Anna Senger

for the CBM collaboration

HADRON IDENTIFICATION WITH THE MUON SETUP OF CBM

8th International Conference on New Frontiers in Physics (ICNFP 2019)

Outline

- Motivation
- CBM detector configurations
- Simulations and reconstruction package
- Muon setup:
  - di-muons
  - hadron reconstruction without PID
  - hadron PID behind muon system
  - preliminary results of hyperon reconstruction using PID
- Conclusions
- Next steps

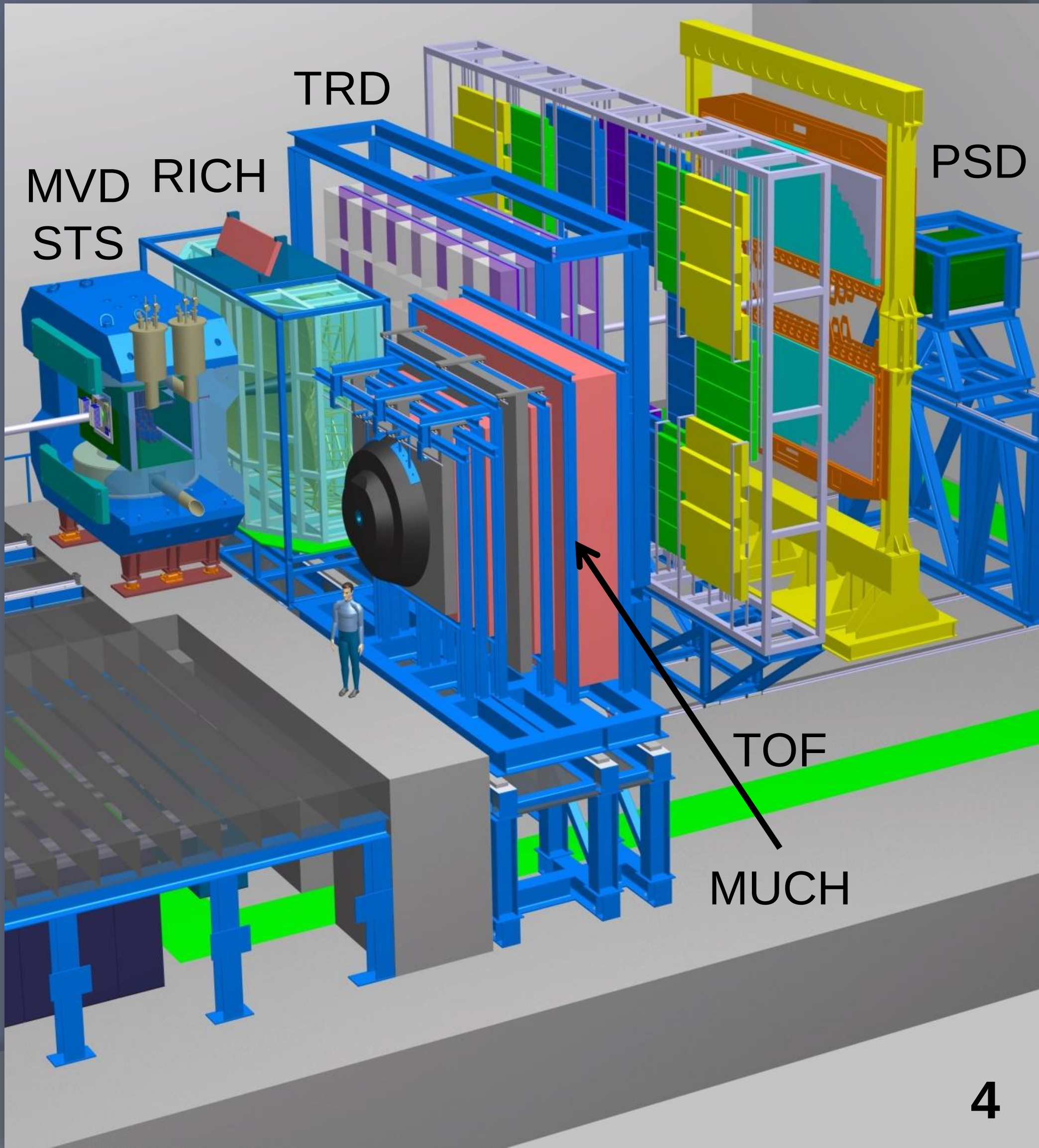
PID ≡ particle identification

Motivation

- A substantial part of the future CBM beam time will be devoted to muon measurements, which can be performed with higher reaction rates than with the detector configuration for electron measurements.
- The overall statistics for multi-strange hyperons would be strongly enhanced, if they could be measured also with the muon setup.
- The simultaneous measurement of hadrons and dileptons, both for the electron and the muon setup, allows for consistency checks of the dilepton results.

CBM detectors for SIS100

Micro-Vertex Detector (MVD)	primary and secondary vertex reconstruction with high precision
Silicon Tracking System (STS)	track, vertex and momentum reconstruction
Muon Chamber System (MUCH)	muon identification
Ring Imaging Cherenkov detector (RICH)	electron identification
Transition Radiation Detector (TRD)	global tracking, electron identification
Time of Flight Detector (TOF)	electron and neutral particle identification
Projectile Spectator Detector (PSD)	reaction plane and centrality determination



CBM setups

- Hadron setup: STS+TOF
  Observables:
  - *hadrons*
  - *hypernuclei*
- Electron setup: (MVD)+STS+RICH+TRD+TOF+PSD
  Observables:
  - *dielectrons*
  - *hadrons*
  - *hypernuclei*
- Muon setup: STS+MUCH+TRD+TOF+(PSD)
  Observables:
  - *dimuons*
  - *hadrons ?*

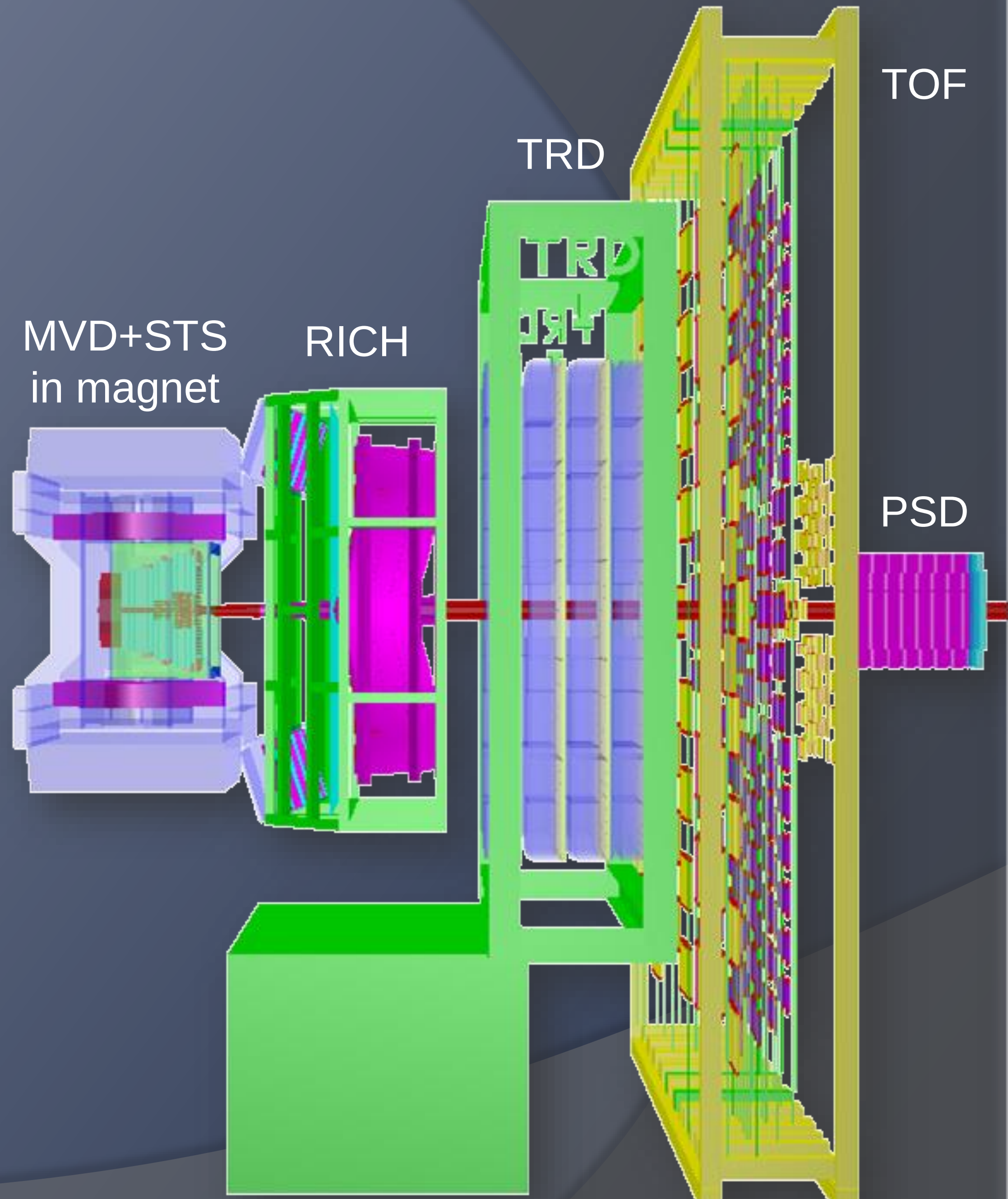
Simulations and software

- CBMROOT
  software package for simulation, reconstruction, and analysis based on the ROOT software toolkit
- UrQMD, PHSD and PLUTO
  as primary particle generators
- GEANT3/4
  simulation software for transport of particles through materials
- Kalman Filter Particle Package (KFPP)
  for particle reconstruction

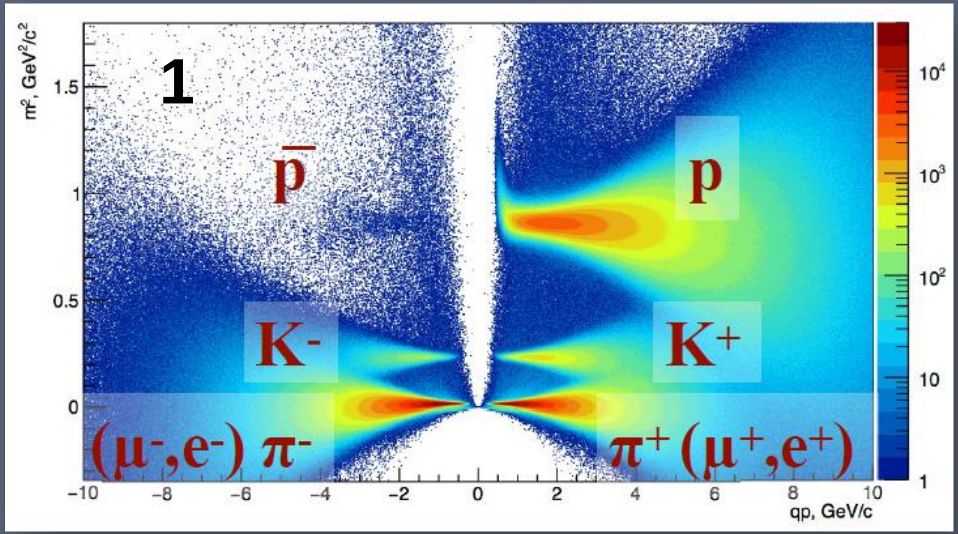
Detector implementation

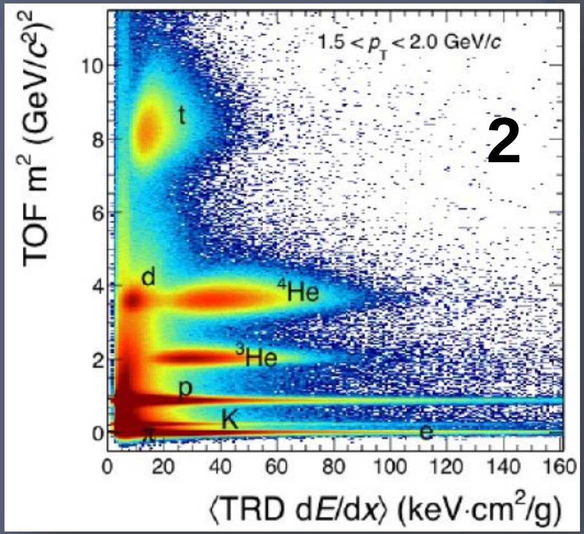
- Geometry of detectors and support structures from technical drawings
- Digitization scheme from detector and electronics tests
- Hit reconstruction from mathematical models

