Status of the incident angle analysis with the SDHCAL

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on behalf of the SDHCAL group

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cfp CIEMAT física de partículas

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Context & Setup

The objective is to check the effect of the incident angle of the particles in the efficiency, multiplicity, energy reconstruction, etc. using the SDHCal as detector.

Data taking was during two test beam in the PS (June 2015) and SPS (May 2015):

- Wide range of energies: 1 - 10 Gev (PS) and 10 - 70 GeV (SPS).
- Several rotation angles: 0º, 10º, 20º and 22º (Later computed with muons).

The SDHCal had 49 GRPC layers installed (multigap and other chambers excluded from the analysis).

Raw Stream-Out & Trivent

Raw *.slcio* byte collections are converted into CalorimeterHits then Trivent does the time event reconstruction and encoding of the hits.

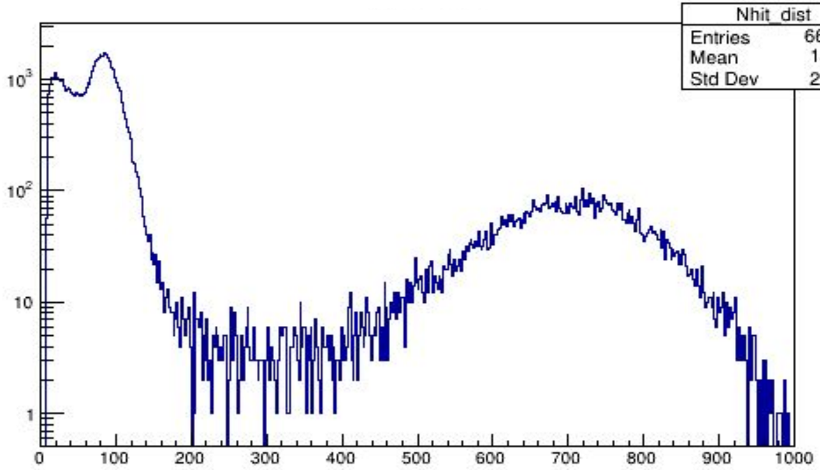
The raw data from 2015 had a DIF header size of 24 bytes and the Slow Control data was not extracted. Before Trivent all the hits from ASICs firing all 64 pad were removed.

Cuts to the reconstructed events:

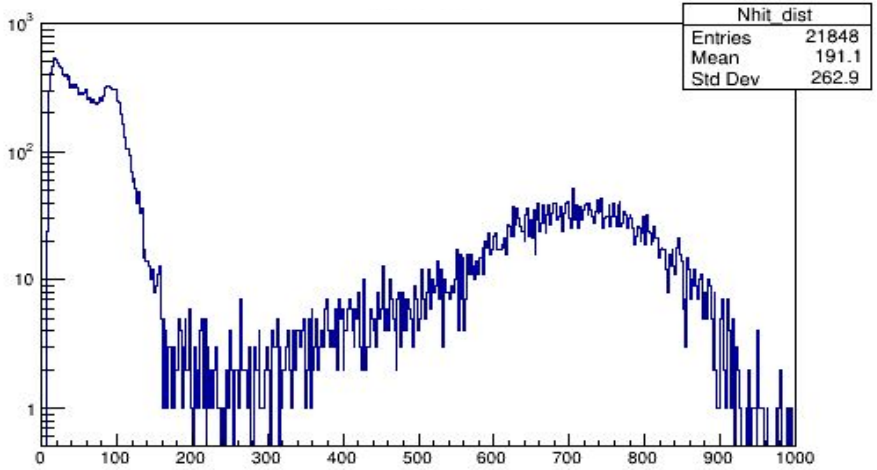
- Total NHit < 200000 in readout (remove electronic noise)
- NHit > 7 in the main bin to start time reconstruction
- NLayers with signal > 7 (removes noise in a single layer)
- NClose GRPCs with signal >= 5 (To be able to reconstruct tracks)
- NHit in the first 10 layers >= 4 & 6 layers >= 3 (This ensures the particle comes from the beam)

Beam NHit distributions, example 40GeV

40 GeV Pions 0º



40 GeV Pions 22º



Particles selection variables

Density: $\rho = \frac{nHit}{nLayers}$

nHit → total number of hits in the detector

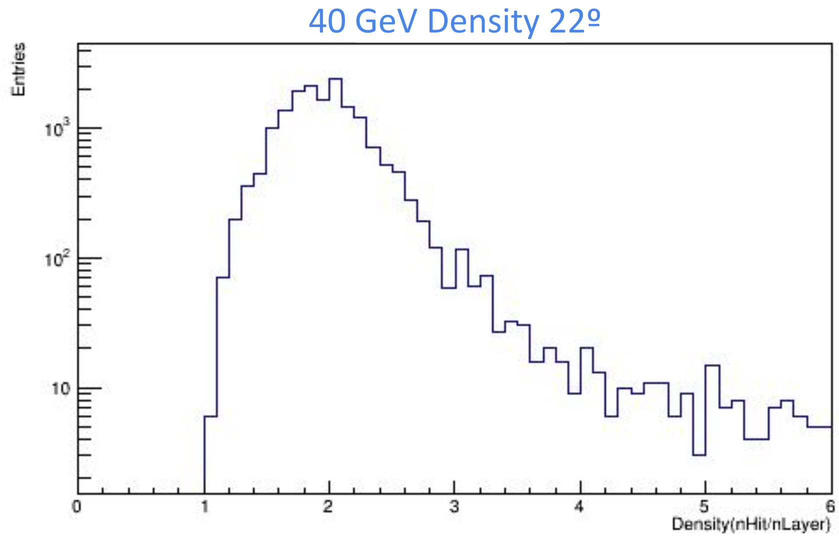
nLayers→ number of layers with signal

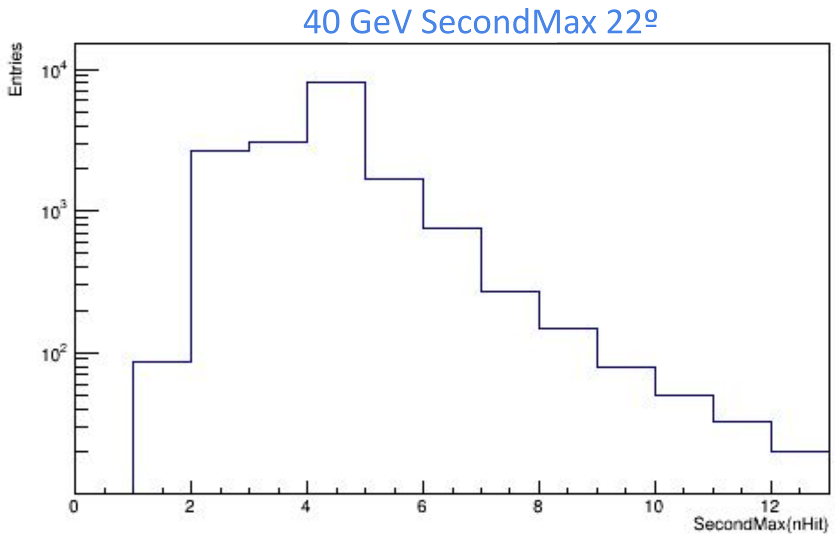
Second maximum of hits in a single layer: Hit_{Max2}

Penetrability Condition (P.C.):

- Layers 00-11: at least 9 with signal
- Layers 12-23: at least 9 with signal
- Layers 24-35: at least 9 with signal
- Layers 36-48: at least 9 with signal

Particle selection variables





Selected cuts: Muons/Cosmics →(density < 3 or SecondMax < 5) and P.C. separates cosmics and muons
Showers → All events that not fall in the above selection

Track reconstruction

Steps for the reconstruction of the track:

- A first approximation by taking the mean value of all clusters in each layer.
- This approximation is fitted to a straight line.
- Then the closest cluster with a distance less than 20.8 mm in X and Y to the previous approximation is selected for each layer. (It is possible that a layer has no cluster selected)
- The final track is the set of selected clusters fitted to a straight line
- Tracks with less than 5 layers with clusters selected are discarded

Finally the following cuts to the slope in the Y axis are applied:

$$|\alpha| < 0.05$$

Angle computing

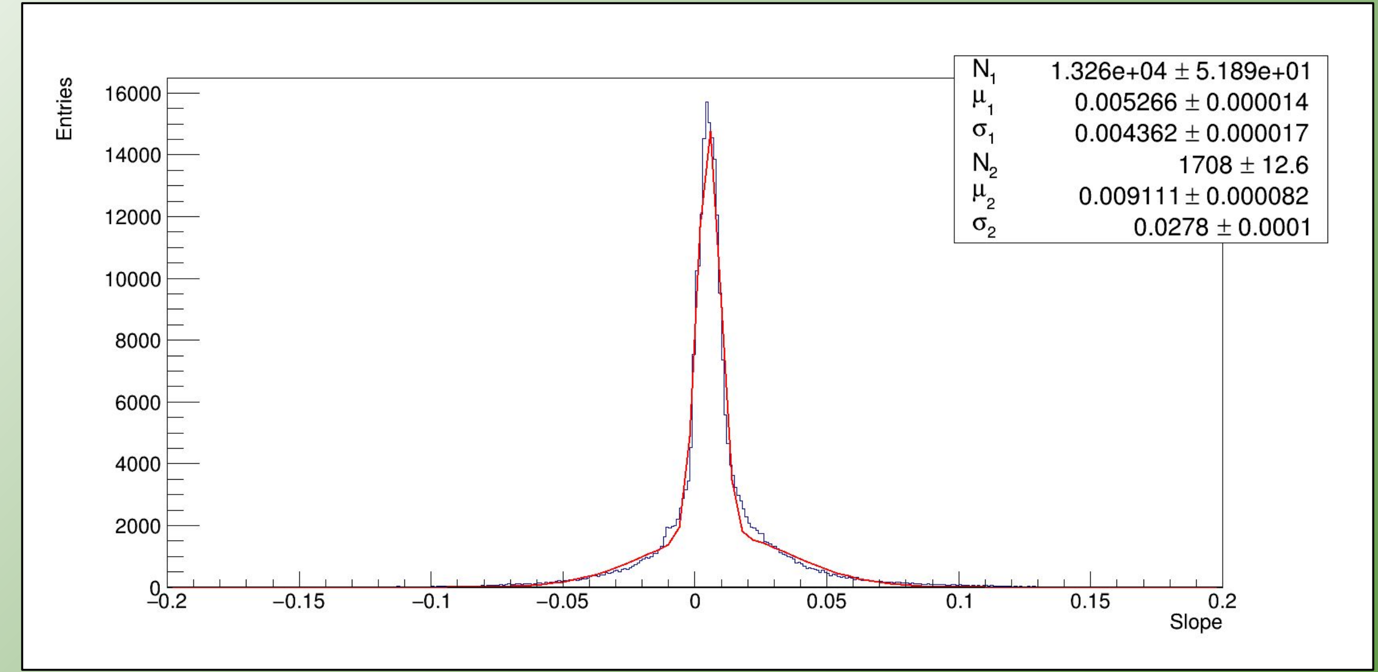
So far the angle of the data have been approximated from measurements during the test beam. However, we will compute a more precise value of the incident angle in the X axis from the tracks of the muons.

The distributions of the slopes are fitted to a Gaussian distribution if they are wide or to a sum of two Gaussians if the main gaussian is thin enough that the background of tracks not properly reconstructed is relevant.

Case A → $Gauss(x) = Ne^{-\frac{(\mu - x)^2}{2\sigma^2}}$

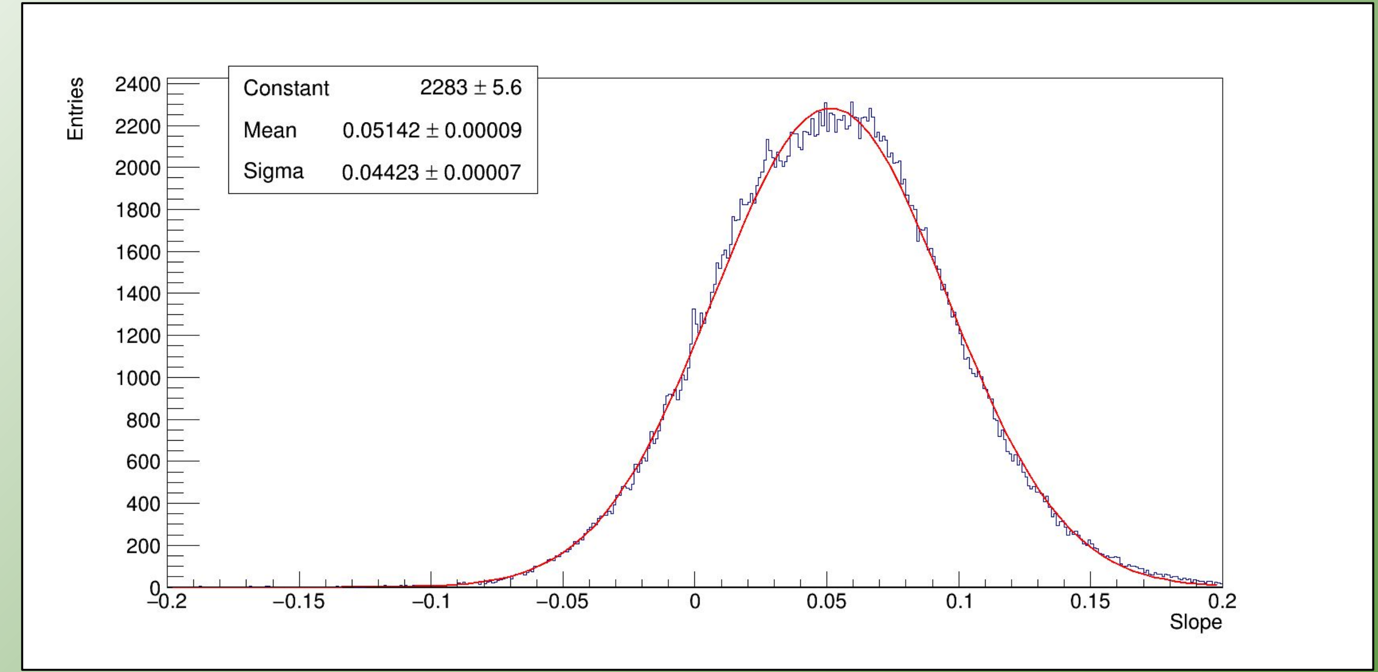
Case B → $f(x) = Gauss_1(x) + Gauss_2(x)$

