

# MPD PWG2 status report

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



MPD Collaboration meeting  
JINR, Dubna, November 8-10, 2022

# Outline

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- ❑ **Introduction : PWG2 tasks**
- ❑ **Preparation to a new round of feasibility study with Bi+Bi at 9.2 GeV :**
  - Light hadrons (prod. #25)
  - Hyperons (prod. #25)
  - Hypernuclei (prod. #29)
  - Hyperon polarization (prod. #30)
- ❑ **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 ( $\Lambda$ ,  $\Sigma$ ,  $\Omega$ ) 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.

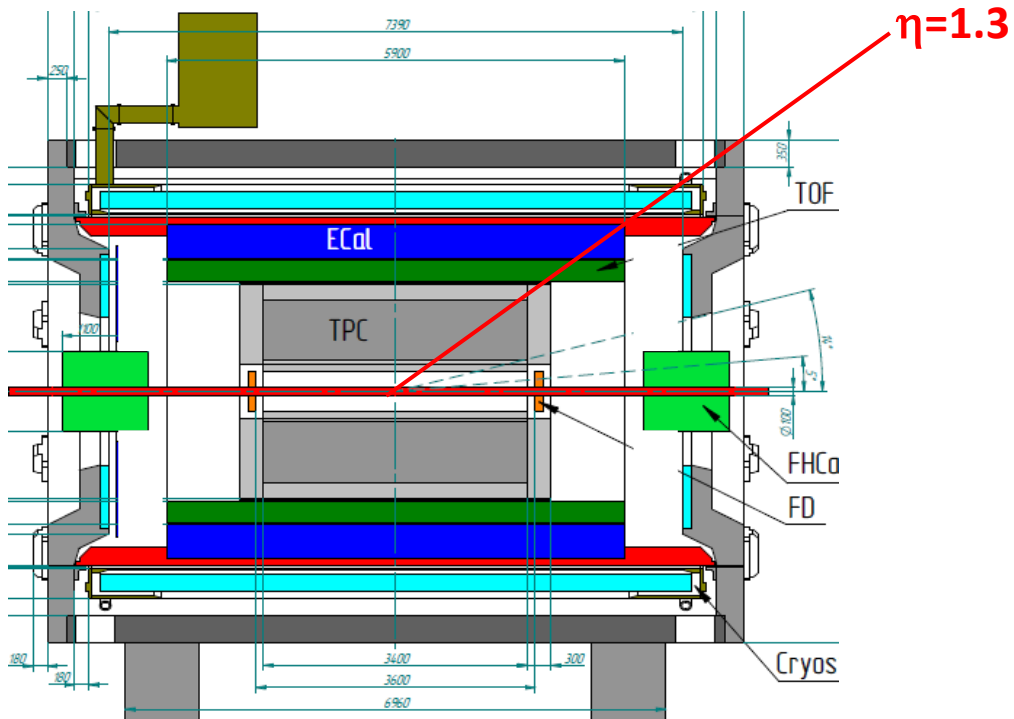
### ▪ **Resonances**

- Production of  $\rho$ ,  $\phi$ ,  $K^*$ ,  $\Lambda(1520)$  etc.

### ▪ **Light nuclei**

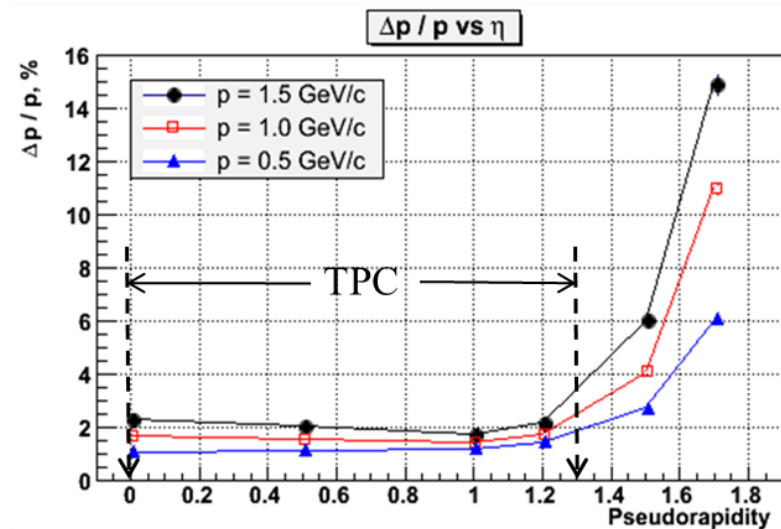
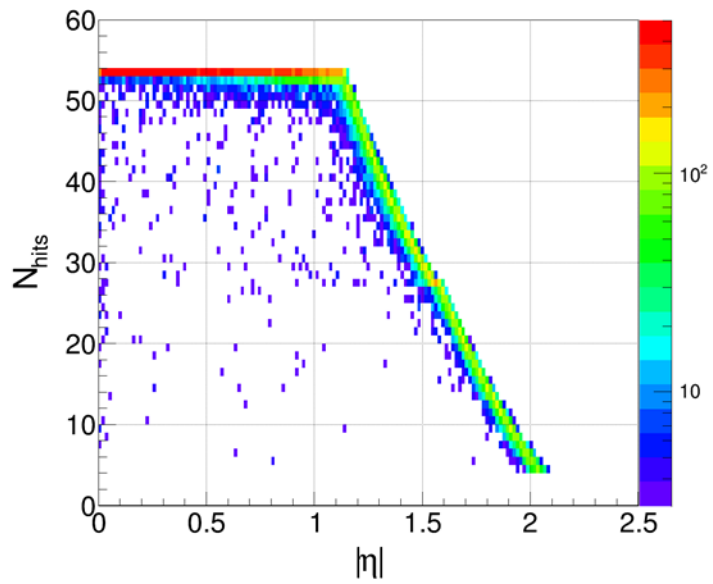
- Production of nucleon clusters (d, t,  $^3\text{He}$ ,  $^4\text{He}$ ) in various reactions (from p+p to Au+Au): spectra, yields, coalescence coefficients.

# 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  $|\eta| < 1.3$ ,  $pT < 3 \text{ GeV}/c$ ,  
limited PID  $1.3 < |\eta| < 1.6$  (dE/dx)



