The first large production. Dielectrons.

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Outline

- Details on the first big Monte Carlo production
- Applicability for charged hadron and neutral meson studies
- New production for (di)electron studies

Big production, setup

- Production details with macro examples are described at https://mpdforum.jinr.ru/t/monte-carlo-production-requests/61/15?u=riabovvg
- Please drop me a line if you have issues with access to the mpdforum.jinr.ru (you should be a member)
- Basic details:
  - ✓ requested for (but not limited to) dielectron studies
  - ✓ 10M minbias UrQMD AuAu@11
  - ✓ mpdroot *dev*-version on the end of 2019
  - ✓ 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
- The production has been started in the end of 2019

Big production, output files

- Production of 11.5M events has been finished at LIT
  → a big **milestone** in the MPD history !!!

- Production files are available at LIT:
  - ✓ UrQMD data:
    /zfs/store6.hydra.local/mpddata/data/models/UrQMD/AuAu/11.0GeV-mb/mp01-2020-500ev-pf
    /eos/eos.jinr.ru/nica/mpd/dirac/mpd.nica.jinr/vo/mpd/sim/urqmd
  - ✓ runMC:
    /zfs/store6.hydra.local/mpddata/data/runMC/dst-2020-01-10-mpg4-500ev/AuAu/11.0GeV-mb/UrQMD/mp01-2020-500ev
    /eos/eos.jinr.ru/nica/mpd/dirac/mpd.nica.jinr/vo/mpd/sim/dst/
  - ✓ reco:
    /zfs/store6.hydra.local/mpddata/data/exp/dst-2020-01-10-mpg4-500ev/AuAu/11.0GeV-mb/UrQMD/mp01-2020-500ev-pf
    /eos/eos.jinr.ru/nica/mpd/dirac/mpd.nica.jinr/vo/mpd/sim/reco/
  - ✓ MicroDst:
    /zfs/store6.hydra.local/mpddata/data/MiniDst/dst-2020-01-10-mpg4-500ev/AuAu/11.0GeV-mb/UrQMD/mp01-2020-500ev
    /eos/eos.jinr.ru/nica/mpd/dirac/mpd.nica.jinr/vo/mpd/sim/reco/MiniDST

- MicroDST and DST have been copied to NICA cluster:
  - ✓ /eos/nica/mpd/sim/data

- Extra ~ 3M files produced with the same setup can be found at:
  - ✓ /eos/nica/mpd/users/riabovvg/ECAL_Tutorial_GeoV3/OUT_urqmd1(28)

- In total **14.5M** minbias AuAu@11 events are now available for analysis

New production for charged hadron and neutral meson studies

- No obvious limitations
- 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 production can be used as a general-purpose minbias simulation as long as you are: 1) not interested in study of single- or di-electrons (some corrections are needed); 2) not interested in resonances (need reweighting to PDG widths)

→ PWG4: The production is good for π^0, η, ω, η' etc. studies, with no extra actions required

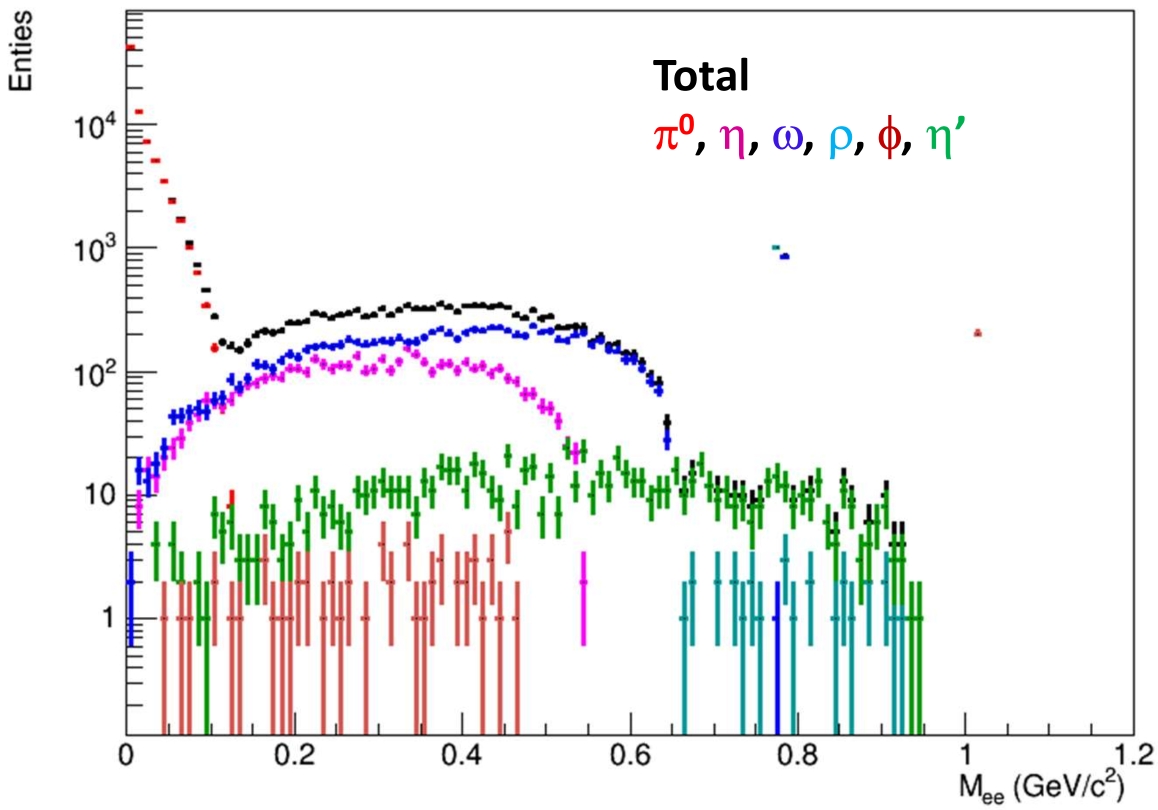
New production for (di)electrons

Issues & problems

- Decays:
  - ✓ UrQMD does not use rare decays, short-lived particles decay in just a few dominant decay channels → LVM are not decayed in e^+e^-;
  - ✓ UrQMD does not decay π^0, η, η'
  - ✓ solution was to declare particles of interest as stable in UrQMD and decay them in Geant 4
  - ✓ since LVM → e^+e^- decays are rare → enhanced BRs by x 20 in Geant 4