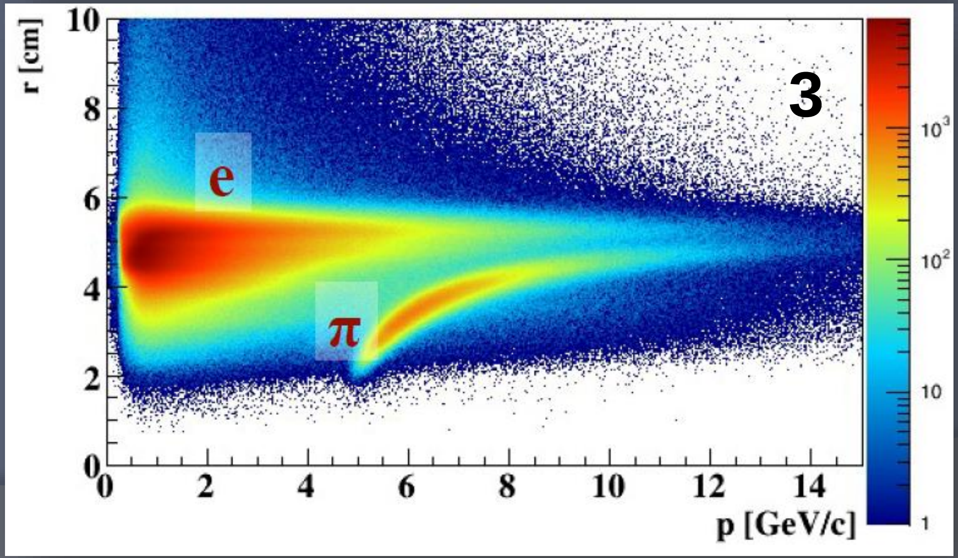
Electron setup



Hadron identification in electron setup





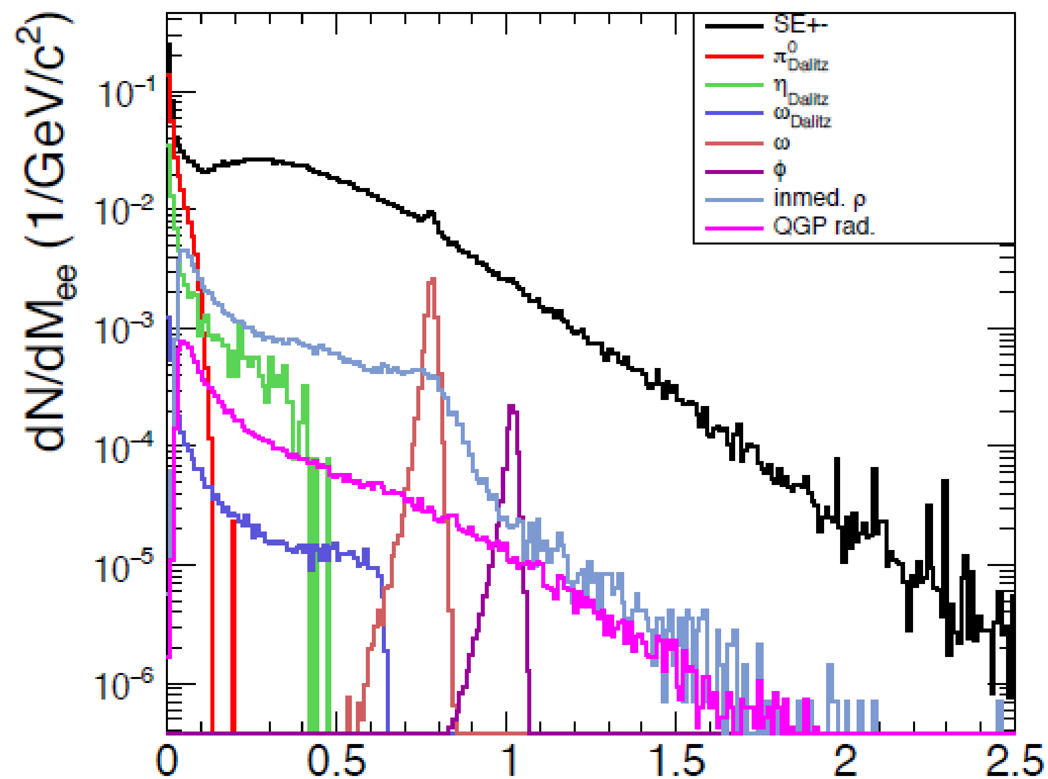


1. TOF hadron identification
2. TRD-TOF d-He separation
3. RICH electron identification

Pictures: Iouri VASSILIEV

Low-mass vector mesons

central UrQMD Au+Au events at 8 A GeV/c

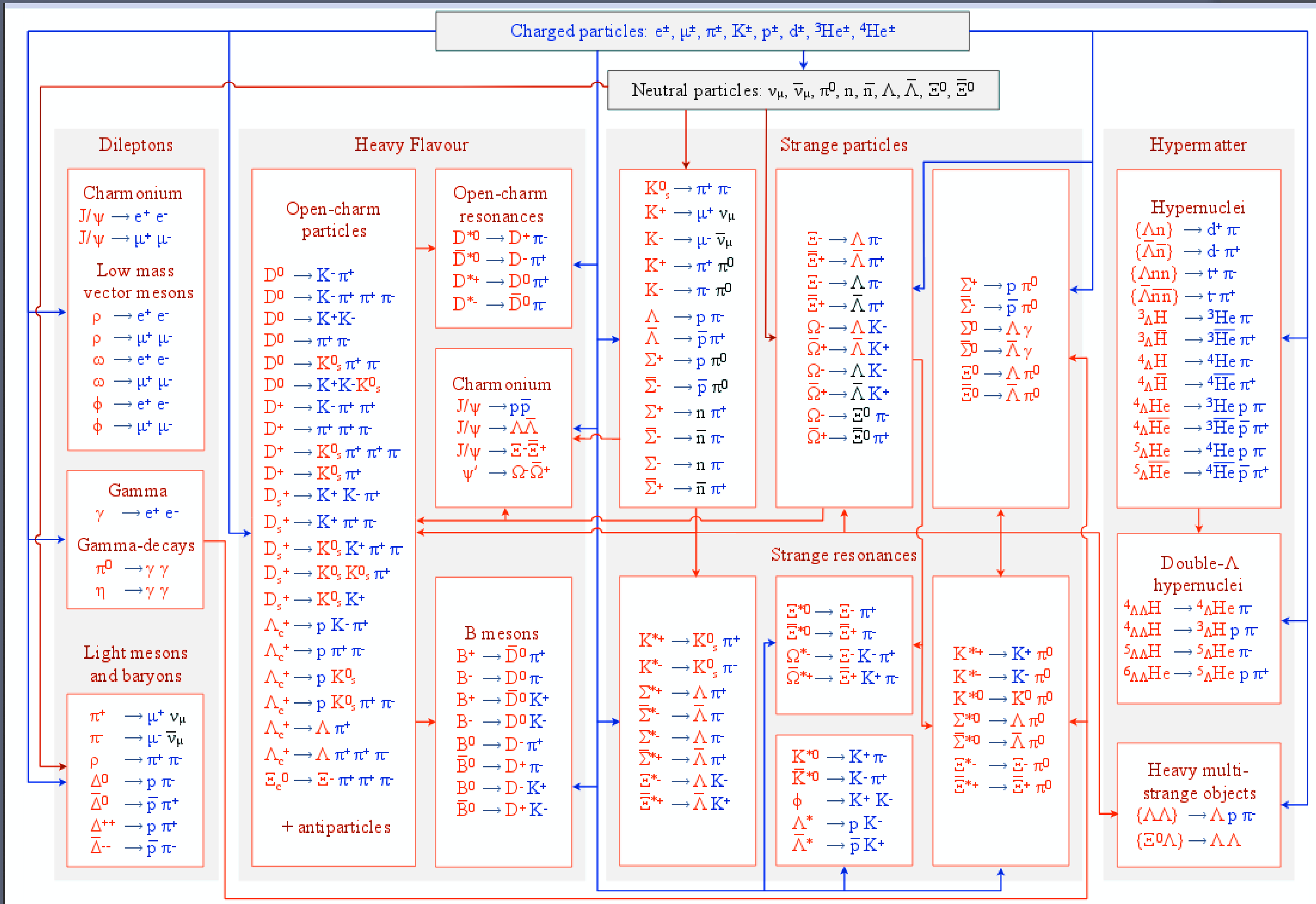


from di-electron analysis task

Electron PID:

- MVD – hit topology: rejection of closed tracks ($\gamma \rightarrow e^+e^-$), vertex reconstruction
- STS – track and momentum reconstruction
- RICH – electron-pion separation via ring radius
- TRD - electron-pion separation via energy loss
- TOF – electron identification via mass distribution

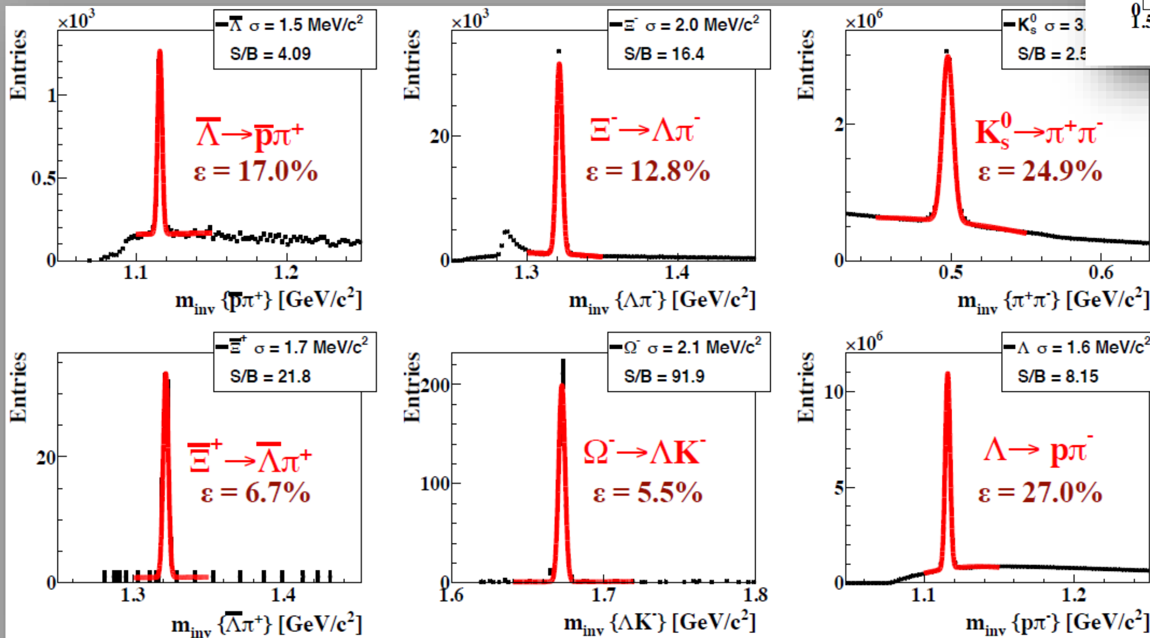
KF Particle Package (KFPP)

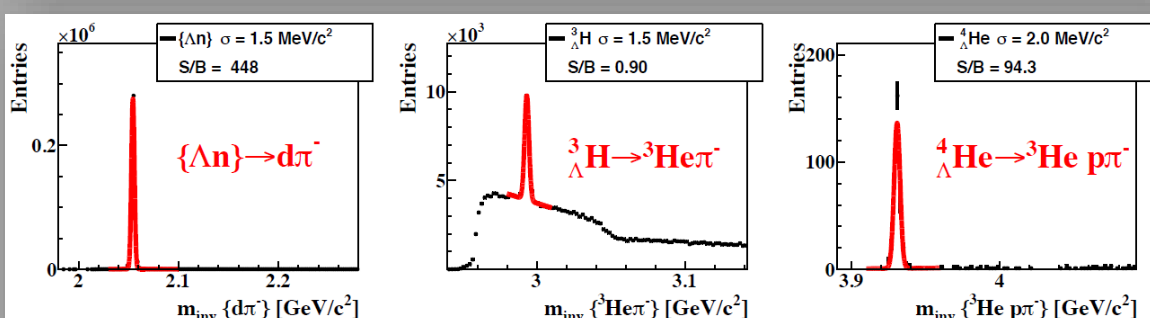


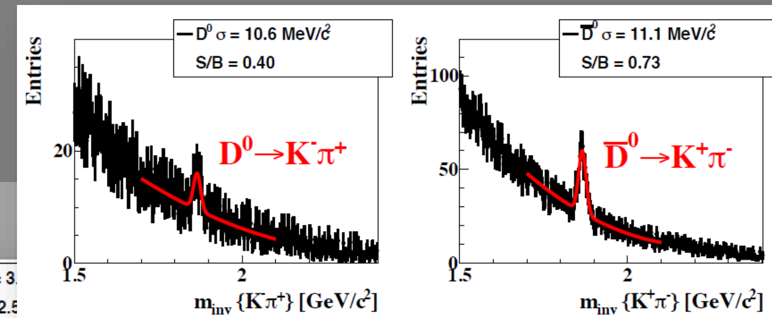
Picture: Maxim ZYZAK

Results of KFPP

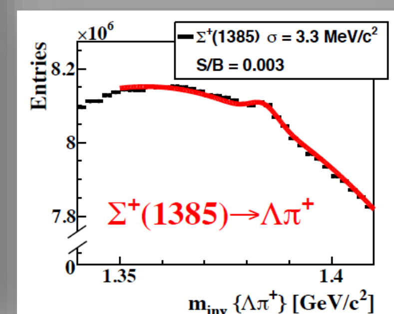
5×10^6 central UrQMD Au+Au events at 10 A GeV/c

