Simulation of the MPD-ECAL

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Outline

- Short reminder
- Coordinate measurements and signal averaging
- Spatial resolution
- Energy resolution
- Detector performance: hadrons, $e^{\pm}$, π^0, η

Reminder

- Last meeting: https://indico.jinr.ru/conferenceDisplay.py?confId=844

- Digitizer (original version provided by Maxim):
  - ✓ fasten up for full event processing
  - ✓ association of towers with MC contributors

- Clusterizer:
  - ✓ signal unfolding based on expected shape of e/m showers
  - ✓ association of clusters with MC contributors
  - ✓ matching of clusters to the closest TPC tracks (dphi, dZ, track index)

- Tested with single photons:
  - ✓ similar performance with MM, AZ

- Tested with multiple photons and full event:
  - ✓ higher reconstruction efficiency, no other parameters are available for comparison
  - ✓ examples of π^0 reconstruction → available down to low momentum

Main issues

- Averaging of tower signals in the cluster:

  $$x = \sum x_i E_i \Big/ \sum E_i$$

  - is it optimal averaging scheme?
  - how others are doing averaging?

- What is achieved spatial resolution for e/m signals?

- Why width of reconstructed π^0 is ~ 10 MeV/c^2 at 2-3 GeV/c?

- How detector performance depends on multiplicity?
  → occupancy ~ 30-50% in minbias AuAu@11 events
  → inevitable overlap of showers

Signal averaging: ALICE-PHOS

- ALICE-PHOS example: $x_{\text{Rec}} = \frac{\sum x_i w_i}{\sum w_i}$
- Need to be tested with MPD-ECAL prototypes → should be planed in advance

$$w_i = E_i/E_{\text{T}}$$

$$w_i = \max\left\{0, \left[w_0 + ln\left(\frac{E_i}{E_T}\right)\right]\right\}$$

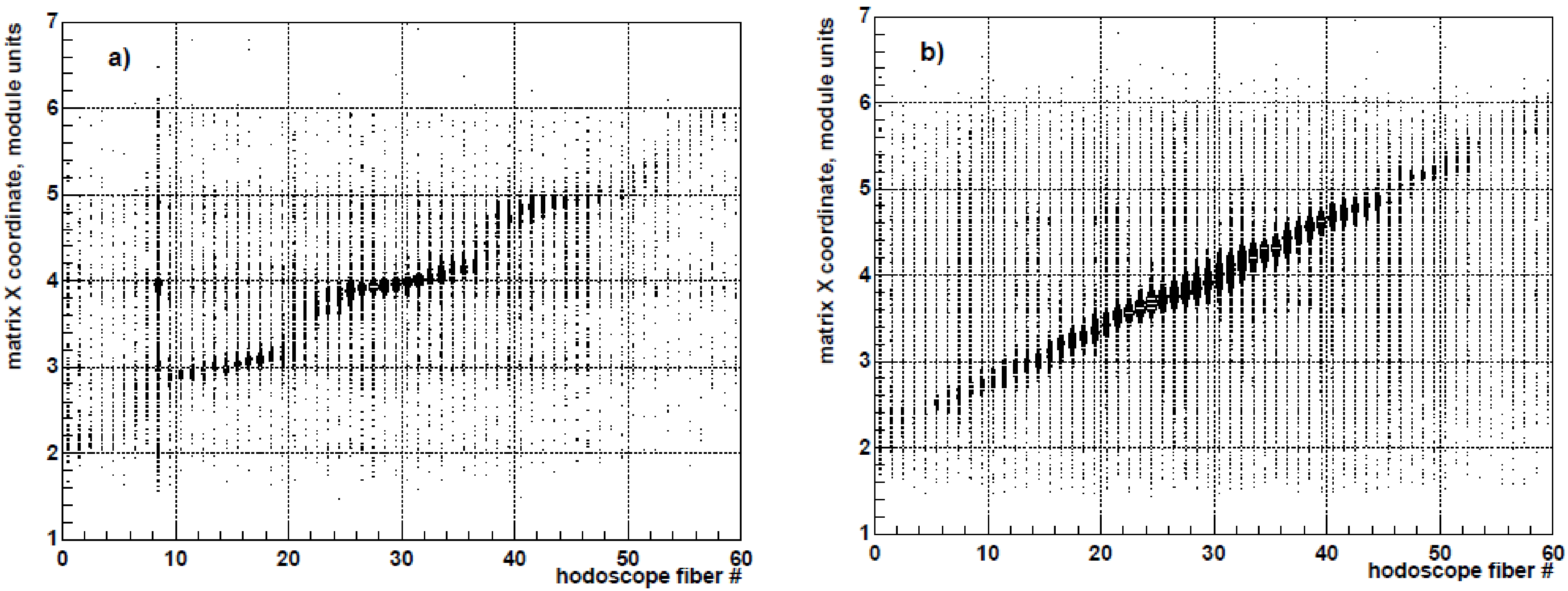
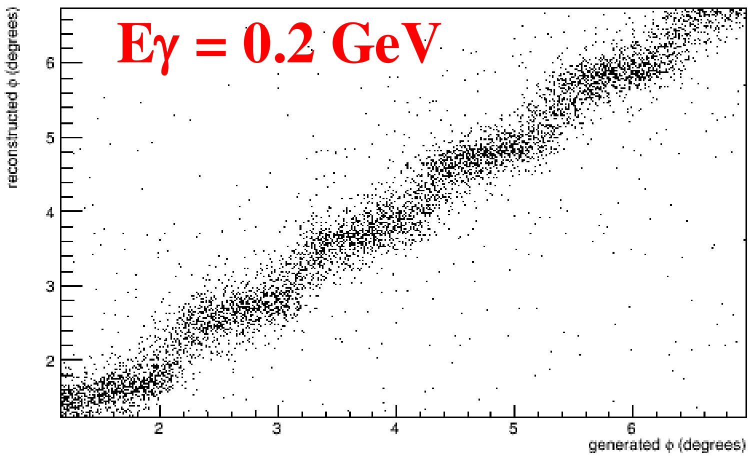


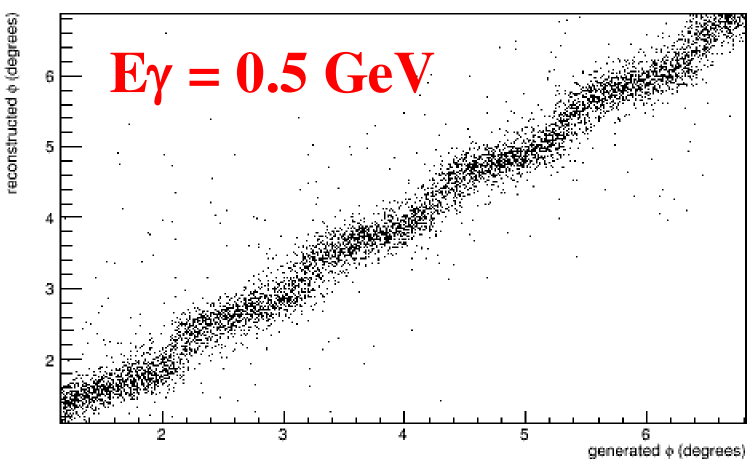
Figure 4.9: The reconstructed coordinate vs. incident coordinate. Beam test data for 2 GeV/c electrons. (a) Linear weights. (b) Logarithmic weights, $w_0 = 4.5$. The incident coordinate corresponds to the hodoscope fibre number. The distance between two adjacent fibres is 1.3 mm.

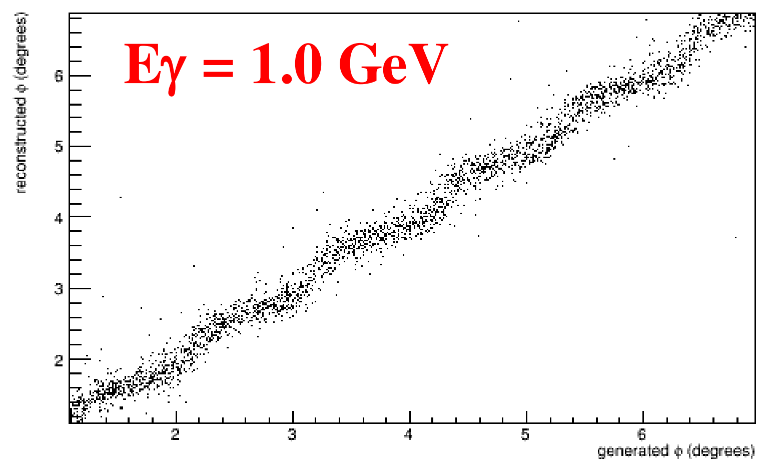
Signal averaging: MPD-ECAL

- MPD-ECAL case: $$x_{\text{Rec}} = \frac{\sum x_i w_i}{\sum w_i} \qquad w_i = E_i / E_{\text{T}}$$



- Generated single photons with $\theta = 90^0$, vertex at (0,0,0)
- φ_{rec} vs. φ_{gen} for a limited range of angles (a few towers)
- Observe a similar step-like structure at all energies





Signal averaging: MPD-ECAL

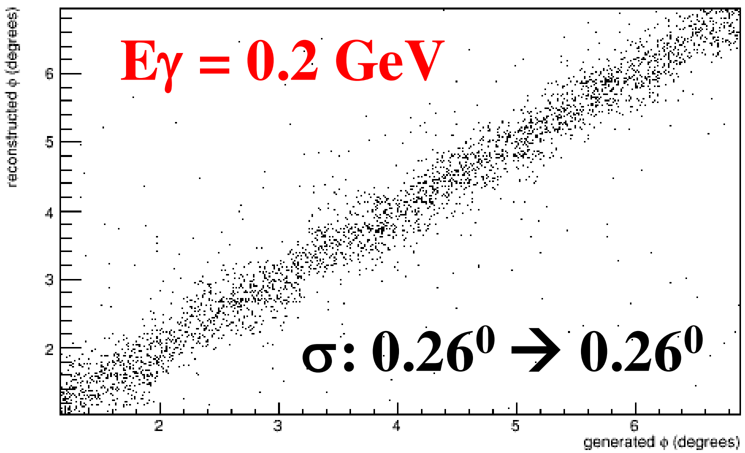
- MPD-ECAL case

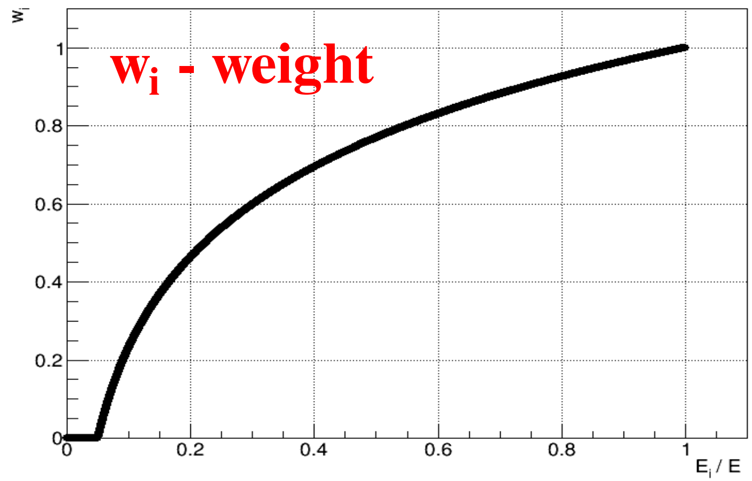
- Tested different averaging schemes:
  - ✓ logarithm of different base
  - ✓ logarithm x polynomial

