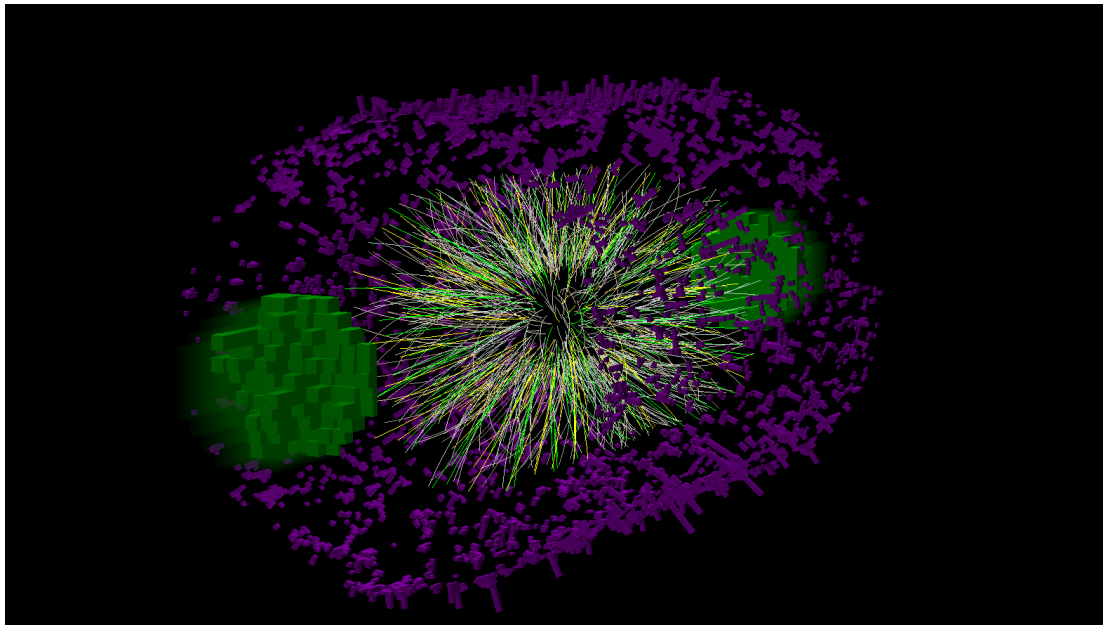
NICA Nuclotron-based Ion Collider fAcility

Status of the MPD centralized Monte Carlo projects and capabilities for the new requests

V. Riabov for the MPD



Monte Carlo simulations: general structure

- Full events with external event generators (URQMD, VHLLE, HSD, LAQGSM, HADGEN …), single particles with BOX, enhanced full events etc.
- Detector geometry, materials, Geant3/Geant4 particle tracking, detector calibrations and performance are simulated based on mpdroot, http://mpd.jinr.ru/howto-install/
- Output: DST, uDST, private trees … tables of reconstructed tracks, clusters, associations etc.

Monte Carlo simulations: usage

- All MPD physics (feasibility) studies must be based on MC simulations using mpdroot
- Mpdroot (as well as fairsoft and fairroot) can be easily installed anywhere, including your laptop
- MC productions are CPU and disk space hungry
- Some small productions can be arranged privately, however, large productions may be a serious problem if you do not have free access to some centralized computing resources usually dedicated to other experiments

Monte Carlo simulations: JINR

- JINR has serious computing resources allocated for the MPD:
  - ✓ LIT (different clusters and supercomputers)
  - ✓ NICA cluster of LHEP (up to 5,000 CPUs)
- Ongoing efforts to unite all available resources using DIRAC …
- Any MPD Collaboration member has a right to request account at LIT or/and at NICA cluster, by default a user gets ~ 0.5 TB of the disk space and a quota of a few hundreds of batch jobs
- The available computing resources are not fully used by the MPD/BM@N Collaborations, resources will not be increased by management unless we demonstrate that we are running short
- Estimations of the resources needed for the MPD operation are not complete and are not transparent

Monte Carlo simulations: JINR

- Since the end of 2019, the MPD runs the centralized Monte Carlo projects operated by Oleg Rogachevsky & Andrey Moshkin, 10M+ events each
- Each production takes several weeks. So far, the requests were not very numerous and the turn-around rate was acceptable, needs may change in the future
- The simulated data sets are available both at LIT and the NICA cluster to all users right away
- The centralized productions are usually suitable for multiple analyses aiming at different observables