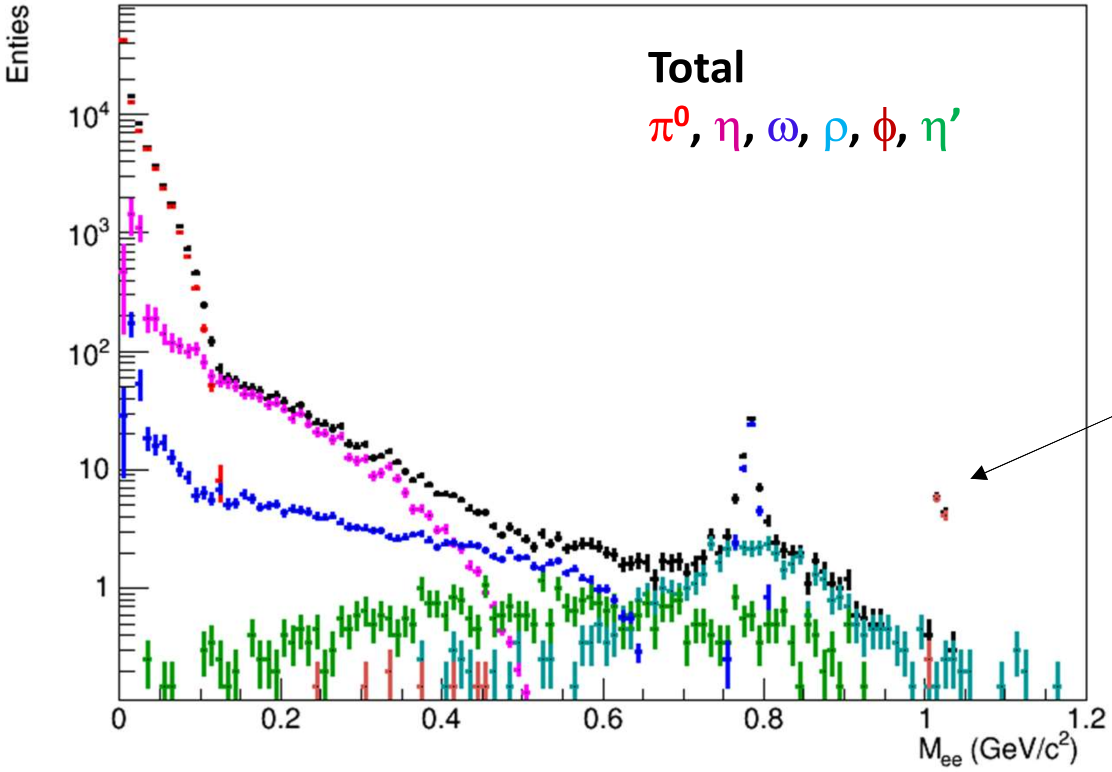
- Consequences and problems:
  - ✓ Geant 4 in default configuration decays resonances with zero width
    → all resonances from the input file, not only LVMs; secondary resonances are ok
    → same input files work fine with Geant 3
  - ✓ Geant 4 in default configuration decays particles only in top 5 decay channels → no Dalitz decays for η or ω, no e^+e^- decays for LVMs … similar problem as for UrQMD
  - ✓ As a solution redefined decay channels for particles in UserDecay.C steering script:
    → added e^+e^- decays for LVMs, enhanced BRs by x20 → ok
    → added Dalitz decays of η and ω as 3-body decays to γe^+e^- → ersatz with wrong phase space

Generated dielectron continuum, “as is”



- 100,000 events
- All problems are clearly seen:
  - ✓ zero width for ρ, ω and ϕ
  - ✓ wrong shapes for Dalitz decays of η and ω
  - ✓ enhanced (x20) rates for ρ, ω and ϕ

Generated dielectron continuum, corrected



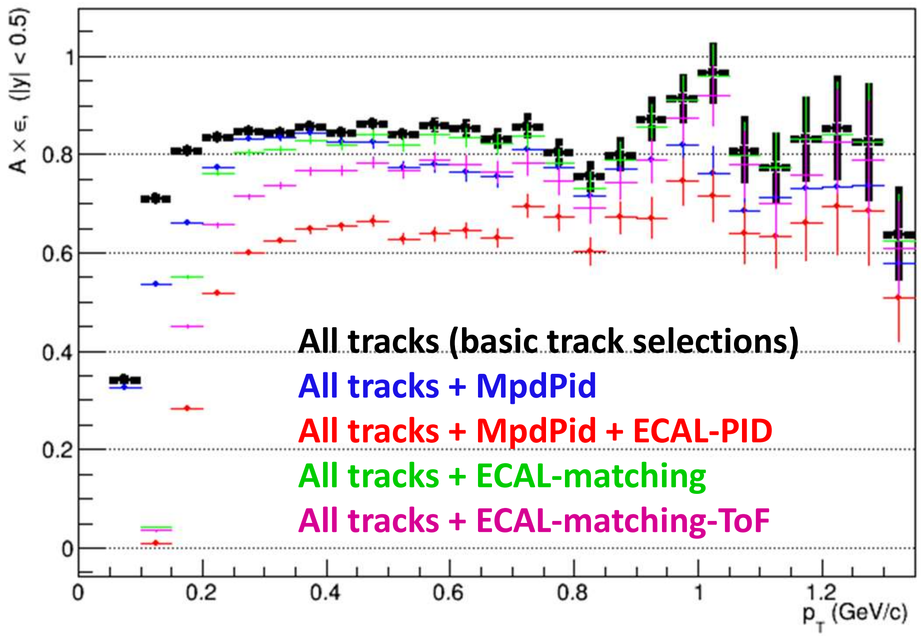
Would have only ~ 20 generated counts for ϕ without BR scaling

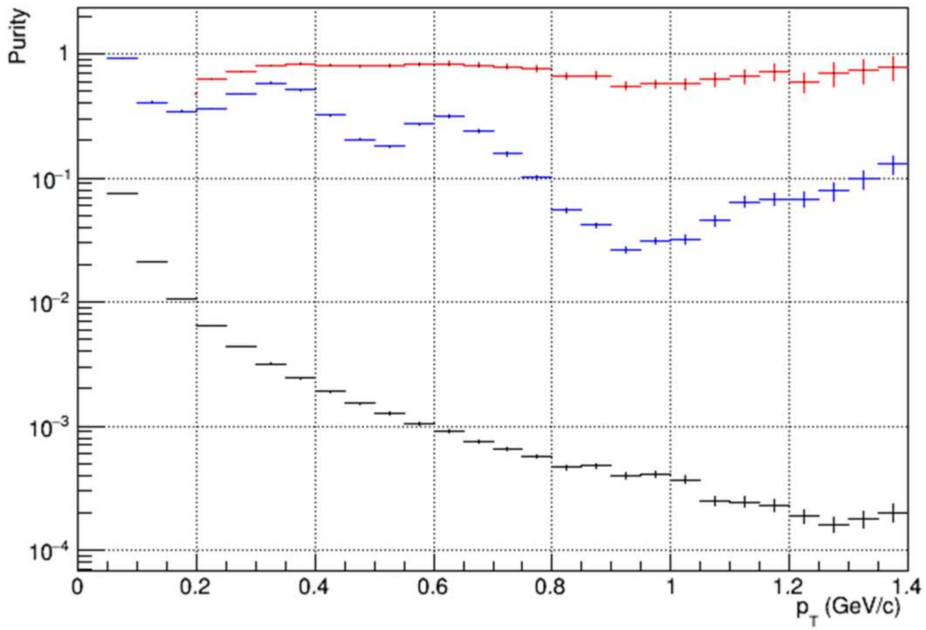
- 100,000 events
- Reweighting & smearing resolves most of the problems:
  - ✓ smeared ρ, ω and ϕ widths to PDG values
  - ✓ reweighted shapes of η and ω Dalitz decay to PHSD shapes (exact shapes are not so important)
  - ✓ scaled e^+e^- pairs from ρ, ω and ϕ decays by 1/20

