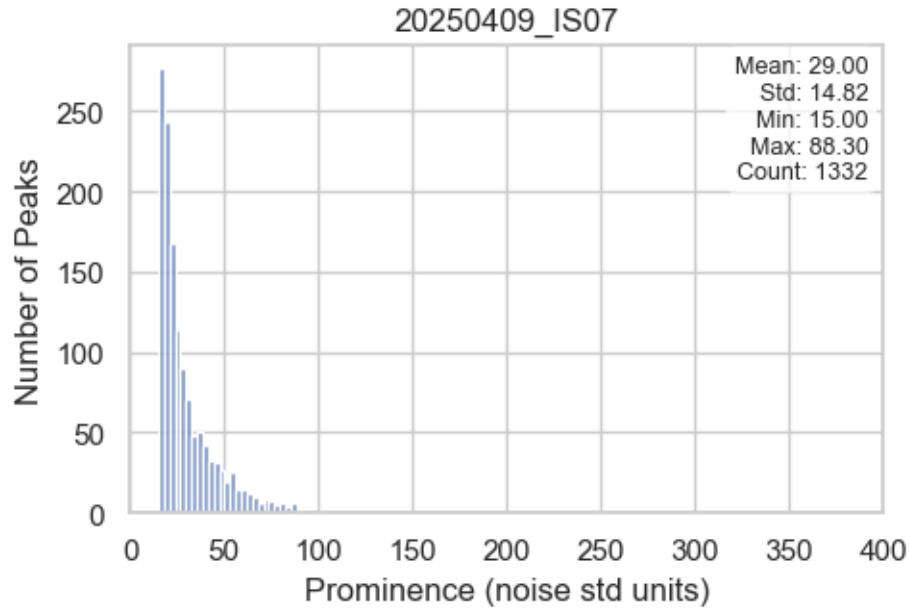
## Distribution of Peak Durations



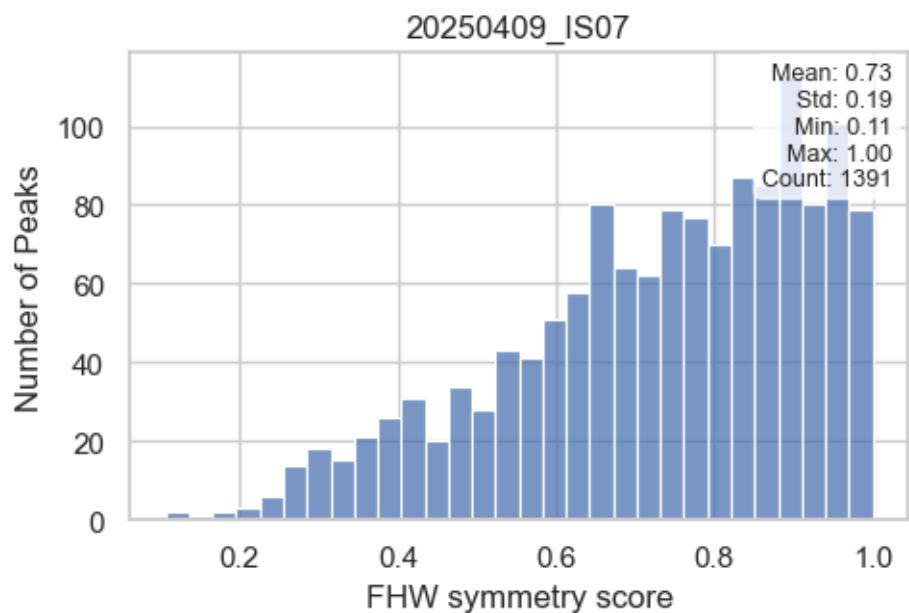
[2025-08-08 14:53:37] [INFO] calcium: Removed 59 outliers from dataset '20250409\_IS07' for column 'Prominence (noise std units)'

[2025-08-08 14:53:37] [INFO] calcium: Lower bound: -8.675000000000008, Upper bound: 91.70000000000002

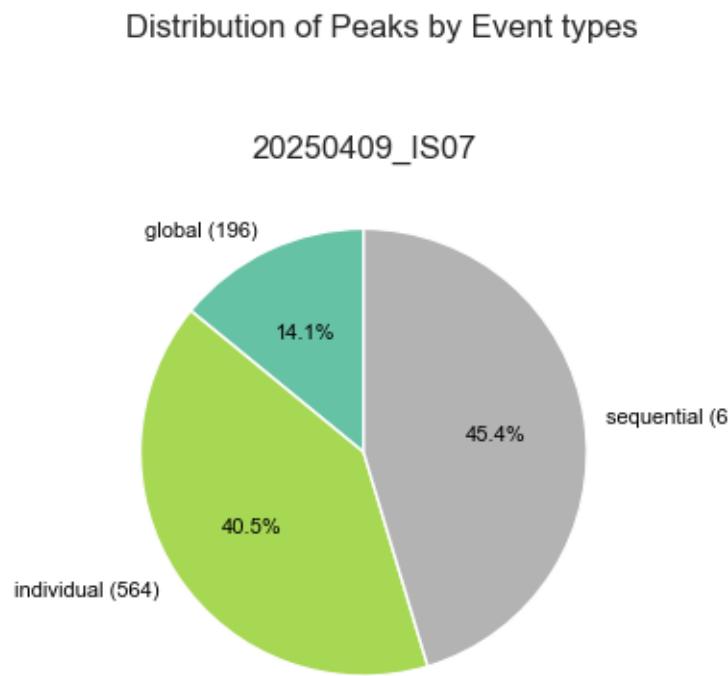
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

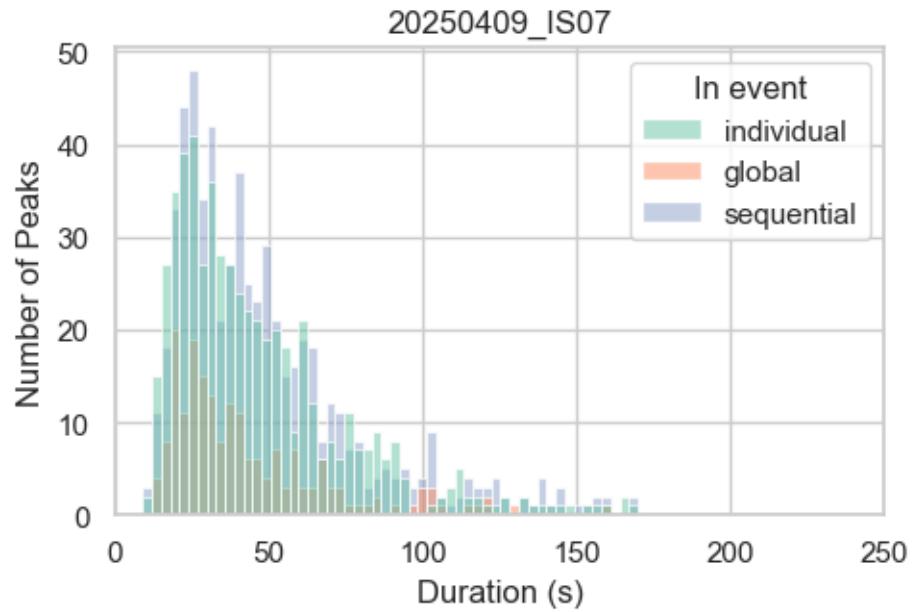


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:53:37] [INFO] calcium: Removed 45 outliers from dataset  
'20250409_IS07' for column 'Duration (s)'
```

```
[2025-08-08 14:53:37] [INFO] calcium: Lower bound: -28.0, Upper bound: 170.0
```

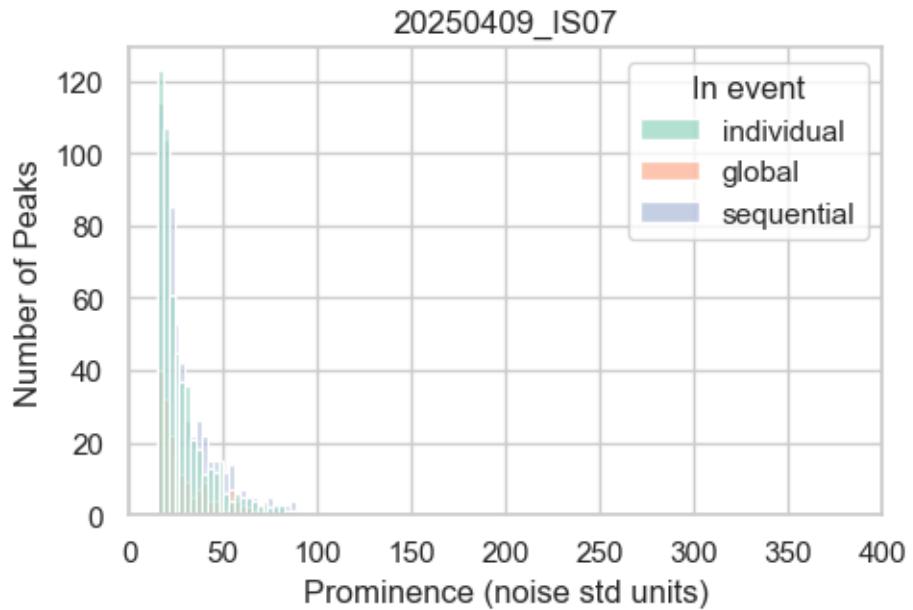
## Distribution of Peak Durations by Group



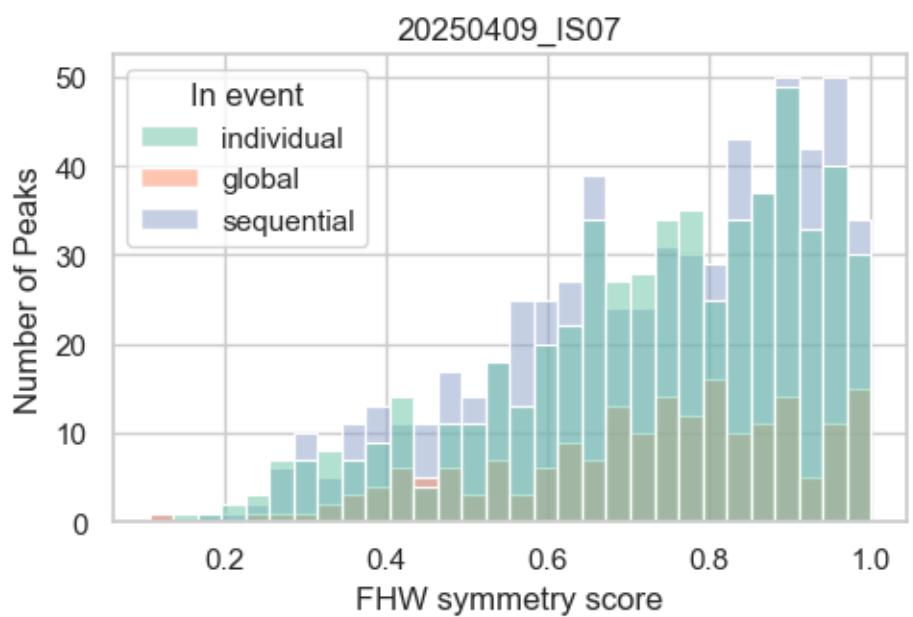
[2025-08-08 14:53:37] [INFO] calcium: Removed 59 outliers from dataset '20250409\_IS07' for column 'Prominence (noise std units)'

[2025-08-08 14:53:37] [INFO] calcium: Lower bound: -8.7, Upper bound: 91.7

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



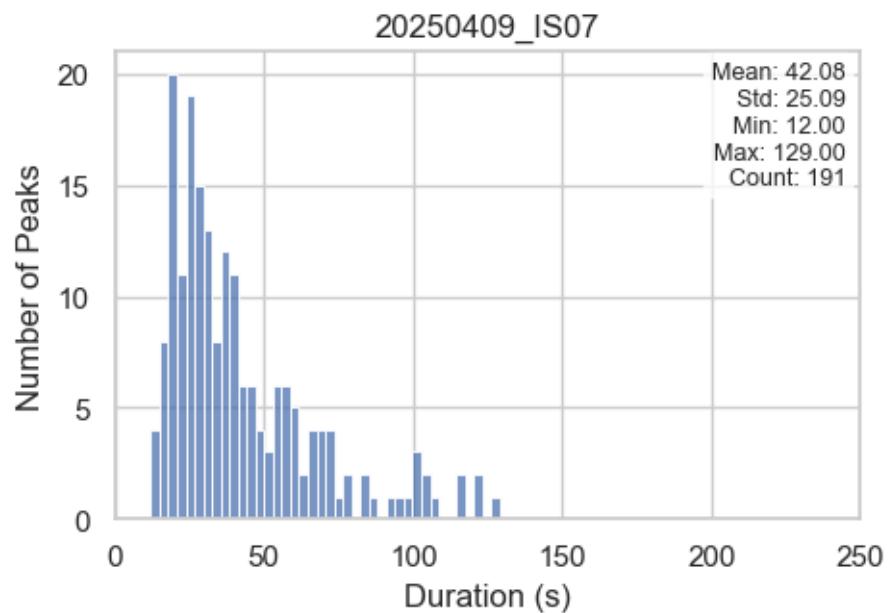
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:53:38] [INFO] calcium: Removed 5 outliers from dataset  
'20250409_IS07' for column 'Duration (s)'
```

```
[2025-08-08 14:53:38] [INFO] calcium: Lower bound: -24.375, Upper bound: 153.0
```

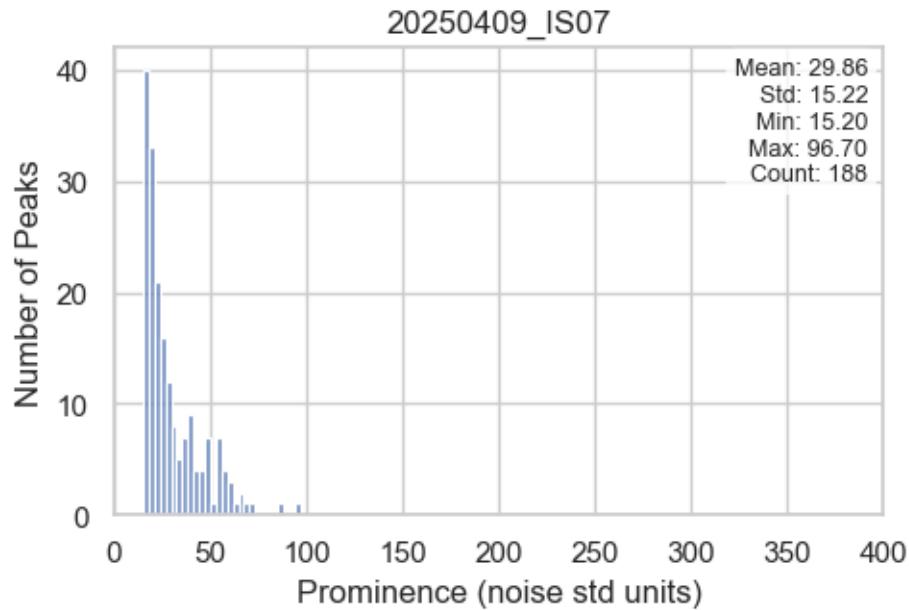
Distribution of Peak Durations



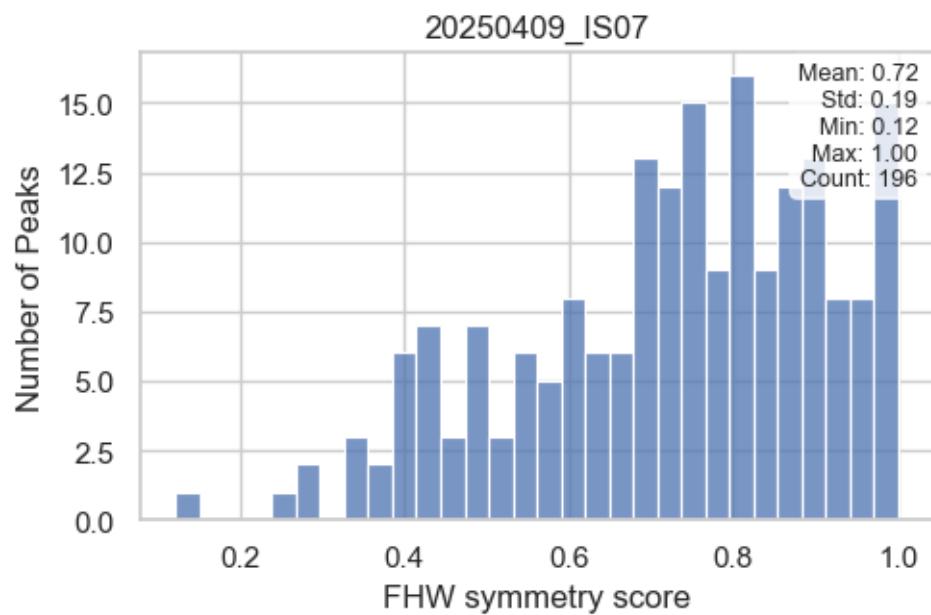
```
[2025-08-08 14:53:38] [INFO] calcium: Removed 8 outliers from dataset  
'20250409_IS07' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:53:38] [INFO] calcium: Lower bound: -12.737499999999994, Upper  
bound: 102.8999999999998
```

## Distribution of Peak Prominences



## Distribution of Peak Symmetry Scores

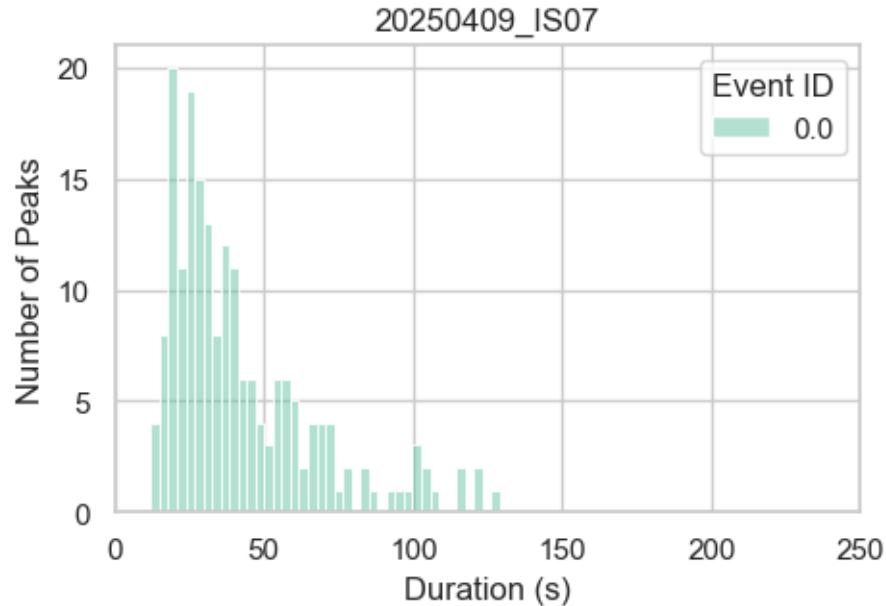


### 1.2.2 Peak statistics in global event per event ID

```
[2025-08-08 14:53:38] [INFO] calcium: Removed 5 outliers from dataset  
'20250409_IS07' for column 'Duration (s)'
```

```
[2025-08-08 14:53:38] [INFO] calcium: Lower bound: -24.4, Upper bound: 153.0
```

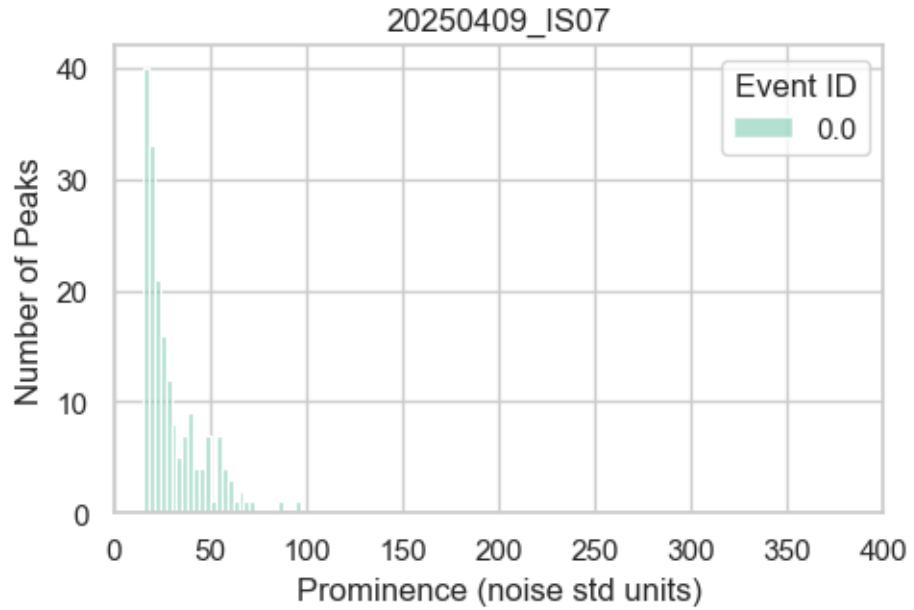
Distribution of Peak Durations by Group



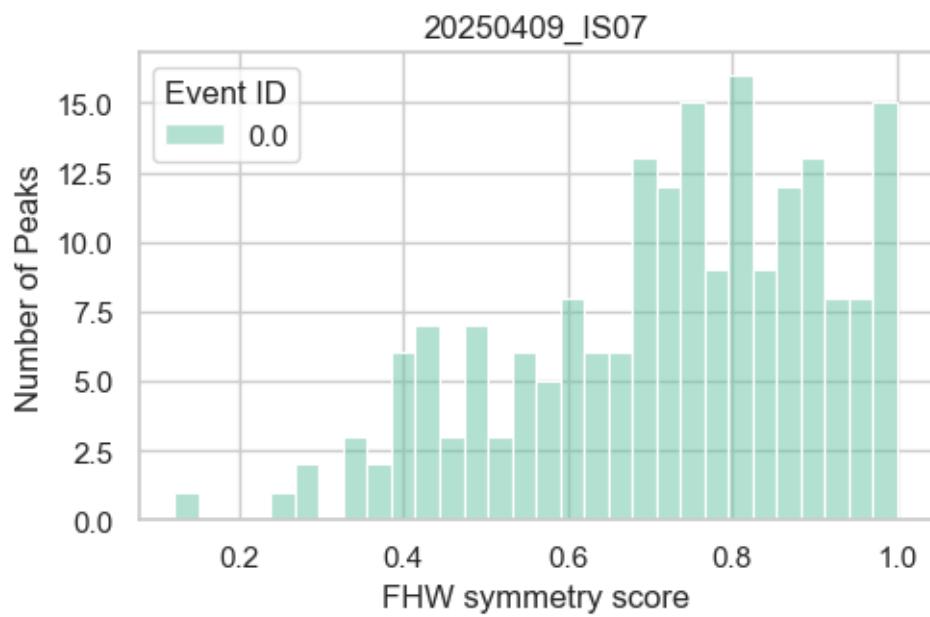
```
[2025-08-08 14:53:38] [INFO] calcium: Removed 8 outliers from dataset  
'20250409_IS07' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:53:38] [INFO] calcium: Lower bound: -12.7, Upper bound: 102.9
```

### Distribution of Peak Prominences by Group



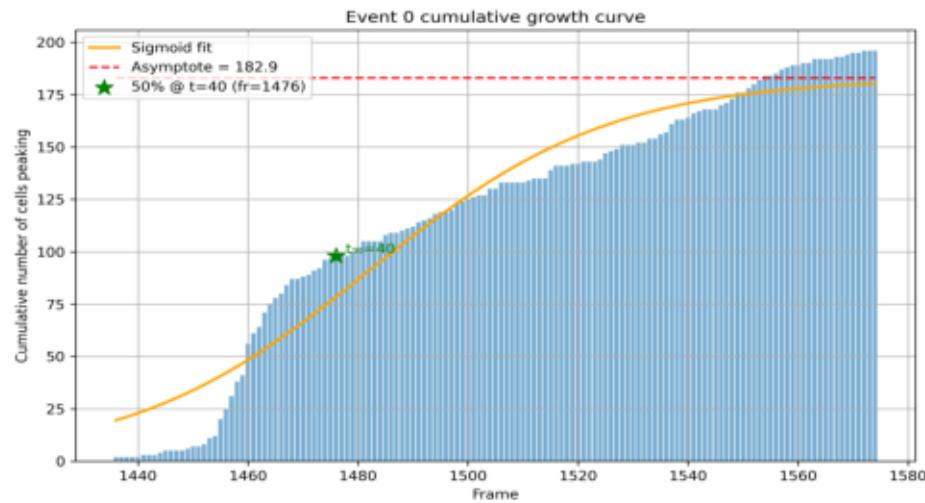
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

Event Activity Overlay (Event ID: 0)

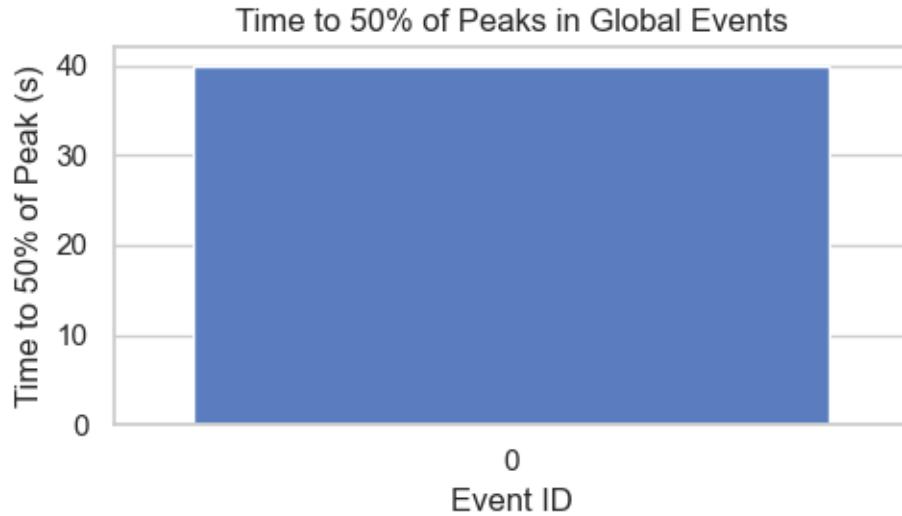
20250409\_IS07



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

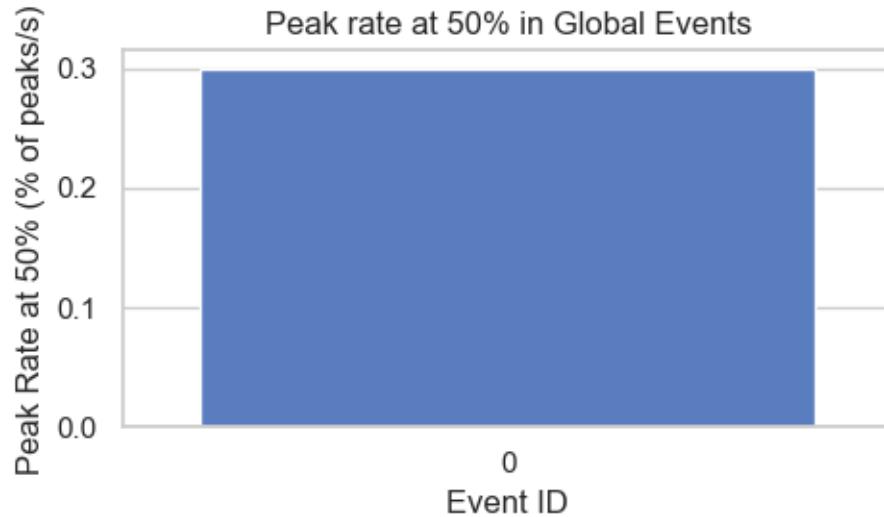
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys
is\visualizers.py:297: FutureWarning:
```

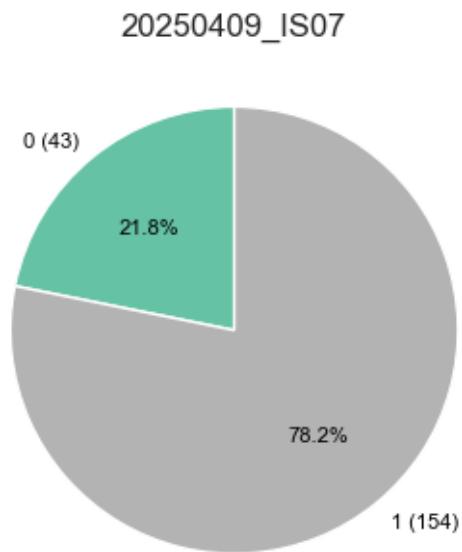
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,
dodge=False, palette=palette, legend=False)
```



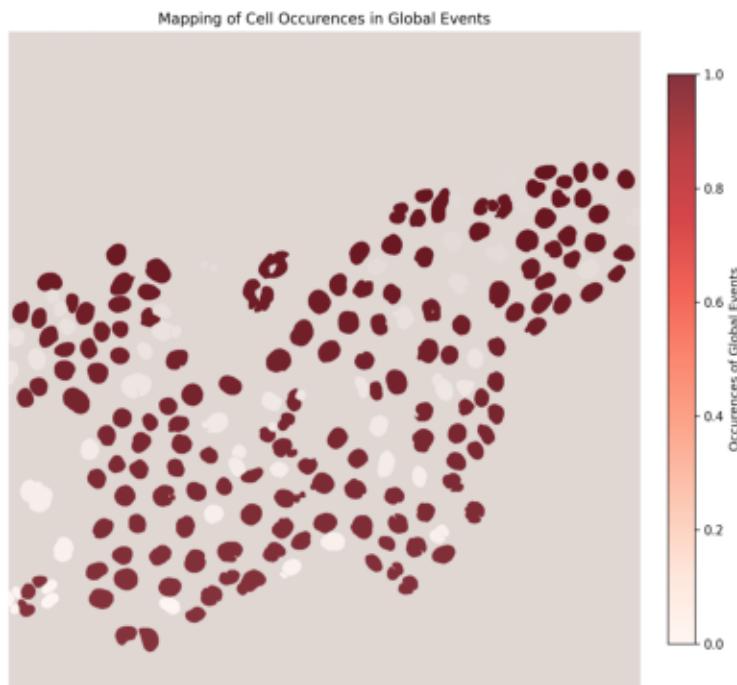
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

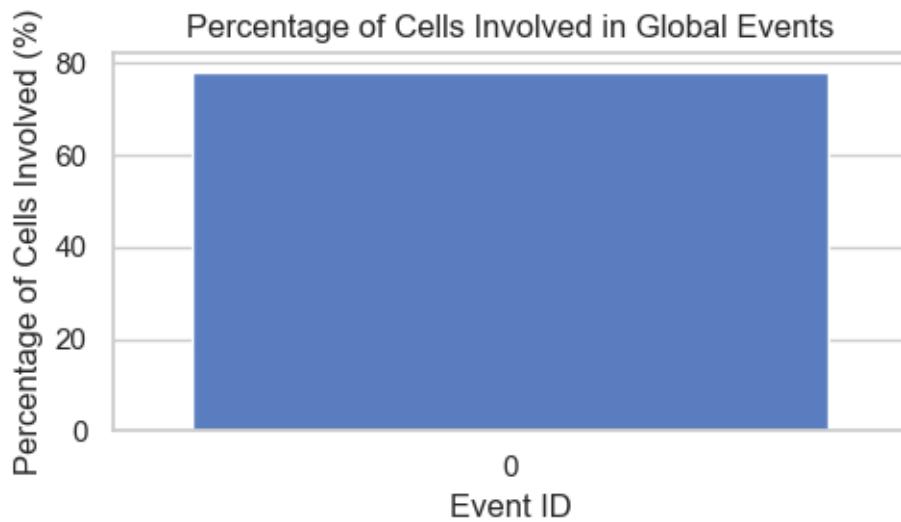
20250409\_IS07



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



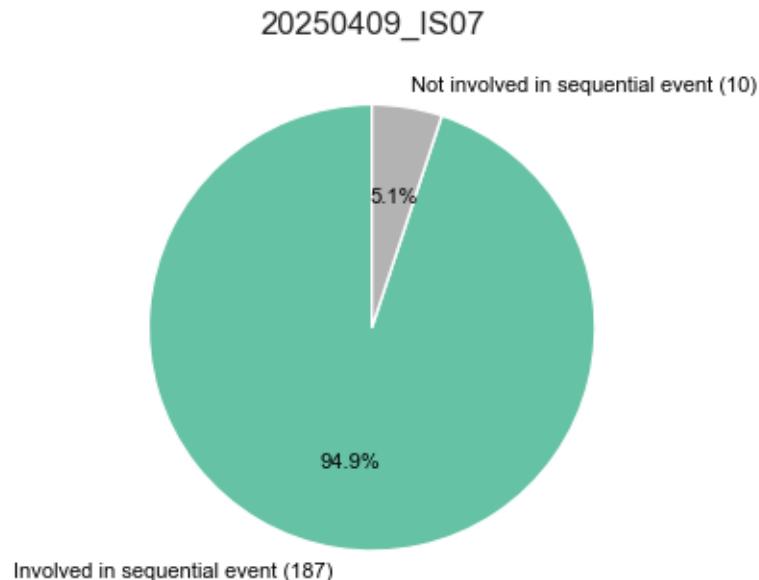
### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: []

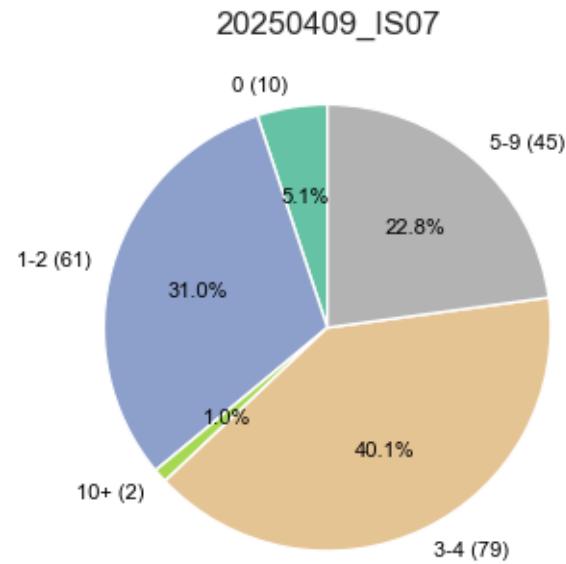
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

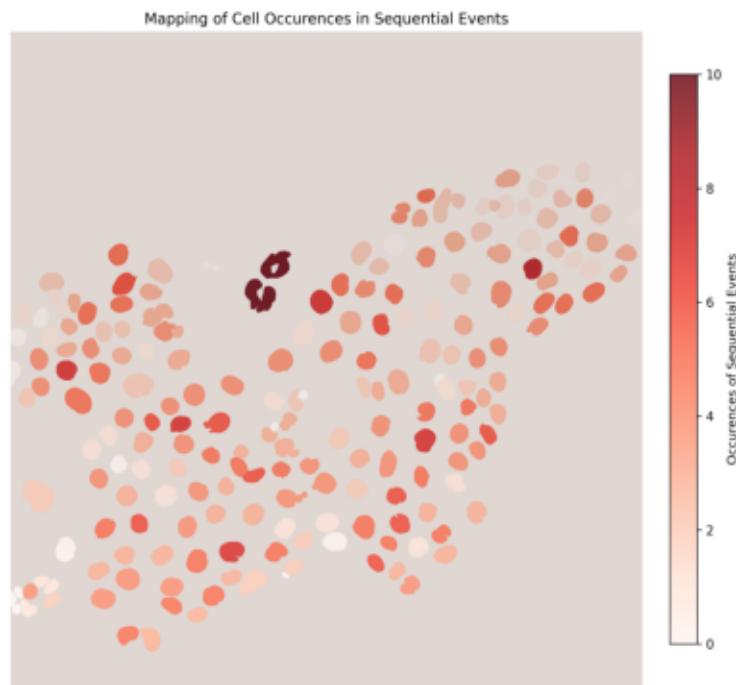


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250409\_IS07

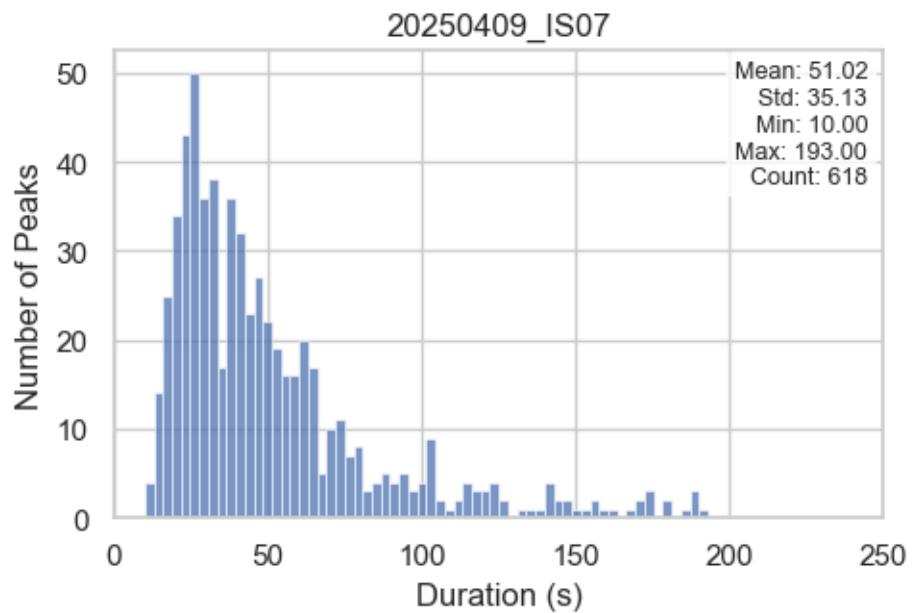


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:53:42] [INFO] calcium: Removed 13 outliers from dataset  
'20250409_IS07' for column 'Duration (s)'
```

```
[2025-08-08 14:53:42] [INFO] calcium: Lower bound: -28.5, Upper bound: 193.5
```

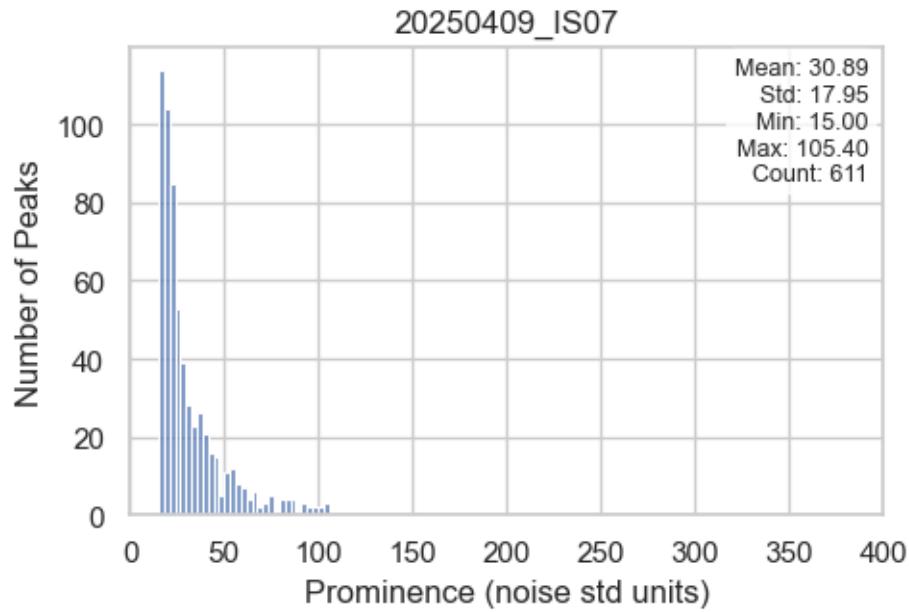
## Distribution of Peak Durations



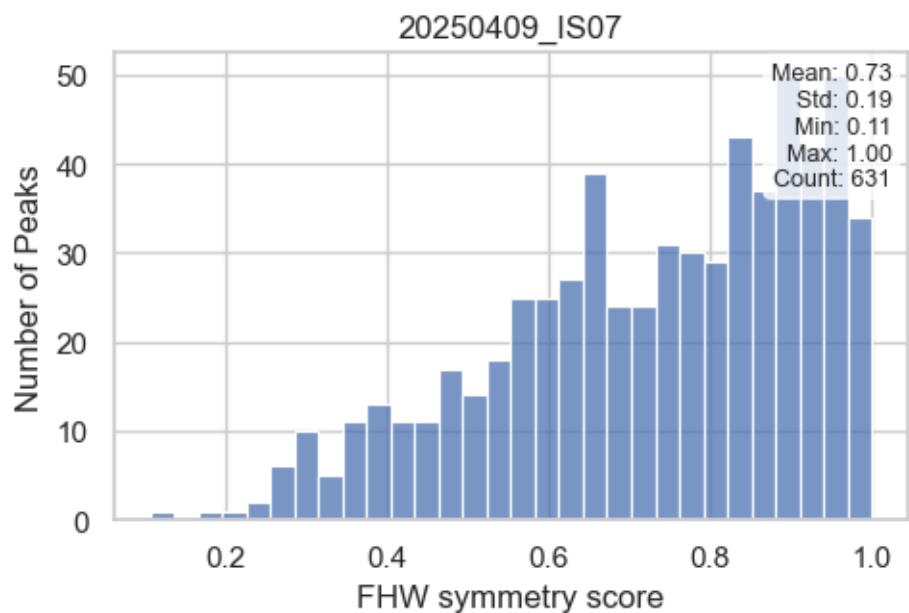
```
[2025-08-08 14:53:42] [INFO] calcium: Removed 20 outliers from dataset '20250409_IS07' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:53:42] [INFO] calcium: Lower bound: -10.275000000000002, Upper bound: 107.025
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

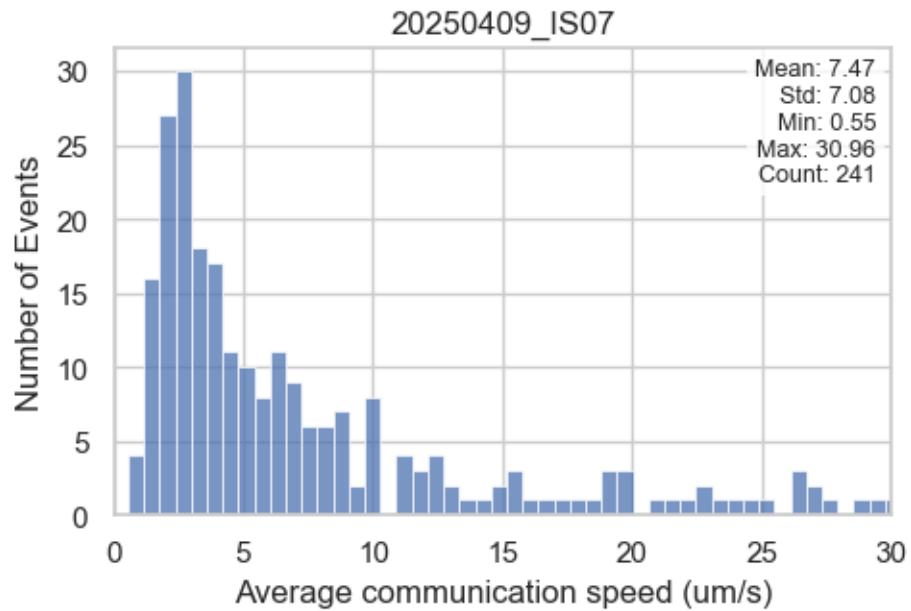


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:53:42] [INFO] calcium: Removed 6 outliers from dataset '20250409\_IS07' for column 'Average communication speed (um/s)'

[2025-08-08 14:53:42] [INFO] calcium: Lower bound: -8.27, Upper bound: 31.659999999999997

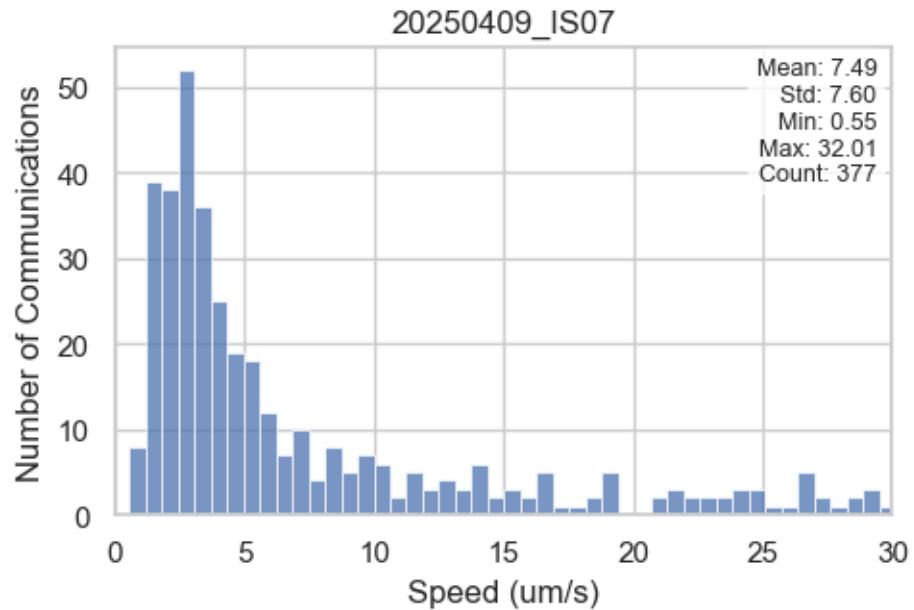
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:53:43] [INFO] calcium: Removed 7 outliers from dataset '20250409\_IS07' for column 'Speed (um/s)'

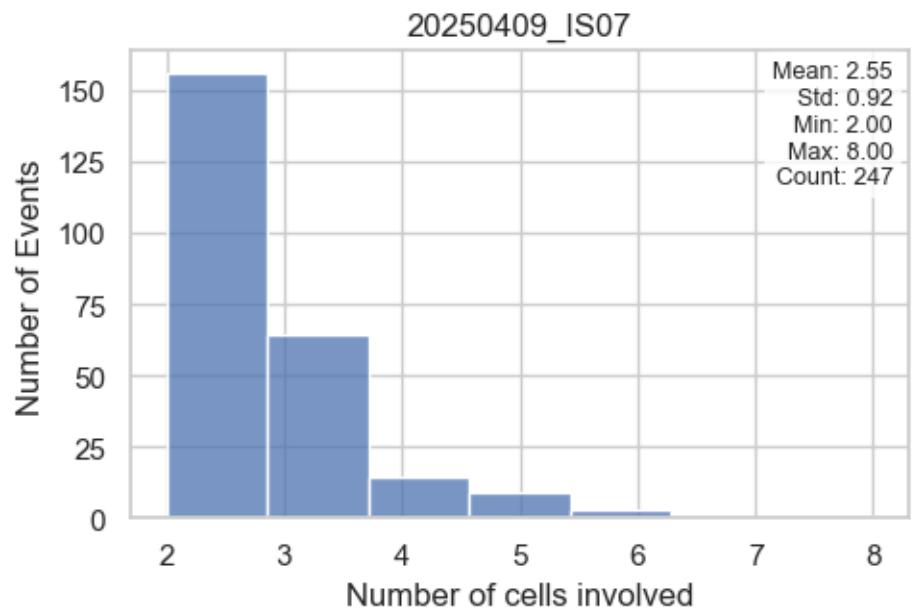
[2025-08-08 14:53:43] [INFO] calcium: Lower bound: -8.673750000000002, Upper bound: 32.397500000000001

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

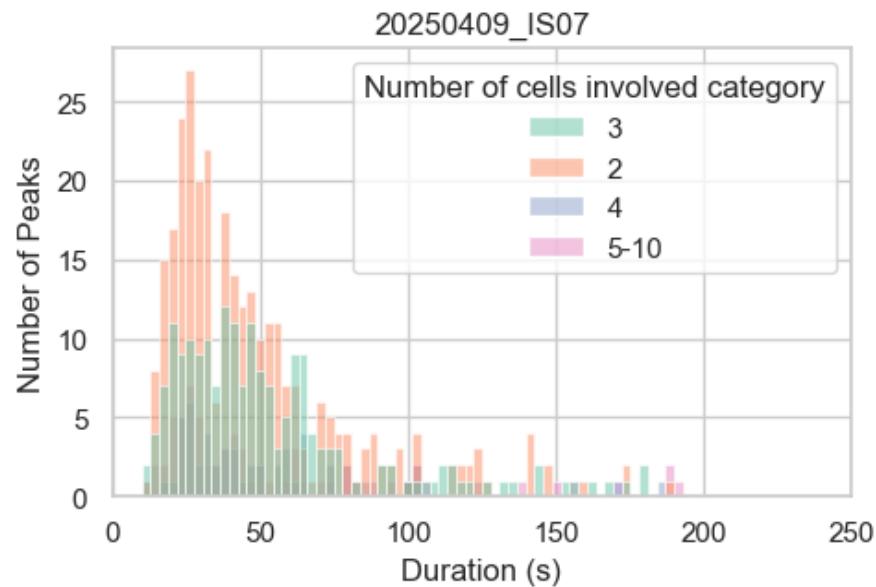


### 1.3.5 Influence of cell count per event on statistics

```
[2025-08-08 14:53:43] [INFO] calcium: Removed 13 outliers from dataset  
'20250409_IS07' for column 'Duration (s)'
```

```
[2025-08-08 14:53:43] [INFO] calcium: Lower bound: -28.5, Upper bound: 193.5
```

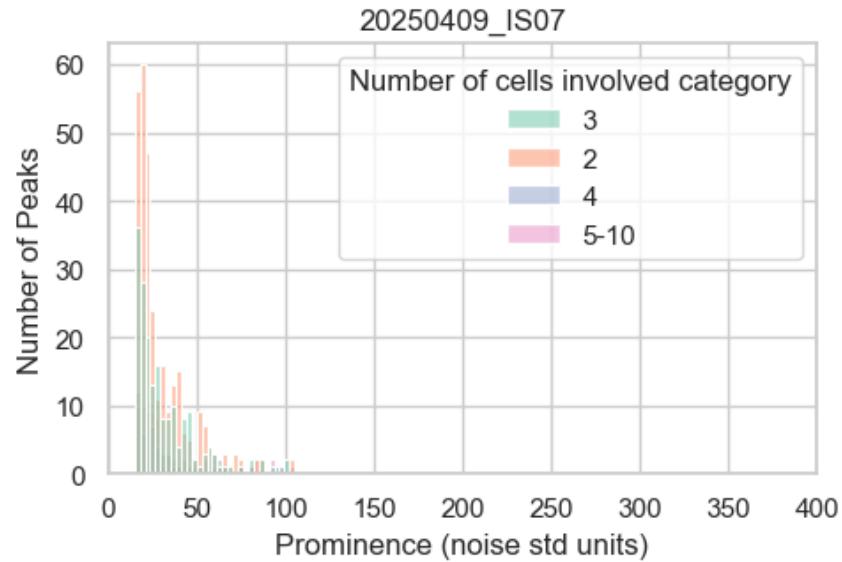
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



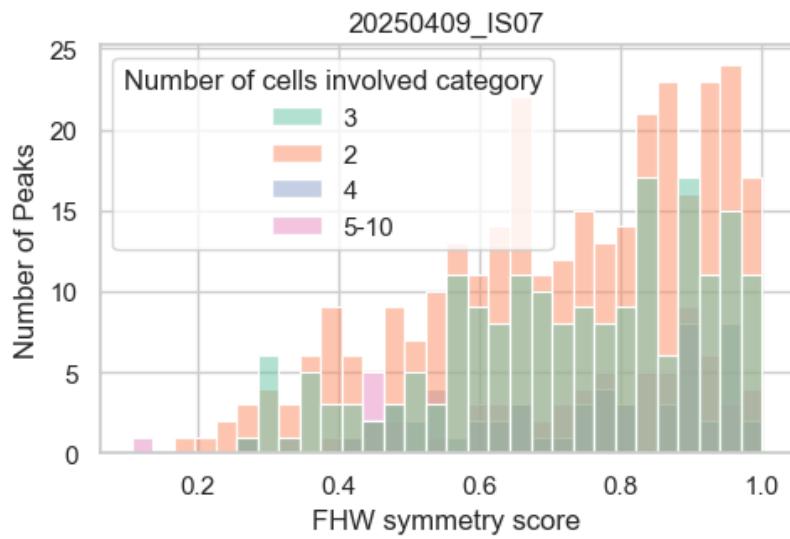
```
[2025-08-08 14:53:43] [INFO] calcium: Removed 20 outliers from dataset  
'20250409_IS07' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:53:43] [INFO] calcium: Lower bound: -10.3, Upper bound: 107.0
```

## Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



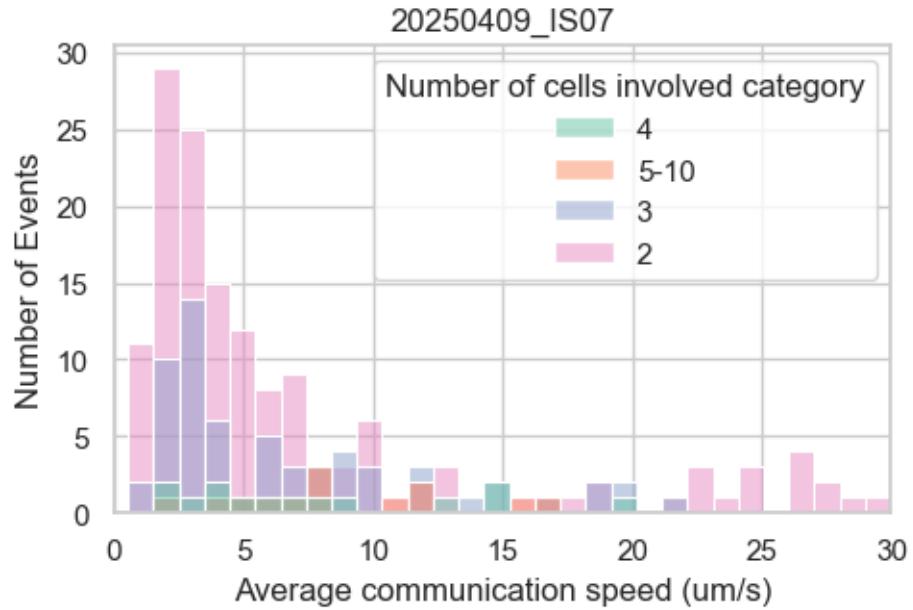
## Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 14:53:44] [INFO] calcium: Removed 6 outliers from dataset
'20250409_IS07' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 14:53:44] [INFO] calcium: Lower bound: -8.3, Upper bound: 31.7
```

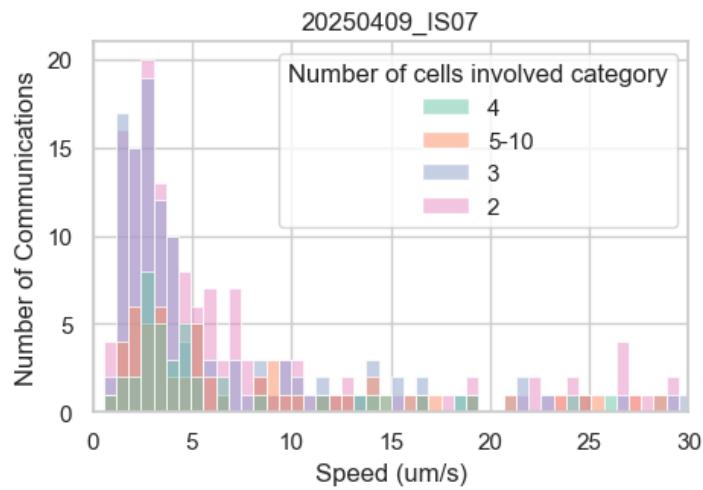
## Distribution of Average Communication Speeds by Number of Cells Involved



```
[2025-08-08 14:53:44] [INFO] calcium: Removed 7 outliers from dataset
'20250409_IS07' for column 'Speed (um/s)'
```

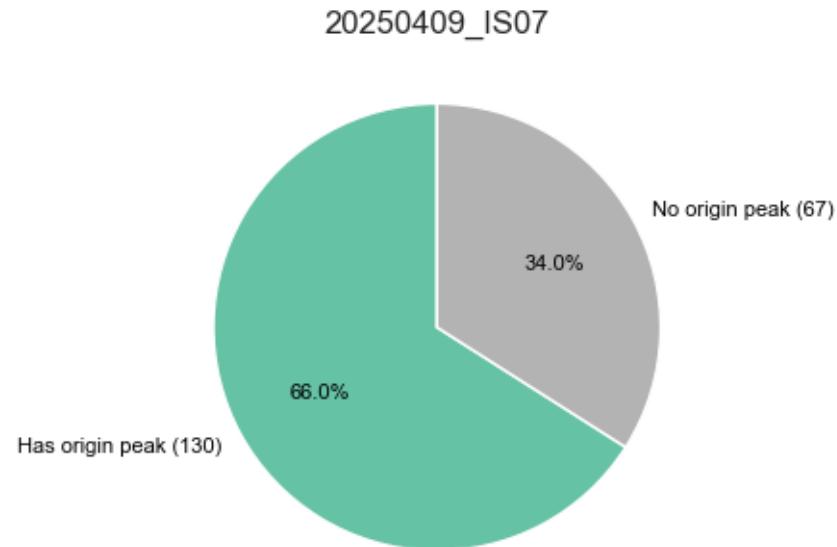
```
[2025-08-08 14:53:44] [INFO] calcium: Lower bound: -8.7, Upper bound: 32.4
```

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

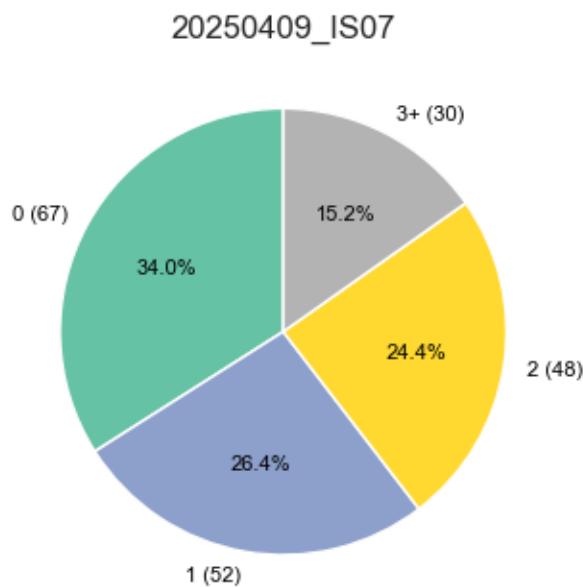


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

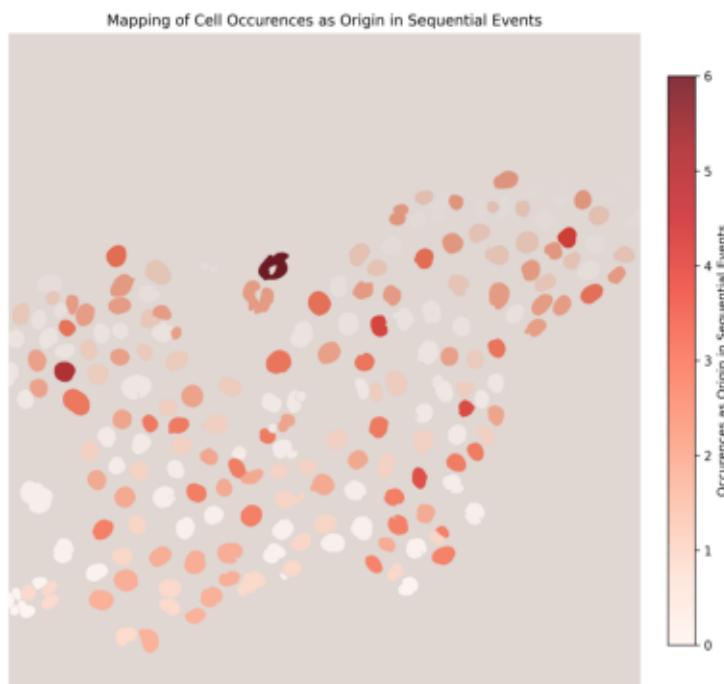


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

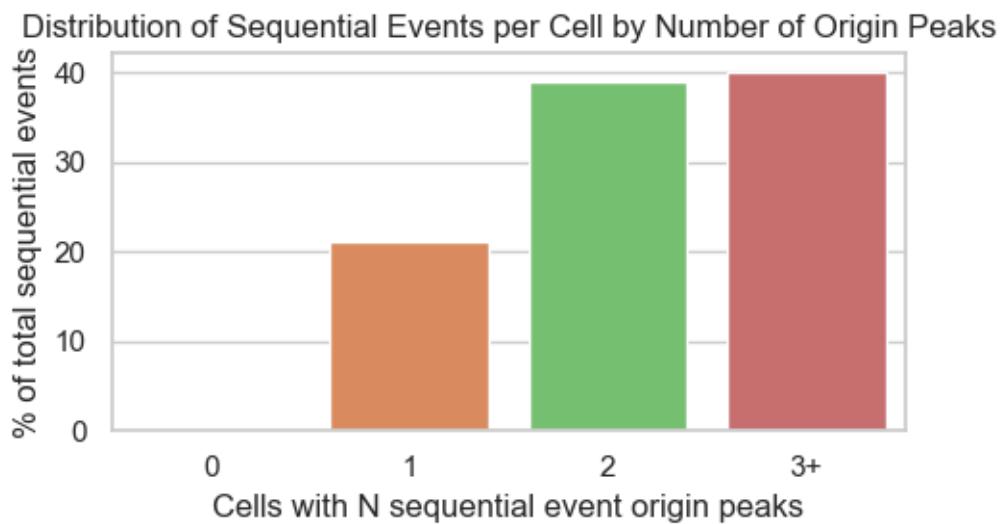
20250409\_IS07



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

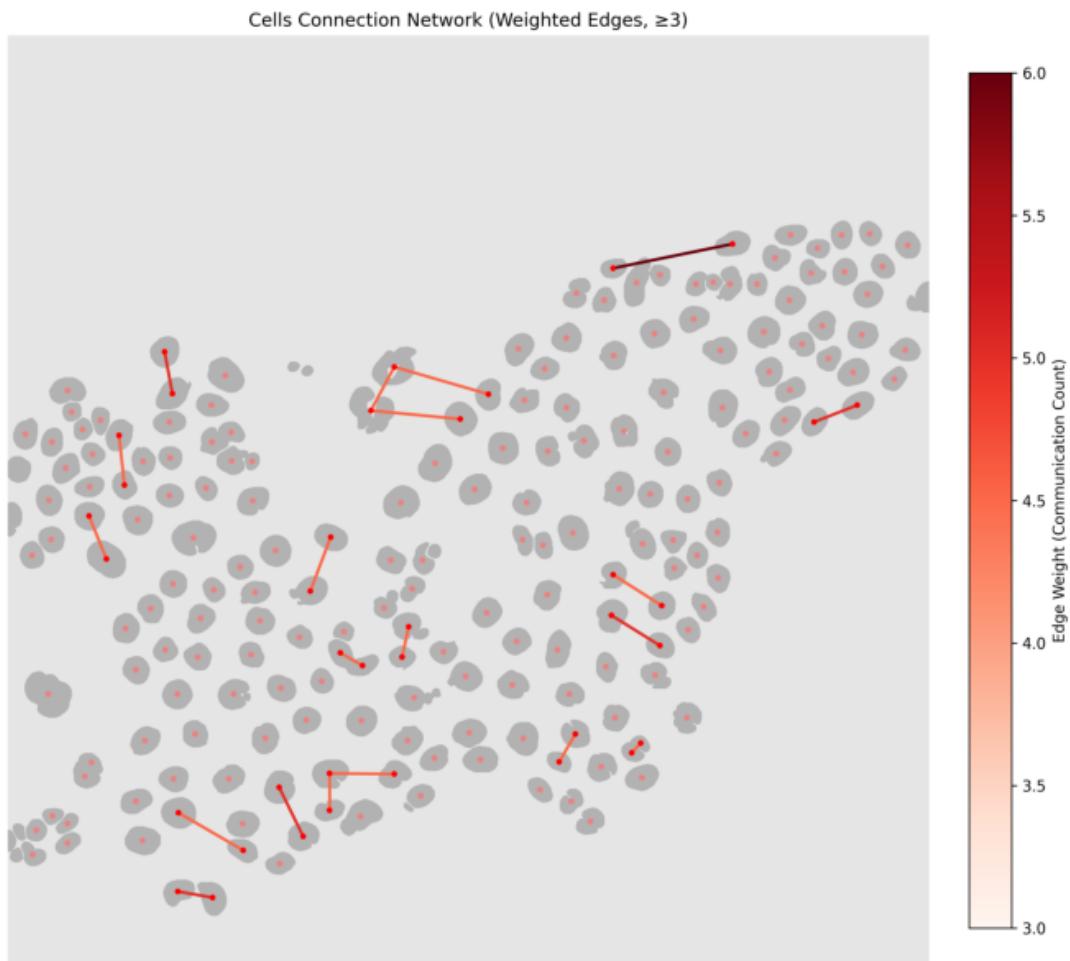
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.3.7 Connection network between cells

Cell Connection Network Graph

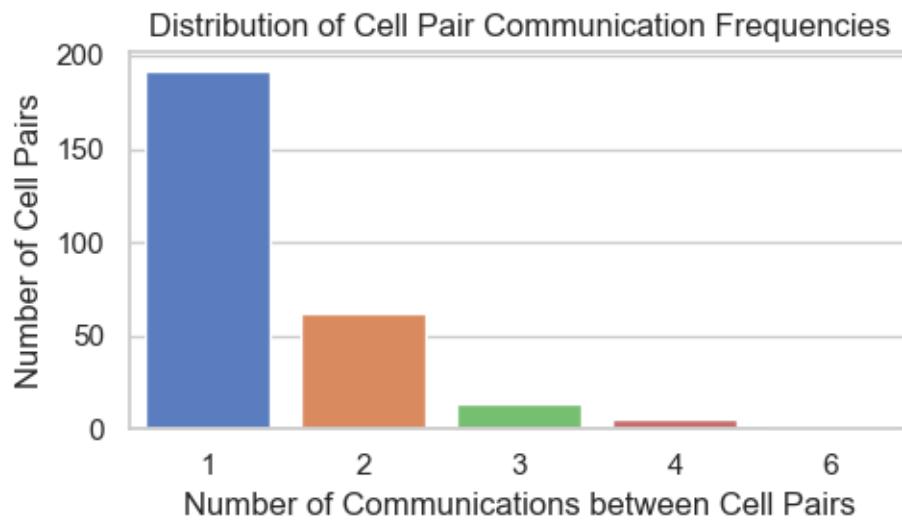
20250409\_IS07



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

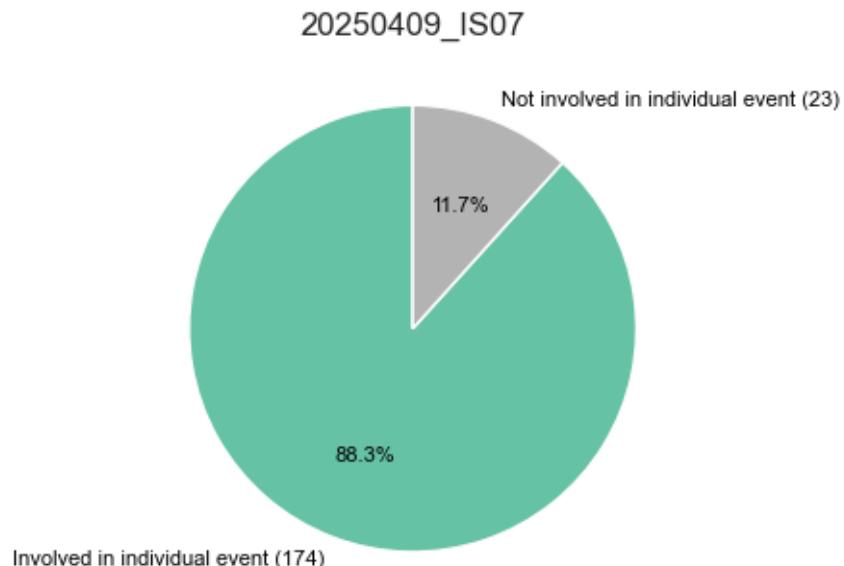
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



## 1.4 INDIVIDUAL EVENTS

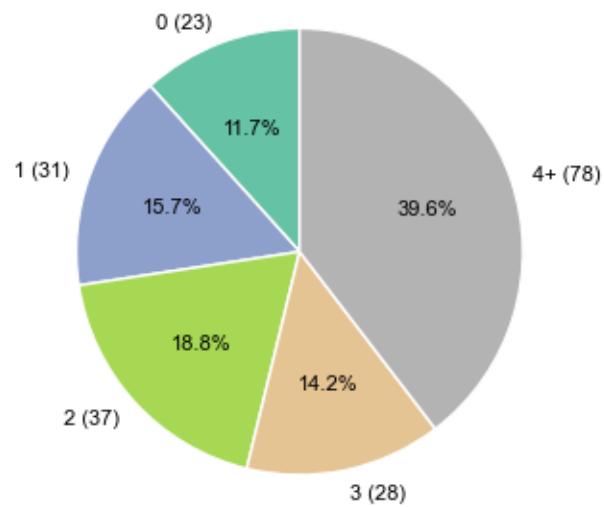
### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events



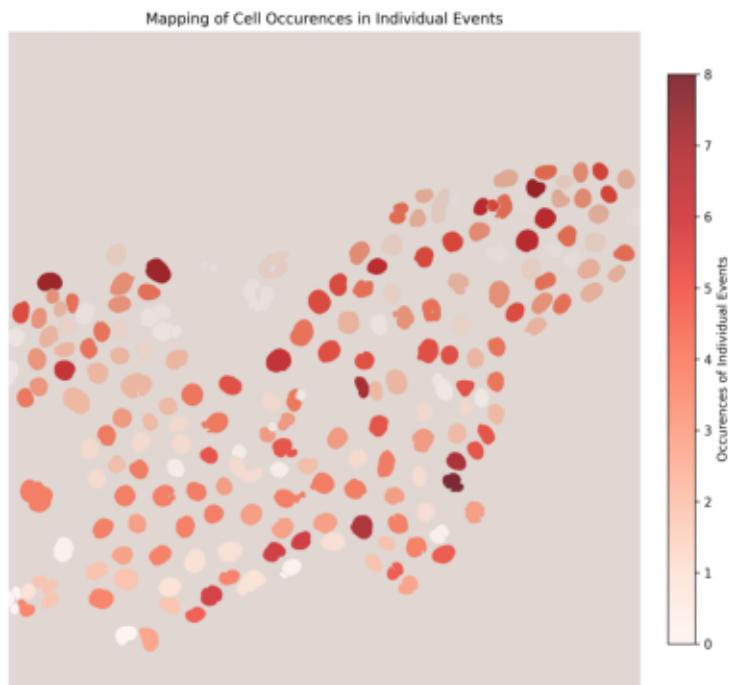
### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)

20250409\_IS07



## Cell Mapping with Occurrences in Individual Events Overlay

20250409\_IS07

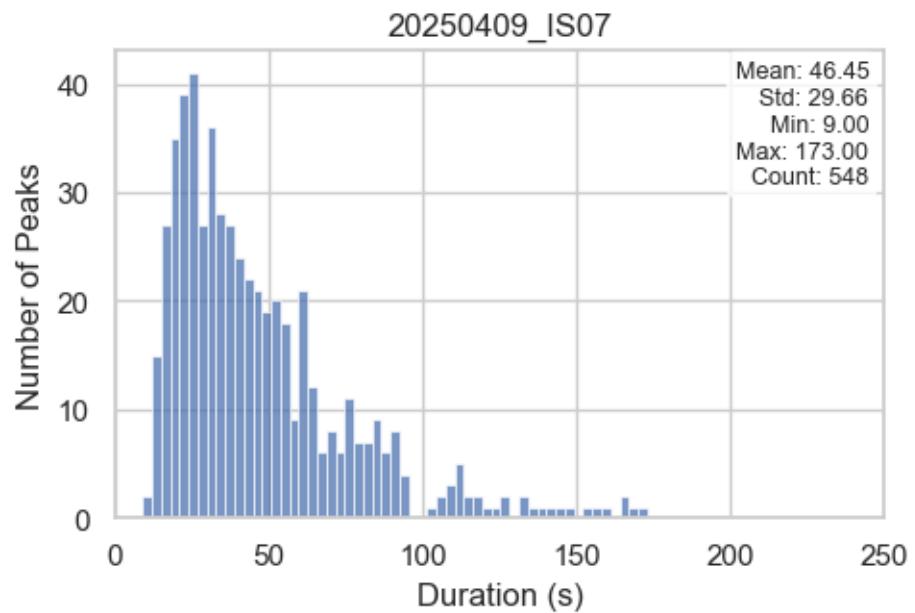


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:53:48] [INFO] calcium: Removed 16 outliers from dataset  
'20250409_IS07' for column 'Duration (s)'
```

```
[2025-08-08 14:53:48] [INFO] calcium: Lower bound: -30.5, Upper bound: 173.0
```

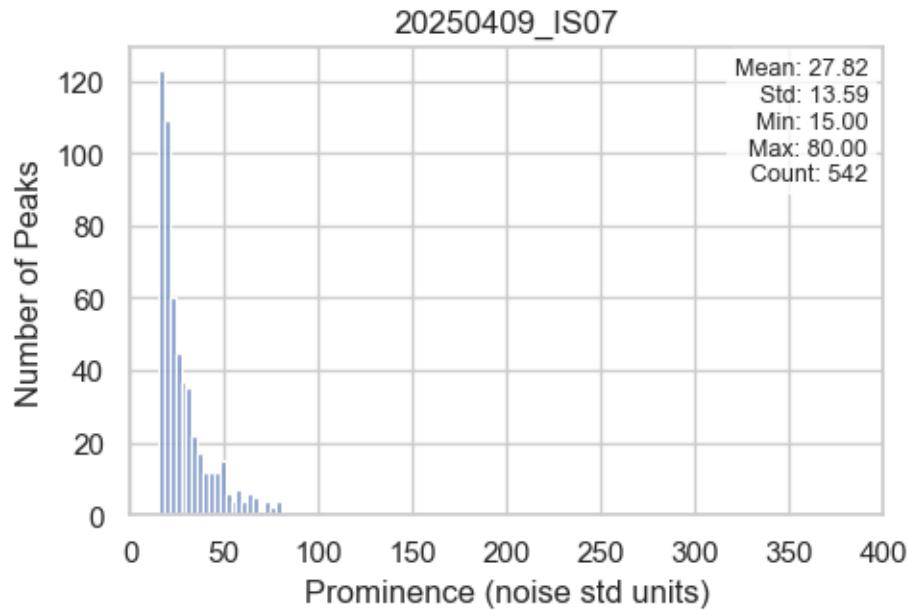
## Distribution of Peak Durations



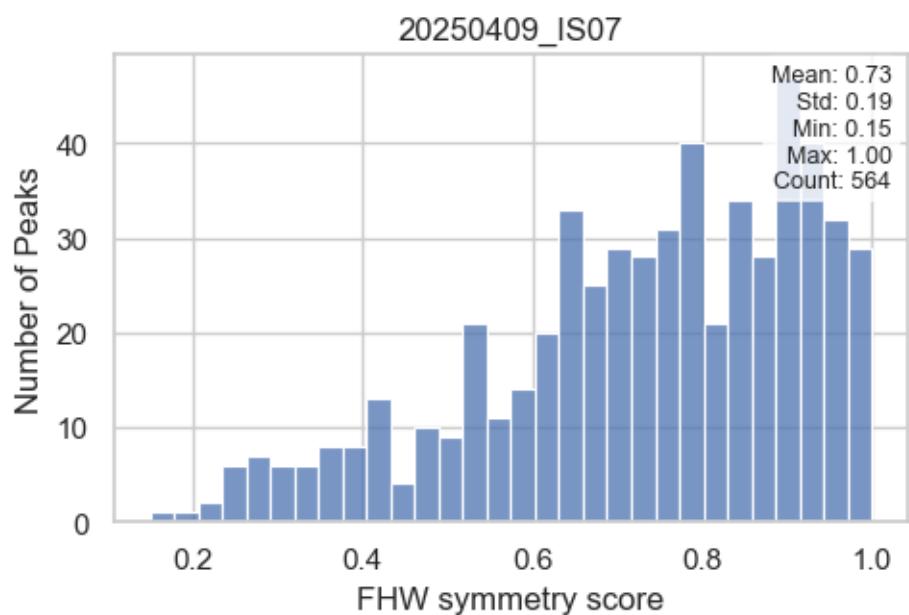
```
[2025-08-08 14:53:48] [INFO] calcium: Removed 22 outliers from dataset  
'20250409_IS07' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:53:48] [INFO] calcium: Lower bound: -5.000000000000036, Upper  
bound: 80.80000000000001
```

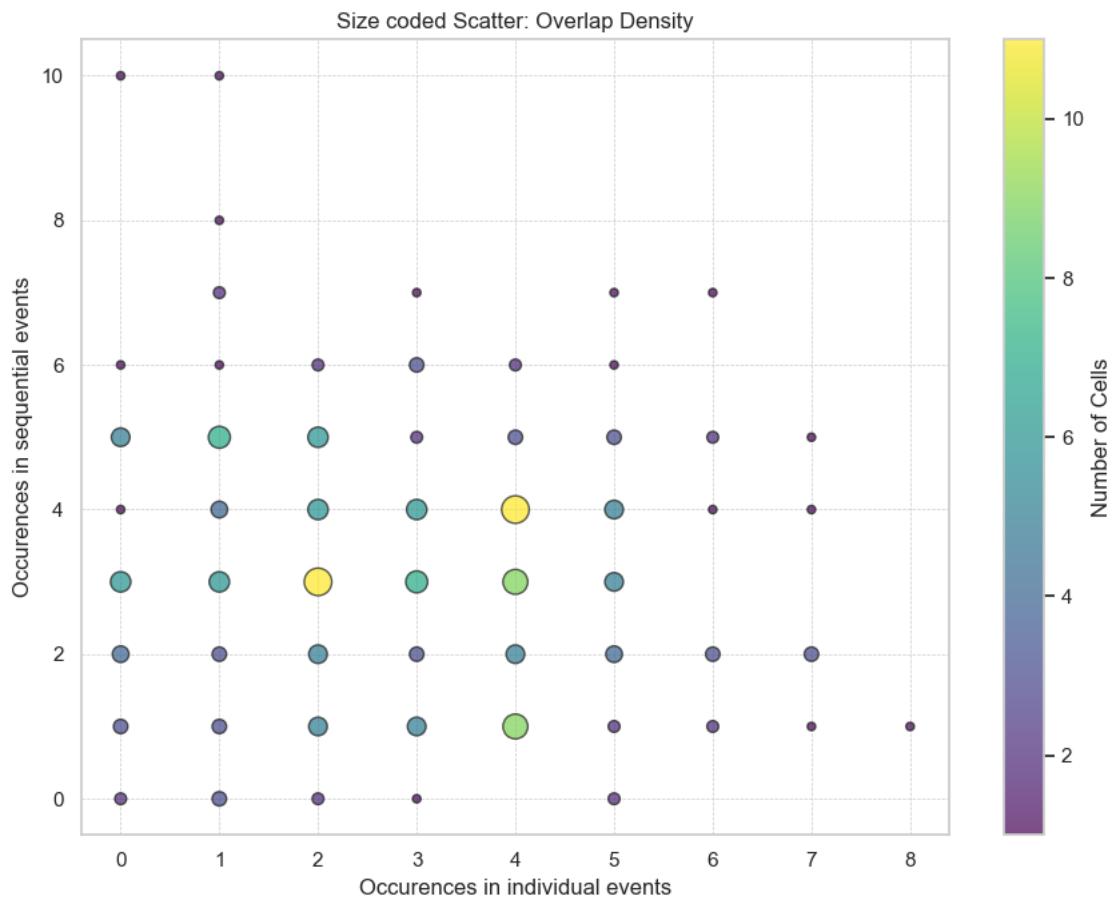
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores



### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 197
- Hoechst image taken at t=1801: 200
- Number of cells difference: absolute 3, relative 1.51%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 333101
- Pixels segmented as cell at t=1801: 378795
- Overlapping pixels between t=0 and t=1801: 317727 (89.26% of total)
- Pixels exclusive to t=0: 15374 (4.61% of total)
- Pixels exclusive to t=1801: 61068 (16.12% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n      "Default Dataset": "/path/to/your/dataset"\n}'
```

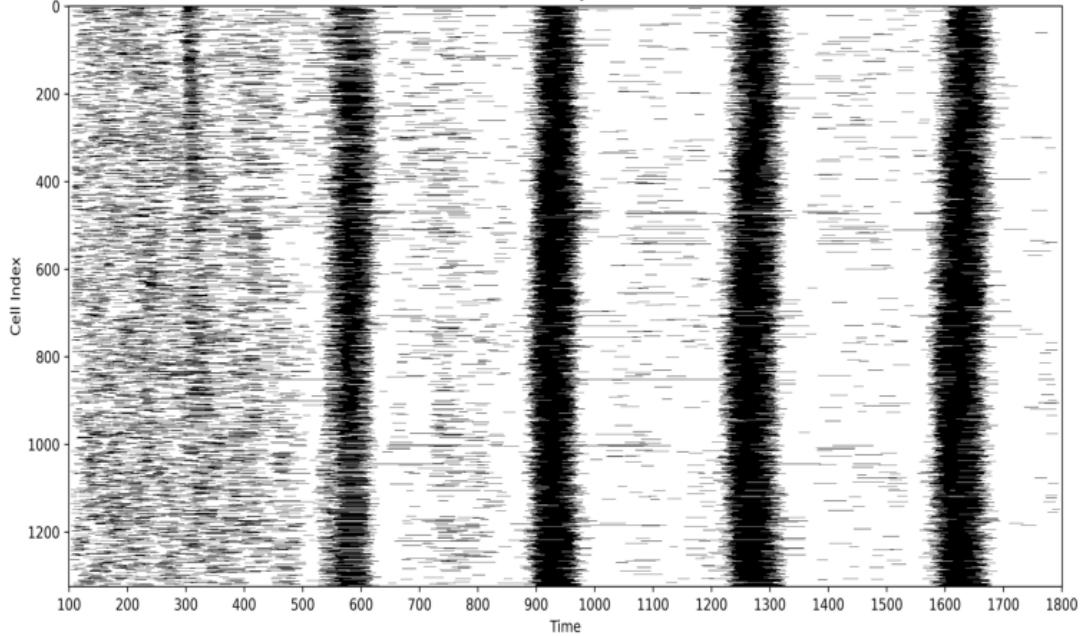
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

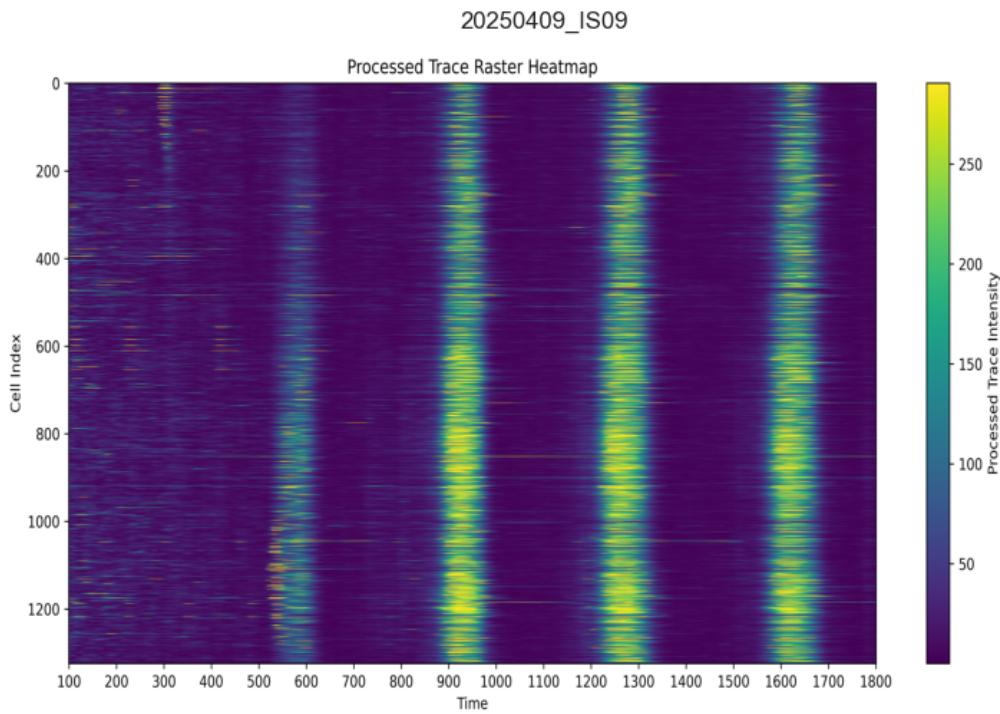
Binary Activity Raster Plot

20250409\_IS09

Binarized Activity Raster Plot



## Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 10638

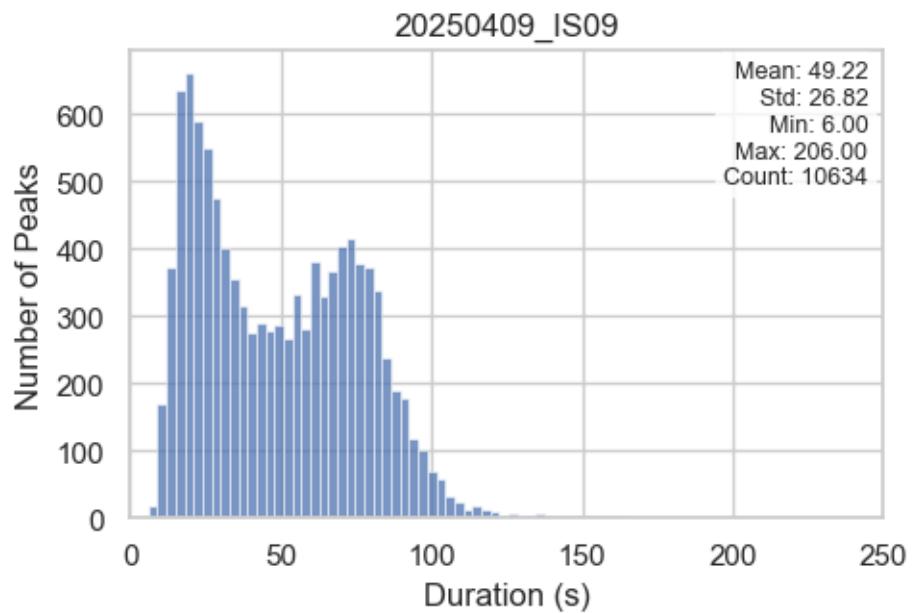
Total number of cells: 1325

### 1.1.3 Peaks statistics

```
[2025-08-08 14:54:38] [INFO] calcium: Removed 4 outliers from dataset  
'20250409_IS09' for column 'Duration (s)'
```

```
[2025-08-08 14:54:38] [INFO] calcium: Lower bound: -44.0, Upper bound: 209.0
```

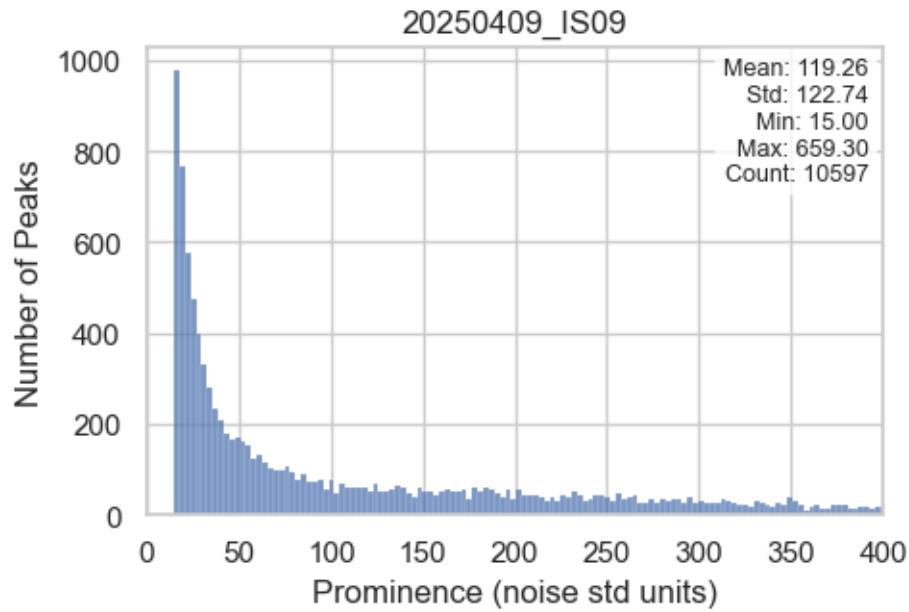
## Distribution of Peak Durations



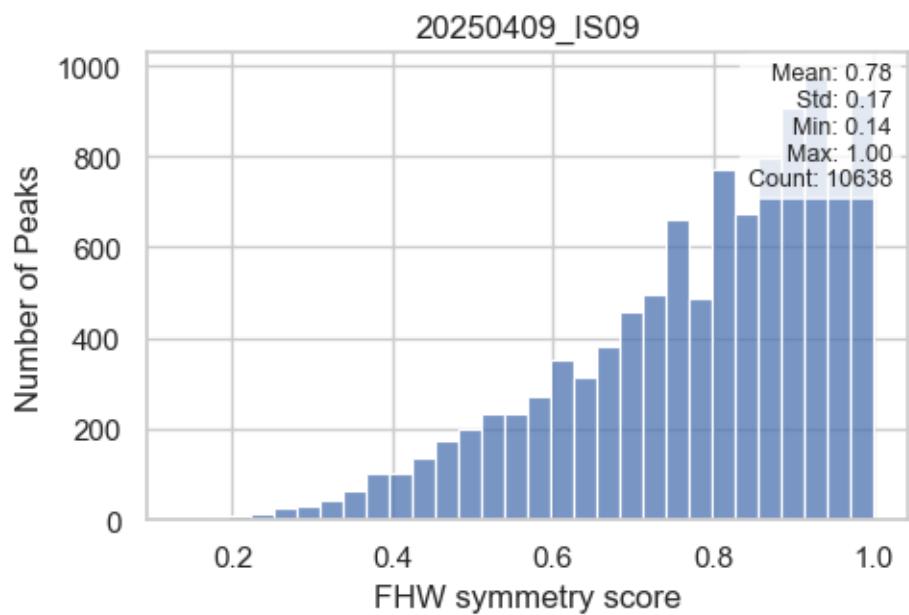
```
[2025-08-08 14:54:38] [INFO] calcium: Removed 41 outliers from dataset  
'20250409_IS09' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:54:38] [INFO] calcium: Lower bound: -211.91250000000002, Upper  
bound: 660.8000000000001
```

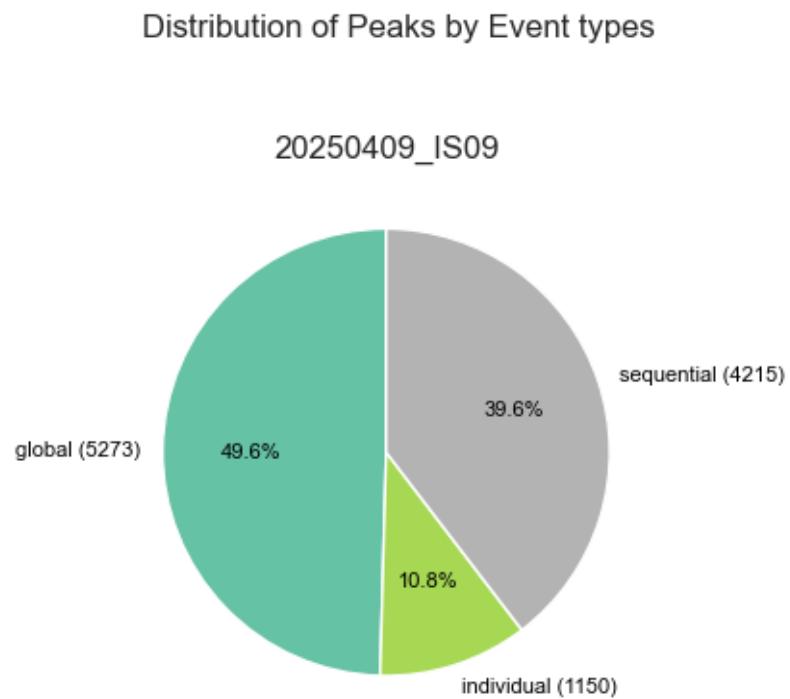
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

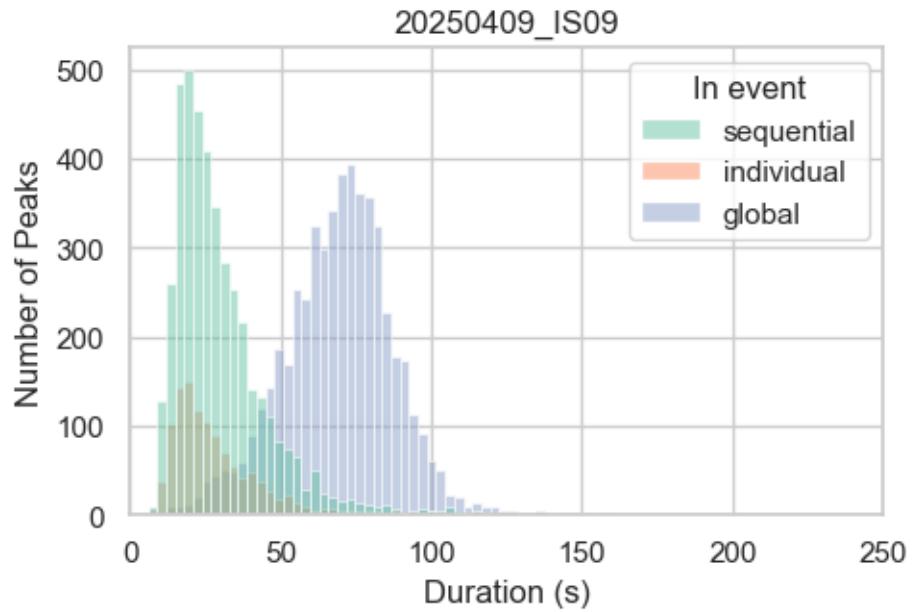


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:54:39] [INFO] calcium: Removed 4 outliers from dataset  
'20250409_IS09' for column 'Duration (s)'
```

```
[2025-08-08 14:54:39] [INFO] calcium: Lower bound: -44.0, Upper bound: 209.0
```

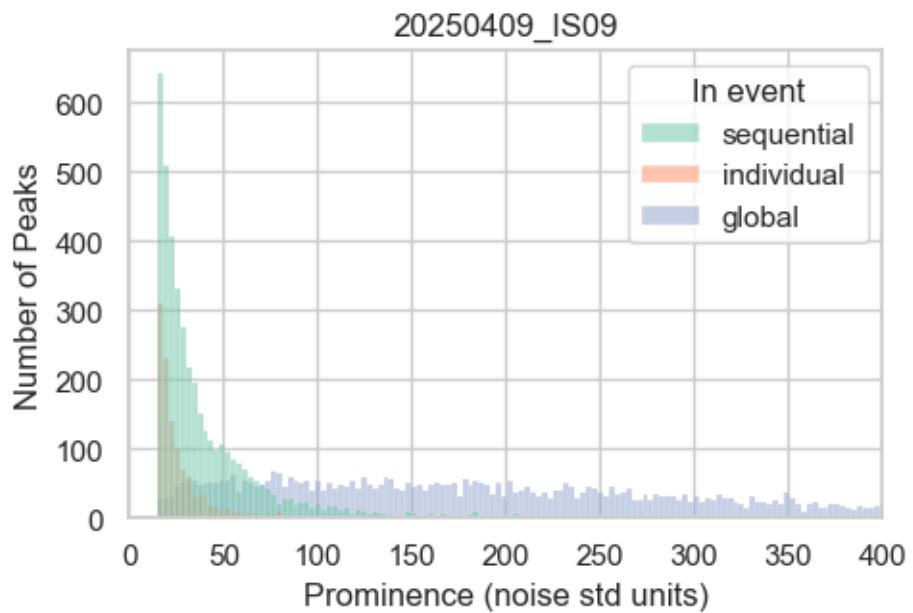
## Distribution of Peak Durations by Group



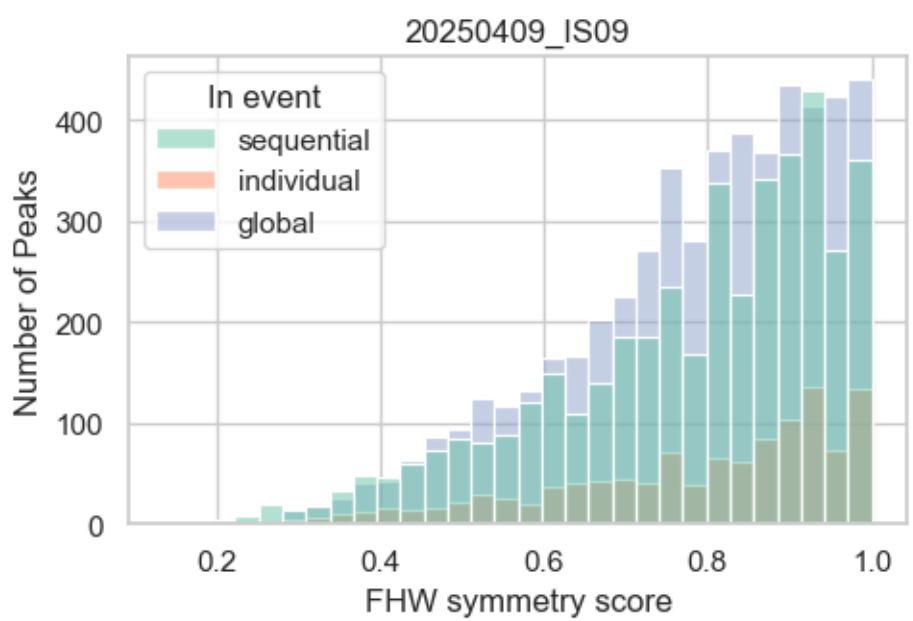
[2025-08-08 14:54:39] [INFO] calcium: Removed 41 outliers from dataset '20250409\_IS09' for column 'Prominence (noise std units)'

[2025-08-08 14:54:39] [INFO] calcium: Lower bound: -211.9, Upper bound: 660.8

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group

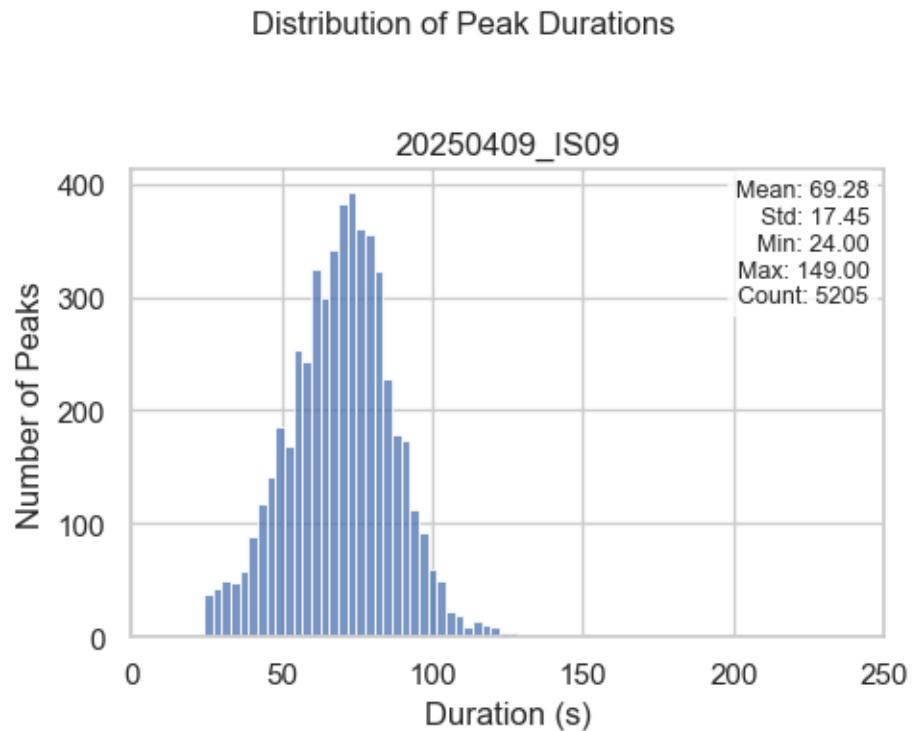


## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:54:40] [INFO] calcium: Removed 68 outliers from dataset  
'20250409_IS09' for column 'Duration (s)'
```

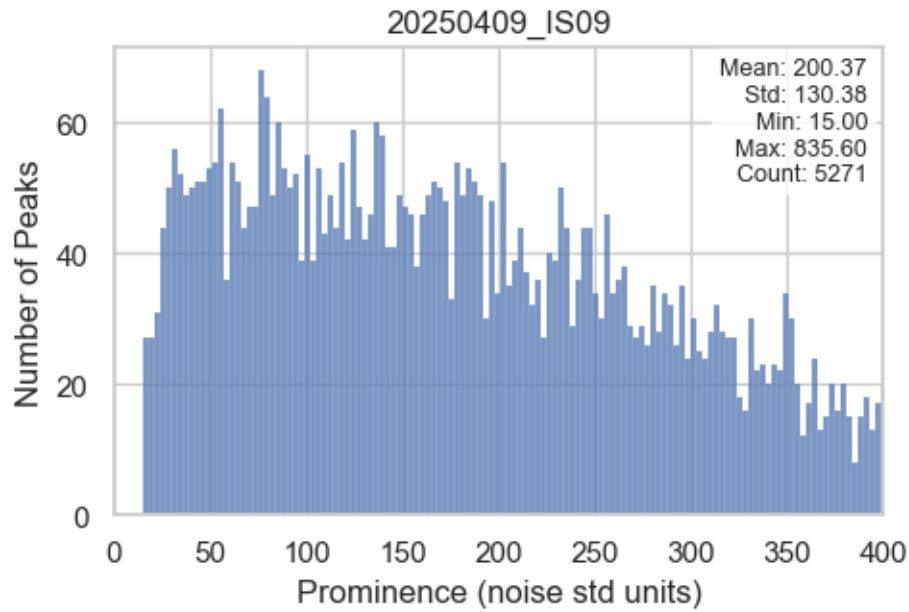
```
[2025-08-08 14:54:40] [INFO] calcium: Lower bound: 23.5, Upper bound: 150.0
```



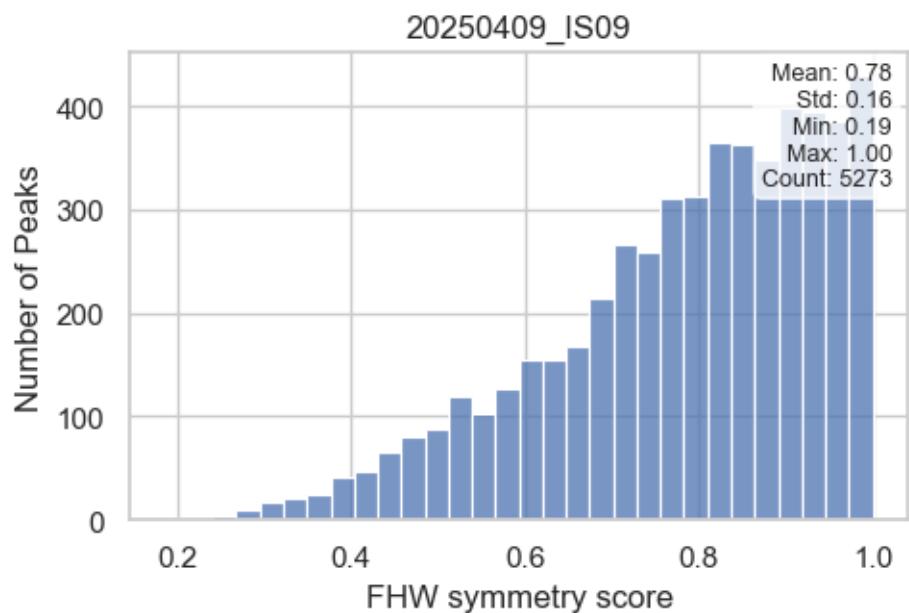
```
[2025-08-08 14:54:40] [INFO] calcium: Removed 2 outliers from dataset  
'20250409_IS09' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:54:40] [INFO] calcium: Lower bound: -182.95, Upper bound: 837.3
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

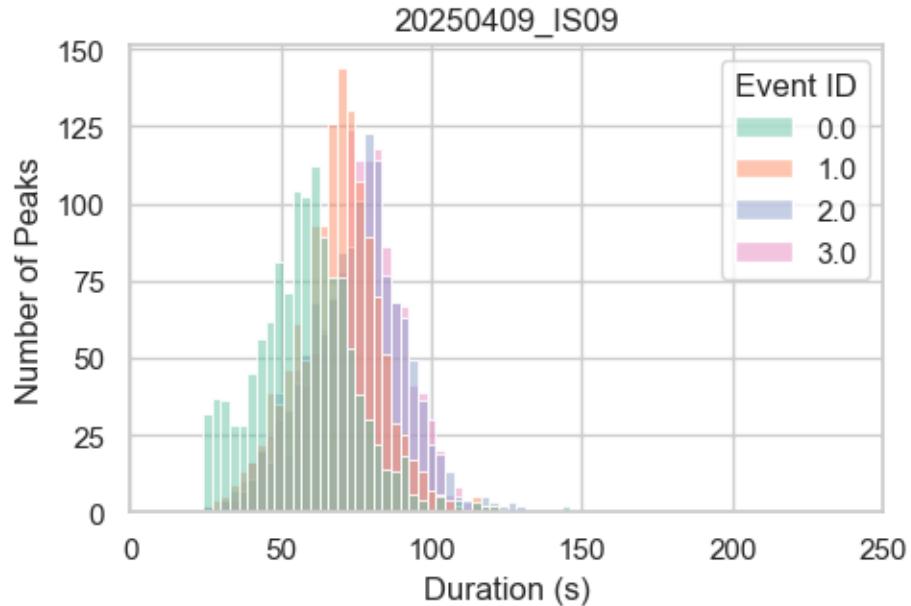


### 1.2.2 Peak statistics in global event per event ID

```
[2025-08-08 14:54:40] [INFO] calcium: Removed 68 outliers from dataset  
'20250409_IS09' for column 'Duration (s)'
```

```
[2025-08-08 14:54:40] [INFO] calcium: Lower bound: 23.5, Upper bound: 150.0
```

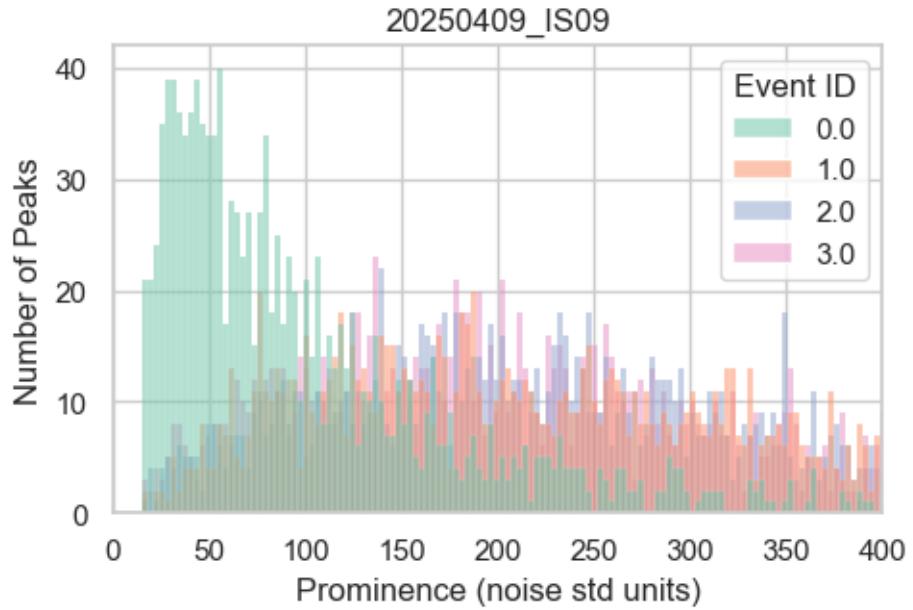
Distribution of Peak Durations by Group



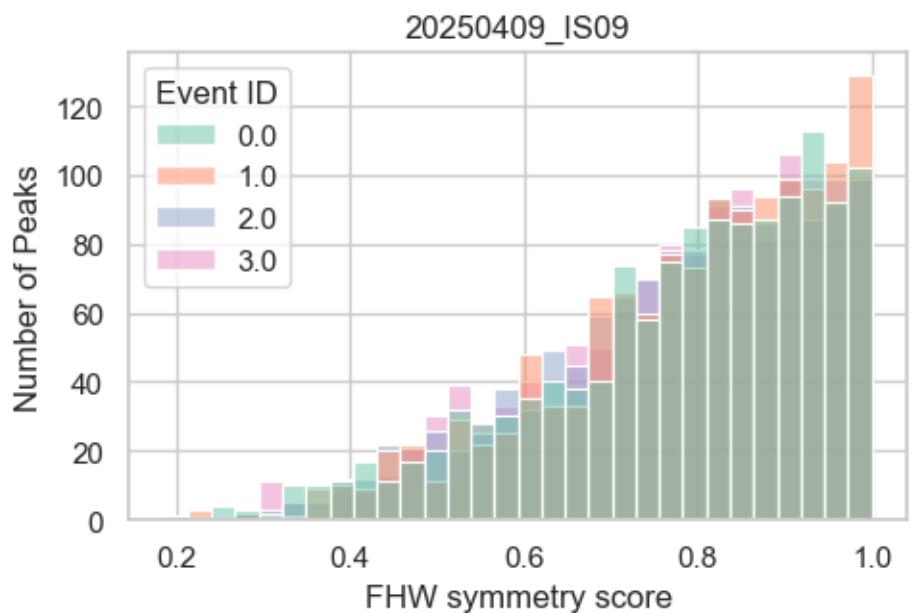
```
[2025-08-08 14:54:41] [INFO] calcium: Removed 2 outliers from dataset  
'20250409_IS09' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:54:41] [INFO] calcium: Lower bound: -182.9, Upper bound: 837.3
```

### Distribution of Peak Prominences by Group



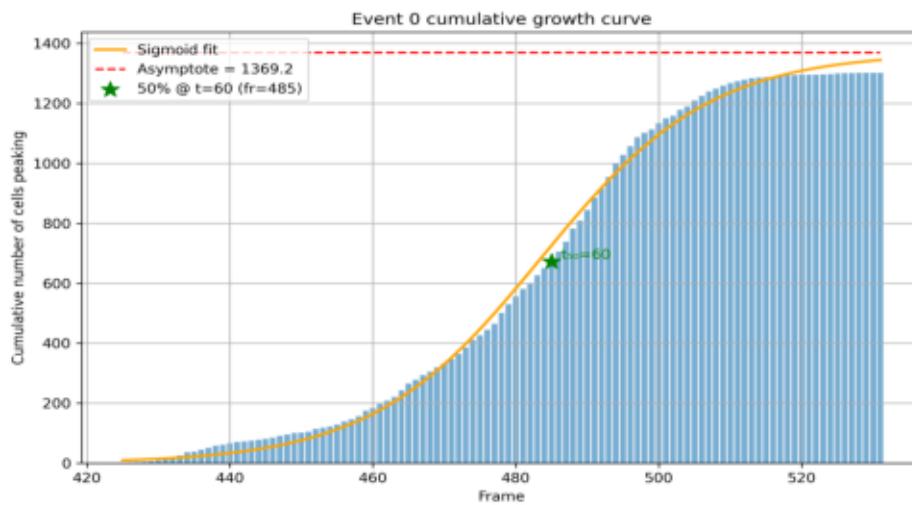
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

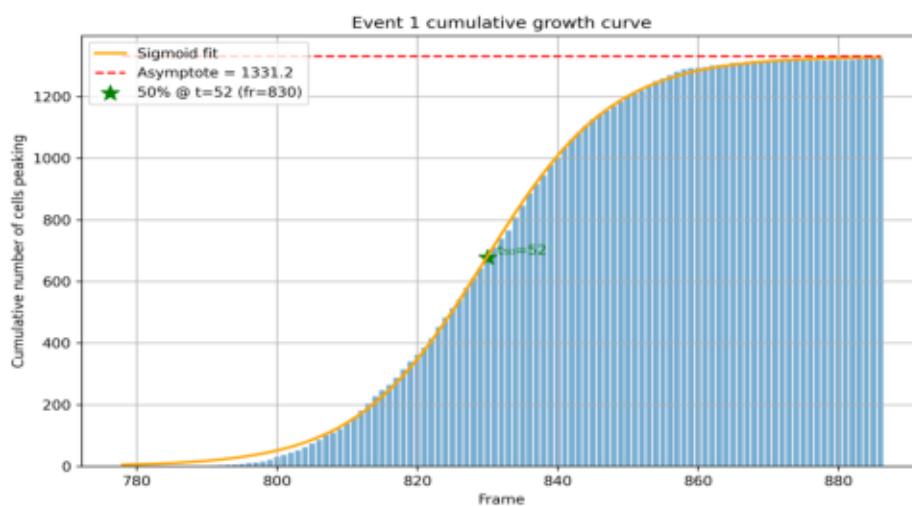
Event Activity Overlay (Event ID: 0)

20250409\_IS09



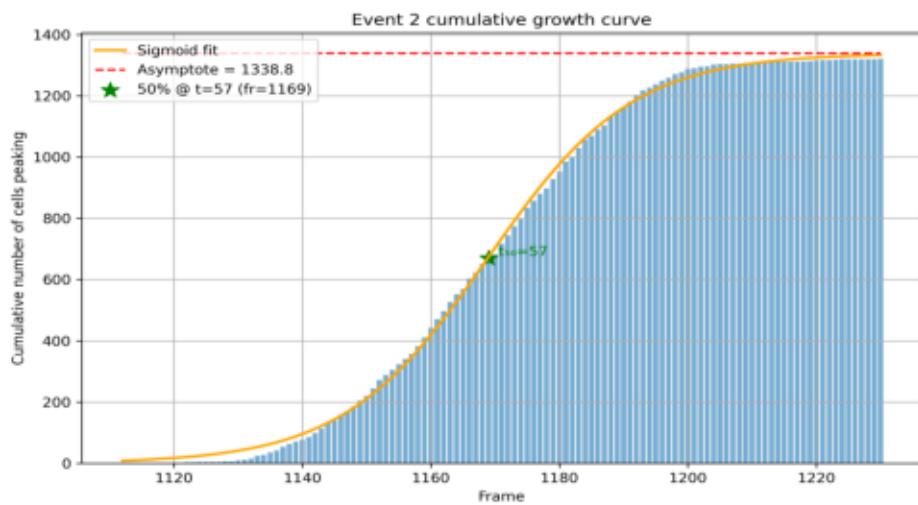
Event Activity Overlay (Event ID: 1)

20250409\_IS09



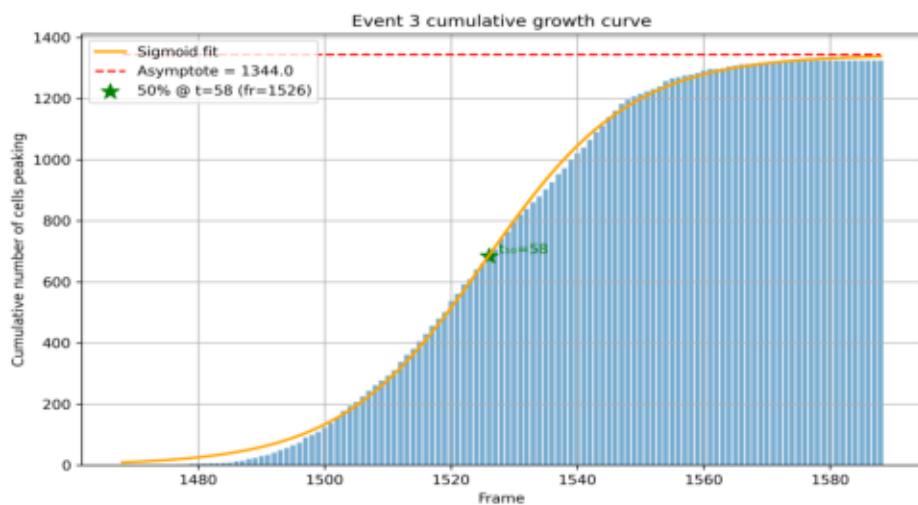
## Event Activity Overlay (Event ID: 2)

20250409\_IS09



## Event Activity Overlay (Event ID: 3)

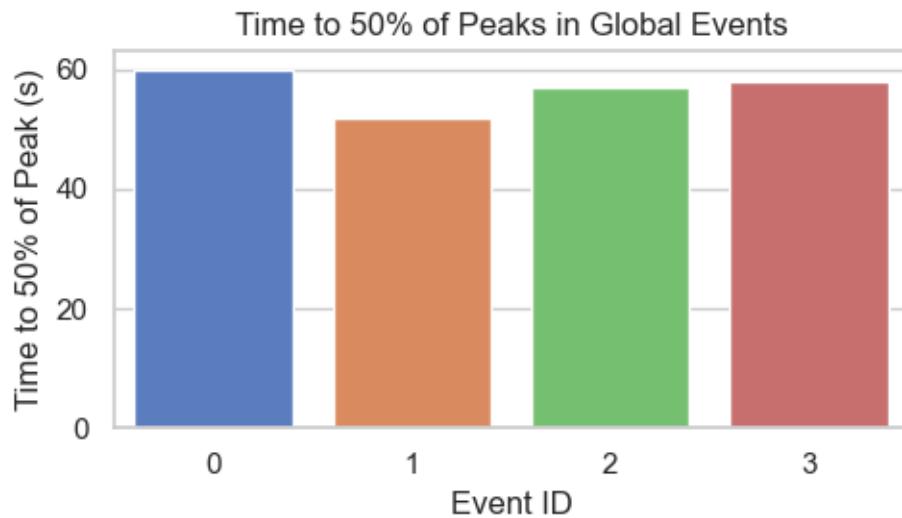
20250409\_IS09



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

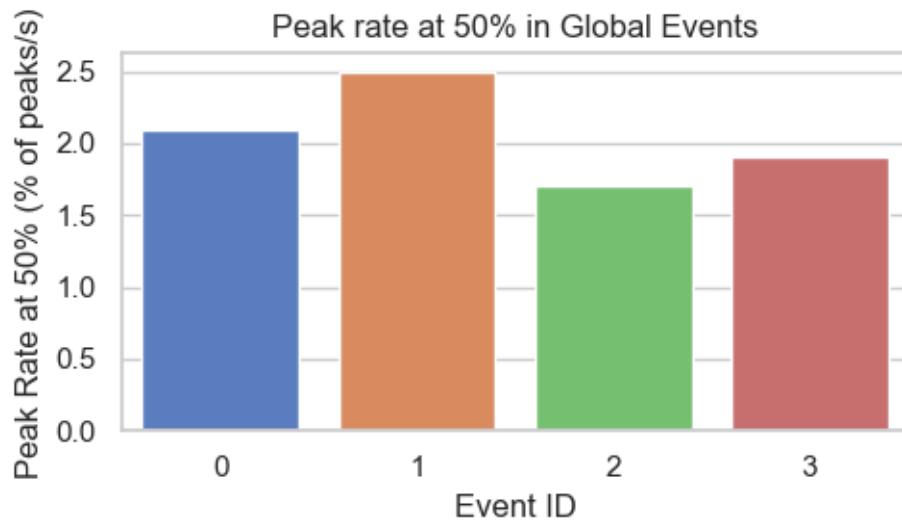
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

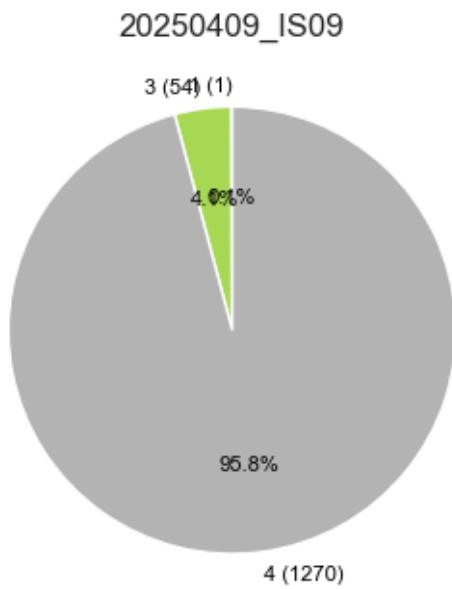
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



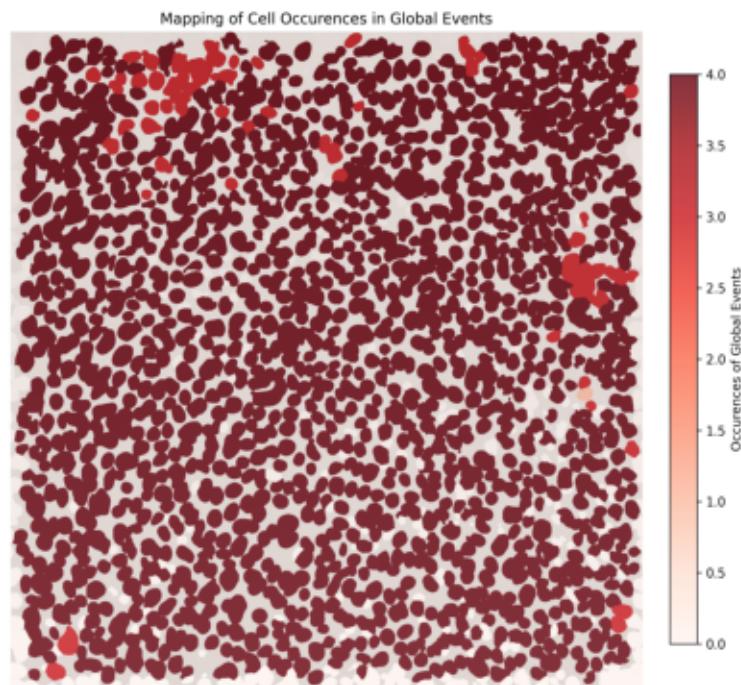
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

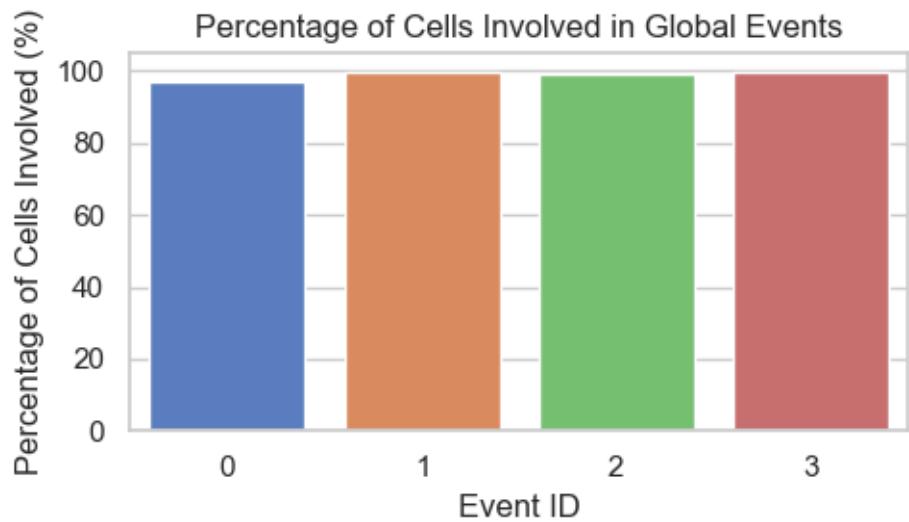
20250409\_IS09



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [348.0, 342.0, 357.0]

Estimated periodicity: 0.983

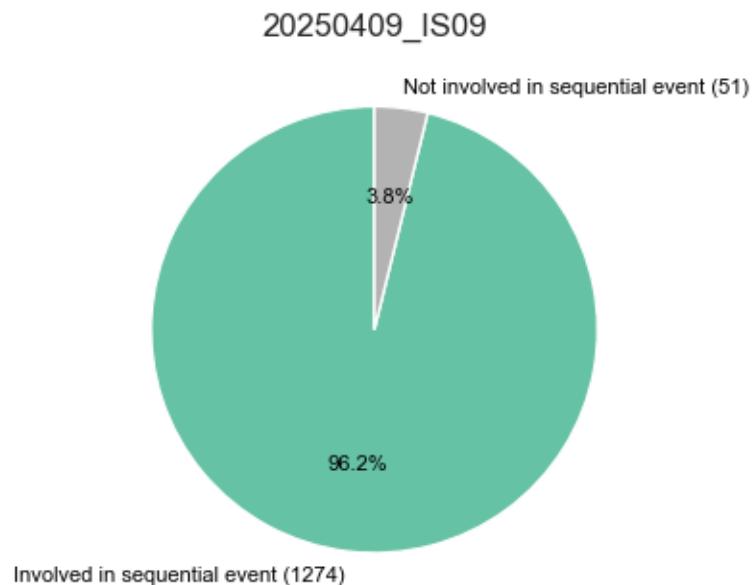
The global events exhibit a regular periodic pattern.

Estimated frequency (1/mean interval): 0.003 Hz

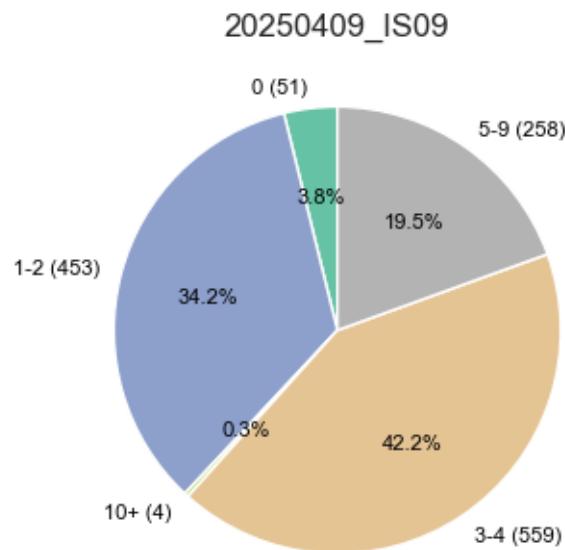
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

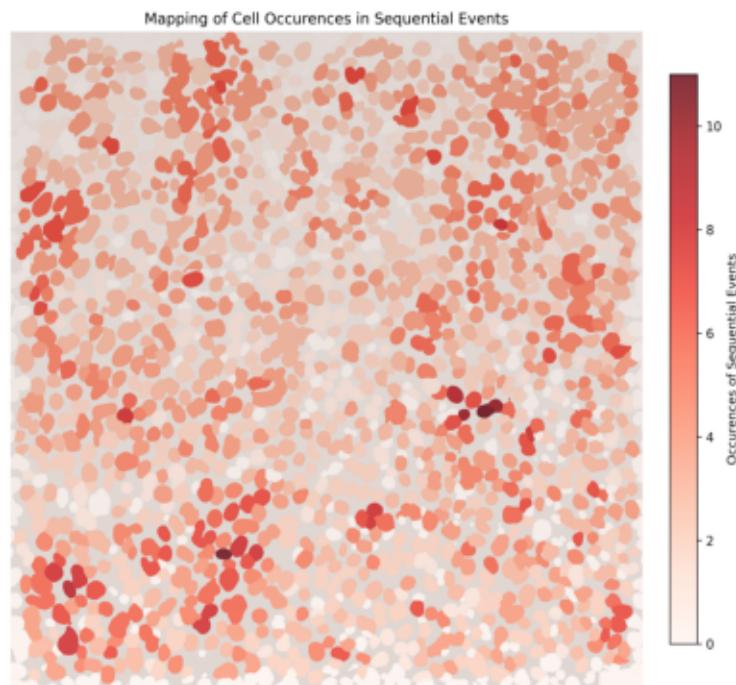


### Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250409\_IS09

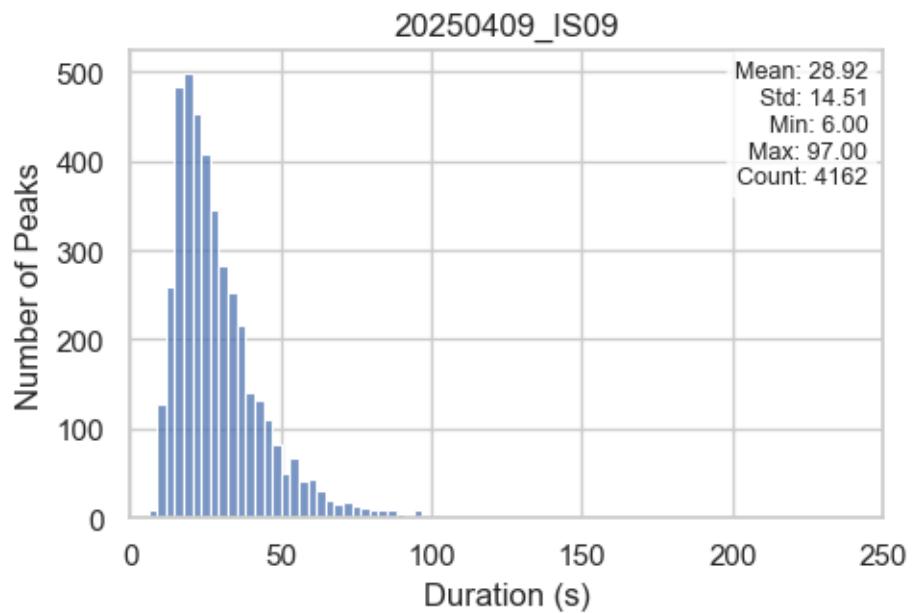


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:54:47] [INFO] calcium: Removed 53 outliers from dataset  
'20250409_IS09' for column 'Duration (s)'
```

```
[2025-08-08 14:54:47] [INFO] calcium: Lower bound: -9.0, Upper bound: 99.0
```

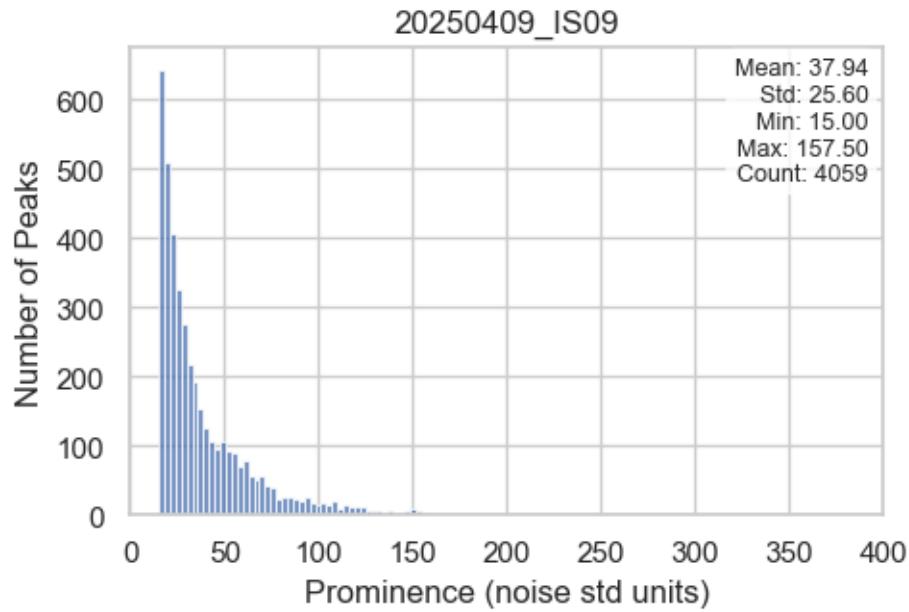
## Distribution of Peak Durations



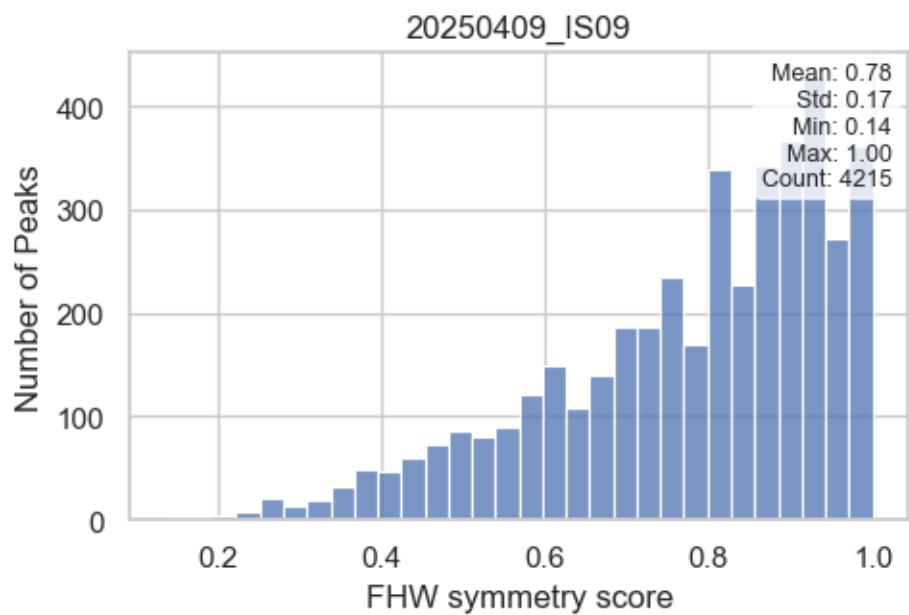
[2025-08-08 14:54:47] [INFO] calcium: Removed 156 outliers from dataset '20250409\_IS09' for column 'Prominence (noise std units)'

[2025-08-08 14:54:47] [INFO] calcium: Lower bound: -25.44999999999992, Upper bound: 157.5499999999998

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

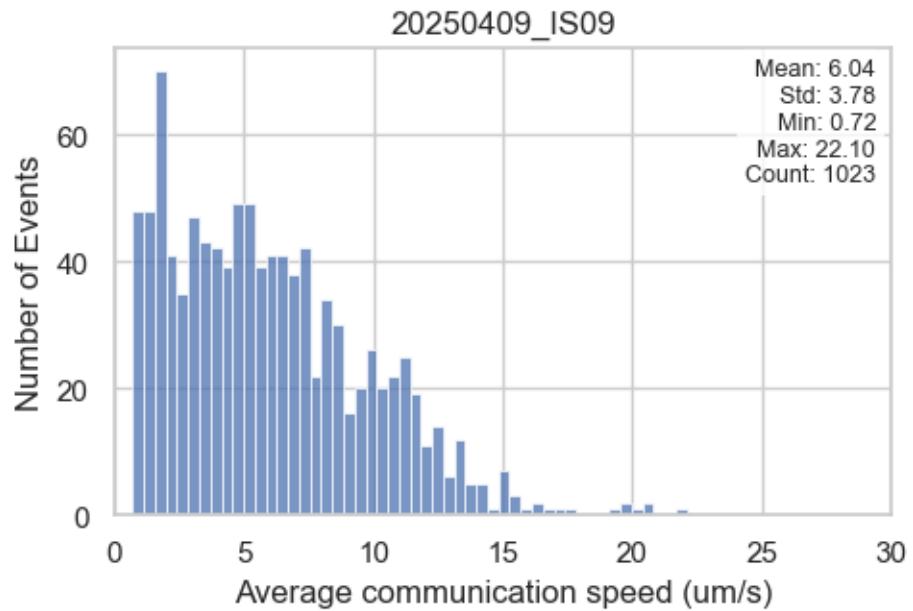


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:54:47] [INFO] calcium: Removed 0 outliers from dataset '20250409\_IS09' for column 'Average communication speed (um/s)'

[2025-08-08 14:54:47] [INFO] calcium: Lower bound: -5.152500000000002, Upper bound: 24.630000000000006

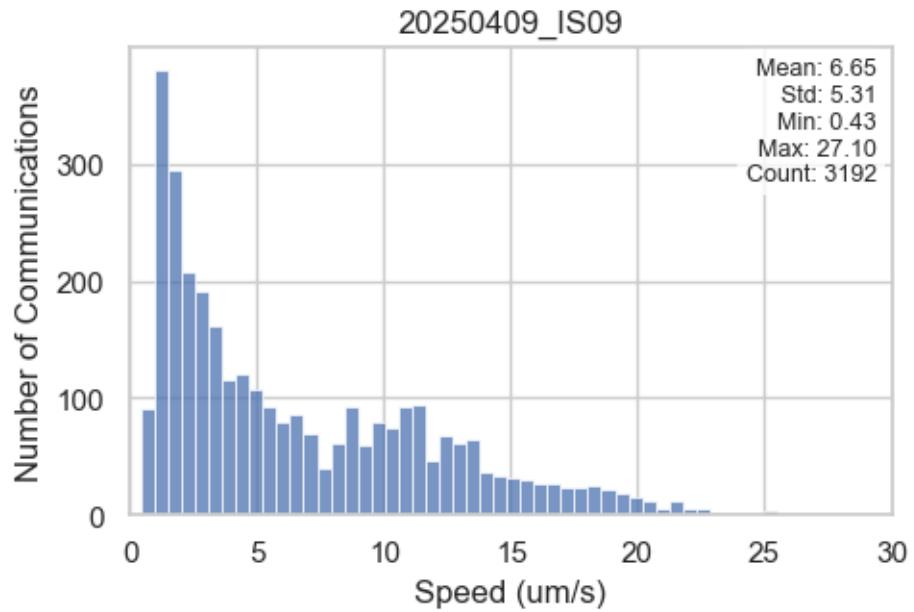
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:54:47] [INFO] calcium: Removed 0 outliers from dataset '20250409\_IS09' for column 'Speed (um/s)'

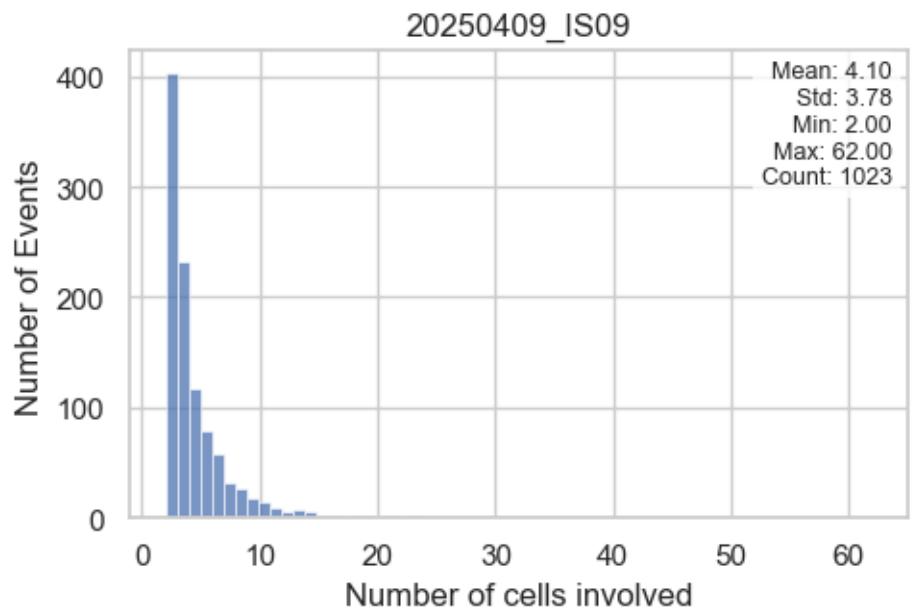
[2025-08-08 14:54:47] [INFO] calcium: Lower bound: -10.47375, Upper bound: 35.63

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

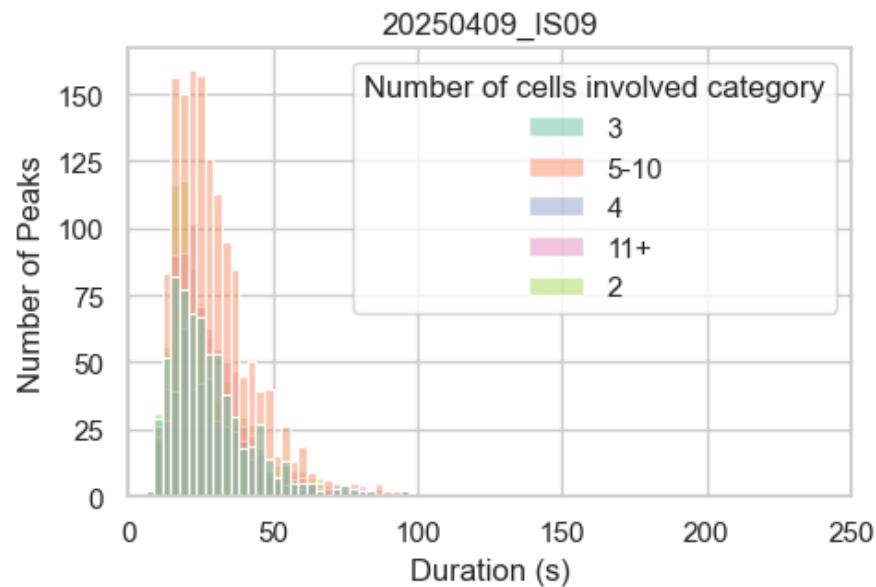


### 1.3.5 Influence of cell count per event on statistics

```
[2025-08-08 14:54:48] [INFO] calcium: Removed 53 outliers from dataset  
'20250409_IS09' for column 'Duration (s)'
```

```
[2025-08-08 14:54:48] [INFO] calcium: Lower bound: -9.0, Upper bound: 99.0
```

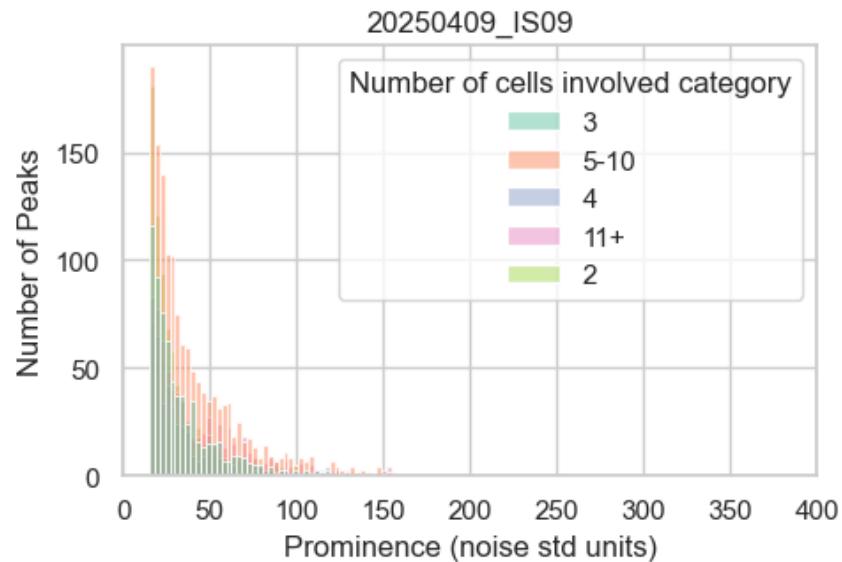
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



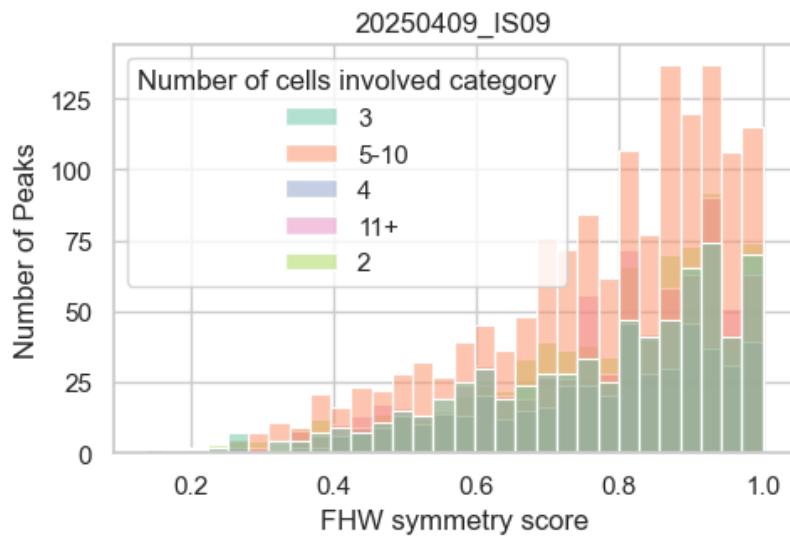
```
[2025-08-08 14:54:48] [INFO] calcium: Removed 156 outliers from dataset  
'20250409_IS09' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:54:48] [INFO] calcium: Lower bound: -25.4, Upper bound: 157.5
```

## Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



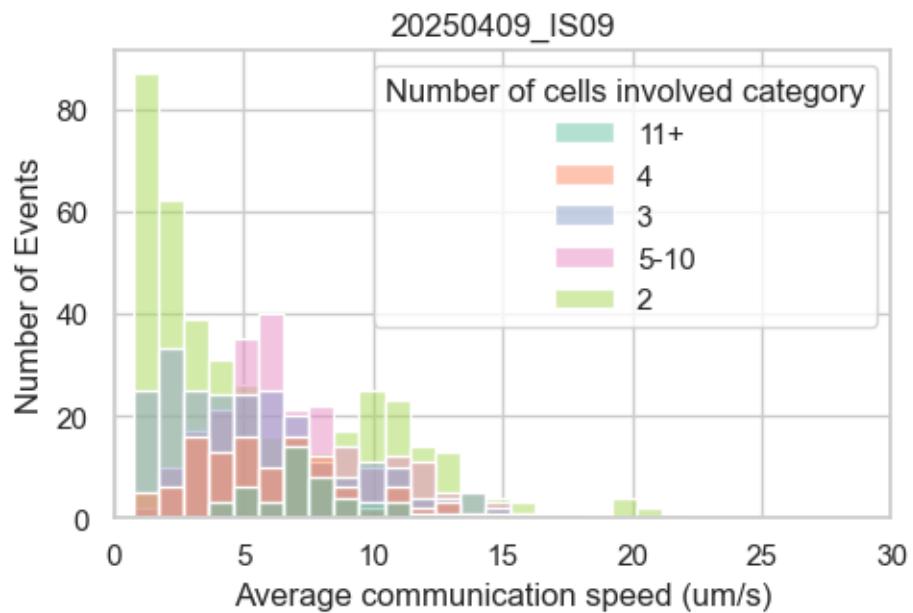
## Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 14:54:49] [INFO] calcium: Removed 0 outliers from dataset
'20250409_IS09' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 14:54:49] [INFO] calcium: Lower bound: -5.2, Upper bound: 24.6
```

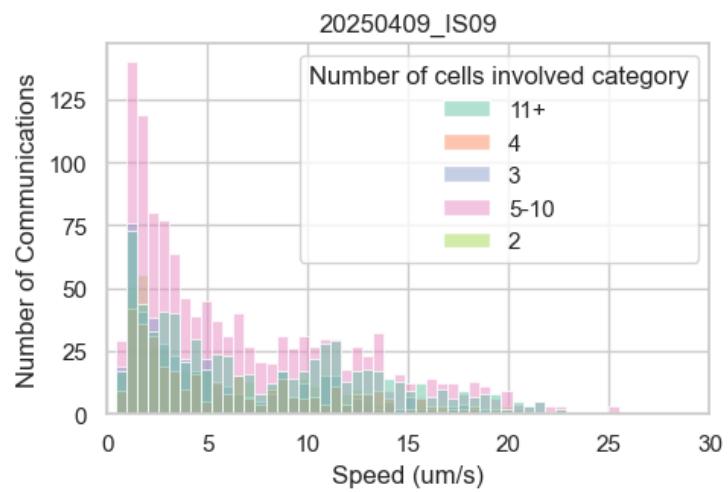
## Distribution of Average Communication Speeds by Number of Cells Involved



```
[2025-08-08 14:54:49] [INFO] calcium: Removed 0 outliers from dataset
'20250409_IS09' for column 'Speed (um/s)'
```

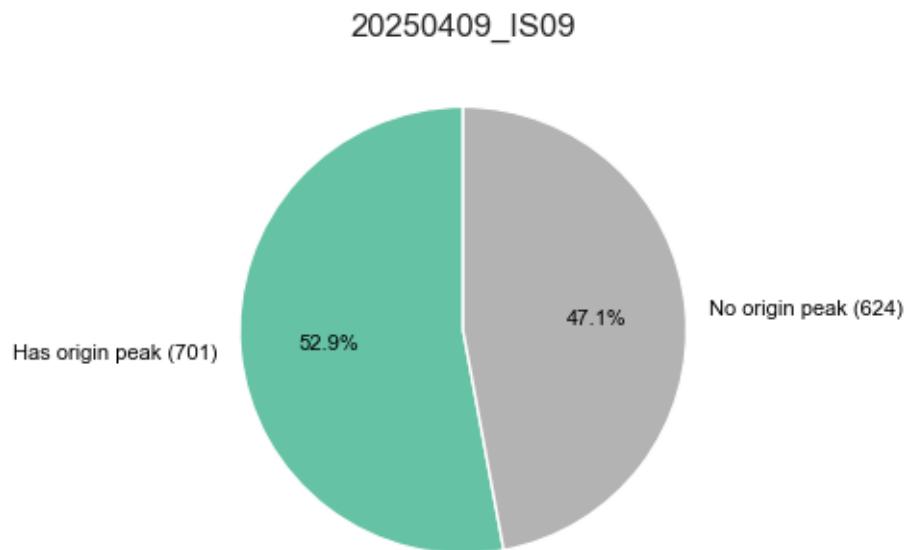
```
[2025-08-08 14:54:49] [INFO] calcium: Lower bound: -10.5, Upper bound: 35.6
```

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

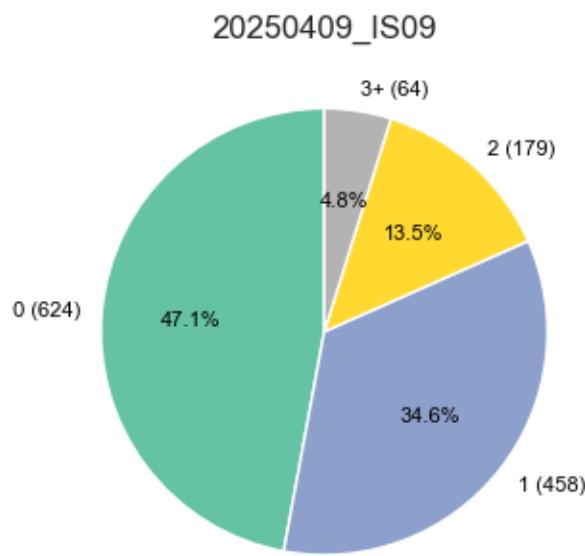


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

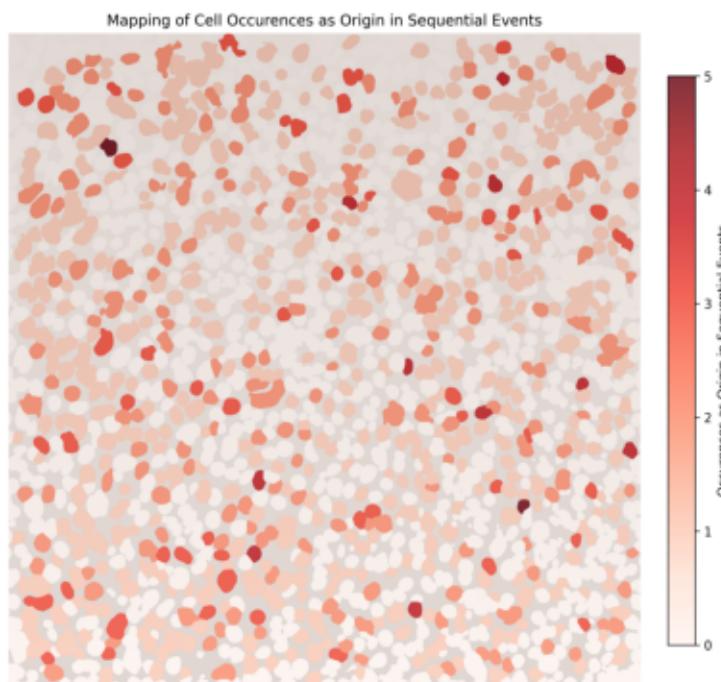


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

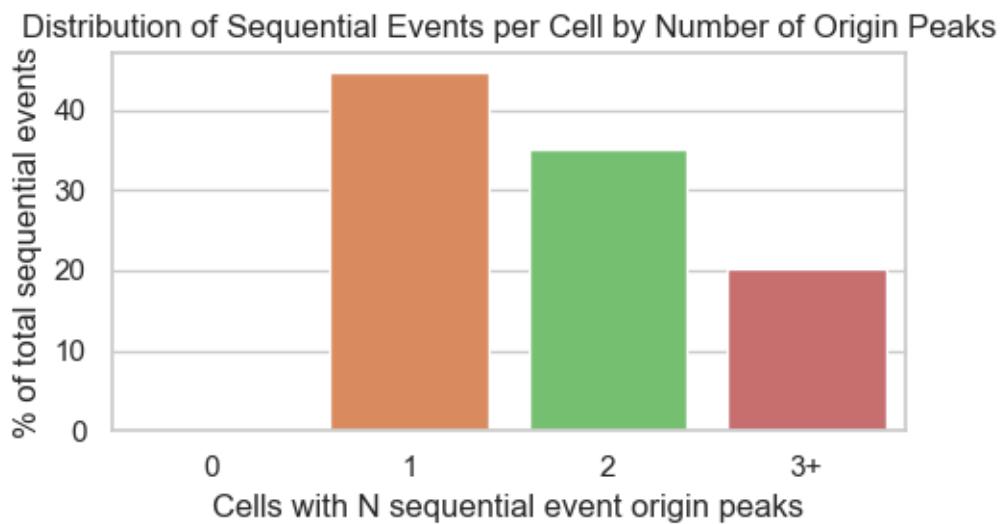
20250409\_IS09



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

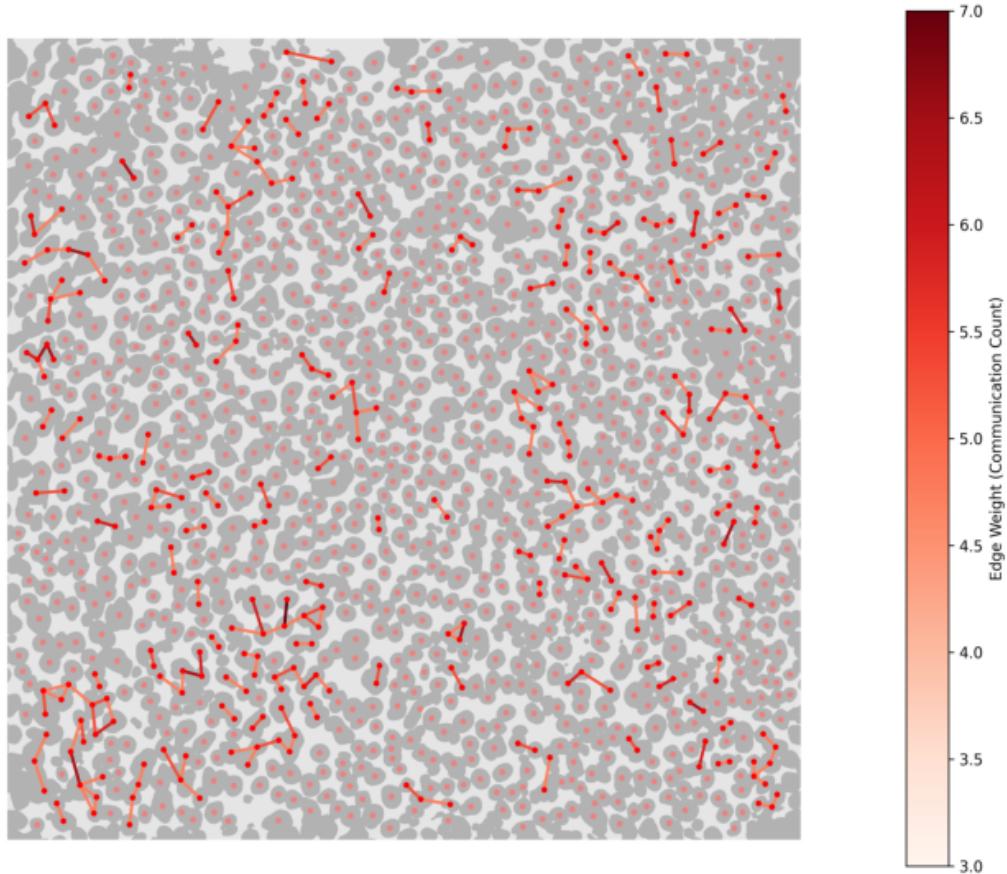


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250409\_IS09

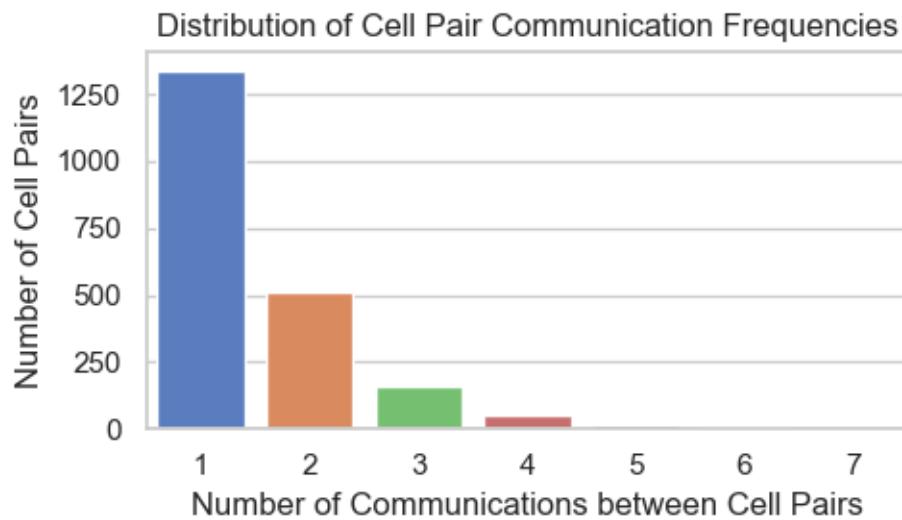
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

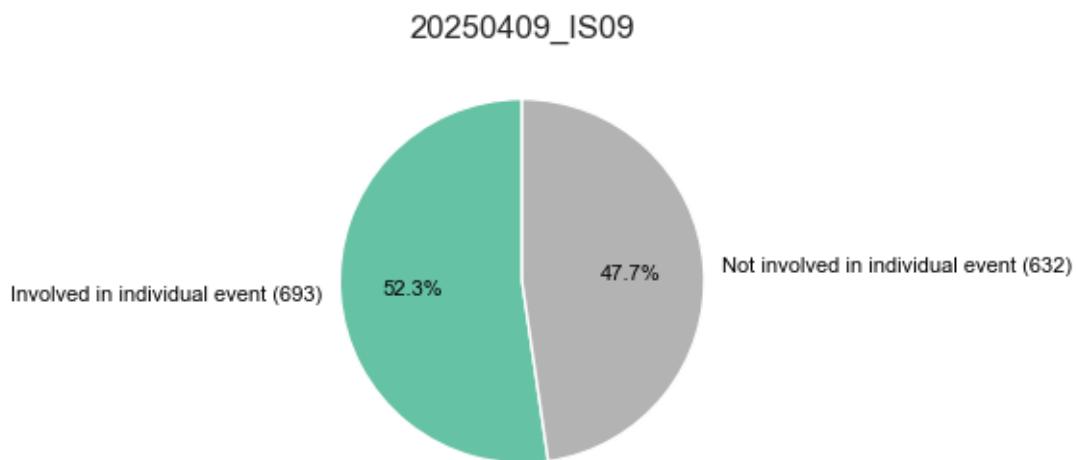
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