Angle computing - 0º SPS



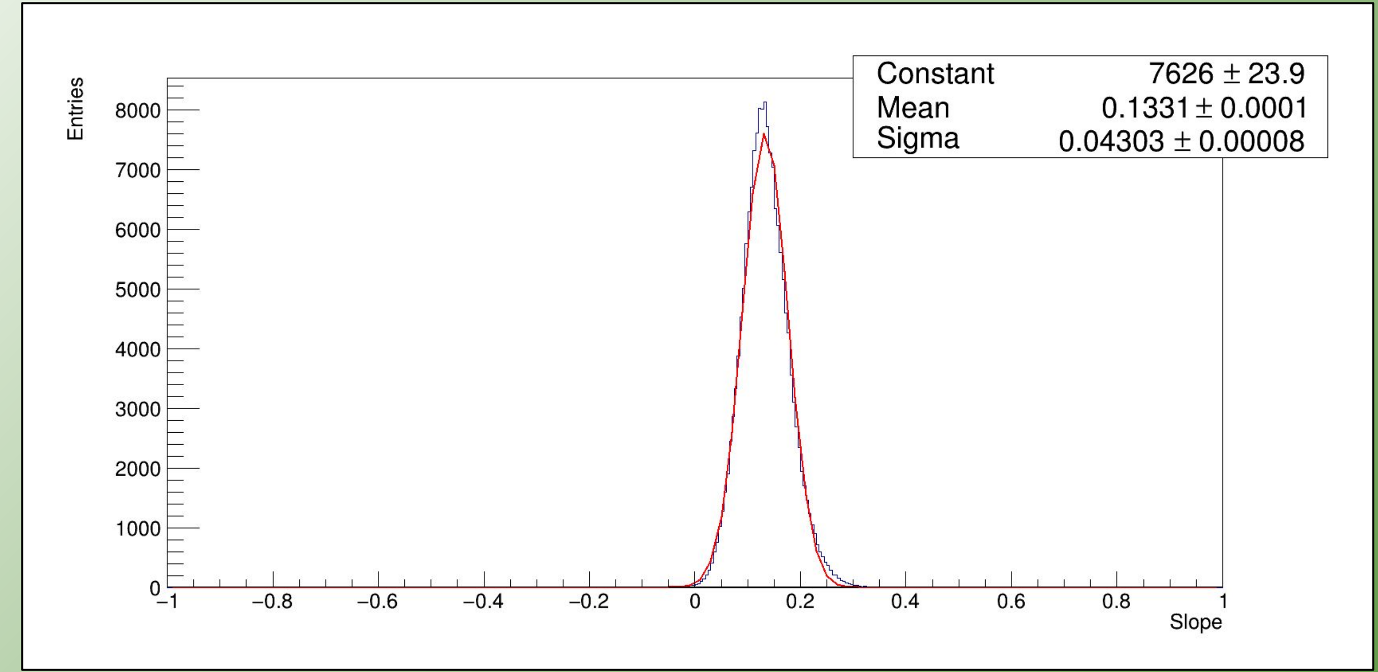
$$\theta_X = 0.30 \pm 0.25$$

Angle computing - 0º PS



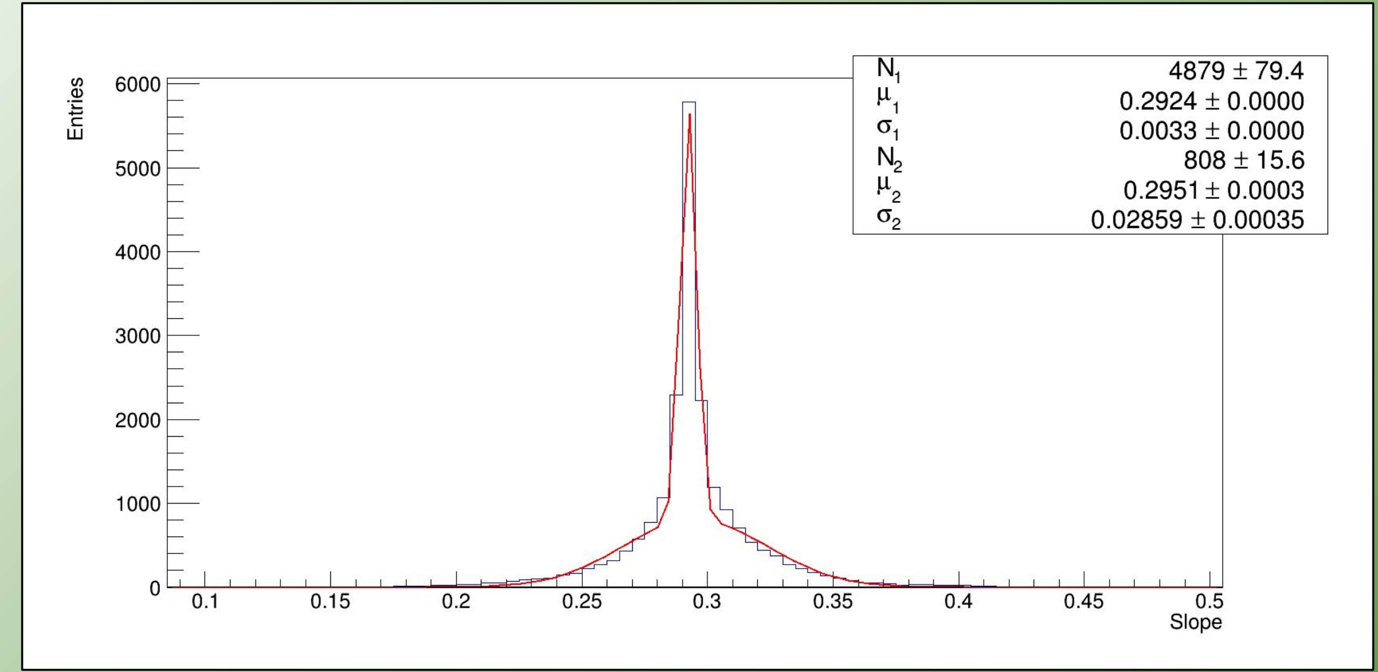
$$\theta_X = 2.95 \pm 2.53$$

Angle computing - 10º



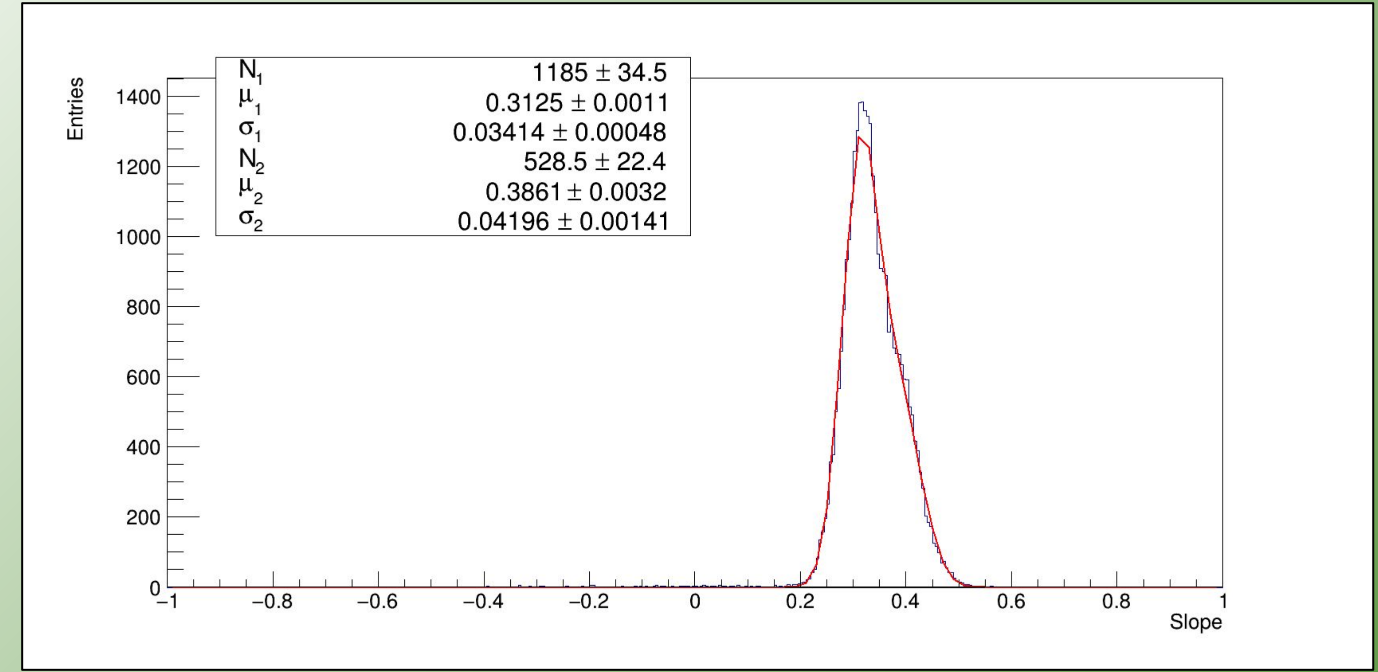
$$\theta_X = 7.63 \pm 2.46$$

Angle computing - 20º SPS



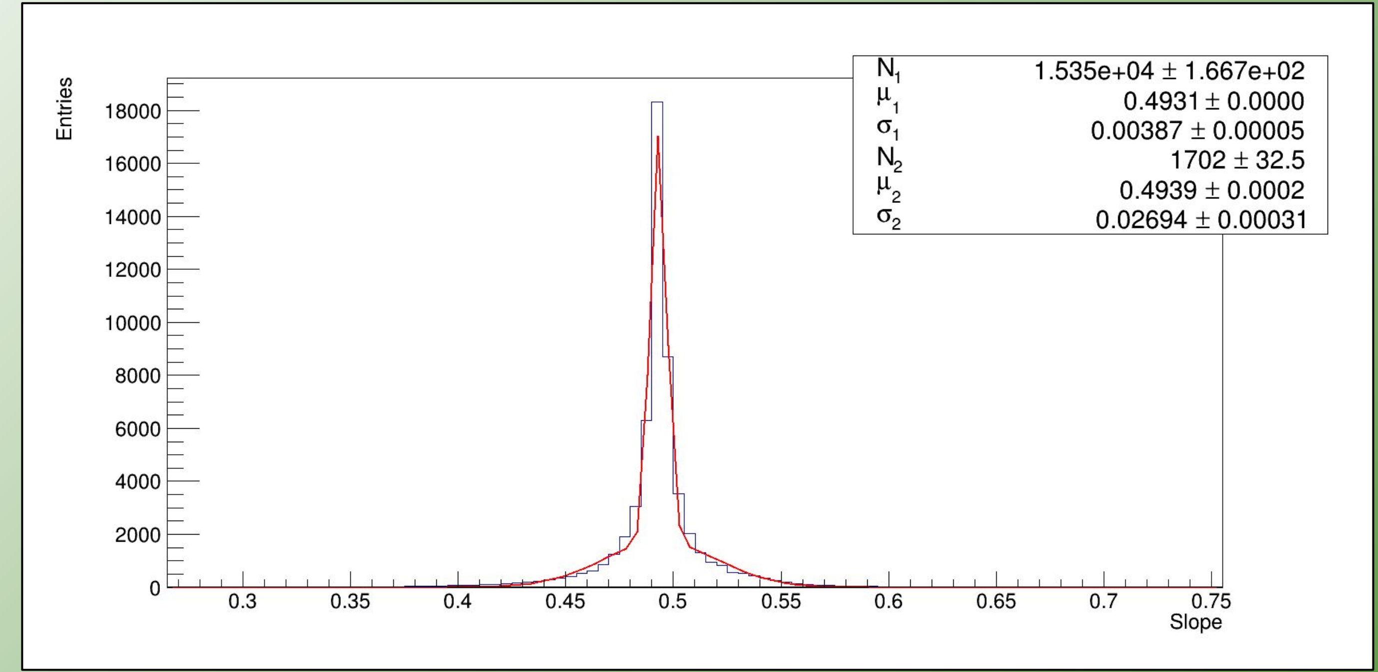
$$\theta_X = 16.75 \pm 0.19$$

Angle computing - 20º PS



$$\theta_X = 17.90 \pm 1.96$$

Angle computing - 22º



$$\theta_X = 28.25 \pm 0.22$$

Muons analysis

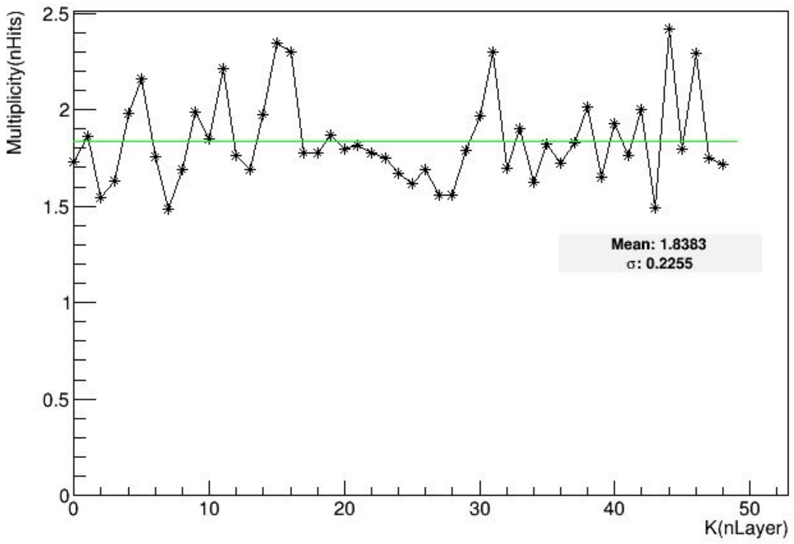
We can use the track of muons to compute the efficiency and multiplicity of each GRPC layer in the prototype. First we recompute the track of the muon using all the chambers but the one we are going to study then:

Efficiency → The layer is efficient if it has a cluster of hits closer than 20.8 mm in X and Y. The final efficiency is the sum of times the layer has been efficient divided by the total number of muons analyzed.

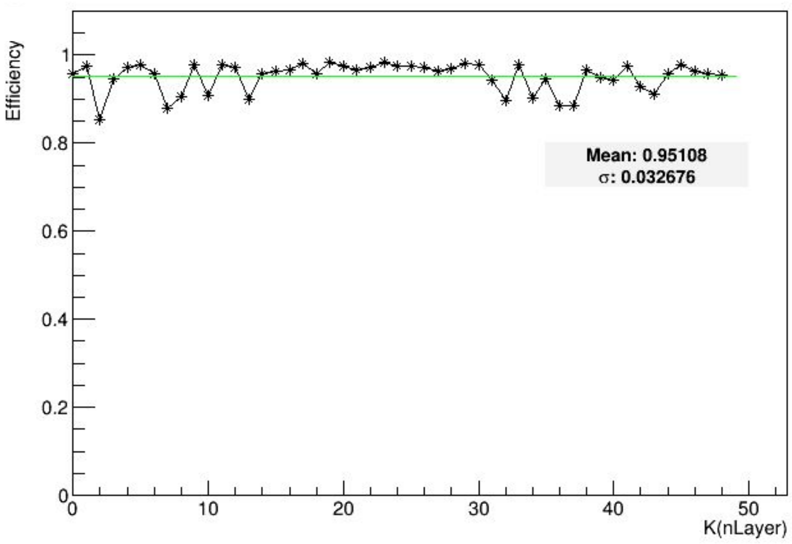
Multiplicity → If the layer is efficient then the multiplicity is the size of the cluster found Then we take the mean by all muons analyzed.

Analysis results 0.3º SPS

Multiplicity



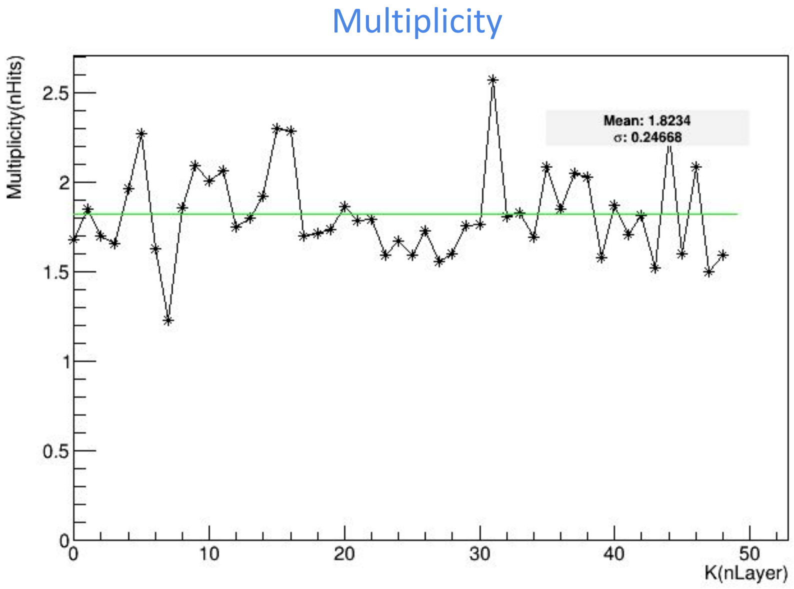
Efficiency

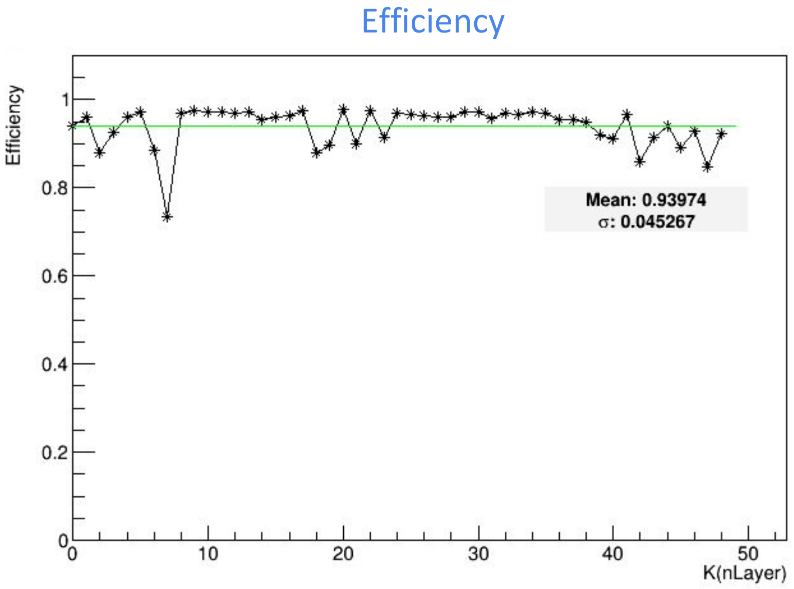


$$\sigma_{Mult} = \frac{1}{nLayers} \sum_{i=1}^{nLayers} (Mean - Mult_i)^2$$

$$\sigma_{Eff} = \frac{1}{nLayers} \sqrt{Mean(1 - Mean/nLayers)}$$

Analysis results 2.95º PS





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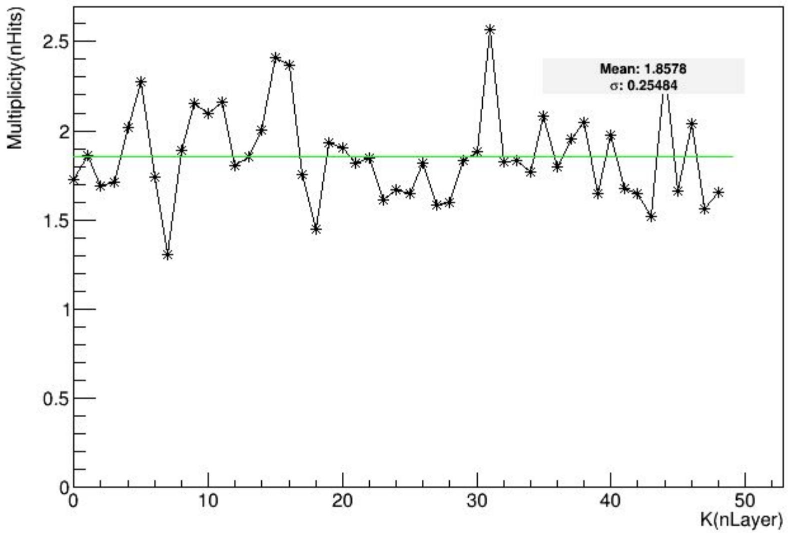

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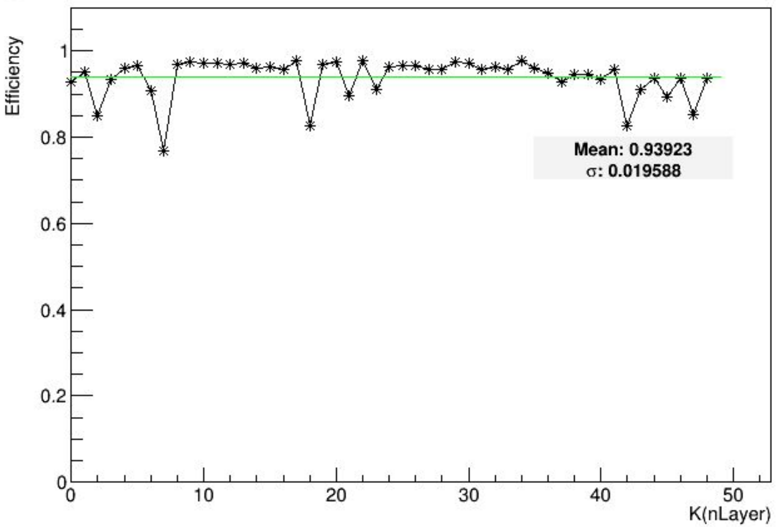

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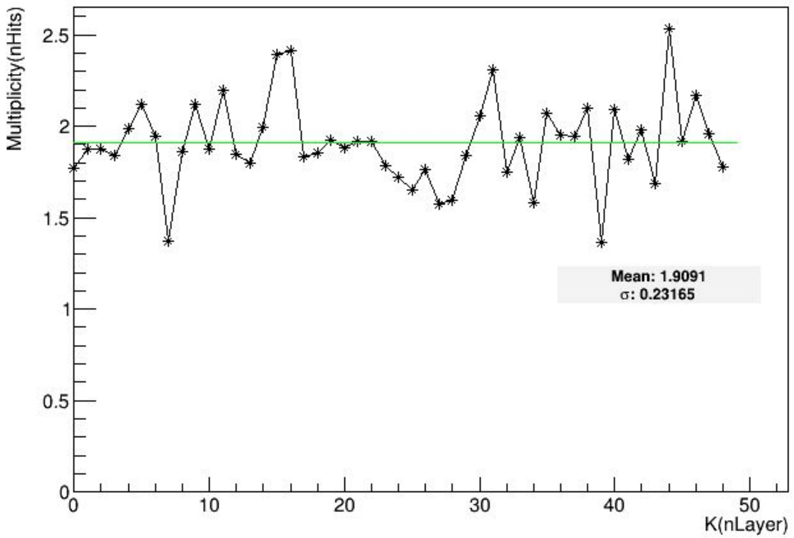
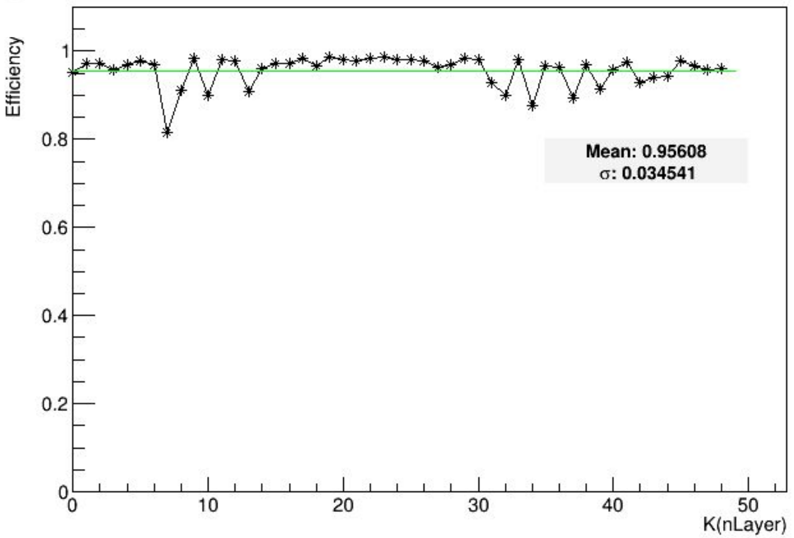


Efficiency



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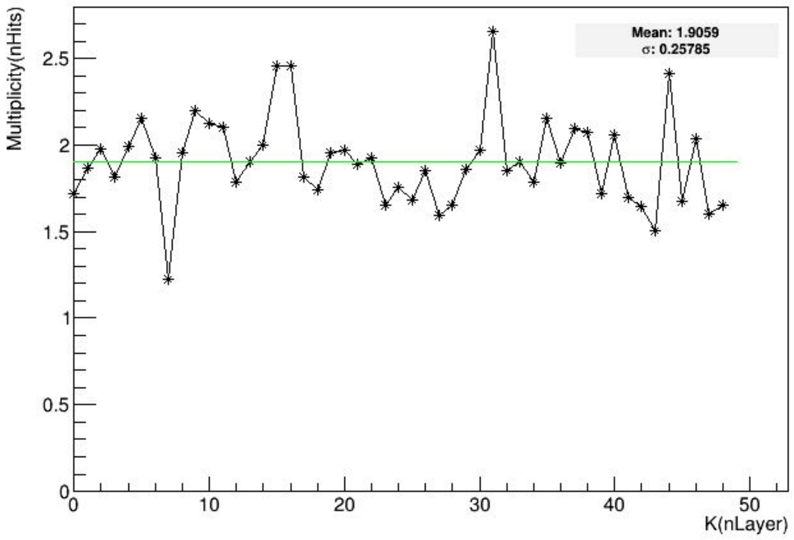

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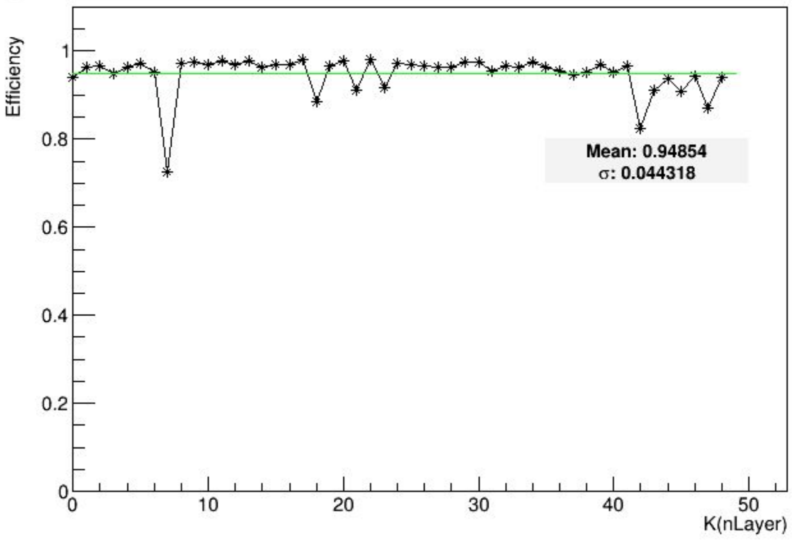

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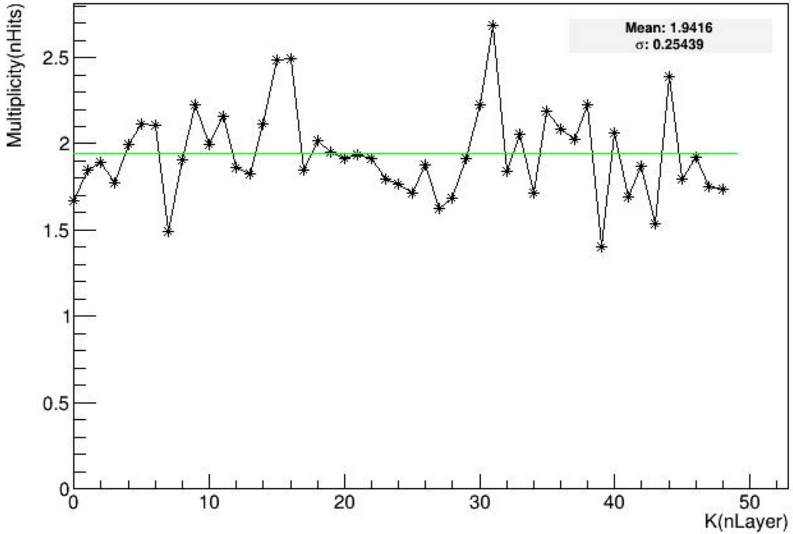
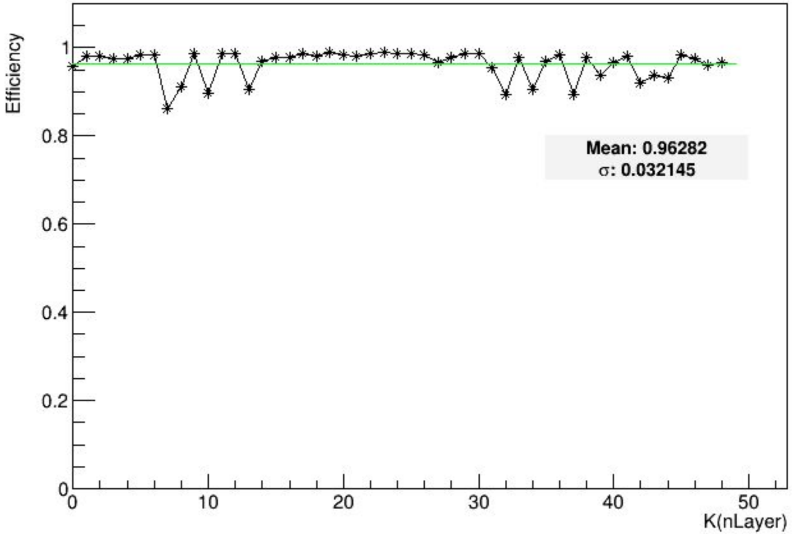
Analysis results 28.25º