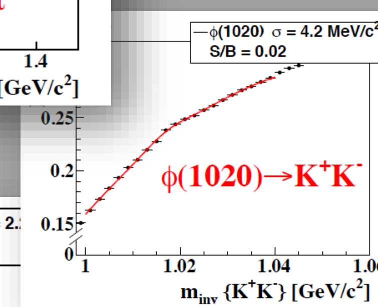


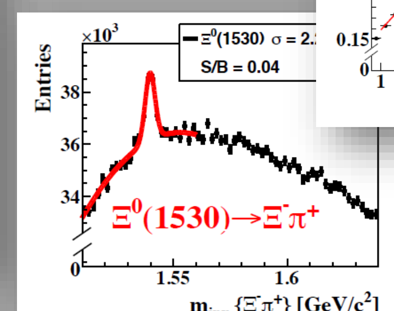




10^{11} central UrQMD Ni+Ni events at 15 A GeV/c

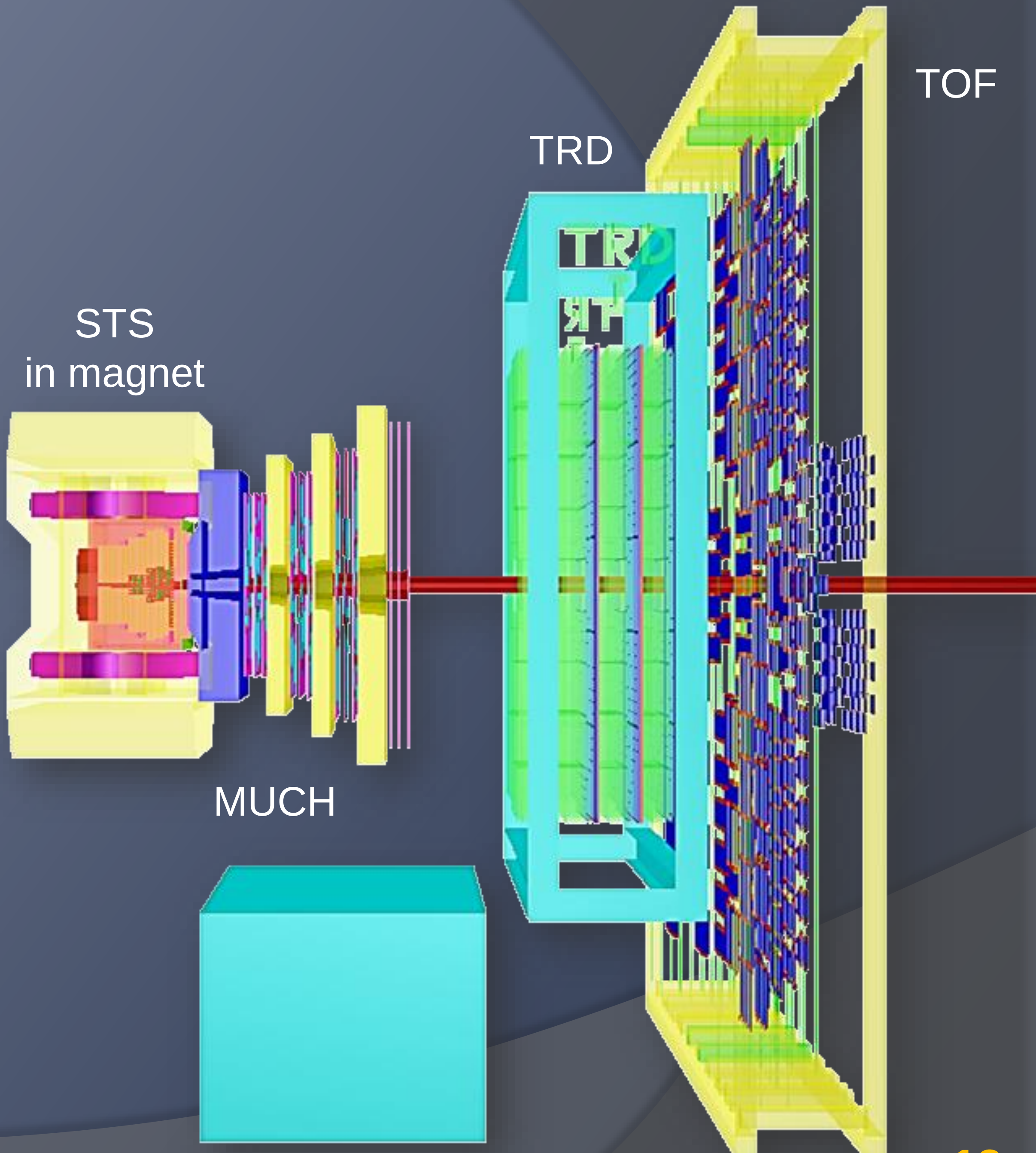






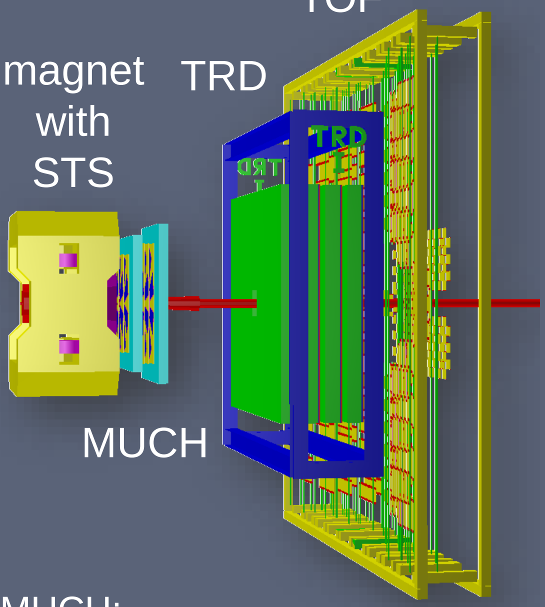
Pictures: Maxim ZYZAK

Muon setup



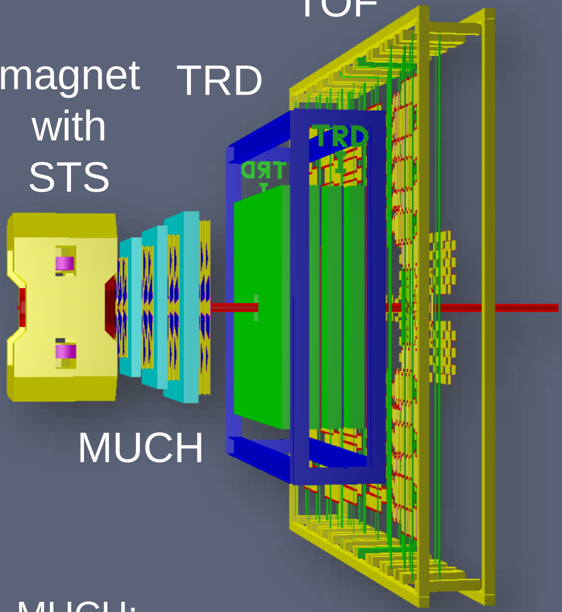
Configurations

for beam energies up to 4 AGeV



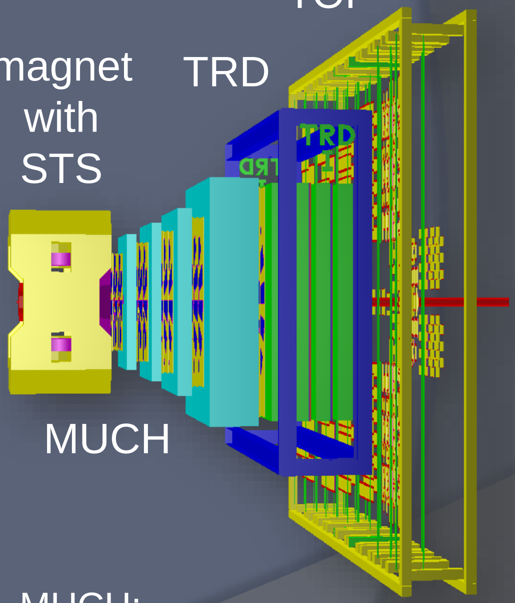
MUCH:
2 GEM stations
absorbers:
60 cm C
(20+20) cm Fe

for beam energies above 4 AGeV



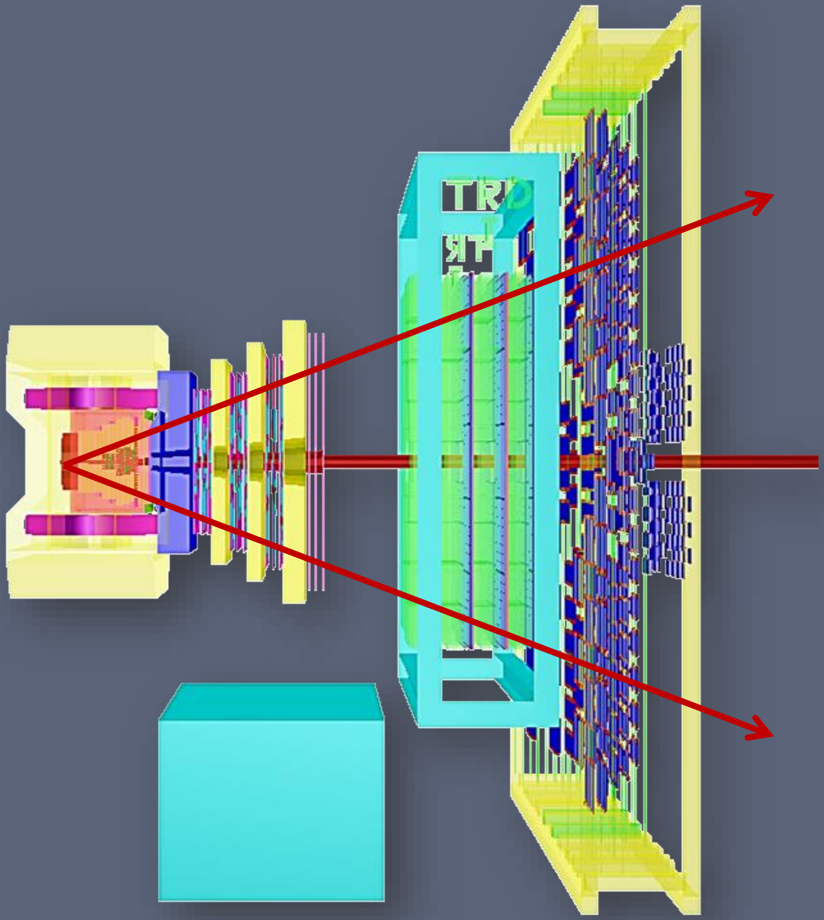
MUCH:
4 GEM stations
absorbers:
60 cm C
(20+20+30) cm Fe

for charmonium measurements



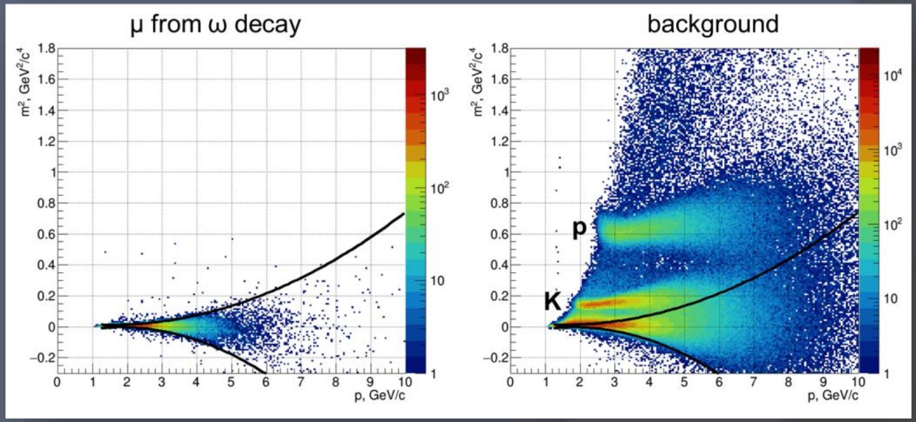
MUCH:
4 GEM stations
absorbers:
60 cm C
(20+20+30+100) cm Fe

Muon reconstruction



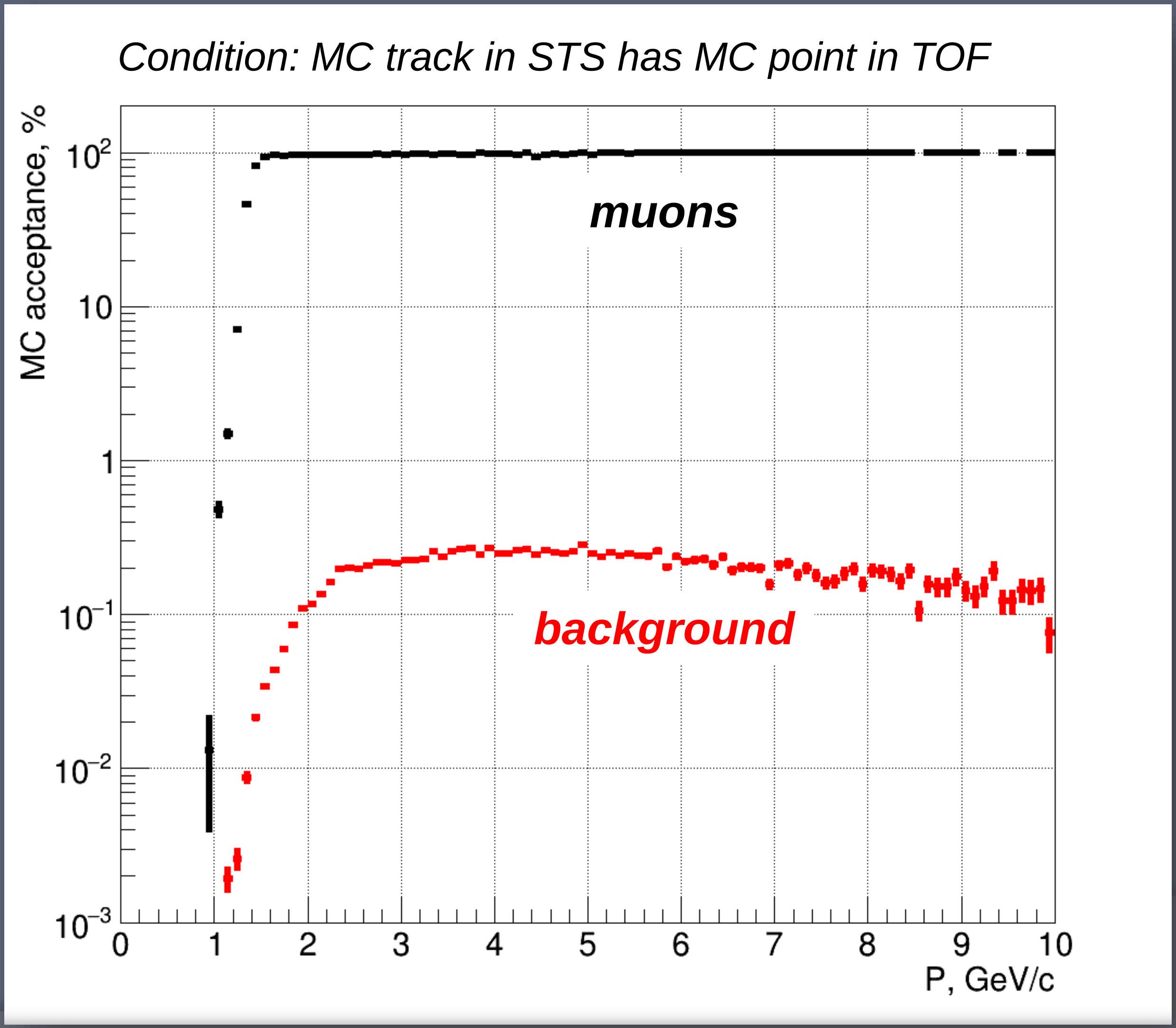
Muon PID

- STS – track, vertex and momentum reconstruction
- MUCH-TRD – track extrapolation
- TOF – muon identification



