Status of reconstruction in ECal

Andrei Maltsev, JINR (Dubna)

SPD Collaboration Meeting

24-27 April 2023

Requirements on ECAL design from physics analyses

Prompt photons:

- interested in p_T > 3-4 GeV, high background from π^0, η, etc.
- Requirement: energy resolution at high (> 5 GeV) energies, π/γ separation

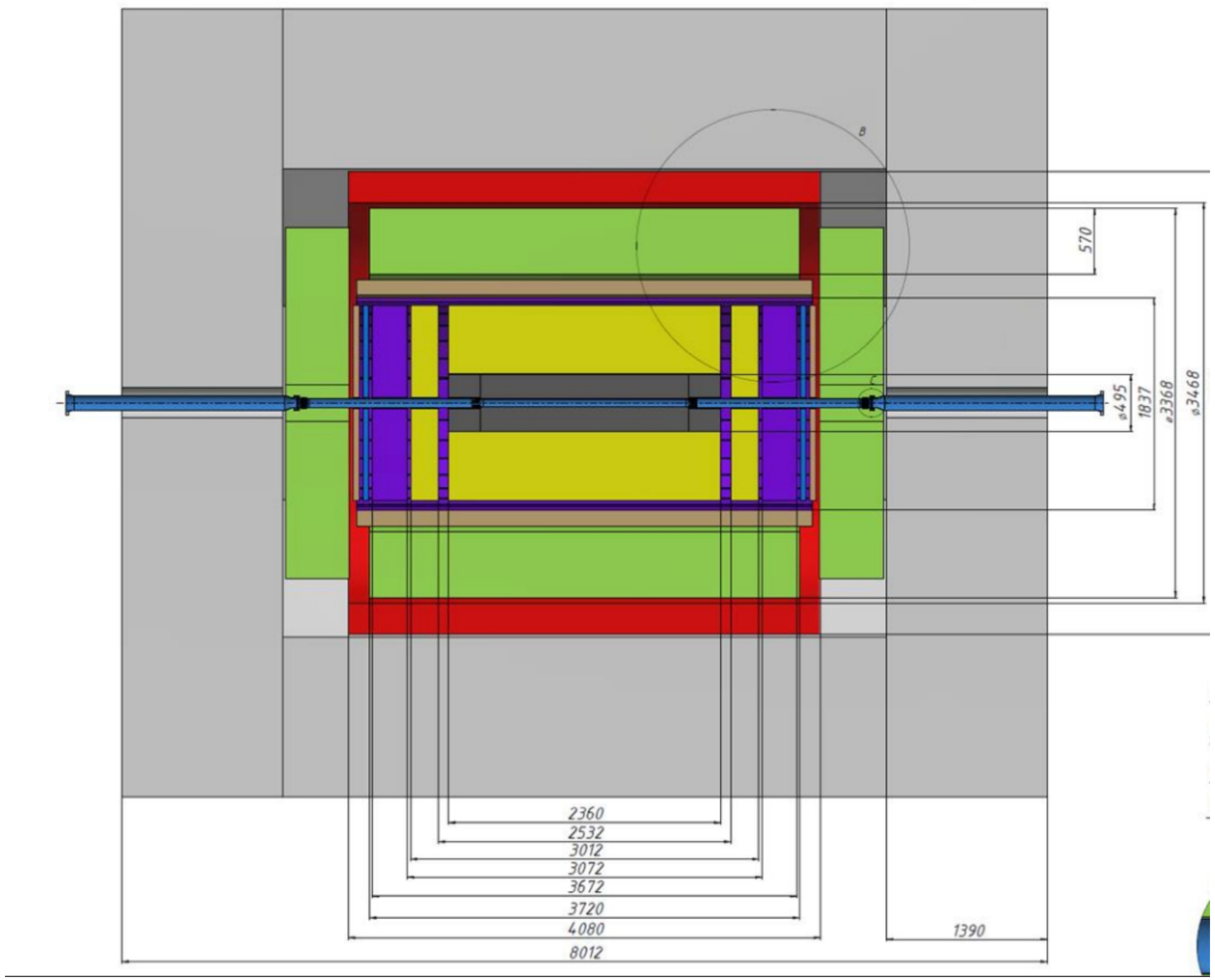
Charmonia (χ_{c1}, χ_{c2}):

