Identified Light and Strange Hadron Spectra at $\sqrt{s_{NN}}$ = 14.5 GeV with STAR at RHIC BES I

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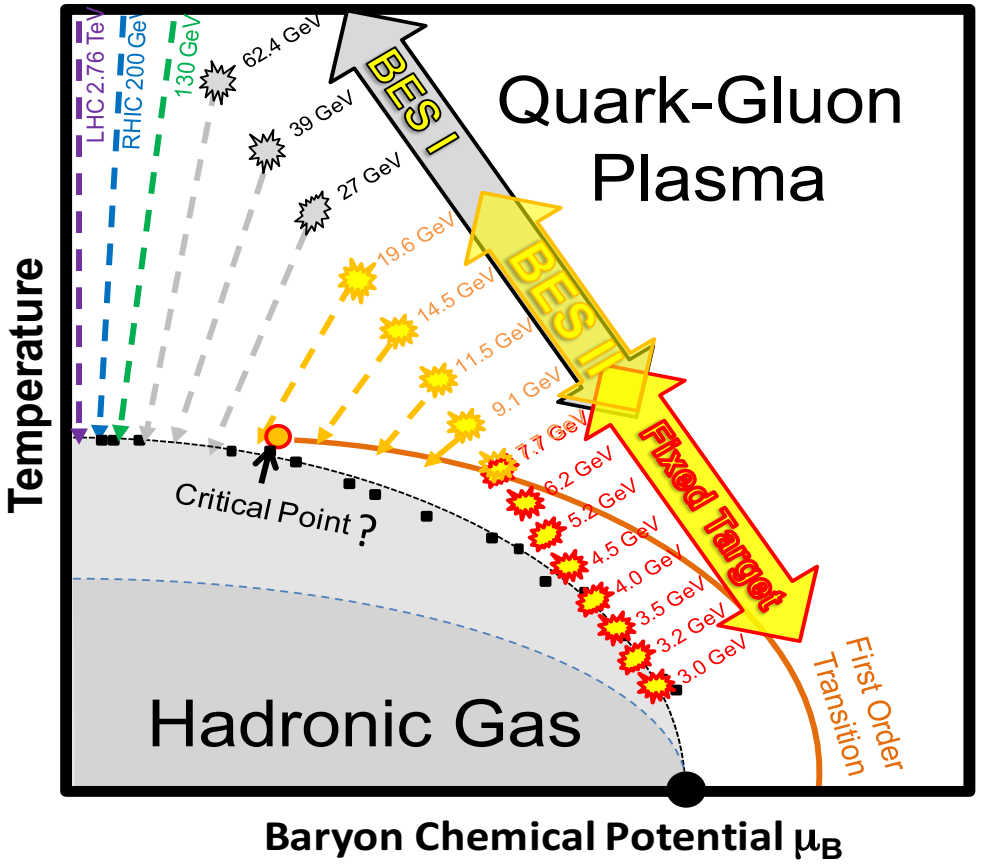
RHIC Beam Energy Scan (BES) Phase I

BES Phase I - Au+Au collisions at 7.7, 11.5, 14.5, 19.6, 27.0, and 39.0 GeV

- Search for Conjectured QCD critical point
- Search for 1st order phase transition
- Search for the onset of key QGP signatures

- $\sqrt{s_{NN}}$ **= 14.5 GeV**
  - Important measurement in the relatively large μ_B gap between 11.5 and 19.6 GeV



$\sqrt{s_{NN}}$ [GeV] =	7.7	11.5	14.5	19.6	27.0	39.0
~μ_B (in central collisions)[MeV]	420	315	260	205	155	115

J. Cleymans, H. Oeschler, K. Redlich, and S. Wheaton, Phys. Rev. C73 (2006) 034905

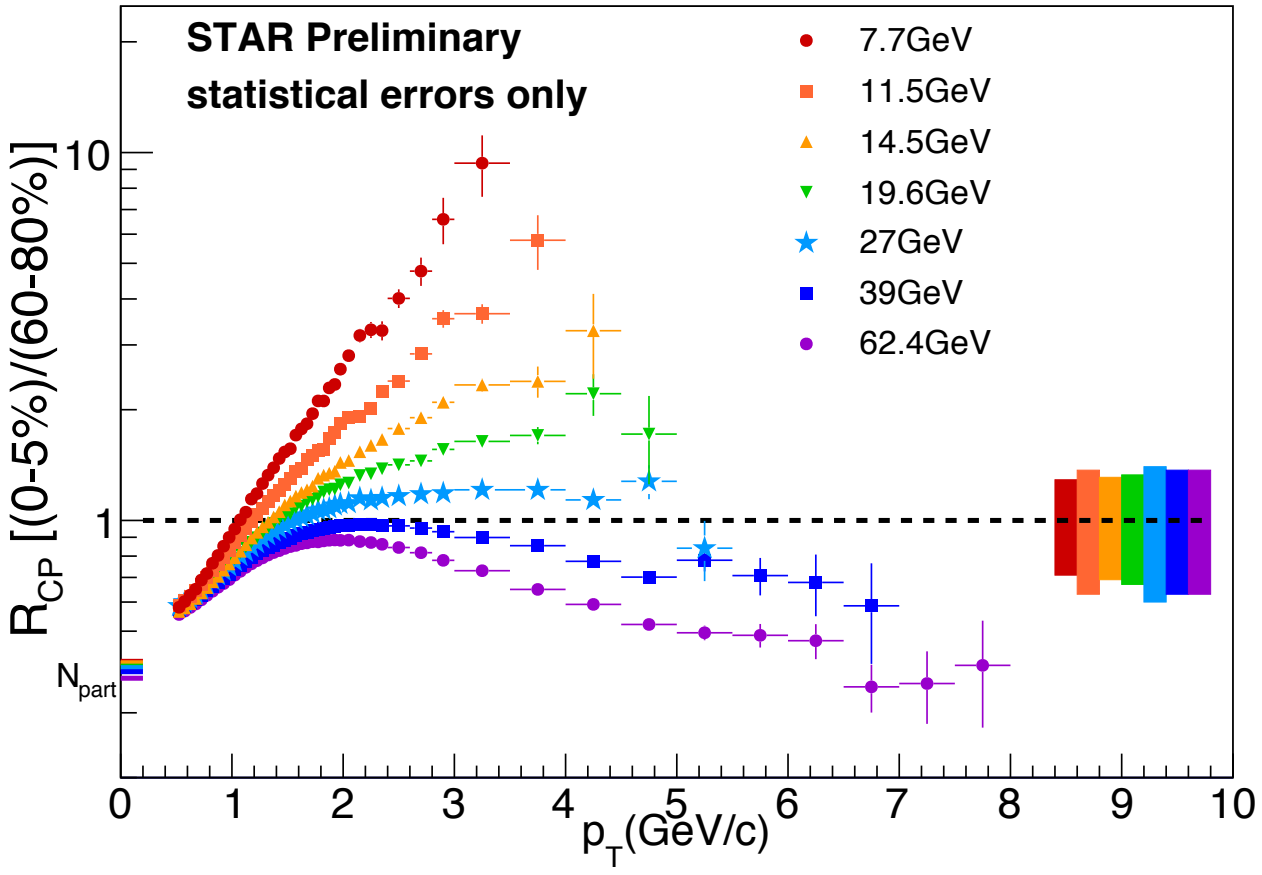
Nuclear Modification Factor R_{CP}

- High p_T suppression $\equiv R_{CP} < 1.0$
  - Strong suppression observed in inclusive charged hadrons at top RHIC energies.
  - Attributed to energy loss in QGP
- Enhancement $\equiv R_{CP} > 1.0$
  - Cold nuclear matter effects, radial flow and coalescence.

R_{CP} vs. R_{AA}

- R_{CP} analysis can be done with a single dataset
- The pp baseline in R_{AA} has no hot nuclear matter effects
- R_{CP} is less sensitive than R_{AA} to cold nuclear matter effects
- R_{CP} has large correlated systematic uncertainty on the calculation of N_{coll} in peripheral events

Inclusive Charged hadrons @ RHIC BES I



- Smooth transition in the intermediate to high p_T range from suppression at $\sqrt{s_{NN}}$ = 39 GeV to strong enhancement at $\sqrt{s_{NN}}$ = 7.7 GeV

Onset of QGP Signatures

Baryon/Meson Ratio eg. (Λ/K^0_S) and (p/π)

- Baryon enhancement observed in Au+Au collisions at top RHIC energies
- Baryon/Meson ratio is sensitive to QGP formation through:
  - Parton recombination
  - Coalescence
- Baryon/Meson ratio is also sensitive to:
  - Radial flow
  - cold nuclear matter effects

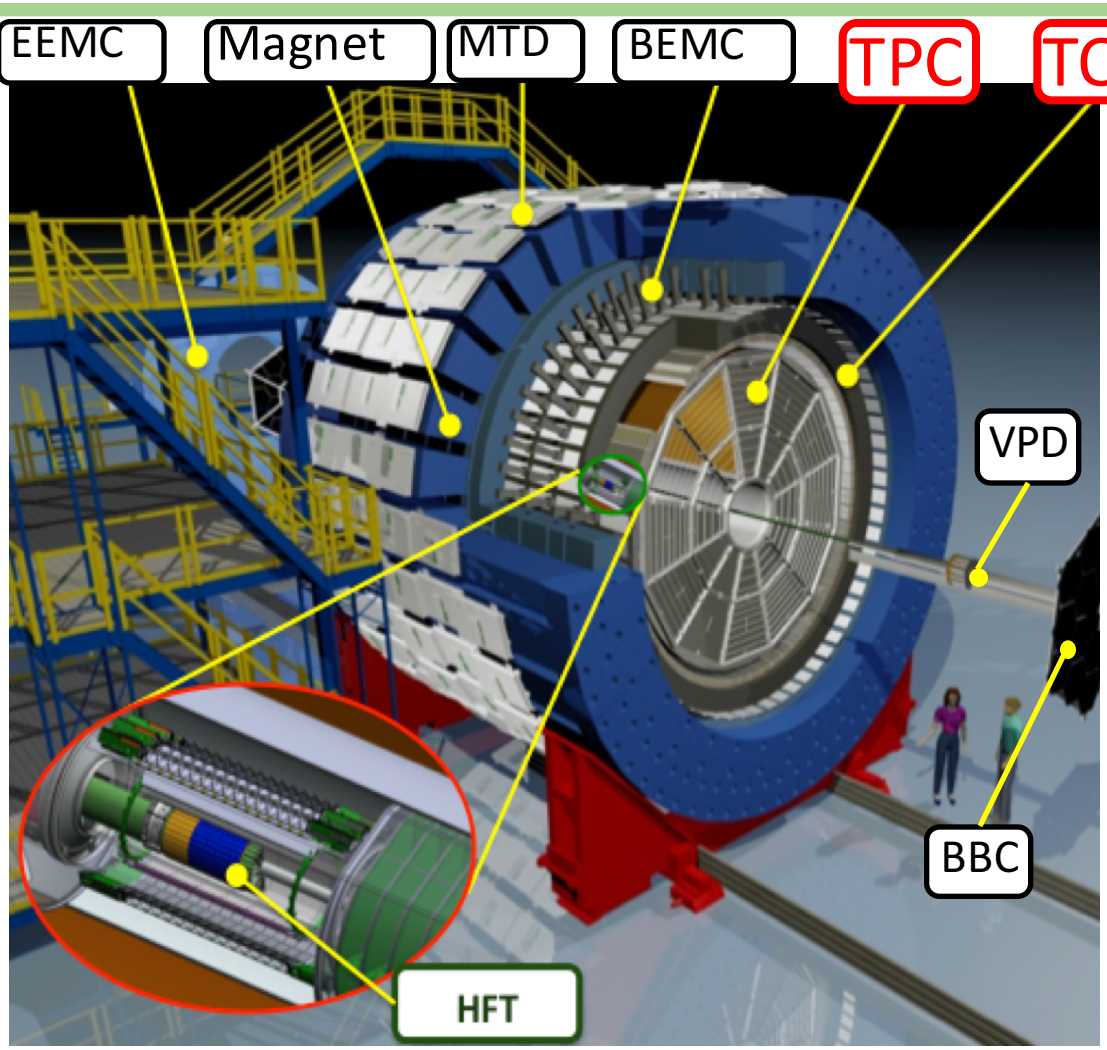
STAR Detector

Time Projection Chamber (TPC)

