Processing of triggerlessly acquired detector's data

PREPROCESSING

Load and prepare the dataset inside a Pandas' DataFrame.

In [61]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from os import listdir
from os.path import isfile, join
from matplotlib.ticker import MultipleLocator
import seaborn as sns

%matplotlib inline
```

Inside each directory there are several files related to different test. Now we want to merge them into the same DataFrame.

In [62]:
```
# Load part of the dataset (all the dataset cause memory erro
r, sometimes also more than two part can cause it)
# List all files inside the directory
directory = "/data/Run000260/"
file_names = [file for file in listdir(directory) if isfile(j
oin(directory, file))]

# Create dataframe by appending the data from each file
data = pd.read_csv(directory + file_names[0])
# It's possible to increase the range for loading more data
 (up to len(file_names)=8)
for i in range(1, 2):
    data = data.append(pd.read_csv(directory + file_names[i
]))
data = data.reset_index(drop=True)
```

In [63]:
```
## TEST ONLY
# Prepare the path to the file
##directory = "/data/Run000260/"
##file_name = "data_000000.txt"

# Load the dataset
##data = pd.read_csv(directory + file_name)
```

In [64]:
```
# Useful constants
Tmax = 390 # ns
L = 42 # mm
Vd = L/(2*Tmax) # mm/ns
pos_offset = 21 # mm
```

```
# Add column of time (ns)
# There is a problem with the precision of the measures, so w
e drop the orbit
# Real time: data['TIME_NS'] = data["ORBIT_CNT"]*3564*25 + da
ta["BX_COUNTER"]*25 + data["TDC_MEAS"]*25/30
data['TIME_NS'] = data["BX_COUNTER"]*25 + data["TDC_MEAS"]*25
/30

# Show first 5 rows
data.head(5)
```

Out[64]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
2	1	0	124	1933476838	2037	18	5
3	1	1	54	1933476838	3224	27	8
4	1	1	115	1933476838	3230	3	8

To compute the constant t_0, which is different for every event, we can use the following relation:

$$T_{MAX} = \frac{t_1 + t_3}{2} + t_2$$

where $t_1 = t_{R_1} - t_0$, $t_2 = t_{R_2} - t_0$ and $t_3 = t_{R_3} - t_0$. Then the relation become:

$$T_{MAX} = \frac{t_{R_1} - t_0 + t_{R_3} - t_0}{2} + t_{R_2} - t_0$$

from which we get:

$$t_0 = \frac{t_{R_1} + t_{R_3} + 2t_{R_2} - 2T_{MAX}}{4}$$

Finally we notice that t_{R_1}, t_{R_2}, t_{R_3} are the times recorded by each cell, which are already available in our dataset.

Before processing the dataset, we have to create some missing columns, in fact the DataFrame with the events must contain the following information:

- CHAMBER, which is the Detector number [1-4];
- LAYER, which is the layer of the cell [1-4];
- CELL, which is in the number of the cell [1-16];
- POSTION, which is the position where a particle traverses the cell [0-21] (in mm).

Column of LAYER

To get the layer we can compute the remainder of the TDC_CHANNEL with 4 (total number of layers), and then we have to remap the values in the following way:

REMAINDER	LAYER
0	1
1	4
2	2

3	3

In [65]:
```
# To get the layer we must get the remainder of the TDC_CHANN
EL with 4
# Then we must reoder the result as described above
data['LAYER'] = data['TDC_CHANNEL'] % 4

# Map 1 --> 4
data.loc[data['LAYER'] == 1,'LAYER'] = 4

# Map 0 -> 1
data.loc[data['LAYER'] == 0,'LAYER'] = 1

# Check the correctness
data.head(5)
```

Out[65]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
2	1	0	124	1933476838	2037	18	5
3	1	1	54	1933476838	3224	27	8
4	1	1	115	1933476838	3230	3	8

Column of CHAMBER

Create the column for the chamber according to the following rules:

- Detector 1 $\rightarrow$ FPGA 0, TDC_CHANNEL in [1-64]
- Detector 2 $\rightarrow$ FPGA 0, TDC_CHANNEL in [65-128]
- Detector 3 $\rightarrow$ FPGA 1, TDC_CHANNEL in [1-64]
- Detector 4 $\rightarrow$ FPGA 1, TDC_CHANNEL in [65-128]

In [66]:
```
# Create column for chamber
# Before create empty column
data['CHAMBER'] = 0

# Detector 1
# Select all rows with FPGA = 0 and TDC_CHANNEL <= 64
data.loc[(data['FPGA'] == 0) & (data['TDC_CHANNEL'] <= 64),'C
HAMBER'] = 1