- need to separate χ_{c1}, χ_{c2} from decay into $J/\psi\ \gamma$
- Requirement: energy resolution at low (< 1 GeV) energies

Online polarizability measurement:

- measure azimuthal asymmetry of π^0 production
- Requirement: energy and position resolution, π/γ separation

ECAL setup



From talk of A.Korzenev (Monday)

- Sampling: 190 layers → 200 layers × (0.5 mm lead + 1.5 scintillator)
    - ~ 5-6% energy resolution @ 1 GeV
    - ~ 1-2% energy resolution @ 8 GeV
- Cell size:
    - barrel: 34 mm (φ) × 48 mm (Z)
    - endcaps: 40 mm × 40 mm
- Barrel inner radius: 1080 mm → 1114 mm
    - minimal distance between γ's from π0 decay with energy of 8 GeV is about 4 cm
- Distance from primary vertex to endcaps: 180 cm → 204 cm

Current reconstruction workflow

1) per-cell energy calibration: energy deposition in scintillator layers → energy deposition in the entire cell

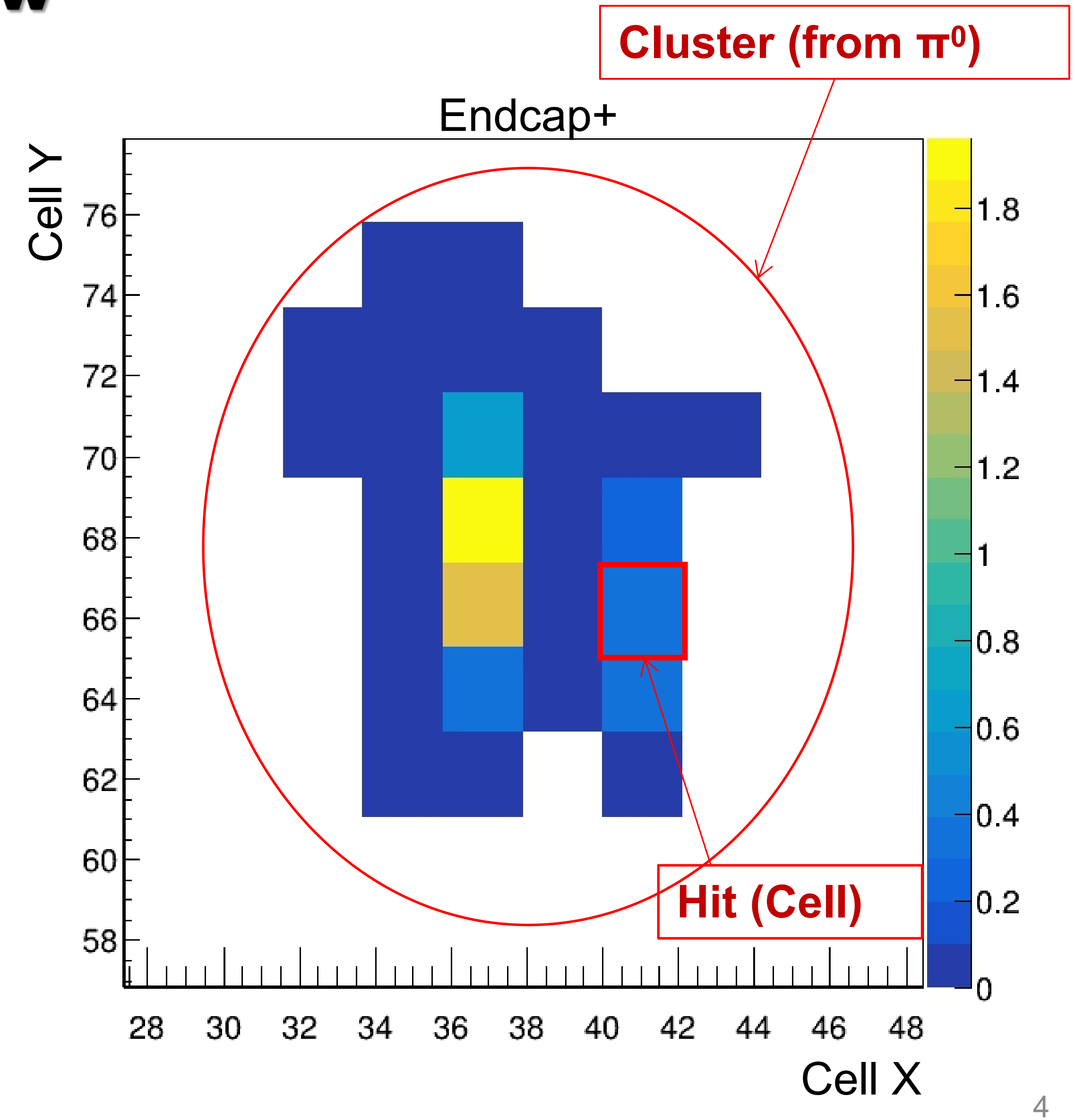
2) clustering: identifying groups of neighboring cells