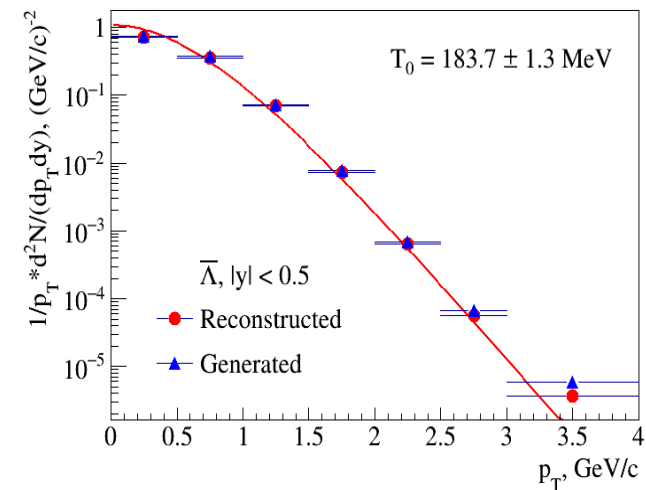
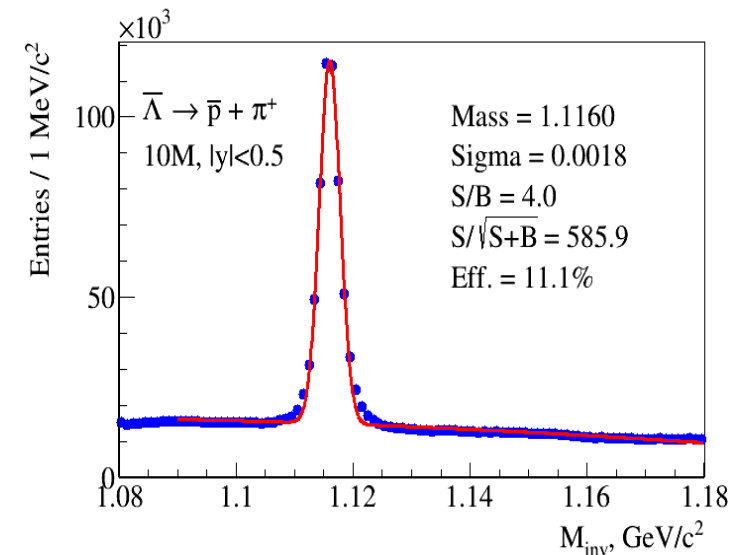
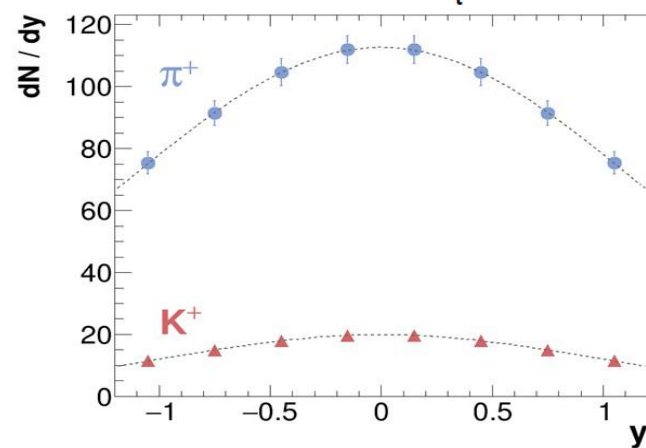
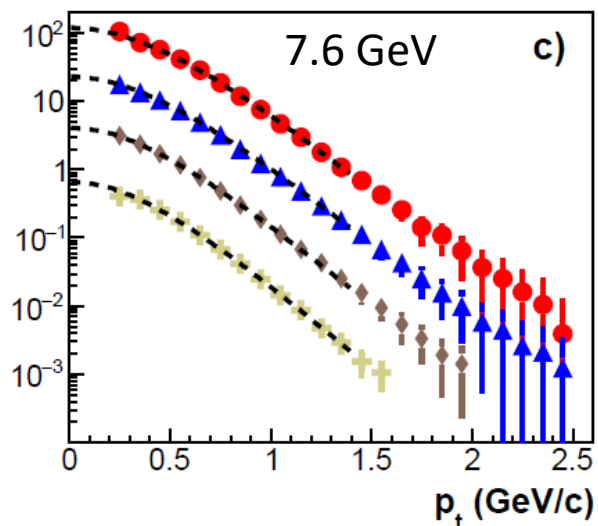
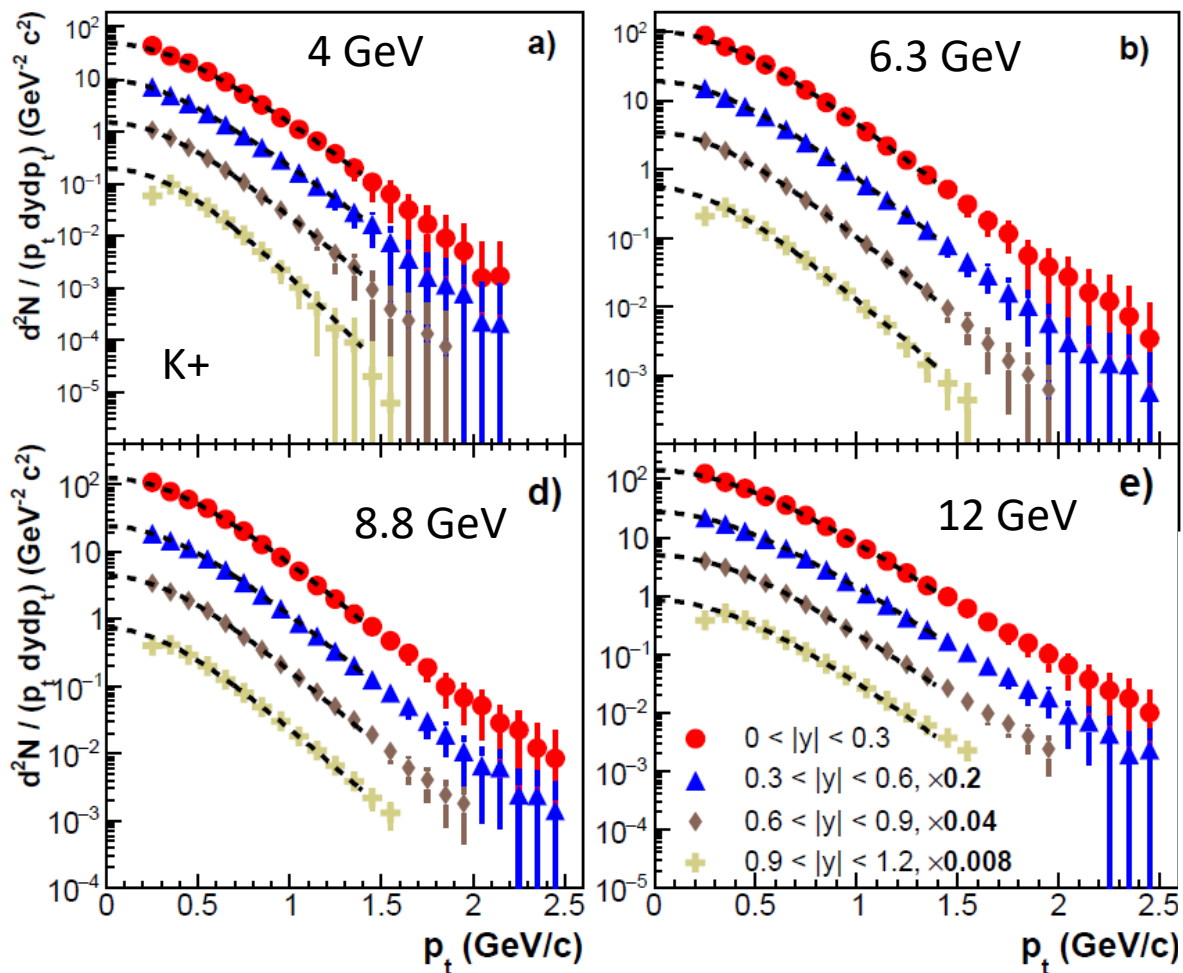
# An (tentative) analysis plan

**The goal** : readiness of all software/analysis tools for the first data taking in 2024 with Bi beams at 9.2 GeV. Several MPD productions will be analyzed by analysis sub-groups and the following topics will be addressed:  
*(in red are those items which were not presented in the first Collaboration paper)*

- **Hadron spectra, yields, ratios : pions, kaons, protons in centrality selected Bi+Bi**
  - realistic centrality selection using TPC multiplicity (MEPhI centrality toolkit)
  - hadron spectra with low magnetic field (low-pT cutoff)?
- **(Anti)Hyperon production in Bi+Bi (Lambda, Ksi, Omega)**
- **Light nuclei spectra, yields, ratios**
- **Hyperon polarization**
- **Hypernuclei reconstruction (invariant mass distributions, pT-spectra, lifetime estimates, etc..)**

# Light hadrons : existing results (some are in physics paper'1)

- Excitation function of hadro-production in the NICA energy range : pT-spectra, rapidity distributions, K/pi-ratio
- Hyperon phase-space and identified hyperon spectra
- Several production (including private ones), UrQMD, PHSD and PHQMD models



# New round of analysis: Light hadrons and hyperons in Bi+Bi

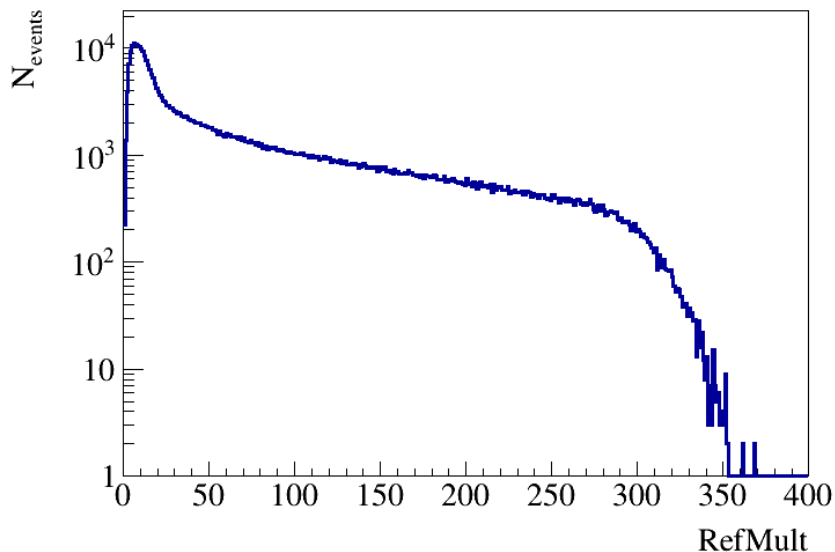
A.Mudrokh, V.Vasendina, A.Zinchenko, V.Kolesnikov

- Production #25 of 50M UrQMD events
- Centrality selection (5-10-20% binning) based on available statistics and specie yields
- Proper PID parameterization and conversion to analysis mDST is ongoing
- Additional hyperon selection method with the TMVA toolkit was tested for old productions

- $p_T > 0.15$  GeV/c
- $|\eta| < 0.5$
- $N_{hits} \geq 16$

**Empty events are discarded!**  
 In order to skip empty event:

- Count  $N_p$  and  $N_n$  within MC track loop;
- if (  $N_p == 166$  &&  $N_n == 418$  ) continue;



## Output from the MEPHl centrality toolkit for MB Bi+Bi

Cent, %	Mult min	Mult max	$\langle N_{part} \rangle$	RMS	$N_{part}$ min	$N_{part}$ max	$N_{coll}$	RMS	$N_{coll}$ min	$N_{coll}$ max
0 – 5	250	376	363.92	23.13	338.91	391.29	835.45	68.11	759.52	913.14
5 – 10	208	250	316.07	25.22	293.63	338.91	690.70	61.21	630.92	759.52
10 – 20	146	208	255.77	29.23	221.58	295.10	526.69	70.78	437.77	635.59
20 – 30	101	146	191.56	24.04	165.03	221.58	361.89	53.44	297.25	437.77
30 – 40	68	101	141.58	20.08	120.71	165.03	243.42	41.04	196.90	297.25
40 – 50	44	68	102.11	16.81	85.66	120.71	157.95	31.31	125.27	196.90
50 – 60	27	44	71.17	13.84	58.16	85.66	97.84	23.26	75.03	125.27
60 – 70	15	27	46.71	11.38	37.13	58.16	56.01	16.93	41.43	75.03
70 – 80	8	15	28.87	8.73	21.63	37.13	29.96	11.22	20.70	41.43
80 – 90	3	8	15.50	6.92	10.21	21.63	13.82	7.46	8.57	20.70
90 – 100	1	2	5.32	3.37	0.41	10.21	3.86	2.96	-1.36	8.57

