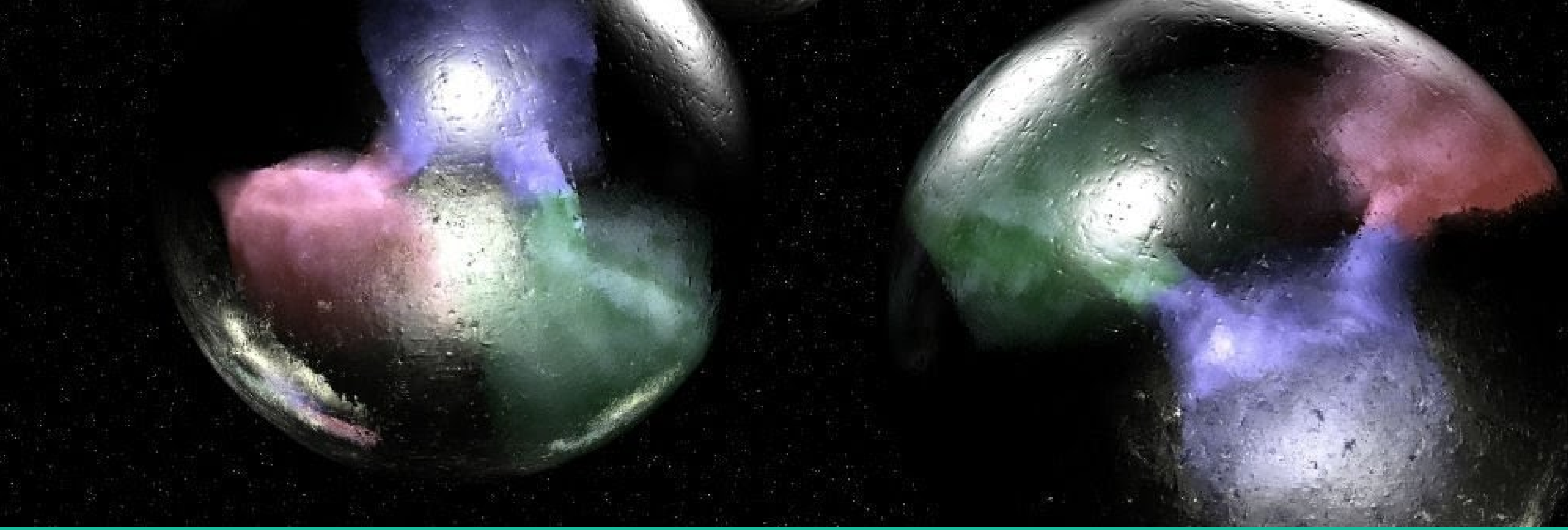


Evolution of the Baryon Chemical Potential as a Function of Rapidity at $\sqrt{s_{NN}}$ = 27 GeV

Matthew Harasty
UC Davis
For the Star Collaboration

APS DNP, Virginia
16 October, 2019

UCDAVIS
UNIVERSITY OF CALIFORNIA

STAR

NSF

Overview

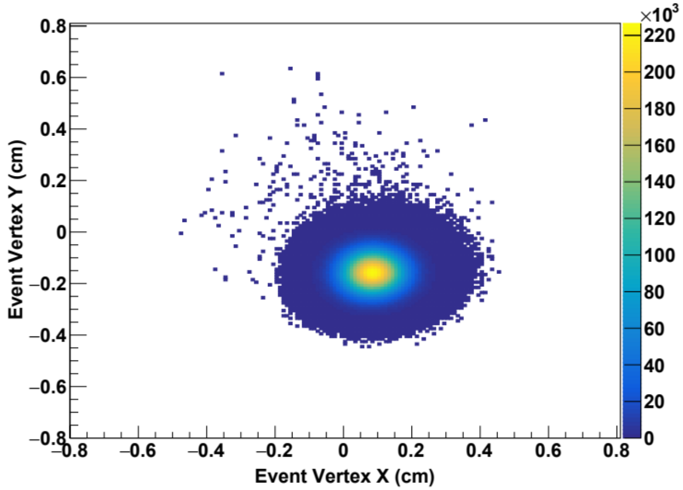
- Data Selection and Quality
- Particle Identification and Yield Extraction
- Corrections to Spectra
- Midrapidity Comparisons to Literature
- Spectra Fits and Particle Ratios
- Baryon Chemical Potential
- Conclusions