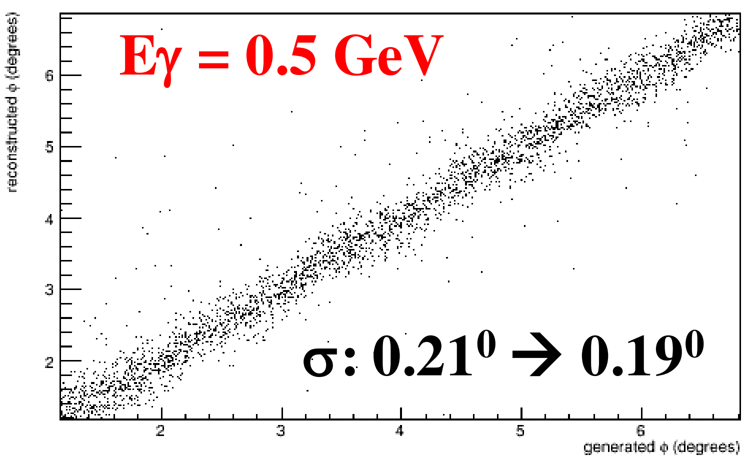
- Criterion of truth:
  - ✓ the best resolution ↔ minimum width of (φ_{rec} - φ_{gen}) distribution

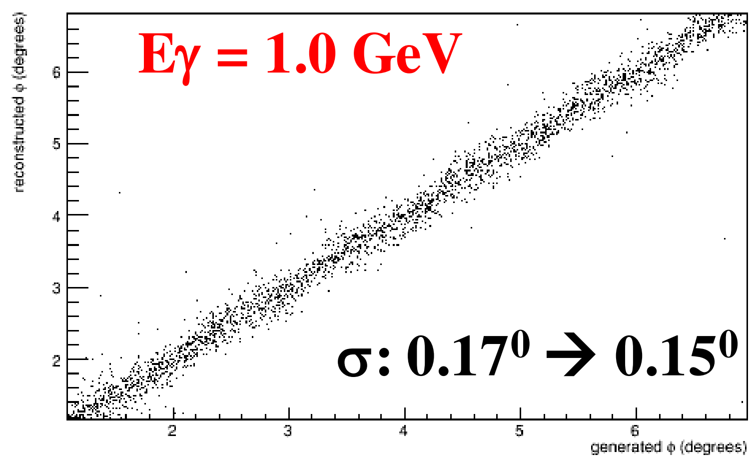
Signal averaging: MPD-ECAL

- MPD-ECAL case: $w_i = \max\left\{0, \left[w_0 + ln\left(\frac{E_i}{E_T}\right)\right]\right\}$ $w_0 = 3.0$





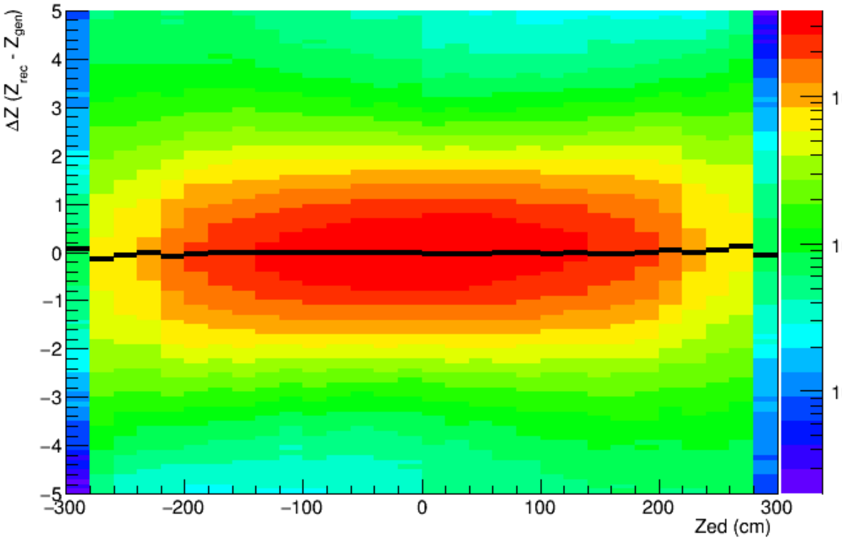




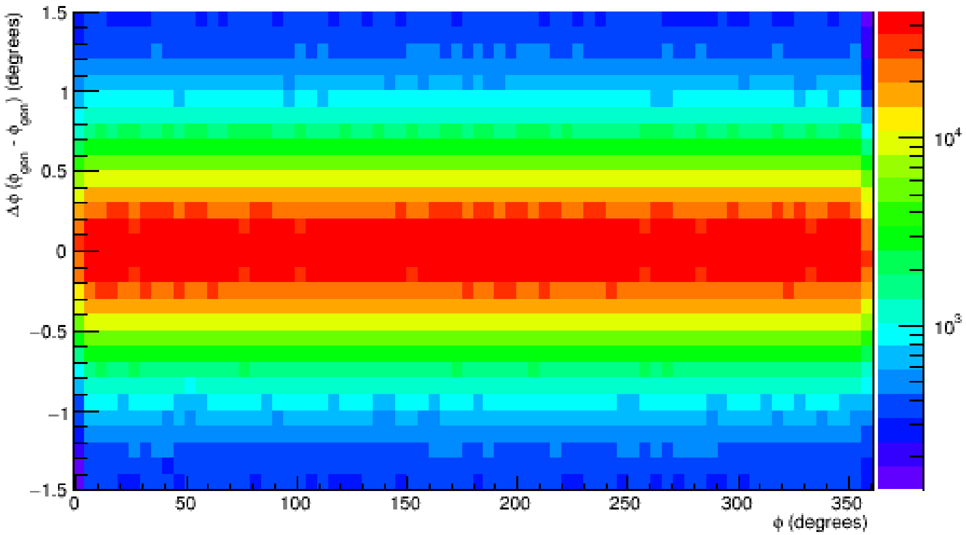
Spatial resolution: MPD-ECAL

- UrQMD, minbias AuAu@11, realistic vertex distribution
- Mostly uniform detector performance in “realistic” environment

resolution in zed (cm) vs. zed

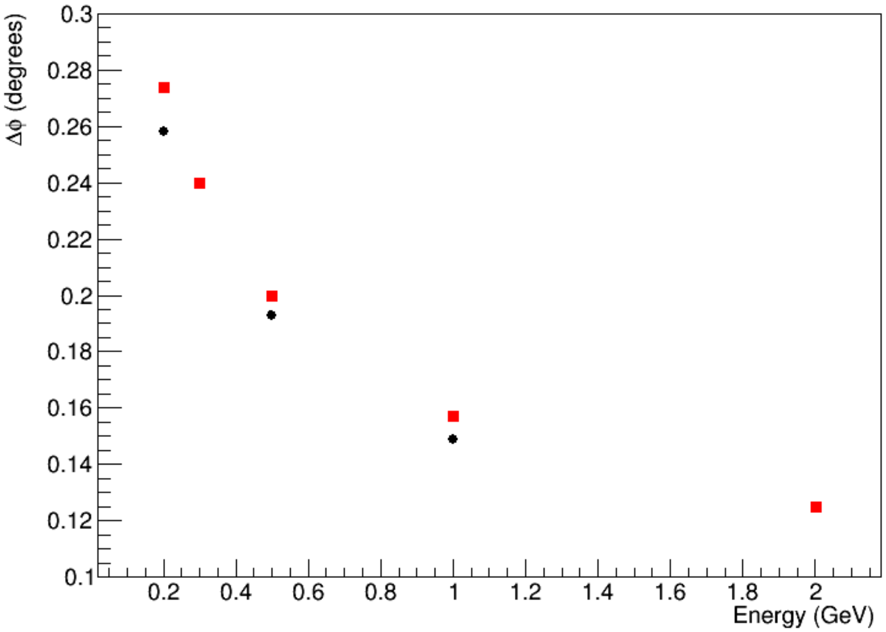


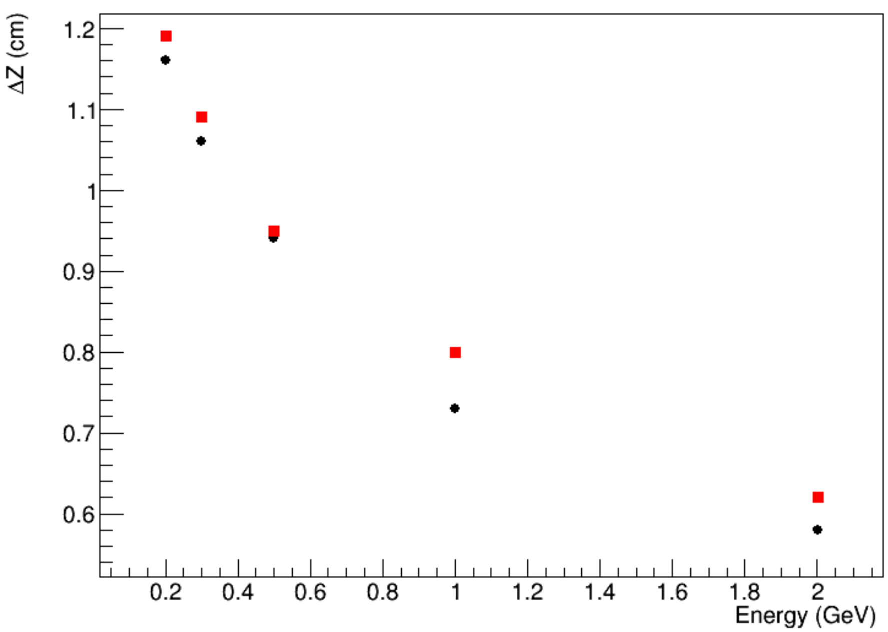
resolution in φ (degrees) vs. φ



Spatial resolution: MPD-ECAL

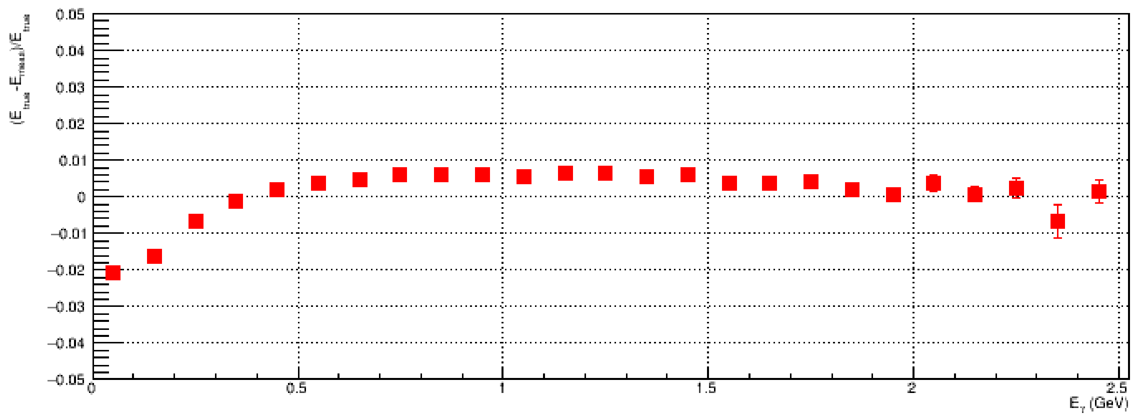
- Black markers – single photons (one per event), realistic vertex distribution
- Red markers – UrQMD, minbias AuAu@11, realistic vertex distribution
- High occupancy worsens the spatial resolution, but not dramatically