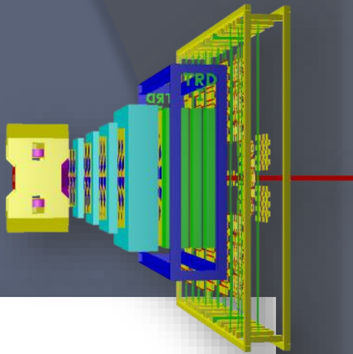
MC acceptance STS+TOF

central UrQMD Au+Au events at 12 A GeV/c

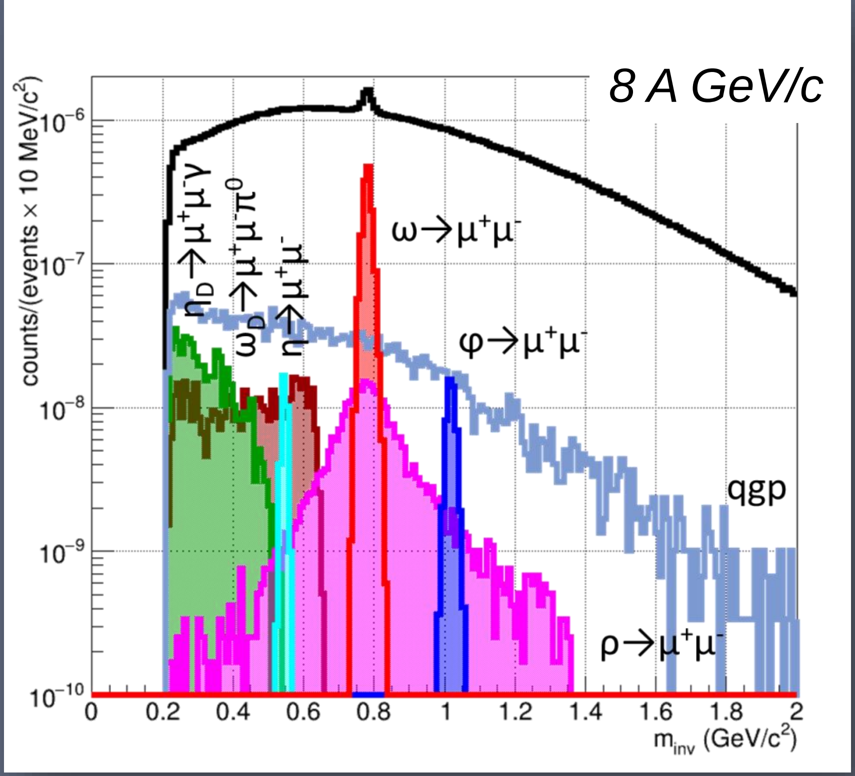


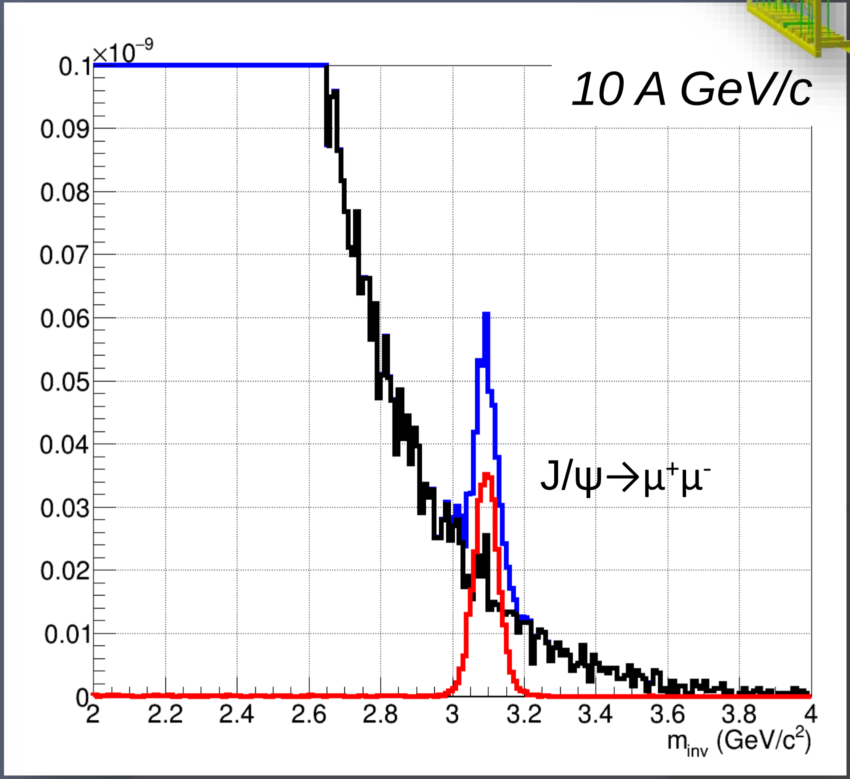
Invariant mass spectra

central UrQMD Au+Au events



MUCH:
4 GEM stations
absorbers:
60 cm C + (20+20+30+100) cm Fe



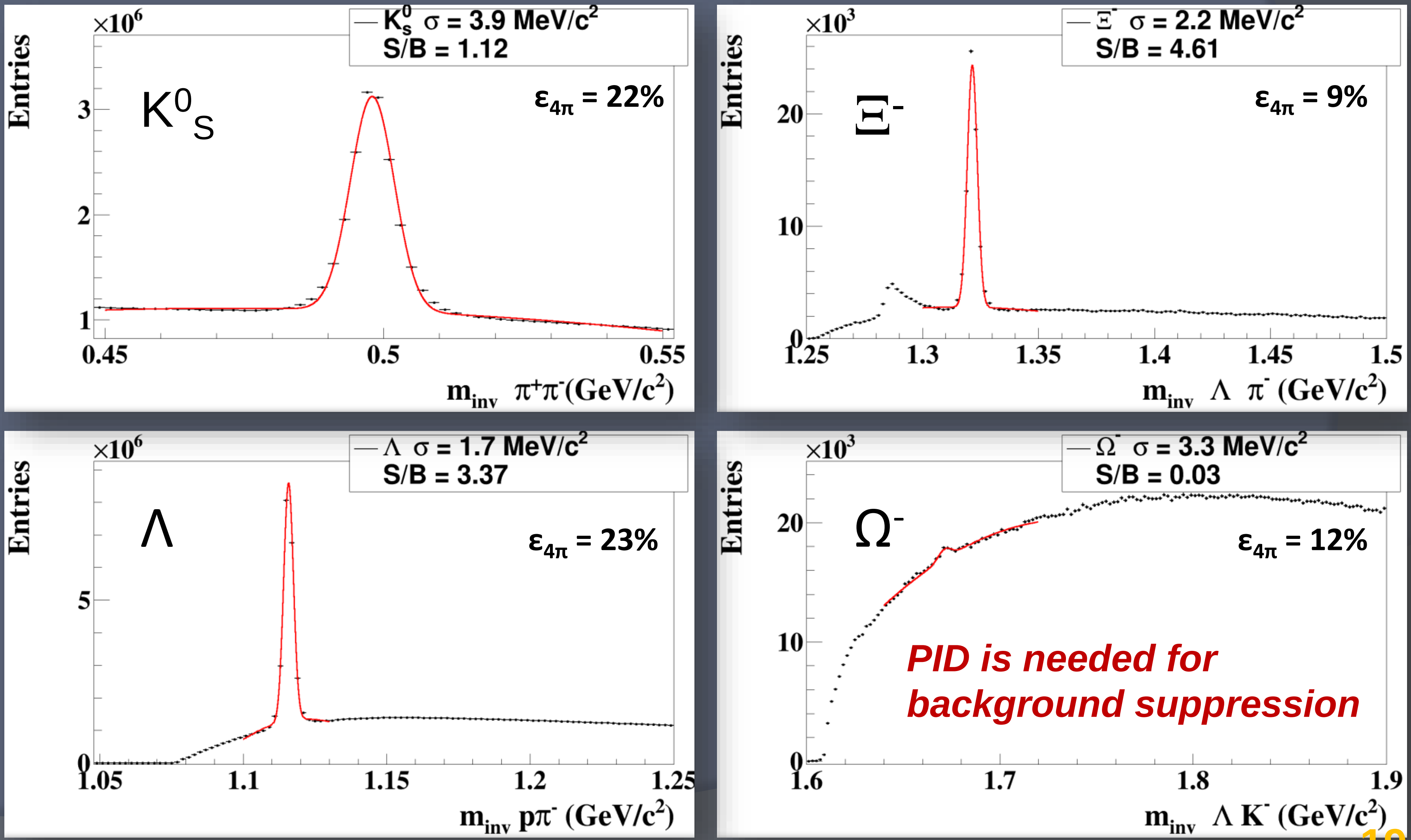


from di-muon analysis task

Hadron reconstruction in STS without TOF PID

Hyperon reconstruction in STS without TOF

5×10^6 central UrQMD Au+Au events at 12 A GeV/c

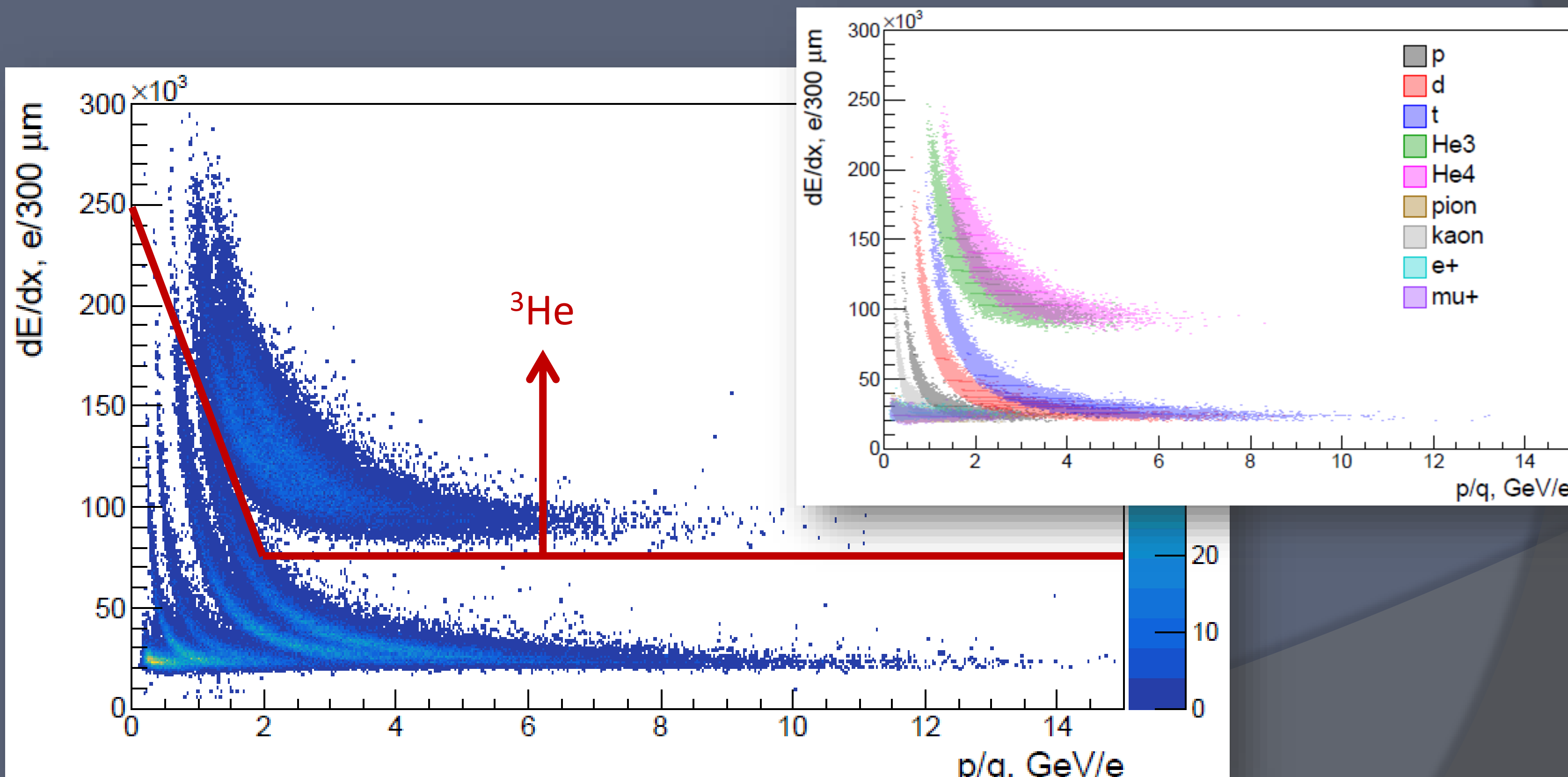


${}_{\Lambda}^{3}H \rightarrow {}^{3}He + \pi^{-}$ PID in STS

central UrQMD Au+Au events at 2 A GeV/c + light fragments

PID in STS:

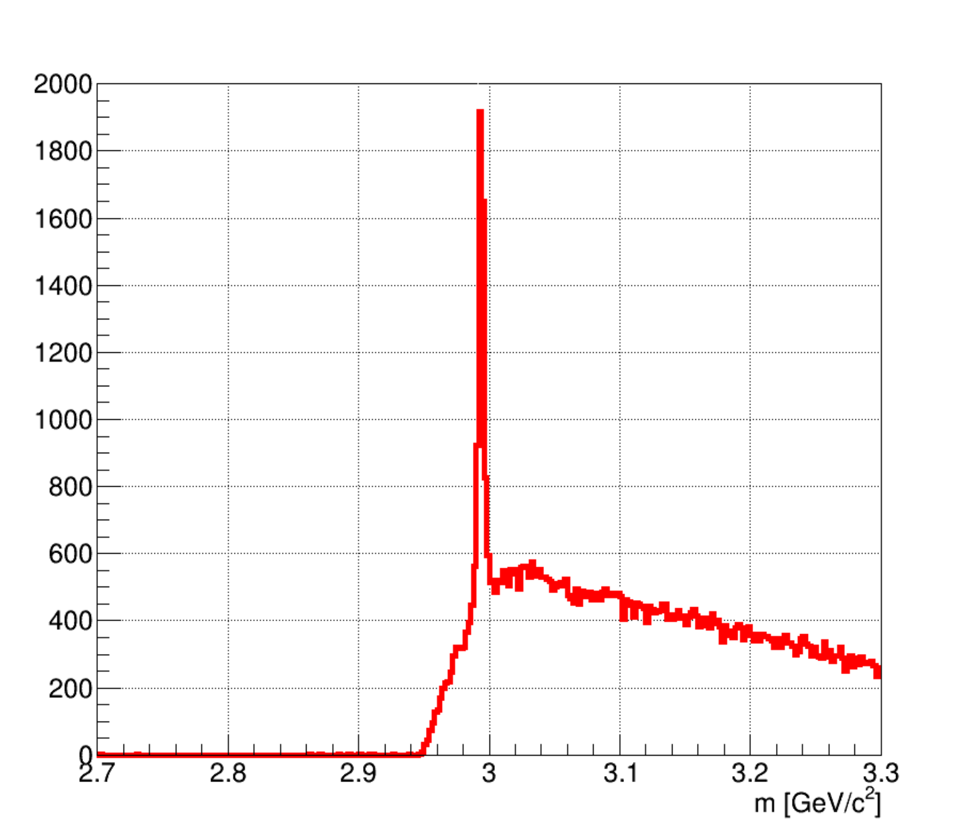
- all negative particles are π^{-}
- positive particles with selected dE/dx are ^{3}He (see picture)



Picture: Maxim TEKLISHYN

${}_{\Lambda}^{3}H \rightarrow {}^{3}He + \pi^{-}$ reconstruction in STS

5×10^{6} central UrQMD Au+Au events at 12 A GeV/c + ${}_{\Lambda}^{3}H$ from thermal generator



reconstruction efficiency
9.5%

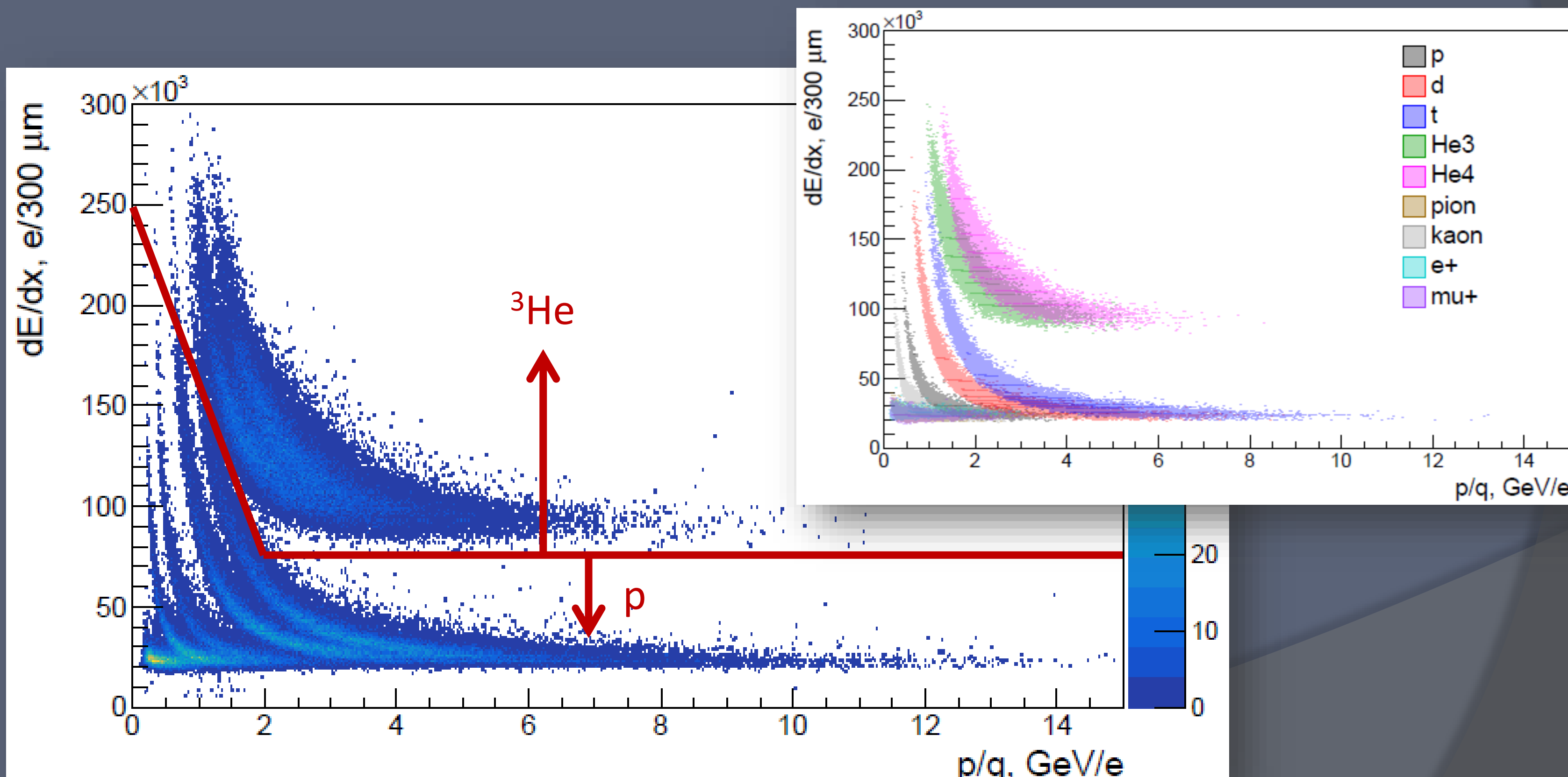
branching ratio: H. Kamada et al., Phys. Rev., Ser. C 57, 1595 (1998)
multiplicity : J. Steinheimer et. all, Phys. Lett. B714, 85, (2012)

