MPD physics performance studies: status and plans

Vadim Kolesnikov
(VBLHEP, JINR)

on behalf of the group

MPD Collaboration meeting
JINR, Dubna, April 16, 2019

Outline

- **NICA/MPD Stage'1 (2021-23) - a reminder**
- **Simulation for MPD physics cases :**
  - Multistrange hyperons
  - Flow analysis status (charged hadrons and hyperons)
  - Ev-by-Ev fluctuations of net-protons
  - ECAL reconstruction and resonances
  - Femtoscopy and correlations
- **Conclusions**

- Talk is based on the materials presented during the RoundTable “Physics at NICA” 15/04/2019

- Almost all MPD physics simulation activities discussed

Round table "Physics at NICA: status & needs"

Monday, 15 April 2019 from 15:00 to 18:00 (Europe/Moscow)
at Build. 215 (241)

Description Vidyo room: Join

Monday, 15 April 2019

15:00 - 15:10 Status of the MPD hyperon analysis *10'*
Speaker: A.Zinchenko,V.Vasendina, V.Kolesnikov (JINR)
Material: **Slides**

15:10 - 15:20 Flow analysis status *10'*
Speaker: P.Parfenov, A.Taranenko (MEPhI)
Material: **Slides**

15:20 - 15:30 Hyperon flow *10'*
Speaker: Mr. Nikolai Geraksiev (JINR)
Material: **Slides**

15:30 - 15:40 PID for charged hadrons and fluctuations *10'*
Speaker: Mr. Alexander Mudrokh (JINR)
Material: **Slides**

15:40 - 15:50 Femtoscopy *10'*
Speaker: L.Malinina (MSU), G.Nigmatkulov (MEPhI)
Material: **Slides**

15:50 - 16:00 ECAL reconstruction and analysis *10'*
Speaker: Dr. Vicktor Riabov (PNPI)
Material: **Slides**

16:00 - 16:10 Centrality determination *10'*
Speaker: A.Ivashkin (INR)

16:10 - 17:10 Discussion on urgent problems & tasks (PWGs and conveners, data format, accou *1h0'*
Speaker: ALL

NICA/MPD experimental strategy in 2021-23

***Experimental strategy**: energy and system size scan from 4 to 11(13,25) GeV to measure a variety of signals systematically changing collision parameters (energy & system size). Reference p+p data will be taken in the same experimental conditions.*

Beam	CM Energy, AGeV	L 2021-23, $cm^{-2} c^{-1}$	L >2023, $cm^{-2} s^{-1}$
Heavy ions (Au)	11	$5 \cdot 10^{25}$	10^{27}
Intermediate (Z/A~0.45)	13	$3 \cdot 10^{26}$	10^{29}
p	25	$\sim 10^{29}$	10^{32}

Limitations by the accelerator:

- *lower luminosity (w/o electron cooling for the collider) <10^{26} @ 7-11A GeV and ~10^{24} at 4A GeV*
- *extra reduction by 40% because of a larger interaction region (beam diamond)*

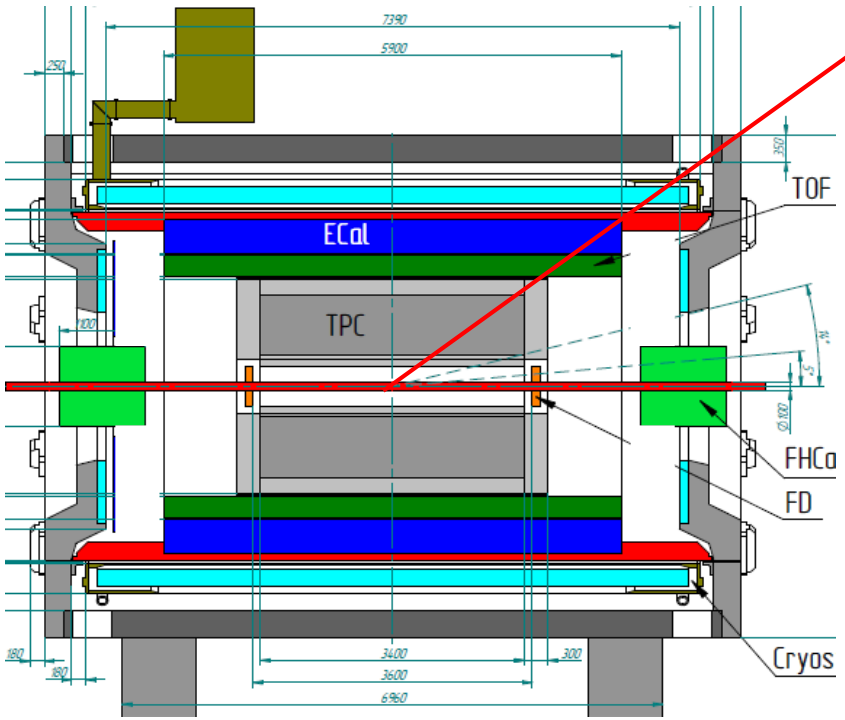
Event rates (rough estimates)

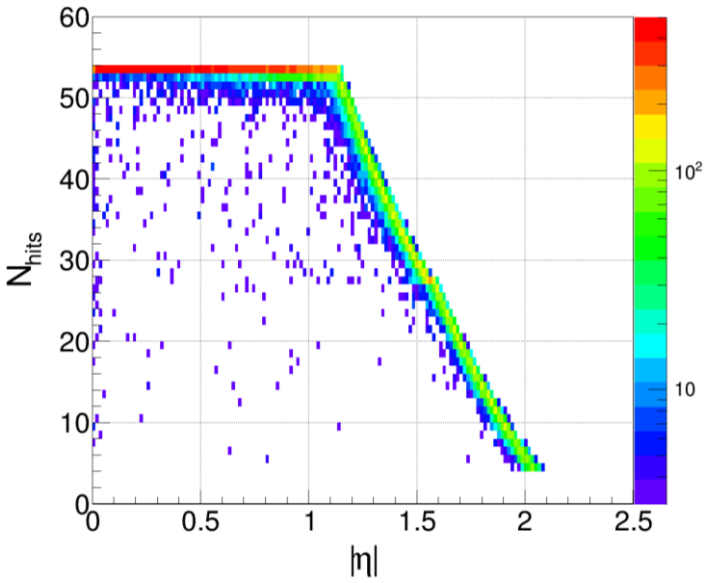
- Au+Au (MinBias, duty factor=0.5) ~100 Hz at 7-11A GeV and only 2 Hz at 4A GeV. For a 10-day beam time period per energy → ~ 90M collisions at 7-11 GeV
- Intermediate: ~100M in 4 days at 7-11 GeV

Beam	Luminosity ($cm^{-2} c^{-1}$)		Data sample per 1 week at √s = 4 GeV	Data sample per 1 week at √s = 11 GeV
	√s=4 GeV	√s=11 GeV		
^{197}Au	$7 \cdot 10^{24}$	$5 \cdot 10^{25}$	$9.1 \cdot 10^{6}$	$6.3 \cdot 10^{7}$

The Goal now is: to define a data taking scenario and potential probes for 2021-23

MPD setup during Stage'1

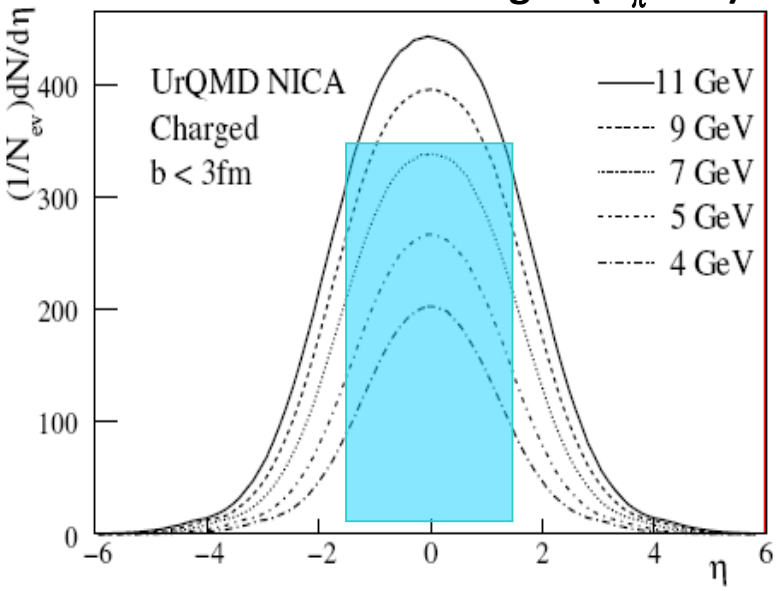


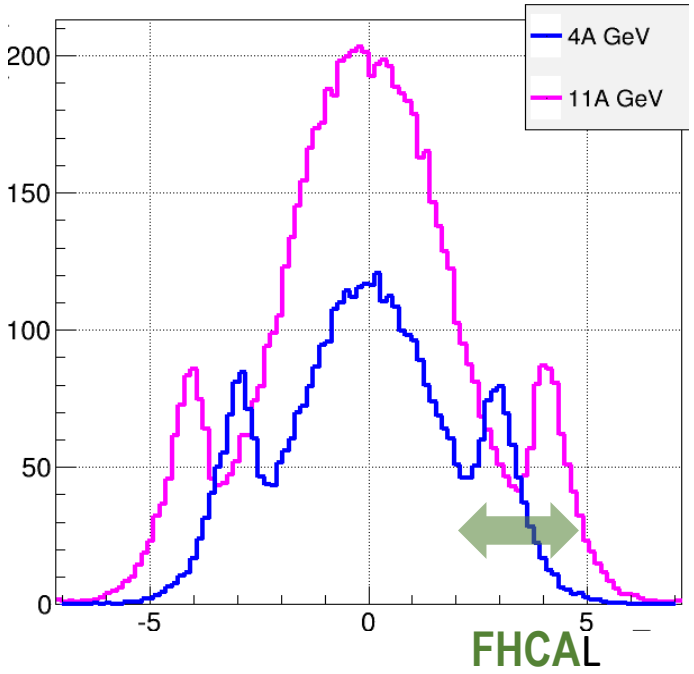


MPD at Stage'1:

- ***TPC*** *tracking:* $|\eta|<1.6$ *(Npoints>15)*
- ***TOF & ECAL*** *coverage:* $|\eta|<1.3$
- ***PID****: combined* $|\eta|<1.3$, $0.1<pT<3$ *GeV/c, limited in* $1.3<|\eta|<1.6$ *(only dE/dx)*

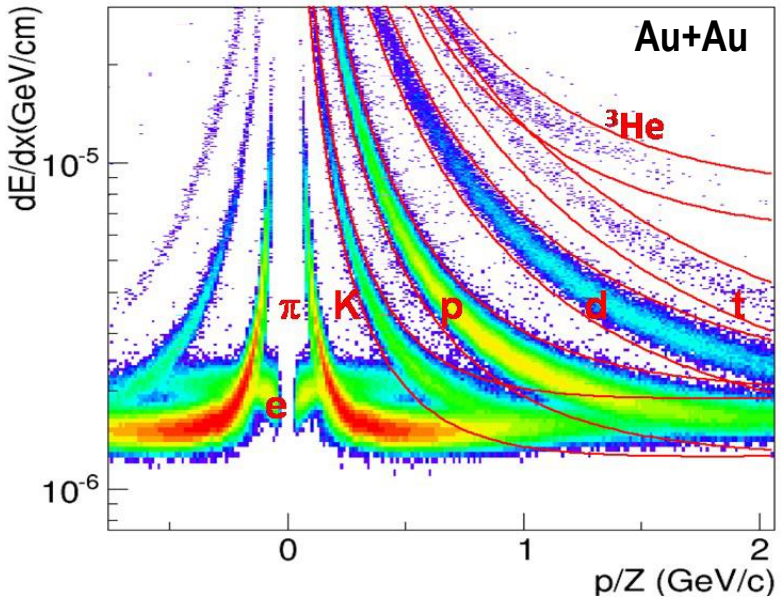
Barrel: ~60% for charged (σ_π~1.3)

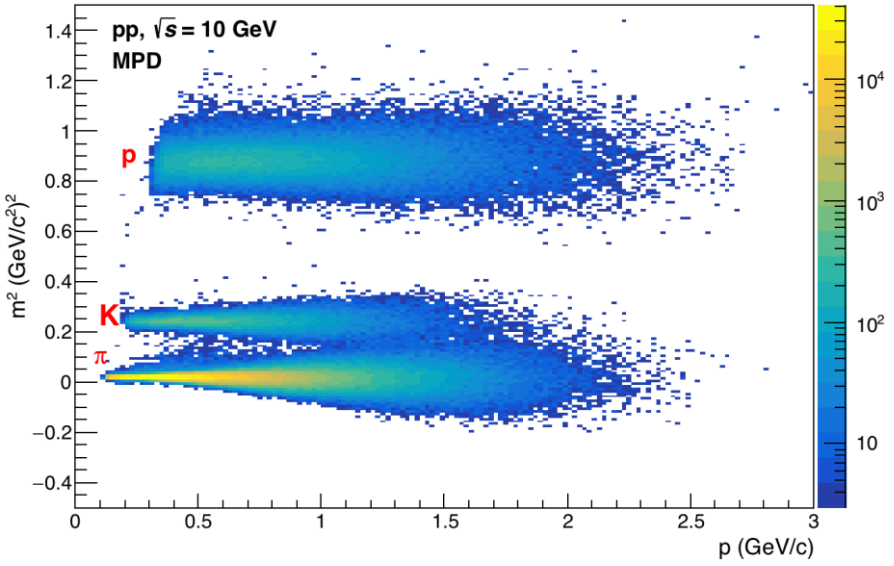


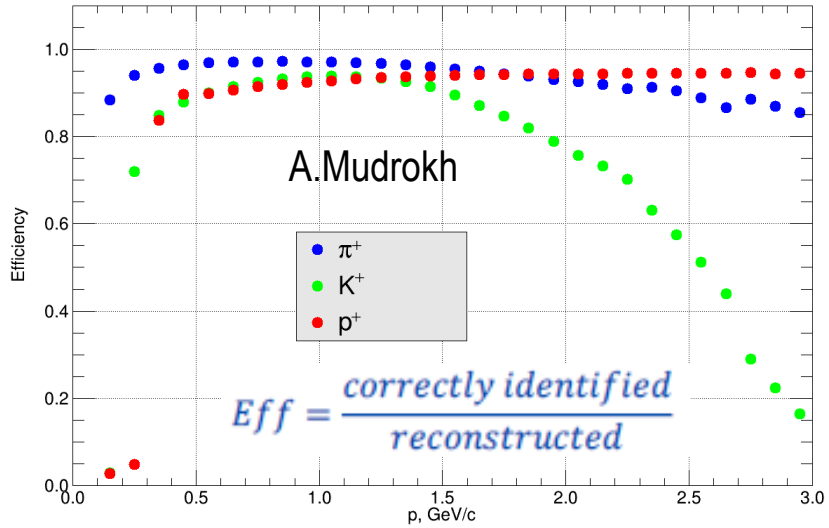


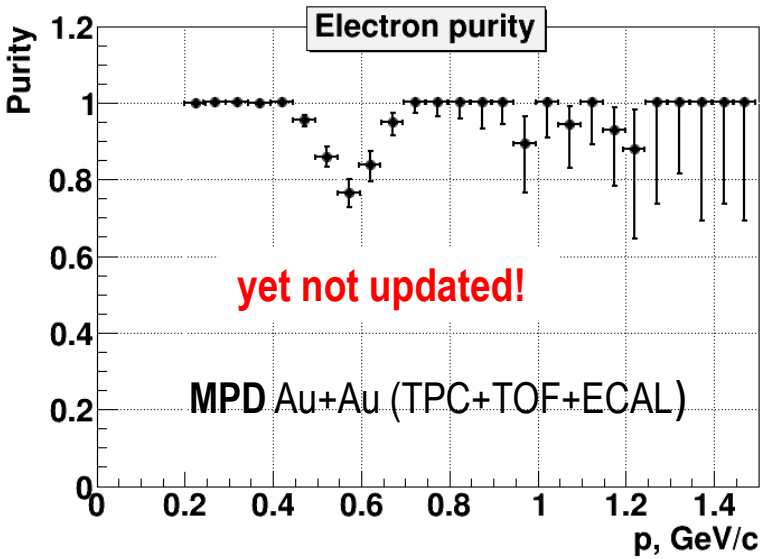
- Phase-space coverage & event characterization
- Low material budget, magnetic field – pT cutoff
- Number of points – tracking and PID

MPD PID performance







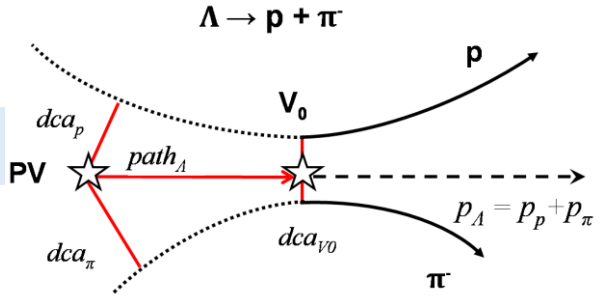


- Combined (dE/dx+TOF) PID for hadrons provides π/K up to 2 GeV/c and K/p up 3 GeV/c
- An extra hadron suppression in the electrons will be provided by ECAL

Strangeness at NICA/MPD: news on (anti)hyperons

V.Vasendina, A.Zinchenko, V.Kolesnikov (JINR)

Study of the centrality dependence for hyperon spectra & yields



Data set: 8M minbias Au+Au @ 11 GeV (PHSD)

MPD setup: TPC & TOF, ideal centrality binning (no FHCAL)

Selection criteria: $|\eta|< 1.3$, $N_{hits} \geq 10$ + standard quality/analysis cuts

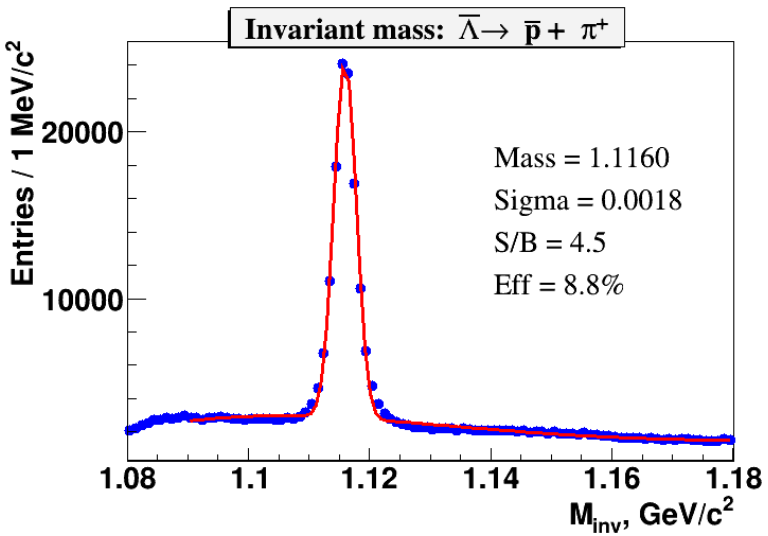
Realistic track reconstruction: clustering in TPC