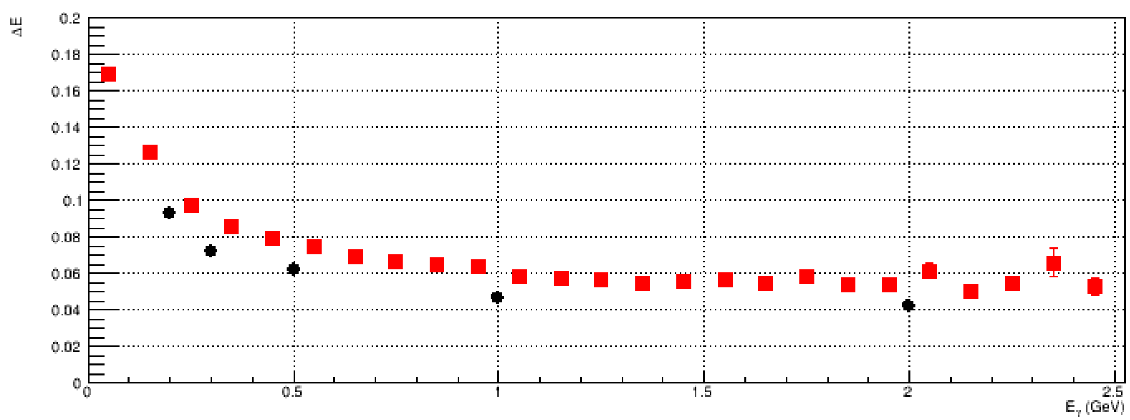




Energy resolution: MPD-ECAL

- Black markers – single photons (one per event) , realistic vertex distribution
- Red markers – UrQMD, minbias AuAu@11, realistic vertex distribution
- Non-linearity < 2% → can be corrected
- Energy resolution is significantly affected by multiplicity (constant term?)

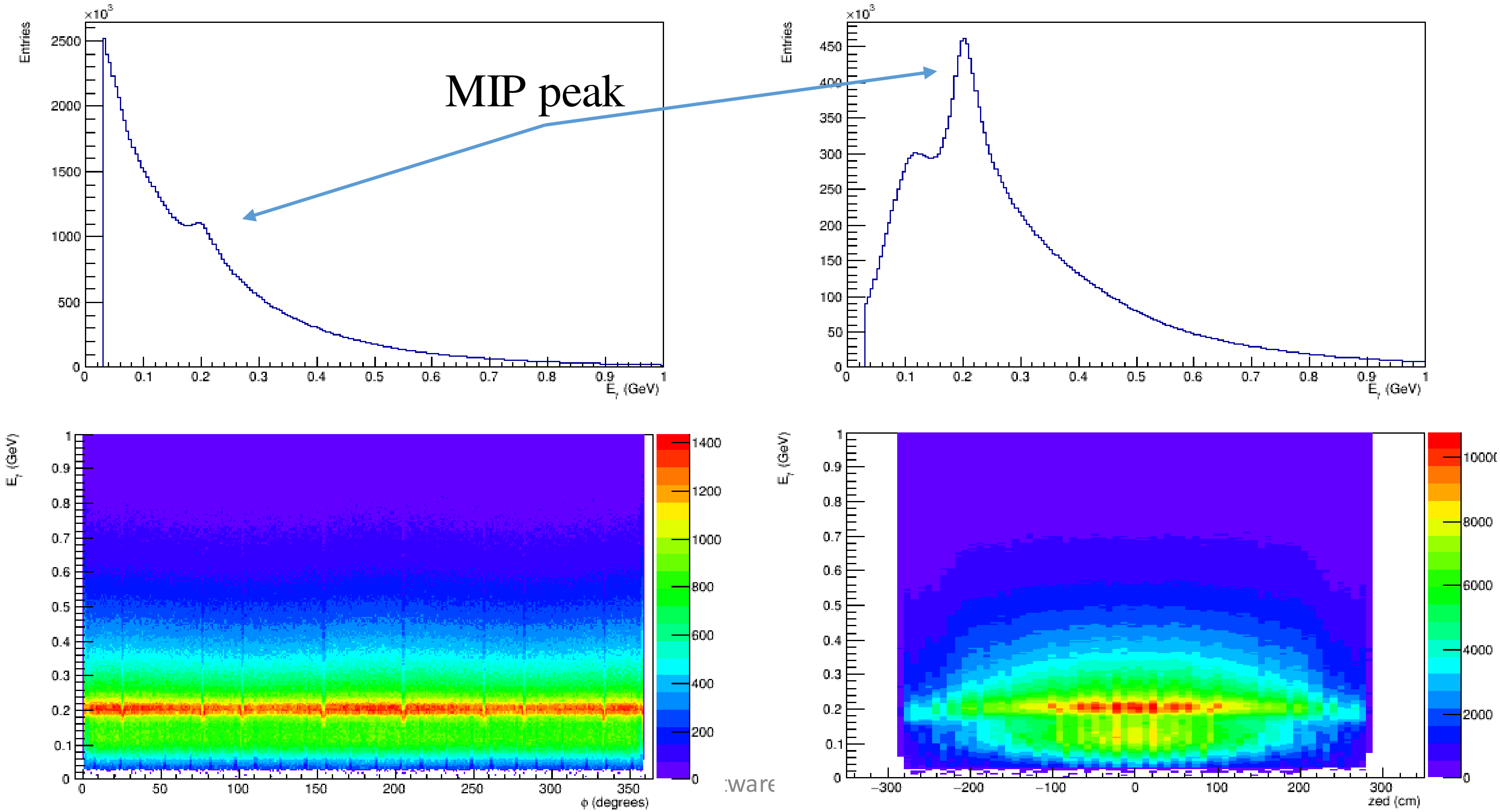




Detector performance: hadrons

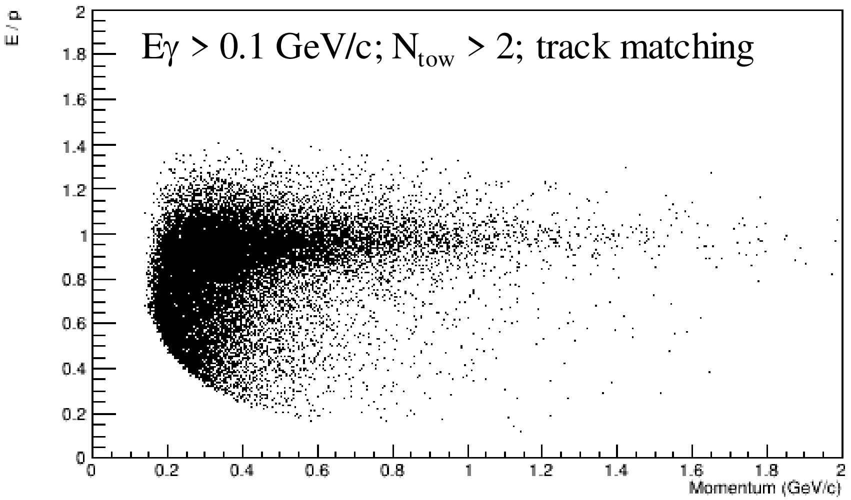
- UrQMD, minbias AuAu@11, realistic vertex distribution
- Peak at E_γ ~ 0.2 GeV should be a MIP → can be used for detector calibration
  → should be tested with prototype tests

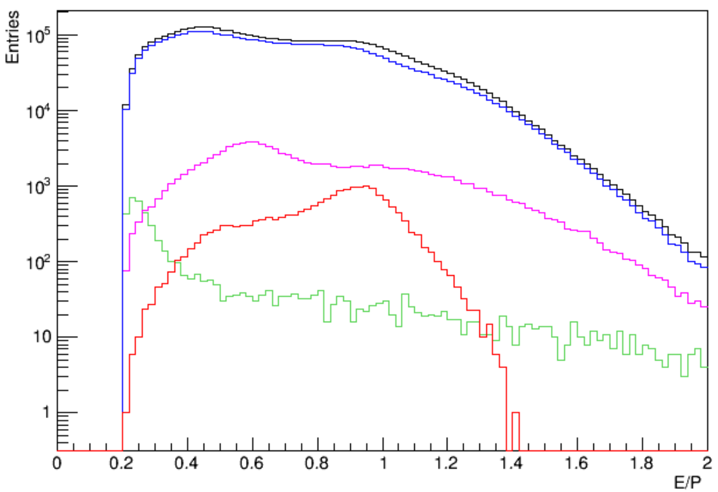
Energy spectrum | Energy spectrum + track matching

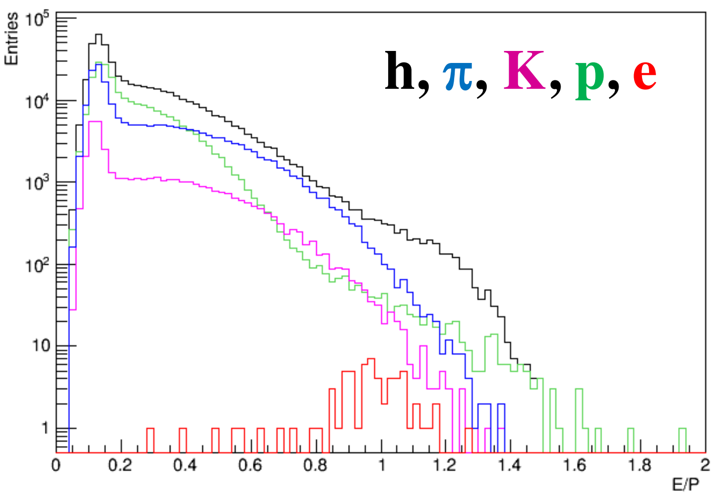


Detector performance: $e^{\pm}$

- UrQMD, minbias AuAu@11, realistic vertex distribution
- E – reconstructed cluster energy
- P – simulated (true) momentum
- E/P ~ 1 at p_T > 0.5 GeV/c, lower energy clusters break up in pieces due to large incidence angles (magnetic field)
- h/e separation power (0.8 < E/p <1.1):
  - ✓ 0.1-0.5 GeV/c → 0.5 (eff ~ 60%)
  - ✓ 0.5-1.0 GeV/c → 0.1 (eff ~ 75%)
  - ✓ 1.0-1.5 GeV/c → 0.04 (eff ~ 80%)
  - ✓ 1.5-2.0 GeV/c → 0.02 (eff ~ 85%)

