

executed

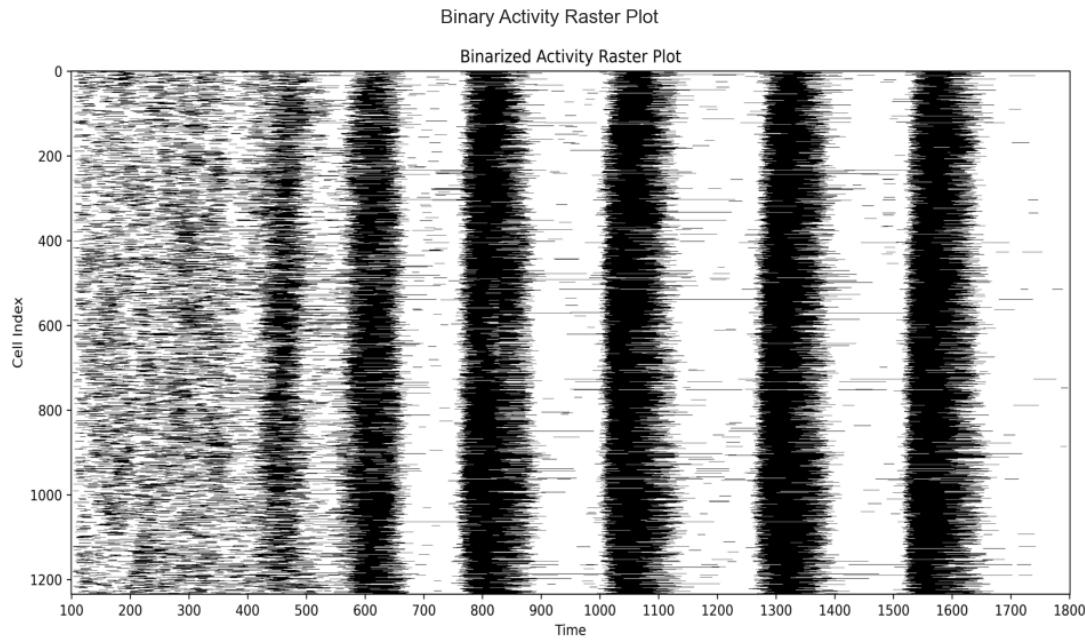
August 27, 2025

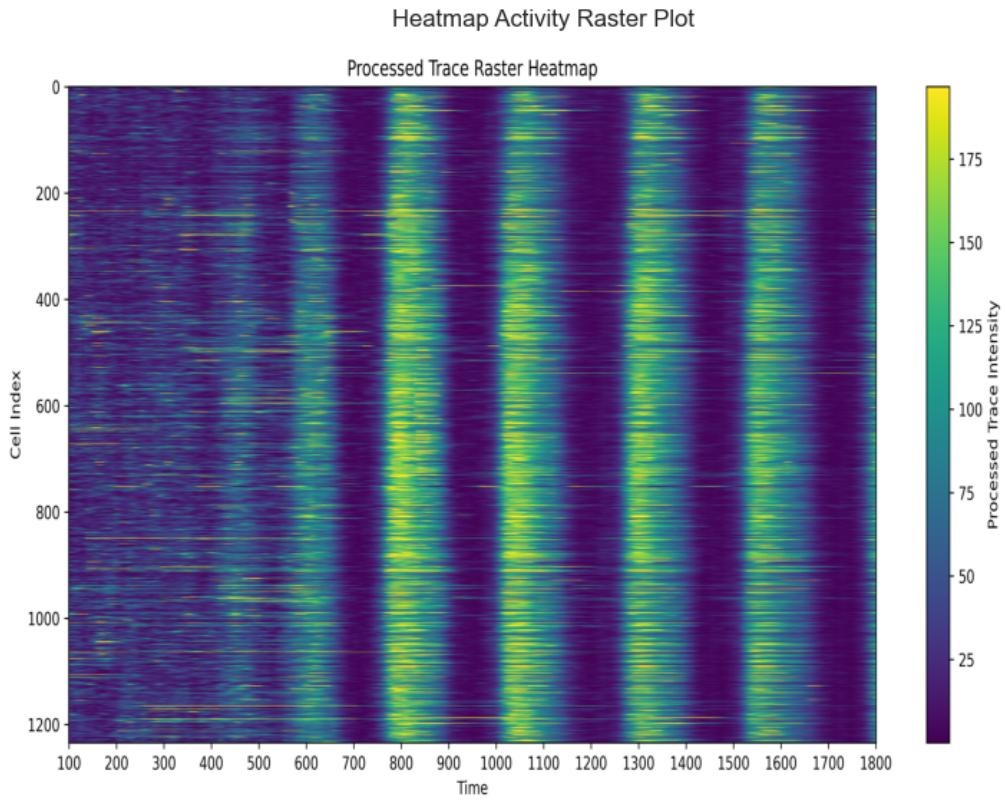
1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

1.0.1 Initialization

1.1 POPULATION

1.1.1 Binary & Heatmap Raster Plot





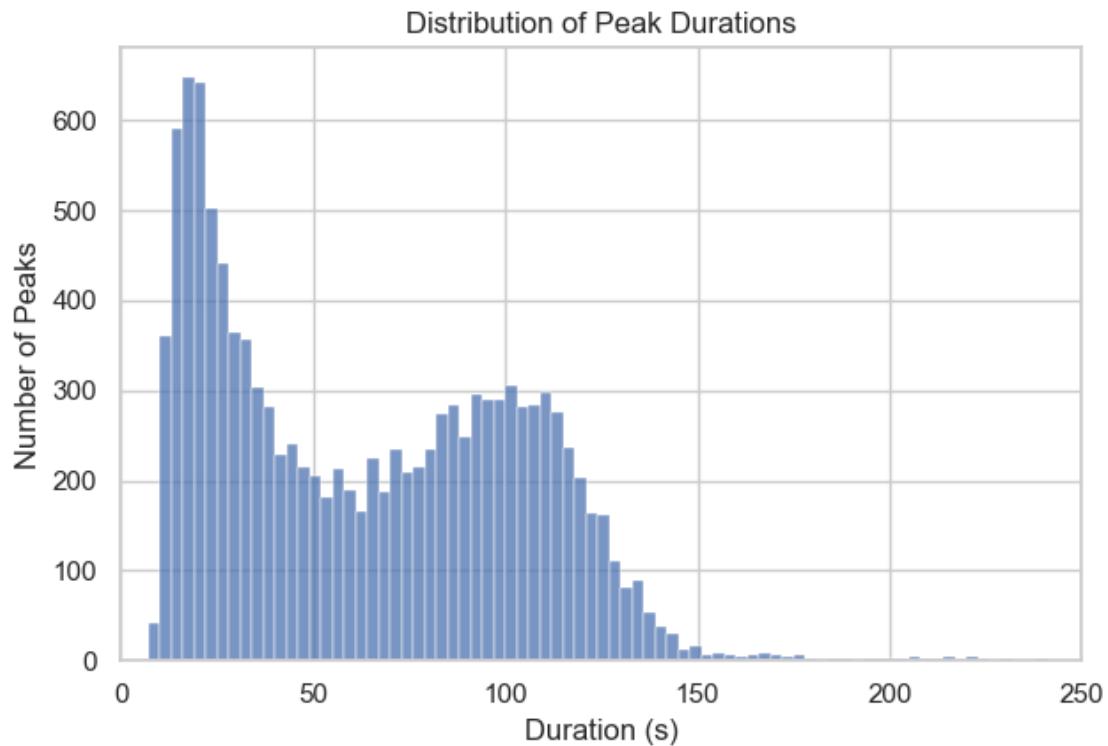
1.1.2 Peaks population

Total number of peaks: 11908

Total number of cells: 1235

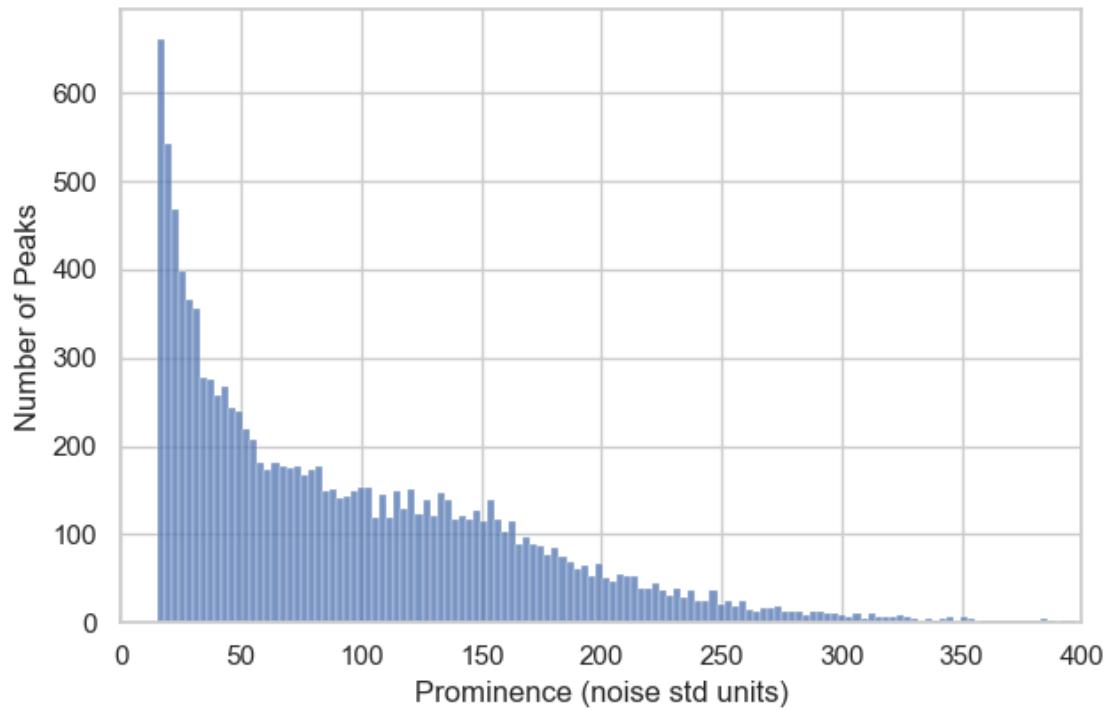
1.1.3 Peaks statistics

```
[2025-08-27 15:01:27] [INFO] calcium: plot_histogram: removed 5 outliers out of 11908 on 'Duration (s)' (lower=-187, upper=310)
```

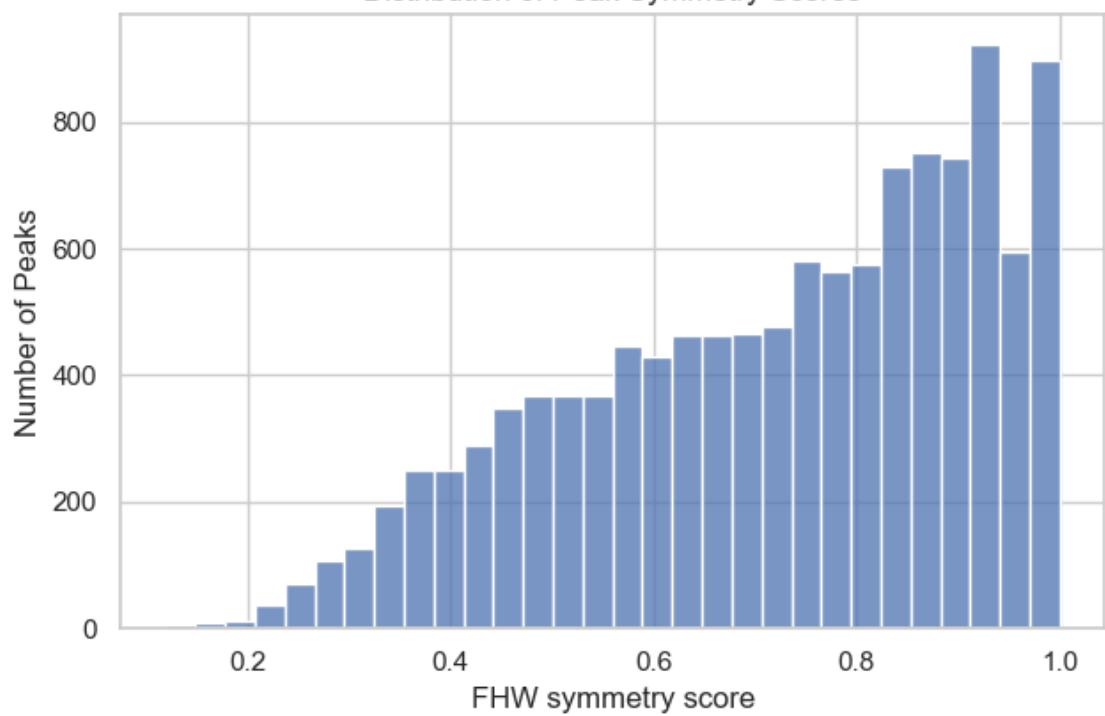


```
[2025-08-27 15:01:27] [INFO] calcium: plot_histogram: removed 14 outliers out of  
11908 on 'Prominence (noise std units)' (lower=-278.6, upper=452.9)
```

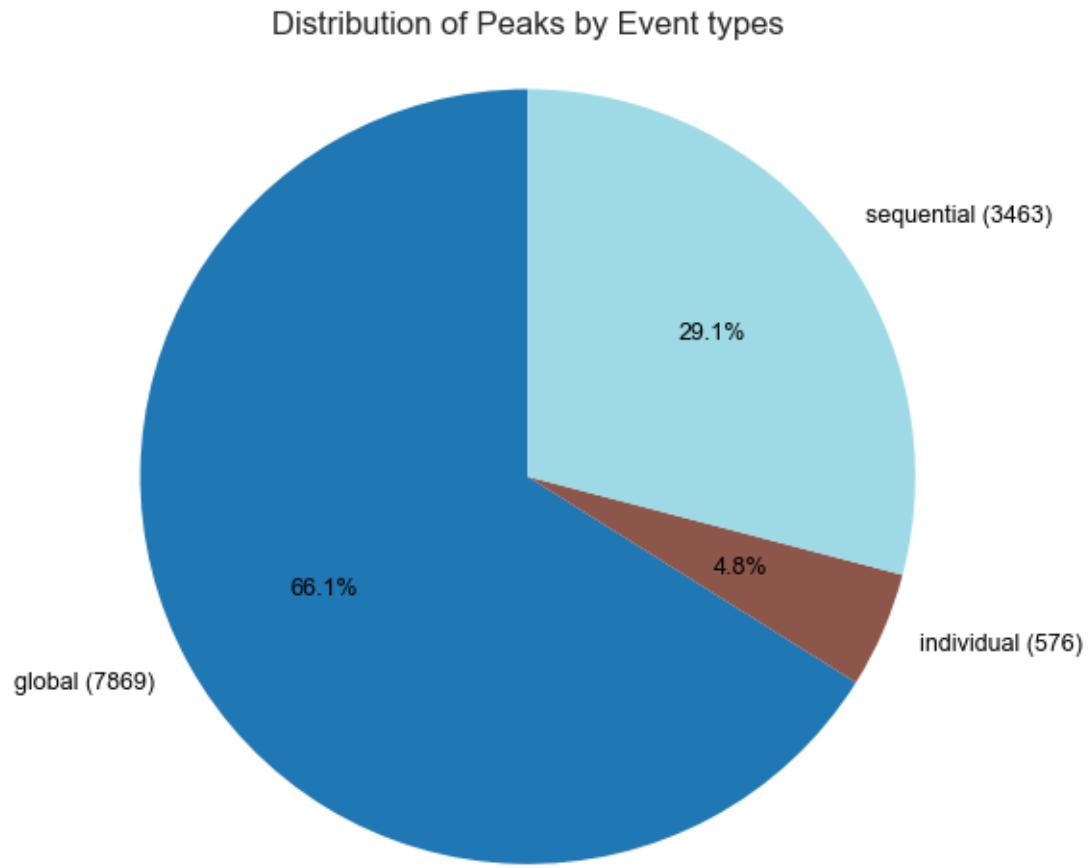
Distribution of Peak Prominences



Distribution of Peak Symmetry Scores

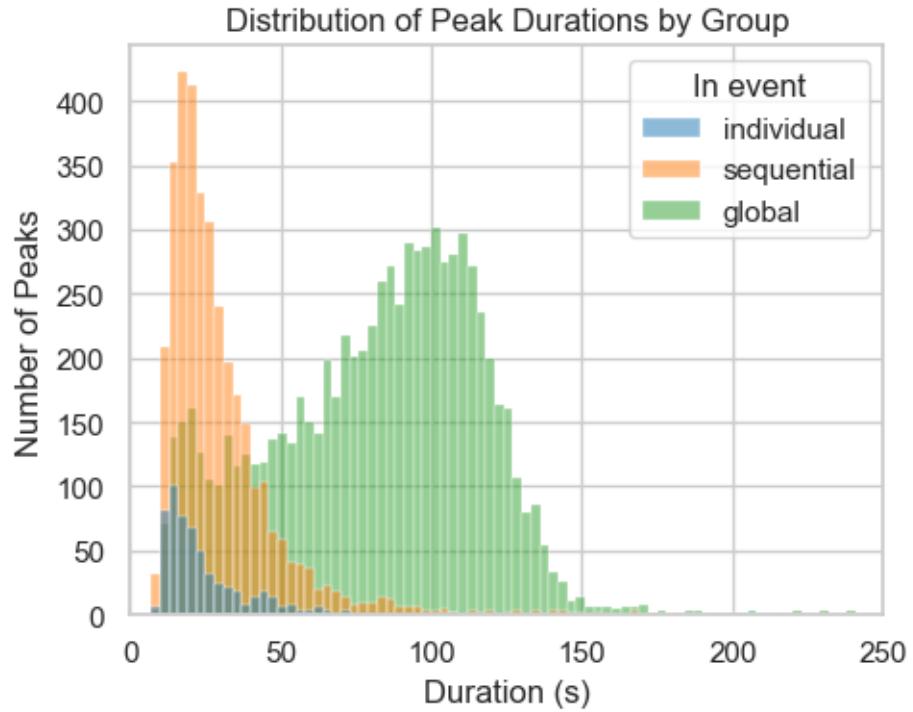


1.1.4 Distribution of peaks per event types

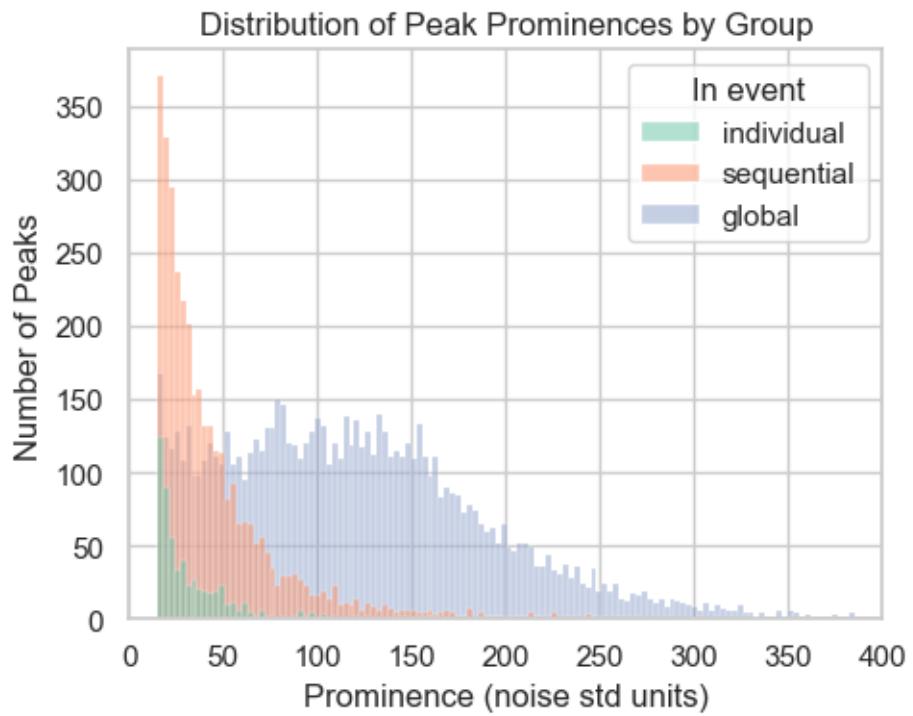


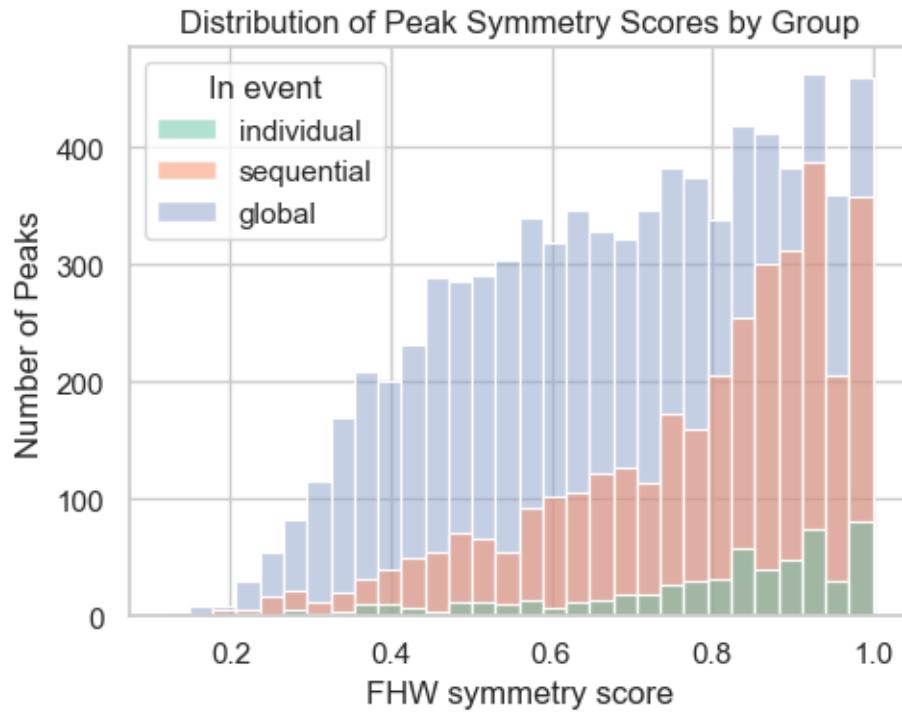
1.1.5 Peaks statistics per event types

```
[2025-08-27 15:01:27] [INFO] calcium: plot_histogram_by_group: removed 5 outliers out of 11908 on 'Duration (s)' (lower=-187, upper=310)
```



```
[2025-08-27 15:01:28] [INFO] calcium: plot_histogram_by_group: removed 14 outliers out of 11908 on 'Prominence (noise std units)' (lower=-278.6, upper=452.9)
```

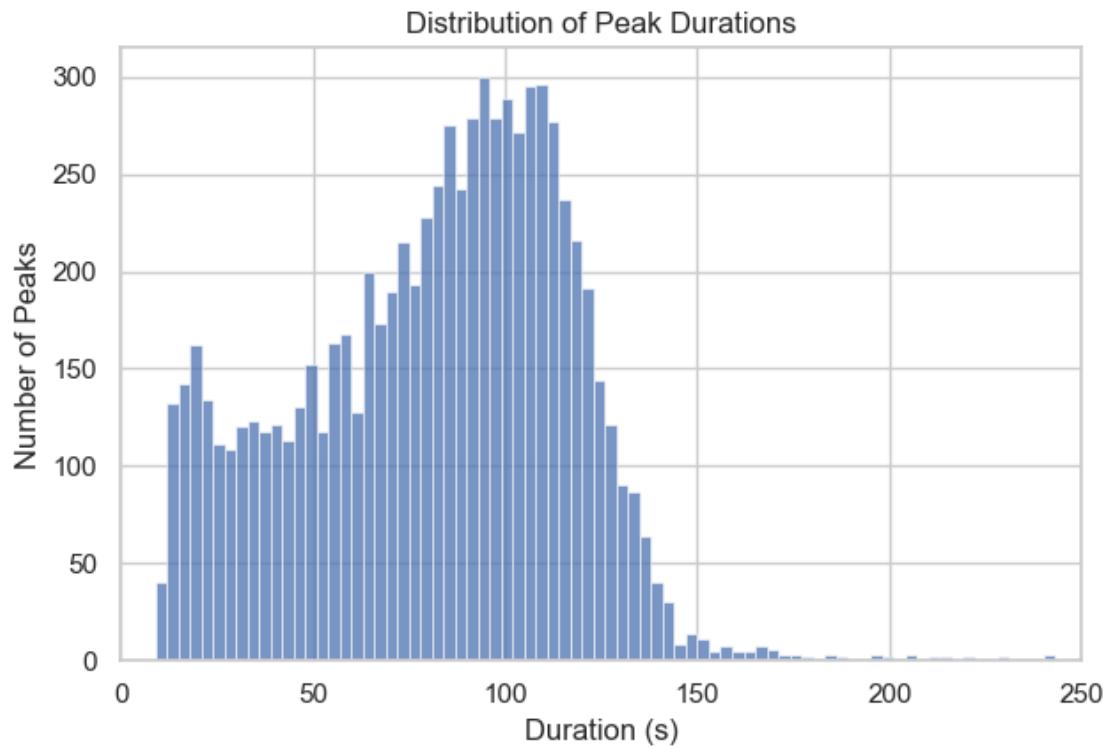




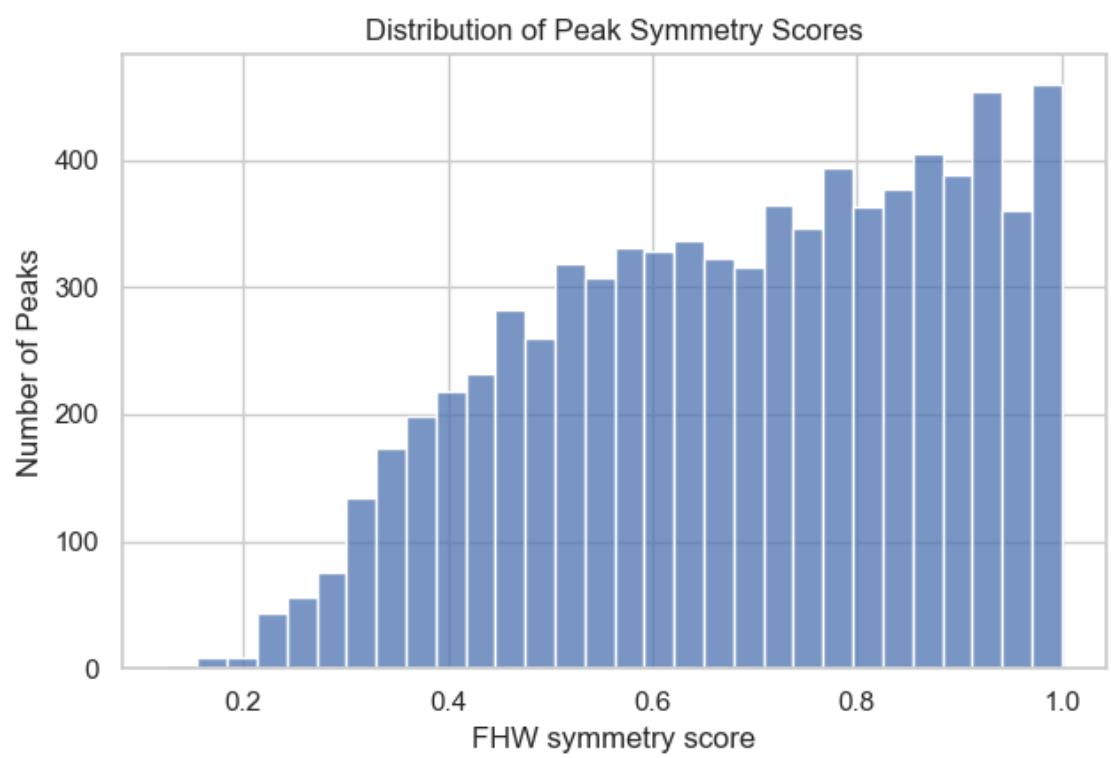
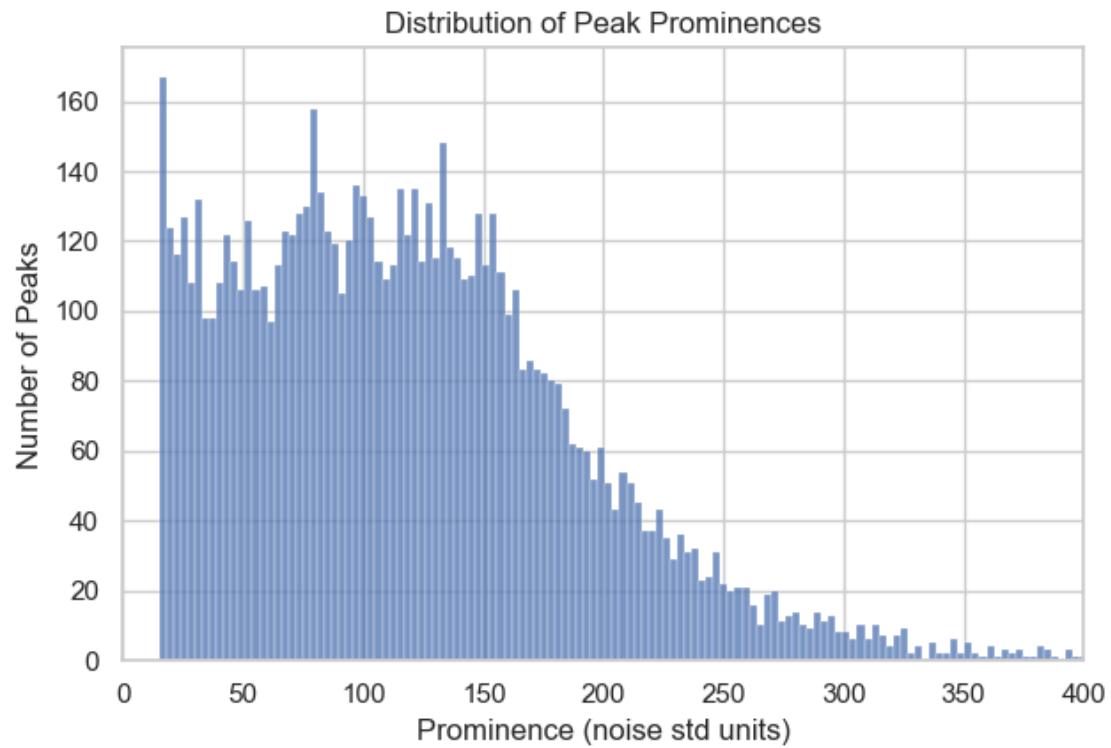
1.2 GLOBAL EVENTS

1.2.1 Peak statistics in global events

```
[2025-08-27 15:01:28] [INFO] calcium: plot_histogram: removed 5 outliers out of 7869 on 'Duration (s)' (lower=-97, upper=260)
```

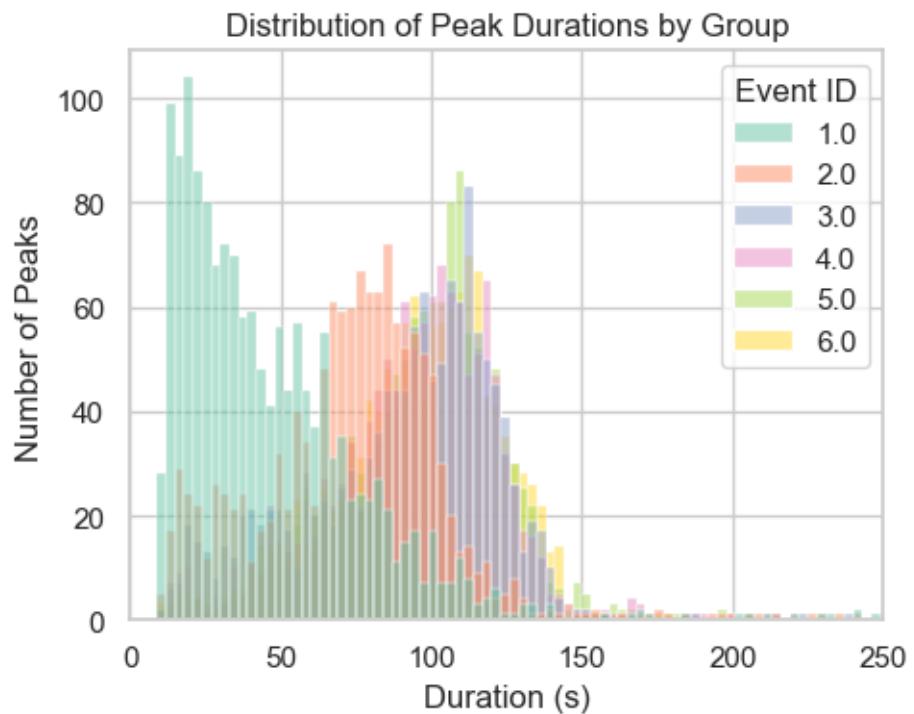


```
[2025-08-27 15:01:28] [INFO] calcium: plot_histogram: removed 16 outliers out of  
7869 on 'Prominence (noise std units)' (lower=-222.7, upper=450.7)
```

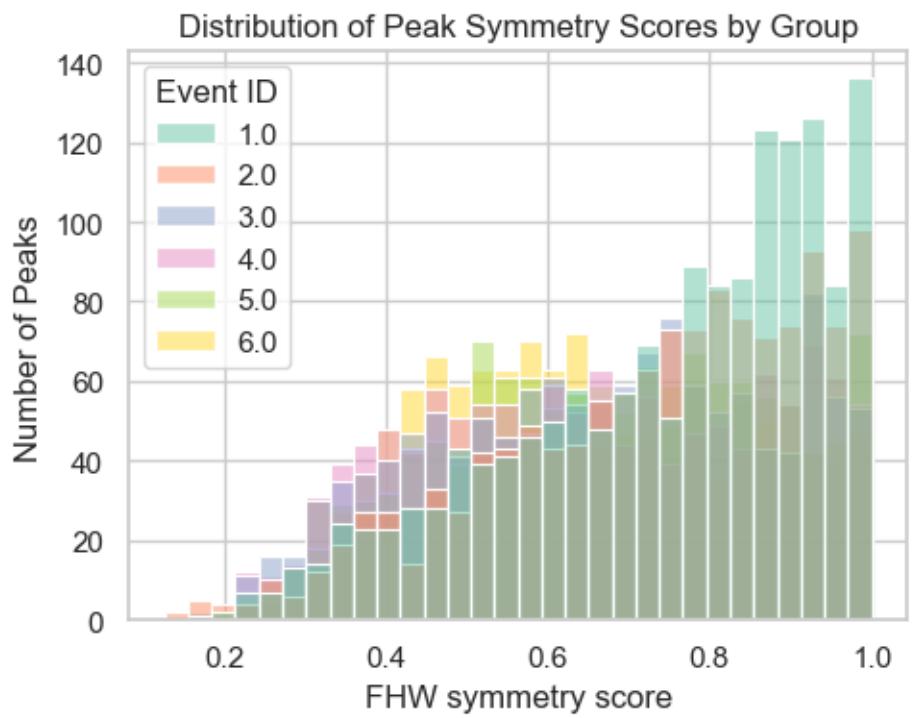
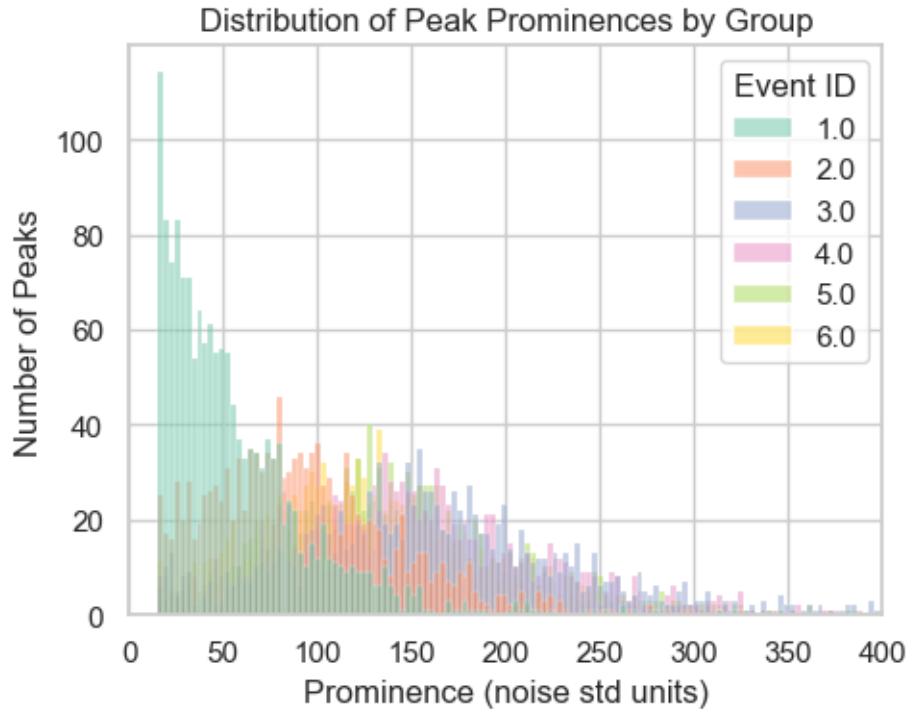


1.2.2 Peak statistics in global event per event ID

[2025-08-27 15:01:29] [INFO] calcium: plot_histogram_by_group: removed 5 outliers out of 7869 on 'Duration (s)' (lower=-97, upper=260)

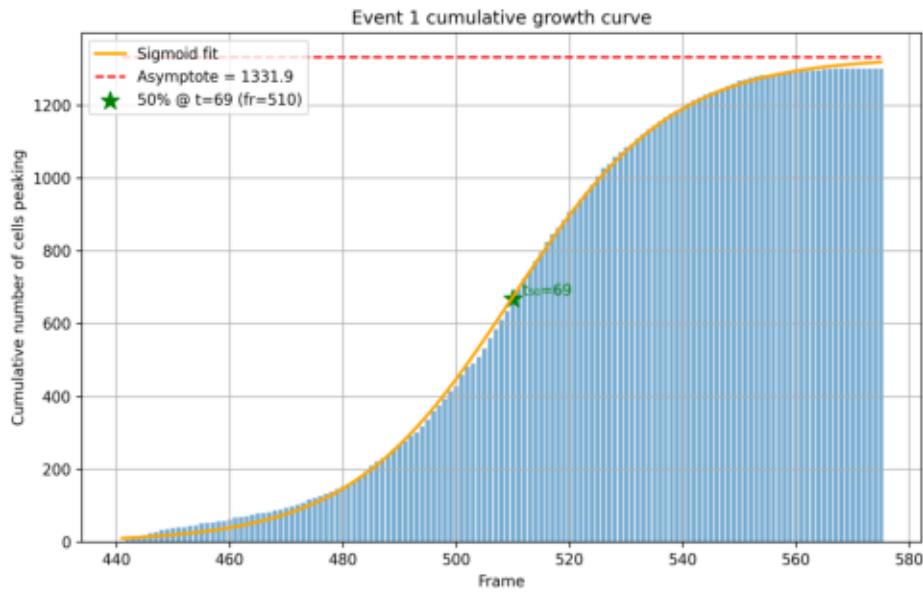


[2025-08-27 15:01:29] [INFO] calcium: plot_histogram_by_group: removed 16 outliers out of 7869 on 'Prominence (noise std units)' (lower=-222.7, upper=450.7)

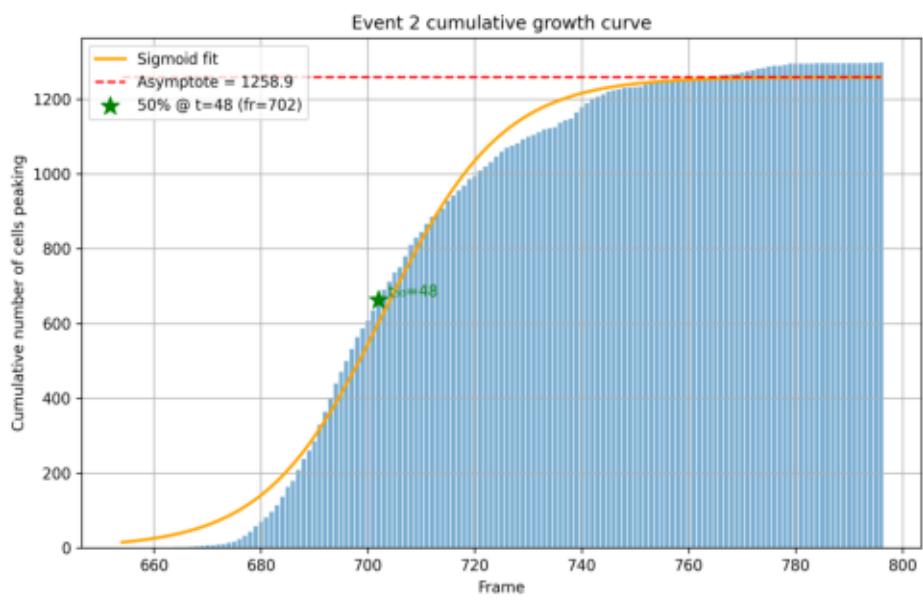


1.2.3 Kinetics of global events

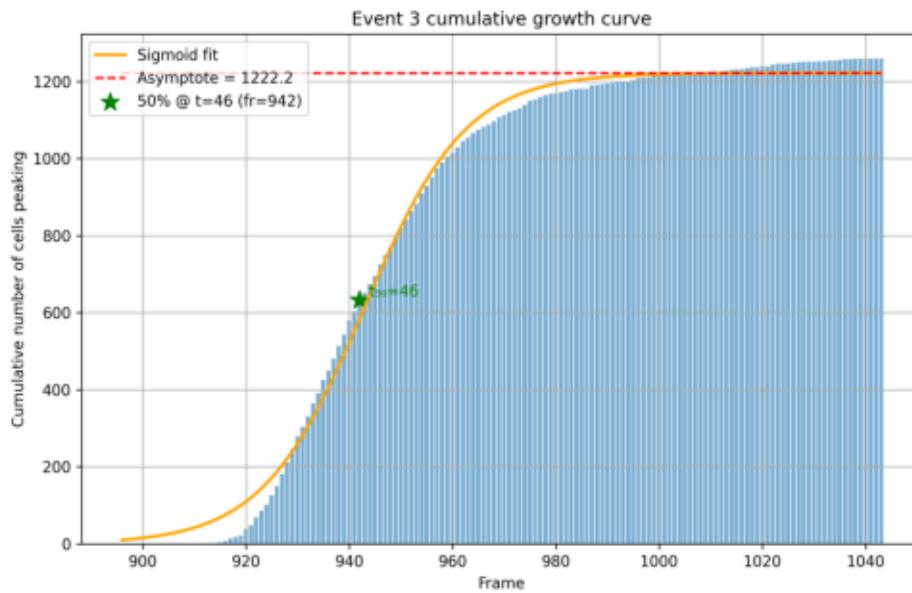
Event Activity Overlay (Event ID: 1)



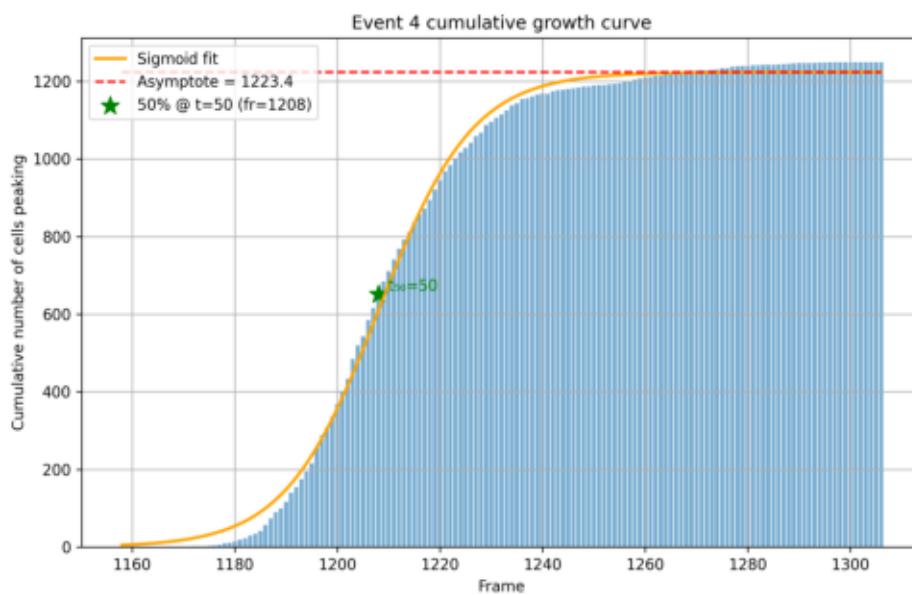
Event Activity Overlay (Event ID: 2)



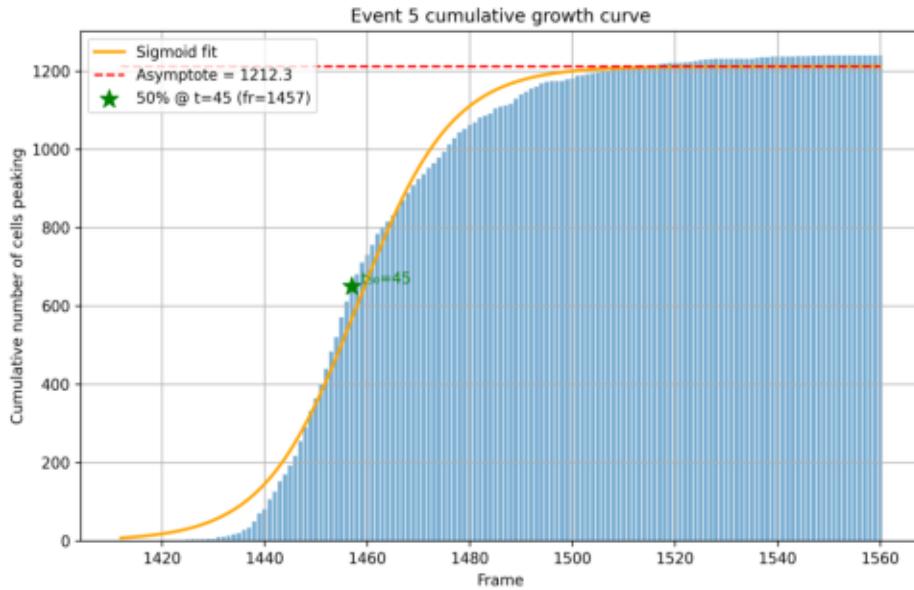
Event Activity Overlay (Event ID: 3)



Event Activity Overlay (Event ID: 4)

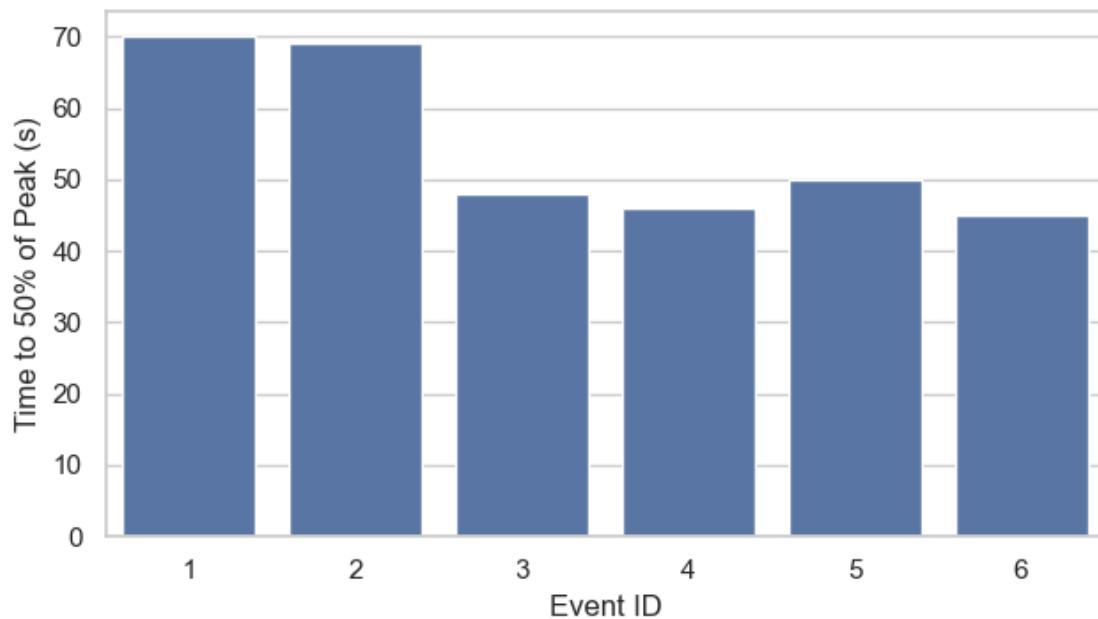


Event Activity Overlay (Event ID: 5)

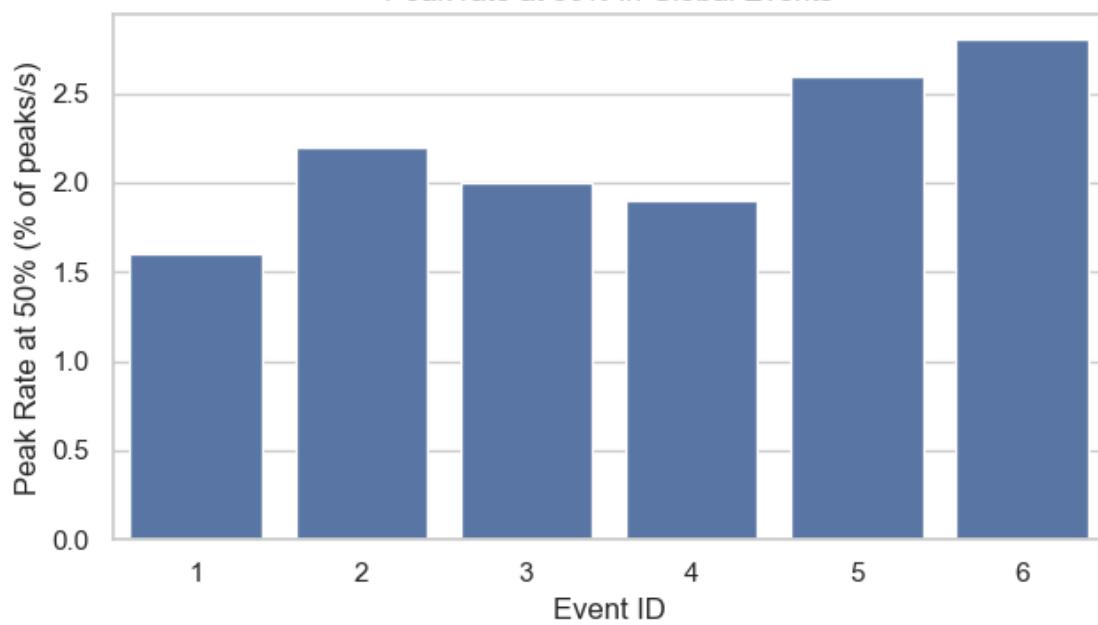


```
[2025-08-27 15:01:33] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\events\event-growth-curve-6.png': [Errno 2] No
such file or directory: 'D:\Mateo\20250618\Output\\IS3\\events\\event-growth-
curve-6.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundError: [Errno 2] No such file or directory:
'D:\Mateo\20250618\Output\\IS3\\events\\event-growth-curve-6.png'
```

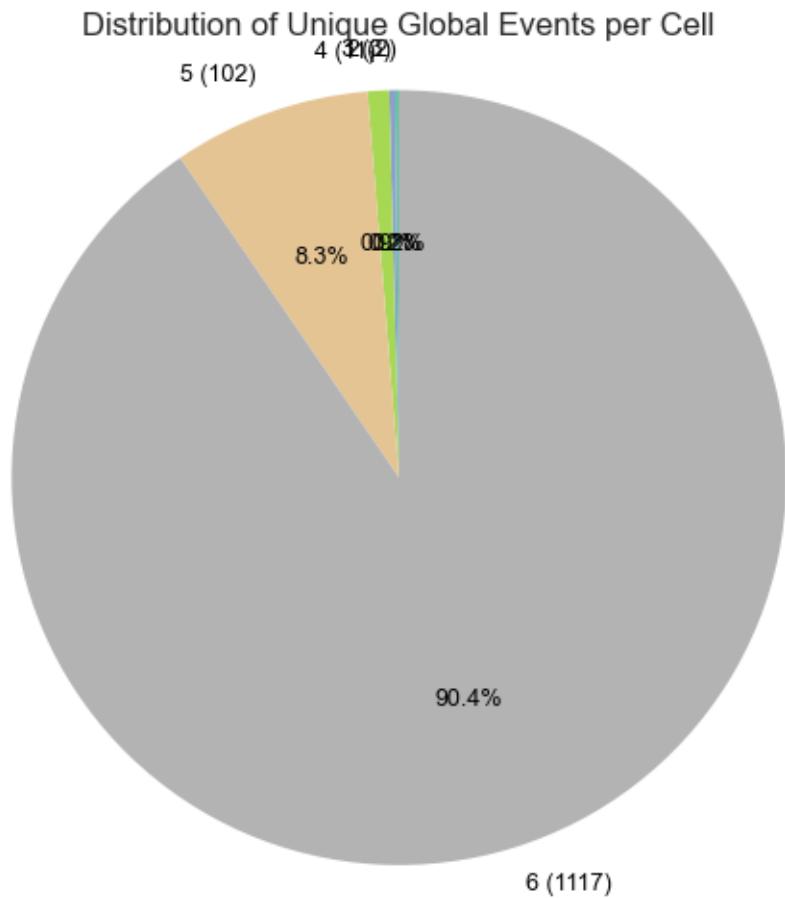
Time to 50% of Peaks in Global Events



Peak rate at 50% in Global Events



1.2.4 Cells Occurrences in global events

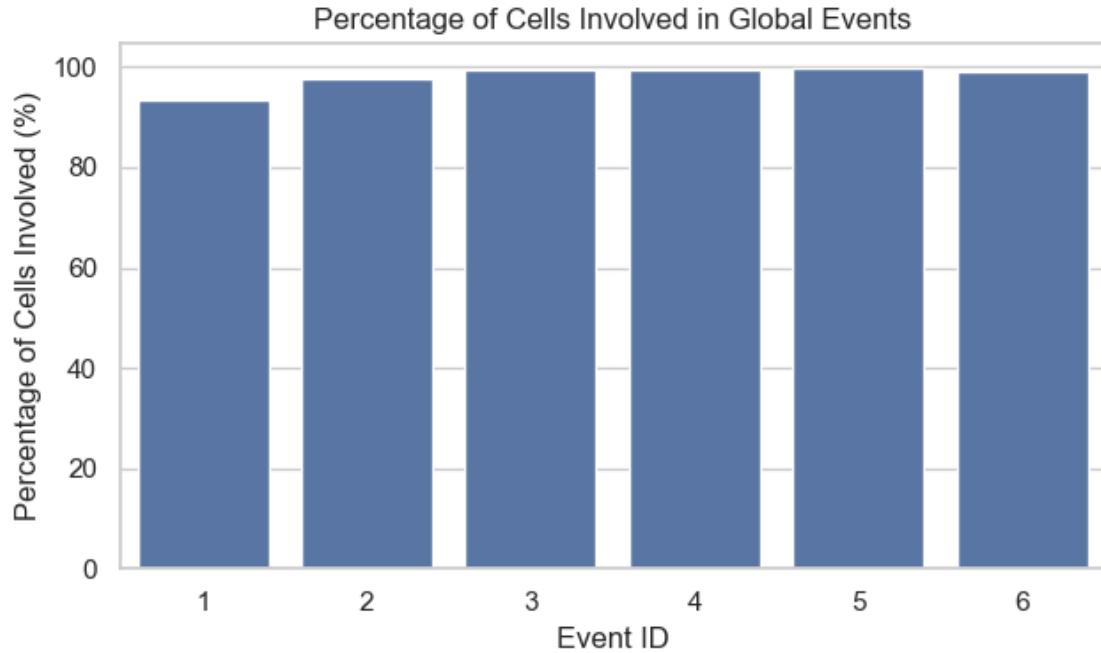


```
[2025-08-27 15:01:34] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\cell_Occurrences_in_global_events_overlay.png': [Errno 2] No such file
or directory: 'D:\\\\Mateo\\\\20250618\\\\Output\\\\IS3\\\\cell-
mapping\\\\cell_Occurrences_in_global_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
```

```

    self.fp = open(fp, "rb")
FileNotFoundError: [Errno 2] No such file or directory:
'D:\Mateo\20250618\Output\IS3\cell-
mapping\cell_Occurrences_in_global_events_overlay.png'

```



1.2.5 Inter-event interval analysis

Intervals between global event peaks: [149.0, 194.0, 242.0, 270.0, 247.0]

Estimated periodicity: 0.835

The global events exhibit a regular periodic pattern.

Estimated frequency (1/mean interval): 0.005 Hz

1.2.6 Early peakers in the events

```

[2025-08-27 15:01:34] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\global_events\global_event_1_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread

```

```

        with img_open(fname) as image:
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
        self._open()
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
        raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:01:34] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\global_events\global_event_2_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
        img = imread(img_path)
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\matplotlib\image.py", line 1512, in imread
        with img_open(fname) as image:
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
        self._open()
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
        raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:01:34] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\global_events\global_event_3_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
        img = imread(img_path)
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\matplotlib\image.py", line 1512, in imread
        with img_open(fname) as image:
    File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
        self._open()

```

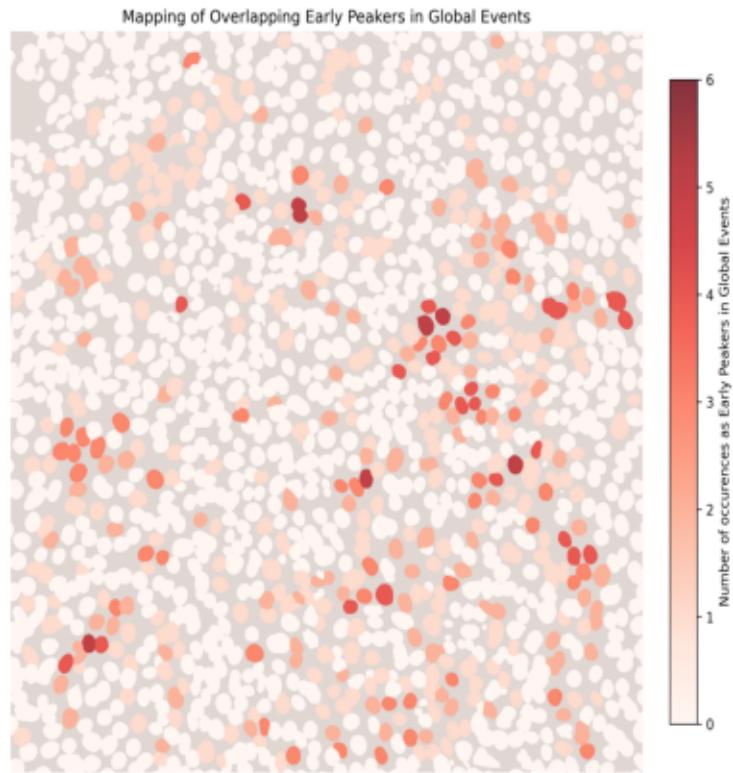
```
File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:01:34] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\global_events\global_event_4_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:01:34] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\global_events\global_event_5_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file
```

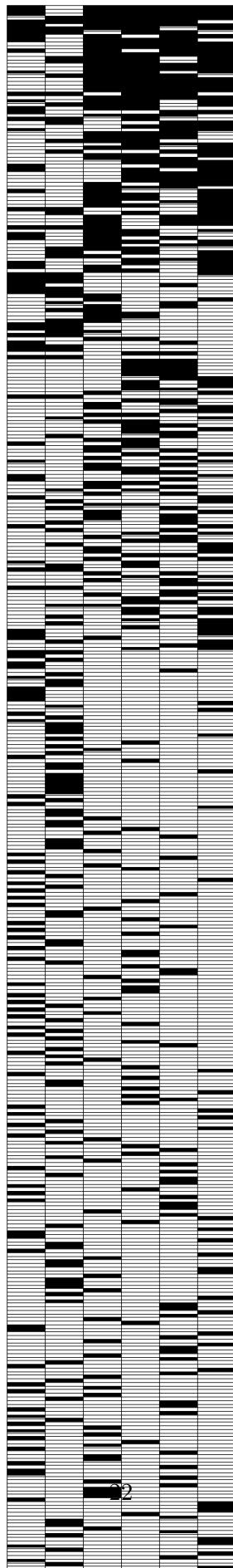
```
[2025-08-27 15:01:35] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\global_events\global_event_6_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file
```

Cell Mapping with Occurrences in Global Events Overlay



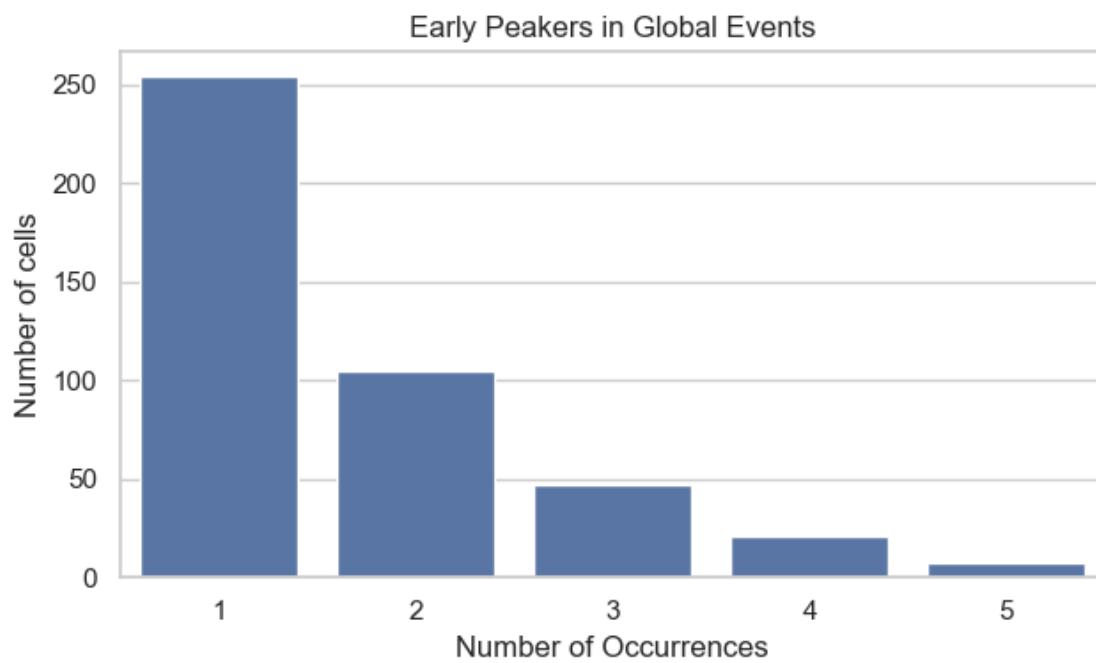
[2025-08-27 15:01:35] [WARNING] calcium: 'total_events' is deprecated and ignored. Using 6 unique event IDs.

[2025-08-27 15:01:35] [INFO] calcium: Early peakers event-matrix: 434 cells x 6 events; black squares: 724

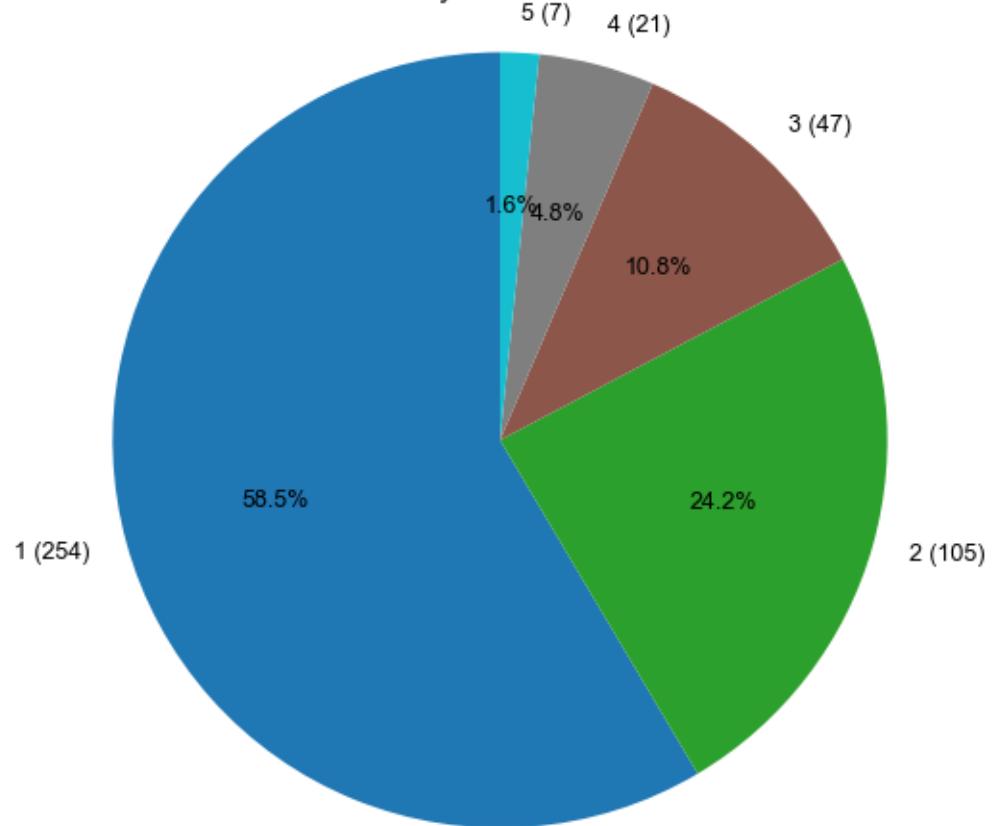


```
[2025-08-27 15:01:36] [INFO] calcium: Saved early peakers heatmap SVG to:  
early_peakers_heatmap.svg
```

```
[19]: array([[1, 0, 1, 1, 1, 1],  
           [1, 0, 1, 1, 1, 1],  
           [1, 0, 1, 1, 1, 1],  
           ...,  
           [1, 0, 0, 0, 0, 0],  
           [0, 1, 0, 0, 0, 0],  
           [0, 0, 0, 0, 0, 1]])
```

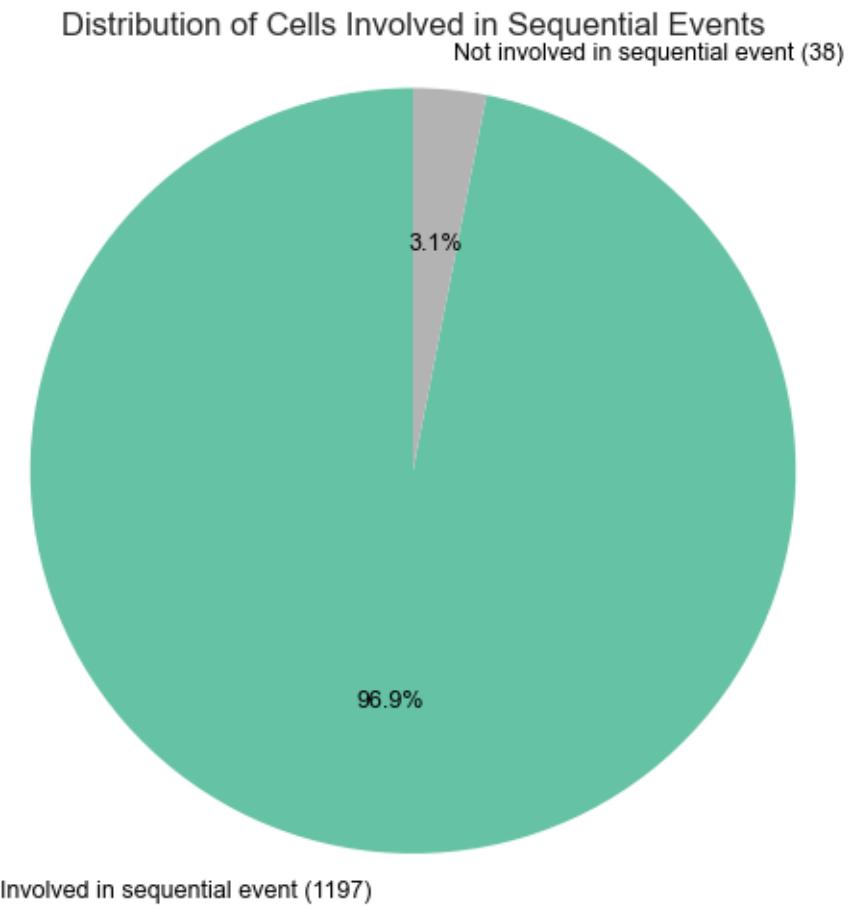


Distribution of Early Peakers in Global Events

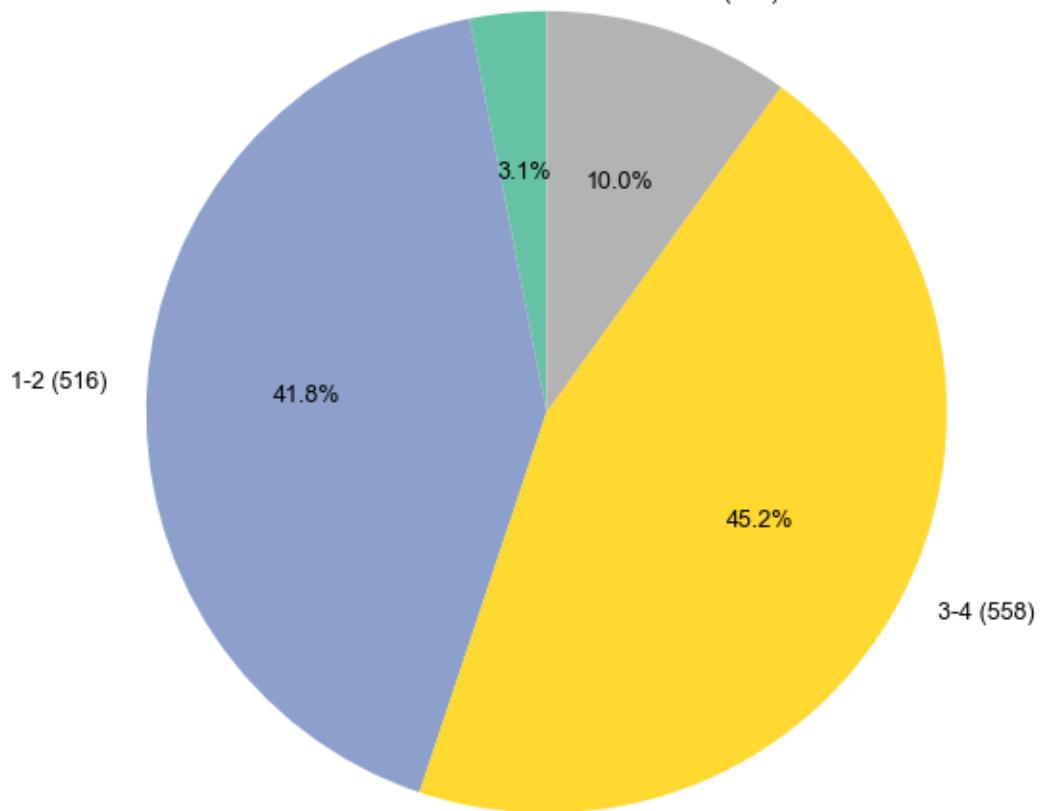


1.3 SEQUENTIAL EVENTS

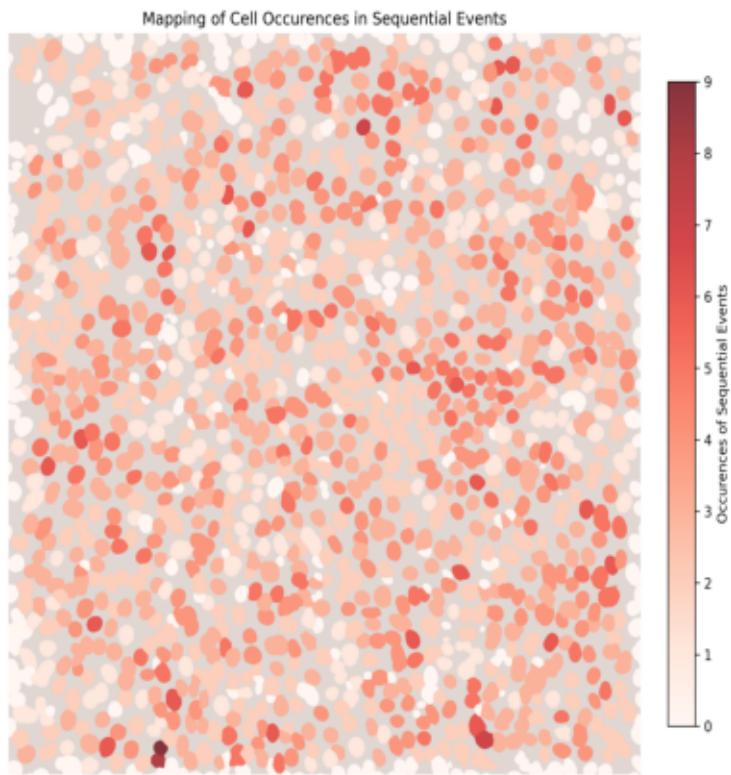
1.3.1 Cells Occurrences in sequential events



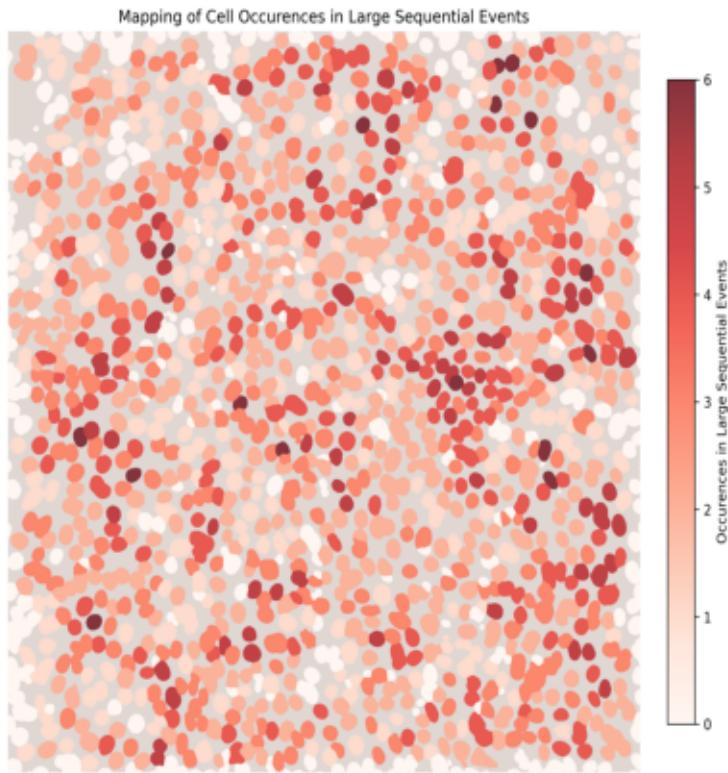
Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



Cell Mapping with Occurrences in Sequential Events Overlay

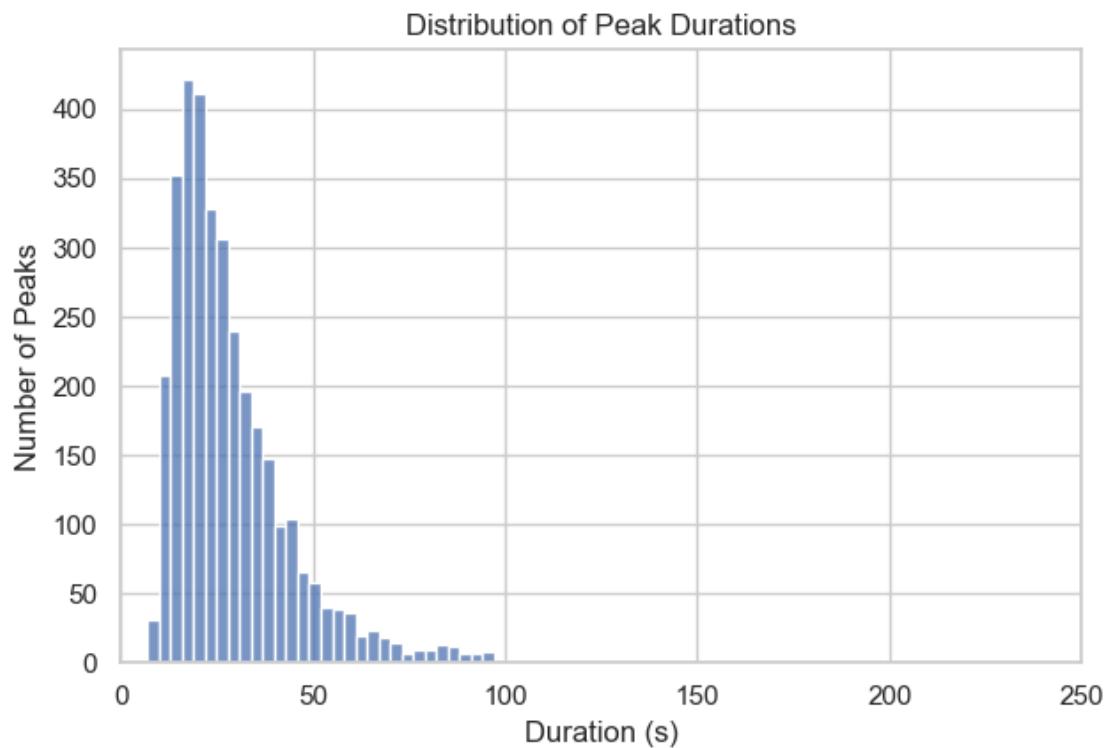


Cell Mapping with Occurrences in Large Sequential Events Overlay (>2)

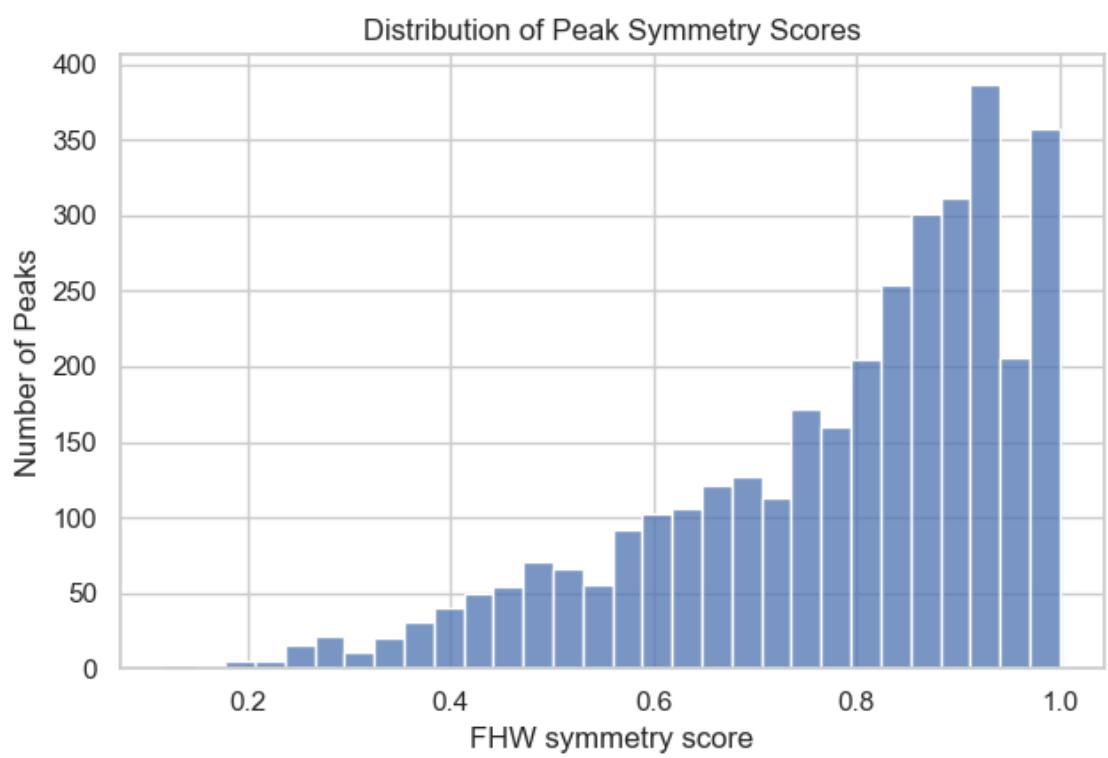
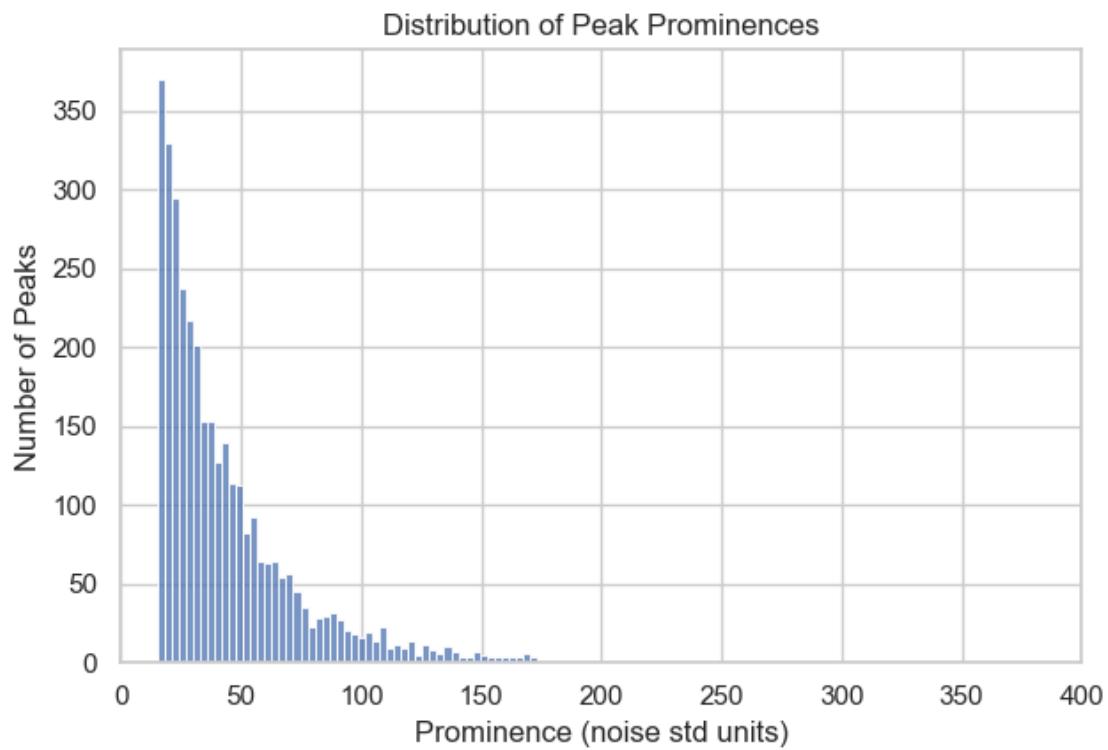


1.3.2 Peaks statistics in sequential events

```
[2025-08-27 15:01:39] [INFO] calcium: plot_histogram: removed 64 outliers out of  
3463 on 'Duration (s)' (lower=-10, upper=98)
```

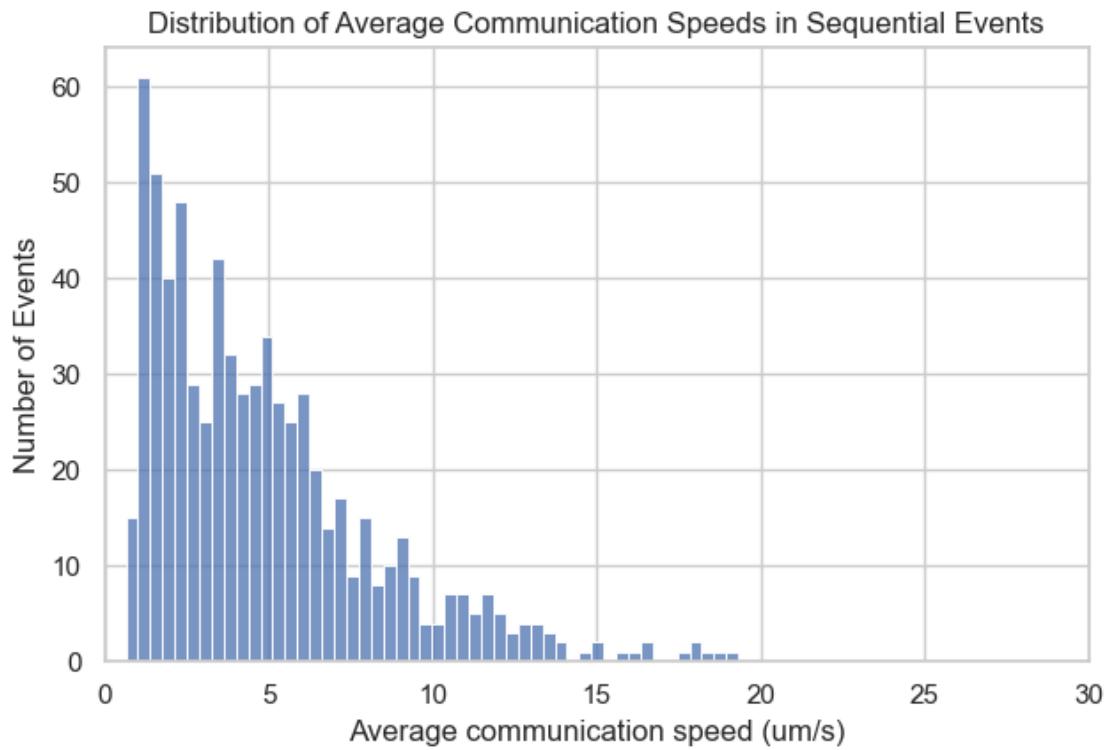


```
[2025-08-27 15:01:39] [INFO] calcium: plot_histogram: removed 71 outliers out of  
3463 on 'Prominence (noise std units)' (lower=-27.9, upper=173.7)
```



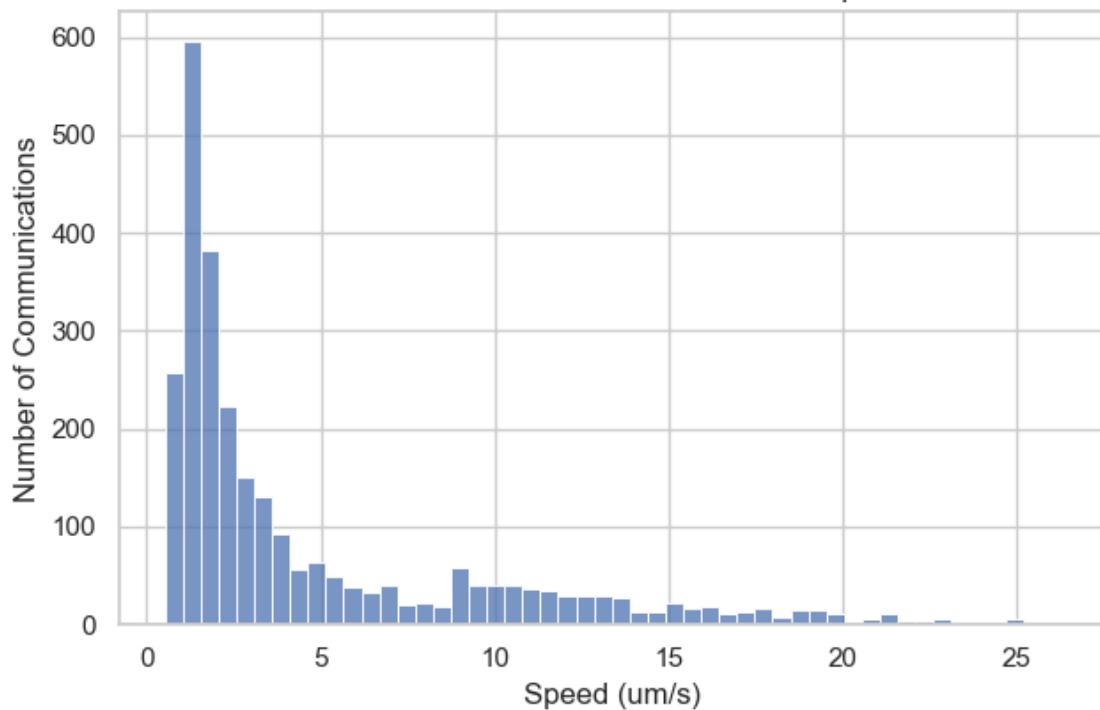
1.3.3 Cell-cell communication speed

[2025-08-27 15:01:39] [INFO] calcium: plot_histogram: removed 2 outliers out of 699 on 'Average communication speed (um/s)' (lower=-10.765, upper=19.44)

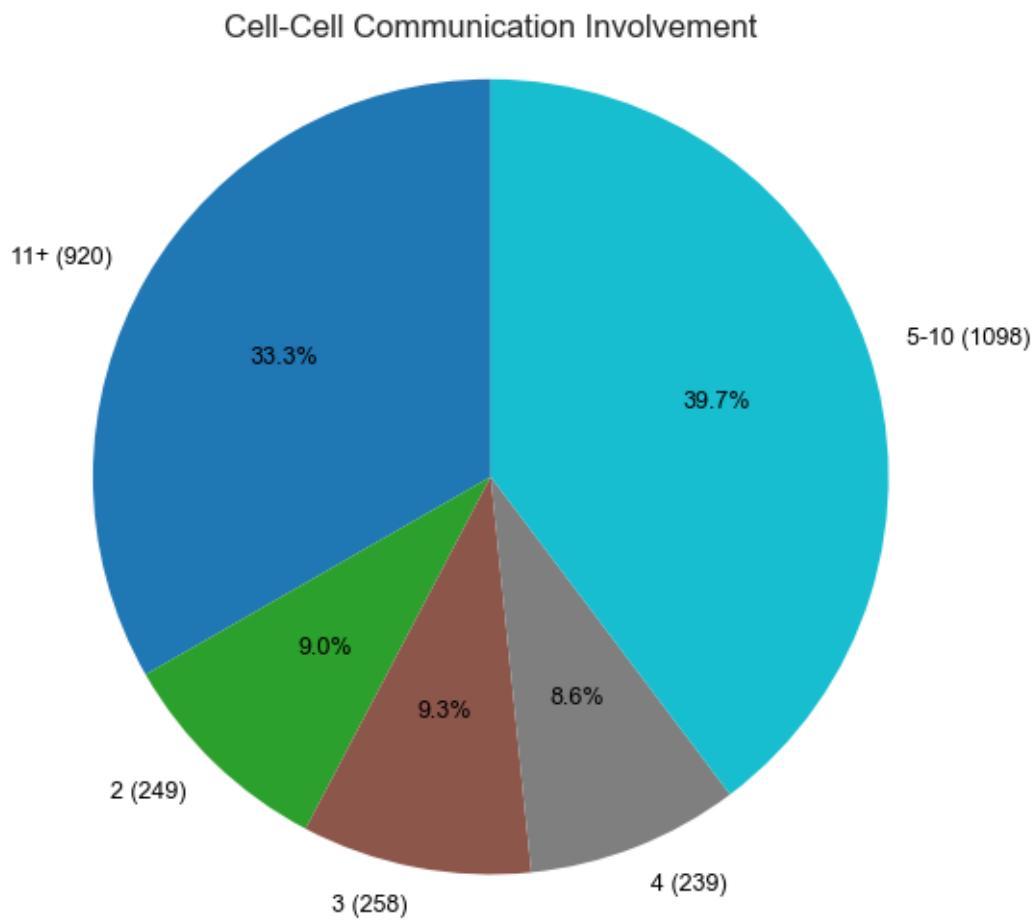


[2025-08-27 15:01:39] [INFO] calcium: plot_histogram: removed 0 outliers out of 2764 on 'Speed (um/s)' (lower=-14.47, upper=33.14)

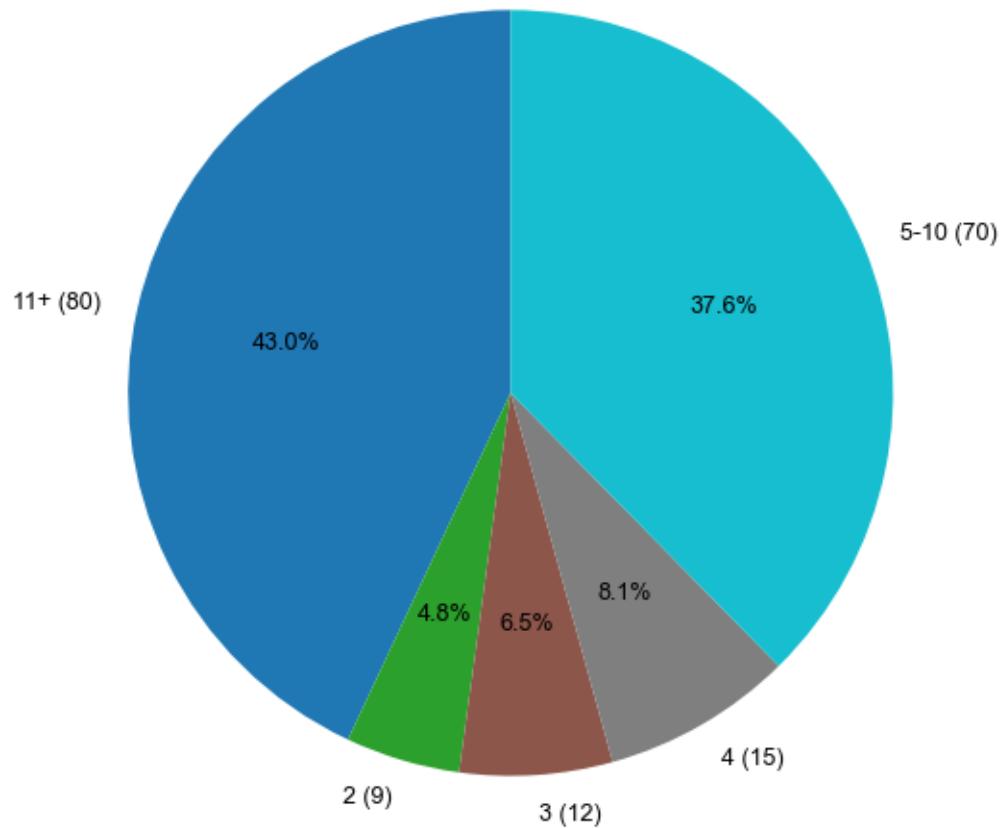
Distribution of Cell-Cell Communication Speeds



1.3.4 Double distribution in cell-cell communication speeds

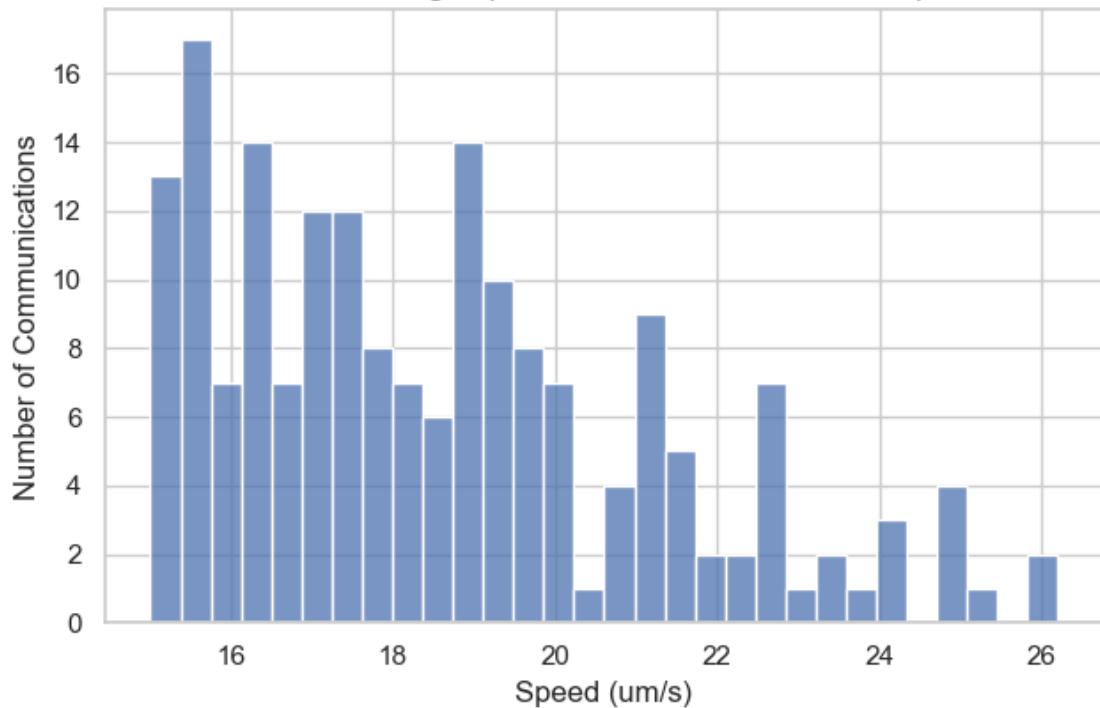


High Speed Cell-Cell Communication Involvement

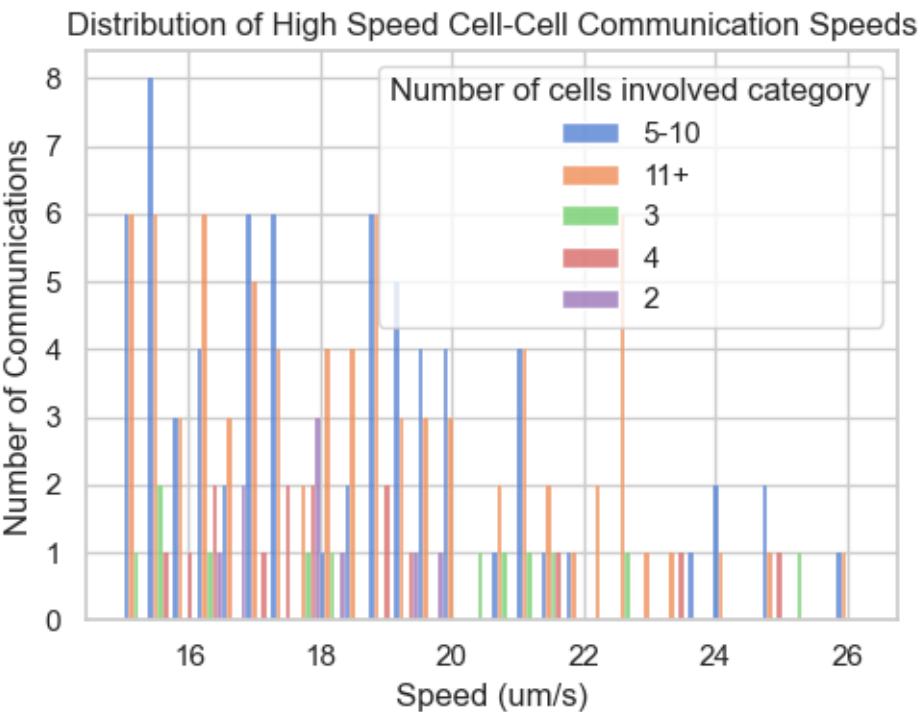


[2025-08-27 15:01:40] [INFO] calcium: plot_histogram: removed 0 outliers out of 186 on 'Speed (um/s)' (lower=5.4775, upper=30.992)

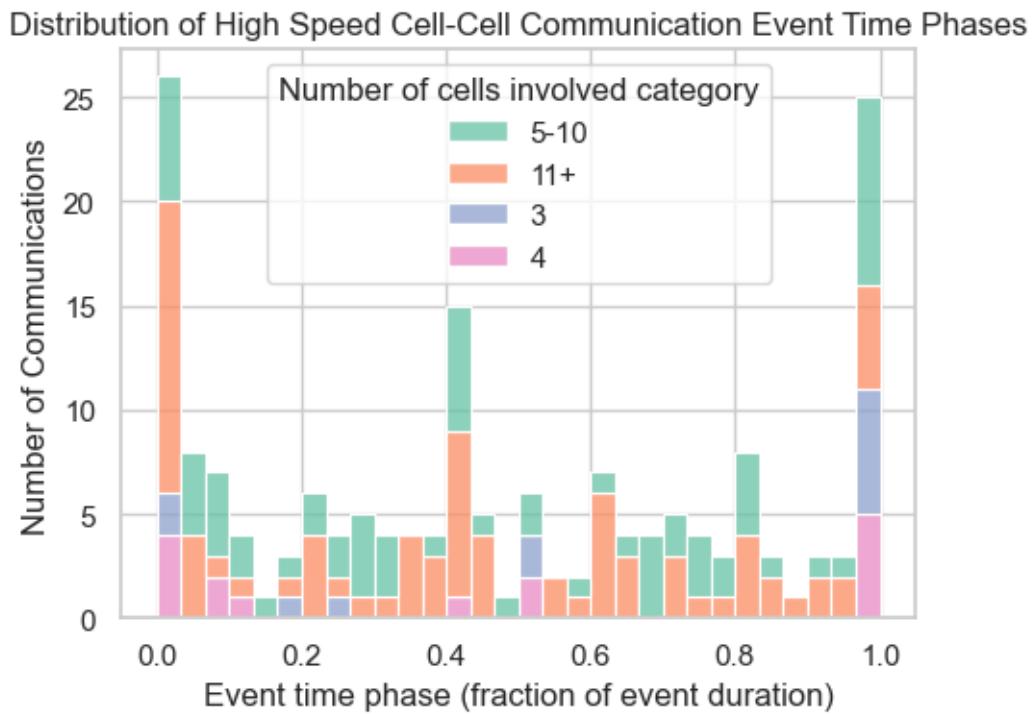
Distribution of High Speed Cell-Cell Communication Speeds



```
[2025-08-27 15:01:40] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 186 on 'Speed (um/s)' (lower=5.4775, upper=30.992)
```