Multiplicity



Efficiency



$$\sigma_{Mult} = \frac{1}{nLayers} \sum_{i=1}^{nLayers} (Mean - Mult_i)^2$$

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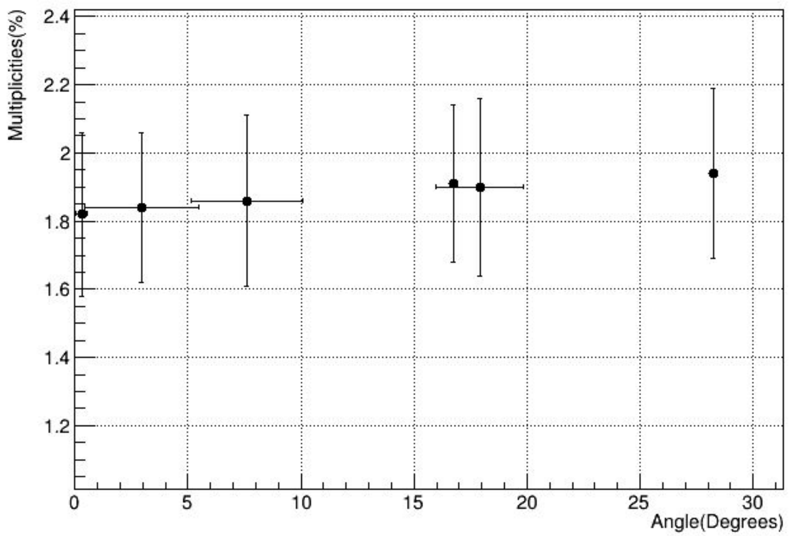
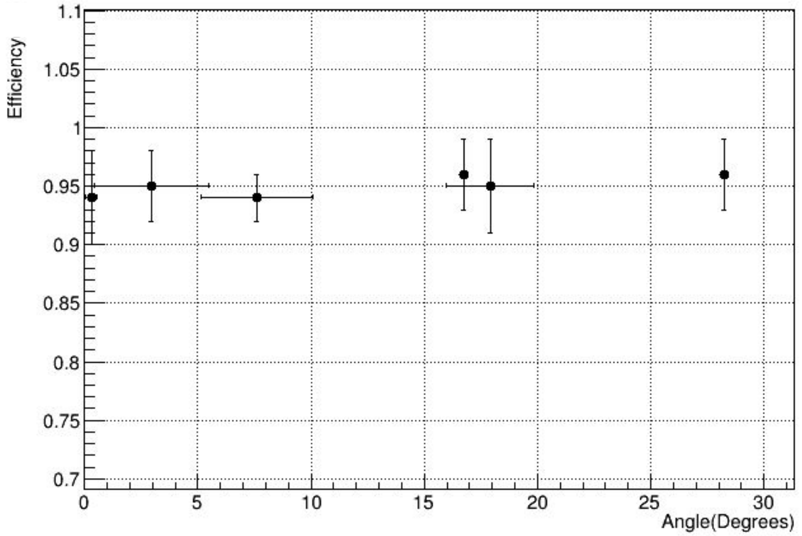
Analysis results all angles

Multiplicity



Efficiency



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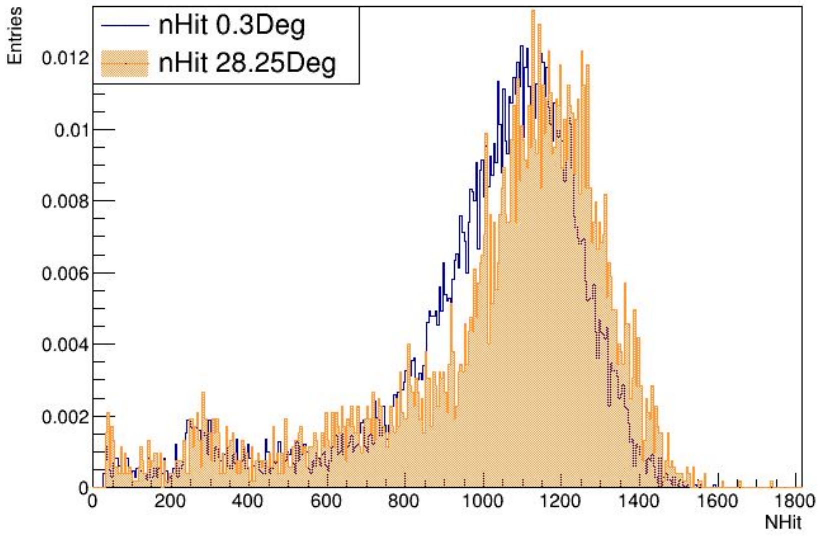
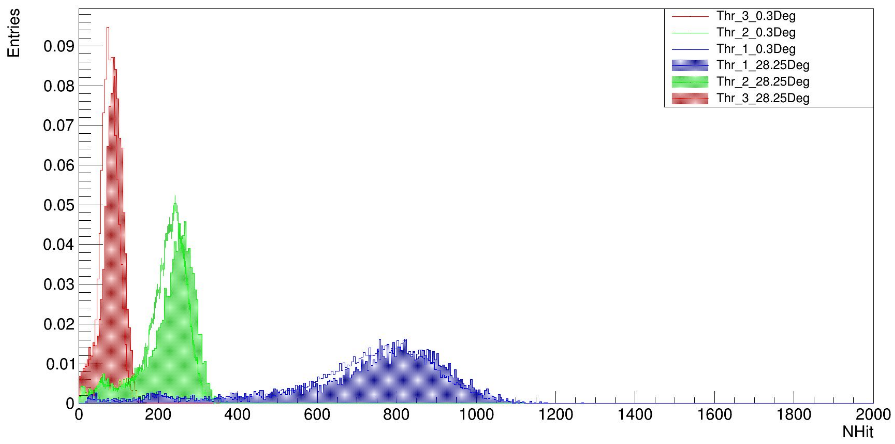
Hit distributions comparison

The effect of the incident angle is also present in the hit distributions and it translates into an effect in the energy reconstruction.

Total nHits distribution



Threshold distributions



Conclusion & next steps

We have shown that indeed there is a slight change in the multiplicity and efficiencies of the chambers due to incident angle.

Now the next steps is to search if the influence of the angle is more noticeable in the energy reconstruction in the semi-digital mode of operation.

Backup

Profiles 0.3º SPS

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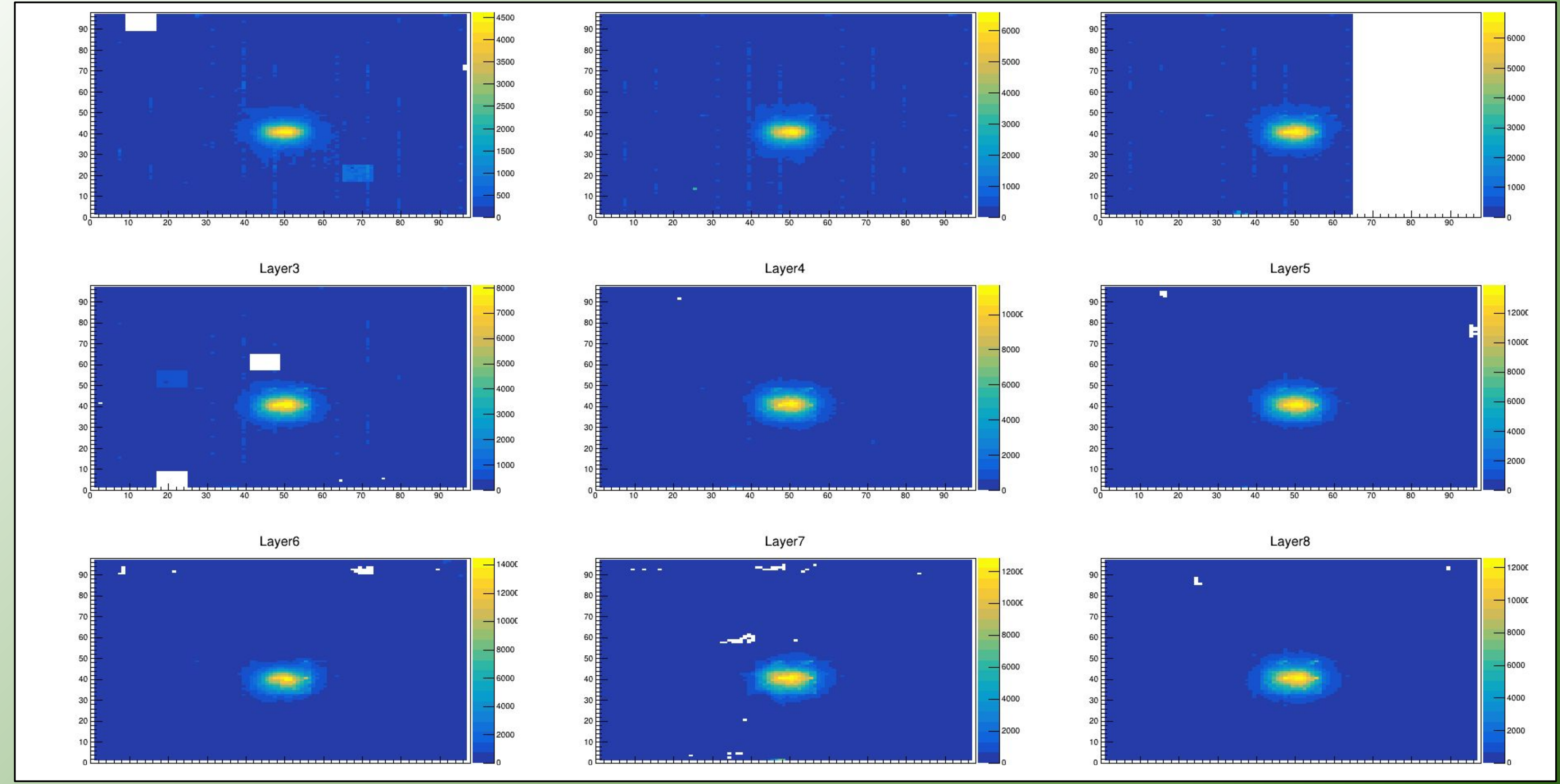

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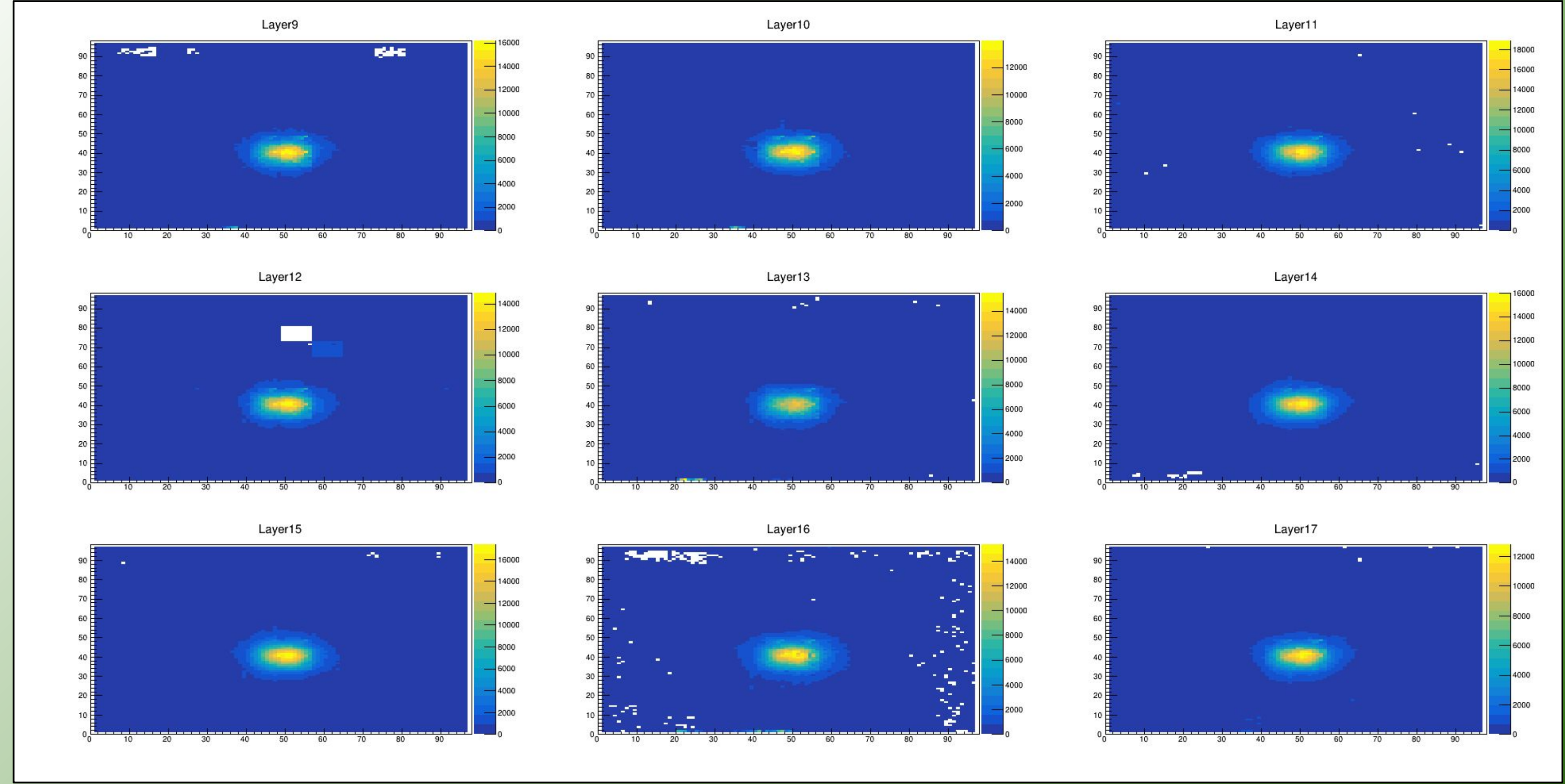

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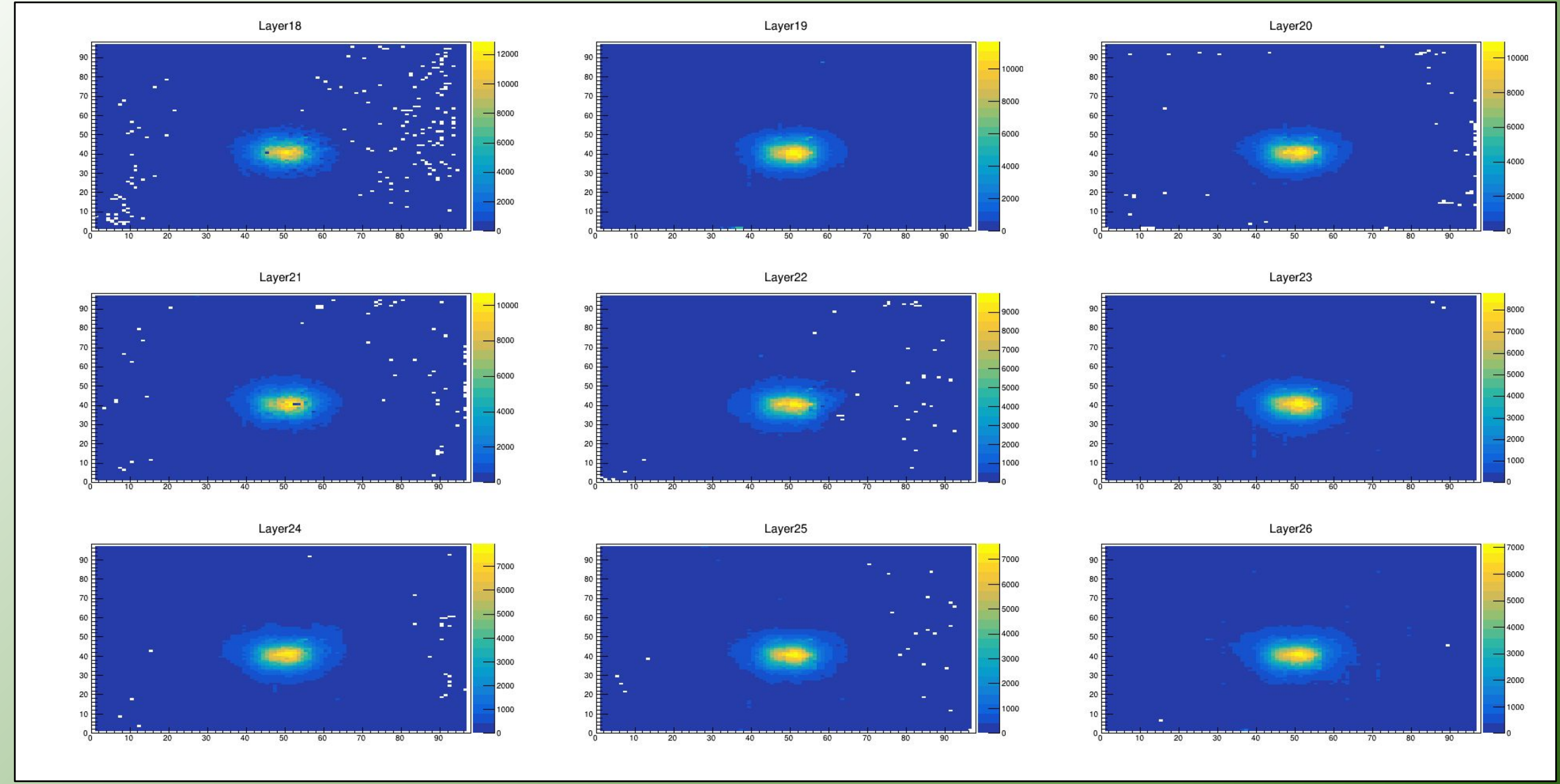

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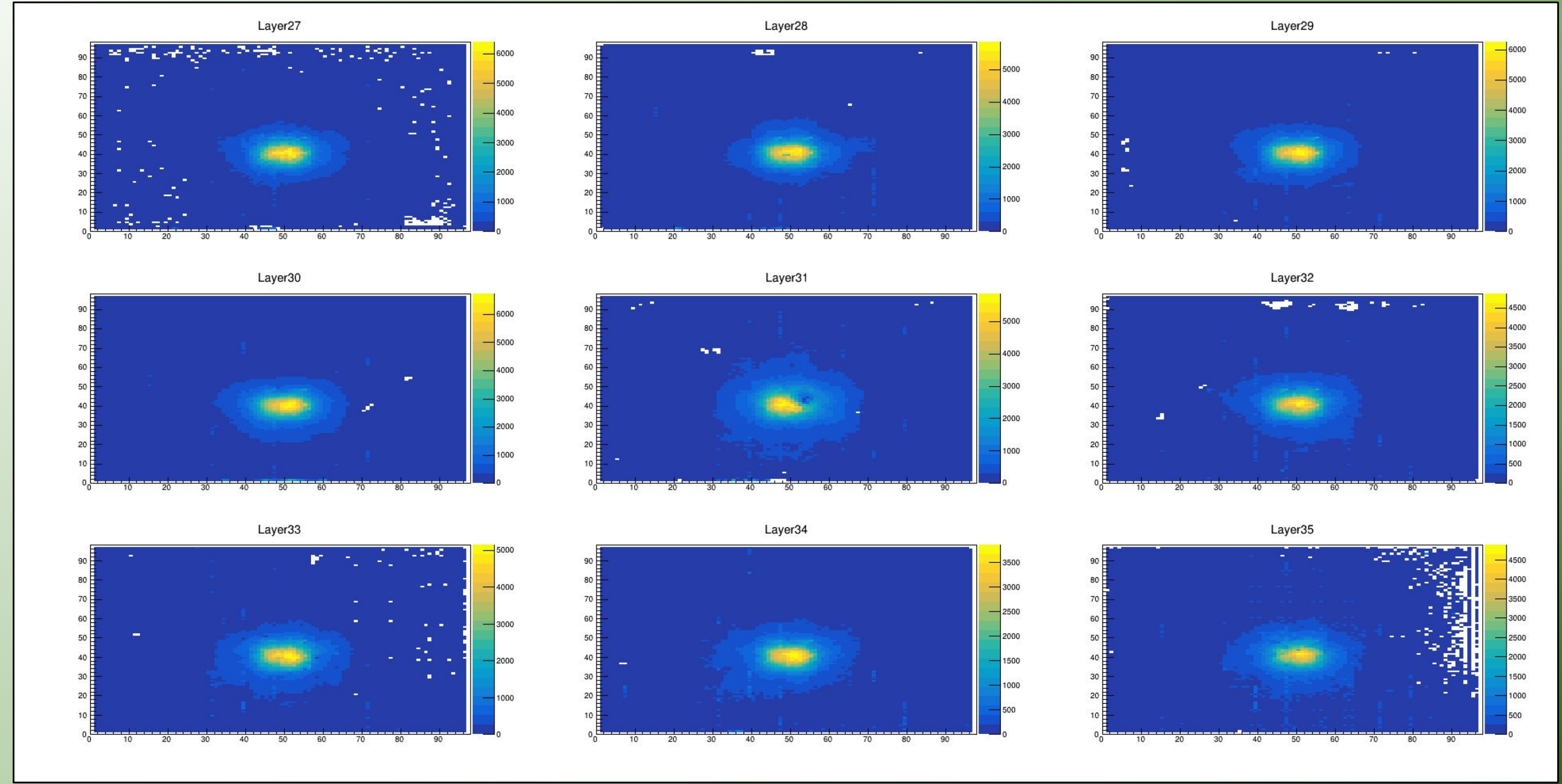