- Charged Particle Tracking
- Momentum reconstruction
- Particle identification from ionization energy loss (dE/dx)
- Pseudorapidity coverage $|\eta| < 1.0$

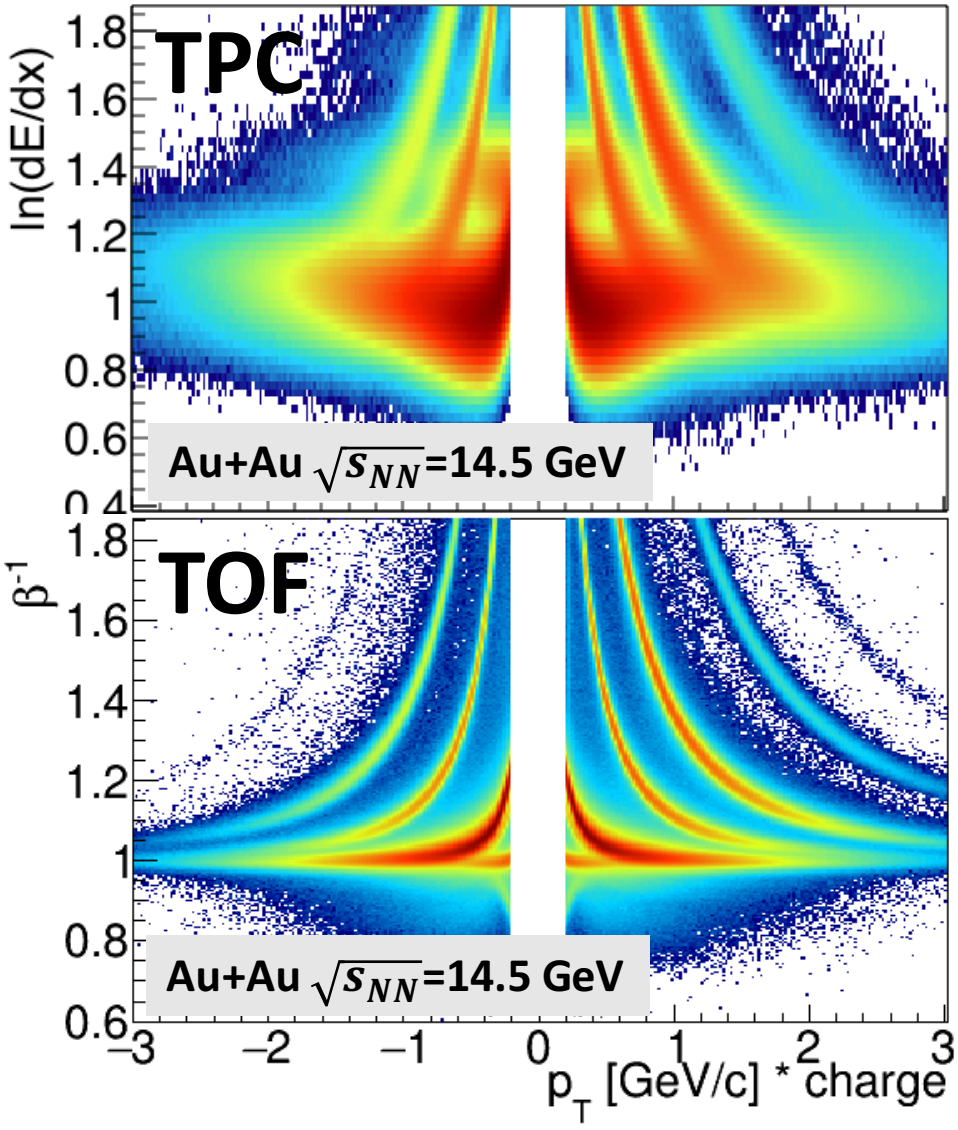
Time Of Flight (TOF) Detector

- Particle identification $1/\beta$
- Pseudorapidity coverage $|\eta| < 0.9$

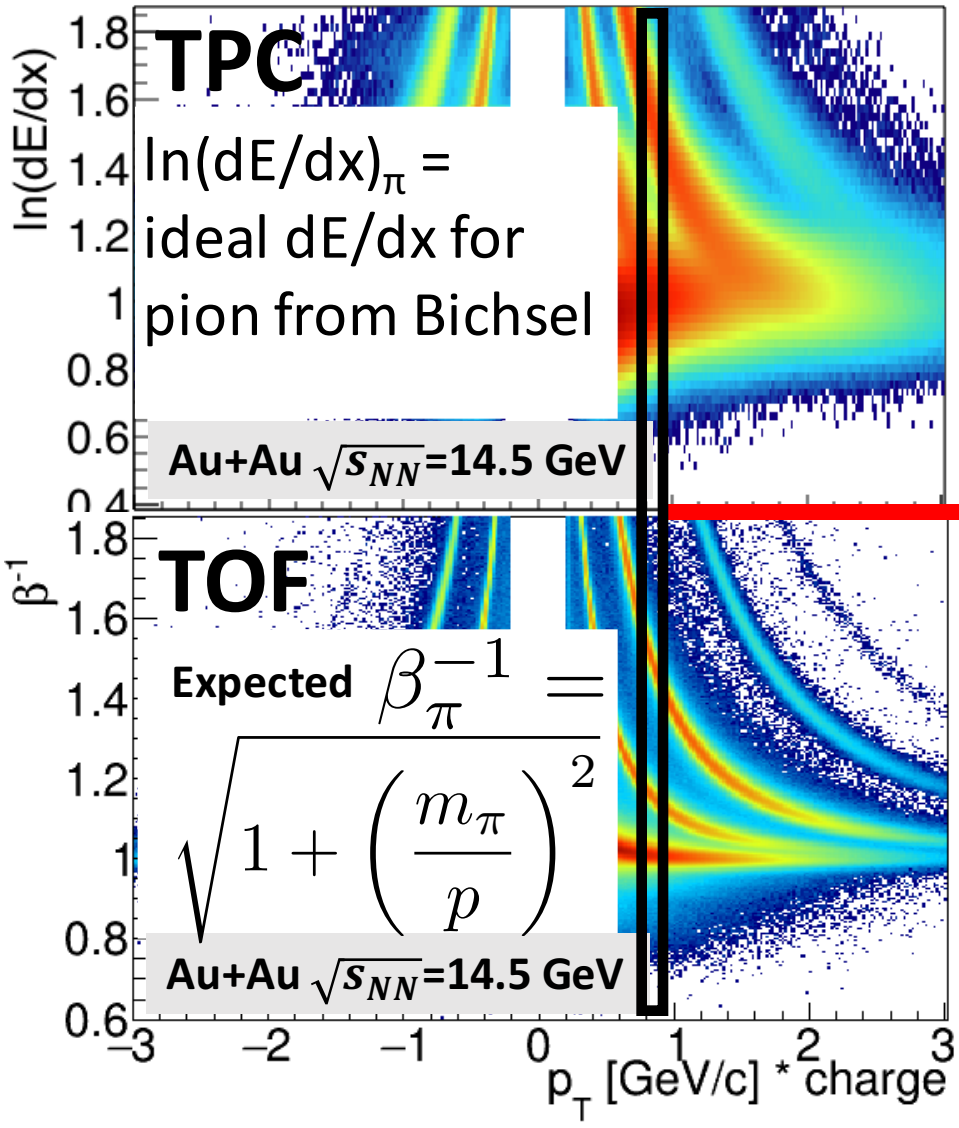


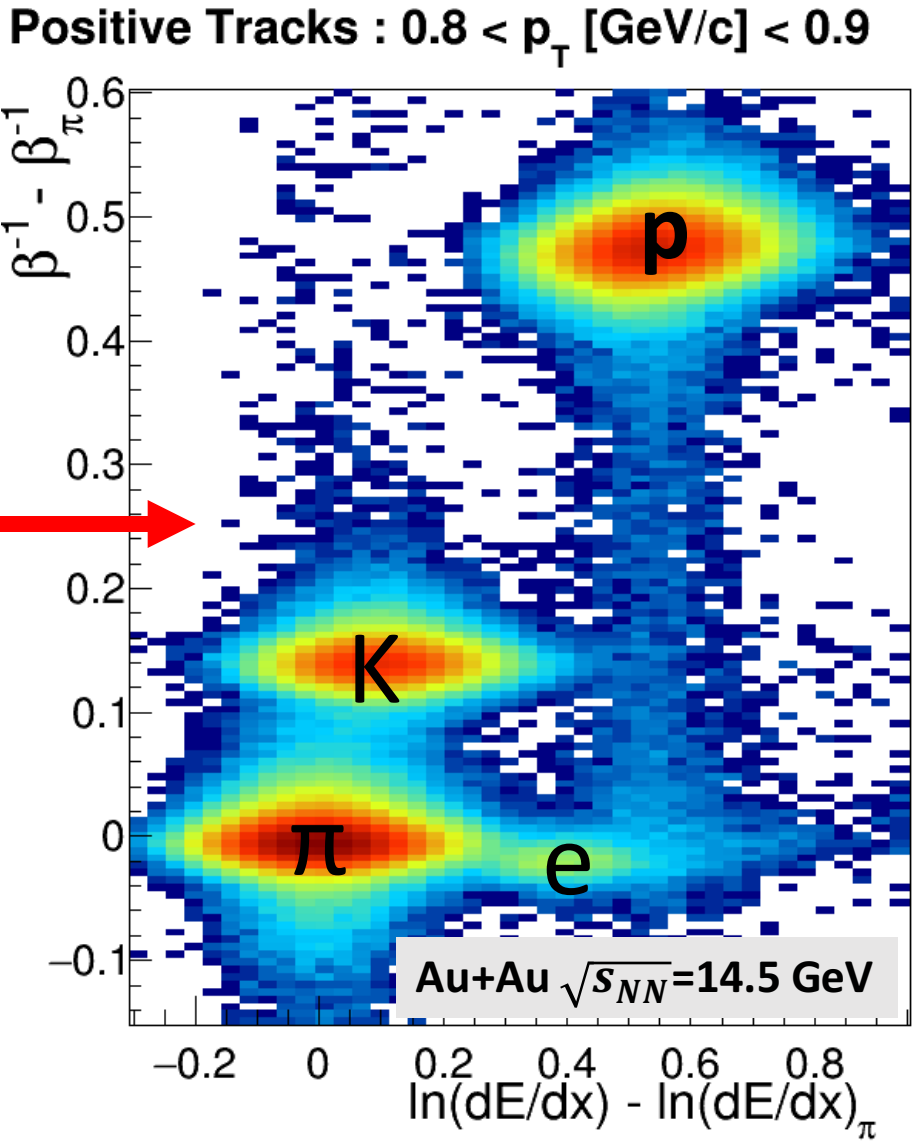
The BBC detectors are used to trigger minimum bias collisions

