A Monte Carlo Study of Hypernuclei production at NICA/MPD

M.Ilieva – *JINR, Dubna, Russia,*
Plovdiv University "P. Hilendarski"
Thesis Advisor: *A. Zinchenko – JINR, Dubna, Russia*

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Outline

❖ Motivation

❖ Analysis details

❖ Event reconstruction and detector preformance

❖ Model predictions

❖ Study of hypernuclei production

$$^4_\Lambda He \rightarrow {}^3He + p + \pi^-$$

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

$$^4_\Lambda H \rightarrow {}^4He + \pi^-$$

❖ Summary

Physics motivation

❖ Understanding production mechanism of exotic objects.

❖ Enhanced production at heavy-Ion collisions.

❖ 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.

More information for discovery of Hypernuclei:
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Event generators and data sets

Generator: DCM-QGSM, Au+Au @ 5A GeV central (0-3 fm),5×10^5 and 6.1×10^7 evens

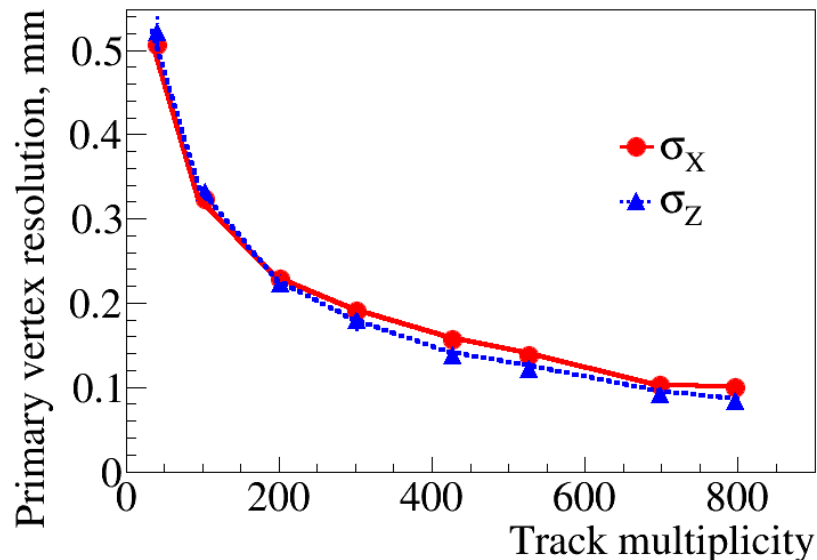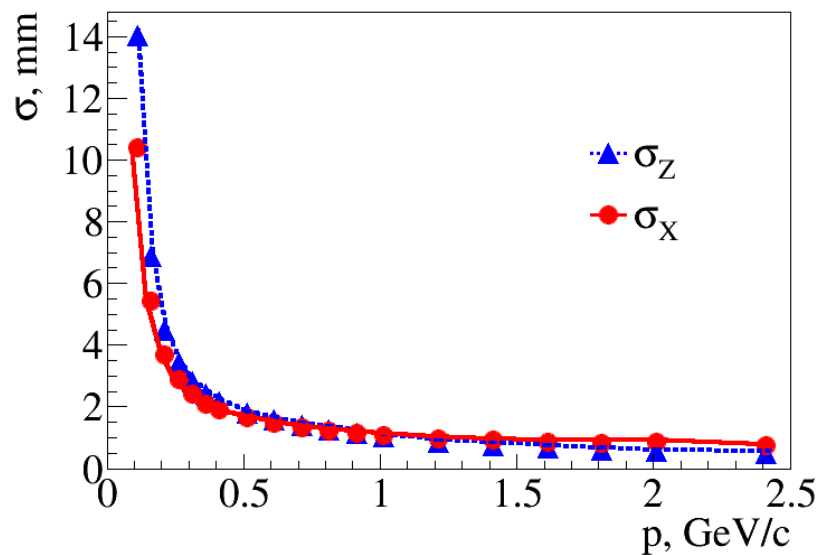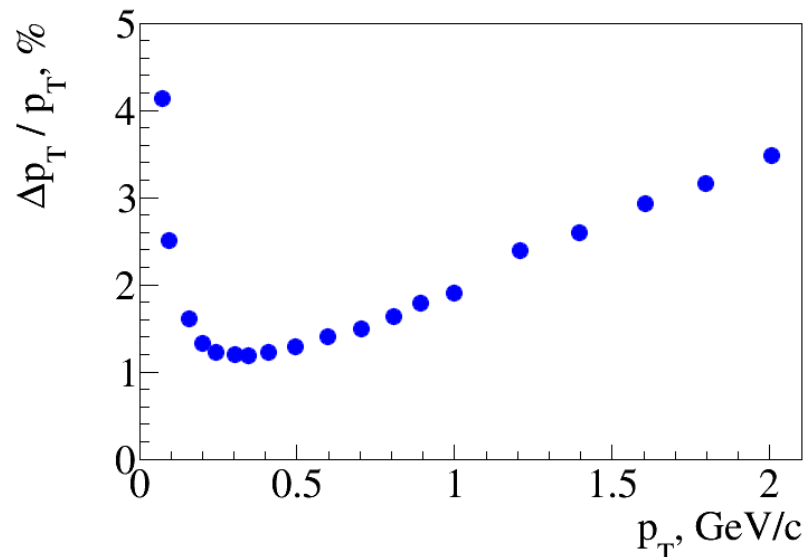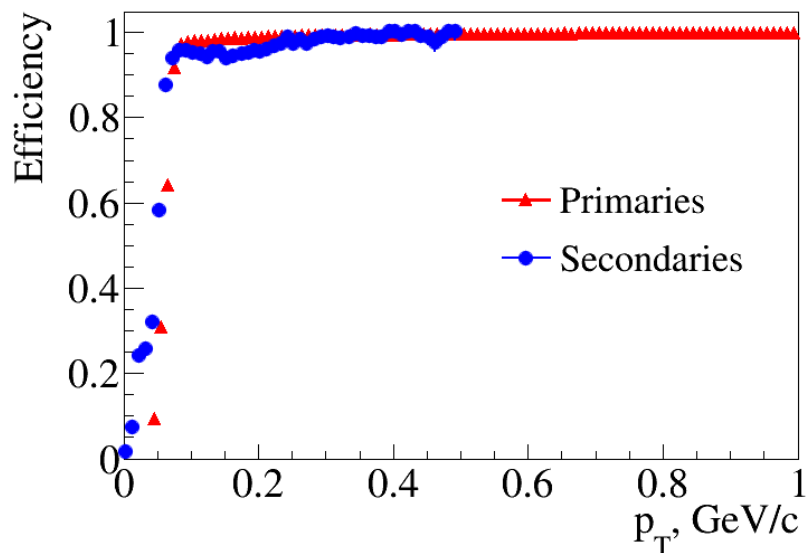❖ **Detectors:** start version of MPD (TOF, TPC, ECAL, FHCal,FD)