# Detector 2
# Select all rows with FPGA = 0 and  64 < TDC_CHANNEL <= 128
data.loc[(data['FPGA'] == 0) & (data['TDC_CHANNEL'] > 64) & (
data['TDC_CHANNEL'] <= 128),'CHAMBER'] = 2

# Detector 3
# Select all rows with FPGA = 1 and TDC_CHANNEL <= 64
data.loc[(data['FPGA'] == 1) & (data['TDC_CHANNEL'] <= 64),
'CHAMBER'] = 3

# Detector 4
# Select all rows with FPGA = 0 and  64 < TDC_CHANNEL <= 128
data.loc[(data['FPGA'] == 1) & (data['TDC_CHANNEL'] > 64) & (
```

```
data['TDC_CHANNEL'] <= 128),'CHAMBER'] = 4

# Check the correctness
data.head(5)
```

Out[66]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
2	1	0	124	1933476838	2037	18	5
3	1	1	54	1933476838	3224	27	8
4	1	1	115	1933476838	3230	3	8

Column of CELL

This column contains the values from 1 to 16. These values can be obtained as follows:

$$\lceil \frac{N_{CHANNEL}\%64}{4} \rceil$$

In [67]:

```
# Create column for cell
data['CELL'] = ((data['TDC_CHANNEL']%64)/4).apply(np.ceil).as
type(int)
# TDC_CHANNEL%64=0 refers always to cell 16 of layer 1
data.loc[data['CELL']==0,'CELL'] = 16

# Check the correctness
data.head(5)
```

Out[67]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
2	1	0	124	1933476838	2037	18	5
3	1	1	54	1933476838	3224	27	8
4	1	1	115	1933476838	3230	3	8

PART 1

The dataset is ready to be processed, so we can start detecting the events through the trigger 139.

In [68]:

```
# Silence warnings
pd.options.mode.chained_assignment = None  # default='warn'

# Search all the orbit with the trigger 139
orbit = data.loc[data['TDC_CHANNEL'] == 139,'ORBIT_CNT']
list_orbit = orbit.values.tolist()
events = data.loc[data['ORBIT_CNT'].isin(list_orbit)]

# Sort data
# It is wrong to order data according to TIME_NS because this
time depends on where the particel has passed
```

```
time depends on where the particel has passed
# inside the cell, in fact if for example the particel passes one cell of the third layer near its center
# the drift time will be small and so TIME_NS can result smaller than the one recorded by one cell in
# the first layer, where the particel has passed the cell far away from its center.
# So we will sort values according to their OBIT_CNT, CHAMBER and LAYER
events = events.sort_values(by = ['ORBIT_CNT','CHAMBER','LAYER'])

# Remove the hits related to the external triggers
events = events[events['TDC_CHANNEL']<129]

events.head(5)
```

Out[68]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
2	1	0	124	1933476838	2037	18	5
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
7	1	1	56	1933476838	3238	8	8
3	1	1	54	1933476838	3224	27	8

In [69]:

```
# Visualization hit matrix function
def show_mat(df):

    # Hit Matrix initialization
    # Select the indexes for each cell and layer
    raw_mat = np.zeros((16, 32))
    rows = np.array((df['CHAMBER']-1)*4+df['LAYER']-1)
    columns = np.array((df['CELL']-1)*2)

    # Count the hits asscociated to each cell
    for i in range(len(rows)):
        raw_mat[rows[i], columns[i]] = raw_mat[rows[i], columns[i]]+1
        raw_mat[rows[i], columns[i]+1] = raw_mat[rows[i], columns[i]+1]+1

    # Reshape the hit matrix
    final_mat = np.zeros((8, 66))

    # Chamber 1, 2
    for i in range(8):
        if (i%2 == 0):
            final_mat[7-i, 1:33] = raw_mat[i, :32]
        else:
            final_mat[7-i, :32] = raw_mat[i, :32]

    # Chamber 3, 4
    for i in range(8, 16):
        if (i%2 == 0):
            final_mat[7-(i-8), 34:66] = raw_mat[i, :32]
        else:
            final_mat[7-(i-8), 33:65] = raw_mat[i, :32]
```

```
    # Show the resutls
    plt.figure(figsize=(20,4))
    ax = plt.imshow(final_mat, cmap='plasma')

    plt.annotate('CHAMBER 1',xy=(0.5, 0.5), xytext=(12,11), f
ontsize=20, color='red')
    plt.annotate('CHAMBER 2',xy=(0.5, 0.5), xytext=(12,-3), f
ontsize=20, color='red')
    plt.annotate('CHAMBER 3',xy=(0.5, 0.5), xytext=(46,11), f
ontsize=20, color='red')
    plt.annotate('CHAMBER 4',xy=(0.5, 0.5), xytext=(46,-3), f
ontsize=20, color='red')

    plt.axvline(x=32.5, color='white', linewidth=2)
    plt.axhline(y=3.5, color='white', linewidth=2)