Particle Identification @ STAR

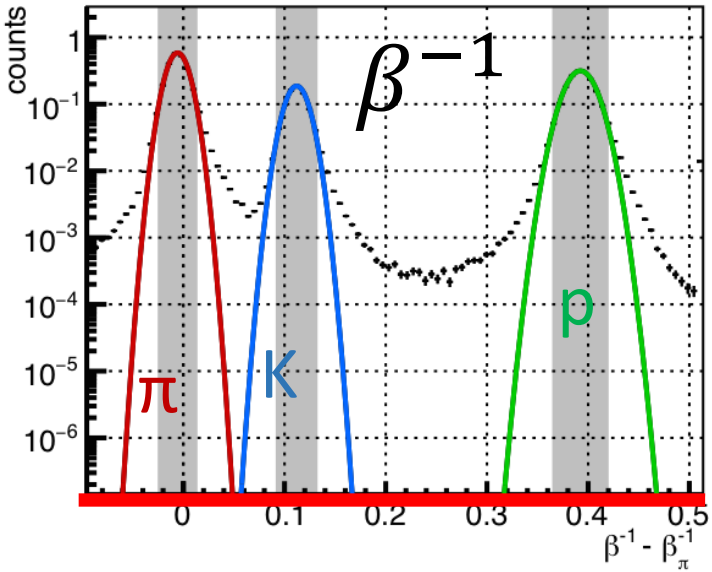


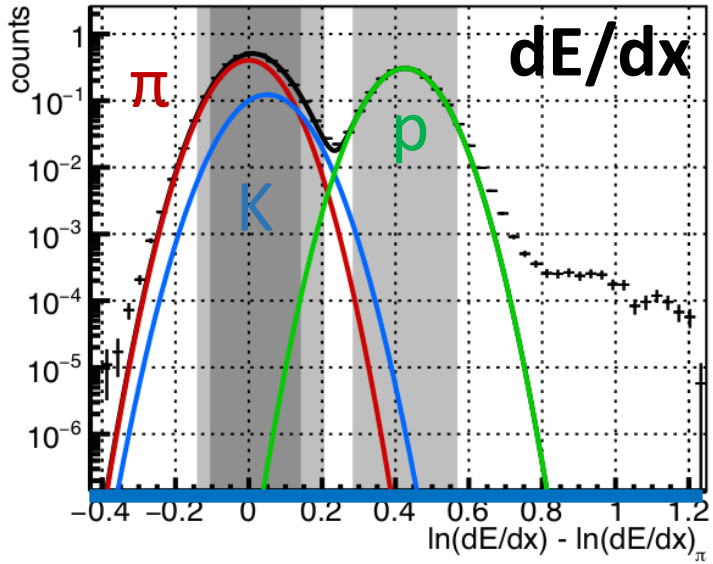
Particle Identification @ STAR

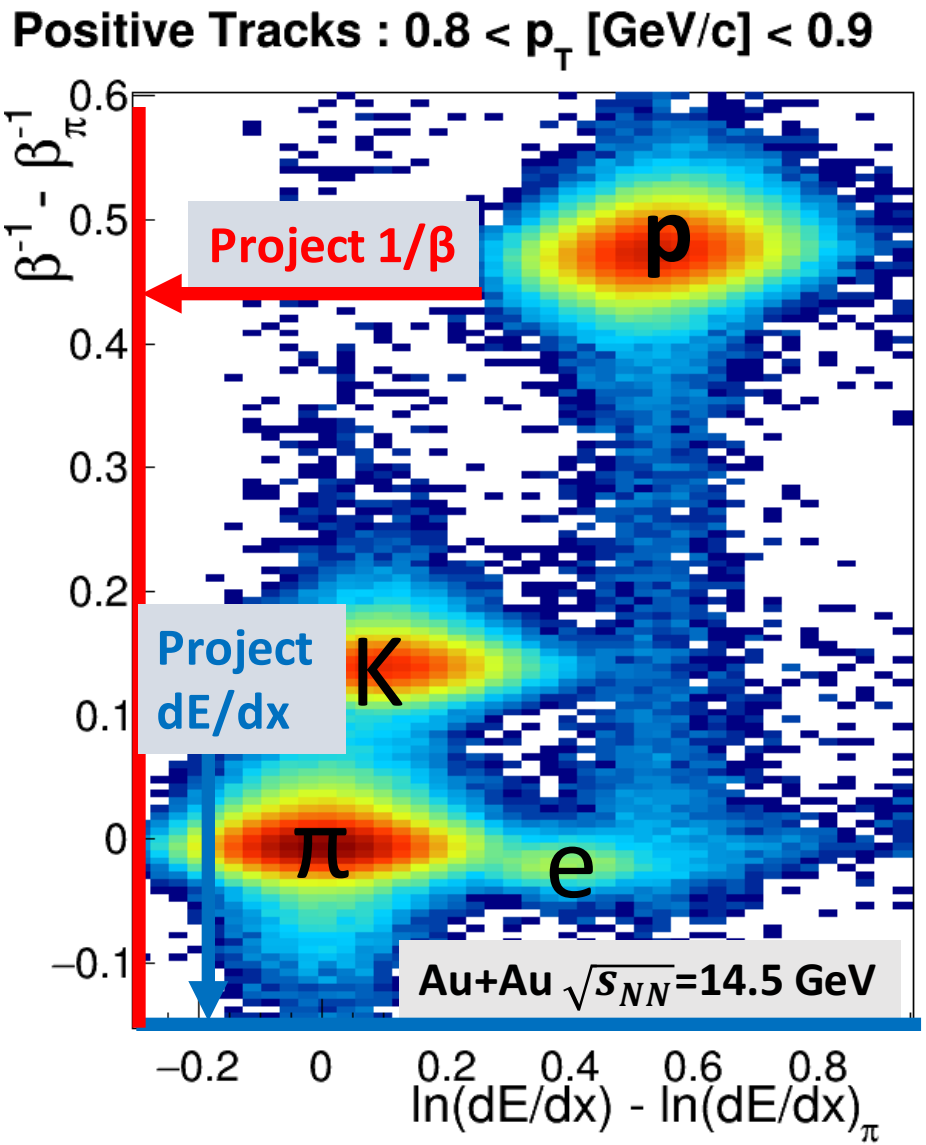




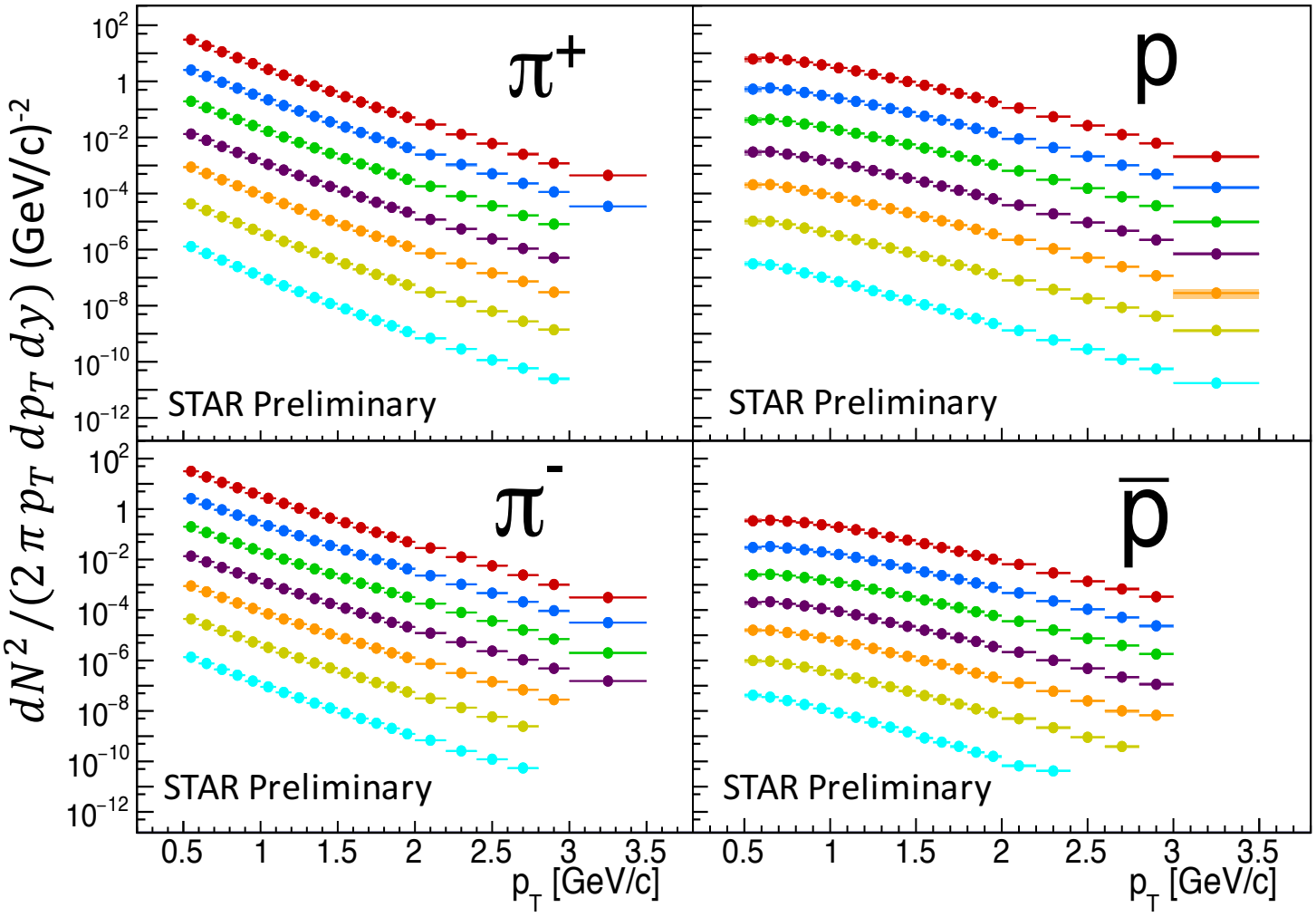
Particle Identification @ STAR







Light Hadron Spectra @ Au+Au$\sqrt{s_{NN}}$=14.5 GeV



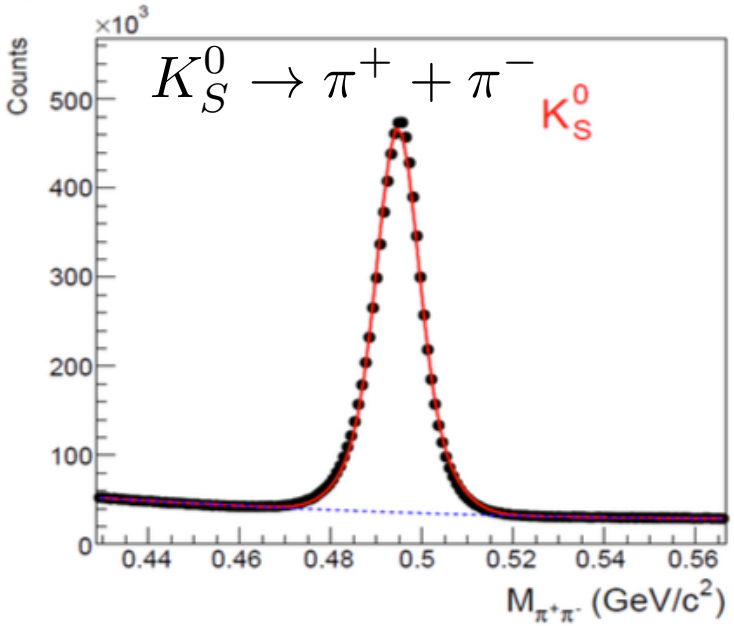
Centrality :

- 0-5% x 1
- 5-10% x 10^{-1}
- 10-20% x 10^{-2}
- 20-30% x 10^{-3}
- 30-40% x 10^{-4}
- 40-60% x 10^{-5}
- 60-80% x 10^{-6}

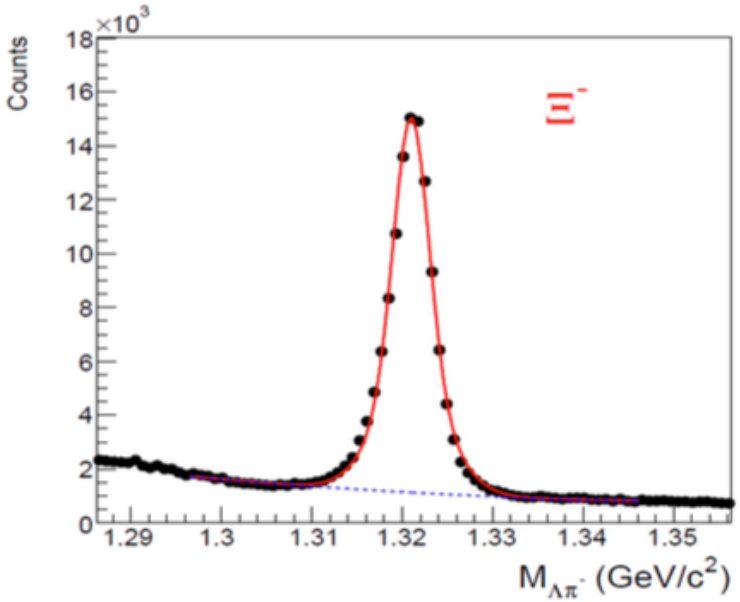
- $|y| < 0.25$
- $\pi^{+/-}$ and $p/\bar{p}$ are weak decay feed-down corrected

