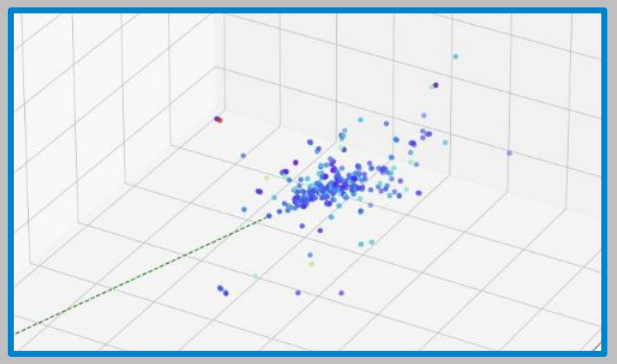
EIC Calorimetry WG Meeting

Argonne NATIONAL LABORATORY

Barrel ECal Calorimetry Performance Studies



M. Żurek, C. Peng

11/15/2021

Task of EMCAL

Yellow Report

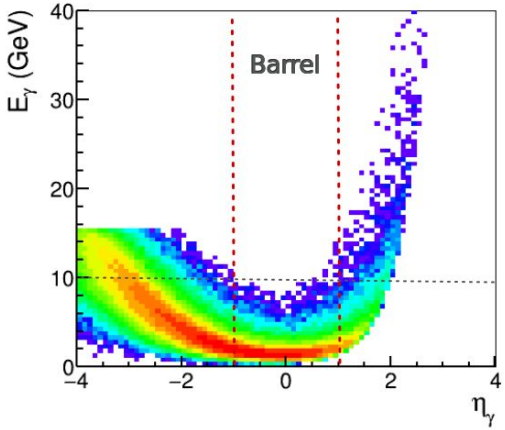
The main tasks of the ECAL can be summarized as:

- Detect the scattered electrons in order to separate them from pions and also improve the energy/momentum resolution at large |η|.
- Detect neutral particles - photons, and measure the energy and the coordinates of the impact.
- PID: separate secondary electrons and positrons from charged hadrons.
- **Provide a spatial resolution of two photons sufficient to identify decays $\pi^0 \rightarrow \gamma\gamma$ at high energies**

Detection of $\pi^0 \rightarrow \gamma\gamma$

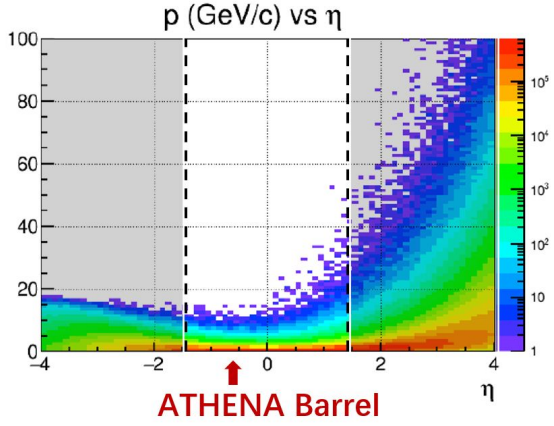
EIC Yellow Report, arXiv:2103.05419 [physics.ins-det]

DVSC photons



Energy of photons from DVCS versus η from the MILOU simulations for the e+p collisions at beam energies of 18×275 GeV

