NICA Nuclotron-based Ion Collider fAcility

MPD-ECAL simulation and physics performance

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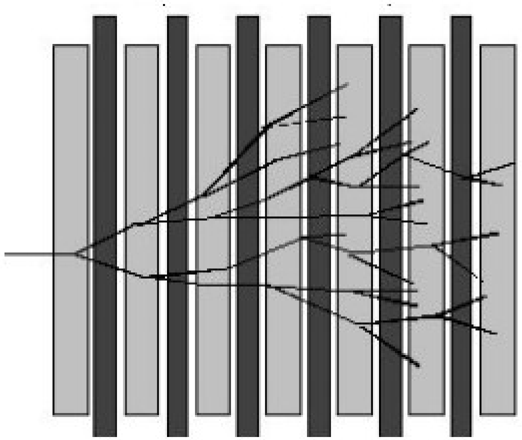
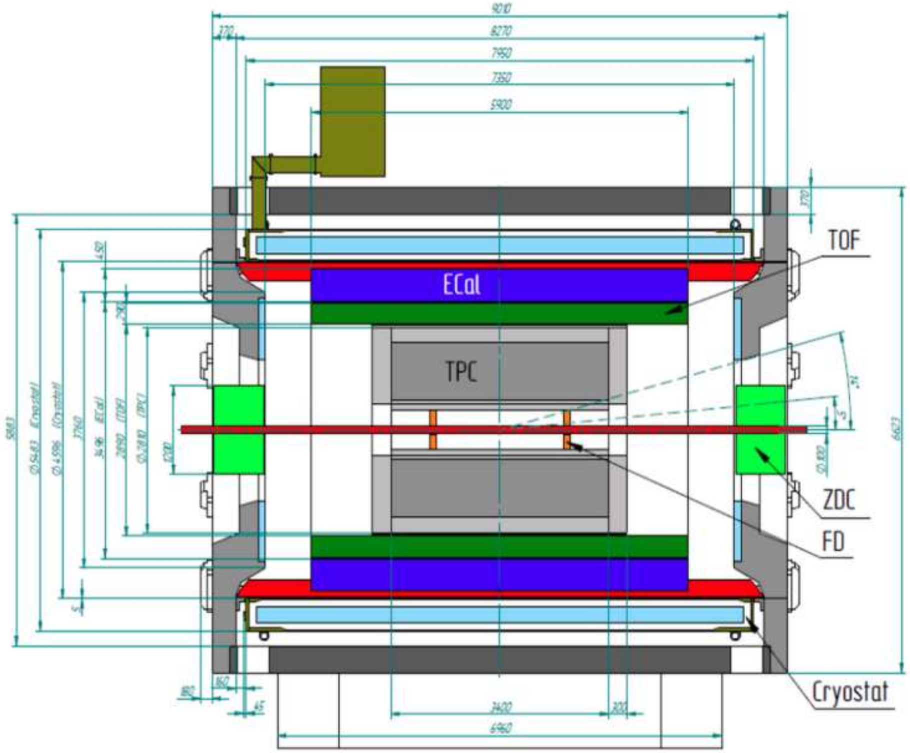


MPD, phase-I



- ECAL is one of the key detector subsystems
- Located right behind the ToF subsystem (R = 168-229 cm; L = 2 x 314 cm)
- Shashlyk-type PbSc calorimeter with projective geometry
- Fine segmentation: 4x4 cm, 38400 towers

Outline

- Simulation of the MPD-ECAL
- Status of the code
- Basic capabilities and performance parameters
- Near future plans
- Summary

This is no a technical presentation.
For technical details please see presentations in the MPD-ECAL software group

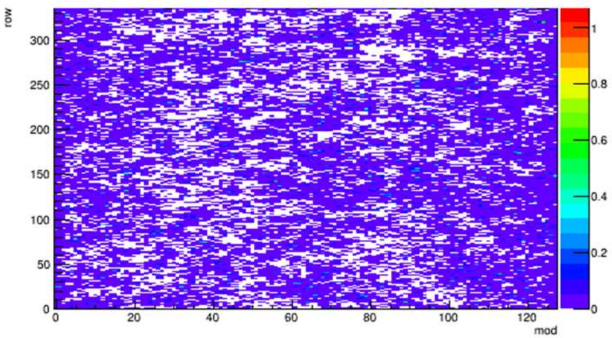
Purpose of this presentation is to popularize use of the MPD-ECAL in physics related studies
and to demonstrate the basic detector capabilities