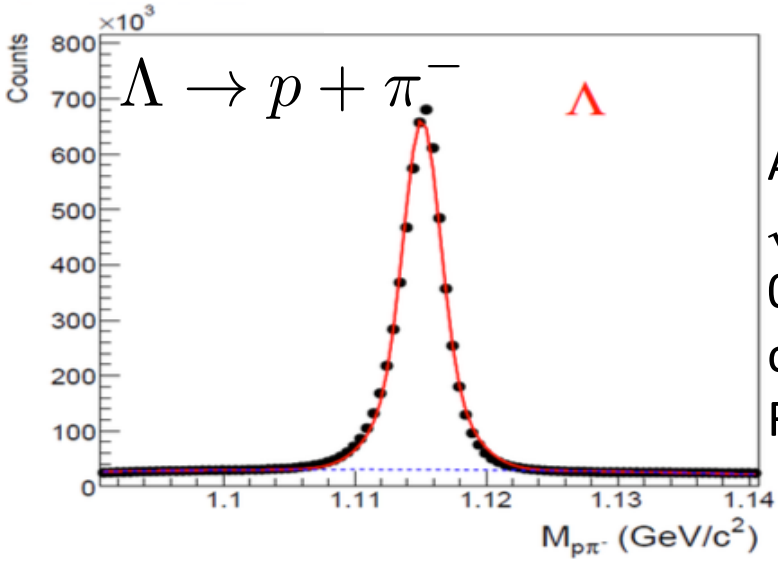
Topological Particle Identification

- Reconstruct secondary vertex from charged decay products
- Use topological cuts
- Extract yield by fitting to invariant mass peak



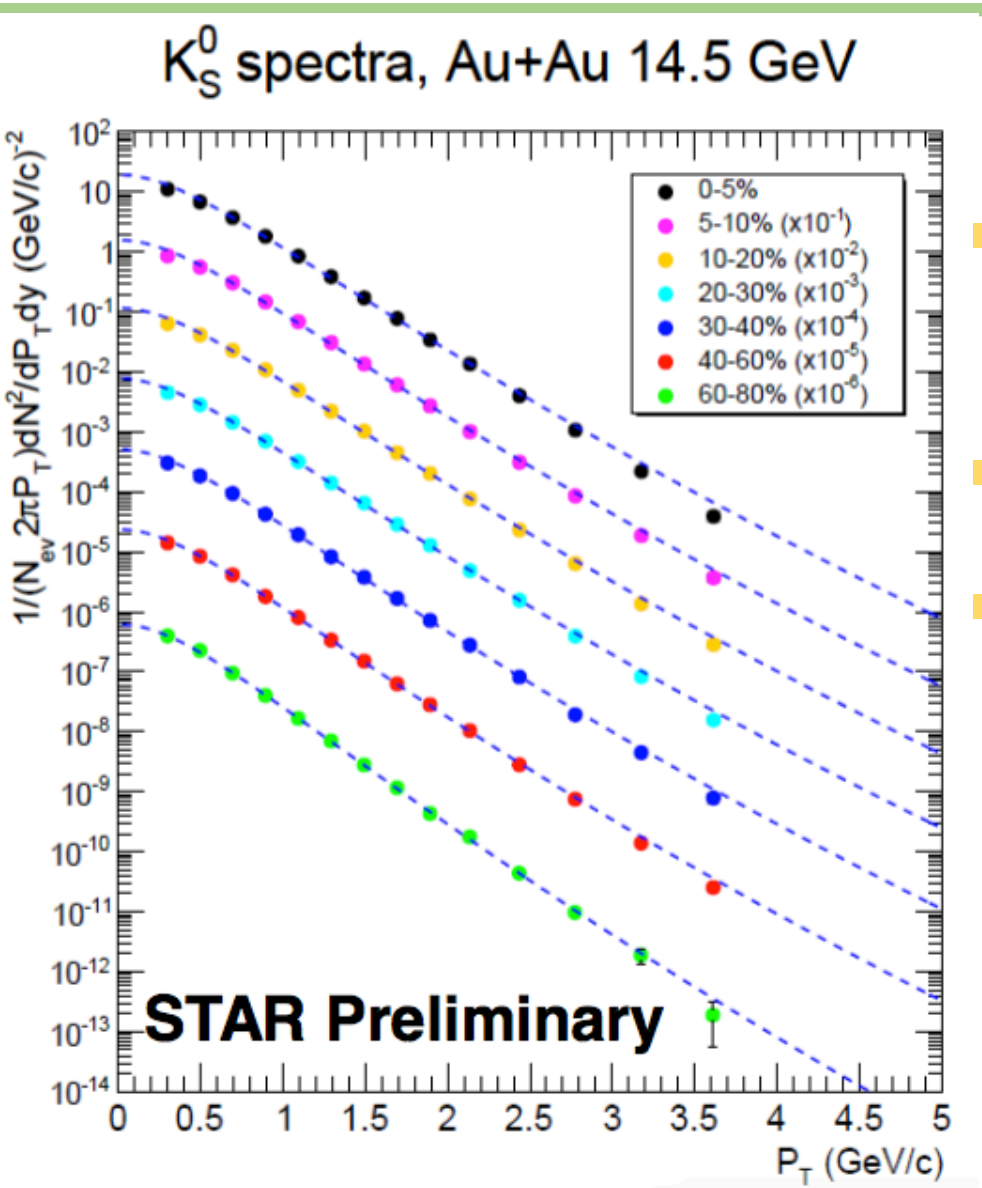
$\Xi^{+(-)} \to \Lambda + \pi^{+(-)} \to (p + \pi^-) + \pi^{+(-)}$





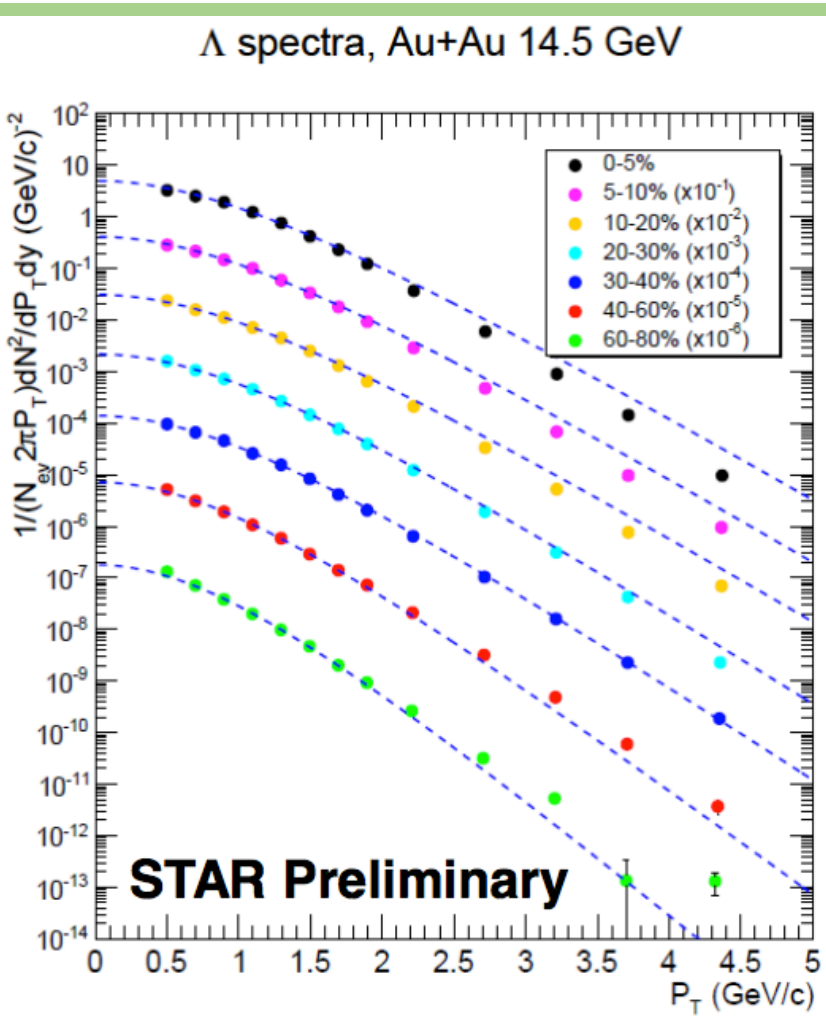
Au+Au
$\sqrt{s_{NN}}$=14.5 GeV
0 – 80% centrality
Full p_T range

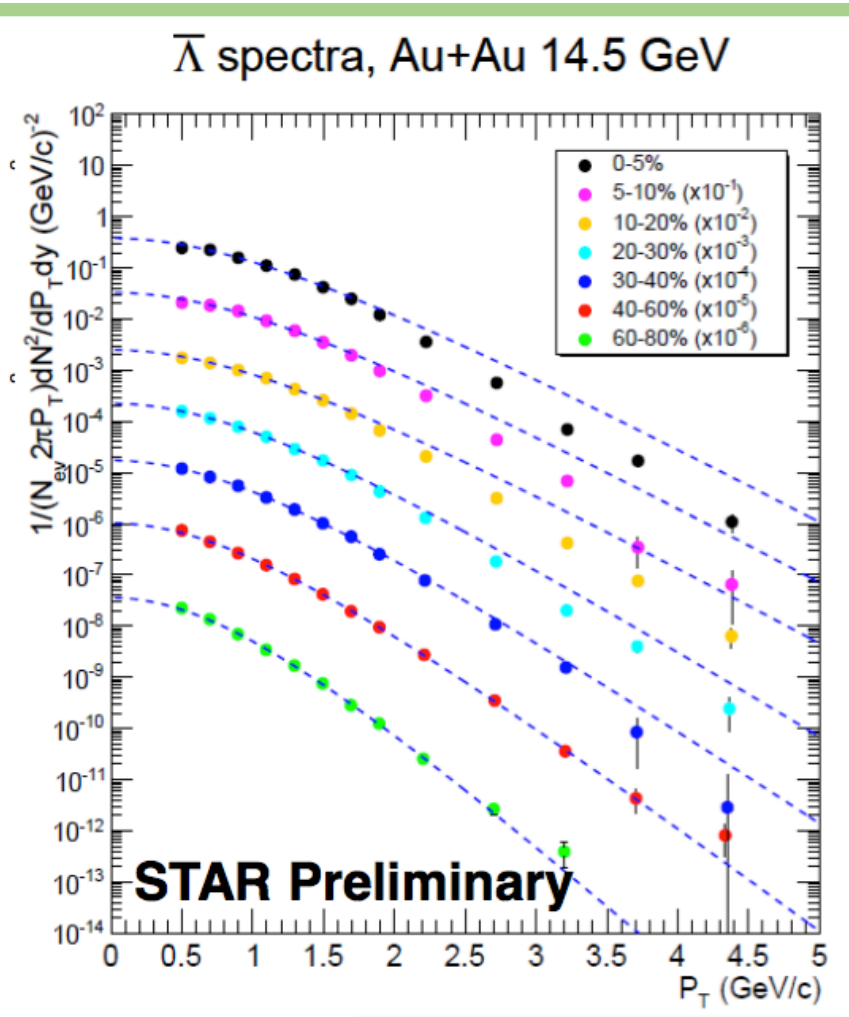
Strange Hadron Spectra @Au+Au $\sqrt{s_{NN}}$ = 14.5 GeV



