A Monte Carlo Study of strange particle production at NICA/MPD

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Outline

- Motivation
- Detector geometry
- Analysis details
  - Event generator
  - Procedure of maximization of significance
- Study of hyperons production

$$\Lambda \rightarrow p + \pi^-$$
$$\Lambda_{bar} \rightarrow p^- + \pi^+$$
$$\Xi^- \rightarrow \Lambda + \pi^- \rightarrow p + \pi^- + \pi^-$$
$$\Omega^- \rightarrow \Lambda + K^-$$

- Study of hypernuclei production

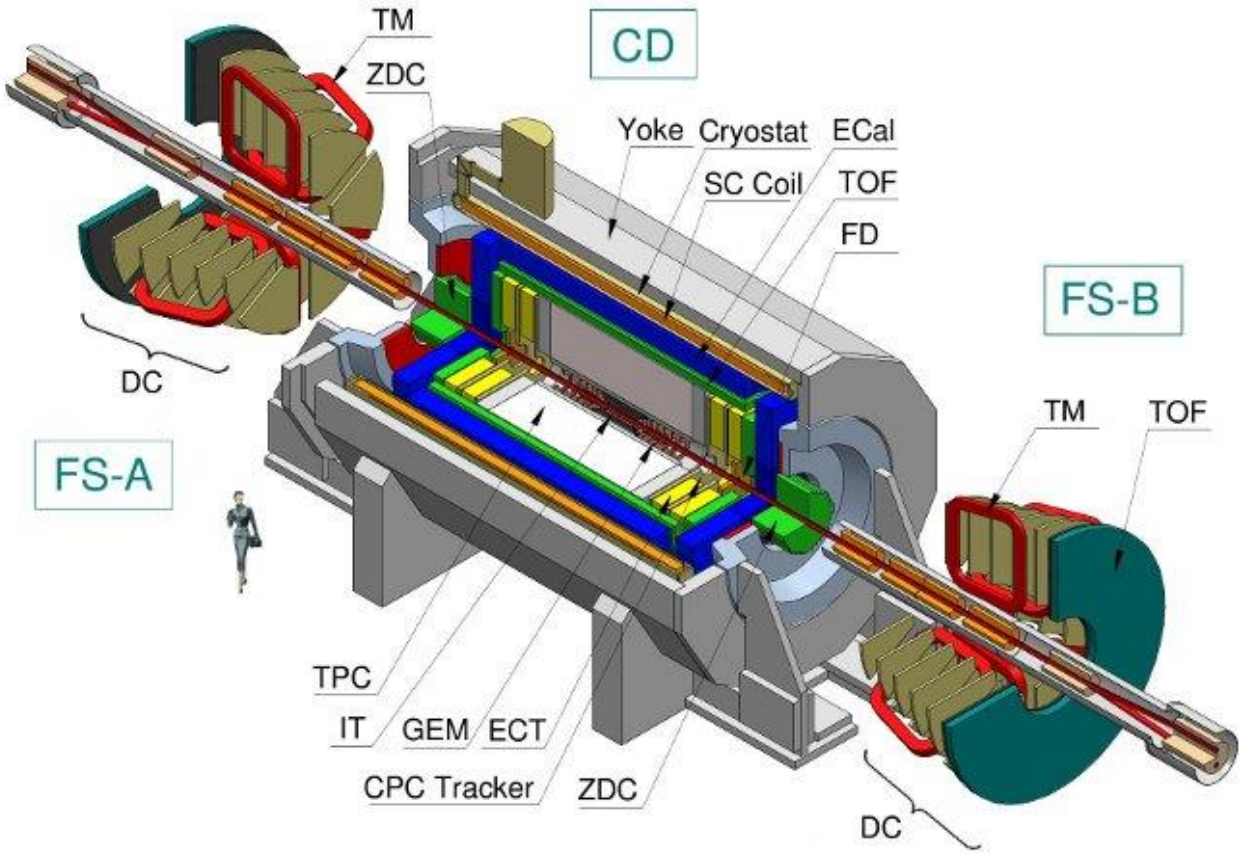
$$^3_\Lambda H \rightarrow {}^3He + \pi^-$$
$$^3_\Lambda H \rightarrow p + d + \pi^-$$

- Summary

Physics motivation

- Heavy strange objects could provide essential signatures of the excited and compressed baryonic matter.
- The study of hyperons helps to understand strong interactions and QGP.
- Hyperons are produced in relatively large quantities and have very attractive experimental features.
- Study of hypernuclei is important for:
  - Understanding the strangeness degrees of freedom in hadronic systems.
  - Study of all populated regions in the three-dimensional chart of the nuclides.
  - Hyperon-nucleus and hyperon-hyperon interaction can be investigated through hypernuclei.
  - Provide info on EOS of neutron stars.