MPD-ECAL, operation conditions

- Compared to calorimeters in other HI collider experiments at RHIC/LHC:
  - ✓ softer signals → bad for resolution, $\sigma(E) \sim 1/\sqrt{E}$
  - ✓ smaller radius, 2 m vs. ~ 5 m → higher signal density and higher importance of spatial resolution

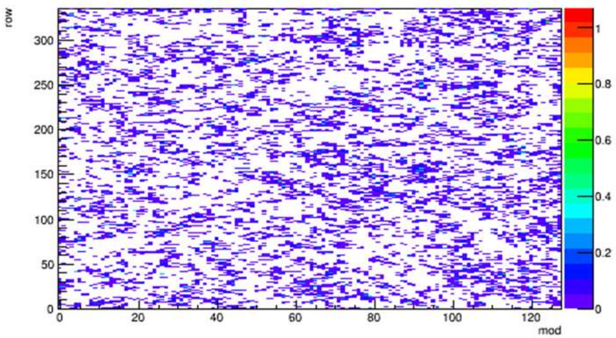
- UrQMD, AuAu@11, b ~ 1 fm → most central collisions
- Optimistic/realistic estimate of the minimum tower threshold is E_{min} ~ 5 MeV
- Occupancy is ~ 27% → comparable to that in higher energy experiments