SIDIS π^0



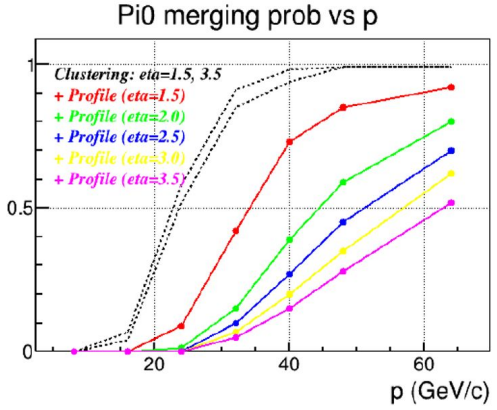
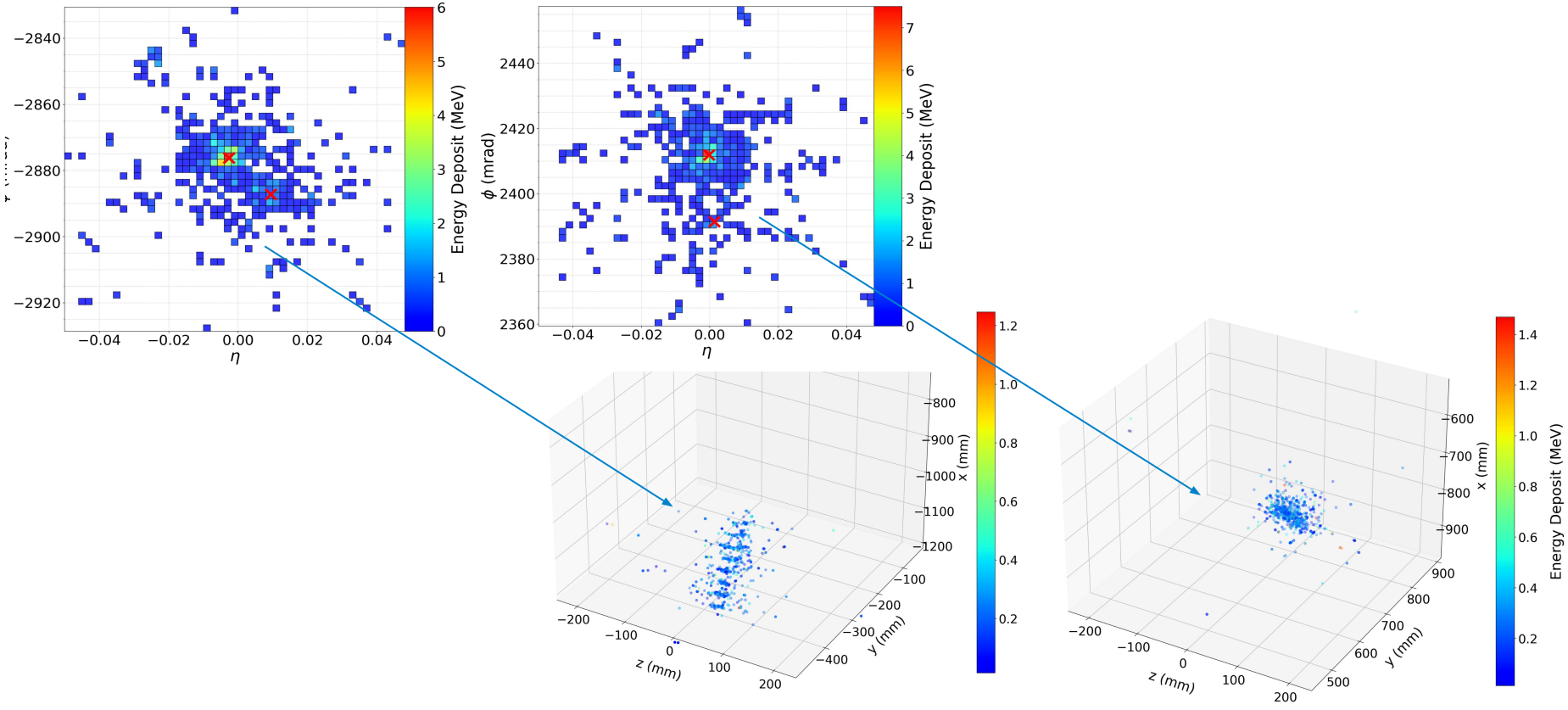


Figure 11.46: Left: The calculated π^0 momentum spectrum for SiDIS at $e + p$ 18 × 275 GeV collisions, using PYTHIA [1371]. **Right**: The probability of two photons to merge, calculated [1517] using GEANT4 [1412] for the cell size of 25 × 25 mm^2 located at 3 m from the interaction point, for the non-projective geometry. For the projective geometry the results for $\eta > 3.5$ would be close to the non-projective curve at for η=3.5.