❖ Track acceptance criterion: $|\eta| < 1.3$, $N_{hits} \geq 15$

❖ Particle identification

❖ Maximization of significance
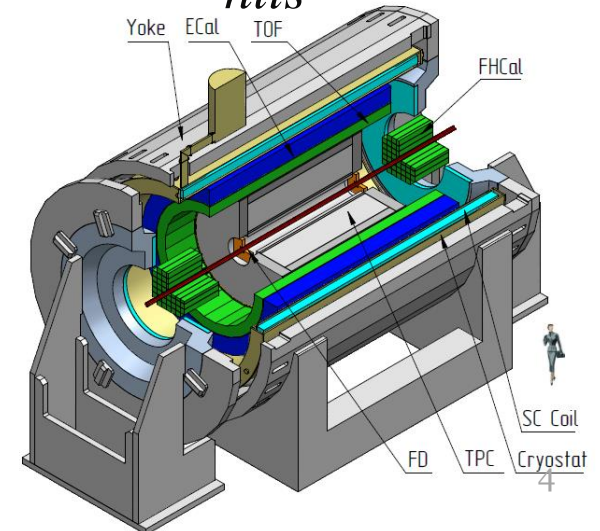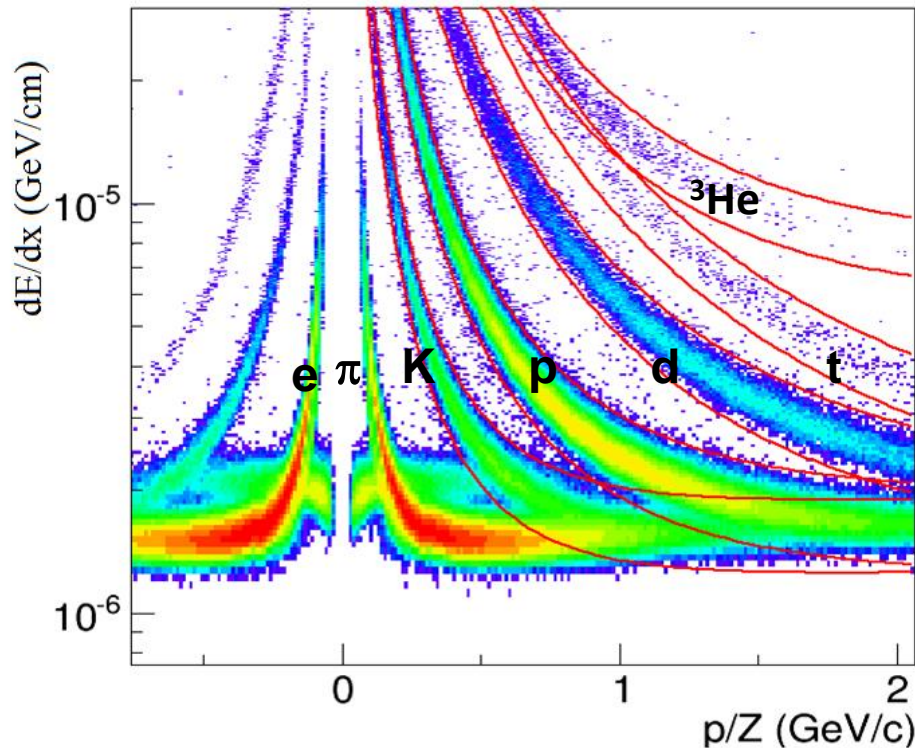
Track Reconstruction and Detector Performance

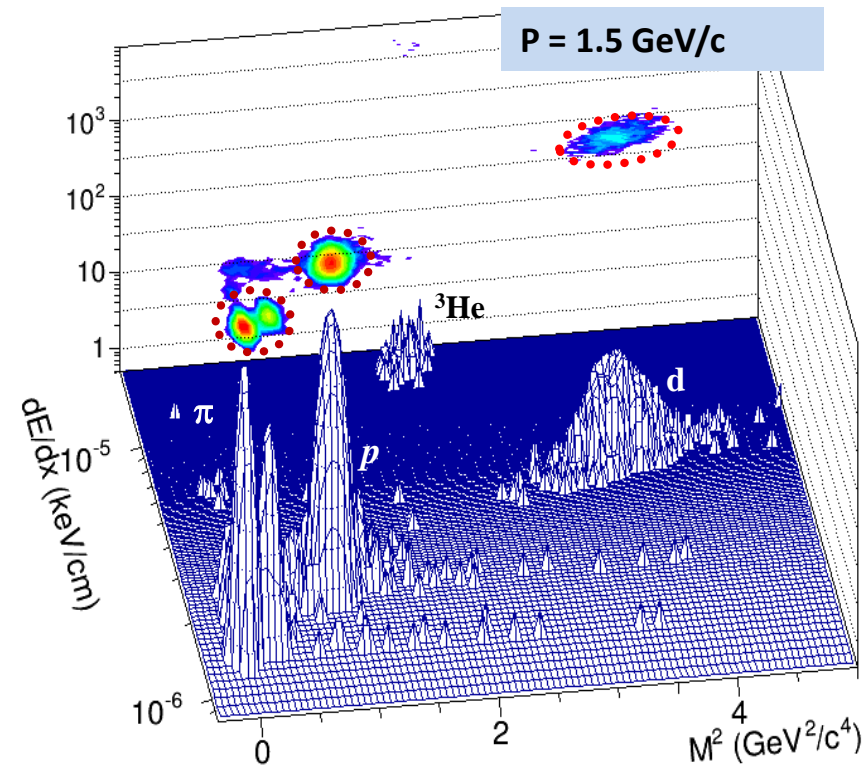# MPD Particle Identification (PID)