Data and Quality Cuts

Data: Au + Au $\sqrt{s_{NN}} = 27\ \mathrm{GeV}$

Detector: Solenoidal Tracker at RHIC

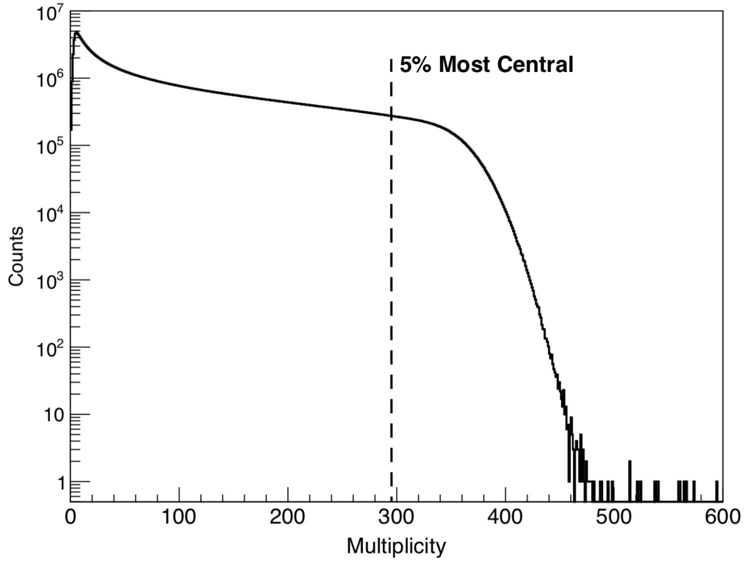
Collected: 13 May - 11 June 2018



Event and Primary Track Cuts

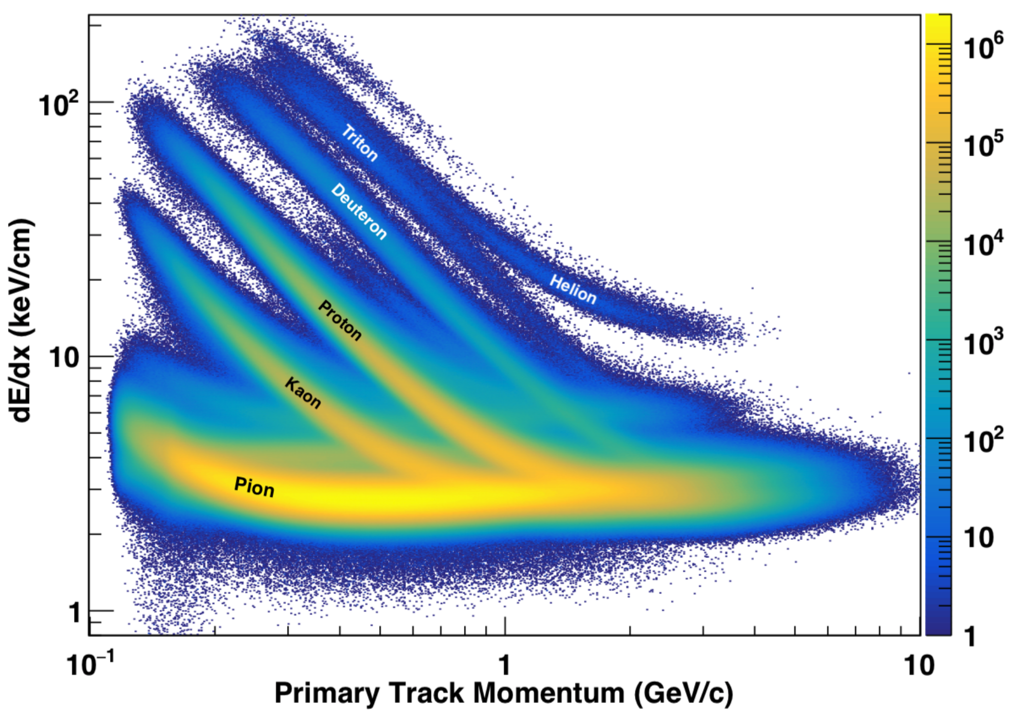
Top 5% Central Collisions