Simulations for π^0 at 20 GeV

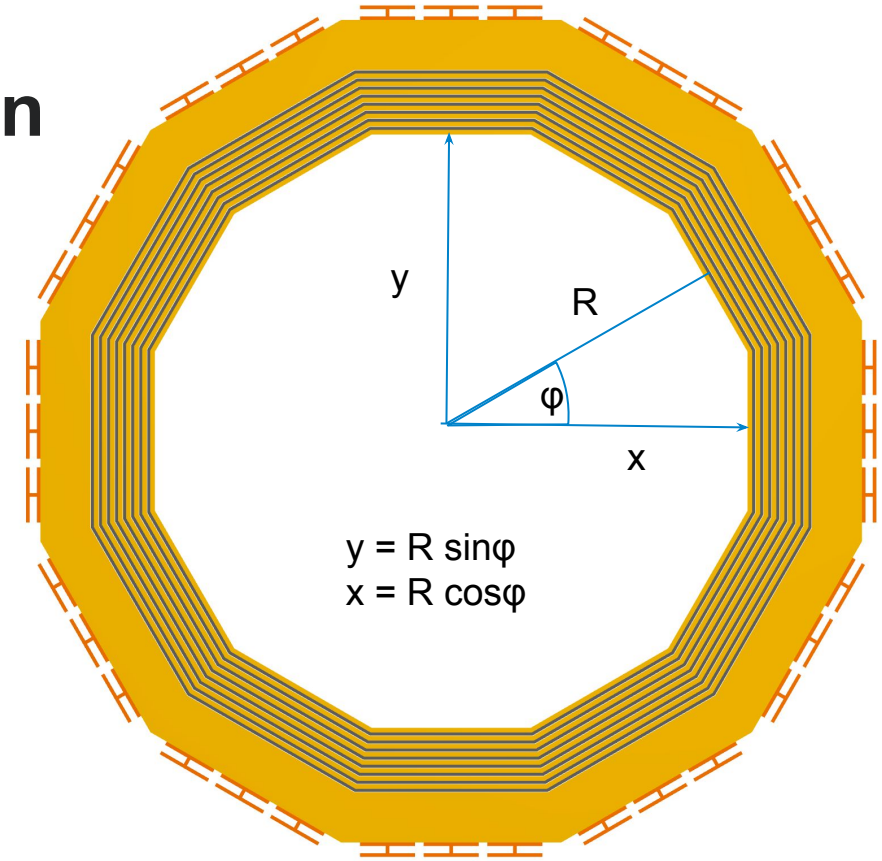


Cluster position resolution

Cluster position resolution

- Photons generated with **η=0**, and **φ=0 deg** (normal incident angle)
- The **difference between generated and reconstructed** θ and φ calculated as a function of photon energy