Multi-Purpose Detector general view



Stage I:

- TPC
- TOF
- Ecal
- ZDC
- FFD

Analysis details

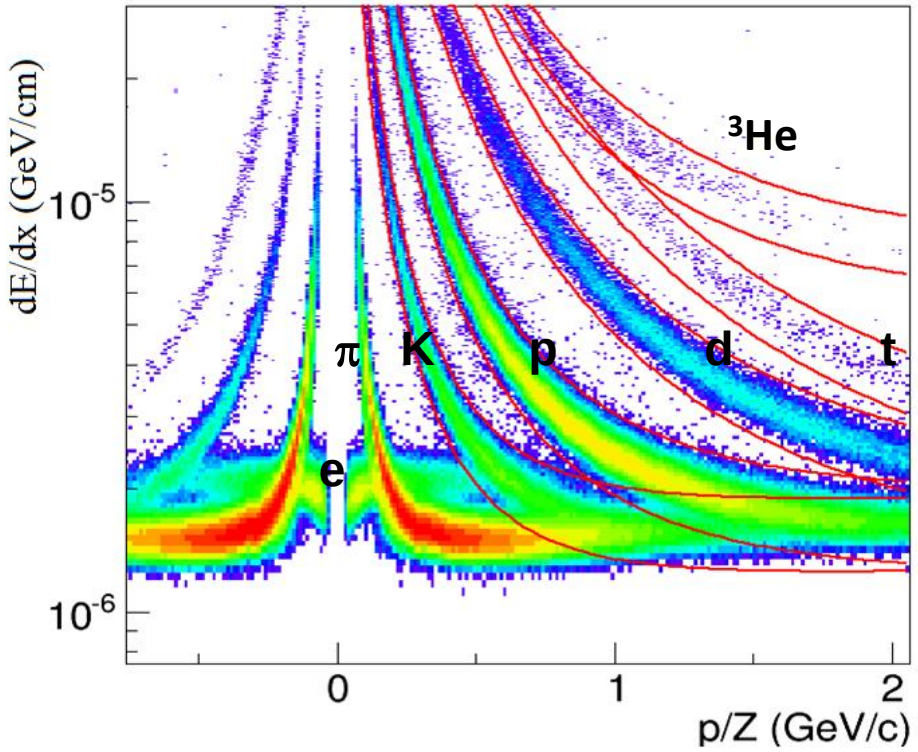
- **Generators:** UrQMD & DCM-QGSM, Au+Au @ 5A GeV & 9A GeV central (0-3 fm), 10k, 40k, 300k, 500k events
- **Detectors:** start version of MPD with up-to-date TPC & TOF
- Track acceptance criterion: $|\eta| < 1.3$, $N_{hits} \geq 10$
- Particle identification in TPC & TOF
- Maximization of significance

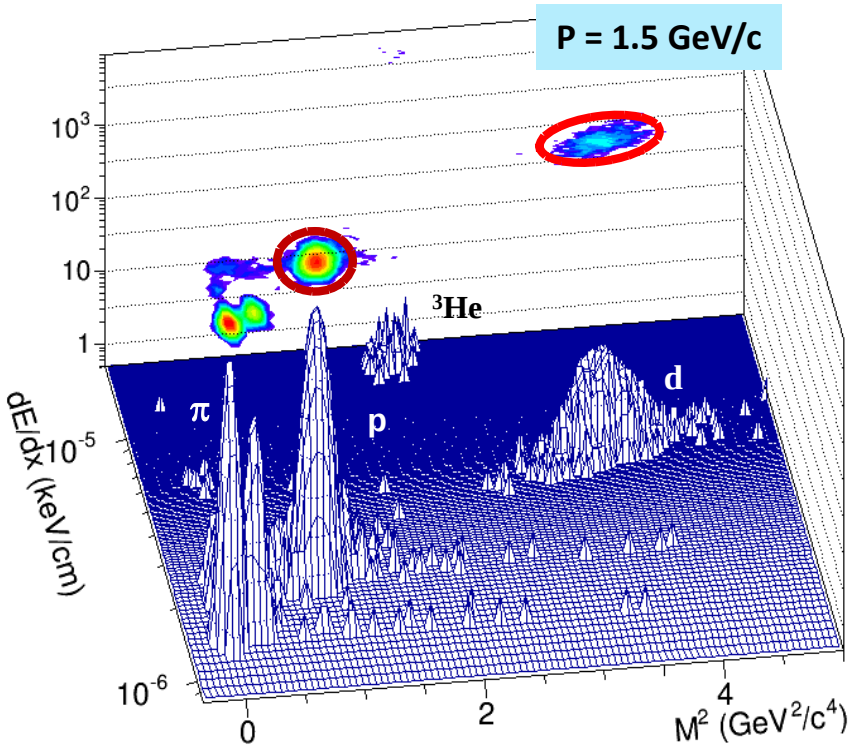
MPD Particle Identification (PID)