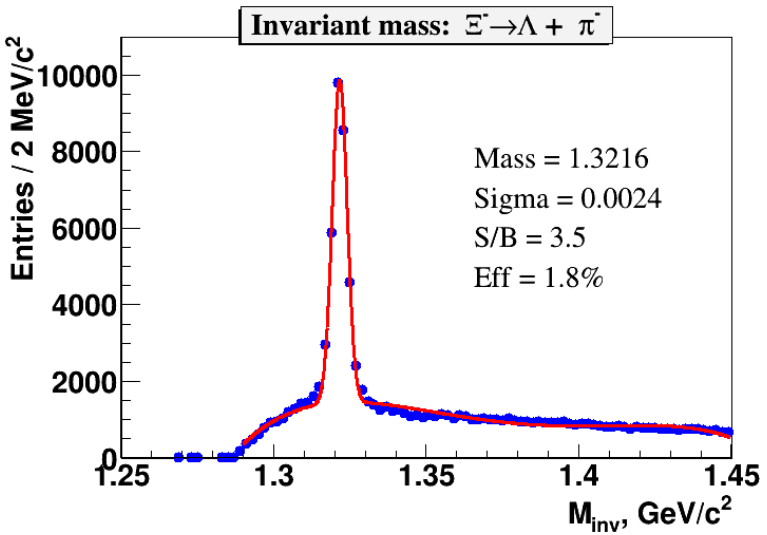
Realistic PID: combined dE/dx+TOF

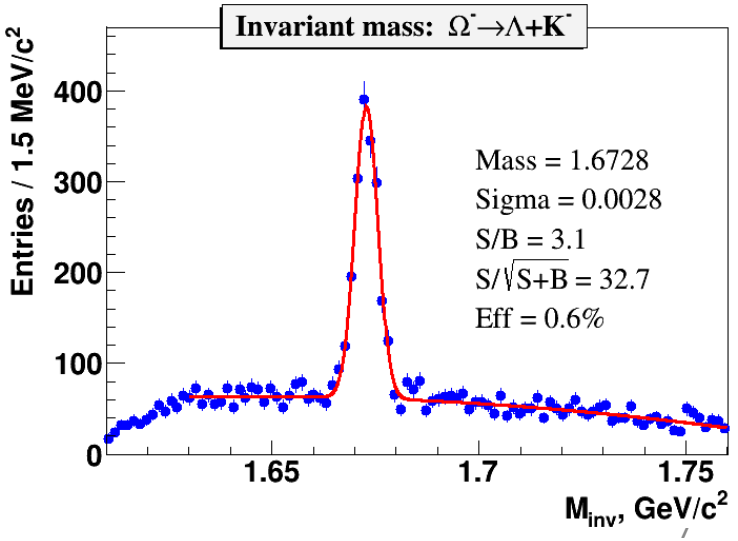
Analysis: secondary vertex finding technique

- **PV** – primary vertex
- **V_0** – vertex of hyperon decay
- **dca** – distance of the closest approach
- **path** – decay length