- The **φ and θ** can be recalculated to **x, y** and **z** at R = 103 cm and spatial resolution can be calculated for coordinates



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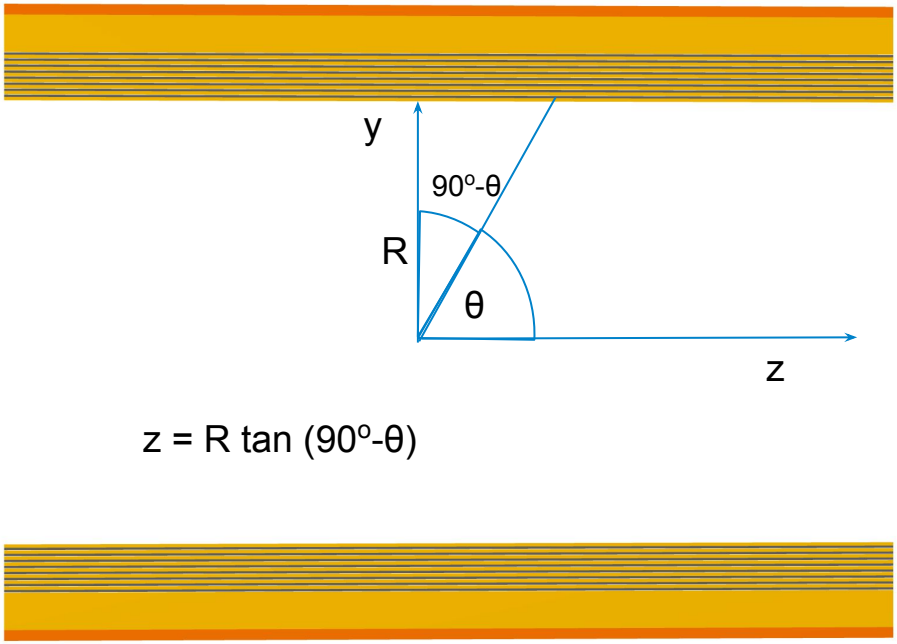
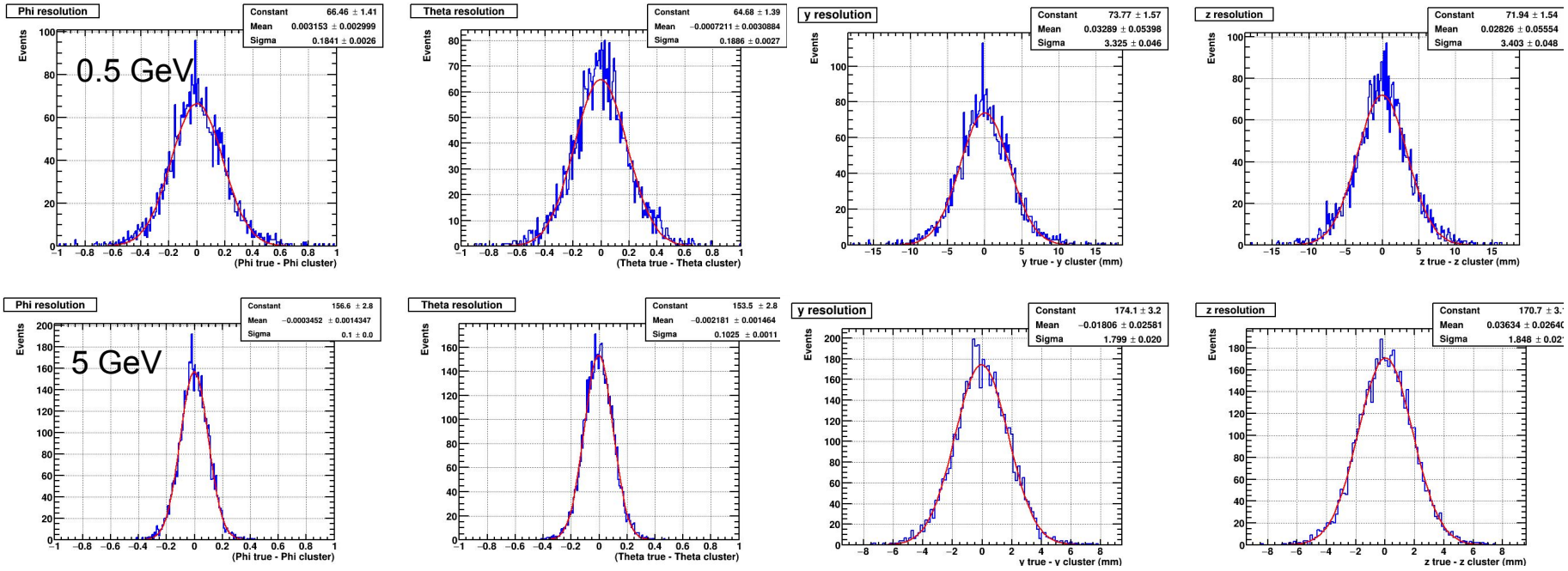


