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Status report

2025/04/09
ZDC ML
WAI YUEN CHAN

Highlight of this month

- Confirmed the effect of carbon fiber in G4 sim output
- Transferring the G4 sim output into common ML readable format
- Plot the ML input as histogram to show the energy distribution in ECAL

ZDC Sim: Material test

- Checking the effect of beam position and spread in the ZDC Sim
- Comparing samples with the following conditions:

Material	θ, ϕ	Shift [mm]
Carbon fiber	0,0	0
Carbon fiber	0,0	15
LYSO	0,0	0
Carbon fiber	20,180	0
Carbon fiber	20,180	15
LYSO	20,180	0

- 10k events within 0.01 GeV – 1 GeV positron beam are generated per sample.
- Energy dump in ECAL and HCAL are separately plotted.

Results (ECal)

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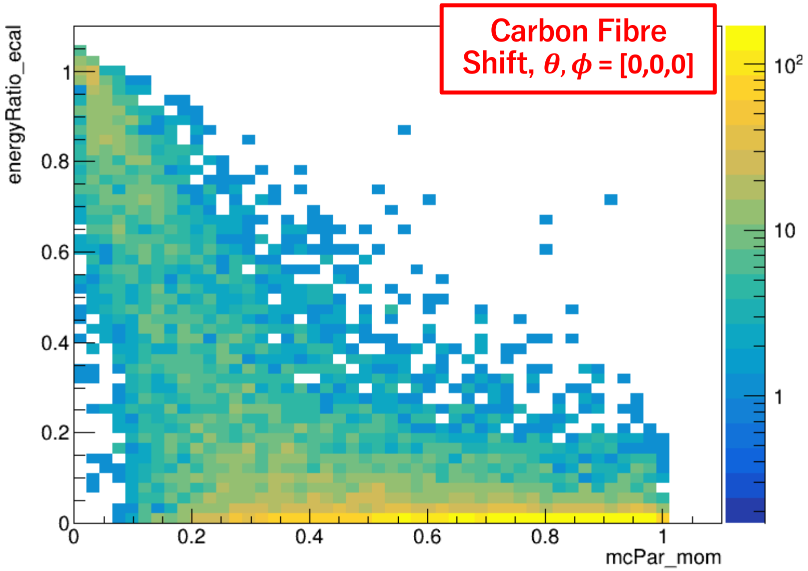

