MPD-ECAL fine calibration and performance studies

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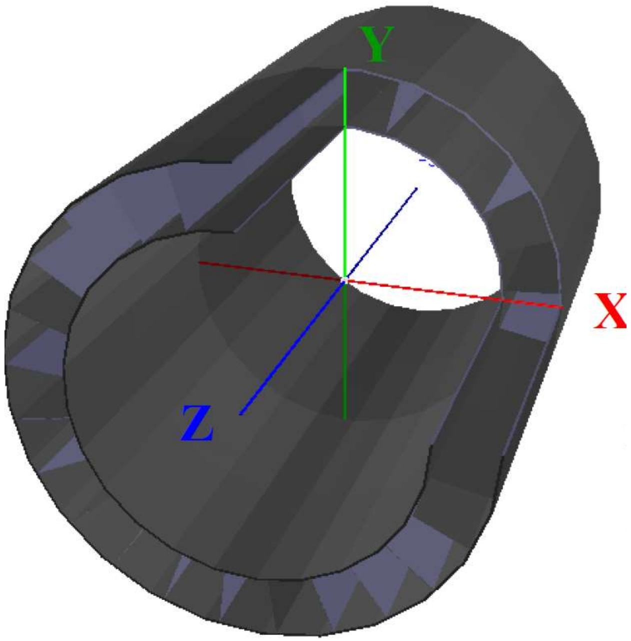
Outline

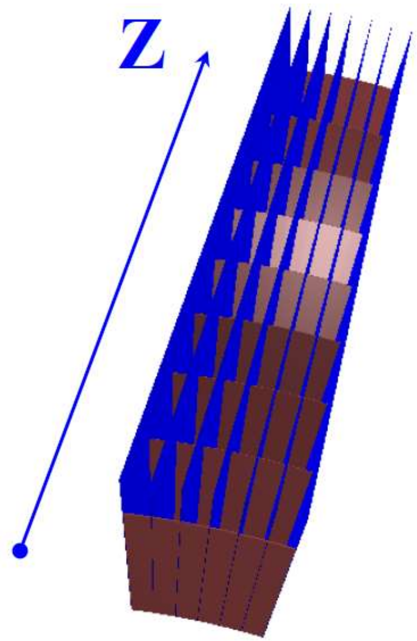
- Last time:
  - ✓ updated emcKI digitizer-clusterizer to work with v.3 ECAL geometry
  - ✓ presented results of basic performance studies with new geometry
    nonhomogeneous geometry and lower light collection → worse special and energy resolution

- Today:
  - ✓ fine tower-by-tower calibration → an attempt to recover some losses in resolution
  - ✓ performance studies and update of performance plots for the next DAC

New geometry and consequences

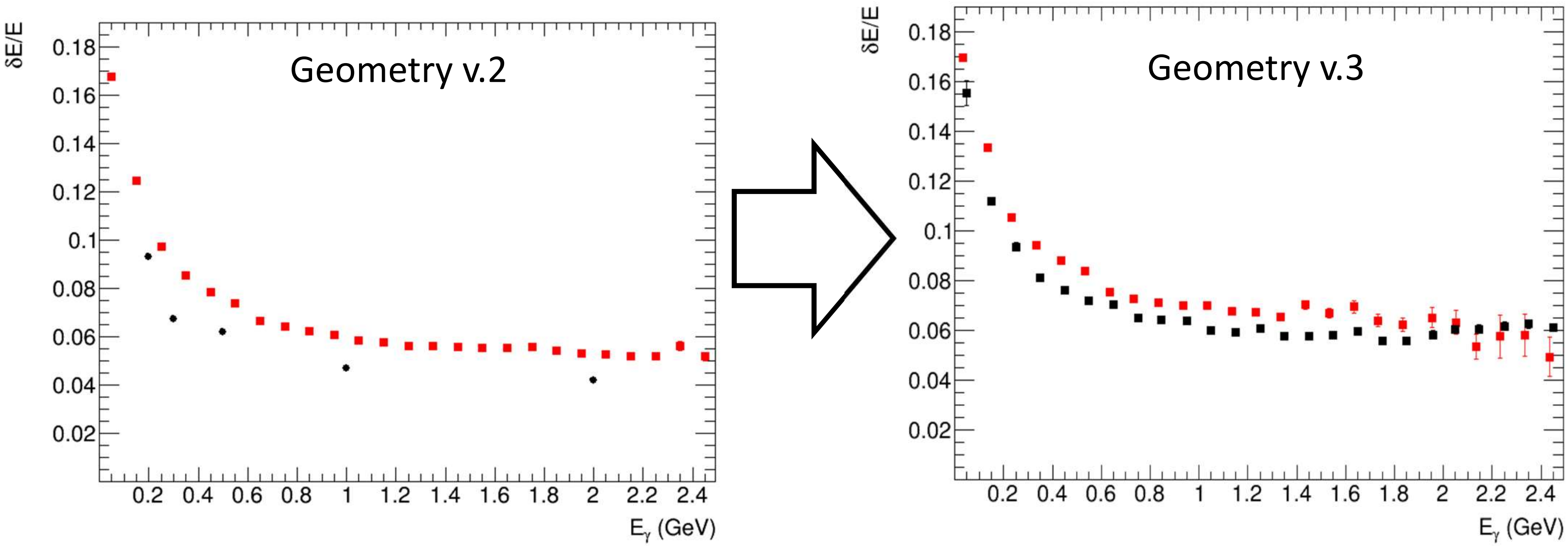
- Nonhomogeneous detector geometry and smaller light collection:
  - ✓ groups of towers are separated by carbon fiber walls of different thickness (2-20 mm)
  - ✓ 2.1 cm of paint in each tower, smaller number of tiles
  - ✓ support structure of 12.7% X_0 in front of the towers (carbon fiber cylinder)





New geometry and consequences

- Black markers – single photons; Red markers – UrQMD; realistic vertex distribution
- Energy resolution is worse by ~ 1%: 5(6)% → 6(7)% at 1 GeV

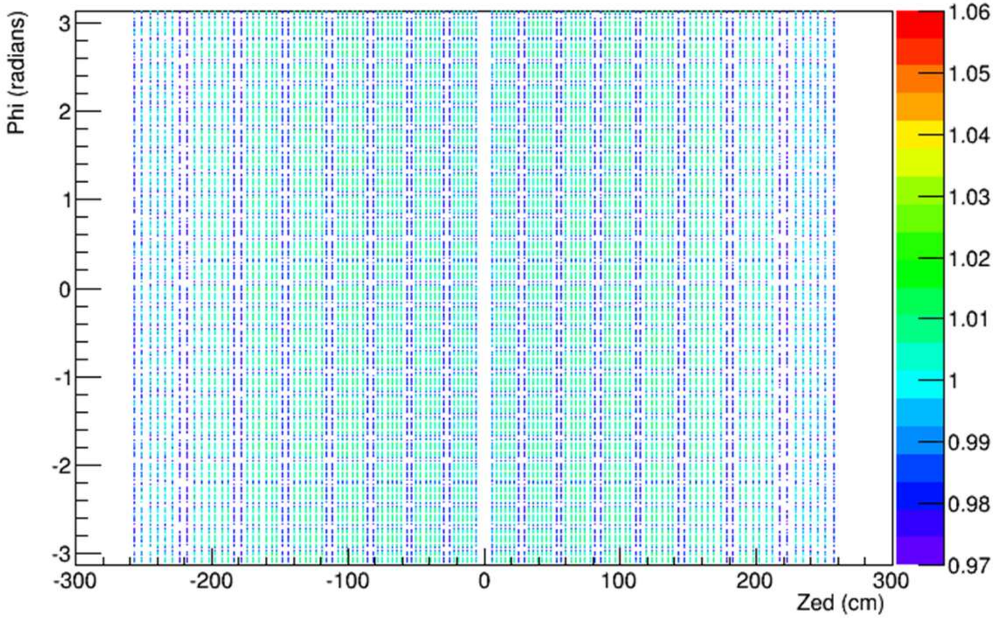


- Deterioration of energy resolution is caused as by nonhomogeneous geometry as by smaller light collection. The former adds to a constant term, the later adds to $1/\sqrt{E}$ term

