Photon ID in the MPD-ECAL

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Outline

- Short reminder
- Photon identification
  - ✓ Charged track veto
  - ✓ Time of Flight
  - ✓ Shower shape
- Conclusion

Reminder

- Last meeting: https://indico.jinr.ru/conferenceDisplay.py?confId=867
- Signal averaging and spatial resolution
- Methods of reduction of shower overlap
- Physics performance:
  - ✓ π^0 vs p_T & centrality
  - ✓ first observation of η
  - ✓ e/h rejection
  - ✓ K_s, ω - no chance for Year-1

→ ECAL is a useful detector in many applications

Today

- Identification of e/m signals:
  - ✓ maximum efficiency for true signals
  - ✓ high rejection power for hadronic signals
  - ✓ suppression of miss-reconstructed e/m signals (signal merging)
  - ✓ applicability for neutral (γ) and charged particles ($e^{\pm}$)

- Most common methods:
  - ✓ charged track veto
  - ✓ time-of-flight
  - ✓ shower shape

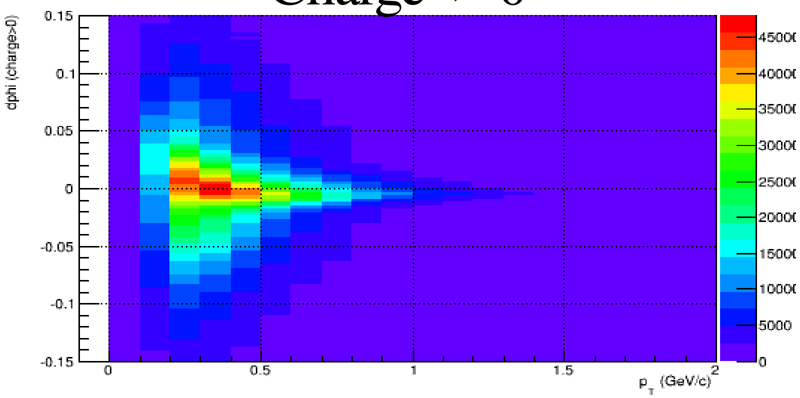
Charge veto cut

Track matching, AuAu@11 (UrQMD)

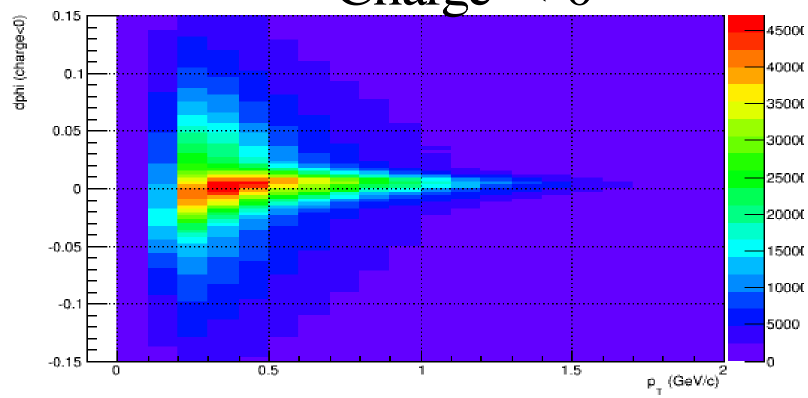
- Distance to a closest TPC track in dPhi (radians) and dZ (cm) vs. track p_T
- dPhi – charge dependent shift at low p_T:
  - ✓ large incident angles due to magnetic field
  - ✓ different detector response to photons and charged tracks (it is true even for $e^{\pm}$)
- Matchings are to be parametrized vs p_T & charge