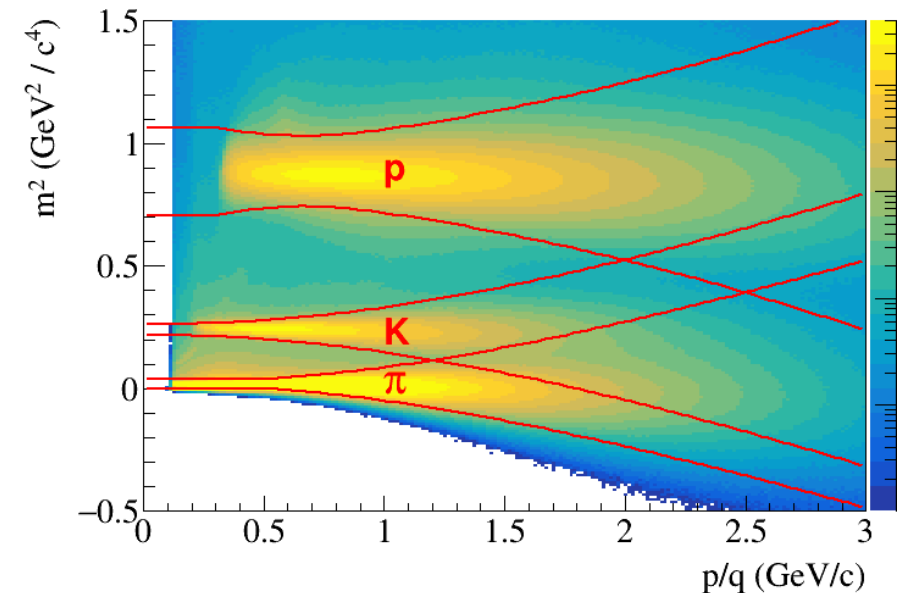
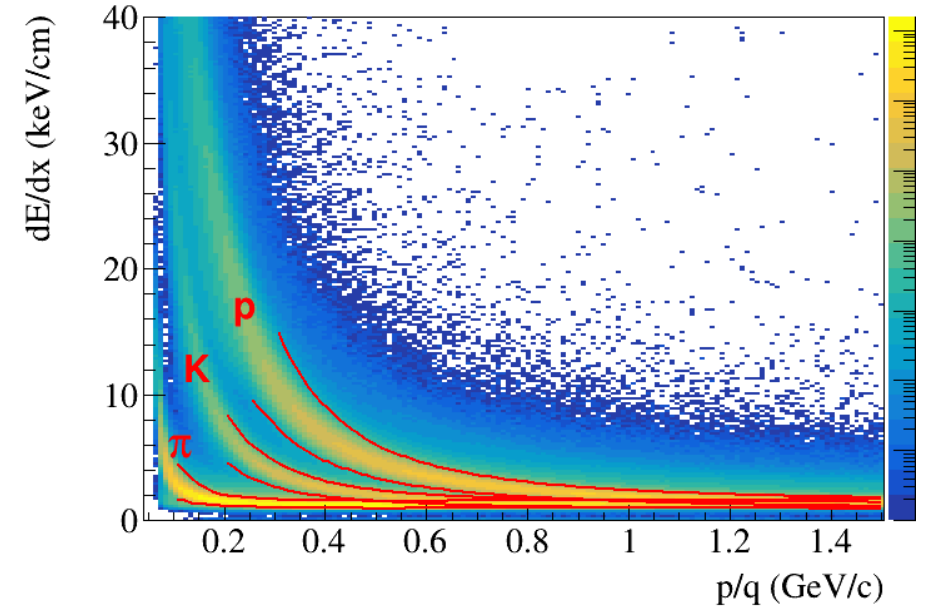
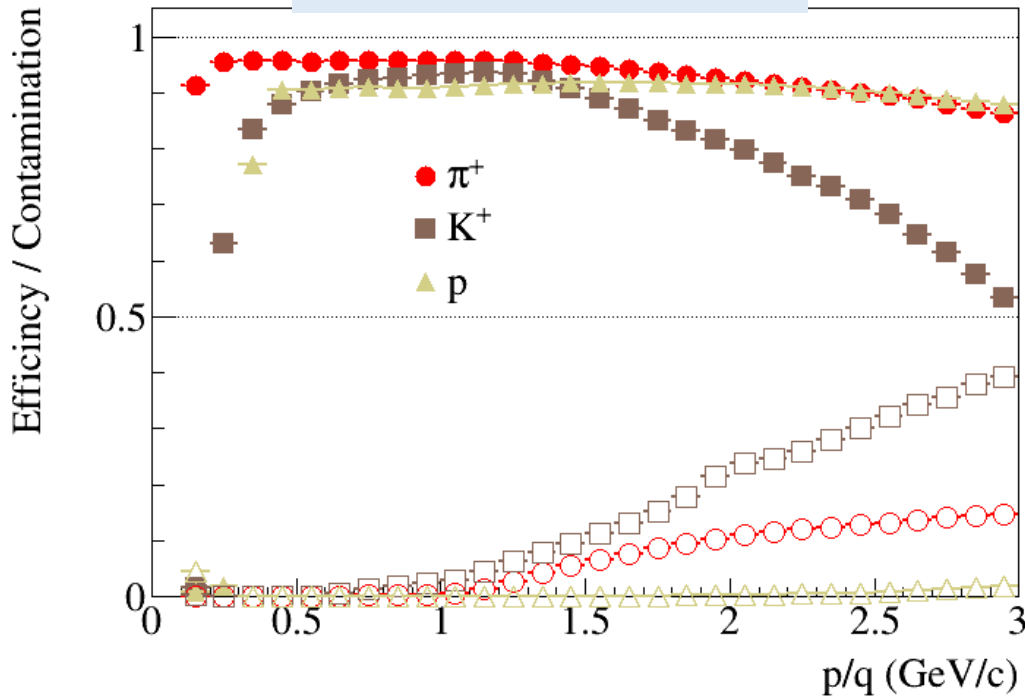


# Light hadrons in Bi+Bi : PID tuning

A.Mudrokh

- QA and PID tuning performed for production **25** (UrQMD)
- mDST production for hyperon analysis has started with proper PID parameterizations

$|Z_{\text{vertex}}| < 50 \text{ cm}$   
 $|\eta| < 1.3$   
 $N_{\text{hits}} \geq 20$



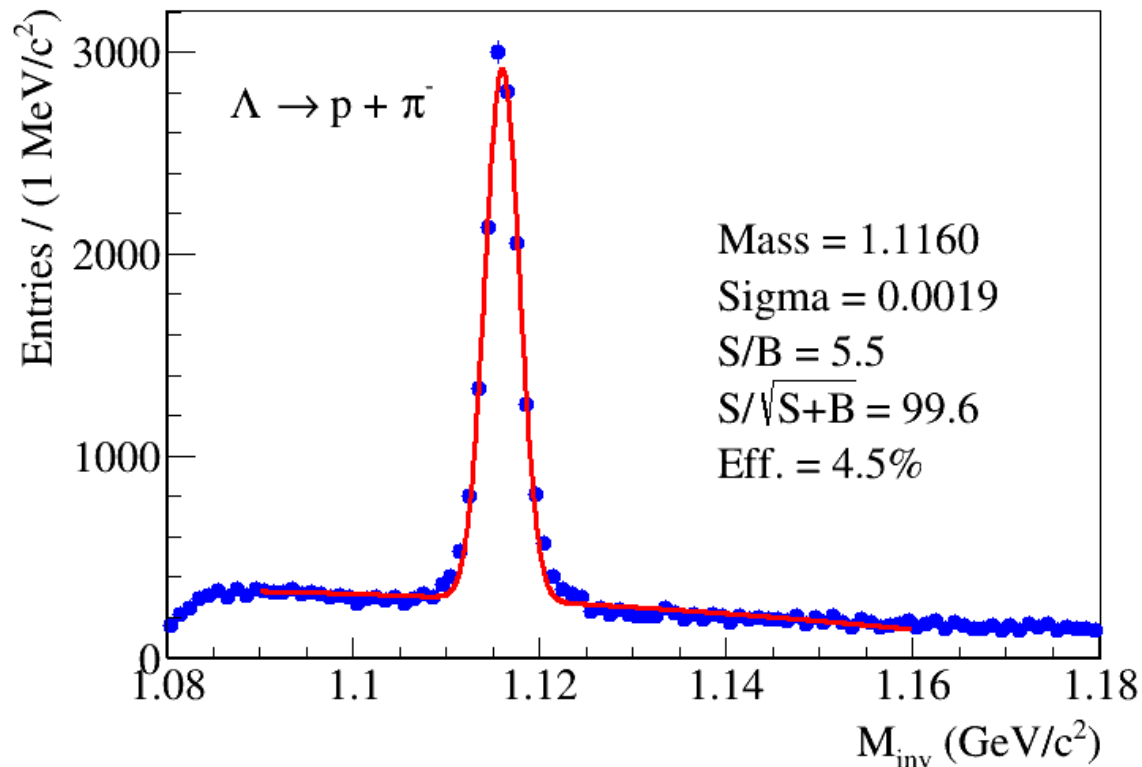


# $\Lambda$ reconstruction: standard method vs TMVA

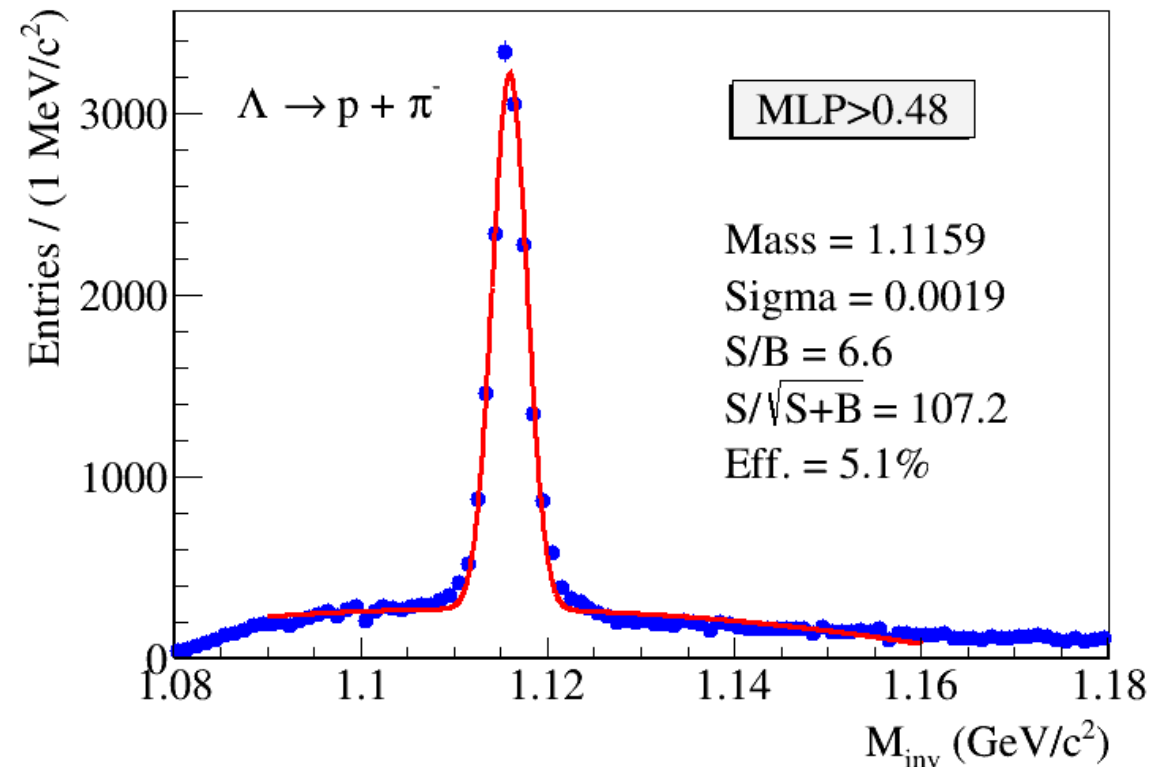
A.Zinchenko, V.Vasendina

- PHSD data set ( $\sim 8$ M events)
- ML approach within the Toolkit for Multivariate Data Analysis with ROOT (TMVA)