- Contribution of nonhomogeneous geometry to the energy resolution can be partly compensated by fine tower-by-tower calibration of the ECAL

Scale variation

- Simulated 40M events: single photons of 500 MeV; realistic vertex distribution
- Divided reconstructed cluster energies by 500 MeV
- Plotted the ratios as a function of coordinates of the central towers (phi, zed)

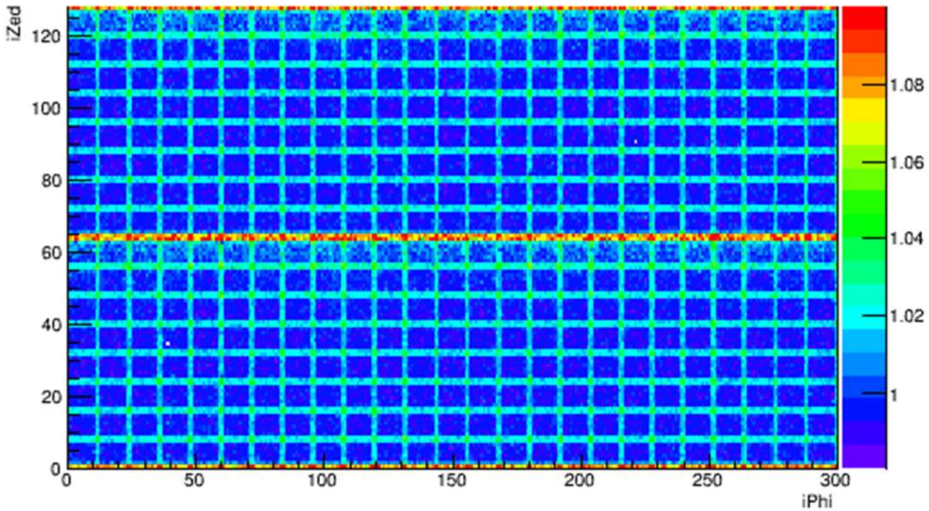


- Observe clear nonhomogenity of the ECAL absolute energy scale
- The nonhomogenity coincides with the geometry structures: : 16 groups in zed and 25 groups in phi
- The closer the cluster to the walls the larger the scale drop (energy leaks)
- Variation of the absolute scale results in worse energy resolution after averaging over the whole detector acceptance

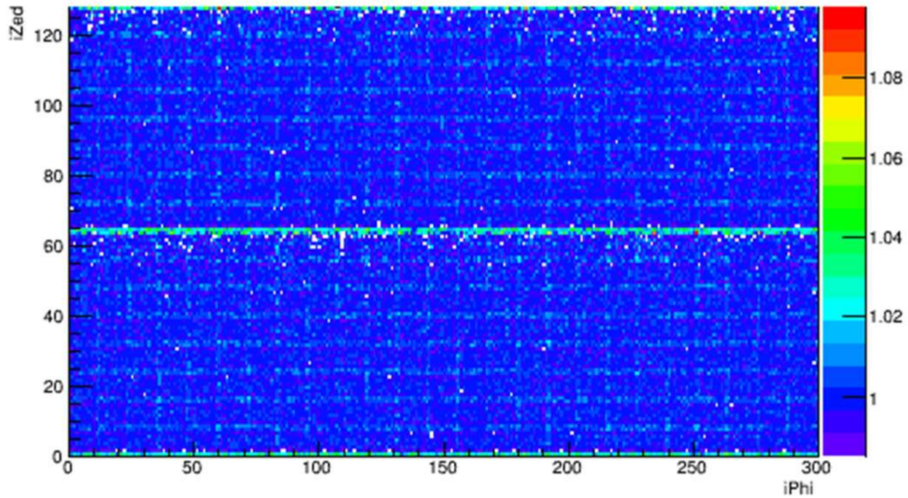
Fine calibration

- Introduced tower-by-tower calibration
- Corrections are evaluated as a ratio of generated to reconstructed cluster energies for central cluster towers
- Process converges in two iterations
- Stored in mpdroot/input/**MpdEmcCalib.root**

Iteration 0



Iteration 2

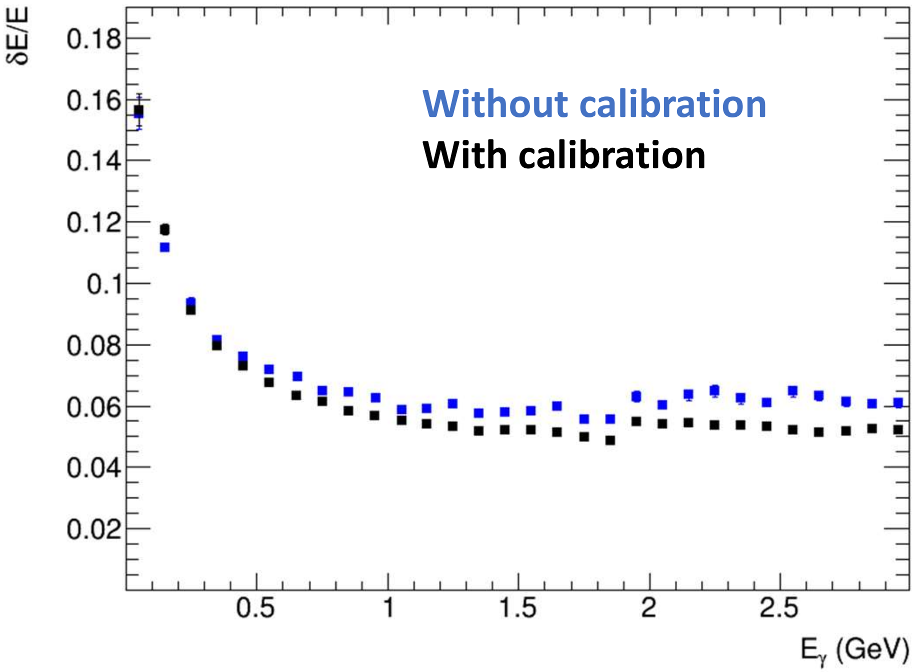


- After tower-by-tower calibration the absolute scale variation is significantly reduced

