

MPD PWG2 status report

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



MPD Collaboration meeting
JINR, Dubna, April 23-25, 2024

Outline

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

PWG2 co-conveners:

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Vadim Kolesnikov (JINR, Dubna, Russia) Vadim.Kolesnikov@cern.ch

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.

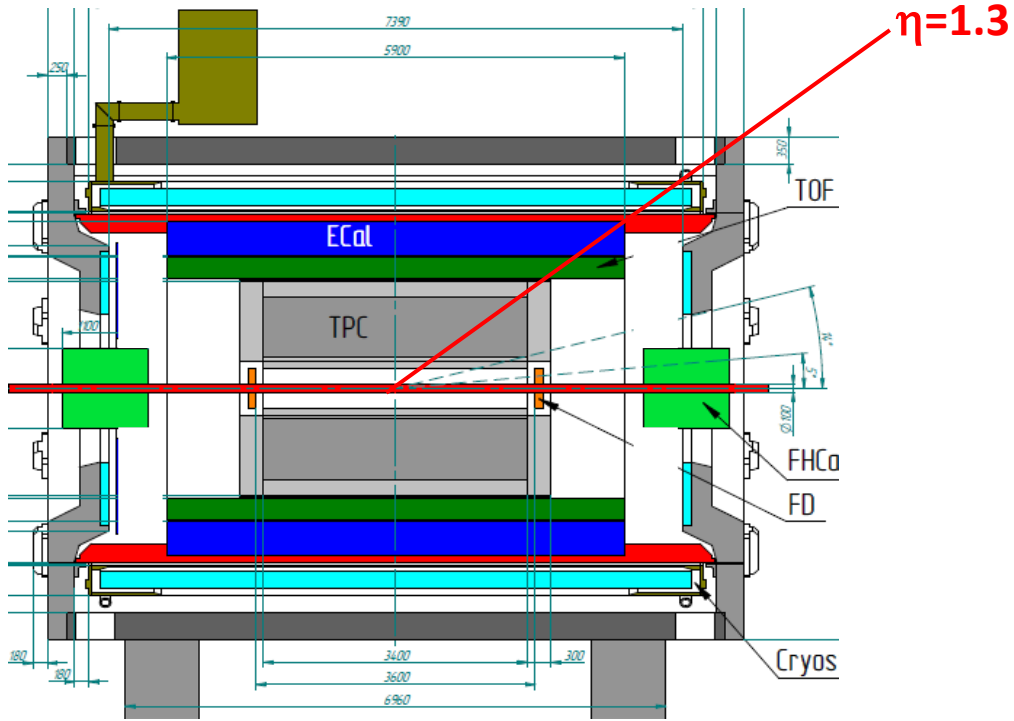
▪ **Resonances**

- 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)

Event centrality definition : centrality wagon (P.Parfenov)

PID : parameterization from A.Mudrokh

Status of hyperon reconstruction in Bi+Bi at 9.2 GeV

V.Vasendina, D.Suvarieva, A.Zinchenko

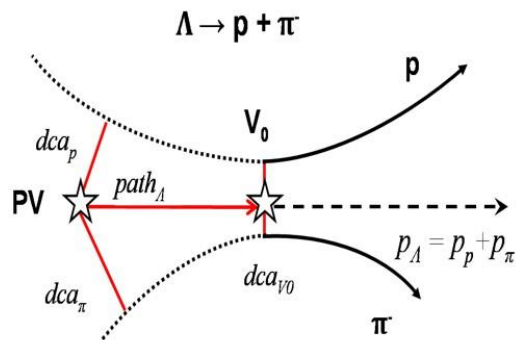
Data Set

- ✓ **Generator:** UrQMD, Min.bias, Bi+Bi @ 9.2 GeV, 50M
- ✓ **Reconstruction & Analysis:** hyperon wagon in the analysis train
- ✓ **Selection:** $|y| < 0.5$, $Z_{pV} = \pm 130$ cm
- ✓ **Centrality bins:** 0-10%, 10-20%, 20-40%, 40-60%, 60-80%

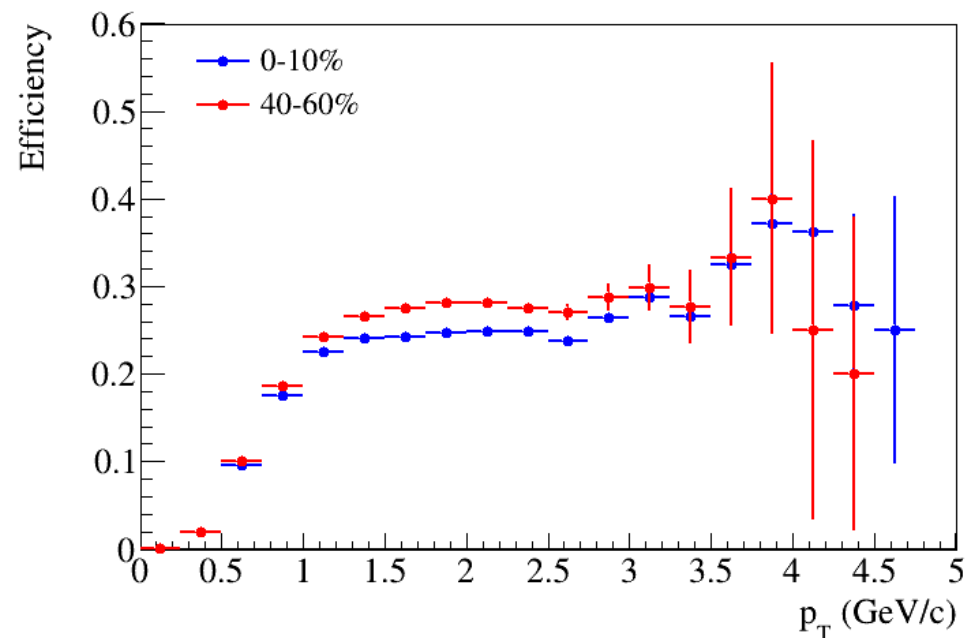
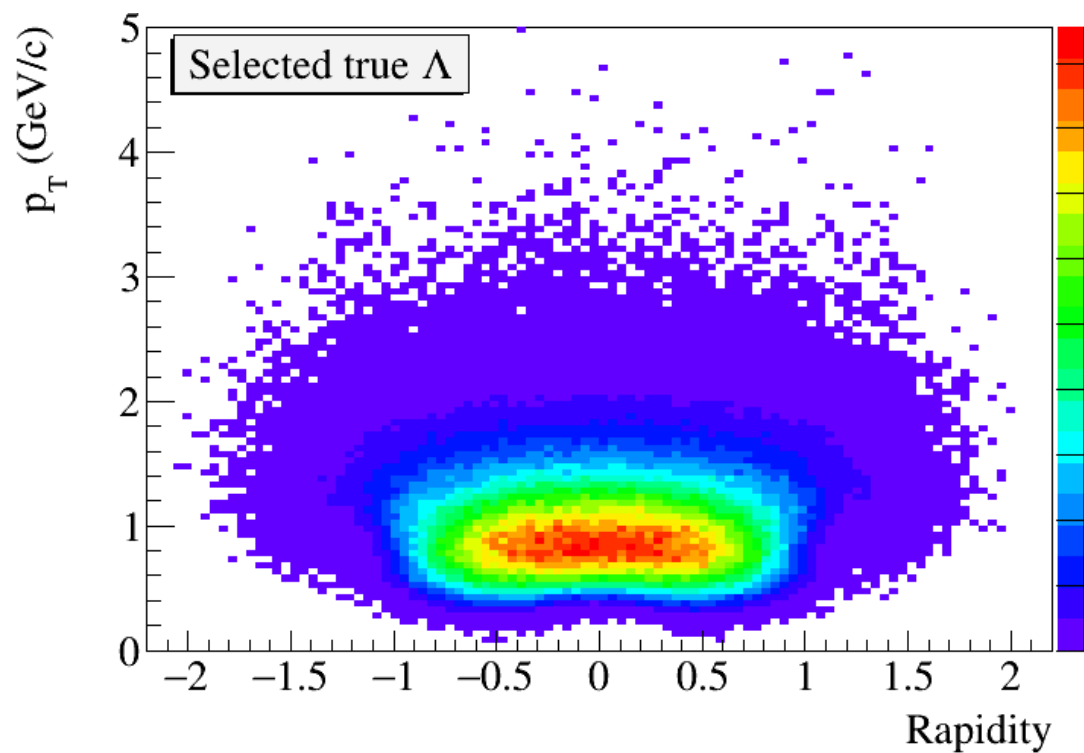
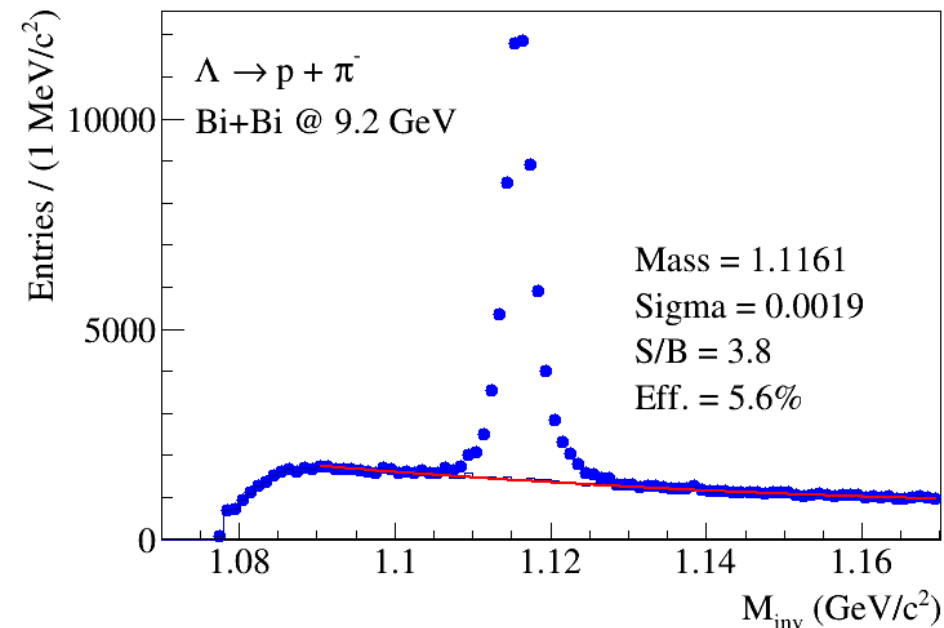
Selection cuts

- ✓ $l0.chi2s[][0] > 11.0$ – normalized π^+ -to-primary vertex impact parameter
- ✓ $l0.chi2s[][1] > 4.7$ – normalized anti(proton)-to-primary vertex impact parameter
- ✓ $l0.chi2h < 7.5$ – chi2 of secondary vertex reconstruction
- ✓ $l0.dsth < 1.0$ — distance of the closest approach
- ✓ $l0.path > 2.4$ – lambda decay path
- ✓ $l0.angle < 0.09$ – lambda momentum and primary-to-secondary vertex vector noncollinearity

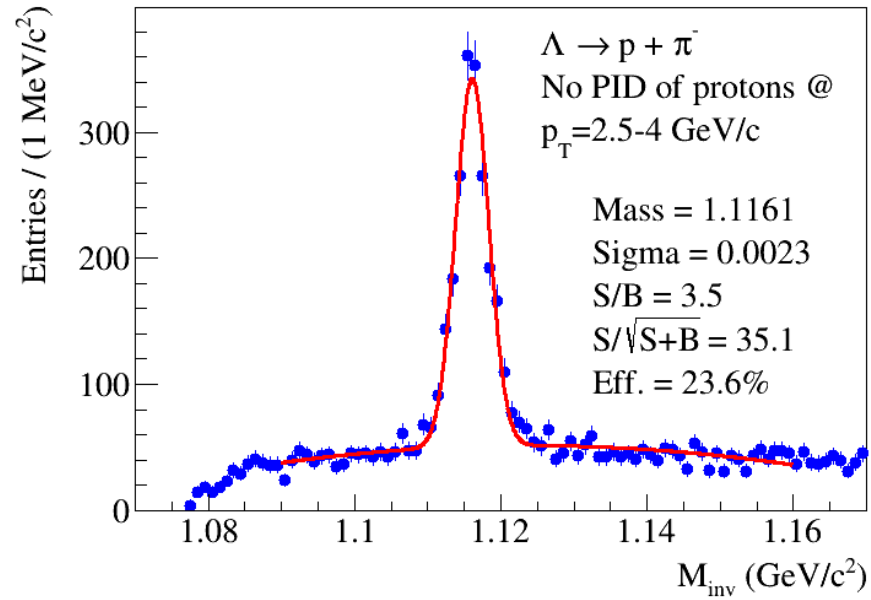
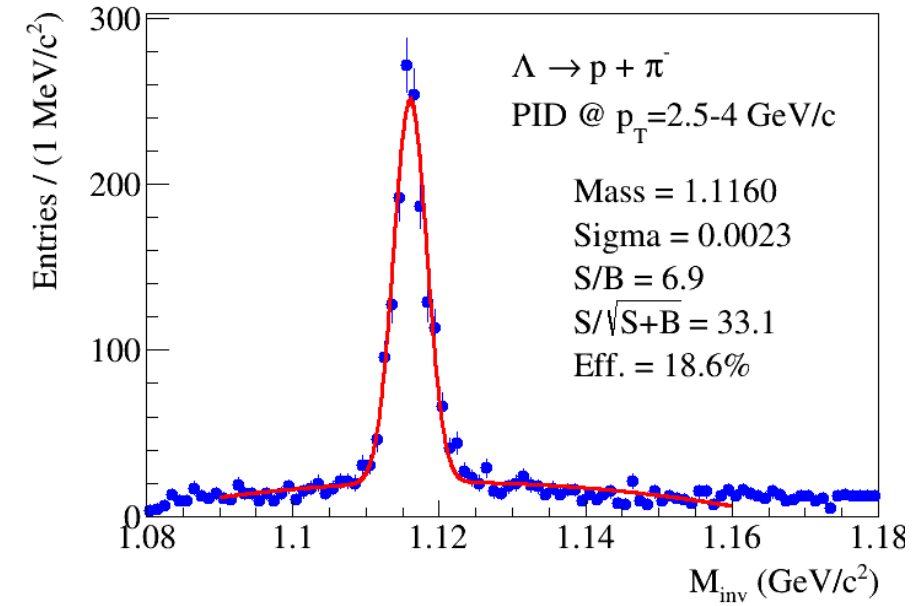
Λ -hyperon reconstruction in MPD