← All pT →

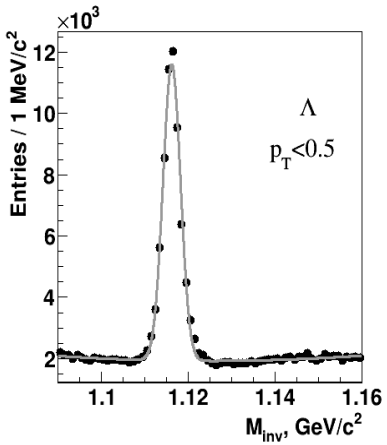


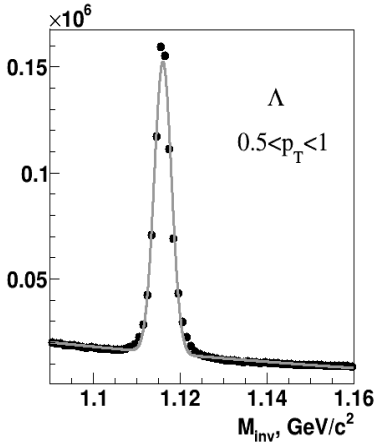


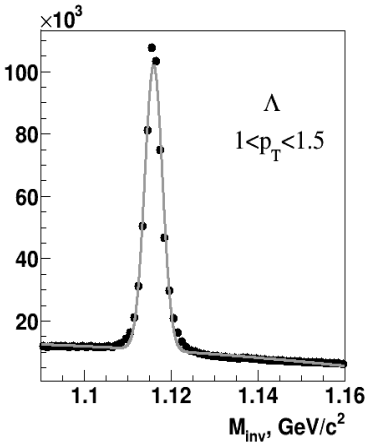


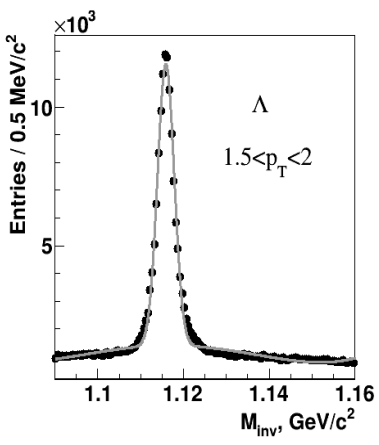
Reconstructed (anti)Lambda in pT-bins

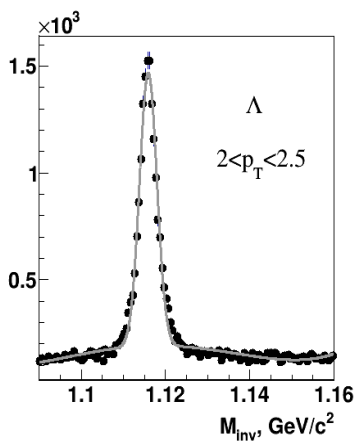
Λ

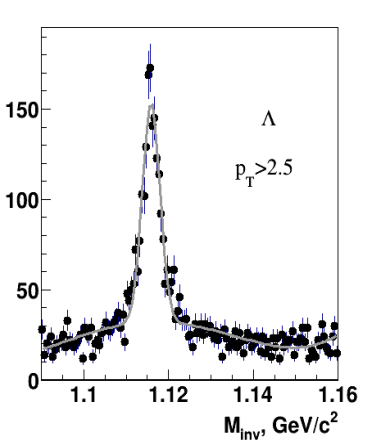




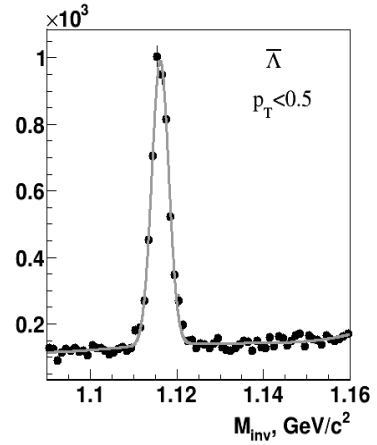


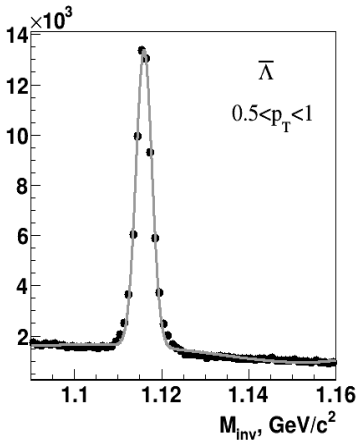


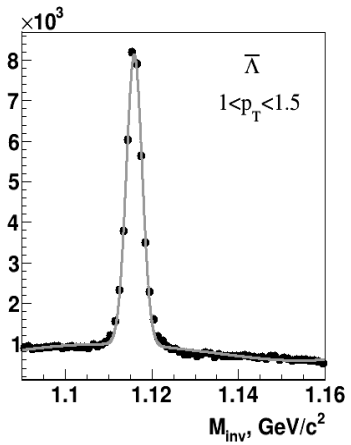


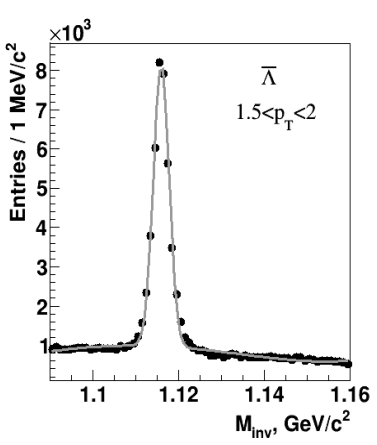


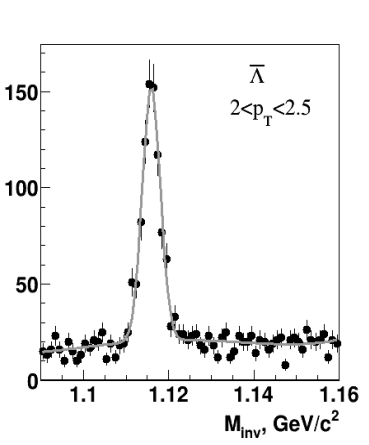
$\overline{\Lambda}$

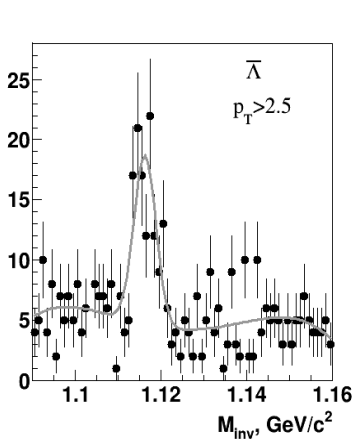




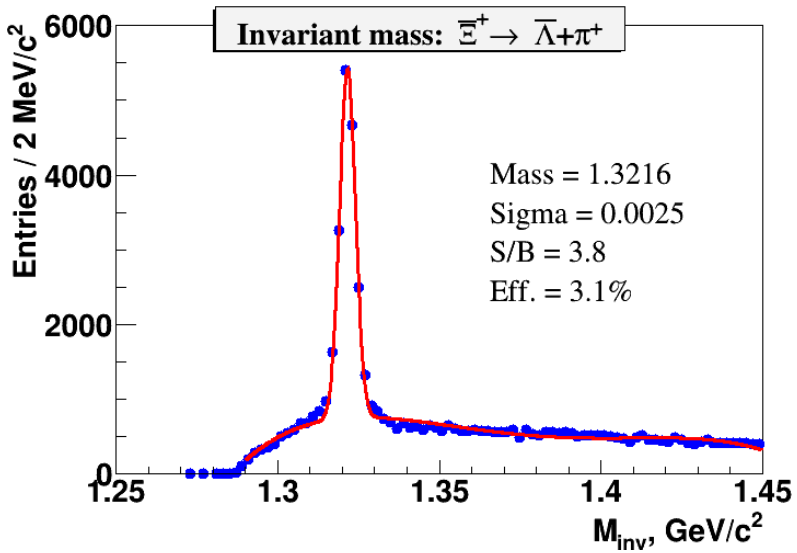


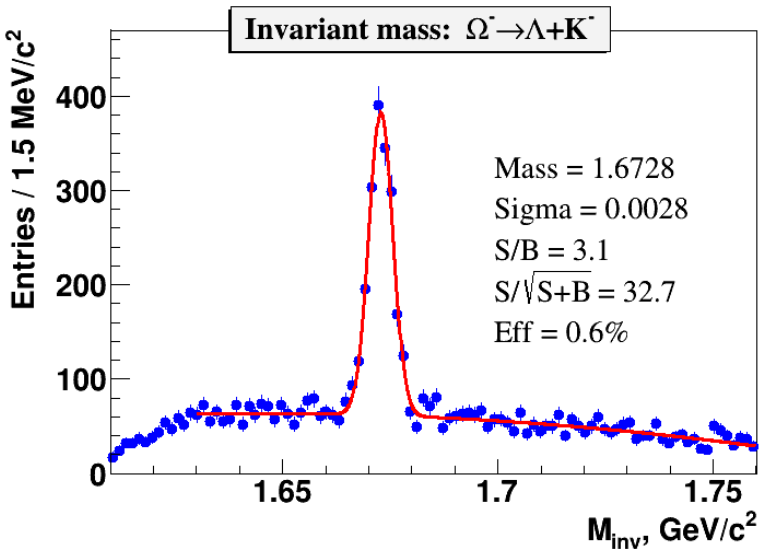


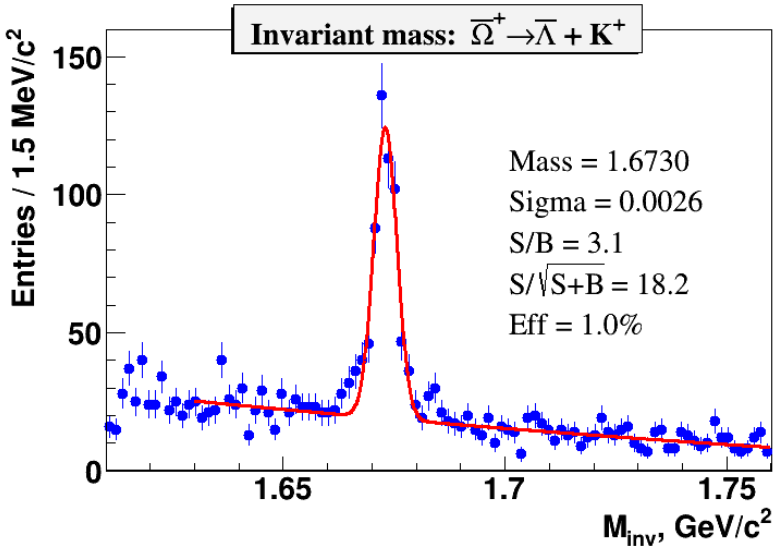


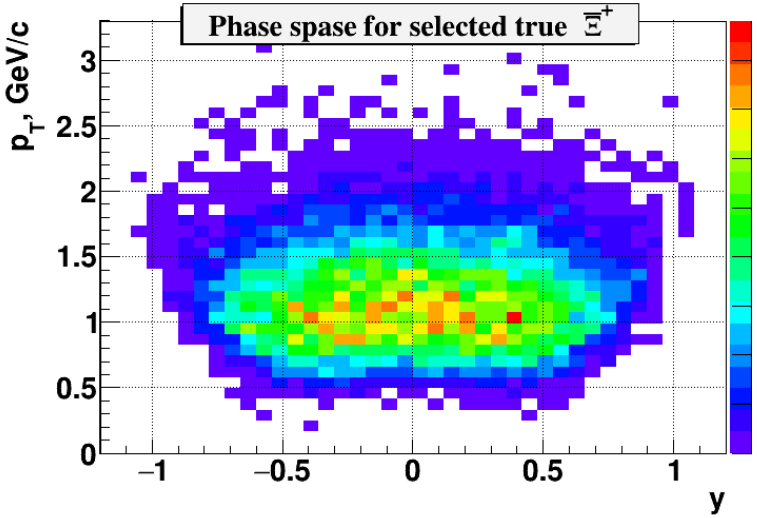


Ξ^+, Ω^-, Ω^+ reconstruction, phase space, statistics

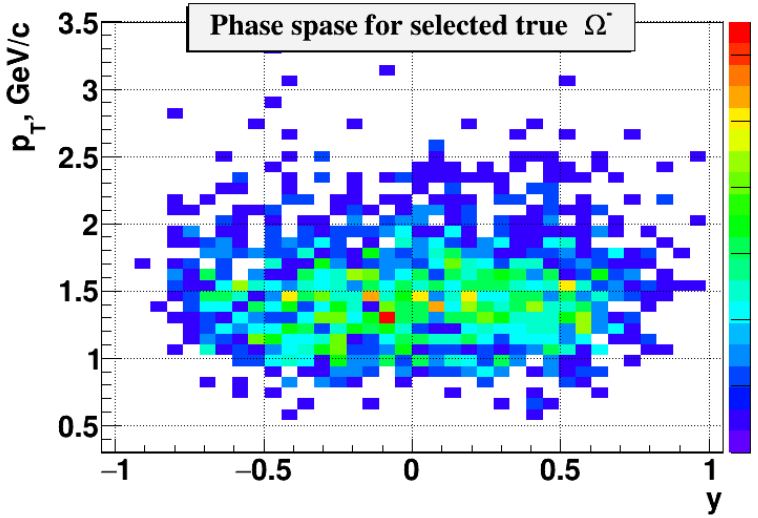




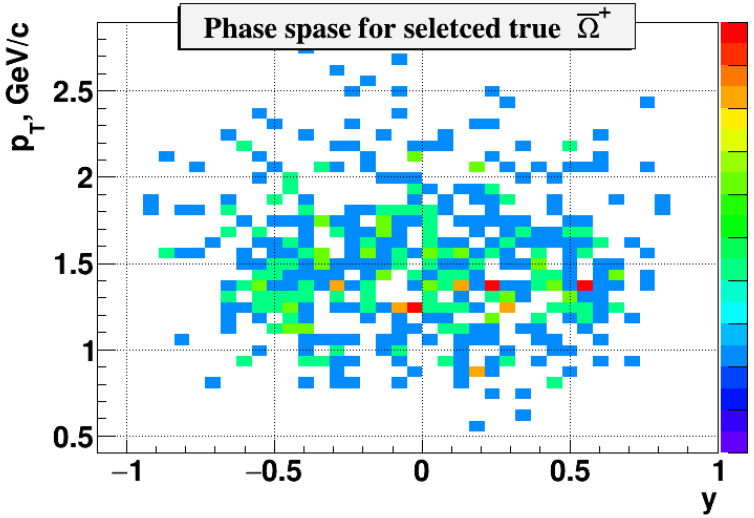




15089 candidates