    # Tick on the axis
    plt.xticks(np.concatenate((np.arange(1.5, 33, 2 ), np.ara
nge(34.5, 66, 2))),
               ['1','2','3','4','5','6','7','8','9','10','11'
,'12','13','14','15','16',
                '1','2','3','4','5','6','7','8','9','10','11'
,'12','13','14','15','16'])
    plt.yticks([x for x in range(8)], ['4','3','2','1','4',
'3','2','1'])
    plt.ylabel('LAYER', fontsize=16)
    plt.xlabel('CELL', fontsize=16)
    plt.colorbar()

# Visualization single event
def show_event(df, eN):
    show_mat(df[df['EVENT_NUMBER']==eN])
```

Computation of t_0

To compute t_0 we have to apply the Talete's equation to the cell alignment inside our dataset. We will limit our search to the following patterns inside the 'LAYER' column:

- 1, 2, 3
- 2, 3, 4

This process can be easily generalized to other patterns.

In [70]:
```
# Make three shifted copy of the LAYER, TIME_NS, CELL and of
 CHAMBER
events['LAYER_1'] = events['LAYER'].shift(-1)
events['LAYER_2'] = events['LAYER'].shift(-2)
events['TIME_NS_1'] = events['TIME_NS'].shift(-1)
events['TIME_NS_2'] = events['TIME_NS'].shift(-2)
events['CELL_1'] = events['CELL'].shift(-1)
events['CELL_2'] = events['CELL'].shift(-2)
events['CHAMBER_1'] = events['CHAMBER'].shift(-1)
events['CHAMBER_2'] = events['CHAMBER'].shift(-2)

# There is a constrains on Chambers, which must be always the
same
mask_pattern_chamber = (events['CHAMBER'] == events['CHAMBER_
1']) & (events['CHAMBER'] == events['CHAMBER_2'])
```

```
# There is also a constrains on cell, which must be applied f
or every pattern
# The sucessive cell hit number has to differ at most by one
 from the previous cell number (1->2 ok, 6->5 ok, 1->3 no)
mask_pattern_cell_123 = ((events['CELL_1']-events['CELL'])>=0
& (abs(events['CELL_1']-events['CELL'])<=1)) & (((events['CEL
L_2']-events['CELL_1'])<=0) & (abs(events['CELL_2']-events['C
ELL_1'])<=1))
mask_pattern_cell_234 = ((events['CELL_1']-events['CELL'])<=0
& (abs(events['CELL_1']-events['CELL'])<=1)) & (((events['CEL
L_2']-events['CELL_1'])>=0) & (abs(events['CELL_2']-events['C
ELL_1'])<=1))

# Search pattern to get the real t0
mask_pattern_123 = (events['LAYER']==1) & (events['LAYER_1']=
=2) & (events['LAYER_2']==3)
mask_pattern_234 = (events['LAYER']==2) & (events['LAYER_1']=
=3) & (events['LAYER_2']==4)

# Compute final mask
mask_pattern = ((mask_pattern_123 & mask_pattern_cell_123) |
(mask_pattern_234 & mask_pattern_cell_234)) & mask_pattern_ch
amber

# Apply the Talete's Theorem for t0 to the patterns
events.loc[mask_pattern, 't0'] = (events['TIME_NS'] + events[
'TIME_NS_2'] + 2*events['TIME_NS_1'] - 2*Tmax)/4

# Populate values of adiacent cell (according to the choosen
 pattern)
events = events.fillna(0)
mask_pattern_time = events['t0']!=0

# We useboolean values to avoid making mistakes when substitu
ting the value of t0
events.loc[mask_pattern_time.shift(1).fillna(False), 't0'] =
events['t0'].shift(1)
events.loc[mask_pattern_time.shift(2).fillna(False), 't0'] =
events['t0'].shift(2)
events = events.fillna(0)

events.head(5)
```

Out[70]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
2	1	0	124	1933476838	2037	18	5
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
7	1	1	56	1933476838	3238	8	8
3	1	1	54	1933476838	3224	27	8

Column POSITION

Only at this point we can create the column with the position, thanks to t_0.