E_{min} = 0 MeV



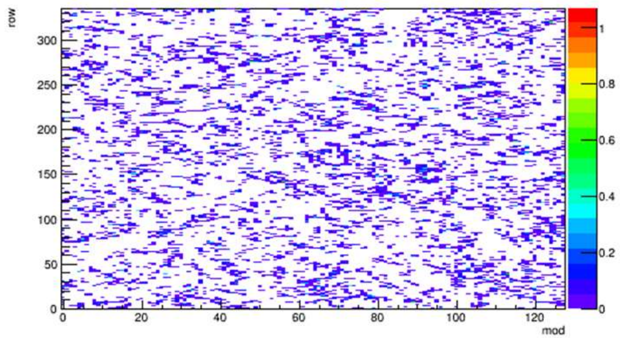
occupancy ~ 0.72

E_{min} = 5 MeV



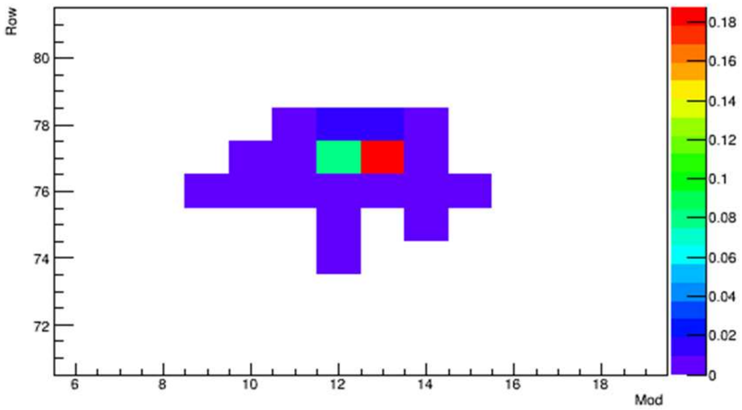
occupancy ~ 0.27

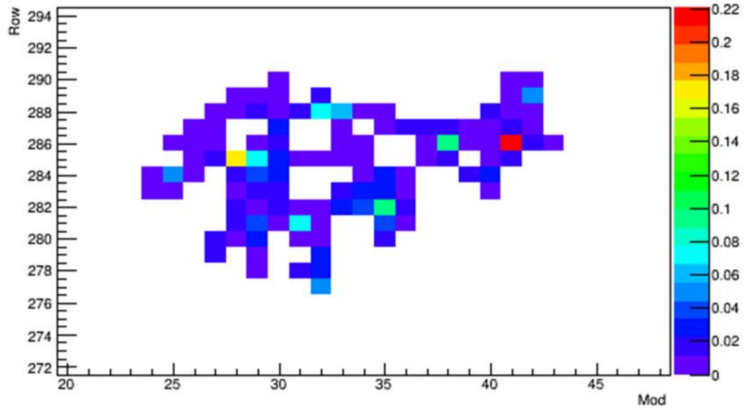
E_{min} = 10 MeV



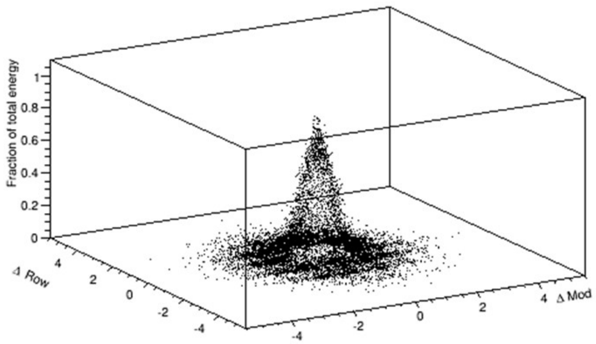
occupancy ~ 0.20

Signal reconstruction and shower merging

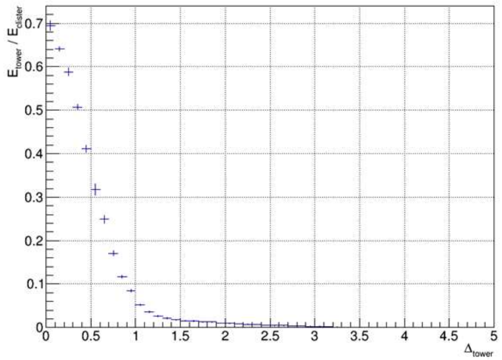




- Clusters are reconstructed as groups of towers surrounding a local maximum and touching each other by at least one side
- Small fraction of clusters is reconstructed as stand alone showers
- Others are reconstructed as groups of merged showers. The merged signals are unfolded using the information about the expected shower shapes



$E_i/\sum E_i$: ΔMod : ΔRow



Status of the code

- The MPD-ECAL simulation code is in Git and is ready to be used by analyzers
- The default digitizer-clusterizer is in mpdroot/emc/emcKI/
  - ✓ works with the latest geometry (V3)
  - ✓ provides the best performance in high multiplicity events
  - ✓ disk space friendly
- The code works and does not add much to the total processing time
- Optimization of the code (better calibrations, more advanced PID selections, consistency checks with the prototype tests etc.) will continue … permanent process

MPD-ECAL output

- The MPD-ECAL output contains a list of all reconstructed showers/clusters
- For each shower/cluster one can get:
  - ✓ full energy, truncated energies counted in the space region where 99% or 98% of the total energy contribution to the shower is expected to be based on the shower shape
  - ✓ coordinates of the shower center of gravity: x, y, z, R, phi, theta
  - ✓ time of flight
  - ✓ track matching: distance to the closest mpdtrack in dphi and dzed (mpdtrack index, dphi, dzed)
  - ✓ MC contributors: list of up to five main MC contributors to the shower sorted by energy (mc index, energy deposition)
  - ✓ e/m PID variables: Chi2/NDF, dispersion cuts
  - ✓ list of towers associated with the reconstructed shower (for recalibration and debugging)

Most common physics tasks

- Photons (yields, flow, correlations):
  - ✓ inclusive
  - ✓ direct

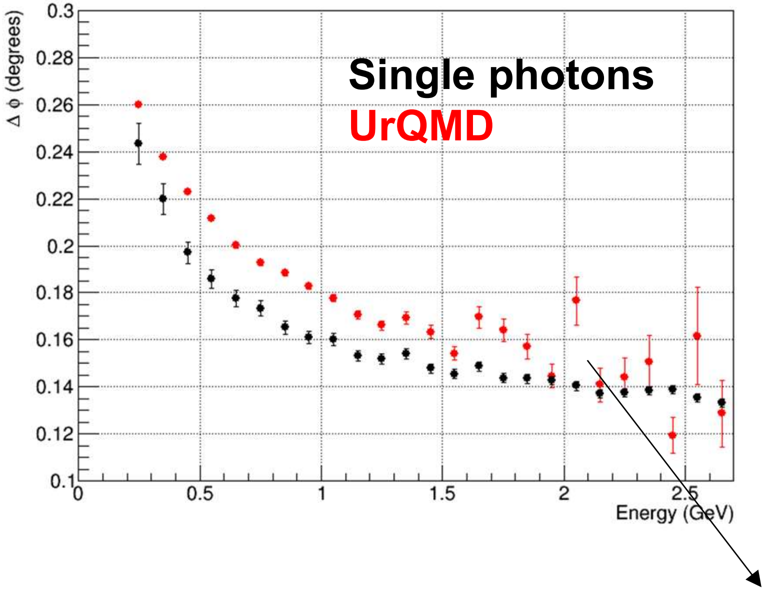
- Neutral mesons (yields, flow):
  - ✓ $\pi^0(\eta) \rightarrow \gamma\gamma$
  - ✓ $K_s \rightarrow \pi^0\pi^0$, $\omega \rightarrow \pi^0\gamma$

