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Perspectives of strangeness study at NICA/MPD from realistic Monte Carlo simulation

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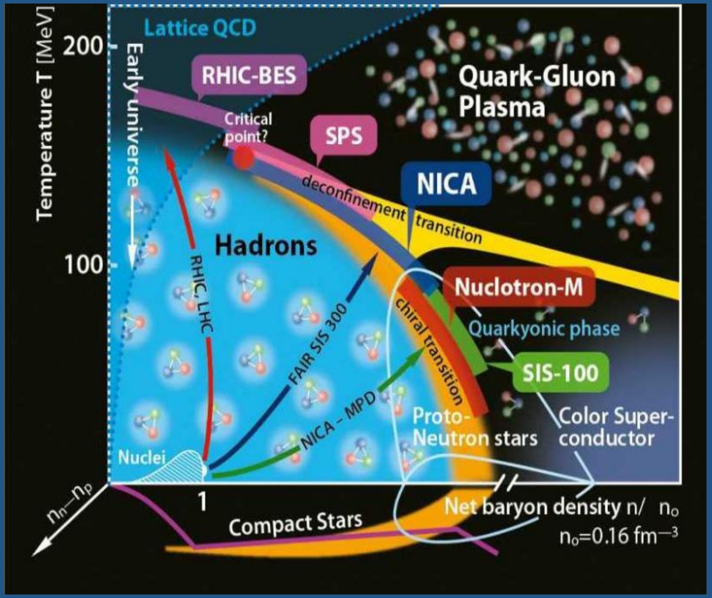
Outline

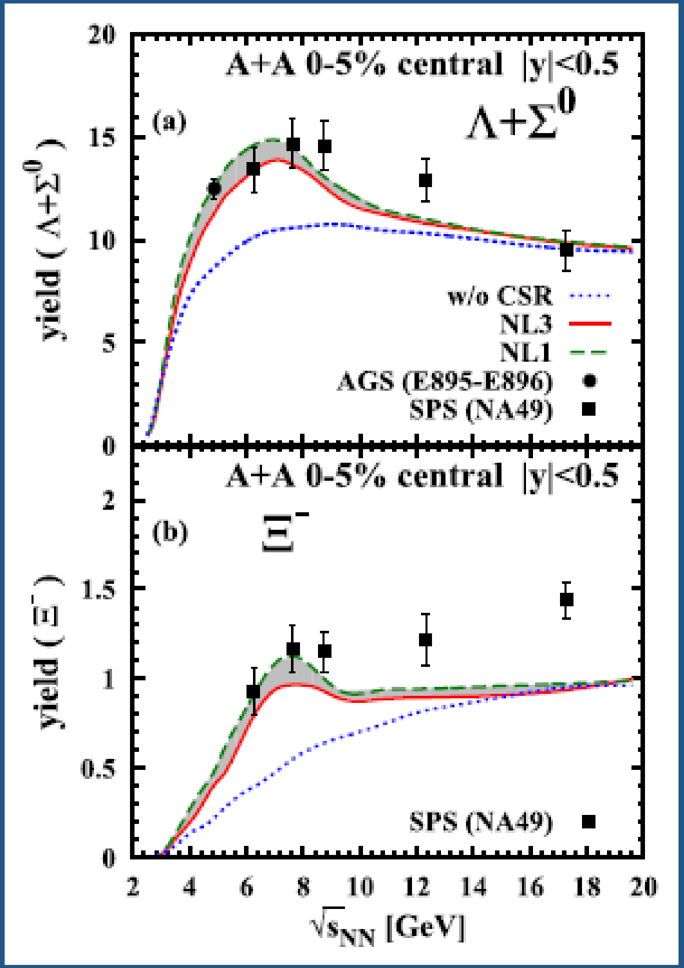
- MPD/NICA project: *niche, tasks and observables*
- NICA Complex: *parameters*
- MPD detector performance: *geometry, tracking, PID*
- Hyperon analysis: *signals, phase space, p_T -spectra*
- Summary

NICA niche for A+A collisions



QCD matter under extreme conditions
(NICA niche – high μ_B)

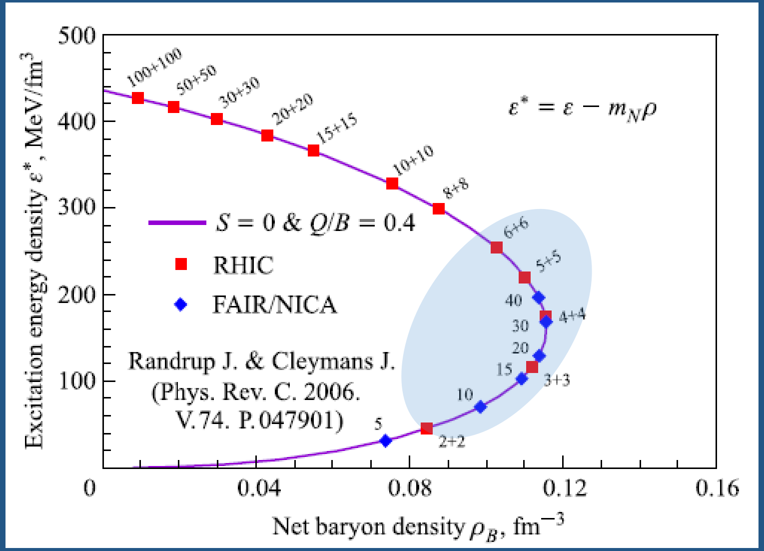
PRC 94, 044912 (2016)



✓ NICA (μB = [320-850] MeV) - highest net baryon density: essential to probe deconfinement and CSR

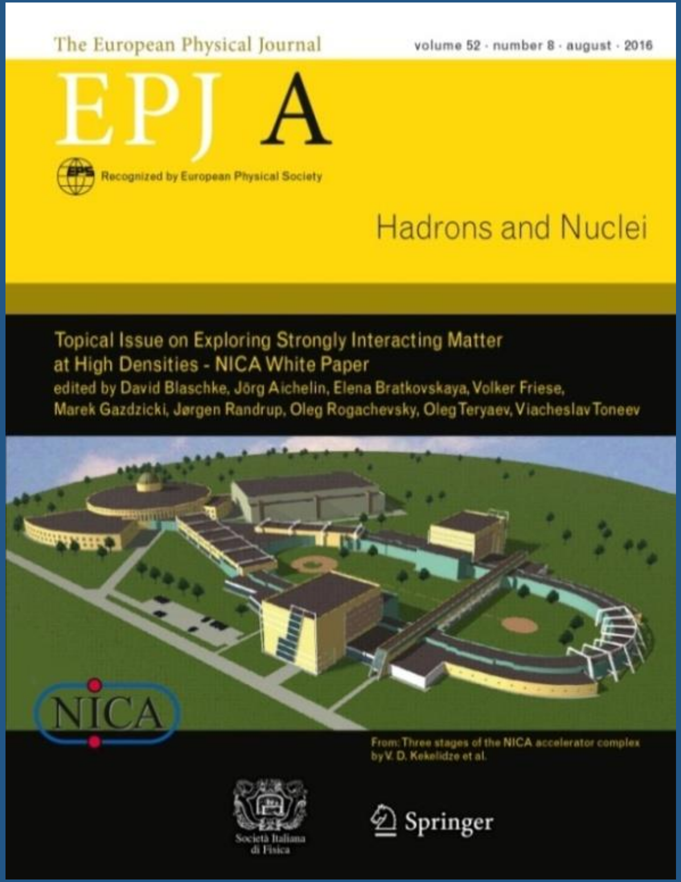
✓ Non-trivial energy dependence of multiple probes: strangeness production, flow, hyperon polarization

✓ High luminosity guarantees sufficient event rate for rare probes (hypernuclei and multistrangeness)



NICA/MPD physics. Tasks and Observables

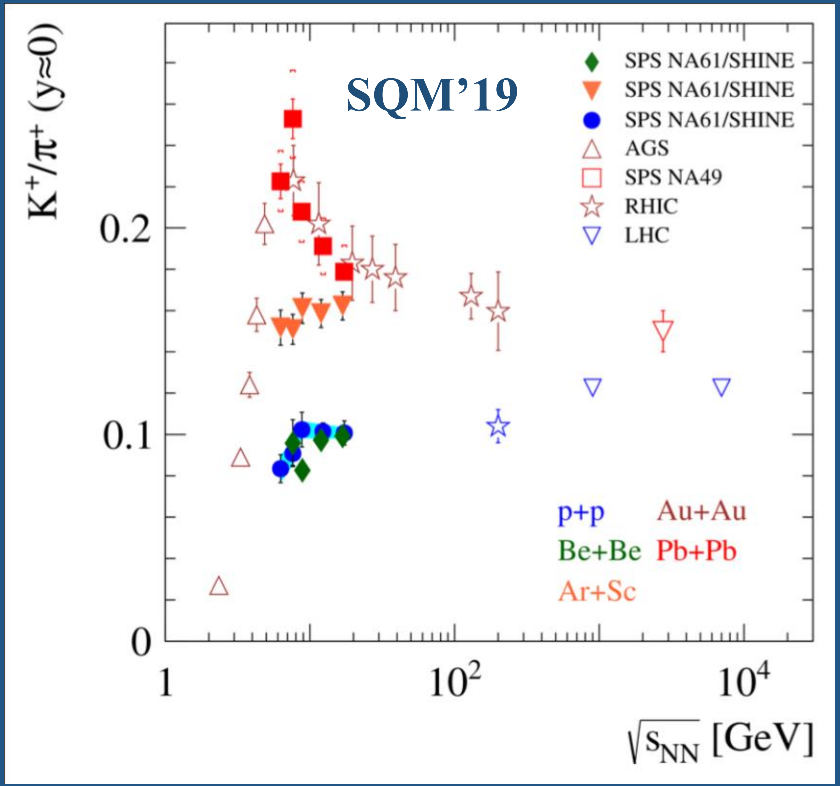
Experimental strategy: energy and system size scan to measure a variety of signals systematically changing collision parameters (energy, centrality, system size). Reference data (i.e. *p*+*p*) will be taken in the same experimental conditions



