A Monte Carlo simulation of the MPD experiment performance for strange particle decay study

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Outline

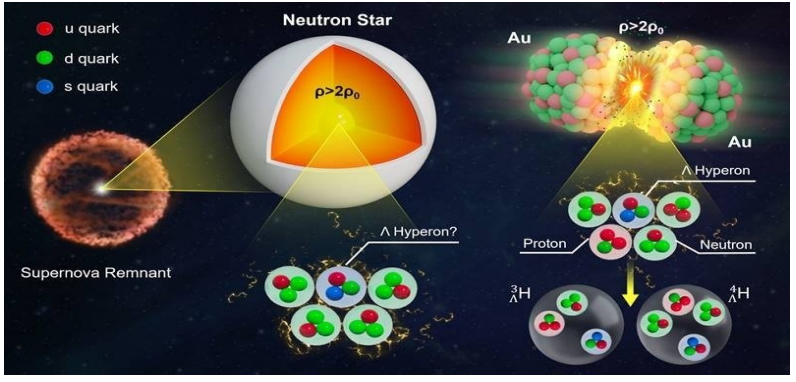
- ***Motivation and Physics Goals***
  - *Why study strange particles in MPD fixed-target mode*
- ***Overview of the Multi-Purpose Detector (MPD) – FXT setup***
  - *Main subsystems relevant for strange particle reconstruction*
- ***Analysis Methodology***
  - *Track reconstruction, PID and Topological Cuts (TC)*
- ***Strange Particle Resonstruction MPD (Collider & FXT Mode)***
  - $\Lambda \rightarrow p + \pi^-$
  - $\Omega^- \rightarrow \Lambda + \pi^-$
  - $\Xi^- \rightarrow \Lambda + K^-$
  - $K^0_s \rightarrow \pi^+ + \pi^-$
- ***Efficiency and p_T – Spectra***
  - *Centrality dependence & Comparison of generated vs reconstucted*
- ***Summary and Outlook***

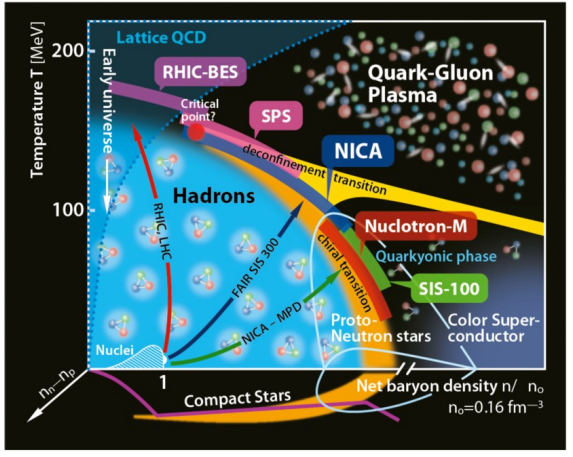
Physics Motivation

- ✓ **Significance of Strange Particles:** Strange hadrons (Λ, K^0_s, Ω) are key probes of the properties of nuclear matter. They serve as indicators of the collision dynamics and the hadronization processes.
- ✓ **Astrophysical Relevance:** They also play important role in understanding matter inside neutron stars.
- ✓ **Quantum Chromodynamics (QCD):** Strangeness provides information on the confinement mechanism and the transition between quark gluon plasma and hadron gas.
- ✓ **Experimental Relevance:** Reconstruction of their weak decays is a valuable test of detector performance.

The Goal of This Study

- ✓ **Simulation of MPD performance for strange particle reconstruction in fixed-target mode:**
  - signal extraction
  - efficiency estimation
  - p_T-spectra for different centralities





Multi – Purpose Detector General View

Time-Projection Chamber (TPC): Main tracking detector

Time-Of-Flight (TOF): Particle identification via time-of-flight

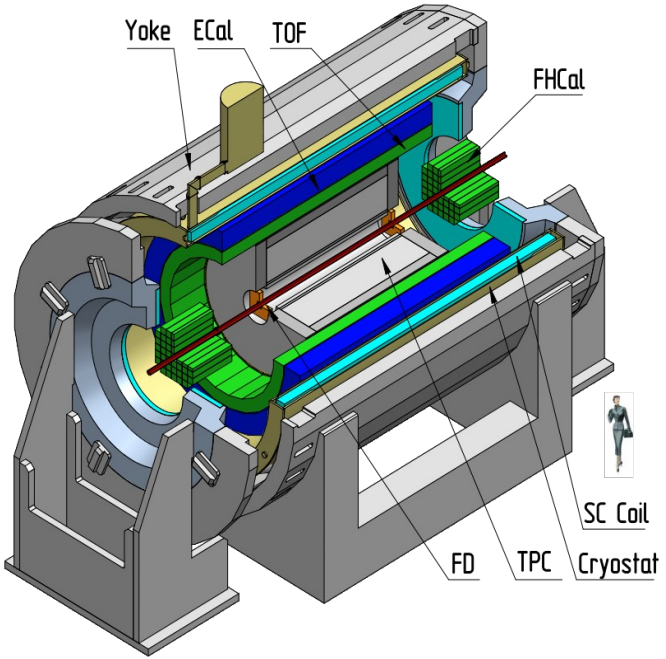
Electromagnetic Calorimeter (Ecal): Measurements of photons and electrons

Forward Hadron Calorimeter (FHCal): Measures centrality and event plane

Forward Detector: Provides fast trigger for **TOF**

Fixed-Target Mode: Wire target at z = **-85 cm**, diameter **50 um**, wire is shifted by **1.4 c**m upwards in Y.

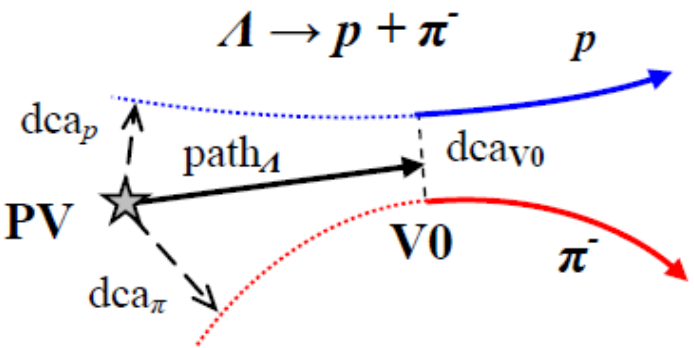
All subdetectors are located inside a superconducting solenoid



- ***http://mpd.jinr.ru/mpd/***

Decay Reconstruction Method

Topological Cuts (TC)



- Primary vertex(**PV**): collision point
- Second vertex(**V0**): decay of **Λ**
- **dca:** distance of closest approach between tracks & to **PV**
- Decay lenght(**path**): distance between **PV** and **V⁰**

Maximization of significance: Significance is defined as **S/√(S+B)**, where **S** and **B** are the total numbers of signal and background combinations inside ±2σ interval around the invariant mass peak position (σ is taken from Gaussian fit of the peak).

Data Set and Analysis Framework

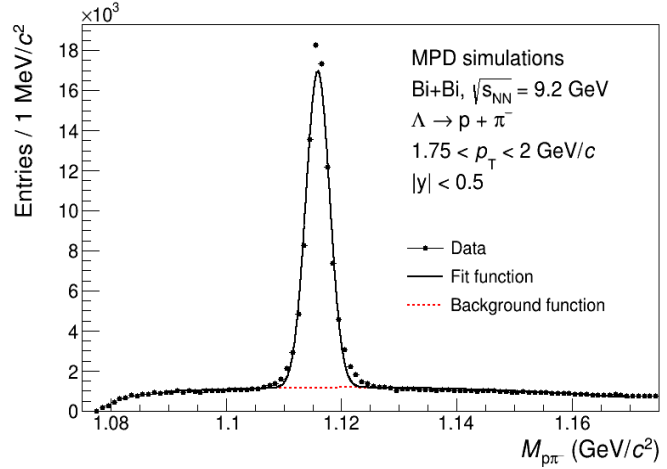
✓ **Event Generation & Simulation**

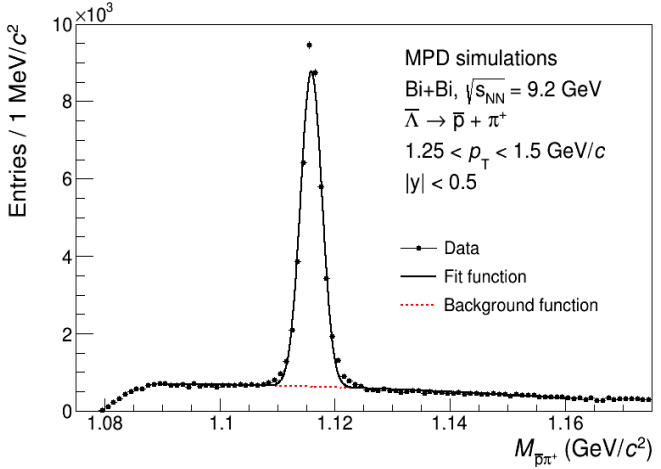
- **Generators:** UrQMD + Geant-4, Min.bias (b = 0-15 fm)
- **System:** Bi+Bi @ 9.2 GeV for Collider Mode & Xe+W @ 2.5 GeV for FXT Mode
- **Statistics:** 15M, 20M and 50M events
- **Detectors setup:** MPD in Collider Mode & MPD in Fixed Target Mode