PID is achieved by dE/dx (TPC) and time-of-flight (TOF) measurements

Mass square calculated using the measurements of momentum (p), time-of-flight (T) and trajectory length (L)

$$m^2 = p^2\left(\frac{c^2T^2}{L^2} - 1\right)$$



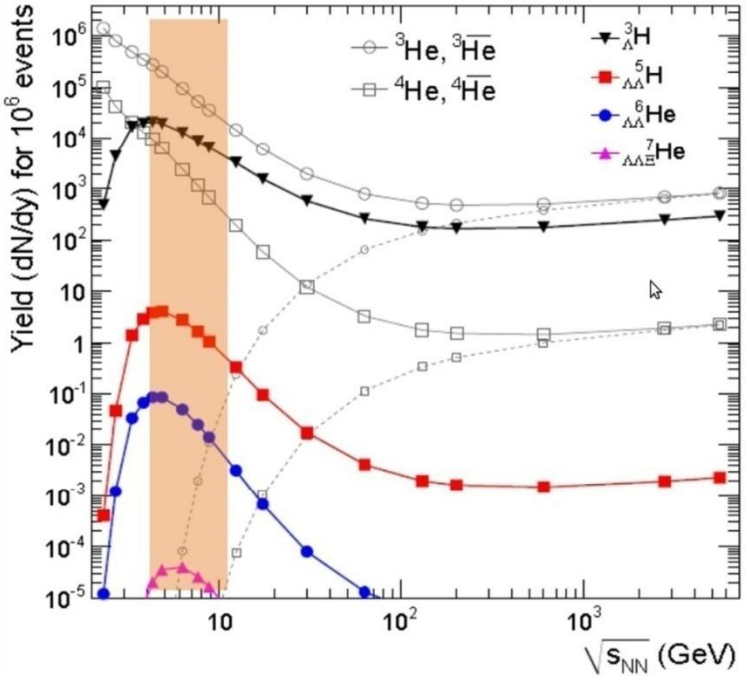


Particles are selected within 3σ cuts in 'dE/dx vs p' (1) or 'dE/dx vs m^2' space in momentum bins (2)

