

# Investigation of $\pi$ , K, p Production Beyond Mid-Rapidity $\sqrt{s_{NN}} = 27$ GeV at STAR

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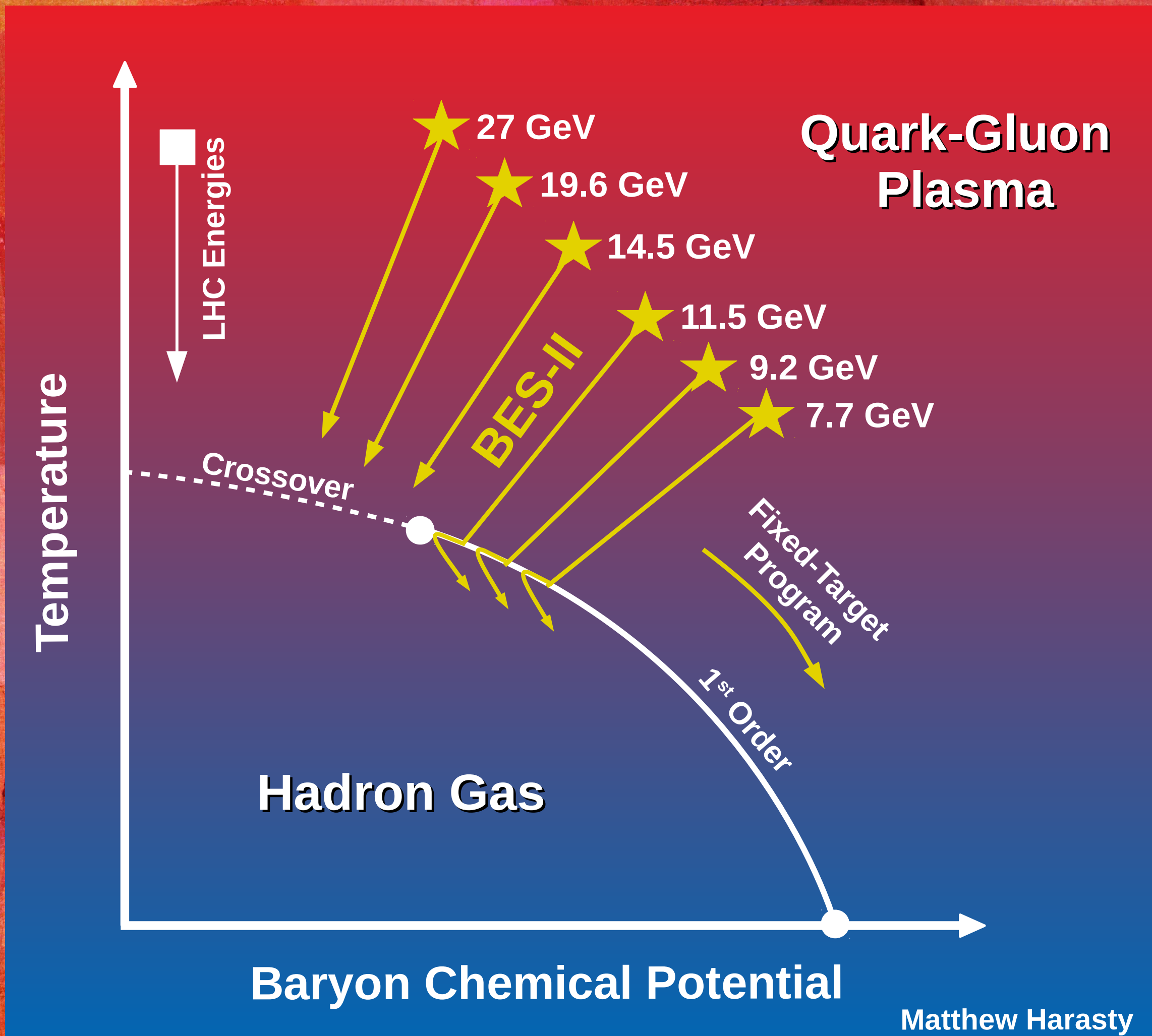
*Matthew Harasty*  
*On Behalf of the STAR Collaboration*  
*American Physical Society, Division of Nuclear Physics*  
*Louisiana, 1 November 2020*

# OVERVIEW

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- Physics motivation
- The dataset
- Extraction of particle yields
- Corrections to yields
- Charged hadron ratios
- Baryon chemical potential
- Conclusions

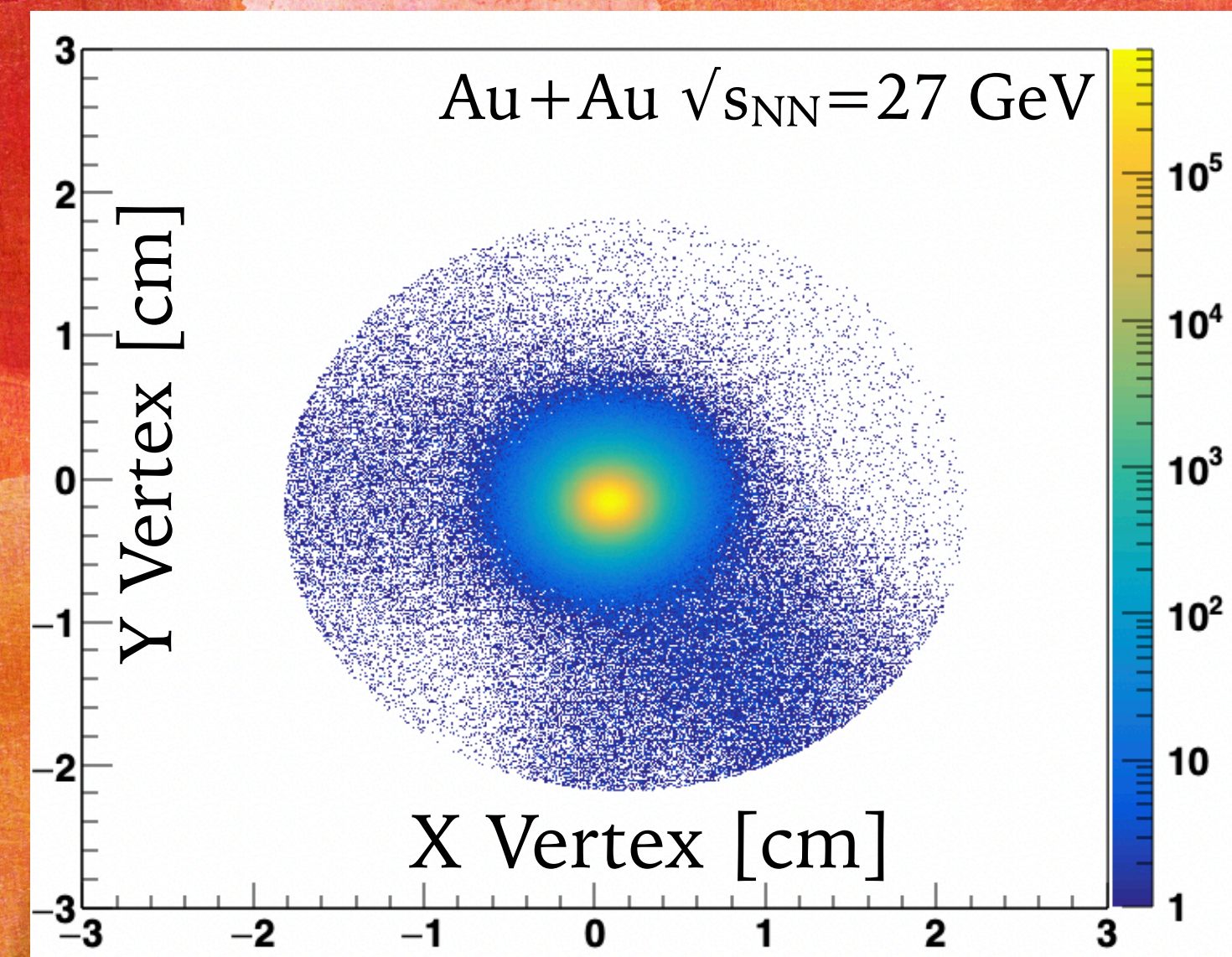
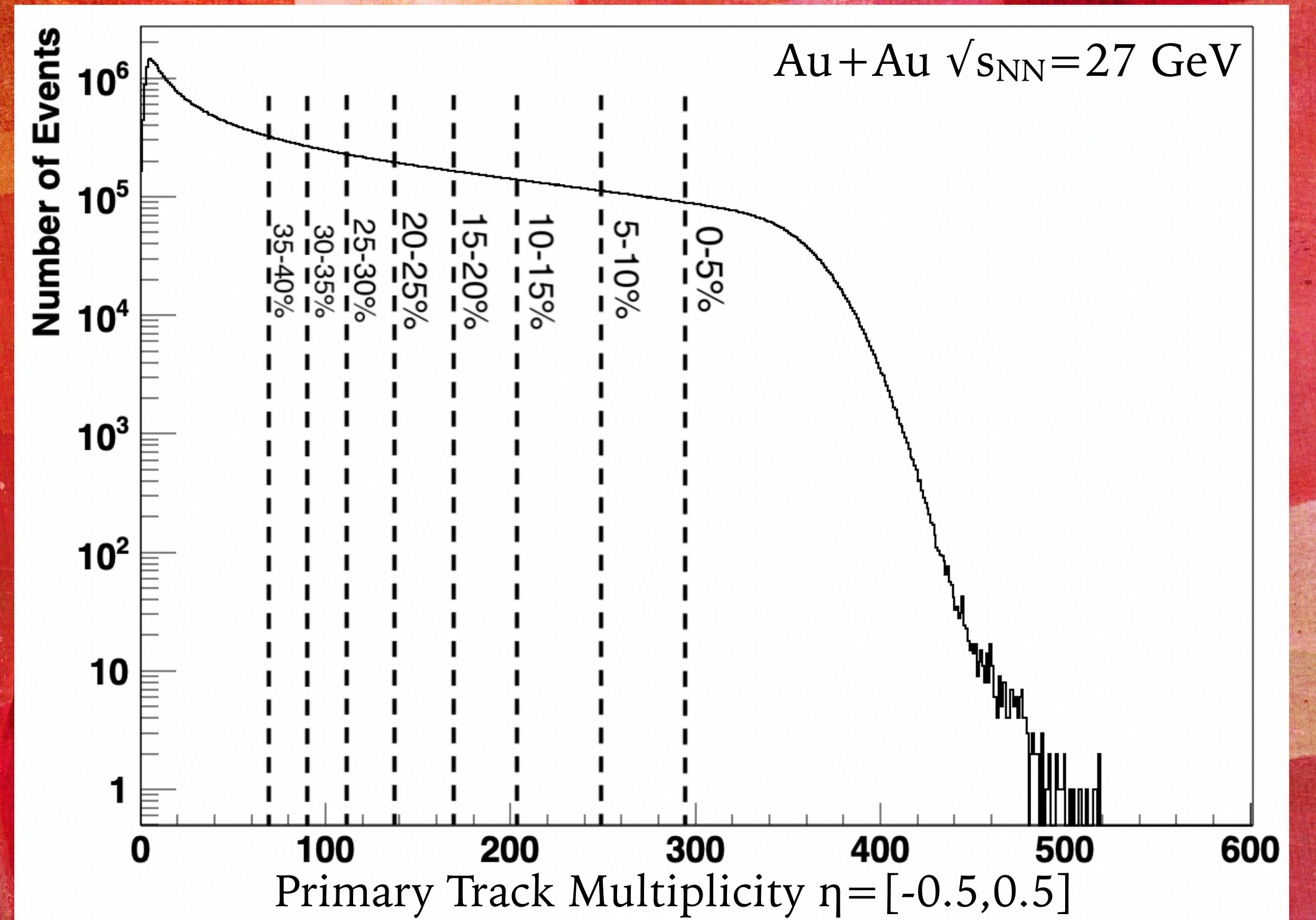
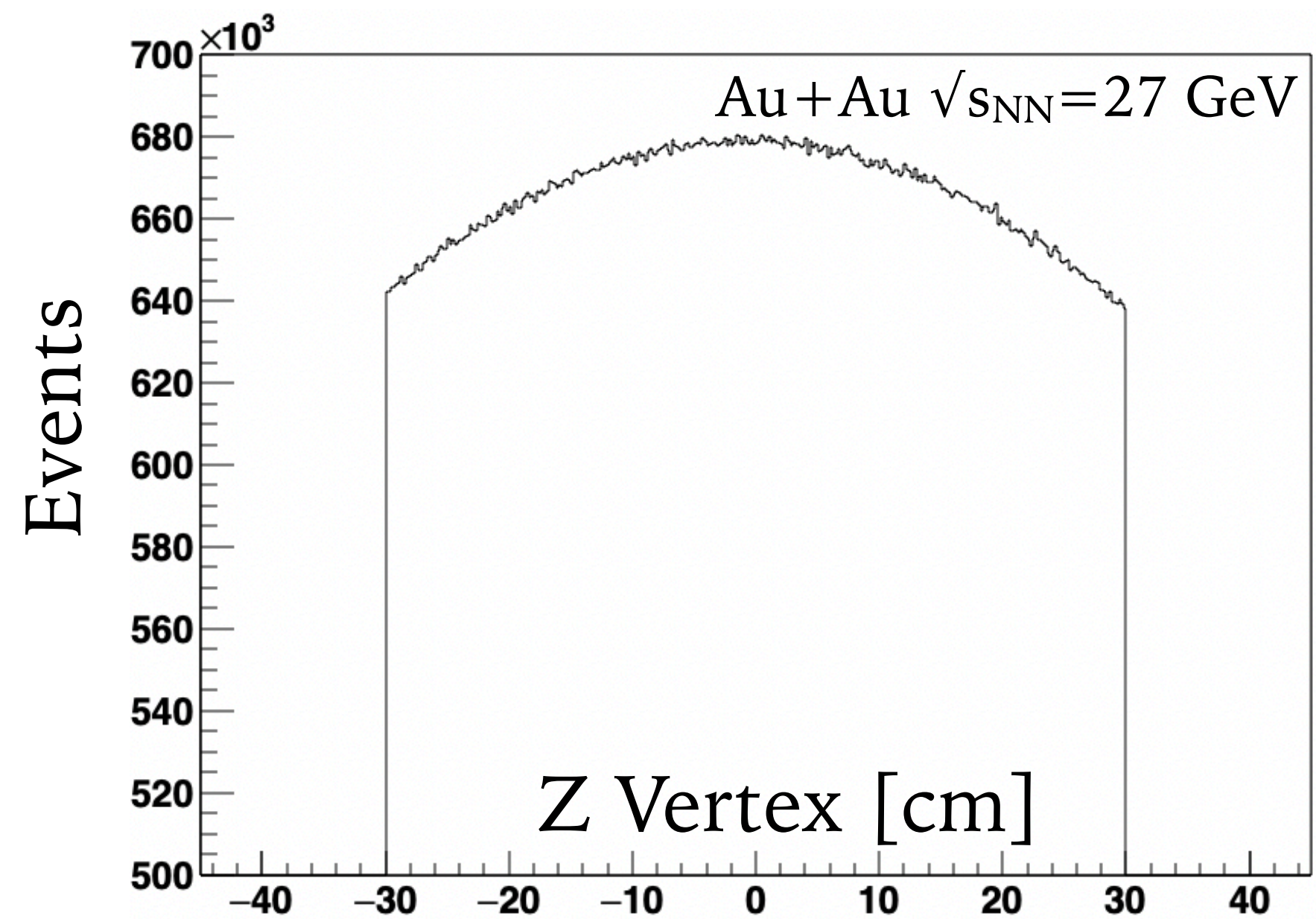
# PHYSICS MOTIVATION