PID is achieved by energy loss (TPC) and time-of-flight (TOF) measurements

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

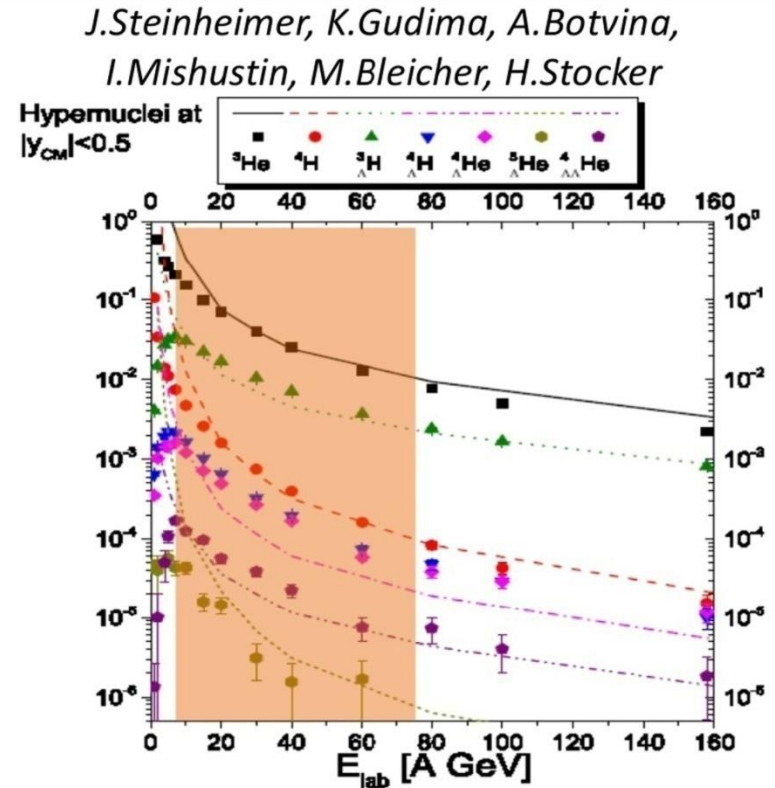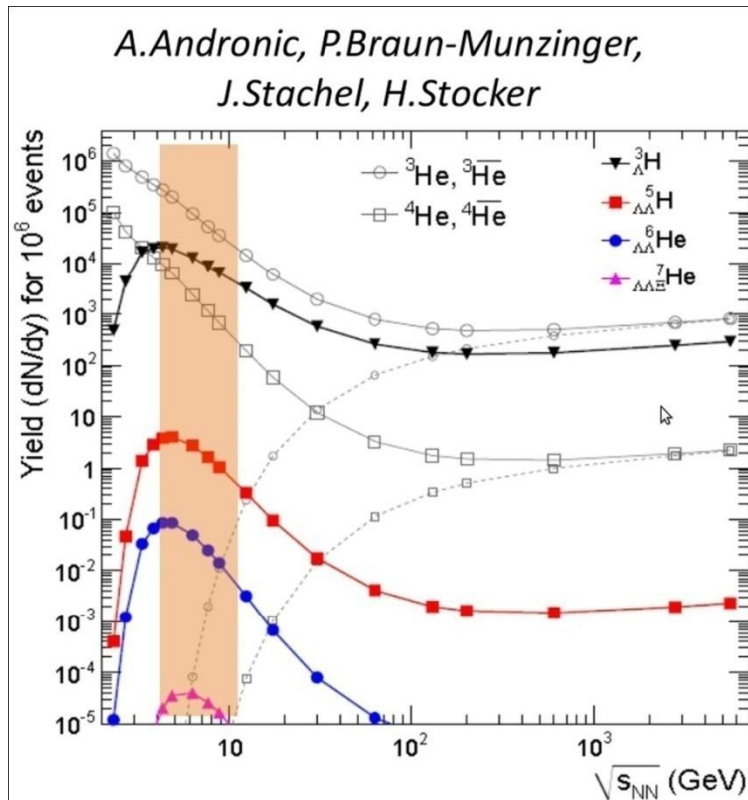$$m^2 = p^2\left(\frac{c^2 T^2}{L^2} - 1\right)$$

π/K separation up to 1.5 Gev/c

π/p separation up to 3 GeV/c

Model predictions

## Statistical hadronization model

DCM-QGSM

- ❖ **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 hypernuclei**

Maximization of significance

1. Significance is defined as $S/\sqrt{(S+B)}$

2. Set of 6-8 cuts, for hypernuclei selection: χ^2_π (dca$_\pi$), χ^2_p (dca$_2$), χ^2_{3He} (dca$_1$), dca$_M$, dca$_{VM}$, path, angle between p and r of Y.

