Week 6 Review

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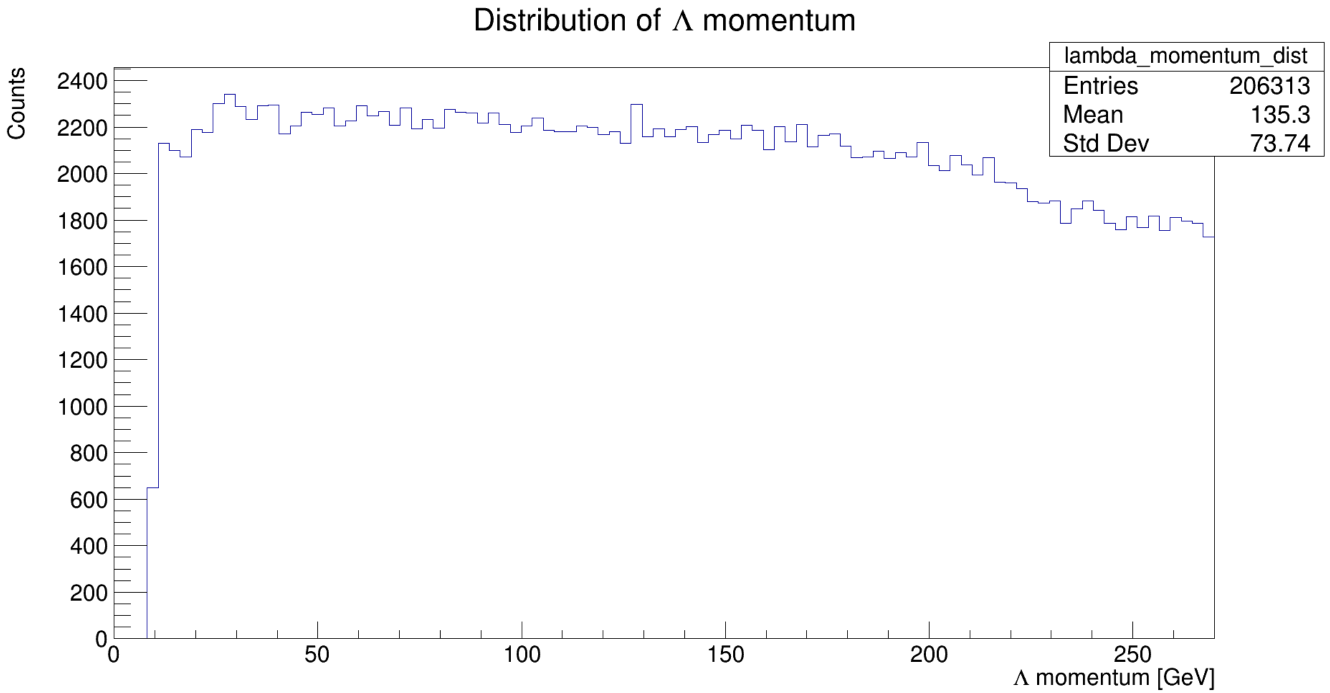
General Notes on ZDC simulation

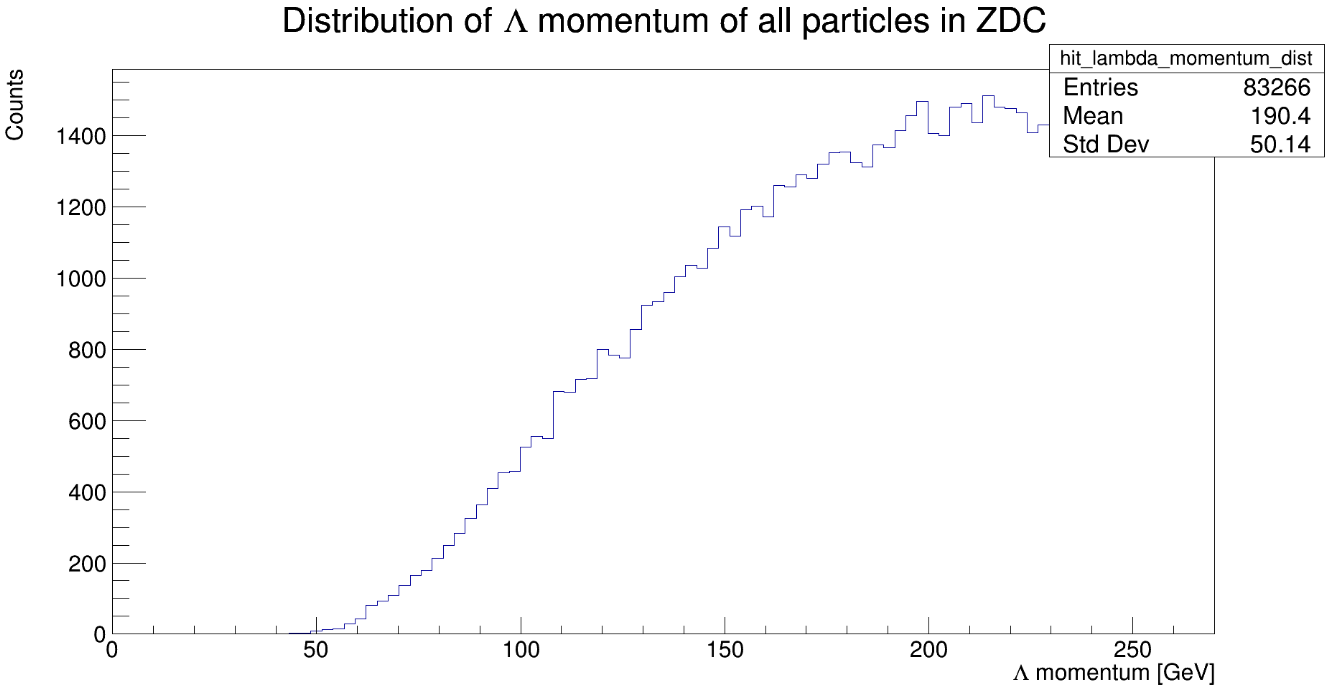
- We spoke to the meson structure group, they don't plan to have simulations ready until September, end of Fall by latest
- Still no message back from software team about event visualization . . .

ZDC Acceptance - Lambda with no angular variance

- Simulated unpolarized lambda events using particle gun
- All spawned at origin, shot directly at ZDC (25mrad) with no angular variation
- 20 GeV to 270 GeV momentum range
- Determine if an event could be reconstructed by checking if all particles land in Ecal
- ~210k total events down to ~84k events when all particles make it to the ZDC
- These plots are the same as the ones I have presented several times, they serve as the baseline to compare to the data with angular variation (after this)

Momentum Distribution





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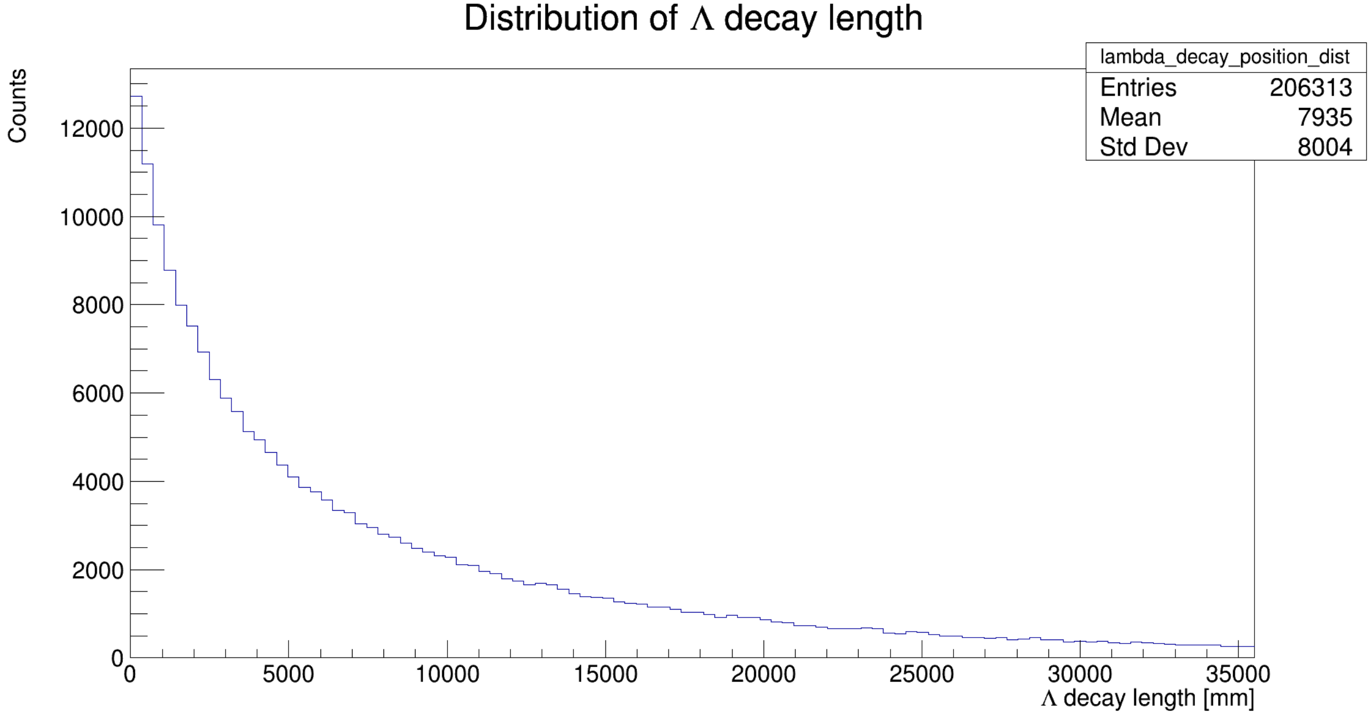
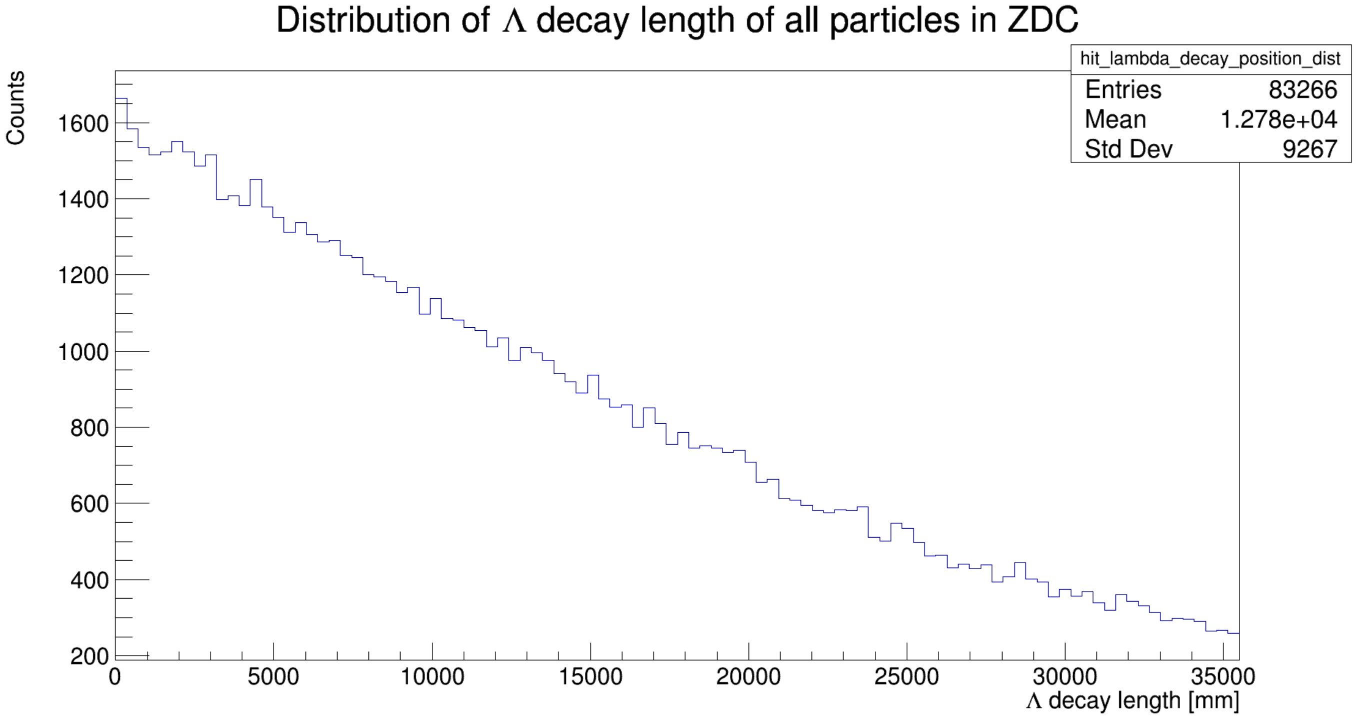
Decay Position Distribution





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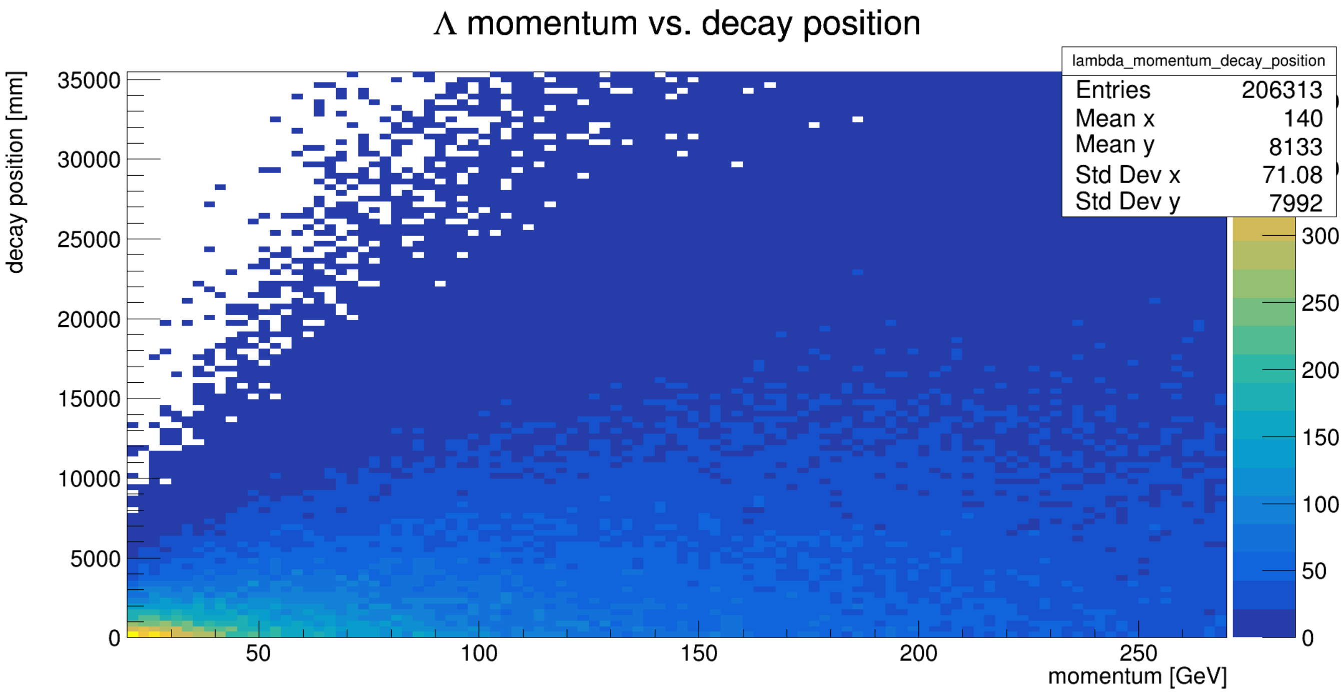
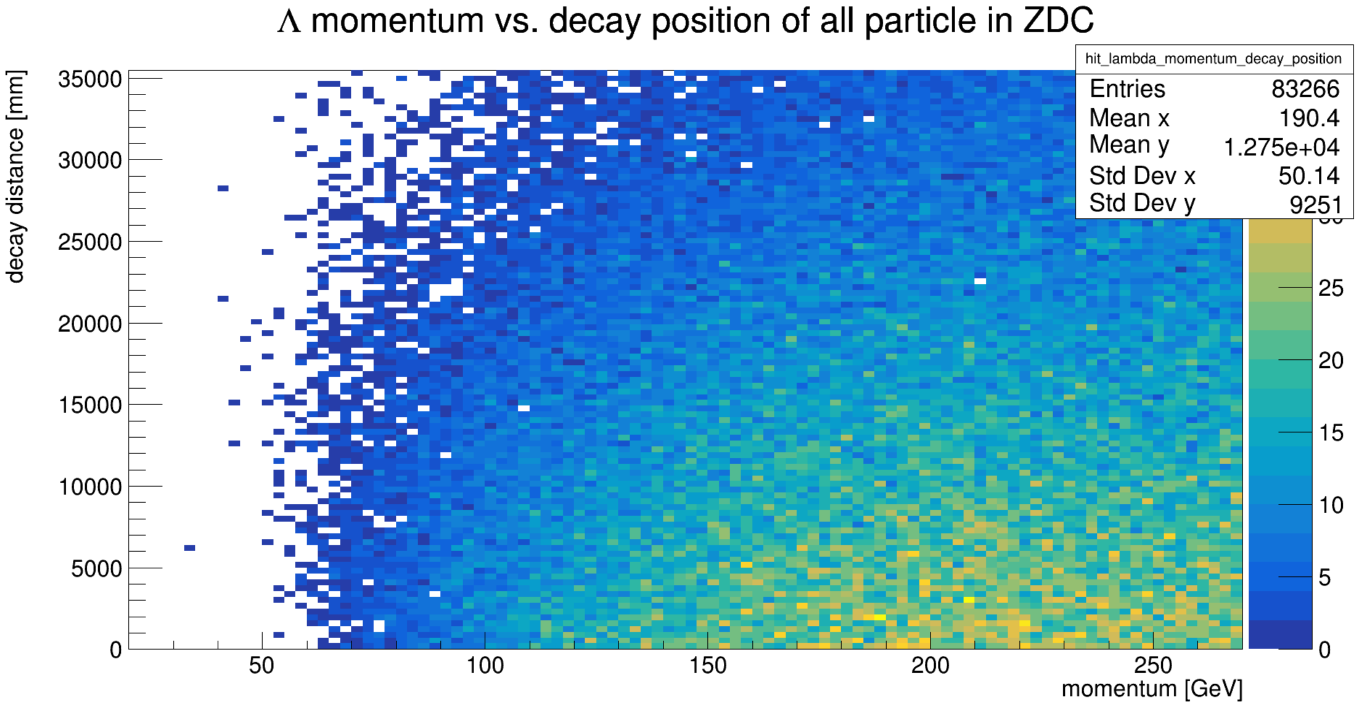
Momentum vs. Decay position