$z = R \tan(90^{o}-\theta)$

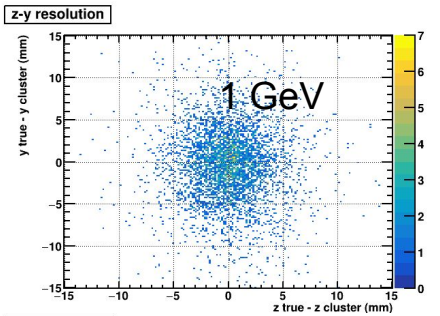
Spatial resolution of cluster position

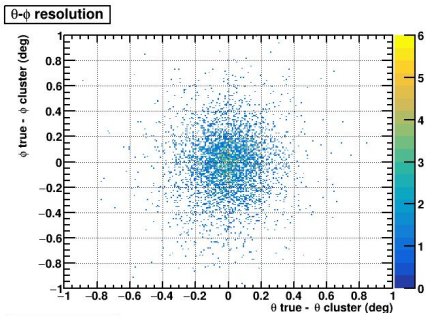
- Photons generated with **η = 0**, and **φ = 0 deg, no MF**

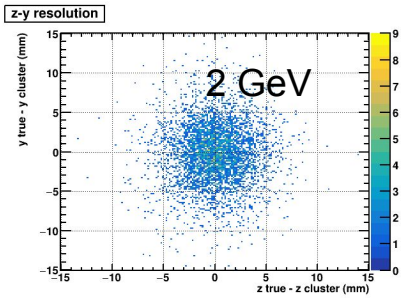


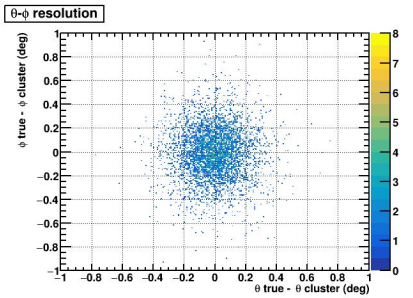
Spatial resolution of cluster position

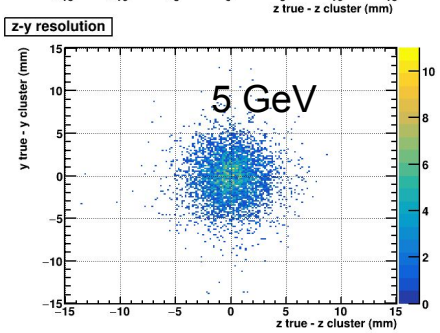
- Photons generated with **η = 0**, and **φ = 0 deg, no MF**