```
In [71]: # Compute the position
```

In [71]:
```
# compute the position
events.loc[events['t0']!=0,'POSITION'] = (events['TIME_NS'] -
events['t0'])*Vd
events = events.fillna(0)

# Now we have to filter false alignmens detected by the mask
 pattern, which can be caused by noise
# So we drop the rows with an unexpected result: such as Posi
tion bigger than 21 mm or smaller than 0 mm
events.loc[(events['POSITION']<0) | (events['POSITION']>=21),
['POSITION','t0']] = 0

events.head(5)
```

Out[71]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
2	1	0	124	1933476838	2037	18	5
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
7	1	1	56	1933476838	3238	8	8
3	1	1	54	1933476838	3224	27	8

In [72]:
```
# Map obit values to a range of int
grouped_orbit = events.groupby('ORBIT_CNT')
# Search all orbits
orbits = list(grouped_orbit.groups.keys())
# Create increasing number list for the events
event_number = np.arange(1, len(orbits)+1)
# Create the map
event_map = dict(zip(orbits, event_number))
# Map values
orbit_to_map = events['ORBIT_CNT']
orbit_mapped = orbit_to_map.map(event_map)
events['EVENT_NUMBER'] = orbit_mapped

events.head(5)
```

Out[72]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
2	1	0	124	1933476838	2037	18	5
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
7	1	1	56	1933476838	3238	8	8
3	1	1	54	1933476838	3224	27	8

5 rows × 21 columns

In [73]:
```
# Final DataFrame showing all the events detected by the 139
 trigger
# When the position is not avaiable is set to 0
events_final = events[['EVENT_NUMBER','ORBIT_CNT','CHAMBER',
'LAYER','CELL','POSITION']]
events_final.set_index(['EVENT_NUMBER','ORBIT_CNT','CHAMBER',
'LAYER'], inplace=True)
```

```python
events_final.sort_index(inplace=True)
events_final.head(12)
```

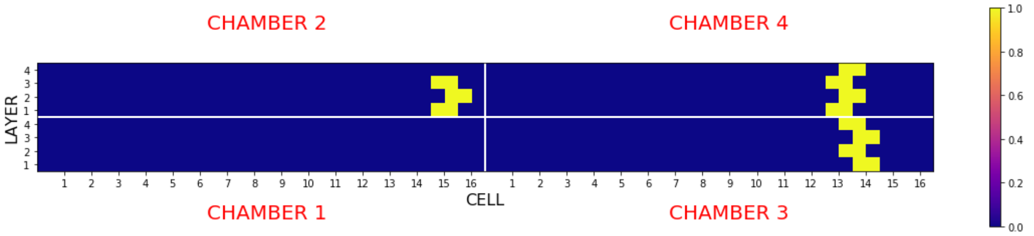
Out[73]:

				CELL	POSITION
EVENT_NUMBER	**ORBIT_CNT**	**CHAMBER**	**LAYER**		
1	**1933476838**	**2**	**1**	15	12.440705
			2	16	8.761218
			3	15	12.036859
		3	**1**	14	19.586538
			2	14	1.592949
			3	14	19.227564
			4	14	1.233974
		4	**1**	13	8.222756
			2	14	12.485577
			3	13	8.806090
			4	14	11.184295
2	**1933476845**	**1**	**1**	1	17.365385

Show the cell alingment inside an event

In [74]:

```python
show_event(events, 1)
```



Plot the distribution of Drift Times

To compute the drift time we easily do:

$$t = t_R - t_0$$

where t_R is the recorded time by each cell.

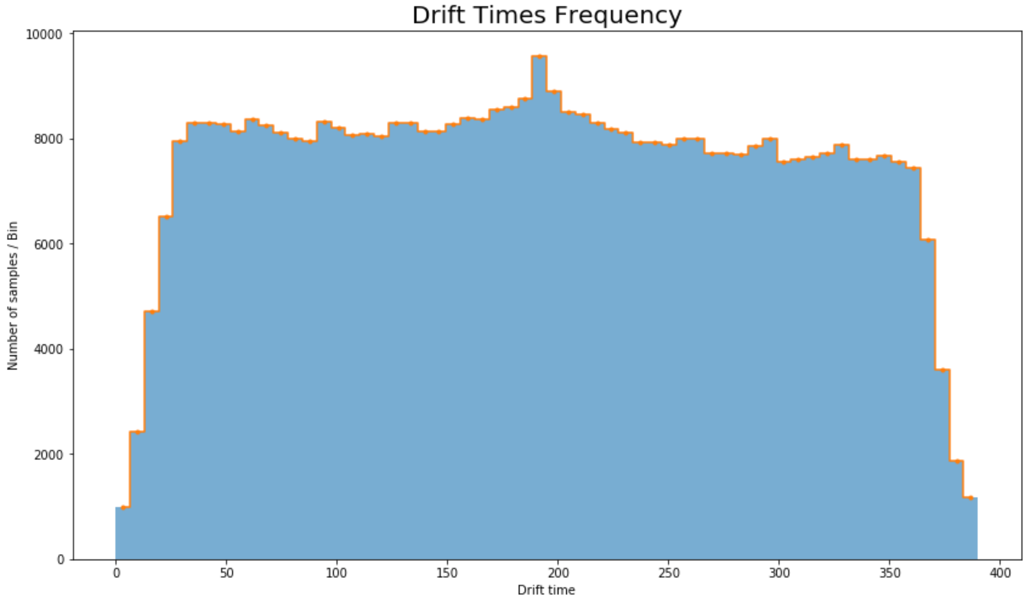
In [75]:

```python
# Select hits where position is different from 0
events_drift = events[events['POSITION']!=0]
# Get all drift times
drift_times = events_drift['TIME_NS']-events_drift['t0']

# Drift Times Frequency
figure = plt.figure(figsize=(14,8))
ax = figure.add_subplot(111)
number_bins = 60
y, edges, bins = ax.hist(drift_times, bins = number_bins, lab
el='Drift Times Frequency', alpha=0.6)
ax.set_ylabel("Number of samples / Bin")
ax.set_xlabel("Drift time")
```

```
ax.set_xlabel("Drift time")
ax.set_title("Drift Times Frequency", fontsize=20)
mean_point = (edges[1:] + edges[:-1])/2
ax.errorbar(mean_point, y, yerr = y**-0.5, marker = '.', drawstyle = 'steps-mid', label = 'error')

plt.show()
```



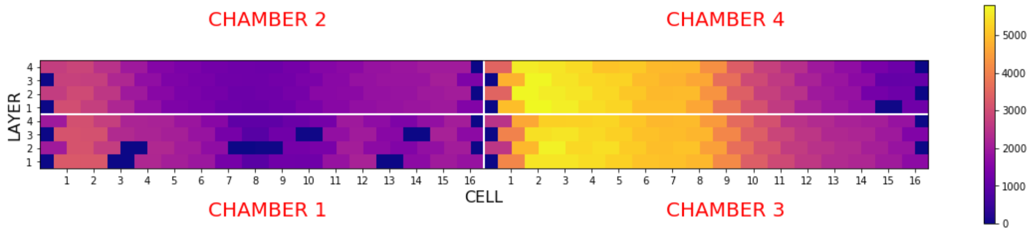
Plot of the Dataframe

Graphical visalization of all the trajectory of the particels.

In [76]:
```
# Visualize all the hit from orbits marked by trigger 139
print('Number of total hits detected:', data[data['TDC_CHANNEL']<129].shape[0])
print('Number of hits belonging to orbit marked by trigger 139:', events.shape[0]/data[data['TDC_CHANNEL']<129].shape[0]*100,"%")
print('Number of events detected using the trigger:', len(event_number))

show_mat(events)
```

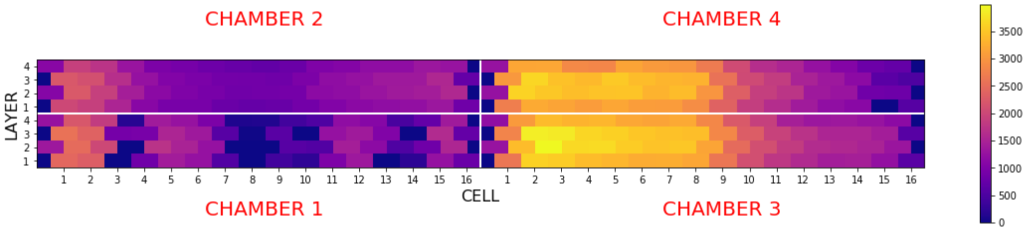
```
Number of total hits detected: 1204224
Number of hits belonging to orbit marked by trigger 139: 58.63203191432823 %
Number of events detected using the trigger: 93733
```



In [77]:
```
# Visualize only hit with a legit calculated position
print('Number of hits which show a legit calculated position:', events[events['POSITION']!=0].shape[0]/data[data['TDC_CHANNEL']<129].shape[0]*100,"%")

