STAR

Measurements of strange hadrons K^0_S, Λ, and Ξ from Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 11.5 and 39 GeV in STAR

Xianglei Zhu (Tsinghua University)

For the STAR Collaboration

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SQM Cracow 2011

Strangeness in Quark Matter,

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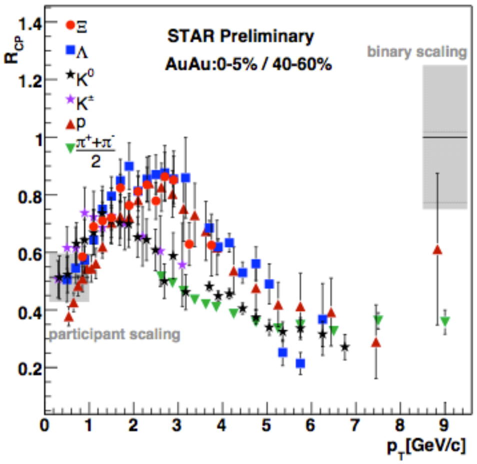
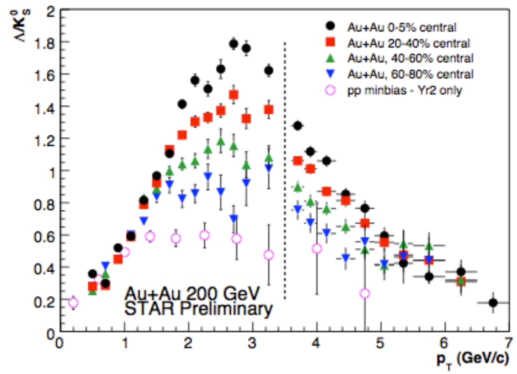
Outline

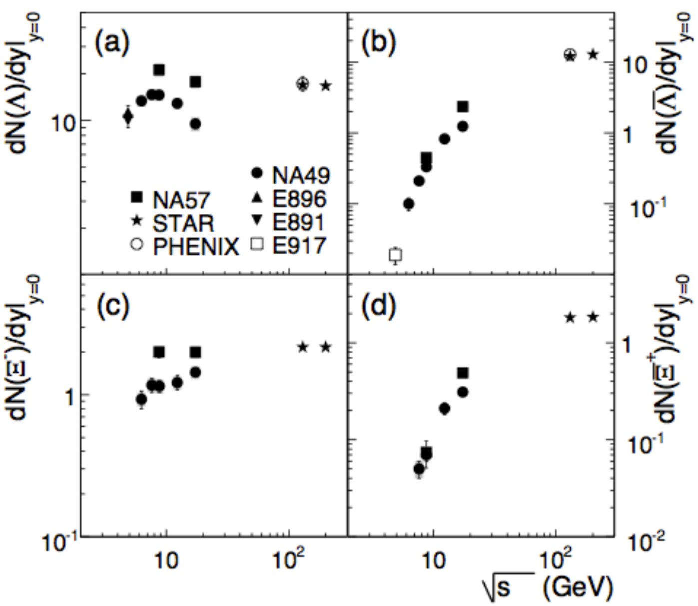
- Motivation for strangeness spectra measurement in STAR beam energy scan (BES)
- Strangeness (K^0_S, Λ, Ξ) production at mid-rapidity in BES
  - p_T spectra
  - $\langle m_T \rangle - m_0$
  - Particle yields
  - Particle ratios
  - Nuclear modification factor: R_{CP}
  - Baryon enhancement: Λ/K^0_S
- Summary

Motivation for strangeness spectra measurement in STAR beam energy scan





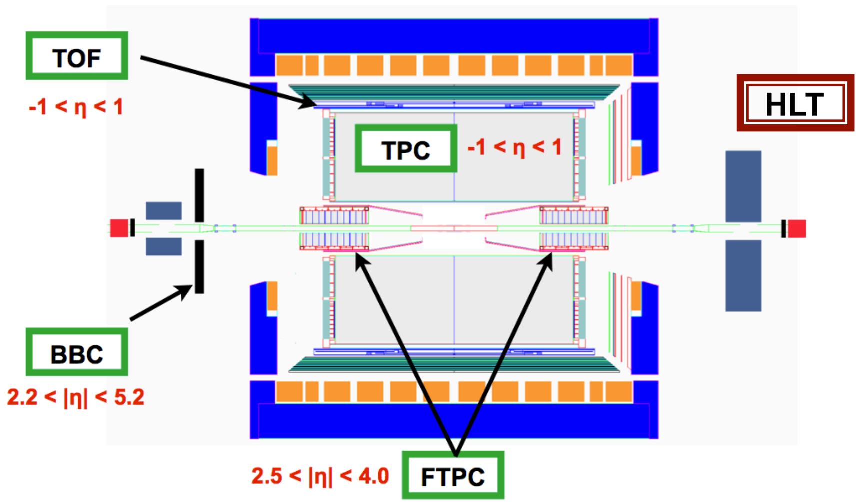
STAR arXiv: 1007.2613



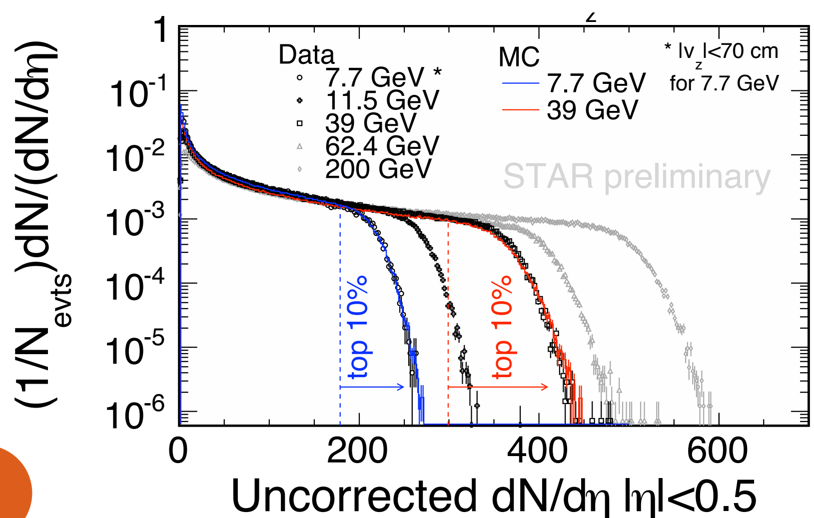
NA49, PRC78, 034918

- Particle ratios:
  Test statistical hadronization model.
  Understand the mechanism of strangeness enhancement at lower energies.
  Exact system profiles at chemical freeze out.
- Nuclear modification factor, Λ/K^0_S ratio:
  parton recombination at lower energies?
- Resolve discrepancy of NA57 and NA49 data.

STAR detector in BES

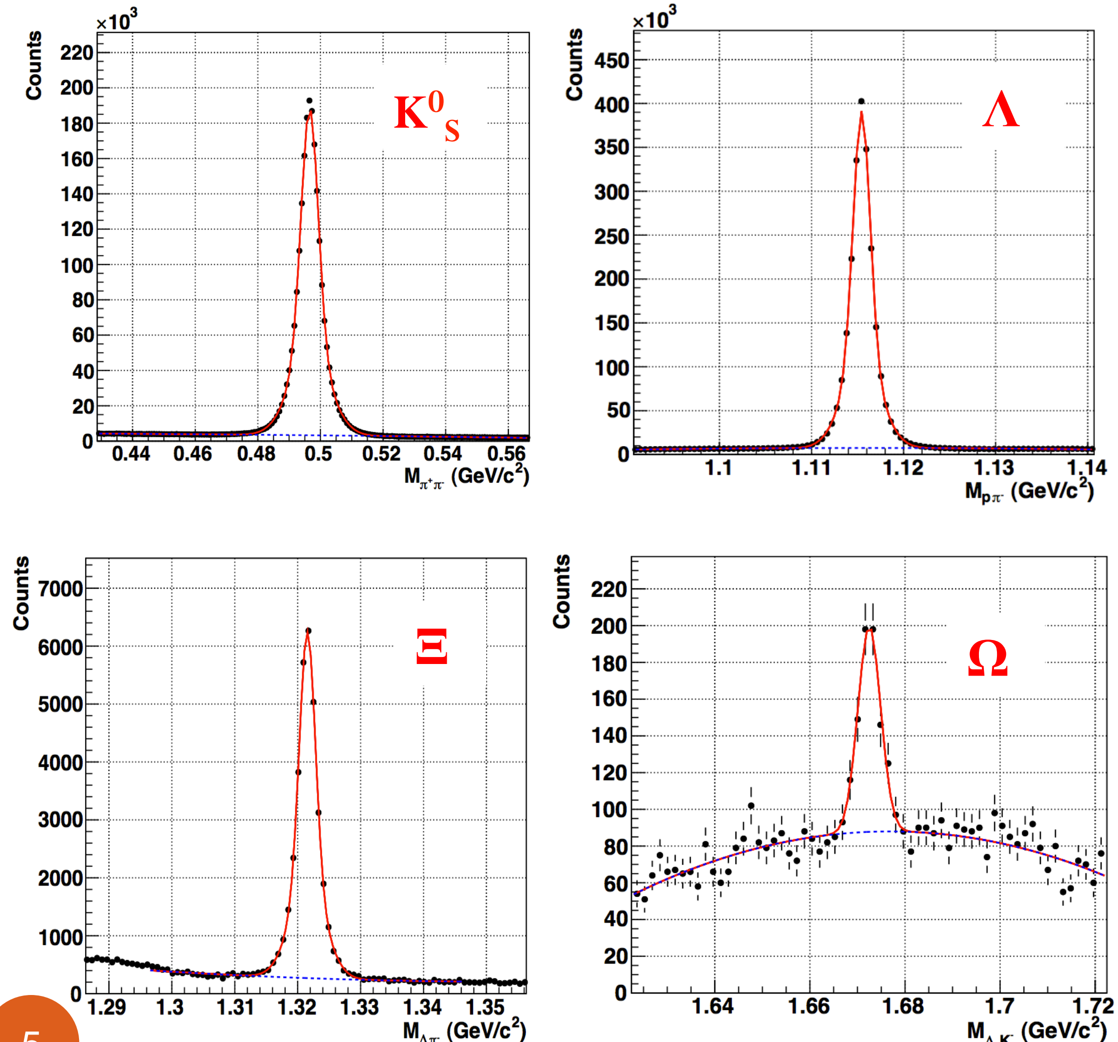


- For strangeness, |y|<1 can be measured. **This analysis focuses on mid-rapidity (|y|<0.5)**
- Centrality is determined by the reference multiplicity of TPC



$\sqrt{s_{NN}}$ (GeV)	Good events (Analyzed) Million MB
7.7	5 (5)
11.5	12.4 (12.4)
39	169 (13.5)