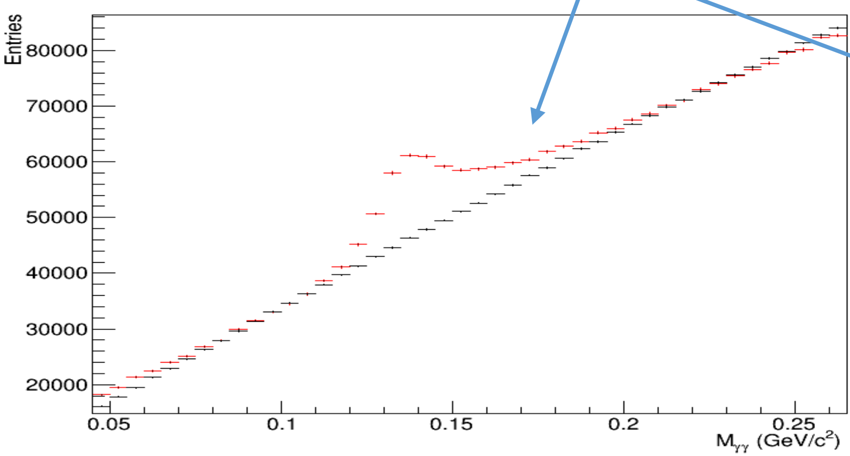


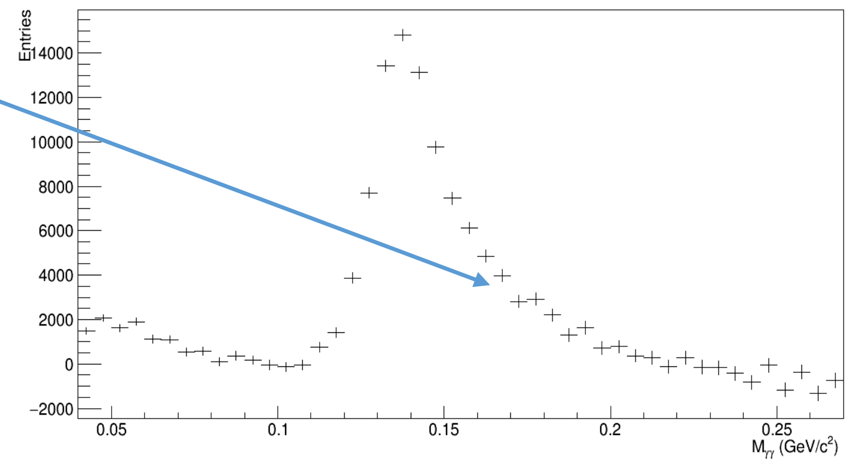




Detector performance: π^0

- UrQMD, minbias AuAu@11, realistic vertex distribution
- $E\gamma > 0.1$ GeV, $|y| < 1.0$, $p_T > 2.0$ GeV/c, track veto
- Non-Gaussian tail due to absorption of low-E clusters by high-E ones (geometrical overlap)

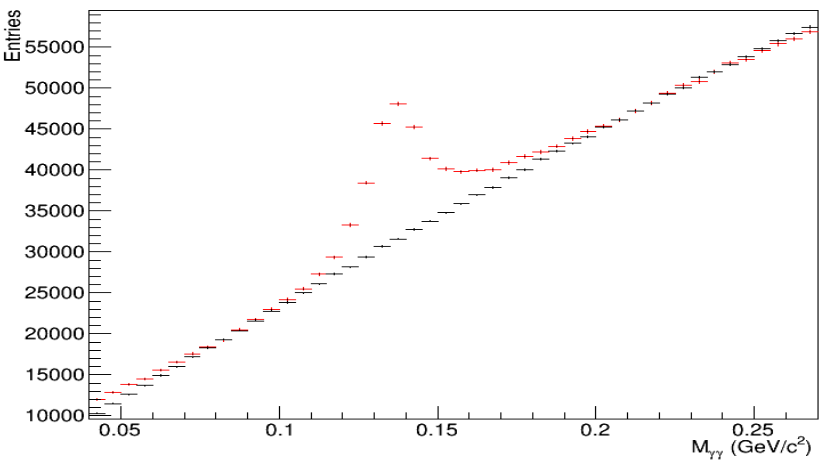


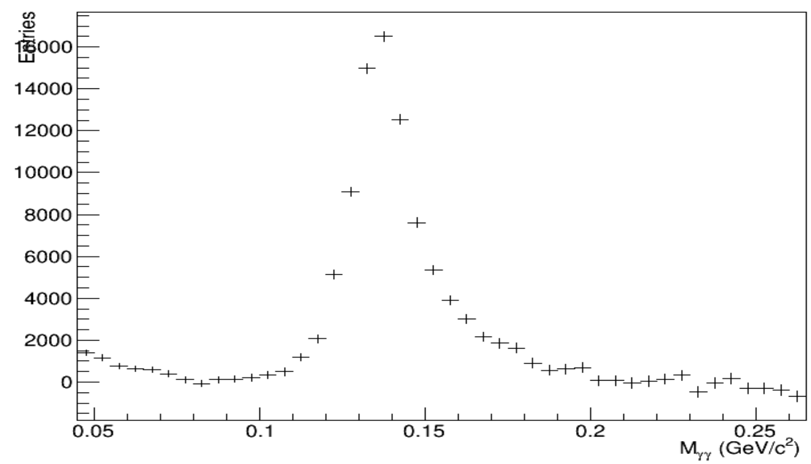


- Similar effects were observed by PHENIX/ALICE, see backup
- Minimization of the overlap:
  - ✓ minimization of the cluster size after unfolding, limiting it to 3x3 cells
  - ✓ counting only towers with energy deposits of > 1% or > 2%
  - ✓ combination of both

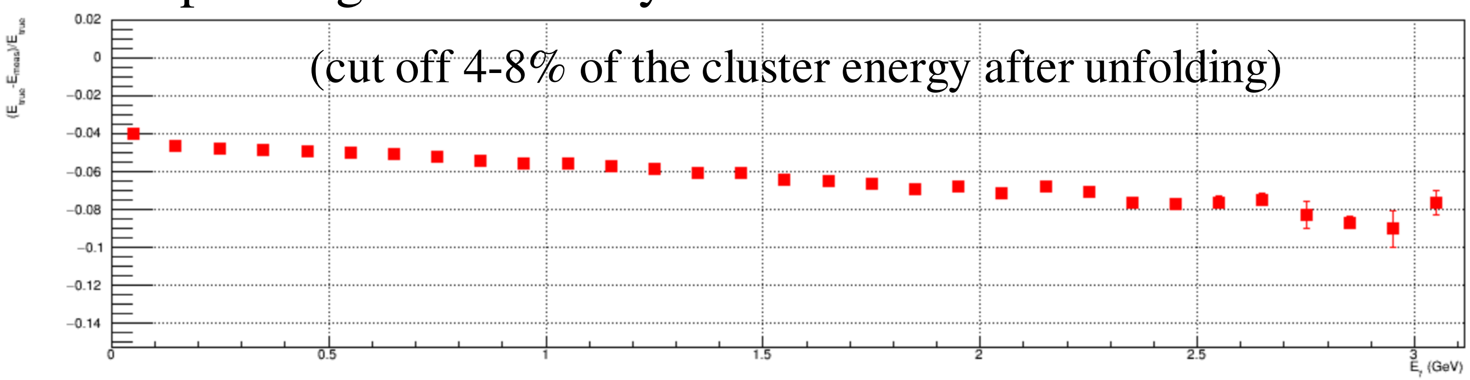
Detector performance: π^0

- UrQMD, minbias AuAu@11, realistic vertex distribution
- $E\gamma > 0.1$ GeV, $|y| < 1.0$, $p_T > 2.0$ GeV/c, track veto
- Tested all methods of minimization. The best performance is achieved by limiting the cluster size after unfolding to 3x3 cells around the cluster center