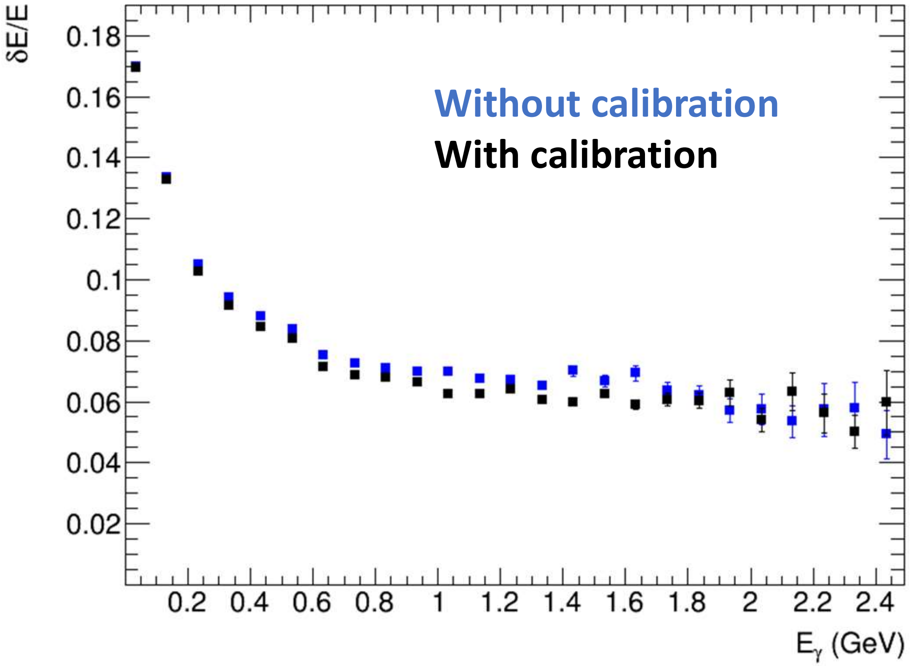
Back to energy resolution

- Compared energy resolutions with/without the fine calibration
- Single photons and UrQMD, minbias AuAu@11; realistic vertex distributions

Single photons



UrQMD, AuAu@11



- Fine calibration reduces the constant term
- Equivalent effect is quadratic subtraction of 2%: $\delta_{NEW} = \sqrt{\delta_{OLD}^2 - 0.02^2}$
- Even after the calibration, the energy resolution with v.3 geometry is worse

Mass production

- All latest advancements in MPD-ECAL simulation software are now committed in Git
- Setup codes for the first MPD Monte Carlo mass production
- Details of the request are described in mpdforum:
  https://mpdforum.jinr.ru/t/monte-carlo-production-requests/61/15?u=riabovvg
  - ✓ Events: UrQMD, minbias AuAu@11; η, $\rho(770)^0$, ω, η', ϕ
  - ✓ Decay modes of η, $\rho(770)^0$, ω, η', ϕ are redefined in mpdroot/gconfig/UserDecay.C to enhance (e^+e^- + X) decay channels (BRs are still on sub-percent level)
  - ✓ Output: standard DSTs and filtered microDSTs

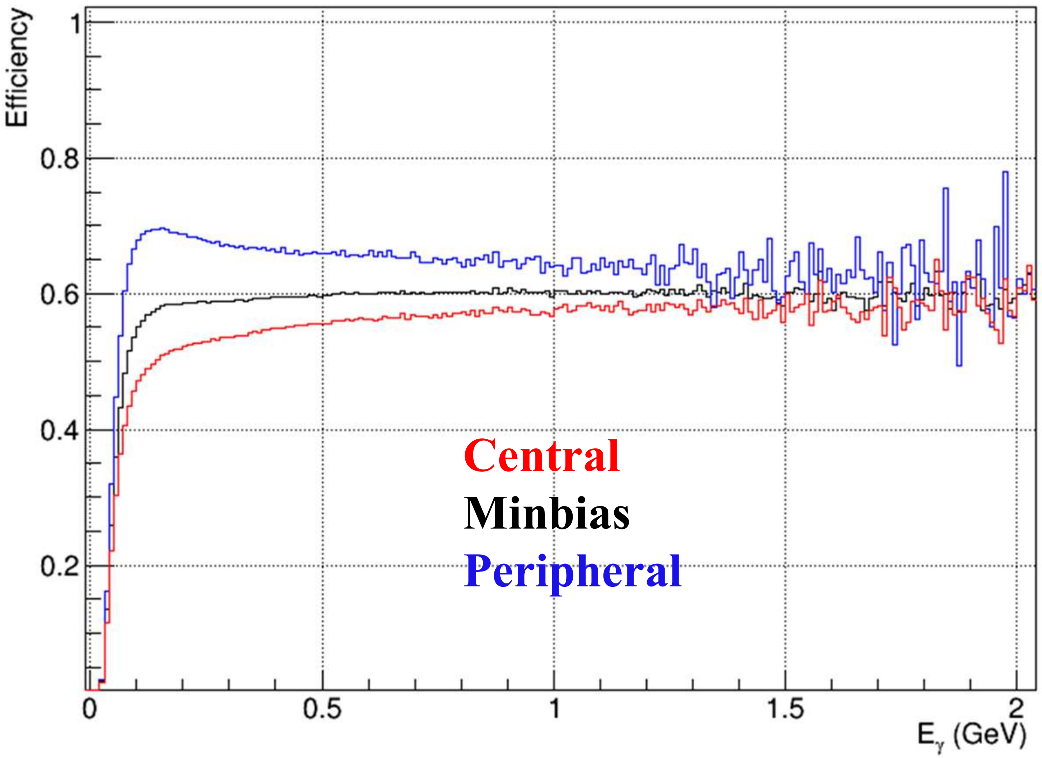
- Production is in progress … output files will be stored at NICA cluster
- Meanwhile, using the same setup simulated 2.5 M event at NICA cluster
- Output DSTs are available for public access at NICA cluster:
  - ✓ /eos/nica/mpd/users/riabovvg/ECAL_Tutorial_GeoV3/OUT_urqmd1 through OUT_urqmd25
- The output was used to estimate the detector performance