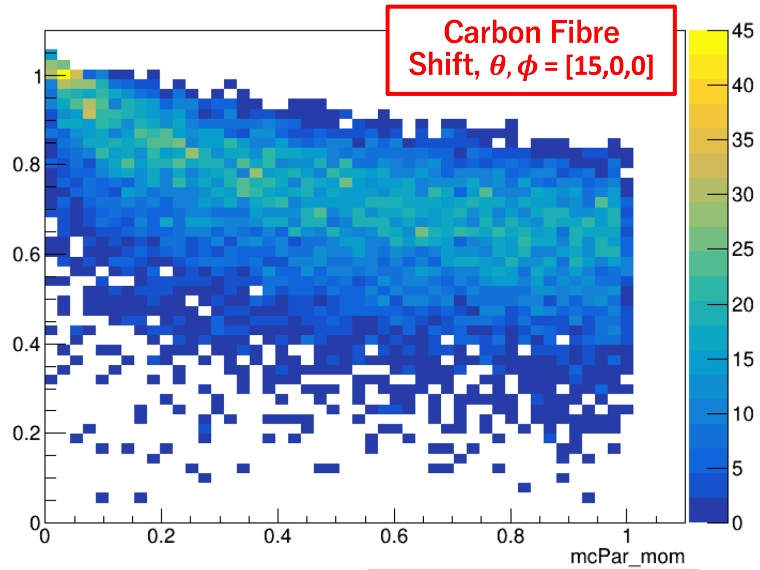

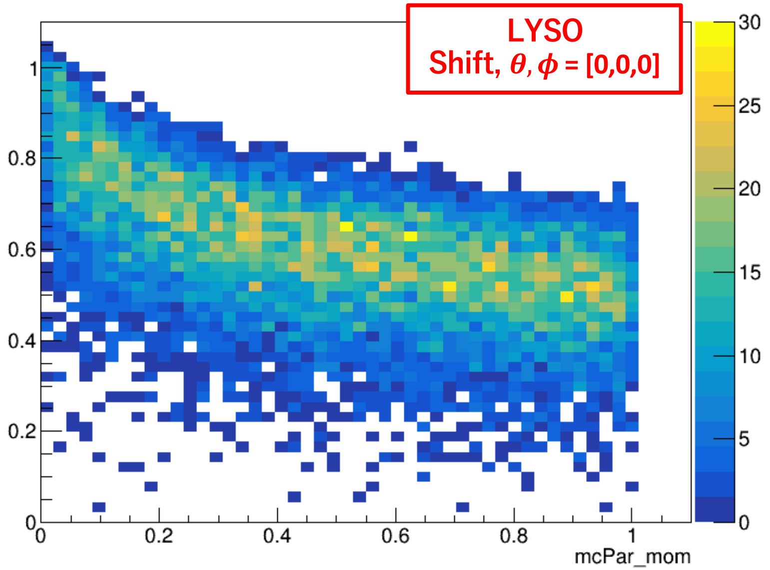

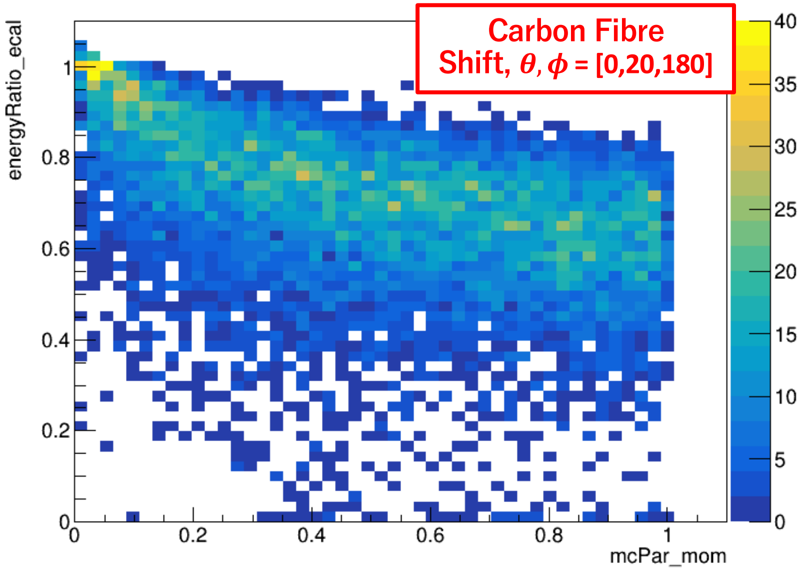

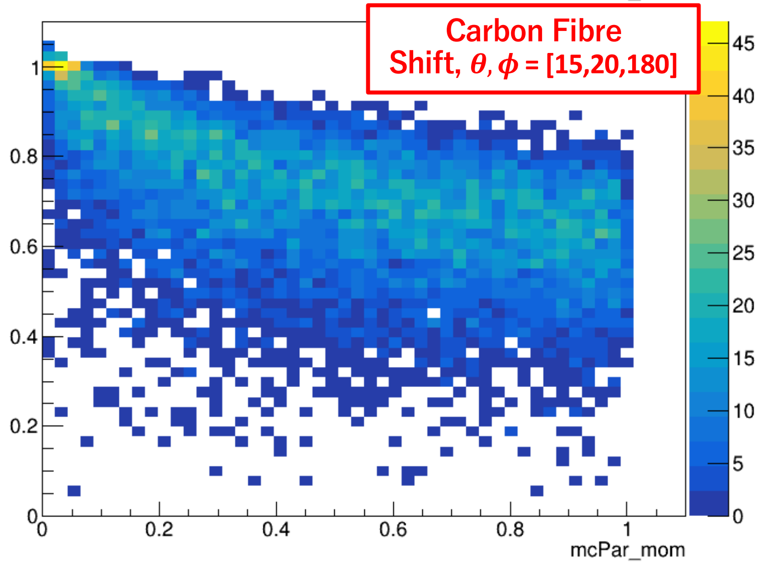

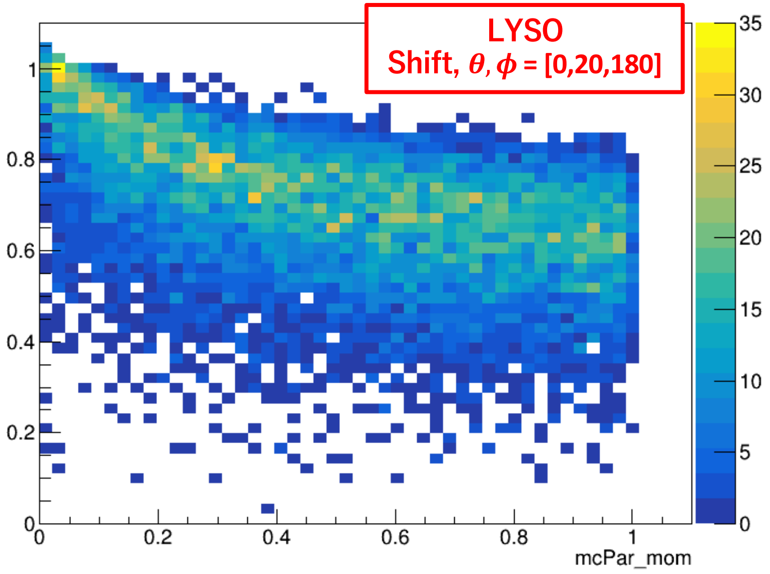

Results (HCal)