Electron identification and purity

- 1M events
- Basic track selection cuts:
  - ✓ TPC-hits > 20;
  - ✓ |y| < 0.5
  - ✓ 2σ matching to PV
  - ✓ p_T > 50 MeV/c
- TPC/TOF-PID:
  - ✓ mpdpid class, probability > 0.9
- EMC-PID:
  - ✓ 2σ track-cluster matching
  - ✓ [-3σ; 2σ] EMC-ToF
  - ✓ 3-4σ < E/p < 1.5

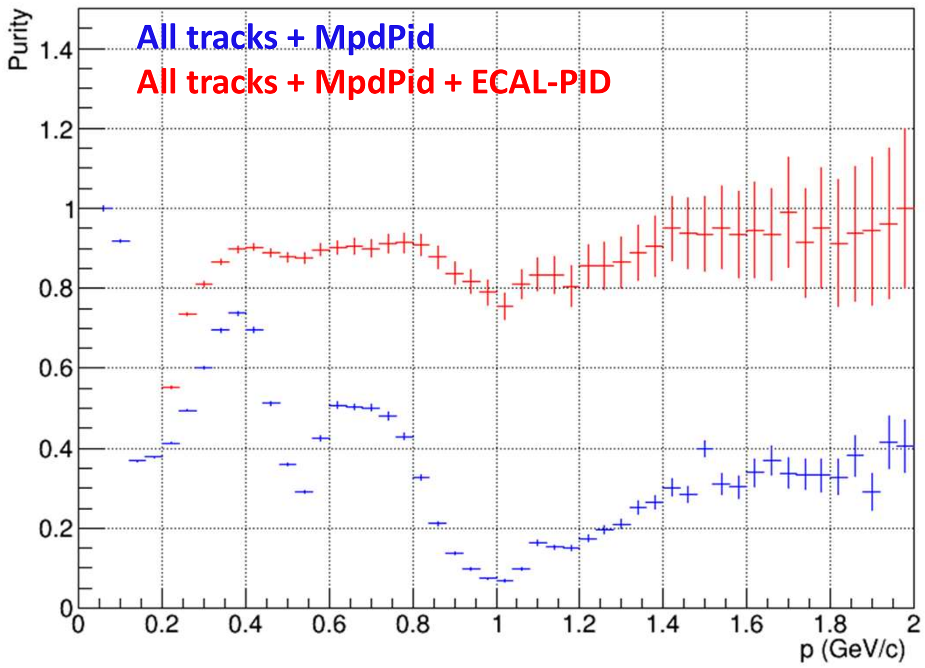
- TPC/TOF-PID (or MpdPid) ensures high efficiency for $e^{\pm}$ selection
- EMC-PID starts to work at p_T > 200 MeV/c, efficiency drop by ~ 20%, higher purity





Electron purity, linear scale

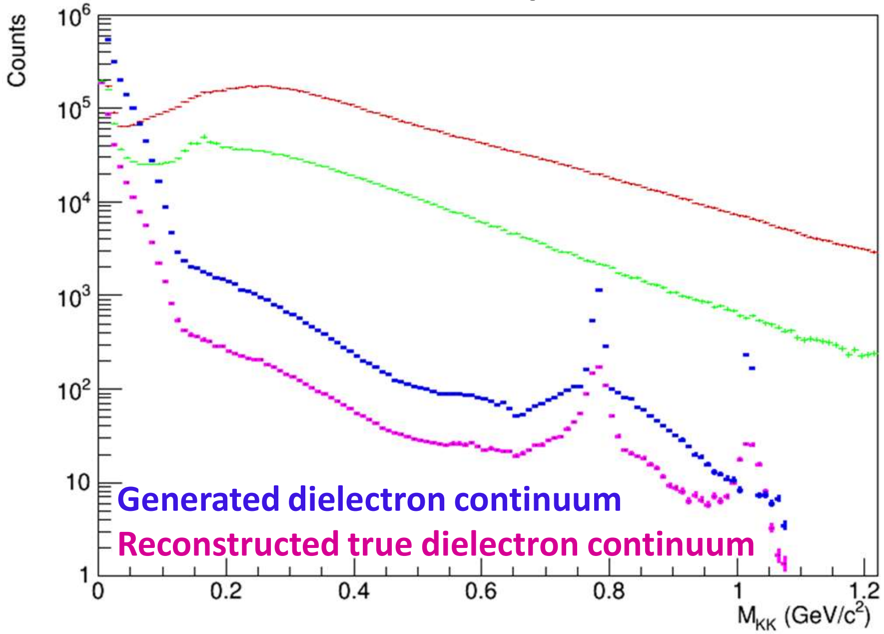
- Same purity in linear scale



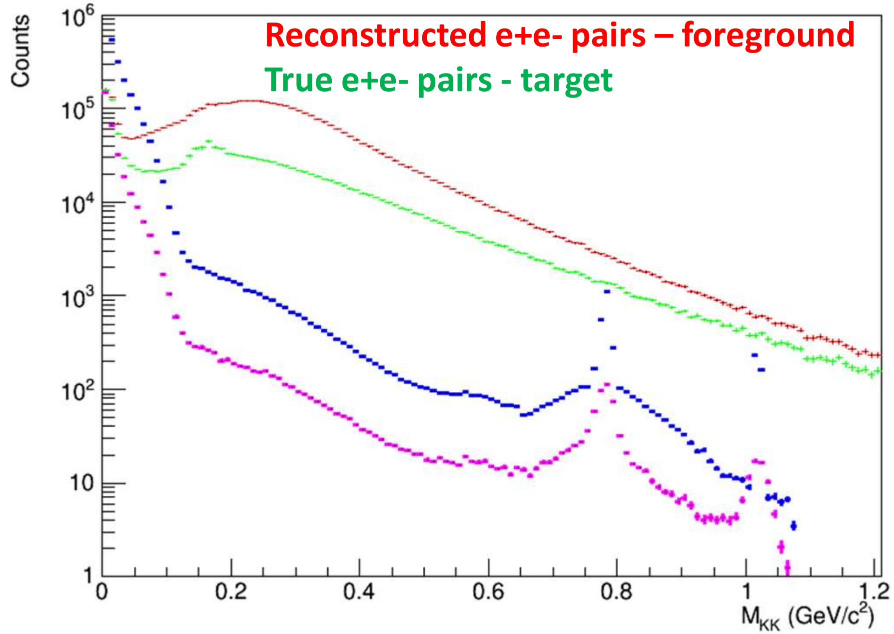
- TPC/TOF-PID: profound drops of purity at π/K/p masses
- ECAL significantly improves electron purity at $p_T > 0.2$ GeV/c
- Electron purity is rather poor at $p_T < 0.3$-0.4 GeV/c even with combined TPC/TOF/EMC-PID