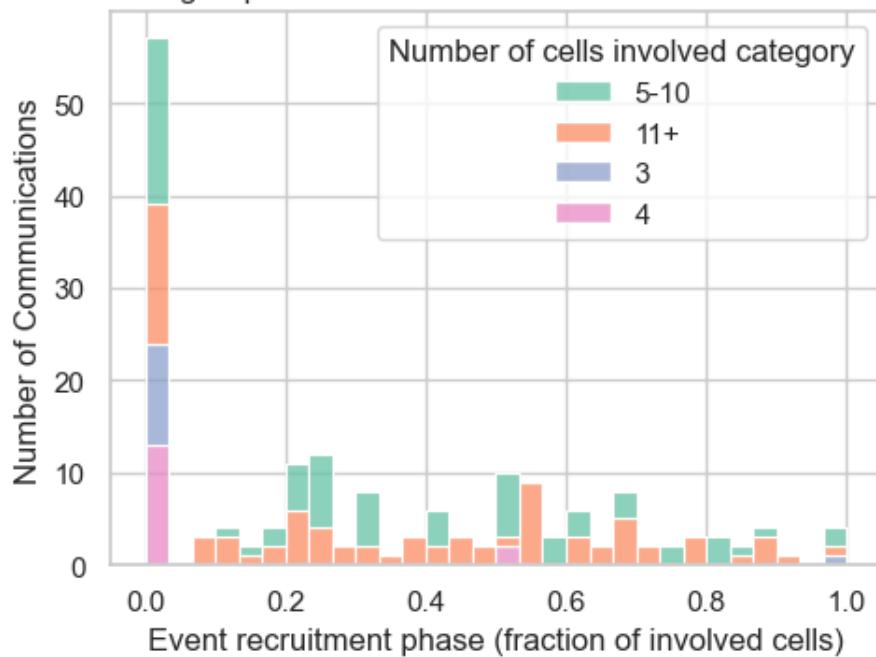


[2025-08-27 15:01:40] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 177 on 'Event time phase (fraction of event duration)' (lower=-1.83, upper=2.72)

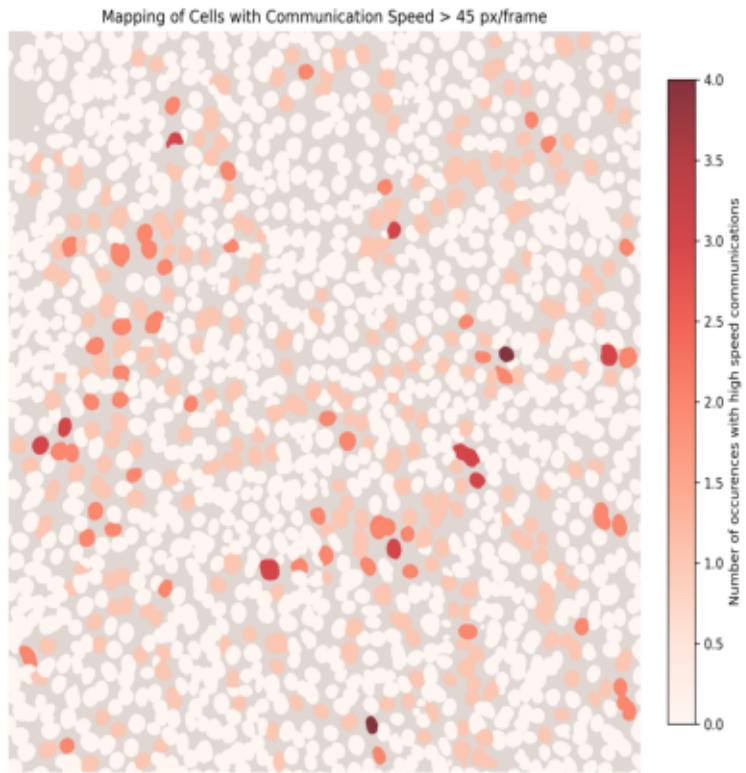


[2025-08-27 15:01:40] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 177 on 'Event recruitment phase (fraction of involved cells)' (lower=-1.68, upper=2.24)

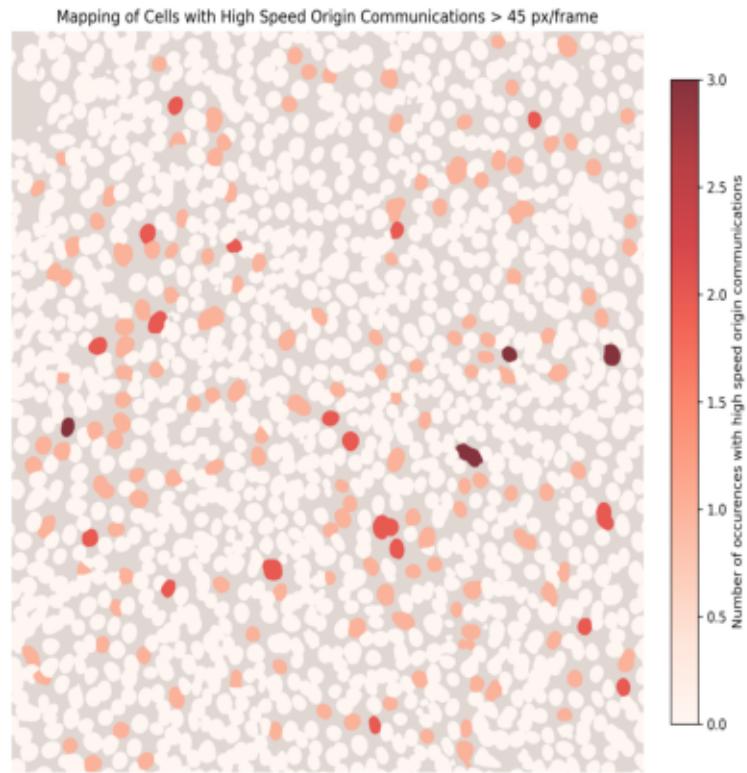
Distribution of High Speed Cell-Cell Communication Event Recruitment Phases



Cell Mapping with High Speed Cells Overlay



Cell Mapping with High Speed Origin Cells Overlay



	Communication ID	Event ID	Origin cell ID	Origin cell peak ID	\
16	3015668256864	9	452	1	
21	3015621625648	11	1473	1	
23	3015667766592	11	1502	1	
32	3015621637984	12	908	0	
36	3015668267184	12	1107	0	
...	
2586	3015668239280	621	1752	3	
2674	3015449255104	655	1934	2	
2677	3015449254336	655	1986	2	
2694	3015449257696	662	1863	0	
2747	3015449252992	691	1996	6	

	Cause cell ID	Cause cell peak ID	Start time (s)	End time (s)	\
16	392	1	161.0	161.0	
21	1468	3	248.0	248.0	
23	1562	1	260.0	260.0	
32	846	0	24.0	24.0	
36	1086	0	11.0	11.0	
...	
2586	1773	3	146.0	147.0	
2674	1986	2	210.0	211.0	
2677	2062	2	211.0	212.0	
2694	1926	1	128.0	129.0	
2747	2020	3	797.0	798.0	
	Duration (s)	Distance (um)	Speed (um/s)	\	
16	0.0	19.13	19.13		
21	0.0	16.98	16.98		
23	0.0	17.56	17.56		
32	0.0	15.94	15.94		
36	0.0	20.20	20.20		
...	
2586	1.0	20.77	20.77		
2674	1.0	18.93	18.93		
2677	1.0	21.29	21.29		
2694	1.0	16.14	16.14		
2747	1.0	17.99	17.99		
	Event time phase (fraction of event duration)	\			
16		0.46			
21		0.39			
23		0.63			
32		0.41			
36		0.03			
...		...			
2586		0.64			
2674		0.06			
2677		0.11			
2694		NaN			
2747		NaN			
	Event recruitment phase (fraction of involved cells)	dataset	\		
16		0.40	20250618_IS3		
21		0.11	20250618_IS3		
23		0.44	20250618_IS3		
32		0.42	20250618_IS3		
36		0.00	20250618_IS3		
...			
2586		0.86	20250618_IS3		
2674		0.00	20250618_IS3		

2677		0.25	20250618_IS3
2694		NaN	20250618_IS3
2747		NaN	20250618_IS3

	Number of cells involved	category	Speed category
16		5-10	High speed
21		11+	High speed
23		11+	High speed
32		11+	High speed
36		11+	High speed
...	
2586		5-10	High speed
2674		5-10	High speed
2677		5-10	High speed
2694		2	High speed
2747		2	High speed

[186 rows x 16 columns]

Origin cell ID	Speed category	High speed	Low speed
300		0	1
301		0	2
302		1	3
304		0	2
305		0	2
...
2073		1	3
2074		0	3
2075		0	6
2078		0	1
2080		1	1

[1003 rows x 2 columns]

Cell ID	Centroid X coordinate (um)	Centroid Y coordinate (um)	\
1	300	454.68	6.50
2	301	309.73	6.50
3	302	384.15	6.50
4	304	251.55	7.15
5	305	25.03	7.15
...
1230	2073	105.62	491.07
1231	2074	166.08	491.07
1232	2075	213.20	491.40
1233	2078	238.22	492.38
1234	2080	63.70	493.03

Number of peaks Is active Occurrences in global events \

1	11	True	6
2	9	True	6
3	20	True	6
4	9	True	6
5	10	True	6
...
1230	7	True	5
1231	9	True	6
1232	14	True	6
1233	8	True	6
1234	9	True	6

Occurrences in global events as early peaker Early peaker event IDs \

1	0	[]
2	0	[]
3	2	[1, 2]
4	0	[]
5	0	[]
...
1230	0	[]
1231	1	[2]
1232	1	[6]
1233	0	[]
1234	0	[]

Occurrences in sequential events \

1	3	
2	2	
3	5	
4	3	
5	2	
...	...	
1230	2	
1231	3	
1232	5	
1233	1	
1234	1	

Occurrences in sequential events as origin \

1	1	
2	1	
3	2	
4	1	
5	2	
...	...	
1230	2	
1231	2	
1232	3	

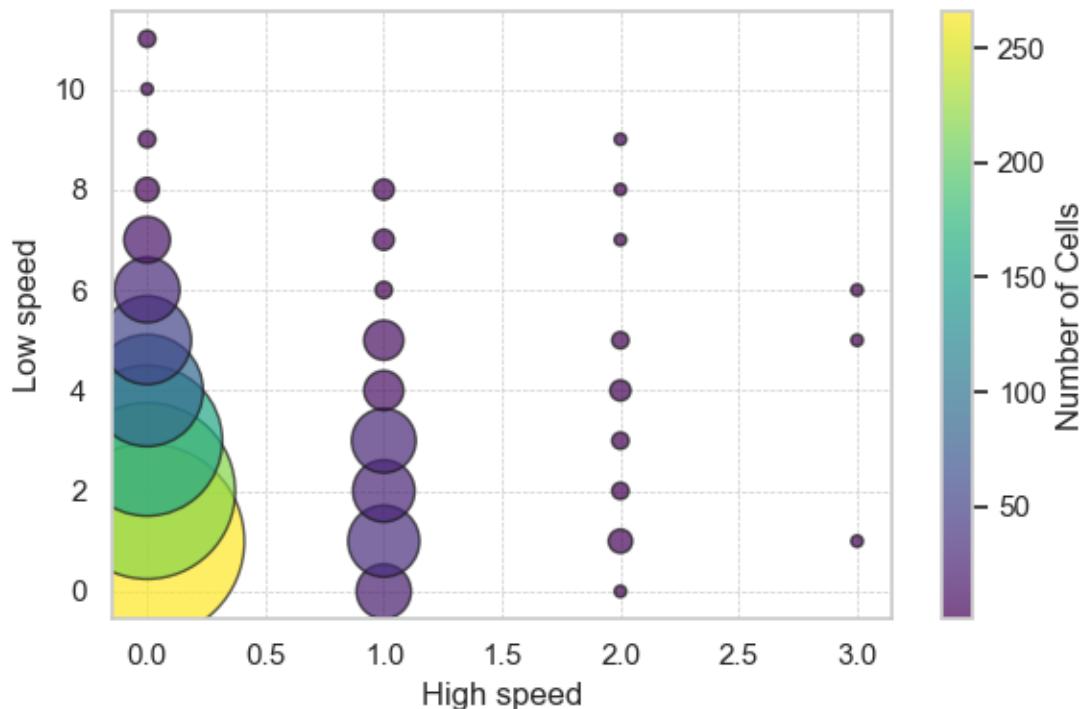
1233		1	
1234		0	
	Occurrences in individual events	Peak frequency (Hz)	\
1	2	0.0065	
2	1	0.0053	
3	3	0.0120	
4	0	0.0053	
5	1	0.0059	
...	
1230	0	0.0041	
1231	0	0.0053	
1232	1	0.0082	
1233	1	0.0047	
1234	2	0.0053	
	Periodicity score	Neighbor count	Neighbors (labels) dataset \
1	0.65	3	[315,318,355] 20250618_IS3
2	0.72	3	[325,349,365] 20250618_IS3
3	0.55	4	[321,354,363,374] 20250618_IS3
4	0.73	3	[324,342,356] 20250618_IS3
5	0.68	2	[317,330] 20250618_IS3
...
1230	0.79	3	[2037,2040,2068] 20250618_IS3
1231	0.70	4	[1998,2008,2049,2060] 20250618_IS3
1232	0.62	4	[2004,2009,2061,2066] 20250618_IS3
1233	0.77	3	[2041,2061,2063] 20250618_IS3
1234	0.72	4	[2029,2035,2036,2071] 20250618_IS3
	Involved in sequential event	Occurrences in sequential events	category \
1	Involved in sequential event		3-4
2	Involved in sequential event		1-2
3	Involved in sequential event		5-9
4	Involved in sequential event		3-4
5	Involved in sequential event		1-2
...
1230	Involved in sequential event		1-2
1231	Involved in sequential event		3-4
1232	Involved in sequential event		5-9
1233	Involved in sequential event		1-2
1234	Involved in sequential event		1-2
	High speed	Low speed	
1	0.0	1.0	
2	0.0	2.0	
3	1.0	3.0	
4	0.0	2.0	
5	0.0	2.0	

```

...
1230      1.0      3.0
1231      0.0      3.0
1232      0.0      6.0
1233      0.0      1.0
1234      1.0      1.0

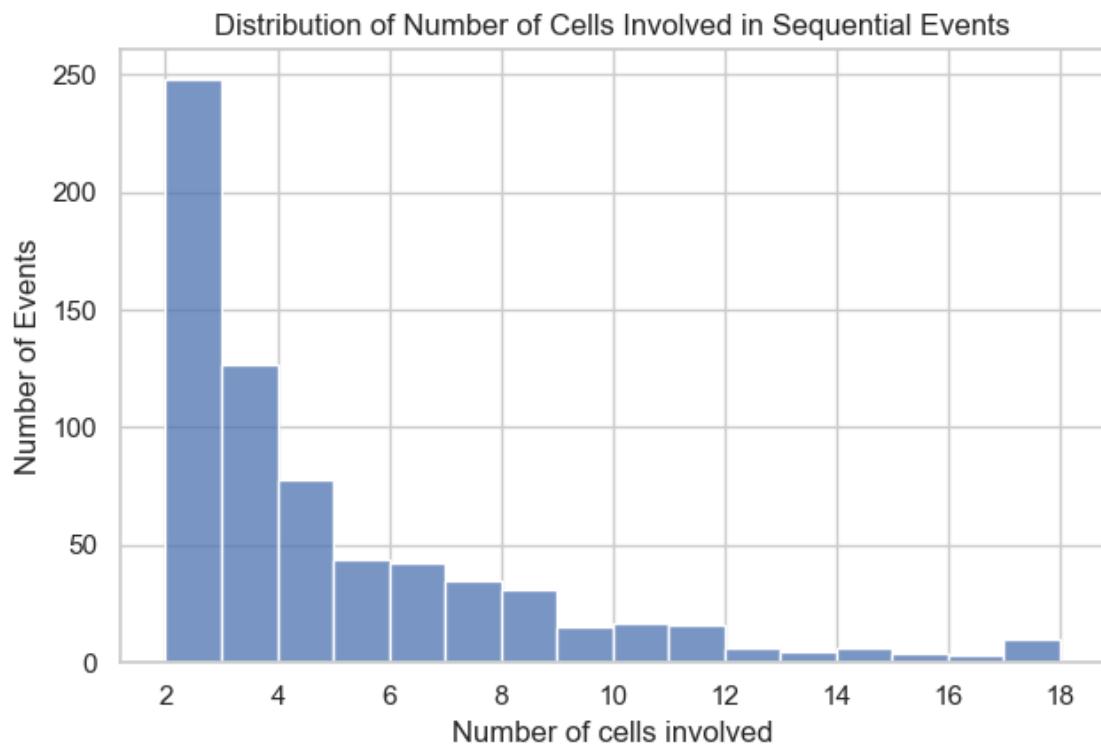
```

[1003 rows x 20 columns]



1.3.5 Number of cells involved per sequential events

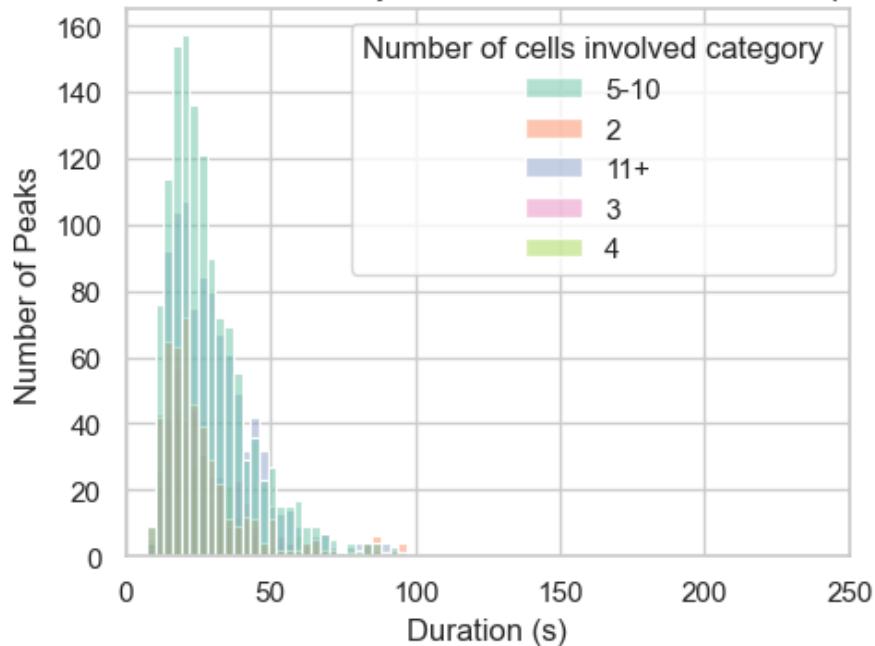
[2025-08-27 15:01:43] [INFO] calcium: plot_histogram: removed 12 outliers out of 699 on 'Number of cells involved' (lower=-10, upper=18)



1.3.6 Influence of cell count per event on statistics

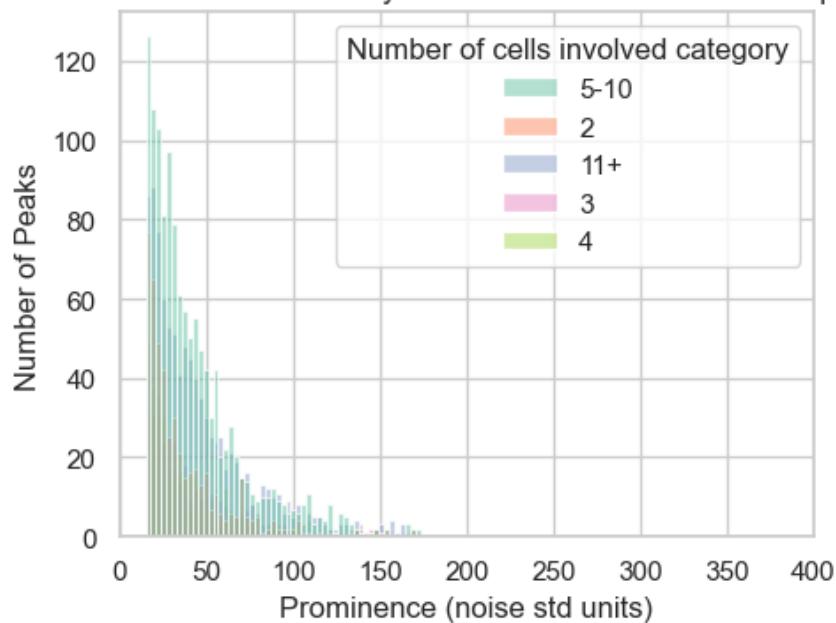
```
[2025-08-27 15:01:43] [INFO] calcium: plot_histogram_by_group: removed 64 outliers out of 3463 on 'Duration (s)' (lower=-10, upper=98)
```

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

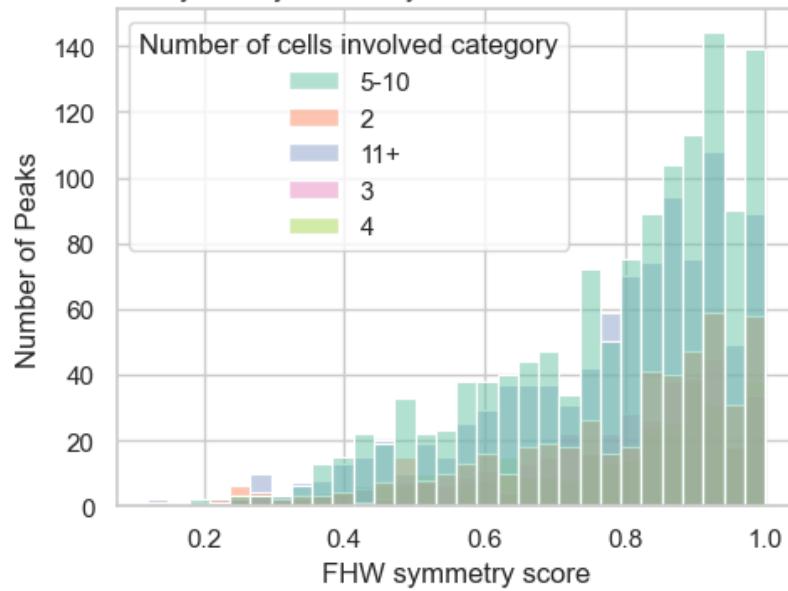


```
[2025-08-27 15:01:44] [INFO] calcium: plot_histogram_by_group: removed 71 outliers out of 3463 on 'Prominence (noise std units)' (lower=-27.9, upper=173.7)
```

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

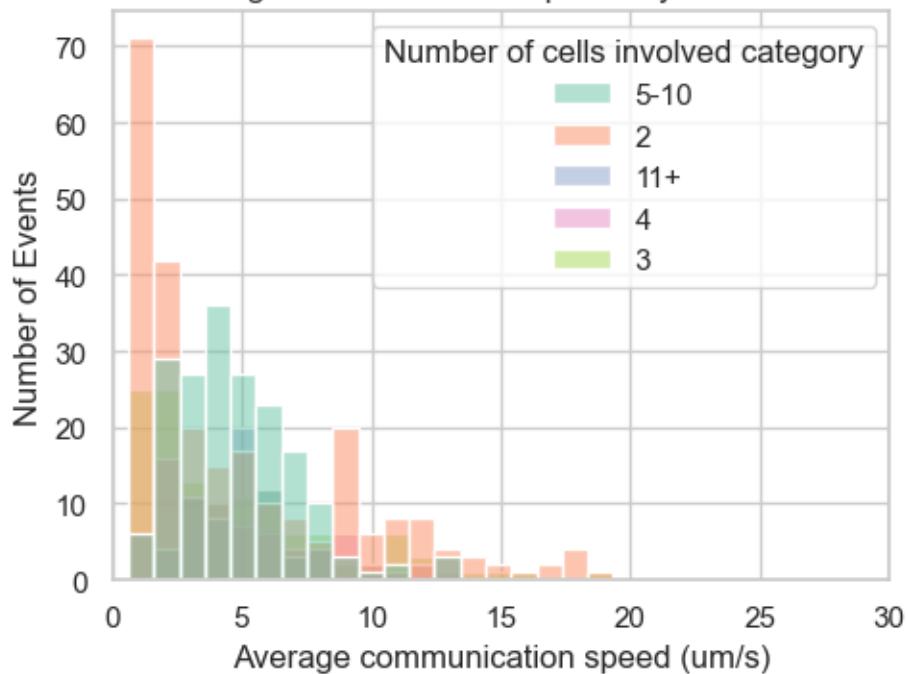


Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events

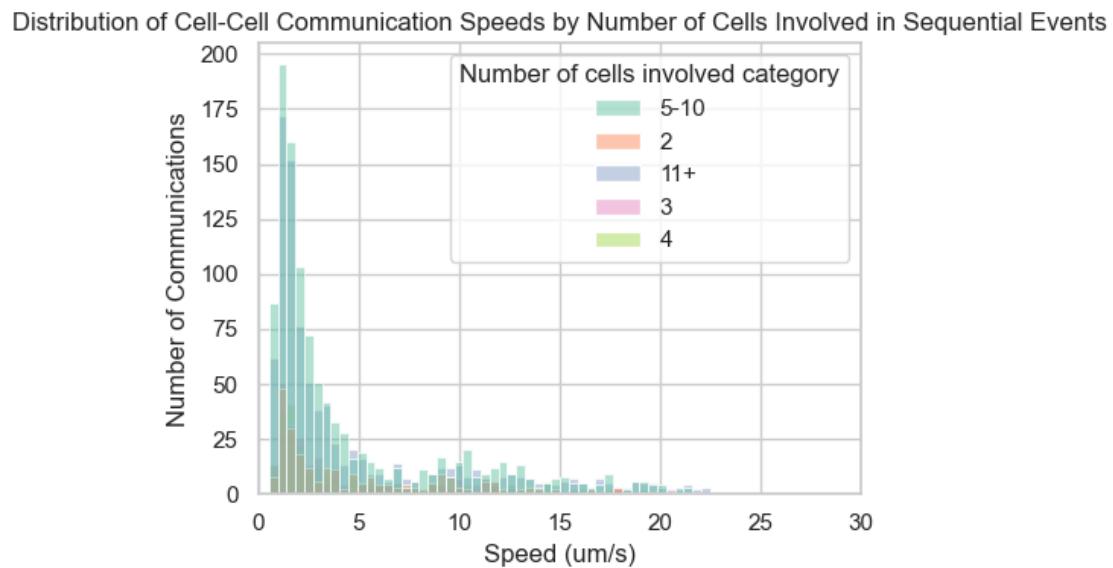


```
[2025-08-27 15:01:44] [INFO] calcium: plot_histogram_by_group: removed 2 outliers out of 699 on 'Average communication speed (um/s)' (lower=-10.765, upper=19.44)
```

Distribution of Average Communication Speeds by Number of Cells Involved

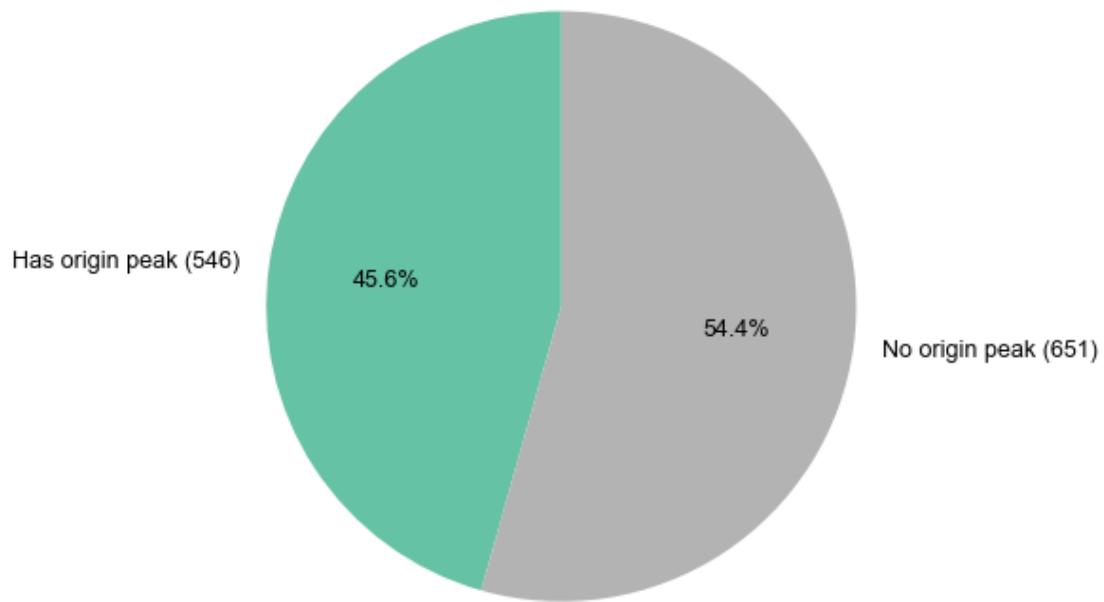


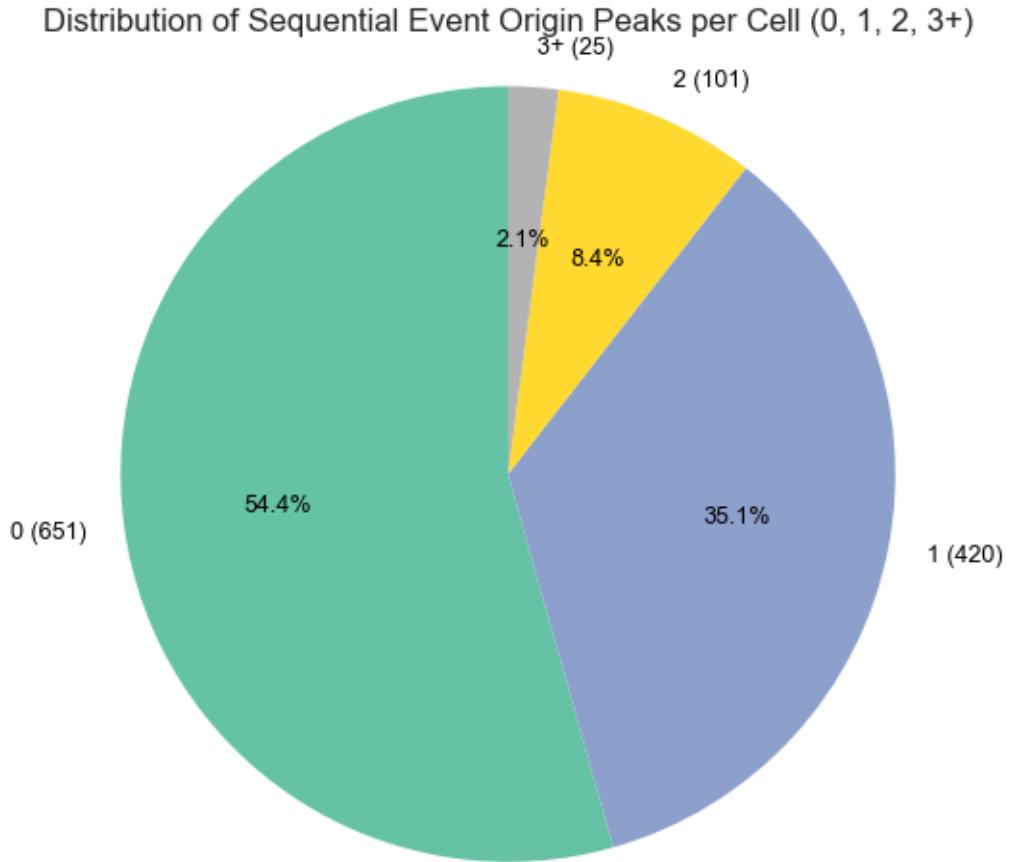
[2025-08-27 15:01:44] [INFO] calcium: plot_histogram_by_group: removed 20 outliers out of 2764 on 'Speed (um/s)' (lower=-14.47, upper=22.56)



1.3.7 Cells Occurrences as origin in sequential events

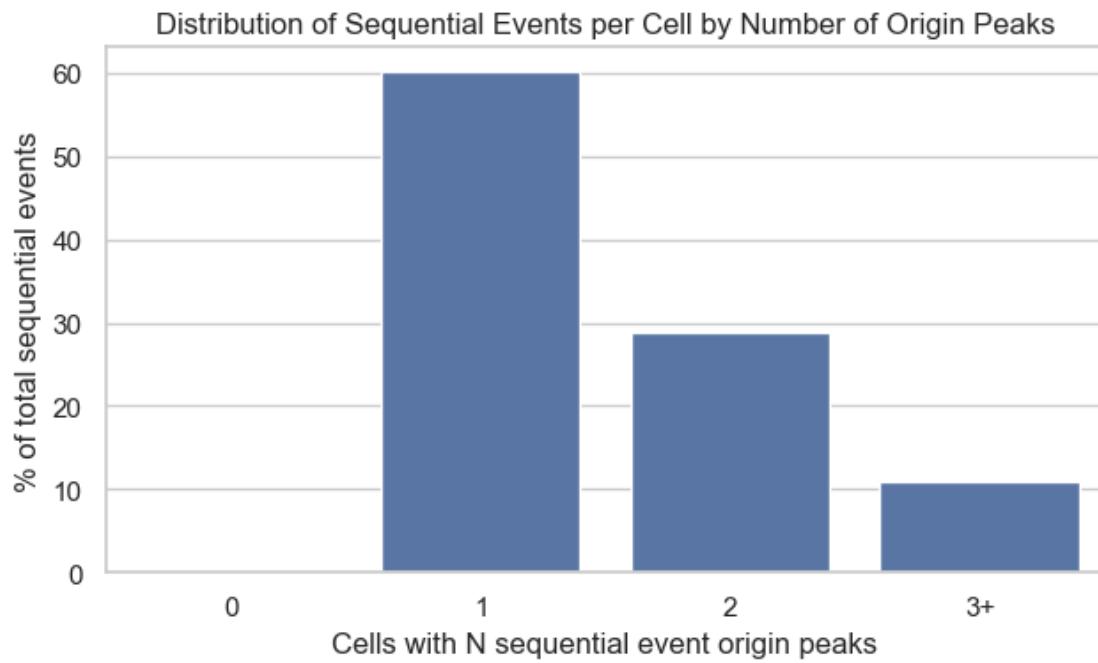
Distribution of Number of Sequential Event Origin Peaks per Cell





```
[2025-08-27 15:01:45] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\cell_Occurrences_in_origin_seq_events_overlay.png': [Errno 2] No such
file or directory: 'D:\\Mateo\\20250618\\Output\\IS3\\cell-
mapping\\cell_Occurrences_in_origin_seq_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundException: [Errno 2] No such file or directory:
```

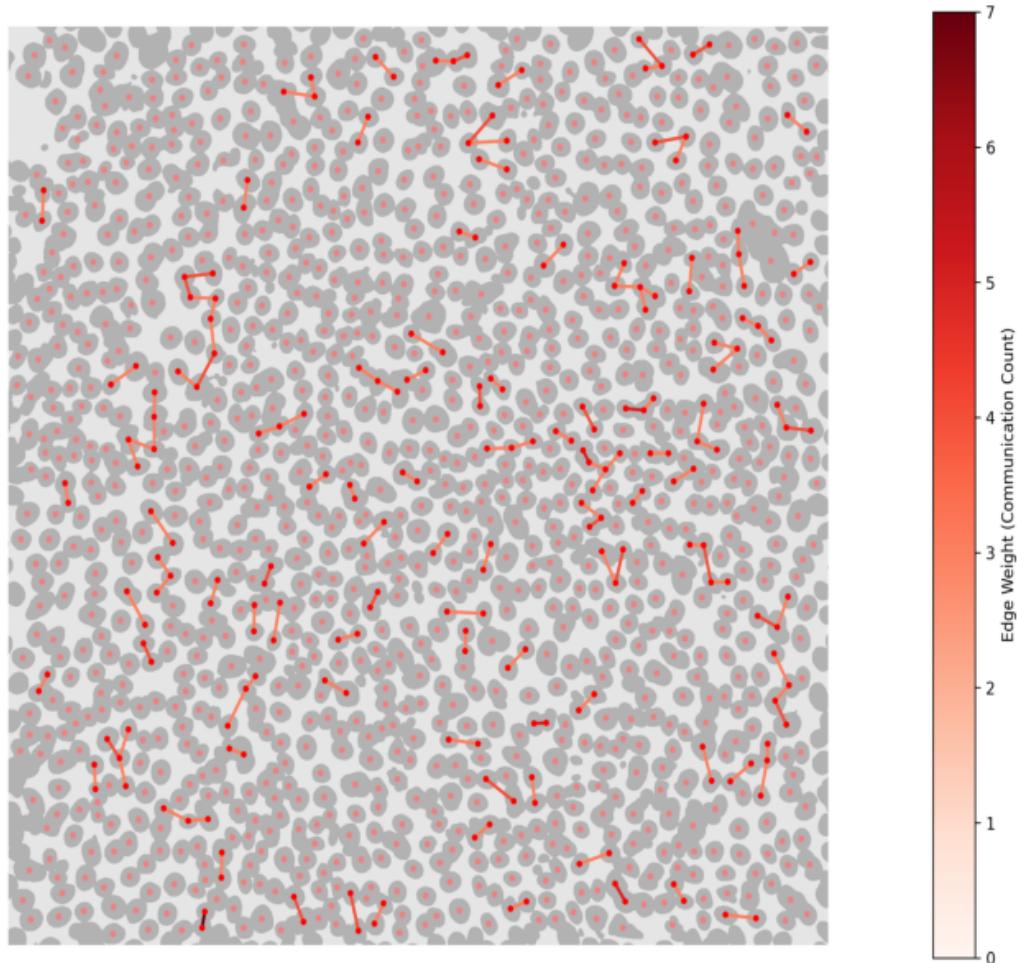
'D:\\Mateo\\20250618\\Output\\IS3\\cell-mapping\\cell_Occurrences_in_origin_seq_events_overlay.png'



1.3.8 Connection network between cells

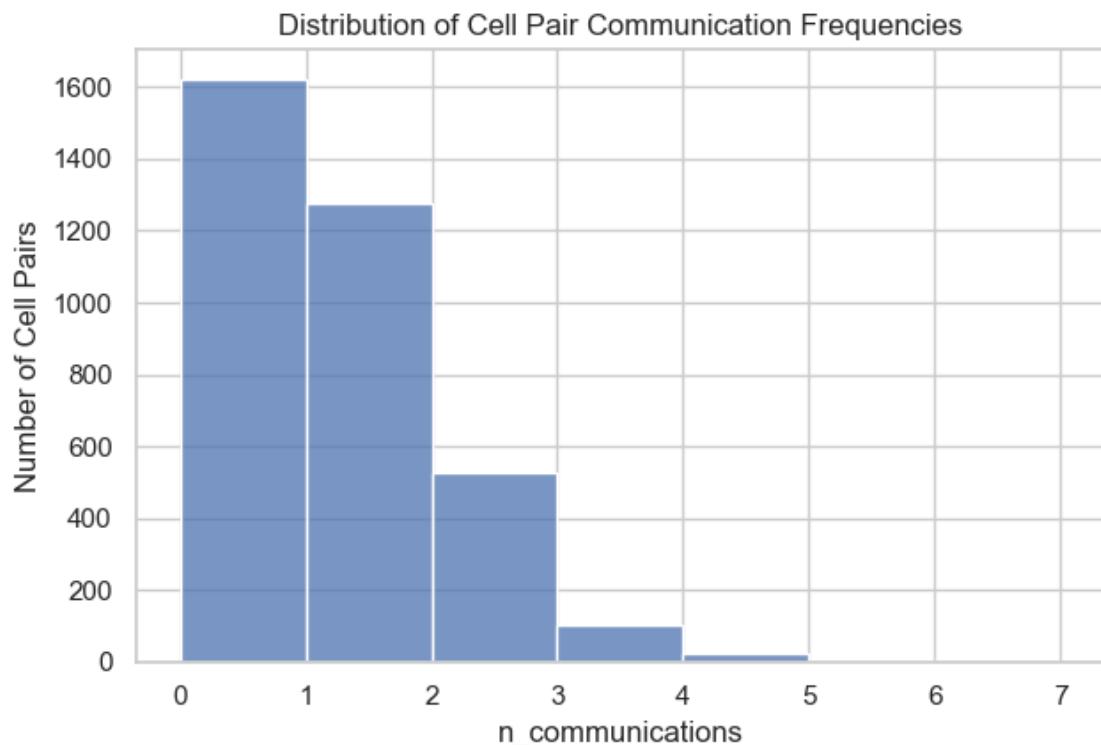
Cell Connection Network Graph

Cells Connection Network (Weighted Edges)



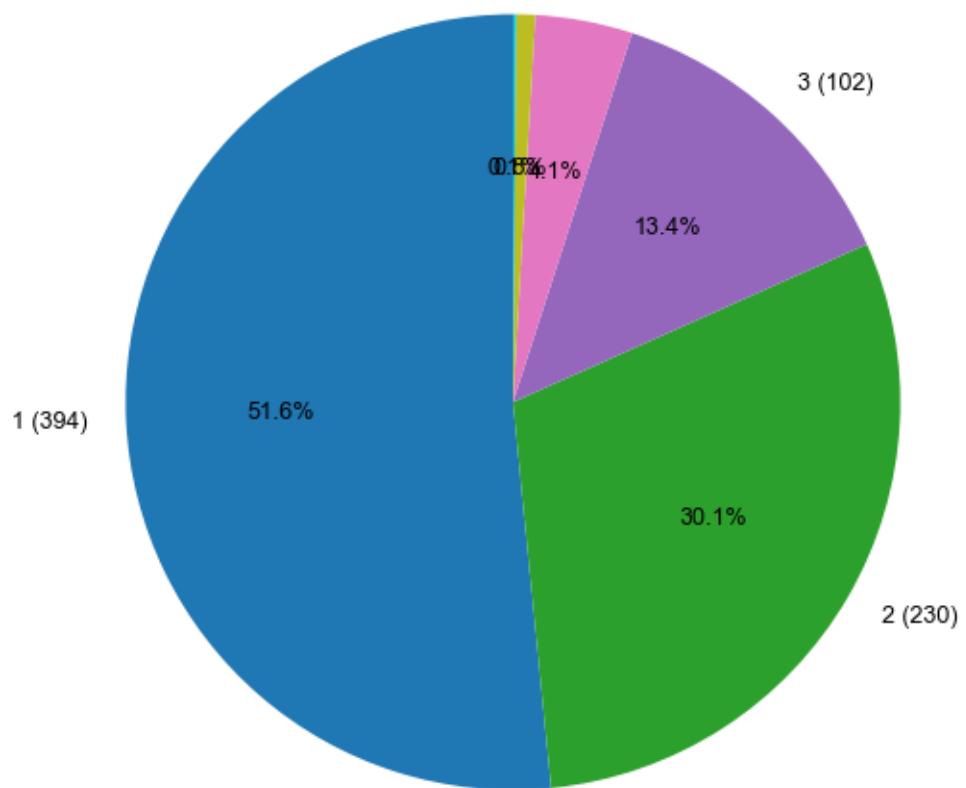
1.3.9 Pair/Trios with high communication networks

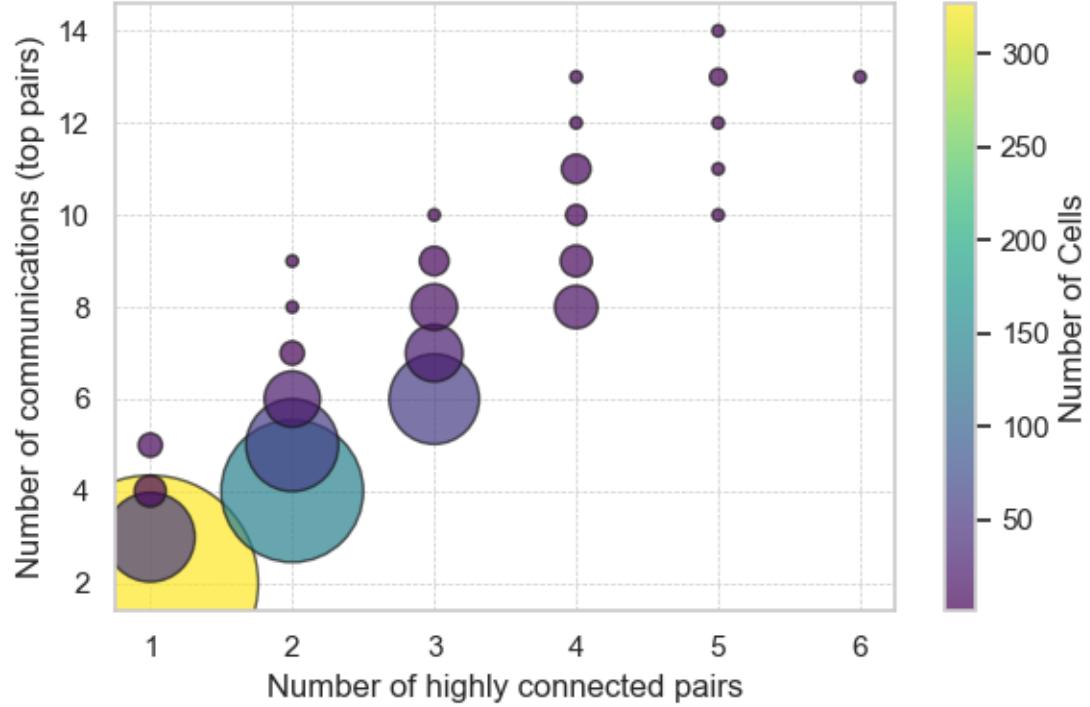
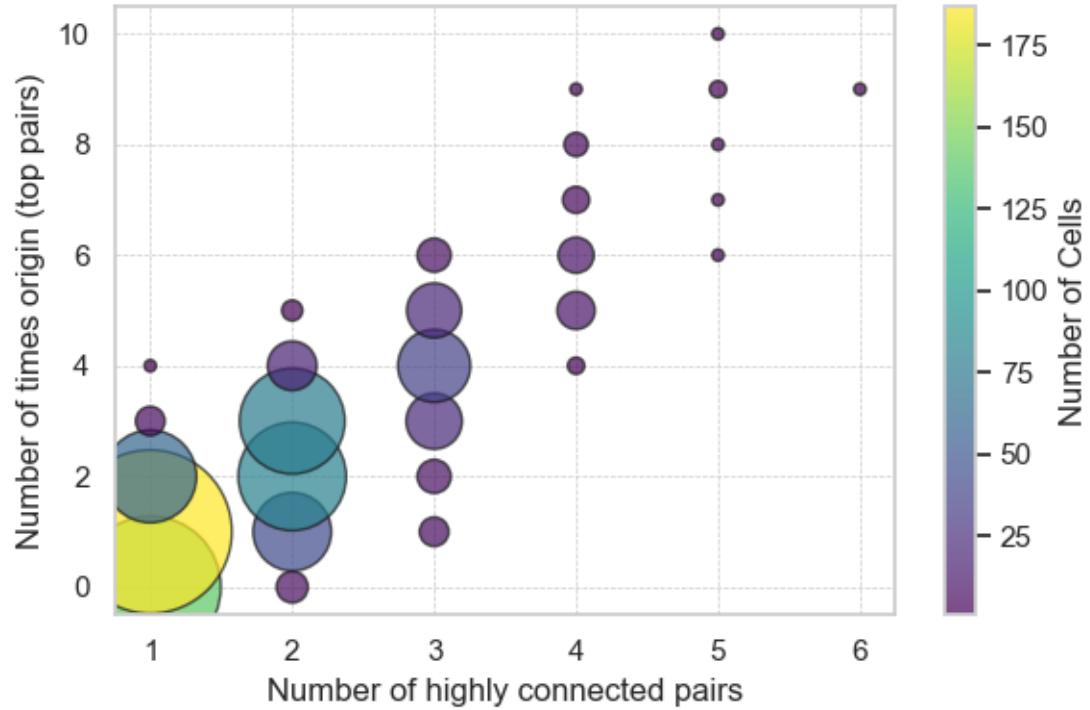
```
[2025-08-27 15:01:46] [INFO] calcium: build_neighbor_pair_stats: built 3558 pairs across 1 datasets (mean distance=15.44 um)
```

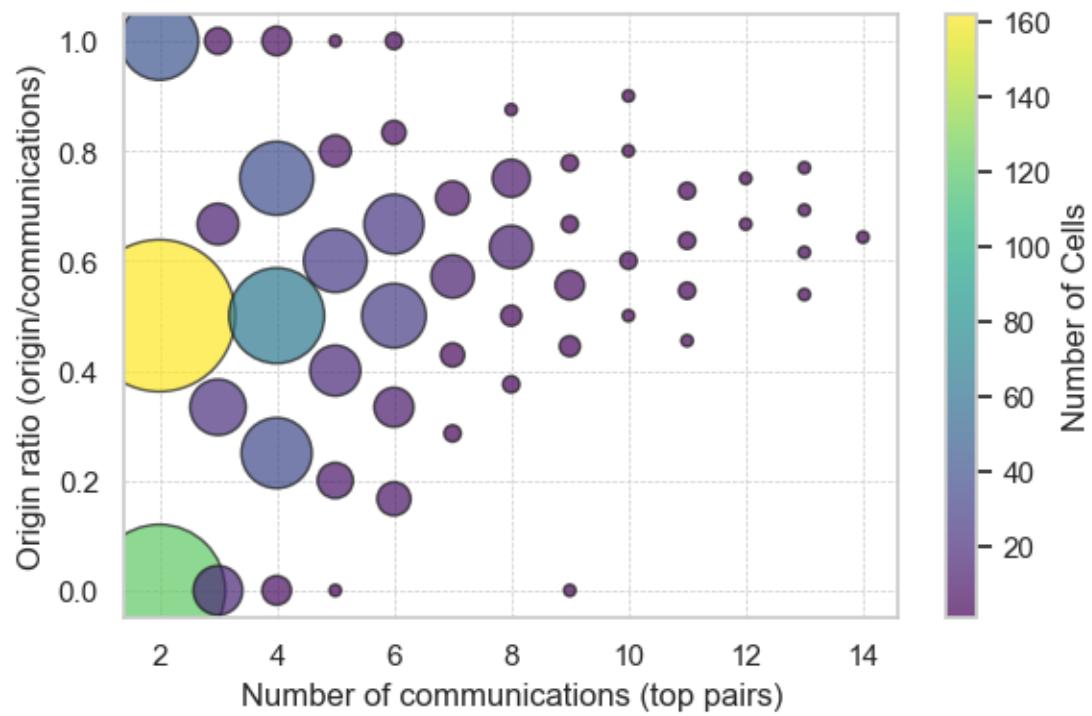
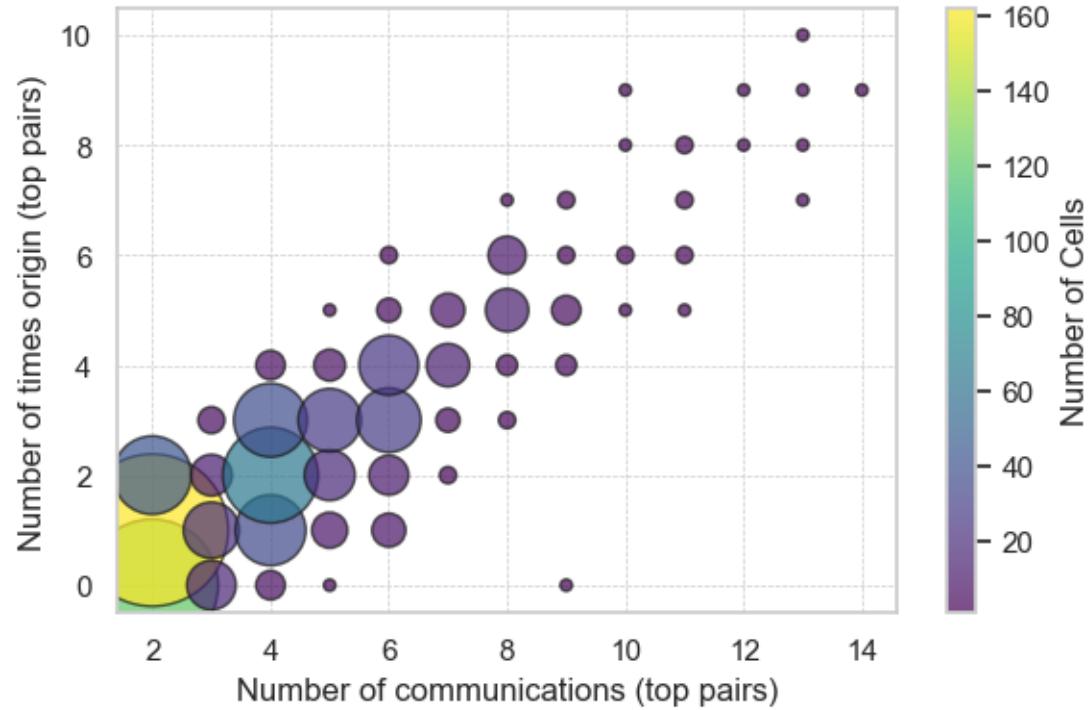


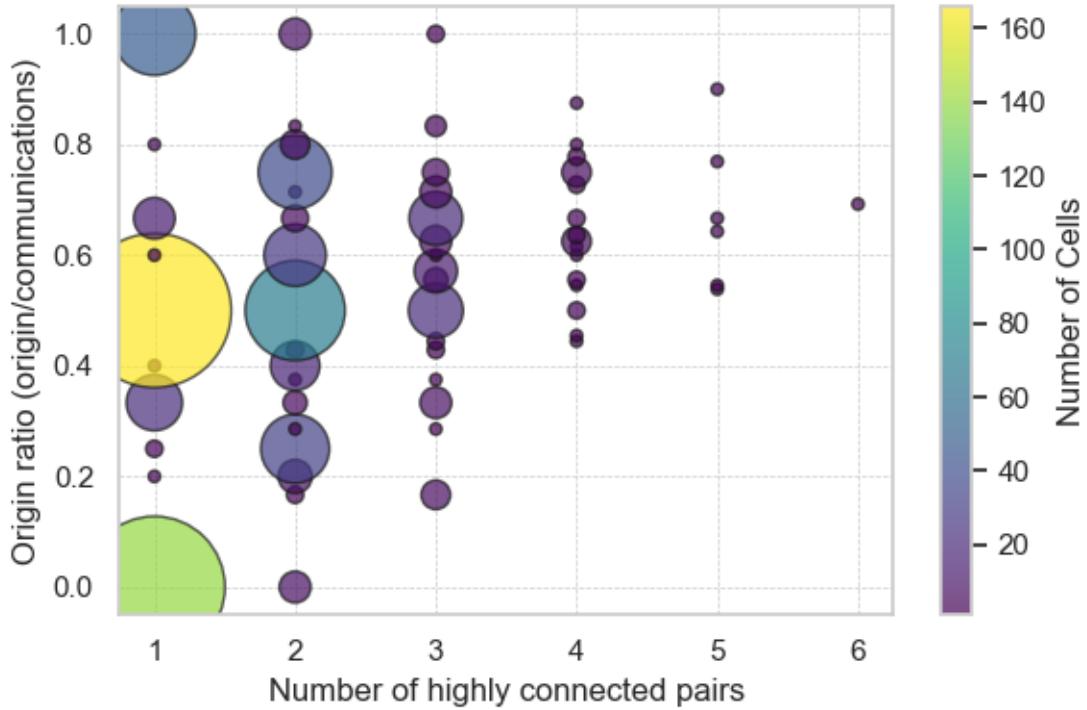
95th percentile threshold: 2.0

Cells involved in multiple pairs highly connected









[2025-08-27 15:01:47] [INFO] calcium: plot_points_mean_std: N=394 for Number of highly connected pairs=1

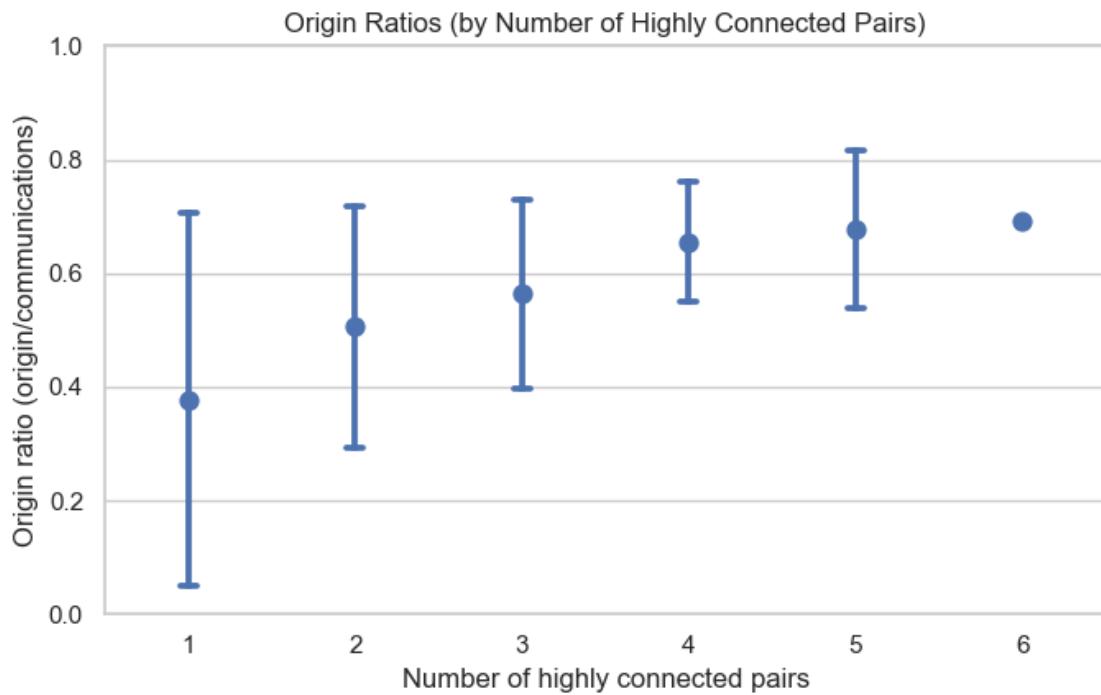
[2025-08-27 15:01:47] [INFO] calcium: plot_points_mean_std: N=230 for Number of highly connected pairs=2

[2025-08-27 15:01:47] [INFO] calcium: plot_points_mean_std: N=102 for Number of highly connected pairs=3

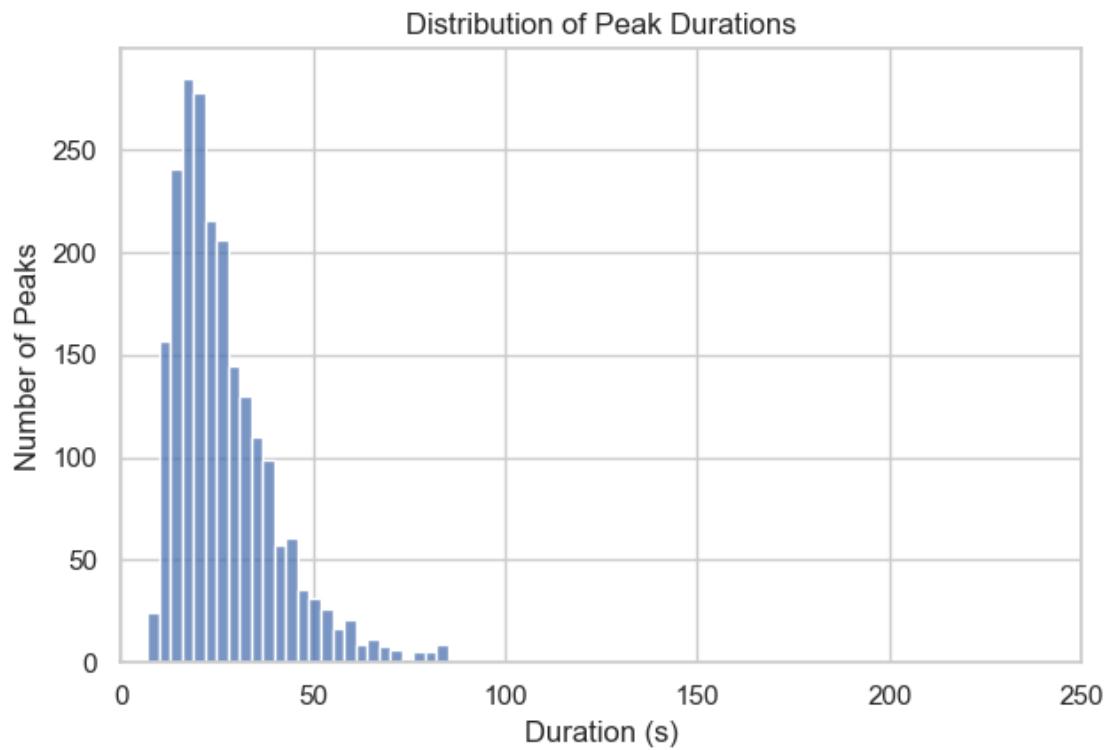
[2025-08-27 15:01:47] [INFO] calcium: plot_points_mean_std: N=31 for Number of highly connected pairs=4

[2025-08-27 15:01:47] [INFO] calcium: plot_points_mean_std: N=6 for Number of highly connected pairs=5

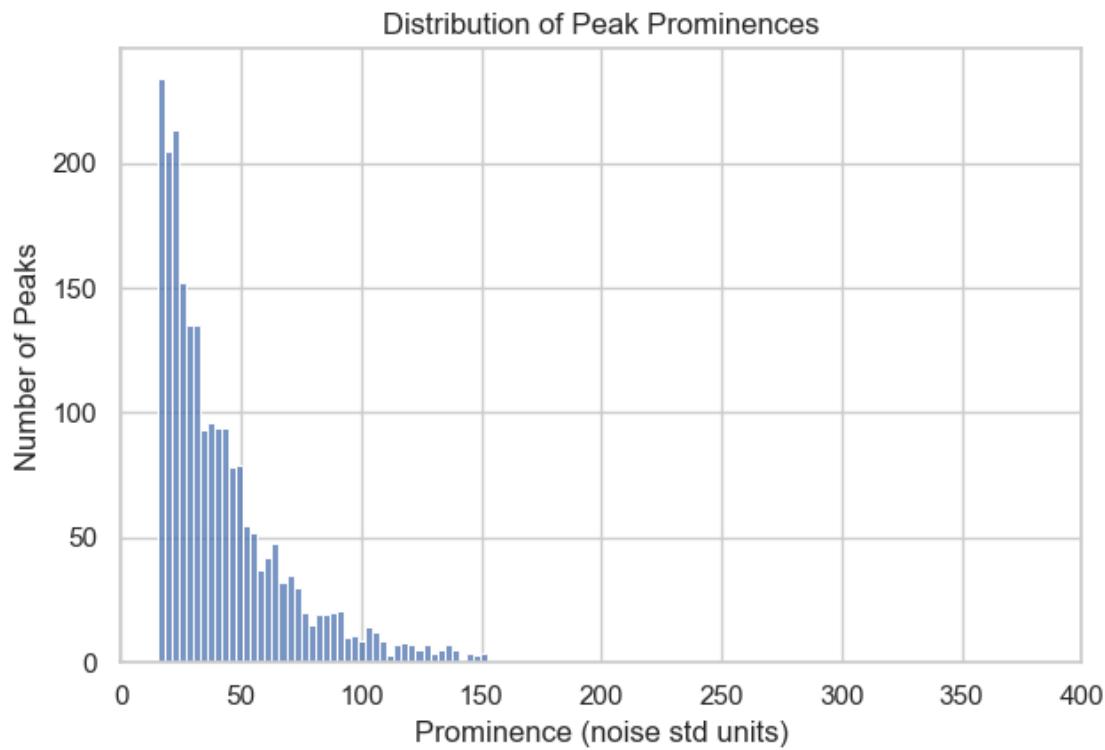
[2025-08-27 15:01:47] [INFO] calcium: plot_points_mean_std: N=1 for Number of highly connected pairs=6

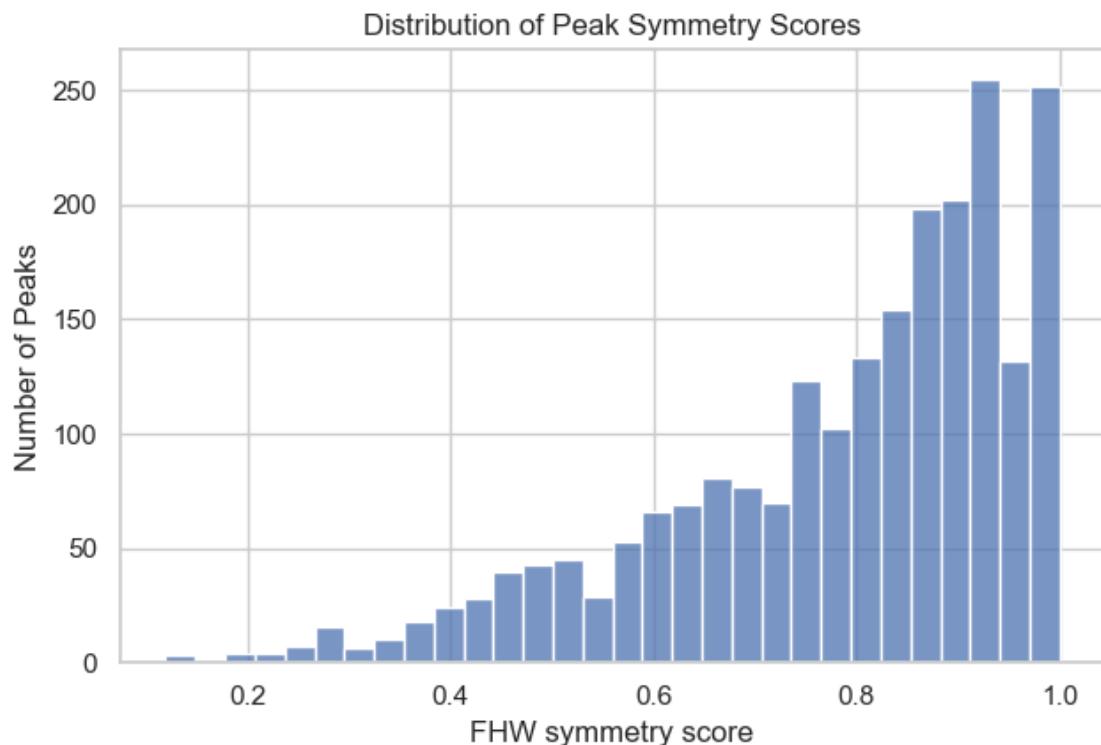


```
[2025-08-27 15:01:48] [INFO] calcium: plot_histogram: removed 49 outliers out of 2244 on 'Duration (s)' (lower=-34, upper=85)
```

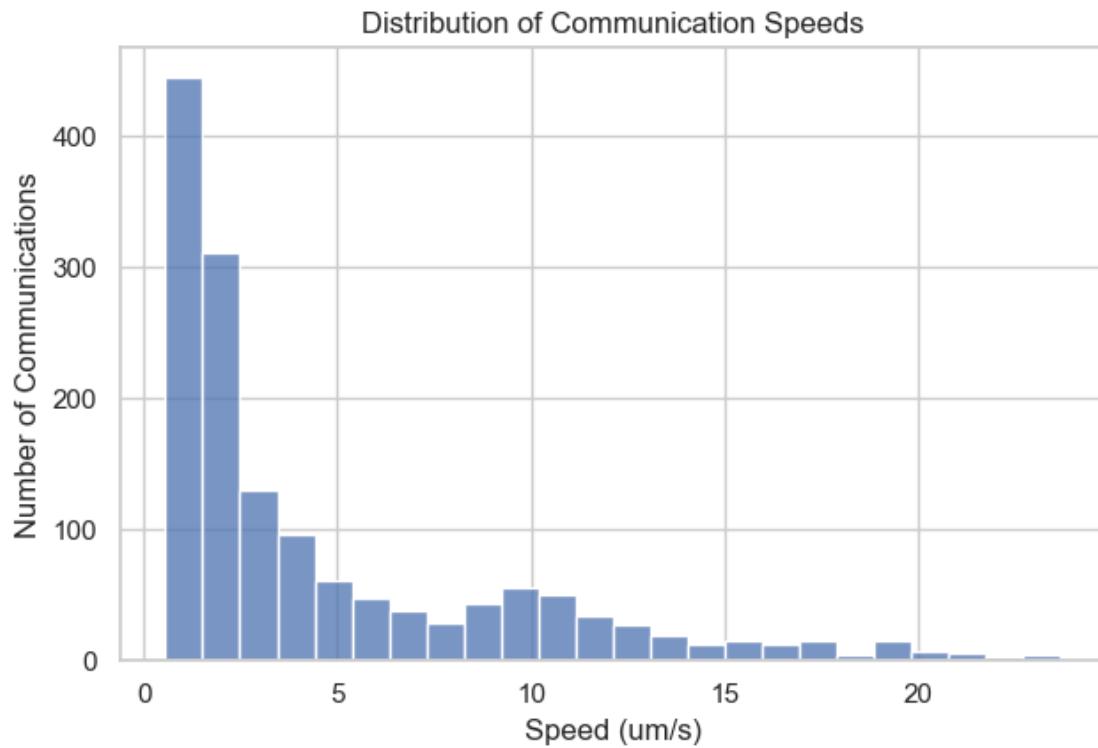


[2025-08-27 15:01:48] [INFO] calcium: plot_histogram: removed 57 outliers out of 2244 on 'Prominence (noise std units)' (lower=-75.85, upper=153.4)

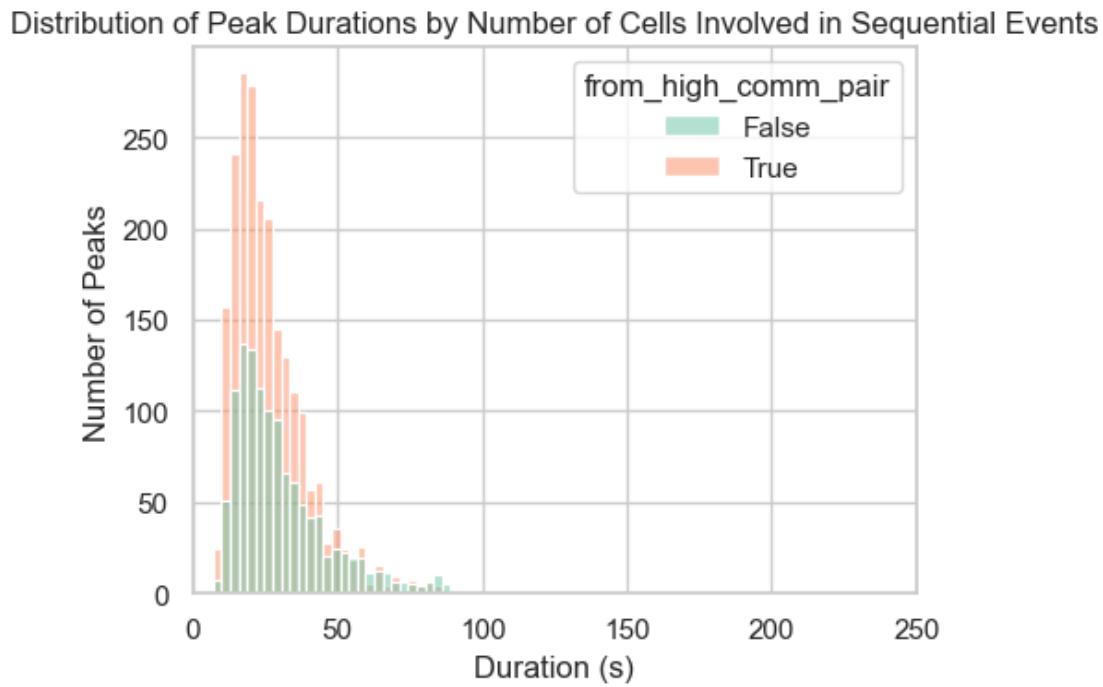




```
[2025-08-27 15:01:48] [INFO] calcium: plot_histogram: removed 6 outliers out of 1488 on 'Speed (um/s)' (lower=-15.355, upper=23.67)
```

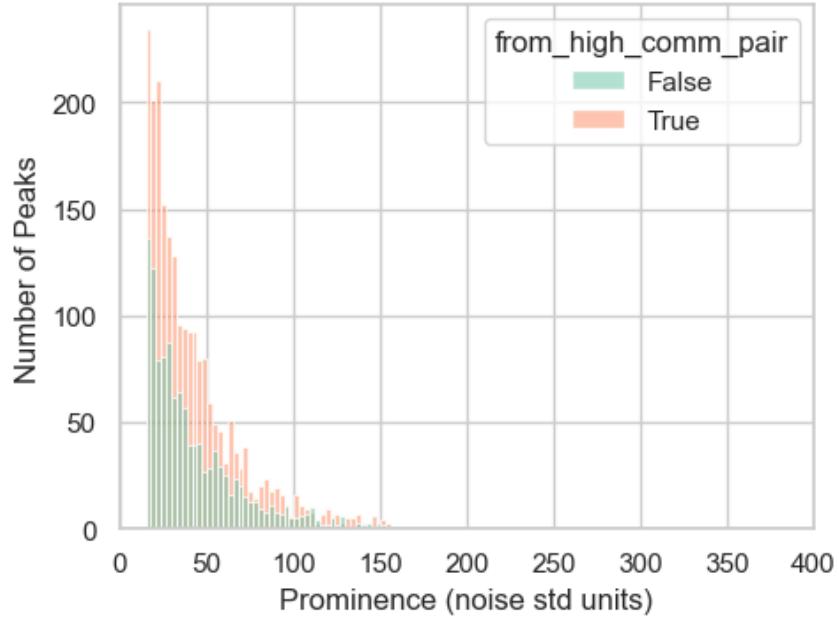


```
[2025-08-27 15:01:48] [INFO] calcium: plot_histogram_by_group: removed 78 outliers out of 3463 on 'Duration (s)' (lower=-37, upper=89)
```

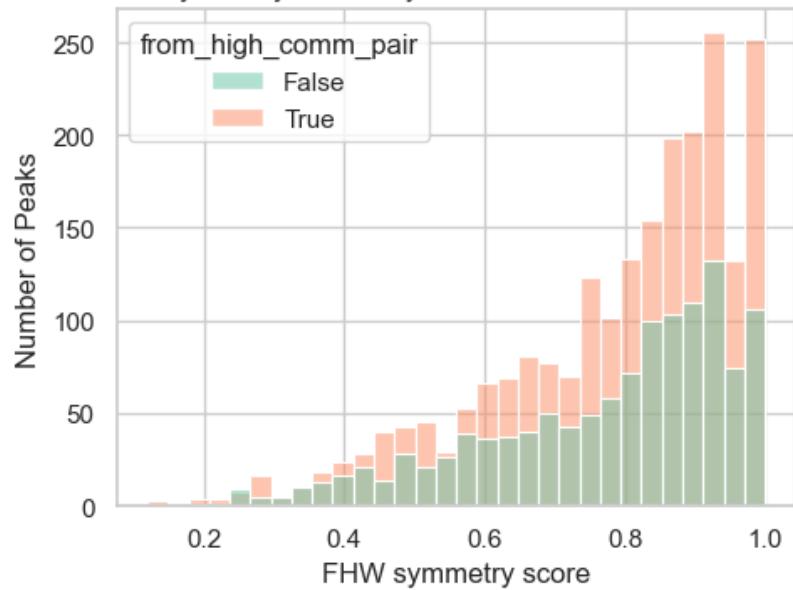


[2025-08-27 15:01:48] [INFO] calcium: plot_histogram_by_group: removed 96 outliers out of 3463 on 'Prominence (noise std units)' (lower=-78.3, upper=156.9)

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

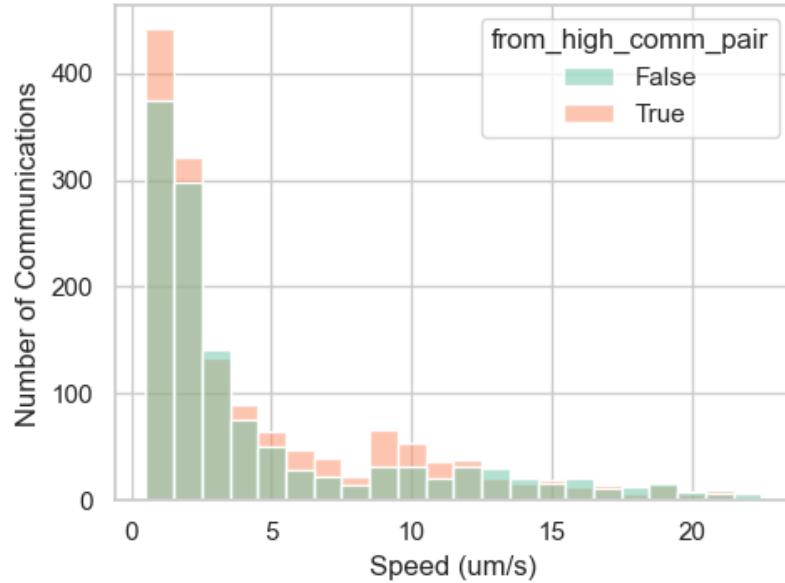


Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



[2025-08-27 15:01:49] [INFO] calcium: plot_histogram_by_group: removed 20 outliers out of 2764 on 'Speed (um/s)' (lower=-14.47, upper=22.56)

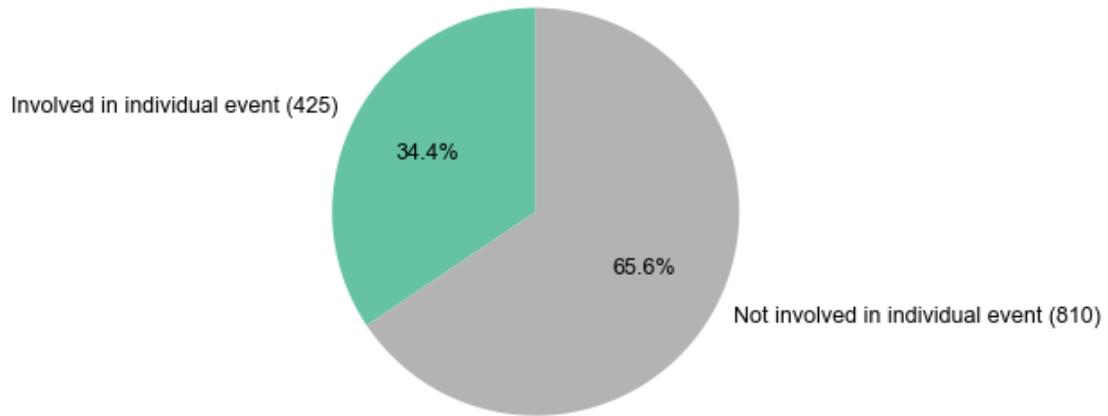
Distribution of Communication Speeds by Number of Cells Involved in Sequential Events



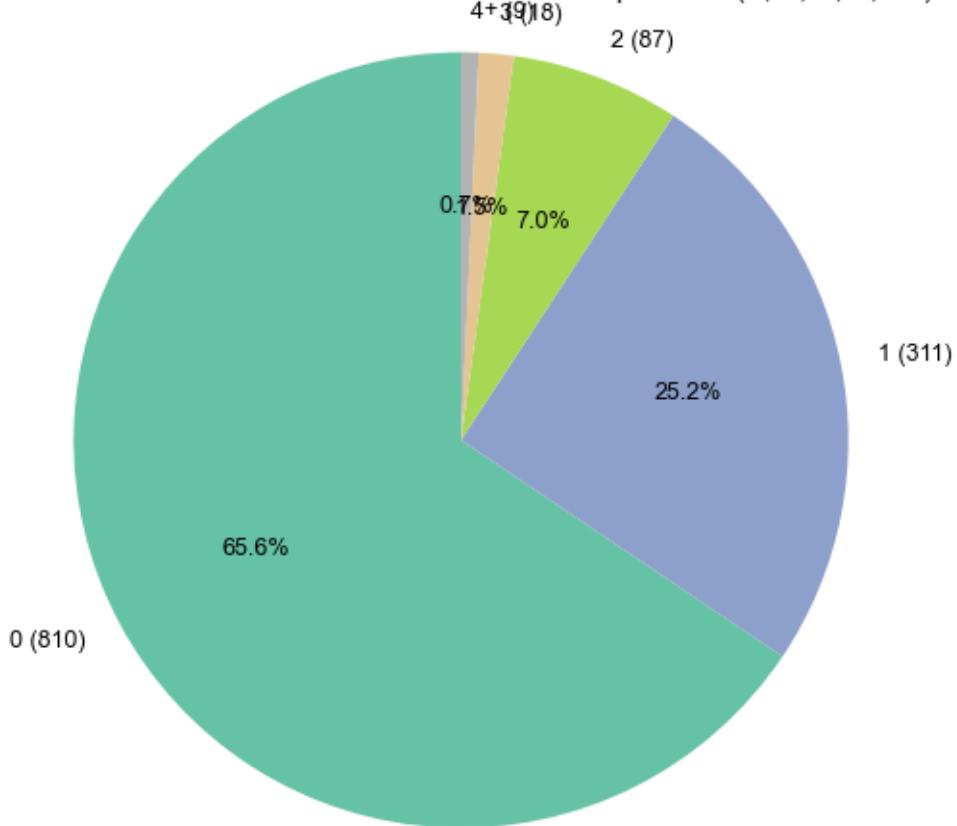
1.4 INDIVIDUAL EVENTS

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+)

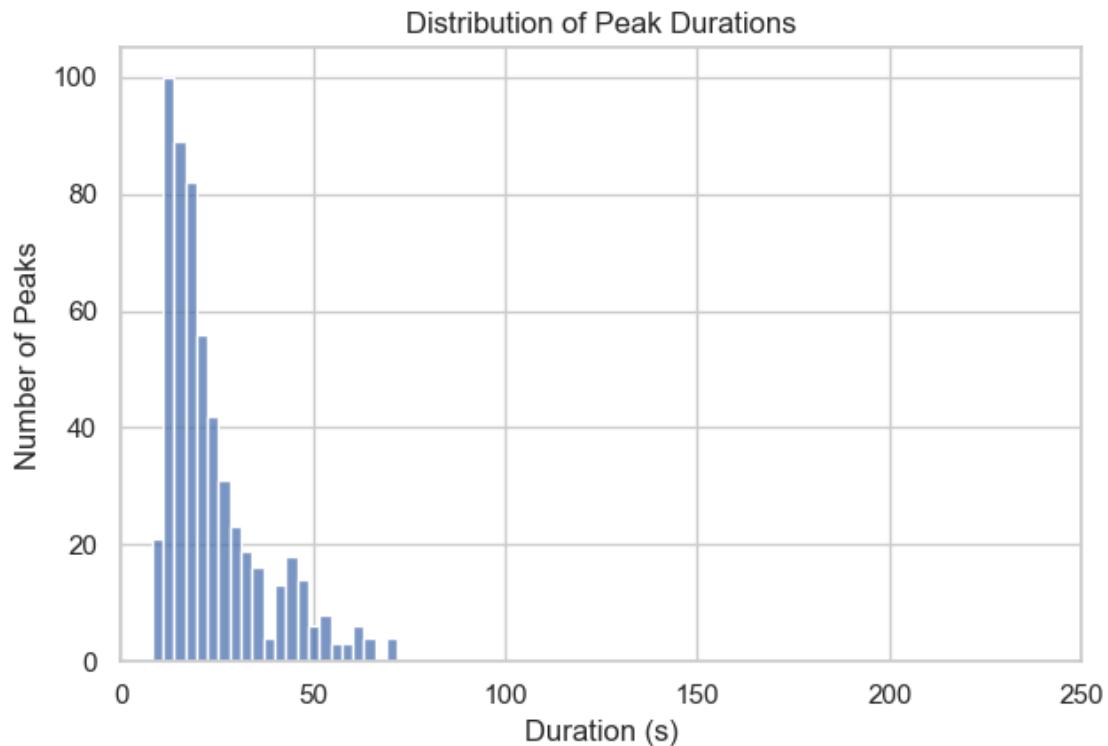


```
[2025-08-27 15:01:49] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS3\cell-
mapping\cell_occurrences_in_individual_events_overlay.png': [Errno 2] No such
file or directory: 'D:\\Mateo\\20250618\\Output\\IS3\\cell-
mapping\\cell_occurrences_in_individual_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundException: [Errno 2] No such file or directory:
```

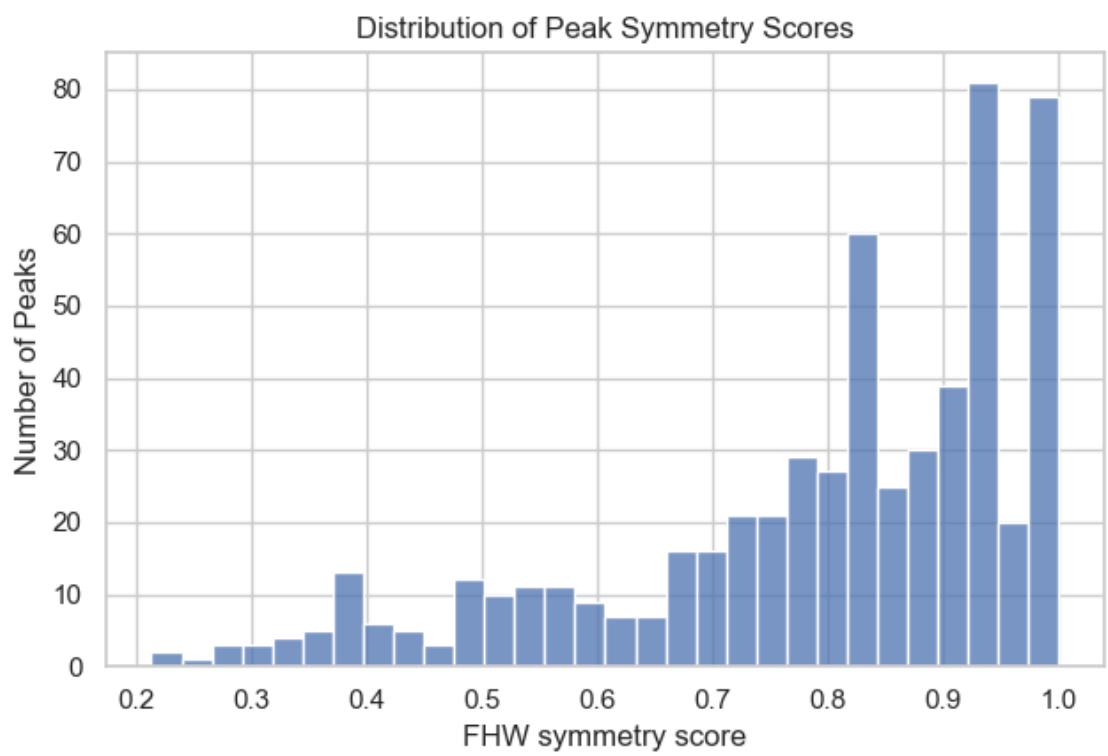
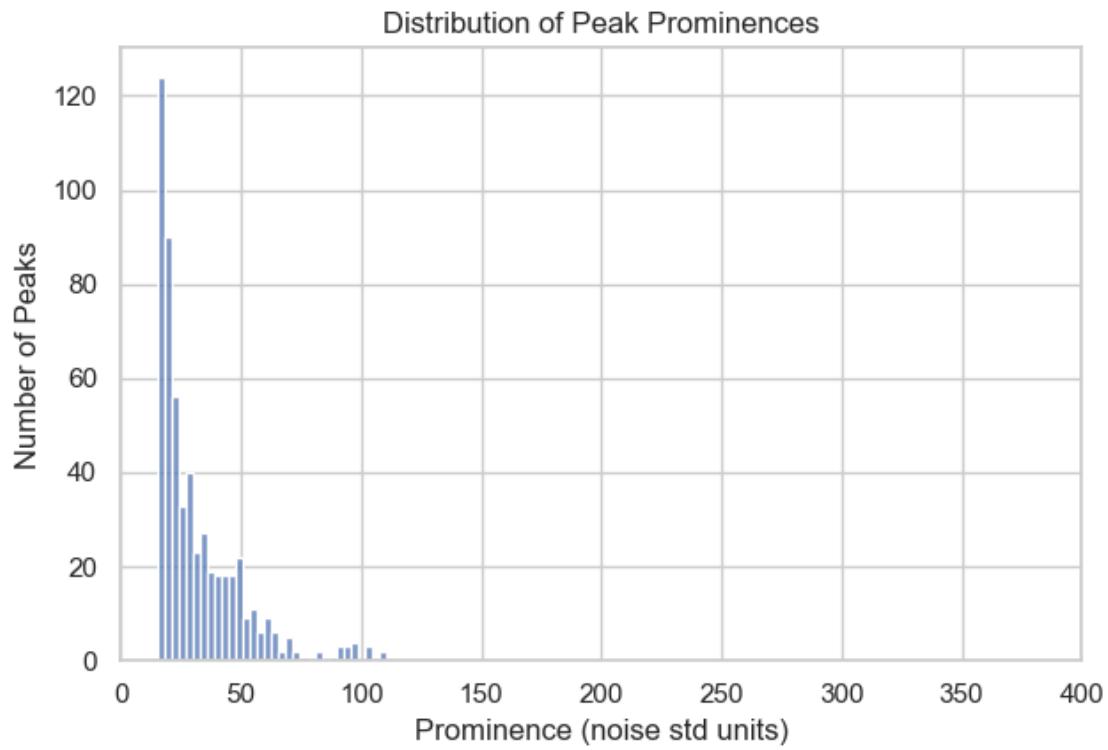
'D:\\Mateo\\20250618\\Output\\IS3\\cell-mapping\\cell_occurrences_in_individual_events_overlay.png'

1.4.2 Peaks statistics in individual events

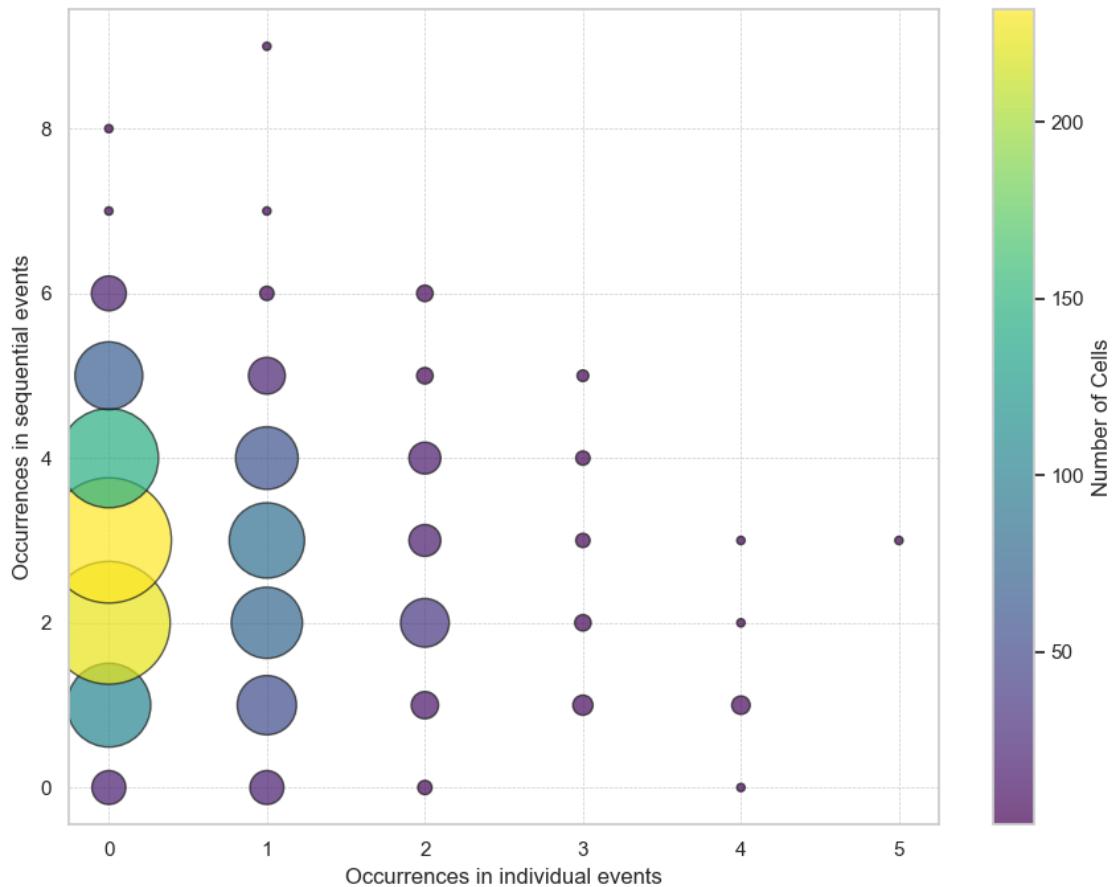
[2025-08-27 15:01:49] [INFO] calcium: plot_histogram: removed 14 outliers out of 576 on 'Duration (s)' (lower=-31, upper=74)



[2025-08-27 15:01:49] [INFO] calcium: plot_histogram: removed 19 outliers out of 576 on 'Prominence (noise std units)' (lower=-52.075, upper=112.77)



1.4.3 Correlation between event activity level & individual activity level



```
[2025-08-27 15:01:50] [INFO] calcium: plot_points_mean_std: removed 0/1235 outliers on 'Occurrences in sequential events' (lower=-4, upper=10)
```

```
[2025-08-27 15:01:50] [INFO] calcium: plot_points_mean_std: N=810 for Occurrences in individual events=0
```

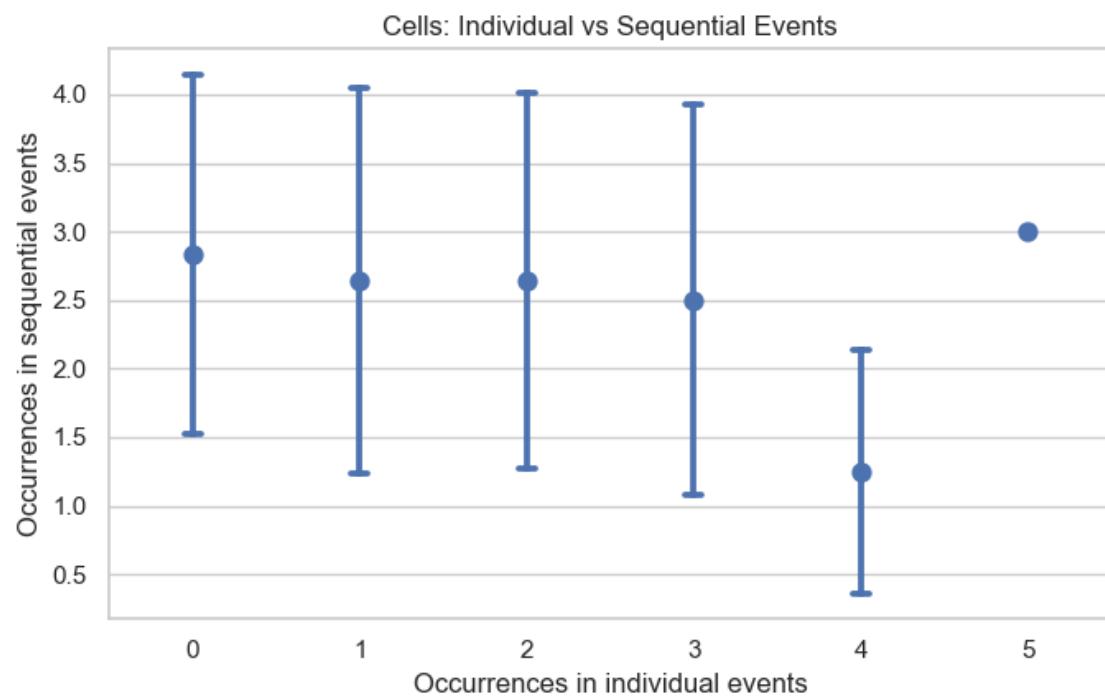
```
[2025-08-27 15:01:50] [INFO] calcium: plot_points_mean_std: N=311 for Occurrences in individual events=1
```

```
[2025-08-27 15:01:50] [INFO] calcium: plot_points_mean_std: N=87 for Occurrences in individual events=2
```

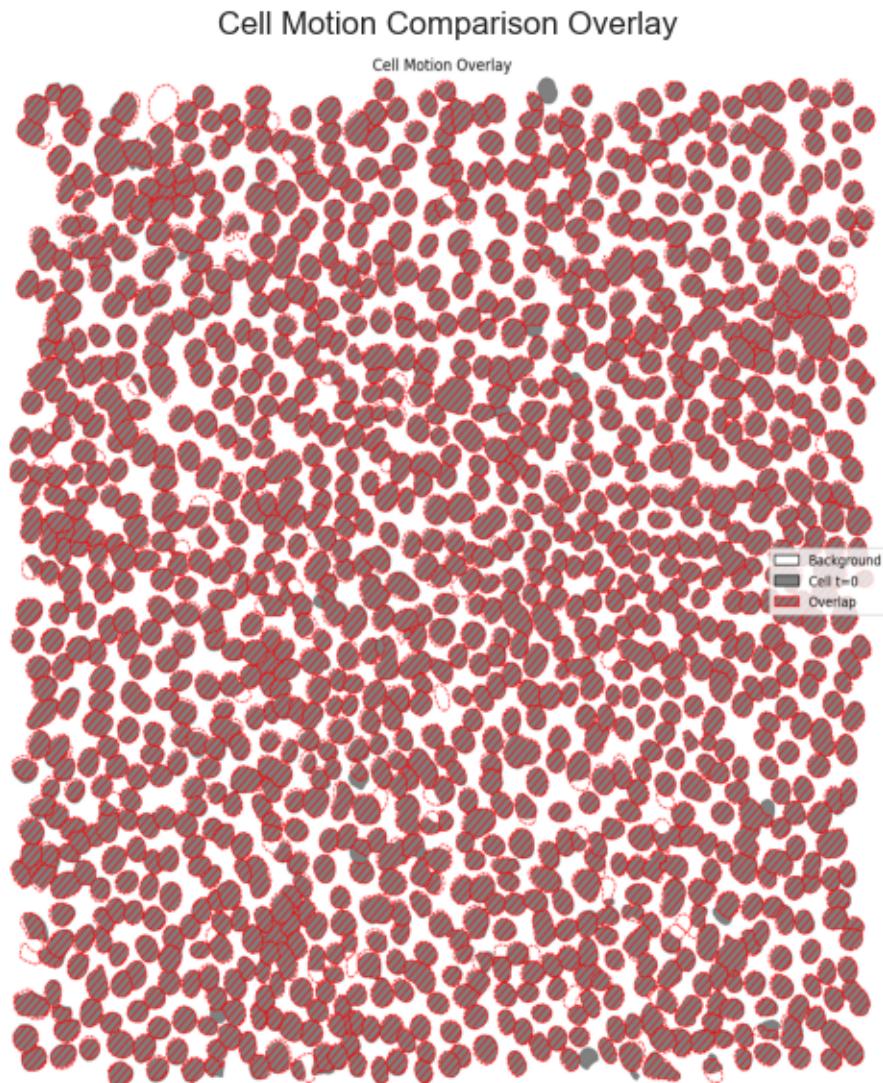
```
[2025-08-27 15:01:50] [INFO] calcium: plot_points_mean_std: N=18 for Occurrences in individual events=3
```

```
[2025-08-27 15:01:50] [INFO] calcium: plot_points_mean_std: N=8 for Occurrences in individual events=4
```

[2025-08-27 15:01:50] [INFO] calcium: plot_points_mean_std: N=1 for Occurrences in individual events=5



1.5 CELLS MOTION



Number of cells:

- Hoechst image taken at t=0: 1235
- Hoechst image taken at t=1801: 1225
- Number of cells difference: absolute 10, relative 0.81%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1303848
- Pixels segmented as cell at t=1801: 1341866
- Overlapping pixels between t=0 and t=1801: 1231473 (93.09% of total)
- Pixels exclusive to t=0: 72375 (5.55% of total)
- Pixels exclusive to t=1801: 110393 (8.23% of total)

executed

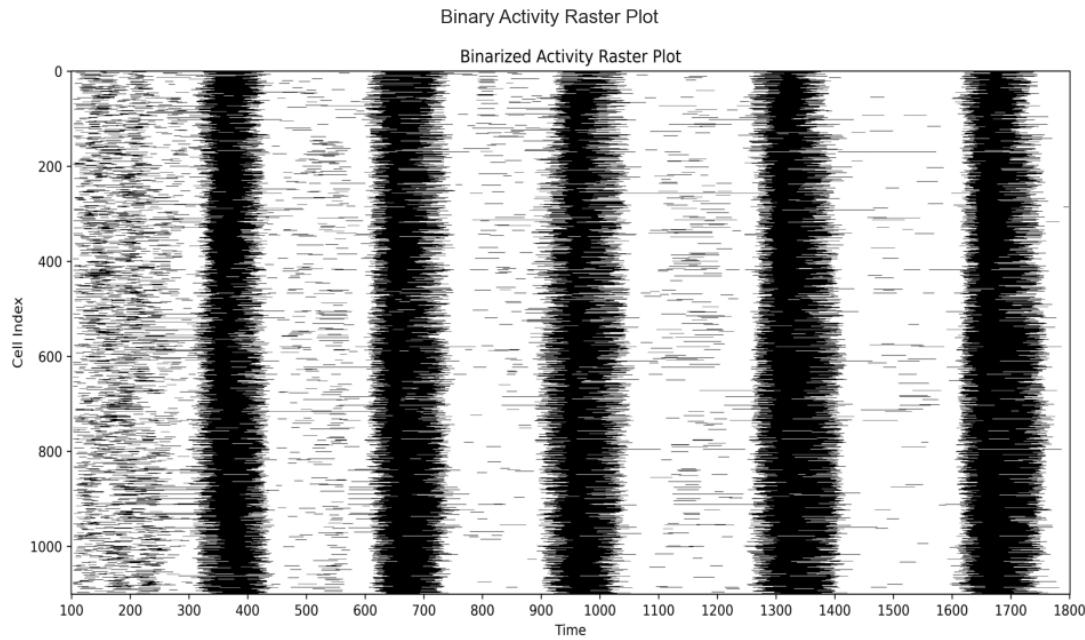
August 27, 2025

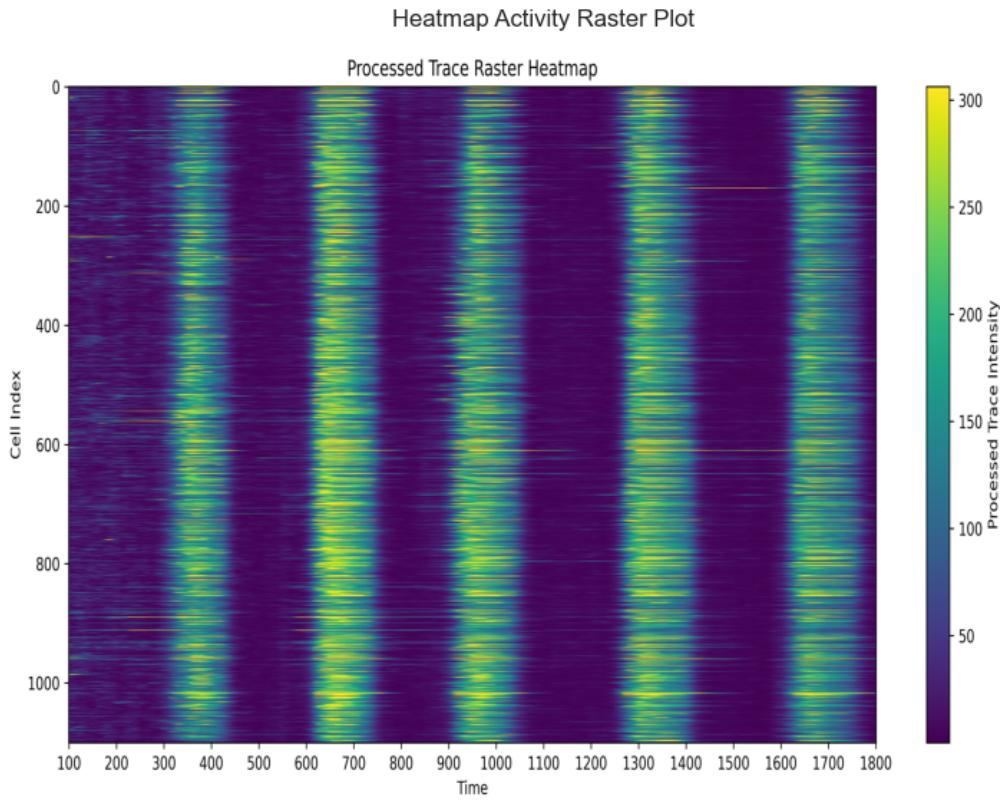
1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

1.0.1 Initialization

1.1 POPULATION

1.1.1 Binary & Heatmap Raster Plot





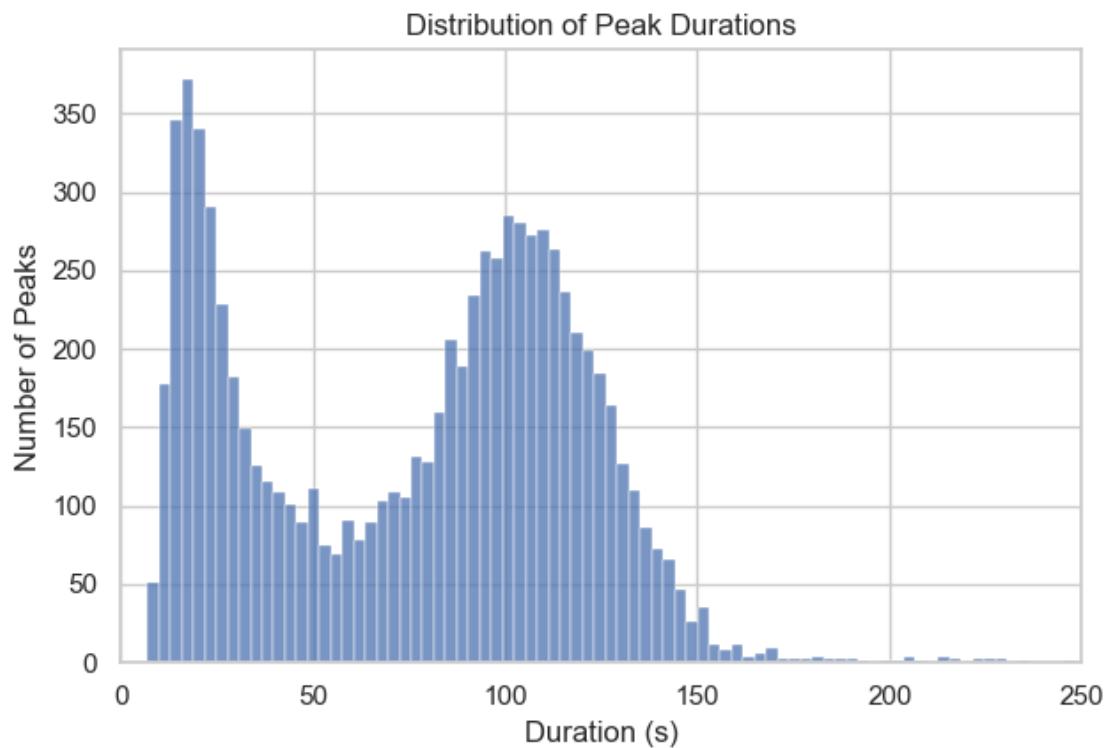
1.1.2 Peaks population

Total number of peaks: 8108

Total number of cells: 1101

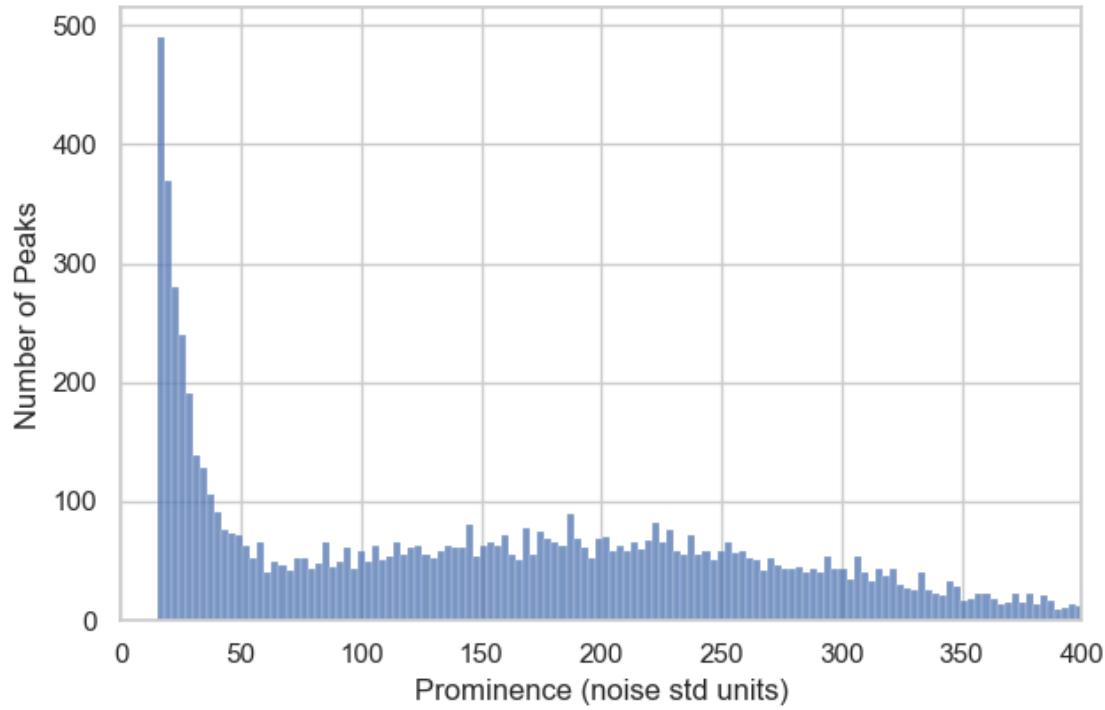
1.1.3 Peaks statistics

```
[2025-08-27 15:02:17] [INFO] calcium: plot_histogram: removed 2 outliers out of  
8108 on 'Duration (s)' (lower=-206, upper=347)
```

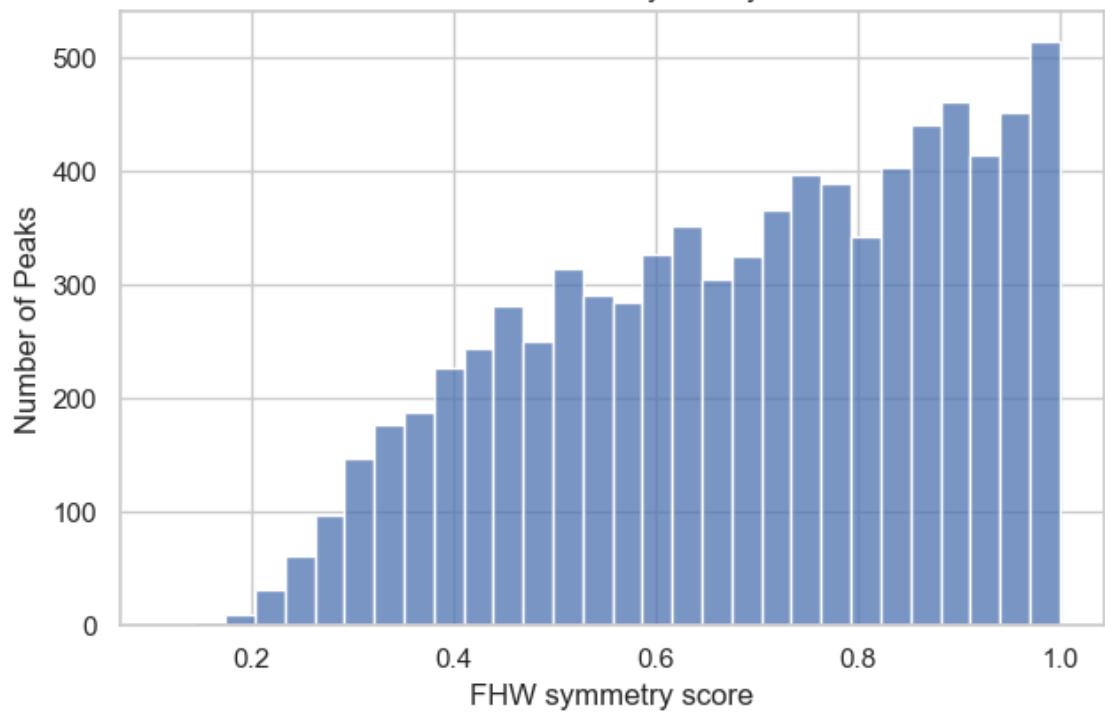


```
[2025-08-27 15:02:17] [INFO] calcium: plot_histogram: removed 0 outliers out of  
8108 on 'Prominence (noise std units)' (lower=-557.7, upper=840.9)
```

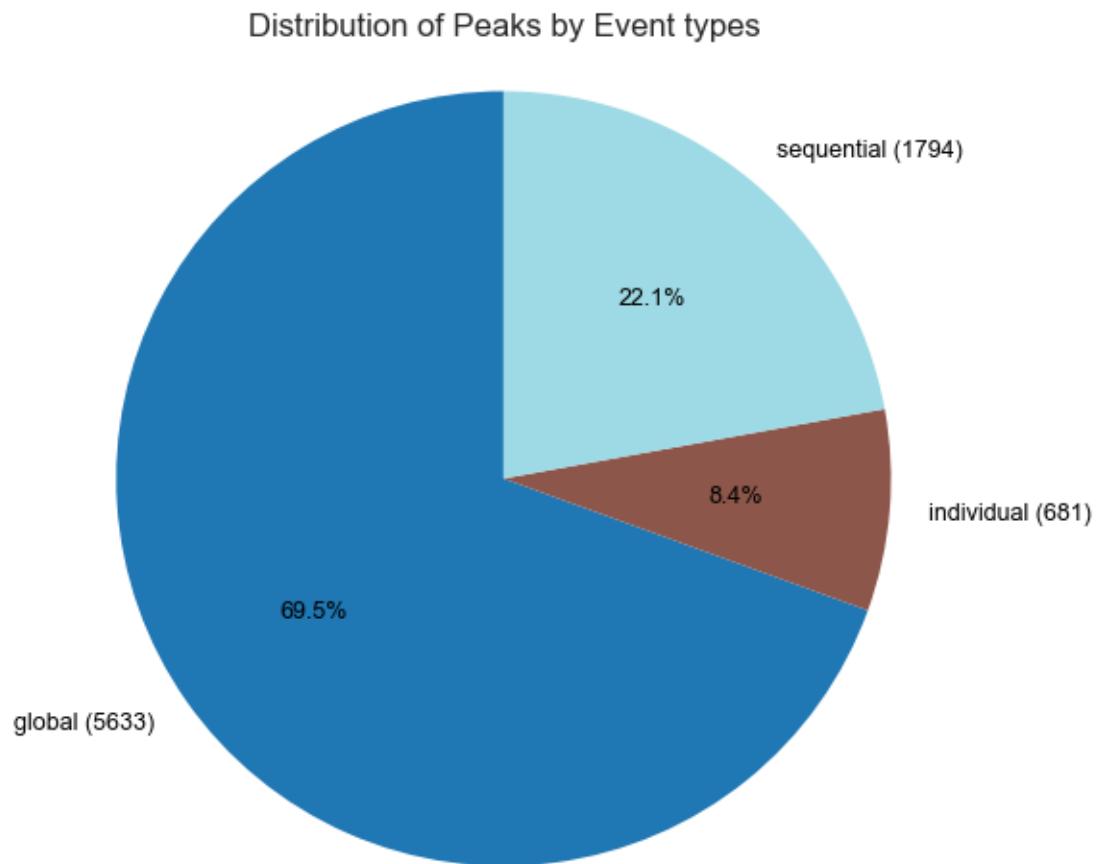
Distribution of Peak Prominences



Distribution of Peak Symmetry Scores

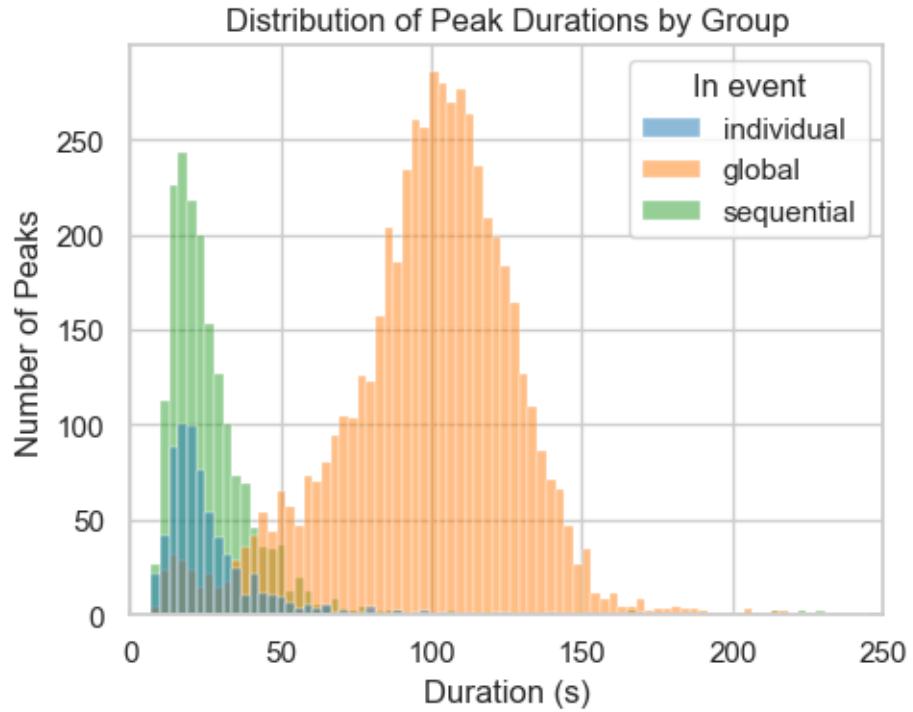


1.1.4 Distribution of peaks per event types

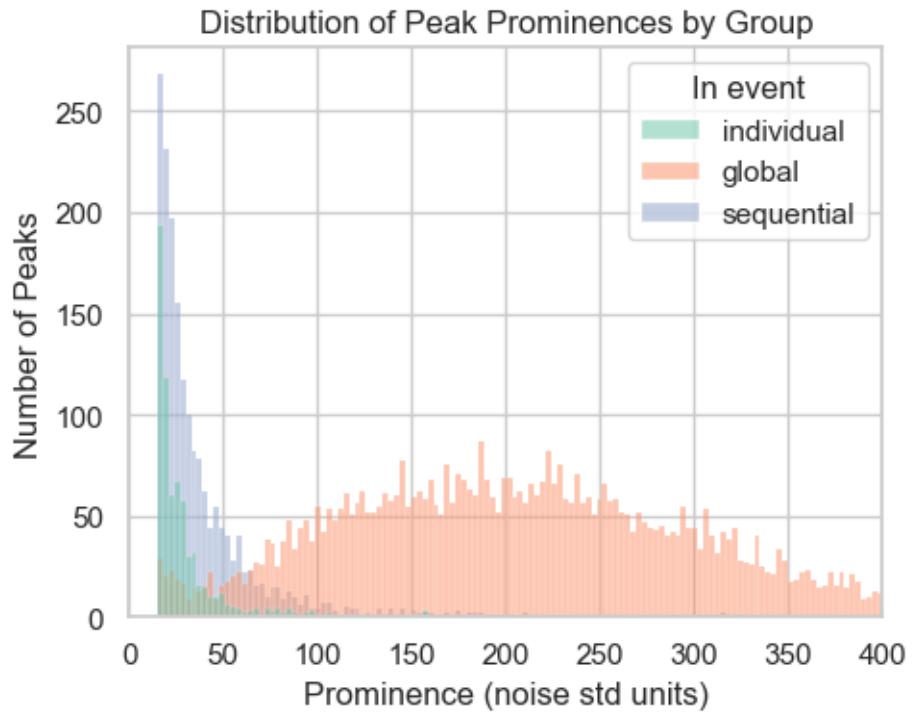


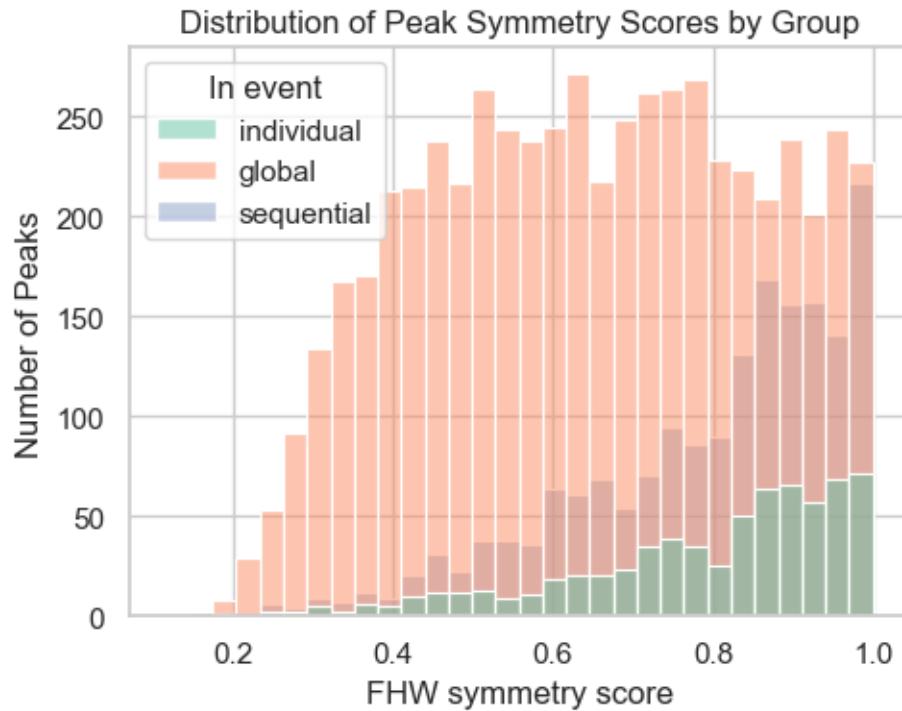
1.1.5 Peaks statistics per event types

```
[2025-08-27 15:02:17] [INFO] calcium: plot_histogram_by_group: removed 2 outliers out of 8108 on 'Duration (s)' (lower=-206, upper=347)
```



```
[2025-08-27 15:02:18] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 8108 on 'Prominence (noise std units)' (lower=-557.7, upper=840.9)
```

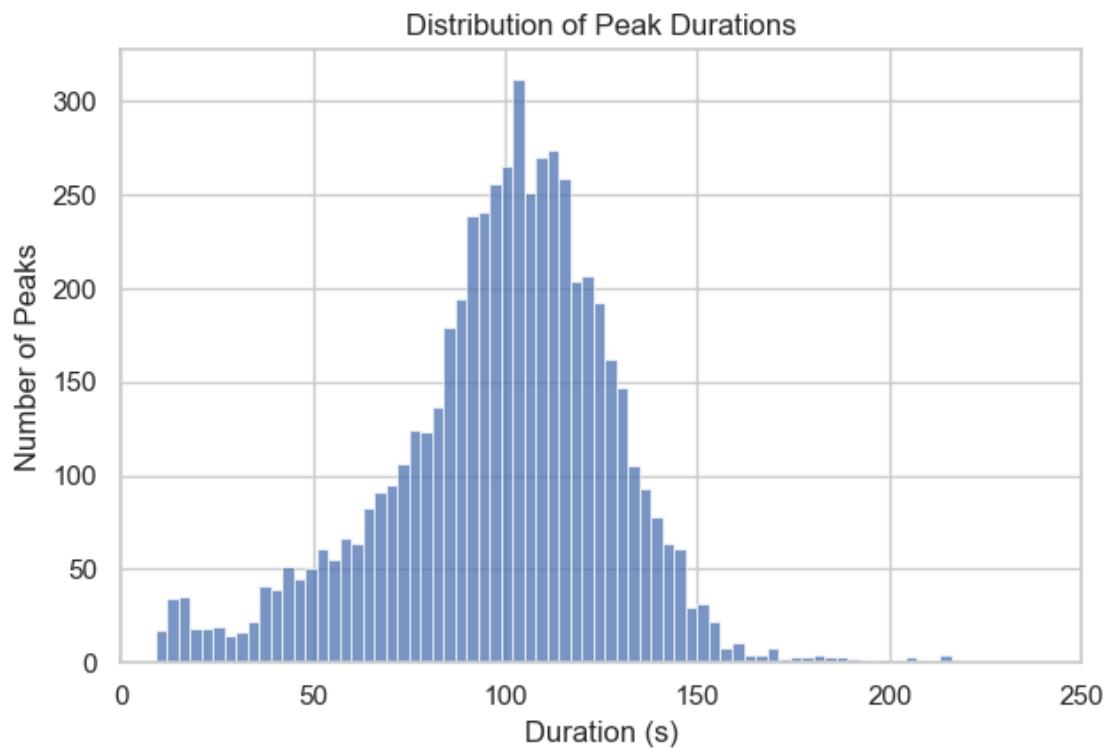




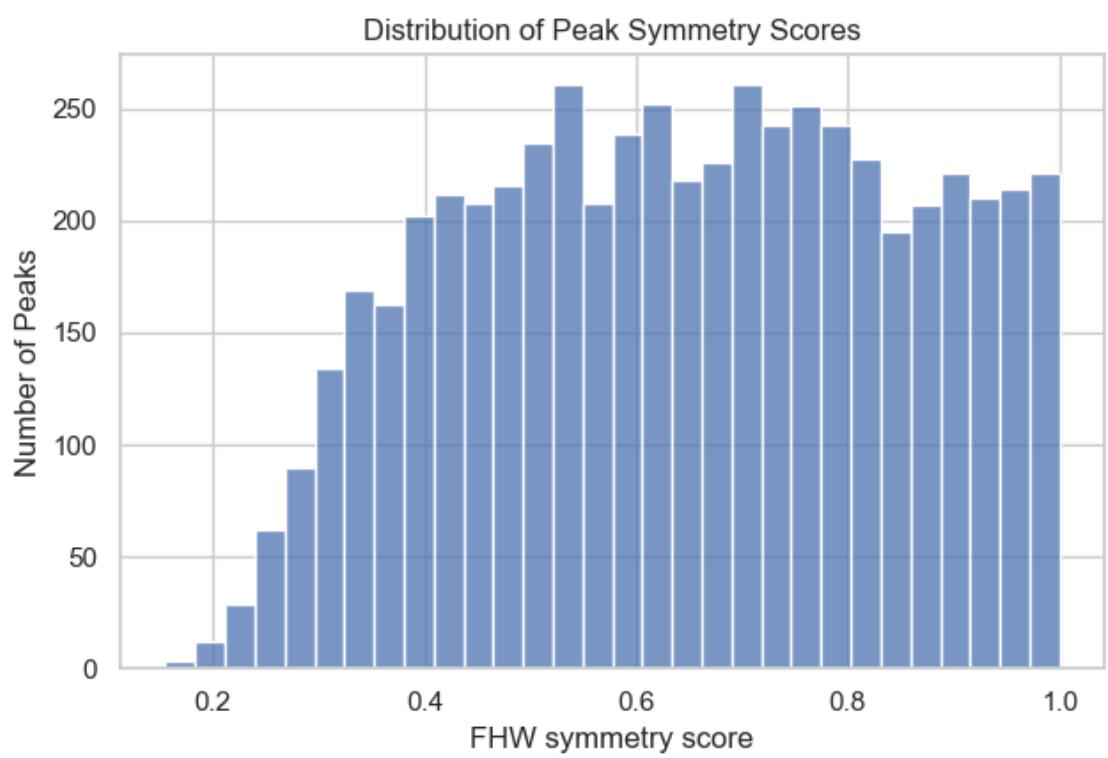
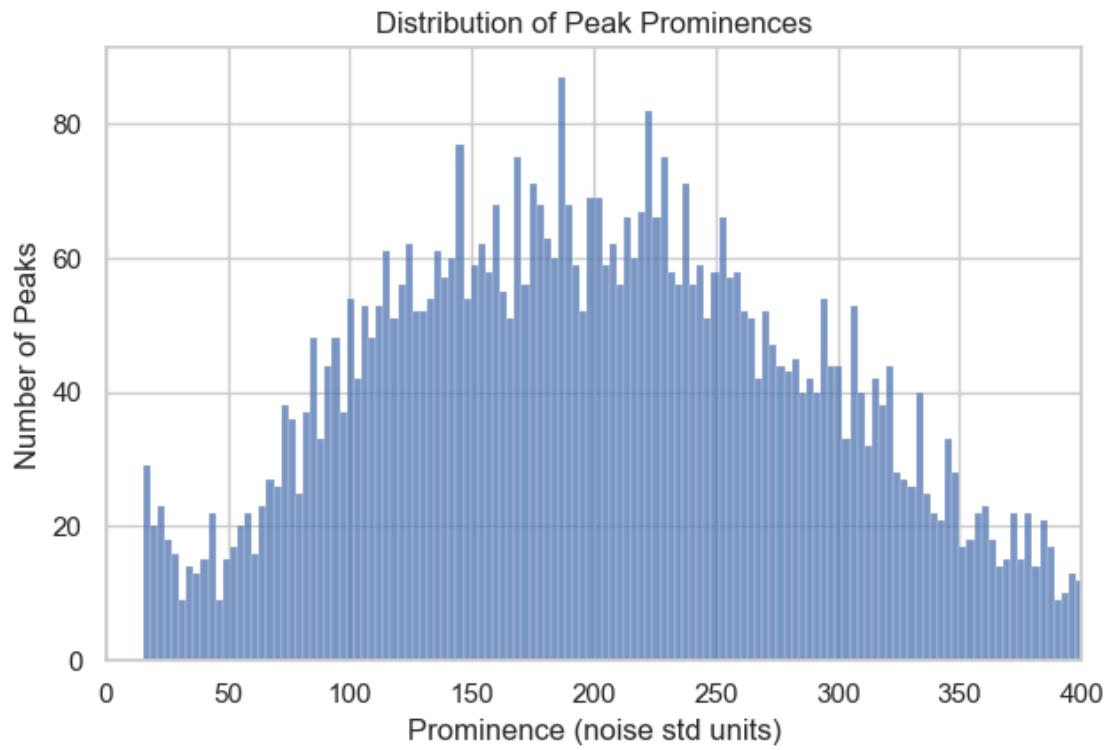
1.2 GLOBAL EVENTS

1.2.1 Peak statistics in global events

```
[2025-08-27 15:02:19] [INFO] calcium: plot_histogram: removed 7 outliers out of 5633 on 'Duration (s)' (lower=-19, upper=219)
```

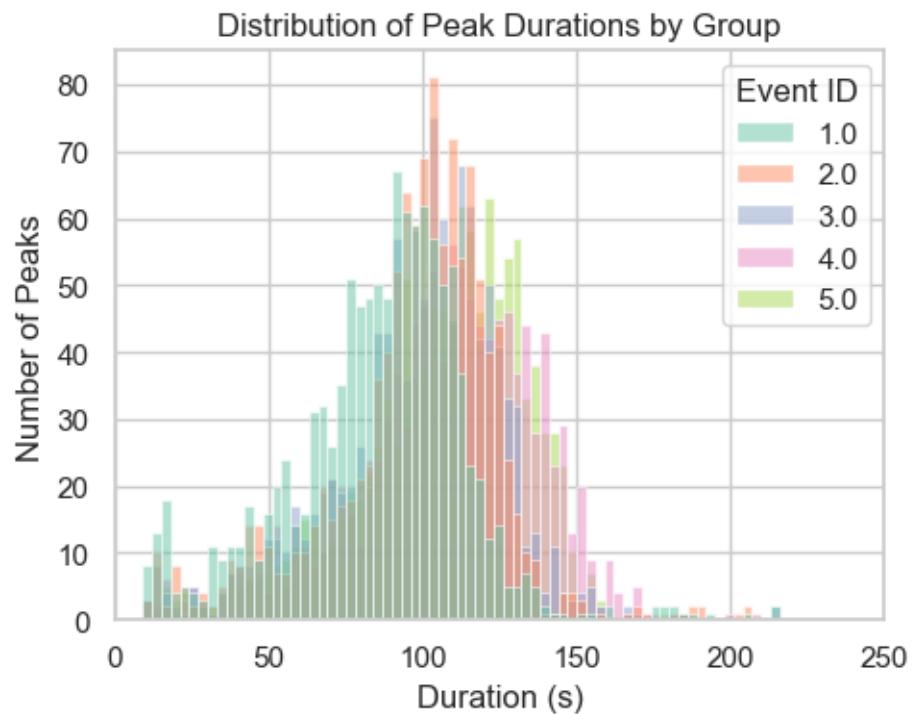


```
[2025-08-27 15:02:19] [INFO] calcium: plot_histogram: removed 0 outliers out of 5633 on 'Prominence (noise std units)' (lower=-273.9, upper=687.2)
```

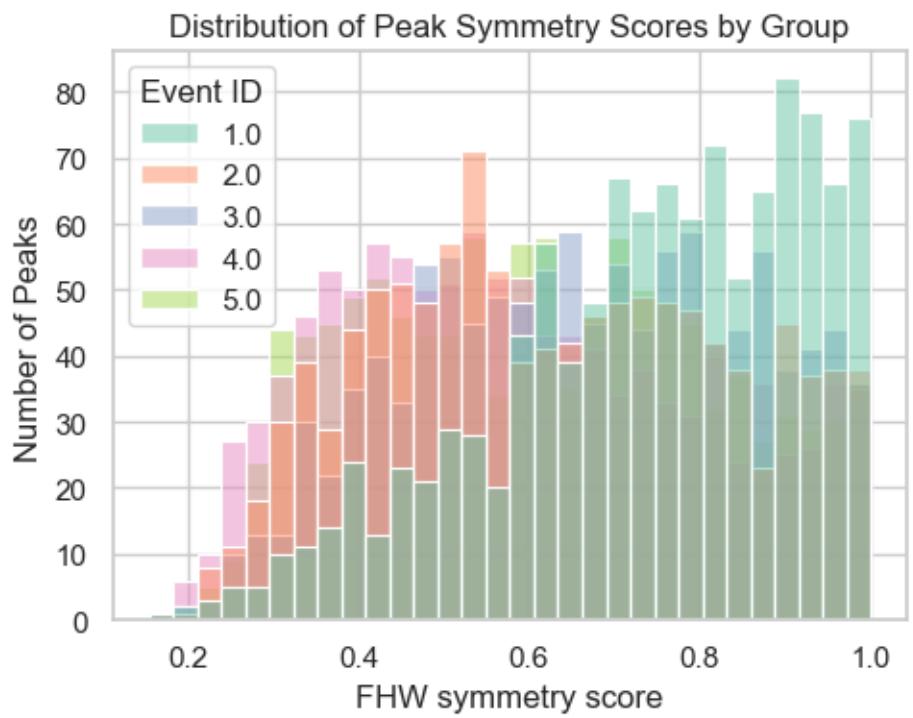
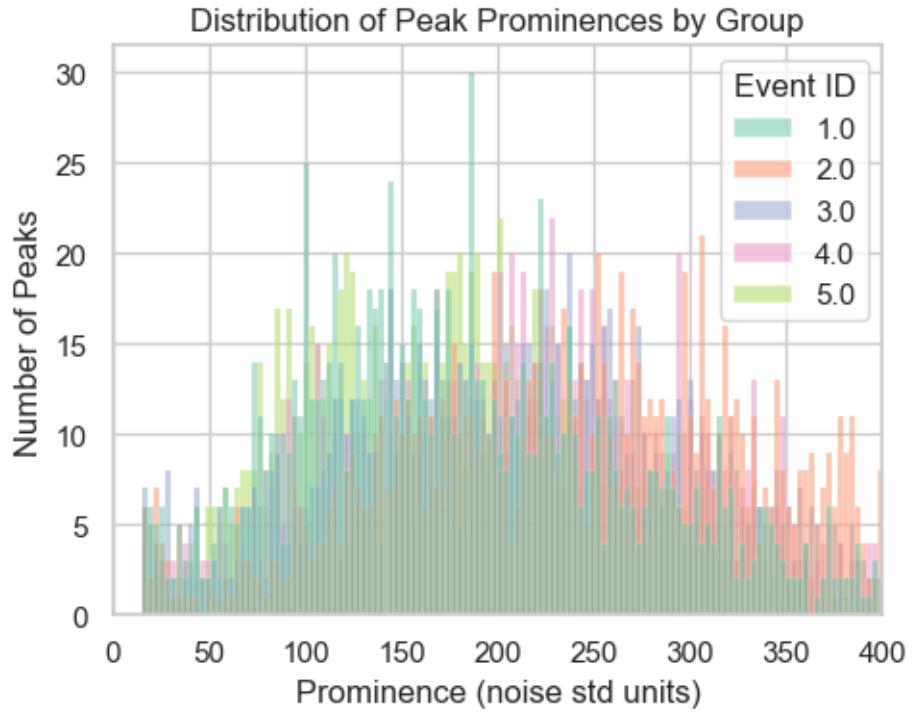


1.2.2 Peak statistics in global event per event ID

[2025-08-27 15:02:19] [INFO] calcium: plot_histogram_by_group: removed 7 outliers out of 5633 on 'Duration (s)' (lower=-19, upper=219)

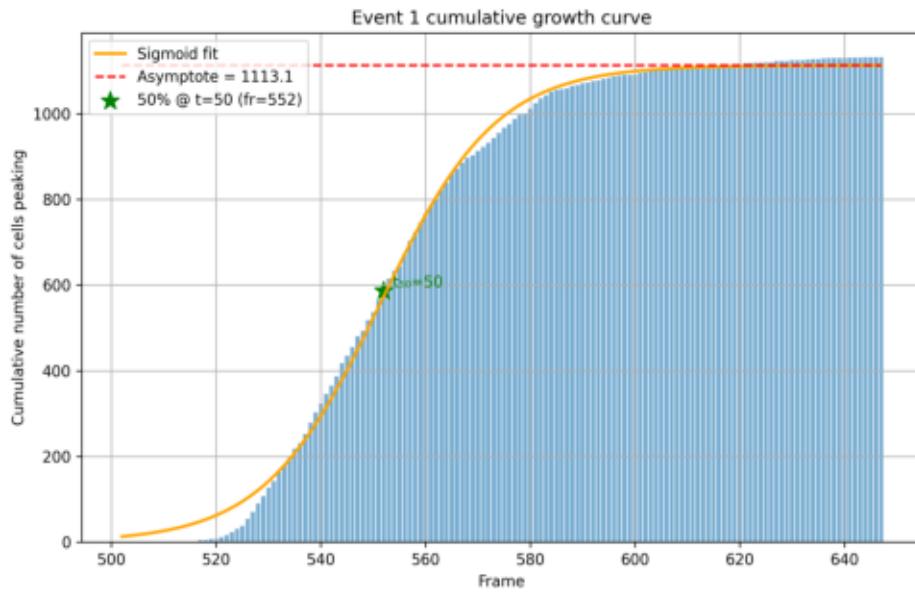


[2025-08-27 15:02:20] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 5633 on 'Prominence (noise std units)' (lower=-273.9, upper=687.2)

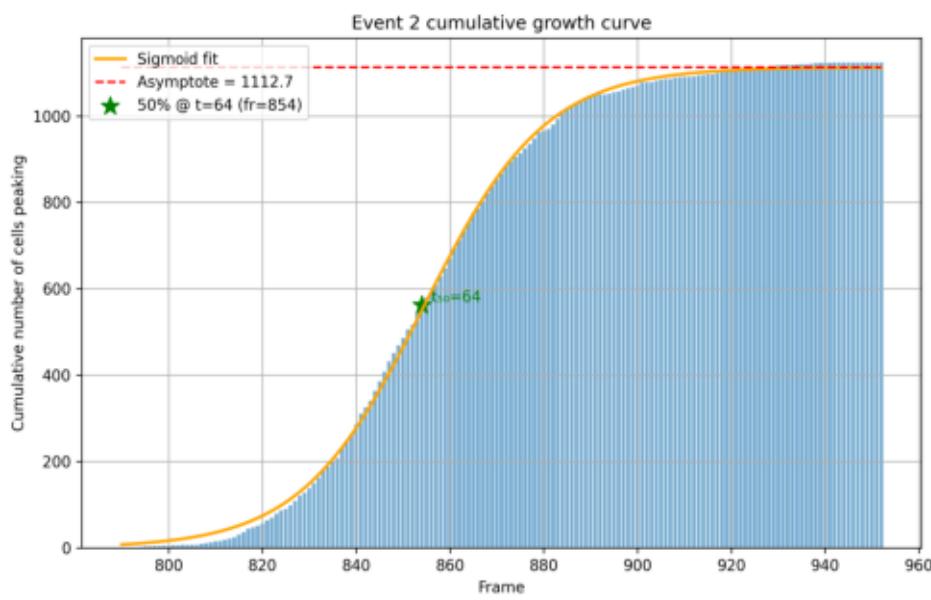


1.2.3 Kinetics of global events

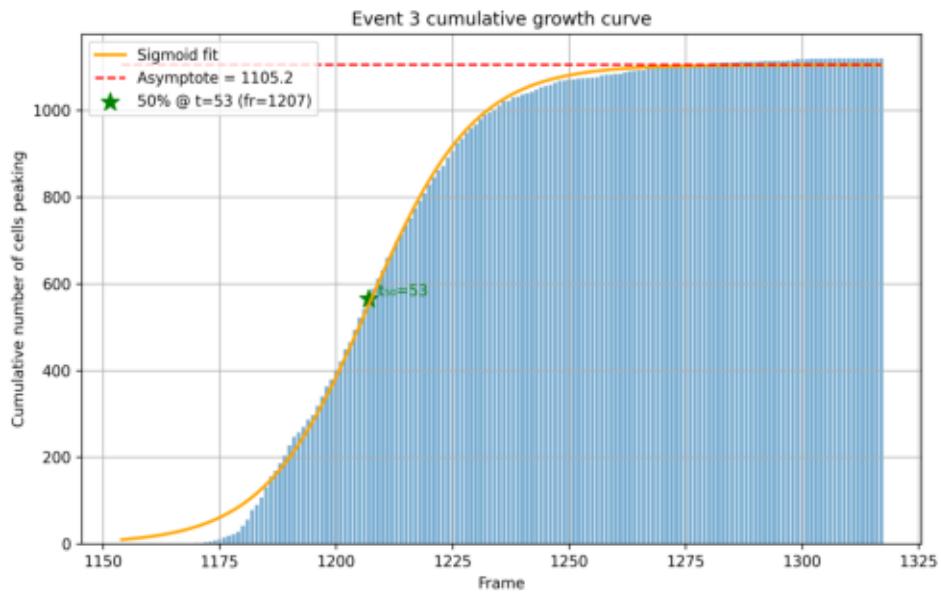
Event Activity Overlay (Event ID: 1)



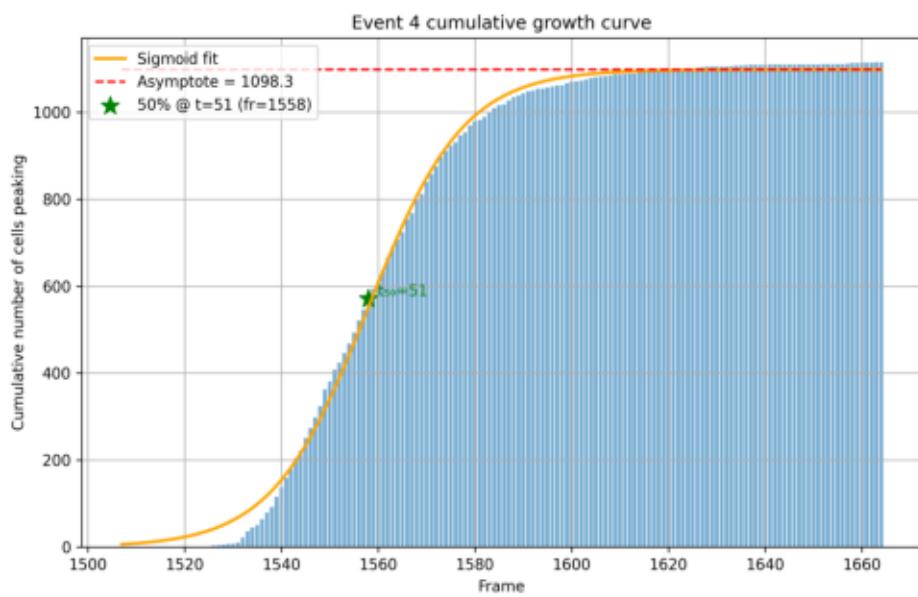
Event Activity Overlay (Event ID: 2)



Event Activity Overlay (Event ID: 3)



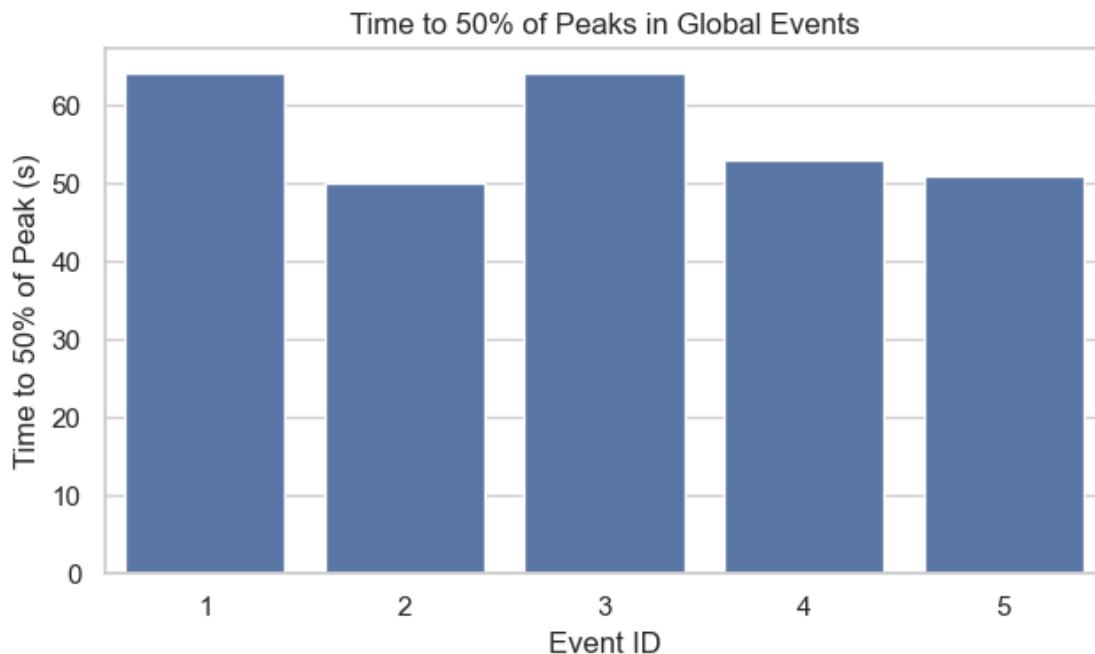
Event Activity Overlay (Event ID: 4)



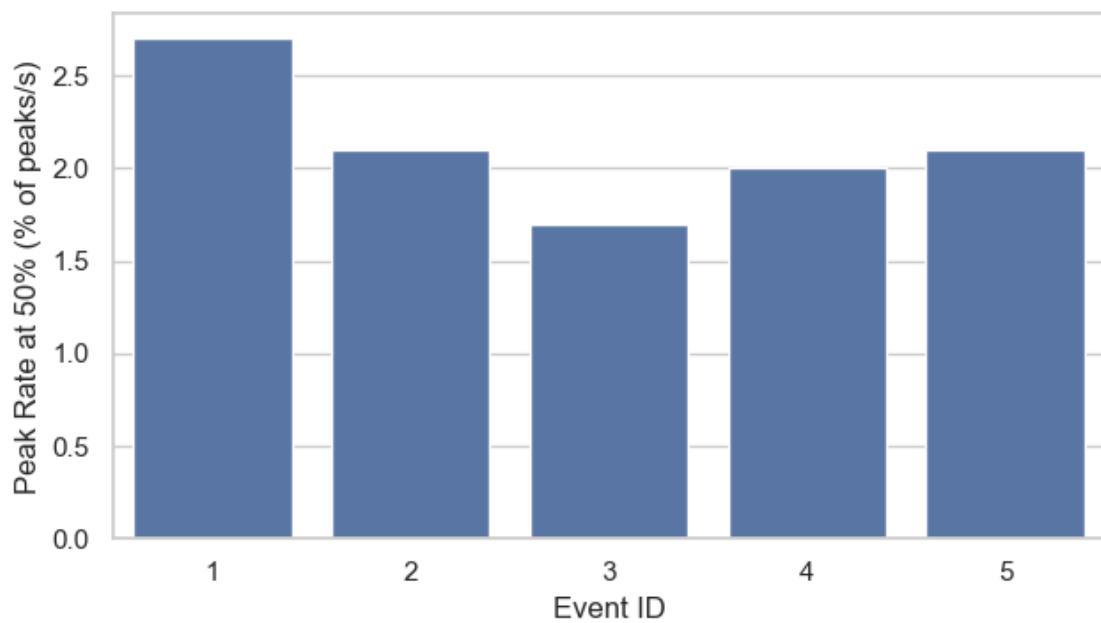
```

[2025-08-27 15:02:23] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\events\event-growth-curve-5.png': [Errno 2] No
such file or directory: 'D:\\Mateo\\20250618\\Output\\IS4\\events\\event-growth-
curve-5.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundError: [Errno 2] No such file or directory:
'D:\\Mateo\\20250618\\Output\\IS4\\events\\event-growth-curve-5.png'

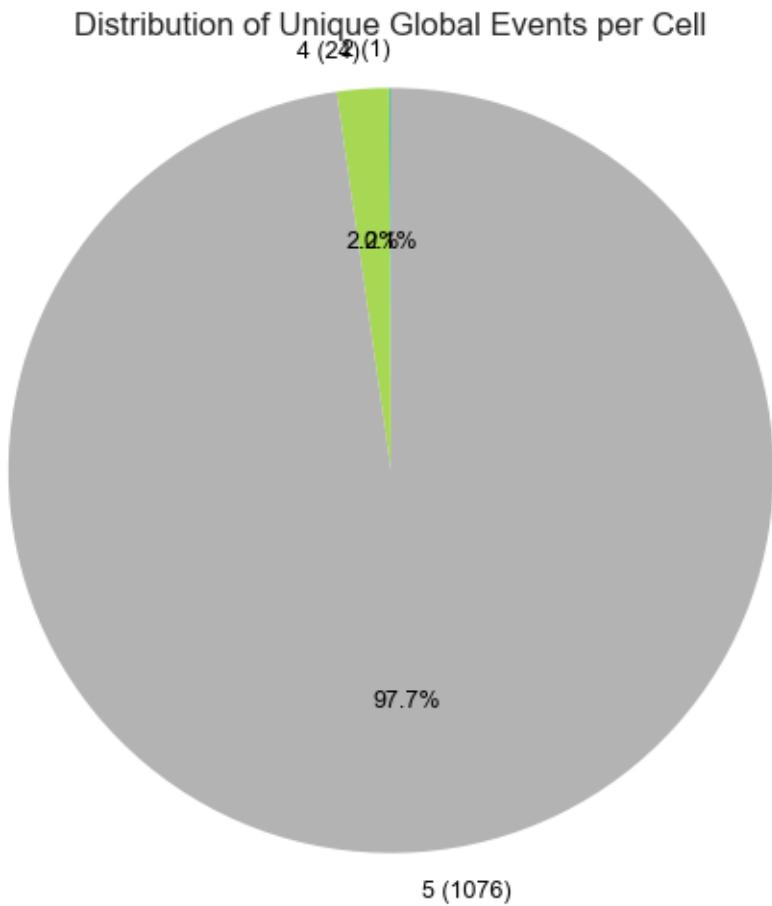
```



Peak rate at 50% in Global Events



1.2.4 Cells Occurrences in global events

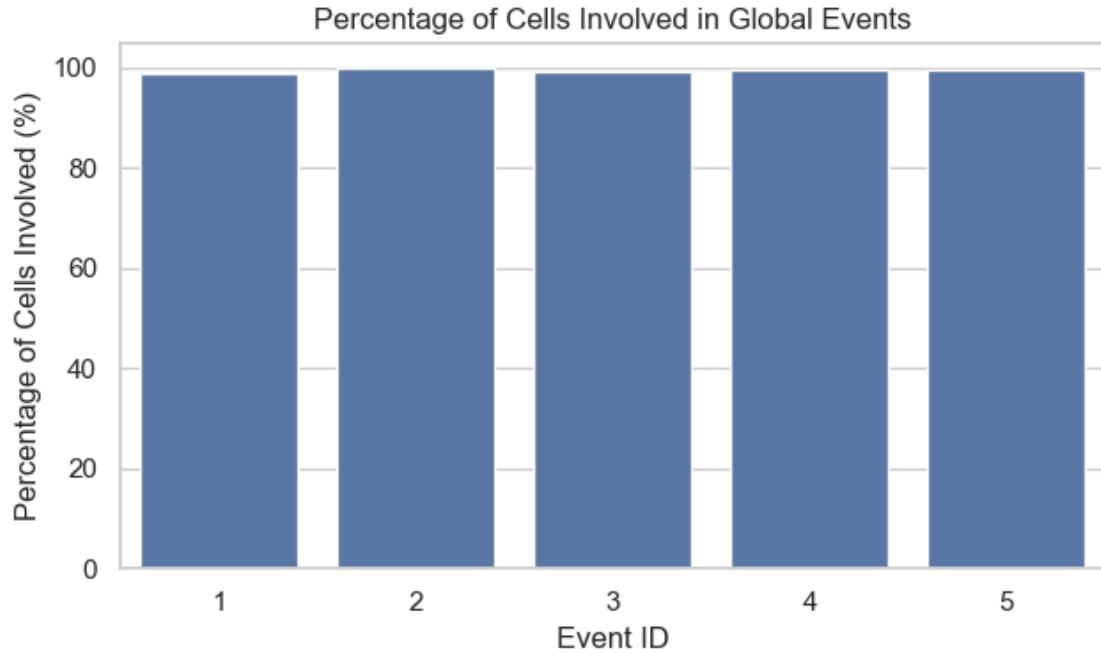


```
[2025-08-27 15:02:24] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\cell-
mapping\cell_Occurrences_in_global_events_overlay.png': [Errno 2] No such file
or directory: 'D:\\\\Mateo\\\\20250618\\\\Output\\\\IS4\\\\cell-
mapping\\\\cell_Occurrences_in_global_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
```

```

    self.fp = open(fp, "rb")
FileNotFoundError: [Errno 2] No such file or directory:
'D:\Mateo\20250618\Output\IS4\cell-
mapping\cell_Occurrences_in_global_events_overlay.png'

```



1.2.5 Inter-event interval analysis

Intervals between global event peaks: [291.0, 304.0, 358.0, 348.0]
 Estimated periodicity: 0.920
 The global events exhibit a regular periodic pattern.
 Estimated frequency (1/mean interval): 0.003 Hz

1.2.6 Early peakers in the events

```

[2025-08-27 15:02:24] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\cell-
mapping\global_events\global_event_1_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:

```

```

  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:02:24] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\cell-mapping\global_events\global_event_2_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:02:24] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\cell-mapping\global_events\global_event_3_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()

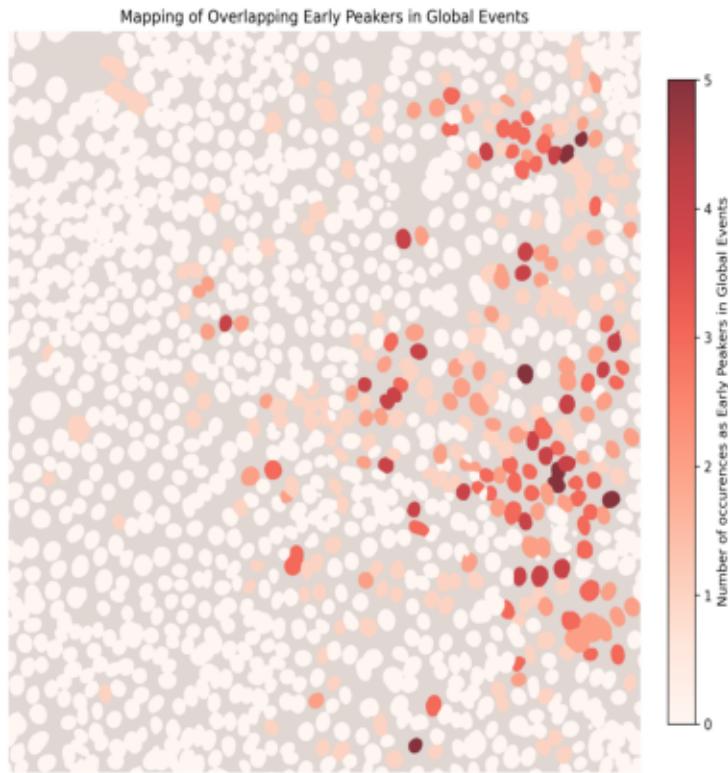
```

```
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:02:24] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\cell-
mapping\global_events\global_event_4_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

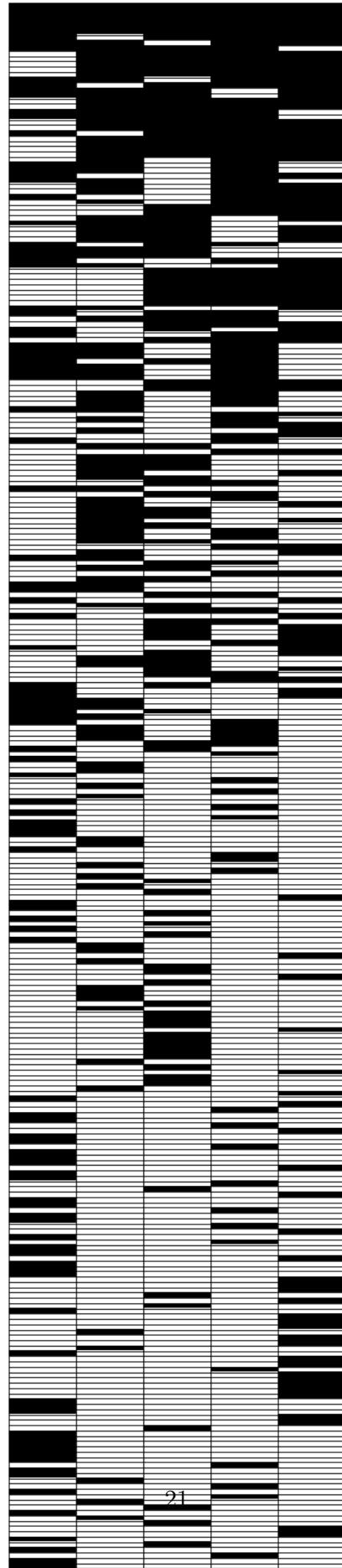
[2025-08-27 15:02:24] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\cell-
mapping\global_events\global_event_5_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file
```

Cell Mapping with Occurrences in Global Events Overlay



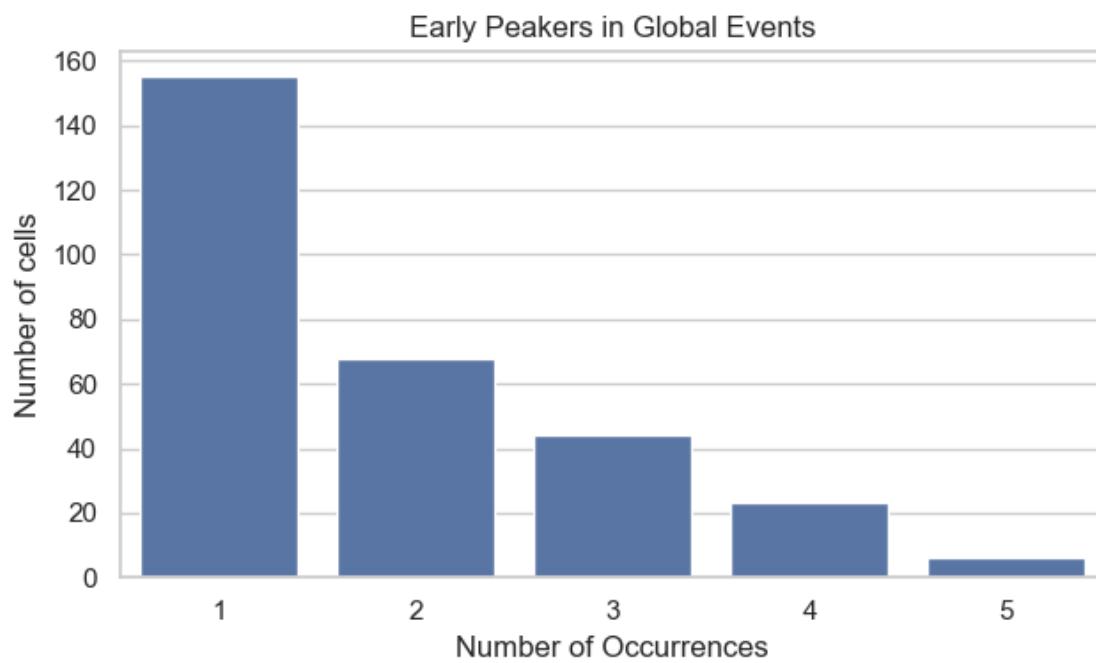
```
[2025-08-27 15:02:25] [WARNING] calcium: 'total_events' is deprecated and ignored. Using 5 unique event IDs.
```

```
[2025-08-27 15:02:25] [INFO] calcium: Early peakers event-matrix: 296 cells x 5 events; black squares: 545
```

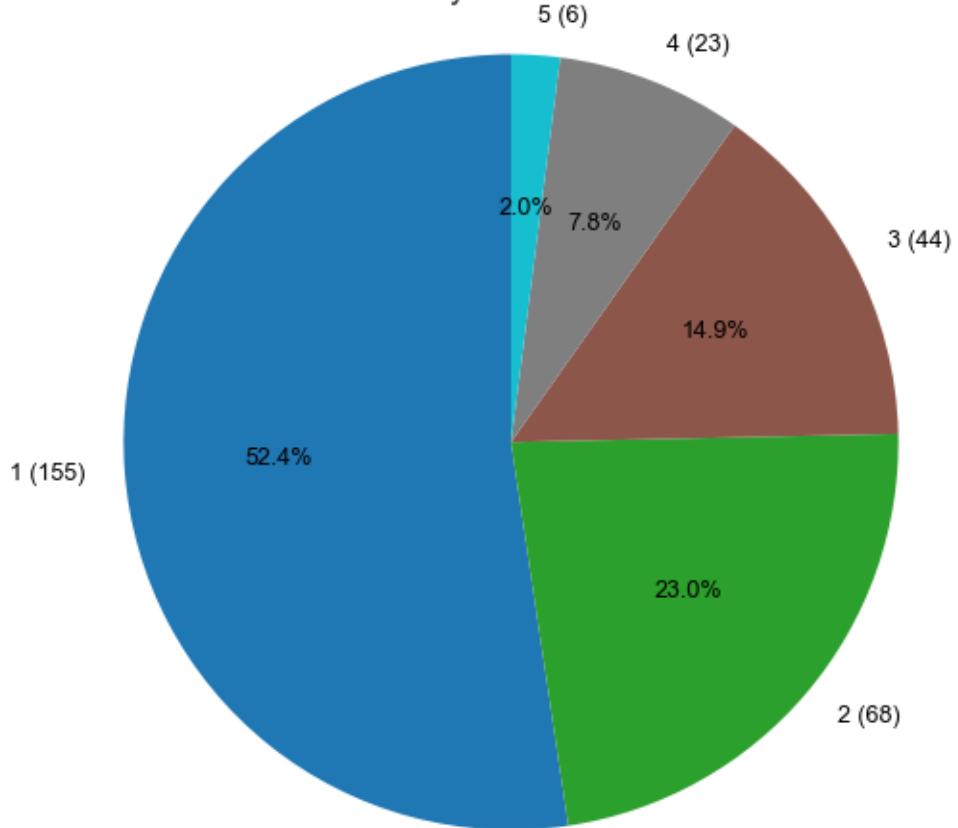


```
[2025-08-27 15:02:26] [INFO] calcium: Saved early peakers heatmap SVG to:  
early_peakers_heatmap.svg
```

```
[19]: array([[1, 1, 1, 1, 1],  
           [1, 1, 1, 1, 1],  
           [1, 1, 1, 1, 1],  
           ...,  
           [1, 0, 0, 0, 0],  
           [1, 0, 0, 0, 0],  
           [1, 0, 0, 0, 0]])
```



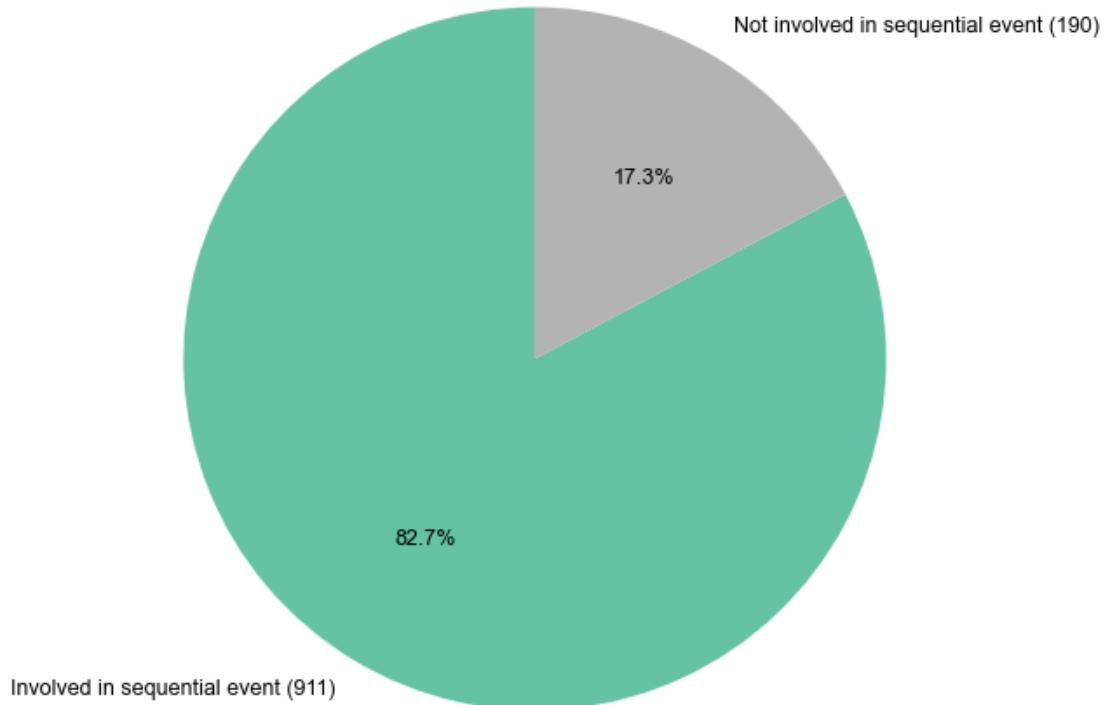
Distribution of Early Peakers in Global Events



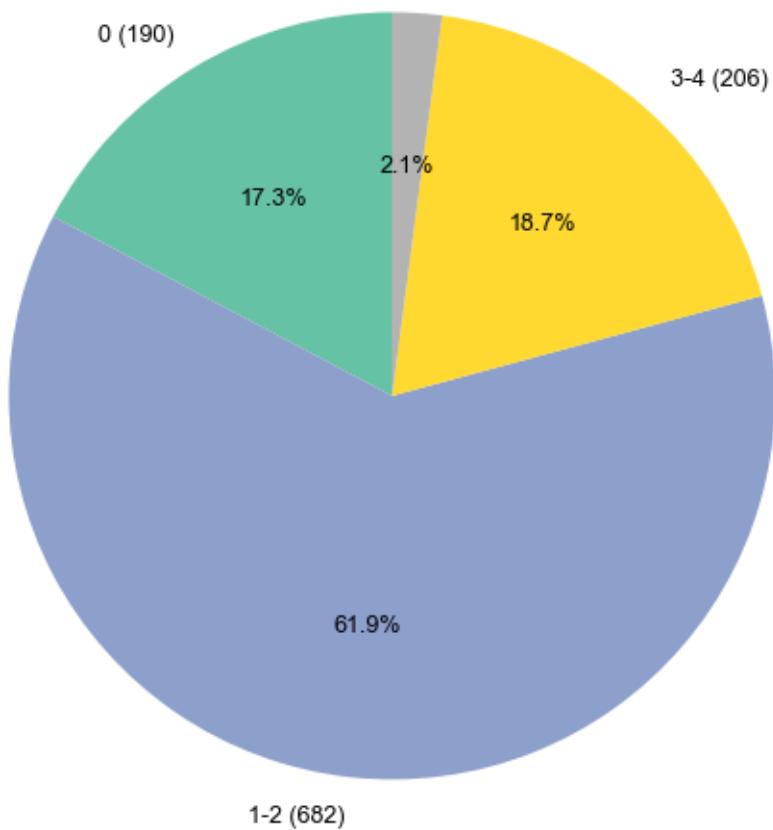
1.3 SEQUENTIAL EVENTS

1.3.1 Cells Occurrences in sequential events

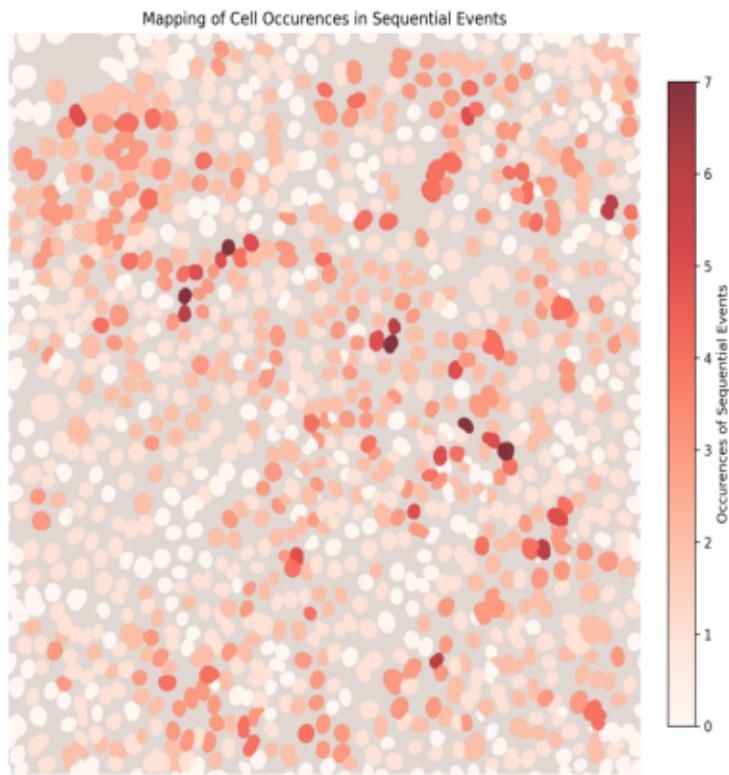
Distribution of Cells Involved in Sequential Events



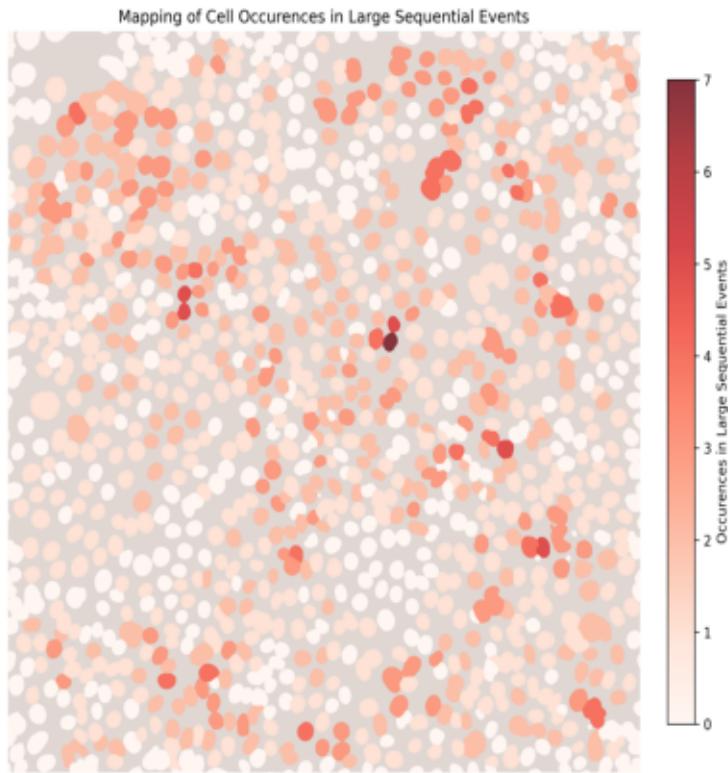
Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)
5-9 (23)



Cell Mapping with Occurrences in Sequential Events Overlay

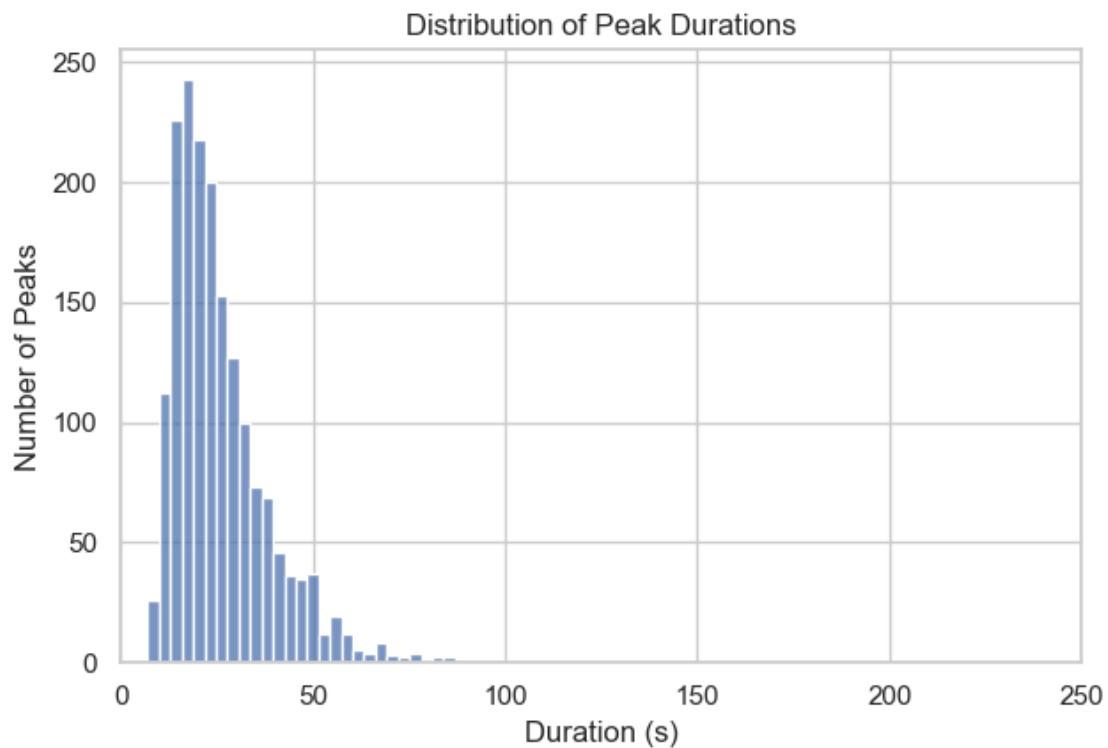


Cell Mapping with Occurrences in Large Sequential Events Overlay (>2)



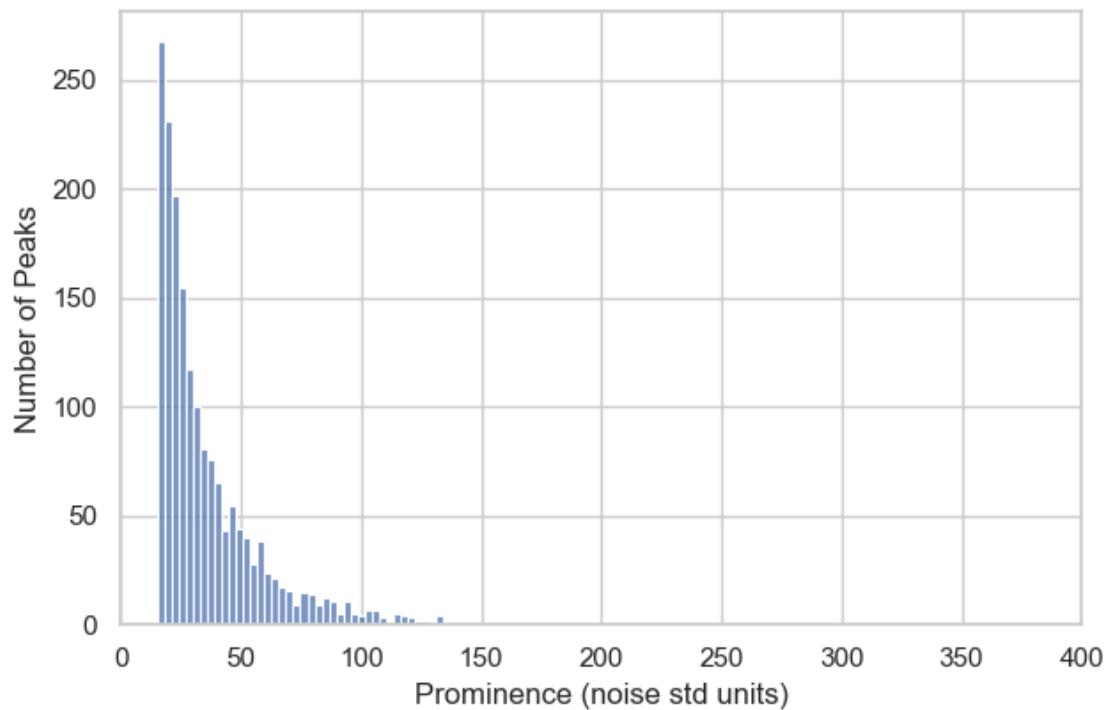
1.3.2 Peaks statistics in sequential events

```
[2025-08-27 15:02:28] [INFO] calcium: plot_histogram: removed 19 outliers out of  
1794 on 'Duration (s)' (lower=-8, upper=88)
```

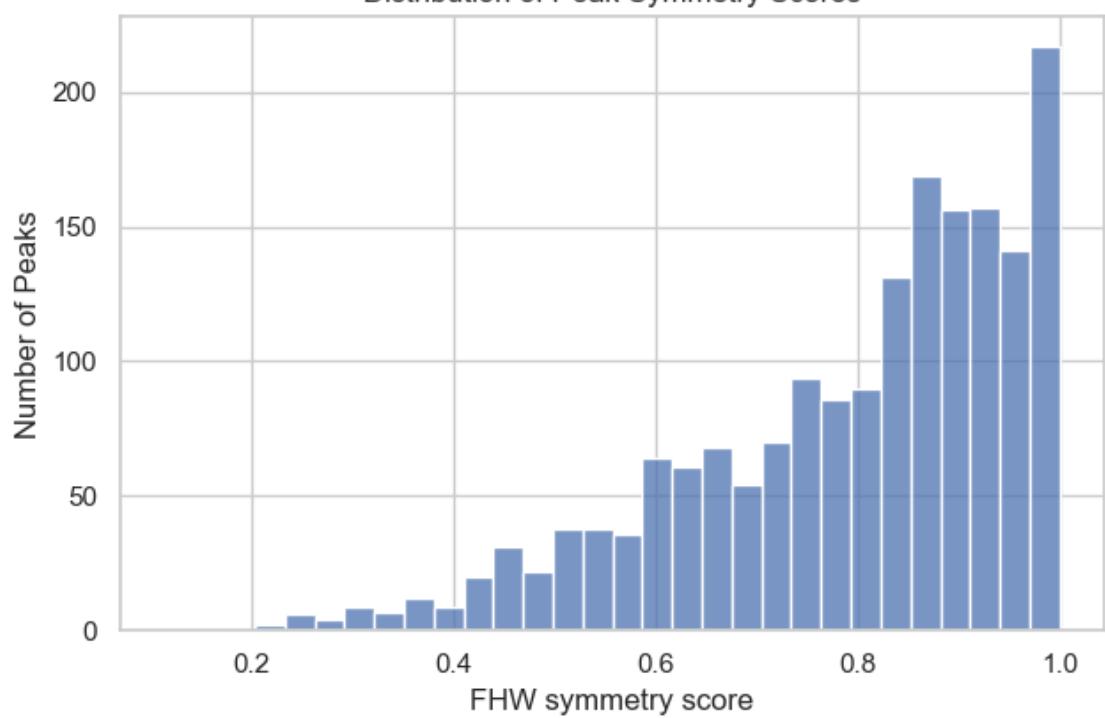


```
[2025-08-27 15:02:28] [INFO] calcium: plot_histogram: removed 44 outliers out of  
1794 on 'Prominence (noise std units)' (lower=-18.062, upper=135.09)
```

Distribution of Peak Prominences

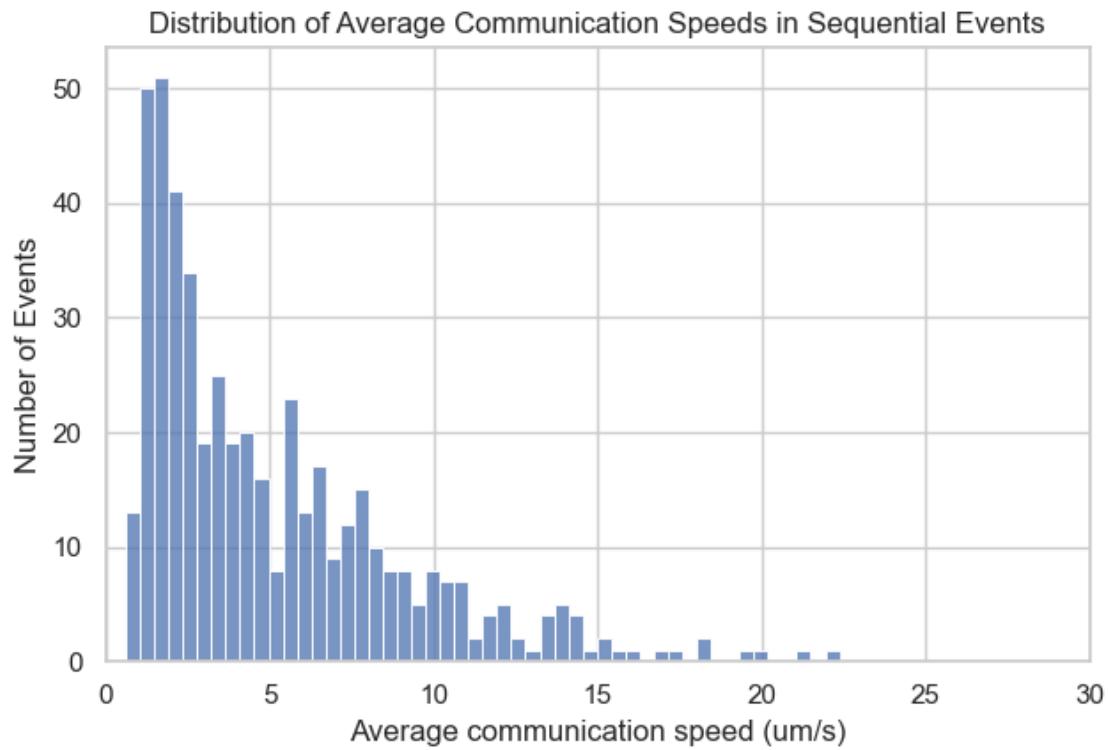


Distribution of Peak Symmetry Scores

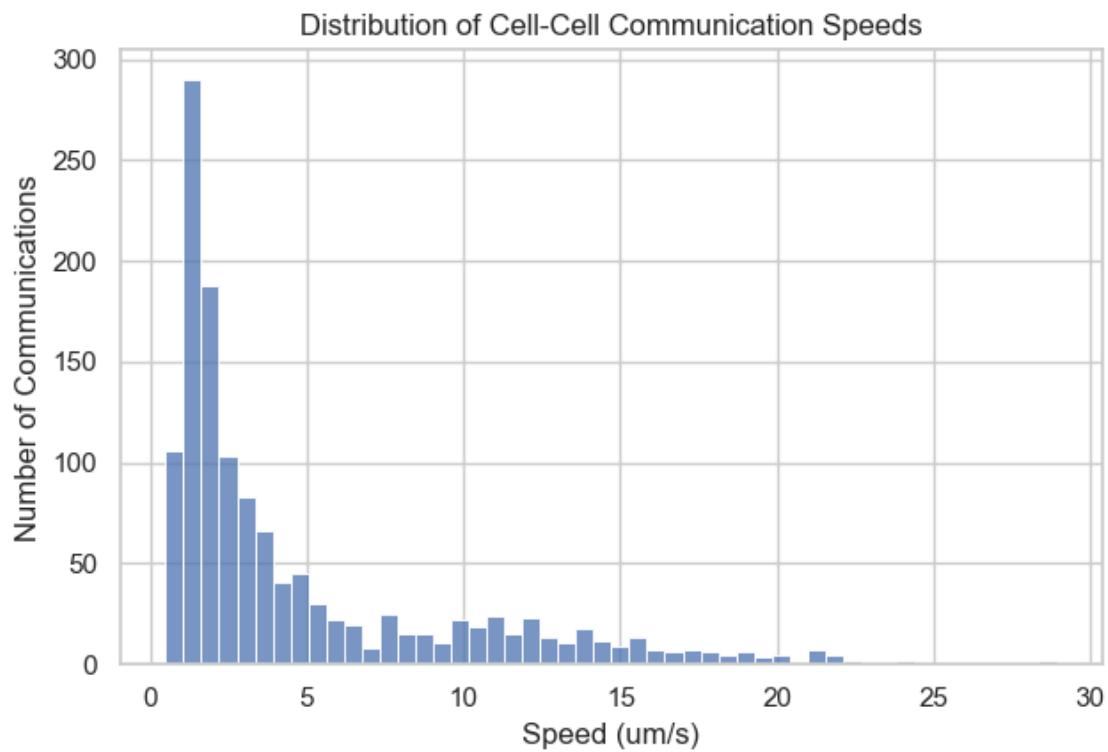


1.3.3 Cell-cell communication speed

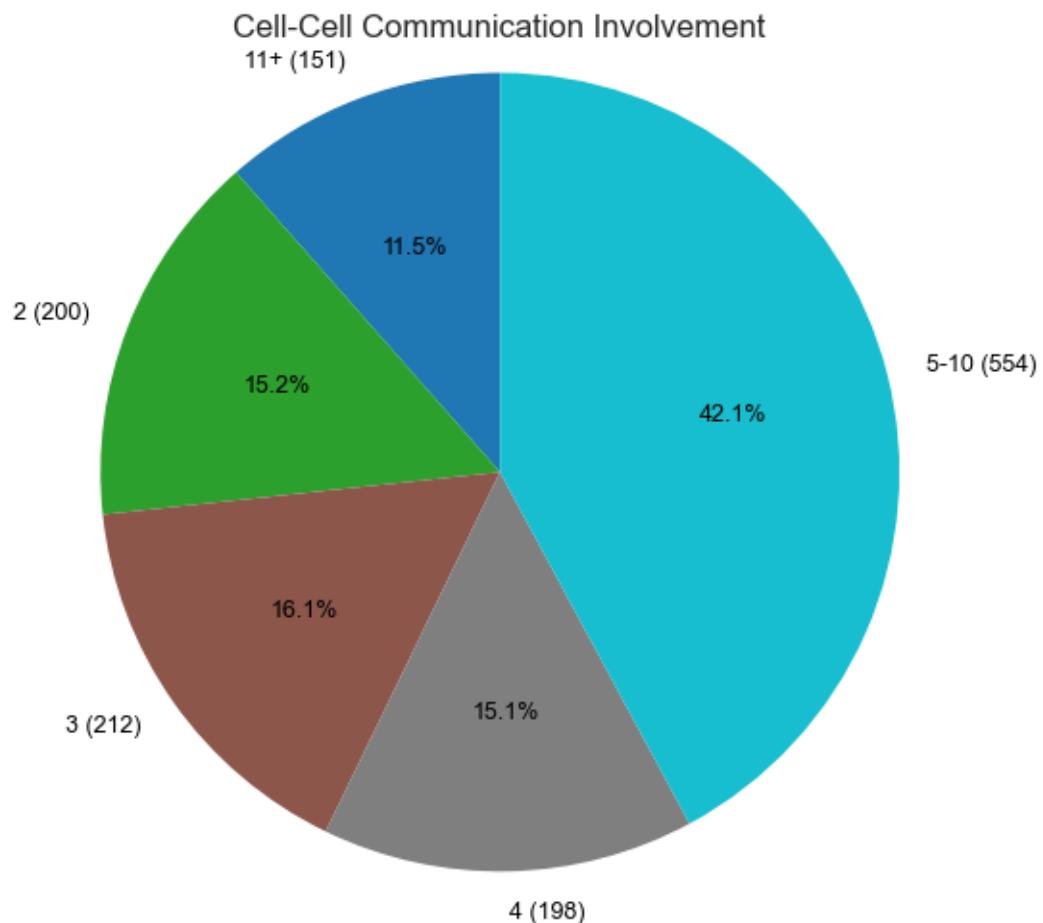
[2025-08-27 15:02:29] [INFO] calcium: plot_histogram: removed 1 outliers out of 479 on 'Average communication speed (um/s)' (lower=-13.585, upper=22.745)



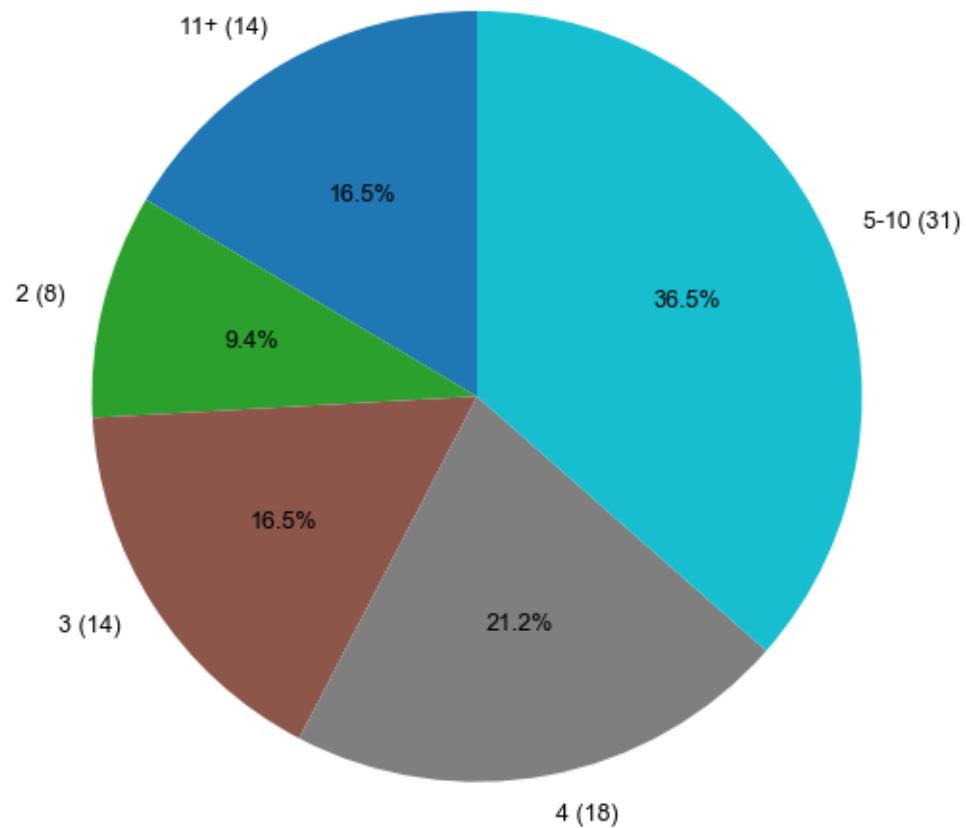
[2025-08-27 15:02:29] [INFO] calcium: plot_histogram: removed 0 outliers out of 1315 on 'Speed (um/s)' (lower=-13.515, upper=31.44)



1.3.4 Double distribution in cell-cell communication speeds

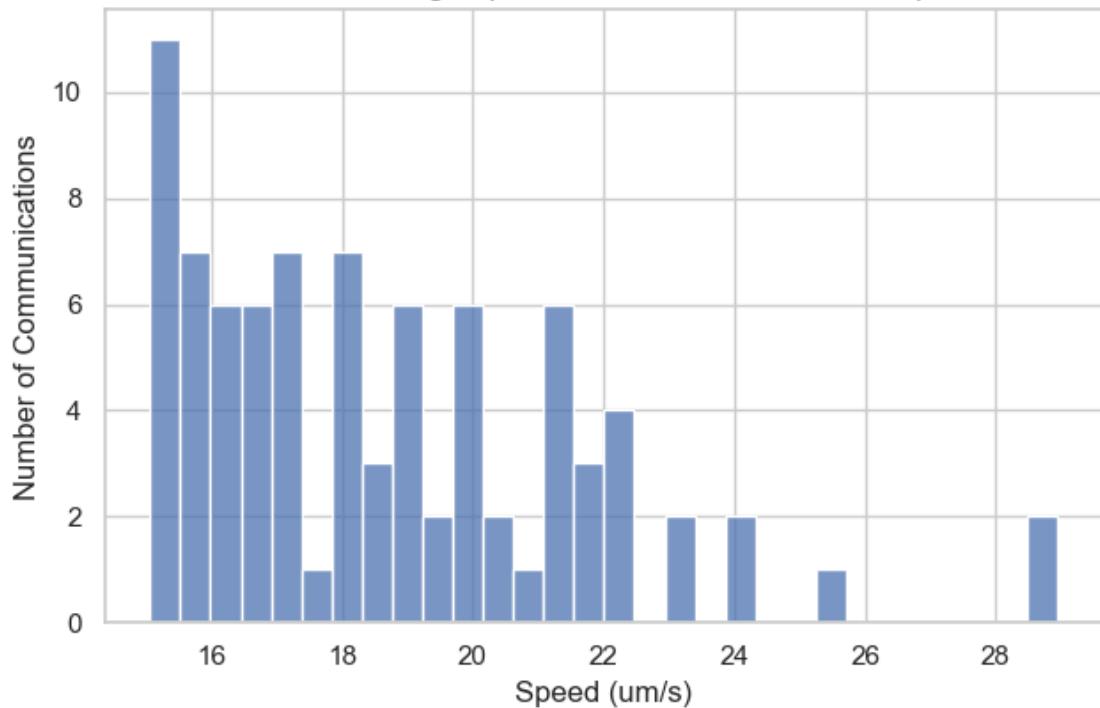


High Speed Cell-Cell Communication Involvement



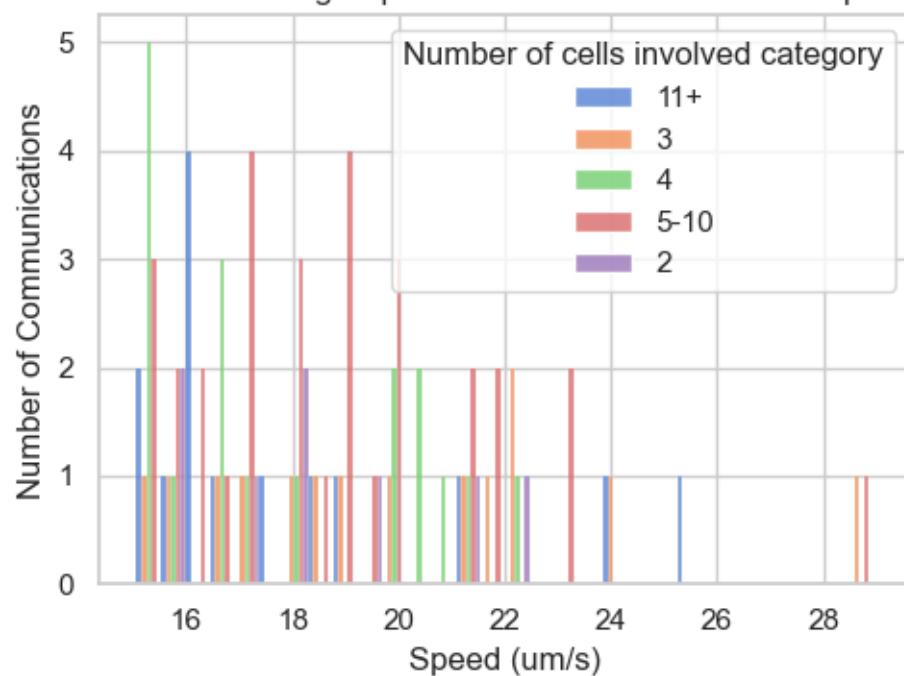
[2025-08-27 15:02:30] [INFO] calcium: plot_histogram: removed 0 outliers out of 85 on 'Speed (um/s)' (lower=3.26, upper=33.43)

Distribution of High Speed Cell-Cell Communication Speeds

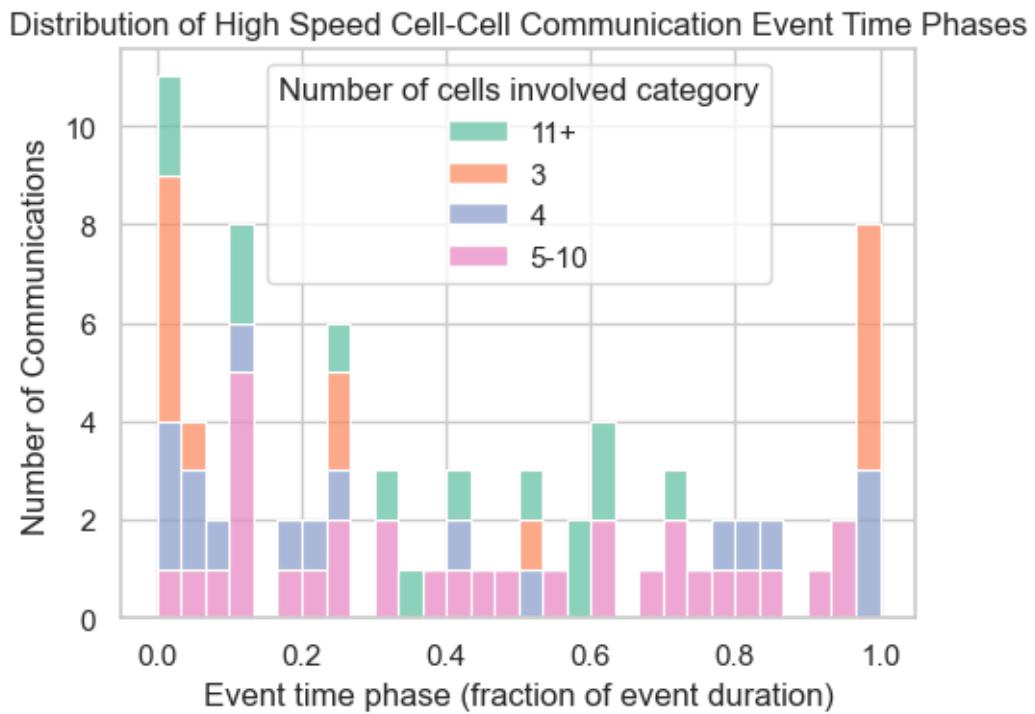


```
[2025-08-27 15:02:30] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 85 on 'Speed (um/s)' (lower=3.26, upper=33.43)
```

Distribution of High Speed Cell-Cell Communication Speeds

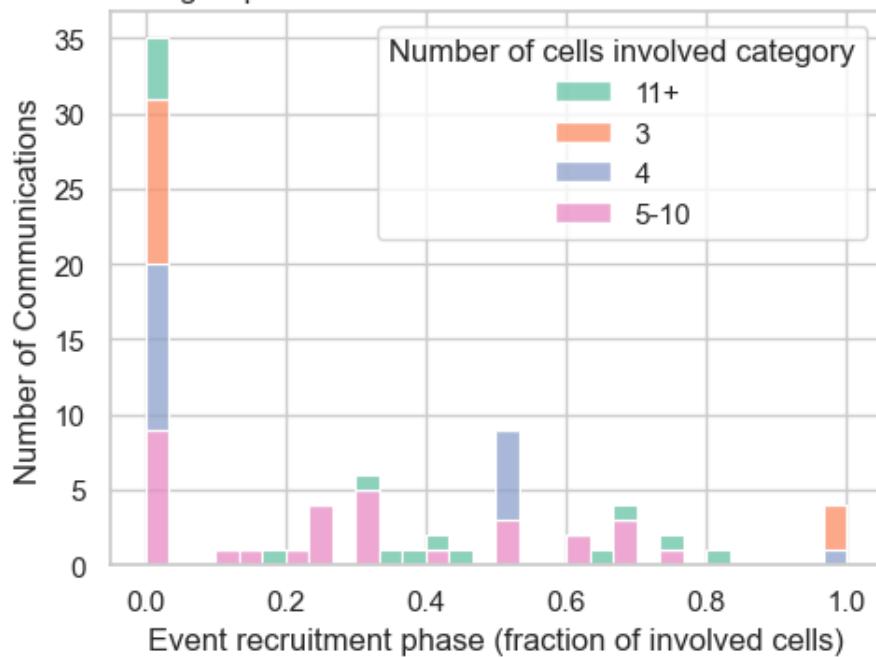


[2025-08-27 15:02:30] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 77 on 'Event time phase (fraction of event duration)' (lower=-1.69, upper=2.51)