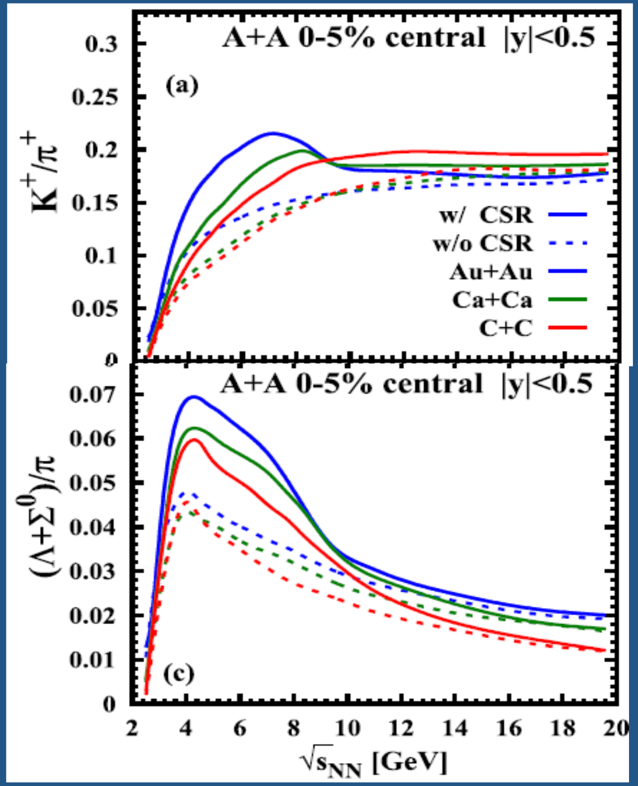
- ✓ *Bulk properties, EOS*
  particle yields & spectra, ratios, femtoscopy, flow
- ✓ *In-Medium modification of hadron properties*
  dileptons and resonances
- ✓ *Deconfinement (chiral) phase transition at high r_B*
  strangeness, Chiral Magnetic (Vortical) effect
- ✓ *QCD Critical Point*
  event-by-event fluctuations and correlations
- ✓ *YN, YY interactions in nuclear matter*
  hypernuclei

NICA/MPD physics cases: strangeness

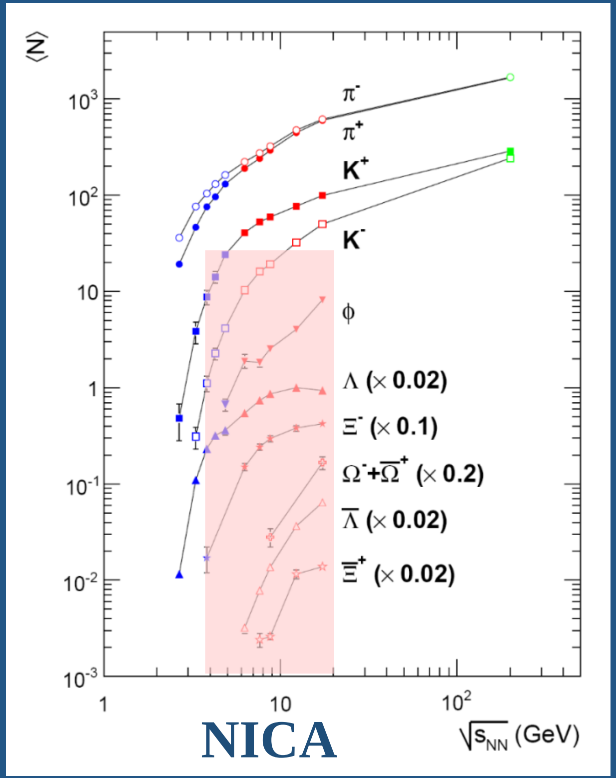
- ✓ Excitation function of hadrons, including strangeness (yields, spectra, and ratios)
- ✓ Nuclear matter EOS, in-medium effects, and chemical equilibration can be probed
- ✓ Hyperons sensitive to early stage and phase transformations in QCD medium
- ✓ Non-monotonic strangeness-to-entropy ratio seen in heaviest systems (phase transformation?)



System size of the energy dependence is not fully understood



Theory predicts the largest effect for the hadron ratios due to CSR in dense matter



Lack of data on multistrangeness in different collision systems at NICA energies!

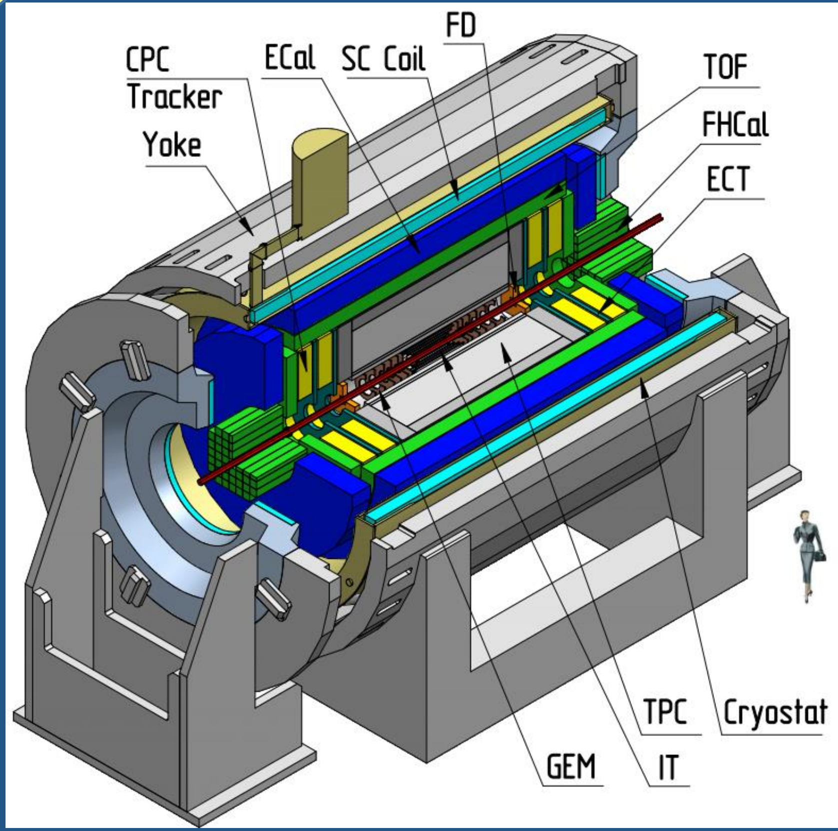
NICA Complex in Dubna

- ✓ 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 (BM@N)

Multi-Purpose Detector for A+A collisions @ NICA

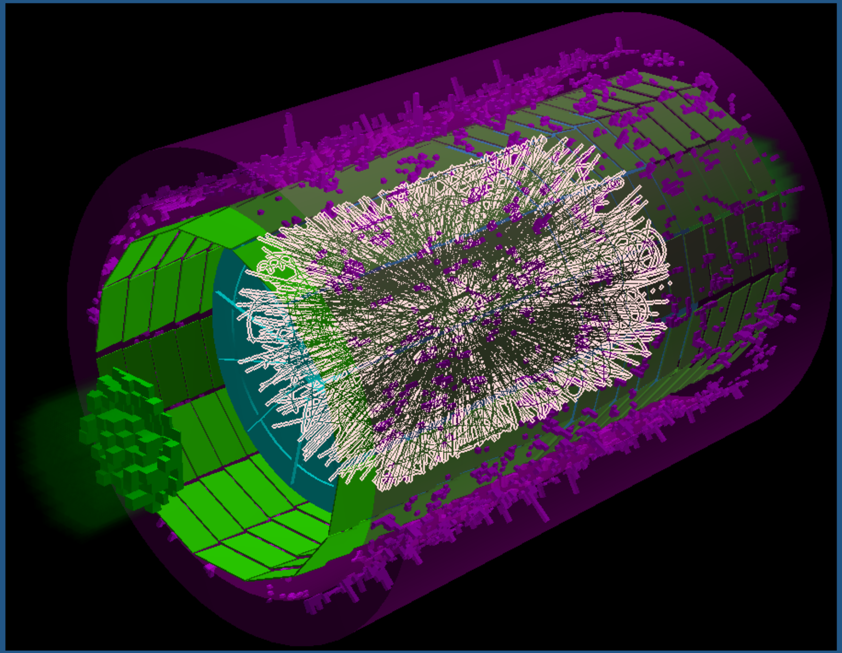


Magnet: 0.5 T superconductor
Tracking: TPC, ECT, IT
Particle ID: TOF, ECAL, TPC
T0, Triggering: FFD
Centrality, Event plane: FHCAL

Stage 1: TPC, TOF, ECAL, ZDC, FFD+ITS(OB)
Stage 2: ITS(IB)+EndCaps (CPC, Straw, TOF, ECAL)

MPD Collaboration:
11 Countries, 475 participants,
38 Institutes and JINR

Au+Au collision in MPD

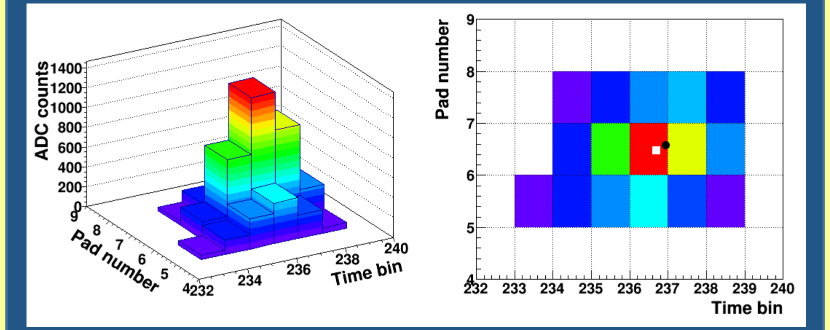


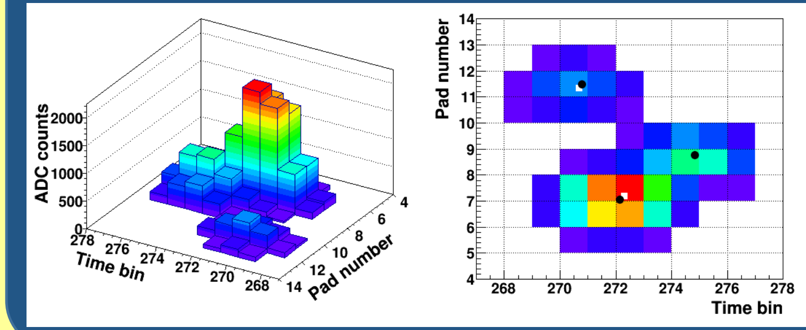
- Hermeticity, homogenous acceptance : 2π in azimuthal angle
- Highly efficient 3-D track reconstruction (|η|<2), high resolution vertexing
- Powerful PID: π/K up to 1.5 GeV/c, K/p up to 3 GeV/c, ECAL for γ, e
- Careful event characterization: impact parameter & event plane reconstruction
- Minimal dead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