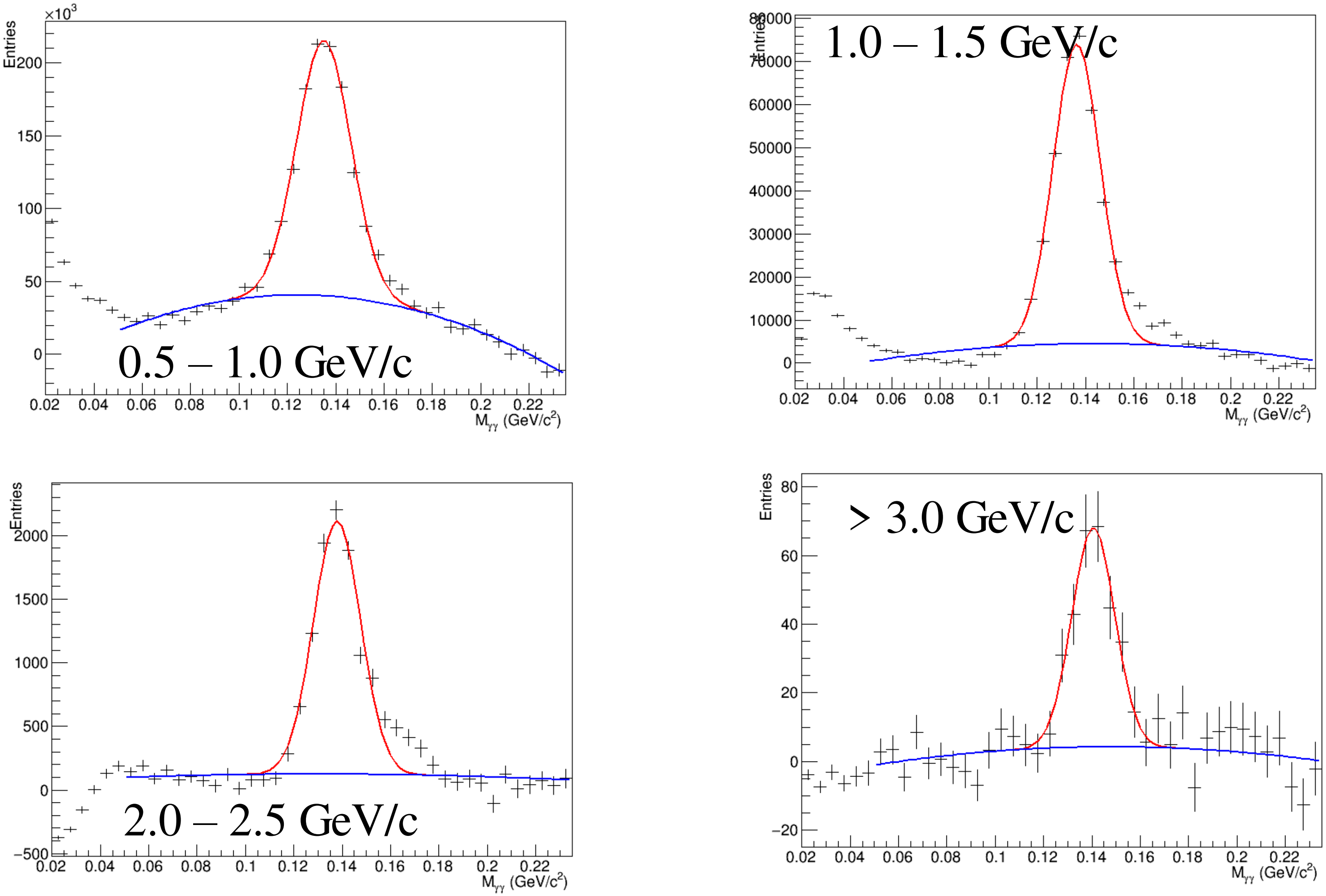


- Corresponding non-linearity correction should have been taken into account



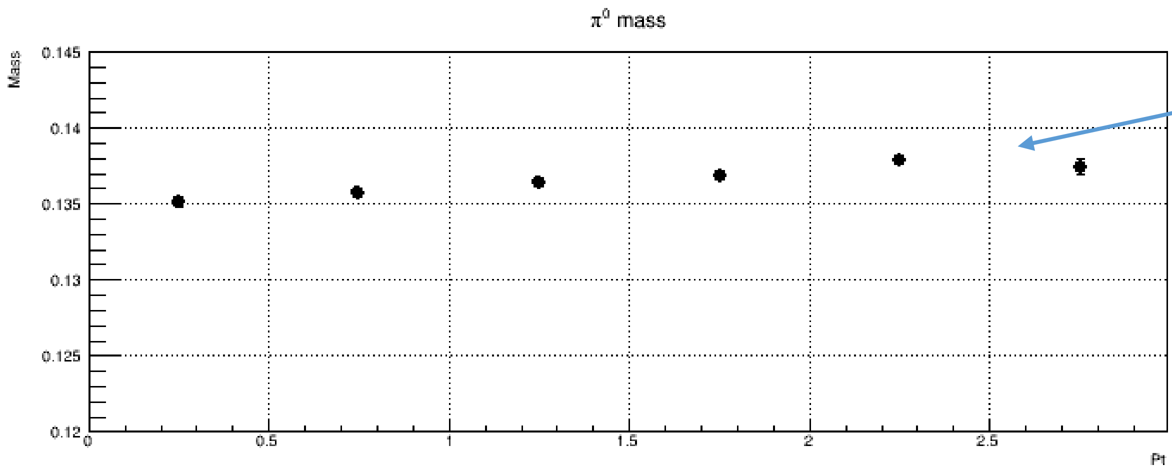
Detector performance: π^0

- UrQMD, ***minbias*** AuAu@11, realistic vertex distribution

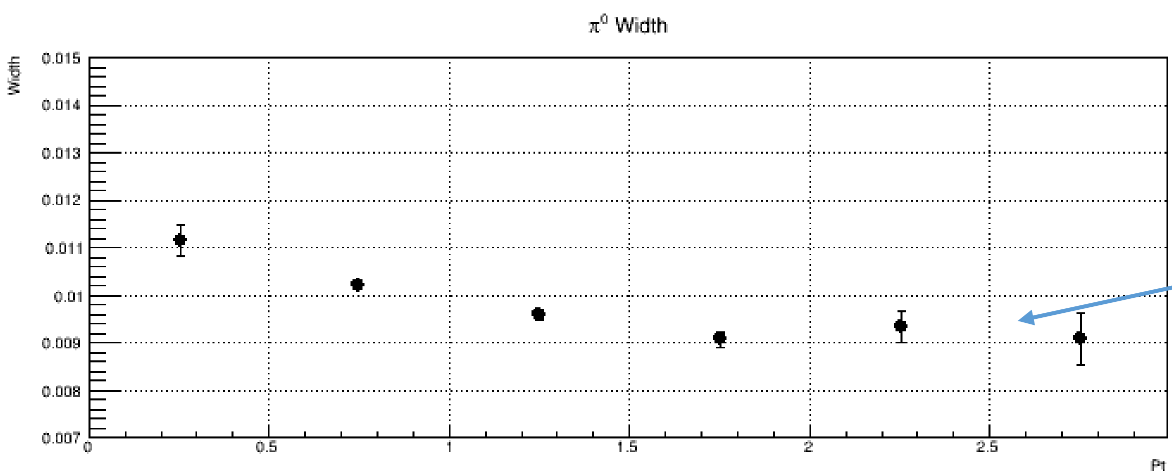


Detector performance: π^0

- UrQMD, ***minbias*** AuAu@11, realistic vertex distribution
- Mass and width



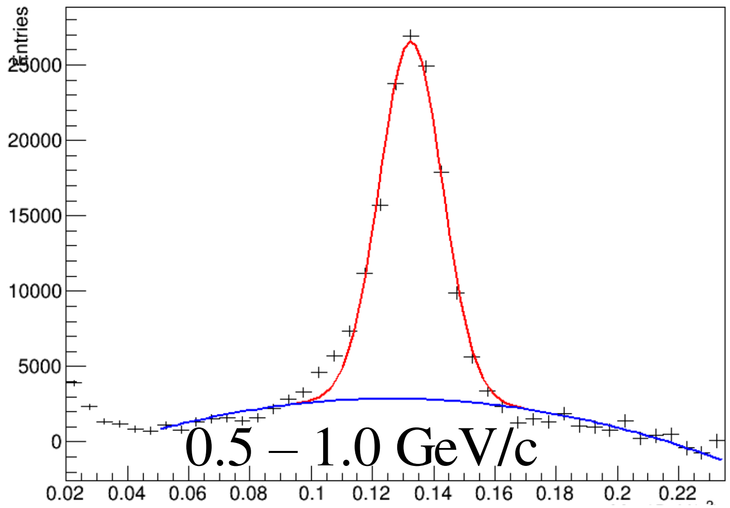
~ 137 MeV/c^2

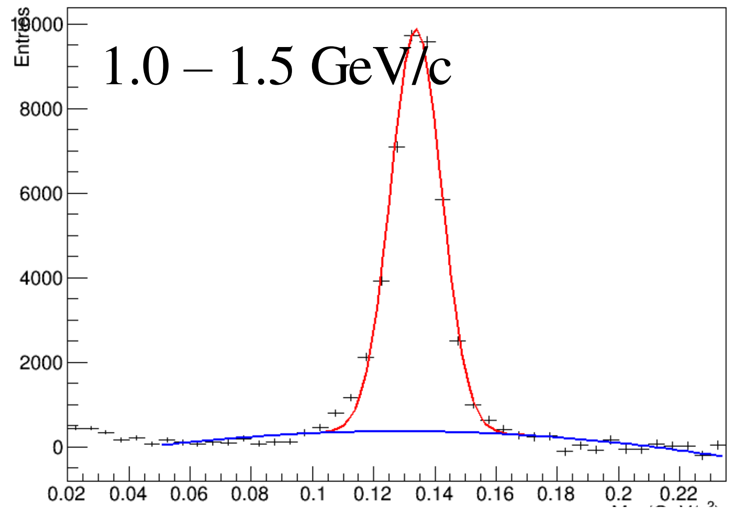


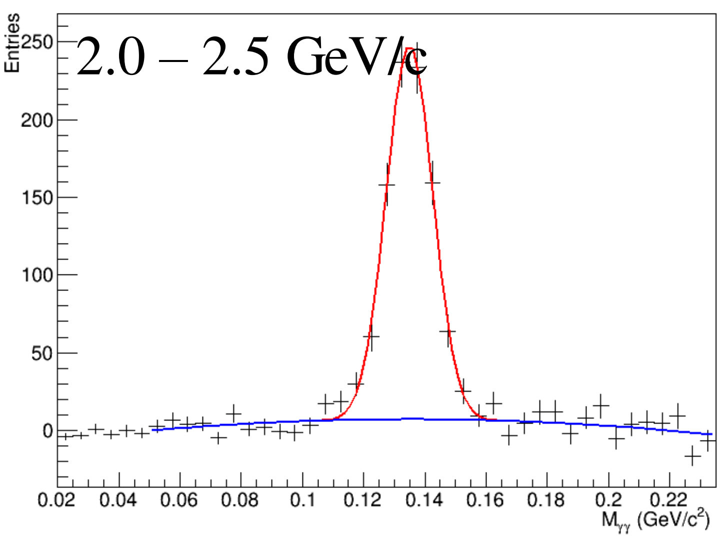
~ 9 MeV/c^2