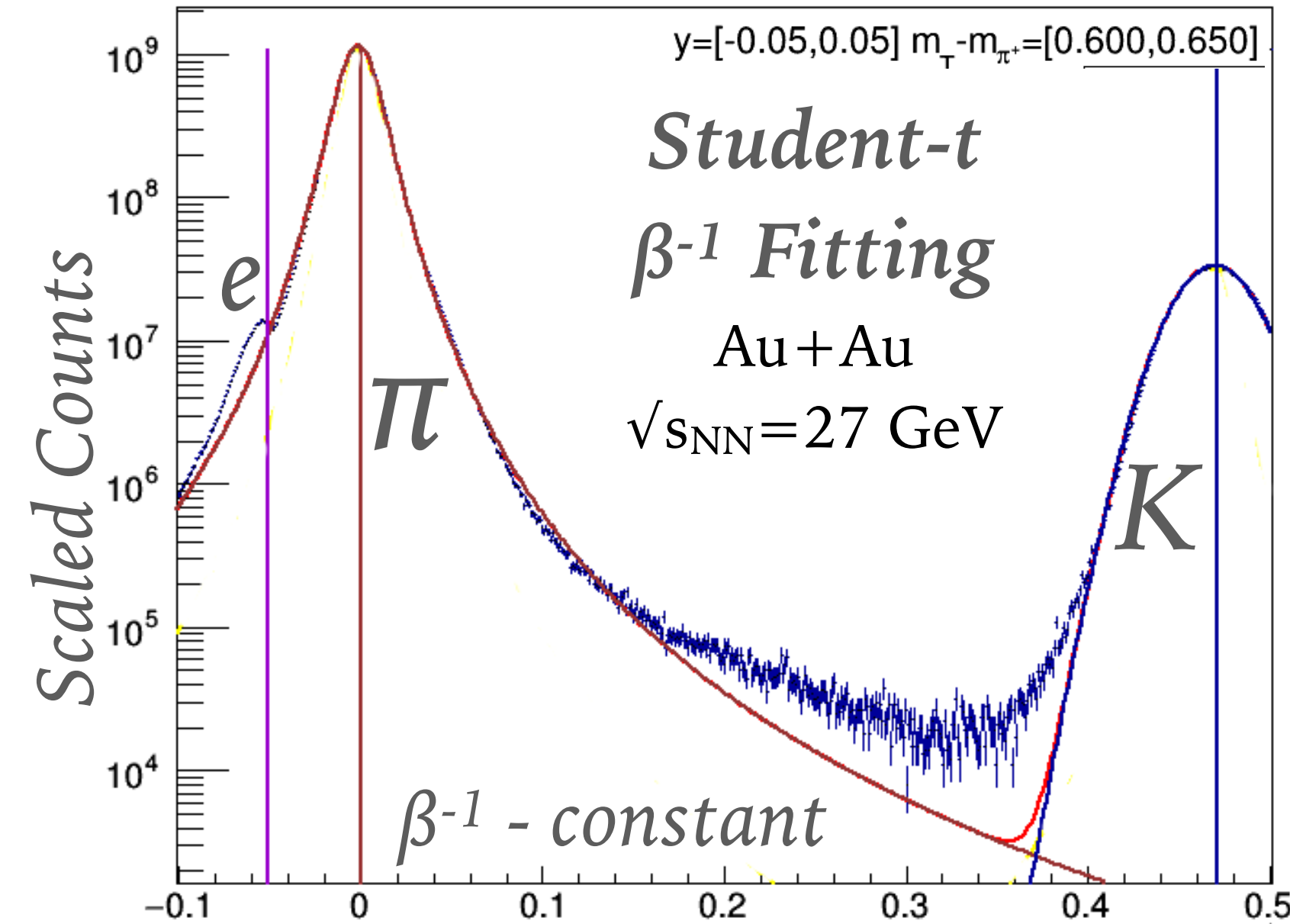
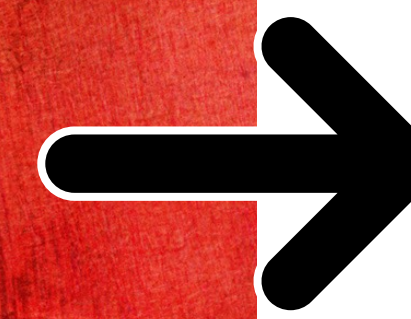
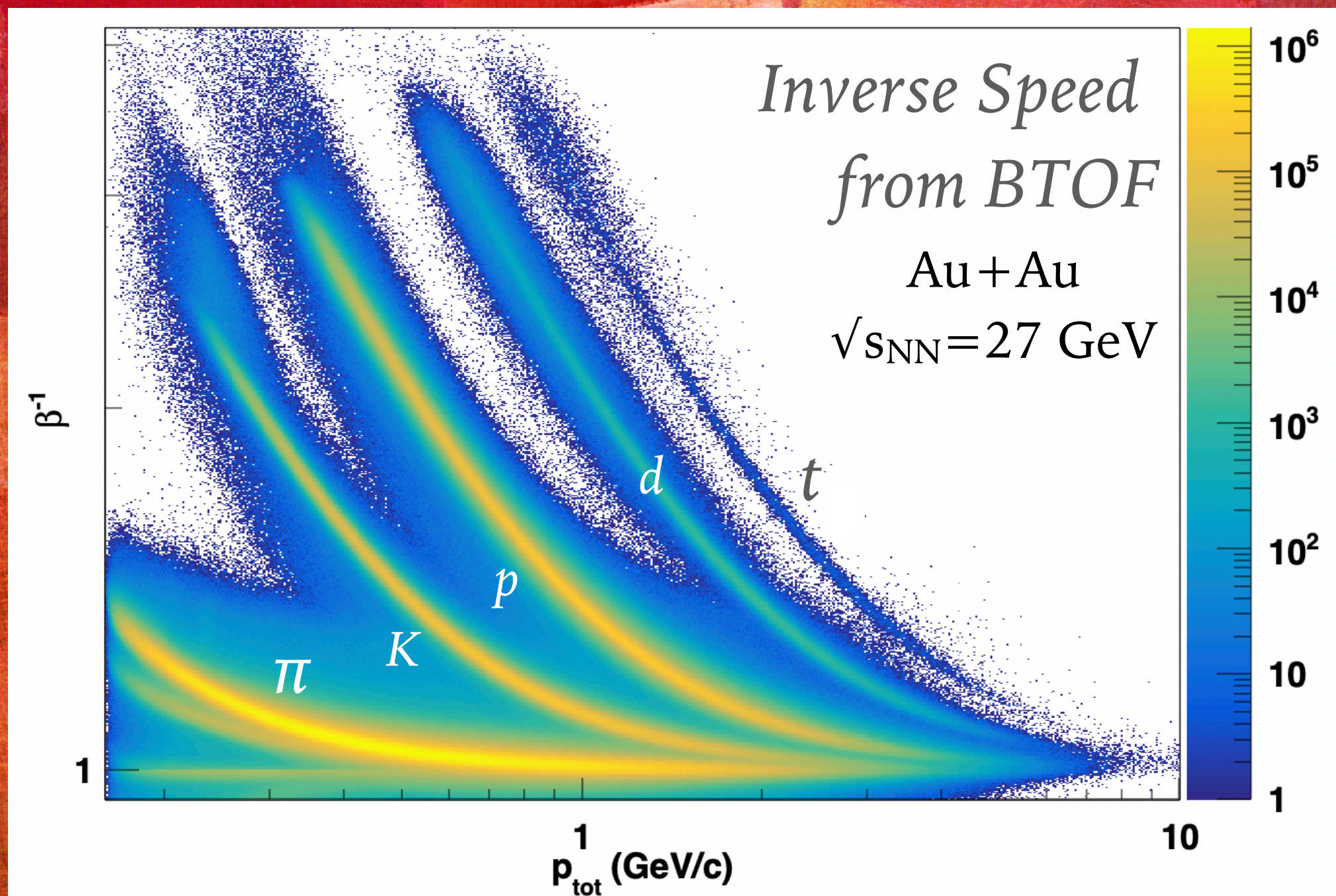
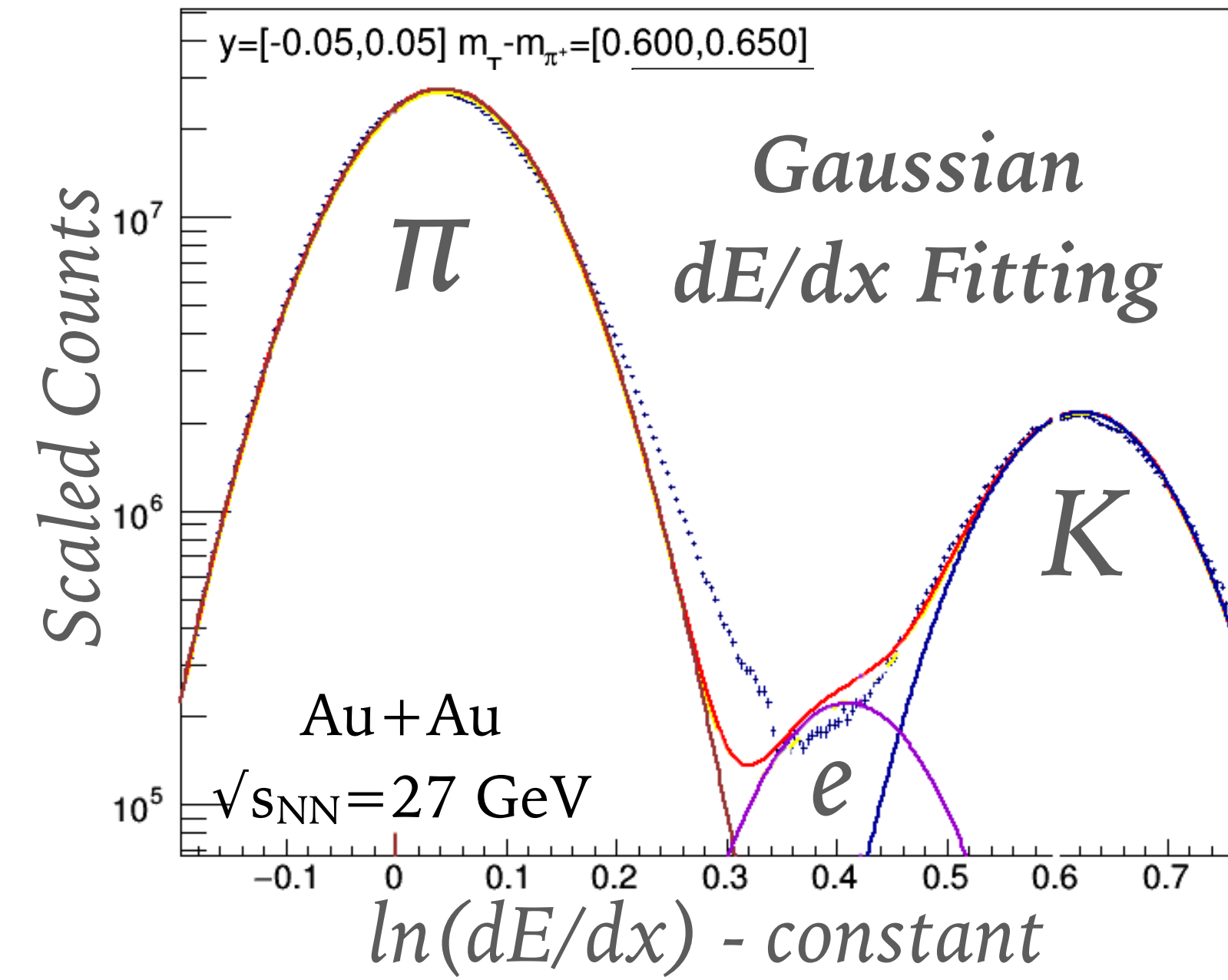
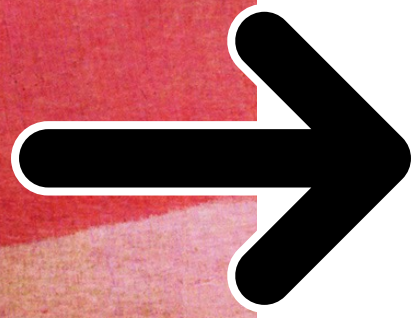
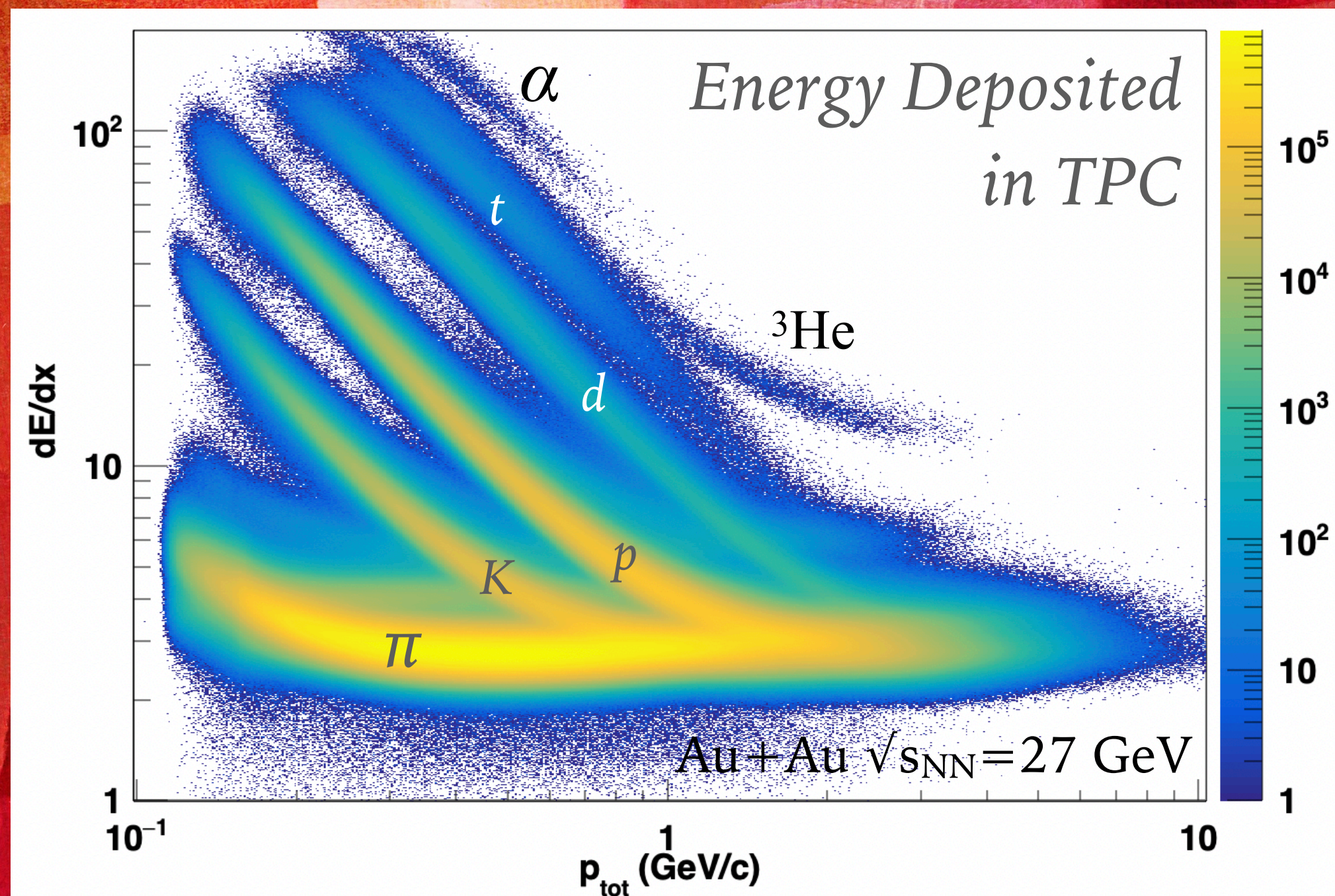
- Where we are on the QCD phase diagram?
- How do modes of particle production change as a function of centrality and rapidity?
- How does the baryon chemical potential change with centrality and rapidity?