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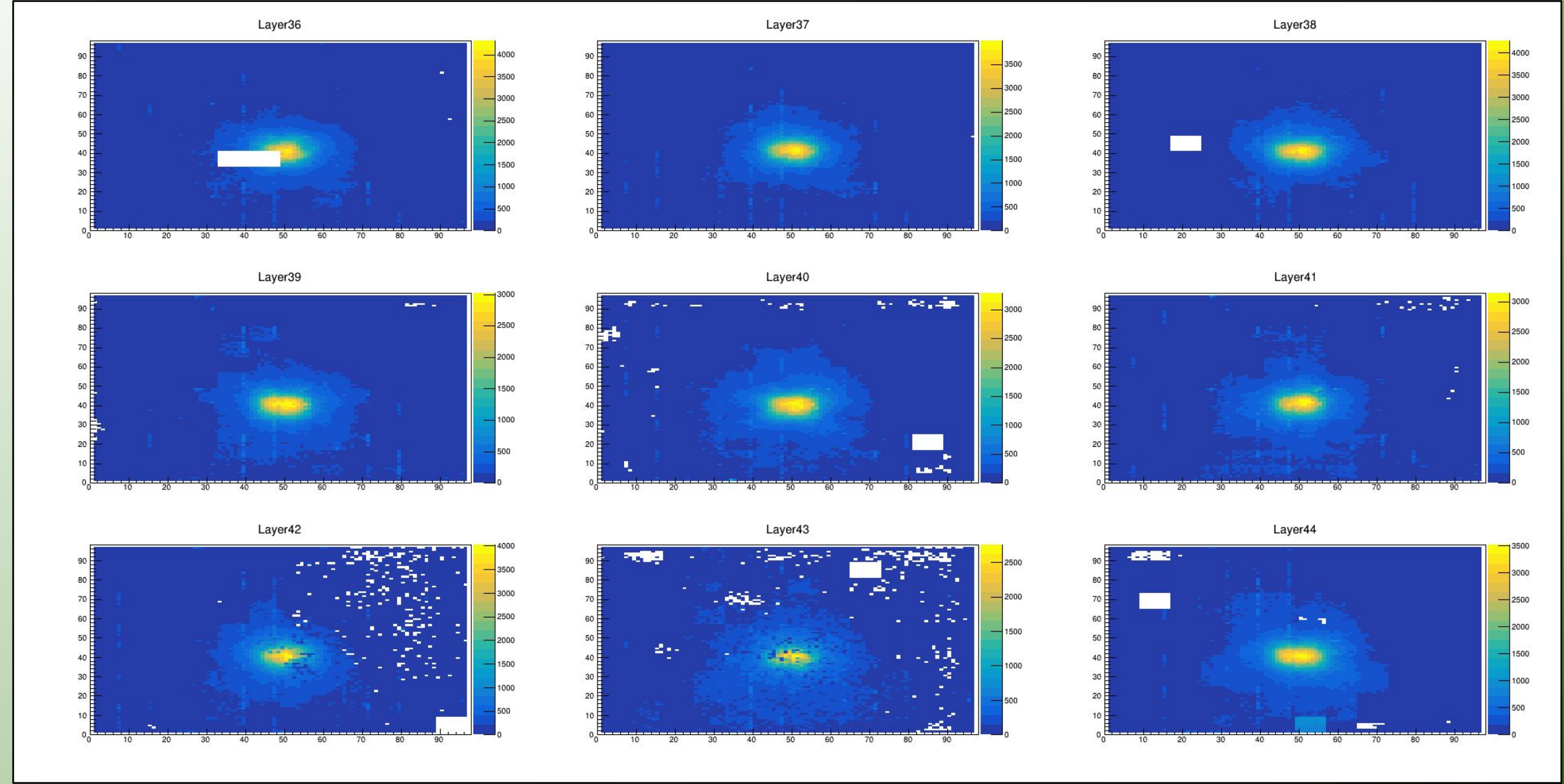

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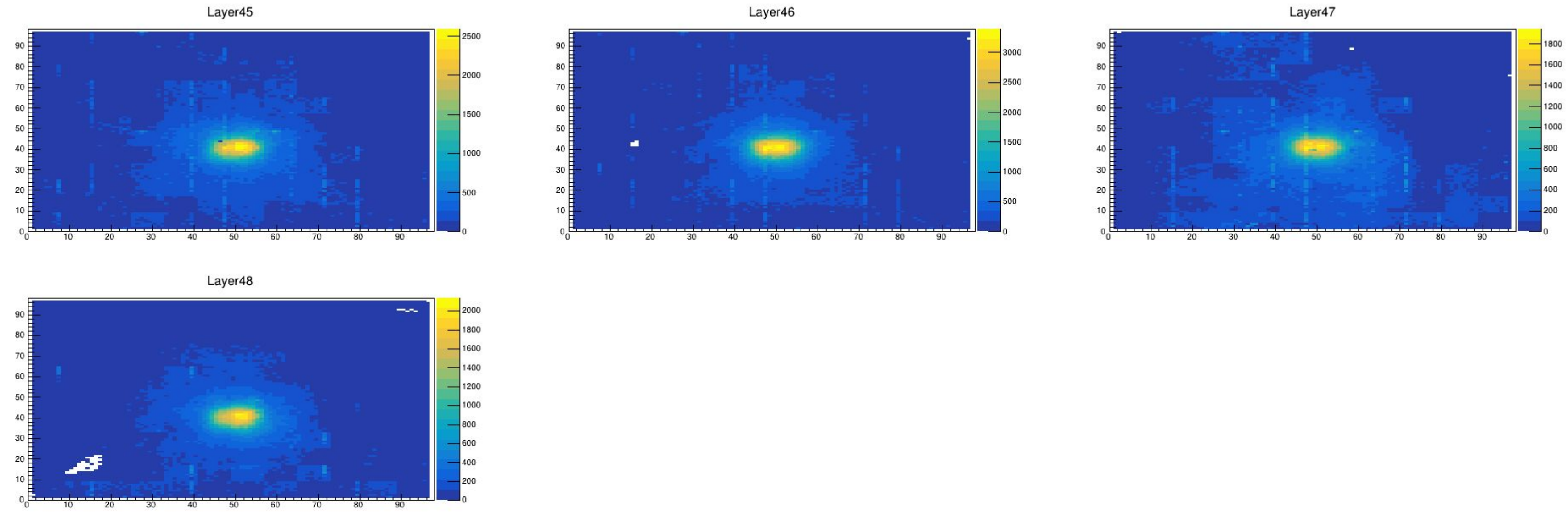

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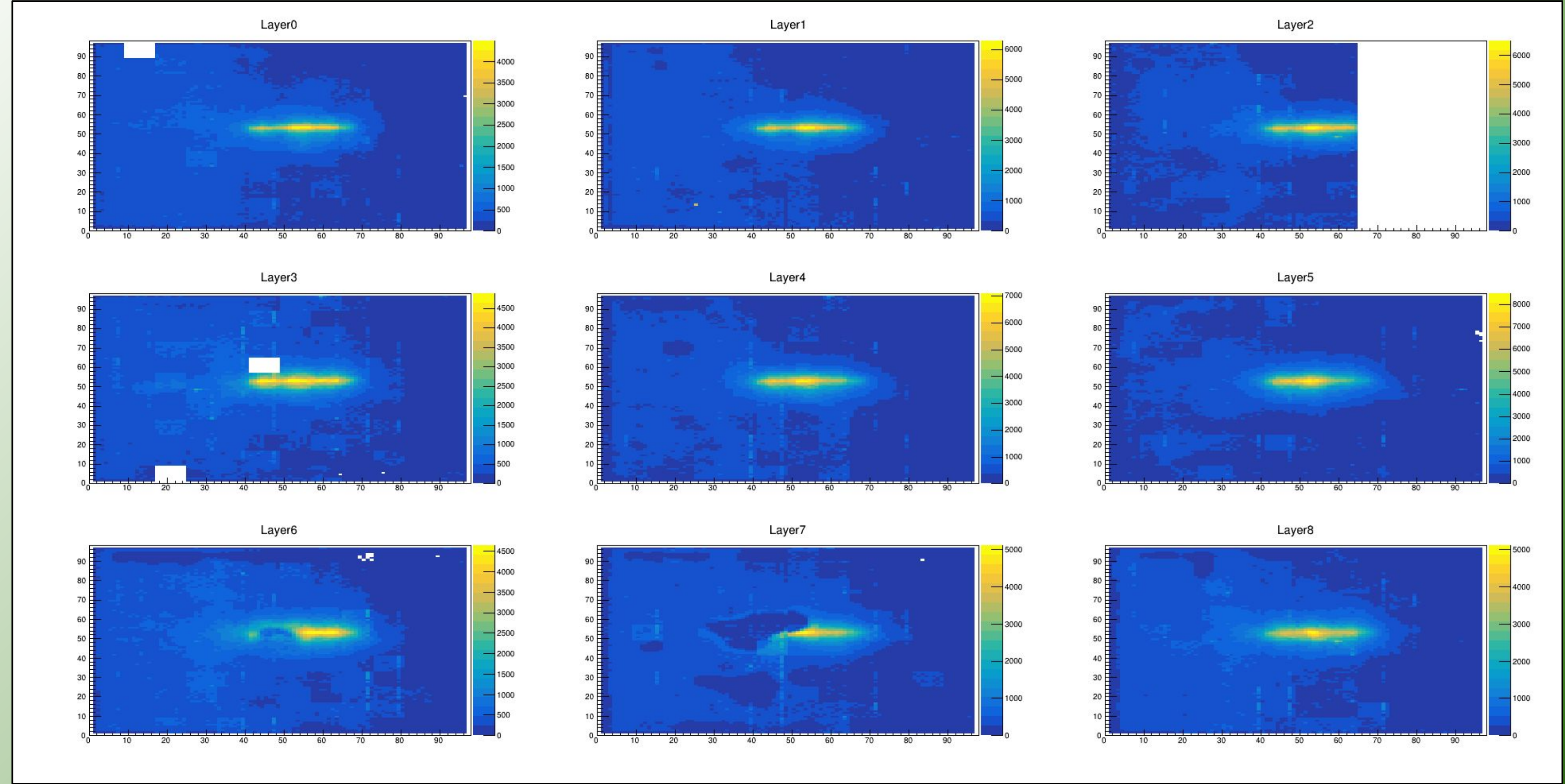

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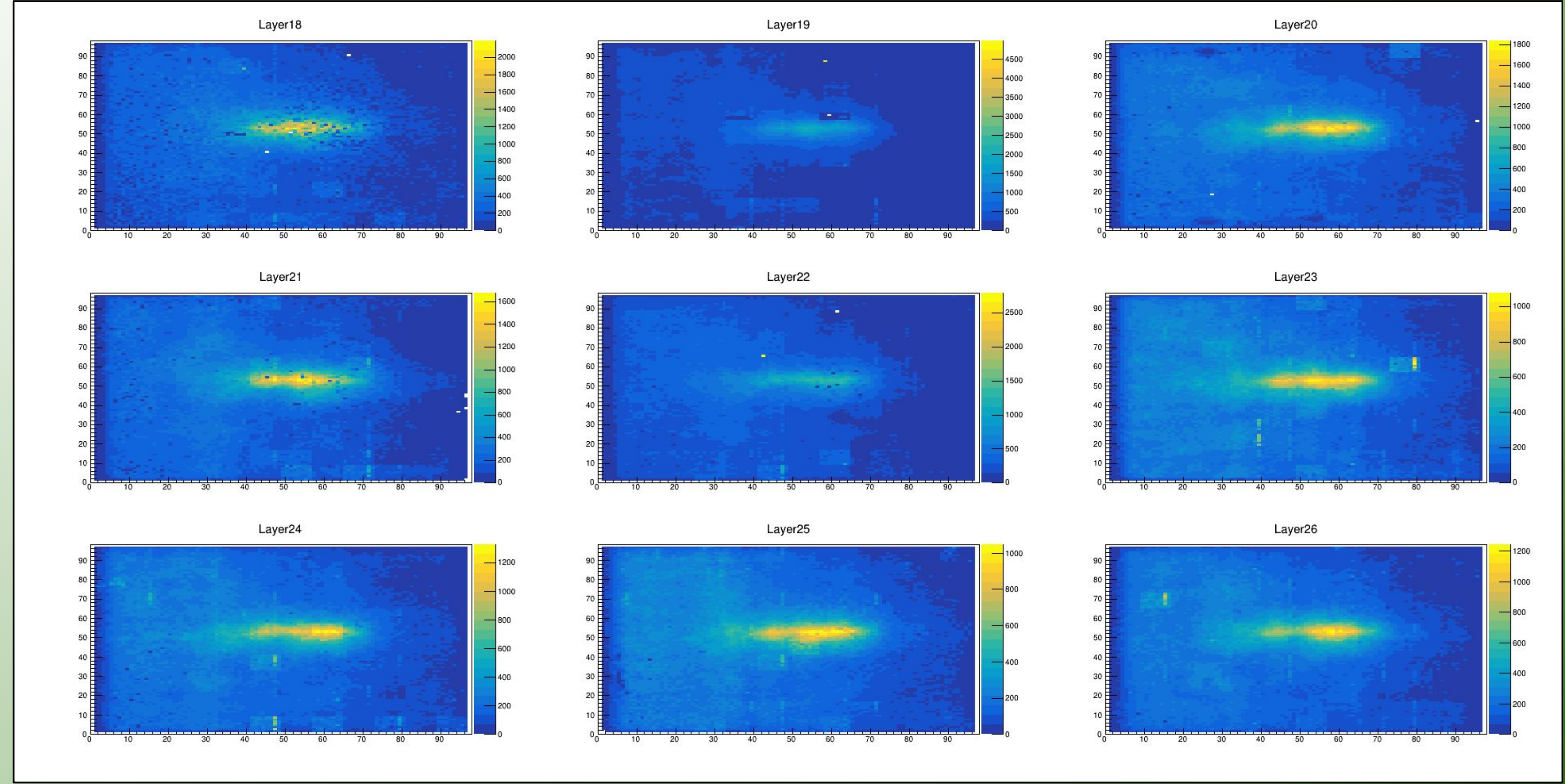

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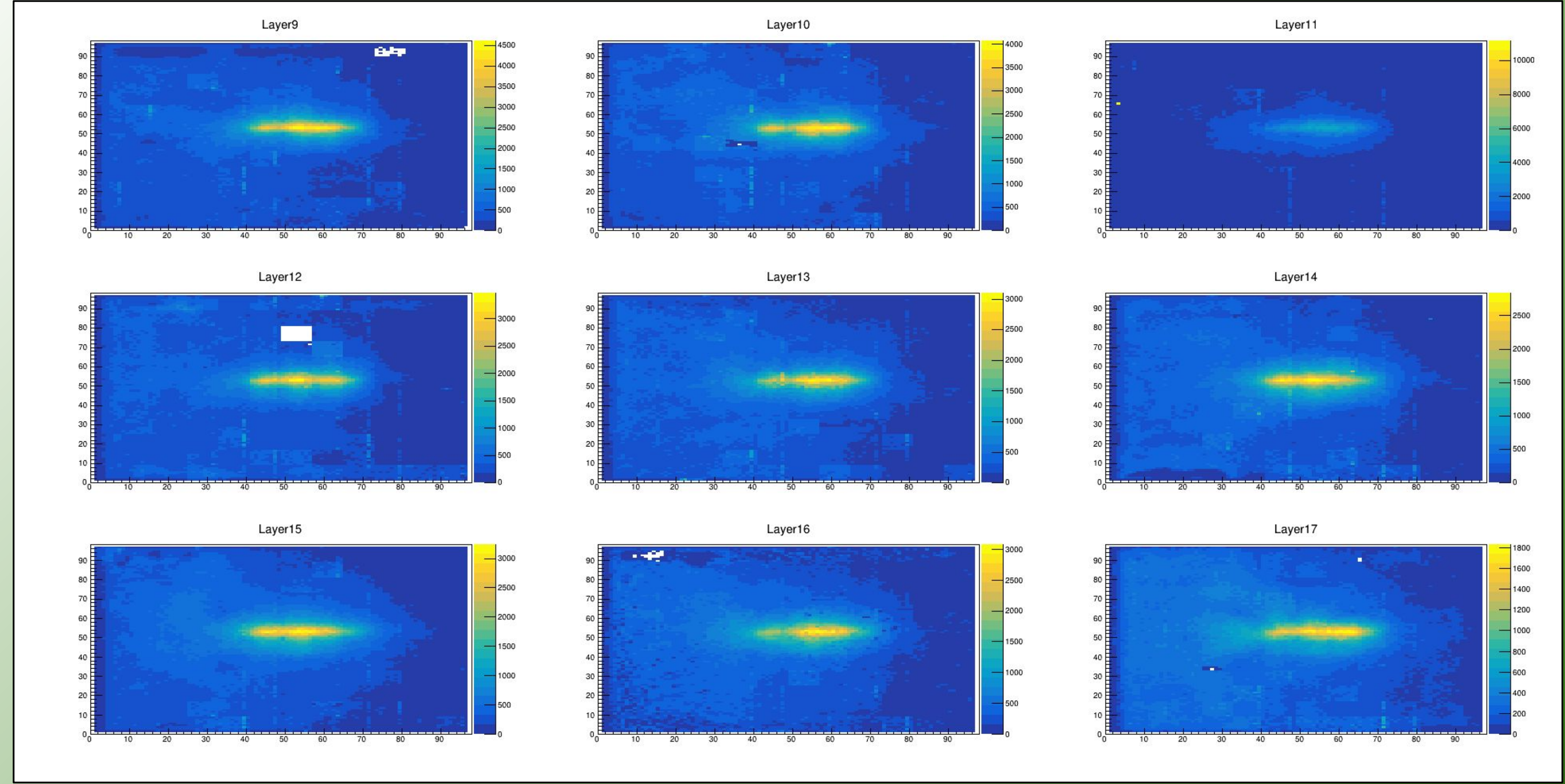

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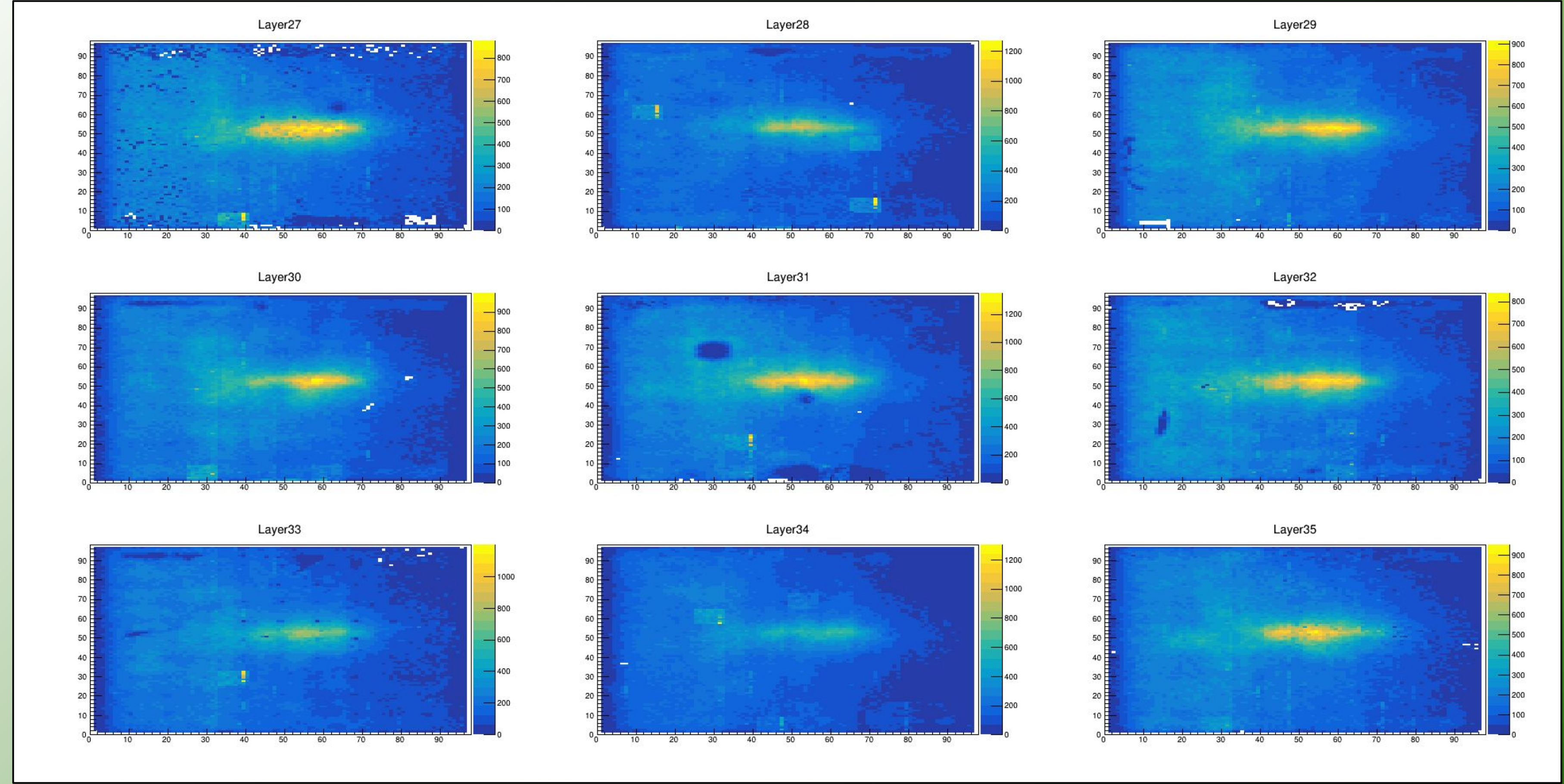

