Study of inclusive π^0 production at SPD

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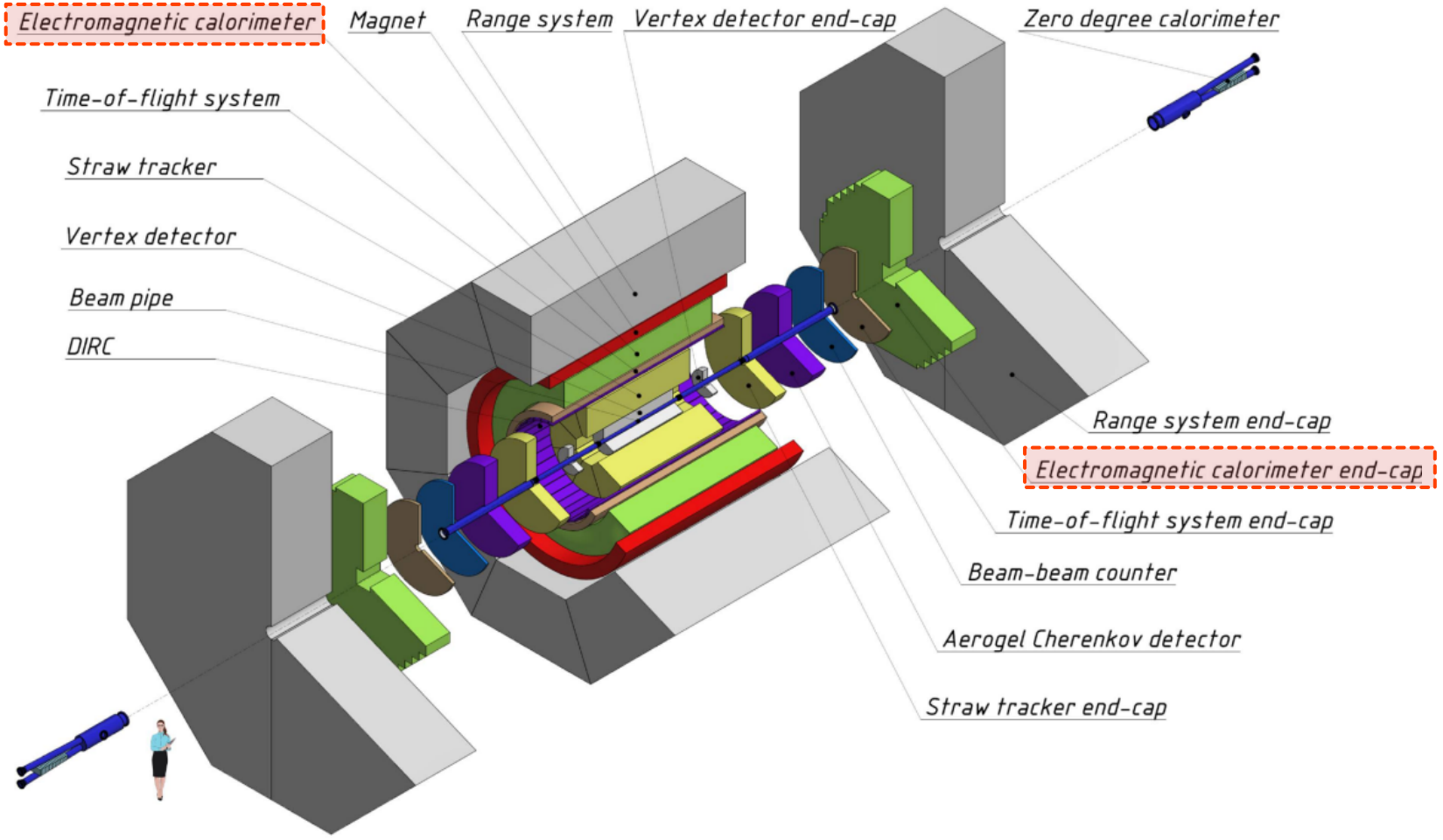
Schematic view of the SPD setup



Goal of study

- The ultimate goal is to measure the transverse single-spin asymmetries (SSA) for π^0. However, one of the first measurements will be the measurement of the cross section for inclusive π^0 production.

- To measure the cross section, it is necessary to know the efficiency of π^0 reconstruction.

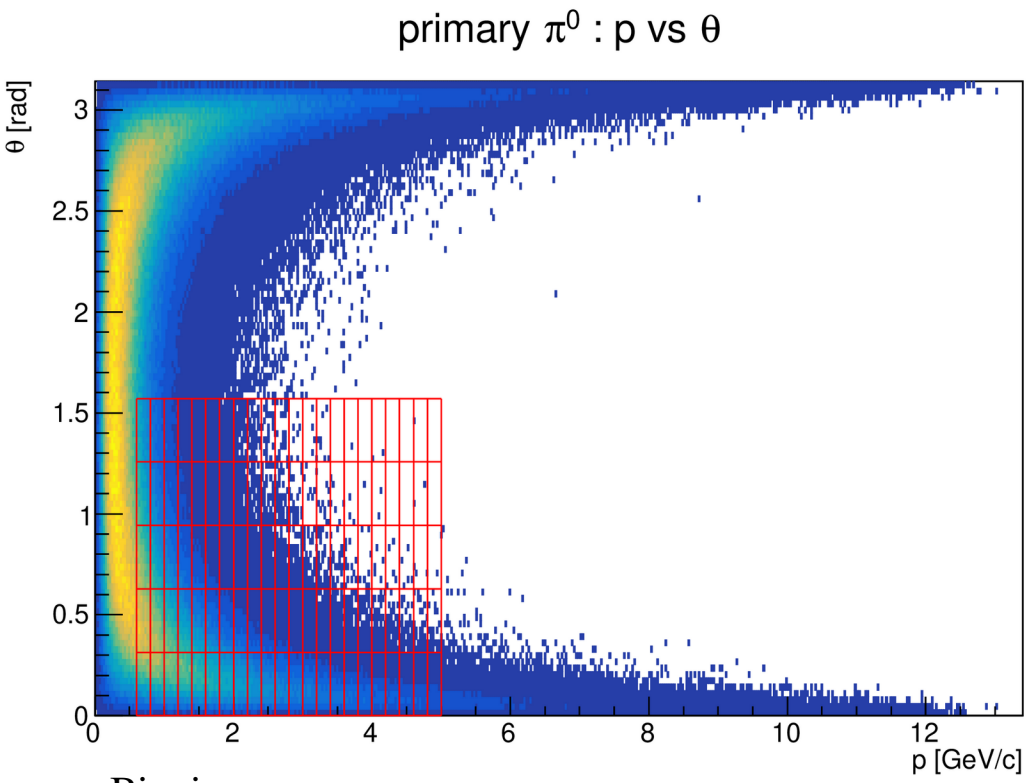
- In this study, the efficiency of π^0 reconstruction efficiency (N_{RC}/N_{MC}) is estimated as a function of momentum p and polar angle θ.

