

MPD PWG2 status report

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



MPD Collaboration meeting
JINR, Dubna, October 14-16, 2024

Outline

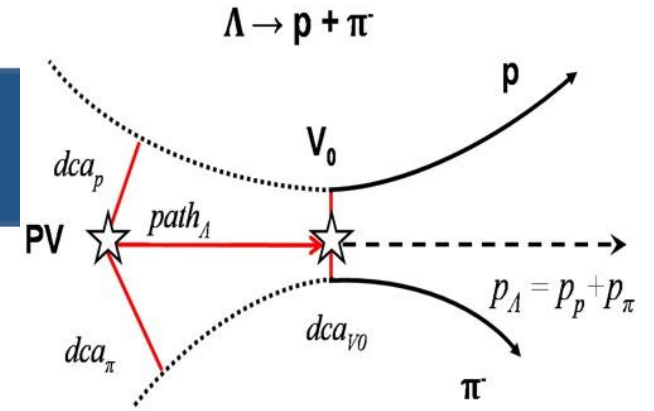
- ❑ **Introduction**
- ❑ **Progress in a new round of feasibility study with Bi+Bi at 9.2 GeV :**
 - Hyperons (prod. #25)
 - Hadrons (prod #29)
 - Light nuclei (prod. #29)
 - Hypernuclei (prod. #29)
- ❑ **Summary**

Status of hyperon reconstruction in Bi+Bi at 9.2 GeV

V.Vasendina, D.Suvarieva, A.Zinchenko

Data Set

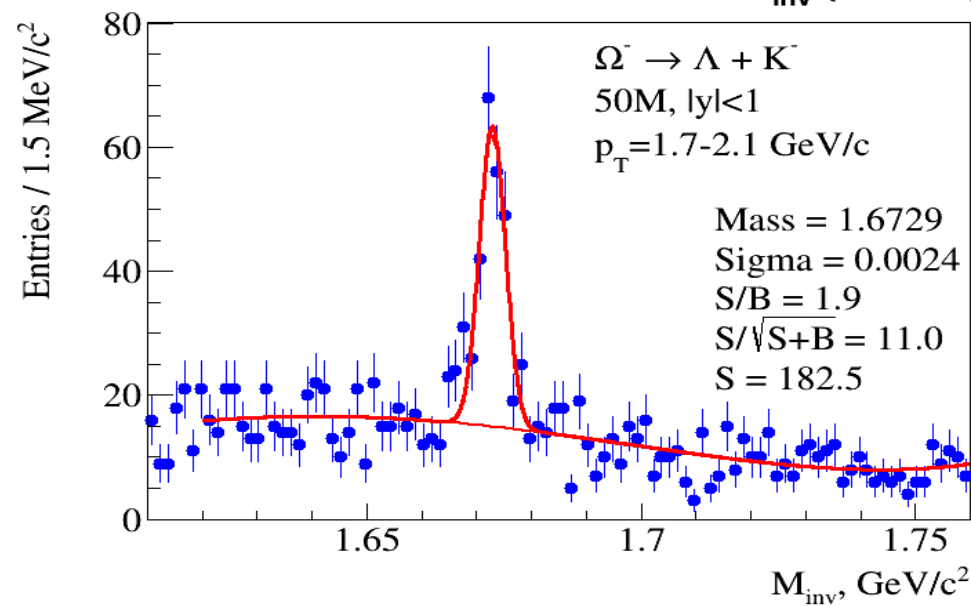
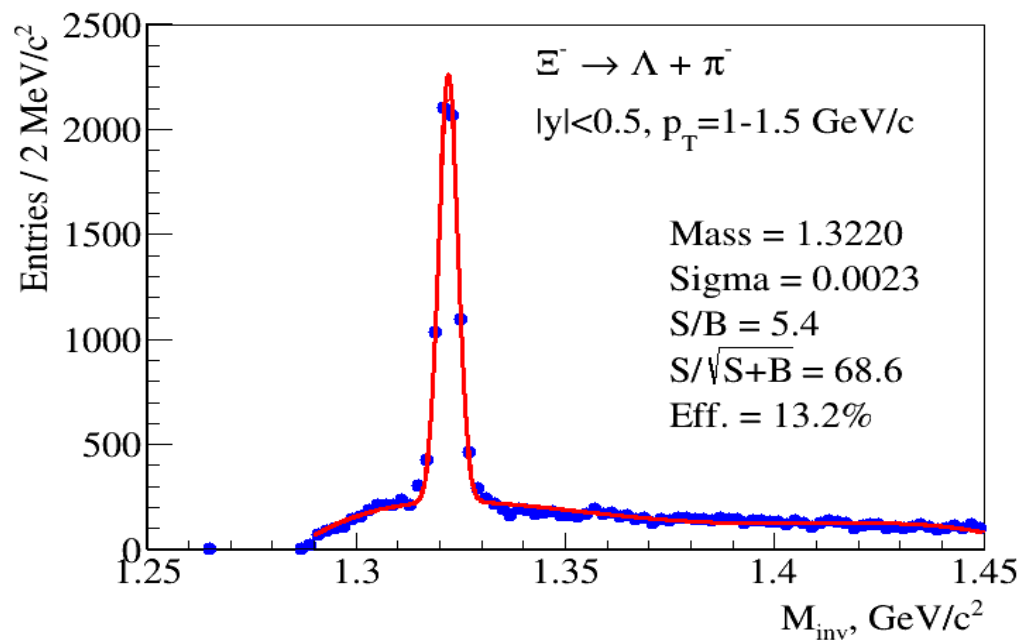
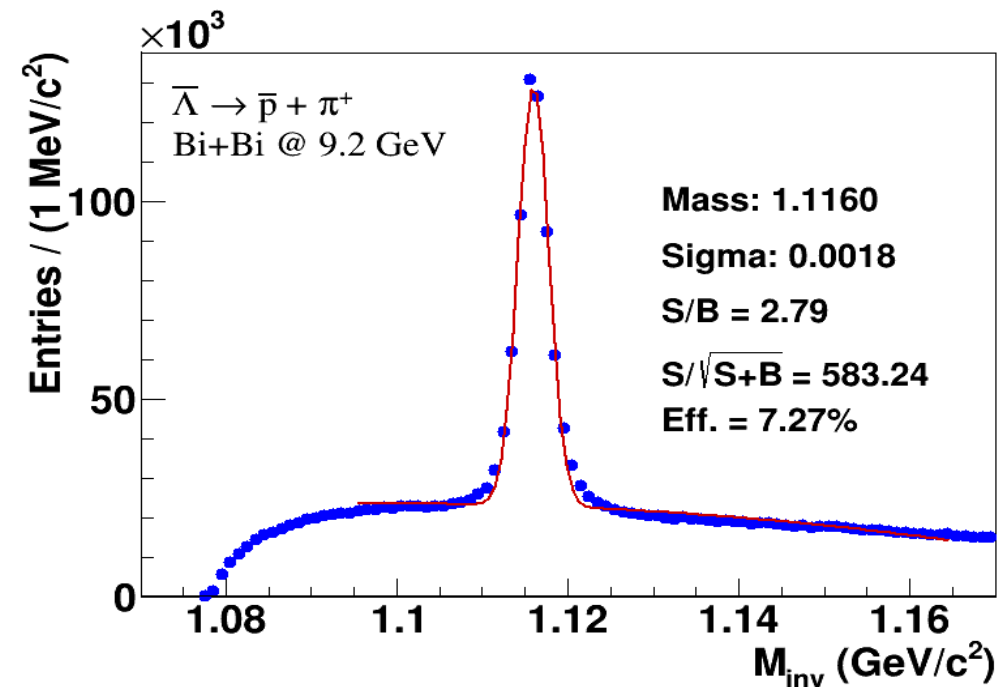
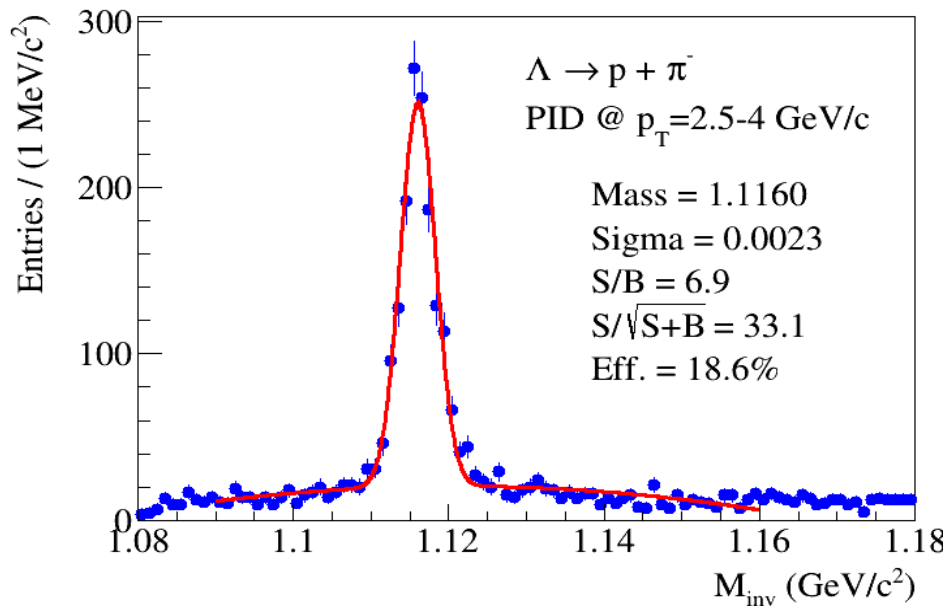
- ✓ **Generator:** UrQMD, Min.bias, Bi+Bi @ 9.2 GeV, 50M
- ✓ **Reconstruction & Analysis:** hyperon wagon in the analysis train
- ✓ **Selection:** $|y| < 0.5$, $Z_{PV} = \pm 130$ cm
- ✓ **Centrality bins:** 0-10%, 10-20%, 20-40%, 40-60%, 60-80%



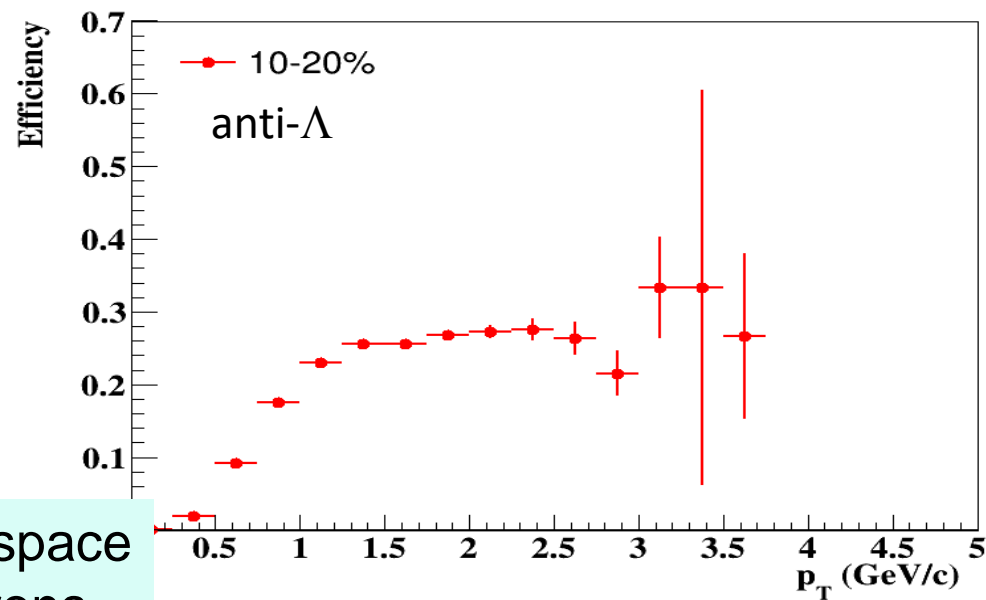
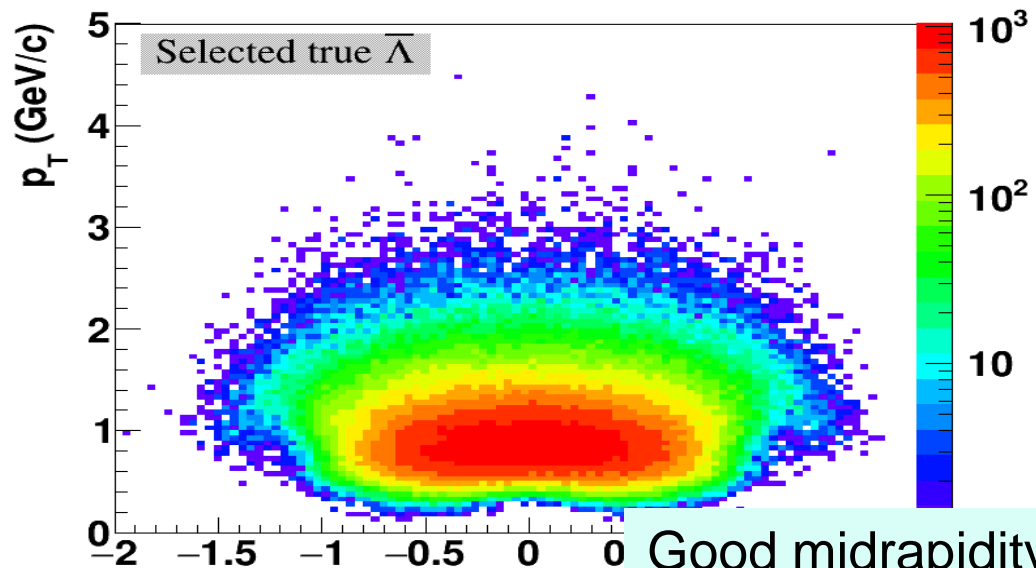
Selection cuts