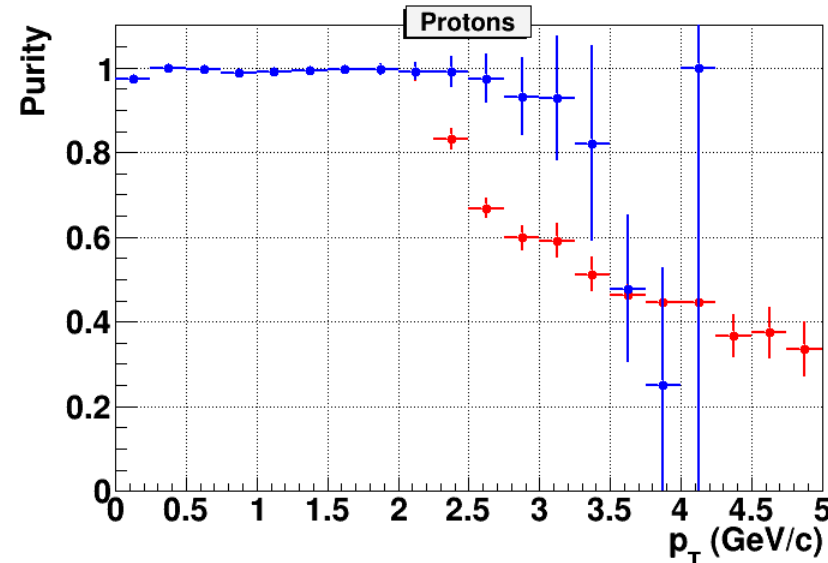
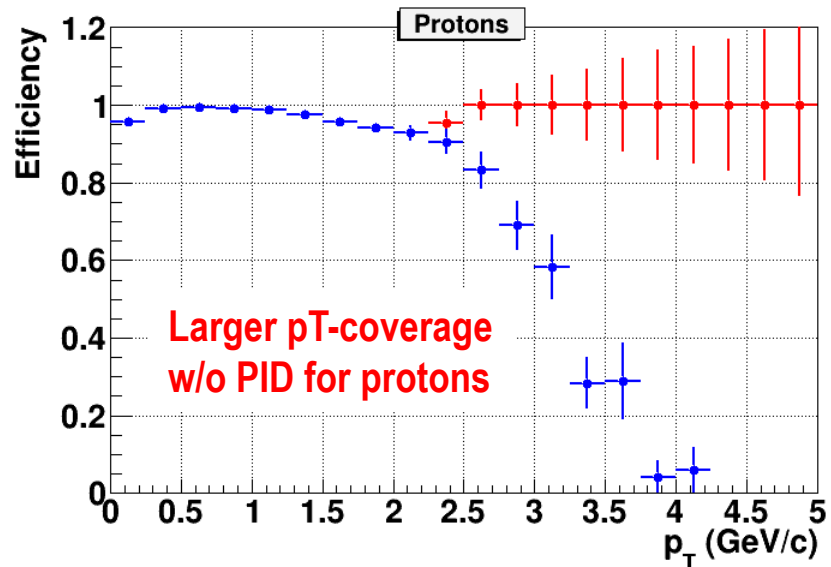
PV - primary vertex
V0 - vertex of decay
dca - distance of closest approach
path - decay length



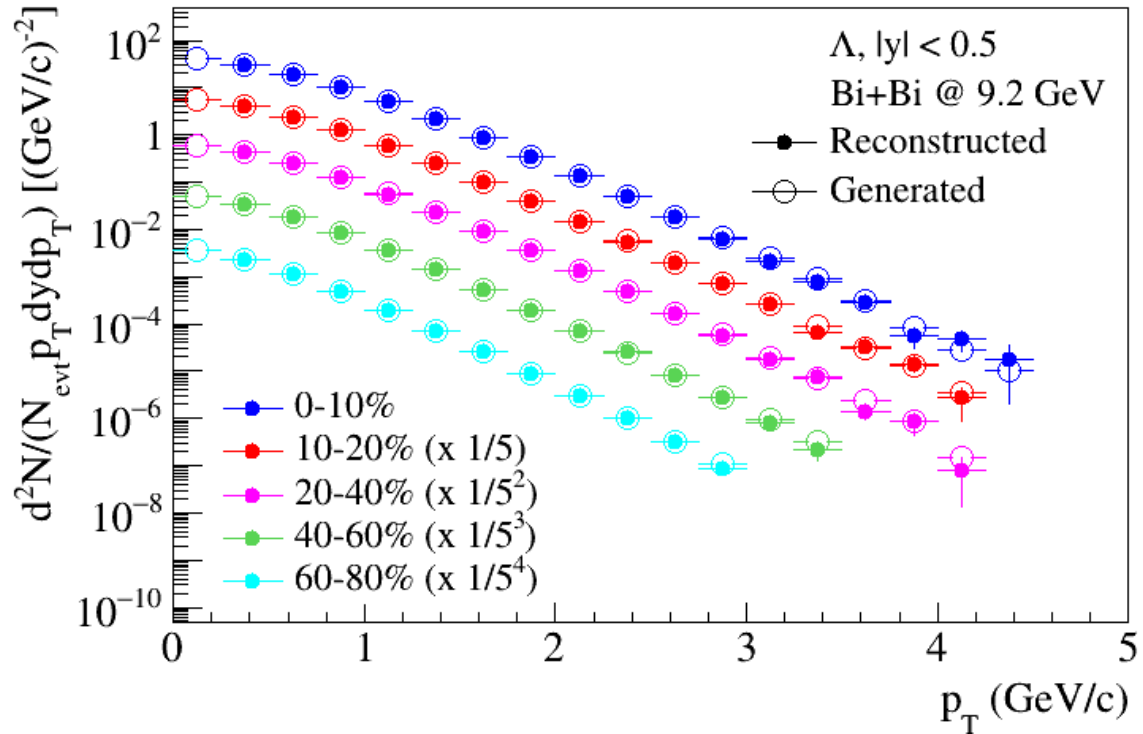
Λ -hyperon reconstruction at high p_T : PID vs pairing of all charge=1 hadrons



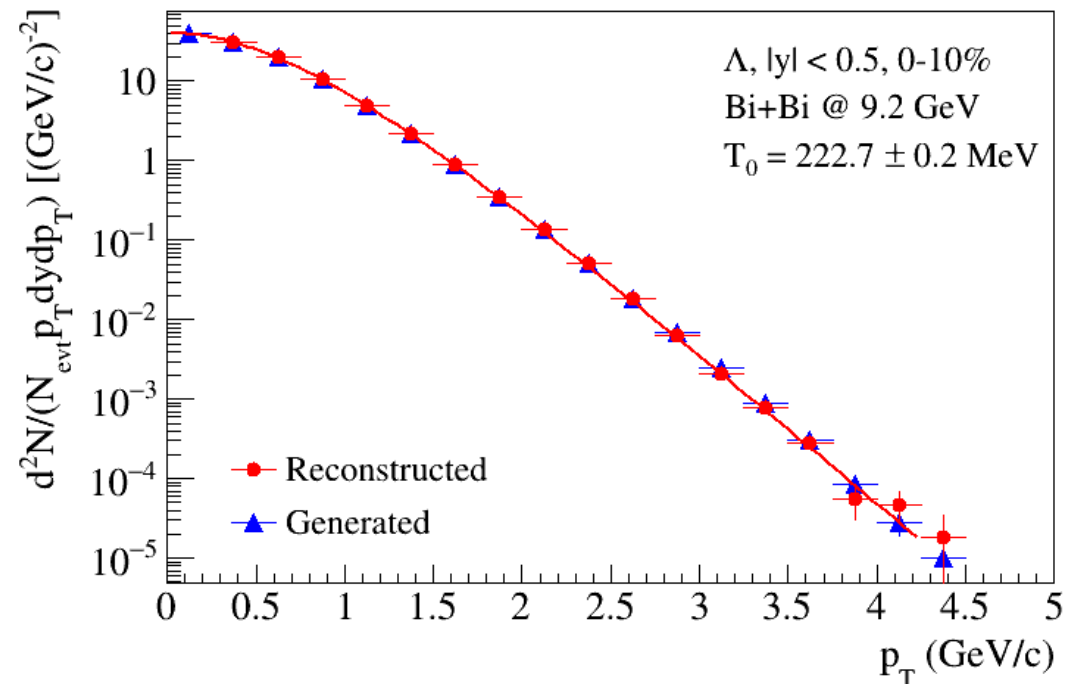
- ~40% gain in the efficiency
- Moderate drop in S/B w/o losing fit quality



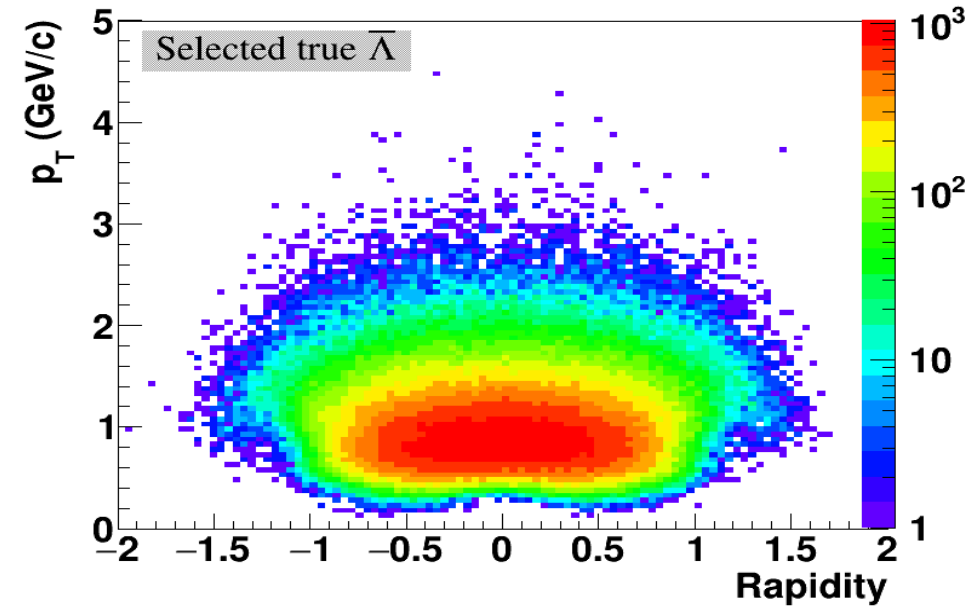
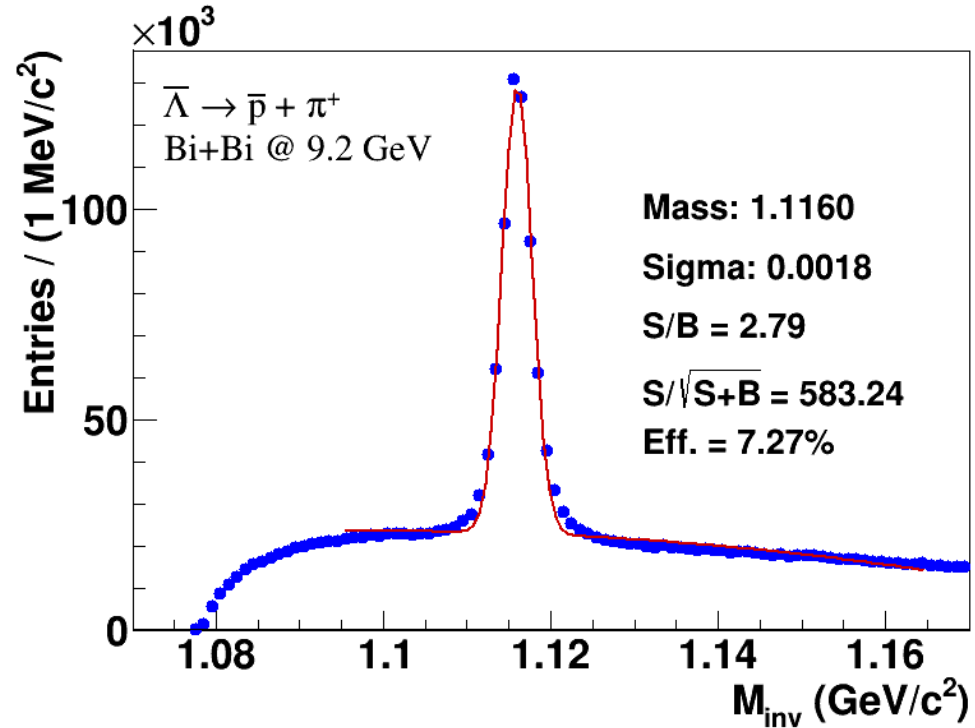
Λ analysis results: fully corrected invariant pT-spectra in centrality bins



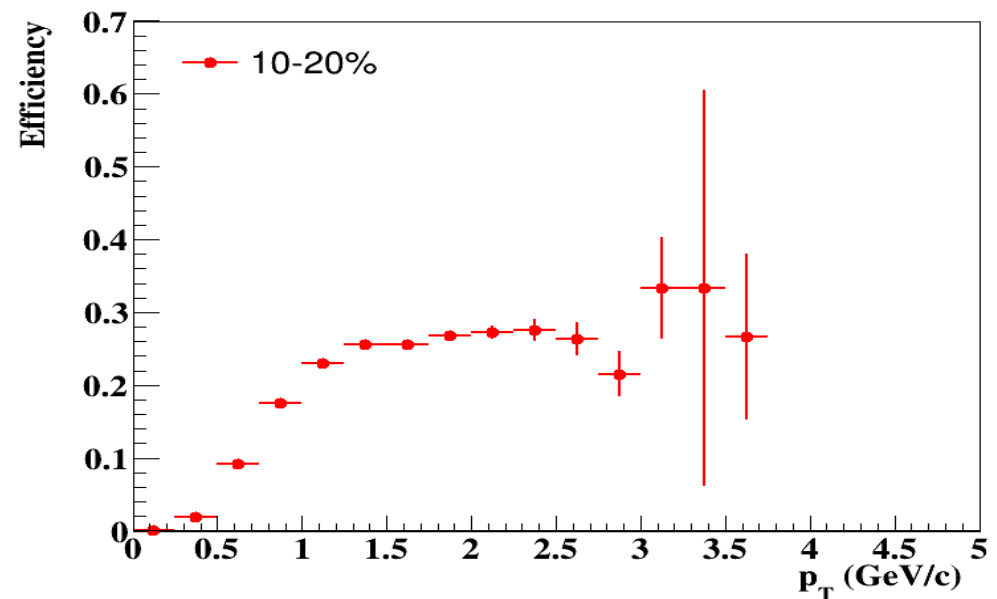
- Invariant pT-spectra of Lambda are reconstructed in several centrality bins
- Reconstructed distributions are consistent with data from model
- Thermal fits applied to data