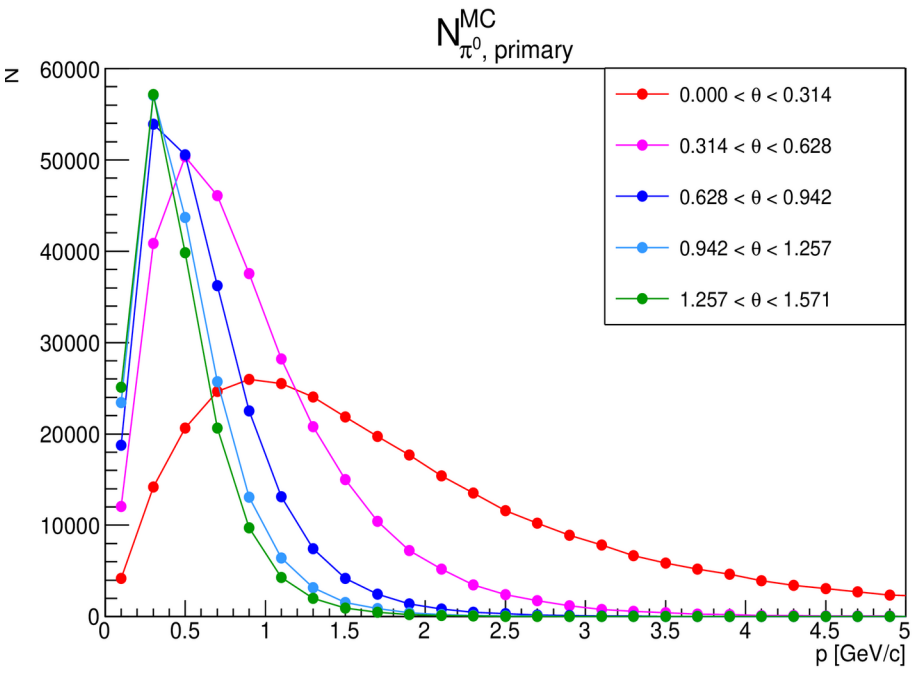
- The contributions of various factors that determine the efficiency are evaluated.

Event generation

- **SpdRoot** is currently the main package for events simulation and reconstruction for the SPD project. It is based on FairSoft / FairRoot package.
- **Pythia8** is used as the primary generator.
- *p*-*p* beams, $\sqrt{s} = 27\,\mathrm{GeV}$
- Minimum bias sample, 600 000 events (~ 0.2 s of data taking)

(p, θ) distribution of π^0 [MC]





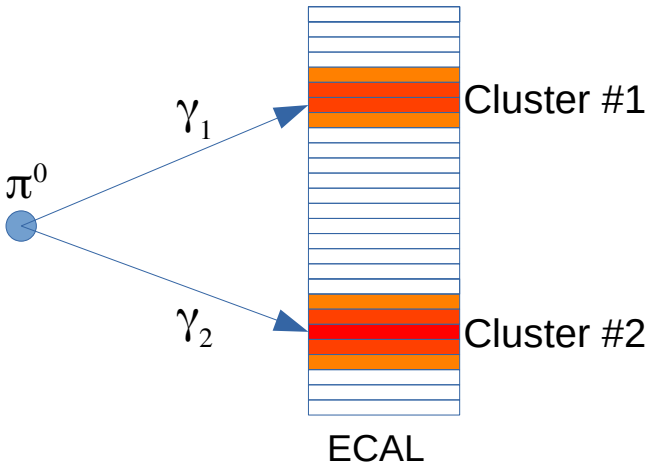
Binning:

$p = 0.6 \,..\, 5.0$ GeV/c, $\Delta p = 0.2$ GeV/c

$\theta = 0 \,..\, 0.5 \cdot \pi$, $\Delta\theta = 0.1 \cdot \pi$

Procedure of π^0 reconstruction

- Loop through all pairs of ECAL clusters.
- Since the association of tracks with clusters is currently not implemented, we take the information about which particle(s) created the cluster from the corresponding MC info object, and then exclude the clusters associated with charged particles.
- Apply cut $E_{cluster} > 300$ MeV to reduce background.
- Calculate the invariant mass for each pair of clusters, assuming that the clusters were produced by photons coming from the primary vertex.

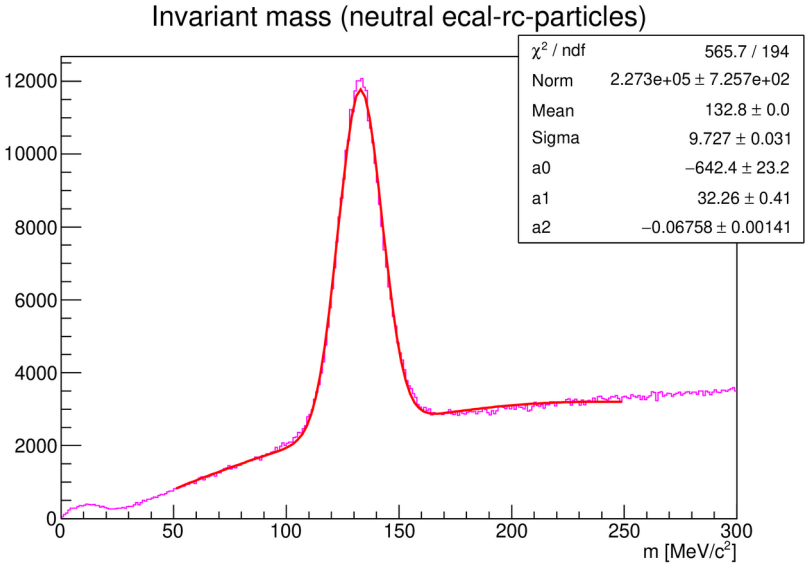


Procedure of π^0 reconstruction

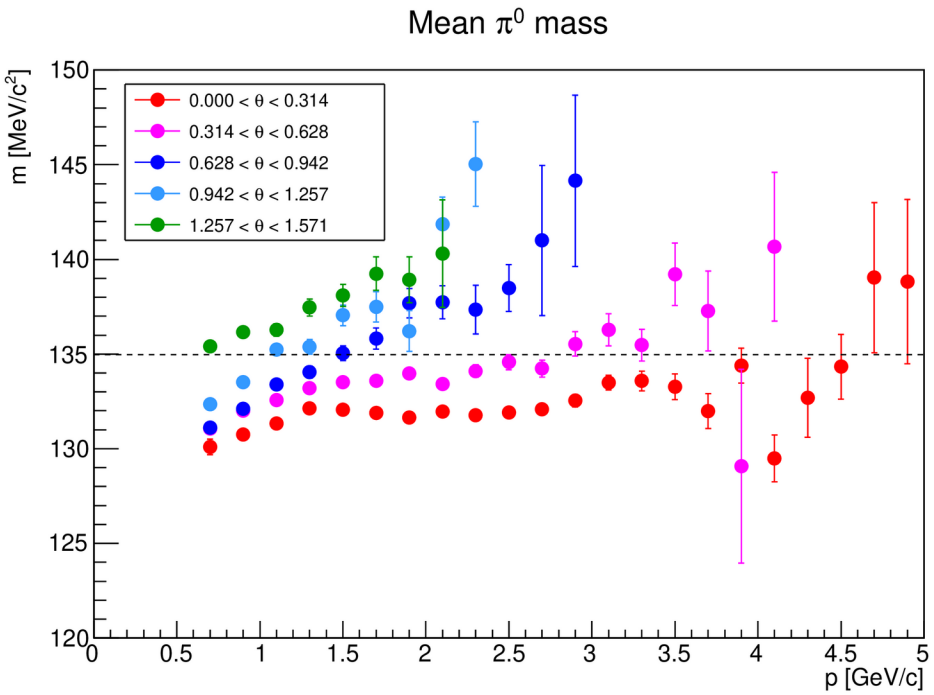
- Invariant mass distribution is fitted by function:

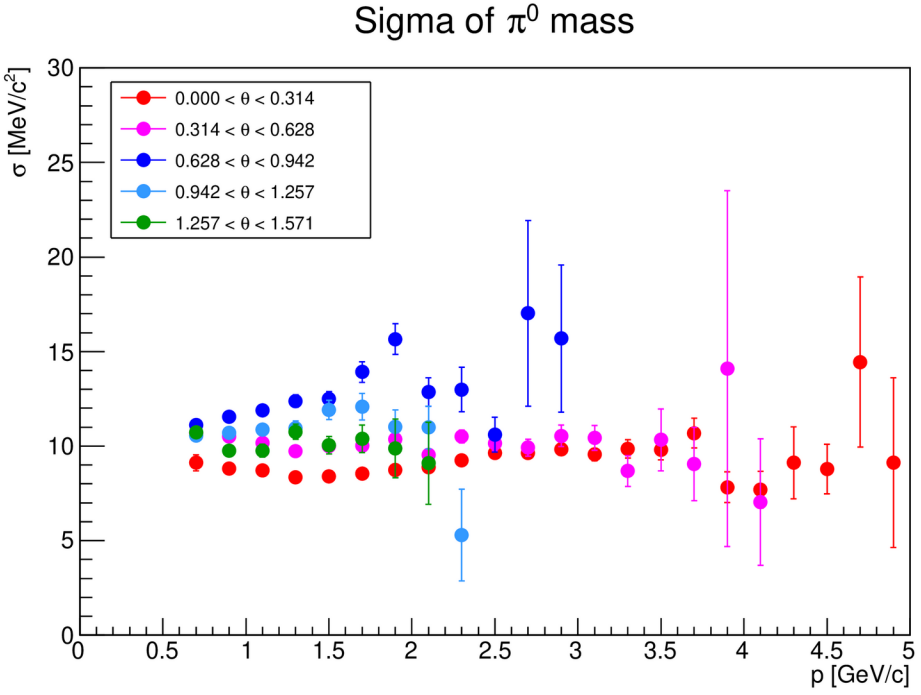
$$f(m) = \frac{I}{\sigma\sqrt{2\pi}}\exp\left[-\frac{(m-\mu)^2}{2\sigma^2}\right] + \underbrace{(a_0 + a_1 m + a_2 m^2)}_{\text{background}}$$

- The procedure described above is applied for each p-θ bin.