dphi

Charge > 0

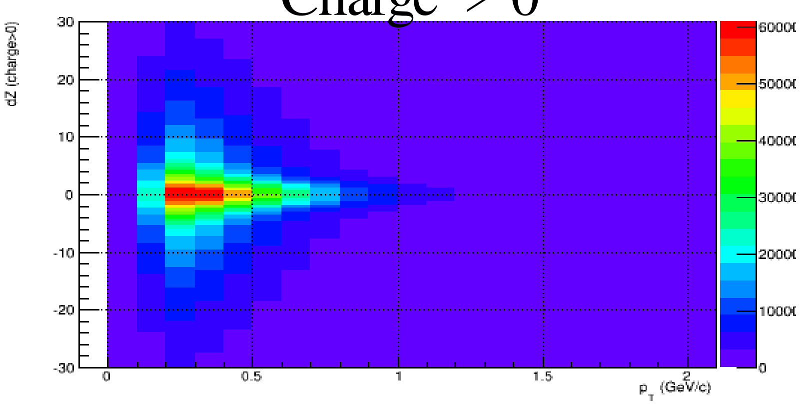


Charge < 0

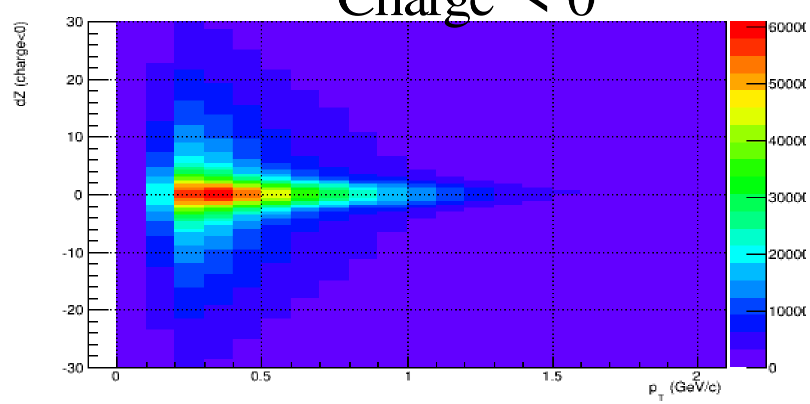


dz

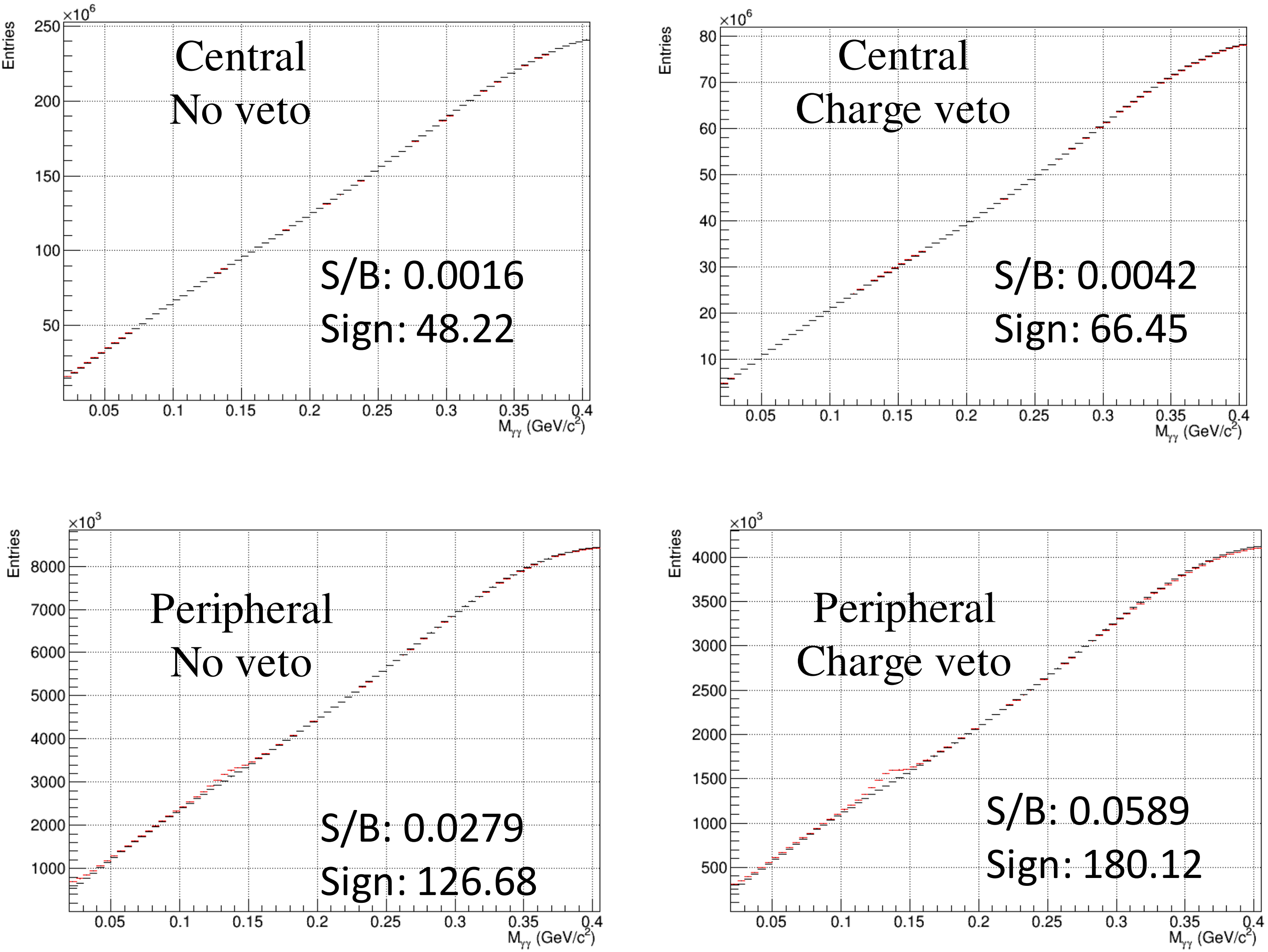
Charge > 0



Charge < 0



Charge veto cut efficiency, AuAu@11 (UrQMD)



- $\pi^0 \to \gamma\gamma$
- $0 < p_T$ (GeV/c) < 1
- Rough veto cut: no tracks in 7x5 cm^2 vicinity of a cluster
- Charge veto cut is similarly efficient in central (0-5 fm) and peripheral (>10 fm) collisions
- S/B improves by a factor of ~ 2.5
- Charge veto cut reduces number of reconstructed π^0 by 1% in peripheral and by 30% in central collisions

Track matching, summary

- PROS:
  - ✓ effectively rejects signals from primary tracks, improves signal significance

- CONS:
  - ✓ multiplicity dependent efficiency → problem of consistency between data and MC
  - ✓ not sensitive to conversion and nuclear reaction in/after the TPC (gas volume, TPC outer walls, TOF etc.)
  - ✓ does not help to identify electrons
  - ✓ does not reject miss-reconstructed (merged) e/m clusters