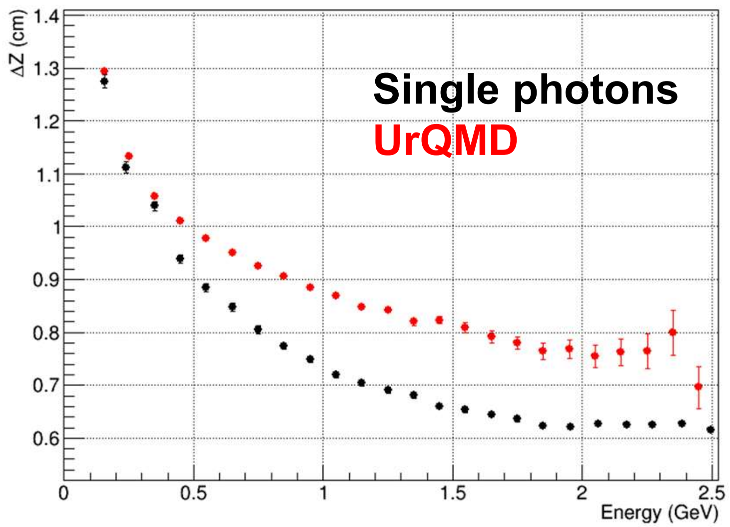
- Electron identification, E/p ~ 1 (yields, flow):
  - ✓ e^+e^- continuum
  - ✓ LVM (ρ, ω, ϕ) $\rightarrow e^+e^-$
  - ✓ e_{HF}

- Hadron identification and rejection by matching/TOF/ShowerShape:
  - ✓ π/K separation up to ~ 0.5 ГэВ/c
  - ✓ K/p separation up to ~ 1 ГэВ/c

MPD-ECAL spatial resolution for photons

- UrQMD, minbias AuAu@11, realistic vertex distribution, selected photons
- Spatial resolution is energy dependent
- Comparable for single photons and photons in high-multiplicity events
- Achieved resolution is good enough → does not significantly affect: (1) the mass resolution for neutral mesons in the expected p_T range of measurements; (2) width of track-to-cluster and cluster-to-track matching

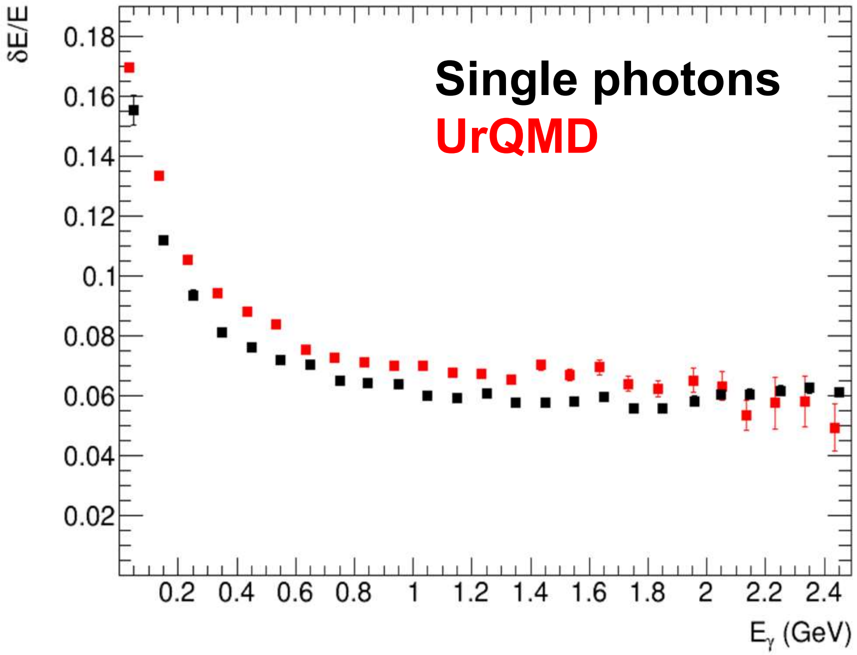




~ 180 cm * tan(0.15 degrees) = 0.5 cm

MPD-ECAL energy resolution for γ/e

- UrQMD, minbias AuAu@11, realistic vertex distribution, selected photons
- Energy resolution is energy dependent, $\delta E/E \sim 1/\sqrt{E}$
- Energy resolution defines width of the reconstructed π^0/η, E/p peaks
- There is still potential for improvement (with better tower-by-tower calibration)



