

MPD PWG2 status report

Vadim Kolesnikov
(VBLHEP, JINR)
on behalf of the group



MPD Collaboration meeting
JINR, Dubna, April 18-20, 2023

Outline

- ❑ **Introduction : PWG2 tasks**
- ❑ **Progress in a new round of feasibility study with Bi+Bi at 9.2 GeV :**
 - Light hadrons (prod. #25)
 - Hyperons (prod. #25)
 - Hyperon polarization (prod. #30)
 - Hypernuclei and light nuclei (prod. #29)
- ❑ **Summary**

PWG2 co-conveners:

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PWG2 physics cases

■ **Light flavor hadron spectra, yields, and ratios**

- Energy, system size and centrality dependence of the production of charged hadrons (pions, kaons, (anti)protons).
- Extraction of transverse momentum spectra, rapidity distributions, mean multiplicities, and particle ratios.
- Nuclear modification factor, antiparticle/particle ratio, radial flow, phase diagram mapping.

■ **Strangeness (hyperons and hypernuclei)**

- Analysis of strange hyperons (Lambda, Ksi, Omega) and their antiparticles: spectra, yields, antiparticle/particle ratio, nuclear modification factor, azimuthal anisotropy (together with PWG3).
- (Anti)Lambda polarization.
- Reconstruction of single and double hypernuclei: spectra, rapidity density, and lifetime.

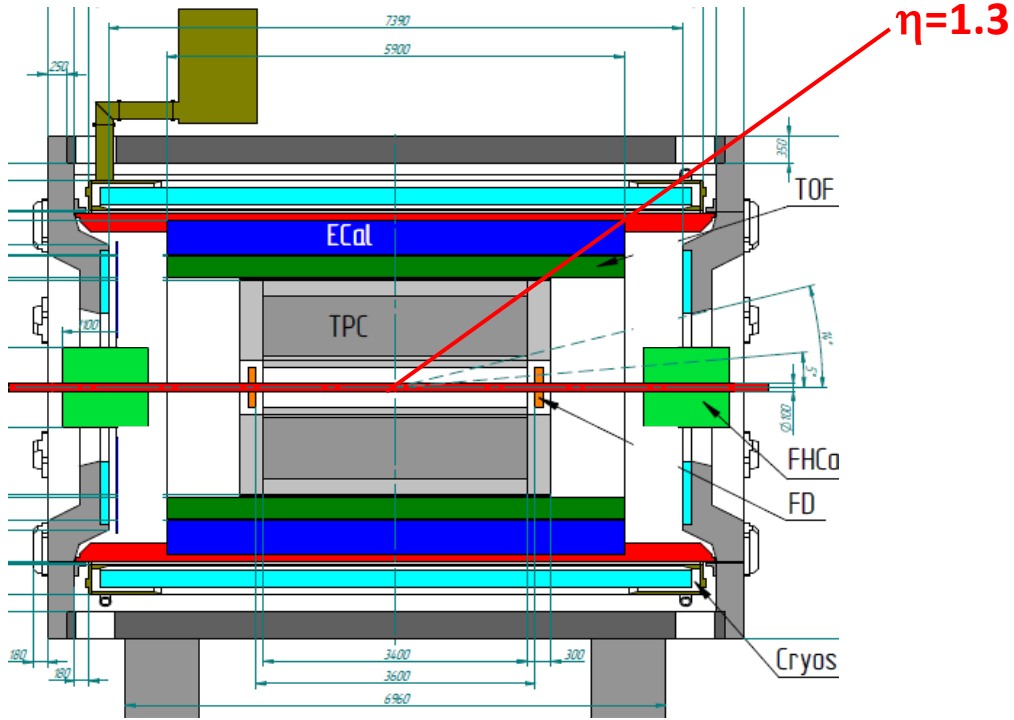
■ **Resonances**

- Production of ρ , ϕ , Kstar, Lambda(1520) etc.

■ **Light nuclei**

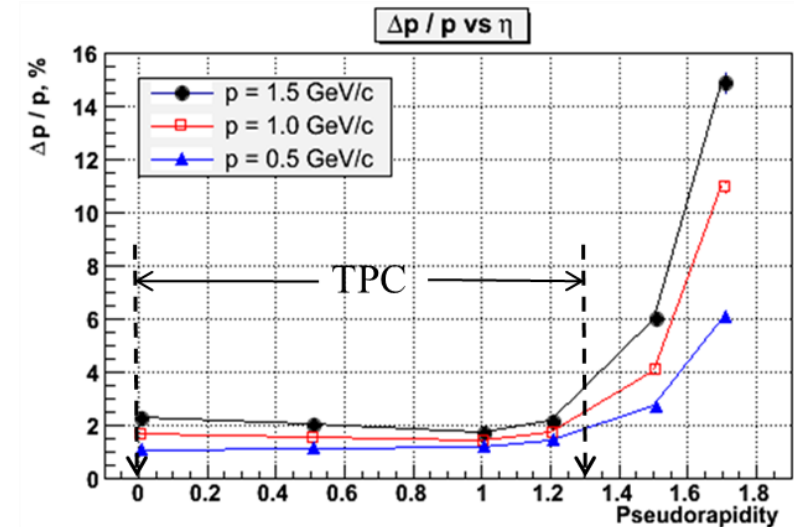
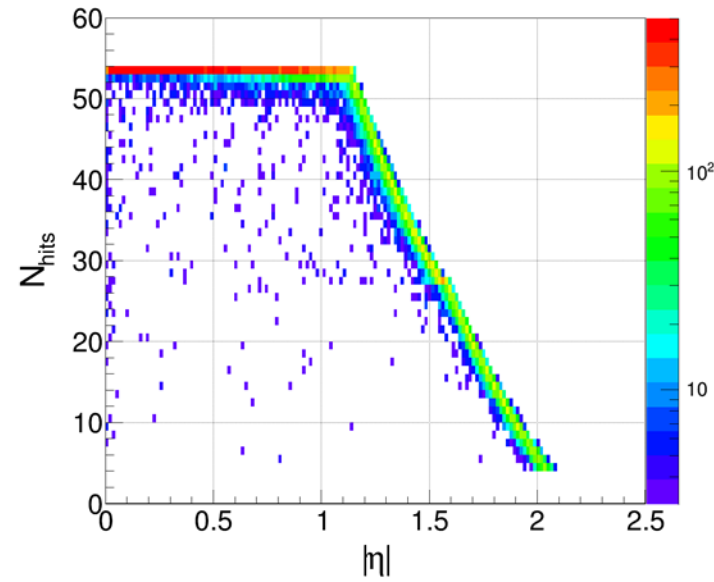
- Production of nucleon clusters (d, t, He3, He4) in various reactions (from p+p to Au+Au): spectra, yields, coalescence coefficients.

MPD setup and overall performance



MPD at Stage'1:

- **TPC tracking:** $|\eta| < 1.6$ ($N_{\text{points}} > 15$)
- **TOF & ECAL coverage:** $|\eta| < 1.3$
- **PID:** TOF+dE/dx combined $|\eta| < 1.3$, $pT < 3$ GeV/c,
limited PID $1.3 < |\eta| < 1.6$ (dE/dx)