Transparent and effective cut → should/can be used

Time of flight cut

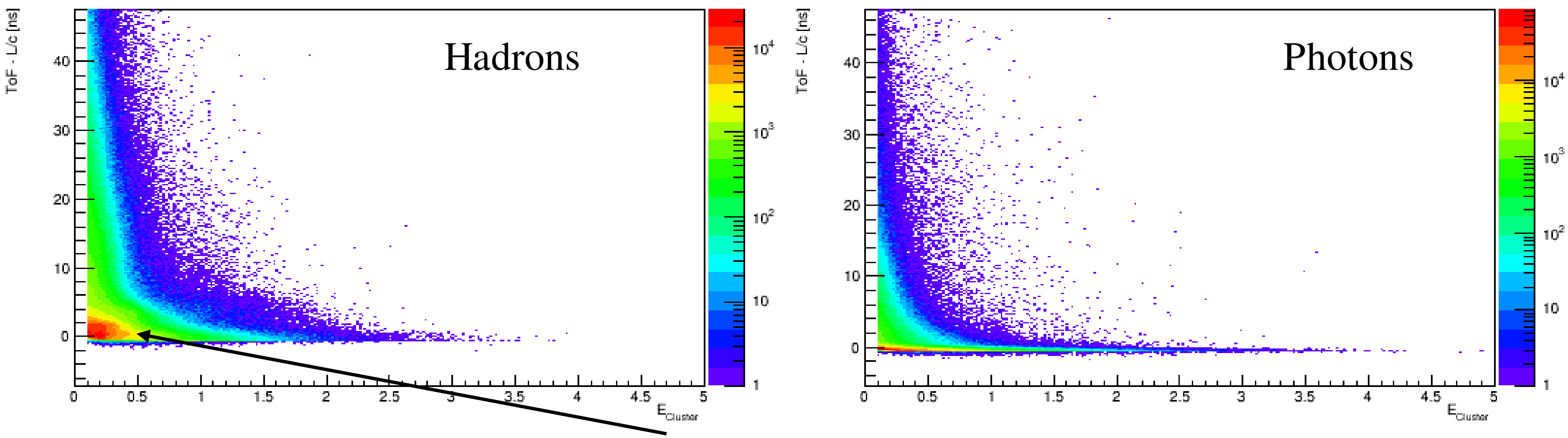
Time-of-Flight

- PROS:
  - ✓ for photons: ToF = $T_{measured} - L/c \sim 0$, L is a path along a line [vertex → cluster]
  - ✓ effectively rejects signals from low-p_T hadrons (longer flight path, slower)

- CONS:
  - ✓ does not reject miss-reconstructed (merged) photonic clusters
  - ✓ very limited applicability for electrons
  - ✓ simulation of time resolution is not realistic/reliable
    - ➢ strong dependence on electronics in data
    - ➢ strong dependence on method in MC
  - ✓ detector timing calibration usually comes last, after full production, requires huge statistics

Simulation of ToF, AuAu@11 (UrQMD)

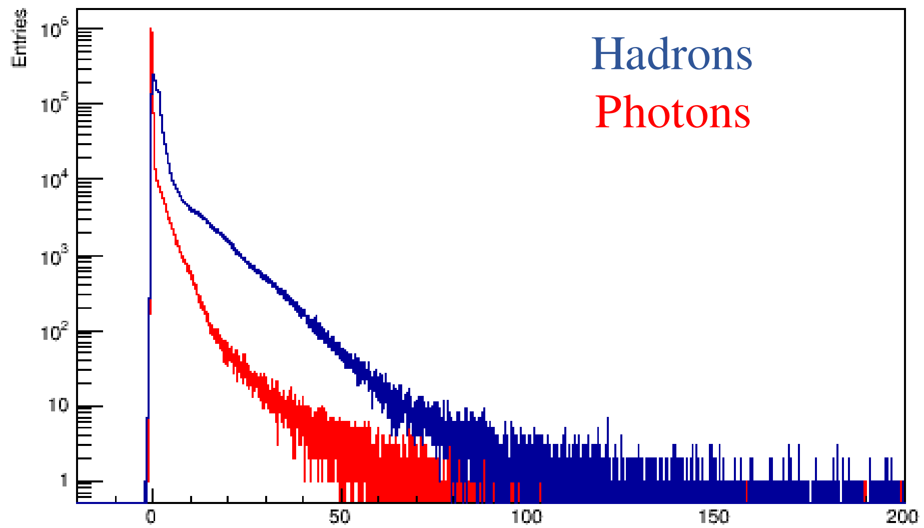
- Utilized just one of possible methods, alternatives exist
- Digit:
  - ✓ Geant point with the smallest time
- Cluster:
  - ✓ time of tower with maximum energy (local maximum - seed for the cluster)
- Simulations account for cluster overlaps & biases
- ToF – L/c vs. cluster energy (expect zero for photons):



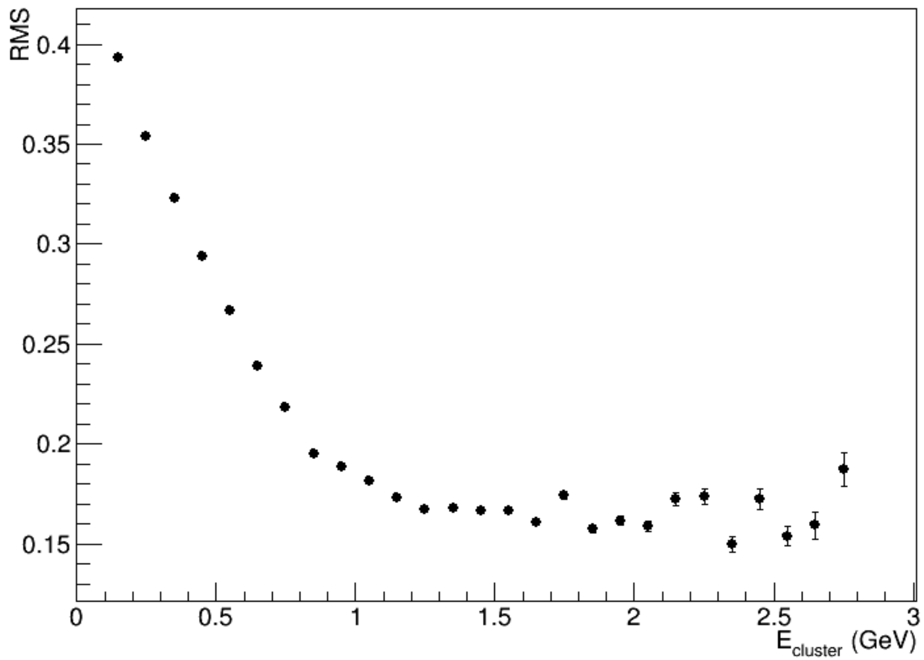
- Time for hadrons ($h^{\pm}$) is shifted towards larger values + long tail, as expected

Simulation of ToF, AuAu@11 (UrQMD)