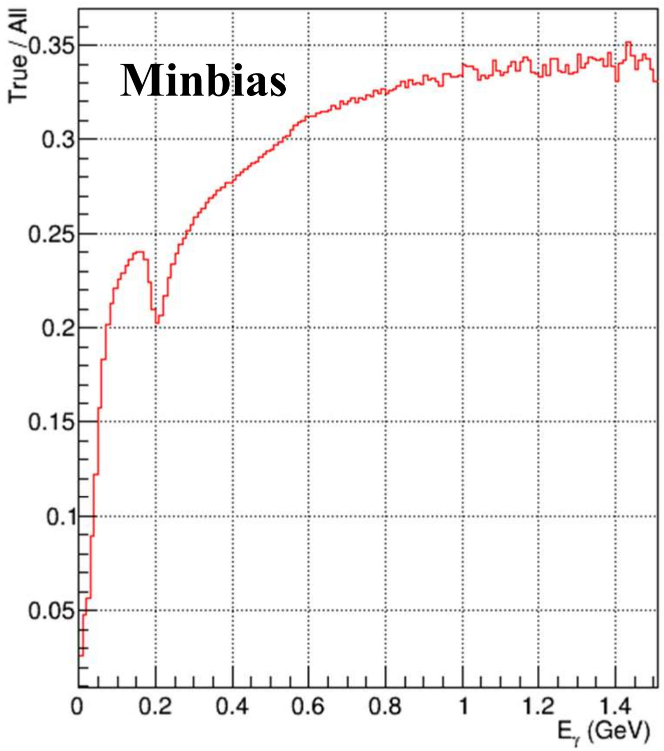
Detector performance

Current status

Photon efficiency & purity

- UrQMD. Minbias AuAu@11; realistic vertex distribution

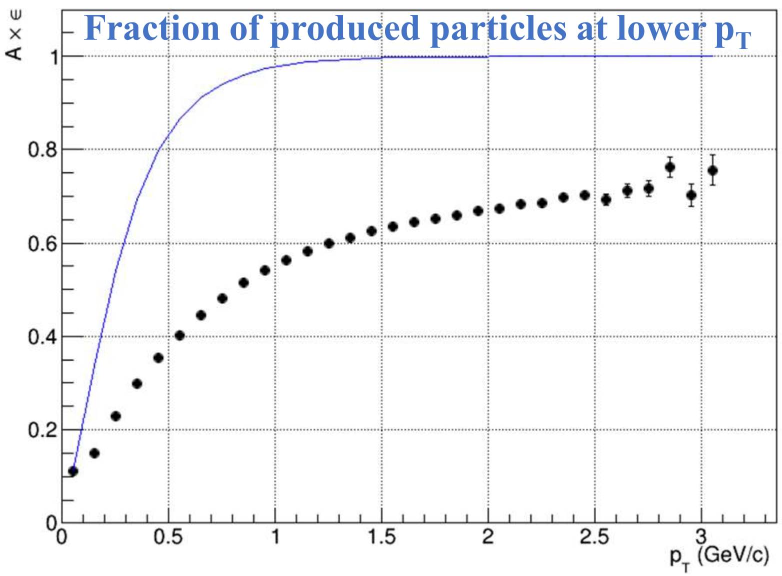


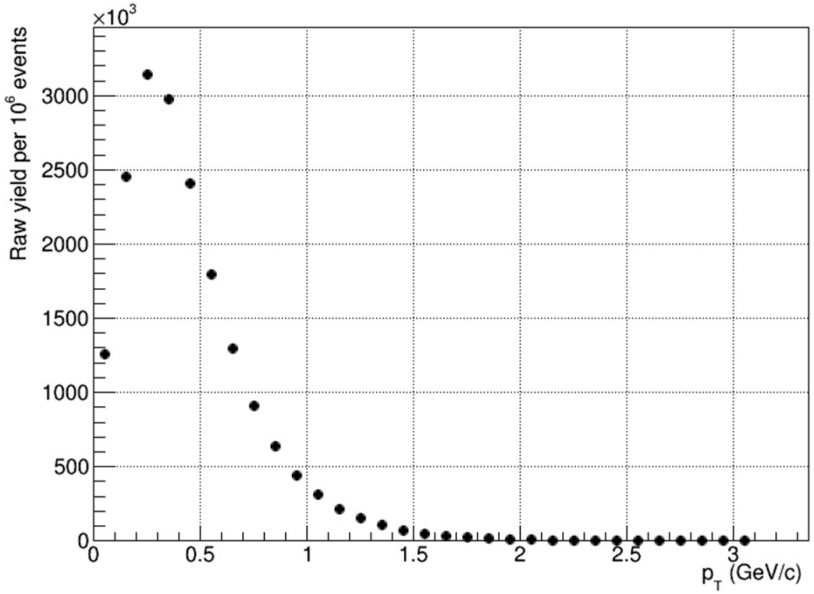


- Only ~ 60% of primary photons reach the ECAL surface, others convert (TOF + carbon fiber support structure)
- Efficiency drop in central collisions is caused by high multiplicity
- The real efficiency is higher because some of the e^+e^- conversion pairs are reconstructed as a single cluster; such clusters differ by shape

π^0 reconstruction

- Minimum cuts for observation of signals:
  - ✓ Events: UrQMD, |z-vertex| < 50 cm
  - ✓ Photons: E > 0 GeV, $T_{reduced}$ < 2 ns
  - ✓ Pairs: |y| < 0.5

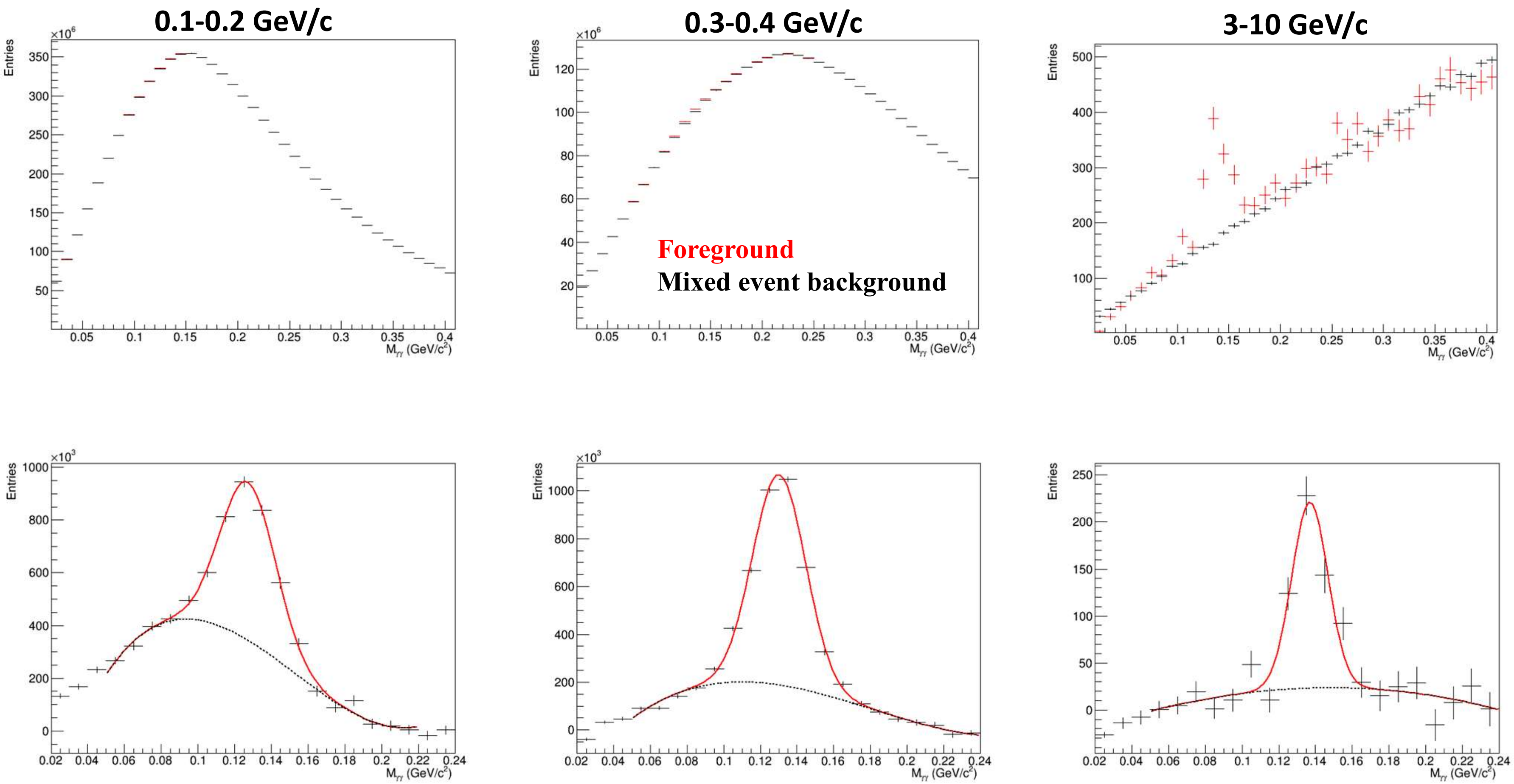




- Efficiency for π^0 is > 10% at p_T > 100 MeV
- Modest improvement of the efficiency at low momentum is still possible → work in progress
- Signal is measurable starting from ~ 100 MeV/c → ~ 90% of the total yield
- Maximum raw yield of π^0 is expected at ~ 300 MeV/c