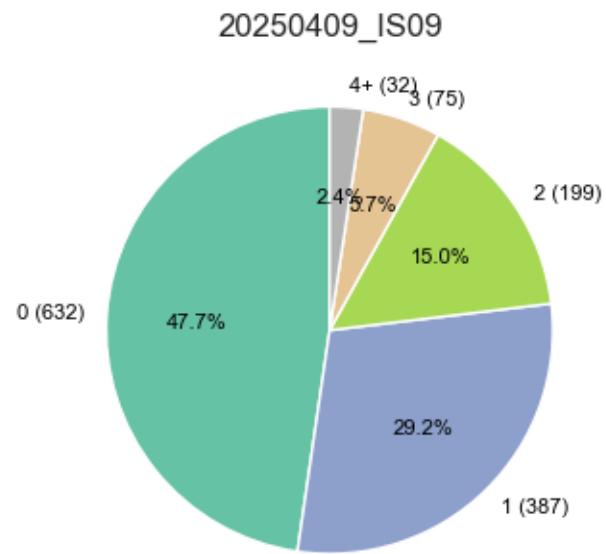
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

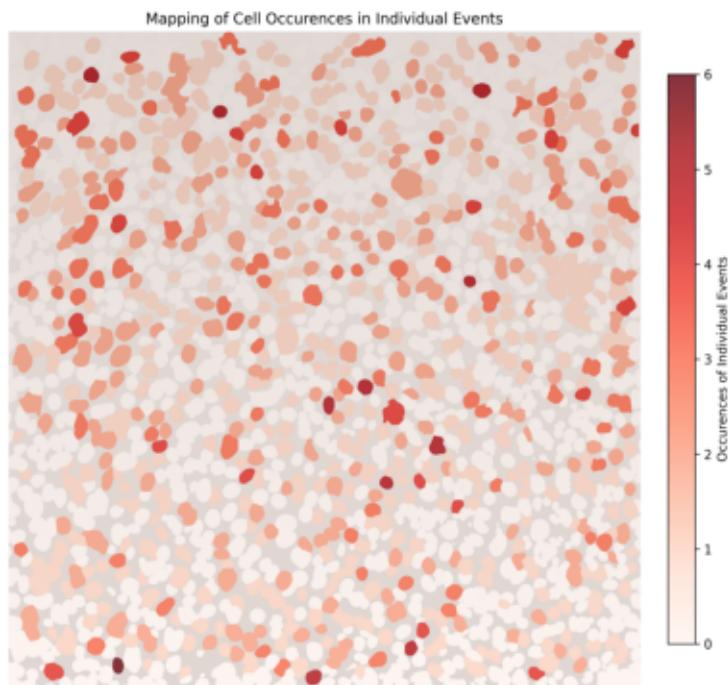


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250409\_IS09

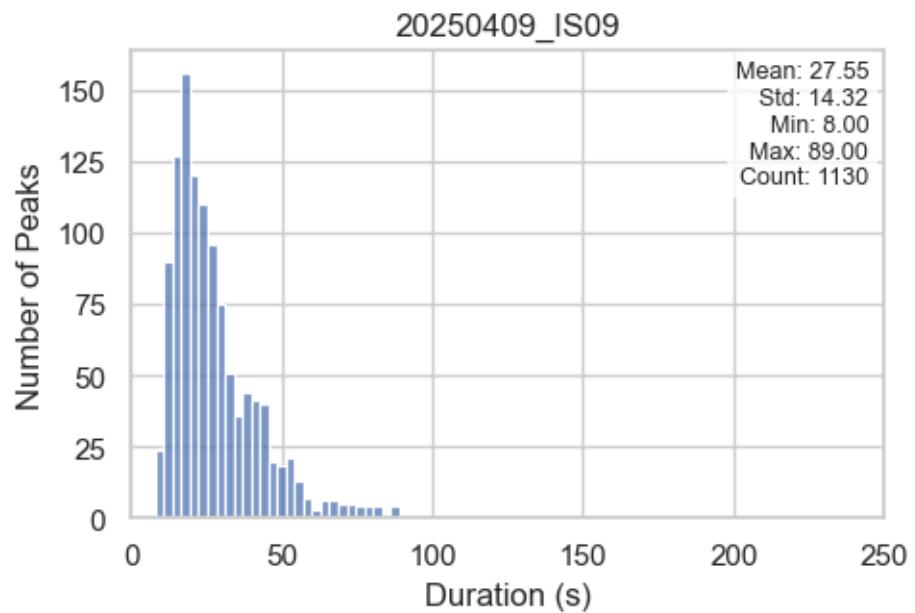


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:54:53] [INFO] calcium: Removed 20 outliers from dataset  
'20250409_IS09' for column 'Duration (s)'
```

```
[2025-08-08 14:54:53] [INFO] calcium: Lower bound: -10.0, Upper bound: 89.0
```

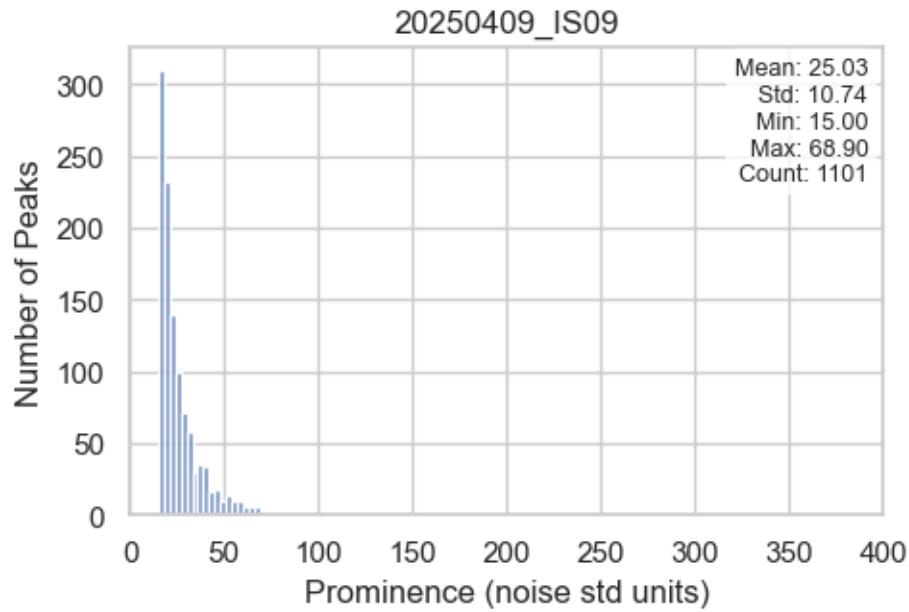
## Distribution of Peak Durations



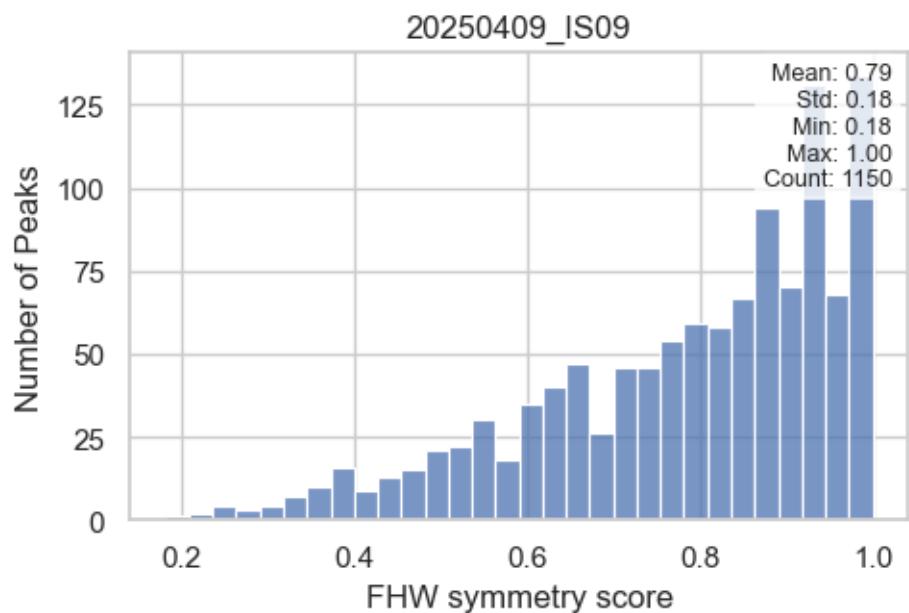
```
[2025-08-08 14:54:53] [INFO] calcium: Removed 49 outliers from dataset  
'20250409_IS09' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:54:53] [INFO] calcium: Lower bound: -1.5000000000000036, Upper  
bound: 68.9
```

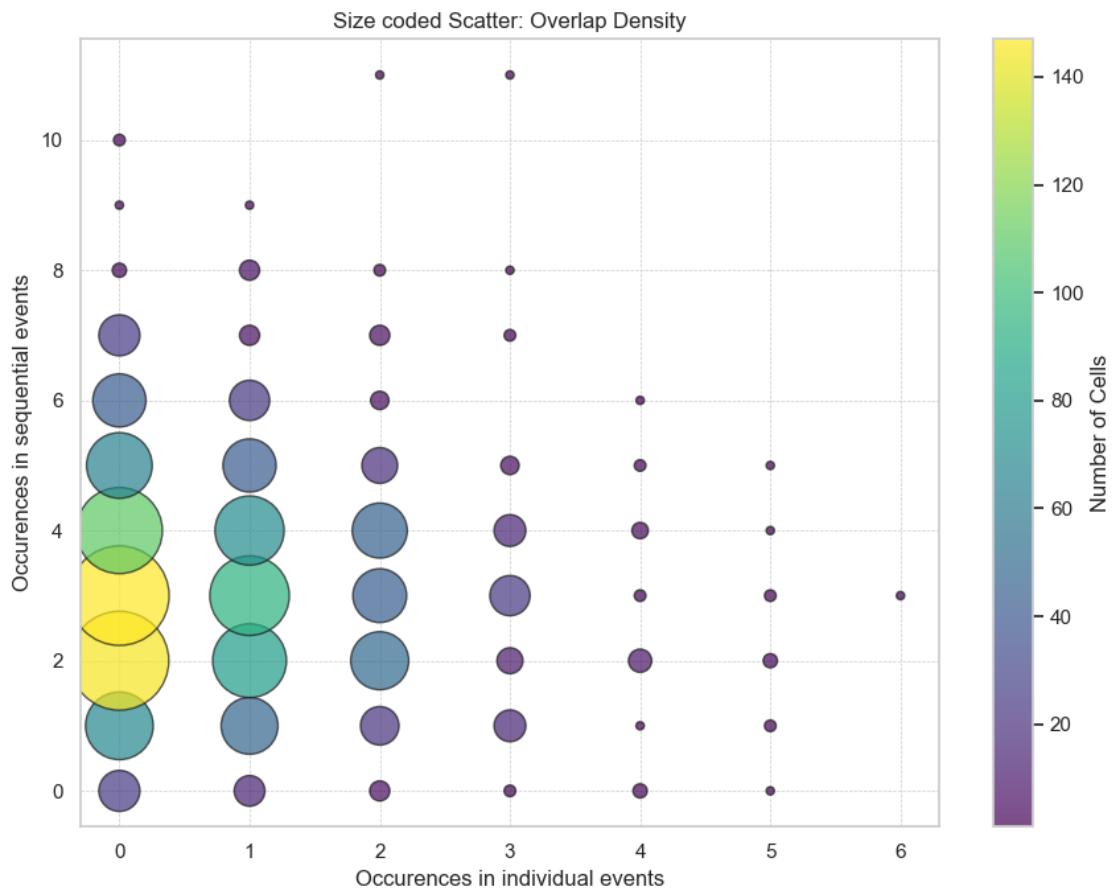
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

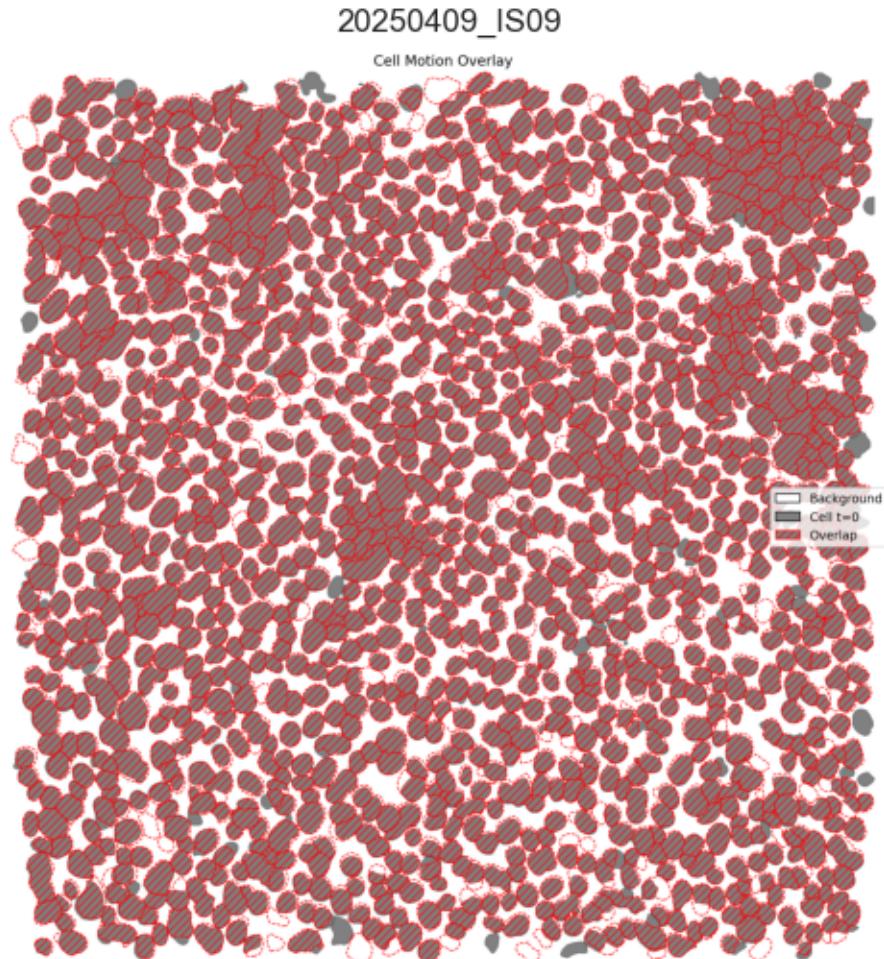


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n      "Default Dataset": "/path/to/your/dataset"\n}'
```

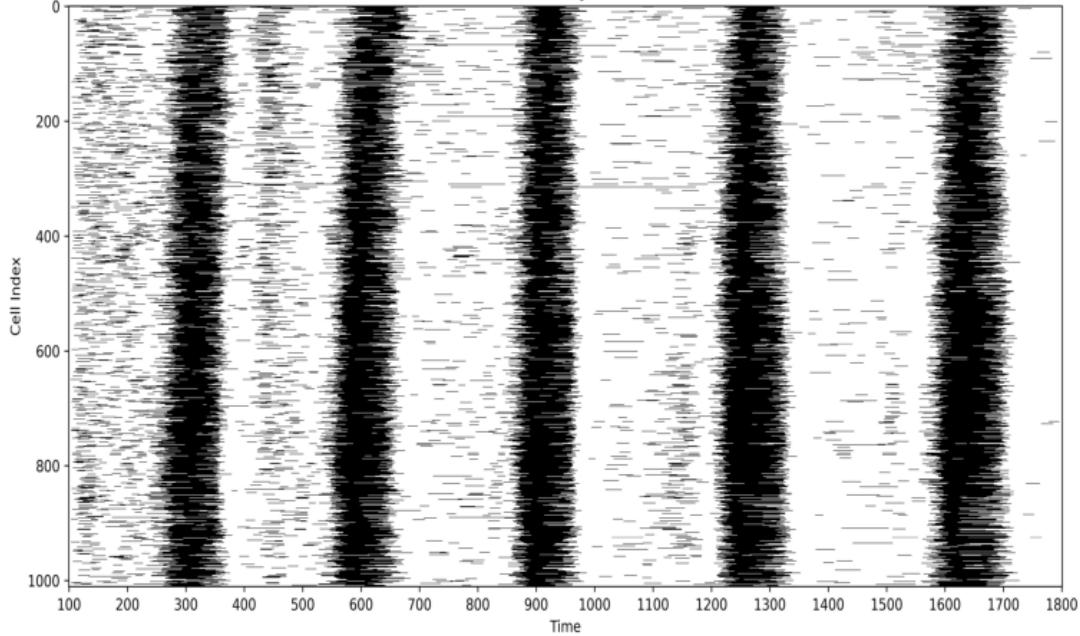
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

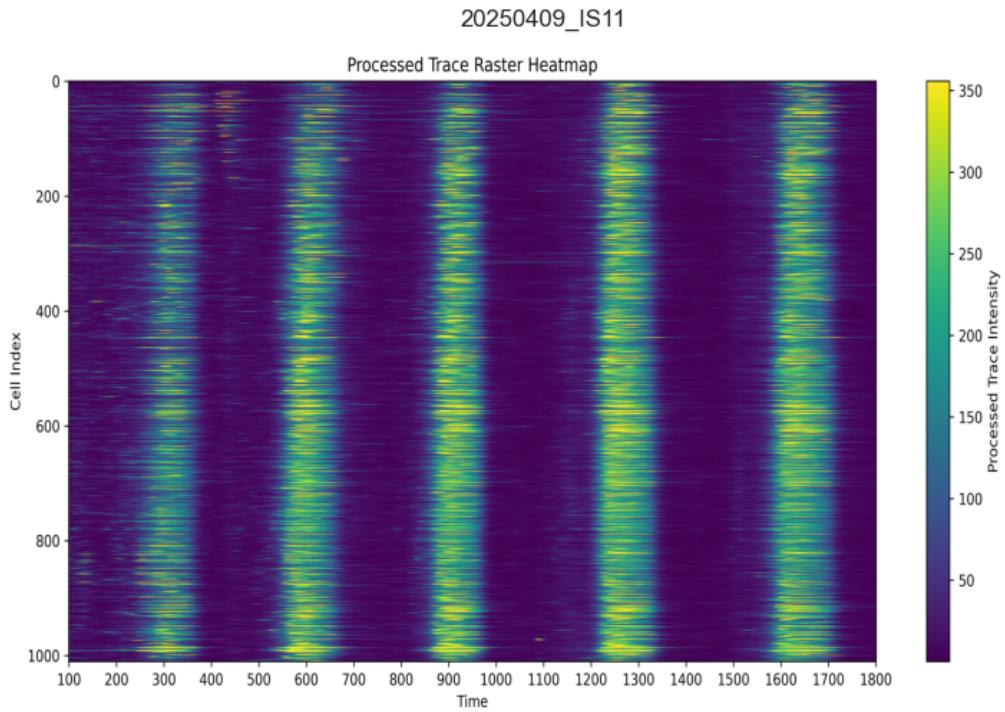
Binary Activity Raster Plot

20250409\_IS11

Binarized Activity Raster Plot



Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 7461

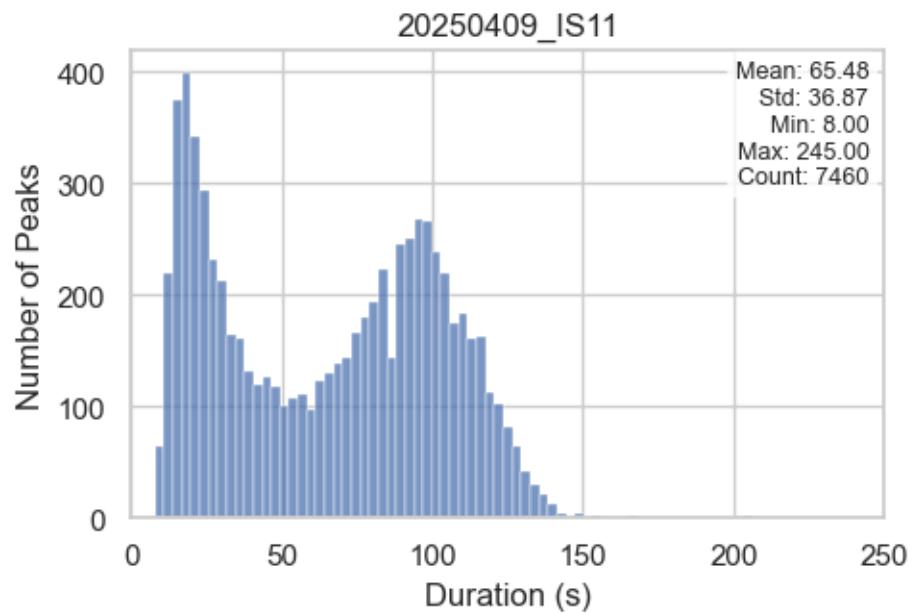
Total number of cells: 1011

### 1.1.3 Peaks statistics

```
[2025-08-08 14:55:45] [INFO] calcium: Removed 1 outliers from dataset  
'20250409_IS11' for column 'Duration (s)'
```

```
[2025-08-08 14:55:45] [INFO] calcium: Lower bound: -75.5, Upper bound: 304.0
```

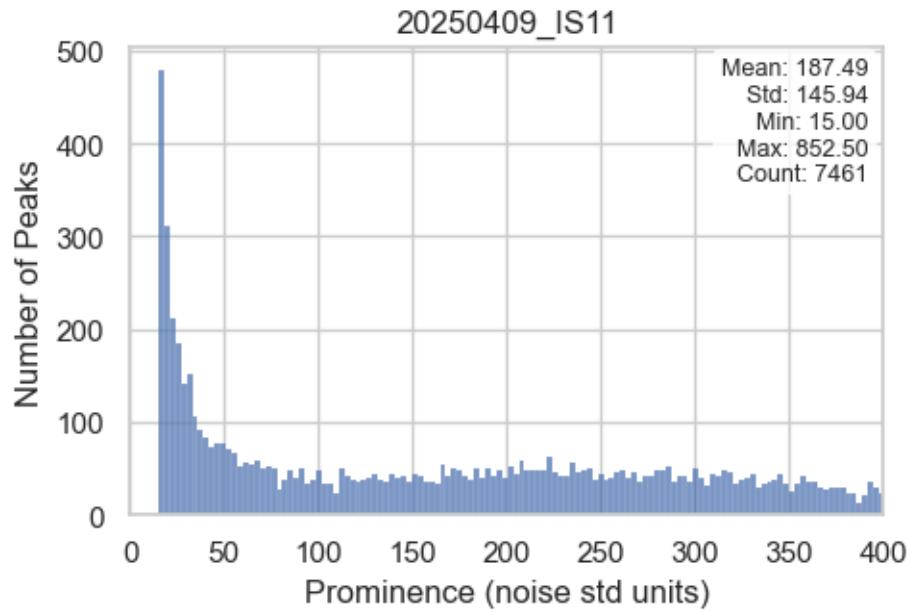
## Distribution of Peak Durations



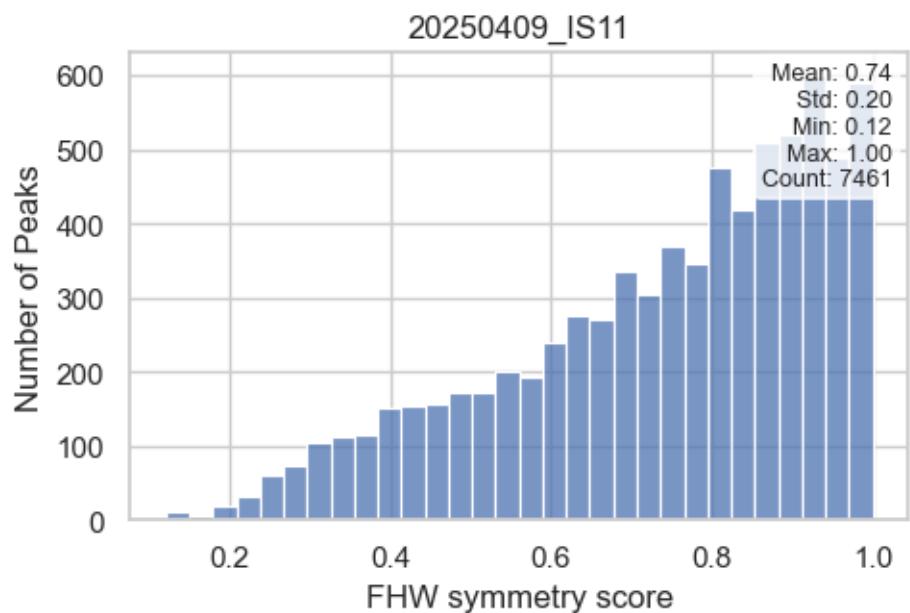
```
[2025-08-08 14:55:46] [INFO] calcium: Removed 0 outliers from dataset '20250409_IS11' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:55:46] [INFO] calcium: Lower bound: -325.8499999999997, Upper bound: 1038.699999999998
```

### Distribution of Peak Prominences

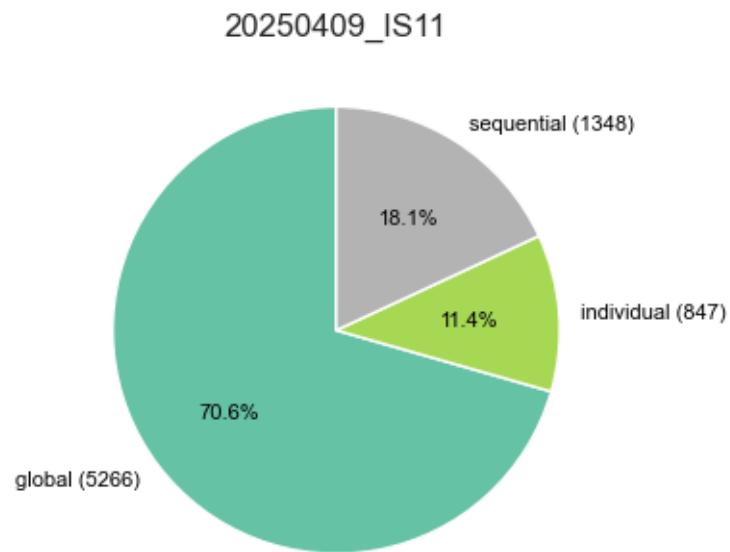


### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

Distribution of Peaks by Event types

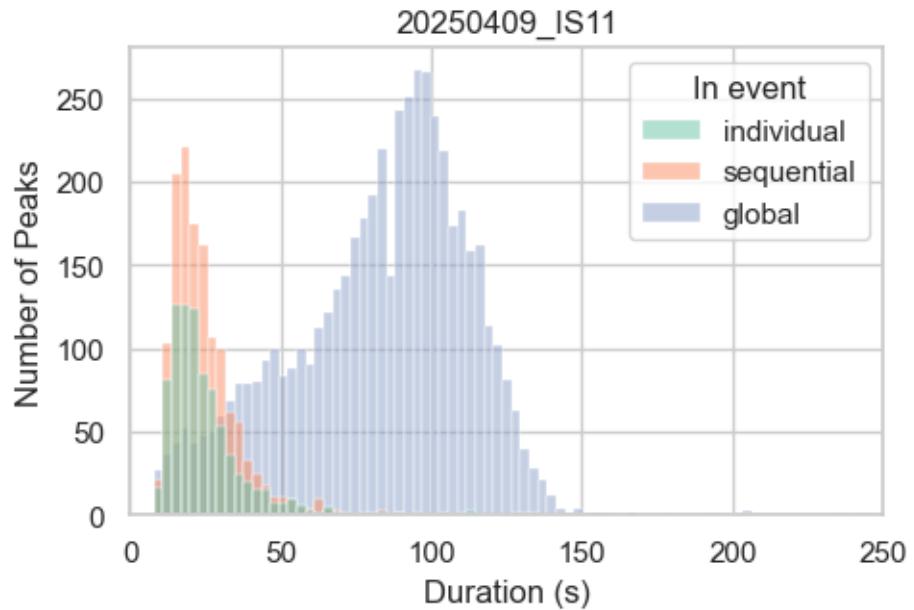


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:55:46] [INFO] calcium: Removed 1 outliers from dataset  
'20250409_IS11' for column 'Duration (s)'
```

```
[2025-08-08 14:55:46] [INFO] calcium: Lower bound: -75.5, Upper bound: 304.0
```

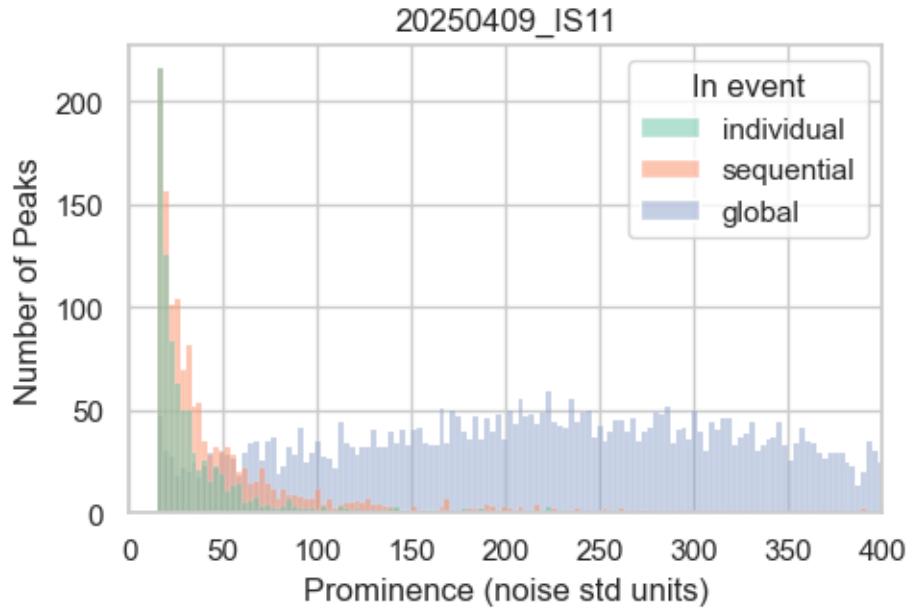
## Distribution of Peak Durations by Group



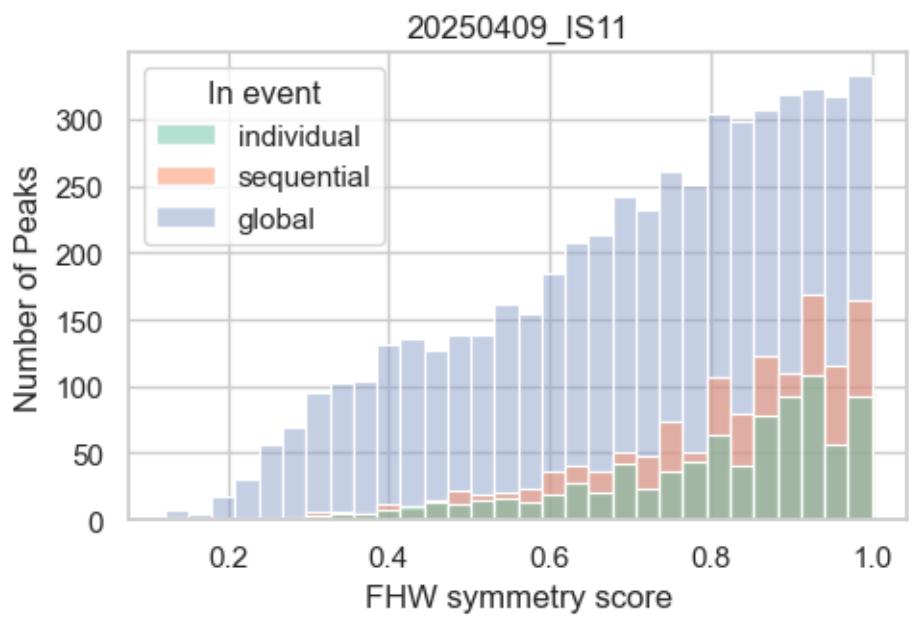
```
[2025-08-08 14:55:46] [INFO] calcium: Removed 0 outliers from dataset  
'20250409_IS11' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:55:46] [INFO] calcium: Lower bound: -325.8, Upper bound: 1038.7
```

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



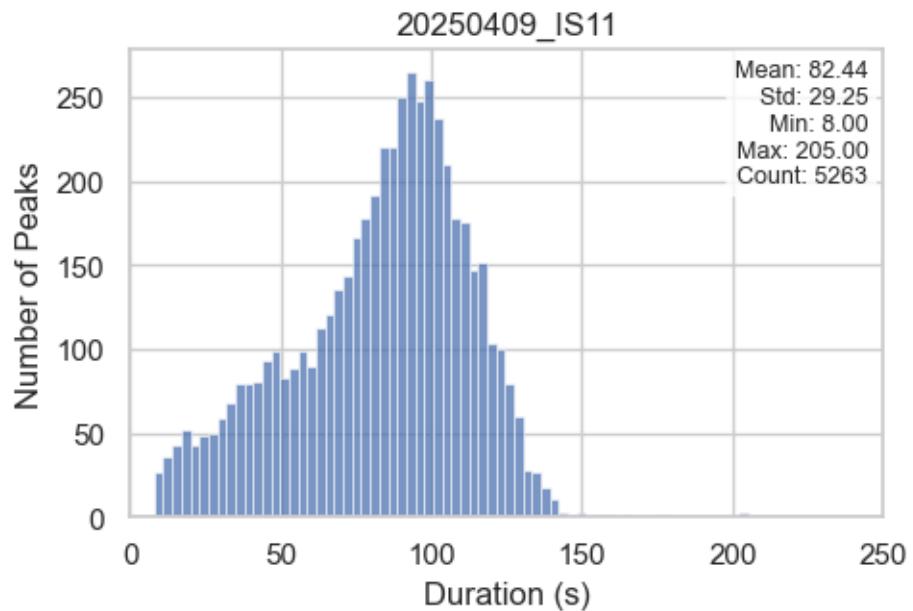
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:55:47] [INFO] calcium: Removed 3 outliers from dataset  
'20250409_IS11' for column 'Duration (s)'
```

```
[2025-08-08 14:55:47] [INFO] calcium: Lower bound: 5.5, Upper bound: 220.0
```

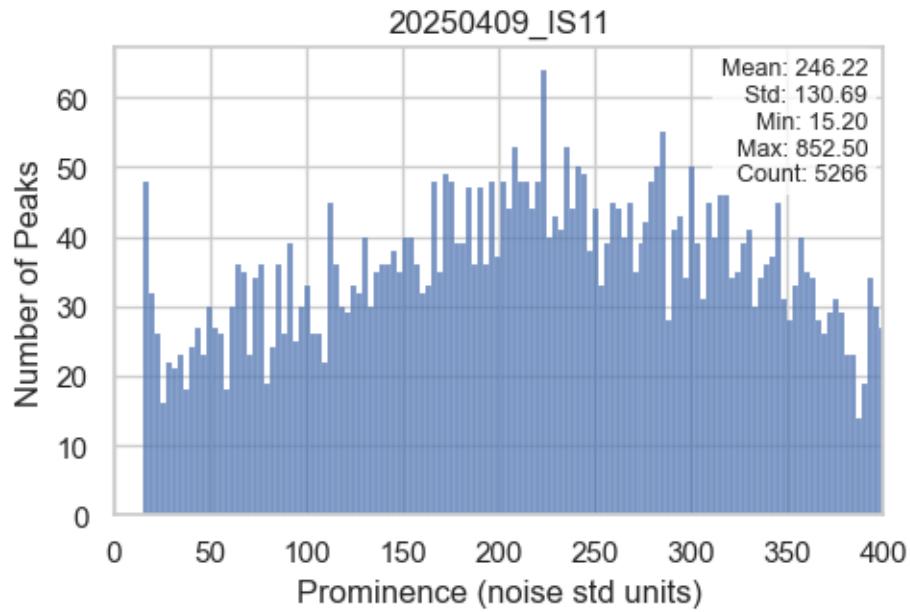
Distribution of Peak Durations



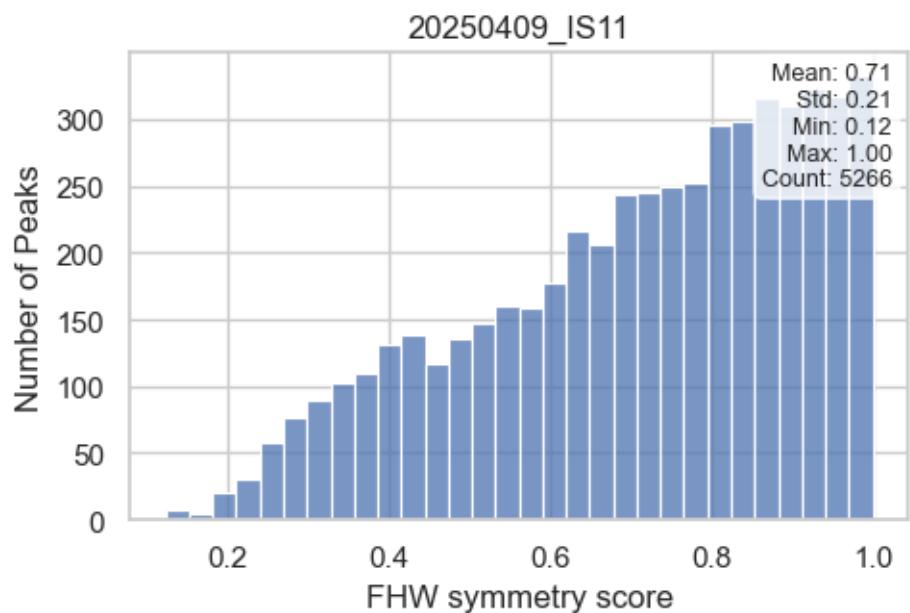
```
[2025-08-08 14:55:47] [INFO] calcium: Removed 0 outliers from dataset  
'20250409_IS11' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:55:47] [INFO] calcium: Lower bound: -131.03749999999997, Upper  
bound: 891.824999999999
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

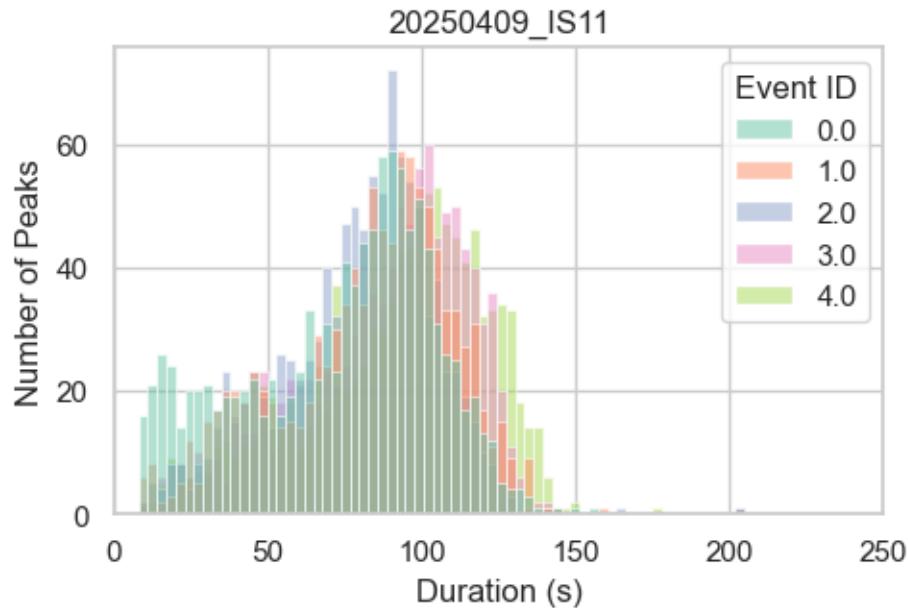


### 1.2.2 Peak statistics in global event per event ID

```
[2025-08-08 14:55:48] [INFO] calcium: Removed 3 outliers from dataset  
'20250409_IS11' for column 'Duration (s)'
```

```
[2025-08-08 14:55:48] [INFO] calcium: Lower bound: 5.5, Upper bound: 220.0
```

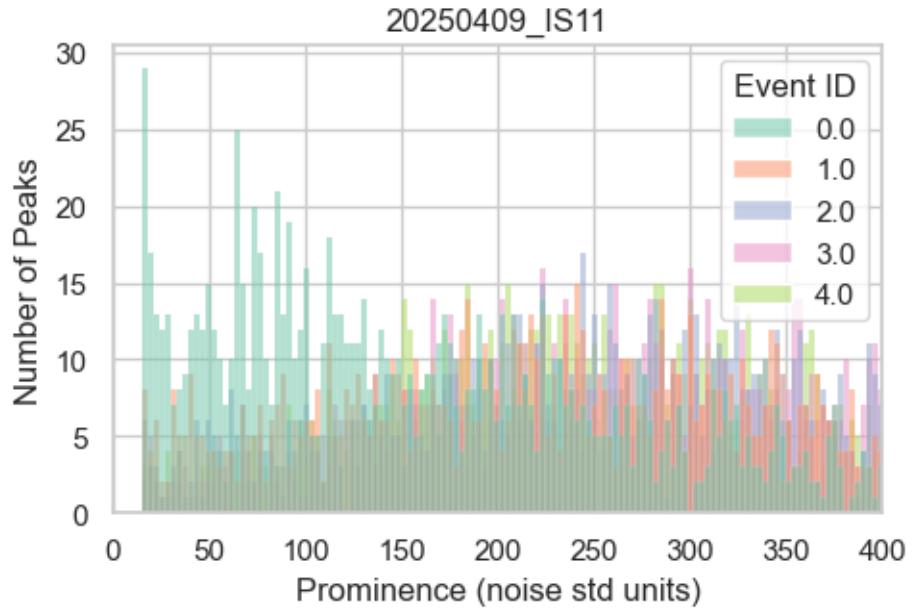
Distribution of Peak Durations by Group



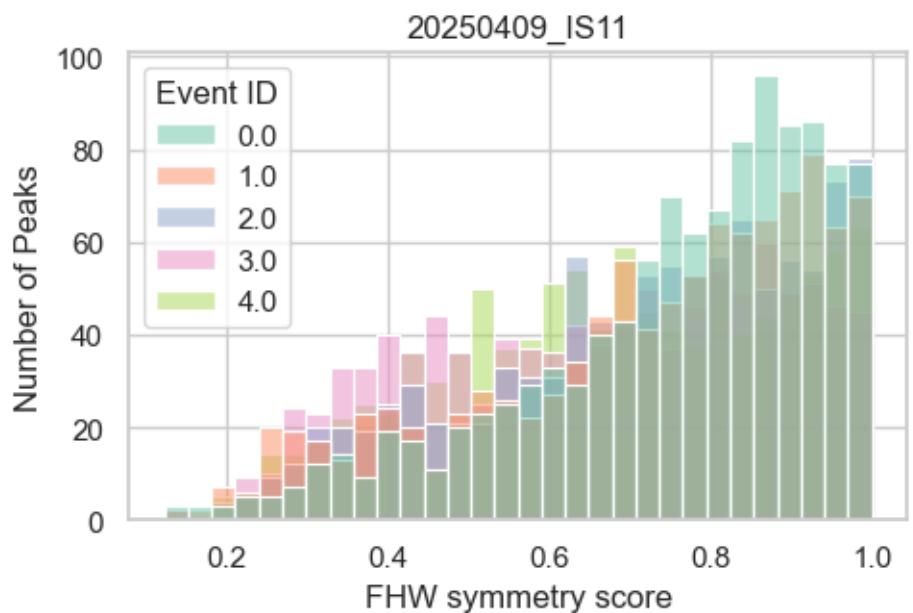
```
[2025-08-08 14:55:48] [INFO] calcium: Removed 0 outliers from dataset  
'20250409_IS11' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:55:48] [INFO] calcium: Lower bound: -131.0, Upper bound: 891.8
```

### Distribution of Peak Prominences by Group



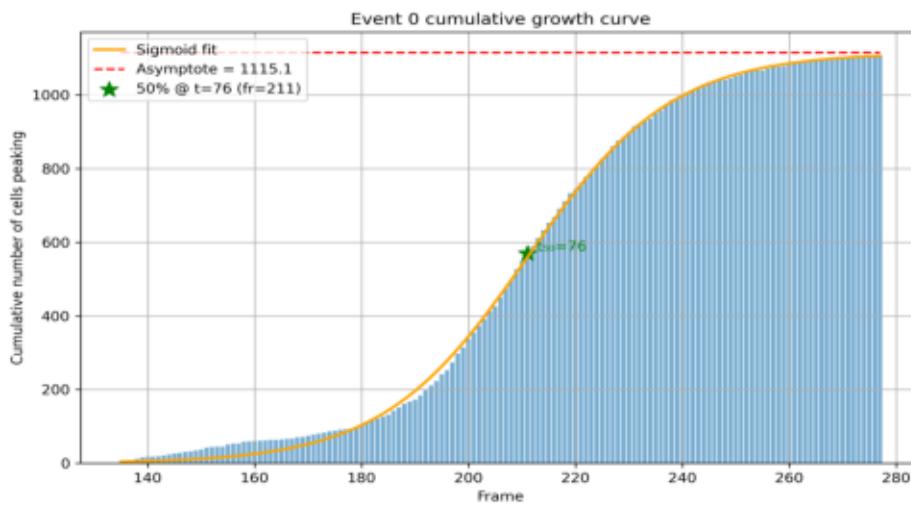
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

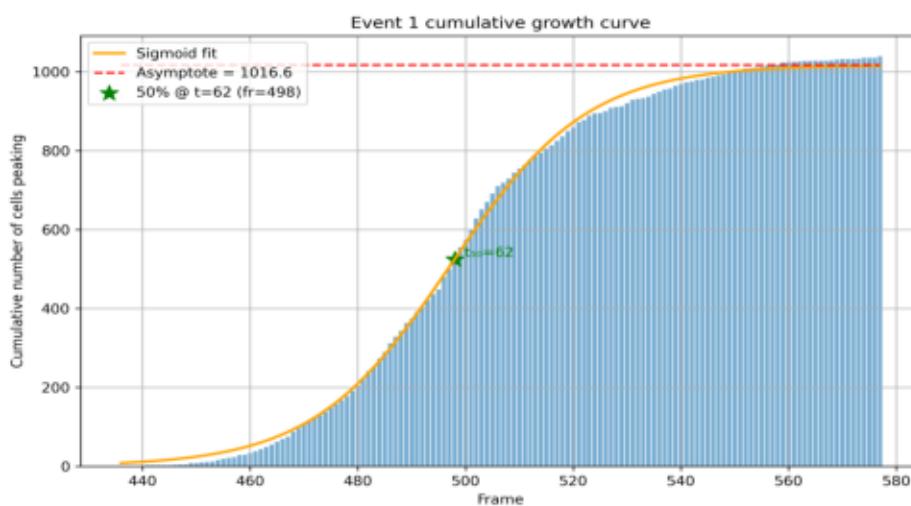
Event Activity Overlay (Event ID: 0)

20250409\_IS11



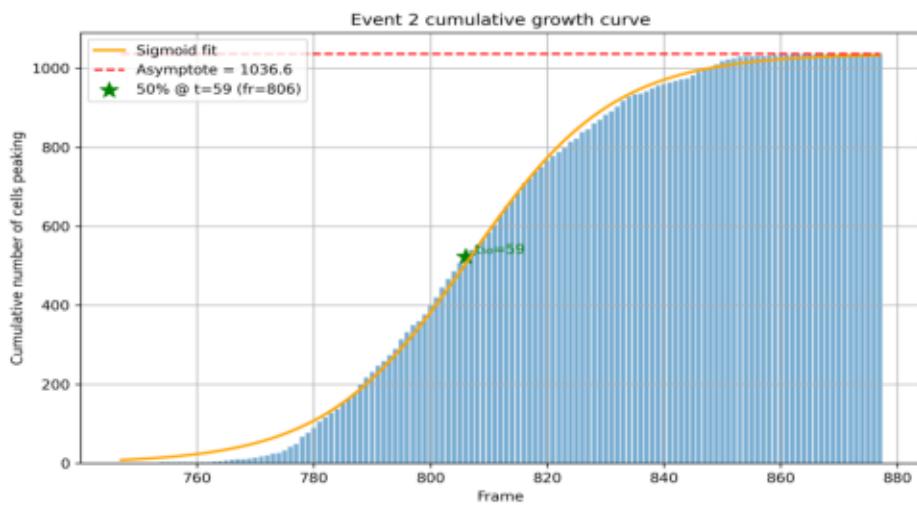
Event Activity Overlay (Event ID: 1)

20250409\_IS11



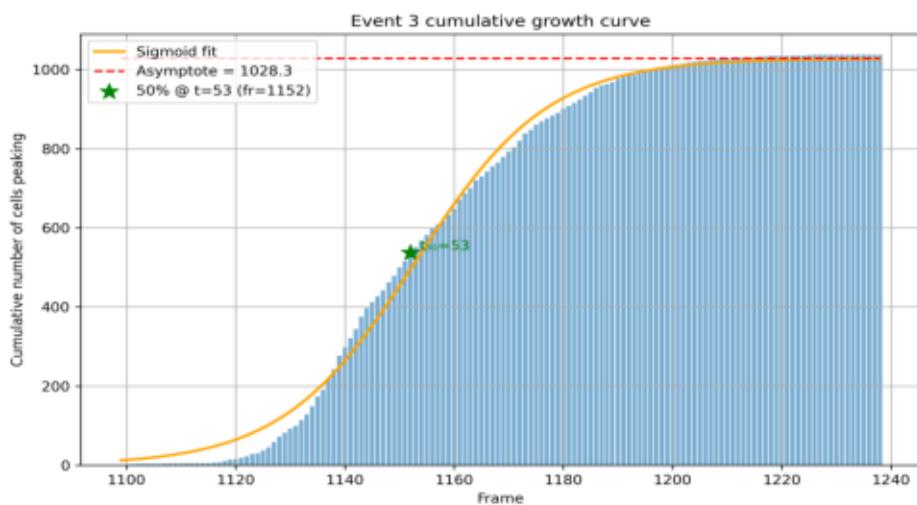
### Event Activity Overlay (Event ID: 2)

20250409\_IS11



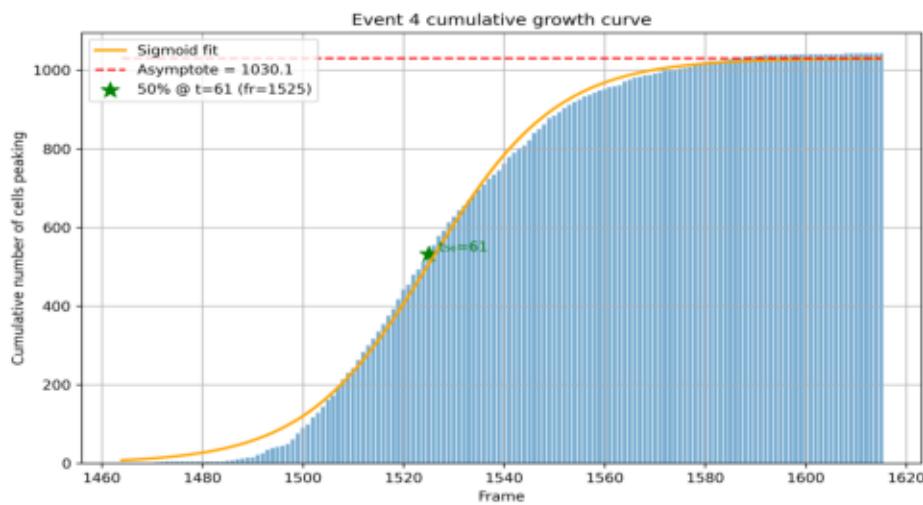
### Event Activity Overlay (Event ID: 3)

20250409\_IS11



## Event Activity Overlay (Event ID: 4)

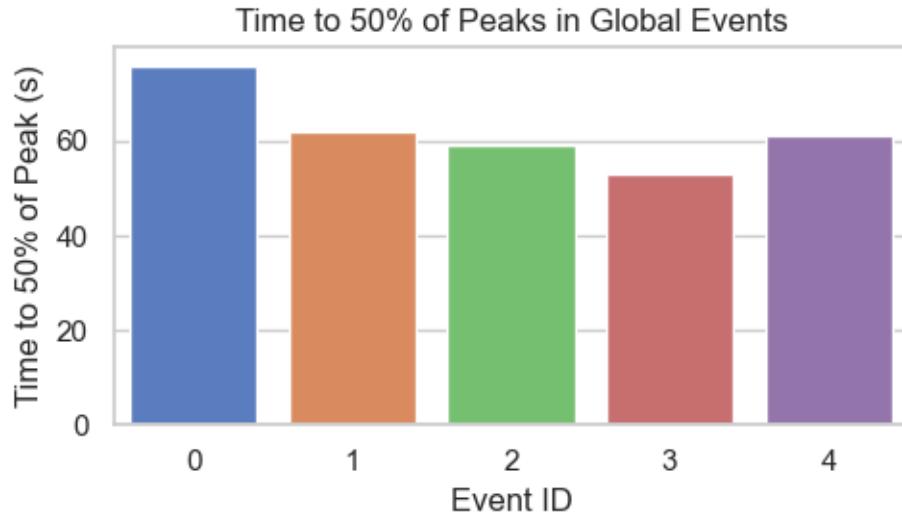
20250409\_IS11



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

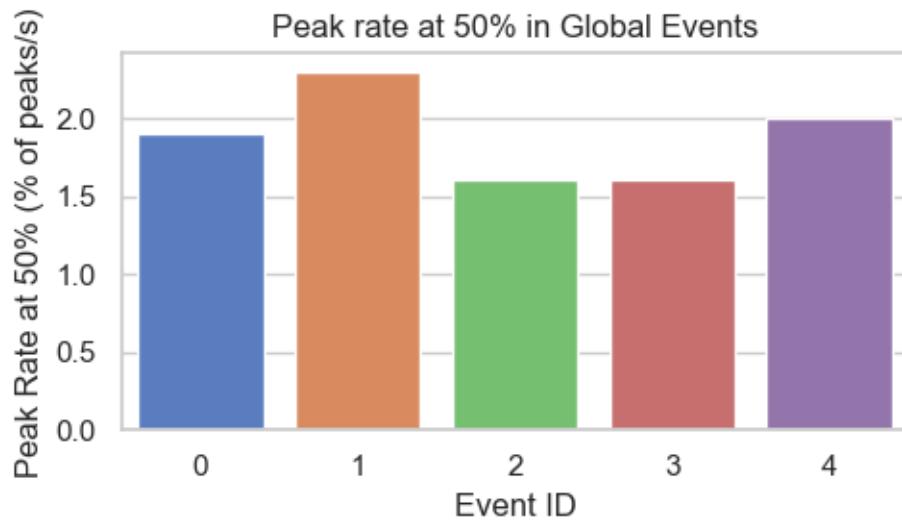
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys
is\visualizers.py:297: FutureWarning:
```

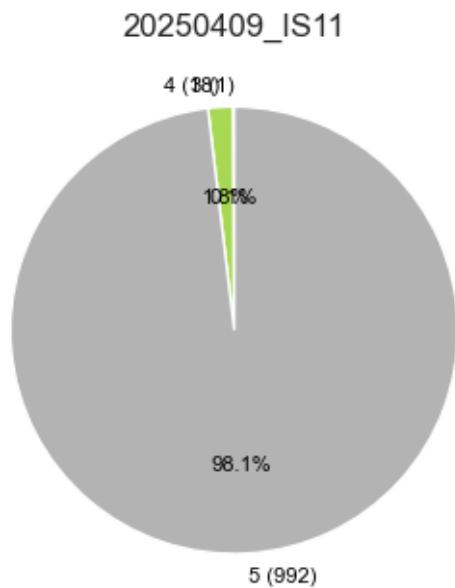
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,
dodge=False, palette=palette, legend=False)
```



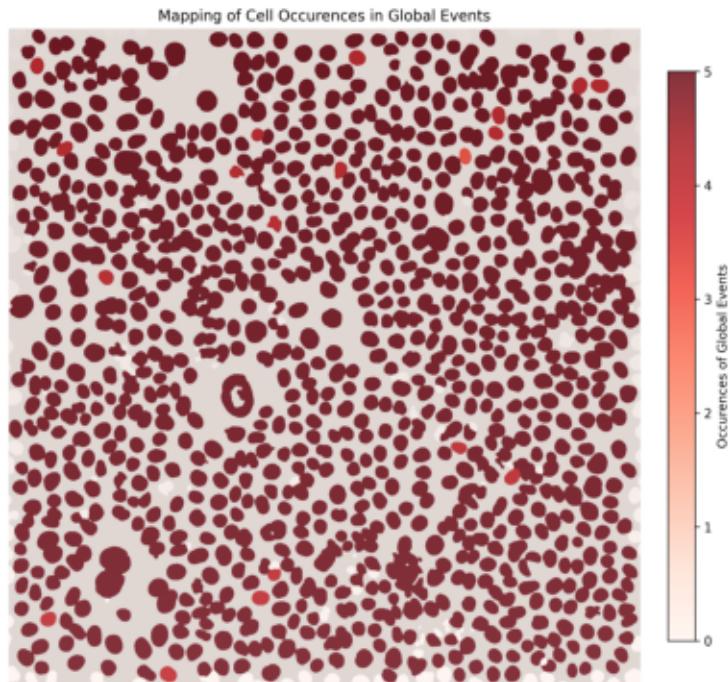
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

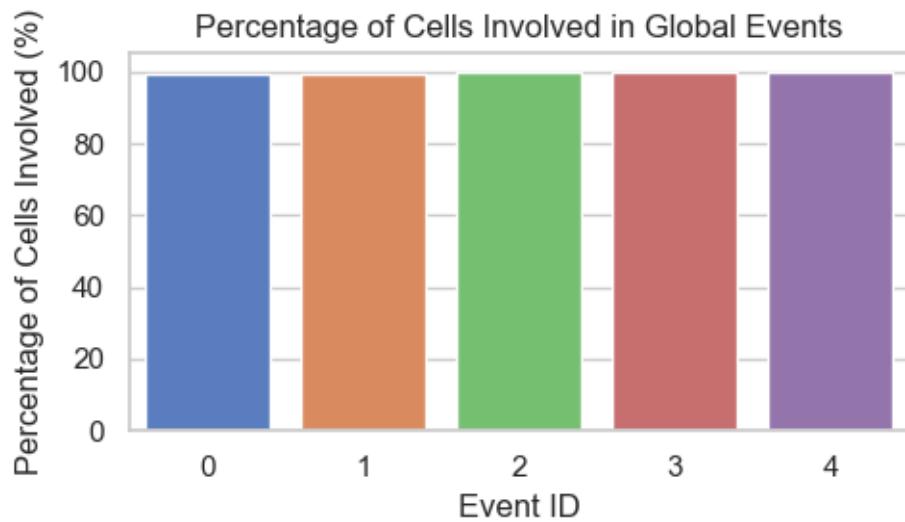
20250409\_IS11



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [288.0, 309.0, 350.0, 377.0]

Estimated periodicity: 0.905

The global events exhibit a regular periodic pattern.

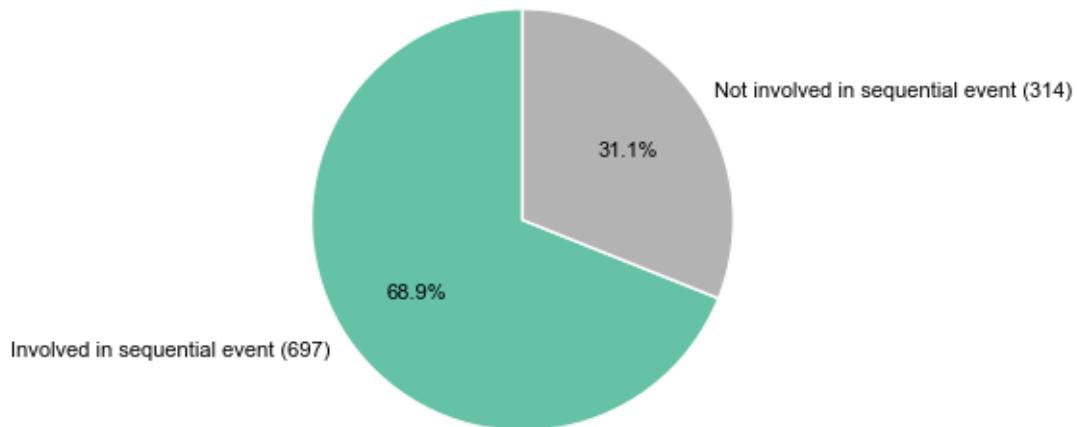
Estimated frequency (1/mean interval): 0.003 Hz

## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

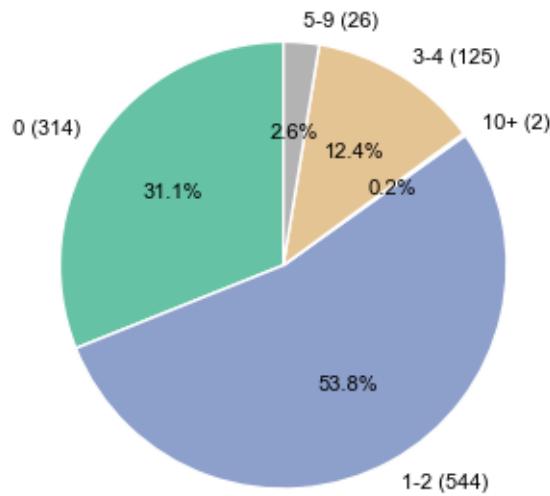
Distribution of Cells Involved in Sequential Events

20250409\_IS11



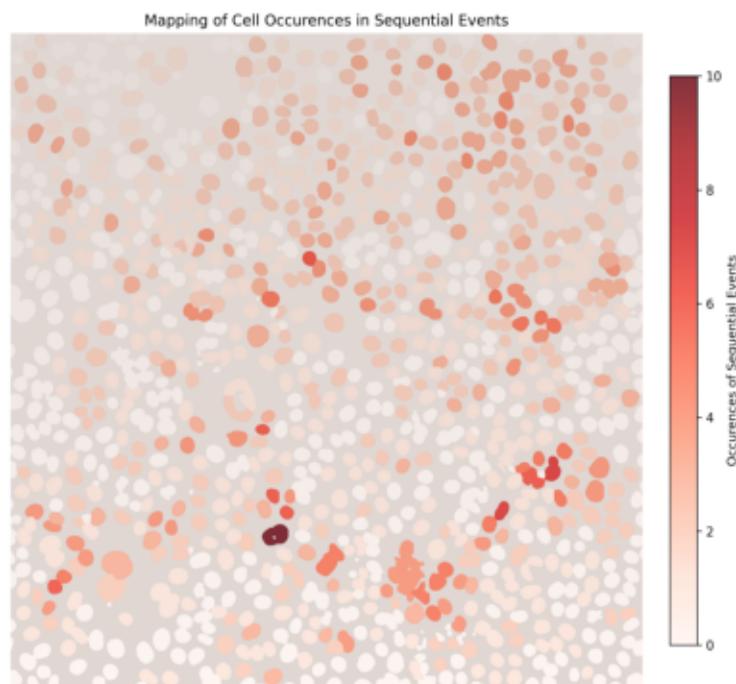
Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)

20250409\_IS11



## Cell Mapping with Occurrences in Sequential Events Overlay

20250409\_IS11

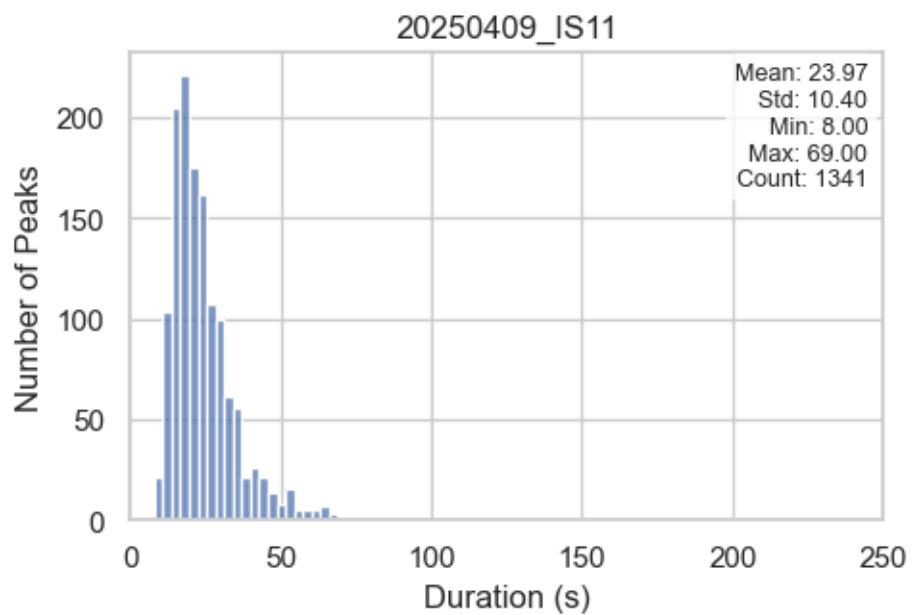


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:55:55] [INFO] calcium: Removed 7 outliers from dataset  
'20250409_IS11' for column 'Duration (s)'
```

```
[2025-08-08 14:55:55] [INFO] calcium: Lower bound: -1.0, Upper bound: 71.0
```

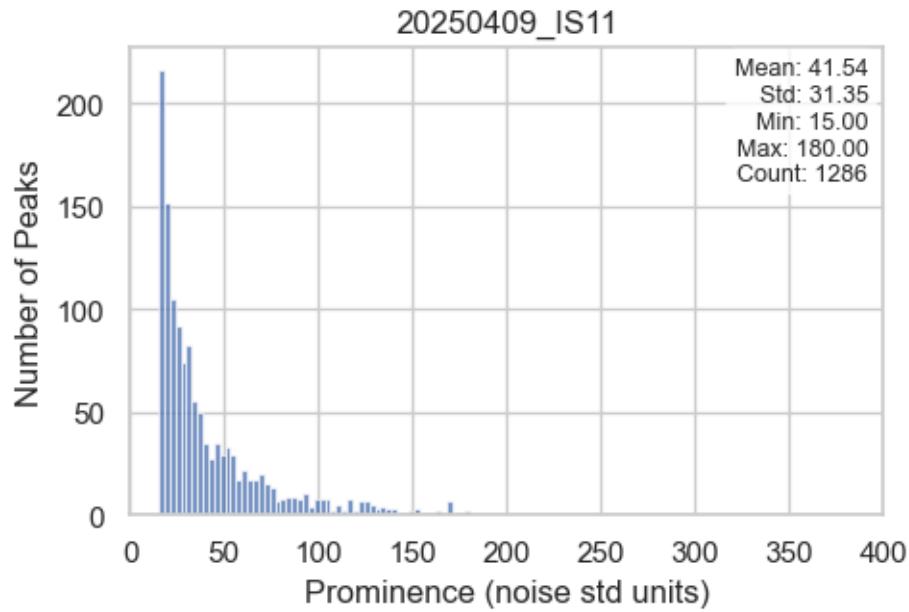
## Distribution of Peak Durations



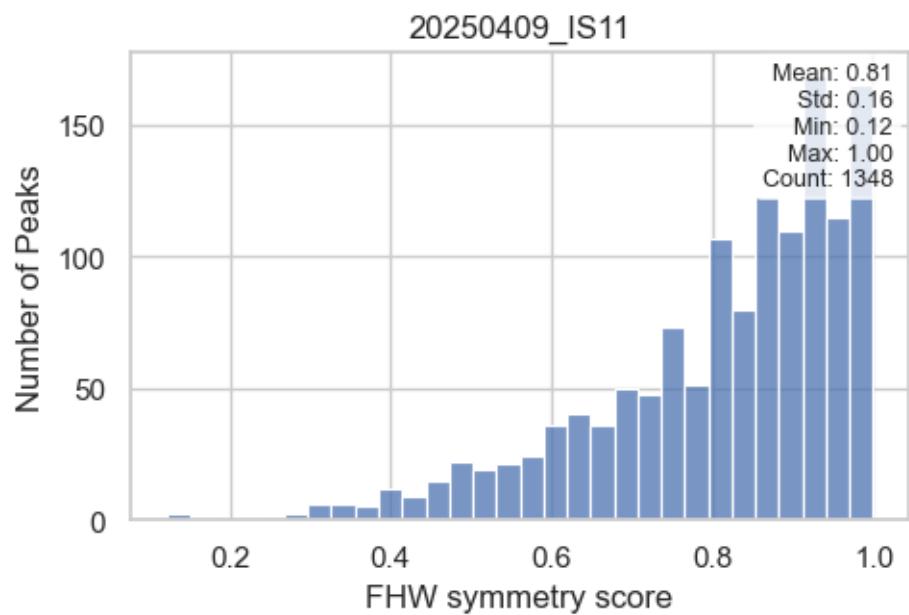
[2025-08-08 14:55:55] [INFO] calcium: Removed 62 outliers from dataset '20250409\_IS11' for column 'Prominence (noise std units)'

[2025-08-08 14:55:55] [INFO] calcium: Lower bound: -33.6875, Upper bound: 181.8624999999998

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

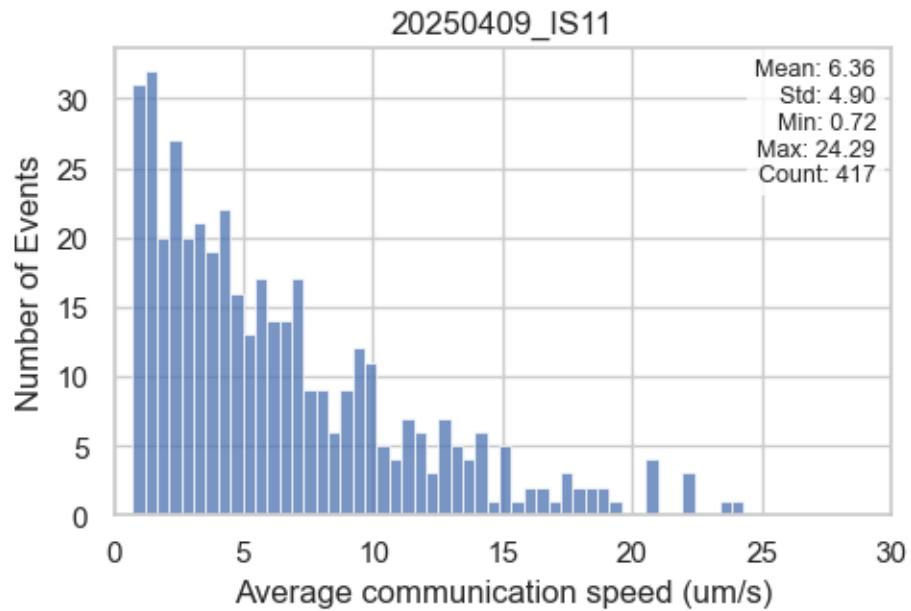


### 1.3.3 Cell-cell communication speed

```
[2025-08-08 14:55:55] [INFO] calcium: Removed 0 outliers from dataset  
'20250409_IS11' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 14:55:55] [INFO] calcium: Lower bound: -7.280000000000003, Upper  
bound: 28.690000000000005
```

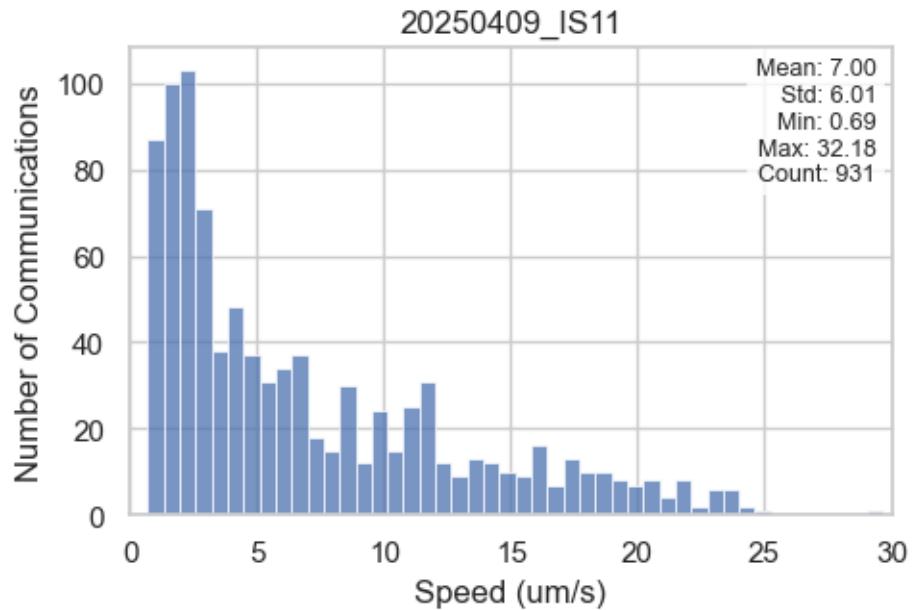
Distribution of Average Communication Speeds in Sequential Events



```
[2025-08-08 14:55:56] [INFO] calcium: Removed 0 outliers from dataset  
'20250409_IS11' for column 'Speed (um/s)'
```

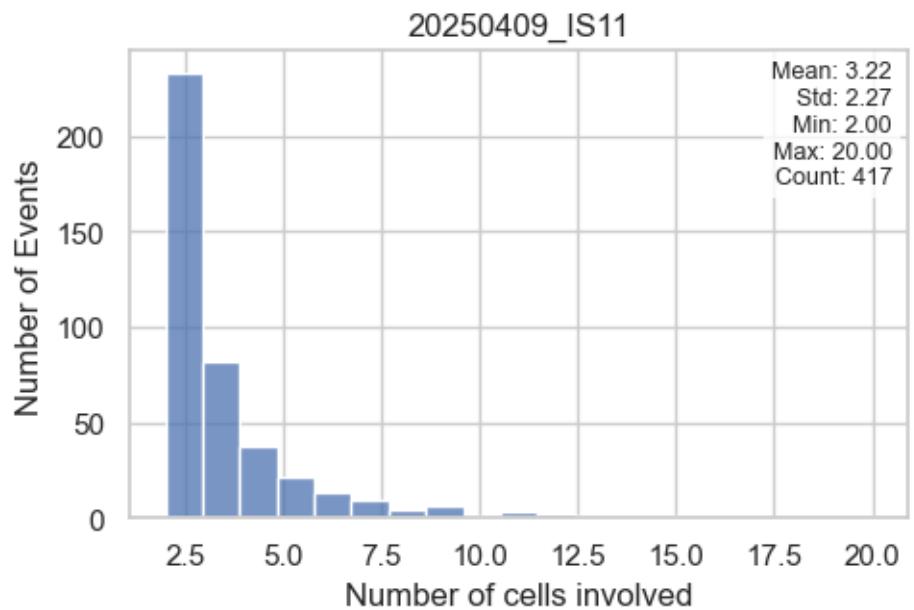
```
[2025-08-08 14:55:56] [INFO] calcium: Lower bound: -10.587500000000002, Upper  
bound: 36.300000000000001
```

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

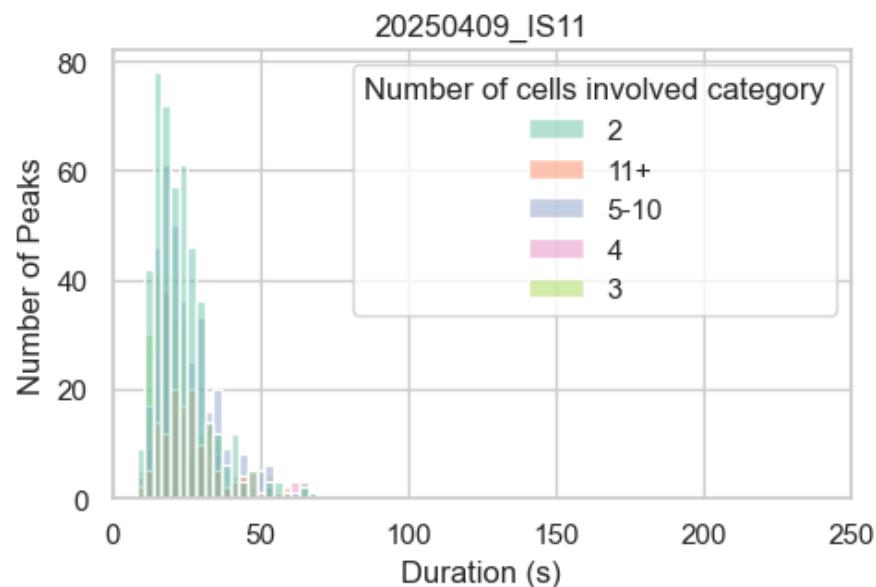


### 1.3.5 Influence of cell count per event on statistics

```
[2025-08-08 14:55:56] [INFO] calcium: Removed 7 outliers from dataset  
'20250409_IS11' for column 'Duration (s)'
```

```
[2025-08-08 14:55:56] [INFO] calcium: Lower bound: -1.0, Upper bound: 71.0
```

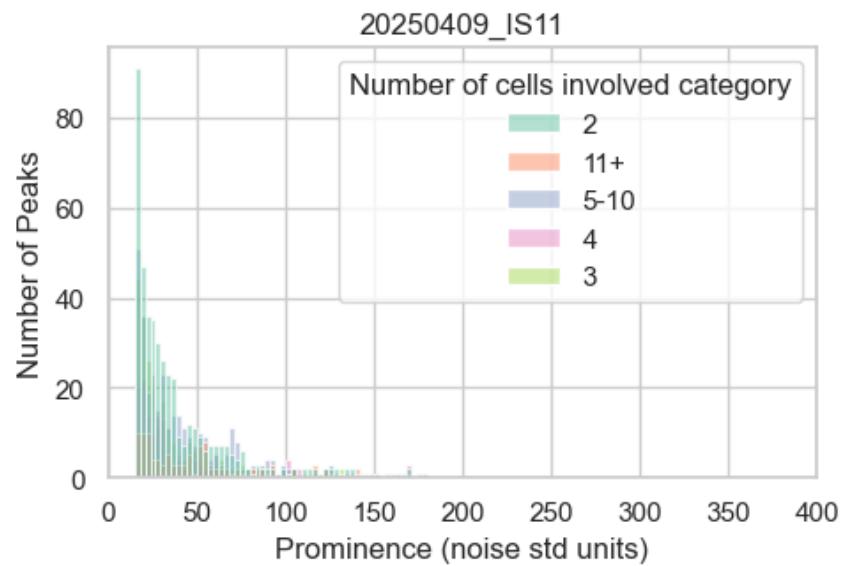
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



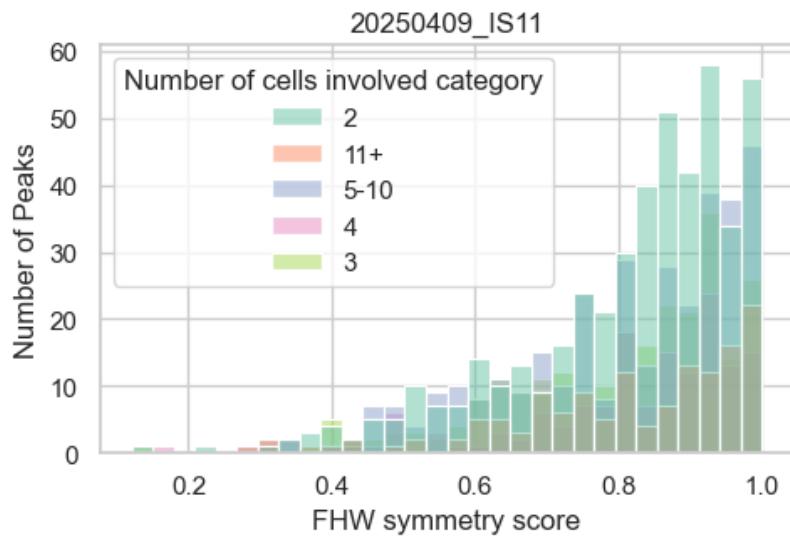
```
[2025-08-08 14:55:56] [INFO] calcium: Removed 62 outliers from dataset  
'20250409_IS11' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:55:56] [INFO] calcium: Lower bound: -33.7, Upper bound: 181.9
```