- ✓ $l0.chi2s[][0] > 11.0$ – 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

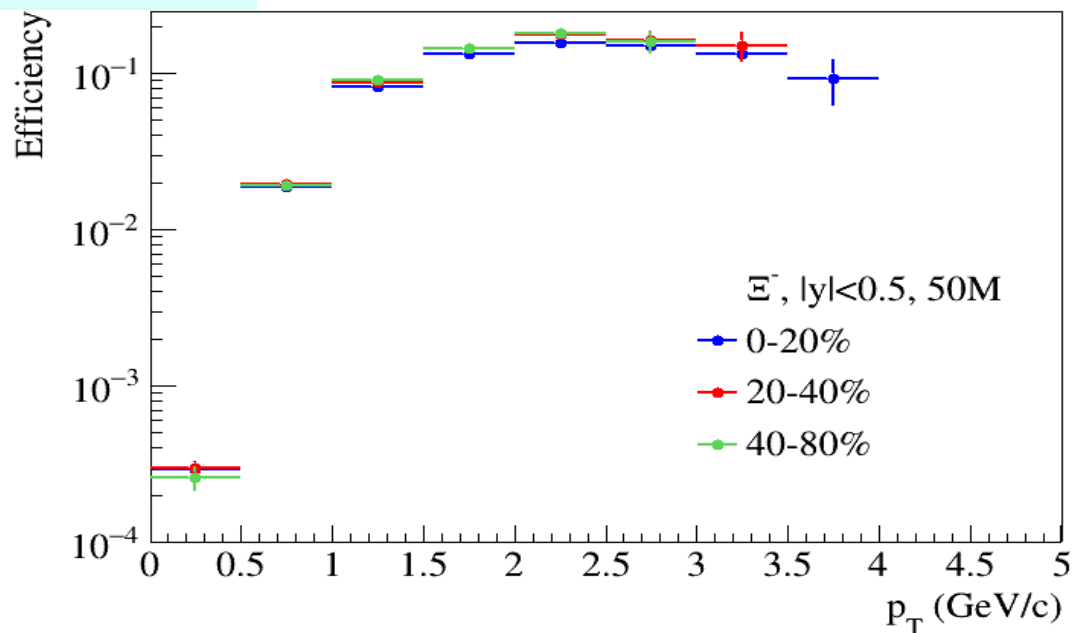
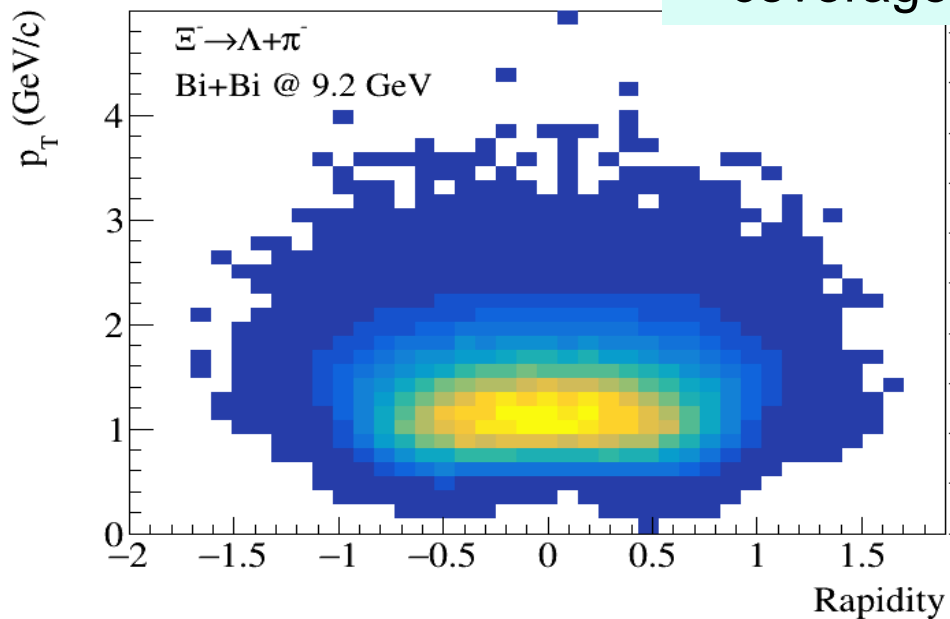
(anti)hyperon reconstruction in MPD: invariant mass



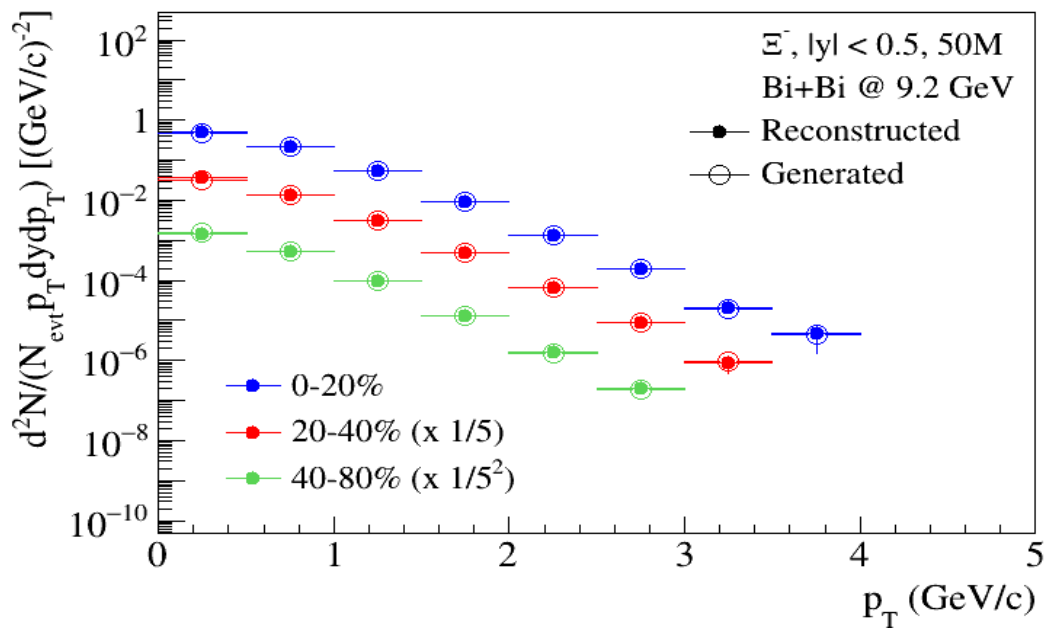
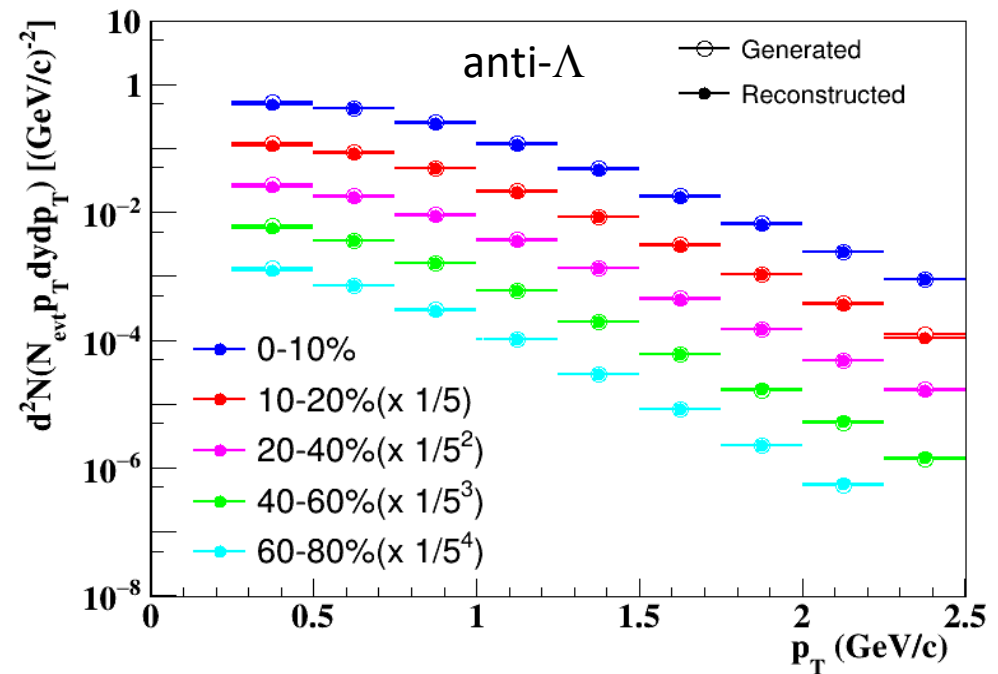
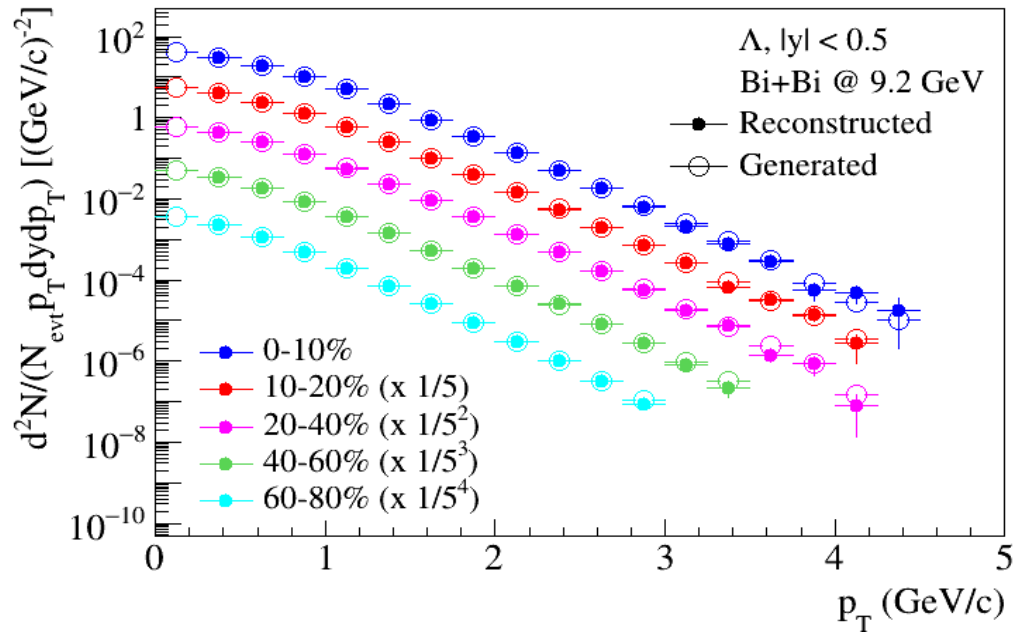
Hyperon reconstruction in MPD: efficiency and phase-space



Good midrapidity phase-space coverage of (anti)hyperons

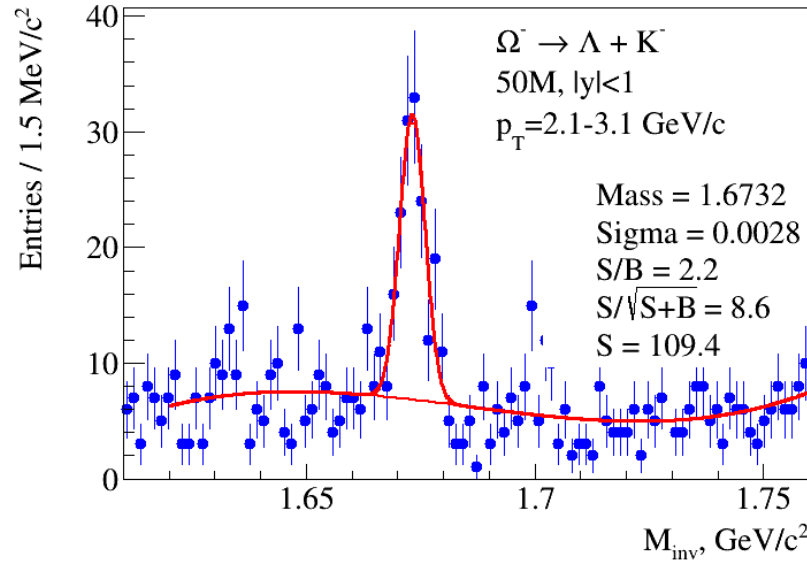
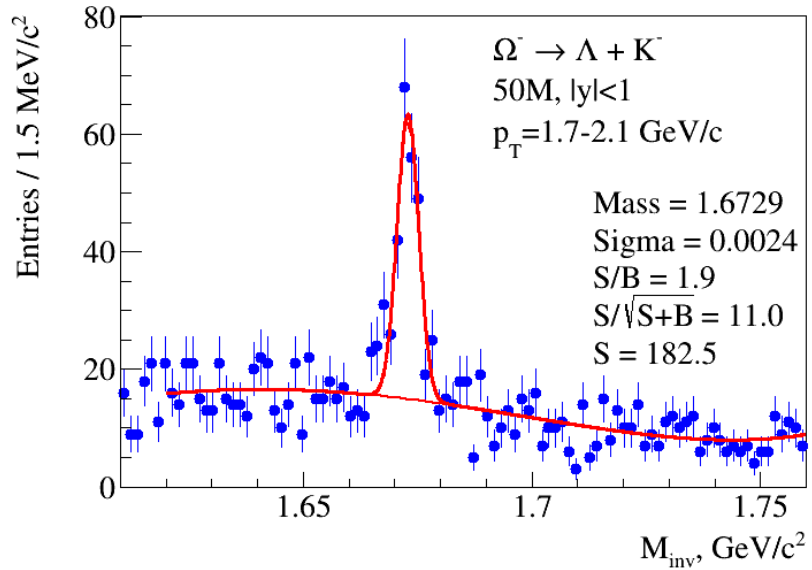