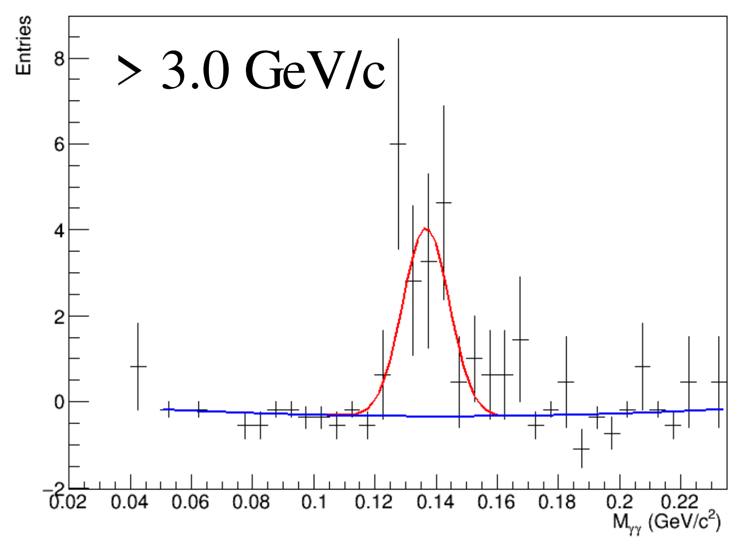
Detector performance: π^0

- UrQMD, ***peripheral*** AuAu@11 (ip > 10 fm), realistic vertex distribution



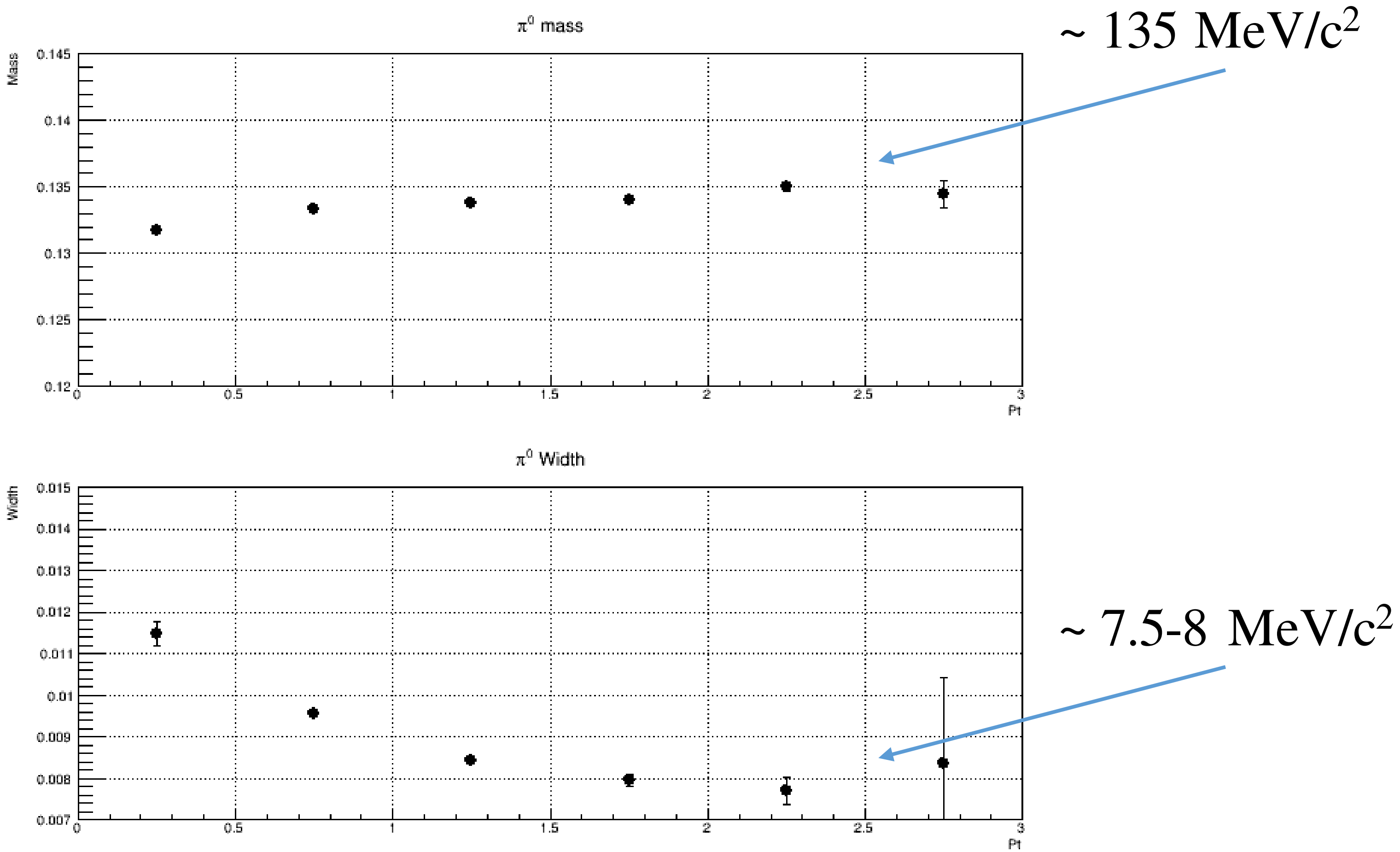






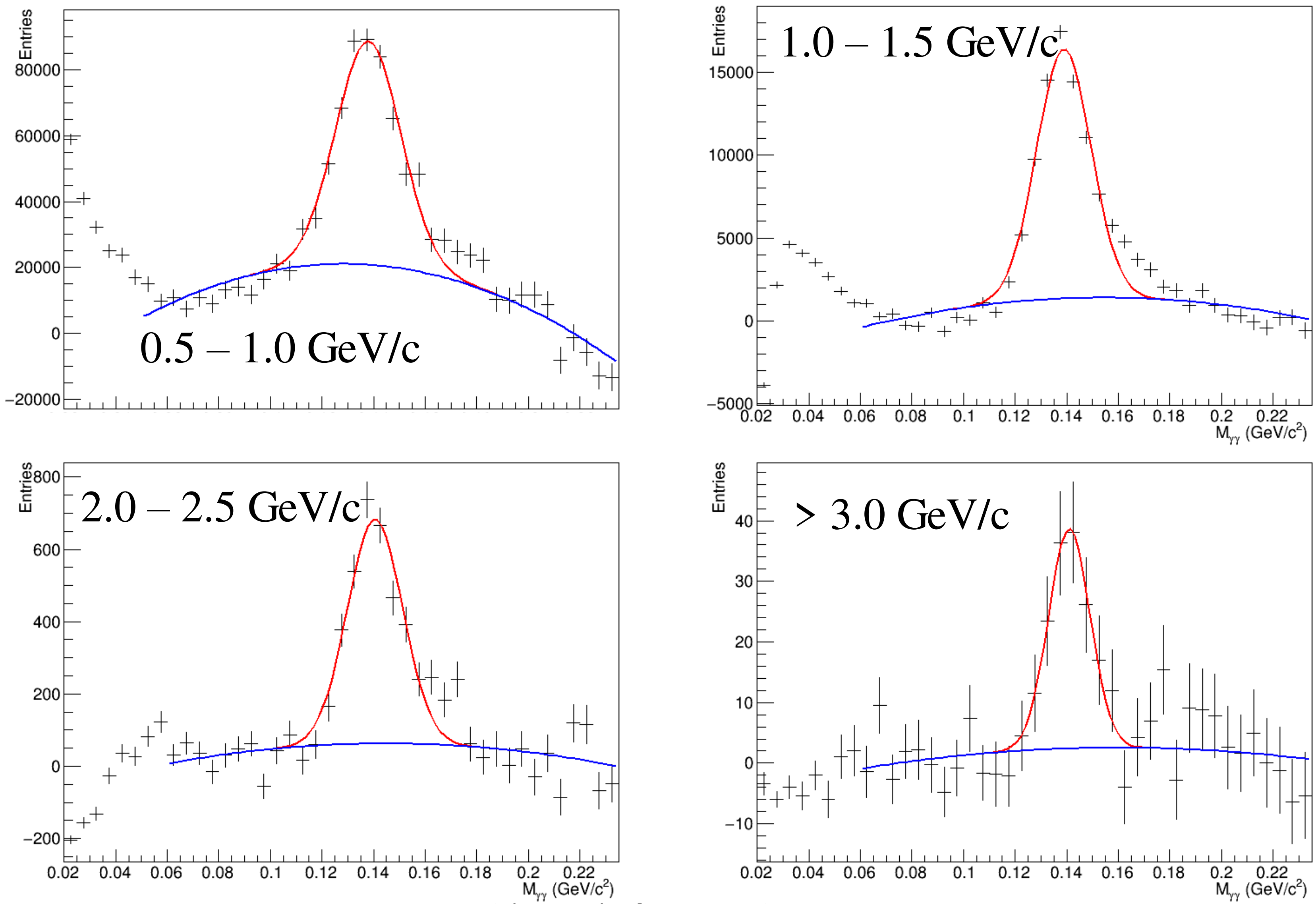
Detector performance: π^0

- UrQMD, ***peripheral*** AuAu@11 (ip > 10 fm), realistic vertex distribution
- Mass and width



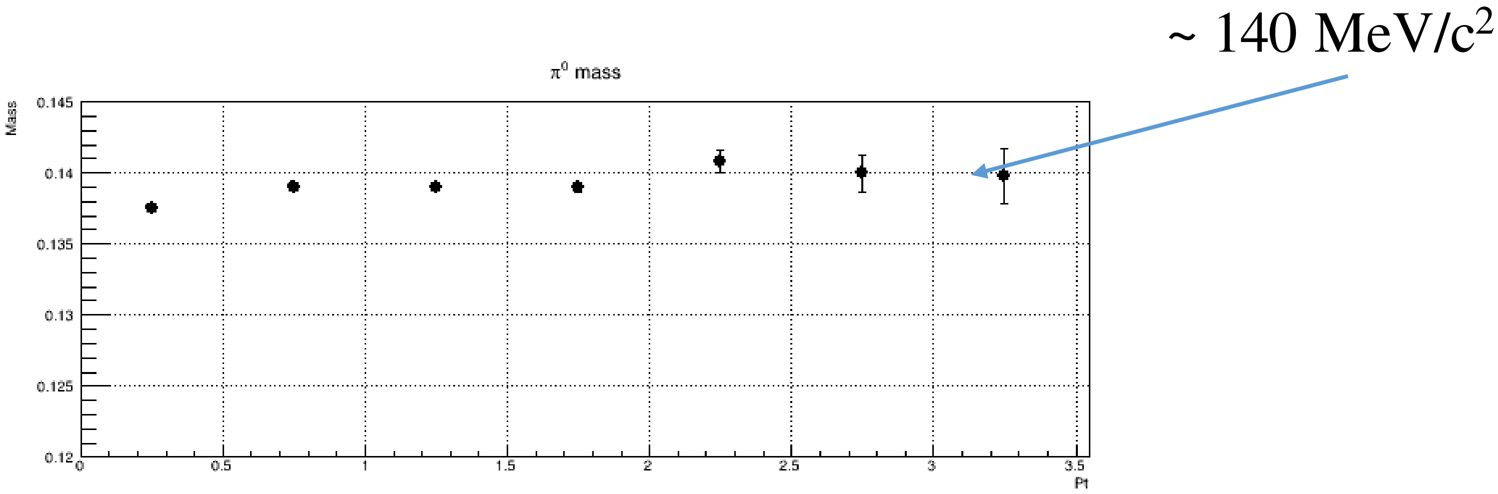
Detector performance: π^0

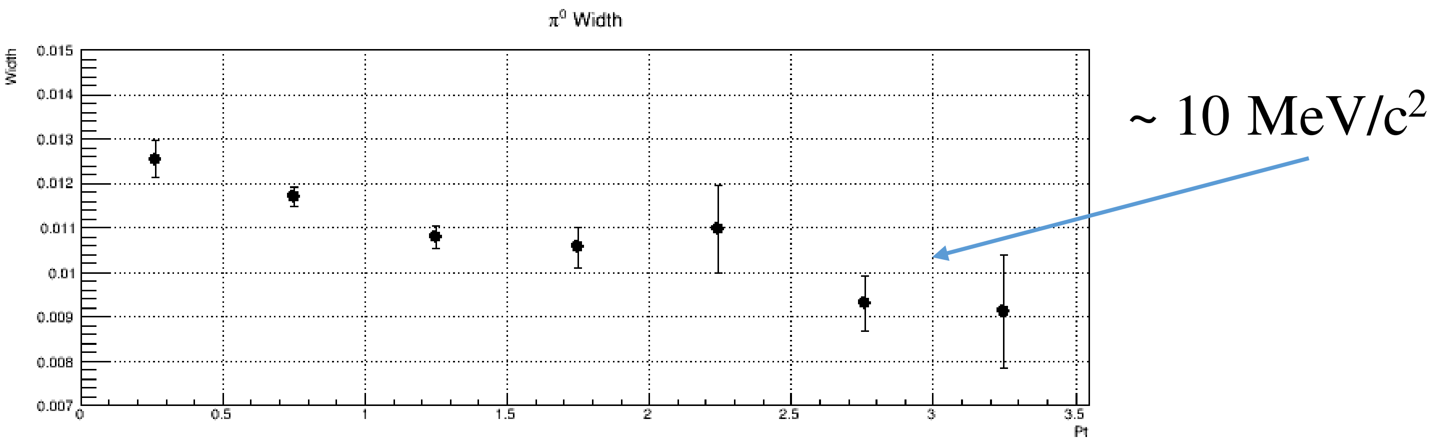
- UrQMD, ***central*** AuAu@11 (ip < 5 fm), realistic vertex distribution