Dielectron spectra, first look

All tracks + TPC/TOF-PID



All tracks + TPC/TOF/EMC-PID

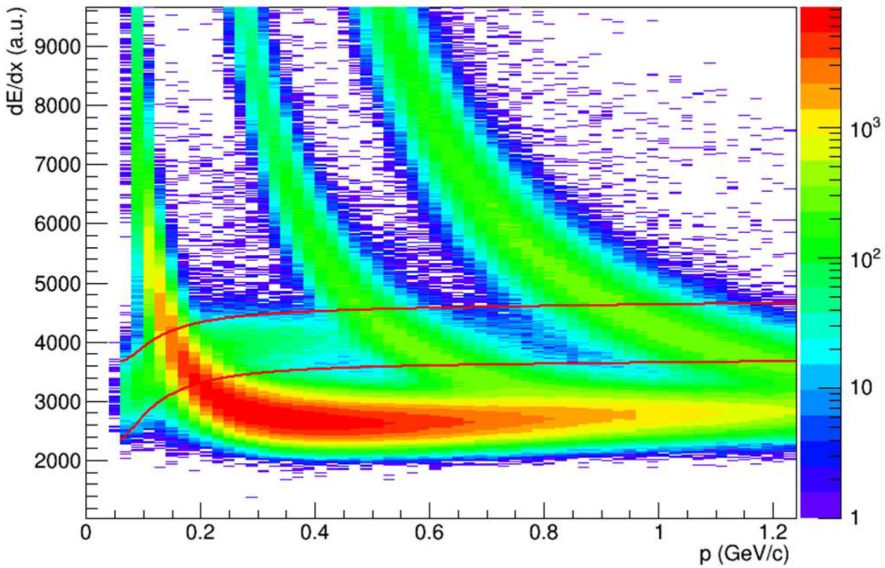


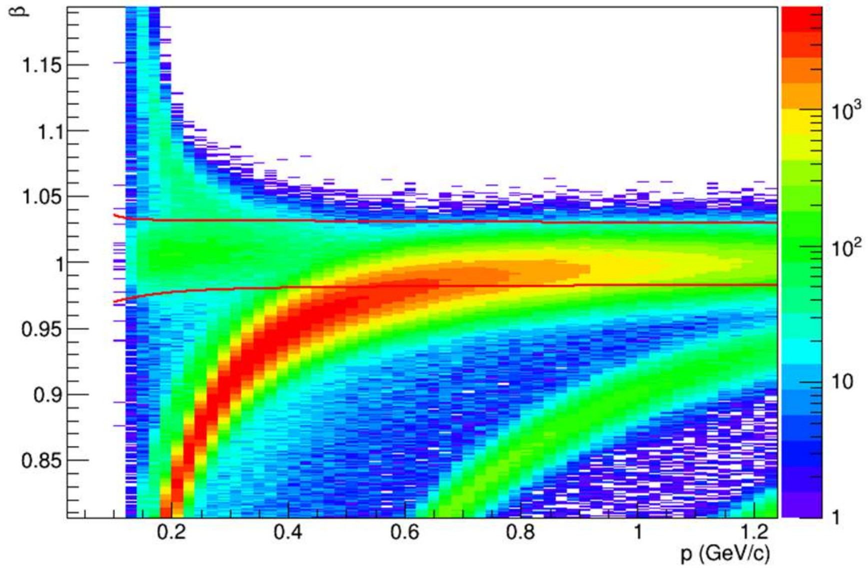
- Hadron contamination determines the combinatorial background
- Quadratic dependence of contamination on electron purity:
  - ✓ purity = 0.9 → ~ 20% contamination to e^+e^- pairs;
  - ✓ purity = 0.7 → ~50% contamination to e^+e^- pairs;
  - ✓ purity = 0.5 → ~75% contamination to e^+e^- pairs;
- Hadron-hadron correlations ($K_s/\rho/\omega/\phi$/etc. $\rightarrow \pi\pi$, KK etc.) will result in irreducible correlated background, which will mimics the signal (enhancement, structures etc.)

→ target electron purity > 95%, electron purity must be improved !!!