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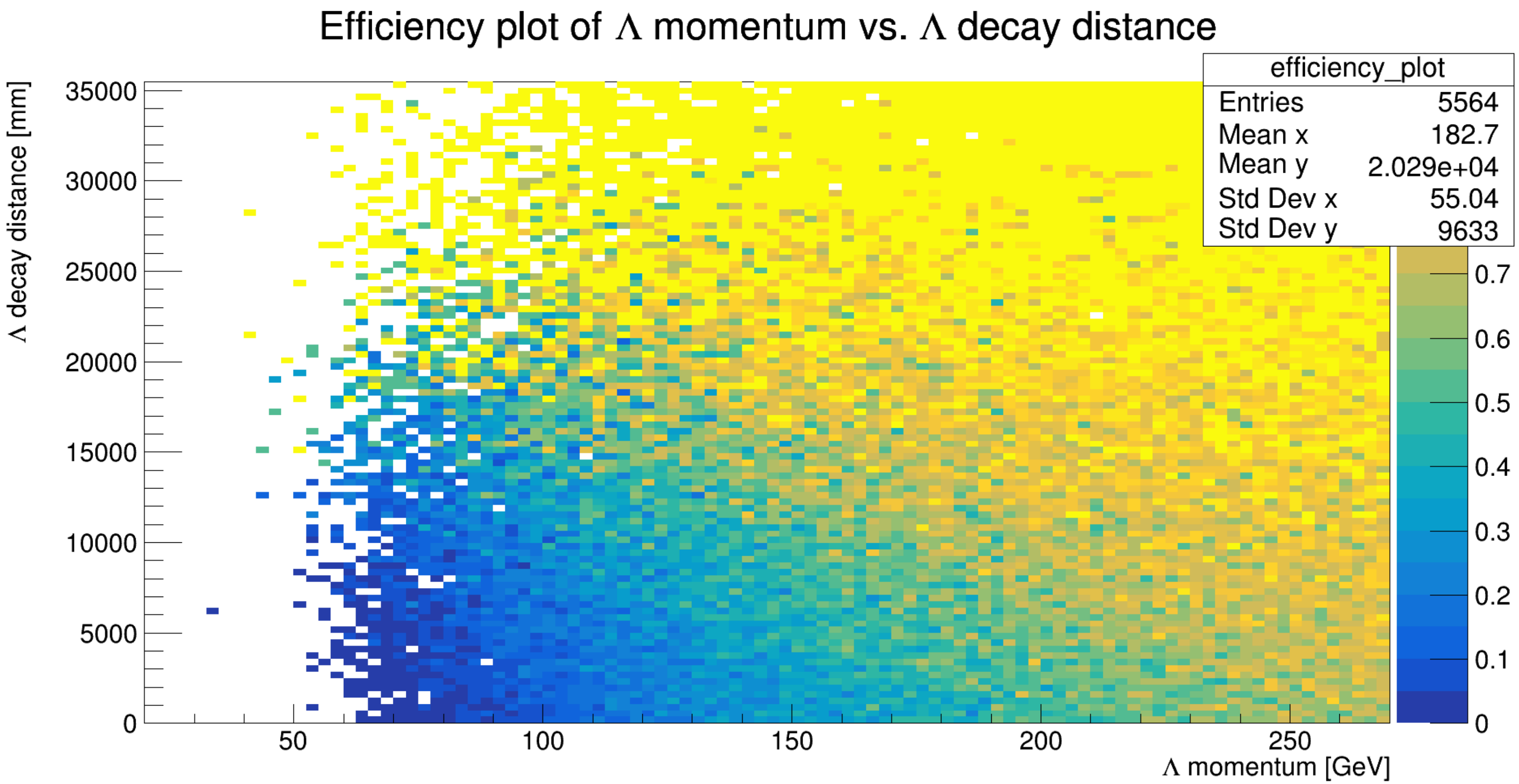
Efficiency Plot

- Made by dividing the previous two plots
- True efficiency will have to be determined by clustering



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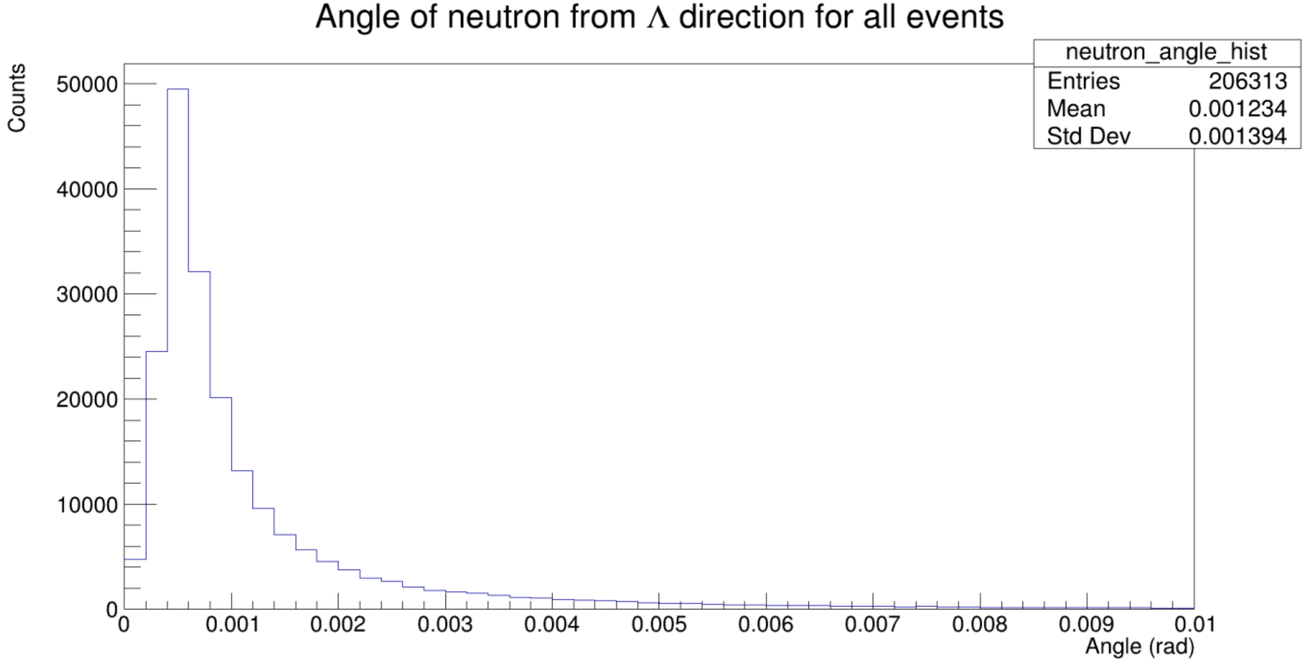
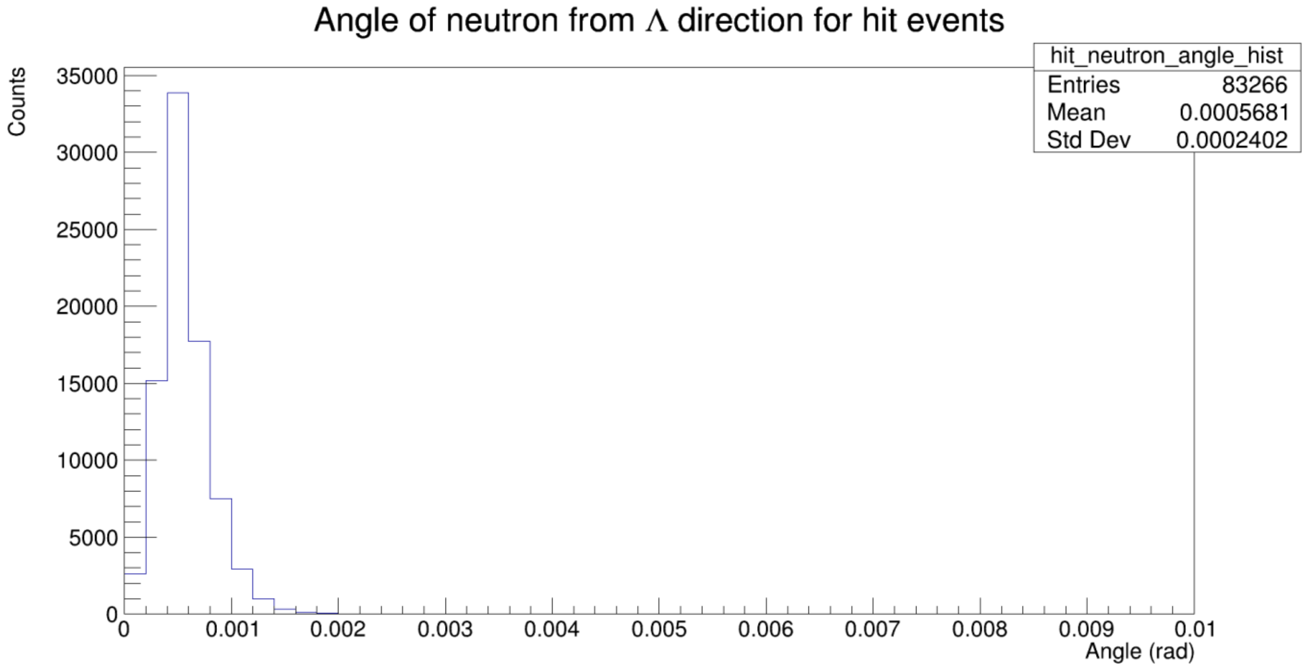
Neutron Angle





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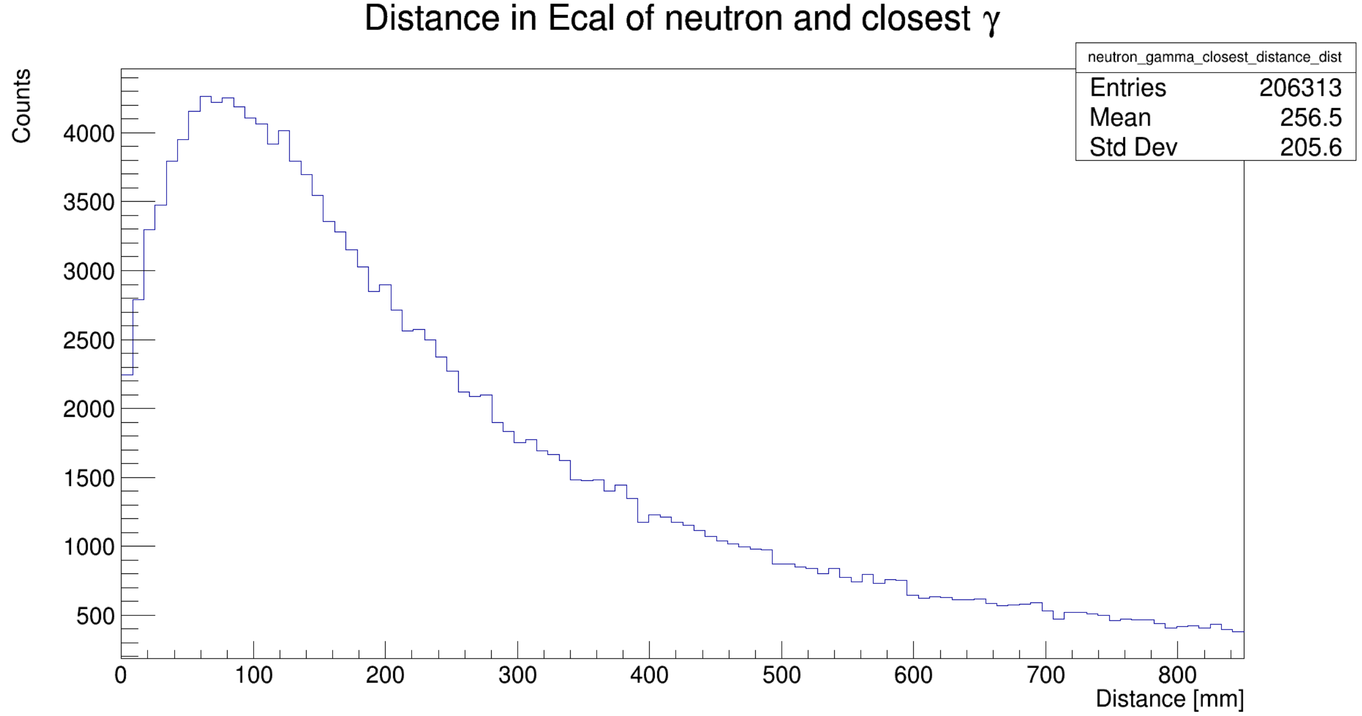
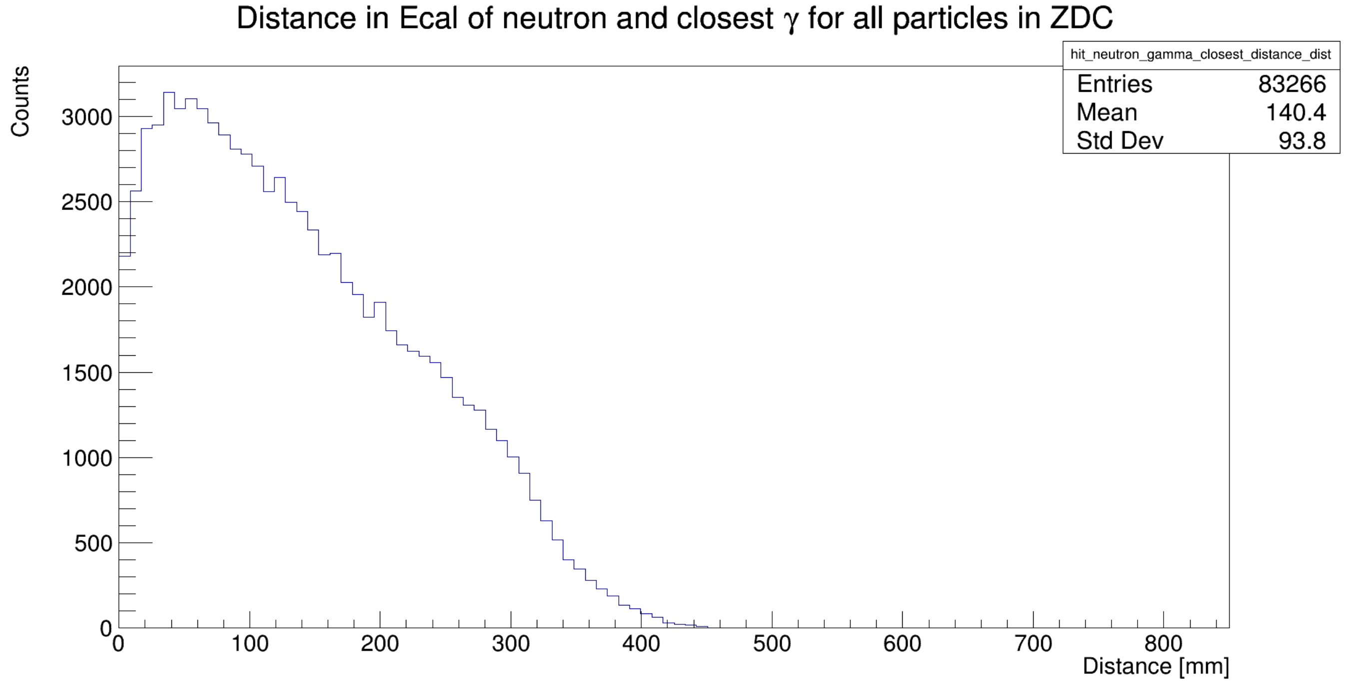
Neutron to closest gamma