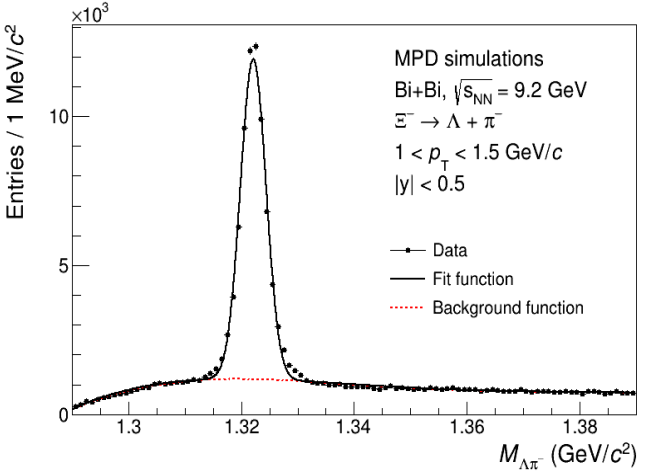
✓ **Reconstruction & Selection**

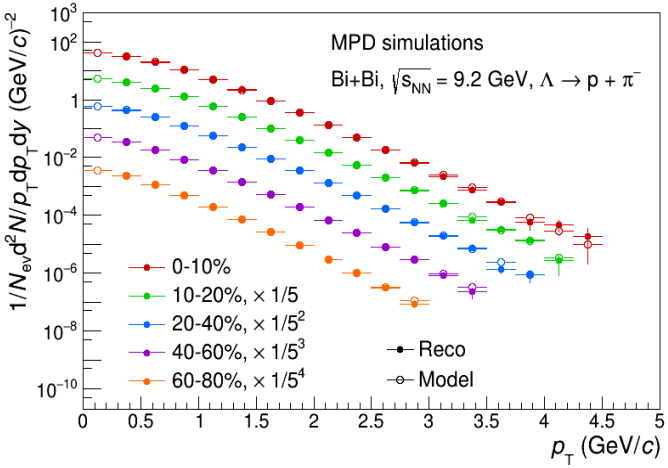
- **Track reconstruction:** two-pass Kalman filter with track seeding using outer hits (1^{st} pass) or leftover inner hits (2^{nd} pass)
- **Track acceptance criterion:** $|\eta| < 1.3$, NTPC_hits ≥ 10
- **Particle Identification:** *dE/dx* in TPC & m^2 in TOF
- **Analysis methods:** Topological Cuts (TC)

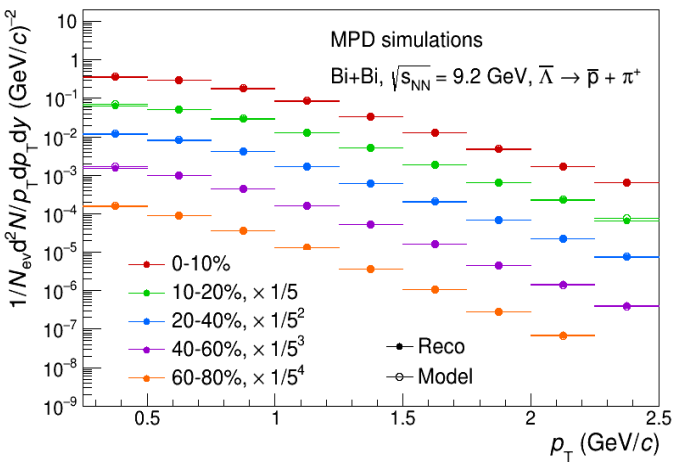
Strange Particle Reconstruction in Collider Mode

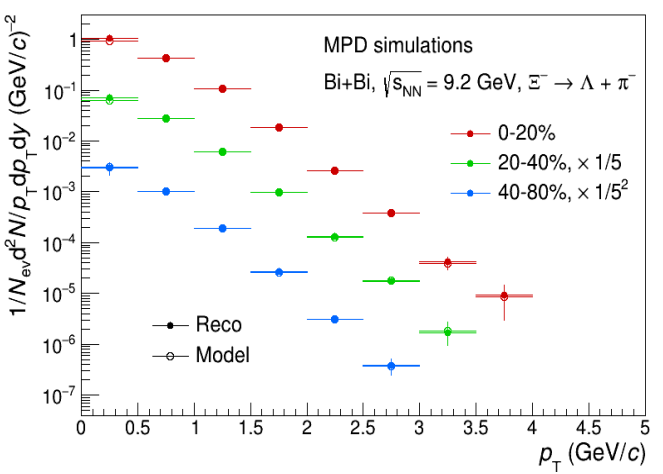






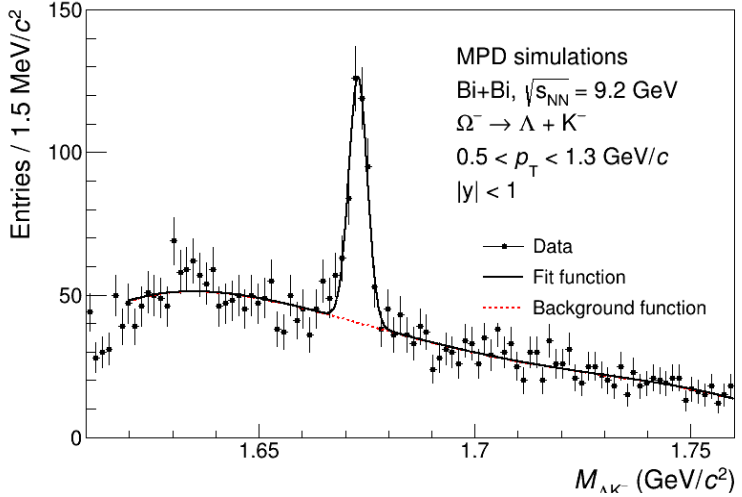


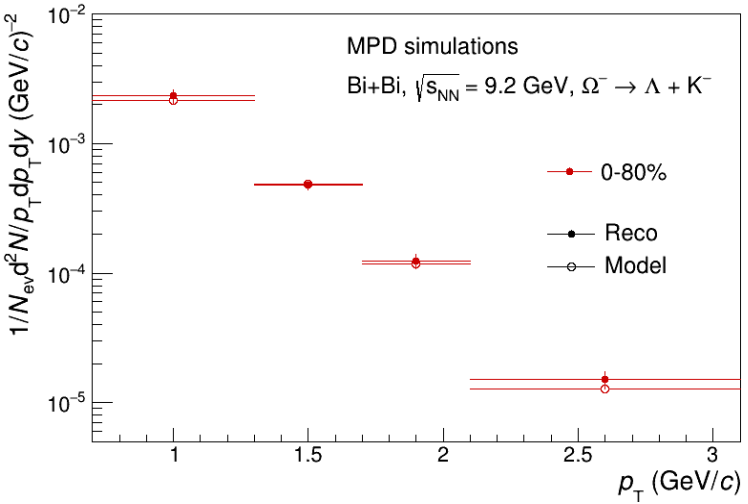


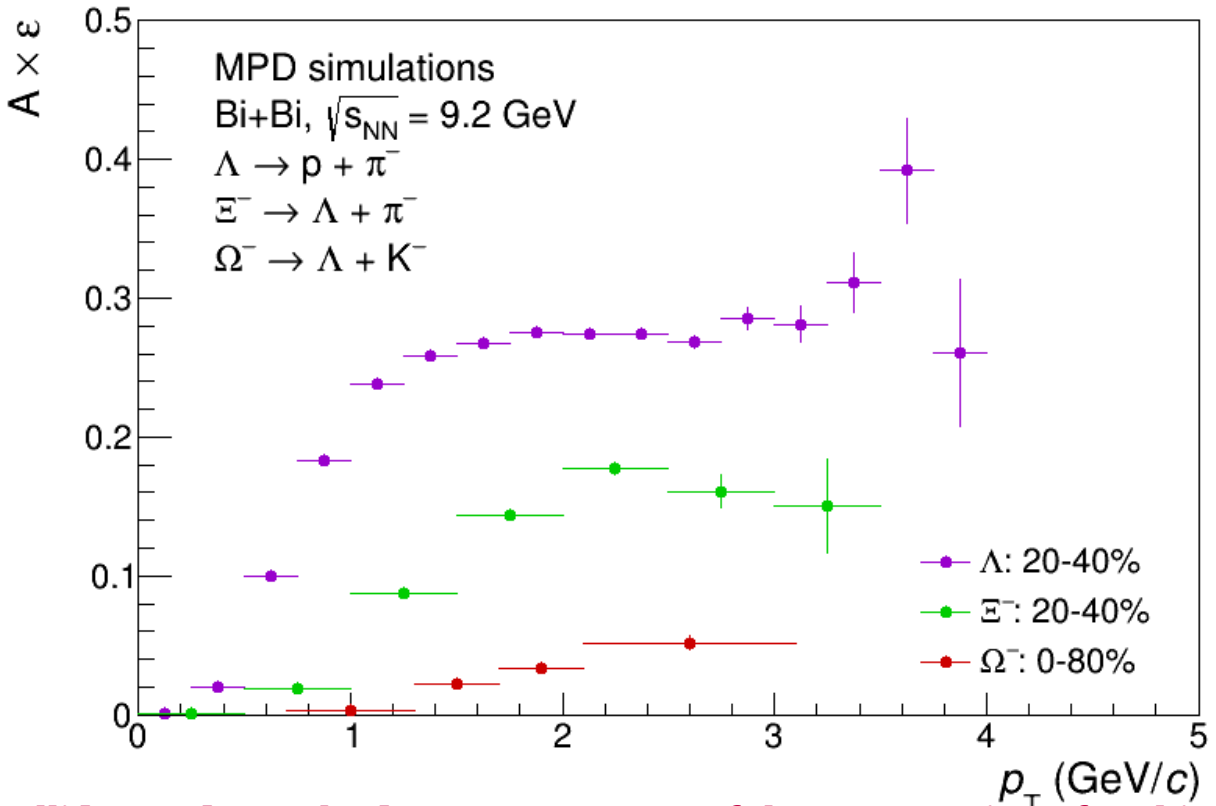


Clear signals in collider mode validate the reconstruction method and confirm its robustness for futher FXT studies.