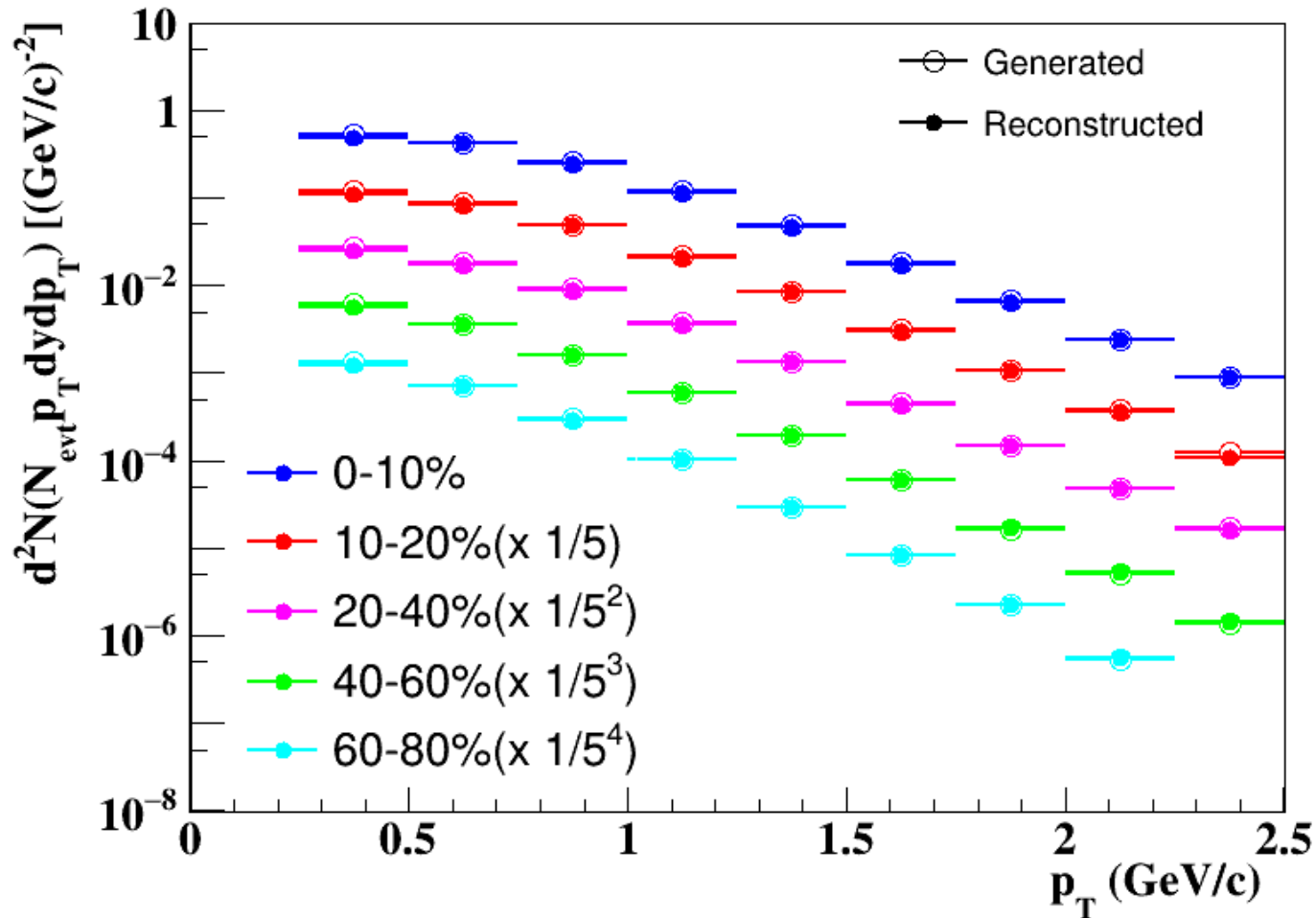
anti- Λ hyperon reconstruction in MPD



- Similar efficiencies for anti- Λ and Λ
- Sufficient phase-space coverage of antihyperons in MPD

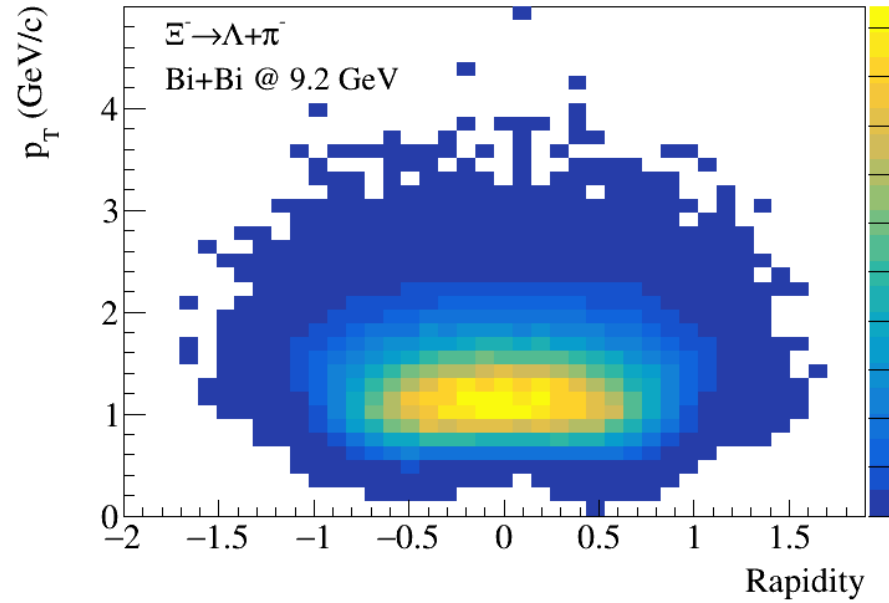
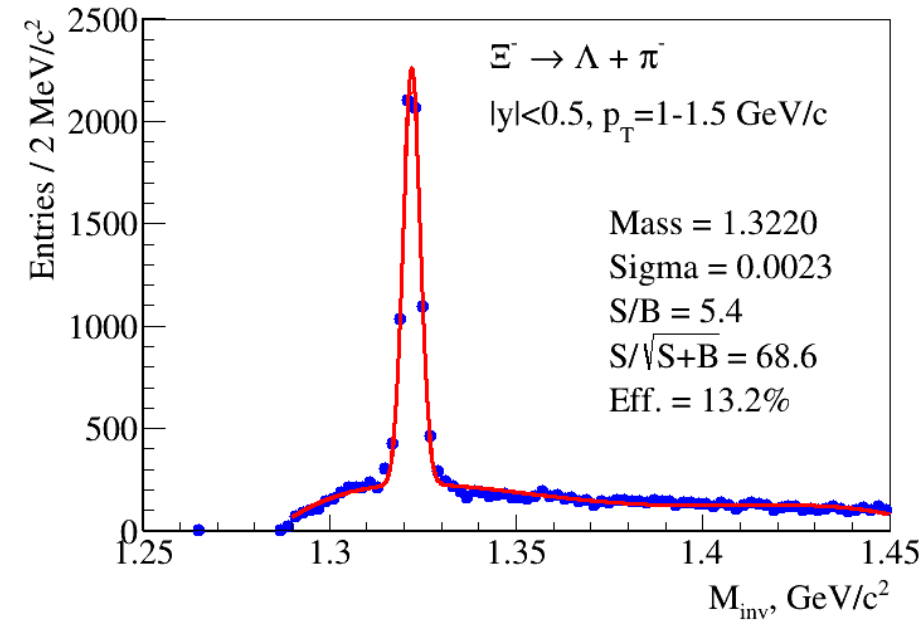


anti- Λ analysis results: fully corrected invariant pT-spectra in centrality bins

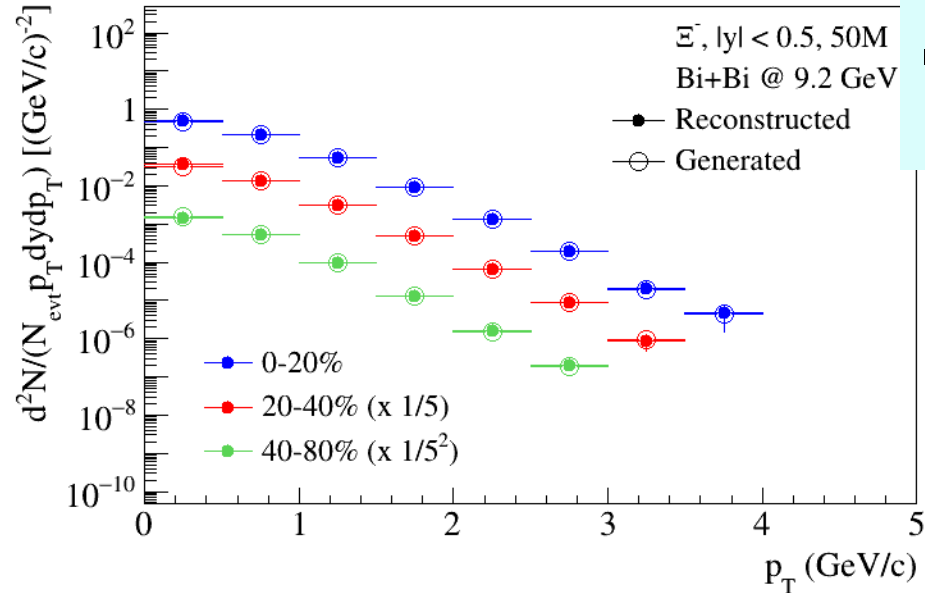
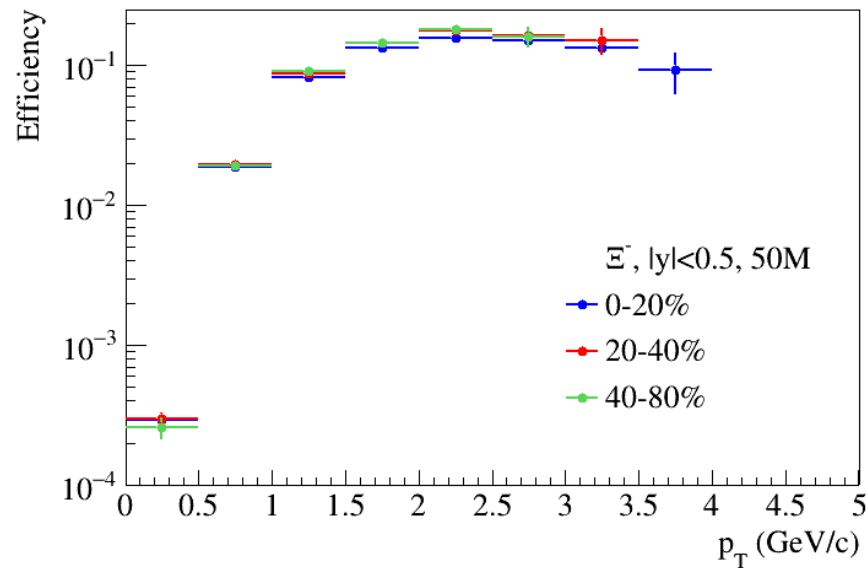


- Invariant pT-spectra of anti-Lambda are reconstructed in several centrality bins
- Reconstructed distributions are consistent with data from model

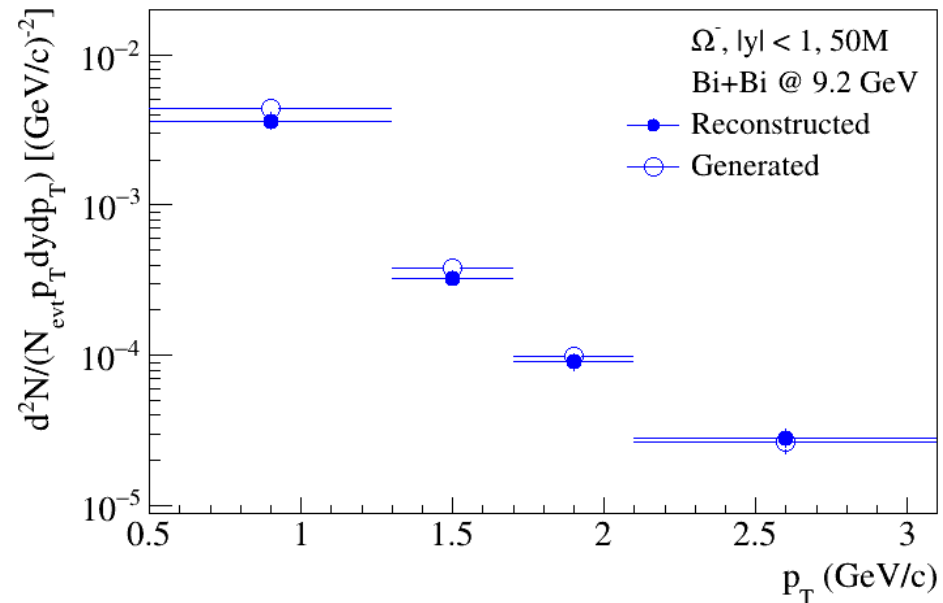
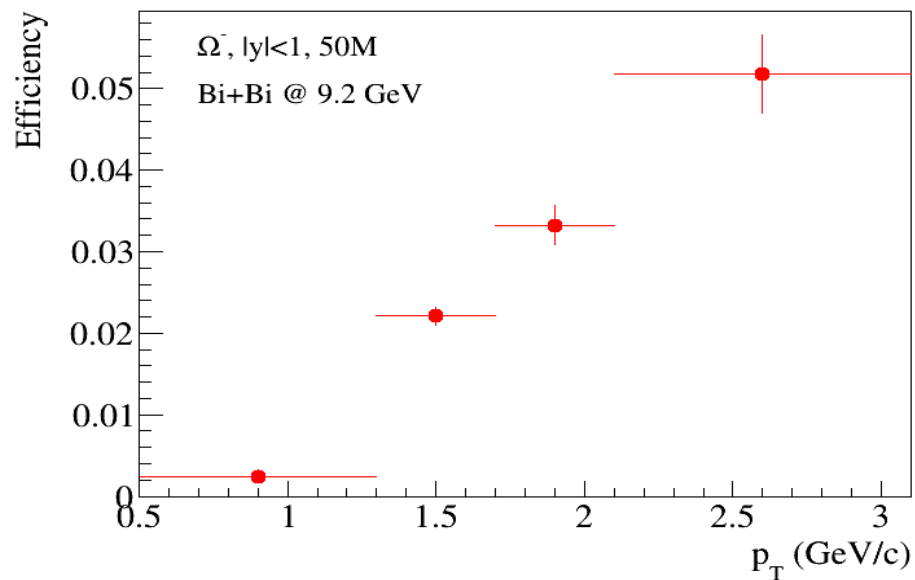
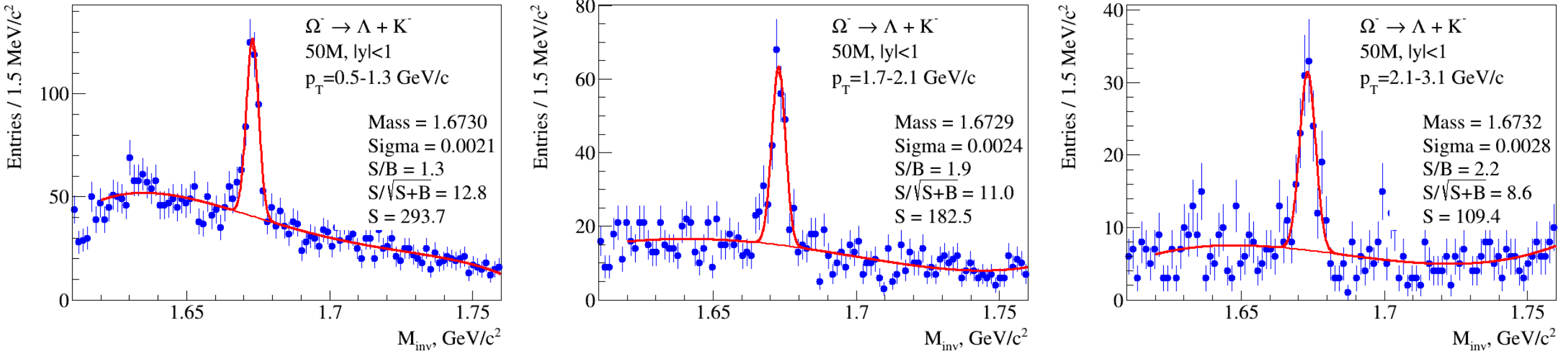
Ξ analysis: efficiency, phase-space and spectra in centrality bins



- Invariant p_T -spectra of Ξ are reconstructed in several centrality bins
- Reconstructed distributions are consistent with data from model
- Good phase-space coverage of Ξ in MPD