${}_{\Lambda}^{4}He \rightarrow {}^{3}He + \pi^{-} + p$

central UrQMD Au+Au events at 2 A GeV/c + light fragments

PID in STS:

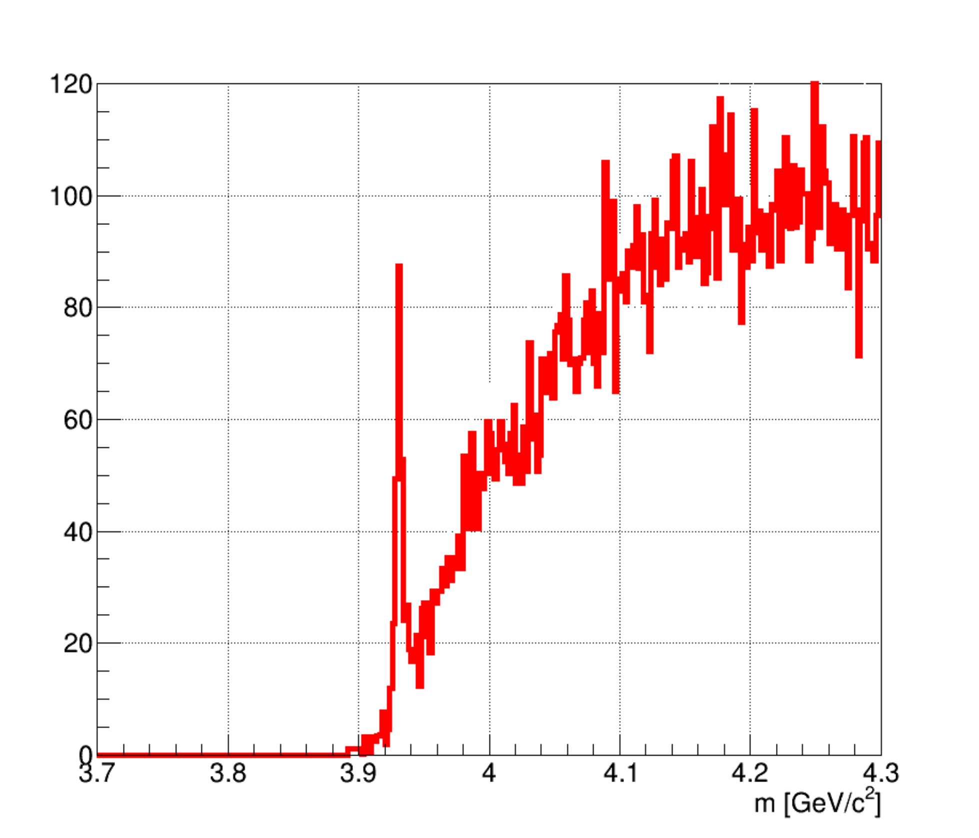
- all negative particles are π^-
- positive particles ^{3}He or p (see picture)



Picture: Maxim TEKLISHYN

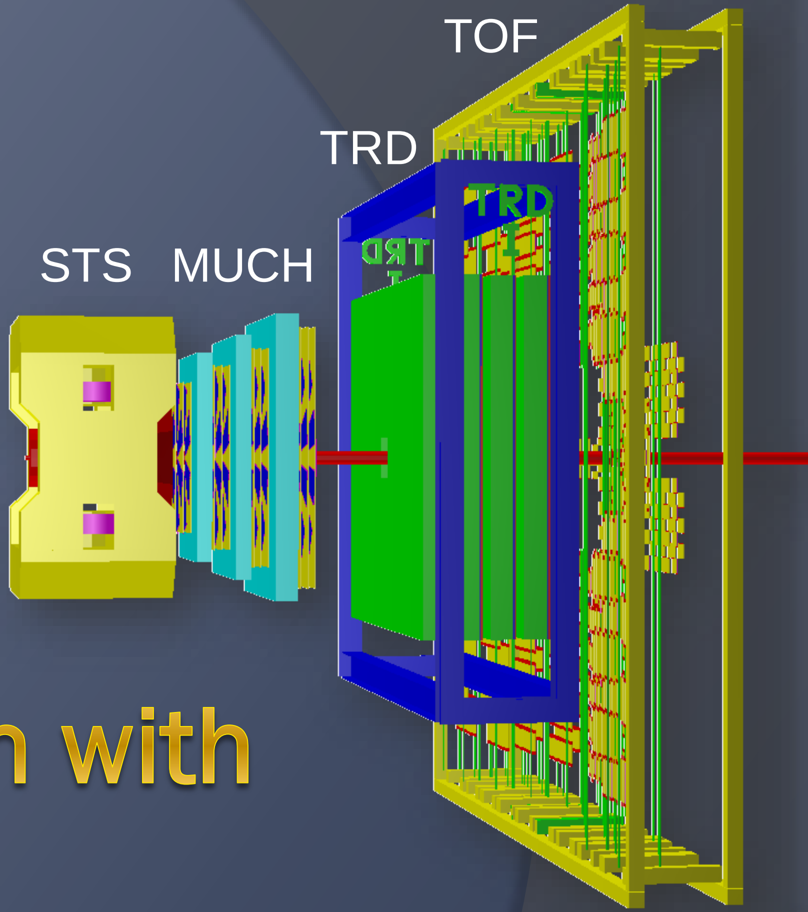
${}_{\Lambda}^{4}He \rightarrow {}^{3}He + \pi^{-} + p$ reconstruction in STS

5×10^{6} central UrQMD Au+Au events at 12 A GeV/c + ${}_{\Lambda}^{4}$He from thermal generator



reconstruction efficiency
5.7%

branching ratio: H. Kamada et al., Phys. Rev., Ser. C 57, 1595 (1998)
multiplicity : J. Steinheimer et. all, Phys. Lett. B714, 85, (2012)

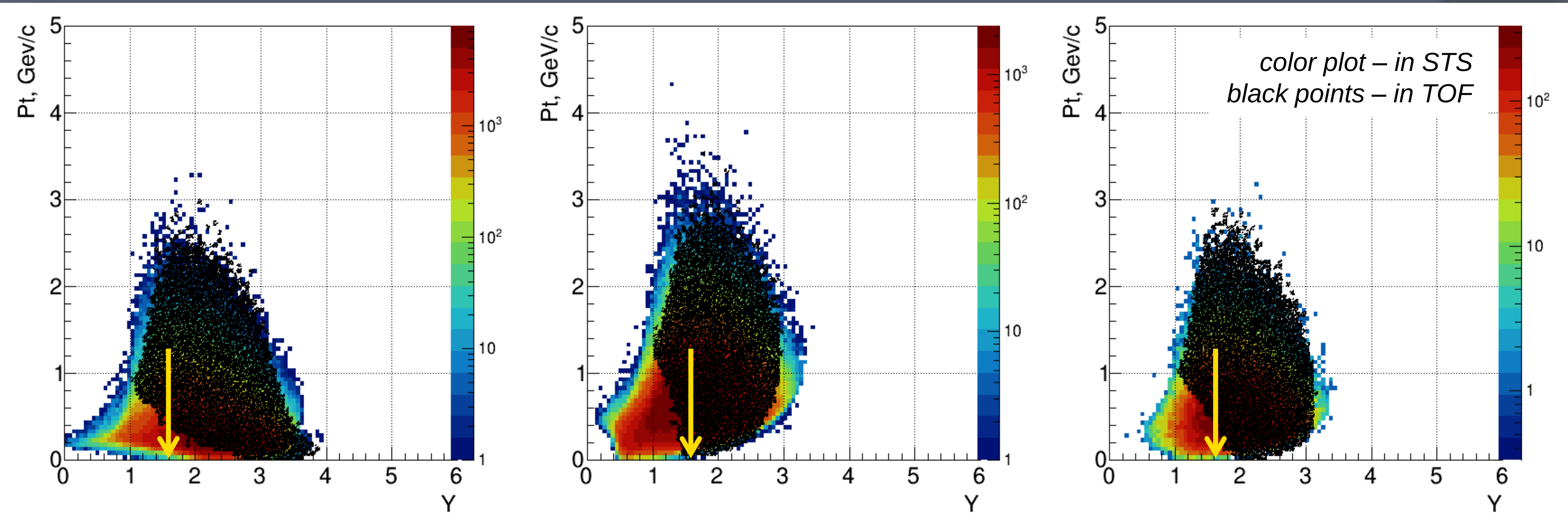


Hadron identification with TOF behind MUCH

MC acceptance

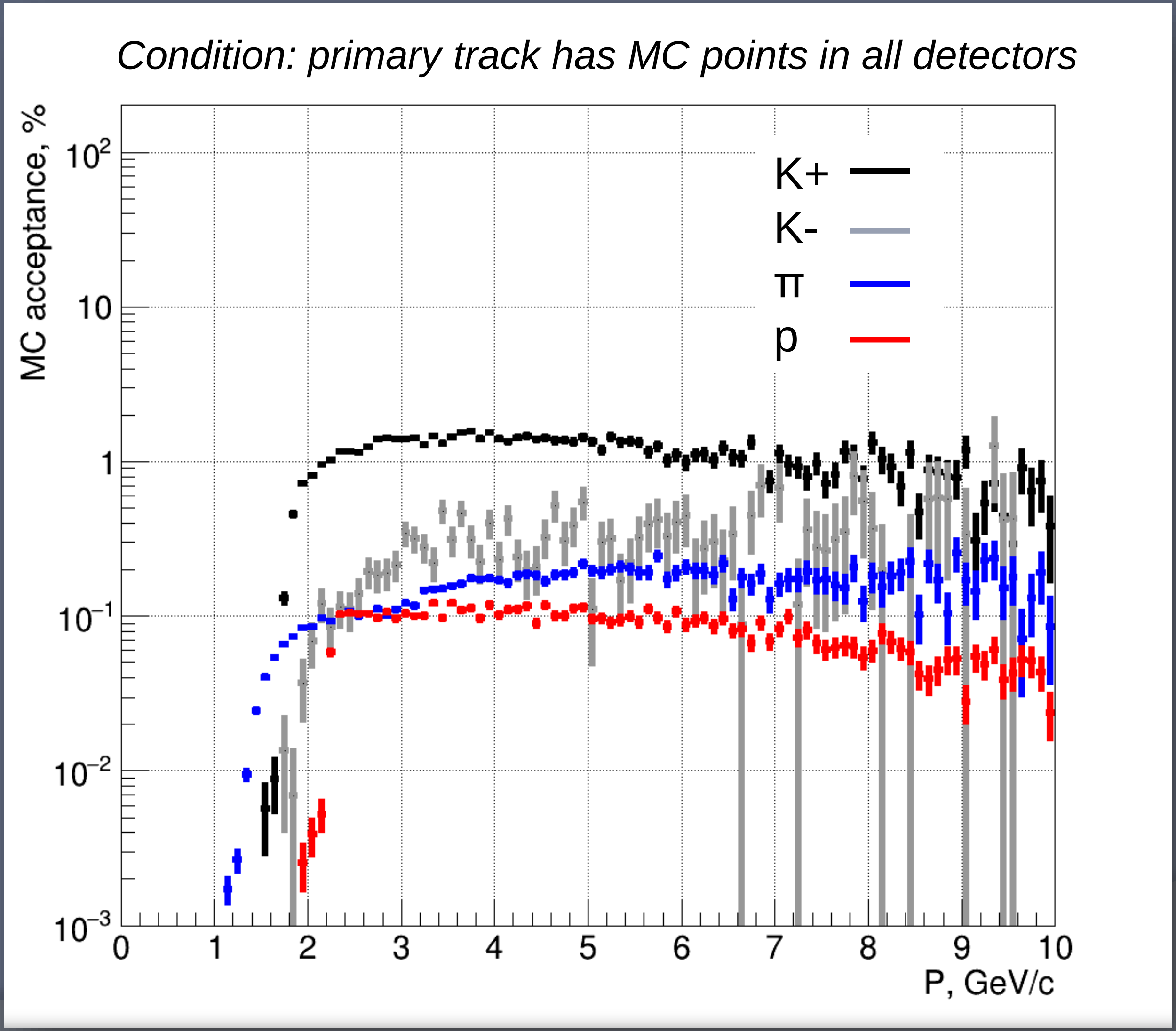
central UrQMD Au+Au events at 12 A GeV/c