Strange Particle Reconstruction in Collider Mode

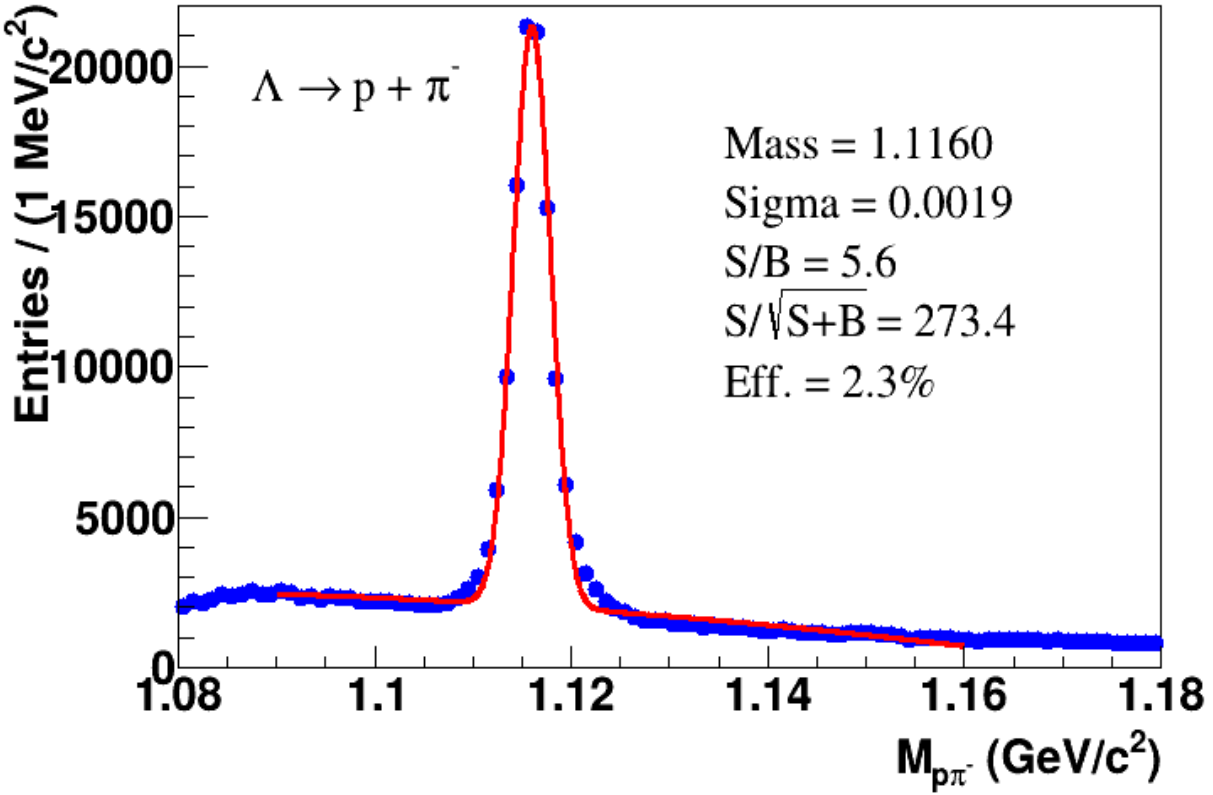






Collider mode results demonstrate successful reconstruction of multi-strange hyperons, validating the method despite lower efficiencies for complex decays.

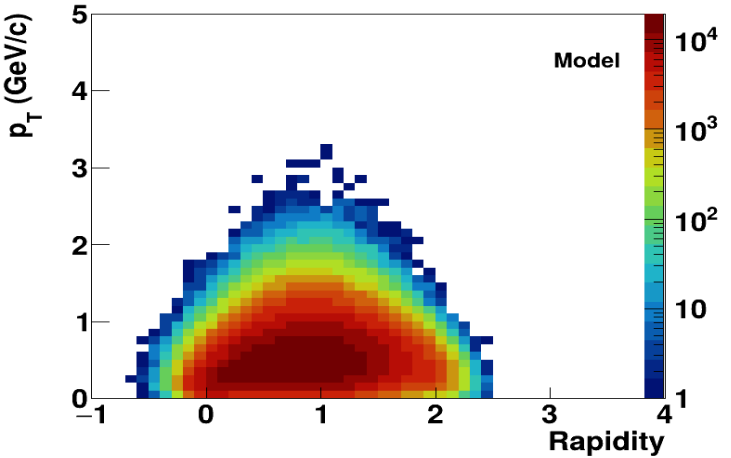
Invariant Mass Λ in MPD FXT Mode

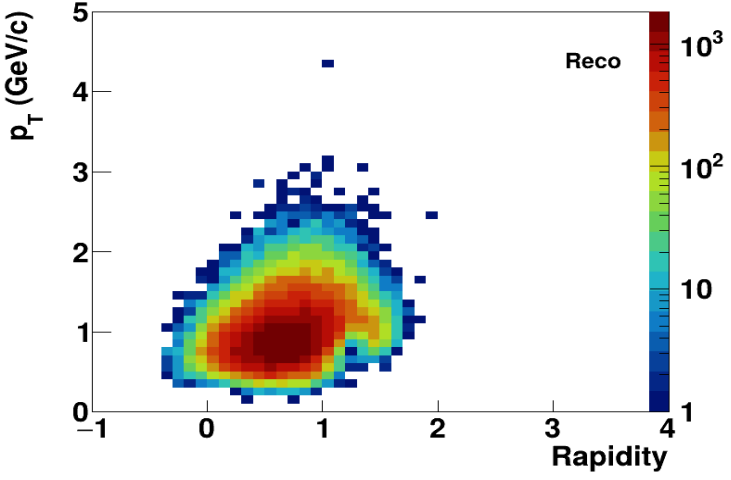


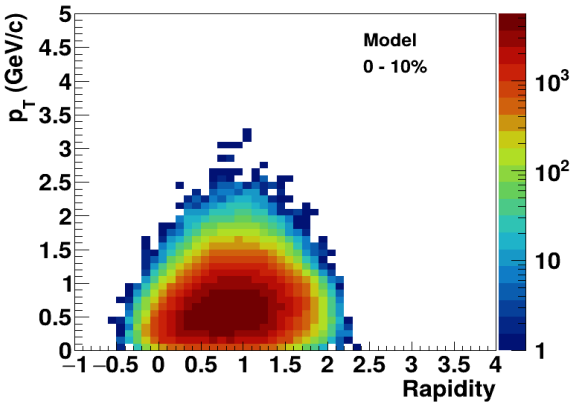
Variable	Cut Value
χ^2_π	> 25
χ^2_p	> 11
χ^2_{V0}	< 10
dca	< 0.8
$path$	> 3
$angle$	< 0.04

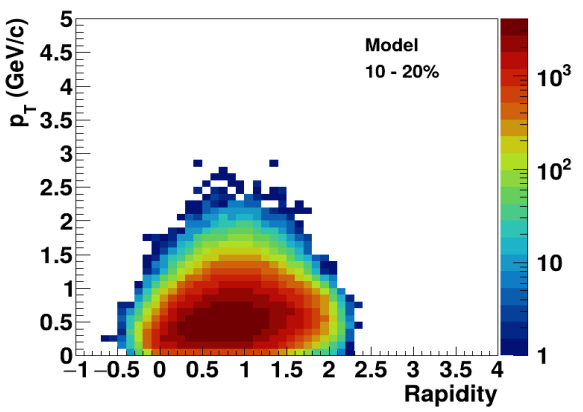
Λ hyperons are clearly reconstructed in FXT mode, with good signal significance and stable efficiency, confirming the reliabillity of topological selection cuts.