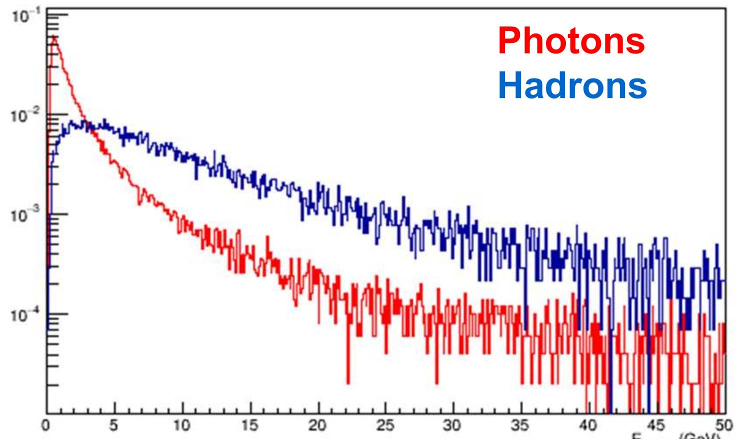
Identification of γ/e

- Photon identification
  - ✓ charged track veto → cut on minimum distance to the closest mpdtrack in dphi/dzed
  - ✓ shower shape → compare measured shower shape with the one expected for e/m signals:

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

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

σ_i^2 is tuned from simulations,
NDF – number of towers in the cluster

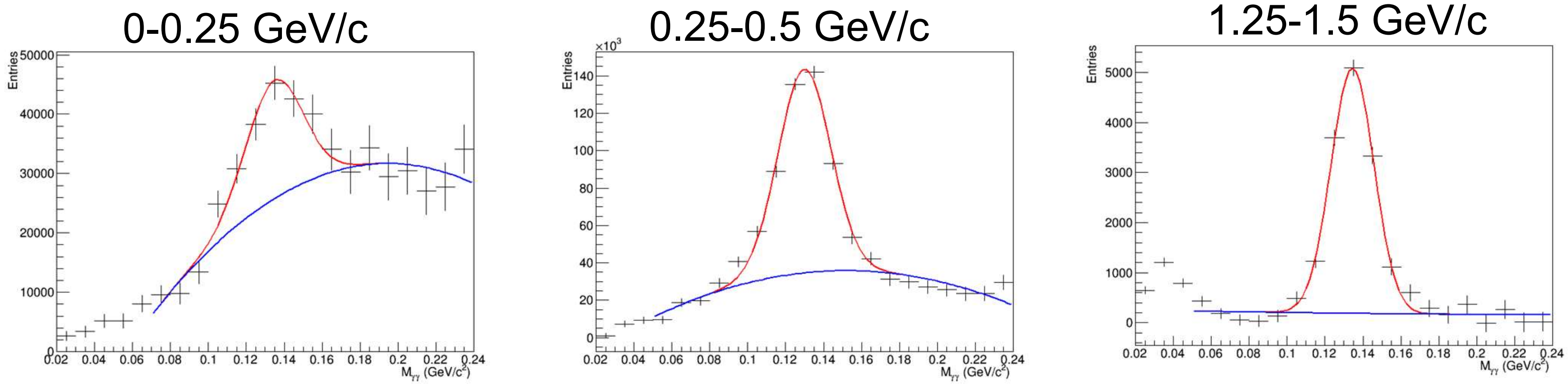


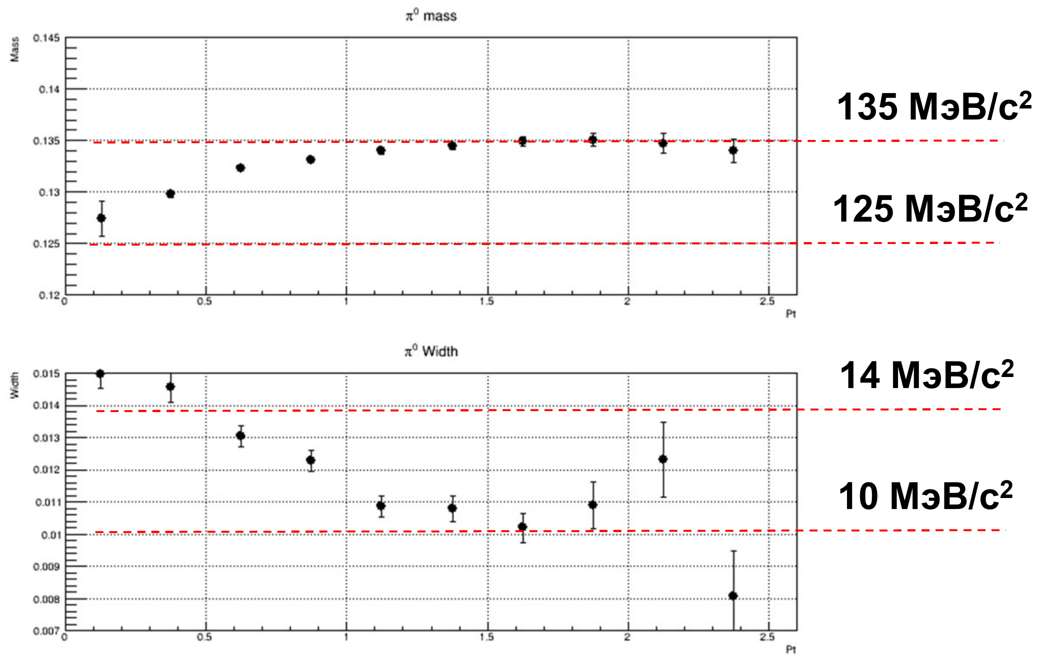
Chi2/NDF

- ✓ Reduced time of flight → $T_{photon} = T_{measured} - L/c \sim 0$, L is a path along a line [vertex → cluster]; effectively rejects signals from low-p_T hadrons (longer flight path, slower); exact ECAL time resolution should be tuned to data, so far the intrinsic time-of-flight resolution is additionally smeared by 500 ps; use only very soft cuts for photon selection, $T_{photon} < 2$ ns

Reconstruction of neutral mesons, π^0

- UrQMD, minbias AuAu@11, realistic vertex distribution



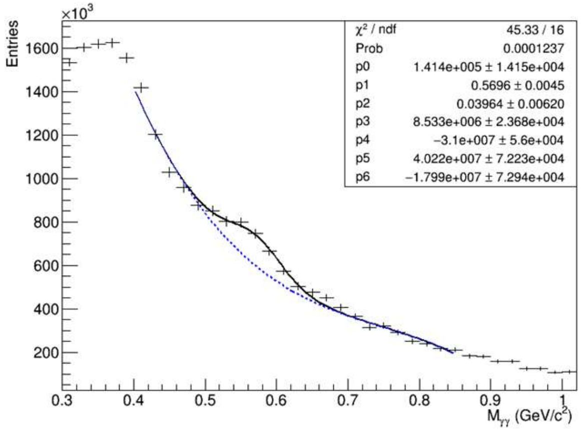


- π^0 can be reconstructed in a wide p_T range with a few hundred thousand events
- Reconstructed mass is close to the PDG value
- Reconstructed width of 10-14 MeV/c^2 is defined by the energy resolution at $p_T < 2$ GeV/c and by spatial resolution at higher momentum