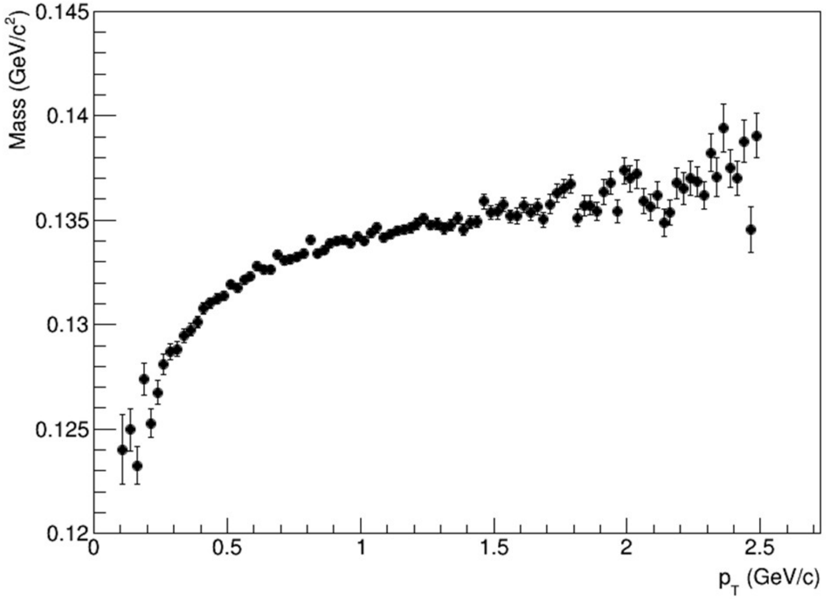
π^0 peak examples

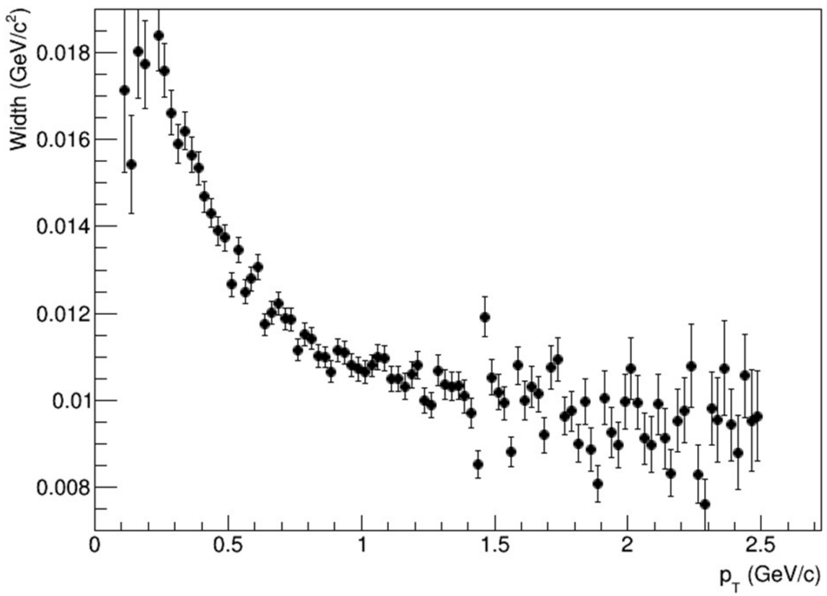
- UrQMD. Minbias AuAu@11, realistic vertex distribution



π^0 mass and width (Gaussian)

- UrQMD. Minbias AuAu@11, realistic vertex distribution

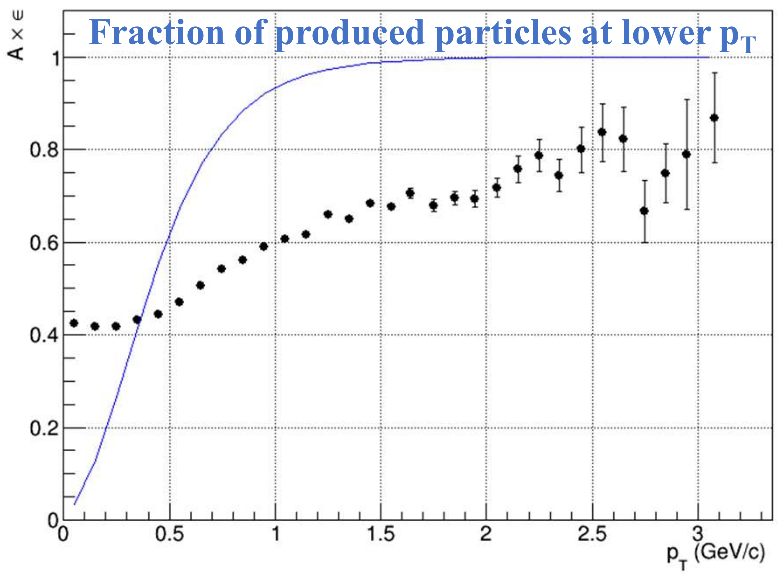


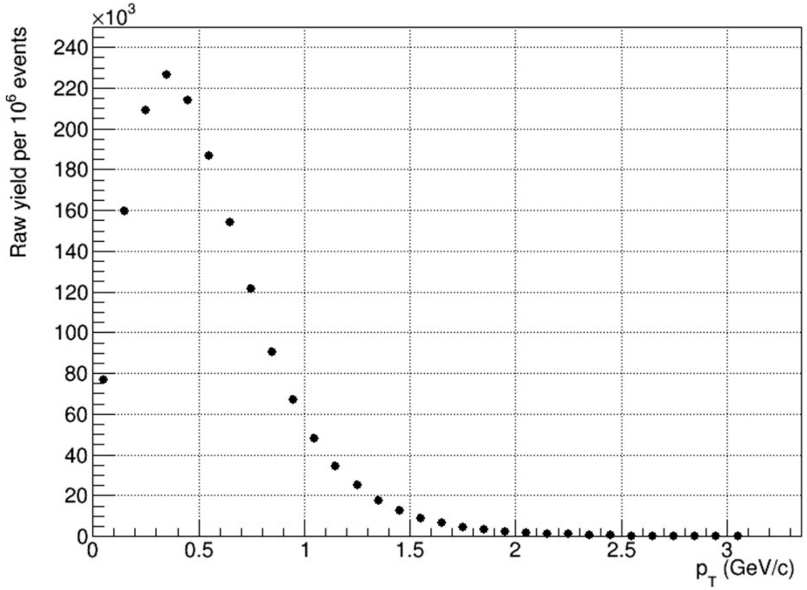


- Mass dependence is due to energy leakage
- Width is driven by single photon energy resolution
- Width is larger with v.3 geometry due to worse energy resolution