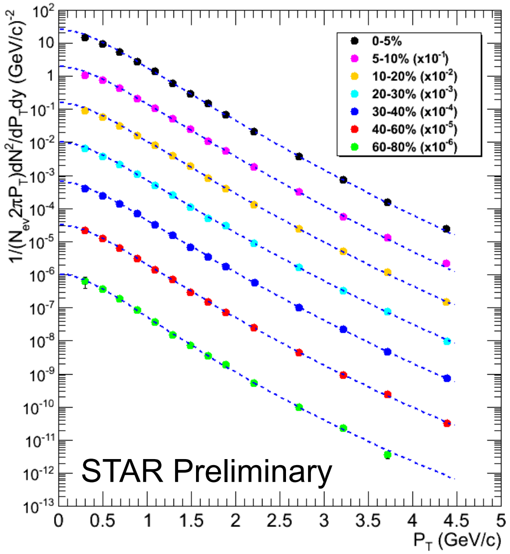
Signals of strangeness particles in $\sqrt{s_{NN}}$ = 7.7 GeV Au+Au collisions



- Very good signals of all weak decay strange particles
- Excellent performance of STAR detector even at the lowest collision energy

Spectra

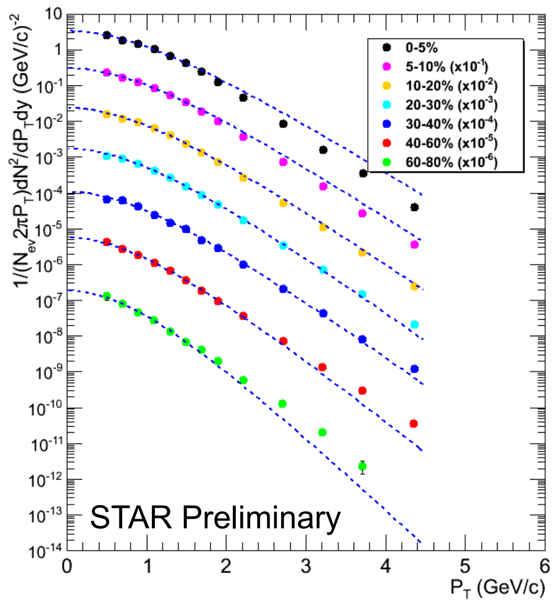
K^0_S spectra, Au+Au 39 GeV



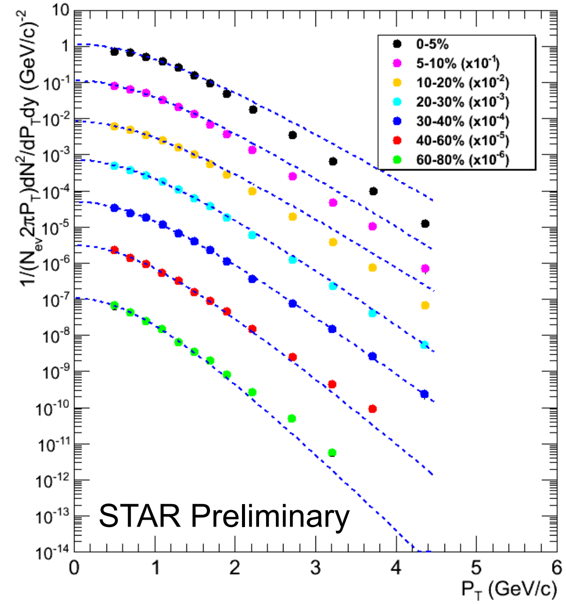
Fitted with Levy (K^0_S), Boltzmann function (others), and m_T exponential function to estimate the systematic error in extrapolation.

Λ spectra are weak decay feed-down corrected

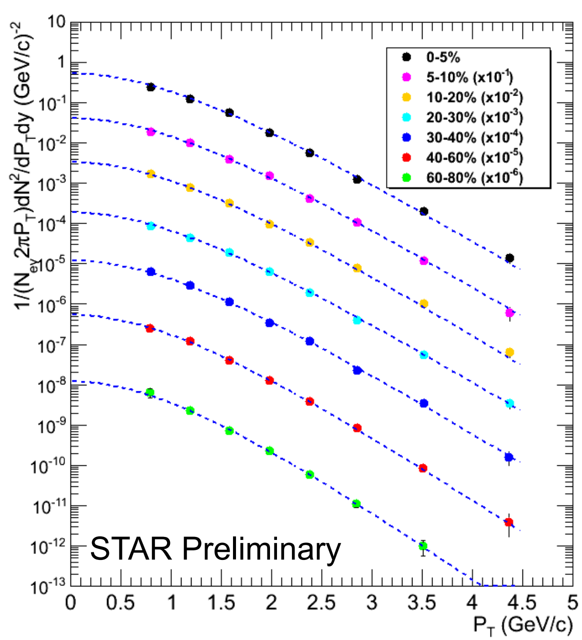
Λ spectra, Au+Au 39 GeV



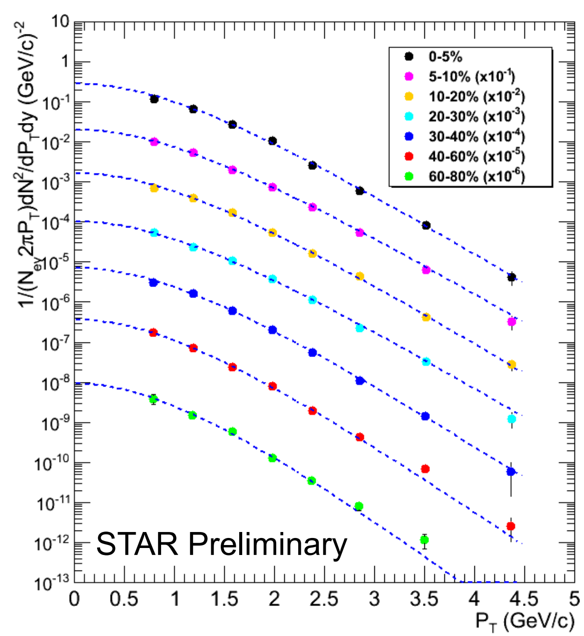
$\overline{\Lambda}$ spectra, Au+Au 39 GeV



Ξ^- spectra, Au+Au 39 GeV

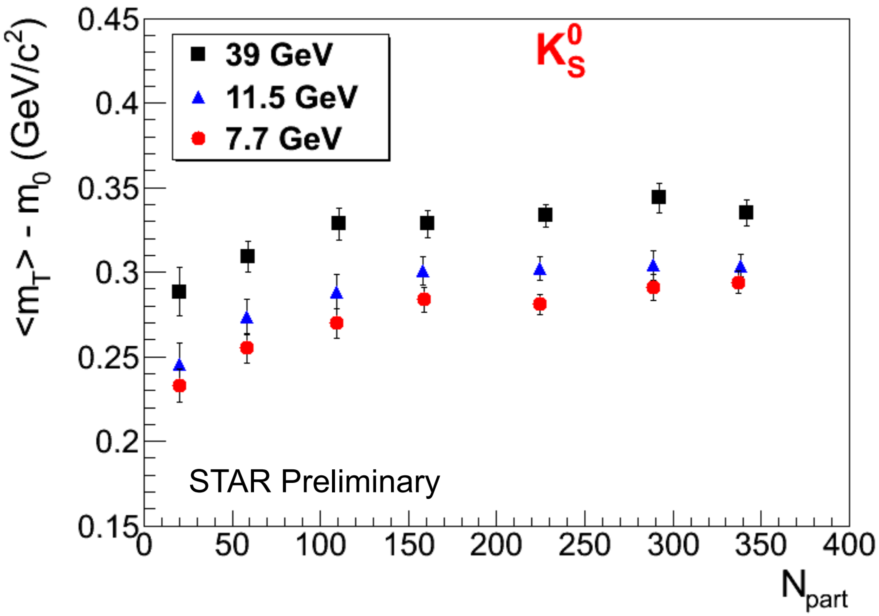


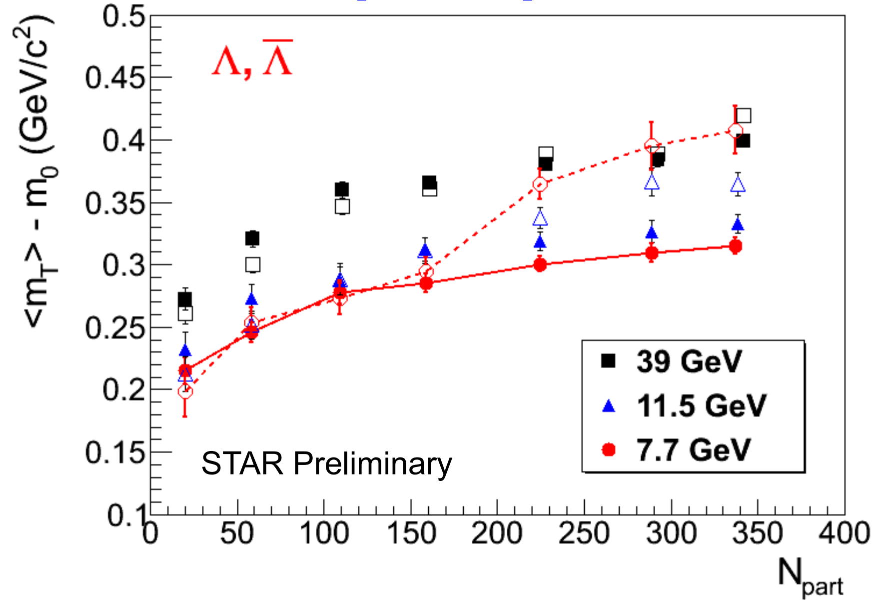
$\overline{\Xi}^+$ spectra, Au+Au 39 GeV