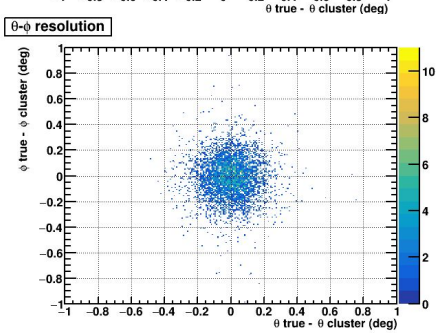


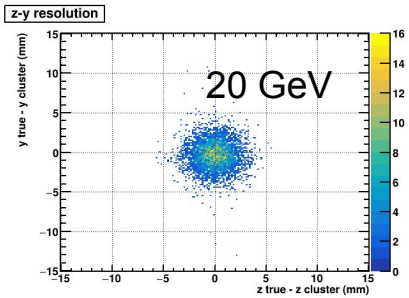


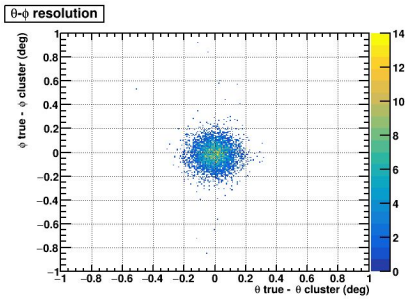




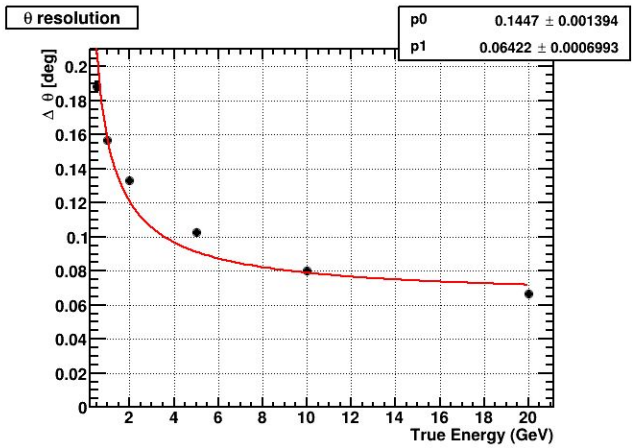


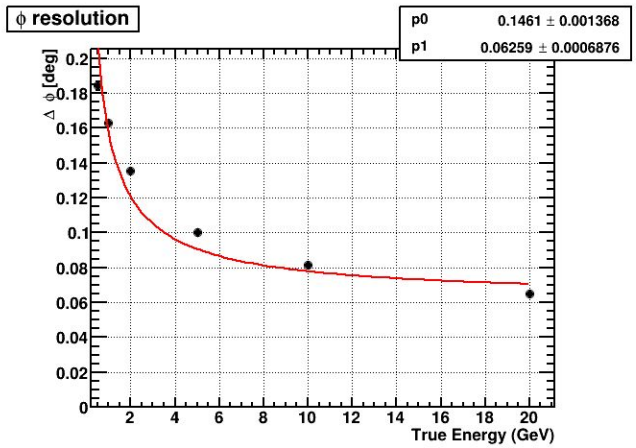






Cluster position resolution



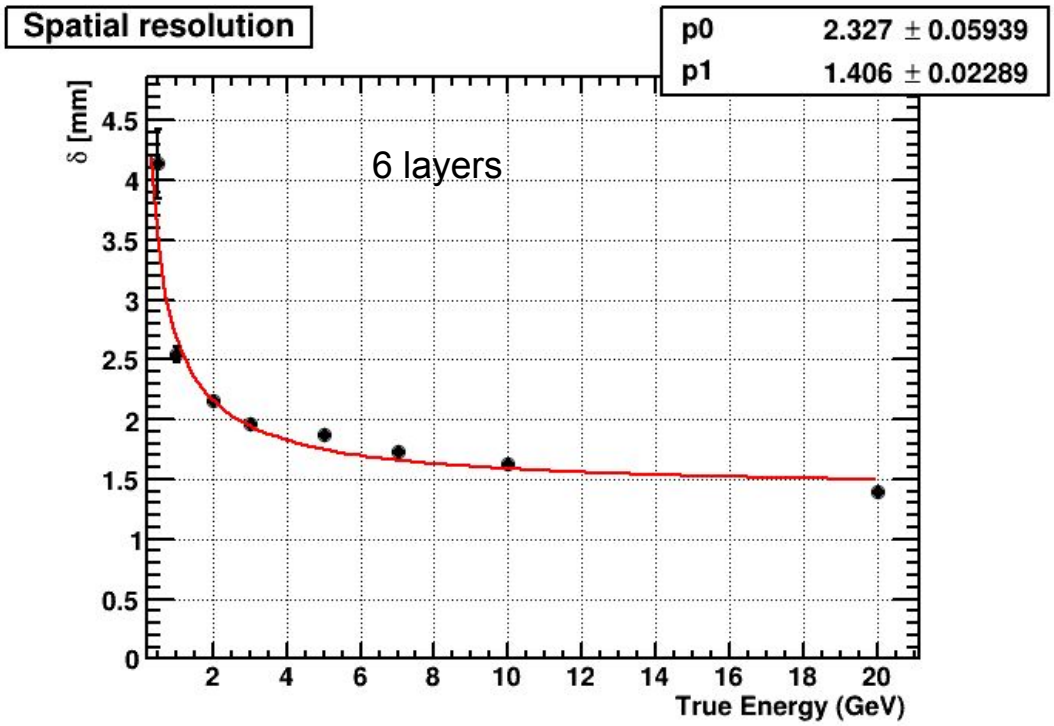


For reference π^0 minimal opening angle
$\eta = 0$, $R = 103$ cm

$\theta_{min} \sim (2m_{\pi 0})/p_{\pi 0} = 0.014$ rad ~ **0.78 deg**
For 103 cm barrel radius this gives ~ **14 mm**

Cluster position resolution

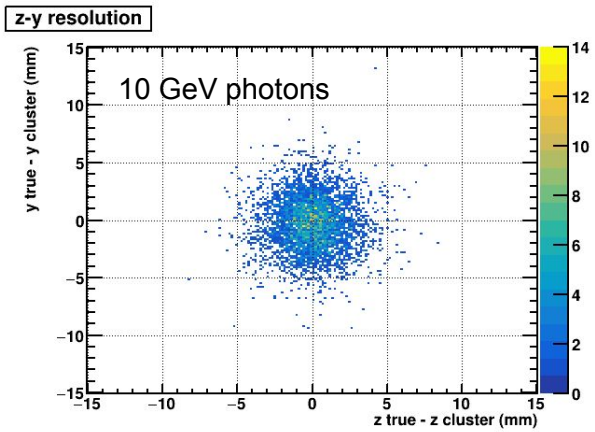
- Photons generated with **η = 0**, and **φ = 0 deg**