pions protons kaons



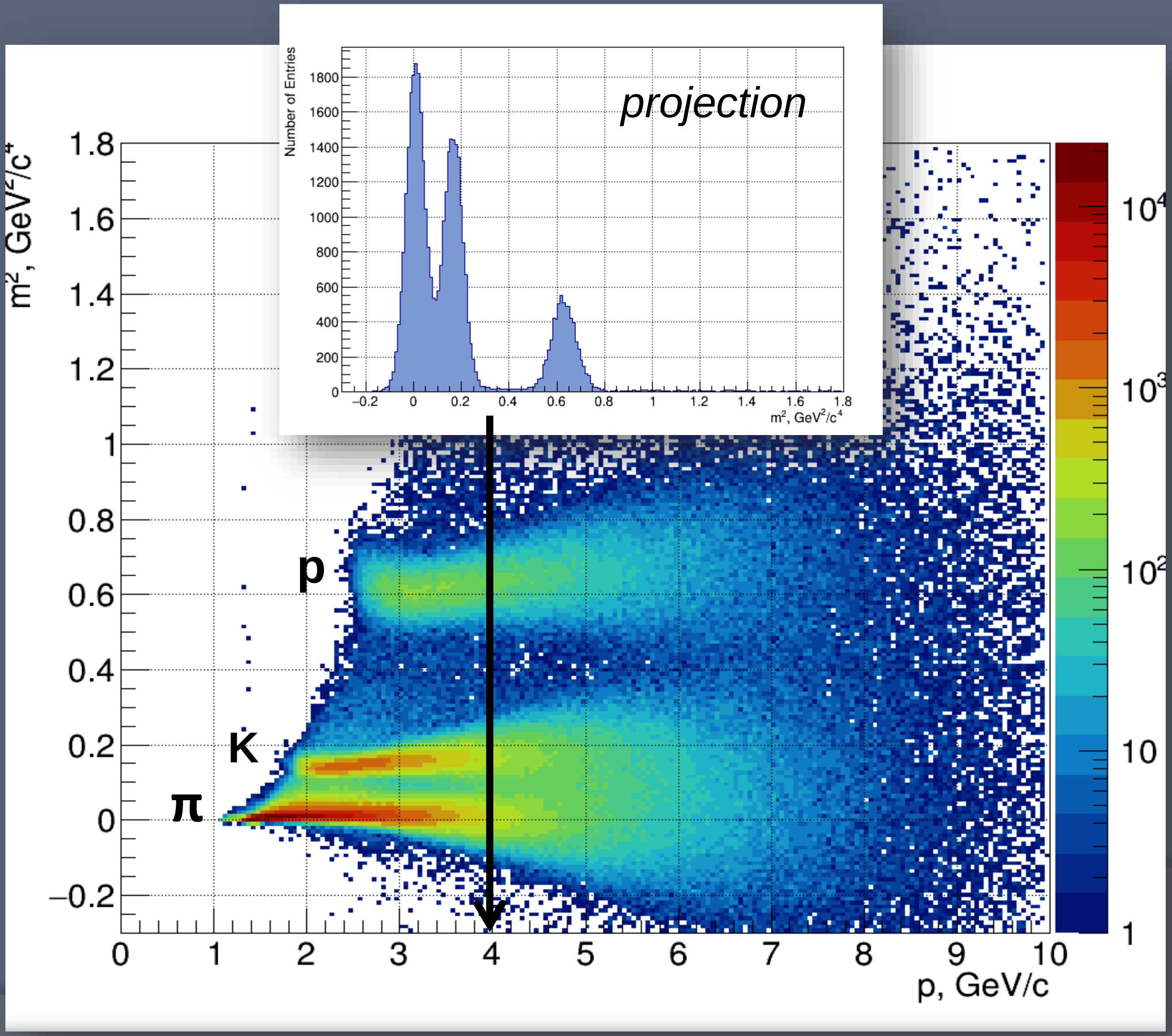
4π MC acceptance

central UrQMD Au+Au events at 12 A GeV/c



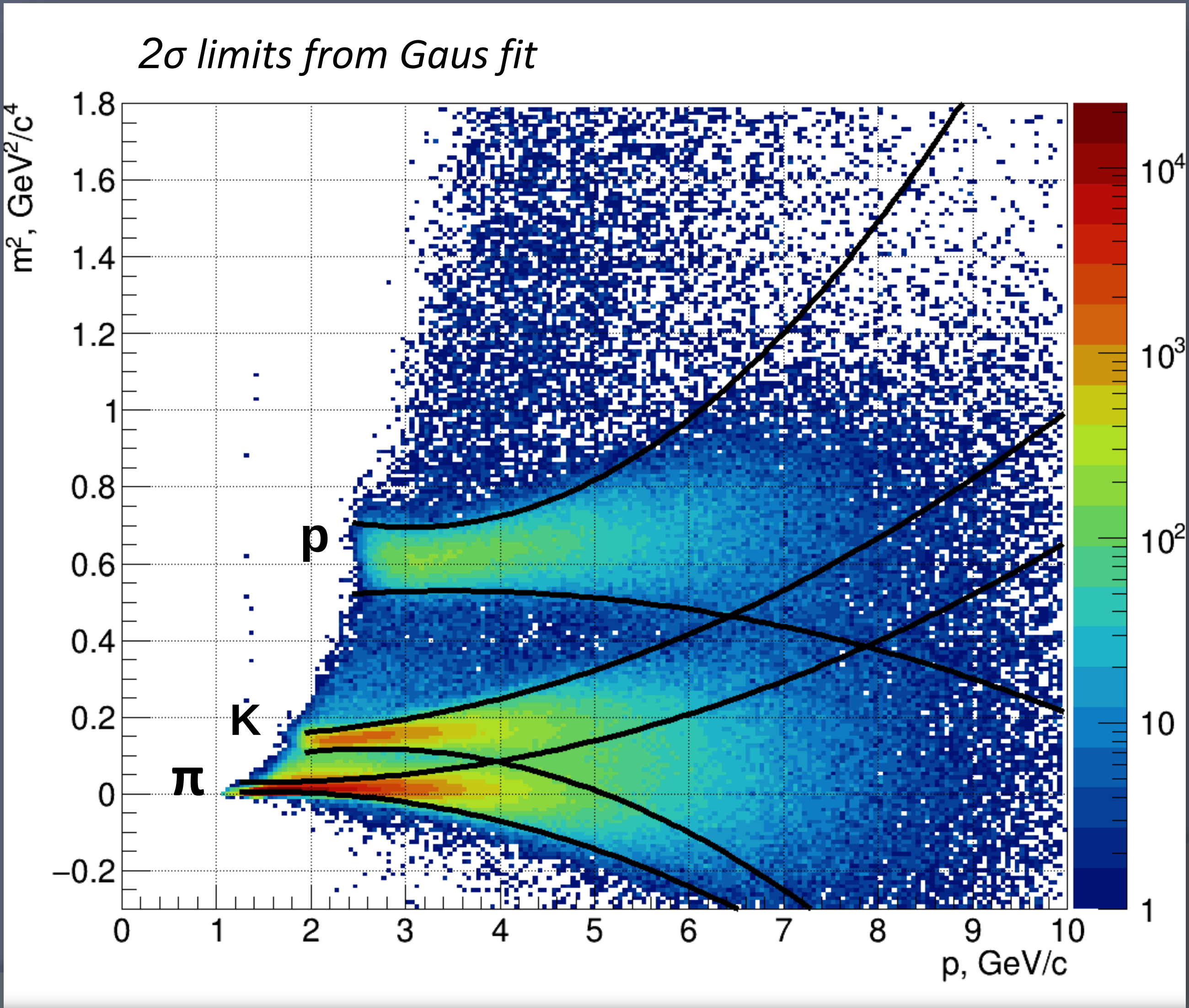
Hadron PID in TOF

5×10^6 central UrQMD Au+Au events at 12 A GeV/c



Hadron PID in TOF

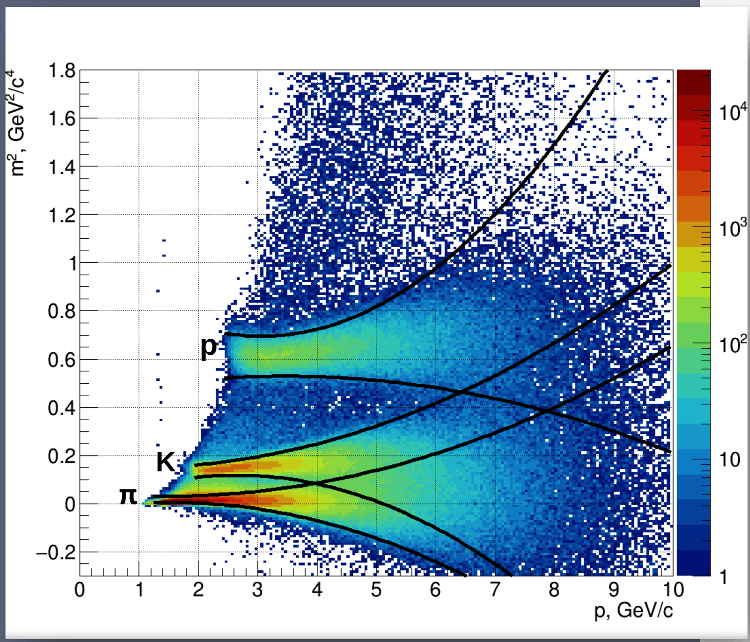
5×10^6 central UrQMD Au+Au events at 12 A GeV/c