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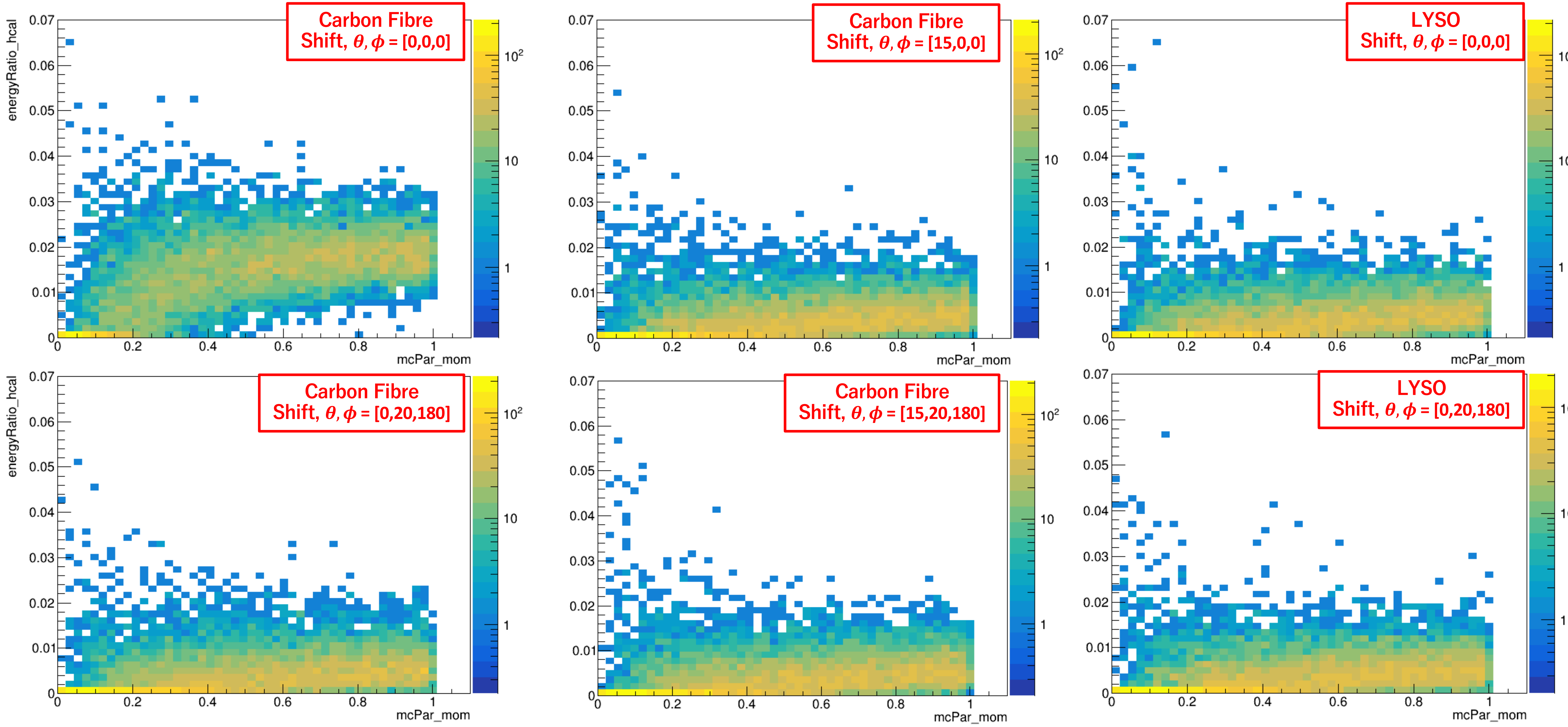

ML Sample preparation

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- Need a larger sample which contain the following info:

Ecal hit related	Position X	Position Y	Position Z	Cell ID	Energy (Sum)
MC particle related	Momentum X	Momentum Y	Momentum Z		

- Fixed vertex (position fixed at [-902.408,-15.000,35488.907])
- $\boldsymbol{\theta}$, $\boldsymbol{\phi}$,shift = [20,180,15]
- Material at the center: Carbon fiber
- 50k events within 0.01 GeV – 20 GeV positron beam are generated.
- First step: modify the input, link up the energy distribution and the Cell ID.