3. Variation of all 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 .
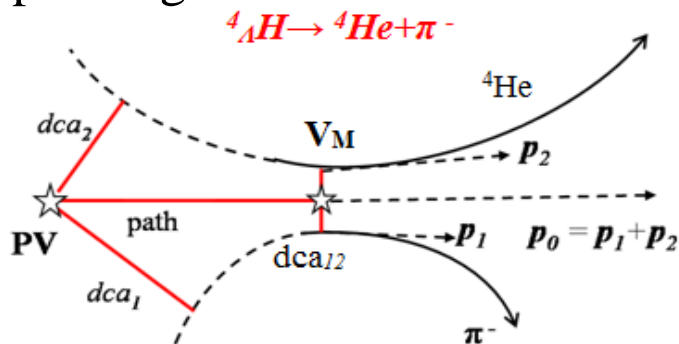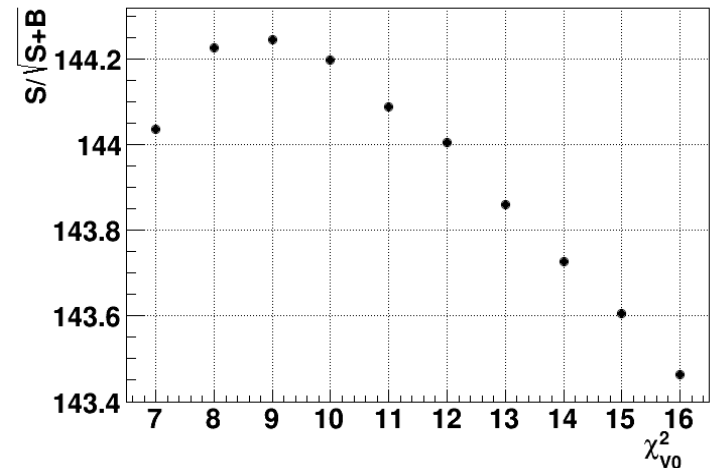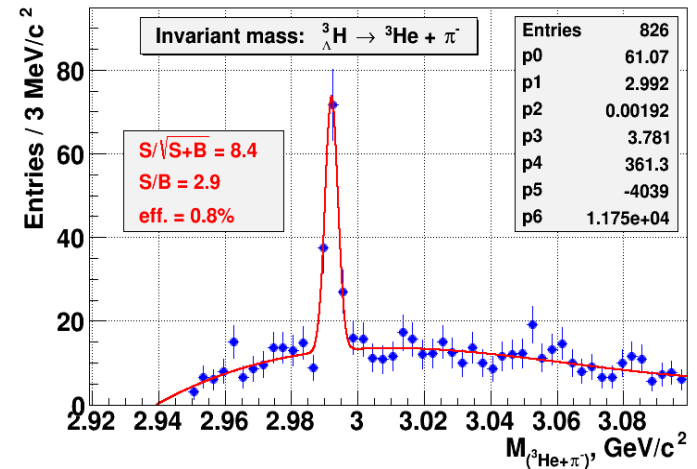
Invariant mass at max. significance:

$$^{4}_{\Lambda}He \rightarrow {}^{3}He + p + \pi^{-} \quad \& \quad {}^{4}_{\Lambda}H \rightarrow {}^{4}He + \pi^{-}$$

