



Beam Energy Dependence of Strange Hadron Production at RHIC

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For the STAR Collaboration

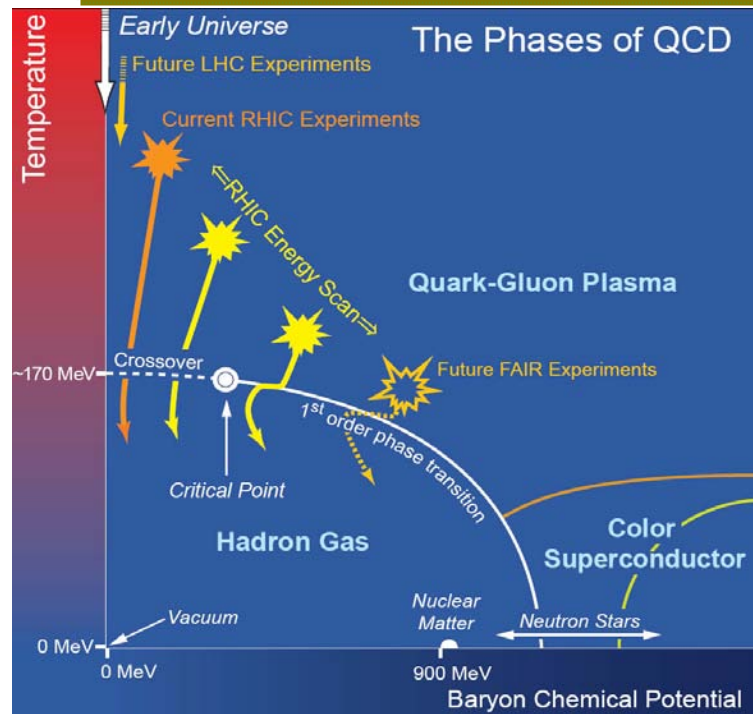


Outline



- Physics Motivation
 - STAR Detector, Data Set & Signal Reconstruction
 - Strangeness Production at mid-rapidity
 - Particle p_T Spectra and Yields
 - Nuclear Modification Factor: R_{cp}
 - Anti-baryon to Baryon Ratios
 - Baryon to Meson Ratios
 - Summary
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Physics Motivation



- BES Program at RHIC:
 - 1) Study the onset of de-confinement and phase boundary;
 - 2) Search for the possible QCD critical point

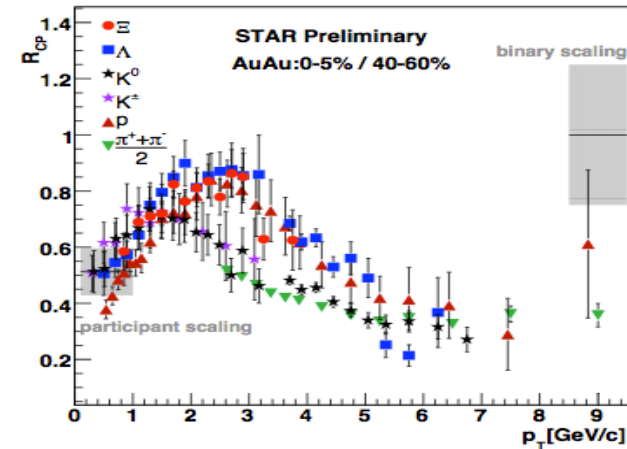
STAR: arXiv: 1007.2613

- Strangeness is sensitive to the collision dynamics in heavy ion collisions.

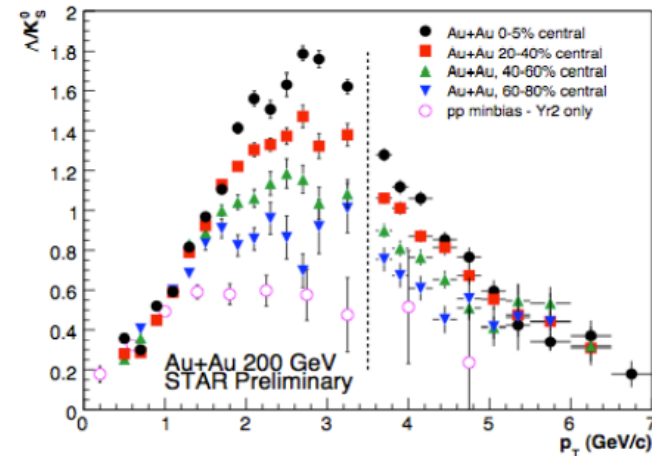
Physics Motivation



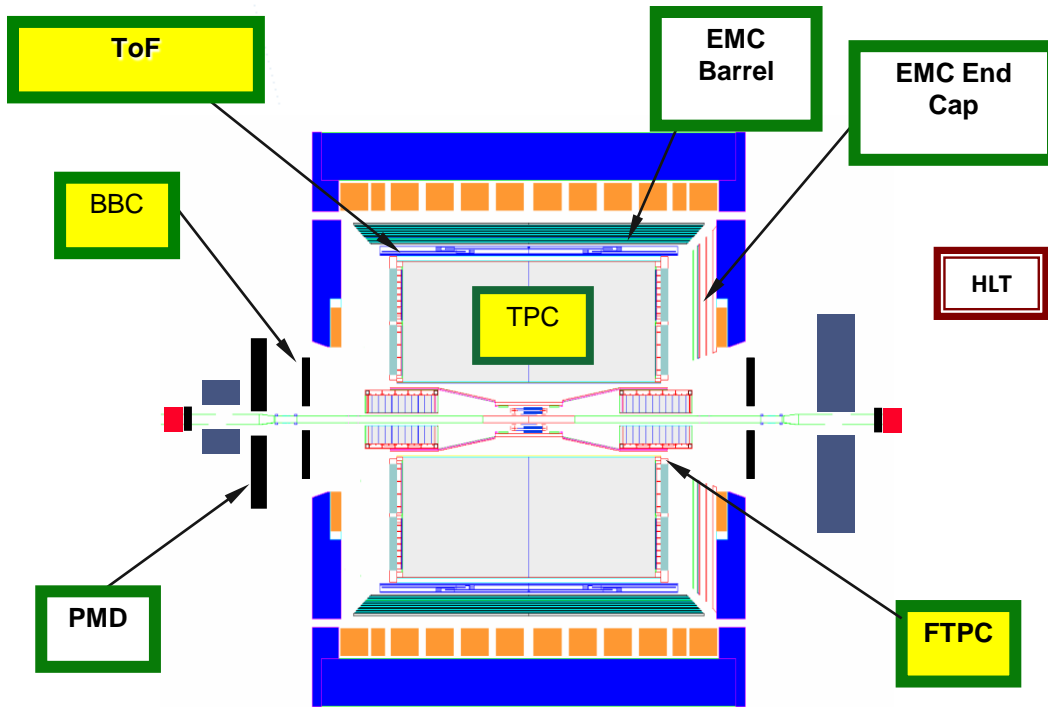
- R_{cp} of baryons and mesons follow different trends at Au+Au 200GeV collisions
---- Partonic energy loss & recombination.
- Baryon-to-meson ratios enhancement at intermediate- p_T in central Au+Au 200GeV collisions
---- Parton recombination.