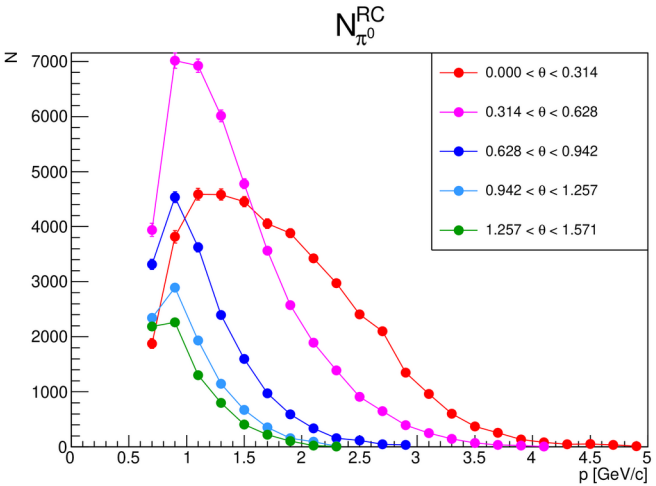
π^0 mean mass and sigma

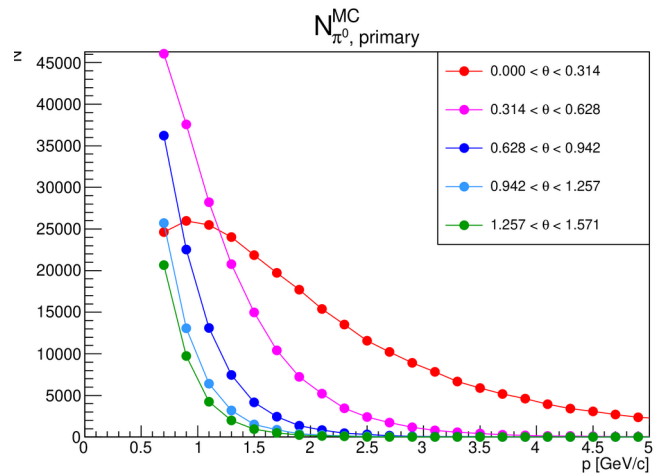


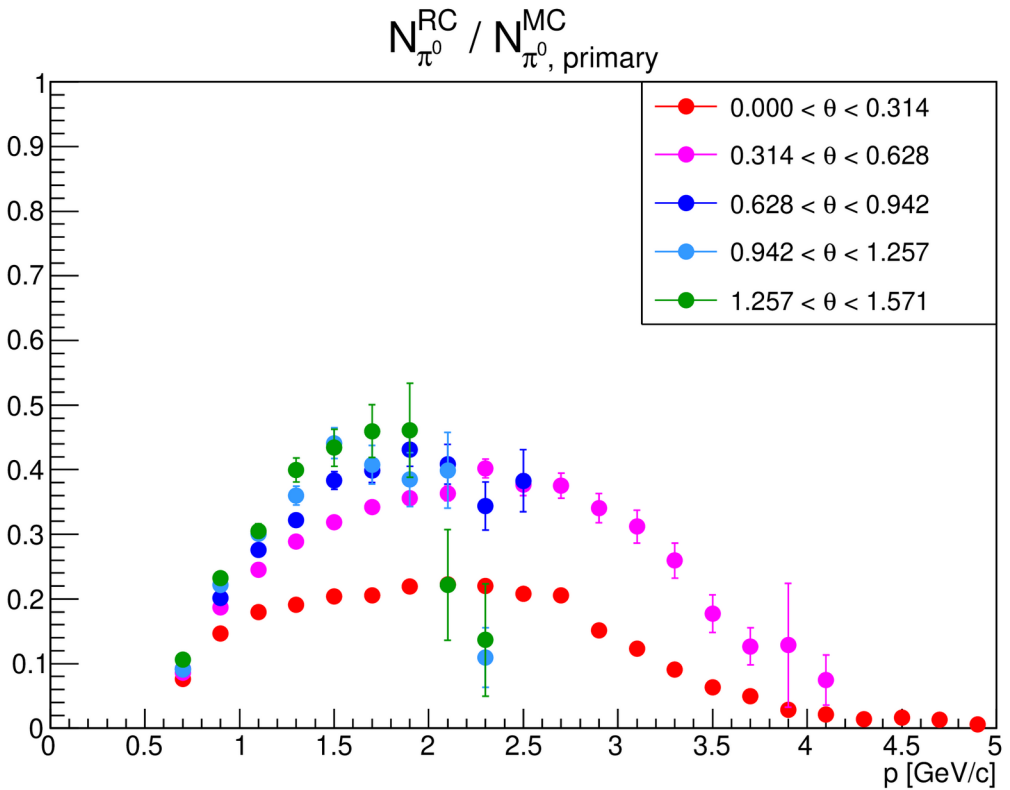


$m_{\pi^0}^{\mathrm{PDG}} = 135\ \mathrm{MeV}/c^2$

π^0 reconstruction efficiency





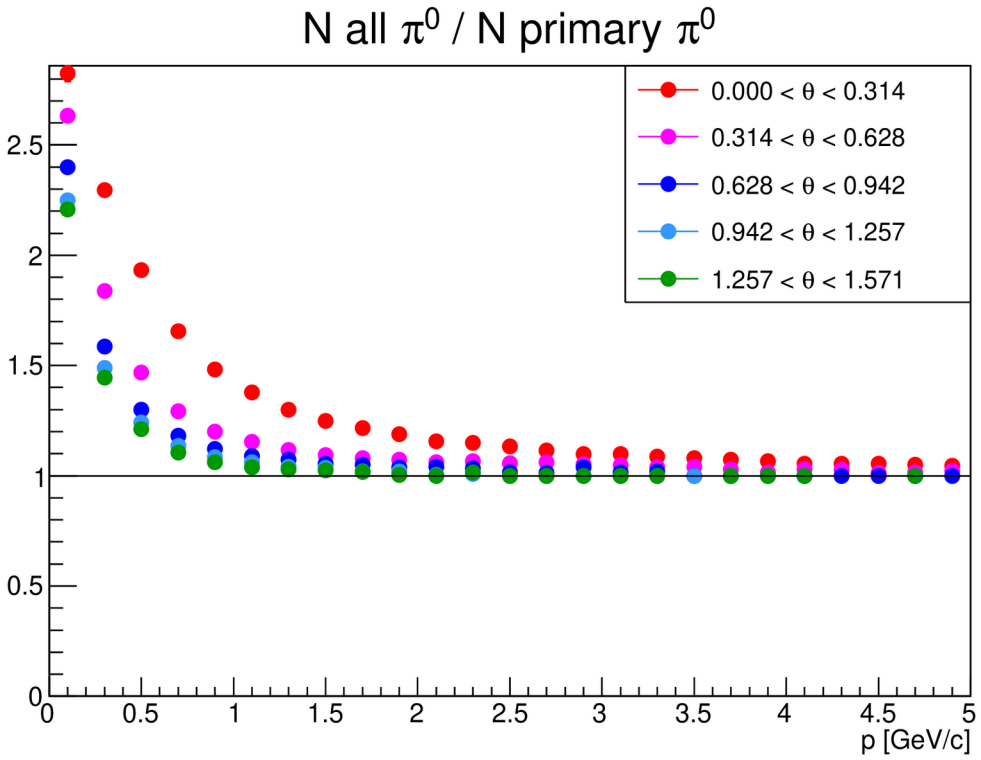


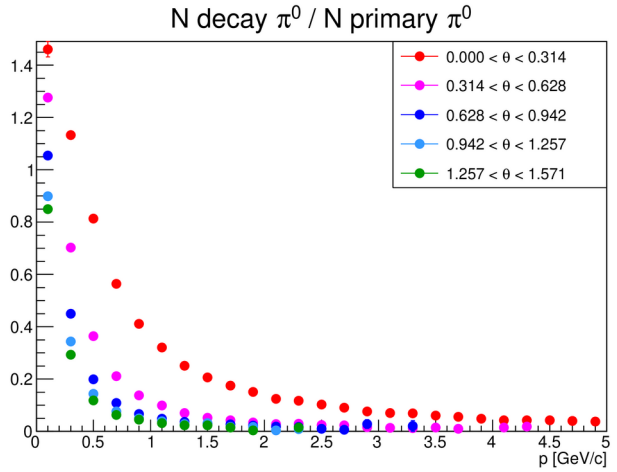
Factors determining π^0 reconstruction efficiency

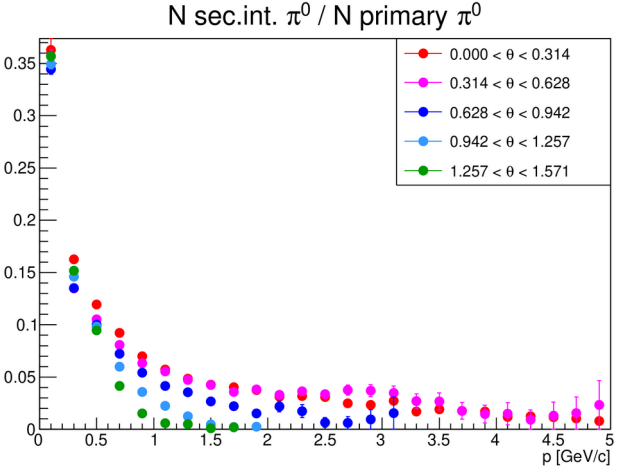
1. Feed down (π^0 from decays and secondary interactions)
2. Geometrical acceptance and loss of γ
3. Both γ may be associated with the same ECAL cluster.
4. Rejection of multi-shower clusters associated with charged particle(s)
5. Cut on cluster energy ($E_{cluster} > 300$ MeV)
6. Mis-reconstructed particle energy $\Rightarrow$ wrong invariant mass

Feed down (π^0 from decays and secondary interactions)

$$N_{\text{all }\pi^0} = N_{\text{primary }\pi^0} + N_{\text{decay }\pi^0} + N_{\text{sec.int. }\pi^0}$$