Model predictions

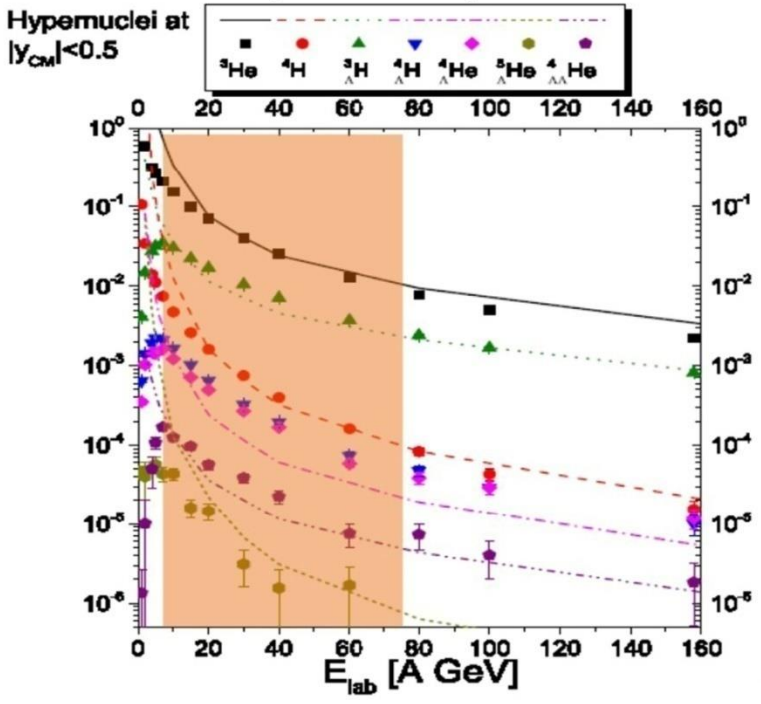
Statistical hadronization model

A.Andronic, P.Braun-Munzinger,
J.Stachel, H.Stocker



DCM-QGSM

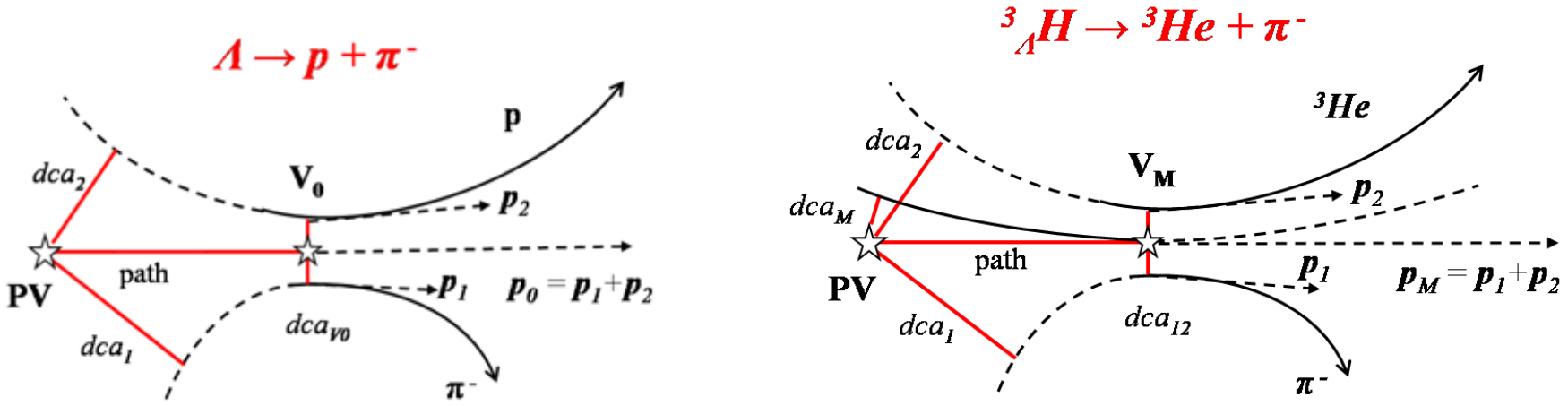
J.Steinheimer, K.Gudima, A.Botvina,
I.Mishustin, M.Bleicher, H.Stocker



- **In heavy-ion reactions:** production of hypernuclei through coalescence of Λ with light fragments.
- **Maximal yield** predicted for √s=4-5A GeV (stat. model) (interplay of Λ and light nuclei excitation function).

➔ **NICA energy range is ideally suited for the search of (double) hypernuclei**

Analysis Method: Secondary Vertex Finding Technique

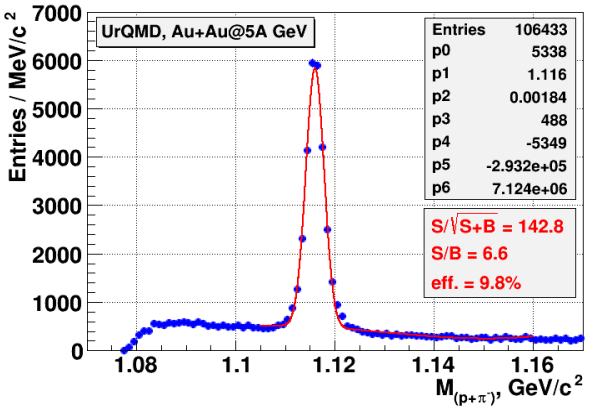


Event topology of two-particle decay of the neutral (left) and charged (right) particle:

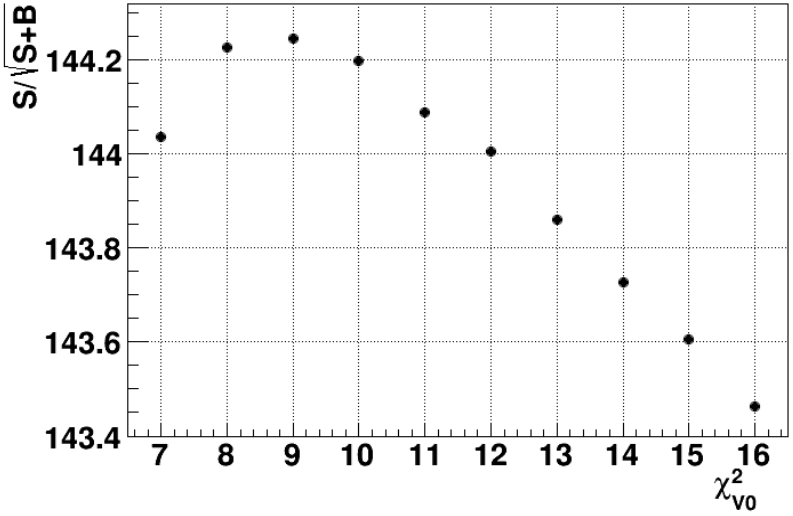
- ✓ PV – primary vertex
- ✓ V_0 – vertex of Λ decay
- ✓ V_M – vertex of $^3_\Lambda H$ decay
- ✓ dca – distance of the closest approach
- ✓ path – decay length

Maximization of significance

1. Significance is defined as $S/\sqrt{(S+B)}$, where S and B are total numbers of signal and background combinations inside ±2σ interval around the peak position.
2. Set of 6 cuts for Λ selection: χ^2_{π} (dca_1), χ^2_{p} (dca_2), χ^2_{V0}, dca_{V0}, path, angle between ***p*** and ***r*** of Λ.
3. Variation of 6 cuts with small steps and production of invariant mass distributions for each set of cuts.
4. Fitting to the sum of gaussian and polynomial functions and computing the significance.
5. Selection of maximum significance with corresponding cuts (see Fig.).



While different physics analyses might prefer different selection quality criteria, the significance looks convenient to quantitatively evaluate effect of different factors on the reconstruction quality.