STAR: arXiv: 1007.2613



Detector and Data Set

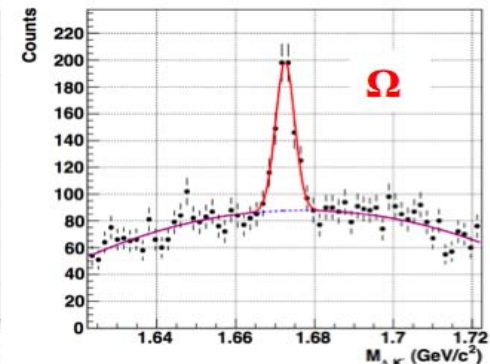
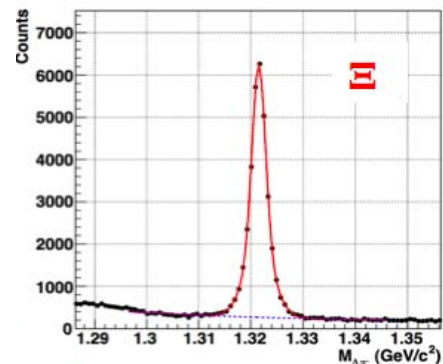
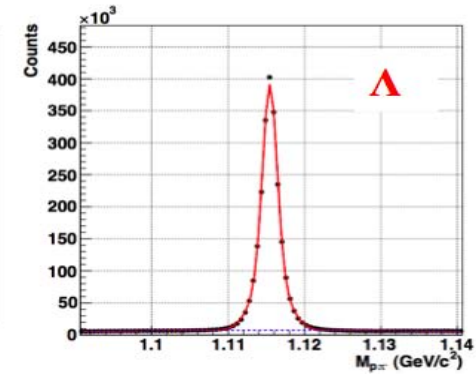
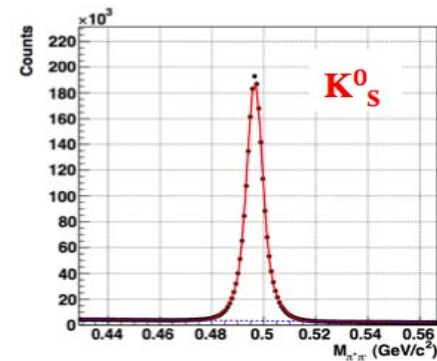
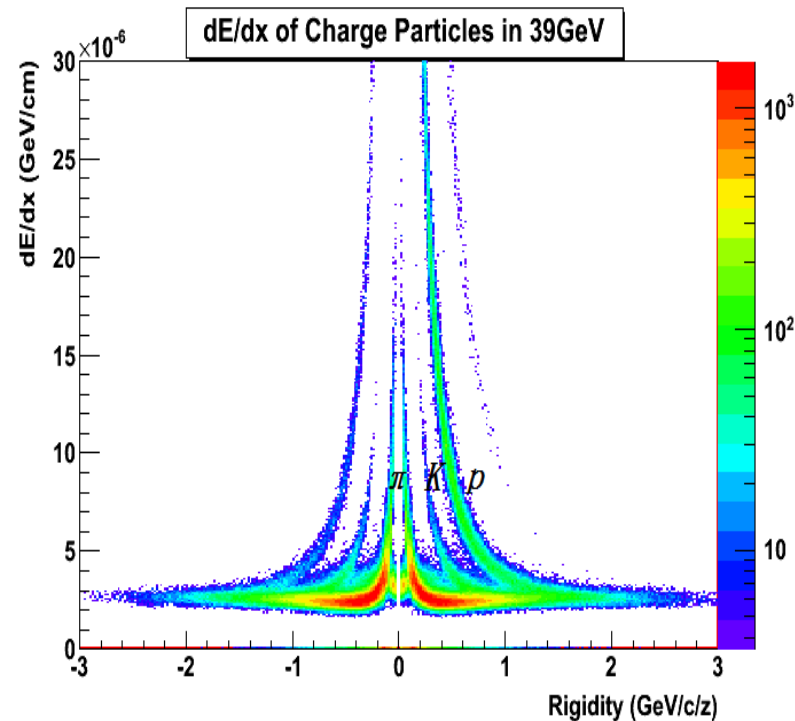


Detector System in Run 10 and Run 11
Beam Energy Scan Program.

Au+Au Collisions

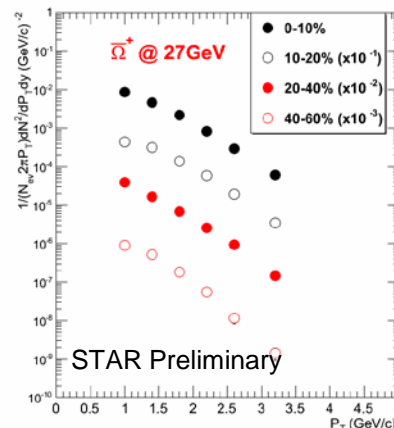
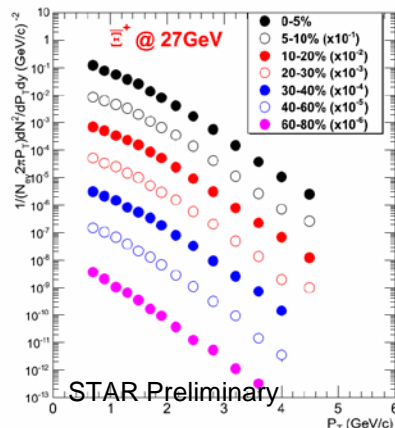
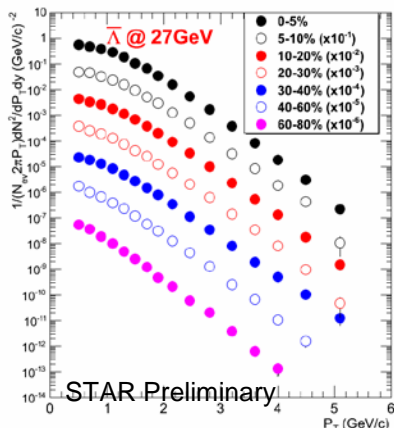
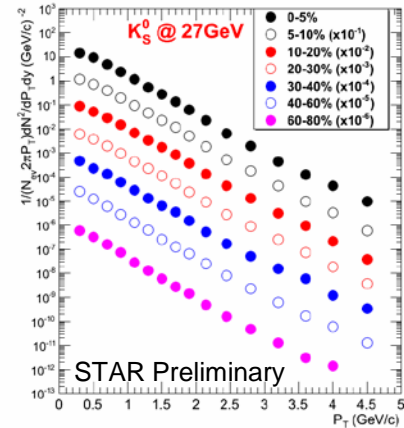
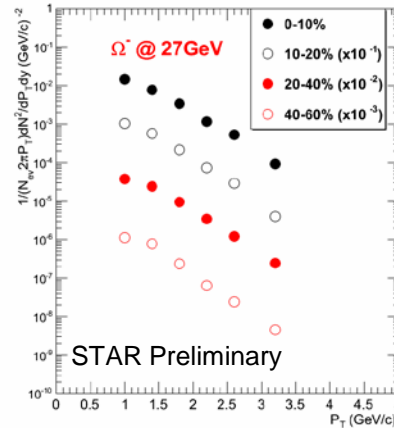
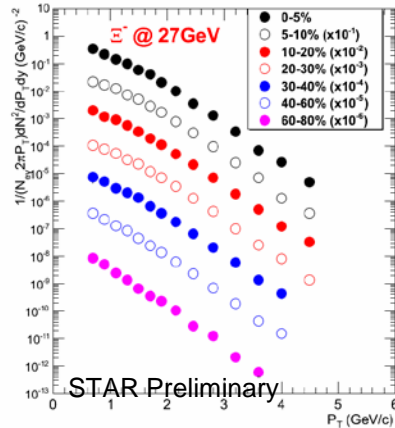
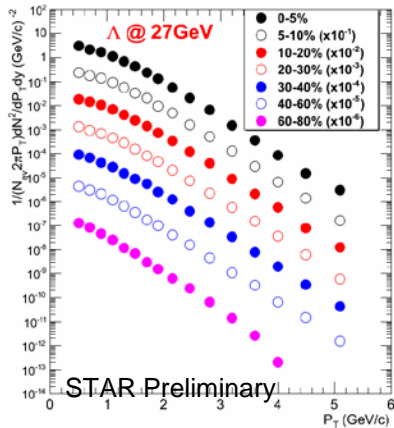
$\sqrt{s_{NN}}$ (GeV)	Good MB events in Million
7.7	~ 4 M
11.5	~ 12 M
19.6	~ 36 M
27	~ 70 M
39	~ 130 M

Signal Reconstruction



- Information from Time Projection Chamber is used for particle identification.

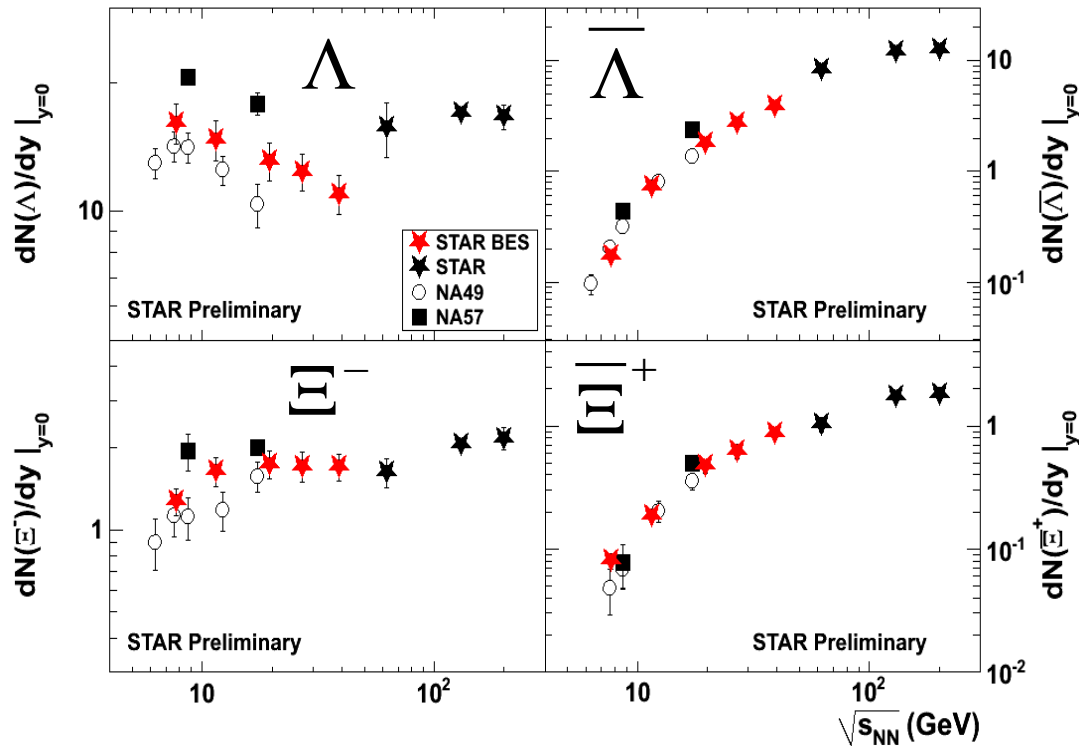
p_T Spectra (27GeV)



Statistical error only

- Λ spectra are corrected for Ξ and Ξ^0 feed-down contribution.