# DATASET & EVENT QUALITY

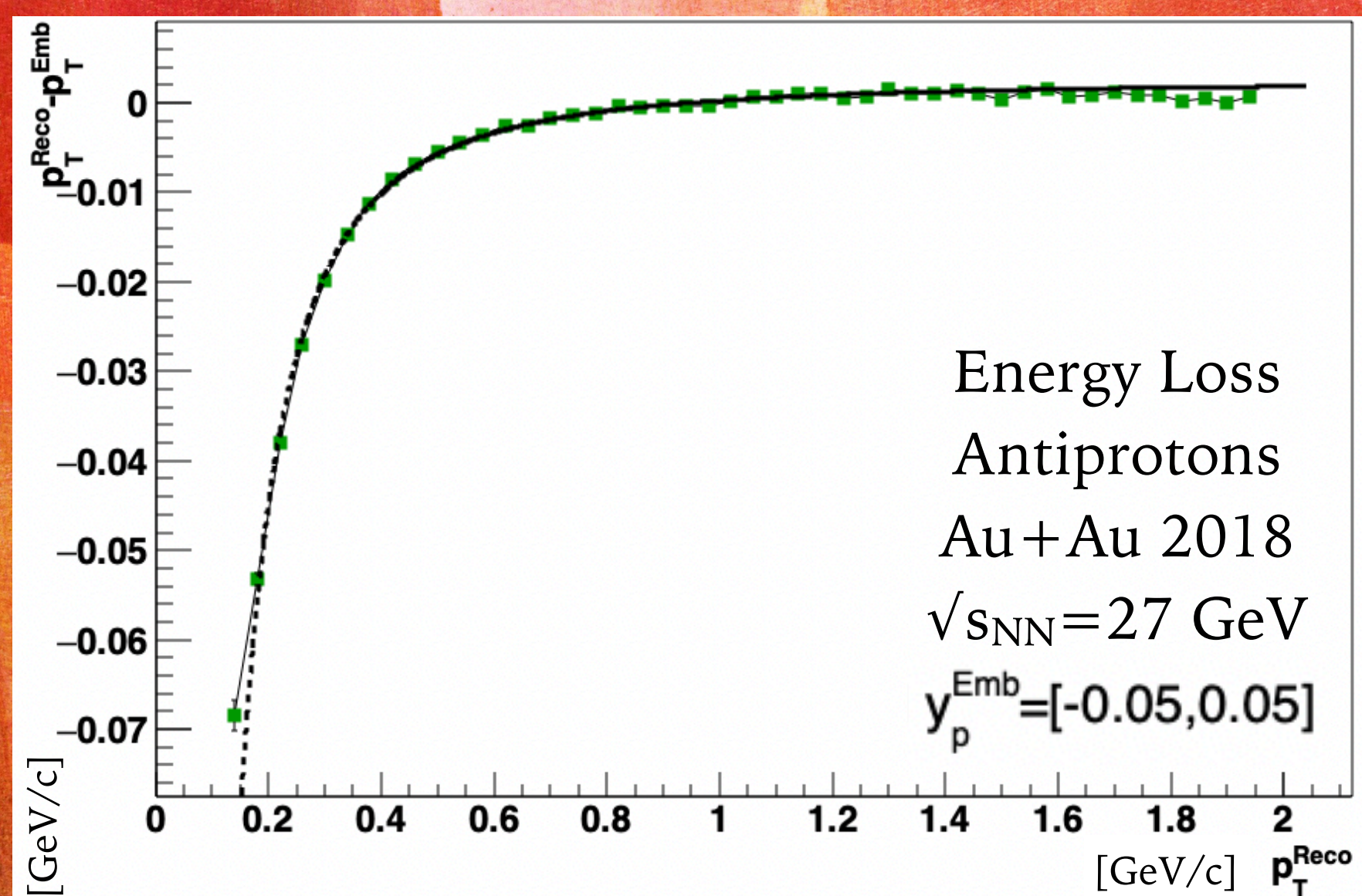
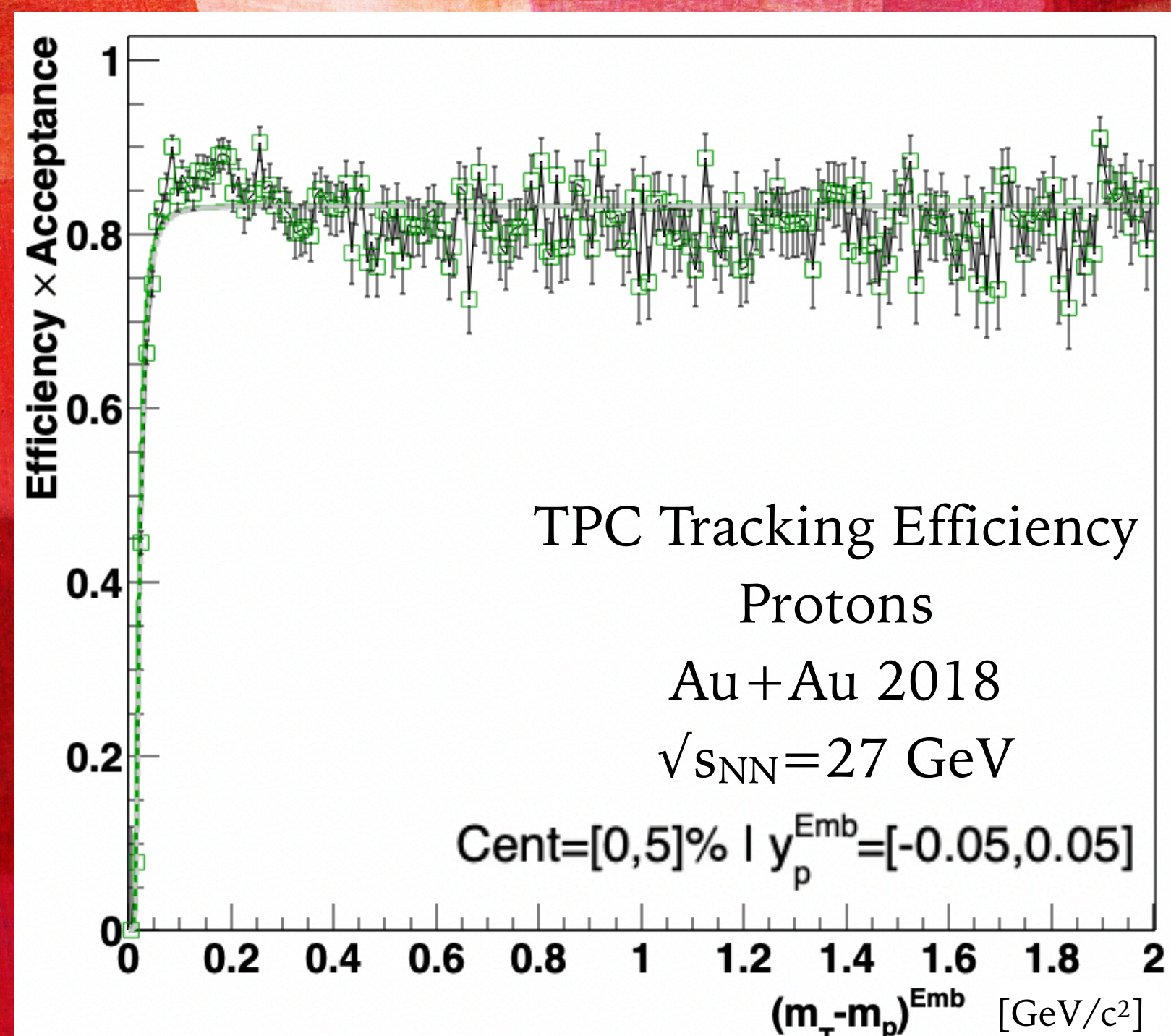
- ▶ Beam Energy Scan - II
- ▶  $\sqrt{s_{NN}} = 27\text{ GeV}$  Au+Au 2018
- ▶ Events used: 200M
- ▶  $V_z = [-30, 30]$  cm
- ▶  $V_r < 2.0$  cm



# EXTRACTING RAW YIELDS

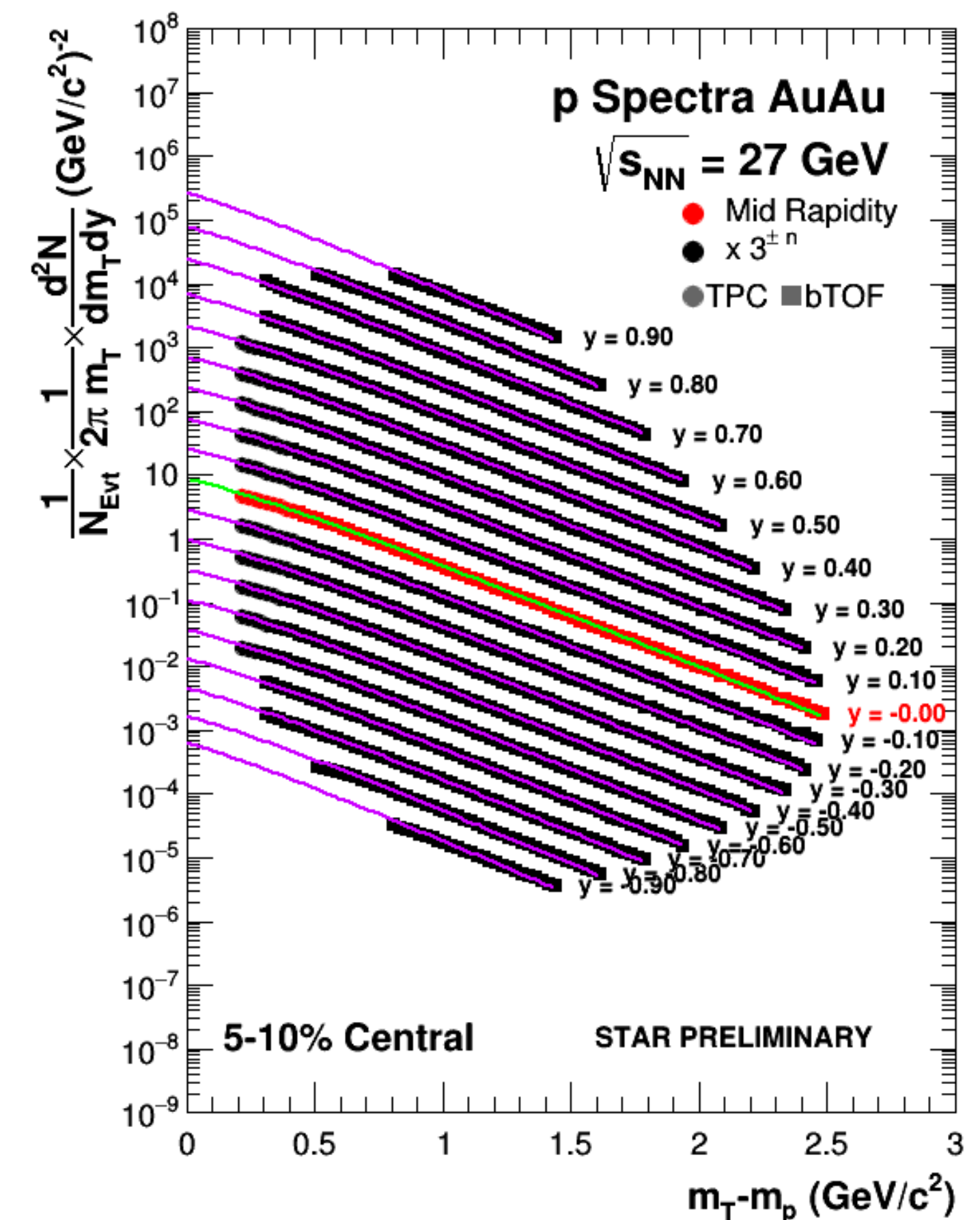
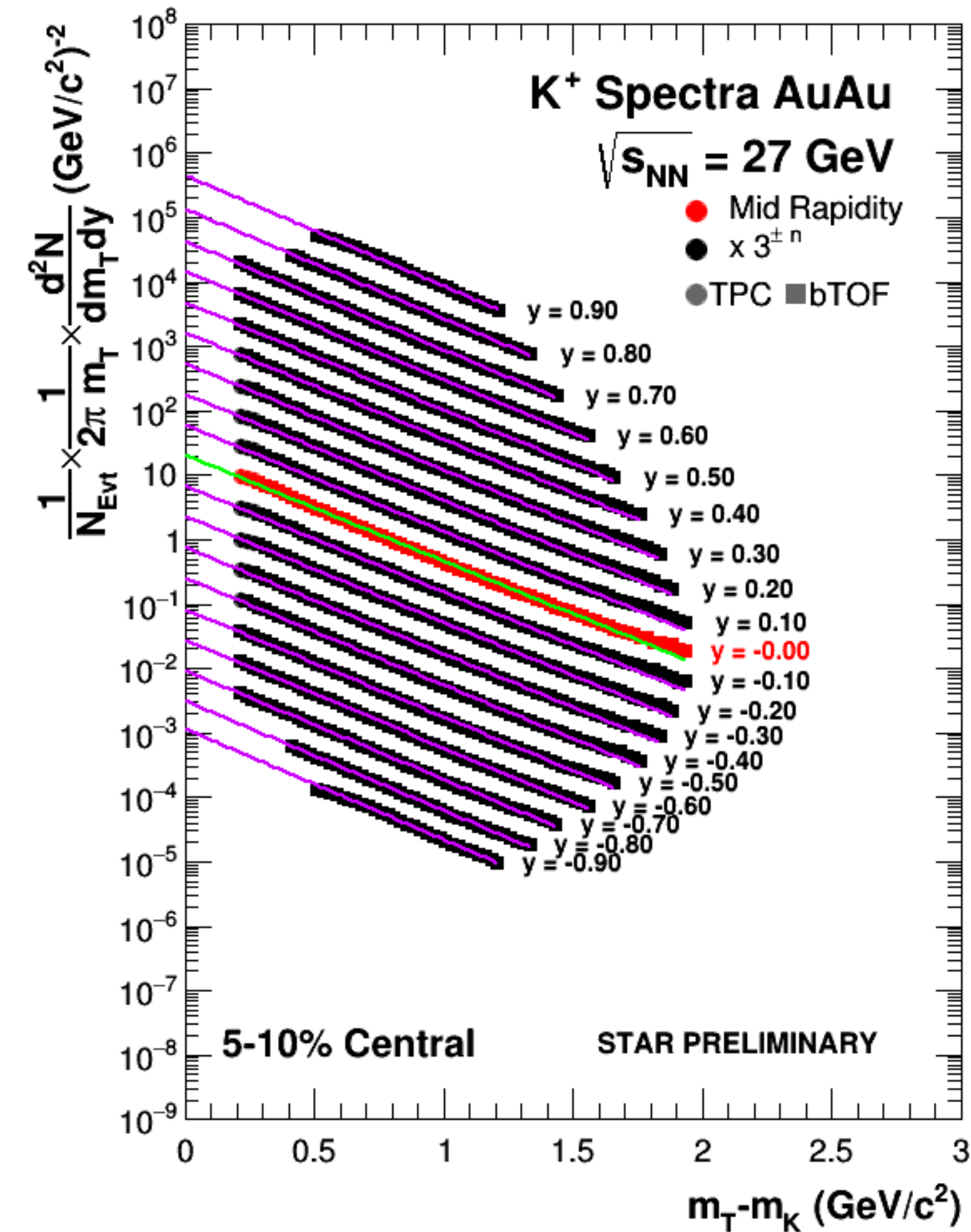
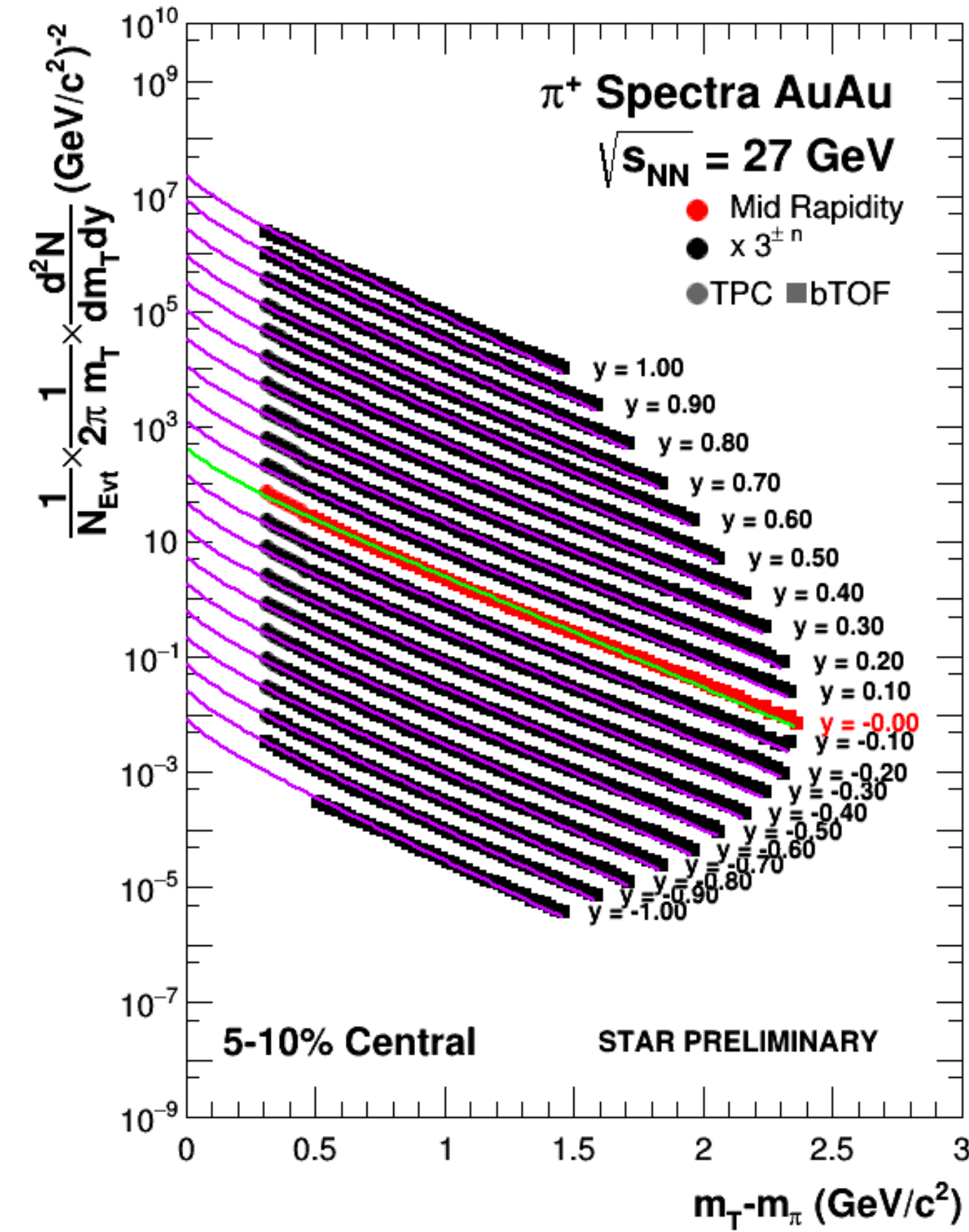