Hyperon analysis results: invariant pT-spectra in centrality bins

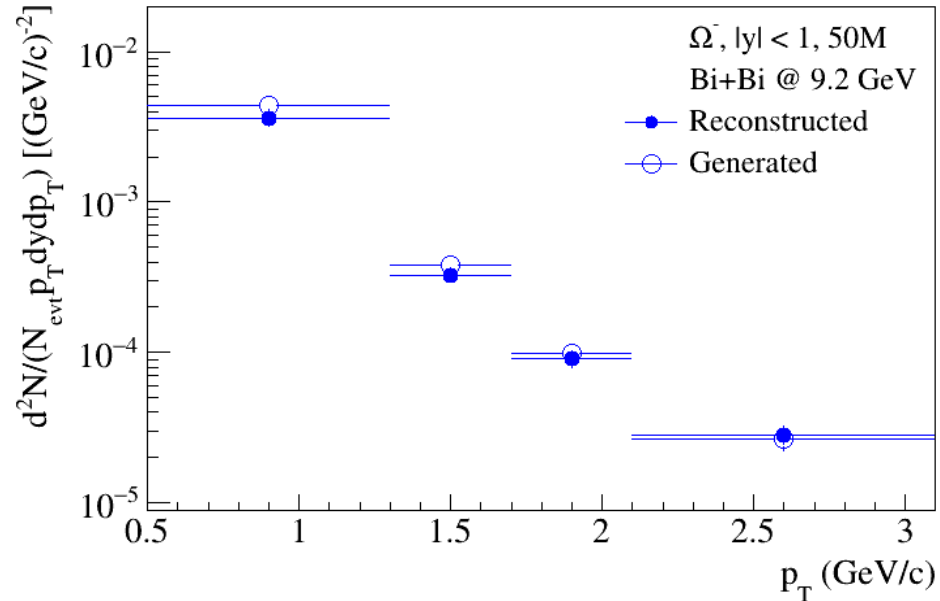
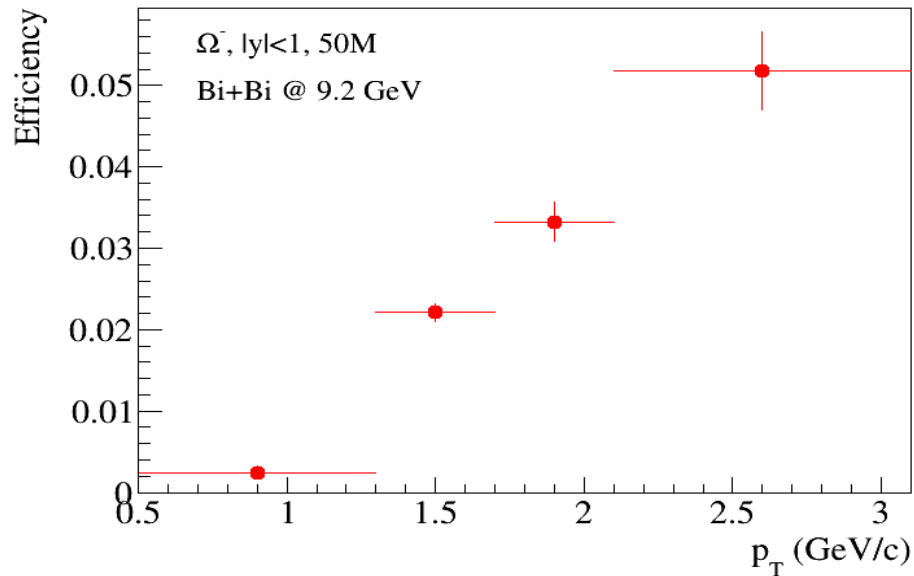


- Invariant pT-spectra of (anti)Lambda and cascades are reconstructed in several centrality bins
- Reconstructed distributions are consistent with those from the model

Ω^- analysis results: invariant pT-spectrum (no centrality binning)



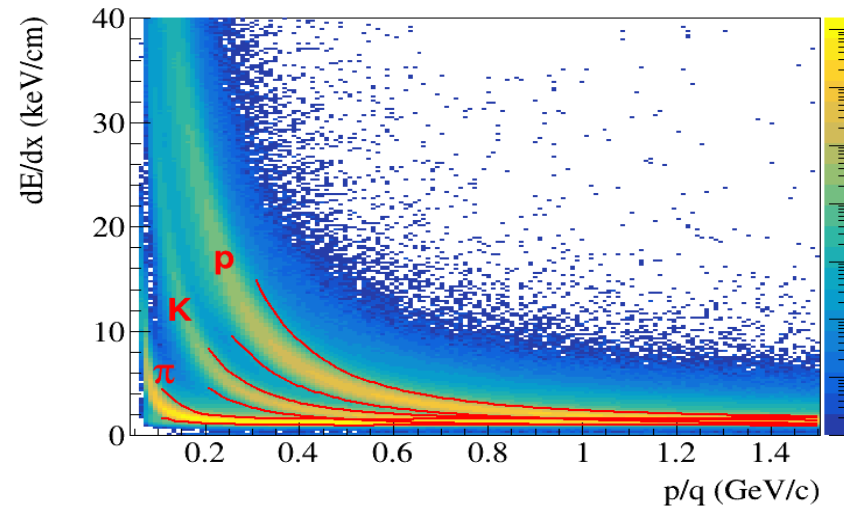
- 50M Bi+Bi events are sufficient only to see an overall signal (w/o centrality selection) for Ω^- in a limited number of pT bins



Hadron spectra and yields in Bi+Bi at 9.2 GeV

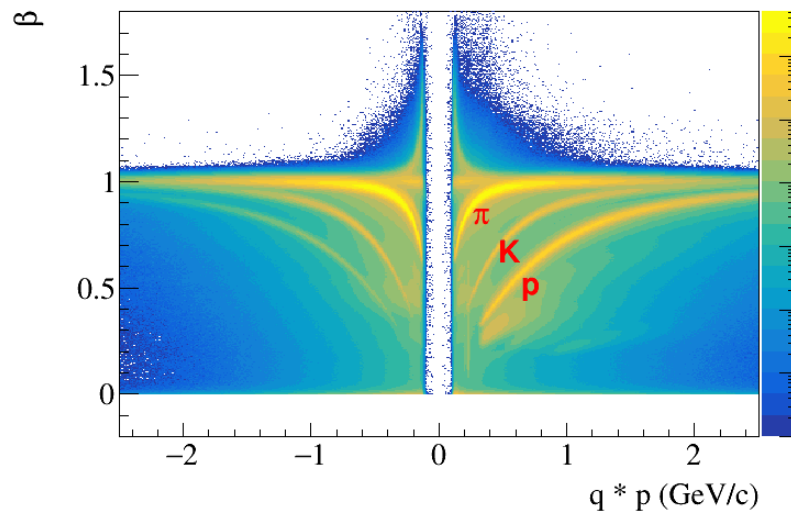
N.Kolomoets

- Production #29 : 20M of PHQMD events
- Centrality selection using the centrality wagon (P.Parfenov)



Vertex & track selection criteria:

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



Combined PID ($dE/dx+TOF$) from MpdPid class

MpdHadronSpectra wagon

Initial developer: Alexander Mudrokh

[mpdroot/physics/MpdHadronSpectra/](#)

- [MpdHadronSpectraParams.h \(*.cxx\)](#): input file readers
- [MpdHadronSpectra.h \(*.cxx\)](#): main source files
- [MpdHadronSpectraLinkDef.h](#)
- [CMakeLists.txt](#)

How to run the MpdHadronSpectra wagon:

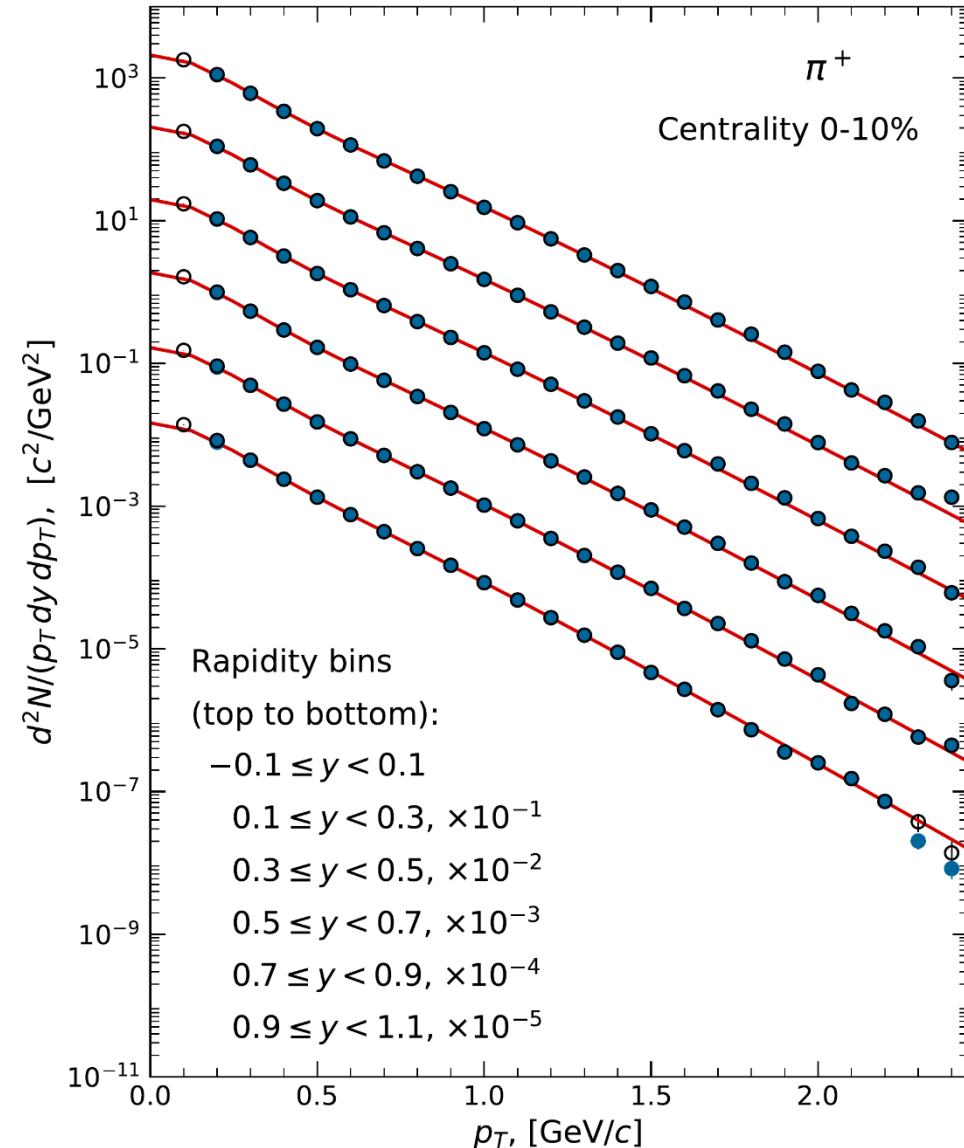
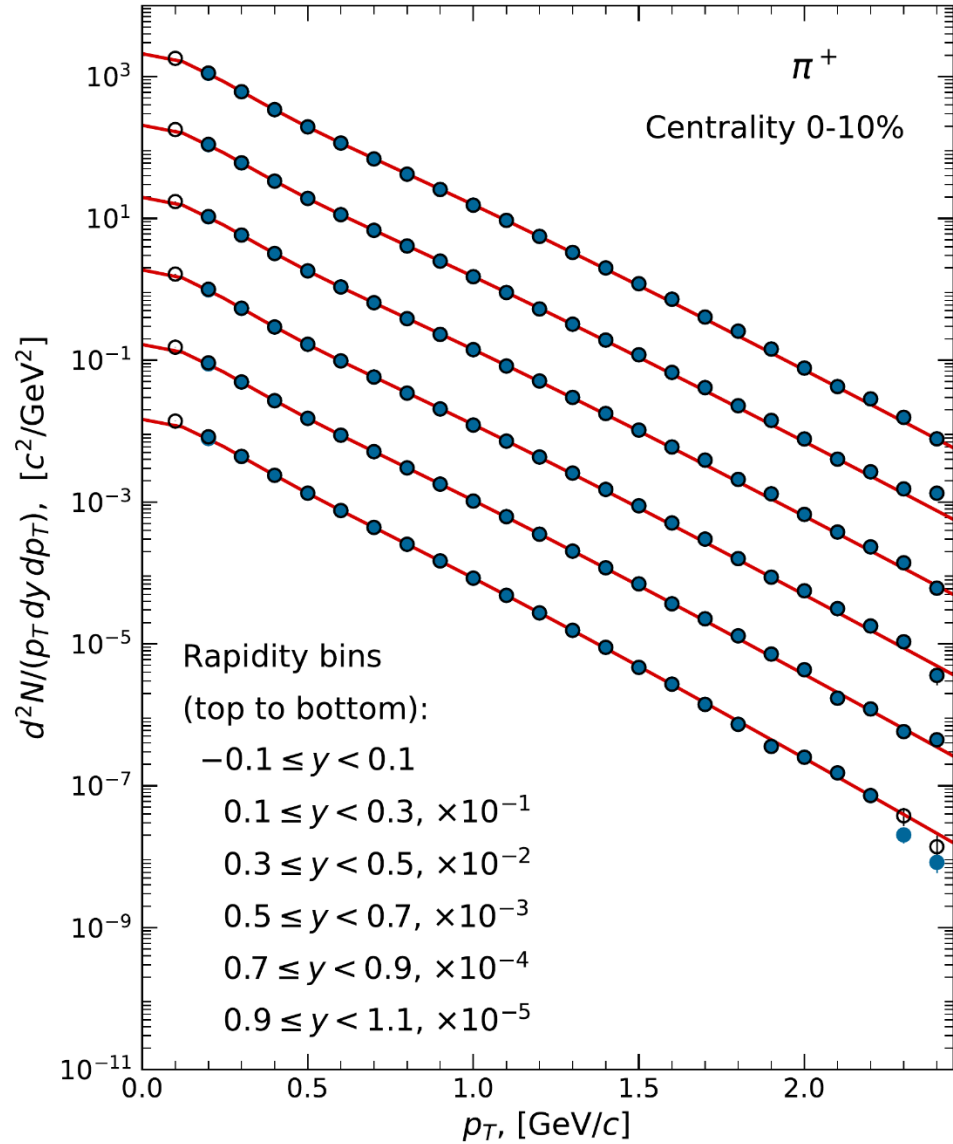
- In [mpdroot/physics/CMakeLists.txt](#) add line
`add_subdirectory(MpdHadronSpectra)`
- In [mpdroot/physics/pairKK/macros/RunAnalyses.C](#) add lines
`MpdHadronSpectra pSpec("pHS", "pHS");`
`man.AddTask(&pSpec);`
- `$ root -b -q -l RunAnalyses.C`