Particle Yields



NA49, PRC78,034918.

7% or 10% most central.
($|y| < 0.4$ or 0.5)

NA57, PLB595,68; JPG32, 427

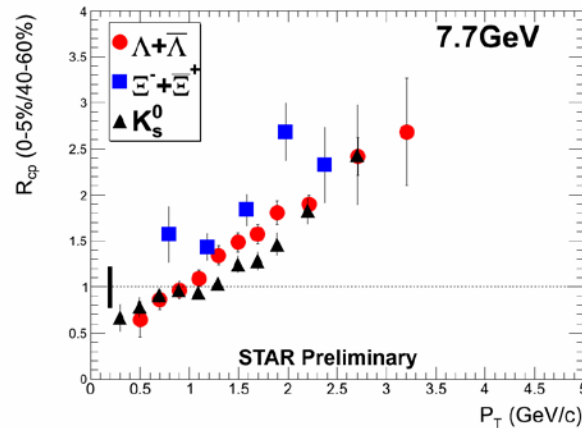
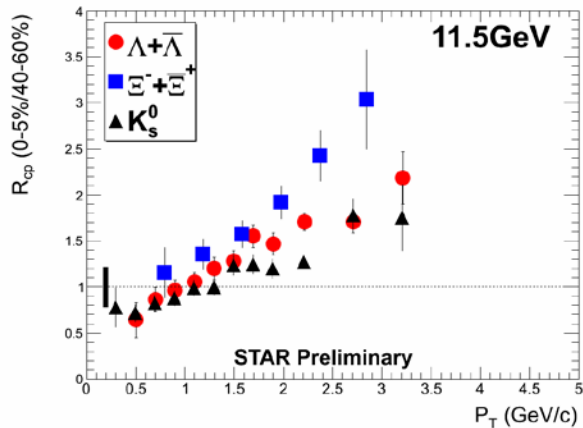
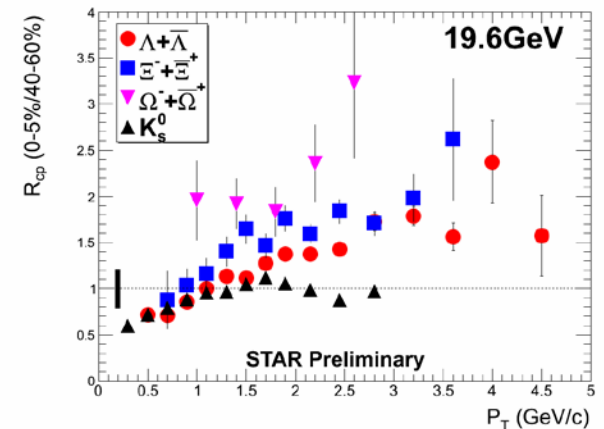
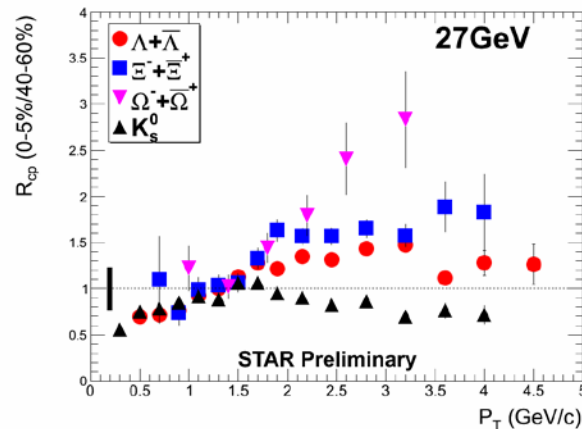
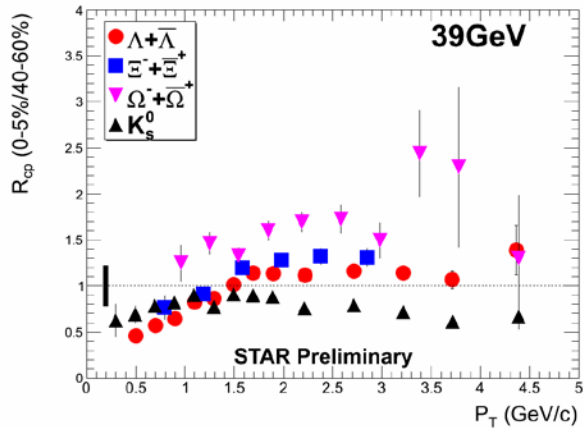
0-4.5% most central,
 $|y| < 0.5$, stat. err. only

STAR,
PRL86,89,92,98; PRC83

0-5% most central,
 $|y| < 0.5$

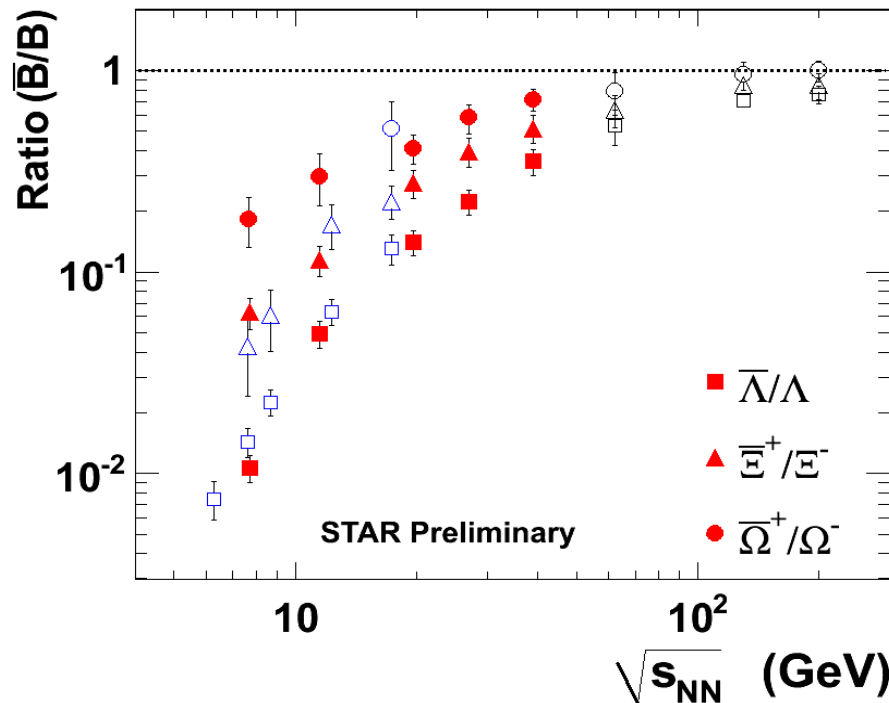
- Central Collisions; Mid-rapidity.
- Statistical + Systematic Error.

Nuclear Modification Factor R_{cp}



Statistical error only
 Omega R_{cp} in 19.6 and 27 GeV:
 (0~10%)/(40~60%)
 Particle R_{cp} difference
 at intermediate p_T
 becomes smaller at
 7.7GeV and 11.5GeV.