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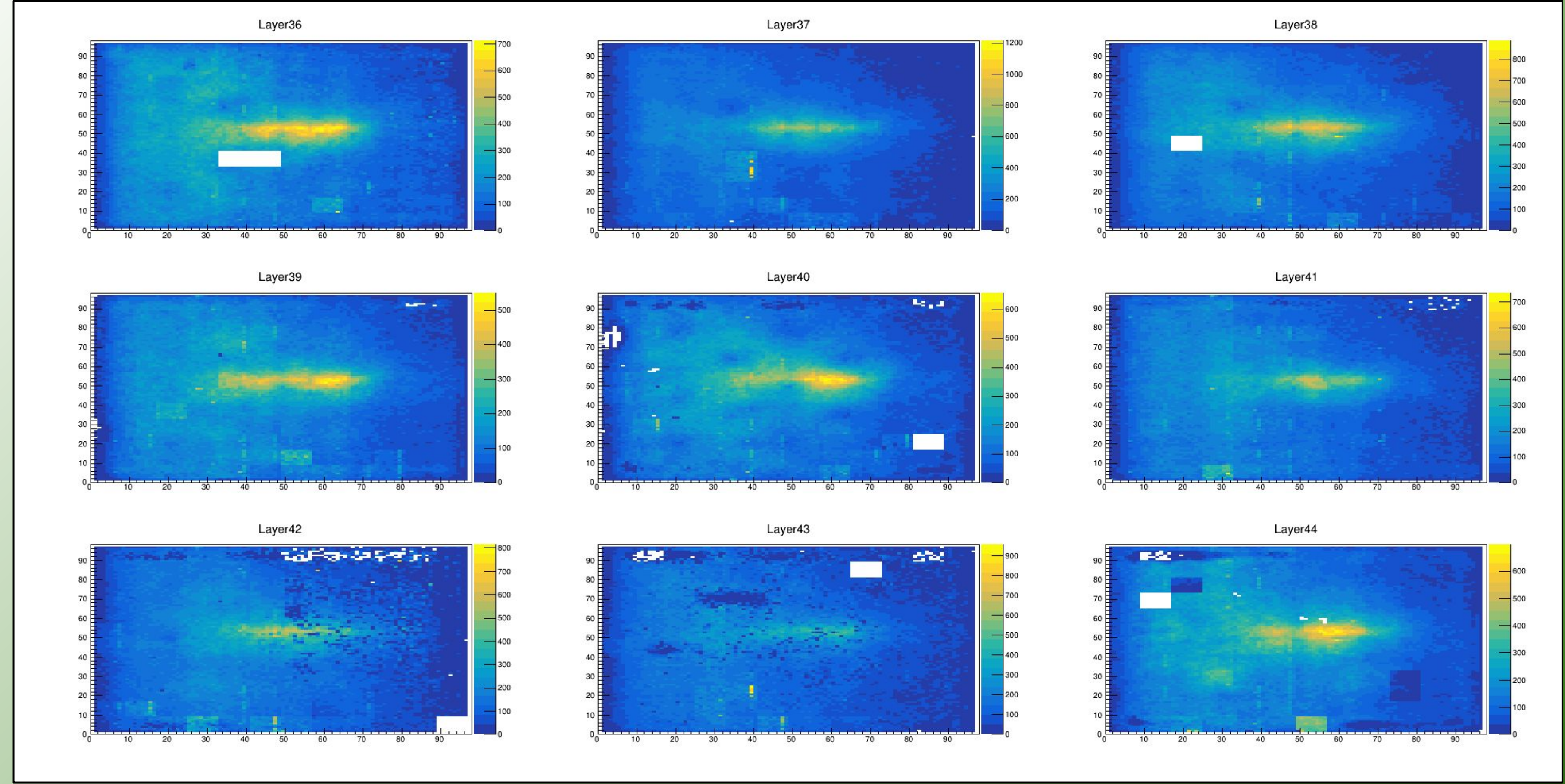

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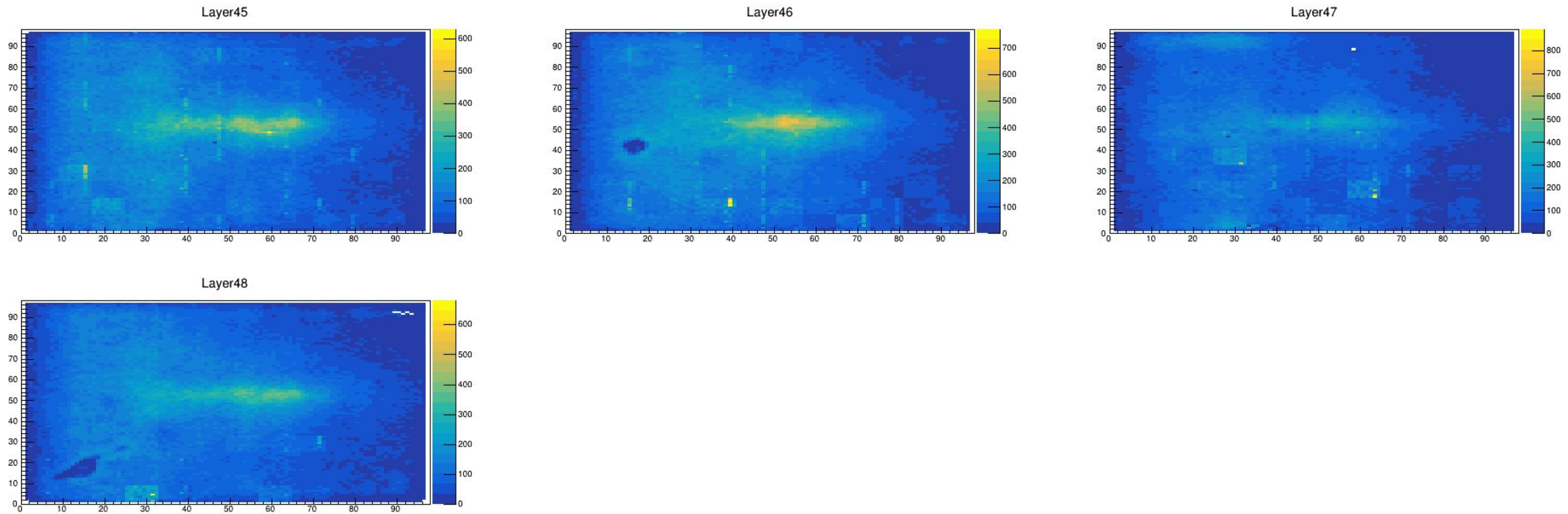

Profiles 7.63°

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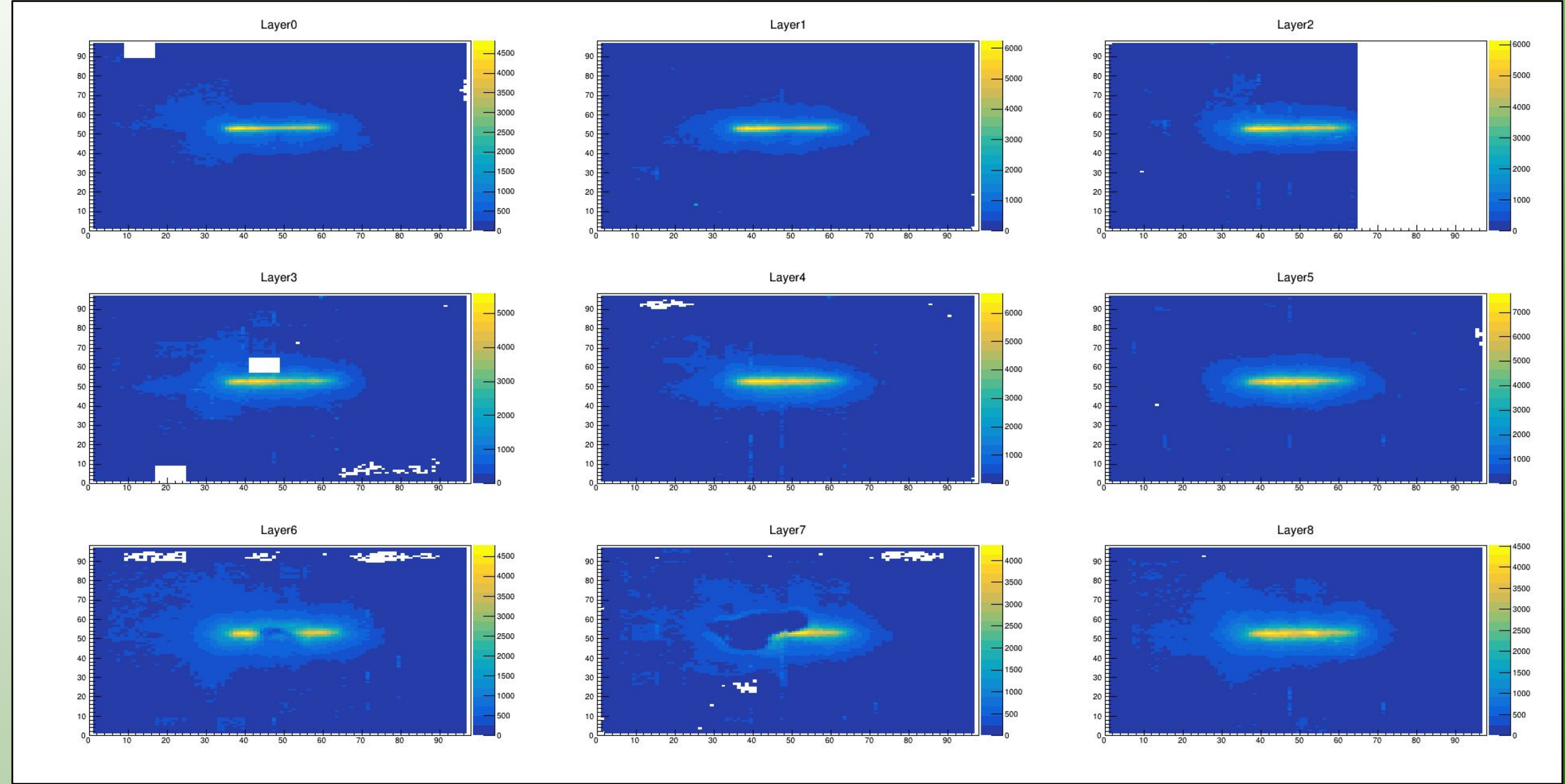

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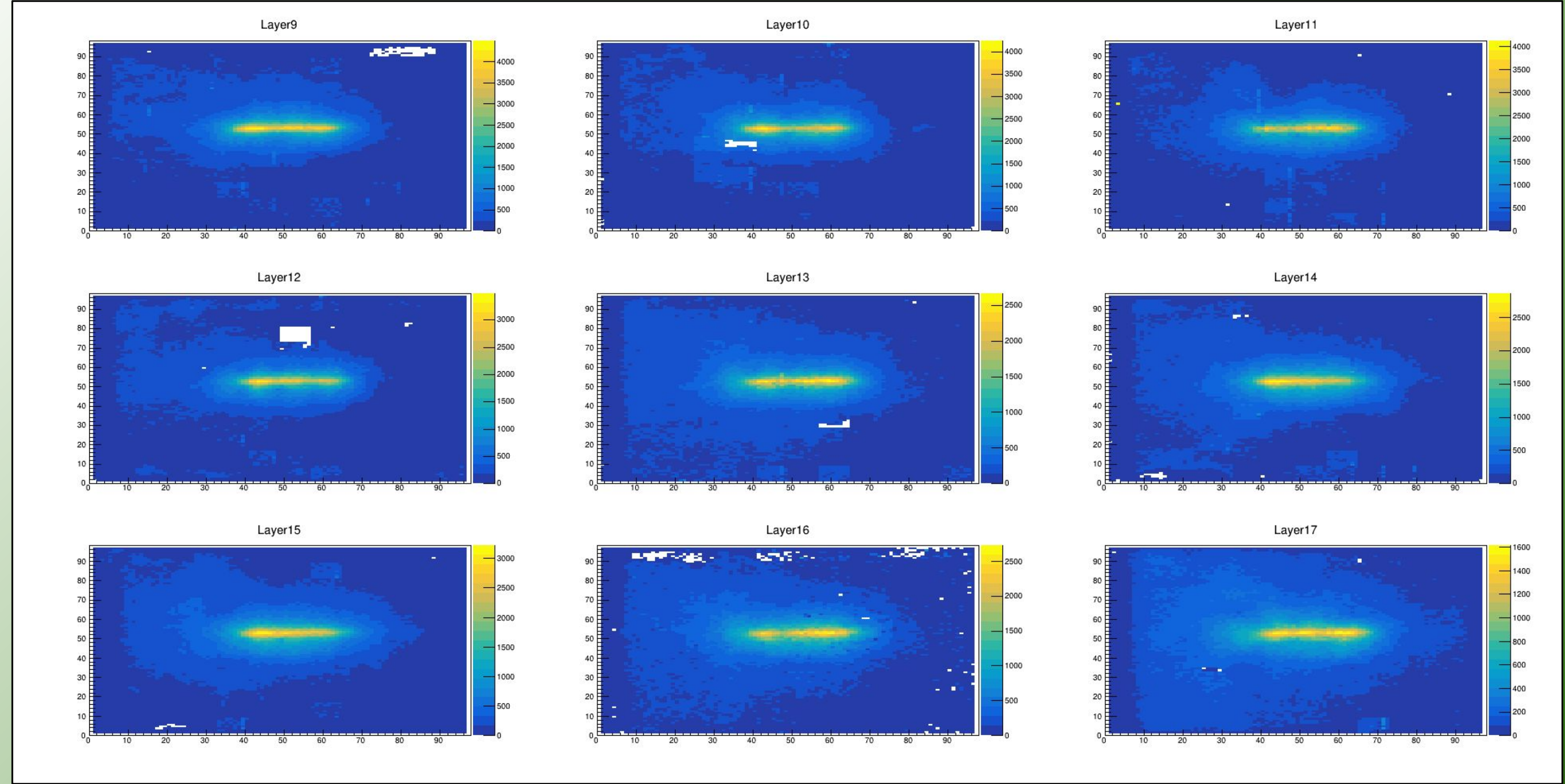

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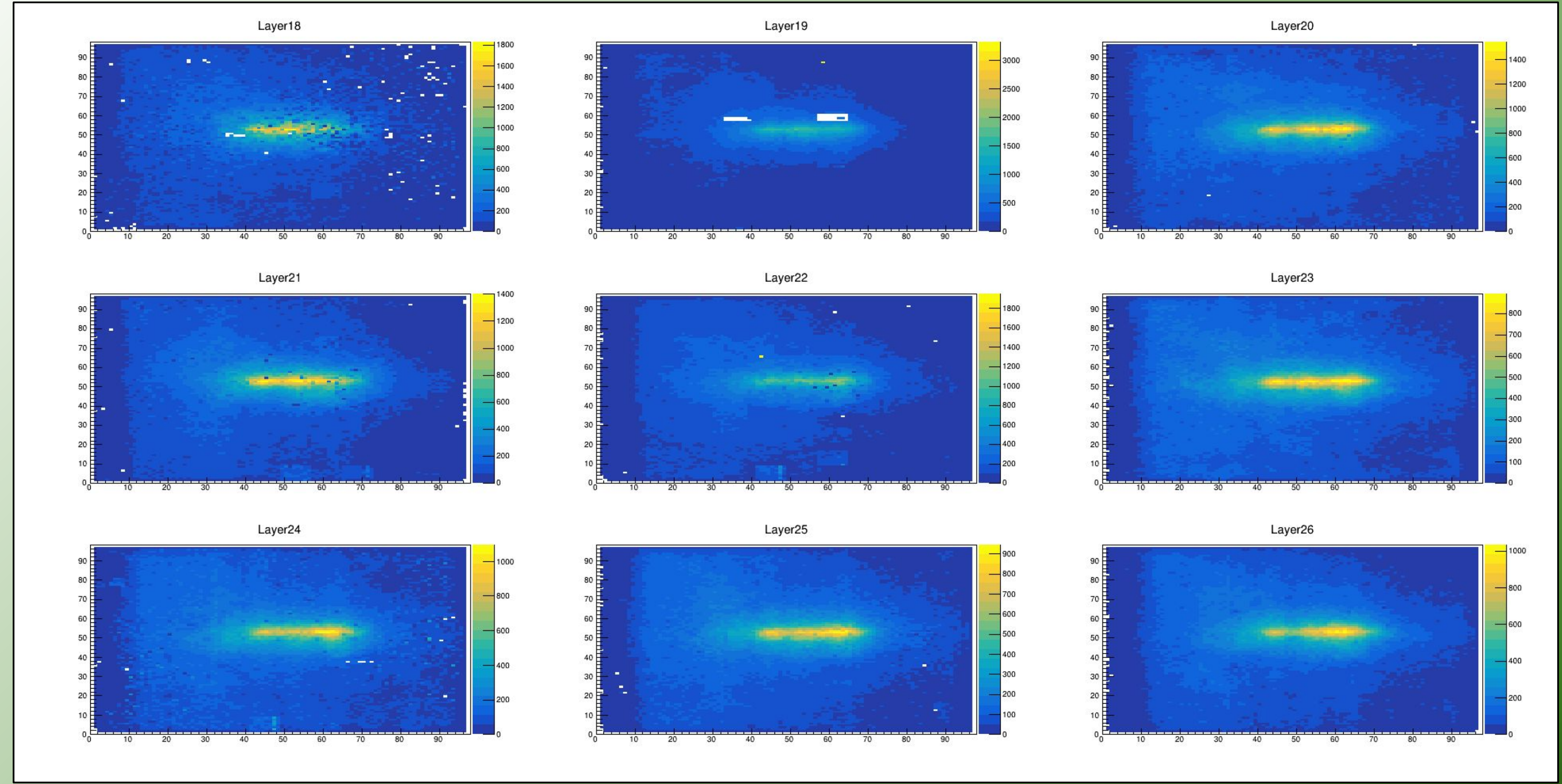

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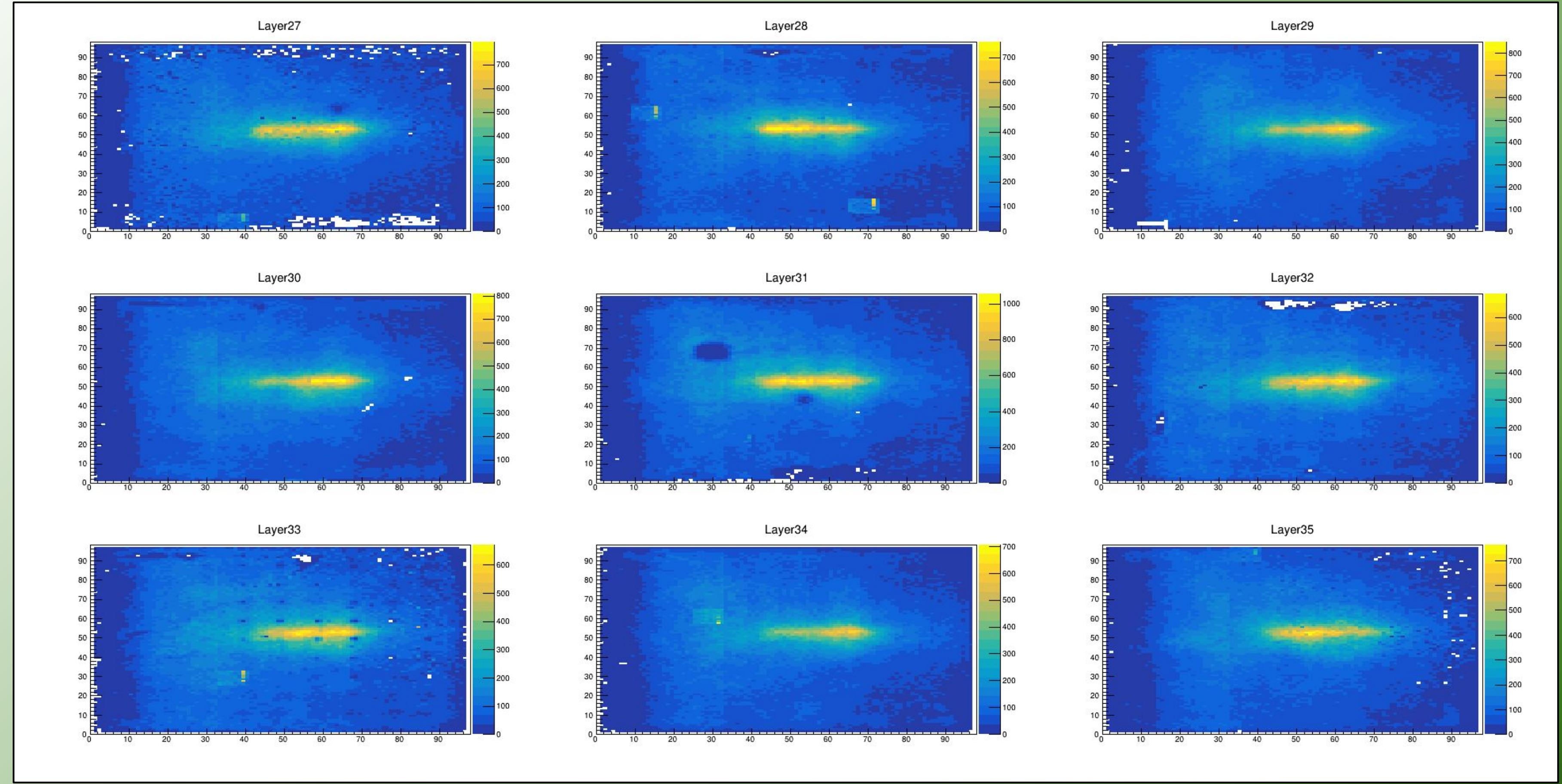

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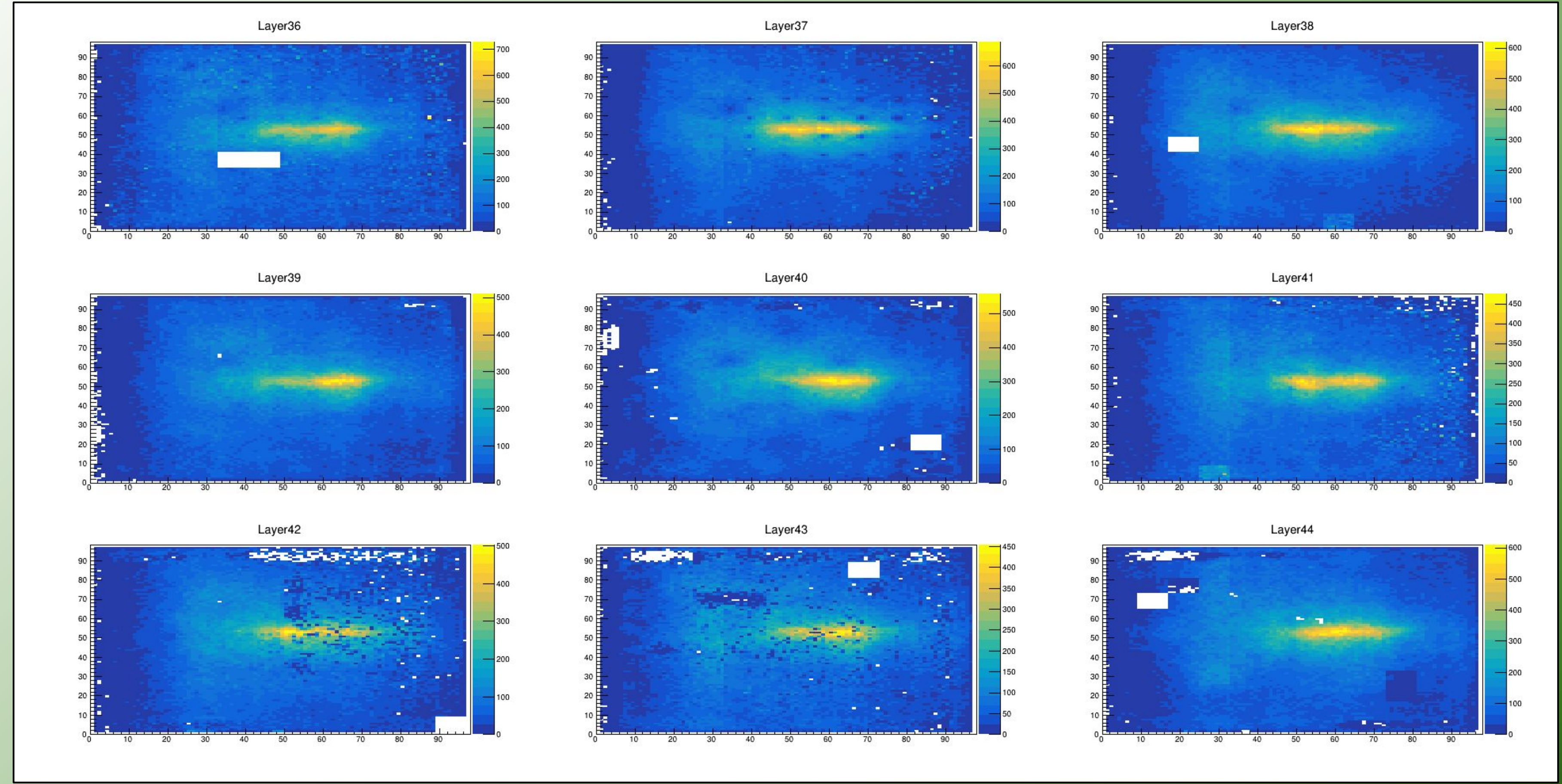
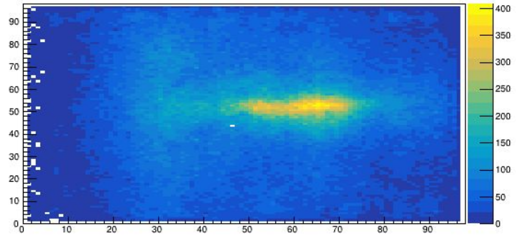