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



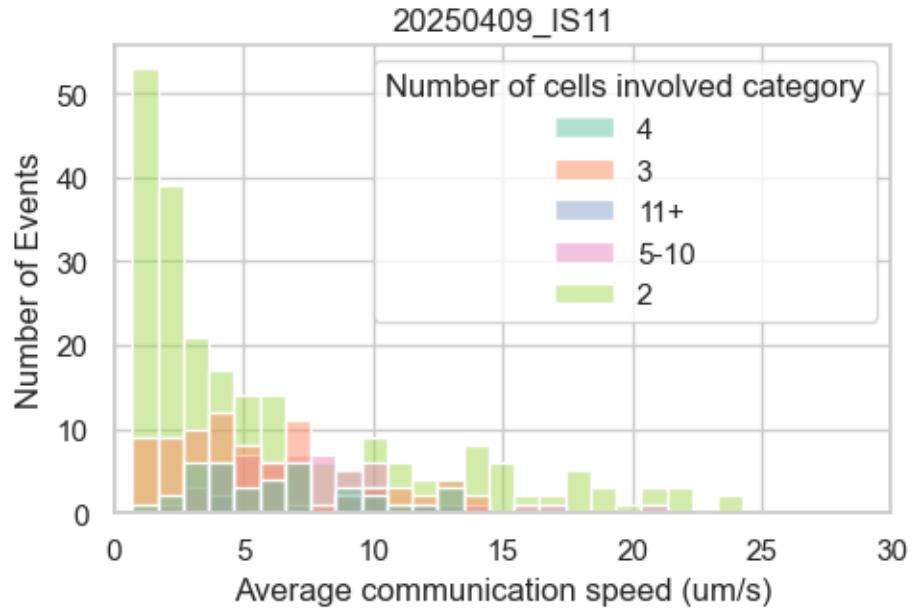
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 14:55:57] [INFO] calcium: Removed 0 outliers from dataset  
'20250409_IS11' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 14:55:57] [INFO] calcium: Lower bound: -7.3, Upper bound: 28.7
```

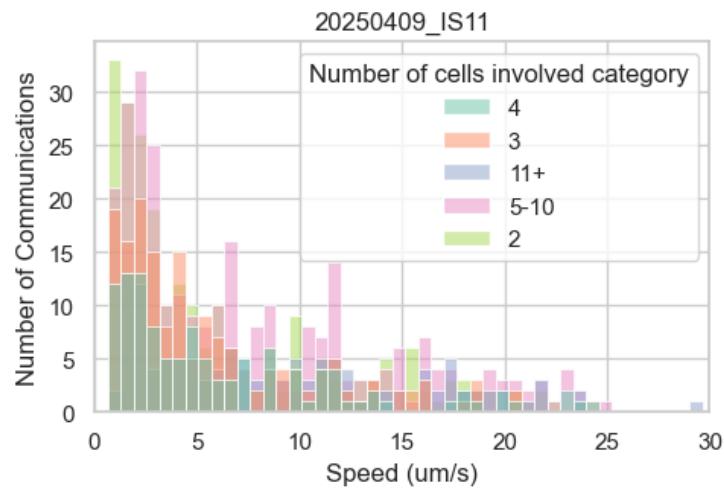
## Distribution of Average Communication Speeds by Number of Cells Involved



```
[2025-08-08 14:55:57] [INFO] calcium: Removed 0 outliers from dataset
'20250409_IS11' for column 'Speed (um/s)'
```

```
[2025-08-08 14:55:57] [INFO] calcium: Lower bound: -10.6, Upper bound: 36.3
```

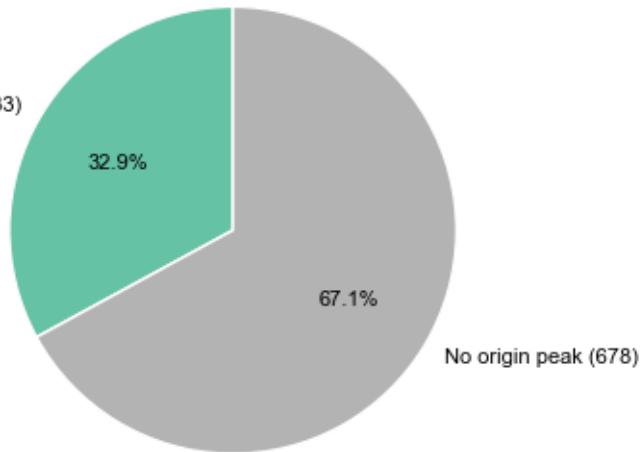
## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events



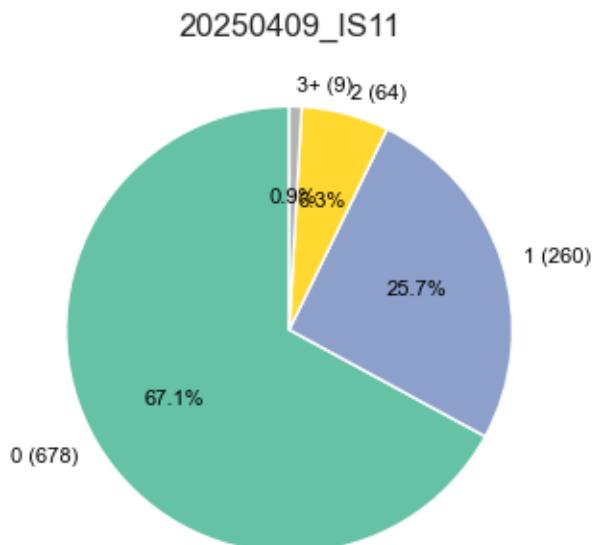
### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

20250409\_IS11  
Has origin peak (333)  
32.9%

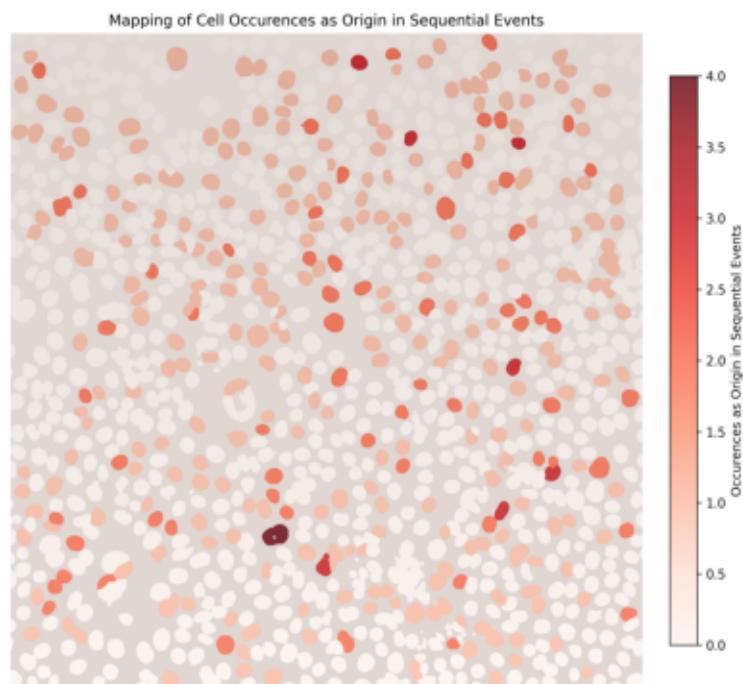


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

20250409\_IS11

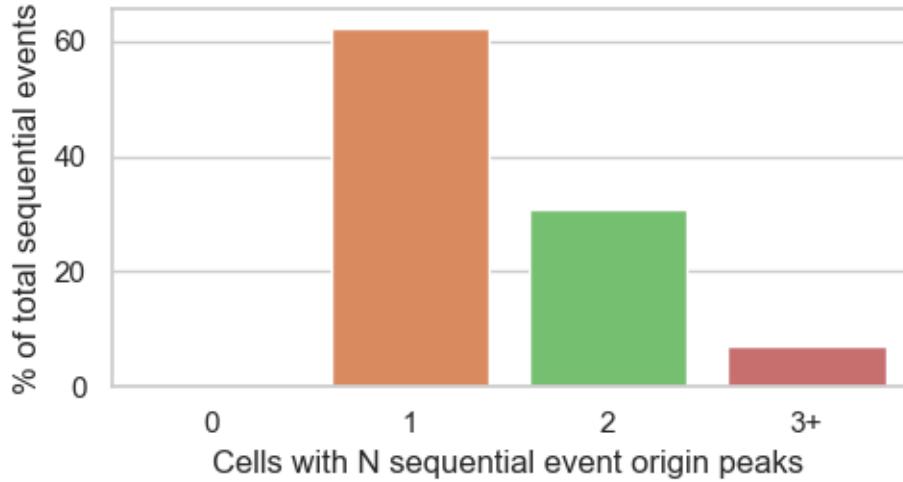


```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

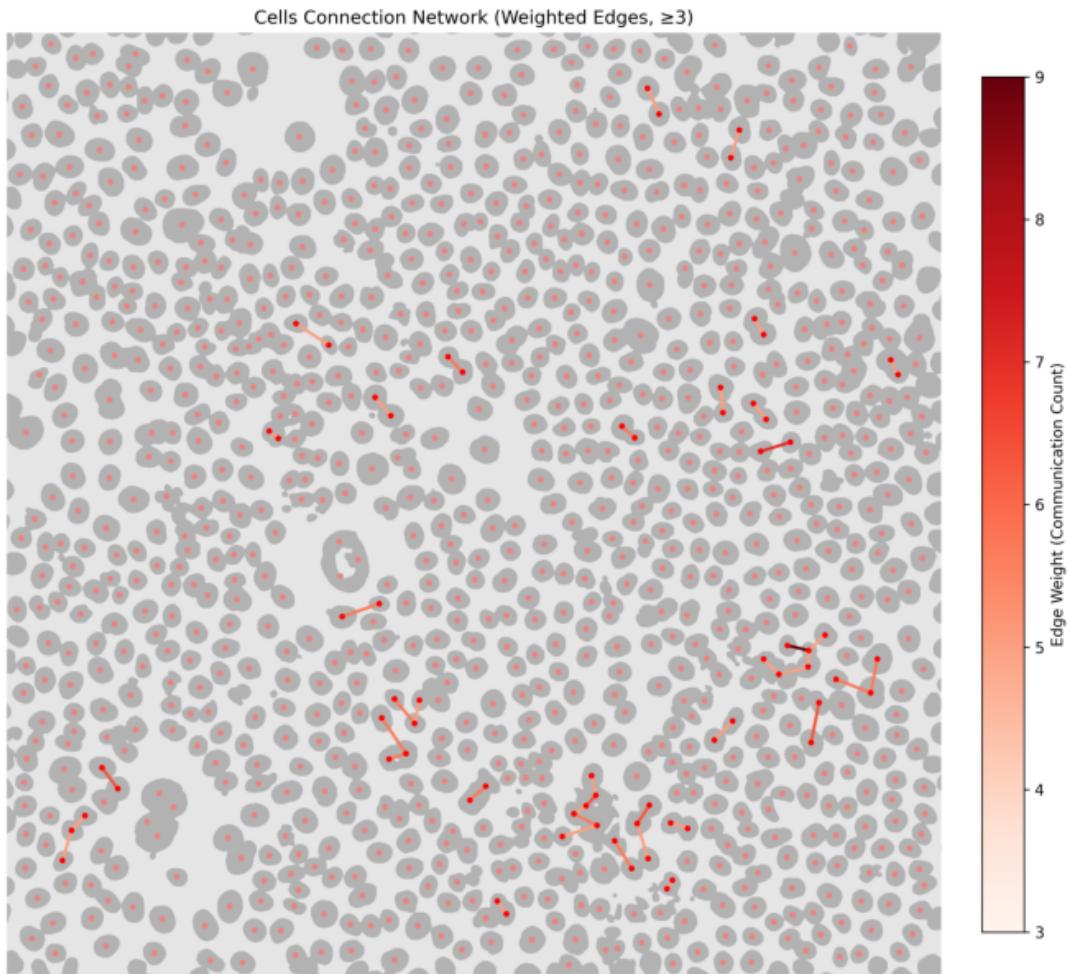
Distribution of Sequential Events per Cell by Number of Origin Peaks



### 1.3.7 Connection network between cells

Cell Connection Network Graph

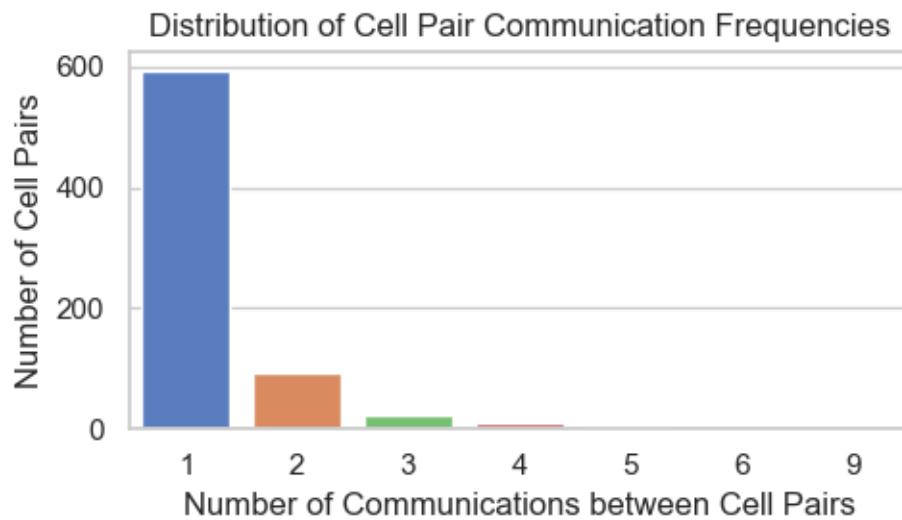
20250409\_IS11



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

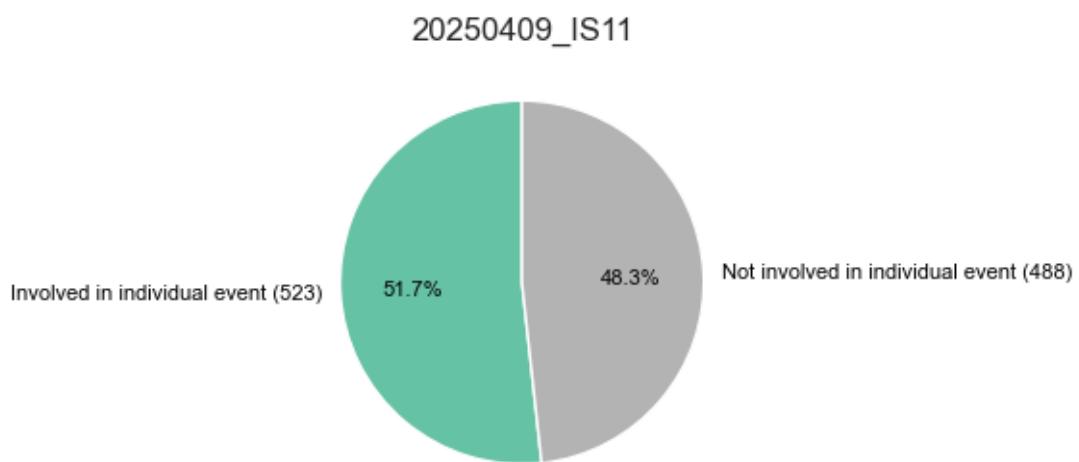
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



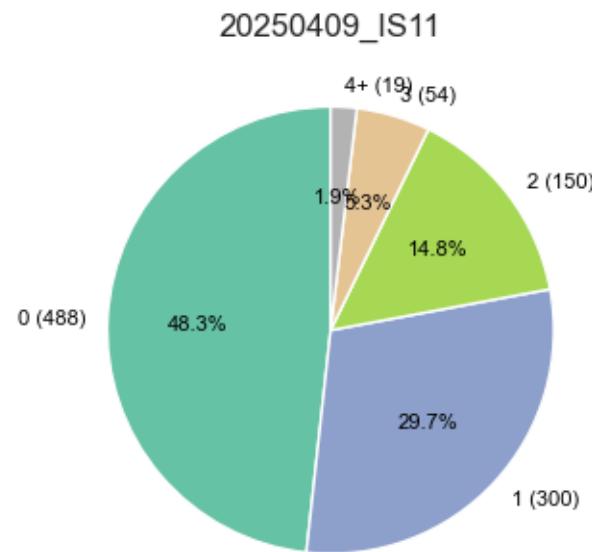
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

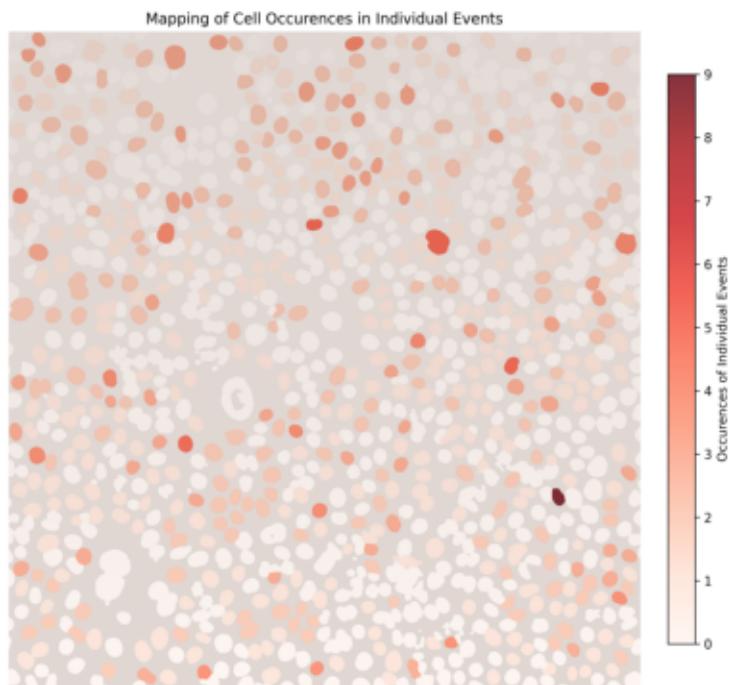


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250409\_IS11

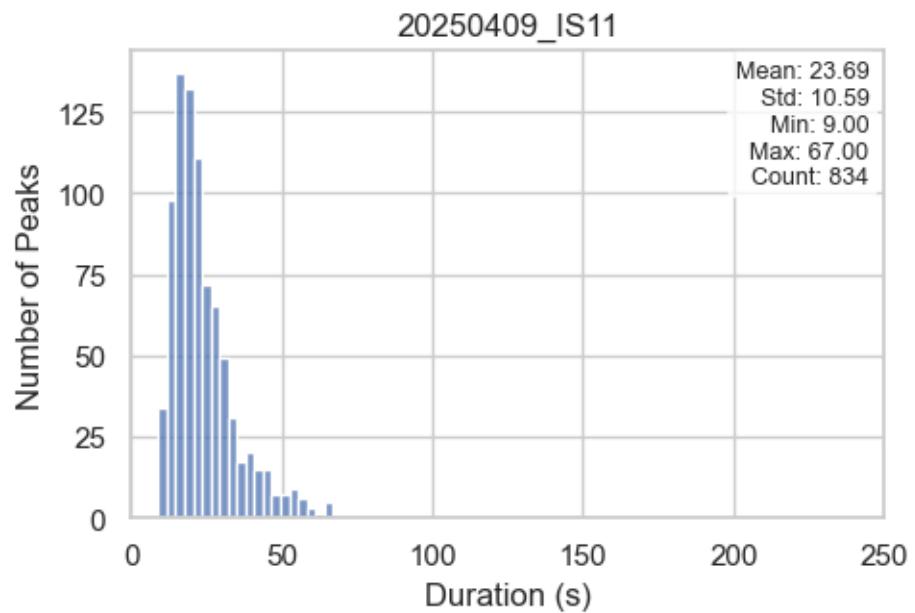


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:56:01] [INFO] calcium: Removed 13 outliers from dataset  
'20250409_IS11' for column 'Duration (s)'
```

```
[2025-08-08 14:56:01] [INFO] calcium: Lower bound: -3.5, Upper bound: 68.0
```

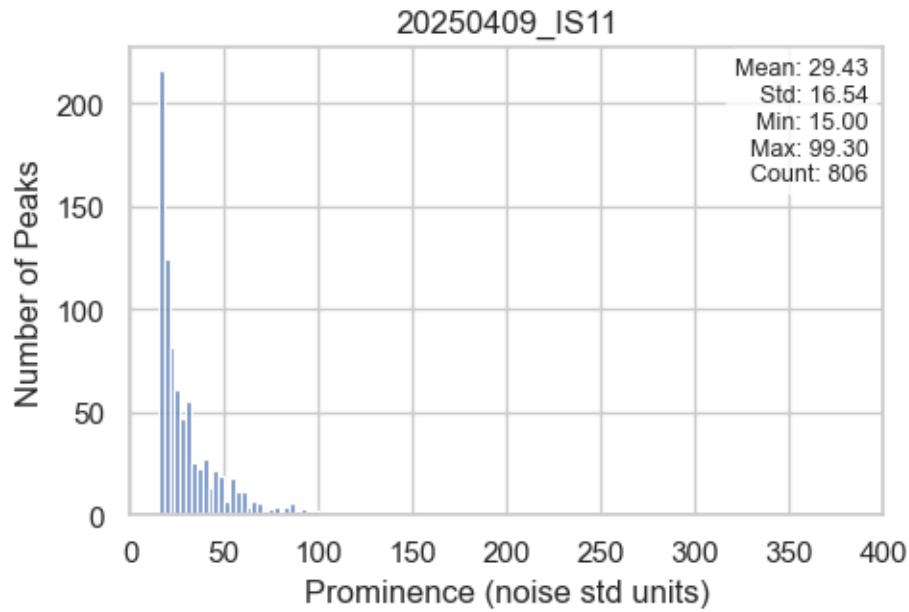
## Distribution of Peak Durations



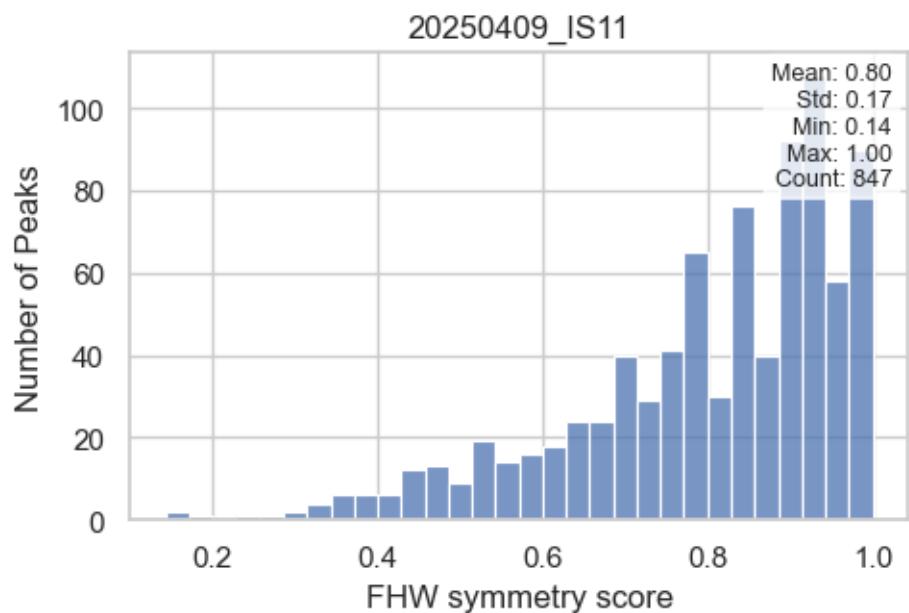
```
[2025-08-08 14:56:01] [INFO] calcium: Removed 41 outliers from dataset '20250409_IS11' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:56:01] [INFO] calcium: Lower bound: -12.925000000000008, Upper bound: 100.1000000000002
```

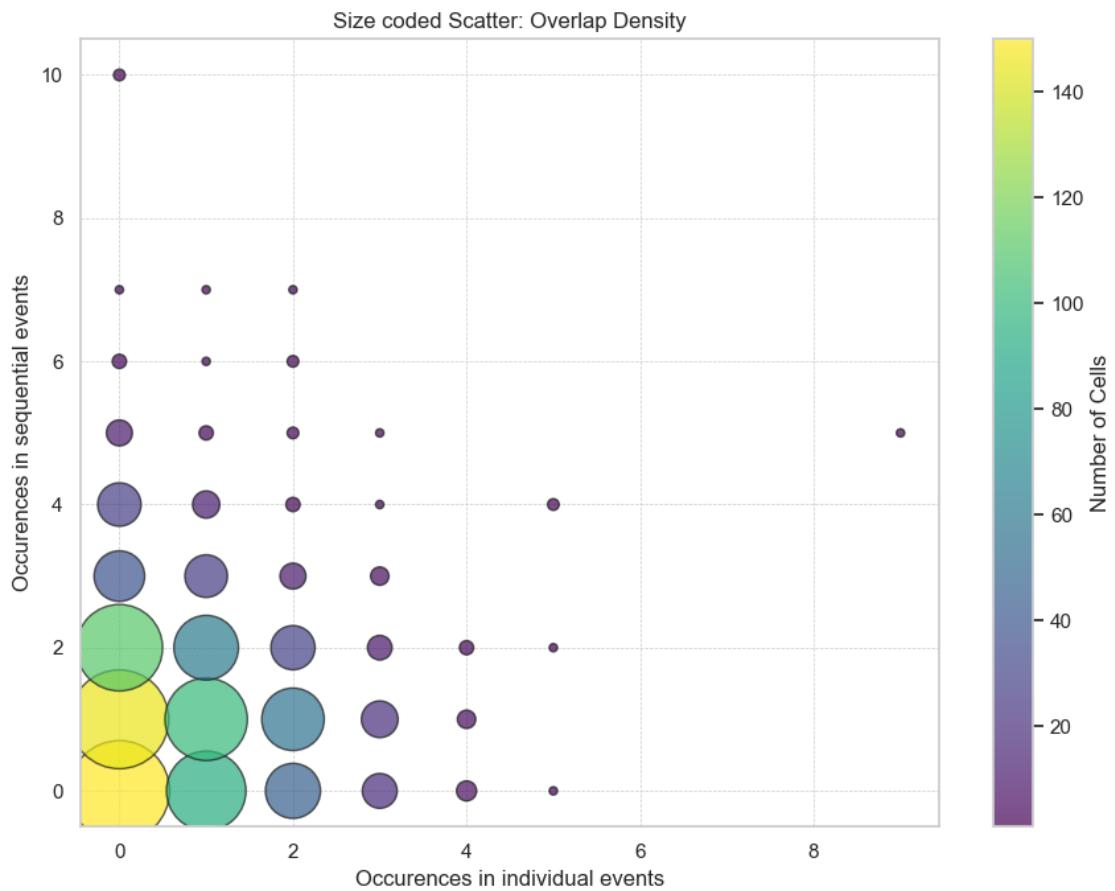
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

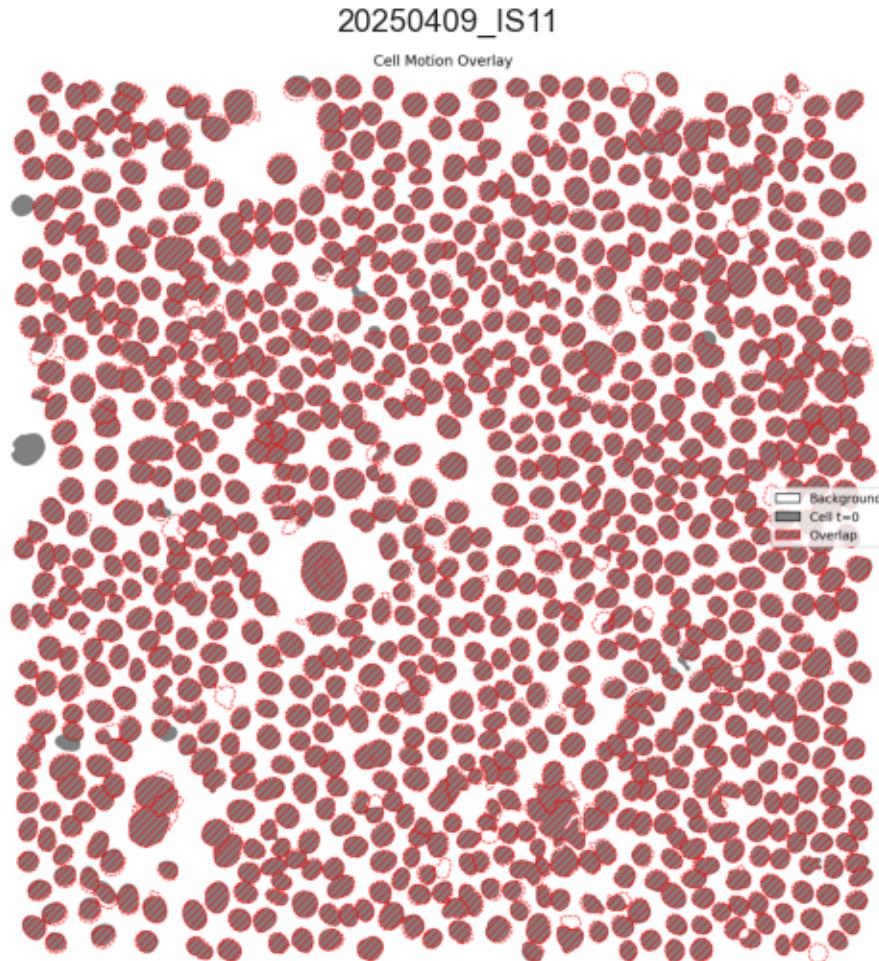


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 1011
- Hoechst image taken at t=1801: 1007
- Number of cells difference: absolute 4, relative 0.40%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1078456
- Pixels segmented as cell at t=1801: 1126020
- Overlapping pixels between t=0 and t=1801: 1020007 (92.54% of total)
- Pixels exclusive to t=0: 58449 (5.42% of total)
- Pixels exclusive to t=1801: 106013 (9.41% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n      "Default Dataset": "/path/to/your/dataset"\n}'
```

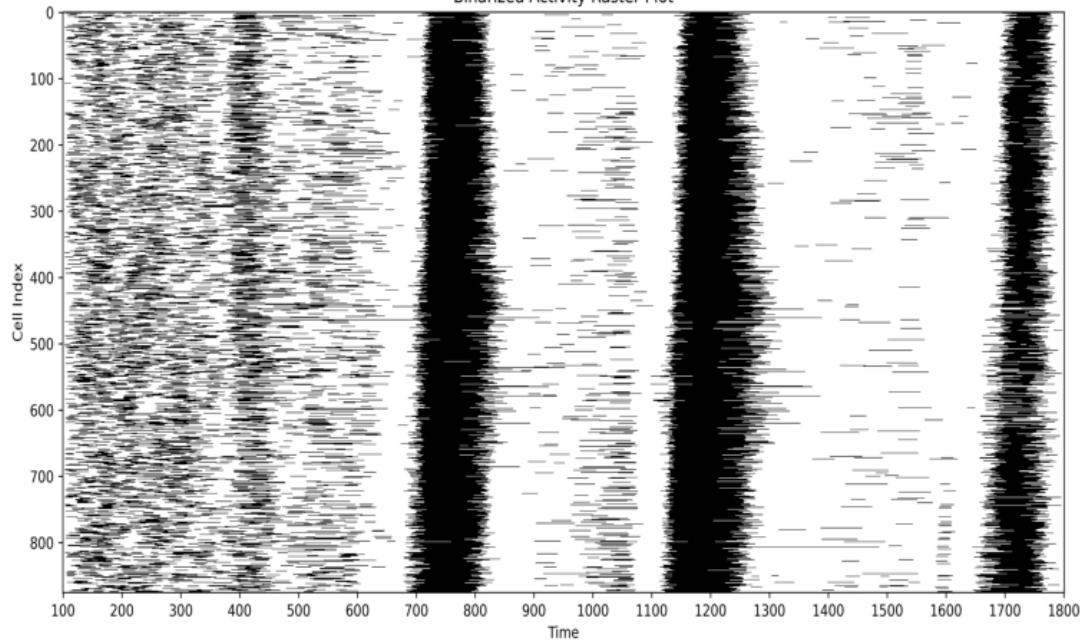
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

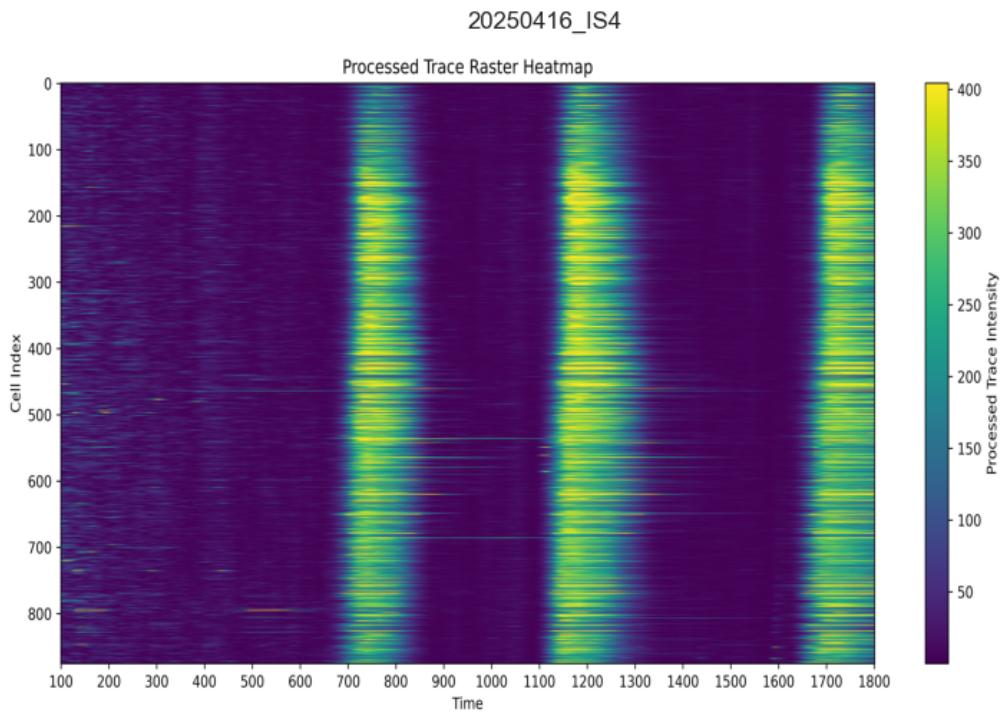
Binary Activity Raster Plot

20250416\_IS4

Binarized Activity Raster Plot



## Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 7049

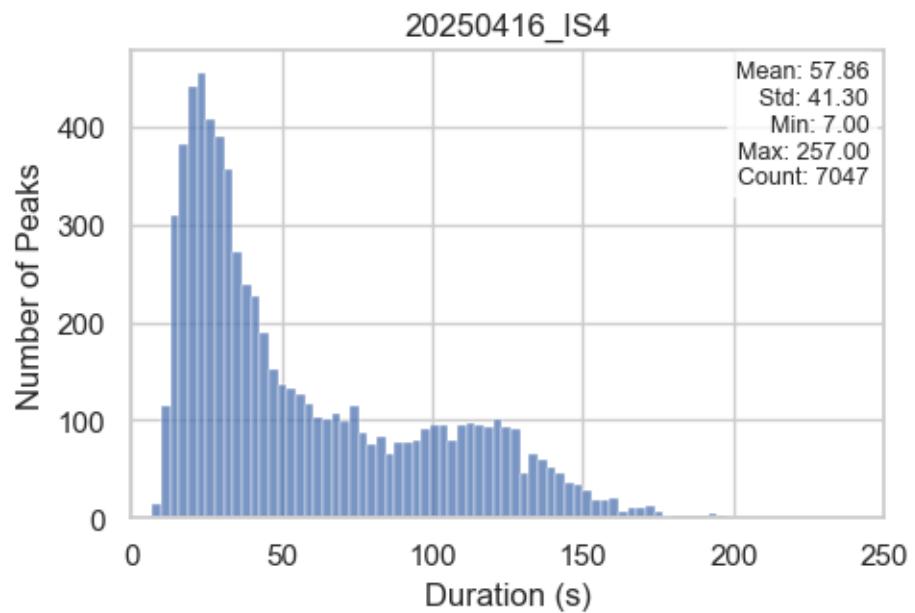
Total number of cells: 876

### 1.1.3 Peaks statistics

```
[2025-08-08 14:58:56] [INFO] calcium: Removed 2 outliers from dataset  
'20250416_IS4' for column 'Duration (s)'
```

```
[2025-08-08 14:58:56] [INFO] calcium: Lower bound: -68.0, Upper bound: 273.0
```

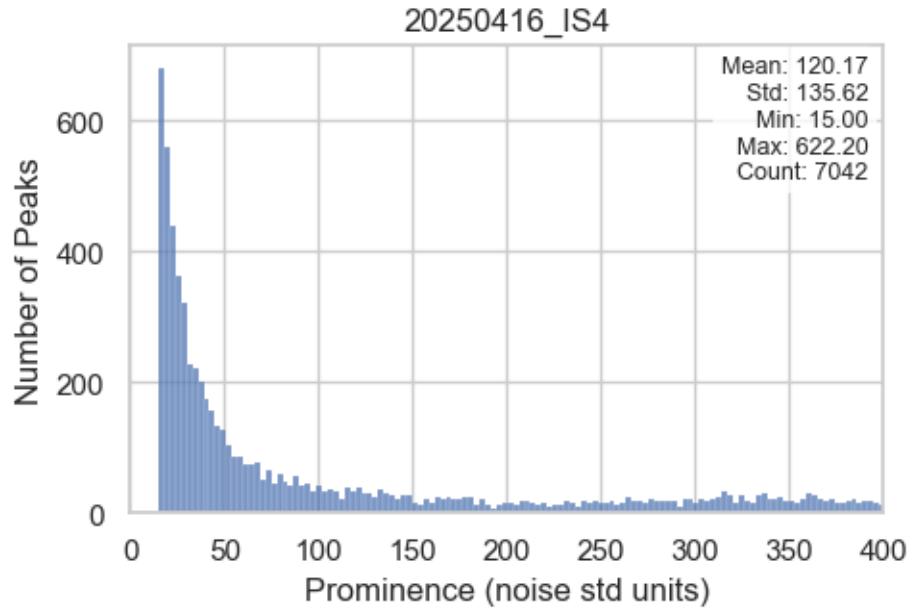
## Distribution of Peak Durations



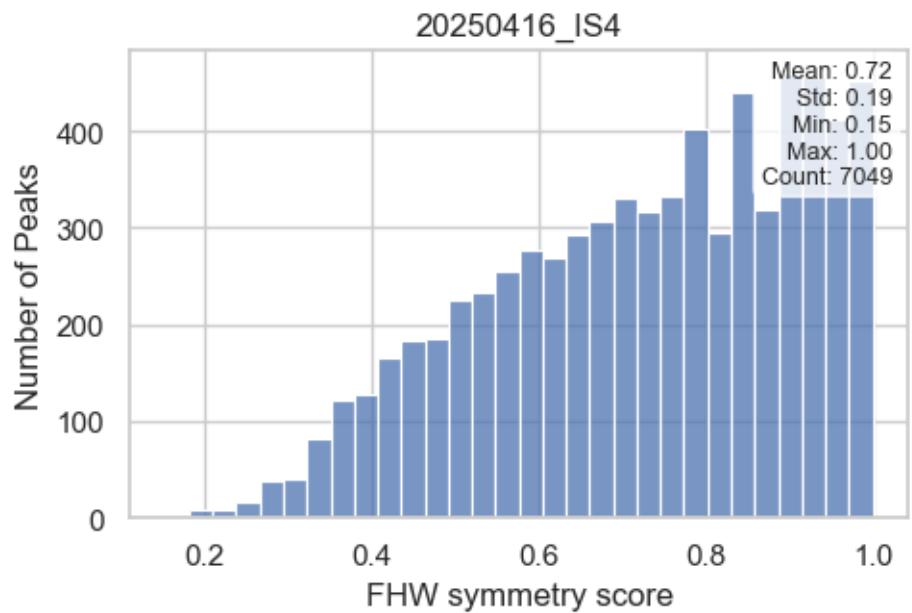
[2025-08-08 14:58:56] [INFO] calcium: Removed 7 outliers from dataset '20250416\_IS4' for column 'Prominence (noise std units)'

[2025-08-08 14:58:56] [INFO] calcium: Lower bound: -201.2999999999998, Upper bound: 627.0

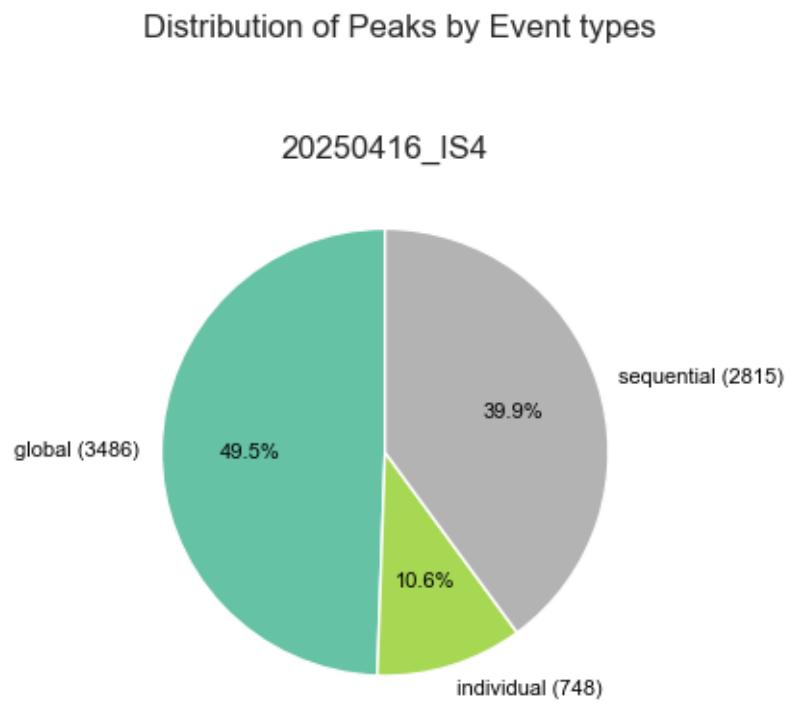
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

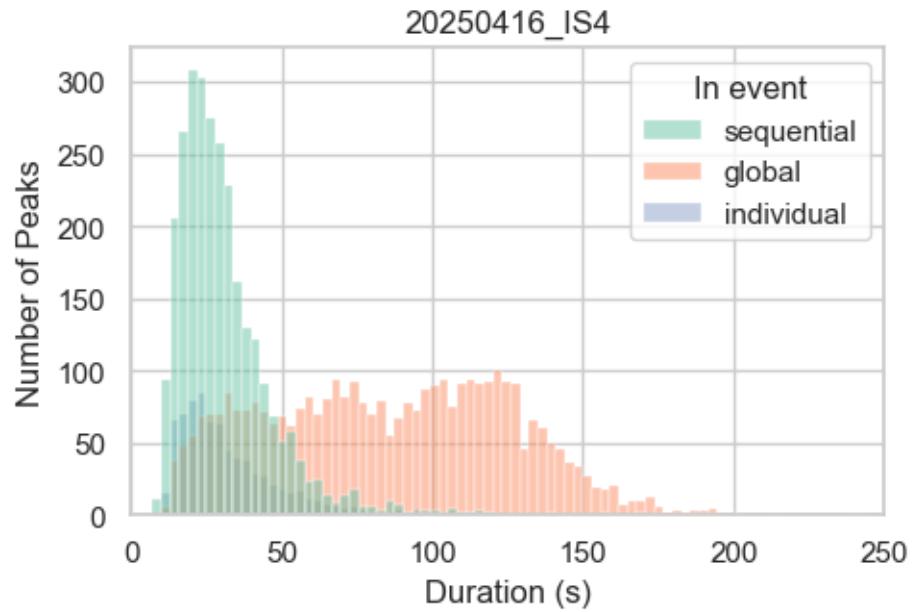


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 14:58:56] [INFO] calcium: Removed 2 outliers from dataset  
'20250416_IS4' for column 'Duration (s)'
```

```
[2025-08-08 14:58:56] [INFO] calcium: Lower bound: -68.0, Upper bound: 273.0
```

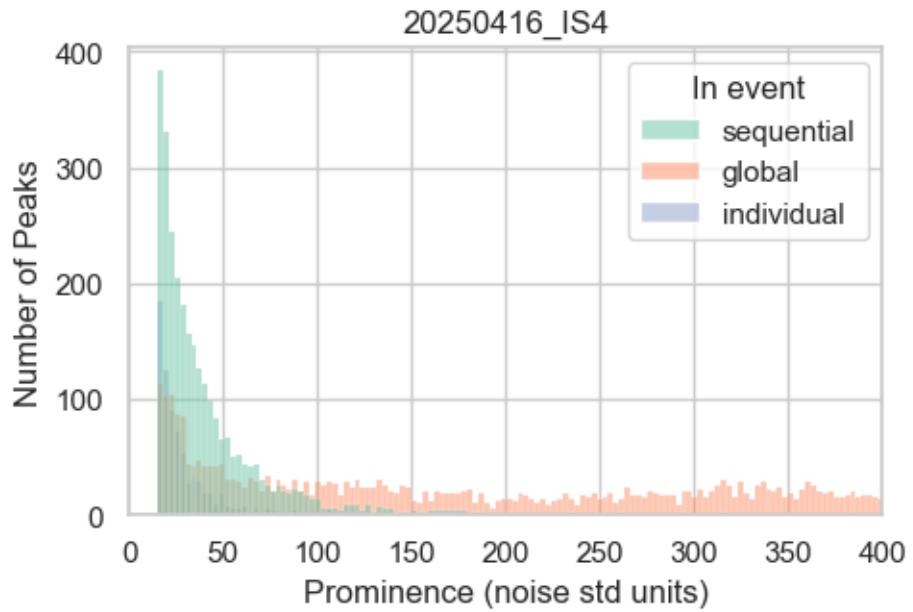
## Distribution of Peak Durations by Group



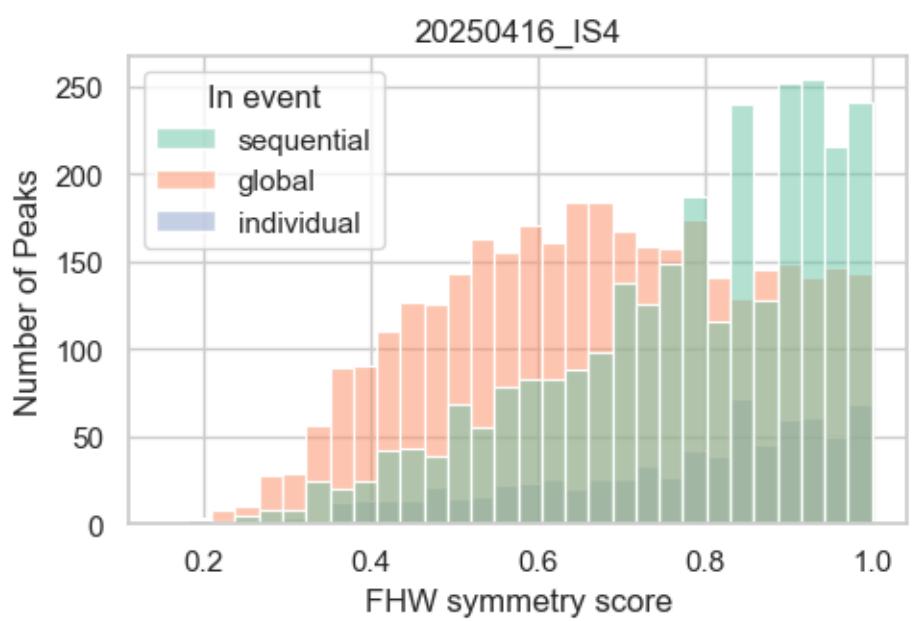
[2025-08-08 14:58:57] [INFO] calcium: Removed 7 outliers from dataset '20250416\_IS4' for column 'Prominence (noise std units)'

[2025-08-08 14:58:57] [INFO] calcium: Lower bound: -201.3, Upper bound: 627.0

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group

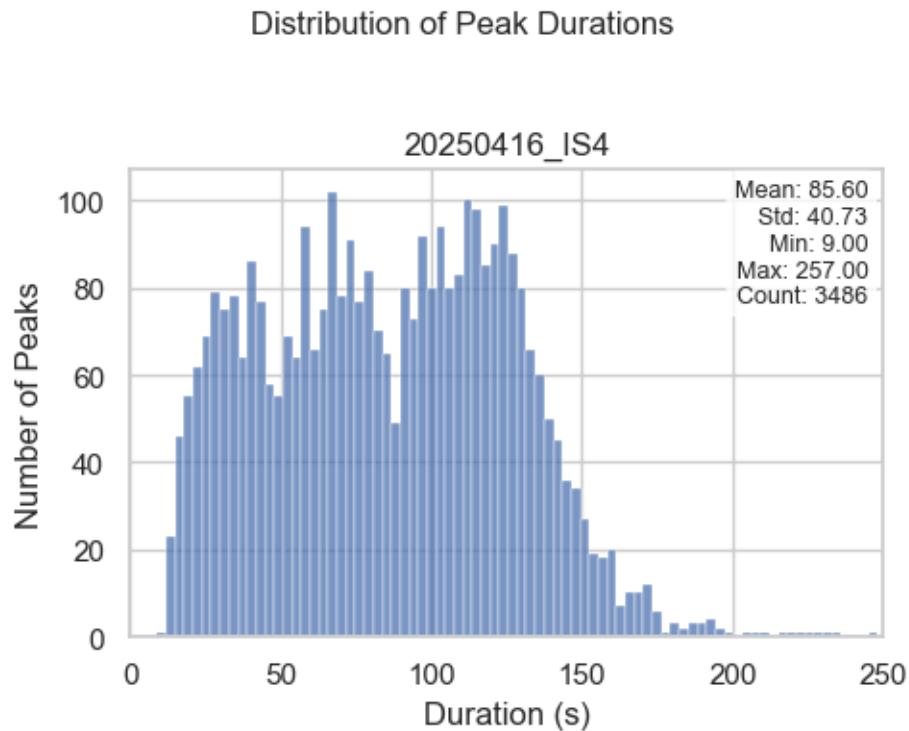


## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 14:58:57] [INFO] calcium: Removed 0 outliers from dataset  
'20250416_IS4' for column 'Duration (s)'
```

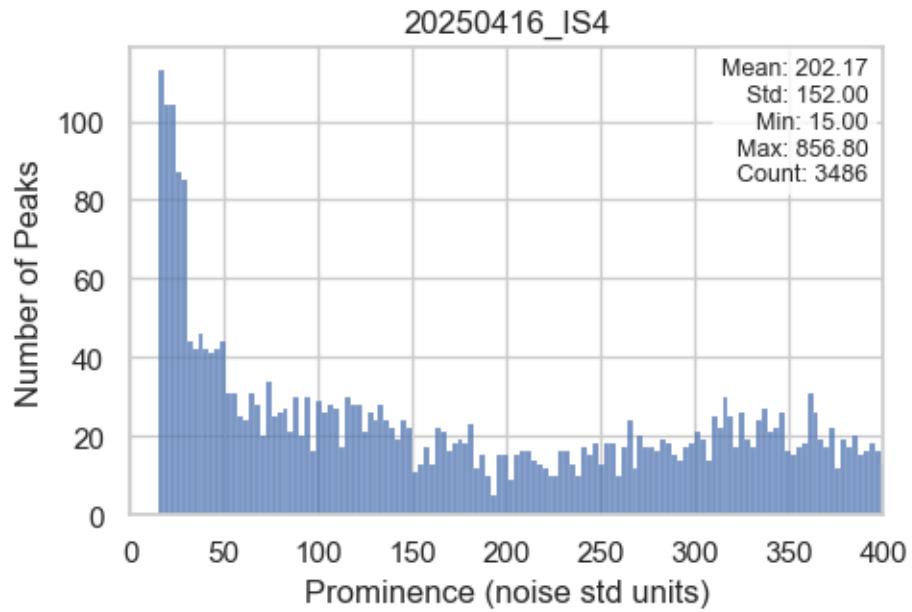
```
[2025-08-08 14:58:57] [INFO] calcium: Lower bound: -46.625, Upper bound: 315.0
```



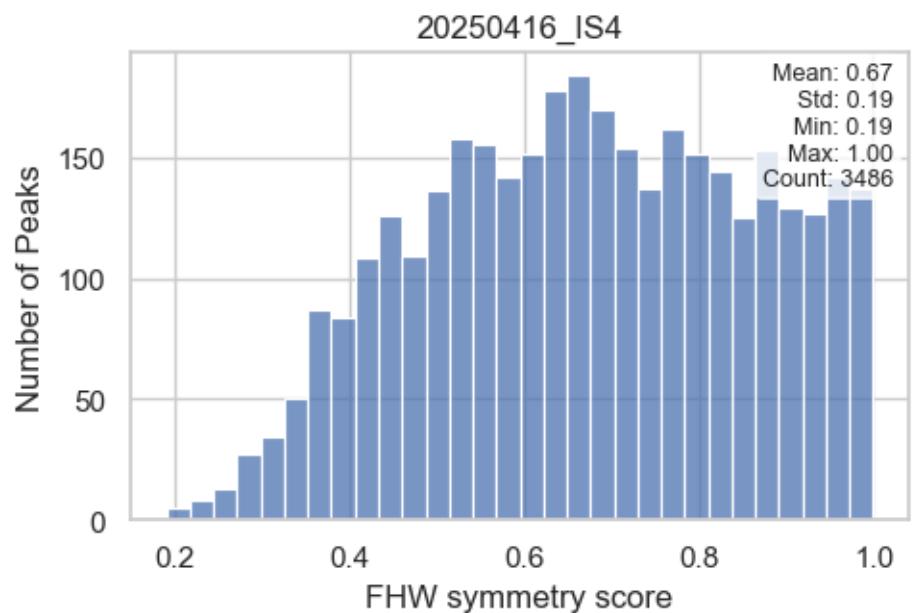
```
[2025-08-08 14:58:58] [INFO] calcium: Removed 0 outliers from dataset  
'20250416_IS4' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:58:58] [INFO] calcium: Lower bound: -346.3125, Upper bound:  
1138.0
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

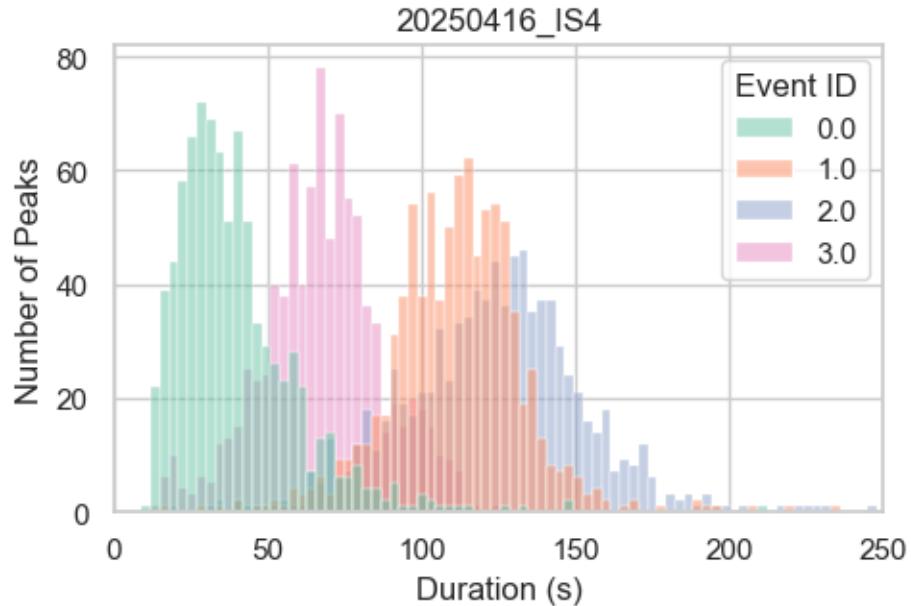


### 1.2.2 Peak statistics in global event per event ID

[2025-08-08 14:58:58] [INFO] calcium: Removed 0 outliers from dataset '20250416\_IS4' for column 'Duration (s)'

[2025-08-08 14:58:58] [INFO] calcium: Lower bound: -46.6, Upper bound: 315.0

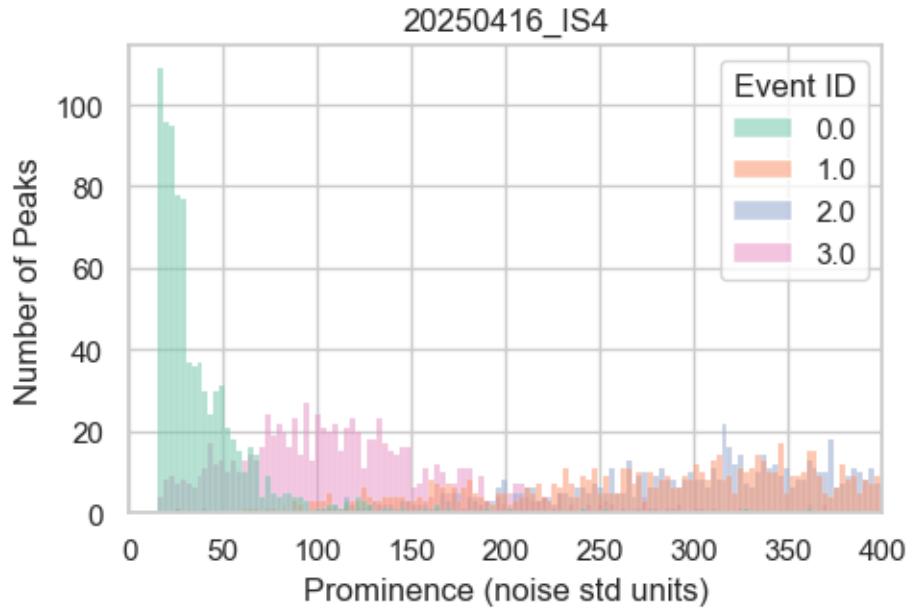
Distribution of Peak Durations by Group



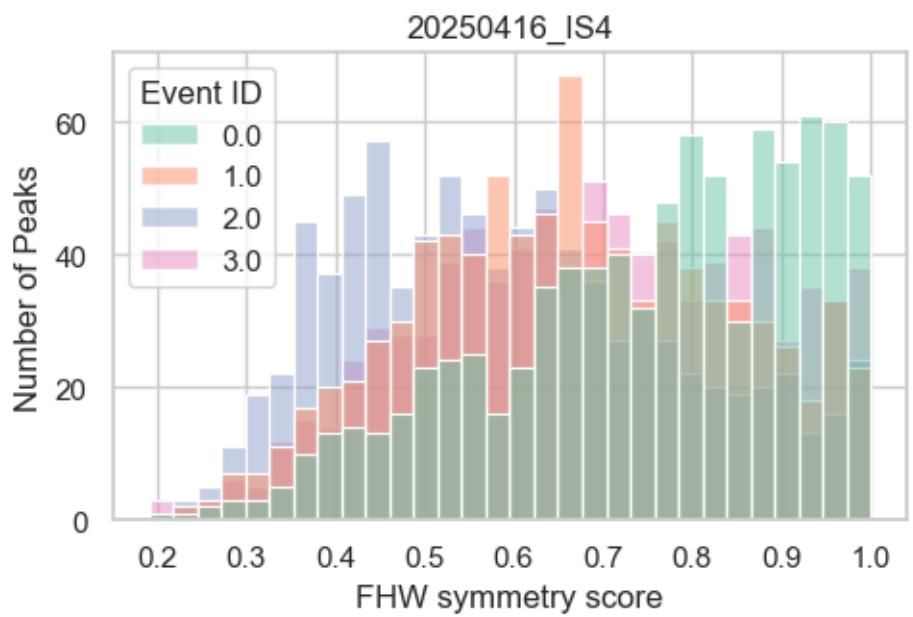
[2025-08-08 14:58:58] [INFO] calcium: Removed 0 outliers from dataset '20250416\_IS4' for column 'Prominence (noise std units)'

[2025-08-08 14:58:58] [INFO] calcium: Lower bound: -346.3, Upper bound: 1138.0

### Distribution of Peak Prominences by Group



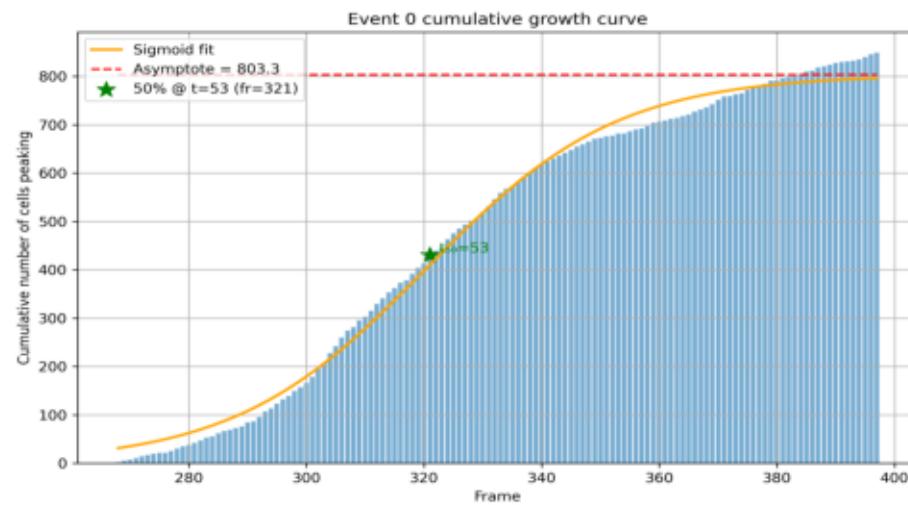
### Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

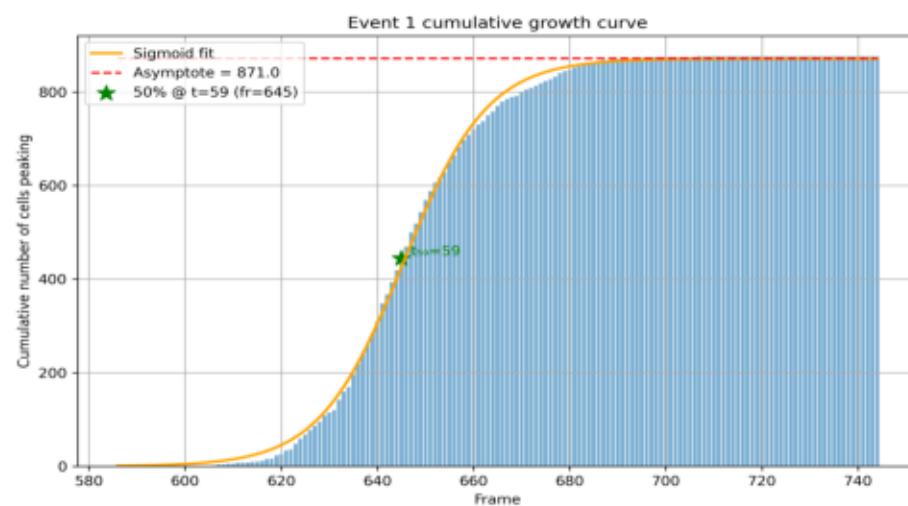
Event Activity Overlay (Event ID: 0)

20250416\_IS4



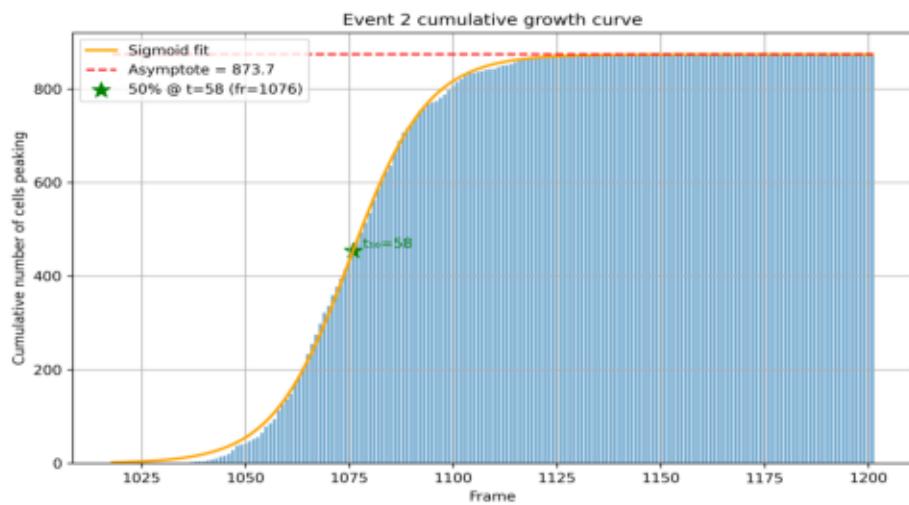
Event Activity Overlay (Event ID: 1)

20250416\_IS4



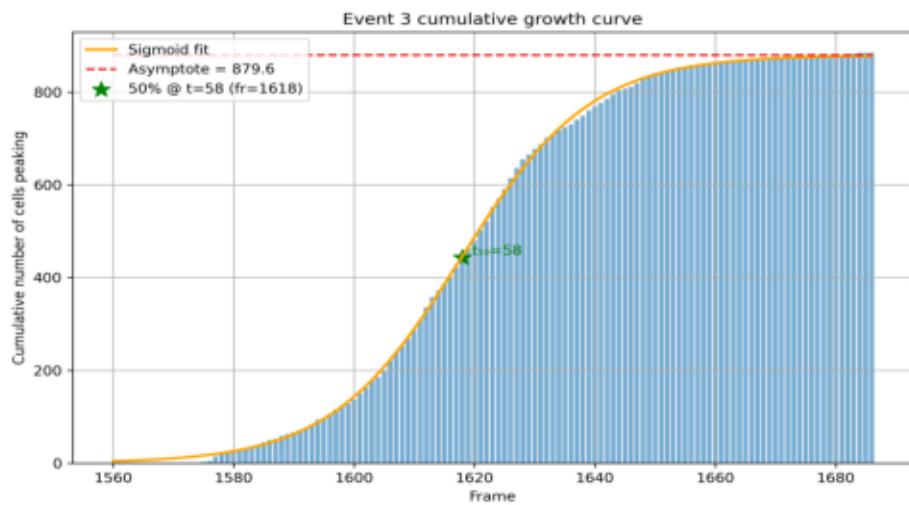
### Event Activity Overlay (Event ID: 2)

20250416\_IS4



### Event Activity Overlay (Event ID: 3)

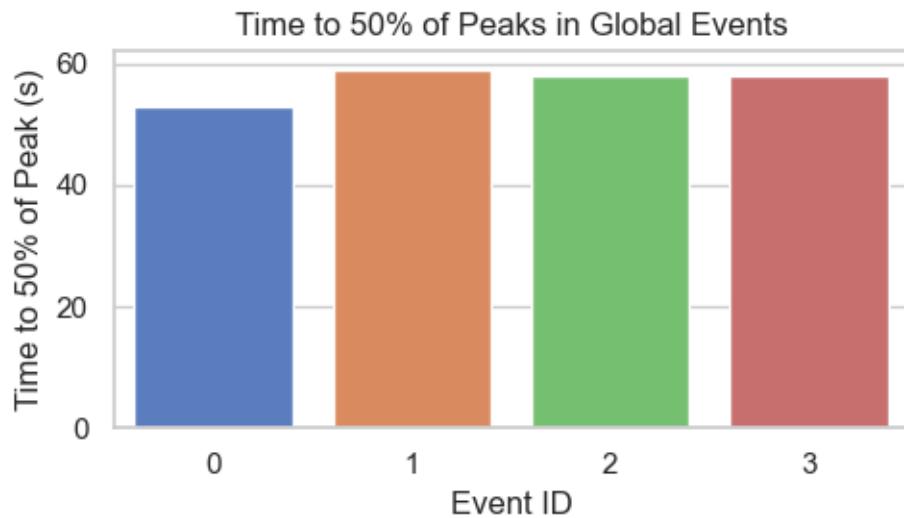
20250416\_IS4



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

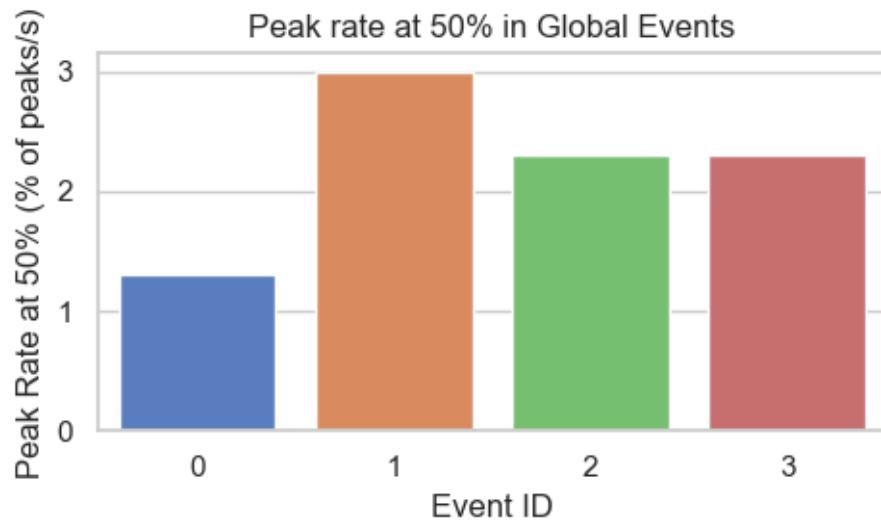
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

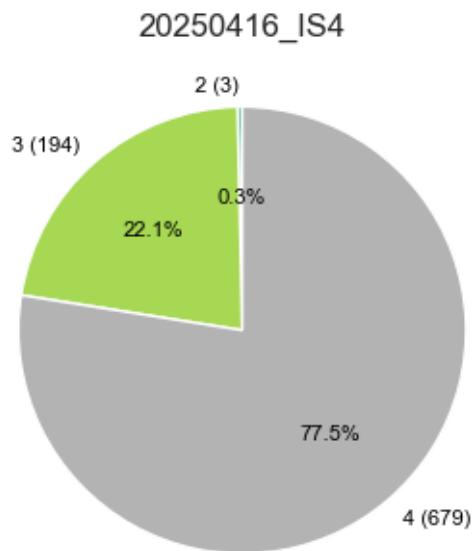
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



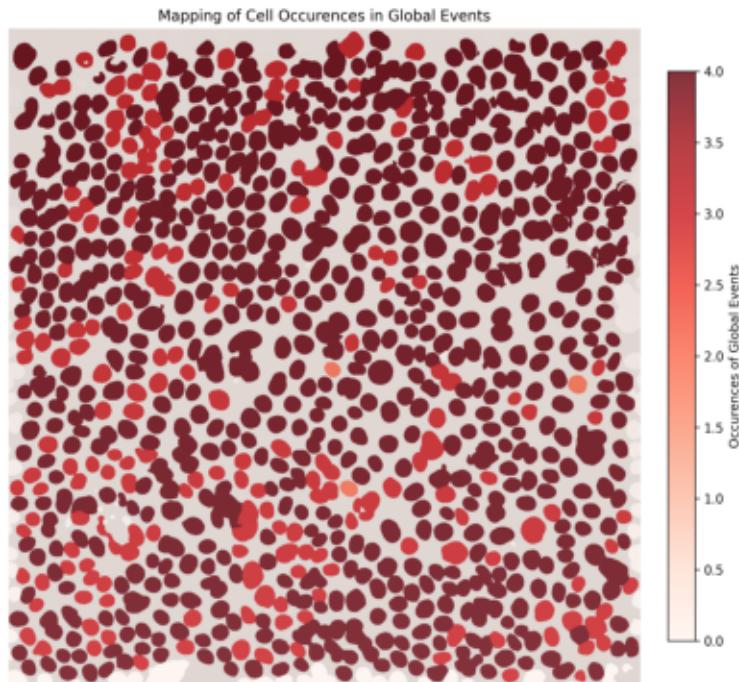
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

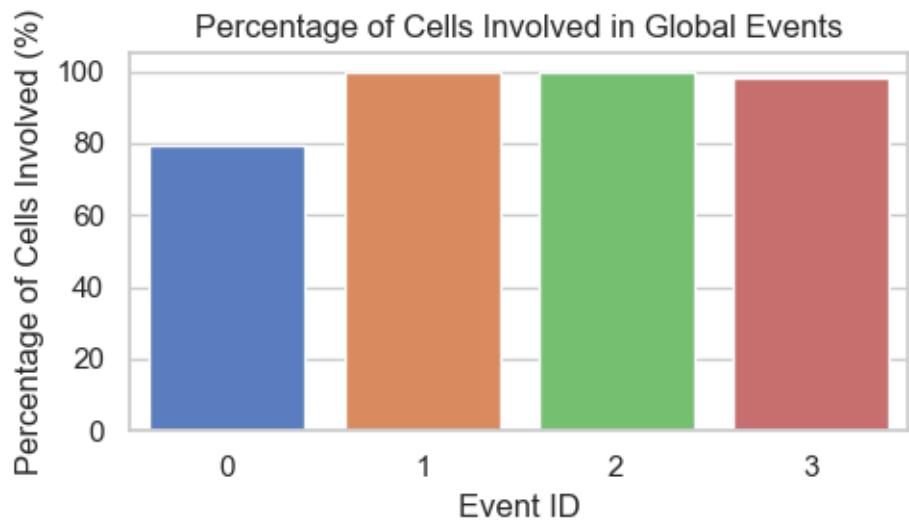
20250416\_IS4



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [343.0, 428.0, 540.0]

Estimated periodicity: 0.844

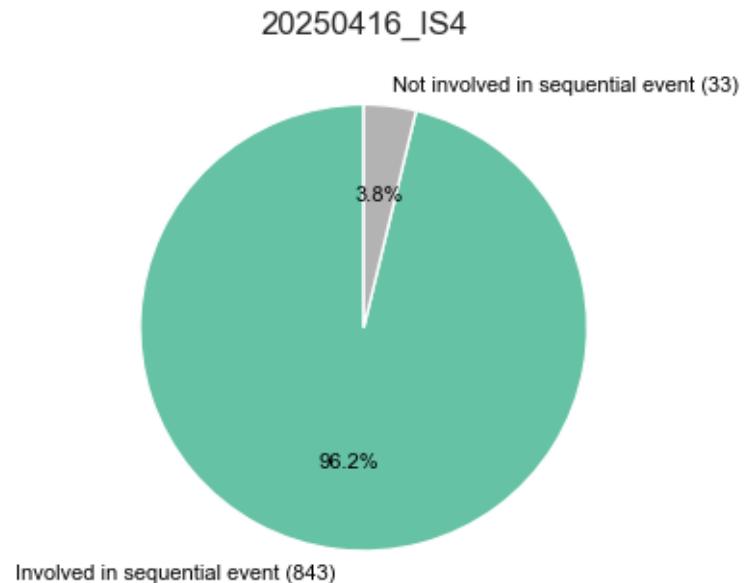
The global events exhibit a regular periodic pattern.

Estimated frequency (1/mean interval): 0.002 Hz

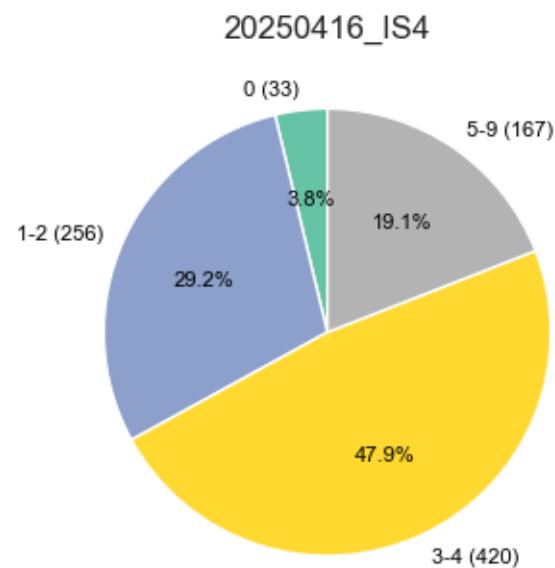
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

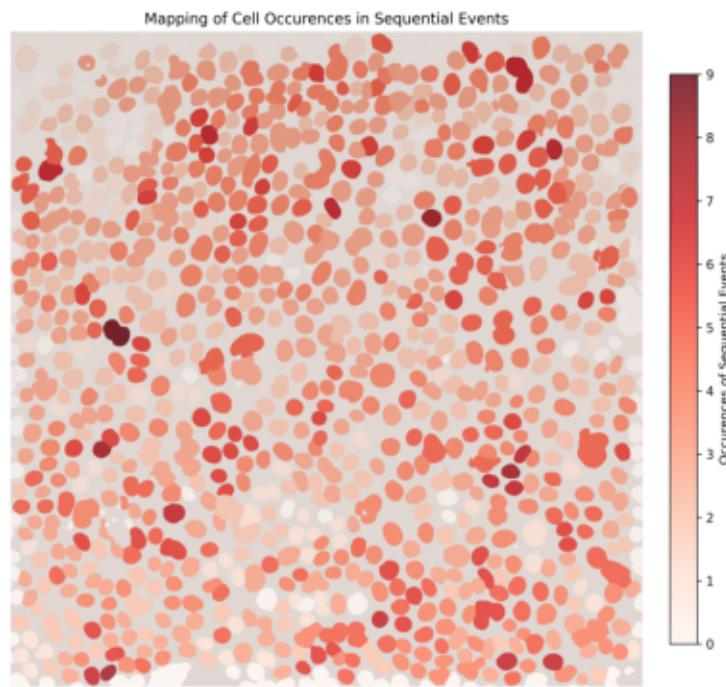


### Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250416\_IS4

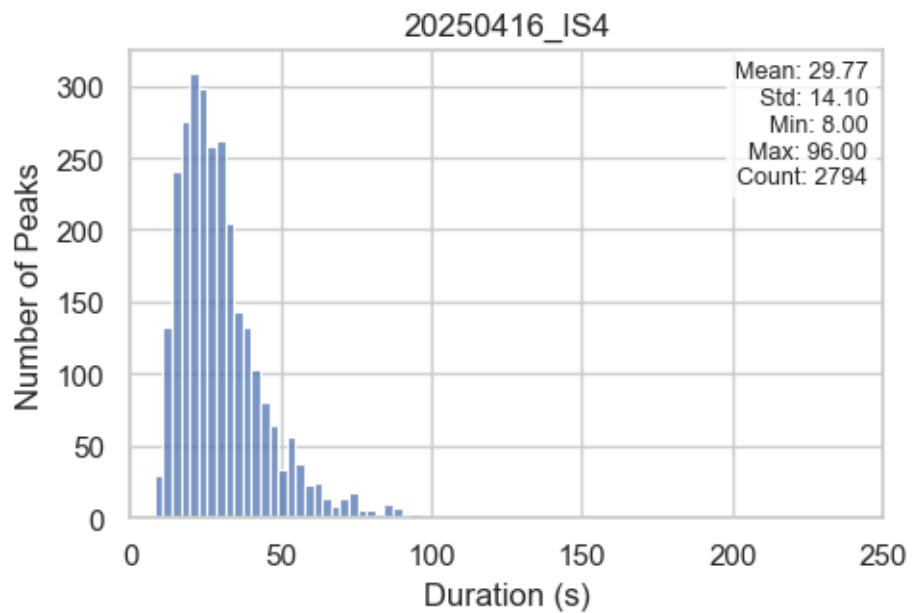


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 14:59:04] [INFO] calcium: Removed 21 outliers from dataset  
'20250416_IS4' for column 'Duration (s)'
```

```
[2025-08-08 14:59:04] [INFO] calcium: Lower bound: -5.5, Upper bound: 96.5
```