# CORRECTIONS



- bToF matching efficiency (data driven)
- TPC tracking efficiency
- Energy loss in TPC (K and p)
- Knockout protons (p Only)
  - Mainly beryllium beam pipe interactions
- Feed-down correction ( $\pi$  and p)

# RAPIDITY DEPENDENT PARTICLE SPECTRA - 5-10% MOST CENTRAL COLLISIONS



**Bose-Einstein:**

$$f_{BE}(m_T - m_0) = A \frac{1}{\exp(m_T/T) - 1}$$

**$m_T - m_K$  Exponential:**

$$f_{m_T}(m_T - m_0) = A \frac{1}{\exp((m_T - m_0)/T)}$$

Fit Function: Blast Wave Model [Schnedermann, et al. PRC 48]

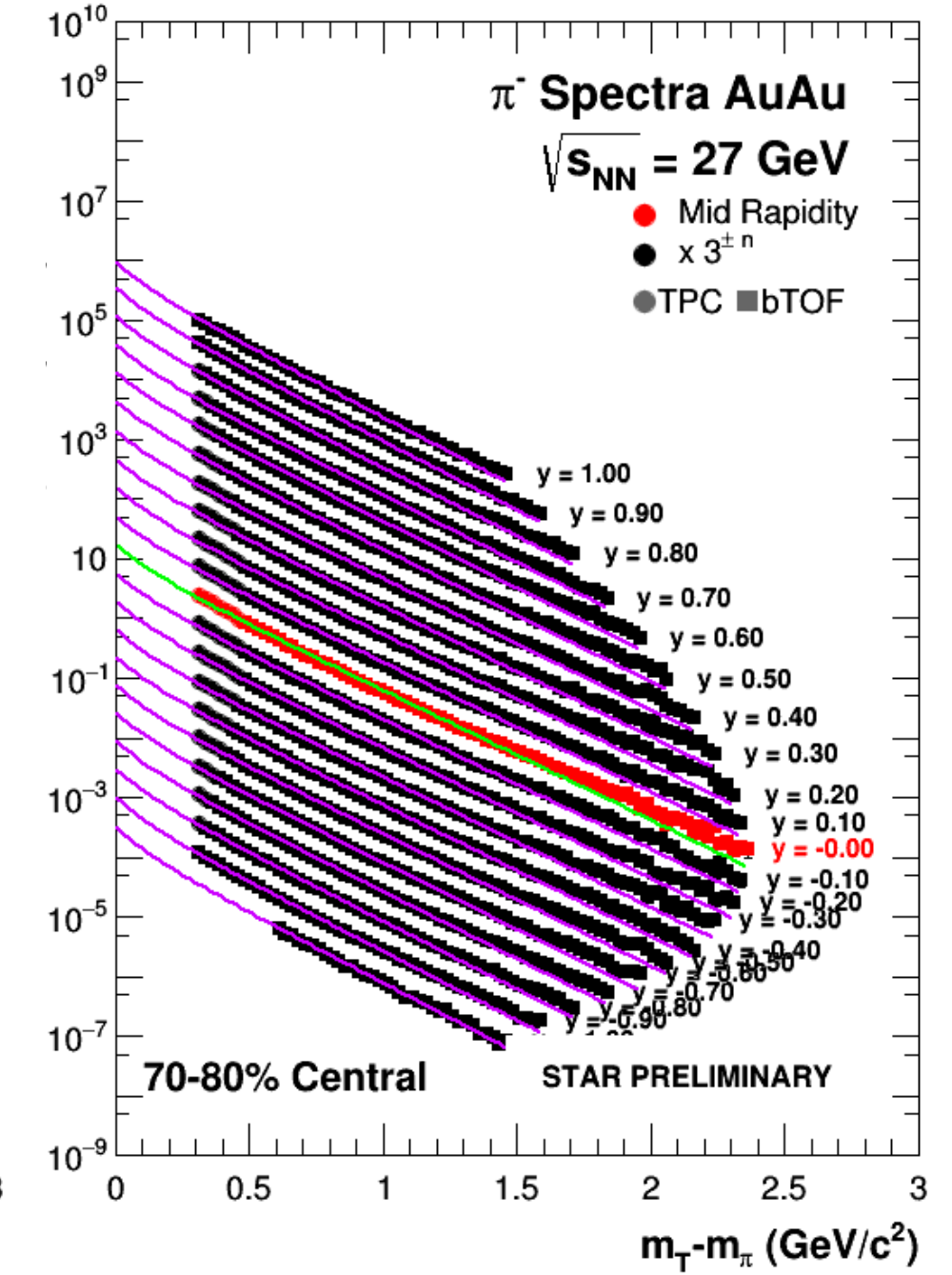
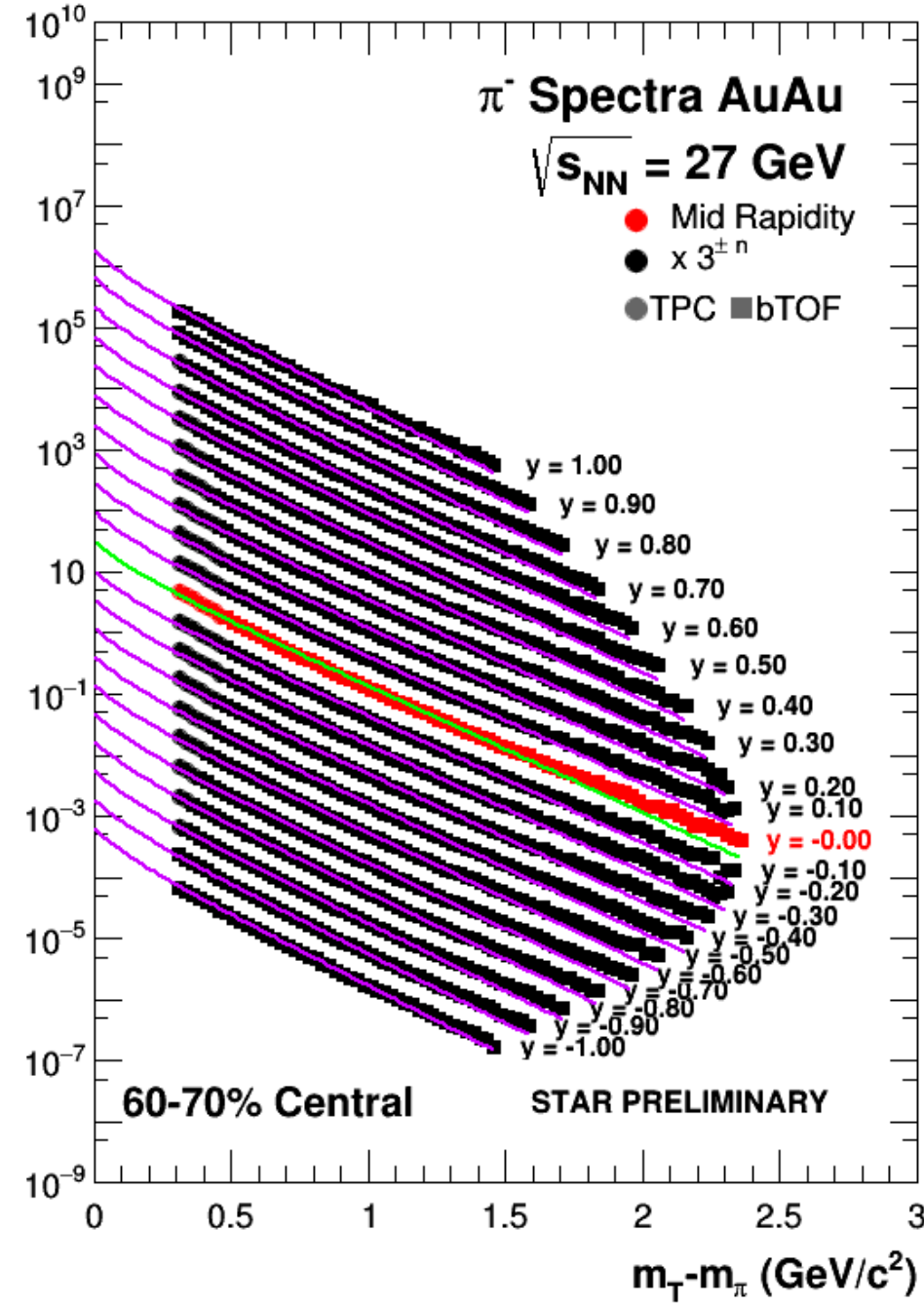
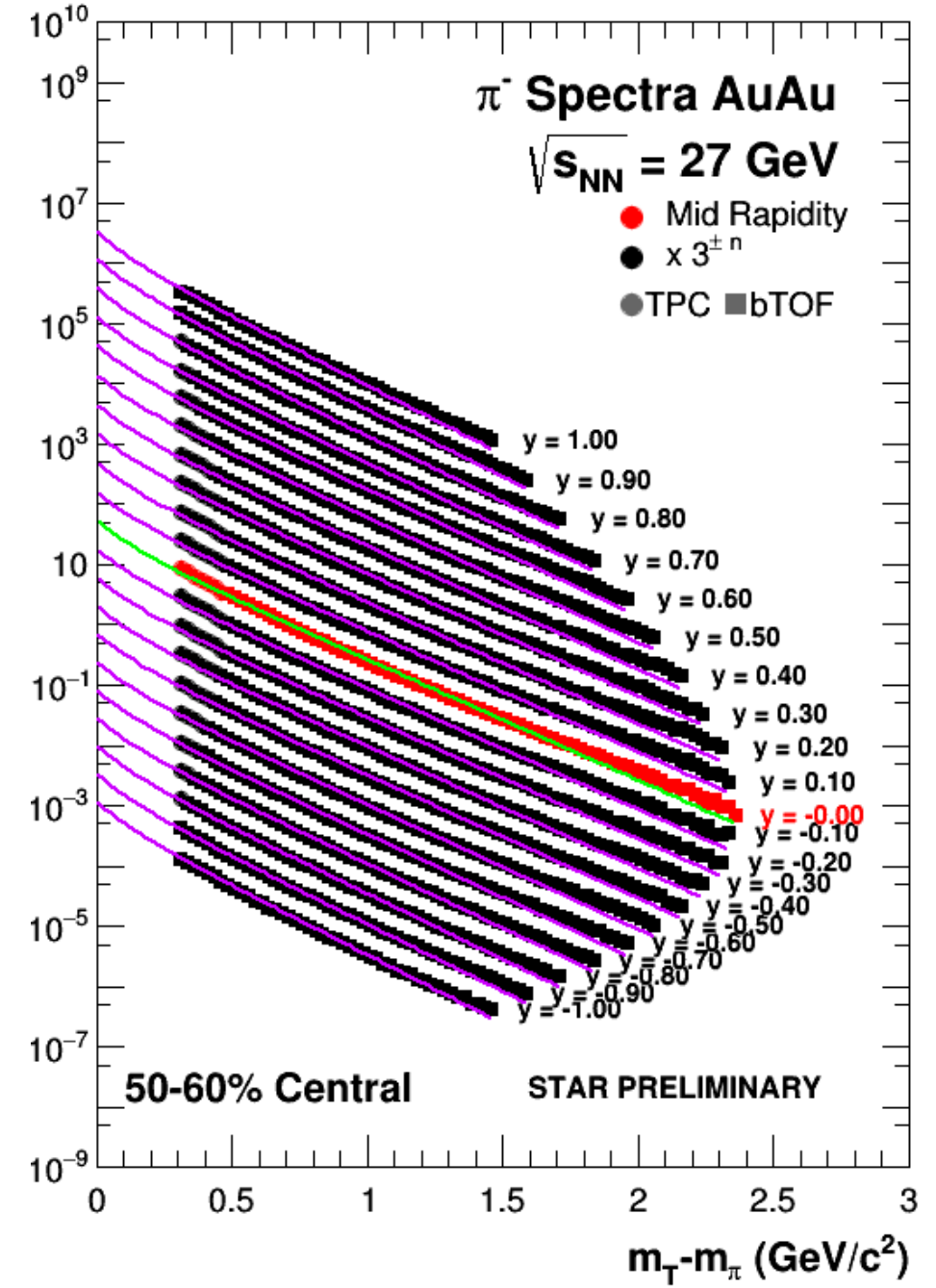
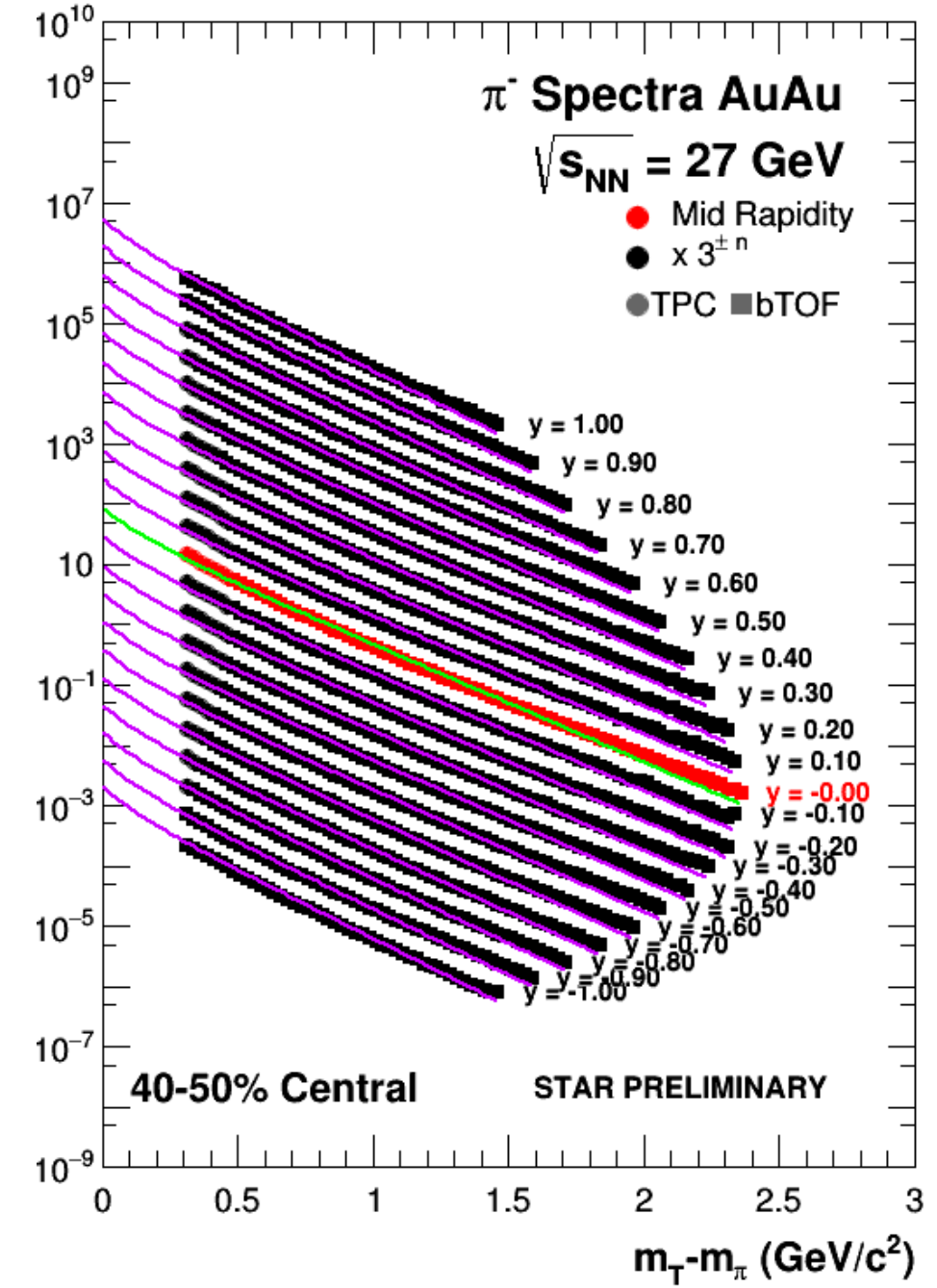
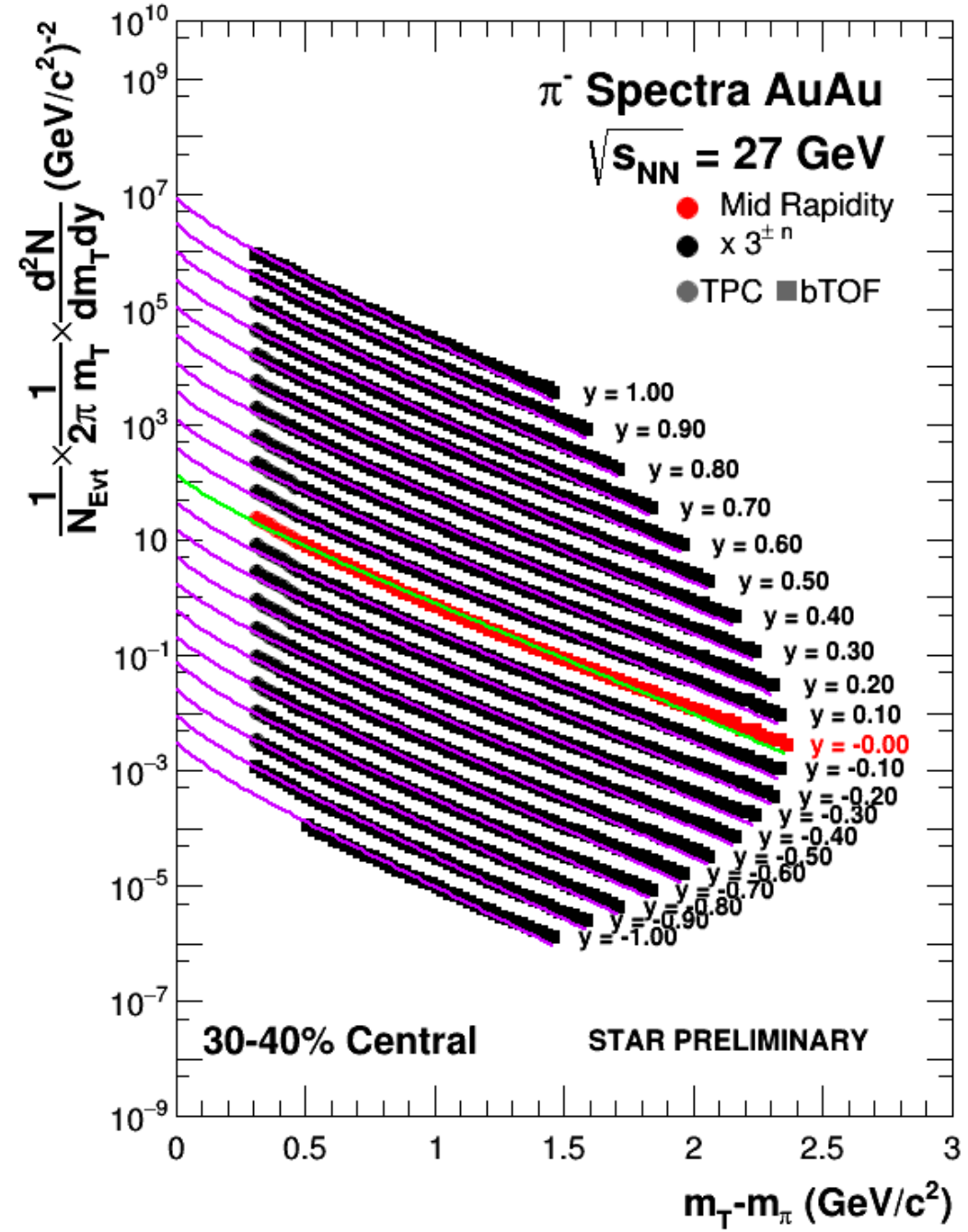
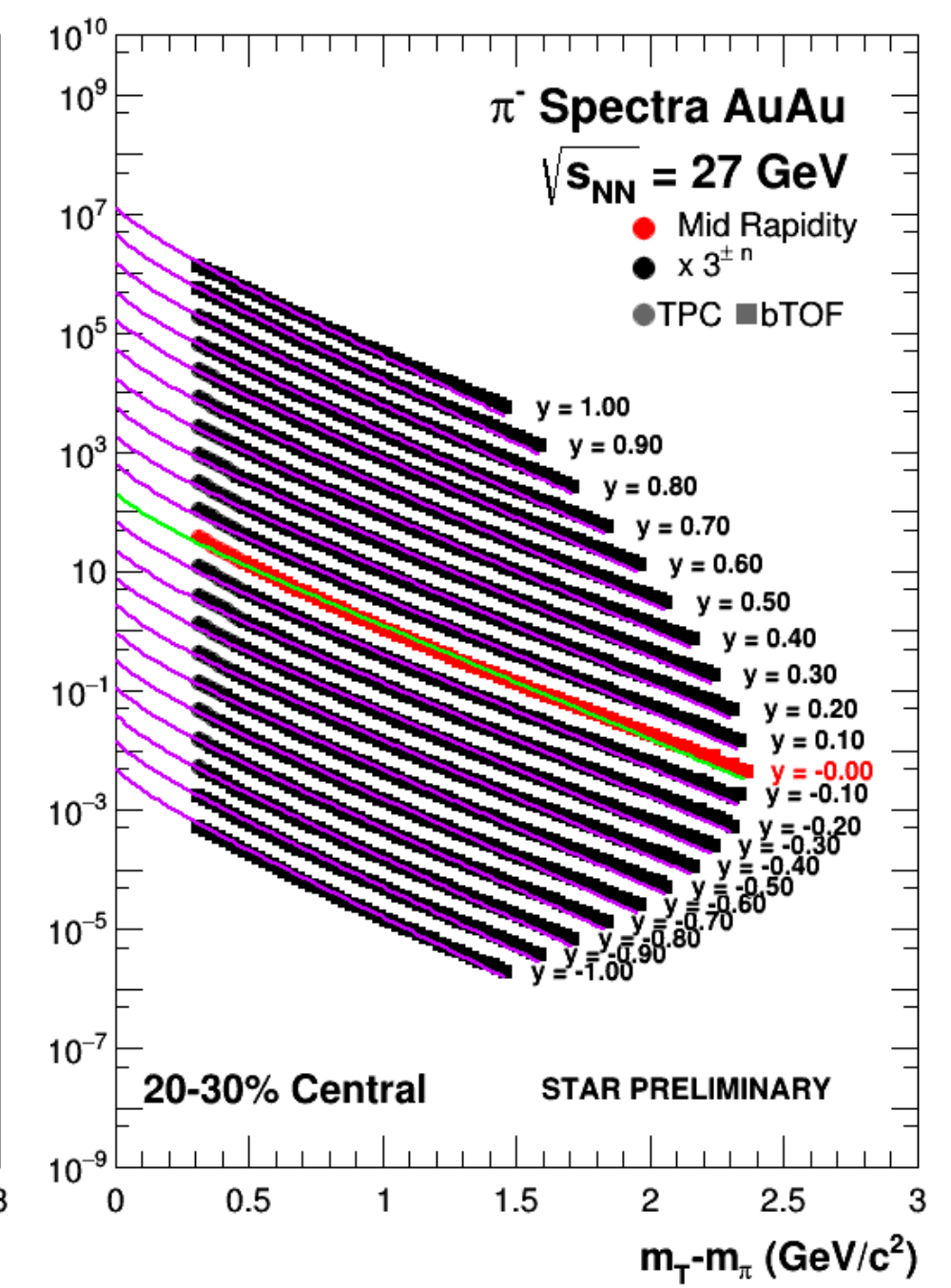
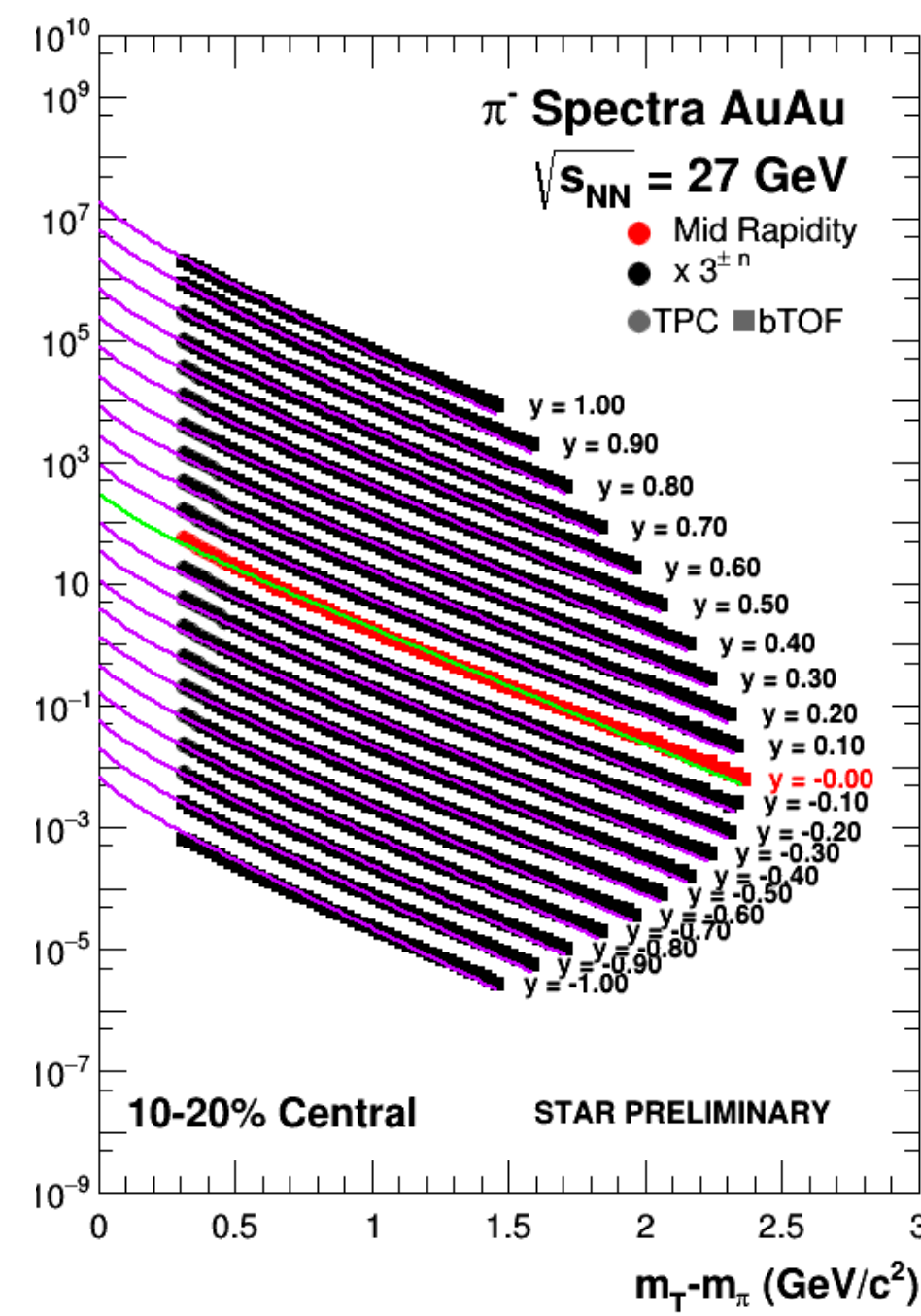
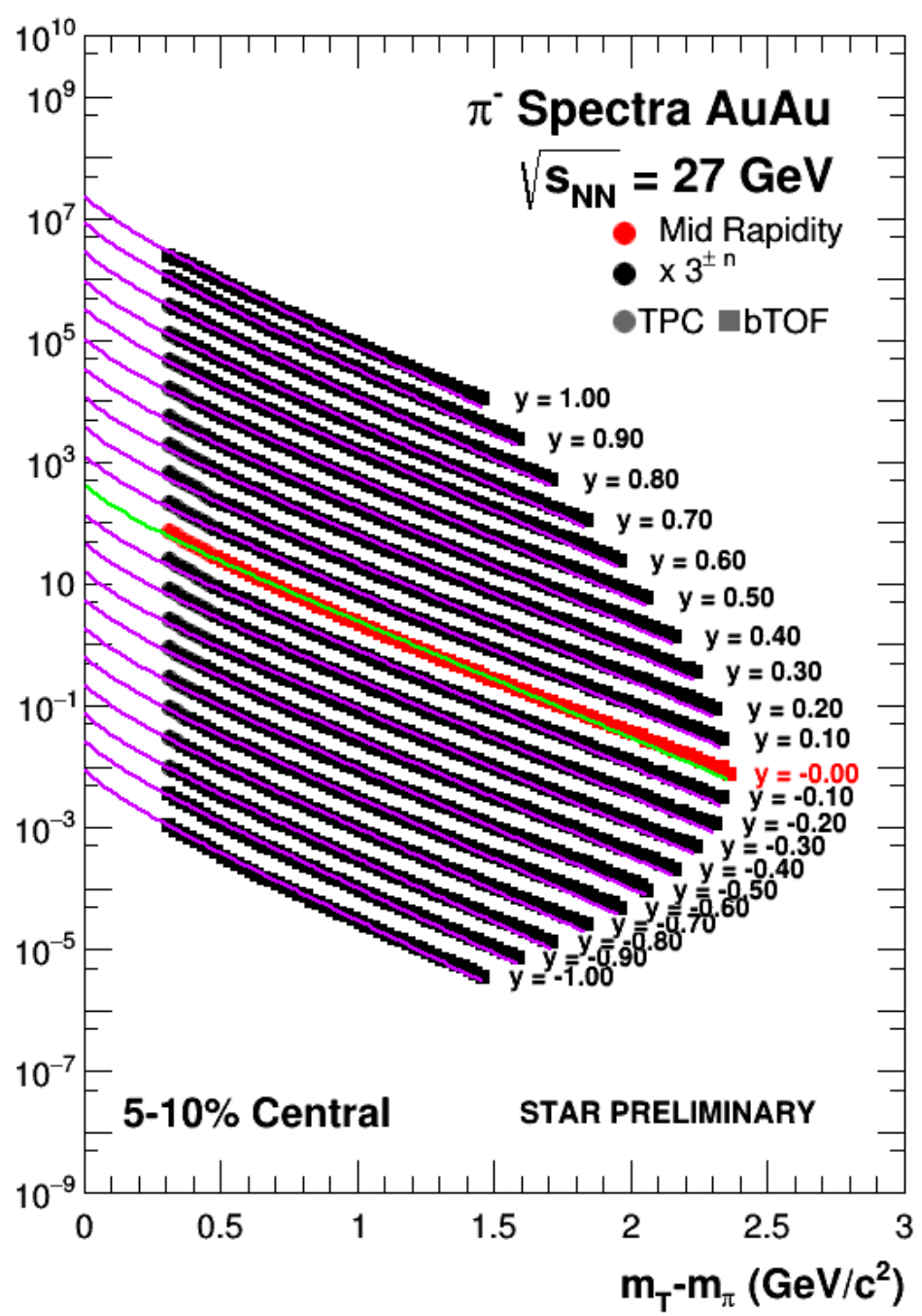
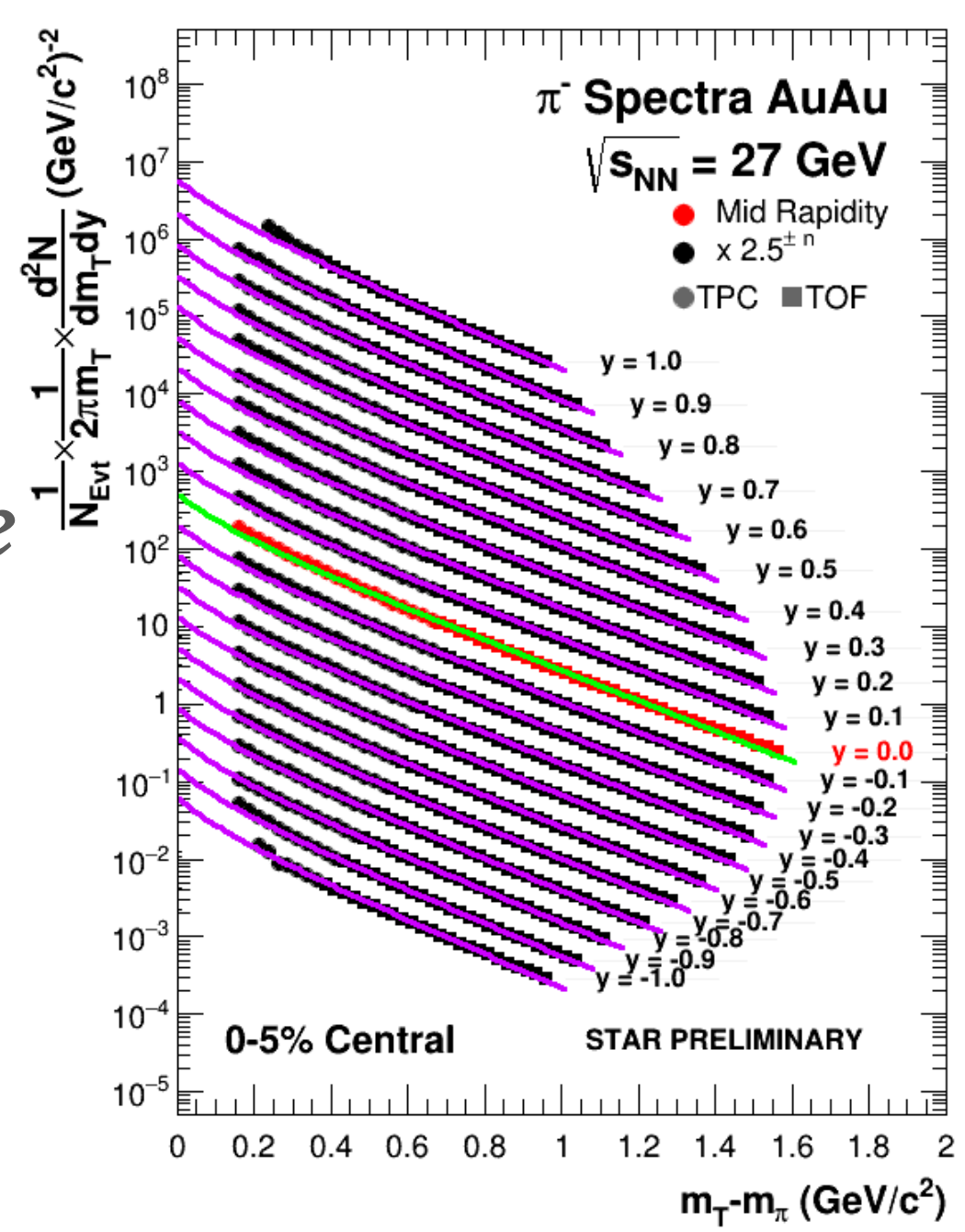
$$\frac{d^2N}{m_T dm_T dy} = A \int_0^R r dr m_T \times I_0 \left( \frac{p_T \sinh \rho(r)}{T_{Kin}} \right) K_1 \left( \frac{m_T \cosh \rho(r)}{T_{kin}} \right)$$