3) reconstruction: get particle position and energy from cluster using empirical expressions

4) π/γ ID: based on cluster shape analysis

Caveats:

- empirical calibrations in the reconstruction step sensitive to ECAL setup, maintenance is time-consuming
- no reconstruction of individual photons in case of π0 ID (yet)
- only full simulation of ECAL showers



A possible approach

1) per-cell energy calibration: energy deposition in scintillator layers → energy deposition in the entire cell

2) clustering: identifying groups of neighboring cells

3) reconstruction: get particle position and energy from cluster

4) π/γ ID: based on cluster shape analysis

1) per-cell energy calibration: energy deposition in scintillator layers → energy deposition in the entire cell

2) clustering: identifying groups of neighboring cells

3) π/γ ID: based on cluster shape analysis

π^0 → 4) reconstruct 2 photons

γ → 4) reconstruct 1 photon

Another possible approach

1) per-cell energy calibration: energy deposition in scintillator layers → energy deposition in the entire cell

2) clustering: identifying groups of neighboring cells

3) reconstruction: get particle position and energy from cluster

4) π/γ ID: based on cluster shape analysis

→

1) per-cell energy calibration: energy deposition in scintillator layers → energy deposition in the entire cell

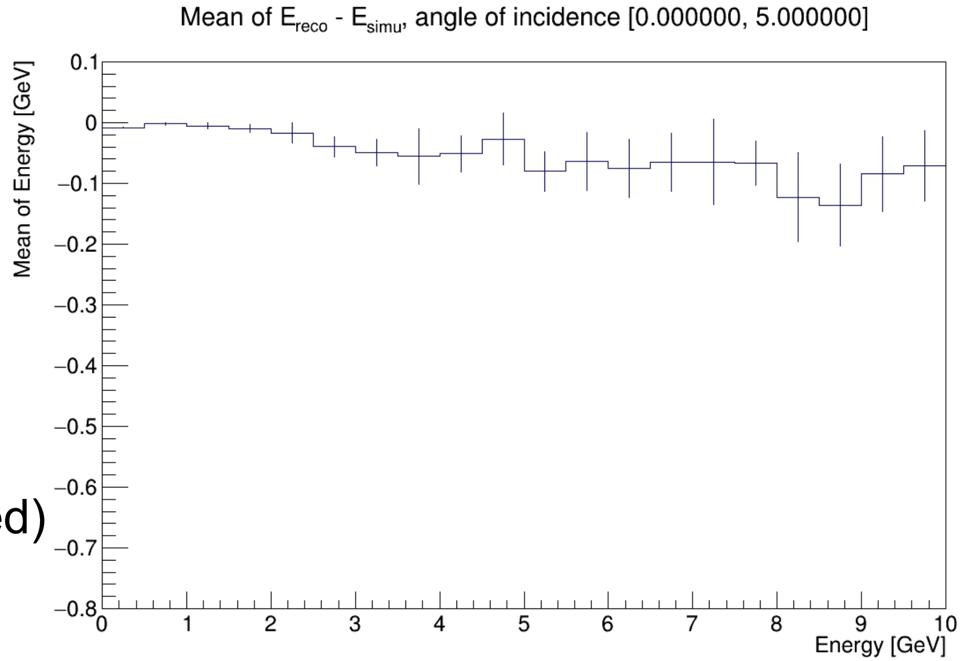
2) clustering+reconstruction+PID

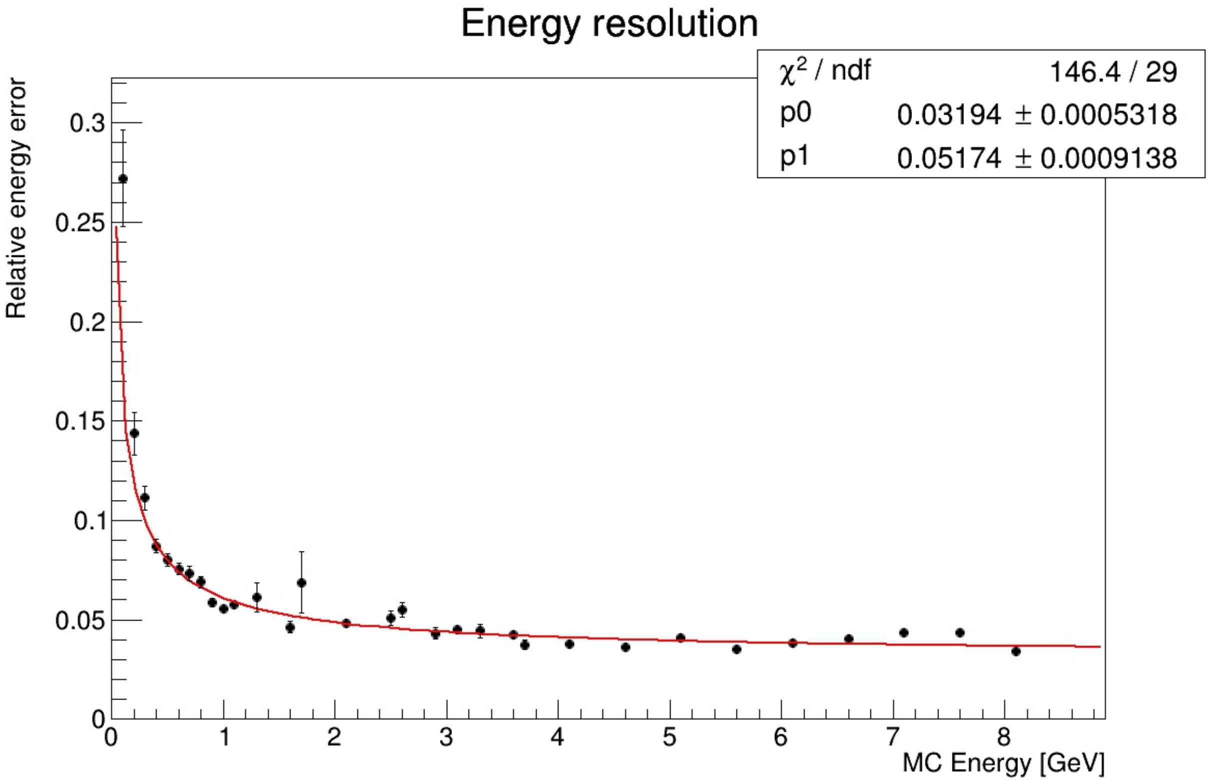
with a convolutional neural network approach