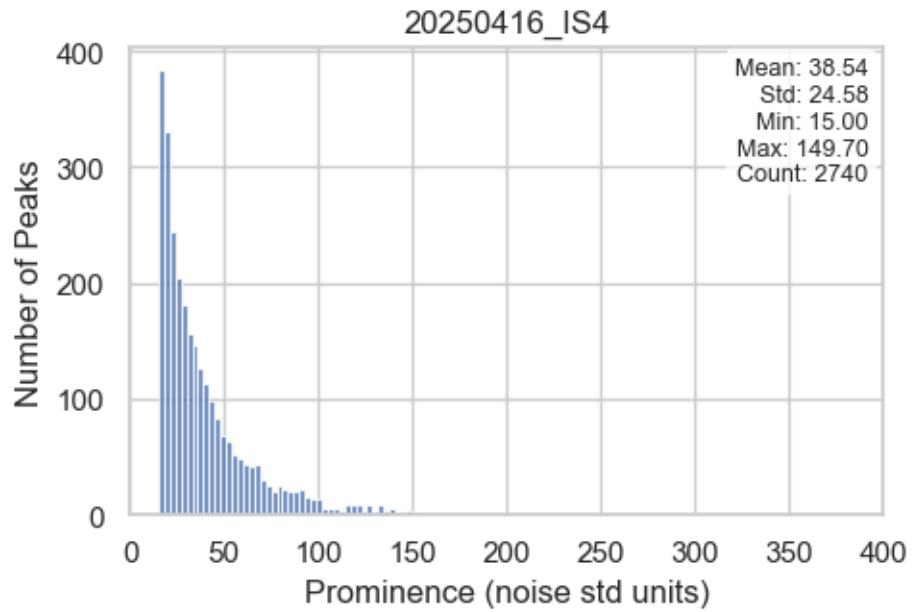
## Distribution of Peak Durations



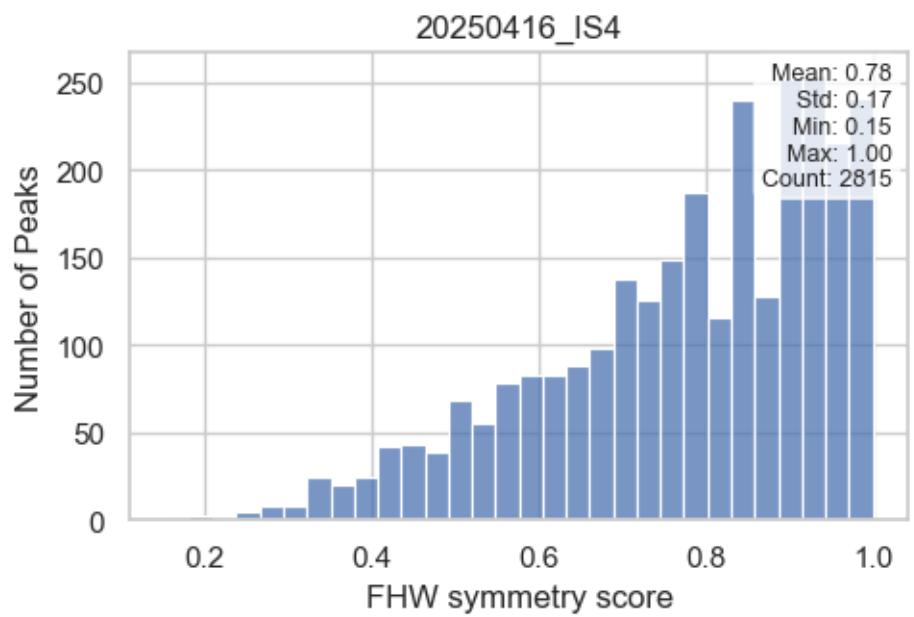
[2025-08-08 14:59:04] [INFO] calcium: Removed 75 outliers from dataset '20250416\_IS4' for column 'Prominence (noise std units)'

[2025-08-08 14:59:04] [INFO] calcium: Lower bound: -22.07499999999996, Upper bound: 149.825

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

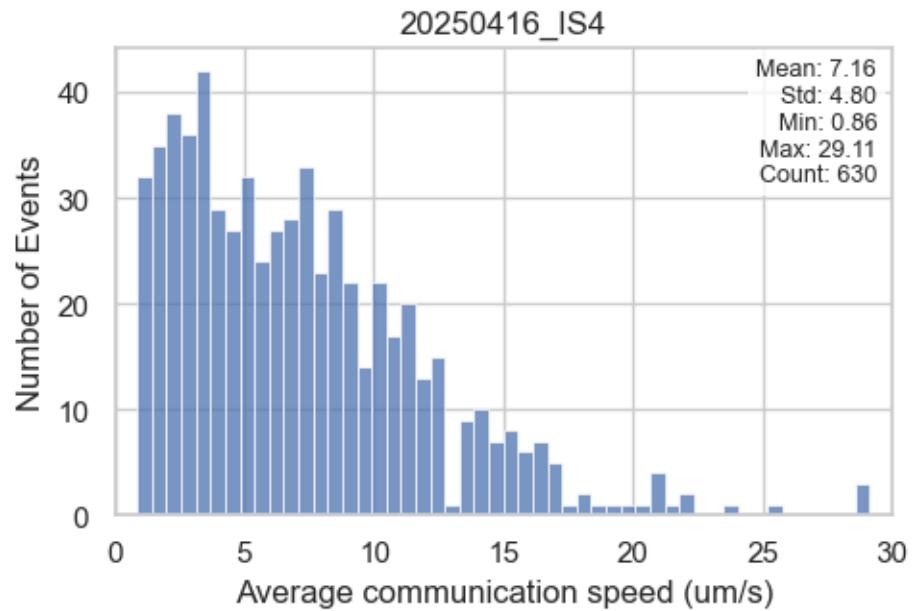


### 1.3.3 Cell-cell communication speed

[2025-08-08 14:59:05] [INFO] calcium: Removed 0 outliers from dataset '20250416\_IS4' for column 'Average communication speed (um/s)'

[2025-08-08 14:59:05] [INFO] calcium: Lower bound: -6.562500000000001, Upper bound: 29.792500000000004

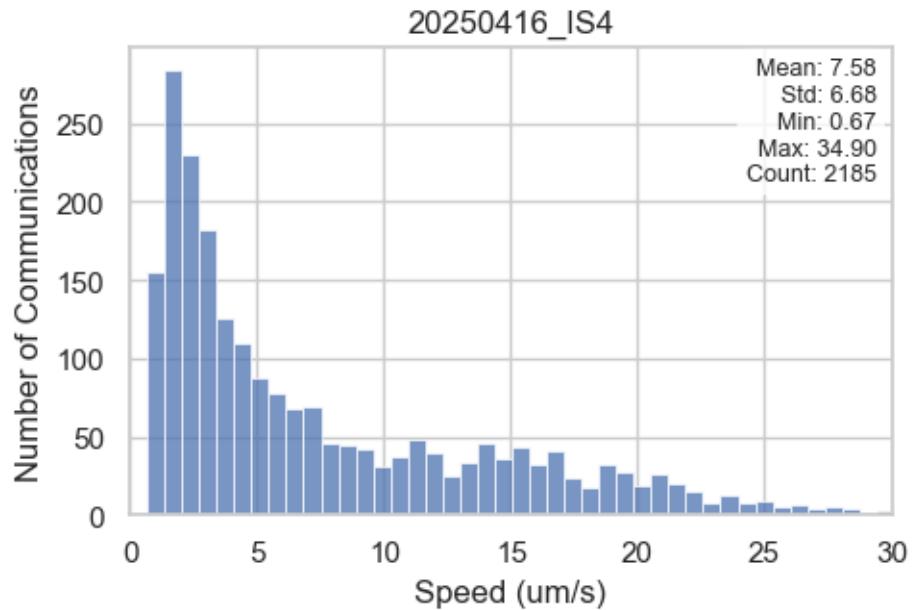
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 14:59:05] [INFO] calcium: Removed 0 outliers from dataset '20250416\_IS4' for column 'Speed (um/s)'

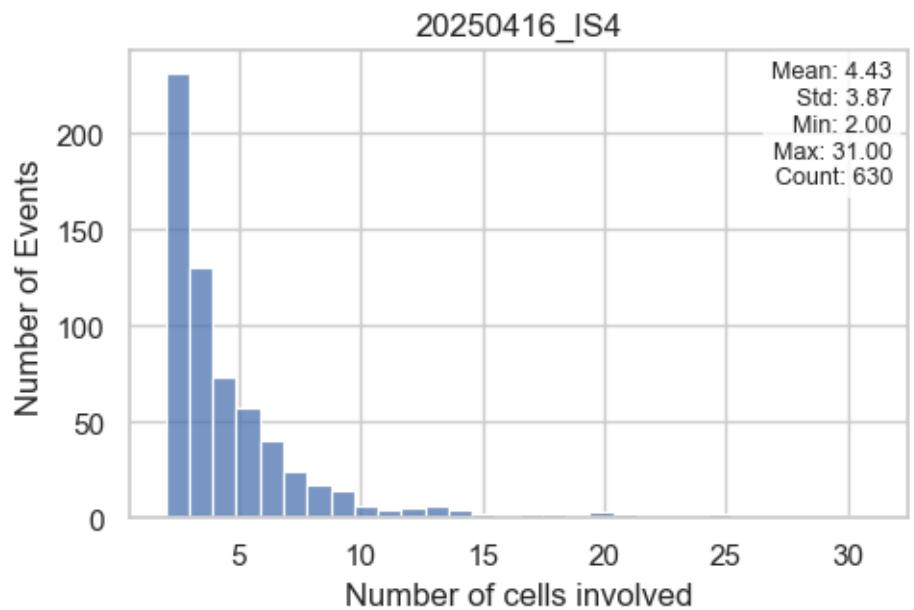
[2025-08-08 14:59:05] [INFO] calcium: Lower bound: -11.685, Upper bound: 39.63

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

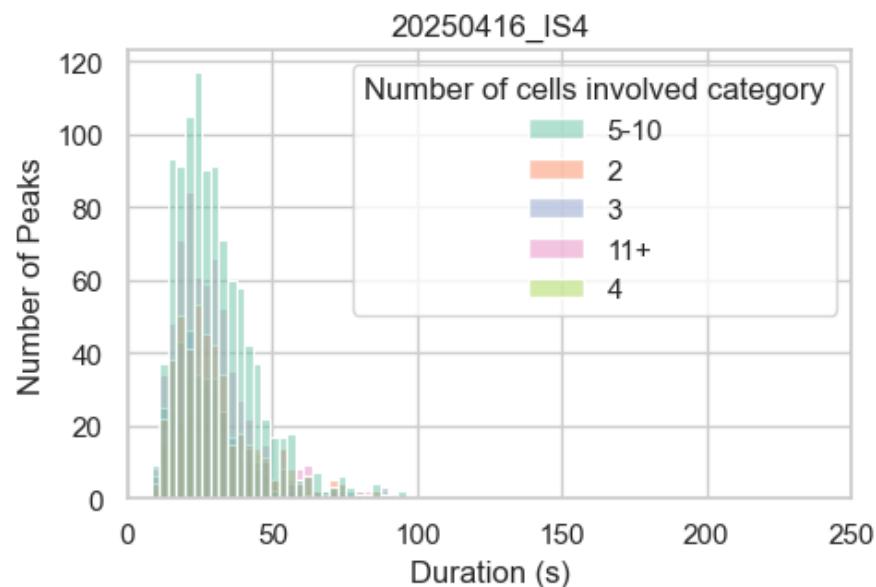


### 1.3.5 Influence of cell count per event on statistics

```
[2025-08-08 14:59:05] [INFO] calcium: Removed 21 outliers from dataset  
'20250416_IS4' for column 'Duration (s)'
```

```
[2025-08-08 14:59:05] [INFO] calcium: Lower bound: -5.5, Upper bound: 96.5
```

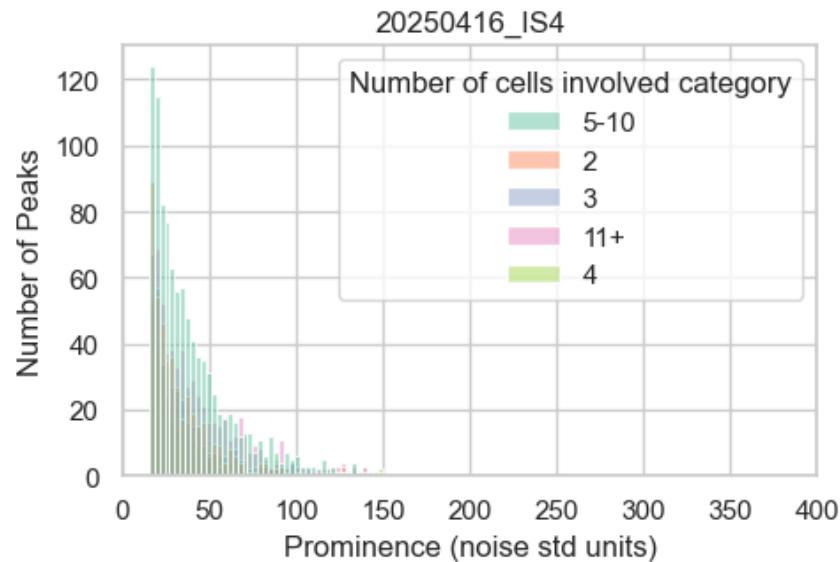
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



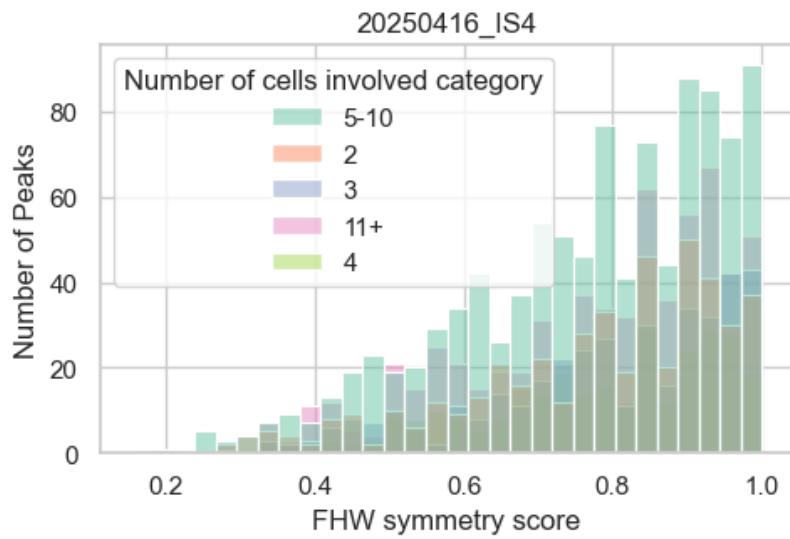
```
[2025-08-08 14:59:05] [INFO] calcium: Removed 75 outliers from dataset  
'20250416_IS4' for column 'Prominence (noise std units)'
```

```
[2025-08-08 14:59:05] [INFO] calcium: Lower bound: -22.1, Upper bound: 149.8
```

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



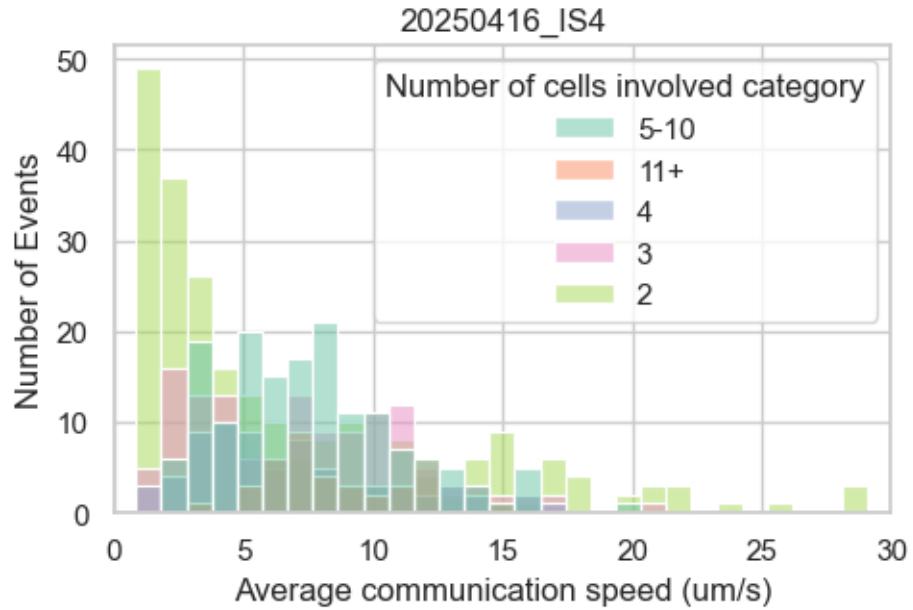
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



[2025-08-08 14:59:06] [INFO] calcium: Removed 0 outliers from dataset '20250416\_IS4' for column 'Average communication speed (um/s)'

[2025-08-08 14:59:06] [INFO] calcium: Lower bound: -6.6, Upper bound: 29.8

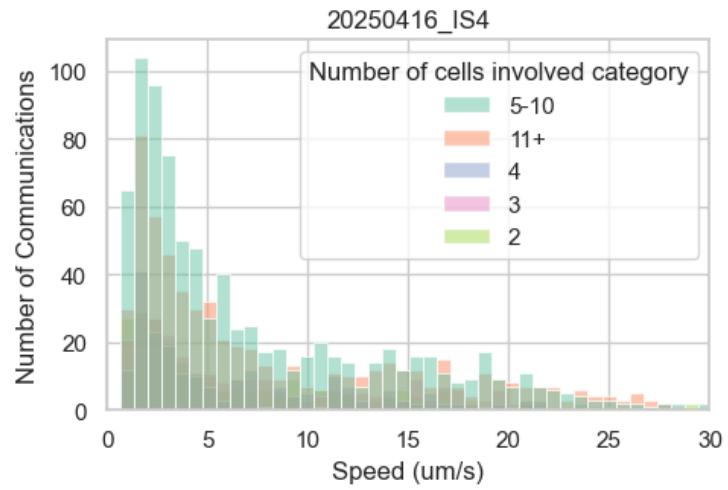
## Distribution of Average Communication Speeds by Number of Cells Involved



```
[2025-08-08 14:59:06] [INFO] calcium: Removed 0 outliers from dataset '20250416_IS4' for column 'Speed (um/s)'
```

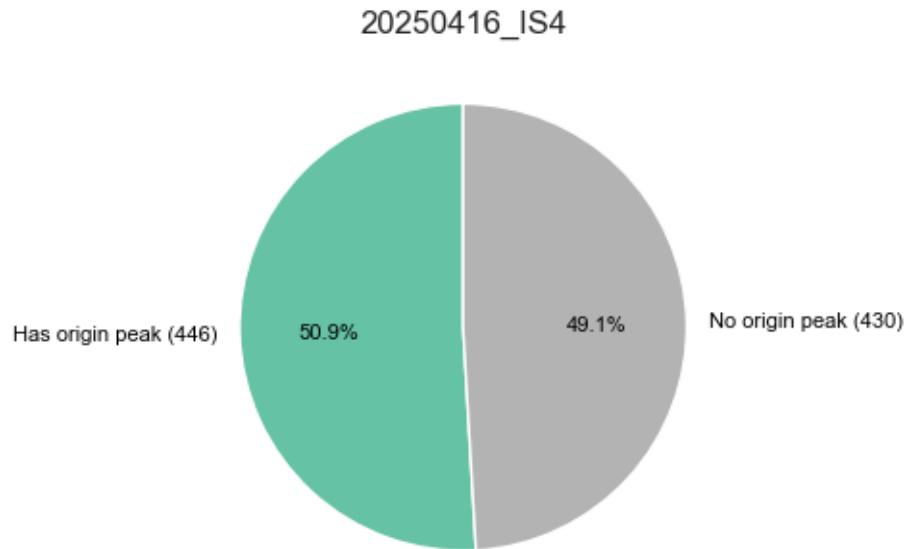
```
[2025-08-08 14:59:06] [INFO] calcium: Lower bound: -11.7, Upper bound: 39.6
```

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

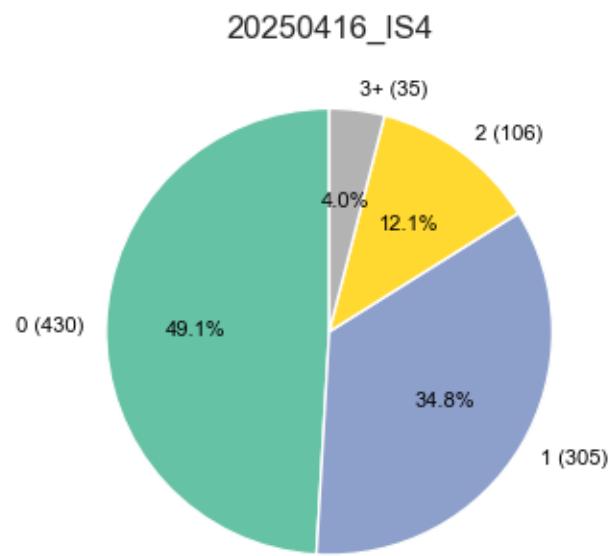


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

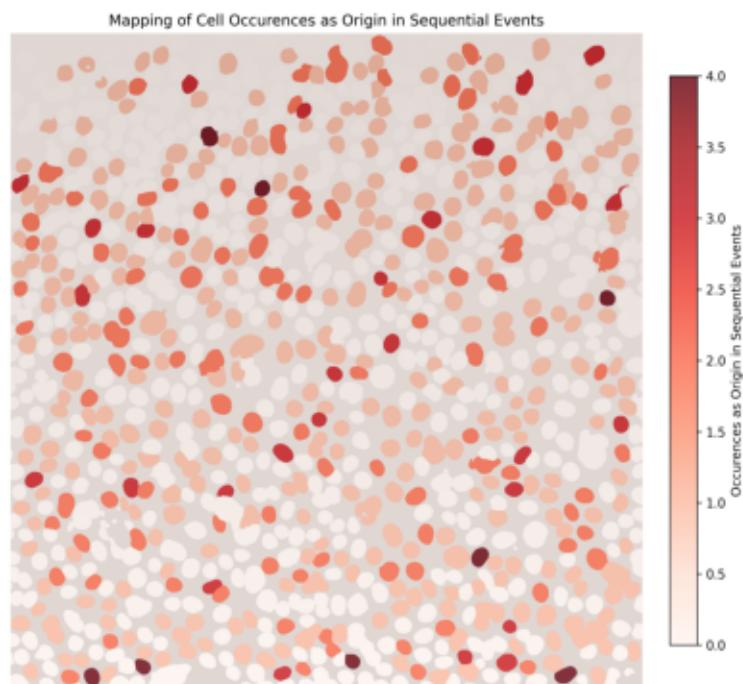


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

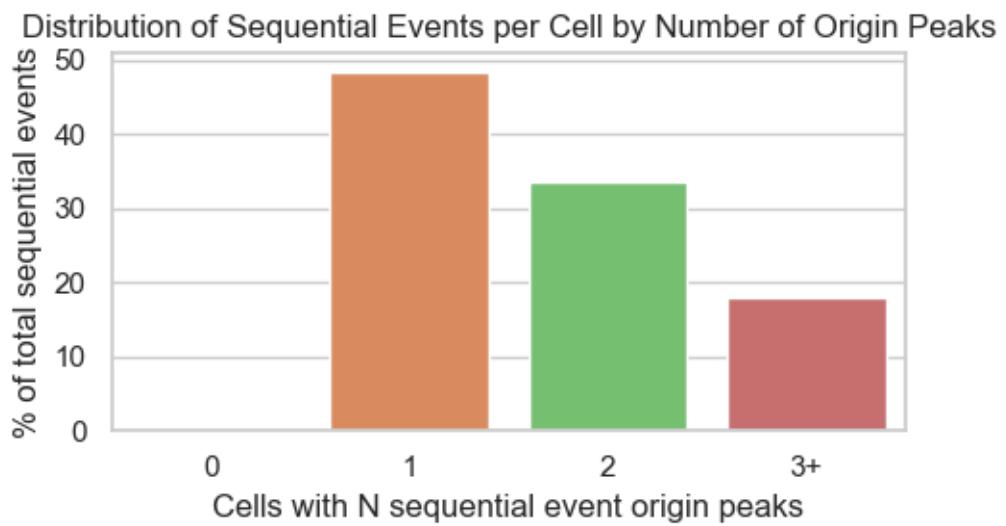
20250416\_IS4



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

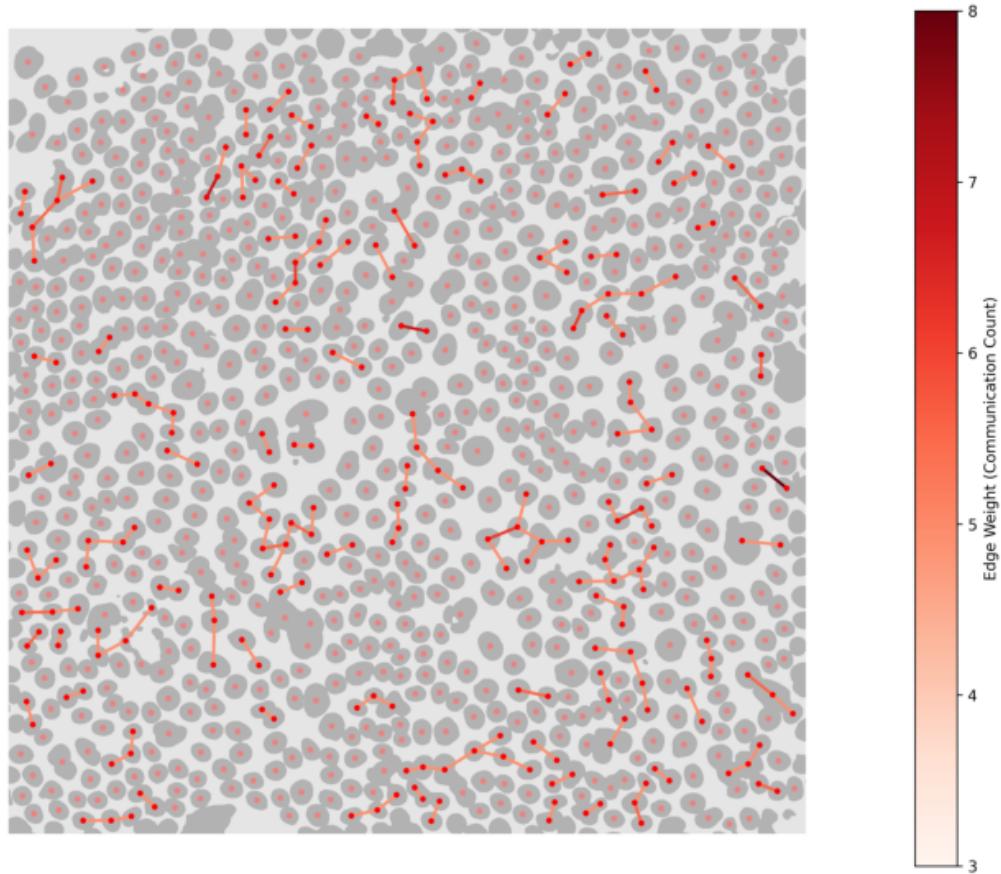


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250416\_IS4

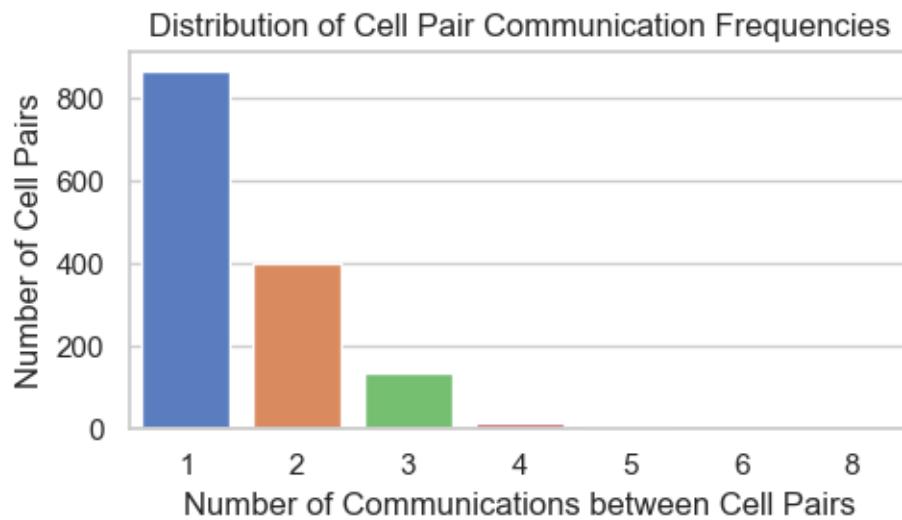
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

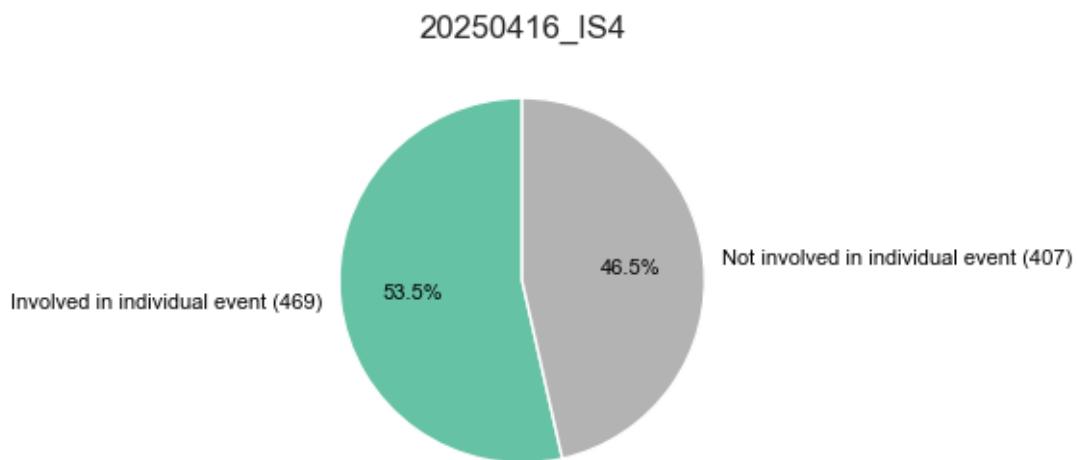
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



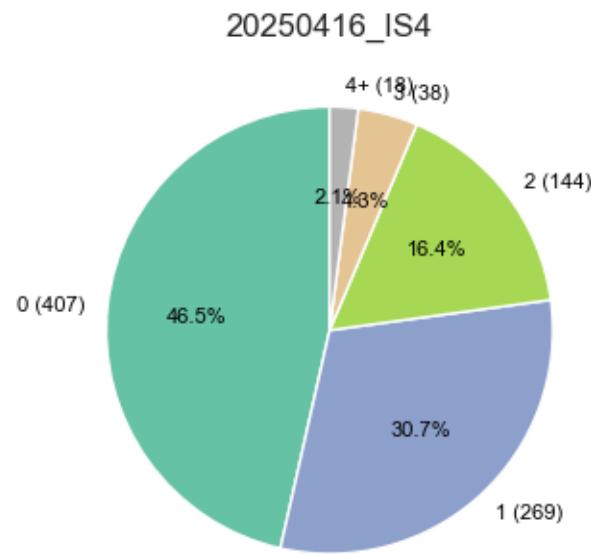
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

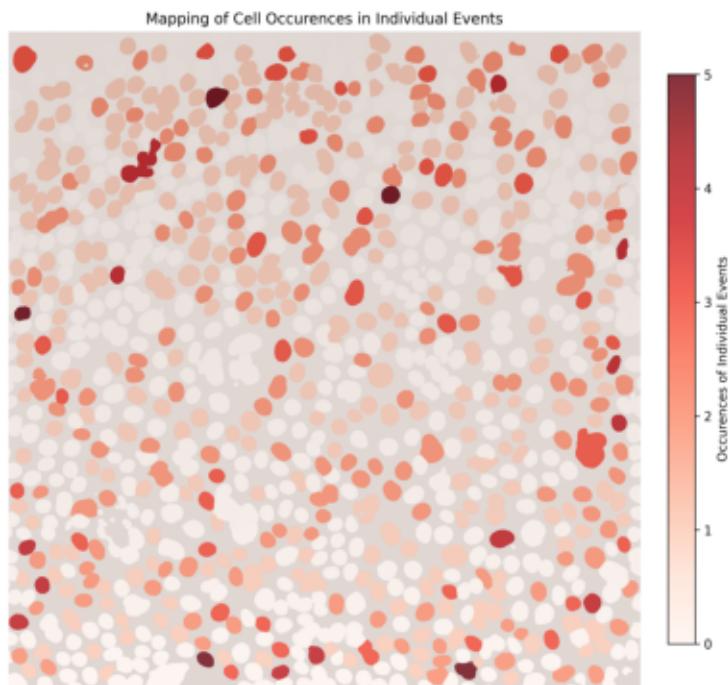


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250416\_IS4

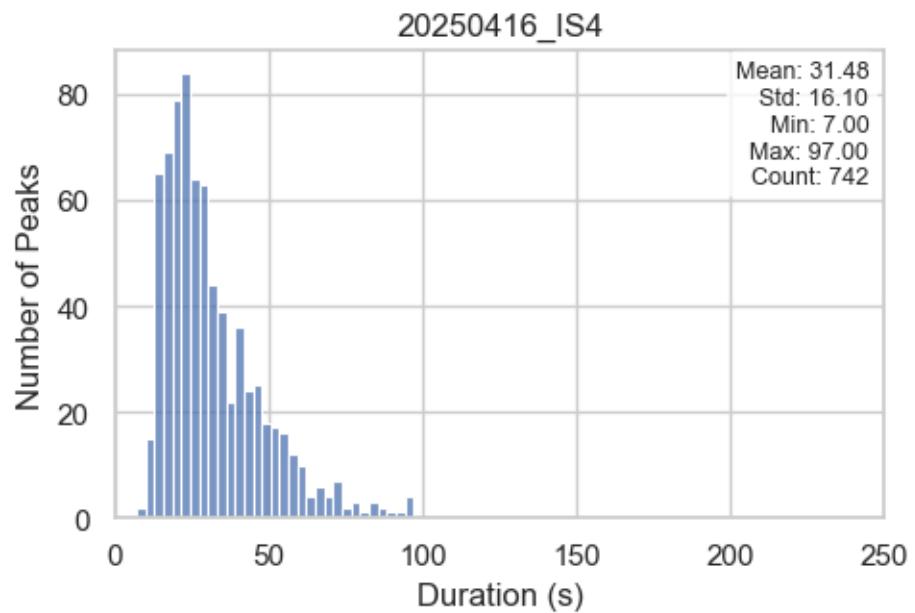


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 14:59:10] [INFO] calcium: Removed 6 outliers from dataset  
'20250416_IS4' for column 'Duration (s)'
```

```
[2025-08-08 14:59:10] [INFO] calcium: Lower bound: -8.875, Upper bound: 97.0
```

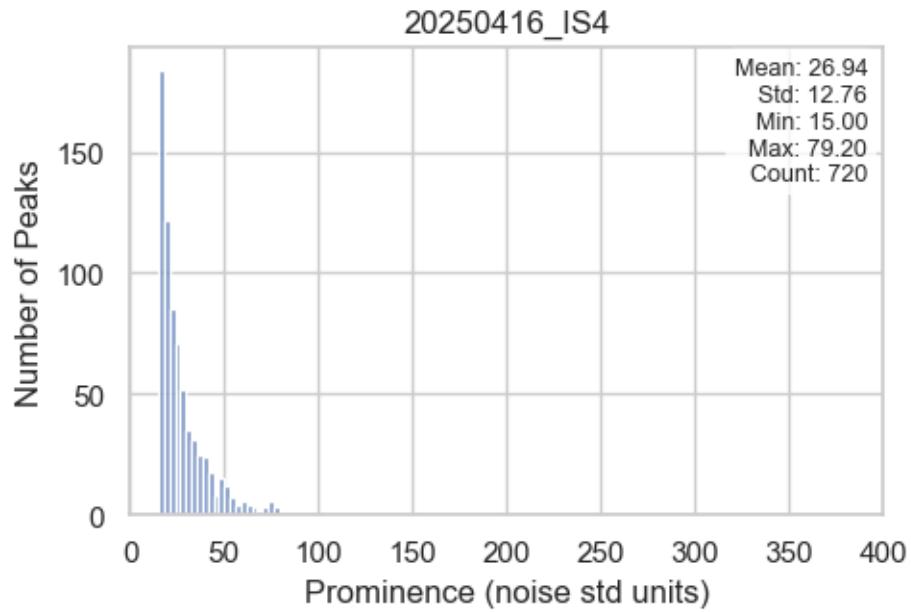
## Distribution of Peak Durations



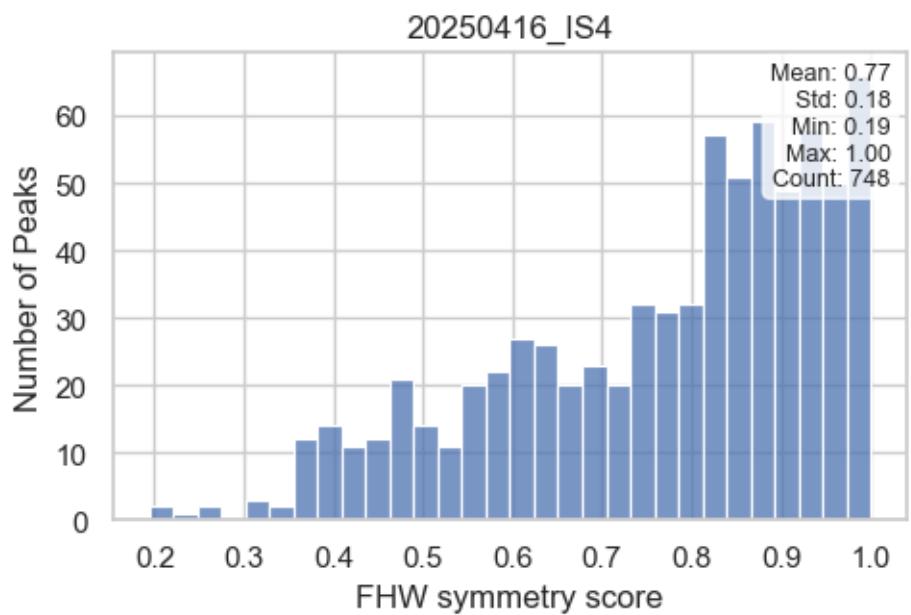
[2025-08-08 14:59:10] [INFO] calcium: Removed 28 outliers from dataset '20250416\_IS4' for column 'Prominence (noise std units)'

[2025-08-08 14:59:10] [INFO] calcium: Lower bound: -4.987499999999997, Upper bound: 79.575

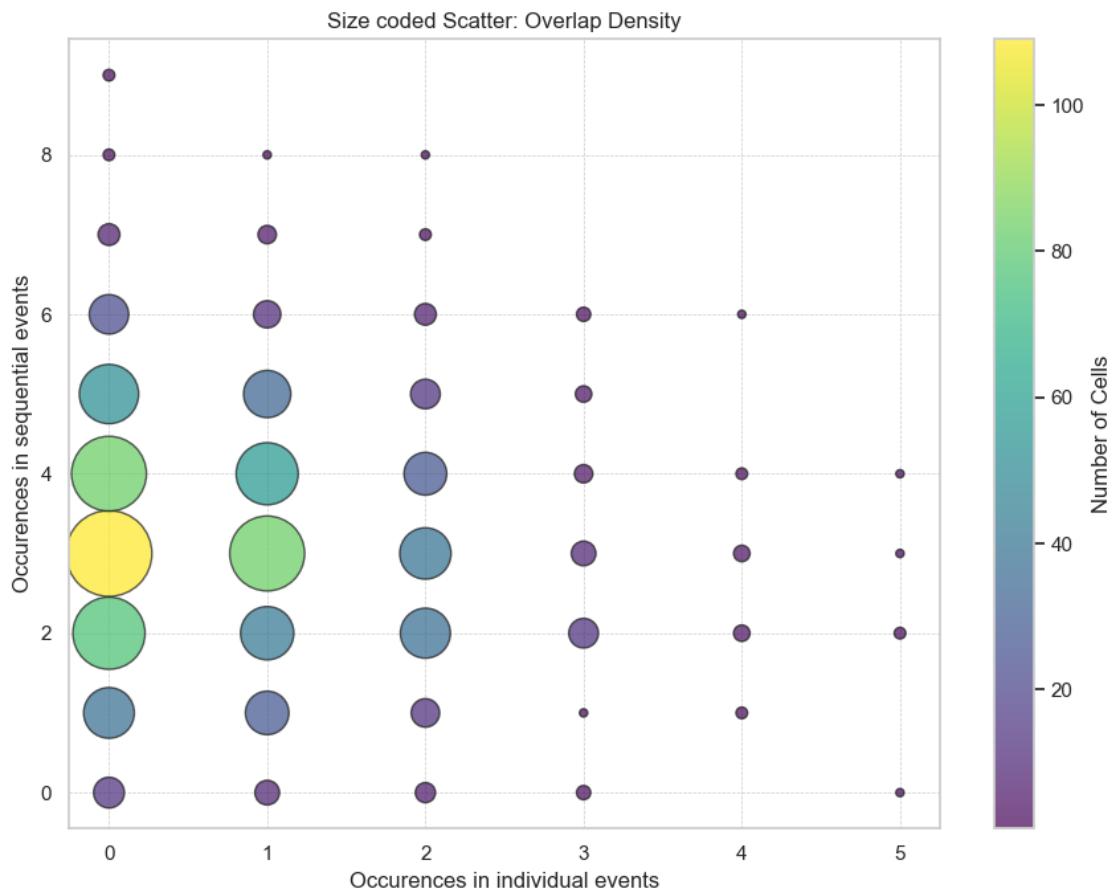
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

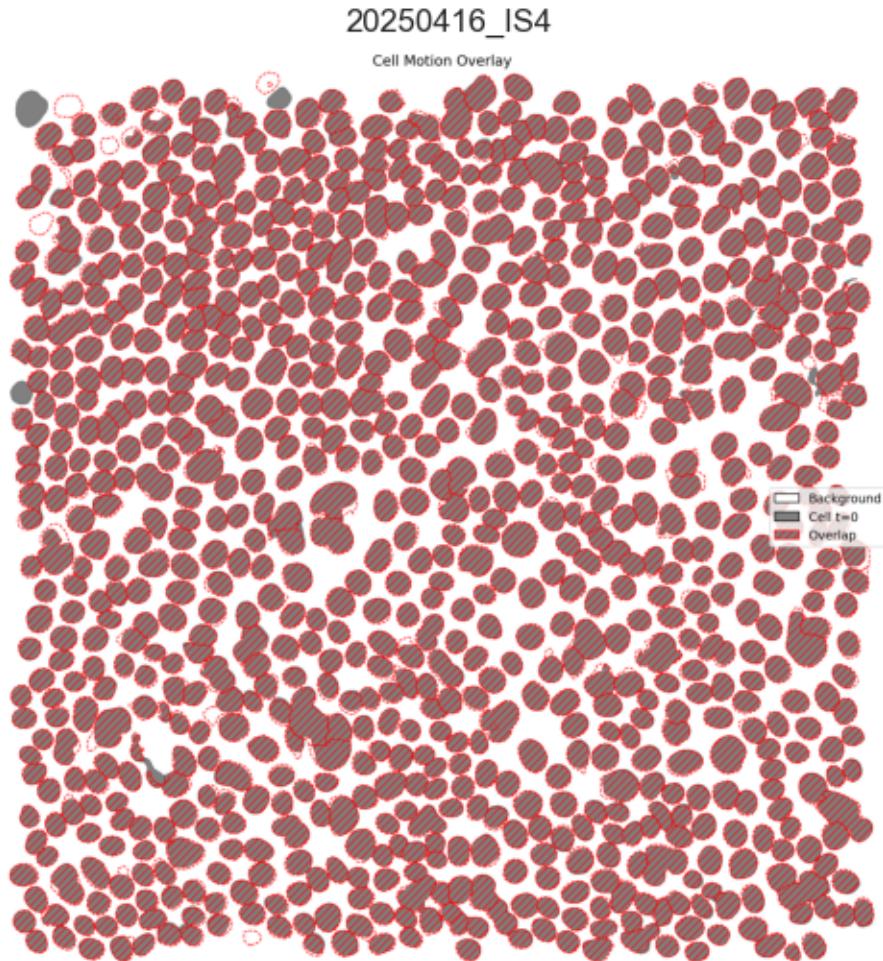


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 876
- Hoechst image taken at t=1801: 868
- Number of cells difference: absolute 8, relative 0.92%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1254566
- Pixels segmented as cell at t=1801: 1290238
- Overlapping pixels between t=0 and t=1801: 1201518 (94.43% of total)
- Pixels exclusive to t=0: 53048 (4.23% of total)
- Pixels exclusive to t=1801: 88720 (6.88% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n      "Default Dataset": "/path/to/your/dataset"\n}'
```

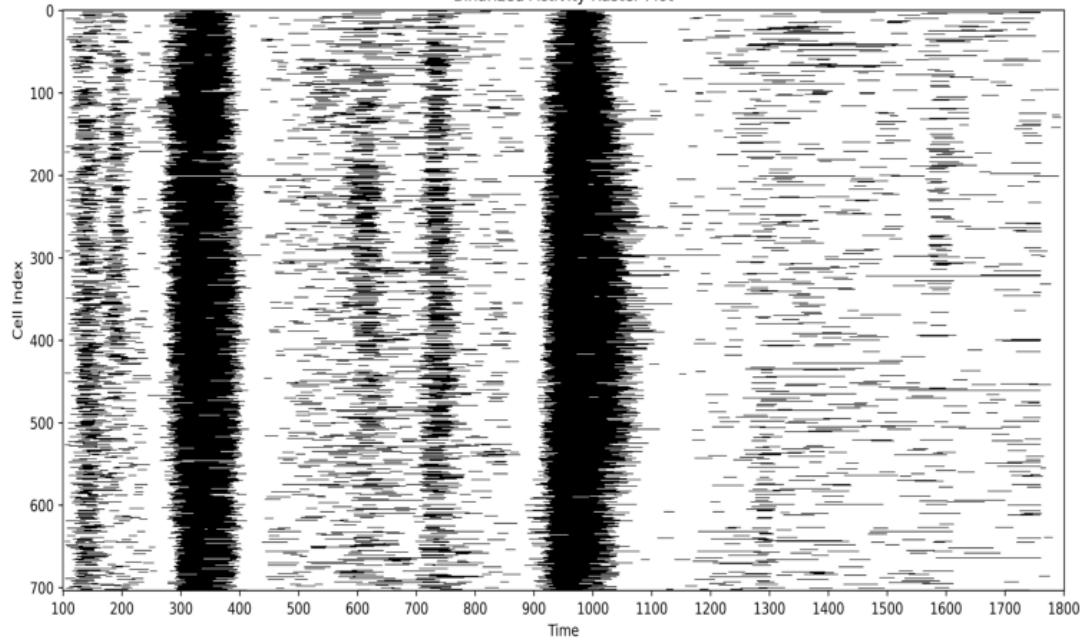
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

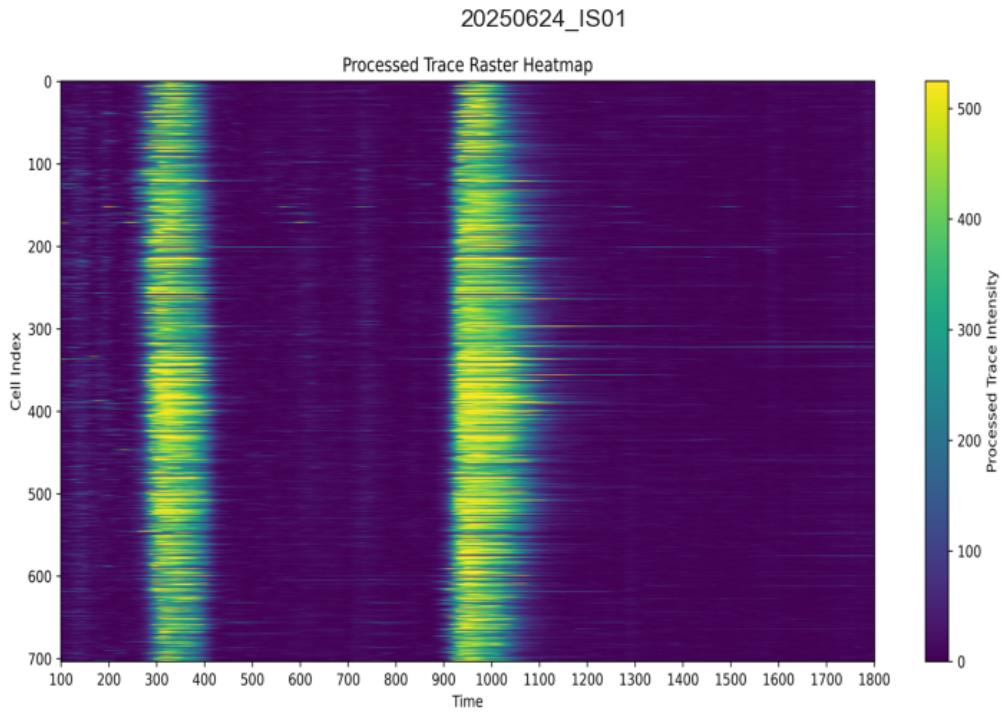
Binary Activity Raster Plot

20250624\_IS01

Binarized Activity Raster Plot



Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 4443

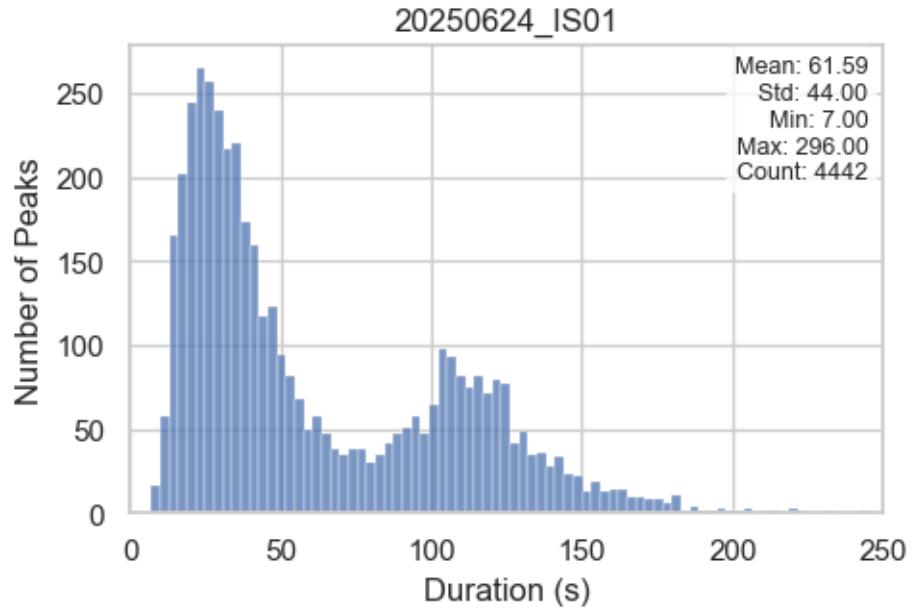
Total number of cells: 704

### 1.1.3 Peaks statistics

```
[2025-08-08 15:17:17] [INFO] calcium: Removed 1 outliers from dataset  
'20250624_IS01' for column 'Duration (s)'
```

```
[2025-08-08 15:17:17] [INFO] calcium: Lower bound: -86.5, Upper bound: 326.0
```

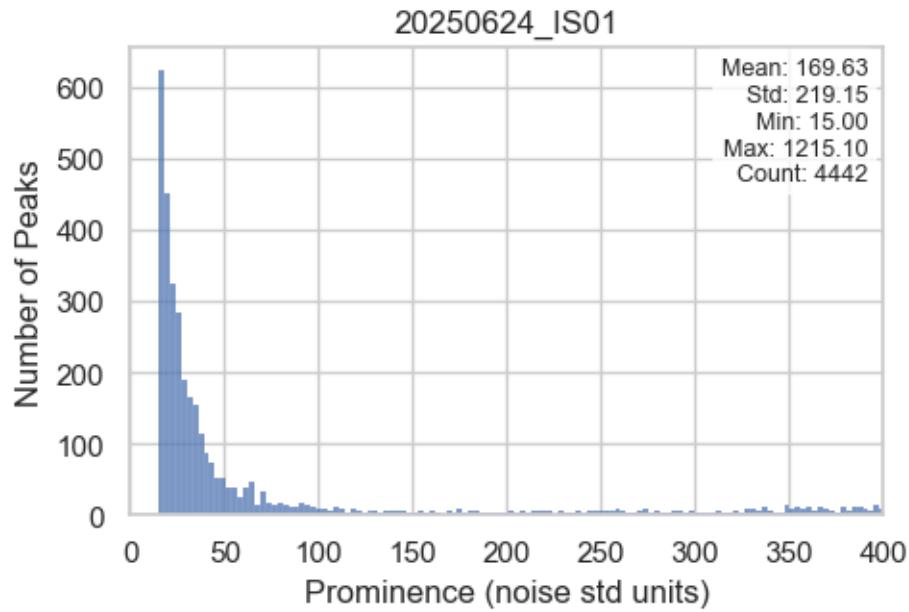
## Distribution of Peak Durations



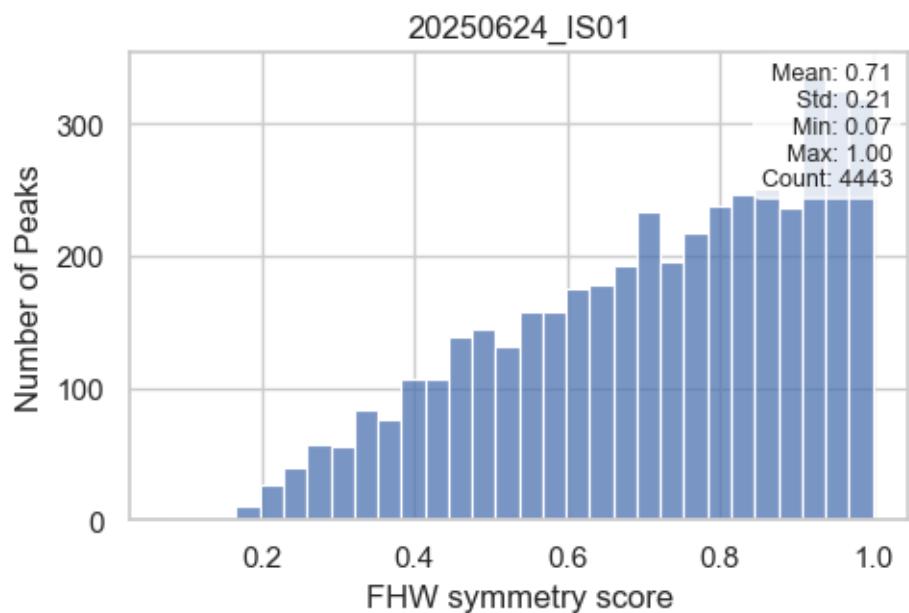
[2025-08-08 15:17:17] [INFO] calcium: Removed 1 outliers from dataset '20250624\_IS01' for column 'Prominence (noise std units)'

[2025-08-08 15:17:17] [INFO] calcium: Lower bound: -453.9250000000001, Upper bound: 1288.200000000003

### Distribution of Peak Prominences

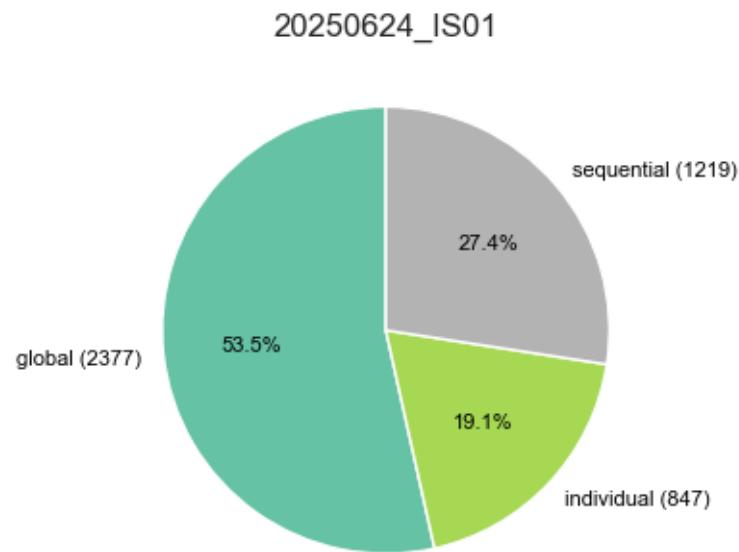


### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

Distribution of Peaks by Event types

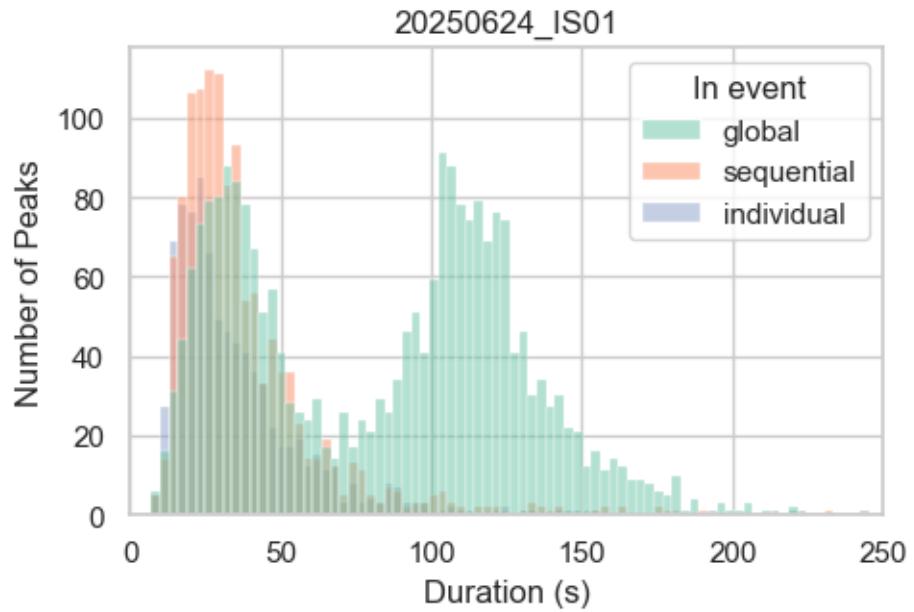


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 15:17:18] [INFO] calcium: Removed 1 outliers from dataset  
'20250624_IS01' for column 'Duration (s)'
```

```
[2025-08-08 15:17:18] [INFO] calcium: Lower bound: -86.5, Upper bound: 326.0
```

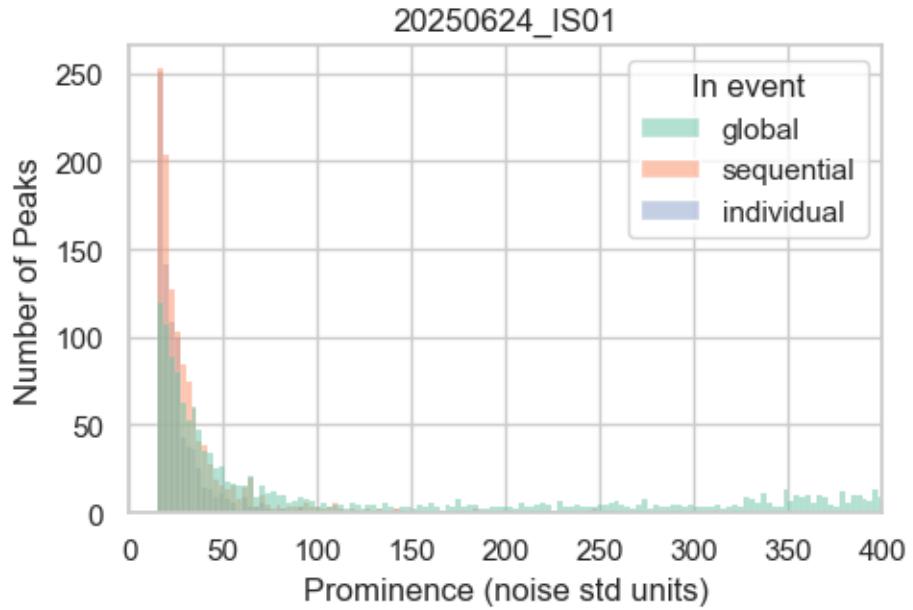
## Distribution of Peak Durations by Group



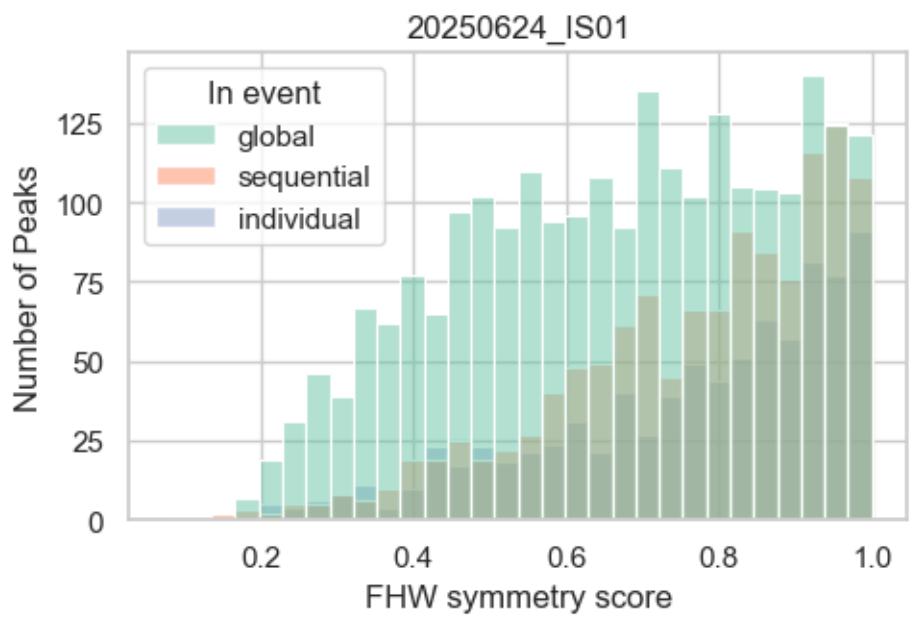
[2025-08-08 15:17:19] [INFO] calcium: Removed 1 outliers from dataset '20250624\_IS01' for column 'Prominence (noise std units)'

[2025-08-08 15:17:19] [INFO] calcium: Lower bound: -453.9, Upper bound: 1288.2

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



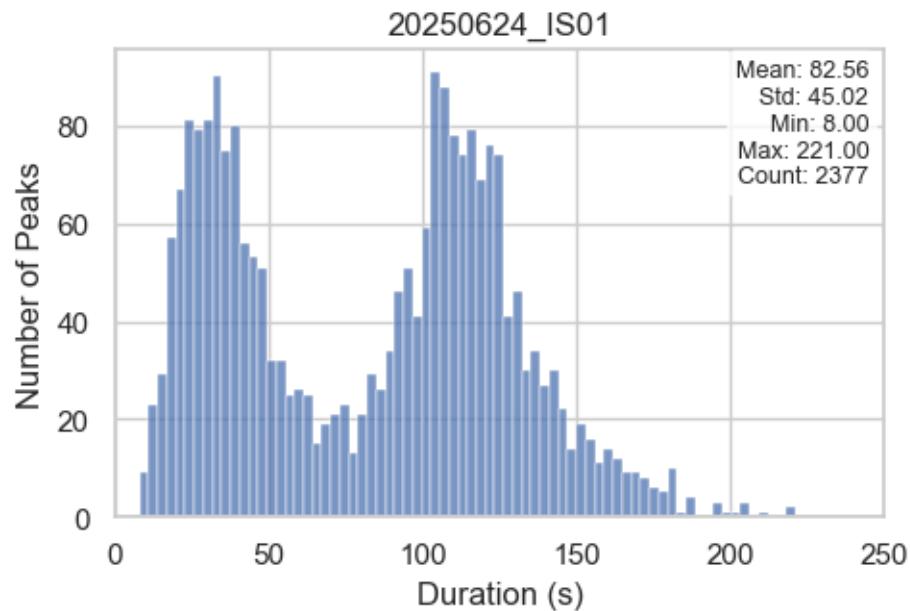
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 15:17:21] [INFO] calcium: Removed 0 outliers from dataset  
'20250624_IS01' for column 'Duration (s)'
```

```
[2025-08-08 15:17:21] [INFO] calcium: Lower bound: -82.0, Upper bound: 358.0
```

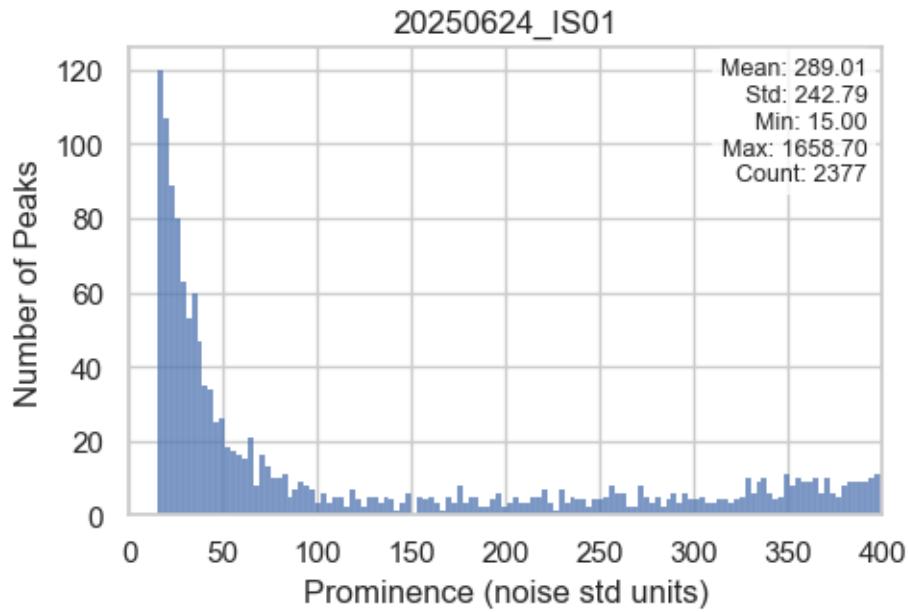
Distribution of Peak Durations



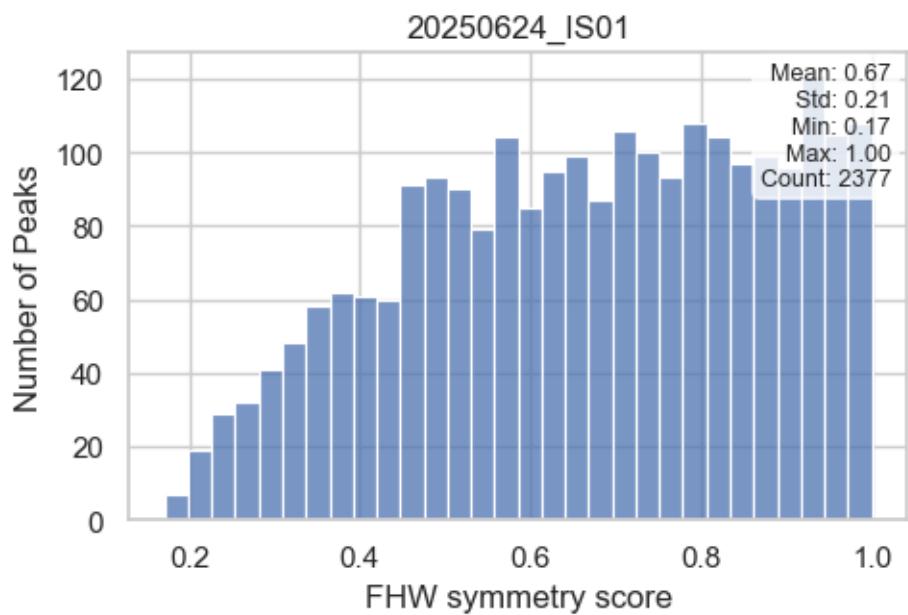
```
[2025-08-08 15:17:21] [INFO] calcium: Removed 0 outliers from dataset  
'20250624_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:17:21] [INFO] calcium: Lower bound: -646.000000000001, Upper  
bound: 1859.8000000000002
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

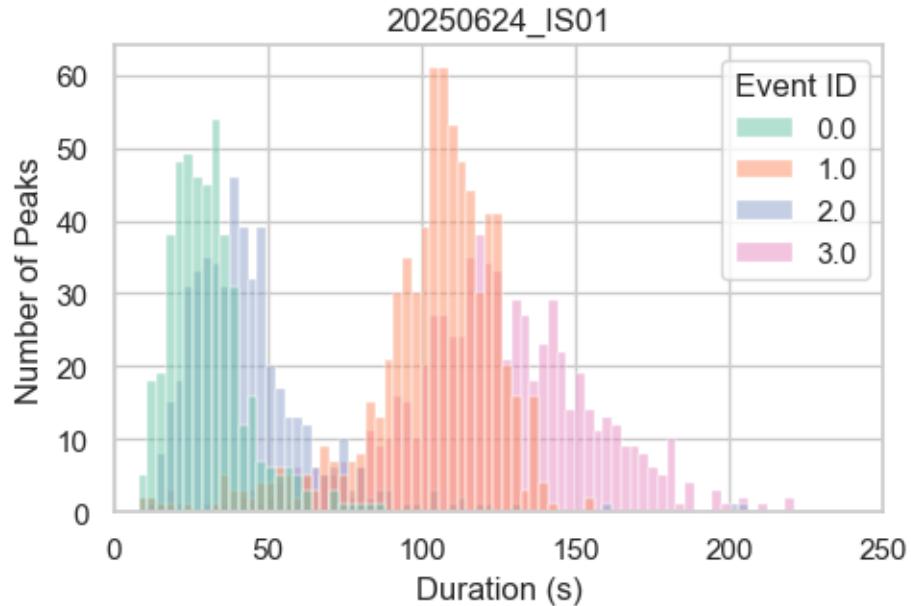


### 1.2.2 Peak statistics in global event per event ID

```
[2025-08-08 15:17:21] [INFO] calcium: Removed 0 outliers from dataset  
'20250624_IS01' for column 'Duration (s)'
```