Available Monte Carlo productions: JINR

- Available MC productions and further requests are discussed in the mpdforum, https://mpdforum.jinr.ru/c/MCPrd: general information, setup macro(s), file storage, Q&A, observed bugs ... information is updated, questions are welcome

- So far, we had only three productions requested and finished:
  - ✓ AuAu@11, UrQMD enhanced with dielectron decays of LVMs
  - ✓ BiBi@9, UrQMD enhanced with dielectron decays of LVMs
  - ✓ AuAu@11, UrQMD with extra injected resonances

- Most of these productions can be used as general(minbias) simulations for physics studies. Please discuss in the forum any expected limitations or bugs

- The wider the feedback the better the quality of analyses and new productions

AuAu@11 and BiBi@9 productions (LVMs)

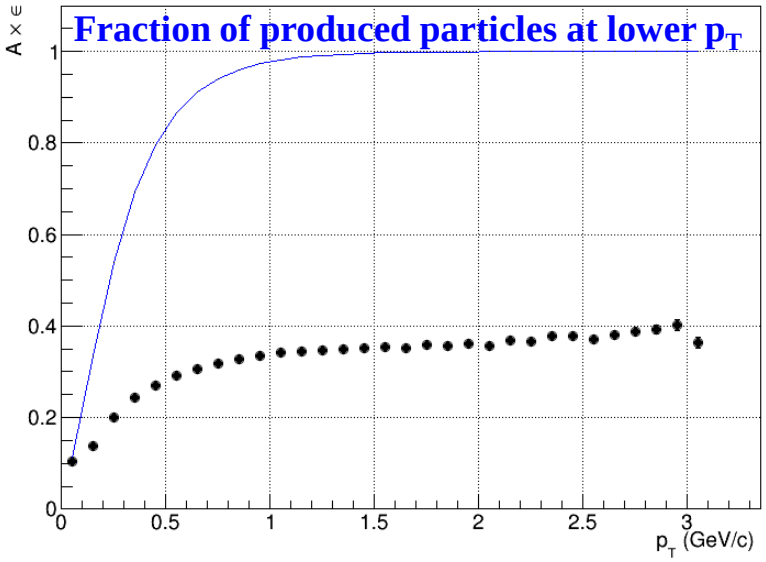
- These are two identical productions for different collision species and energies
- Basic details:
  - ✓ requested for (but not limited to) dielectron studies
  - ✓ 15M minbias UrQMD AuAu@11, 10M minbias UrQMD BiBi@9
  - ✓ mpdroot version, beginning of 2020
  - ✓ Geant-4 for particle propagation through the materials (due to simulation of ECAL)
  - ✓ η, ρ, ω, ϕ, η' are decayed in Geant; decay channels with e^+e^- pairs are enhanced by x20
- More details and discussions:
  - ✓ AuAu@11: https://mpdforum.jinr.ru/t/the-first-centralized-production-auau-11/219
  - ✓ BiBi@9: https://mpdforum.jinr.ru/t/the-second-centralized-production-bibi-9/220
- Known bugs:
  - ✓ Resonances are decayed with zero width
  - ✓ η and ω Dalitz decays are simulated as simple 3-body decays
  - ✓ AuAu@11: reaction plane is simulated within $0\text{-}30^0$, fixed for BiBi@9