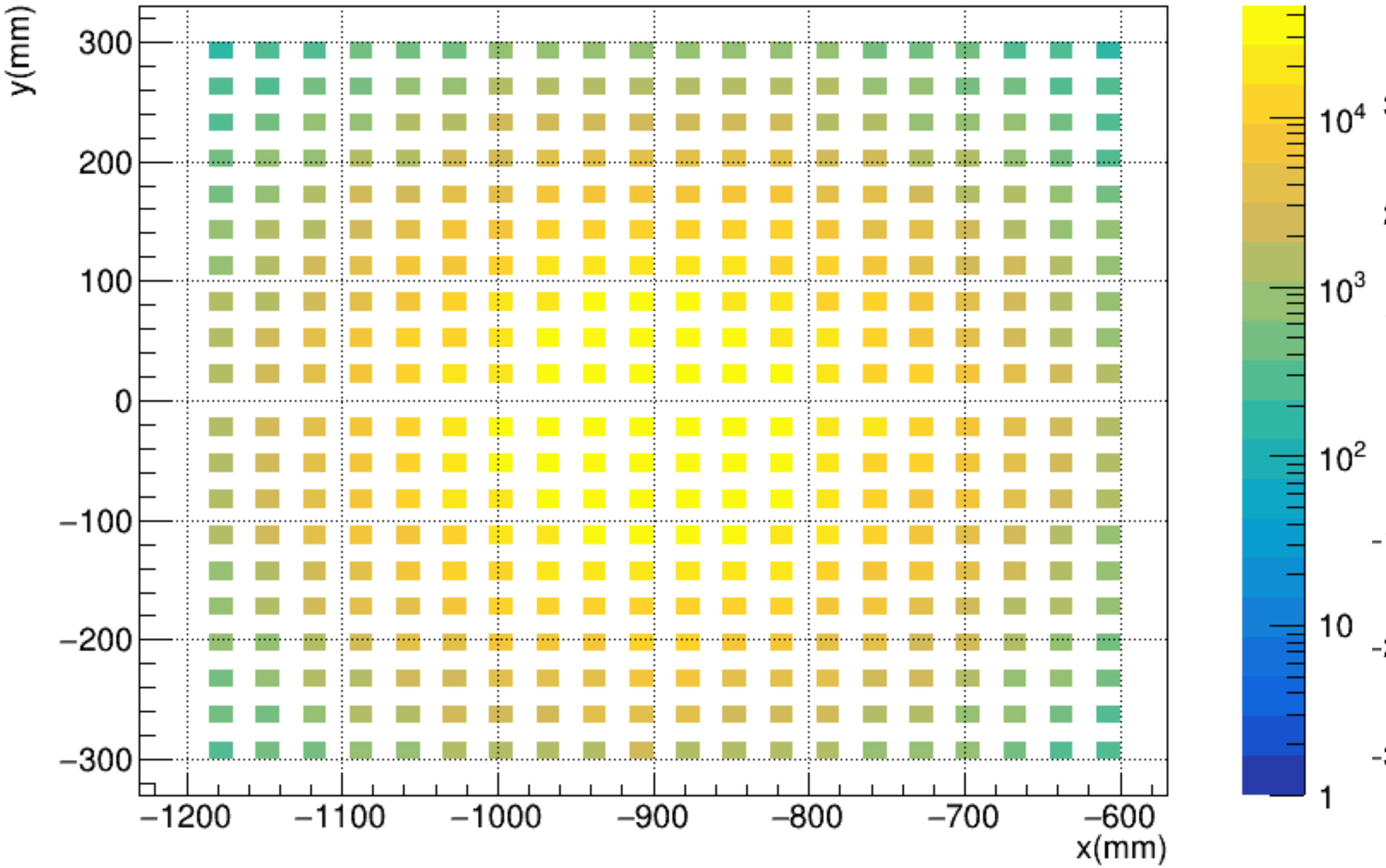
ML input: array

- We make use of the ROOT file structure (looping over entries), we can make a 20x20 2D array to store the energy per cell.
- A print out with energy per cell (amplified by 10000 times for visual purpose) in 1 example event has been shown as a 2D array:

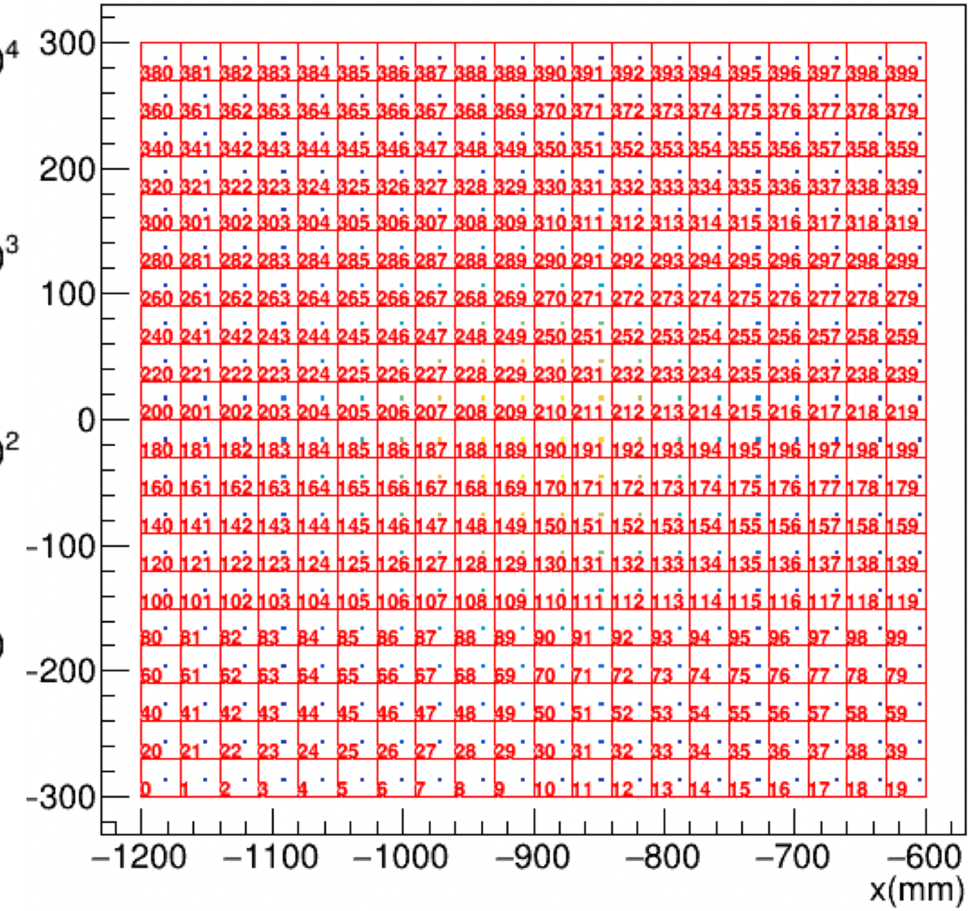
```
[[  0   0   0   0   0   0   0   0   0   0  10   3  12   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   7  37   4   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0]
 [  0   0   0   0   0   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   5   0   0  14   2   0   0   0   0   0]
 [  0   0   0   0   0   0   5   0   0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   8  25   0   0   5   0   0   6   0   6]
 [  0   0   0   0   0   0   0   0   0   0  12  13  33  14   4   3  18   0   0   0]
 [  0   0   0   0   0   0   0   0   5   1  47 163 141  39  36  12   3   0   0   0]
 [  0   0   0   0   0   0   0   2   0  13 196  33 210  81   8   7   3   0   0   0]
 [  0   0   0   0   0   0   0   2   0  13  60 196 217  47  22   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   5   2  12  34  29   6   9   7   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   4   0  89  28  51   6   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   1  11   0   5  50   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   1   0   0   3   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   6   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0]]
```