Anti-baryon to Baryon Ratio



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

Central Collisions

- STAR BES data lie in a trend with NA49 data
- \bar{B}/B ratios increase with number of strange quarks at low energies
 $\bar{\Omega}^+/\Omega^- > \bar{\Sigma}^+/\Sigma^- > \bar{\Lambda}/\Lambda$

Anti-baryon to Baryon Ratio

$$n_i = \frac{g_i}{(2\pi^2)} \gamma_S^{|S_i|} m_i^2 T K_2(m_i/T) \exp(\mu_i/T)$$

$$\frac{\bar{\Lambda}}{\Lambda} = \exp\left(-\frac{2\mu_B}{T} + \frac{2\mu_S}{T}\right)$$

$$\ln\left(\frac{\bar{\Lambda}}{\Lambda}\right) = -\frac{2\mu_B}{T} + \frac{2\mu_S}{T}$$

$$\frac{\bar{\Xi}^+}{\Xi^-} = \exp\left(-\frac{2\mu_B}{T} + \frac{4\mu_S}{T}\right)$$



$$\ln\left(\frac{\bar{\Xi}^+}{\Xi^-}\right) = -\frac{2\mu_B}{T} + \frac{4\mu_S}{T}$$

$$\frac{\bar{\Omega}^+}{\Omega^-} = \exp\left(-\frac{2\mu_B}{T} + \frac{6\mu_S}{T}\right)$$

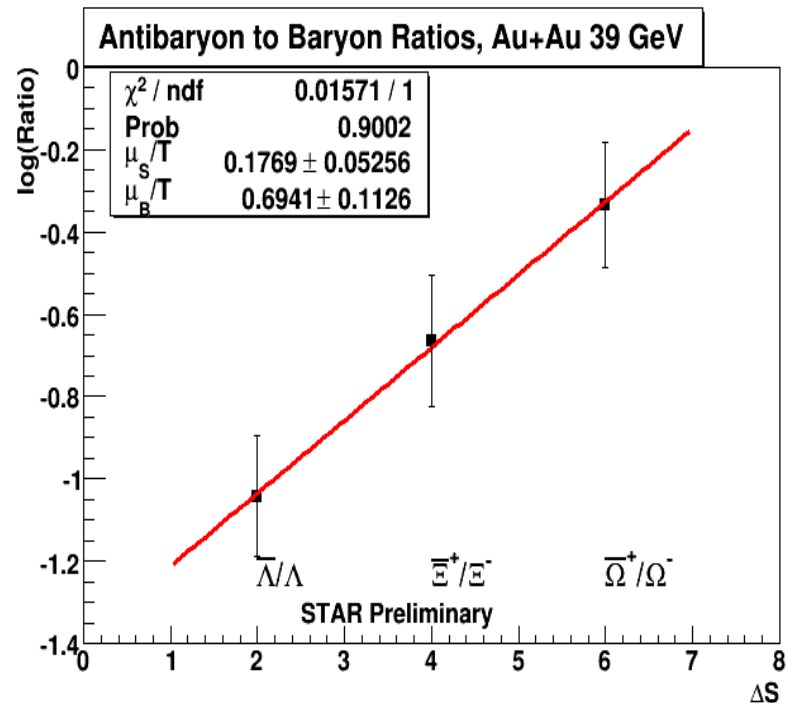
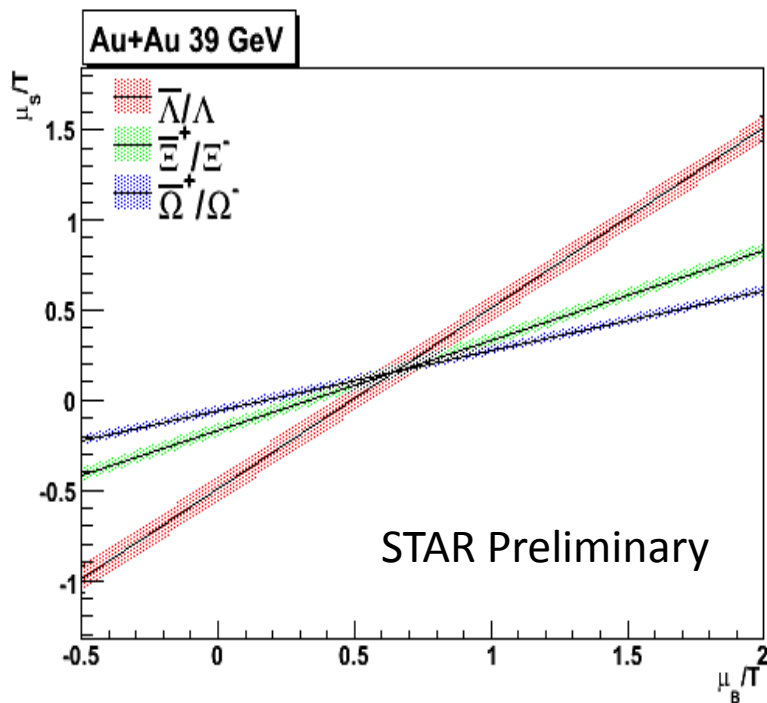
$$\ln\left(\frac{\bar{\Omega}^+}{\Omega^-}\right) = -\frac{2\mu_B}{T} + \frac{6\mu_S}{T}$$

- T is the temperature.
- μ_B is the baryon chemical potential.
- μ_S is the strangeness chemical potential.

(arXiv:nucl-th/9704046v1 by J.Cleymans & Phys. Rev. C 71(2005)054901)

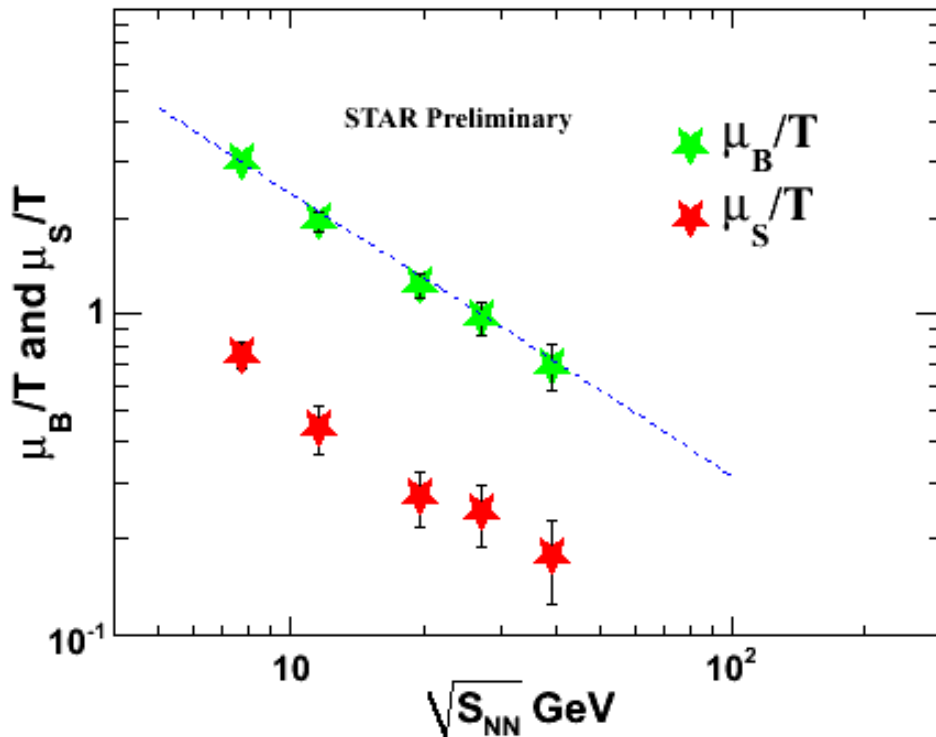
Anti-baryon to Baryon Ratio

$$\ln(\text{Ratio}) = -\frac{2\mu_B}{T} + \frac{\mu_S}{T} \times \Delta S$$



- Statistical error only.

Anti-baryon to Baryon Ratio



$$T \approx T_0 - b\mu_B^2$$

$$\mu_B = \alpha \frac{\log \sqrt{S_{NN}}}{(\sqrt{S_{NN}})^\beta}$$

Where:

$$T_0 = 167.5 \text{ MeV}$$

$$b = 0.1583 \text{ GeV}^{-2}$$

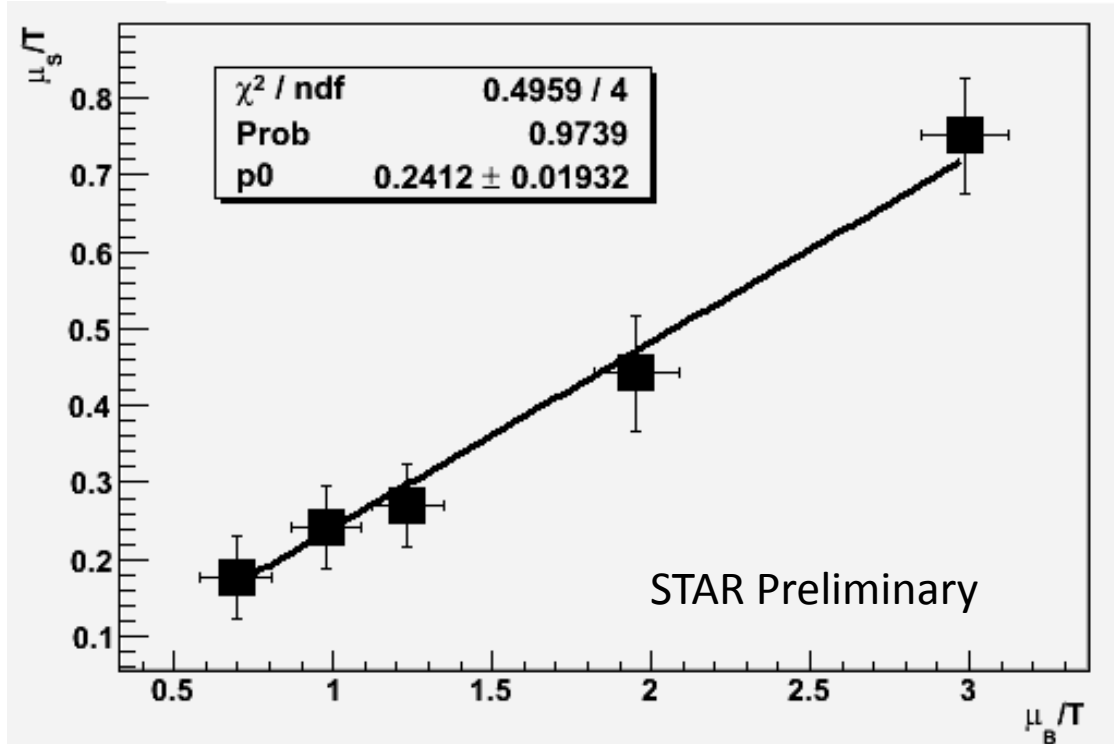
$$\alpha = 2.06$$

$$\beta = 1.13$$

Parameters are from the fitting of published data of AGS, SPS and RHIC 130 GeV data.

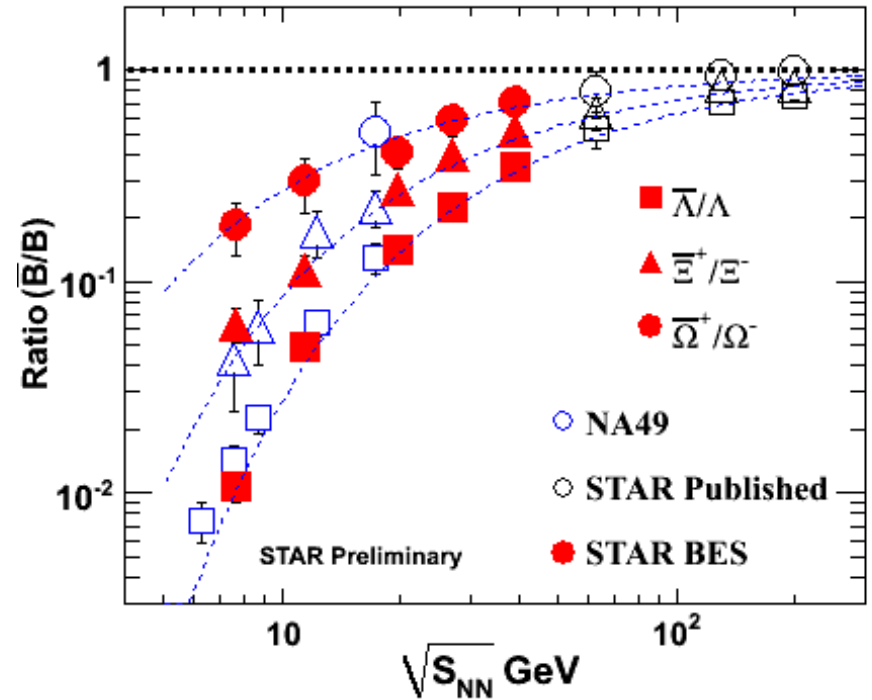
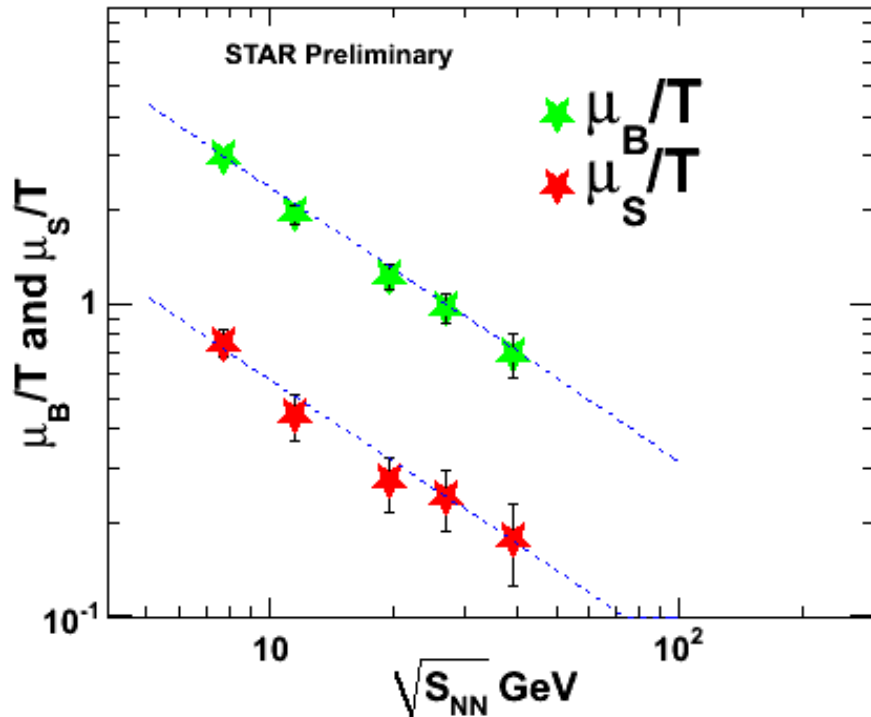
- Reference: F.Becattini et al. Phys Rev C 73, 044905 (2006)
- Statistical error only.

Anti-baryon to Baryon Ratio



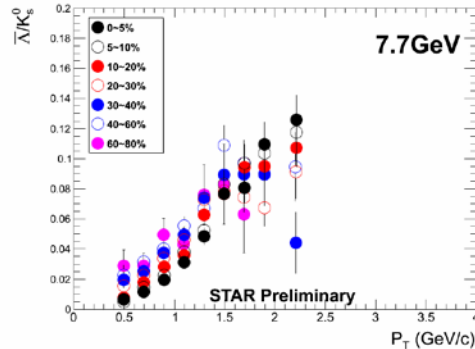
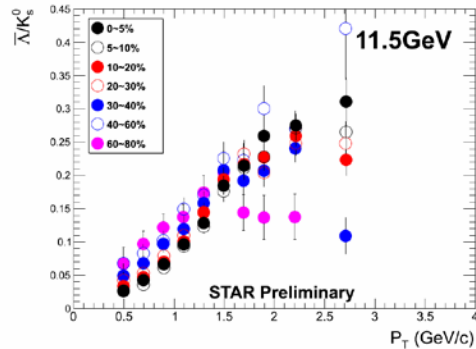
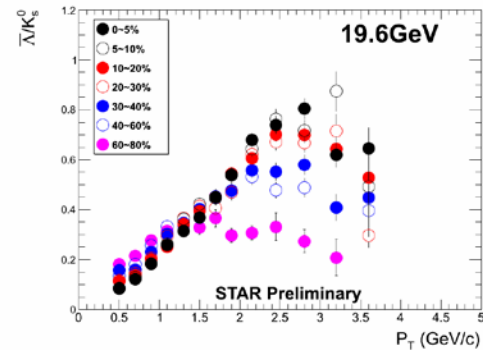
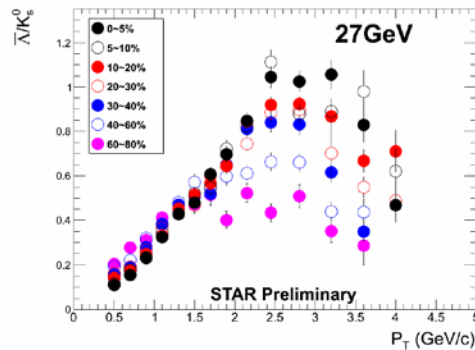
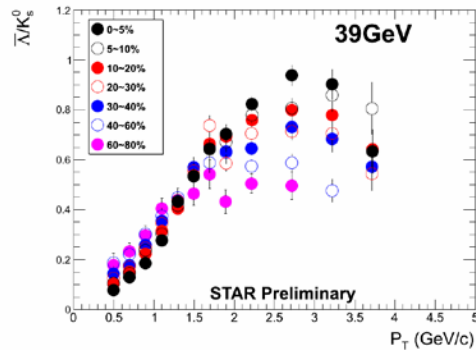
- Try to get a relationship between μ_B/T and μ_S/T .
- Use a linear function to fit μ_B/T and μ_S/T .