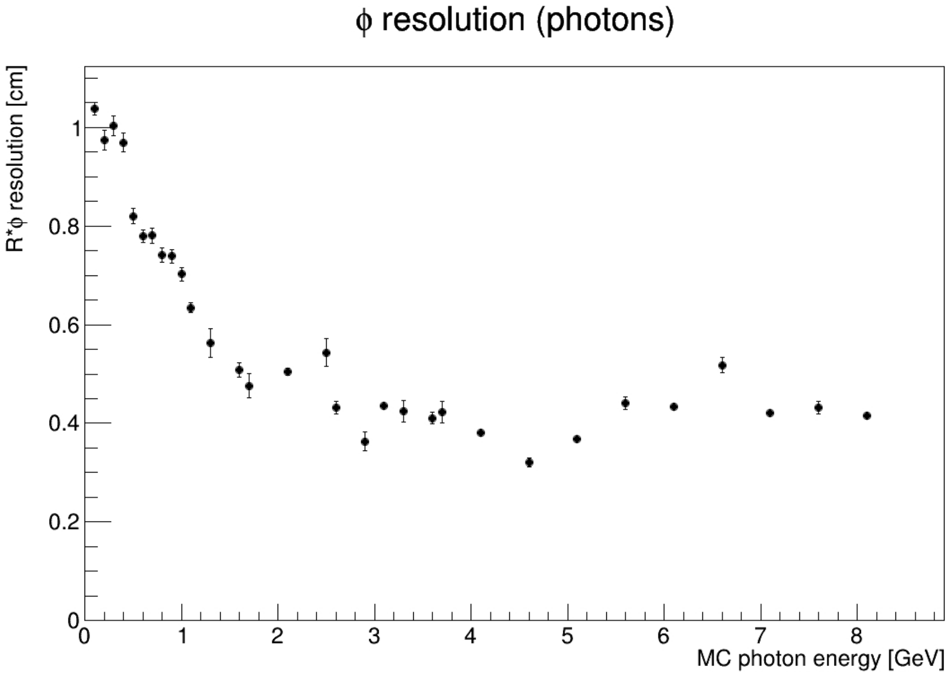
Still in research stage

Status of photon reconstruction

- using weighted average with empirical corrections depending on energy/angle
- repository of performance tests for ECAL: $SPDROOT/macro/performance-tests/ecal-reconstruction
- pictures are shown for pre-January geometry (to be updated)







Status of pi/gamma separation

Input parameters

- X/Y for endcaps or Z/ϕ for barrel, inputs shown in red

Energy distribution

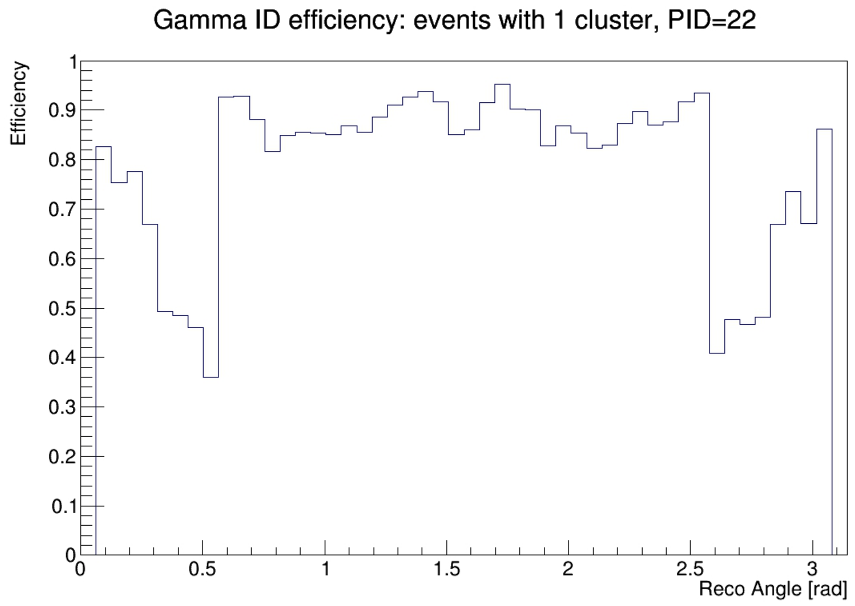
- S_1, M_2 – cells with first and second largest energies
- S_9, S_{25} – sum of energies in 3×3, 5×5 regions around cell with highest energy
- S_6 – maximum energy in 3×2 region containing both first and second largest energy cells
- $\frac{S_1}{S_9}, \frac{S_9-S_1}{S_{25}-S_1}, \frac{M_2+S_1}{S_4}, \frac{S_6}{S_9}, \frac{M_2+S_1}{S_9}, \frac{S_4}{S_{25}}$