MpdHadronSpectra.cxx (principally)

```
#include "MpdTrack.h"  
#include "MpdMCTrack.h"  
#include "MpdVertex.h"  
  
ClassImp(MpdHadronSpectra);  
  
void ProcessEvent(MpdAnalysisEvent &event){...}  
  
void FillMcSpectra(MpdAnalysisEvent &event){...}  
void FillMcTOFSpectra(MpdAnalysisEvent &event){...}  
void FillRcSpectra(MpdAnalysisEvent &event){...}  
  
void FillTPCEfficiency(MpdAnalysisEvent &event){...}  
void FillTOFEfficiency(MpdAnalysisEvent &event){...}  
void FillTOFMCefficiency(MpdAnalysisEvent &event){...}  
void FillPIDefficiency(MpdAnalysisEvent &event){...}  
void FillDCAcontribution(MpdAnalysisEvent &event){...}  
void FillCoordEfficiency(MpdAnalysisEvent &event){...}  
void FillSplitting(MpdAnalysisEvent &event){...}  
  
bool selectEvent(MpdAnalysisEvent &event){...}  
  
double Eloss_Pi(double *x, double *par){...}  
double Eloss_Kplus(double *x, double *par){...}  
double Eloss_Kminus(double *x, double *par){...}  
double Eloss_Proton(double *x, double *par){...}  
double Eloss_AntiProton(double *x, double *par){...}
```

Charged pion pT-spectra in Bi+Bi at 9.2 GeV

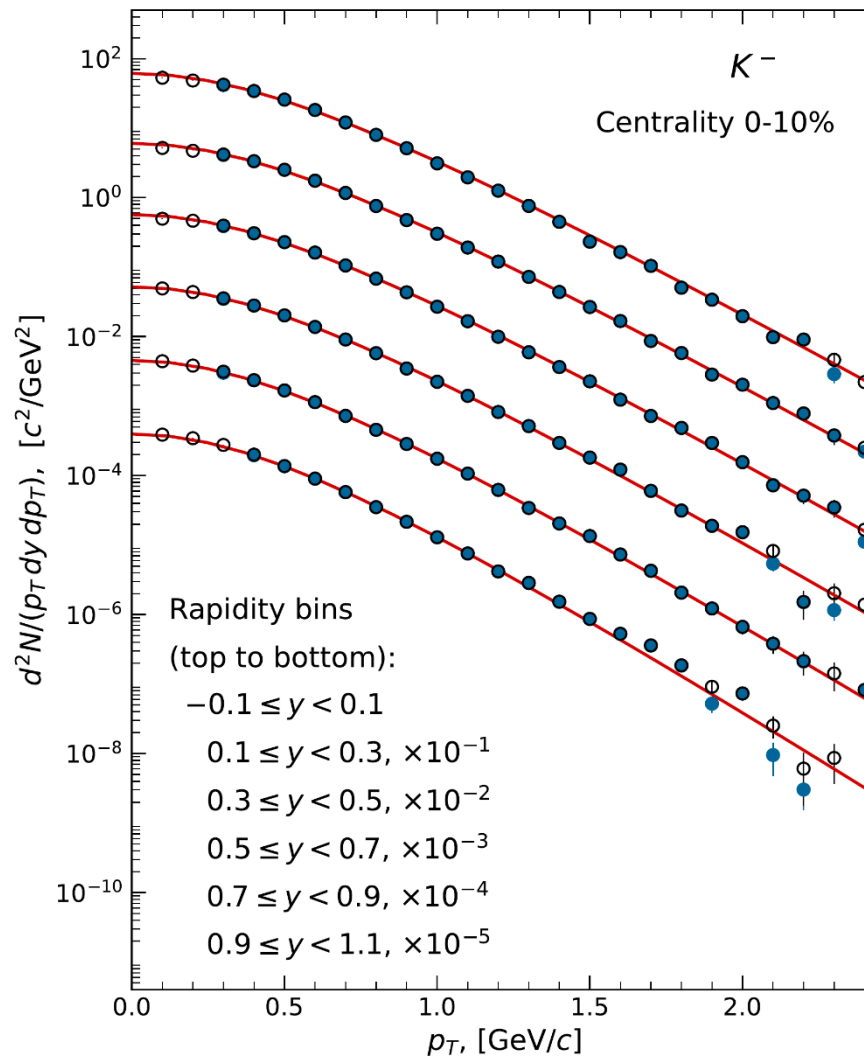
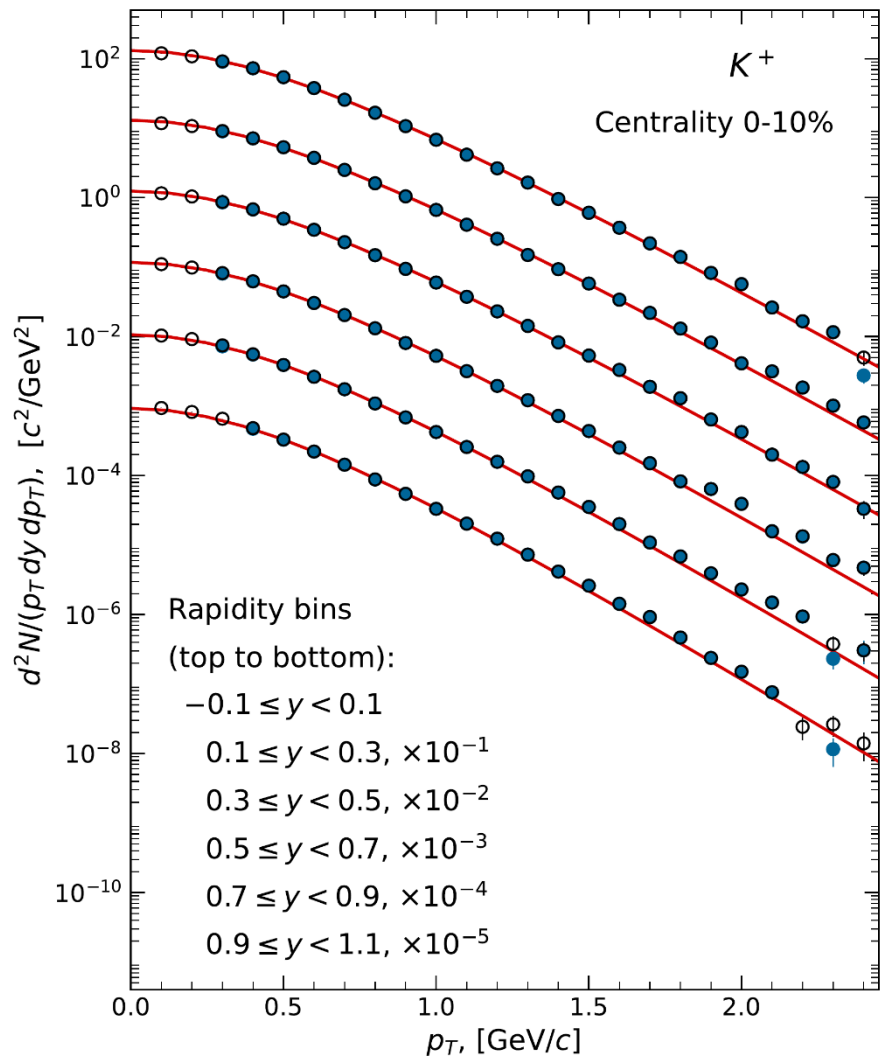
- Invariant pT-spectra are reconstructed in several rapidity bins.
- Double-exponent is used for extrapolation that is below 10%