Profiles 7.63º

Layer45



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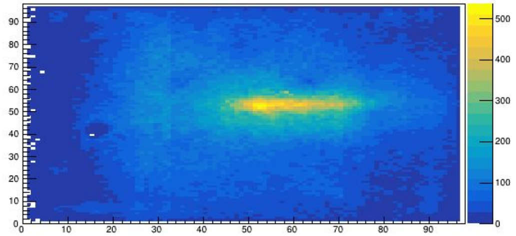

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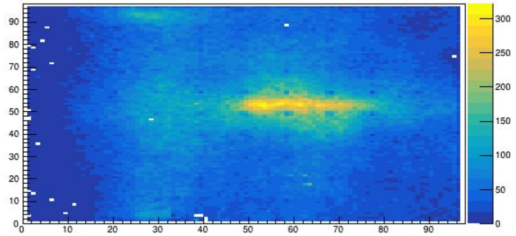

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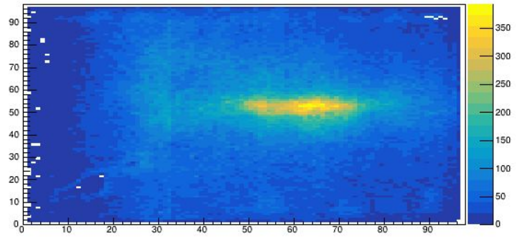

Profiles 16.75º SPS

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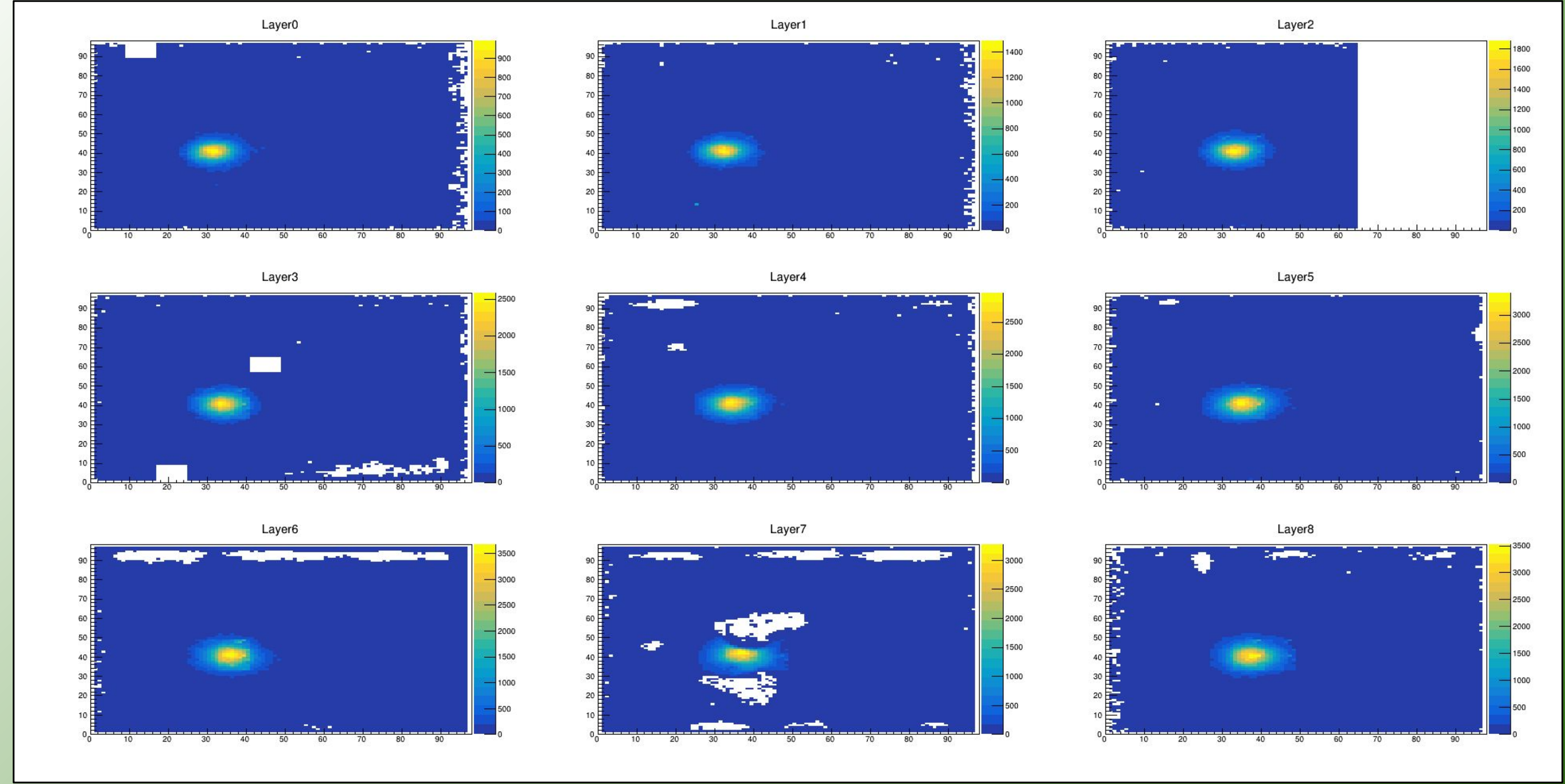

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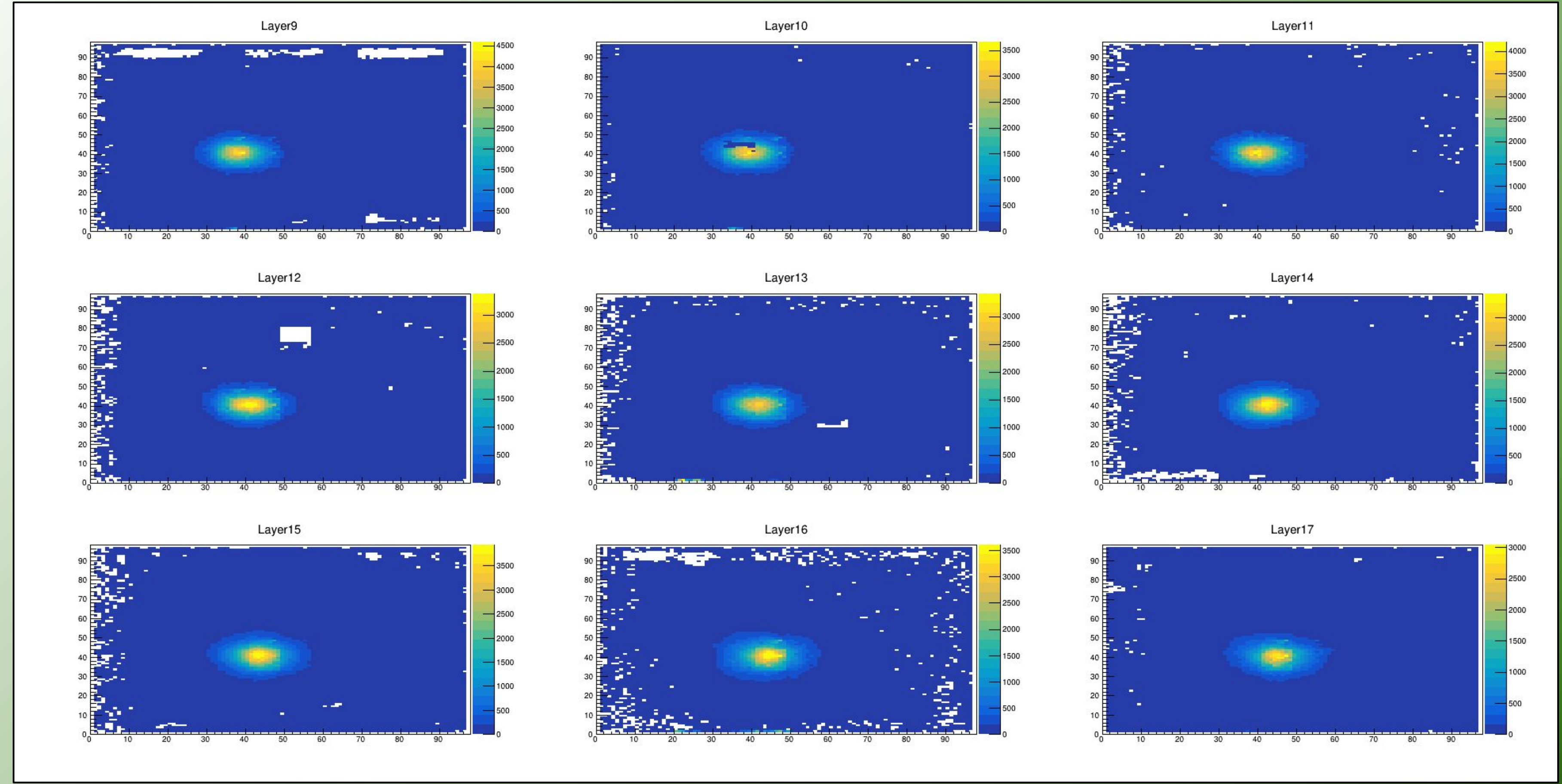

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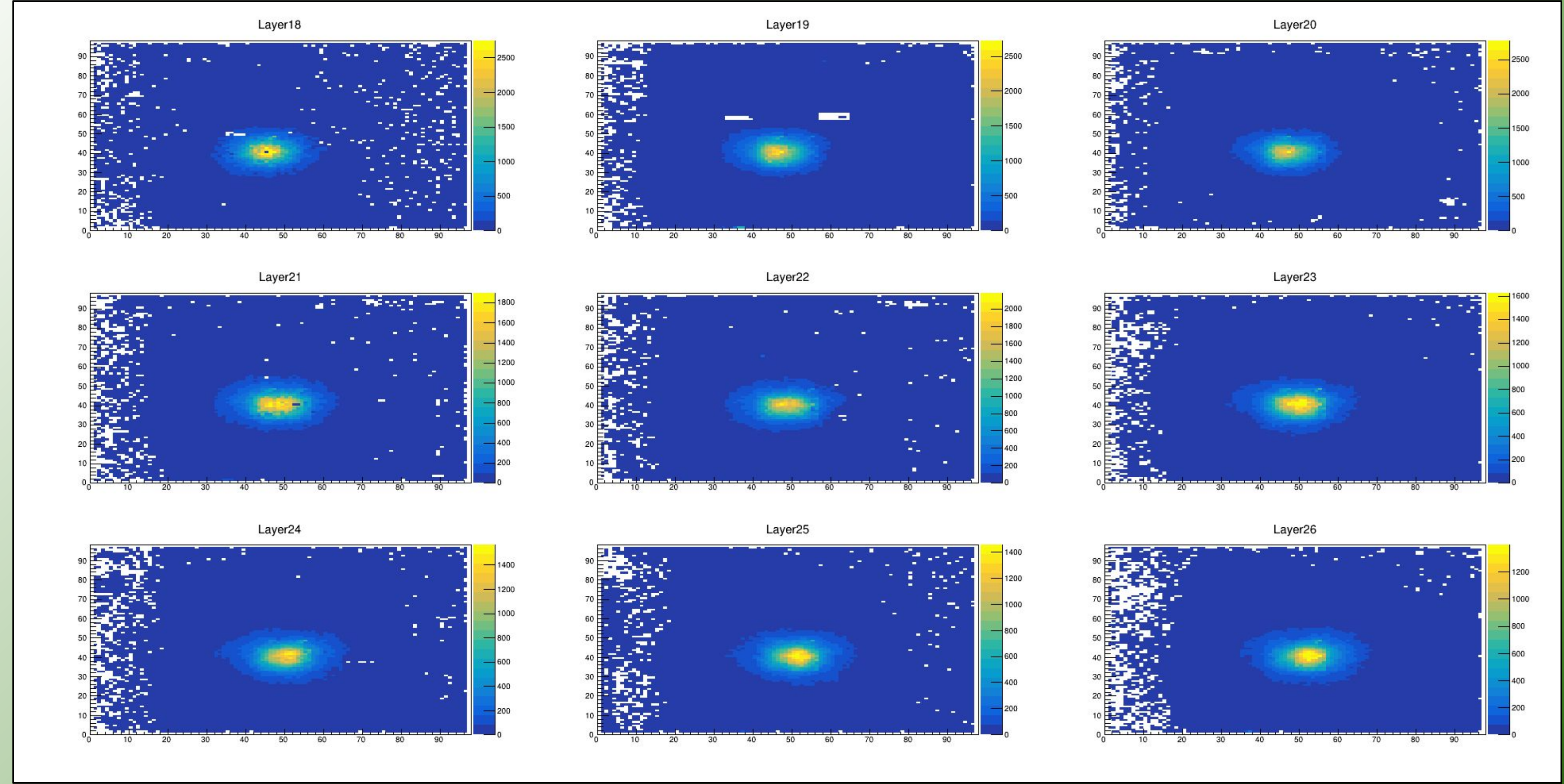

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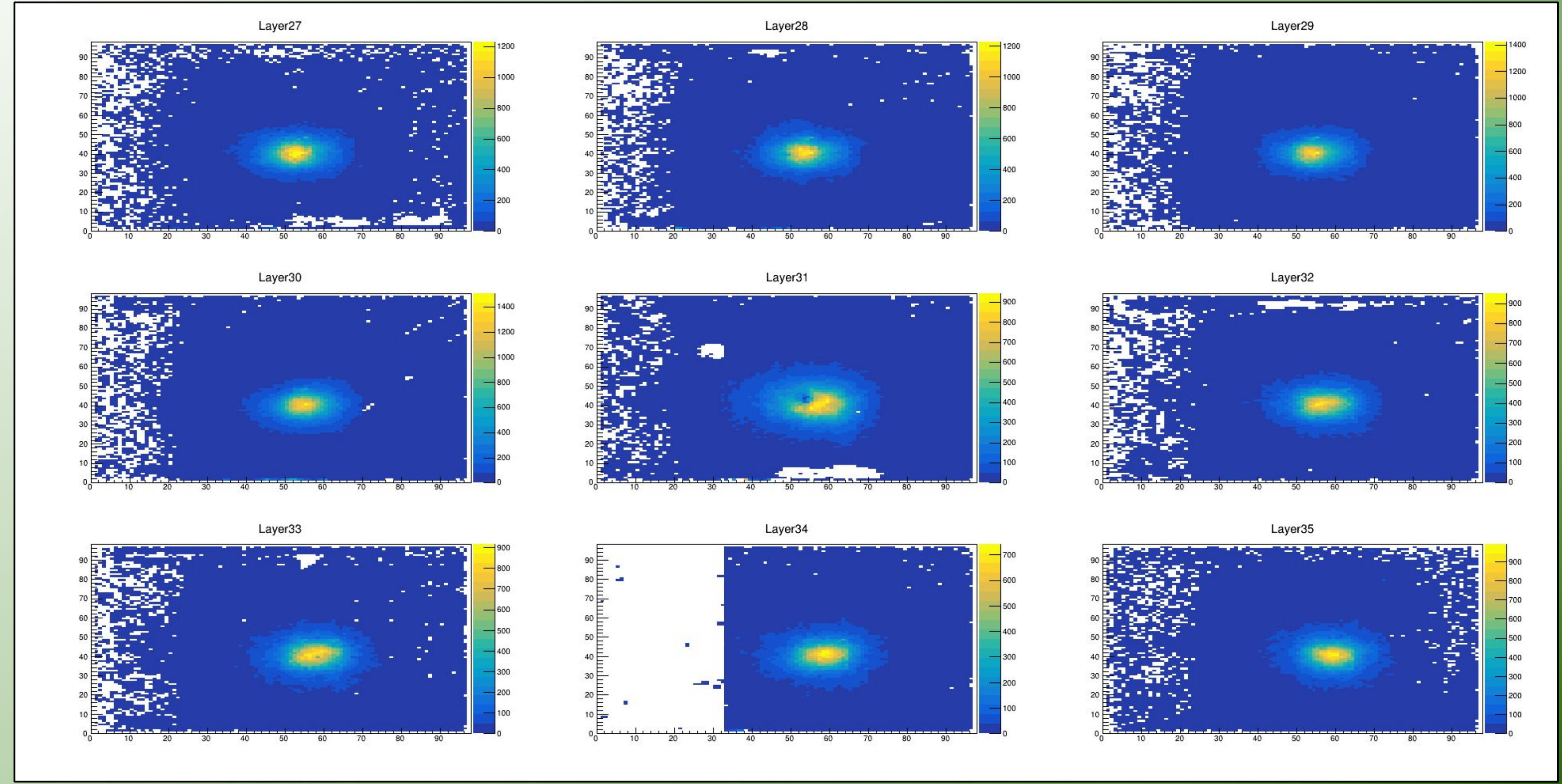

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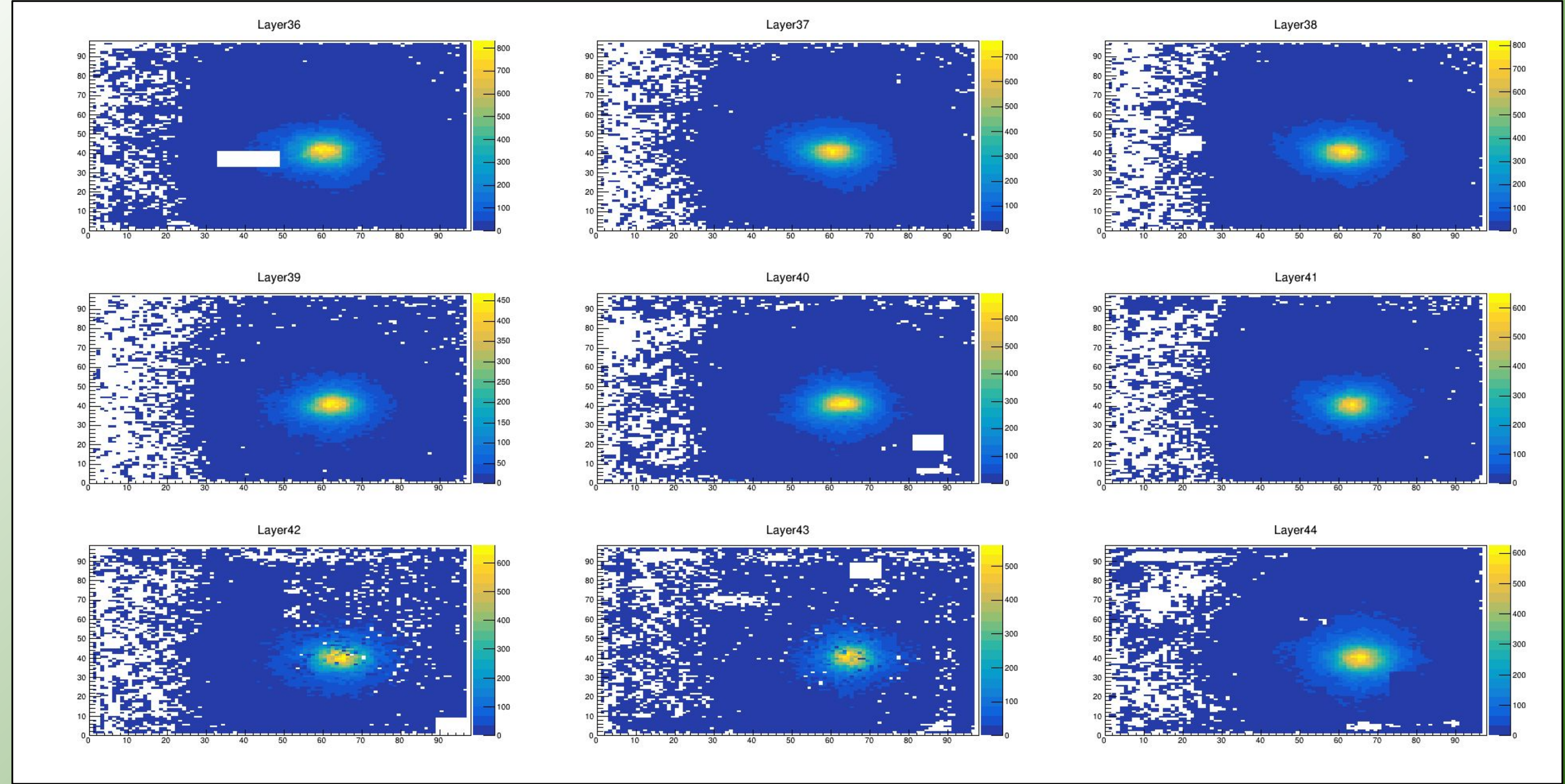