➤ Spectra fit over extended rapidity coverage

Radial flow pushes protons to higher  $p_T$



# Centrality Dependence Of $\pi^-$ Spectra (Other $\pi$ , $K$ , $p$ also measured)

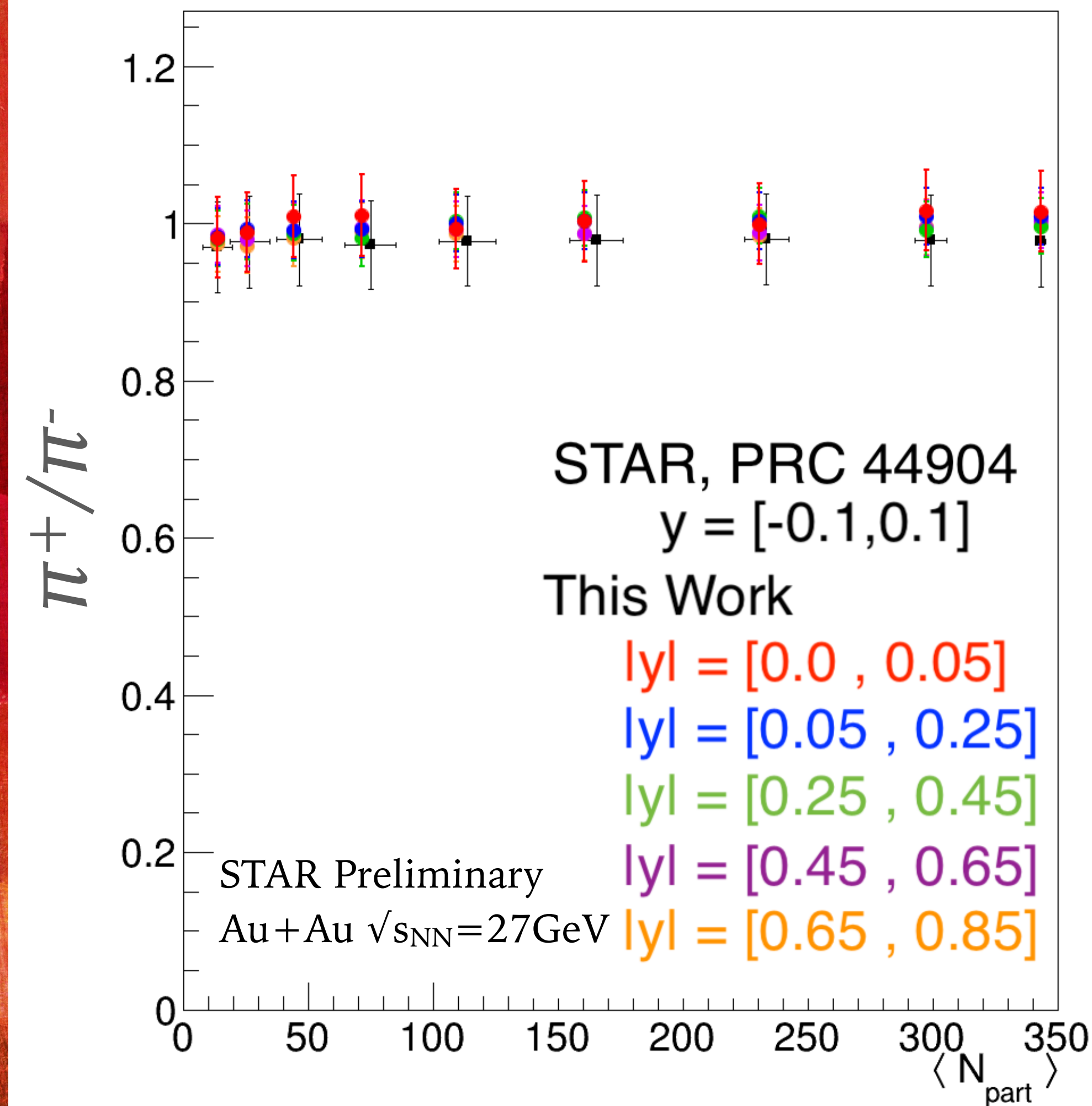
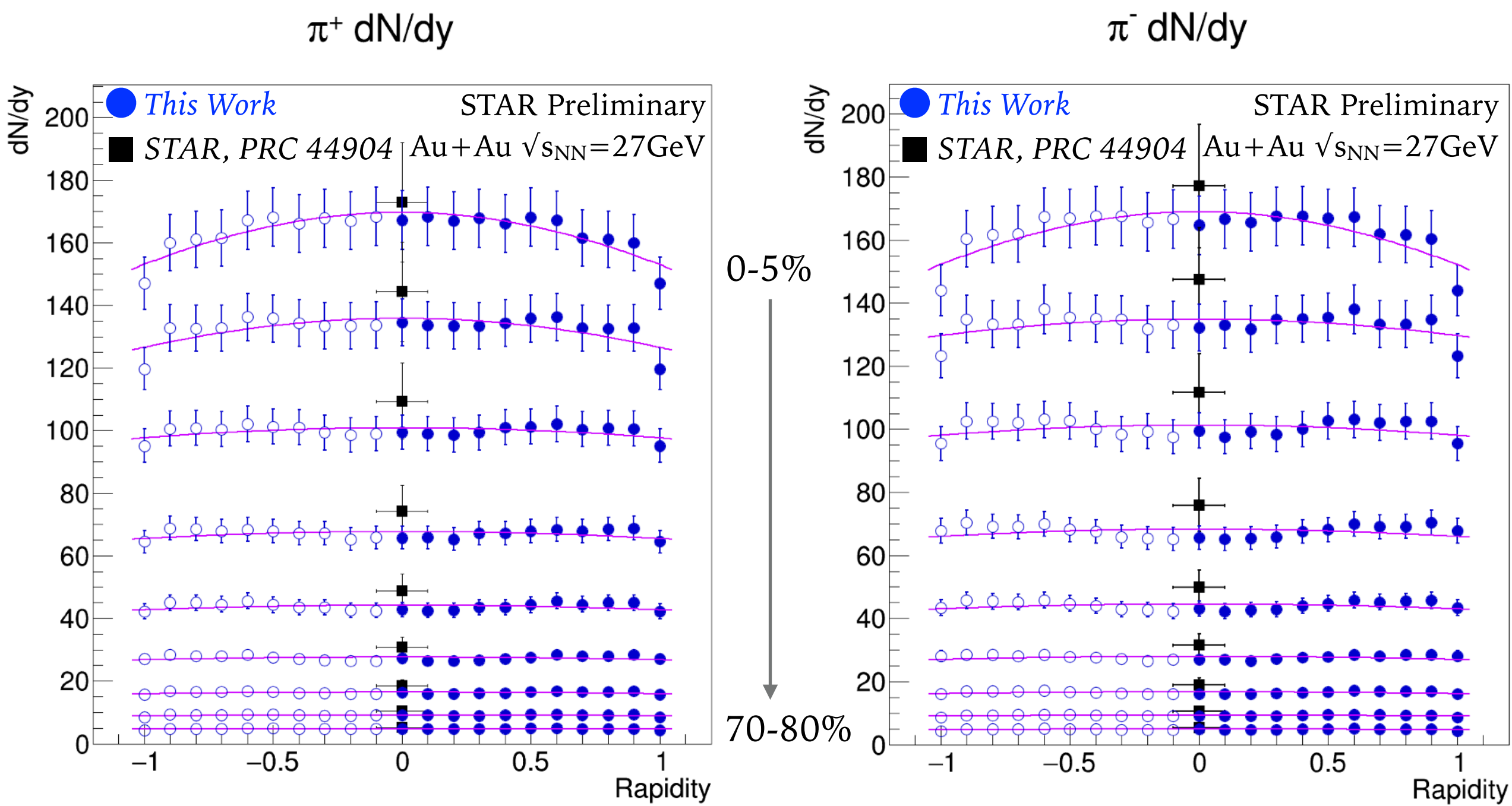






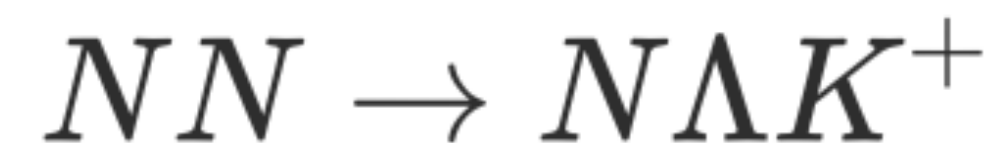
# PION PRODUCTION

- Thermally produced
- Charge chemical potential ( $\mu_Q$ )
- Little variation in ratio by centrality