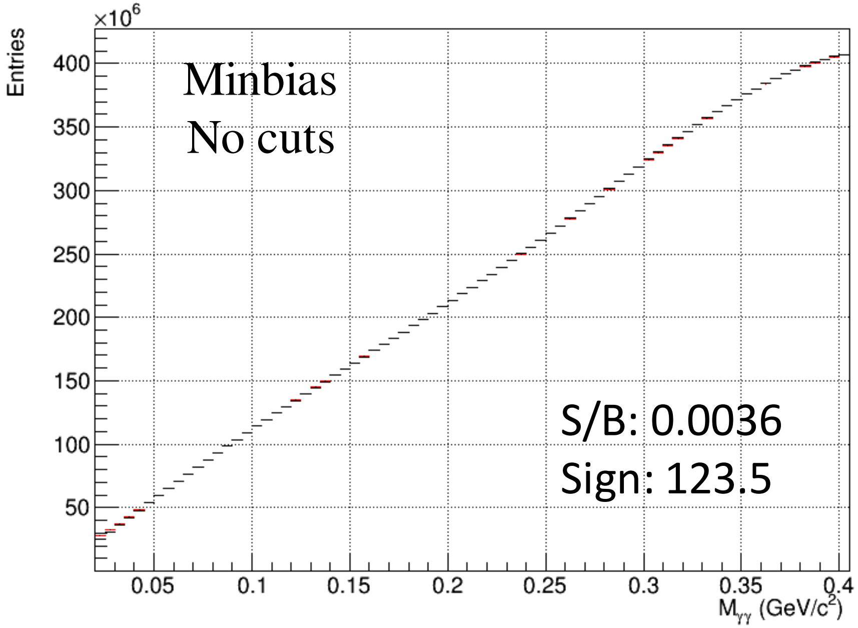
- Time (energy integrated) :

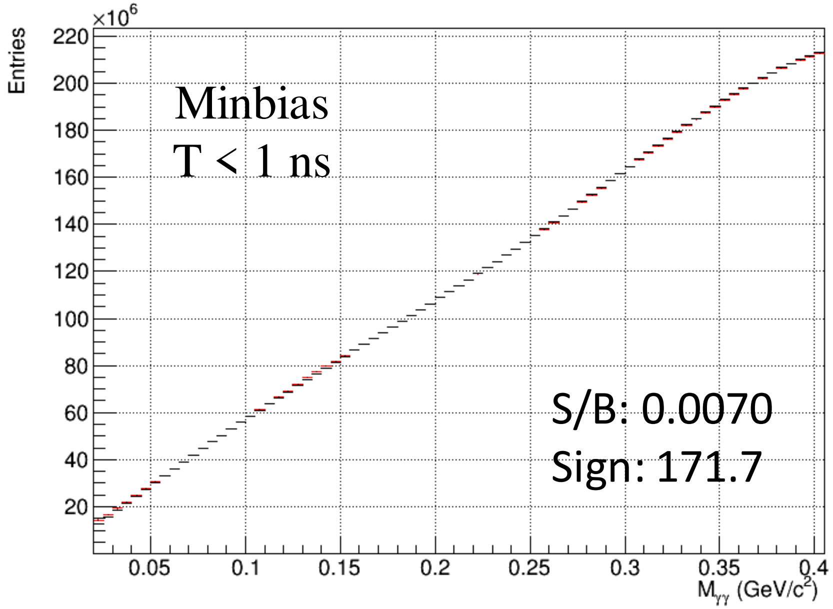


- Energy resolution (RMS) for photons vs. energy:



Efficiency of ToF cut, AuAu@11 (UrQMD)





- $\pi^0 \to \gamma\gamma$
- $0 < p_T$ (GeV/c) < 1
- Timing cut of $T < 1$ ns is efficient
- S/B improves by a factor of ~ 2
- Timing cut reduces number of reconstructed π^0 by 0.5% only
- Results are most optimistic and not realistic → see next page

Time-of-Flight, summary

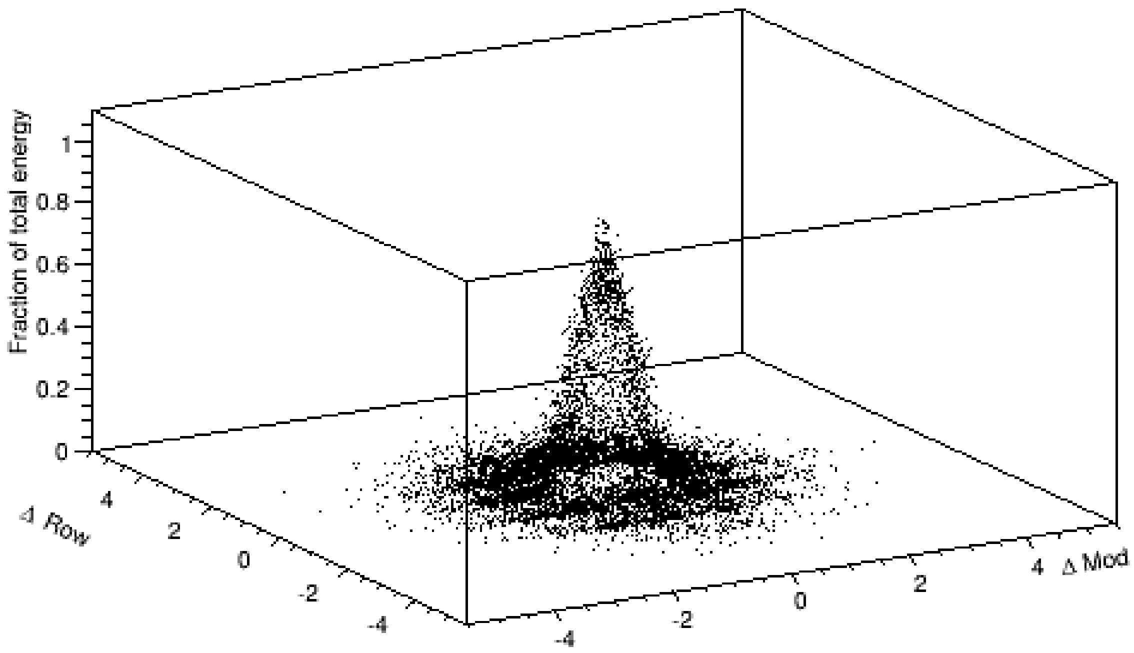
- Time of flight cut is very efficient for photons
- Significant uncertainties for the reached realistic/simulated time resolution
- Eventually, time resolution is to be tuned to data → prototype tests
- To be more realistic (for now only):
  - ✓ additionally smear timing by 0.5 ns
  - ✓ use a cautions cut of T < 2 ns