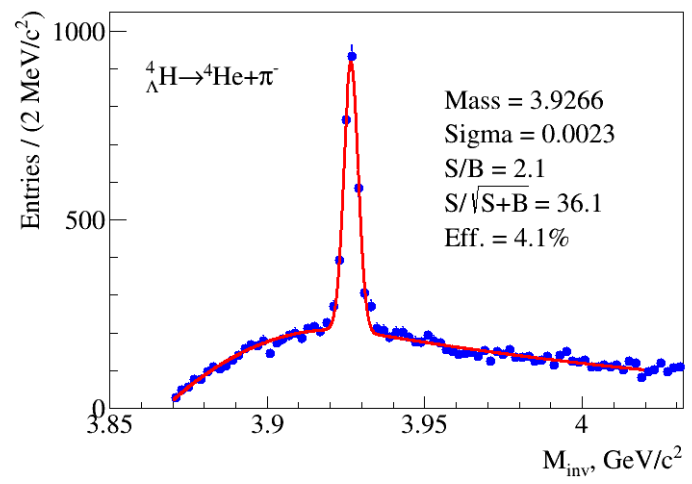
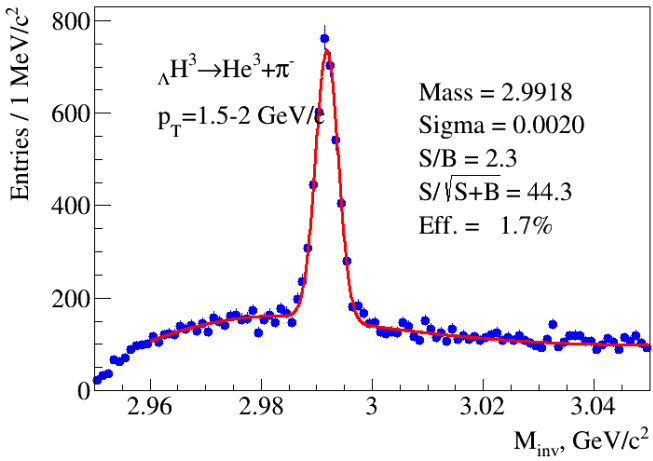
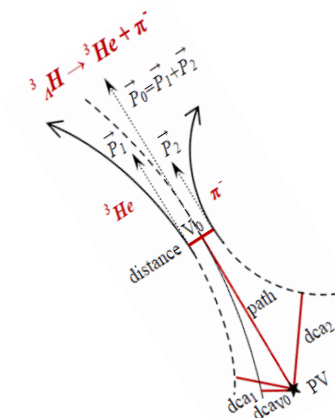


Ω^- analysis results: fully corrected invariant p_T -spectrum (no centrality binning)

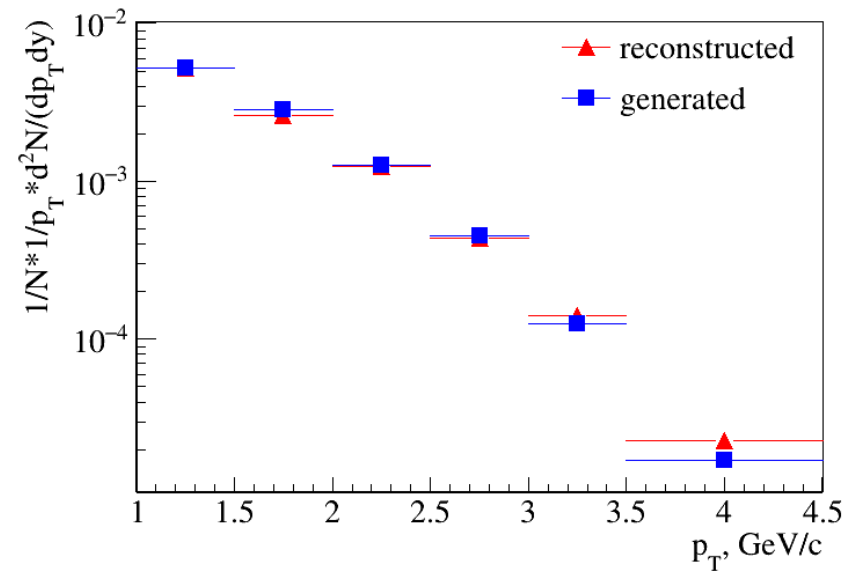
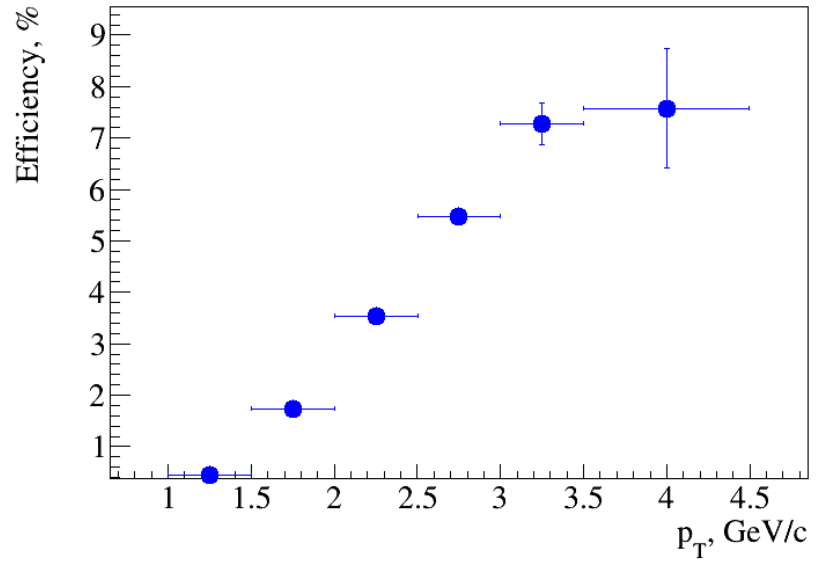


Hypertritons in MPD: yields, spectra, lifetime

V.Vasendina, A.Zinchenko, V.Kireyeu



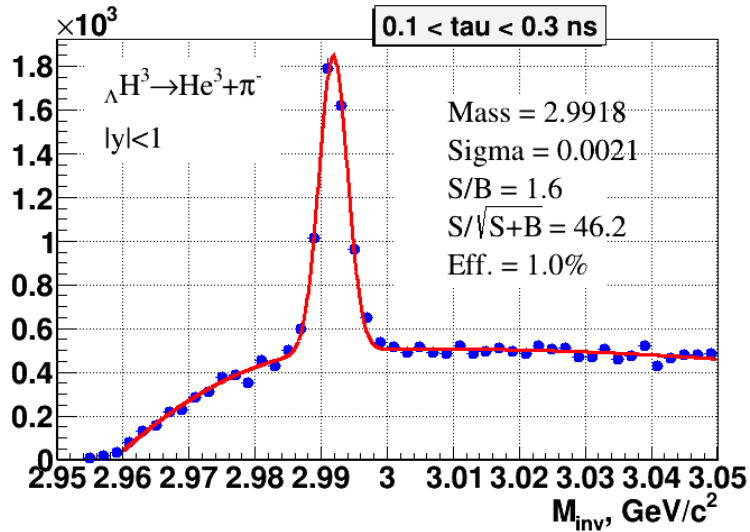
- PHQMD models Bi+Bi at 9.2 GeV
- Full event simulation and reconstruction
- A set of topological cuts aimed at maximizing significance



- Invariant spectrum of hypertritons is reconstructed up $p_T=4.5$ GeV/c
- With a larger data sets, p_T -spectra and rapidity densities can be obtained in centrality selected Bi+Bi collisions over a large phase space shedding light to the formation details and collective behavior of hypernuclei

Hypertritons in MPD: yields, spectra, lifetime

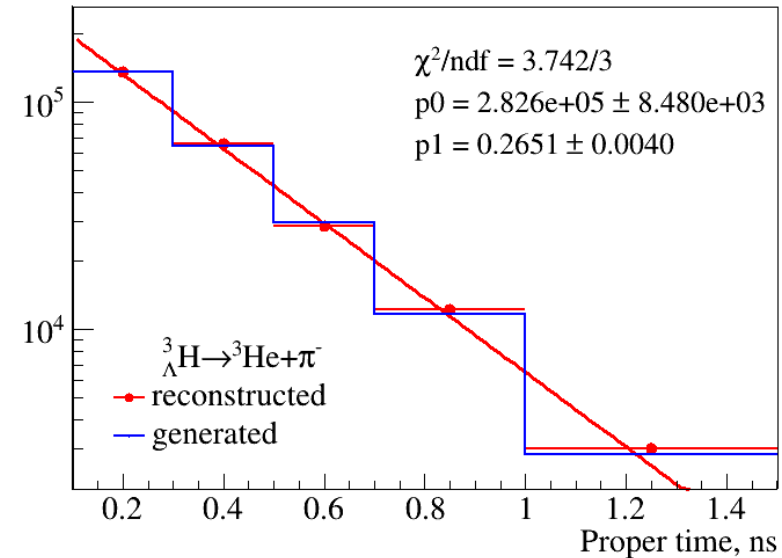
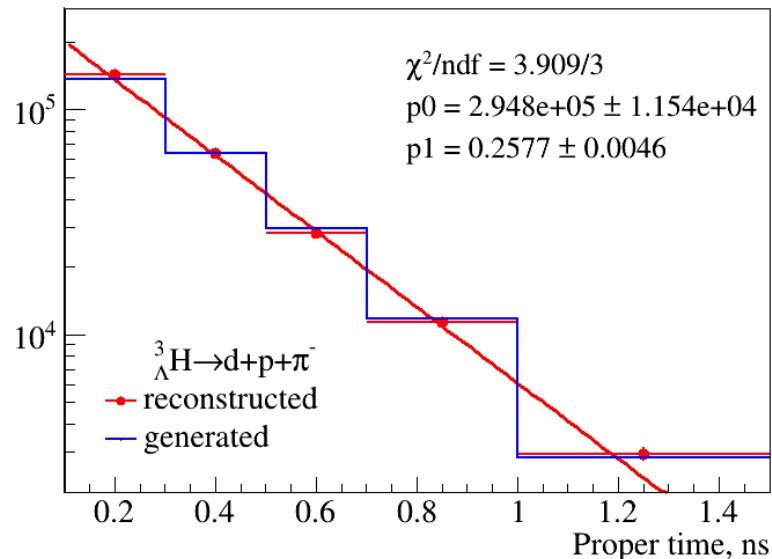
- Hypertritons are reconstructed in several τ bins
- 2- and 3-prong decay modes were studied separately to estimate systematics



$$\tau = ML/p \quad (p - \text{momentum, } M - \text{hypertriton mass, } L - \text{track length})$$

Results for different decay modes are consistent

$$N(\tau) = N(0) \exp\left(-\frac{\tau}{\tau_0}\right) = N(0) \exp\left(-\frac{ML}{cp\tau_0}\right),$$



Light nuclei in production #29 (PHQMD model)

V.Kireyeu

- 20M events from the PHQMD event generator for (hyper)nuclei

Wagons:

- "evCentrality" – for the centrality selection via charged particles in the TPC.
- "evPID" – for the deuterons selection via the "N-Sigma" method for the TPC dE/dx information.
- "Nuclei" – dE/dx and phase-space plots for light nuclei (only deuterons for a while), under development.

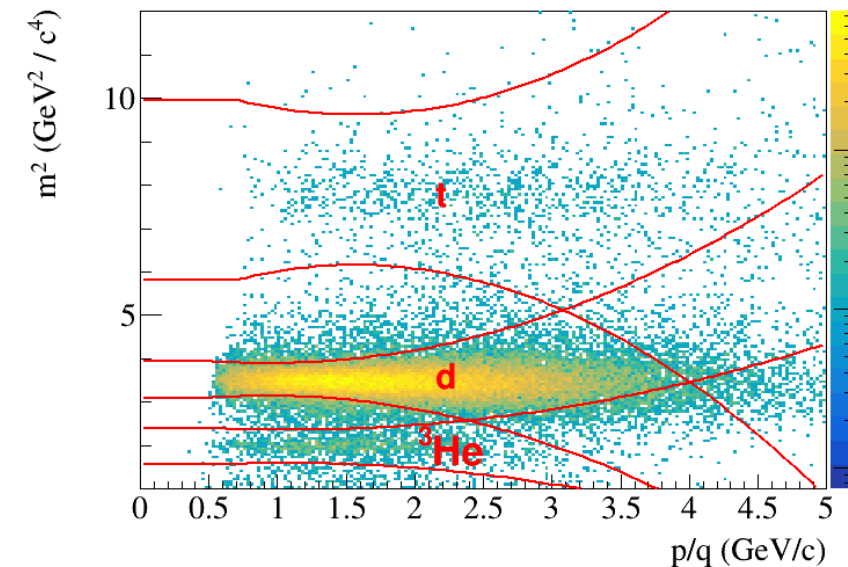
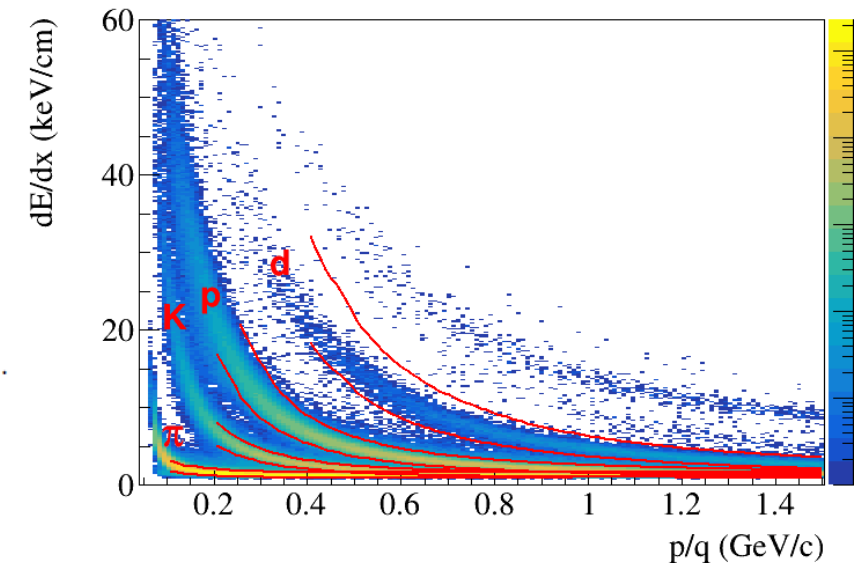
Event cuts:

- Primary vertex exists
- Primary vertex is reconstructed ($! = 0$)
- Primary vertex $Z < 130$ cm

Track cuts:

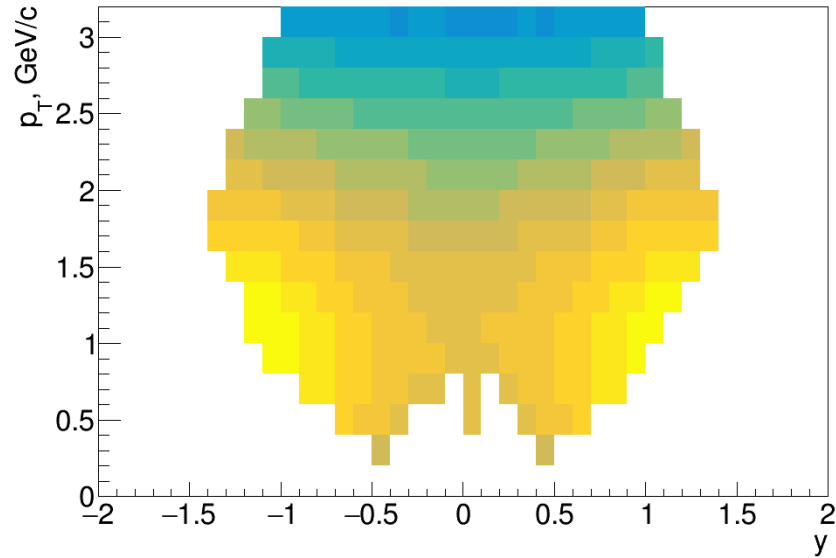
- $N_{hits} > 10$
- $|p_T| > 50$ MeV/c
- $|DCA_{x,y,z}| < 2.0$

Additional momentum cut for the Bethe-Bloch fits case (not wagon-PID): $P > 0.2$ for deuterons and $P > 0.4$ for He^4 .