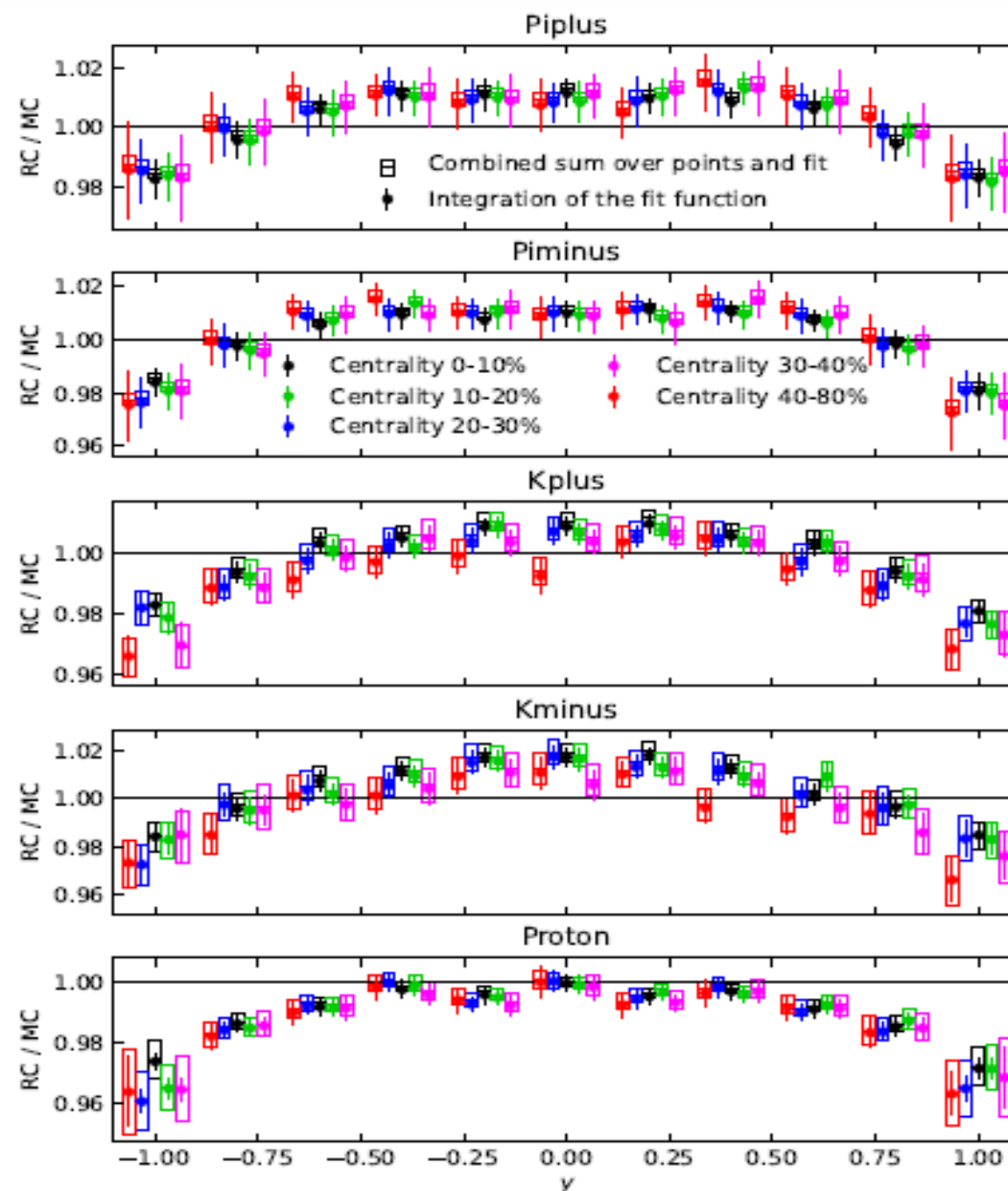
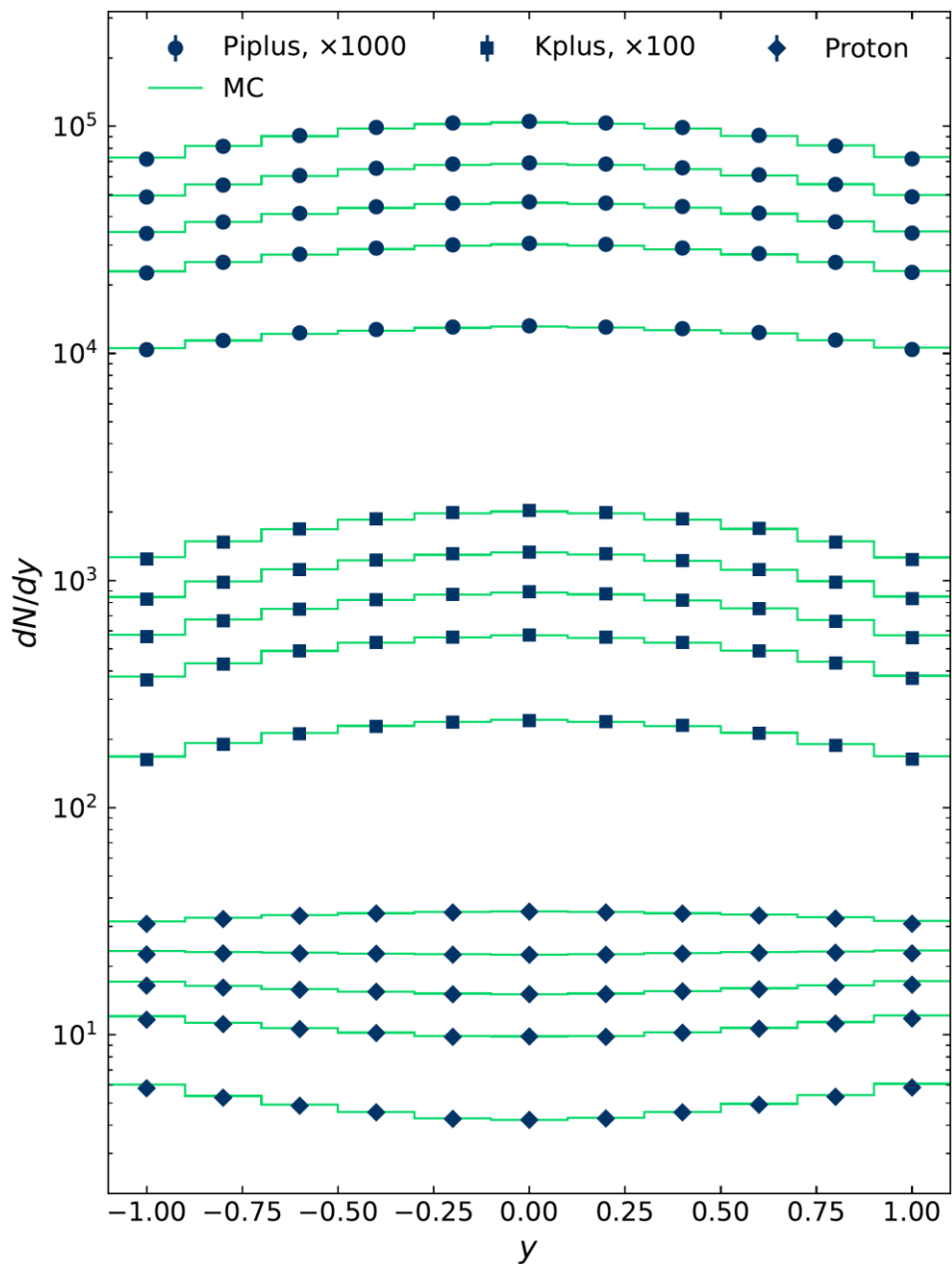
pT-spectra of charged kaons in Bi+Bi at 9.2 GeV

- Invariant pT-spectra are reconstructed in several rapidity bins.
- Blast Wave fits used for extrapolation that ~15%

$$\frac{d^2N}{p_T dp_T dy} = C(y) \cdot m_T \int_0^1 \chi d\chi \exp \left[-\frac{m_T \operatorname{ch} \rho \operatorname{ch}(y - \eta)}{T} \right] I_0 \left(\frac{p_T \operatorname{sh} \rho}{T} \right)$$



Rapidity spectra of hadrons in Bi+Bi at 9.2 GeV

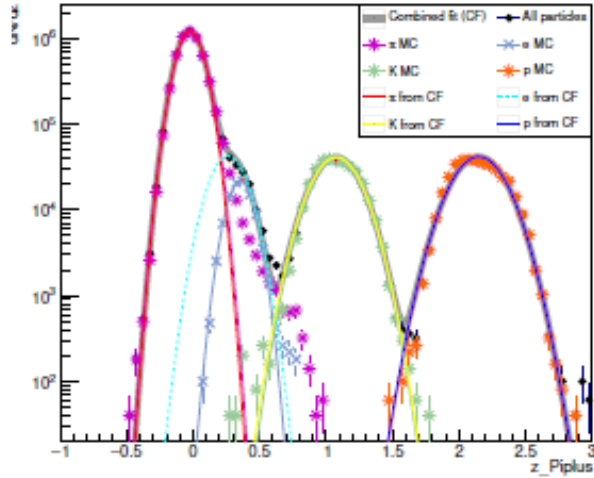


STAR PID vs MPD PID (test of approaches)

- PID from STAR: dE/dx ($0 < p < p_{\text{cut}}(m)$), then m^2 at $p > p_{\text{cut}}$

$$z_i = \ln \left(\frac{\langle dE/dx \rangle}{\langle dE/dx \rangle_i^{BB}} \right)$$

$0.25 < p_T < 0.35 \text{ GeV}/c$



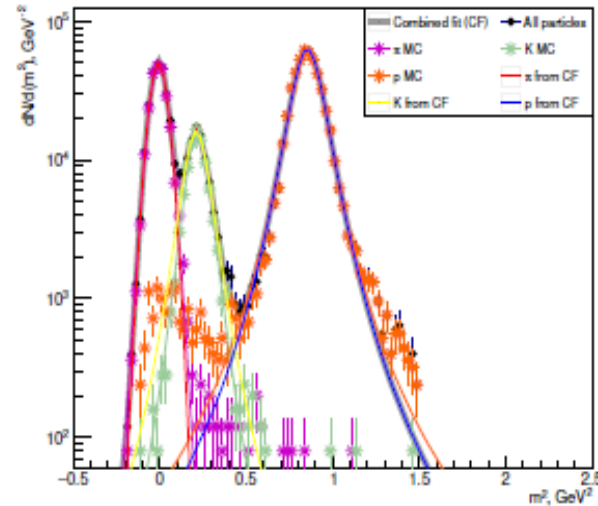
$$f(x) = N \exp[-(x - \mu)^2 / (2\sigma^2)] / \sqrt{2\pi\sigma^2}$$

	N	μ	σ
π	273790 ± 569	-0.025 ± 0.000	0.087 ± 0.000
π (MC)	271475 ± 520	-0.020 ± 0.000	0.090 ± 0.000
N (MC)	275900	$[N_{\text{MC}} - N] / N = 0.01$	
e	13056 ± 210	0.264 ± 0.003	0.121 ± 0.000
e (MC)	4856 ± 70	0.358 ± 0.001	0.088 ± 0.001
N (MC)	4911		
K	16386 ± 128	1.08 ± 0.00	0.157 ± 0.001
K (MC)	16121 ± 127	1.08 ± 0.00	0.154 ± 0.001
N (MC)	16380	$[N_{\text{MC}} - N] / N = -0.00$	
p	18429 ± 136	2.15 ± 0.00	0.175 ± 0.001
p (MC)	18371 ± 136	2.15 ± 0.00	0.173 ± 0.001
N (MC)	19009	$[N_{\text{MC}} - N] / N = 0.03$	

Fit p_T sections with sum of StudentT PDFs.

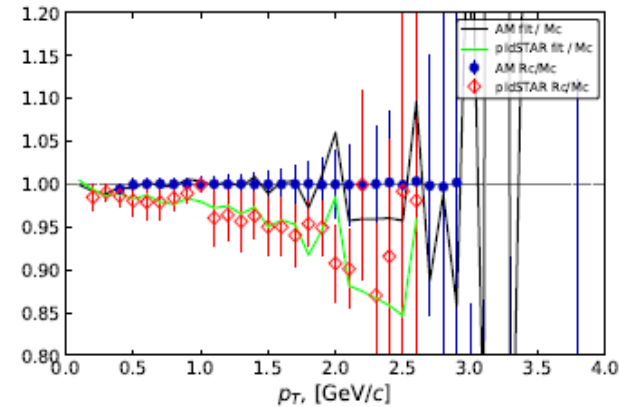
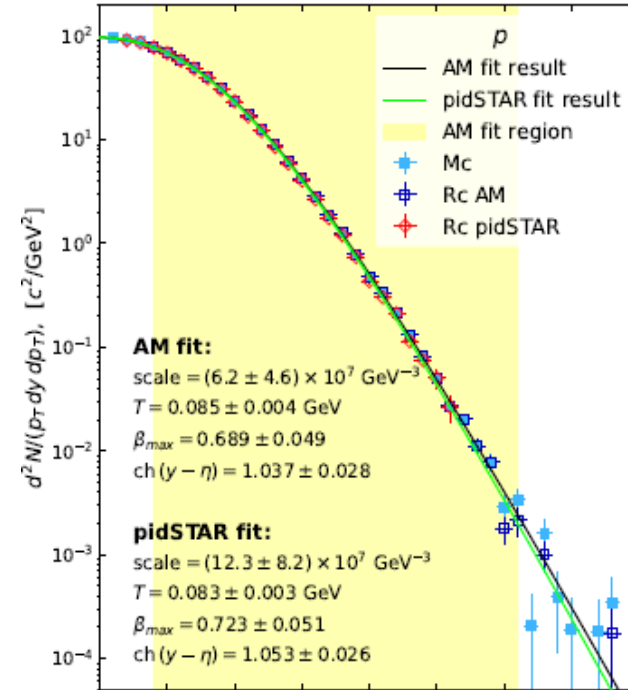
$$f(x) = N \cdot \frac{\left(\frac{\nu}{\nu + (x - \mu)^2 / \sigma^2} \right)^{(1+\nu)/2}}{\sqrt{\nu} \sigma B\left(\frac{\nu}{2}, \frac{1}{2}\right)}$$

