Prospects for a study of strangeness and hypernuclei production at NICA/MPD

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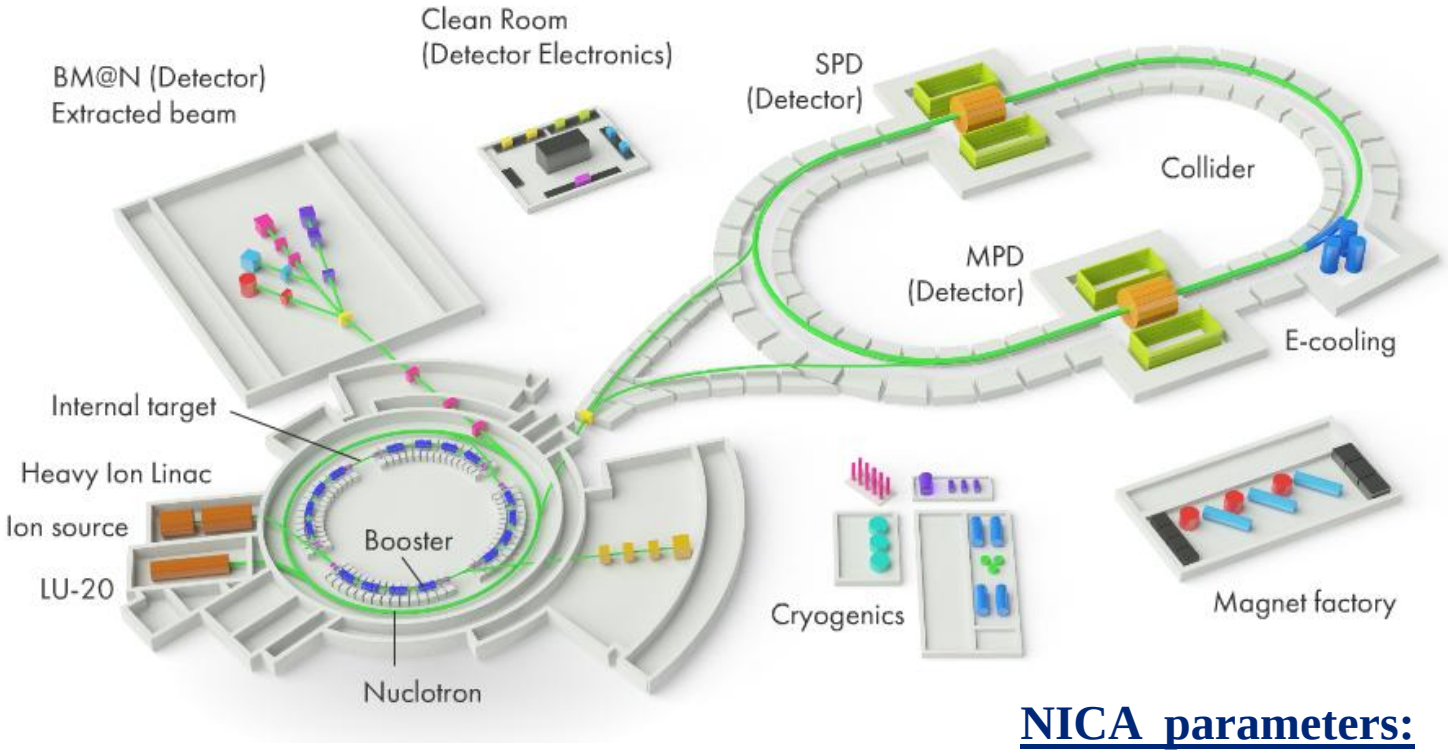
ICPPA-2018, 22-26 October 2018,
Moscow, Russia

Outline

- MPD/NICA project
- MPD performance:
  - Track reconstruction
  - Particle identification
- Motivation & Data set
- Hyperon reconstruction
- Hypernuclei reconstruction

NICA complex



- New flagship project at JINR (Dubna)
- Based on the technological development of the Nuclotron facility
- Optimal usage of the existing infrastructure
- Modern facility incorporating new technological concepts

NICA parameters:

Beams : p, d(h)..$^{197}Au^{79+}$
Collision energy : 4-11 GeV (nuclei)
Luminosity : 10^{27} $cm^{-2}s^{-1}$ (Au), 10^{32} (p)
2 Interaction points : MPD and SPD
Fixed target : 1-6A GeV beams

The MPD Apparatus

Magnet: 0.5 T superconductor

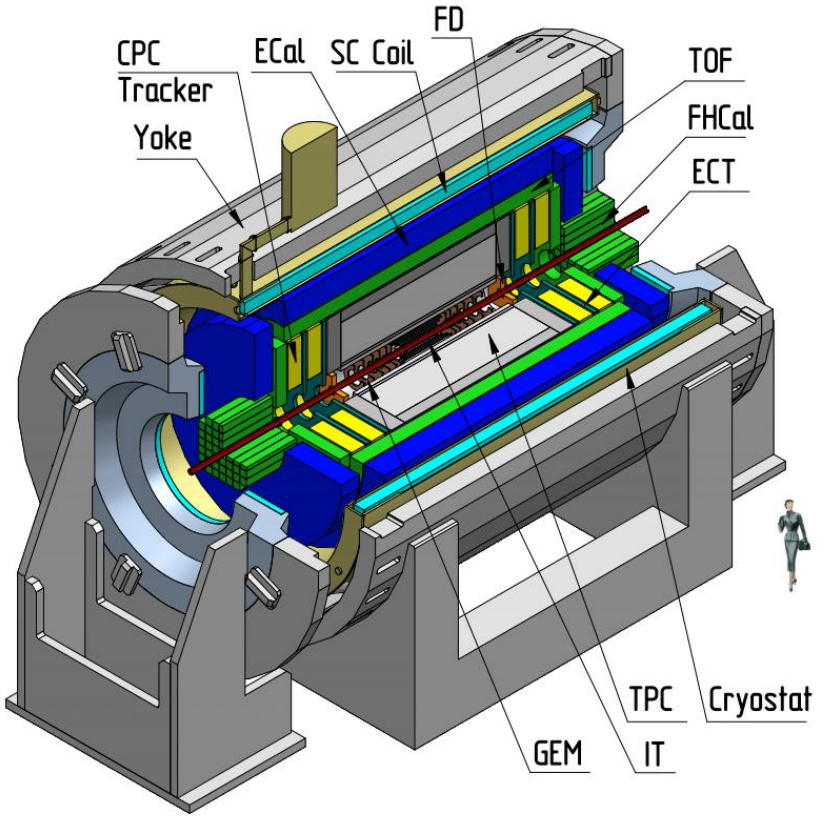
Tracking: TPC, ECT, IT

ParticleID: TOF, ECal, TPC

T_0, Triggering: FD

Centrality, Event plane: FHCal

Stage 1: TPC, Barrel TOF & ECal, FHCal, FD
Stage 2: IT+EndCaps (tracker, TOF, ECal)

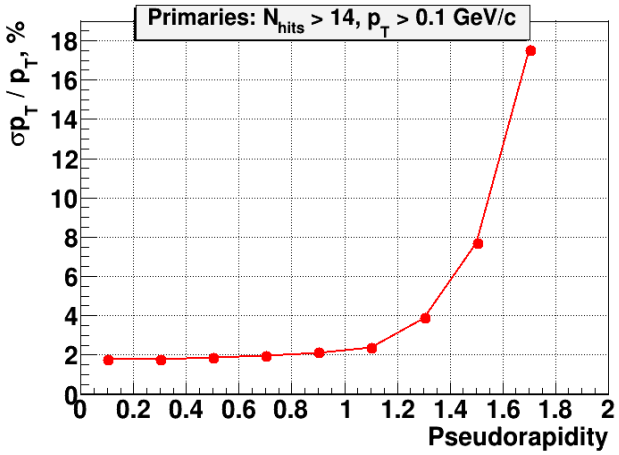


Requirements to the apparatus:

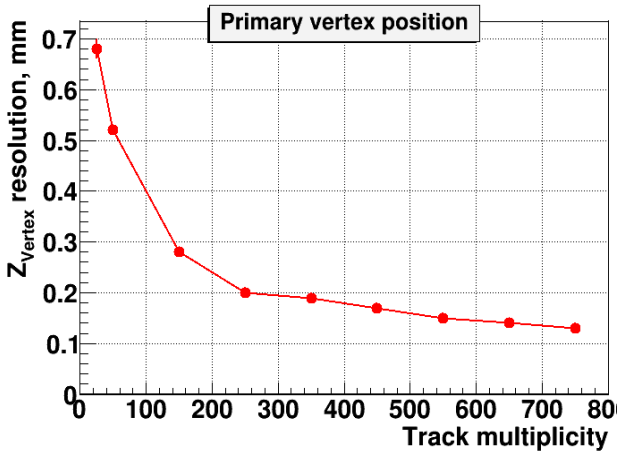
- Hermeticity, homogenous acceptance : 2π in azimuthal angle
- Highly efficient 3-D track reconstruction (|η|<2), high resolution vertexing
- Powerful PID: π/K up to 1.5 GeV/c, K/p up to 3 GeV/c, ECAL for γ, e
- Careful event characterization: impact parameter & event plane reconstruction
- Minimal dead time, event rate capability up to ~ 6 kHz