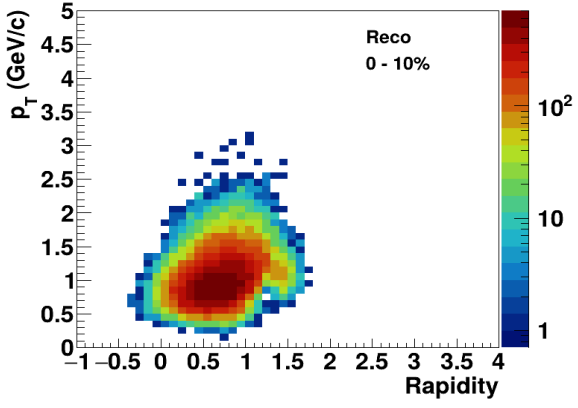
Λ Phase Space: Model vs Reconstruction

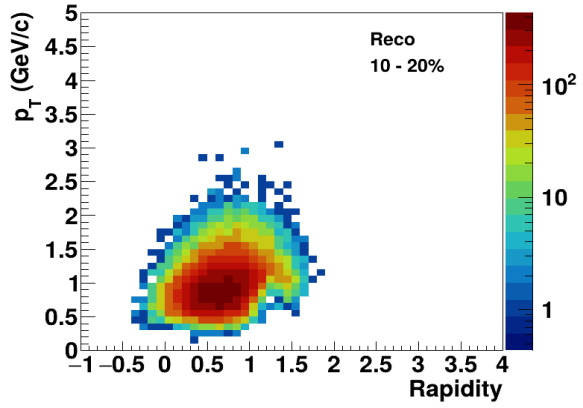






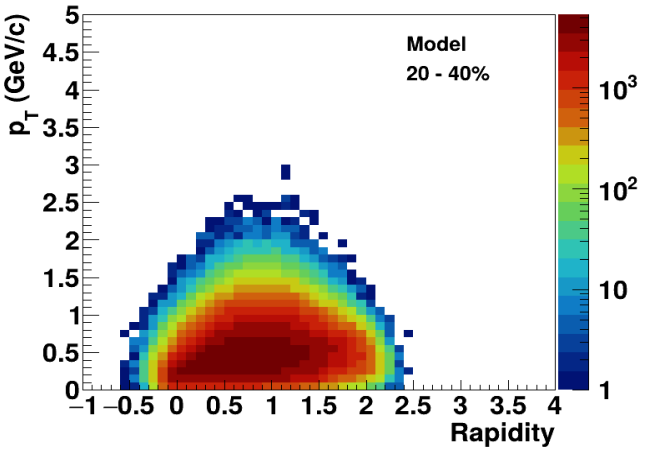


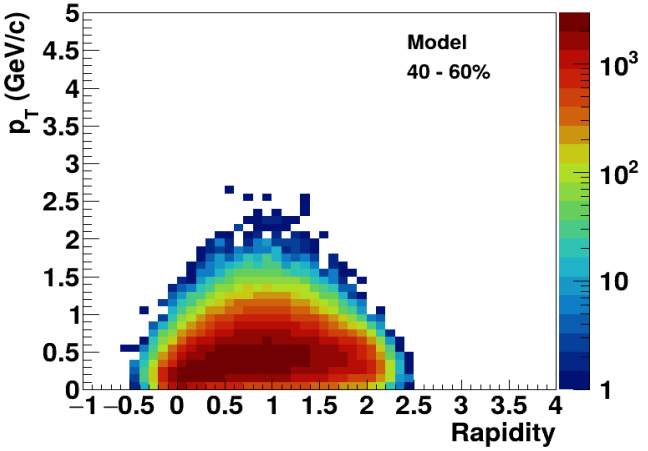


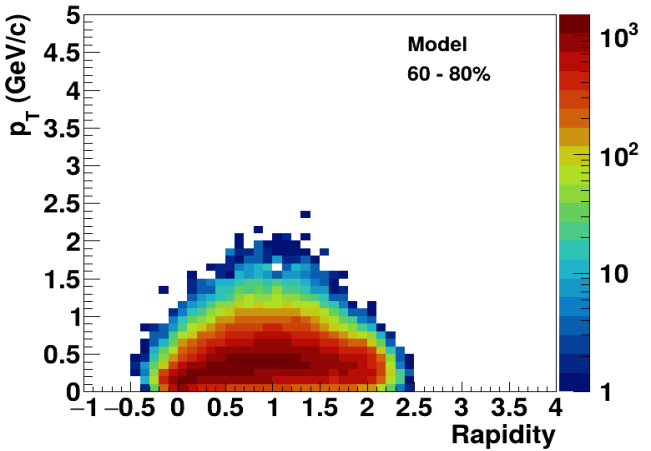


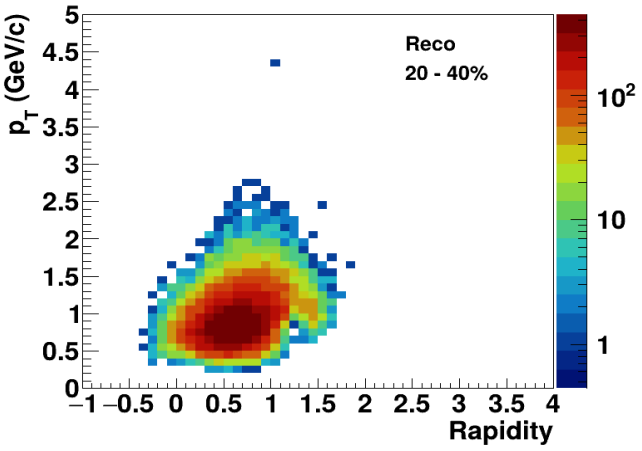
- ✓ ***Selection: y = ±0.2 (y= 0.986)***
- ✓ ***Centrality bins: 0-10%, 10-20%, 20-40%, 40-60%, 60-80%***