η reconstruction

- Minimum cuts for observation of signals:
  - ✓ Events: UrQMD, |z-vertex| < 50 cm
  - ✓ Photons: E > 0.1 GeV, $T_{reduced}$ < 2 ns; N_{towers} > 2; Chi2/NDF < 4.0
  - ✓ Pairs: |y| < 0.5

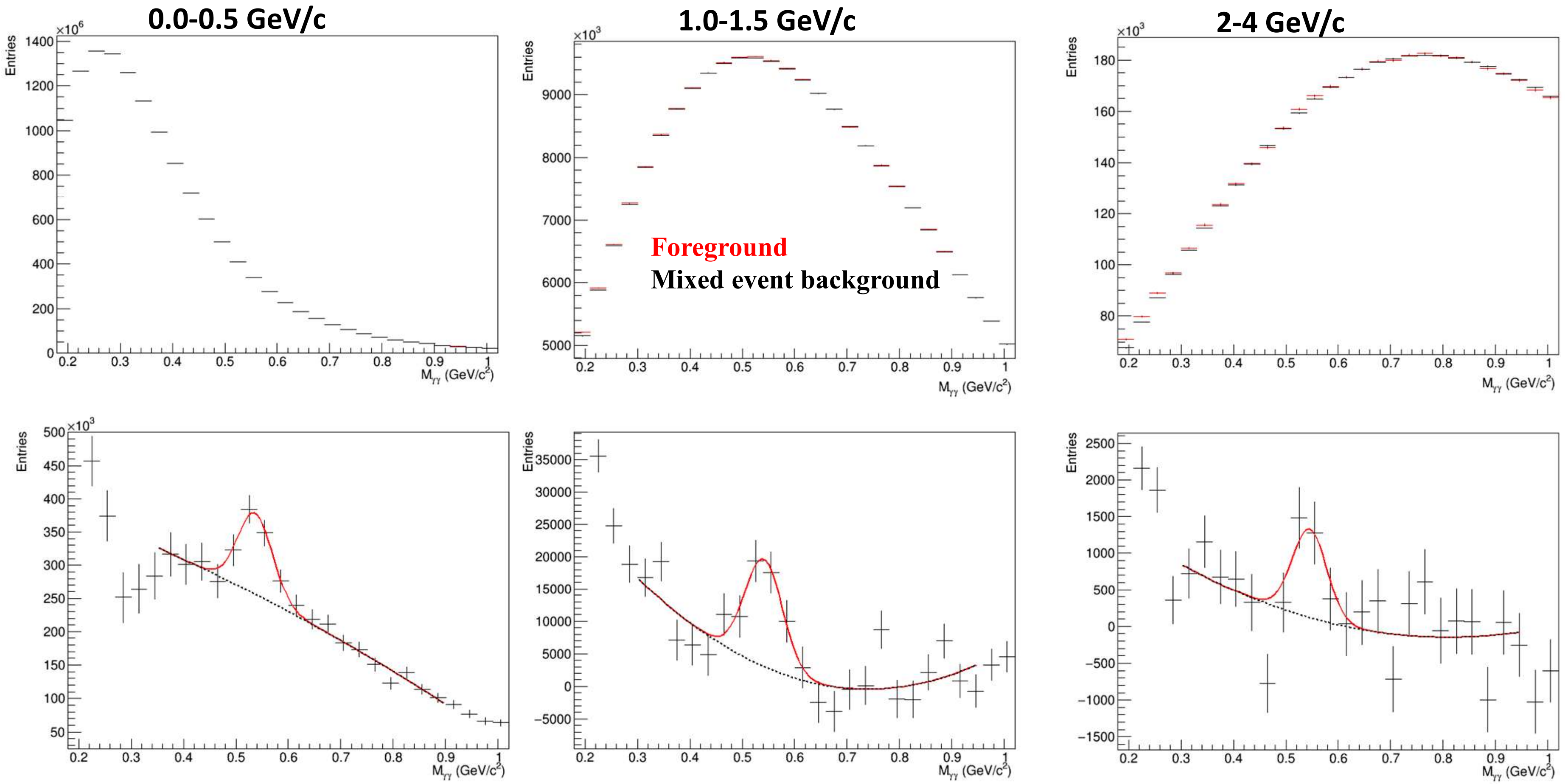




- Efficiency for η is > 40% at p_T > 100 MeV
- Modest improvement of the efficiency at low momentum is still possible → work in progress
- Maximum raw yield of η is expected at ~ 400 MeV/c

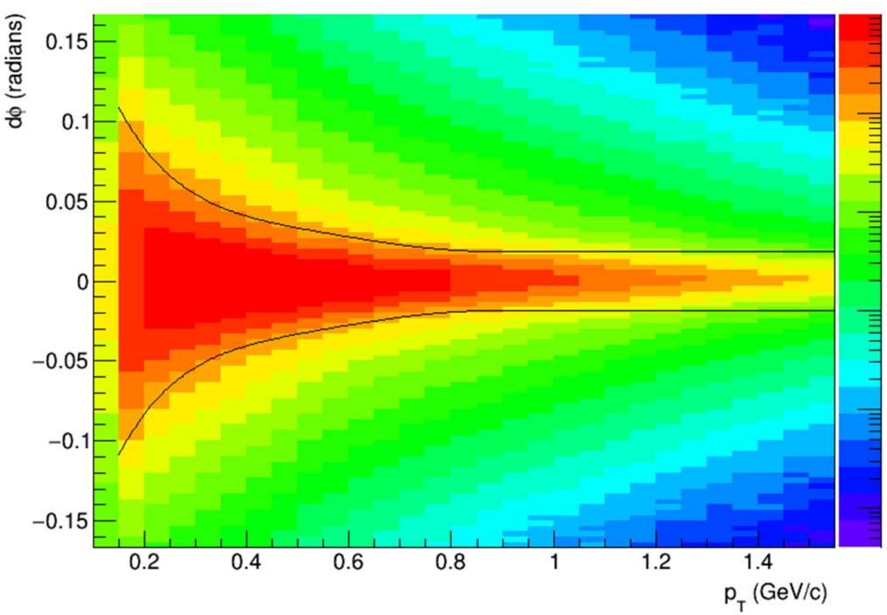
η peak examples

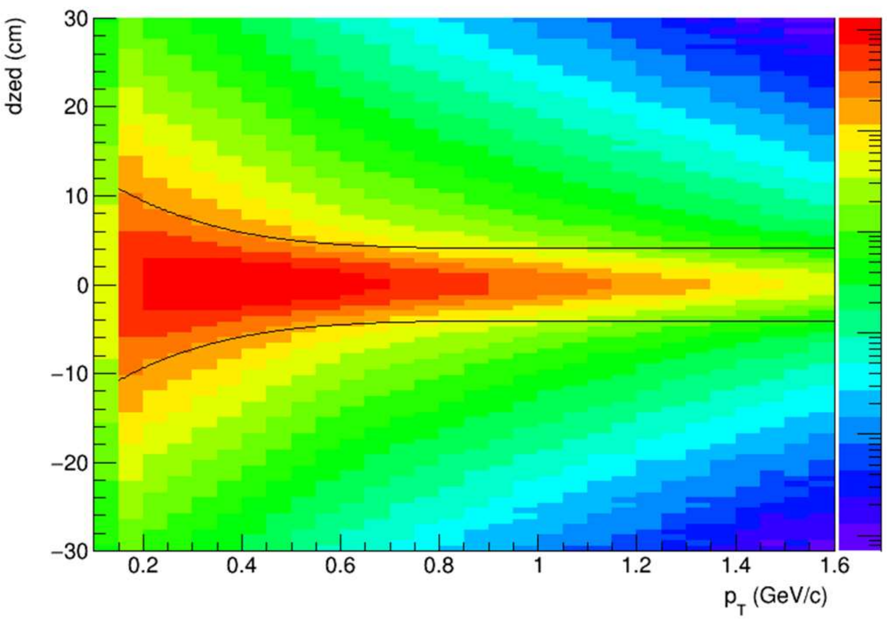
- Signals are observed after background subtraction
- Higher statistics is needed for numerical studies of mass and width