- Statistical Uncertainties only
- $|y| < 0.5$
- Fit with Levy function

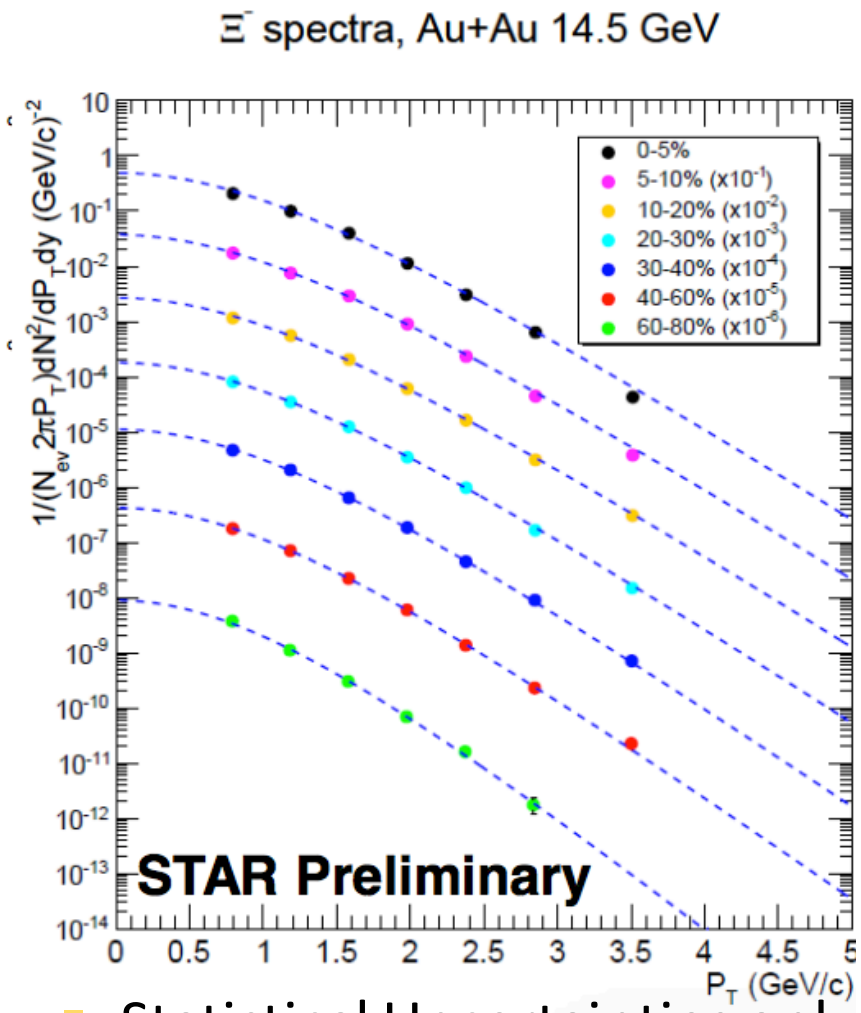
Strange Hadron Spectra @Au+Au $\sqrt{s_{NN}}$ = 14.5 GeV

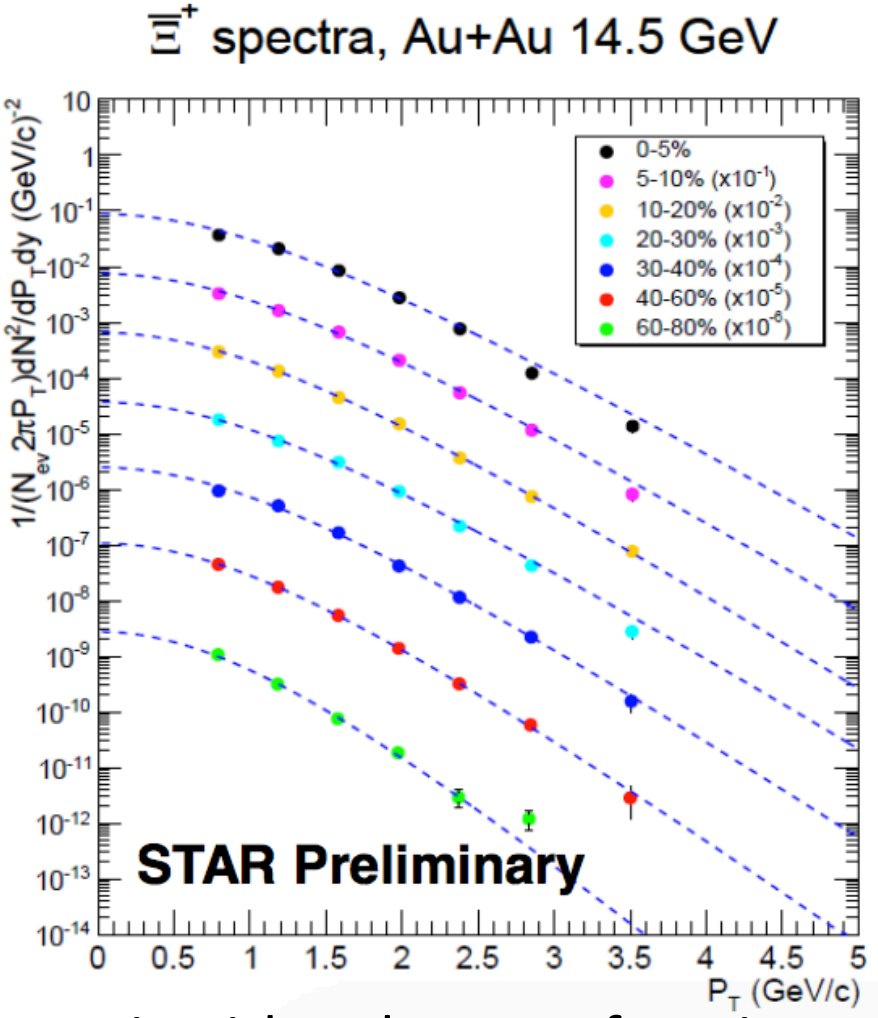




- Statistical Uncertainties only
- |y| < 0.5
- Λ spectra are weak decay feed-down corrected
- Fit with Boltzmann function

Strange Hadron Spectra @Au+Au $\sqrt{s_{NN}}$ = 14.5 GeV

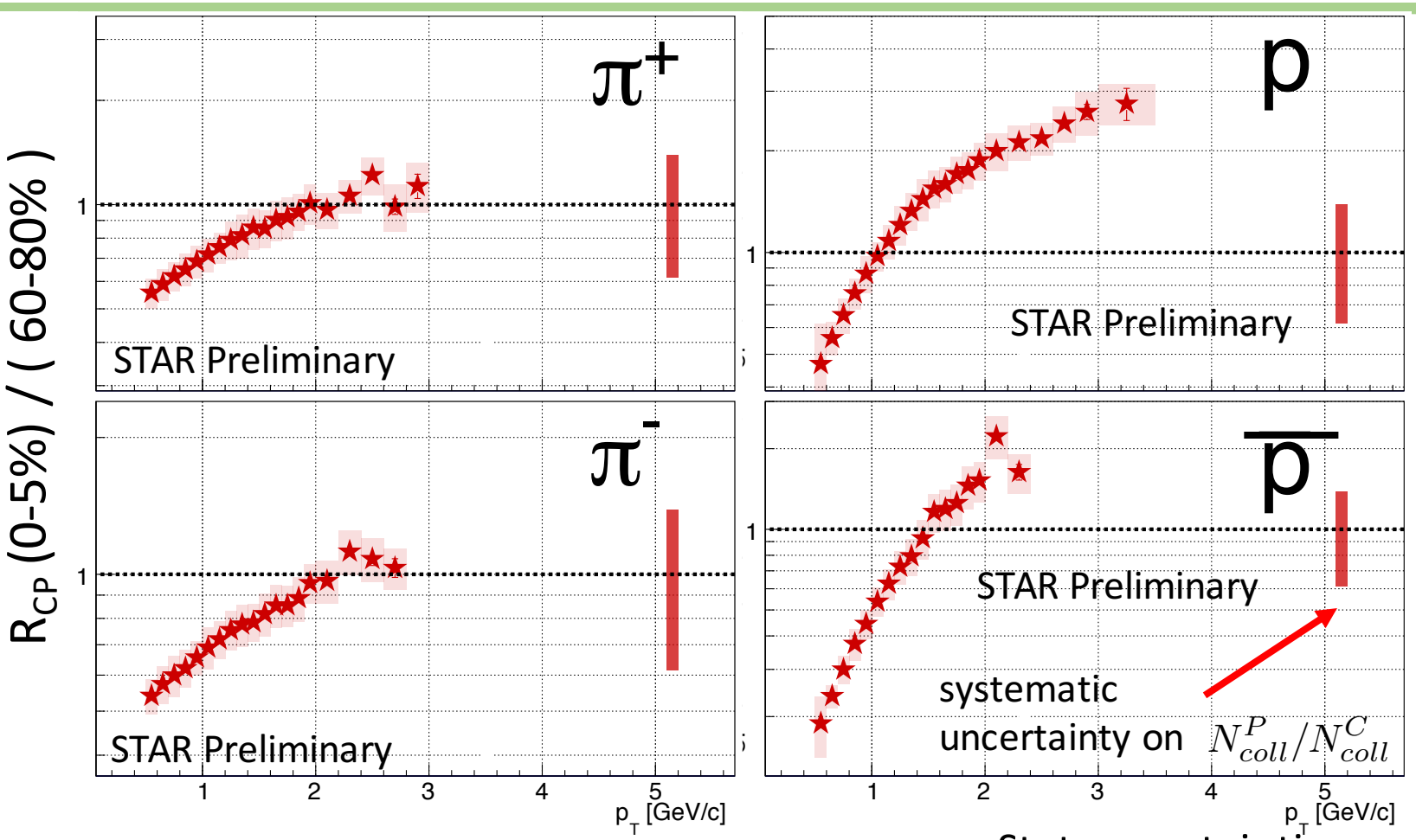




- Statistical Uncertainties only
- |y| < 0.5

- Fit with Boltzmann function

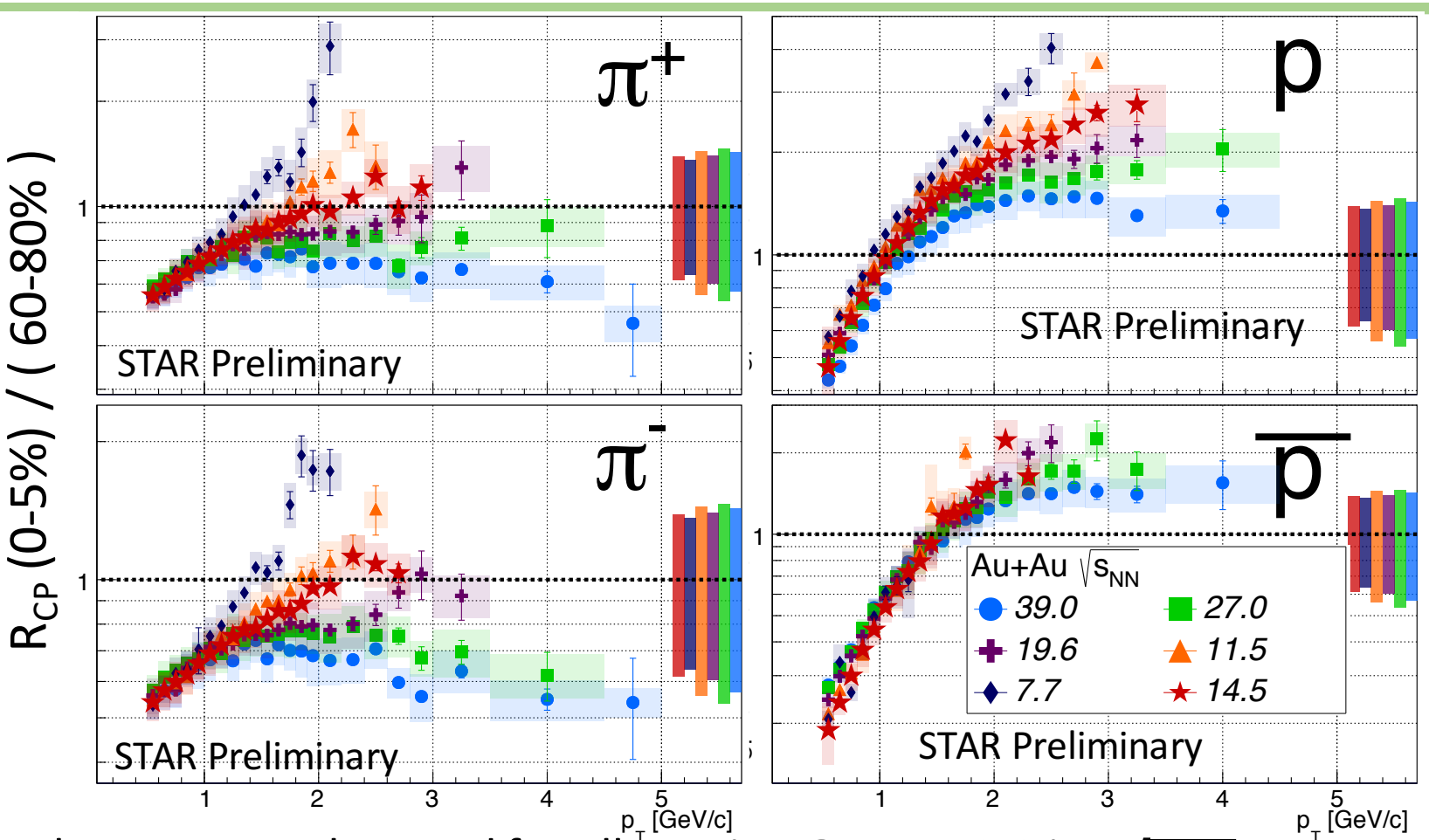
R_{CP} (0-5%)/(60-80%)@ Au+Au $\sqrt{s_{NN}}$ = 14.5