show_mat(events[events['POSITION']!=0])
```

```
Number of hits which show a legit calculated position: 37.263
25002657313 %
```



Plot of the Hits per Event

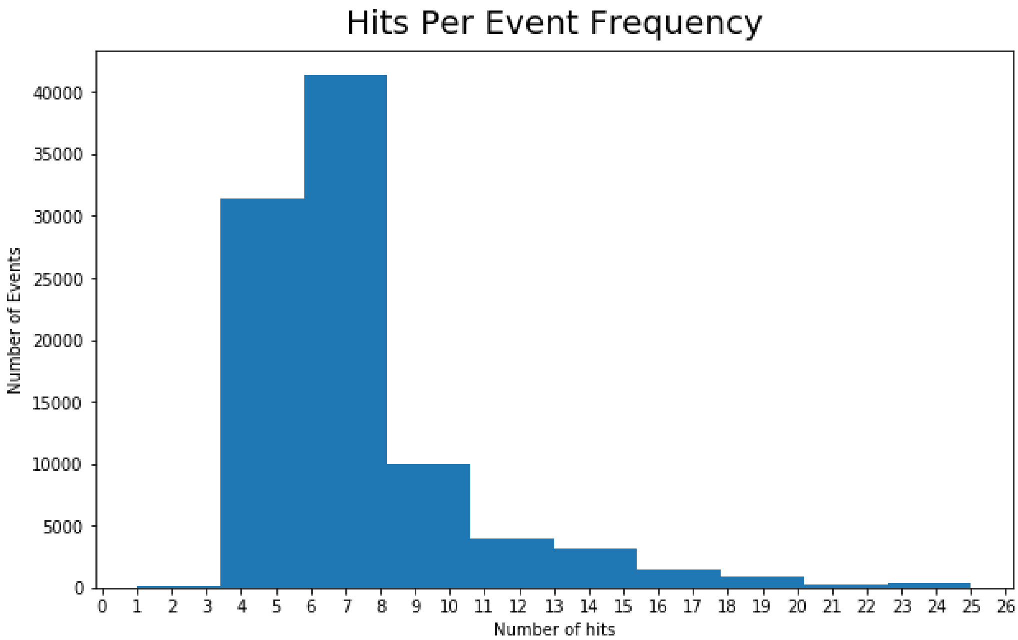
Now we plot the Histogram of the number of hits per event. We willconsider all the hits belonging to the same triggered orbit.

In [78]:
```
# Group the events by event number
grouped_ev_num = events.groupby('EVENT_NUMBER')

# Create a new list containing the number of hits per event
hits_per_event = []

# For every event count the number of hits (i.e. return the l
enght of the array containing the hits of a certain event)
for i in grouped_ev_num.groups.keys():
    hits_per_event.append(len(np.array(grouped_ev_num.groups[
i])))
hits_per_event = np.array(hits_per_event)
```

In [79]:
```
# Plot the distribution of Hits/Event
fig = plt.figure(figsize=(10,6))
ax = fig.add_subplot(1, 1, 1)
ax.xaxis.set_major_locator(MultipleLocator(1.000))
ax.set_title("Hits Per Event Frequency", fontsize=20, vertica
lalignment='bottom')
ax.set_xlabel('Number of hits')
ax.set_ylabel('Number of Events')
ax.hist(hits_per_event[hits_per_event<=25], bins=10);
```



PART 2

Now we have to repeat the previous computation without the help of the external trigger 139, so we restart from the dataframe 'data'. To find the events we can use the orbits, the previous pattern and the mean trigger equation.

In [80]:
```
# Remove unreal hit rows and sort the dataframe
data = data[data['TDC_CHANNEL']<129]
total_hits = data.shape[0]
data = data.sort_values(by = ['ORBIT_CNT','CHAMBER','LAYER'])

# Make three shifted copy of the LAYER, TIME_NS, CELL and of
 CHAMBER
data['LAYER_1'] = data['LAYER'].shift(-1)
data['LAYER_2'] = data['LAYER'].shift(-2)
data['TIME_NS_1'] = data['TIME_NS'].shift(-1)
data['TIME_NS_2'] = data['TIME_NS'].shift(-2)
data['CELL_1'] = data['CELL'].shift(-1)
data['CELL_2'] = data['CELL'].shift(-2)
data['CHAMBER_1'] = data['CHAMBER'].shift(-1)
data['CHAMBER_2'] = data['CHAMBER'].shift(-2)

# There is a constrains on Chambers, which must be always the
same
mask_pattern_chamber = (data['CHAMBER'] == data['CHAMBER_1'])
& (data['CHAMBER'] == data['CHAMBER_2'])

# There is also a constrains on cell, which must be applied f
or every pattern
# The sucessive cell hit number has to differ at most by one
 from the previous cell number (1->2 ok, 6->5 ok, 1->3 no)
mask_pattern_cell_123 = ((data['CELL_1']-data['CELL'])>=0 & (
abs(data['CELL_1']-data['CELL'])<=1)) & (((data['CELL_2']-dat
a['CELL_1'])<=0) & (abs(data['CELL_2']-data['CELL_1'])<=1))
mask_pattern_cell_234 = ((data['CELL_1']-data['CELL'])<=0 & (
abs(data['CELL_1']-data['CELL'])<=1)) & (((data['CELL_2']-dat
a['CELL_1'])>=0) & (abs(data['CELL_2']-data['CELL_1'])<=1))