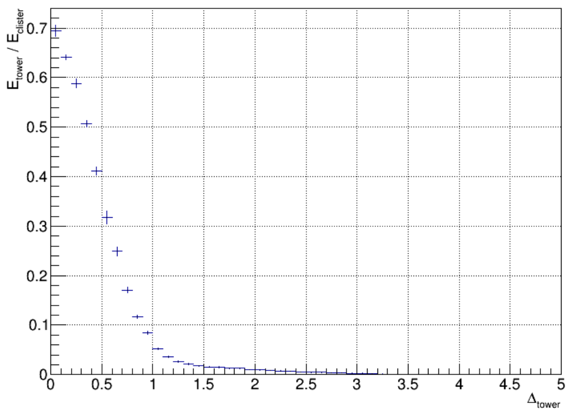
Effective but not transparent cut → should be used with caution

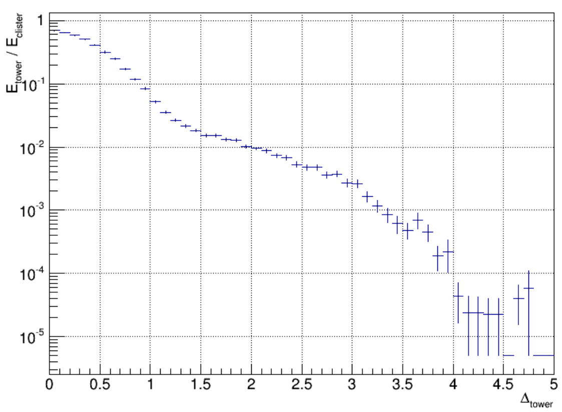
Shower shape

Shower shape in the MPD-ECAL

- Simulated for single photons: , $E_i/\sum E_i$: ΔMod : ΔRow
- Shower shape shows weak energy dependence
- Same shower shape is used to unfold merged clusters at reconstruction







Shower shape cut, Chi2/NDF

- Compare measured distribution of tower energies in a cluster with the expected one:

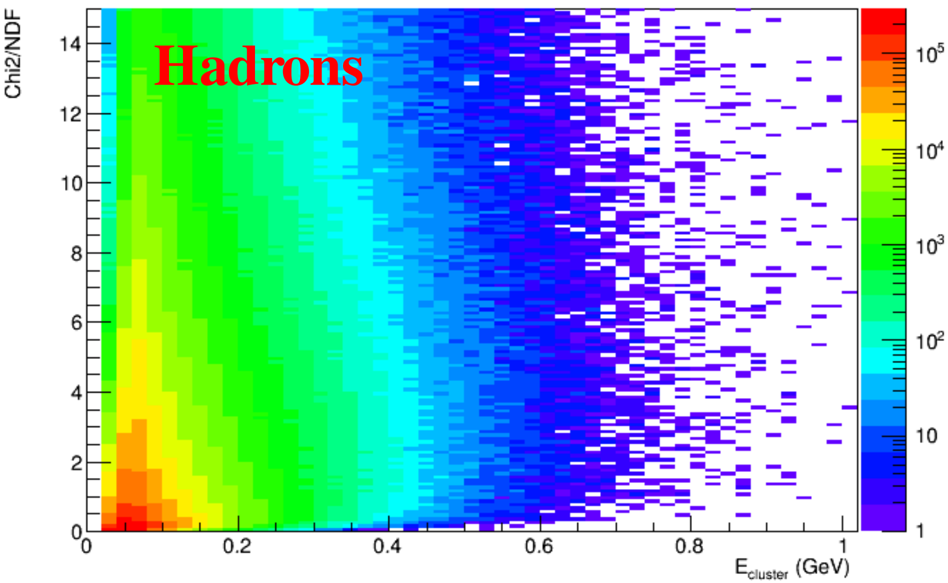
$$\mathrm{Chi2} = \sum_i \frac{\left(E_i^{measured} - E_i^{expected}\right)^2}{\sigma_i^2}$$

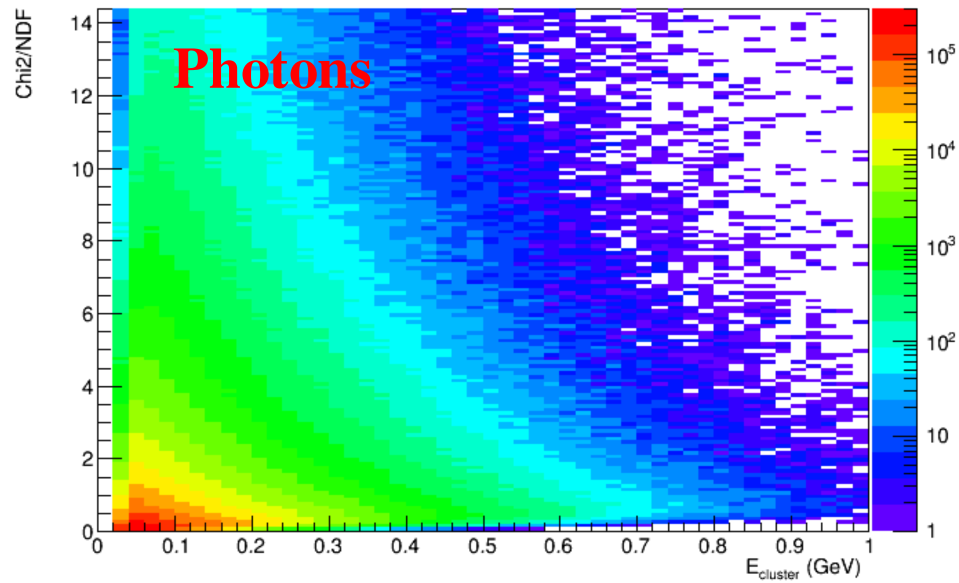
- $E_i^{expected}$ is calculated for each tower based on the known shower shape
- σ_i^2 is expected fluctuation of the energy distribution (empirical tuning):

$$\sigma_i^2 = A \cdot E_i^{expected} \cdot \left(1 - \frac{E_i^{expected}}{E}\right), \mathrm{A} = 0.008\ \mathrm{GeV}$$