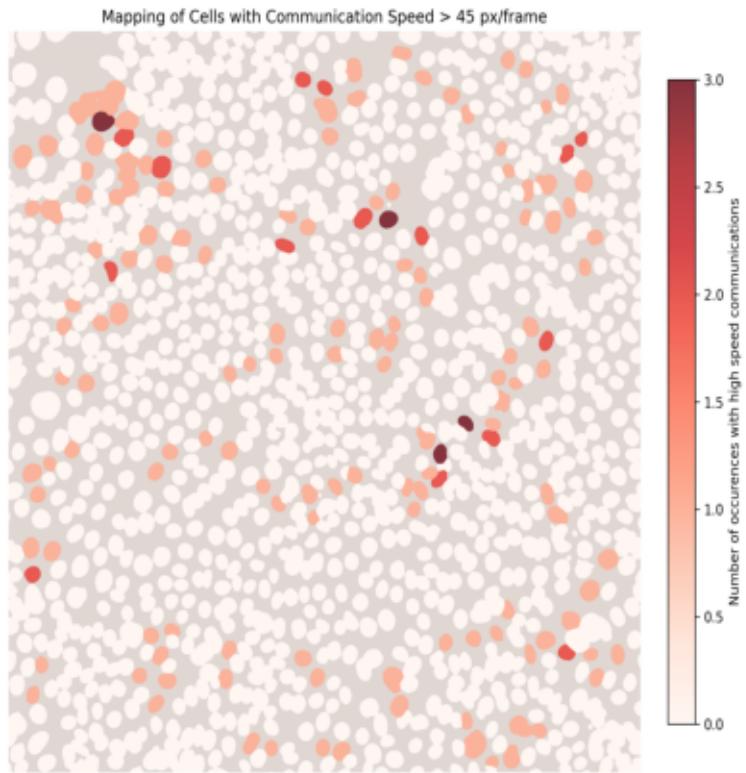


[2025-08-27 15:02:30] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 77 on 'Event recruitment phase (fraction of involved cells)' (lower=-1.5, upper=2)

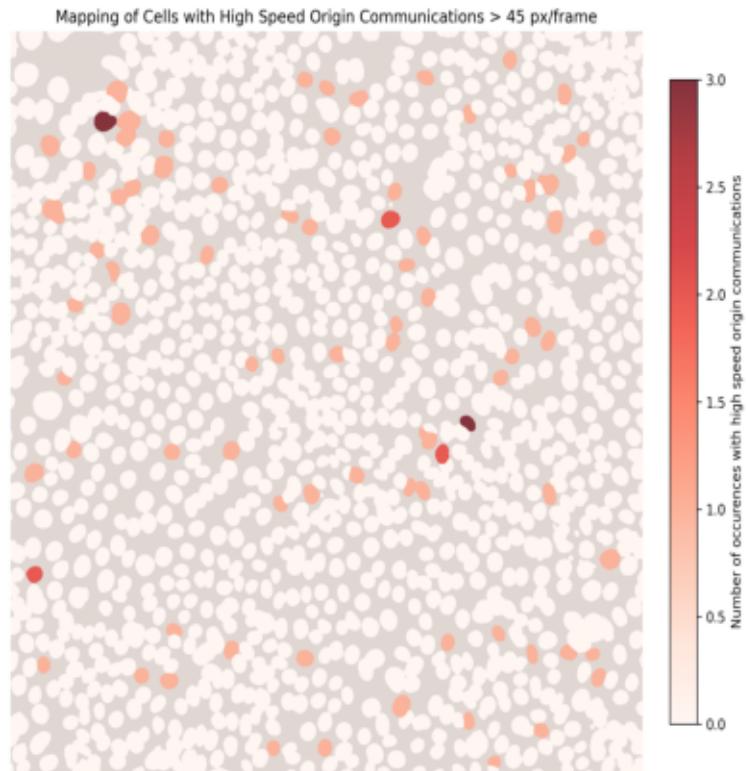
Distribution of High Speed Cell-Cell Communication Event Recruitment Phases



Cell Mapping with High Speed Cells Overlay



Cell Mapping with High Speed Origin Cells Overlay



	Communication ID	Event ID	Origin cell ID	Origin cell peak ID	\
15	3015667988560	8	380		6
18	3015667984384	8	261		3
23	3015593961760	9	1126		8
26	3015593954080	11	1206		1
29	3015593963104	12	962		0
...
1211	3015482455712	433	1624		1
1227	3015482454320	440	1549		3
1240	3015482457152	445	1571		1
1296	3015482449136	473	1794		0
1297	3015482455136	474	1725		2

	Cause cell ID	Cause cell peak ID	Start time (s)	End time (s)	\
15	336	4	701.0	701.0	
18	284	4	708.0	709.0	
23	1183	4	749.0	749.0	
26	1183	0	96.0	96.0	
29	969	0	38.0	38.0	
...	
1211	1672	1	65.0	66.0	
1227	1618	2	450.0	451.0	
1240	1614	1	119.0	120.0	
1296	1785	0	47.0	48.0	
1297	1716	2	444.0	445.0	
	Duration (s)	Distance (um)	Speed (um/s)	\	
15	0.0	17.70	17.70		
18	1.0	15.71	15.71		
23	0.0	16.90	16.90		
26	0.0	17.15	17.15		
29	0.0	19.35	19.35		
...	
1211	1.0	18.06	18.06		
1227	1.0	19.99	19.99		
1240	1.0	17.06	17.06		
1296	1.0	15.55	15.55		
1297	1.0	15.17	15.17		
	Event time phase (fraction of event duration)	\			
15		0.12			
18		0.59			
23		0.00			
26		0.77			
29		0.39			
...		...			
1211		0.25			
1227		0.06			
1240		NaN			
1296		0.06			
1297		1.00			
	Event recruitment phase (fraction of involved cells)	dataset	\		
15		0.00	20250618_IS4		
18		0.64	20250618_IS4		
23		0.00	20250618_IS4		
26		0.00	20250618_IS4		
29		0.00	20250618_IS4		
...			
1211		0.33	20250618_IS4		
1227		0.00	20250618_IS4		

1240		NaN	20250618_IS4
1296		0.00	20250618_IS4
1297		1.00	20250618_IS4

	Number of cells involved	category	Speed category
15		11+	High speed
18		11+	High speed
23		3	High speed
26		4	High speed
29		5-10	High speed
...	
1211		5-10	High speed
1227		4	High speed
1240		2	High speed
1296		3	High speed
1297		3	High speed

[85 rows x 16 columns]

Origin cell ID	Speed category	High speed	Low speed
231		0	1
233		0	1
237		0	1
239		0	3
247		0	2
...
1780		0	2
1782		0	1
1784		0	1
1785		0	1
1794		1	0

[644 rows x 2 columns]

Cell ID	Centroid X coordinate (um)	Centroid Y coordinate (um)	\
1	231	248.30	8.45
2	233	119.28	9.10
5	237	167.70	10.40
6	239	466.38	9.75
12	247	456.62	13.97
...
1089	1780	162.83	489.45
1091	1782	116.67	490.10
1093	1784	304.53	490.10
1094	1785	397.15	488.48
1100	1794	381.88	491.40

Number of peaks	Is active	Occurrences in global events	\
-----------------	-----------	------------------------------	---

1	7	True	5
2	7	True	5
5	8	True	5
6	7	True	4
12	6	True	5
...
1089	9	True	5
1091	8	True	5
1093	6	True	5
1094	6	True	5
1100	6	True	5

Occurrences in global events as early peaker Early peaker event IDs \

1	0	[]
2	0	[]
5	0	[]
6	0	[]
12	0	[]
...
1089	0	[]
1091	0	[]
1093	1	[1]
1094	0	[]
1100	0	[]

Occurrences in sequential events \

1	1	
2	1	
5	3	
6	2	
12	1	
...	...	
1089	2	
1091	1	
1093	1	
1094	1	
1100	1	

Occurrences in sequential events as origin \

1	1	
2	1	
5	1	
6	1	
12	0	
...	...	
1089	2	
1091	1	
1093	0	

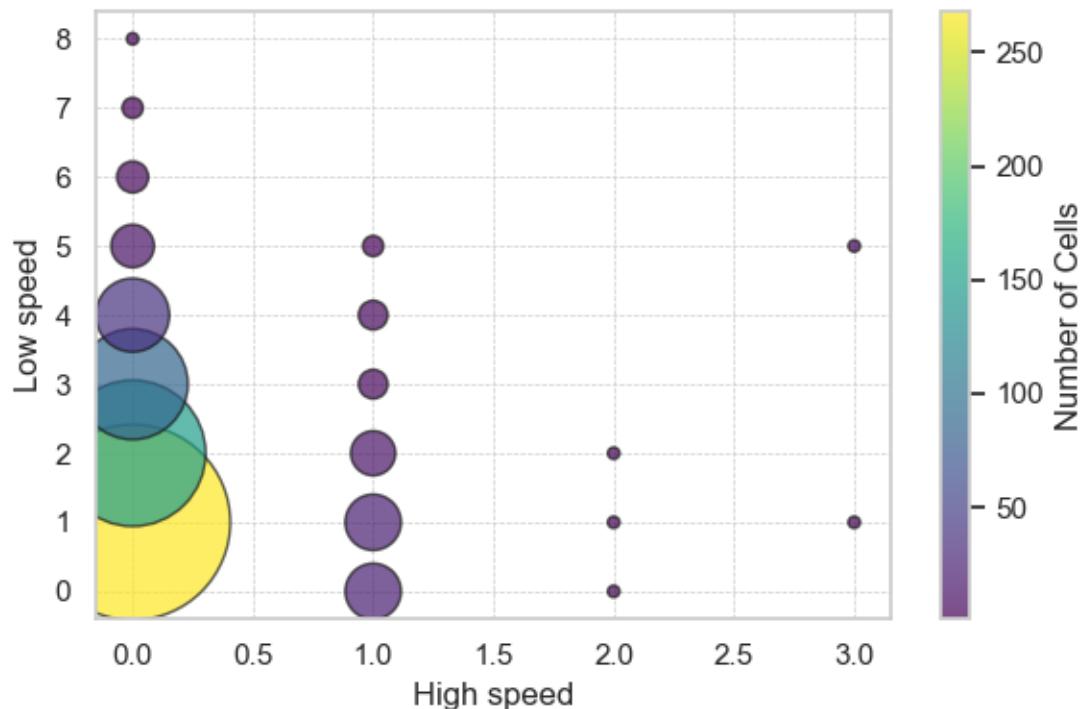
1094			0	
1100			1	
	Occurrences in individual events	Peak frequency (Hz)	\	
1	1	0.0041		
2	1	0.0041		
5	0	0.0047		
6	1	0.0041		
12	0	0.0035		
...		
1089	1	0.0053		
1091	2	0.0047		
1093	0	0.0035		
1094	0	0.0035		
1100	0	0.0035		
	Periodicity score	Neighbor count	Neighbors (labels)	dataset \
1	0.71	2	[263, 276]	20250618_IS4
2	0.68	4	[240, 260, 269, 270]	20250618_IS4
5	0.61	3	[248, 271, 273]	20250618_IS4
6	0.68	4	[242, 247, 250, 274]	20250618_IS4
12	0.86	4	[239, 252, 274, 290]	20250618_IS4
...
1089	0.69	2	[1742, 1756]	20250618_IS4
1091	0.64	4	[1712, 1733, 1748, 1755]	20250618_IS4
1093	0.74	3	[1745, 1754, 1776]	20250618_IS4
1094	0.82	4	[1716, 1753, 1779, 1794]	20250618_IS4
1100	0.83	3	[1749, 1753, 1785]	20250618_IS4
	Involved in sequential event	Occurrences in sequential events	category \	
1	Involved in sequential event			1-2
2	Involved in sequential event			1-2
5	Involved in sequential event			3-4
6	Involved in sequential event			1-2
12	Involved in sequential event			1-2
...
1089	Involved in sequential event			1-2
1091	Involved in sequential event			1-2
1093	Involved in sequential event			1-2
1094	Involved in sequential event			1-2
1100	Involved in sequential event			1-2
	High speed	Low speed		
1	0.0	1.0		
2	0.0	1.0		
5	0.0	1.0		
6	0.0	3.0		
12	0.0	2.0		

```

...
1089      0.0      2.0
1091      0.0      1.0
1093      0.0      1.0
1094      0.0      1.0
1100      1.0      0.0

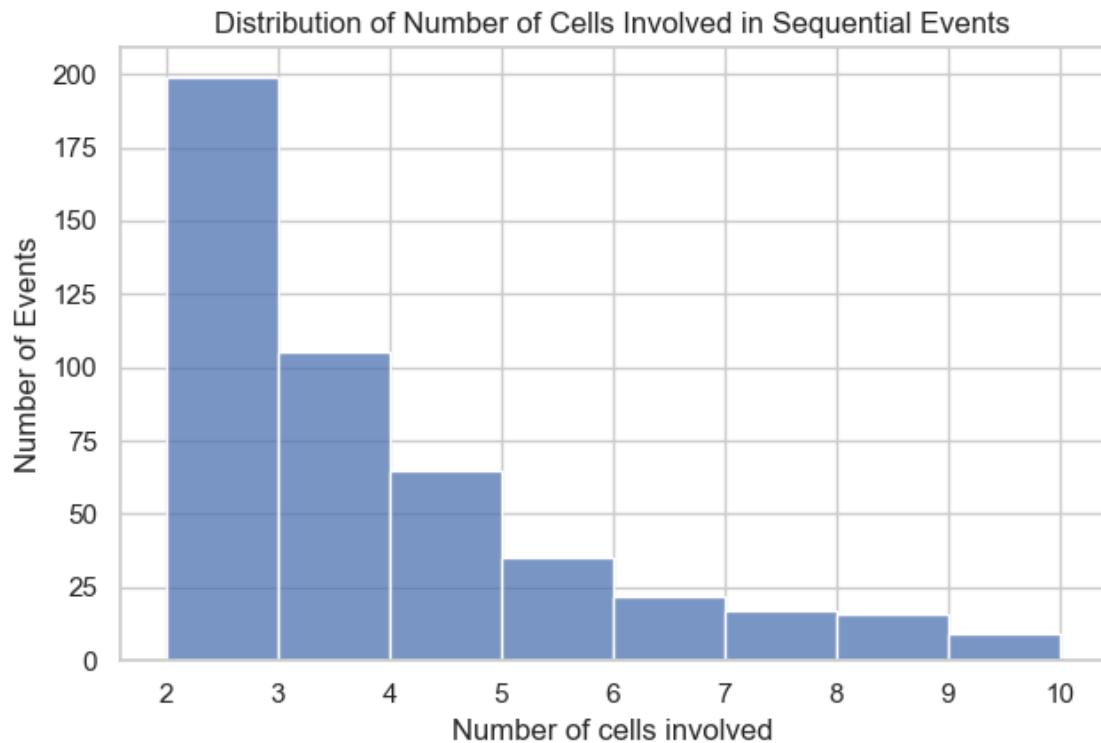
```

[644 rows x 20 columns]



1.3.5 Number of cells involved per sequential events

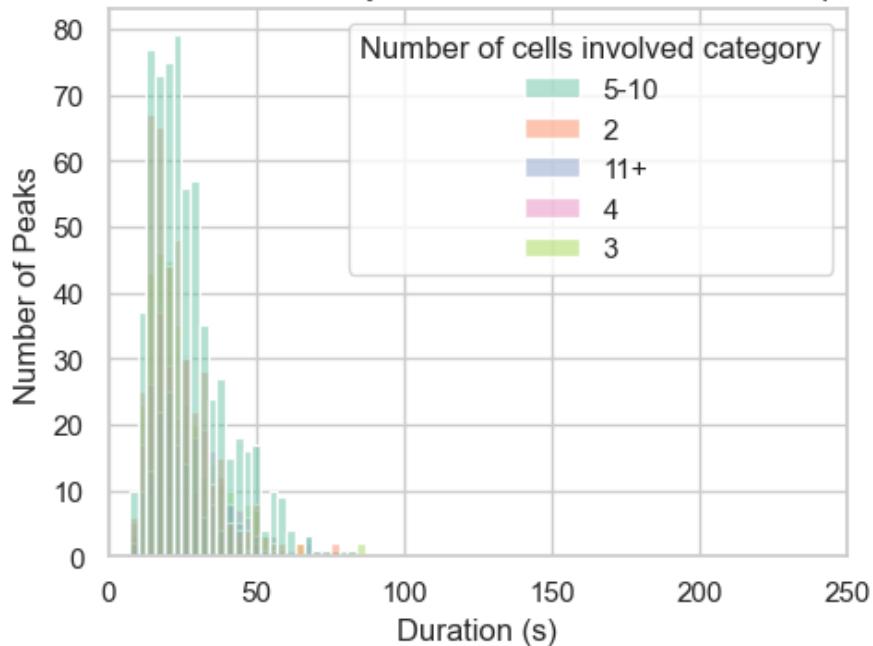
[2025-08-27 15:02:33] [INFO] calcium: plot_histogram: removed 11 outliers out of 479 on 'Number of cells involved' (lower=-4, upper=10)



1.3.6 Influence of cell count per event on statistics

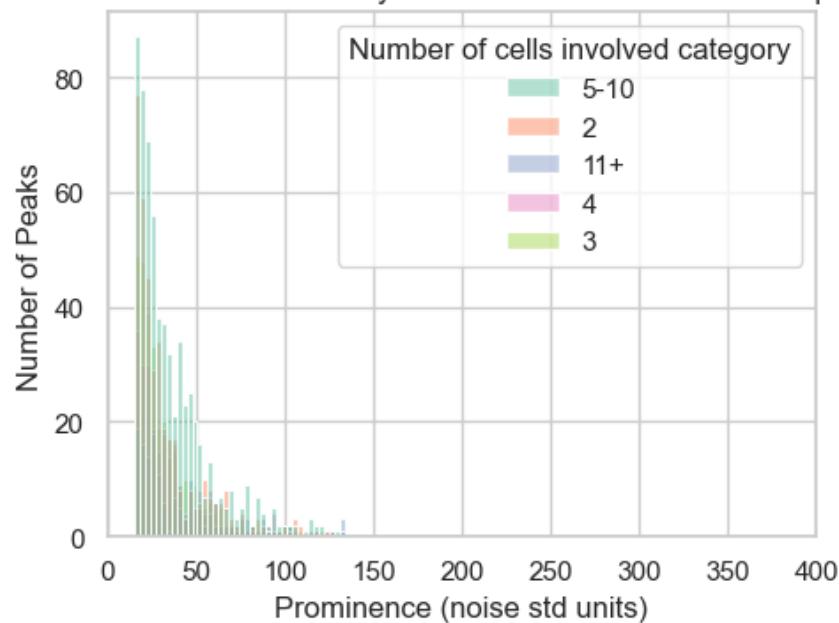
```
[2025-08-27 15:02:33] [INFO] calcium: plot_histogram_by_group: removed 19 outliers out of 1794 on 'Duration (s)' (lower=-8, upper=88)
```

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

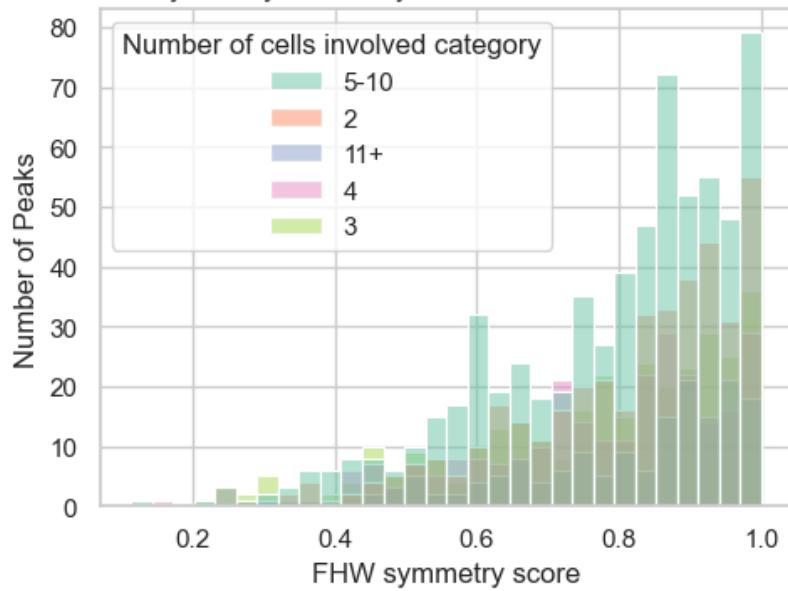


```
[2025-08-27 15:02:33] [INFO] calcium: plot_histogram_by_group: removed 44 outliers out of 1794 on 'Prominence (noise std units)' (lower=-18.062, upper=135.09)
```

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

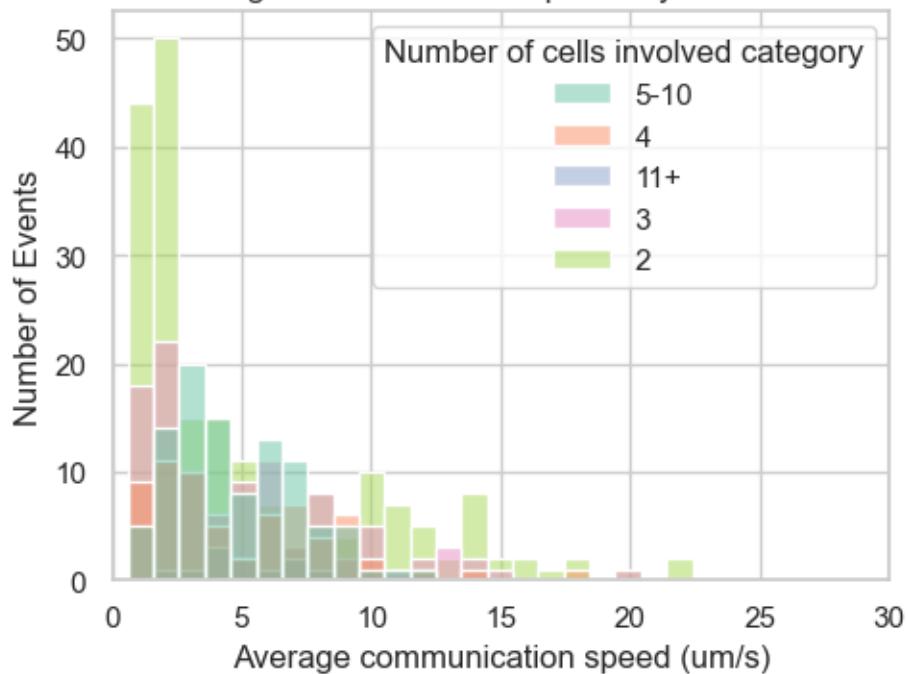


Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



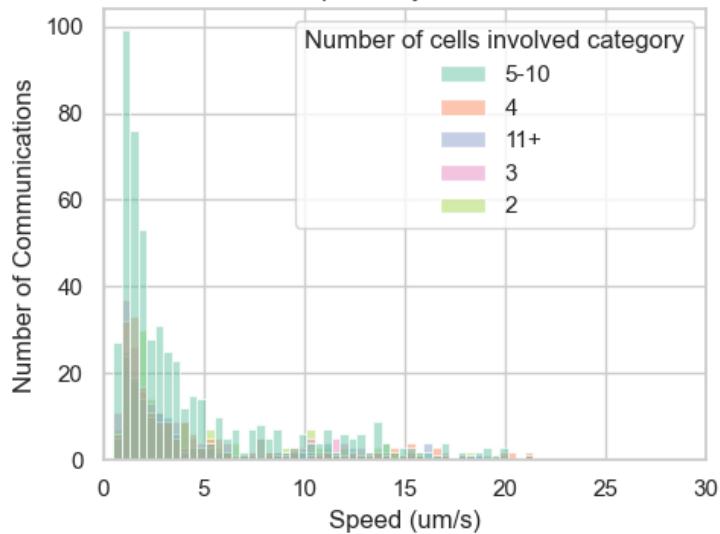
```
[2025-08-27 15:02:34] [INFO] calcium: plot_histogram_by_group: removed 1 outliers out of 479 on 'Average communication speed (um/s)' (lower=-13.585, upper=22.745)
```

Distribution of Average Communication Speeds by Number of Cells Involved



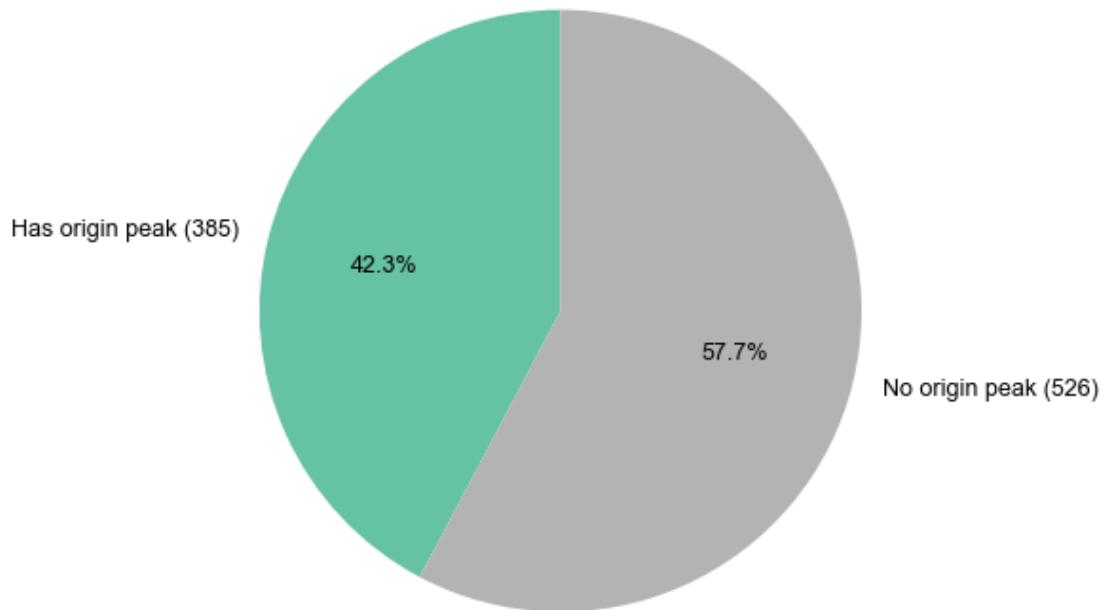
[2025-08-27 15:02:34] [INFO] calcium: plot_histogram_by_group: removed 17 outliers out of 1315 on 'Speed (um/s)' (lower=-13.515, upper=21.45)

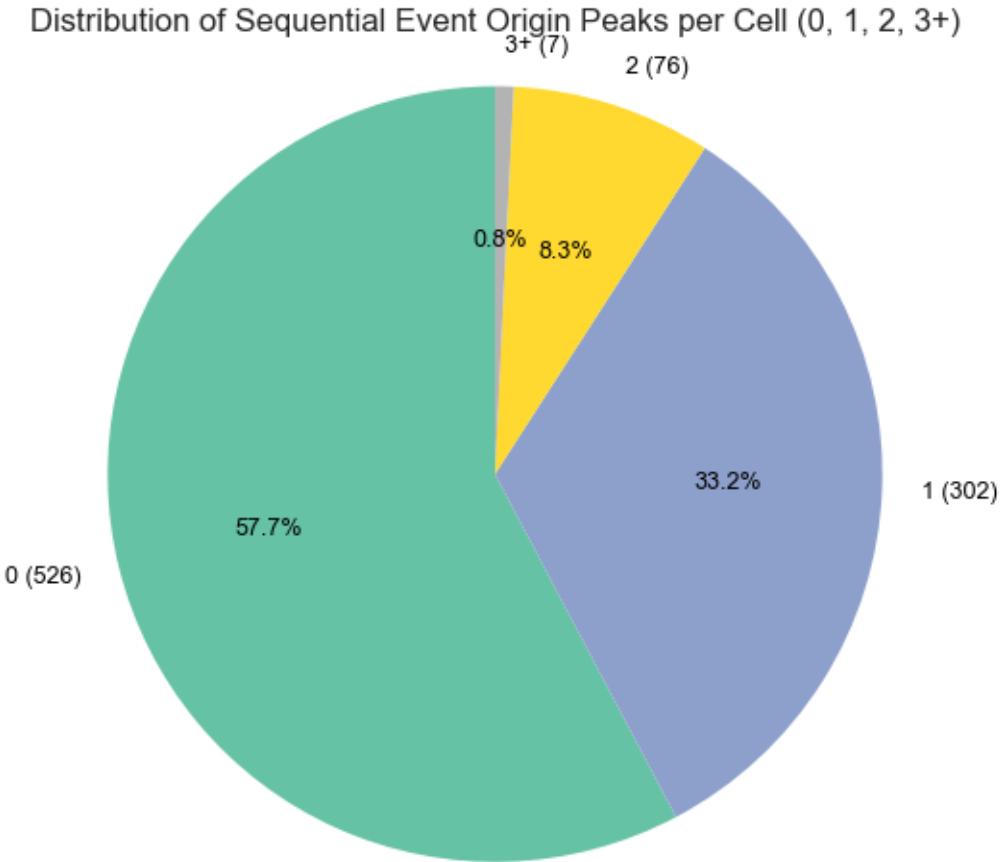
Distribution of Cell-Cell Communication Speeds by Number of Cells Involved in Sequential Events



1.3.7 Cells Occurrences as origin in sequential events

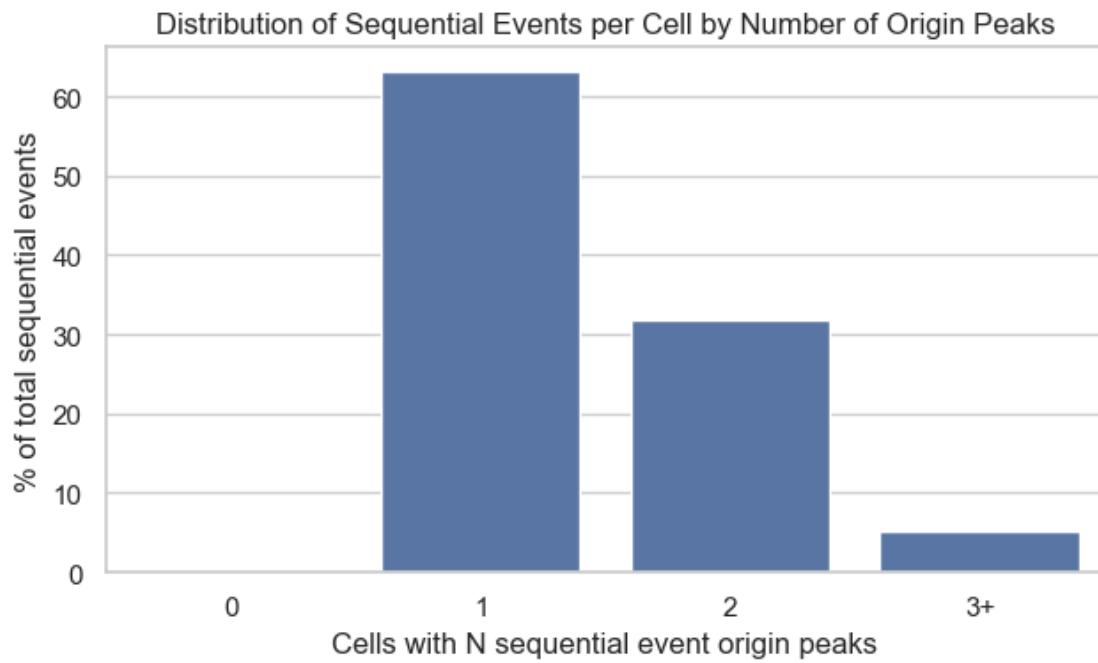
Distribution of Number of Sequential Event Origin Peaks per Cell



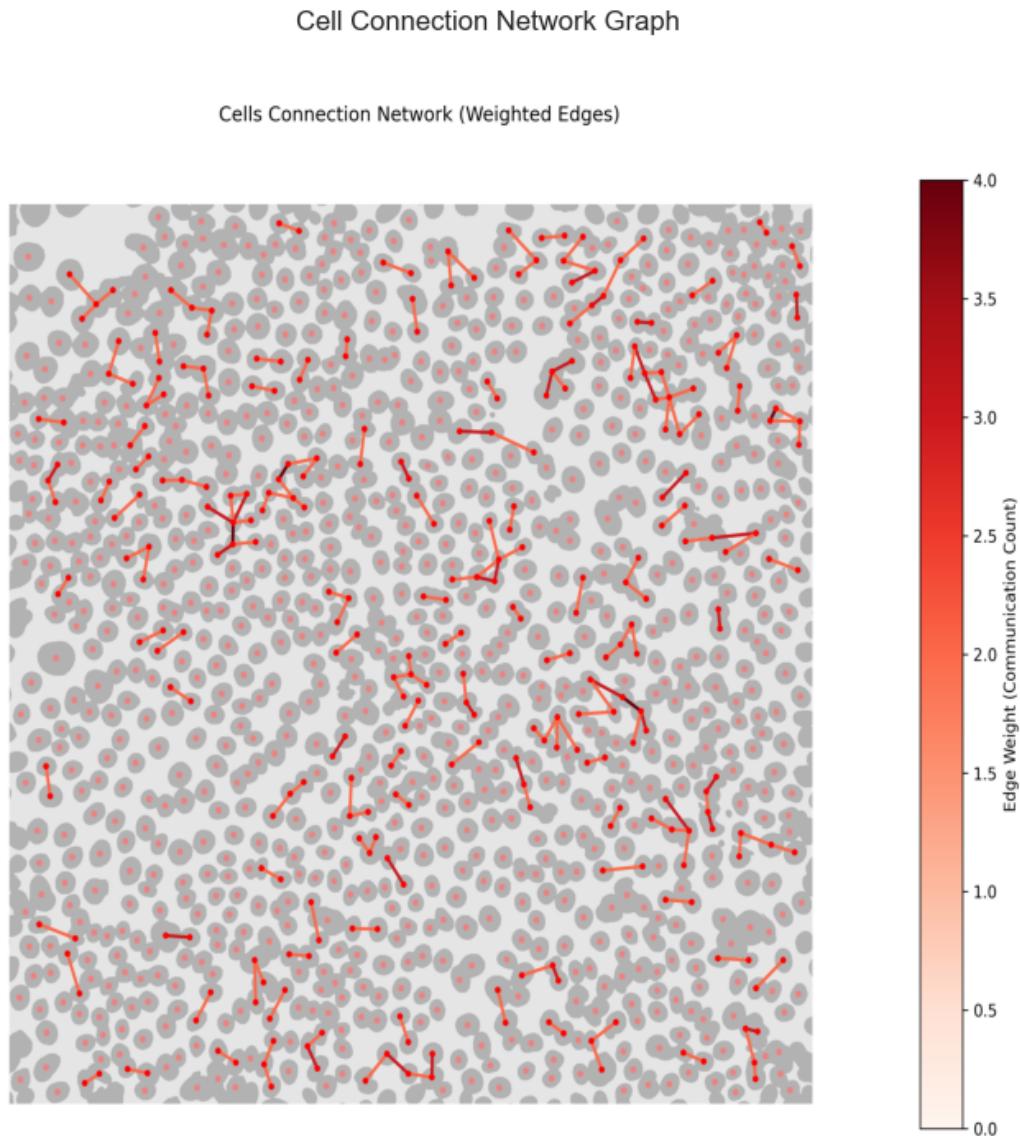


```
[2025-08-27 15:02:34] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\cell-
mapping\cell_Occurrences_in_origin_seq_events_overlay.png': [Errno 2] No such
file or directory: 'D:\\Mateo\\20250618\\Output\\IS4\\cell-
mapping\\cell_Occurrences_in_origin_seq_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundException: [Errno 2] No such file or directory:
```

'D:\\Mateo\\20250618\\Output\\IS4\\cell-mapping\\cell_Occurrences_in_origin_seq_events_overlay.png'

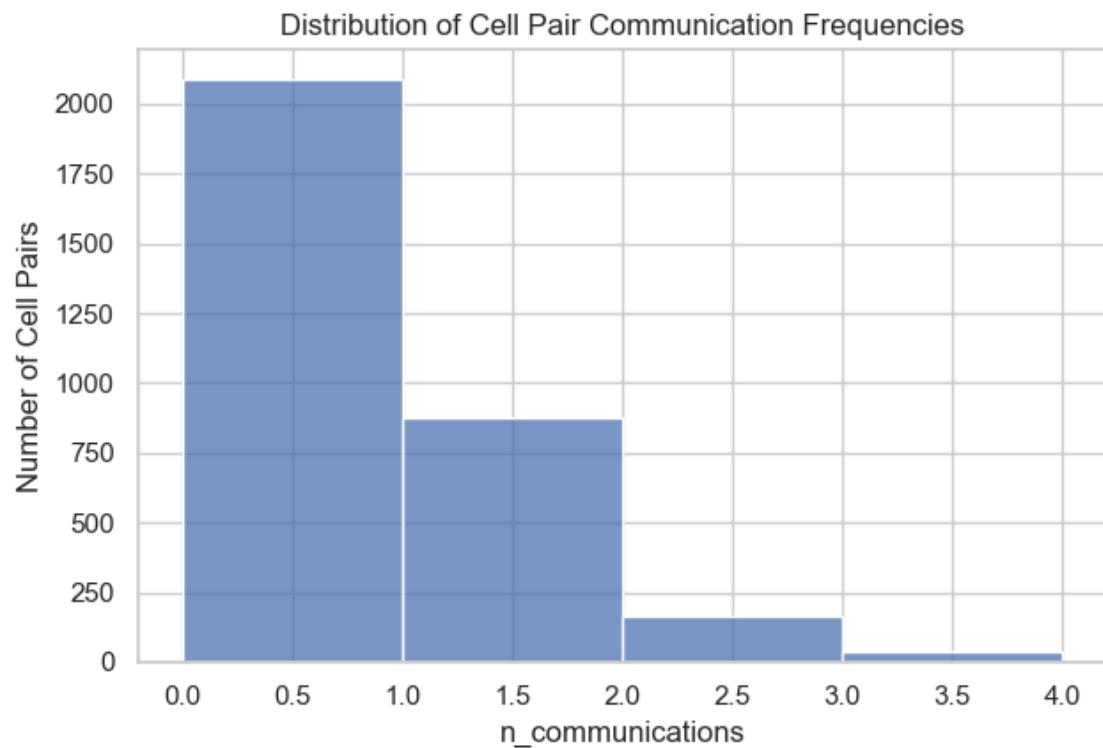


1.3.8 Connection network between cells



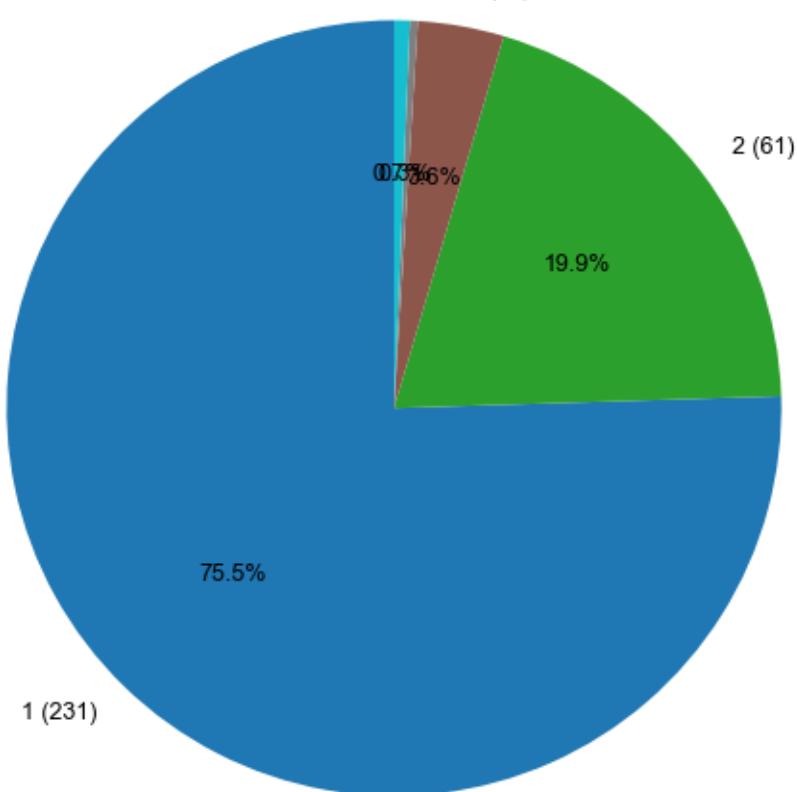
1.3.9 Pair/Trios with high communication networks

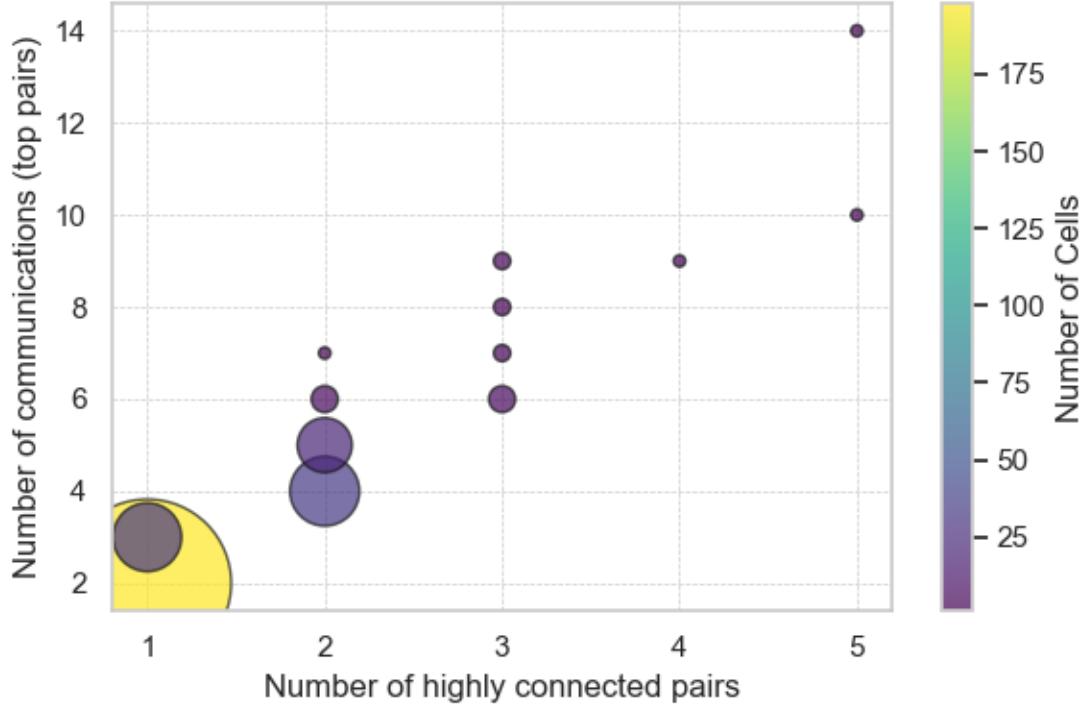
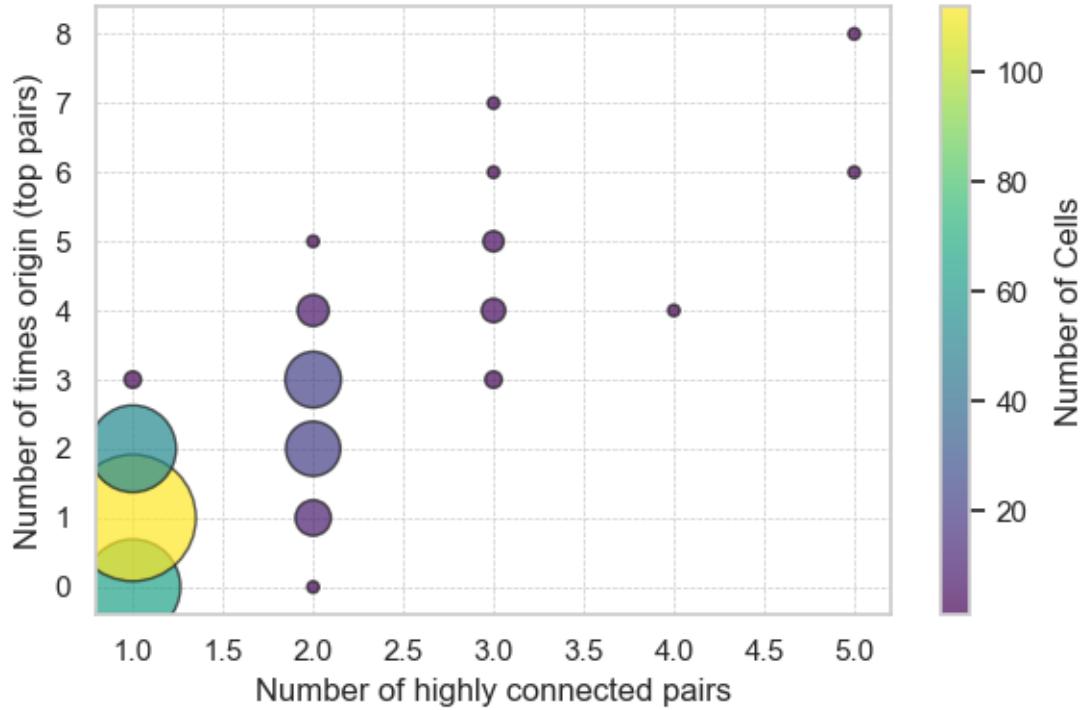
```
[2025-08-27 15:02:36] [INFO] calcium: build_neighbor_pair_stats: built 3162 pairs across 1 datasets (mean distance=16.33 um)
```

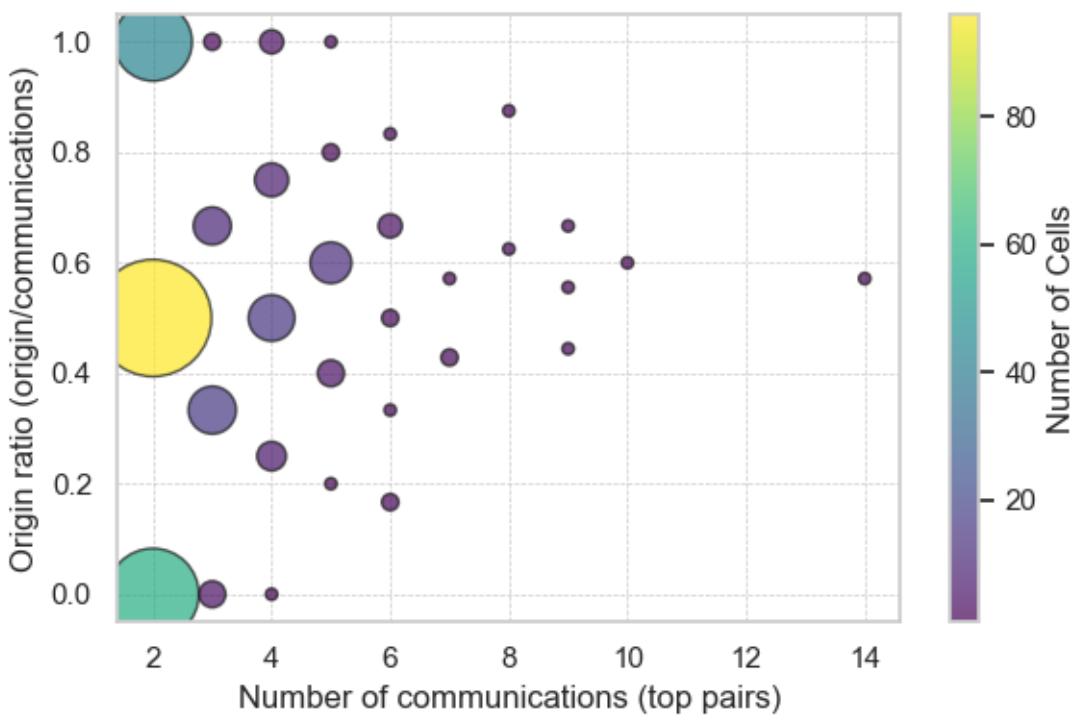
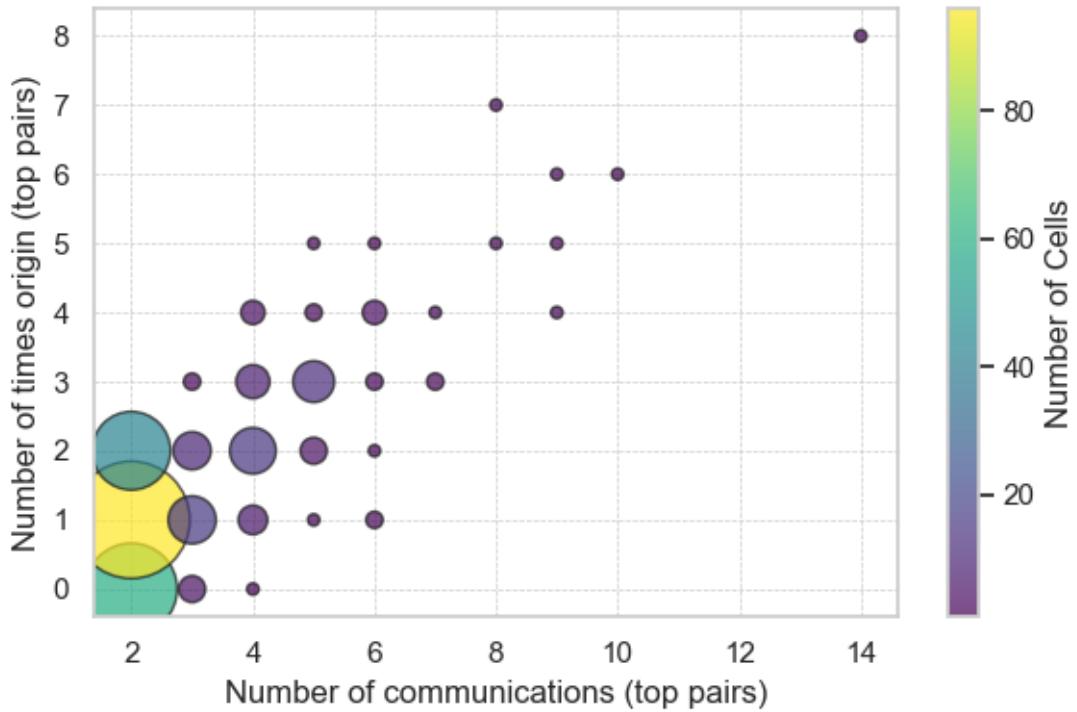


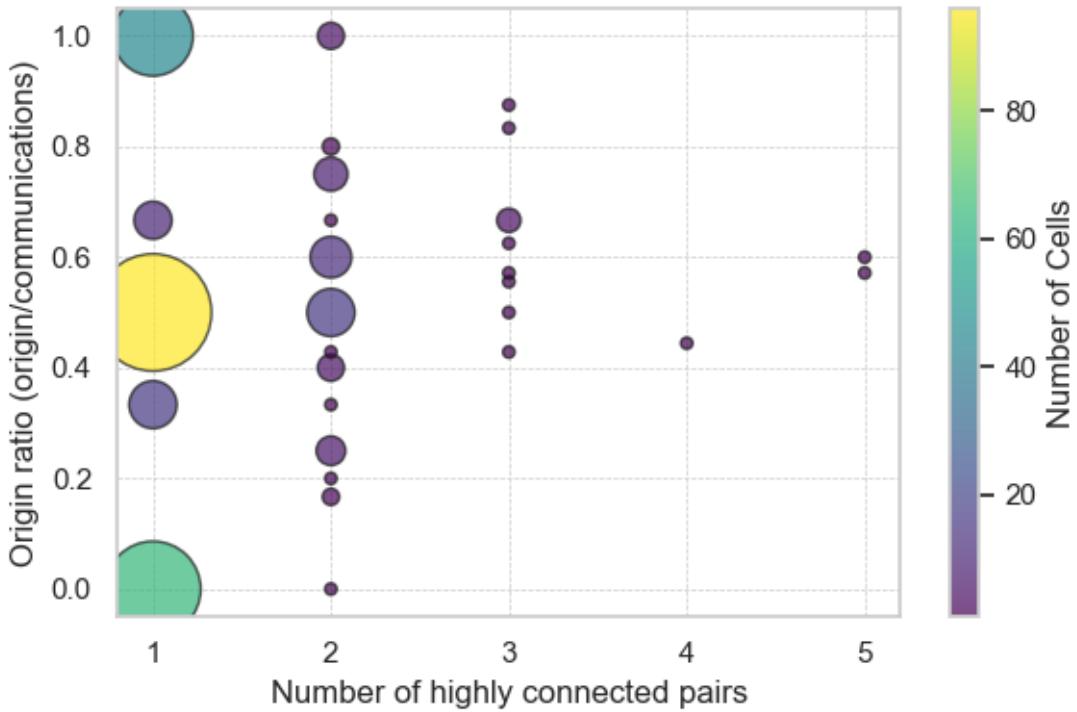
95th percentile threshold: 2.0

Cells involved in multiple pairs highly connected









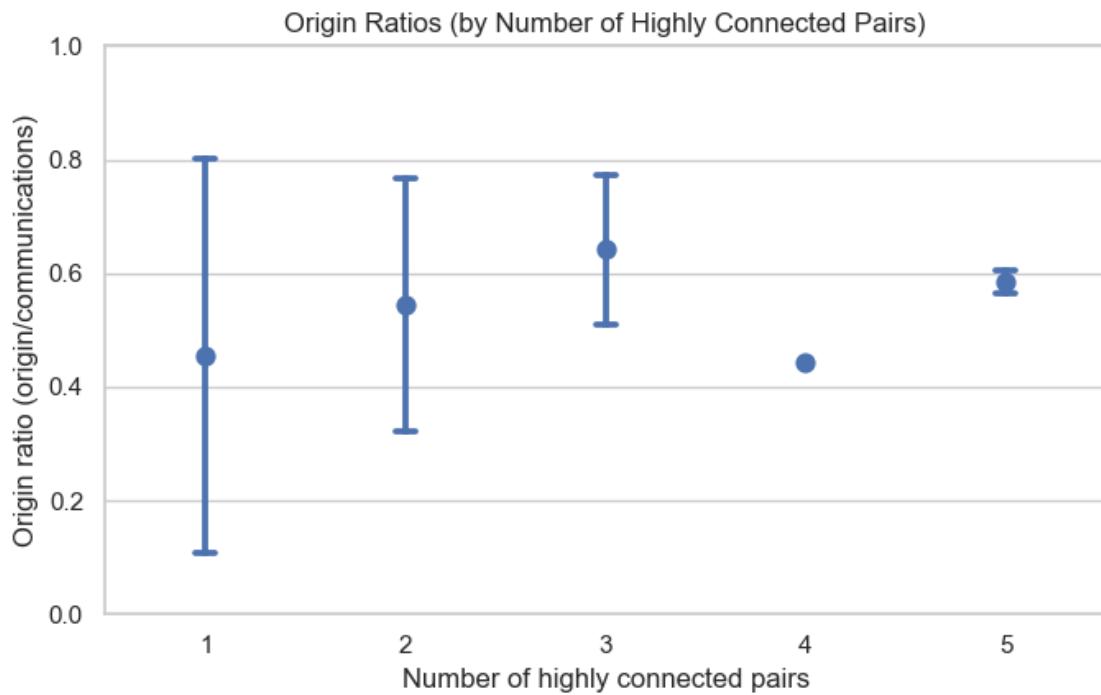
[2025-08-27 15:02:37] [INFO] calcium: plot_points_mean_std: N=231 for Number of highly connected pairs=1

[2025-08-27 15:02:37] [INFO] calcium: plot_points_mean_std: N=61 for Number of highly connected pairs=2

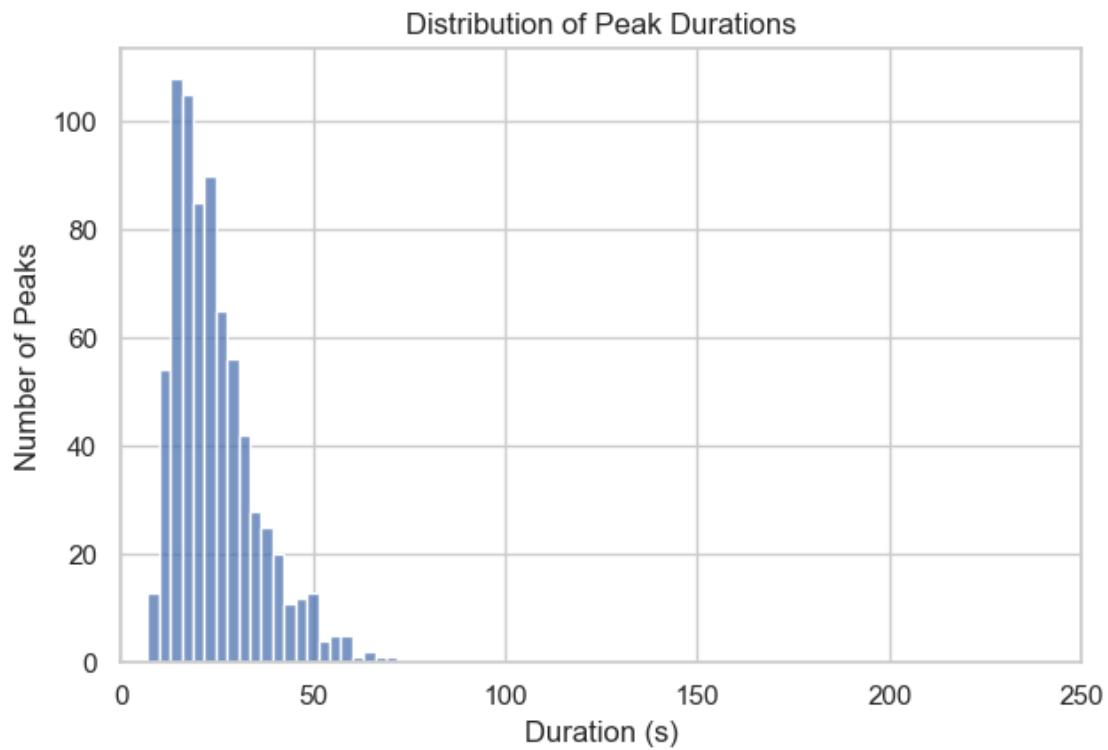
[2025-08-27 15:02:37] [INFO] calcium: plot_points_mean_std: N=11 for Number of highly connected pairs=3

[2025-08-27 15:02:37] [INFO] calcium: plot_points_mean_std: N=1 for Number of highly connected pairs=4

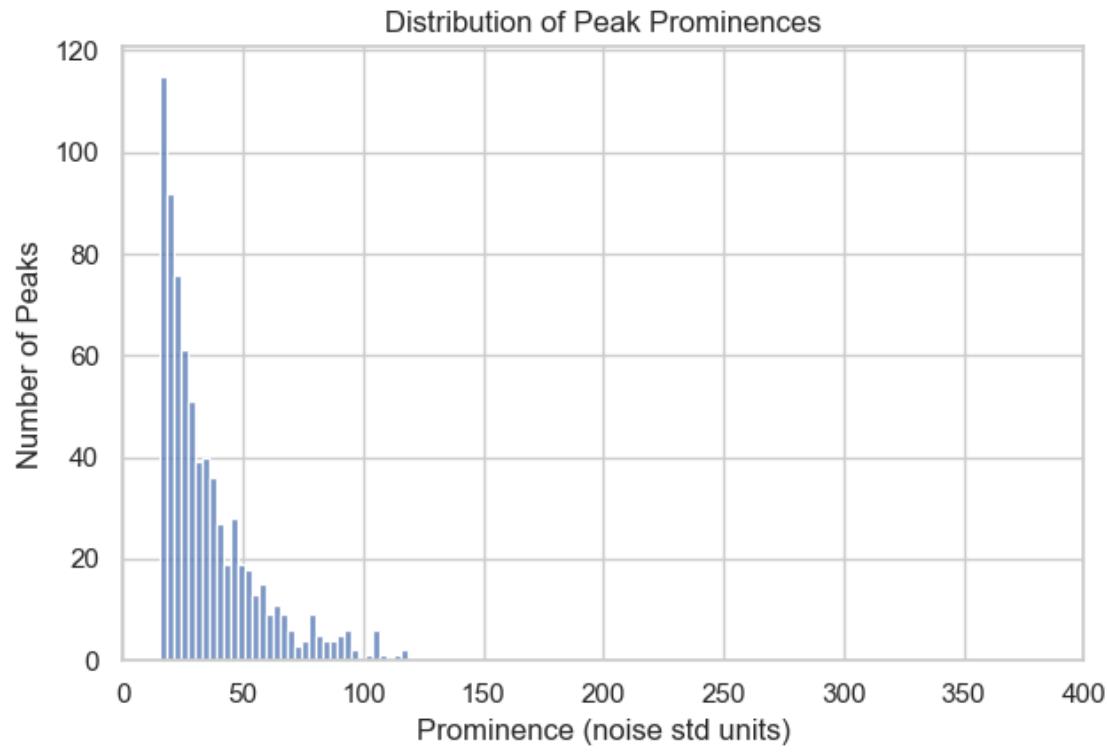
[2025-08-27 15:02:37] [INFO] calcium: plot_points_mean_std: N=2 for Number of highly connected pairs=5

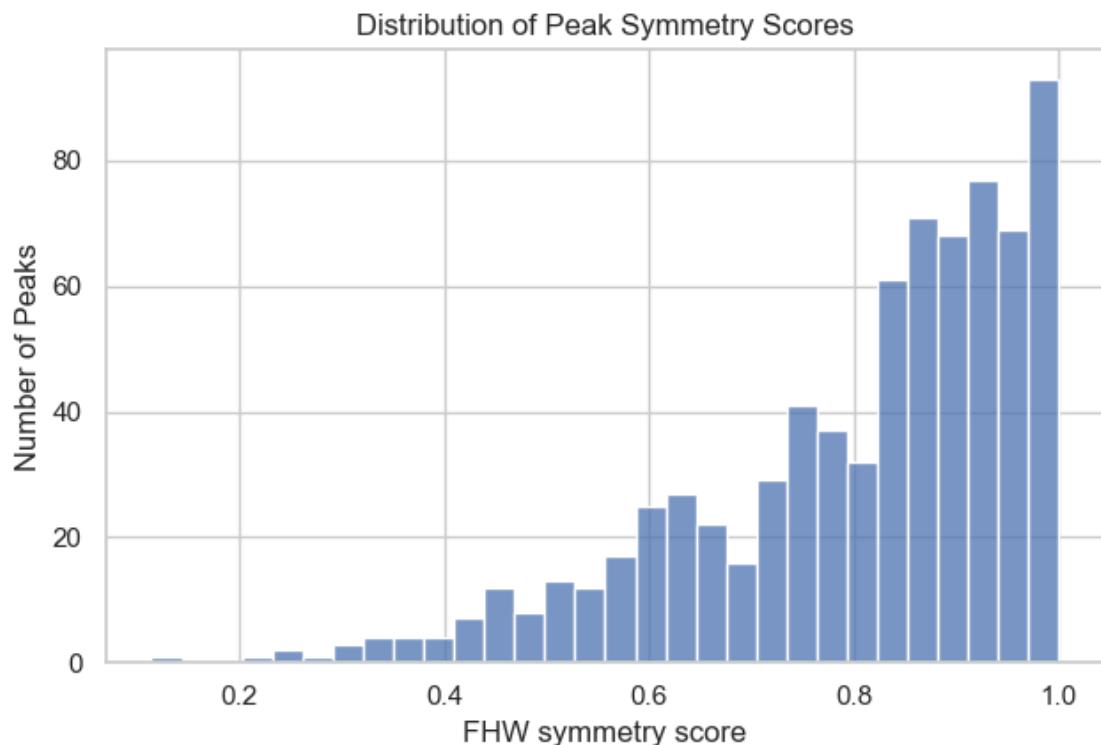


```
[2025-08-27 15:02:37] [INFO] calcium: plot_histogram: removed 11 outliers out of 757 on 'Duration (s)' (lower=-26, upper=72)
```

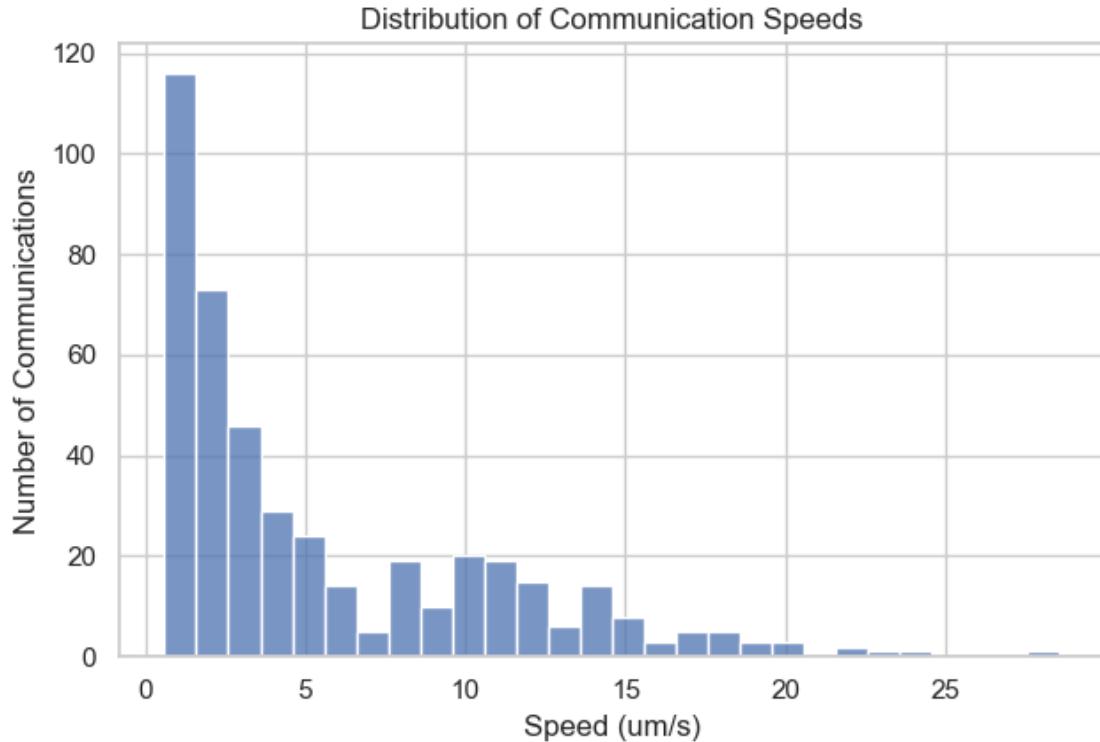


[2025-08-27 15:02:37] [INFO] calcium: plot_histogram: removed 20 outliers out of 757 on 'Prominence (noise std units)' (lower=-57.8, upper=124.2)

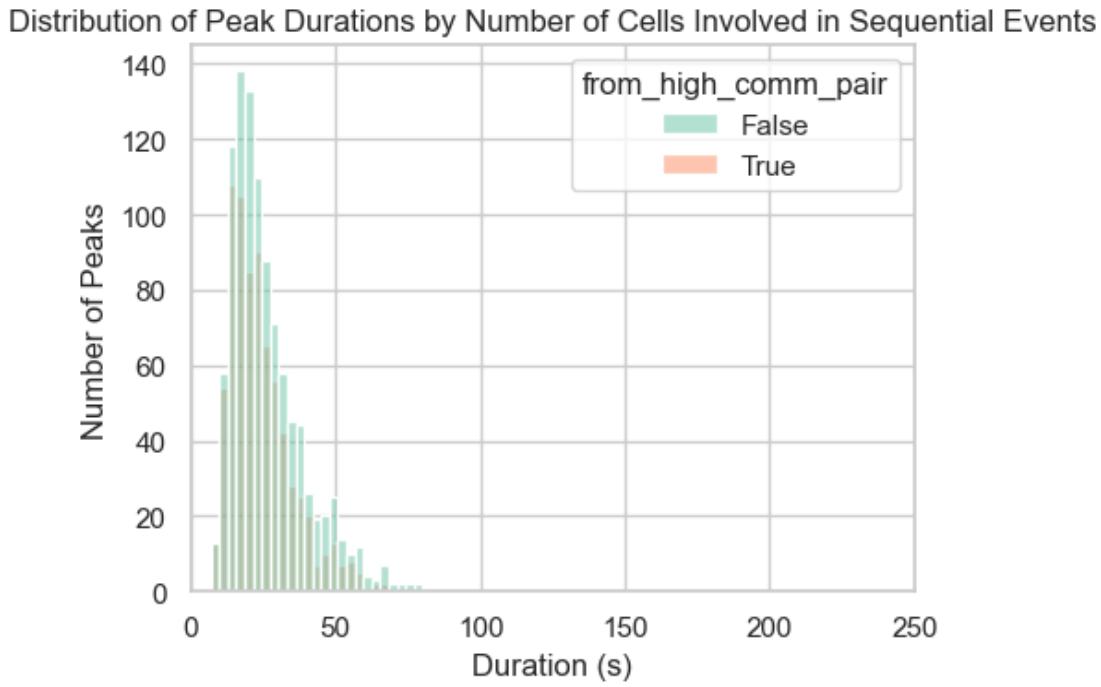




```
[2025-08-27 15:02:37] [INFO] calcium: plot_histogram: removed 0 outliers out of 442 on 'Speed (um/s)' (lower=-21.225, upper=31.905)
```

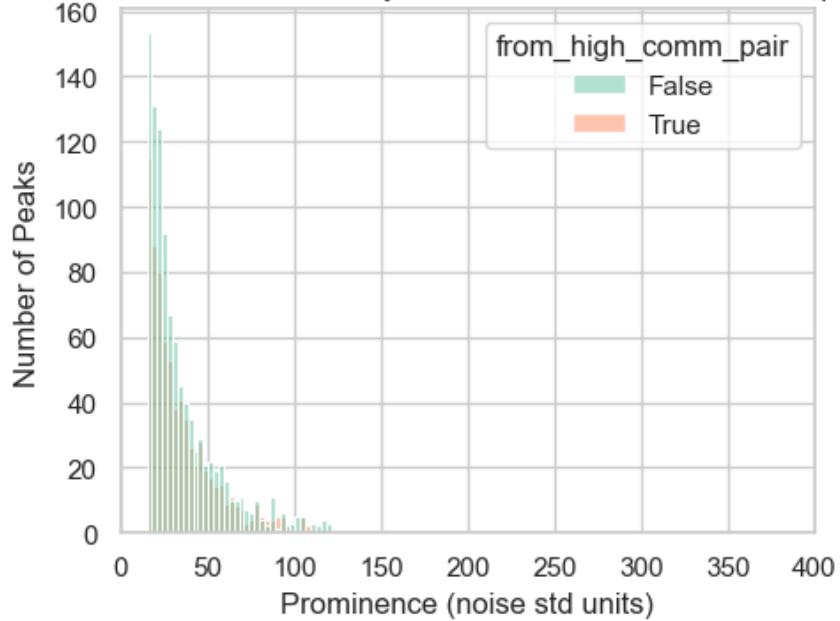


```
[2025-08-27 15:02:37] [INFO] calcium: plot_histogram_by_group: removed 23 outliers out of 1794 on 'Duration (s)' (lower=-32, upper=80)
```

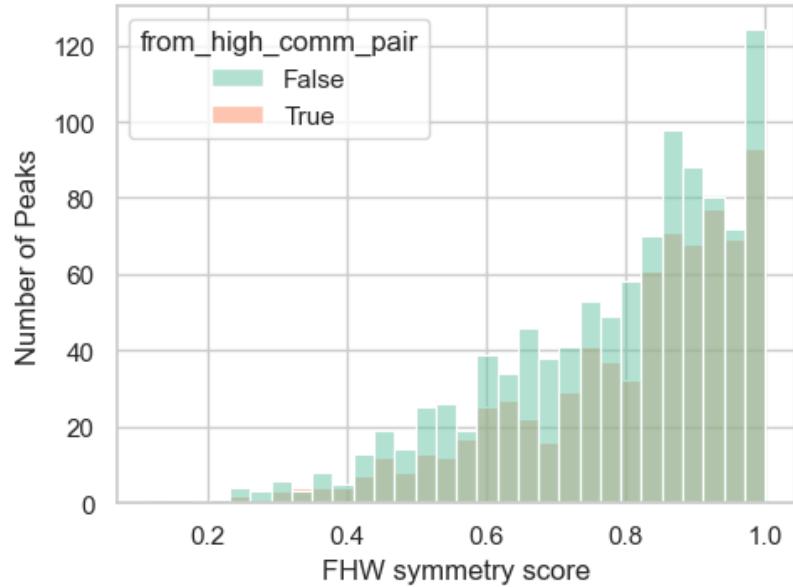


[2025-08-27 15:02:38] [INFO] calcium: plot_histogram_by_group: removed 53 outliers out of 1794 on 'Prominence (noise std units)' (lower=-56.35, upper=122.32)

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

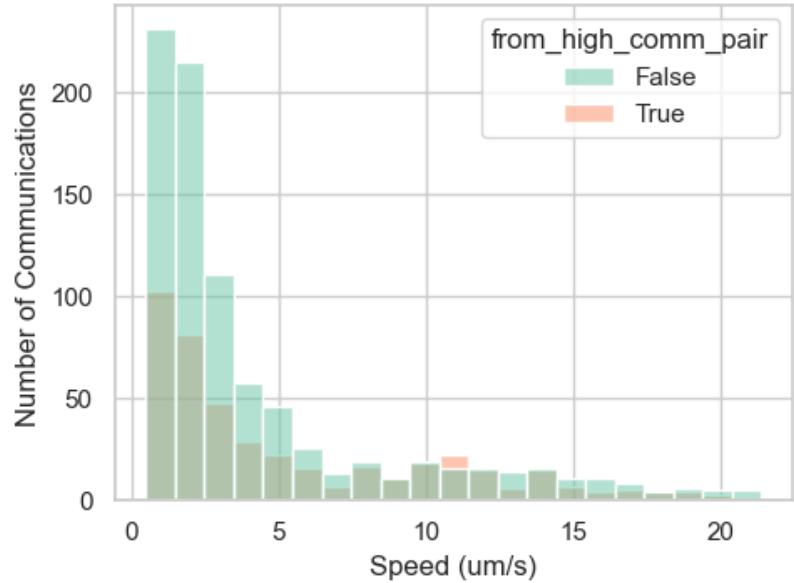


Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



[2025-08-27 15:02:38] [INFO] calcium: plot_histogram_by_group: removed 17 outliers out of 1315 on 'Speed (um/s)' (lower=-13.515, upper=21.45)

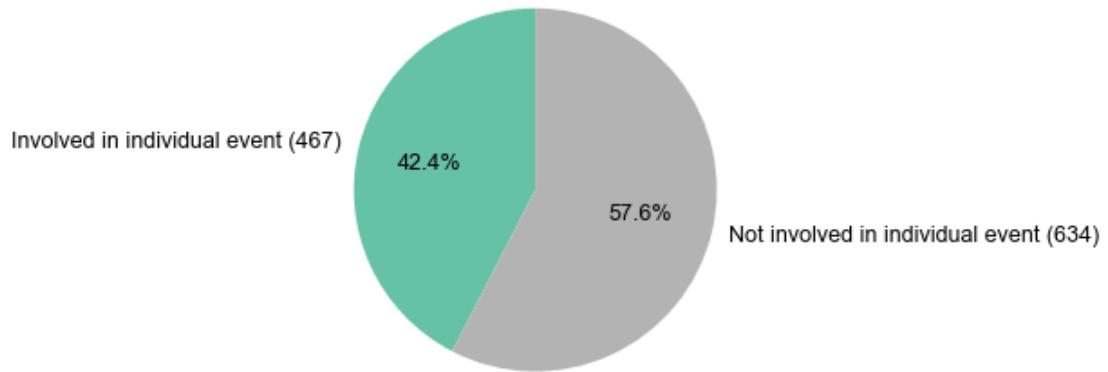
Distribution of Communication Speeds by Number of Cells Involved in Sequential Events



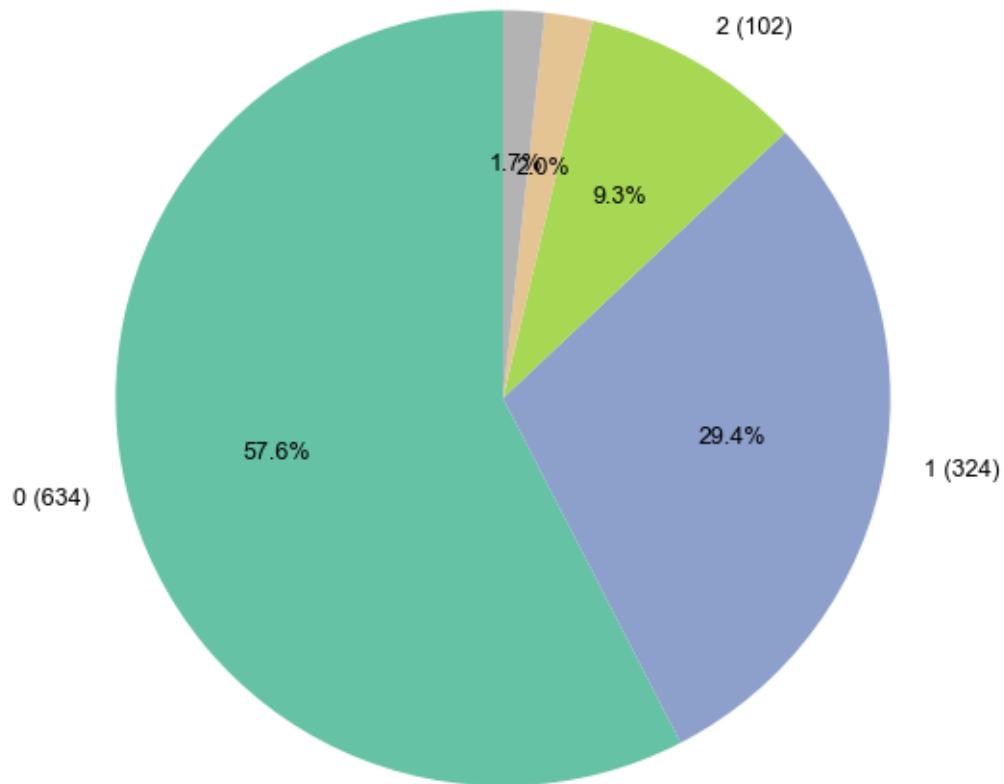
1.4 INDIVIDUAL EVENTS

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+)

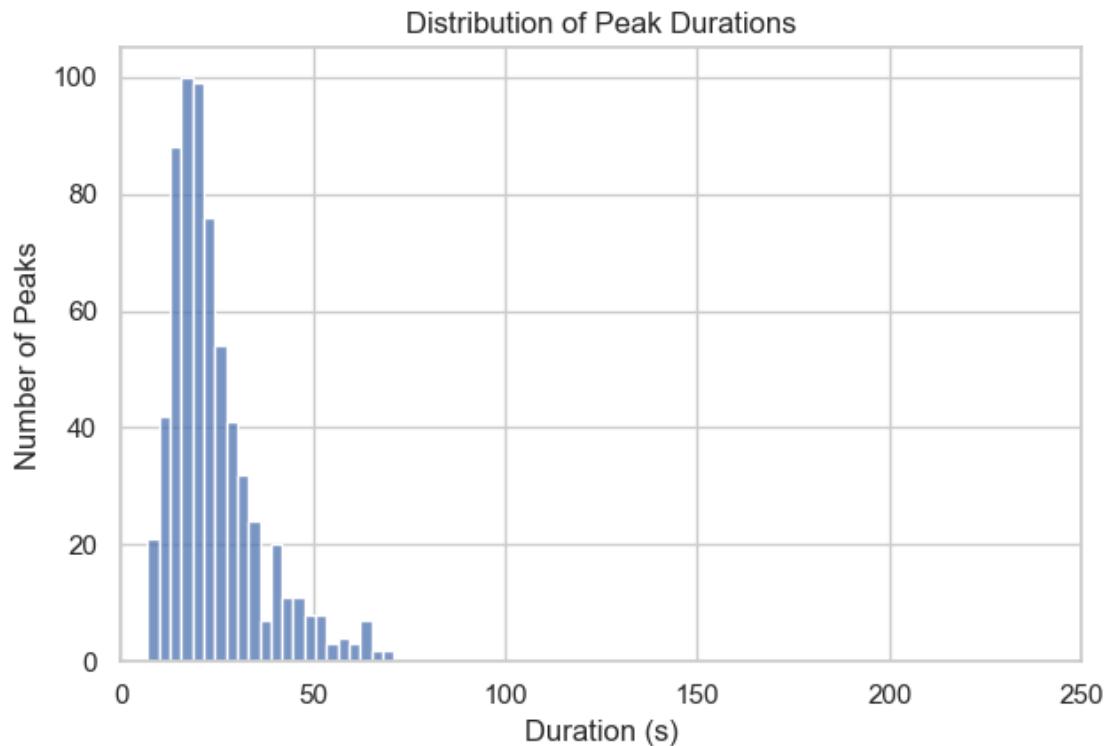


```
[2025-08-27 15:02:38] [ERROR] calcium: Failed to read image
'D:\Mateo\20250618\Output\IS4\cell-
mapping\cell_occurrences_in_individual_events_overlay.png': [Errno 2] No such
file or directory: 'D:\\Mateo\\20250618\\Output\\IS4\\cell-
mapping\\cell_occurrences_in_individual_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundException: [Errno 2] No such file or directory:
```

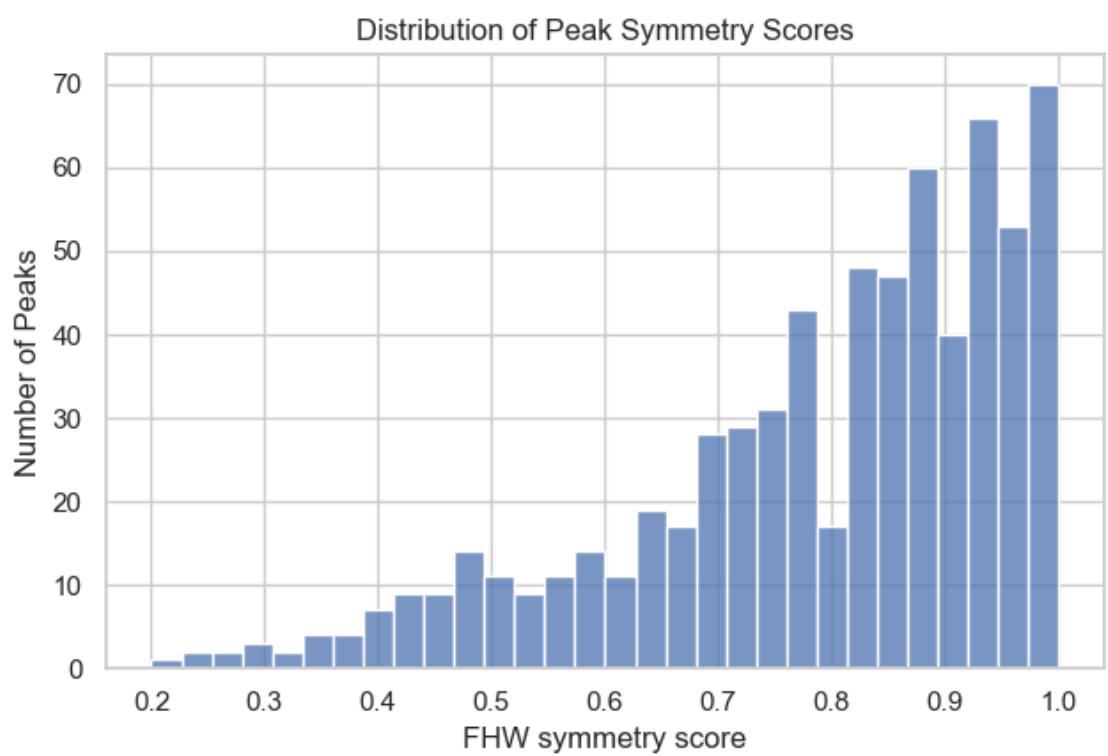
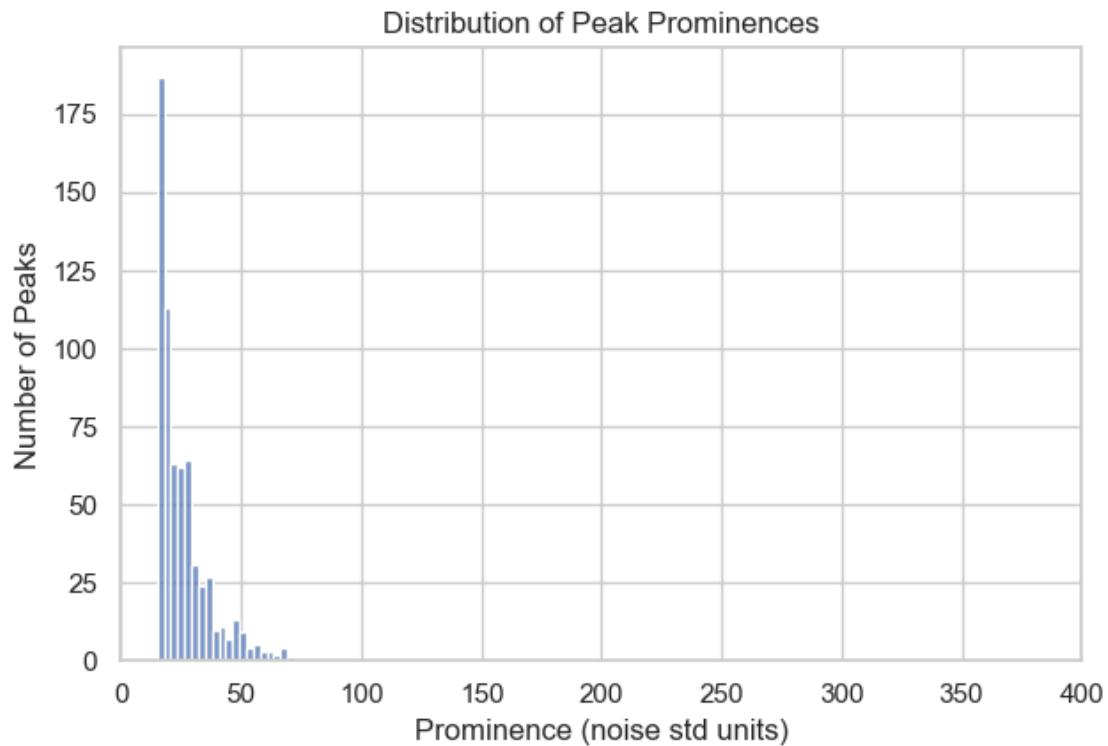
'D:\\Mateo\\20250618\\Output\\IS4\\cell-mapping\\cell_occurrences_in_individual_events_overlay.png'

1.4.2 Peaks statistics in individual events

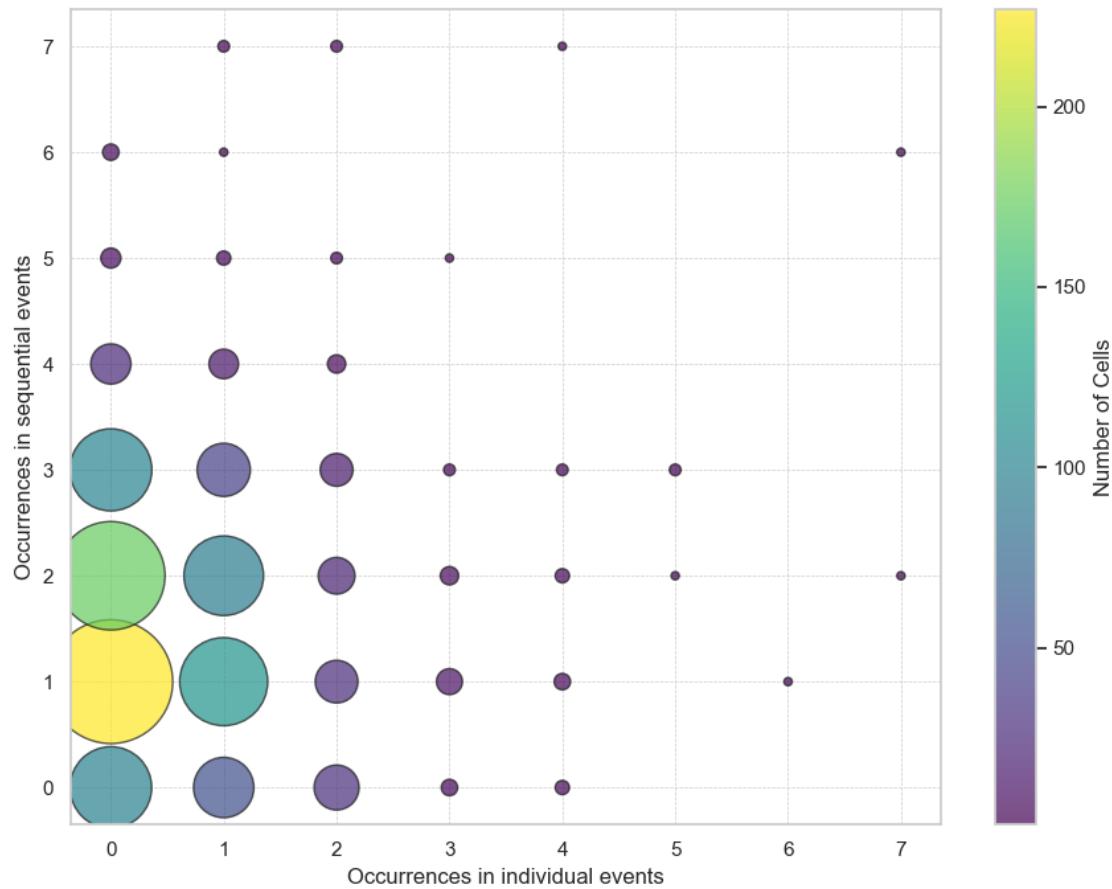
[2025-08-27 15:02:39] [INFO] calcium: plot_histogram: removed 18 outliers out of 681 on 'Duration (s)' (lower=-26, upper=72)



[2025-08-27 15:02:39] [INFO] calcium: plot_histogram: removed 38 outliers out of 681 on 'Prominence (noise std units)' (lower=-23.9, upper=72.7)



1.4.3 Correlation between event activity level & individual activity level



```
[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: removed 11/1101 outliers on 'Occurrences in sequential events' (lower=-2, upper=5)
```

```
[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: N=630 for Occurrences in individual events=0
```

```
[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: N=321 for Occurrences in individual events=1
```

```
[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: N=100 for Occurrences in individual events=2
```

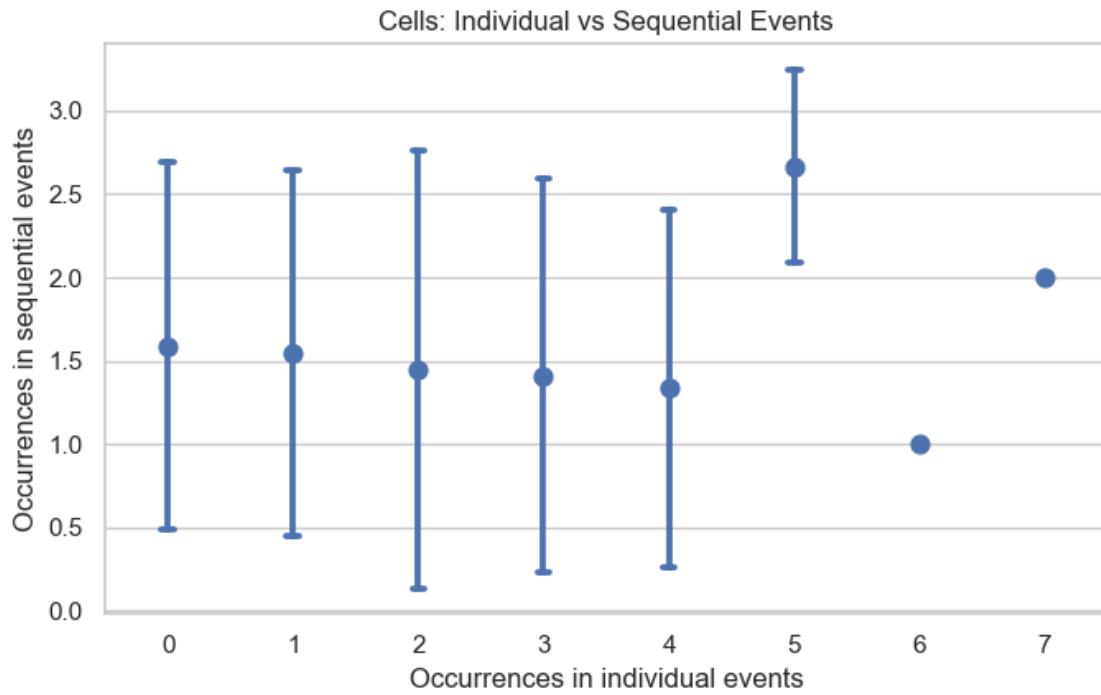
```
[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: N=22 for Occurrences in individual events=3
```

```
[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: N=12 for Occurrences in individual events=4
```

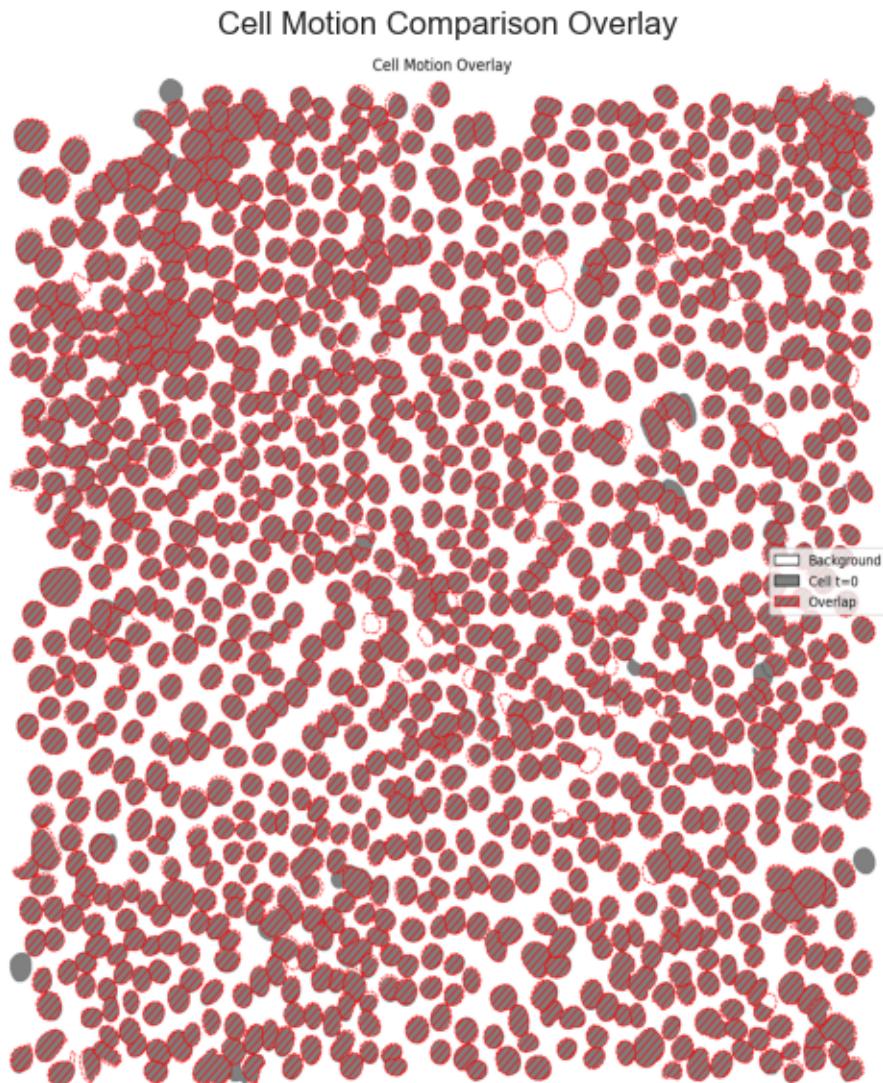
[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: N=3 for Occurrences in individual events=5

[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: N=1 for Occurrences in individual events=6

[2025-08-27 15:02:40] [INFO] calcium: plot_points_mean_std: N=1 for Occurrences in individual events=7



1.5 CELLS MOTION



Number of cells:

- Hoechst image taken at t=0: 1101
- Hoechst image taken at t=1801: 1102
- Number of cells difference: absolute 1, relative 0.09%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1194845
- Pixels segmented as cell at t=1801: 1213495
- Overlapping pixels between t=0 and t=1801: 1128249 (93.69% of total)
- Pixels exclusive to t=0: 66596 (5.57% of total)
- Pixels exclusive to t=1801: 85246 (7.03% of total)

executed

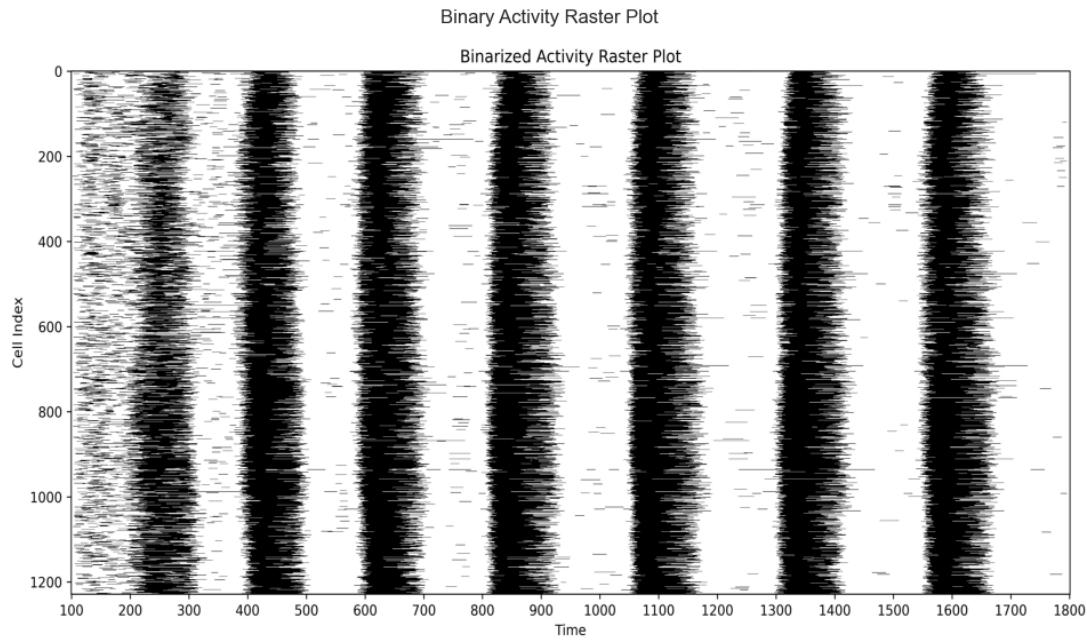
August 27, 2025

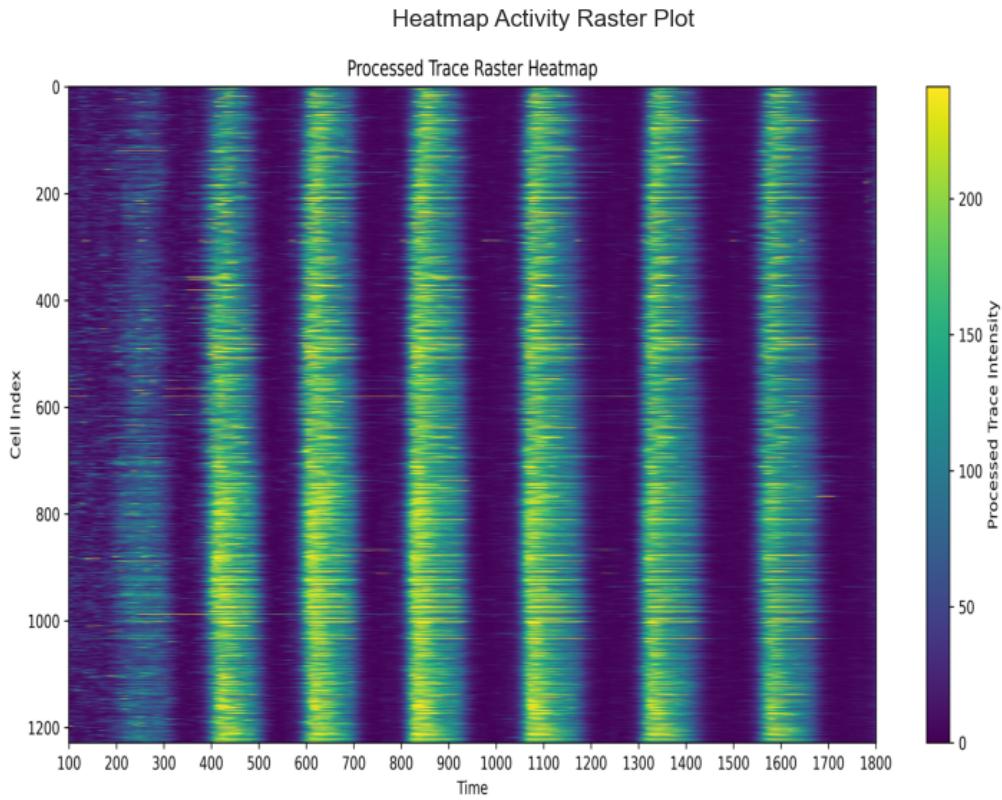
1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