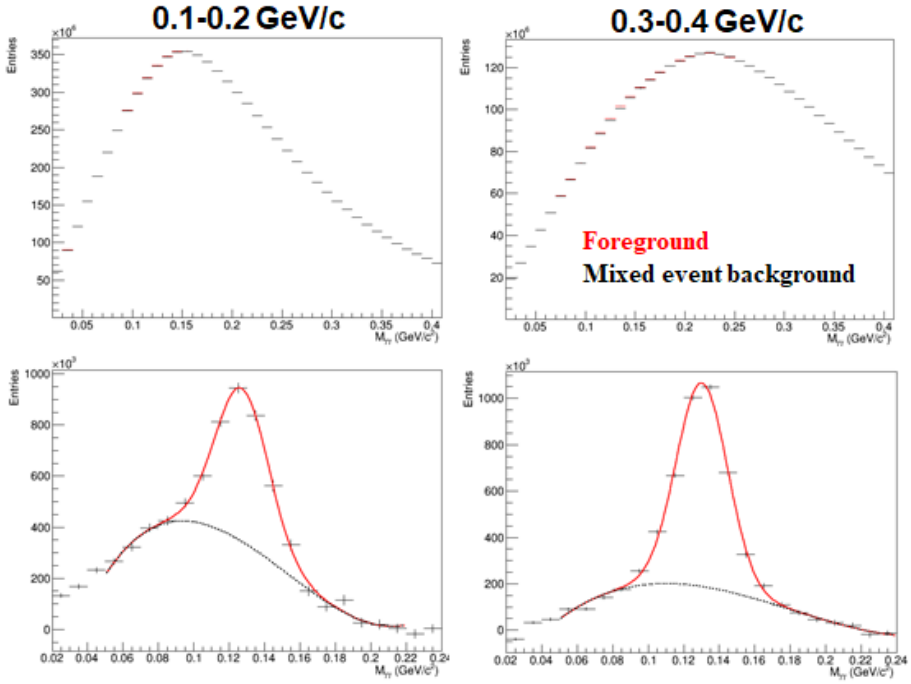
AuAu@11 and BiBi@9 productions (LVMs)

- Are these production useful for general use? Yes, there are no obvious limitations except for a few specific cases (to be judged by analyzers)
- Enhanced BRs for e^+e^- decays for LVMs are of no importance for hadronic decays, hadronic BRs are affected by a small faction of a percent
- Extra contamination by electrons from enhanced decays of LVMs is negligible. Electron sample is totally dominated by electrons from Dalitz decays of π^0
- Total multiplicity is not affected
- The productions can be used ‘as is’ for most of the applications as long as you are :
  - ✓ not interested in study of single- or di-electrons (some corrections are needed for enhanced BRs, Dalitz decays and LVM widths, see PWG4 presentations for details)
  - ✓ not interested in resonances (some corrections are needed to reweight widths)
  - ✓ not interested in flow for AuAu@11 case

AuAu@11 and BiBi@9 productions: π^0

- No limitations for neutral meson studies, no extra actions are needed
- Optimized cuts for better significance:
  - ✓ Events: UrQMD, |z-vertex| < 50 cm
  - ✓ Photons: E > 0 GeV, $T_{reduced}$ < 2 ns,
  - ✓ PID: charged track veto, Chi2/NDF < 4.0
  - ✓ Pairs: |y| < 0.5