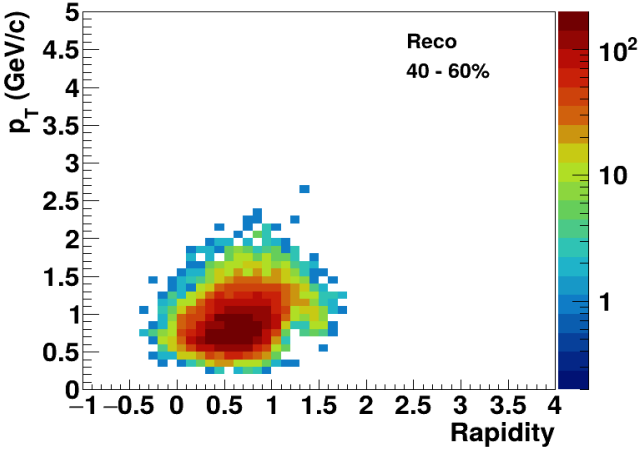
Λ Phase Space: Model vs Reconstruction

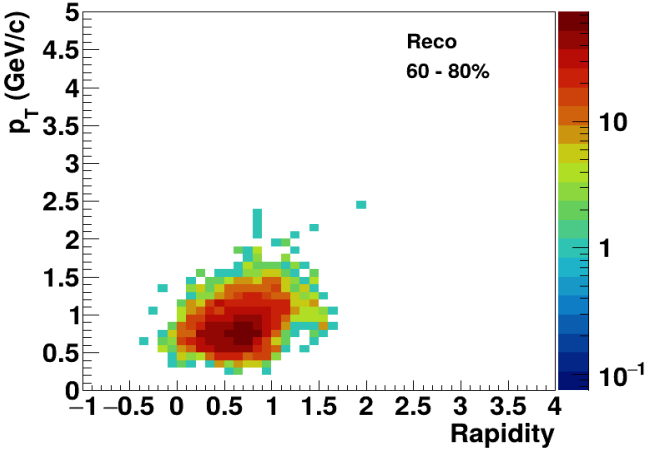




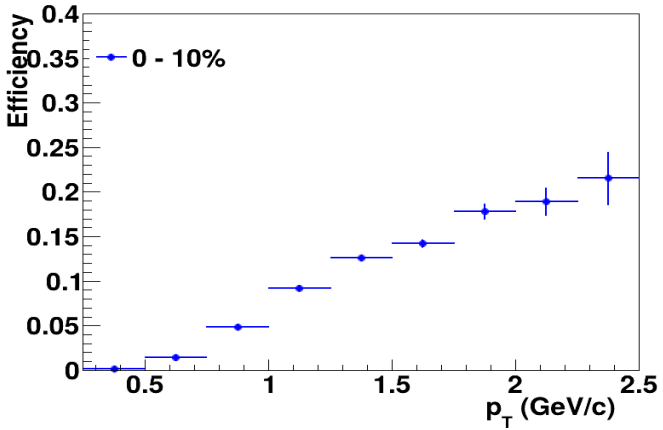


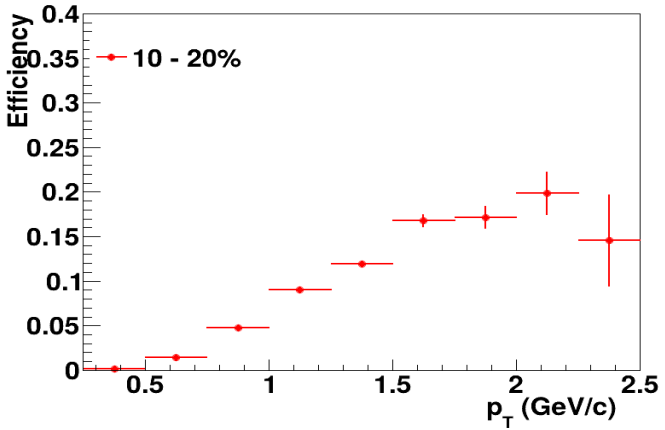


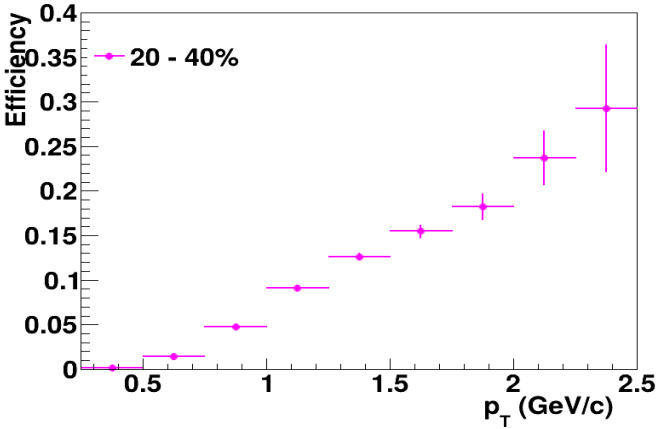


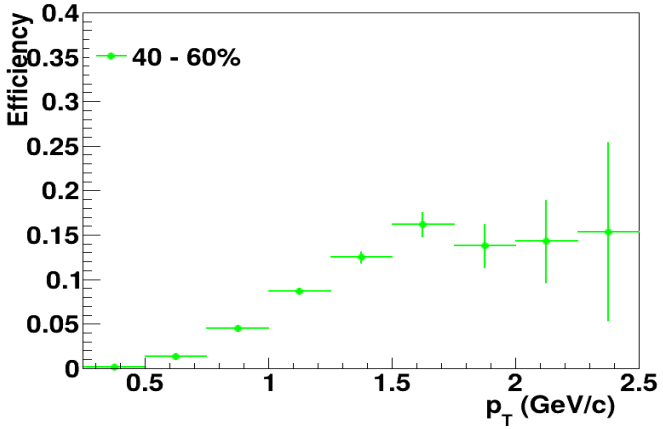


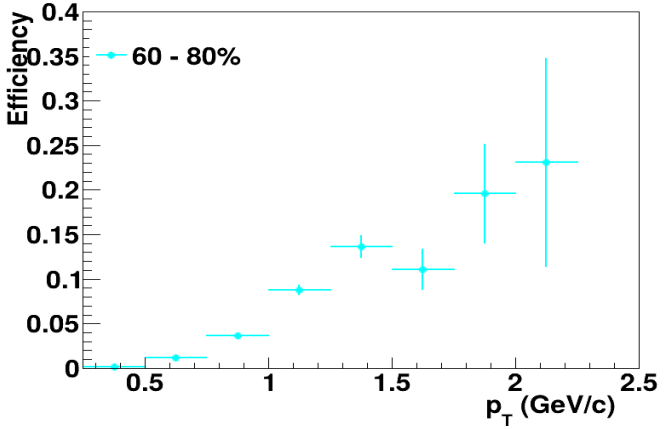
Λ Reconstruction Efficiency in Centrality Classes

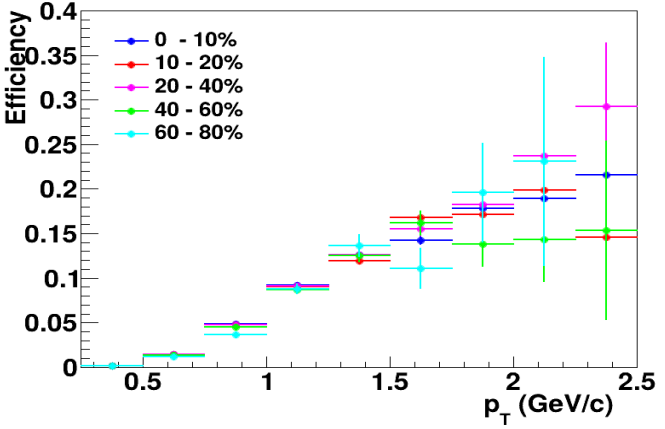






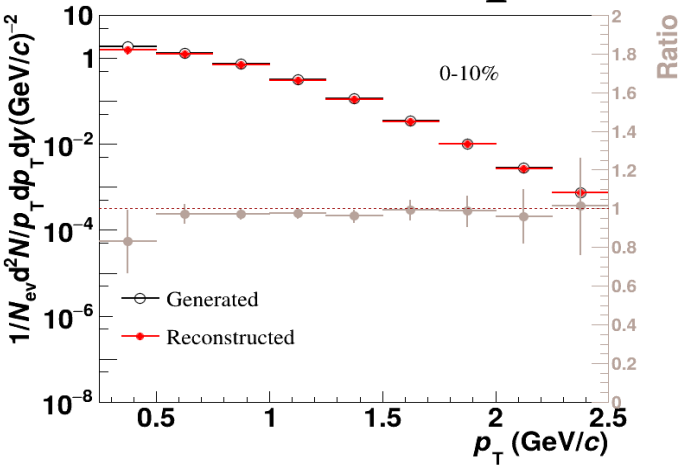


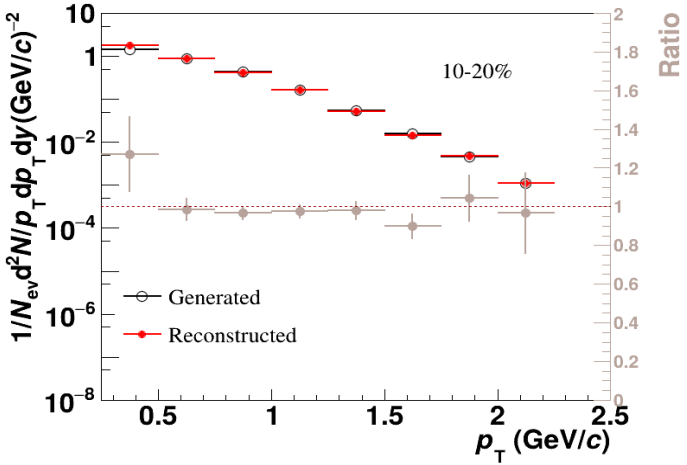


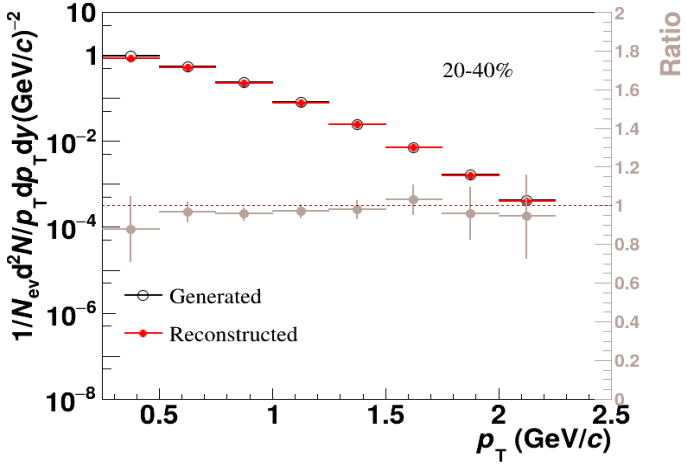


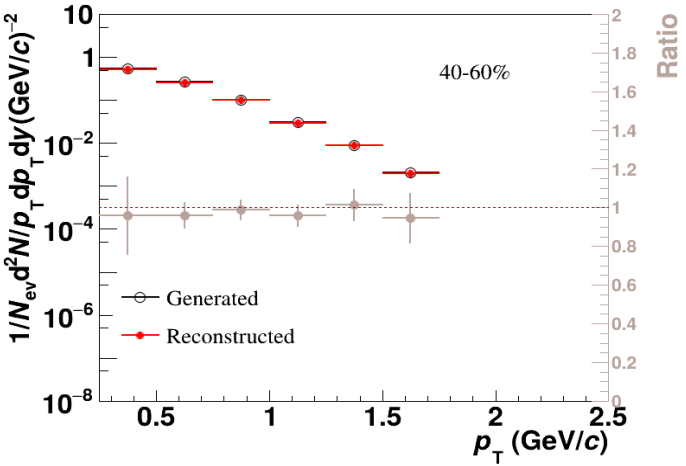
Reconstruction efficiency increases with p_T for all centralities.