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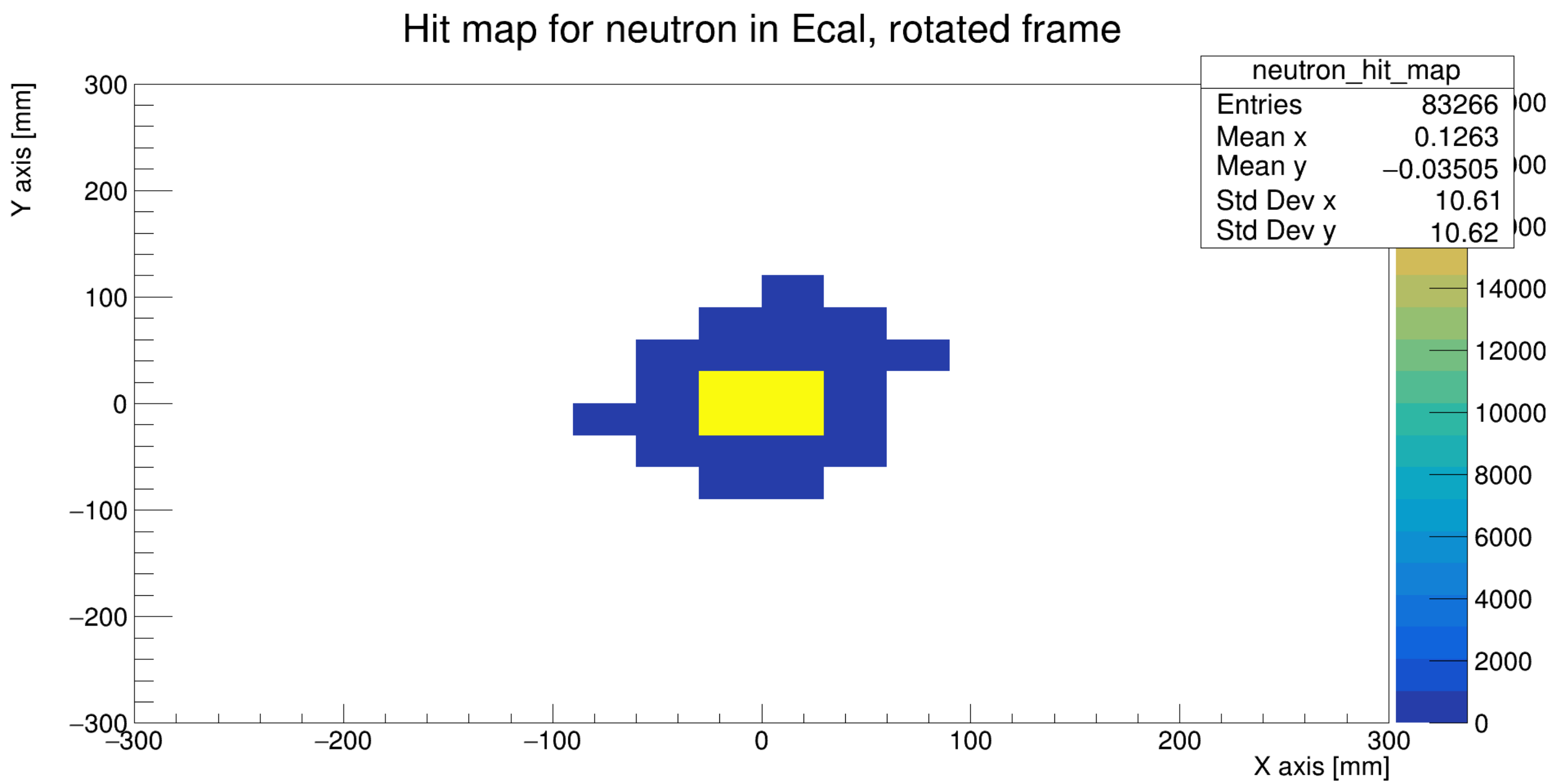
Neutron hit map



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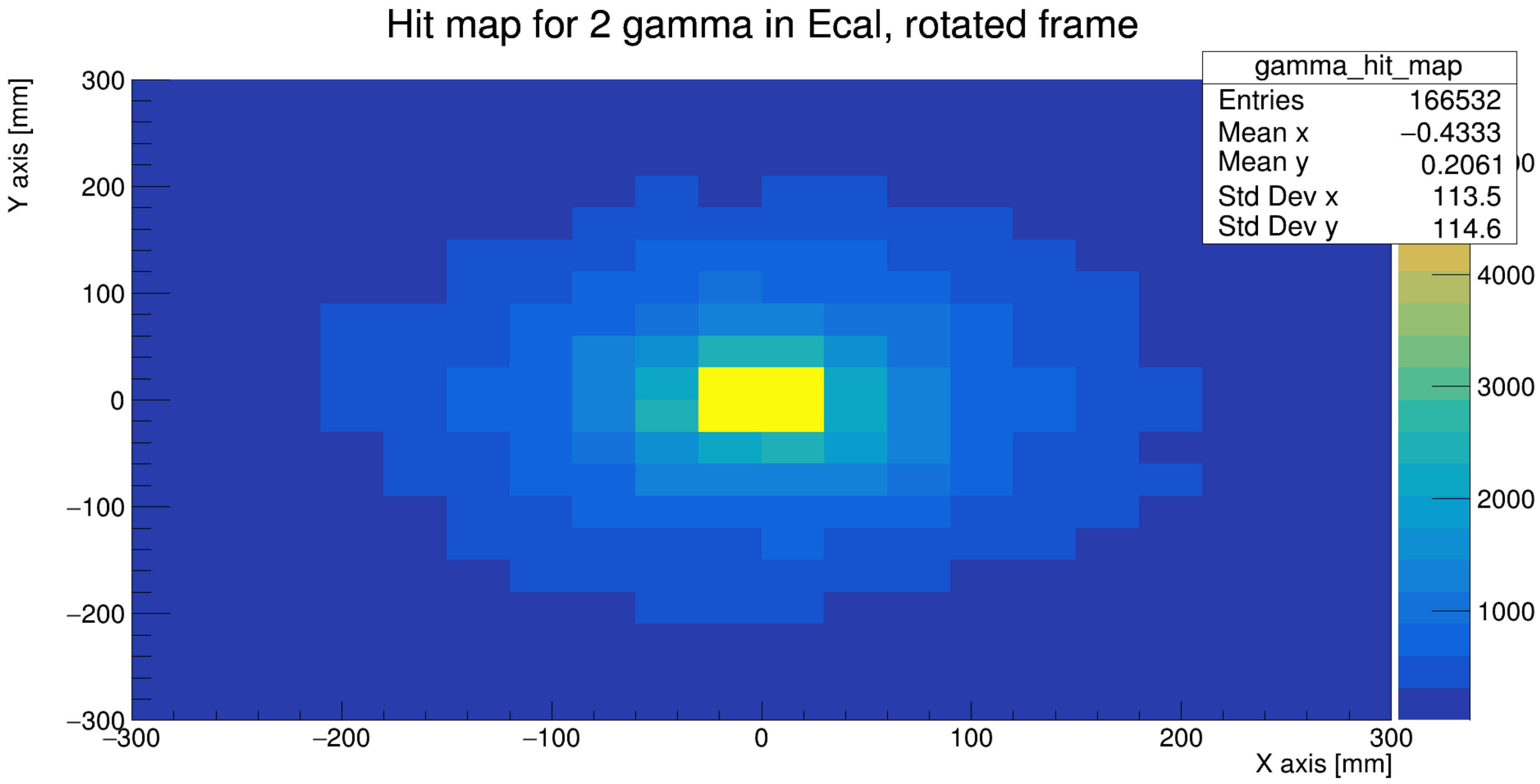
2gamma hit map



ZDC Acceptance - Lambda with angular variance

- Simulated unpolarized lambda events, all spawned at origin, shot with theta and phi angles to cover the whole front face of ZDC
- 20 GeV to 270 GeV momentum range
- Determine if an event could be reconstructed by checking if all particles land in Ecal
- ~140k total events down to ~15k events when all particles make it to the ZDC
- Added kinematic variable: lambda angle from proton beam pipeline
- Bins have been reduced from 100 to 25 for many due to lack of statistics

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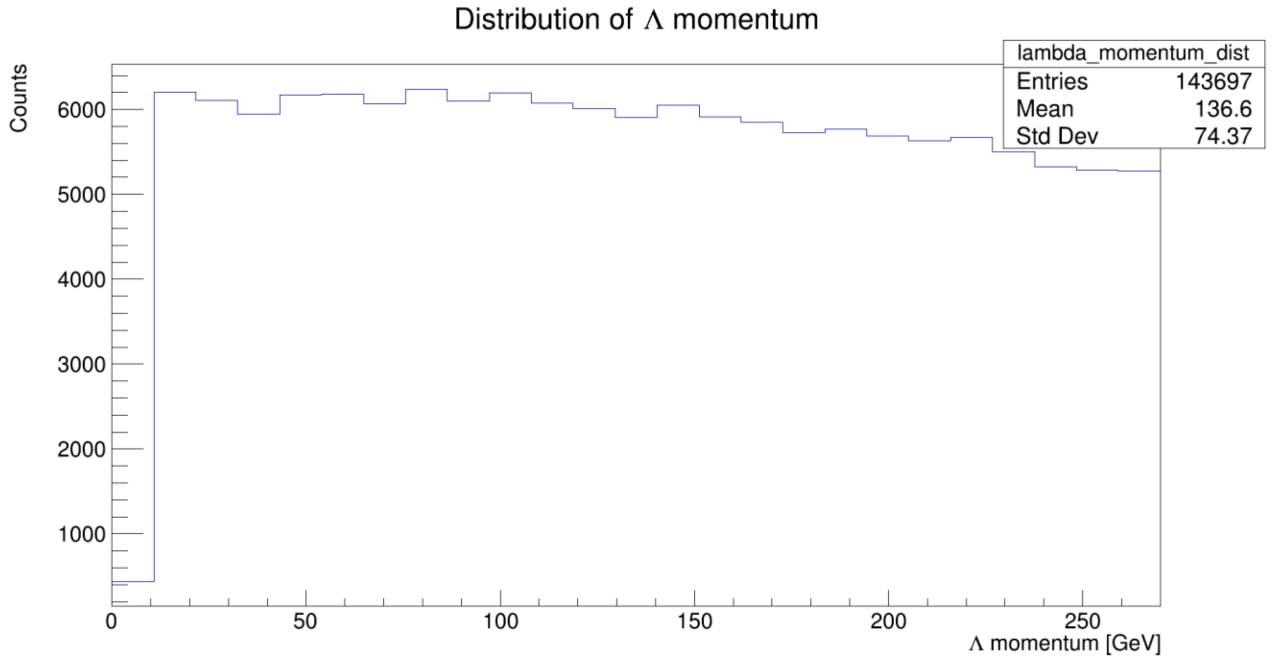
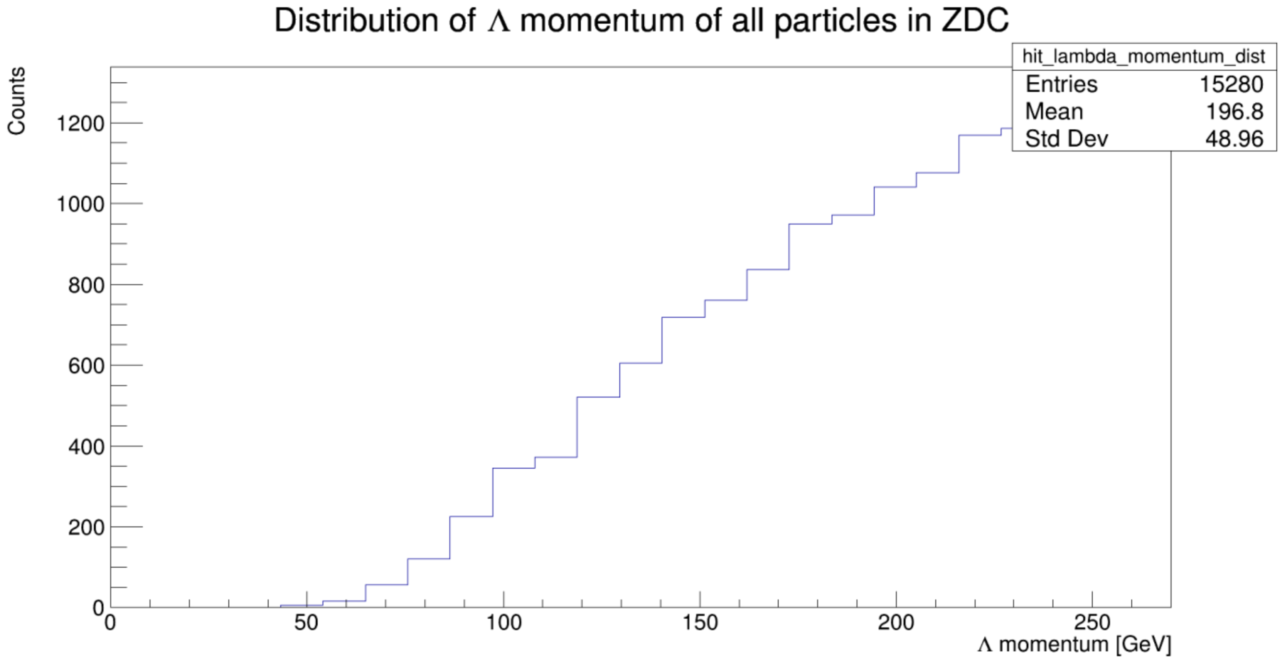
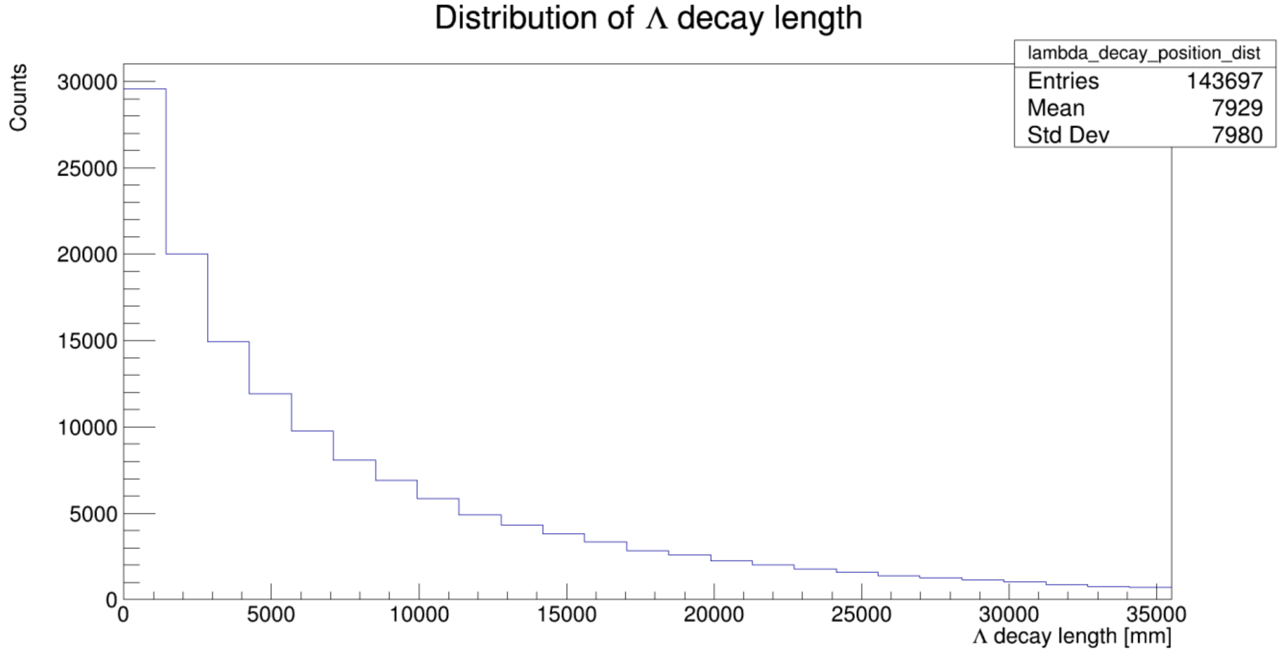
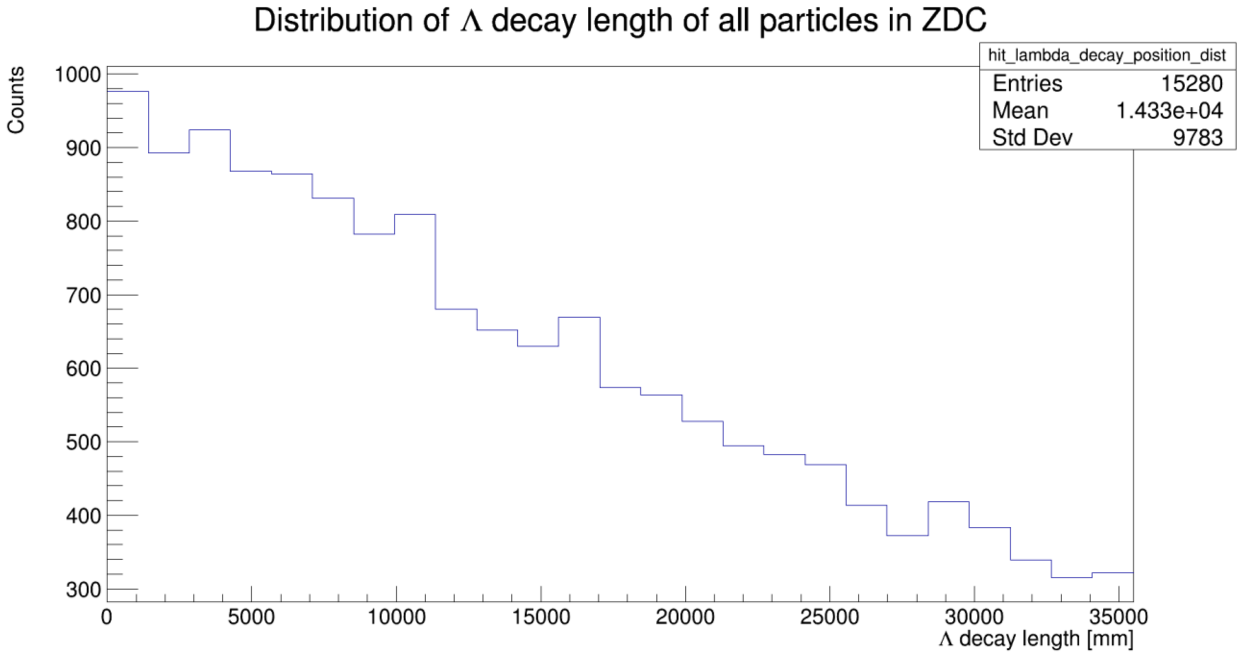
Momentum Distribution