DCM-QGSM, Au+Au @ 5A GeV, central (0-3 fm), 6.1×10^{7} events ~61 hours @ 6 kHz.
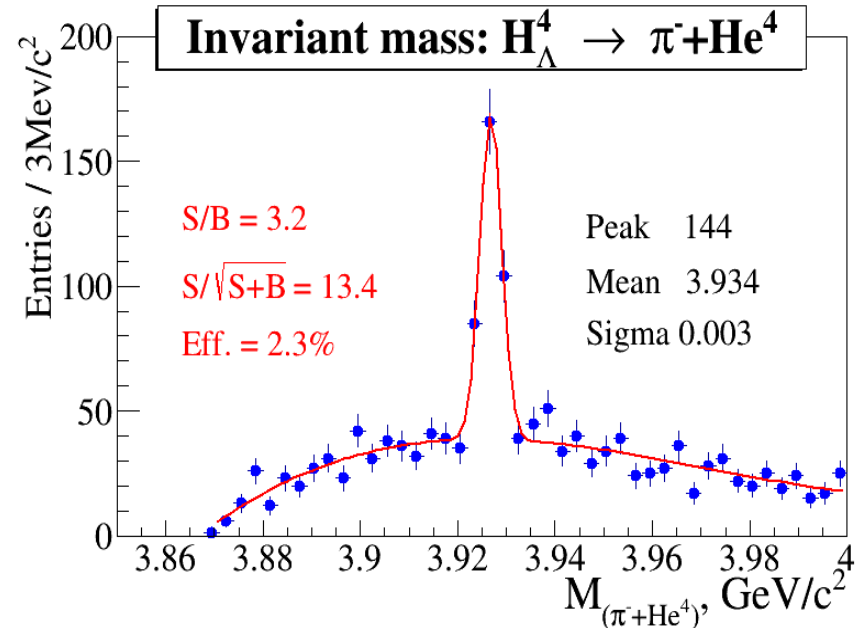