MPD tracking

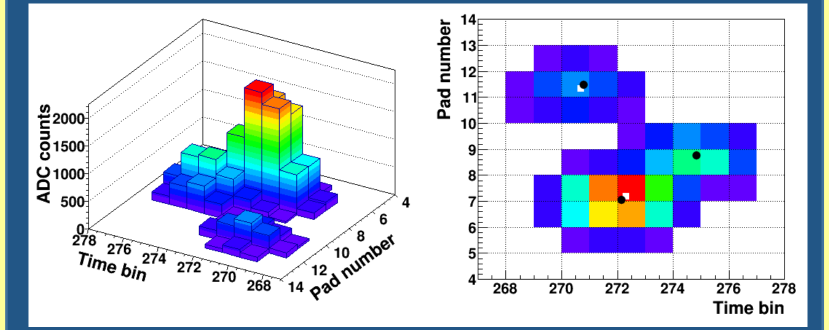
Cluster Topologies

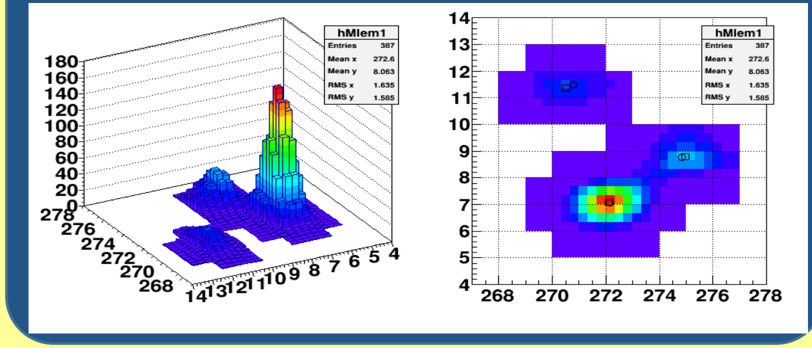
✓ Bla bla bla



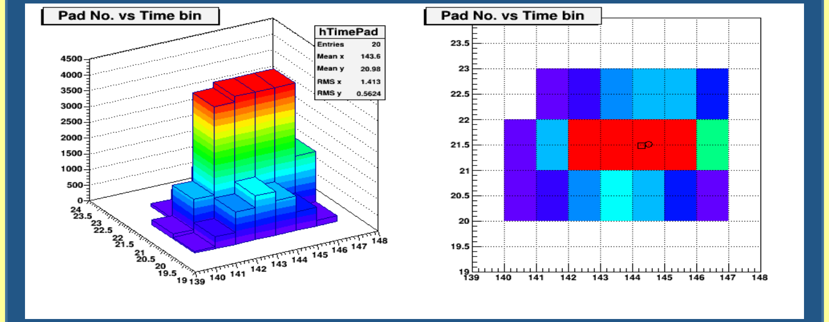


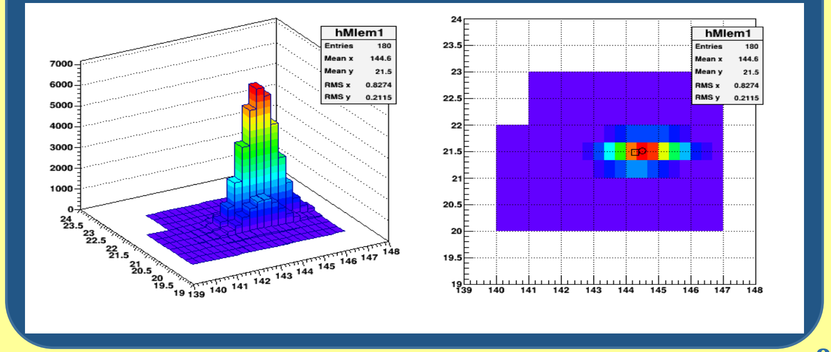
MLEM procedure (Bayesian unfolding)