```
[2025-08-08 15:17:21] [INFO] calcium: Lower bound: -82.0, Upper bound: 358.0
```

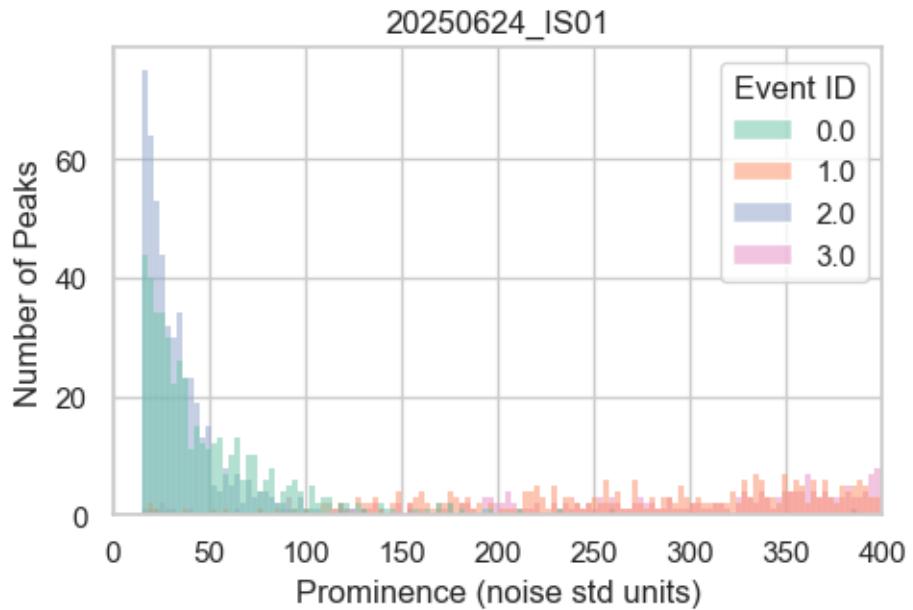
Distribution of Peak Durations by Group



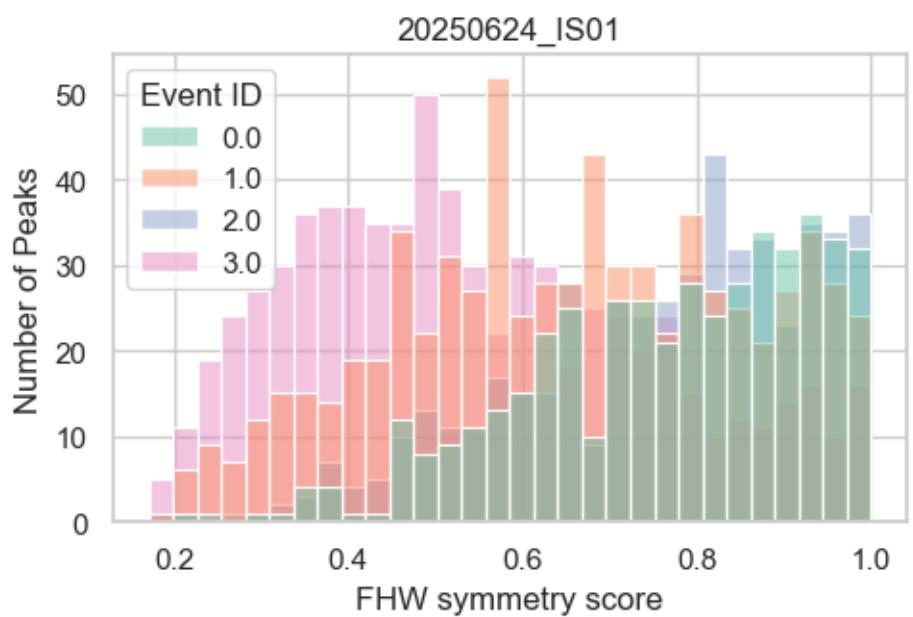
```
[2025-08-08 15:17:22] [INFO] calcium: Removed 0 outliers from dataset  
'20250624_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:17:22] [INFO] calcium: Lower bound: -646.0, Upper bound: 1859.8
```

Distribution of Peak Prominences by Group



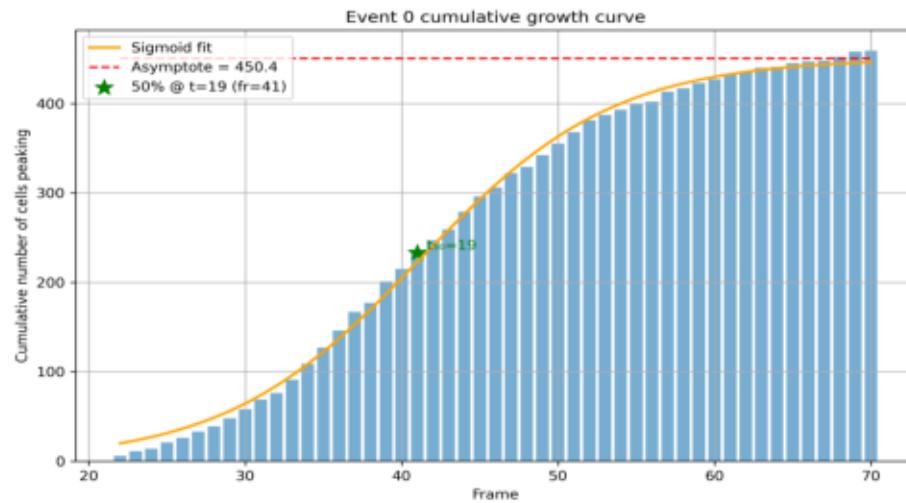
Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

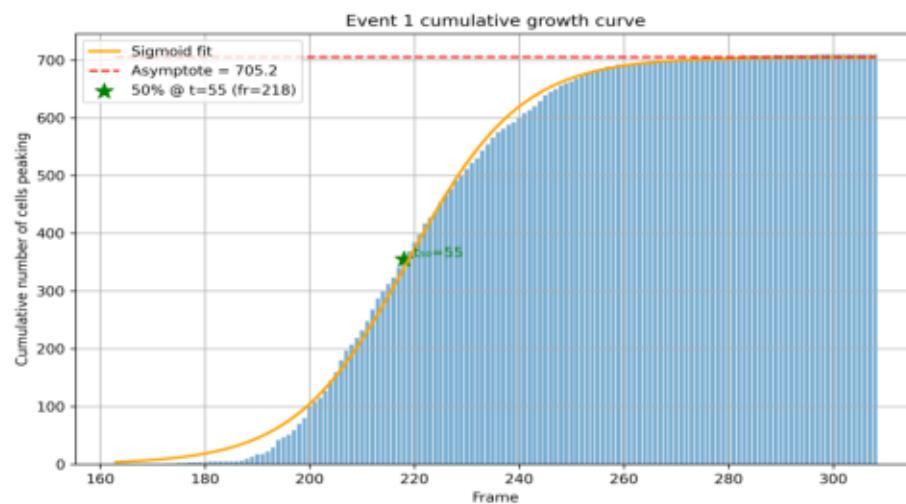
Event Activity Overlay (Event ID: 0)

20250624\_IS01



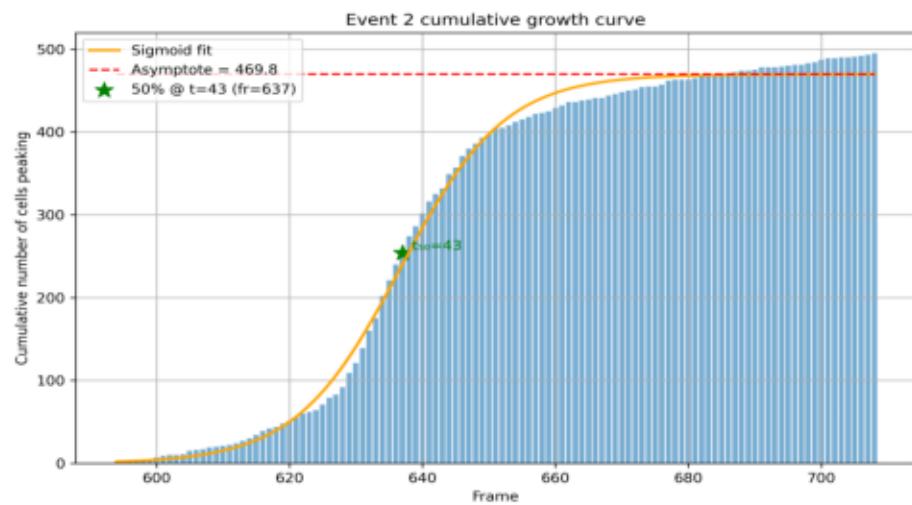
Event Activity Overlay (Event ID: 1)

20250624\_IS01



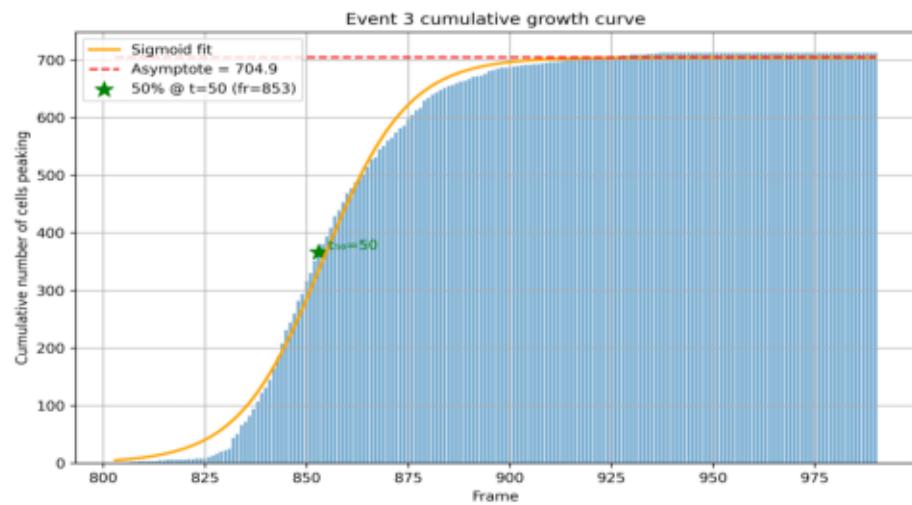
### Event Activity Overlay (Event ID: 2)

20250624\_IS01



### Event Activity Overlay (Event ID: 3)

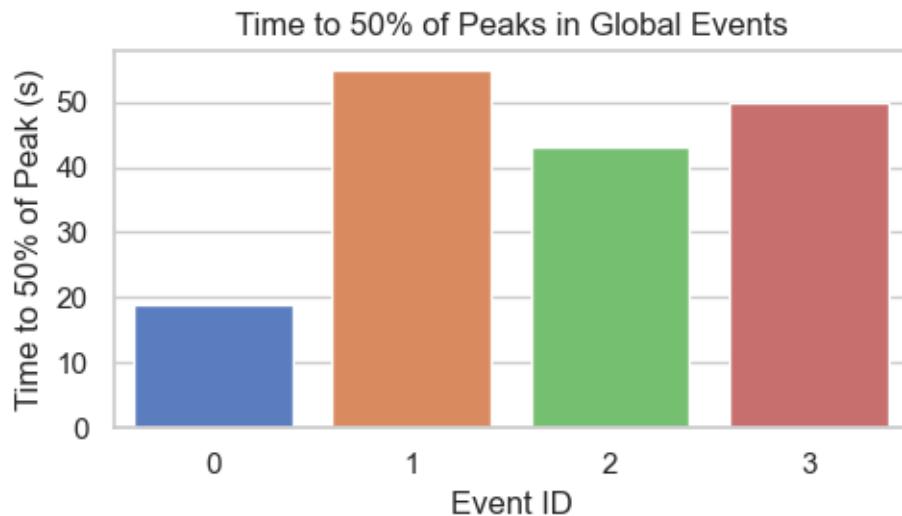
20250624\_IS01



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

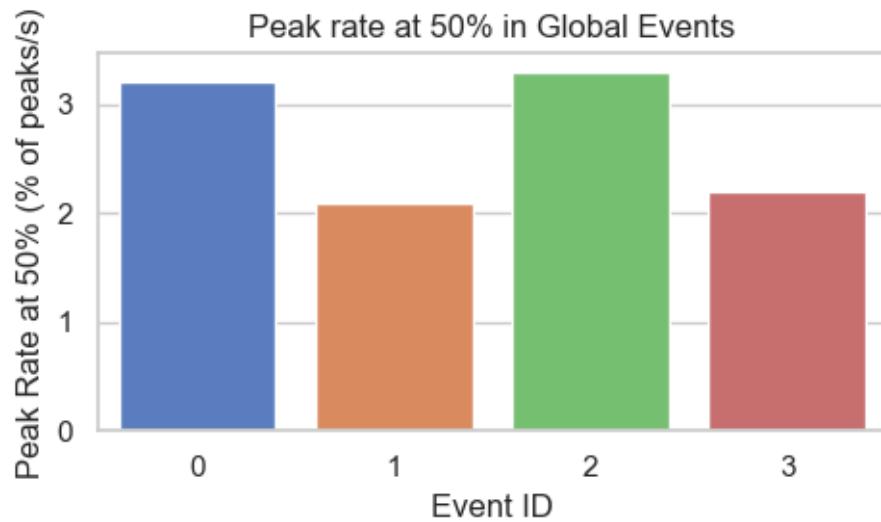
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

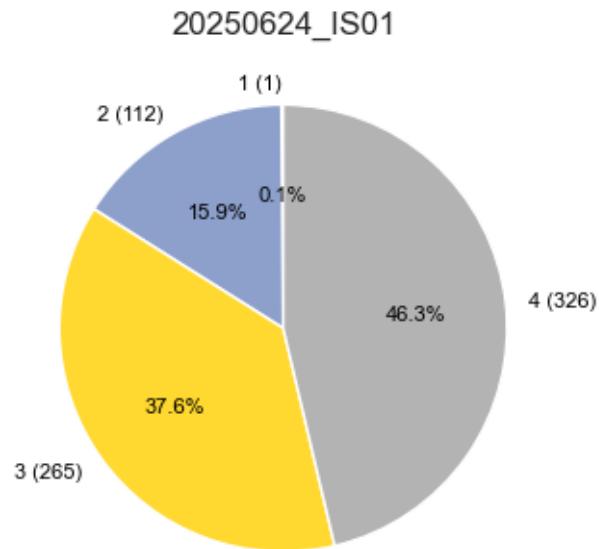
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



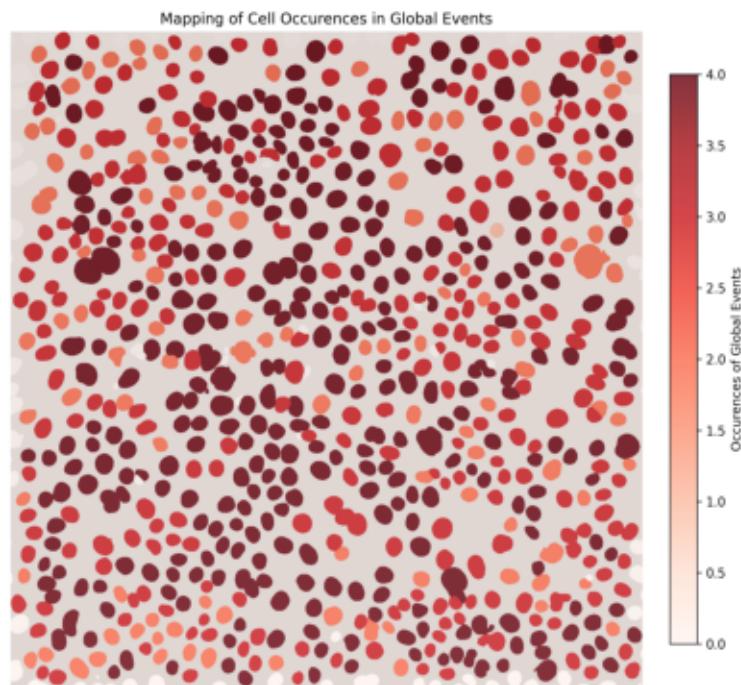
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

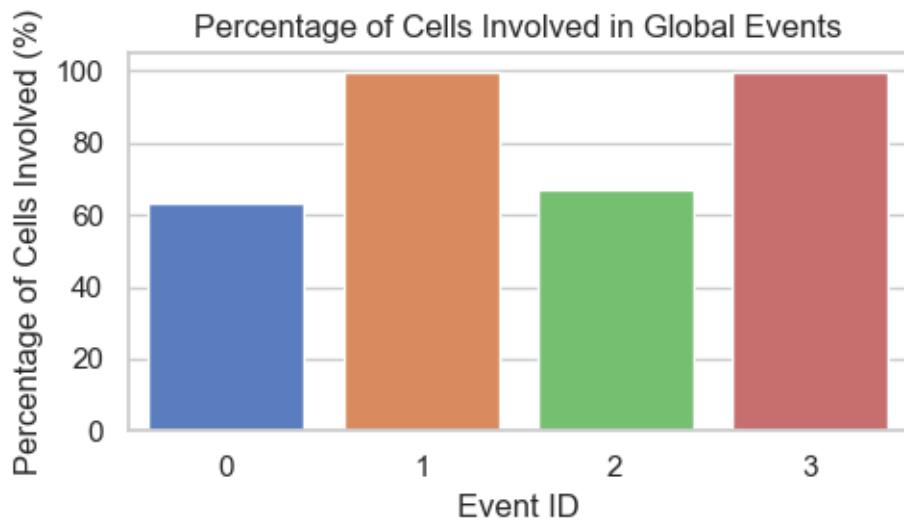
20250624\_IS01



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.2.5 Inter-event interval analysis

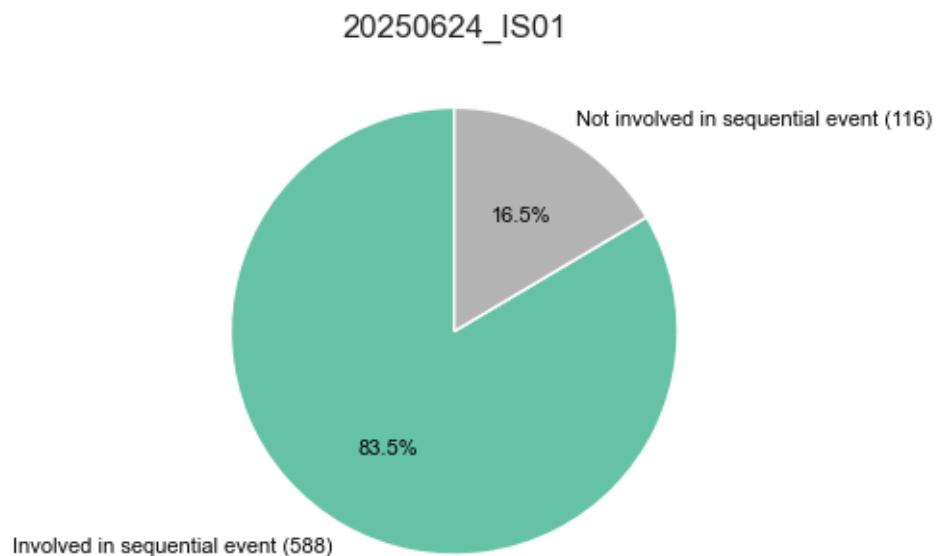
Intervals between global event peaks: [188.0, 407.0, 232.0]

Estimated periodicity: 0.745

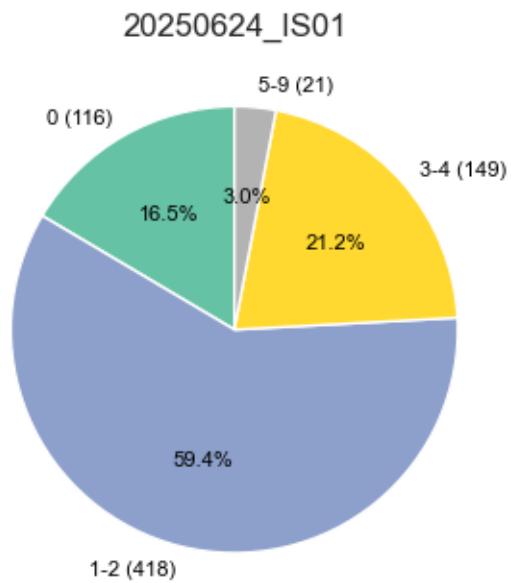
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequential events

Distribution of Cells Involved in Sequential Events

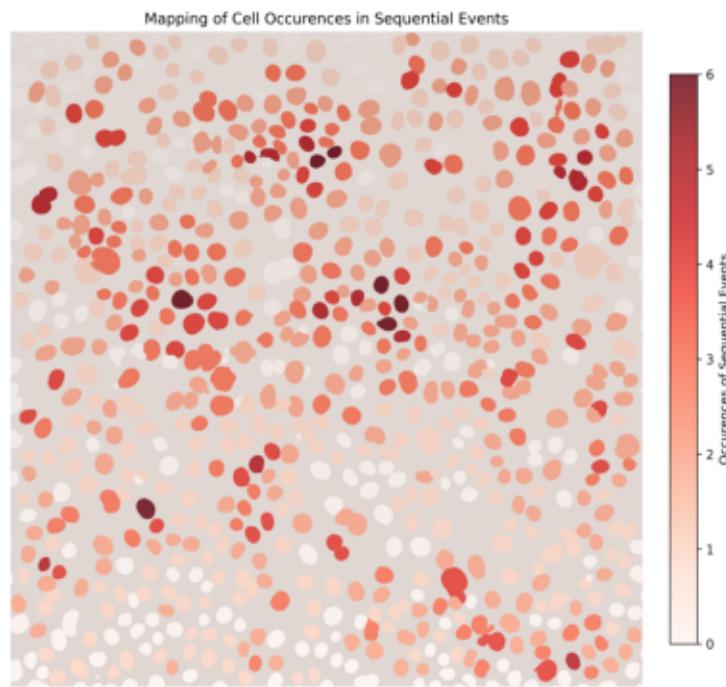


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250624\_IS01

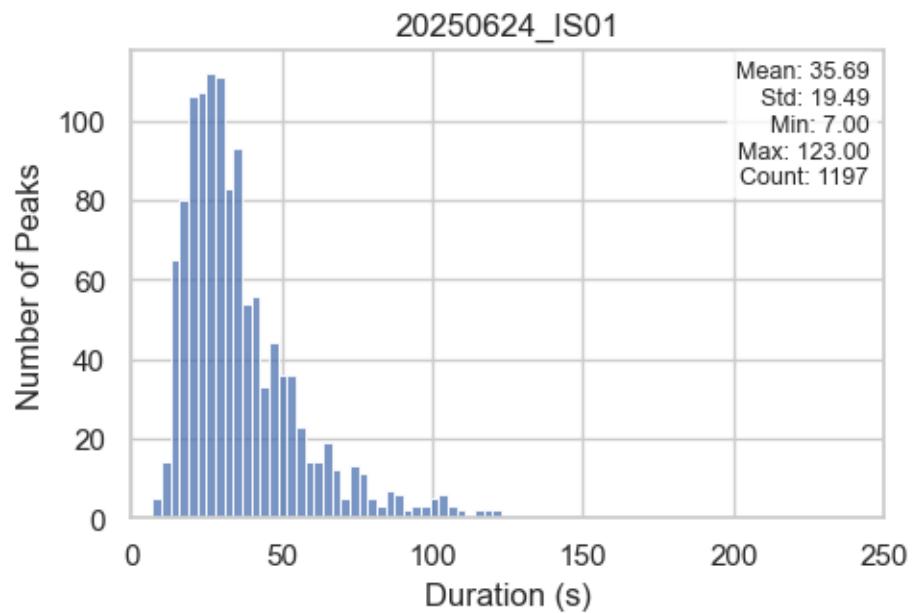


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 15:17:30] [INFO] calcium: Removed 22 outliers from dataset  
'20250624_IS01' for column 'Duration (s)'
```

```
[2025-08-08 15:17:30] [INFO] calcium: Lower bound: -12.5, Upper bound: 125.5
```

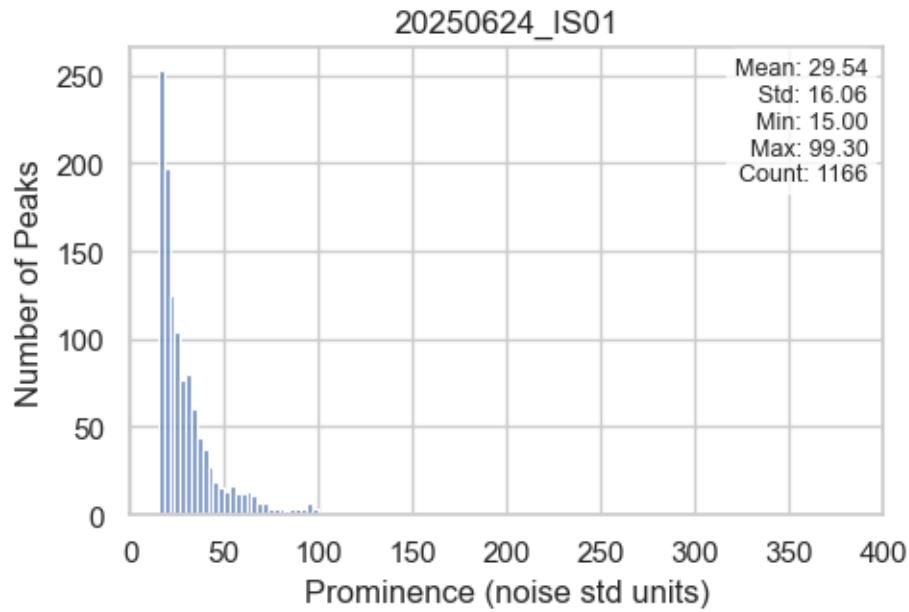
## Distribution of Peak Durations



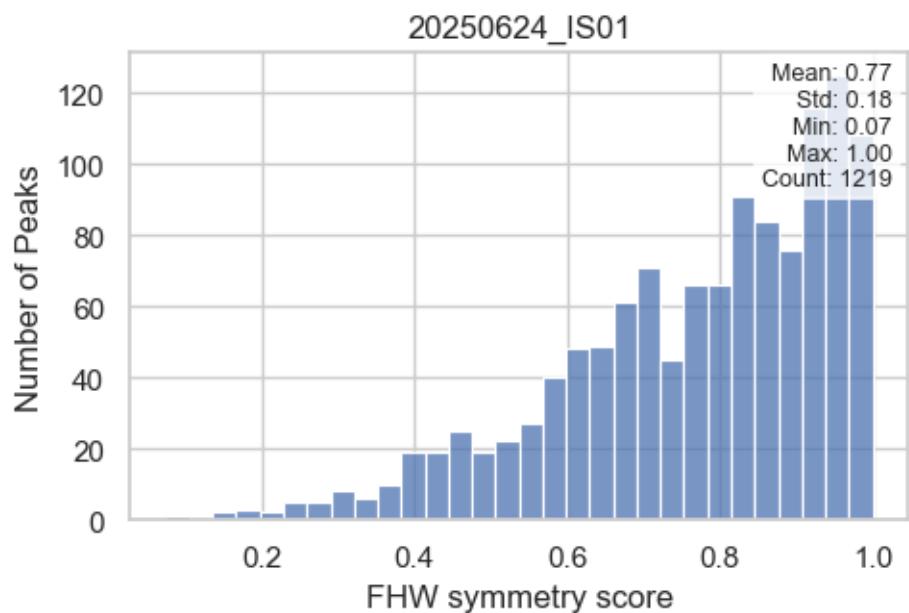
```
[2025-08-08 15:17:30] [INFO] calcium: Removed 53 outliers from dataset '20250624_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:17:30] [INFO] calcium: Lower bound: -8.324999999999992, Upper bound: 99.37499999999999
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

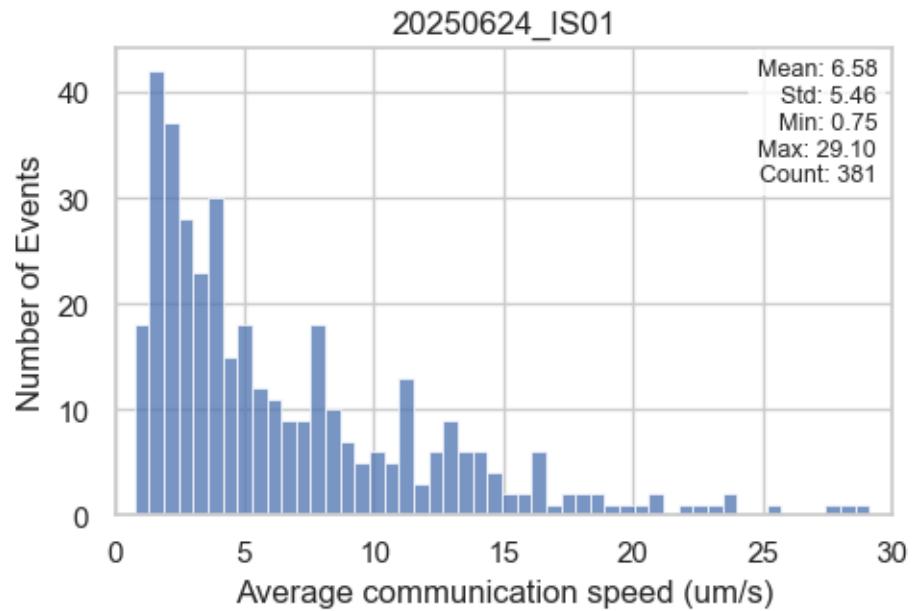


### 1.3.3 Cell-cell communication speed

[2025-08-08 15:17:31] [INFO] calcium: Removed 1 outliers from dataset '20250624\_IS01' for column 'Average communication speed (um/s)'

[2025-08-08 15:17:31] [INFO] calcium: Lower bound: -7.798750000000002, Upper bound: 29.642500000000005

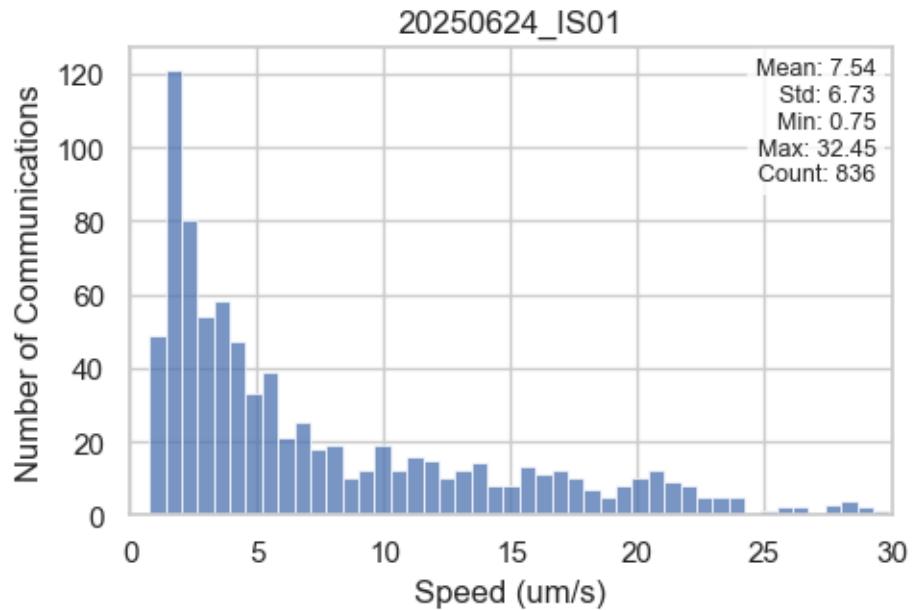
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 15:17:31] [INFO] calcium: Removed 1 outliers from dataset '20250624\_IS01' for column 'Speed (um/s)'

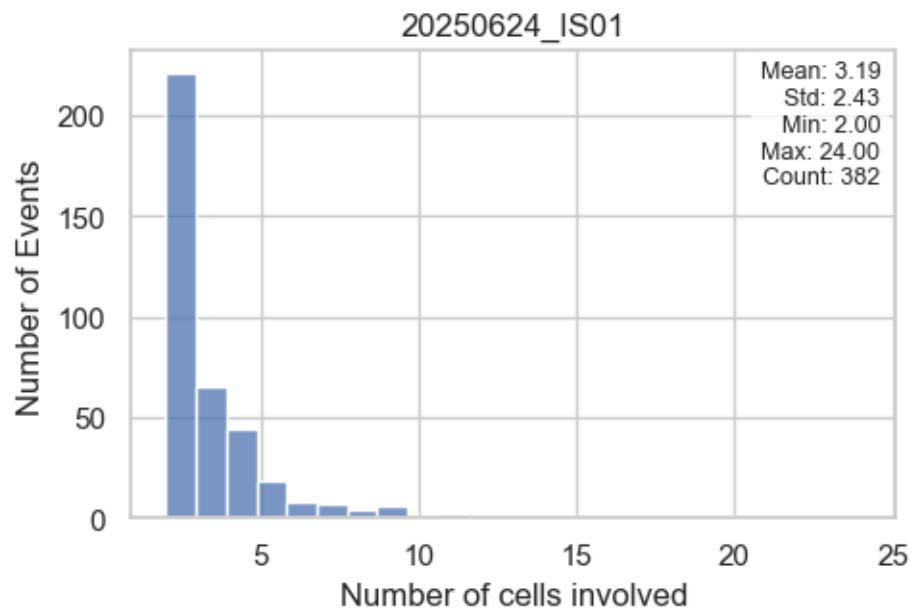
[2025-08-08 15:17:31] [INFO] calcium: Lower bound: -11.03, Upper bound: 37.69999999999996

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

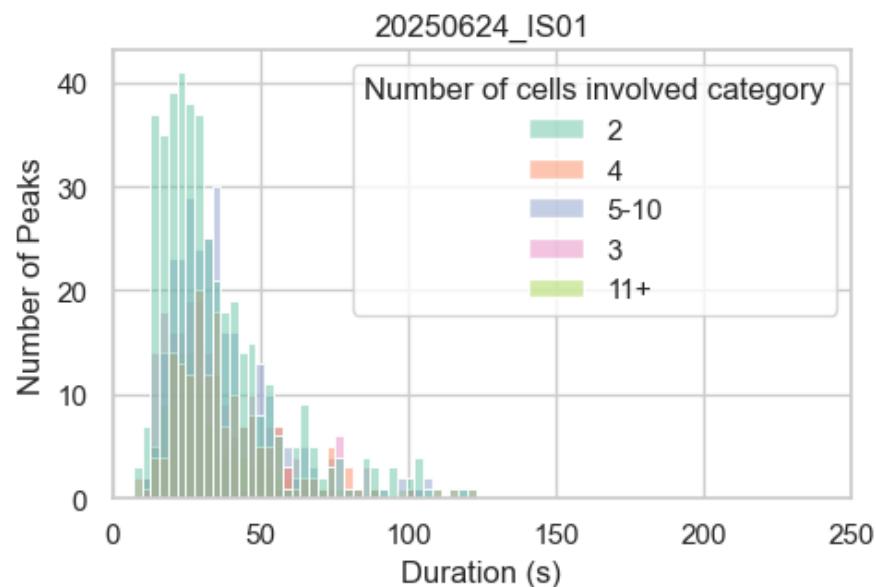


### 1.3.5 Influence of cell count per event on statistics

```
[2025-08-08 15:17:32] [INFO] calcium: Removed 22 outliers from dataset  
'20250624_IS01' for column 'Duration (s)'
```

```
[2025-08-08 15:17:32] [INFO] calcium: Lower bound: -12.5, Upper bound: 125.5
```

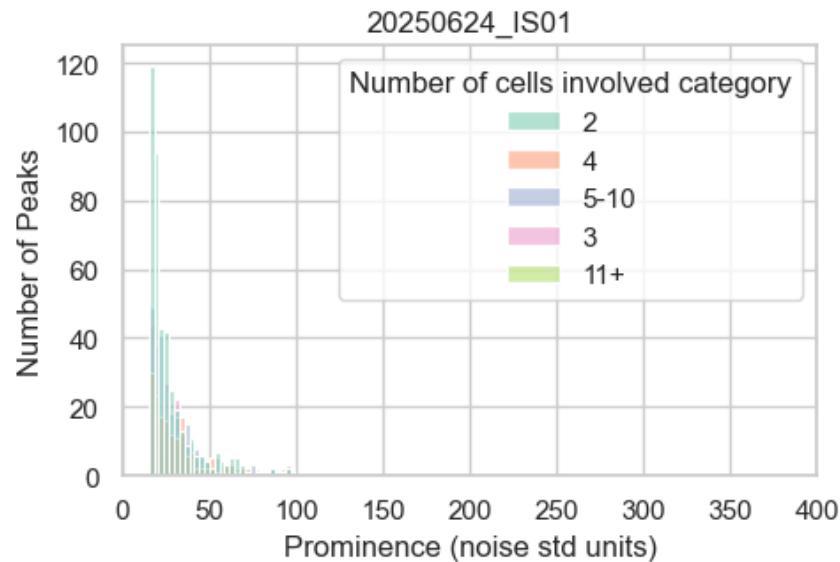
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



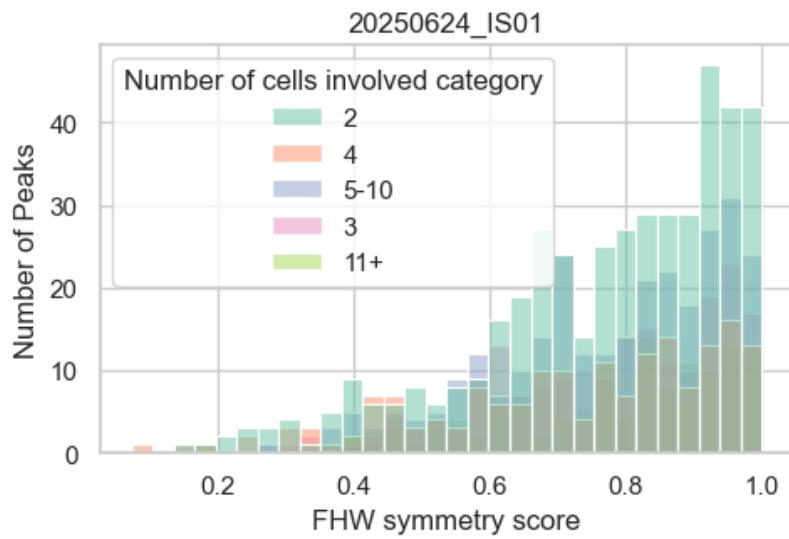
```
[2025-08-08 15:17:32] [INFO] calcium: Removed 53 outliers from dataset  
'20250624_IS01' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:17:32] [INFO] calcium: Lower bound: -8.3, Upper bound: 99.4
```

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



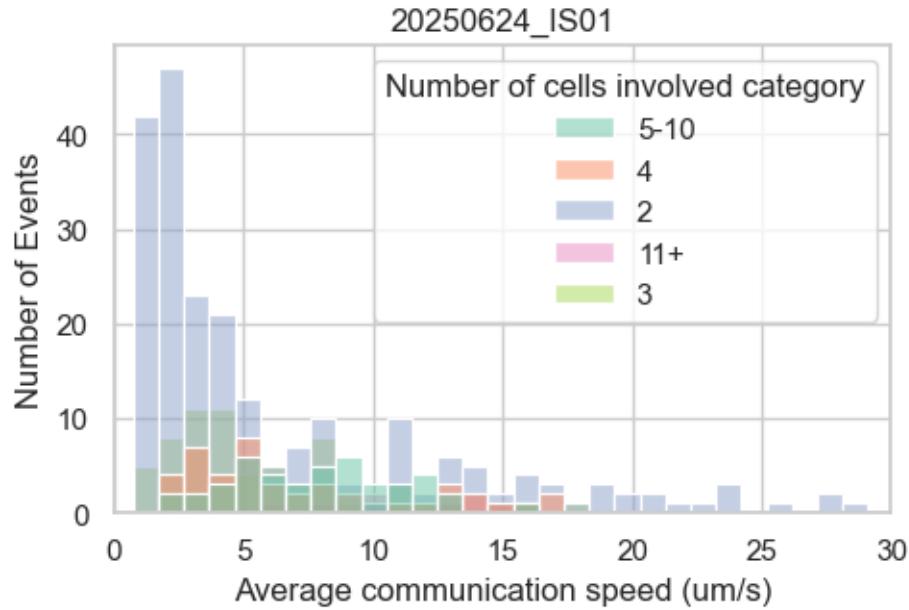
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



[2025-08-08 15:17:33] [INFO] calcium: Removed 1 outliers from dataset '20250624\_IS01' for column 'Average communication speed (um/s)'

[2025-08-08 15:17:33] [INFO] calcium: Lower bound: -7.8, Upper bound: 29.6

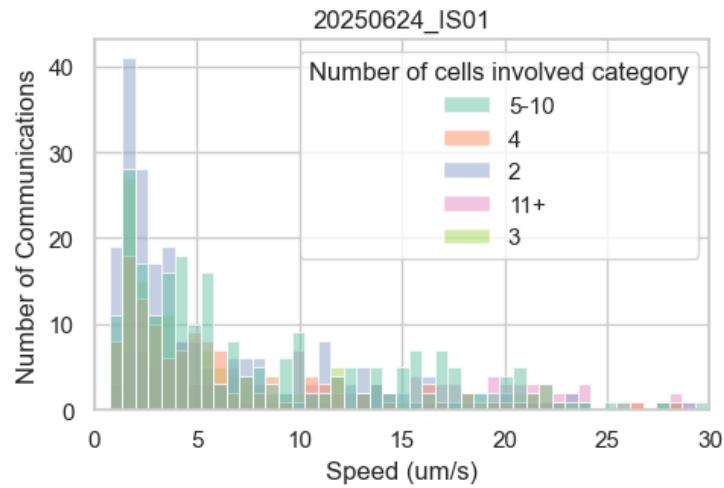
## Distribution of Average Communication Speeds by Number of Cells Involved



```
[2025-08-08 15:17:33] [INFO] calcium: Removed 1 outliers from dataset
'20250624_IS01' for column 'Speed (um/s)'
```

```
[2025-08-08 15:17:33] [INFO] calcium: Lower bound: -11.0, Upper bound: 37.7
```

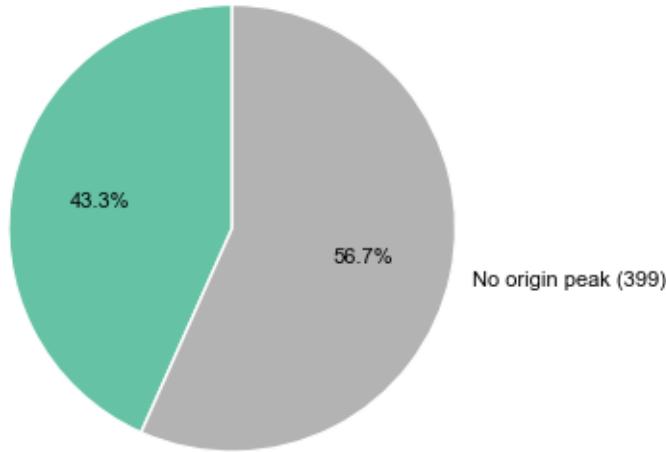
## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events



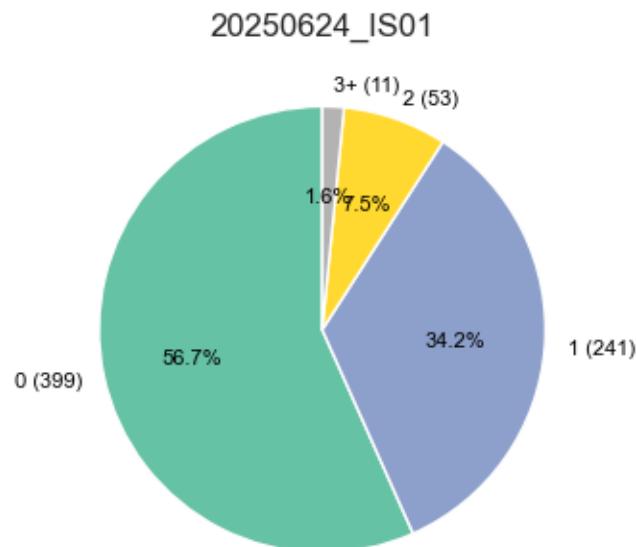
### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

Has origin peak (305)

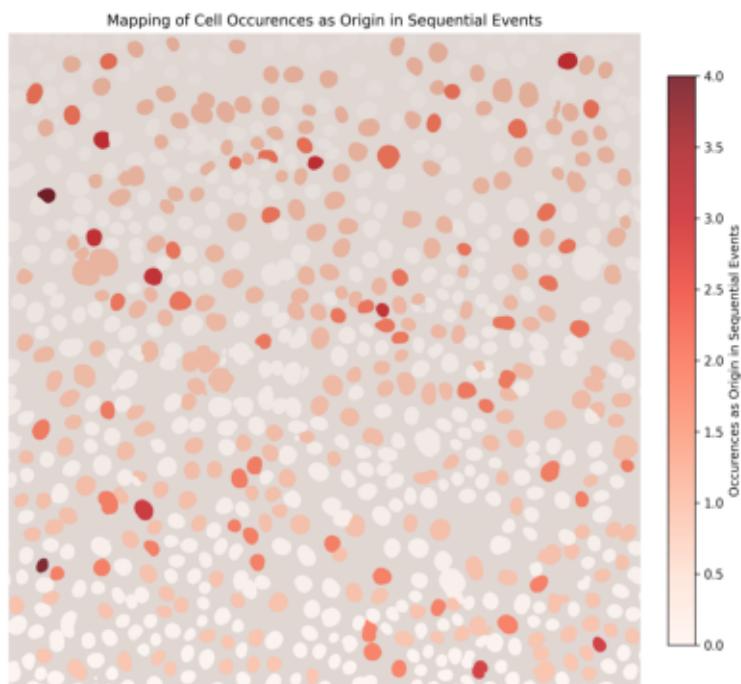


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

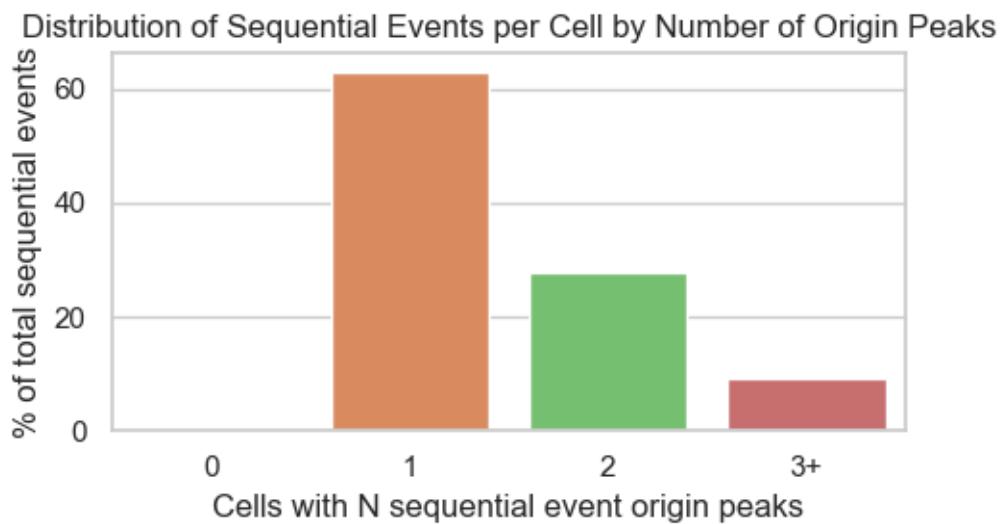
20250624\_IS01



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

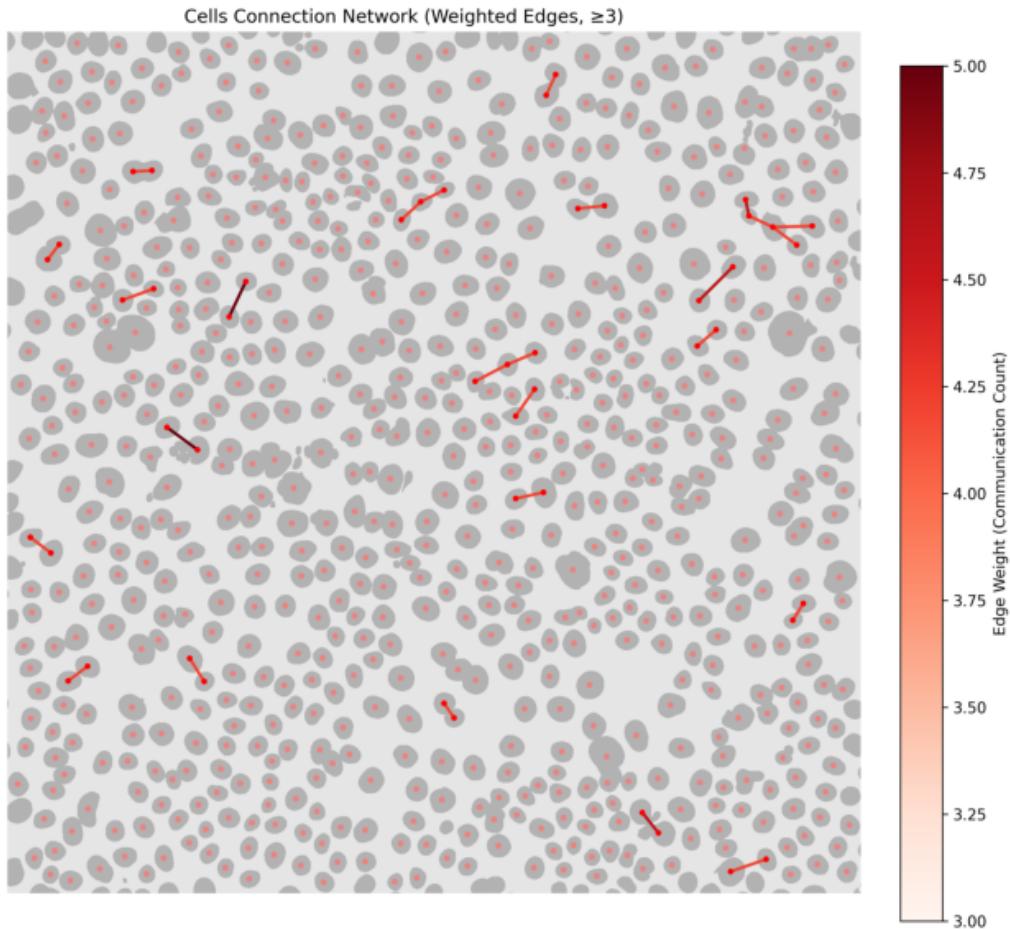
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.3.7 Connection network between cells

Cell Connection Network Graph

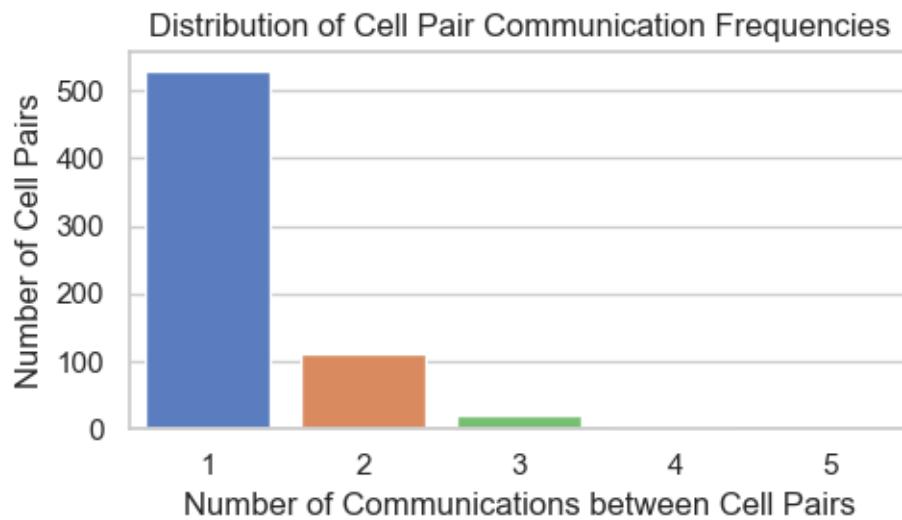
20250624\_IS01



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

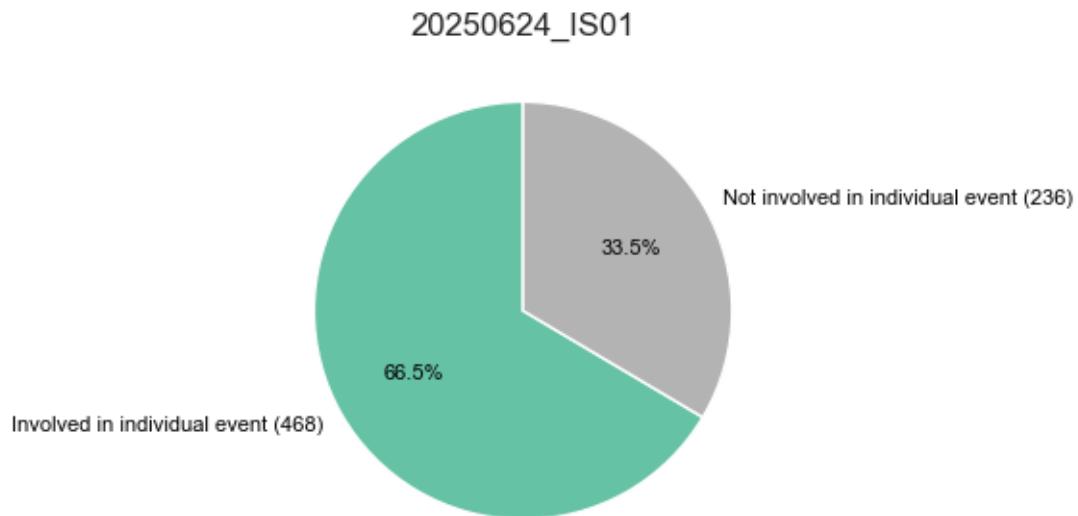
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



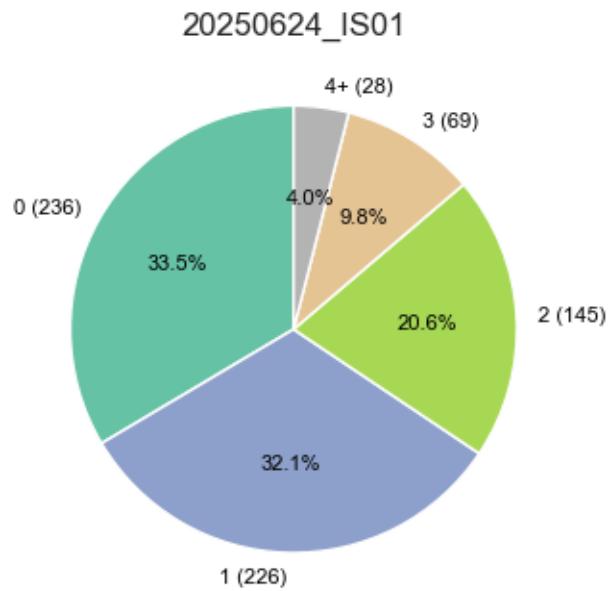
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

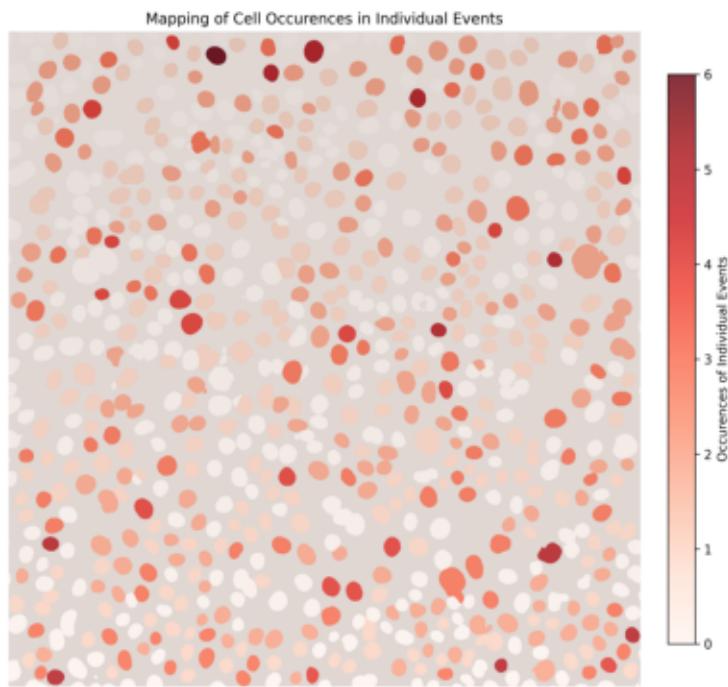


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250624\_IS01

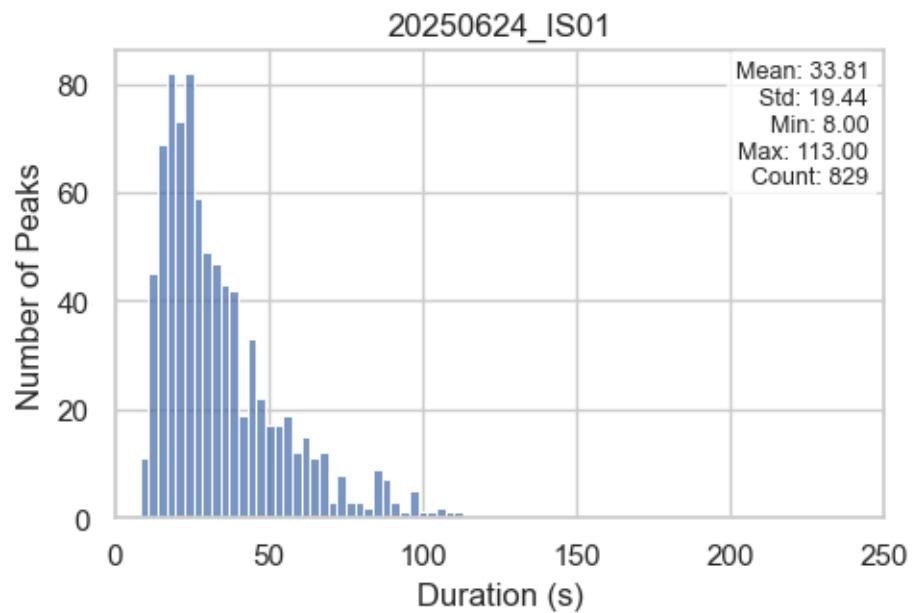


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 15:17:38] [INFO] calcium: Removed 18 outliers from dataset  
'20250624_IS01' for column 'Duration (s)'
```

```
[2025-08-08 15:17:38] [INFO] calcium: Lower bound: -16.0, Upper bound: 116.0
```

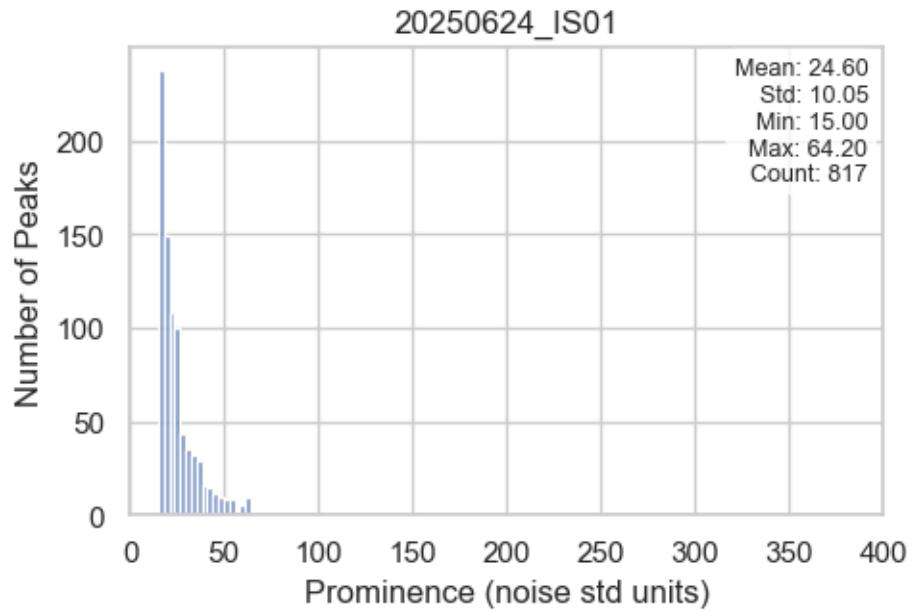
## Distribution of Peak Durations



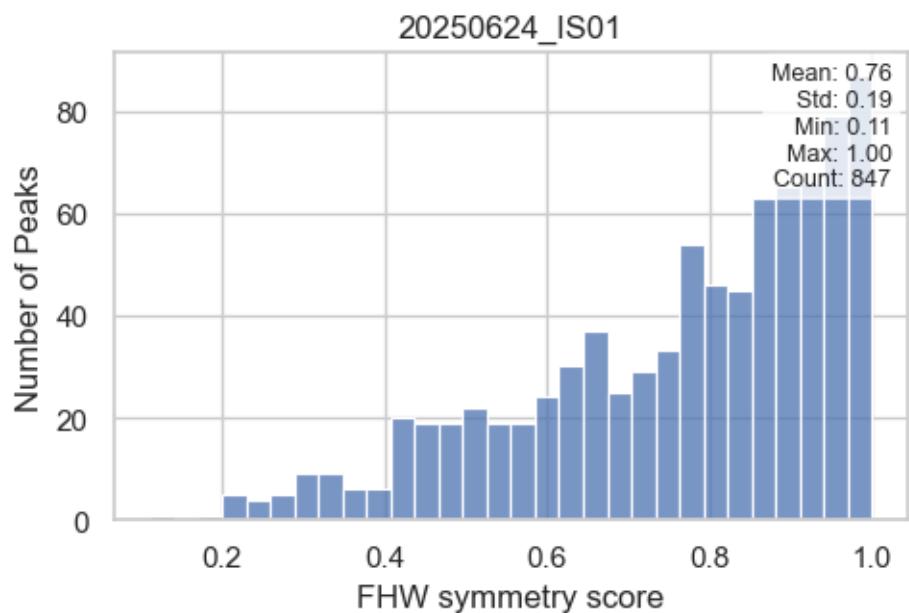
[2025-08-08 15:17:38] [INFO] calcium: Removed 30 outliers from dataset '20250624\_IS01' for column 'Prominence (noise std units)'

[2025-08-08 15:17:38] [INFO] calcium: Lower bound: -0.0500000000000426, Upper bound: 64.30000000000001

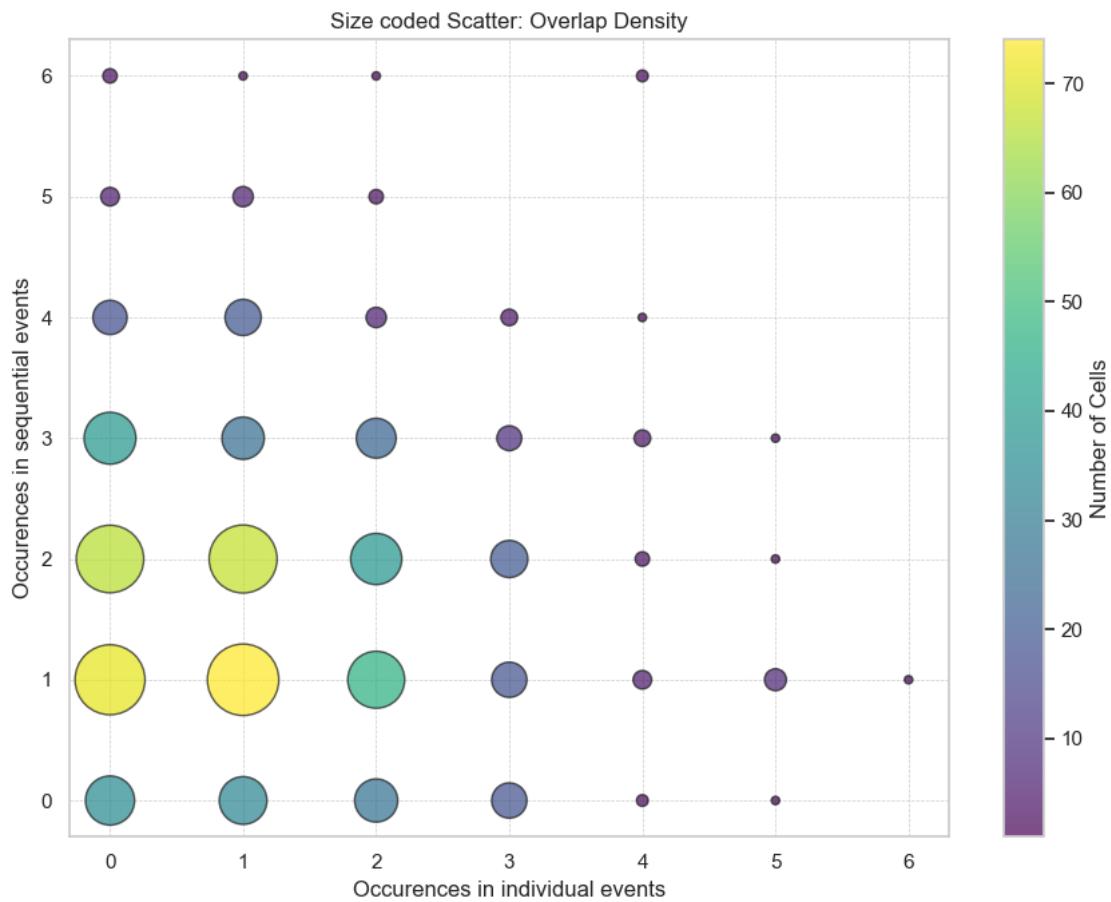
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

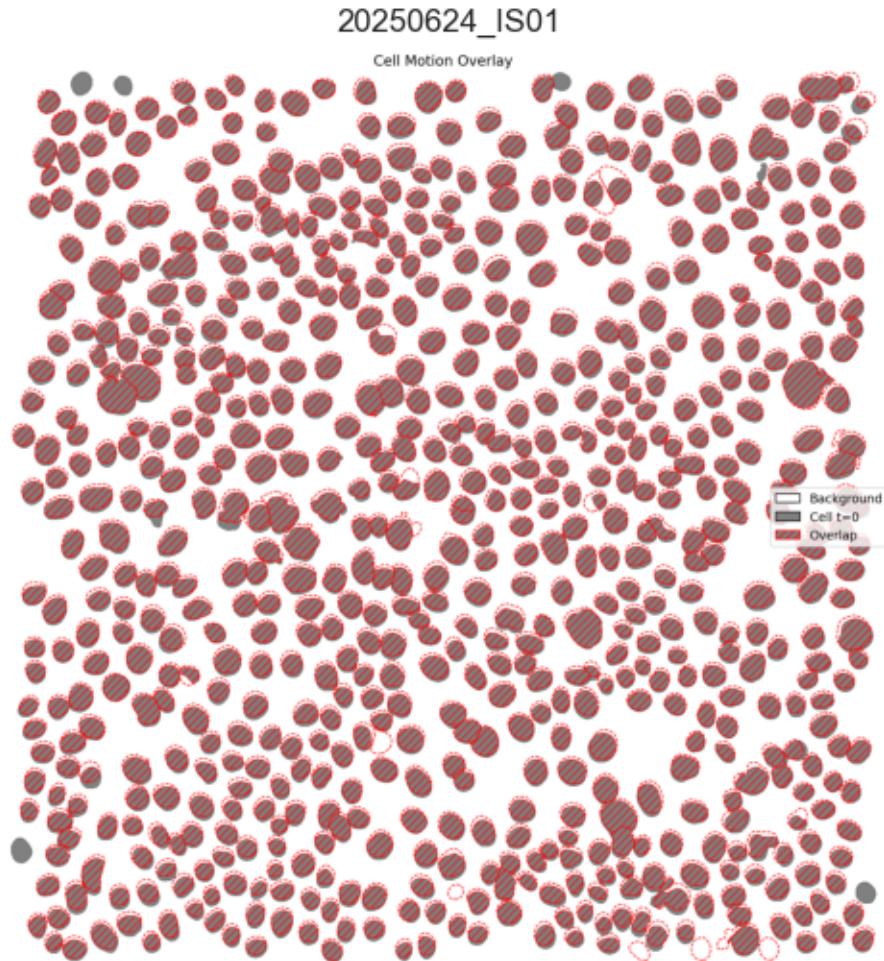


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 704
- Hoechst image taken at t=1801: 700
- Number of cells difference: absolute 4, relative 0.57%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 864200
- Pixels segmented as cell at t=1801: 858437
- Overlapping pixels between t=0 and t=1801: 706604 (82.04% of total)
- Pixels exclusive to t=0: 157596 (18.24% of total)
- Pixels exclusive to t=1801: 151833 (17.69% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n    "Default Dataset": "/path/to/your/dataset"\n}'
```

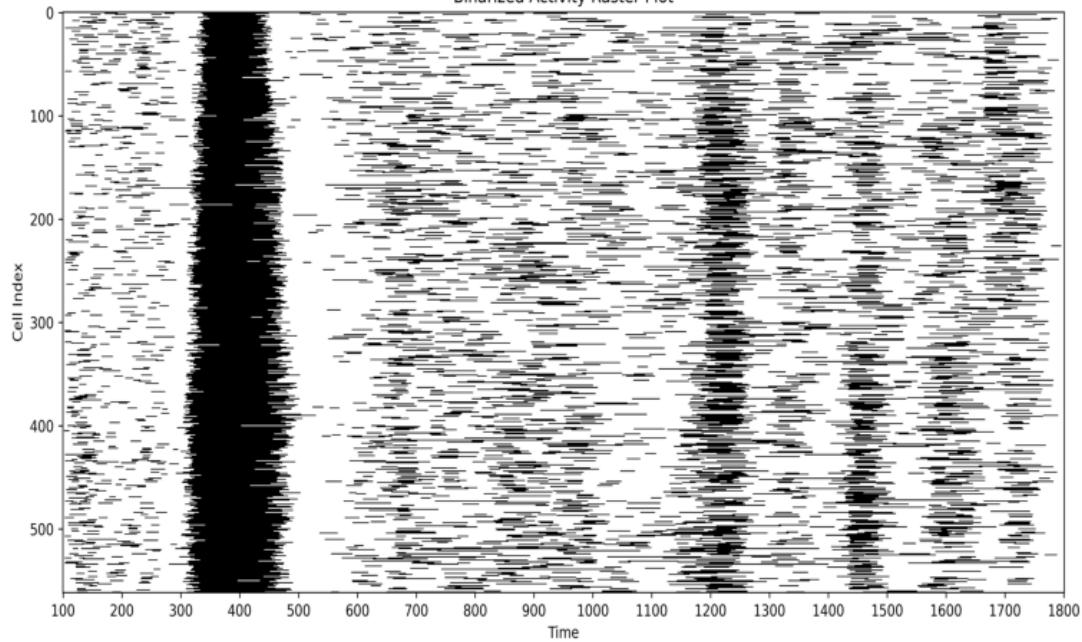
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

Binary Activity Raster Plot

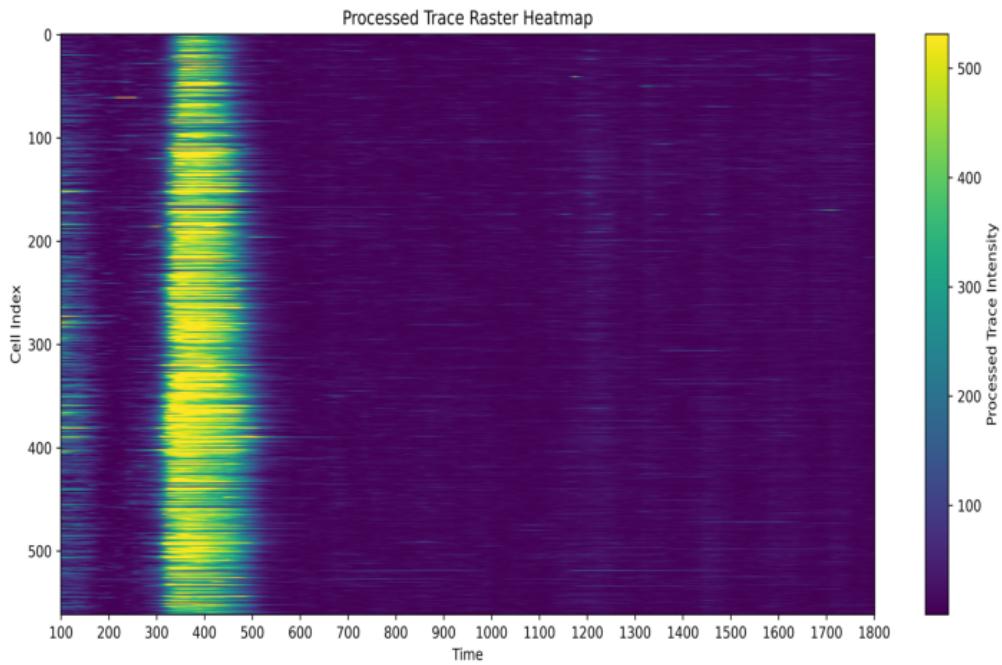
20250624\_IS03

Binarized Activity Raster Plot



Heatmap Activity Raster Plot

20250624\_IS03



### 1.1.2 Peaks population

Total number of peaks: 4143

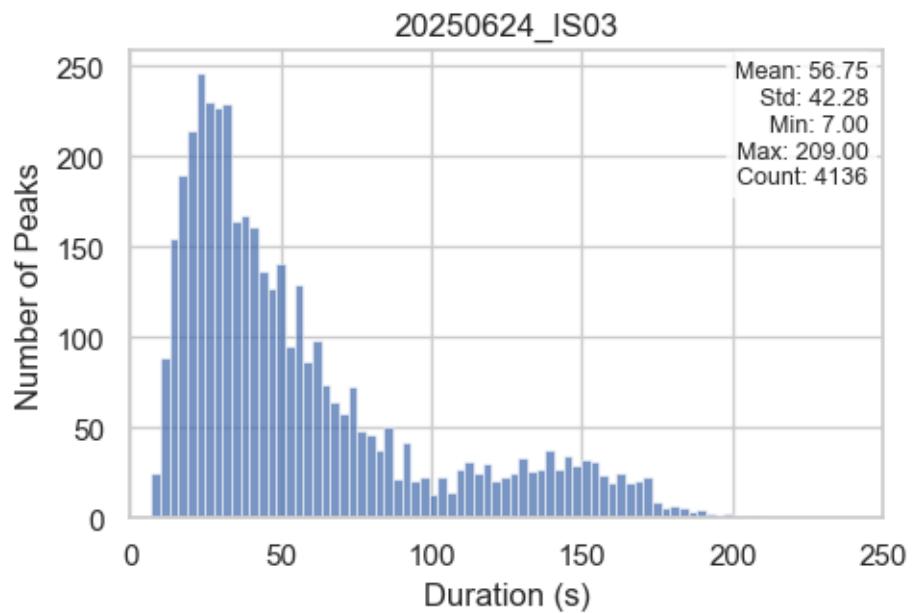
Total number of cells: 562

### 1.1.3 Peaks statistics

```
[2025-08-08 15:18:38] [INFO] calcium: Removed 7 outliers from dataset  
'20250624_IS03' for column 'Duration (s)'
```

```
[2025-08-08 15:18:38] [INFO] calcium: Lower bound: -44.5, Upper bound: 214.0
```

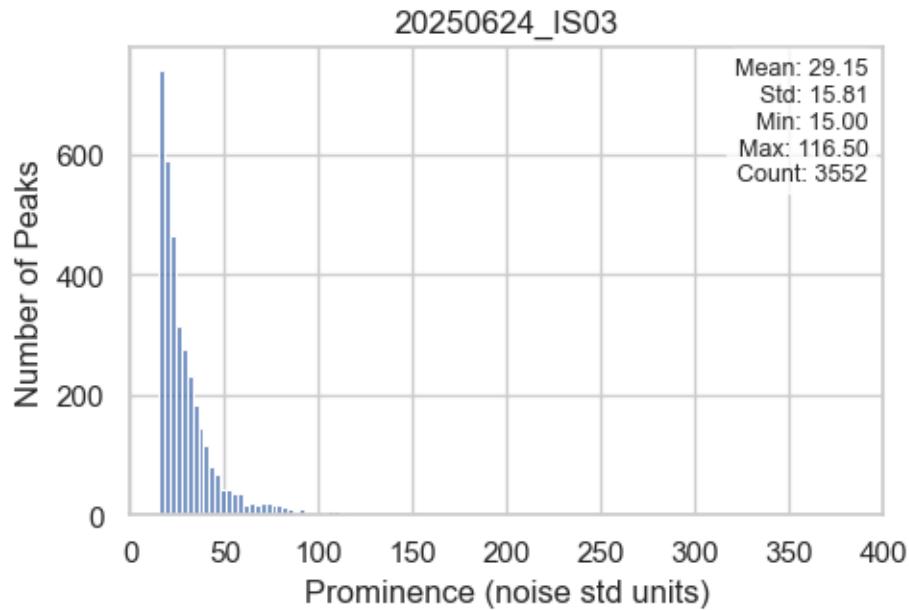
## Distribution of Peak Durations



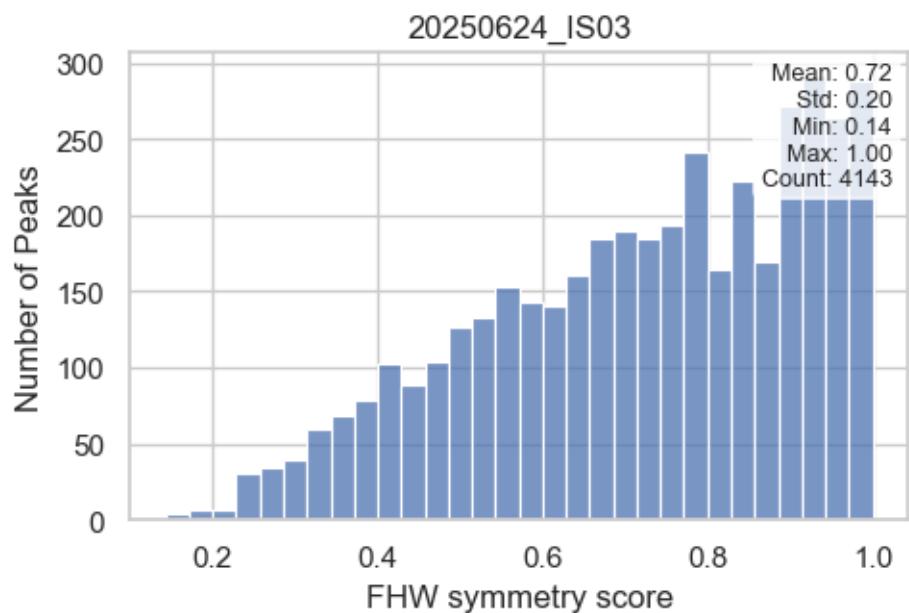
```
[2025-08-08 15:18:38] [INFO] calcium: Removed 591 outliers from dataset '20250624_IS03' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:18:38] [INFO] calcium: Lower bound: -17.52499999999988, Upper bound: 117.4999999999997
```

## Distribution of Peak Prominences

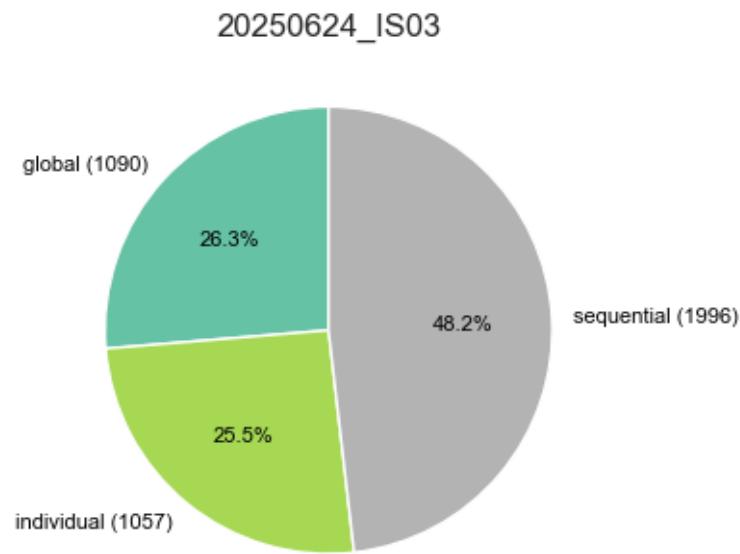


## Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

Distribution of Peaks by Event types

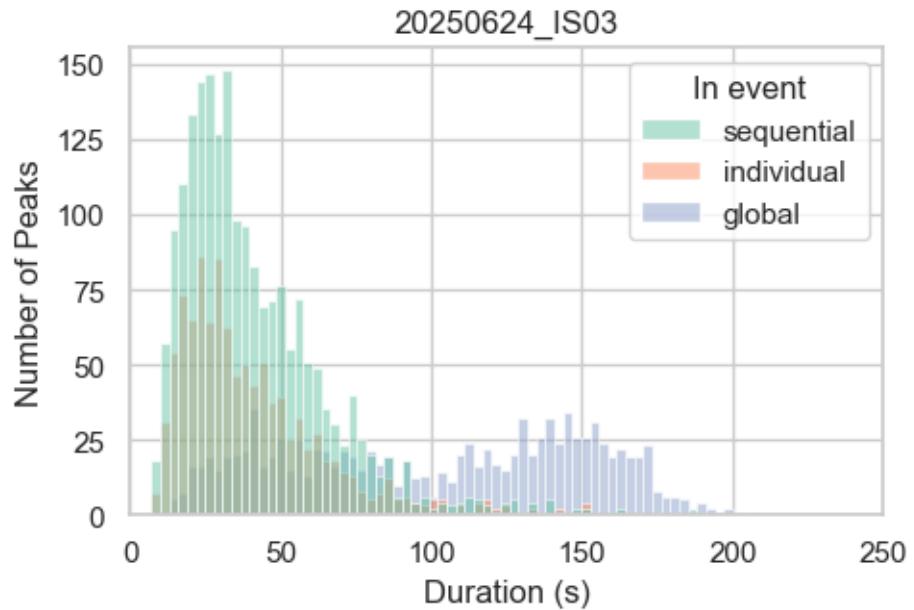


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 15:18:38] [INFO] calcium: Removed 7 outliers from dataset  
'20250624_IS03' for column 'Duration (s)'
```

```
[2025-08-08 15:18:38] [INFO] calcium: Lower bound: -44.5, Upper bound: 214.0
```

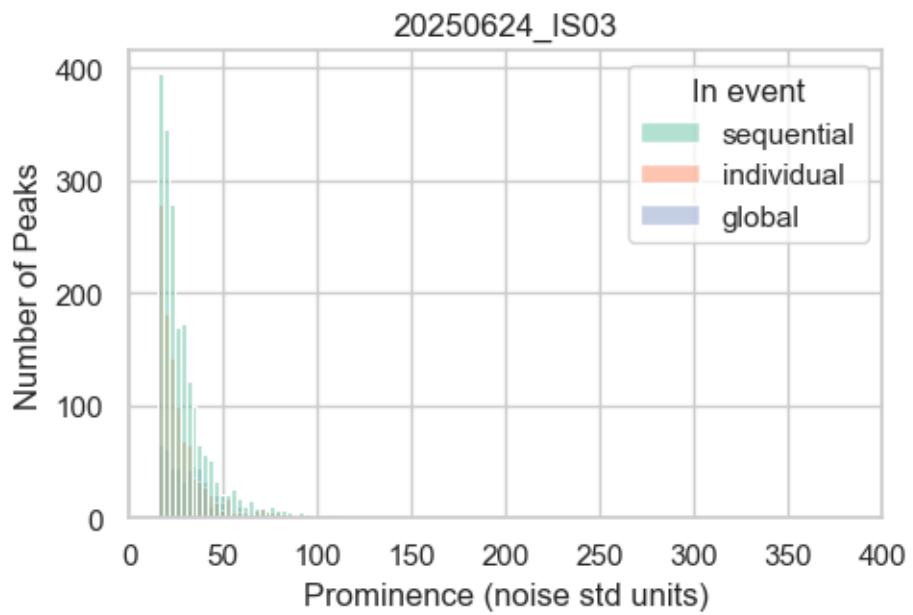
## Distribution of Peak Durations by Group



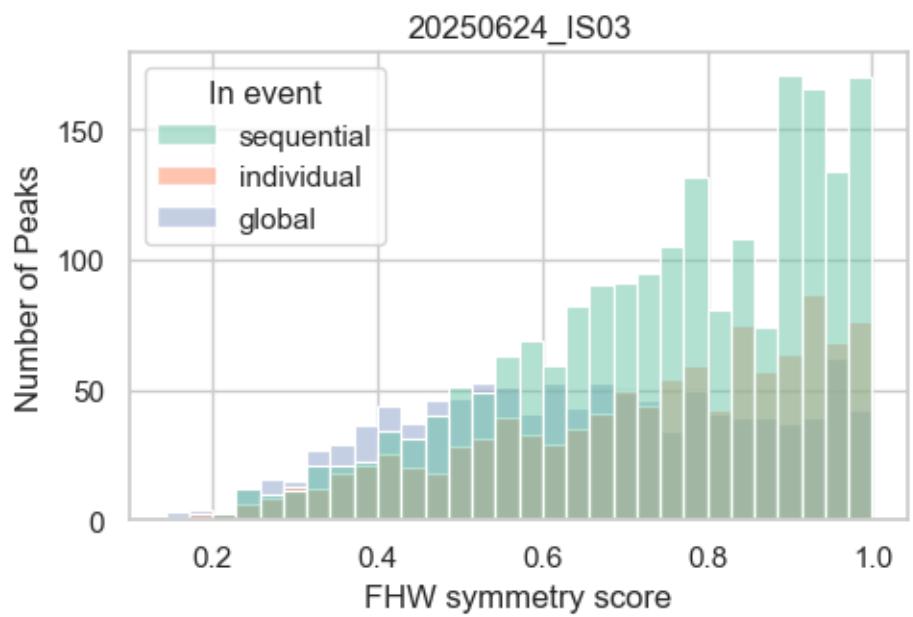
[2025-08-08 15:18:39] [INFO] calcium: Removed 591 outliers from dataset '20250624\_IS03' for column 'Prominence (noise std units)'

[2025-08-08 15:18:39] [INFO] calcium: Lower bound: -17.5, Upper bound: 117.5

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



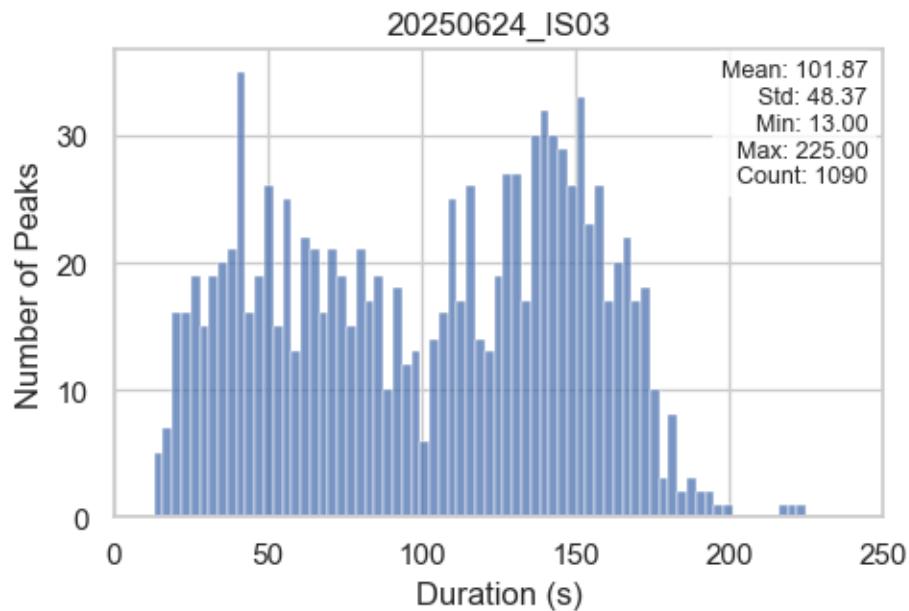
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 15:18:39] [INFO] calcium: Removed 0 outliers from dataset  
'20250624_IS03' for column 'Duration (s)'
```

```
[2025-08-08 15:18:39] [INFO] calcium: Lower bound: -73.5, Upper bound: 405.0
```

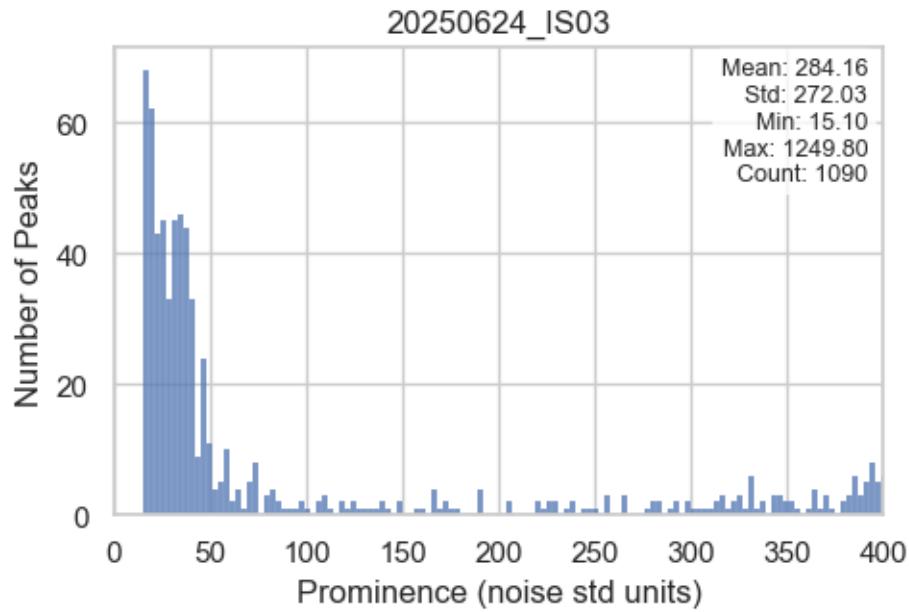
Distribution of Peak Durations



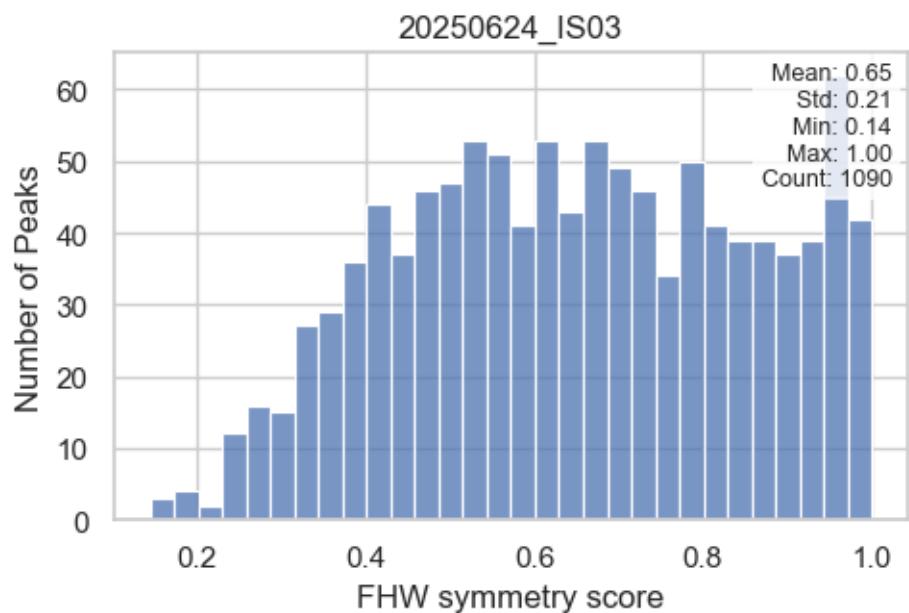
```
[2025-08-08 15:18:39] [INFO] calcium: Removed 0 outliers from dataset  
'20250624_IS03' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:18:39] [INFO] calcium: Lower bound: -708.7375, Upper bound:  
2003.725
```

## Distribution of Peak Prominences



## Distribution of Peak Symmetry Scores

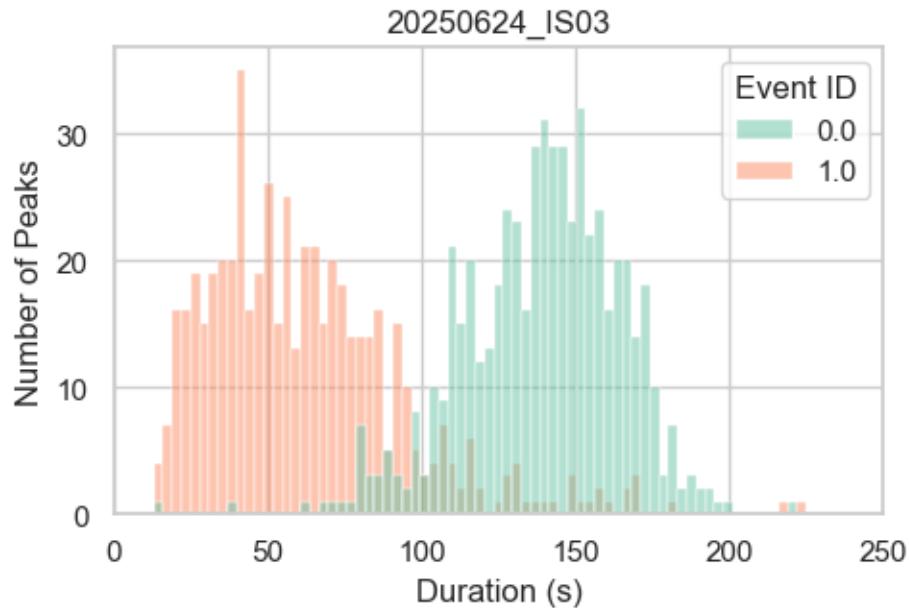


### 1.2.2 Peak statistics in global event per event ID