Electron identification, TPC & TOF

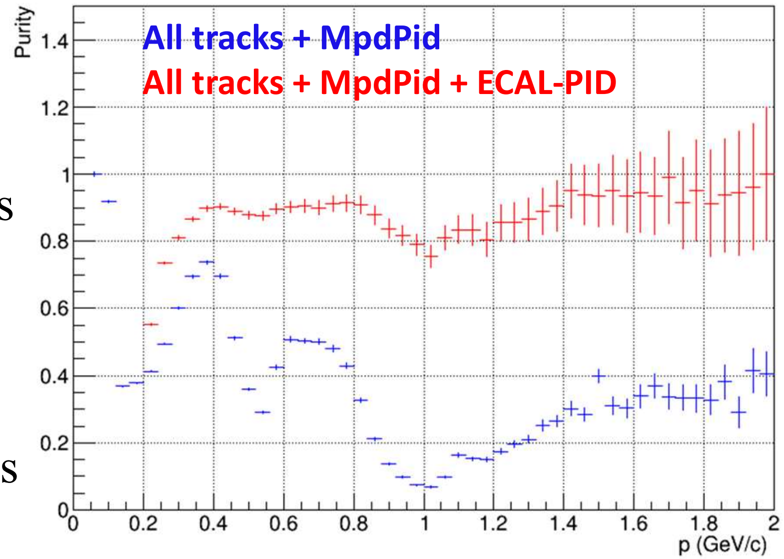
2σ eID bands



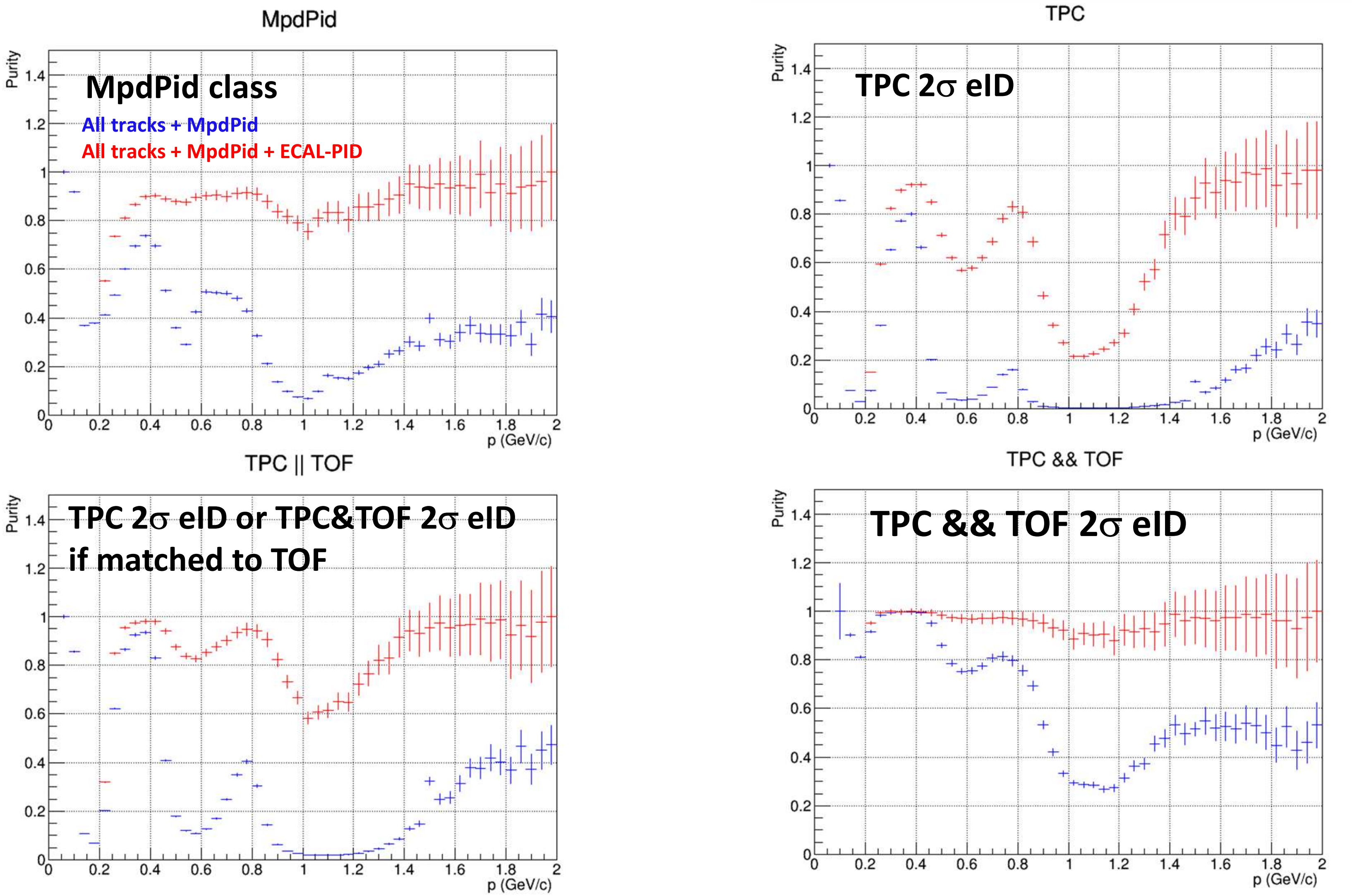


- TOF effectively turns on only at p > 150 MeV/c
- Reliable eID with the TPC is possible only at very low momentum, 3σ pion veto cut effectively limits the momentum range to p_T < 50-70 MeV/c → domain of conversion and Dalitz decay electrons → not really interested
- Should additionally consider TPC & TOF n-σ cuts

(same plot as in slide 11)

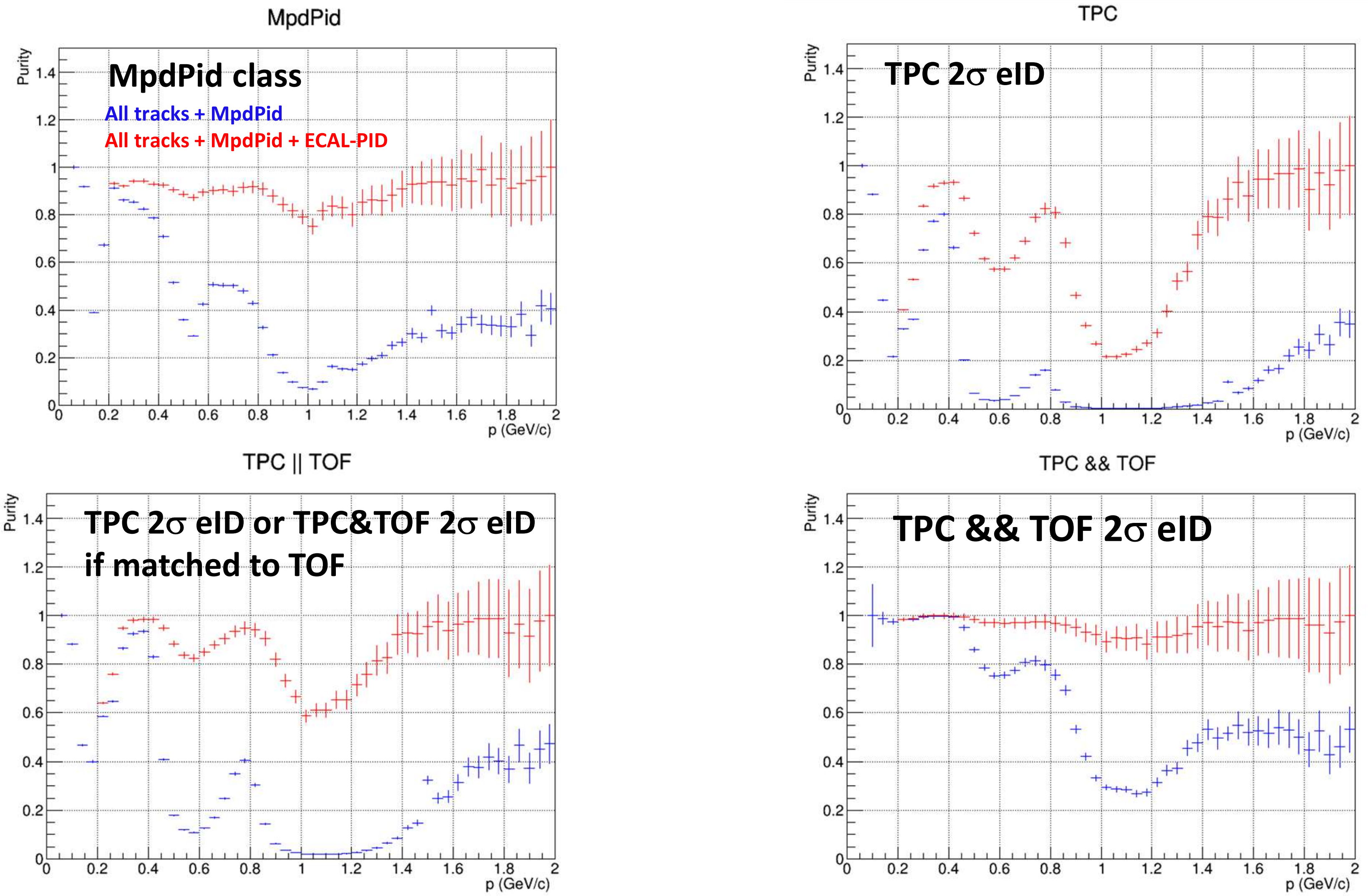


Electron purity, different eID selections



- MpdPid class in general works better than TPC and TPC || TOF options
- None of the options provides the needed purity