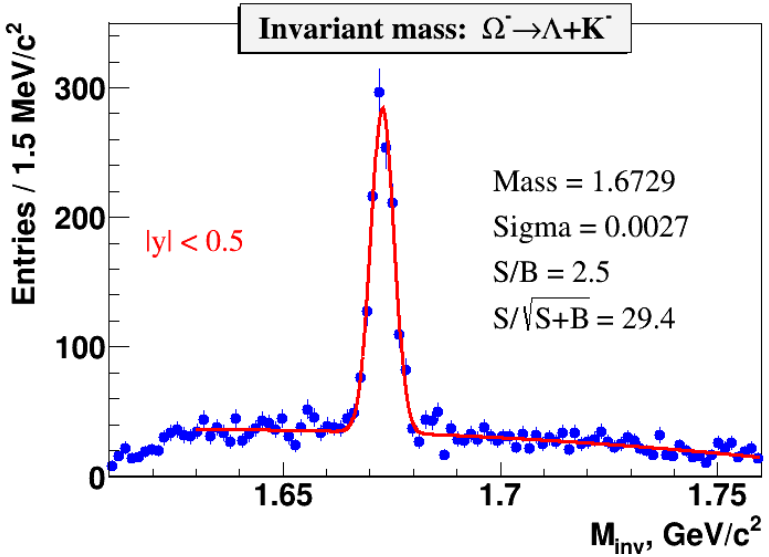


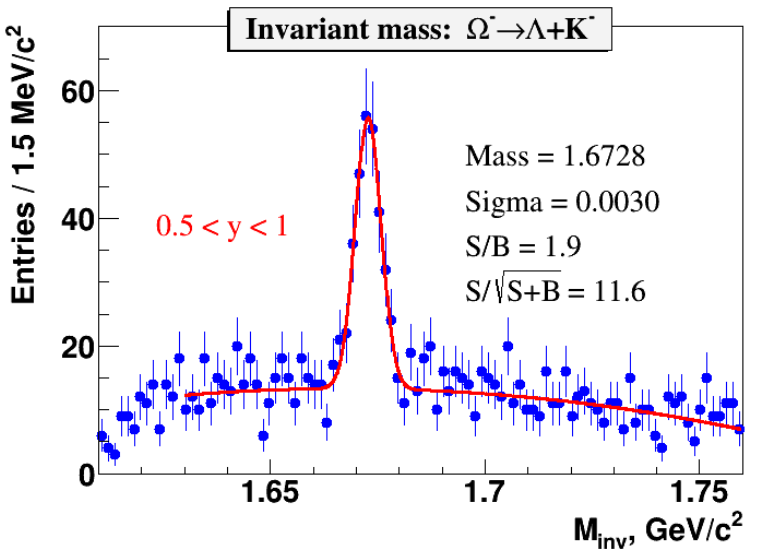
1531 entries

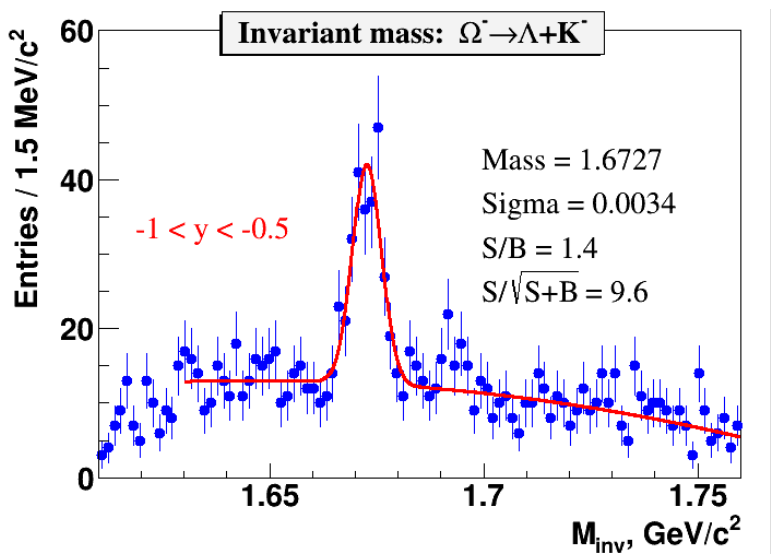


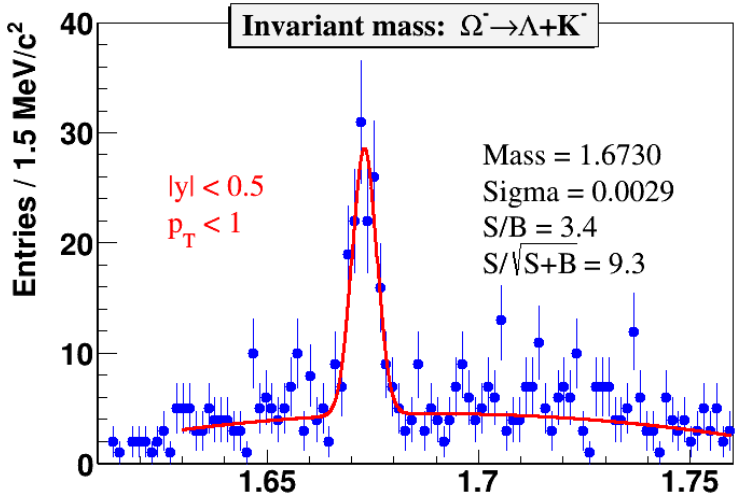
502 entries

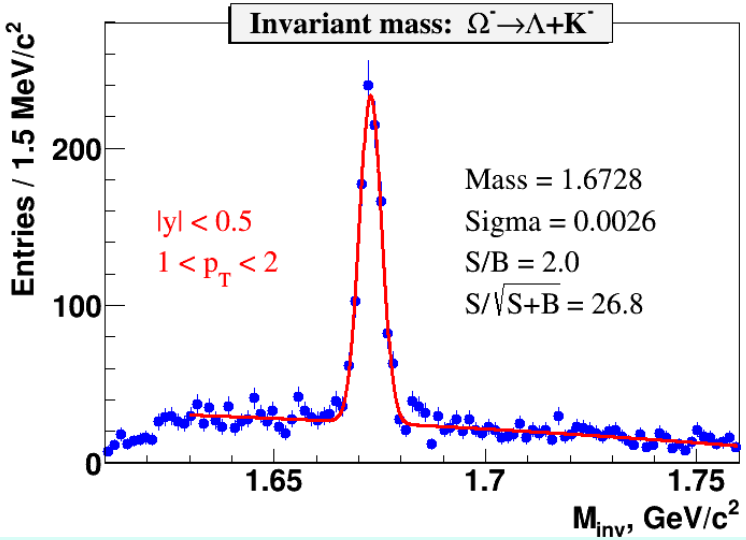
Ω^- statistics in bins of y & p_t

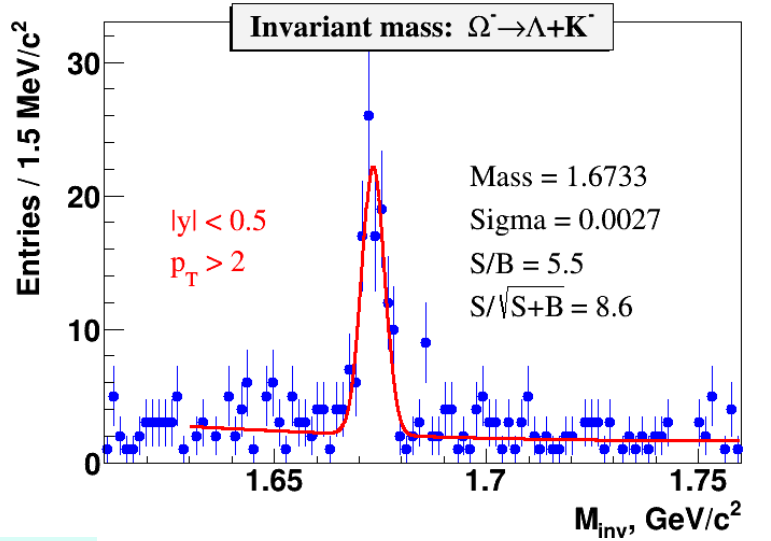










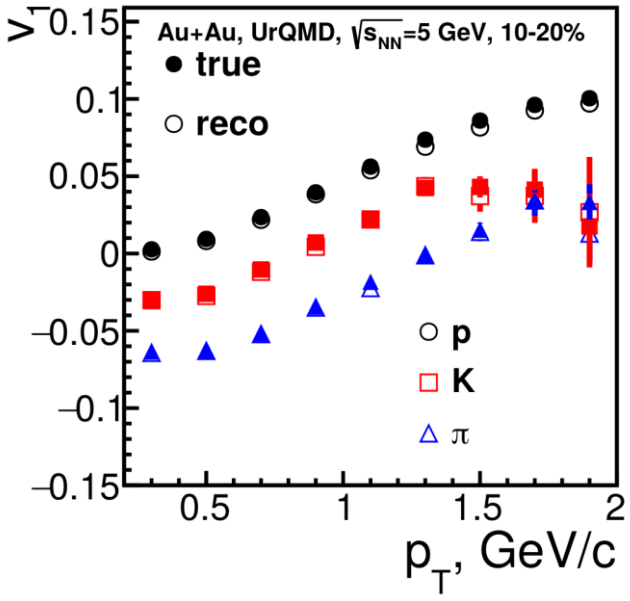


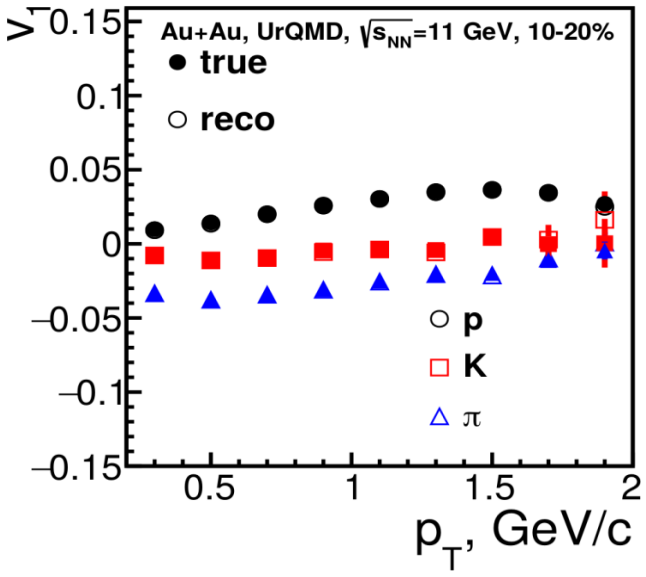
Status of the study & plans

- Analysis for (anti)Lambda invariant spectra finished
- Analysis for Ksi ongoing, heavier specie need larger statistics

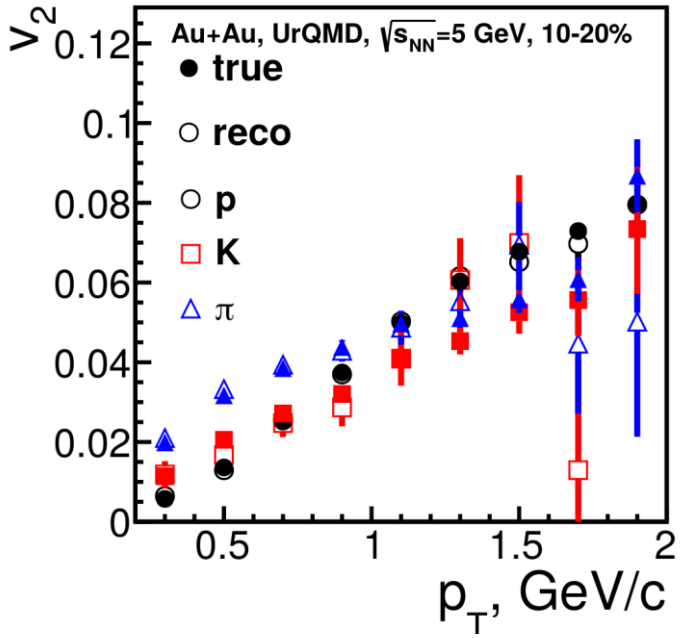
Anisotropic flow at MPD

A.Taranenko (MEPhI) + team, I.Selyuzhenkov (GSI, MEPhI)



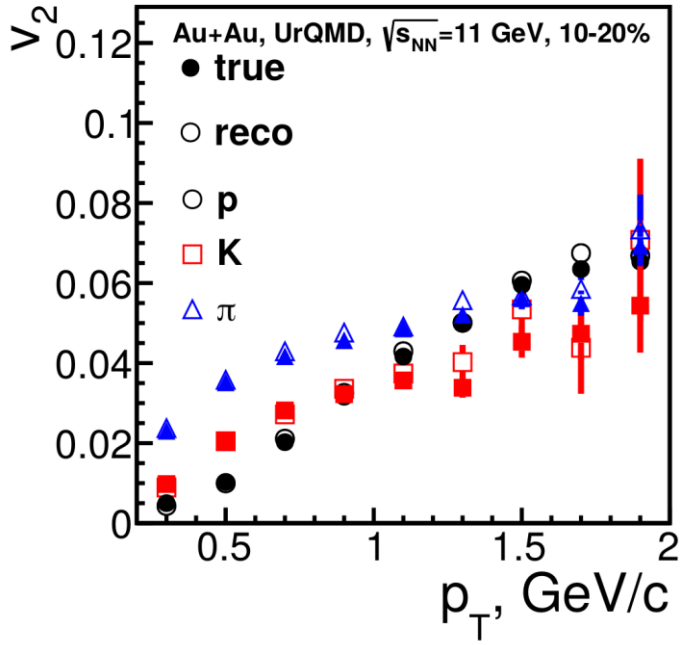


- 4M Au+Au events at 5 and 11 GeV
- Recent MPD reconstruction chain, realistic PID
- N_{points}>32, DCA cut, 0.2<pT<2 GeV/c, |η|<1.5
- Hadronic shower simulation in FHCAL (GEANT4)
- Event plane reconstruction with FHCAL