```
[2025-08-08 15:18:40] [INFO] calcium: Removed 0 outliers from dataset  
'20250624_IS03' for column 'Duration (s)'
```

```
[2025-08-08 15:18:40] [INFO] calcium: Lower bound: -73.5, Upper bound: 405.0
```

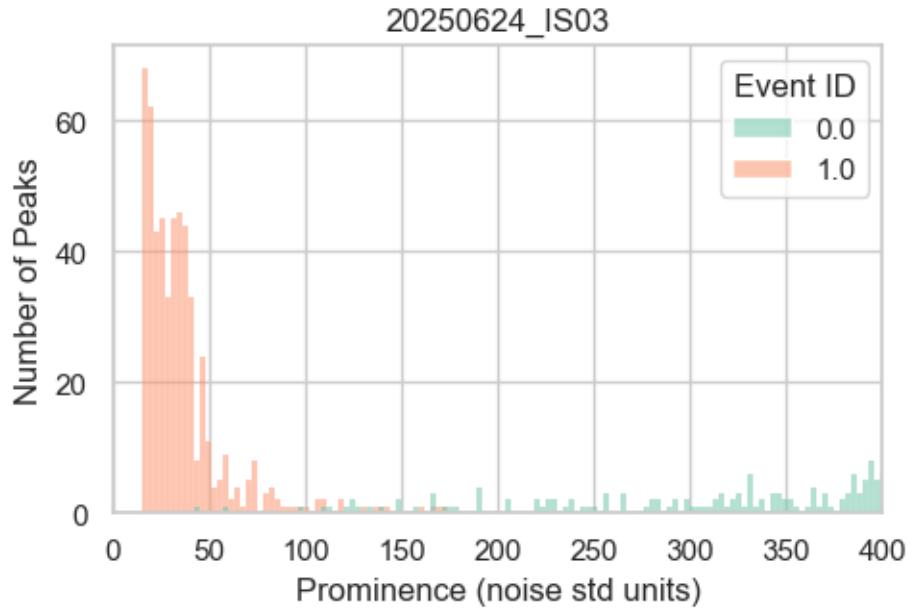
Distribution of Peak Durations by Group



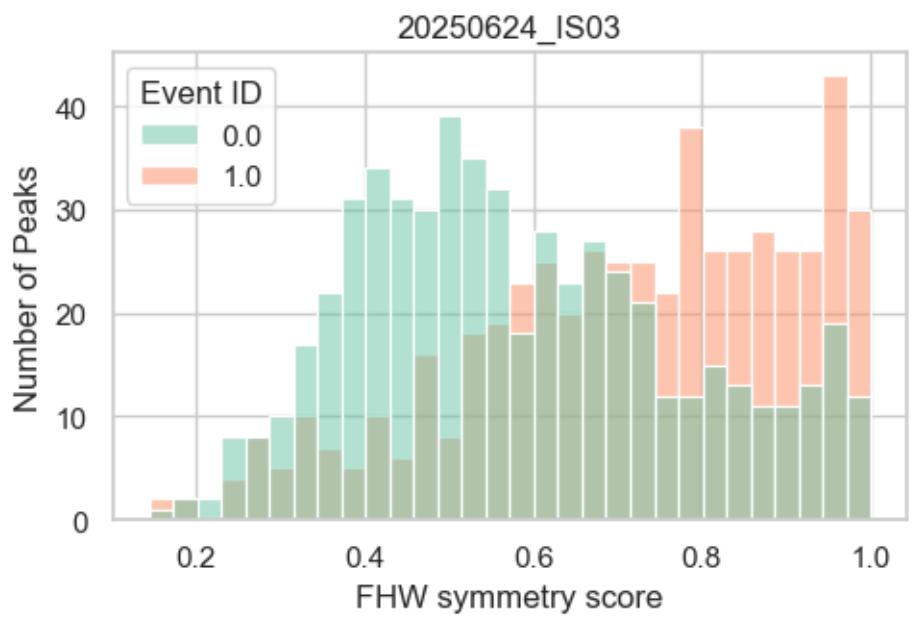
```
[2025-08-08 15:18:40] [INFO] calcium: Removed 0 outliers from dataset  
'20250624_IS03' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:18:40] [INFO] calcium: Lower bound: -708.7, Upper bound: 2003.7
```

Distribution of Peak Prominences by Group



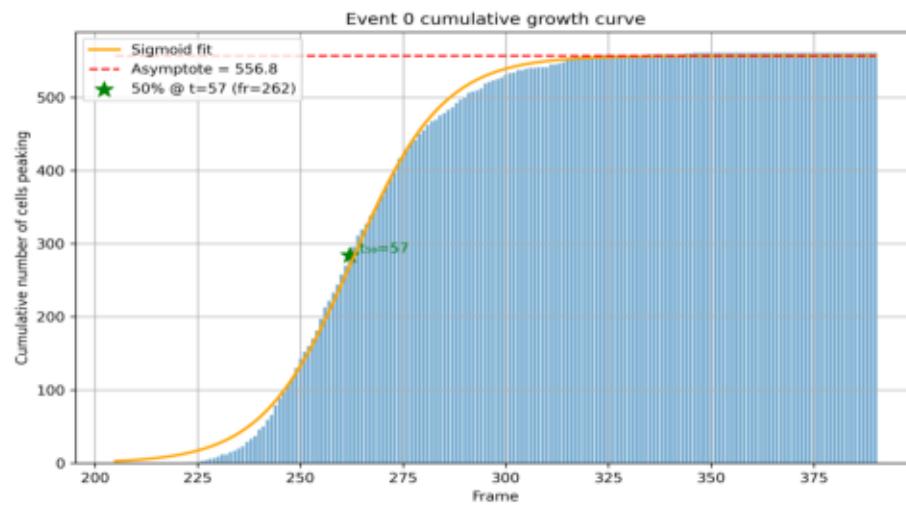
Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

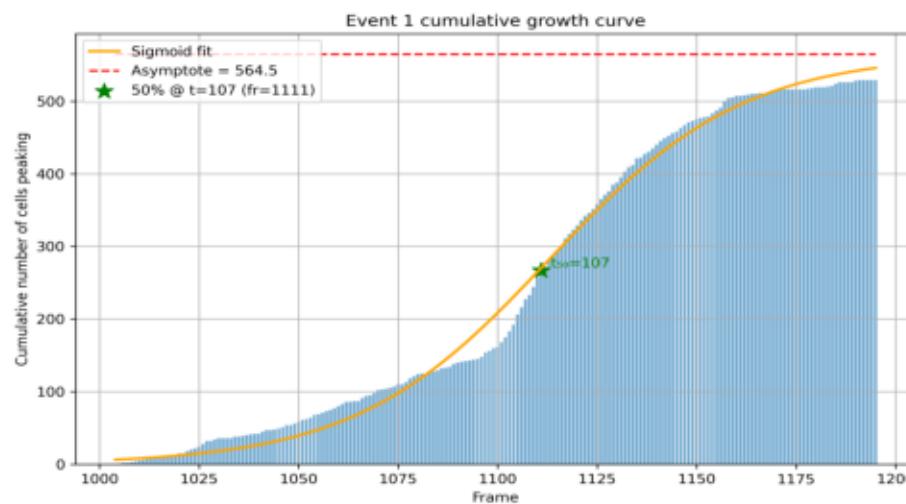
Event Activity Overlay (Event ID: 0)

20250624\_IS03



Event Activity Overlay (Event ID: 1)

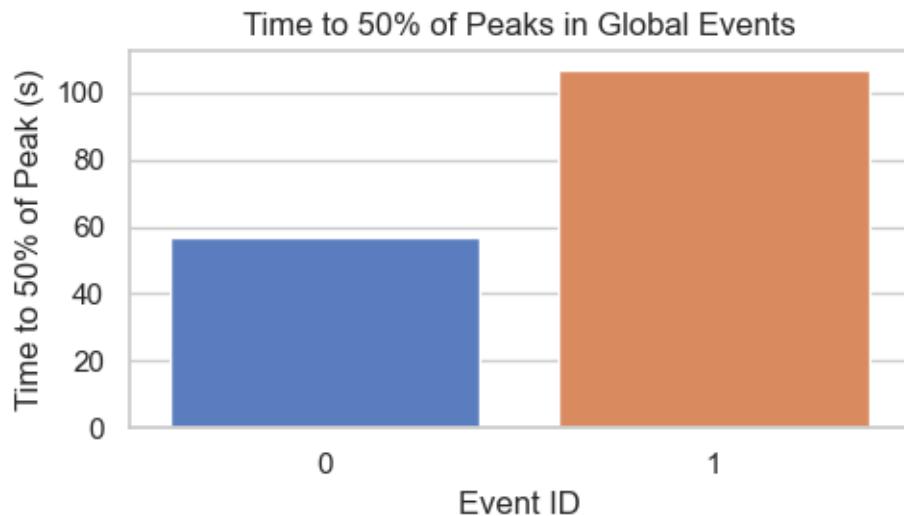
20250624\_IS03



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

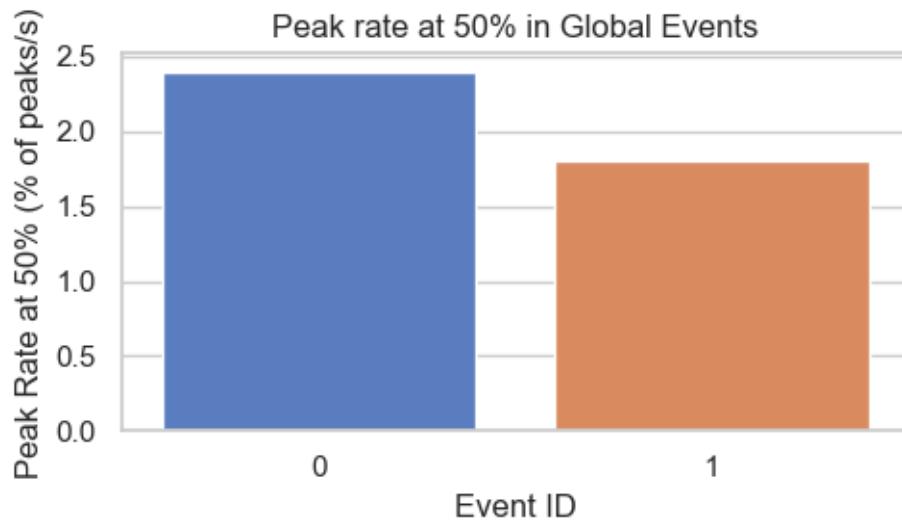
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

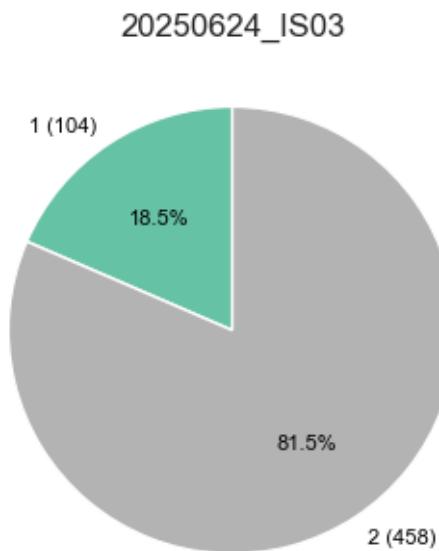
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



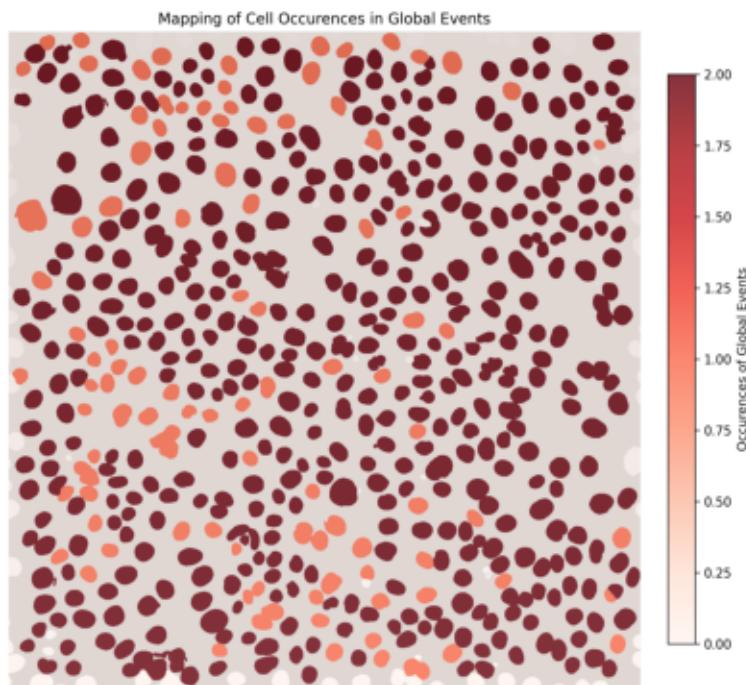
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

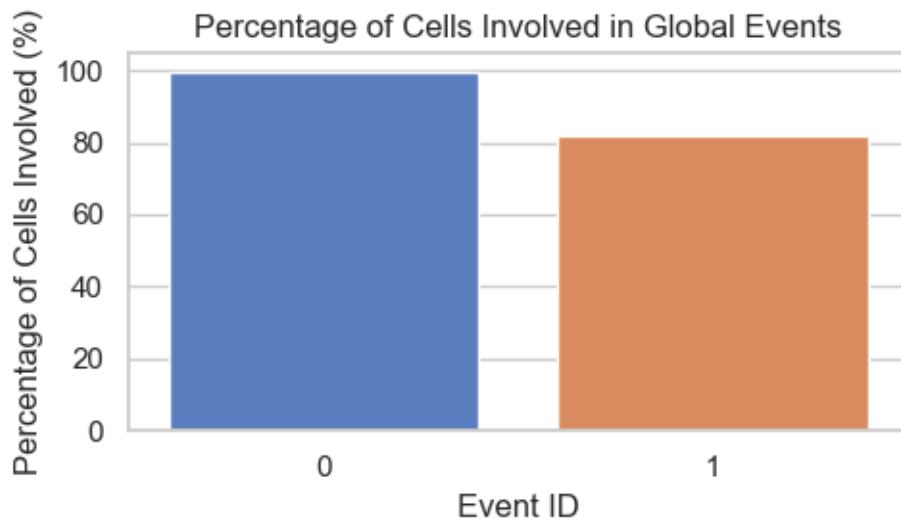
20250624\_IS03



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



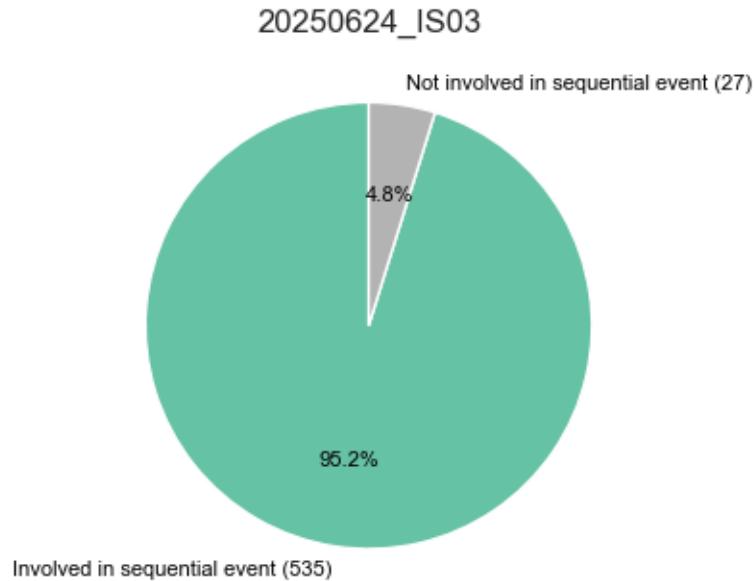
### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [832.0]

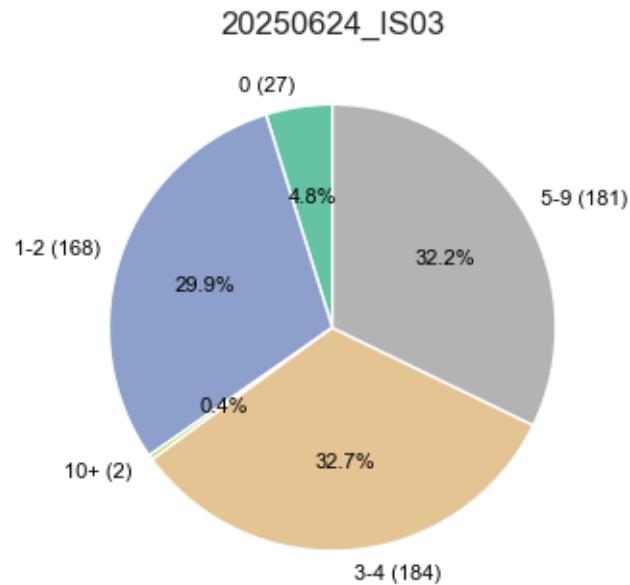
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

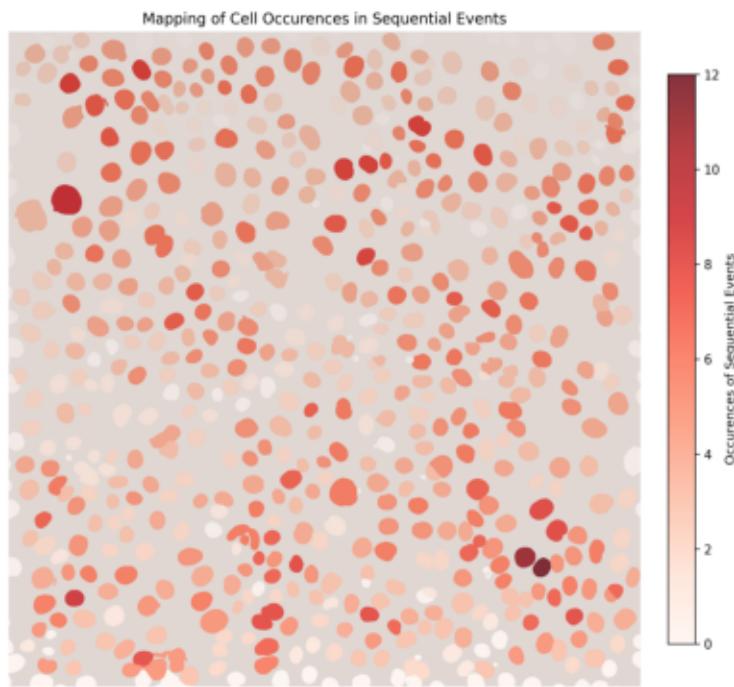


Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250624\_IS03

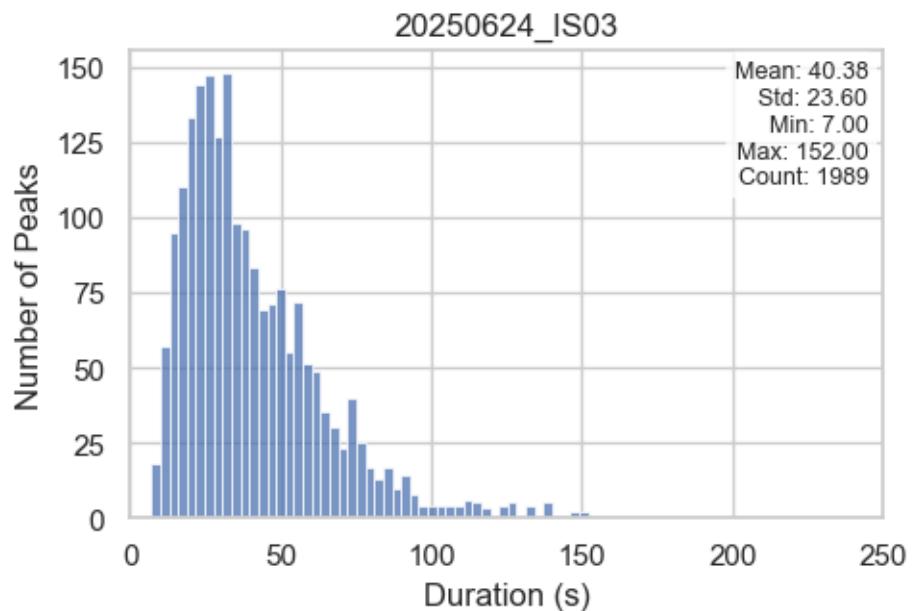


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 15:18:46] [INFO] calcium: Removed 7 outliers from dataset  
'20250624_IS03' for column 'Duration (s)'
```

```
[2025-08-08 15:18:46] [INFO] calcium: Lower bound: -22.0, Upper bound: 158.0
```

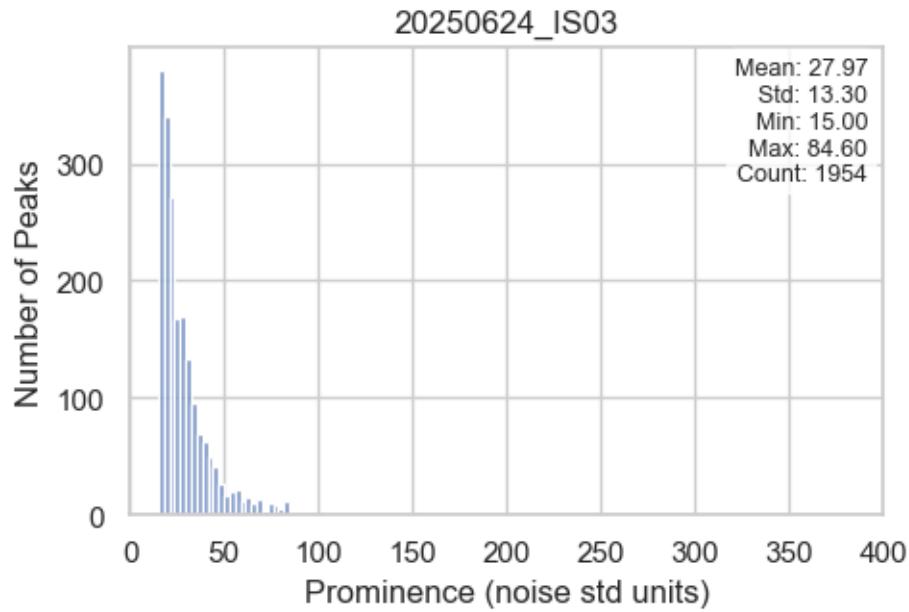
## Distribution of Peak Durations



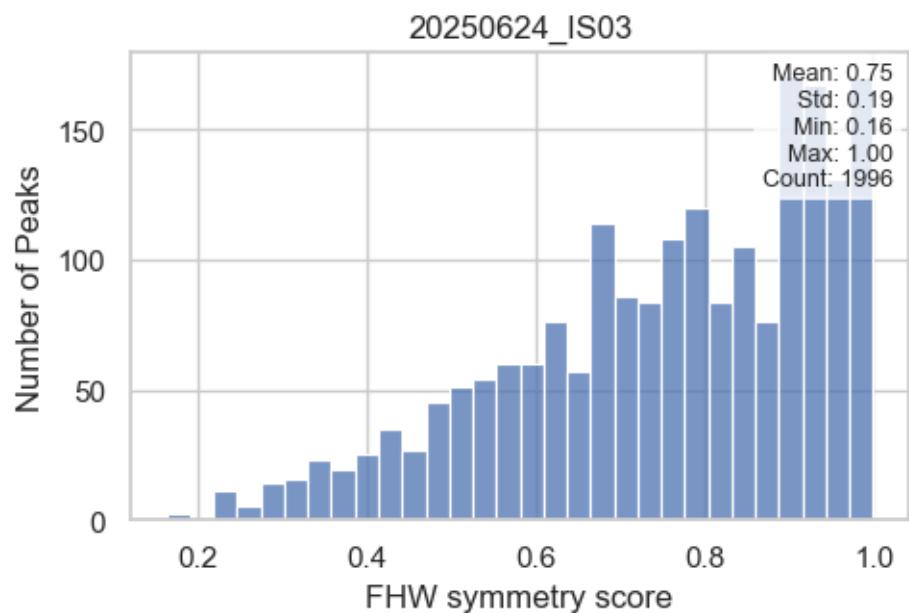
```
[2025-08-08 15:18:46] [INFO] calcium: Removed 42 outliers from dataset '20250624_IS03' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:18:46] [INFO] calcium: Lower bound: -3.137499999999992, Upper bound: 84.6124999999998
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

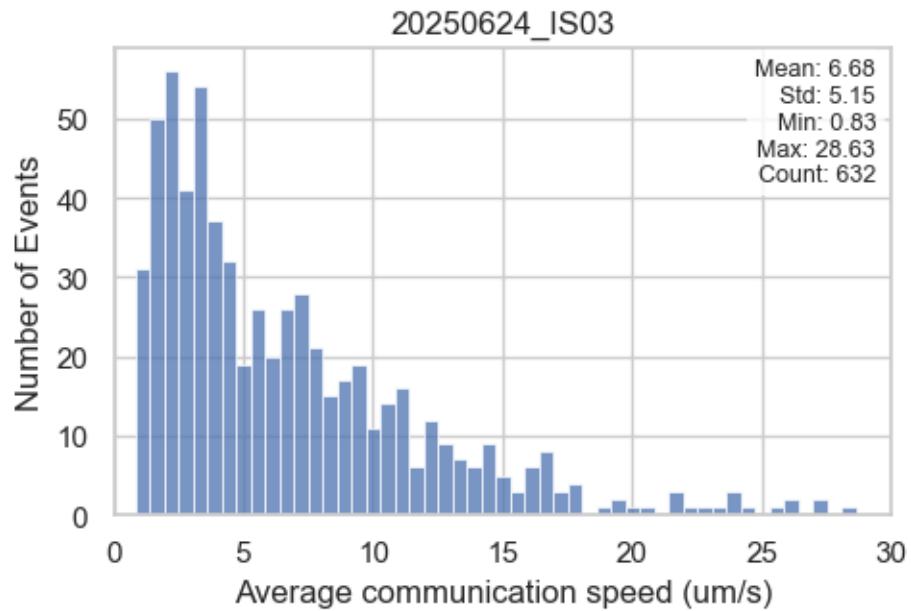


### 1.3.3 Cell-cell communication speed

[2025-08-08 15:18:46] [INFO] calcium: Removed 6 outliers from dataset '20250624\_IS03' for column 'Average communication speed (um/s)'

[2025-08-08 15:18:46] [INFO] calcium: Lower bound: -6.97625, Upper bound: 28.7875

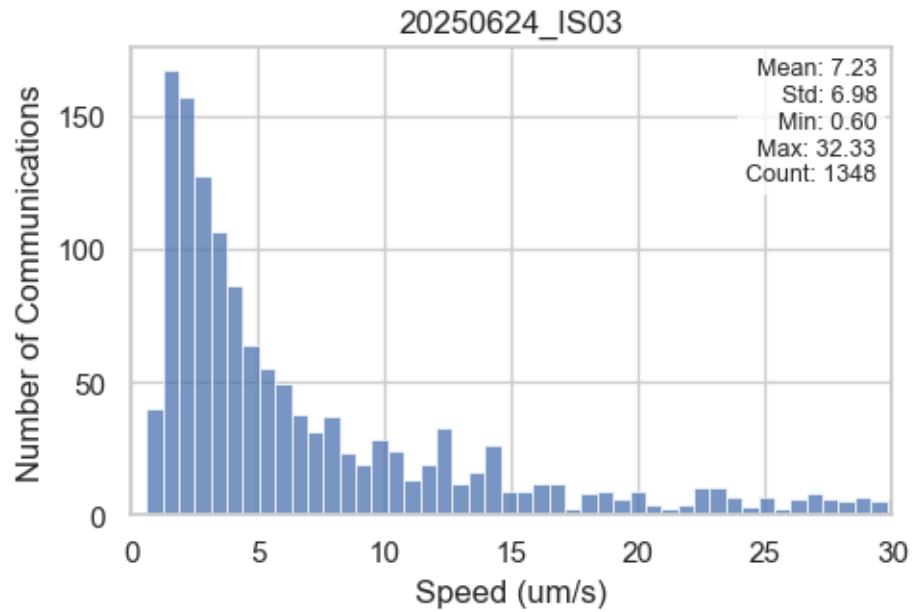
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 15:18:47] [INFO] calcium: Removed 10 outliers from dataset '20250624\_IS03' for column 'Speed (um/s)'

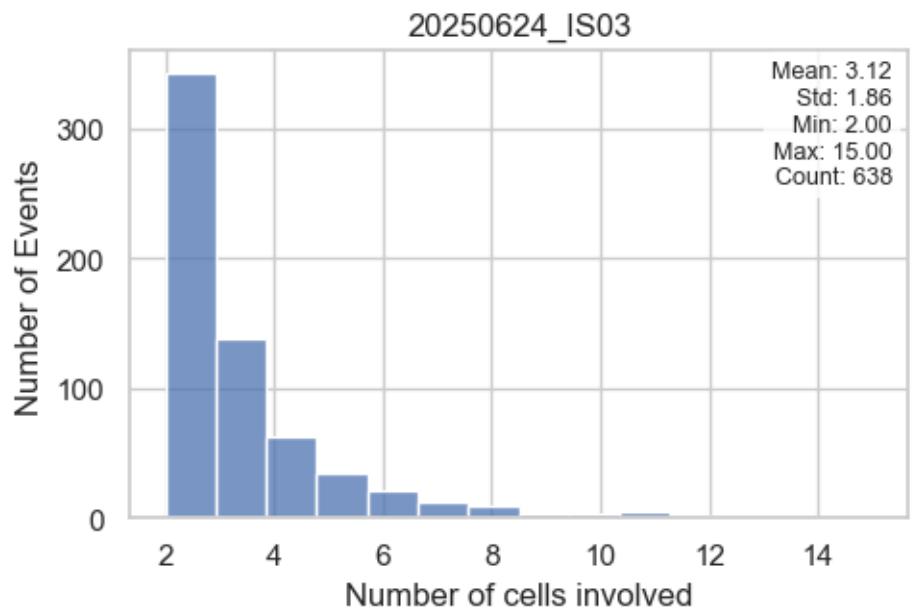
[2025-08-08 15:18:47] [INFO] calcium: Lower bound: -8.95375, Upper bound: 32.64

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

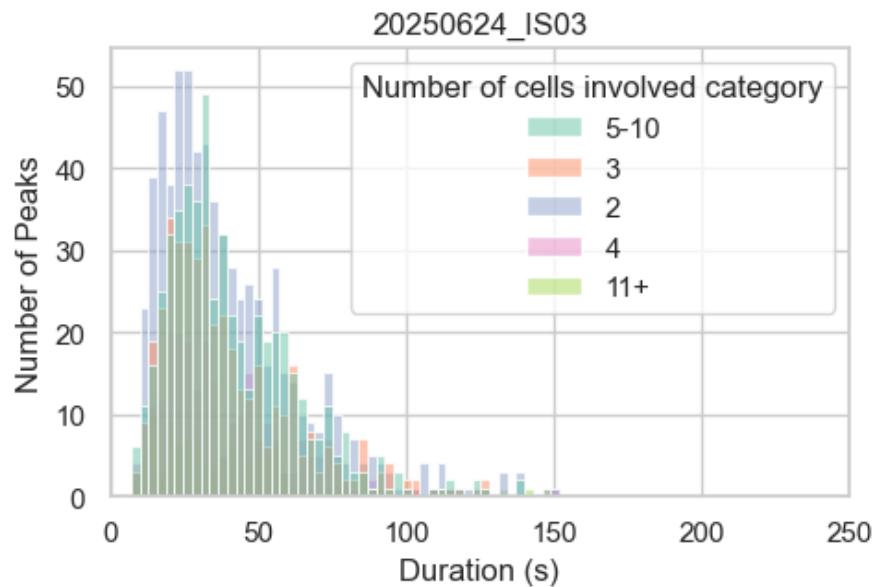


### 1.3.5 Influence of cell count per event on statistics

[2025-08-08 15:18:47] [INFO] calcium: Removed 7 outliers from dataset '20250624\_IS03' for column 'Duration (s)'

[2025-08-08 15:18:47] [INFO] calcium: Lower bound: -22.0, Upper bound: 158.0

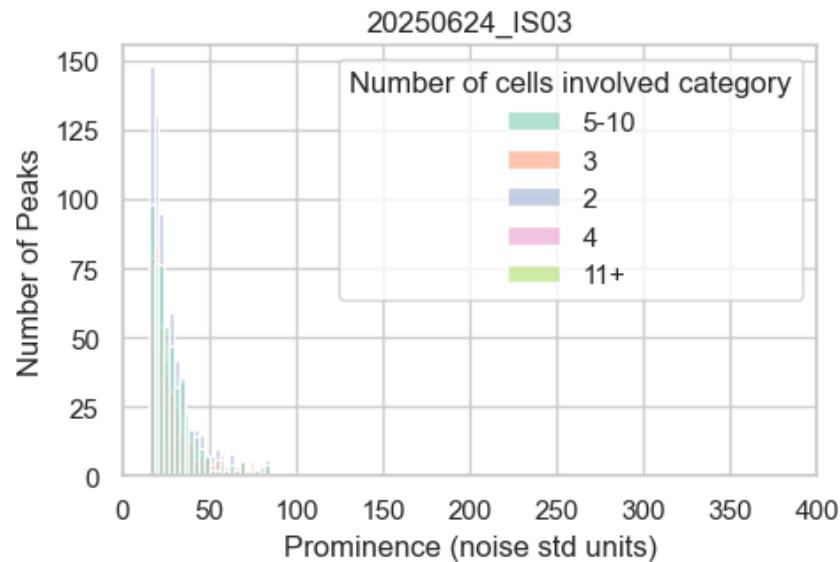
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



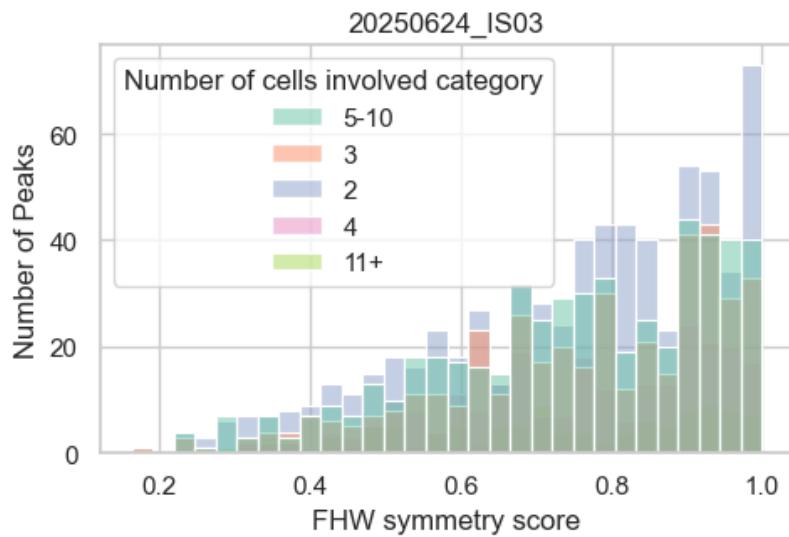
[2025-08-08 15:18:47] [INFO] calcium: Removed 42 outliers from dataset '20250624\_IS03' for column 'Prominence (noise std units)'

[2025-08-08 15:18:47] [INFO] calcium: Lower bound: -3.1, Upper bound: 84.6

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



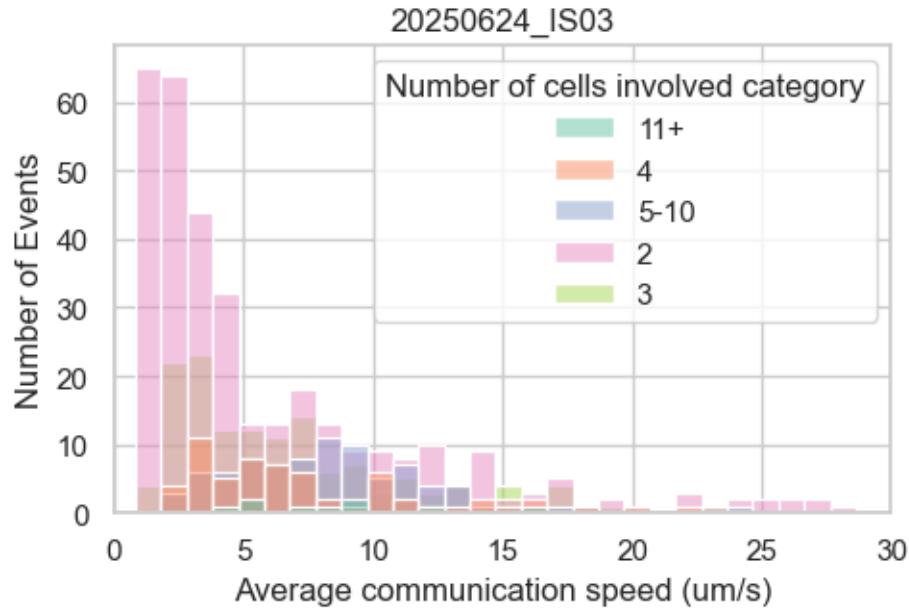
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 15:18:48] [INFO] calcium: Removed 6 outliers from dataset  
'20250624_IS03' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 15:18:48] [INFO] calcium: Lower bound: -7.0, Upper bound: 28.8
```

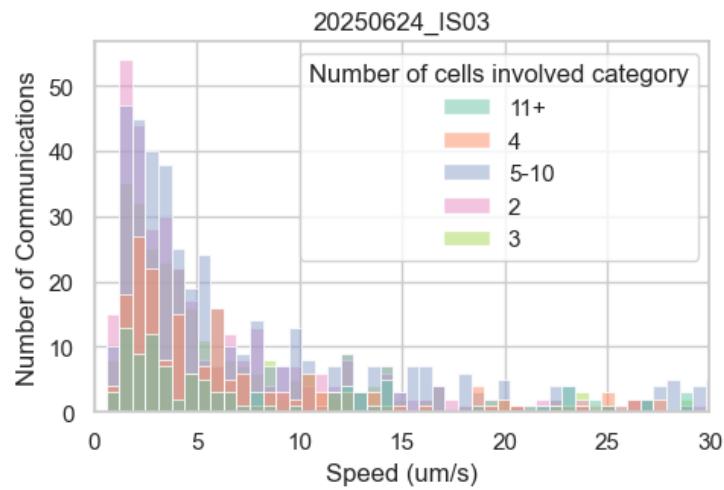
## Distribution of Average Communication Speeds by Number of Cells Involved



[2025-08-08 15:18:48] [INFO] calcium: Removed 10 outliers from dataset '20250624\_IS03' for column 'Speed (um/s)'

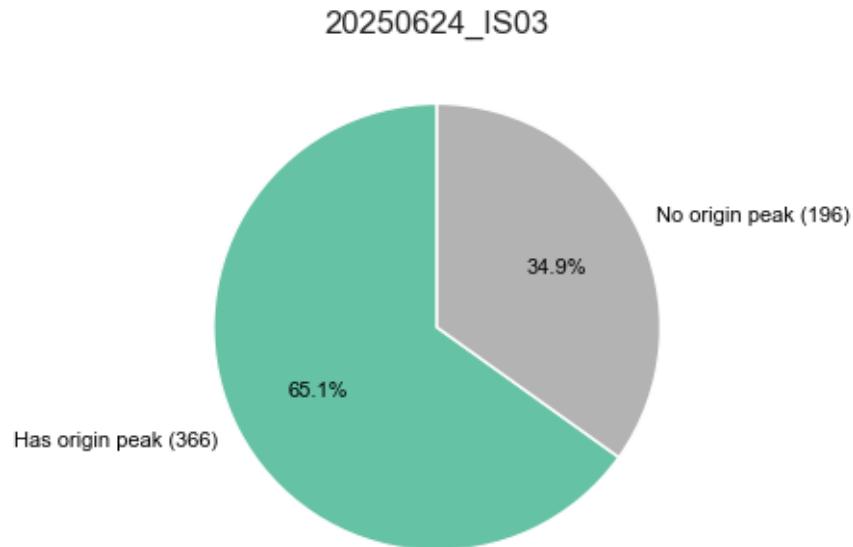
[2025-08-08 15:18:48] [INFO] calcium: Lower bound: -9.0, Upper bound: 32.6

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

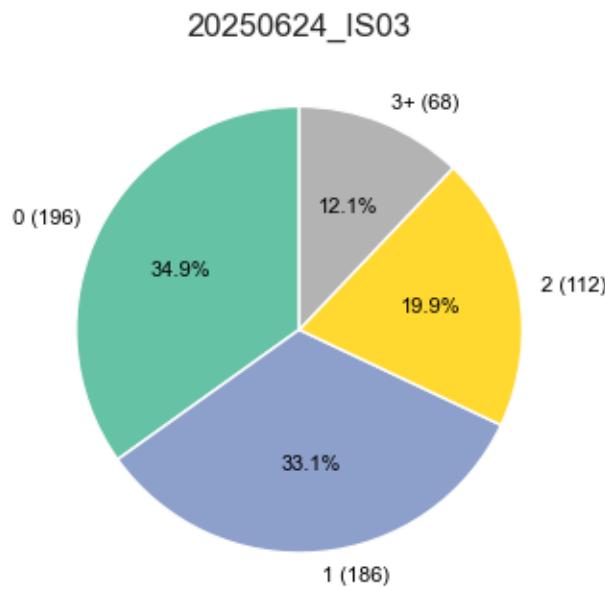


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

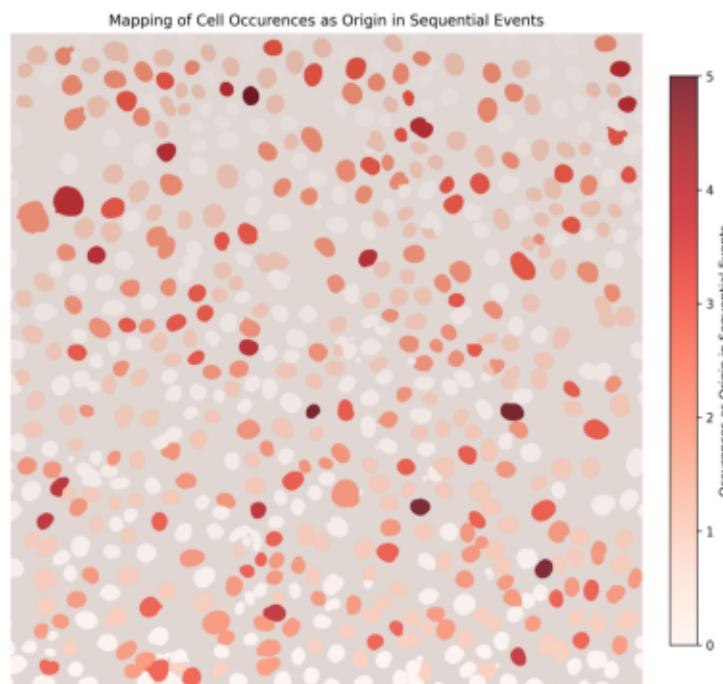


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

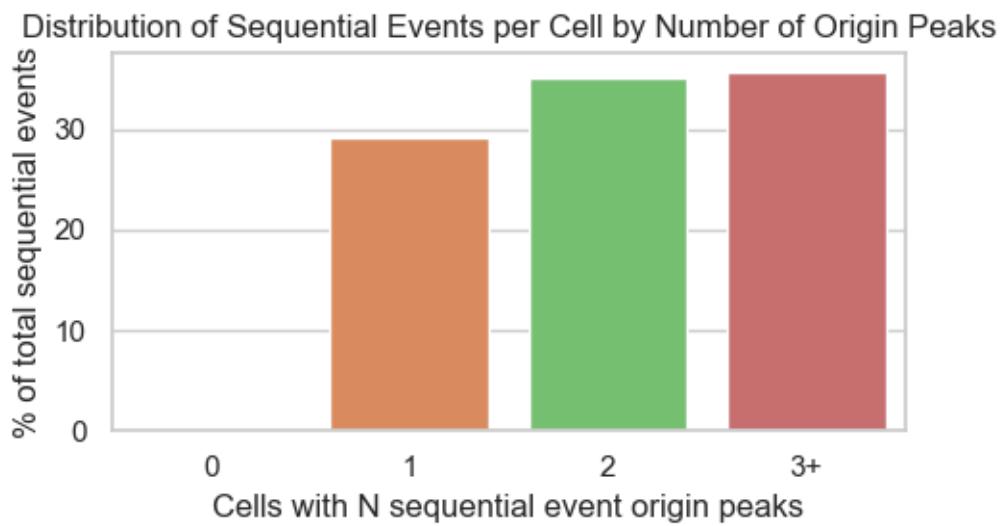
20250624\_IS03



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

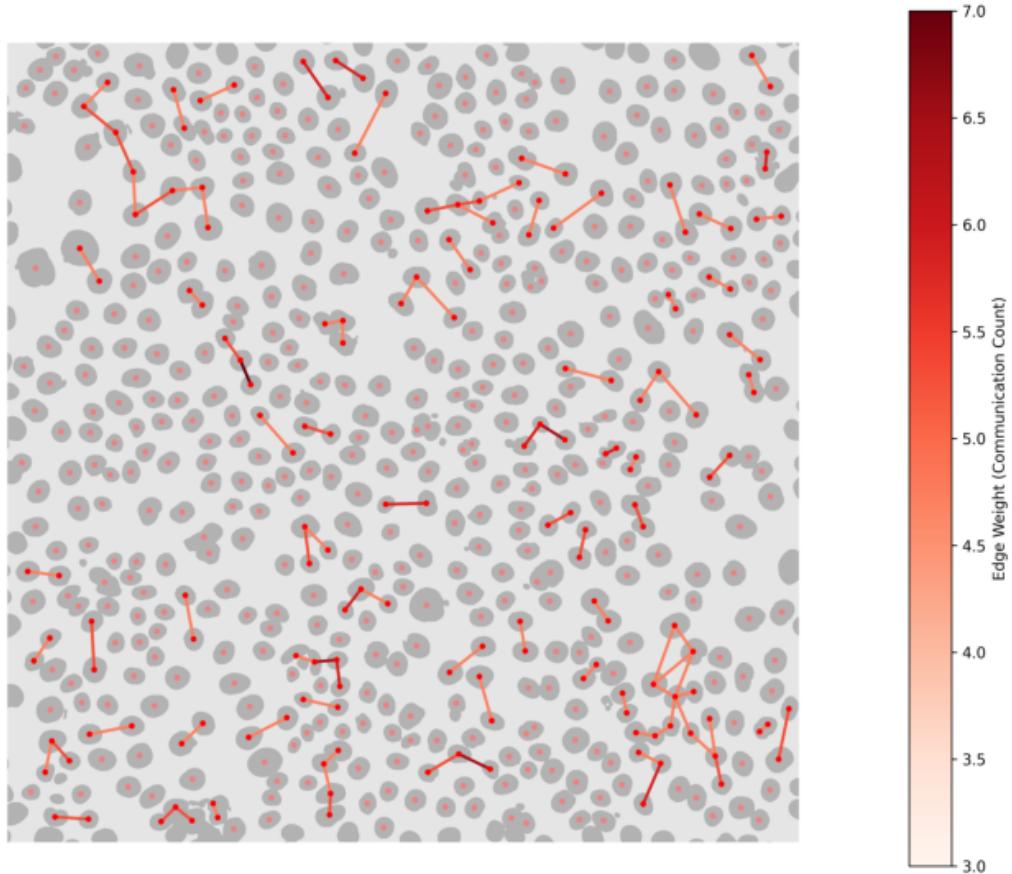


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250624\_IS03

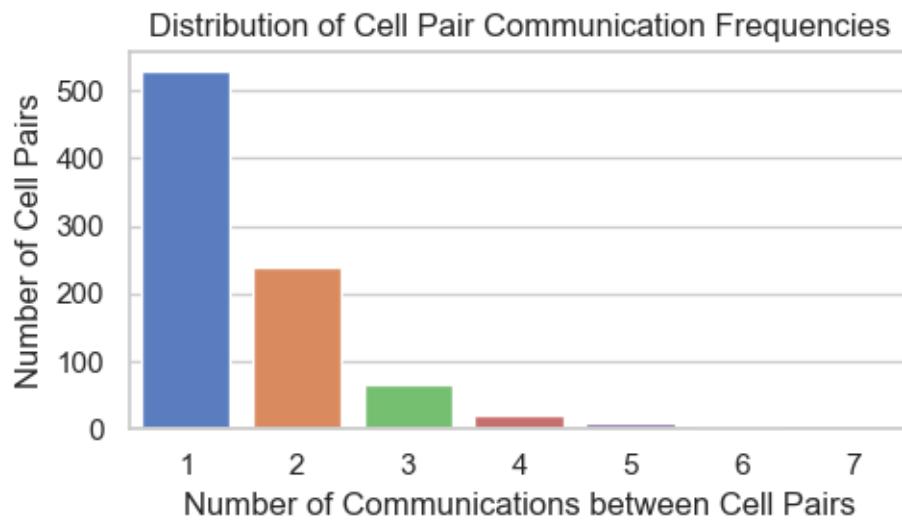
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

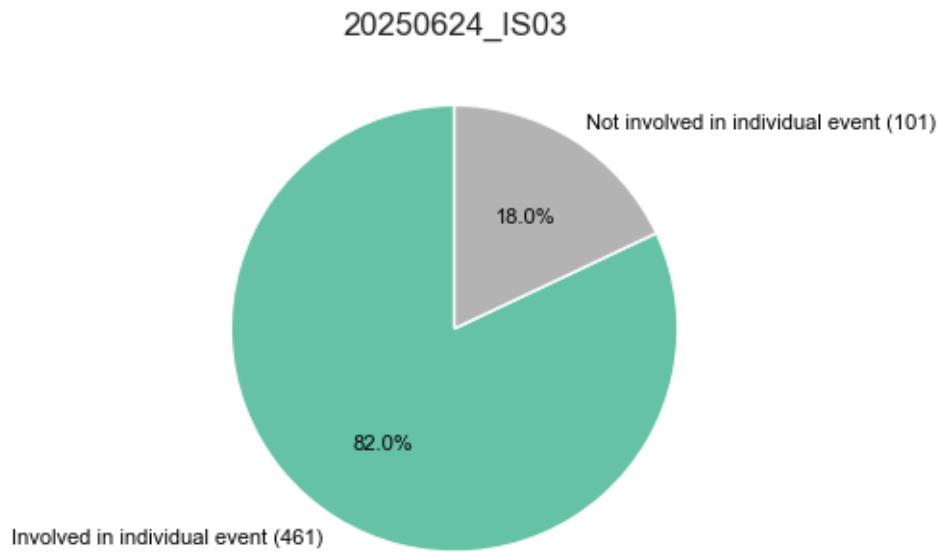
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



## 1.4 INDIVIDUAL EVENTS

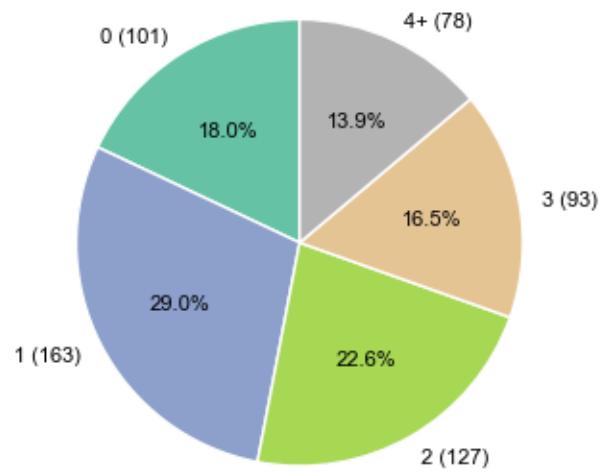
### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events



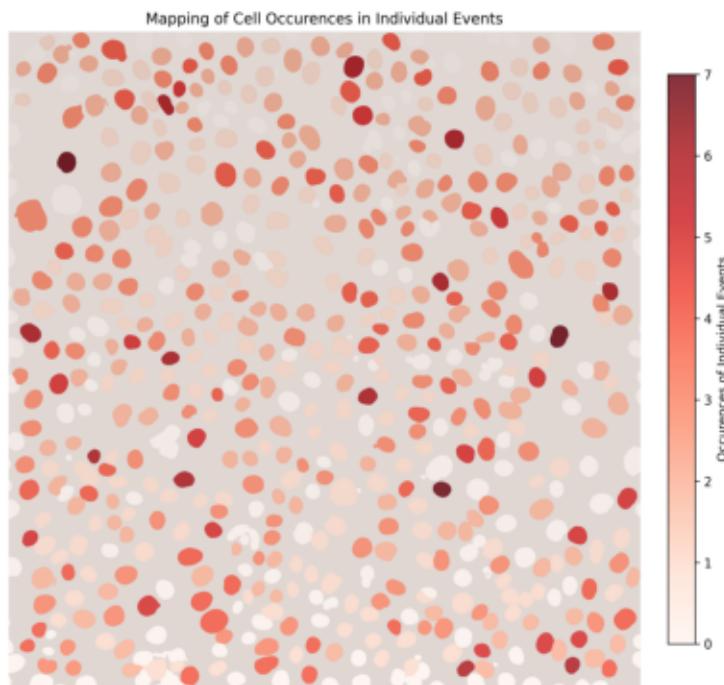
### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)

20250624\_IS03



## Cell Mapping with Occurrences in Individual Events Overlay

20250624\_IS03

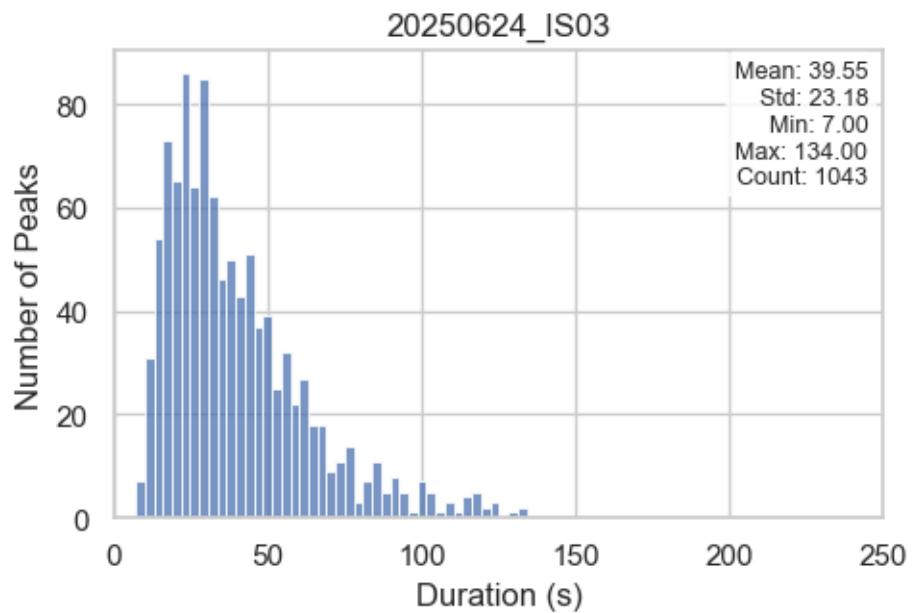


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 15:18:52] [INFO] calcium: Removed 14 outliers from dataset  
'20250624_IS03' for column 'Duration (s)'
```

```
[2025-08-08 15:18:52] [INFO] calcium: Lower bound: -19.0, Upper bound: 135.0
```

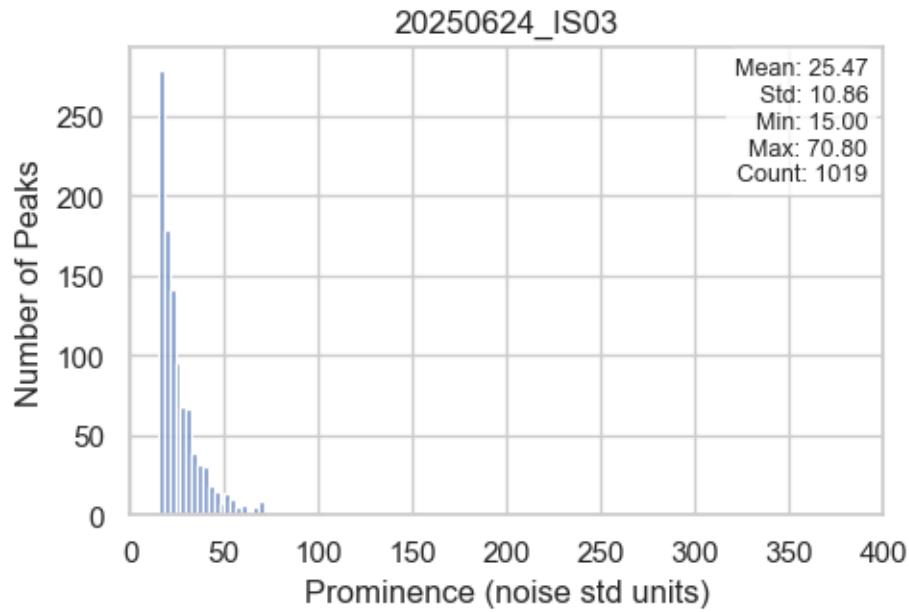
## Distribution of Peak Durations



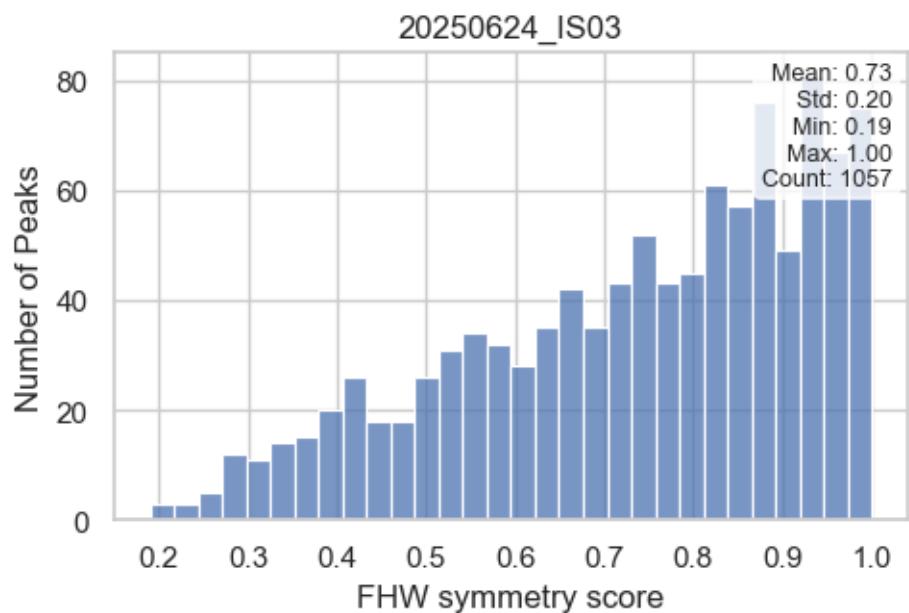
```
[2025-08-08 15:18:52] [INFO] calcium: Removed 38 outliers from dataset  
'20250624_IS03' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:18:52] [INFO] calcium: Lower bound: -2.299999999999997, Upper  
bound: 71.39999999999999
```

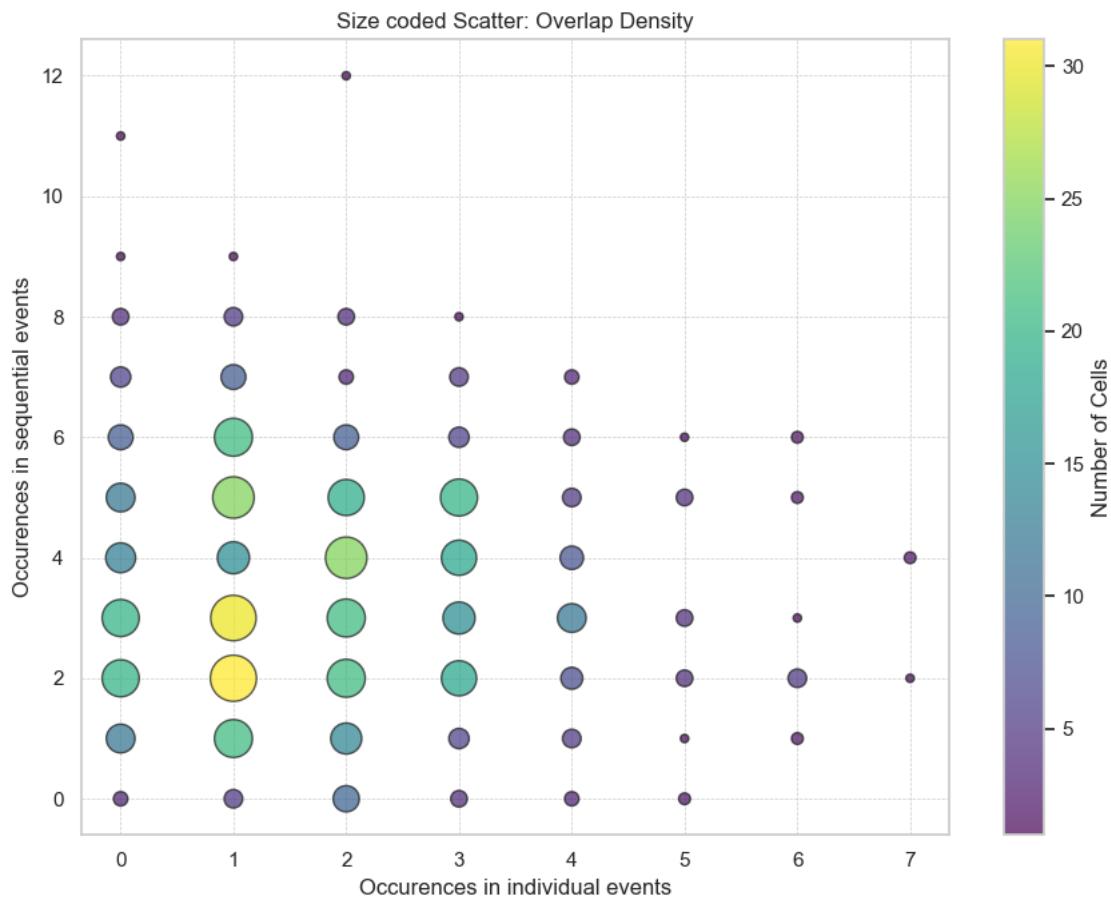
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

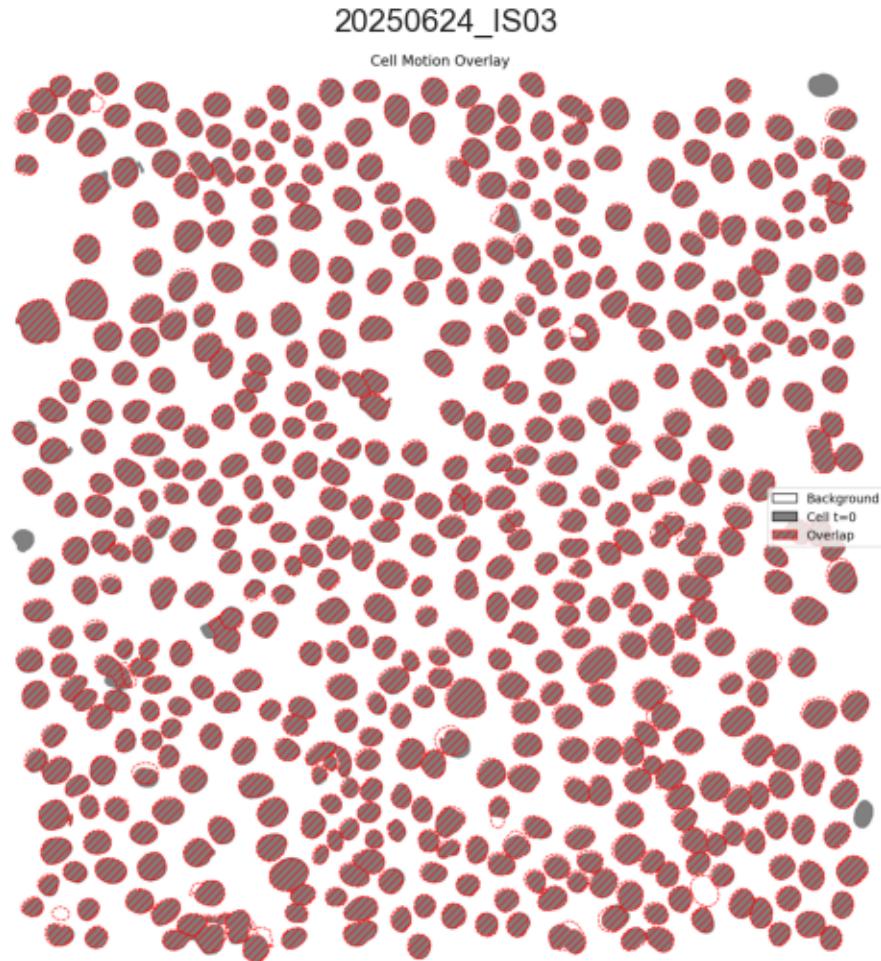


### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay



Number of cells:

- Hoechst image taken at t=0: 562
- Hoechst image taken at t=1801: 552
- Number of cells difference: absolute 10, relative 1.80%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 780011
- Pixels segmented as cell at t=1801: 787021
- Overlapping pixels between t=0 and t=1801: 725792 (92.63% of total)
- Pixels exclusive to t=0: 54219 (6.95% of total)
- Pixels exclusive to t=1801: 61229 (7.78% of total)

executed

August 8, 2025

# 1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

## 1.0.1 Initialization

```
[2]: '\ncontrol_paths = {\n    "Default Dataset": "/path/to/your/dataset"\n}'
```

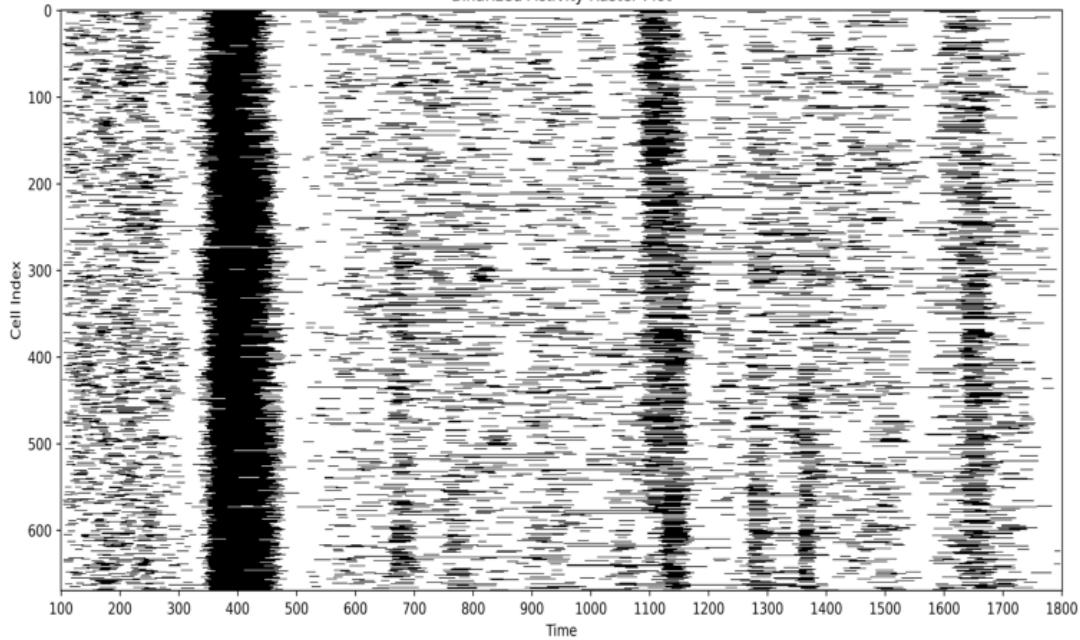
## 1.1 POPULATION

### 1.1.1 Binary & Heatmap Raster Plot

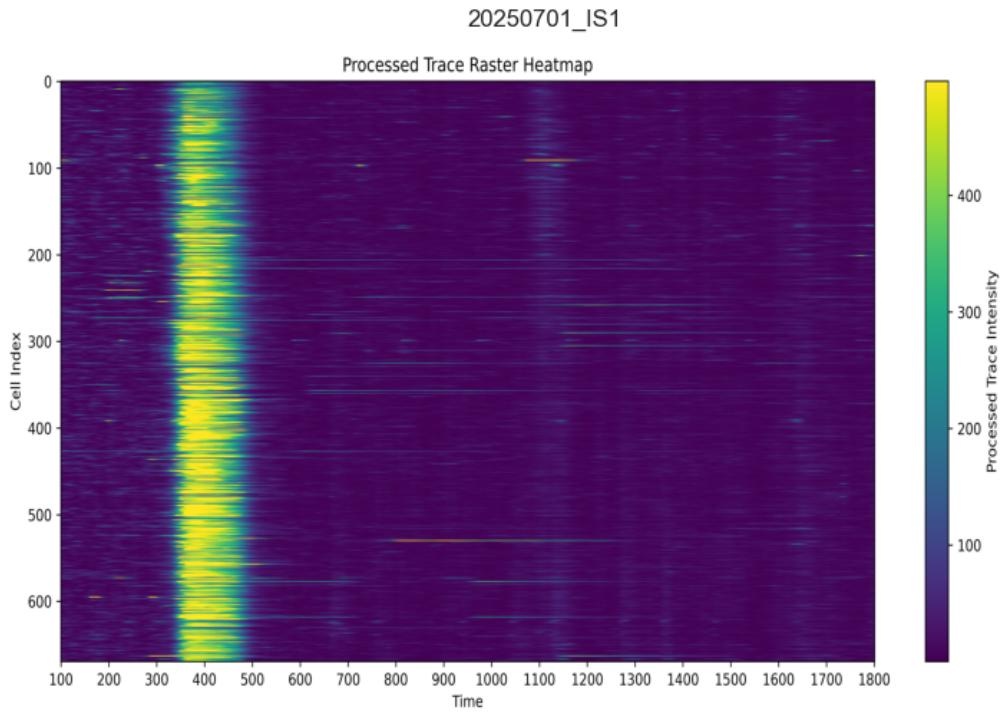
Binary Activity Raster Plot

20250701\_IS1

Binarized Activity Raster Plot



## Heatmap Activity Raster Plot



### 1.1.2 Peaks population

Total number of peaks: 5765

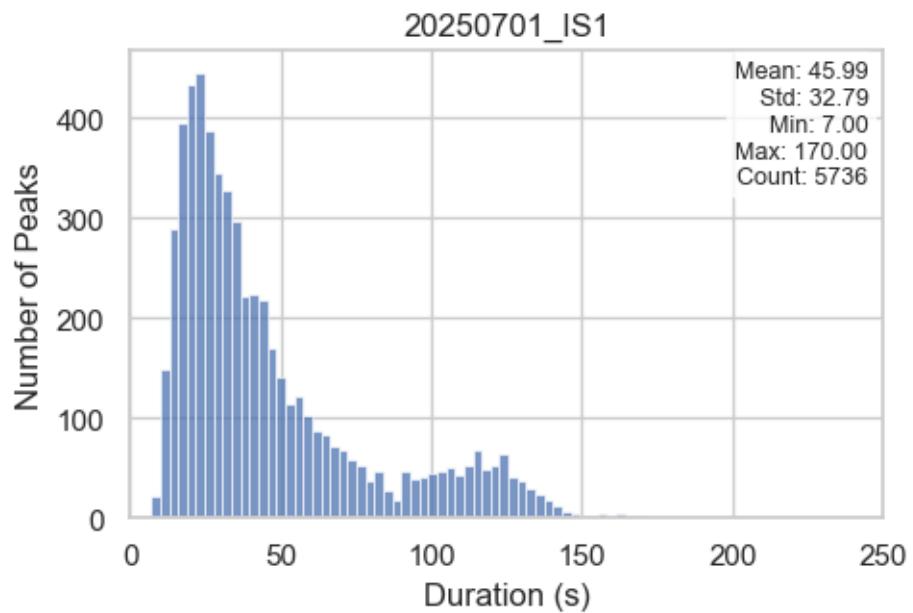
Total number of cells: 670

### 1.1.3 Peaks statistics

```
[2025-08-08 15:24:42] [INFO] calcium: Removed 29 outliers from dataset  
'20250701_IS1' for column 'Duration (s)'
```

```
[2025-08-08 15:24:42] [INFO] calcium: Lower bound: -33.5, Upper bound: 170.0
```

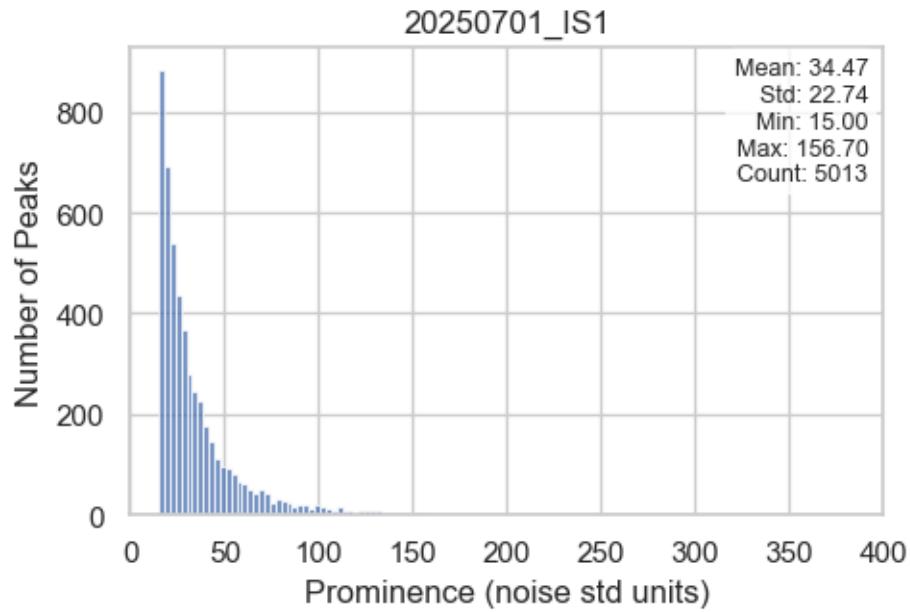
## Distribution of Peak Durations



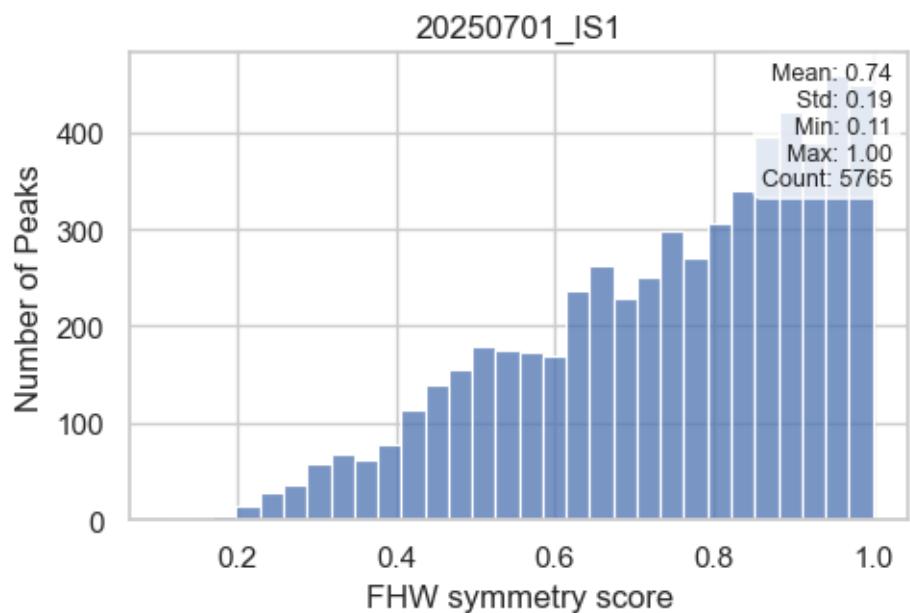
[2025-08-08 15:24:43] [INFO] calcium: Removed 752 outliers from dataset '20250701\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 15:24:43] [INFO] calcium: Lower bound: -31.45, Upper bound: 158.3

### Distribution of Peak Prominences

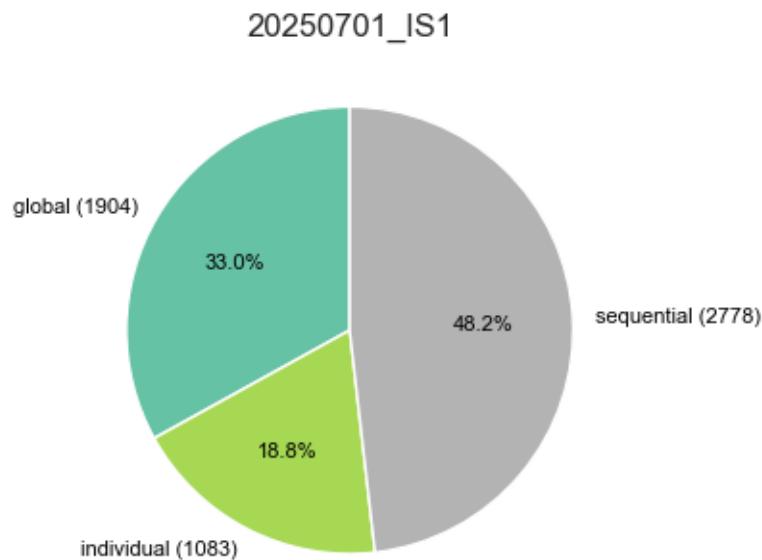


### Distribution of Peak Symmetry Scores



#### 1.1.4 Distribution of peaks per event types

Distribution of Peaks by Event types

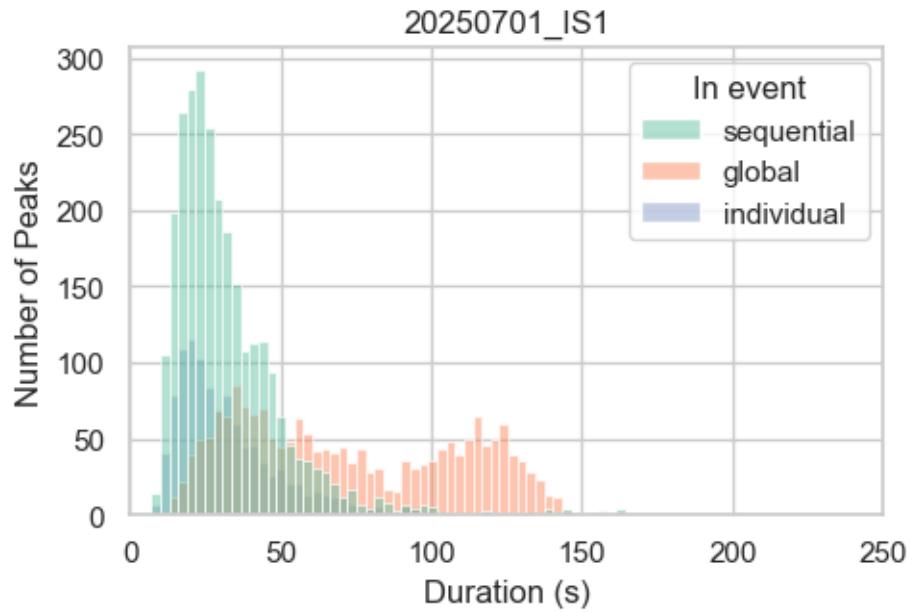


#### 1.1.5 Peaks statistics per event types