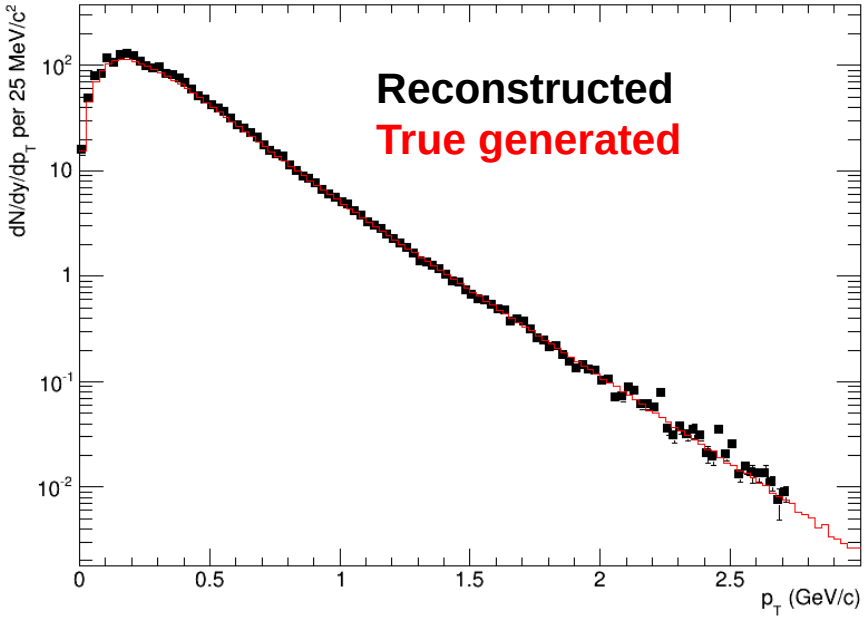


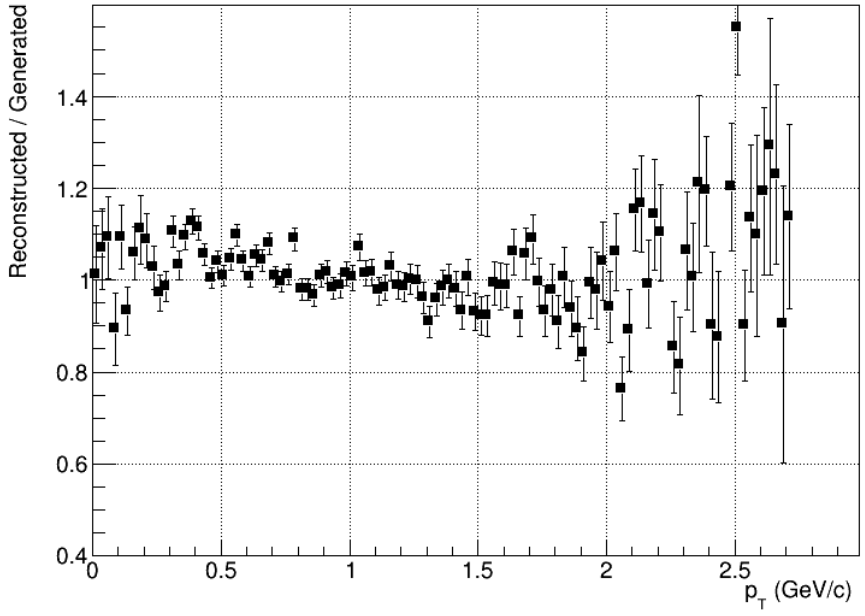
- The efficiency and the S/B improve with increasing momentum

AuAu@11 and BiBi@9 productions: π^0

- Optimized cuts for better significance:
- 4M events AuAu@11

- ✓ Events: UrQMD, |z-vertex| < 50 cm
- ✓ Photons: E > 0 GeV, $T_{reduced}$ < 2 ns,
- ✓ PID: charged track veto, Chi2/NDF < 4.0
- ✓ Pairs: |y| < 0.5

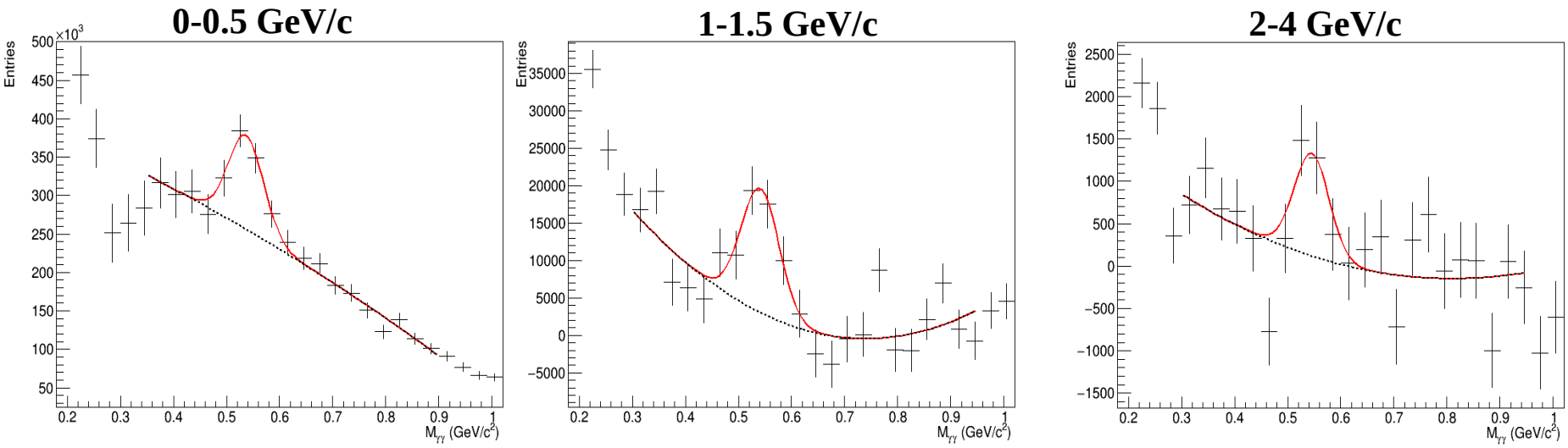




- The fully corrected reconstructed spectrum matches the generated one within uncertainties
- Measurements are possible from ~ 25 MeV/c momentum, too good to be true in real life ???
- The main measurement uncertainties at low momentum are from non-Gaussian peak shapes
  → ignore lower efficiencies and tune cuts to gain better control of the peak shapes