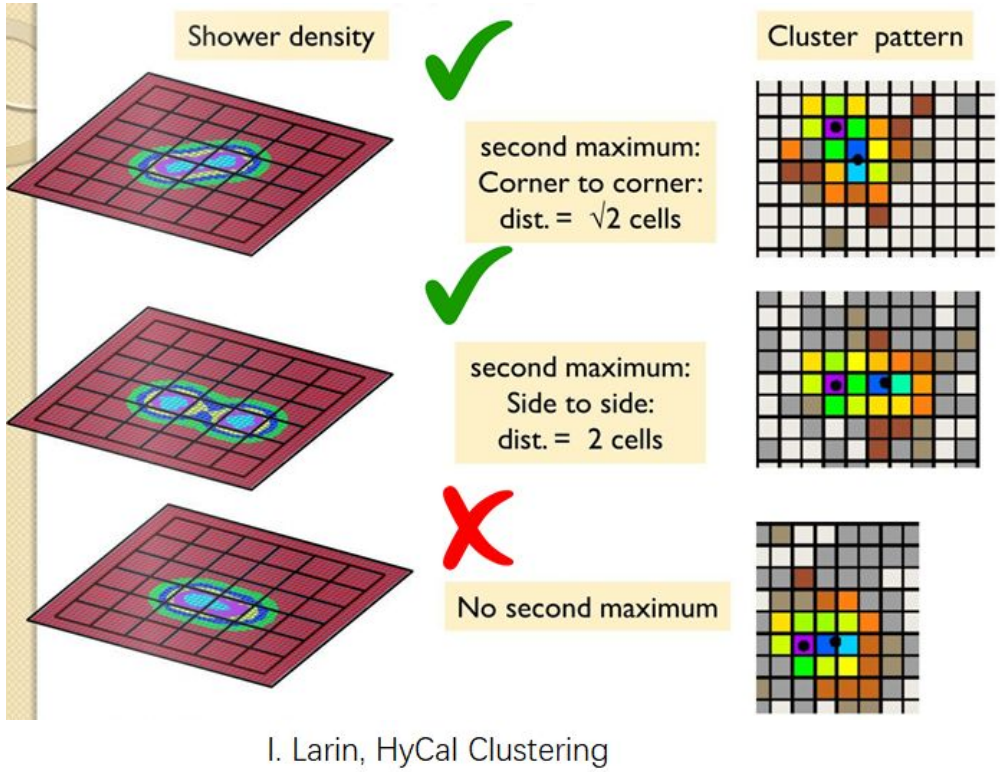


Resolution:
2.32(mm)/√E ⊕ 1.4 mm

Hard Limit for Cluster Merging

- For **modular calorimeters**, cell size is the limit
  - No reliable splitting for hits in neighboring cells or the same cell
- For **pixel sensors**, cluster profile is used (3σ + 3σ spatial resolution)
  - Single pixel Edep (MIP) cannot locate the center





I. Larin, HyCal Clustering

Merging probability for $\pi^0 \rightarrow \gamma\gamma$

Fast simulation of π^0 decays in barrel region

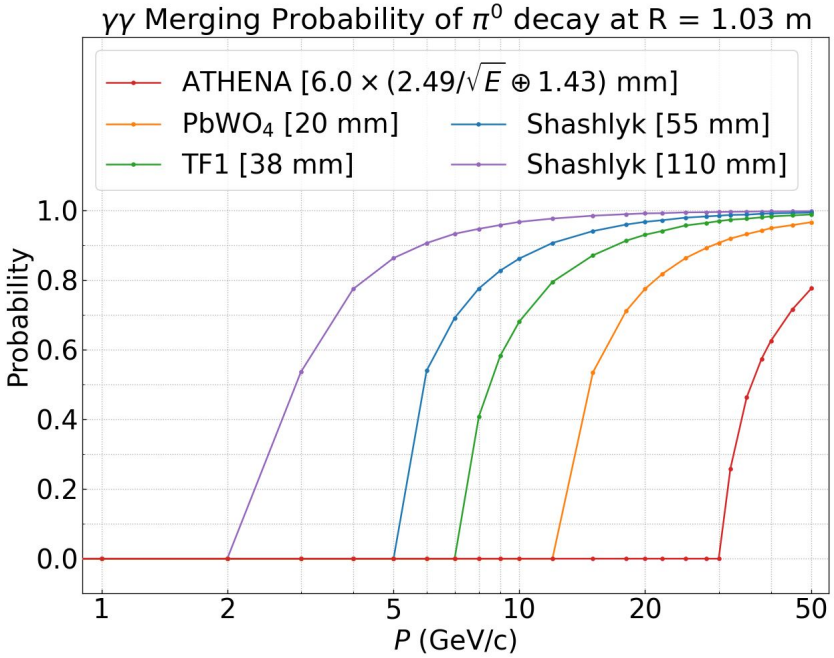
Detection of photons at R = 1.03 m

Cut out-of-acceptance events

Cut very low energy events (photon energy > 100 MeV)

Hard limit of merging

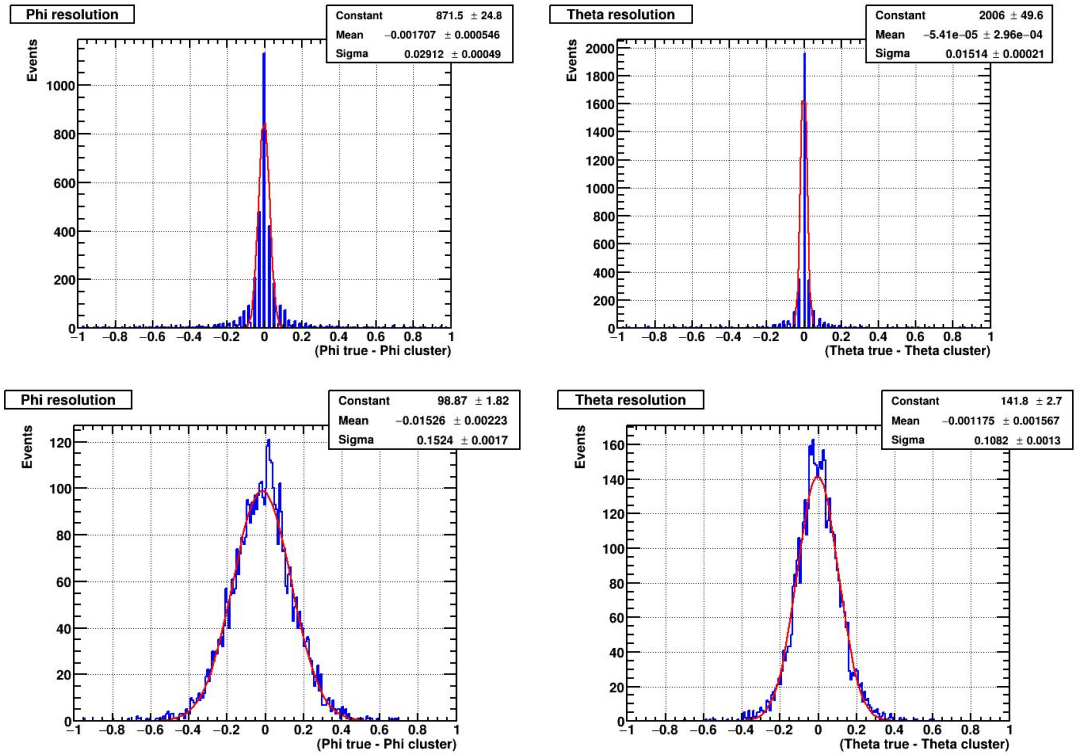
- Cell size for modular calo
- 6 sigma for AstroPix