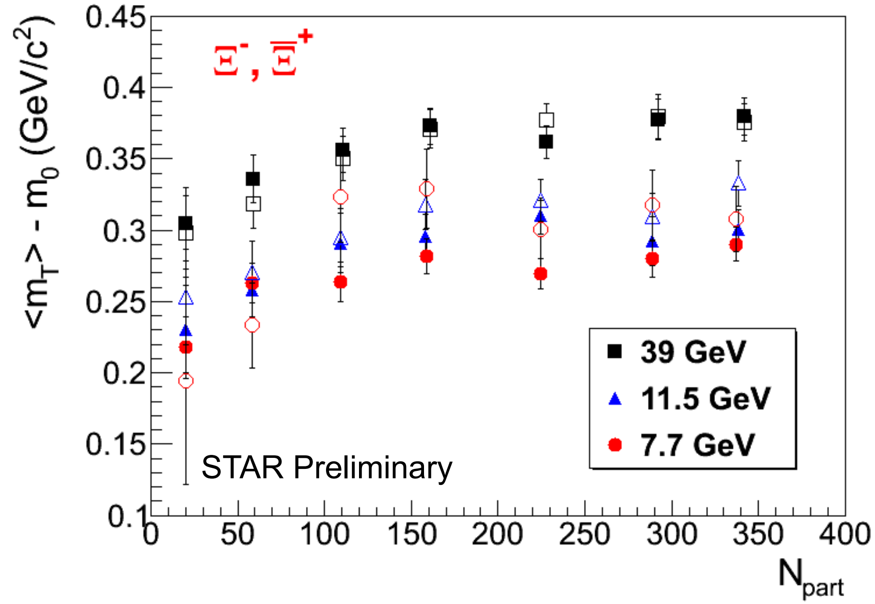


Solid, particle;
Open, anti-particles

$\langle m_T \rangle - m_0$

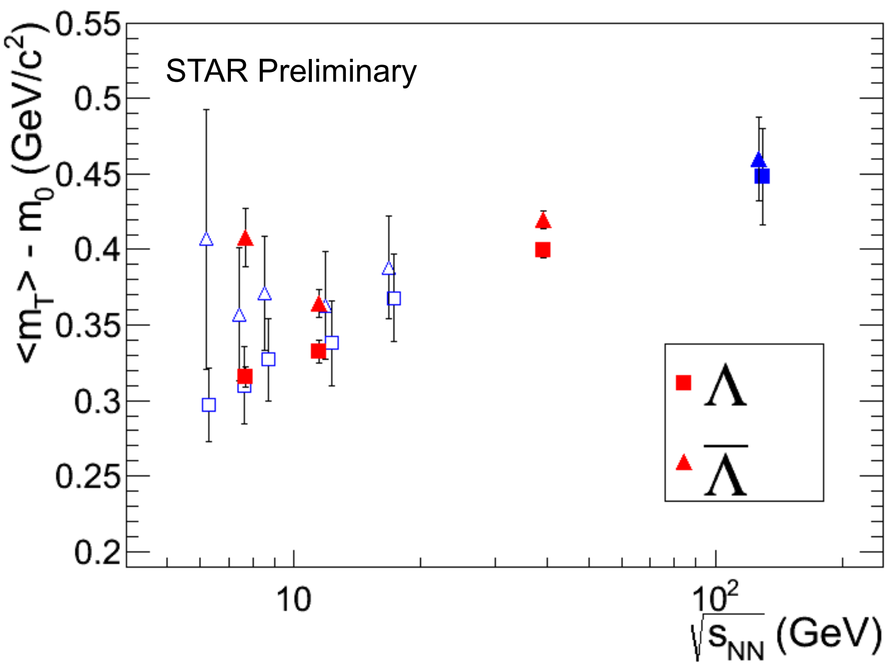


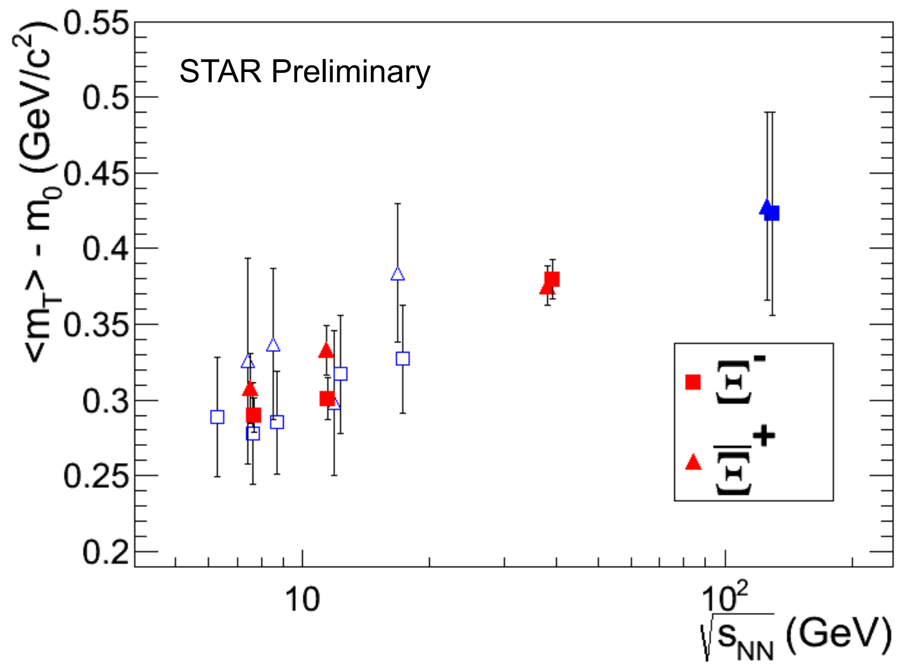




- **Statistical error only !**
- $\langle m_T \rangle - m_0$ increases as the increase of centrality
- $\bar{\Lambda}$ $\langle m_T \rangle - m_0$ increases much faster than other particles with the increase of centrality at Au+Au 7.7 GeV

Compared with the published data





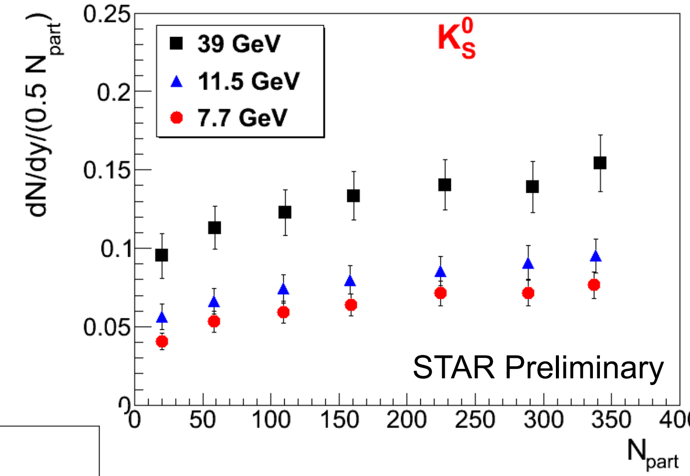
Solid red, STAR BES, 0-5% most central, statistical error only.

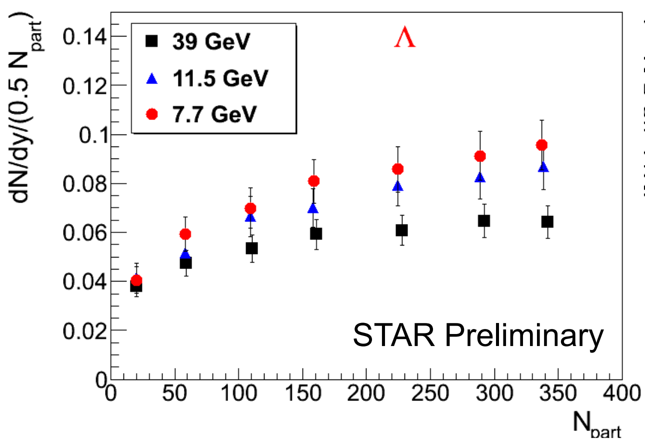
Solid blue, STAR published, most central, PRL 89, 092301; PRL92, 182301.

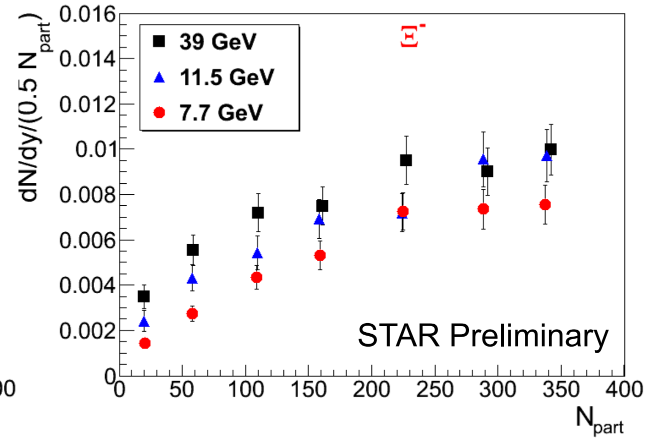
Open, NA49, most central, from NA49, PRC78, 034918

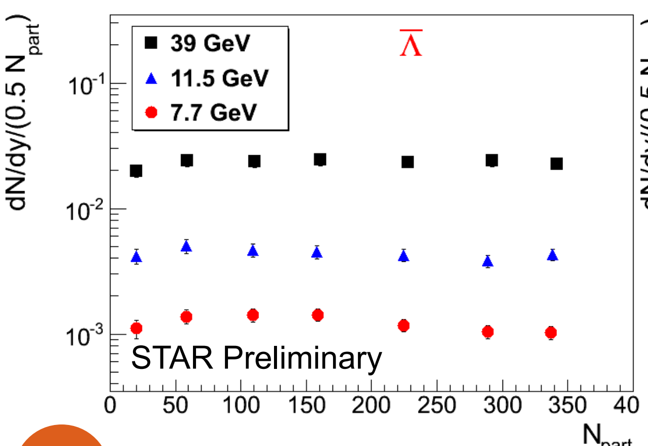
STAR BES data matches the NA49 data well.