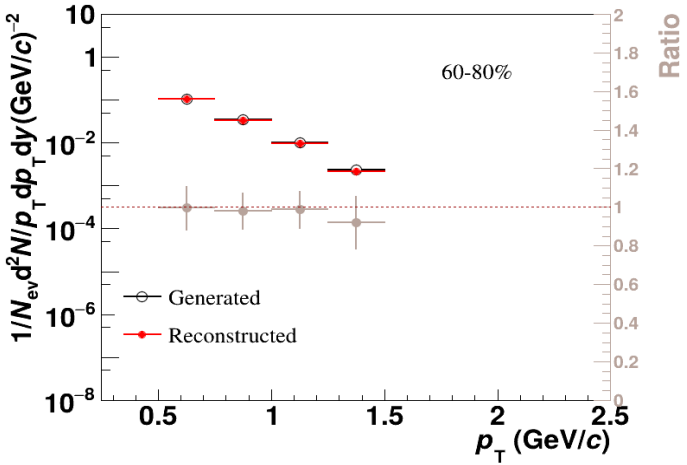
Invariant p_T -spectrum of Λ in Centrality Classes

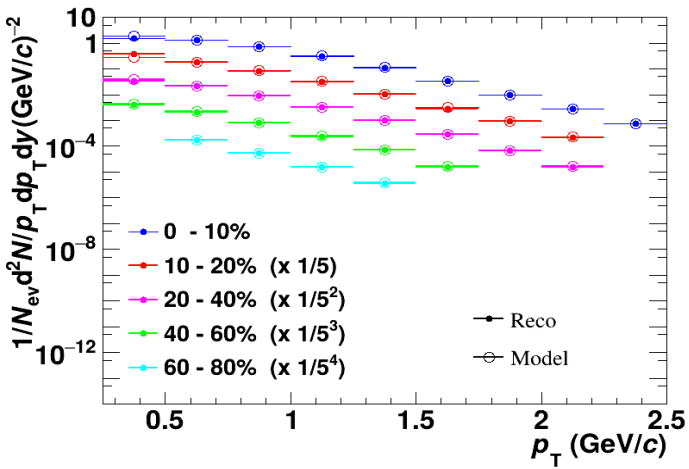






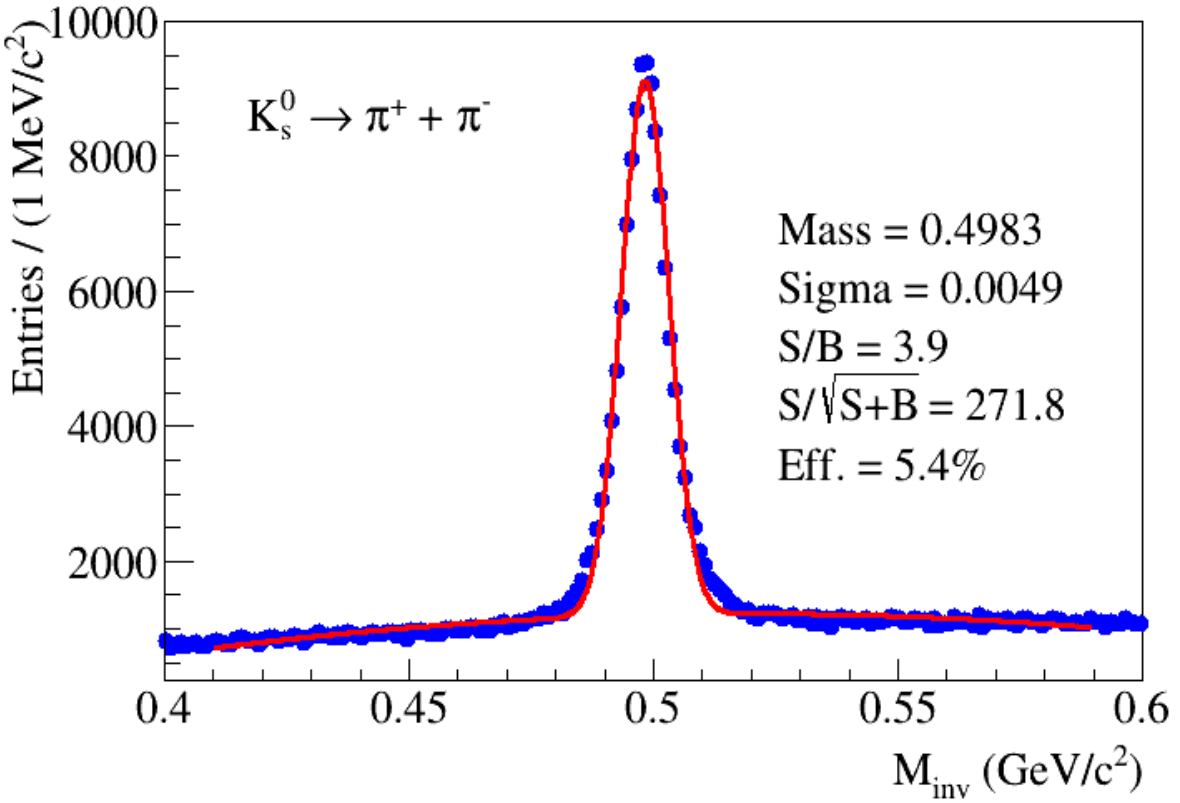






Generated and reconstructed Λ spectra are in good agreement for all centralities.

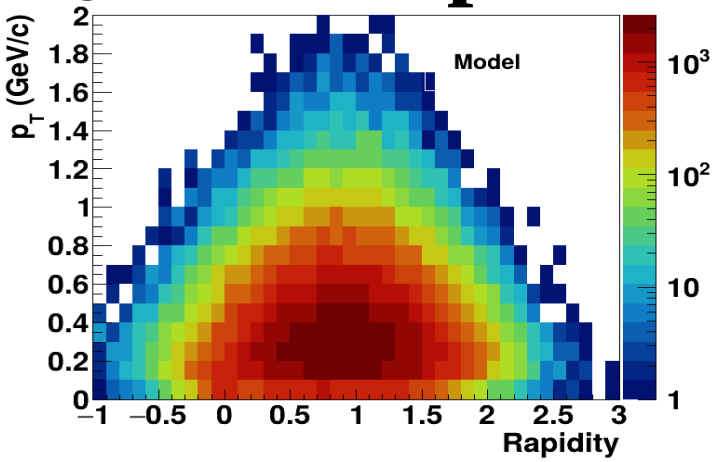
Invariant Mass K^0_s in MPD FXT Mode

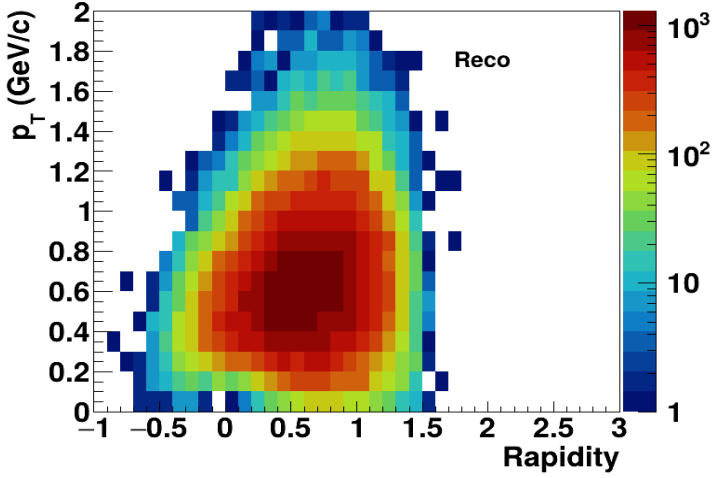


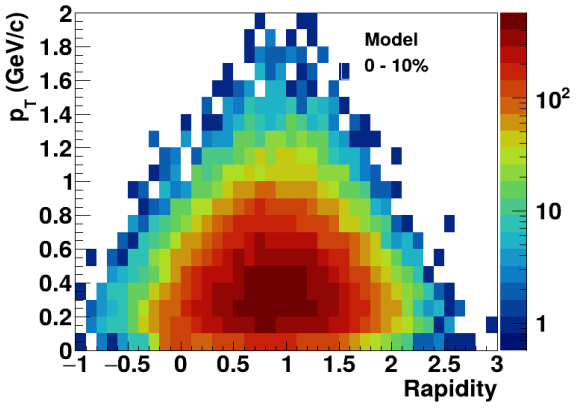
Variable	Cut Value
$\chi^2_{\pi-}$	> 12
$\chi^2_{\pi+}$	> 14
χ^2_{V0}	< 11
dca	< 1
$angle$	< 0.15

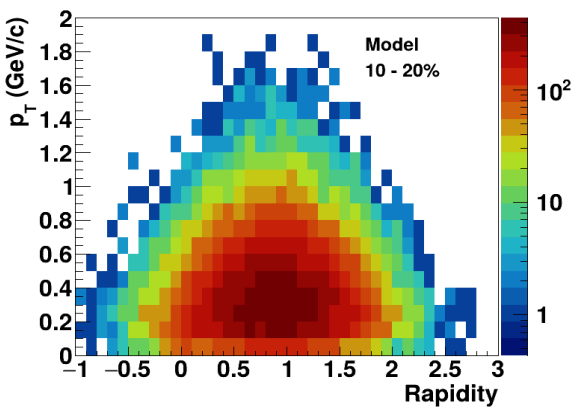
Applied topological cuts ensure good signal significance and efficiency.