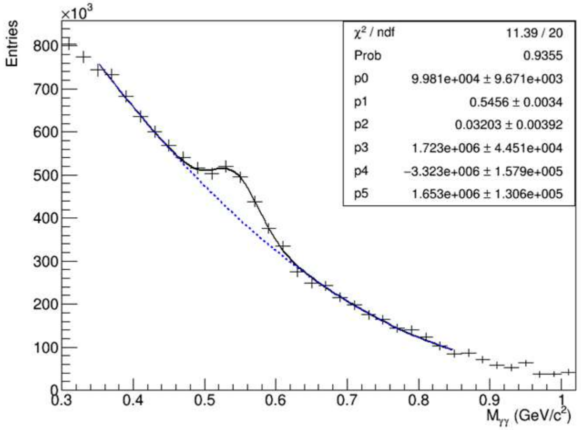
Reconstruction of neutral mesons, η

- UrQMD, minbias AuAu@11, realistic vertex distribution

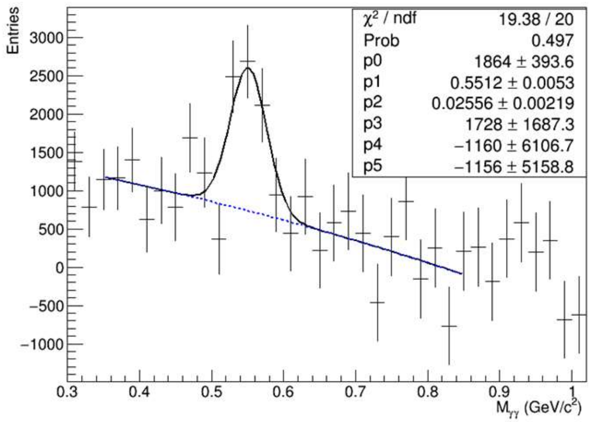
0-0.5 GeV/c



0.5-1 GeV/c



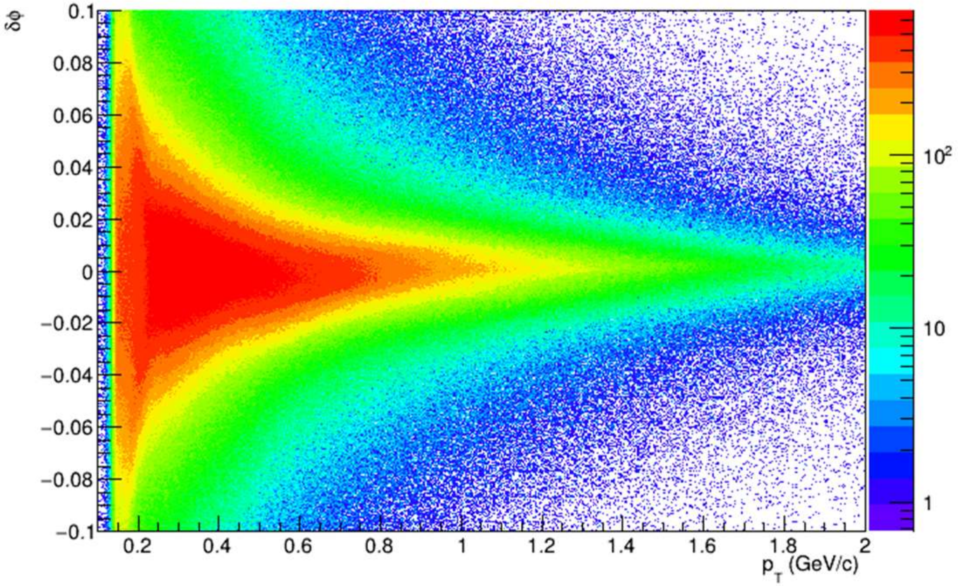
2-3 GeV/c

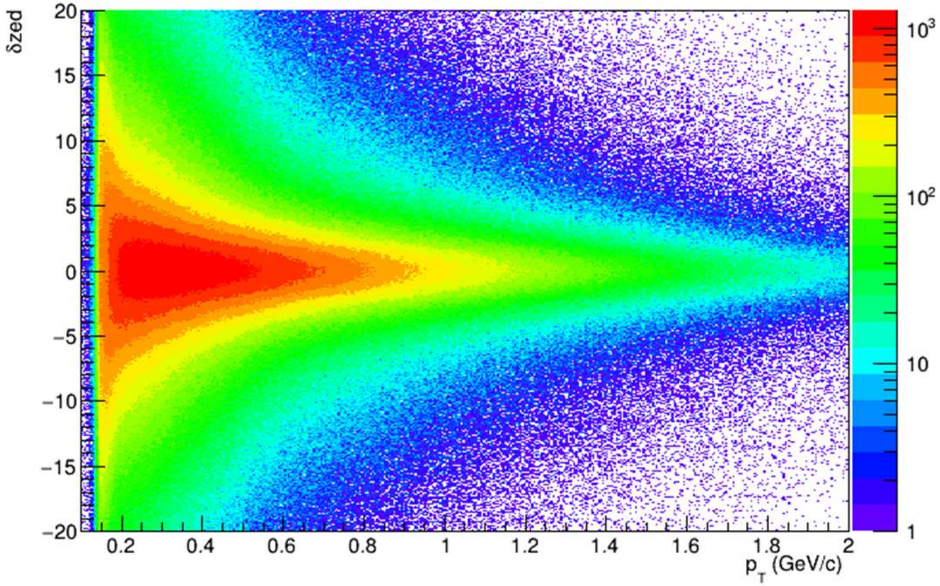


- η can be reconstructed in a wide p_T range with a few million events
- Reconstructed mass is close to the PDG value
- Reconstructed width of ~ 30 MeV/c^2 is totally defined by the energy resolution

Track-to-cluster matching

- UrQMD; realistic vertex distribution
- Matching in dphi is wider at low p_T due to track bending in the magnetic field
- Matching distributions are to be parameterized as a function of charge and p_T
- Parameterized mean(p_T) and sigma(p_T) can be used for track matching selections in terms of 'n-sigma deviations'
- Matching distributions show that tracks with p_T < 150 MeV/c do not reach the detector surface
- Worse spatial resolution for hadrons is driven by the fact that the center of gravity for hadrons is uniformly distributed in the depth of the calorimeter