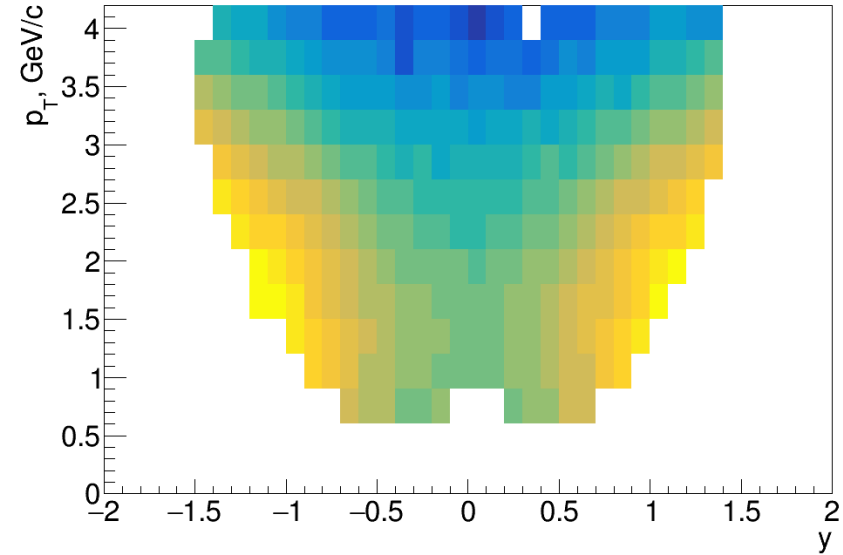


Light nuclei (d, ^3He) : phase-space and efficiency

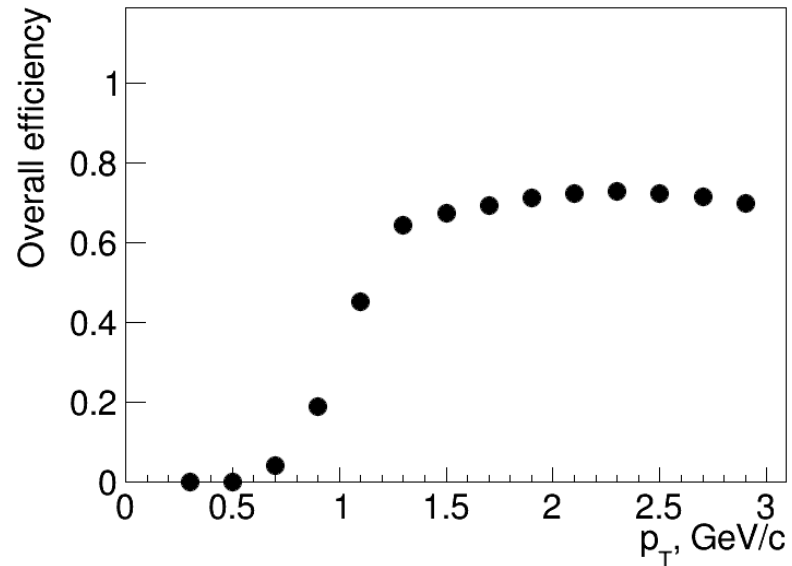
Deuterons Bi+Bi, $\sqrt{s_{\text{NN}}} = 9.2$ GeV, 0 - 20 %



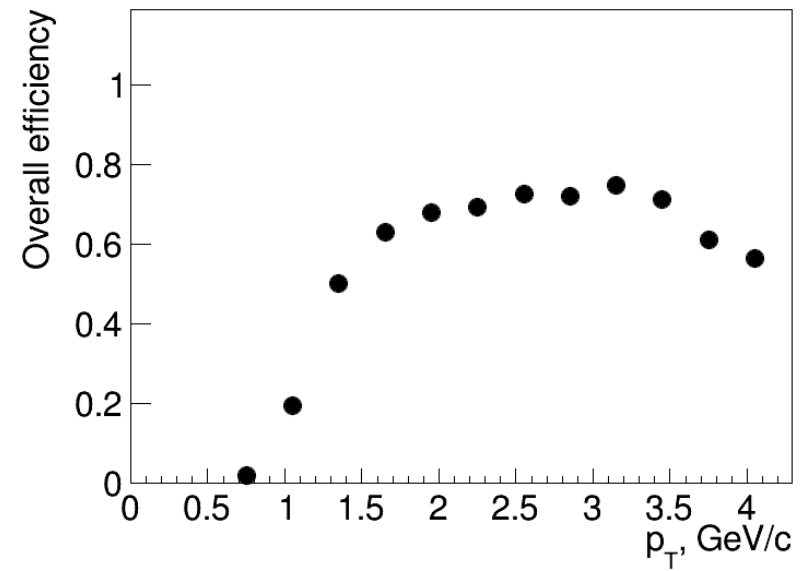
^3He in Bi+Bi, $\sqrt{s_{\text{NN}}} = 9.2$ GeV, 0 - 20 %



Bi+Bi, $\sqrt{s_{\text{NN}}} = 9.2$ GeV, d, 0 - 20%, $-0.5 < y < 0.5$

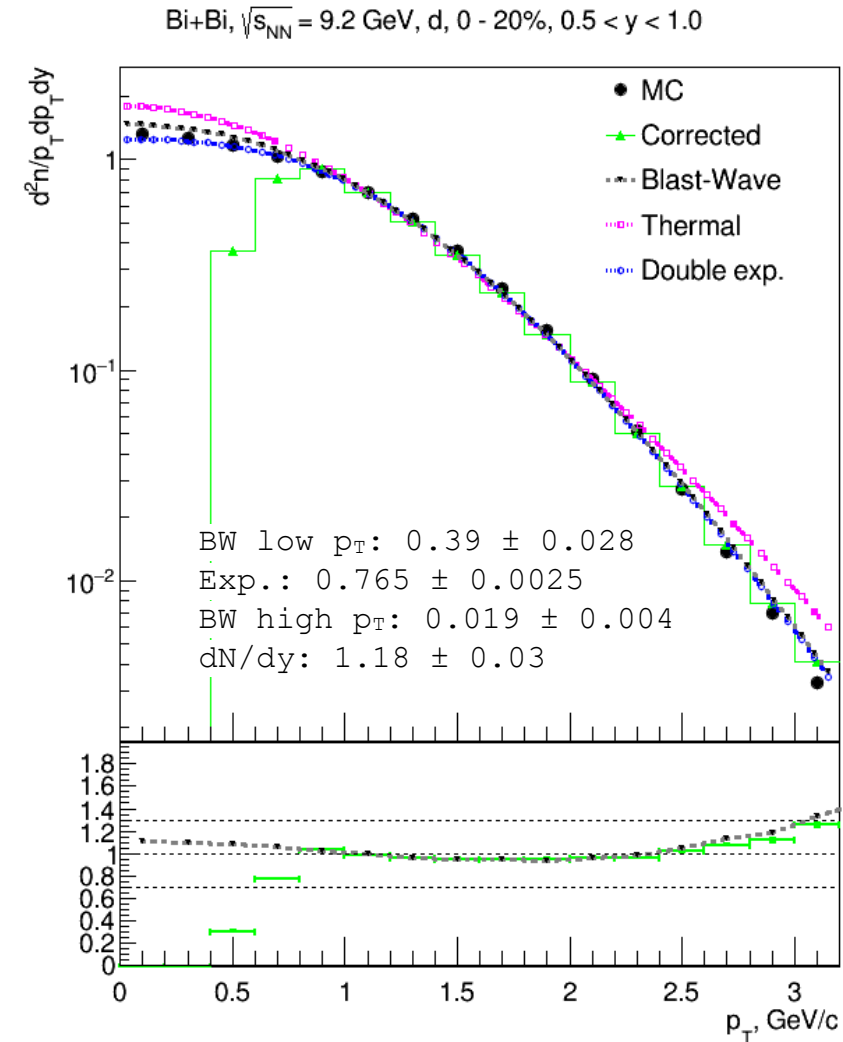
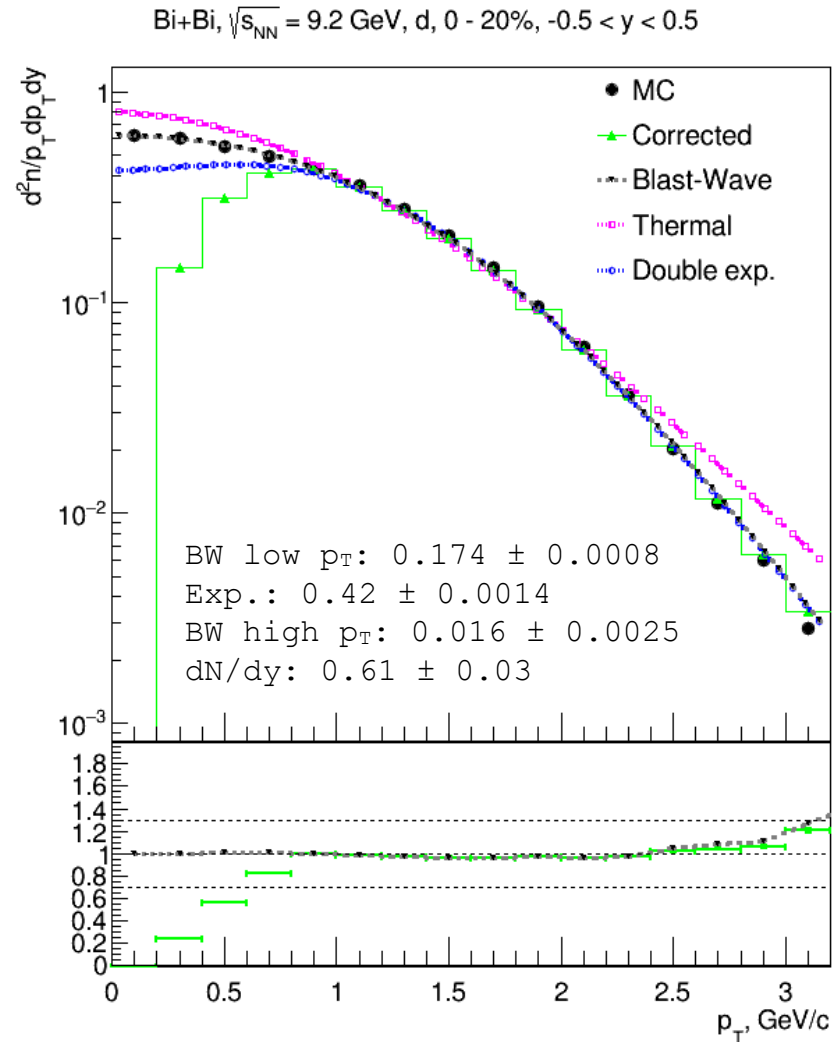
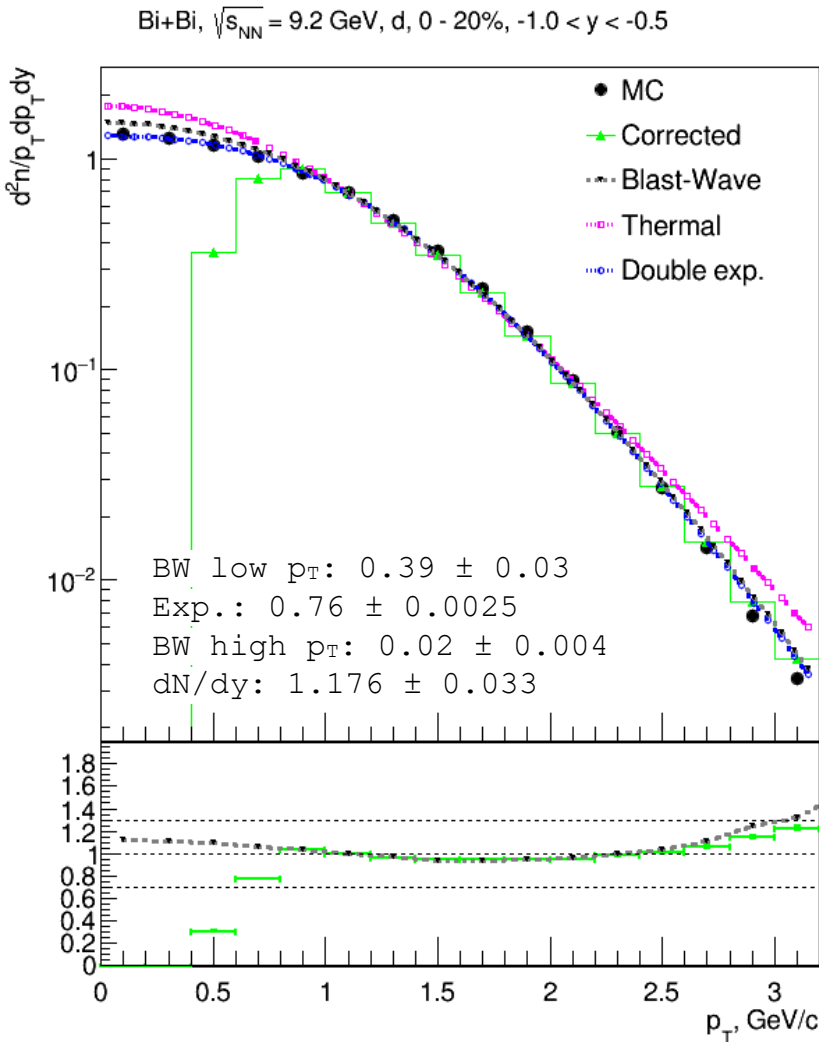