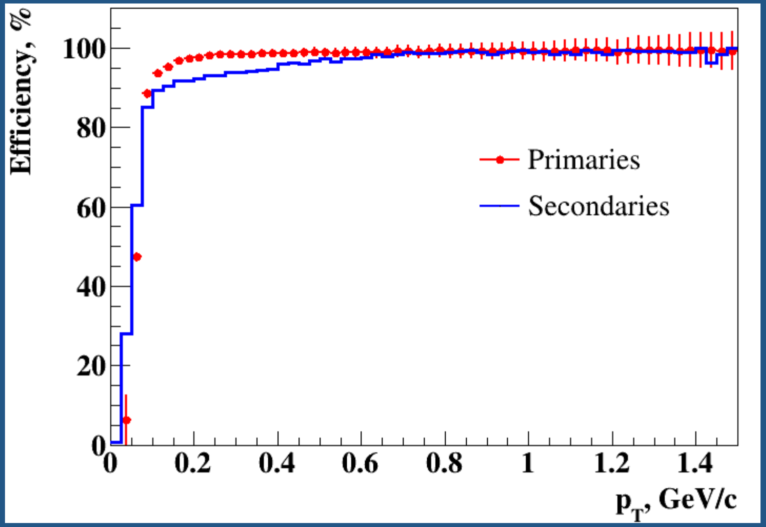


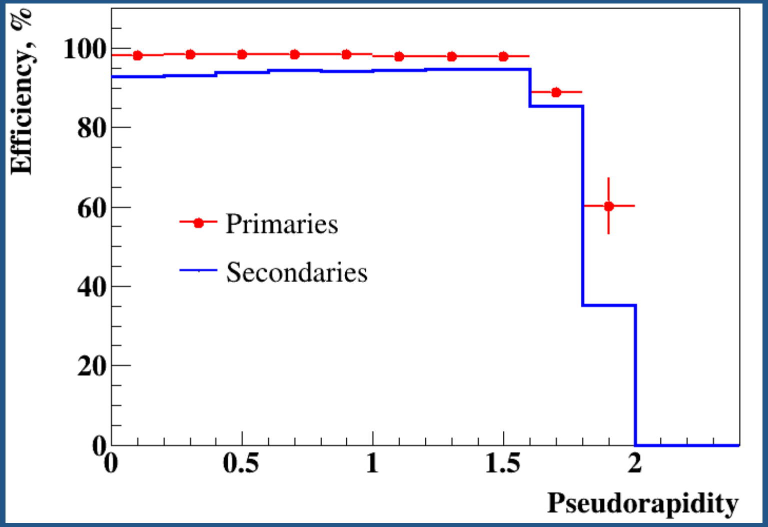
MLEM procedure - information recovery





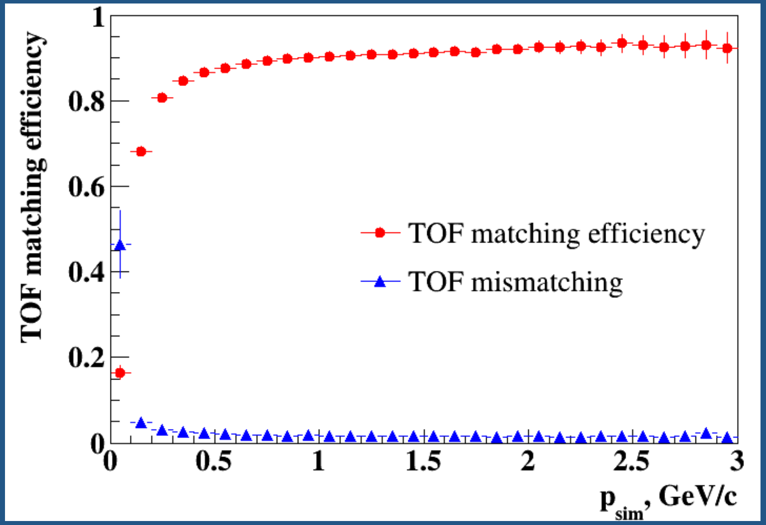
MPD tracking

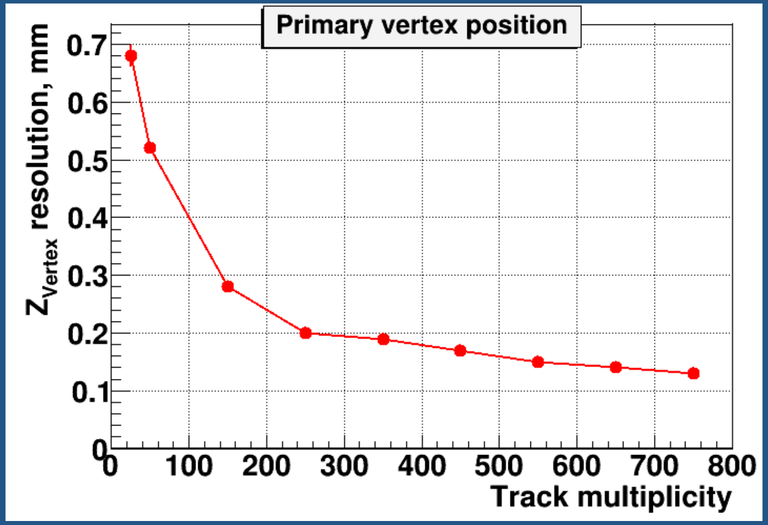


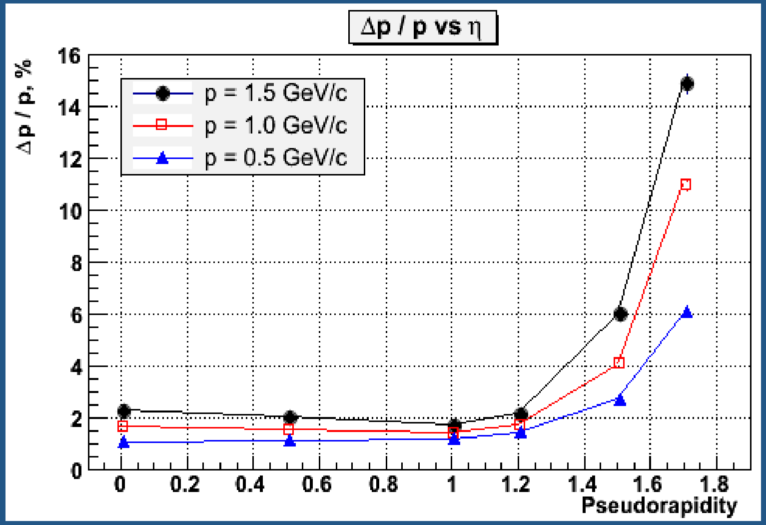


Based on realistic event simulation within the MPDRoot framework

- ✓ High tracking efficiency over the reaction phase-space
- ✓ Good vertexing





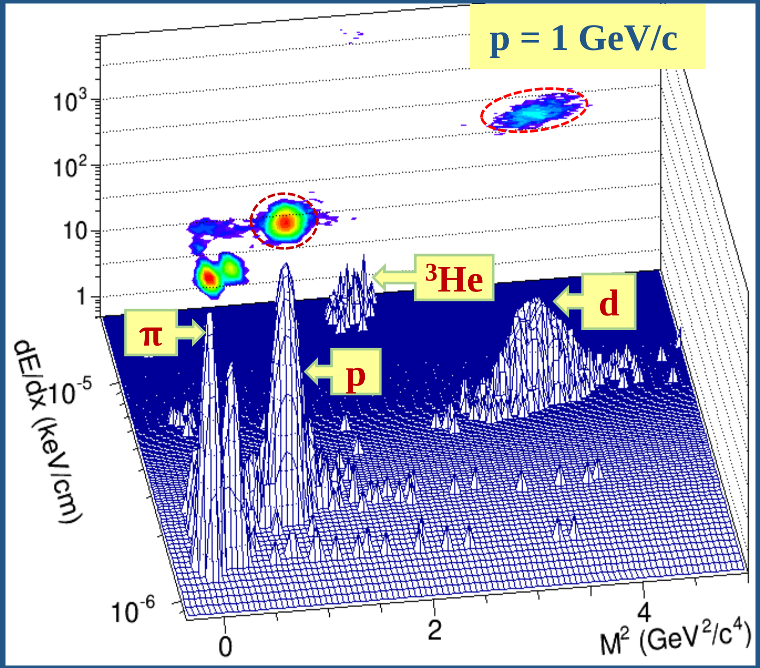


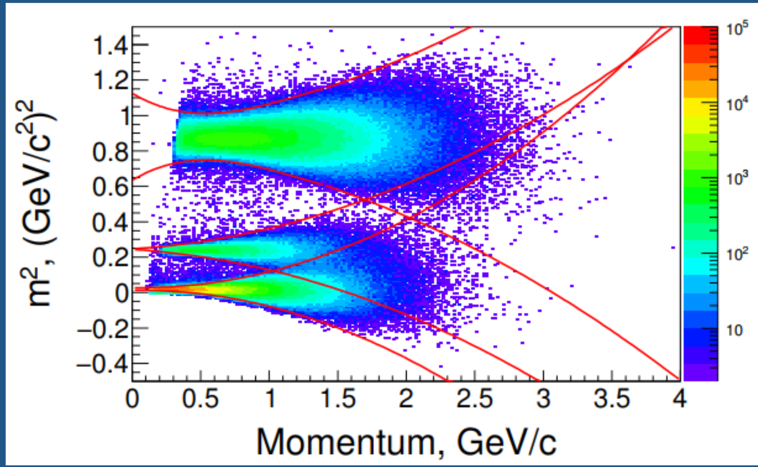
PID performance at MPD

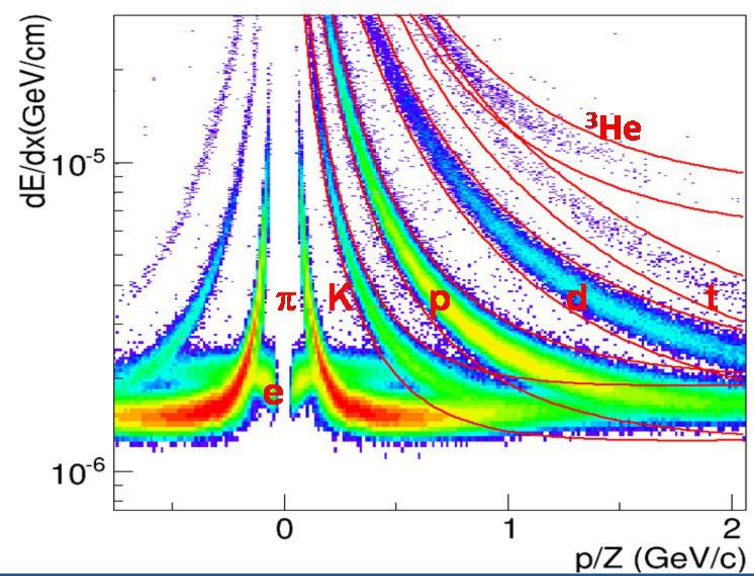
Combined (*dE/dx*+TOF) PID for hadrons provides *π/K* up to 2 GeV/c and *K/p* up 3 GeV/c

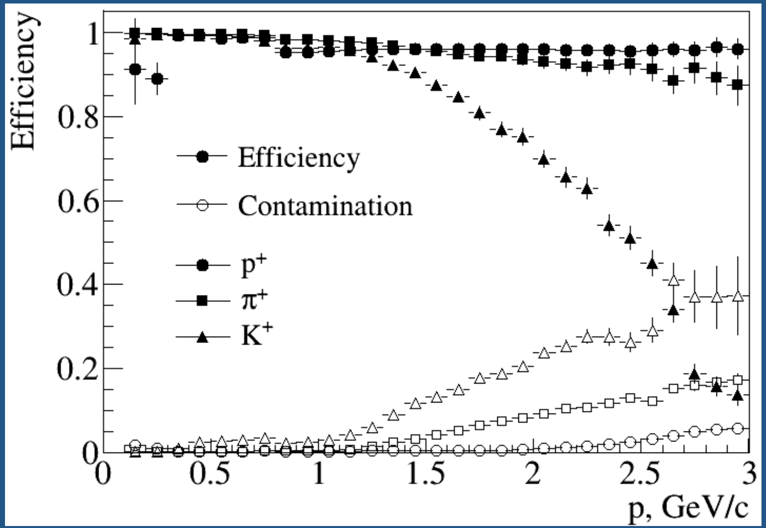
Mass square calculated using the measurements of momentum (p), time-of-flight (T) and trajectory length (L):

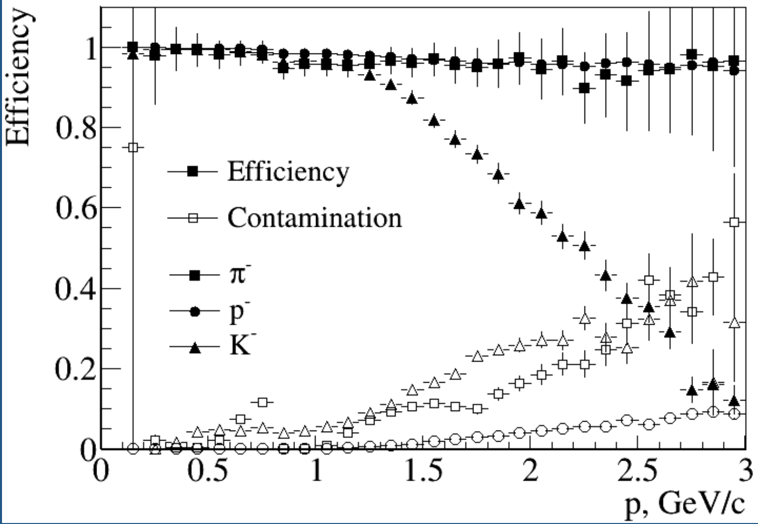
$$m^2 = p^2\left(\frac{c^2T^2}{L^2} - 1\right)$$











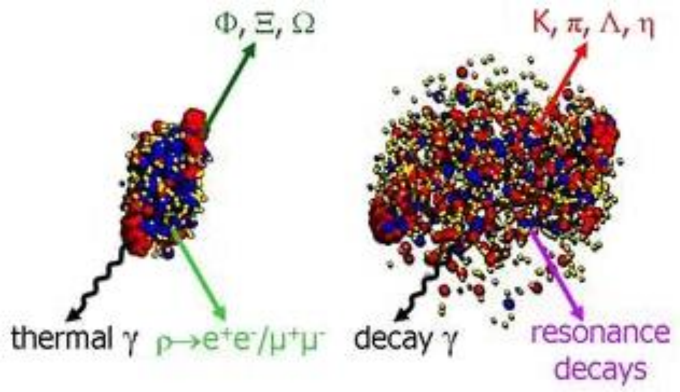
Data set

- ✓ **Generators:** PHSD, Au+Au @ 11 GeV, min. bias, 8M events (~6 hours of running time at starting luminosity - 1/20 of design value)
- ✓ **Detectors:** start version of MPD with up-to-date TPC & TOF
- ✓ **Cluster / hit reconstruction:** precluster finder *(group of adjacent pixels in time bin – pad space*) ; hit finder *("peak-and-valley" algorithm either in time bin – pad space (for simple topologies) or in time-transverse coordinate pixel space after Bayesian unfolding (for more complicated topologies))*→ COG around local maxima
- ✓ **Track reconstruction:** two-pass Kalman filter with track seeding using outer hits (*1st pass*) or leftover inner hits (*2nd pass*)
- ✓ **Track acceptance criterion:** $|\eta| < 1.3$, $N_{hits} \geq 10$
- ✓ **Particle Identification:** dE/dx in TPC & β in TOF
- ✓ **Vertex reconstruction:** Kalman filter based formalism working on MpdParticle objects

Physics Motivation and Analysis Goals

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.