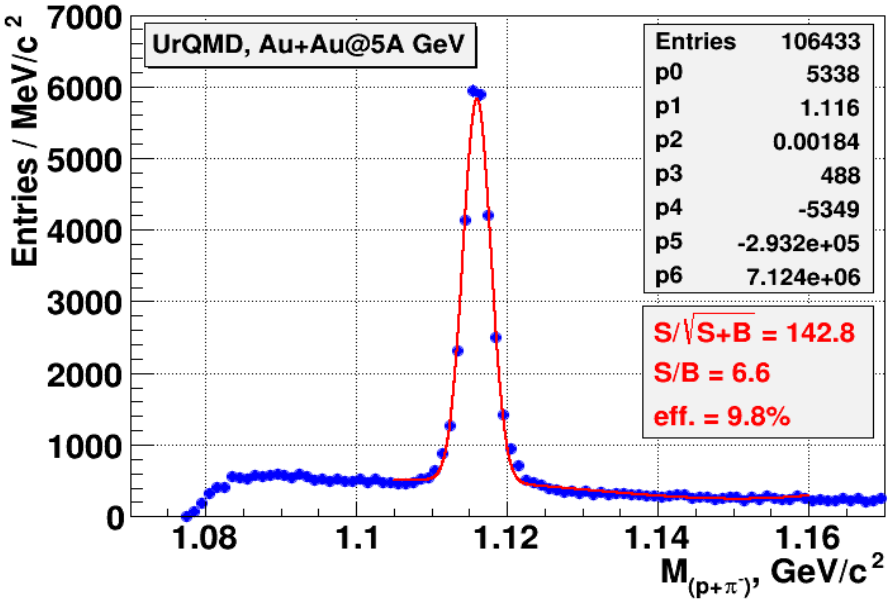


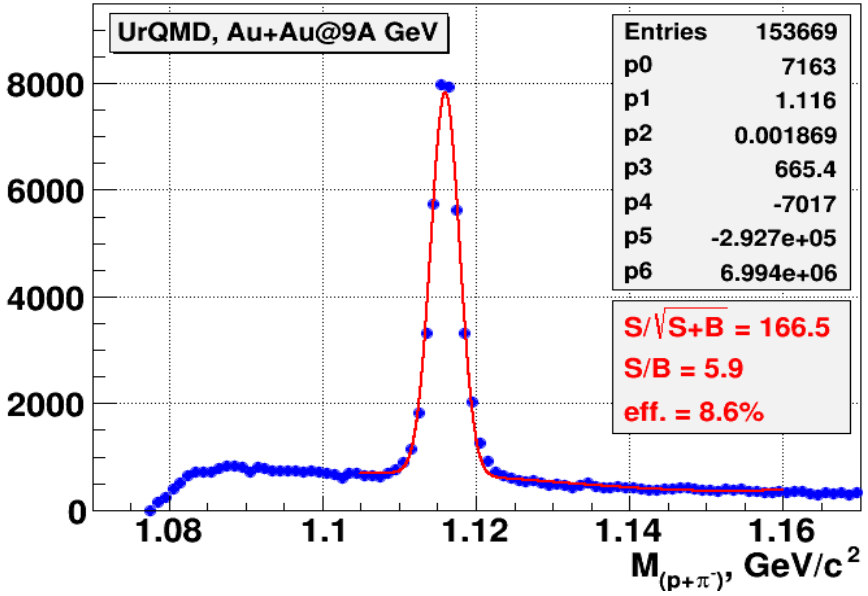
Invariant mass at max. significance:

$\Lambda \rightarrow p + \pi^-$

UrQMD, Au+Au @ 5A and 9A GeV, central (0-3 fm), 10k events – 30s of running time at the NICA collision rate of 6 kHz.