Anti-baryon to Baryon Ratio



- The blue curve take the parameterization in Slide 13 and fitting function in Slide 14.

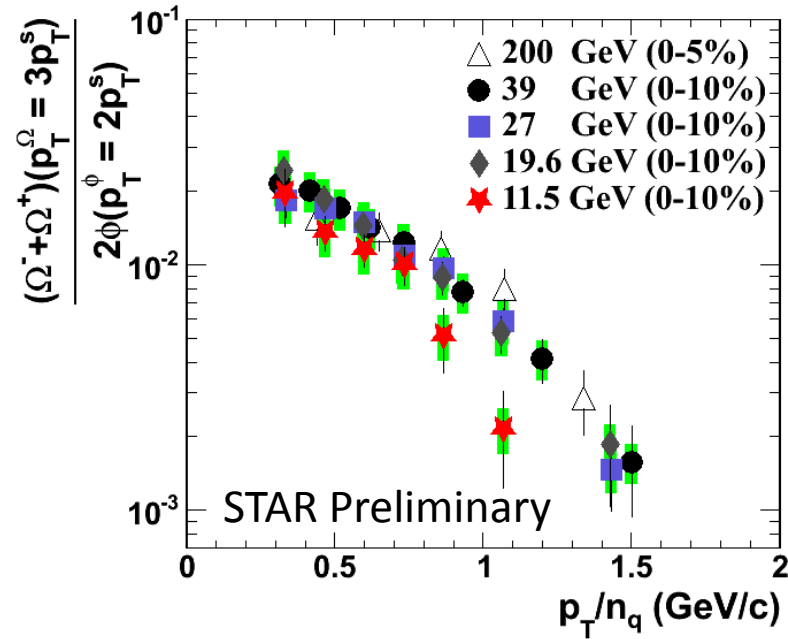
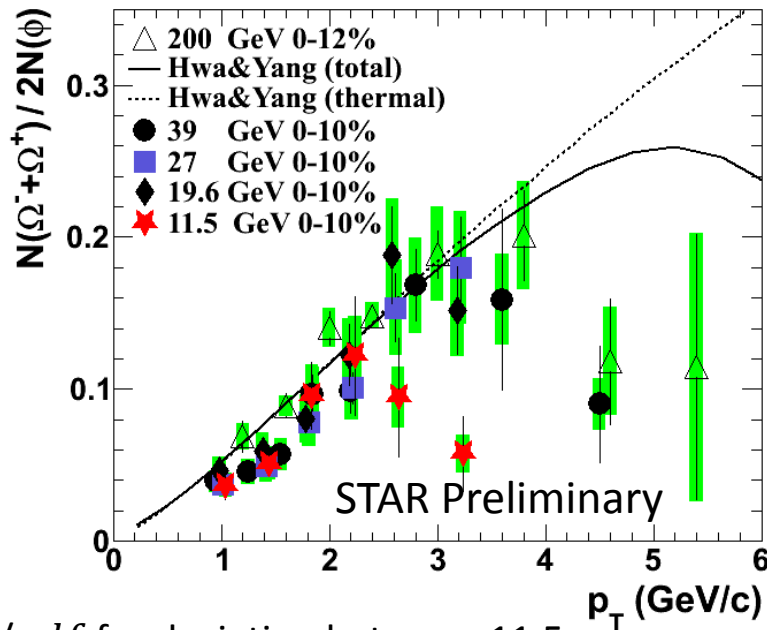
$\bar{\Lambda} / K_S^0$ Ratio



Statistical error only

- At $p_T \sim 2 \text{ GeV}/c$, the $\bar{\Lambda} / K_S^0$ magnitude decreases with decreasing energy, the separation of central and peripheral decreases as well.

Omega/phi Ratio



χ^2/ndf for deviation between 11.5 and 19.6 GeV ($p_T > 2.4$ GeV/c) is 8.3/2

Statistical error + Systematic error

Hwa & Yang, Phys. Rev. C 75, 054904(2007), Phys. Rev. C 78, 034907 (2008)

- Ω/ϕ ratio and derived strange quark p_T distributions indicate a separation between 19.6 GeV and 11.5 GeV.

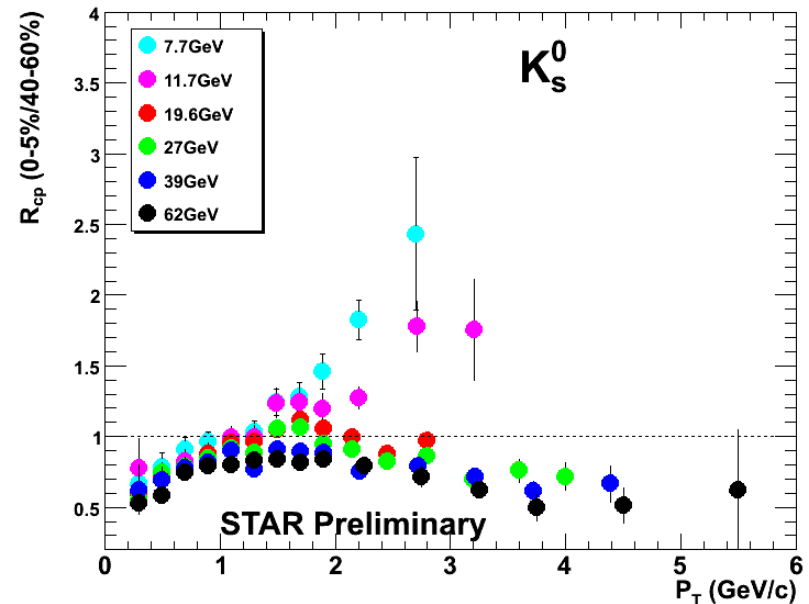
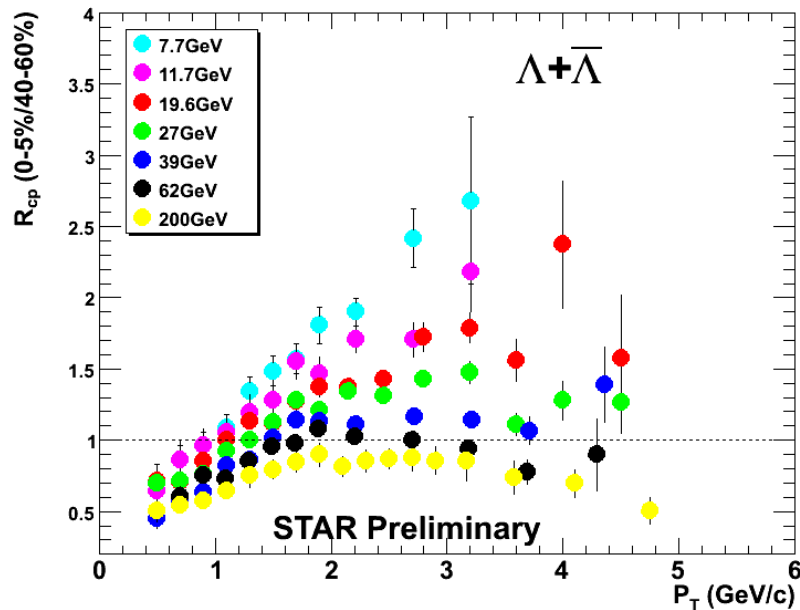
Summary



- Measurements of strange hadron production in RHIC Beam Energy Scan have been reported;
- Anti-baryon to baryon ratios increase with beam energy and number of strange quarks, and the ratios are consistent with statistical thermal model;
- $\bar{\Lambda} / K_S^0$ shows less centrality dependence in lower beam energies, and decreases with the increase of beam energy;
- Ω/ϕ ratio indicates a separation between 19.6 GeV and 11.5 GeV, χ^2/ndf for deviation of Ω/ϕ ratios between 11.5 and 19.6 GeV ($p_T > 2.4 \text{ GeV}/c$) is 8.3/2.