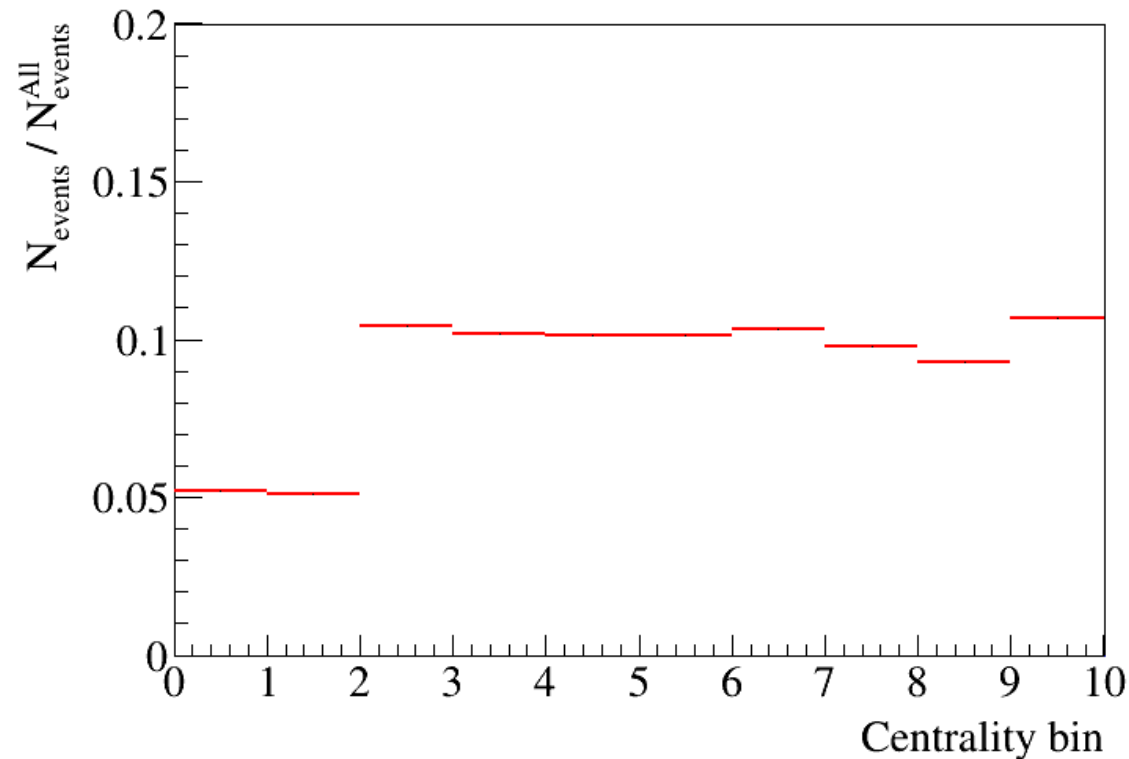


Hadrons in Bi+Bi at 9.2 GeV

A.Mudrokh

Goal: rapidity & pT-spectra, total yields and ratios of identified hadrons (π , K, p) in centrality selected Bi+Bi

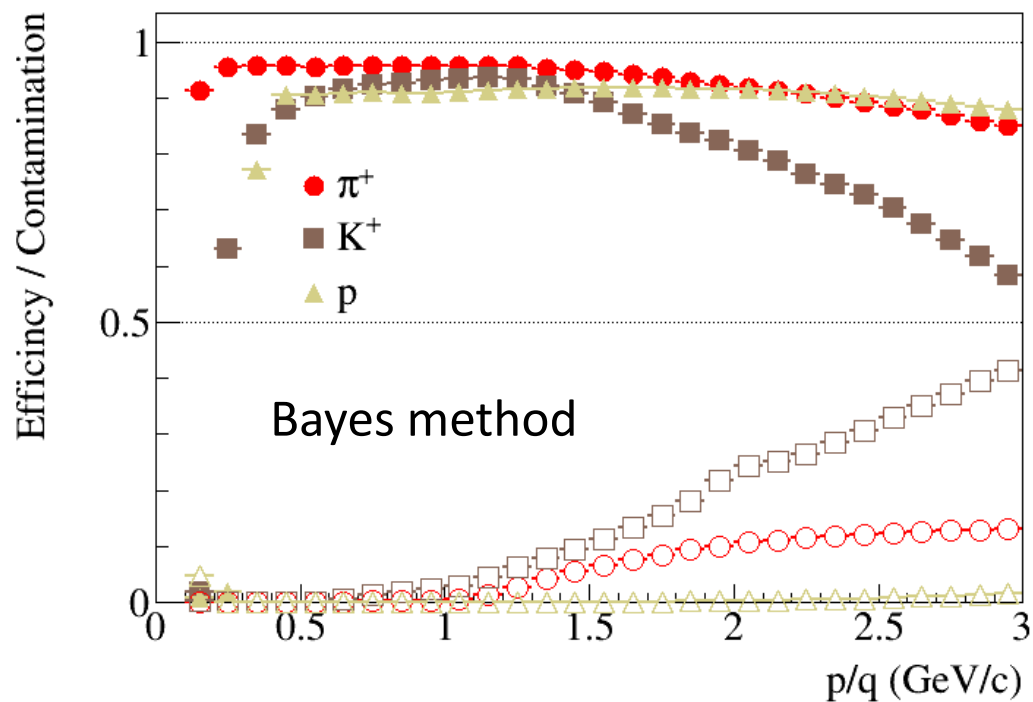
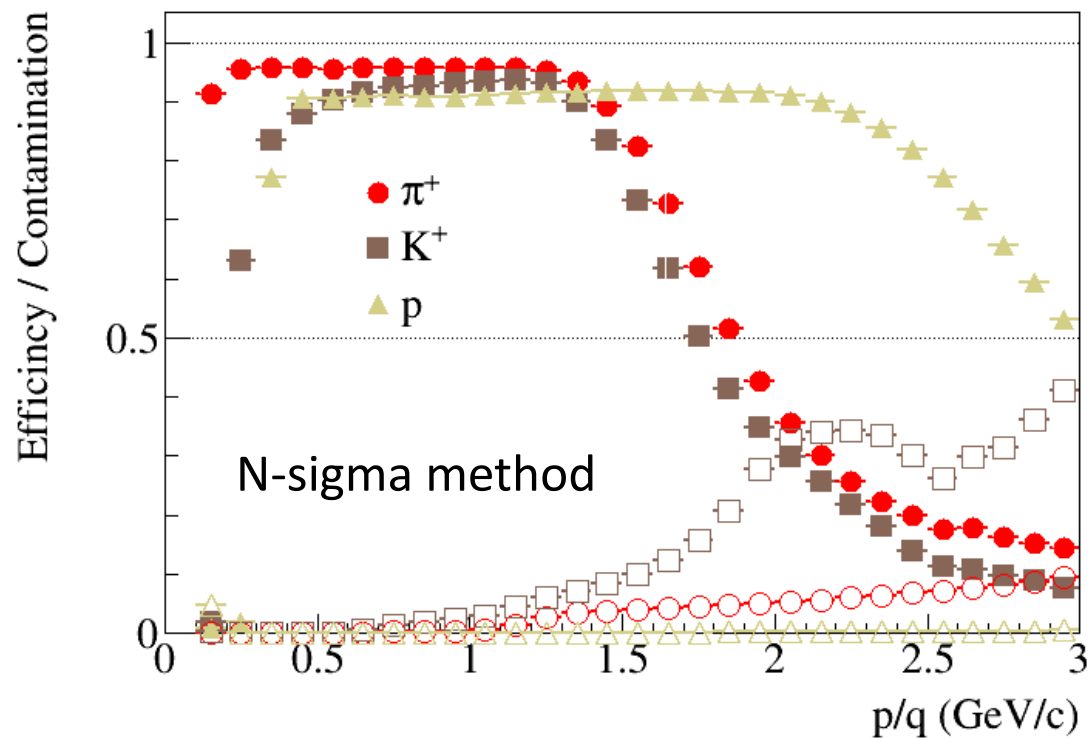
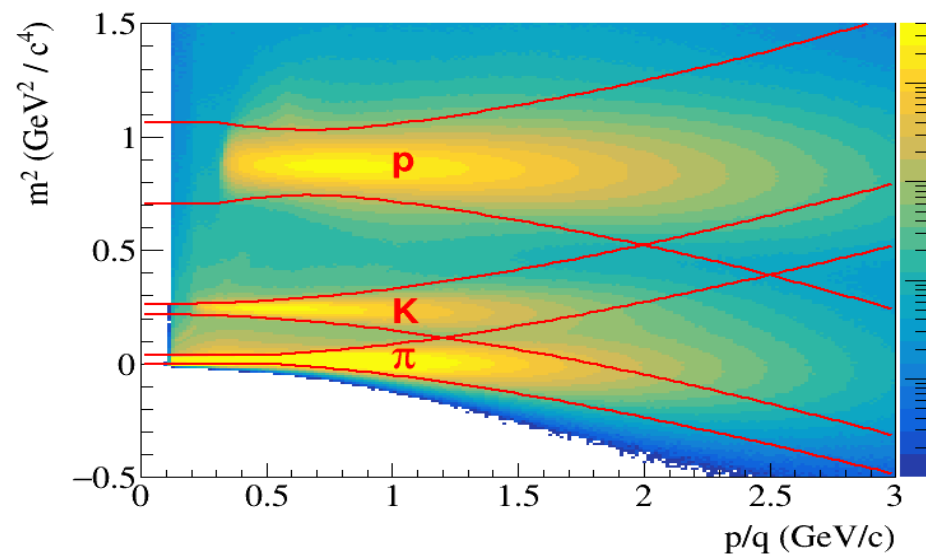
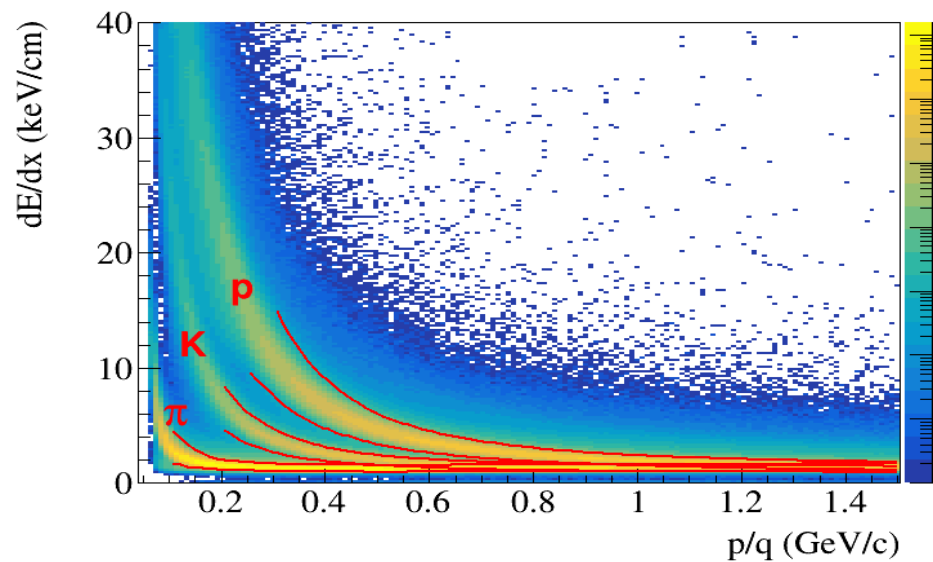
- Production #25 : 50M of UrQMD events
- Centrality selection (5-10% binning) implementing the centrality wagon (from V.Riabov)
- Conversion to mDST, PID using dE/dx and TOF, standard analysis chain