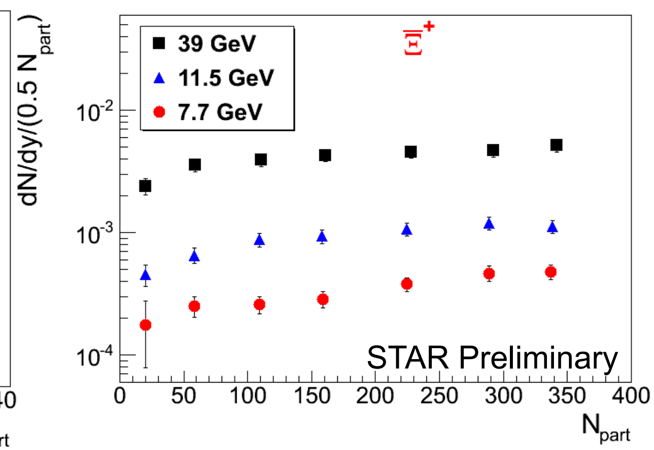
Yield ($|y|<0.5$)





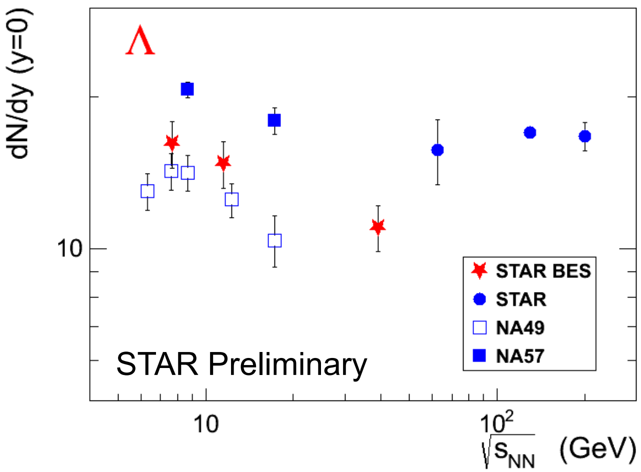


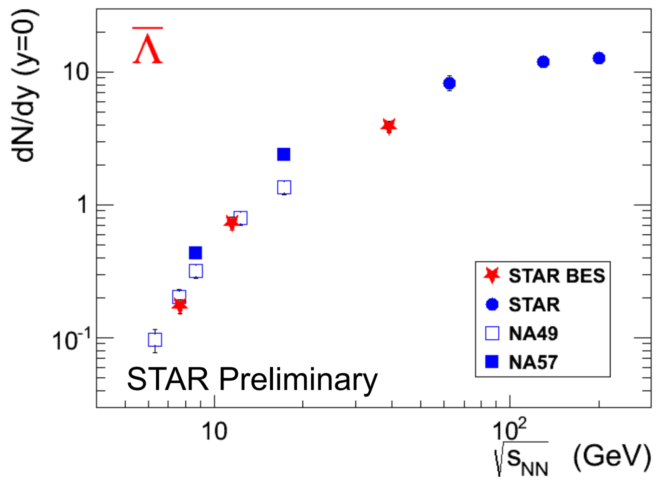


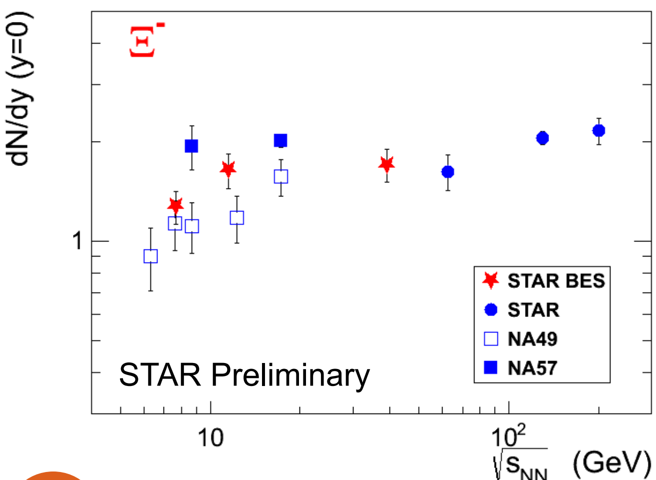


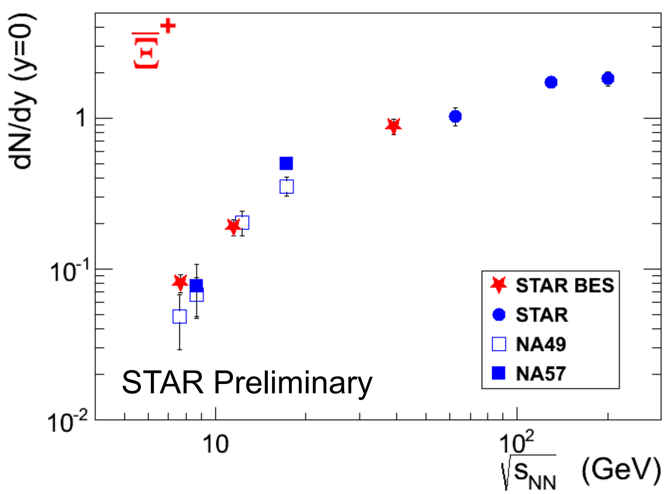
- K^0_S, Λ, Ξ^- and $\bar{\Xi}^+$ Yield per participant increase with the increase of centrality
- $\bar{\Lambda}$ yield per participant does not show centrality dependence at three energies
- Systematic error in yields due to correction factors is set to 10% (STAR, PRC83)

Compared with the published data









- STAR BES particle yield at mid-rapidity consistent with NA49 in general.

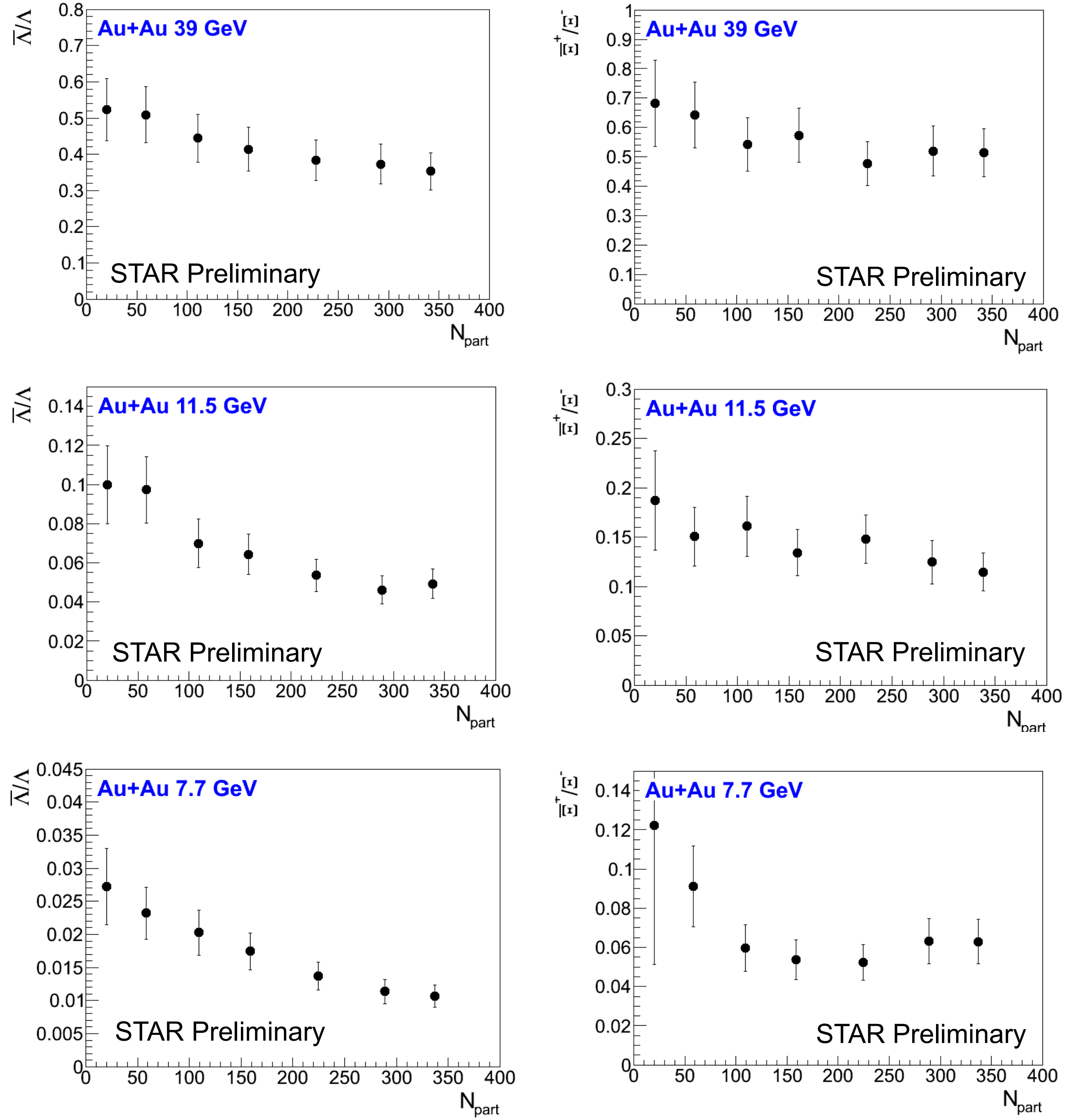
NA49, PRC78,034918.
7% or 10% most central.
(|y|<0.4 or 0.5)

NA57, PLB595,68; JPG32, 427
0-4.5% most central,
|y|<0.5, stat. err. only

STAR, PRL86,89,92,98;PRC83
0-5% most central,
|y|<0.5

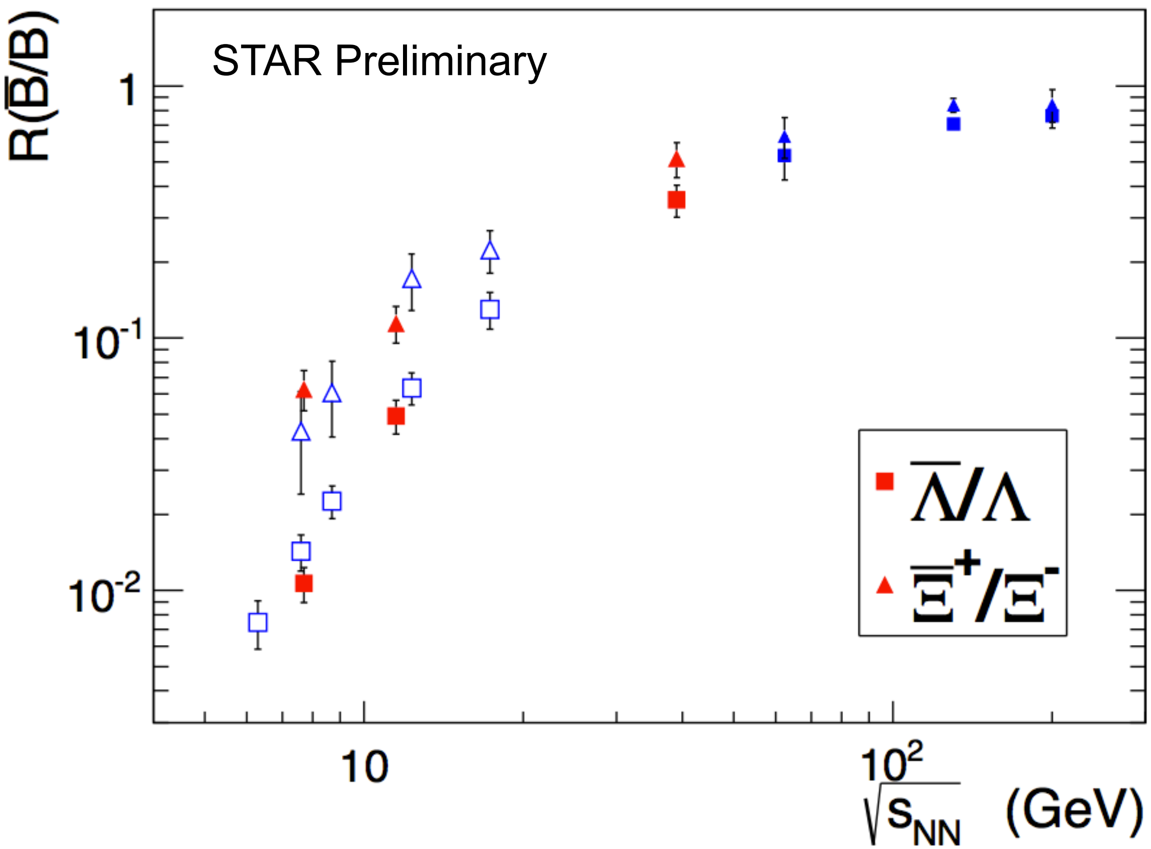
***The NA57 and NA49 yields have been scaled by the corresponding number of wounded nucleons: dN/dy / Nw * Npart(STAR)**