1.0.1 Initialization

1.1 POPULATION

1.1.1 Binary & Heatmap Raster Plot





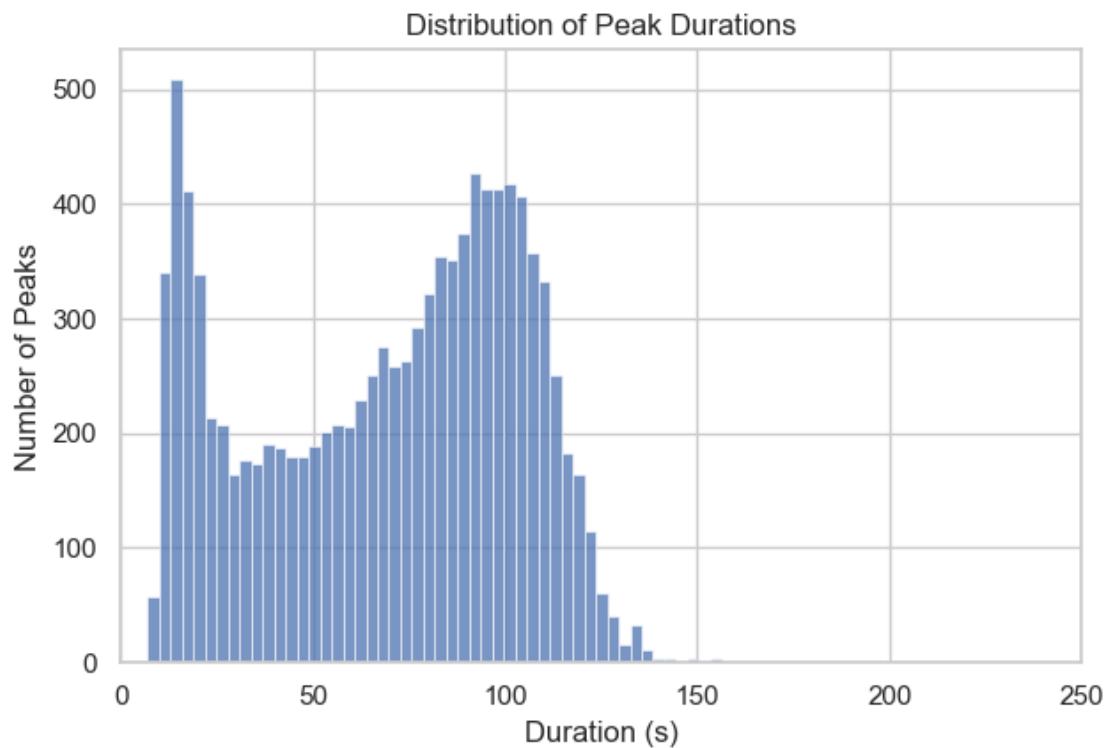
1.1.2 Peaks population

Total number of peaks: 10758

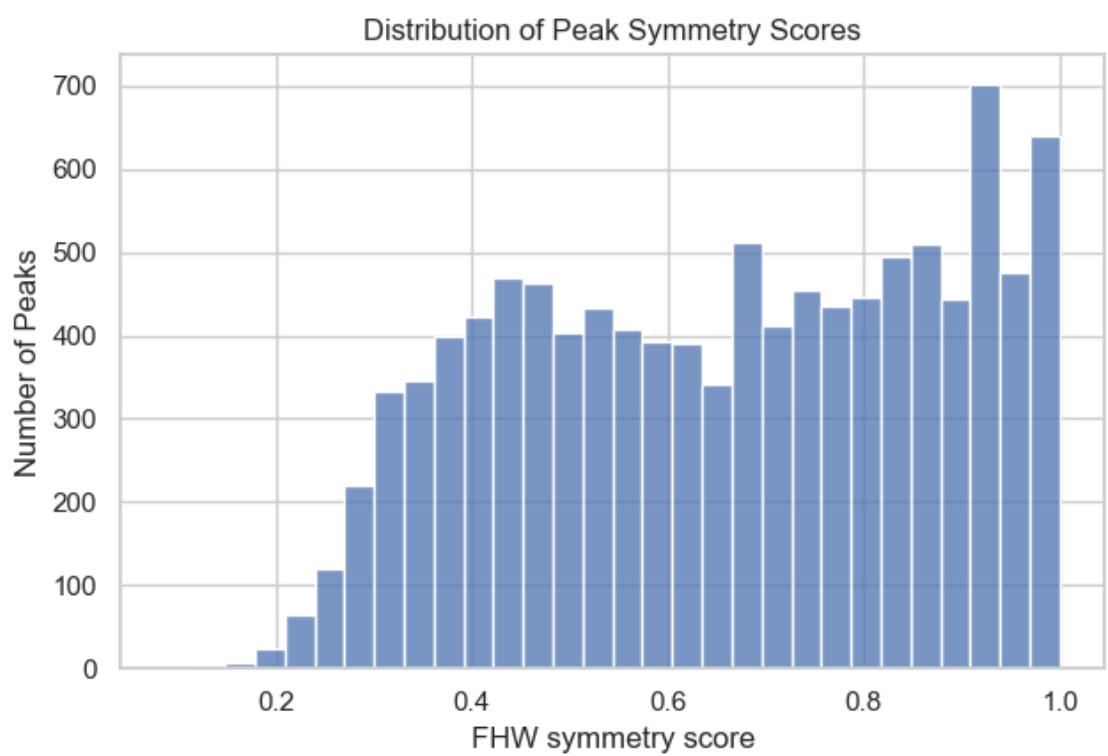
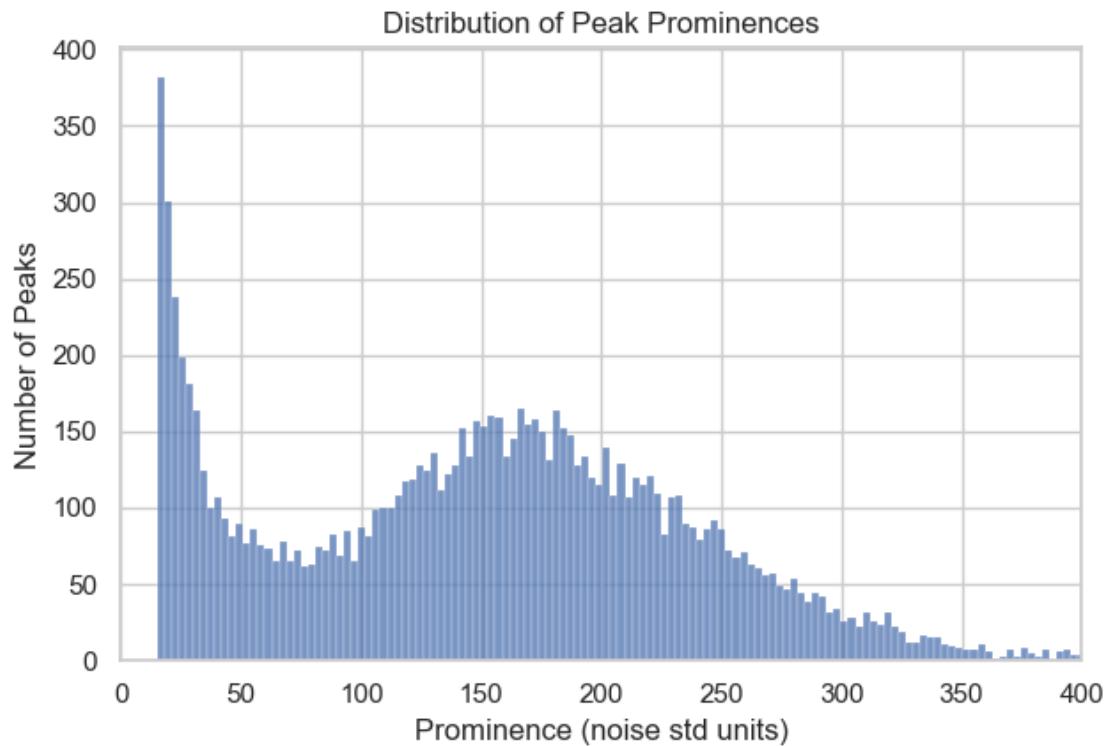
Total number of cells: 1229

1.1.3 Peaks statistics

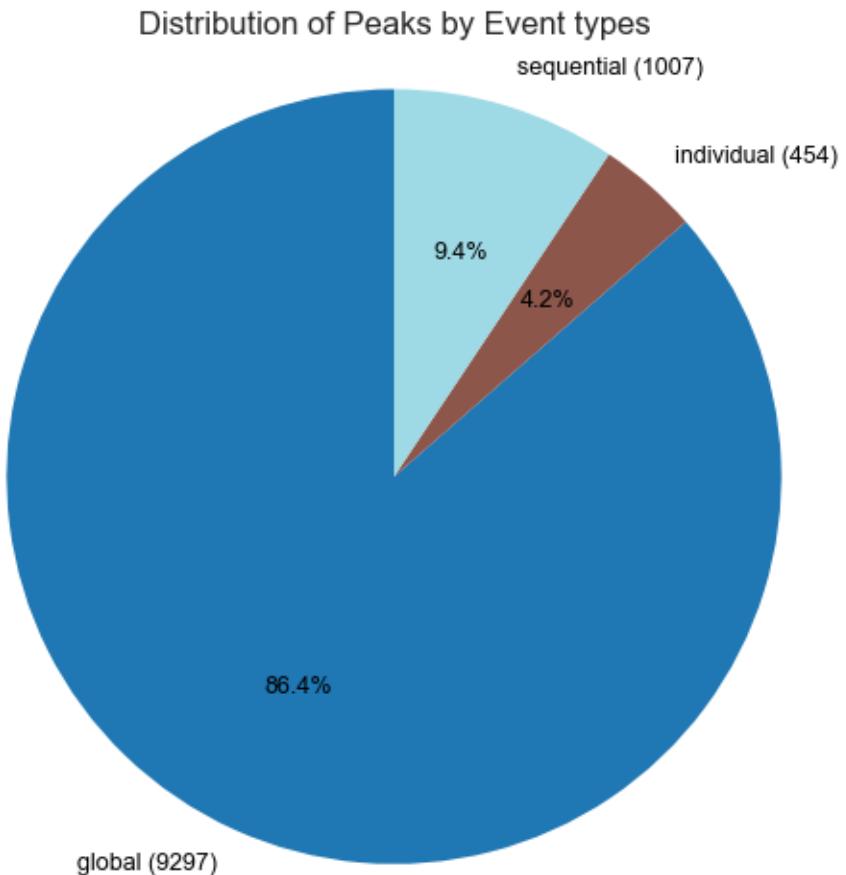
```
[2025-08-27 15:09:13] [INFO] calcium: plot_histogram: removed 0 outliers out of  
10758 on 'Duration (s)' (lower=-139, upper=274)
```



```
[2025-08-27 15:09:13] [INFO] calcium: plot_histogram: removed 3 outliers out of  
10758 on 'Prominence (noise std units)' (lower=-322.4, upper=608.95)
```

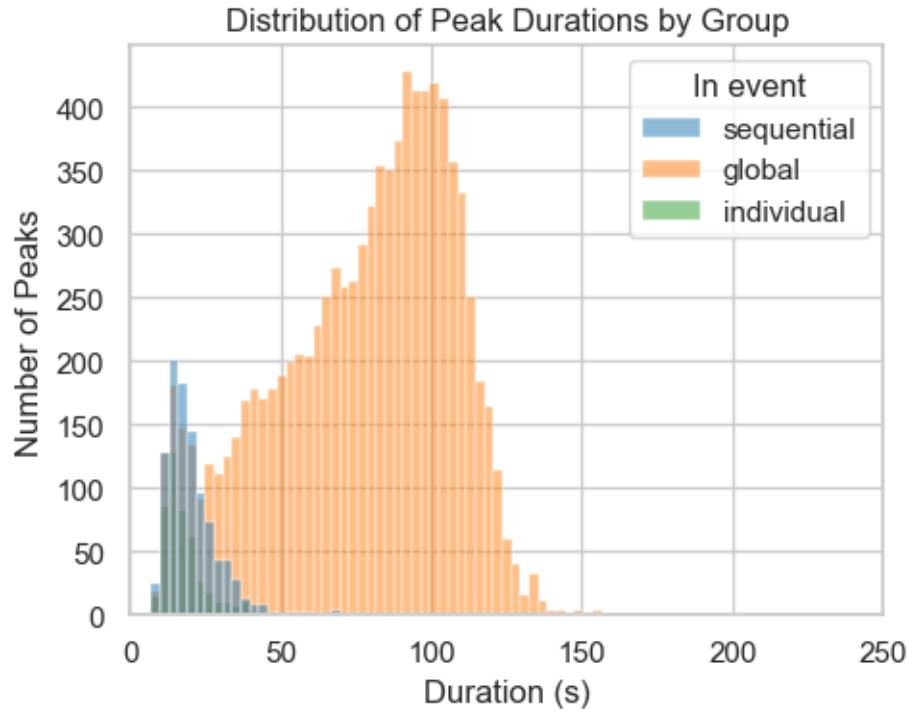


1.1.4 Distribution of peaks per event types

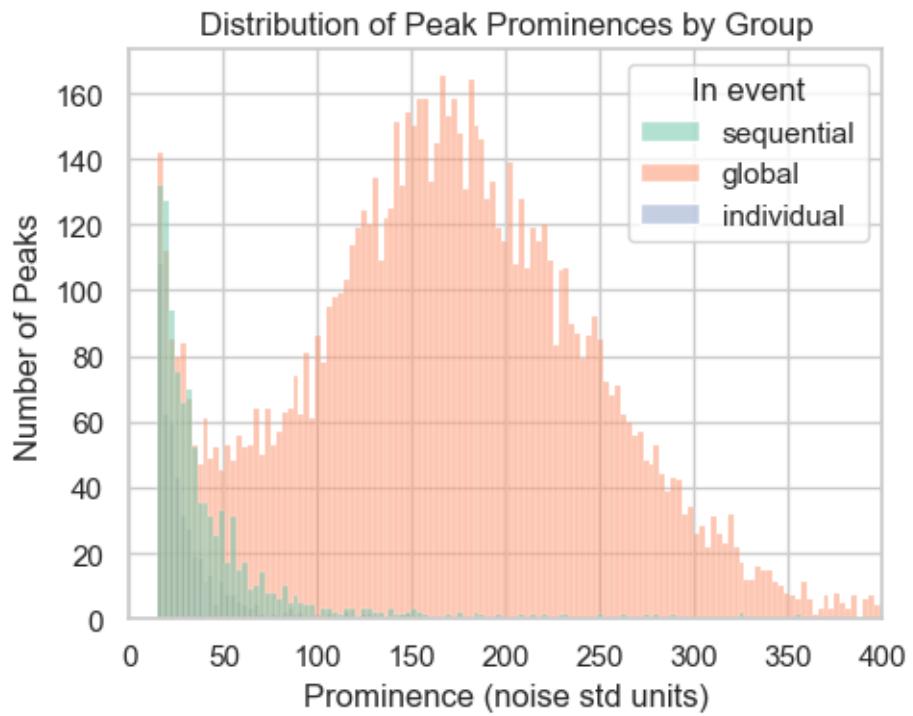


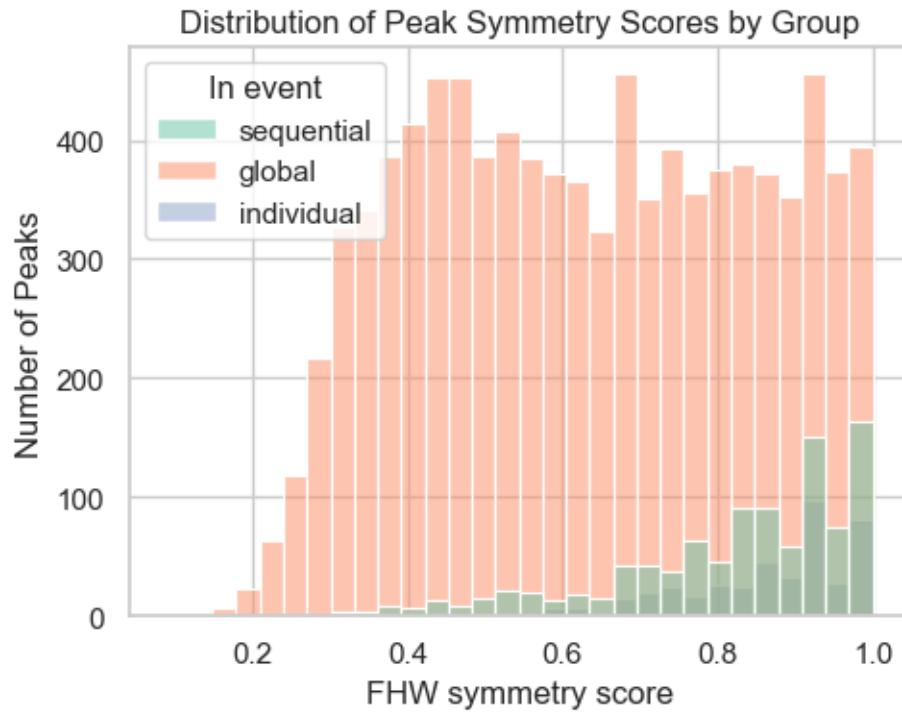
1.1.5 Peaks statistics per event types

```
[2025-08-27 15:09:14] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 10758 on 'Duration (s)' (lower=-139, upper=274)
```



```
[2025-08-27 15:09:14] [INFO] calcium: plot_histogram_by_group: removed 3 outliers out of 10758 on 'Prominence (noise std units)' (lower=-322.4, upper=608.95)
```

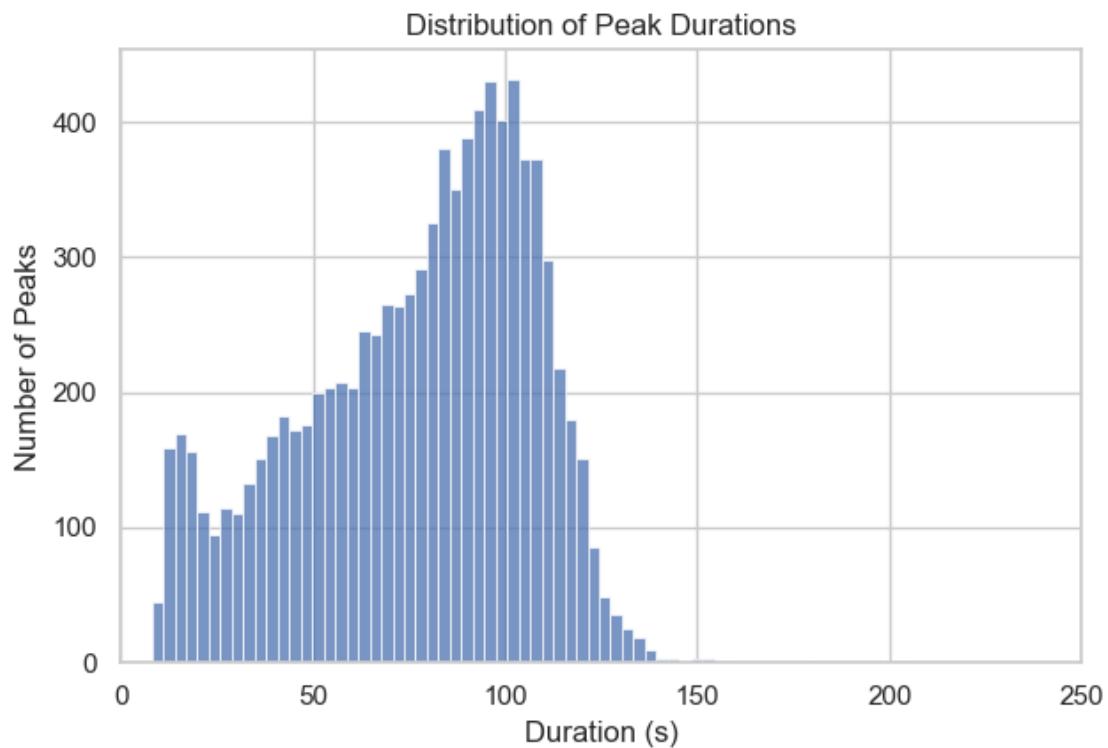




1.2 GLOBAL EVENTS

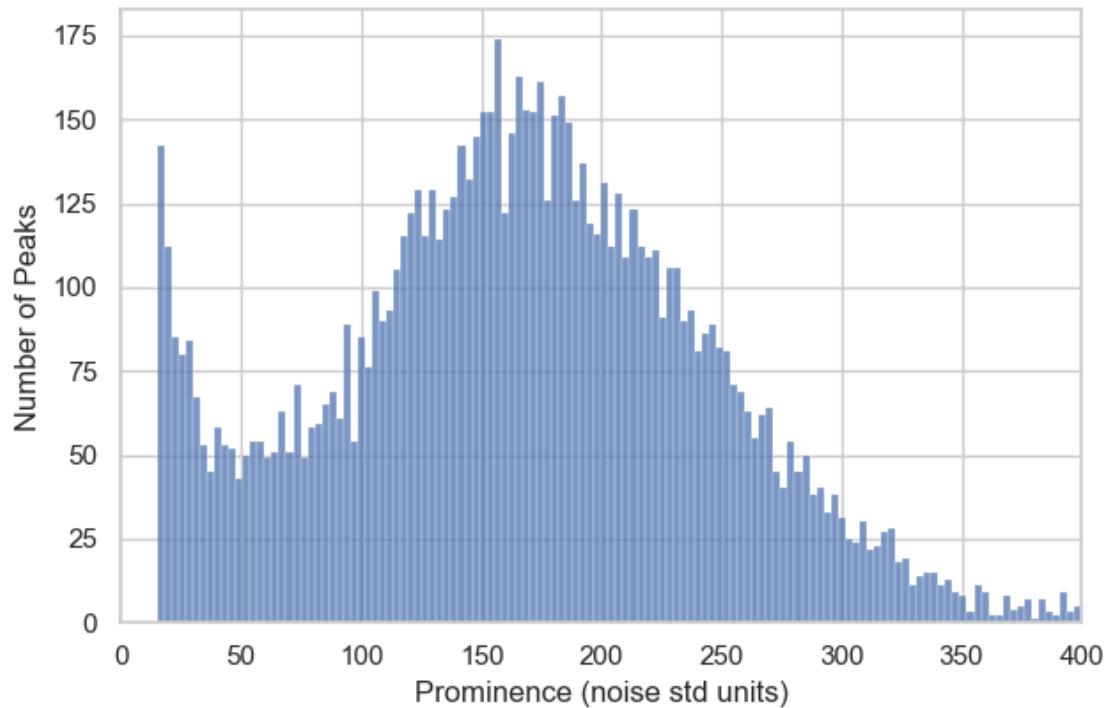
1.2.1 Peak statistics in global events

```
[2025-08-27 15:09:15] [INFO] calcium: plot_histogram: removed 1 outliers out of  
9297 on 'Duration (s)' (lower=-80, upper=235)
```

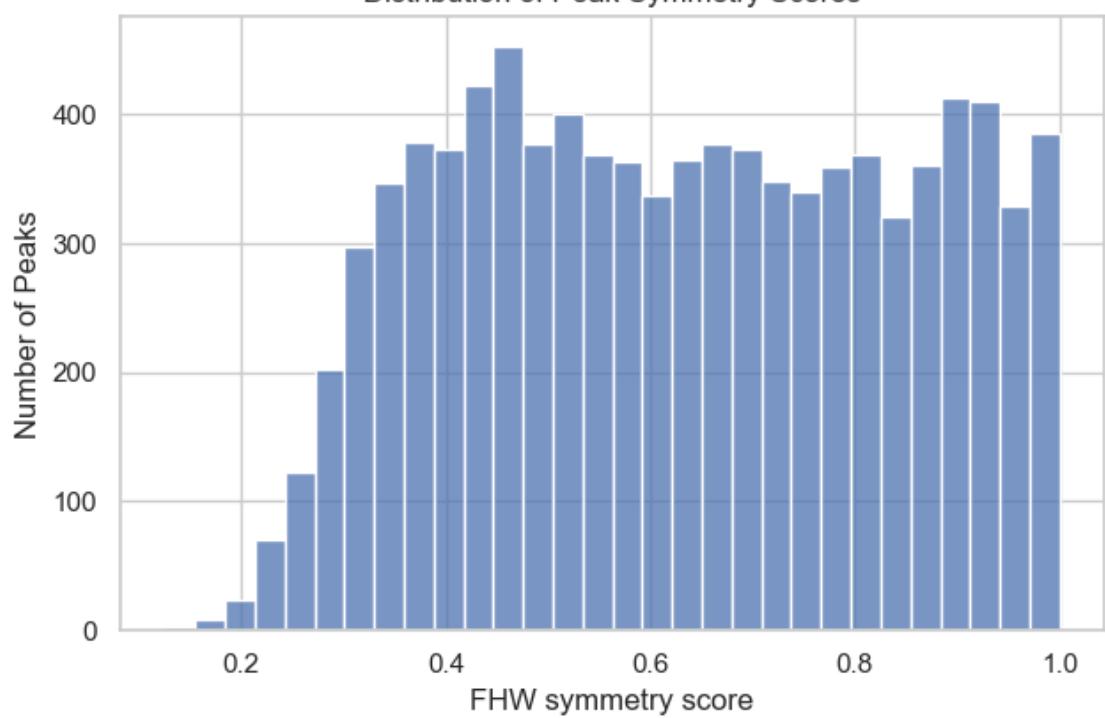


```
[2025-08-27 15:09:15] [INFO] calcium: plot_histogram: removed 5 outliers out of  
9297 on 'Prominence (noise std units)' (lower=-197, upper=531)
```

Distribution of Peak Prominences

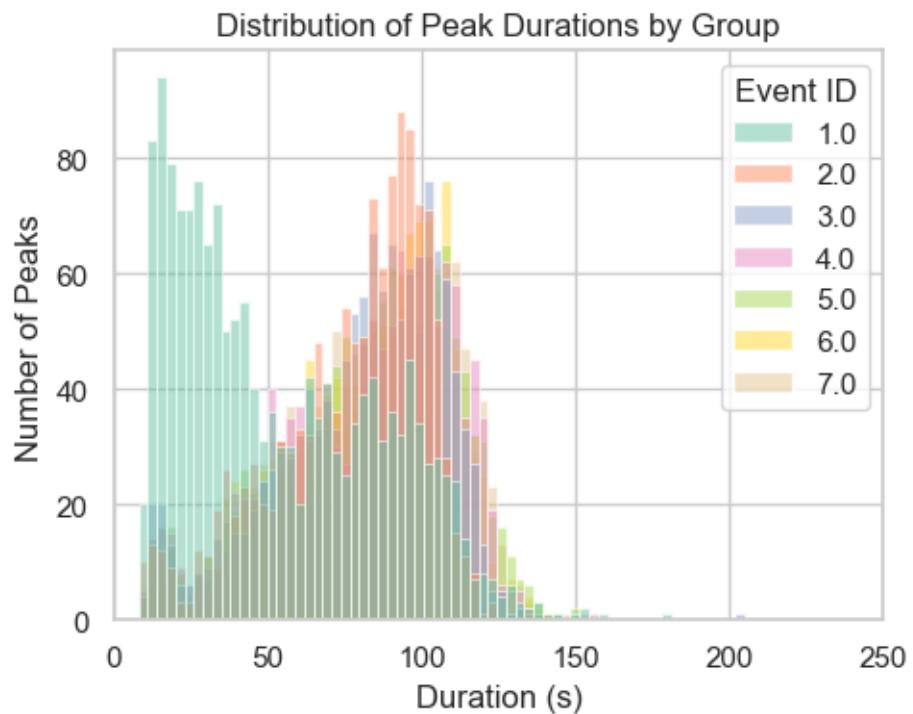


Distribution of Peak Symmetry Scores

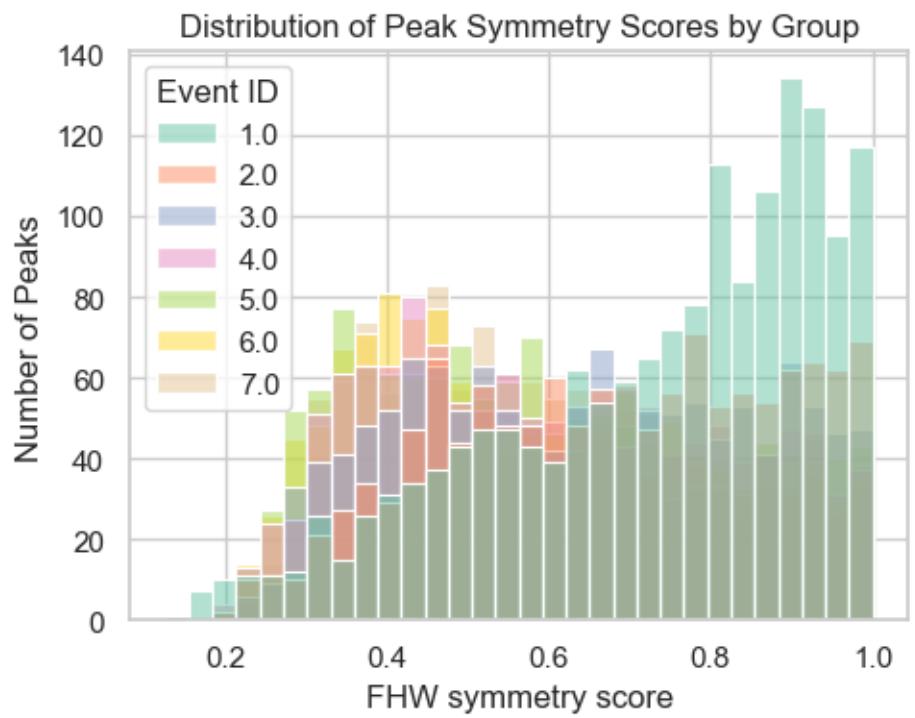
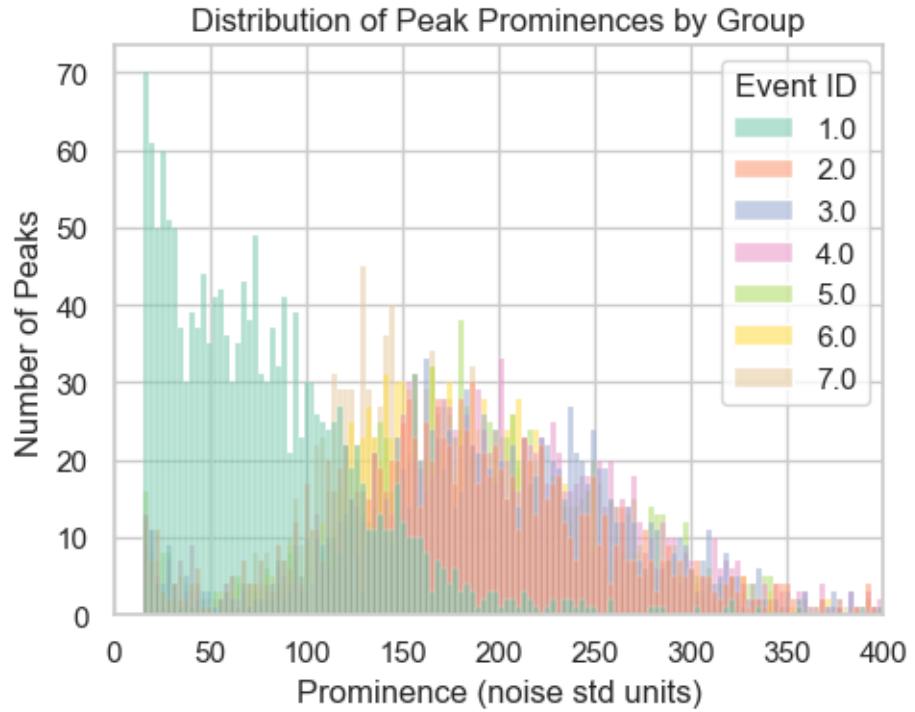


1.2.2 Peak statistics in global event per event ID

[2025-08-27 15:09:15] [INFO] calcium: plot_histogram_by_group: removed 1 outliers out of 9297 on 'Duration (s)' (lower=-80, upper=235)

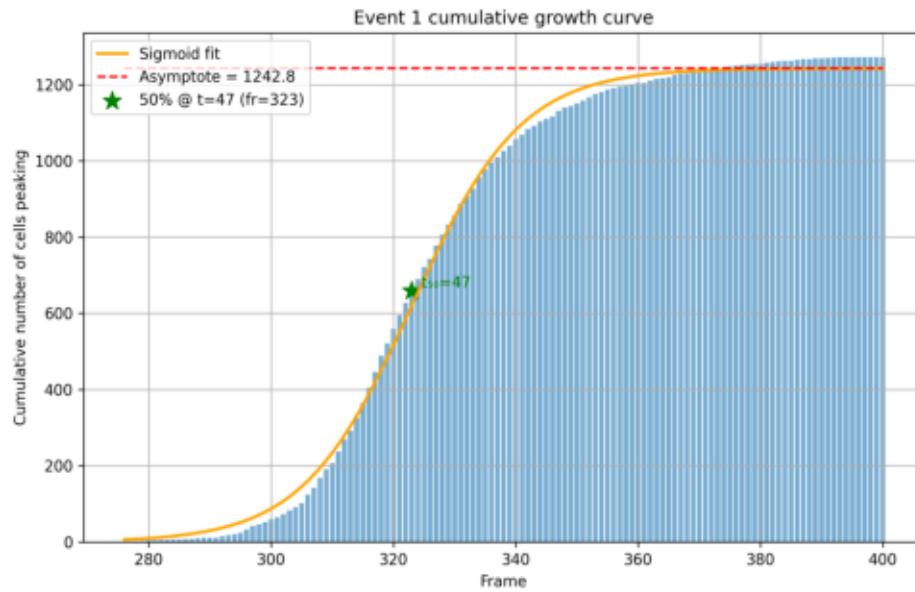


[2025-08-27 15:09:16] [INFO] calcium: plot_histogram_by_group: removed 5 outliers out of 9297 on 'Prominence (noise std units)' (lower=-197, upper=531)

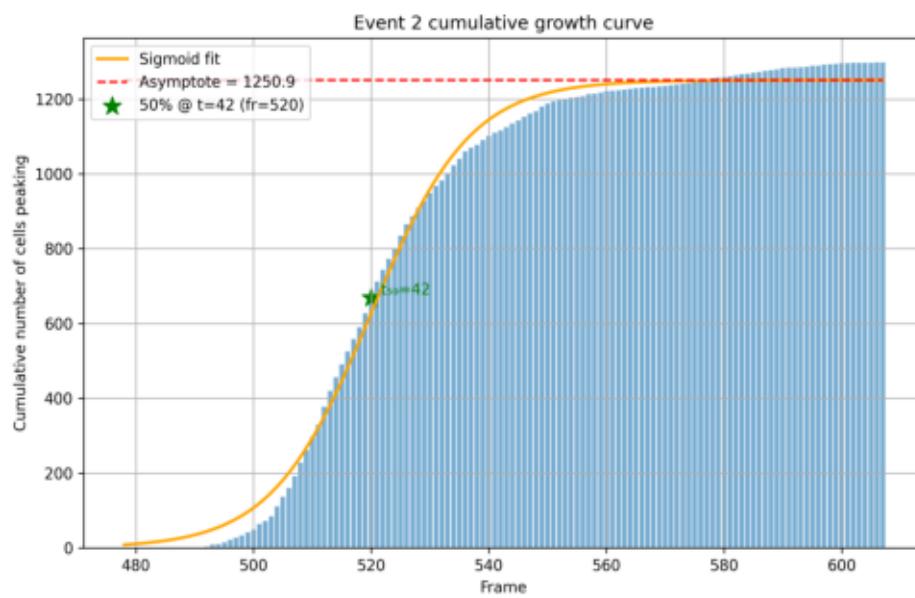


1.2.3 Kinetics of global events

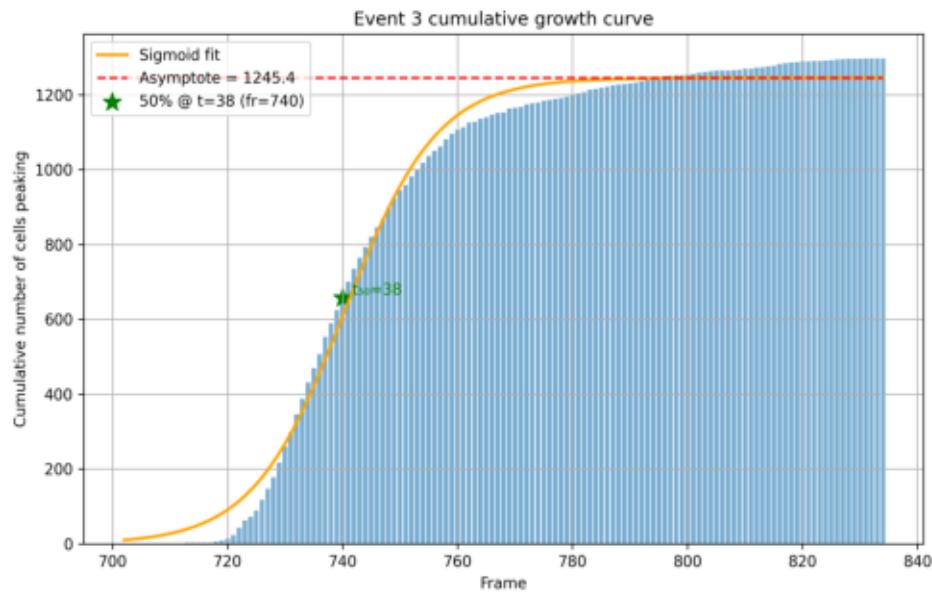
Event Activity Overlay (Event ID: 1)



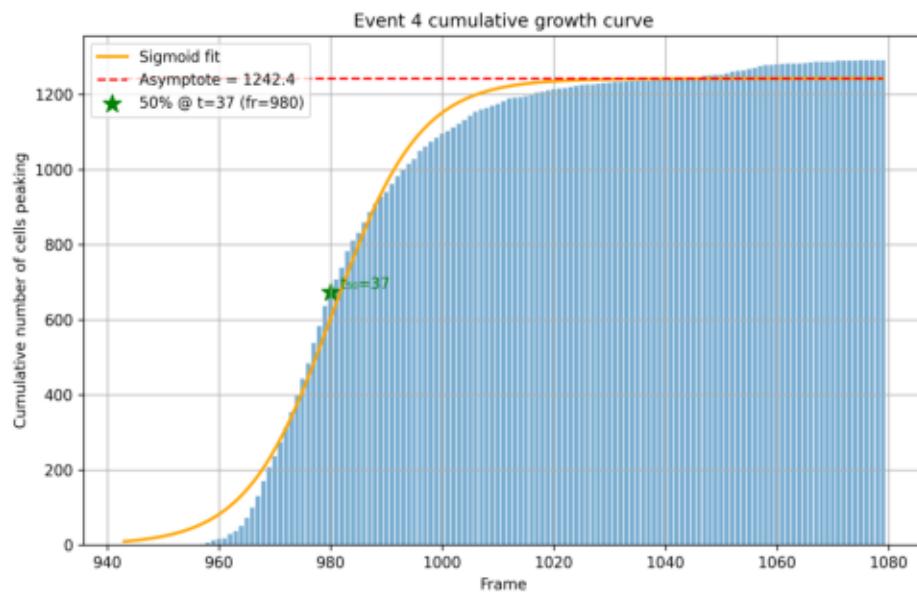
Event Activity Overlay (Event ID: 2)



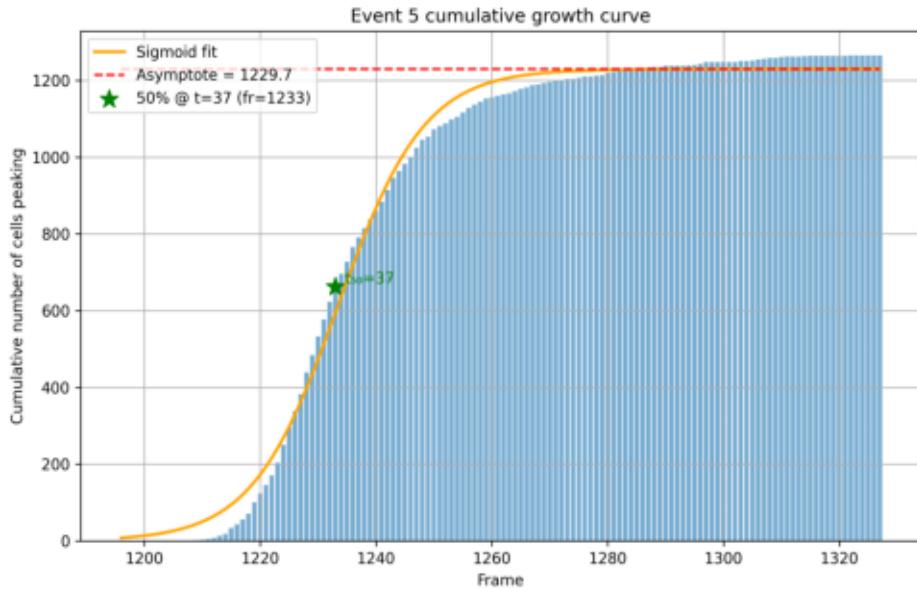
Event Activity Overlay (Event ID: 3)



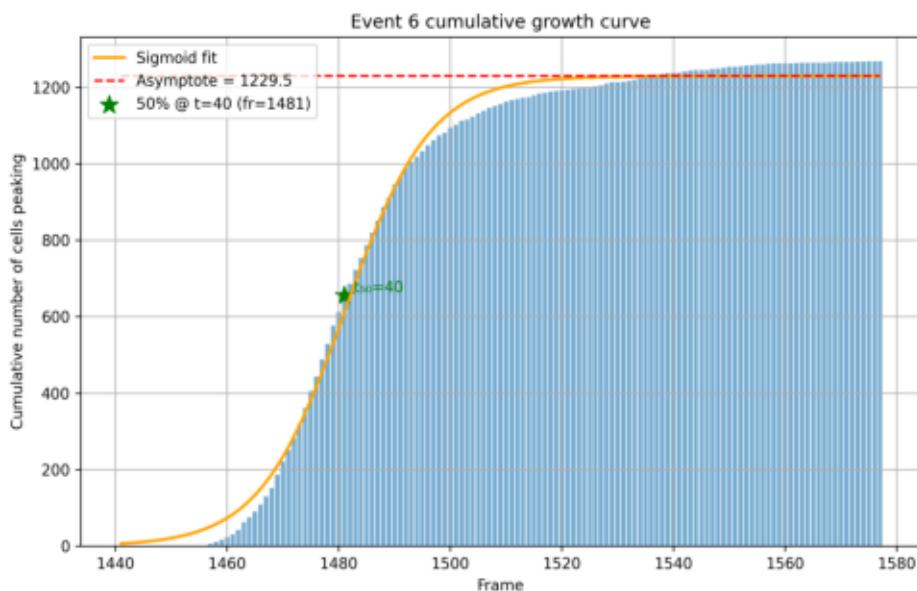
Event Activity Overlay (Event ID: 4)



Event Activity Overlay (Event ID: 5)



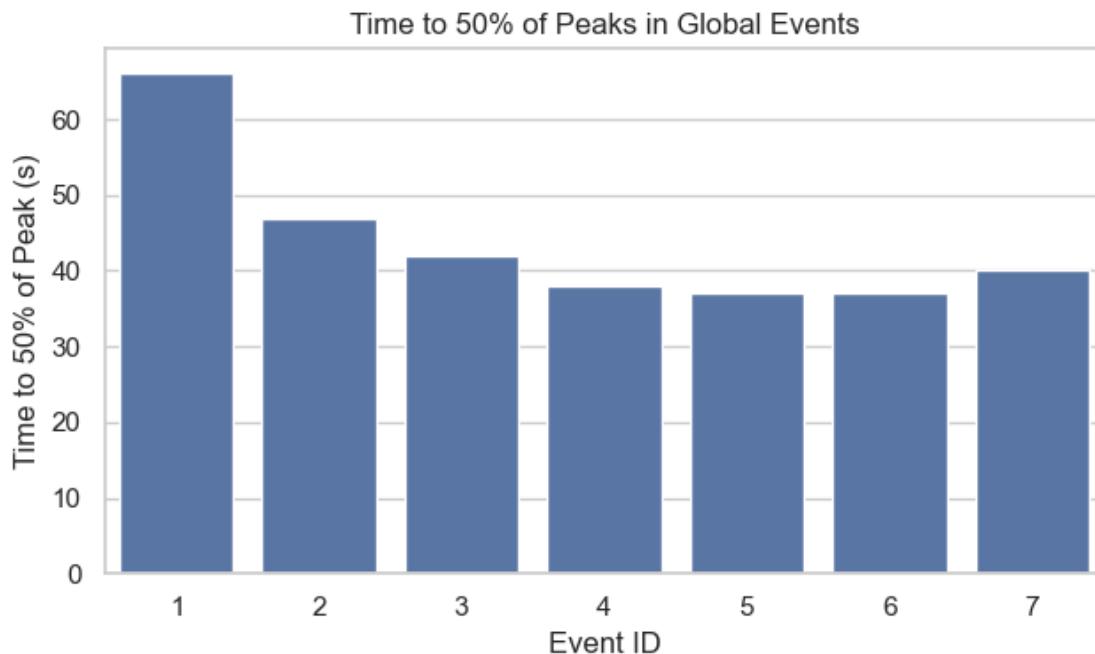
Event Activity Overlay (Event ID: 6)



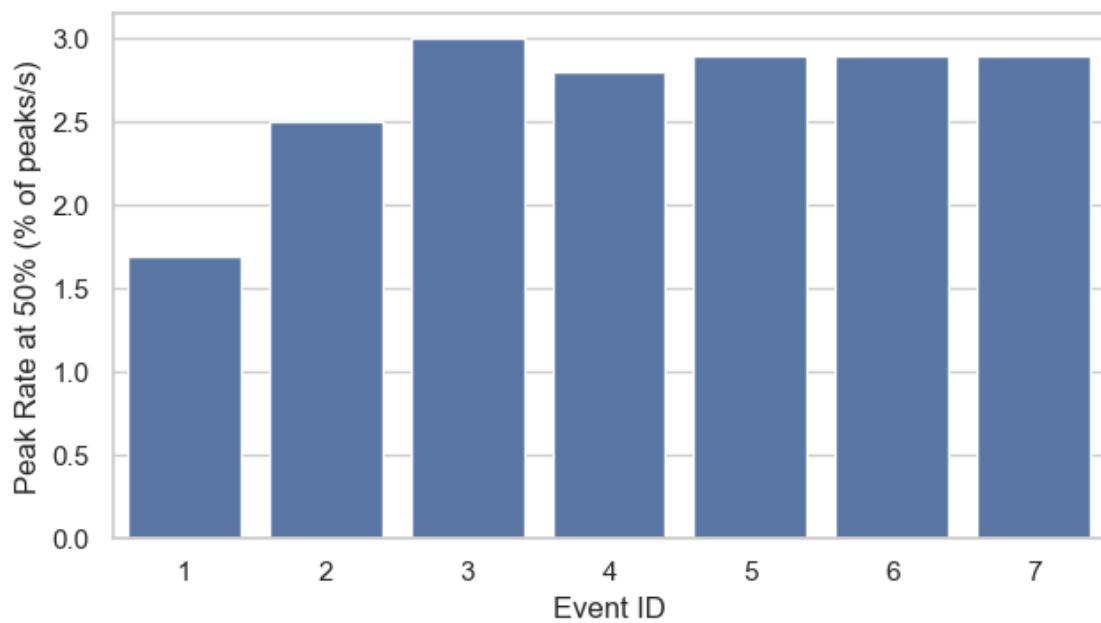
```

[2025-08-27 15:09:20] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\events\event-growth-curve-7.png': [Errno 2] No
such file or directory: 'D:\\Mateo\\20250624\\Output\\IS07\\events\\event-
growth-curve-7.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundError: [Errno 2] No such file or directory:
'D:\\Mateo\\20250624\\Output\\IS07\\events\\event-growth-curve-7.png'

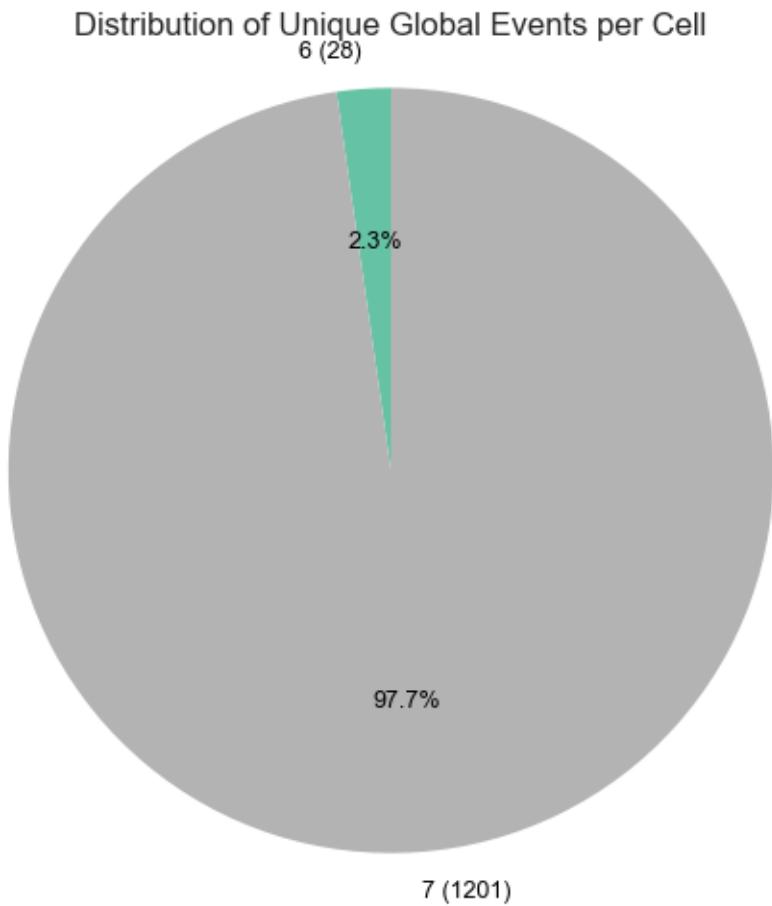
```



Peak rate at 50% in Global Events



1.2.4 Cells Occurrences in global events

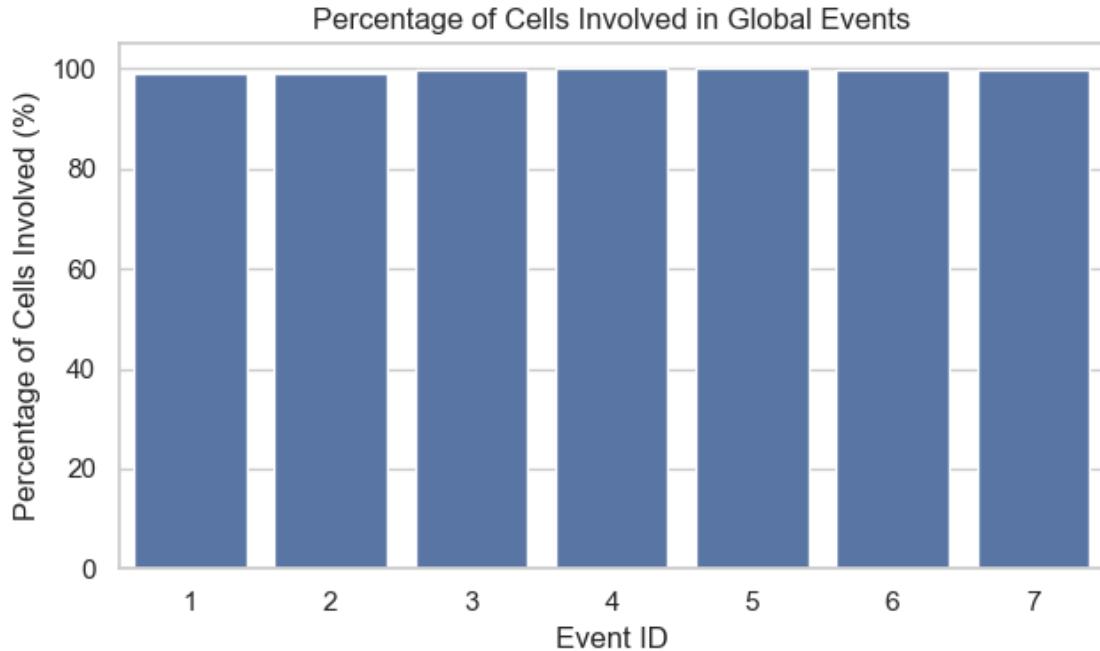


```
[2025-08-27 15:09:20] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\cell_Occurrences_in_global_events_overlay.png': [Errno 2] No such file
or directory: 'D:\\\\Mateo\\\\20250624\\\\Output\\\\IS07\\\\cell-
mapping\\\\cell_Occurrences_in_global_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
```

```

    self.fp = open(fp, "rb")
FileNotFoundError: [Errno 2] No such file or directory:
'D:\Mateo\20250624\Output\IS07\cell-
mapping\cell_Occurrences_in_global_events_overlay.png'

```



1.2.5 Inter-event interval analysis

Intervals between global event peaks: [174.0, 198.0, 224.0, 241.0, 253.0, 247.0]
 Estimated periodicity: 0.887
 The global events exhibit a regular periodic pattern.
 Estimated frequency (1/mean interval): 0.004 Hz

1.2.6 Early peakers in the events

```

[2025-08-27 15:09:21] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\global_events\global_event_1_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:

```

```

  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:09:21] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\global_events\global_event_2_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:09:21] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\global_events\global_event_3_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-

```

```
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

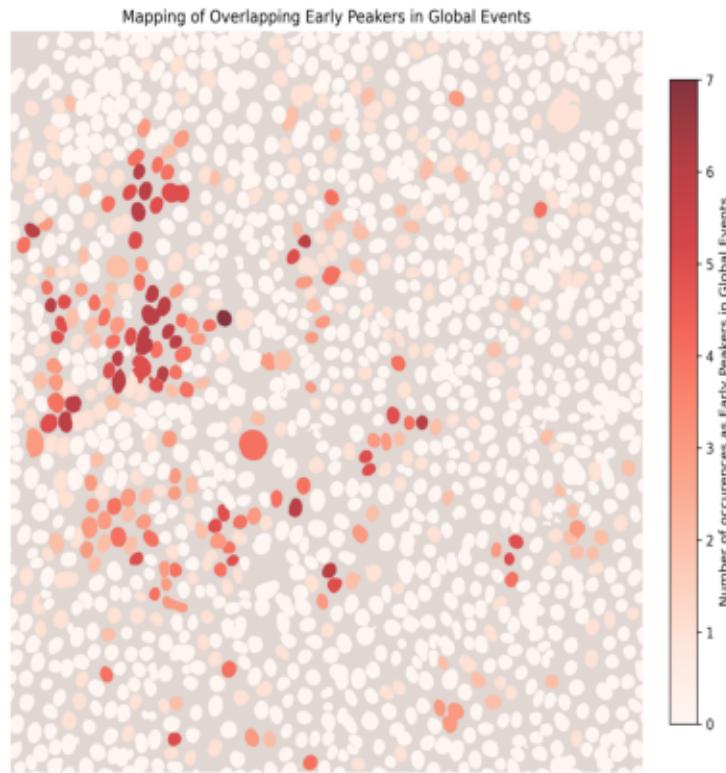
[2025-08-27 15:09:21] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\global_events\global_event_4_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:09:21] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\global_events\global_event_5_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file
```

```
[2025-08-27 15:09:21] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\global_events\global_event_6_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

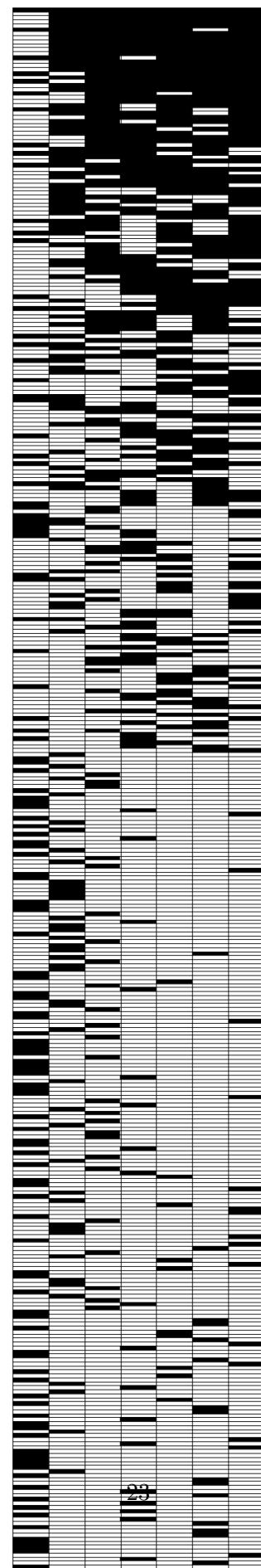
[2025-08-27 15:09:21] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\global_events\global_event_7_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file
```

Cell Mapping with Occurrences in Global Events Overlay



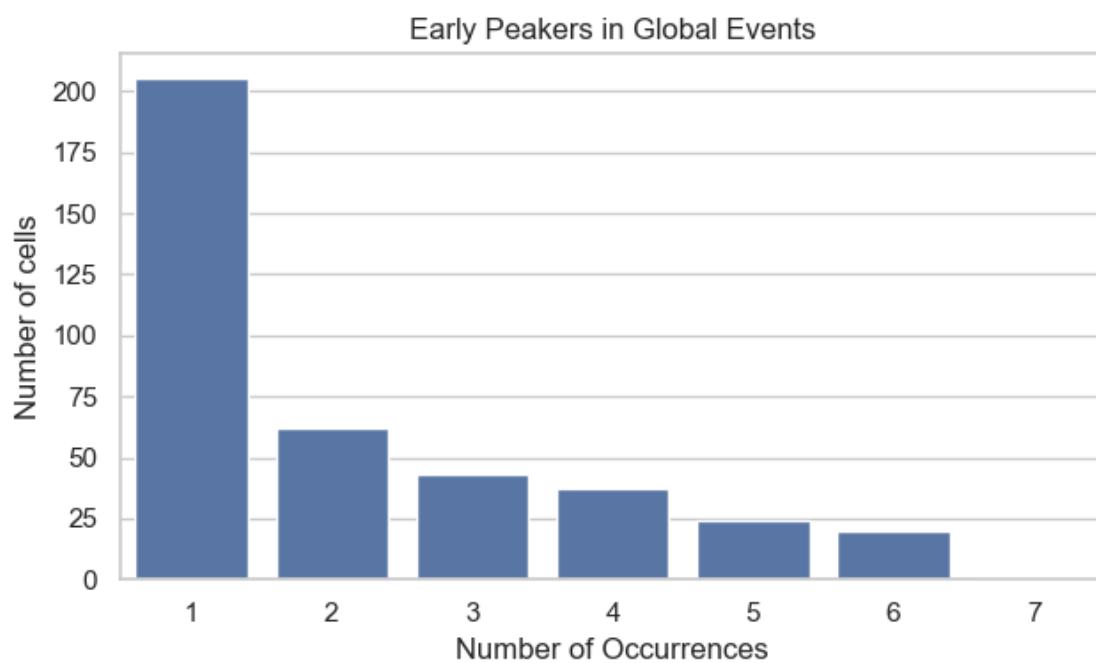
```
[2025-08-27 15:09:22] [WARNING] calcium: 'total_events' is deprecated and ignored. Using 7 unique event IDs.
```

```
[2025-08-27 15:09:22] [INFO] calcium: Early peakers event-matrix: 392 cells x 7 events; black squares: 853
```

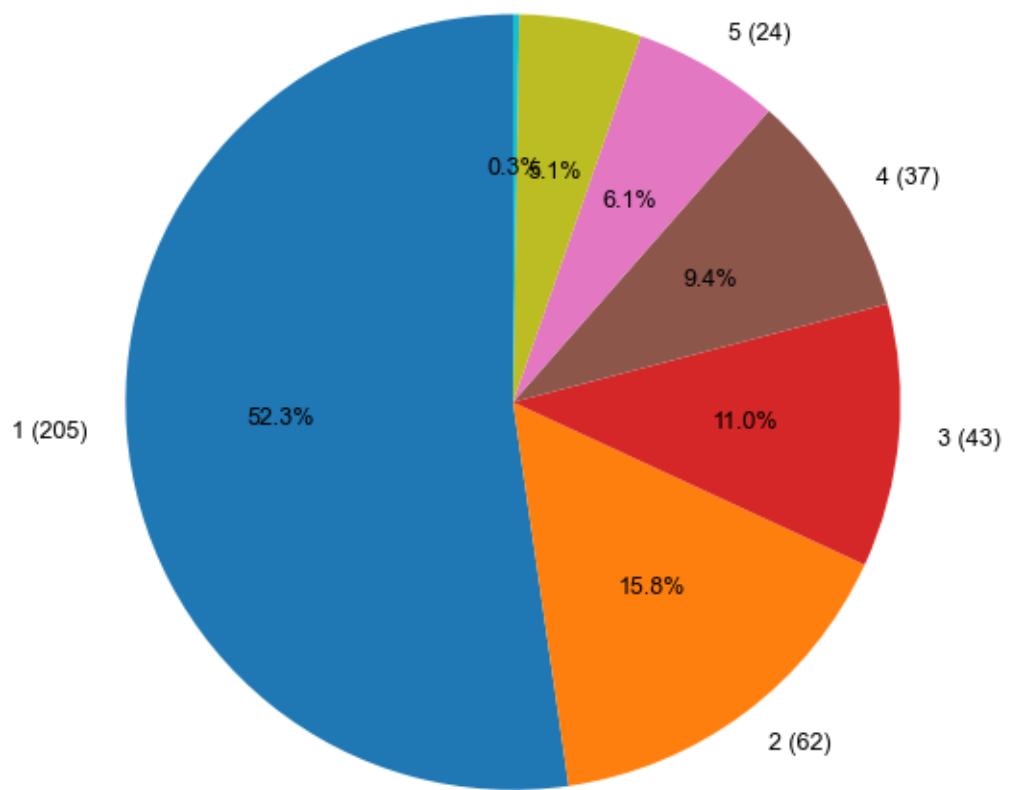


```
[2025-08-27 15:09:23] [INFO] calcium: Saved early peakers heatmap SVG to:  
early_peakers_heatmap.svg
```

```
[19]: array([[1, 1, 1, ..., 1, 1, 1],  
           [0, 1, 1, ..., 1, 1, 1],  
           [0, 1, 1, ..., 1, 1, 1],  
           ...,  
           [0, 0, 0, ..., 0, 0, 0],  
           [0, 0, 0, ..., 0, 1, 0],  
           [1, 0, 0, ..., 0, 0, 0]])
```



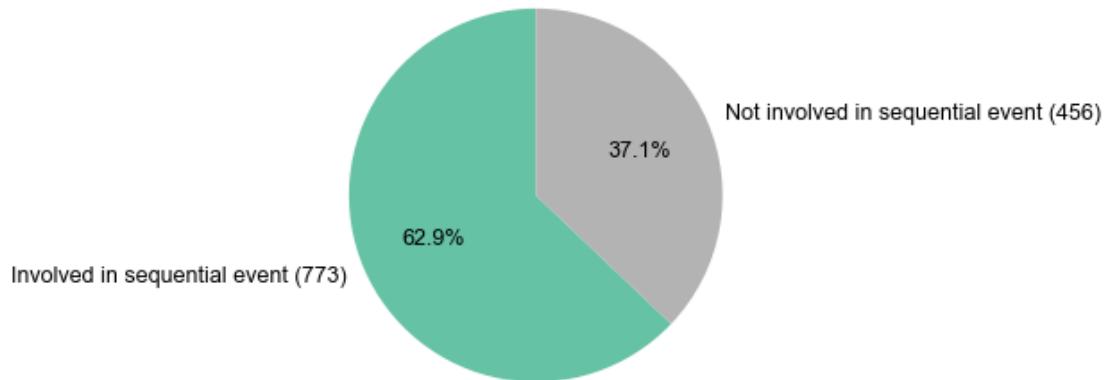
Distribution of Early Peakers in Global Events



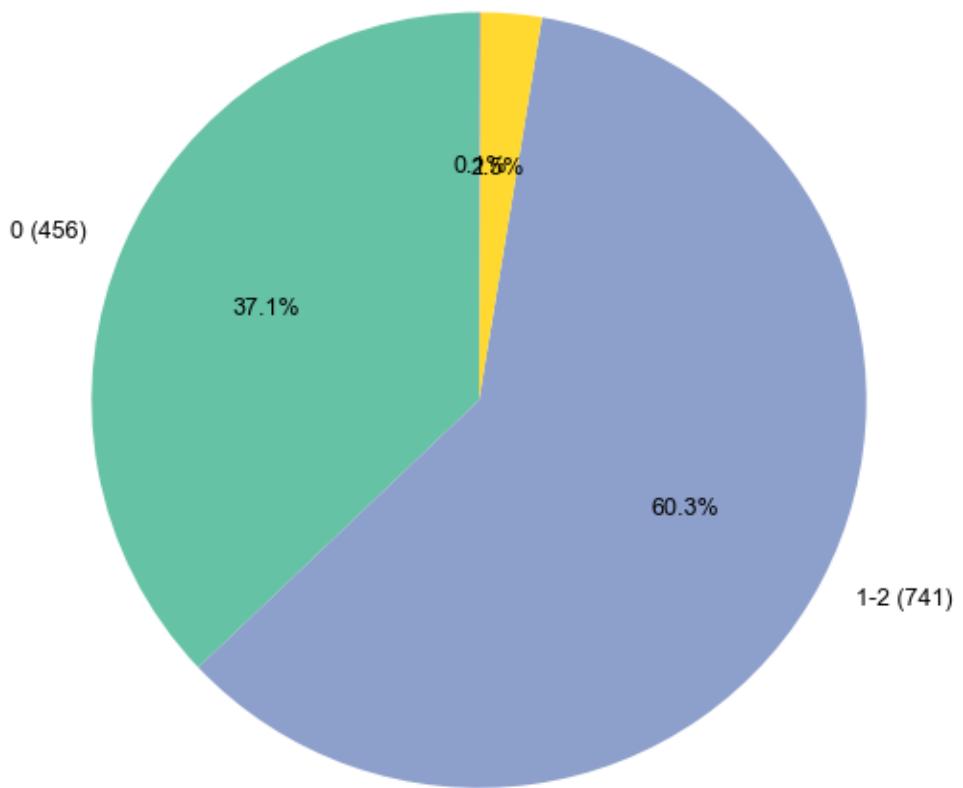
1.3 SEQUENTIAL EVENTS

1.3.1 Cells Occurrences in sequential events

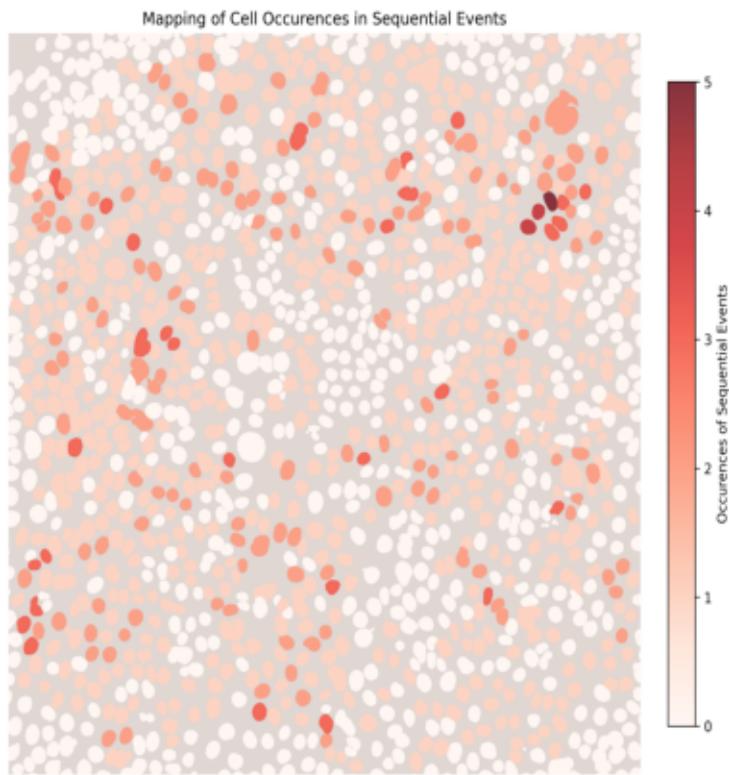
Distribution of Cells Involved in Sequential Events



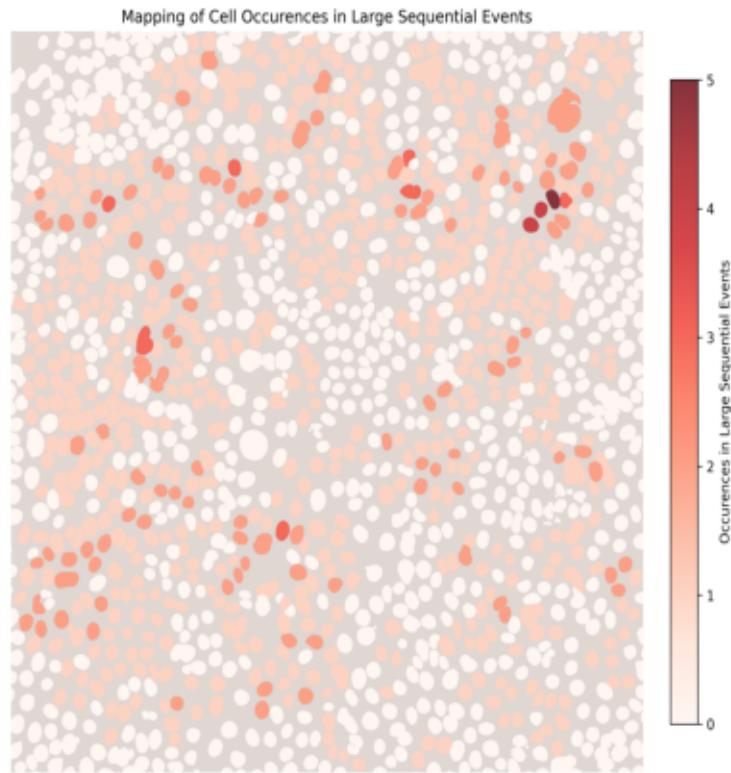
Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)
5-9 (34) (31)



Cell Mapping with Occurrences in Sequential Events Overlay

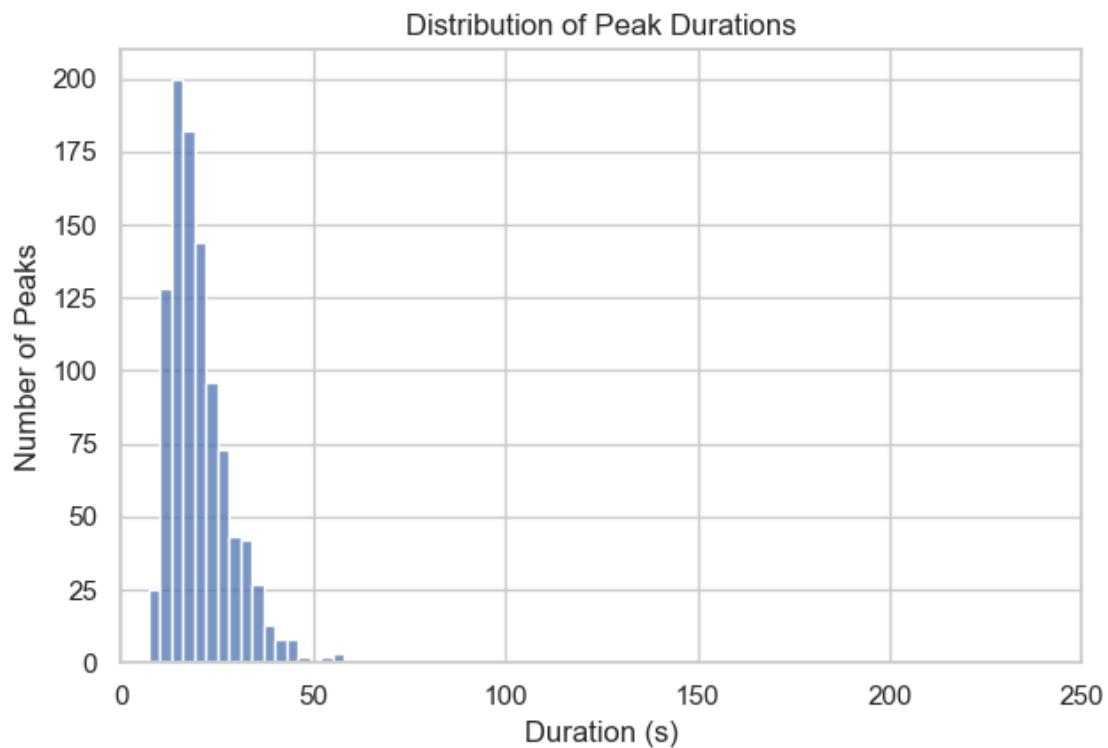


Cell Mapping with Occurrences in Large Sequential Events Overlay (>2)



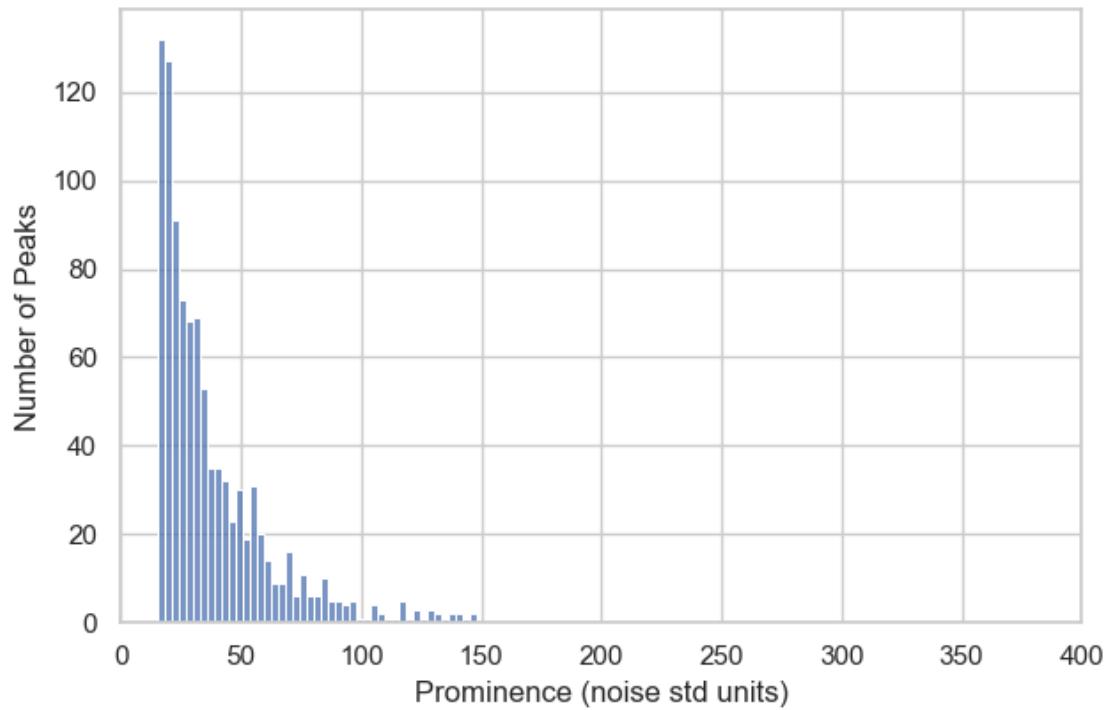
1.3.2 Peaks statistics in sequential events

```
[2025-08-27 15:09:25] [INFO] calcium: plot_histogram: removed 11 outliers out of  
1007 on 'Duration (s)' (lower=-1, upper=59)
```

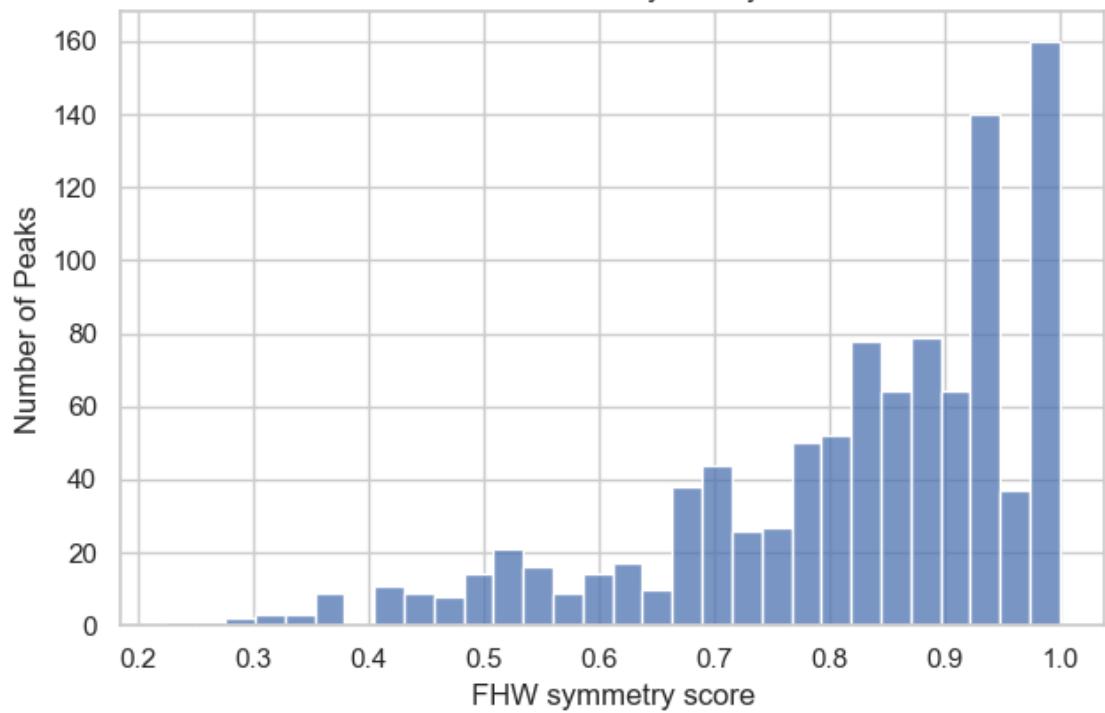


```
[2025-08-27 15:09:25] [INFO] calcium: plot_histogram: removed 30 outliers out of  
1007 on 'Prominence (noise std units)' (lower=-21.775, upper=148.33)
```

Distribution of Peak Prominences

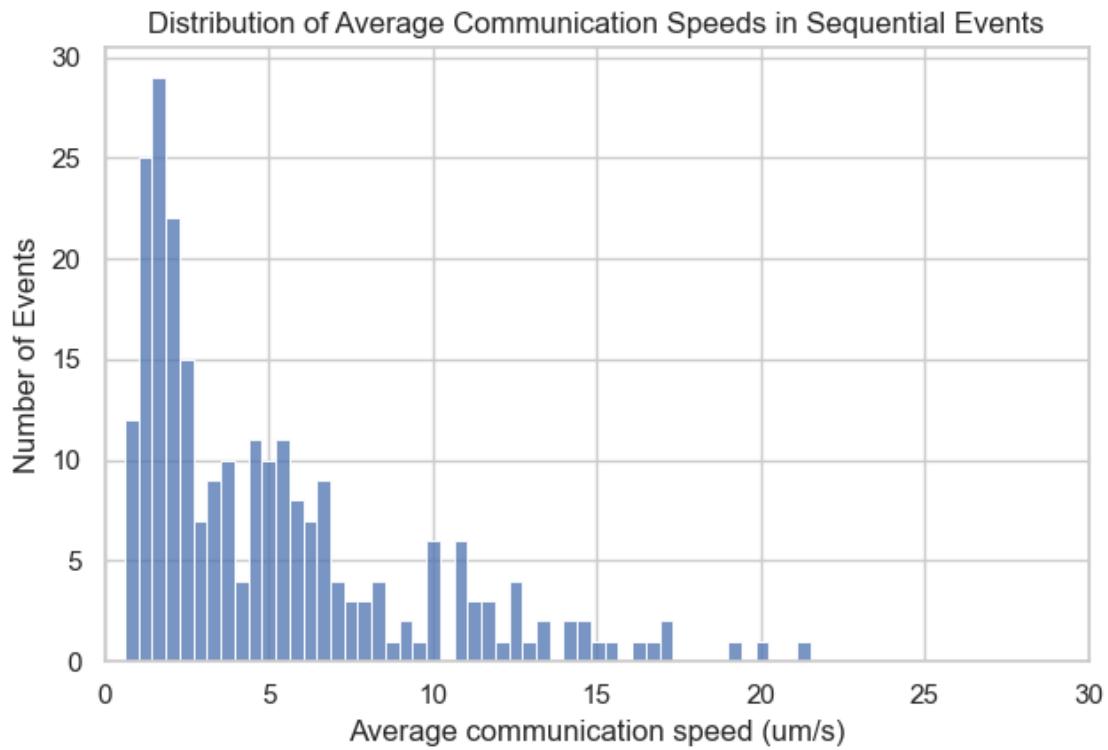


Distribution of Peak Symmetry Scores



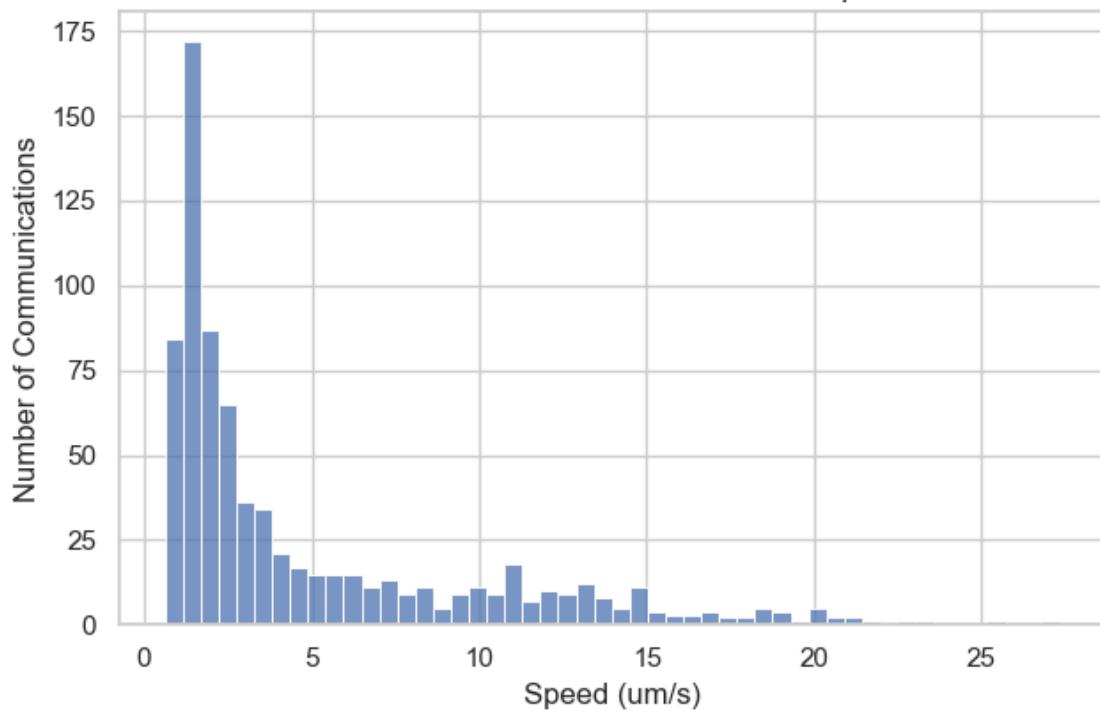
1.3.3 Cell-cell communication speed

[2025-08-27 15:09:25] [INFO] calcium: plot_histogram: removed 0 outliers out of 246 on 'Average communication speed (um/s)' (lower=-13.125, upper=21.525)

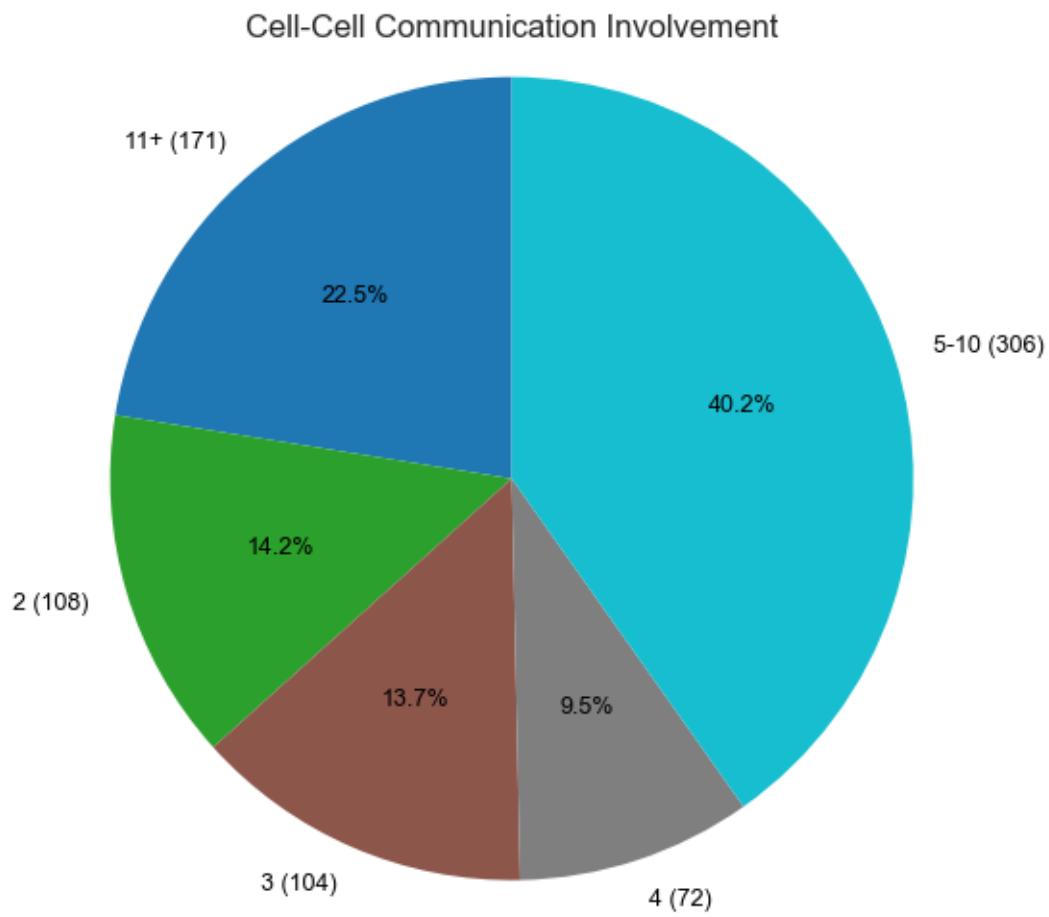


[2025-08-27 15:09:26] [INFO] calcium: plot_histogram: removed 0 outliers out of 761 on 'Speed (um/s)' (lower=-14.97, upper=34.35)

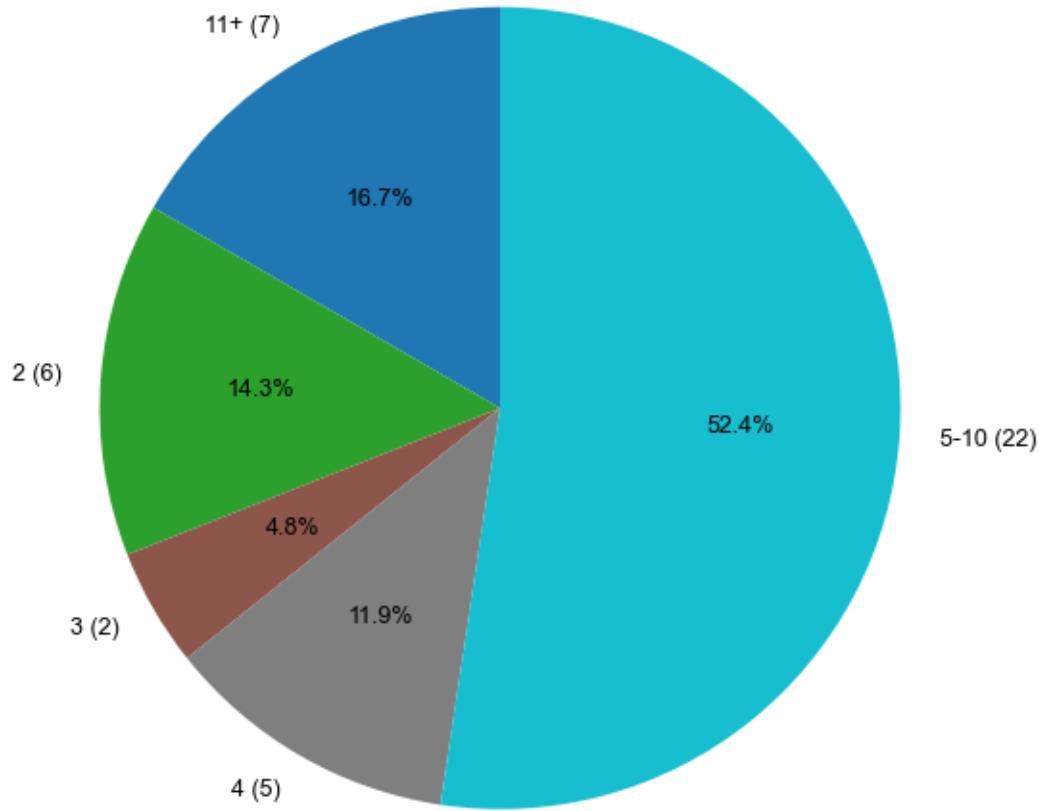
Distribution of Cell-Cell Communication Speeds



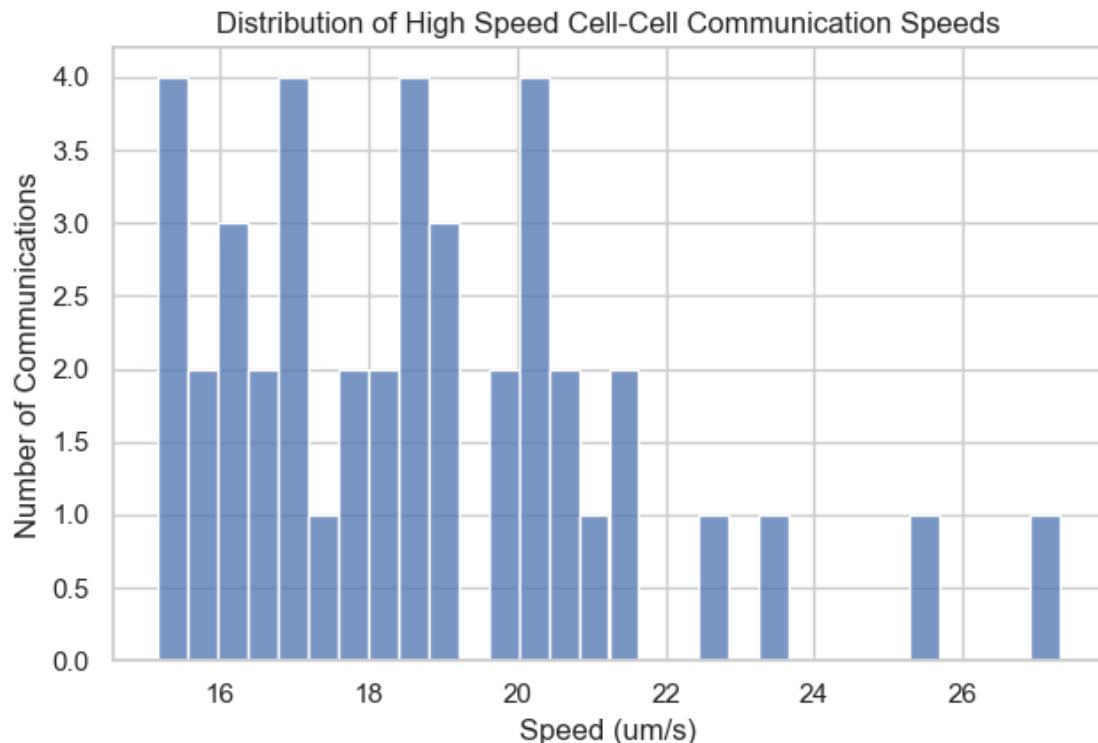
1.3.4 Double distribution in cell-cell communication speeds



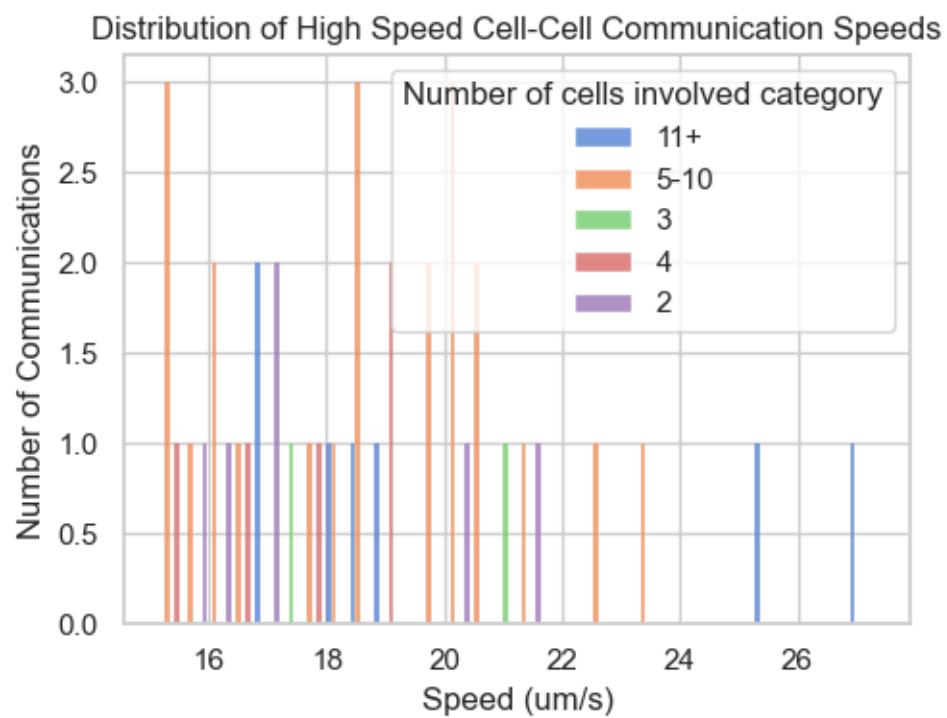
High Speed Cell-Cell Communication Involvement



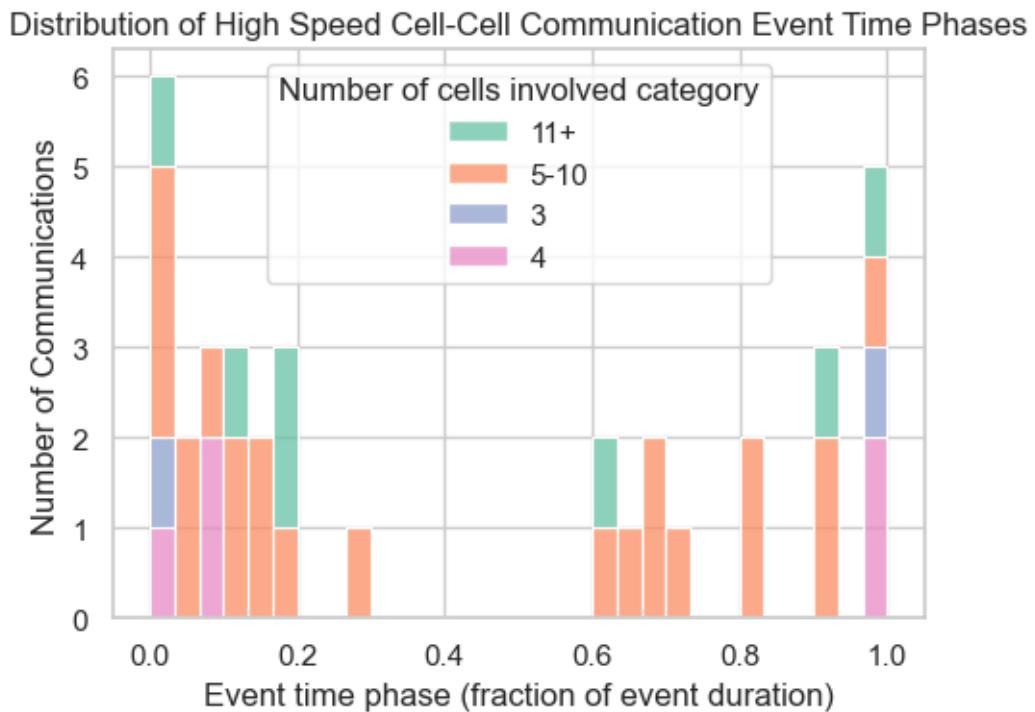
[2025-08-27 15:09:26] [INFO] calcium: plot_histogram: removed 0 outliers out of 42 on 'Speed (um/s)' (lower=6.3875, upper=30.52)



```
[2025-08-27 15:09:26] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 42 on 'Speed (um/s)' (lower=6.3875, upper=30.52)
```

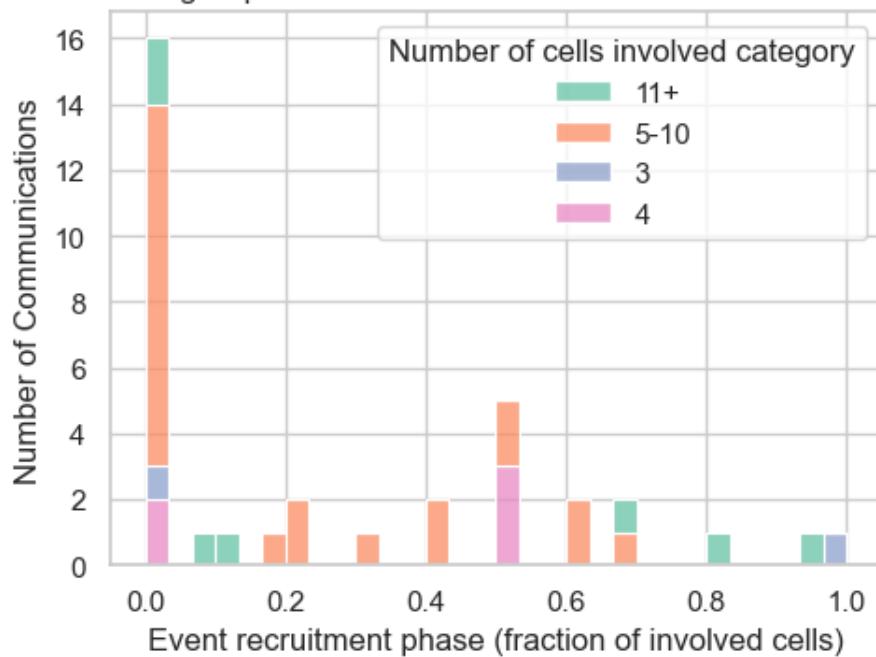


```
[2025-08-27 15:09:26] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 36 on 'Event time phase (fraction of event duration)' (lower=-2.165, upper=3.05)
```

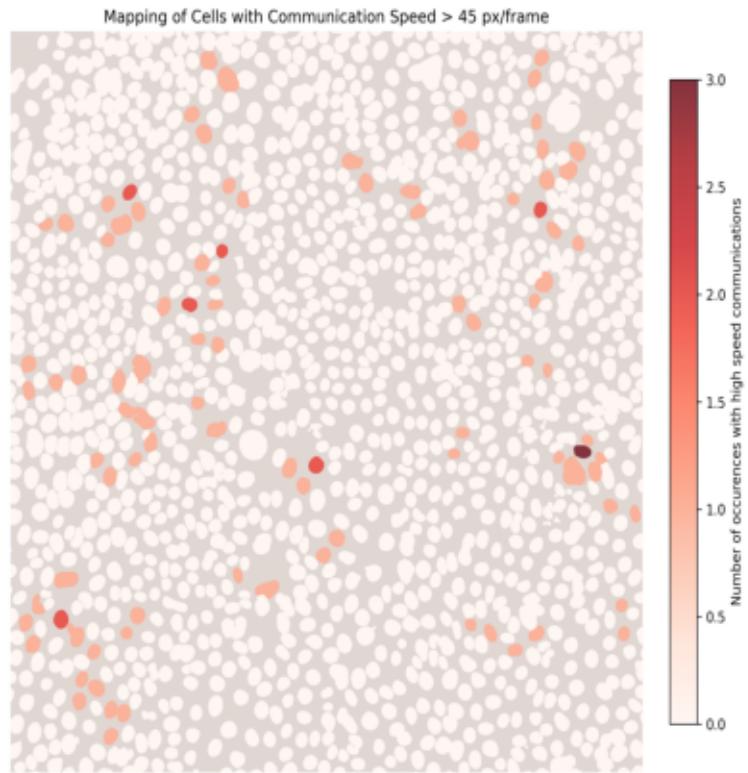


```
[2025-08-27 15:09:27] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 36 on 'Event recruitment phase (fraction of involved cells)' (lower=-1.5, upper=2)
```

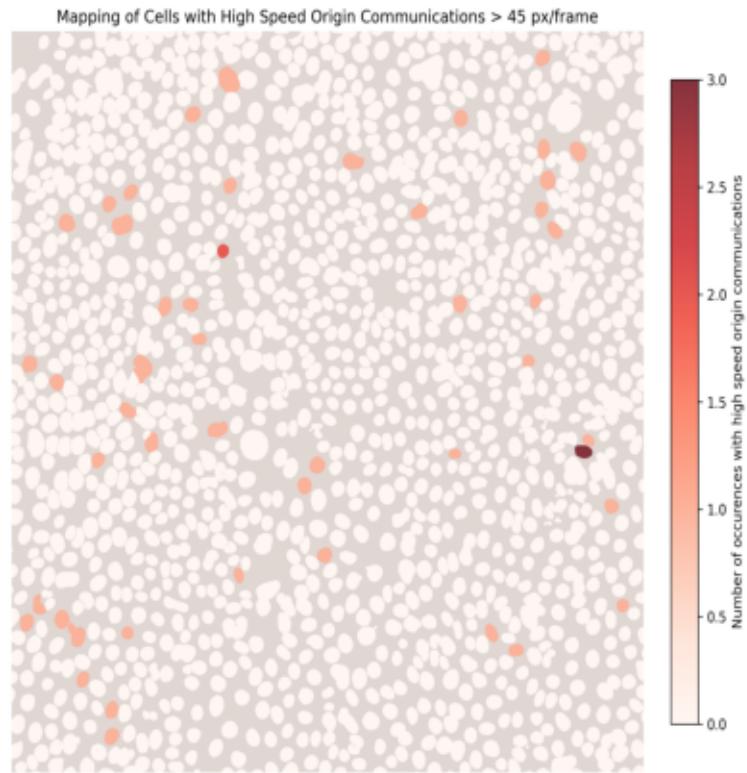
Distribution of High Speed Cell-Cell Communication Event Recruitment Phases