- σ_i^2 is tuned from simulations (different versions tried)
- NDF – number of towers in the cluster

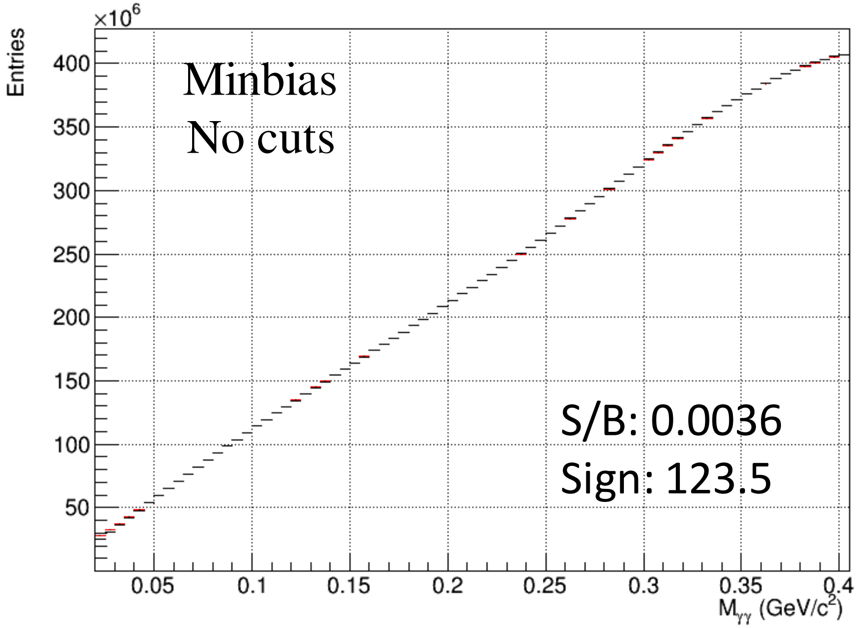
Chi2/NDF distributions, AuAu@11 (UrQMD)

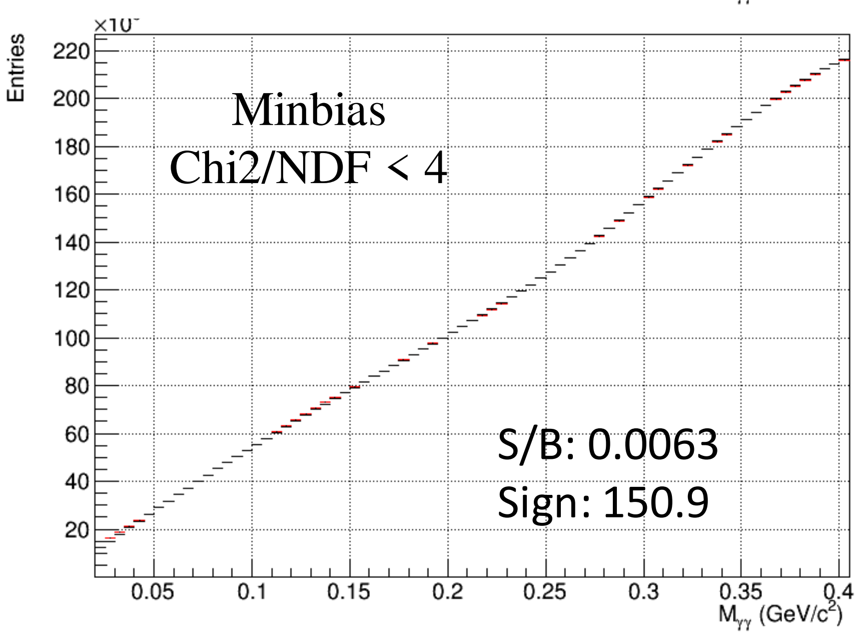




- Shower shapes are obviously different for photons and hadrons
- Shower shape can be analyzed only for clusters with number of towers > 1

Chi2/NDF cut, AuAu@11 (UrQMD)