Back Up

Nuclear Modification Factor R_{cp}

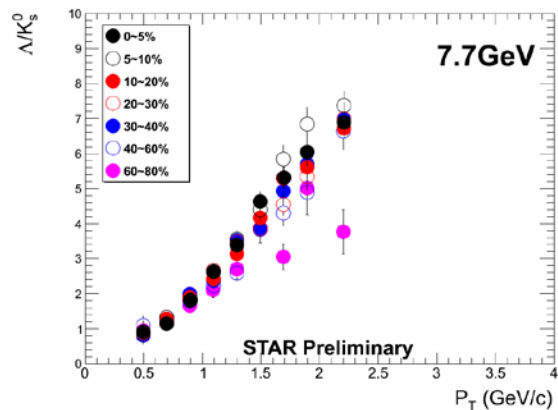
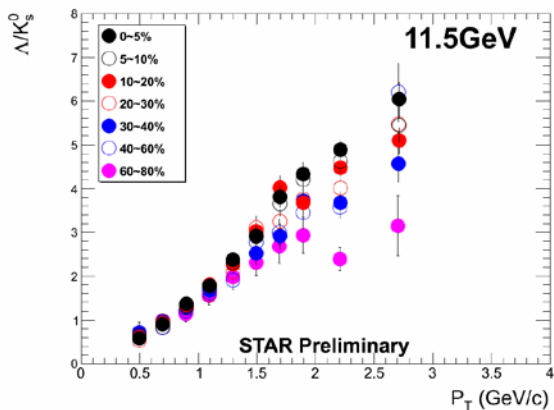
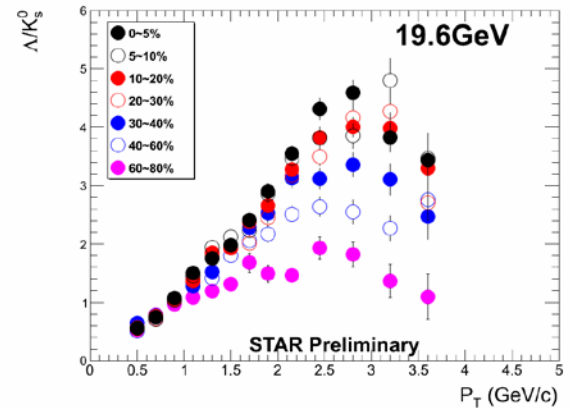
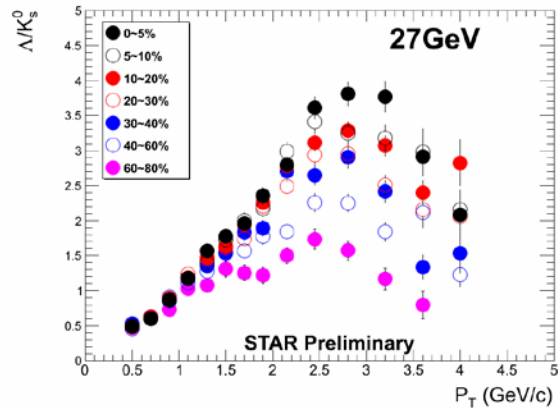
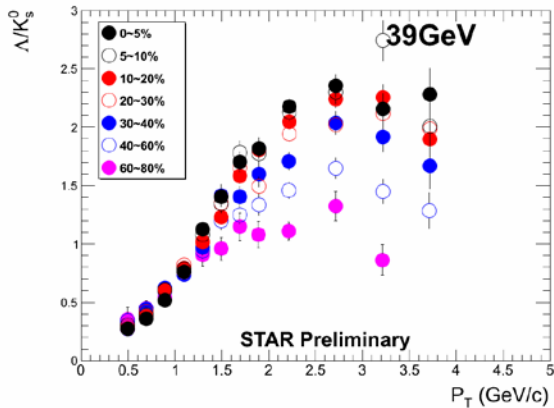


- Statistical error only.
- R_{cp} decrease with the increase of beam energy.
- R_{cp} of K_s^0 is suppressed in Au+Au above 19.6GeV.

Phys. Rev. Lett 98(2007)062301

Rhys. Rev. C 83(2011)24901

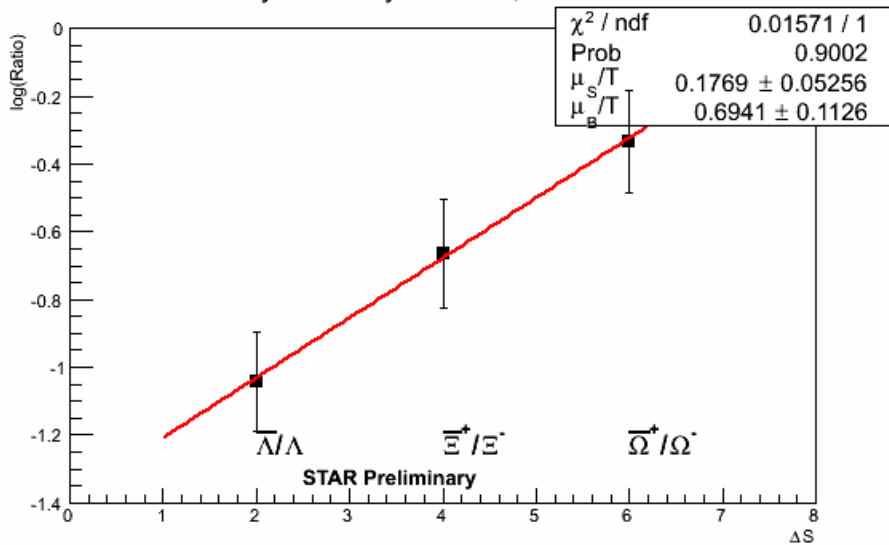
Λ / K_s^0 Ratio



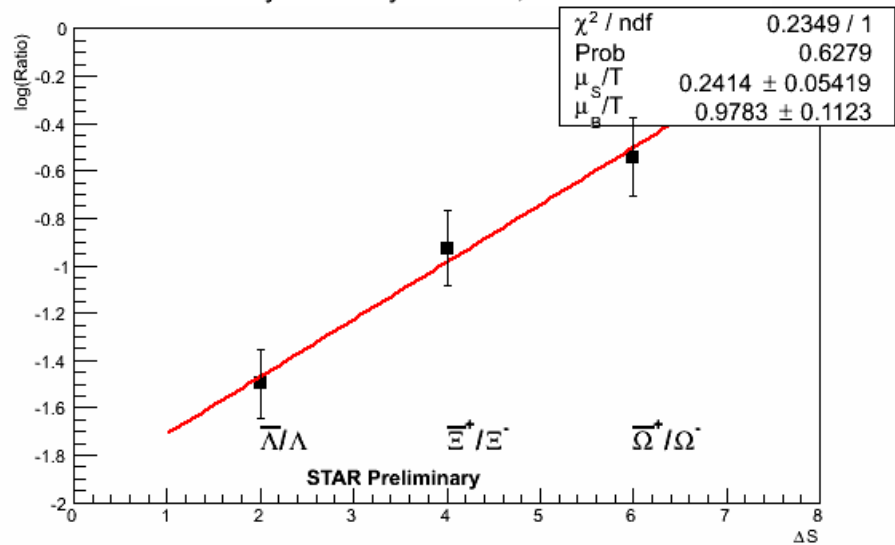
Statistical error only

- Centrality dependence seems to be smaller in lower energy.

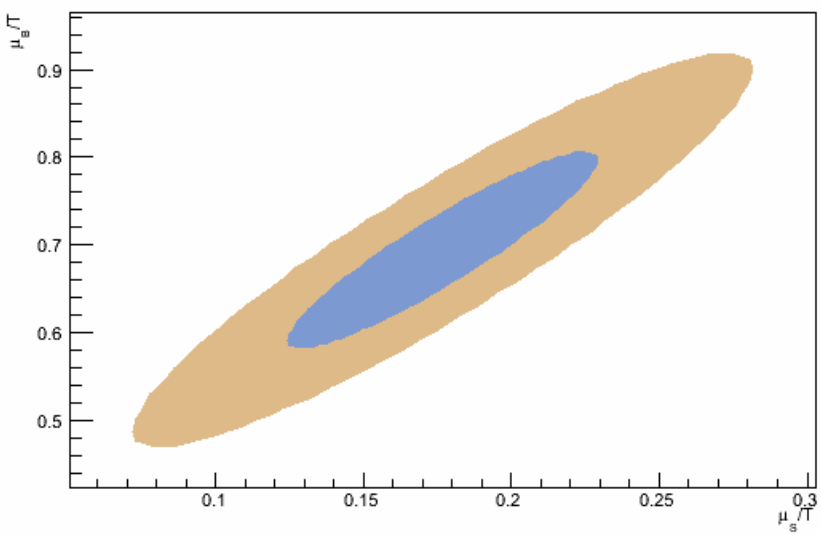
Antibaryon to Baryon Ratios, Au+Au 39 GeV



