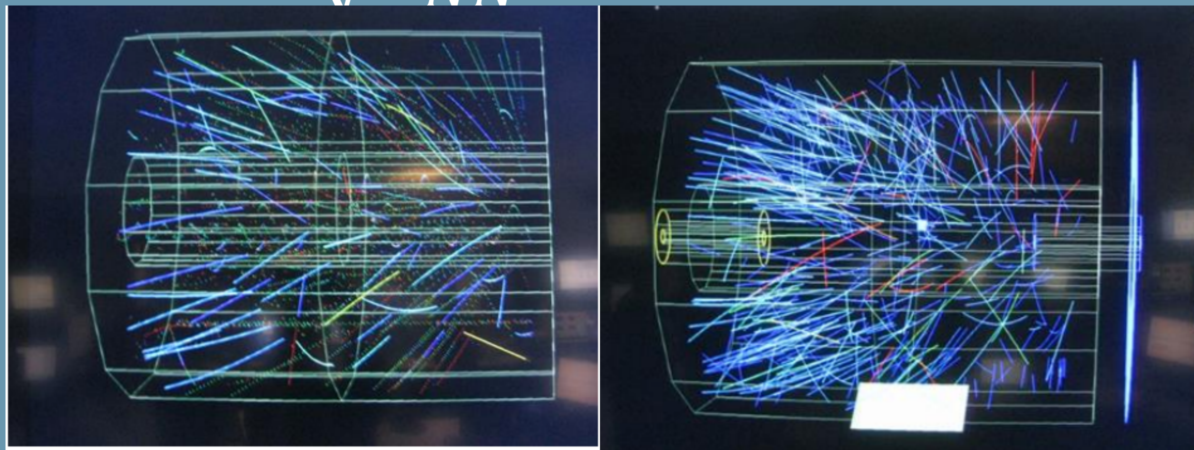
Strange Hadrons (K_S^0 and Λ) Production in Fixed-Target Al+Au at $\sqrt{S_{NN}}$ = 4.9 GeV and Au+Au at $\sqrt{S_{NN}}$ = 4.5 GeV in STAR



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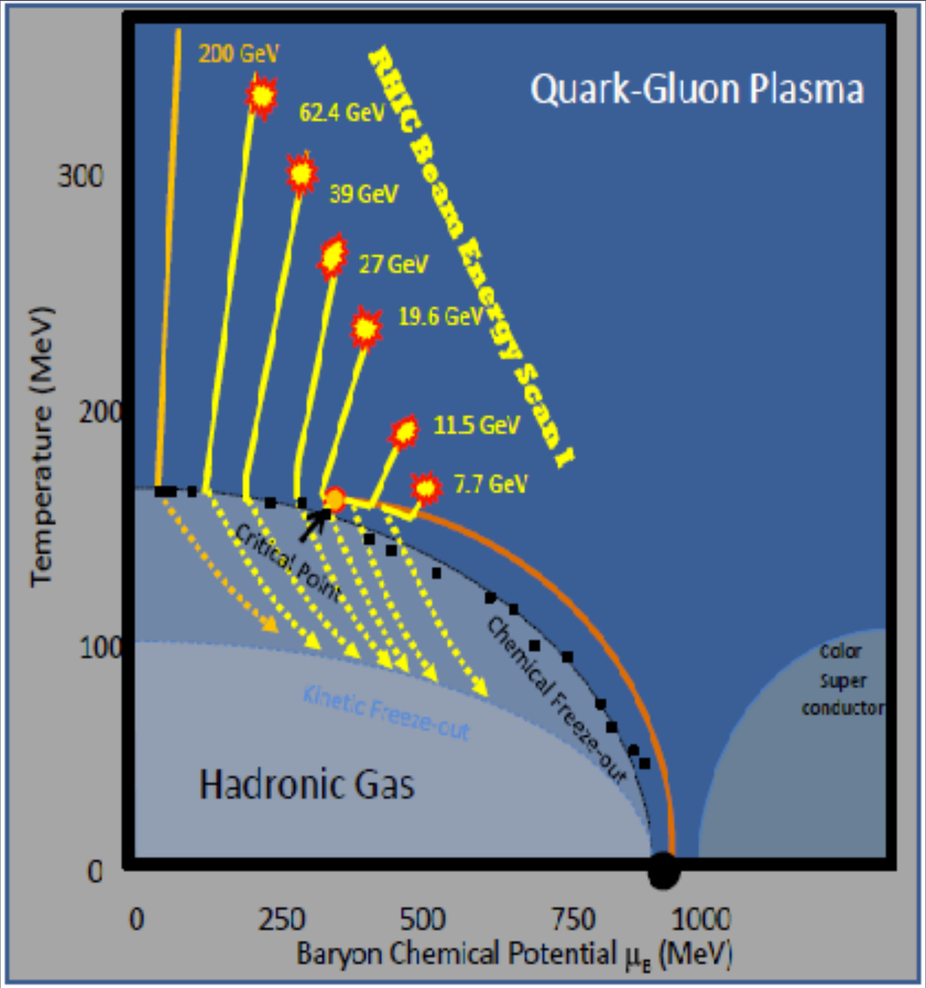
Critical Point and Onset of Deconfinement CPOD 2017

Stony Brook University

Outline

- Introduction to Fixed-Target (FXT) Program
- Overview of STAR Detector
- STAR FXT Geometry
- Mid-rapidity K_S^0 and Λ production in FXT Au+Au and Al+Au collisions
  - p_T and m_T-m_0 spectra
  - Particle yields and comparison with AGS experiments
- Future upgrades and FXT program
- Summary

BES-I Program

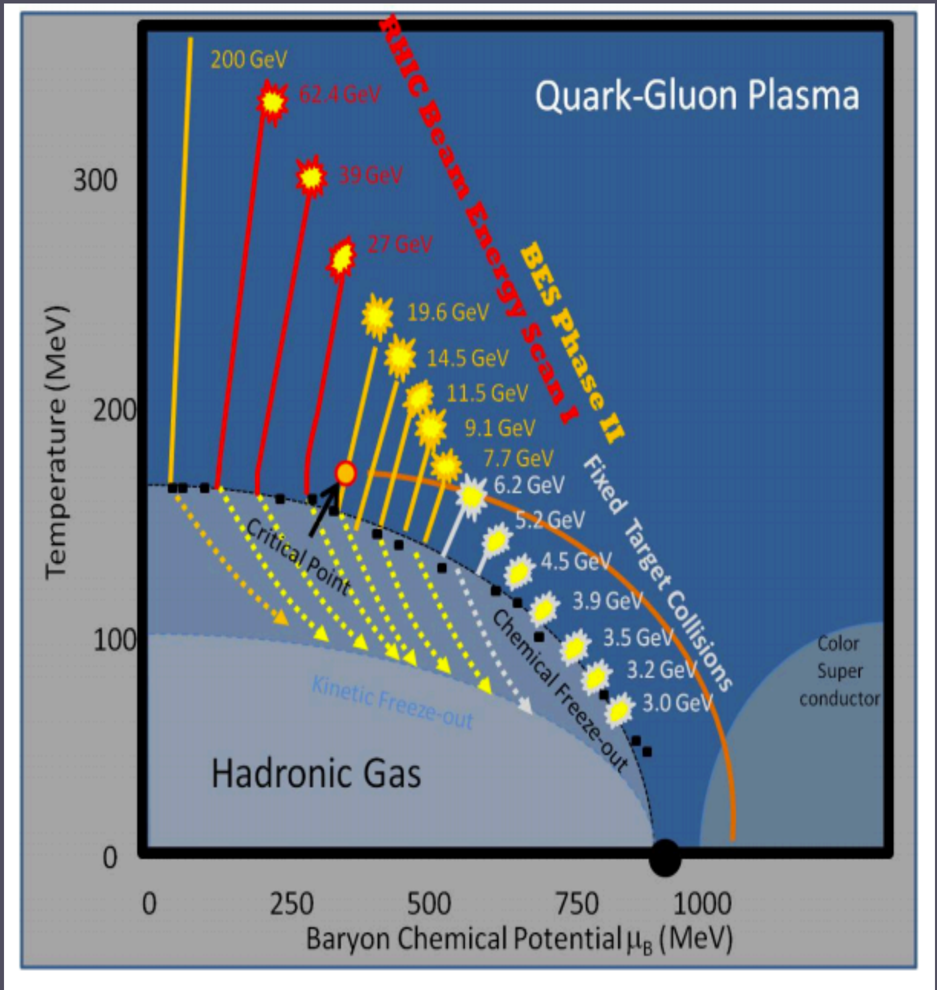


STAR, arXiv:1007.2613

- BES phase I at RHIC
  - Study the **onset of de-confinement** and **phase boundary**
  - Search the **QCD critical point**
  - Turn-off of QGP signals
  - Softening of the equation of state
  - Find evidence of the possible first-order phase transition
- Systematic study of Au+Au collisions at 7.7, 11.5, 14.5, 19.6, 27, 39 GeV (BES Phase-I)

Need to probe lower energies!