Track reconstruction in TPC

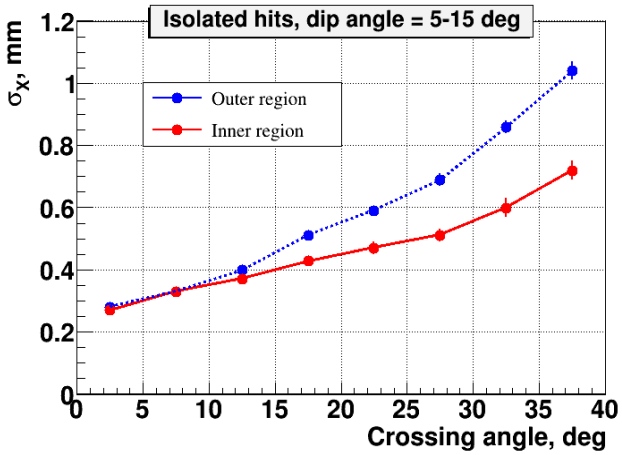
Momentum resolution

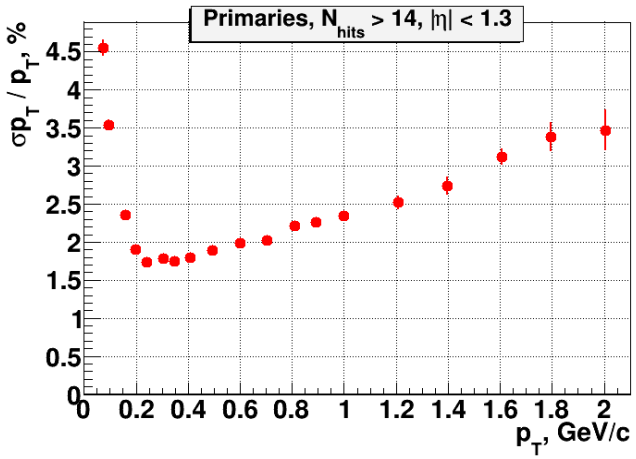


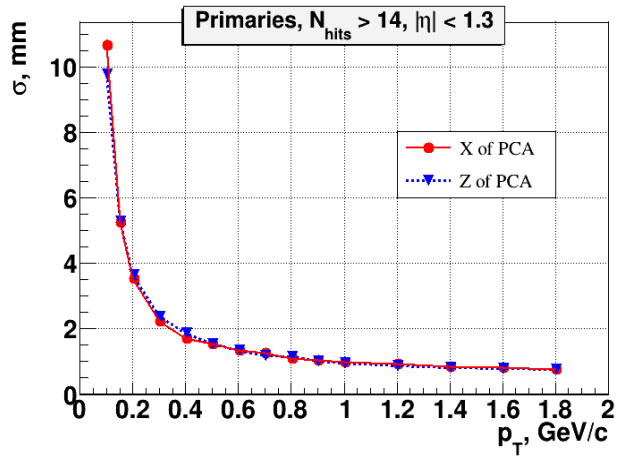
Track pointing accuracy

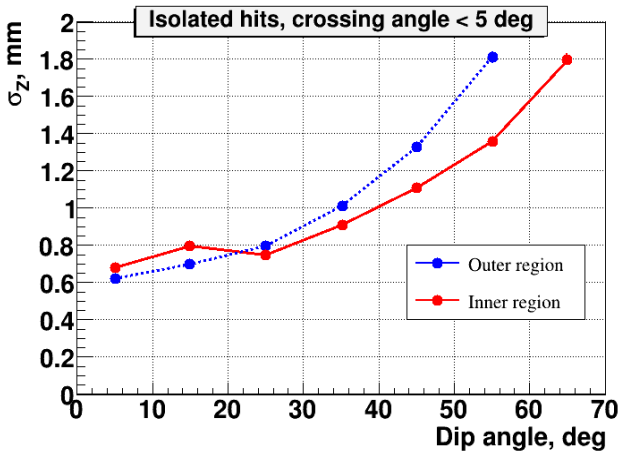


Coordinate resolution



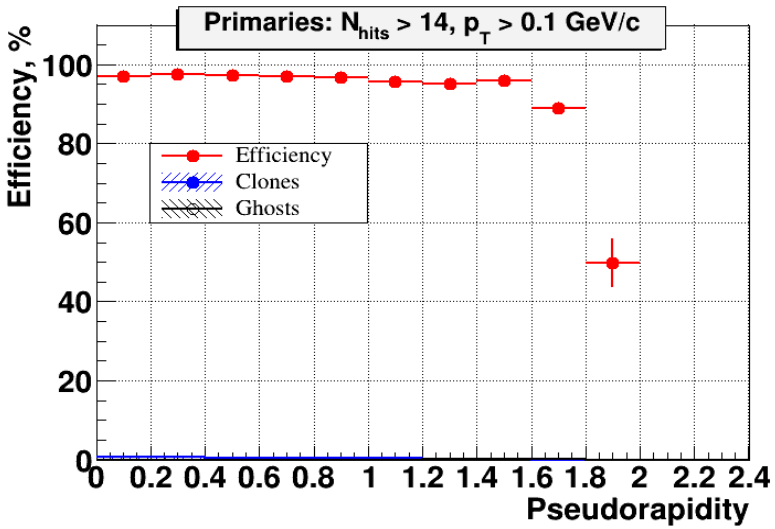


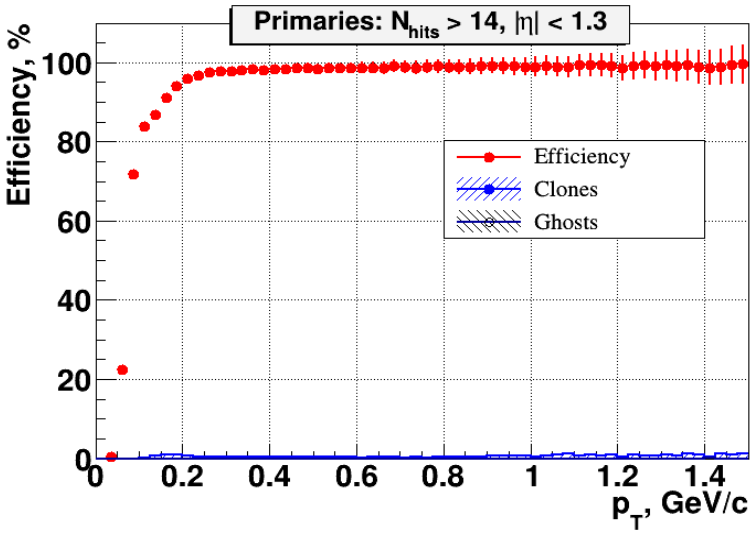


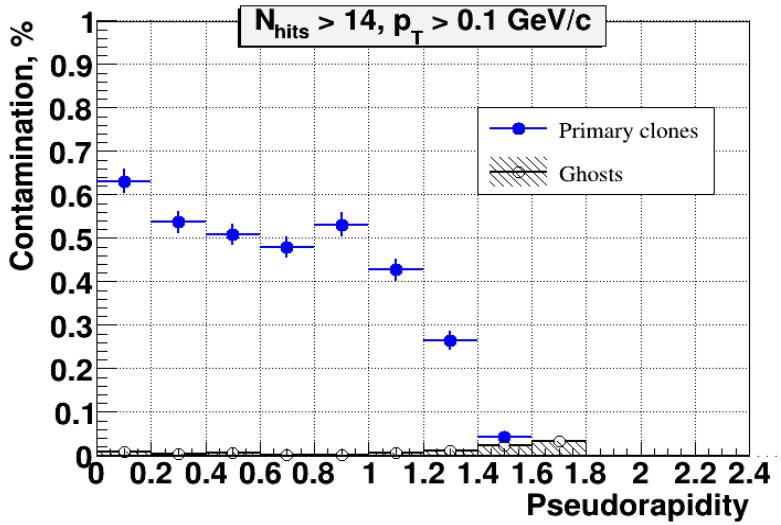


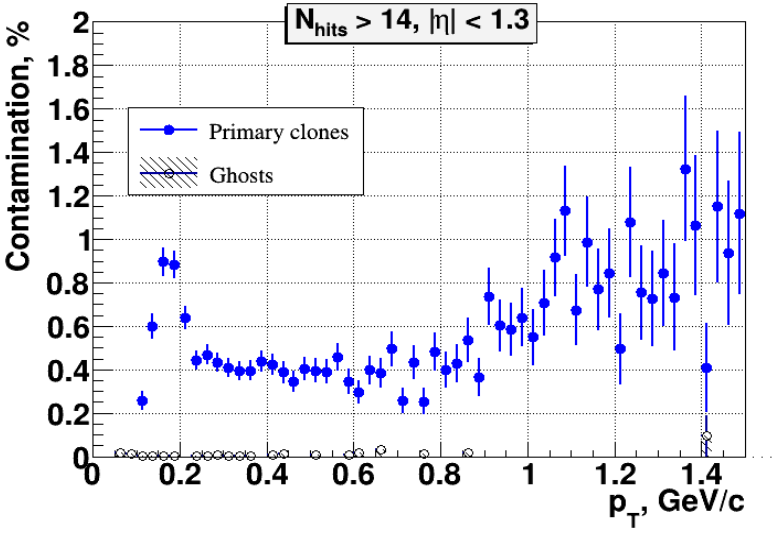
Track reconstruction efficiency

Primary tracks

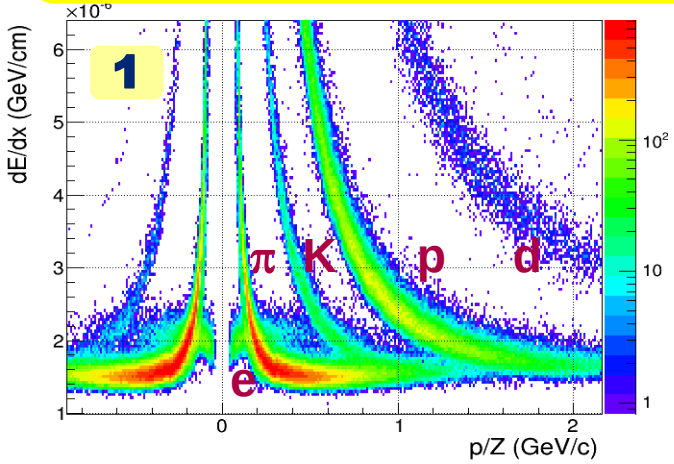


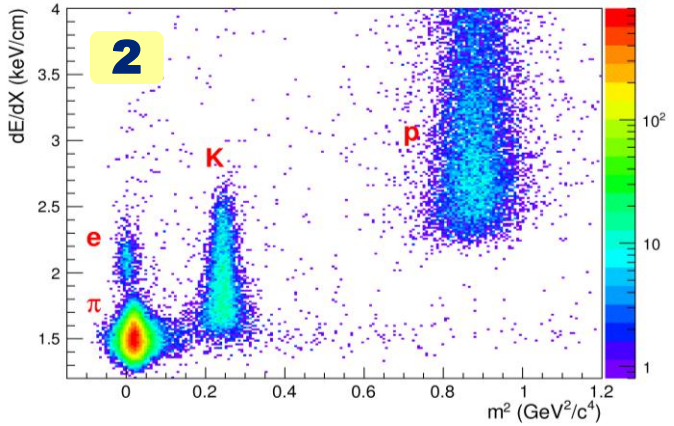






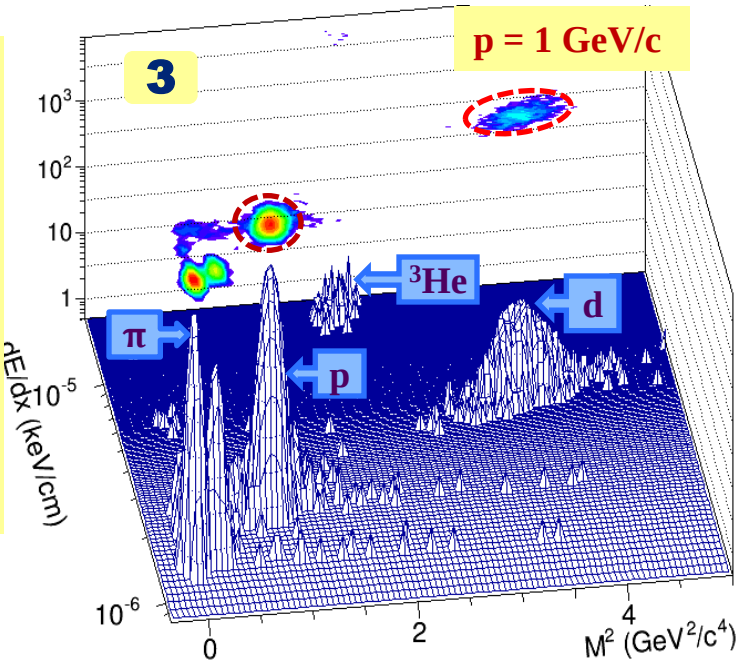
MPD Particle Identification (PID)





Requirements :

- Hadron (π, K, p) identification up to 3 GeV/c, midrapidity nuclei PID
- Electron PID with hadron suppression up to 10^5
- Secondary vertex reconstruction – hyperons & hypernuclei @ midrapidity



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

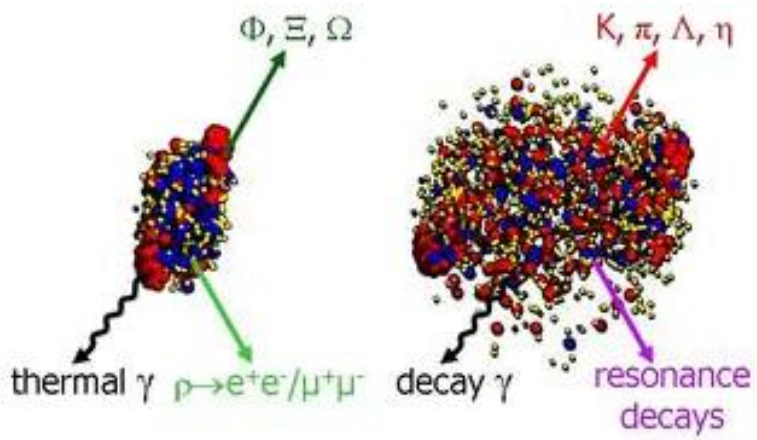
$$m^2 = p^2\left(\frac{c^2T^2}{L^2} - 1\right)$$

PID methods (in combination with measure of momentum in the B-field):