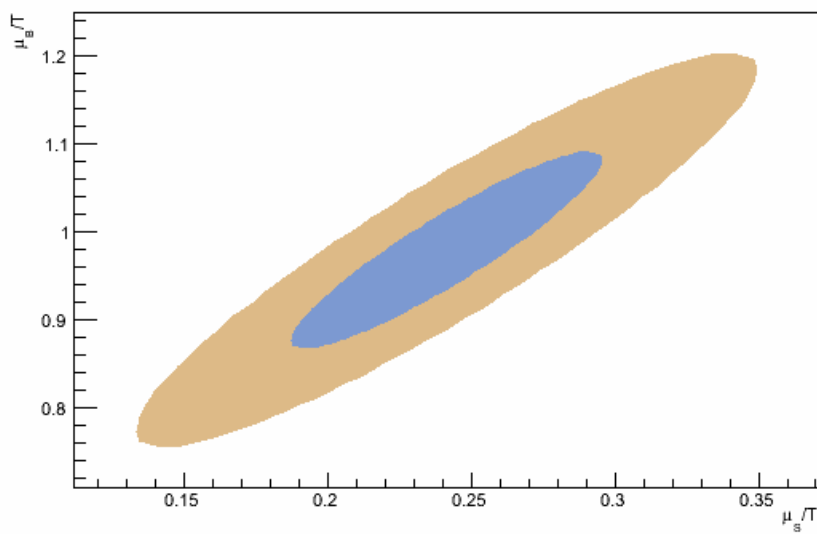
Antibaryon to Baryon Ratios, Au+Au 27 GeV



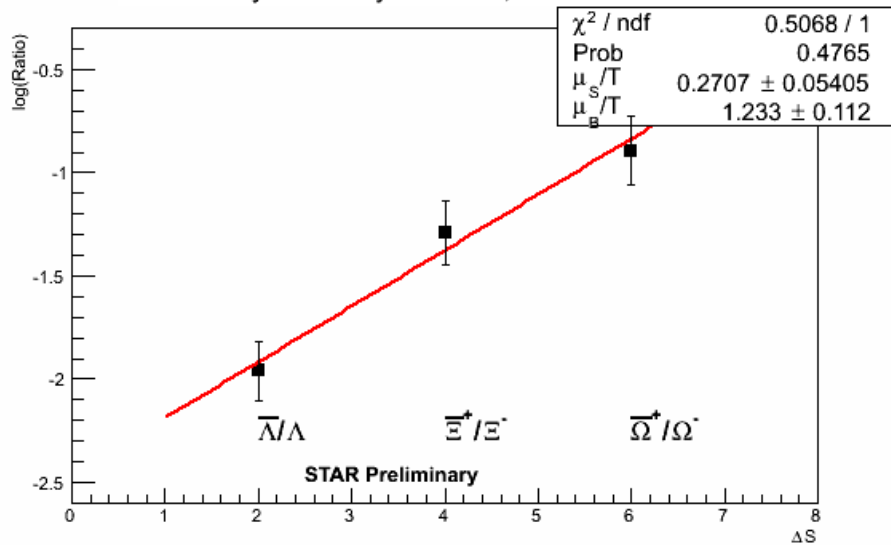
Fitting Parameter Contour



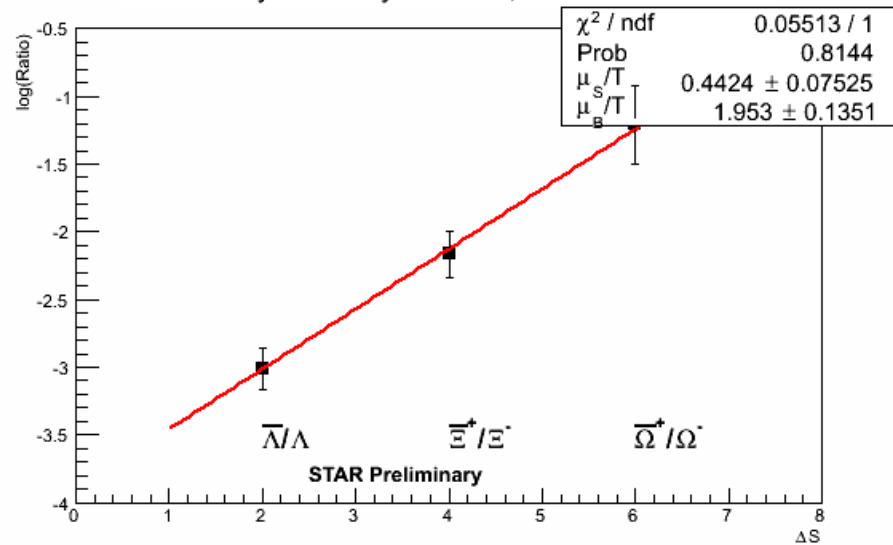
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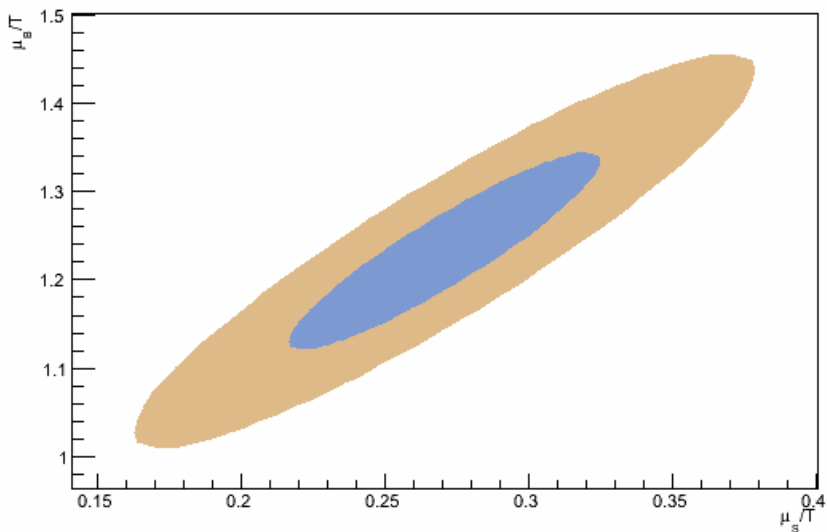
Antibaryon to Baryon Ratios, Au+Au 19.6 GeV



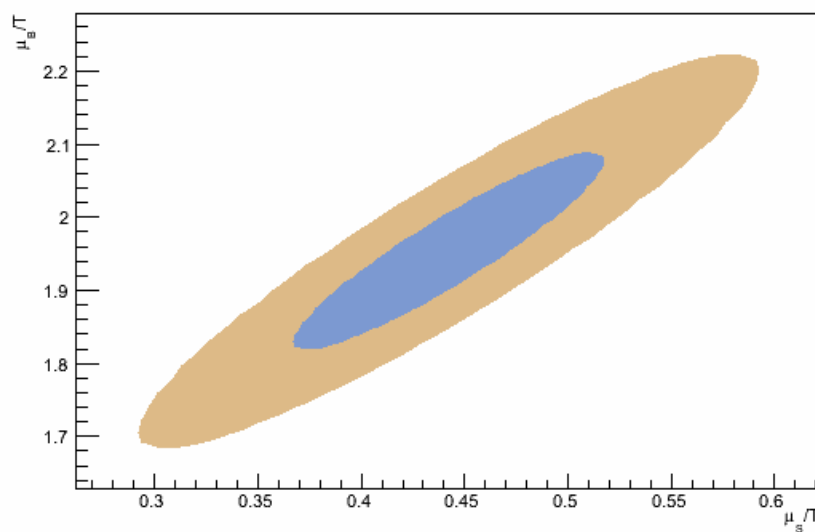
Antibaryon to Baryon Ratios, Au+Au 11.5 GeV



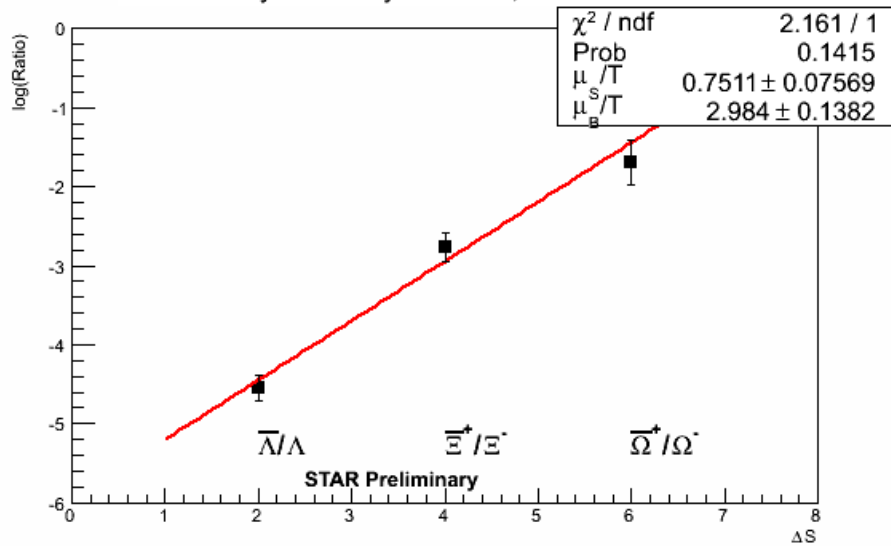
Fitting Parameter Contour



Fitting Parameter Contour



Antibaryon to Baryon Ratios, Au+Au 7.7 GeV



Fitting Parameter Contour