Decay Position Distribution





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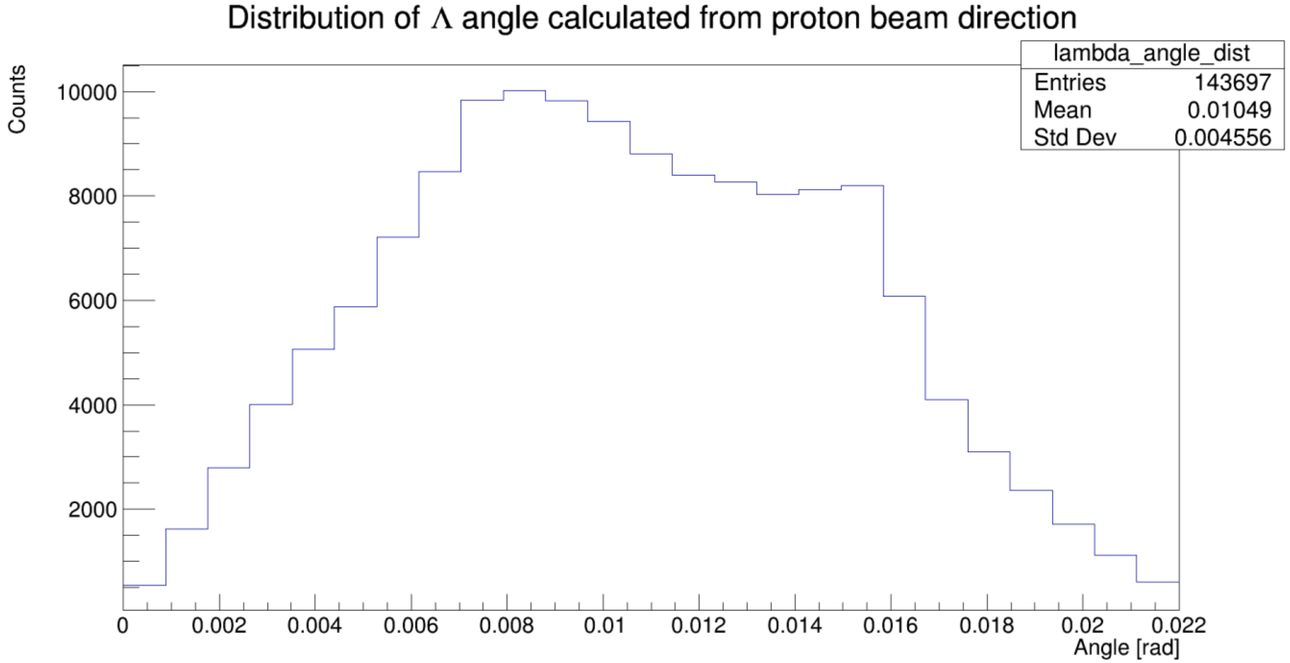
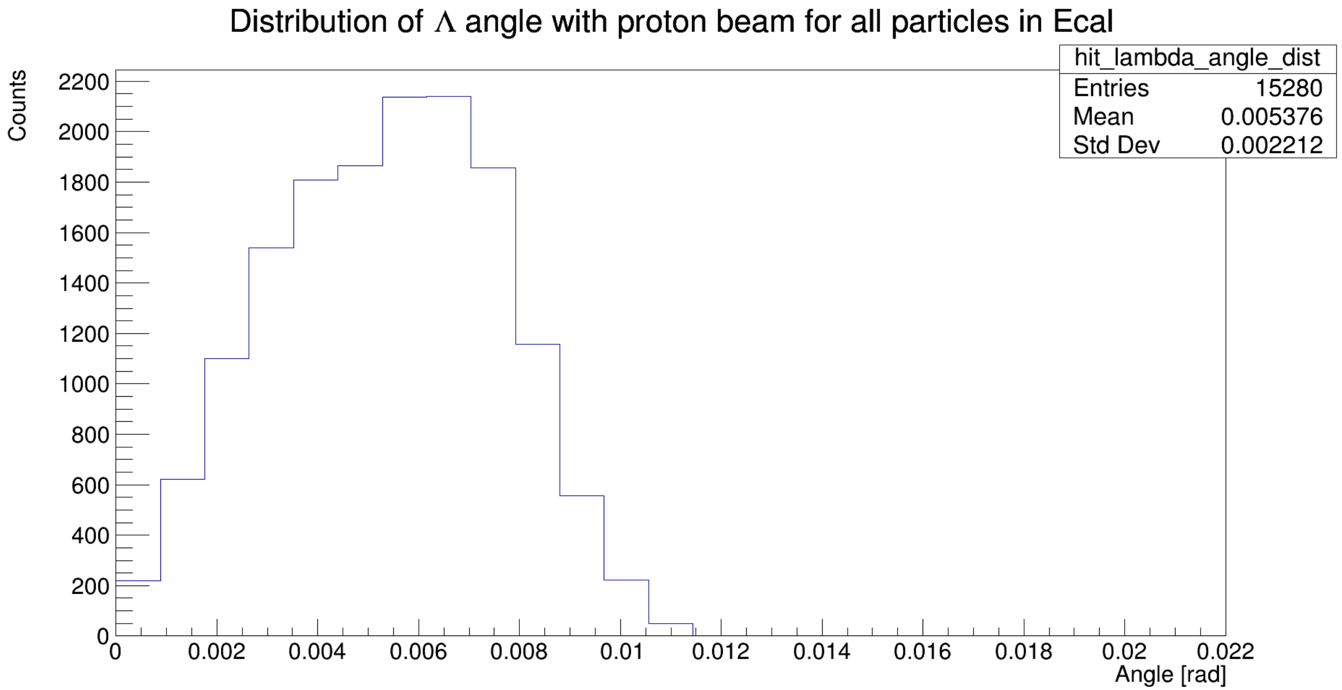
Angular Distribution





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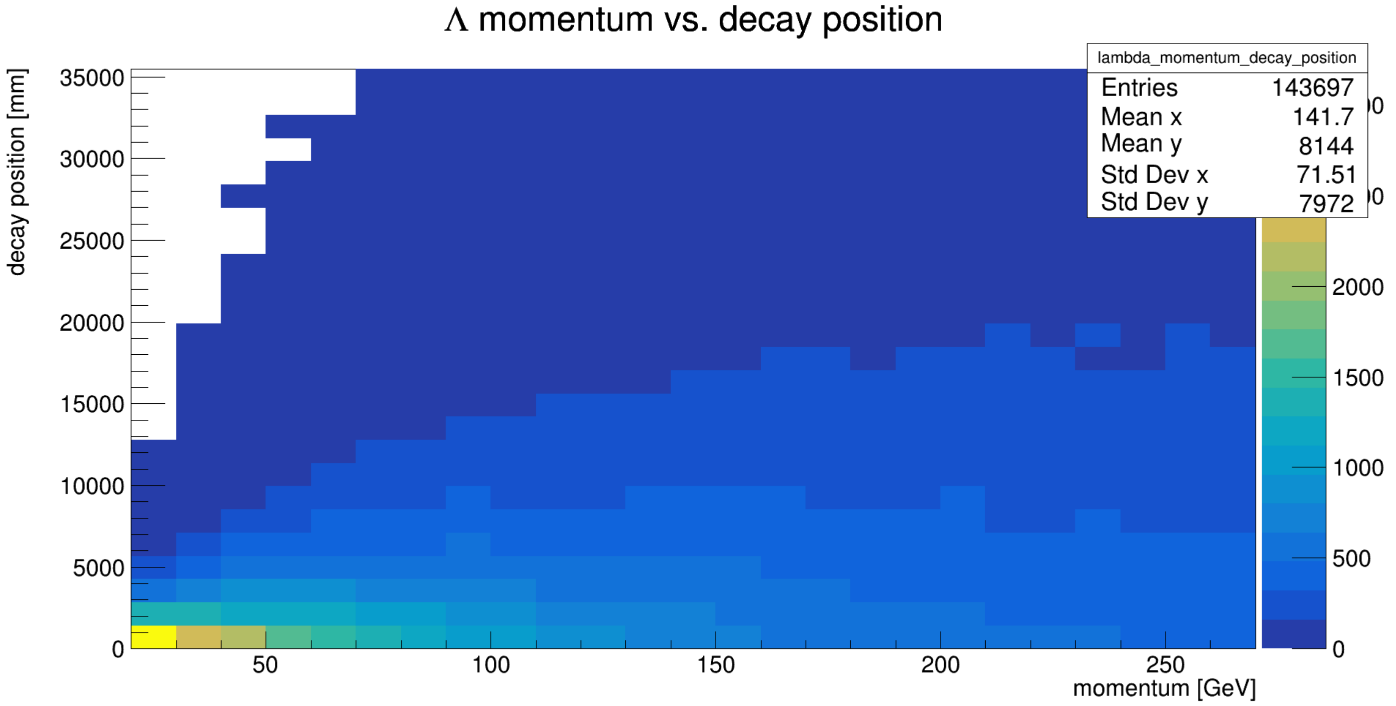
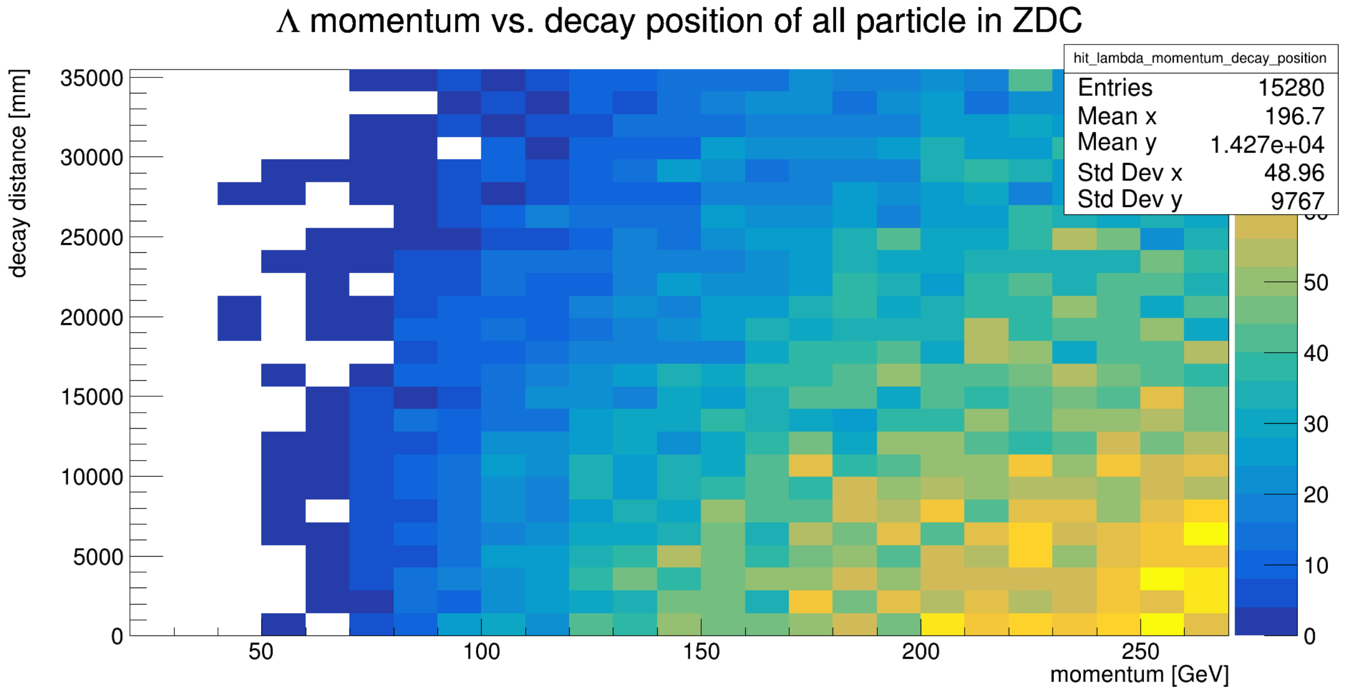
Momentum vs. Decay position





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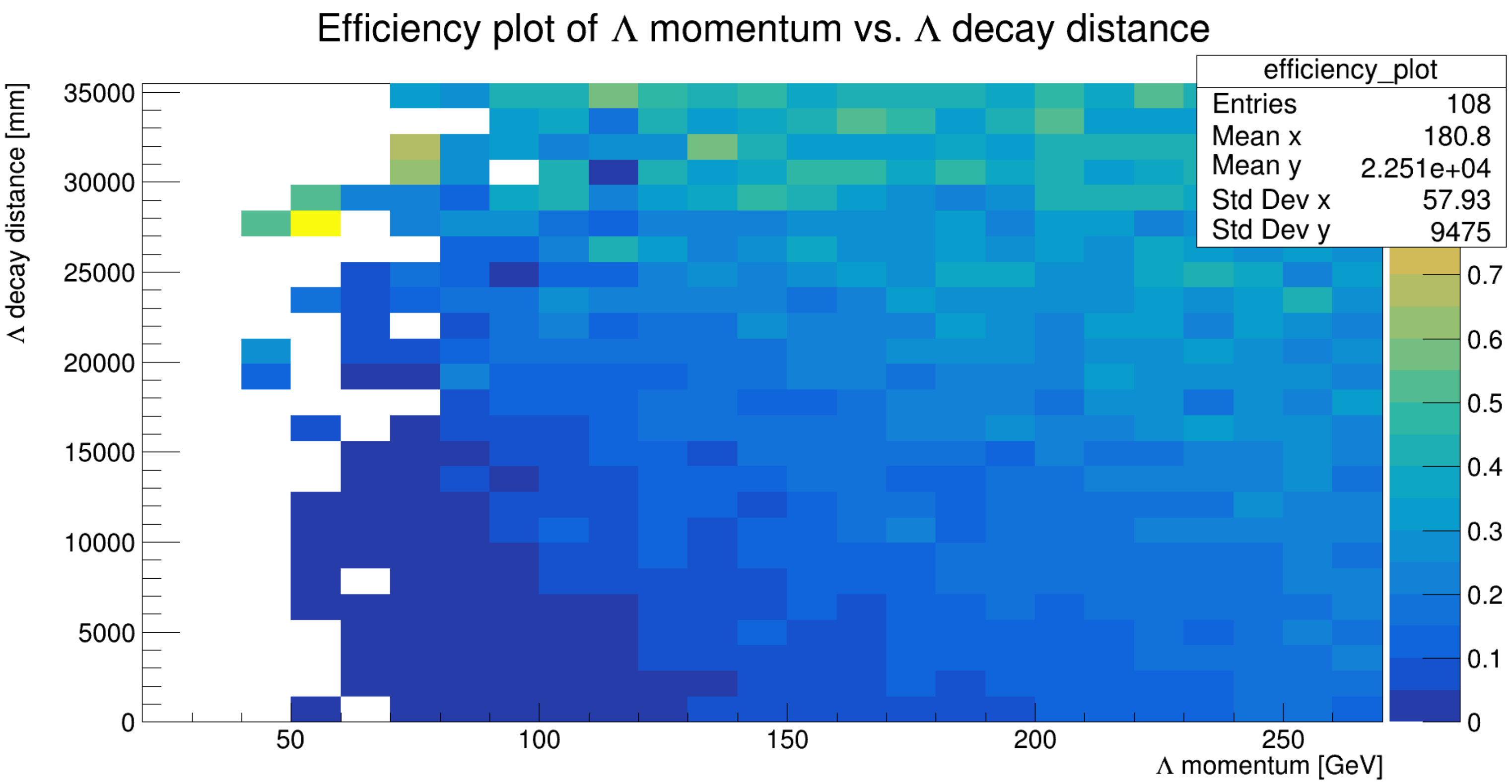
Efficiency Plot for momentum vs. Decay position

- Made by dividing the previous two plots



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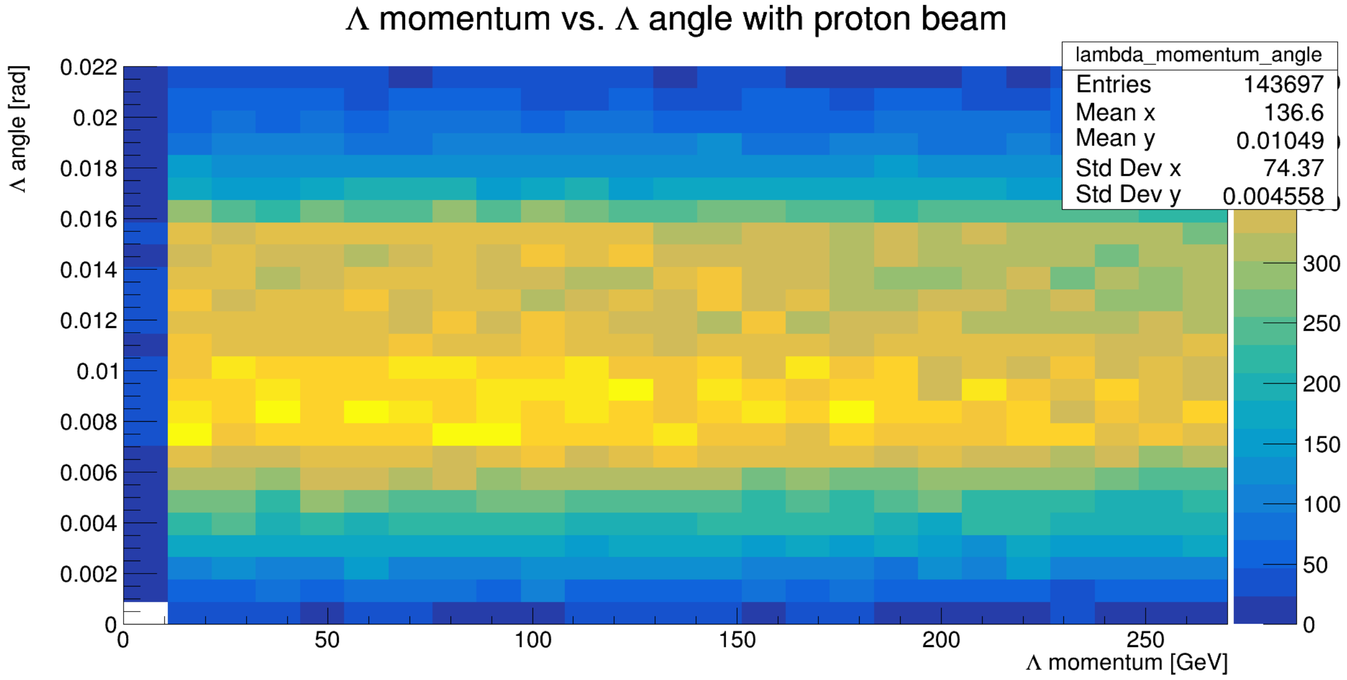
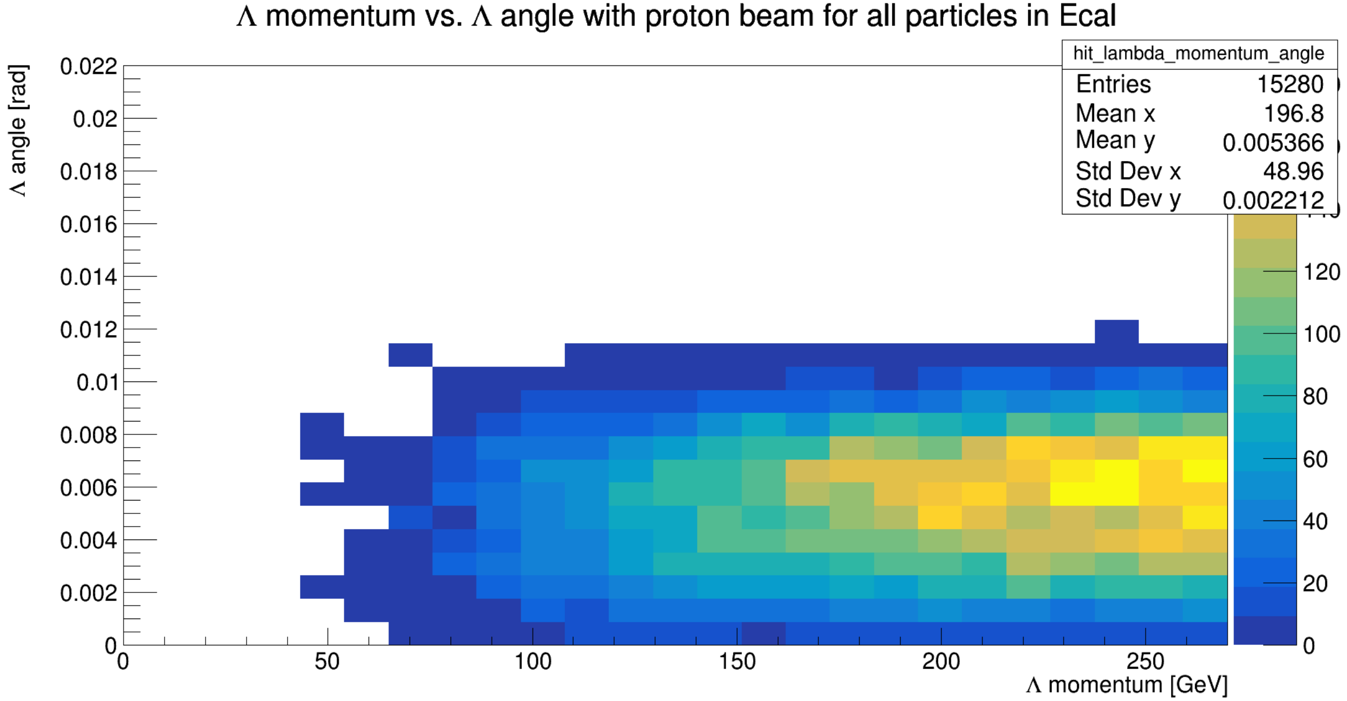
Momentum vs. Angle