Detector performance: π^0

- UrQMD, ***central*** AuAu@11 (ip < 5 fm), realistic vertex distribution
- Mass and width



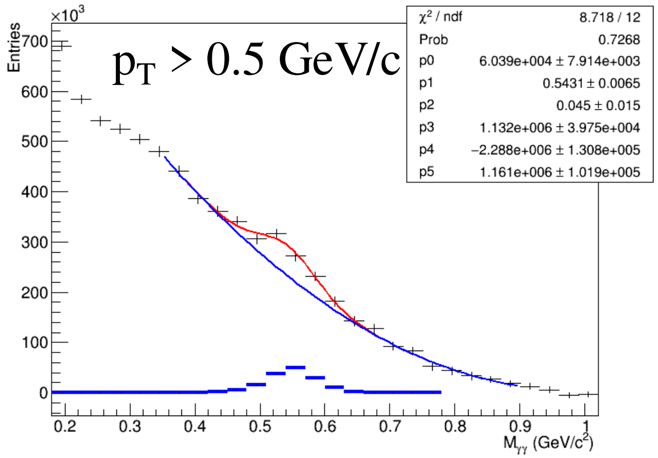


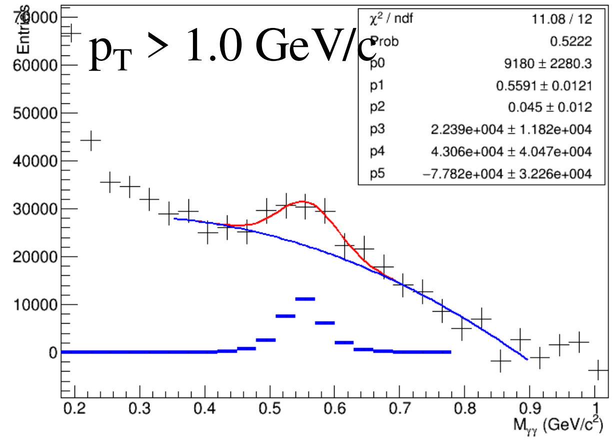
Conclusions: π^0

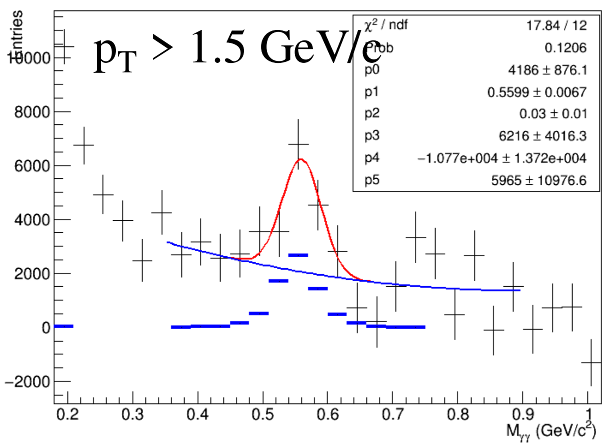
- UrQMD, AuAu@11, realistic vertex distribution
- Underlying event in high multiplicity events results in irreducible effects:
  - ✓ energy scale is multiplicity dependent (+ 2% in most central coll.)
  - ✓ energy resolution is multiplicity dependent + tails
- Limitation of the cluster size after unfolding to 3x3 cells:
  - ✓ helps to reduce effect of geometrical overlap
  - ✓ improves shape and reduces width of the reconstructed π^0
  - ✓ improves energy resolution and ceffectively uts-off tails in energy resolution distribution in high multiplicity events
  - ✓ worsens energy resolution in low multiplicity events
- Summary:
  - ✓ keep 3x3 cluster size as a default (Ecore) + add keep alternative variants in cluster info (E, E1p, E2p)
  - ✓ potentially, can tune the absolute energy scale based on event multiplicity → little practical sense since analyses will be centrality differentiated

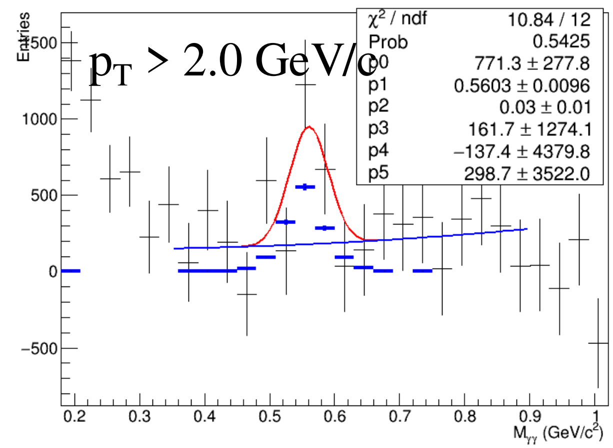
Detector performance: η

- UrQMD, minbias AuAu@11, realistic vertex distribution
- Observe with expected mass/width, numerical studies need more statistics



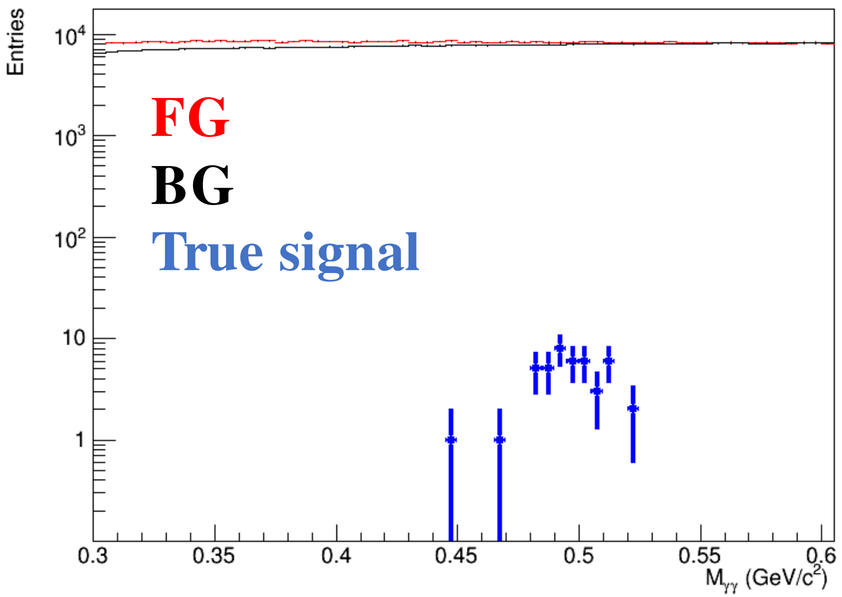


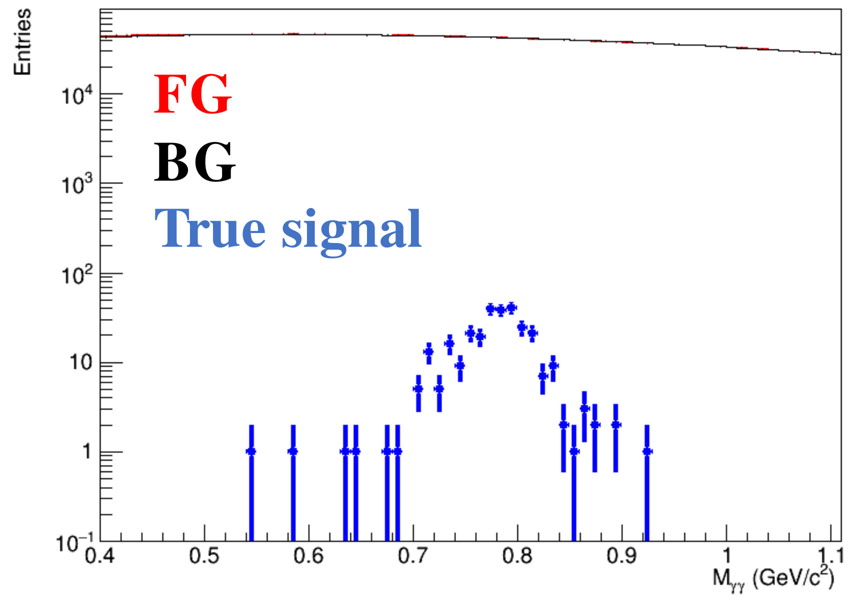




Detector performance: K_s, ω

- UrQMD, minbias AuAu@11, realistic vertex distribution
- $K_s \to \pi^0\pi^0$, $\omega \to \pi^0\gamma$
- With current statistics can look at $p_T > 1$ GeV/c → tiny S/B ratio
- Measurements will be possible at $p_T > 2\text{-}3$ GeV/c → need ~ 100M
  → not the first year task?