ECAL Cell ID grid system

#Event count per cell



Corresponding cell ID



2D Histogram

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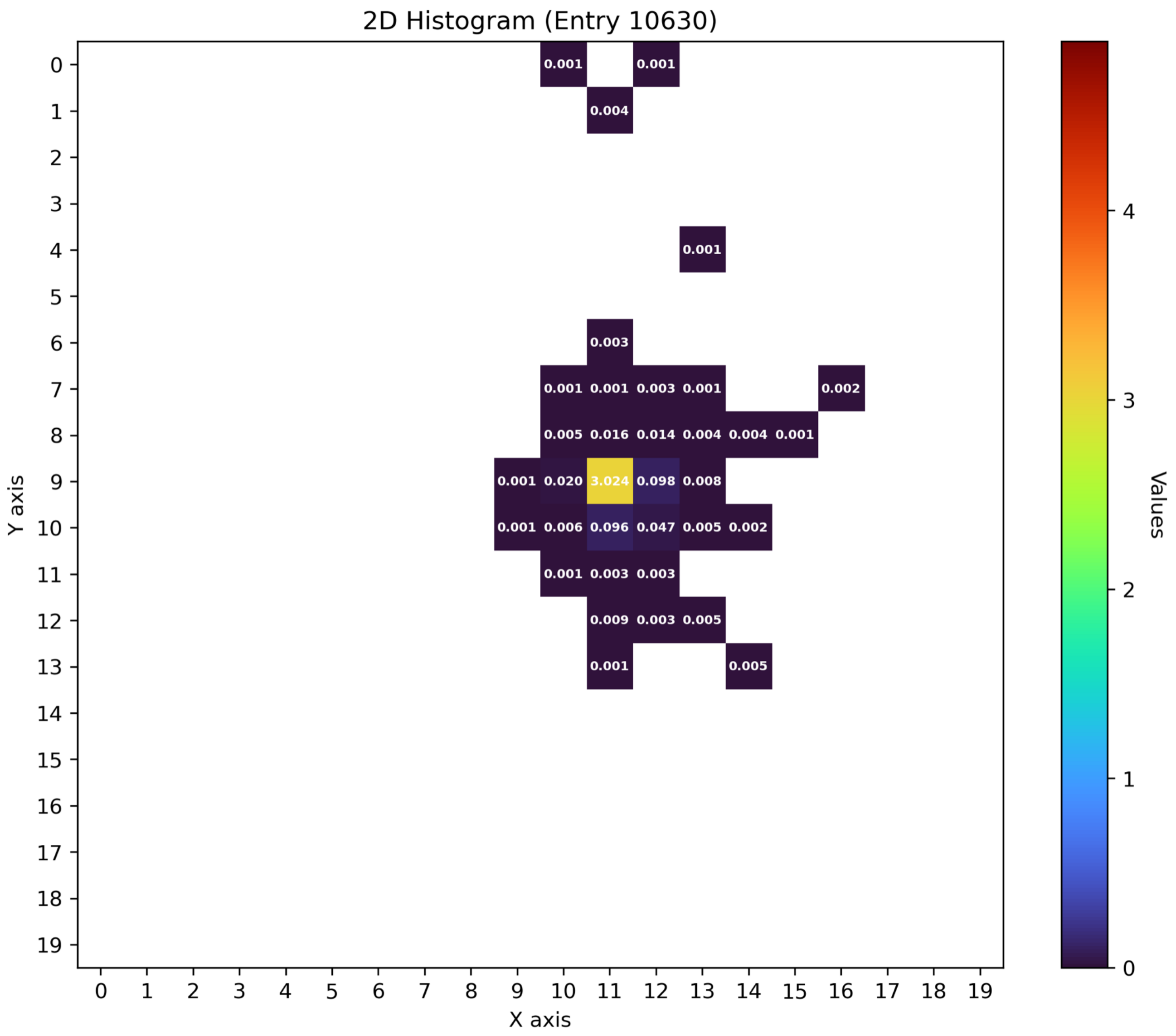
- We can transfer the array into 2D Histogram for each single event.
- Plotting positron events

```
[[   0   0   0   0   0   0   0   0   0   0  10   3  12   0   0   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   7  37   4   0   0   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0]
 [   0   0   0   0   0   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   5   0   0  14   2   0   0   0   0   0]
 [   0   0   0   0   0   0   5   0   0   0   0   0   0   0   0   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   8  25   0   0   5   0   0   6   0   6]
 [   0   0   0   0   0   0   0   0   0   0  12  13  33  14   4   3  18   0   0   0]
 [   0   0   0   0   0   0   0   0   5   1  47 163 141  39  36  12   3   0   0   0]
 [   0   0   0   0   0   0   0   2   0  13 196  33 210  81   8   7   3   0   0   0]
 [   0   0   0   0   0   0   0   2   0  13  60 196 217  47  22   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   5   2  12  34  29   6   9   7   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   4   0  89  28  51   6   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   1  11   0   5  50   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   1   0   0   3   0   0   0   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   0   0   0   0   6   0   0   0   0   0]
 [   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0]]
```