Vertex & track selection criteria for centrality:

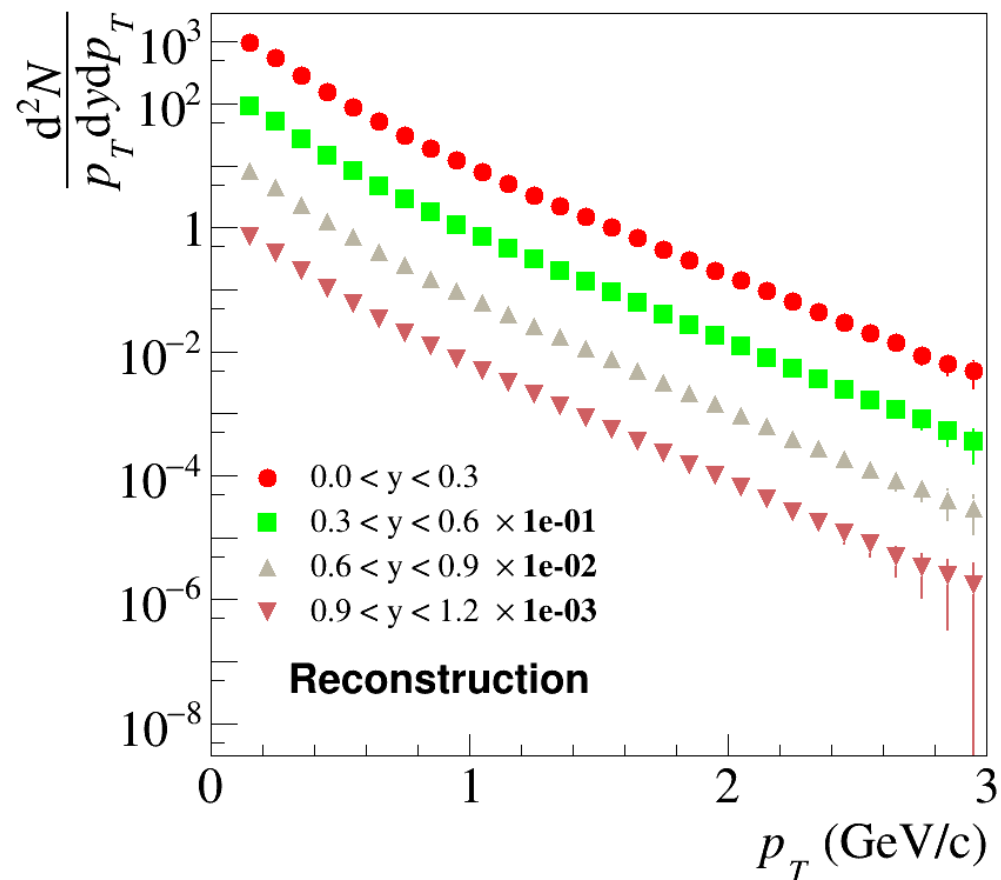
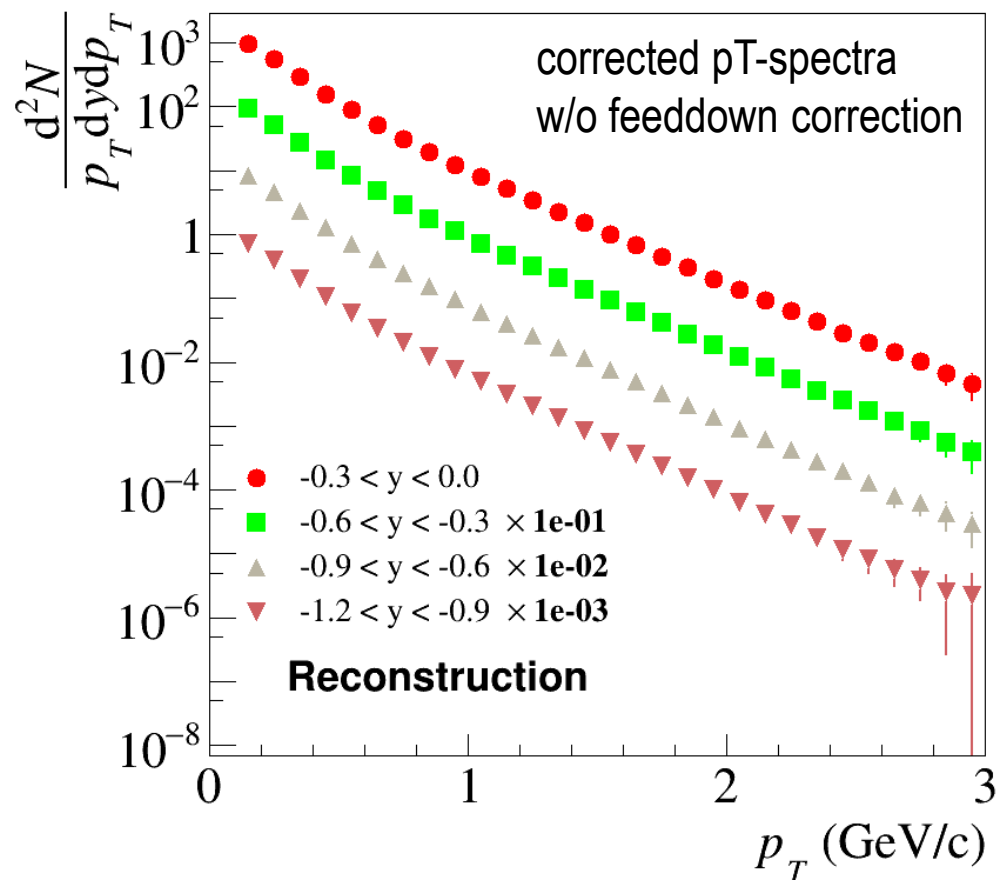
- Cut on vertex Z coordinate: $|V_z| < 130$ cm
- Number of hits for accepted tracks: $N_{\text{hits}} \geq 10$
- Pseudorapidity range: $|\eta| < 1.3$
- Minimal pT for accepted tracks: $p_T > 0.1$ GeV/c
- DCA for accepted tracks: $|DCA_{x,y,z}| < 2$ cm