Plans for 2019:

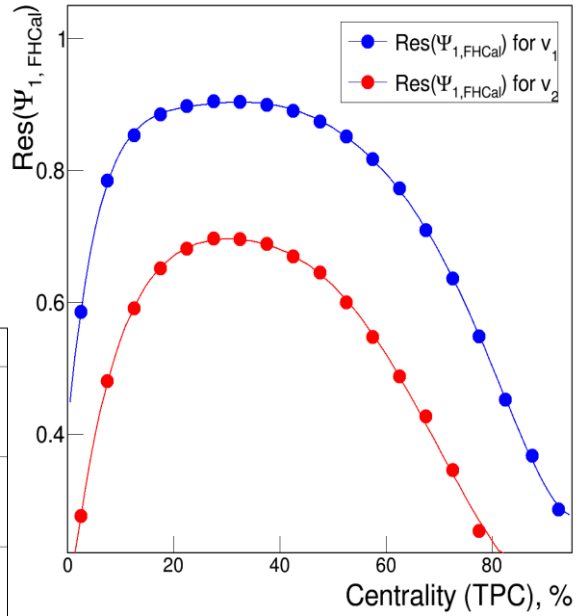
- Detailed comparison of HI data with models at NICA energies
- Unified format of reco data for the flow picoDSTs
- Detailed systematic study of anisotropic flow of charged hadrons (different methods of centrality and event plane determination, alternative methods for flow coefficients extraction)

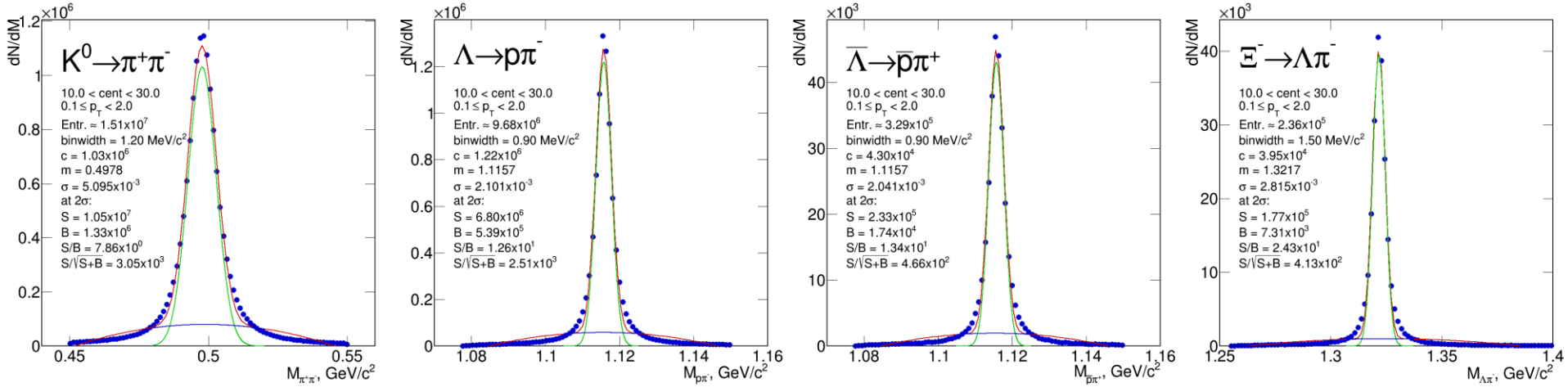


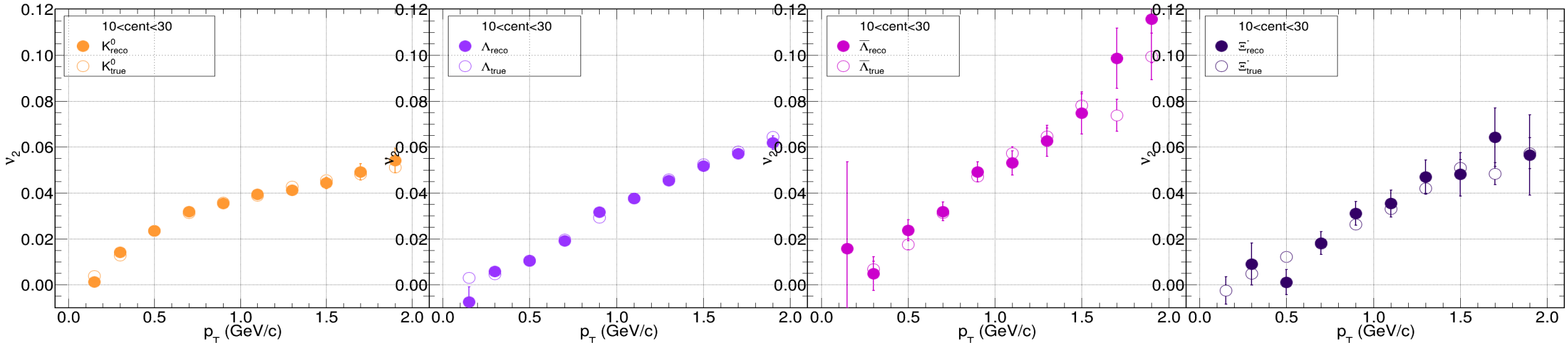
Hyperon Flow

N.Geraksiev (JINR, Plovdiv Univ.)

- 15M Au+Au at 11 GeV (UrQMD)
- Recent tracking & V0 reco, MC PID
- Event plane - FHCAL







Ev-by-Ev fluctuation: cumulants of conserved quantities

A. Mudrokh (JINR)

- Au+Au collisions central (0<b<1 fm), only 50k UrQMD events!
- Cumulants within |y| < 0.5 and 0.3 < pT < 1.8 GeV/c (0.4<pT<0.8 GeV/c to compare with STAR)
- Combined PID (protons instead of net-protons)

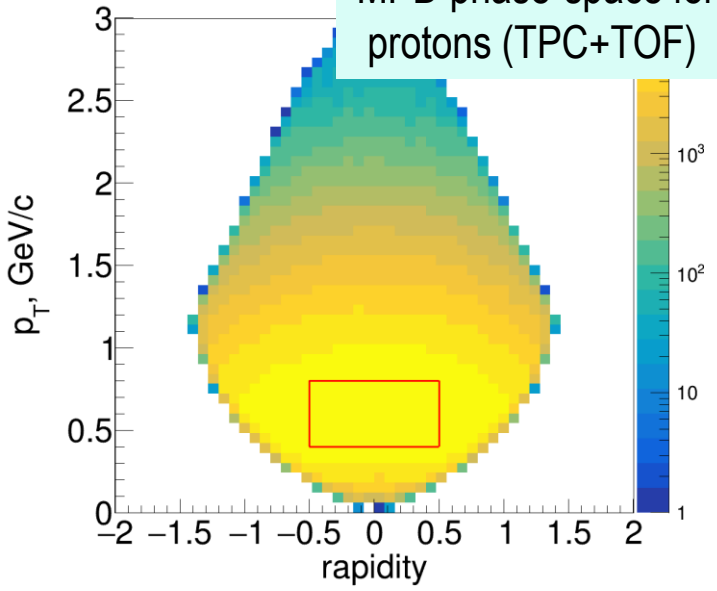
Cumulant ratios are compared to susceptibilities, allowing fireball volume cancellation

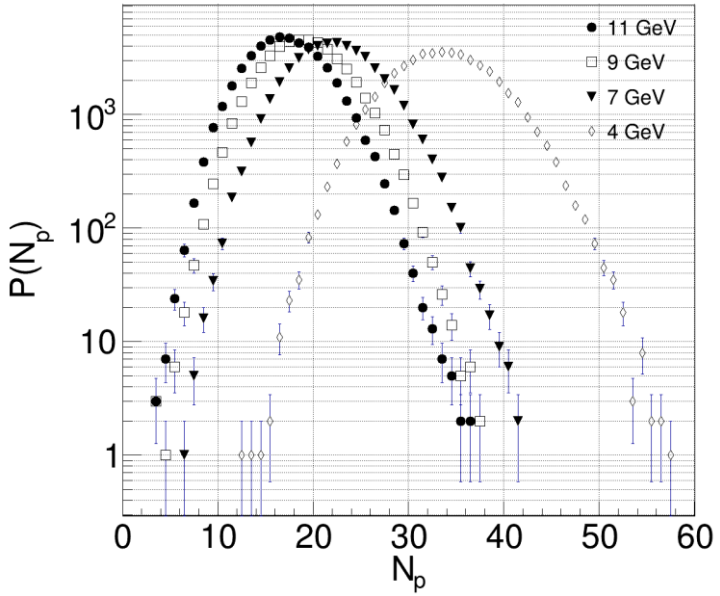
$$S\sigma = \frac{C_3}{C_2} = \frac{\chi_3}{\chi_2}$$