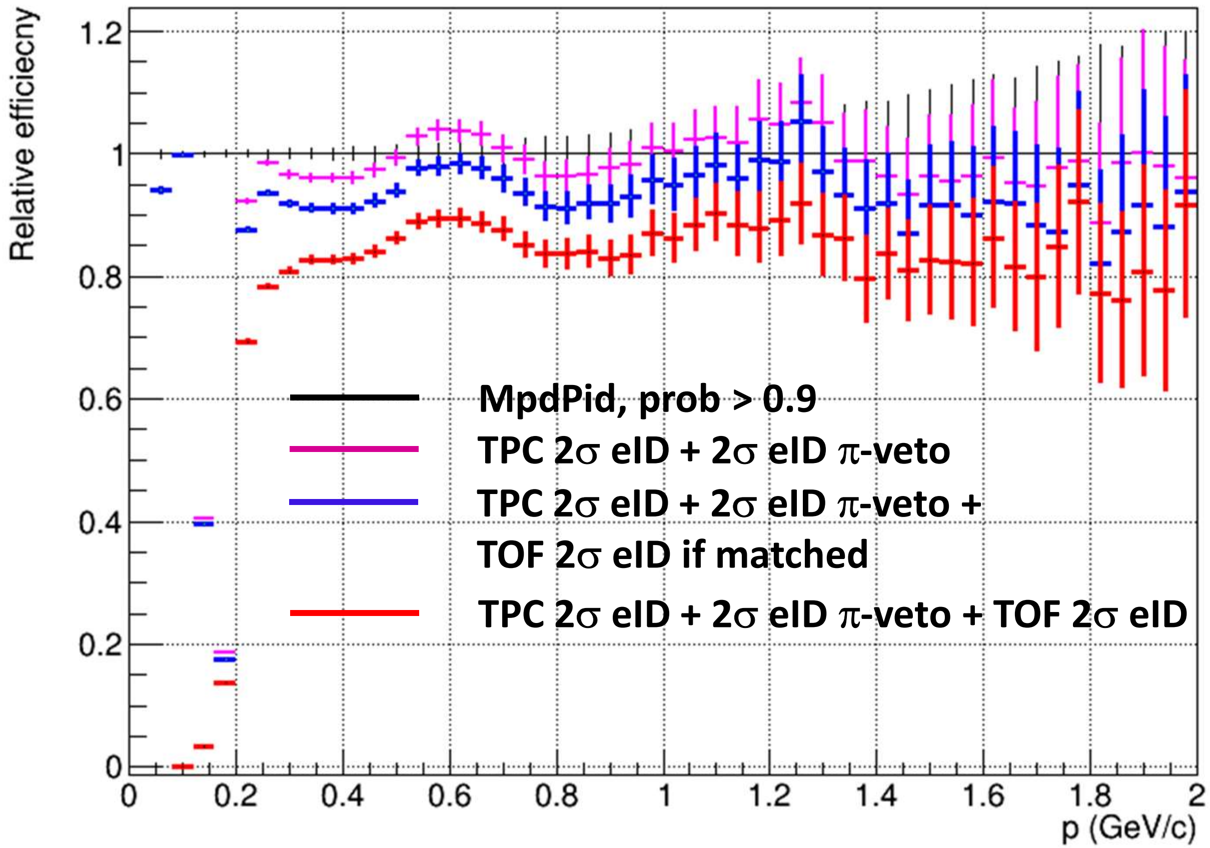
Electron purity, same + 2σ TPC-PID π-veto

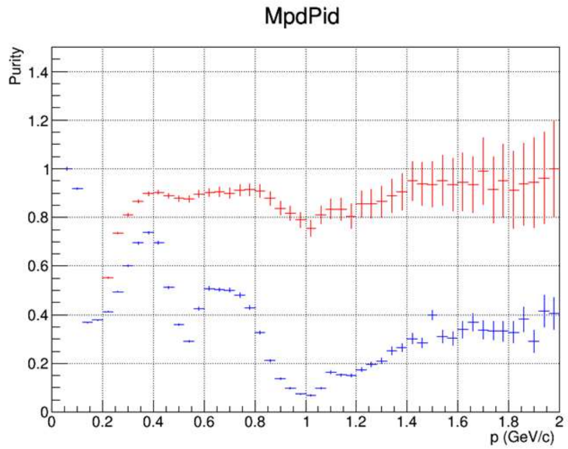


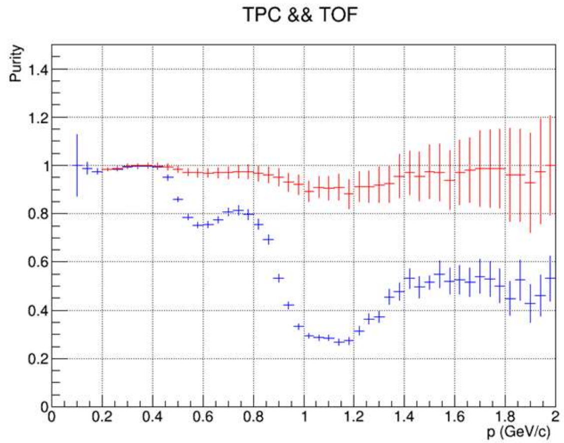
- 2σ TPC-PID π-veto improves purity as expected
- Option TPC && TPF eID + 2σ TPC-PID π-veto provides the needed purity
- At what cost?

Relative efficiency

- Electron reconstruction efficiency with respect to default MpdPid + EMC eID option, see red curve in slide 10