Bi+Bi, $\sqrt{s_{\text{NN}}} = 9.2$ GeV, He3, 0 - 20%, $-0.5 < y < 0.5$



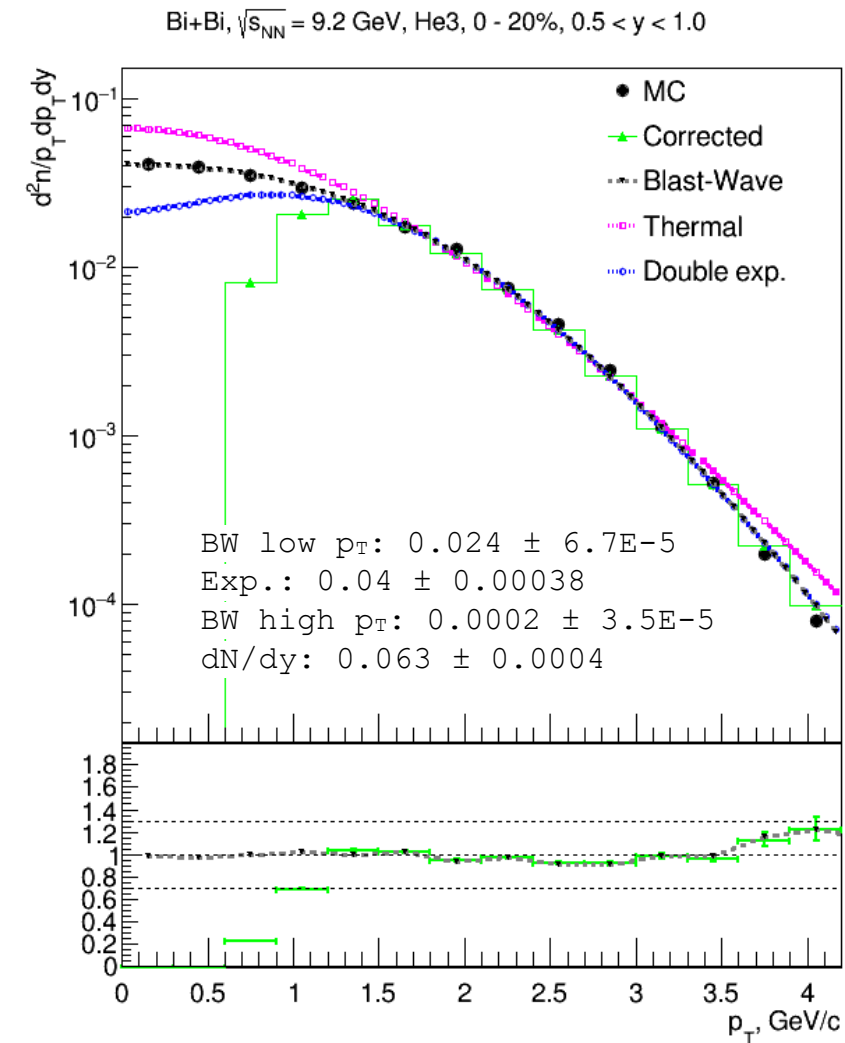
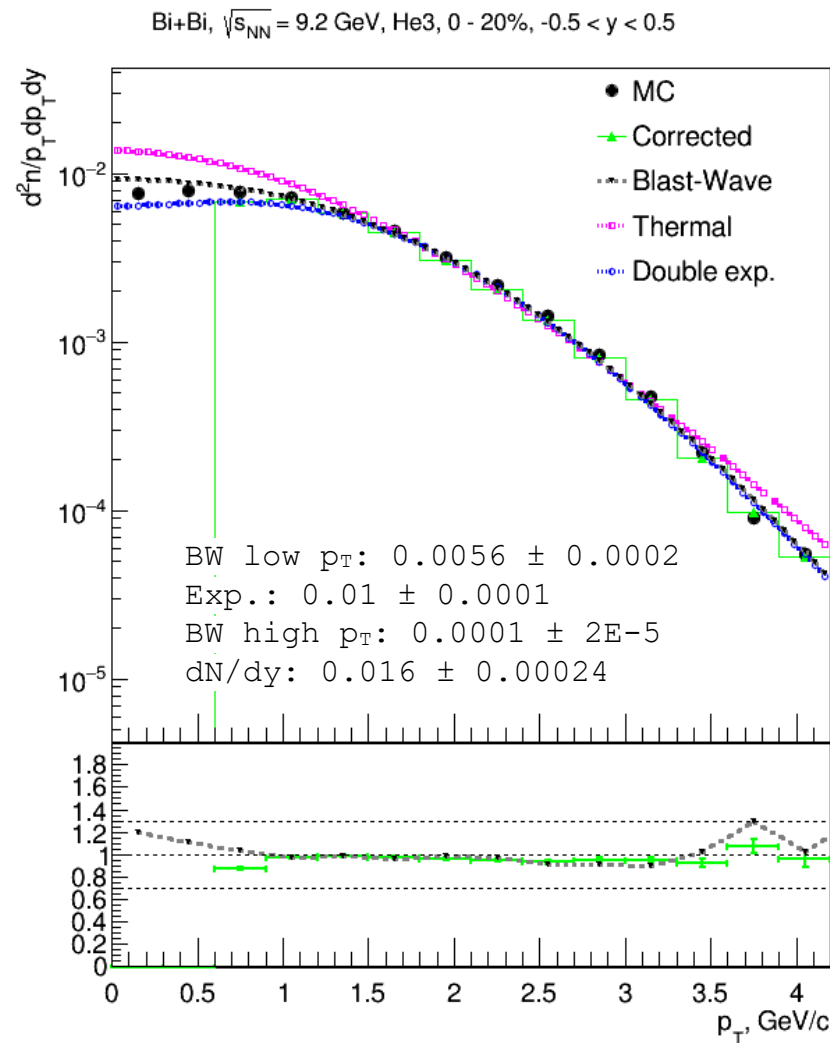
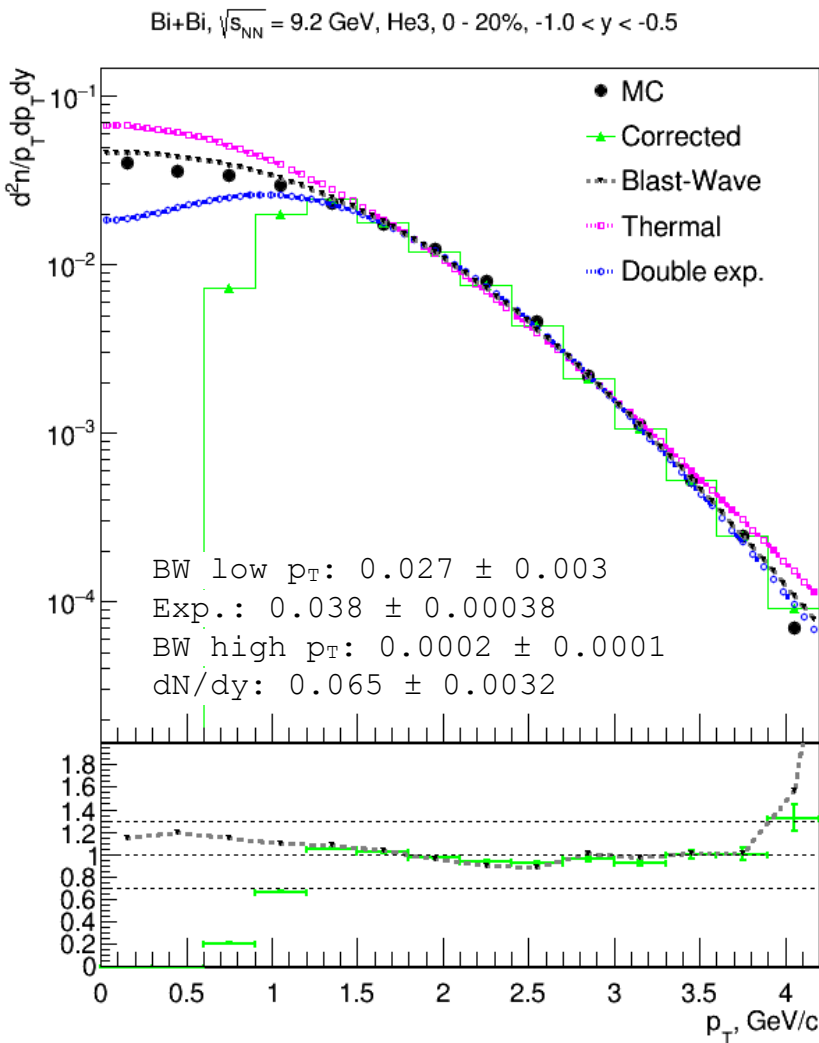
Light nuclei : d invariant spectra

- Estimation of the extrapolation part in the cluster yields is not yet finished
- Testing of the optimal p_T -spectra shape

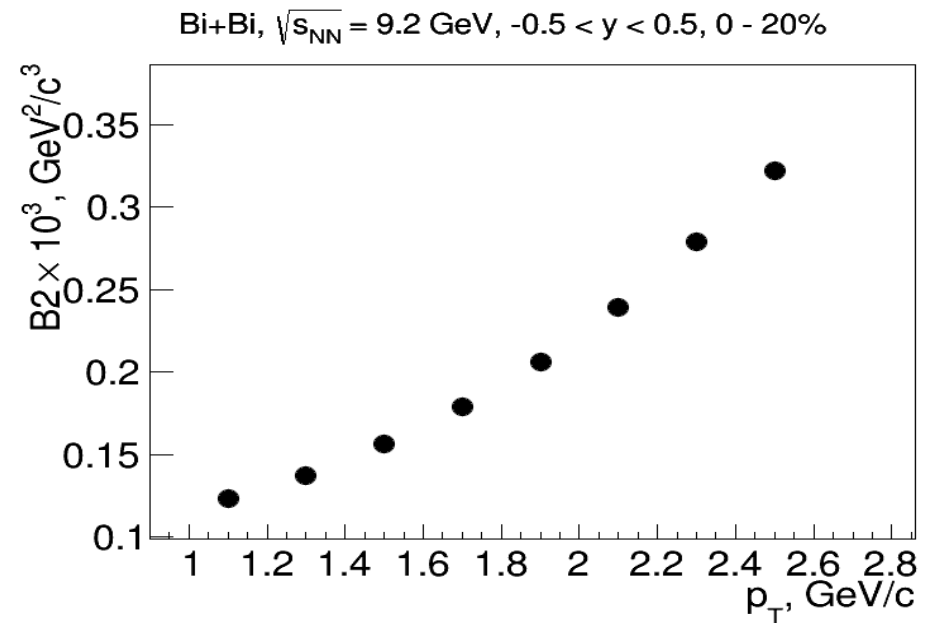
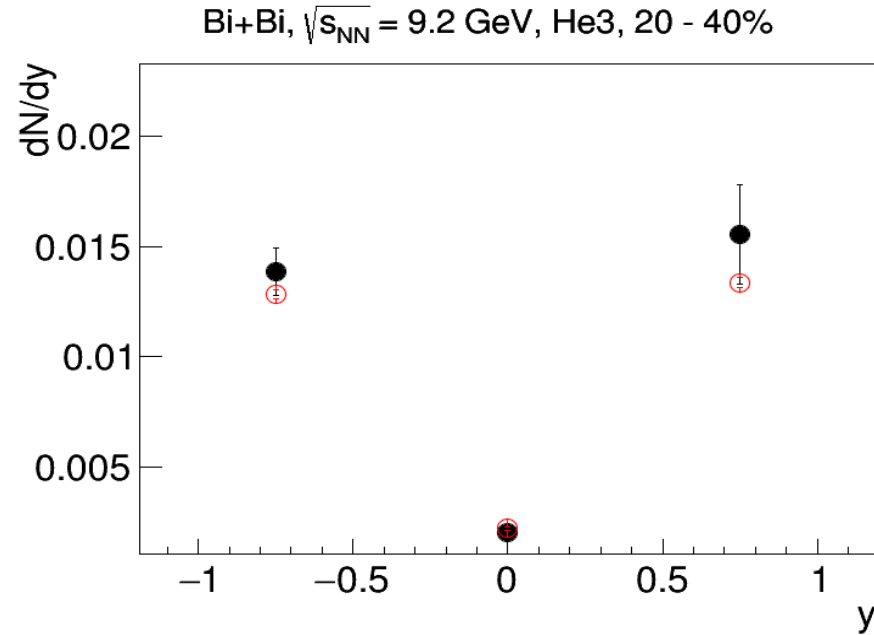
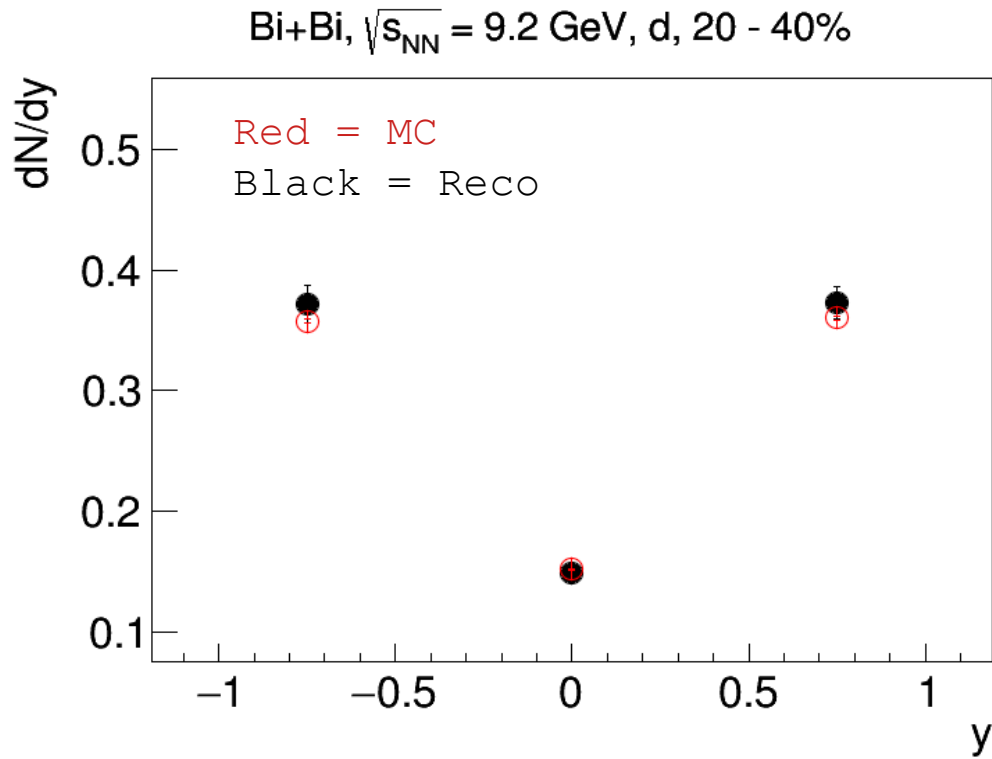


Light nuclei : ^3He invariant spectra

- Estimation of the extrapolation part in the cluster yields is not yet finished
- Testing of the optimal p_T -spectra shape



Light nuclei : rapidity spectra, particle ratios



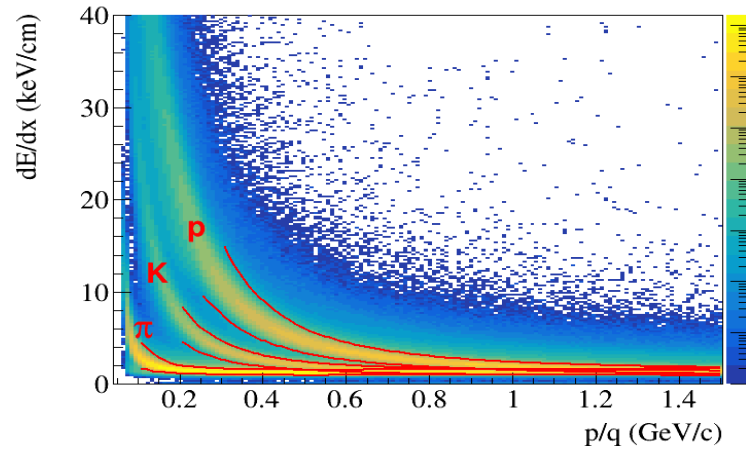
Ongoing analysis
will be finished by the end of May

Hadron spectra and yields in Bi+Bi at 9.2 GeV

N.Kolomoets

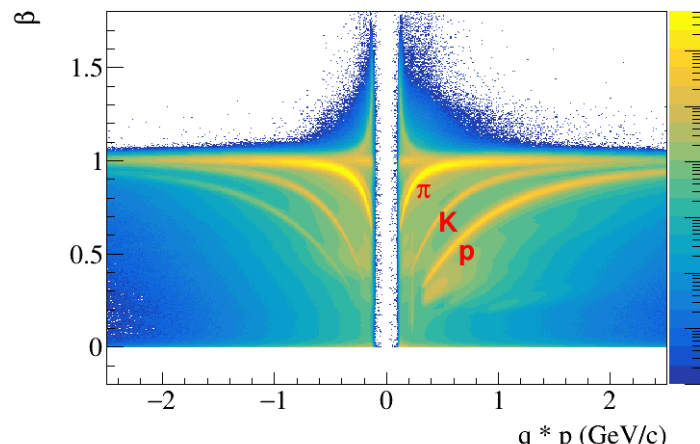
Goal: rapidity & pT-spectra, total yields and ratios of identified hadrons (π , K, p) in centrality selected Bi+Bi

- Production #29 : 20M of PHQMD events
- Centrality selection (5-10% binning) implemented in the centrality wagon (P.Parfenov)