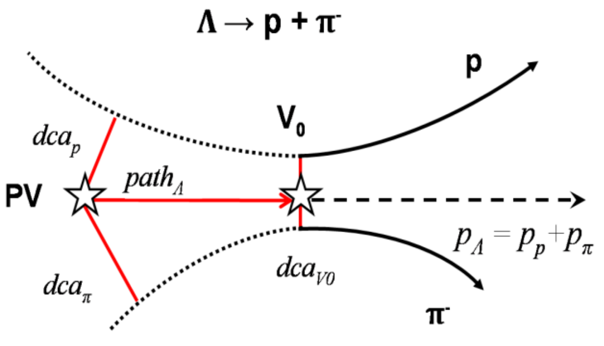


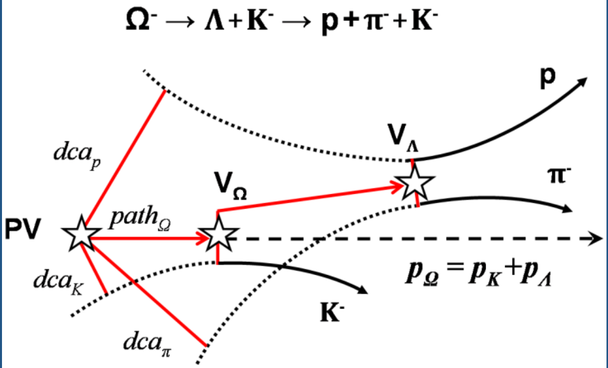
Analysis Goals

- ✓ Secondary Vertex Reconstruction algorithms development for multistrangeness analysis
- ✓ Optimization of selection criteria in p_T and centrality
- ✓ Analysis macros for invariant spectra reconstruction
- ✓ Estimates of MPD efficiency and expected event rates
- ✓

Analysis Method

Secondary Vertex Finding Technique



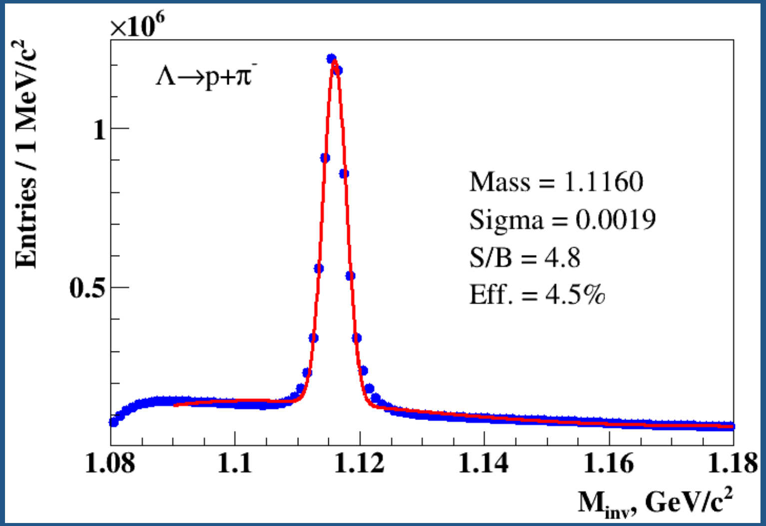


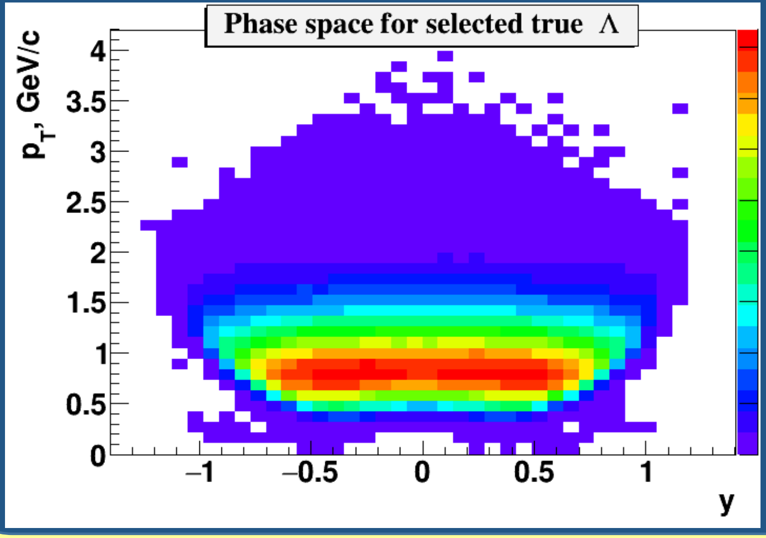
Event topology:

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

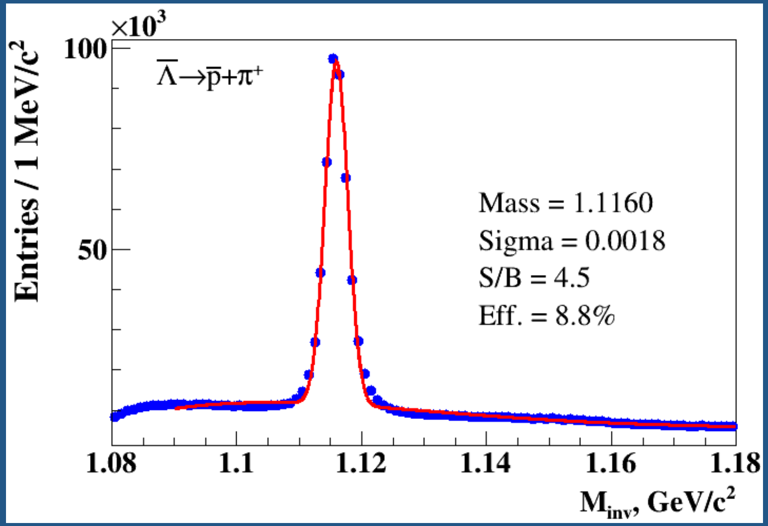
Λ, Λ_{bar}, Ξ^- reconstruction and Phase space