# KAON PRODUCTION

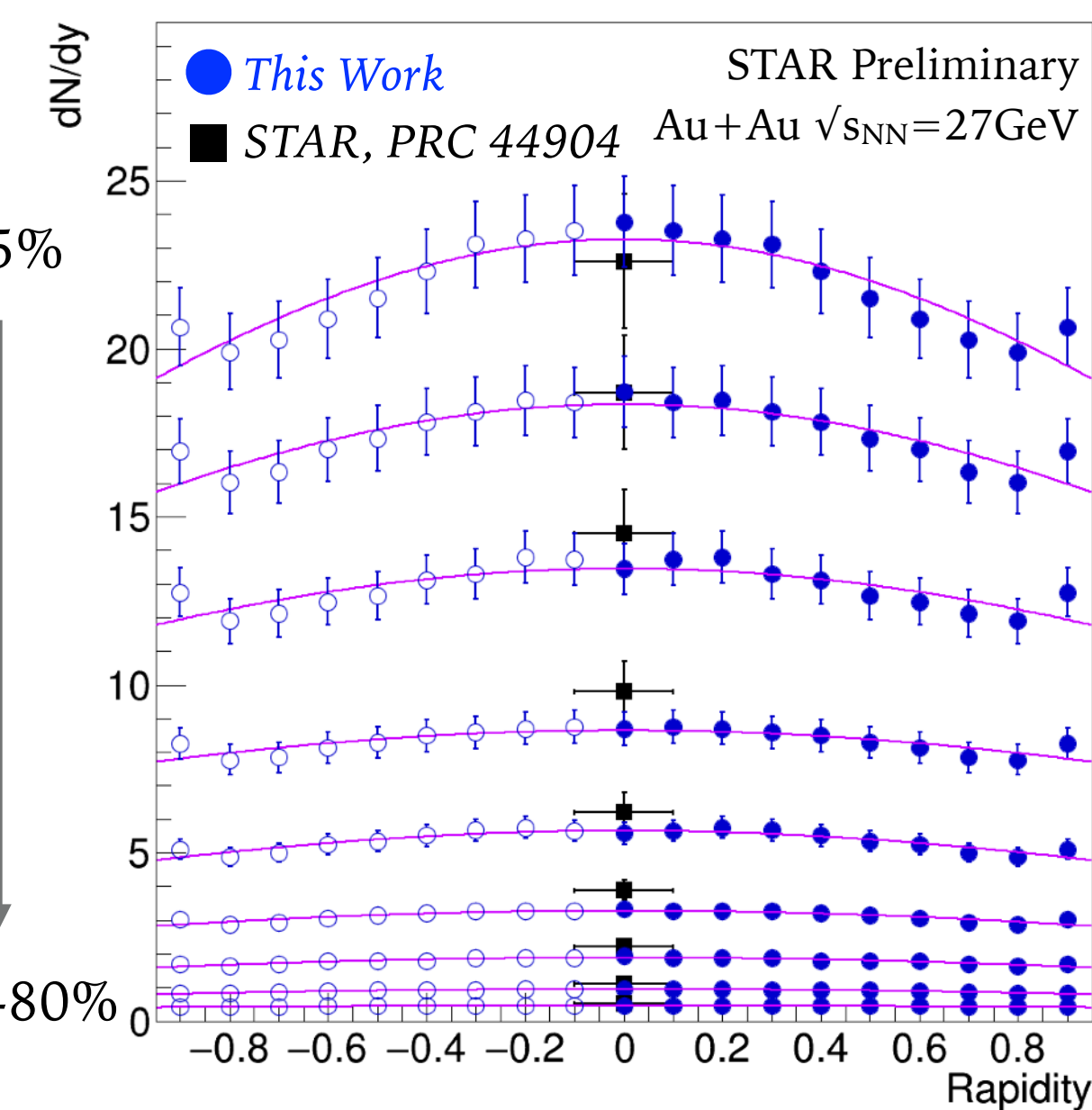
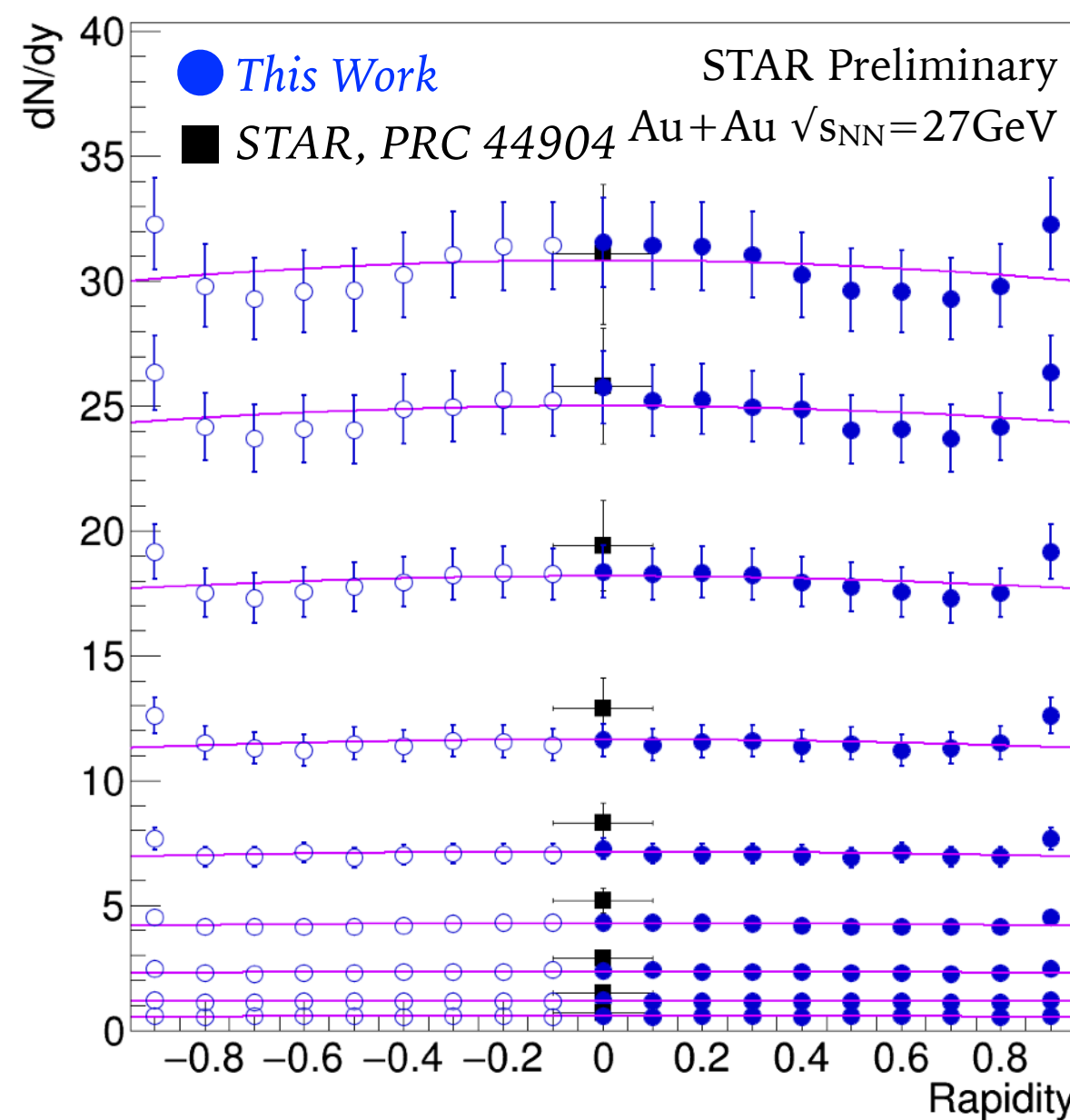
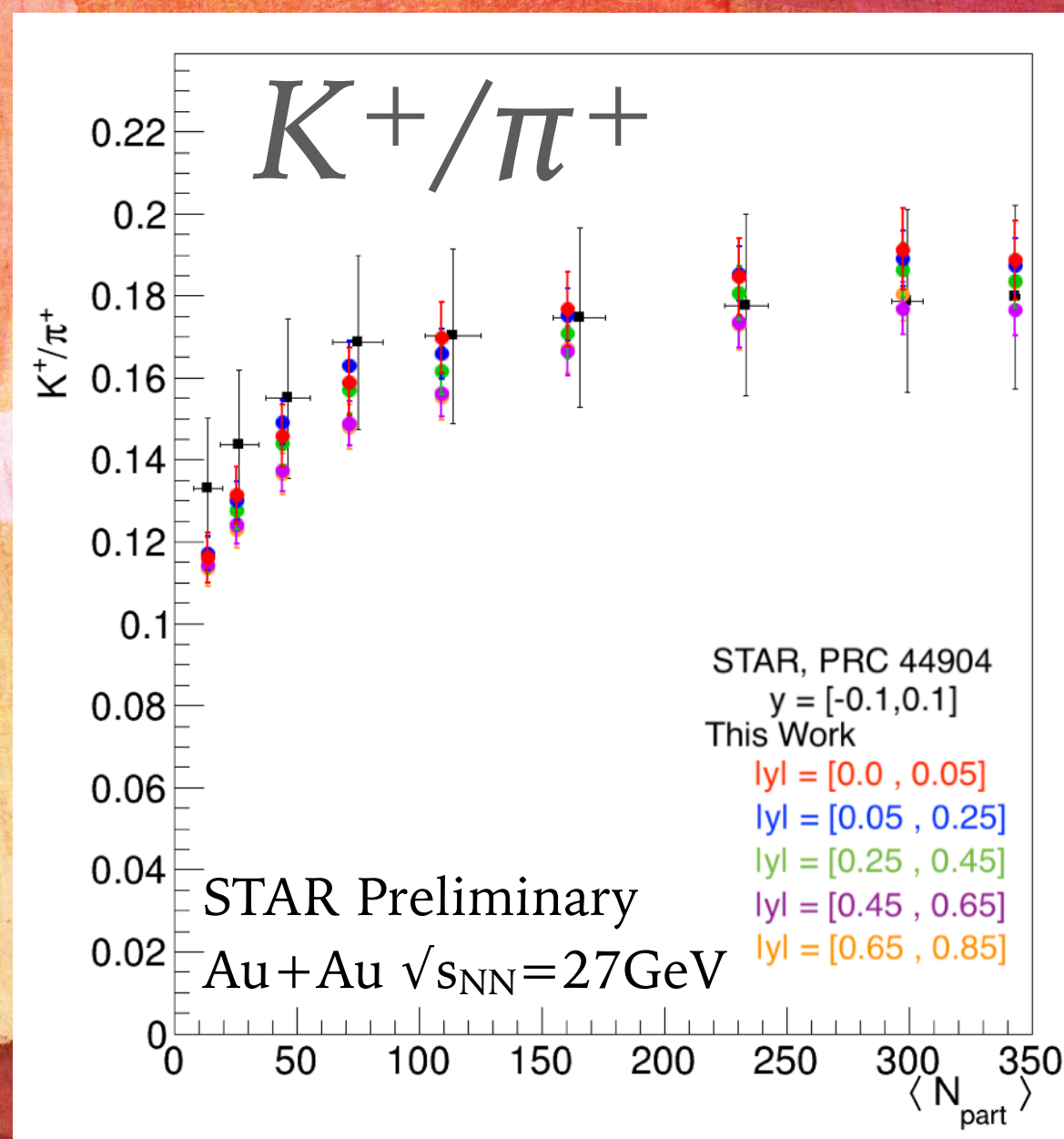
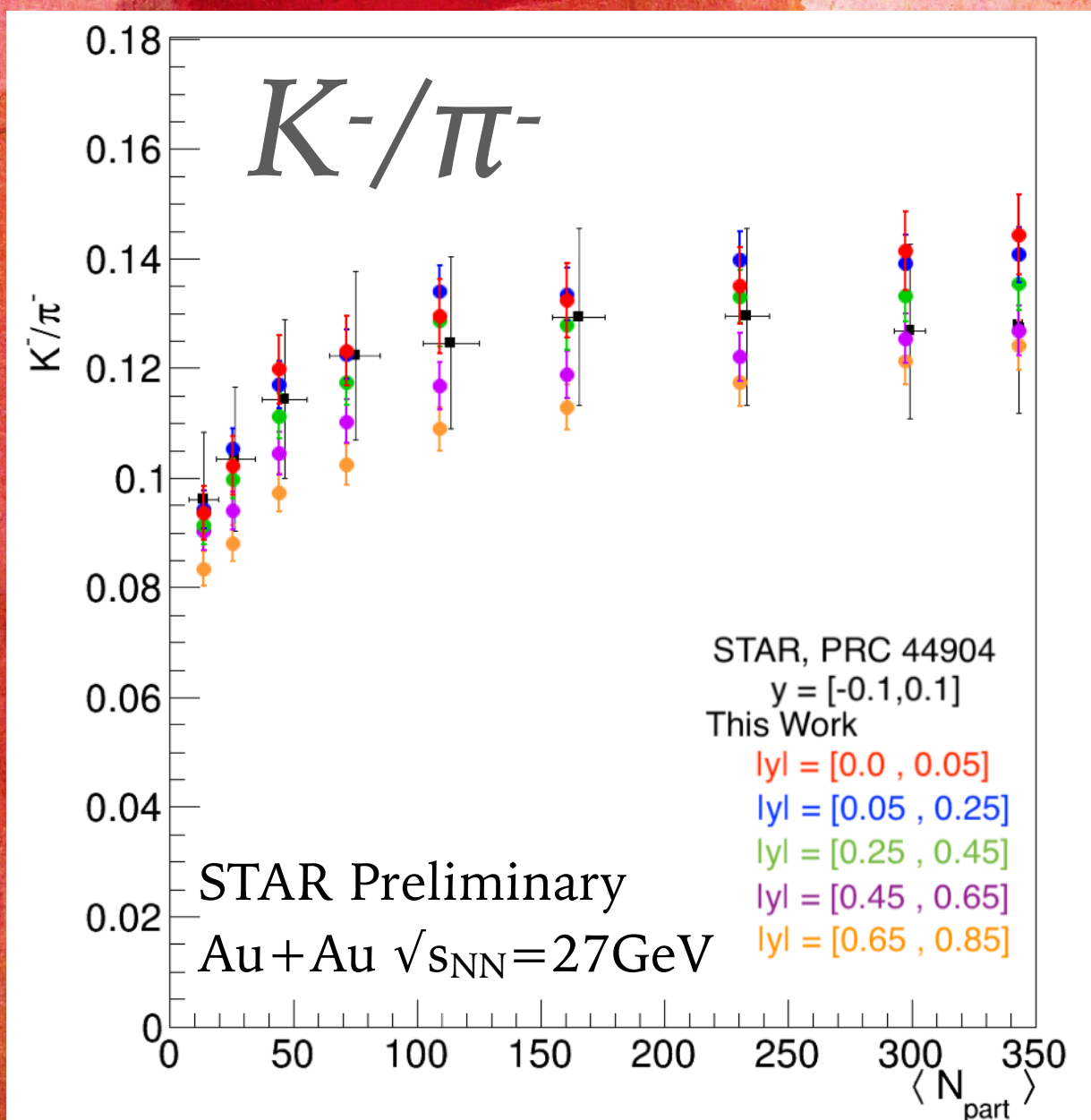
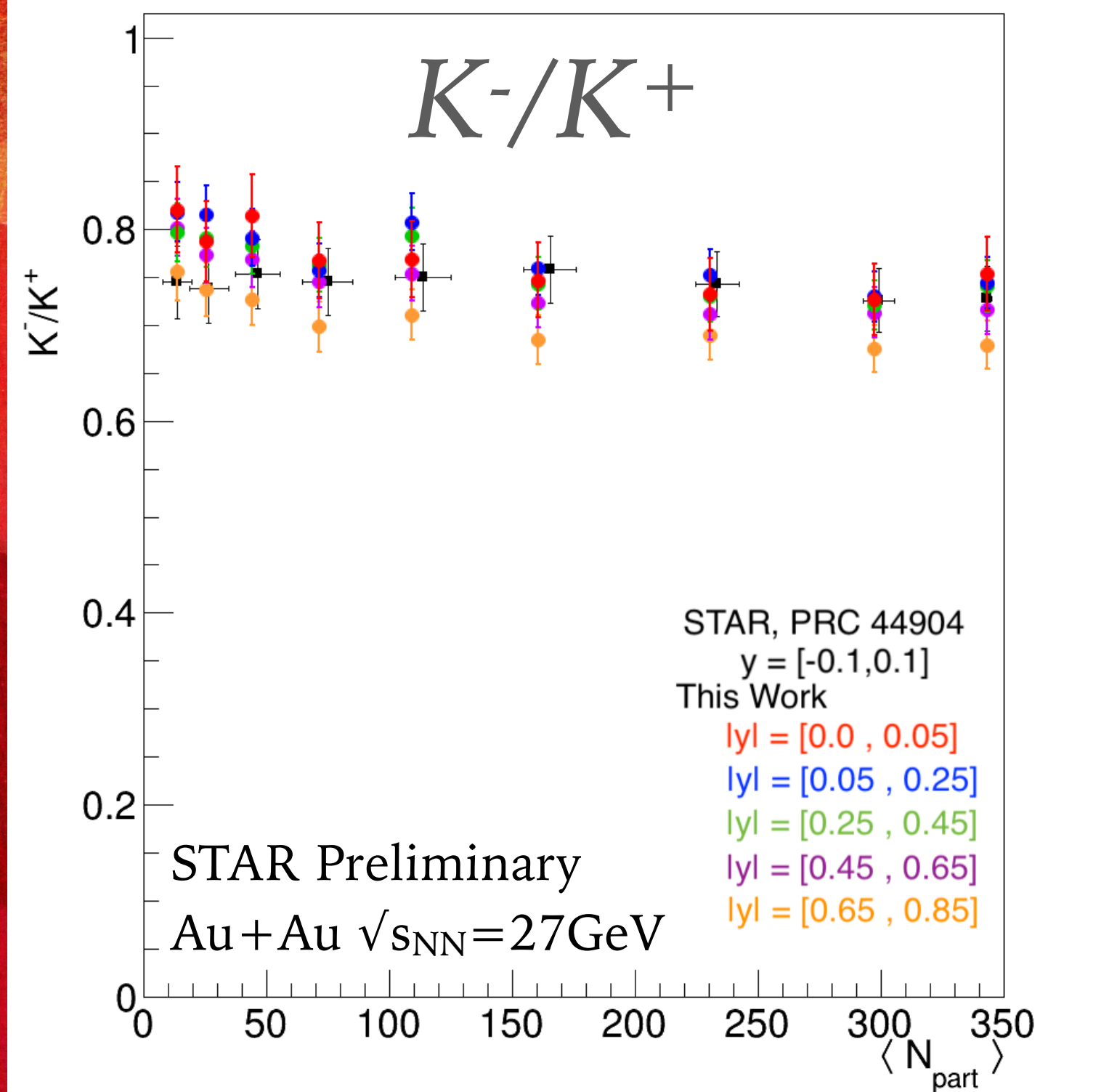
- Thermal production of  $K^+$  and  $K^-$
- $\sim 1/3$  of  $K^+$ : associated production



- Associated production increases with  $y$
- Strangeness chemical potential ( $\mu_s$ )