Vertex & track selection criteria:

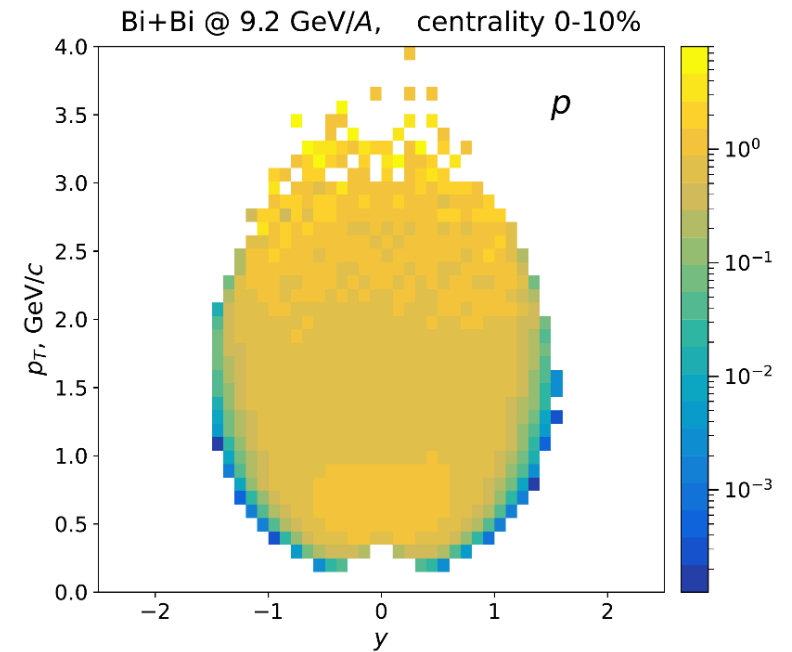
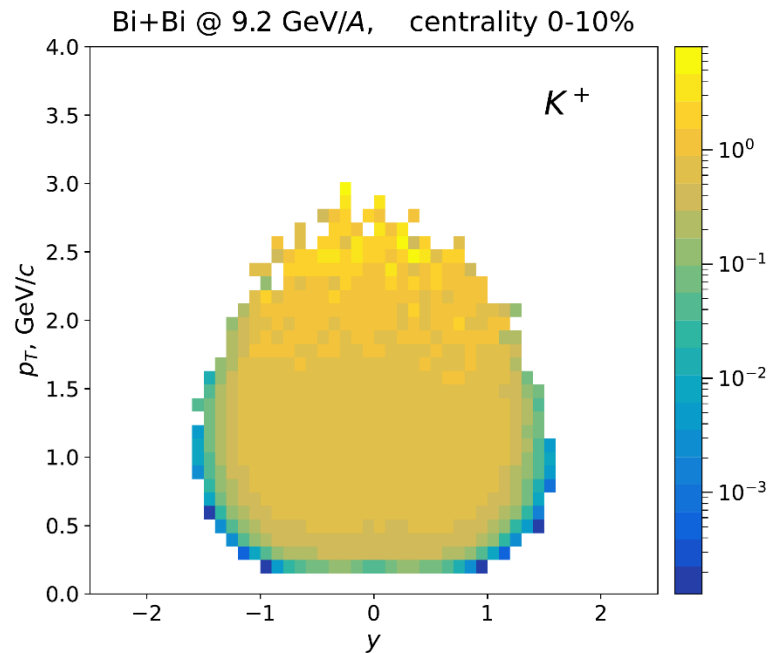
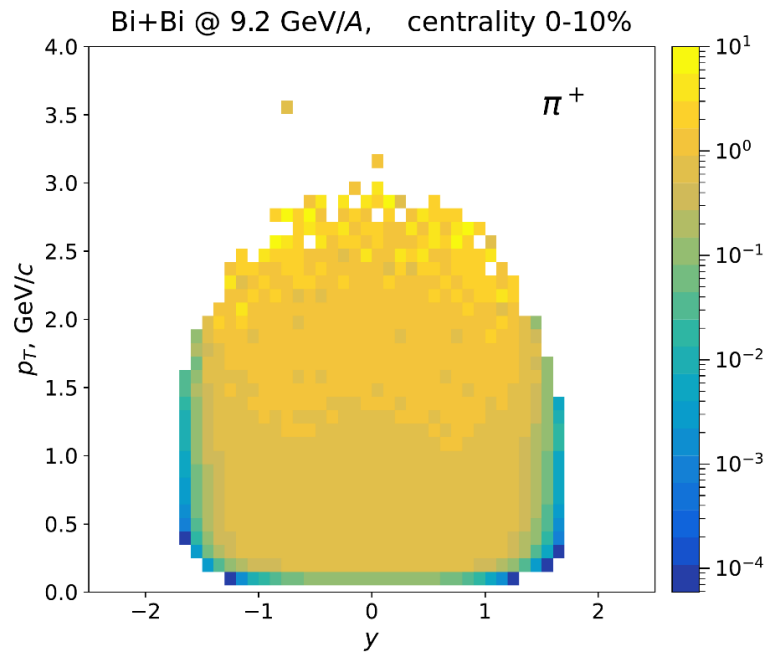
- Cut on vertex Z coordinate: $|V_z| < 100$ cm
- Number of hits on a track: $N_{\text{hits}} \geq 20$
- DCAs at the Main vertex: $|DCA_{x,y,z}| < 3$ cm



Combined PID ($dE/dx+TOF$) from A.Mudrokh

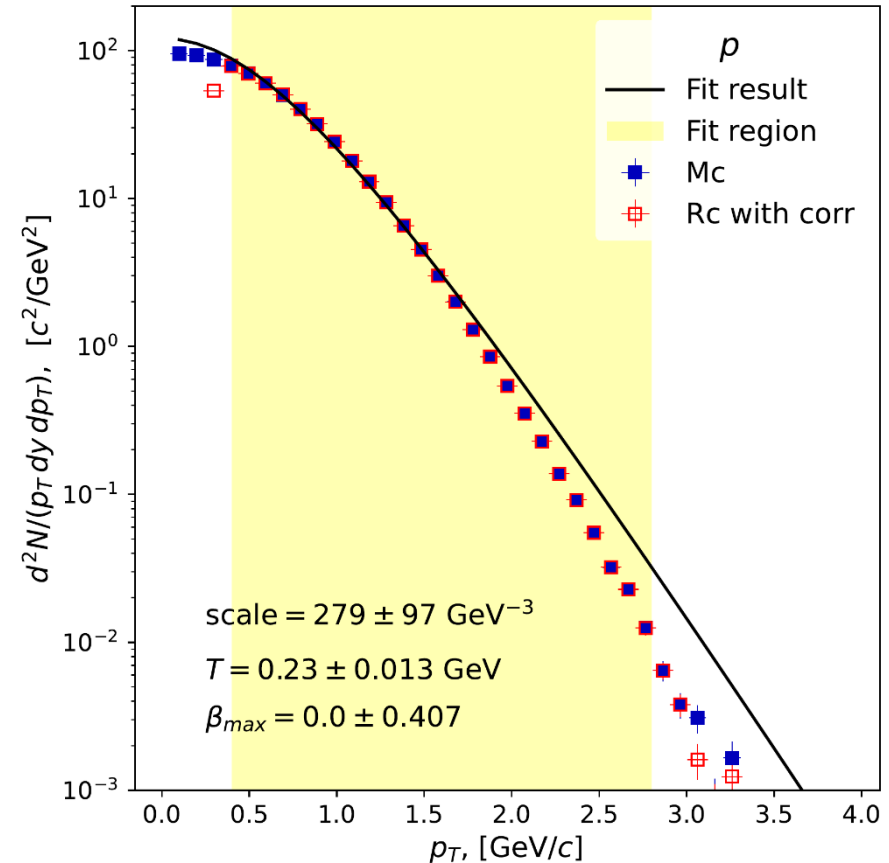
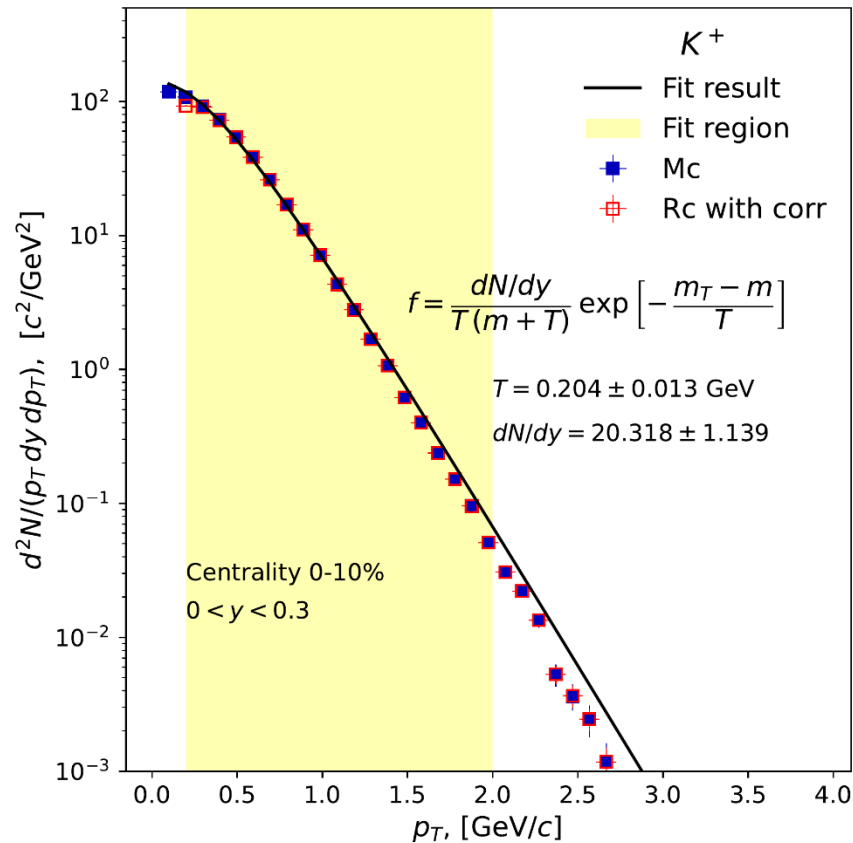
Light nuclei (π , K , p) : phase-space and efficiency

- Preliminary, no detailed prepared info about purities, contaminations and efficiencies yet (in progress)



Light nuclei (π , K, p) : pT-spectra and yields

- Status : (very) preliminary. Testing of fit functions, estimation of the extrapolations.
- No final error assessments.



The estimated finish of the analysis: May-June

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 → slowly **progressing** prior to current time

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**THE EUROPEAN
PHYSICAL JOURNAL A**



Regular Article - Experimental Physics

Performance study of the hyperon global polarization measurements with MPD at NICA

Elizaveta Nazarova^{1,a}, Vadim Kolesnikov¹, Petr Parfenov^{1,2}, Arkadiy Taranenko², Oleg Teryaev¹, Valerii Troshin^{1,2}, Vadym Voronyuk¹, Alexander Zinchenko¹

¹ Joint Institute for Nuclear Research, 141980 Dubna, Russia

² National Research Nuclear University MEPhI, 115409 Moscow, Russia

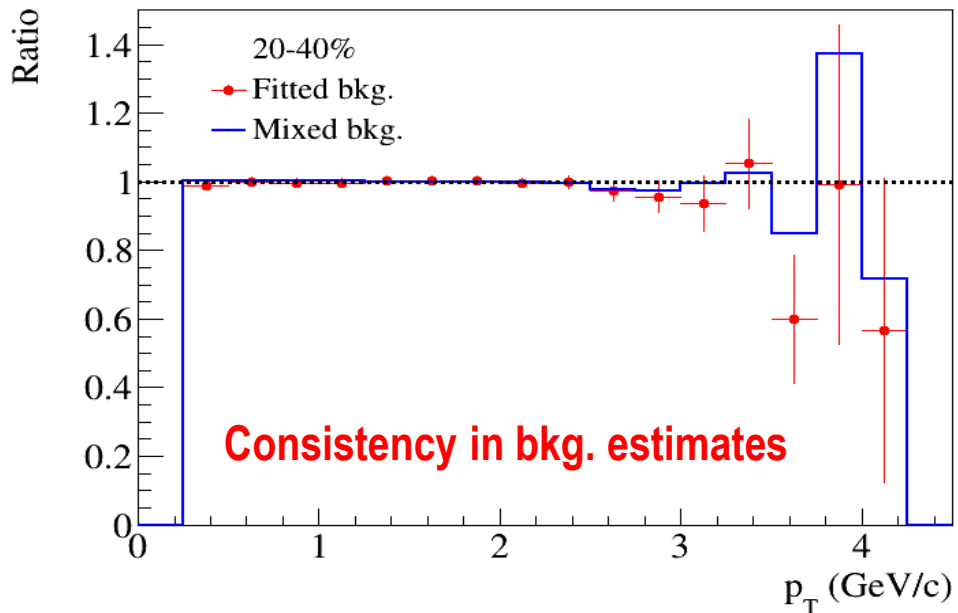
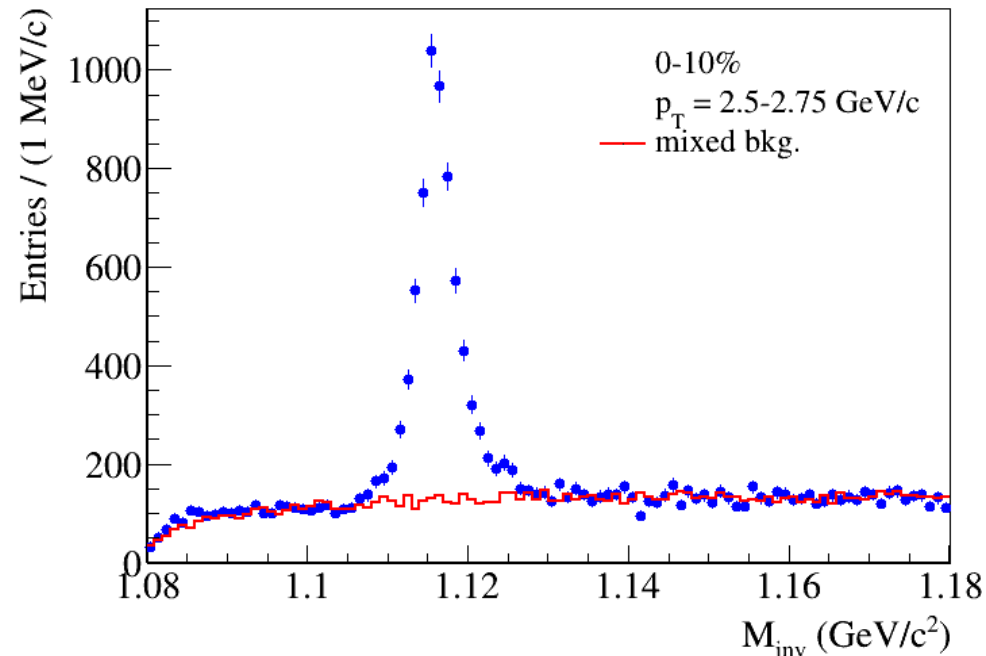
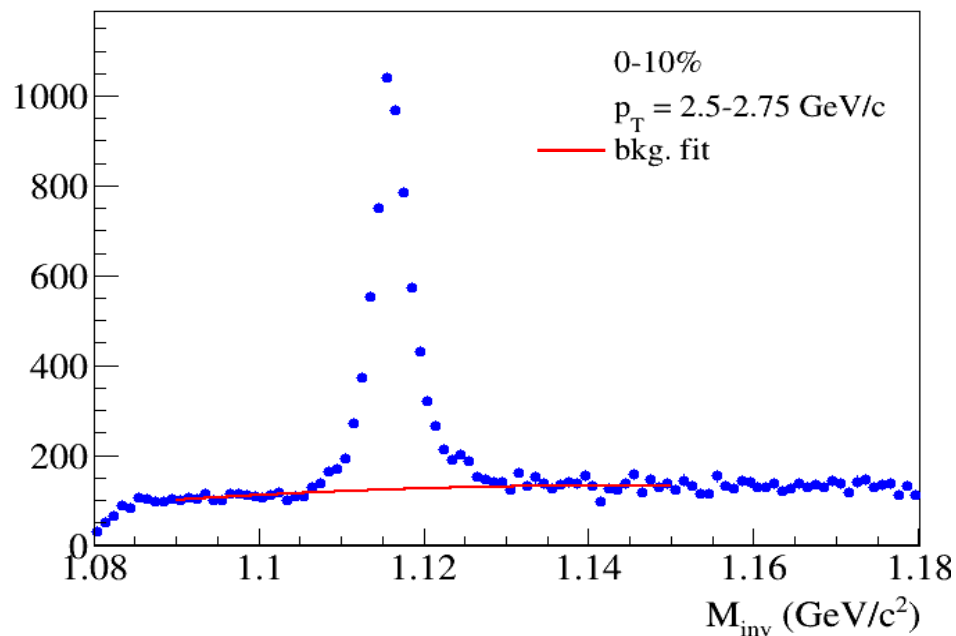
Summary

- **Status of the PWG2 analyses (25/04/2024) :**
 - Prod. 25 (UrQMD) for hyperon studies - **finished**
 - Prod. 29 (PHQMD) for light nuclei and hypernuclei – **in the completion**
 - Prod. 30 (PHSD) dedicated to Lambda-hyperon polarization studies – **finished, under PWG3 authority from now**
 - Light hadrons : change in the production (#25 → #29), change in person (AM→NK) - **progressing**

Thank you for your attention!