- Enhancement observed for protons
- Pions around unity for p_T>2.0 GeV/c

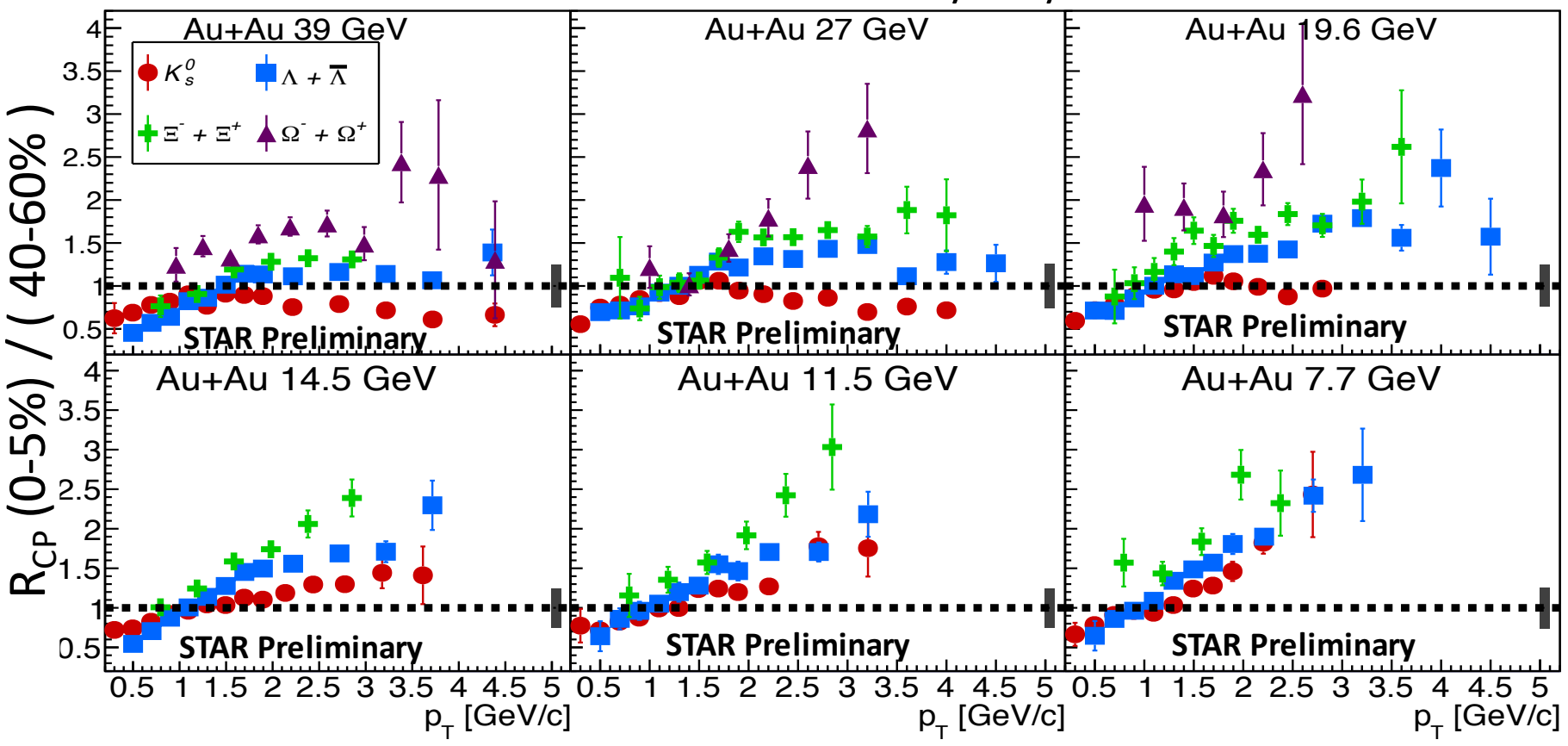
- Stat. uncertainties – vertical bars
- Syst. uncertainties - vertical boxes
- Bin width – horizontal box size

R_{CP} (0-5%)/(60-80%)@ BES I Energies



- Enhancement observed for all species @ p_T > ~2.0 in $\sqrt{s_{NN}}$ = 14.5 GeV and below – key signature of QGP no longer visible at these energies
- R_{CP} of different energies splits between p_T ~ 1.5 – 3.0 GeV/c (except in $\bar{p}$)
- R_{CP} of $\sqrt{s_{NN}}$ =7.7, 11.5, 19.6, 27, 39 GeV shown previously at CPOD 2013

Strange Hadron R_{CP} (0-5%)/(40-60%)@ BES I Energies



For $\sqrt{s_{NN}}$ = 14.5 GeV and below:

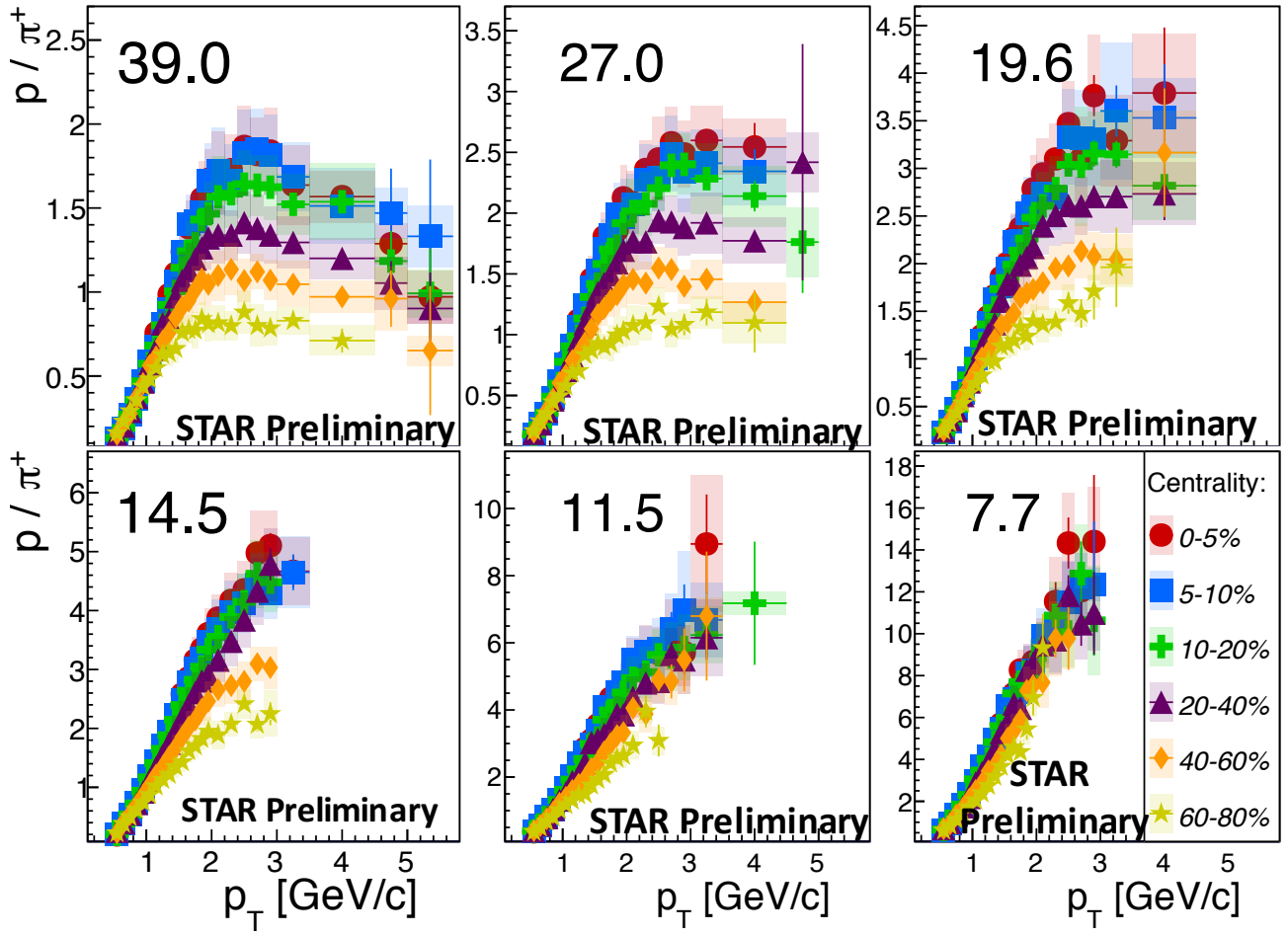
- R_{CP} is greater than or equal to 1 for p_T > ~1.5 GeV/c
- R_{CP} particle type dependence becomes less significant
- Specifically baryon vs. meson difference at intermediate p_T becomes less pronounced

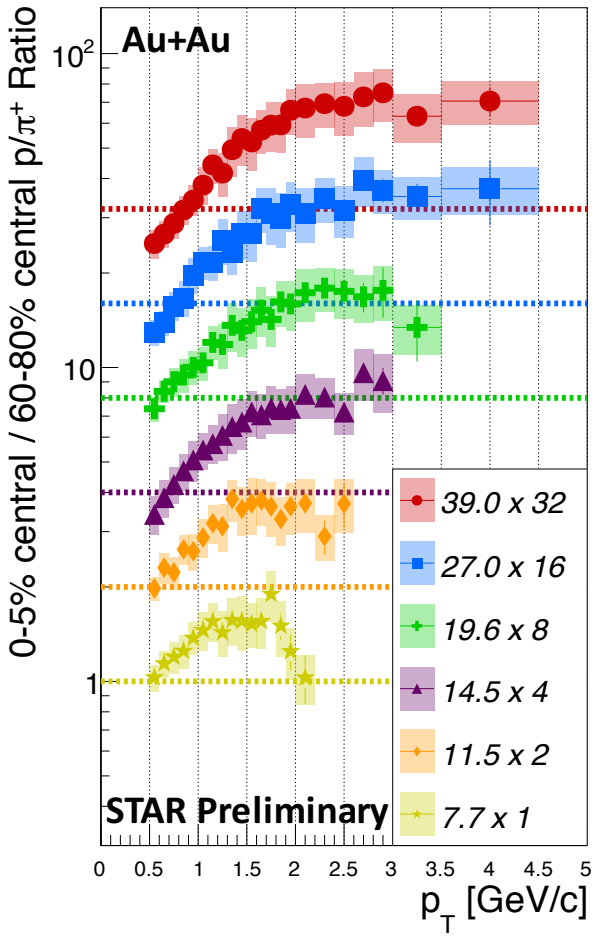
Ω R_{CP} in 19.6 and 27 GeV : (0-10%) / (40-60%)