Hadron in Bi+Bi at 9.2 GeV: PID



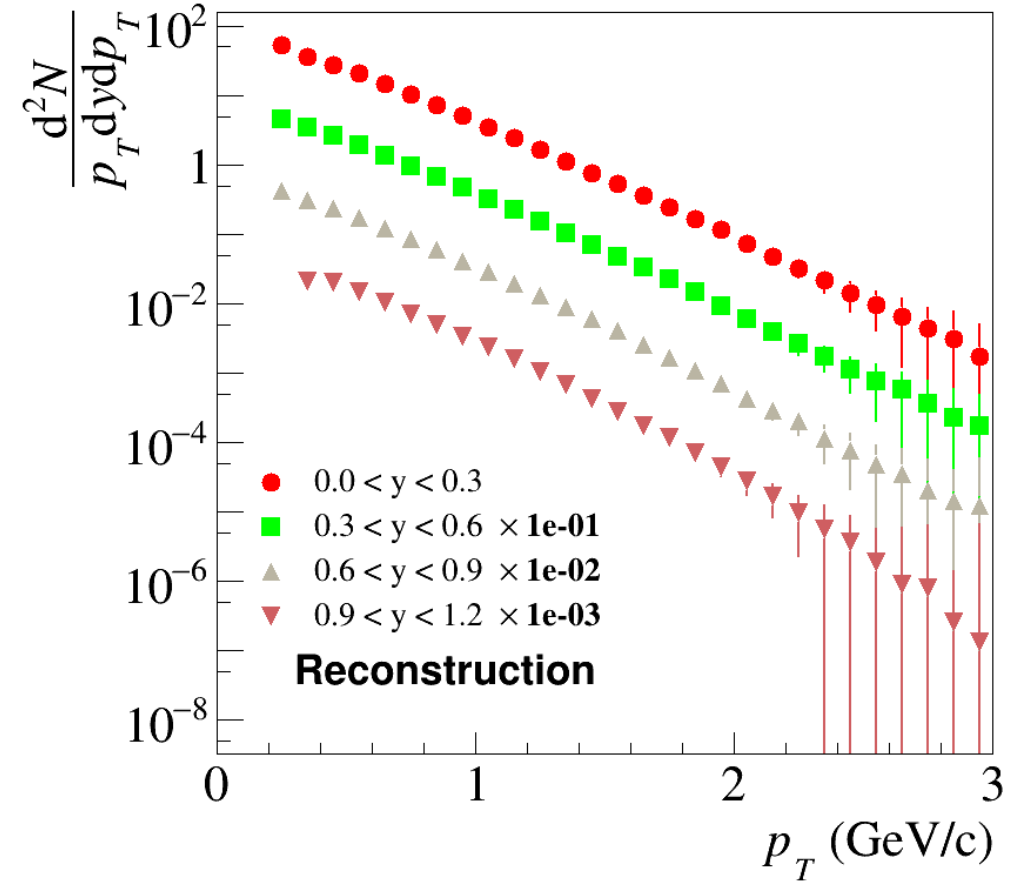
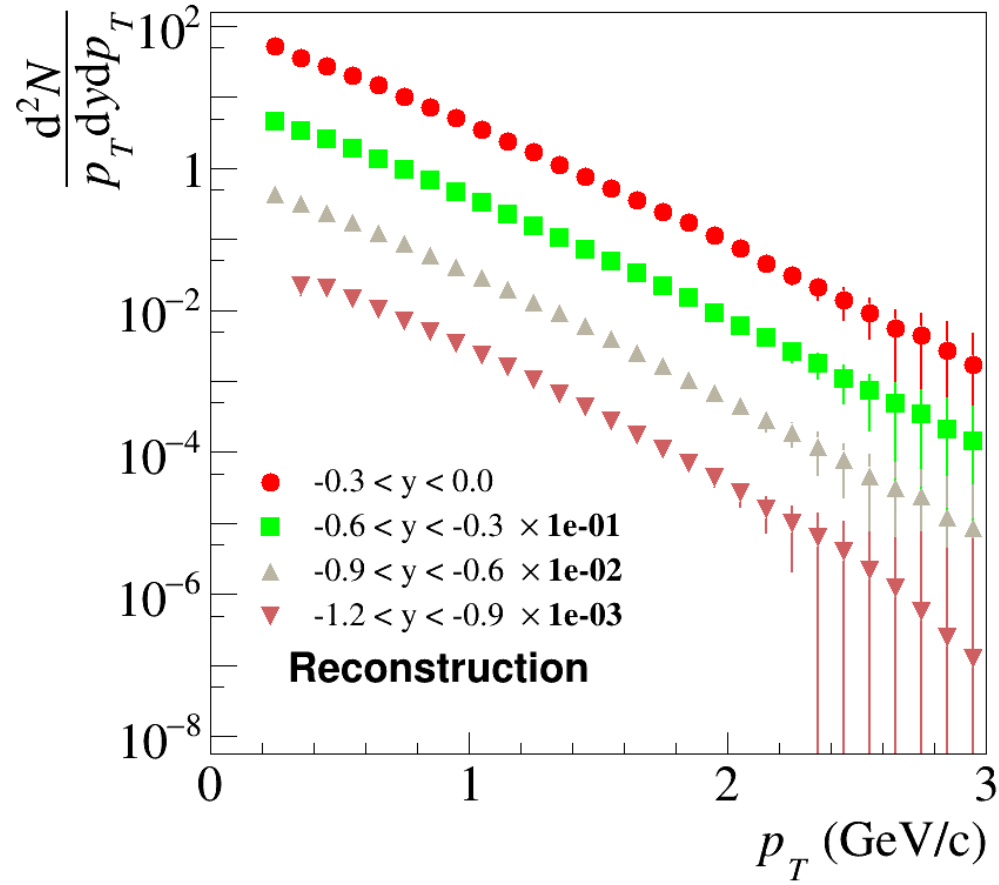
Hadron in Bi+Bi at 9.2 GeV: π^+ spectra

0 – 5% centrality bin



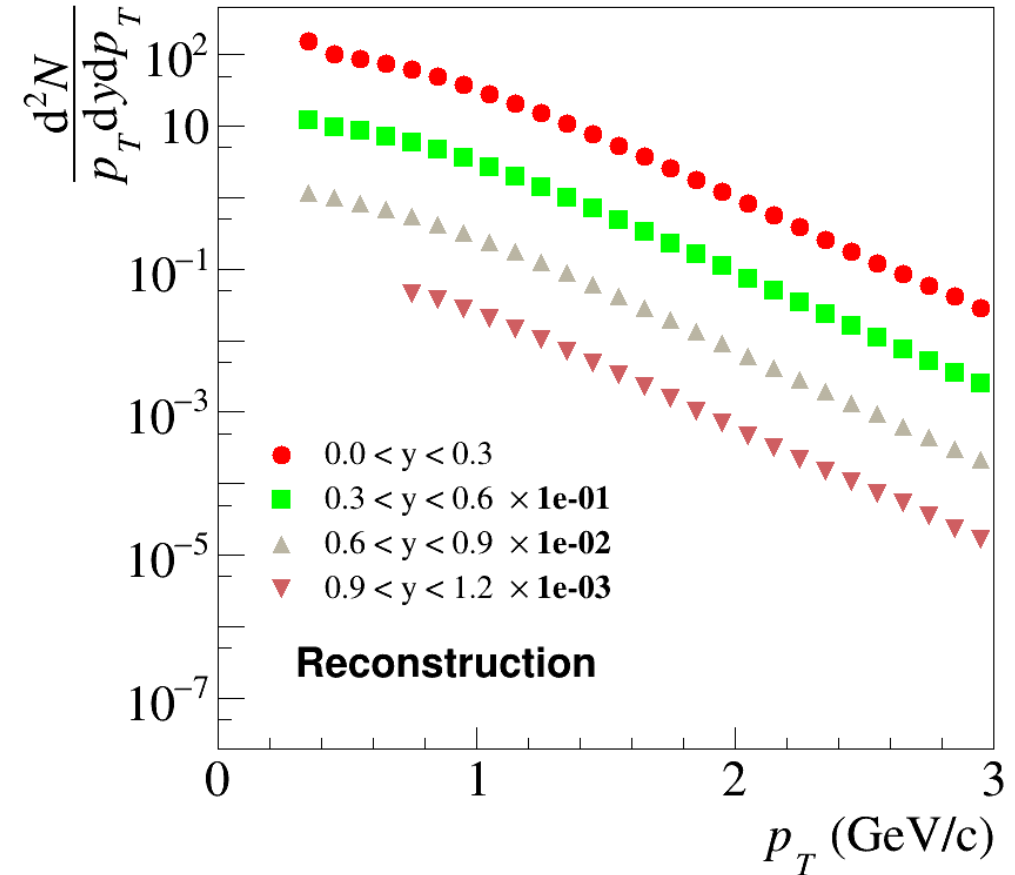
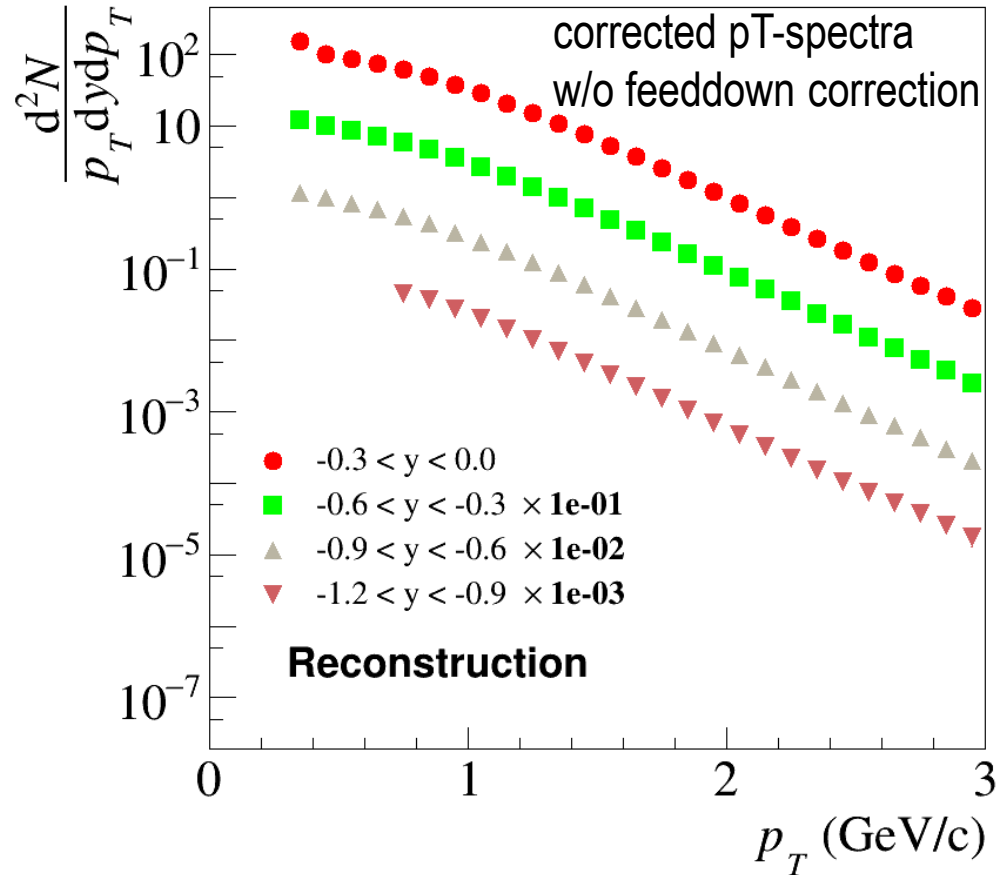
Hadron in Bi+Bi at 9.2 GeV: K⁺ spectra