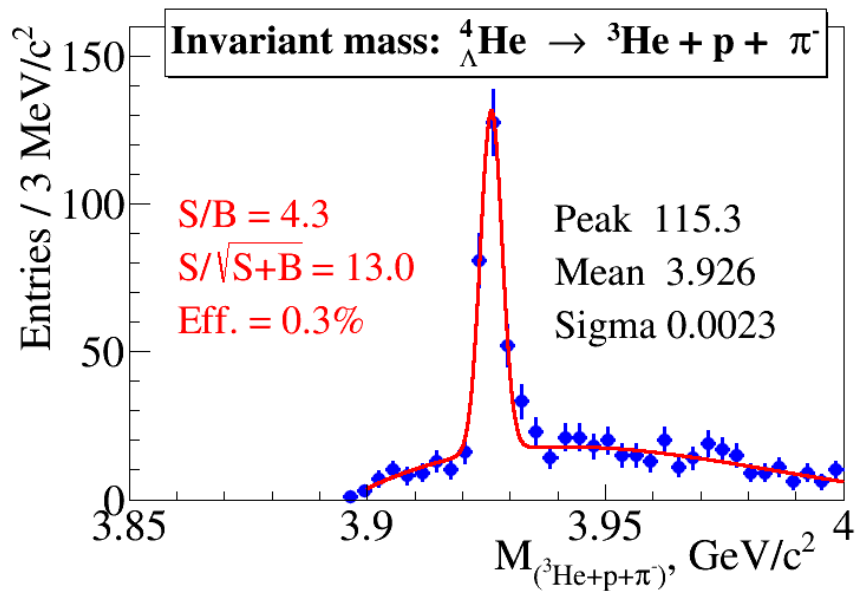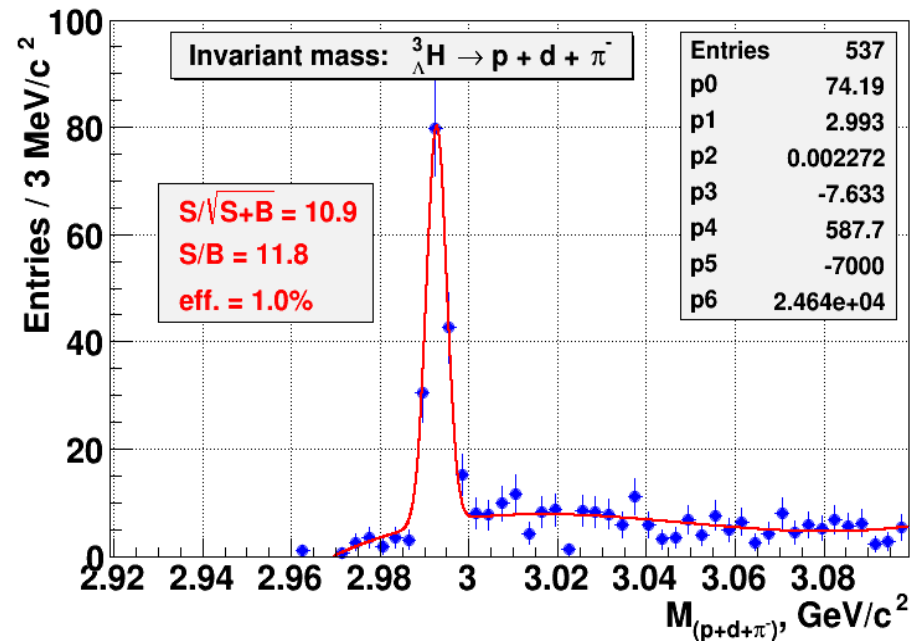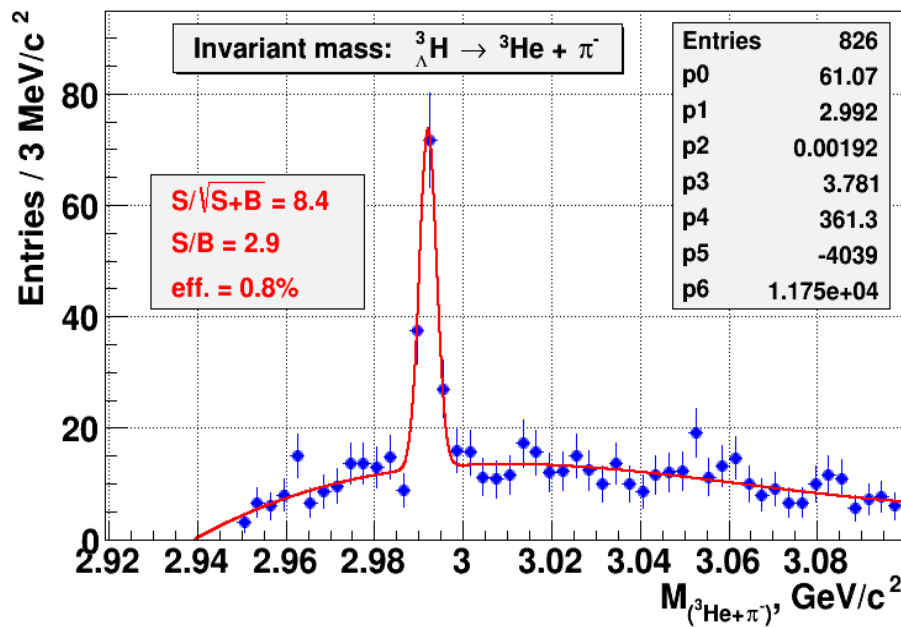