Fig.1: Energy loss (dE/dx) in the TPC gas
Fig.2: Combined dE/dx and TOF
Fig.3: Particle selection within ‘dE/dx vs m^2‘ space in momentum bins

Hyperons: Physics Motivation

- The study of hyperons helps to understand strong interactions and QGP.
- Hyperons (especially Λ) are produced in relatively large quantities and have very attractive experimental features (resonance structure and simple decay mode). They can serve as detector performance monitoring tools

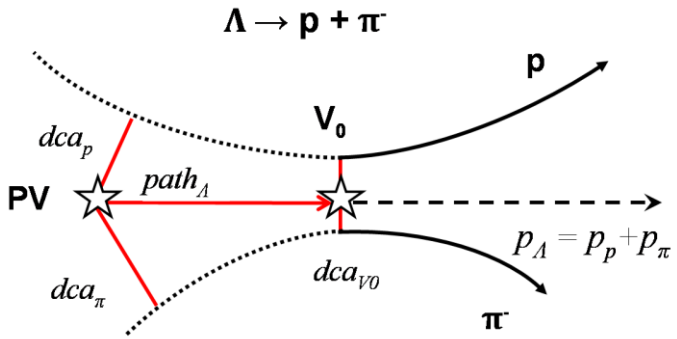


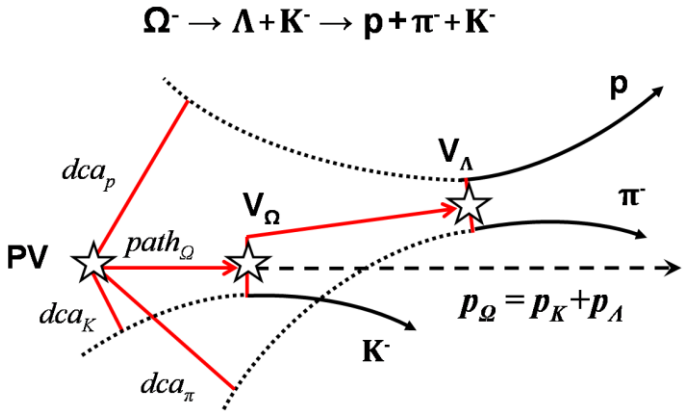
Messengers from the dense fireball: UrQMD

Data set & Analysis

- **Generator:** PHSD, Au+Au @ 11 GeV, minbias, 2M events
- **Detectors:** start version of MPD with up-to-date TPC & TOF
- **Track acceptance criterion:** $|\eta| < 1.3$, $N_{hits} \geq 10$
- Realistic track reconstruction (with clustering in TPC)
- Realistic particle identification in TPC & TOF

Analysis Method: Secondary Vertex Finding Technique

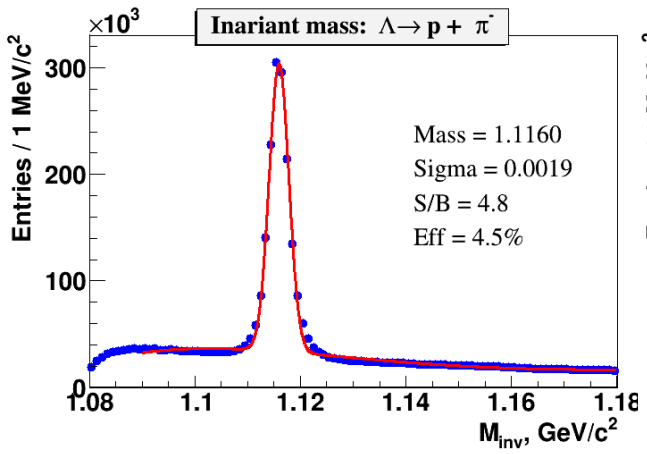


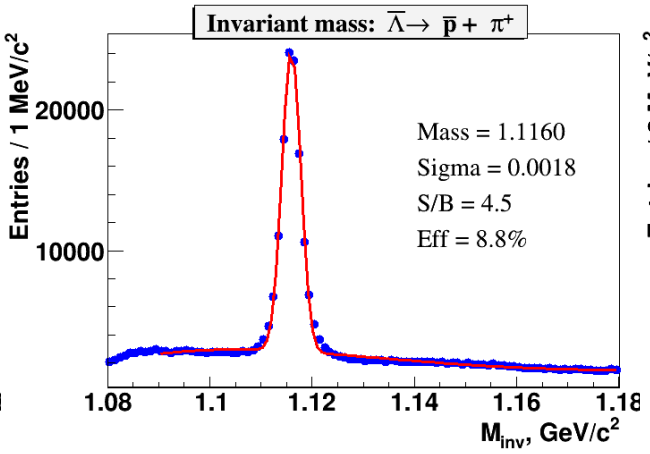


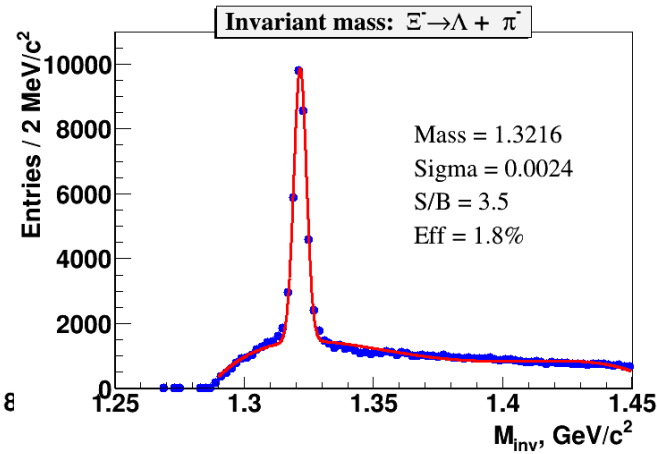
Event topology:

- PV – primary vertex
- V_0 – vertex of hyperon decay
- dca – distance of the closest approach
- path – decay length