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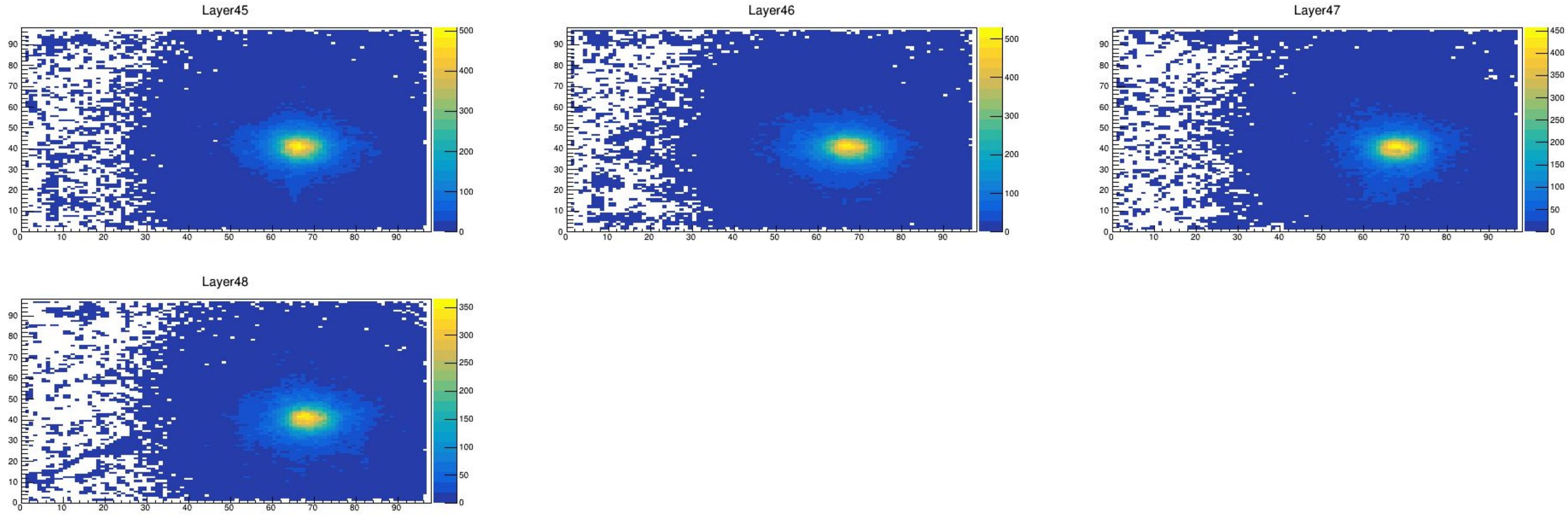

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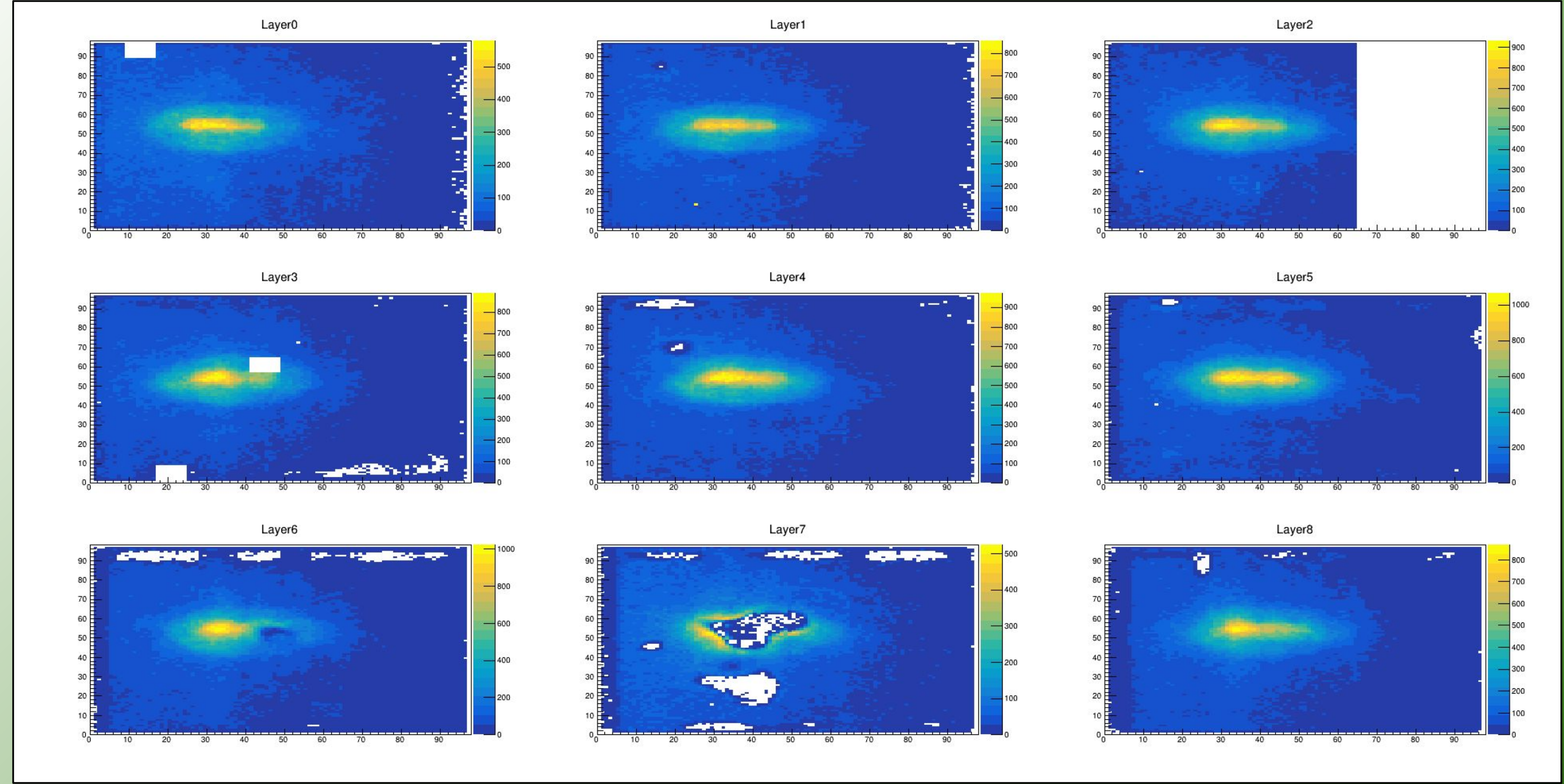

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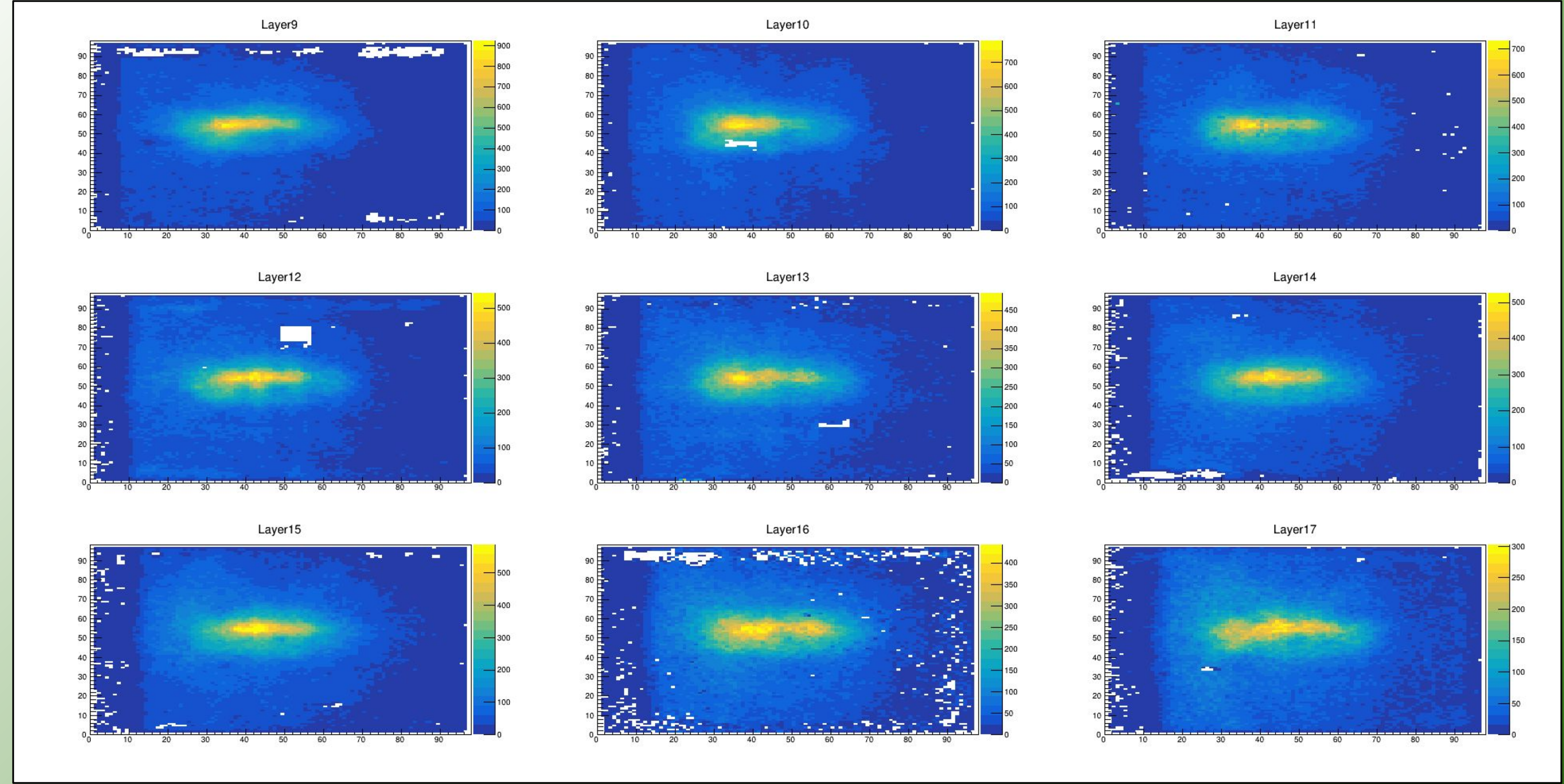

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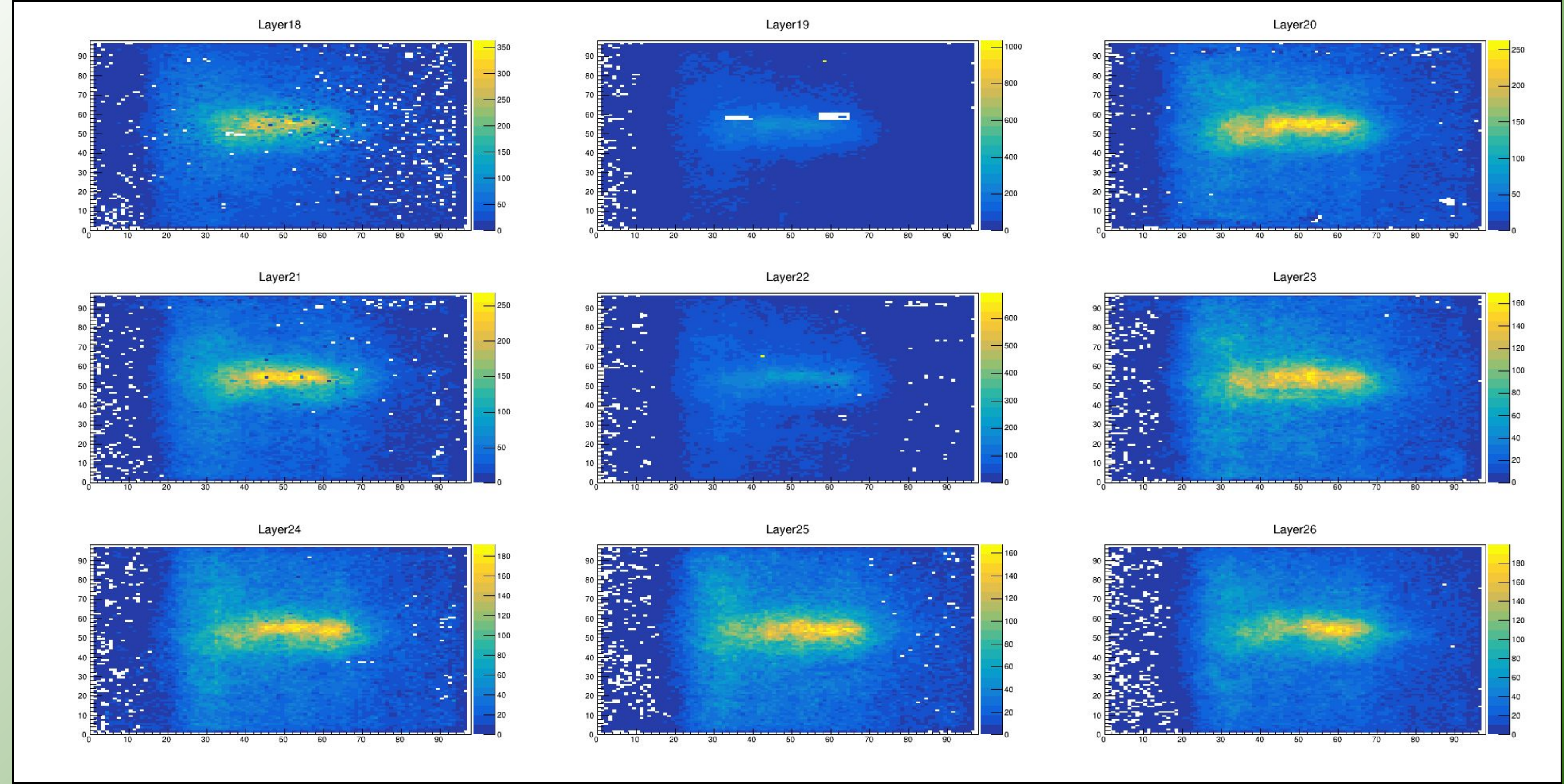

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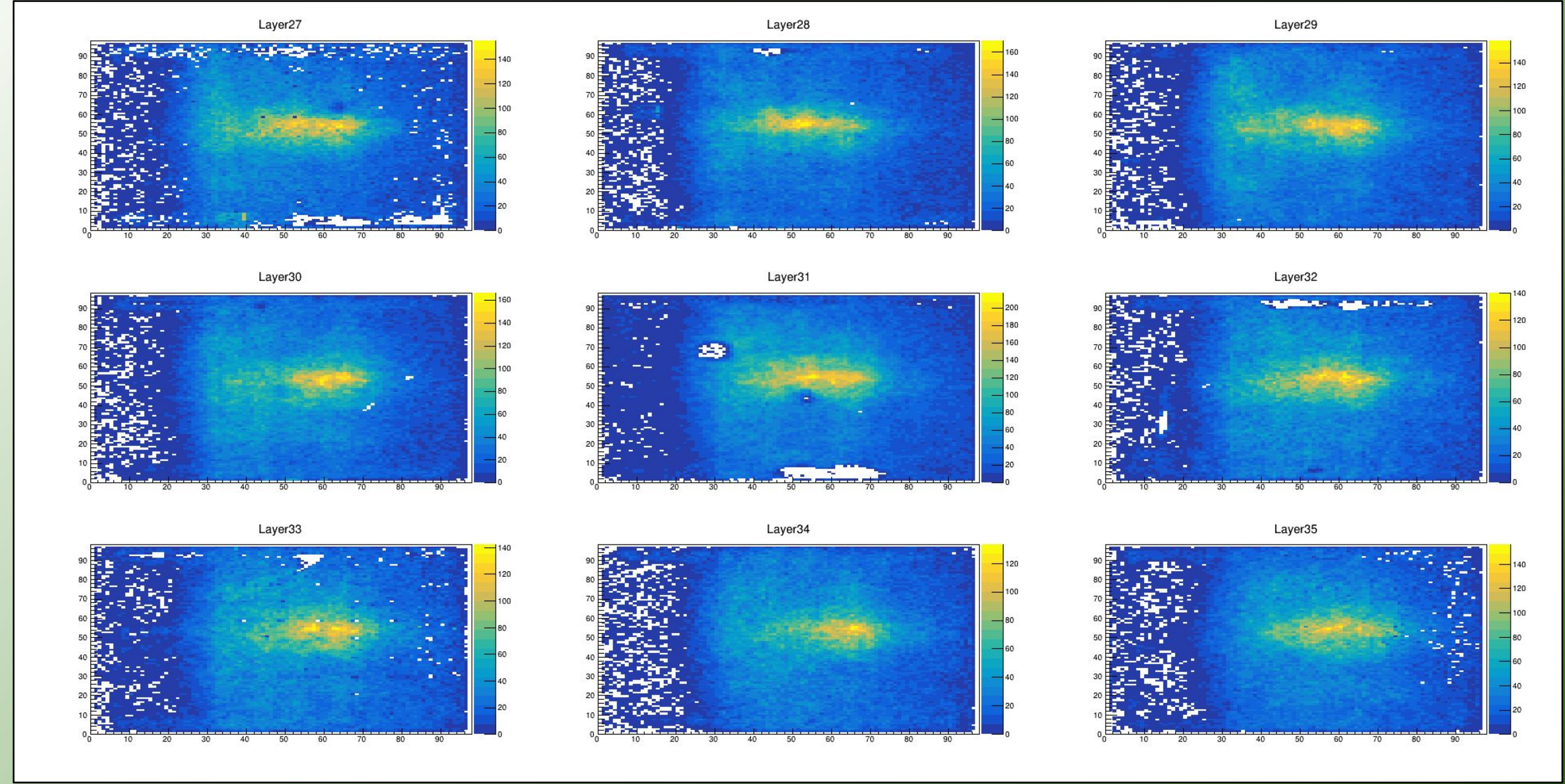
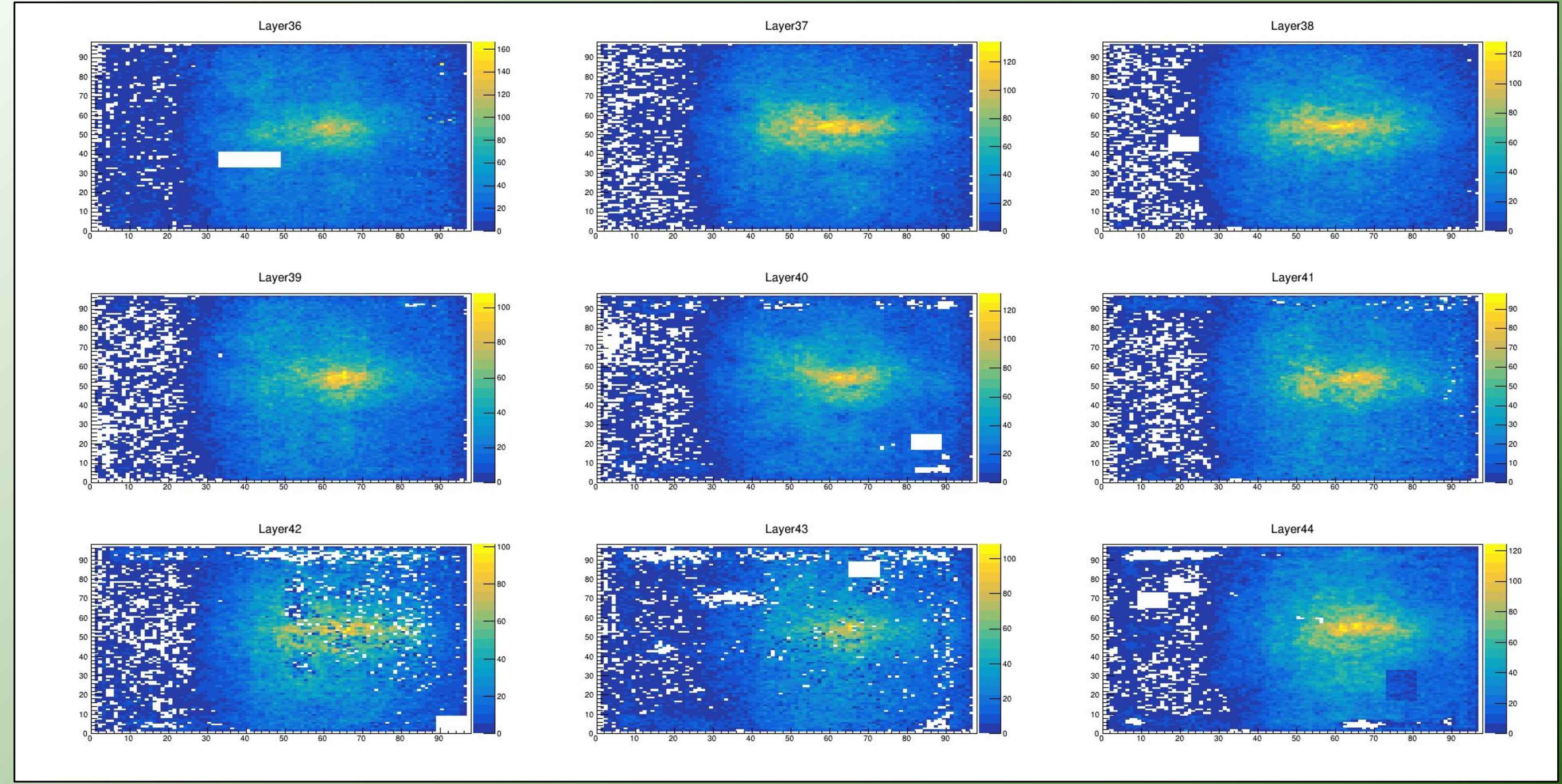