Cluster position resolution from 6 AstroPix layers

Position resolution

- Further improvements for the position resolution from single hit position in first layers



Simple algorithm:

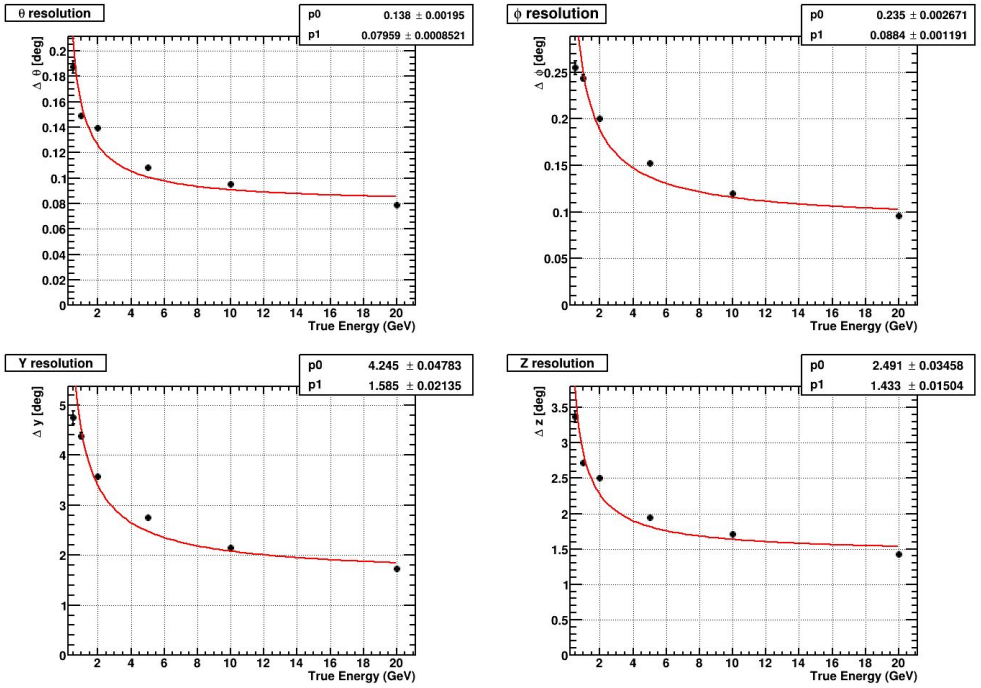
1) Take 1st imaging layer with registered hits
2) If nhits = 1, take position of this hit
3) If nhits > 1, take position of the hit closest to the cluster position determined before

Example for 5 GeV photons, $\eta = 0$, and $\varphi = 0$ deg, w/ MF

Backup

Spatial resolution

- photons generated with **η = 0**, and **φ = 0 deg, w/ MF**



Spatial resolution

- Yellow Report summary table

Type	R_M, mm	cell size, mm	σ_E/E at 1 GeV	δ mm	ϵ, mm $\text{GeV}^{0.5}$	Ref
$PbWO_4$	20	20	2.9%	0.4	2.6	[1513]
$PbWO_4$	20	22	3.9%	0.3	2.6	[1514]
TF1	37	38	5.7%	0.5	6.0	[1515]
Shashlyk	41	55	8.4%	1.6	5.7	[1499]
Shashlyk	59	110	4.7%	3.3	15.4	[1516]

Table 11.28: The coordinate resolutions observed with several detectors for the normal incident angle θ_I. The resolution is parametrized using Equation 11.7. The stochastic factor ϵ appears to be approximately proportional to the cell size.