Bbar/B



- Bbar/B ratios show similar centrality dependence at three energies:
  decrease with the increase of centrality

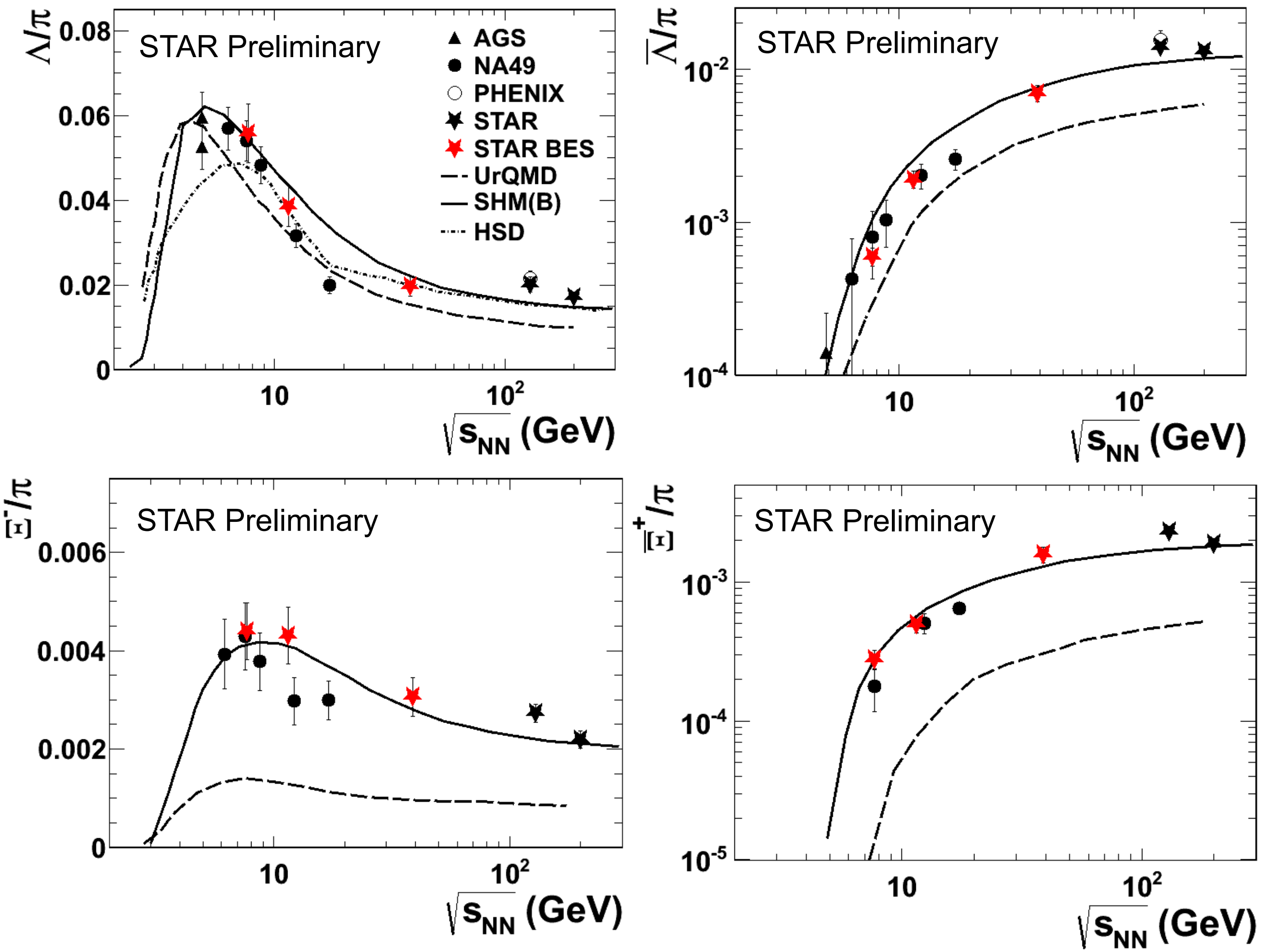
Excitation function of Bbar/B ratios



Solid red: STAR BES
Solid blue: STAR published
Open blue: NA49

STAR BES data lies in a trend with NA49 data

Compare with models



SHM(B): statistical hadronization model,
A. Andronic et.al.,NPA772

UrQMD: M. Bleicher et.al., JPG25, 1859

HSD: E.Bratkovskaya et.al, PRC69; W. Cassing and E. Bratkovskaya, Phys. Rept. 308

NA49: PRC78,034918

AGS: E896, PRL88; E917, PRL87; E891, PLB382; E802, PRC57

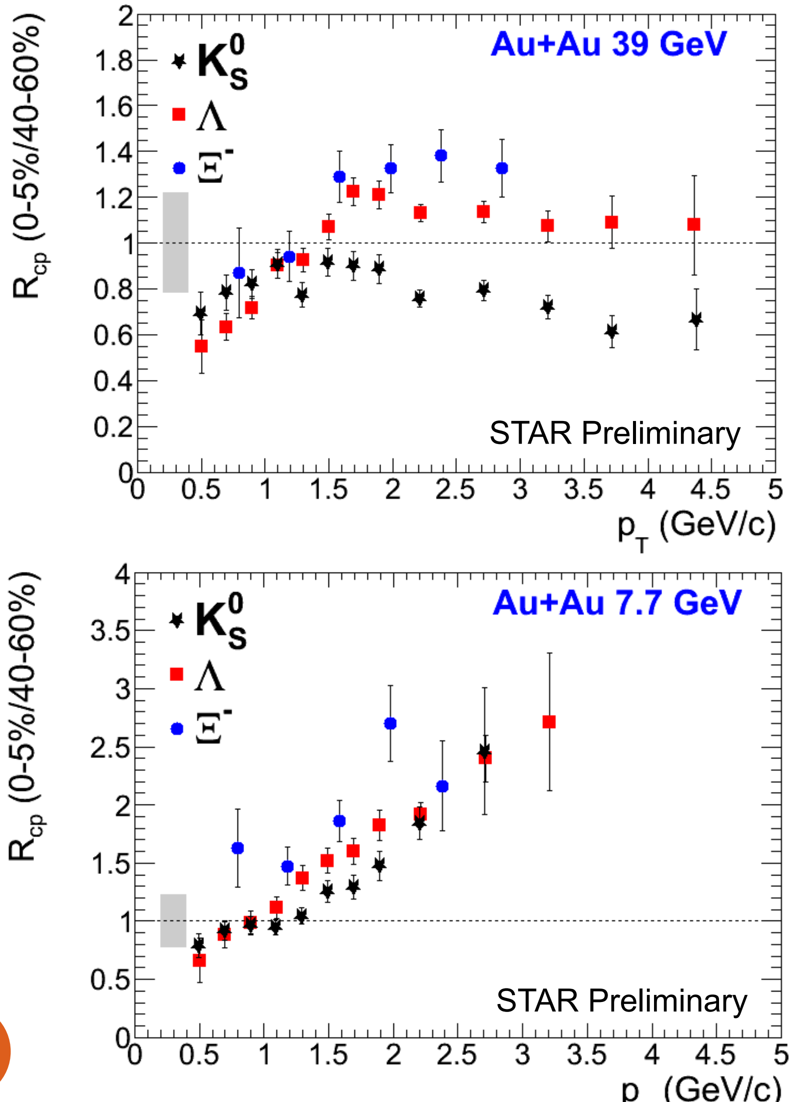
PHENIX: PRL88, 242301

STAR: PRL89,092301; PRL92, 182301; PRL89, 092301; PRL98, 062301; PLB595, 143; PRL92, 112301

The π yield in denominator is $1.5(\pi^+ + \pi^-)$, for $|y|<0.1$, data taken from L. Kumar (STAR), QM2011

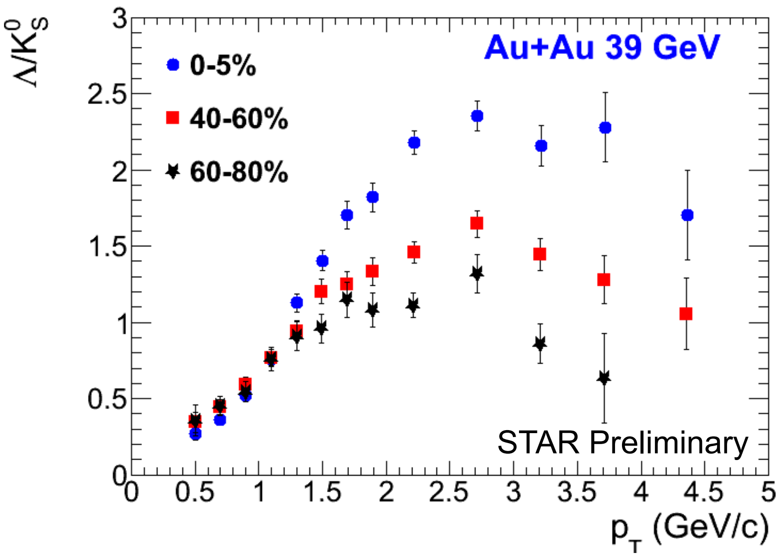
STAR BES data agree well with the statistical hadronization model at three energies