Standard method of Topological Cuts (6 cuts)



TMVA method (8 cuts)

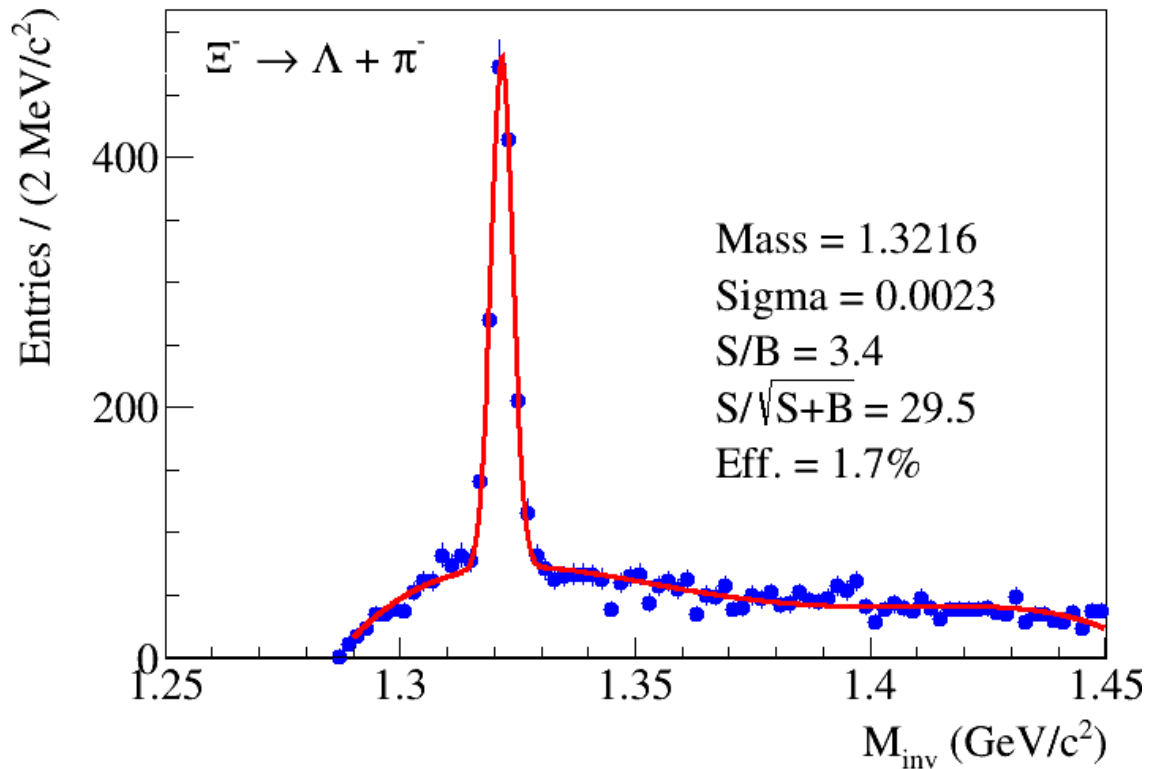


Better Lambda selectivity with TMVA

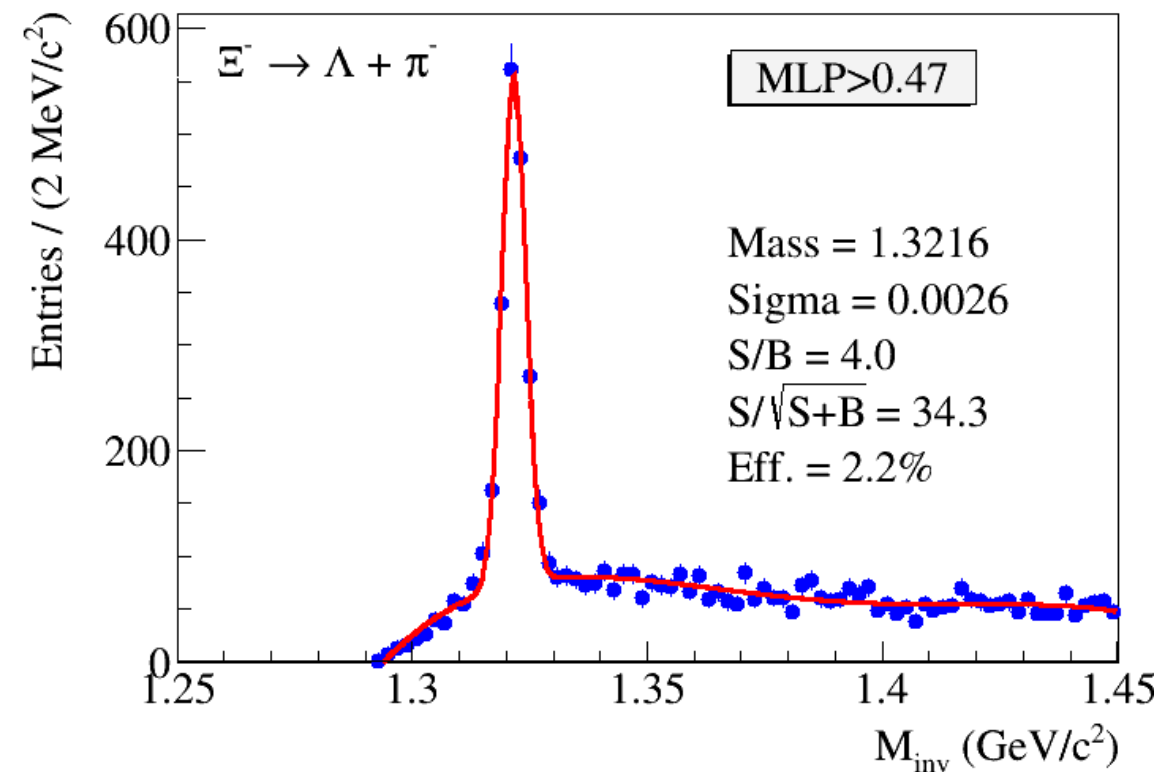
# $\Xi^-$ reconstruction: standard method vs TMVA

- PHSD data set (~8M events)
- ML approach within the Toolkit for Multivariate Data Analysis with ROOT (TMVA)

Standard method of topological cuts (13 cuts)



TMVA method (15 cuts)