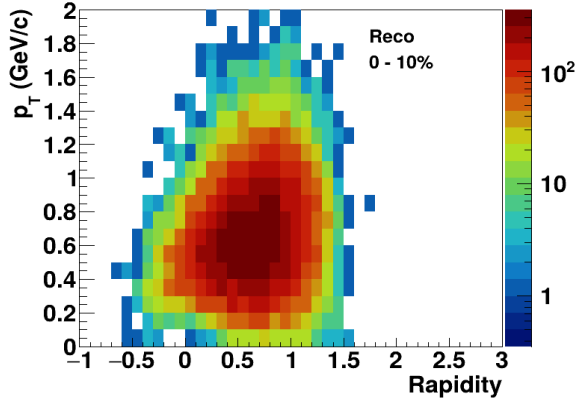
K^0_S Phase Space: Model vs Reconstruction

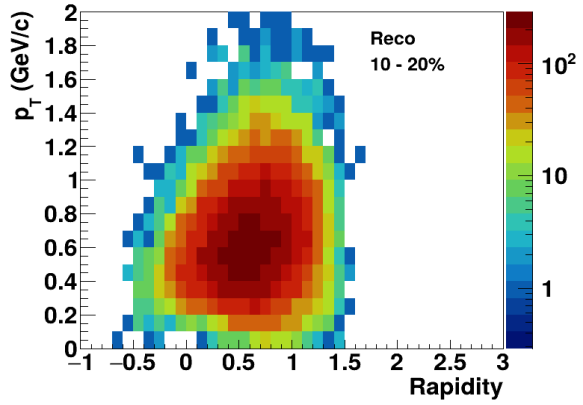






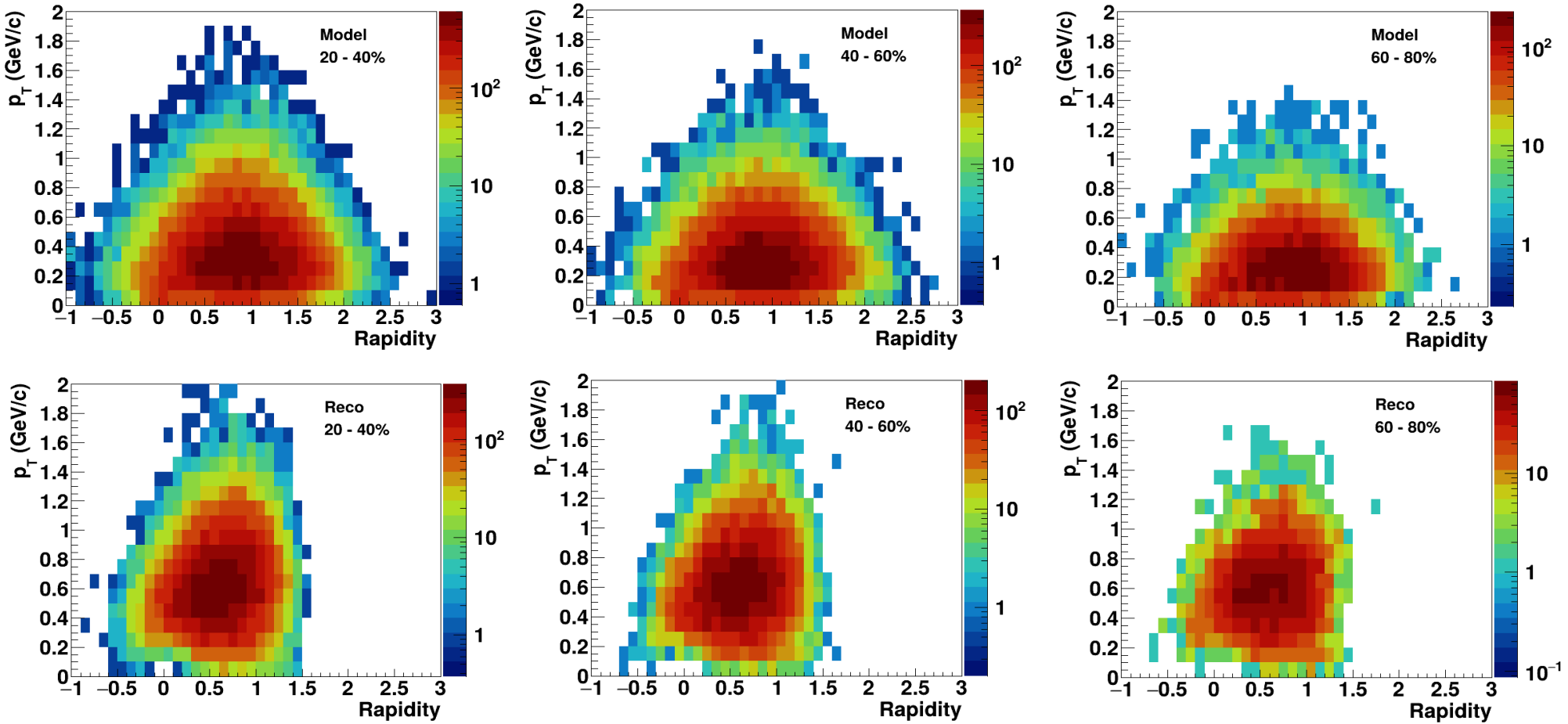




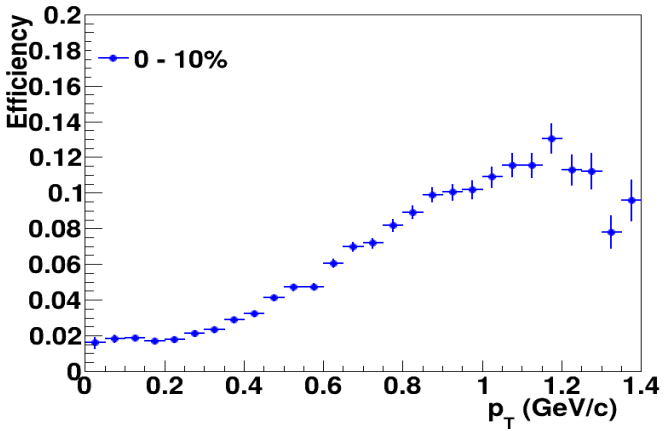


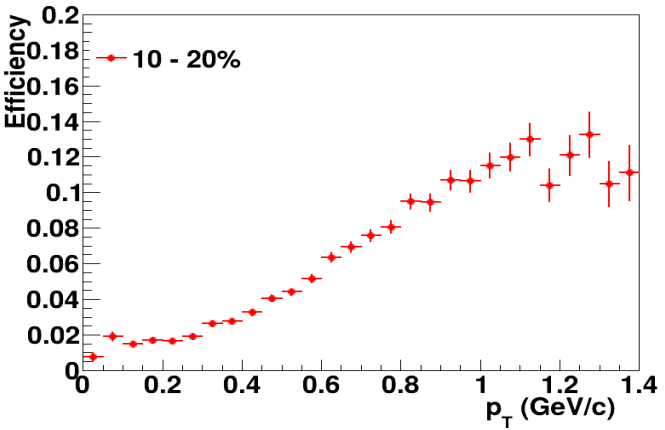
- ✓ **Selection: $y = \pm 0.3$ (y= 0.986)**
- ✓ **Centrality bins: 0-10%, 10-20%, 20-40%, 40-60%, 60-80%**

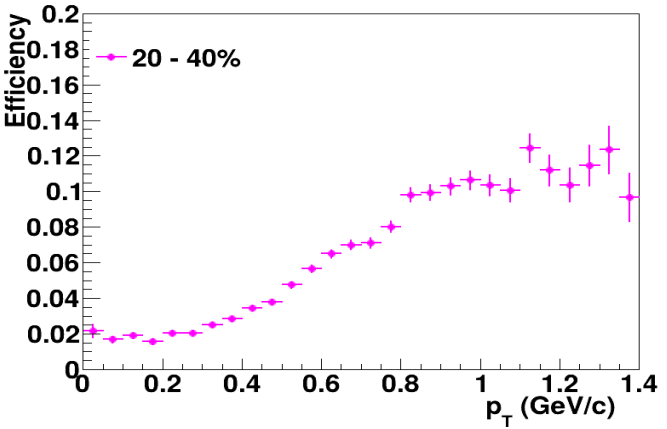
K^0_S Phase Space in Centrality Intervals