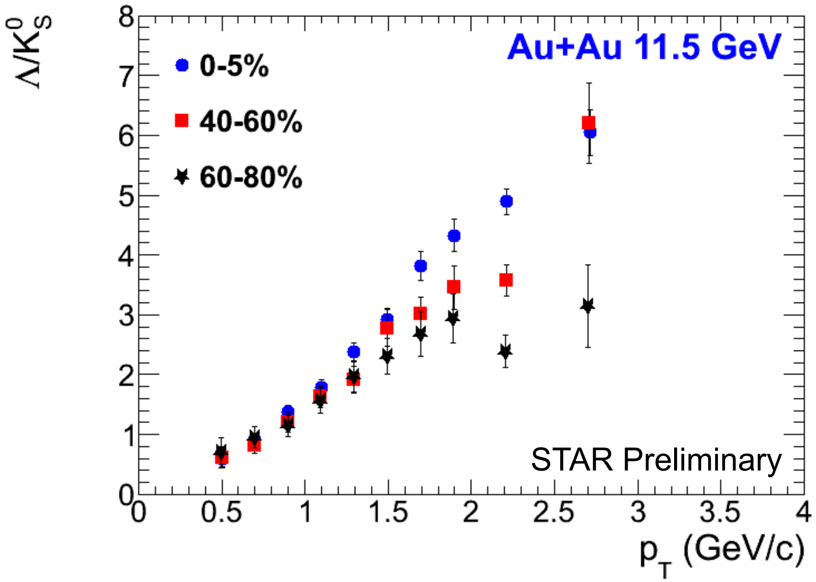
R_{CP}

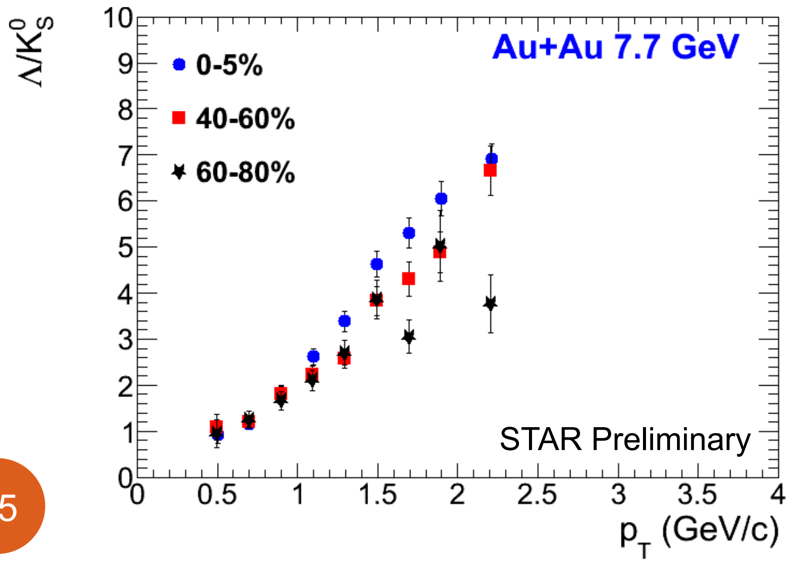


- R_{CP} of strange particles at 39 GeV show similar trend as that in higher energies.
- At 11.5 and 7.7 GeV, all particles R_{CP} are larger than 1 at intermediate p_T.

Λ/K^0_S ratio







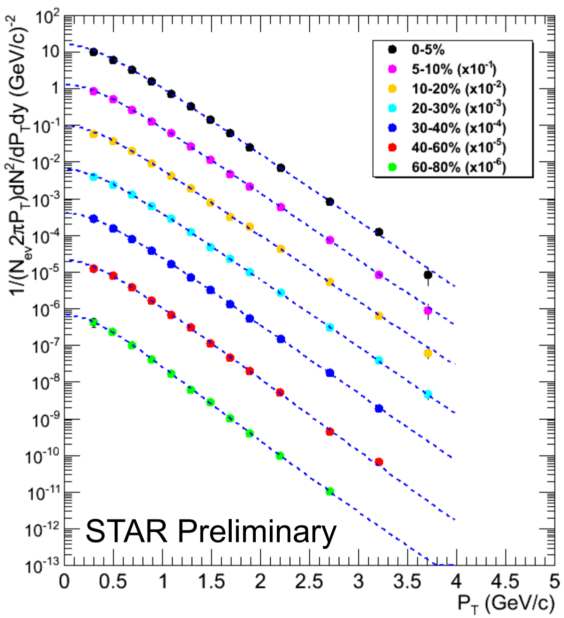
Λ/K^0_S values increase with the decrease of beam energy from 39 to 7.7 GeV.

Summary

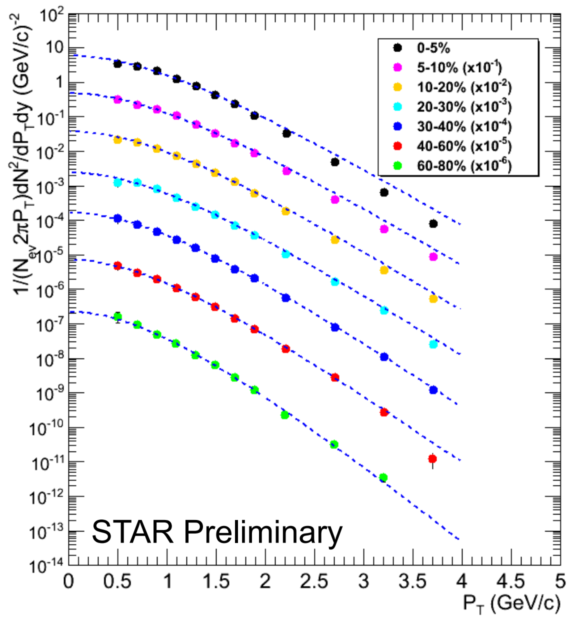
- STAR has accumulated significant amount of data for strangeness study in Beam Energy Scan.
- STAR data ($\langle m_T \rangle - m_0$, particle yields, ratios) shows good agreement with NA49 data in general.
- STAR particle ratios (Λ/π, Ξ/π) in most central collisions agree well with the statistical hadronization model at three energies.
- K^0_S, Λ and Ξ's R_{CP} are all much larger than 1 at 11.5 and 7.7 GeV.
- Λ/K^0_S values keep increasing with the decrease of collision energy from 39 to 7.7 GeV
- Systematic errors from detector acceptance and efficiencies are the expected values, full systematics study is on-going.

Backup

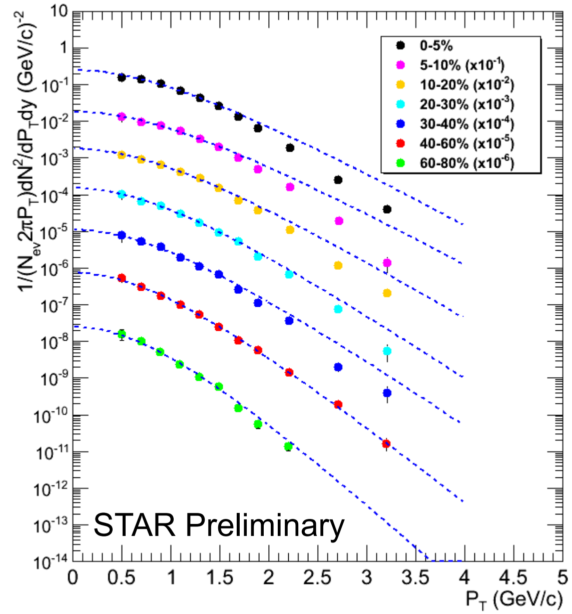
K^0_S spectra, Au+Au 11.5 GeV



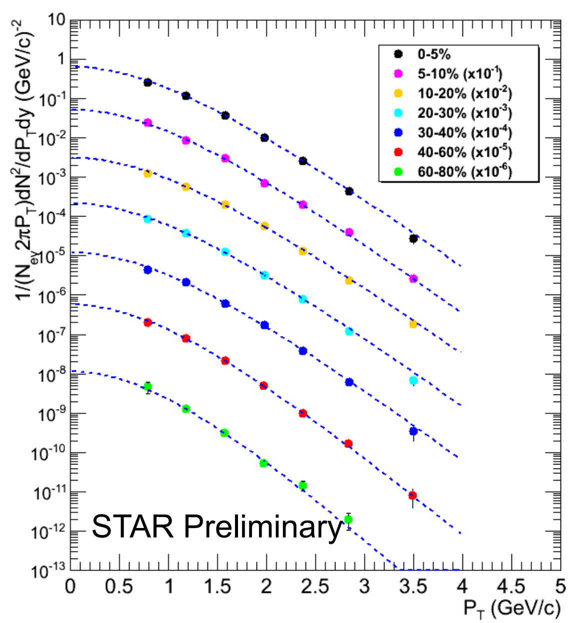
Λ spectra, Au+Au 11.5 GeV



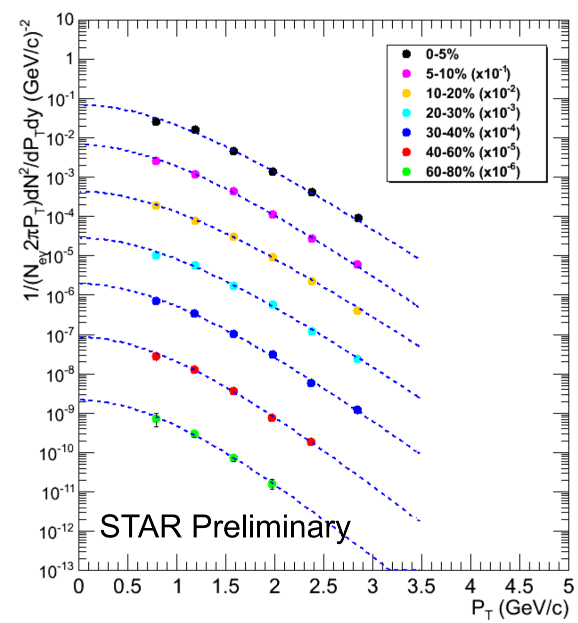
$\overline{\Lambda}$ spectra, Au+Au 11.5 GeV