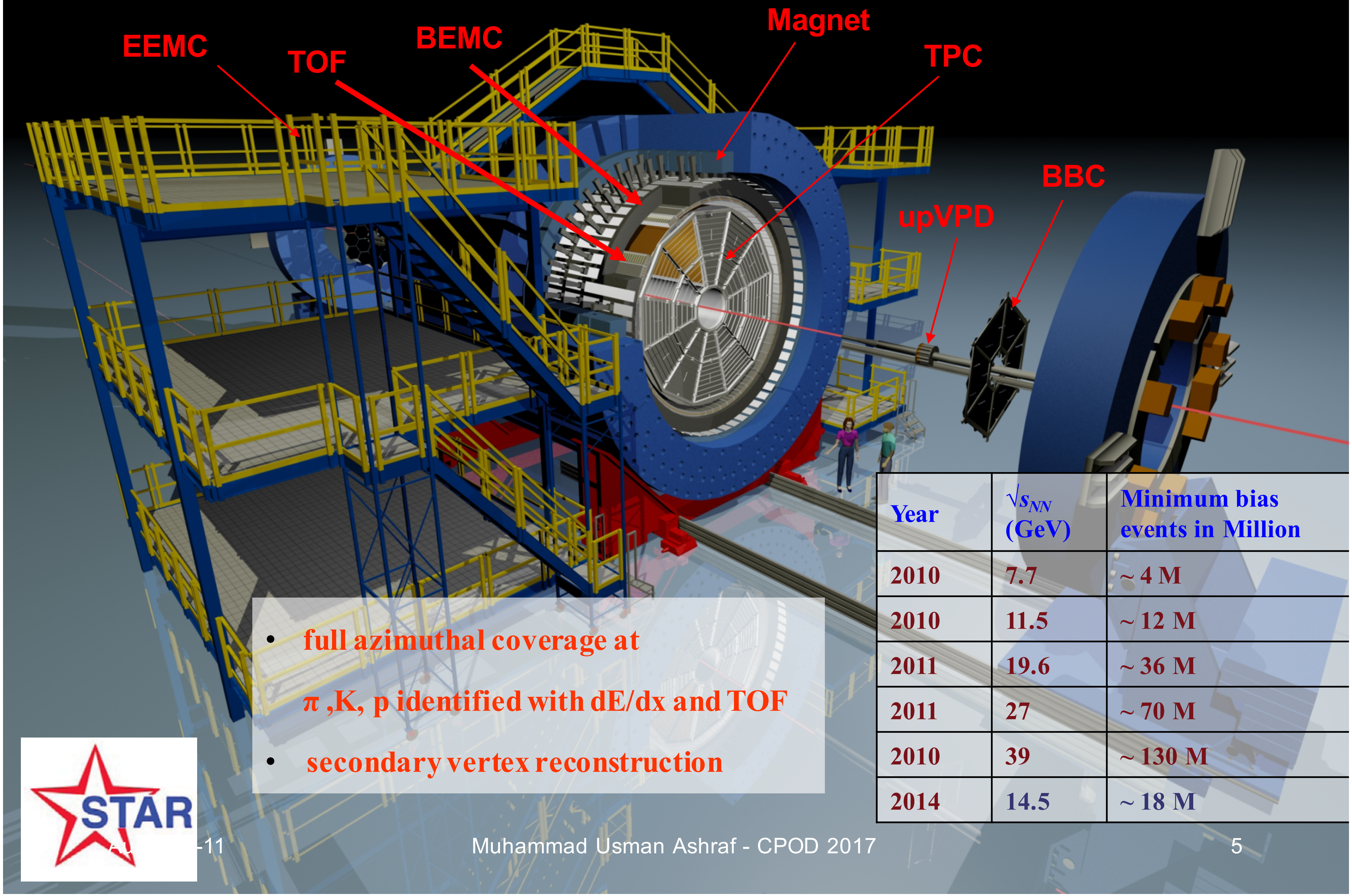
Motivation for a Fixed-Target Program



- NA49 has reported that the onset of deconfinement may occurs at 7 GeV, the low end of BES range.

- How to achieve low energy?
  - By installing a target inside the beam pipe and using RHIC beam as projectile.
  - It can extend the μ_B range from 400 MeV to about 720 MeV
  - Provide control measurements for searches of the critical point and onset of deconfinement

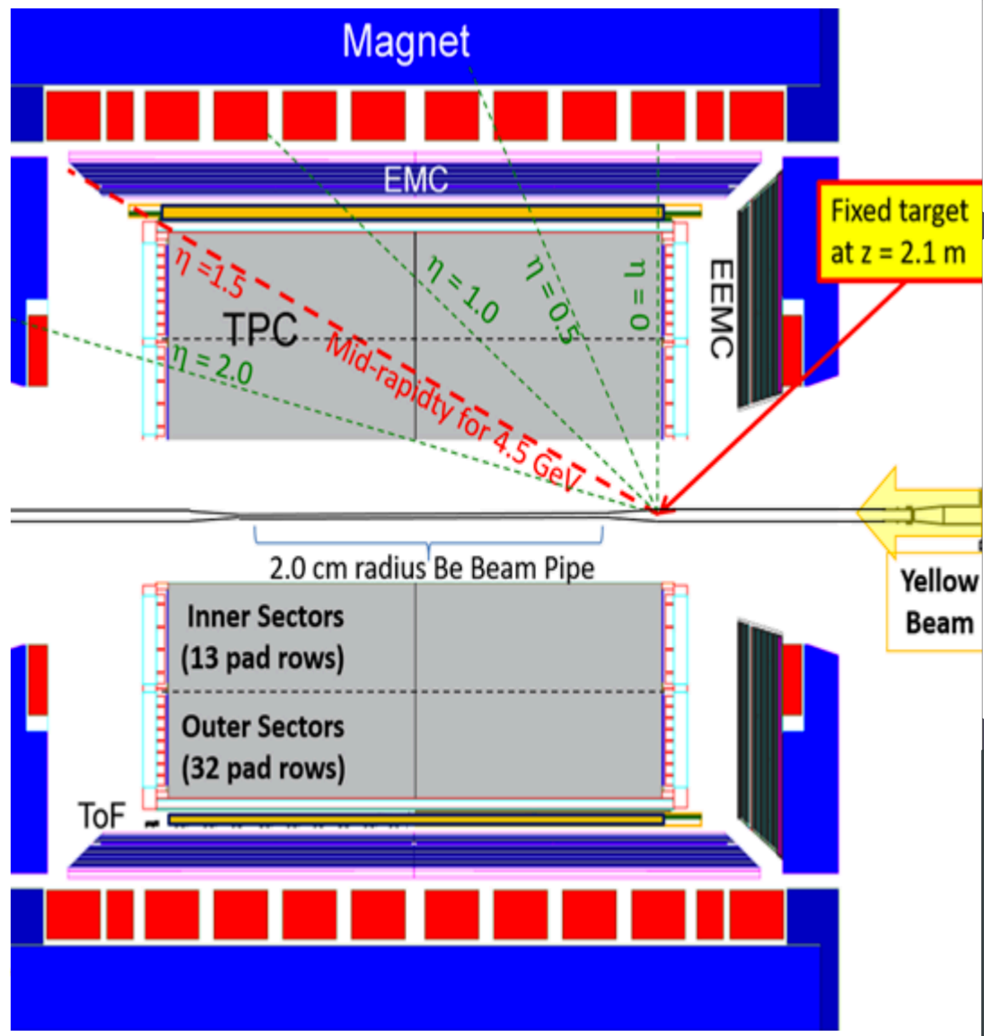
The Solenoidal Tracker At RHIC (STAR)



- full azimuthal coverage at
- π ,K, p identified with dE/dx and TOF
- secondary vertex reconstruction

Year	$\sqrt{s_{NN}}$ (GeV)	Minimum bias events in Million
2010	7.7	~ 4 M
2010	11.5	~ 12 M
2011	19.6	~ 36 M
2011	27	~ 70 M
2010	39	~ 130 M
2014	14.5	~ 18 M

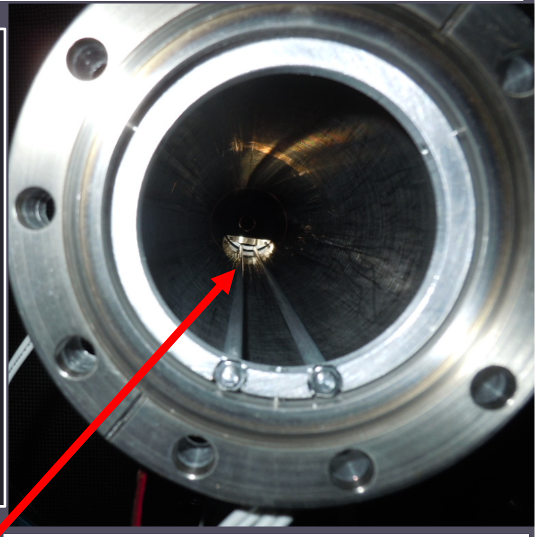
Fixed-Target Geometry

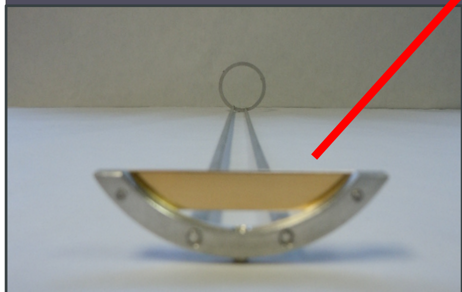


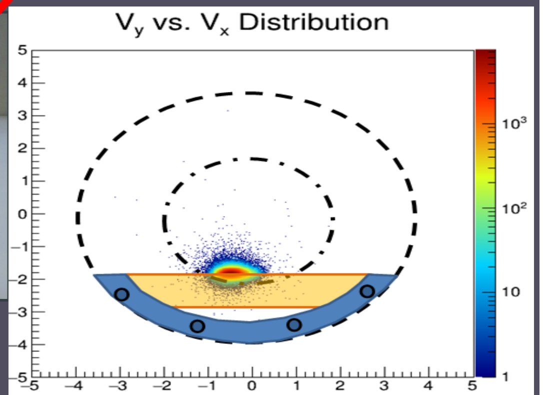
→target is outside of the STAR TPC at ~211 cm

→Gold foil is 1mm thick with about 4% of interaction probability

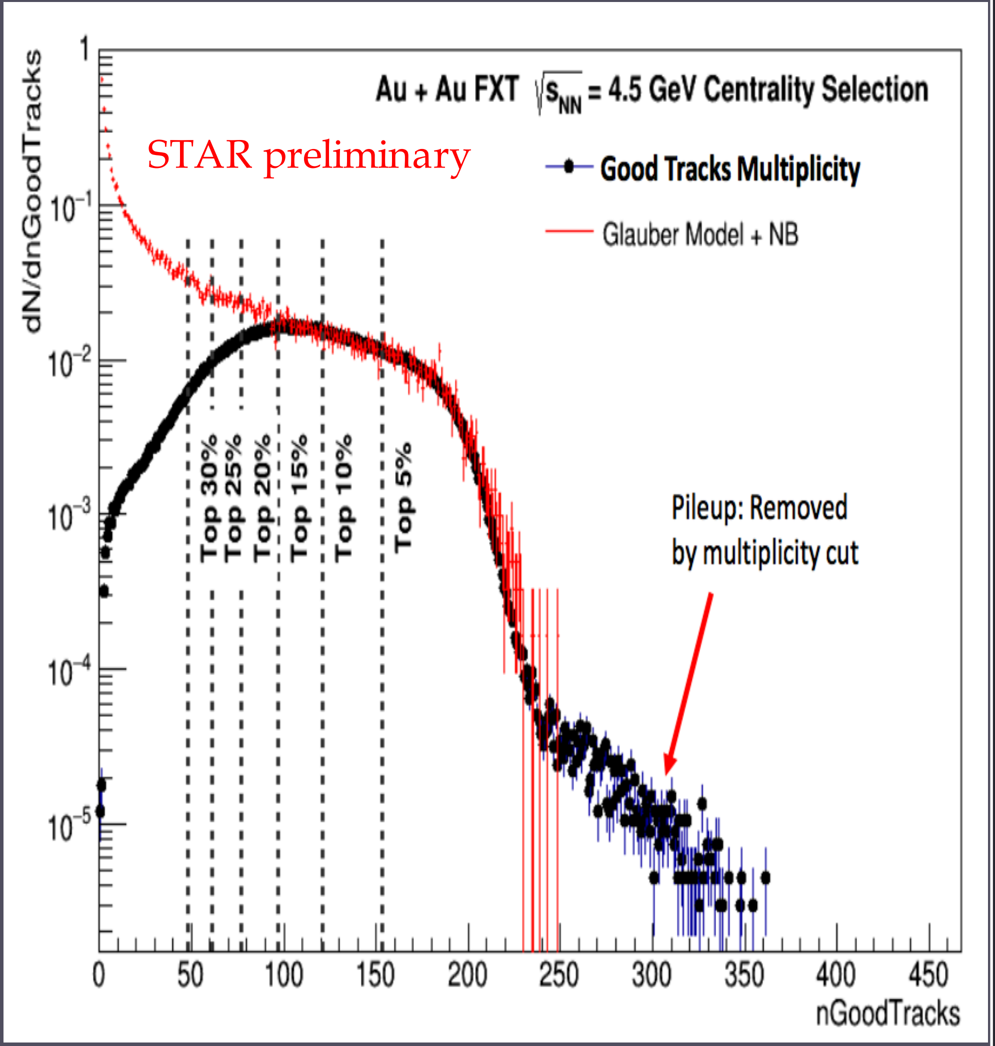
→1.3M Au+Au events with top 30% centrality trigger