PID in TPC & TOF

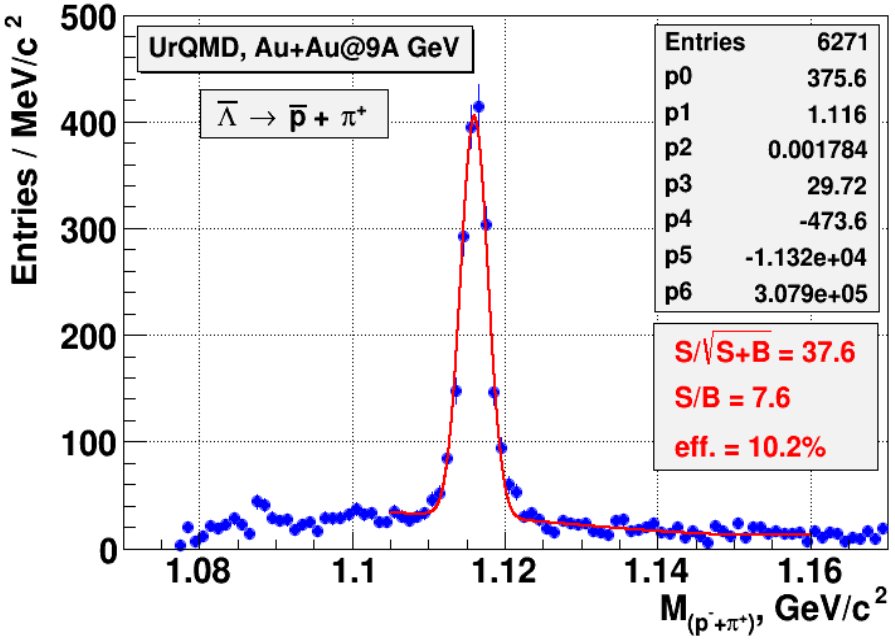


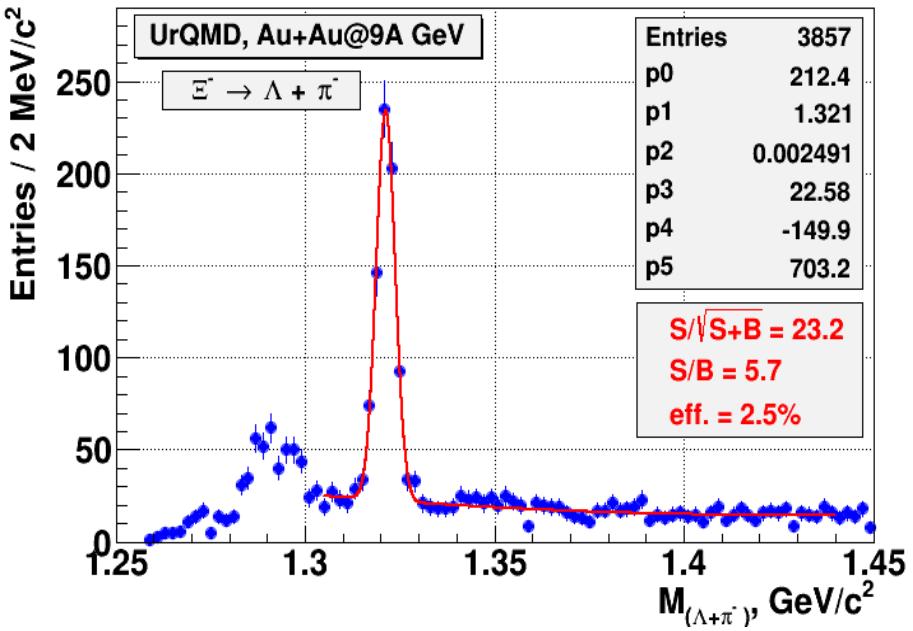


Invariant mass at max. significance:

$\Lambda_{bar} \rightarrow p^- + \pi^+$ & $\Xi^- \rightarrow \Lambda + \pi^-$

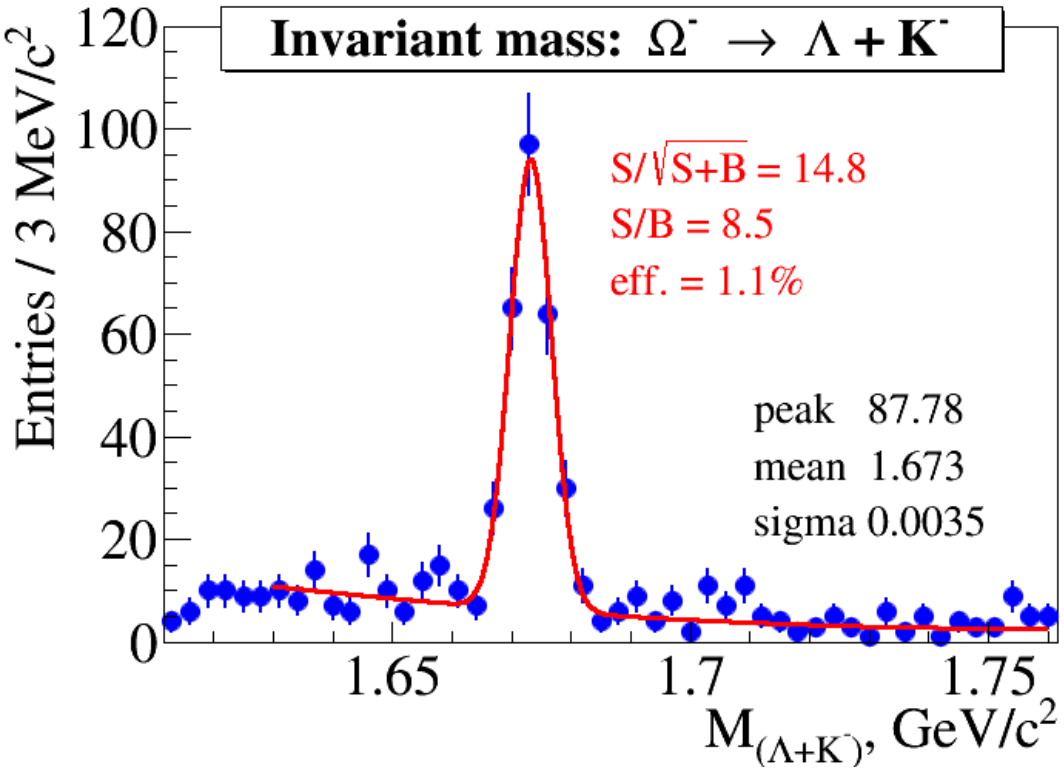
UrQMD, Au+Au @ 9A GeV, central (0-3 fm), 40k events – 2 min. @ 6 kHz. PID in TPC & TOF