0 – 5% centrality bin



Hadron in Bi+Bi at 9.2 GeV: proton spectra

0 – 5% centrality

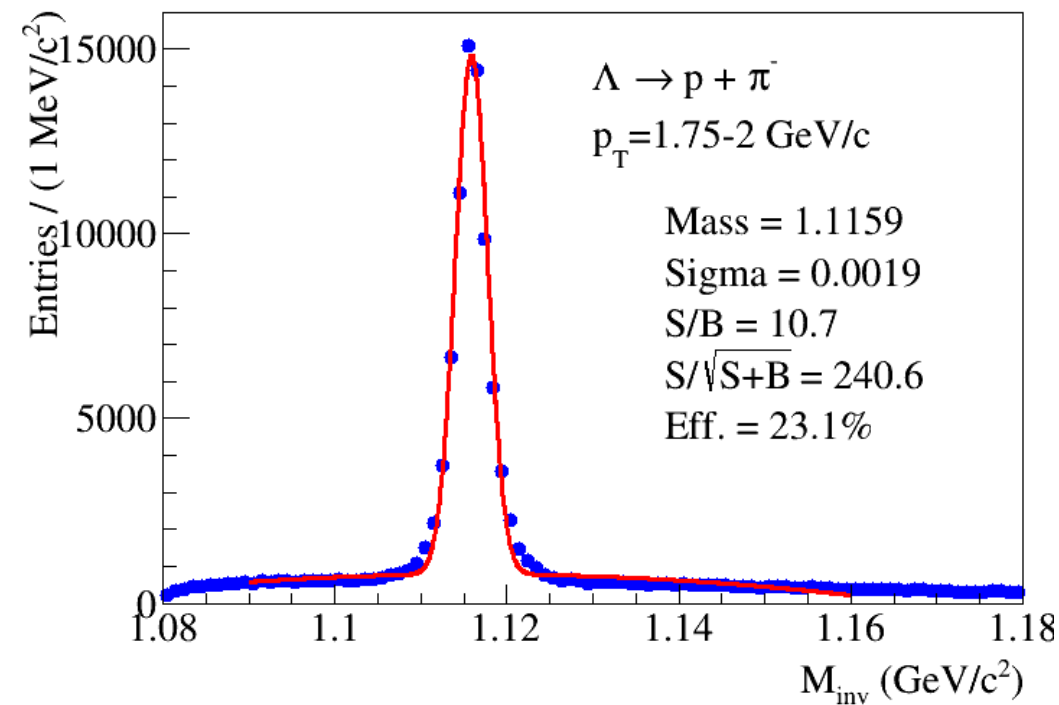
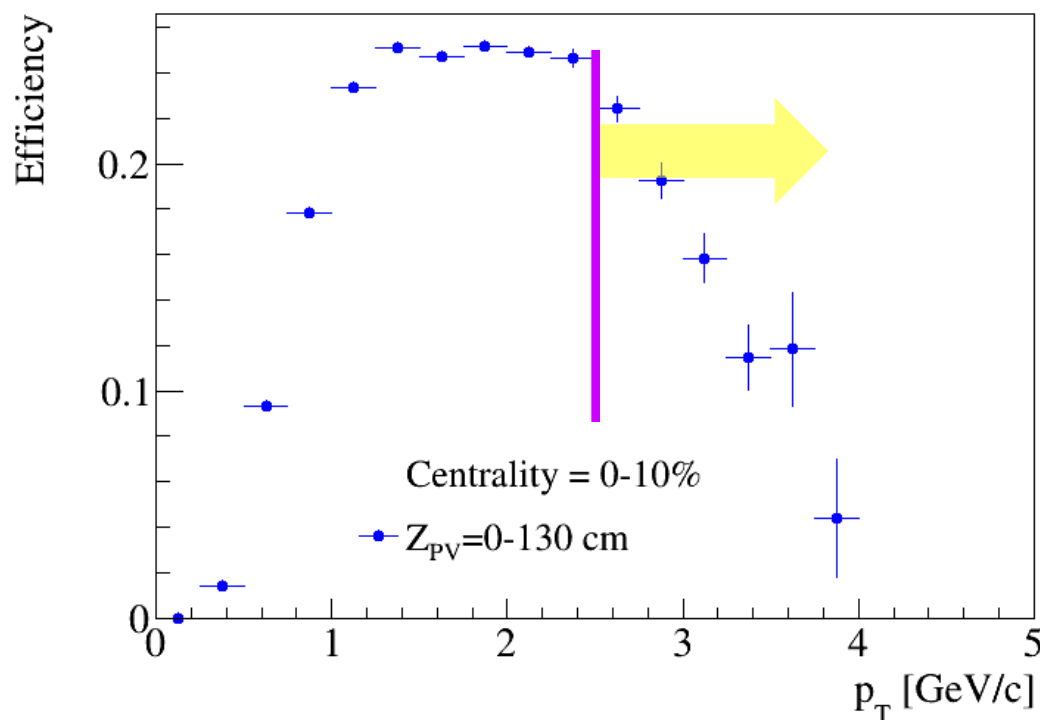