$1.25 < p_T < 1.35 \text{ GeV}/c$

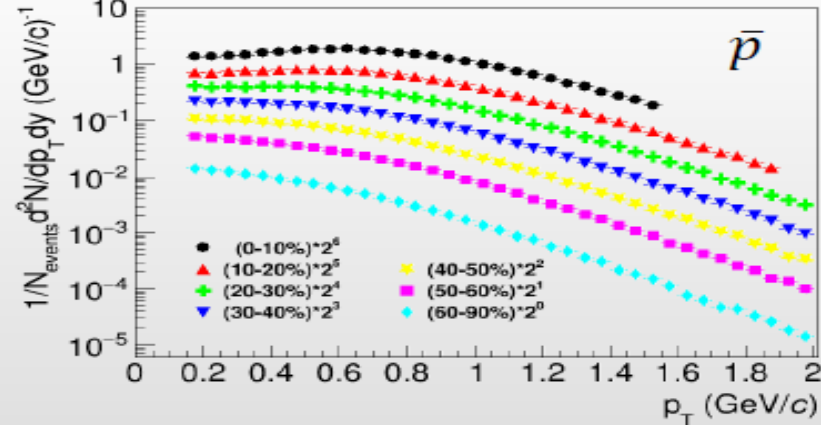
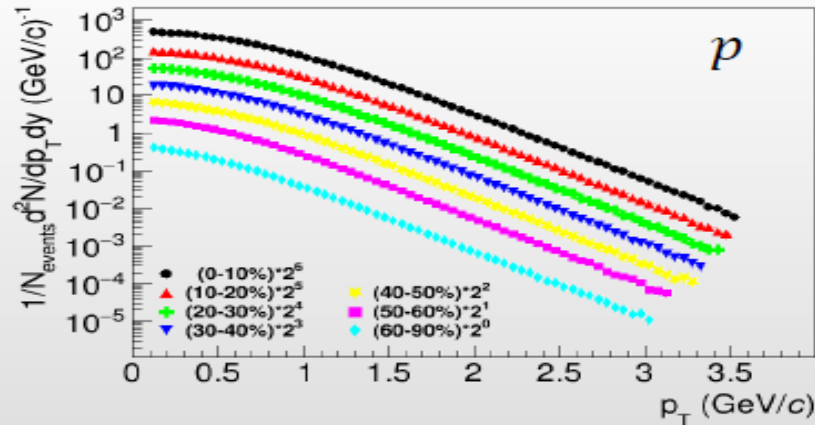
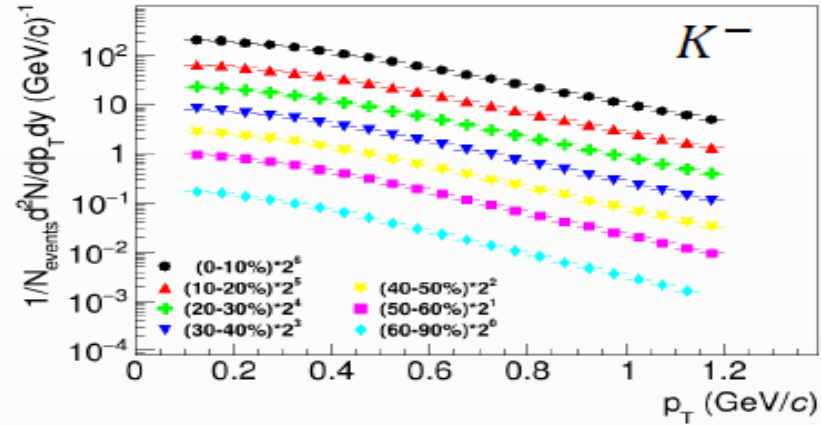
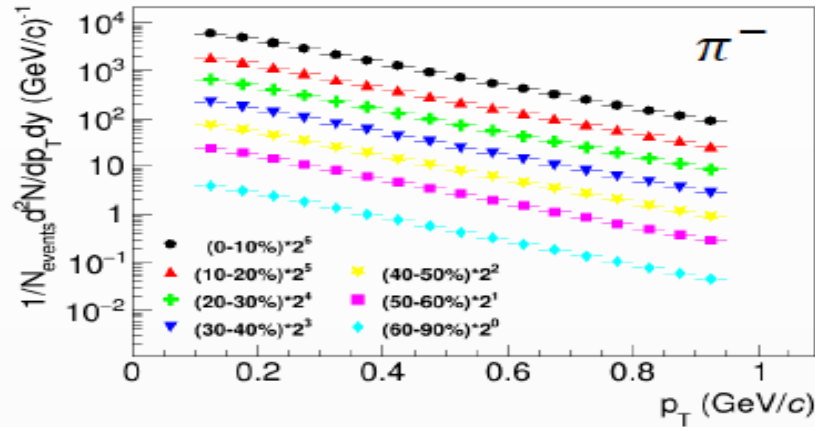


$$f(x) = \text{StudentT}(x, N, \mu, \sigma, \nu)$$

	N	μ	σ	ν
π	5872 ± 83	-0.007 ± 0.001	0.046 ± 0.001	45.6 ± 35.2
π (MC)	5790 ± 76	-0.005 ± 0.001	0.046 ± 0.001	14.4 ± 2.9
N (MC)	5905	$[N_{\text{MC}} - N] / N = 0.01$		
K	2622 ± 70	0.211 ± 0.002	0.061 ± 0.002	3.51 ± 0.74
K (MC)	2207 ± 47	0.217 ± 0.001	0.052 ± 0.002	4.34 ± 0.56
N (MC)	2249	$[N_{\text{MC}} - N] / N = -0.14$		
p	12674 ± 115	0.854 ± 0.001	0.074 ± 0.001	3.11 ± 0.18
p (MC)	12688 ± 113	0.854 ± 0.001	0.072 ± 0.001	2.66 ± 0.12
N (MC)	13131	$[N_{\text{MC}} - N] / N = 0.04$		



- ❖ Request 25: BiBi@9.2 GeV (UrQMD), 50 M events \rightarrow full event/detector reconstruction
- ❖ $\pi/K/p$ identification based on n-sigma selections in the TPC/TOF \rightarrow good for the first-day measurements



Good enough coverage for dN/dy , $\langle p_T \rangle$ and β/T (BW-fits) measurements

Unmeasured low- p_T range is as small as possible with the existing track reconstruction methods

Sampled yields $> 92\%$ for all species

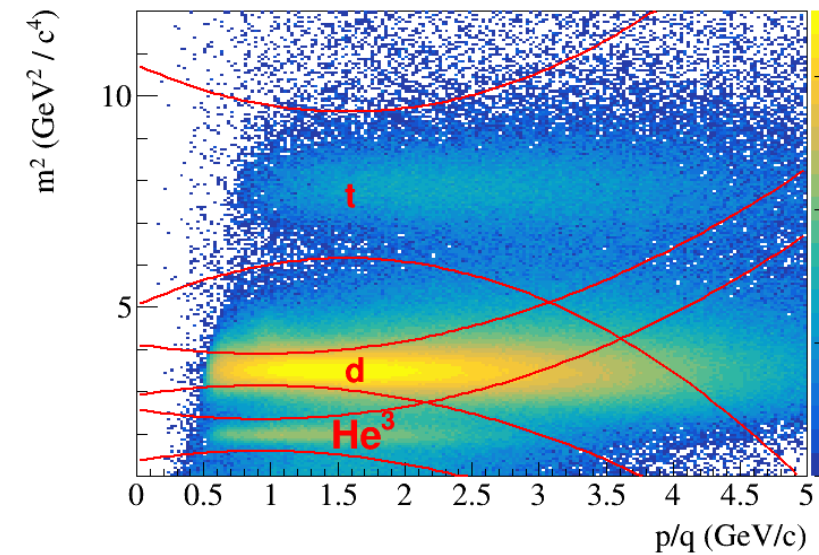
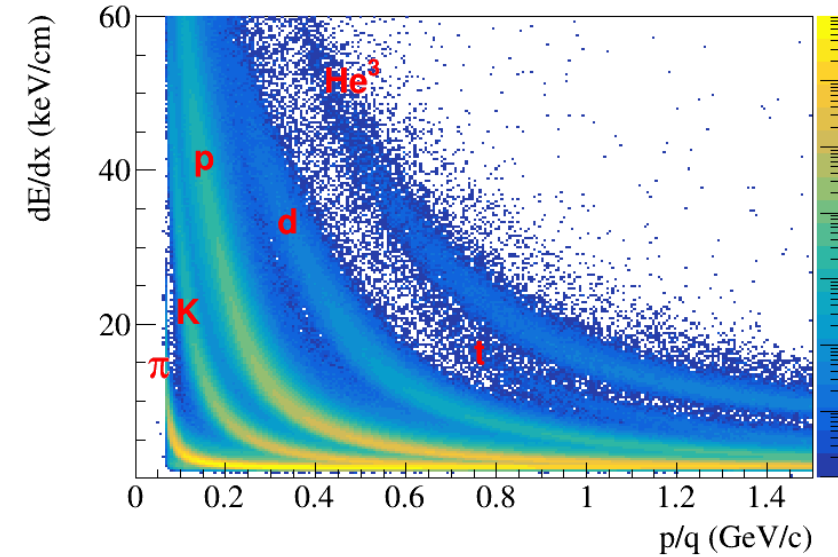
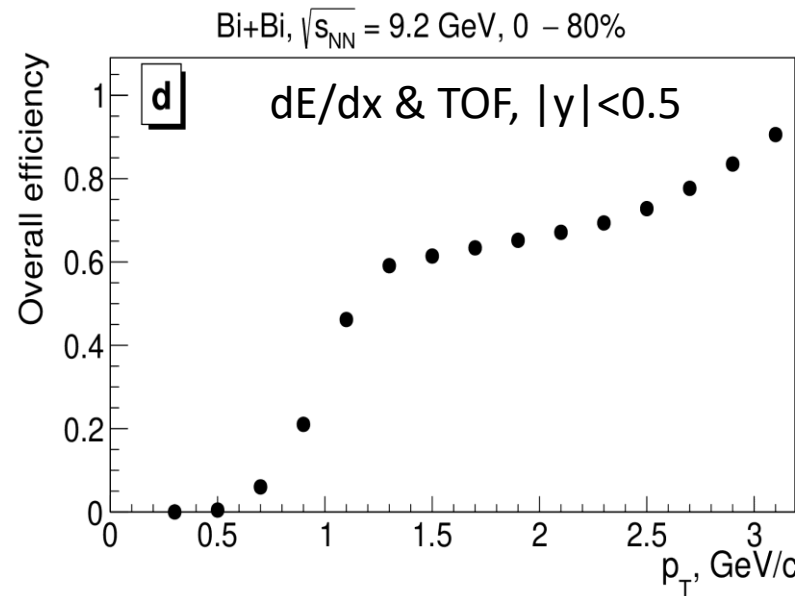
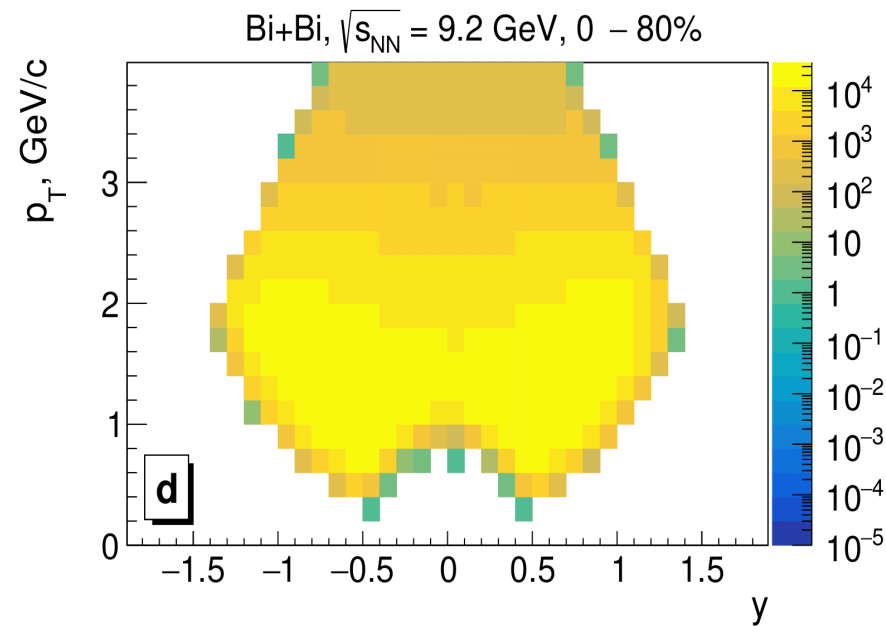
Light nuclei in Bi+Bi (production #29, PHQMD)

V.Kireyeu

- 20M events from the PHQMD event generator for (hyper)nuclei
- Analysis chain is realized as a wagon + postprocessing macros
- Reported at the MPD Cross-PWG 17.09.2024

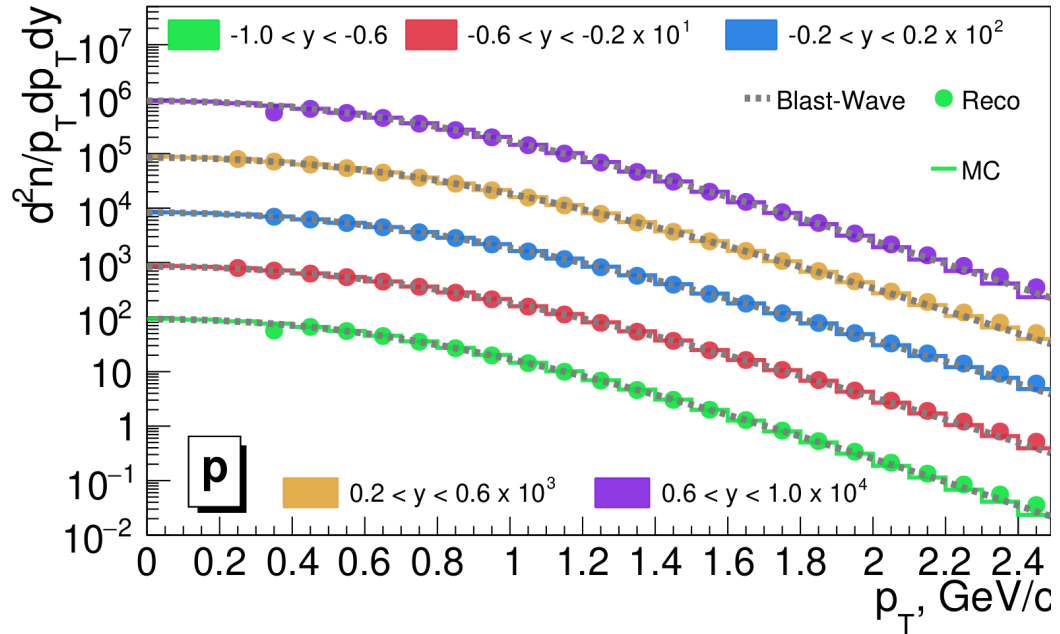
Analysis details:

- Used extra wagons: “evCentrality”, “evPID”
- Standard event&track selection: Vertex_Z, N_hits, DCA, pT
- PID: based on recent A.Mudrokh parameters for dE/dx and m^2