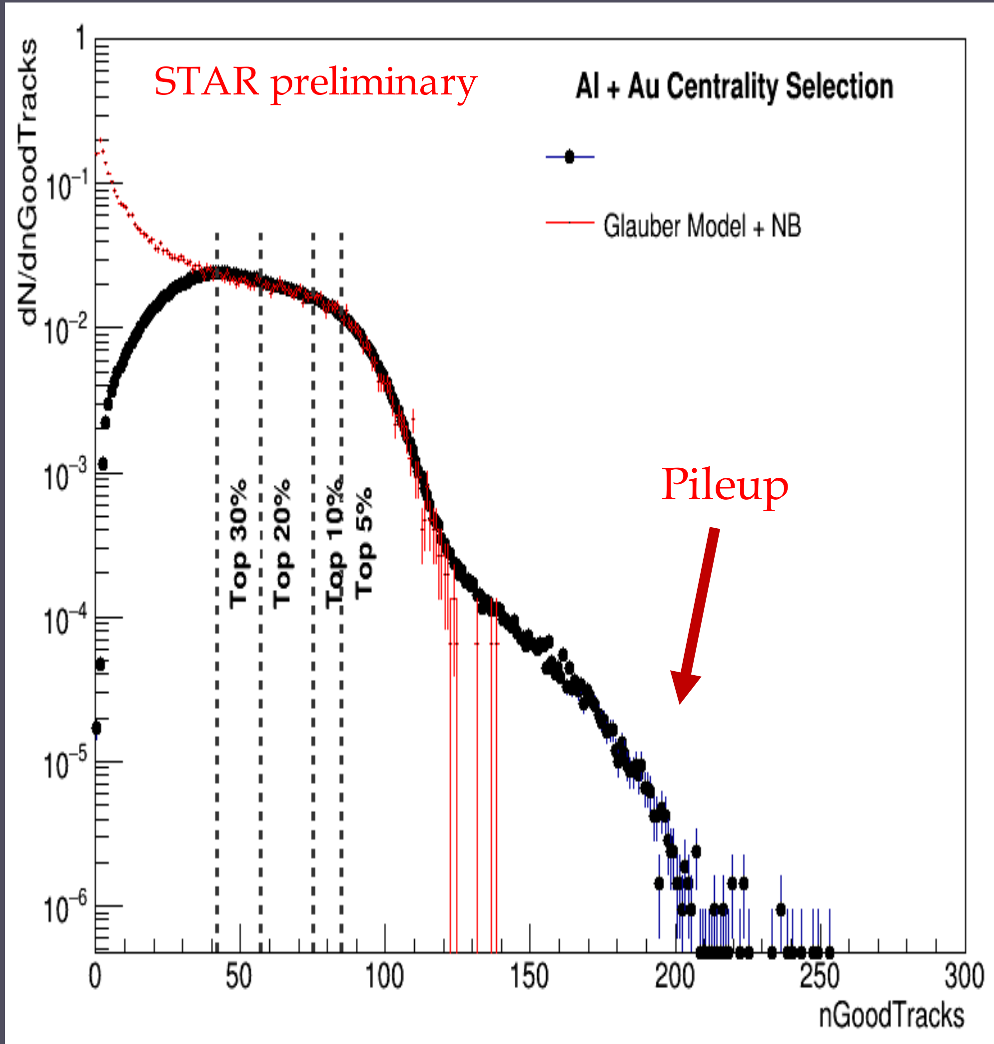


Centrality Determination for Au+Au at $\sqrt{S_{NN}} = 4.5$ GeV



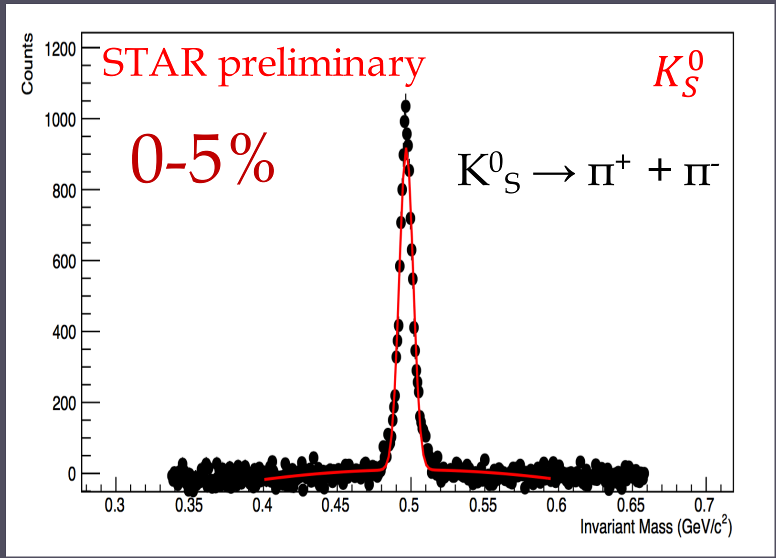
- Pileup has been removed by multiplicity cut.
- 15%-30% centralities are biased toward the more central collisions.
- nGoodTracks are those tracks which pass through basic QA cuts.
- This biasing is minimal for more central events.

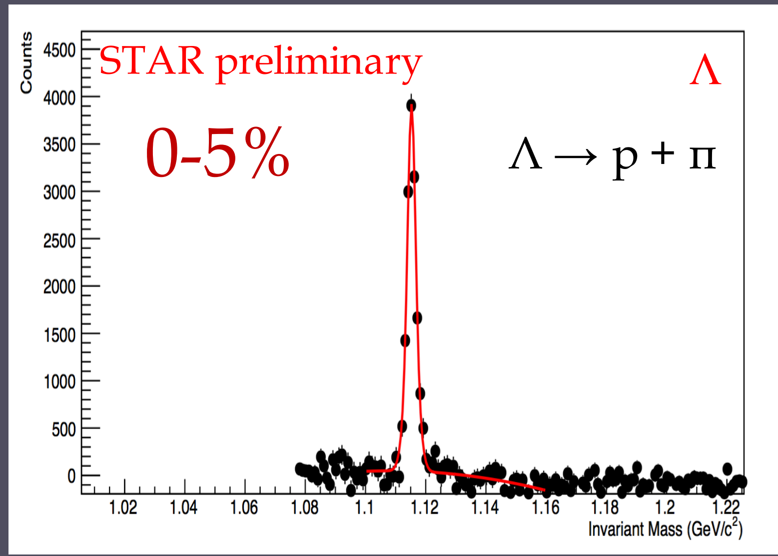
Centrality Determination for Al+Au at $\sqrt{S_{NN}} = 4.9$ GeV



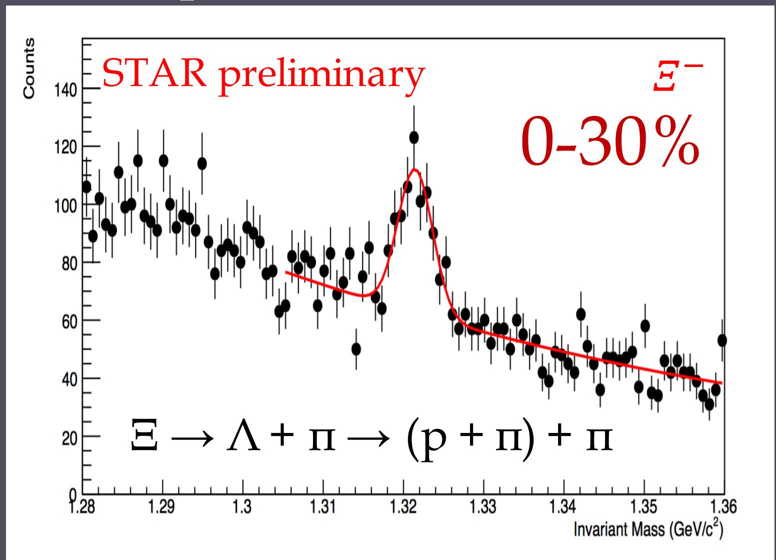
- 3.4 M Al+Au events collected with the top 30% centrality.
- It is not a beam pipe study.
- Pileup has been removed by multiplicity cut.