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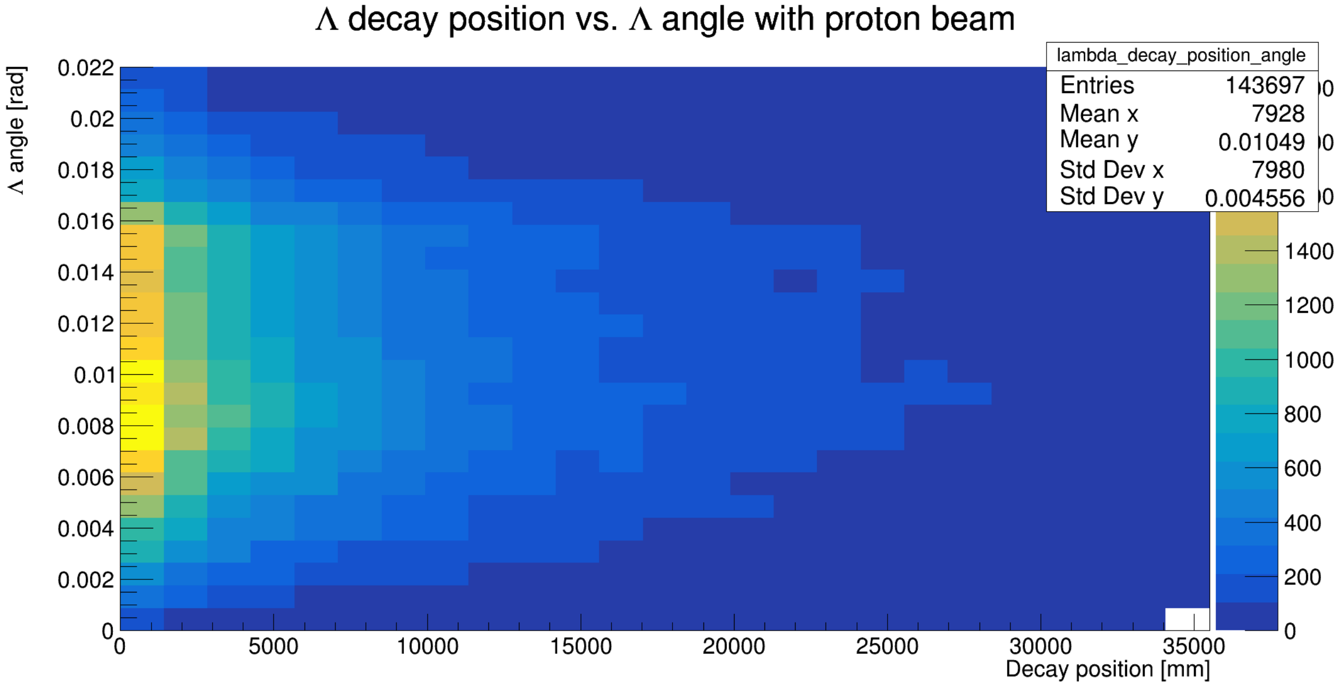
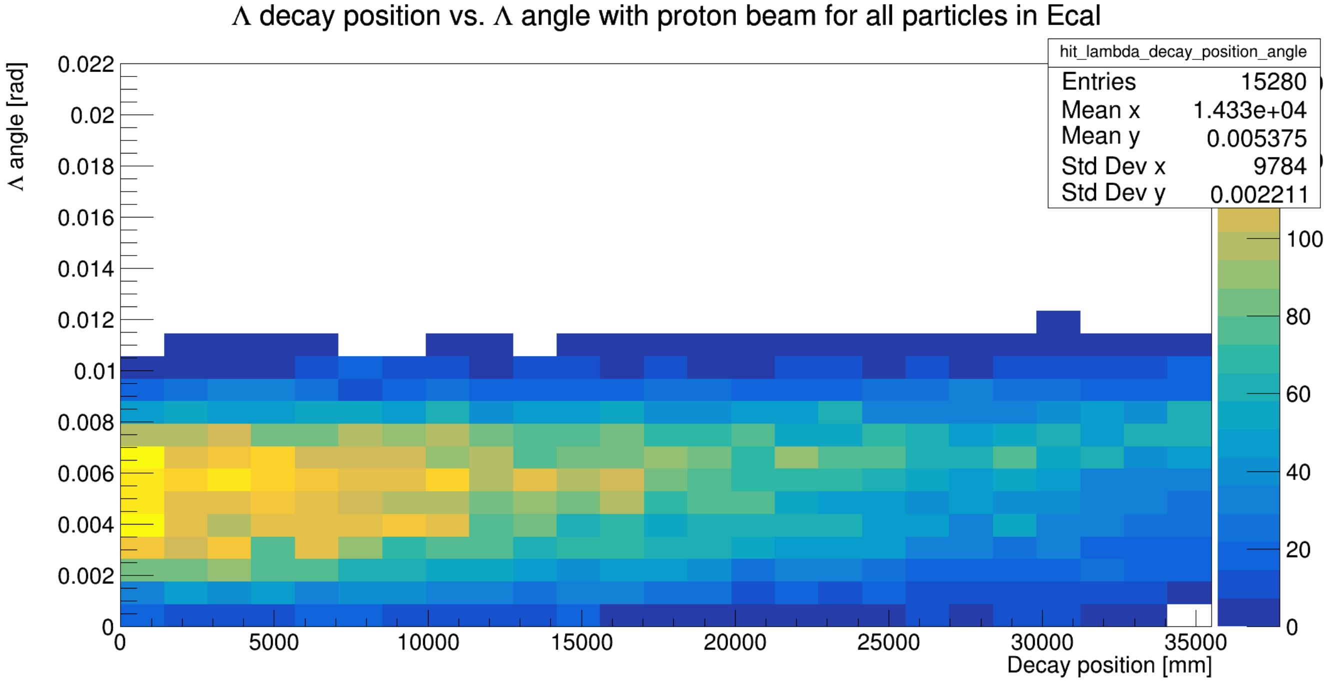
Decay position vs. Angle





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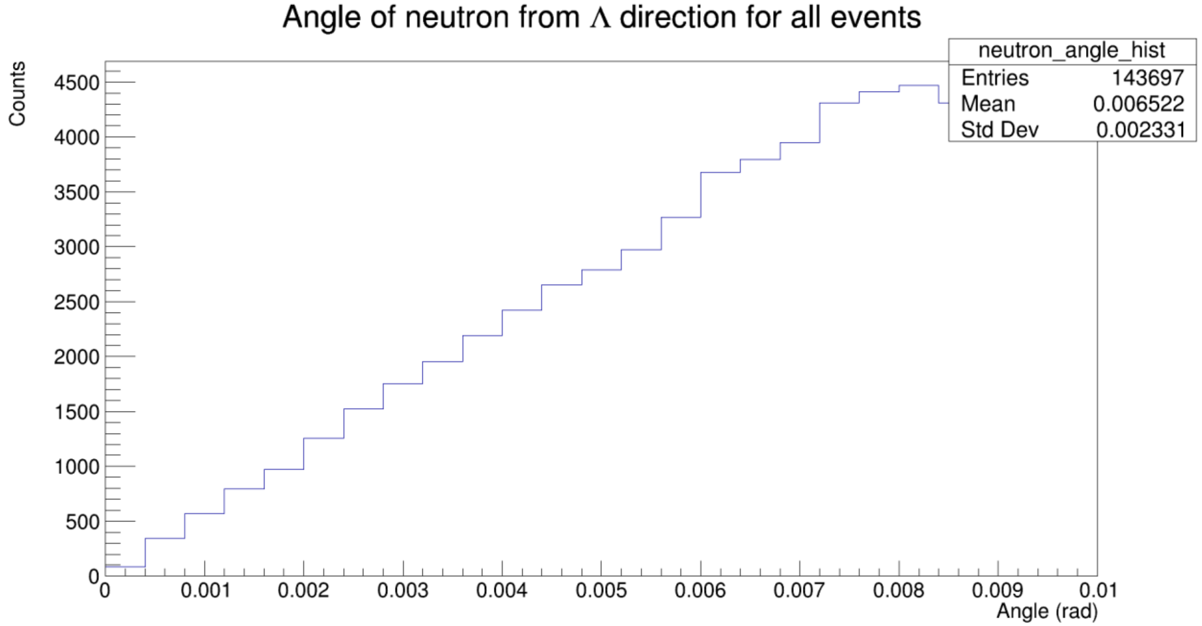
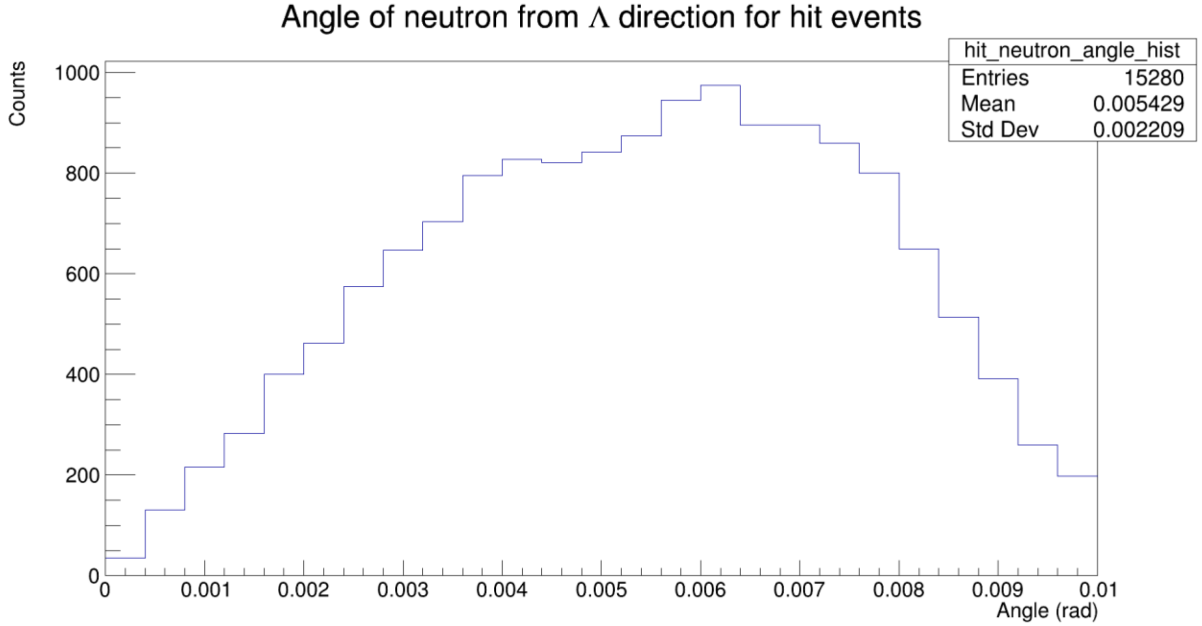
Neutron Angle