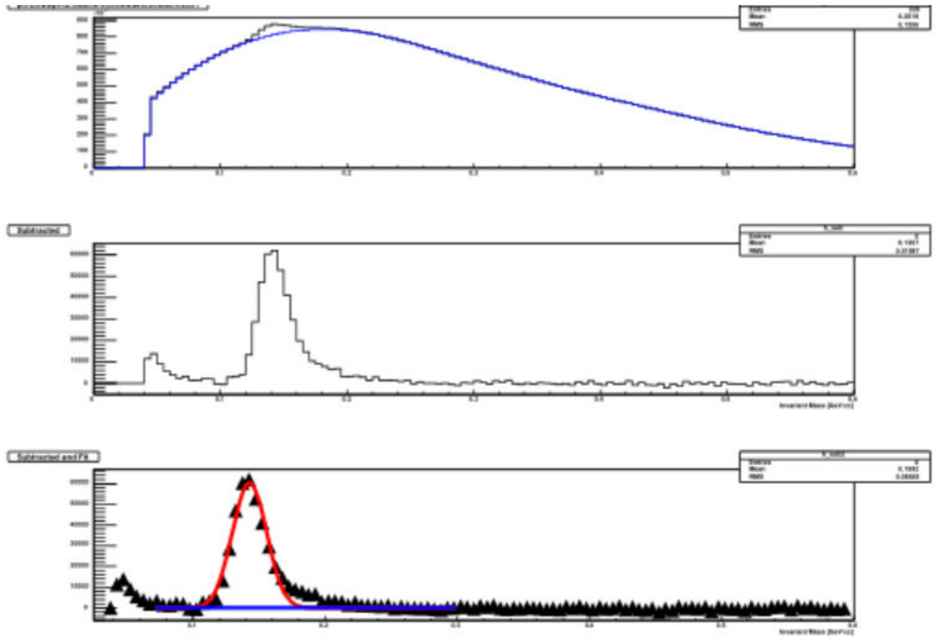




Conclusions

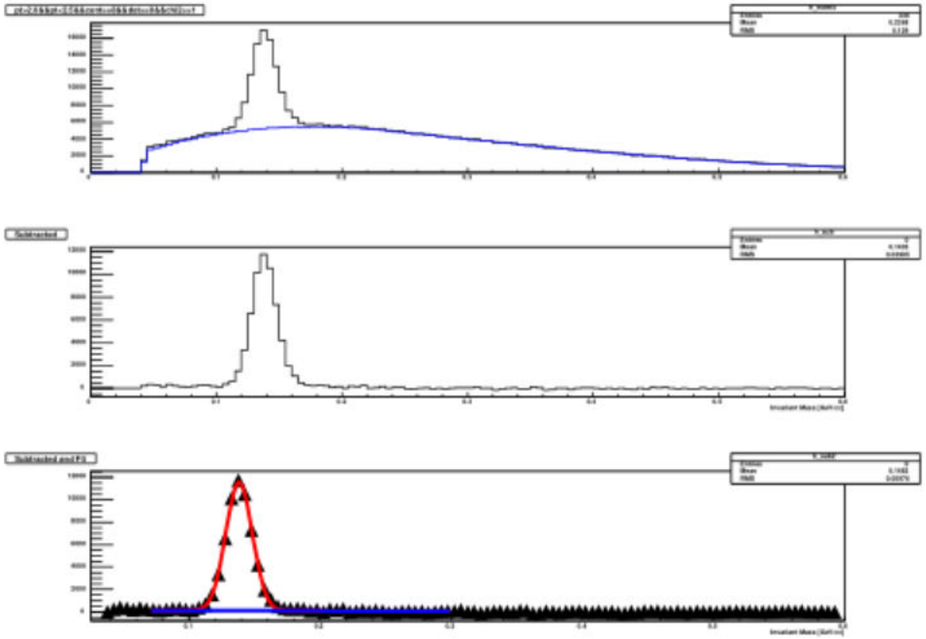
- Clusterizer is basically ready, performance of the detector is clear and predictable; it is compatible with other experiments
- Need to develop methods for rejection of hadronic and “defective/mis-reconstructed” e/m clusters based on the measured shower shape
- New geometry and/or any other low-level modifications will require tuning of the clusterizer and preferred methods

BACKUP



```
energy scale checking
Input file : ./run/scan20050620_stripe12/merged.root
Pt range, conditions : pt>2.0&&pt<2.5&&cent==0&&det==0&&chi2==1
Normalization Region 1 : (0.085 , 0.086) (0.250 , 0.450)
Fit Region :  (0.060 , 0.300)
Fit Result ...
CHI2 / ndf : 6.453956
Parameter 0 (Const) : 60441.567717 +- 774.501673
          1 (Mean)   : 0.142745 +- 0.000187
          2 (Sigma)  : 0.012874 +- 0.000203
Two-sigma : (0.116998, 0.168493)   Bin : (24, 34)
by only integration gaussian  : 398529.000000 +- 5118.641226
```

Figure 8: Sample output of π^0 extraction program. This plot shows π^0-peak measured in the PbSc in the range $2.0 < pT < 2.5$ GeV in our most central events (0-5%). The top plot shows the invariant mass distribution in real events along with the scaled mixed events background. The middle plot shows the π^0 after background subtraction, and finally, the bottom plot shows the Gaussian fit to the π^0 peak.

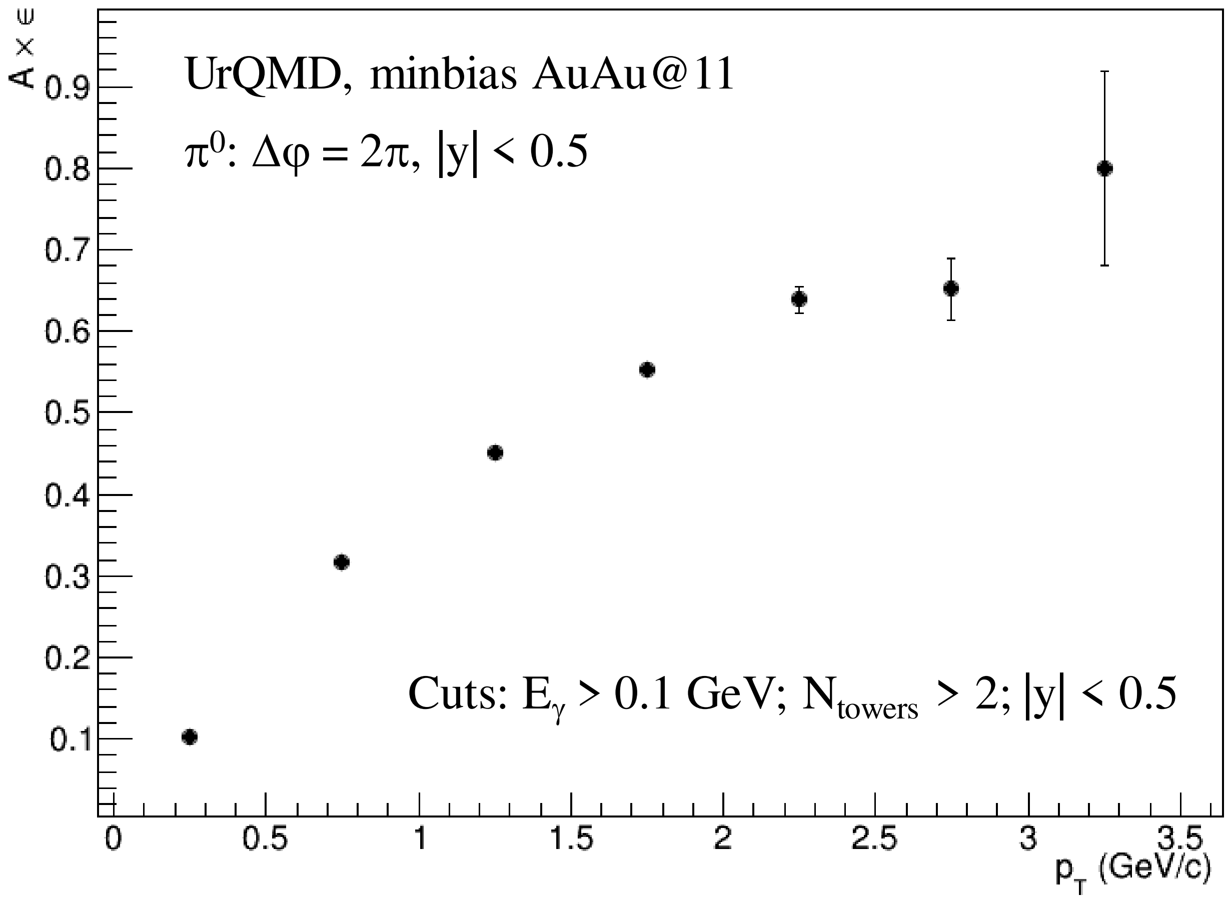


```
energy scale checking
Input file : ./run/scan20050620_stripe12/merged.root
Pt range, conditions : pt>2.0&&pt<2.5&&cent==8&&det==0&&chi2==1
Normalization Region 1 : (0.085 , 0.086) (0.250 , 0.450)
Fit Region : (0.060 , 0.300)
Fit Result ...
CHI2 / ndf : 1.497457
Parameter 0 (Const) : 11497.390968 +- 91.297651
1 (Mean) : 0.138113 +- 0.000084
2 (Sigma) : 0.010063 +- 0.000083
Two-sigma : (0.117988, 0.158238) Bin : (24, 32)
by only integration gaussian : 60744.622070 +- 477.654396
```

Figure 9: Sample output of the π^0 extraction program showing the π^0 peak as measured in the PbSc in the range $2.0 < pT < 2.5$ GeV in our most peripheral (80-93%) events.

π^0, AuAu@11 (UrQMD)

- Аксептанс x эффективность: $\Delta\varphi = 2\pi$, $|\eta| < 0.5$, размытие вершины



С чем сравнить?

π^0 reconstruction by Yan Huang

Generator → Transport → Digitizer → Cluster → Recpoint → Match

Selection of Photon

Photon selection → Invariant mass reconstruction → Subtract the Background

The method of π^0 reconstruction

$x^2 \leq 15.0$ && $E/p \leq 0.8$

$M_{\gamma\gamma}=\sqrt{2E_{\gamma 1}E_{\gamma 2}(1-\cos(\theta_{12}))}$

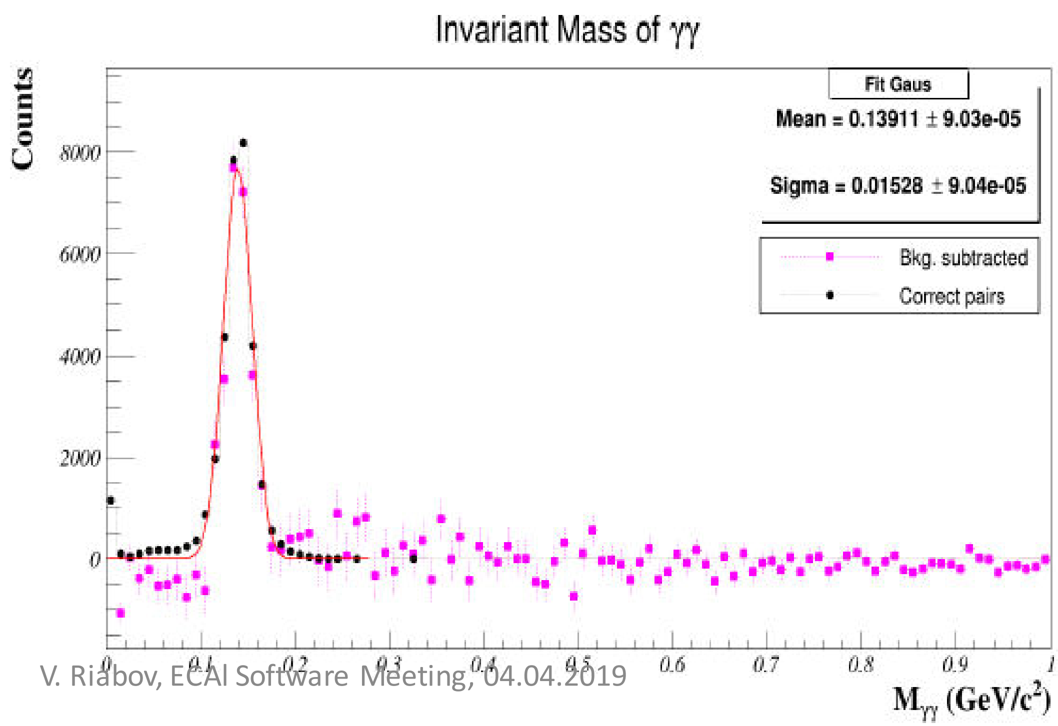
Event mixed method and scaling

1.HypYpt Generator;

2.Multiplicity 200;

3.Geometry:

- magnet_v4
- tpc_v8
- tof_v7
- emc_v2



С чем сравнить?

π^0 reconstruction by A. Zinchenko

1.UrQMD Generator;

2.Au+Au;

3.Events 5000;