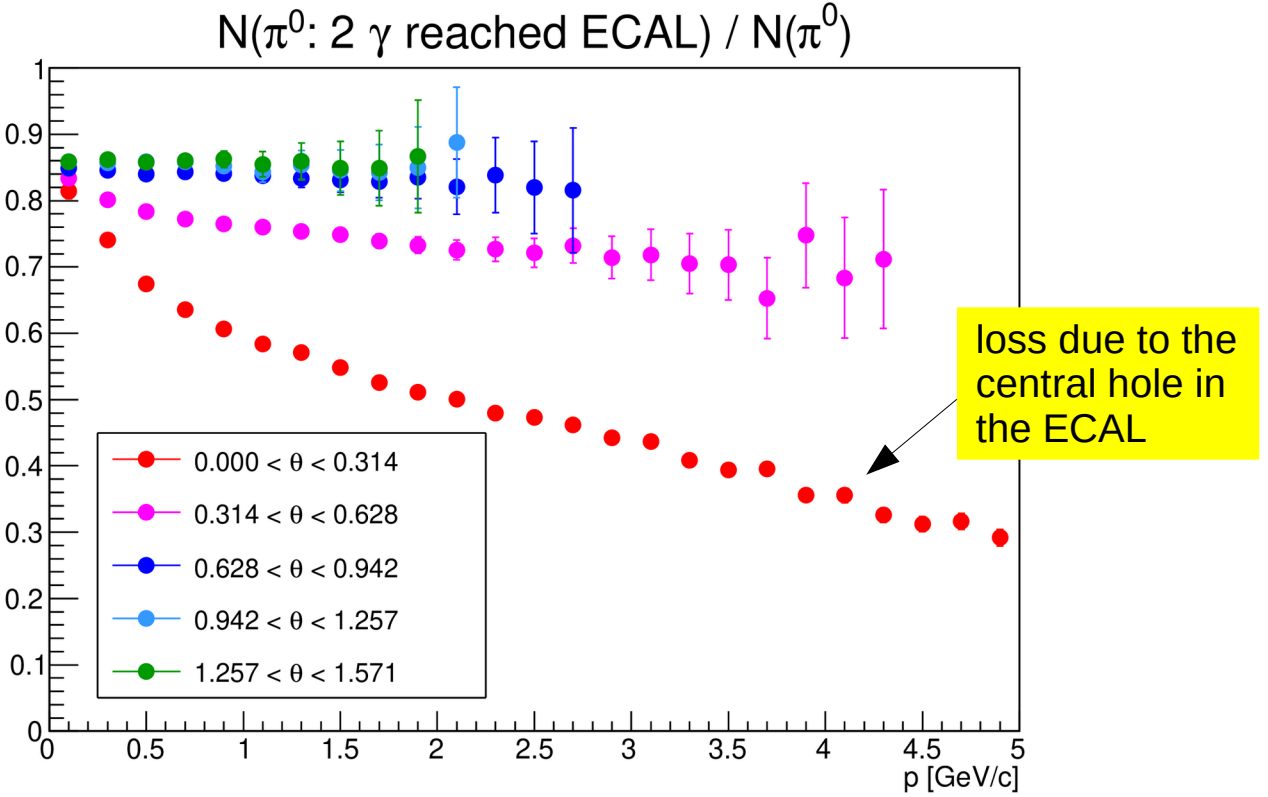






Geometrical acceptance + γ loss: π^0

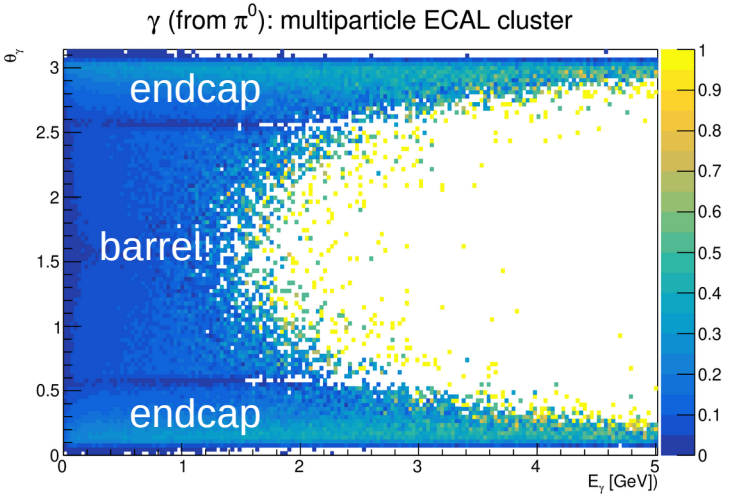
Check whether both γ particles from π^0 decay reached ECAL.

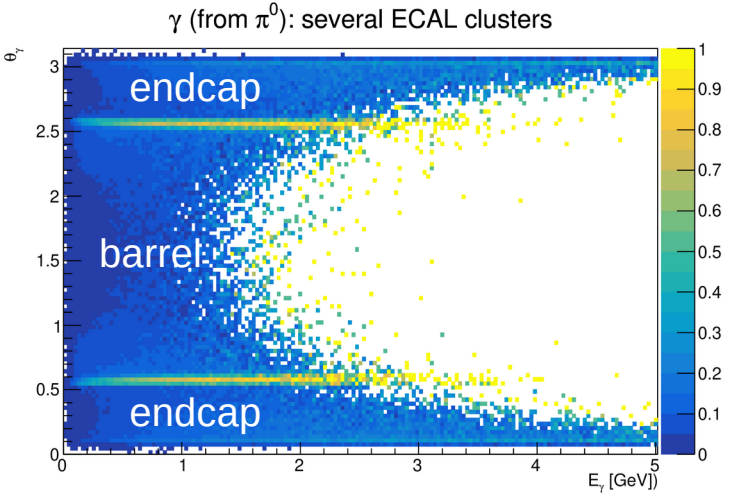


ECAL clusters: complicated cases

- However, one reconstructed cluster may be produced by more than one closely flying particles («*multi-particle clusters*»), especially in the **endcaps**.

- On the contrary, one particle may produce *several clusters*.
  This typically happens in the area of **overlap of barrel and endcaps**.

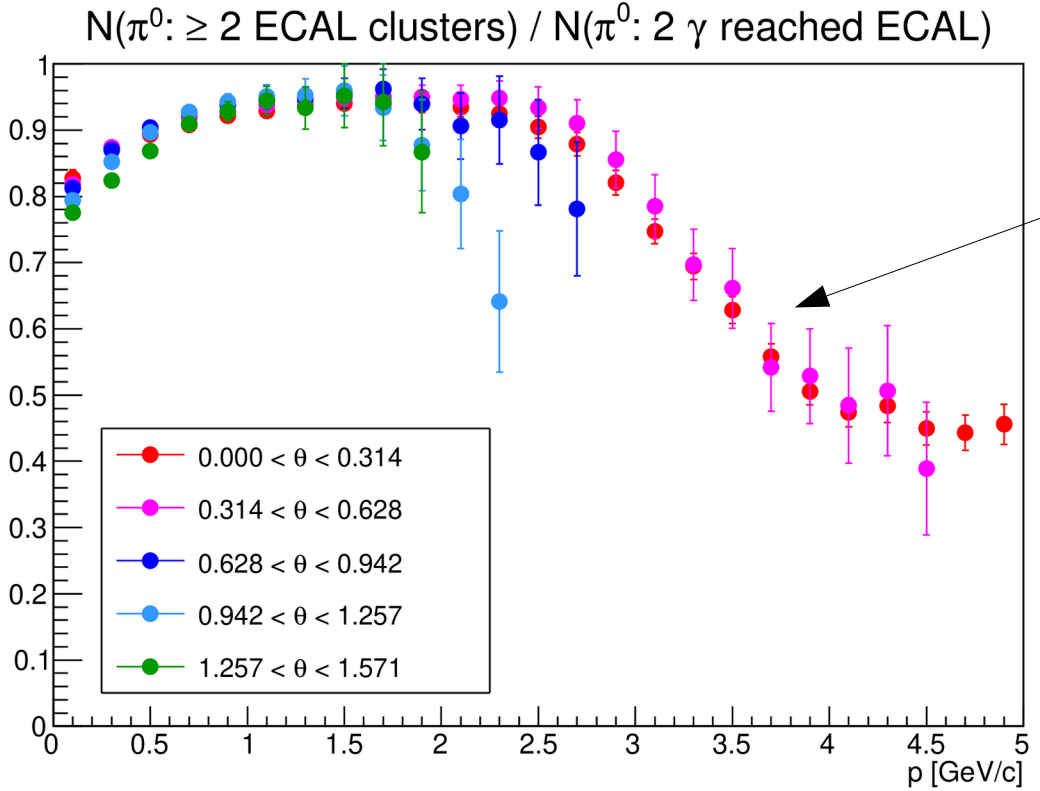


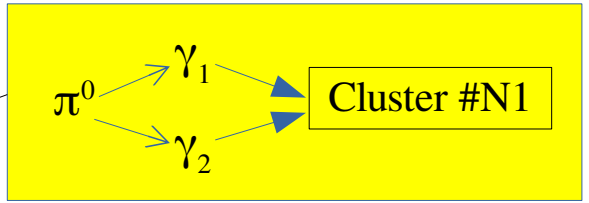


(plots are normalized to number of all γ from π^0 decays)

Loss of π^0 when γ's are associated with the same cluster

- Check whether exist at least two different ECAL clusters associated with γ particles from π^0 decay.