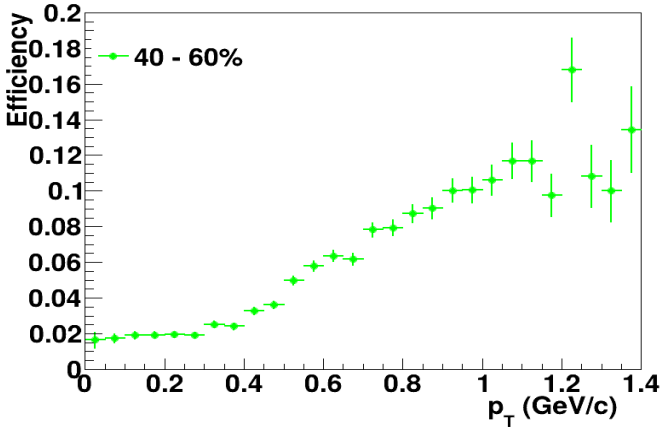


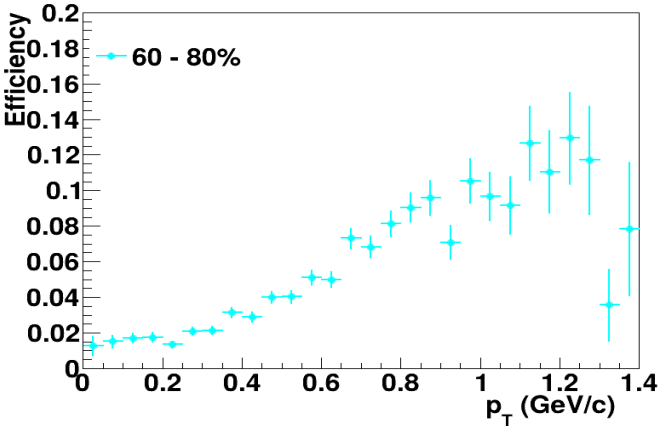
K_S^0 Reconstruction Efficiency in Centrality Classes

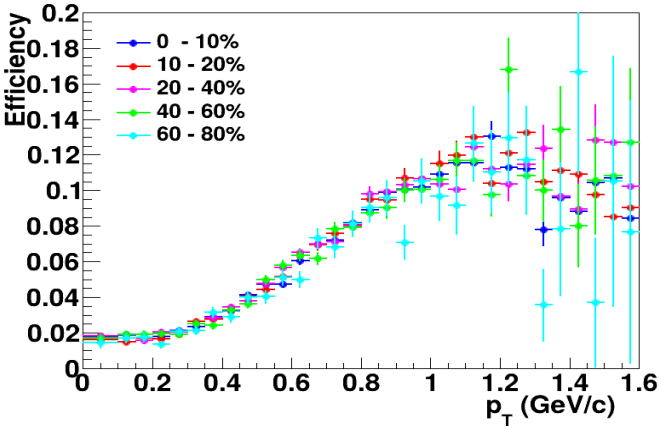






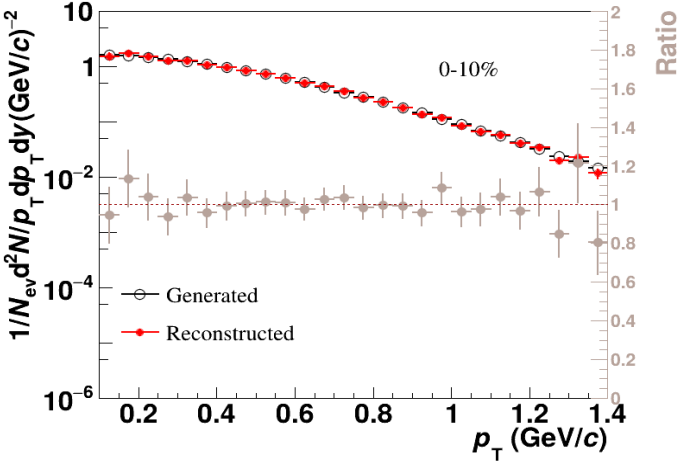


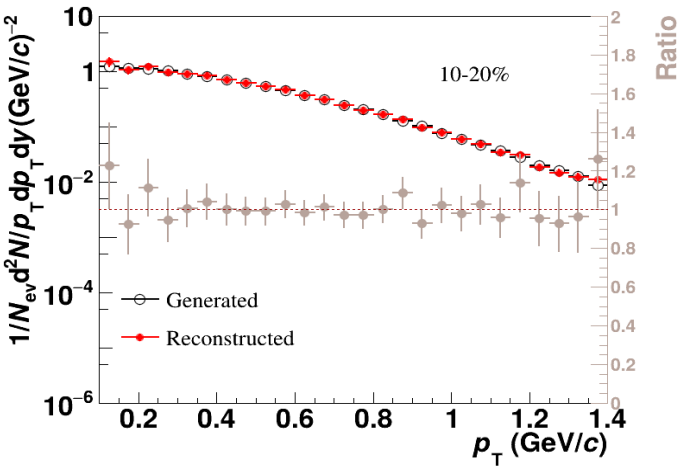


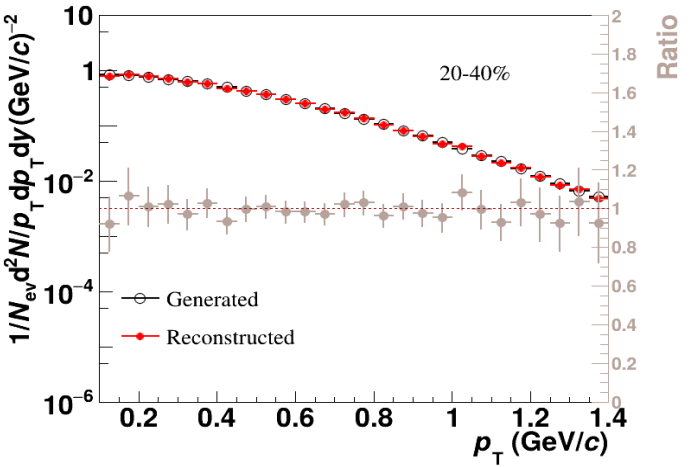


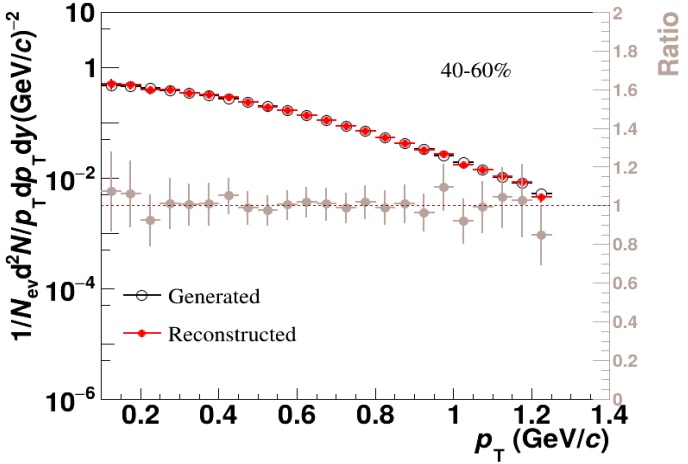
K_s^0 reconstruction follows the Λ trend, reaching ~14% efficiency.

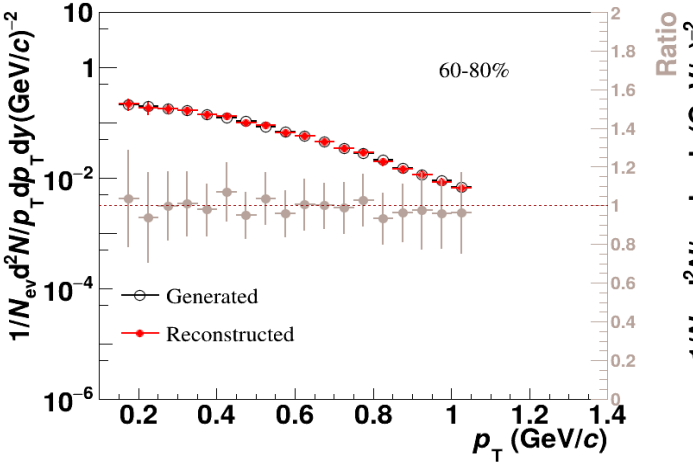
Invariant p_T-spectrum of K^0_S in Centrality Classes

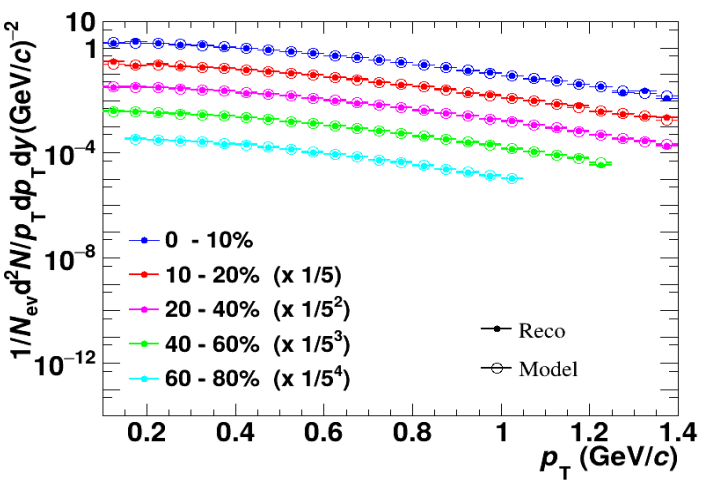












Summary

- **The MPD detector shows good performance in FXT mode for strange particle studies using the same reconstruction procedure as for the collider mode.**
- **Invariant mass and p_T-spectra are reliably reconstructed, showing agreement with generated distributions.**
- **The analysis methodology, validated in Collider Mode is proven in FXT conditions.**
- **These results confirm the feasibility of strange particle studies with MPD in the FXT setup and provide a solid basis for future physics measurements.**

Thank you for your attetion!