In plans: analysis in all centrality bins and for all charges

Hyperons in Bi+Bi at 9.2 GeV

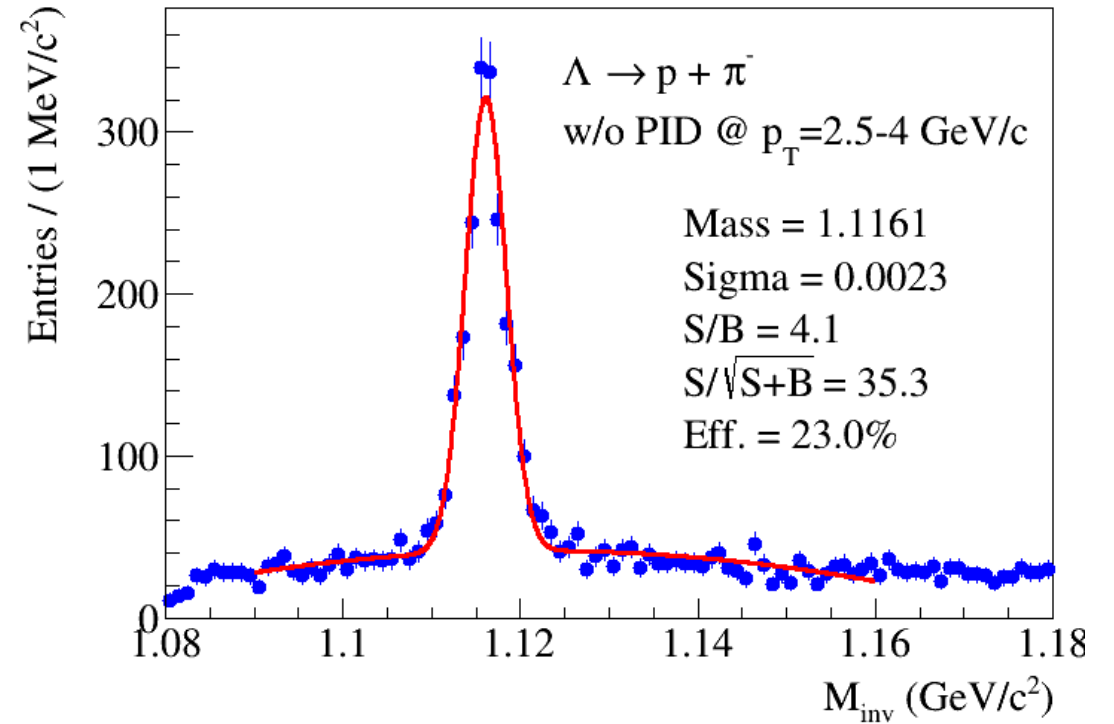
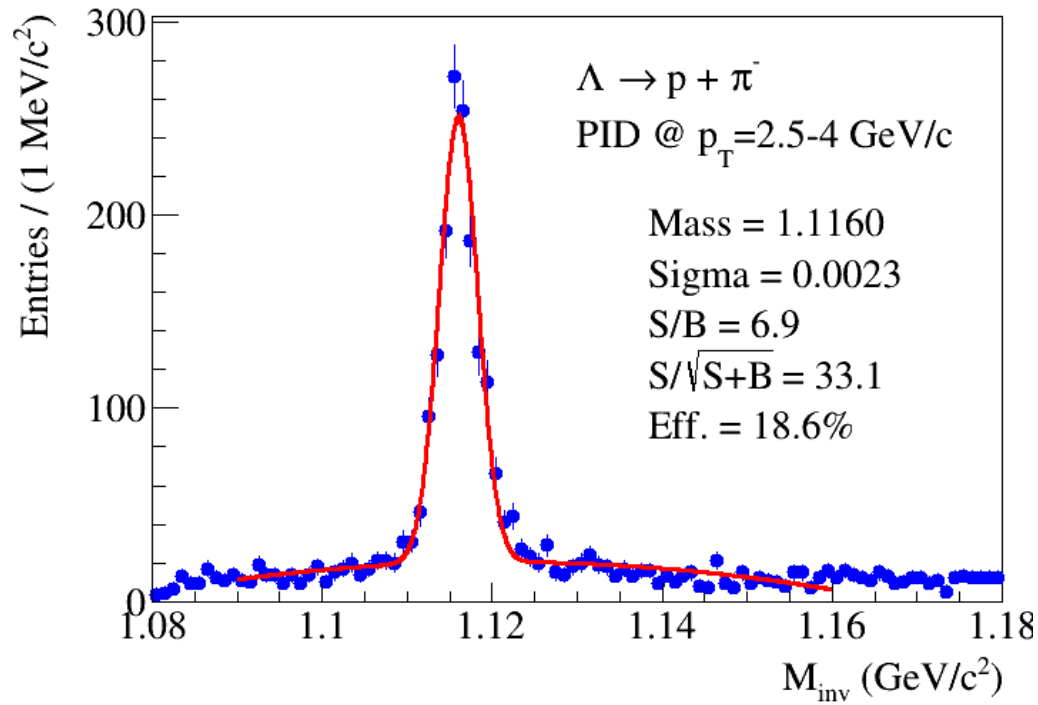
V.Vasendina and A.Zinchenko

- Production #25 of 50M UrQMD events
- Centrality selection (10-20% binning), narrower p_T -binning ($0.5 \rightarrow 0.25$ GeV/c)
- Conversion to analysis mDST is in process (based on the particular topology for each specie)
- But, drop in the reconstruction efficiency above $p_T=2.5$ GeV/c (n-sigma PID for protons constrains)
- Change to the “no-PID” mode, only topology selection cuts



Hyperons in Bi+Bi at 9.2 GeV: no-PID mode at high pT

- Production #25 of 50M UrQMD events
- Test of the “no-PID” mode with only topology selection criteria



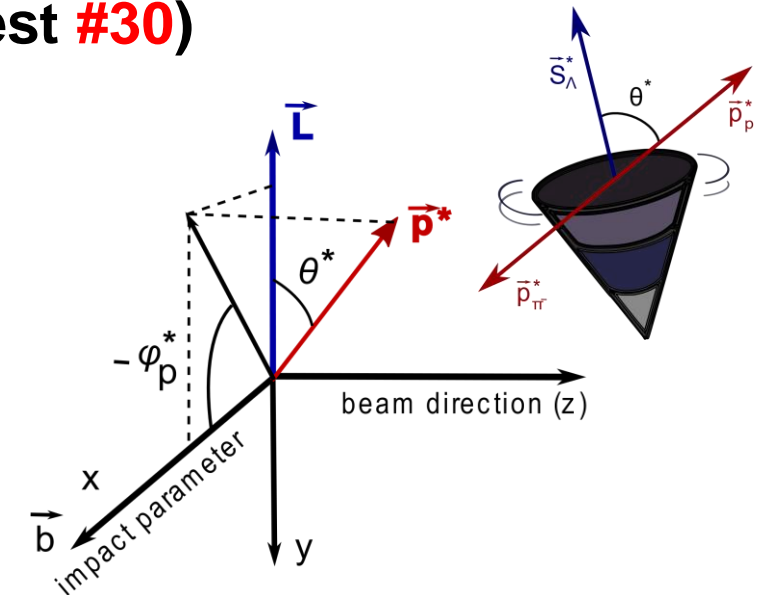
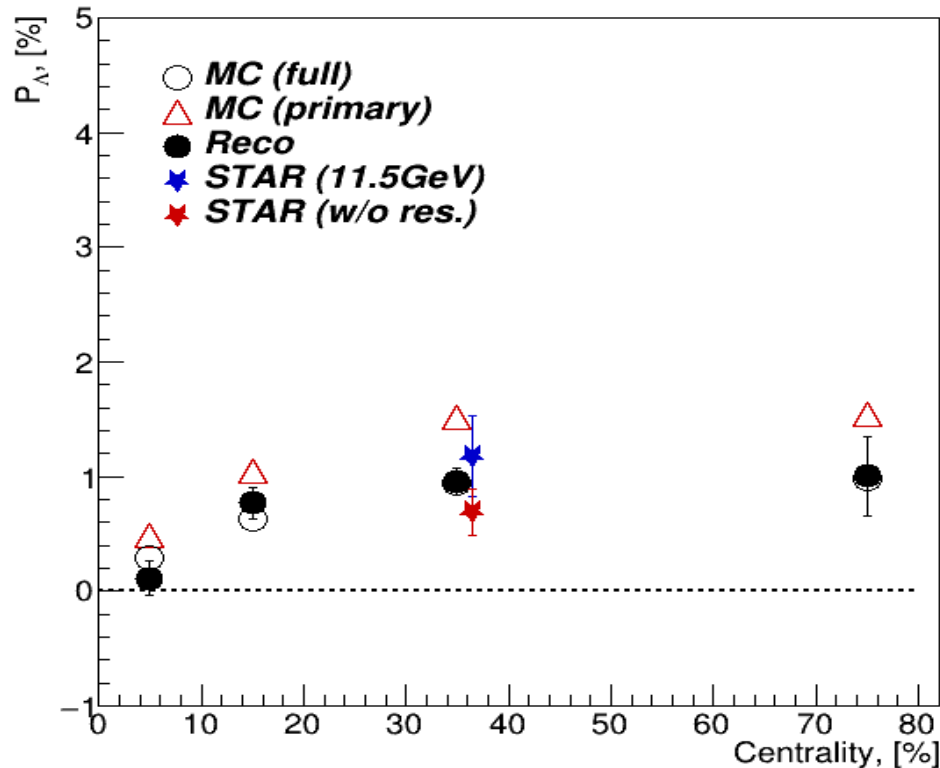
Gain in efficiency and drop in S/B-ratio for the no-PID mode

The analysis process is ongoing...