Baryon/Meson Ratio : p/π^+ @ BES I

- Separation between centralities decreases with decreasing $\sqrt{s_{NN}}$
- "Double ratio" peak p_T value changes with $\sqrt{s_{NN}}$
- "Double ratio" for $\sqrt{s_{NN}} = 7.7$ GeV turns over

$$\frac{\text{(0-5\%) Central (Red)}}{\text{(60-80\%) Peripheral (Yellow)}}$$

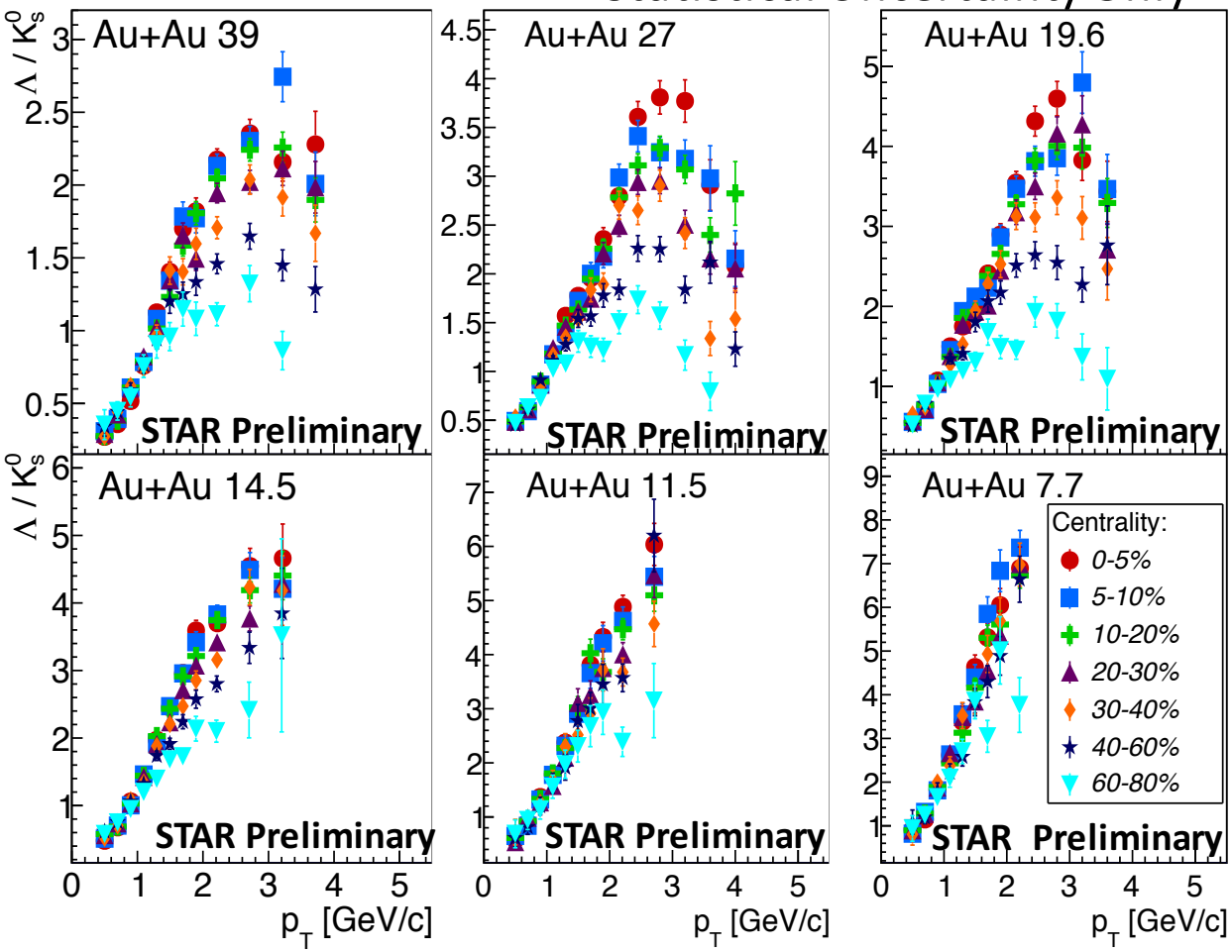




Baryon/Meson Ratio : Λ/K_s^0 @ BES I

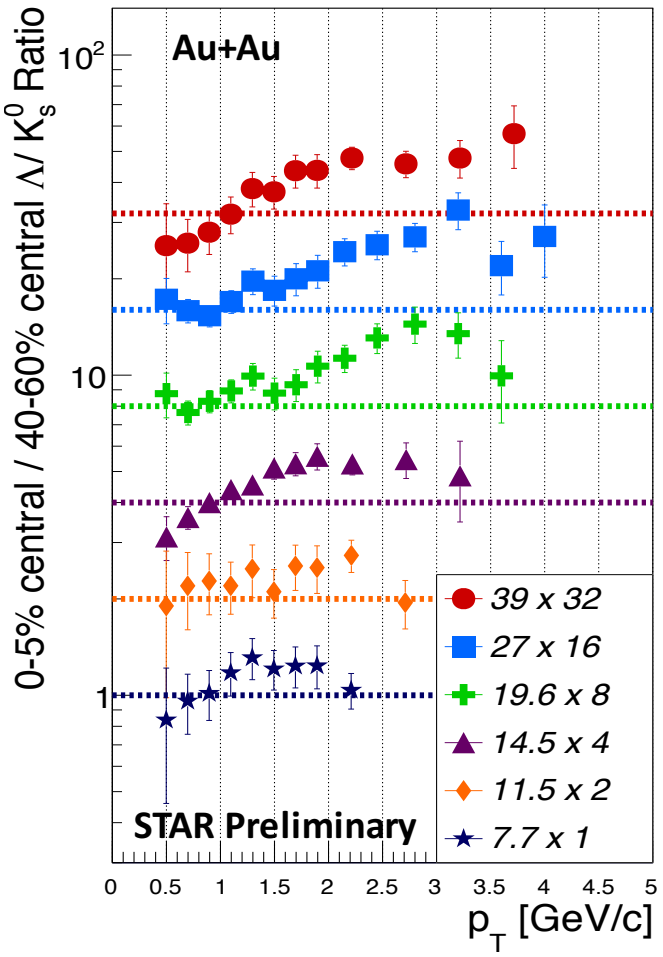
- Separation between centralities decreases with decreasing $\sqrt{s_{NN}}$
- "Double ratio" peak p_T value changes with $\sqrt{s_{NN}}$
- "Double ratio" for $\sqrt{s_{NN}}$ = 7.7 consistent with unity

Statistical Uncertainty Only



(0-5%) Central **(Red)**

(40-60%) Peripheral **(Dark Blue)**



Conclusions

Au+Au Collisions at $\sqrt{s_{NN}}$ = 14.5 GeV

- New (at QM15) STAR results in the large μ_B gap between 11.5 and 19.6 GeV
- Completes the RHIC Beam Energy Scan Phase I

Onset of QGP signatures

- R_{CP} from $\sqrt{s_{NN}}$ = 14.5 GeV in both light and strange hadrons agrees with the trends from other BES I energies
- No evidence of suppression at intermediate p_T in the R_{CP} of all species for energies at and below $\sqrt{s_{NN}}$ = 14.5 GeV
- Baryon/Meson ratios show evidence for change in collision dynamics for $\sqrt{s_{NN}}$ below 19.6 GeV

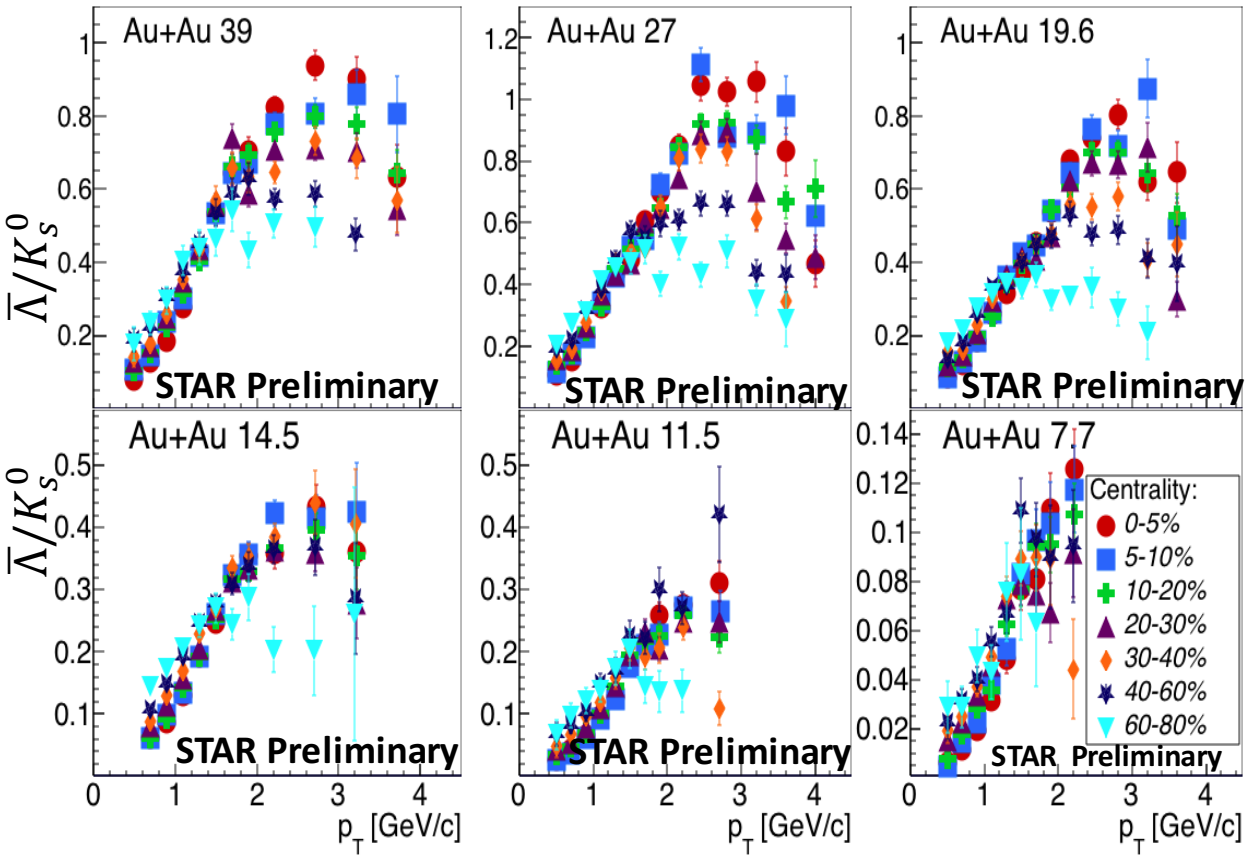
Beam Energy Scan Phase II is needed for conclusive results

- More statistics – push kinematic reach to higher p_T
- More energies below $\sqrt{s_{NN}}$ = 20 GeV

THANK YOU

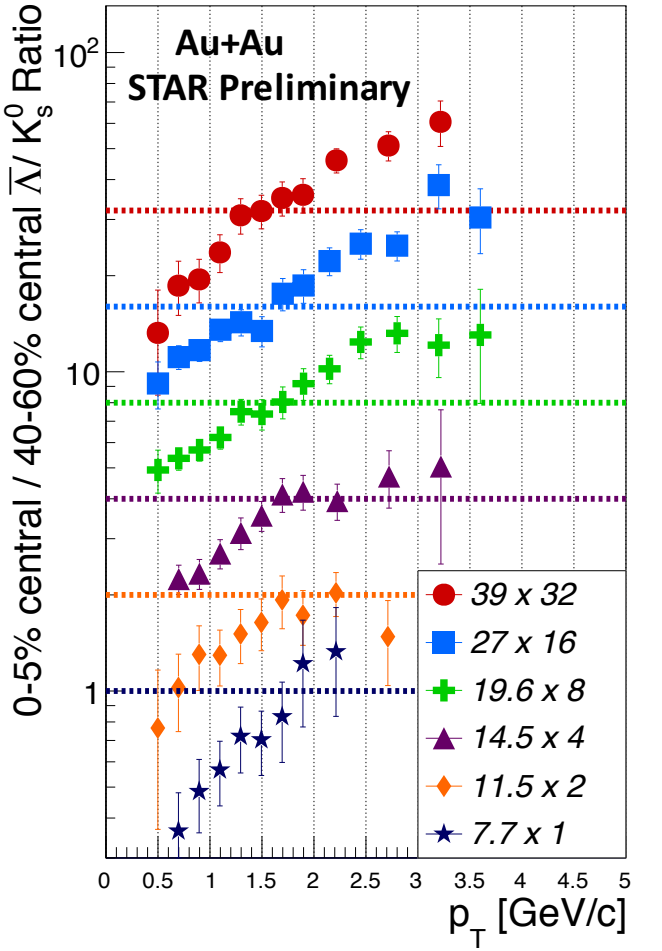
Baryon/Meson Ratio : $\bar{\Lambda}/K_s^0$ @ BES I