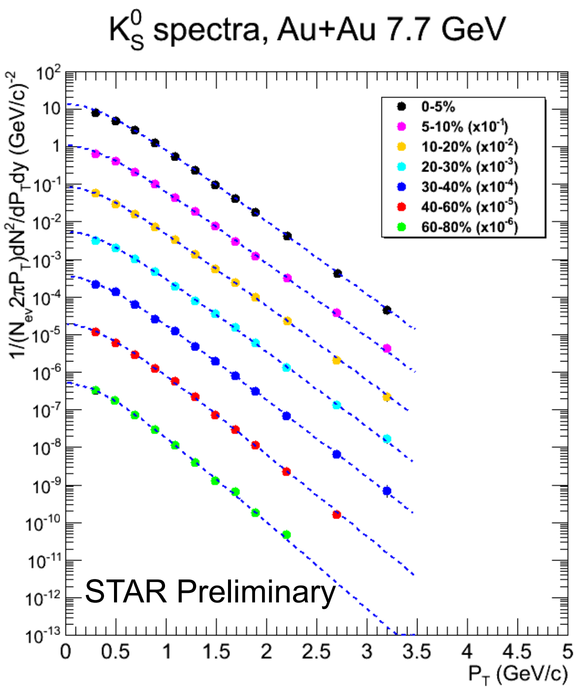


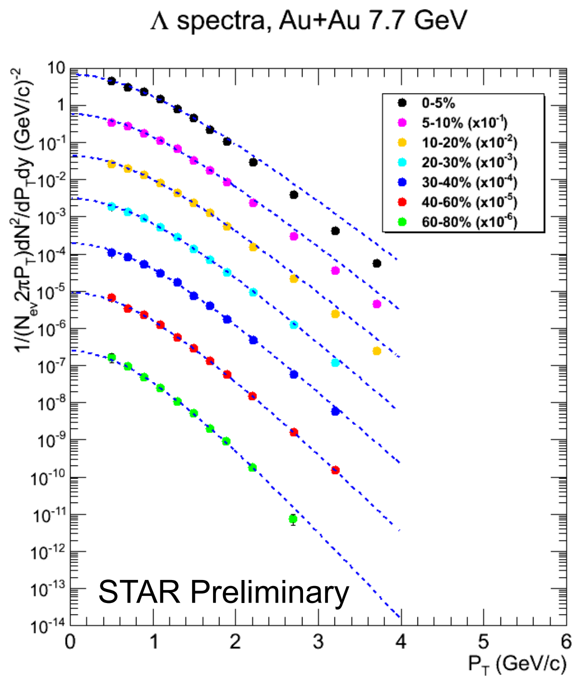
Ξ^- spectra, Au+Au 11.5 GeV



$\overline{\Xi}^+$ spectra, Au+Au 11.5 GeV




K^0_S spectra, Au+Au 7.7 GeV
0-5%
5-10% (x10^-1)
10-20% (x10^-2)
20-30% (x10^-3)
30-40% (x10^-4)
40-60% (x10^-5)
60-80% (x10^-6)
STAR Preliminary
$1/(N_{ev}2\pi P_T)dN^2/dP_Tdy$ (GeV/c)^-2
P_T (GeV/c)


Λ spectra, Au+Au 7.7 GeV
0-5%
5-10% (x10^-1)
10-20% (x10^-2)
20-30% (x10^-3)
30-40% (x10^-4)
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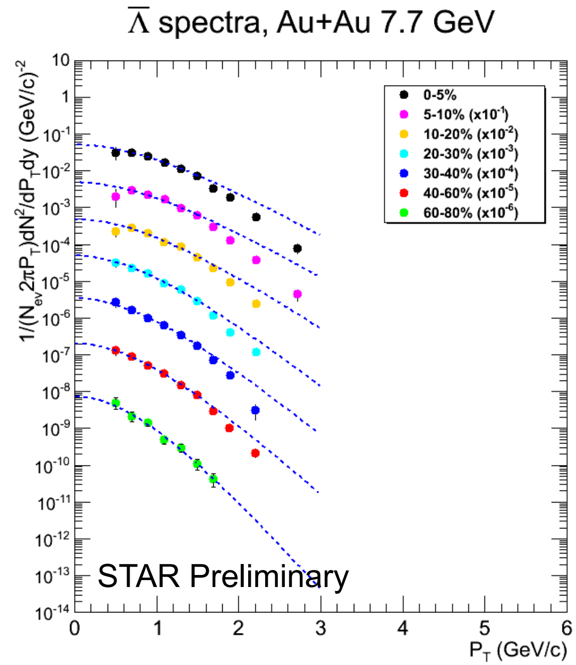
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0-5%
5-10% (x10^-1)
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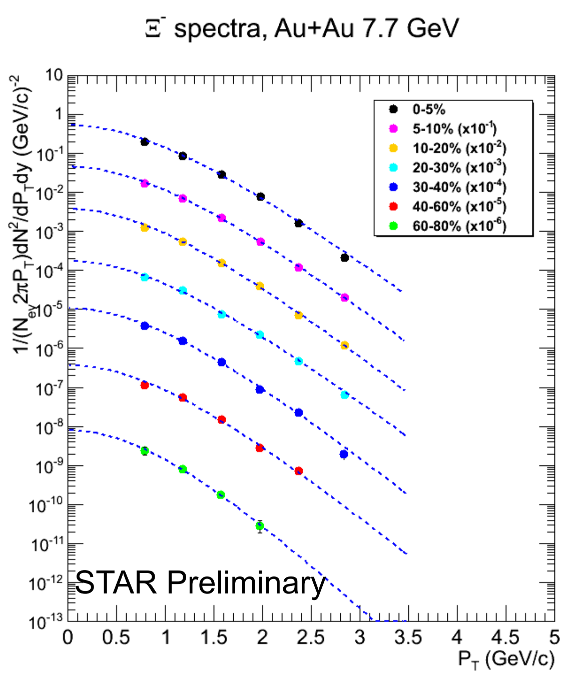
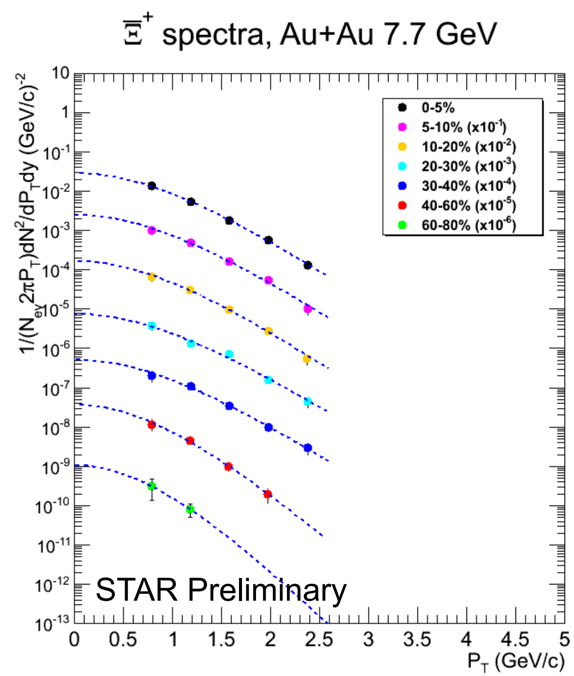

Ξ^- spectra, Au+Au 7.7 GeV
0-5%
5-10% (x10^-1)
10-20% (x10^-2)
20-30% (x10^-3)
30-40% (x10^-4)
40-60% (x10^-5)
60-80% (x10^-6)
STAR Preliminary
$1/(N_{ev}2\pi P_T)dN^2/dP_Tdy$ (GeV/c)^-2
P_T (GeV/c)