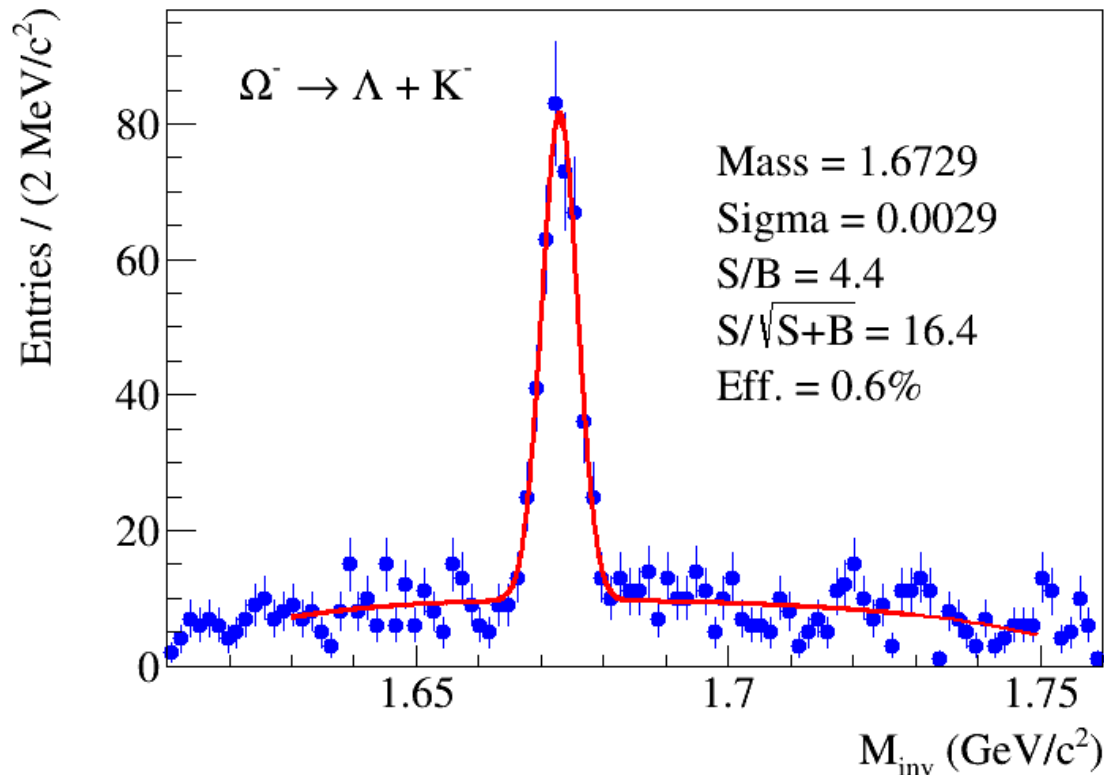


Improvement in Ksi selectivity with TMVA

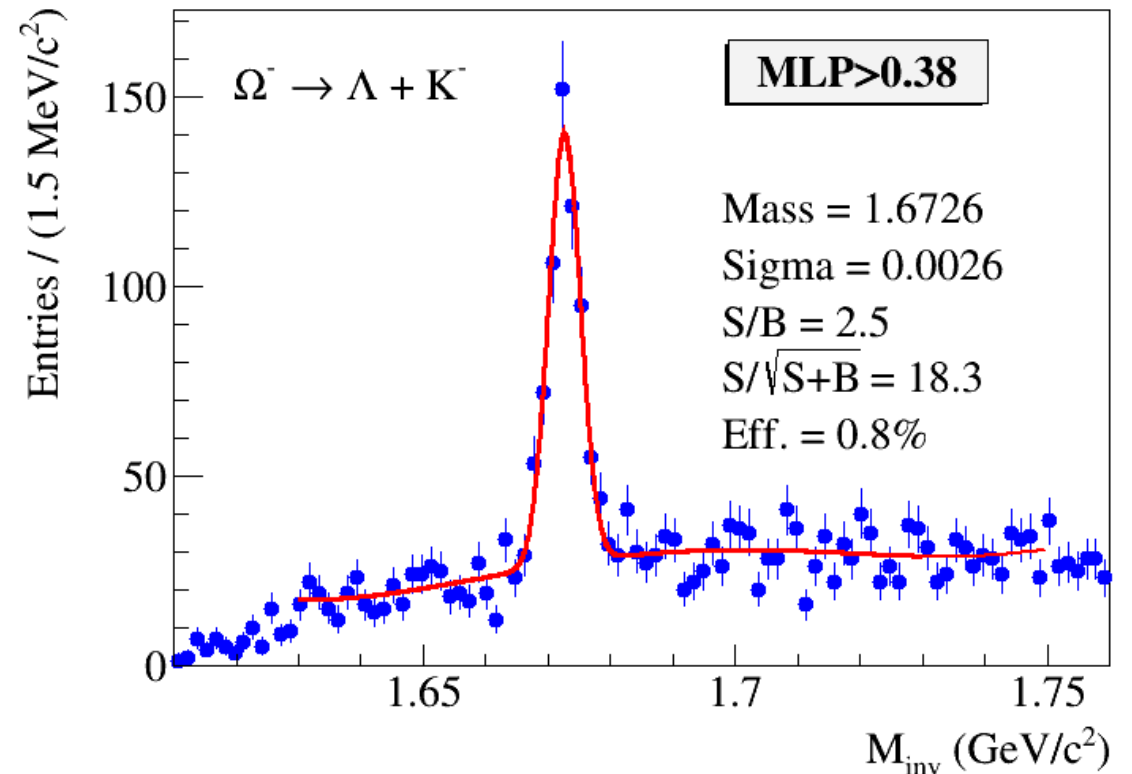
# $\Omega^-$ reconstruction: standard method vs TMVA

- PHSD data set ( $\sim 8$ M events)
- ML approach within the Toolkit for Multivariate Data Analysis with ROOT (TMVA)

Method of topological cuts (13 cuts)



TMVA method (16 cuts)



Better Omega selectivity with TMVA

## New analysis of hadron spectra and yields : what can be added for Physics paper'2?

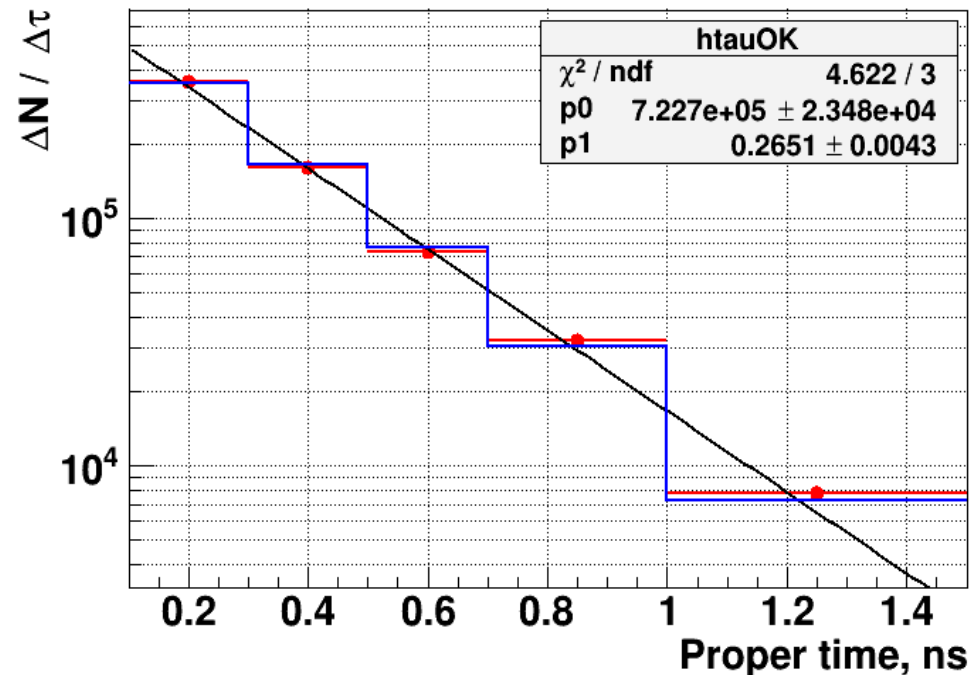
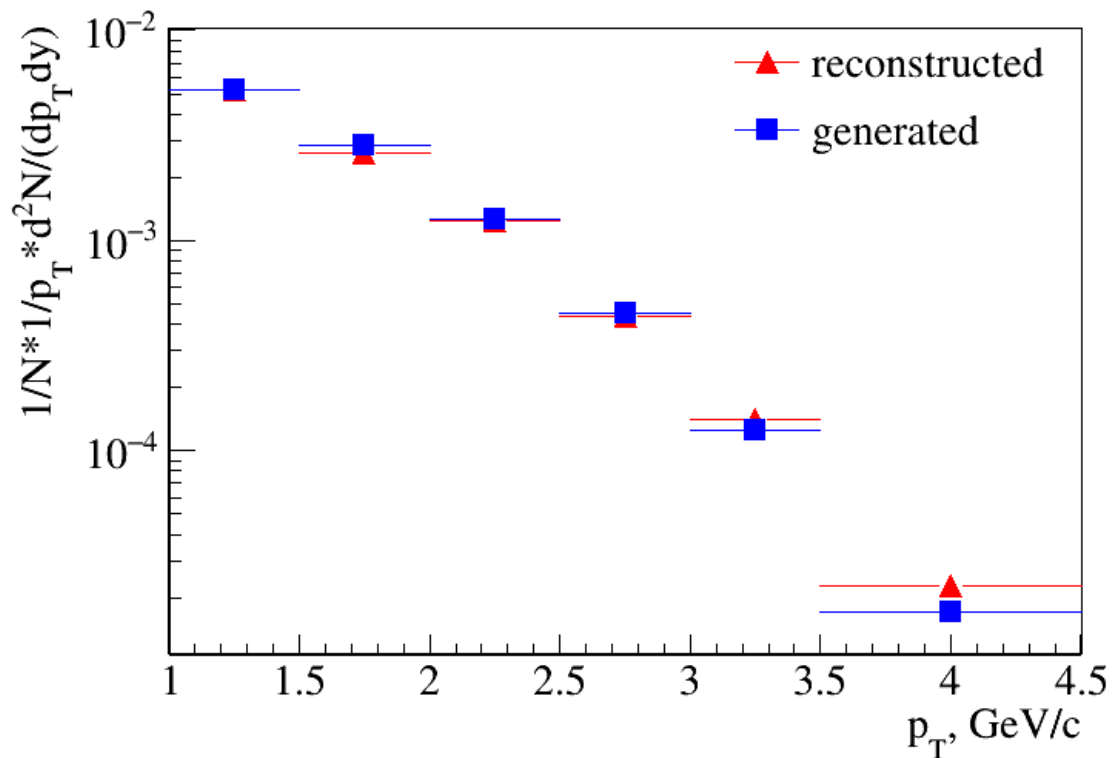
- (Again) spectra in rapidity bins, rapidity spectra, total yields in **centrality selected** Bi+Bi (pions, kaons, protons, hyperons)
- Particle yields and ratios, meson-to-baryon ratio,  $R_{cp}$ , etc.
- Deeper inside into QCD diagram mapping analysis (thermal statistical fits of hadron production data) and analysis of transverse dynamics (BW and T,  $\beta$  with different profiles) – **expert's manpower is needed**