Global hyperon polarization at NICA/MPD (request #30)

E.Nazarova

- Bi-Bi @ 9.2GeV, 15M MB events, b [0,12] fm (PHSD)
- Global hyperon polarization (Thermodynamical approach)
- Higher polarization for anti-Lambda w.r.t. Lambda
- Transfer of polarization vector to MCTracks
- Centrality determined through TPC multiplicity
- Event plane resolution estimated via FHCAL
- Analysis implemented/structured as an MPD train (chain of wagons)



$$\overline{P}_{\Lambda/\bar{\Lambda}} = \frac{8}{\pi\alpha} \frac{1}{R_{EP}^1} \langle \sin(\Psi_{EP}^1 - \phi_p^*) \rangle$$

Results are in good agreement with MC values

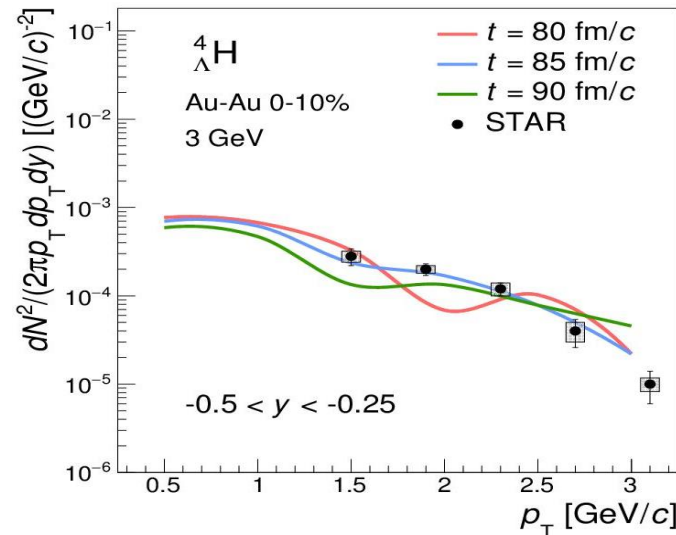
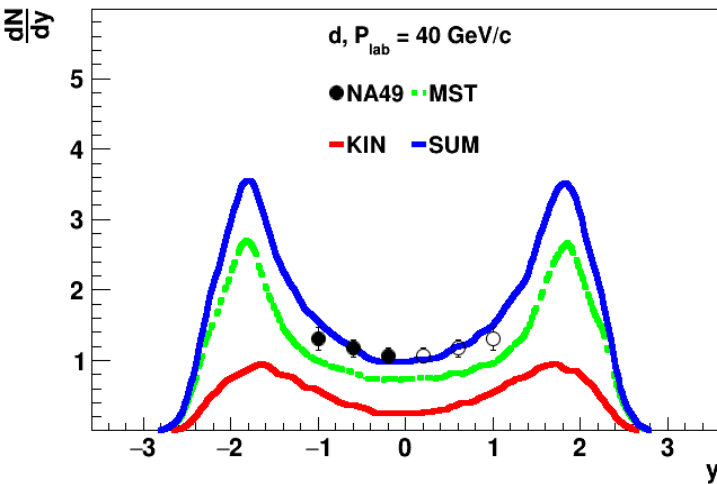
More details from Lisa during this session

New production #29 (PHQMD model)

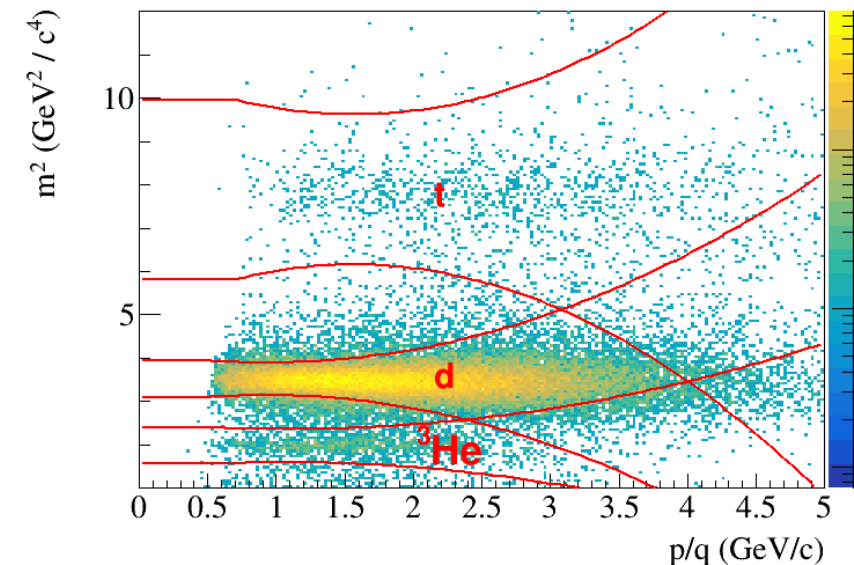
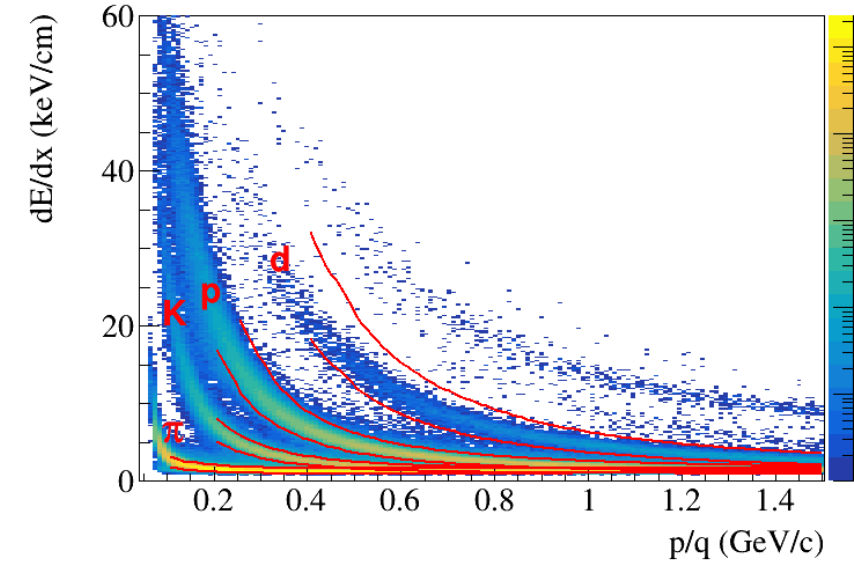
- 20M events from the PHQMD event generator

Goal : light nuclei and hypernuclei production in Bi+Bi

PHQMD predictions in A+A



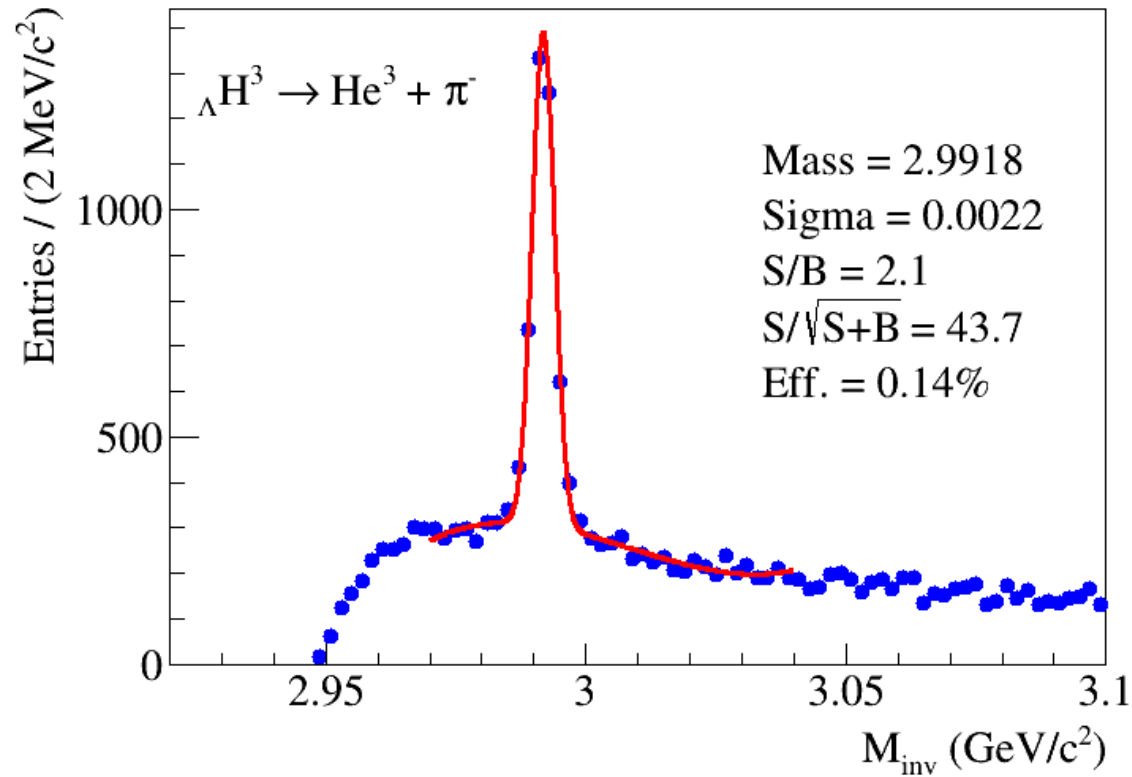
- All events are reconstructed
- Waiting for the final PID tuning for hadrons and nuclei
- New complementary ML approach for hypernuclei selection has tested