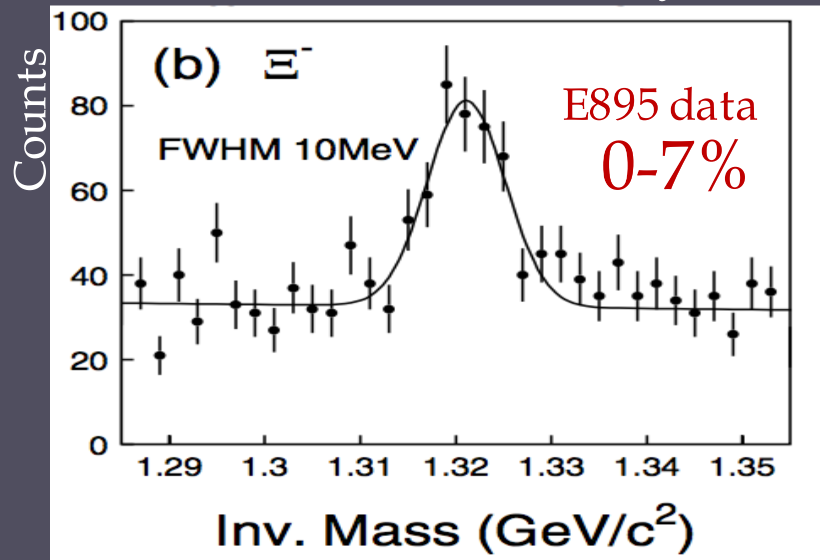
Particle Reconstruction Au+Au $\sqrt{S_{NN}}$ = 4.5 GeV





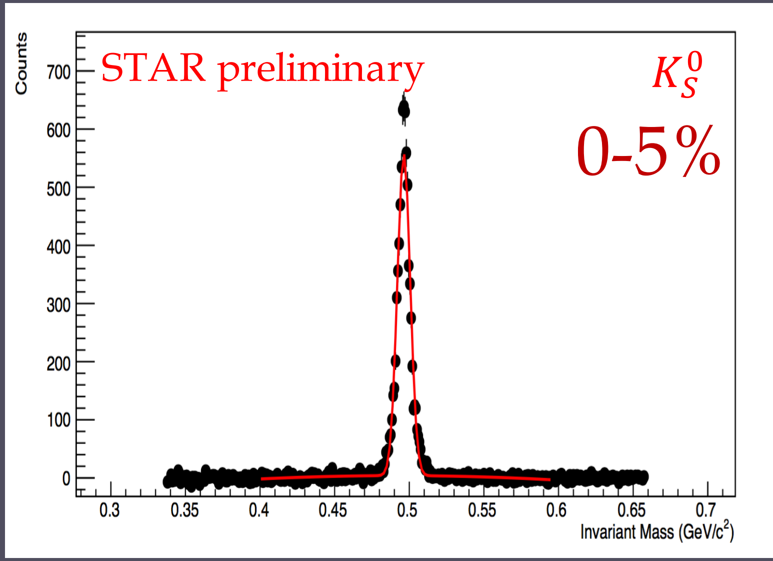
π ,K, p are identified with TPC dE/dx reconstruct the secondary vertex

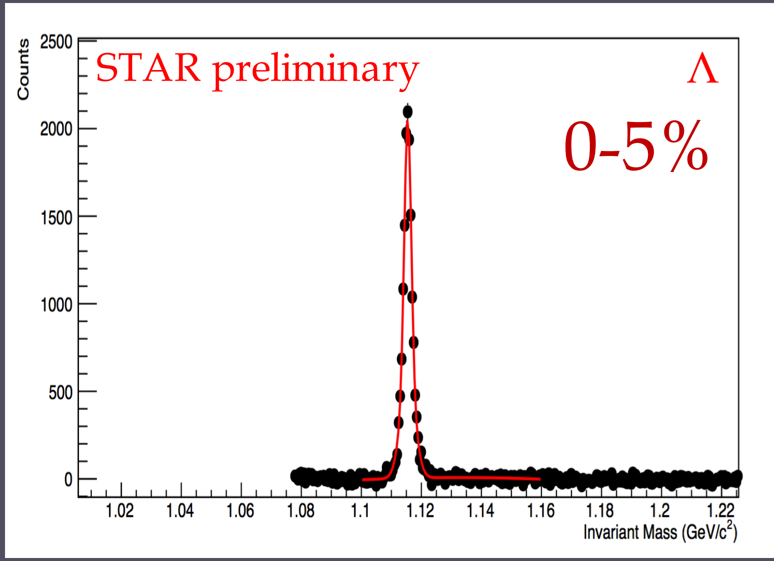




E895, PhysRevLett.91. (2003) 202301

Particle Reconstruction in Al+Au $\sqrt{S_{NN}}$ = 4.9 GeV



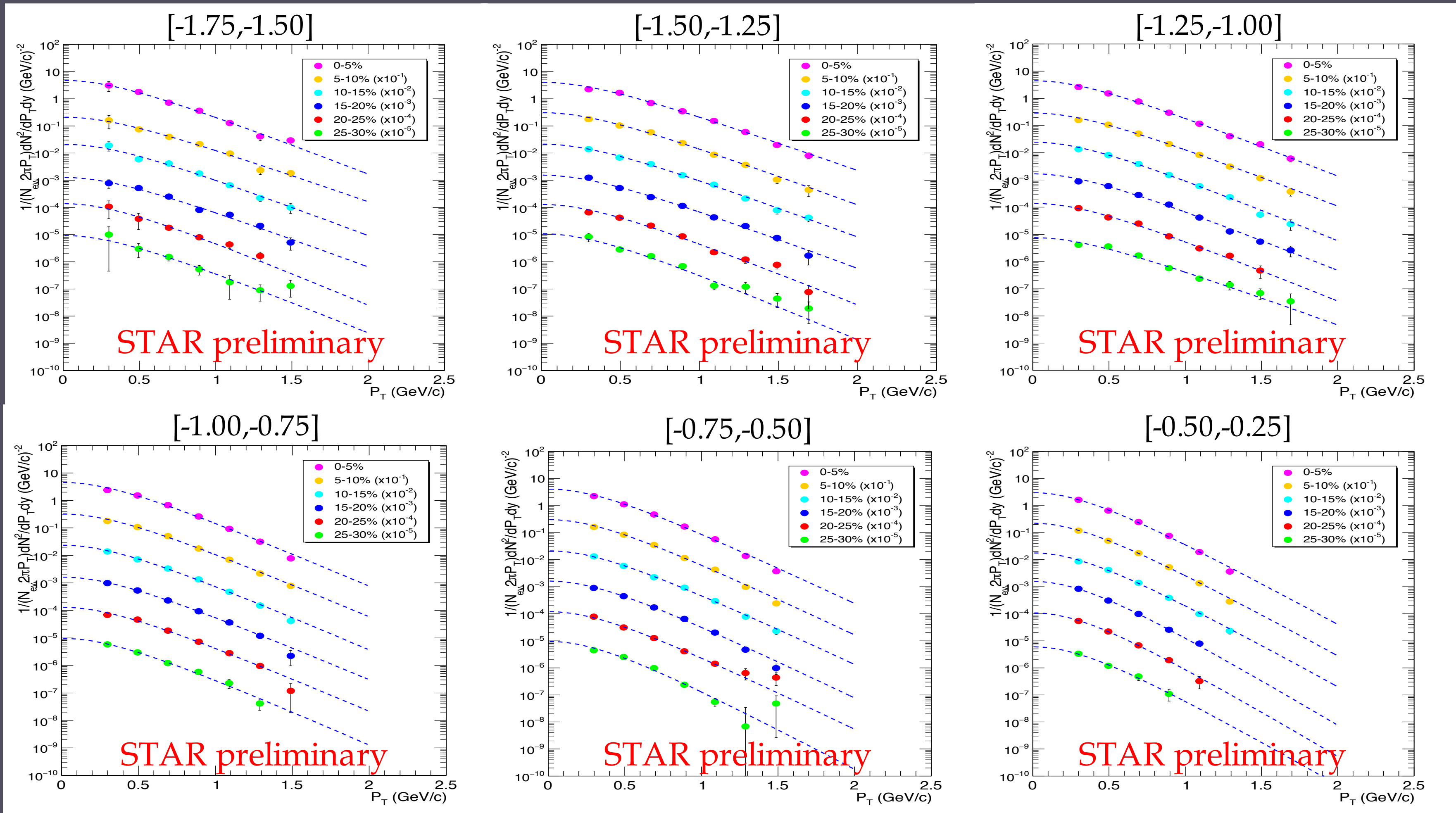


Al+Au at $\sqrt{S_{NN}}$ = 4.9 GeV, 0-5%

→ $K^0_S \to \pi^+ + \pi^-$
→ $\Lambda \to p + \pi$

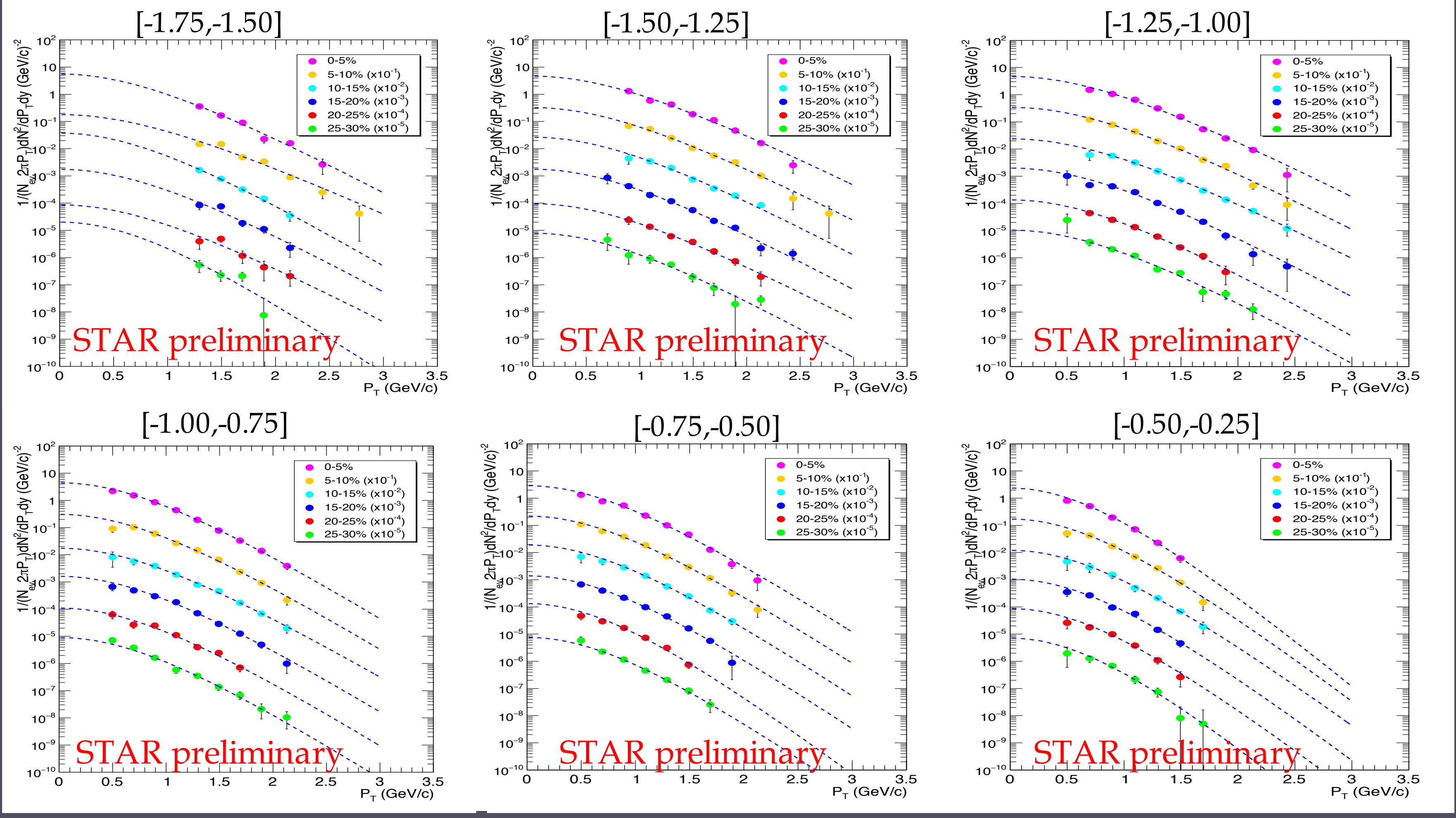
- ❑ π ,K, p are identified with TPC dE/dx
- ❑ Secondary vertex reconstruction

p_T spectra of K_S^0 in Au+Au $\sqrt{S_{NN}}$ = 4.5 GeV



- ➢ K_S^0 Spectra in **Different rapidity bins for FXT Au+Au at $\sqrt{S_{NN}}$ = 4.5 GeV.**
- ➢ Statistical errors only.
- ➢ 15-30% trigger is biased towards the most central.
  - → Spectra are extrapolated to high p_T with Stefan-Boltzmann fitting function.