# Hypernuclei in MPD : analysis'2021

- 40M events of Bi+Bi at 9 GeV (PHQMD model), analysis 2021-22
- H3L invariant spectra and lifetime, estimates for heavier specie
- Not included to the MPD physics performance paper'1

$$\tau = [0.1 - 1.5] \text{ ps}$$
$$p1 = 265 \pm 4 \text{ ps}$$

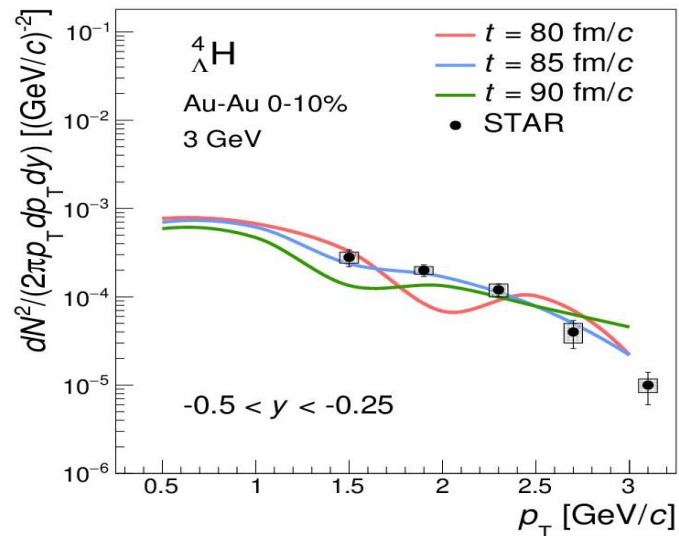
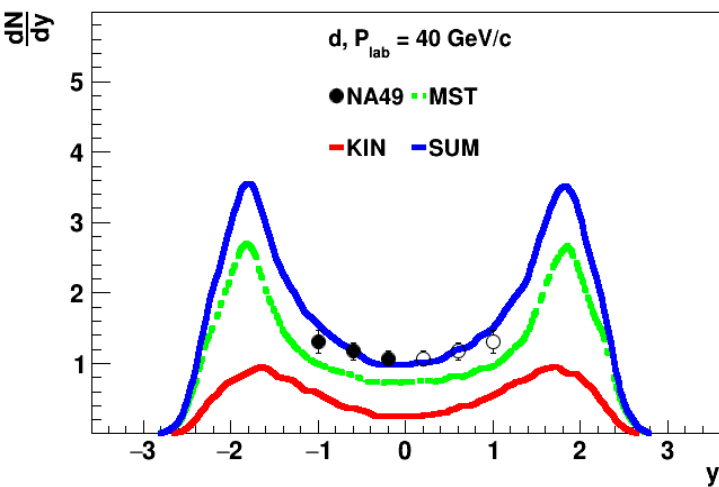
Fit:  $dN/d\tau = p0 * \exp(-\tau/p1)$ ,  $p1$  - lifetime



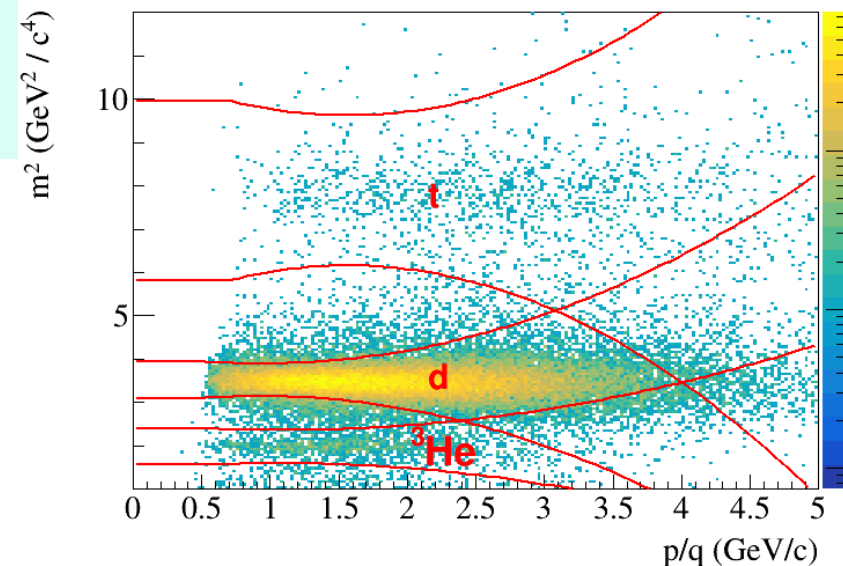
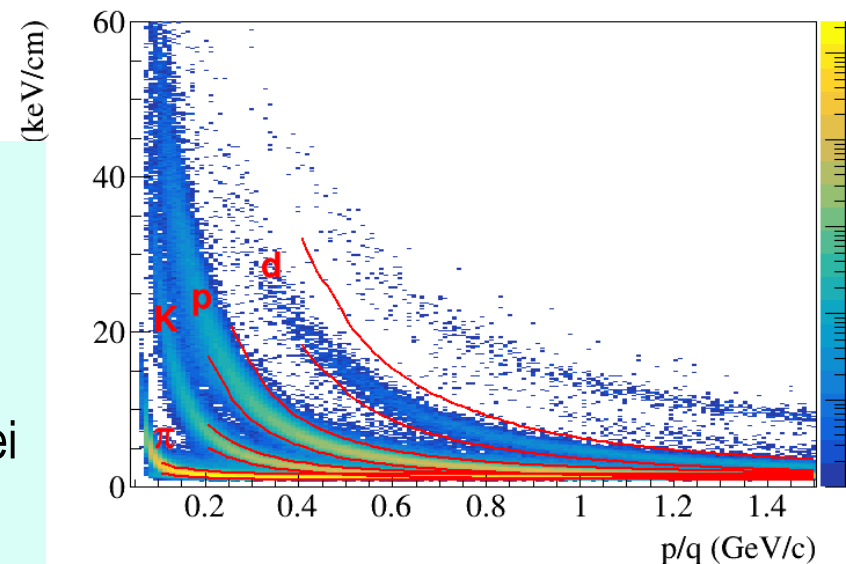
# New production #29 (PHQMD model)

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

## PHQMD predictions in A+A



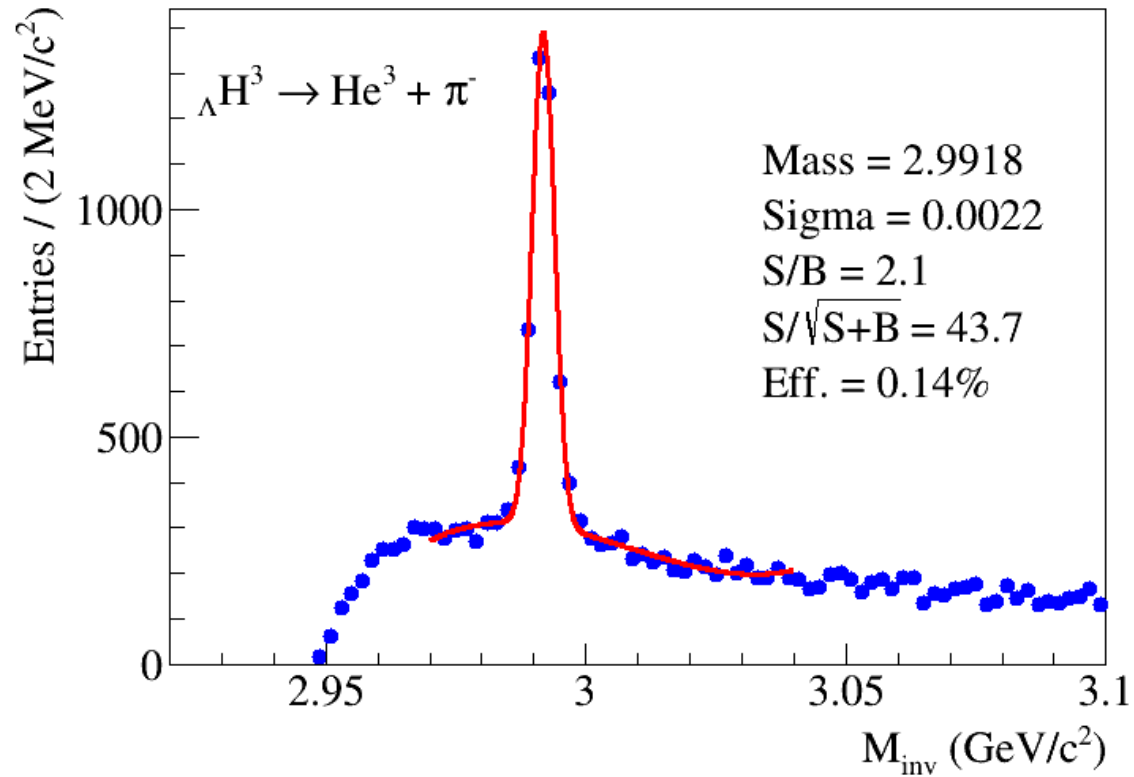
- QA for the request t#29
- Production is ongoing
- Final PID tuning for hadrons and nuclei left for the end of the production
- New complementary ML approach for hypernuclei selection tested



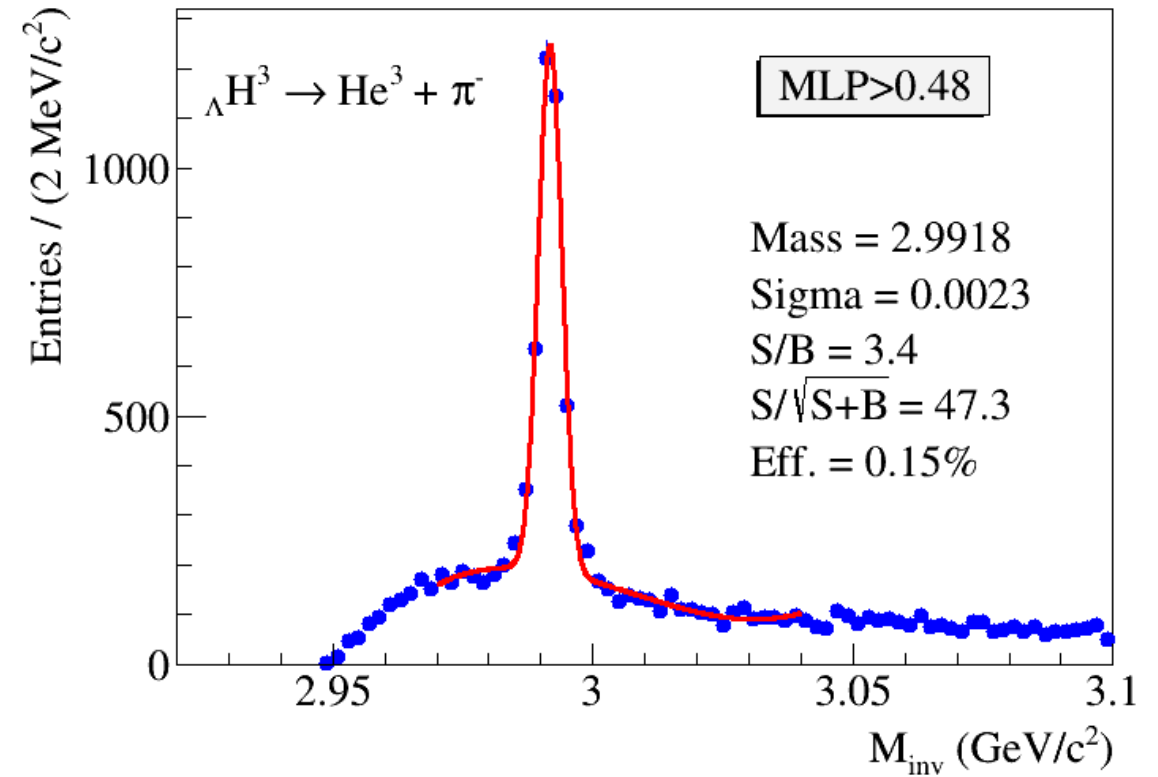
# ${}^3_{\Lambda}\text{H}$ reconstruction (2-prong): standard chain vs TMVA