Track-to-cluster matching

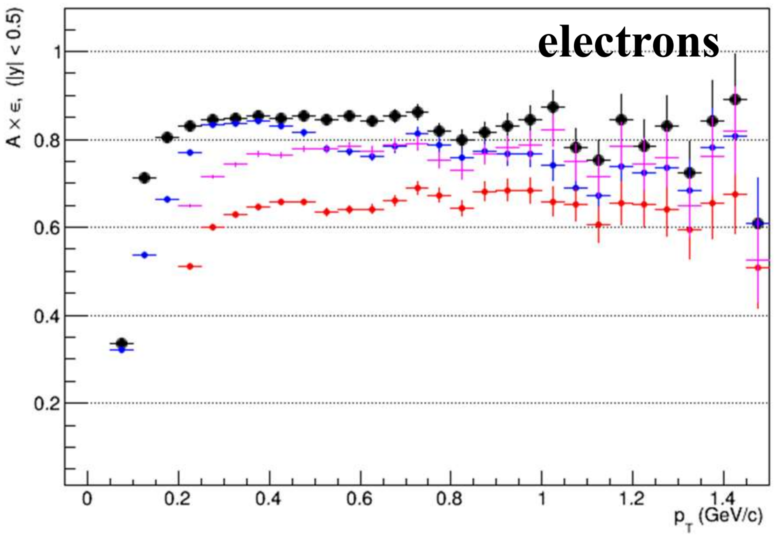
- UrQMD. Minbias AuAu@11; realistic vertex distribution
- Track-to-cluster matching relates cluster information (E, tof, shower shape) to tracks
- Black bands show 2σ matchings in dφ and dzed
- Matching in dφ is generally wider at low p_T due to track bending in magnetic field
- Only tracks with p_T > 150 MeV/c effectively reach the ECAL

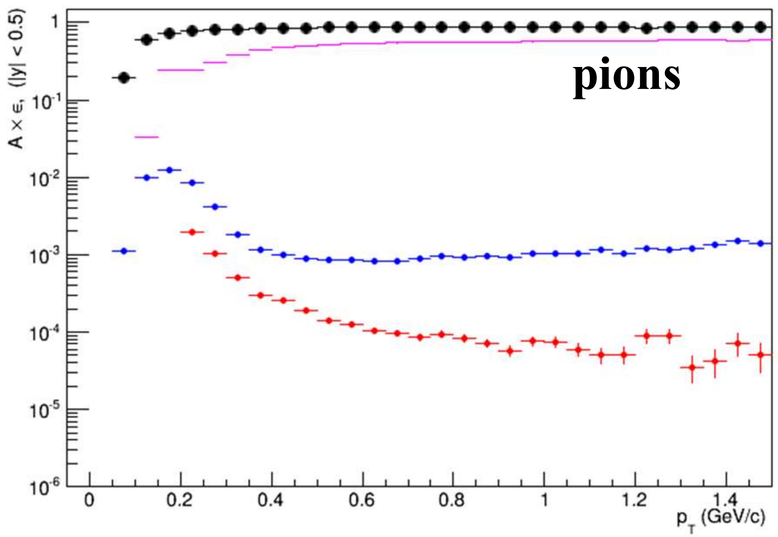




eID efficiency and hadron rejection

- UrQMD. Minbias AuAu@11; realistic vertex distribution
- eID efficiency and hadron rejection

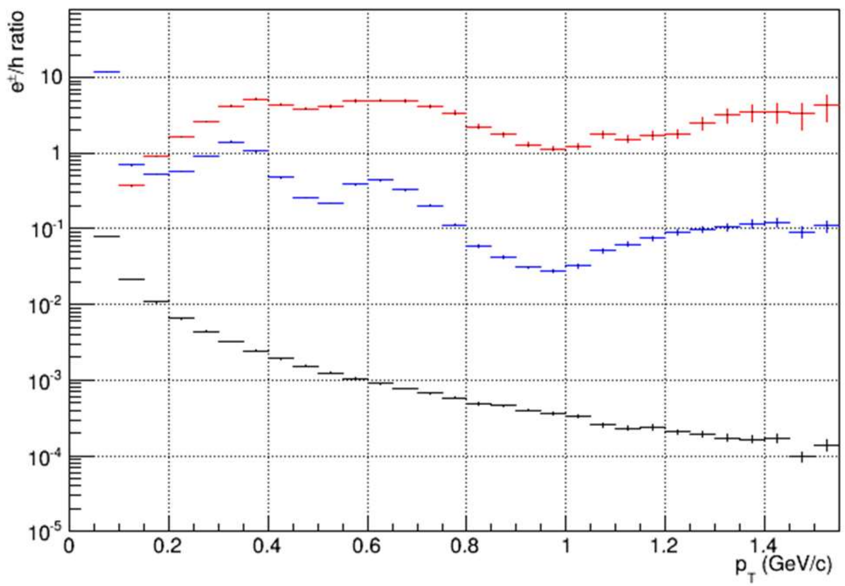




All tracks

All tracks + TPC/TOF-PID

All tracks + TPC/TOD-PID + ECAL-PID (ToF + E/p)