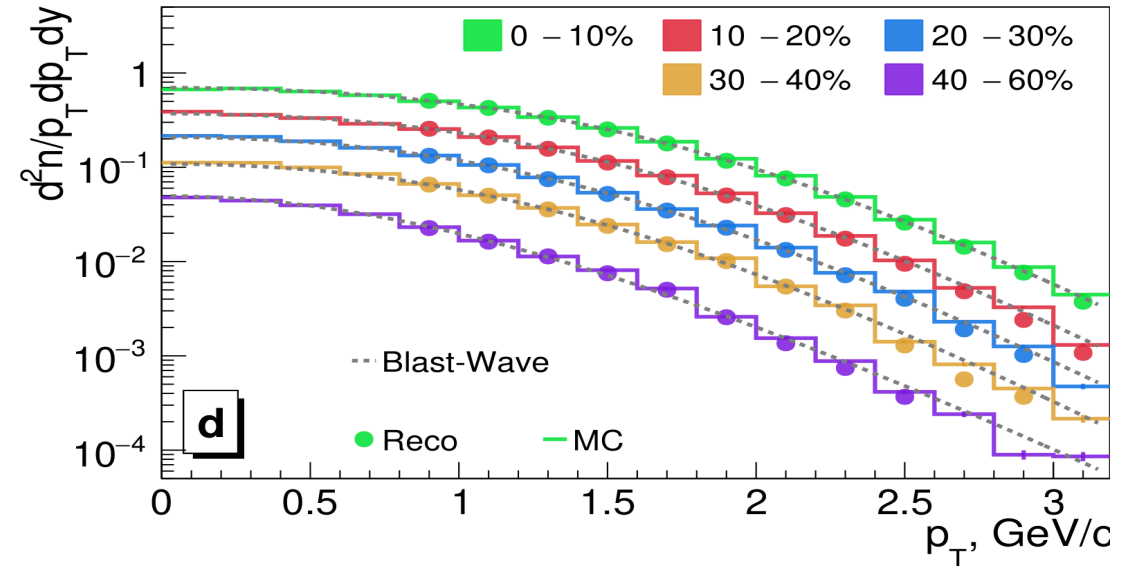
Protons and light nuclei spectra in Bi+Bi

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

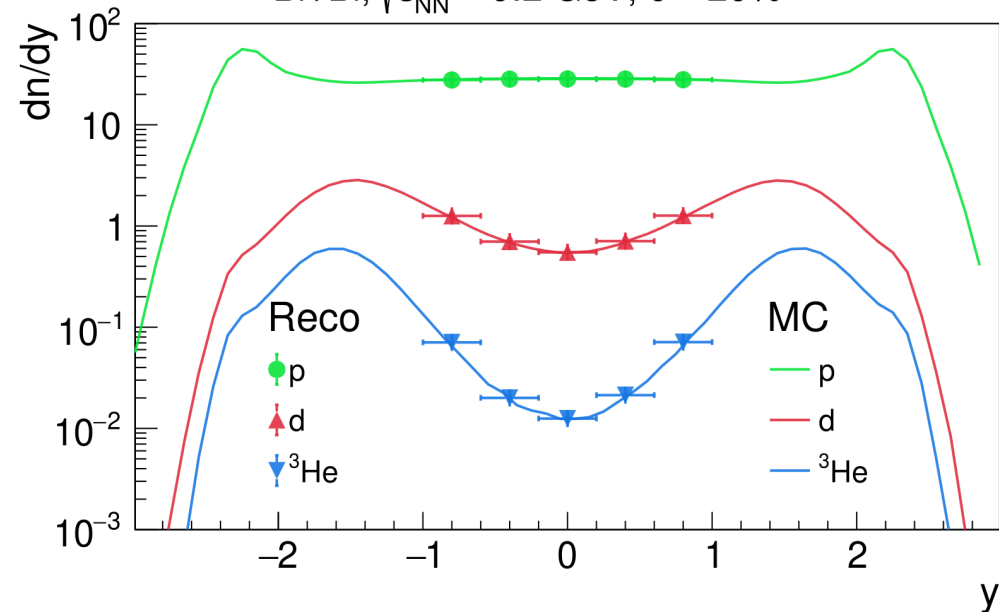


- Proton and light nuclei spectra within $|y| < 1$
- Invariant p_T -spectra in rapidity bins, good agreement between Reco and MC distributions
- Midrapidity yields, spectra, ratios in centrality selected Bi+Bi
- Contamination of secondaries relies on MC!

Bi+Bi, $\sqrt{s_{NN}} = 9.2$ GeV, $|y| < 0.2$

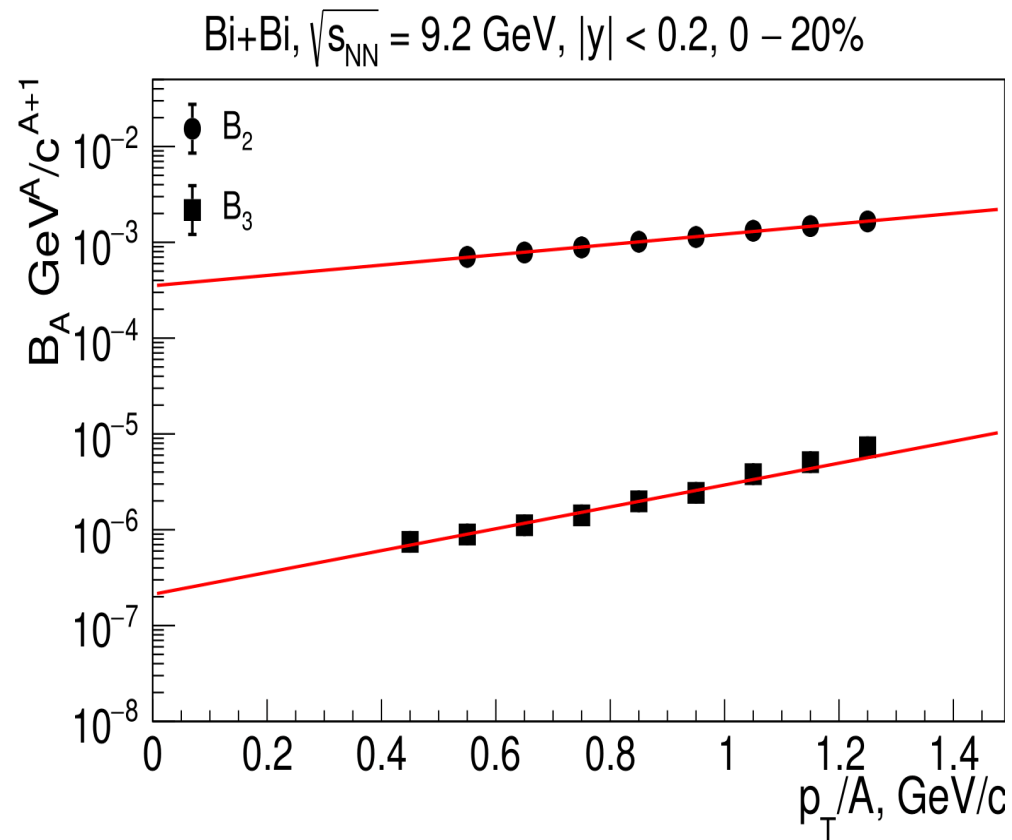
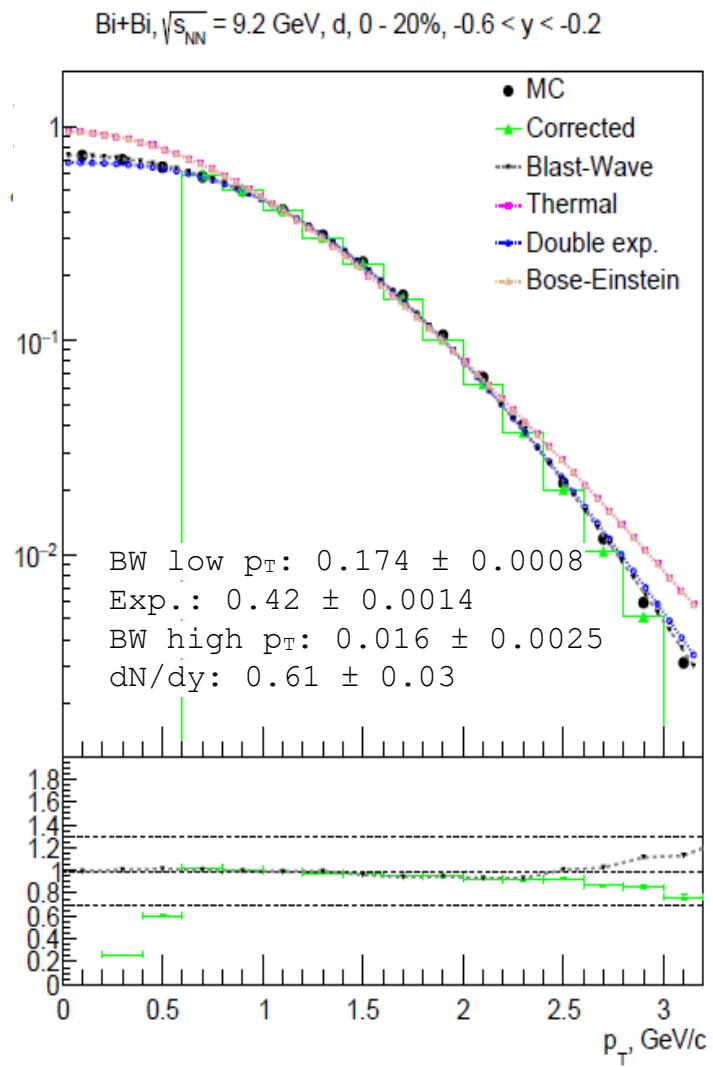
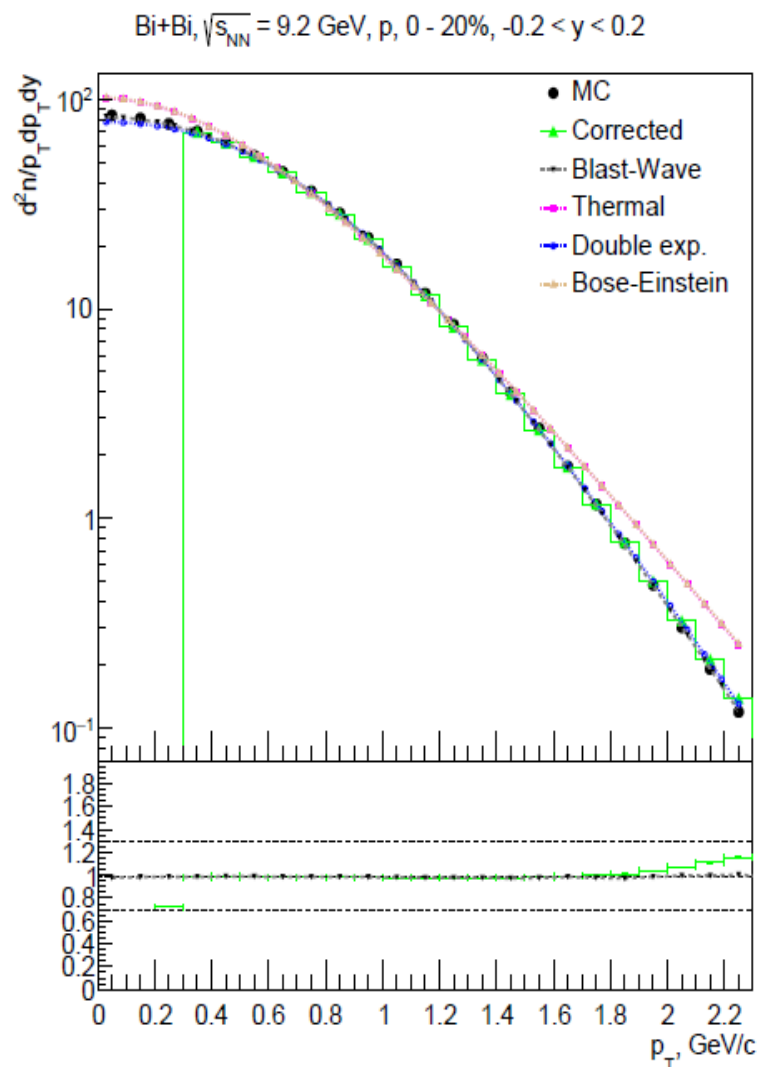