AuAu@11 and BiBi@9 productions: η

- 15 M events AuAu@11

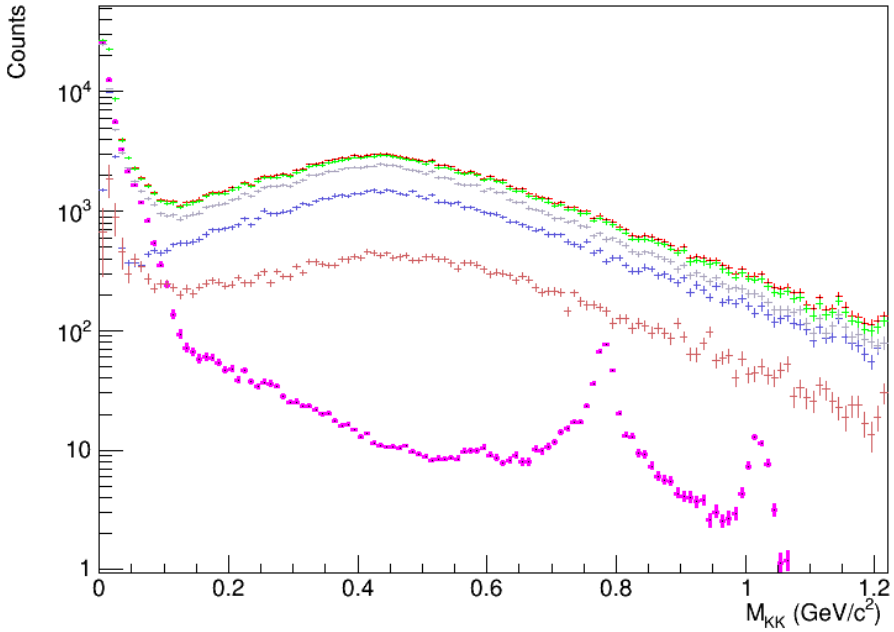


- η is produced at much lower rate compared to π^0; $\eta \to \gamma\gamma$ is a much wider peak
  → need larger statistics for observation and measurements
- Signal is observed with 15M sampled AuAu@11 events
- MC closure test is in progress
- Multiplicity dependent study needs higher statistics (embedded simulations)

AuAu@11 and BiBi@9 productions: e^+e^-

i	Dilepton channels	
1	Dalitz decay of π^0:	$\pi^0 \to \gamma e^+ e^-$
2	Dalitz decay of η:	$\eta \to \gamma l^+ l^-$
3	Dalitz decay of ω:	$\omega \to \pi^0 l^+ l^-$
4	Dalitz decay of Δ:	$\Delta \to N l^+ l^-$
5	Direct decay of ω:	$\omega \to l^+ l^-$
6	Direct decay of ρ:	$\rho \to l^+ l^-$
7	Direct decay of ϕ:	$\phi \to l^+ l^-$
8	Direct decay of J/Ψ:	$J/\Psi \to l^+ l^-$
9	Direct decay of Ψ':	$\Psi' \to l^+ l^-$
10	Dalitz decay of η':	$\eta' \to \gamma l^+ l^-$
11	pn bremsstrahlung:	$pn \to pn l^+ l^-$
12	$\pi^\pm N$ bremsstrahlung:	$\pi^\pm N \to \pi N l^+ l^-$

eID withTPC/TOF/EMC-PID



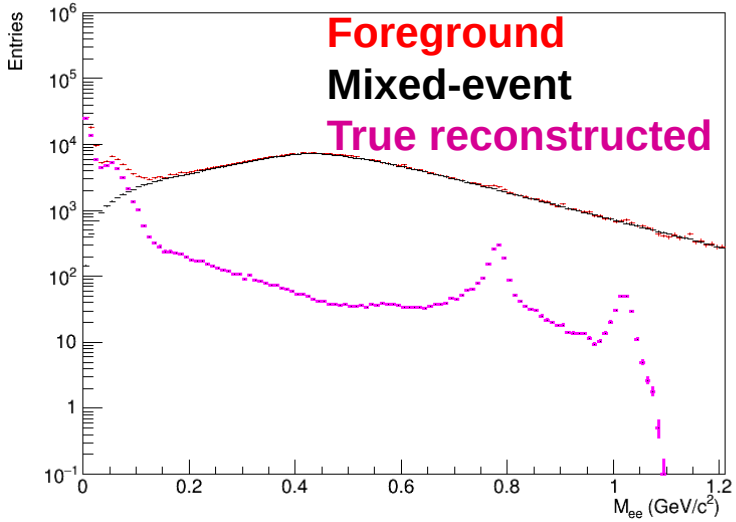
Reconstructed e+e- pairs – foreground
True e+e- pairs
Pairs with at least one π^0 Dalitz electron
Pairs with at least one conversion electron
Pairs with at least one η Dalitz electron