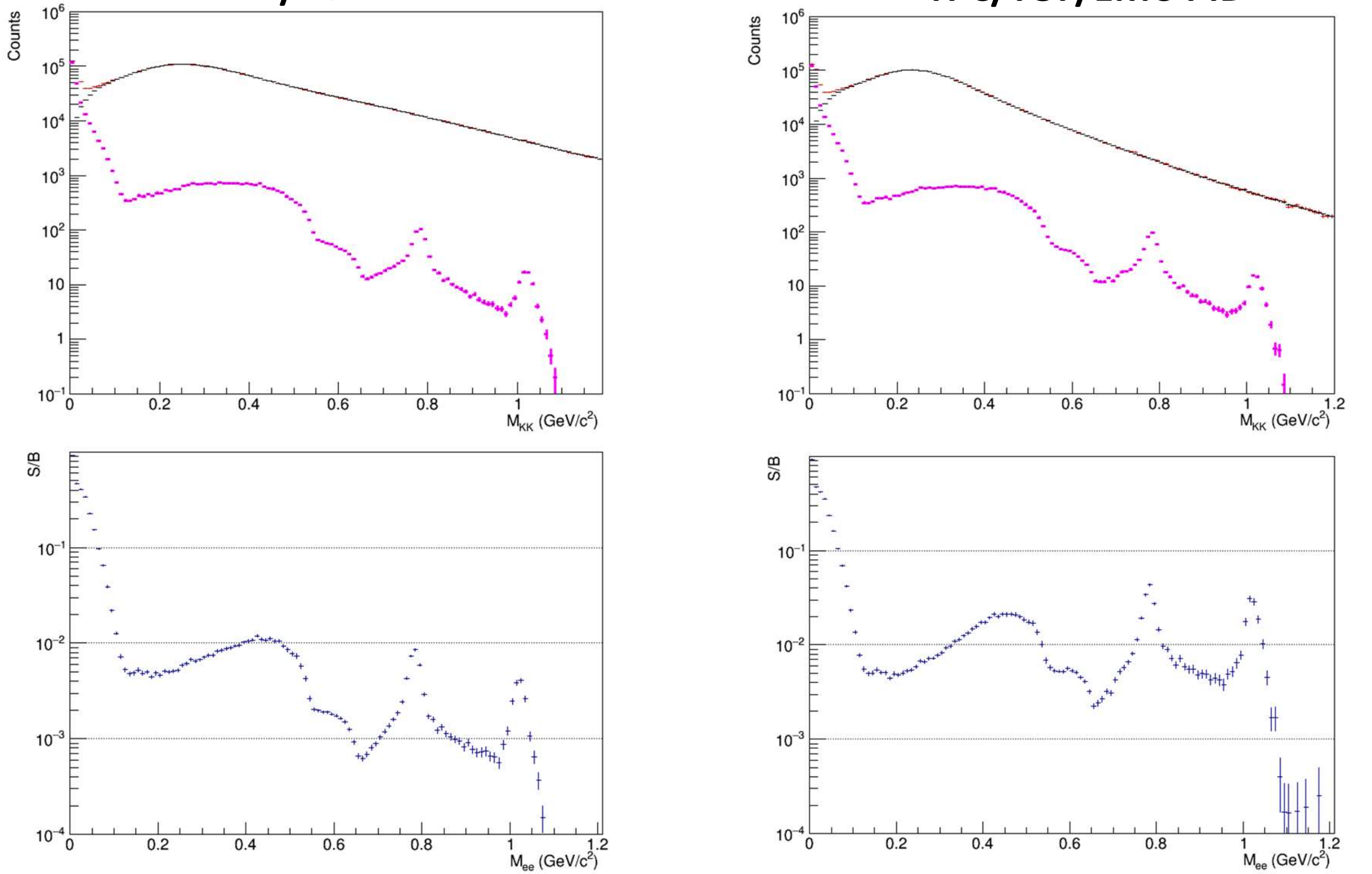


- ECAL improves electron identification at $p_T > 0.2$ GeV/c by E/p and ToF
- e/h ratio improves by
  - ~ 3-4 at 0.3 GeV/c
  - ~ 10-20 at 0.5 GeV/c
  - ~ 50-70 at 1 GeV/c

Dielectrons, first look - I

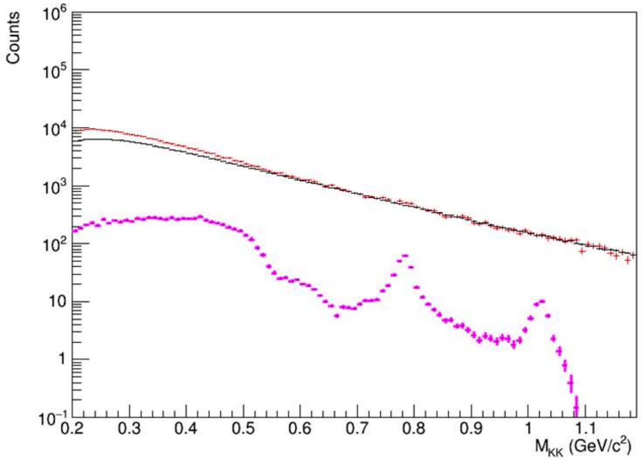
- UrQMD. Minbias AuAu@11; realistic vertex distribution
- EMC-PID is added for electron tracks with p_T > 150 MeV/c
- EMC-PID significantly improves S/B: peak significance for ω/ϕ (1.1/0.32) → (2.16/0.86)

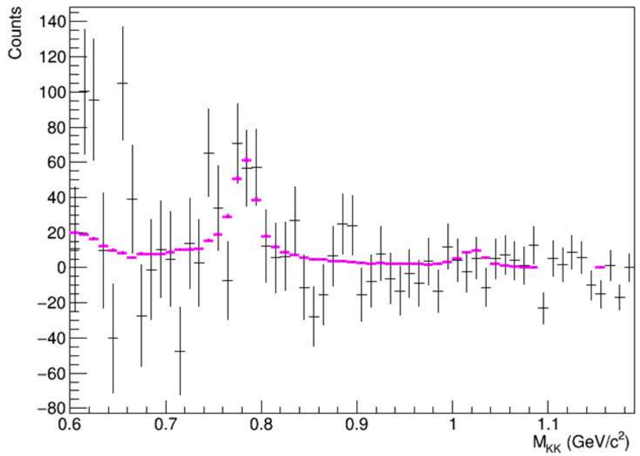
TPC/TOF-PID **TPC/TOF/EMC-PID**

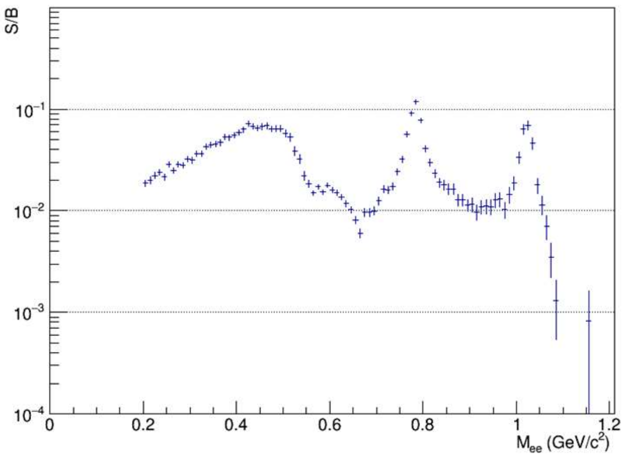


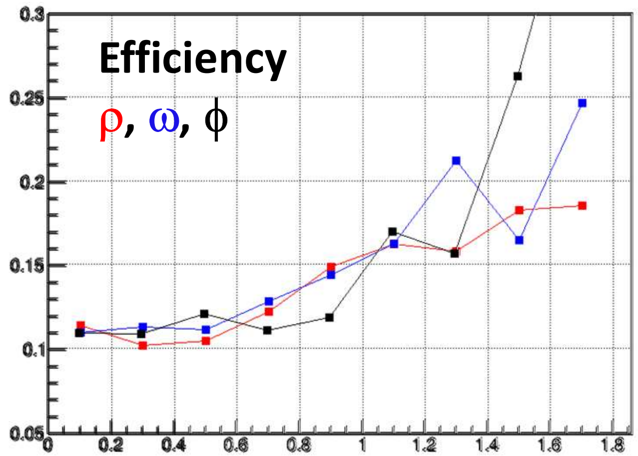
Dielectrons, first look - II

- UrQMD. Minbias AuAu@11; realistic vertex distribution
- TPC/TOF/EMC-PID
- e^+e^- tracks are rejected if they pair in a combination witt Minv < 0.2 GeV/c in the event
- Further improvement of S/B: peak significance for ω/ϕ (2.16/0.86) → (2.9,1.02)









Conclusions

- Fine calibration reduces the constant term in the energy resolution; improvement is quite modest
- The ‘final’ code is in Git, first mass production is in progress
- The basic detector parameters are evaluated and presented

Please report any problems ……..

BACKUP