Expected yield of $^{4}_{\Lambda}He$: for MPD (10 weeks) @ 5A GeV: **$1.4*10^{5}$**

Expected yield of $^{4}_{\Lambda}H$: for MPD (10 weeks) @ 5A GeV: **$1.9*10^{5}$**

Invariant mass at max. significance:

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

DCM-QGSM, Au+Au @ 5A GeV, central (0-3 fm), 5x10^5 events - 30 minutes @6 kHz. PID in TPC & TOF

Expected yield of $^3_\Lambda H$: for NICA (10 weeks) @ 5A GeV: **8.1*10^5**

Efficiency vs detector acceptance cut

Factor	Eff,% $^3_\Lambda H$ 2-prong	Eff,% $^3_\Lambda H$ 3-prong	Eff,% $^4_\Lambda H$	Eff, % $^4_\Lambda He$
Branching ratio	24.6	36.4	75.0	32.0
$\|\eta\| < 1.3$	14.9	19.8	48.9	28.1
$\|\eta\| < 1.3,\ p_T > 0.05$ GeV/c	14.2	15.7	48.3	25.3
$\|\eta\| < 1.3,\ p_T > 0.1$ GeV/c	8.9	6.2	35	16.4
$\|\eta\| < 1.3,\ p_T > 0.2$ GeV/c	0.7	0.1	4.0	0.18
Reconstructed $\|\eta\| < 1.3$	7.9	8.3	27.7	9.4
Maximum significance	0.8	1.0	2.3	0.3

Summary

❖ MPD start version will provide a good opportunity for a study of the hypernuclei production at NICA.

❖ Procedures for reconstruction of different species hypernuclei have been developed.

❖ Mass resolution of 3 MeV/c^2 has been achieved.

Thank you for your attention!