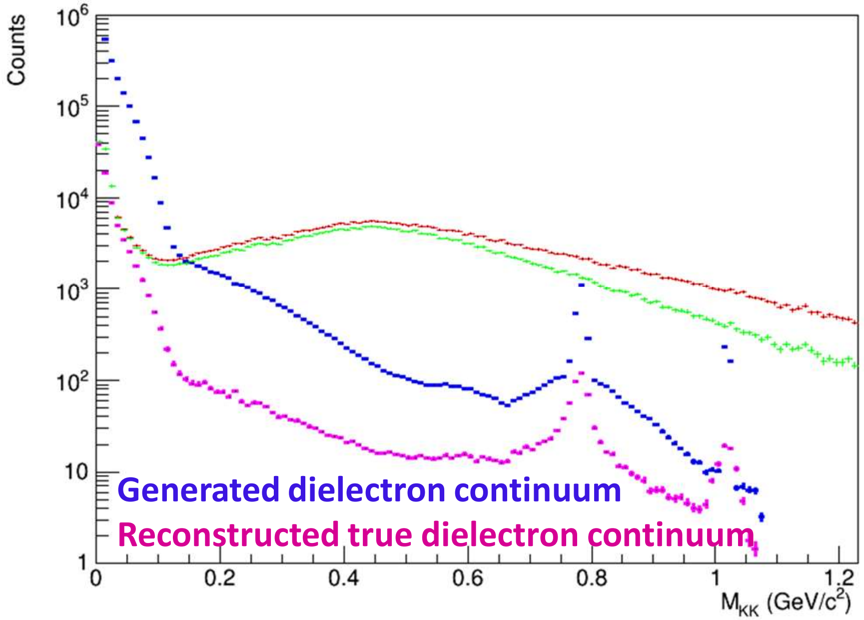


- Efficiency rapidly drops at $p_T < 250$ MeV/c and at $p_T < 100$ MeV/c the reconstruction efficiency becomes critically small (~ a percent)
- Some fine tuning is possible by changing width of the π veto cut

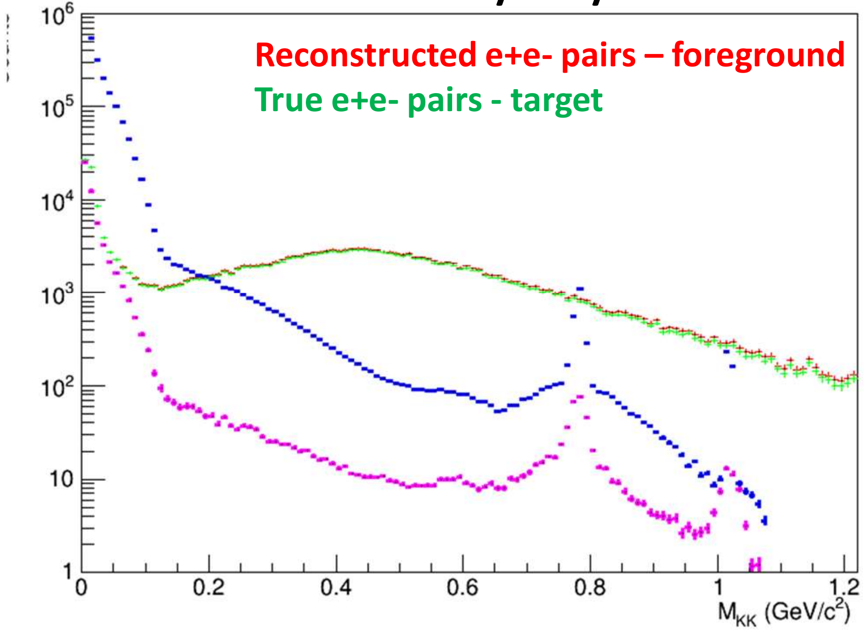
→ High signal purity is achievable at the cost of lower efficiency, especially at $p_T < 200$ MeV/c

Dielectron spectra, second look

All tracks + TPC/TOF-PID



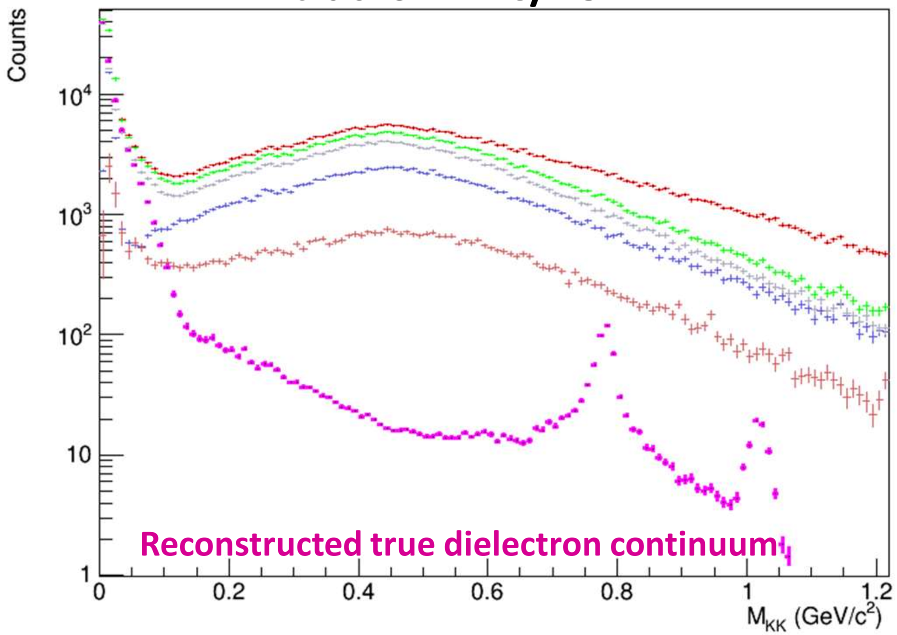
All tracks + TPC/TOF/EMC-PID



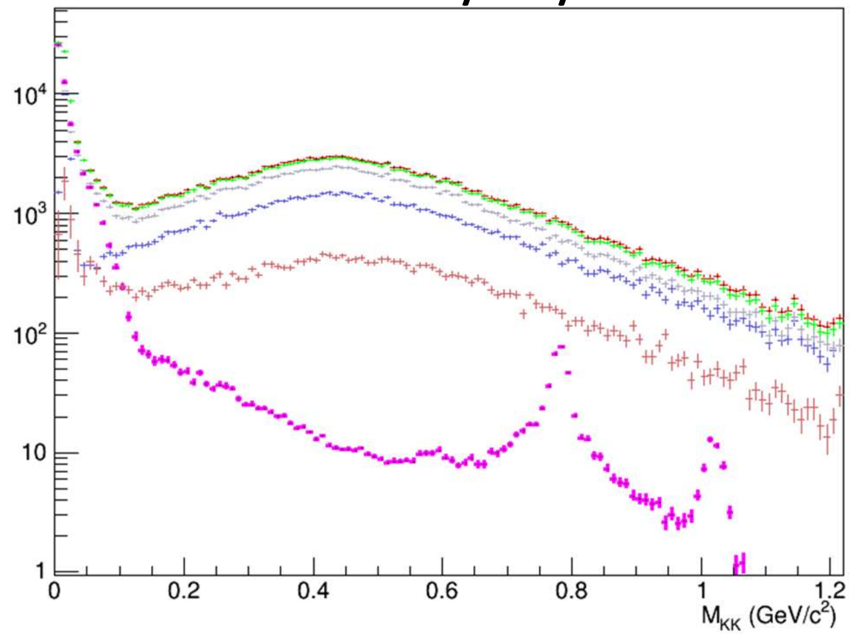
- Hadron contamination at low momentum is largely suppressed
- Effective hadron suppression at high p_T or mass is possible only with EMC-PID
- With the achieved electron purity (> 95%) most of the measured signal are true e^+e^- pairs from different sources, even at low momentum