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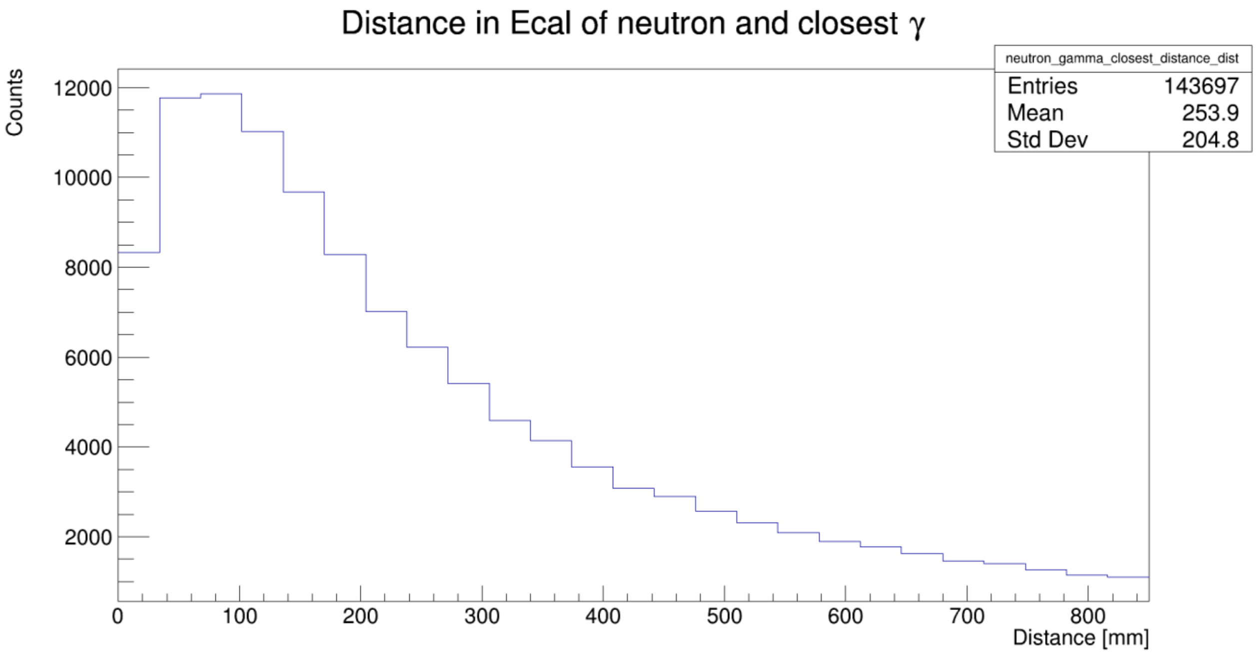
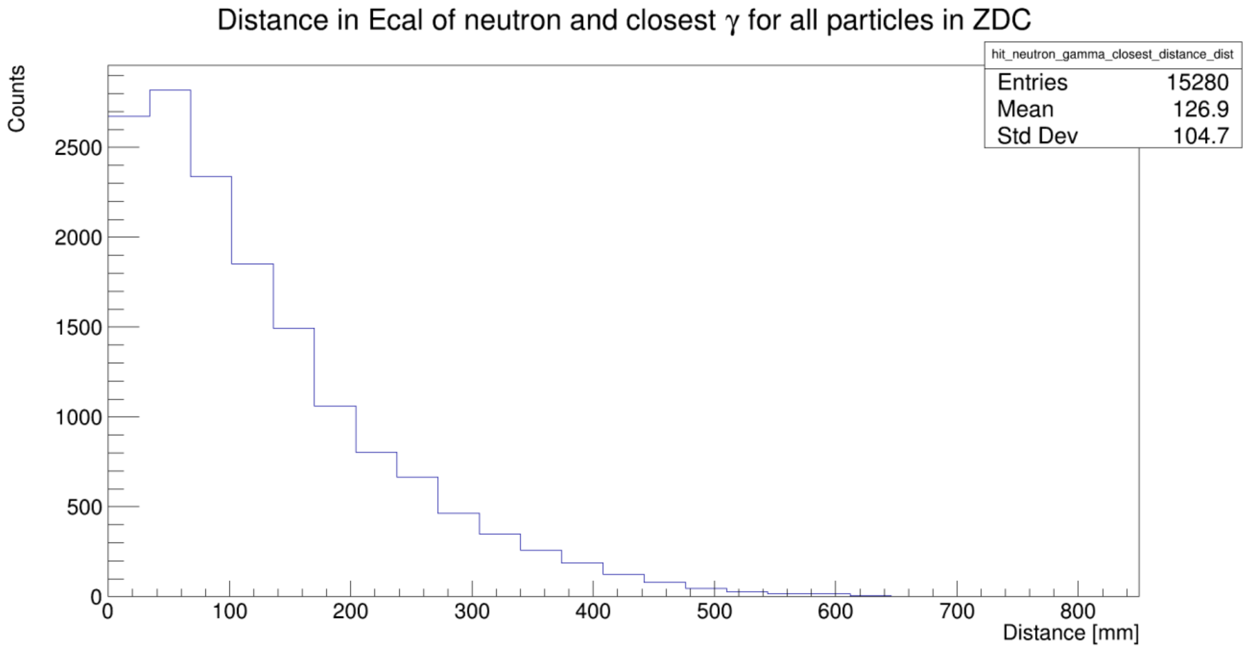
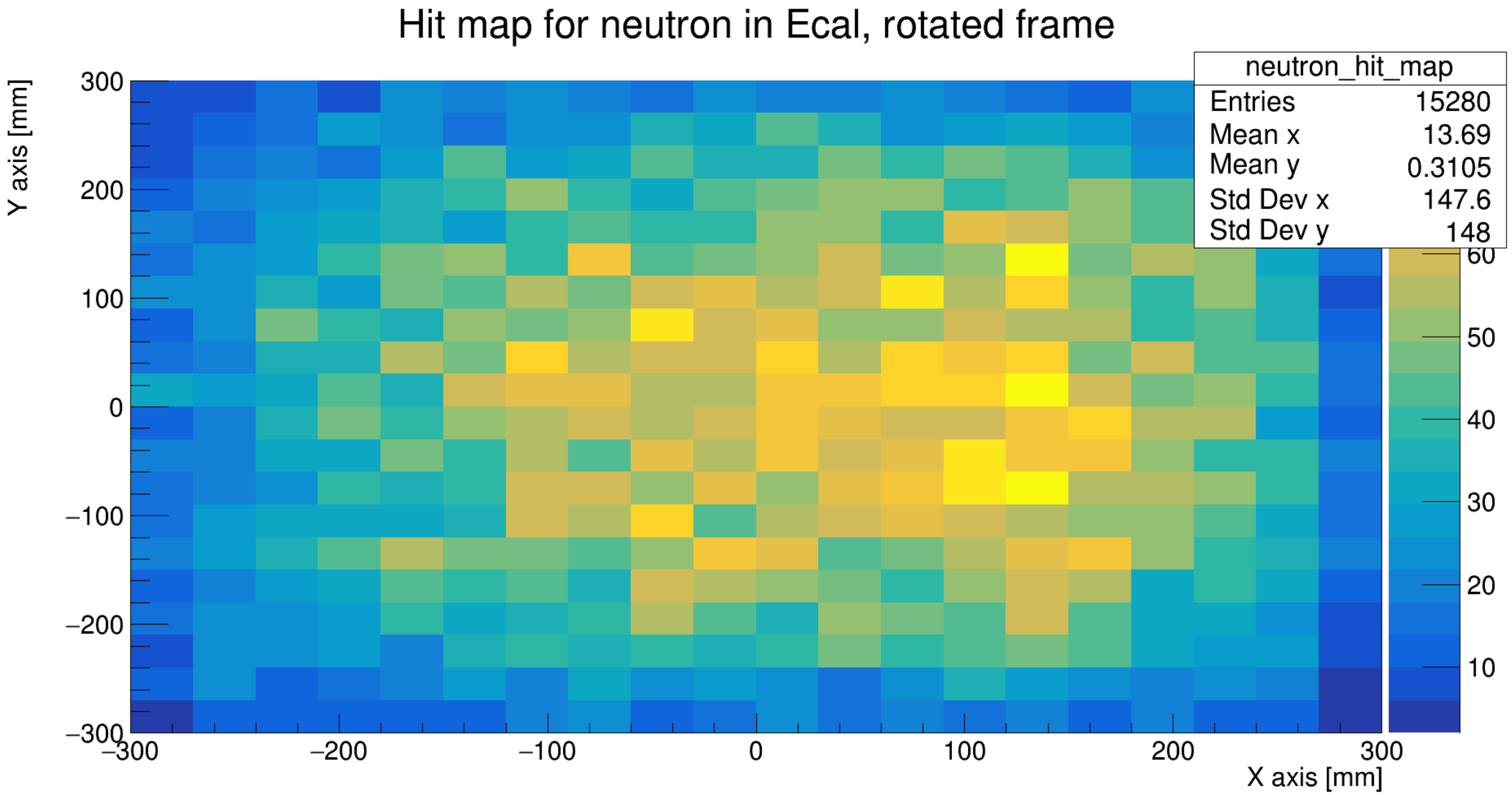
Neutron to closest gamma

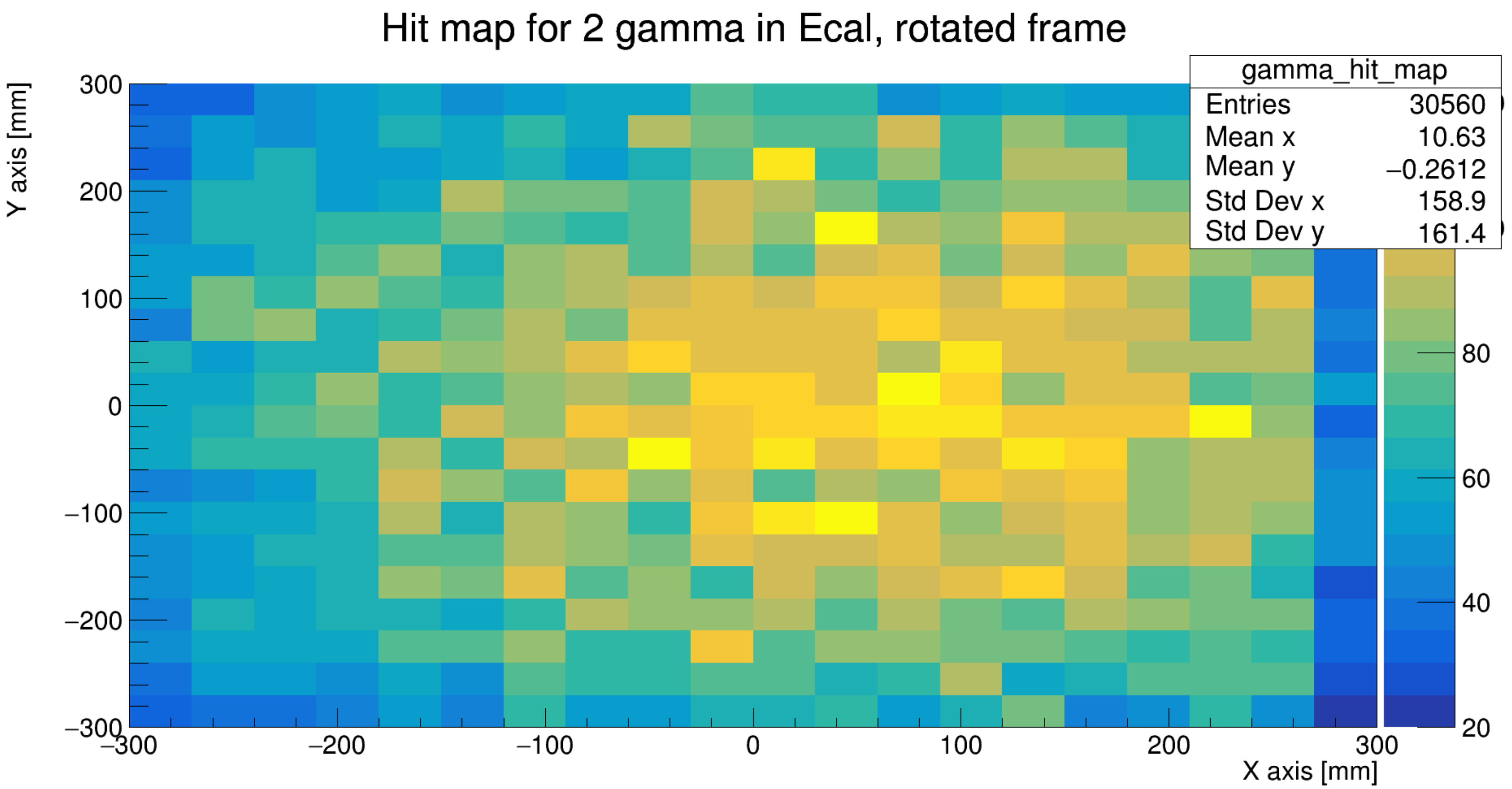




Neutron hit map



2gamma hit map



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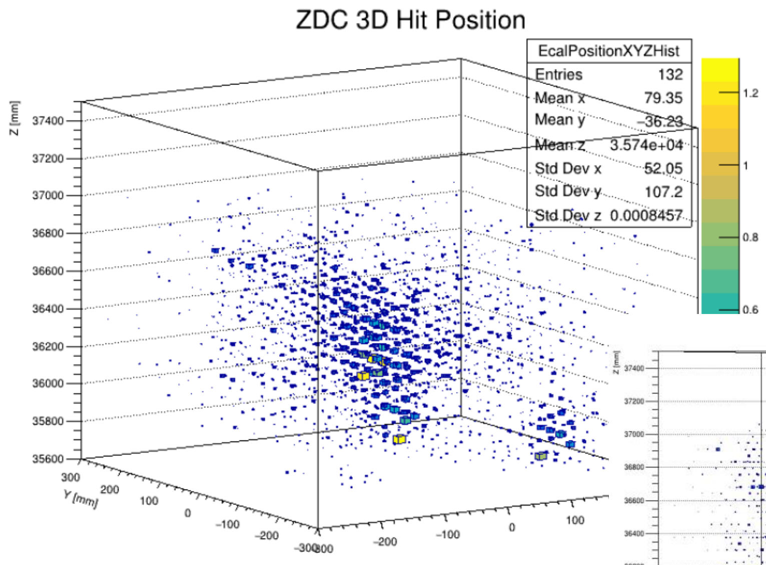
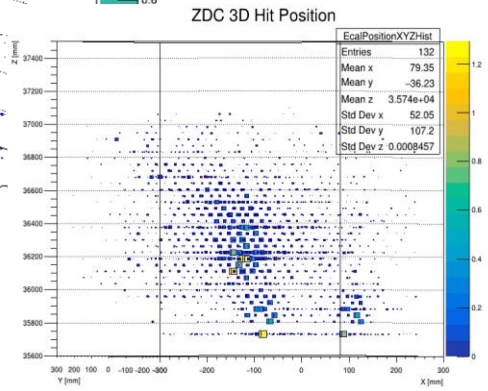
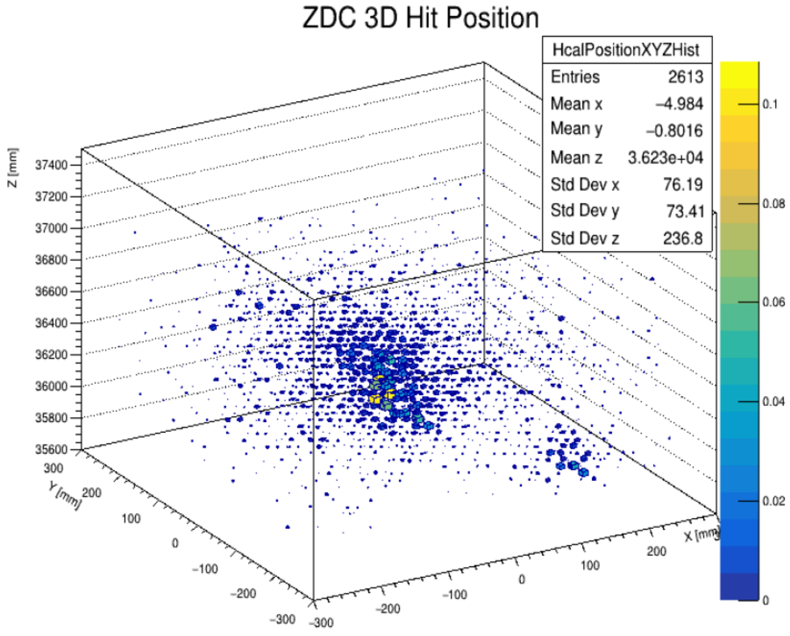
ZDC Clustering - 3D Event View

- Interactive event view where we can get a 3D hitmap for any event for full ZDC and HCal only





Full ZDC



HCal only

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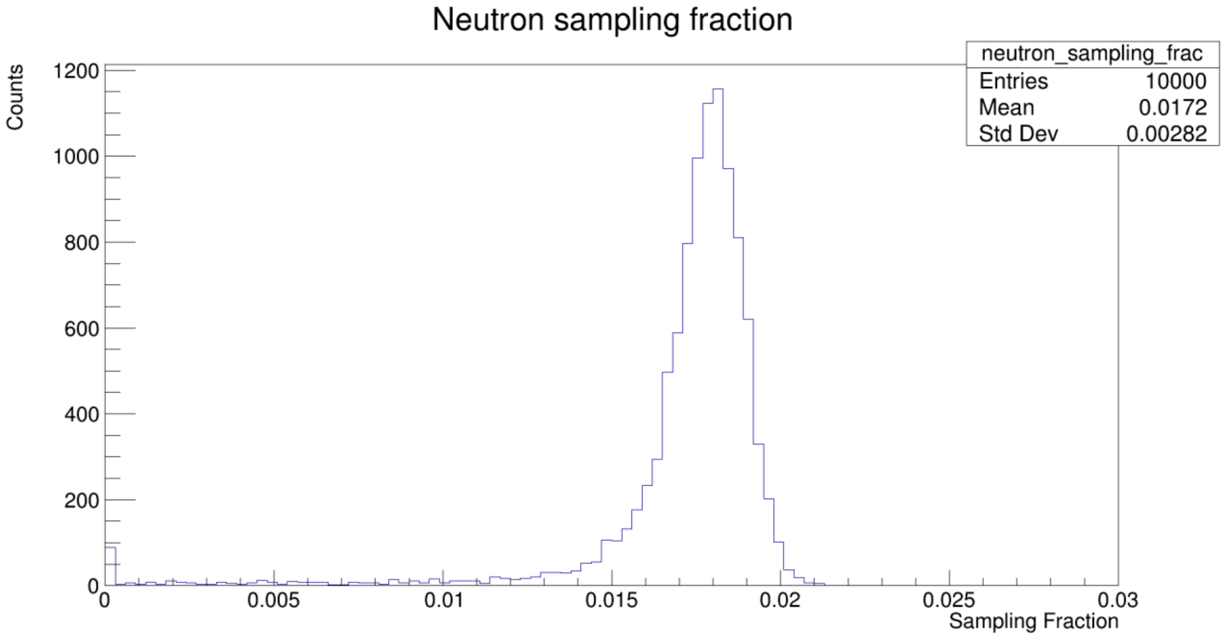
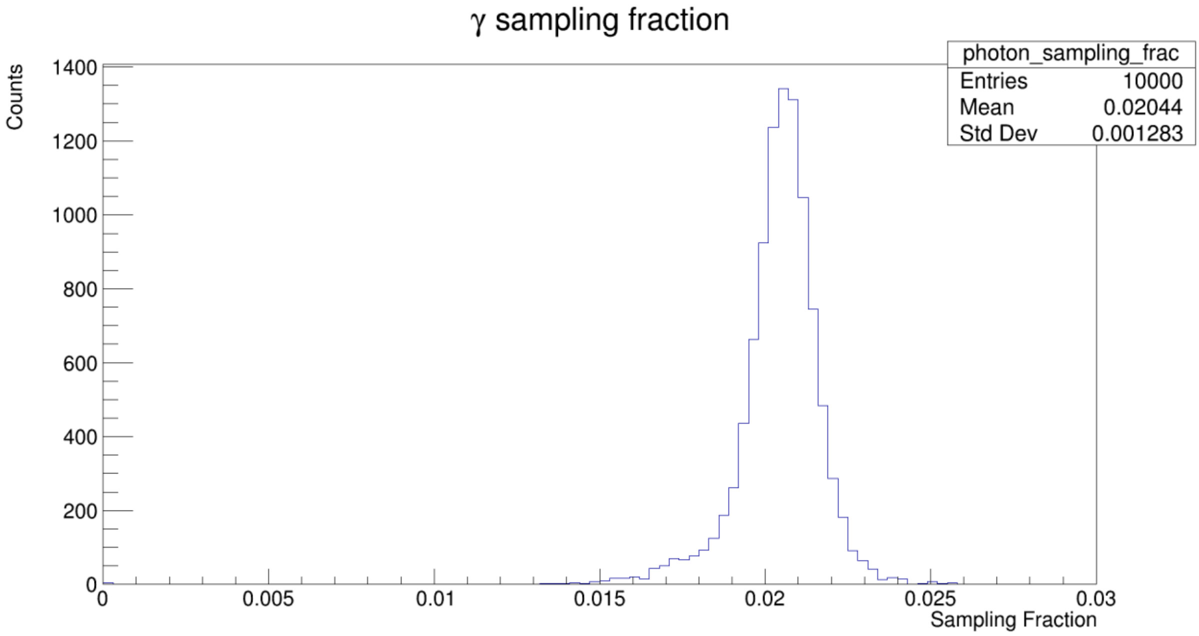
ZDC Clustering - Sampling Fractions

- Calculated sampling fractions for the Hcal for 10k 20-220 GeV neutrons hitting just the Hcal and10k 5 GeV to 50 GeV single photons hitting both the Ecal and Hcal
- For photon, I summed up total energy deposited in Ecal and subtracted that from original photon energy





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ZDC Clustering - ML Efforts Overview 1