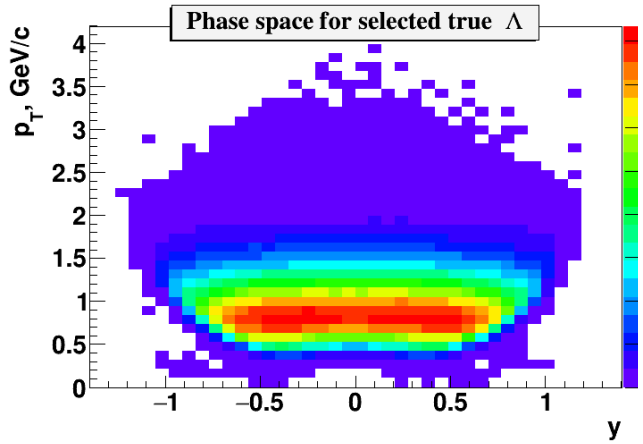
Hyperon reconstruction

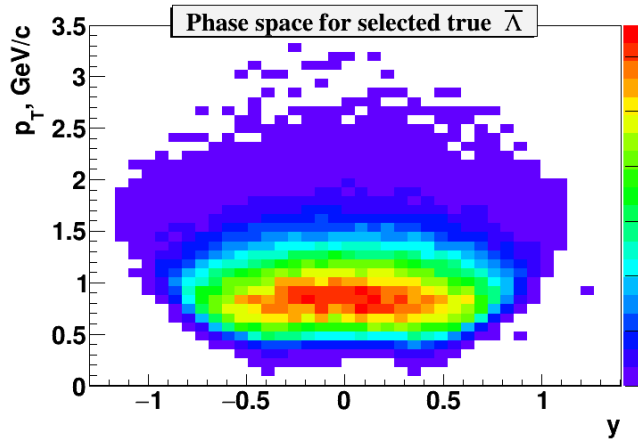


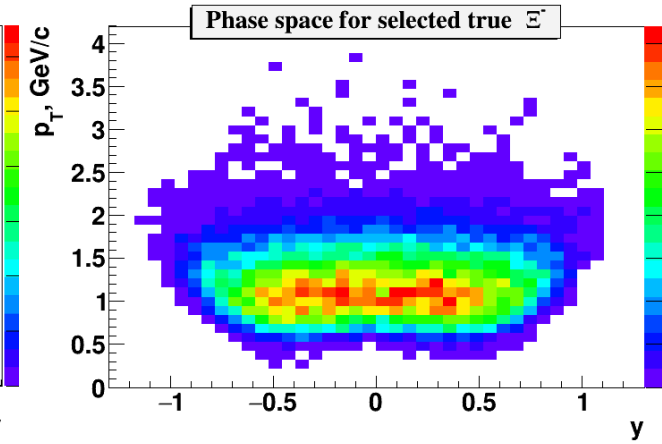




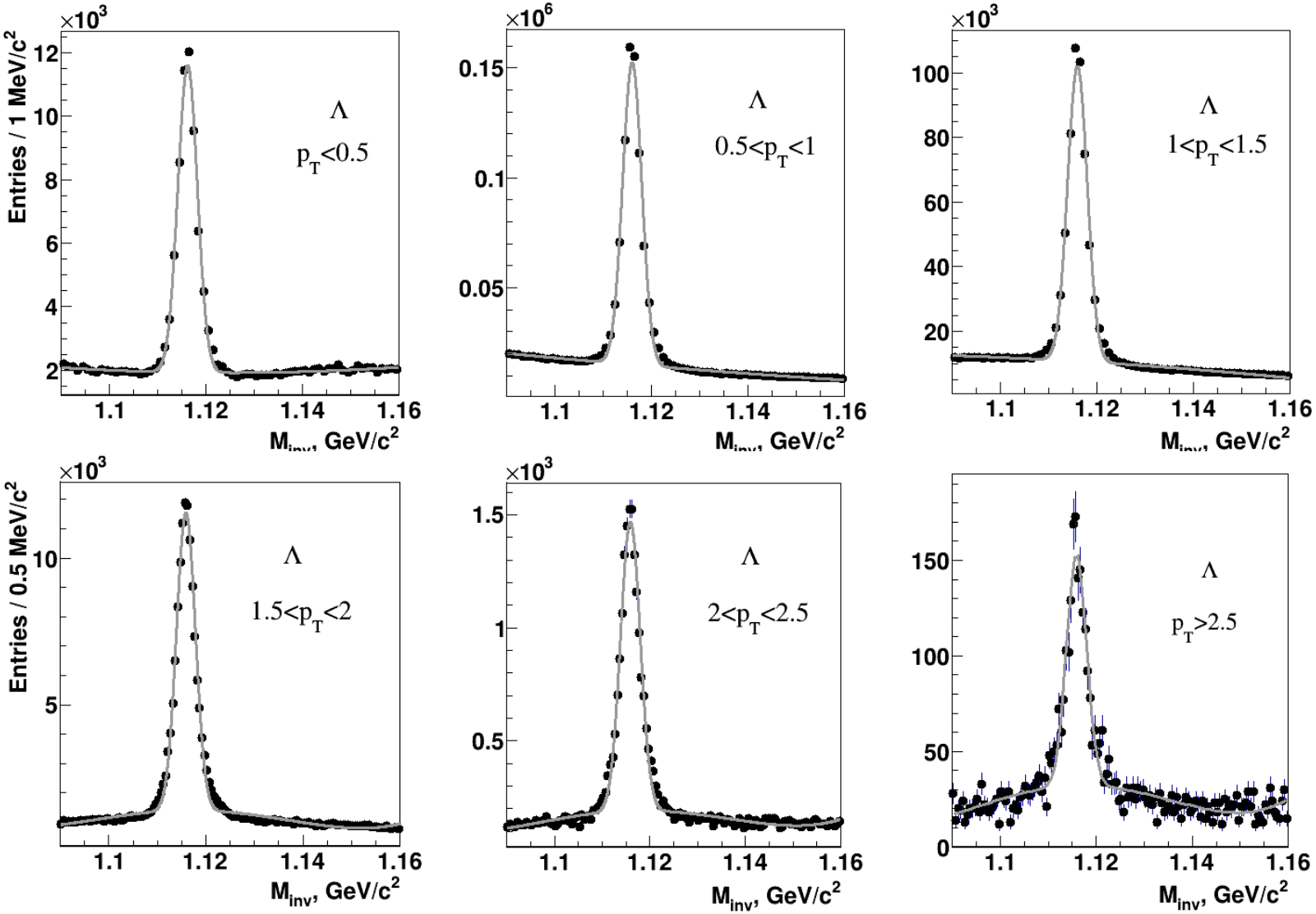
Phase space for reconstructed and selected true hyperons