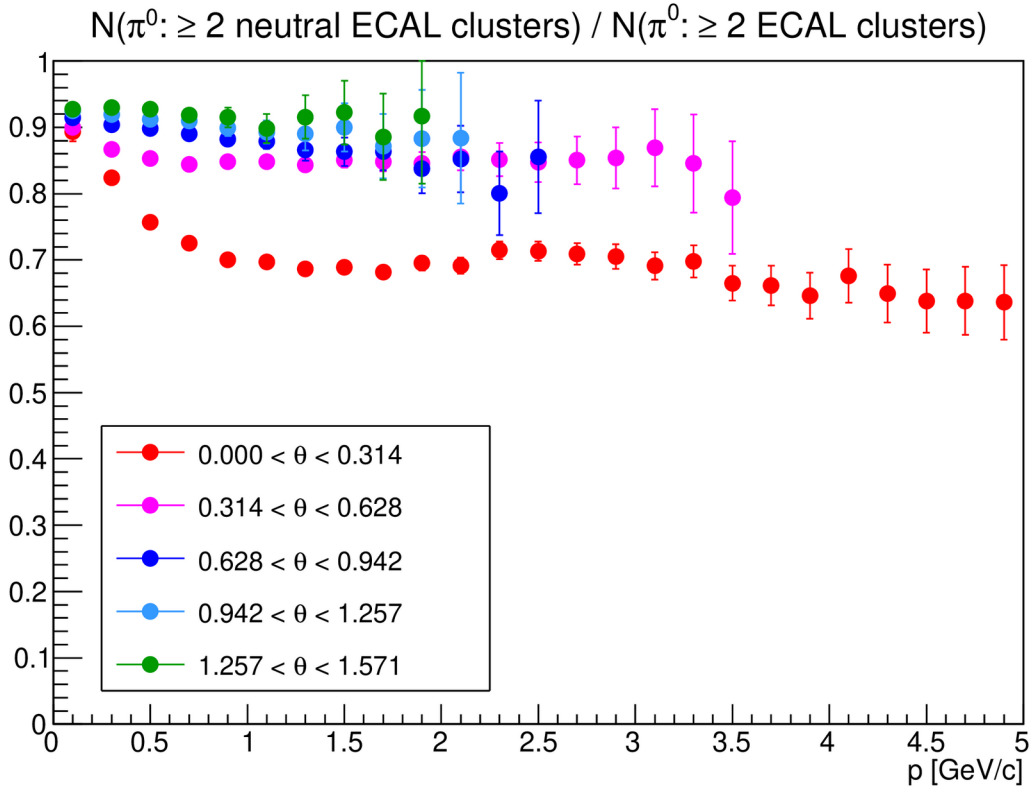


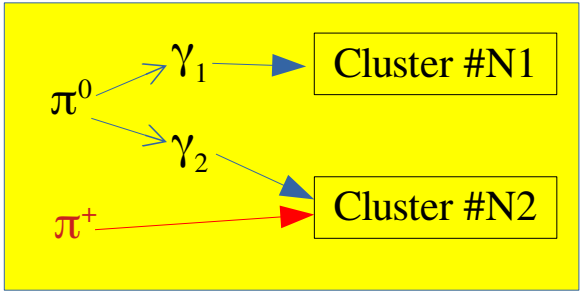


Exclusion of “charged” clusters

Multi-particle clusters may be associated also with a charged particle, e.g. (π^+ γ).

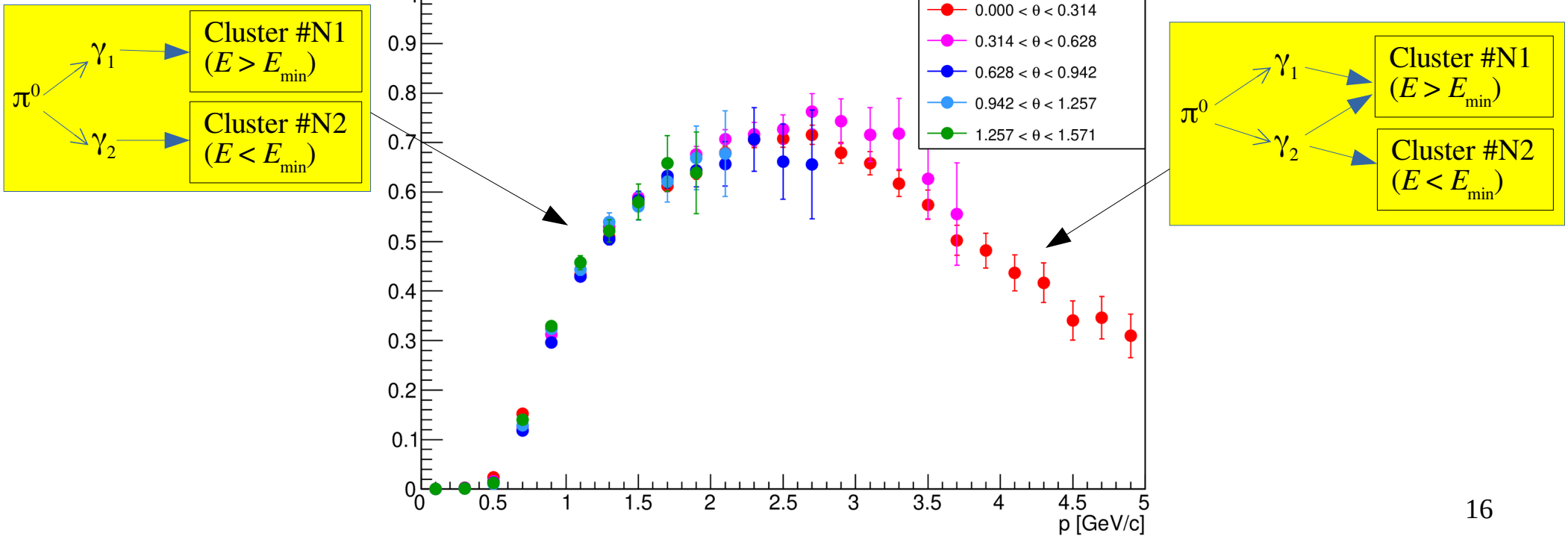
Such cases are excluded.