# Search pattern to get the real t0
mask_pattern_123 = (data['LAYER']==1) & (data['LAYER_1']==2)
& (data['LAYER_2']==3)
mask_pattern_234 = (data['LAYER']==2) & (data['LAYER_1']==3)
& (data['LAYER_2']==4)

# Compute final mask
mask_pattern = ((mask_pattern_123 & mask_pattern_cell_123) |
(mask_pattern_234 & mask_pattern_cell_234)) & mask_pattern_ch
amber


# Apply the Talete's Theorem for t0 to the patterns
data.loc[mask_pattern, 't0'] = (data['TIME_NS'] + data['TIME_
NS_2'] + 2*data['TIME_NS_1'] - 2*Tmax)/4

# Populate values of adiacent cell (according to the choosen
 pattern)
data = data.fillna(0)
mask_pattern_time = data['t0']!=0
data.loc[mask_pattern_time.shift(1).fillna(False), 't0'] = da
ta['t0'].shift(1)
```

```
data.loc[mask_pattern_time.shift(2).fillna(False), 't0'] = da
ta['t0'].shift(2)
data = data.fillna(0)

# Compute the position
data.loc[data['t0']!=0,'POSITION'] = (data['TIME_NS'] - data[
't0'])*Vd
data = data.fillna(0)

# Now we have to filter false event, which can be caused by n
oise
# So we drop the rows with an unexpected result: such as Posi
tion bigger than 21 mm or smaller than 0 mm
data.loc[(data['POSITION']<0) | (data['POSITION']>=21), ['POS
ITION','t0']] = 0

data = data[data['POSITION']!=0]

data.head(5)
```

Out[80]:

	HEAD	FPGA	TDC_CHANNEL	ORBIT_CNT	BX_COUNTER	TDC_MEAS	T
2	1	0	124	1933476838	2037	18	5
0	1	0	126	1933476838	2034	26	5
1	1	0	123	1933476838	2037	9	5
7	1	1	56	1933476838	3238	8	8
3	1	1	54	1933476838	3224	27	8

In [81]:

```
# Recreate the final events DataFrame
# Map obit values to a range of int
grouped_orbit = data.groupby('ORBIT_CNT')
# Search all orbits
orbits = list(grouped_orbit.groups.keys())
# Create increasing number list for the events
event_number = np.arange(1, len(orbits)+1)
# Create the map
event_map = dict(zip(orbits, event_number))
# Map values
orbit_to_map = data['ORBIT_CNT']
orbit_mapped = orbit_to_map.map(event_map)
data['EVENT_NUMBER'] = orbit_mapped