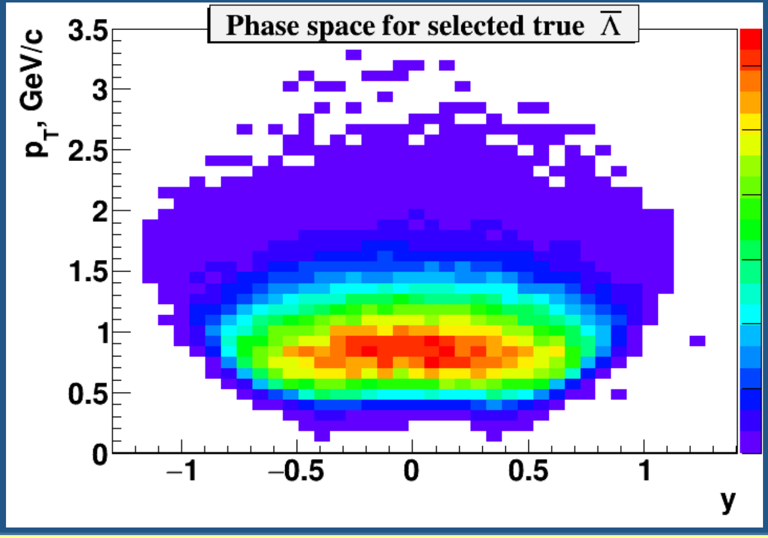
Eff. (for |y|<0.5) =10.4%



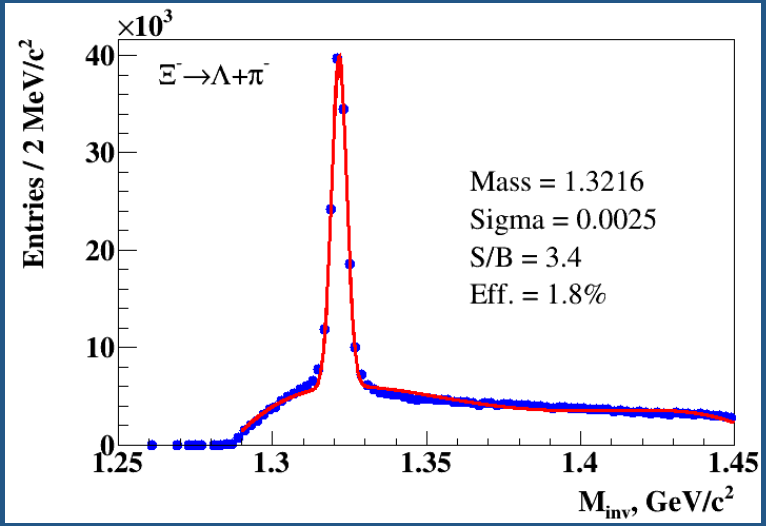


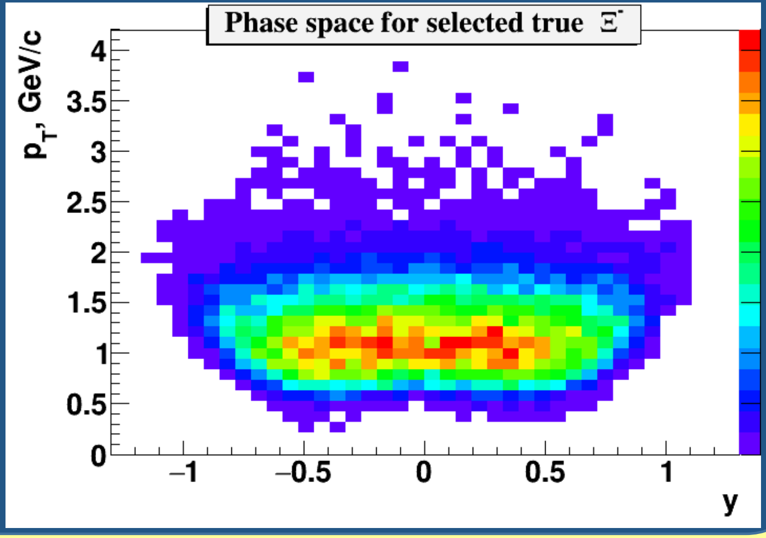
Eff. (for |y|<0.5) =14.1%





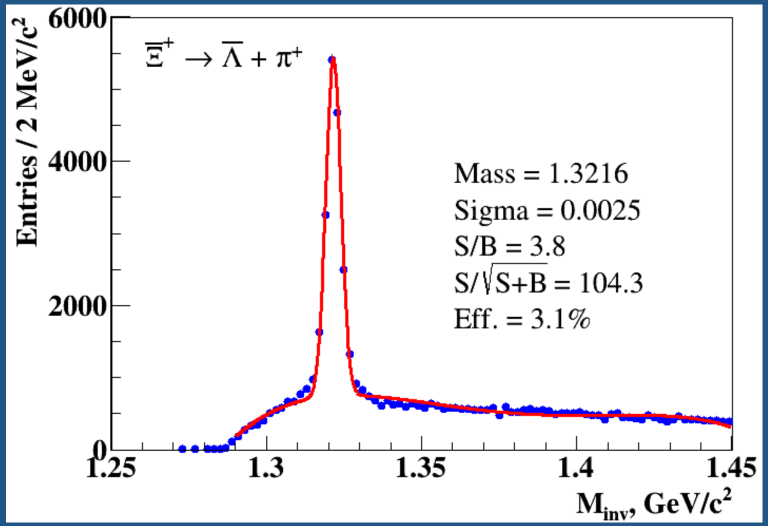
Eff. (for |y|<0.5) =3.6%

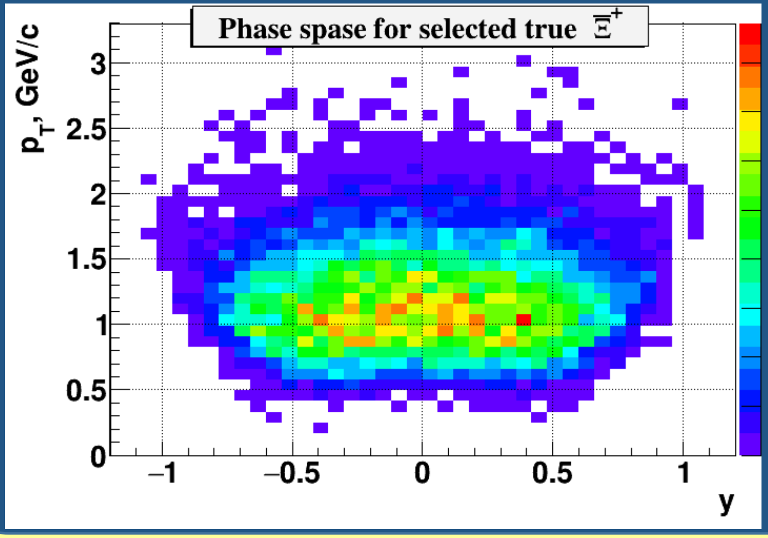




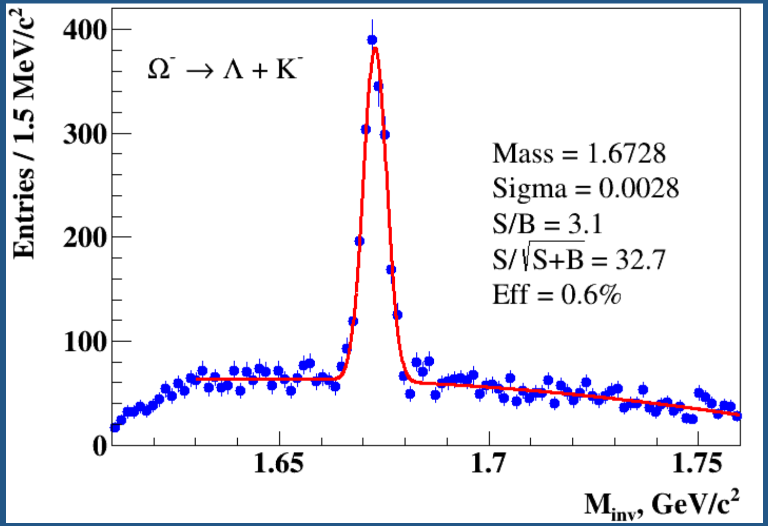
Ξ^+, Ω^-, Ω^+ reconstruction and Phase space