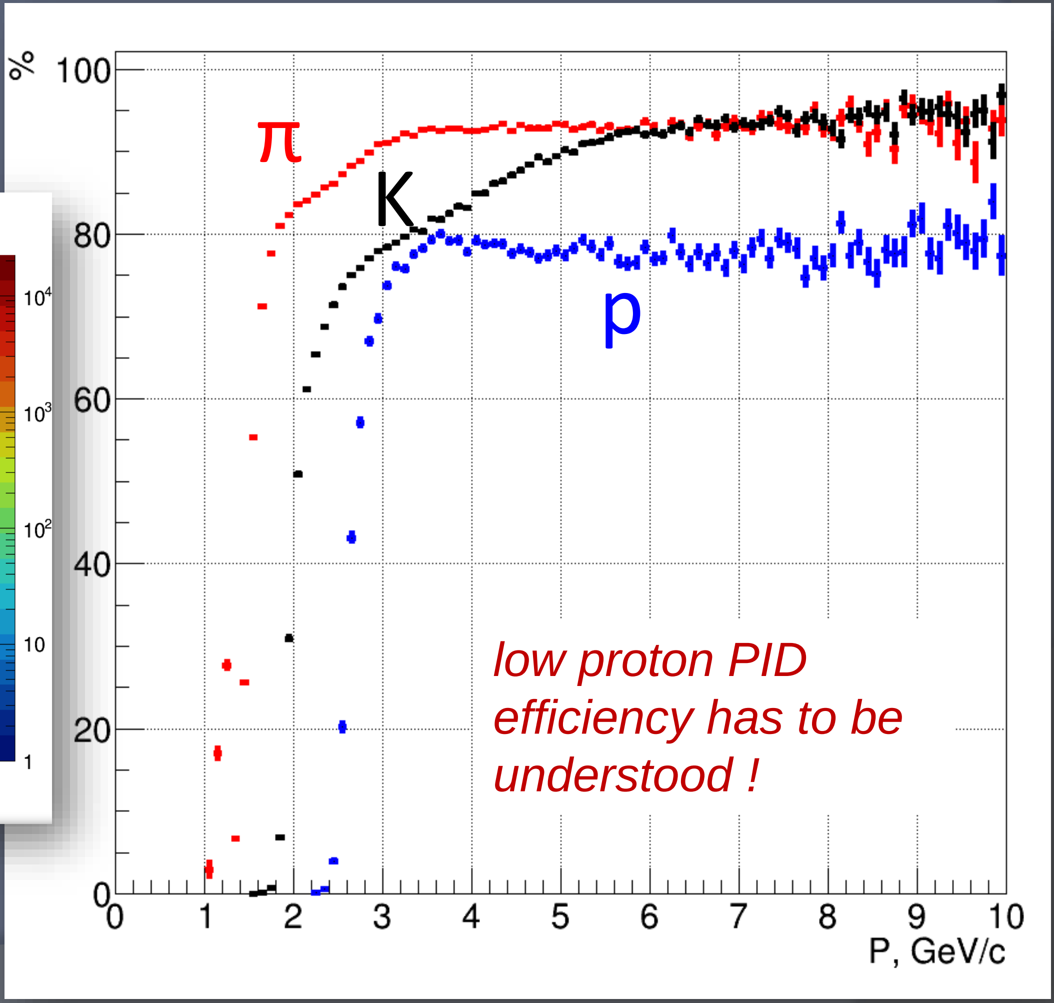


TOF PID efficiency for particles passing MUCH

5×10⁶ central UrQMD Au+Au events at 12 A GeV/c

inclusive the tracking and matching efficiency

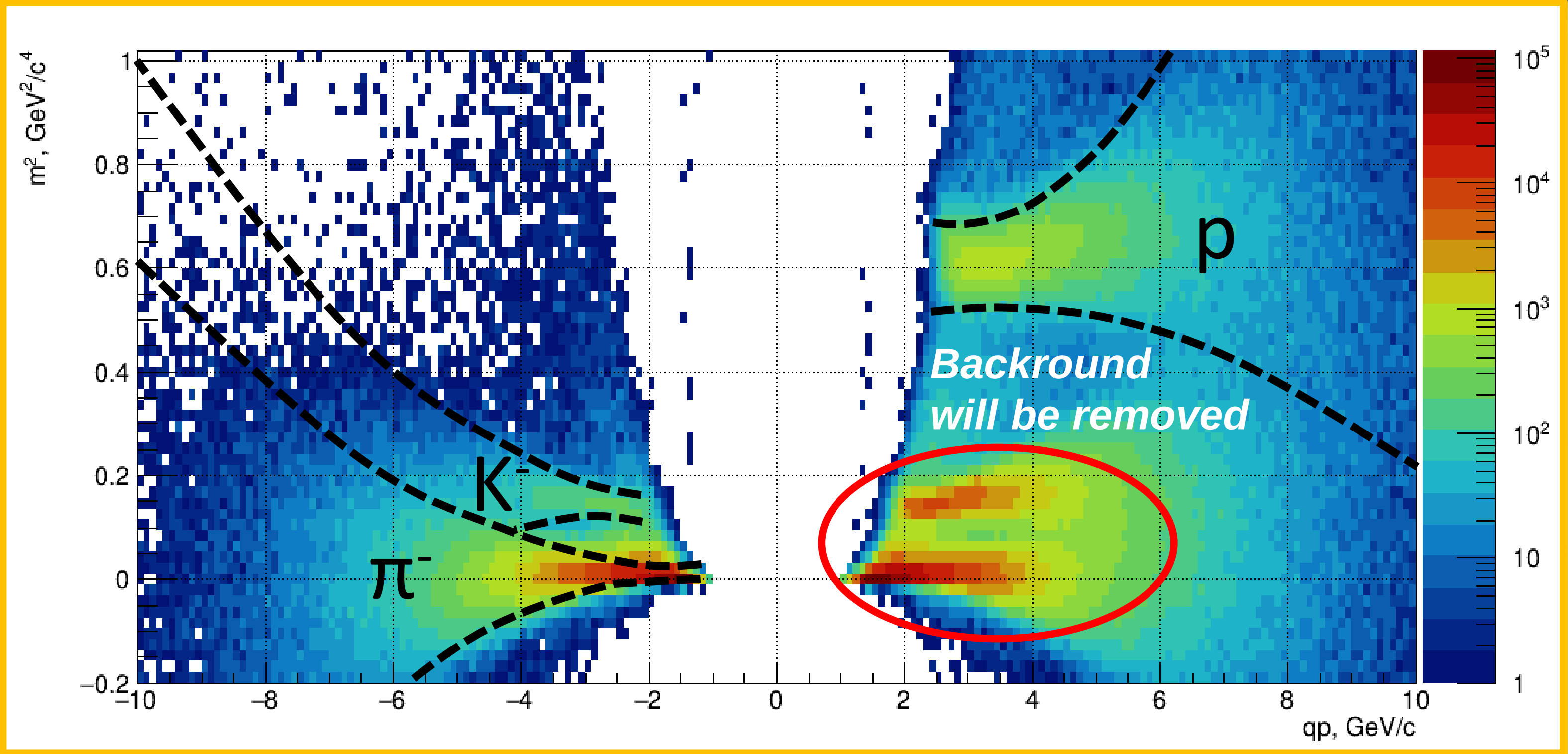




Ω-background suppression strategy

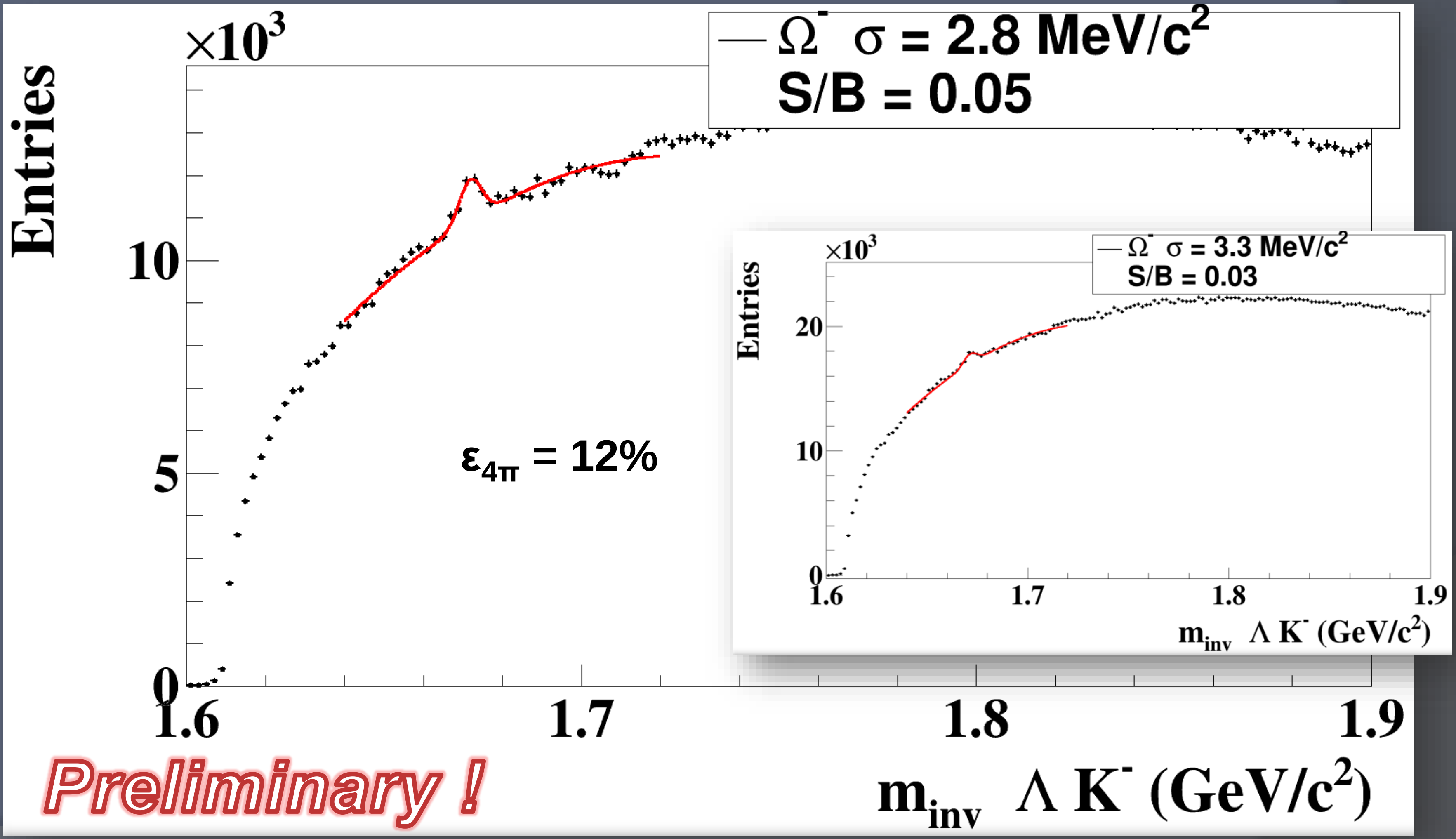
5×10⁶ central UrQMD Au+Au events at 12 A GeV/c

- tracks in STS without TOF hit – without PID
- tracks with TOF hit



Ω-background suppression with PID

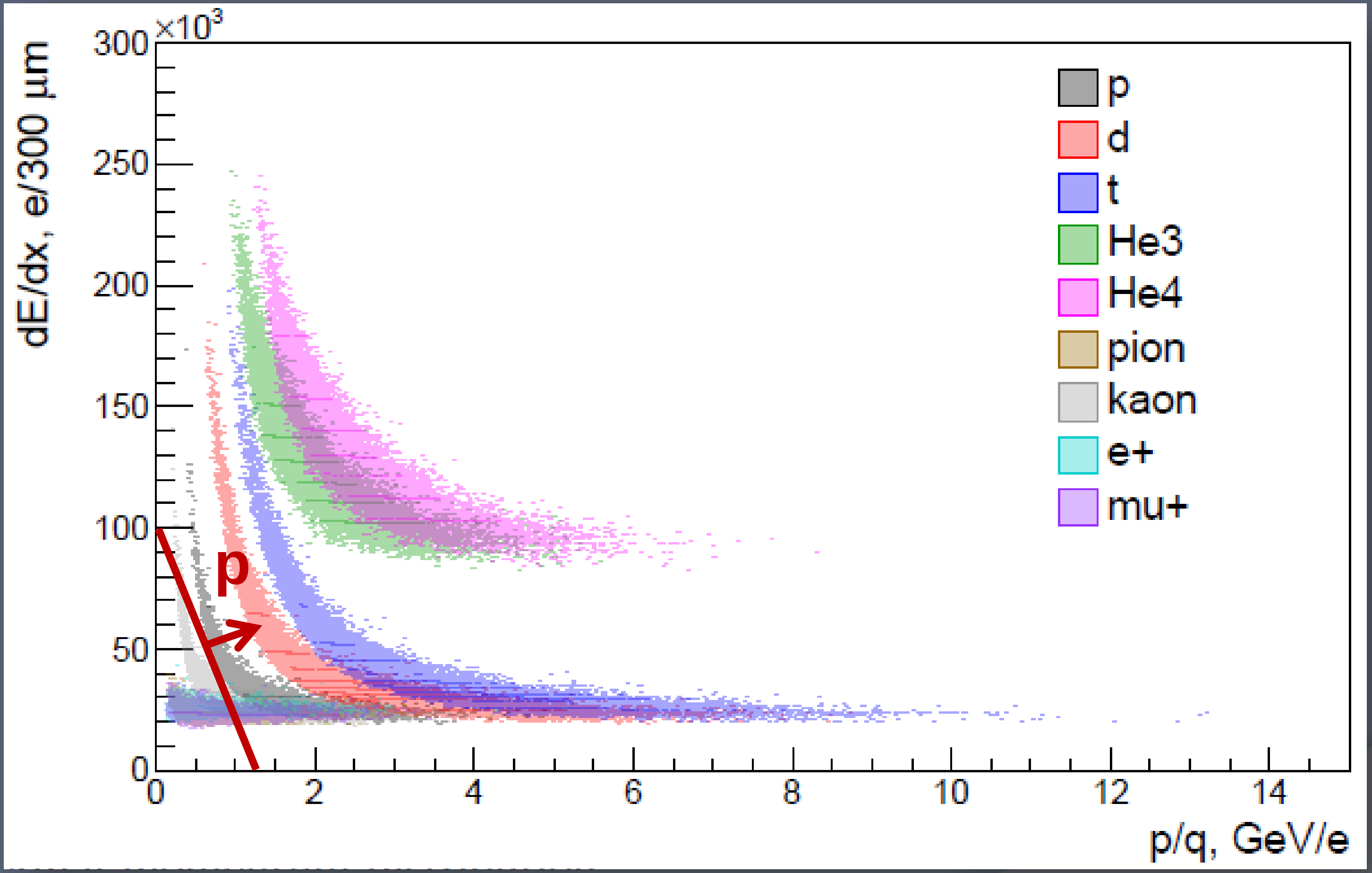
5×10^6 central UrQMD Au+Au events at 12 A GeV/c



Preliminary !

p PID in STS (?)

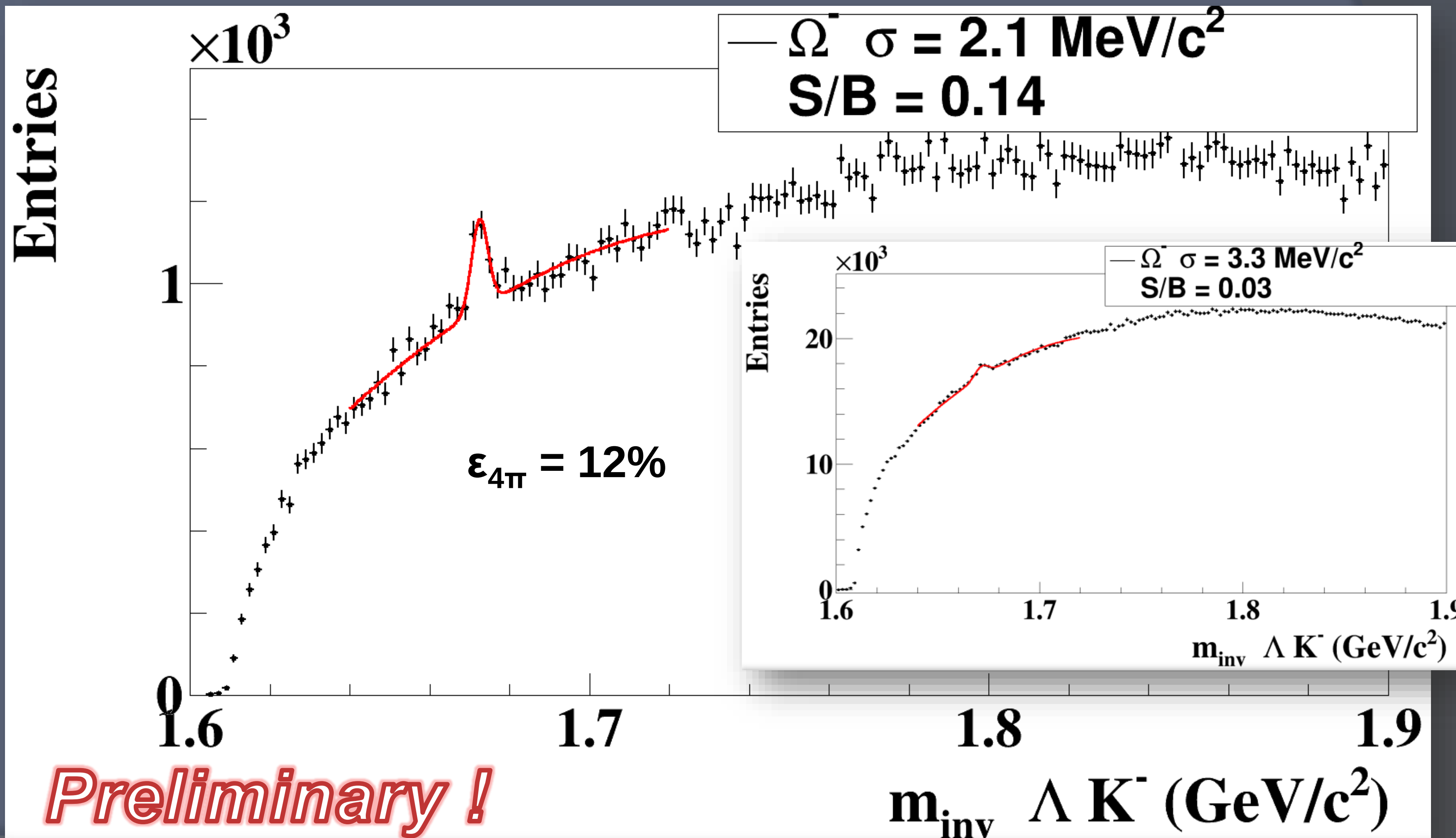
central UrQMD Au+Au events at 2 A GeV/c + light fragments



Picture: Maxim TEKLISHYN

Ω-background suppression with PID in STS and TOF

5×10⁶ central UrQMD Au+Au events at 12 A GeV/c



Conclusions

- Hypernuclei can be reconstructed without TOF identification using dE/dx information from STS

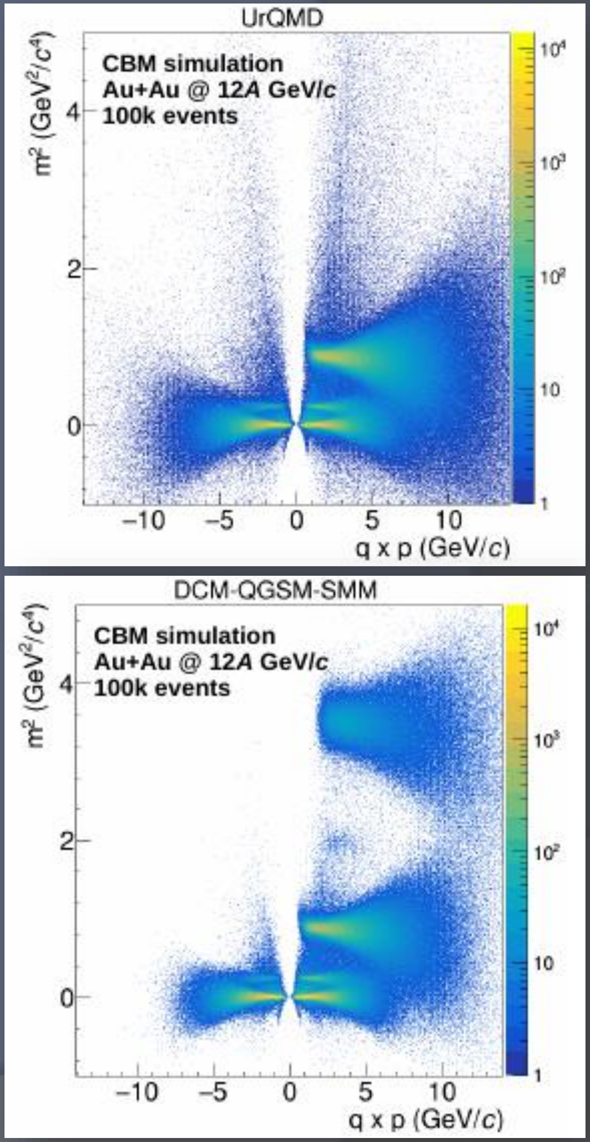
- Hyperons can be identified by the STS without TOF during muon measurements with reduced S/B. Their yield can be used for the physics analysis, and also as consistency check between muon and electron measurements