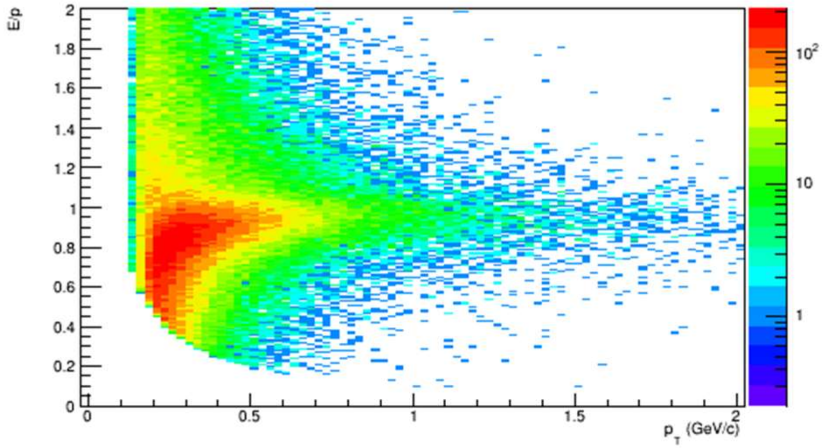




$e^{\pm}$/h rejection

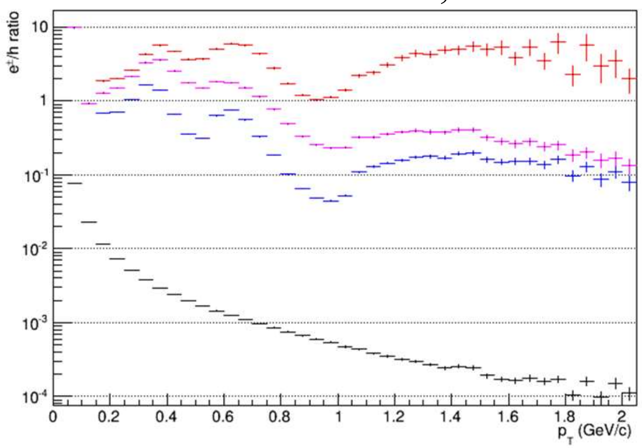
- UrQMD, minbias AuAu@11, realistic vertex distribution

- E/p, E – energy, p – momentum:
  - ✓ E/p is meaningful at $p_T > 200$ MeV/c
  - ✓ E/p ~ 1 at $p_T > 0.5$ GeV/c
  - ✓ E/p is rather wide at $0.2 < p_T < 0.5$ GeV/c, low energy signals break up due to large incident angles (magnetic field)

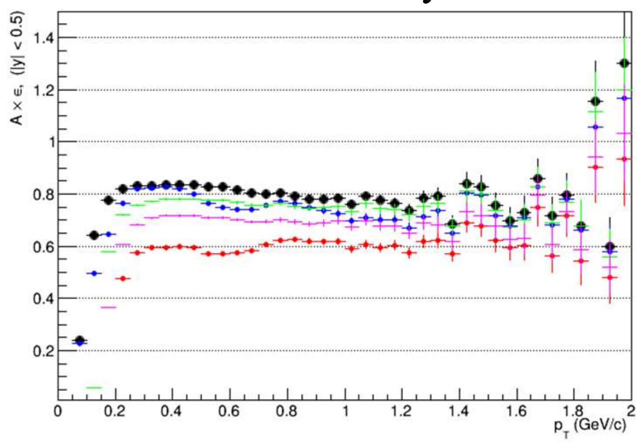


All tracks
Tracks + TPC-TOF
Tracks + TPC-TOF + ECAL-TOF
Tracks + TPC-TOF + ECAL-TOF + ECAL-EtoP

Reconstructed tracks, e/h ratio



Reconstruction efficiency for electrons



- ePID/ECAL improves purity of electron sample (e/h) in expense of somewhat smaller efficiency

Near future plan

- Create ECAL Tutorial/Examples/How-to subsections in the mpdforum ~ 1 week
- Run large centralized MC production for 10 million events → setup in ~ 1-2 weeks
- Unite the MPD-ECAL software group and PWG4, studies become more physics oriented → beginning of the next year

Summary

- ✓ The MPD-ECAL simulation code is now available for public use
- ✓ Basic ECAL performance parameters are known, please think how to use the detector in your physics studies
- ✓ ECAL simulation support and electromagnetic signal studies will be available in PWG4 starting from the next year
- ✓ Consider to join if you are interested


2020
HAPPY NEW YEAR

BACKUP