$K^+$  dN/dy

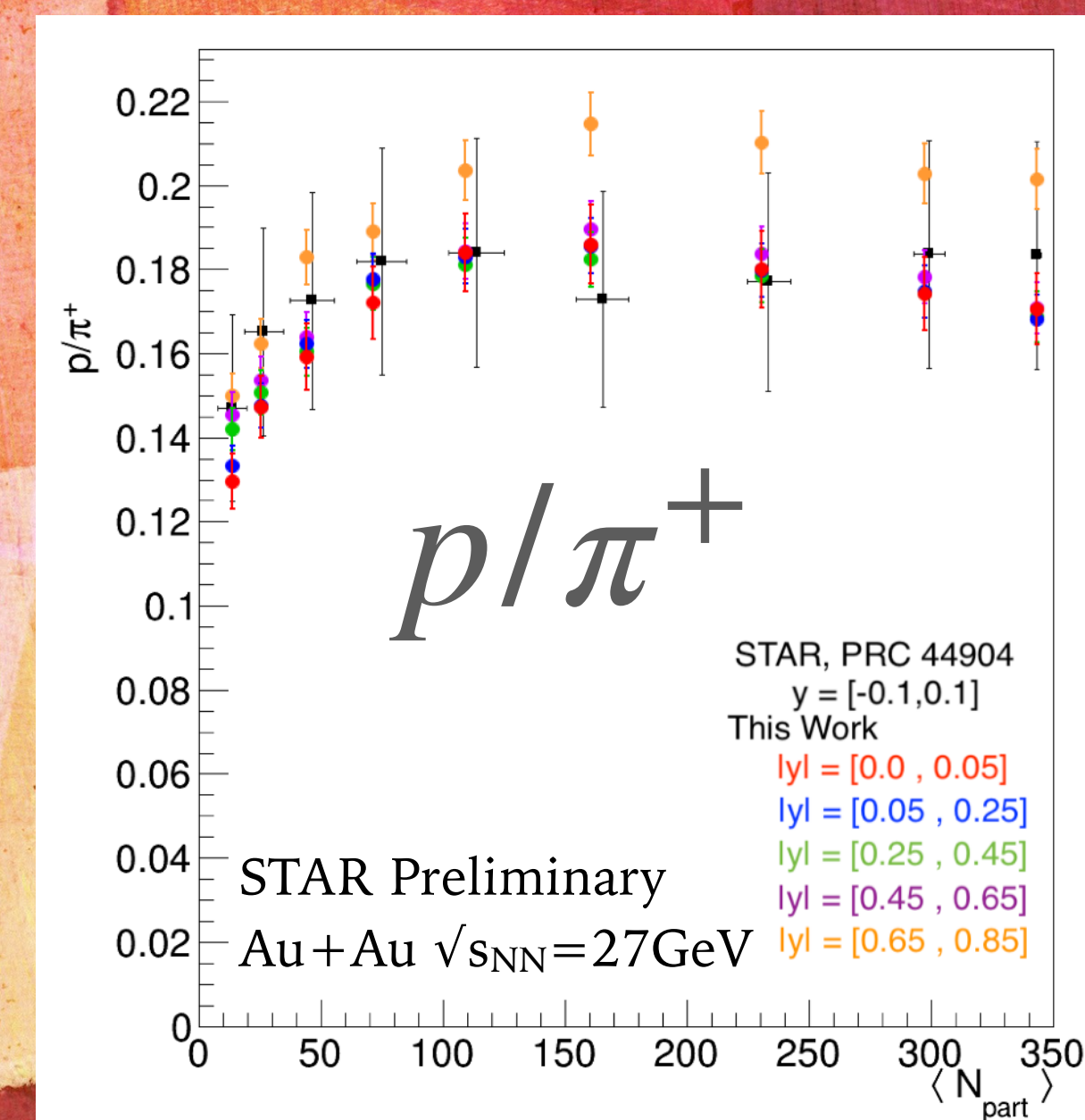
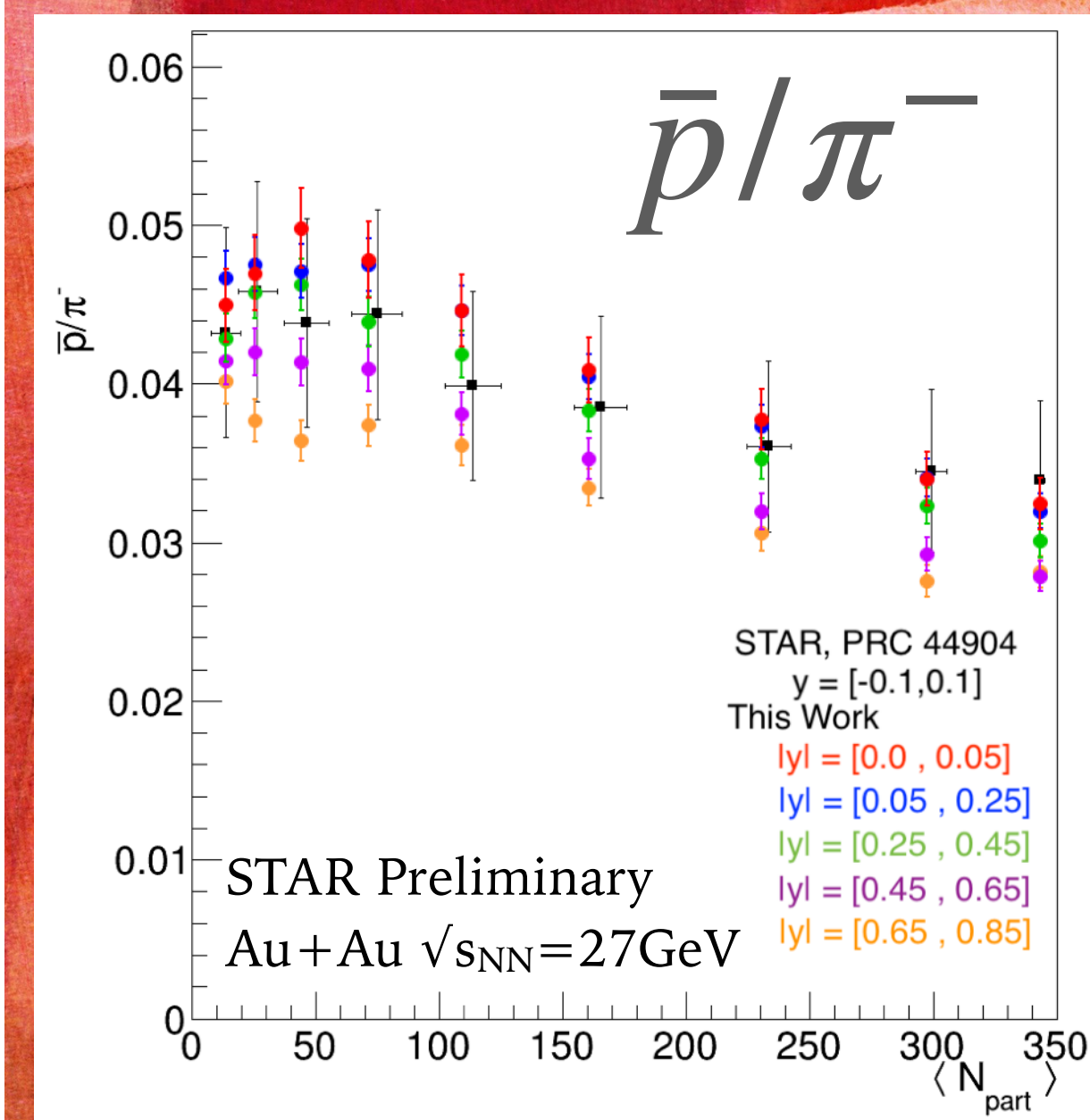
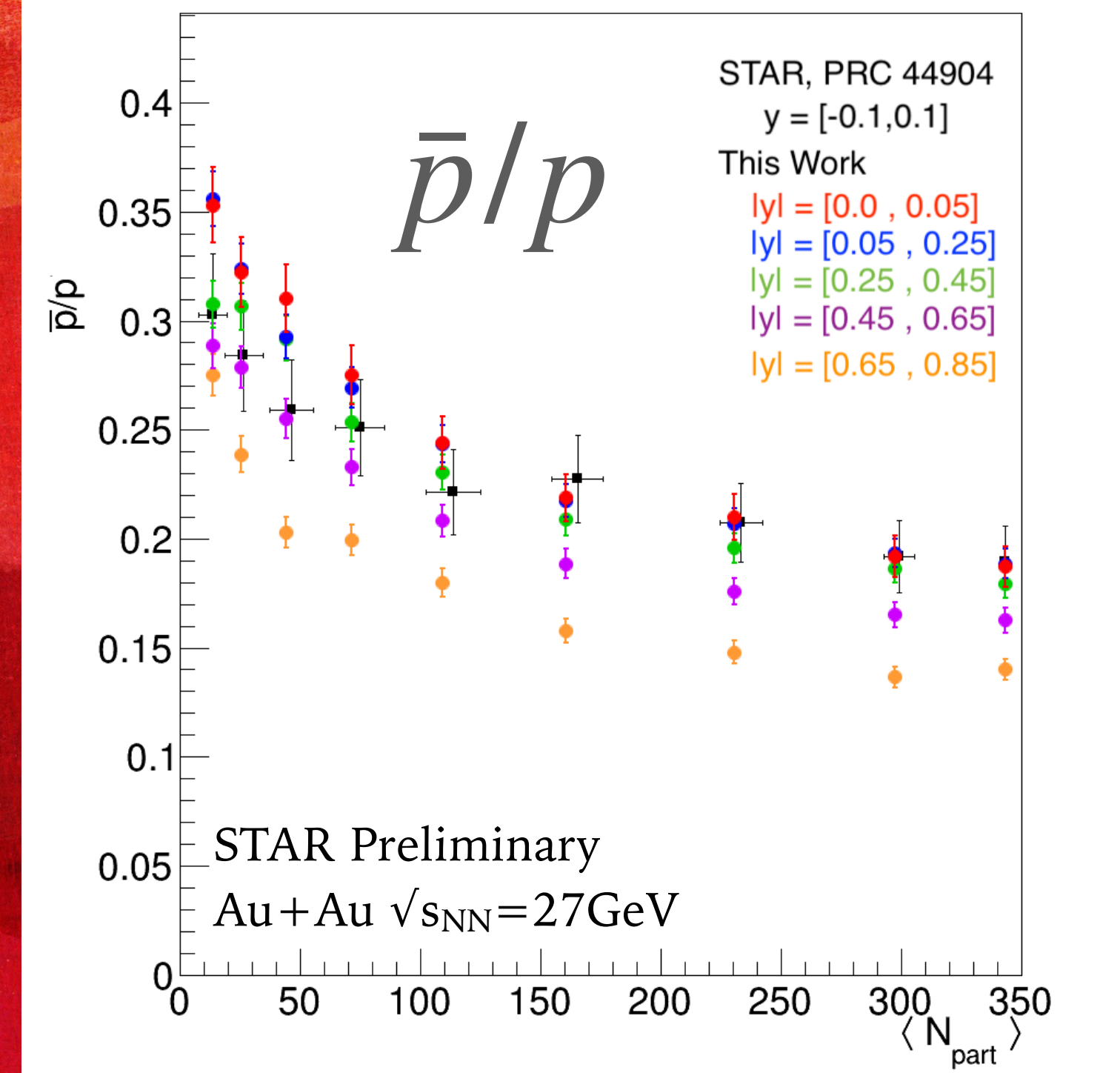
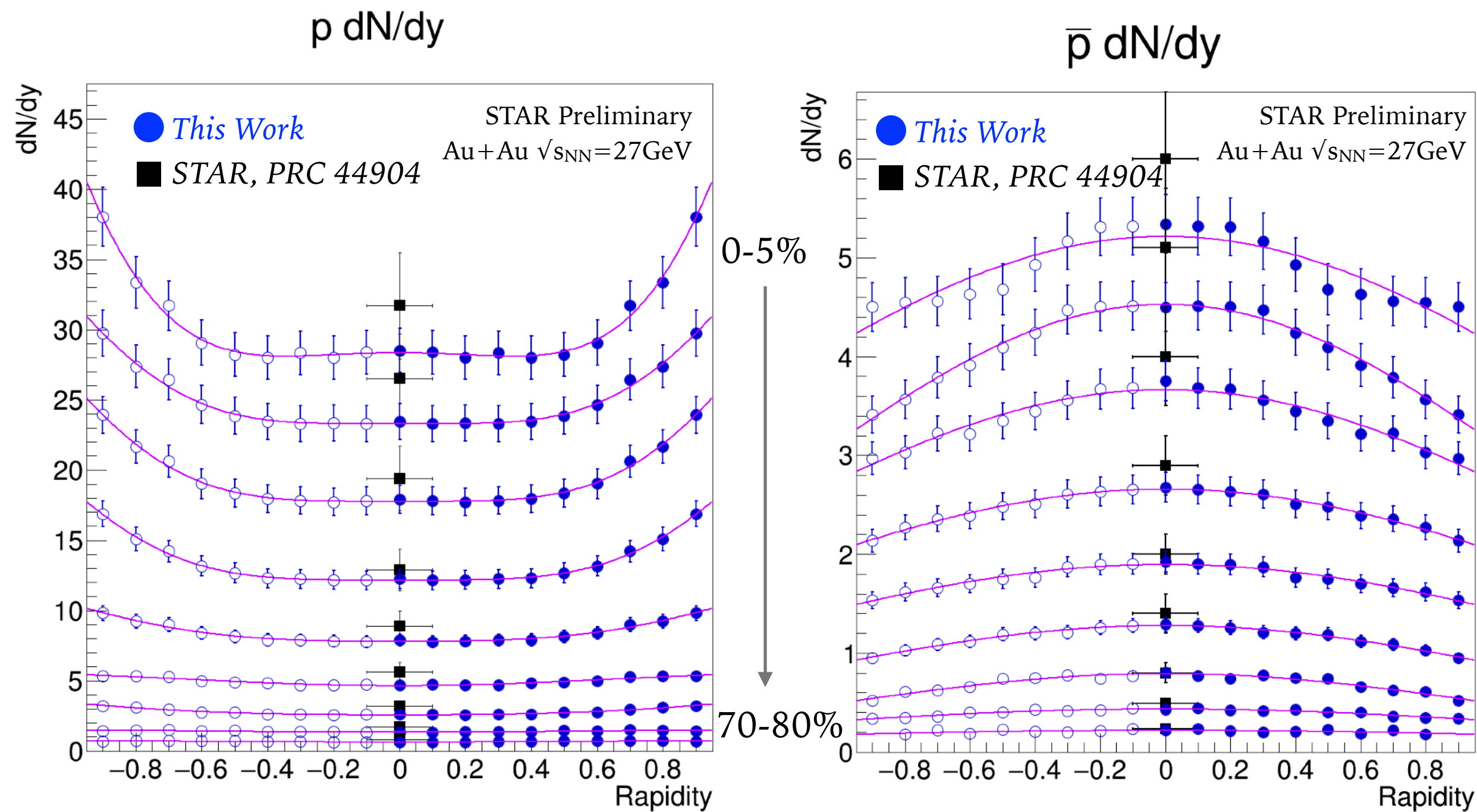
$K^-$  dN/dy





# PROTON PRODUCTION

- Thermal and participant protons
- Baryon stopping
- Baryon chemical potential ( $\mu_B$ )
- New results were feed-down corrected, while the previous results were not.



# BARYON CHEMICAL POTENTIAL FROM PROTON RATIO

$$\frac{N_{\bar{p}}}{N_p} = e^{-\frac{2(\mu_B + \mu_Q)}{T_{ch}}}$$

$$\mu_B = -\frac{T_{ch}}{2} \ln \frac{N_{\bar{p}}}{N_p} - \mu_Q$$

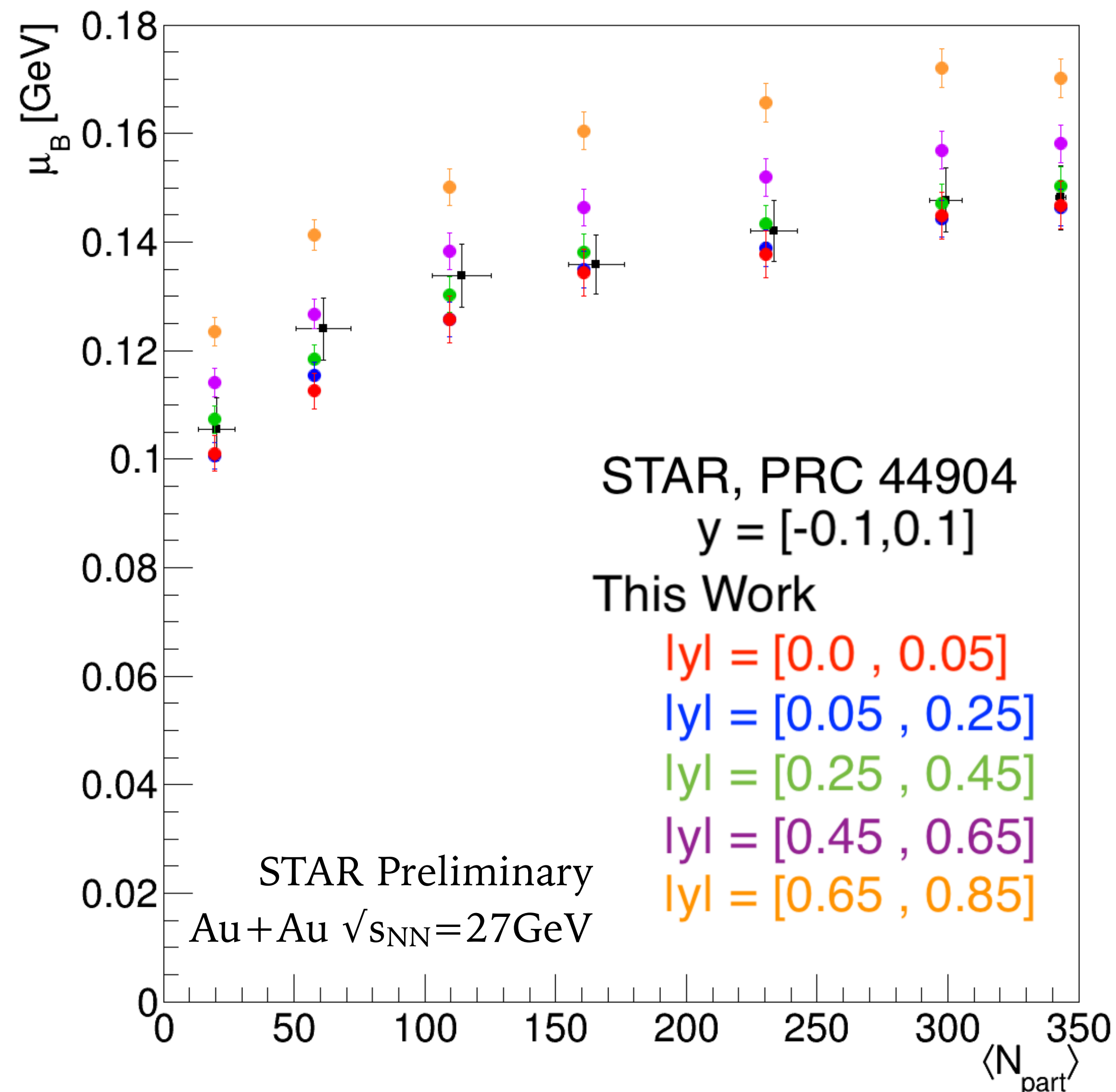
$T_{ch}$  for each  $N_{part}$  are fixed

[STAR, PRC 44904 (2017)]

$$\mu_Q = -12.9 \text{ MeV}$$

[Mekjian, PLB 651 (1993)]

- $\Delta\mu_B \sim 25 \text{ MeV}$  for 1 unit of rapidity
- Peripheral events extend coverage:
  - $\mu_B = [100\text{MeV}, 170\text{MeV}]$



# CONCLUSIONS

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- Analysis of BES-II data underway
- $\sqrt{s_{NN}} = 27$  GeV:  $\pi$ , K, p production has been measured beyond mid-rapidity
- Centrality dependence of particle production has been studied
- Future Work:
  - Offset vertices to extend rapidity coverage
  - Other collider energies:
    - $\sqrt{s_{NN}}$  : 19.6, (17.1), 14.6, 11.5, 9.2, 7.7 GeV

# REFERENCES

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- [1] STAR, “Bulk Properties of the Medium Produced in the Relativistic Heavy-Ion Collisions from the Beam Energy Scan Program” Phys. Rev. C 96 p44904 (2017)
- [2] Schnedermann, Sollfrank, and Heinz. “Thermal phenomenology of hadrons from 200A GeV S+S collisions” Phys. Rev. C 48 p2462-2475 (1993)
- [3] Mekjain, Aram. “Properties of baryonic, electric and strangeness chemical potentials” Phys. Lett. B 651 p33-38 (2007)



*Thank You  
for Your Attention*