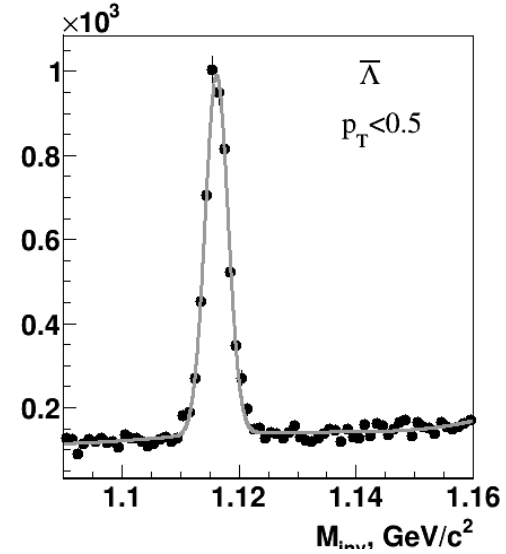


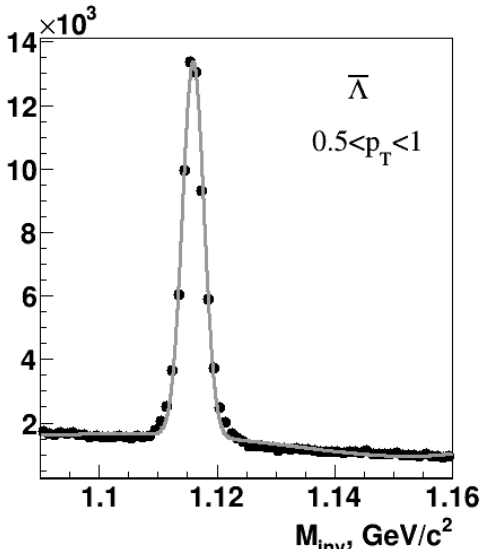


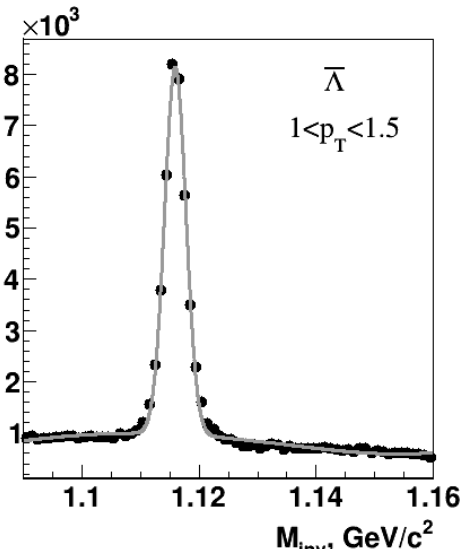
Λ reconstruction: p_T dependence

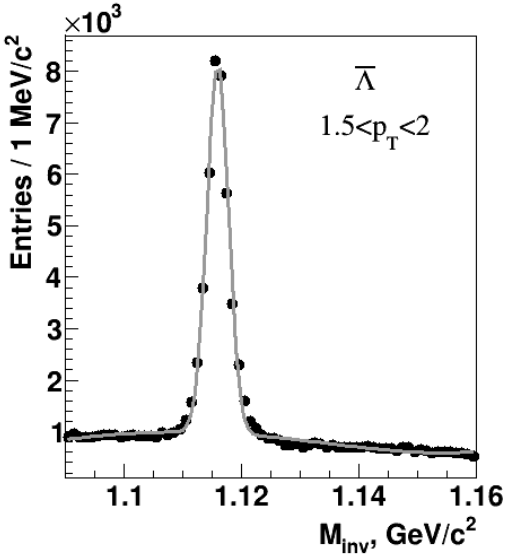


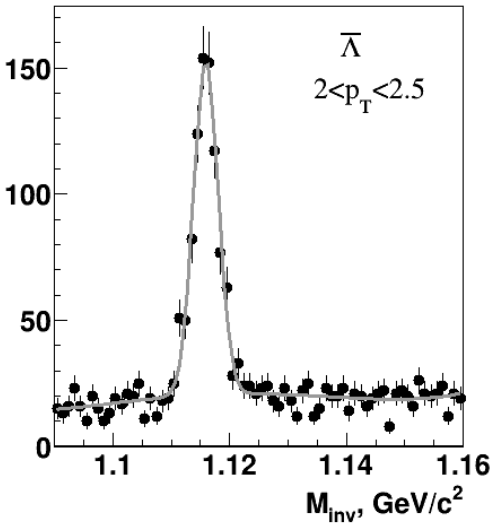
Λ_{bar} reconstruction: p_T dependence

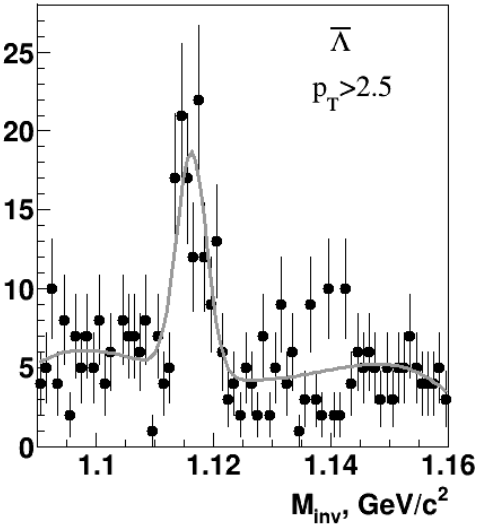




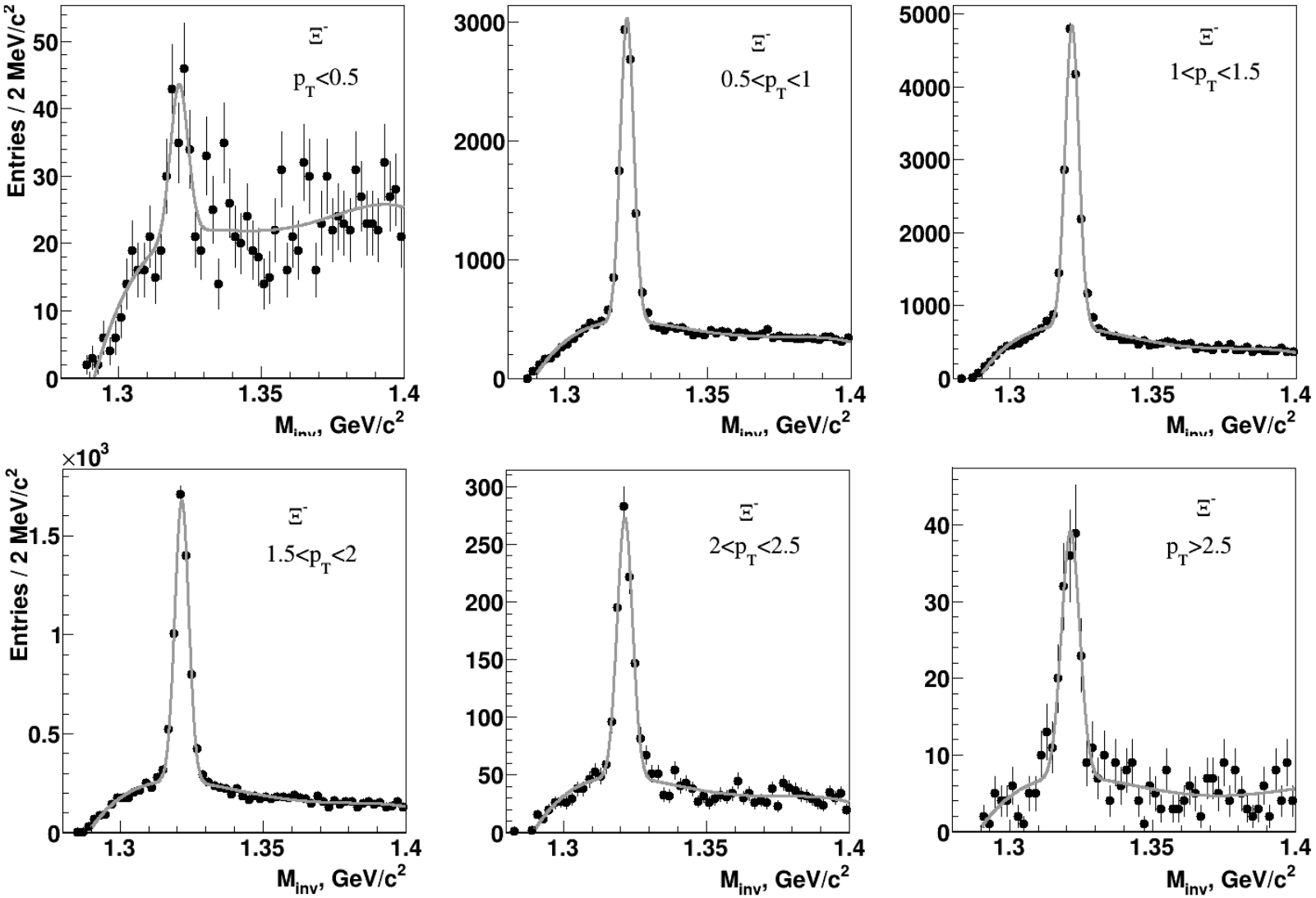




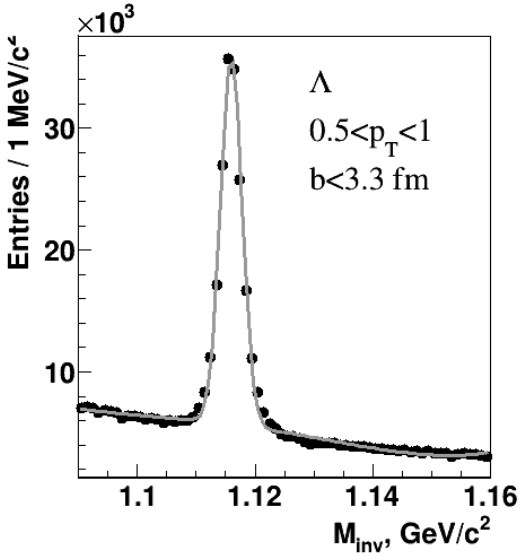


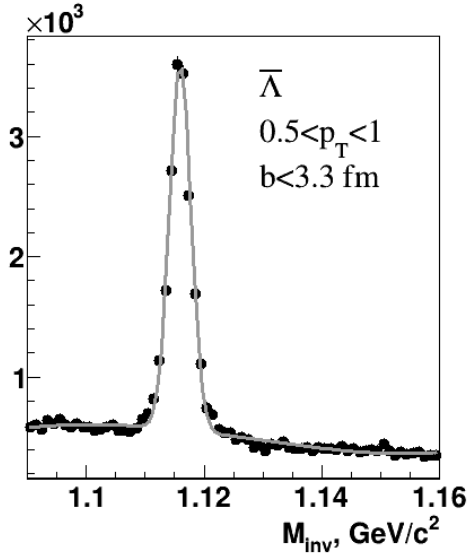


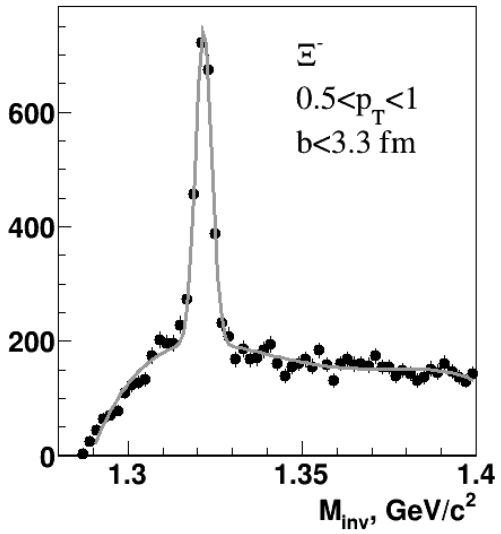
Ξ^- reconstruction: p_T dependence

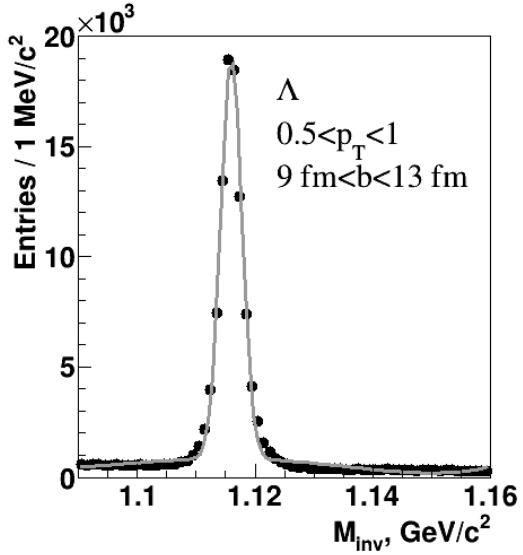


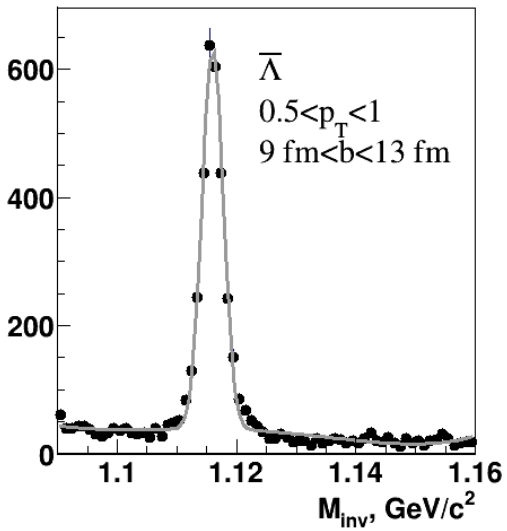
Hyperons @ different b

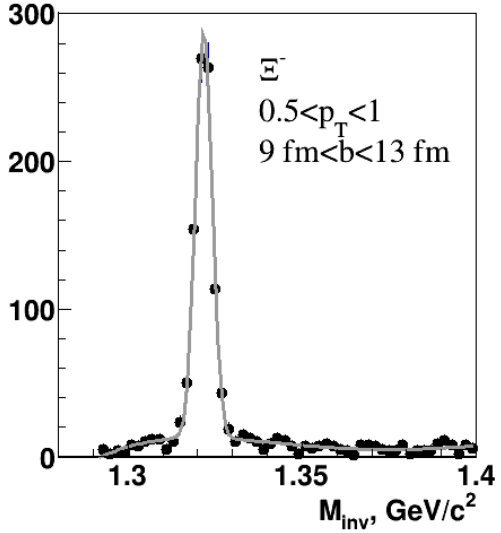




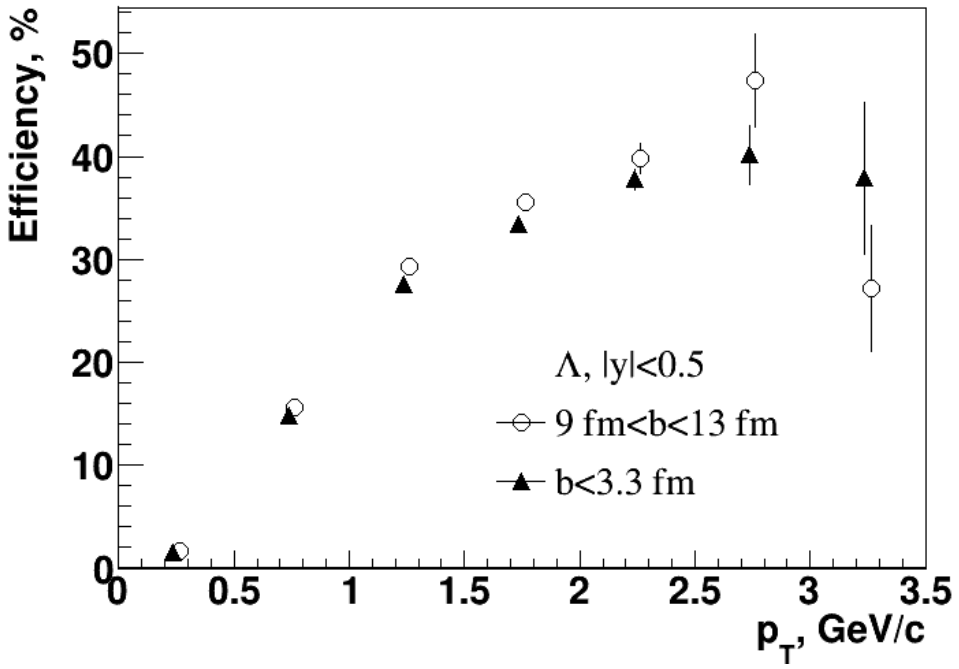






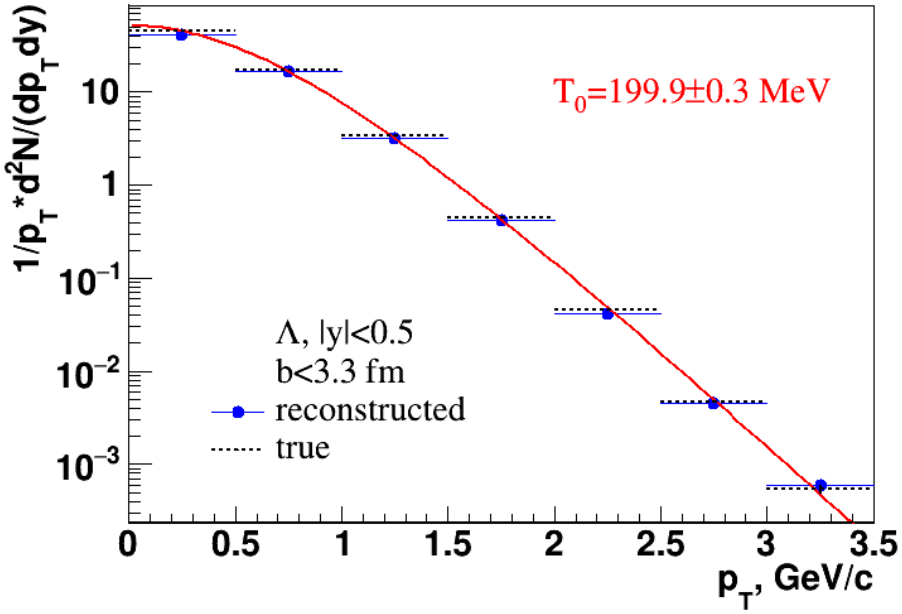


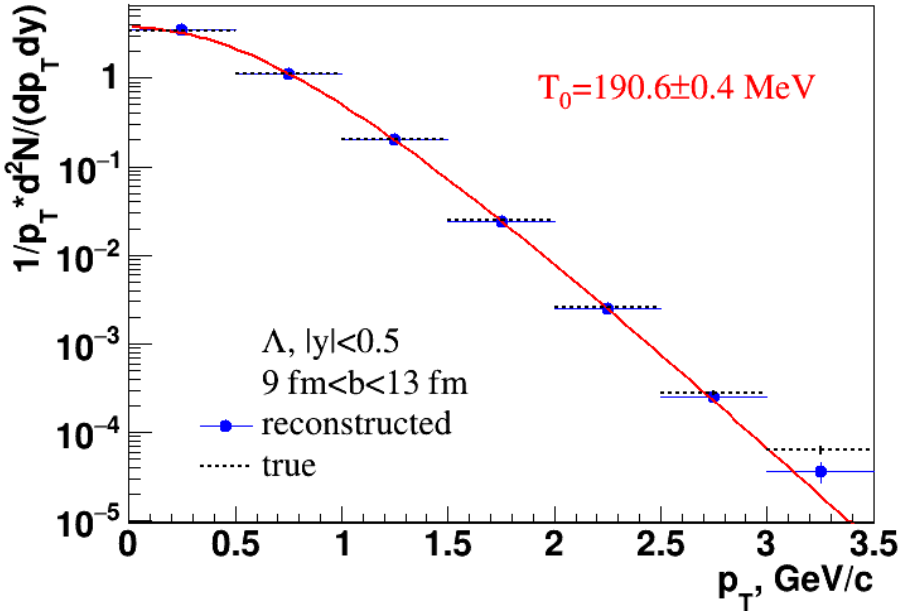
Efficiency of Λ reconstruction