- 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 (7 cuts)



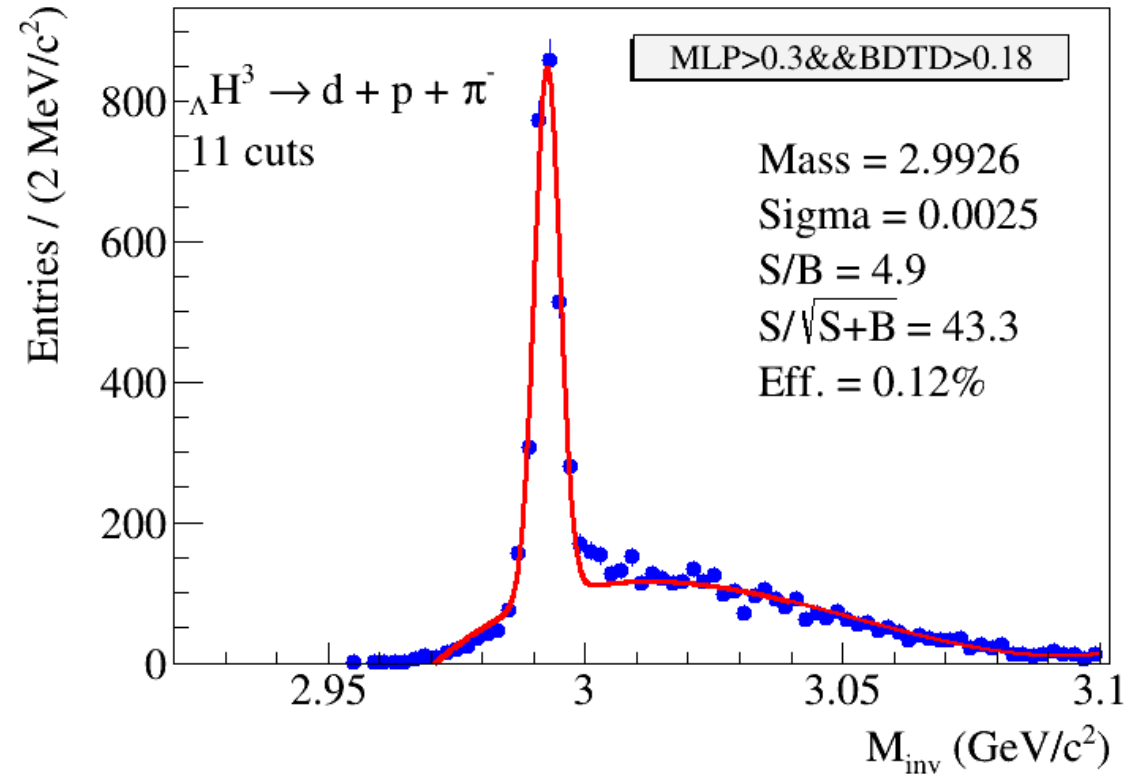
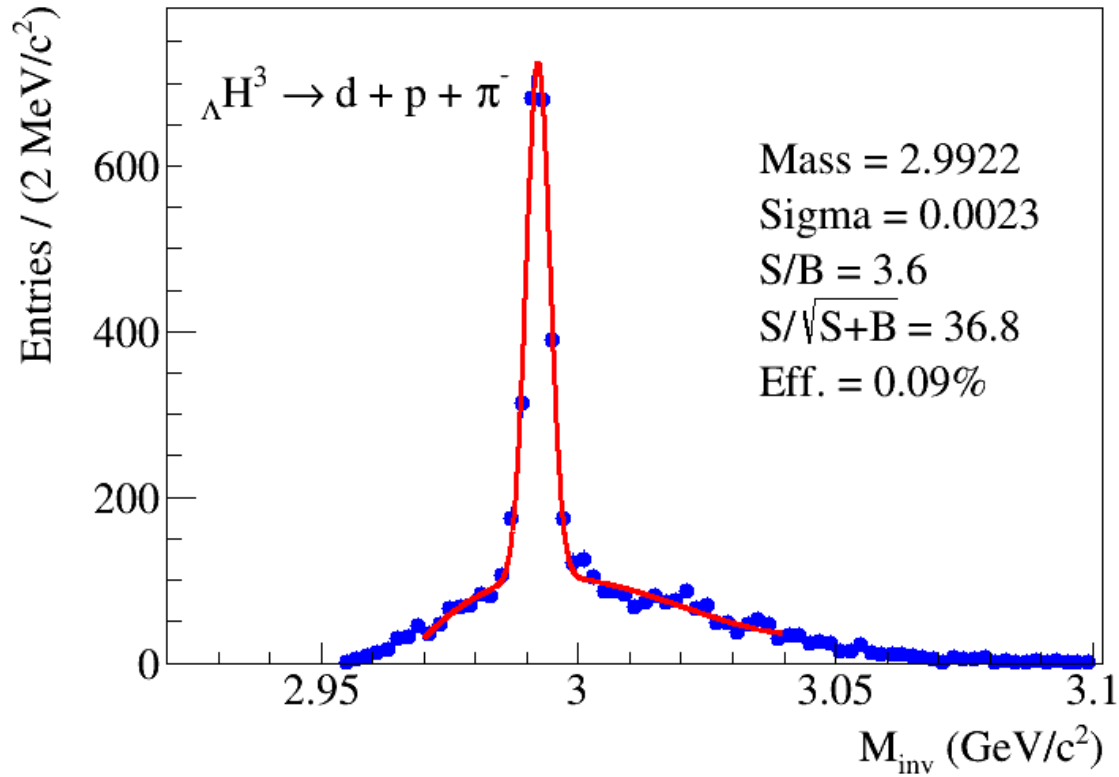
TMVA method (8 cuts)