Bi+Bi, $\sqrt{s_{NN}} = 9.2$ GeV, 0 – 20%



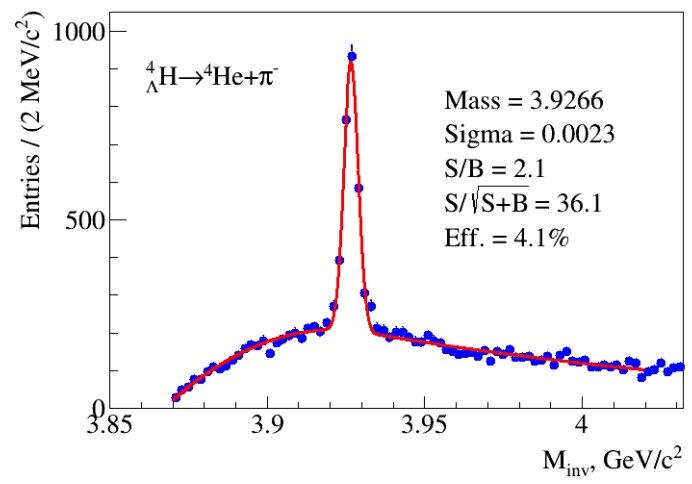
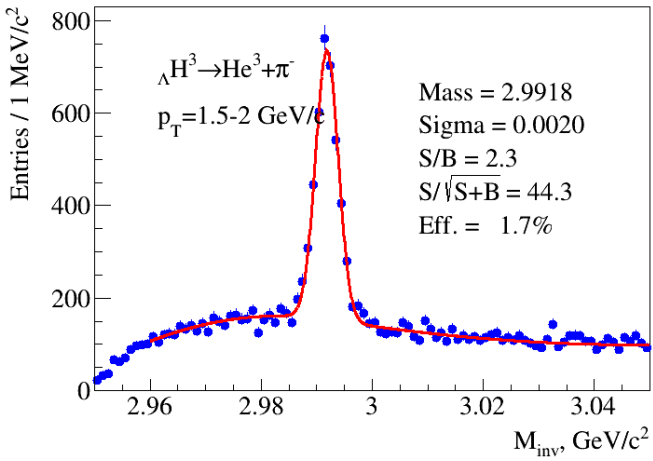
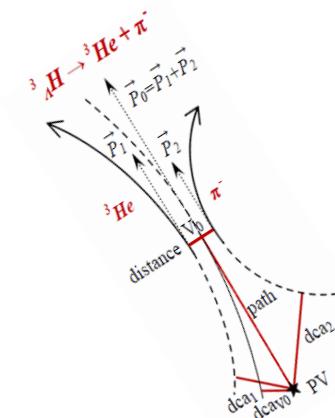
Protons & light nuclei : pT-spectra and coalescence

- Optimal fit to pT-spectra is a BW-based one.
- Estimation of the extrapolation and uncertainty for ratios ($B_{2,3}$)

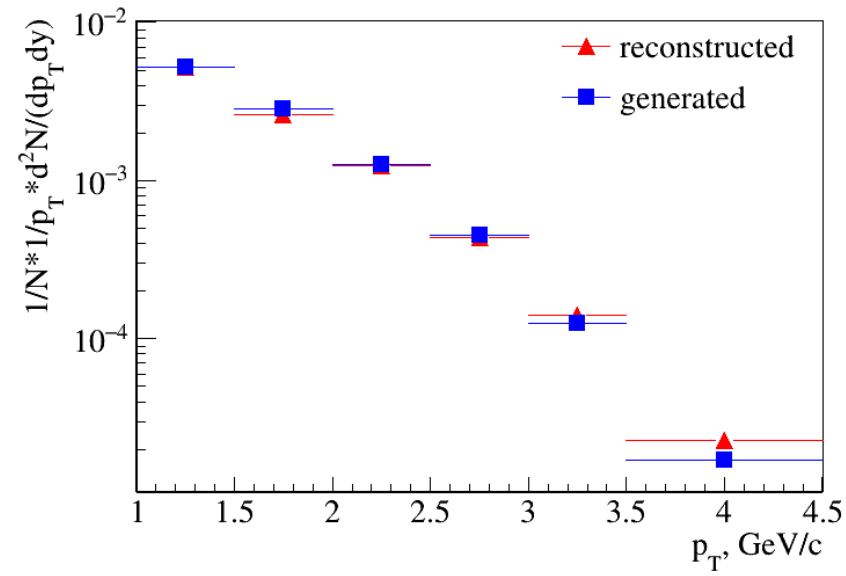
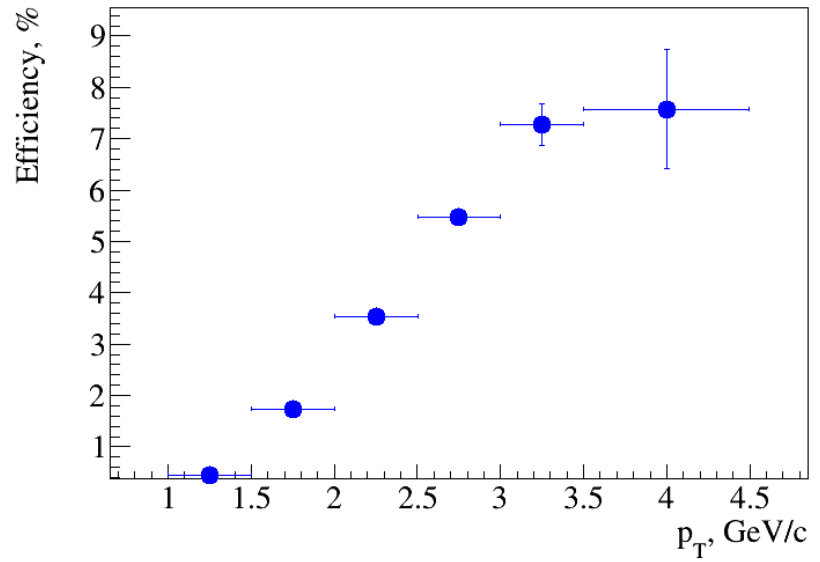


Hypertritons in MPD: yields, spectra, lifetime

V.Vasendina, A.Zinchenko, V.Kireyeu



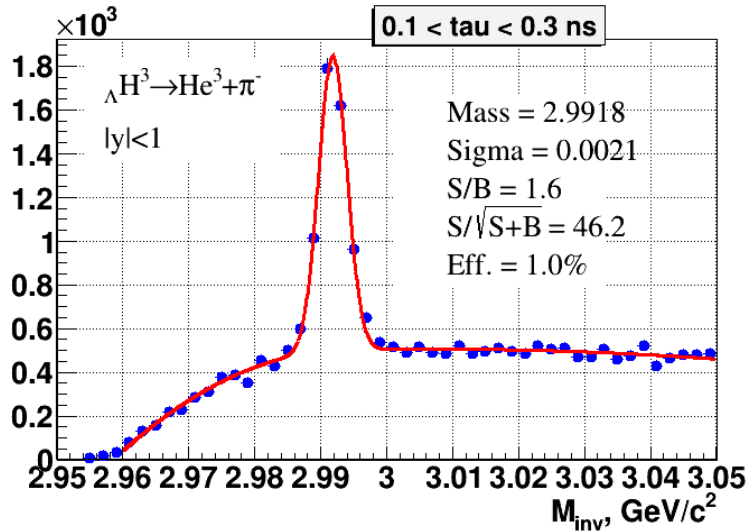
- PHQMD models Bi+Bi at 9.2 GeV
- Full event simulation and reconstruction
- A set of topological cuts aimed at maximizing significance



- 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

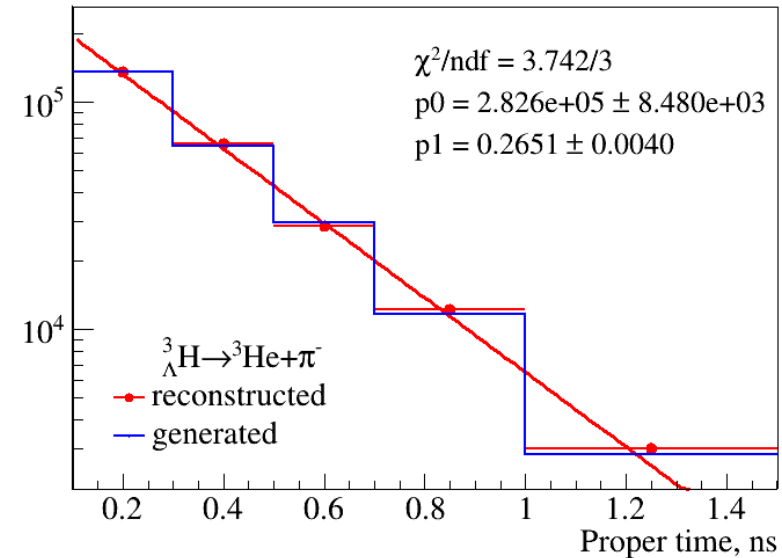
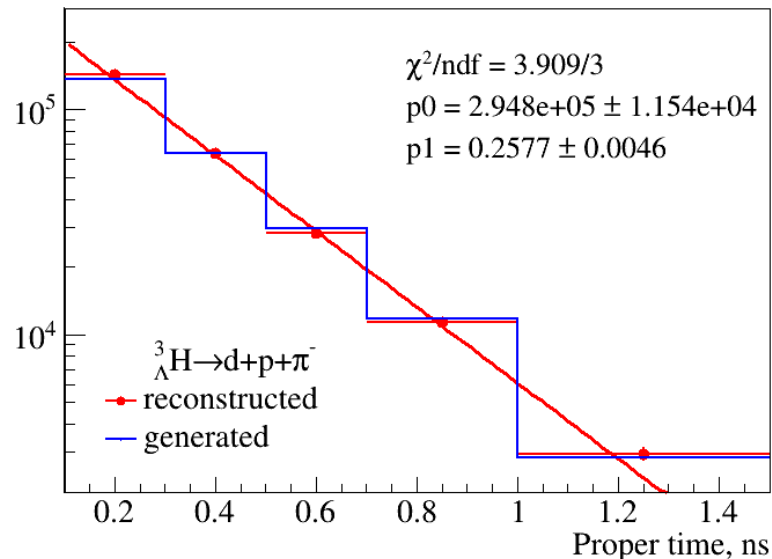
- Hypertritons are reconstructed in several τ bins
- 2- and 3-prong decay modes were studied separately to estimate systematics



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

Results for different decay modes are consistent

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



Summary

Status of the PWG2 analyses (16/10/2024) :

- *Hyperons (anti) Λ , Ξ , Ω* (prod. #25 UrQMD) - **finished, description of the results has drafted**
- *Light hadrons (π , K , p)* (prod. #29 PHQMD) - **finished, description of the results has drafted**
- *Light nuclei (d , ^3He)* (prod. #29 PHQMD) - **finished, description of the results has drafted**
- *Hypertritons* (prod. #29 PHQMD) - **finished, description of the results has drafted**

Thank you for your attention!

Extra slides

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 (Λ , Σ , Ω) and their antiparticles: spectra, yields, antiparticle/particle ratio, nuclear modification factor, azimuthal anisotropy (together with PWG3).
- (Anti) Λ polarization.
- Reconstruction of single and double hypernuclei: spectra, rapidity density, and lifetime.

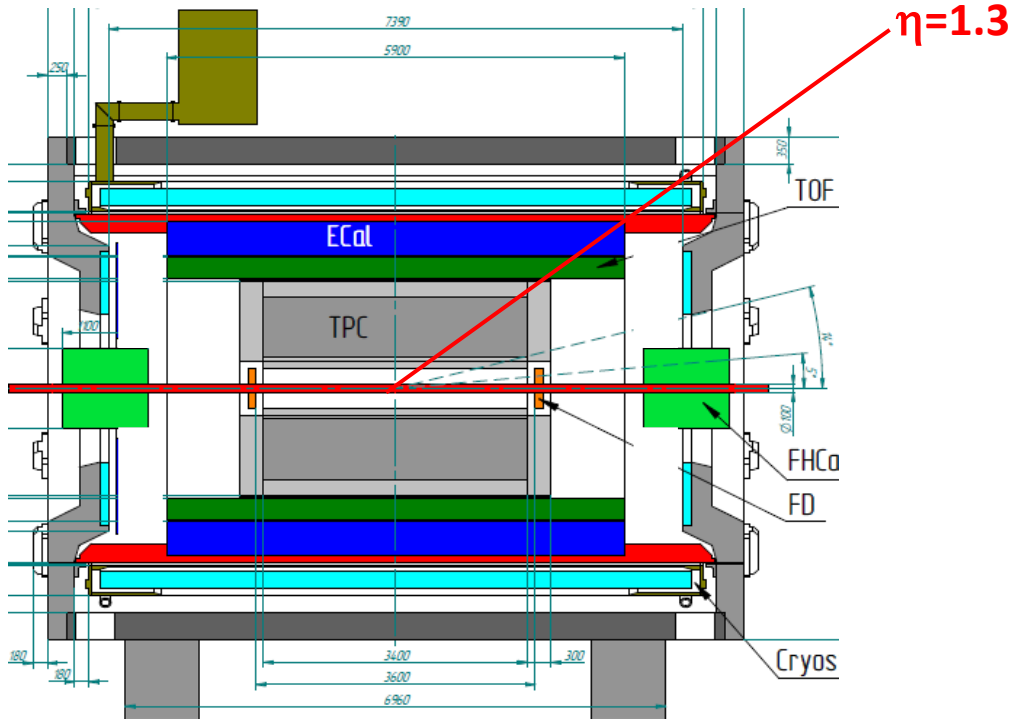
▪ **Resonances**

- Production of ρ , ϕ , K^* , $\Lambda(1520)$ etc.

▪ **Light nuclei**

- Production of nucleon clusters (d, t, ^3He , ^4He) 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

Light nuclei (d, ^3He) : phase-space for 'dE/dx & TOF' vs 'dE/dx || TOF'

Bi+Bi, $\sqrt{s_{\text{NN}}} = 9.2 \text{ GeV}$, 0 – 80%

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