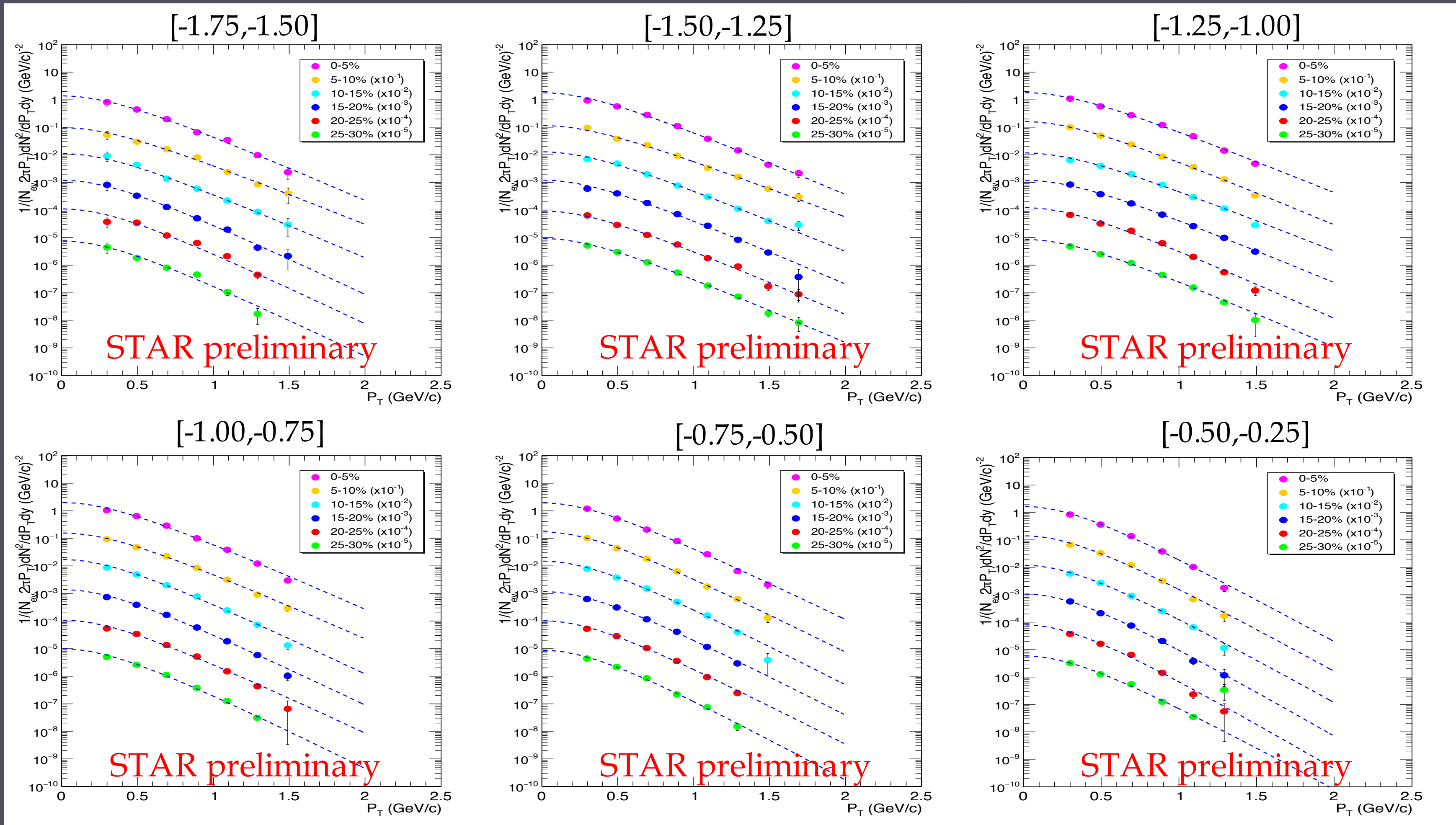
p_T spectra of Λ in Au+Au $\sqrt{S_{NN}}$ = 4.5 GeV



- Λ Spectra in **Different rapidity bins for FXT Au+Au at $\sqrt{S_{NN}}$ = 4.5 GeV.**
- Statistical errors only.
- 15-30% trigger is biased towards the most central.

  → Spectra are extrapolated to high p_T with Stefan-Boltzmann fitting function.

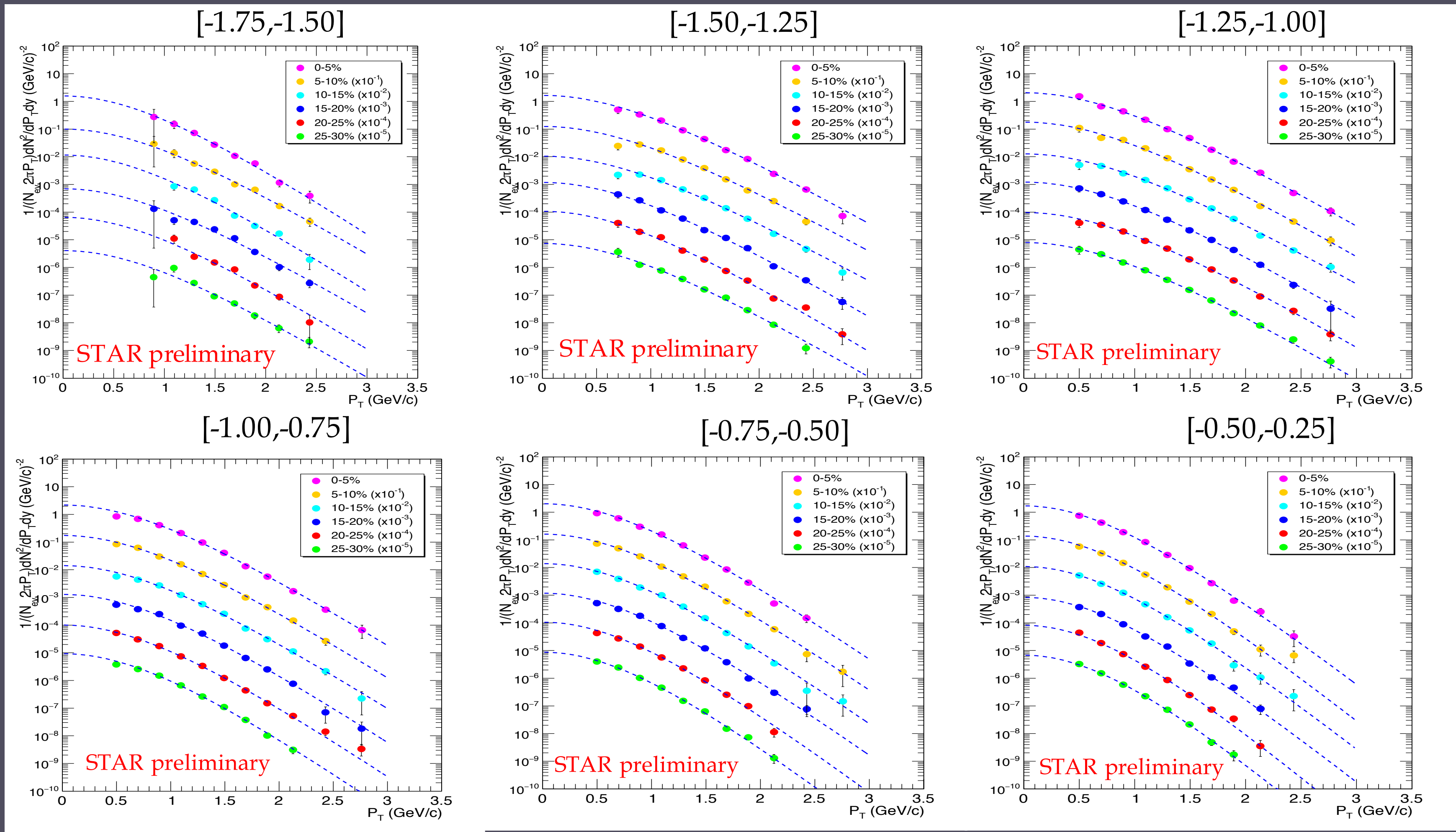
p_T spectra of K_S^0 in Al+Au $\sqrt{S_{NN}}$ = 4.9 GeV



- K_S^0 Spectra in **Different rapidity bins for FXT Al+Au at $\sqrt{S_{NN}}$ = 4.9 GeV.**
- Statistical errors only.