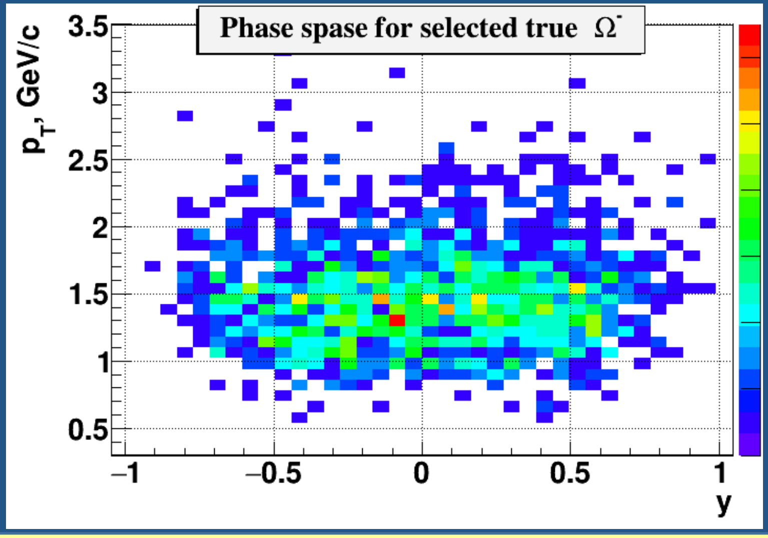
Eff. (for |y|<0.5) =4.7%



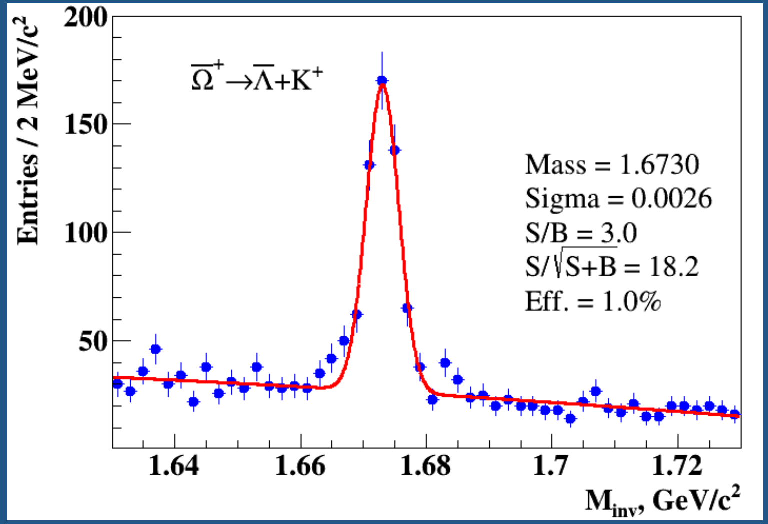


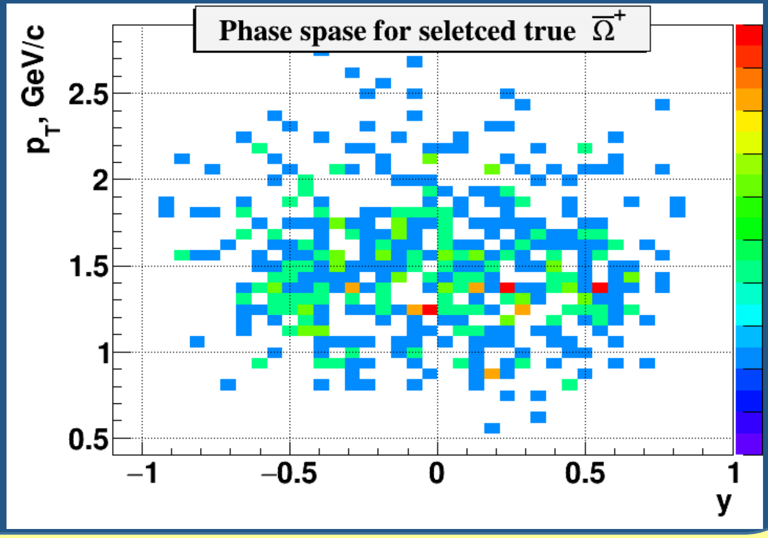
Eff. (for |y|<0.5) =1.1%



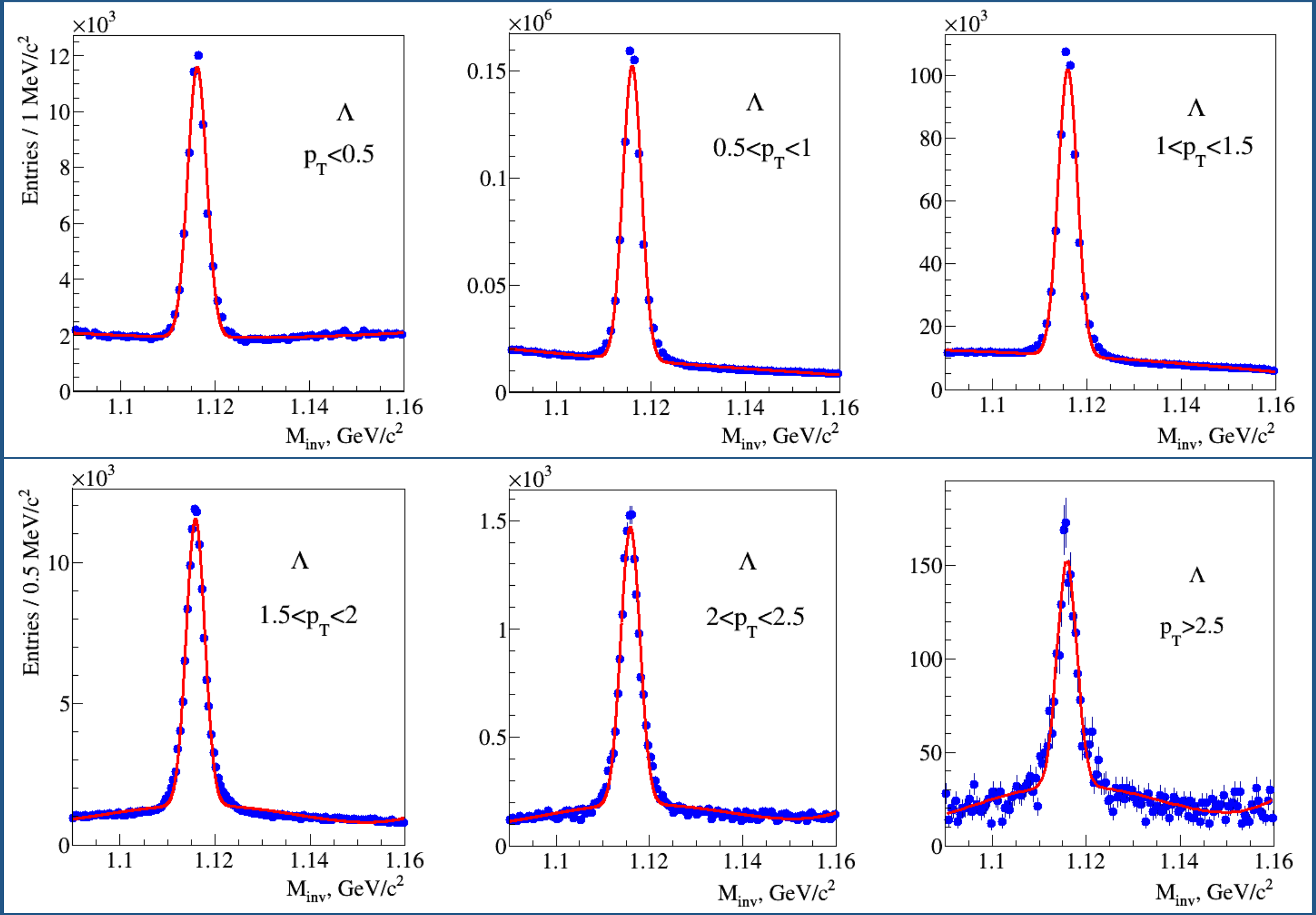


Eff. (for |y|<0.5) =1.5%

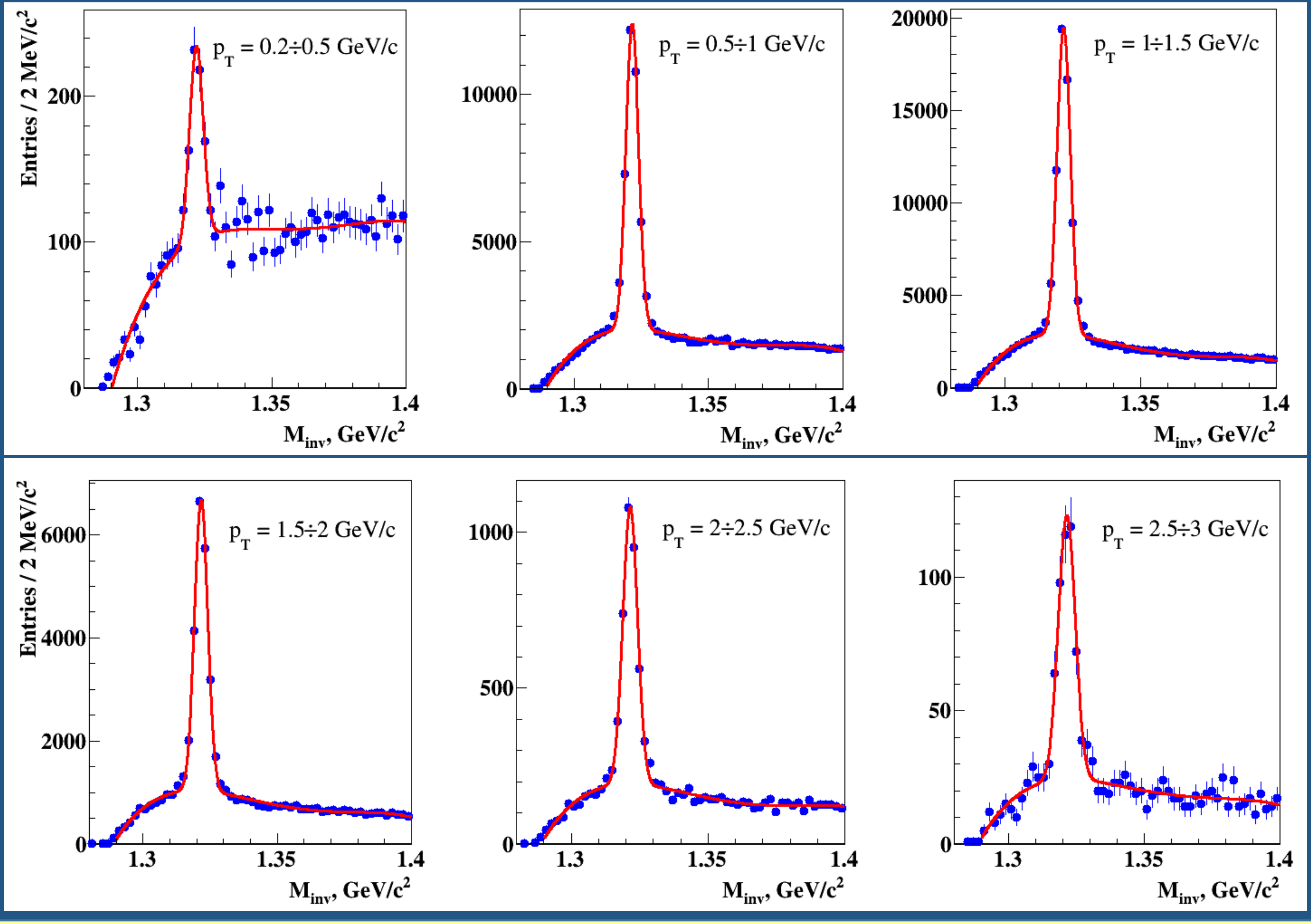




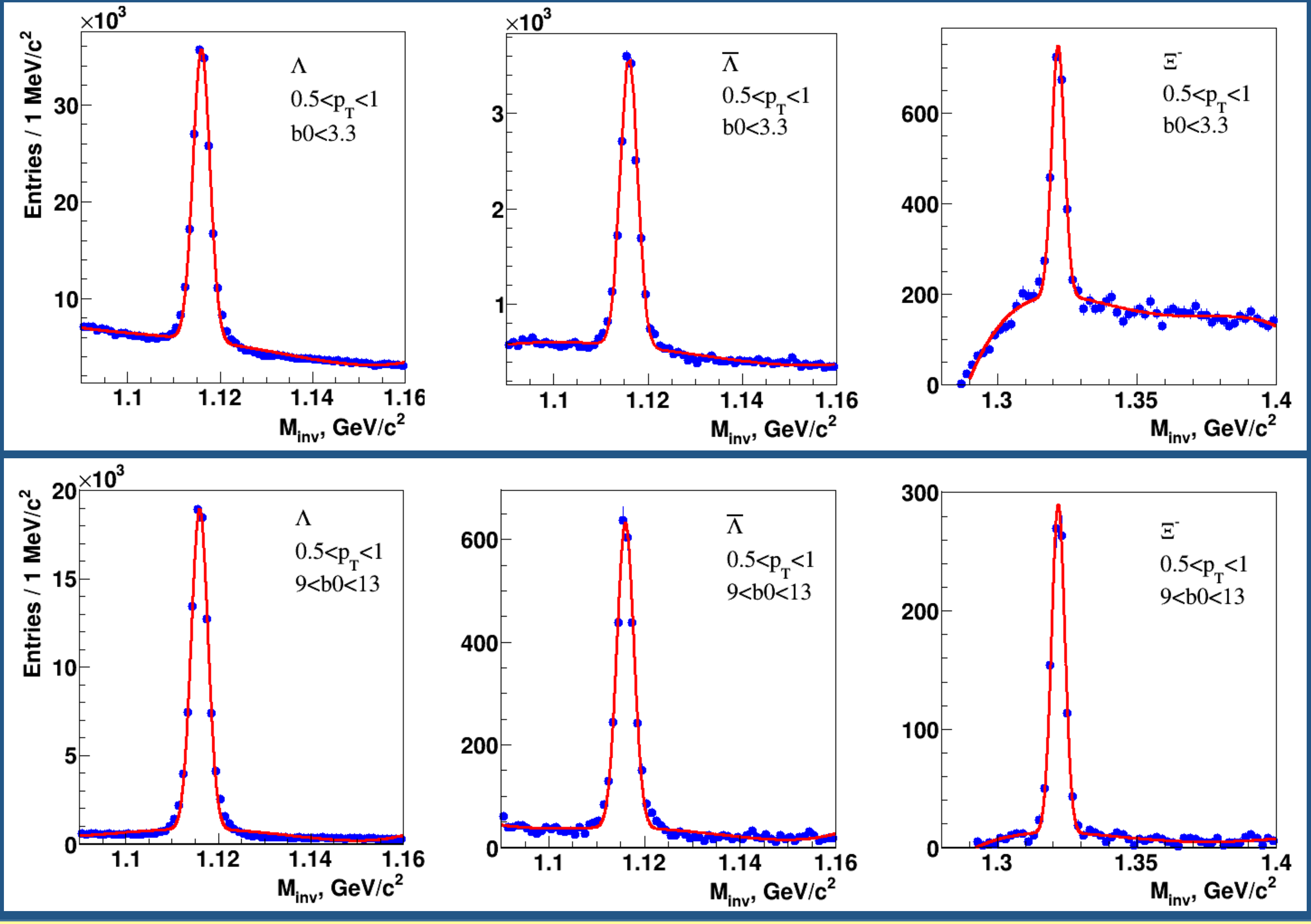
p_T dependence of Λ for all centralities