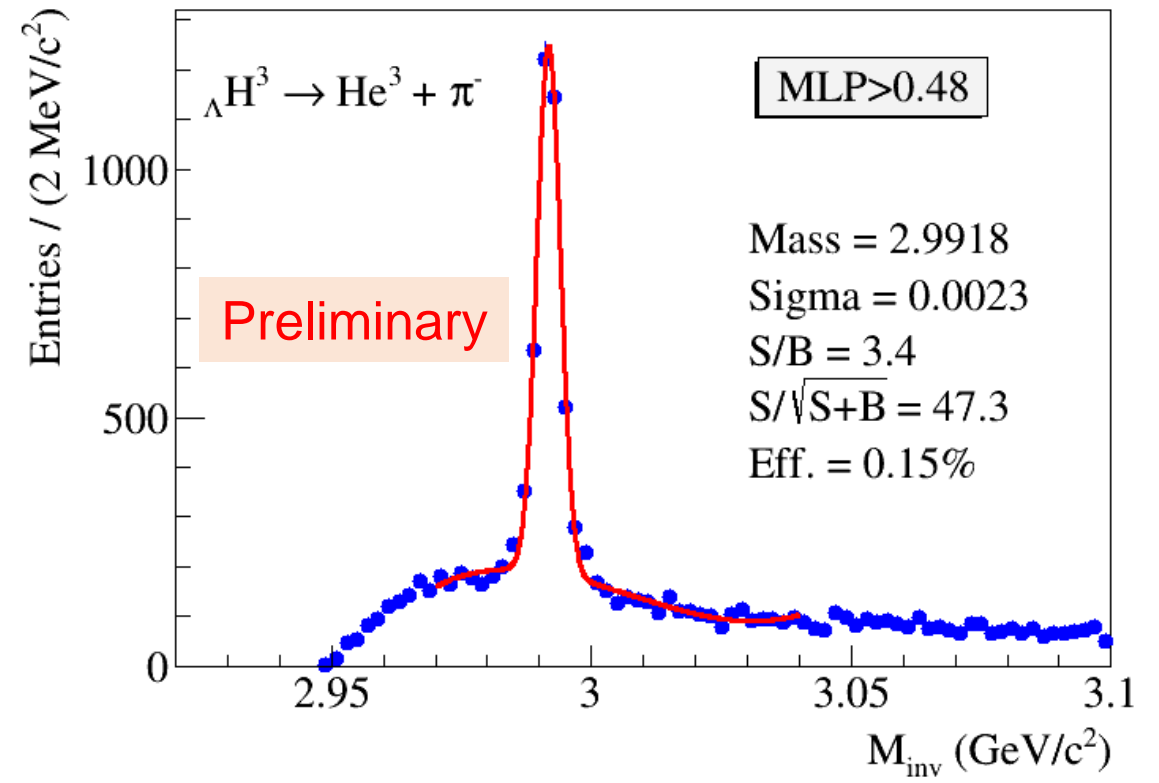
${}^3_{\Lambda}\text{H}$ reconstruction (2-prong): standard chain vs TMVA

- Standard chains – set of 7 cuts optimized in semi-automatic mode to maximize significance
- Machine learning approach – TMVA (Multivariate Data Analysis with ROOT)

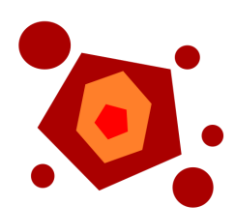
Standard method of topological cuts



ML-based TMVA approach



Better selectivity of hypertritons with the TMVA toolkit



Parton-Hadron-Quantum-Molecular Dynamics project (recent news)

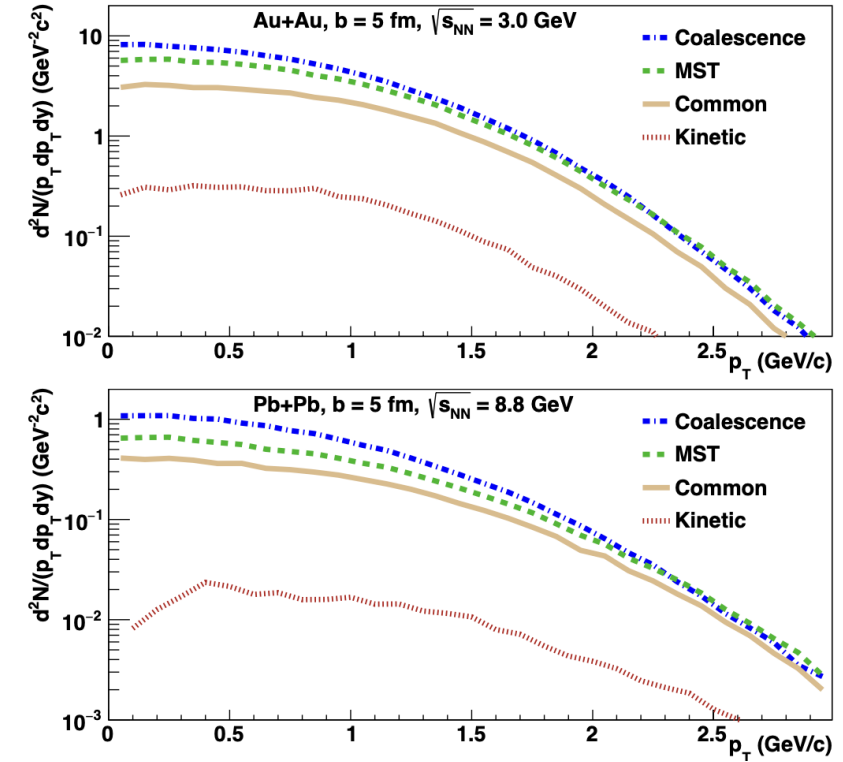
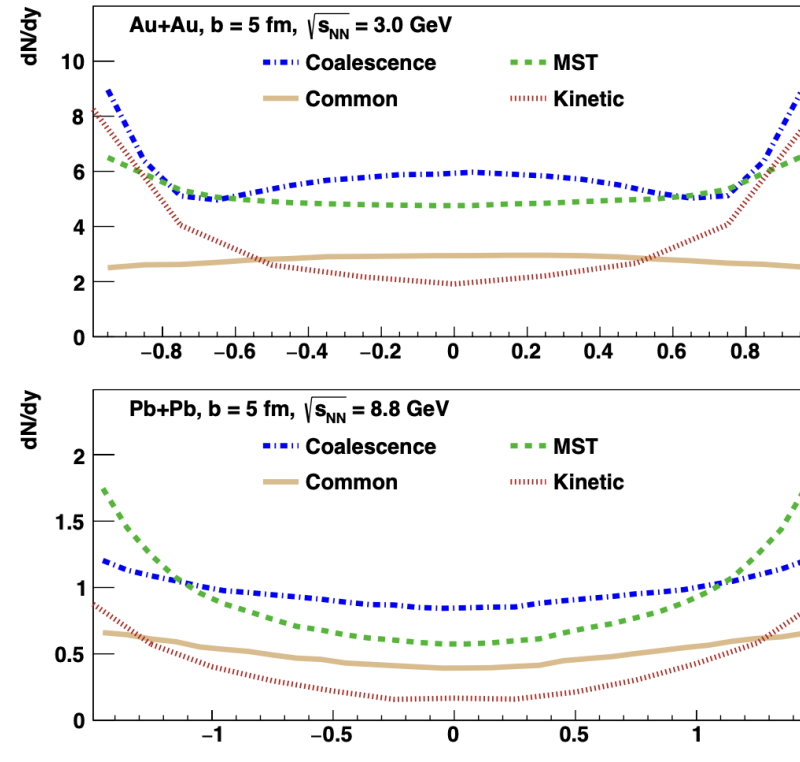
V. Kireyeu et. al, work in progress.

Theory/model predictions: can the cluster formation mechanism be identified experimentally?

PHQMD: a self-consistent n-body microscopic transport approach for the description of heavy-ion collisions and dynamical cluster formation from low to ultra-relativistic energies.

Cluster formation:

- Potential interaction: gathering of nucleons during time evolution tracked by clusterization algorithms (like MST).
- Kinetic mechanism: deuteron production by $3 \rightarrow 2$ hadronic reactions (G.Cociariv:2303.02279).



- The rapidity and p_T -distributions allow discrimination between different mechanisms of cluster formation
- Large phase-space coverage for nucleons and light nuclei is crucial for such studies




Publication activities and conferences

- Not as active as before (geopolitical constrains and switch to centralized data analysis scheme)
- Only several publications/proceedings from conferences in Russia
- Needs to be improved in future



Communication

Feasibility Study of Hypernucleus Production at NICA/MPD

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Summary

- Analysis of several new productions has started within PWG2
 - Prod. 25 (UrQMD) will be the base for hadron and hyperon studies
 - Prod. 29 (PHQMD) for (hyper)nuclei
 - Prod. 30 (PHSD) dedicated to (anti)Lambda-hyperon polarization studies
- The rate of the progress is steadily increased

Thank you for your attention!