Invariant mass at max. significance: $\Omega^- \rightarrow \Lambda + K^-$

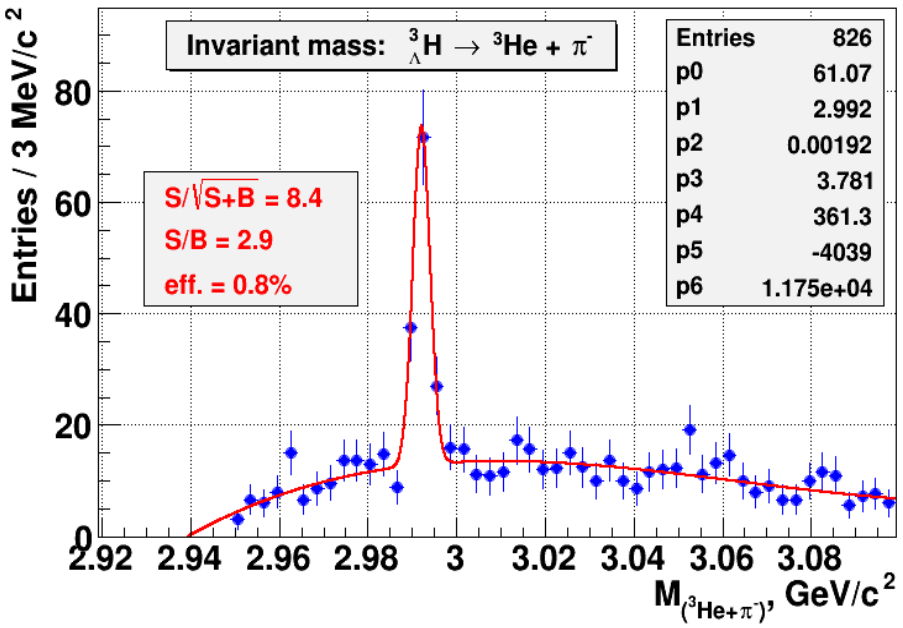
UrQMD, Au+Au @ 9A GeV, central (0-3 fm), 300k events – 17 min. @ 6 kHz. PID in TPC & TOF

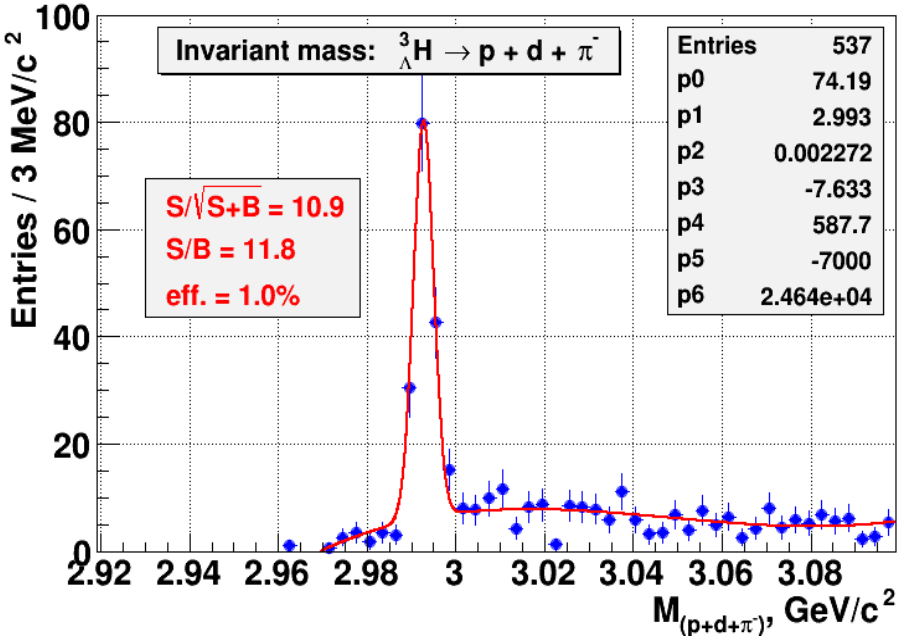


Invariant mass at max. significance:

$^{3}_{\Lambda}H \rightarrow {}^{3}He+\pi^{-}$ & $^{3}_{\Lambda}H \rightarrow p+d+\pi^{-}$

DCM-QGSM, Au+Au @ 5A GeV, central (0-3 fm), 500k events - 30 minutes @6 kHz. PID in TPC & TOF





Expected yield of $^{3}_{\Lambda}H$ for MPD (10 weeks) @ 5A GeV: **$9.1*10^5$**

Summary

- MPD start version will provide a good opportunity for a study of the strangeness production at NICA (mass resolution 2-3 MeV/c^2 and high enough yields).
- Work is ongoing on the reconstruction of more rare strange probes (Ω^+ hyperons, double-Λ hypernuclei).
- Effects of increased detector acceptance (higher η-coverage, detector upgrade) as well as more realistic detector response simulation are under evaluation.

Thank you for your attention!