Extra slides

Λ -hyperon reconstruction in MPD: background estimates



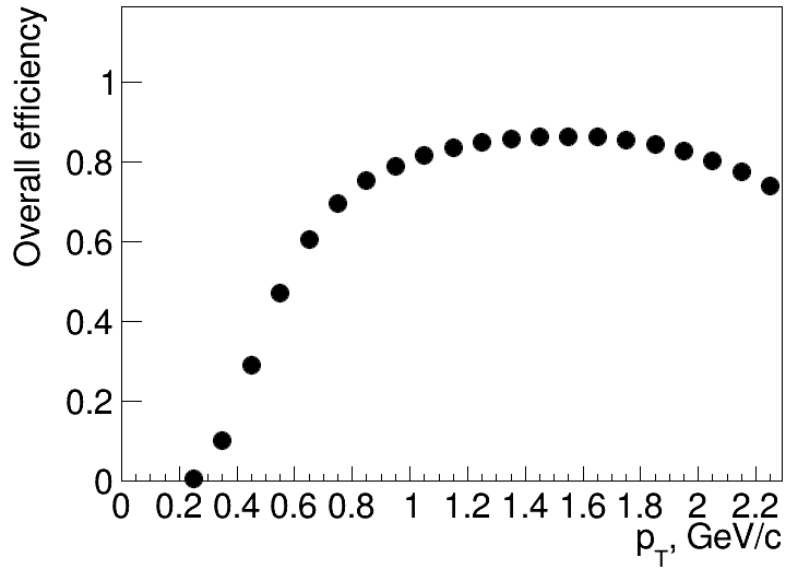
Study of systematic uncertainties and improvements in the analysis chain:

- Background estimates (fit vs. mixed background)
- Varying PID modes for high- p_T protons

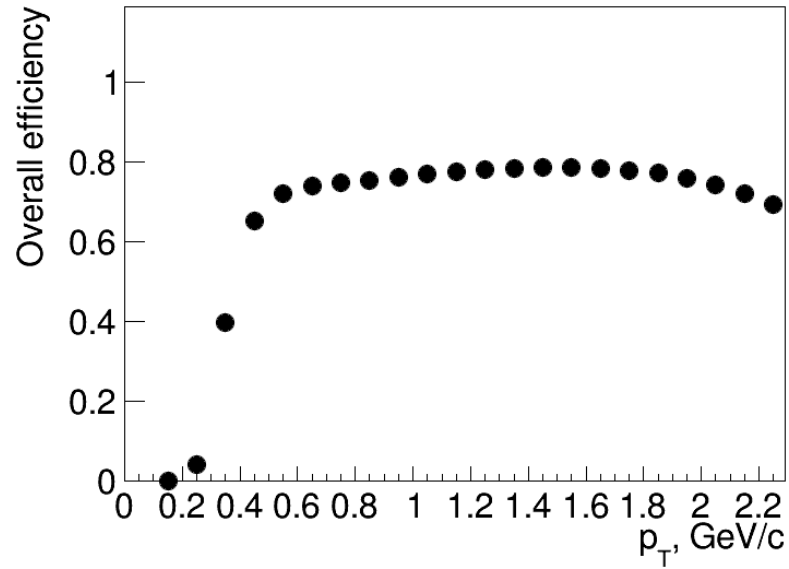
PHQMD #29: Protons

Overall efficiency

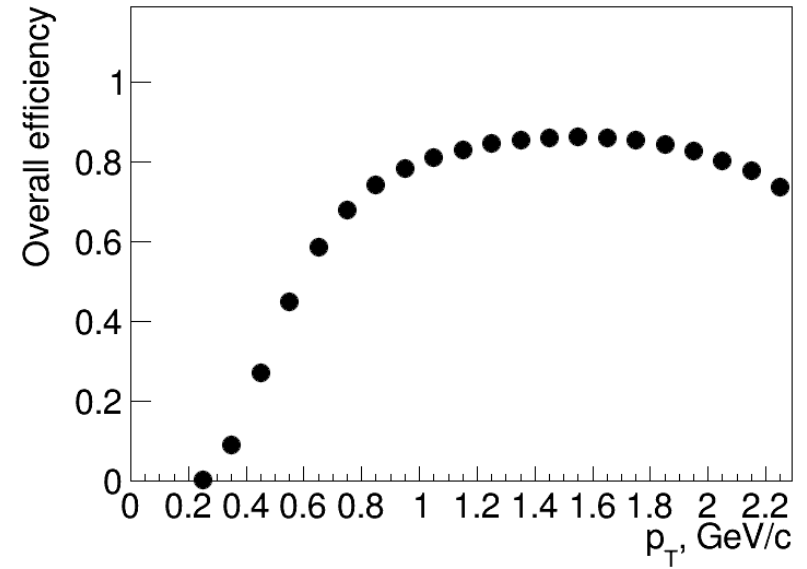
Bi+Bi, $\sqrt{s_{NN}} = 9.2$ GeV, p, 0 - 20%, $-1.0 < y < -0.5$



Bi+Bi, $\sqrt{s_{NN}} = 9.2$ GeV, p, 0 - 20%, $-0.5 < y < 0.5$



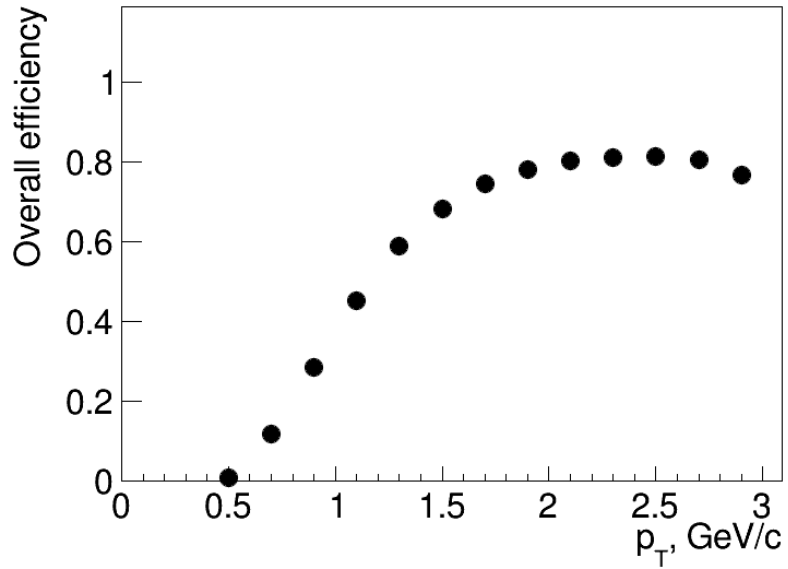
Bi+Bi, $\sqrt{s_{NN}} = 9.2$ GeV, p, 0 - 20%, $0.5 < y < 1.0$



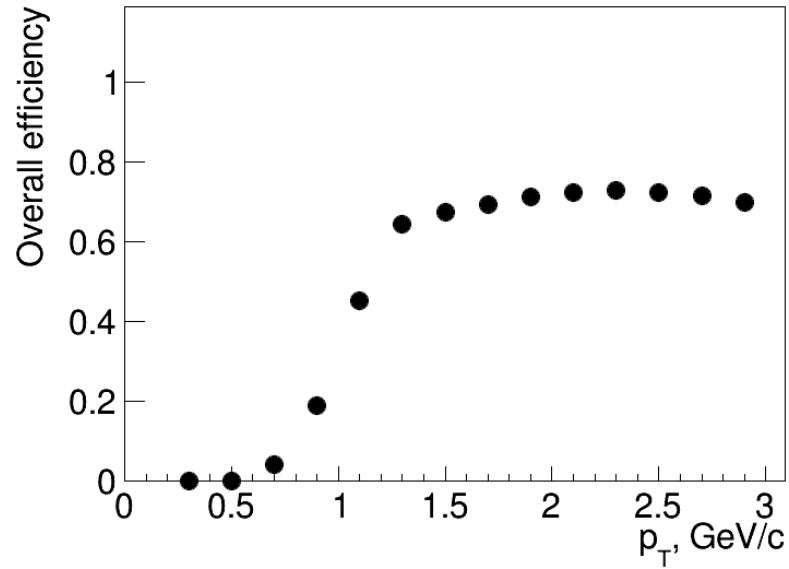
PHQMD #29 Deuterons

Overall efficiency

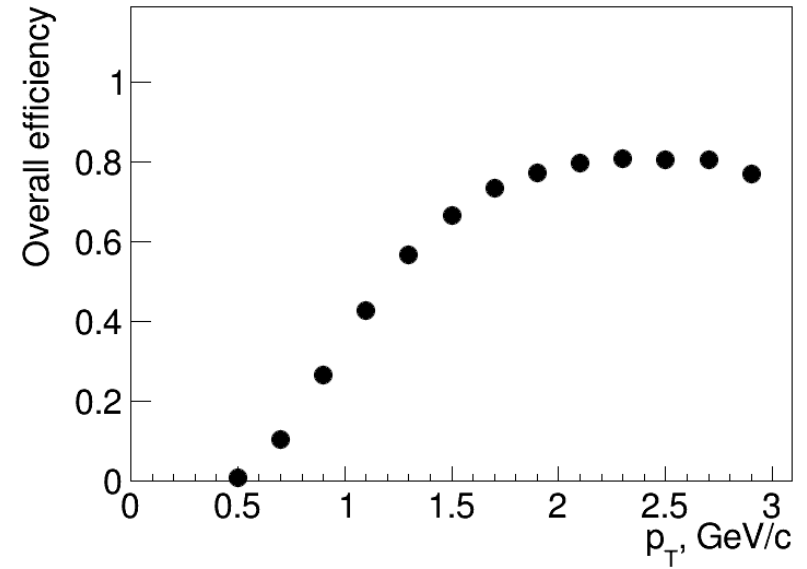
Bi+Bi, $\sqrt{s_{NN}} = 9.2$ GeV, d, 0 - 20%, $-1.0 < y < -0.5$



Bi+Bi, $\sqrt{s_{NN}} = 9.2$ GeV, d, 0 - 20%, $-0.5 < y < 0.5$



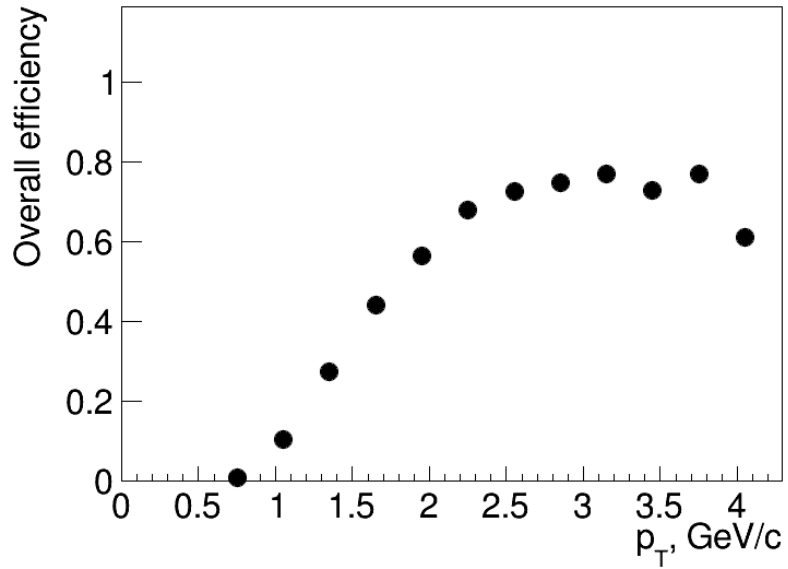
Bi+Bi, $\sqrt{s_{NN}} = 9.2$ GeV, d, 0 - 20%, $0.5 < y < 1.0$



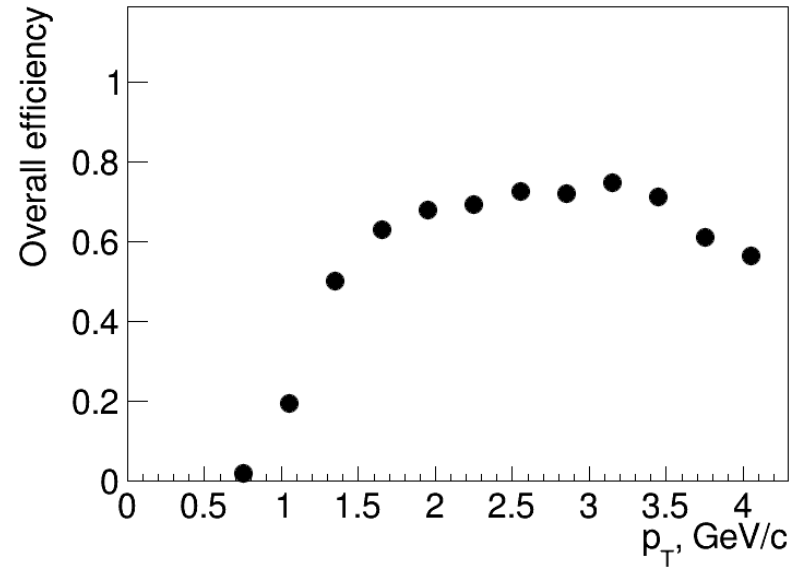
${}^3\text{He}$

Overall efficiency

Bi+Bi, $\sqrt{s_{\text{NN}}} = 9.2$ GeV, He3, 0 - 20%, $-1.0 < y < -0.5$



Bi+Bi, $\sqrt{s_{\text{NN}}} = 9.2$ GeV, He3, 0 - 20%, $-0.5 < y < 0.5$



Bi+Bi, $\sqrt{s_{\text{NN}}} = 9.2$ GeV, He3, 0 - 20%, $0.5 < y < 1.0$