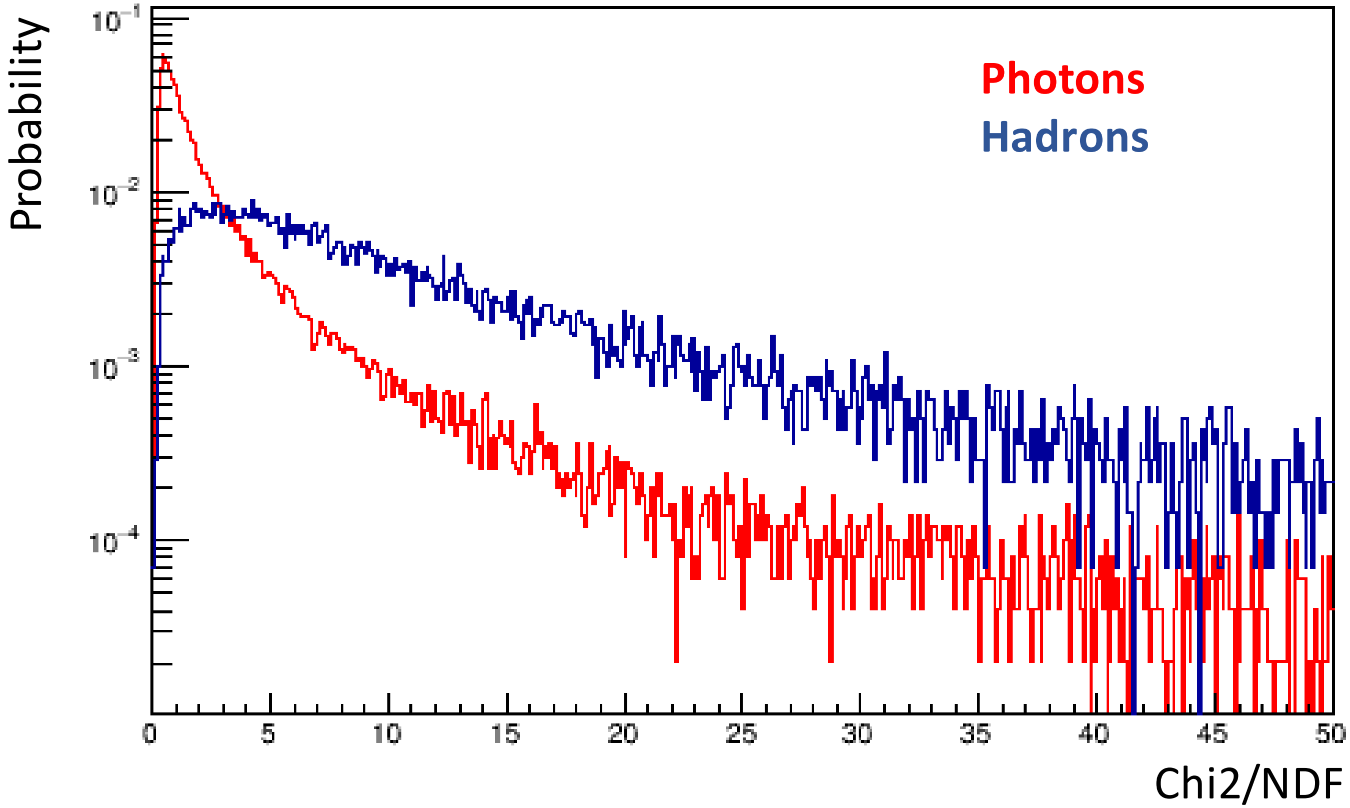




- $\pi^0 \rightarrow \gamma\gamma$
- $0 < p_T$ (GeV/c) < 1
- Chi2/NDF < 4 cut is almost as efficient as timing cut of T < 1 ns
- S/B improves by a factor of ~ 2
- Chi2/NDF < 4 cut reduces number of reconstructed π^0 by 16%. At this π^0 peak becomes narrower → cut mostly rejects pairs with miss-reconstructed clusters

Chi2/NDF cut, AuAu@11 (UrQMD)

- Chi2/NDF cut us most effective at high energies
- Probability for a cluster with E > 0.5 GeV to have a particular value of Chi2/NDF (distributions are normalized to unity)



Chi2/NDF, summary

- PROS:
  - ✓ based on ECAL information only, available on day-1
  - ✓ rejects hadronic and miss-reconstructed e/m clusters
  - ✓ works for photons
  - ✓ works for electrons with $p_T > 0.3$ GeV/c
  - ✓ very efficient at higher energies

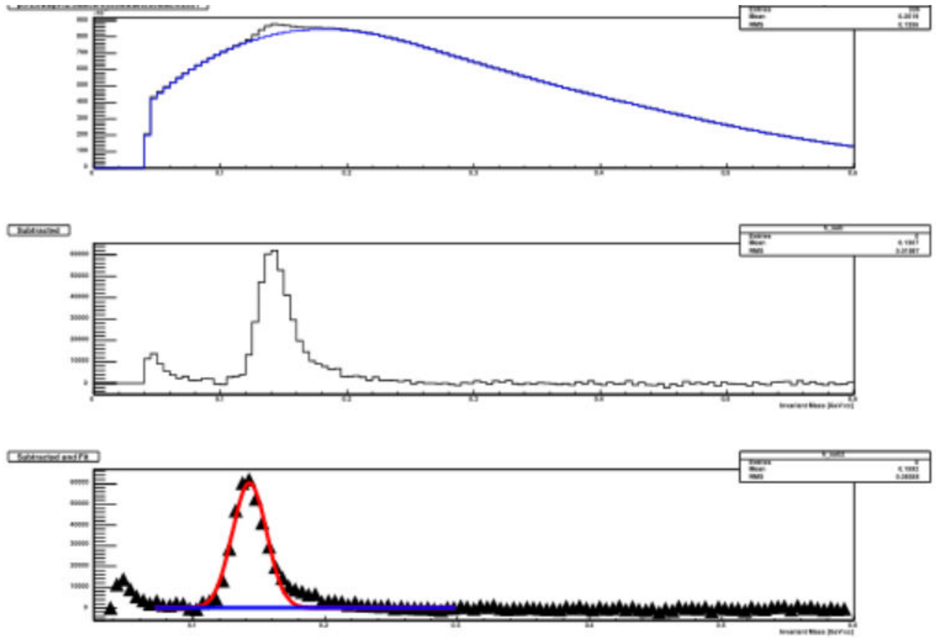
- CONS:
  - ✓ not very efficient for small, low-E clusters