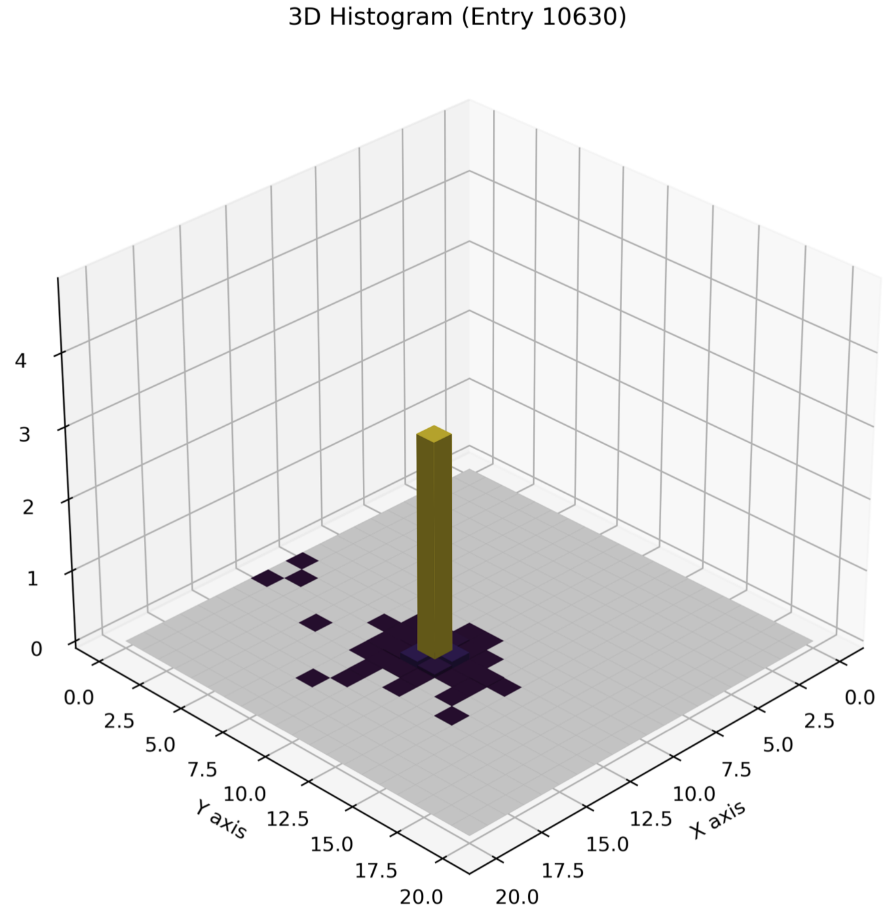


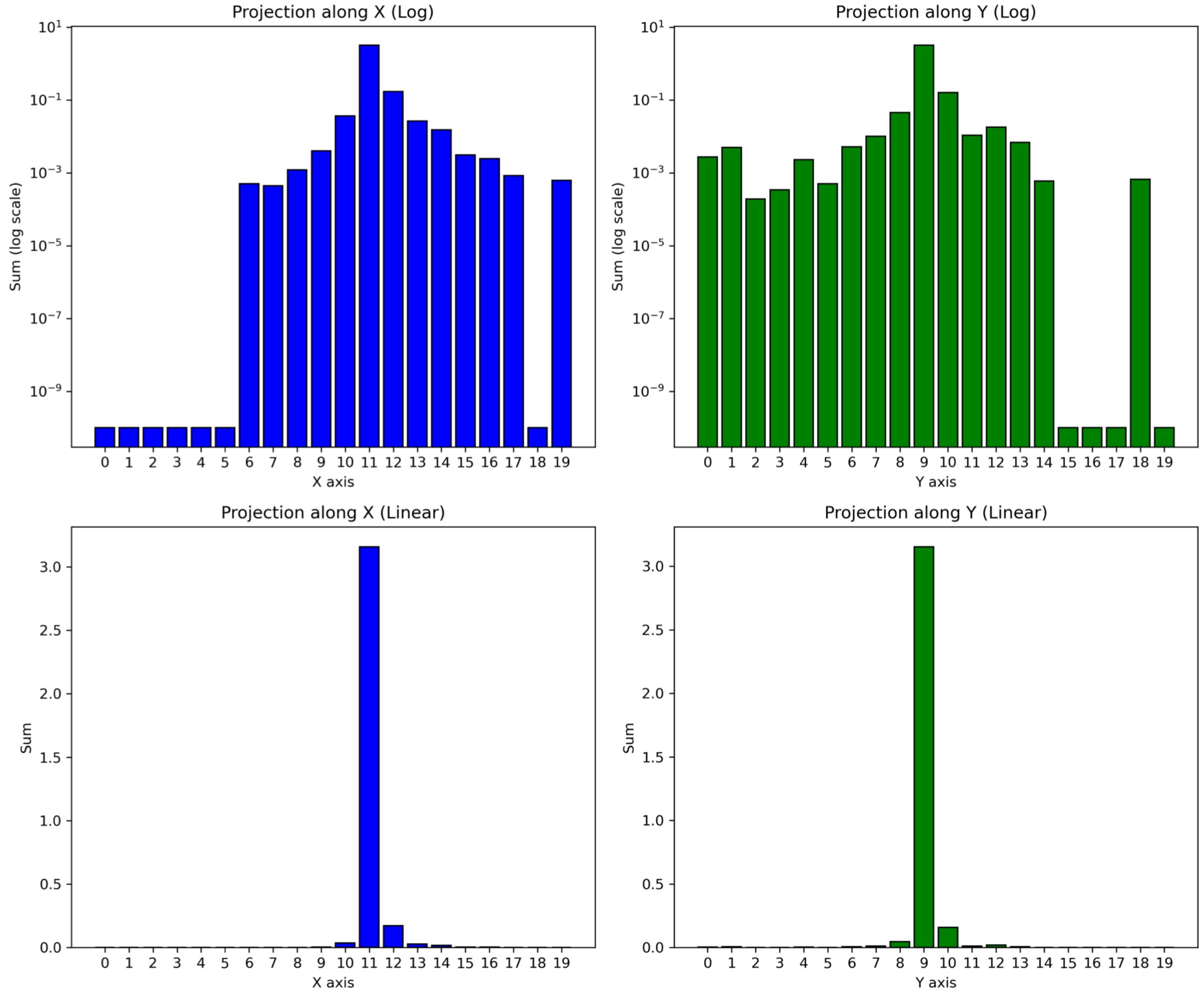
2D Histogram

- For each event we have also record the sum of energy and the number of cell which have energy >= 0.001 GeV

```
Entry 10630 2D array:
[[0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  3.  0.1 0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.1 0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]
 [0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. ]]
Total sum of all elements: 3.4
Number of elements >= 0.001: 35
```