- CSM, ATLAS and BELLE 2 work for calorimeter clustering has been with Graph Attention Networks (GAT)
- GATs work by turning each event into a graph and then treating those graphs as inputs to an attention convolution network
- Graphs are composed of nodes which have two aspects: features (x,y,z,E) and edges which connect nodes (determined by detector geometry)
- This lets us capture the geometric relation of neighboring cells, specifically between different geometries (Ecal, Hcal, WSi)

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ZDC Clustering - ML Efforts Overview 2

- Attention convolution is a generalization of convolution to the graph structure (rather than the typical grid structure for pictures)
- Attention mechanism works by determining attention coefficients for neighboring node's features to every node which are then used in a linear transform to make new features

ZDC Clustering - ML Efforts Overview 3

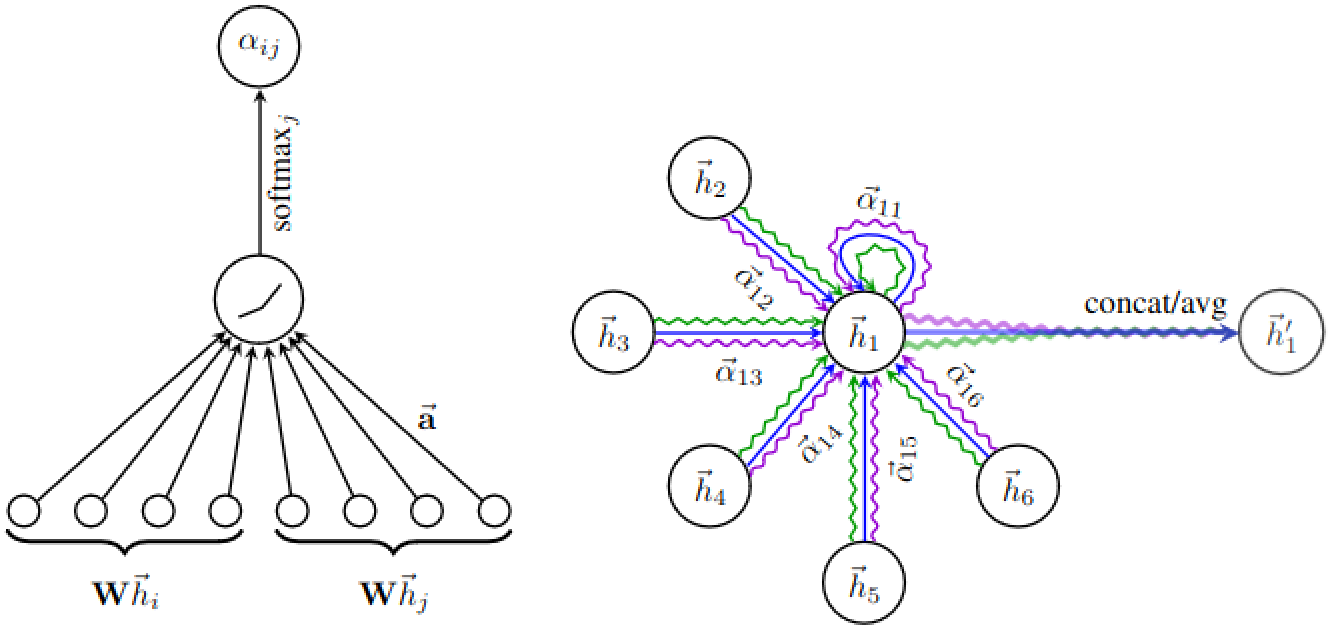

Figure 1: **Left:** The attention mechanism $a(\mathbf{W}\vec{h}_i, \mathbf{W}\vec{h}_j)$ employed by our model, parametrized by a weight vector $\vec{\mathbf{a}} \in \mathbb{R}^{2F'}$, applying a LeakyReLU activation. **Right:** An illustration of multi-head attention (with $K = 3$ heads) by node 1 on its neighborhood. Different arrow styles and colors denote independent attention computations. The aggregated features from each head are concatenated or averaged to obtain $\vec{h}'_1$.

Veličković, P., Cucurull, G., Casanova, A., Romero, A., Liò, P., & Bengio, Y. (2018). Graph Attention Networks. *arXiv [Stat.ML]*. Retrieved from http://arxiv.org/abs/1710.10903

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ZDC Clustering - ML Efforts Overview 4

- Other experiments have focused on supervised models: MC data is prepared with known labels (which cluster the hit belongs to) and the model is evaluated by how well it predicts the label
- Alternative approach is using self-supervising methods: MC data is prepared without labels and the model is evaluated by how well it can reconstruct the data by extracting latent features
- This works by expanding the input features and then restricting them to see if the model can encode the latent features into a space where we can extract them
- I have successfully tested the model's reconstruction ability one single events and am currently moving onto batching the events to see if it can generalize
- From there, I can examine if latent features can be extracted

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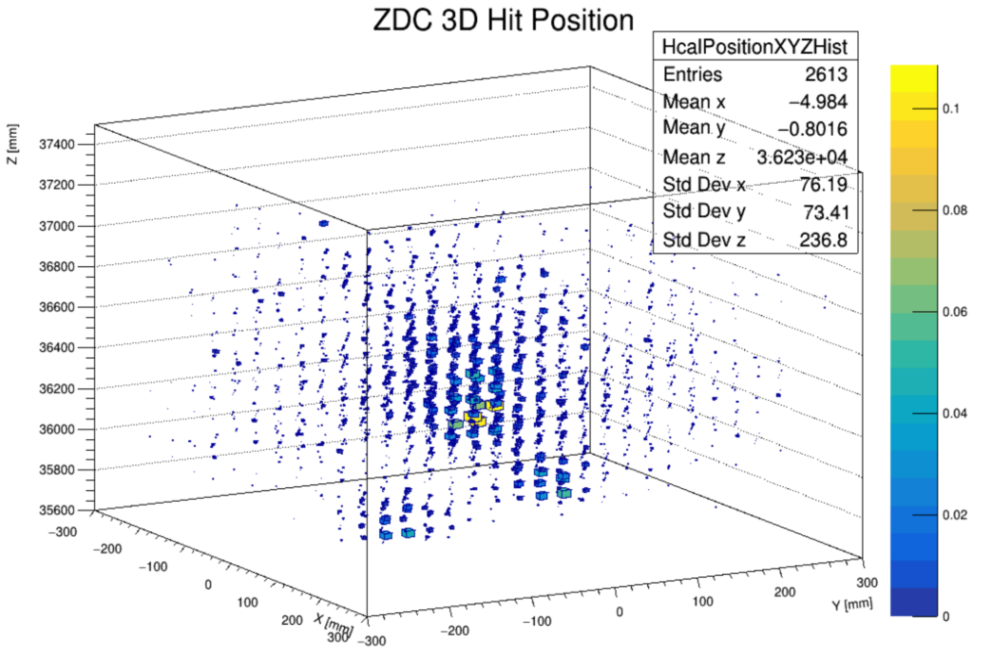
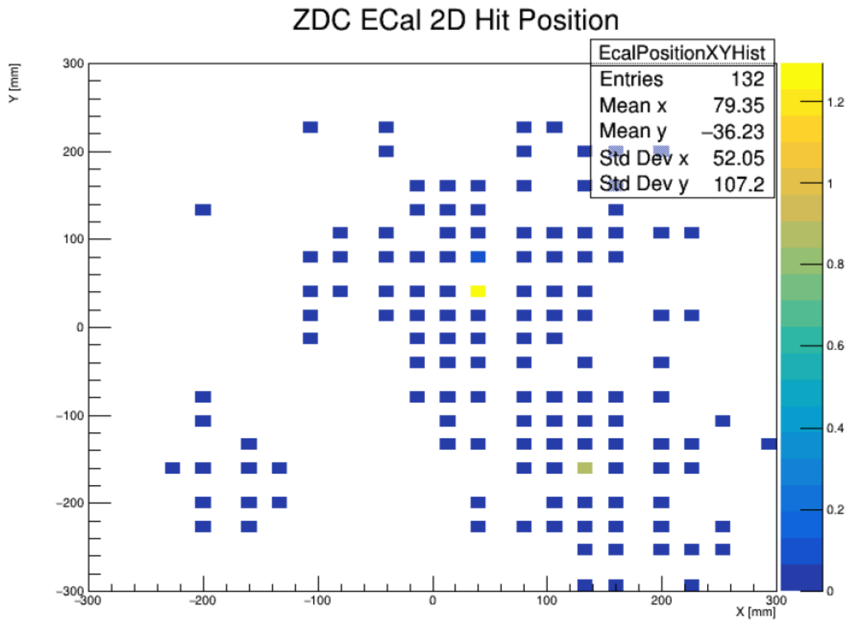
ZDC Clustering - Algorithm Clustering

- Objective is to develop a modified version of the DBSCAN (Density-Based Spatial Clustering of Applications with Noise) to perform clustering
  - DBSCAN works by separating regions of high density from those that are sparser. Want to modify it so that it also accounts for the energy of the hits as well as the density
  - Two parameters: epsilon (distance between points), min points (minimum number of points needed to make a cluster)
- Currently able to implement unmodified DBSCAN algorithm to perform clustering in the HCal in 3D but it needs to be tuned and modified in order to work well

ZDC Clustering - Algorithm Clustering

- Event 1: 3 Distinct clusters in the HCal and we can see hits from neutron and both photons in the ECal





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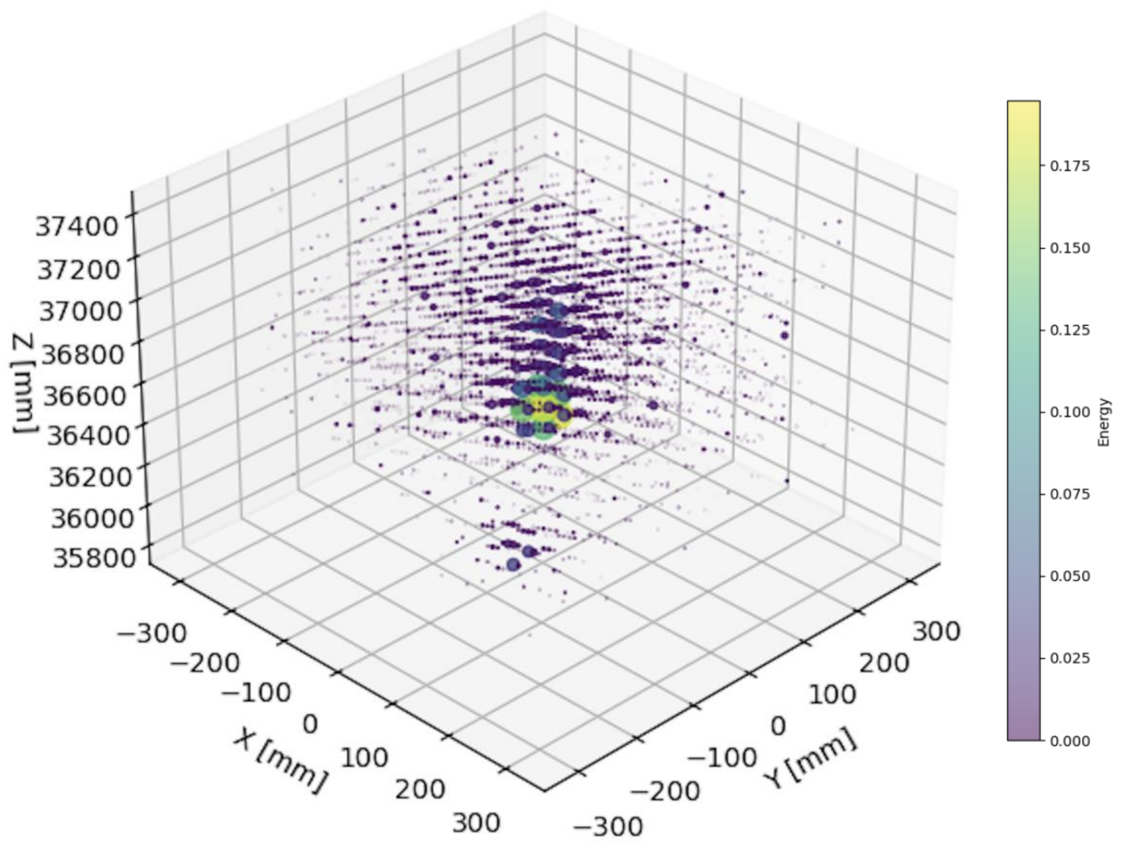
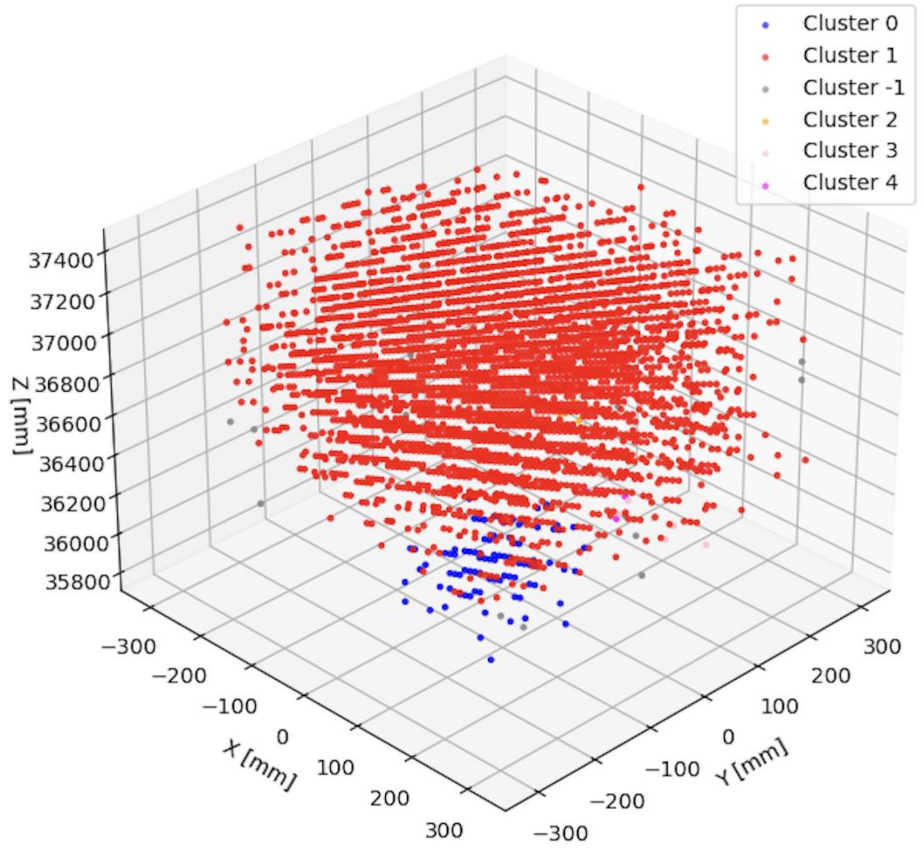
ZDC Clustering - Algorithm Clustering





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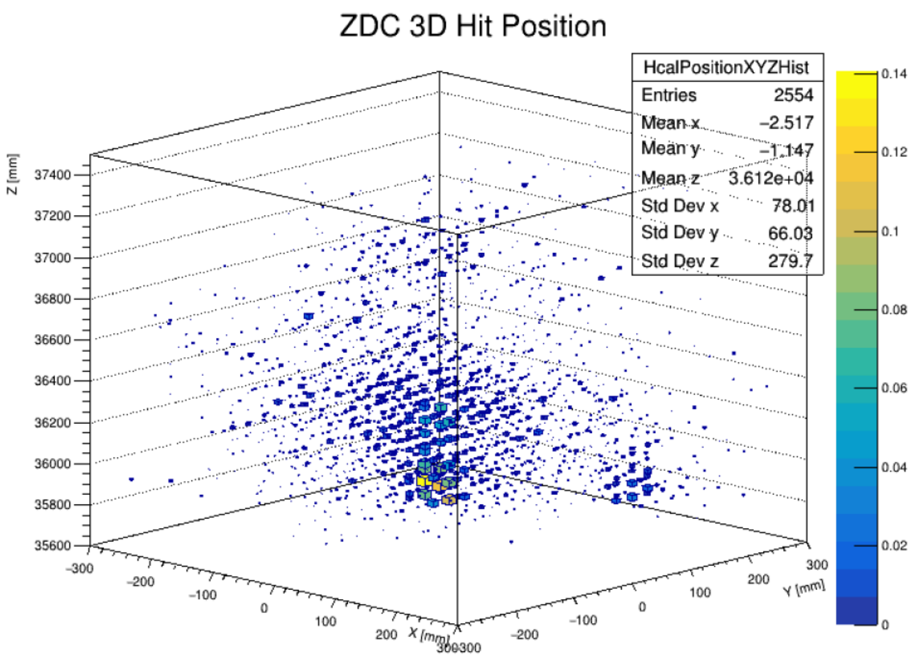
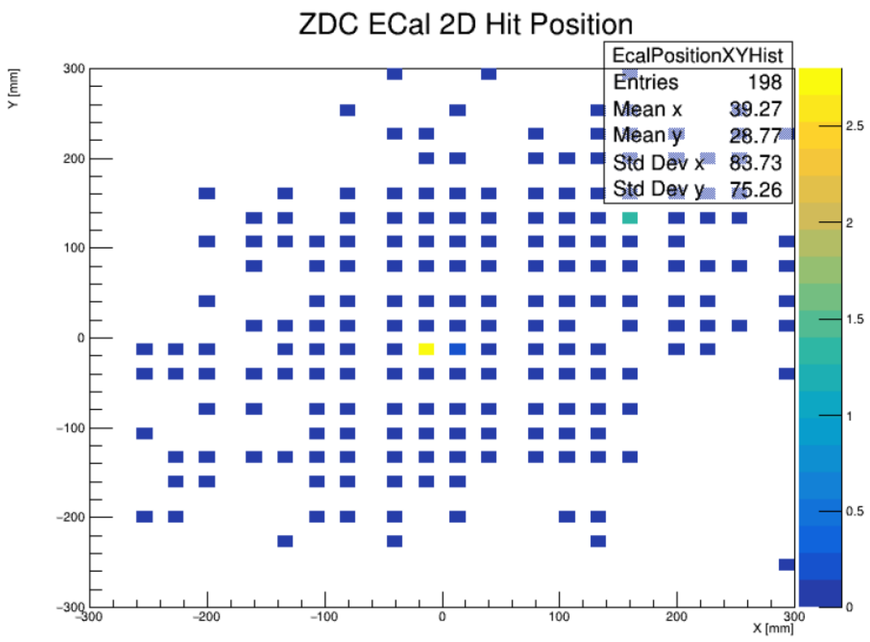
ZDC Clustering - Algorithm Clustering