$\overline{\Xi}^+$ spectra, Au+Au 7.7 GeV
0-5%
5-10% (x10^-1)
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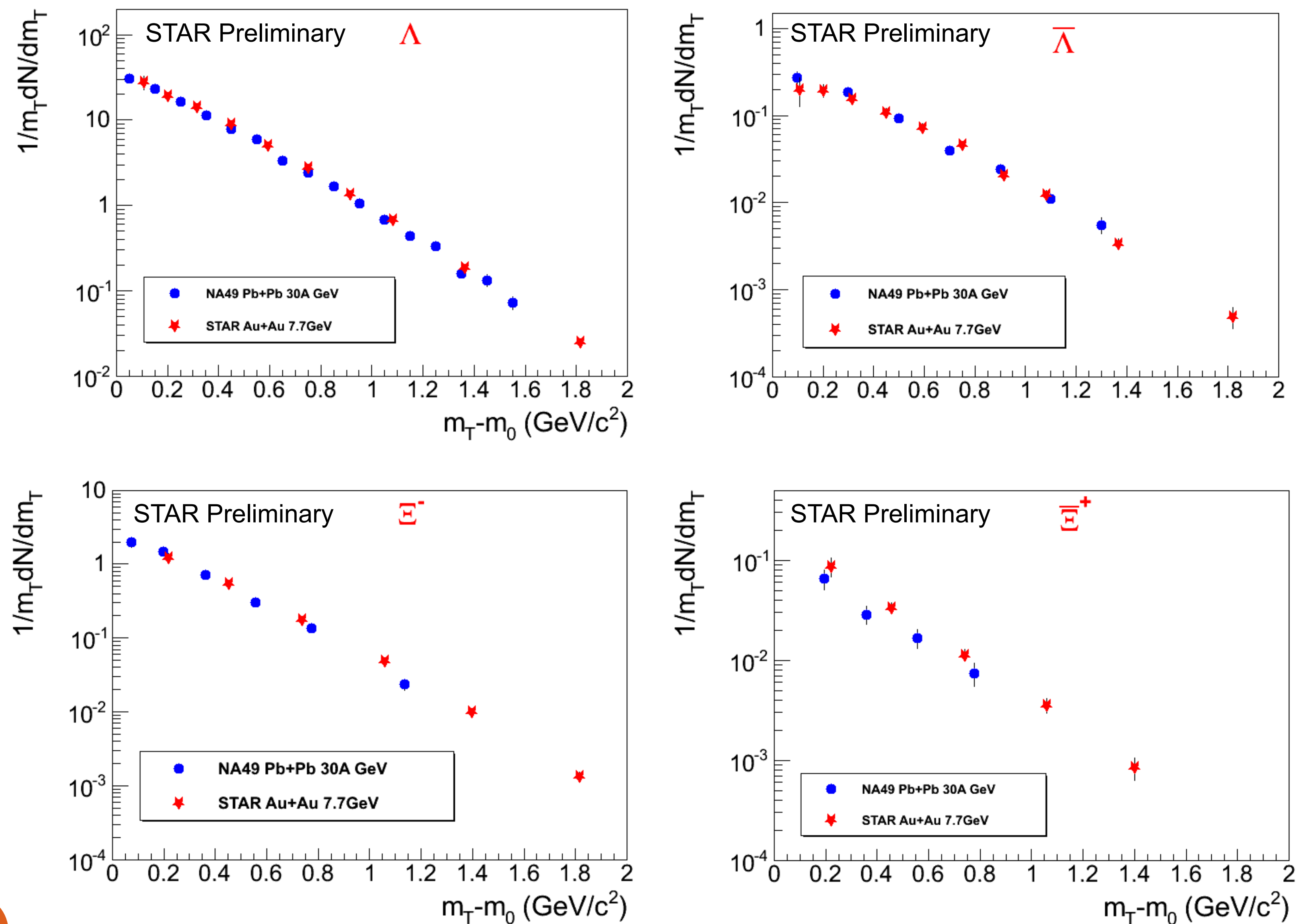
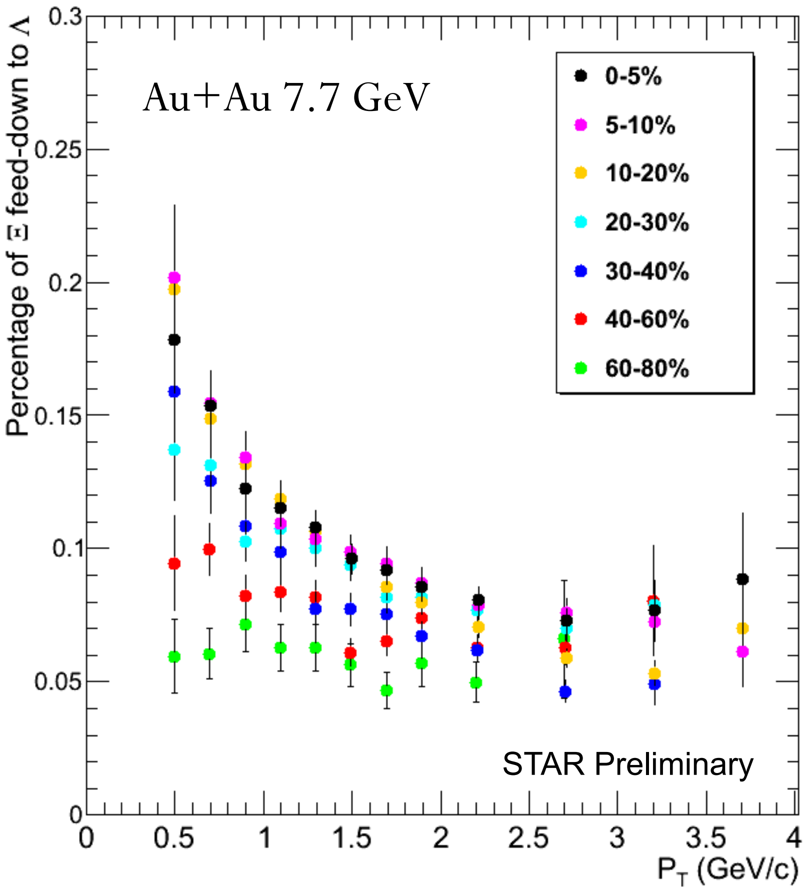
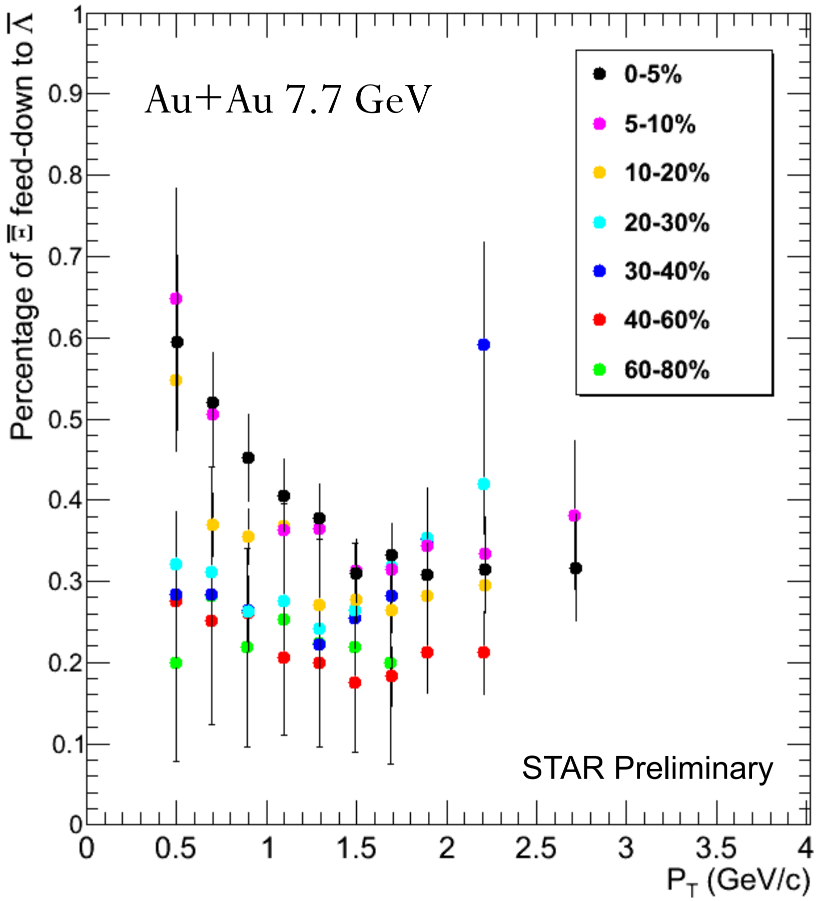
STAR Preliminary
$1/(N_{ev}2\pi P_T)dN^2/dP_Tdy$ (GeV/c)^-2
P_T (GeV/c)

Comparison to NA49 most central spectra

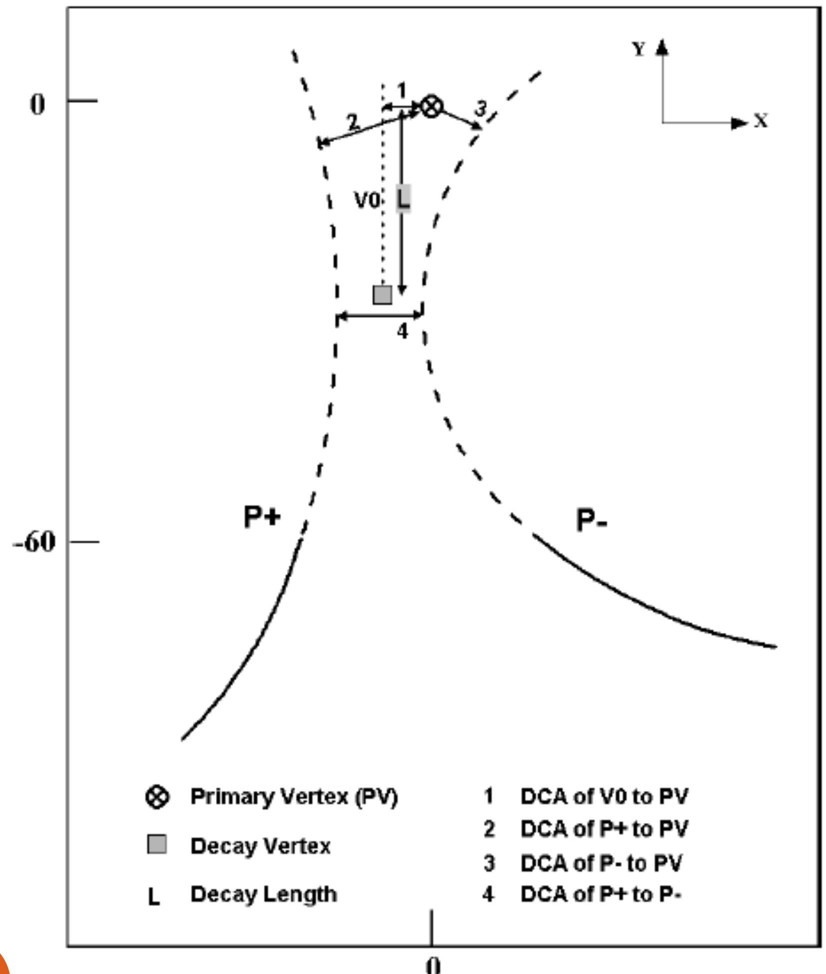


Weak decay feed down contribution to Λ uncorrected yield





Strangeness reconstruction in STAR



Strange particles are reconstructed with their secondary TPC tracks through weak decay topology, thanks to the full azimuthal coverage of TPC.

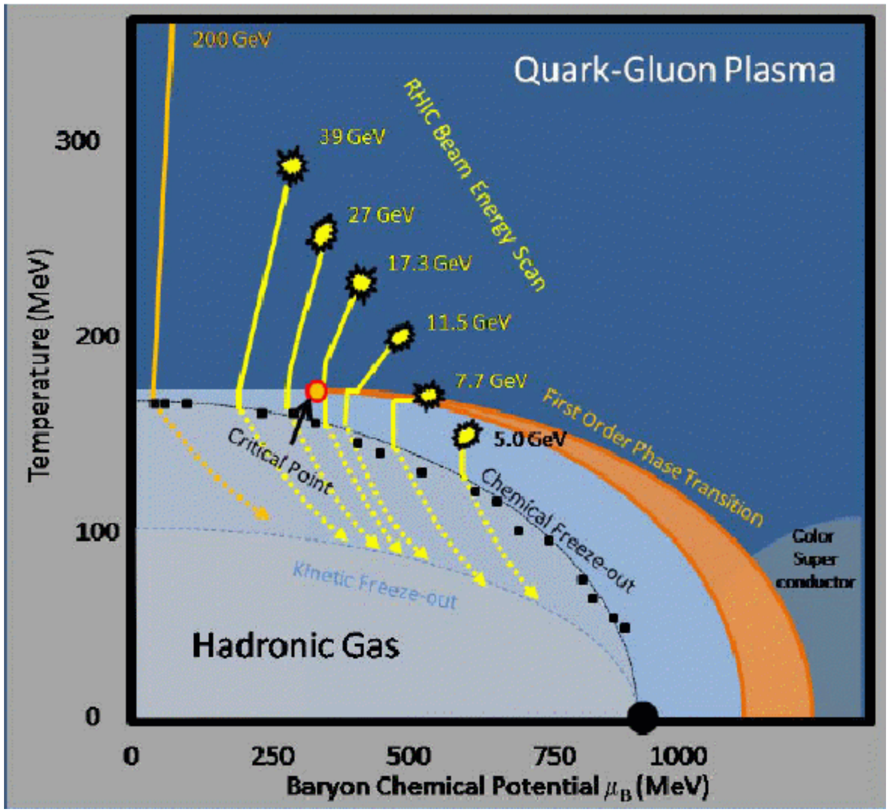
$$K_s^0 \to \pi^+\pi^-,\ c\tau = 2.68\text{cm}$$

$$\Lambda \to p\pi, c\tau = 7.89\text{cm}$$

$$\Xi \to \Lambda\pi \to p\pi\pi, c\tau = 4.91\text{cm}$$

$$\Omega \to \Lambda K \to p\pi K, c\tau = 2.46\text{cm}$$

The beam energy scan in STAR



STAR, arXiv:1007.2613

- Lattice QCD estimates indicate that the critical point falls within the interval $250 < \mu_B < 450$ MeV [Karsch 2004, Fodor and Katz 2004, Gavai and Gupta 2005]
- Experiment evidence for either critical point or first order phase transition is key issue to understand the QCD phase diagram.
- The black closed circles are current heavy-ion experimental calculations of the chemical freeze-out temperature, T_{ch}, and μ_B based on statistical model fits to the measured particle ratios
- The yellow curves show the estimated trajectories of the possible collision energies at RHIC.
- **In 2010, three energies have been scanned: 7.7, 11.5 and 39 GeV**