$$\kappa\sigma^2 = \frac{C_4}{C_2} = \frac{\chi_4}{\chi_2}$$

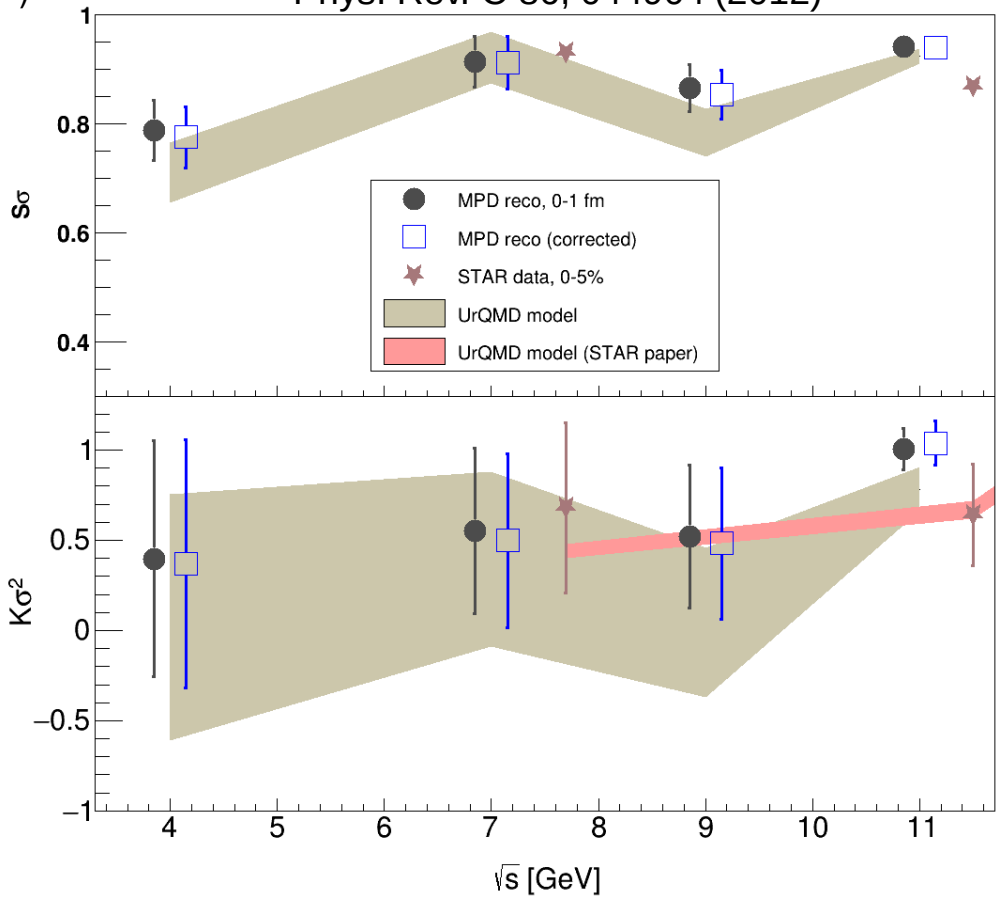
- **Comparison with data in the STAR acceptance Indicates correctness of the feasibility study procedure and results**
- **MPD provides a larger phase-space for E-by-Ev studies (from 30 to 70 PIDed protons/event in the rectangular area)**

MPD phase-space for protons (TPC+TOF)





Corrections for the inefficiency:
A..Bzdak and V. Koch,
Phys. Rev. C 86, 044904 (2012)



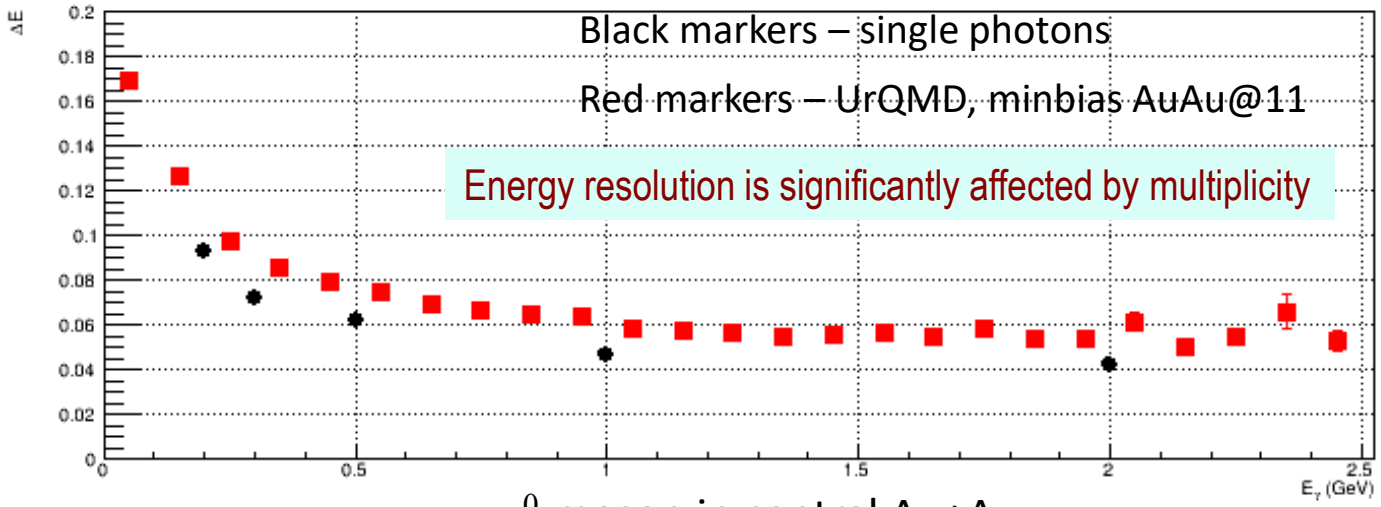
Status of the study & plans

- Improved corrections
- Larger statistics (~10M for several energies)
- Other conserved charges

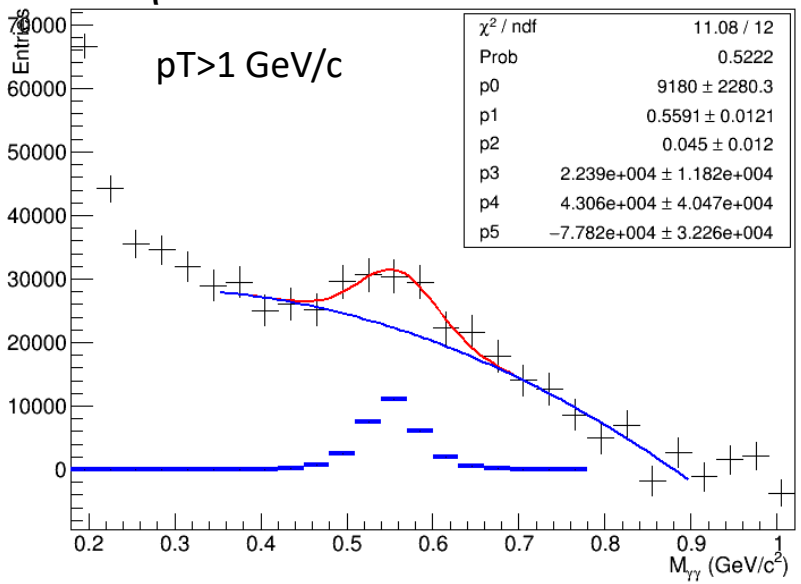
ECAL simulation

V.Riabov + team (JINR, PNPI, Tsinghua)

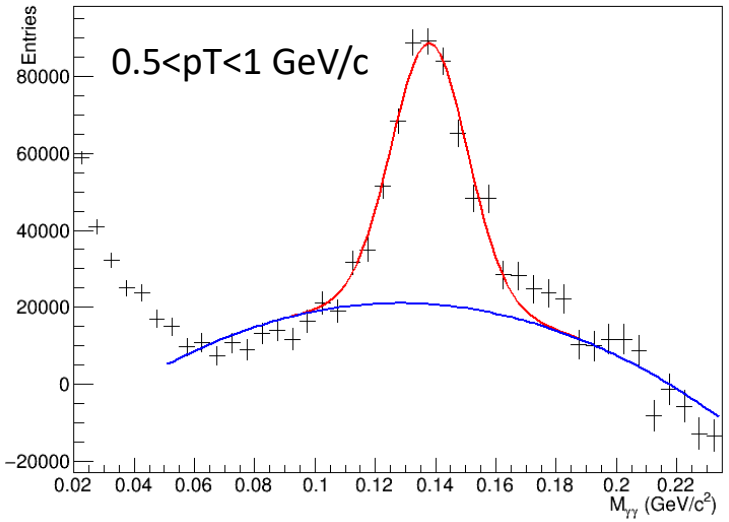
- Several groups participating in ECAL reconstruction & analysis
- Clusterizing, energy/space resolution, e/h separation, overlapping effects investigated
- π^0 (η) reconstruction demonstrated in Au+Au collisions

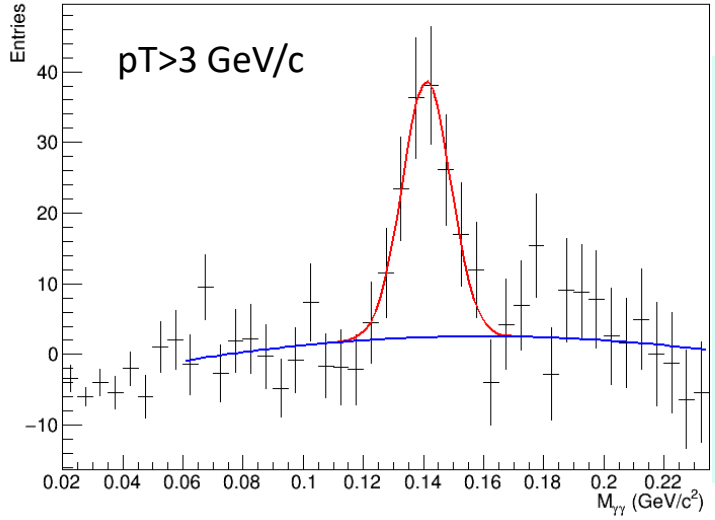


η-meson in minbias Au+Au



π^0-meson in central Au+Au





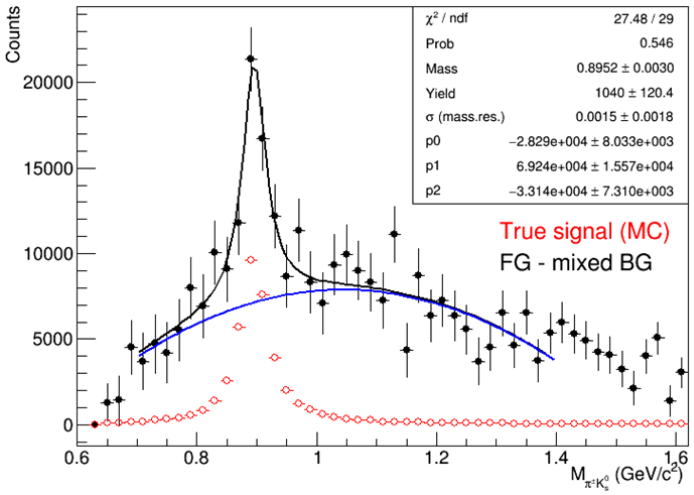
April'19 Status:

- Clusterizer is ready, ECAL performance is predictable
- Need methods for rejection of hadronic and misreconstructed clusters based on the measured shower shape
- New geometry and/or any other low-level modifications requires tuning of the clusterizer and preferred methods