- Event 2: 2 Distinct clusters in the HCal but we cannot really distinguish neutron and both photon hits well





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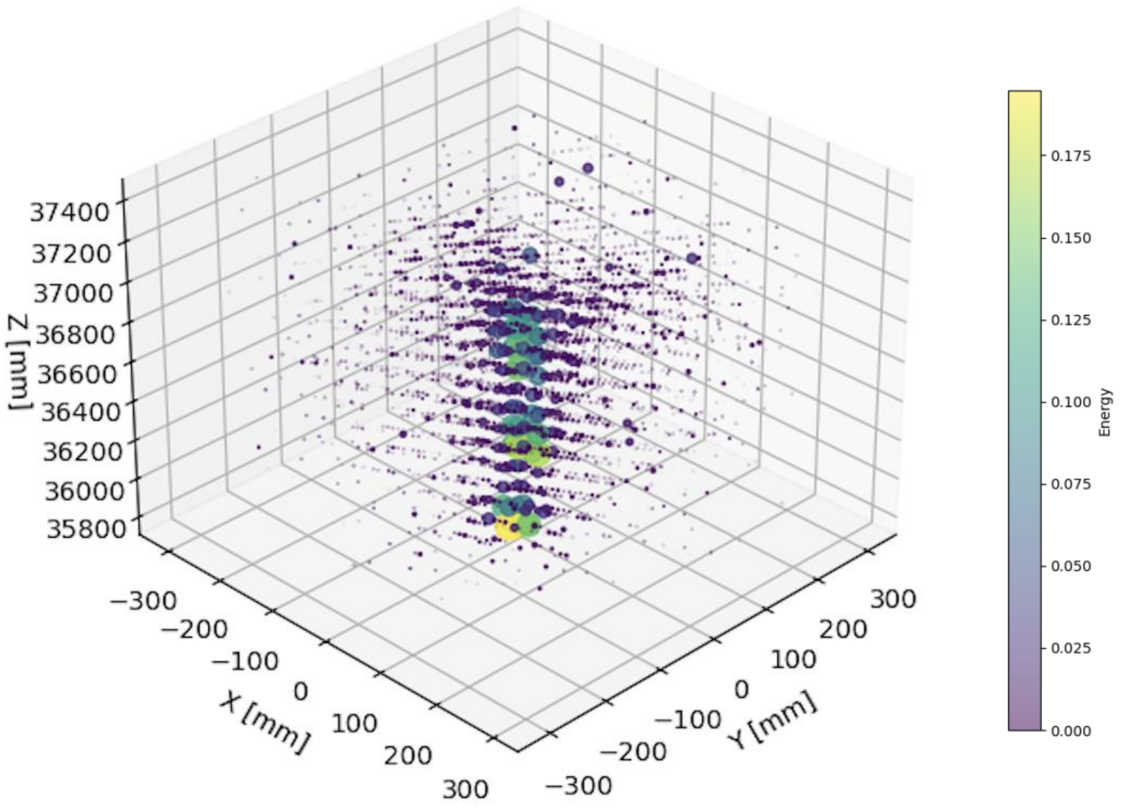
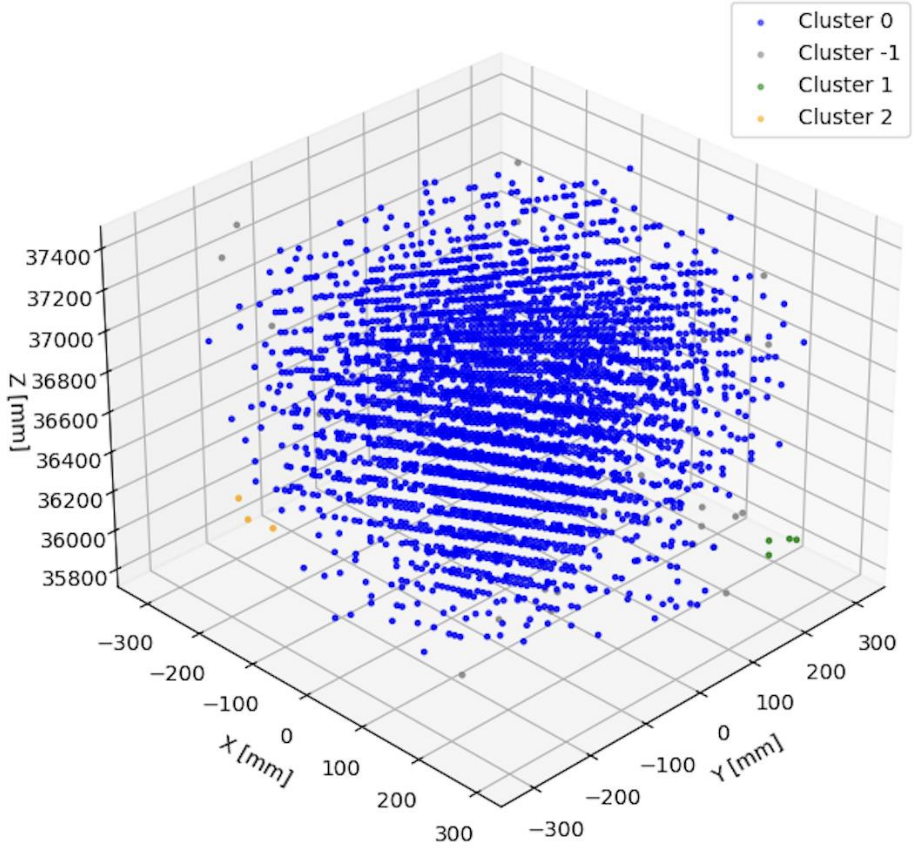
ZDC Clustering - Algorithm Clustering





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ZDC Clustering - Algorithm Clustering

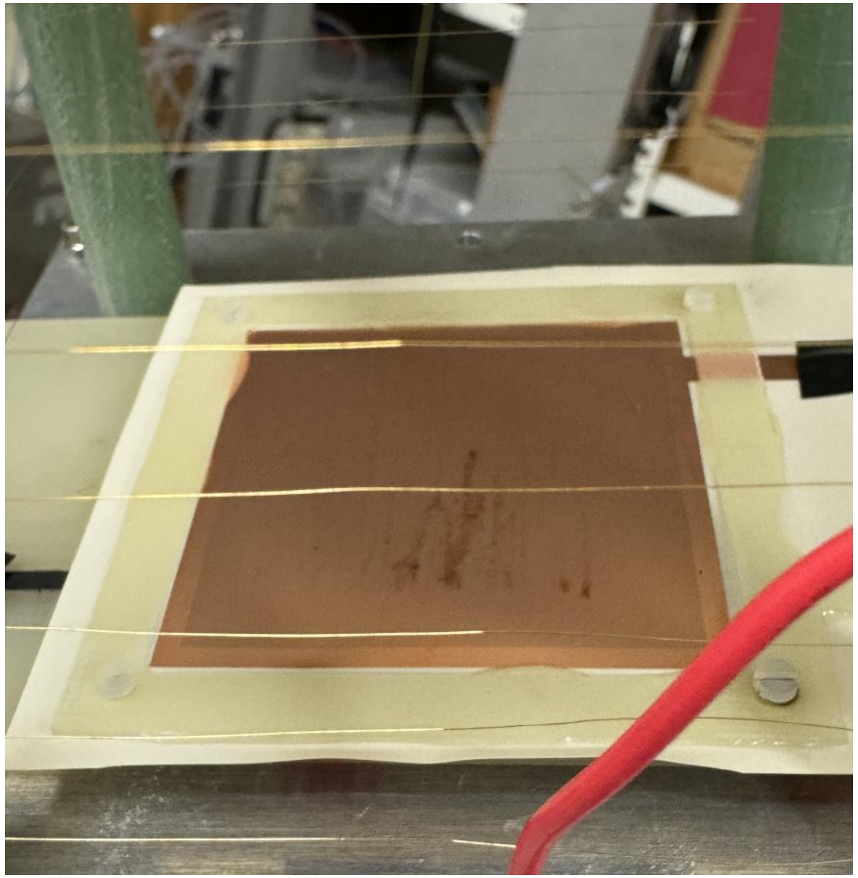
Next Steps:

- Tune the parameters
- Modify algorithm so that it also accounts for the energy of the hits
    - Need to be careful here as the energy deposited by the neutron is different than the photons in both the ECal and HCal
- Implement the algorithm for the full ZDC (currently implemented only for the HCal)
- Potentially use ECal hits as "seeds" to better determine the number of clusters and guess core points

TPC Efforts

- Debugging continues:
- We removed the euxenite stone, and tested cosmics for an evening
- We observed less hits
- We found a problem with the voltage divider and resoldered wires
- Then we placed iron-55 into the TPC and took data at several GEM voltages
- We collected some good data before sparking destroyed the GEM
- GEM condition is unstable, it constantly sparks and can't hold high voltages anymore
- New GEM is currently drying

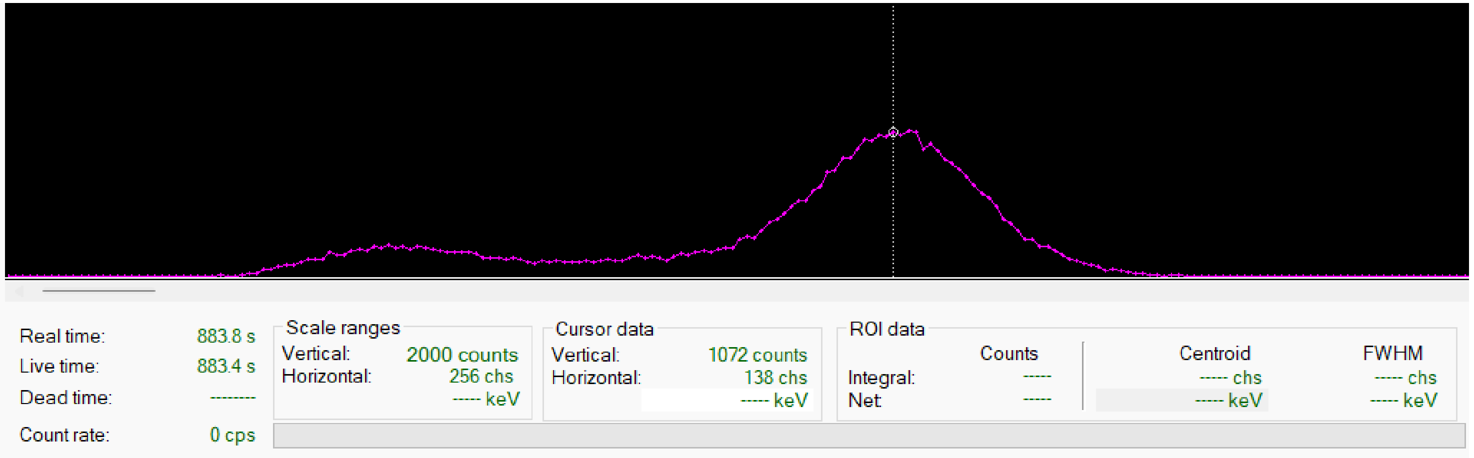
TPC Efforts

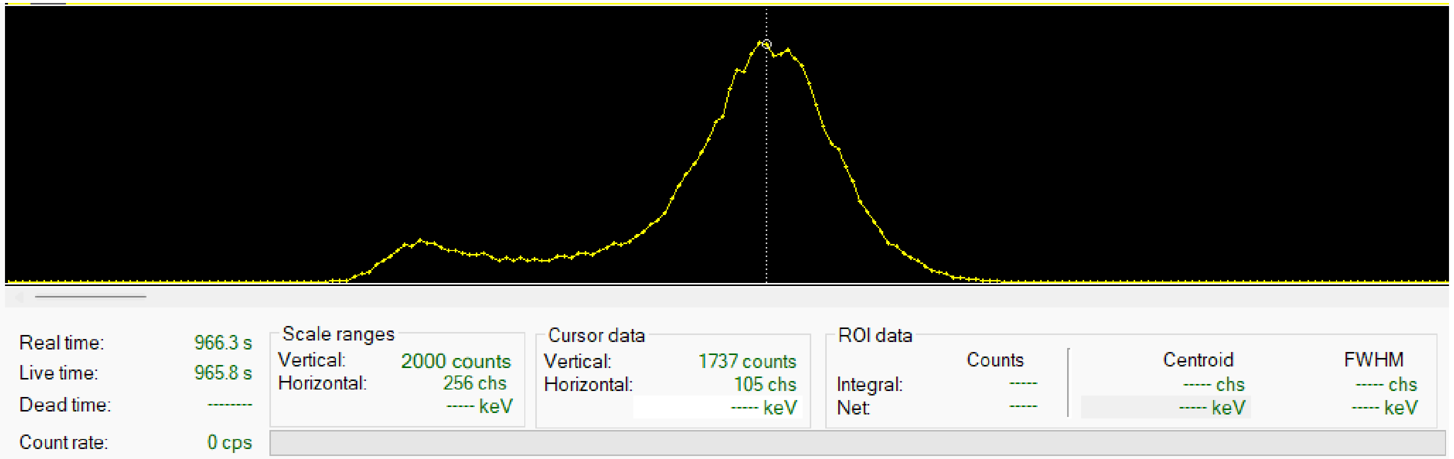


Damaged GEM foil

TPC Iron 55 Plots

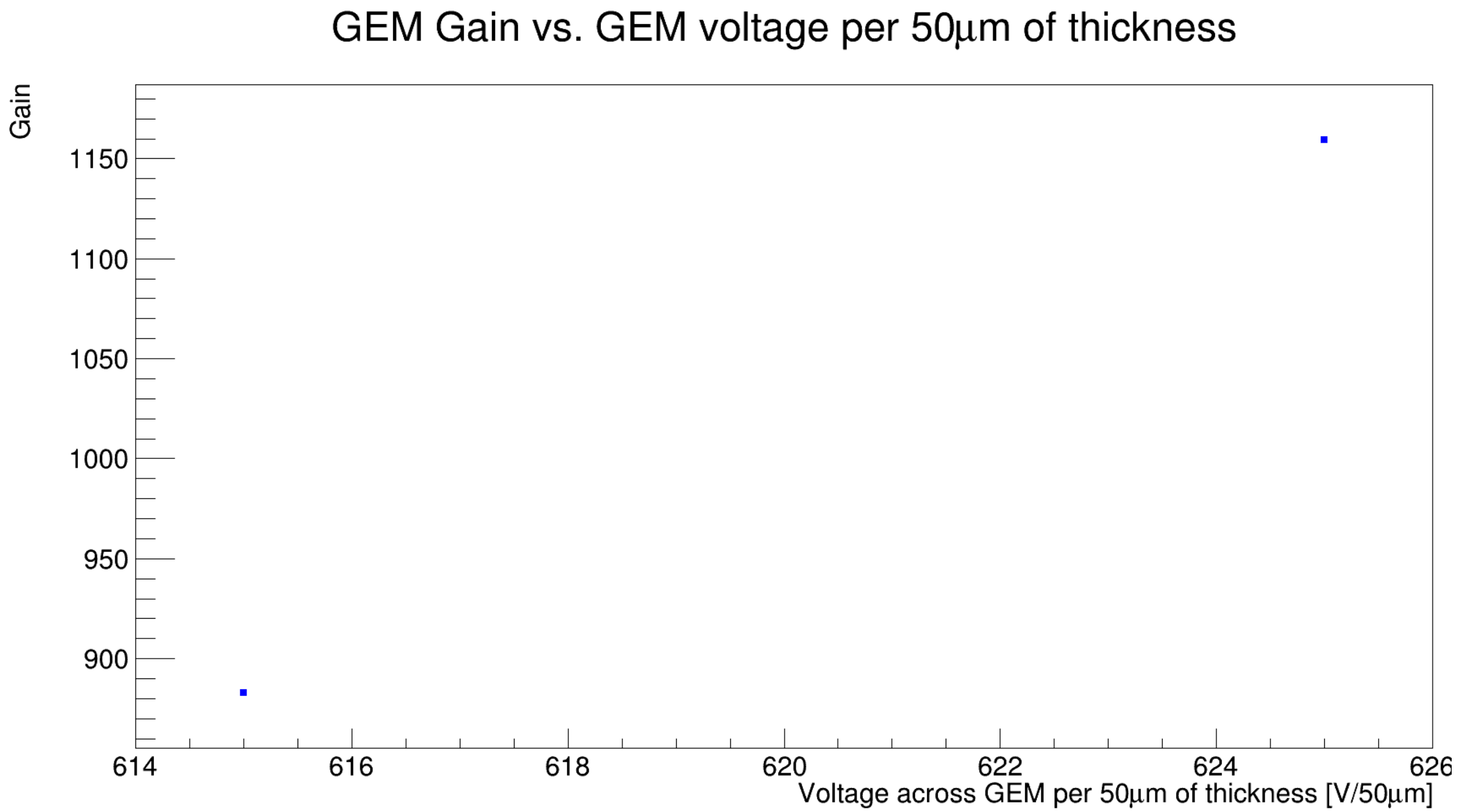
- Plots for spectrum: x-axis is channel and y-axis is counts
- Top plot is for GEM voltage 1250V and field voltage -900V, bottom plot is for GEM voltage 1230V and field voltage –900
- Top peak is located at channel 138 -> 84.2mV
- Bottom peak is located at channel 105 -> 64.1mV
- Unfortunately, the GEM died before we could collect more data





TPC Iron 55 Plots 2

- With the previous data, we may calculate the gain of the GEM
- Calculated using the known energy of the larger peak



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