Cell Mapping with High Speed Cells Overlay



Cell Mapping with High Speed Origin Cells Overlay



	Communication ID	Event ID	Origin cell ID	Origin cell peak ID	\
1	2016529545728	8	407	0	
20	2016529412592	9	1589	0	
40	2016530129792	9	1626	0	
46	2016529543088	11	488	0	
48	2016529534352	11	557	0	
51	2016529546640	12	894	0	
66	2016944782832	15	1155	0	
92	2016651990048	18	796	0	
123	2016530129216	21	1620	0	
138	2016651995616	25	1267	0	
139	2016530126480	25	1216	0	
149	2016651998448	27	1134	0	

157	2016651995664	28	588	0
164	2016530128304	31	1555	0
167	2016651998592	32	1798	0
171	2016530132768	32	1855	0
199	2016529411872	39	1564	0
207	2016529405968	40	949	0
233	2016529411440	42	436	0
250	2016529401744	47	542	1
275	2016529408464	51	1433	0
283	2016591156448	52	1003	0
286	2016529413840	53	1193	0
294	2016529410912	54	809	0
308	2016529410192	56	800	0
346	2016529407120	67	1319	0
348	2016529401552	68	659	1
349	2016529403616	68	659	1
358	2016529409712	72	1186	8
359	2016529406592	72	1186	8
360	2016529404768	72	1186	8
391	2016529414752	80	273	0
432	2016529412832	95	336	2
438	2016529410336	101	344	4
455	2016591151312	109	596	0
512	2016591153568	136	605	0
561	2016591156928	158	980	0
568	2016591158416	161	956	0
610	2016591166144	185	1164	0
651	2016530129408	201	1483	0
696	2016530130752	219	1659	0
717	2016530133104	227	1595	2

	Cause cell ID	Cause cell peak ID	Start time (s)	End time (s)	\
1	352	0	37.0	37.0	
20	1491	0	21.0	21.0	
40	1661	0	16.0	17.0	
46	557	0	34.0	34.0	
48	530	0	34.0	34.0	
51	905	0	30.0	30.0	
66	1203	0	46.0	46.0	
92	851	0	66.0	66.0	
123	1604	0	51.0	52.0	
138	1216	0	10.0	10.0	
139	1224	0	10.0	11.0	
149	1059	0	54.0	54.0	
157	592	0	20.0	20.0	
164	1621	0	66.0	67.0	
167	1753	0	27.0	27.0	
171	1805	0	20.0	21.0	

199	1589	1	58.0	58.0
207	971	0	72.0	72.0
233	493	0	45.0	45.0
250	514	1	61.0	61.0
275	1398	0	22.0	22.0
283	988	0	16.0	17.0
286	1141	0	22.0	22.0
294	800	1	71.0	71.0
308	802	0	19.0	19.0
346	1339	0	9.0	9.0
348	686	1	264.0	265.0
349	735	1	264.0	264.0
358	1236	10	1592.0	1592.0
359	1200	8	1592.0	1593.0
360	1242	6	1592.0	1593.0
391	237	1	74.0	75.0
432	371	2	247.0	248.0
438	391	5	409.0	410.0
455	626	0	23.0	24.0
512	638	0	8.0	9.0
561	999	0	50.0	51.0
568	1035	0	60.0	61.0
610	1205	0	25.0	26.0
651	1513	0	19.0	20.0
696	1618	0	22.0	23.0
717	1646	5	248.0	249.0

	Duration (s)	Distance (um)	Speed (um/s)	\
1	0.0	18.84	18.84	
20	0.0	27.30	27.30	
40	1.0	18.27	18.27	
46	0.0	20.50	20.50	
48	0.0	22.61	22.61	
51	0.0	16.08	16.08	
66	0.0	16.36	16.36	
92	0.0	16.79	16.79	
123	1.0	16.55	16.55	
138	0.0	17.23	17.23	
139	1.0	21.21	21.21	
149	0.0	23.30	23.30	
157	0.0	15.33	15.33	
164	1.0	18.92	18.92	
167	0.0	18.53	18.53	
171	1.0	18.75	18.75	
199	0.0	20.50	20.50	
207	0.0	17.08	17.08	
233	0.0	18.33	18.33	
250	0.0	18.75	18.75	

275	0.0	15.41	15.41
283	1.0	18.76	18.76
286	0.0	15.71	15.71
294	0.0	20.17	20.17
308	0.0	20.15	20.15
346	0.0	20.18	20.18
348	1.0	17.88	17.88
349	0.0	21.38	21.38
358	0.0	16.71	16.71
359	1.0	18.93	18.93
360	1.0	15.55	15.55
391	1.0	19.81	19.81
432	1.0	16.32	16.32
438	1.0	17.16	17.16
455	1.0	15.17	15.17
512	1.0	21.52	21.52
561	1.0	20.21	20.21
568	1.0	17.88	17.88
610	1.0	16.79	16.79
651	1.0	25.53	25.53
696	1.0	20.02	20.02
717	1.0	15.63	15.63

Event time phase (fraction of event duration) \	
1	0.60
20	0.10
40	0.02
46	0.67
48	0.67
51	0.91
66	0.00
92	1.00
123	0.11
138	0.00
139	1.00
149	0.64
157	0.15
164	0.07
167	0.29
171	0.04
199	0.83
207	0.91
233	0.90
250	0.18
275	0.17
283	0.06
286	0.12
294	0.70

308	0.00
346	NaN
348	1.00
349	0.00
358	0.00
359	1.00
360	1.00
391	0.60
432	NaN
438	NaN
455	0.07
512	NaN
561	0.81
568	0.07
610	NaN
651	0.17
696	0.14
717	NaN

	Event recruitment phase (fraction of involved cells)	dataset \
1	0.67	20250624_IS07
20	0.07	20250624_IS07
40	0.00	20250624_IS07
46	0.00	20250624_IS07
48	0.00	20250624_IS07
51	0.60	20250624_IS07
66	0.00	20250624_IS07
92	0.94	20250624_IS07
123	0.00	20250624_IS07
138	0.00	20250624_IS07
139	1.00	20250624_IS07
149	0.43	20250624_IS07
157	0.00	20250624_IS07
164	0.50	20250624_IS07
167	0.20	20250624_IS07
171	0.00	20250624_IS07
199	0.50	20250624_IS07
207	0.82	20250624_IS07
233	0.50	20250624_IS07
250	0.00	20250624_IS07
275	0.20	20250624_IS07
283	0.00	20250624_IS07
286	0.17	20250624_IS07
294	0.40	20250624_IS07
308	0.00	20250624_IS07
346	NaN	20250624_IS07
348	0.33	20250624_IS07
349	0.00	20250624_IS07

358	0.00	20250624_IS07
359	0.50	20250624_IS07
360	0.50	20250624_IS07
391	0.60	20250624_IS07
432	NaN	20250624_IS07
438	NaN	20250624_IS07
455	0.00	20250624_IS07
512	NaN	20250624_IS07
561	0.67	20250624_IS07
568	0.00	20250624_IS07
610	NaN	20250624_IS07
651	0.12	20250624_IS07
696	0.00	20250624_IS07
717	NaN	20250624_IS07

	Number of cells involved	category	Speed category
1		11+	High speed
20		11+	High speed
40		11+	High speed
46		5-10	High speed
48		5-10	High speed
51		5-10	High speed
66		5-10	High speed
92		11+	High speed
123		5-10	High speed
138		3	High speed
139		3	High speed
149		5-10	High speed
157		5-10	High speed
164		4	High speed
167		5-10	High speed
171		5-10	High speed
199		5-10	High speed
207		11+	High speed
233		5-10	High speed
250		11+	High speed
275		5-10	High speed
283		5-10	High speed
286		5-10	High speed
294		5-10	High speed
308		5-10	High speed
346		2	High speed
348		5-10	High speed
349		5-10	High speed
358		4	High speed
359		4	High speed
360		4	High speed
391		5-10	High speed

432	2	High speed
438	2	High speed
455	5-10	High speed
512	2	High speed
561	5-10	High speed
568	4	High speed
610	2	High speed
651	11+	High speed
696	5-10	High speed
717	2	High speed

Speed category	High speed	Low speed
Origin cell ID		
198	0	2
201	0	1
206	0	2
216	0	1
218	0	1
...
1860	0	2
1868	0	1
1872	0	2
1890	0	1
1904	0	1

[458 rows x 2 columns]

Cell ID	Centroid X coordinate (um)	Centroid Y coordinate (um)	\
4	198	143.65	7.15
7	201	429.32	7.48
11	206	455.65	8.12
18	216	291.85	12.35
20	218	470.28	13.00
...
1187	1860	250.58	476.12
1195	1868	401.70	477.75
1198	1872	329.23	478.73
1208	1890	253.83	485.23
1219	1904	262.28	487.50

Number of peaks	Is active	Occurrences in global events	\
4	8	True	7
7	10	True	7
11	9	True	7
18	9	True	7
20	9	True	7
...
1187	11	True	7
1195	10	True	7

1198	8	True	7
1208	8	True	7
1219	9	True	7

Occurrences in global events as early peaker Early peaker event IDs \

4	0	[]
7	1	[1]
11	0	[]
18	0	[]
20	0	[]
...
1187	0	[]
1195	0	[]
1198	0	[]
1208	0	[]
1219	0	[]

Occurrences in sequential events \

4	1
7	1
11	1
18	1
20	1
...	...
1187	2
1195	1
1198	1
1208	1
1219	1

Occurrences in sequential events as origin \

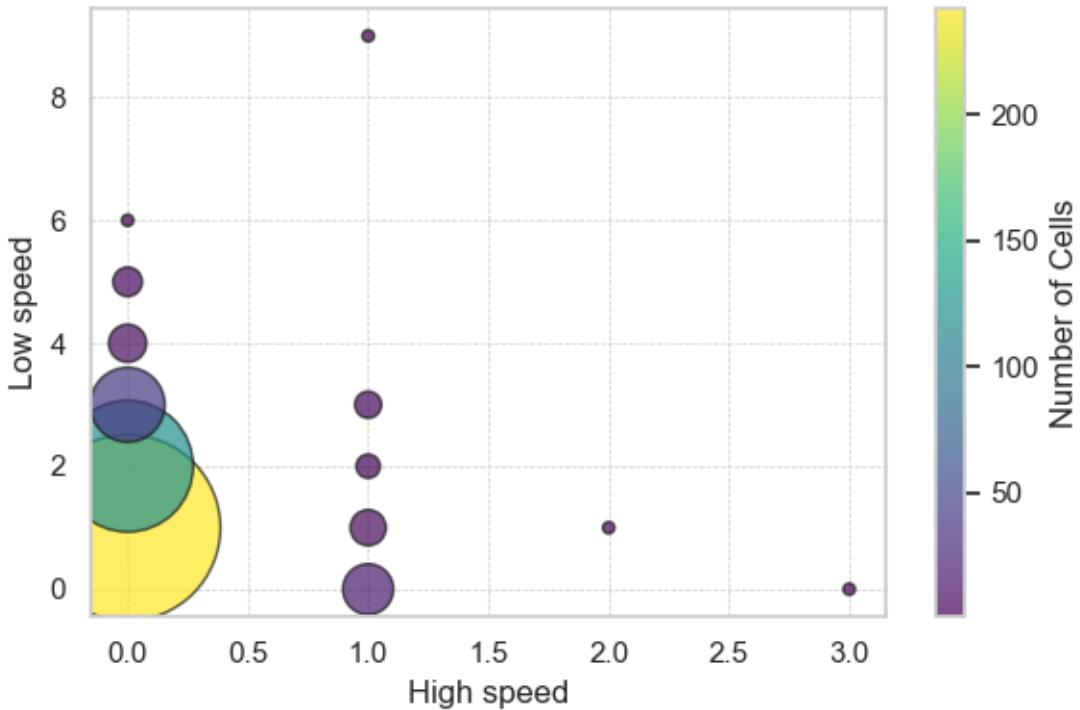
4	1
7	0
11	1
18	1
20	0
...	...
1187	2
1195	1
1198	1
1208	0
1219	0

Occurrences in individual events Peak frequency (Hz) \

4	0	0.0047
7	1	0.0059
11	1	0.0053
18	0	0.0053

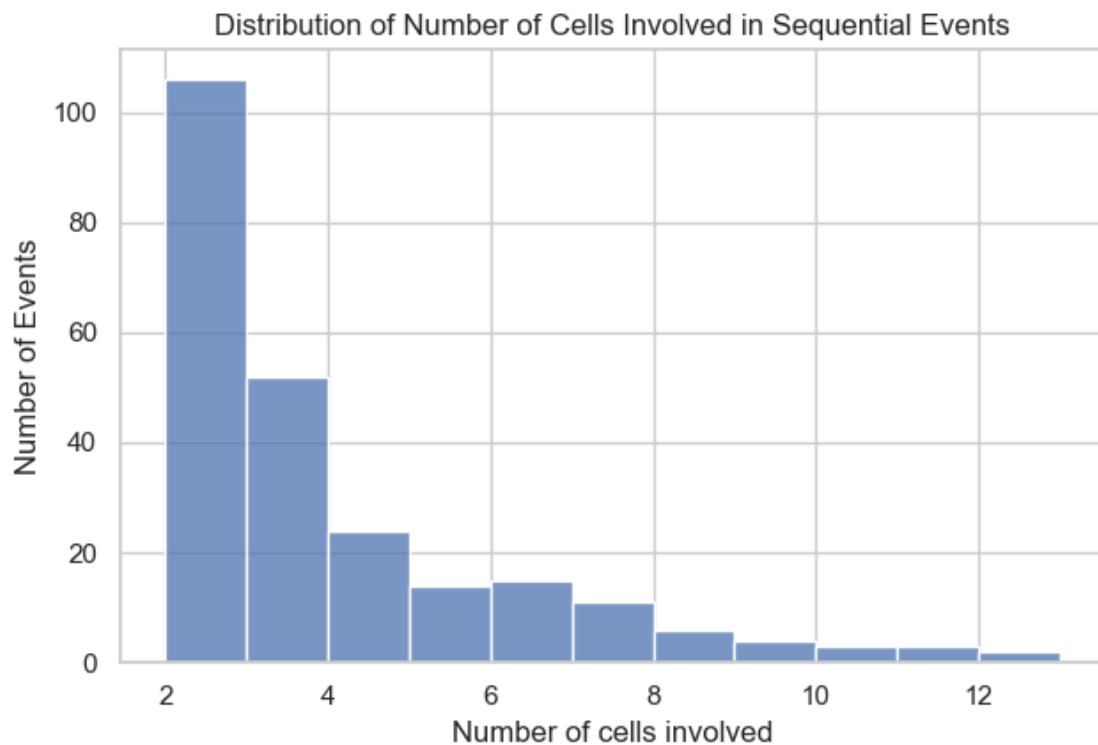
20		1	0.0053	
...	
1187		2	0.0065	
1195		1	0.0059	
1198		0	0.0047	
1208		0	0.0047	
1219		1	0.0053	
Periodicity score Neighbor count Neighbors (labels) \				
4	0.83	3	[194,236,237]	
7	0.66	4	[195,229,235,255]	
11	0.68	3	[218,235,249]	
18	0.72	4	[221,233,260,264]	
20	0.72	4	[193,206,244,249]	
...	
1187	0.61	6	[1827,1830,1859,1867,1890,1904]	
1195	0.64	6	[1821,1823,1857,1883,1895,1900]	
1198	0.81	5	[1812,1833,1861,1875,1909]	
1208	0.77	4	[1859,1860,1904,1915]	
1219	0.72	4	[1860,1867,1890,1919]	
dataset Involved in sequential event \				
4	20250624_IS07	Involved in sequential event		
7	20250624_IS07	Involved in sequential event		
11	20250624_IS07	Involved in sequential event		
18	20250624_IS07	Involved in sequential event		
20	20250624_IS07	Involved in sequential event		
...		
1187	20250624_IS07	Involved in sequential event		
1195	20250624_IS07	Involved in sequential event		
1198	20250624_IS07	Involved in sequential event		
1208	20250624_IS07	Involved in sequential event		
1219	20250624_IS07	Involved in sequential event		
Occurrences in sequential events category High speed Low speed				
4		1-2	0.0	2.0
7		1-2	0.0	1.0
11		1-2	0.0	2.0
18		1-2	0.0	1.0
20		1-2	0.0	1.0
...
1187		1-2	0.0	2.0
1195		1-2	0.0	1.0
1198		1-2	0.0	2.0
1208		1-2	0.0	1.0
1219		1-2	0.0	1.0

[458 rows x 20 columns]



1.3.5 Number of cells involved per sequential events

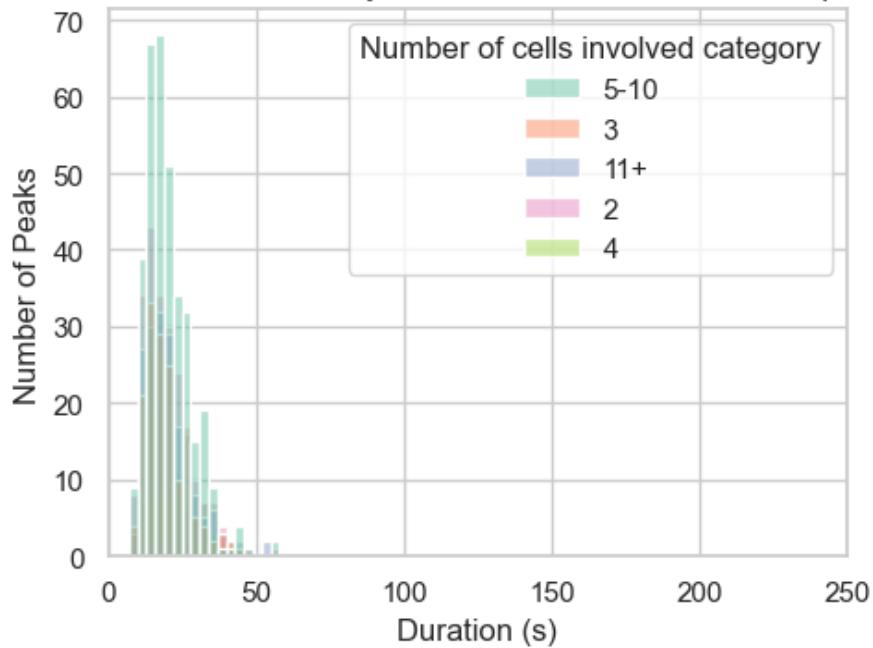
```
[2025-08-27 15:09:29] [INFO] calcium: plot_histogram: removed 6 outliers out of  
246 on 'Number of cells involved' (lower=-7, upper=14)
```



1.3.6 Influence of cell count per event on statistics

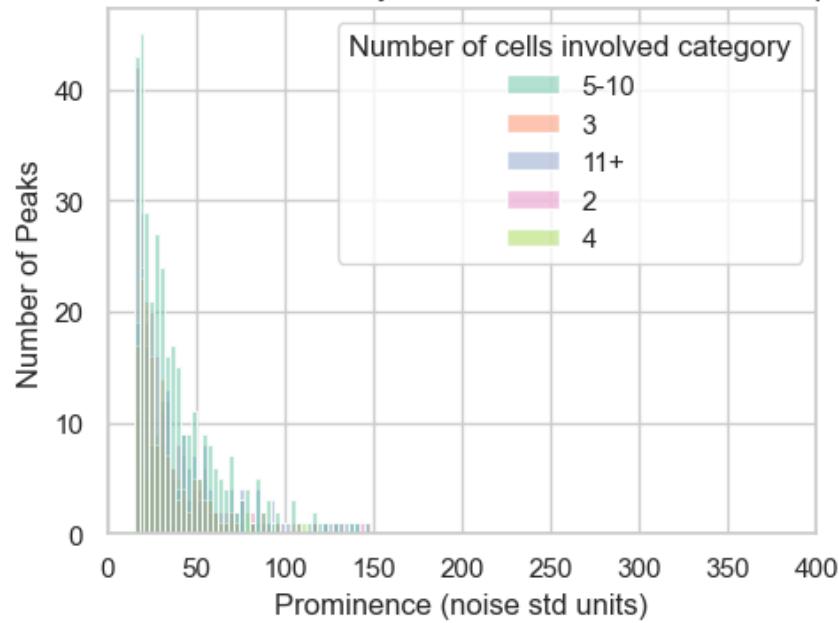
```
[2025-08-27 15:09:29] [INFO] calcium: plot_histogram_by_group: removed 11 outliers out of 1007 on 'Duration (s)' (lower=-1, upper=59)
```

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

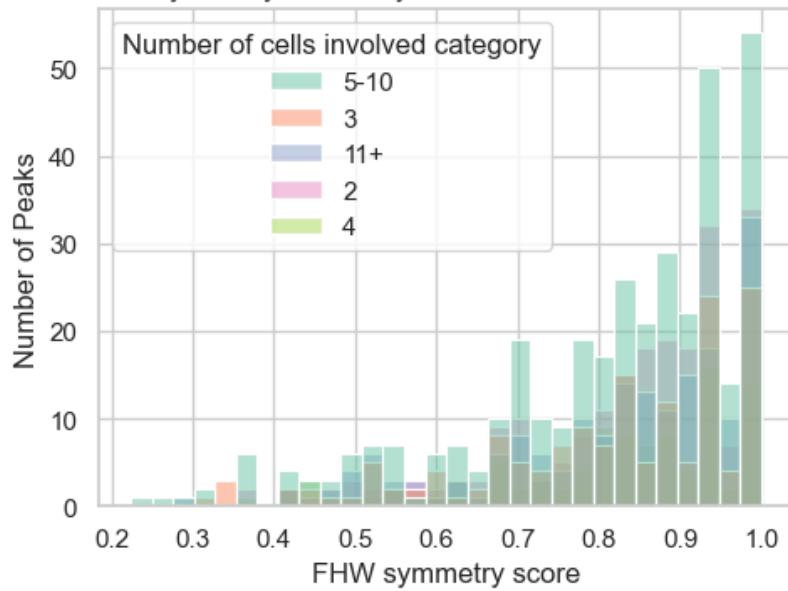


```
[2025-08-27 15:09:29] [INFO] calcium: plot_histogram_by_group: removed 30 outliers out of 1007 on 'Prominence (noise std units)' (lower=-21.775, upper=148.33)
```

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

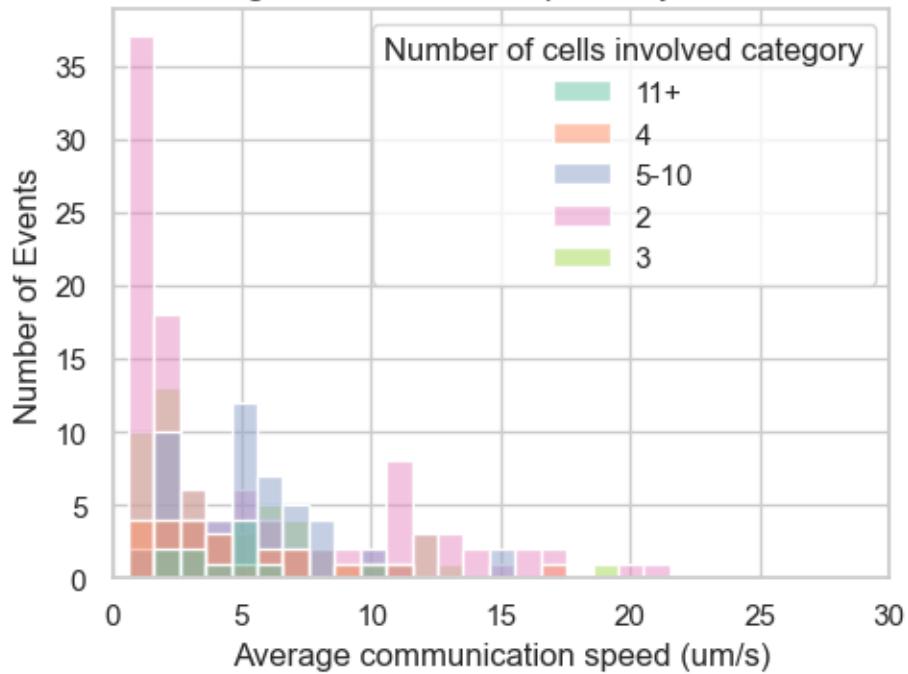


Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events

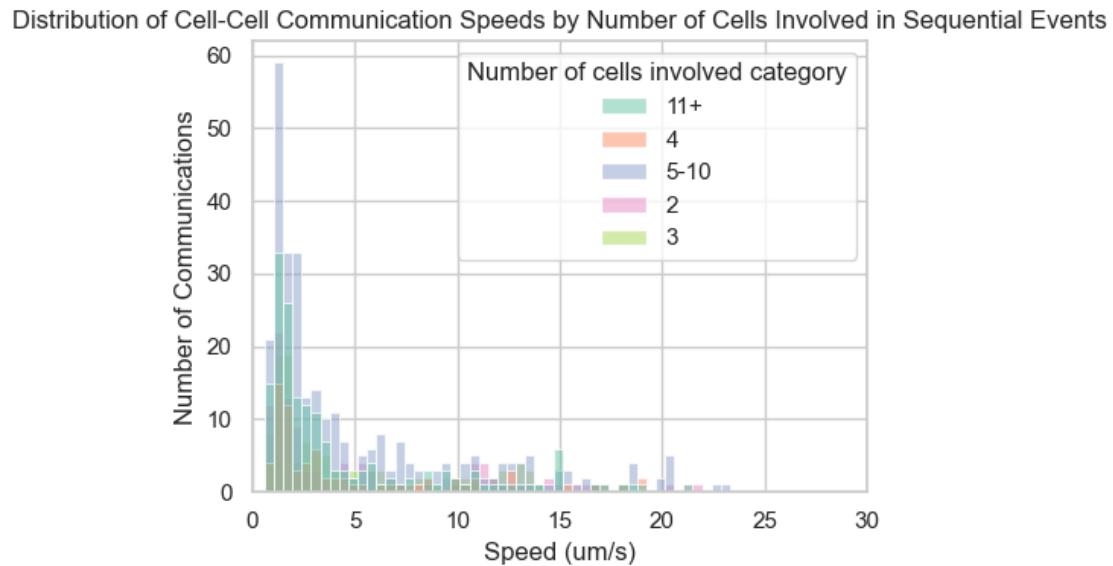


```
[2025-08-27 15:09:30] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 246 on 'Average communication speed (um/s)' (lower=-13.125, upper=21.525)
```

Distribution of Average Communication Speeds by Number of Cells Involved

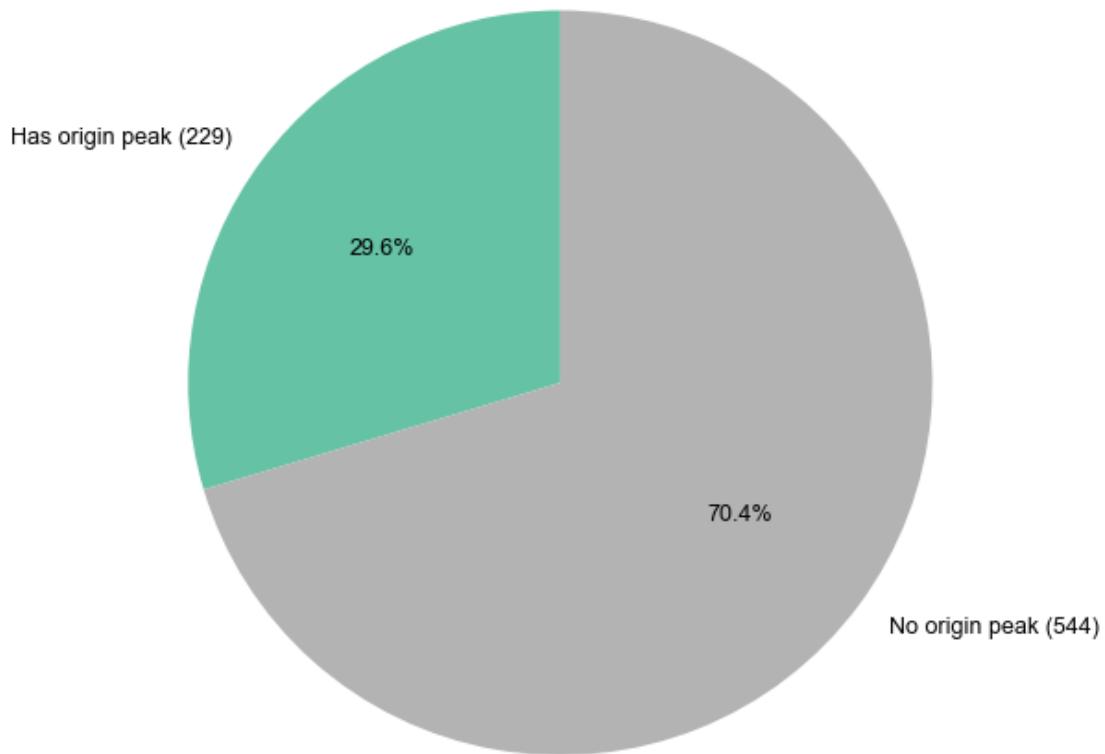


[2025-08-27 15:09:30] [INFO] calcium: plot_histogram_by_group: removed 2 outliers out of 761 on 'Speed (um/s)' (lower=-14.97, upper=23.39)

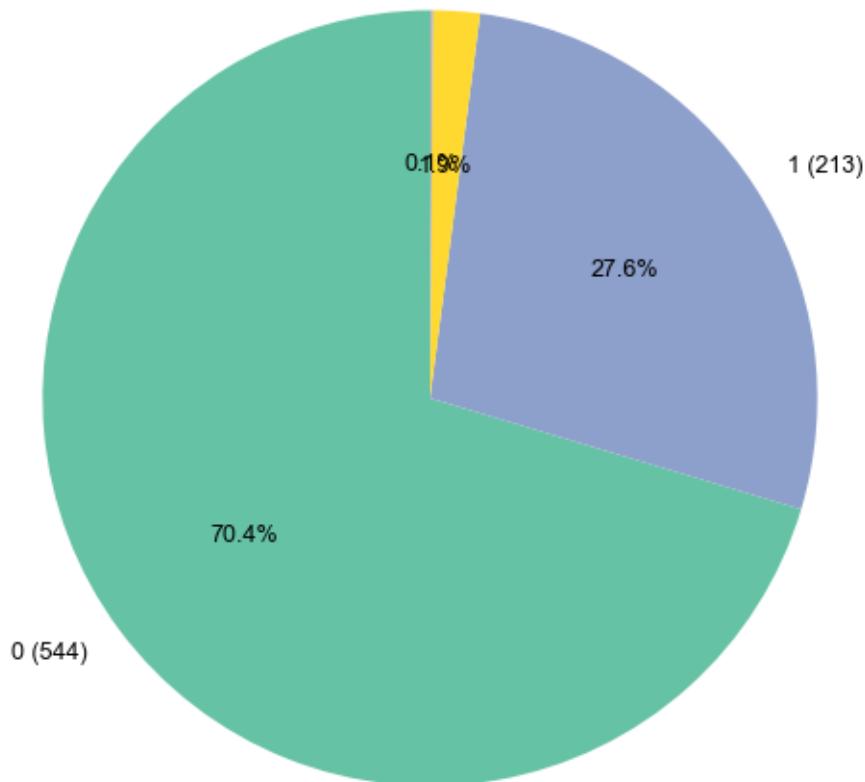


1.3.7 Cells Occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

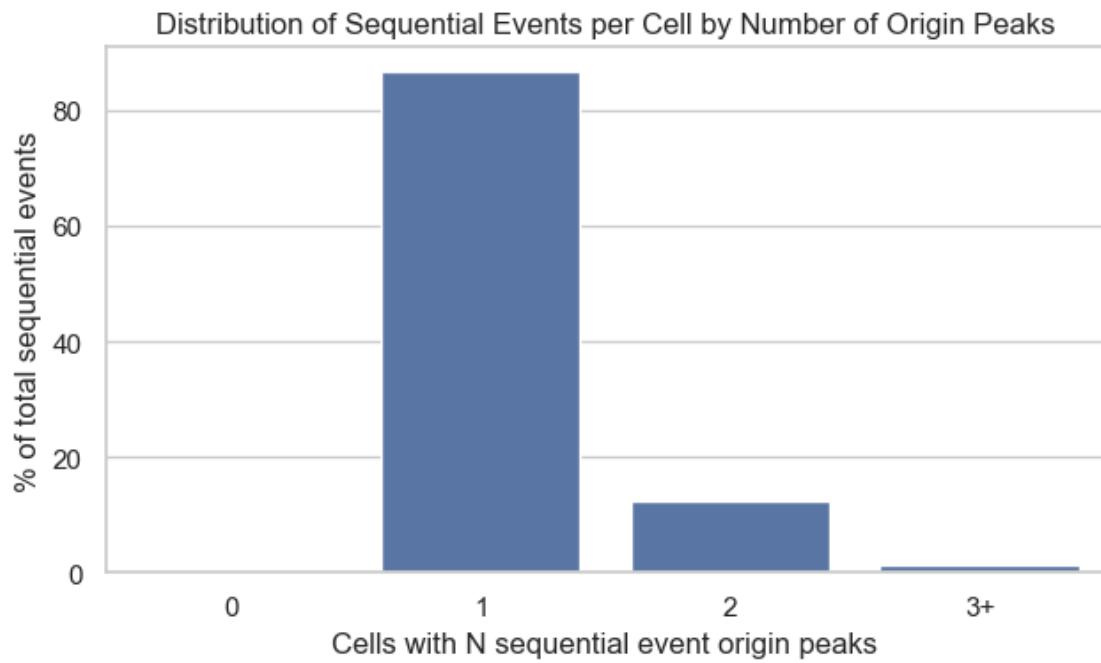


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



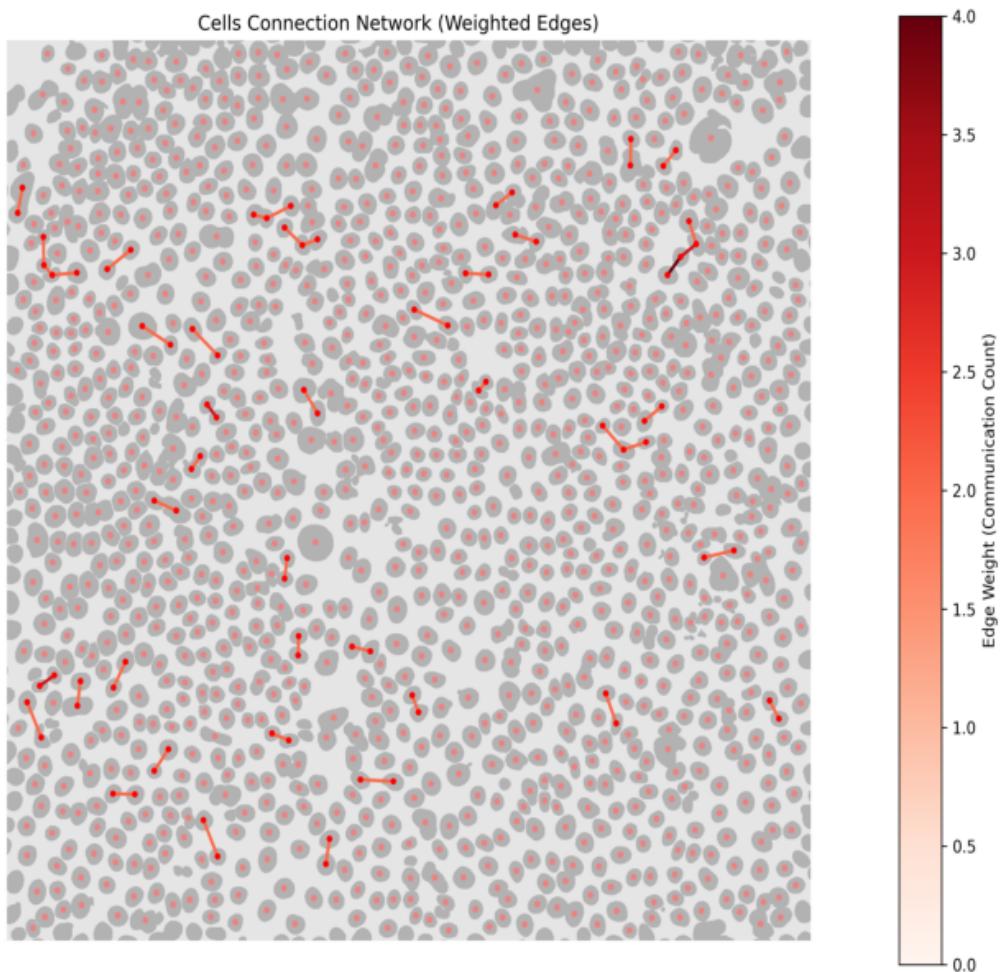
```
[2025-08-27 15:09:31] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\cell_Occurrences_in_origin_seq_events_overlay.png': [Errno 2] No such
file or directory: 'D:\\Mateo\\20250624\\Output\\IS07\\cell-
mapping\\cell_Occurrences_in_origin_seq_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundException: [Errno 2] No such file or directory:
```

'D:\\Mateo\\20250624\\Output\\IS07\\cell-mapping\\cell_Occurrences_in_origin_seq_events_overlay.png'



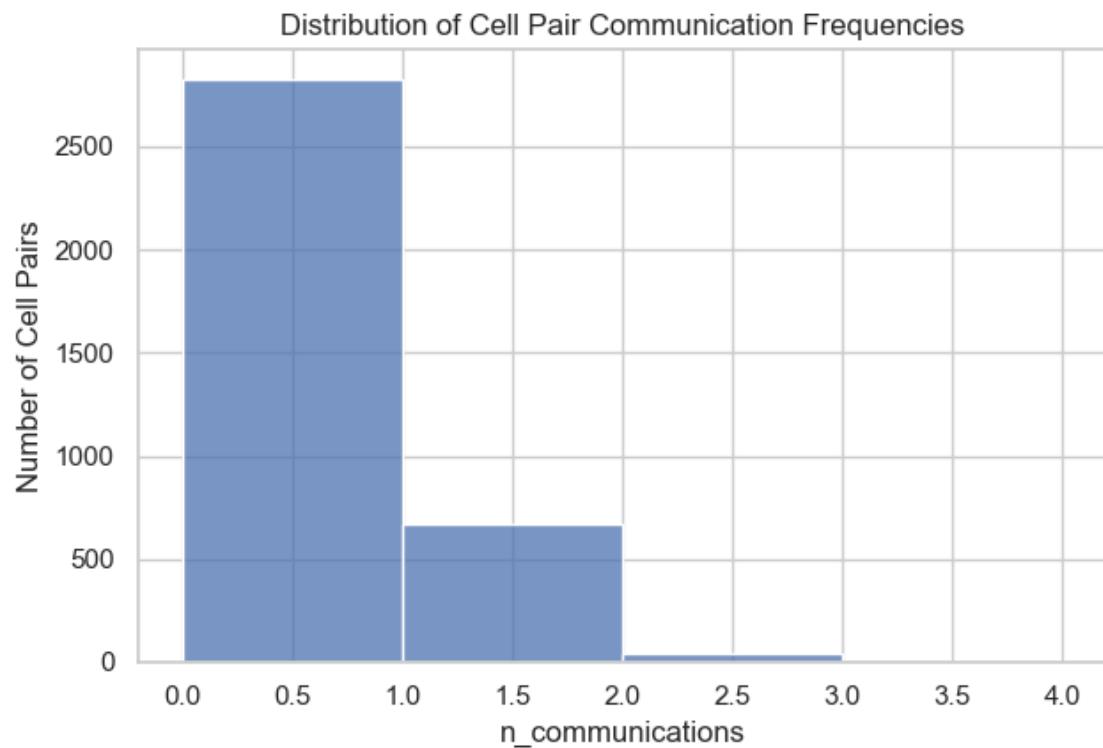
1.3.8 Connection network between cells

Cell Connection Network Graph

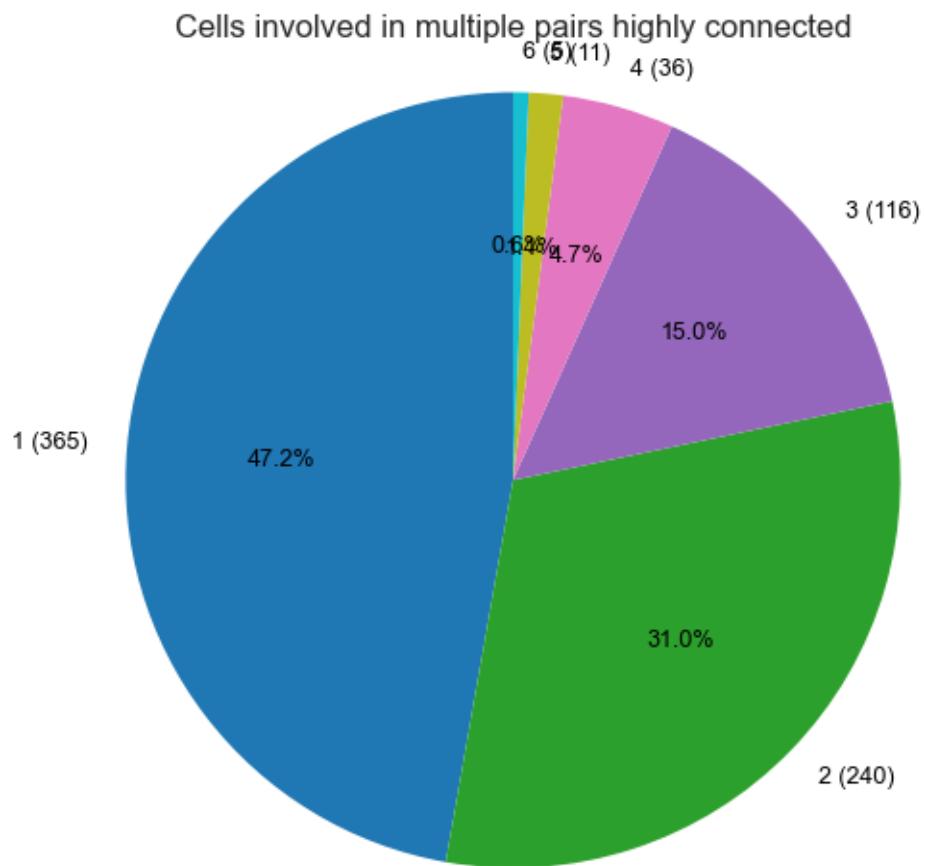


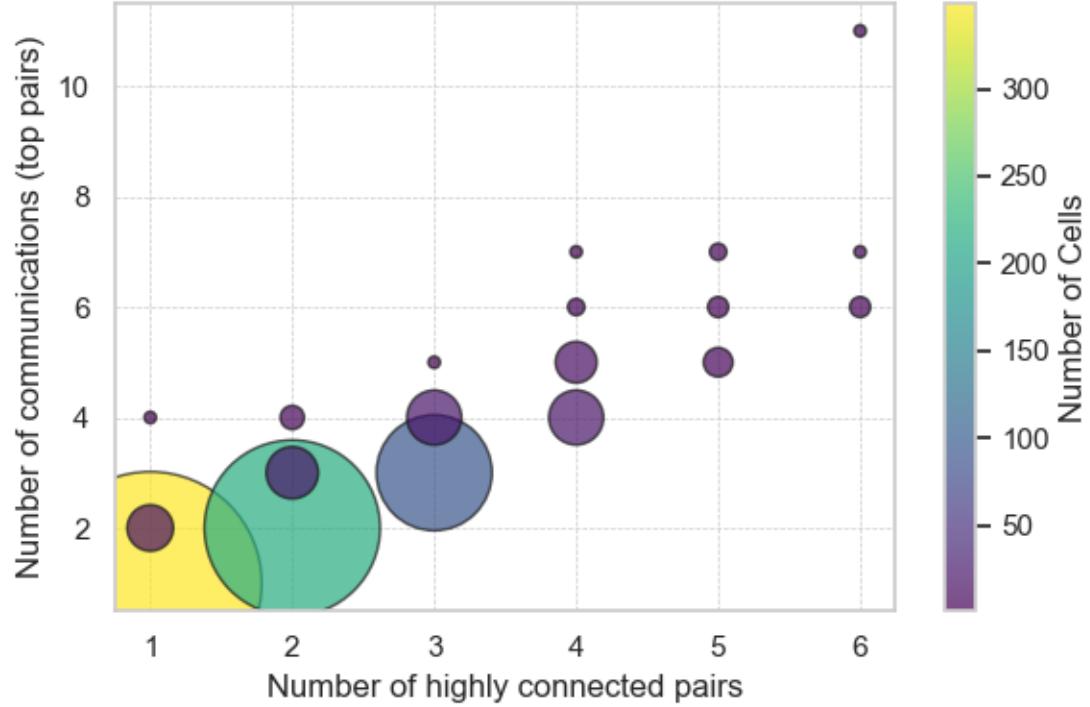
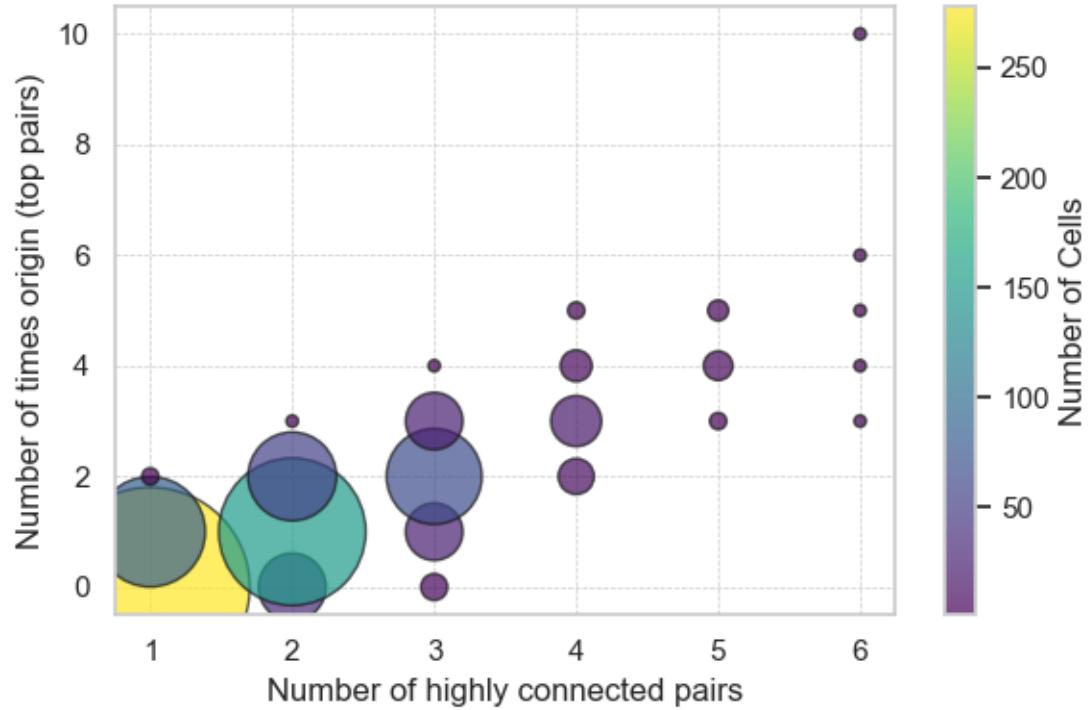
1.3.9 Pair/Trios with high communication networks

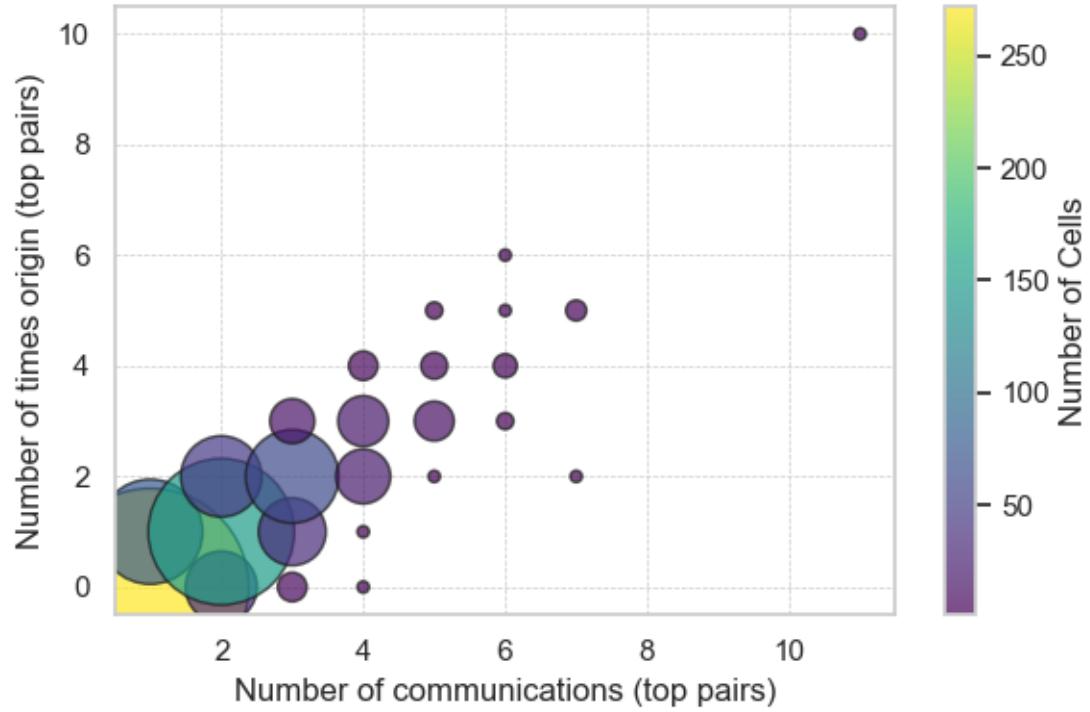
```
[2025-08-27 15:09:33] [INFO] calcium: build_neighbor_pair_stats: built 3537 pairs across 1 datasets (mean distance=15.47 um)
```

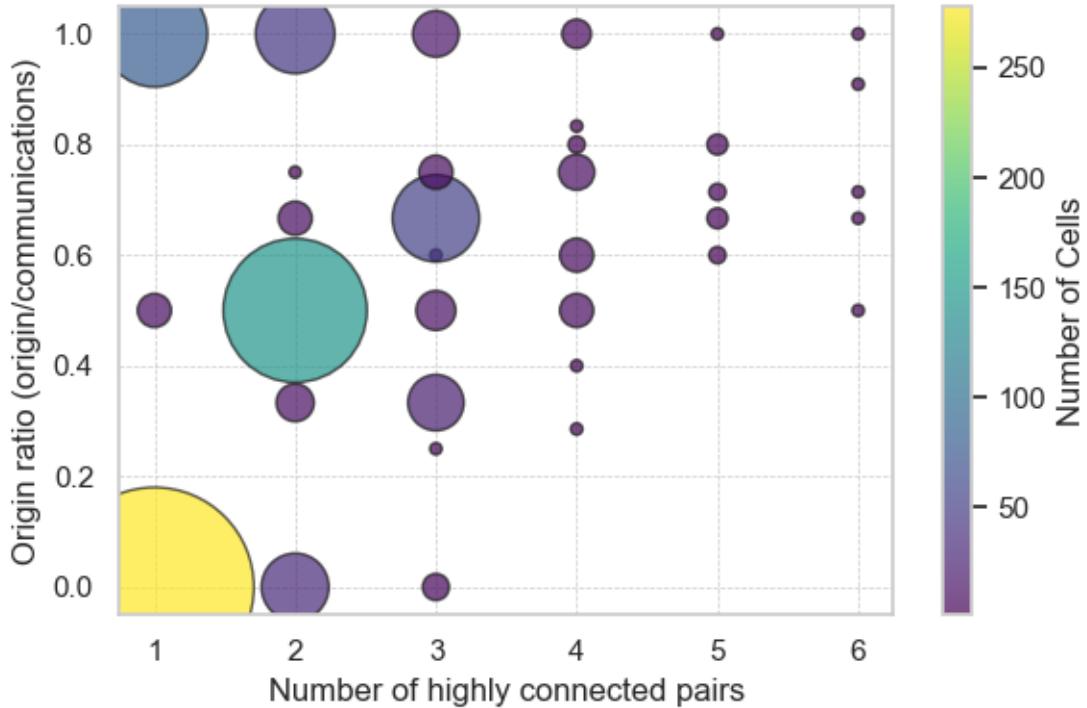


95th percentile threshold: 1.0









[2025-08-27 15:09:34] [INFO] calcium: plot_points_mean_std: N=365 for Number of highly connected pairs=1

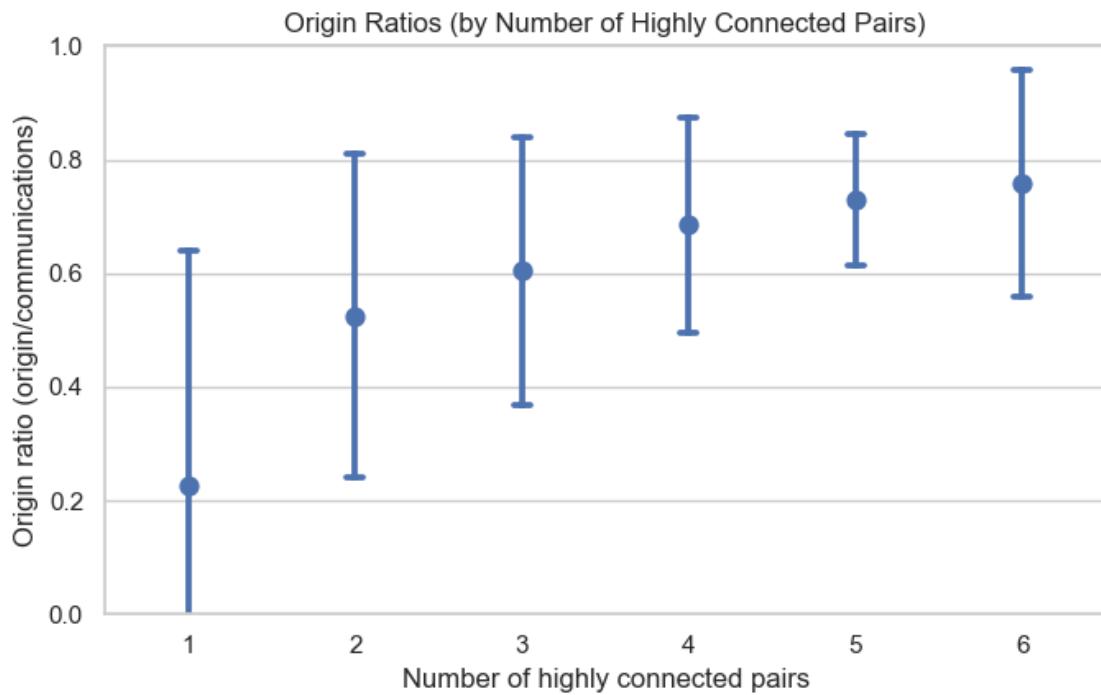
[2025-08-27 15:09:34] [INFO] calcium: plot_points_mean_std: N=240 for Number of highly connected pairs=2

[2025-08-27 15:09:34] [INFO] calcium: plot_points_mean_std: N=116 for Number of highly connected pairs=3

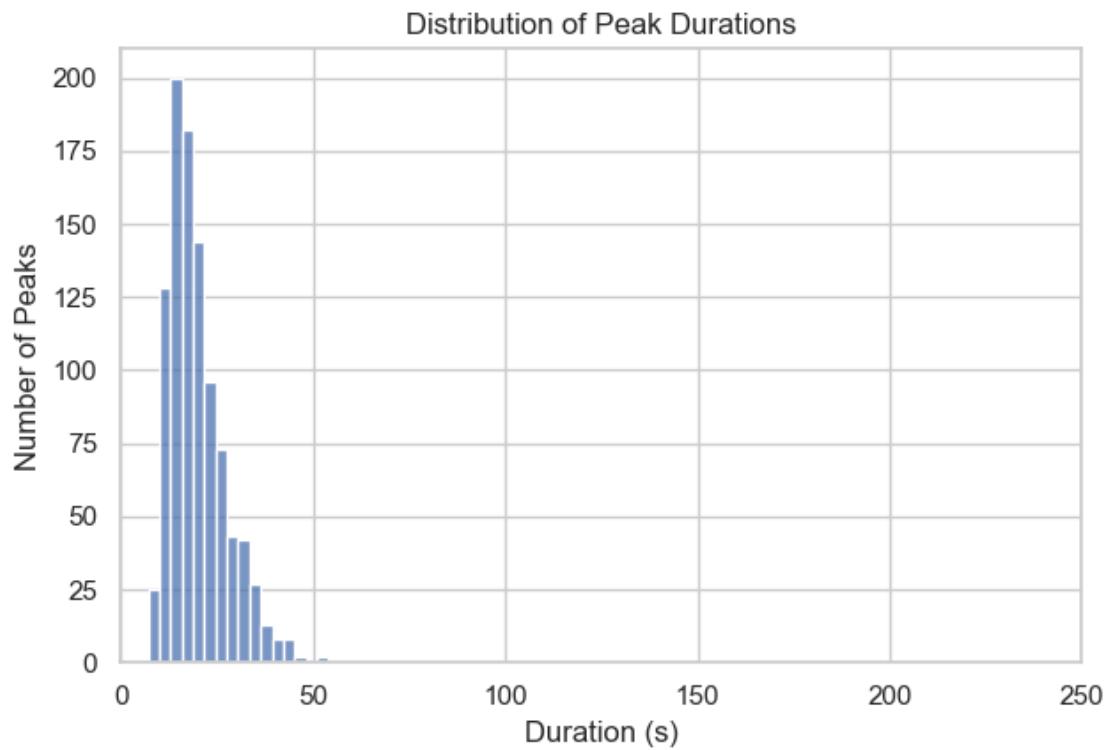
[2025-08-27 15:09:34] [INFO] calcium: plot_points_mean_std: N=36 for Number of highly connected pairs=4

[2025-08-27 15:09:34] [INFO] calcium: plot_points_mean_std: N=11 for Number of highly connected pairs=5

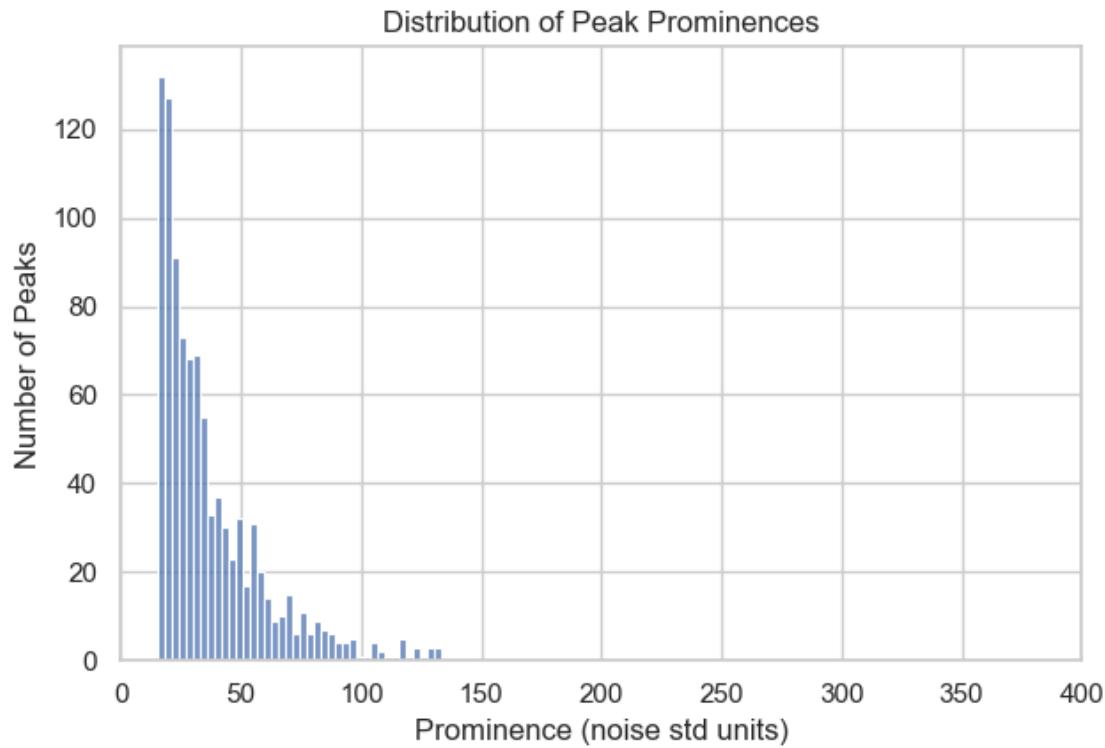
[2025-08-27 15:09:34] [INFO] calcium: plot_points_mean_std: N=5 for Number of highly connected pairs=6

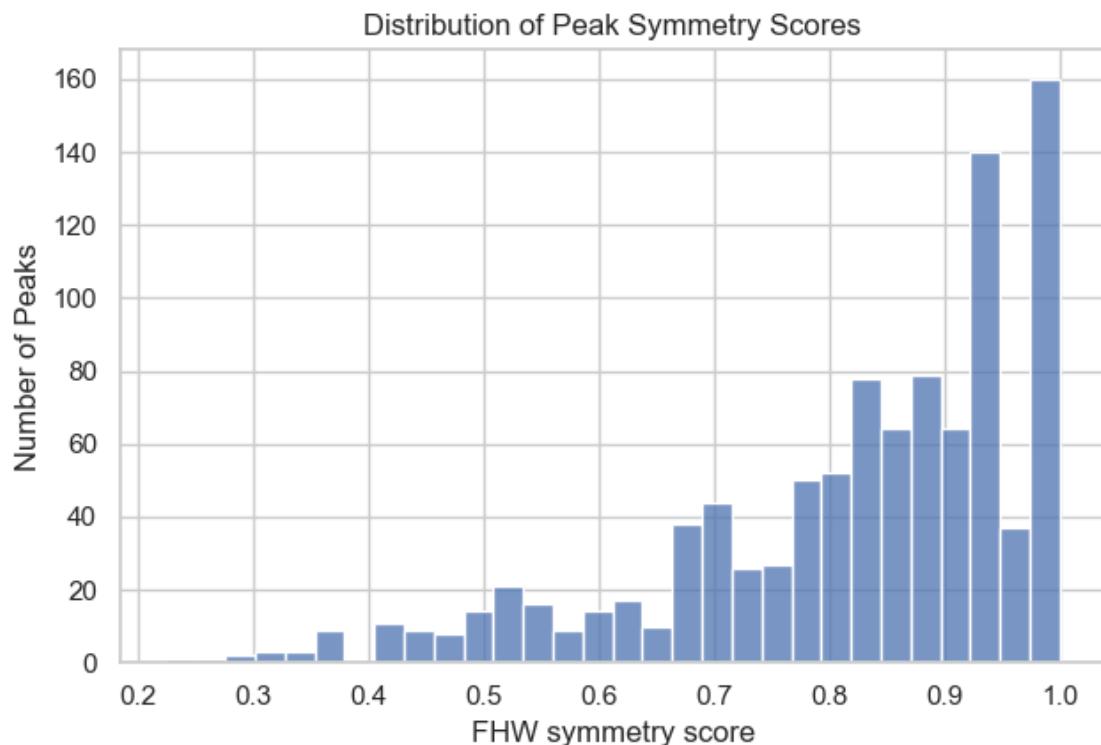


```
[2025-08-27 15:09:34] [INFO] calcium: plot_histogram: removed 14 outliers out of 1007 on 'Duration (s)' (lower=-16, upper=54)
```

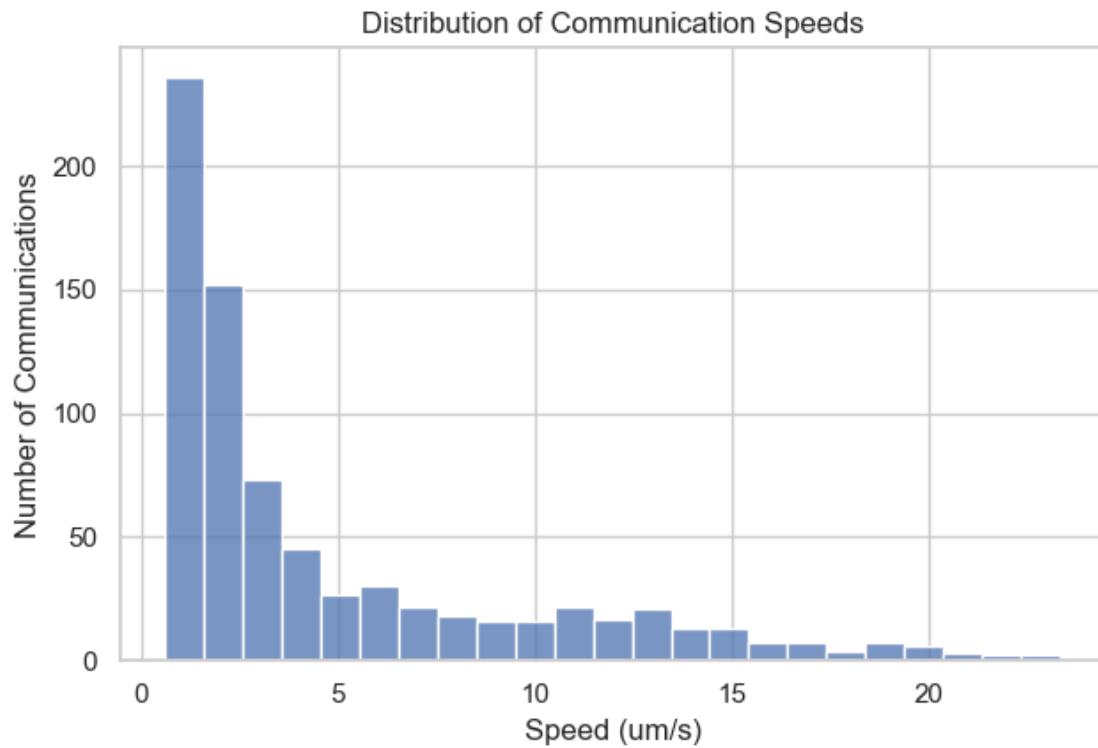


[2025-08-27 15:09:34] [INFO] calcium: plot_histogram: removed 37 outliers out of 1007 on 'Prominence (noise std units)' (lower=-64.3, upper=134.15)

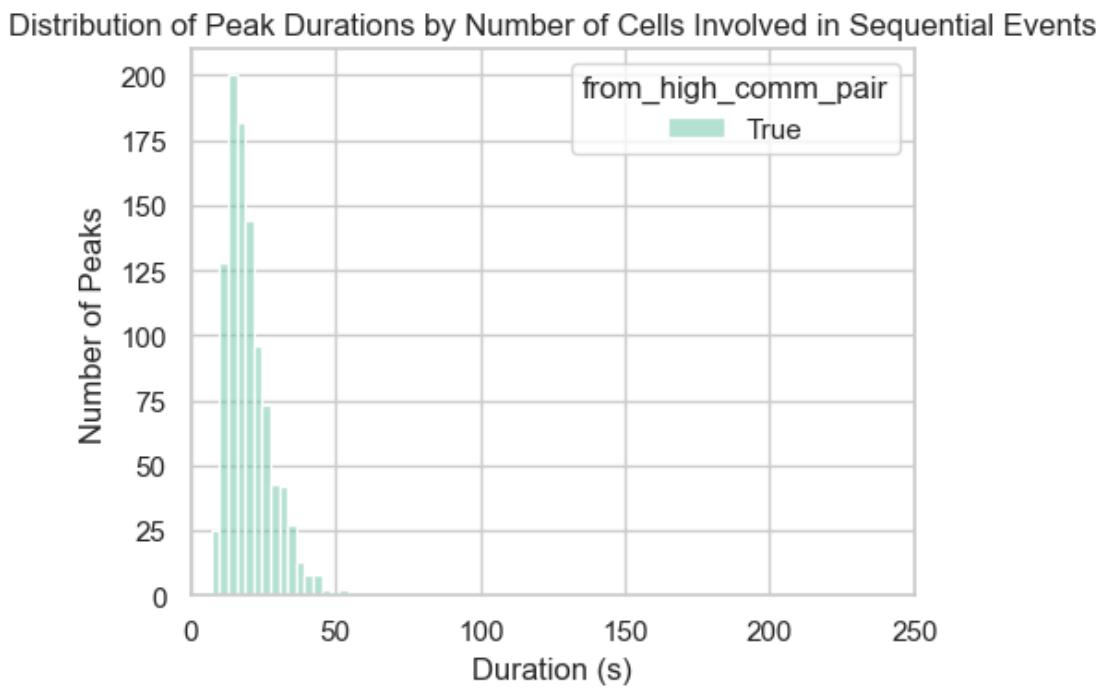




```
[2025-08-27 15:09:34] [INFO] calcium: plot_histogram: removed 2 outliers out of 761 on 'Speed (um/s)' (lower=-14.97, upper=23.39)
```

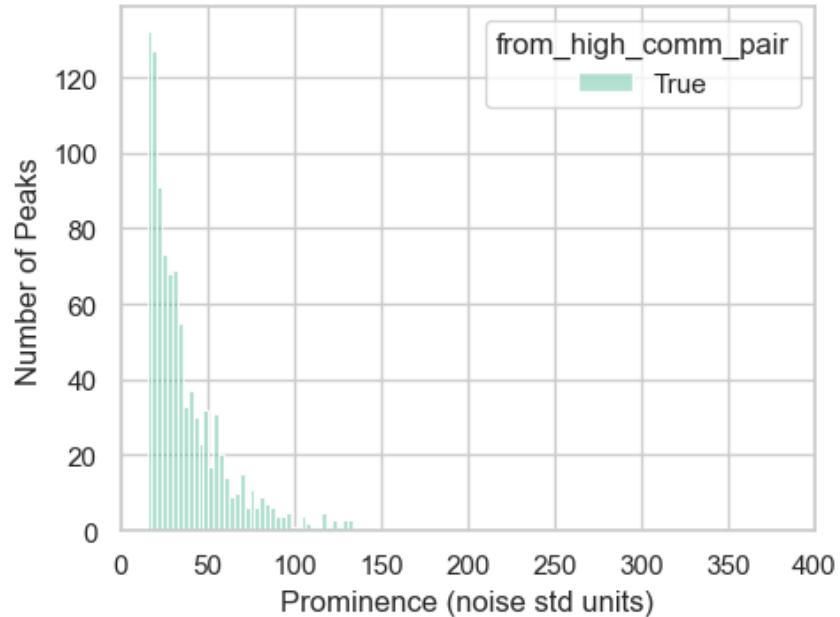


```
[2025-08-27 15:09:35] [INFO] calcium: plot_histogram_by_group: removed 14 outliers out of 1007 on 'Duration (s)' (lower=-16, upper=54)
```

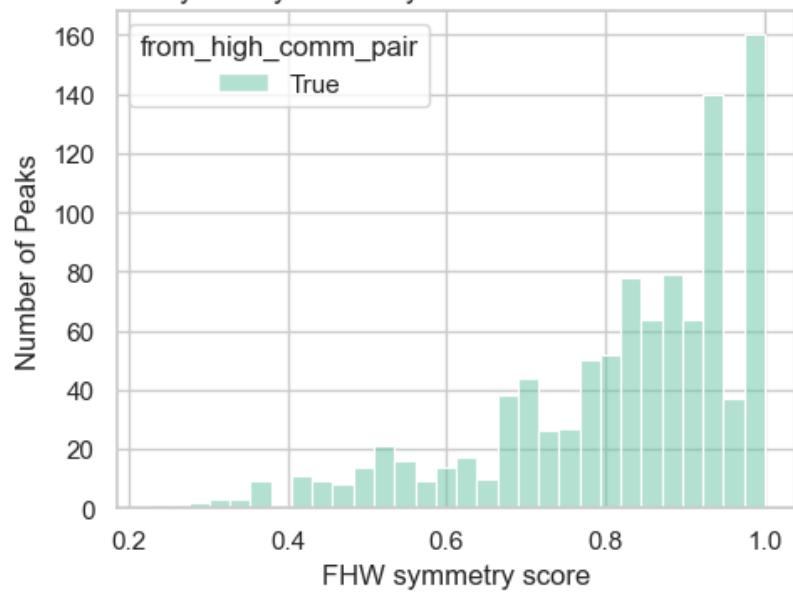


```
[2025-08-27 15:09:35] [INFO] calcium: plot_histogram_by_group: removed 37 outliers out of 1007 on 'Prominence (noise std units)' (lower=-64.3, upper=134.15)
```

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

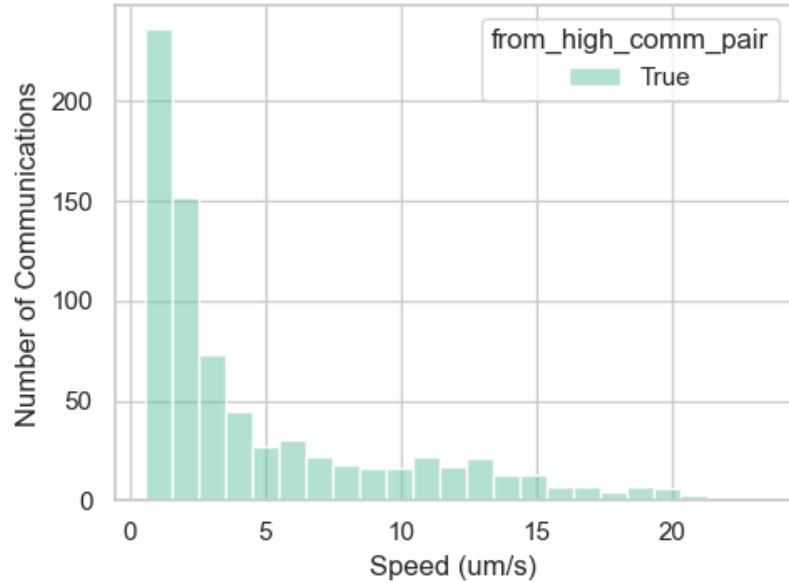


Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



[2025-08-27 15:09:35] [INFO] calcium: plot_histogram_by_group: removed 2 outliers out of 761 on 'Speed (um/s)' (lower=-14.97, upper=23.39)

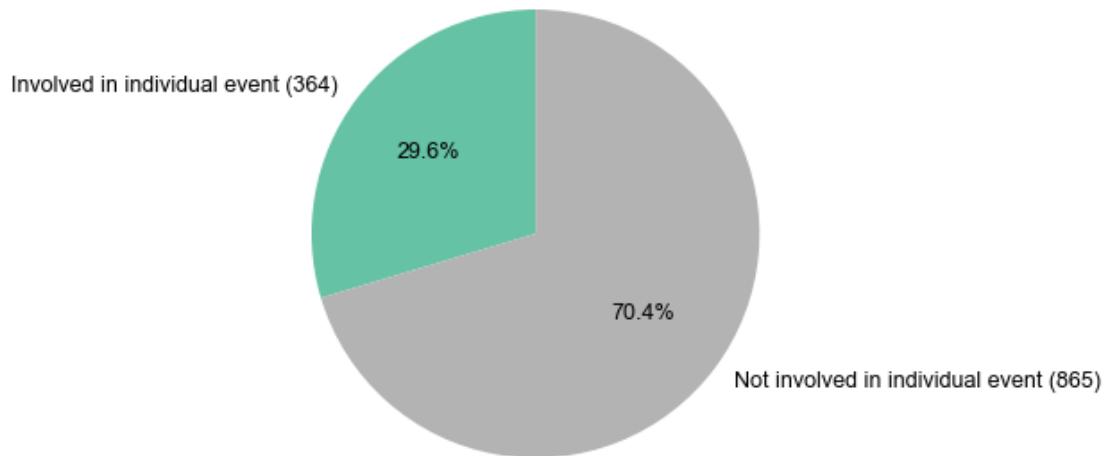
Distribution of Communication Speeds by Number of Cells Involved in Sequential Events



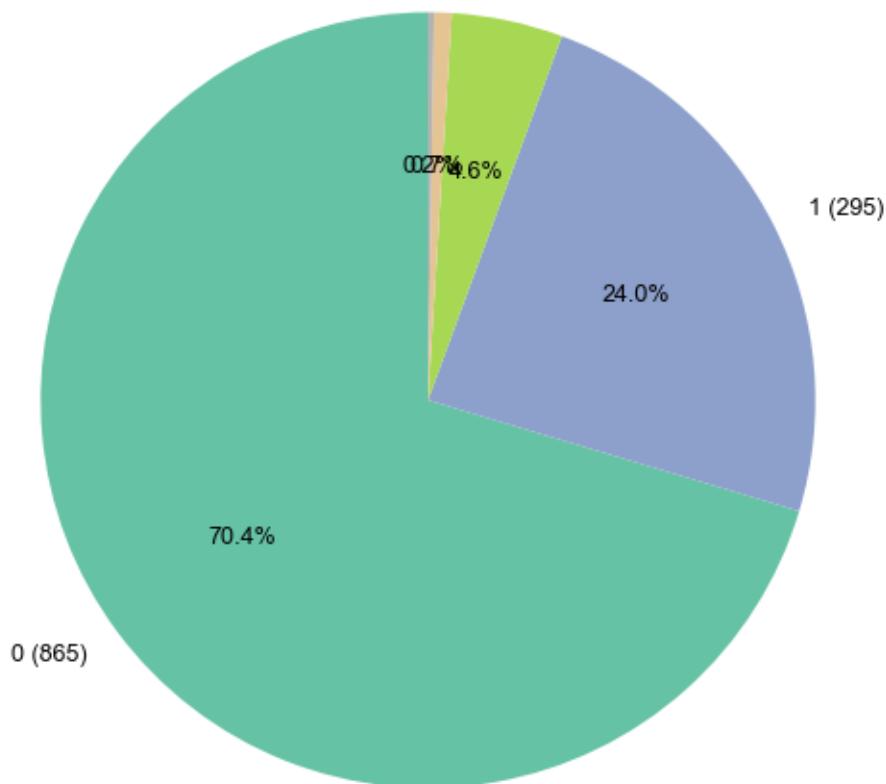
1.4 INDIVIDUAL EVENTS

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+)

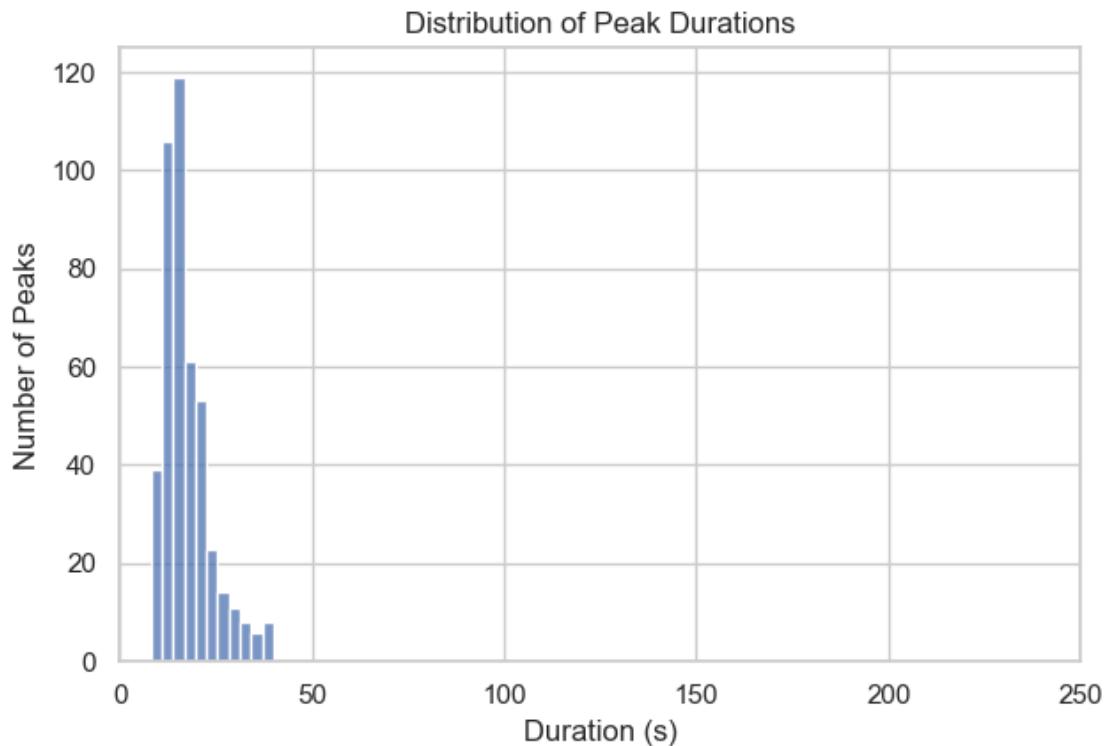


```
[2025-08-27 15:09:35] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS07\cell-
mapping\cell_occurrences_in_individual_events_overlay.png': [Errno 2] No such
file or directory: 'D:\\Mateo\\20250624\\Output\\IS07\\cell-
mapping\\cell_occurrences_in_individual_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundException: [Errno 2] No such file or directory:
```

```
'D:\\Mateo\\20250624\\Output\\IS07\\cell-  
mapping\\cell_occurrences_in_individual_events_overlay.png'
```

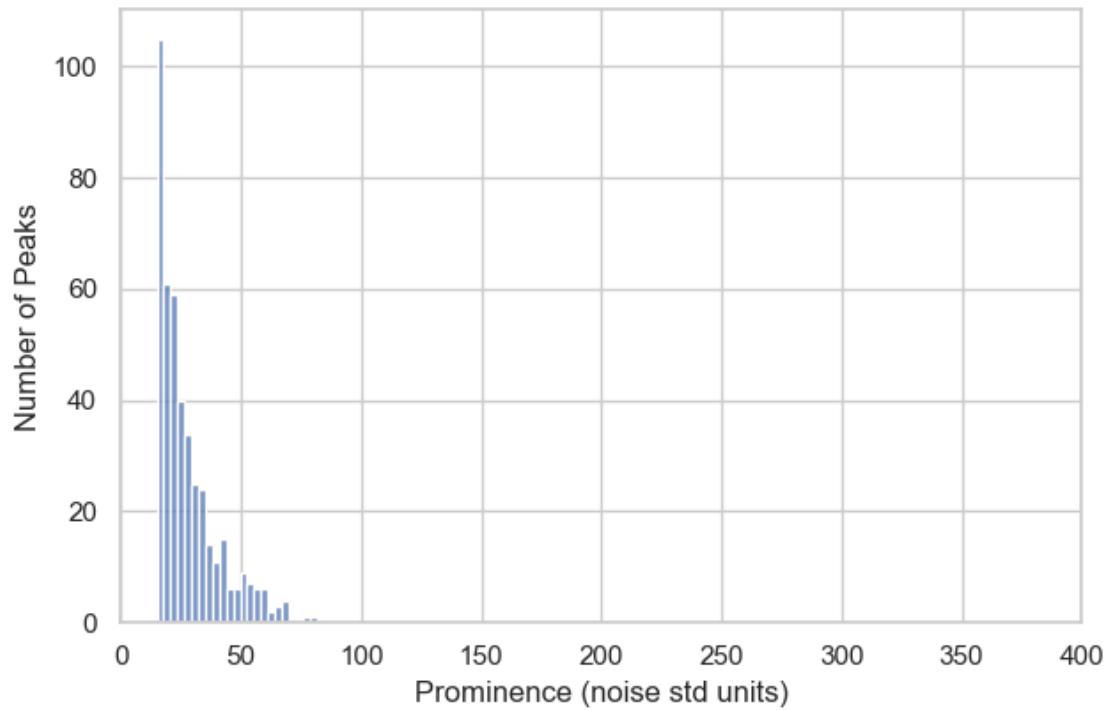
1.4.2 Peaks statistics in individual events

```
[2025-08-27 15:09:36] [INFO] calcium: plot_histogram: removed 6 outliers out of  
454 on 'Duration (s)' (lower=-8, upper=41)
```

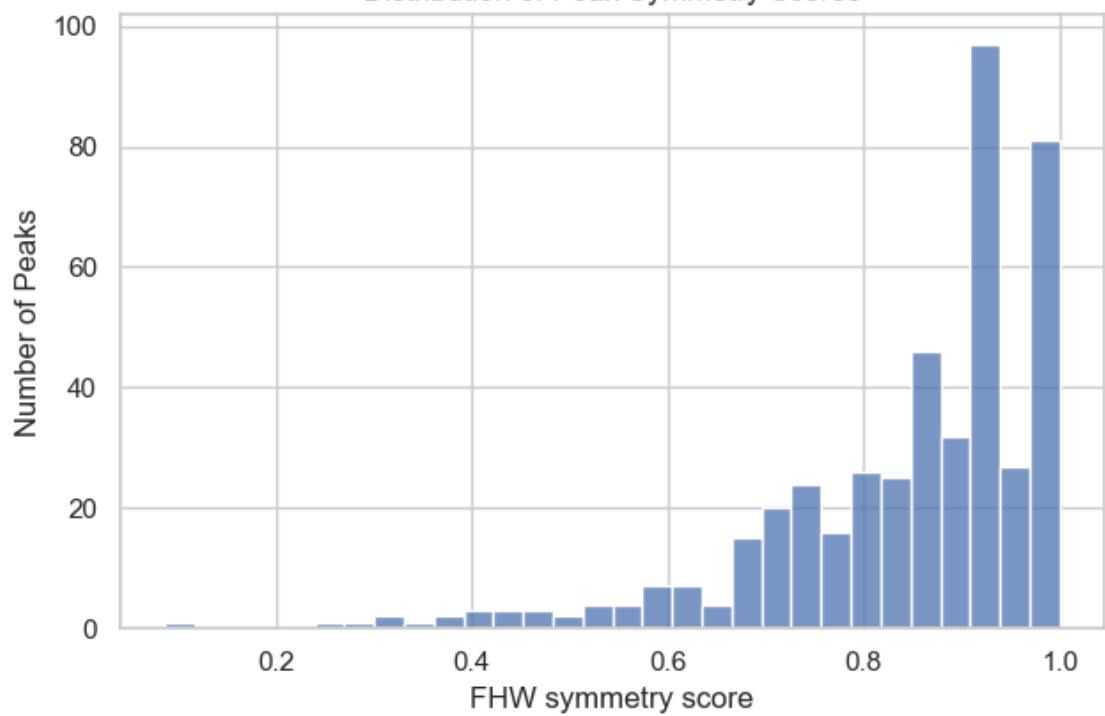


```
[2025-08-27 15:09:36] [INFO] calcium: plot_histogram: removed 15 outliers out of  
454 on 'Prominence (noise std units)' (lower=-30, upper=82.7)
```

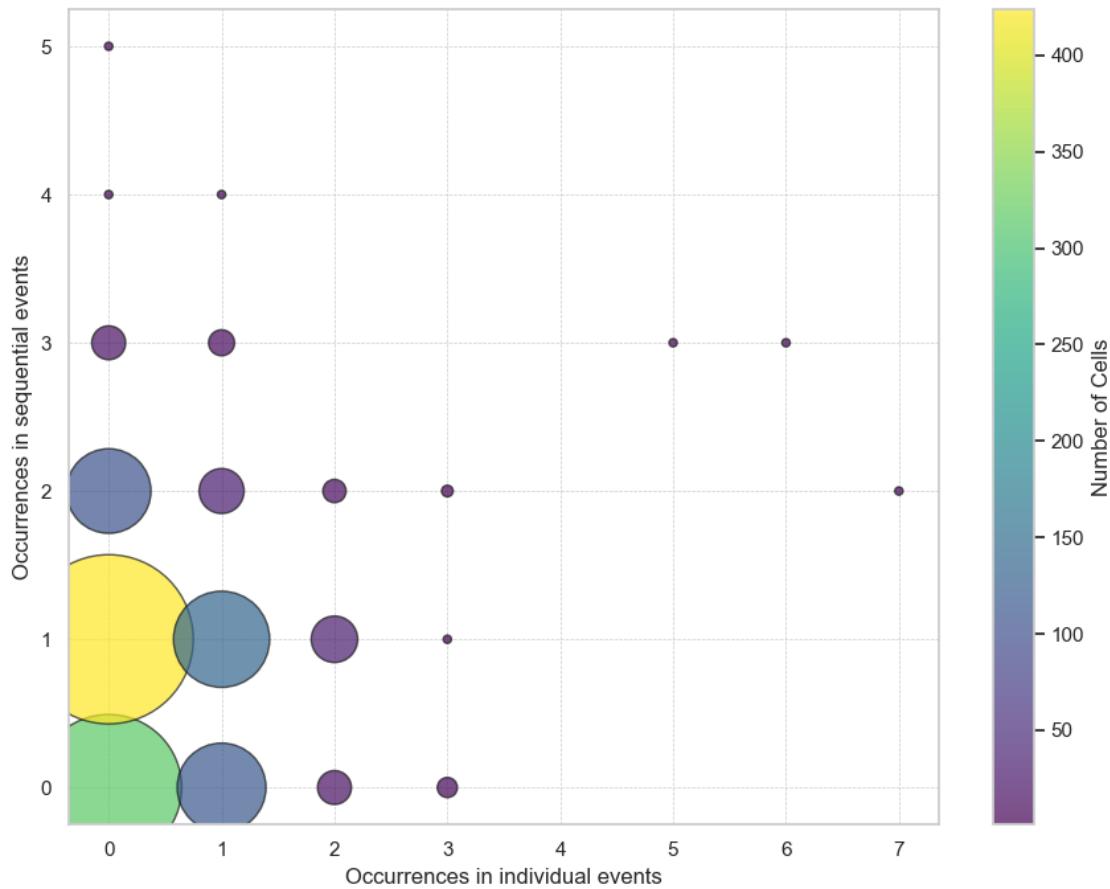
Distribution of Peak Prominences



Distribution of Peak Symmetry Scores



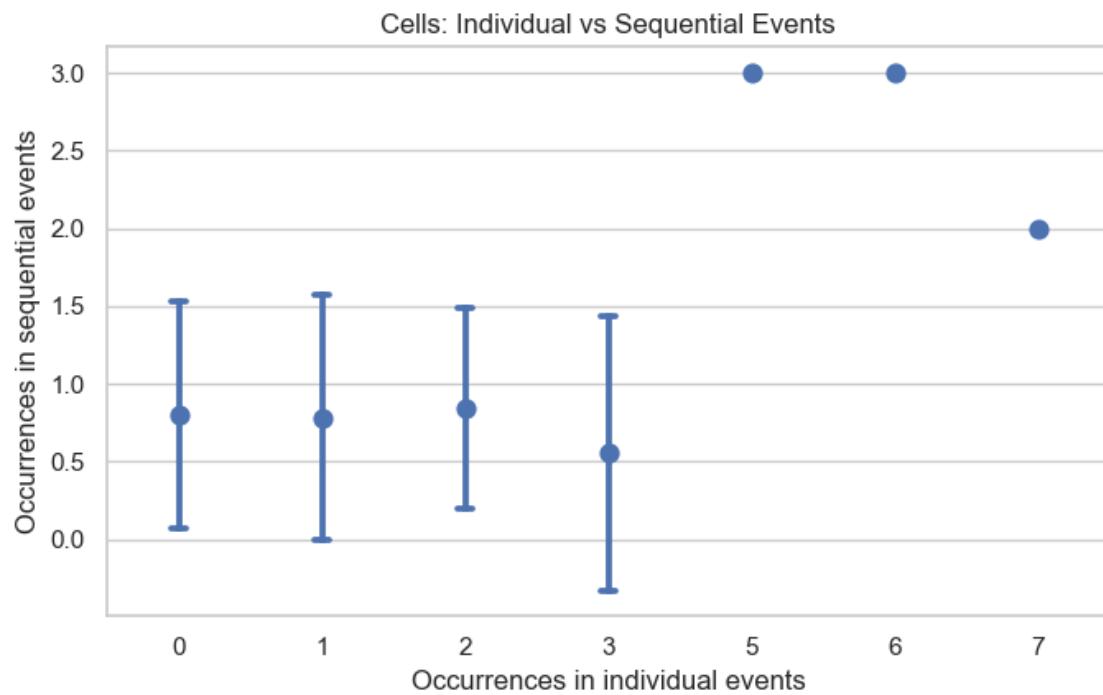
1.4.3 Correlation between event activity level & individual activity level



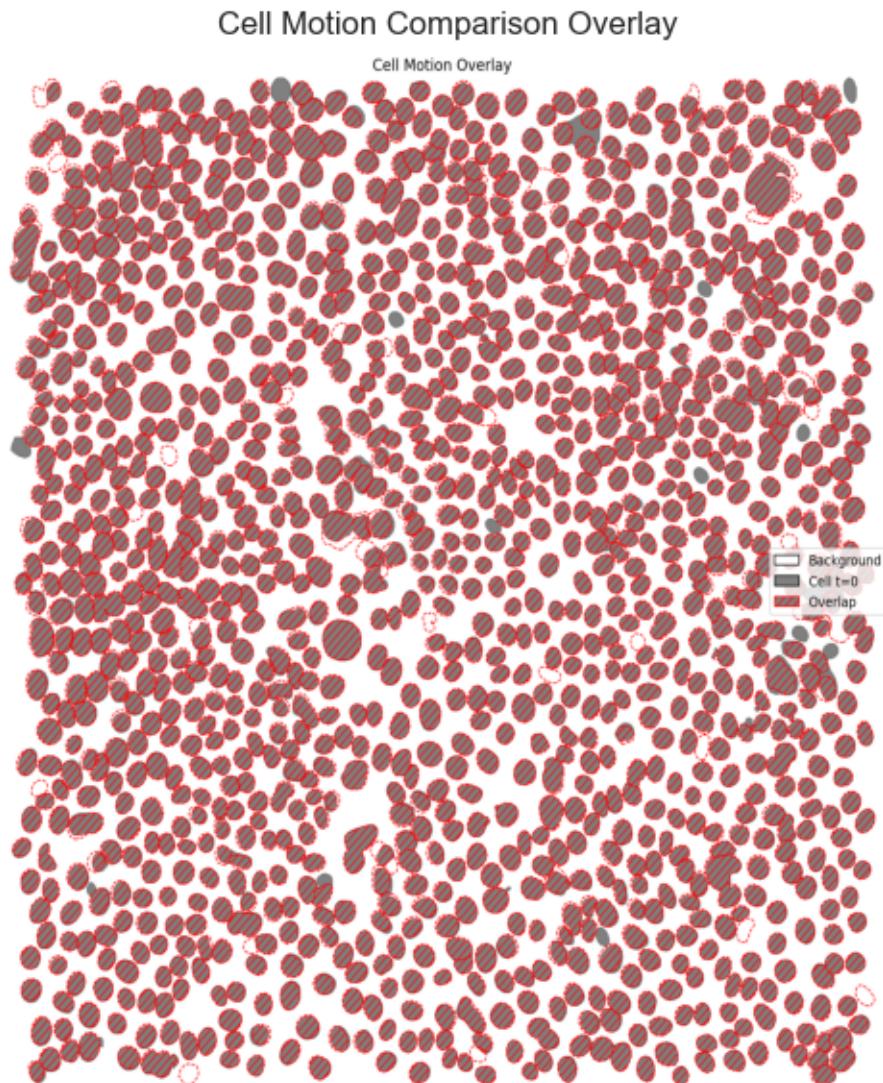
```
[2025-08-27 15:09:36] [INFO] calcium: plot_points_mean_std: removed 1/1229 outliers on 'Occurrences in sequential events' (lower=-3, upper=4)
[2025-08-27 15:09:36] [INFO] calcium: plot_points_mean_std: N=864 for Occurrences in individual events=0
[2025-08-27 15:09:36] [INFO] calcium: plot_points_mean_std: N=295 for Occurrences in individual events=1
[2025-08-27 15:09:36] [INFO] calcium: plot_points_mean_std: N=57 for Occurrences in individual events=2
[2025-08-27 15:09:36] [INFO] calcium: plot_points_mean_std: N=9 for Occurrences in individual events=3
[2025-08-27 15:09:36] [INFO] calcium: plot_points_mean_std: N=1 for Occurrences in individual events=5
```

[2025-08-27 15:09:36] [INFO] calcium: plot_points_mean_std: N=1 for Occurrences in individual events=6

[2025-08-27 15:09:36] [INFO] calcium: plot_points_mean_std: N=1 for Occurrences in individual events=7



1.5 CELLS MOTION



Number of cells:

- Hoechst image taken at t=0: 1229
- Hoechst image taken at t=1801: 1232
- Number of cells difference: absolute 3, relative 0.24%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1112223
- Pixels segmented as cell at t=1801: 1108659
- Overlapping pixels between t=0 and t=1801: 1016859 (91.57% of total)
- Pixels exclusive to t=0: 95364 (8.57% of total)
- Pixels exclusive to t=1801: 91800 (8.28% of total)

executed

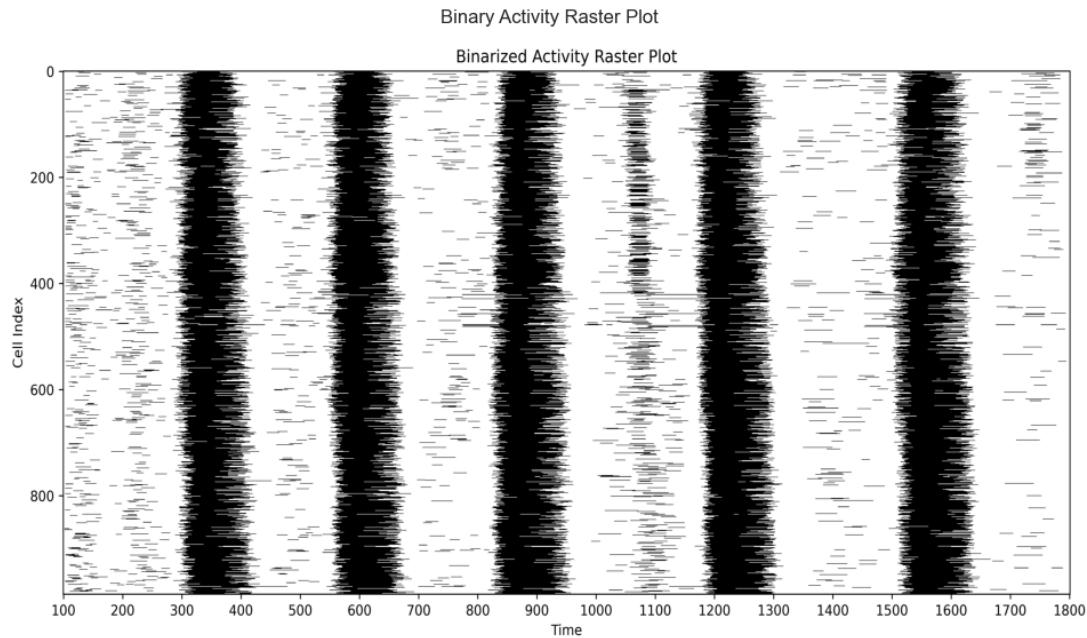
August 27, 2025

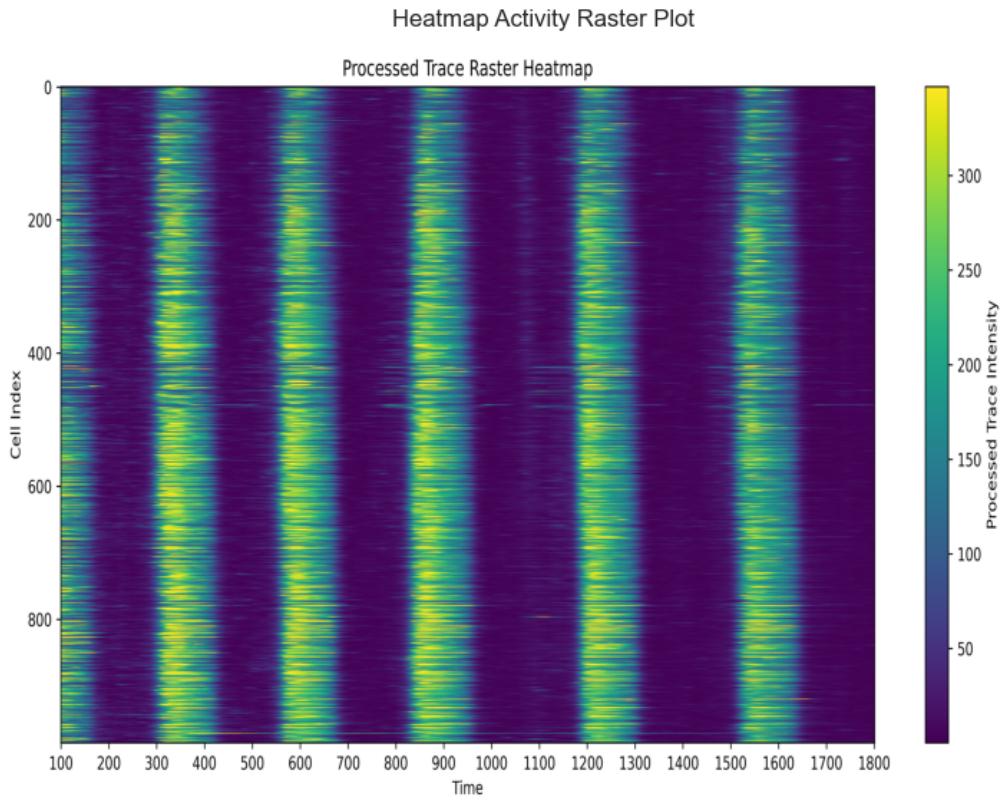
1 ANALYSIS OF AN IMAGE SEQUENCE AFTER DATA GENERATION USING THE CALCIUM CHARACTERIZATION PIPELINE