Efficiency of true Λ in p_T&b bins for |y|<0.5: (reco & select Λ) / (all gen Λ)

p_T spectrum of Λ





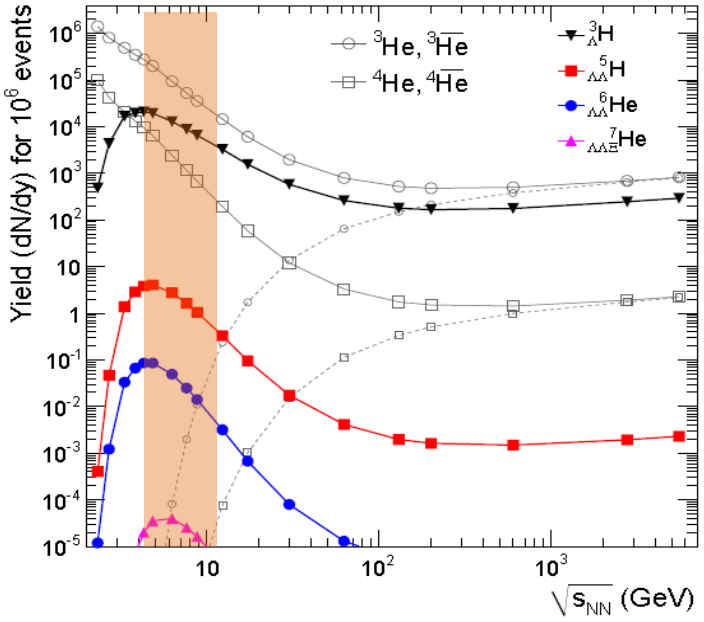
Reconstructed spectrum: fit of selected Λ in each bin (Gauss ± 3σ) / Eff.

Hypernuclei: Physics Motivation

- Precise information on Y-N interaction: nuclear EOS, astrophysics
- Hypernuclei ground, excited states and life times: critical assessments for QCD calculations and model predictions
- Production mechanism of bound states with hyperons: coalescence versus spectators-participants interactions, exotic states, dibaryons

To study hypernuclei, MPD detector must be able to detect and identify light nuclei in a wide rapidity range as well to have a good capability for precise secondary vertex reconstruction

Hypernuclei production enhanced at high baryon densities (NICA)



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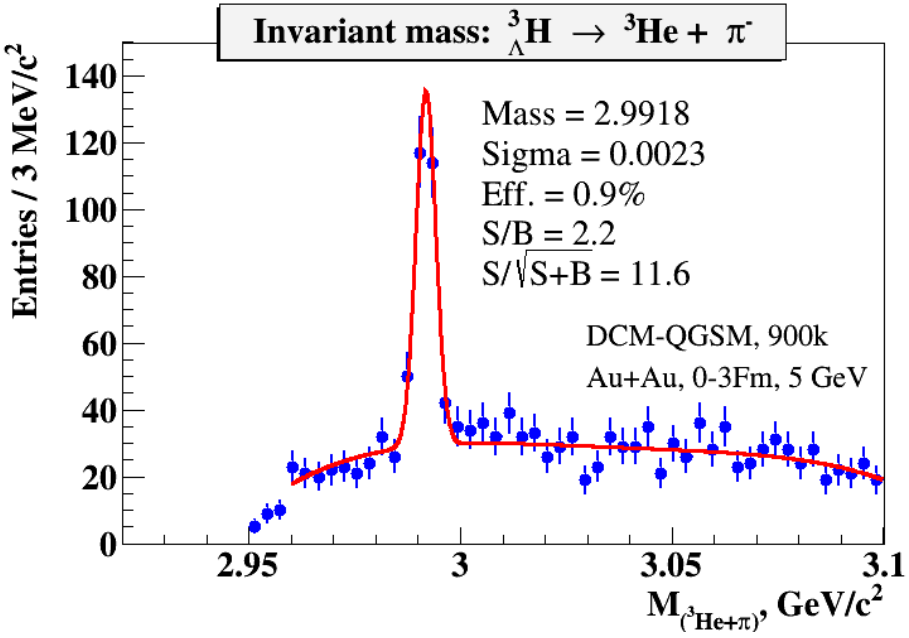