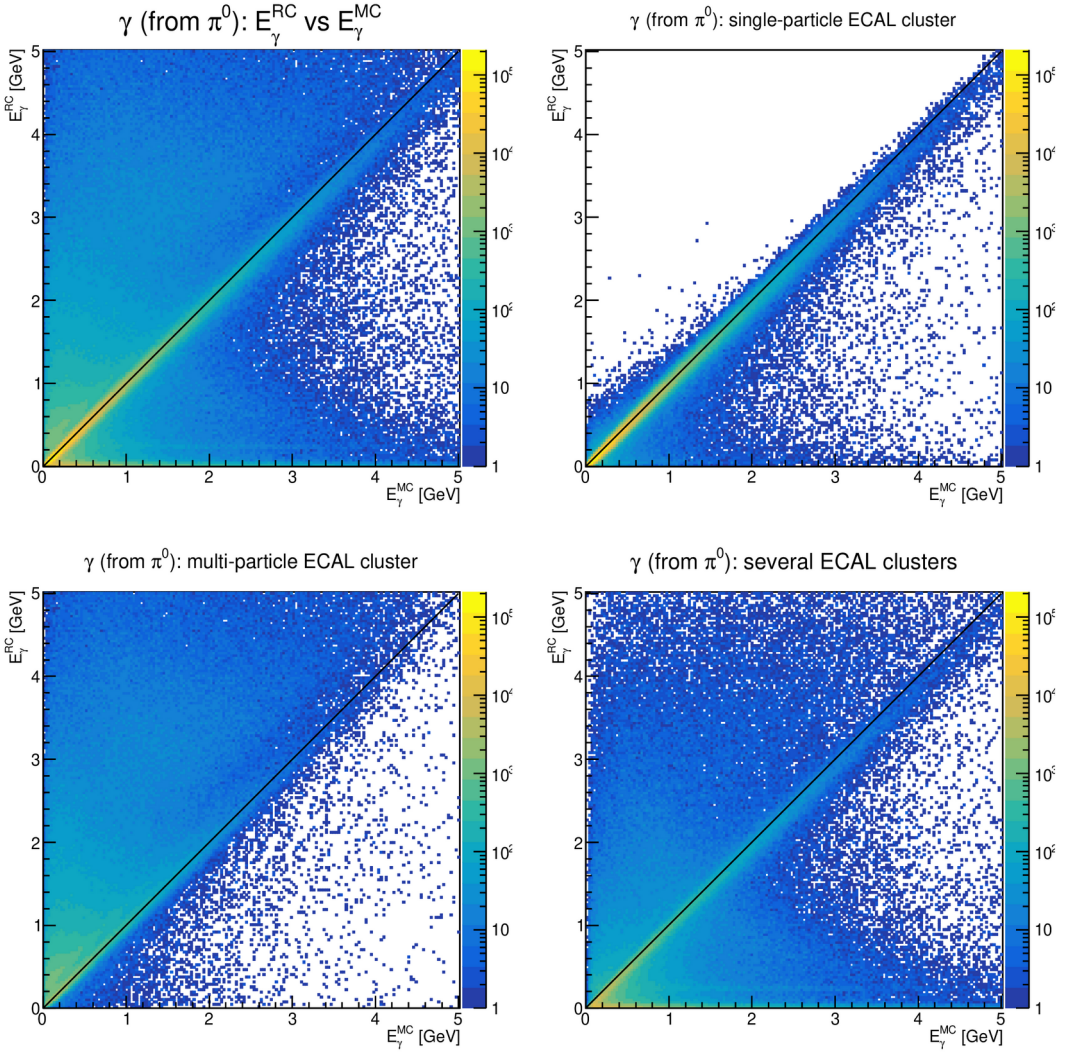


Cut on minimal cluster energy

- Require that energy of clusters associated with γ particles from π^0 decay is above E_{min} ($E_{cluster} > E_{min}$).