1.0.1 Initialization

1.1 POPULATION

1.1.1 Binary & Heatmap Raster Plot





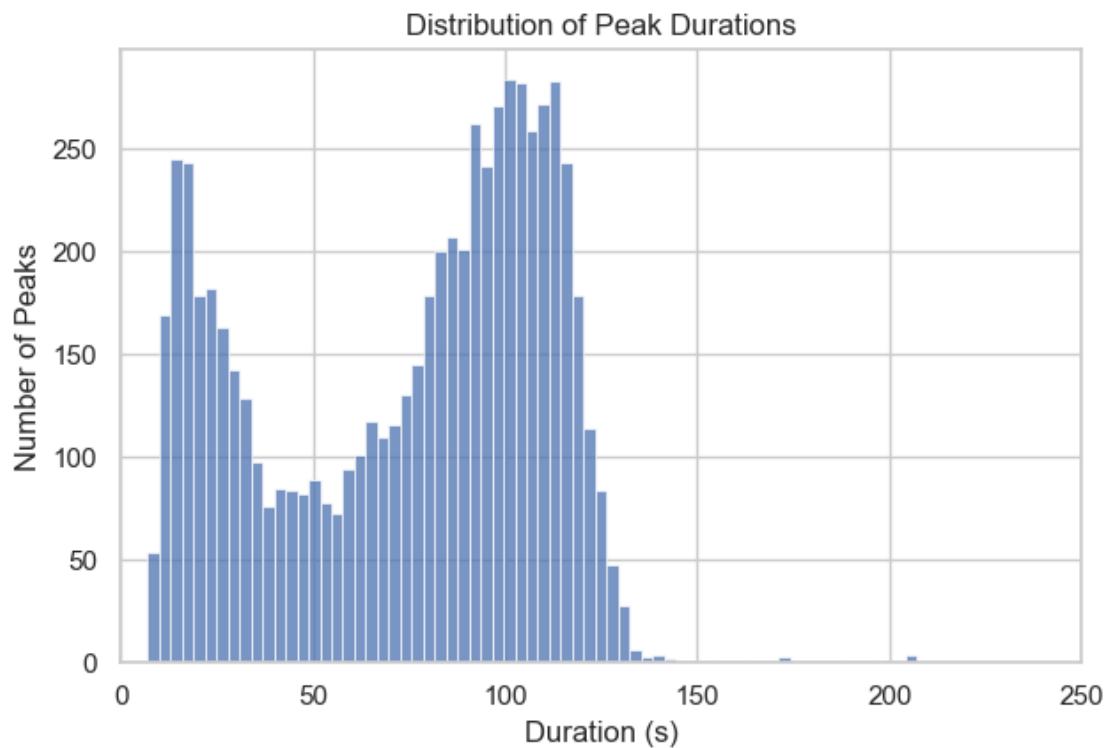
1.1.2 Peaks population

Total number of peaks: 6657

Total number of cells: 986

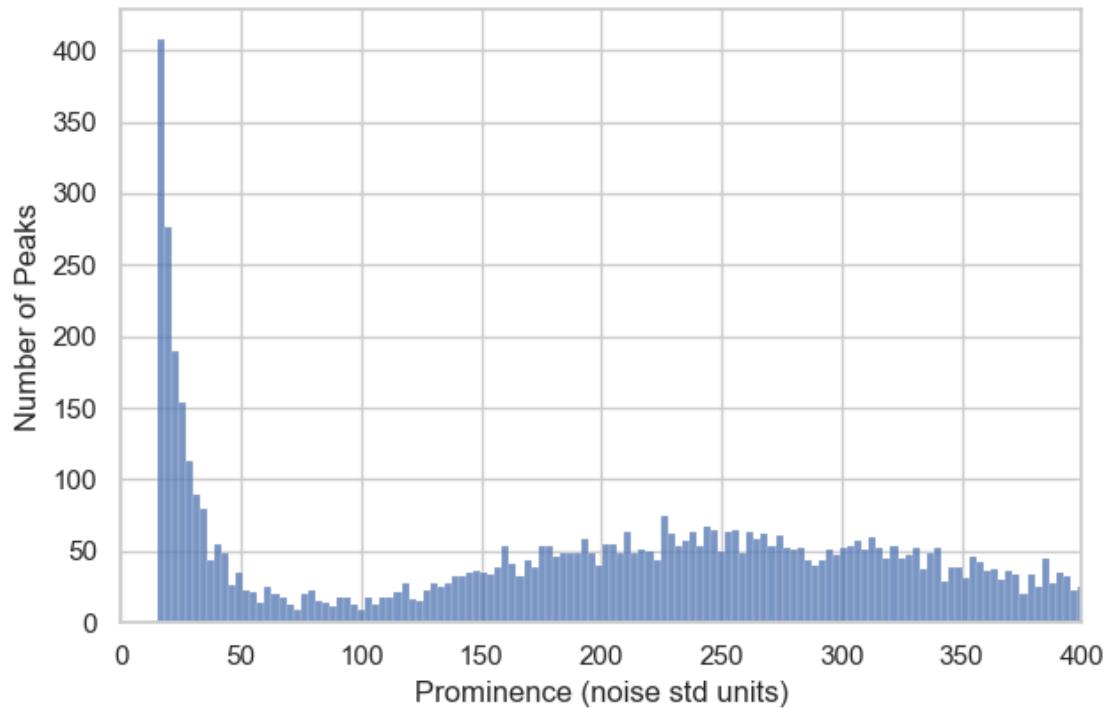
1.1.3 Peaks statistics

```
[2025-08-27 15:10:04] [INFO] calcium: plot_histogram: removed 0 outliers out of 6657 on 'Duration (s)' (lower=-156, upper=299)
```

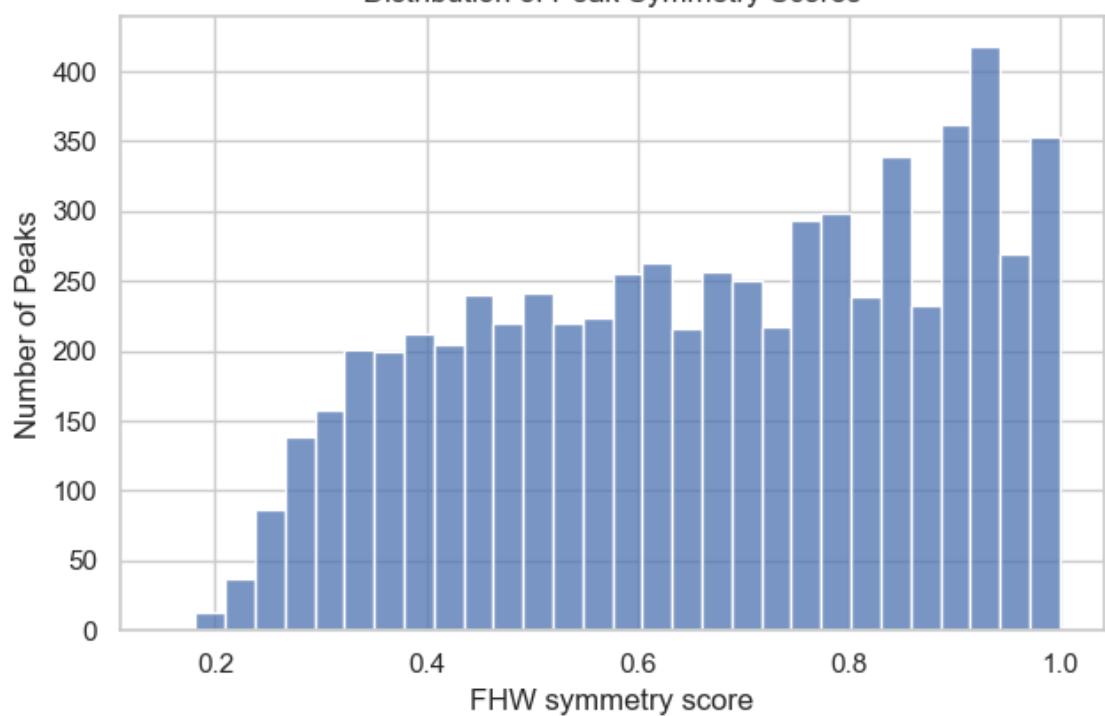


```
[2025-08-27 15:10:04] [INFO] calcium: plot_histogram: removed 0 outliers out of  
6657 on 'Prominence (noise std units)' (lower=-636.3, upper=1024.1)
```

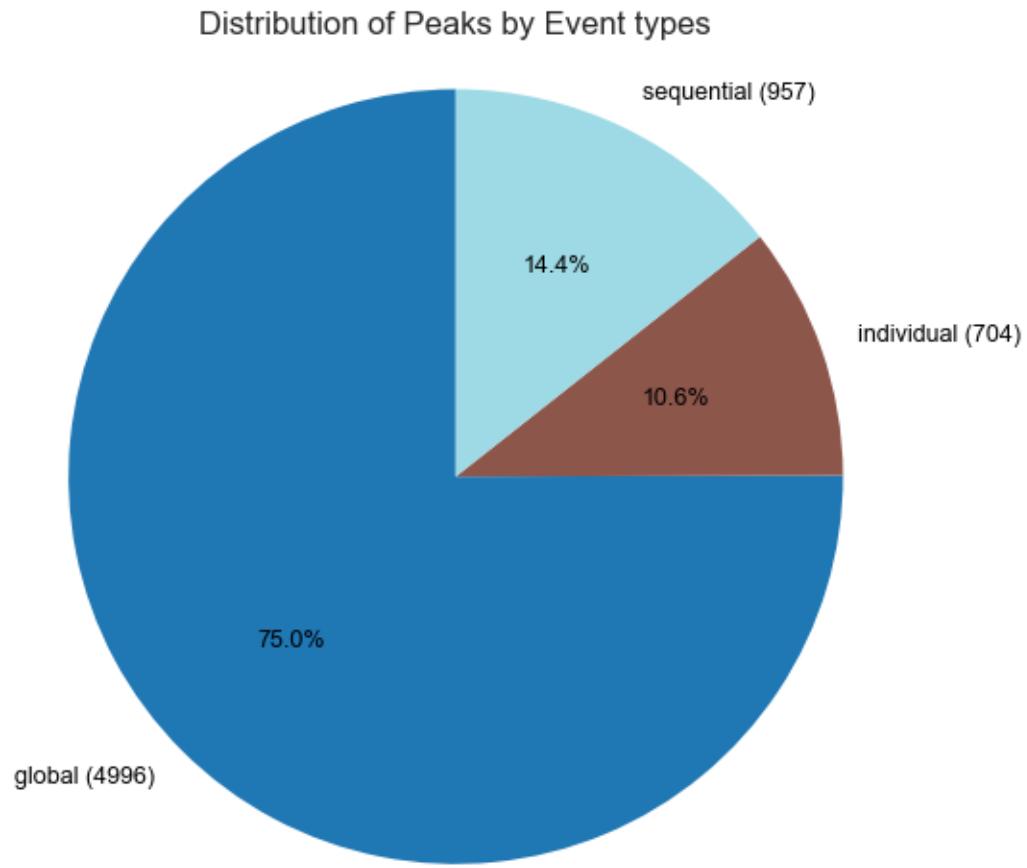
Distribution of Peak Prominences



Distribution of Peak Symmetry Scores

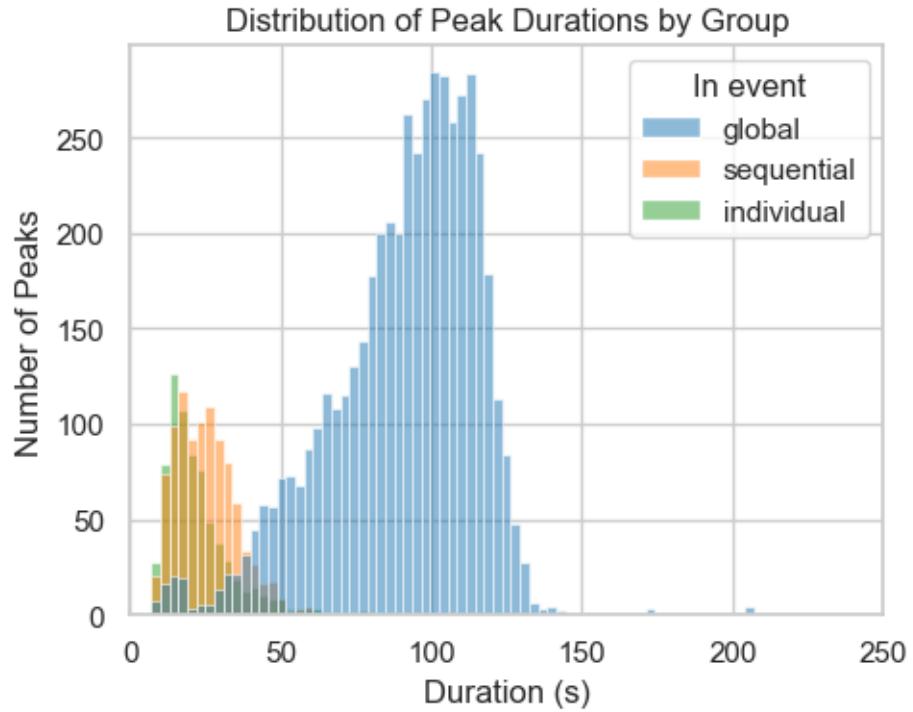


1.1.4 Distribution of peaks per event types

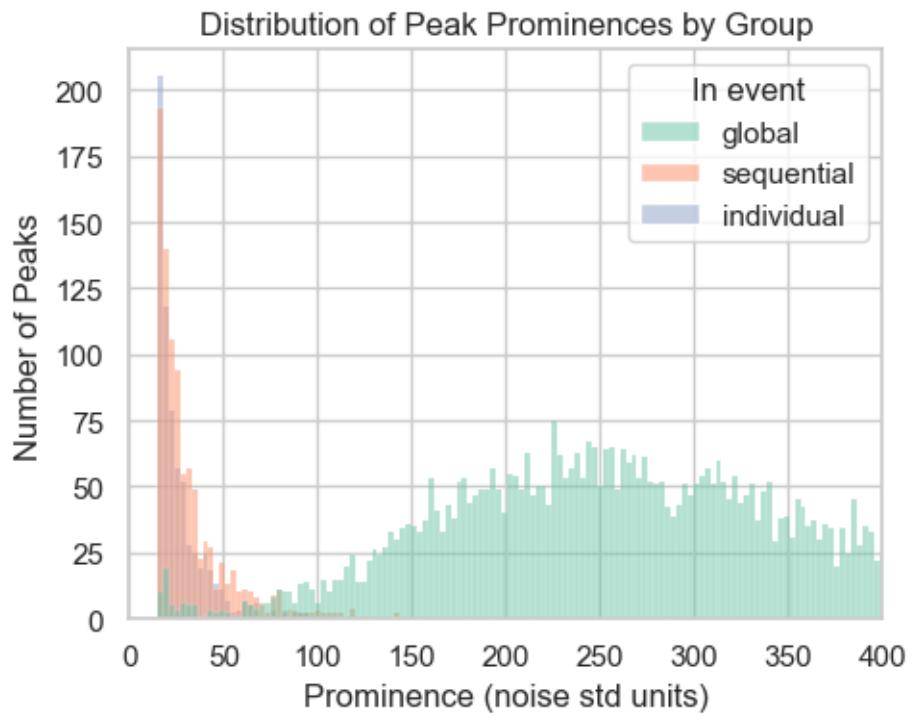


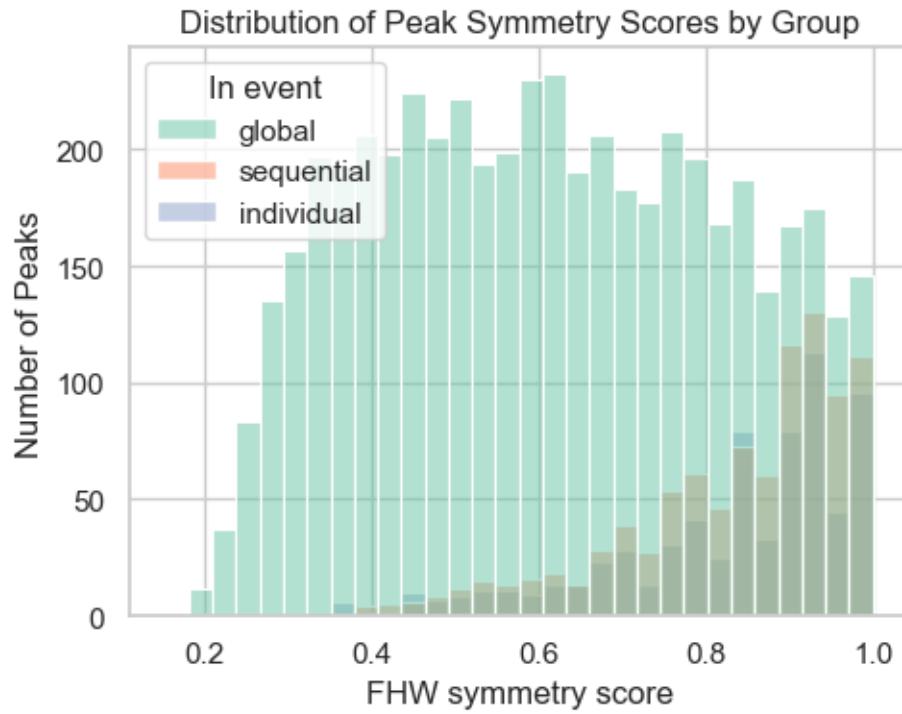
1.1.5 Peaks statistics per event types

```
[2025-08-27 15:10:05] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 6657 on 'Duration (s)' (lower=-156, upper=299)
```



```
[2025-08-27 15:10:05] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 6657 on 'Prominence (noise std units)' (lower=-636.3, upper=1024.1)
```

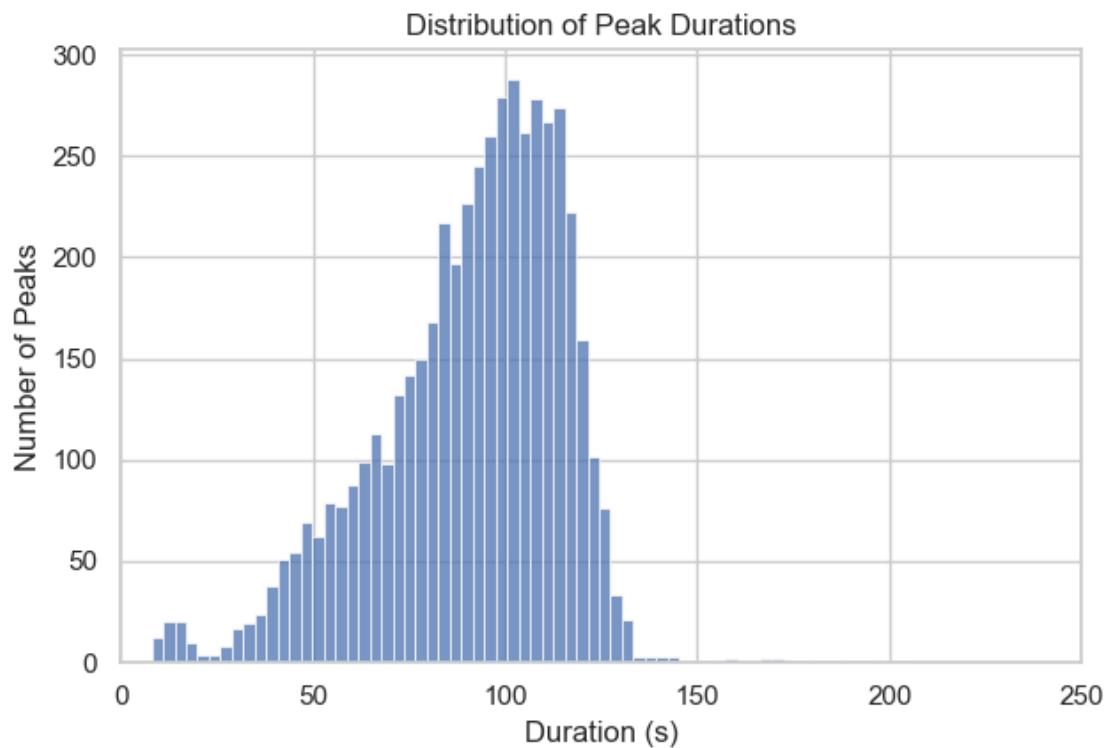




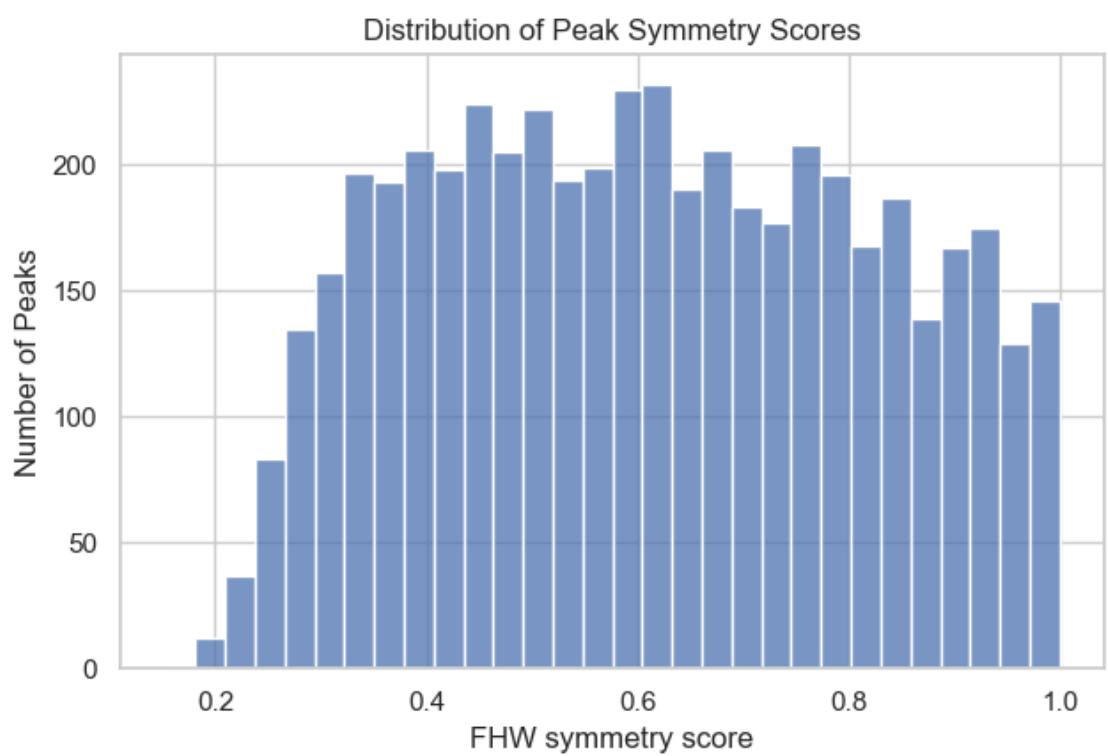
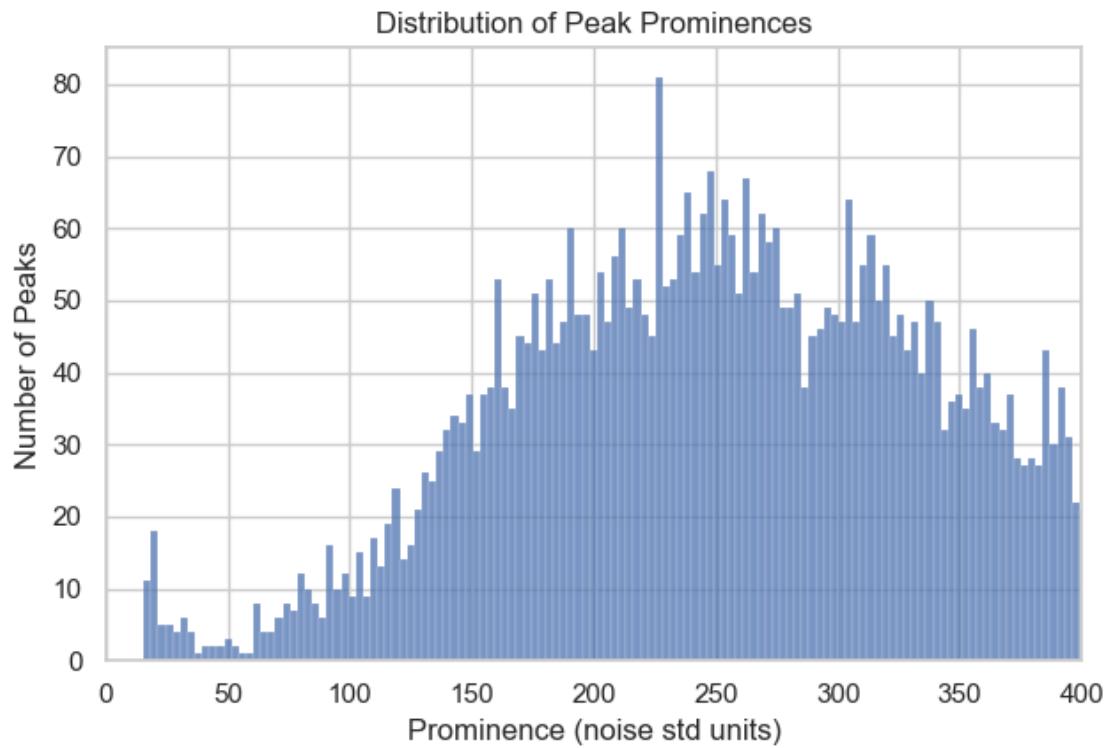
1.2 GLOBAL EVENTS

1.2.1 Peak statistics in global events

```
[2025-08-27 15:10:06] [INFO] calcium: plot_histogram: removed 3 outliers out of 4996 on 'Duration (s)' (lower=-19, upper=205)
```

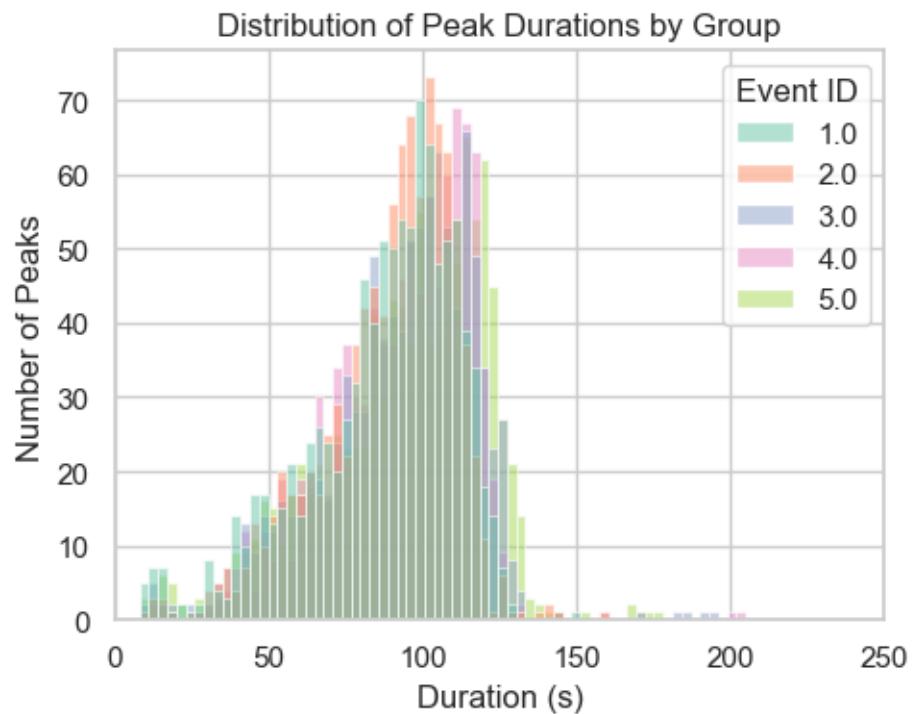


```
[2025-08-27 15:10:06] [INFO] calcium: plot_histogram: removed 2 outliers out of  
4996 on 'Prominence (noise std units)' (lower=-224.8, upper=760.1)
```

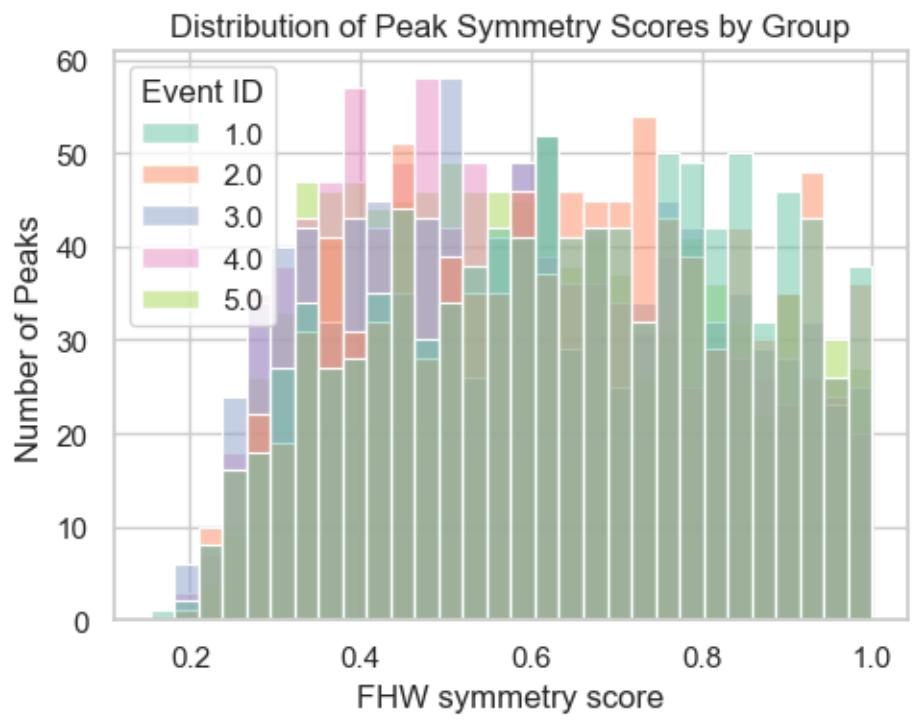
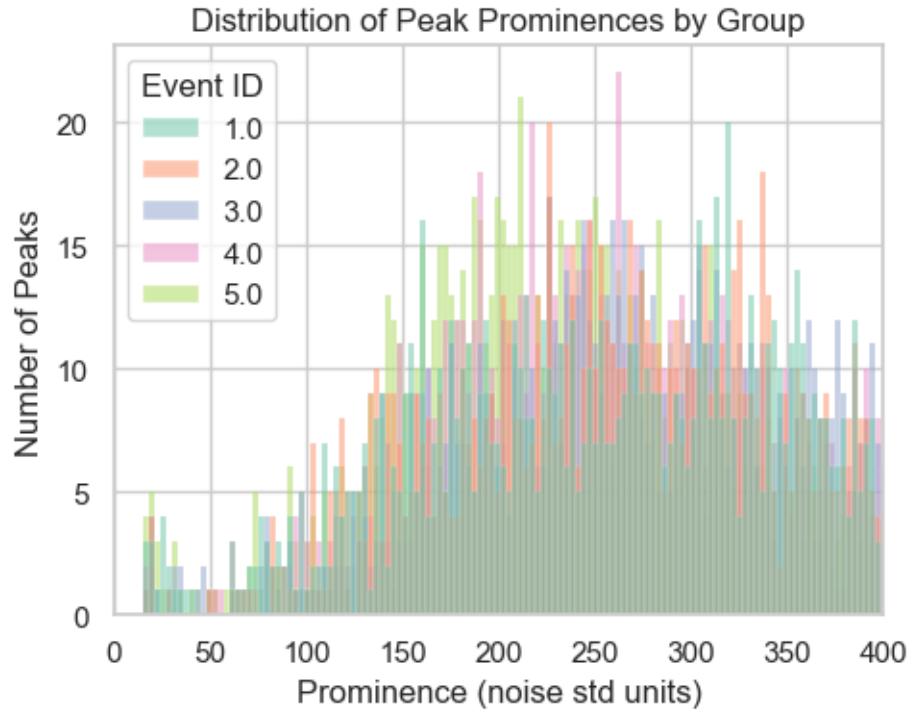


1.2.2 Peak statistics in global event per event ID

[2025-08-27 15:10:07] [INFO] calcium: plot_histogram_by_group: removed 3 outliers out of 4996 on 'Duration (s)' (lower=-19, upper=205)

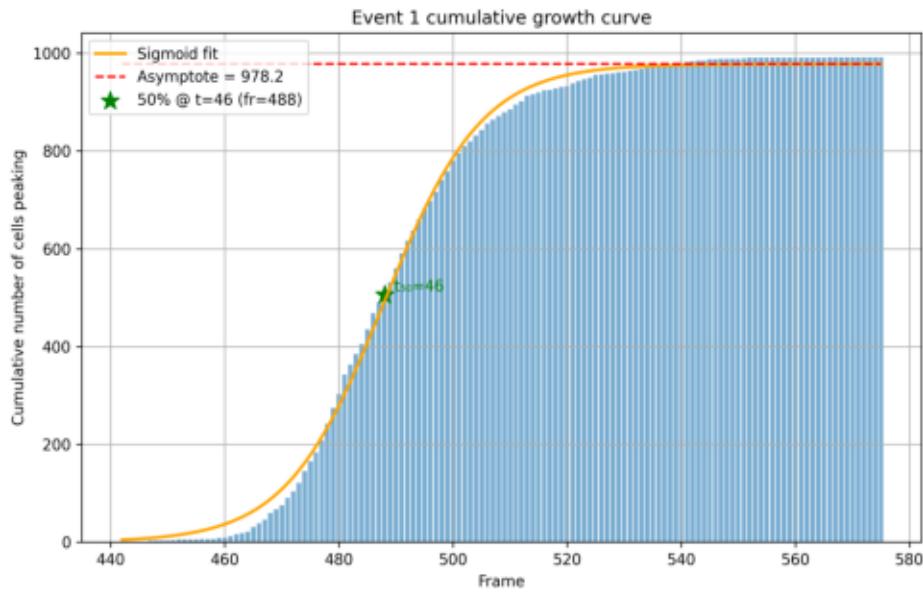


[2025-08-27 15:10:07] [INFO] calcium: plot_histogram_by_group: removed 2 outliers out of 4996 on 'Prominence (noise std units)' (lower=-224.8, upper=760.1)

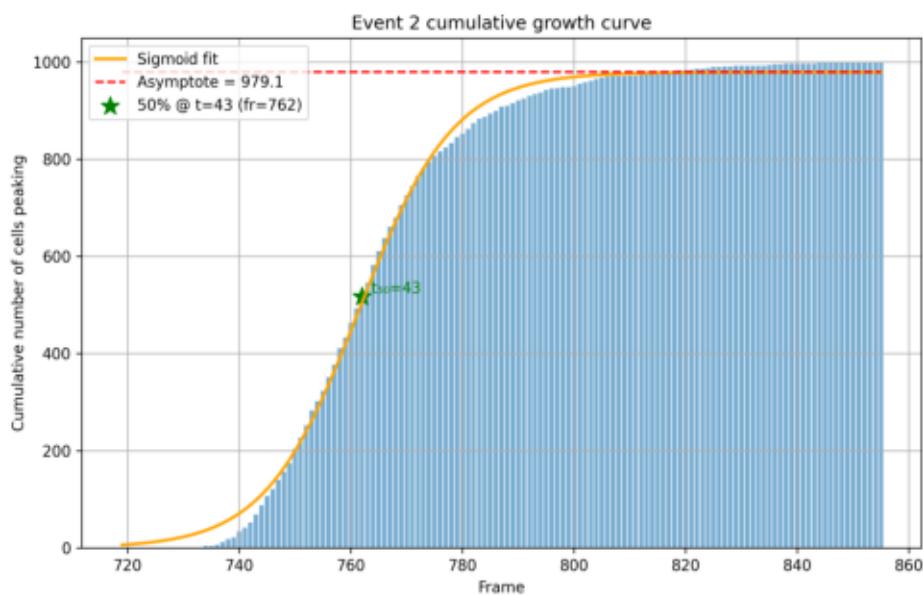


1.2.3 Kinetics of global events

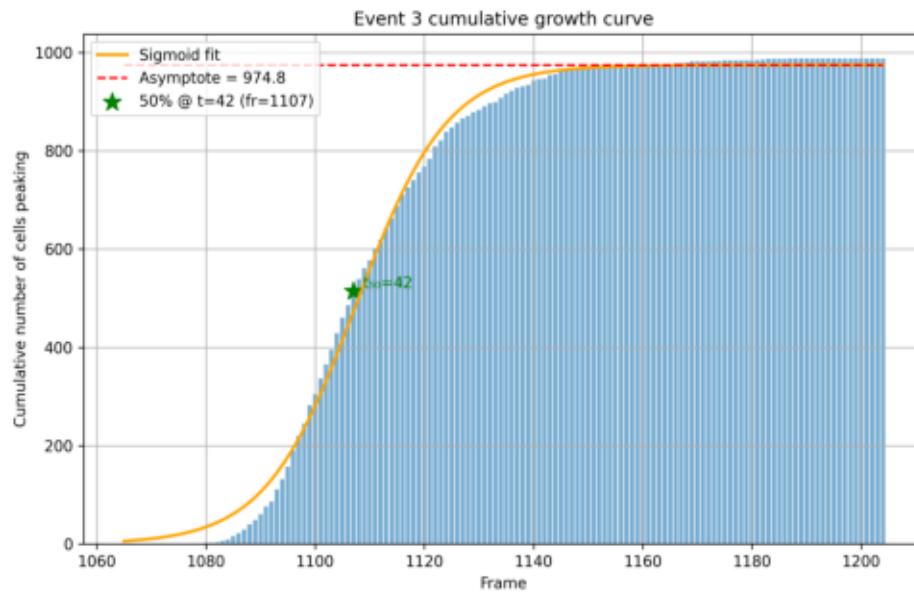
Event Activity Overlay (Event ID: 1)



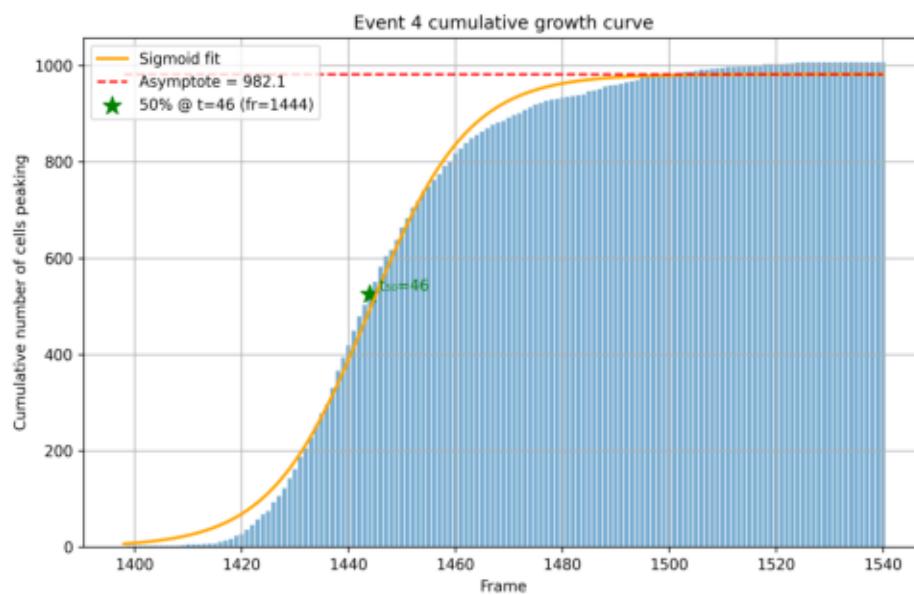
Event Activity Overlay (Event ID: 2)



Event Activity Overlay (Event ID: 3)



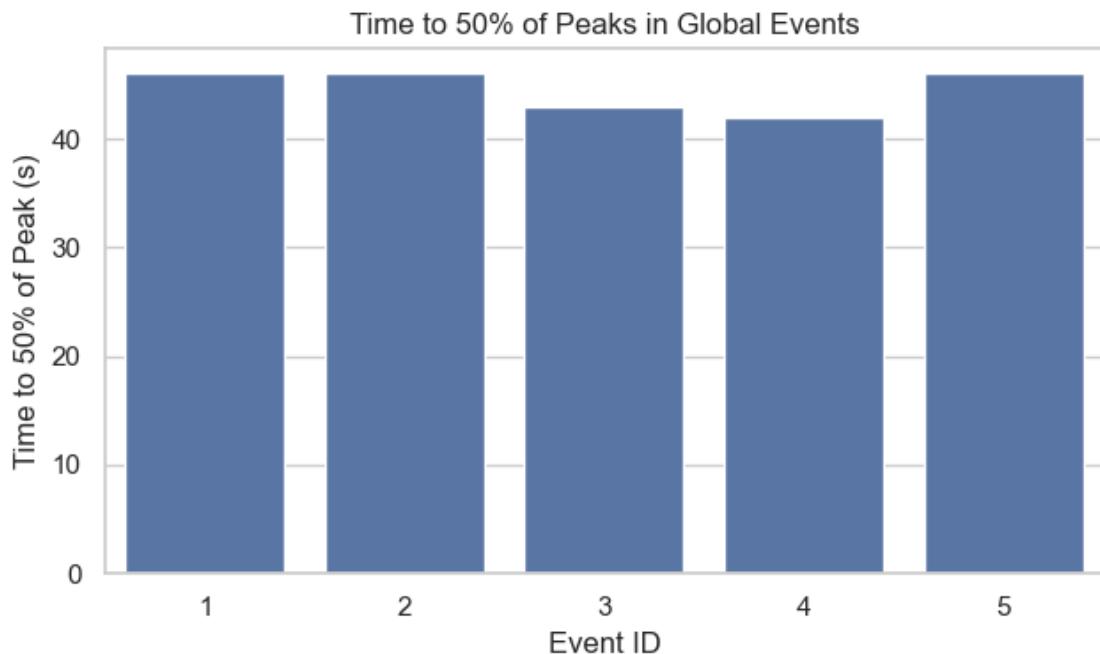
Event Activity Overlay (Event ID: 4)

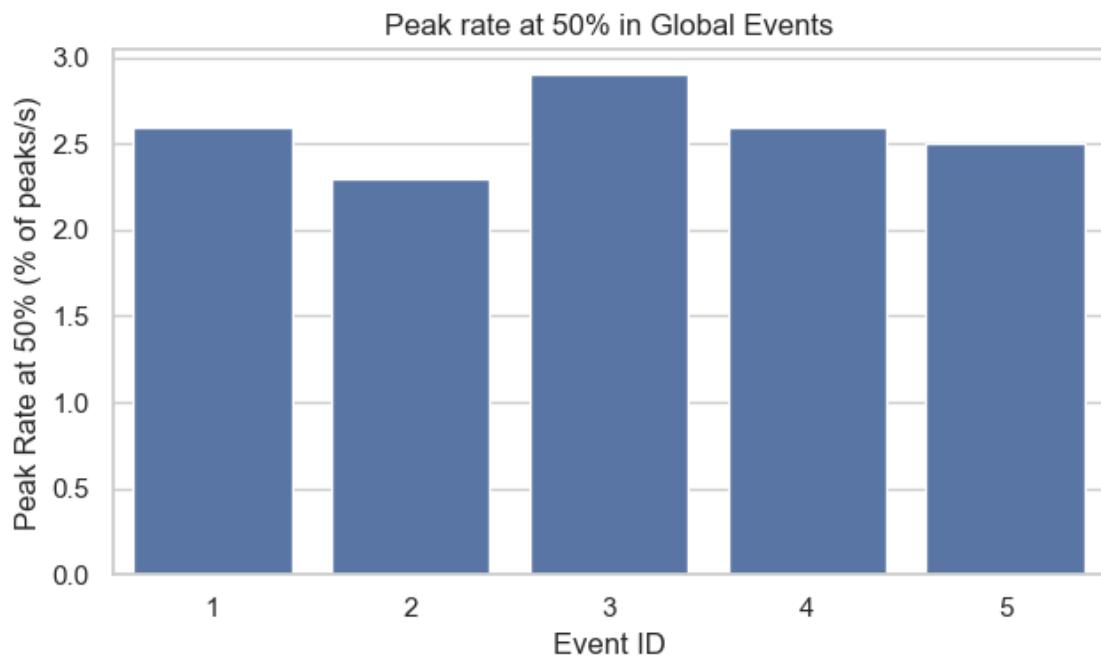


```

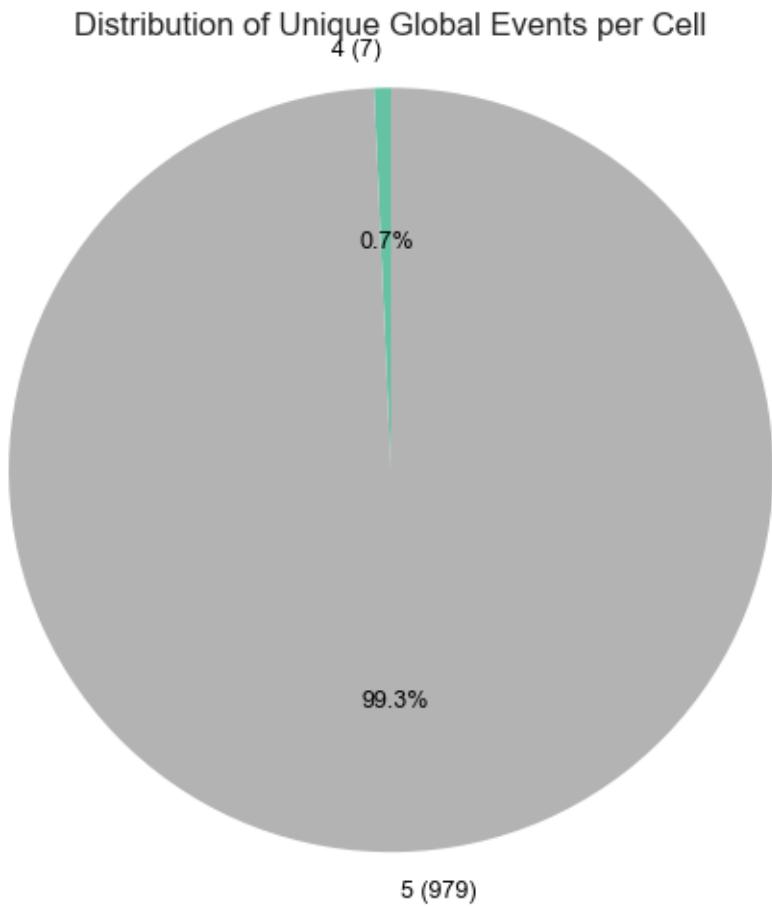
[2025-08-27 15:10:11] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\events\event-growth-curve-5.png': [Errno 2] No
such file or directory: 'D:\\Mateo\\20250624\\Output\\IS08\\events\\event-
growth-curve-5.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundException: [Errno 2] No such file or directory:
'D:\\Mateo\\20250624\\Output\\IS08\\events\\event-growth-curve-5.png'

```





1.2.4 Cells Occurrences in global events

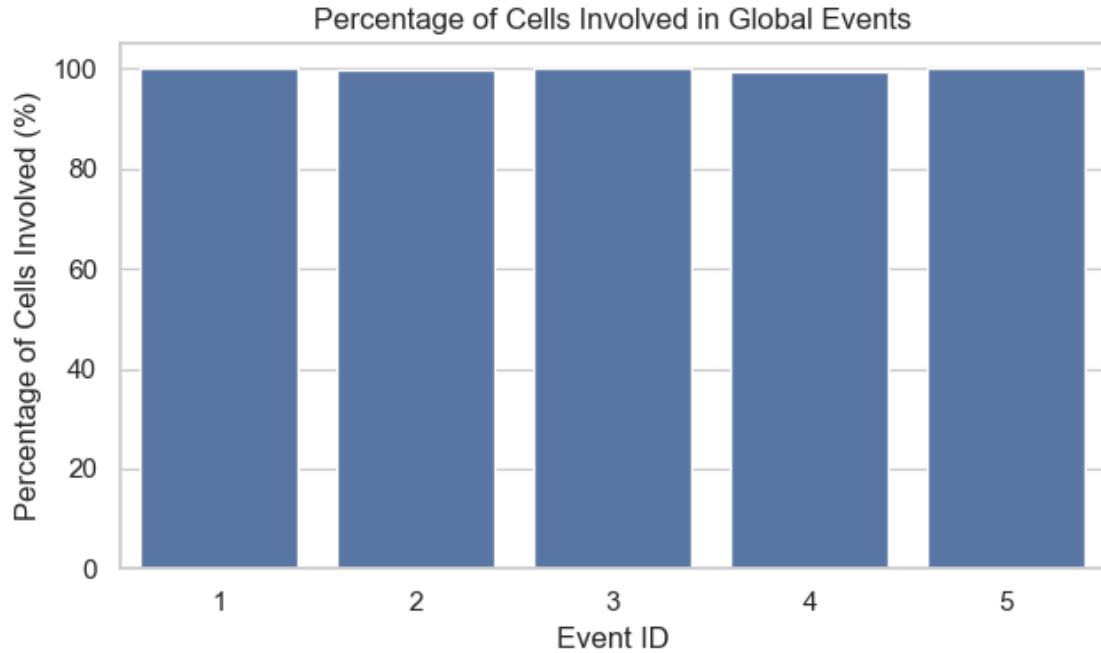


```
[2025-08-27 15:10:11] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\cell-
mapping\cell_Occurrences_in_global_events_overlay.png': [Errno 2] No such file
or directory: 'D:\\\\Mateo\\\\20250624\\\\Output\\\\IS08\\\\cell-
mapping\\\\cell_Occurrences_in_global_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
```

```

    self.fp = open(fp, "rb")
FileNotFoundError: [Errno 2] No such file or directory:
'D:\Mateo\20250624\Output\IS08\cell-
mapping\cell_Occurrences_in_global_events_overlay.png'

```



1.2.5 Inter-event interval analysis

Intervals between global event peaks: [258.0, 276.0, 344.0, 337.0]
 Estimated periodicity: 0.890
 The global events exhibit a regular periodic pattern.
 Estimated frequency (1/mean interval): 0.003 Hz

1.2.6 Early peakers in the events

```

[2025-08-27 15:10:11] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\cell-
mapping\global_events\global_event_1_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:

```

```

  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:10:11] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\cell-
mapping\global_events\global_event_2_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:10:11] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\cell-
mapping\global_events\global_event_3_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterization\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semester_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-

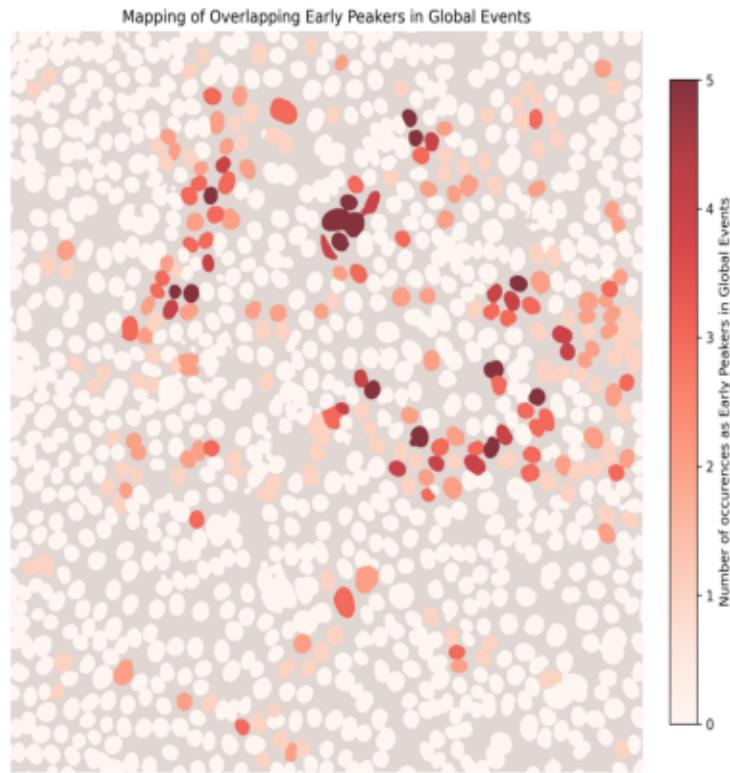
```

```
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

[2025-08-27 15:10:11] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\cell-
mapping\global_events\global_event_4_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file

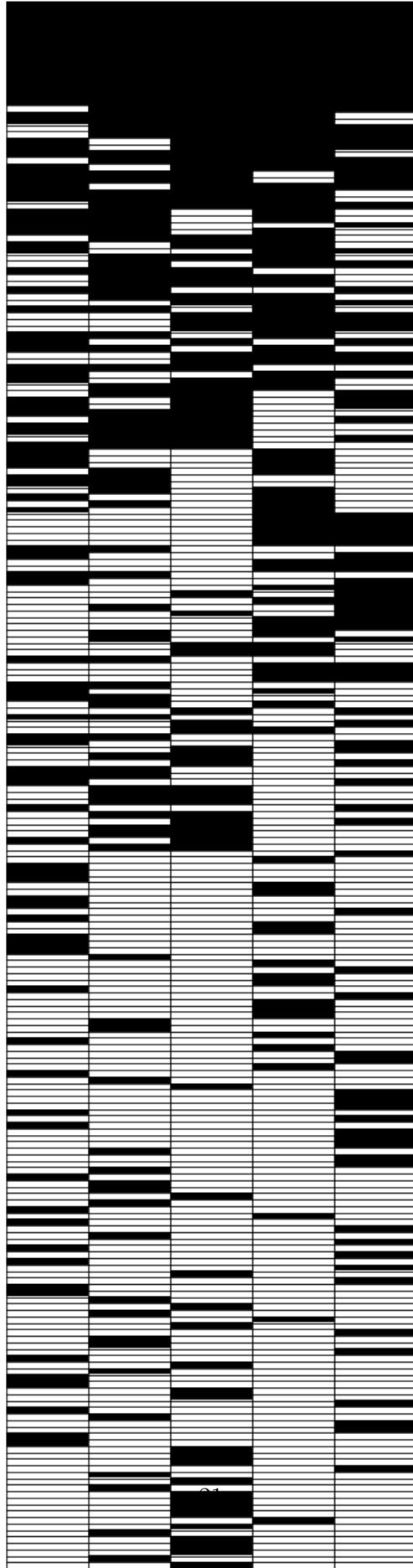
[2025-08-27 15:10:12] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\cell-
mapping\global_events\global_event_5_early_peakers_overlay.png': not a PNG file
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 144, in __init__
    self._open()
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\PngImagePlugin.py", line 757, in _open
    raise SyntaxError(msg)
SyntaxError: not a PNG file
```

Cell Mapping with Occurrences in Global Events Overlay



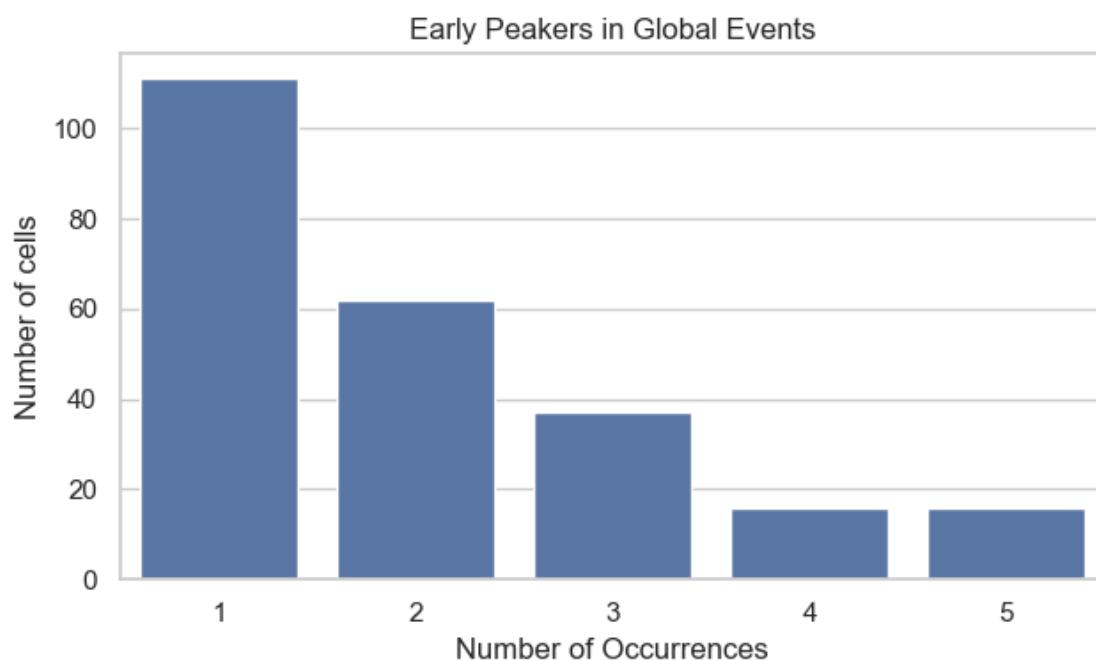
[2025-08-27 15:10:12] [WARNING] calcium: 'total_events' is deprecated and ignored. Using 5 unique event IDs.

[2025-08-27 15:10:12] [INFO] calcium: Early peakers event-matrix: 242 cells x 5 events; black squares: 490

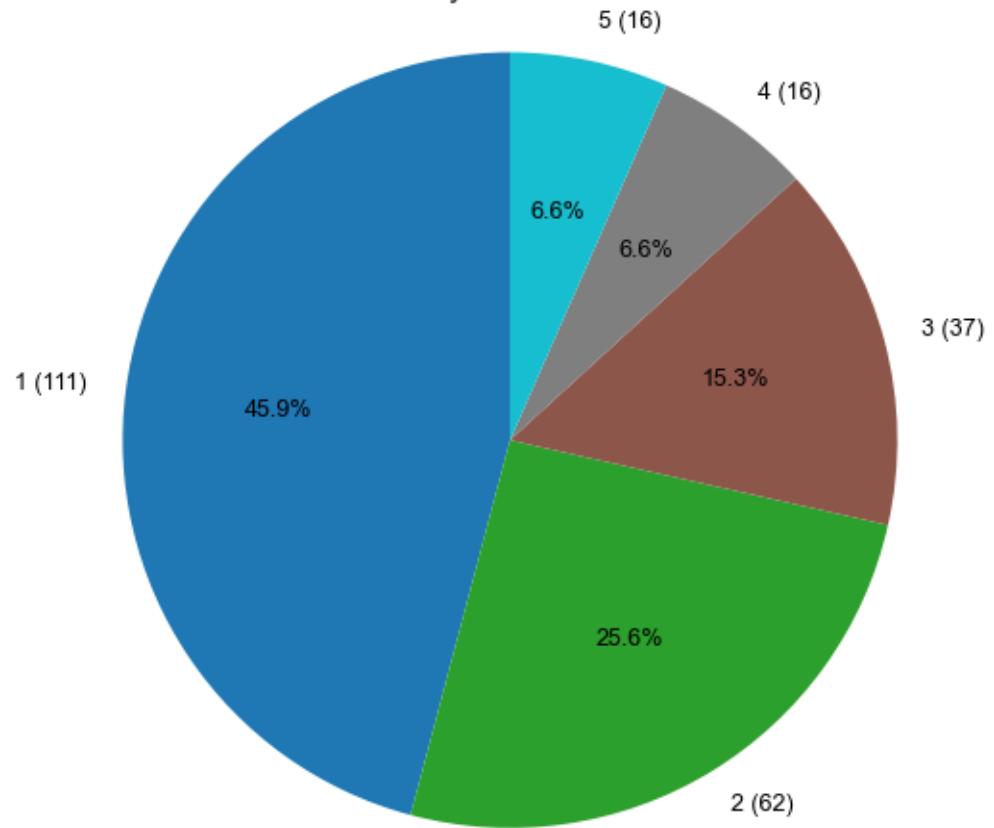


```
[2025-08-27 15:10:13] [INFO] calcium: Saved early peakers heatmap SVG to:  
early_peakers_heatmap.svg
```

```
[19]: array([[1, 1, 1, 1, 1],  
           [1, 1, 1, 1, 1],  
           [1, 1, 1, 1, 1],  
           ...,  
           [0, 0, 1, 0, 0],  
           [0, 1, 0, 0, 0],  
           [0, 0, 1, 0, 0]])
```



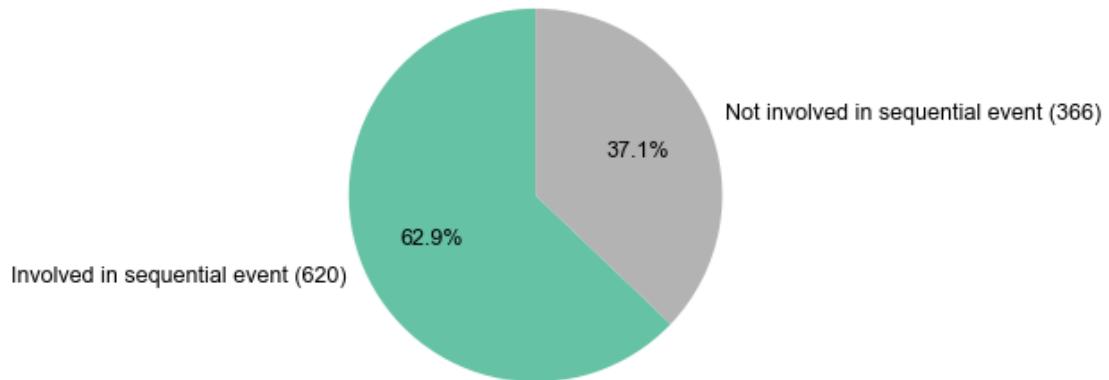
Distribution of Early Peakers in Global Events



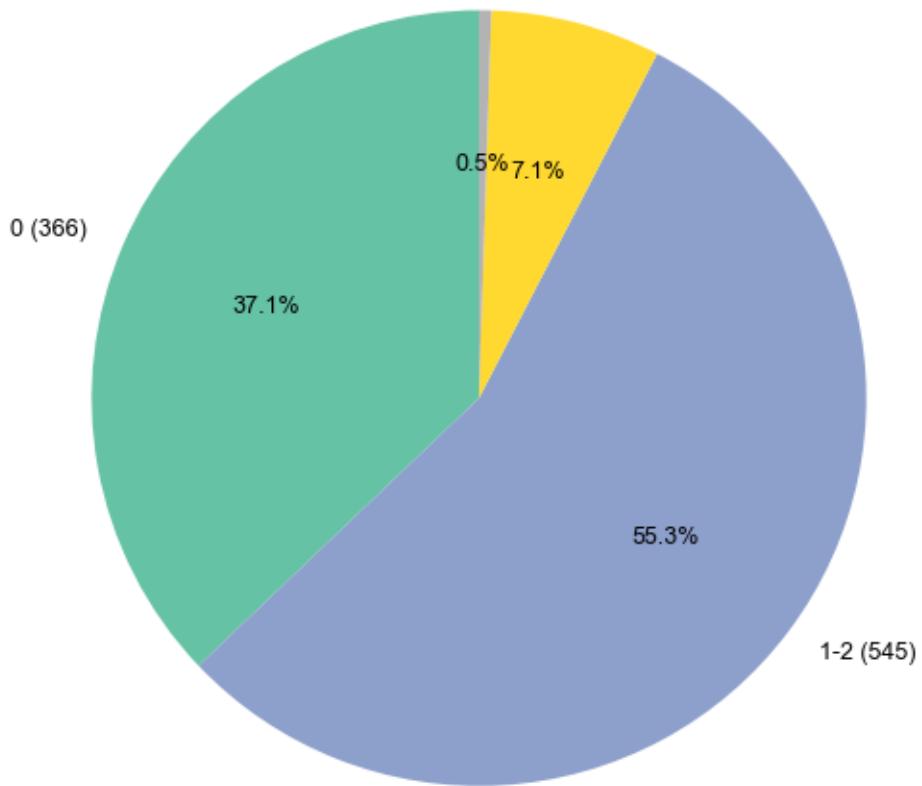
1.3 SEQUENTIAL EVENTS

1.3.1 Cells Occurrences in sequential events

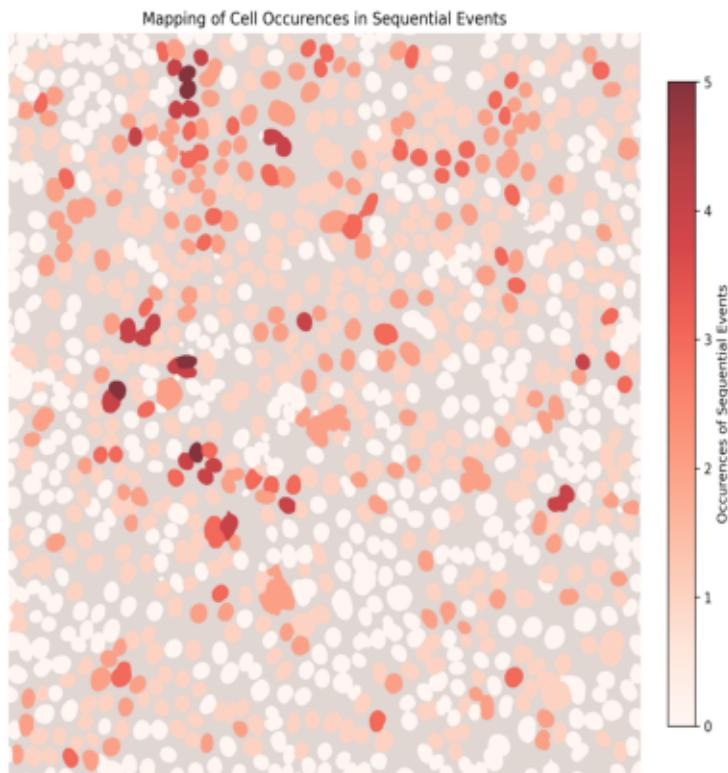
Distribution of Cells Involved in Sequential Events



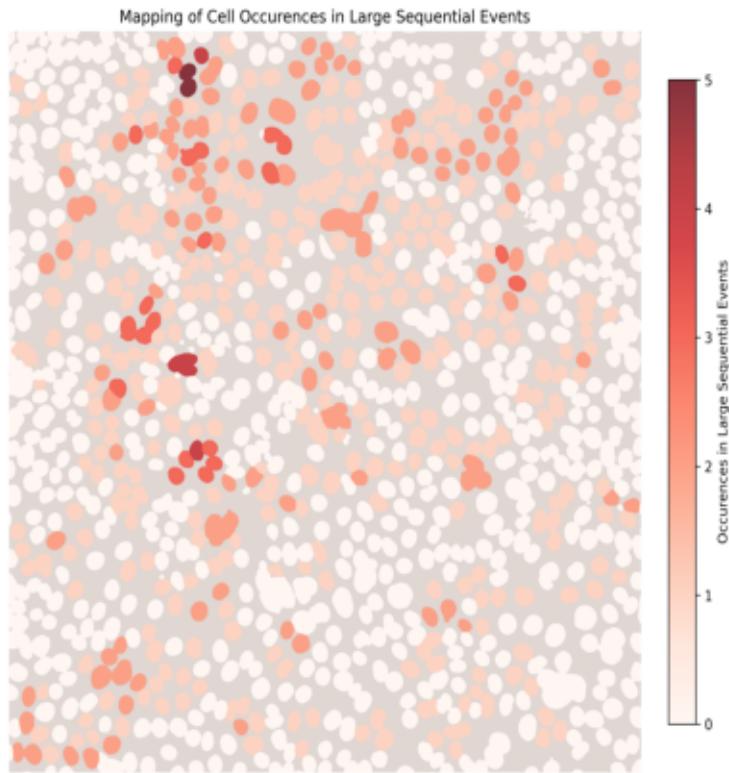
Distribution of Sequential Event Occurrences per Cell (0, 1-2, 3-4, 5-9, 10+)



Cell Mapping with Occurrences in Sequential Events Overlay

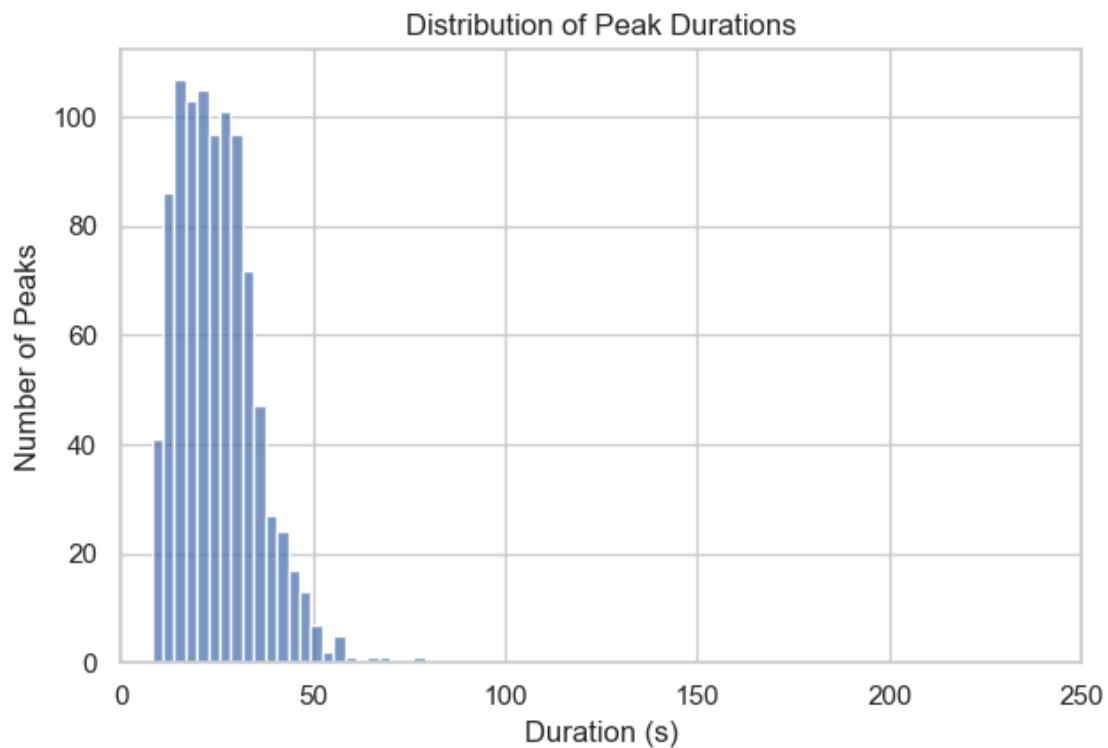


Cell Mapping with Occurrences in Large Sequential Events Overlay (>2)

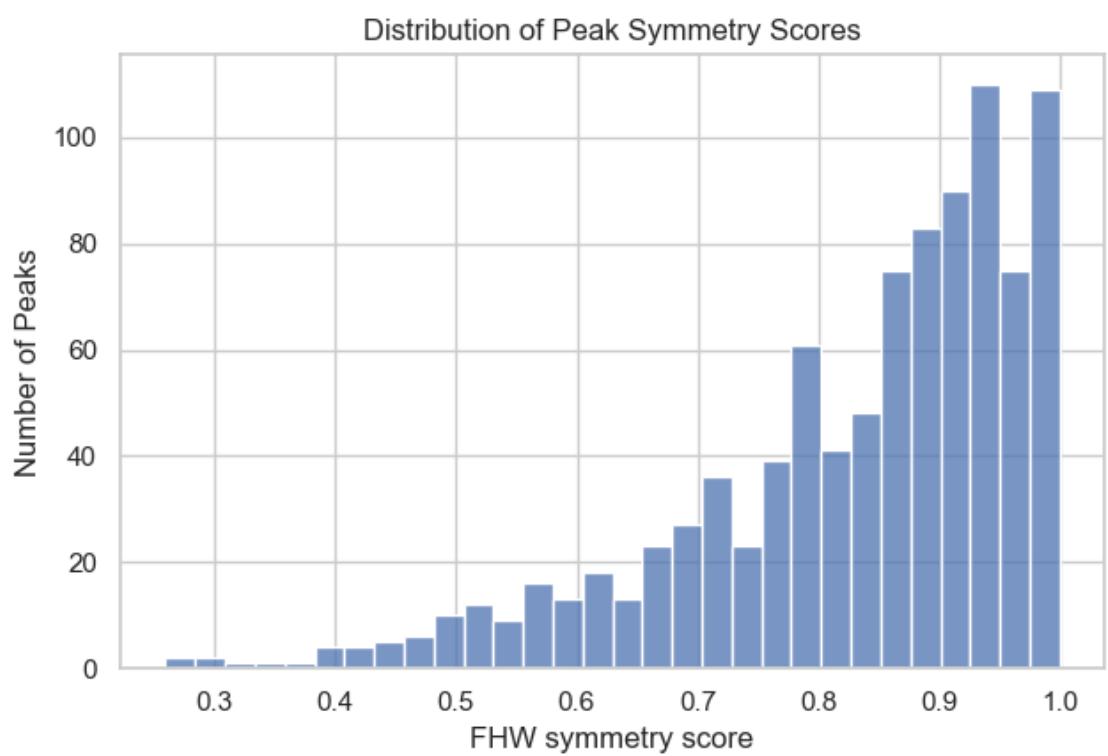
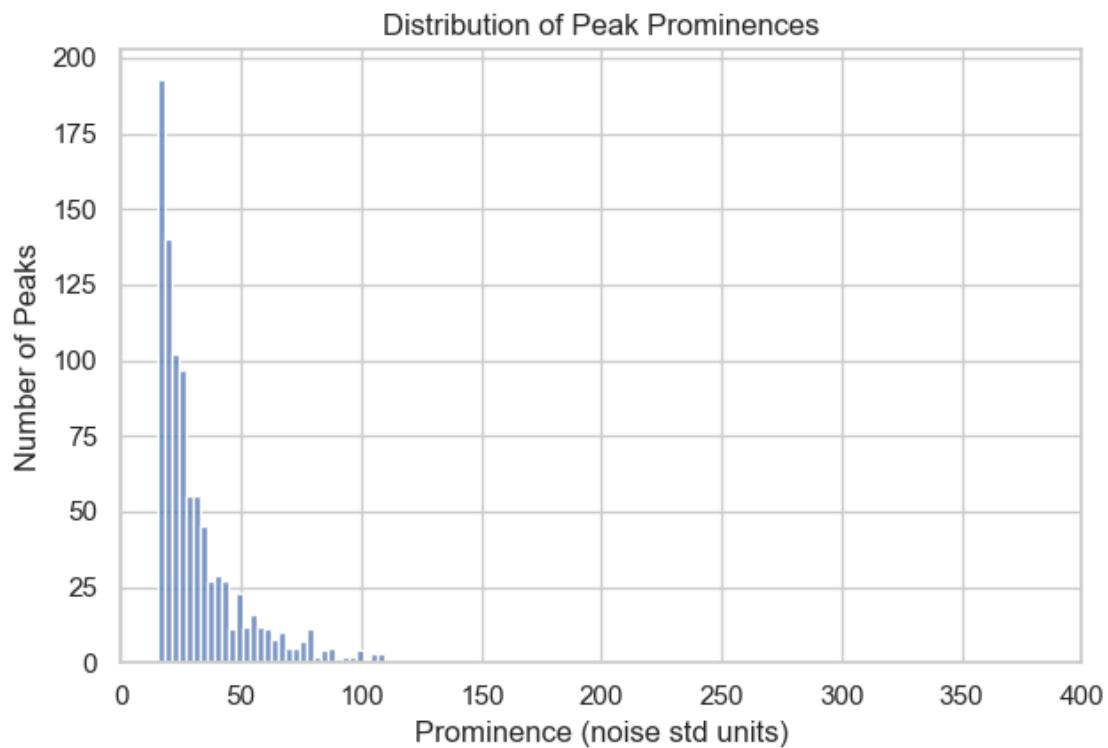


1.3.2 Peaks statistics in sequential events

```
[2025-08-27 15:10:16] [INFO] calcium: plot_histogram: removed 2 outliers out of 957 on 'Duration (s)' (lower=-4, upper=80)
```

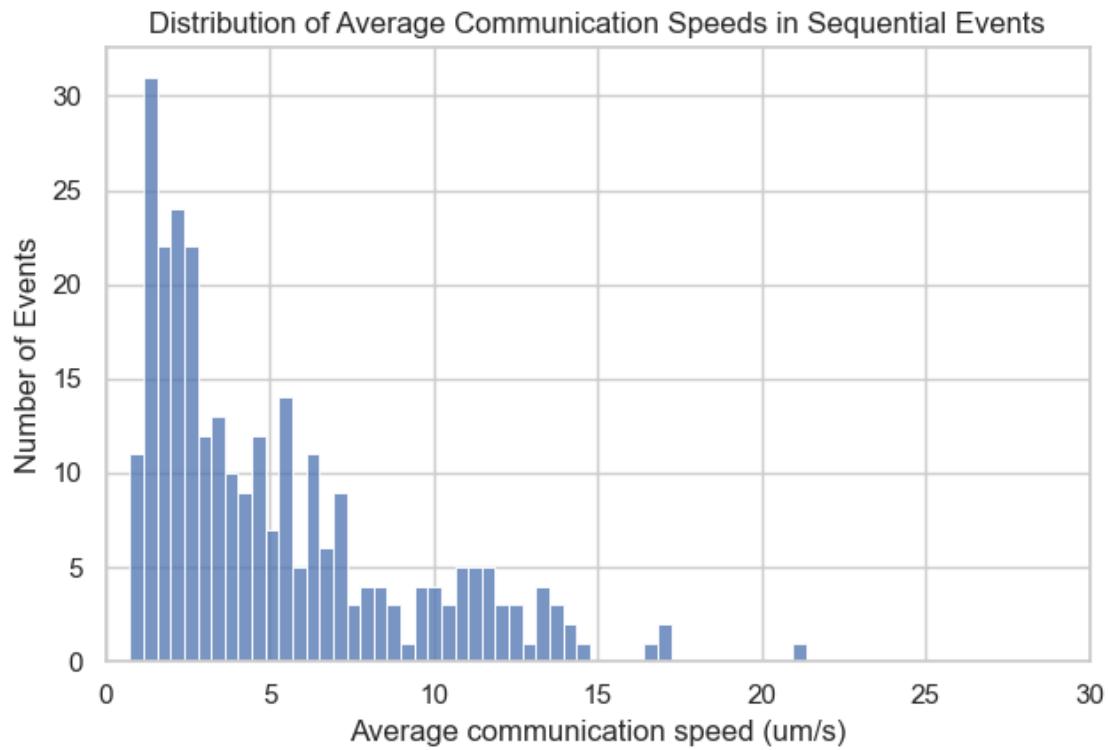


```
[2025-08-27 15:10:16] [INFO] calcium: plot_histogram: removed 30 outliers out of 957 on 'Prominence (noise std units)' (lower=-11.5, upper=109.7)
```

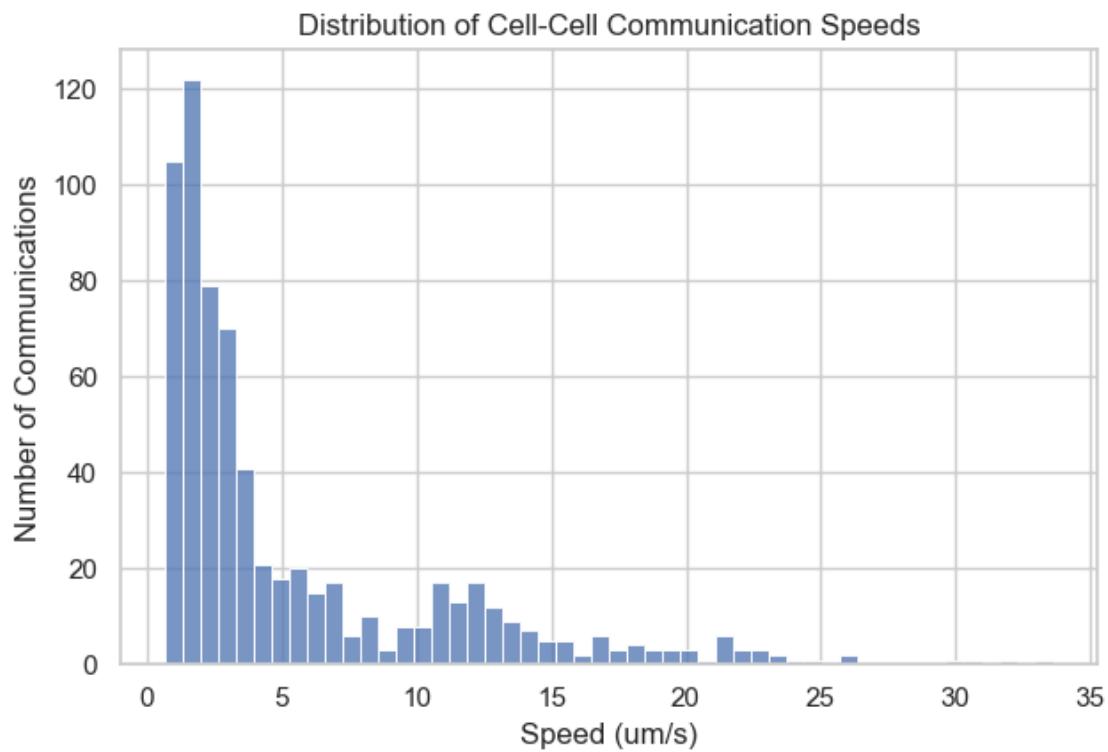


1.3.3 Cell-cell communication speed

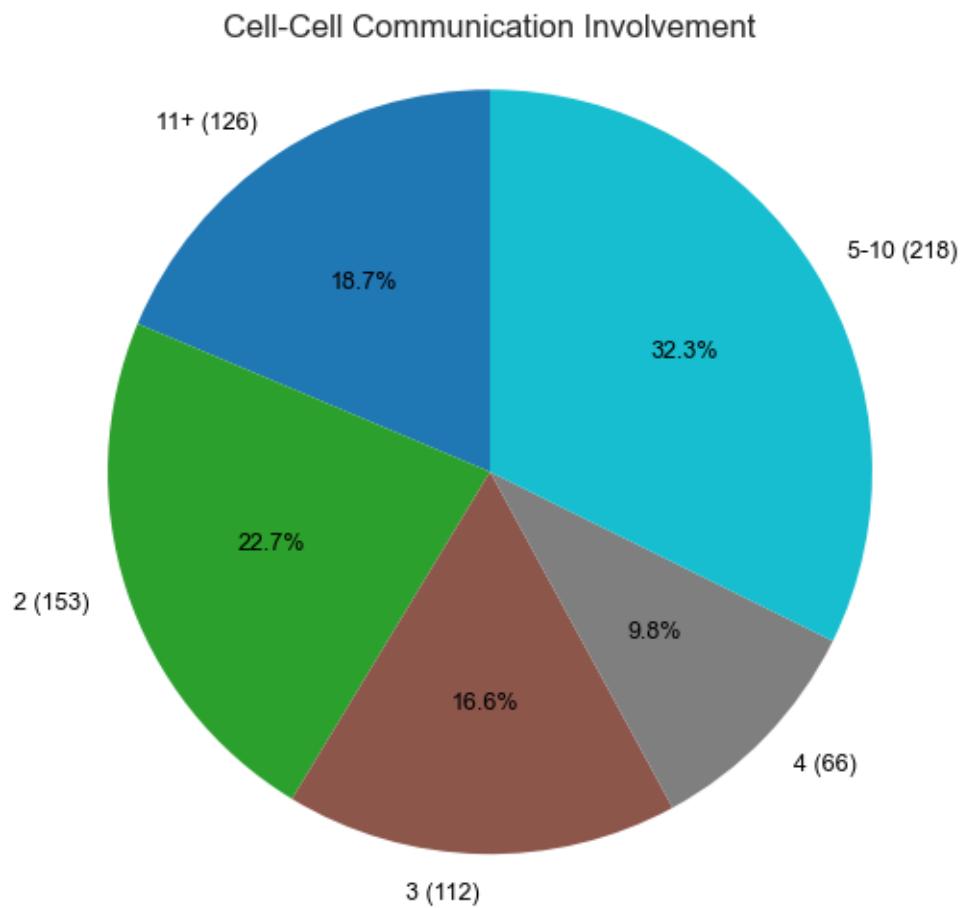
[2025-08-27 15:10:16] [INFO] calcium: plot_histogram: removed 2 outliers out of 282 on 'Average communication speed (um/s)' (lower=-12.505, upper=21.655)



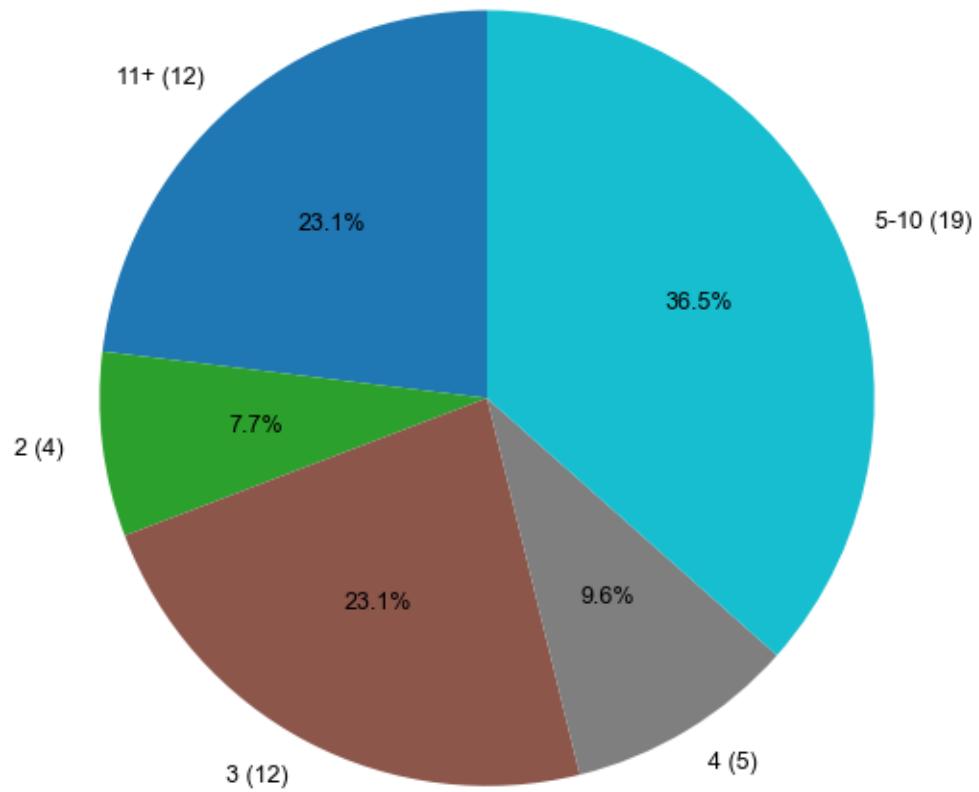
[2025-08-27 15:10:16] [INFO] calcium: plot_histogram: removed 0 outliers out of 675 on 'Speed (um/s)' (lower=-14.715, upper=34.38)



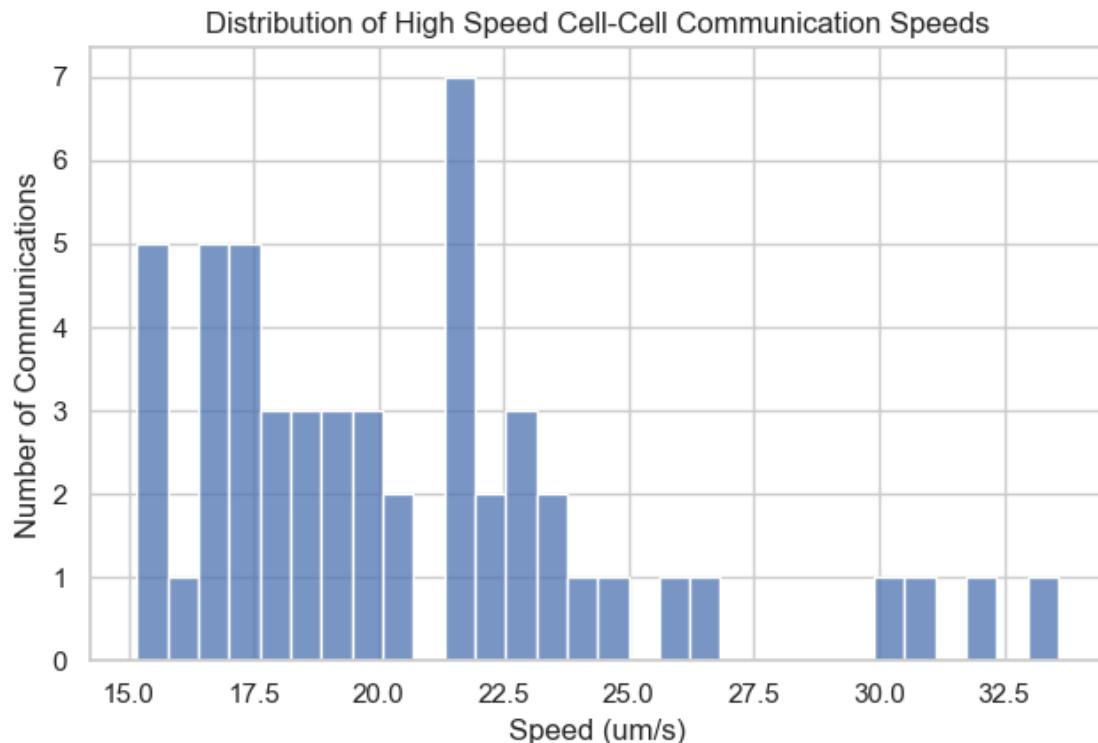
1.3.4 Double distribution in cell-cell communication speeds



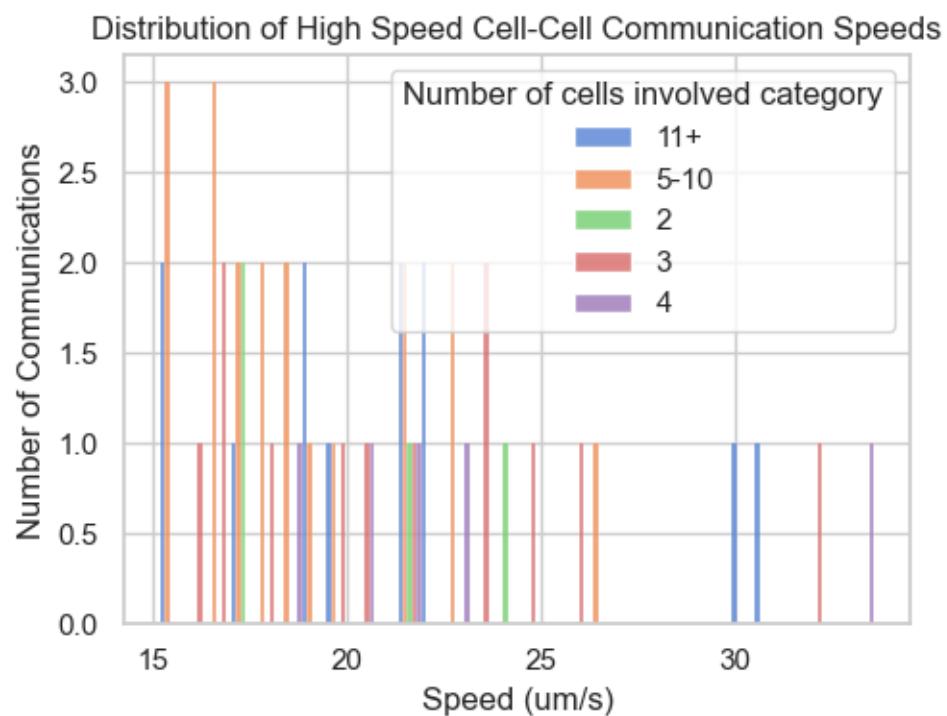
High Speed Cell-Cell Communication Involvement



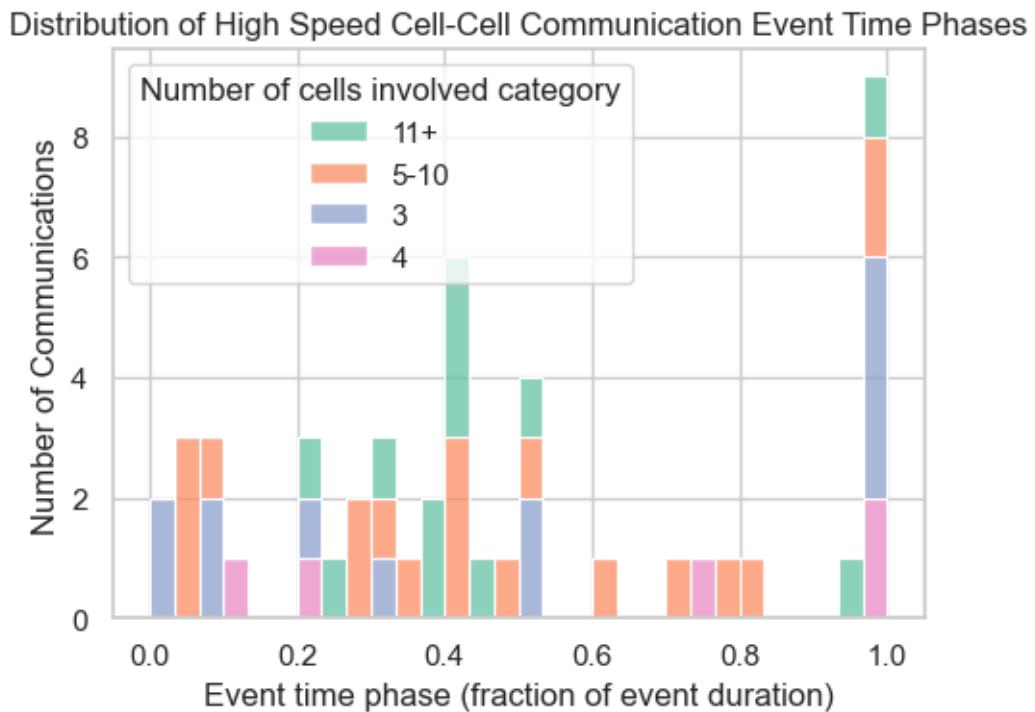
```
[2025-08-27 15:10:17] [INFO] calcium: plot_histogram: removed 0 outliers out of 52 on 'Speed (um/s)' (lower=1.5, upper=37.988)
```



```
[2025-08-27 15:10:17] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 52 on 'Speed (um/s)' (lower=1.5, upper=37.988)
```

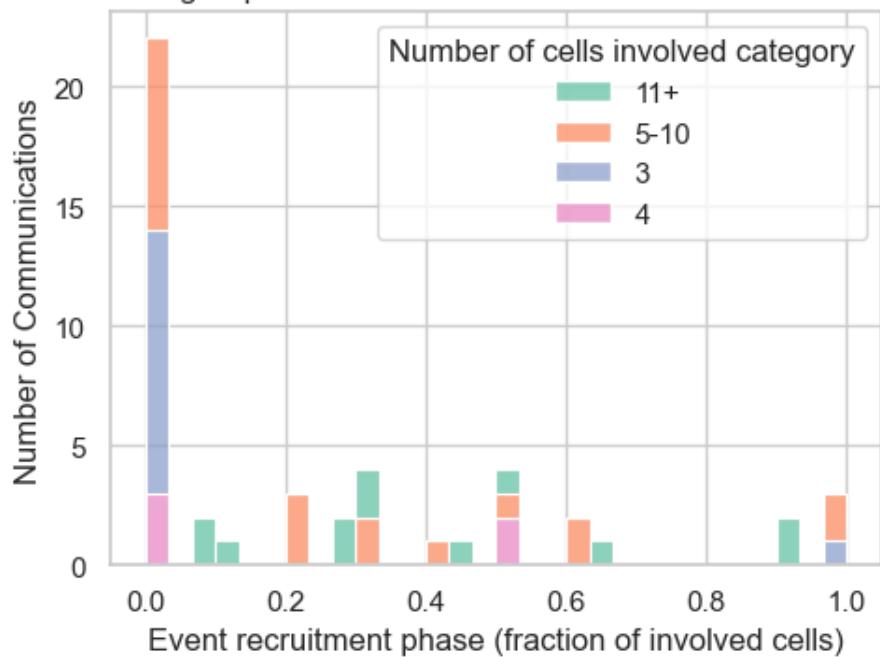


```
[2025-08-27 15:10:17] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 48 on 'Event time phase (fraction of event duration)' (lower=-1.33, upper=2.3275)
```

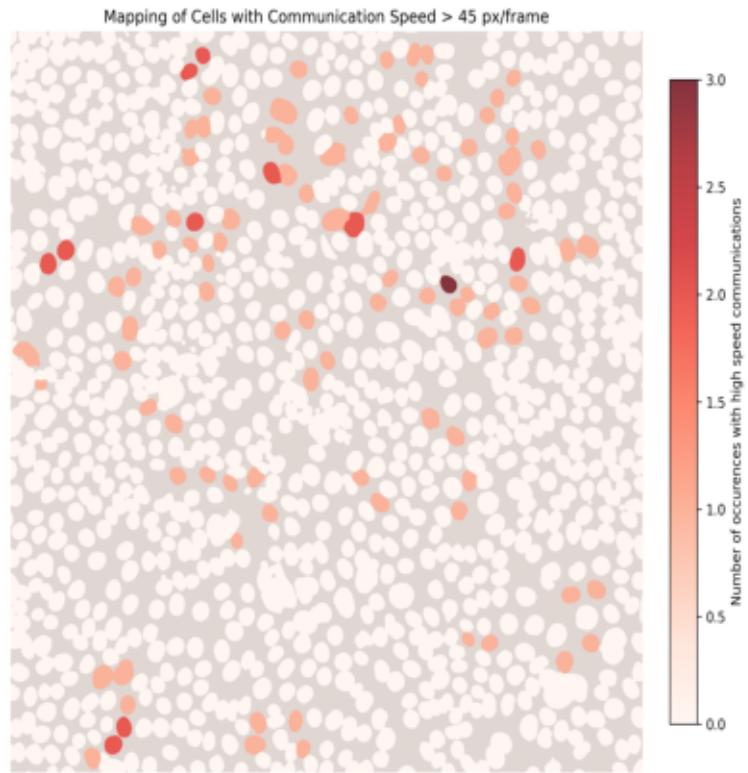


```
[2025-08-27 15:10:17] [INFO] calcium: plot_histogram_by_group: removed 0 outliers out of 48 on 'Event recruitment phase (fraction of involved cells)' (lower=-1.3875, upper=1.85)
```

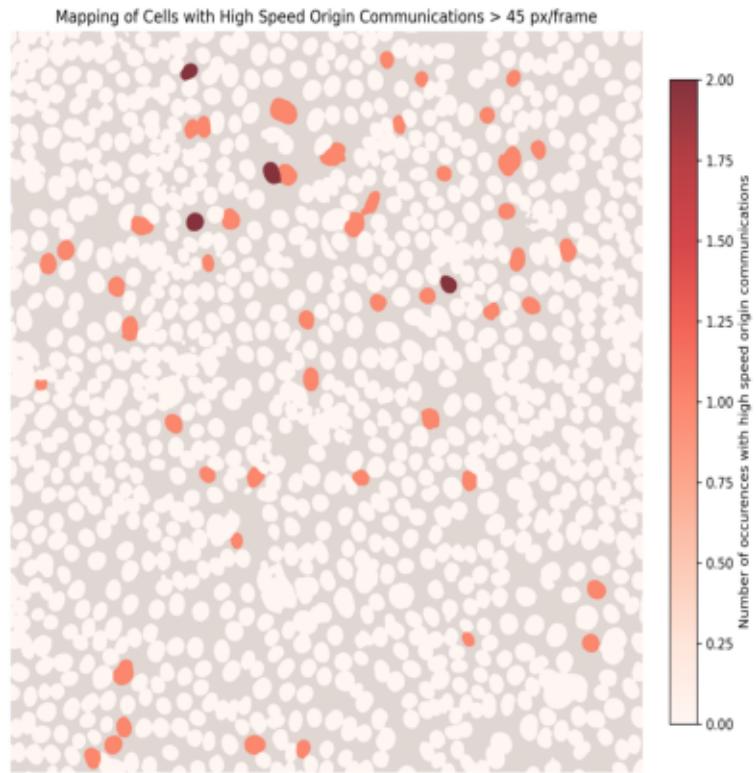
Distribution of High Speed Cell-Cell Communication Event Recruitment Phases



Cell Mapping with High Speed Cells Overlay



Cell Mapping with High Speed Origin Cells Overlay



	Communication ID	Event ID	Origin cell ID	Origin cell peak ID	\
1	2016529908112	6	595	4	
3	2016529915072	6	671	3	
9	2016529911760	6	456	3	
14	2016529911664	6	586	6	
41	2016584151104	6	501	6	
68	2016529914016	9	731	4	
69	2016529921408	9	713	3	
72	2016584150912	9	713	3	
105	2016529919488	17	300	0	
108	2016529912432	17	406	0	
114	2016584148128	17	411	1	
129	2016529911424	20	1464	0	