# Final DataFrame
events_final = data[['EVENT_NUMBER','ORBIT_CNT','CHAMBER','LA
YER','CELL','POSITION']]
events_final.set_index(['EVENT_NUMBER','ORBIT_CNT','CHAMBER',
'LAYER'], inplace=True)
events_final.sort_index(inplace=True)
events_final.head(10)
```

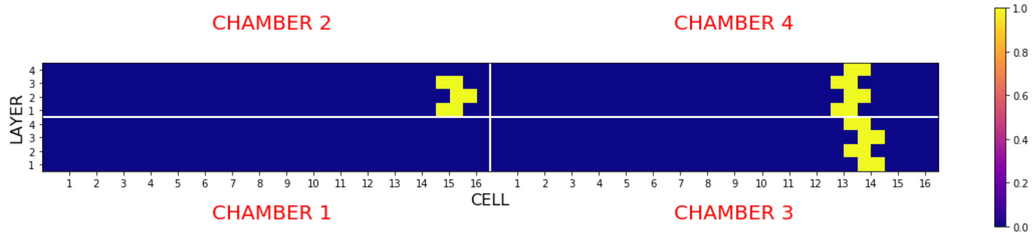
Out[81]:

				CELL	POSITION
EVENT_NUMBER	**ORBIT_CNT**	**CHAMBER**	**LAYER**		
		2	**1**	15	12.440705
			2	16	8.761218
			3	15	12.036859

1	**1933476838**	**3**	**1**	14	19.586538
			2	14	1.592949
			3	14	19.227564
			4	14	1.233974
		4	**1**	13	8.222756
			2	14	12.485577
			3	13	8.806090

Show the cell alingment inside an event

In [82]:
```
show_event(events, 1)
```

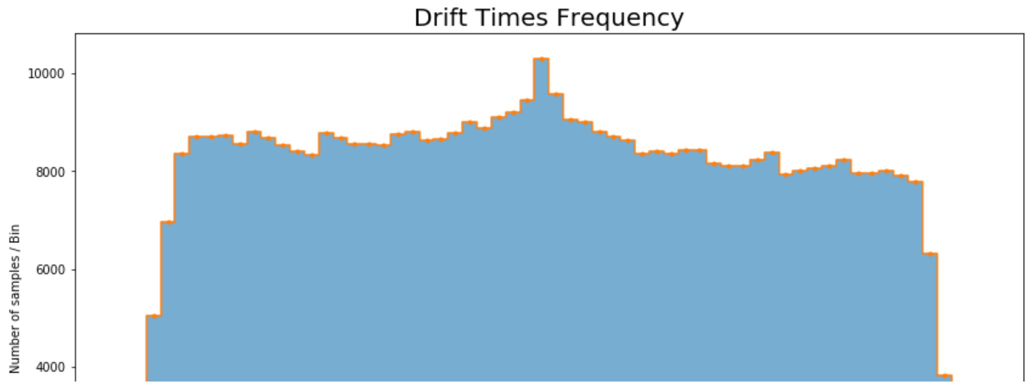


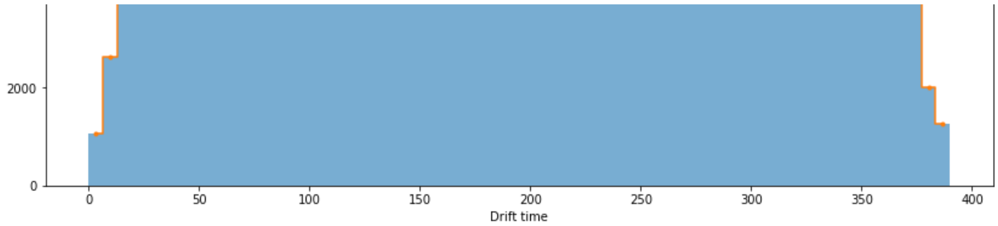
Plot the distribution of Drift Times

In [27]:
```
# Select hits where position is different from 0
events_drift = data
# Get all drift times
drift_times = events_drift['TIME_NS']-events_drift['t0']

# Drift Times Frequency
figure = plt.figure(figsize=(14,8))
ax = figure.add_subplot(111)
number_bins = 60
y, edges, bins = ax.hist(drift_times, bins = number_bins, lab
el='Drift Times Frequency', alpha=0.6)
ax.set_ylabel("Number of samples / Bin")
ax.set_xlabel("Drift time")
ax.set_title("Drift Times Frequency", fontsize=20)
mean_point = (edges[1:] + edges[:-1])/2
ax.errorbar(mean_point, y, yerr = y**-0.5, marker = '.', draw
style = 'steps-mid', label = 'error')

plt.show()
```



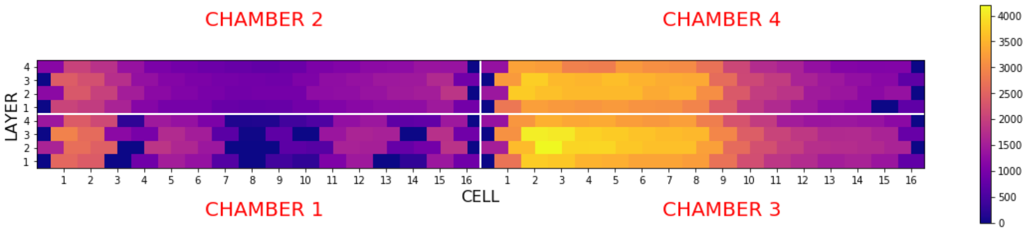


Plot of the Dataframe

In [28]:
```
print('Number of hit belongig to an event:', data.shape[0]/to
tal_hits*100,"%")
print('Number of events detected using the trigger:', len(eve
nt_number))

show_mat(data)
```

```
Number of hit belongig to an event: 39.41201969068878 %
Number of events detected using the trigger: 93514
```



Plot of the Hits per Event

In [37]:
```
# Group the events by event number
grouped_ev_num = data.groupby('EVENT_NUMBER')

# Create a new list containing the number of hits per event
hits_per_event = []

# For every event count the number of hits (i.e. return the l
enght of the array containing the hits of a certain event)
for i in grouped_ev_num.groups.keys():
    hits_per_event.append(len(np.array(grouped_ev_num.groups[
```