1D, 3D Histogram





- 1D and 3D histogram will help us to identify any decay product hit the ECAL

2D Histogram (Summed)

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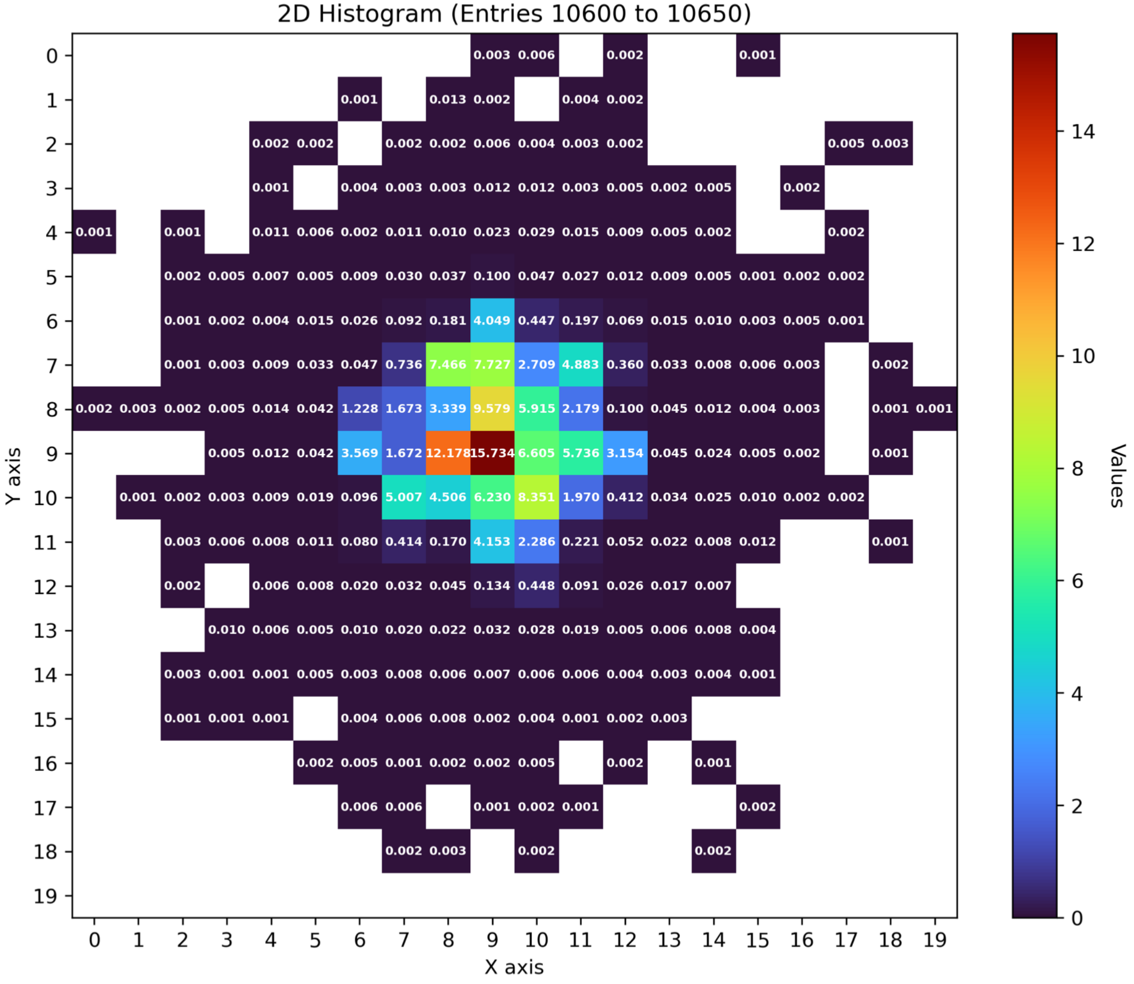
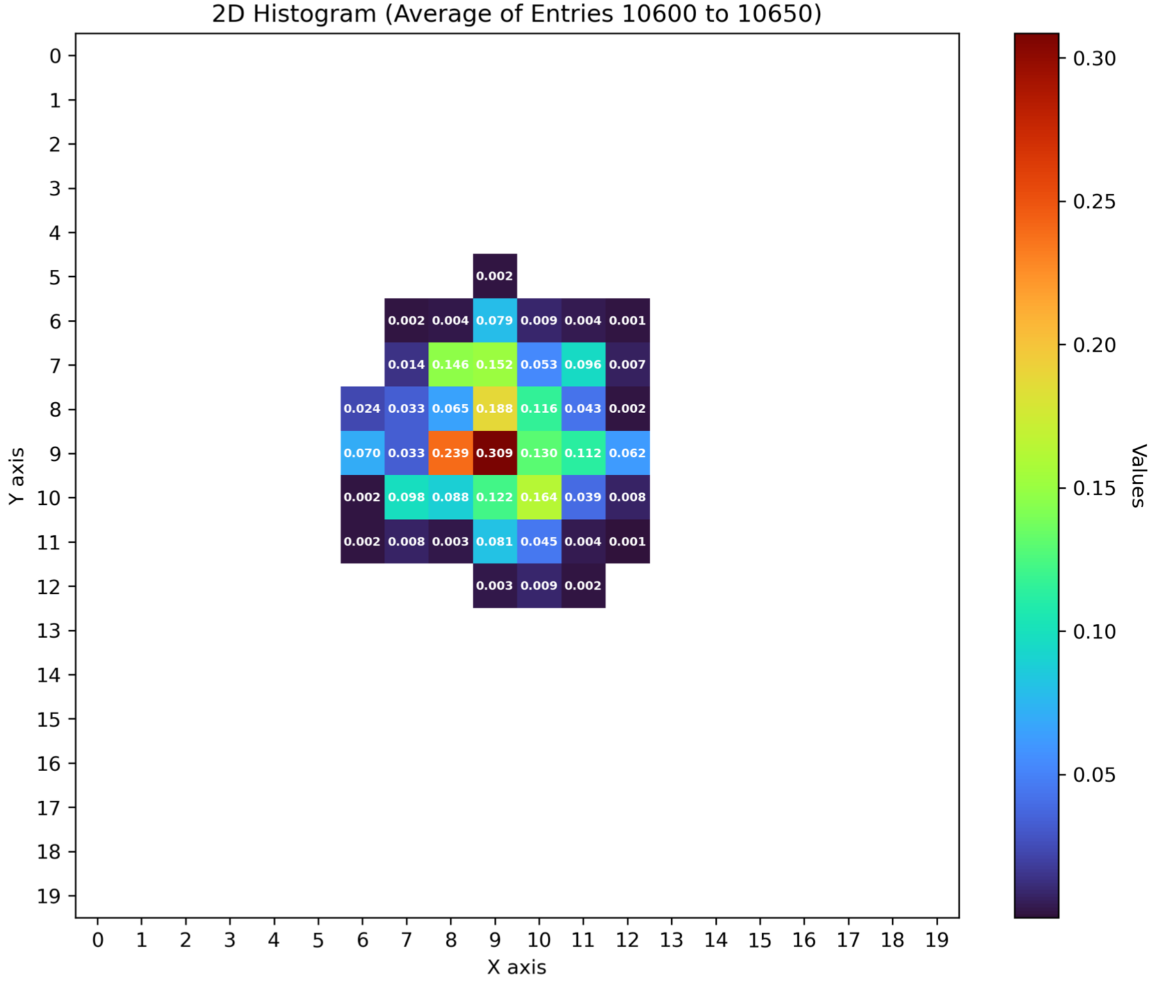
- 2D histogram for multiple events are also available.