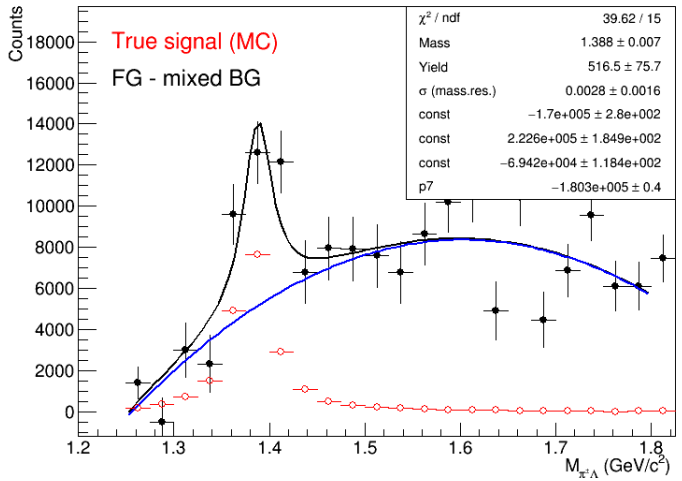
Study of resonances and conversion in MPD

Evgeny Kryshen, Viktor Riabov + PNPI team

$K^*(892)^{\pm} \rightarrow \pi^{\pm}K_s$ ($K_s \rightarrow \pi^+\pi^+$)

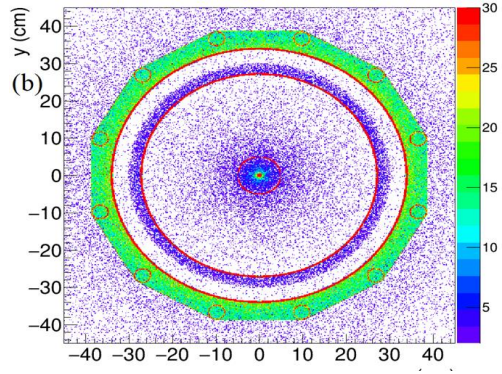


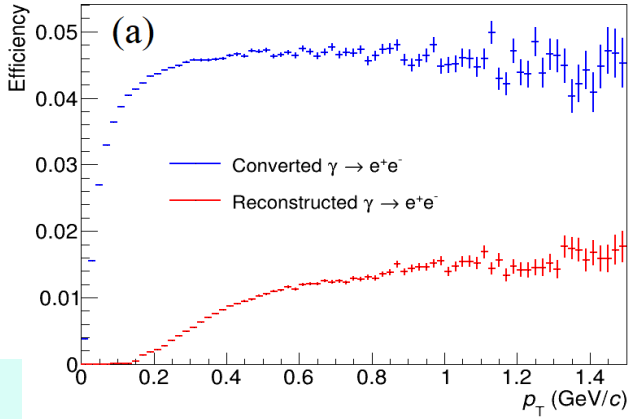
$\Sigma(1385)^{\pm} \rightarrow \pi^{\pm}\Lambda$ ($\Lambda \rightarrow p\pi$)



Resonances:

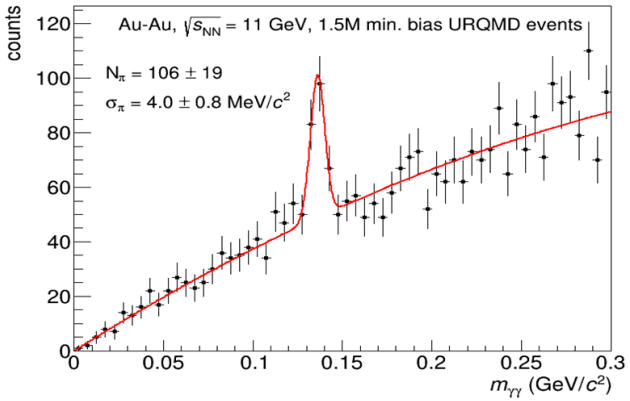
- 300k minbias AuAu@11 UrQMD
- Reconstruction chain for resonances tested, results are promising
- In plans – increasing statistics





Conversion:

- Standard MPD configuration studied
- Reconstruction efficiency for conversion pairs ~1%. It can be increased by adding converter to the setup – under investigation



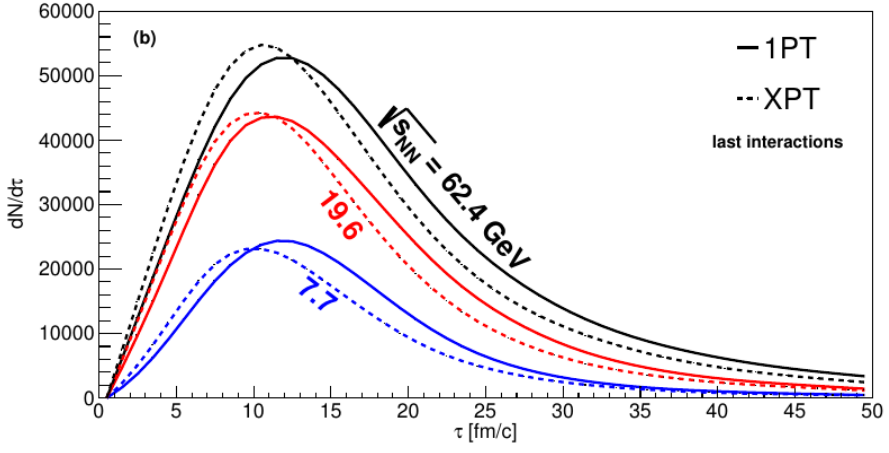
Femtoscopy and correlations at MPD

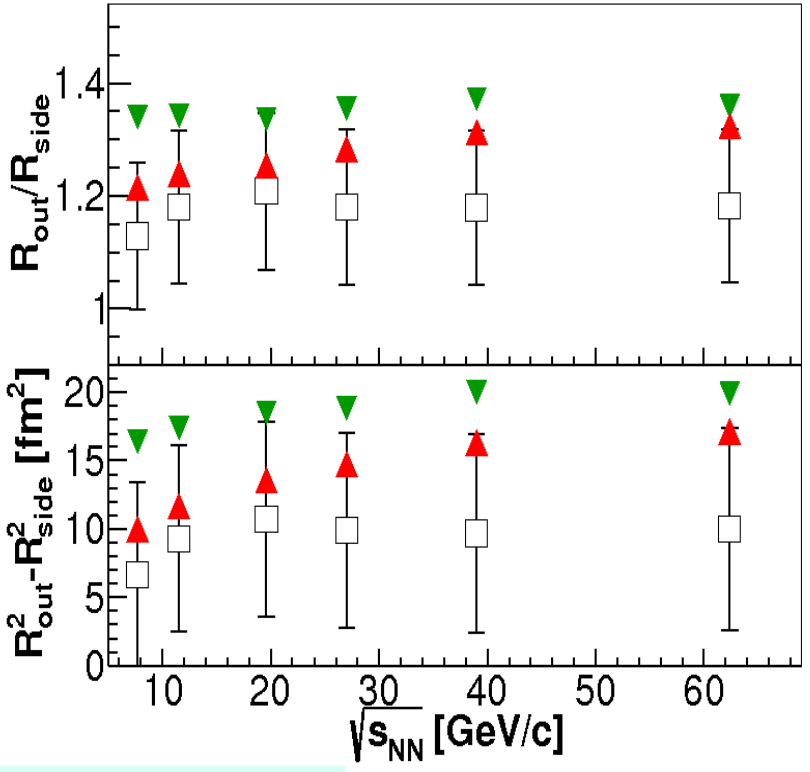
SINP MSU, ITEP, MEPhI, JINR

Study of collective effects and dynamics of quark-hadron phase transitions via femtoscopic correlations of hadrons and factorial moments of particle multiplicity at NICA energies

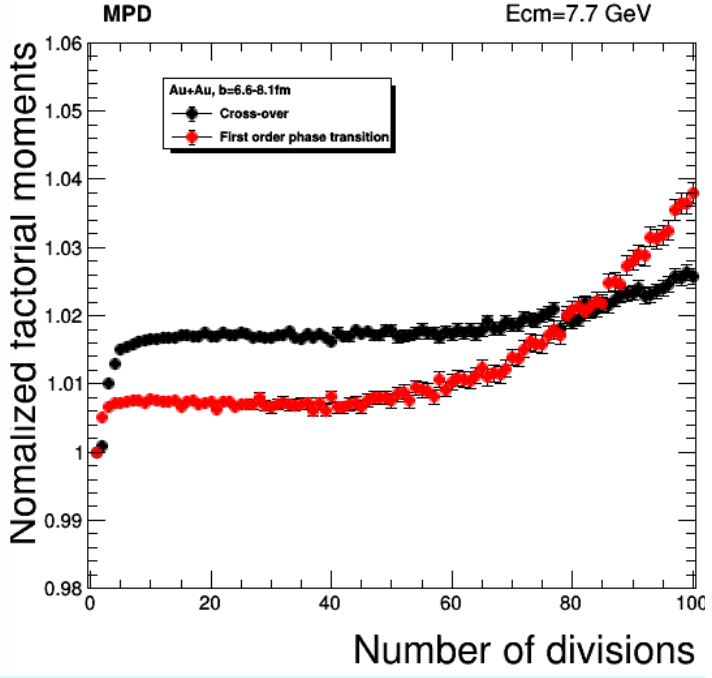
vHLLE+UrQMD with different EoS

Energy dependence of pion emission time





F2 as a function of the number of divisions of the rapidity interval [-1,1] with crossover and the 1-st order phase transition



Femtoscopy (plans):

- Further femto-soft development (different particles types, two-track effects, particle ID, CF distortions)
- 3D CF analysis for particles heavier than pions
- Different particle pairs: πK, K+K-, πp, πΛ, ΛΛ - influence of cascade phase and emission asymmetries

Factorila moments (plans):

- construct higher order moments
- compare different event generations
- investigate factorial moments with event mixing technique
- testing other methods with moments of the multiplicity distributions

Conclusions

- MPD physics simulation for the Stage'1 period is ongoing

  Steady progressing : *Multistrangeness, Flow, Femto, ECAL, resonances*

  Slow developing or Frozen : *Dileptons, Hypernuclei, Ev-by-Event fluctuations*

- The progress is expected to speed up once all PWGs are formed and MoU signed.

  Successful RFBR grant program for NICA enable us to make our work more intense and efficient

Thank you for your attention!