Effective and transparent cut → should/can be used

Conclusion

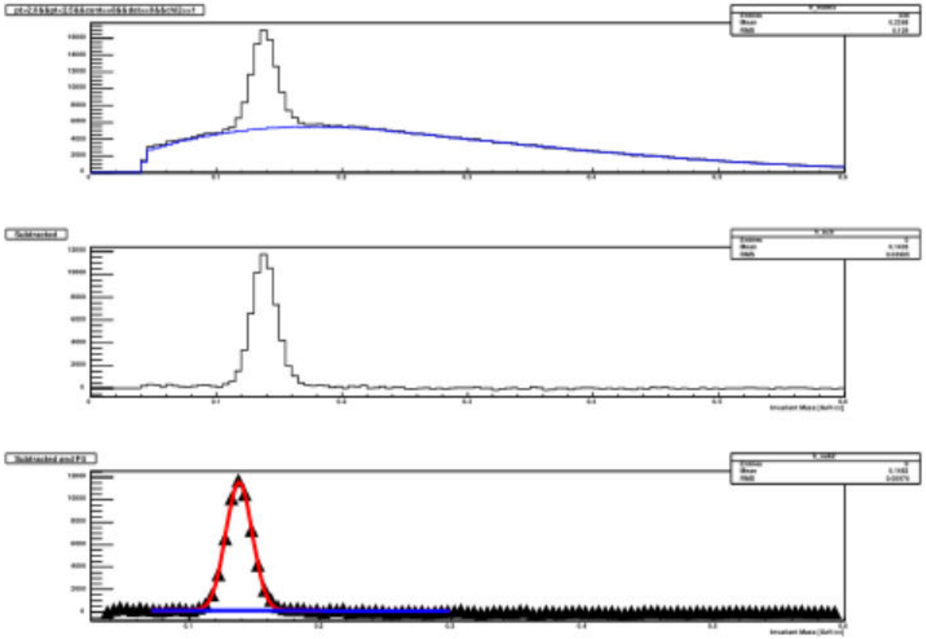
- Studied three methods of cluster identification :
  - ✓ charged track veto
  - ✓ time-of-flight
  - ✓ shower shape
- All methods work providing comparable efficiency for photon ID
- All methods have advantages and obvious disadvantages/limitations
- Methods are not additive, results are correlated
- Optimal combination of different ID methods → to be studied

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.

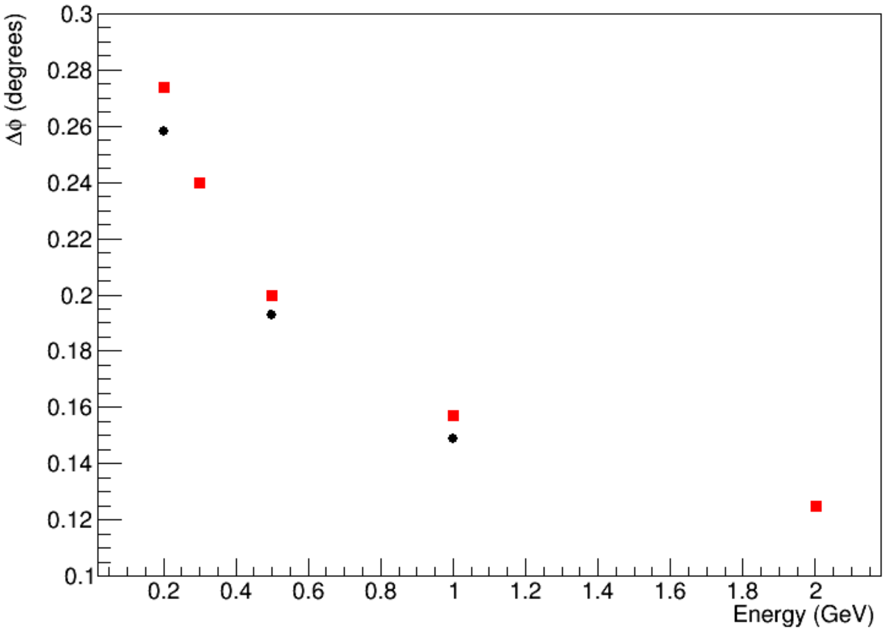


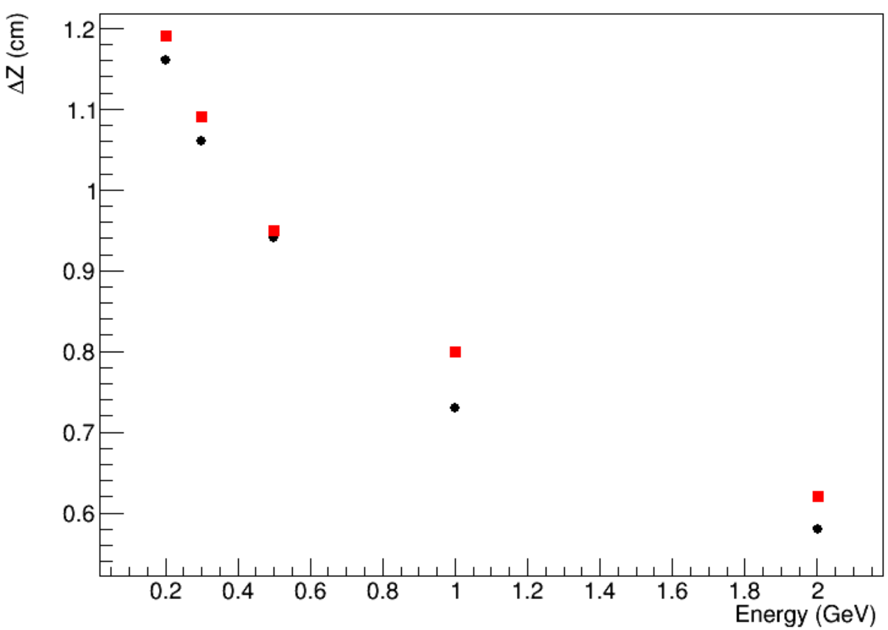
```
energy scale checking
Input file : ./run/scan20050620_stripe12/merged.root
Pt range, conditions : pt>2.0&&pt<2.5&&cent==8&&det==0&&chi2==1
Normalization Region 1 : (0.085 , 0.086) (0.250 , 0.450)
Fit Region : (0.060 , 0.300)
Fit Result ...
CHI2 / ndf : 1.497457
Parameter 0 (Const) : 11497.390968 +- 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.

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





π^0, AuAu@11 (UrQMD)

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