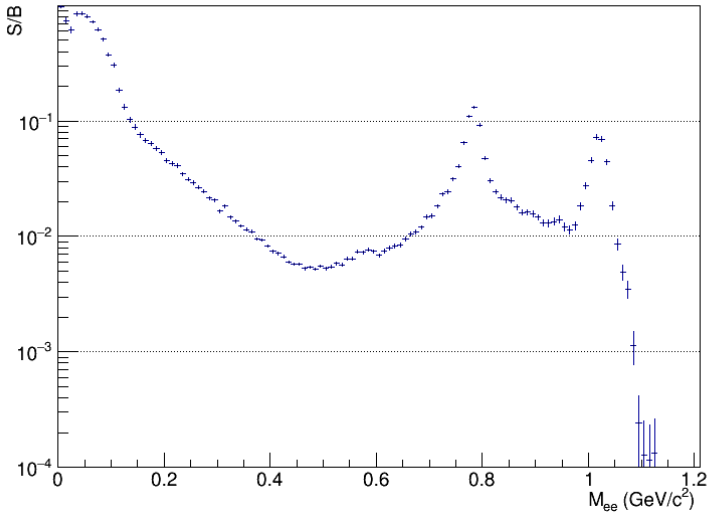
- Only a few event generators can simulate the dielectron signals
- Some additional corrections are needed to use the productions for e^+e^- studies
- With TPC/TOF/EMCal the MPD provides clean sample of identified electrons

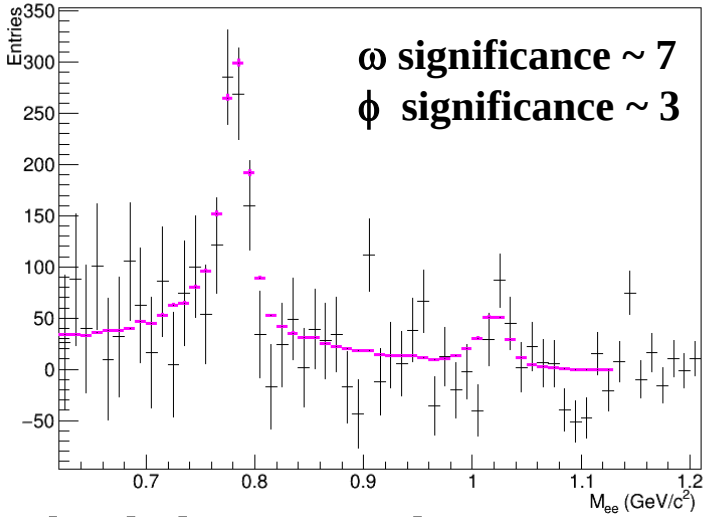
- Combinatorial background is driven by Dalitz decays of π^0 → irreducible
- Then follows conversion and Dalitz decays of η