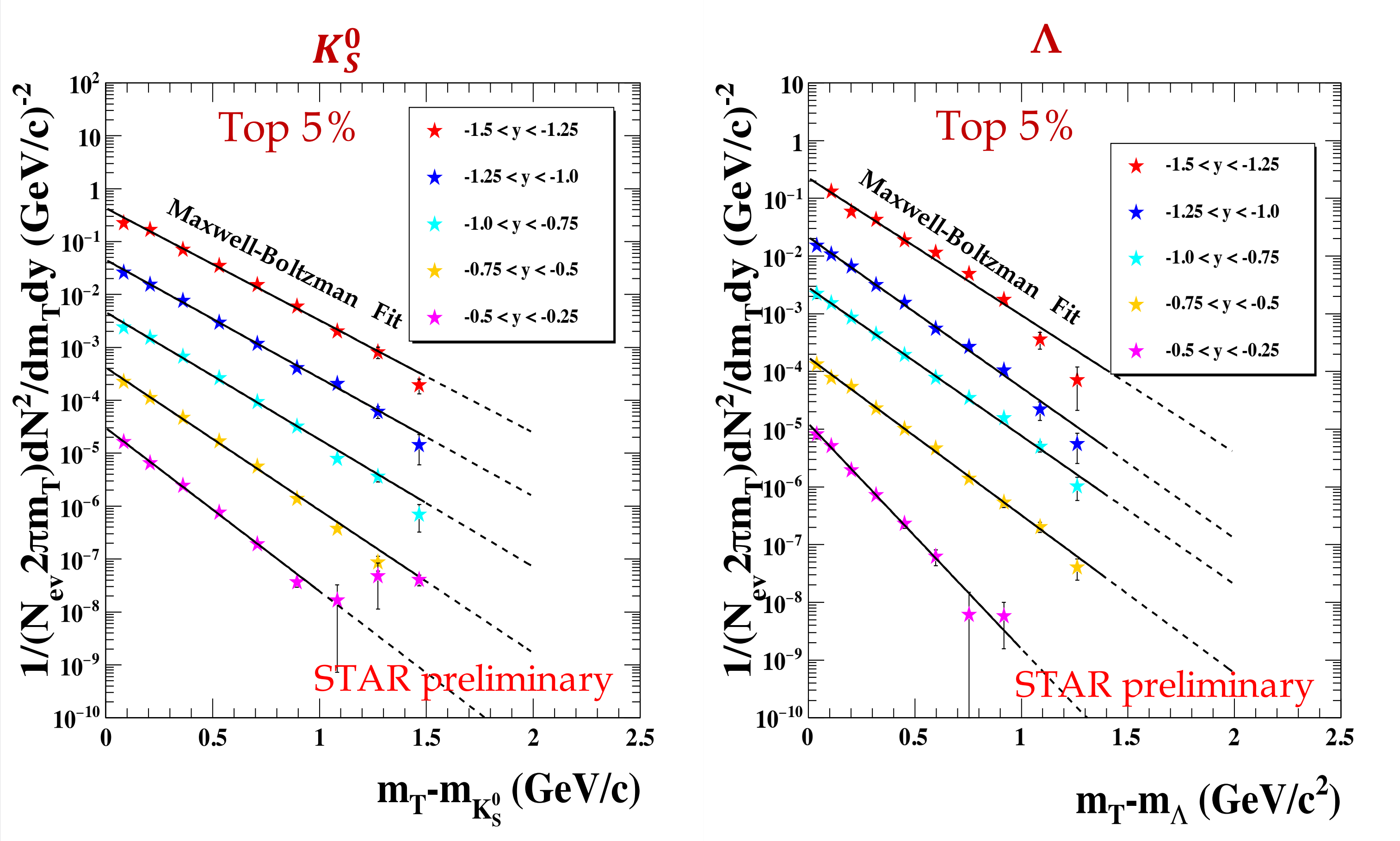
→ Spectra are extrapolated to high p_T with Stefan-Boltzmann fitting function.

p_T spectra of Λ in Al+Au $\sqrt{S_{NN}}$ = 4.9 GeV



- ➢ Λ Spectra in **Different rapidity bins for FXT Al+Au at $\sqrt{S_{NN}}$ = 4.9 GeV.**
- ➢ Statistical errors only.
- → Spectra are extrapolated to high p_T with Stefan-Boltzmann fitting function.

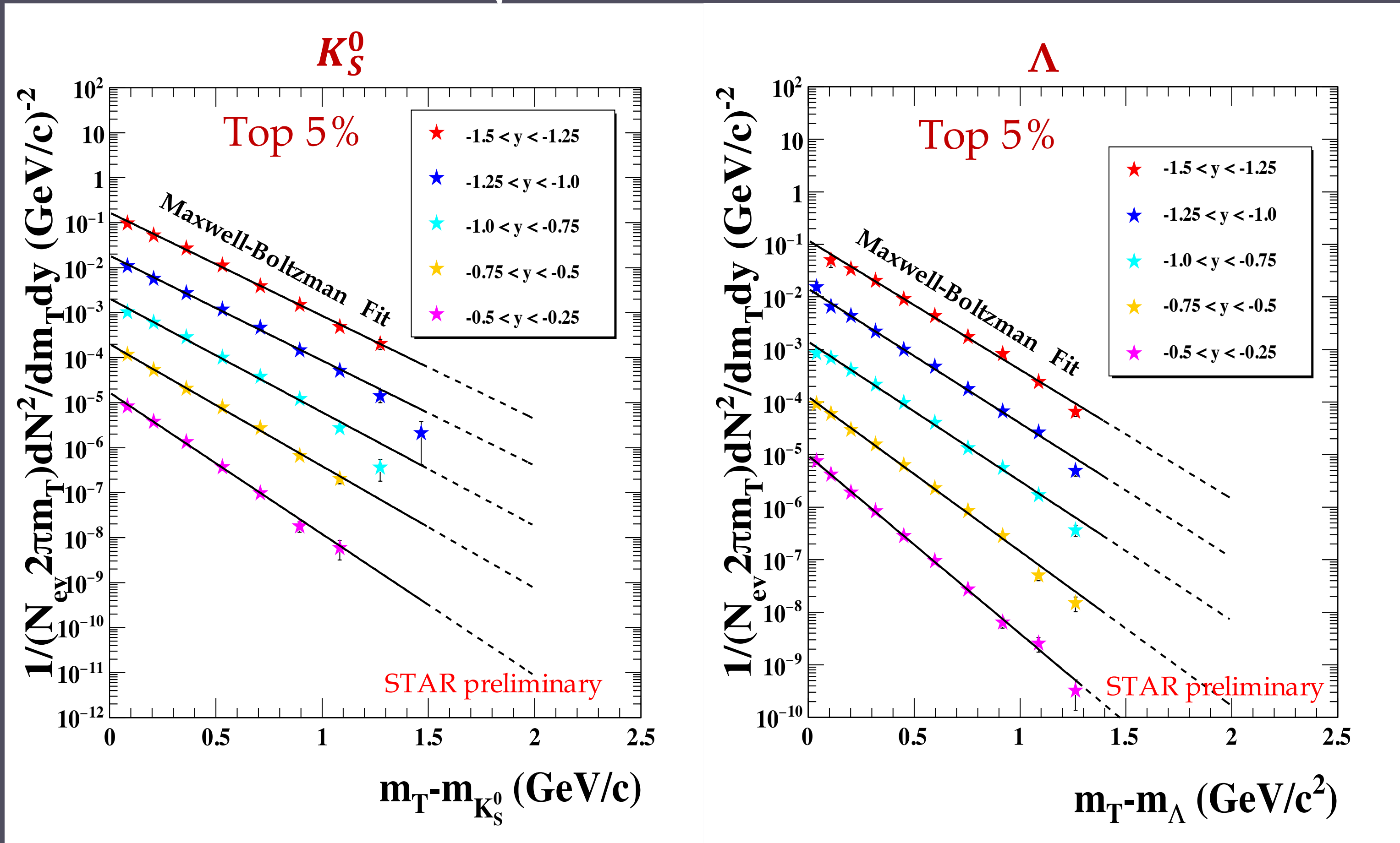
m_T-m_0 spectra of K_S^0 and Λ in Au+Au at $\sqrt{S_{NN}} = 4.5$ GeV



- m_T-m_0 Spectra in **Different rapidity bins for FXT Au+Au at $\sqrt{S_{NN}}$ = 4.5 GeV.**
- Errors are statistical only.

→ Solid line fit to data and dashed is extrapolation with fitting function.

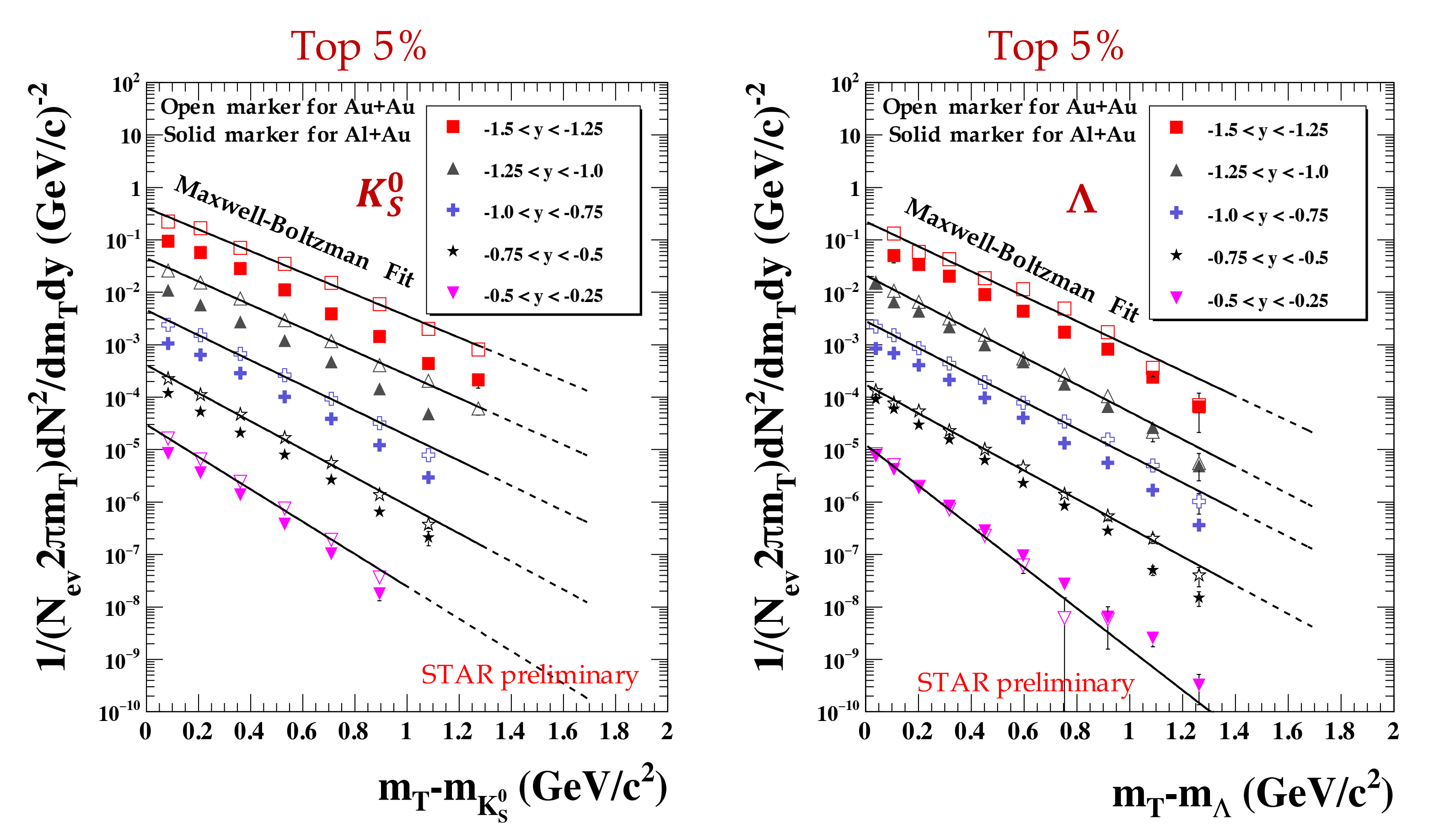
m_T-m_0 spectra of K_S^0 and Λ in Al+Au at $\sqrt{s_{NN}}$ = 4.9 GeV



- m_T-m_0 Spectra in **Different rapidity bins for FXT Al+Au at $\sqrt{s_{NN}}$ = 4.9 GeV.**
- Errors are statistical only.