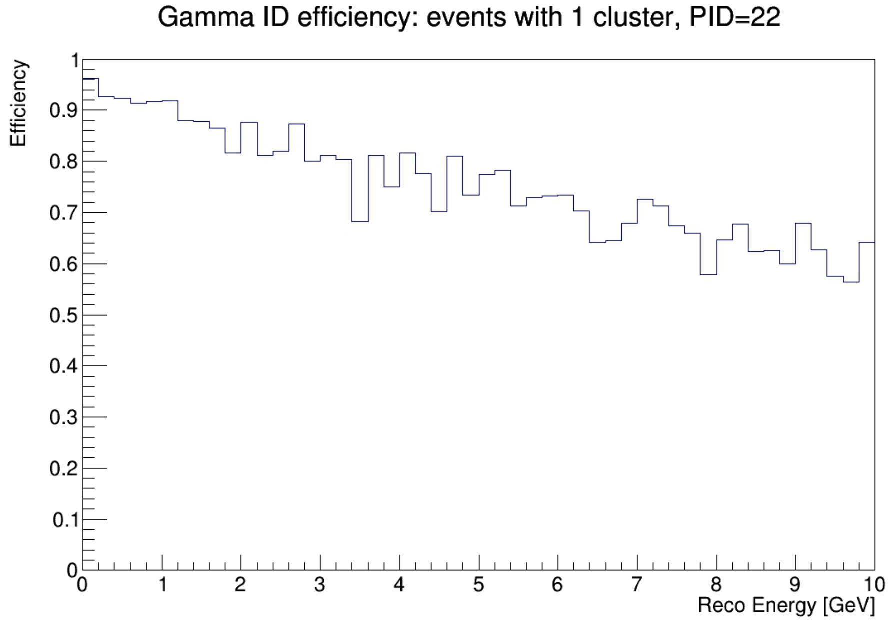
Size/shape

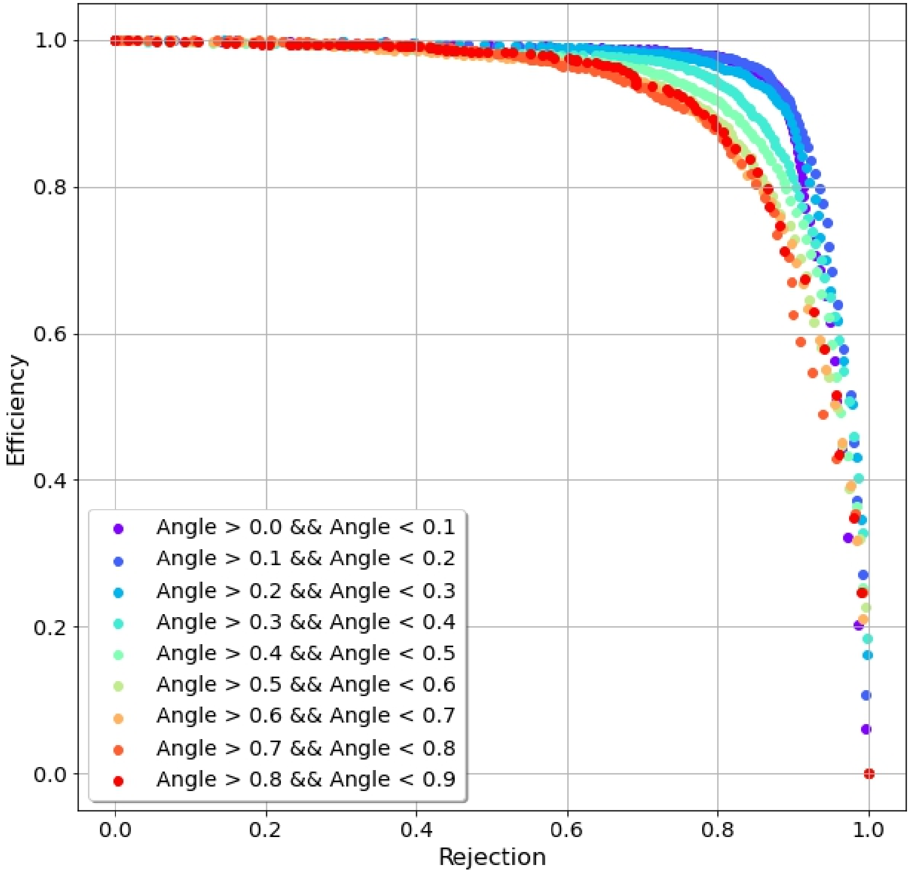
- $|x_{cog}|_{25} = |\frac{\sum_{i=1}^{25} E_i X_i^{rel}}{S_{25}}|$, $|y_{cog}|_{25} = |\frac{\sum_{i=1}^{25} E_i Y_i^{rel}}{S_{25}}|$
- $S_{\alpha\beta} = \frac{\sum_{i=1}^{N} e_i(\alpha_i-\alpha_c)(\beta_i-\beta_c)}{\sum_{i=1}^{N} e_i}$, $\alpha, \beta : X, Y$
- $\rightarrow S_{XX}, S_{YY}, S_{XY}$
- $r2 = <r^2> = S_{XX} + S_{YY} = \frac{\sum_{i=1}^{N} e_i((x_i-x_c)^2+(y_i-y_c)^2)}{\sum_{i=1}^{N} e_i}$
- $\kappa = \sqrt{1 - 4\frac{S_{XX}S_{YY}-S_{XY}^2}{(S_{XX}+S_{YY})^2}} = \sqrt{1 - 4\frac{\det S}{\mathrm{Tr}^2 S}}$
- Angle θ of incidence