2D Histogram with other particles

- In order to start the ML training, we need samples from other particles (classes) as well.
- Here we generated G4 sim samples with the following conditions:
  - Fixed vertex (position fixed at [-902.408,0.000,35488.907])
  - $\boldsymbol{\theta}, \boldsymbol{\phi}$,shift = [20,180,0]
  - Material at the center: Carbon fiber
  - 5k events within 10 GeV – 15 GeV
  - Particles : $e^+, e^-, \gamma, p, n, \Lambda$

2D Histogram with different particles

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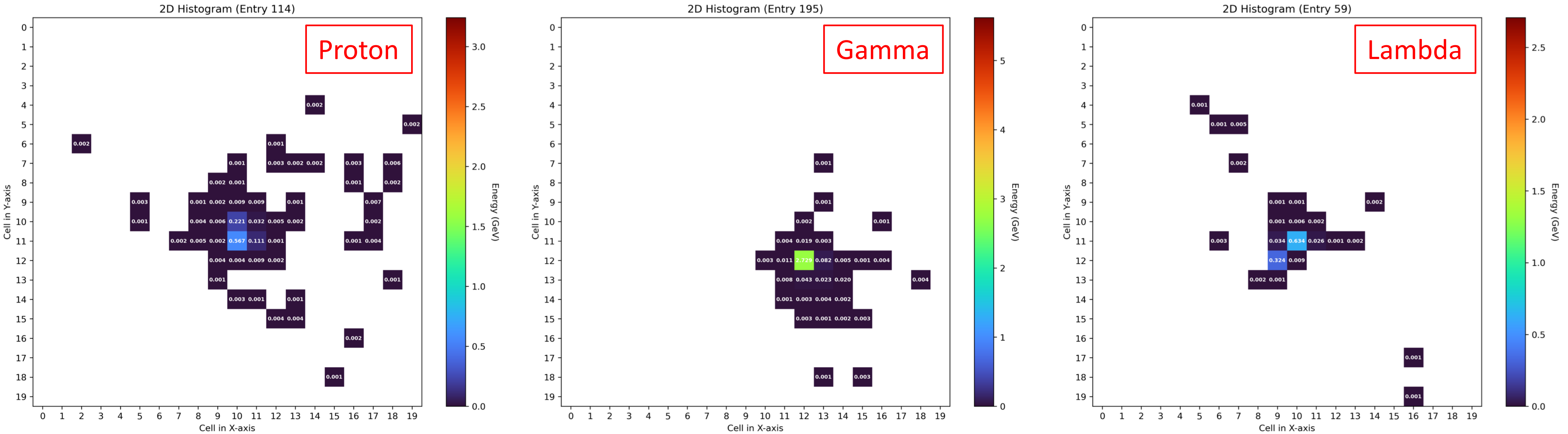

- For hadrons, we might better add HCAL info including HCAL cell ID as the input parameter.
- At the moment maybe we can use e^+, γ, p to arrange our CNN structure.

Pending & Outlook

Pending items

- We need to test the job submission pipeline
- In order to show the energy distribution in a 2D array, we need HCAL Cell ID info as well (As HCAL have a depth in z direction, we might eventually need a 3D array instead)

Outlook

- We don’t need all type of particles at the moment, a binary classification is a good and simple starting point
- We can try to run the actually ML code:
    1. Check does it actually read samples as expected
    2. Adjust the CNN structure (for ECAL only)