**Better selectivity of hypertritons with the TMVA toolkit**



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

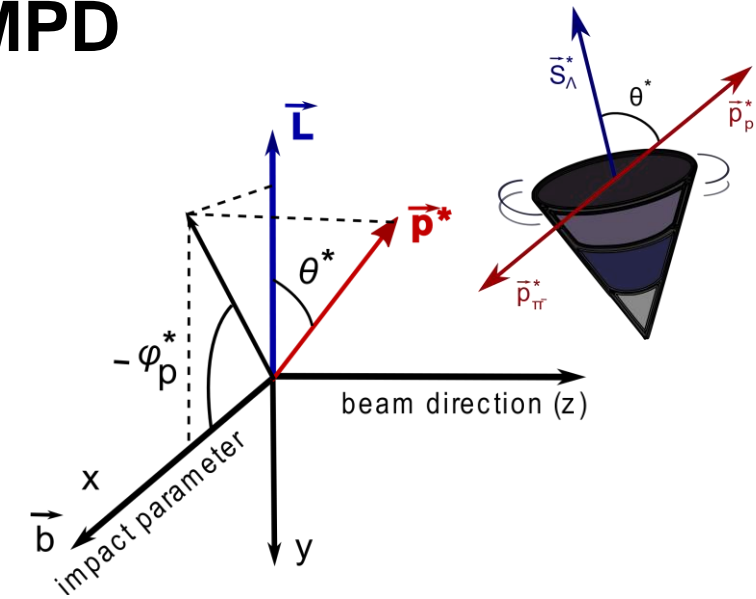


**TMVA also indicates better selectivity for 3-prong decay mode**

# Global hyperon polarization at NICA/MPD

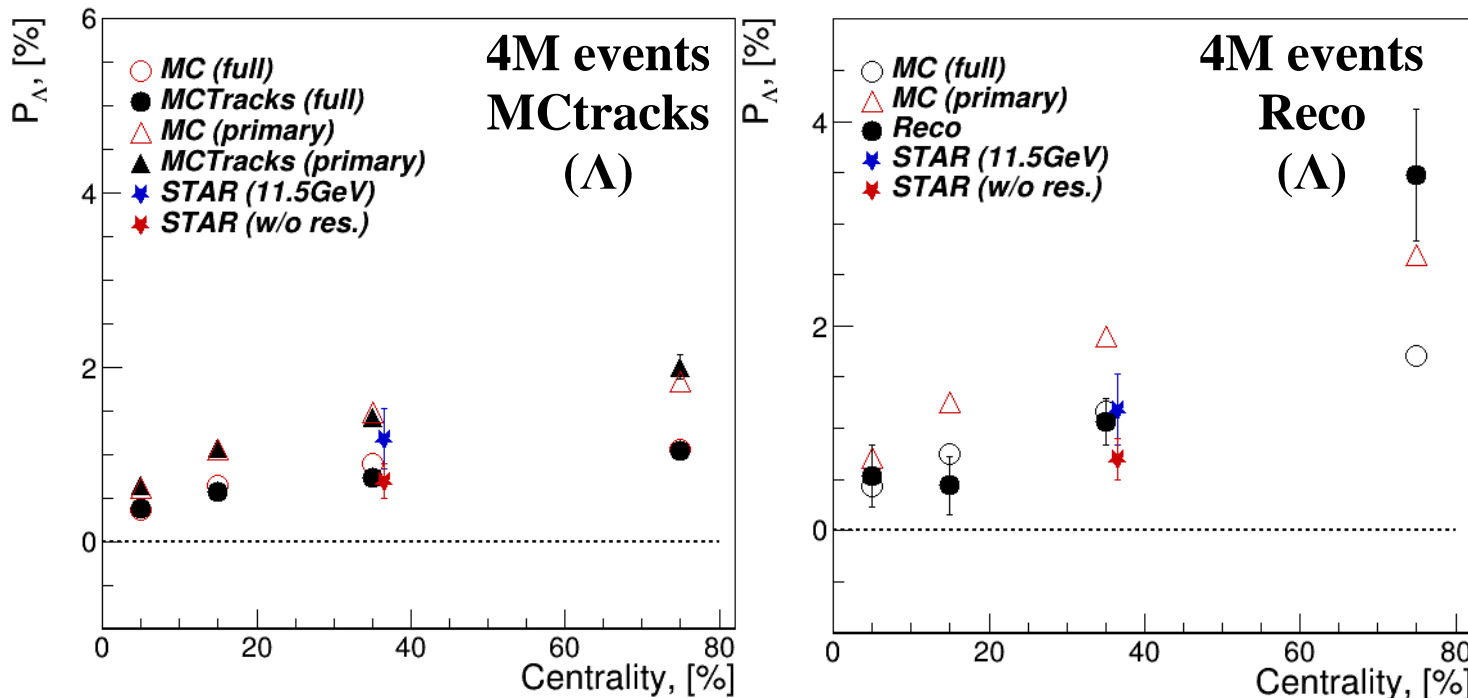
E.Nazarova, V.Voronyuk

- Bi-Bi @ 9.2 GeV, 4M MB events,  $b$  [0,12] fm (PHSD, private production)
- Global hyperon polarization (Thermodynamical approach)
- Higher polarization for anti-Lambda w.r.t. Lambda
- Transfer of polarization vector to MCTracks
- Transfer of polarization during hyperon decays (feed-down) → **Corrected!**
- Centrality determined through TPC multiplicity
- Event plane resolution estimated via FHCAL



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

More details in <https://indico.jinr.ru/event/3260/>



## • Global polarization analysis

- «Event plane» method
- Fit of  $N_{\Lambda}(\Delta\phi_p^*)$
- Accurately returns values of global polarization for (Anti)Lambda (using MC/Reco Tracks)

# Global hyperon polarization at NICA/MPD (2)

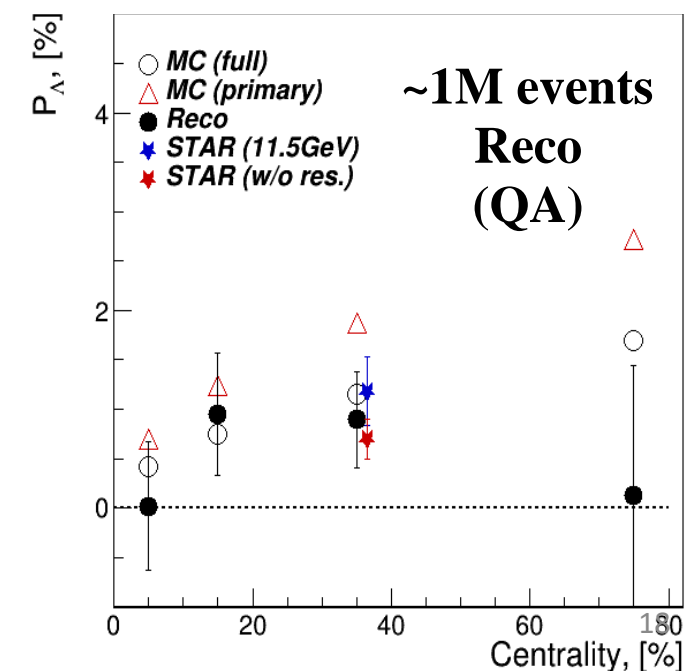
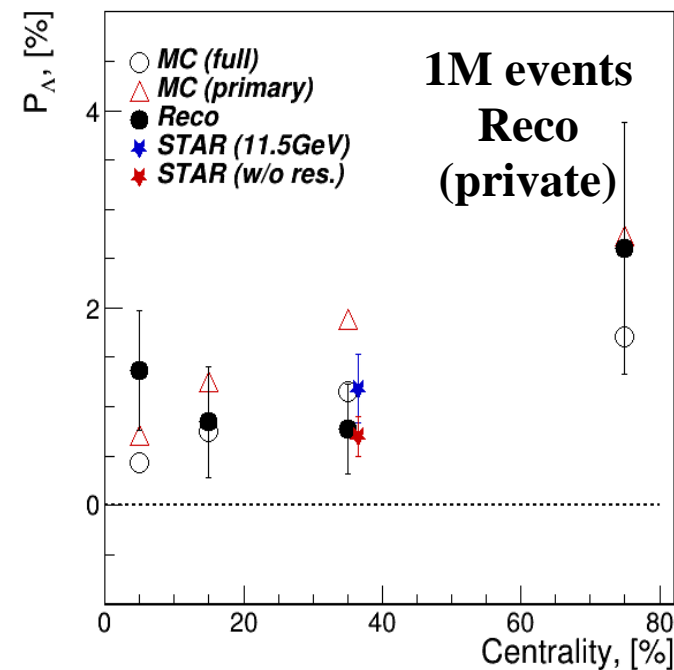
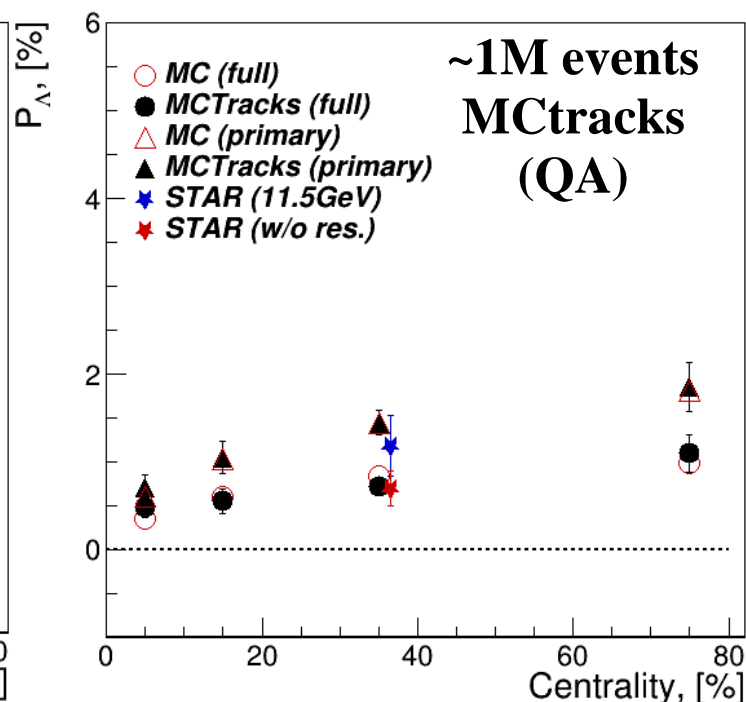
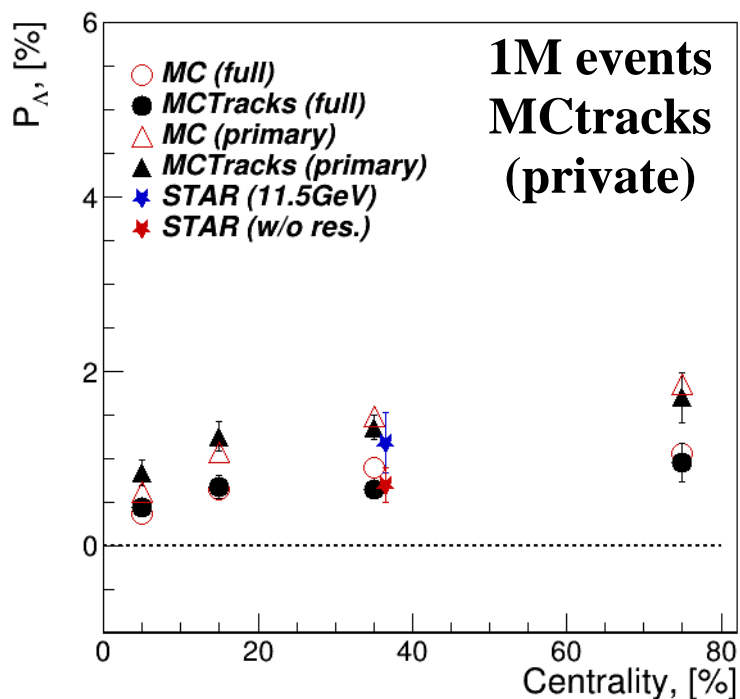
• Bi-Bi @ 9.2 GeV, 15M MB events, PHSD,  $b$  [0,12]fm ([Request 30](#))

› QA tests (~900k events) show no problems

› Signal of polarization is present, extracted values from fitting correspond to the mean polarization

› Results are in good agreement with the ones from the private production

› Full official production is under way



# Summary

- **Data from several new productions will be analyzed soon within PWG2**
- **Prod. 25 (UrQMD) will be the base for hadron and hyperon studies once mDST are ready**
- **Prod. 29 (PHQMD) will be used for (hyper)nuclei, the DST production rate is sufficient**
- **Prod. 30 (PHSD), a one dedicated to (anti)Lambda-hyperon polarization studies.**

**Problems in the analysis have solved.**

***Thank you for your attention!***