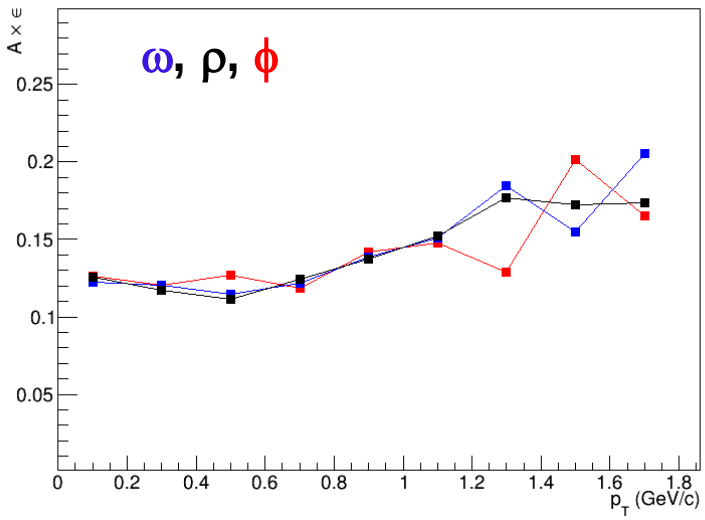
AuAu@11 and BiBi@9 productions: e^+e^-

- ~ 15M events AuAu@11 events, full statistics of the large MC production





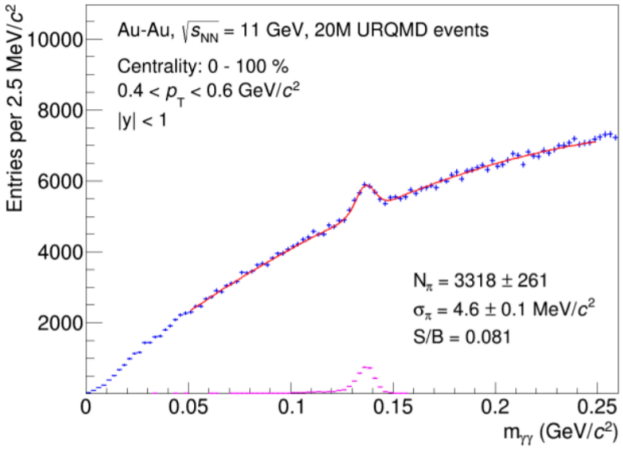


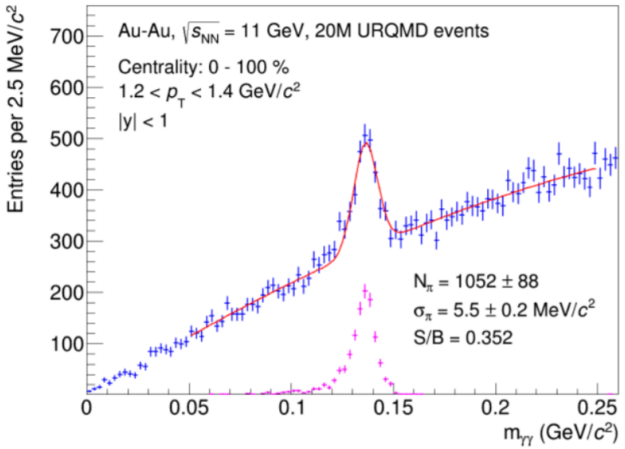


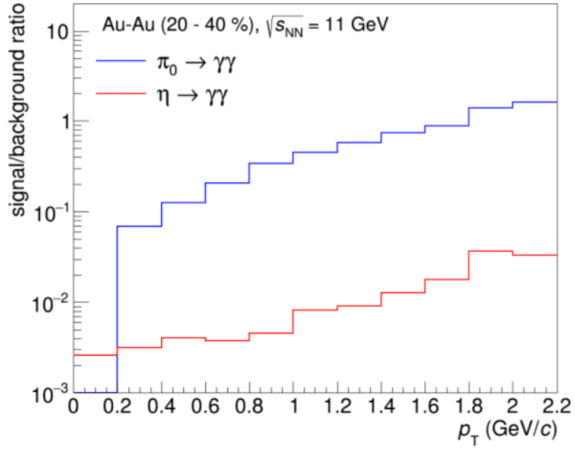
- The dielectron analysis is statistics hungry
- First results for LVM would need ~ 100M sampled AuAu@11 events

AuAu@11 and BiBi@9 productions: γ

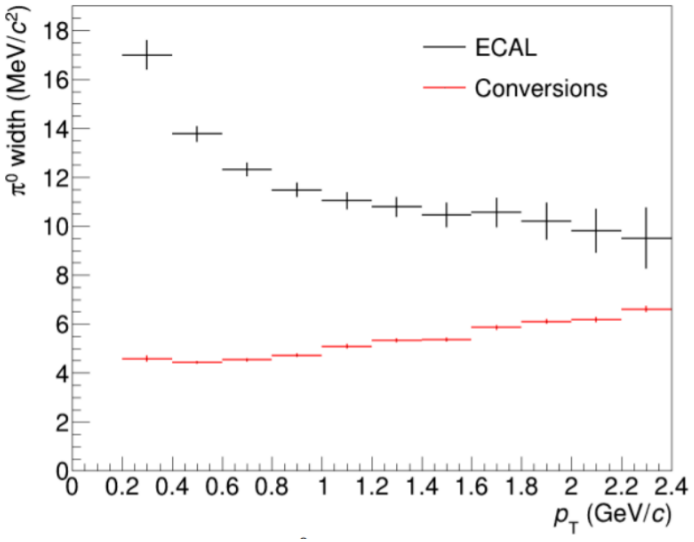
- No limitations for photon-conversion studies, no extra actions are needed
- S/B ratio is high enough, mixed-event subtraction is not required