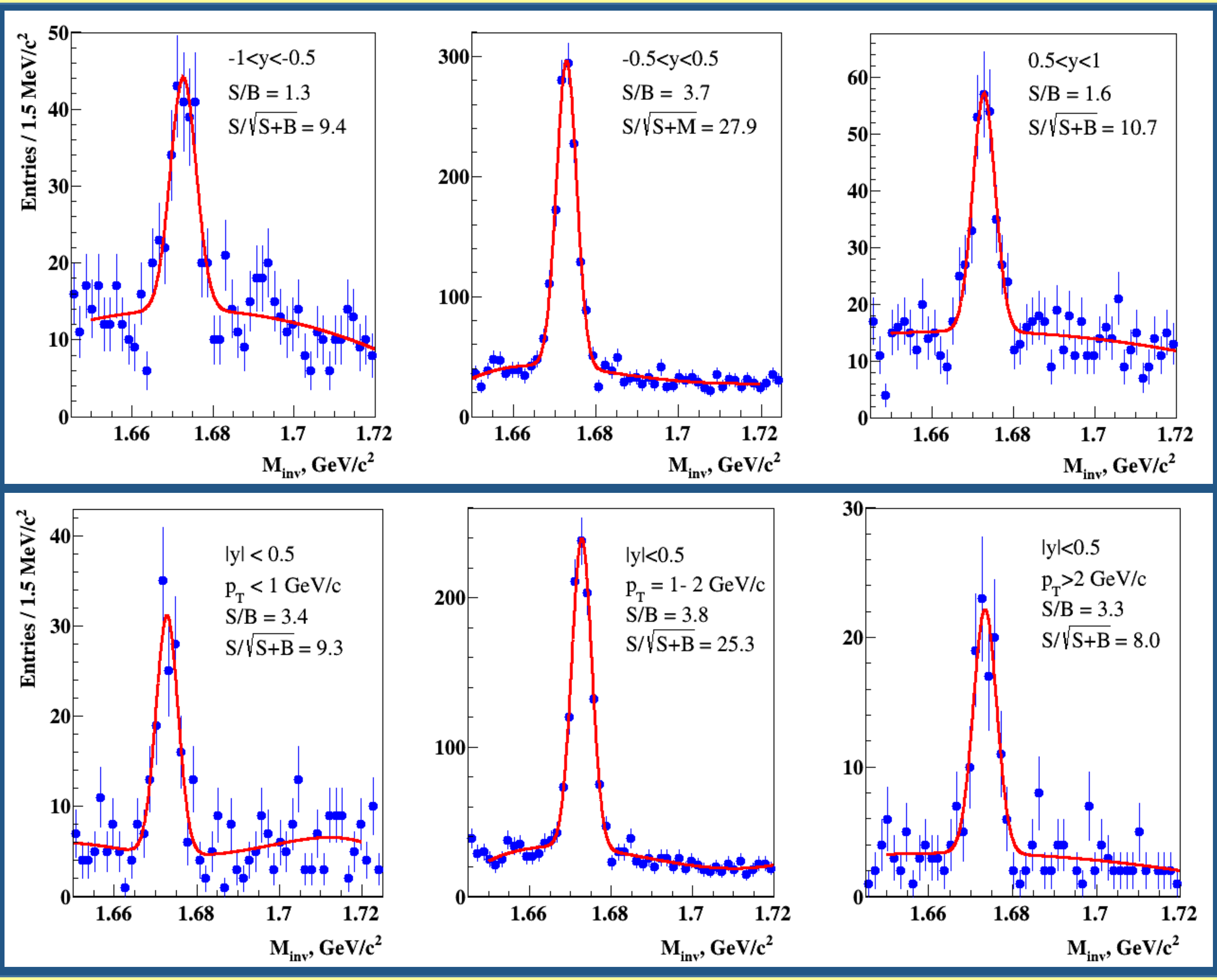
p_T dependence of Ξ^- for all centralities



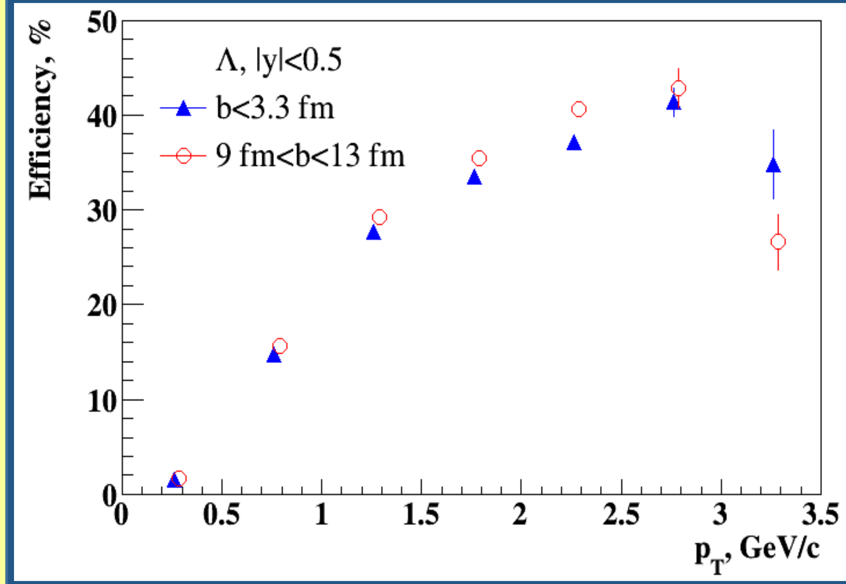
p_T dependence for different centralities

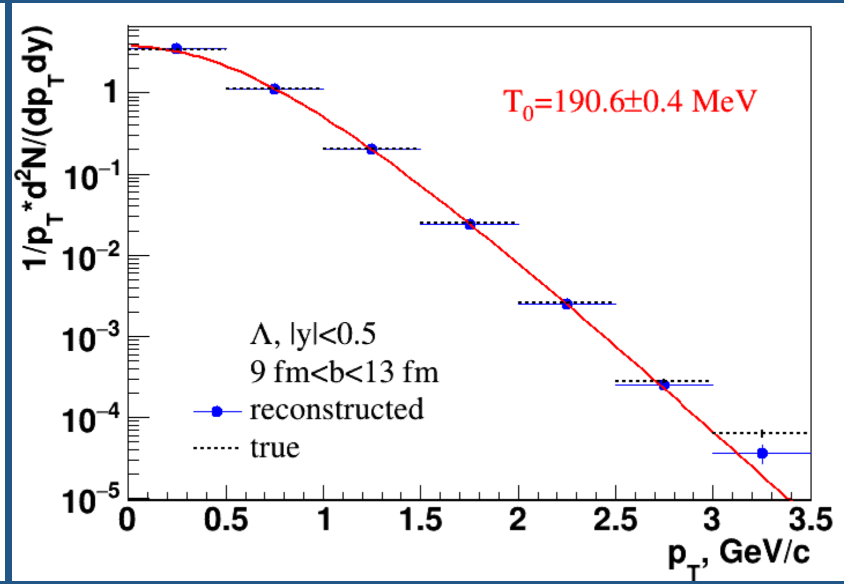


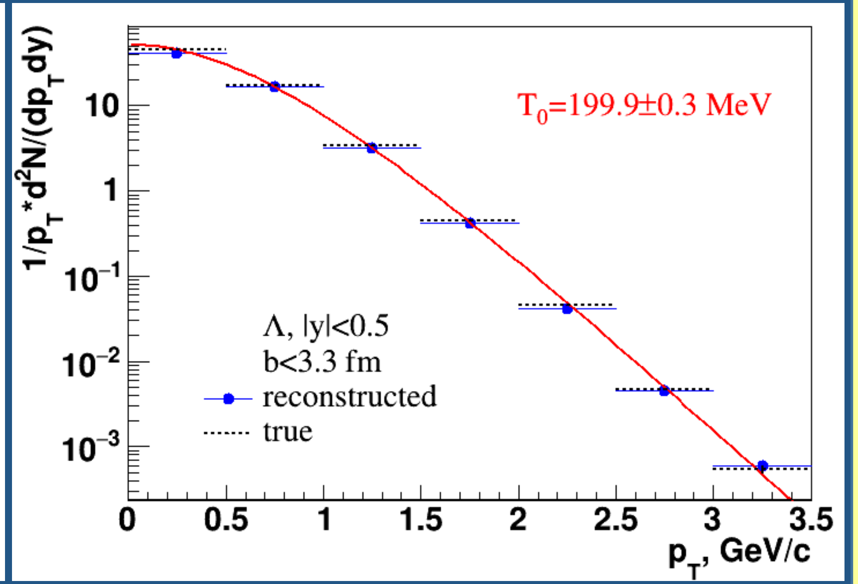
Ω^- hyperon: y & p_T dependence



Λ reconstruction: efficiency and invariant p_T spectrum



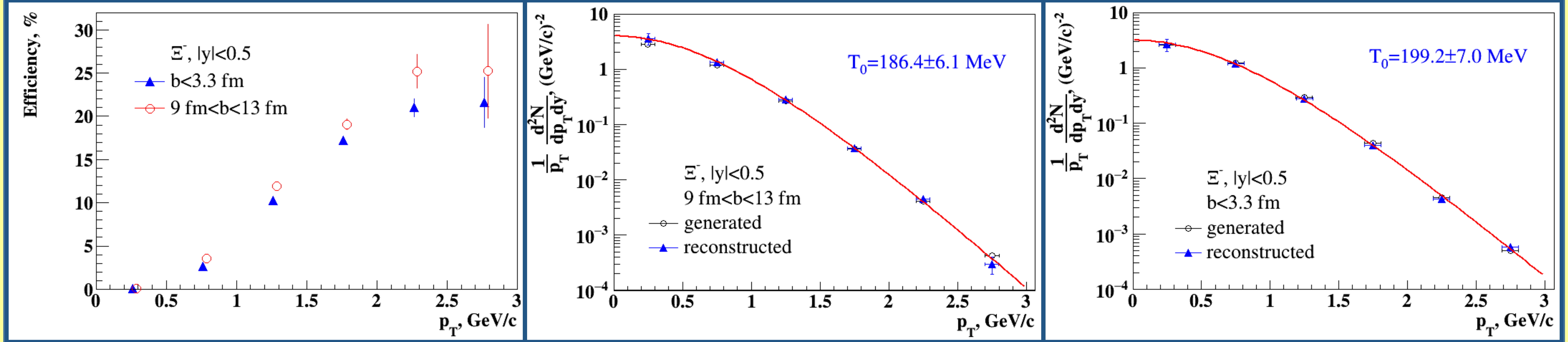




Efficiency of true Λ in p_T and b bins for $|y|<0.5$: (reco & select Λ) / (all gen Λ)

Reconstructed spectrum:
fit of selected Λ in each bin (Gauss $\pm 3\sigma$) / Eff.

Ξ^- reconstruction: efficiency and invariant p_T spectrum



Efficiency of true Ξ- in p_T and b bins for $|y|<0.5$: (reco & select Ξ^-) / (all gen Ξ^-)

Reconstructed spectrum:
fit of selected Ξ^- in each bin (Gauss $\pm 3\sigma$) / Eff.

Summary and Acknowledgments

- Hyperon-related activity is ongoing
- Some analyses require dedicated event generators
- Statistics is an issue for multistrange hyperons – future developments might help

This work was supported by the Russian Foundation for Basic Research (RFBR): grant No. 18-02-40060

Thank you for attention!