- The TOF PID for particles passing MUCH helps to suppress background

Next steps

- Hyponuclei reconstruction with muon setup: simulations with DCM-QGSM-SMM as input and GEANT4 for transport
- Implementation of TOF PID for muon setup in standard KFPP
- Use TRD dE/dx separation for light fragments and background suppression

Electron setup



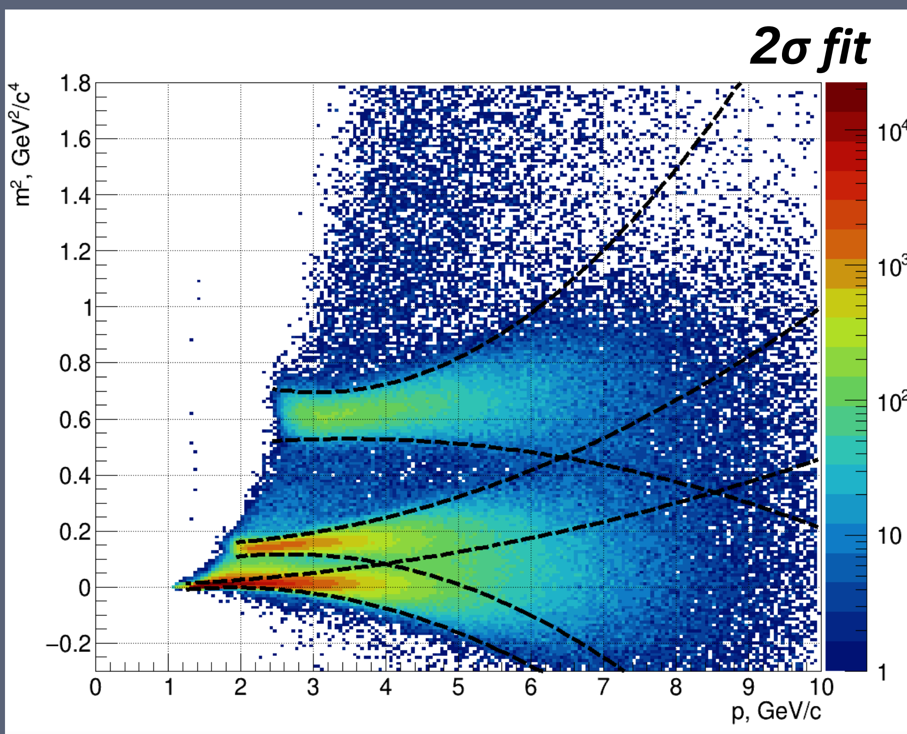
Picture: Oleg GOLOSOV

Backup

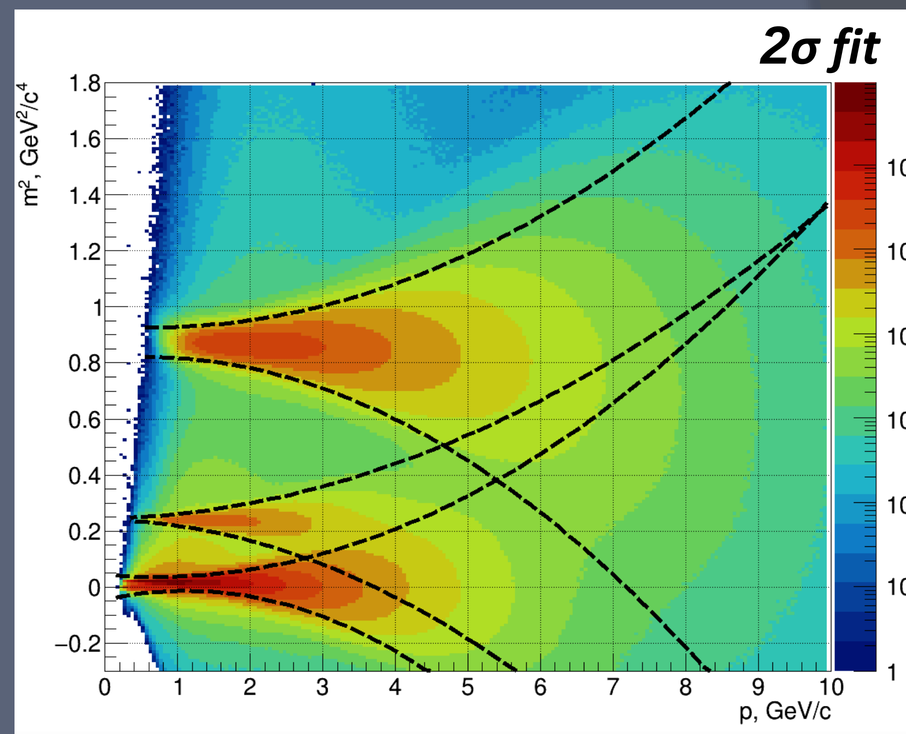
Particle identification in TOF in muon and electron setups

5×10^6 central UrQMD Au+Au events at 12 A GeV/c

muon setup



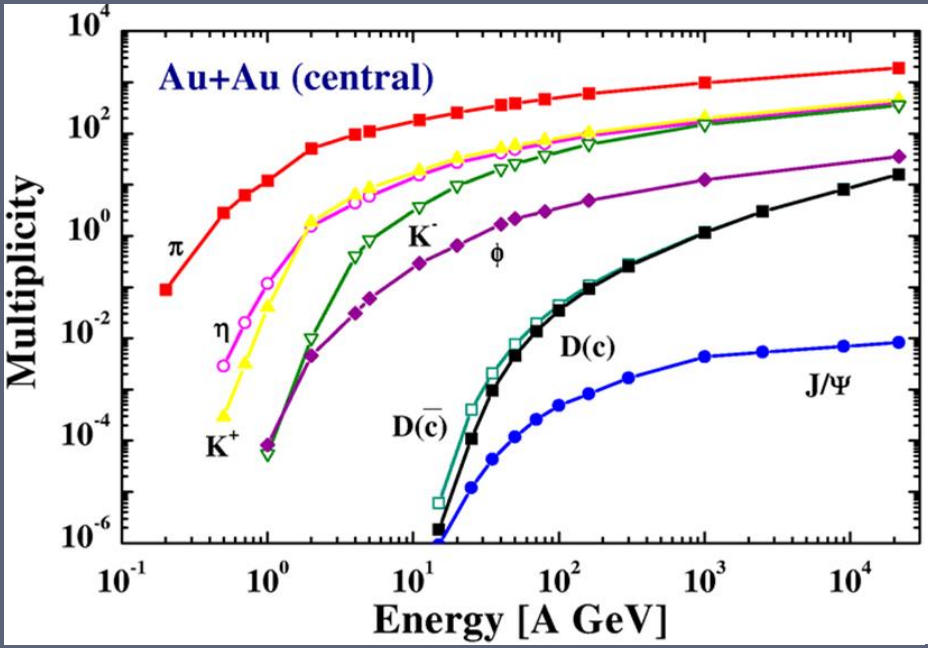
electron setup

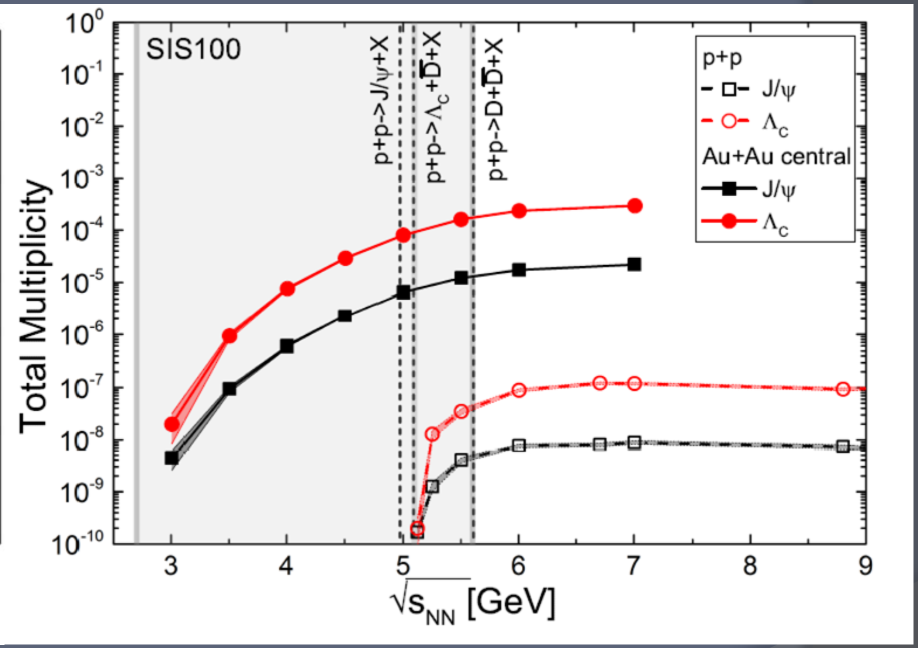


Predictions for J/ψ (SIS100)

W. Cassing, E. Bratkovskaya, A. Sibirtsev
Nucl. Phys. A 691 (2001) 753

J. Steinheimer, A. Botvina, M. Bleicher
arXiv:1605.03439v1





HSD calculation

http://fias.uni-frankfurt.de/~phsd-project/HSD

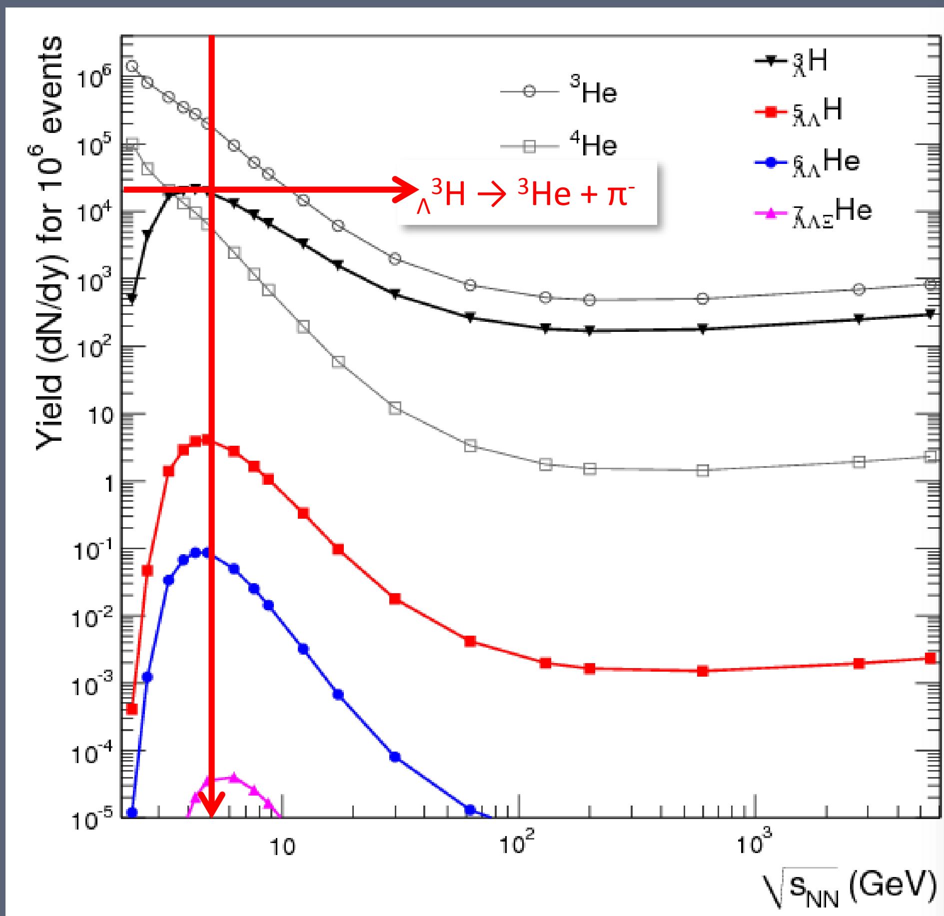
UrQMD calculation
including subthreshold charm production via
$N^* \rightarrow \Lambda_c + D$ and $N^* \rightarrow N + J/\psi$

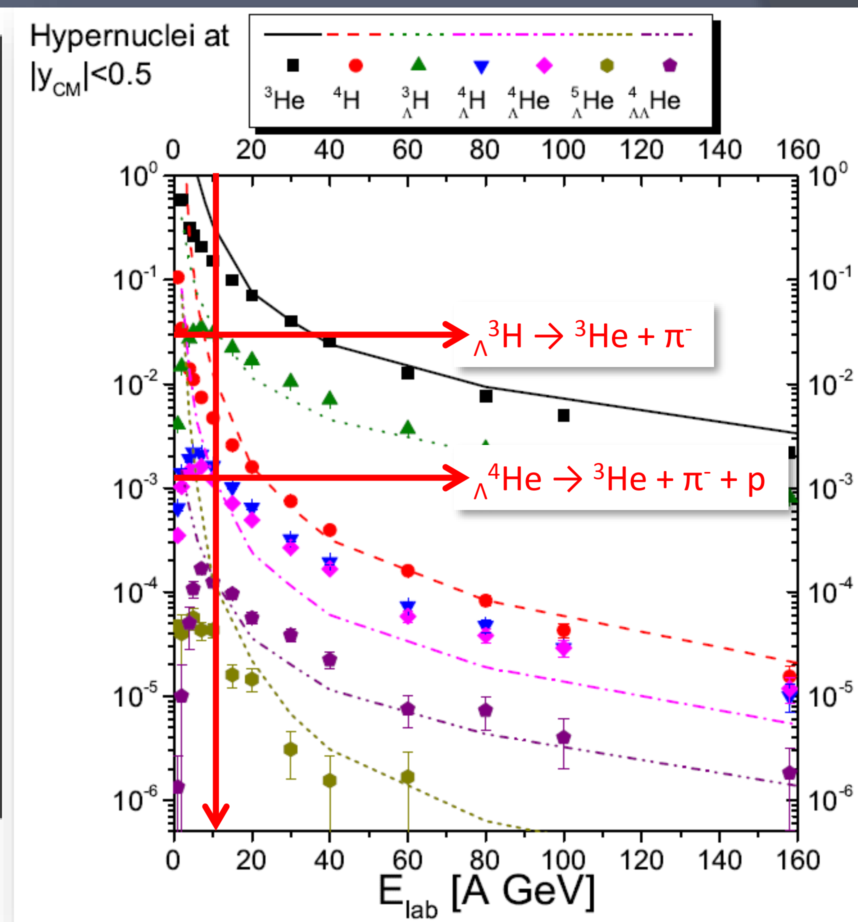
Central Au+Au collisions 10 A GeV : $M_{J/\psi}$ = $\underline{1.7 \cdot 10^{-7}}$

Central Au+Au collisions 10 A GeV: $M_{J/\psi}$ = $\underline{5 \cdot 10^{-6}}$

Hypernuclei production in A+A collisions

central UrQMD Au+Au events at 12 A GeV/c





A. Andronic et al., Phys. Lett. B697 (2011) 203

J. Steinheimer et al., arXiv:1203.2547 (2012)