Statistical Uncertainty Only

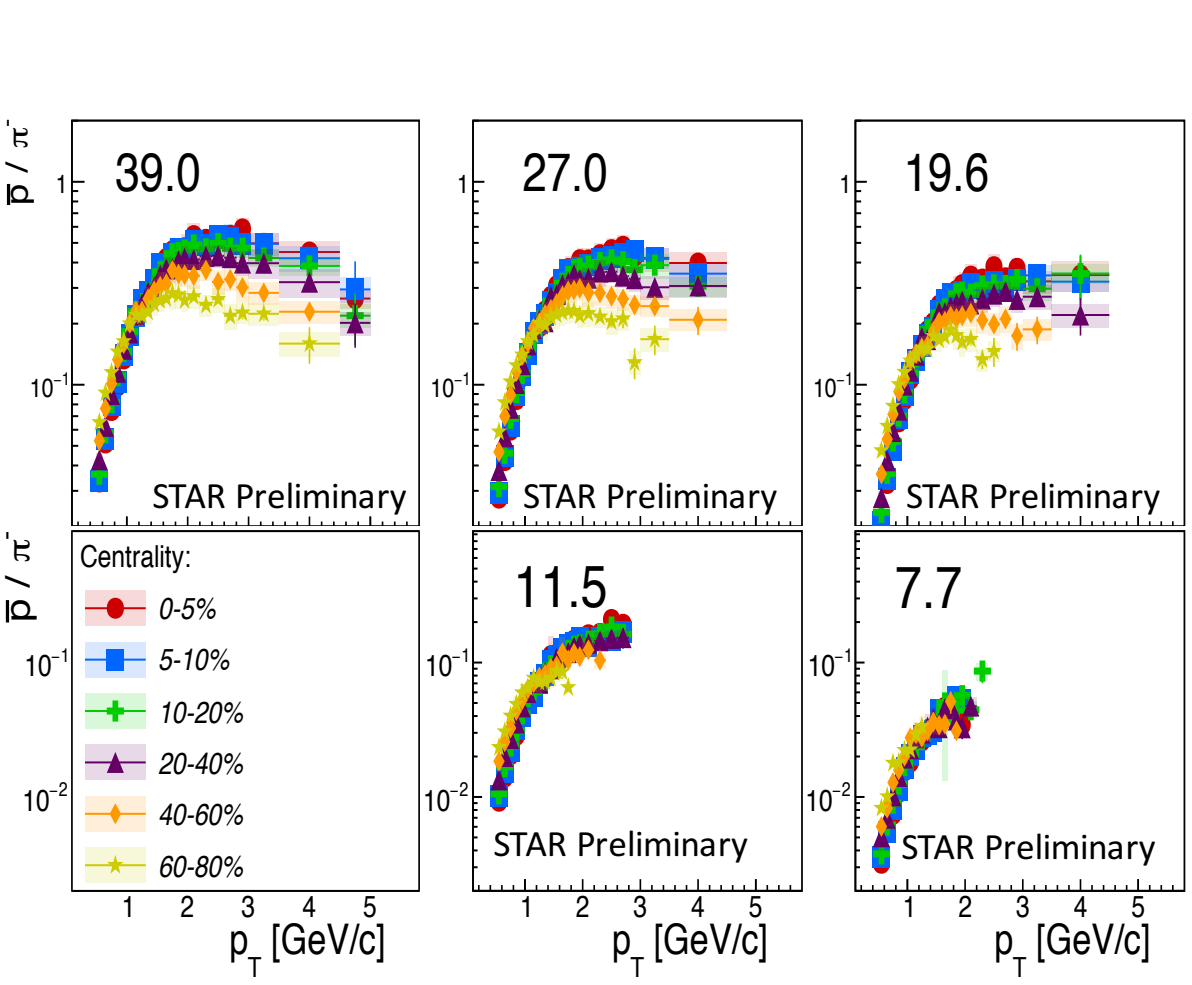


(0-5%) Central **(Red)**

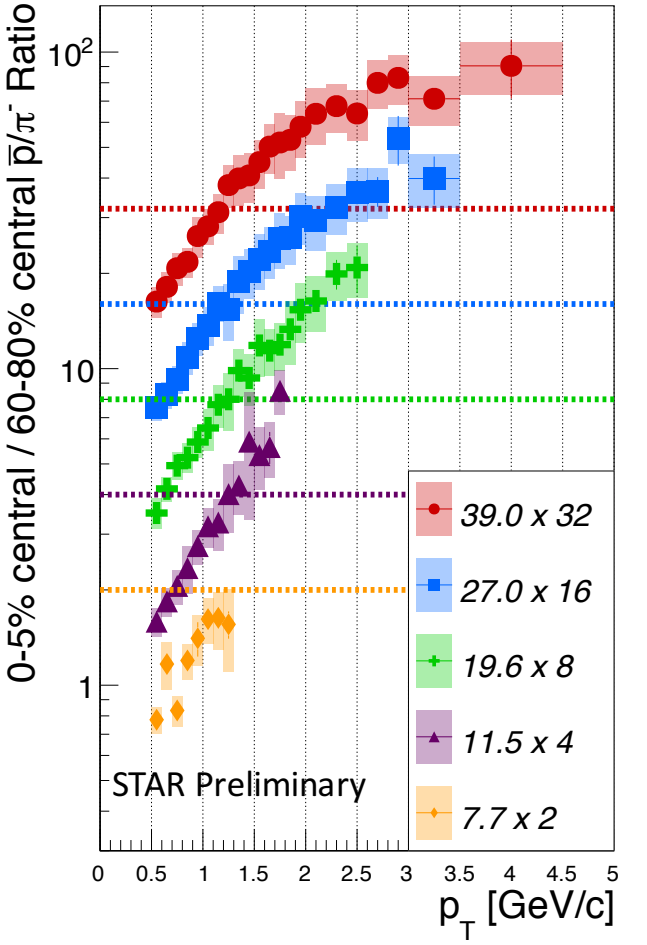
(40-60%) Peripheral **(Dark Blue)**



Baryon/Meson Ratio p-bar/π^- @ BES I

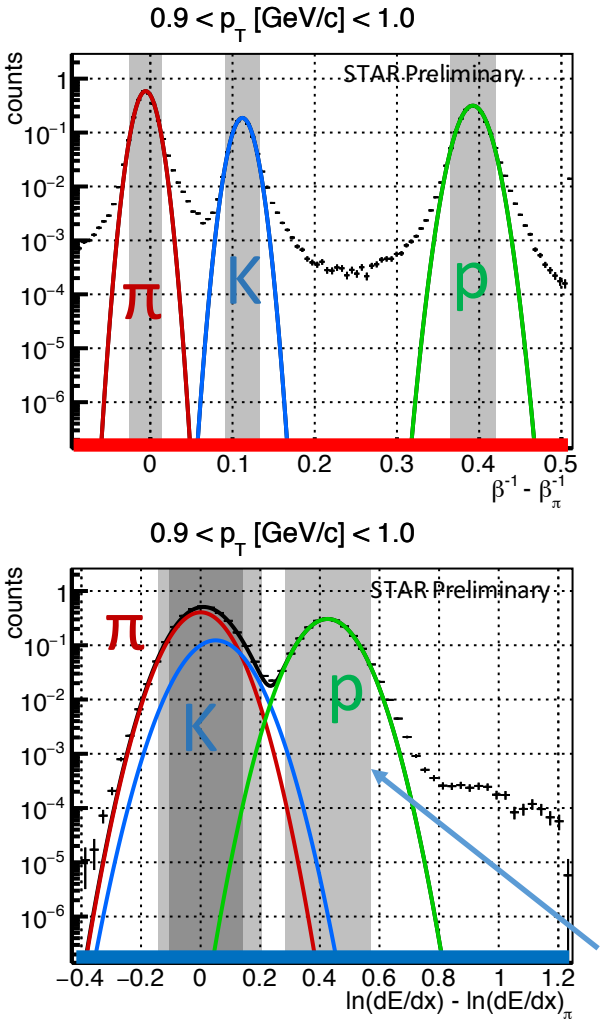


Most Central (Red)
Most Peripheral (Yellow)

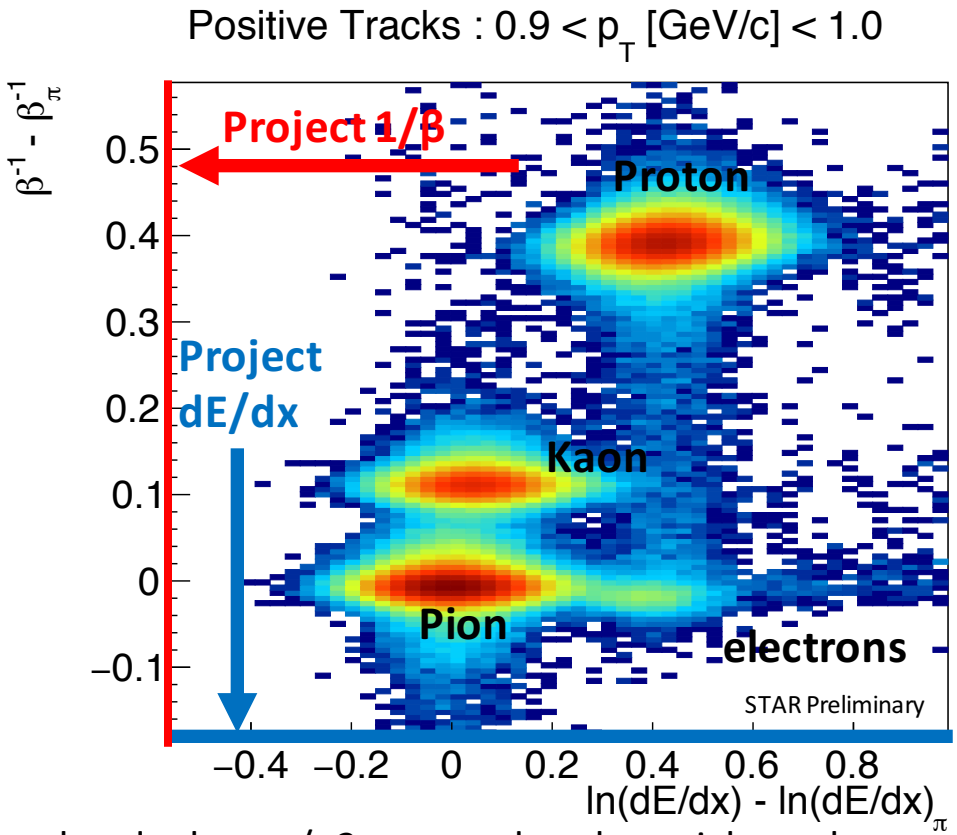


$\pi^{+(-)}$, $K^{+(-)}$, and (anti-)proton particle identification

Extract yields by simultaneously fitting the dE/dx and 1/β distributions.



Combined TPC + TOF for a single p_T bin



- Grey bands show +/- 2σ around each particle peak
- The pion and kaon peaks are merged in dE/dx but are still well separated in 1/β
- The black band is the total fit result