Profiles 17.90º PS



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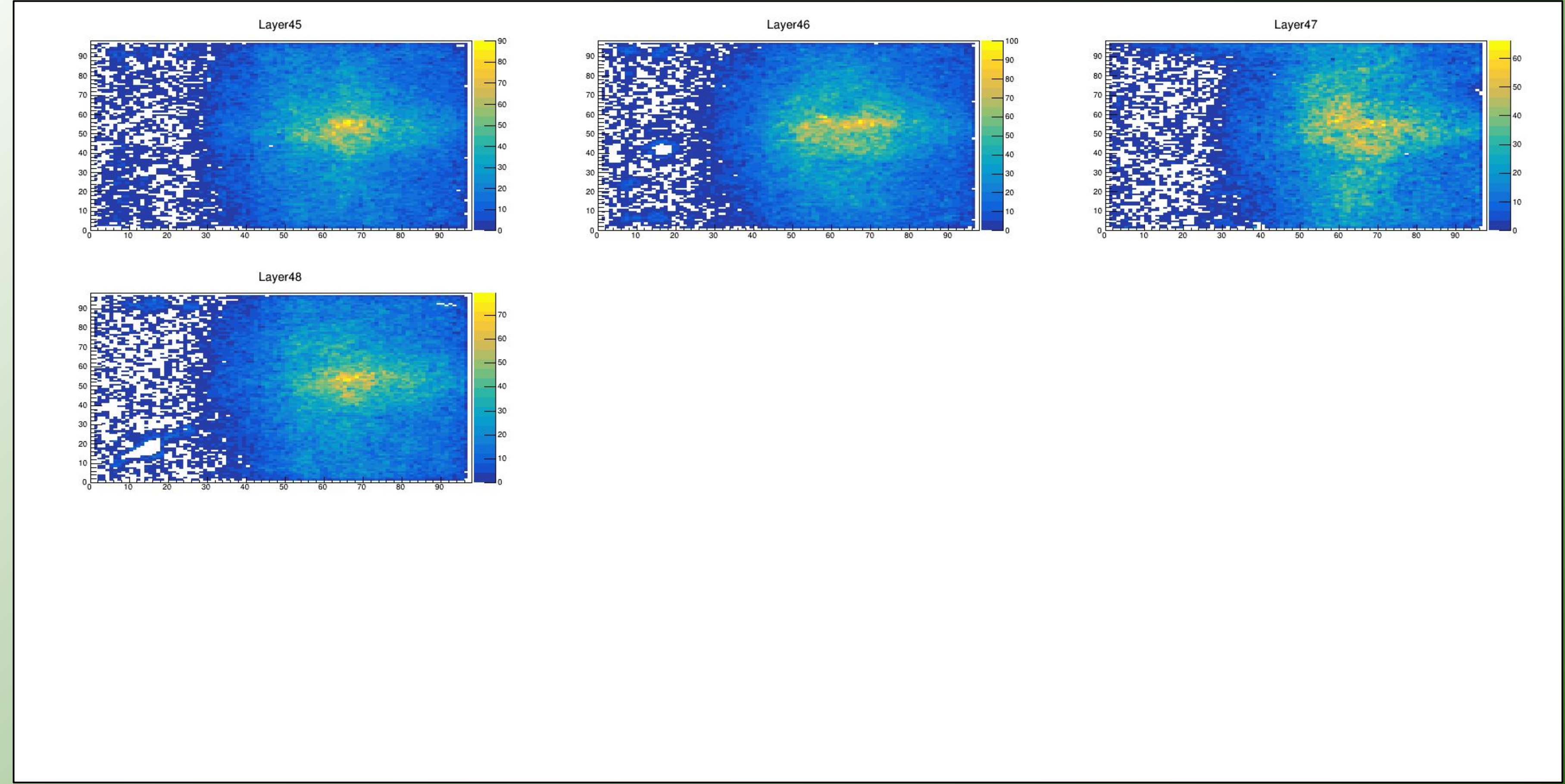
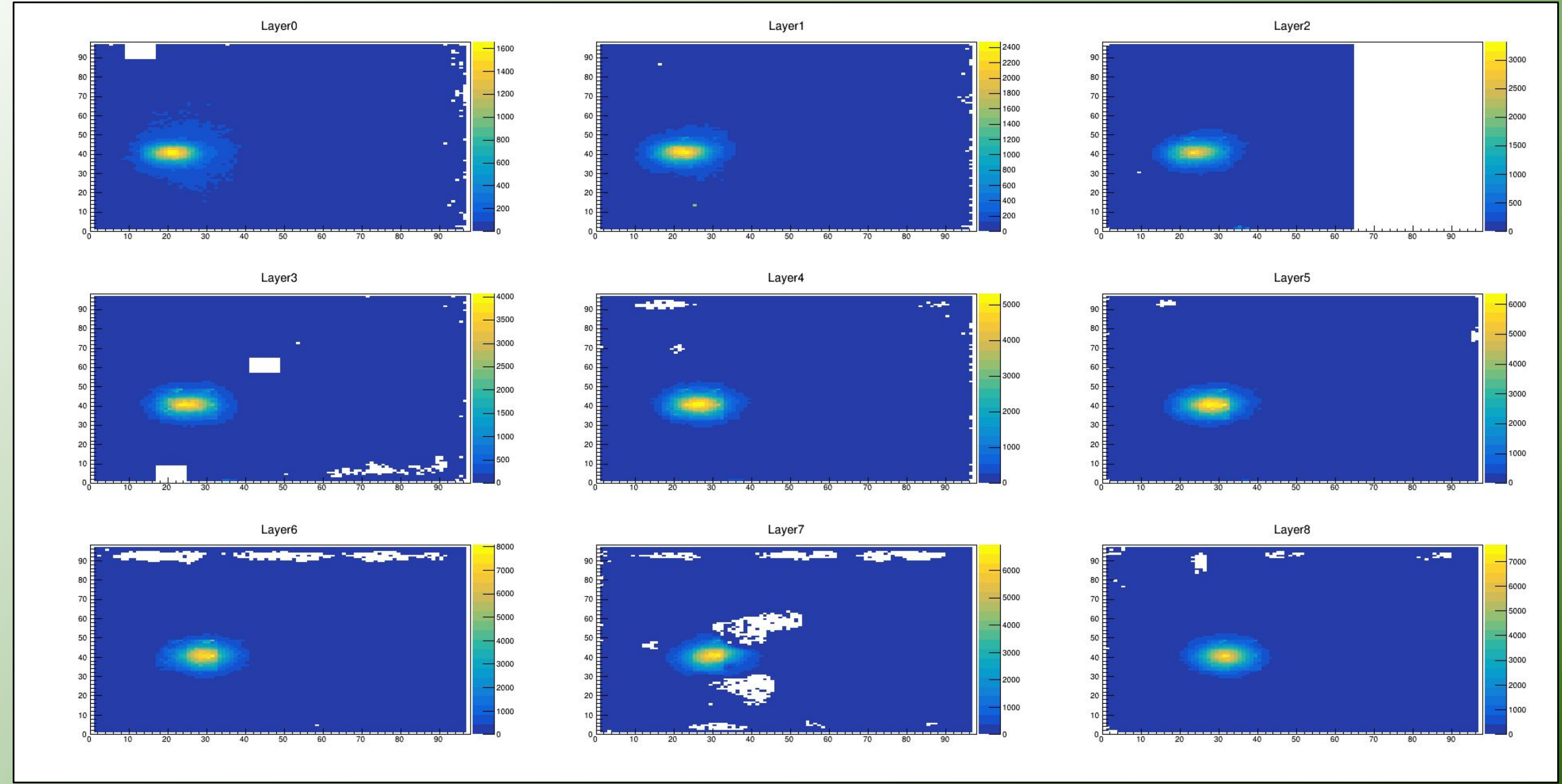


Profiles 28.25º

Profiles 28.25º



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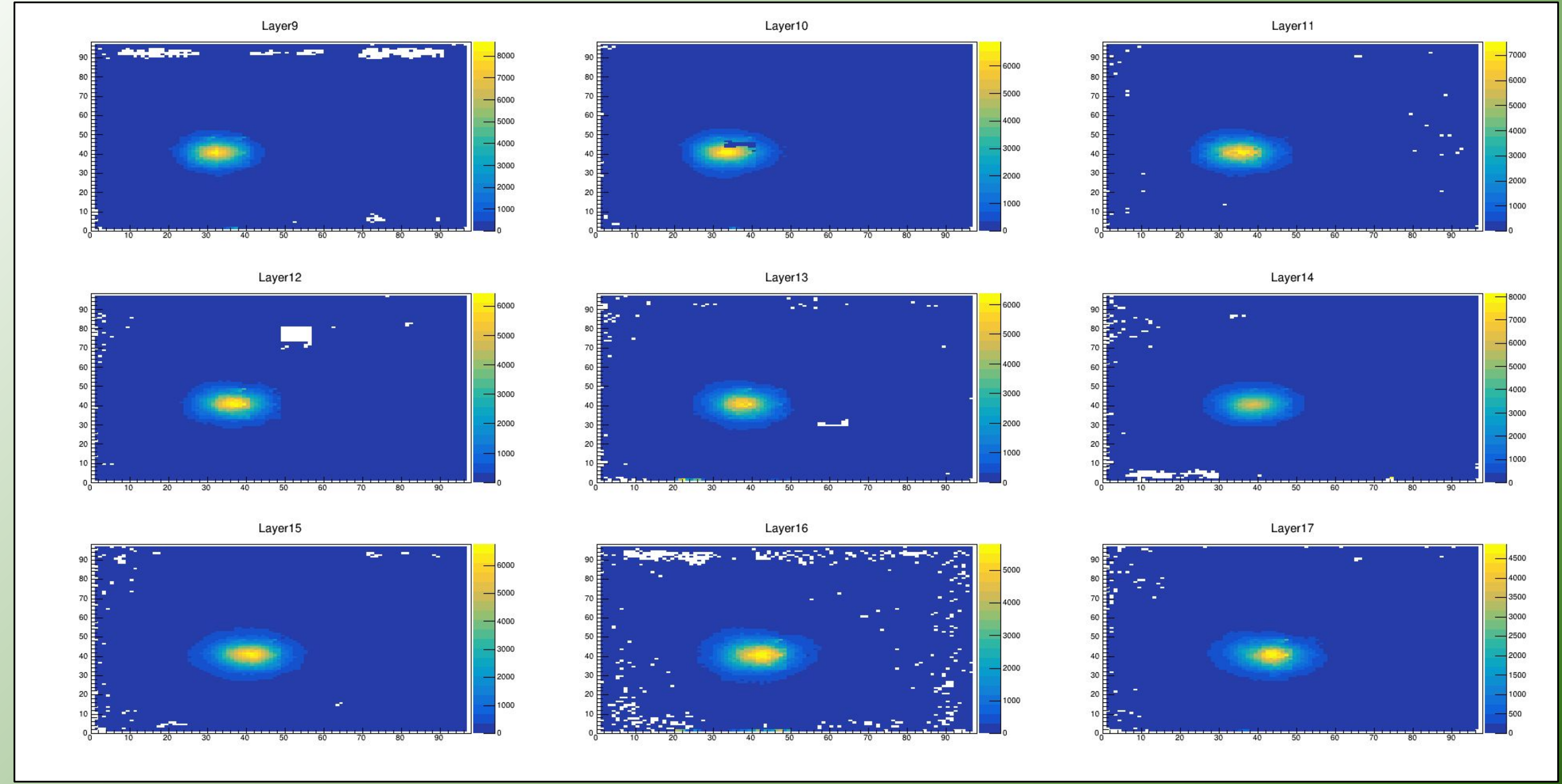

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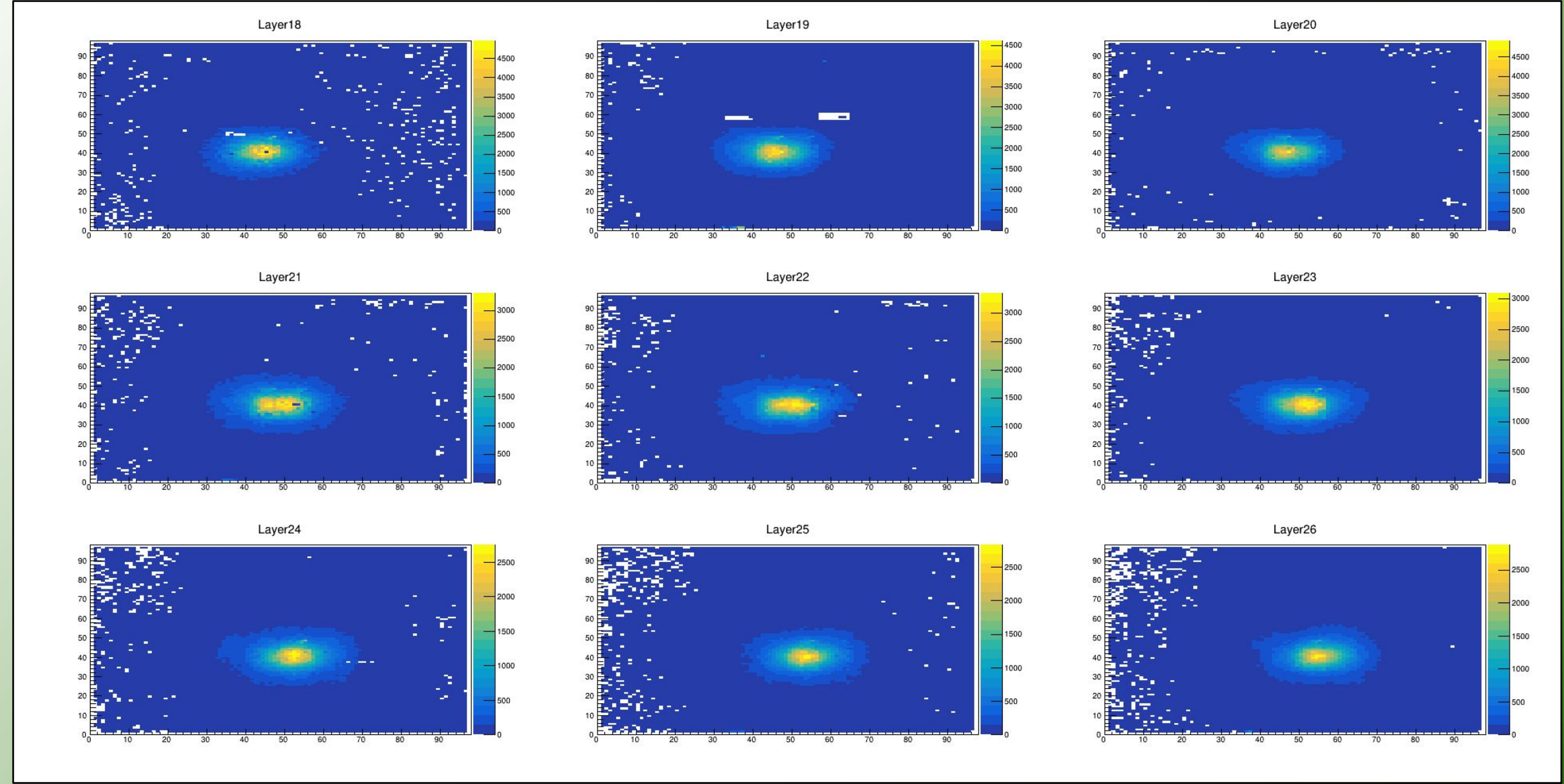

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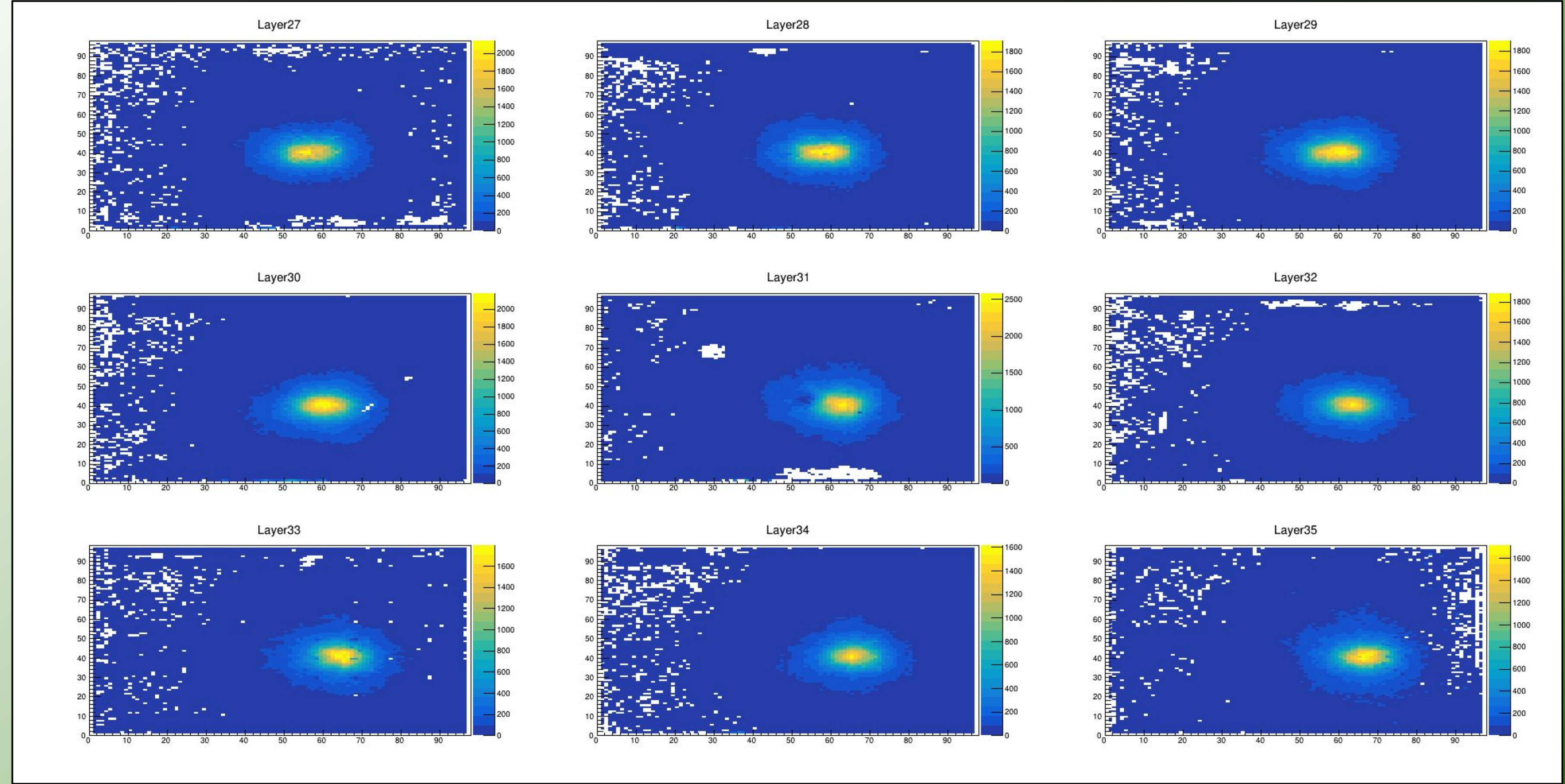

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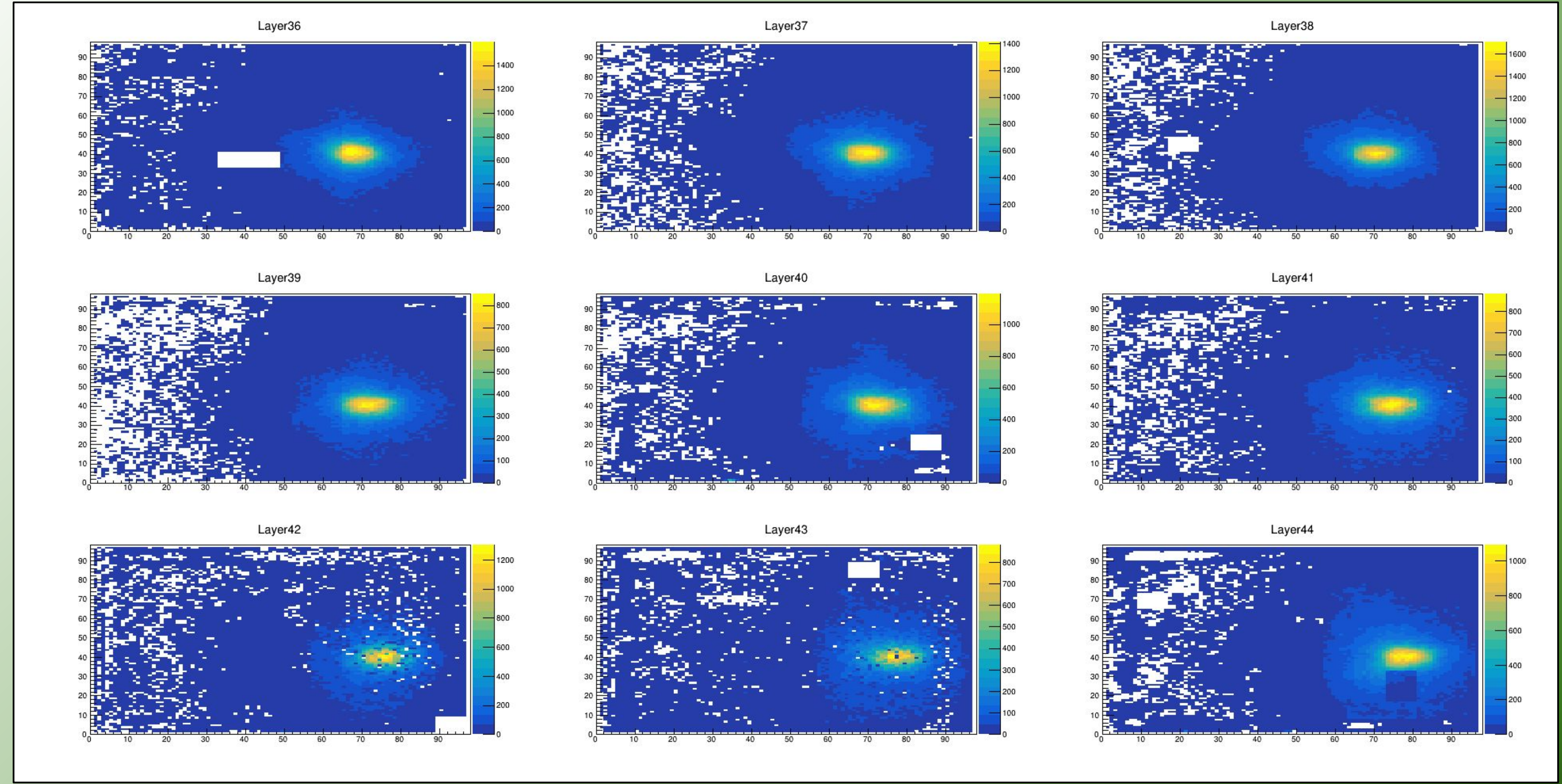

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