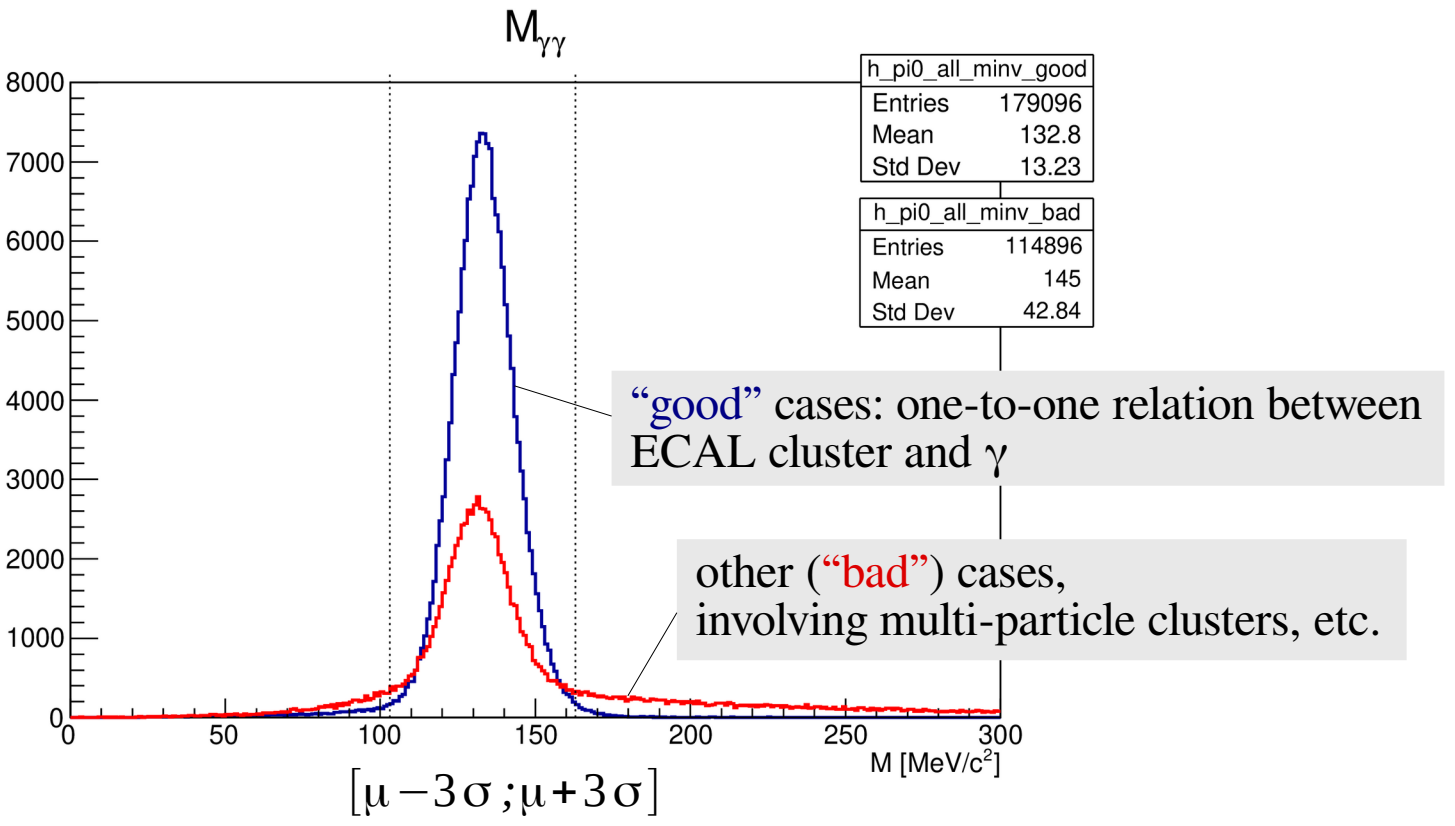
γ (from π^0) : E^{RC} vs E^{MC}



energy is overestimated

energy may be underestimated

Mis-reconstructed energy / invariant mass

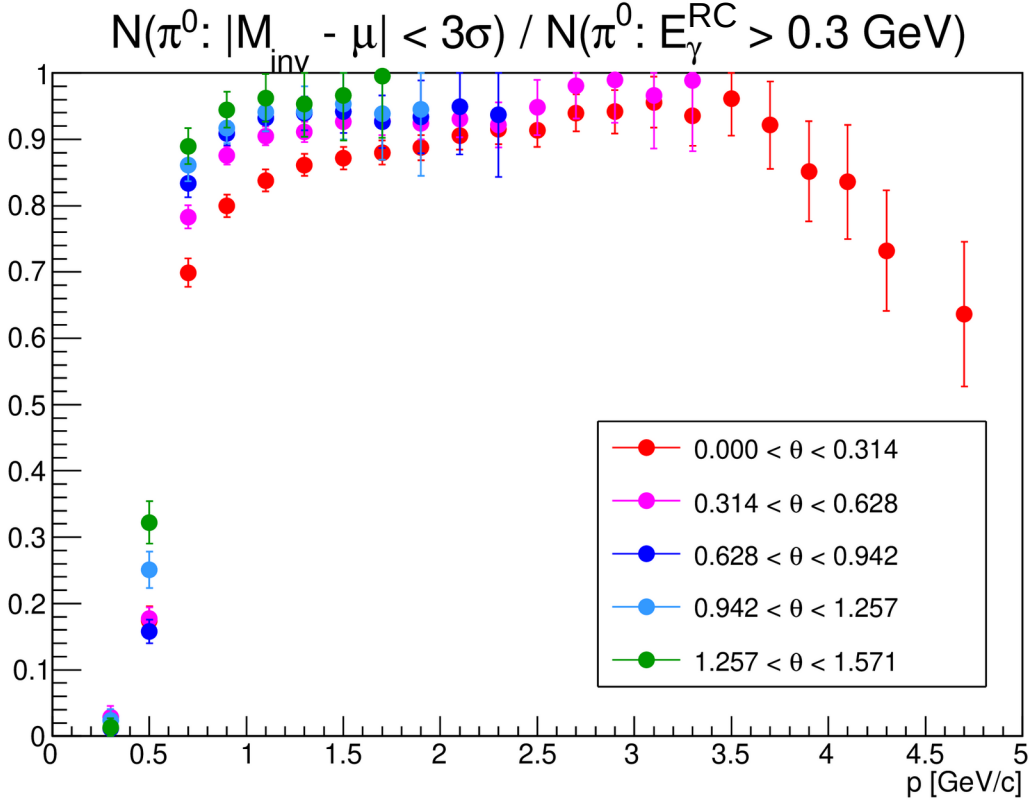


$\mu = 133\,\mathrm{MeV}$, $\sigma = 10\,\mathrm{MeV}$

Mis-reconstructed energy / invariant mass

Mis-reconstructed photon energy may lead to incorrect invariant mass.

Exclude π^0 mesons with invariant mass outside $[\mu - 3\sigma; \mu + 3\sigma]$ range.



Summary of correction factors

$$c = c_{feed\,down} \cdot c_{geom+loss} \cdot c_{ecalreco} \cdot c_{excl.charged} \cdot c_{Ecut} \cdot c_{misrec}$$

$$c_{feed\,down} = \frac{N(\pi^0)}{N(\text{primary}\,\pi^0)}$$

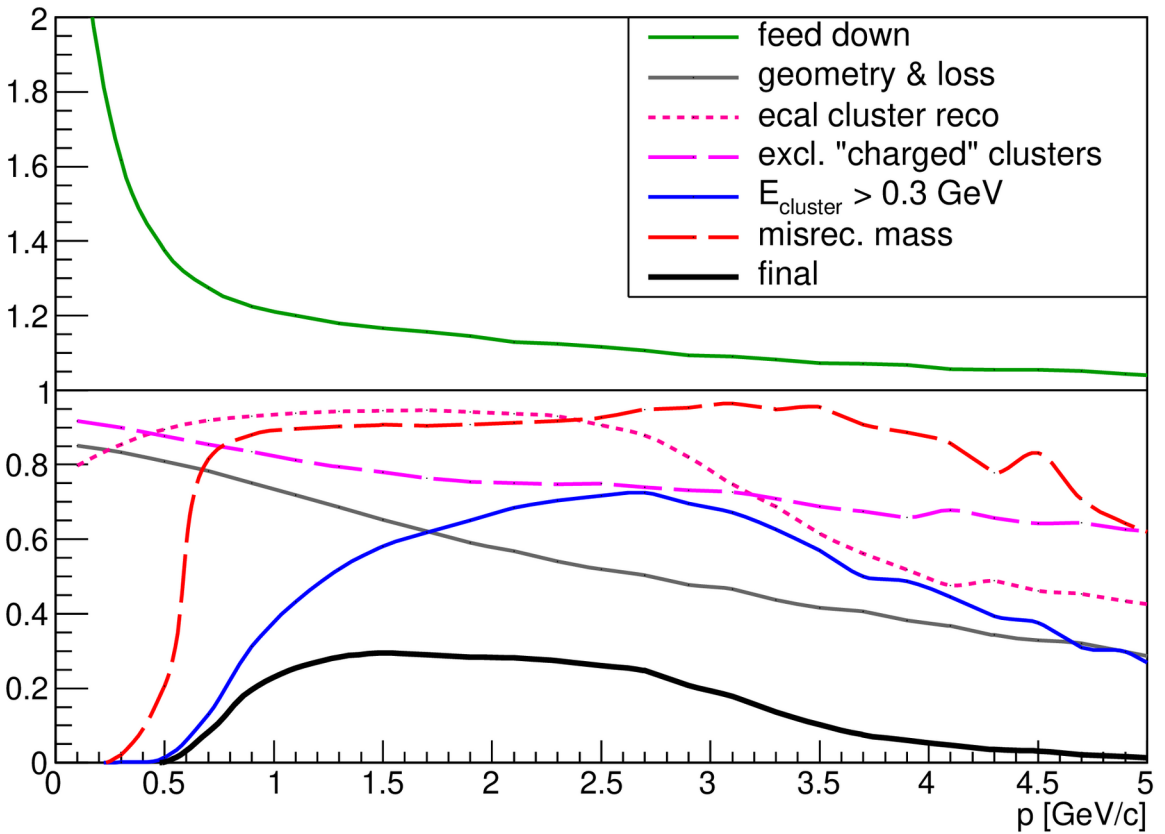
$$c_{geom+loss} = \frac{N(\pi^0 : \text{both}\,\gamma\ \text{reached ECAL})}{N(\pi^0)}$$

$$c_{ecalreco} = \frac{N(\pi^0 : \geq 2\,\text{ECAL clusters})}{N(\pi^0 : \text{both}\,\gamma\ \text{reached ECAL})}$$

$$c_{excl.charged} = \frac{N(\pi^0 : \geq 2\,\text{ECAL neutral clusters})}{N(\pi^0 : \geq 2\,\text{ECAL clusters})}$$

$$c_{Ecut} = \frac{N(\pi^0 : \text{both}\,E_\gamma^{RC} > 0.2\,\text{GeV})}{N(\pi^0 : \geq 2\,\text{ECAL neutral clusters})}$$

$$c_{misrec} = \frac{N(\pi^0 : |M_{inv} - \mu| < 3\,\sigma)}{N(\pi^0 : \text{both}\,E_\gamma^{RC} > 0.2\,\text{GeV})}$$



Conclusions

- A detailed analysis of various factors affecting the efficiency of π^0 reconstruction has been presented.
- Work is underway on the multi-shower reconstruction algorithm for ECAL clusters.
- The inclusive π^0 production cross section will be one of the first measurements once the SPD experiment starts data taking.
- These measurements will be used to improve the MC models of π^0 production.