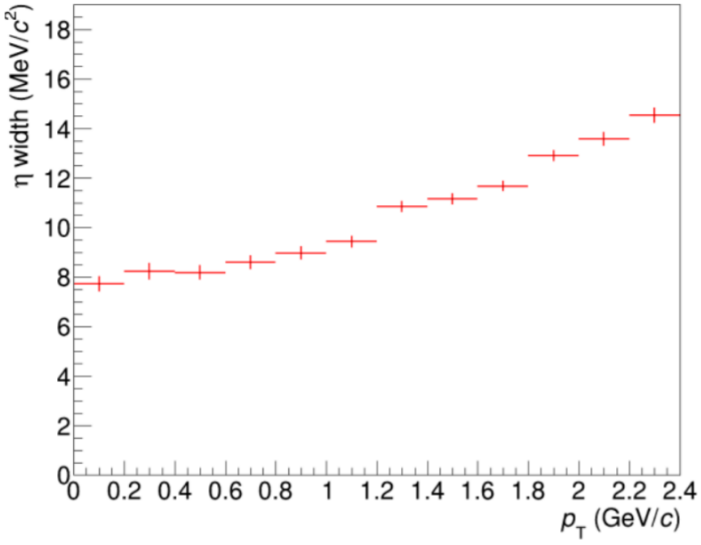






- PCM resolution for photons and neutral mesons is much better compared to the ECAL !!!





AuAu@11 (resonances)

- This is a dedicated simulation for resonance studies
- Basic details:
  - ✓ requested for (but not limited to) resonance studies vs. centrality
  - ✓ 10M minbias UrQMD AuAu@11
  - ✓ Each event is injected with 10 particles: $\rho^0(770)$, ϕ, 4 $K^*(892)^{0/+/-}$, $\Lambda(1520)$, $\Sigma(1385)^{+/-}$ and Ξ (1530)
  - ✓ Injected particles have flat p_T [0,3] and rapidity [-1, 1] distributions
  - ✓ Geant-3 for particle propagation through the materials (ECAL is not reliable)
- More details and discussions:
  - ✓ AuAu@11: https://mpdforum.jinr.ru/t/the-third-centralized-production-auau-11/221
- Known bugs:
  - ✓ none so far

AuAu@11 (resonances)

- Is this production useful for general use? Yes, but with some caution (to be judged by analyzers)
- Injected particles can be rejected, these are the first 10 particles in the MC stack. All reconstructed tracks originating from them or their daughters can be dropped.
- Total multiplicity is not significantly affected in (semi)central collisions
- However, total multiplicity is noticeably affected in peripheral collisions → vertex reconstruction efficiency and resolution, ???

The production is finishing right now

Expected new MC requests

- There are no request in the pipe line right now → a good moment to jump in
- New requests are expected in the near future (1-2 weeks):
  - ✓ Heavy-ion collisions with detector misalignment and miscalibrations
  - ✓ General purpose productions for new collision systems (PbPb ???, AuAu@9 ???)
  - ✓ New production for LVMs with fixed problem of resonance widths and Dalitz decays
- Any interested analyzer can request a new centralized production at the PWG meeting: physics motivation, setup macro(s), needed statistics etc.
- PWG conveners merge obtained requests at the Physics Coordination meetings and lunch the productions
- The larger the circle of involved people the smaller the probability of bugs

Summary

- ✓ The MPD now has an option of centralized Monte Carlo productions
- ✓ The option is available for everyone via the PWG
- ✓ So far, we did not have problems with available resources
- ✓ New resources will be requested if needed, the infrastructure should be continuously operated and tested, requests for new resources should be properly formulated based on real needs
- ✓ Centralized productions reviewd/tested by many analyzers is the only way to increase reliability of the physics studies in the MPD: bug reports, user typos&mistaces etc.

→ be proactive and submit new requests to advance/enhance your studies

BACKUP