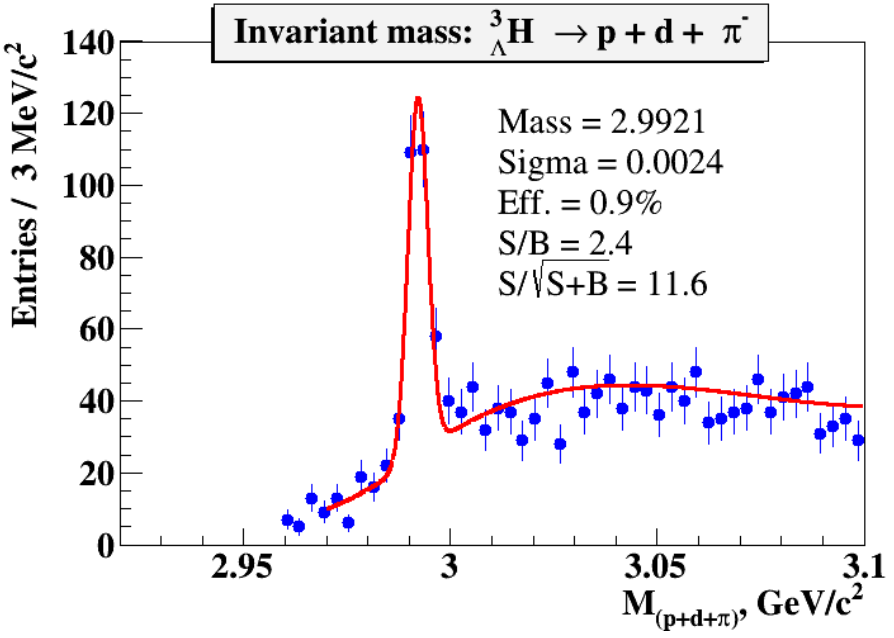
Particle	Yield/10 w (NICA)	
	8 GeV	11 GeV
$_\Lambda H^3$	$4.5 \cdot 10^3$	$1.6 \cdot 10^3$

Data set & $_{\Lambda}H^{3}$ reconstruction

- **Generator:** DCM-QGSM, Au+Au @ 5 GeV, central (0-3 fm), 900k events
- **Detectors:** start version of MPD with up-to-date TPC & TOF
- **Track acceptance criterion:** $|\eta| < 1.3$, $N_{hits} \geq 10$
- Realistic track reconstruction (with clustering in TPC)
- Realistic particle identification in TPC & TOF





Summary and plans

- The MPD detector offers a good opportunity for a study of the strangeness production in heavy-ion collisions at NICA
- The event reconstruction software was created and tested on Monte-Carlo simulated event samples
- We are in the process of developing and testing of analyses procedures and obtaining well-grounded physics performance numbers

Thank you for attention!