→ Solid line fit to data and dashed is extrapolation with fitting function.

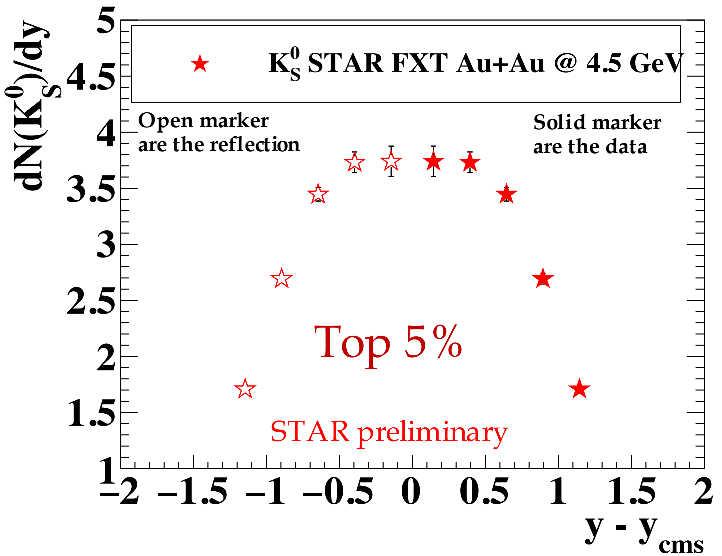
Comparison of m_T-m_0 spectra with Au+Au and Al+Au

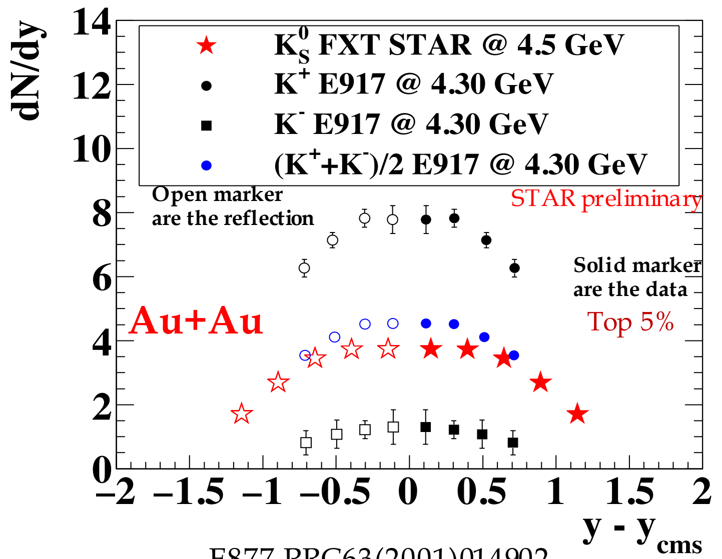


- m_T-m_0 Spectra in **Different rapidity bins for FXT Au+Au at $\sqrt{S_{NN}}$ = 4.5 GeV and Al+Au at $\sqrt{S_{NN}}$ = 4.9 GeV.**
- Errors are statistical only.

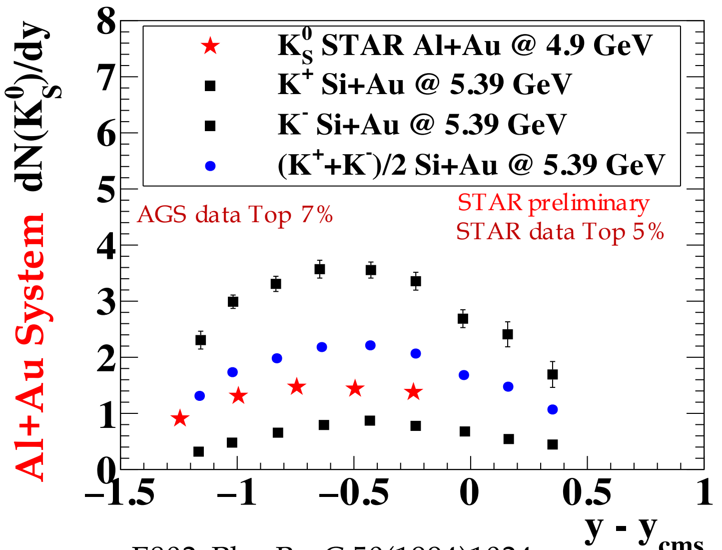
→ Solid line fit to data and dashed is extrapolation with fitting function.

K_S^0 Yield in Au+Au and Al+Au





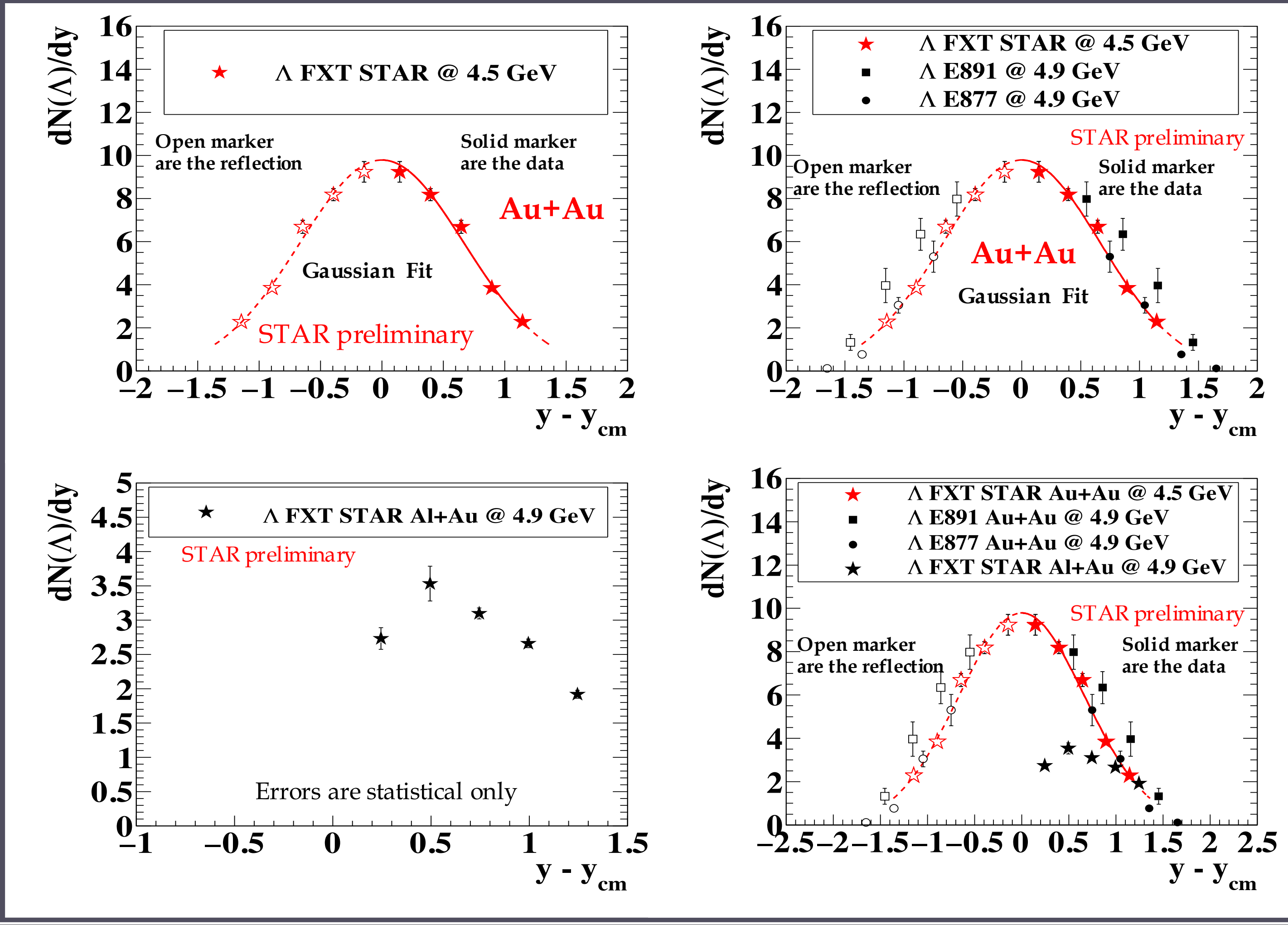
E877,PRC63(2001)014902



E802, PhysRevC.50(1994)1024

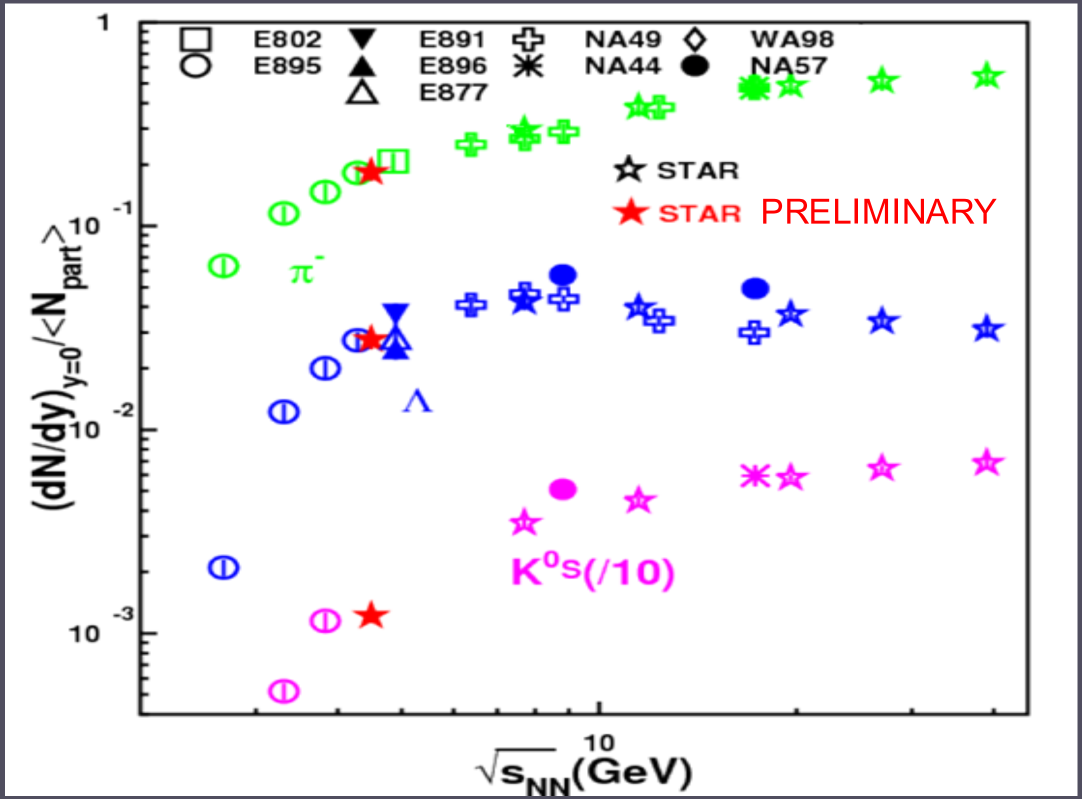
- Amplitude and width of rapidity density, dN/dy, are in good agreement with AGS experiments.
- Errors are statistical only.
- K_S^0 data lies between K^+ and K^-.