- Neural network with inputs corresponding to the shower shape parameters
- Output: value from 0 (γ) to 1 (π^0)

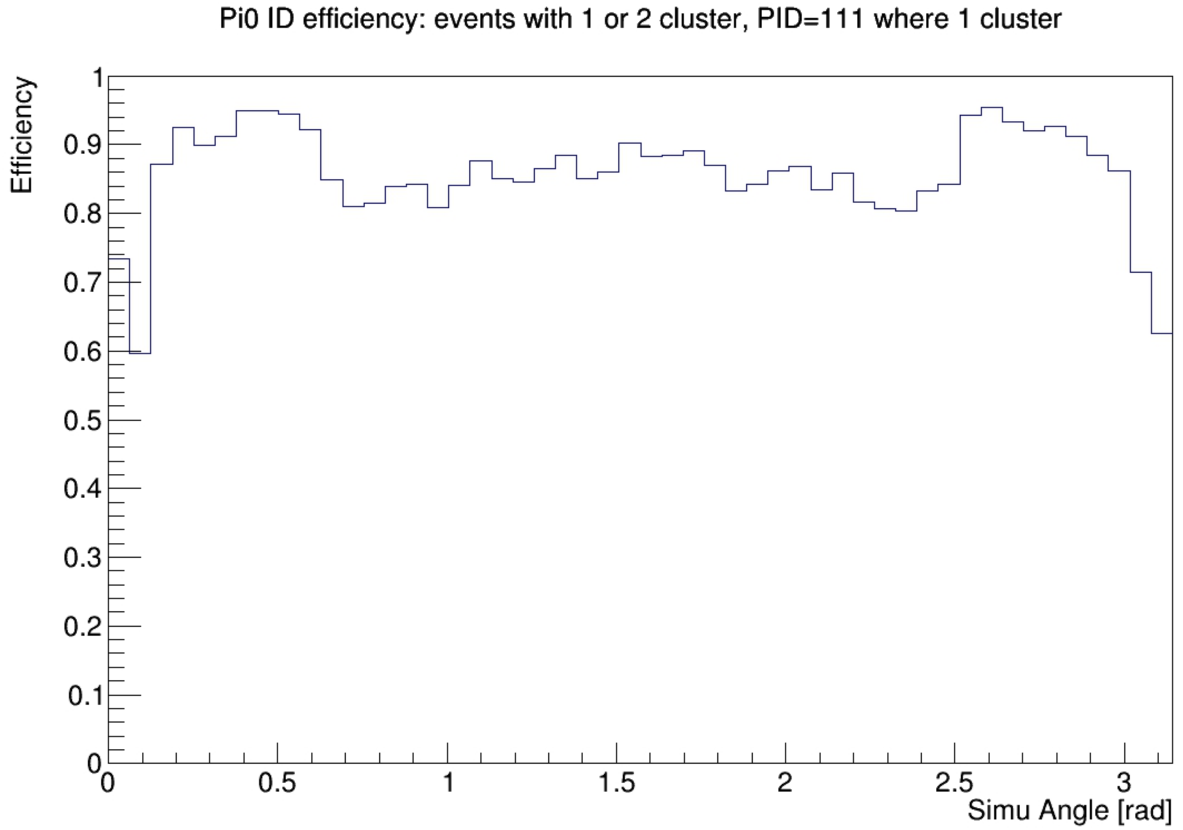
Status of pi/gamma separation

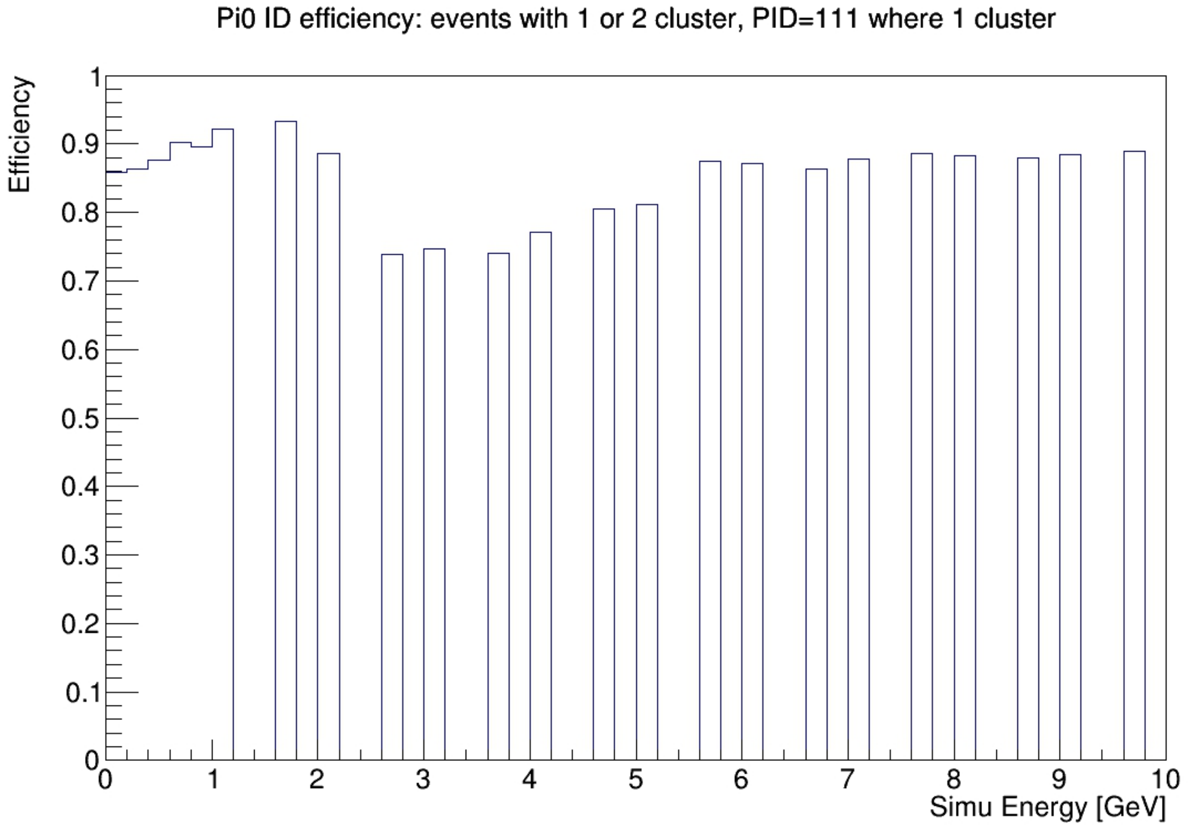






Status of pi/gamma separation





70-90% π^0 detection efficiency

Conclusions

- Reconstruction works at the level of 1%, changes from the newest geometry updates to be studied
- π0 ID gives 80-90% π0 rejection efficiency at 70-80% photon detection efficiency
- Presently, in SPDROOT photon reconstruction and π/γ separation are done as separate steps, no reconstruction of individual photons from π^0 yet

Next steps:

- Review cases of clusters in barrel/endcap gap region, both for reconstruction and π/γ separation
- Reconstruct energies/positions of individual photons in case of being ID'd as π^0
- Research a more robust approach to reconstructing photons (machine learning?) and compare to a “traditional” method