135	2016529923184	22	1100	5
148	2016584144576	24	300	7
158	2016529912336	27	1400	0
161	2016529914496	29	751	4
172	2016918189200	30	783	6
178	2016529917040	32	454	5
188	2016529921216	33	383	7
192	2016584143808	33	310	7
201	2016529922848	36	595	0
205	2016529923376	37	1618	0
210	2016529923280	39	497	3
211	2016529922608	39	497	3
213	2016529922560	40	642	5
218	2016529922800	41	1103	0
230	2016529919632	45	556	0
231	2016529918720	45	598	0
240	2016918185120	49	1563	3
242	2016529920016	50	663	0
245	2016529919680	51	746	0
247	2016529919536	52	898	1
275	2016529920832	60	1096	5
282	2016529920688	62	1310	4
287	2016584149904	64	374	1
308	2016529920880	72	279	1
310	2016584145920	74	315	3
328	2016584142320	80	474	5
348	2016584139728	91	498	0
385	2016584154512	118	571	5
392	2016584148608	123	602	3
404	2016584148704	132	649	0
406	2016584148176	133	672	0
435	2016584144624	143	758	3
441	2016584148320	148	773	0
484	2016918176672	175	888	5
506	2016918186896	185	983	3
517	2016918189728	191	973	3
535	2016918186224	200	1091	8
568	2016918189392	224	1221	0
632	2016918190448	261	1407	3
665	2016918184736	280	1602	1

	Cause cell ID	Cause cell peak ID	Start time (s)	End time (s)	\
1	630	6	972.0	972.0	
3	723	3	974.0	974.0	
9	384	3	969.0	969.0	
14	625	4	969.0	969.0	
41	541	4	960.0	961.0	
68	713	3	973.0	974.0	

				\
69	730	3	974.0	974.0
72	752	6	974.0	975.0
105	272	0	127.0	127.0
108	346	0	105.0	105.0
114	468	0	105.0	106.0
129	1469	0	32.0	32.0
135	1144	5	969.0	969.0
148	272	7	1380.0	1381.0
158	1409	0	115.0	115.0
161	804	3	976.0	976.0
172	854	3	976.0	977.0
178	426	7	1638.0	1638.0
188	451	8	1640.0	1641.0
192	349	7	1636.0	1637.0
201	584	0	21.0	21.0
205	1599	0	21.0	21.0
210	423	4	657.0	658.0
211	444	4	657.0	658.0
213	672	5	973.0	973.0
218	1162	0	45.0	45.0
230	598	0	14.0	14.0
231	590	0	14.0	14.0
240	1520	4	1004.0	1005.0
242	712	1	139.0	139.0
245	702	0	39.0	39.0
247	825	1	391.0	391.0
275	1109	4	993.0	993.0
282	1321	5	983.0	983.0
287	295	0	118.0	119.0
308	270	1	359.0	360.0
310	271	2	648.0	649.0
328	540	4	977.0	978.0
348	465	0	10.0	11.0
385	663	7	1637.0	1638.0
392	640	3	1002.0	1003.0
404	635	1	113.0	114.0
406	642	0	28.0	29.0
435	807	3	973.0	974.0
441	788	0	10.0	11.0
484	849	5	893.0	894.0
506	947	7	984.0	985.0
517	1011	3	988.0	989.0
535	1094	7	1642.0	1643.0
568	1165	0	14.0	15.0
632	1441	3	992.0	993.0
665	1556	0	129.0	130.0

Duration (s) Distance (um) Speed (um/s) \

1	0.0	15.62	15.62
3	0.0	18.89	18.89
9	0.0	29.94	29.94
14	0.0	17.46	17.46
41	1.0	19.81	19.81
68	1.0	18.03	18.03
69	0.0	16.73	16.73
72	1.0	17.01	17.01
105	0.0	15.40	15.40
108	0.0	21.48	21.48
114	1.0	19.20	19.20
129	0.0	17.15	17.15
135	0.0	22.56	22.56
148	1.0	15.40	15.40
158	0.0	17.10	17.10
161	0.0	24.61	24.61
172	1.0	22.23	22.23
178	0.0	22.28	22.28
188	1.0	26.23	26.23
192	1.0	18.39	18.39
201	0.0	17.05	17.05
205	0.0	18.75	18.75
210	1.0	25.75	25.75
211	1.0	21.57	21.57
213	0.0	16.68	16.68
218	0.0	21.43	21.43
230	0.0	19.33	19.33
231	0.0	15.62	15.62
240	1.0	15.17	15.17
242	0.0	16.28	16.28
245	0.0	18.79	18.79
247	0.0	23.55	23.55
275	0.0	19.82	19.82
282	0.0	20.46	20.46
287	1.0	30.73	30.73
308	1.0	21.37	21.37
310	1.0	17.19	17.19
328	1.0	21.69	21.69
348	1.0	21.81	21.81
385	1.0	33.58	33.58
392	1.0	21.43	21.43
404	1.0	16.46	16.46
406	1.0	16.68	16.68
435	1.0	18.17	18.17
441	1.0	20.16	20.16
484	1.0	18.16	18.16
506	1.0	22.98	22.98
517	1.0	22.74	22.74

535	1.0	23.41	23.41
568	1.0	31.92	31.92
632	1.0	24.36	24.36
665	1.0	19.74	19.74

	Event time phase (fraction of event duration)	\
1		0.46
3		0.51
9		0.39
14		0.39
41		0.20
68		0.27
69		0.27
72		0.36
105		1.00
108		0.41
114		0.43
129		0.52
135		0.06
148		1.00
158		NaN
161		1.00
172		0.32
178		0.42
188		0.42
192		0.08
201		0.48
205		0.72
210		1.00
211		1.00
213		0.33
218		0.82
230		0.42
231		0.42
240		1.00
242		0.00
245		1.00
247		0.00
275		0.62
282		1.00
287		0.25
308		NaN
310		NaN
328		0.96
348		0.06
385		0.20
392		0.75
404		0.08

406	1.00
435	0.04
441	0.50
484	0.50
506	0.10
517	0.79
535	0.20
568	0.08
632	NaN
665	0.33

	Event recruitment phase (fraction of involved cells)	dataset	\
1	0.51	20250624_IS08	
3	0.65	20250624_IS08	
9	0.27	20250624_IS08	
14	0.27	20250624_IS08	
41	0.09	20250624_IS08	
68	0.20	20250624_IS08	
69	0.20	20250624_IS08	
72	0.60	20250624_IS08	
105	0.92	20250624_IS08	
108	0.08	20250624_IS08	
114	0.31	20250624_IS08	
129	0.00	20250624_IS08	
135	0.00	20250624_IS08	
148	1.00	20250624_IS08	
158	NaN	20250624_IS08	
161	0.00	20250624_IS08	
172	0.45	20250624_IS08	
178	0.33	20250624_IS08	
188	0.50	20250624_IS08	
192	0.00	20250624_IS08	
201	0.33	20250624_IS08	
205	0.33	20250624_IS08	
210	0.00	20250624_IS08	
211	0.00	20250624_IS08	
213	0.00	20250624_IS08	
218	0.20	20250624_IS08	
230	0.00	20250624_IS08	
231	0.00	20250624_IS08	
240	1.00	20250624_IS08	
242	0.00	20250624_IS08	
245	0.00	20250624_IS08	
247	0.00	20250624_IS08	
275	0.40	20250624_IS08	
282	0.50	20250624_IS08	
287	0.11	20250624_IS08	
308	NaN	20250624_IS08	

310		NaN	20250624_IS08
328		0.90	20250624_IS08
348		0.00	20250624_IS08
385		0.00	20250624_IS08
392		0.50	20250624_IS08
404		0.00	20250624_IS08
406		1.00	20250624_IS08
435		0.00	20250624_IS08
441		0.00	20250624_IS08
484		0.00	20250624_IS08
506		0.00	20250624_IS08
517		0.60	20250624_IS08
535		0.00	20250624_IS08
568		0.00	20250624_IS08
632		NaN	20250624_IS08
665		0.00	20250624_IS08

	Number of cells involved	category	Speed category
1		11+	High speed
3		11+	High speed
9		11+	High speed
14		11+	High speed
41		11+	High speed
68		5-10	High speed
69		5-10	High speed
72		5-10	High speed
105		11+	High speed
108		11+	High speed
114		11+	High speed
129		5-10	High speed
135		5-10	High speed
148		5-10	High speed
158		2	High speed
161		3	High speed
172		11+	High speed
178		11+	High speed
188		5-10	High speed
192		5-10	High speed
201		5-10	High speed
205		5-10	High speed
210		3	High speed
211		3	High speed
213		5-10	High speed
218		5-10	High speed
230		5-10	High speed
231		5-10	High speed
240		5-10	High speed
242		3	High speed

245	4	High speed
247	3	High speed
275	5-10	High speed
282	4	High speed
287	11+	High speed
308	2	High speed
310	2	High speed
328	11+	High speed
348	5-10	High speed
385	4	High speed
392	4	High speed
404	3	High speed
406	3	High speed
435	5-10	High speed
441	3	High speed
484	3	High speed
506	4	High speed
517	5-10	High speed
535	3	High speed
568	3	High speed
632	2	High speed
665	3	High speed

Speed category High speed Low speed

Origin cell ID

248	0	1
250	0	1
254	0	1
256	0	1
258	0	3
...
1610	0	1
1613	0	1
1614	0	2
1616	0	1
1618	1	2

[369 rows x 2 columns]

	Cell ID	Centroid X coordinate (um)	Centroid Y coordinate (um) \
1	248	220.03	6.50
2	250	171.60	9.43
4	254	131.95	10.72
6	256	307.45	11.38
7	258	121.23	12.03
..
974	1610	6.83	485.23
976	1613	18.85	486.53
977	1614	32.50	486.53

979	1616	48.43	487.50
980	1618	64.35	489.12

	Number of peaks	Is active	Occurrences in global events	\
1	8	True	5	
2	6	True	5	
4	7	True	5	
6	9	True	5	
7	13	True	5	
..	
974	8	True	5	
976	7	True	5	
977	7	True	5	
979	10	True	5	
980	7	True	5	

	Occurrences in global events as early peaker	Early peaker event IDs	\
1	0	[]	
2	0	[]	
4	0	[]	
6	0	[]	
7	0	[]	
..	
974	0	[]	
976	0	[]	
977	0	[]	
979	0	[]	
980	0	[]	

	Occurrences in sequential events	\
1	1	
2	1	
4	2	
6	2	
7	3	
..	...	
974	2	
976	1	
977	1	
979	3	
980	2	

	Occurrences in sequential events as origin	\
1	1	
2	1	
4	0	
6	1	
7	2	

..
 974 0
 976 0
 977 1
 979 1
 980 1

	Occurrences in individual events	Peak frequency (Hz)	Periodicity score	\
1	2	0.0047	0.80	
2	0	0.0035	0.71	
4	0	0.0041	0.79	
6	2	0.0053	0.67	
7	5	0.0076	0.59	
..	\
974	1	0.0047	0.68	
976	0	0.0041	0.68	
977	1	0.0041	0.77	
979	2	0.0059	0.64	
980	0	0.0041	0.77	

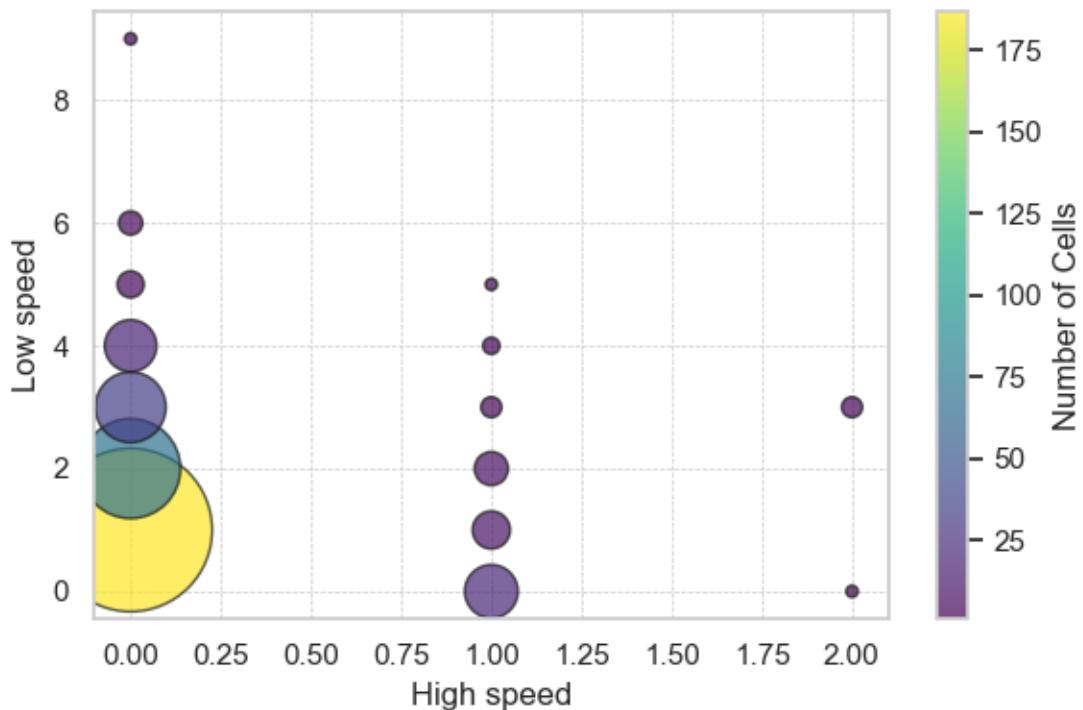
	Neighbor count	Neighbors (labels)	dataset	\
1	3	[252, 273, 295]	20250624_IS08	
2	3	[272, 305, 306]	20250624_IS08	
4	4	[258, 272, 287, 300]	20250624_IS08	
6	2	[270, 279]	20250624_IS08	
7	3	[254, 269, 287]	20250624_IS08	
..	\
974	3	[1558, 1578, 1613]	20250624_IS08	
976	3	[1578, 1610, 1614]	20250624_IS08	
977	4	[1578, 1579, 1613, 1616]	20250624_IS08	
979	4	[1579, 1592, 1614, 1618]	20250624_IS08	
980	4	[1584, 1592, 1599, 1616]	20250624_IS08	

	Involved in sequential event	Occurrences in sequential events category	\
1	Involved in sequential event	1-2	
2	Involved in sequential event	1-2	
4	Involved in sequential event	1-2	
6	Involved in sequential event	1-2	
7	Involved in sequential event	3-4	
..	\
974	Involved in sequential event	1-2	
976	Involved in sequential event	1-2	
977	Involved in sequential event	1-2	
979	Involved in sequential event	3-4	
980	Involved in sequential event	1-2	

	High speed	Low speed	
1	0.0	1.0	

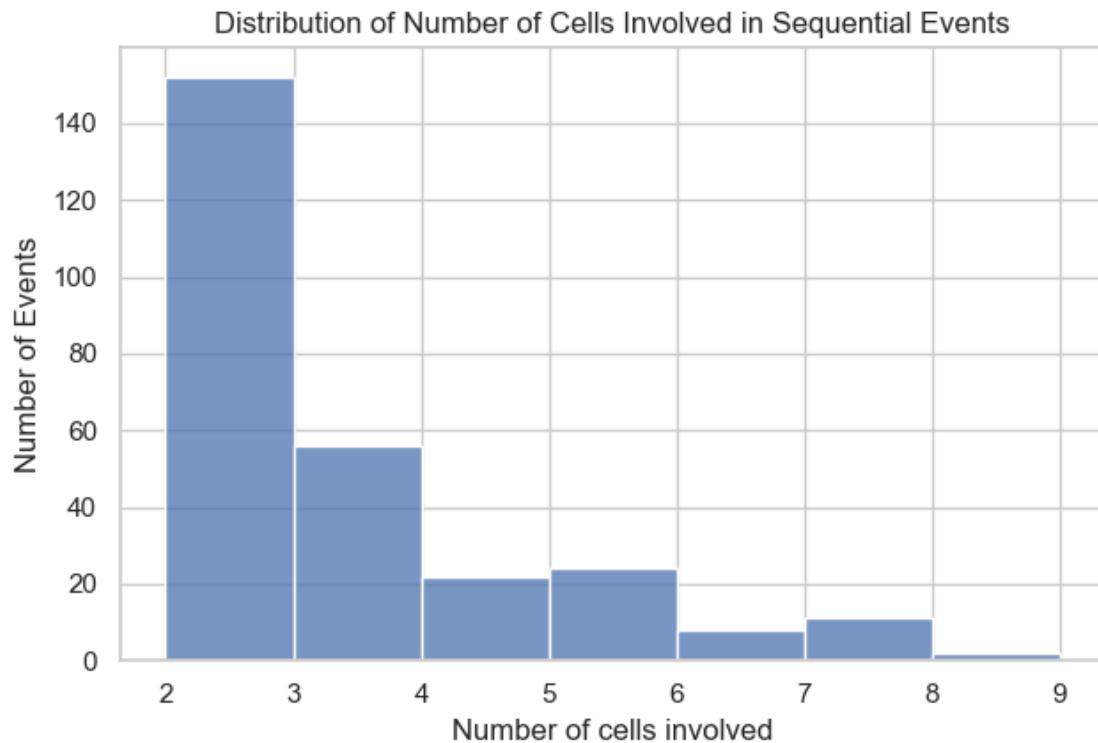
2	0.0	1.0
4	0.0	1.0
6	0.0	1.0
7	0.0	3.0
..
974	0.0	1.0
976	0.0	1.0
977	0.0	2.0
979	0.0	1.0
980	1.0	2.0

[369 rows x 20 columns]



1.3.5 Number of cells involved per sequential events

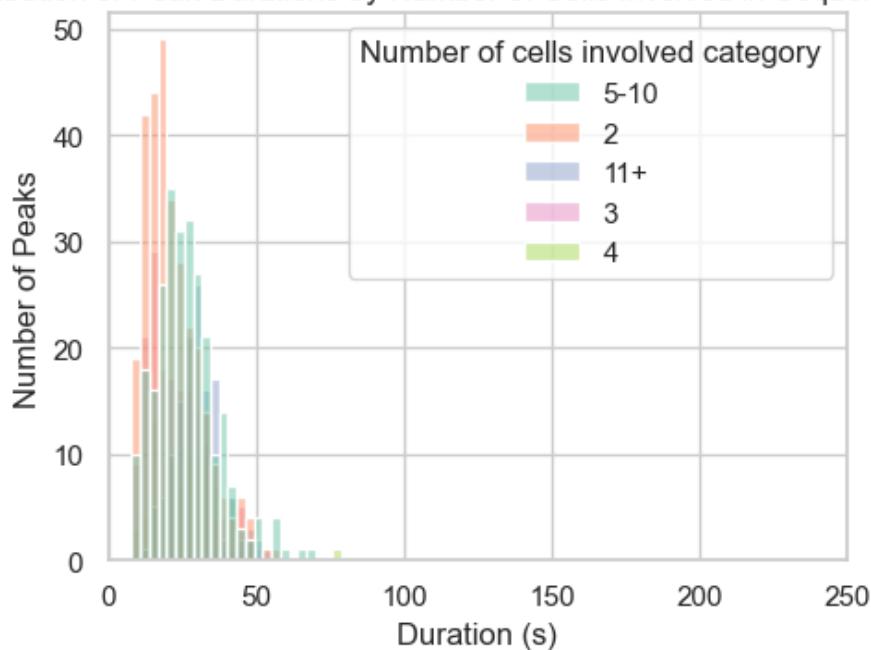
[2025-08-27 15:10:20] [INFO] calcium: plot_histogram: removed 7 outliers out of 282 on 'Number of cells involved' (lower=-4, upper=10)



1.3.6 Influence of cell count per event on statistics

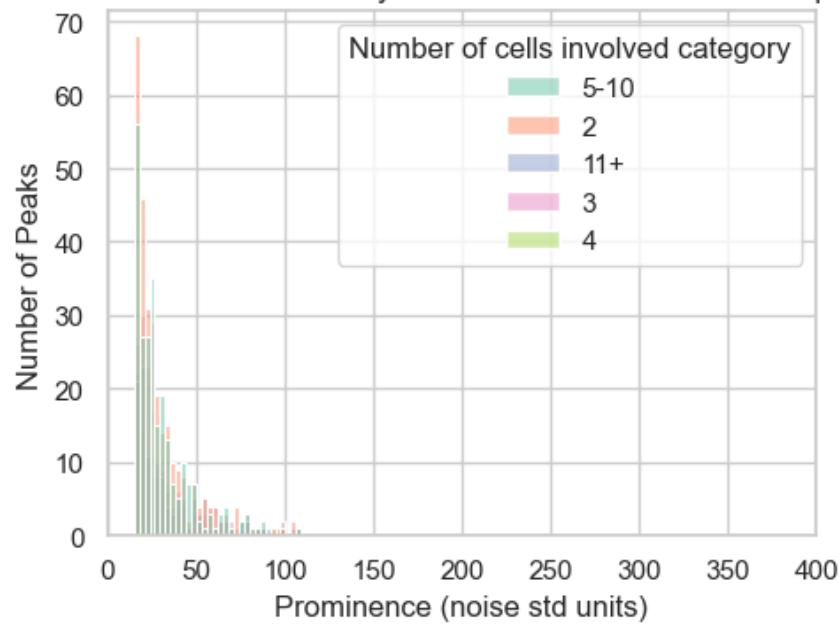
```
[2025-08-27 15:10:20] [INFO] calcium: plot_histogram_by_group: removed 2 outliers out of 957 on 'Duration (s)' (lower=-4, upper=80)
```

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

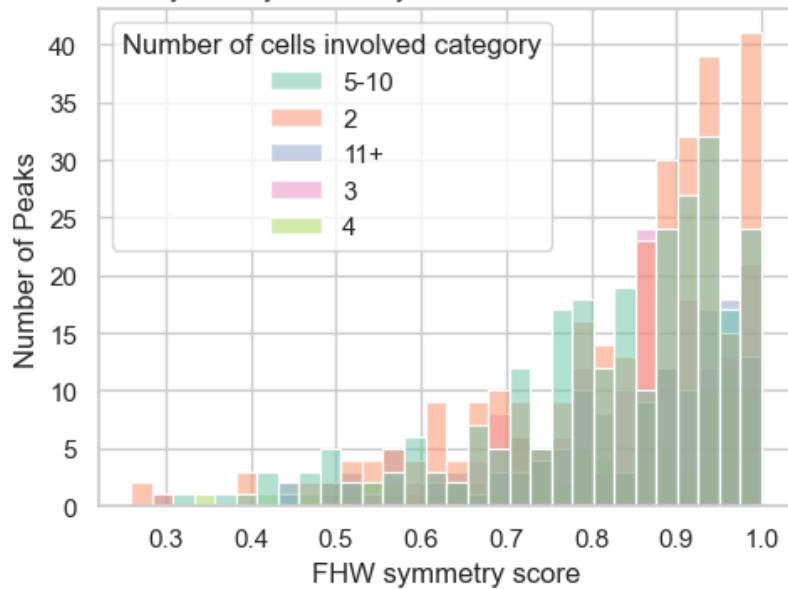


[2025-08-27 15:10:20] [INFO] calcium: plot_histogram_by_group: removed 30 outliers out of 957 on 'Prominence (noise std units)' (lower=-11.5, upper=109.7)

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

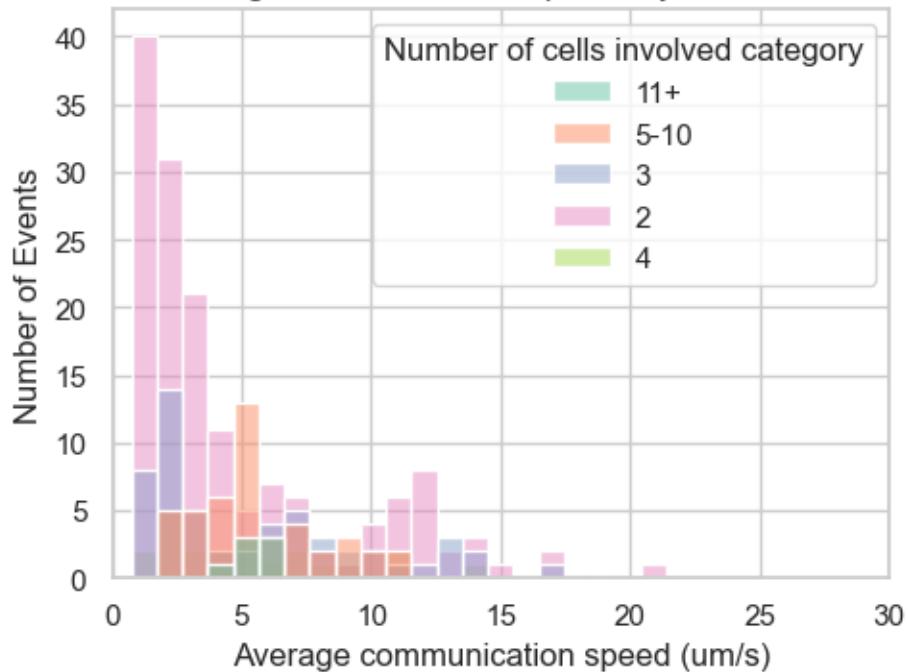


Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events

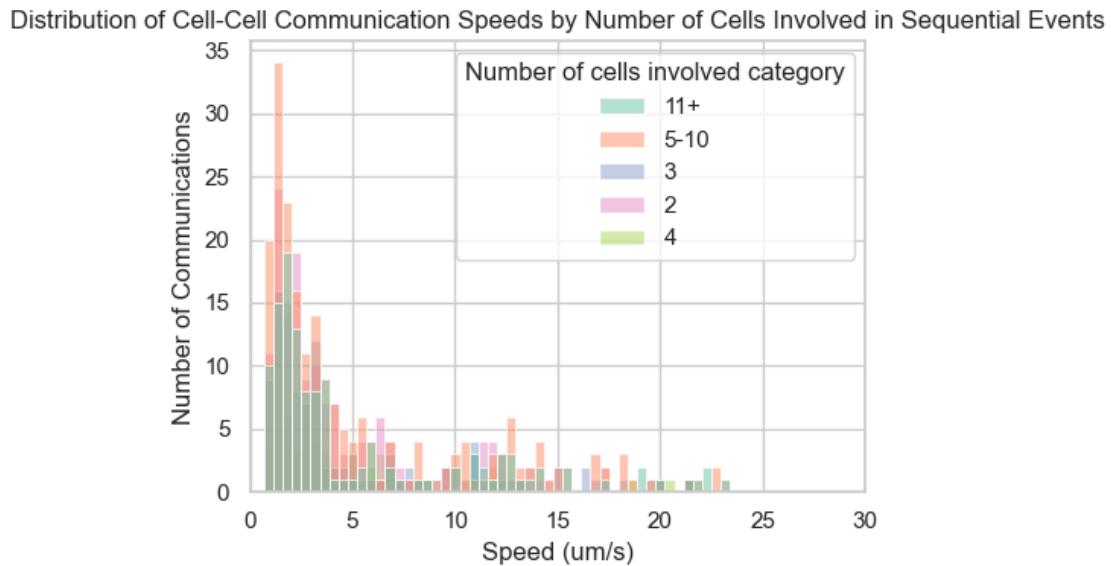


```
[2025-08-27 15:10:21] [INFO] calcium: plot_histogram_by_group: removed 2 outliers out of 282 on 'Average communication speed (um/s)' (lower=-12.505, upper=21.655)
```

Distribution of Average Communication Speeds by Number of Cells Involved

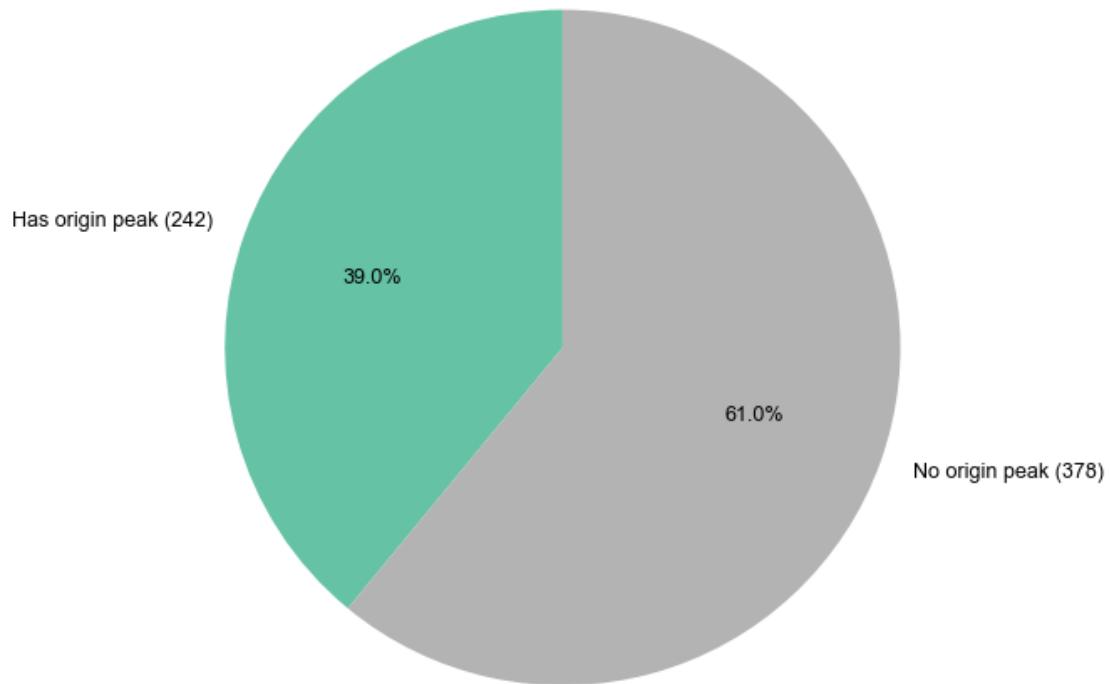


```
[2025-08-27 15:10:21] [INFO] calcium: plot_histogram_by_group: removed 9 outliers out of 675 on 'Speed (um/s)' (lower=-14.715, upper=23.47)
```

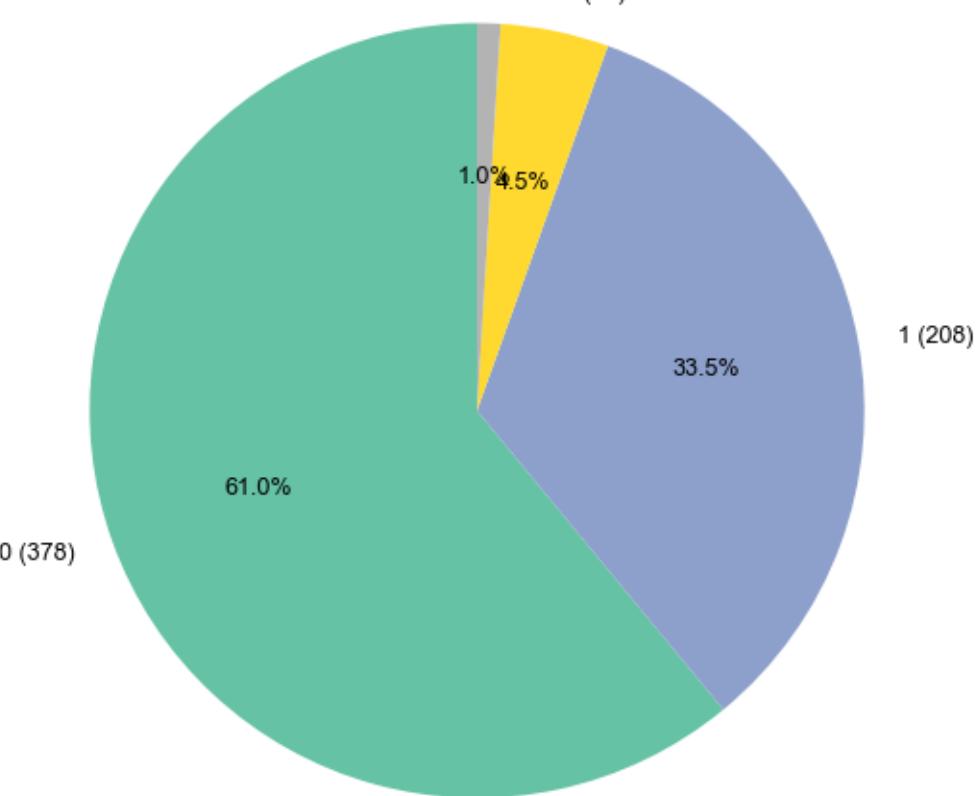


1.3.7 Cells Occurrences as origin in sequential events

Distribution of Number of Sequential Event Origin Peaks per Cell

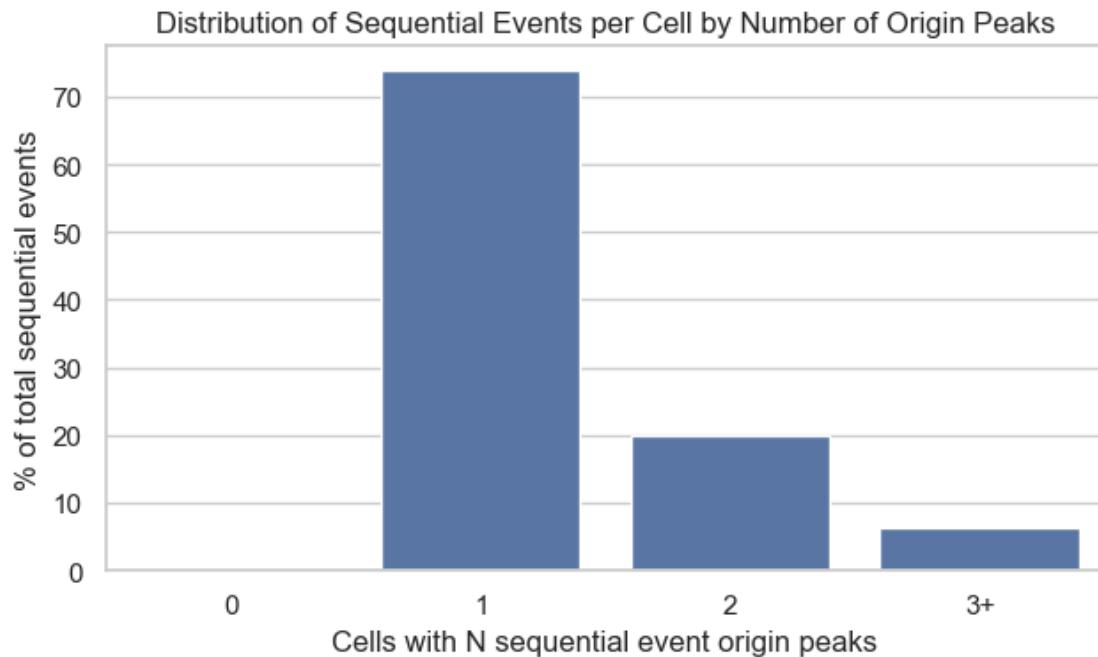


Distribution of Sequential Event Origin Peaks per Cell (0, 1, 2, 3+)



```
[2025-08-27 15:10:22] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\cell-
mapping\cell_Occurrences_in_origin_seq_events_overlay.png': [Errno 2] No such
file or directory: 'D:\\Mateo\\20250624\\Output\\IS08\\cell-
mapping\\cell_Occurrences_in_origin_seq_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
```

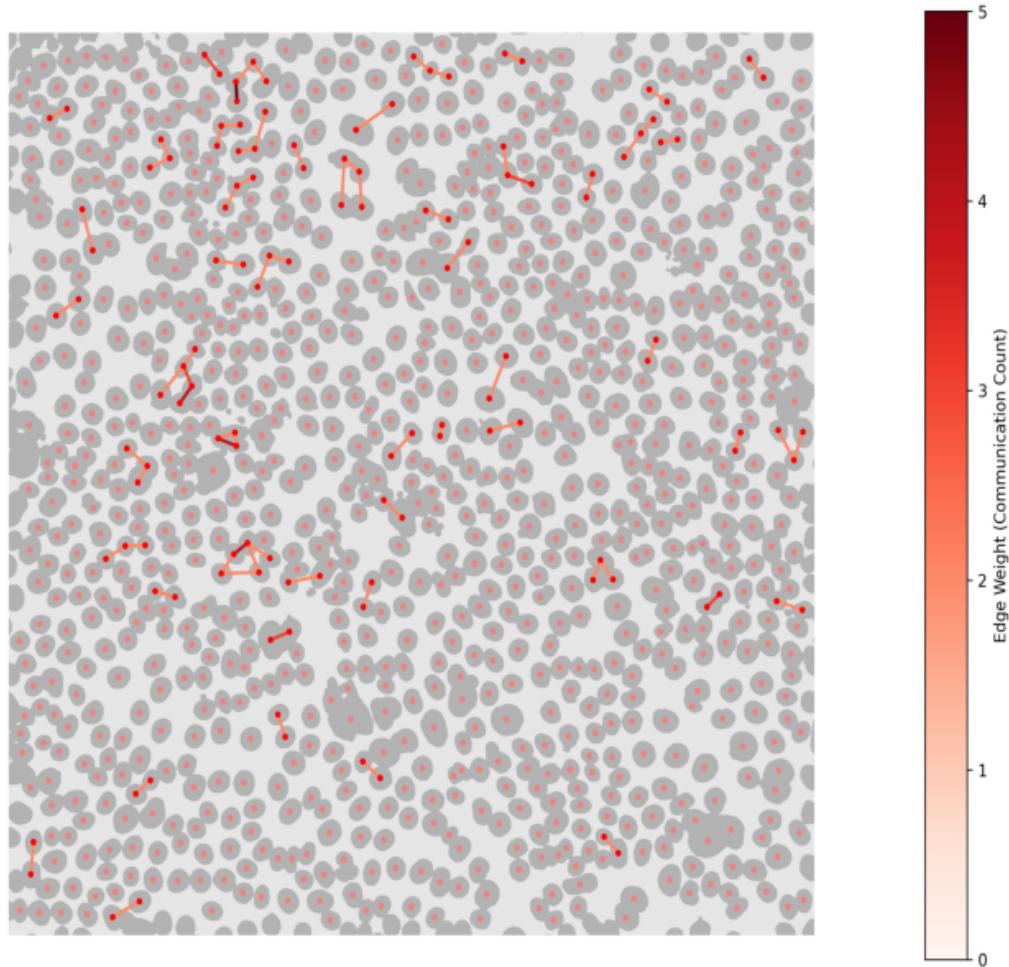
```
packages\PIL\ImageFile.py", line 132, in __init__  
    self.fp = open(fp, "rb")  
FileNotFoundException: [Errno 2] No such file or directory:  
'D:\\Mateo\\20250624\\Output\\IS08\\cell-  
mapping\\cell_Occurrences_in_origin_seq_events_overlay.png'
```



1.3.8 Connection network between cells

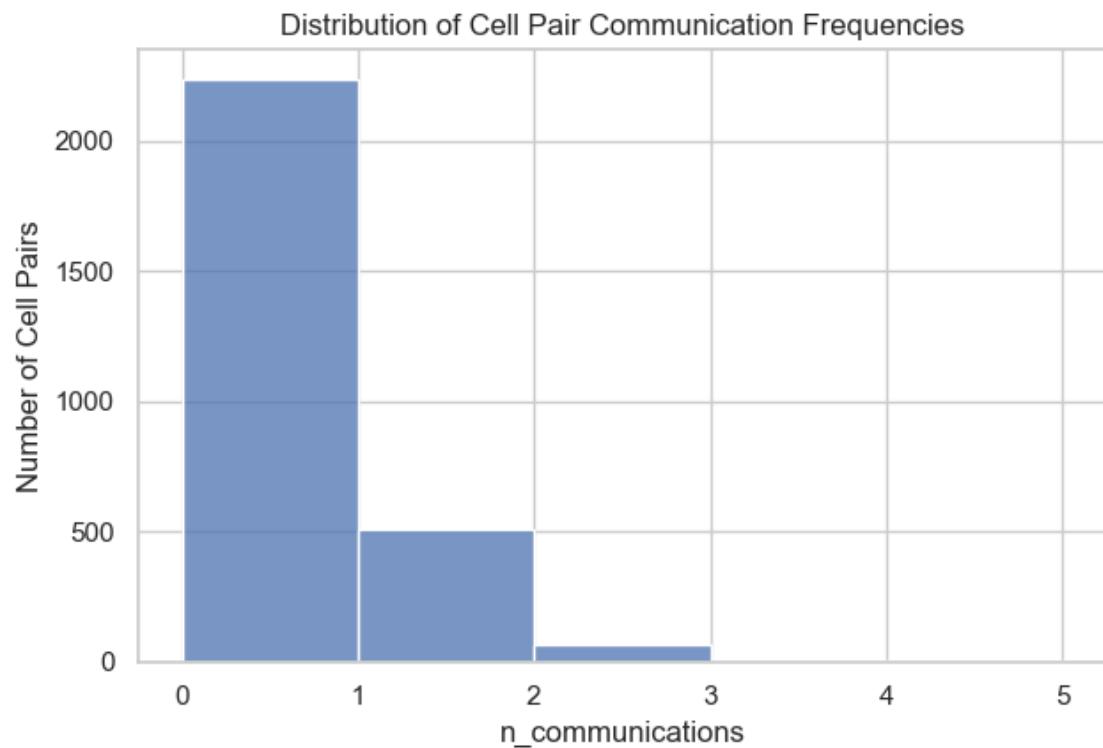
Cell Connection Network Graph

Cells Connection Network (Weighted Edges)

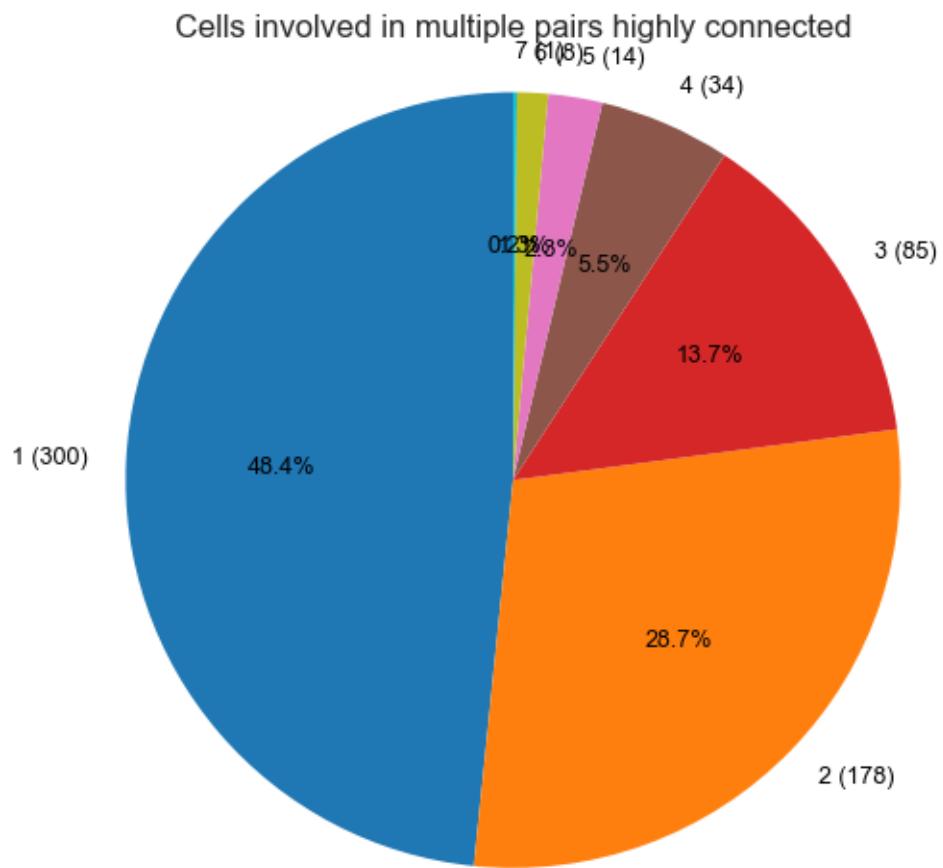


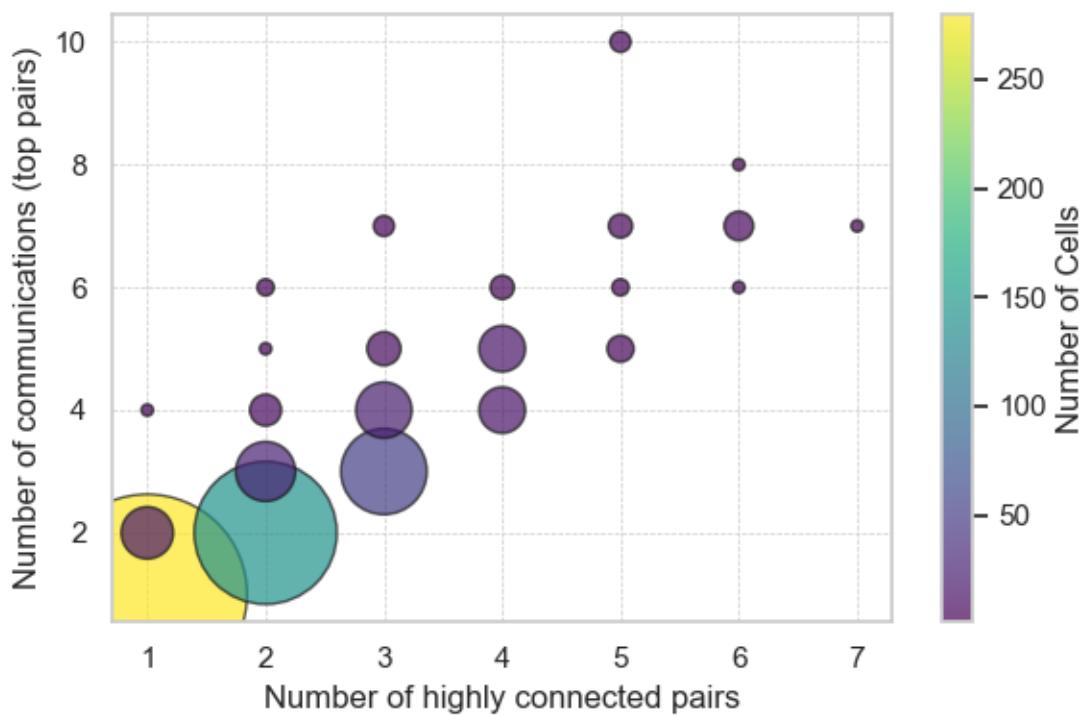
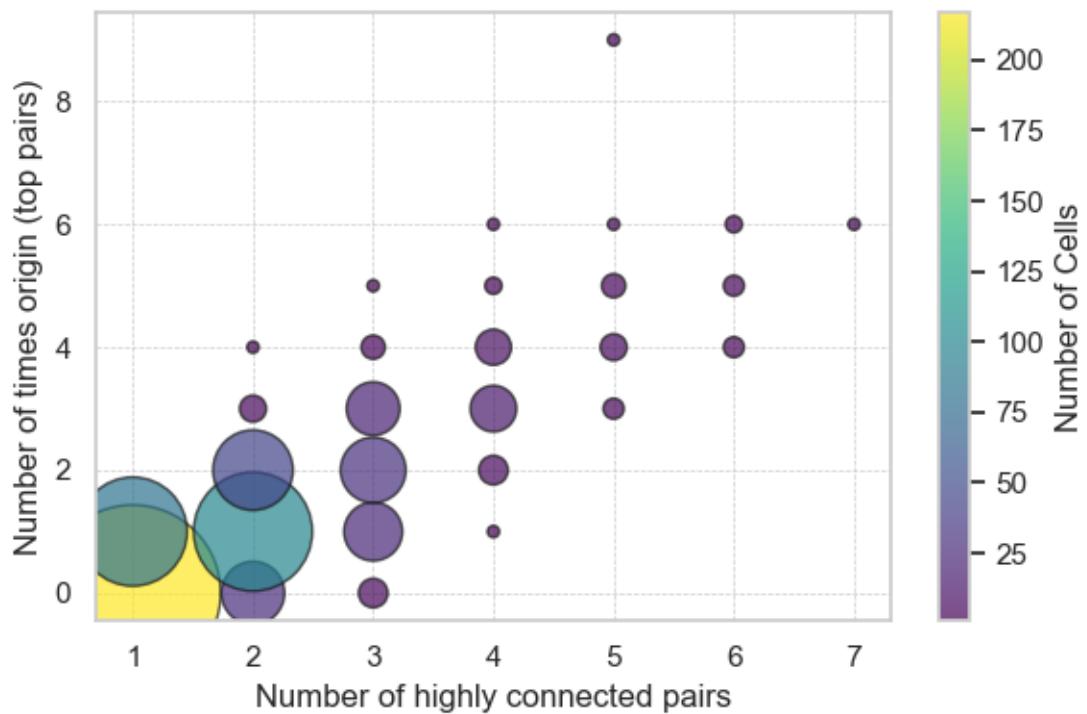
1.3.9 Pair/Trios with high communication networks

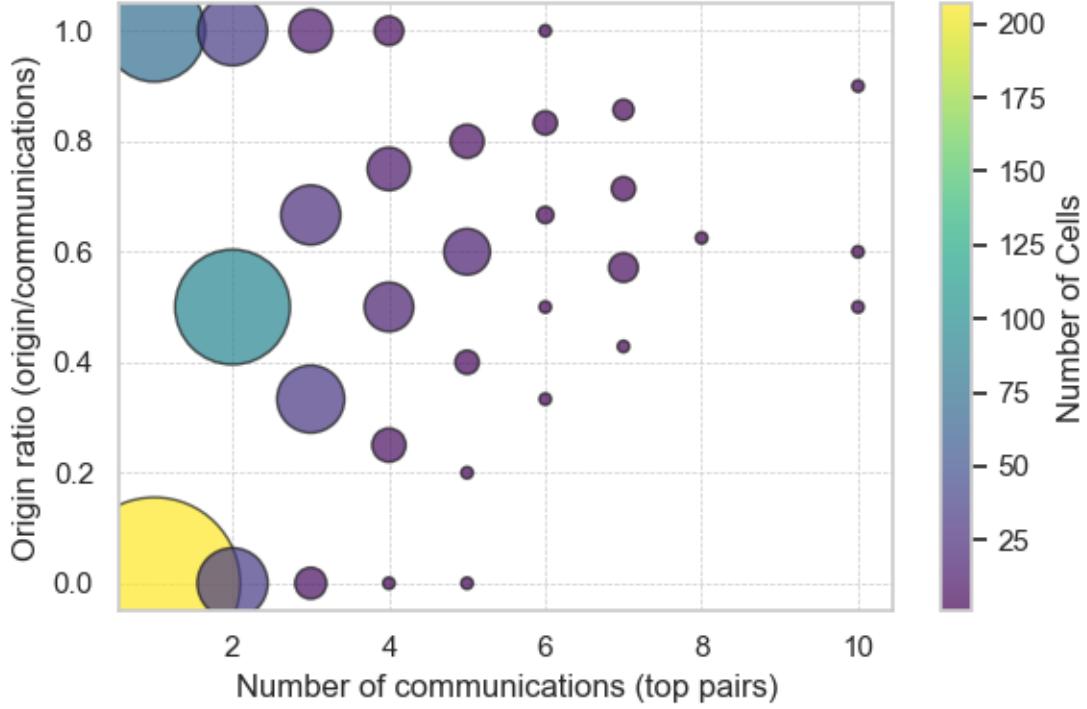
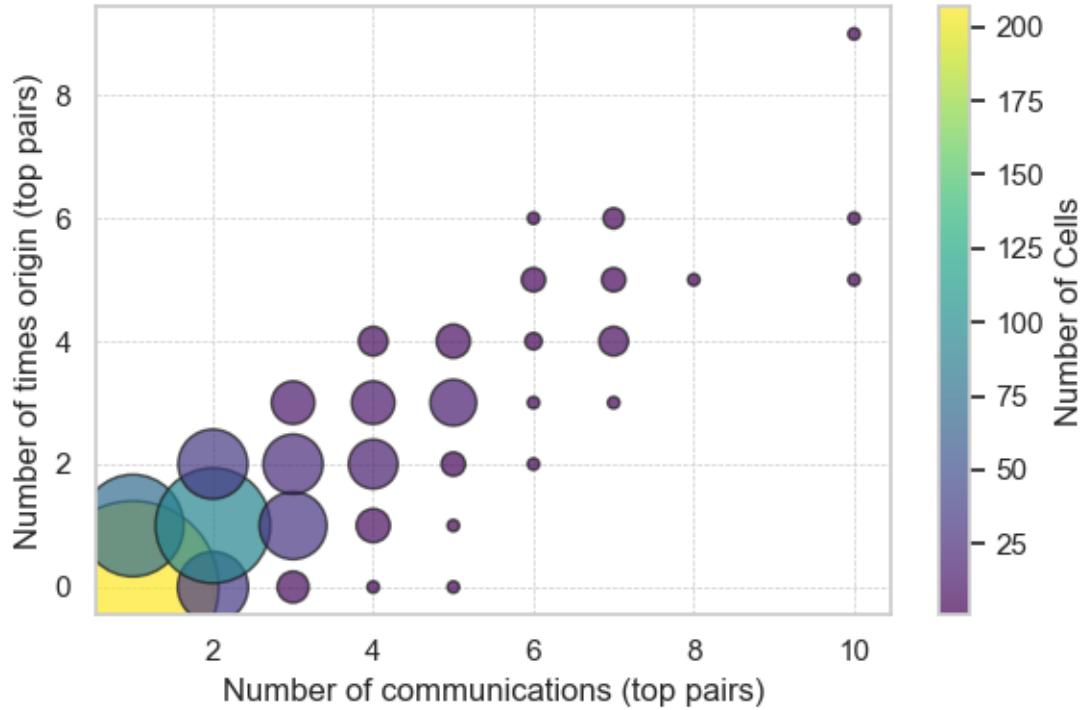
```
[2025-08-27 15:10:23] [INFO] calcium: build_neighbor_pair_stats: built 2823 pairs across 1 datasets (mean distance=17.24 um)
```

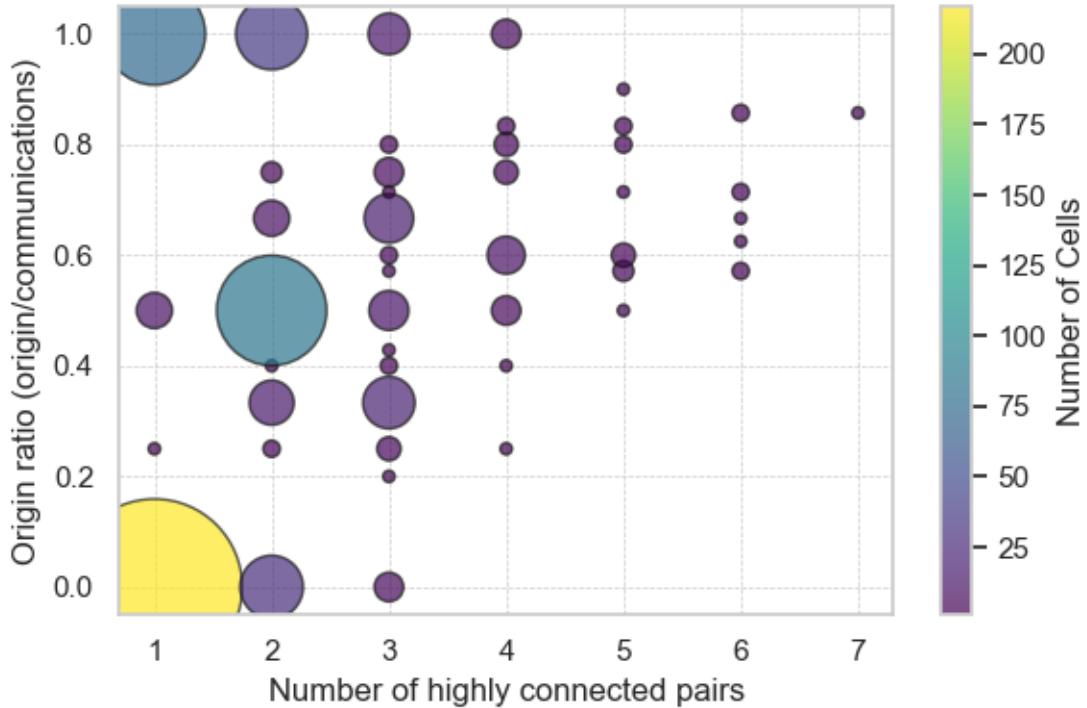


95th percentile threshold: 1.0









[2025-08-27 15:10:24] [INFO] calcium: plot_points_mean_std: N=300 for Number of highly connected pairs=1

[2025-08-27 15:10:24] [INFO] calcium: plot_points_mean_std: N=178 for Number of highly connected pairs=2

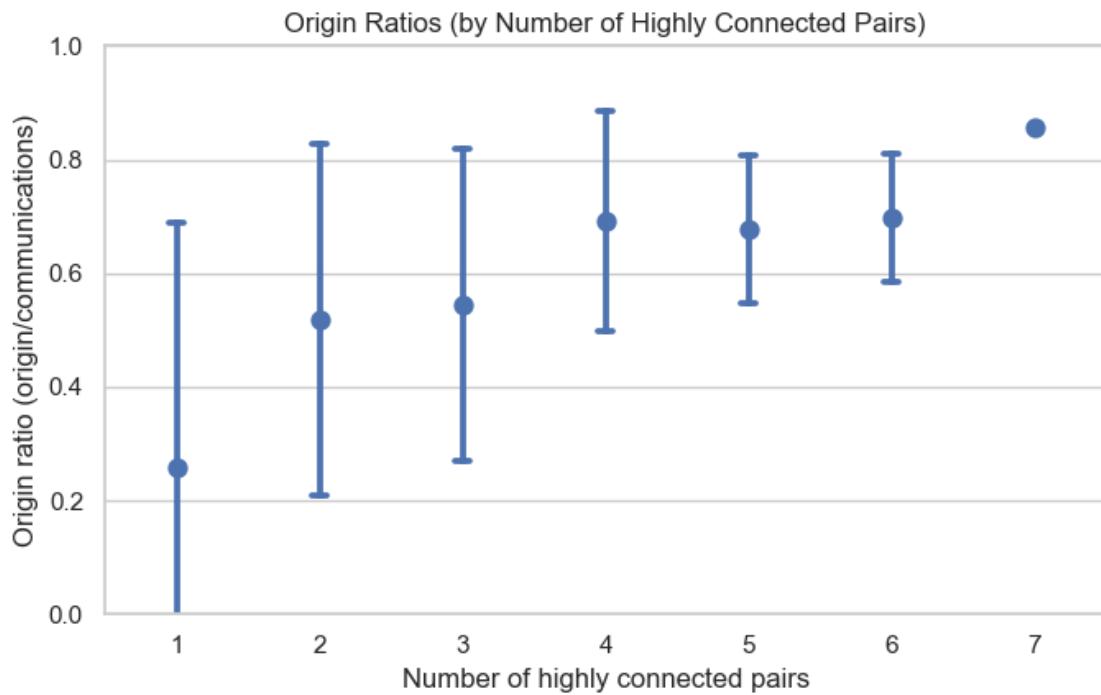
[2025-08-27 15:10:24] [INFO] calcium: plot_points_mean_std: N=85 for Number of highly connected pairs=3

[2025-08-27 15:10:24] [INFO] calcium: plot_points_mean_std: N=34 for Number of highly connected pairs=4

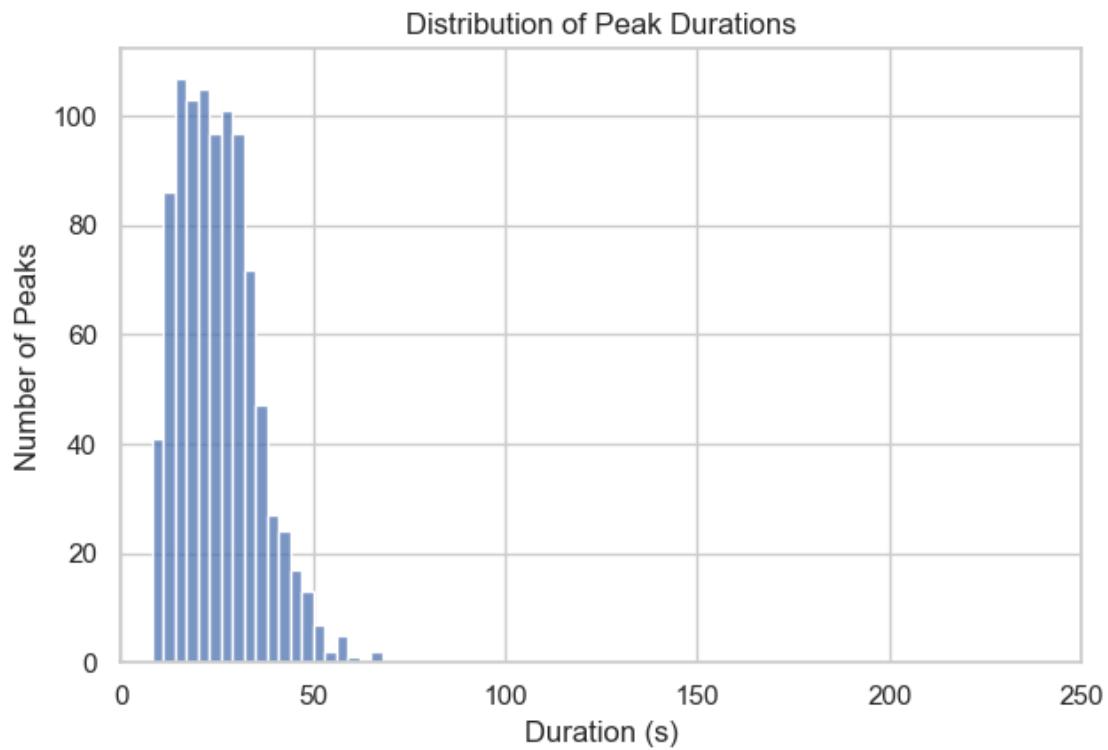
[2025-08-27 15:10:24] [INFO] calcium: plot_points_mean_std: N=14 for Number of highly connected pairs=5

[2025-08-27 15:10:24] [INFO] calcium: plot_points_mean_std: N=8 for Number of highly connected pairs=6

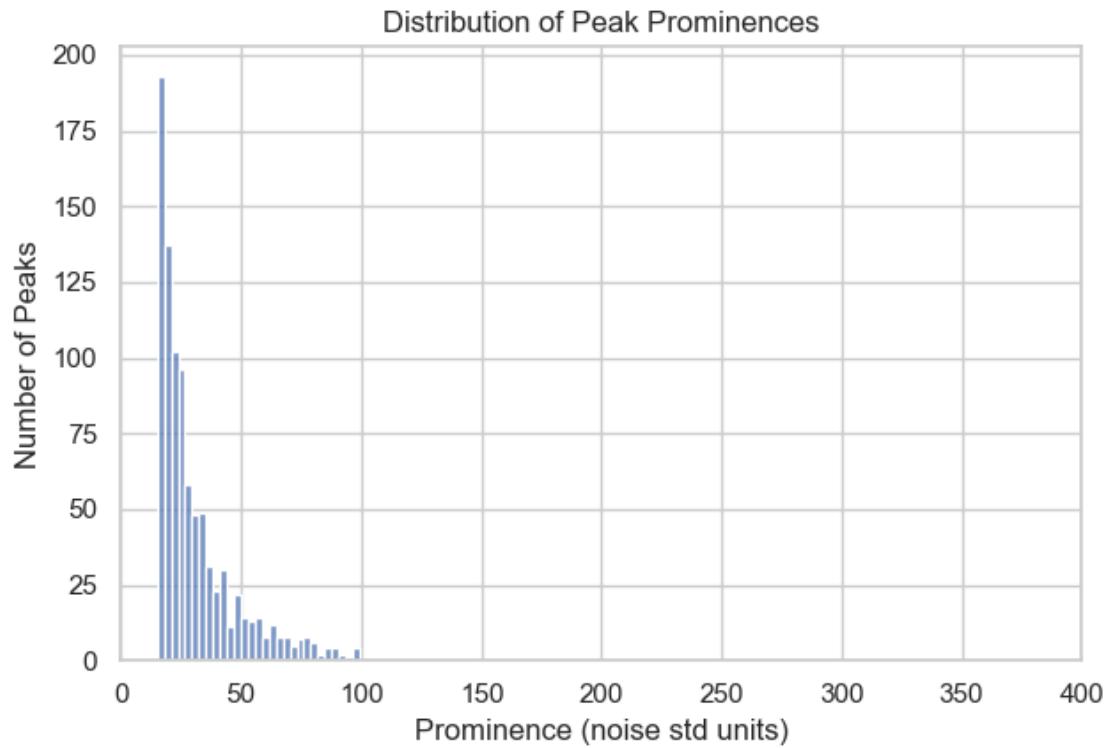
[2025-08-27 15:10:24] [INFO] calcium: plot_points_mean_std: N=1 for Number of highly connected pairs=7

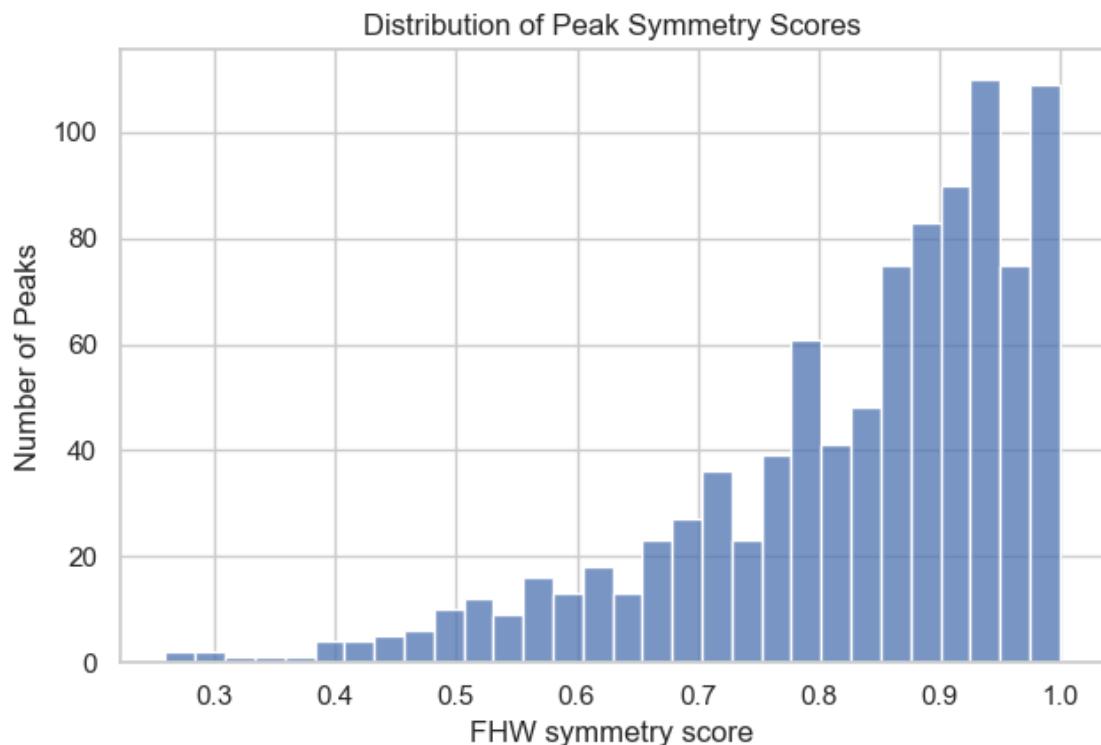


```
[2025-08-27 15:10:25] [INFO] calcium: plot_histogram: removed 3 outliers out of 957 on 'Duration (s)' (lower=-25, upper=73)
```

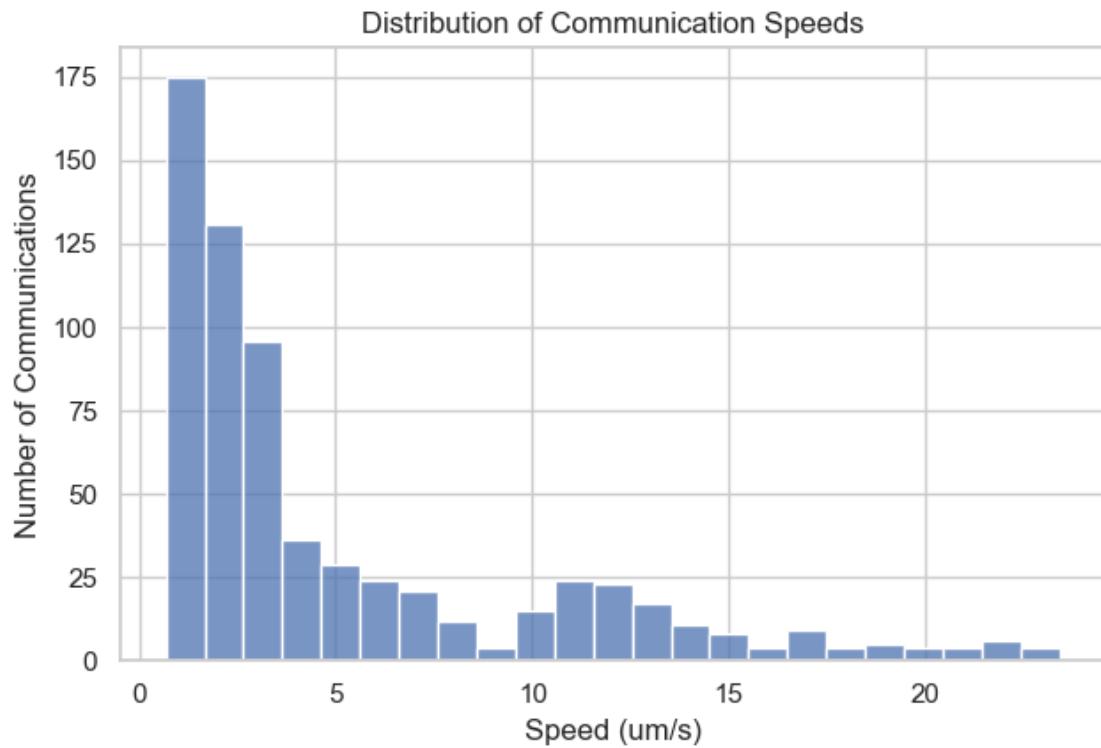


[2025-08-27 15:10:25] [INFO] calcium: plot_histogram: removed 37 outliers out of 957 on 'Prominence (noise std units)' (lower=-41.8, upper=99.6)

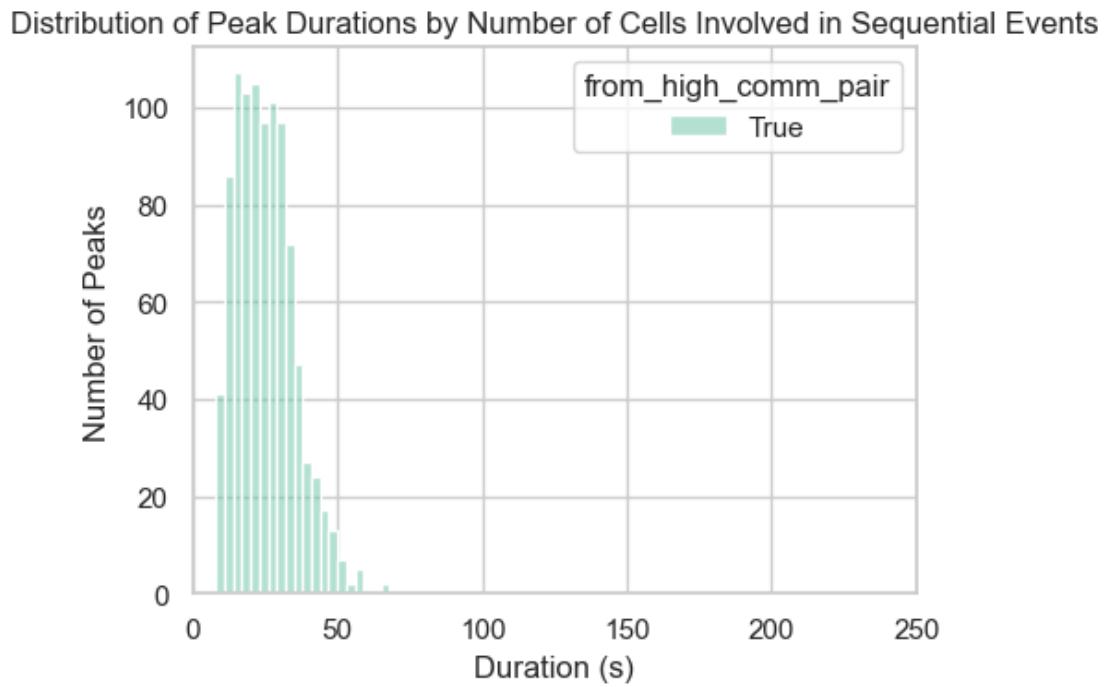




```
[2025-08-27 15:10:25] [INFO] calcium: plot_histogram: removed 9 outliers out of 675 on 'Speed (um/s)' (lower=-14.715, upper=23.47)
```

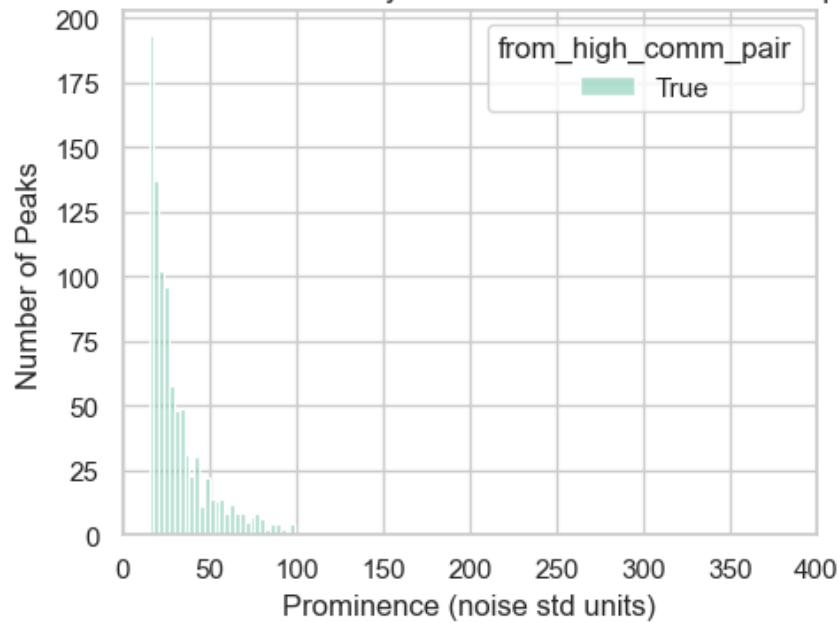


```
[2025-08-27 15:10:25] [INFO] calcium: plot_histogram_by_group: removed 3 outliers out of 957 on 'Duration (s)' (lower=-25, upper=73)
```

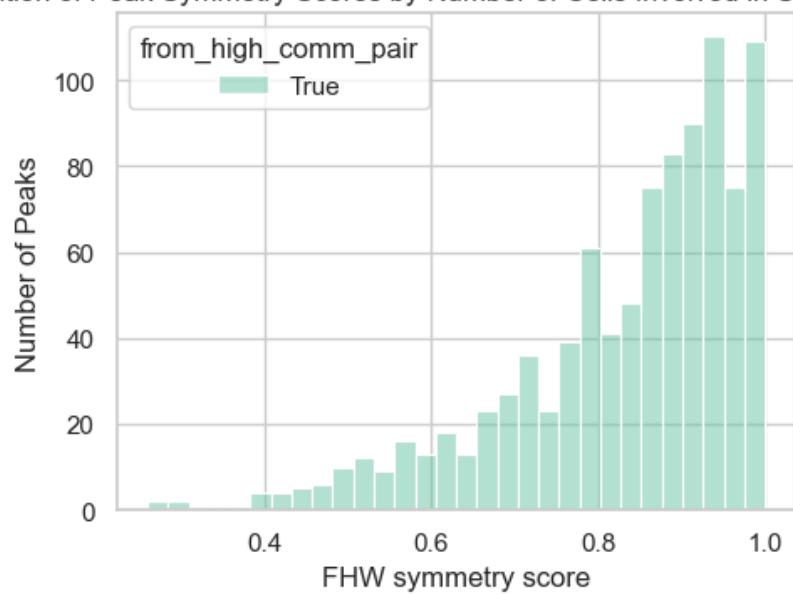


[2025-08-27 15:10:25] [INFO] calcium: plot_histogram_by_group: removed 37 outliers out of 957 on 'Prominence (noise std units)' (lower=-41.8, upper=99.6)

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

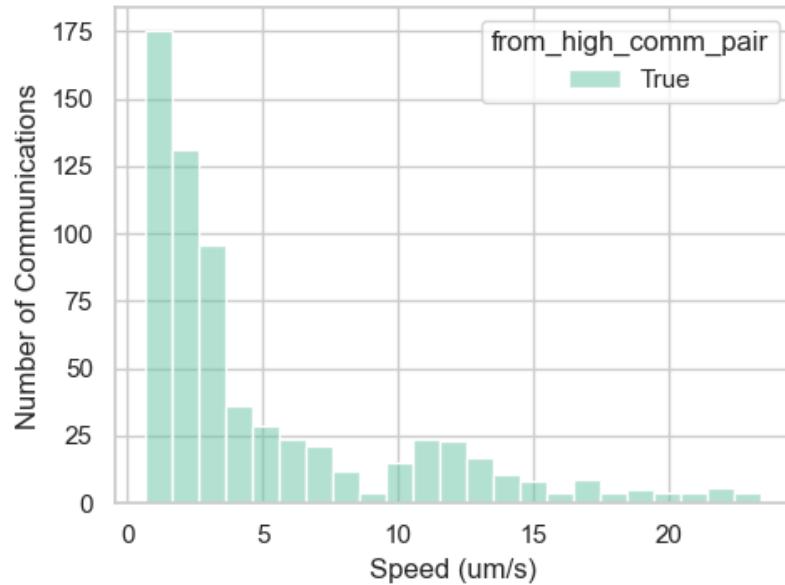


Distribution of Peak Symmetry Scores by Number of Cells Involved in Sequential Events



```
[2025-08-27 15:10:26] [INFO] calcium: plot_histogram_by_group: removed 9 outliers out of 675 on 'Speed (um/s)' (lower=-14.715, upper=23.47)
```

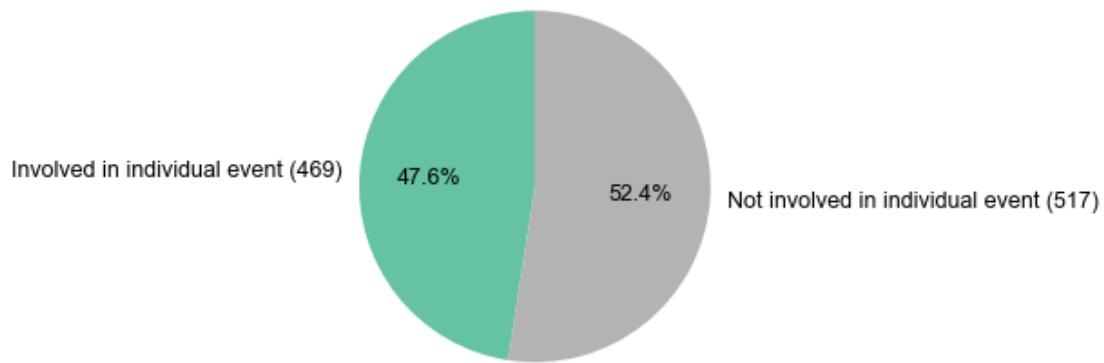
Distribution of Communication Speeds by Number of Cells Involved in Sequential Events

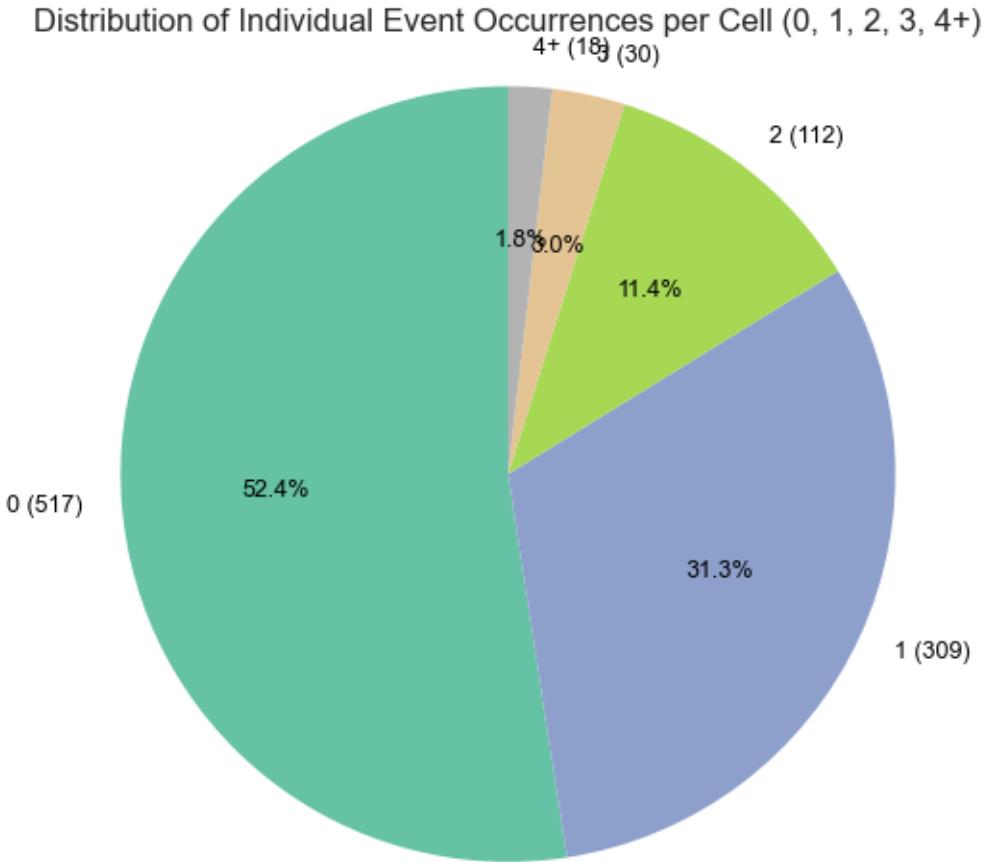


1.4 INDIVIDUAL EVENTS

1.4.1 Cells Occurrences in individual events

Distribution of Cells Involved in Individual Events



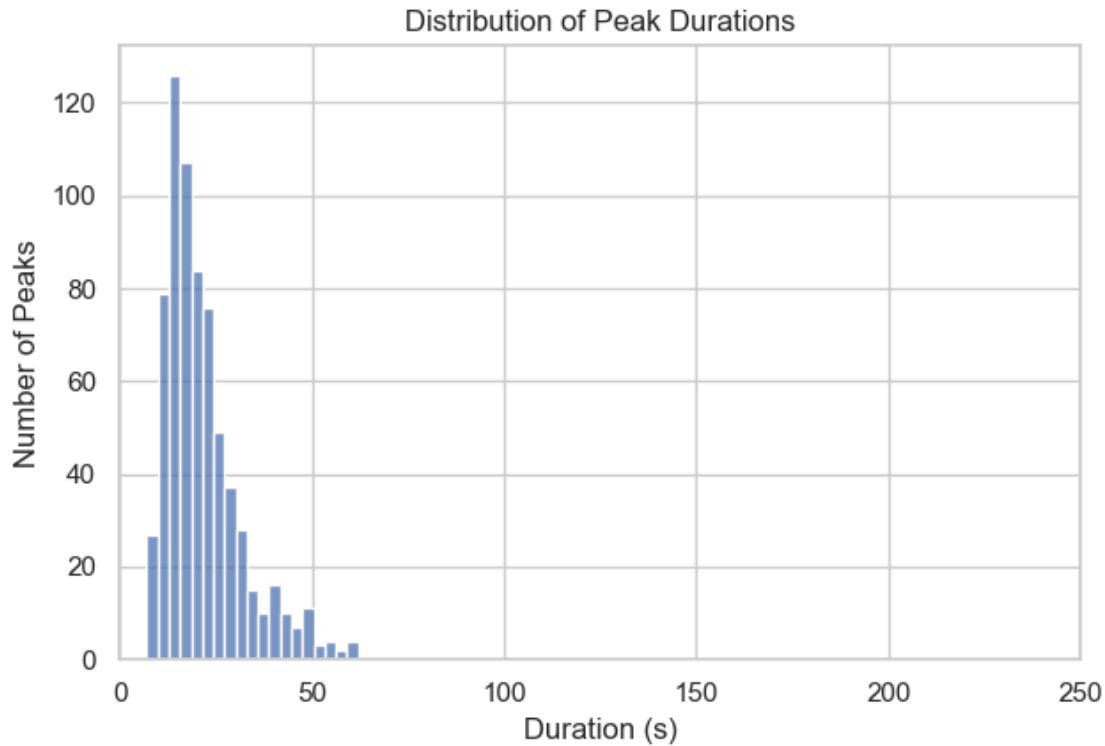


```
[2025-08-27 15:10:26] [ERROR] calcium: Failed to read image
'D:\Mateo\20250624\Output\IS08\cell-
mapping\cell_occurrences_in_individual_events_overlay.png': [Errno 2] No such
file or directory: 'D:\\Mateo\\20250624\\Output\\IS08\\cell-
mapping\\cell_occurrences_in_individual_events_overlay.png'
Traceback (most recent call last):
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\src\calcium_activity_characterizatio
n\analysis\visualizers.py", line 243, in visualize_image
    img = imread(img_path)
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\matplotlib\image.py", line 1512, in imread
    with img_open(fname) as image:
  File "C:\Users\poseidon\OneDrive\Documents\01_ETHZ\Master_Degree\Spring_Semest
er_2025\Master_Thesis\Coding\Image_analysis\.venv\lib\site-
packages\PIL\ImageFile.py", line 132, in __init__
    self.fp = open(fp, "rb")
FileNotFoundException: [Errno 2] No such file or directory:
```

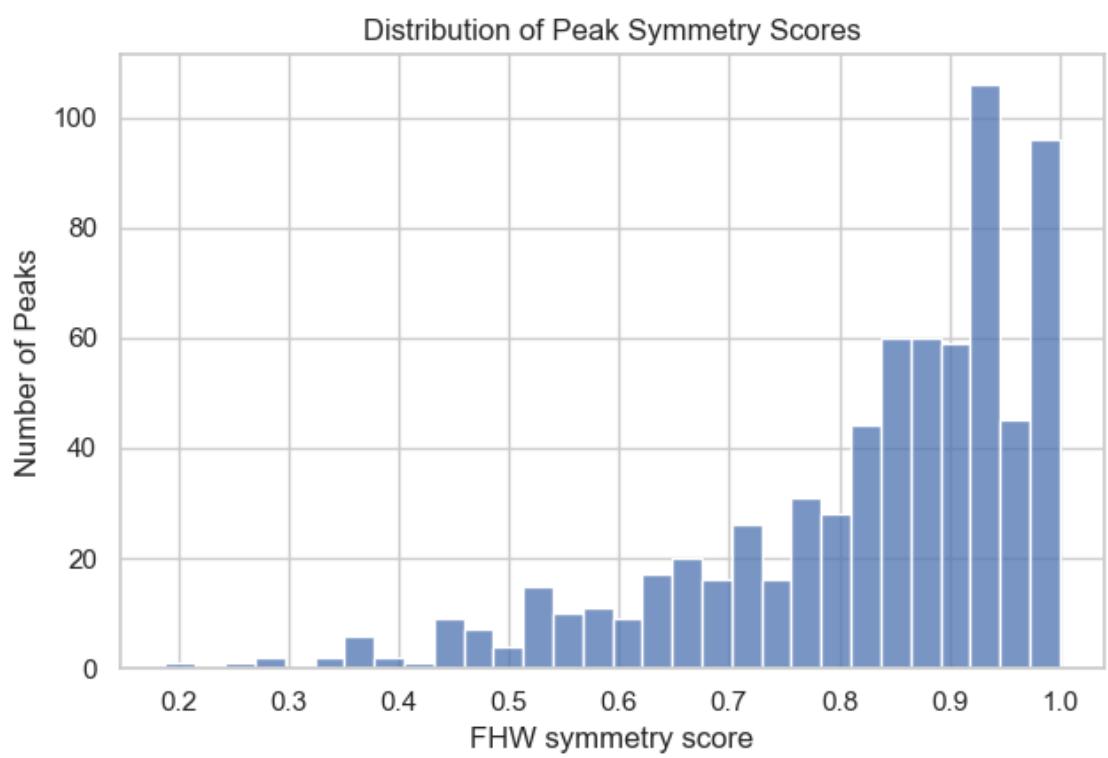
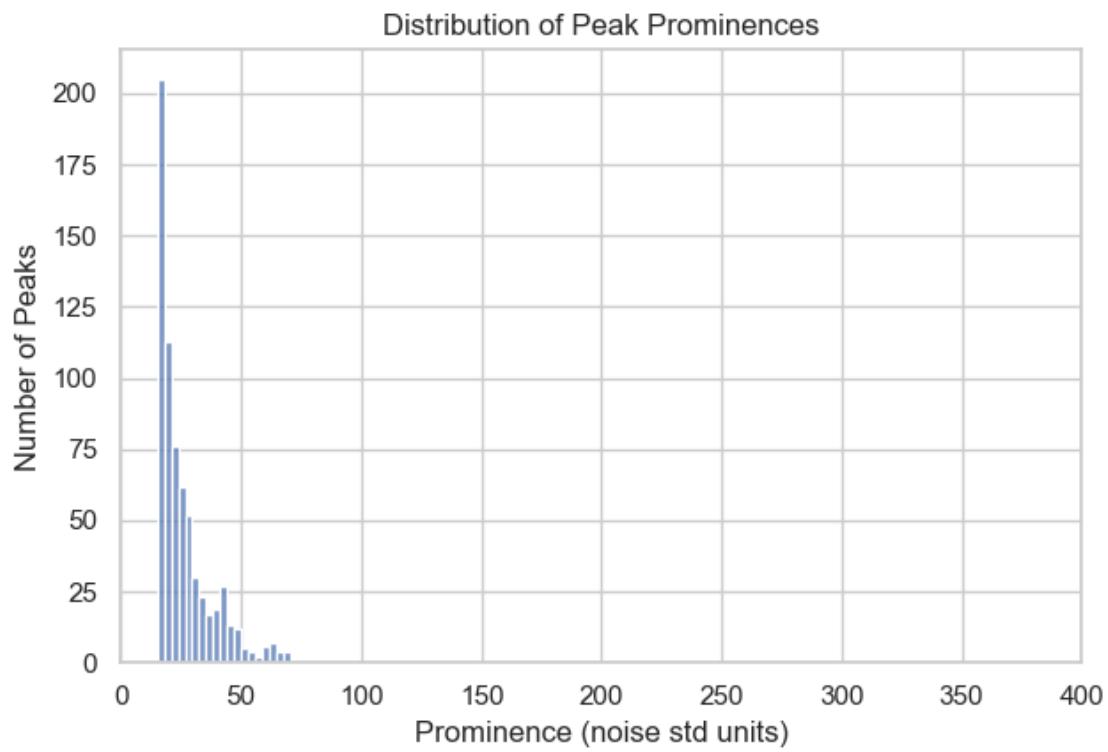
```
'D:\\Mateo\\20250624\\Output\\IS08\\cell-  
mapping\\cell_occurrences_in_individual_events_overlay.png'
```

1.4.2 Peaks statistics in individual events

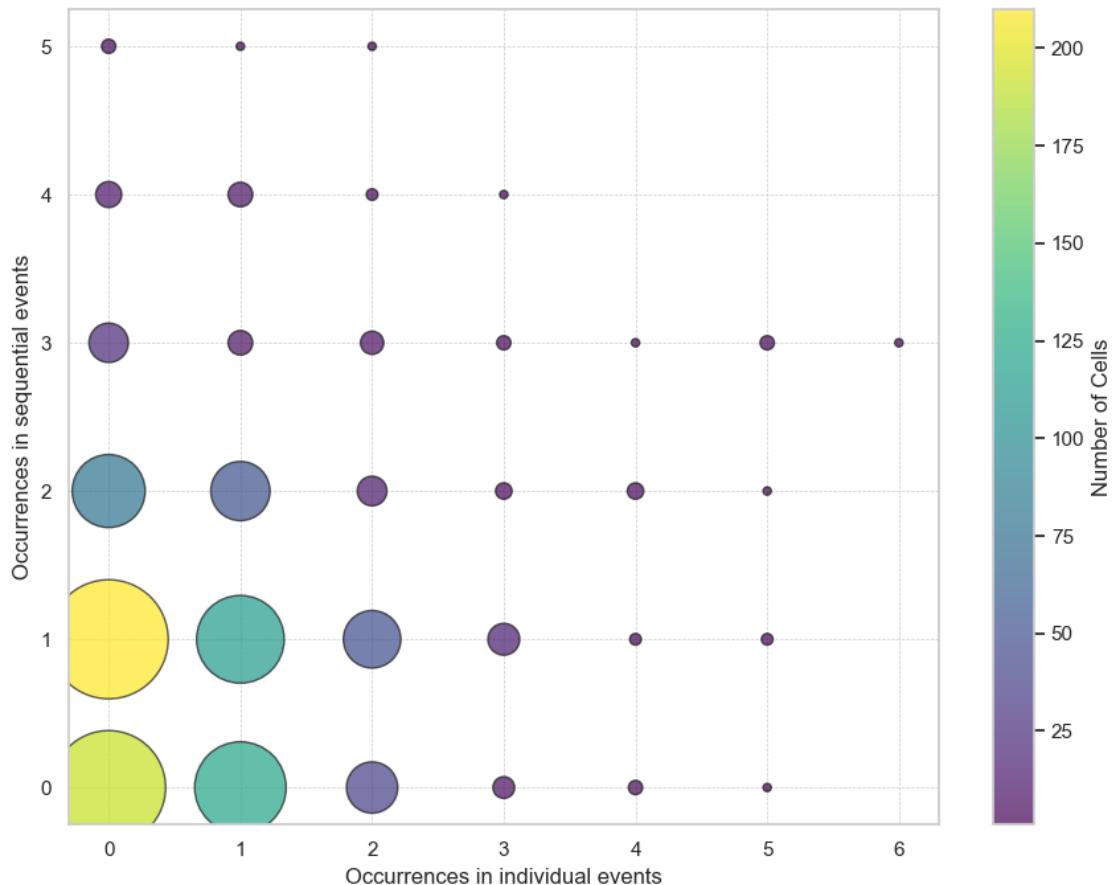
```
[2025-08-27 15:10:26] [INFO] calcium: plot_histogram: removed 9 outliers out of  
704 on 'Duration (s)' (lower=-22, upper=62)
```



```
[2025-08-27 15:10:26] [INFO] calcium: plot_histogram: removed 23 outliers out of  
704 on 'Prominence (noise std units)' (lower=-23.375, upper=72)
```



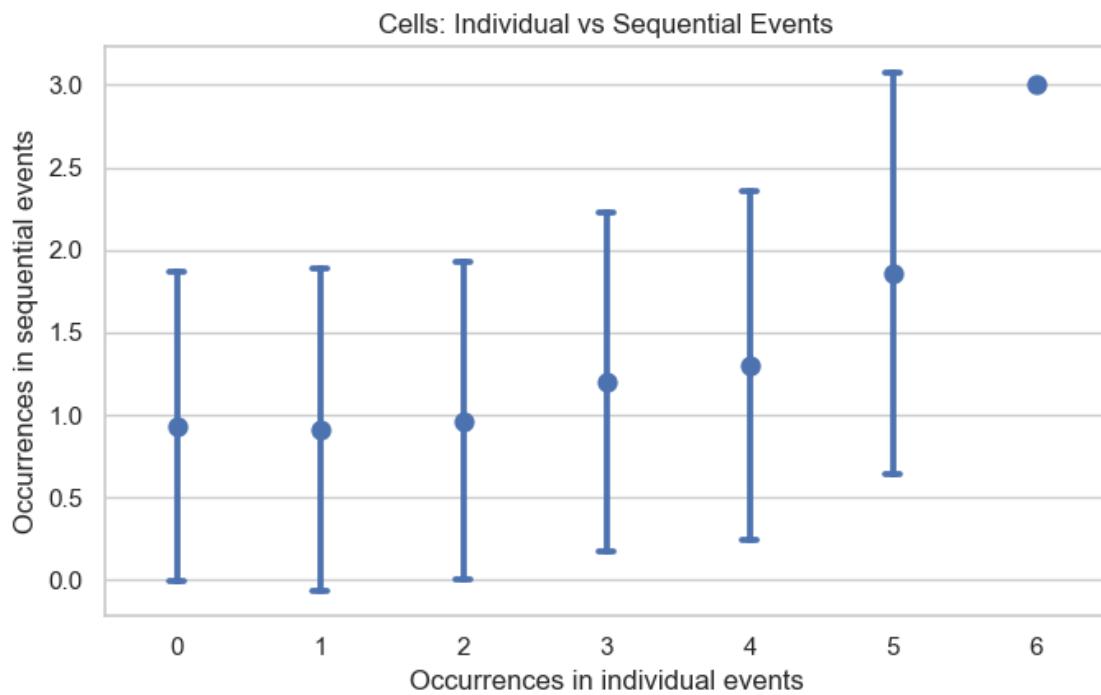
1.4.3 Correlation between event activity level & individual activity level



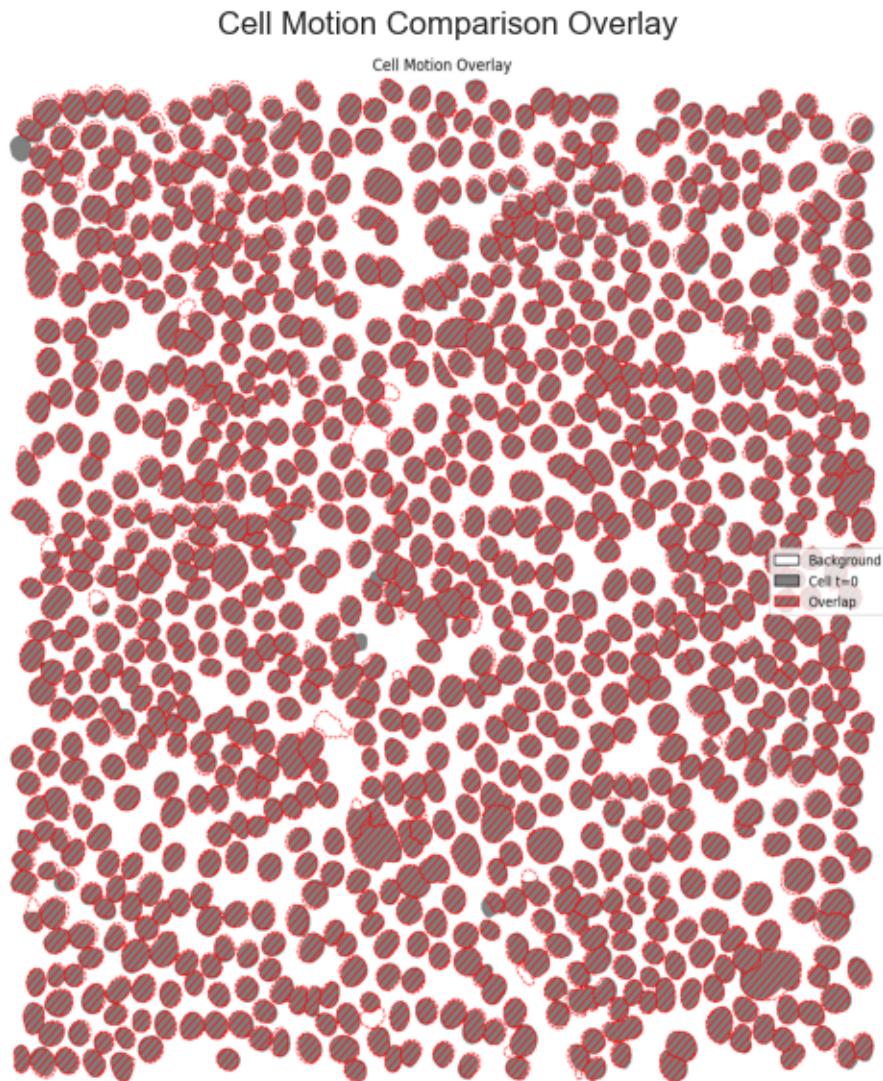
```
[2025-08-27 15:10:27] [INFO] calcium: plot_points_mean_std: removed 5/986 outliers on 'Occurrences in sequential events' (lower=-3, upper=4)
[2025-08-27 15:10:27] [INFO] calcium: plot_points_mean_std: N=514 for Occurrences in individual events=0
[2025-08-27 15:10:27] [INFO] calcium: plot_points_mean_std: N=308 for Occurrences in individual events=1
[2025-08-27 15:10:27] [INFO] calcium: plot_points_mean_std: N=111 for Occurrences in individual events=2
[2025-08-27 15:10:27] [INFO] calcium: plot_points_mean_std: N=30 for Occurrences in individual events=3
[2025-08-27 15:10:27] [INFO] calcium: plot_points_mean_std: N=10 for Occurrences in individual events=4
```

[2025-08-27 15:10:27] [INFO] calcium: plot_points_mean_std: N=7 for Occurrences in individual events=5

[2025-08-27 15:10:27] [INFO] calcium: plot_points_mean_std: N=1 for Occurrences in individual events=6



1.5 CELLS MOTION



Number of cells:

- Hoechst image taken at t=0: 986
- Hoechst image taken at t=1801: 978
- Number of cells difference: absolute 8, relative 0.81%

Pixel-level cell segmentation:

- Total number of pixels in image: 4194304
- Pixels segmented as cell at t=0: 1189778
- Pixels segmented as cell at t=1801: 1192283
- Overlapping pixels between t=0 and t=1801: 1104953 (92.77% of total)
- Pixels exclusive to t=0: 84825 (7.13% of total)
- Pixels exclusive to t=1801: 87330 (7.32% of total)