Dielectron spectra, sources of pairs

All tracks + TPC/TOF-PID



All tracks + TPC/TOF/EMC-PID

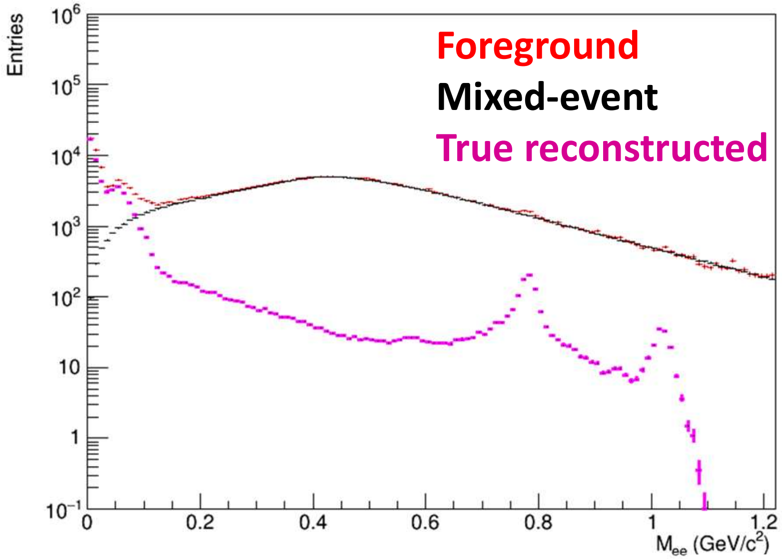


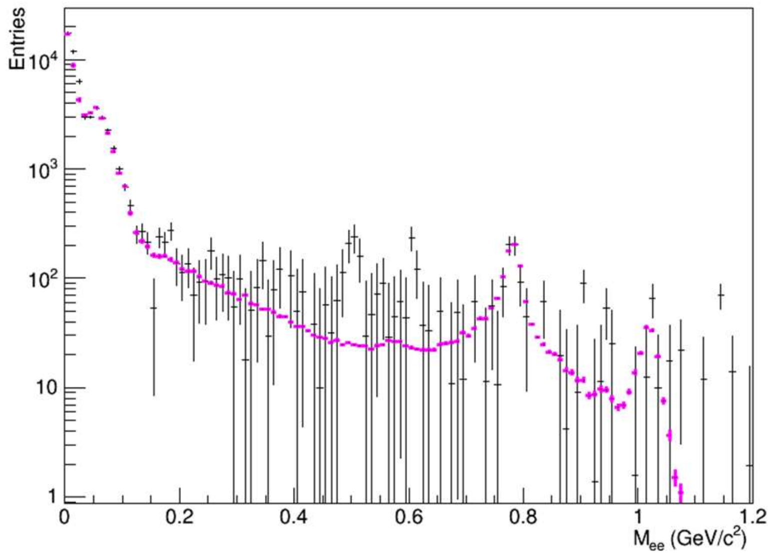
Reconstructed e+e- pairs – foreground
True e+e- pairs – target
Pairs with at least one π^0 Dalitz electron
Pairs with at least one conversion electron
Pairs with at least one η Dalitz electron

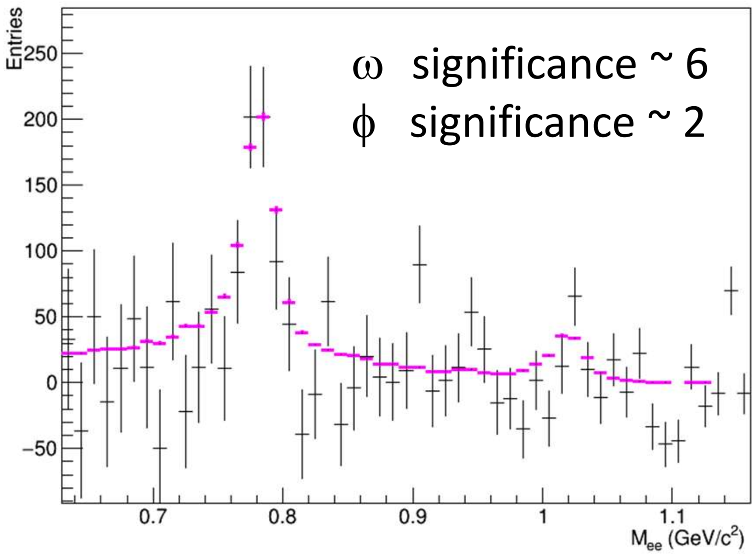
- The dominant source of dielectron pairs – Dalitz decays of π^0, mostly irreducible
- The second main source of pairs – conversion electrons:
  - ✓ contribution can be reduced by analysis cuts → subject of further studies …
- The third main source of pairs – Dalitz decays of η, mostly irreducible

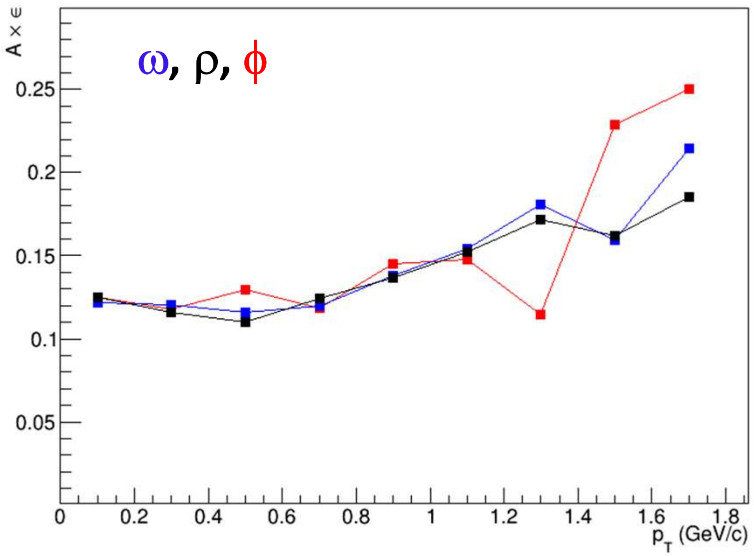
→ The dominant sources of combinatorial background are irreducible

Current status, work in progress ….









- ~ 10M events

Conclusions

- The first large MC production is done and is ready to be used for different analyses
- Some technical problems need to be resolved (width of resonances, Dalitz decays etc.) for the future Geant 4 production(s)
- High purity of the electron sample (> 95%) can be achieved at the expense of somewhat lower efficiency by using TPC/TOF/ECAL
- The lowest-p_T reach is ~ 100-150 MeV/c at purity > 95%, efficiency rapidly drops
- High purity at p_T > 500 MeV/c can be achieved only with the ECAL
- The main source of e^+e^- pairs is π^0 Dalitz decays, practically irreducible
- Extra studies are needed to suppress background from conversions