```
[2025-08-08 15:24:43] [INFO] calcium: Removed 29 outliers from dataset  
'20250701_IS1' for column 'Duration (s)'
```

```
[2025-08-08 15:24:43] [INFO] calcium: Lower bound: -33.5, Upper bound: 170.0
```

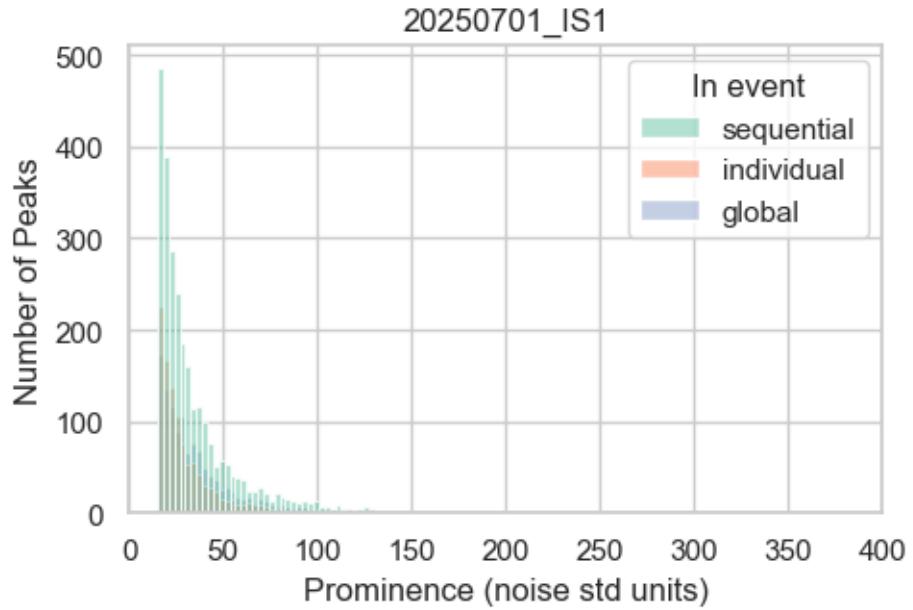
## Distribution of Peak Durations by Group



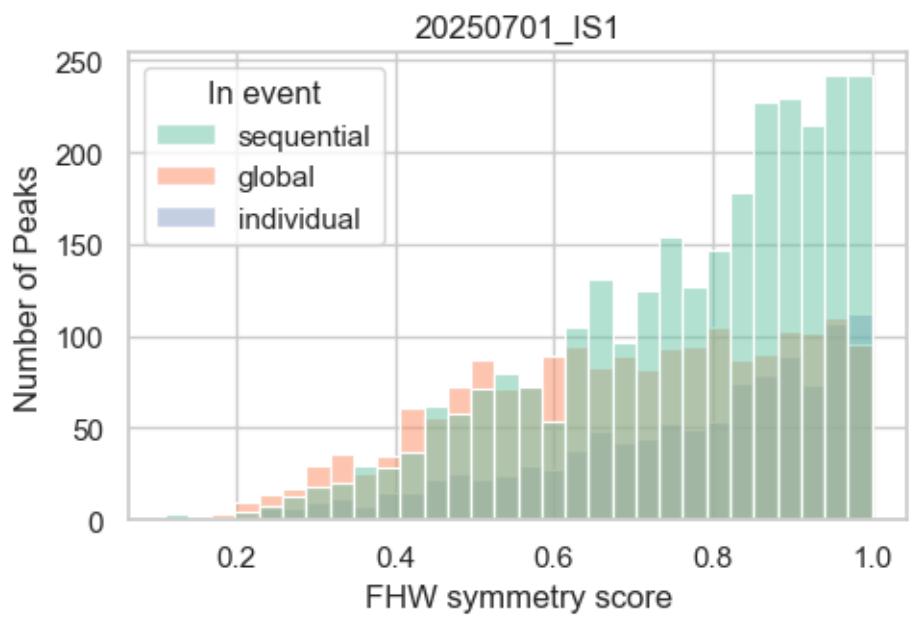
[2025-08-08 15:24:44] [INFO] calcium: Removed 752 outliers from dataset '20250701\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 15:24:44] [INFO] calcium: Lower bound: -31.4, Upper bound: 158.3

### Distribution of Peak Prominences by Group



### Distribution of Peak Symmetry Scores by Group



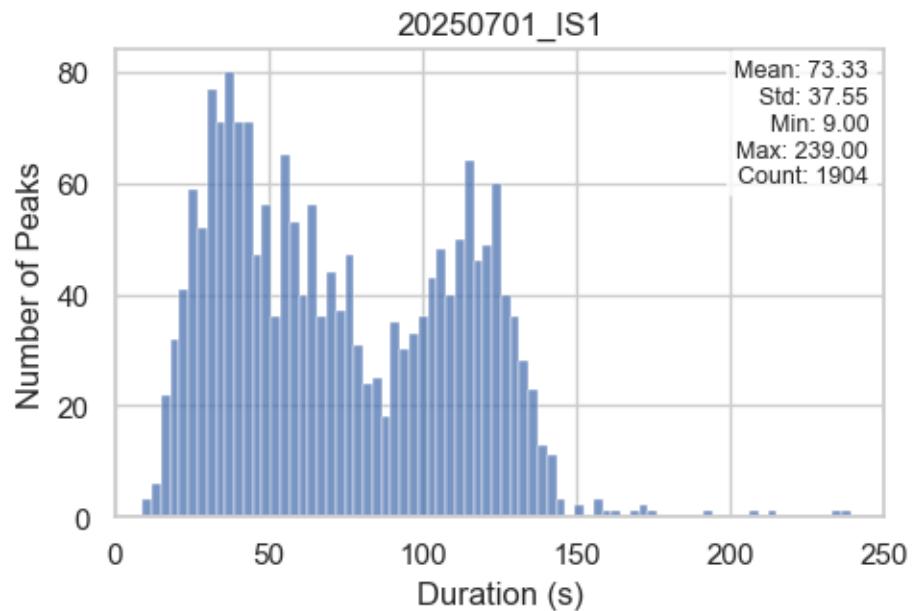
## 1.2 GLOBAL EVENTS

### 1.2.1 Peak statistics in global events

```
[2025-08-08 15:24:44] [INFO] calcium: Removed 0 outliers from dataset  
'20250701_IS1' for column 'Duration (s)'
```

```
[2025-08-08 15:24:44] [INFO] calcium: Lower bound: -62.0, Upper bound: 312.0
```

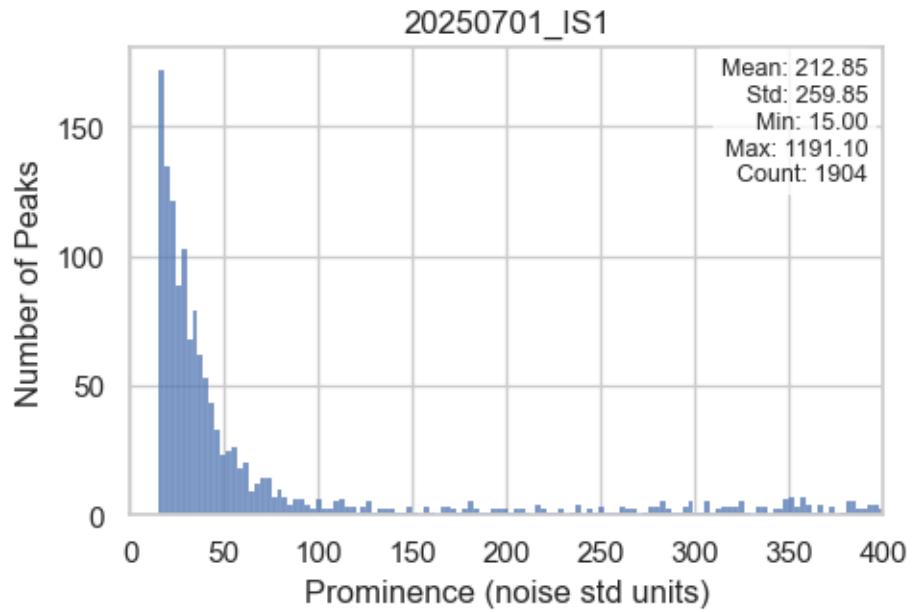
Distribution of Peak Durations



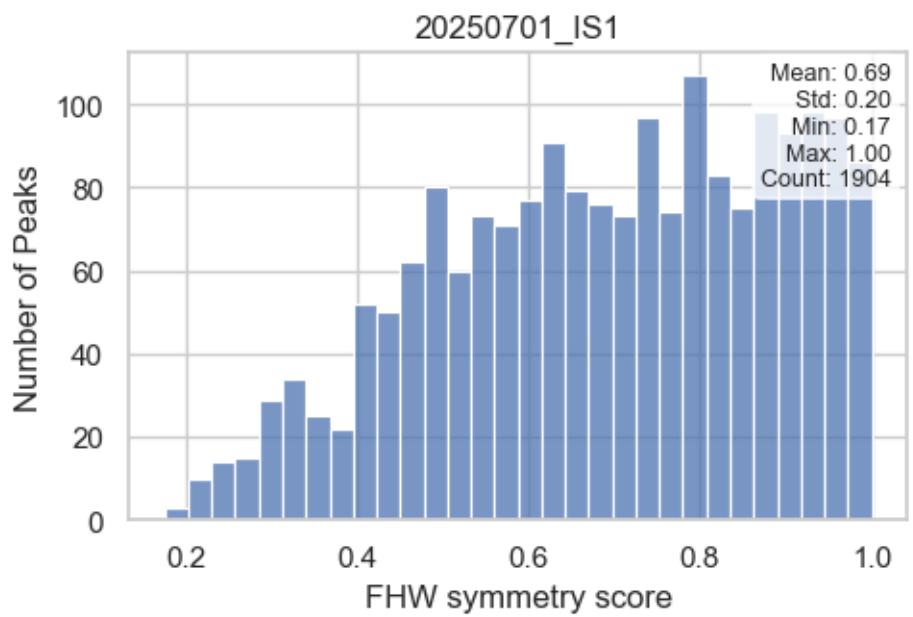
```
[2025-08-08 15:24:44] [INFO] calcium: Removed 0 outliers from dataset  
'20250701_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:24:44] [INFO] calcium: Lower bound: -569.5875, Upper bound:  
1611.3000000000002
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

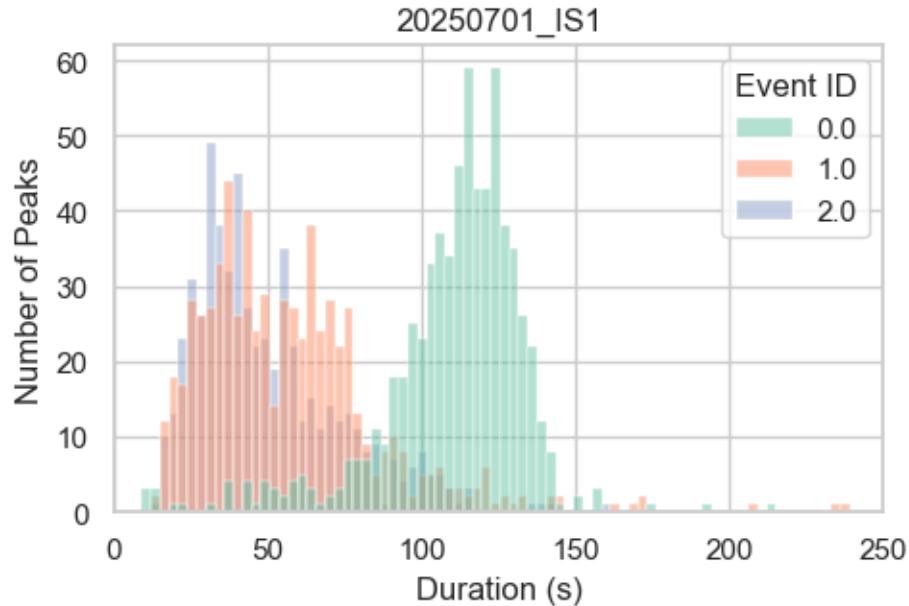


### 1.2.2 Peak statistics in global event per event ID

[2025-08-08 15:24:45] [INFO] calcium: Removed 0 outliers from dataset '20250701\_IS1' for column 'Duration (s)'

[2025-08-08 15:24:45] [INFO] calcium: Lower bound: -62.0, Upper bound: 312.0

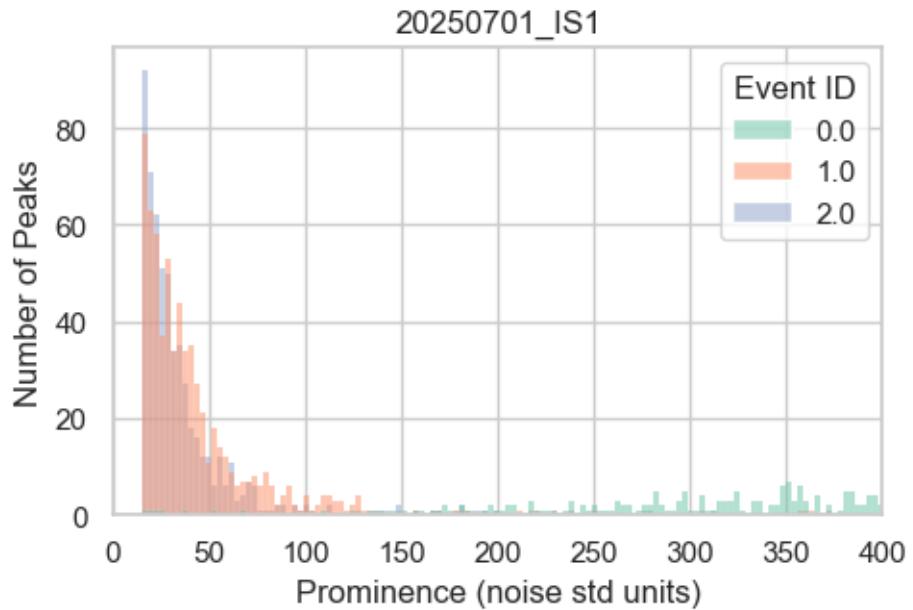
Distribution of Peak Durations by Group



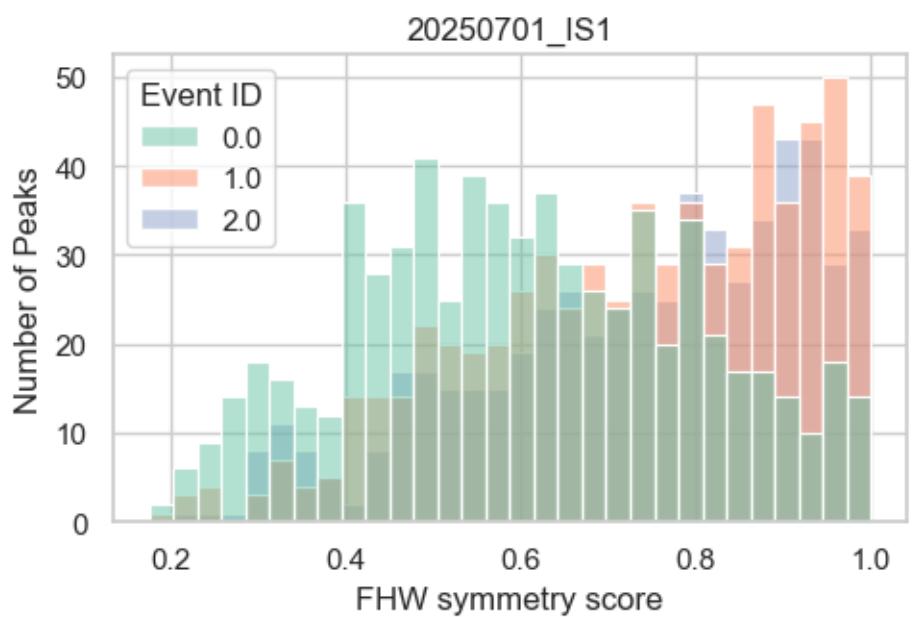
[2025-08-08 15:24:45] [INFO] calcium: Removed 0 outliers from dataset '20250701\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 15:24:45] [INFO] calcium: Lower bound: -569.6, Upper bound: 1611.3

Distribution of Peak Prominences by Group



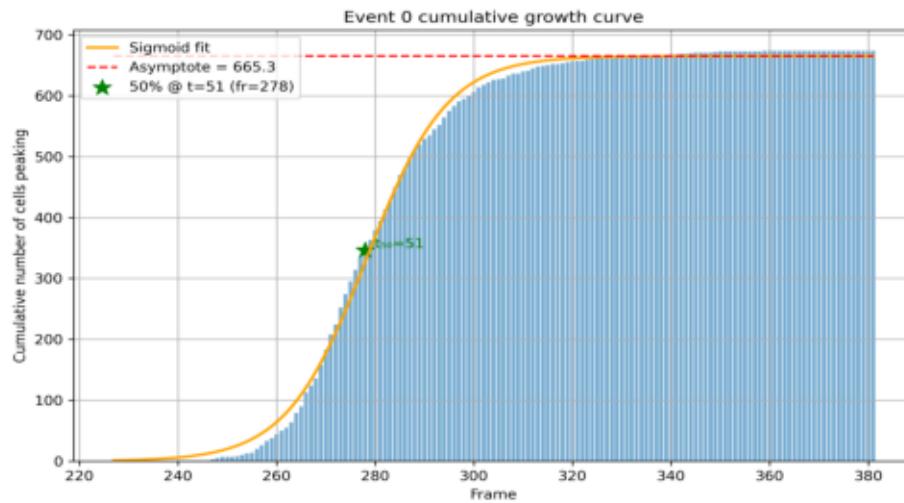
Distribution of Peak Symmetry Scores by Group



### 1.2.3 Kinetics of global events

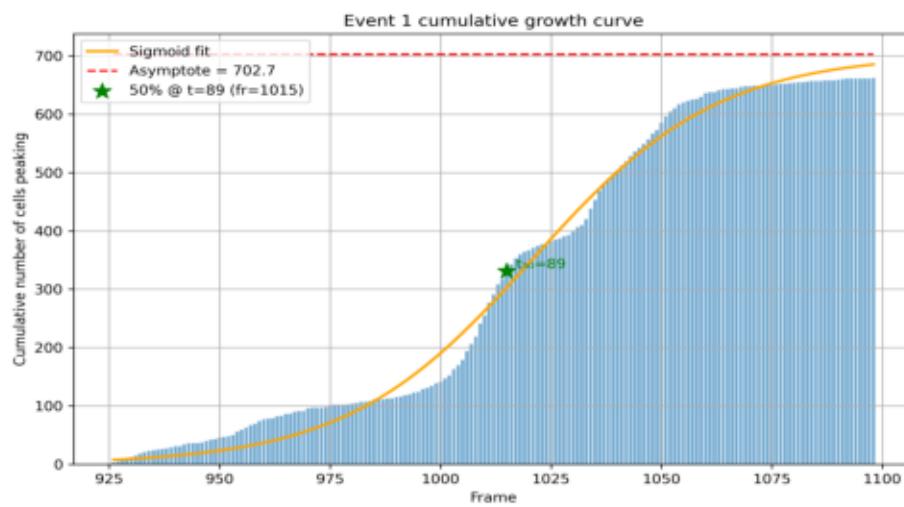
Event Activity Overlay (Event ID: 0)

20250701\_IS1



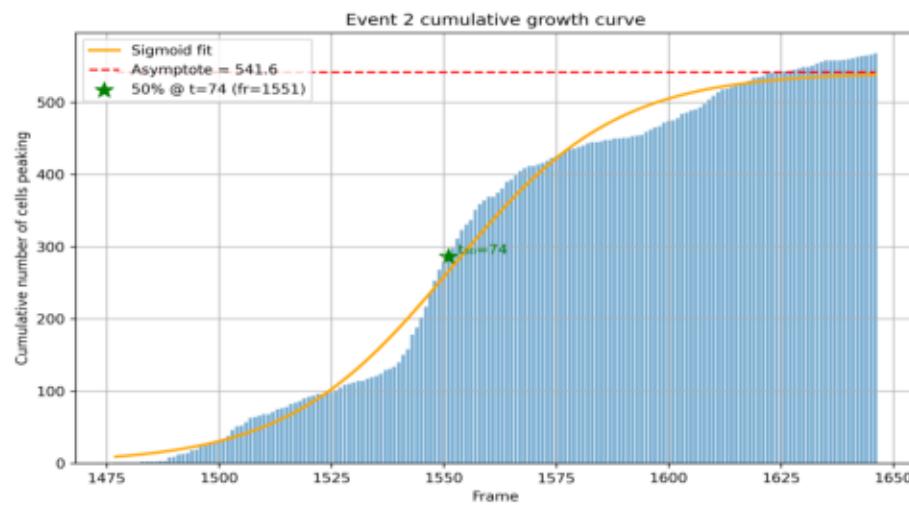
Event Activity Overlay (Event ID: 1)

20250701\_IS1



## Event Activity Overlay (Event ID: 2)

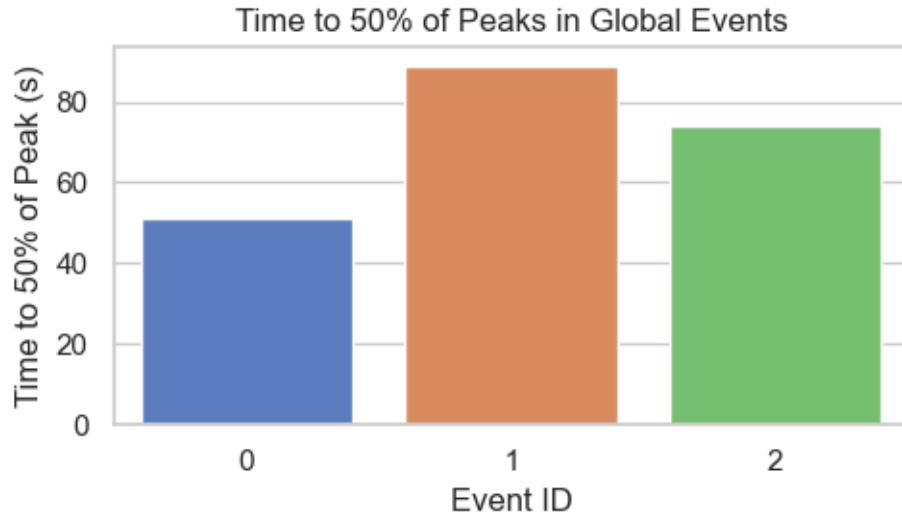
20250701\_IS1



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analyses\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.
```

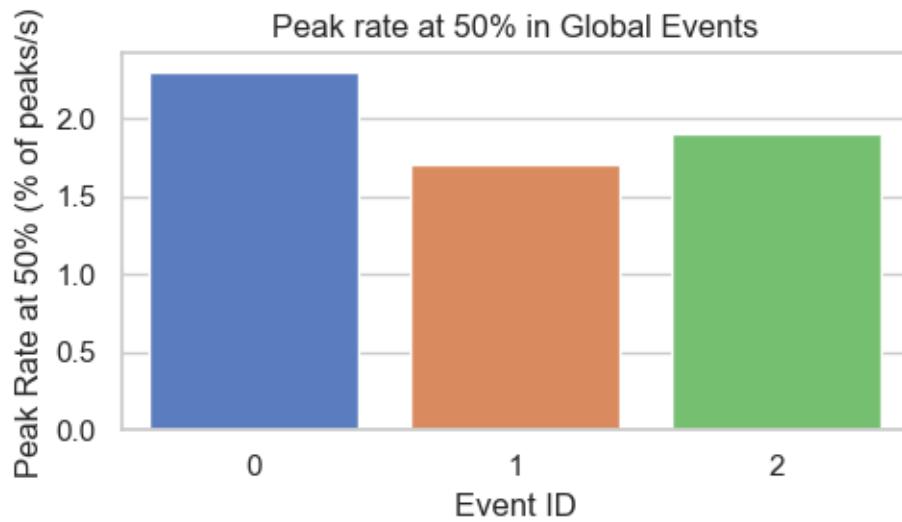
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column, dodge=False, palette=palette, legend=False)
```



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys
is\visualizers.py:297: FutureWarning:
```

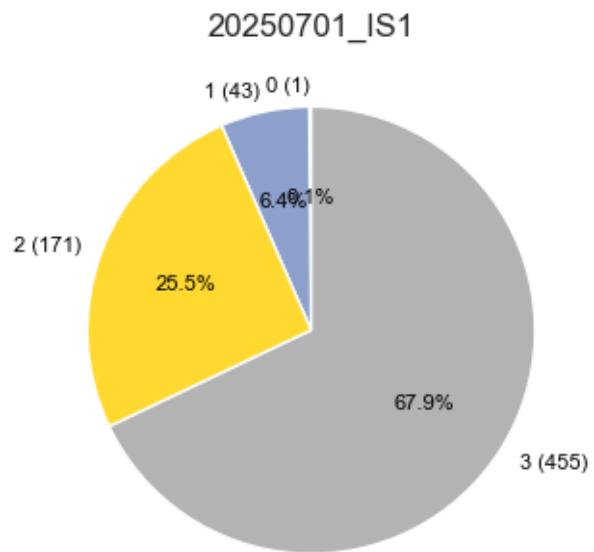
Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,
dodge=False, palette=palette, legend=False)
```



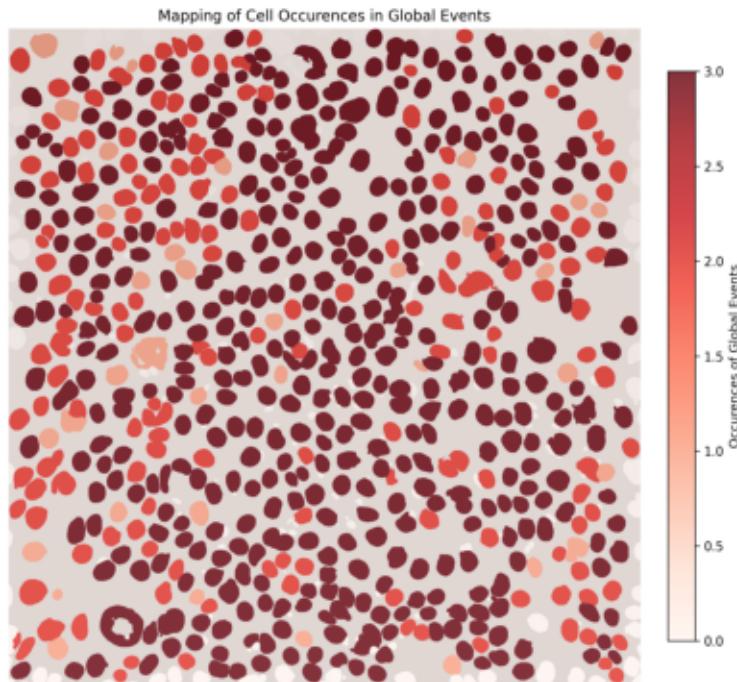
#### 1.2.4 Cells occurrences in global events

Distribution of Unique Global Events per Cell



## Cell Mapping with Occurrences in Global Events Overlay

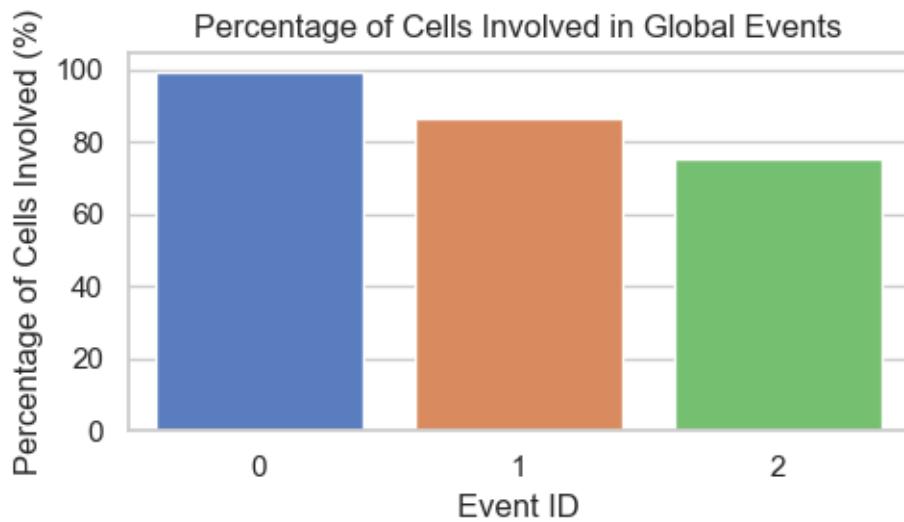
20250701\_IS1



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



### 1.2.5 Inter-event interval analysis

Intervals between global event peaks: [744.0, 523.0]

Estimated periodicity: 0.851

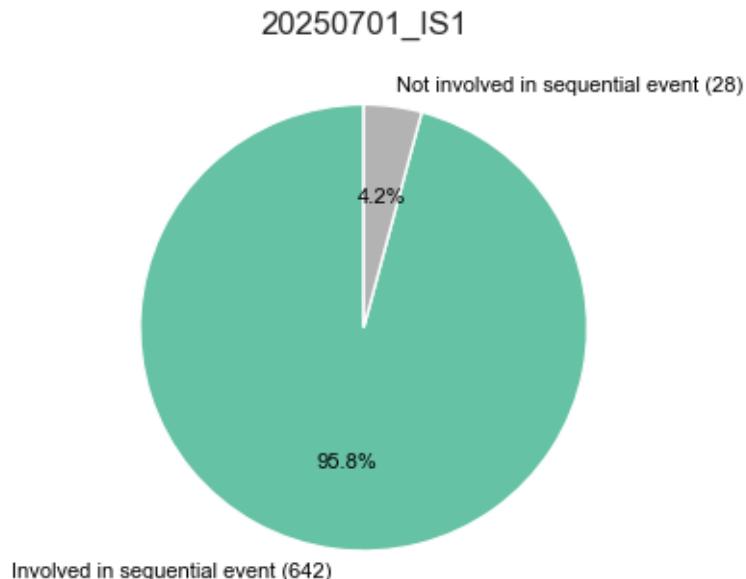
The global events exhibit a regular periodic pattern.

Estimated frequency (1/mean interval): 0.002 Hz

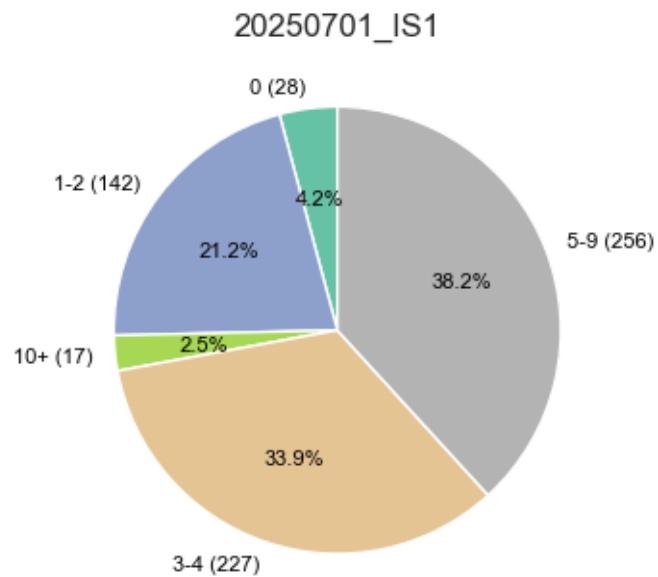
## 1.3 SEQUENTIAL EVENTS

### 1.3.1 Cells occurrences in sequencial events

Distribution of Cells Involved in Sequential Events

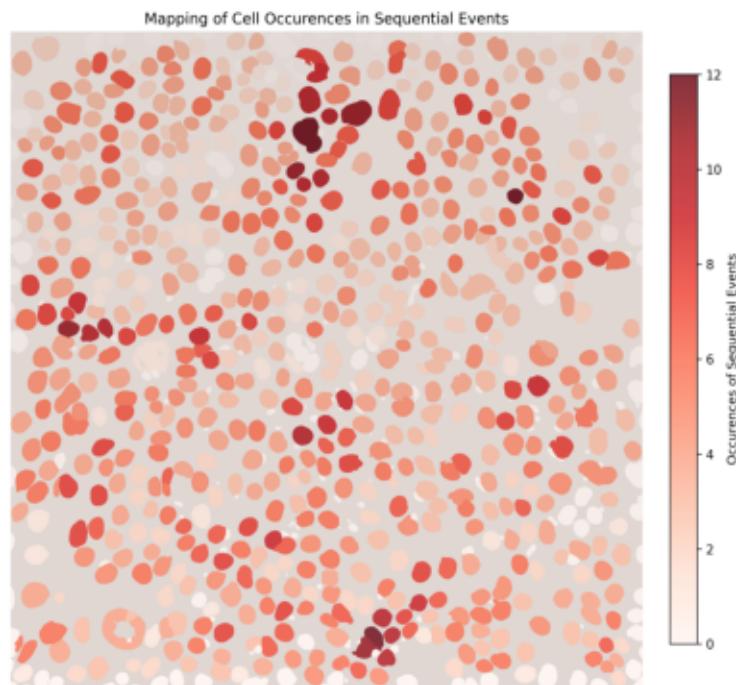


### Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



## Cell Mapping with Occurrences in Sequential Events Overlay

20250701\_IS1

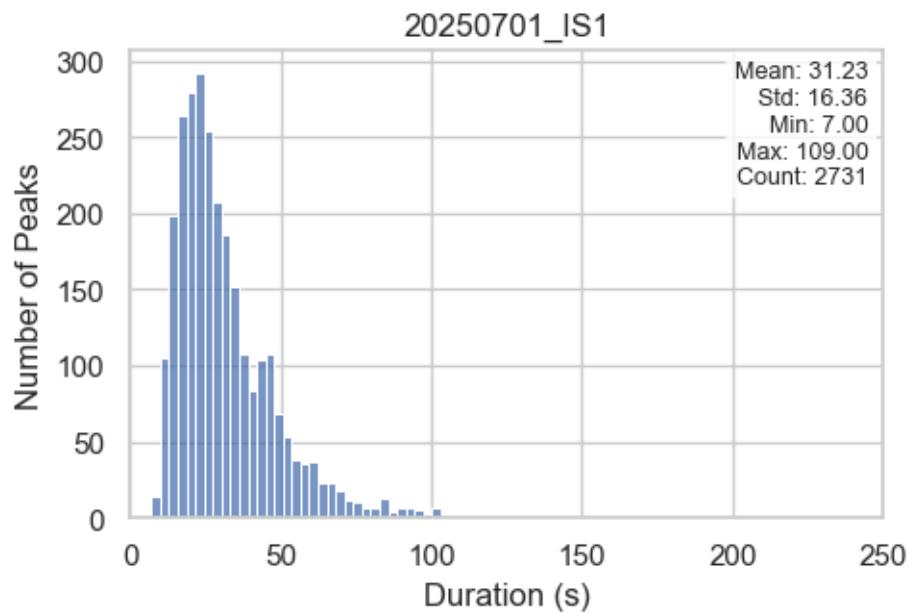


### 1.3.2 Peaks statistics in sequential events

```
[2025-08-08 15:24:51] [INFO] calcium: Removed 47 outliers from dataset  
'20250701_IS1' for column 'Duration (s)'
```

```
[2025-08-08 15:24:51] [INFO] calcium: Lower bound: -10.0, Upper bound: 110.0
```

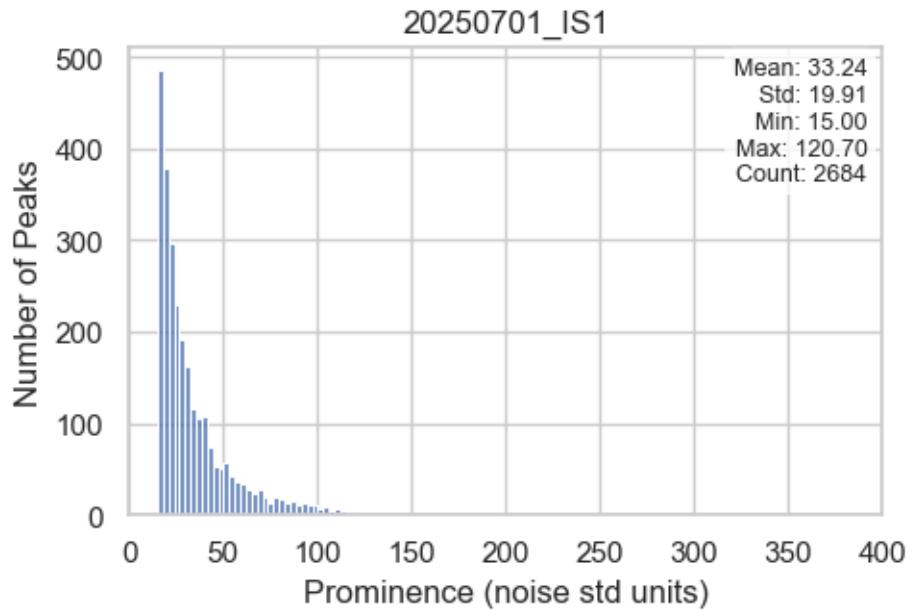
## Distribution of Peak Durations



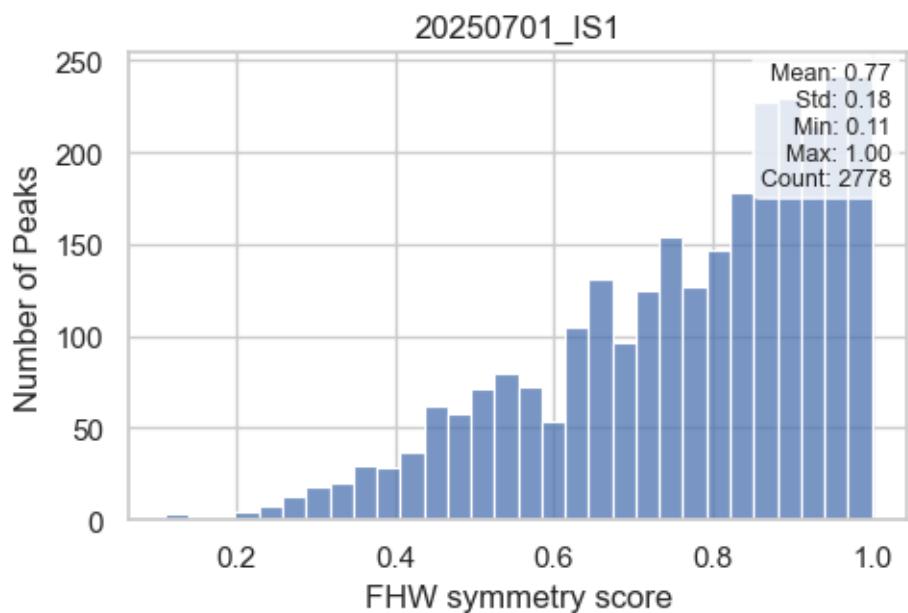
```
[2025-08-08 15:24:51] [INFO] calcium: Removed 94 outliers from dataset '20250701_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:24:51] [INFO] calcium: Lower bound: -14.59999999999998, Upper bound: 121.0
```

### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores

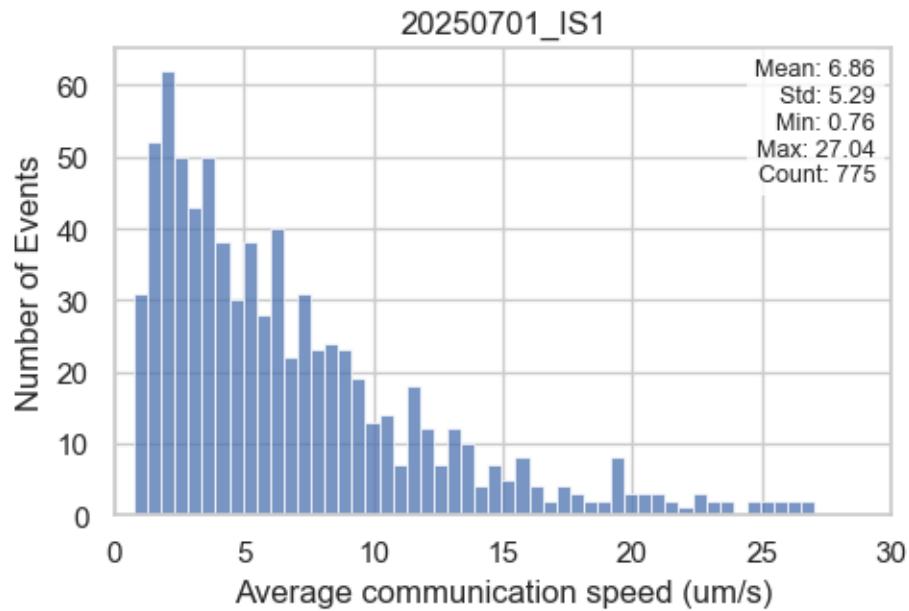


### 1.3.3 Cell-cell communication speed

[2025-08-08 15:24:51] [INFO] calcium: Removed 0 outliers from dataset '20250701\_IS1' for column 'Average communication speed (um/s)'

[2025-08-08 15:24:51] [INFO] calcium: Lower bound: -6.474999999999998, Upper bound: 27.734999999999996

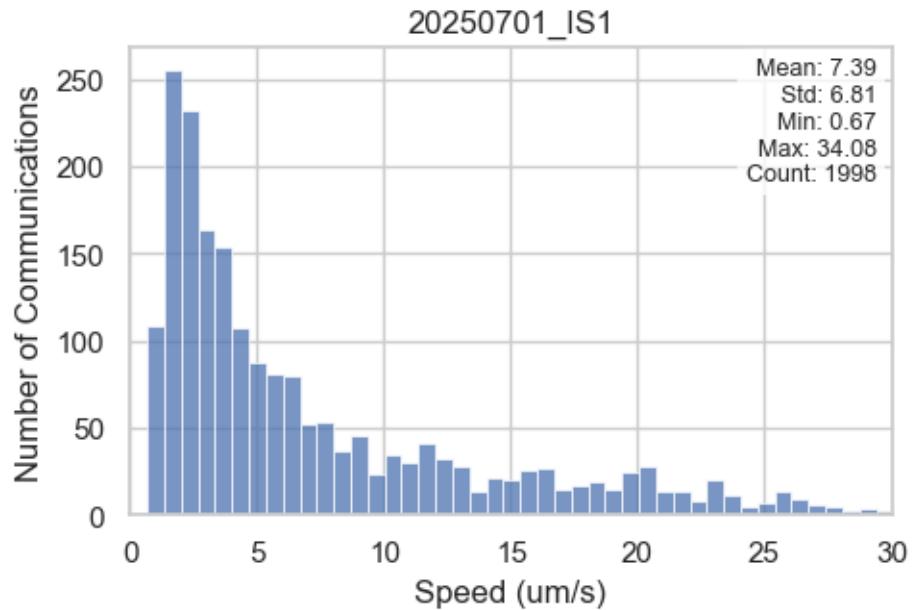
Distribution of Average Communication Speeds in Sequential Events



[2025-08-08 15:24:52] [INFO] calcium: Removed 5 outliers from dataset '20250701\_IS1' for column 'Speed (um/s)'

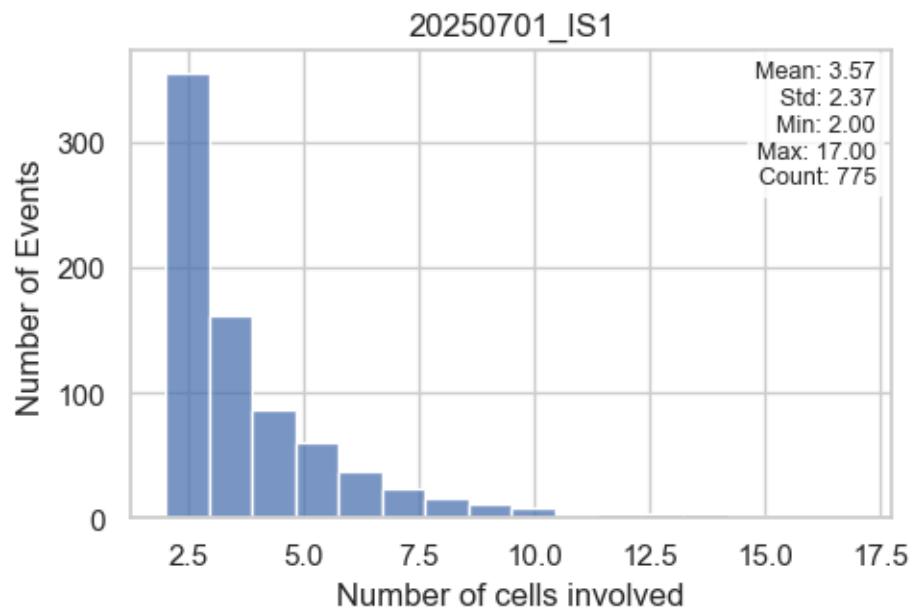
[2025-08-08 15:24:52] [INFO] calcium: Lower bound: -9.912500000000001, Upper bound: 35.16

### Distribution of Cell-Cell Communication Speeds



#### 1.3.4 Number of cells involved per sequential events

##### Distribution of Number of Cells Involved in Sequential Events

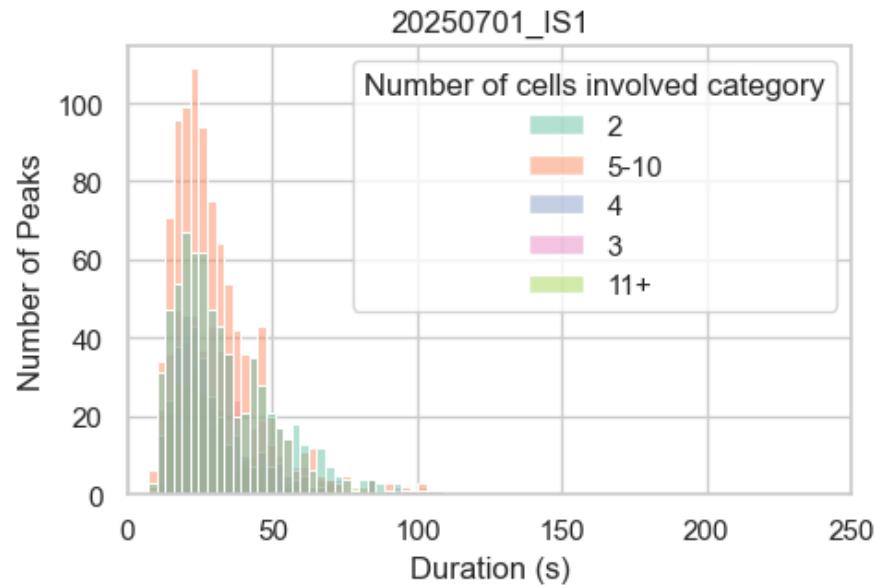


### 1.3.5 Influence of cell count per event on statistics

```
[2025-08-08 15:24:52] [INFO] calcium: Removed 47 outliers from dataset  
'20250701_IS1' for column 'Duration (s)'
```

```
[2025-08-08 15:24:52] [INFO] calcium: Lower bound: -10.0, Upper bound: 110.0
```

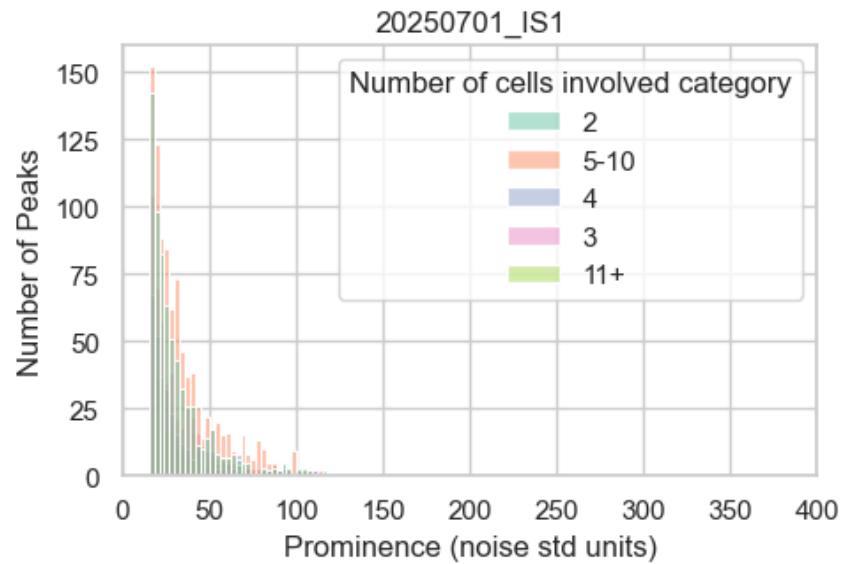
Distribution of Peak Durations by Number of Cells Involved in Sequential Events



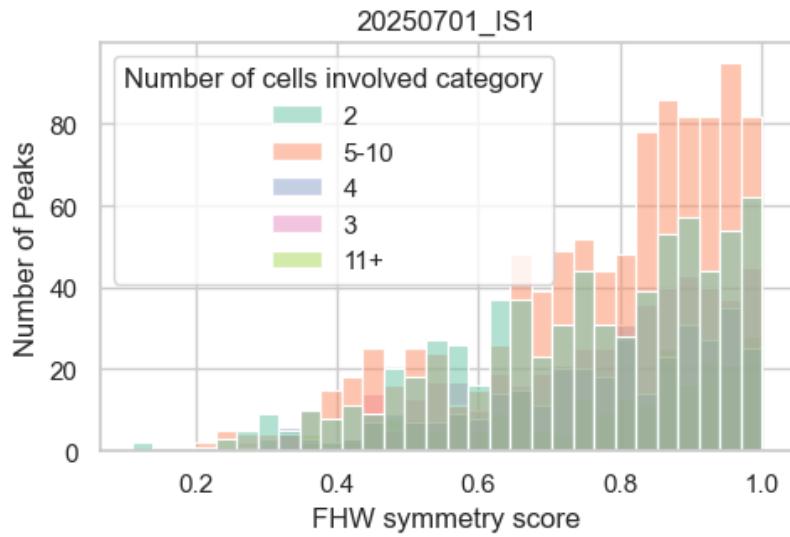
```
[2025-08-08 15:24:52] [INFO] calcium: Removed 94 outliers from dataset  
'20250701_IS1' for column 'Prominence (noise std units)'
```

```
[2025-08-08 15:24:52] [INFO] calcium: Lower bound: -14.6, Upper bound: 121.0
```

### Distribution of Peak Prominences by Number of Cells Involved in Sequential Events



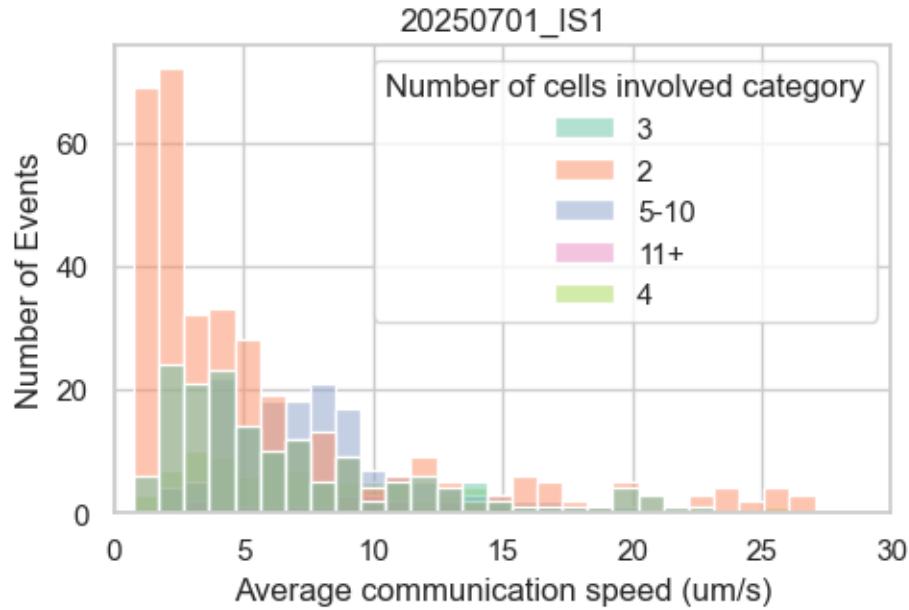
### Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-08 15:24:53] [INFO] calcium: Removed 0 outliers from dataset  
'20250701_IS1' for column 'Average communication speed (um/s)'
```

```
[2025-08-08 15:24:53] [INFO] calcium: Lower bound: -6.5, Upper bound: 27.7
```

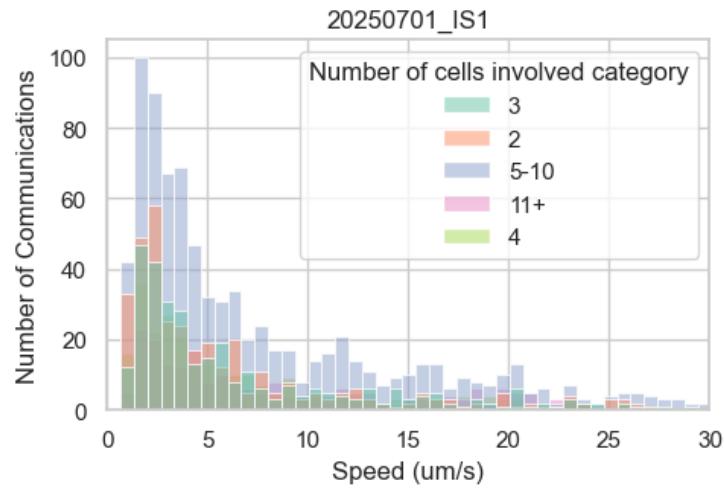
## Distribution of Average Communication Speeds by Number of Cells Involved



```
[2025-08-08 15:24:53] [INFO] calcium: Removed 5 outliers from dataset '20250701_IS1' for column 'Speed (um/s)'
```

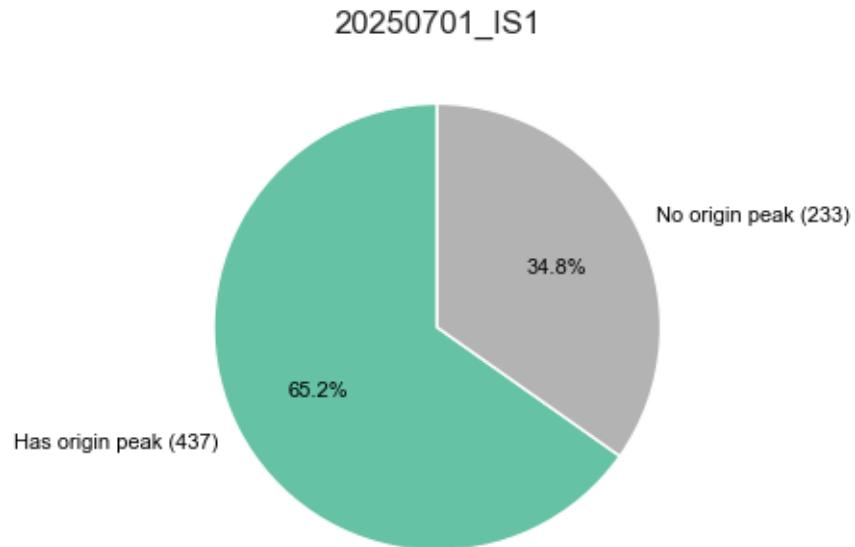
```
[2025-08-08 15:24:53] [INFO] calcium: Lower bound: -9.9, Upper bound: 35.2
```

## Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events

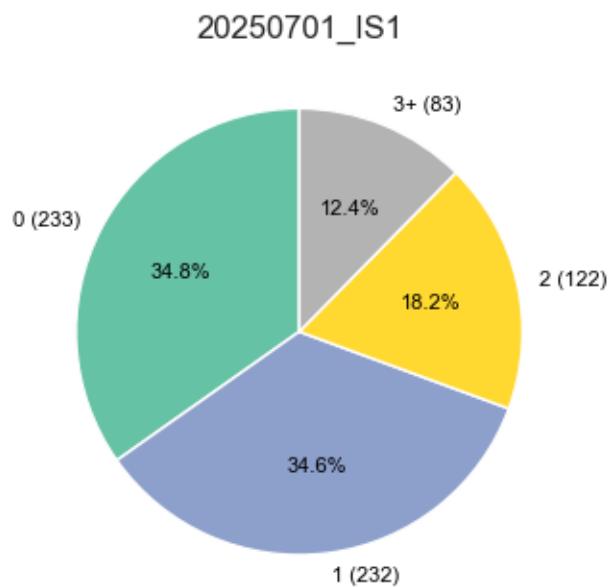


### 1.3.6 Cells occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

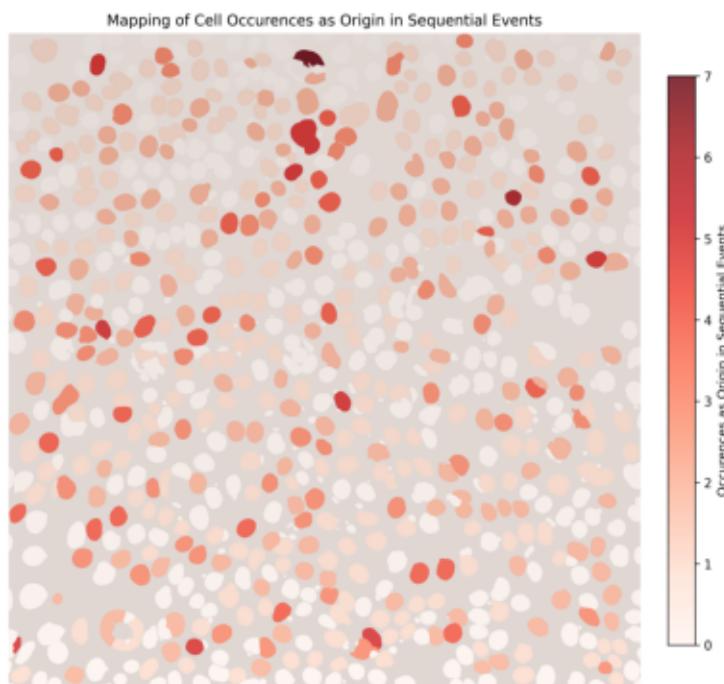


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



## Cell Mapping with Origin Peaks Overlay

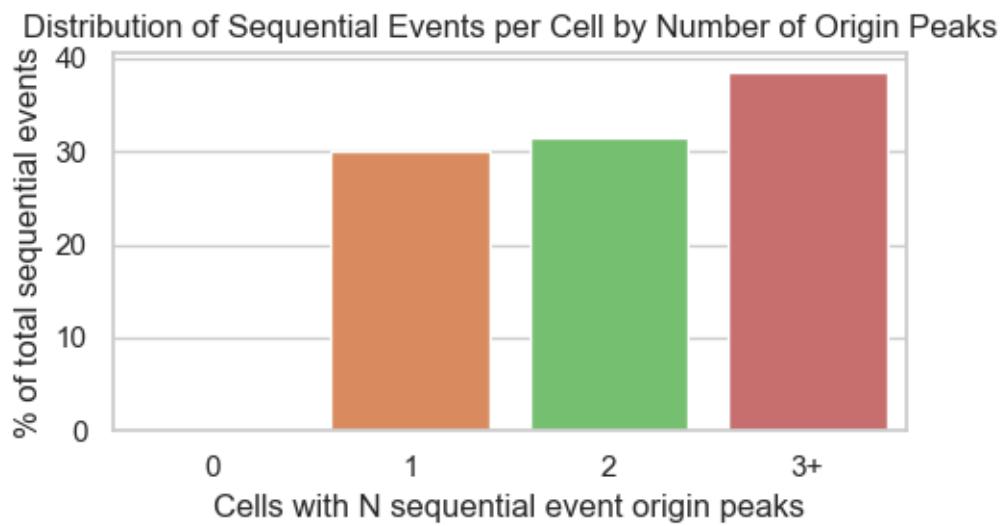
20250701\_IS1



C:\Users\poseidon\OneDrive\Documents\01\_ETHZ\Master\_Degree\Spring\_Semester\_2025\Master\_Thesis\Coding\Image\_analysis\src\calcium\_activity\_characterization\analyses\visualizers.py:297: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effect.

```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```

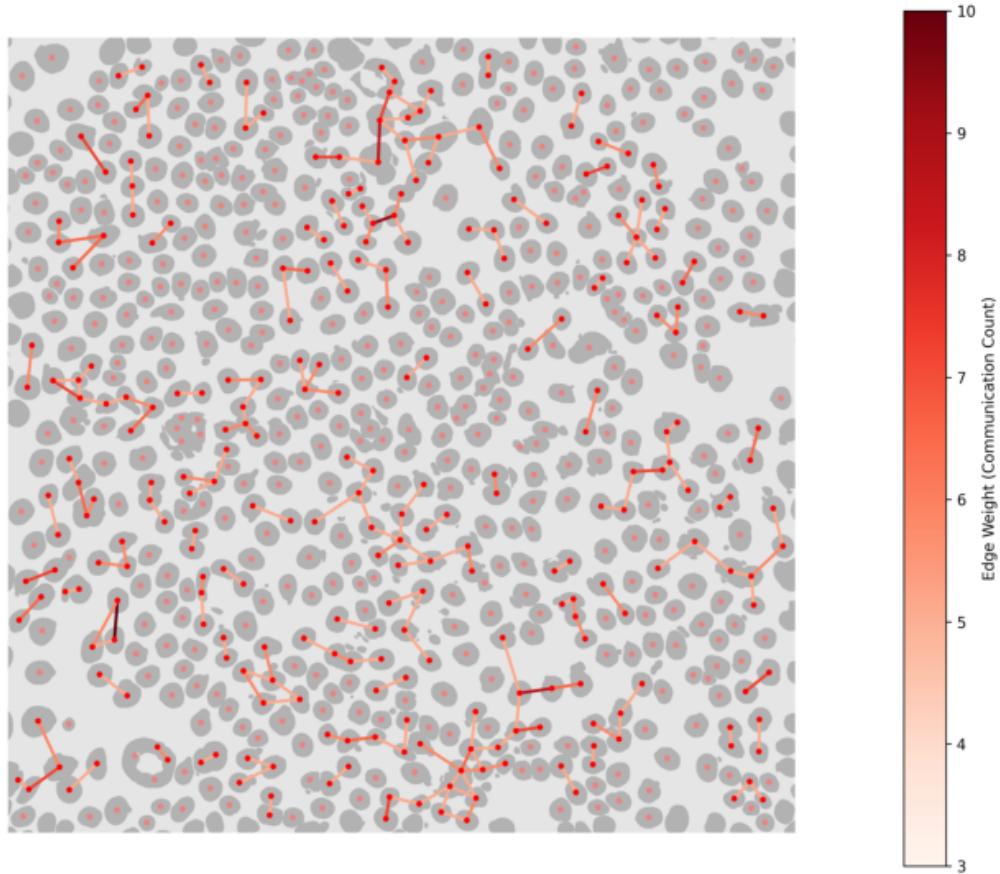


### 1.3.7 Connection network between cells

Cell Connection Network Graph

20250701\_IS1

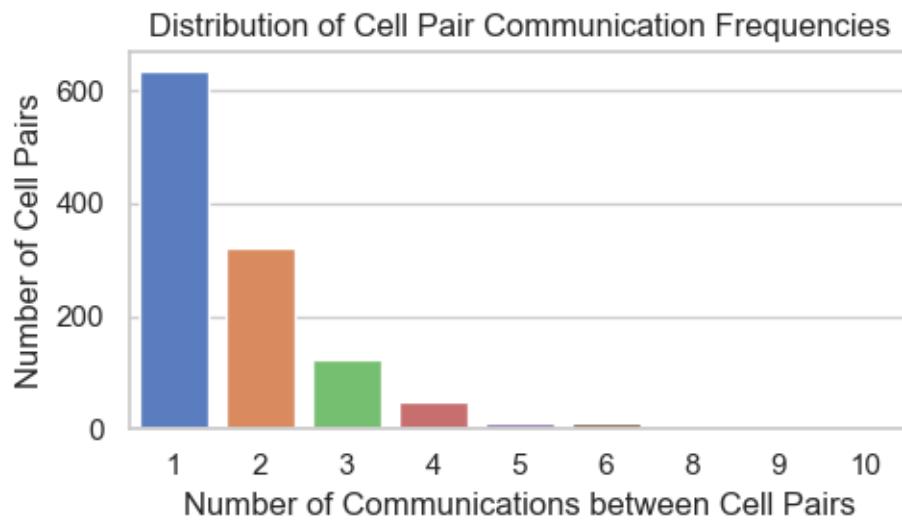
Cells Connection Network (Weighted Edges,  $\geq 3$ )



```
C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\  
Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analys  
is\visualizers.py:297: FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in  
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same  
effect.
```

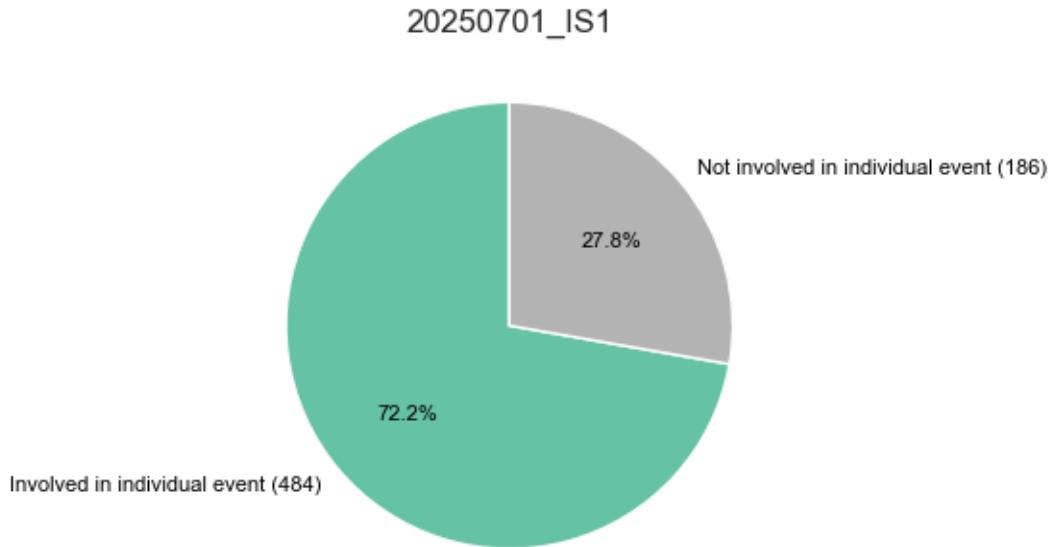
```
sns.barplot(data=df, x=axis_column, y=value_column, hue=hue_column,  
dodge=False, palette=palette, legend=False)
```



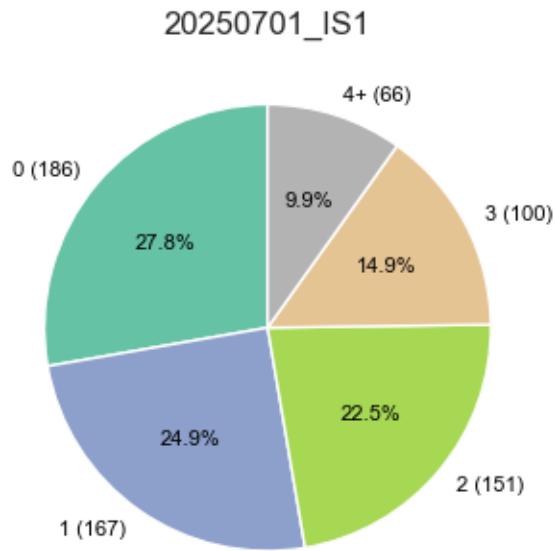
## 1.4 INDIVIDUAL EVENTS

### 1.4.1 Cells occurrences in individual events

Distribution of Cells Involved in Individual Events

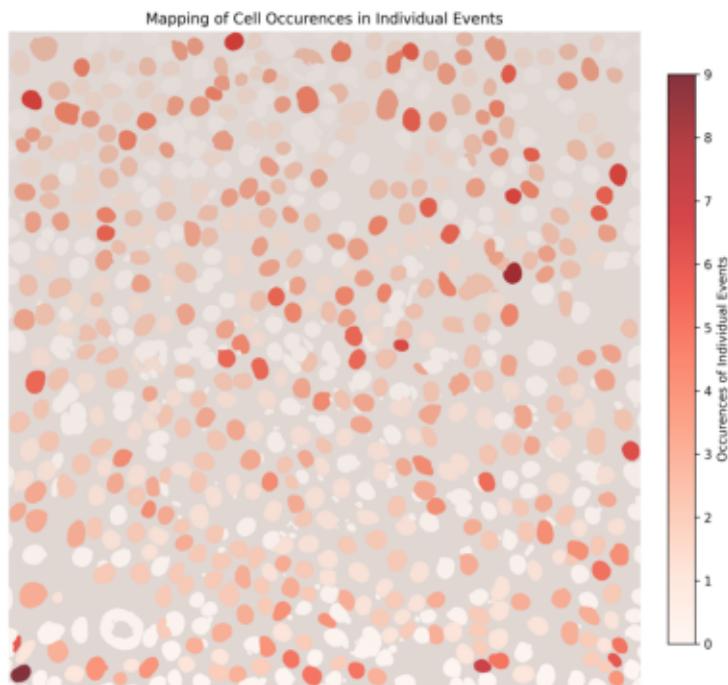


### Distribution of Individual Event Occurrences per Cell (0, 1, 2, 3, 4+)



## Cell Mapping with Occurrences in Individual Events Overlay

20250701\_IS1

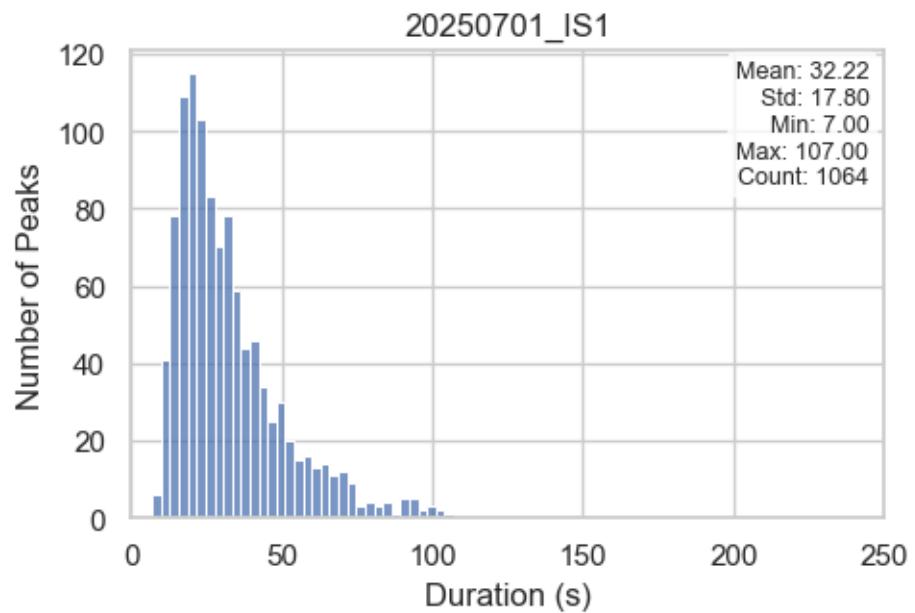


### 1.4.2 Peaks statistics in individual events

```
[2025-08-08 15:24:58] [INFO] calcium: Removed 19 outliers from dataset  
'20250701_IS1' for column 'Duration (s)'
```

```
[2025-08-08 15:24:58] [INFO] calcium: Lower bound: -14.0, Upper bound: 107.0
```

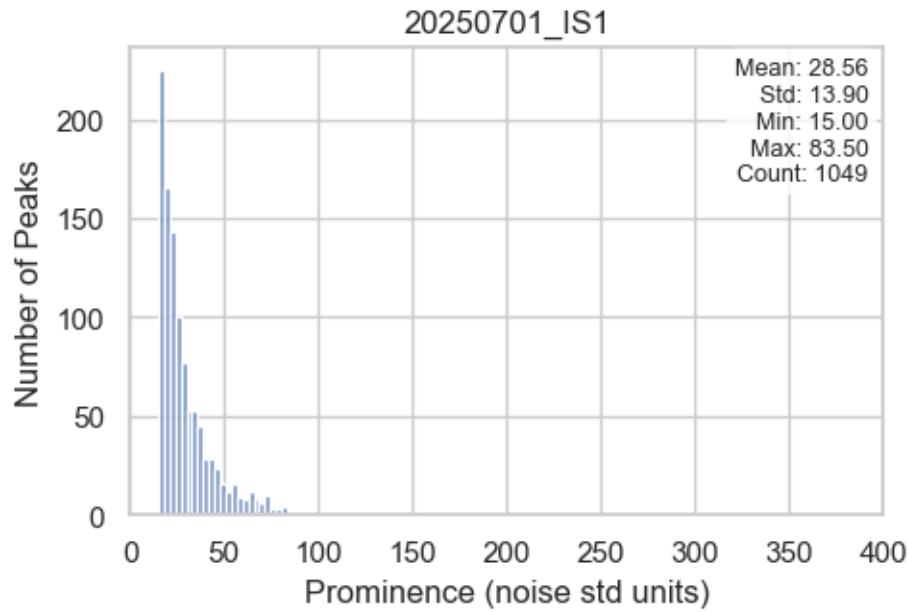
## Distribution of Peak Durations



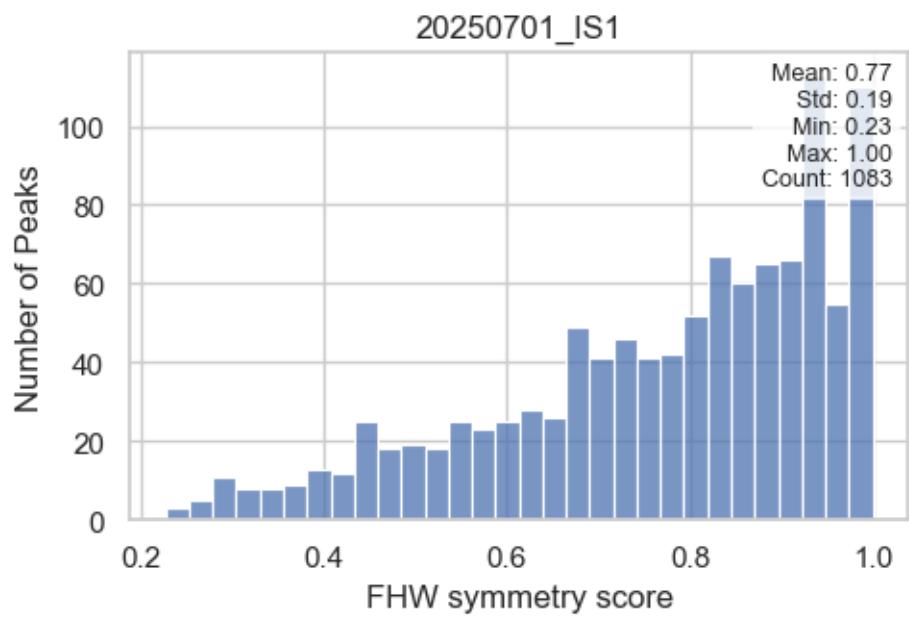
[2025-08-08 15:24:58] [INFO] calcium: Removed 34 outliers from dataset '20250701\_IS1' for column 'Prominence (noise std units)'

[2025-08-08 15:24:58] [INFO] calcium: Lower bound: -7.0, Upper bound: 86.5

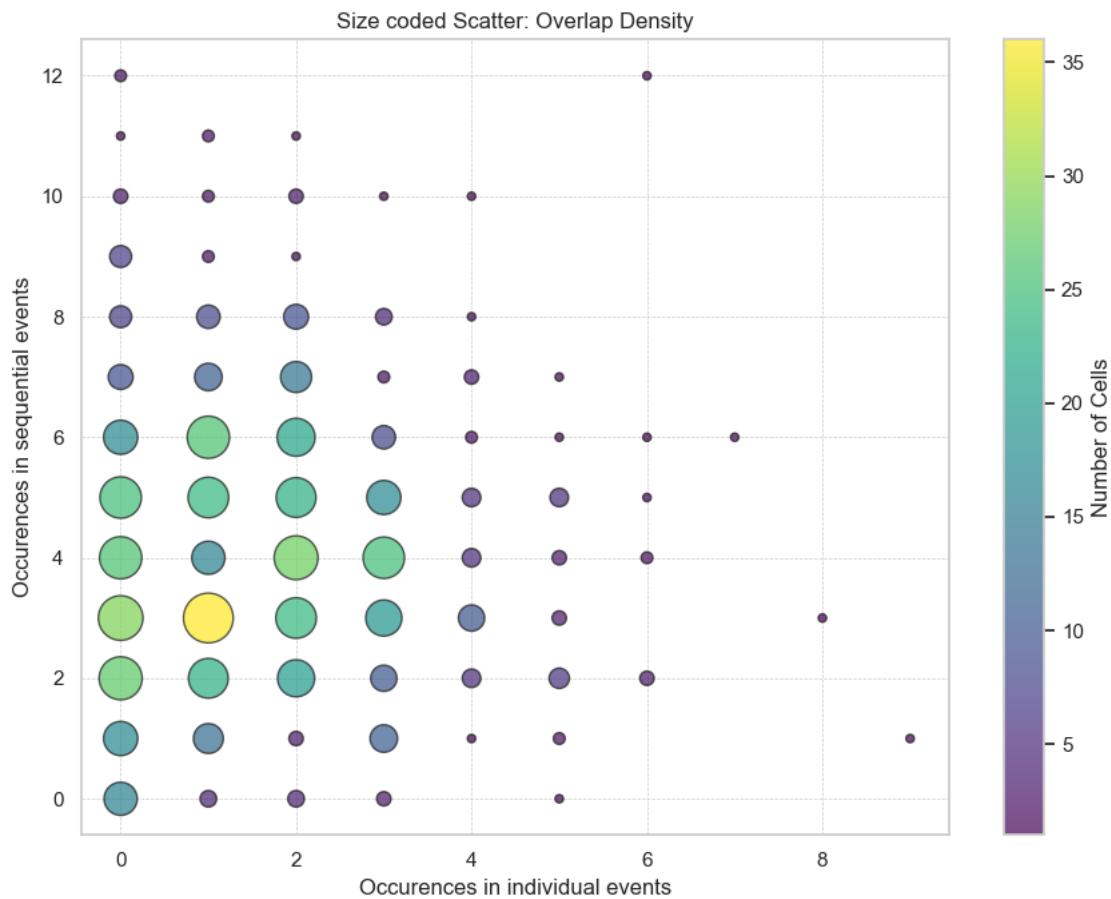
### Distribution of Peak Prominences



### Distribution of Peak Symmetry Scores



### 1.4.3 Correlation between event activity level & individual activity level



## 1.5 CELLS MOTION

Cell Motion Comparison Overlay