Λ Yield Au+Au and Al+Au



- Amplitude and width of rapidity density, dN/dy, of Λ in Au+Au @ 4.5 GeV are consistent with AGS experiments.
- Due to the asymmetric system, the dN/dy rapidity distribution shape is different from A+A.
- The Al+Au data lies below Au+Au data due to asymmetric system.

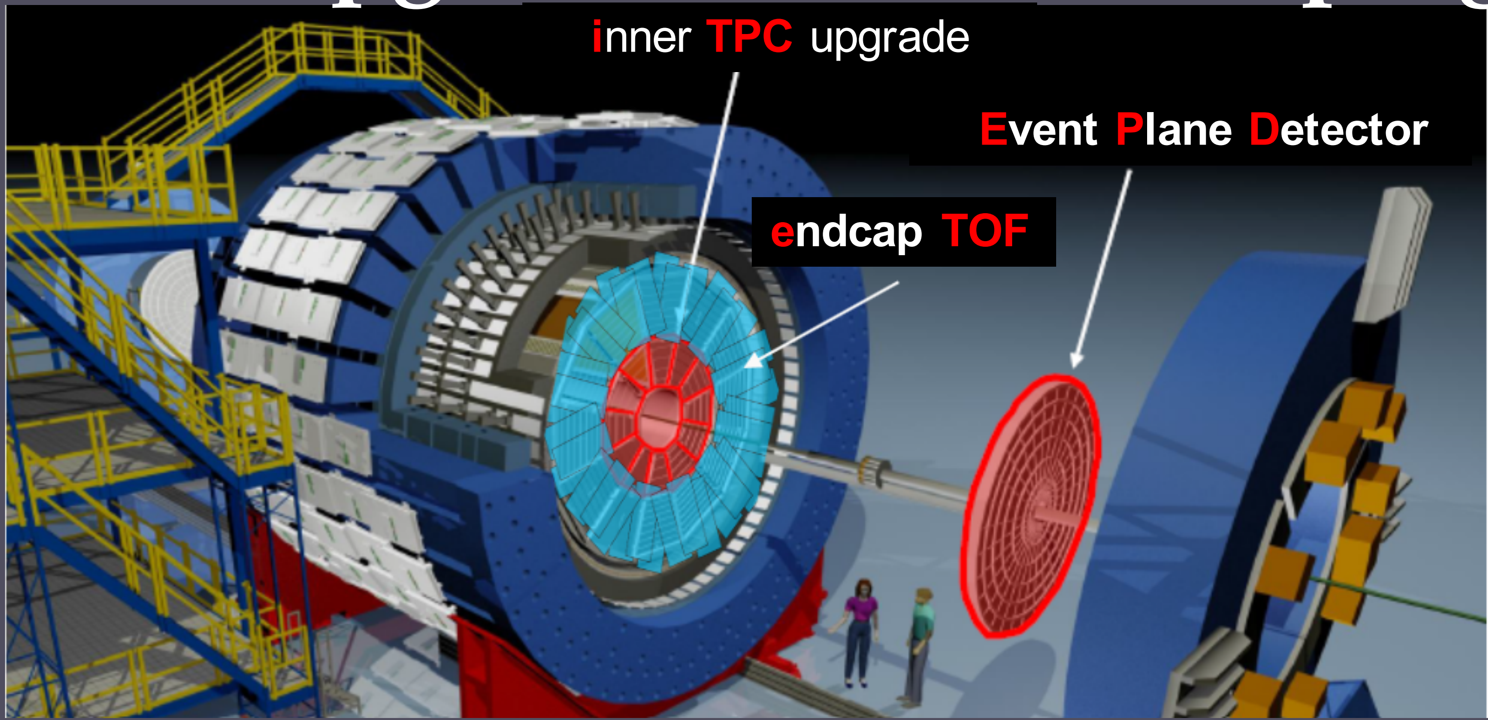
Particle Yield comparison in Au+Au at $\sqrt{S_{NN}} = 4.5$ GeV with different experiments



- E895: Phys. Rev. C 68 (2003) 054905
- E895: NPA 698 (2002) 495c
- E802: NPA 610 (1996) 139c
- E877: Phys. Rev. C 63 (2001) 014902
- E891: PLB 382 (1996) 35 E896: Phys. Rev. Lett. 88, 062301
- NA44: Phys. Rev. C 66 (2002) 044907
- NA49: JPG 30 (2004) S701
- NA49: Phys. Rev. Lett. 93 (2004) 022302
- Phys. Rev. Lett. 93 (2004) 022302
- NA57: JPG:NPP32 (2006) 2065
- WA98: Phys. Rev. C 67 (2003) 014906

- The excitation function of integrated yield, dN/dy, at mid-rapidity, scaled by the average number of participants.
- K_S^0 points are scaled by factor of 10.
- STAR data is a in good agreement with various AGS and CERN experiments.

The STAR Upgrades and the FXT program



iTPC Upgrade:

- ✓ Improved dE/dx resolution
- ✓ Better momentum resolution
- ✓ Extends η coverage from 1.0 to 1.5
- ✓ p_T >60 MeV/c
- ✓ Ready in 2019

Star Note 0644 : Technical Design Report for the iTPC Upgrade

EndCap TOF Upgrade:

- ✓ Mid-rapidity coverage is critical
- ✓ Needed for PID at mid-rapidity
- ✓ **-1.6<η<-1.1**
- ✓ Allows higher energy range of FXT program
- ✓ Ready in 2019

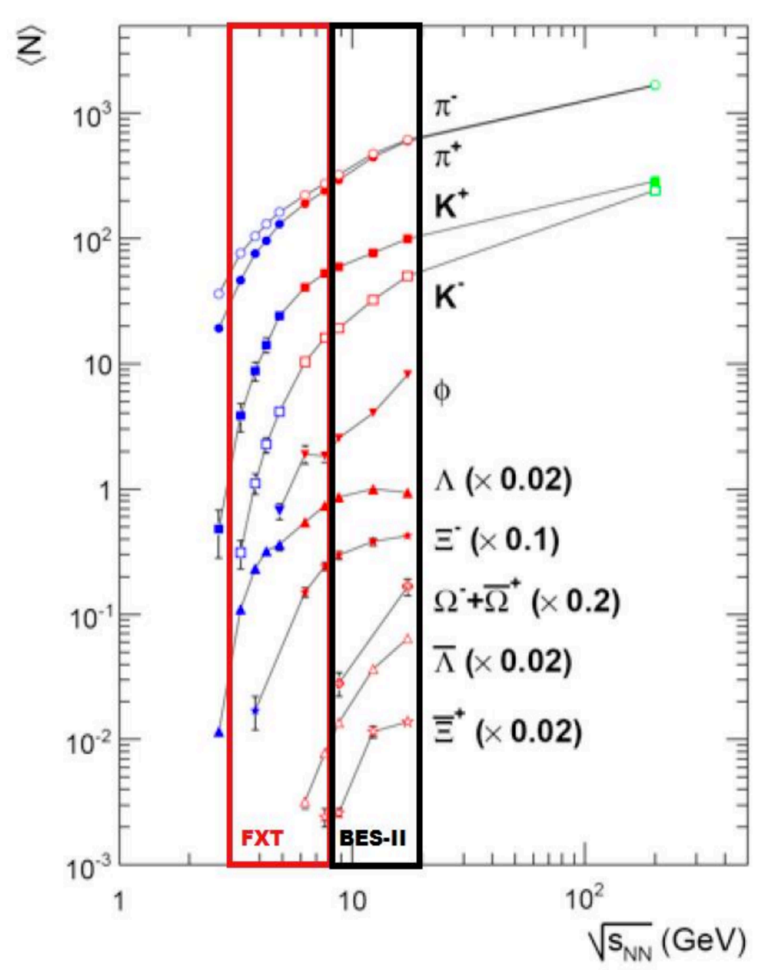
https://arxiv.org/pdf/1609.05102.pdf

EPD Upgrade:

- ✓ Better trigger
- ✓ Reduces background
- ✓ Improves event plane resolution
- ✓ **2.1<|η|<5.1**
- ✓ Ready in 2018

Star Note 0666 : An Event Plane Detector for STAR

Strange Particles in FXT and BES-II



C. Blume, J. Phys. G31, S57 (2005).

- ❑ Clear signals for K_S^0, Λ and Ξ^- are observed in Au+Au at 4.5 GeV FXT test run
- ❑ Clear signals for K_S^0 and Λ are observed in Al+Au at 4.9 GeV FXT test run.
- ❑ Have not seen $\overline{\Lambda}$ and $\mathbf{\Omega}$, due to low statistics.
- ❑ After upgrade we need ~100M events for each energy and hoping to see the $\overline{\Lambda}$, $\mathbf{\Omega}$ and Ξ^- .

Summary

- These results show that STAR has a capability to run in the fixed-target as well as in the collider mode.
- K_S^0 and Λ m_T-m_0 spectra are in a good agreement with the AGS experiments.
- Width and amplitude of K_S^0 and Λ for Au+Au and Al+Au, rapidity densities dN/dy, are in a good agreement with AGS experiments.
- FXT program proposed during RHIC BES-II will extend the energy down to $\sqrt{s_{NN}}$ = 3.0 GeV (μ_B=720 MeV).
- iTPC, eTOF and EPD upgrades will allow more comprehensive and refined measurements.

Thank You!