16 Million Events after Cuts

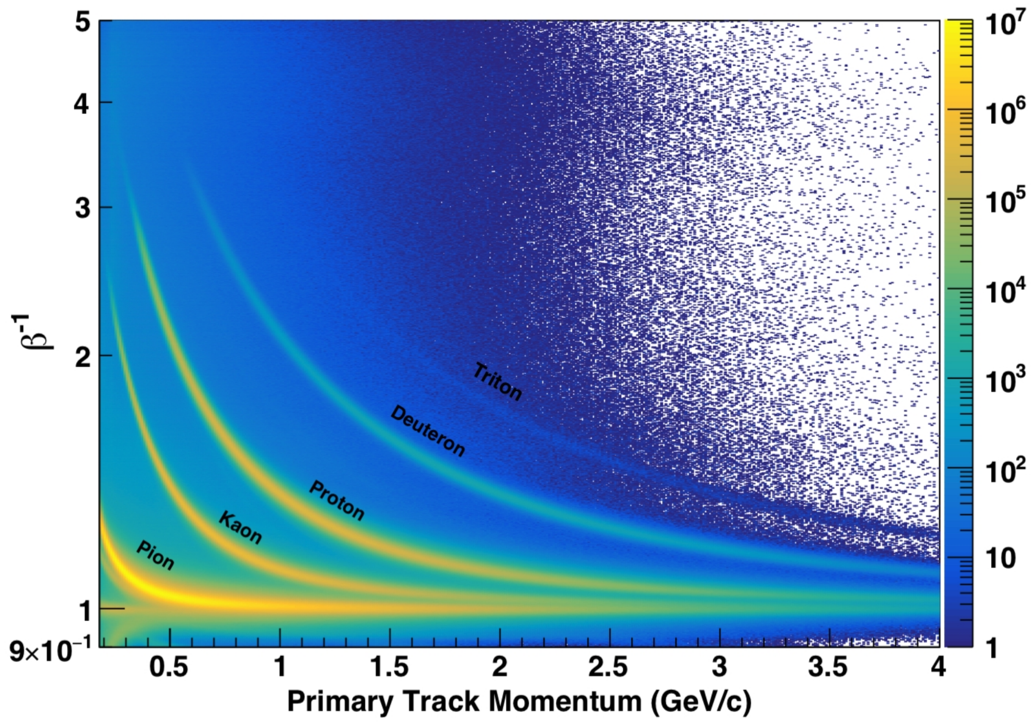


Particle Identification

Energy Loss



Time of Flight



Yield Extraction

- **Rapidity and m_T-m_0 binning**

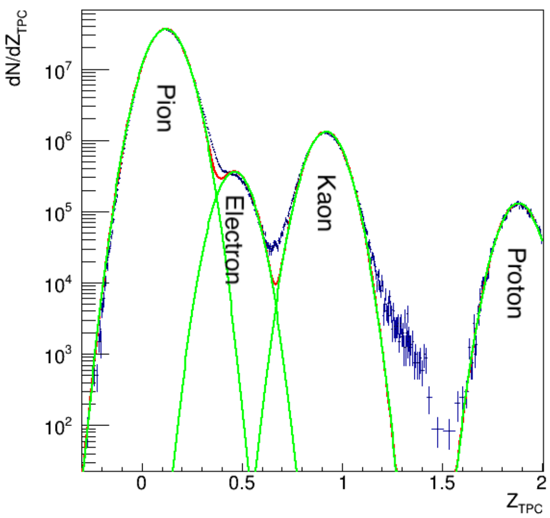
$$m_T^2 = m_0^2 + p_T^2$$

- **Fit Modified dE/dx**

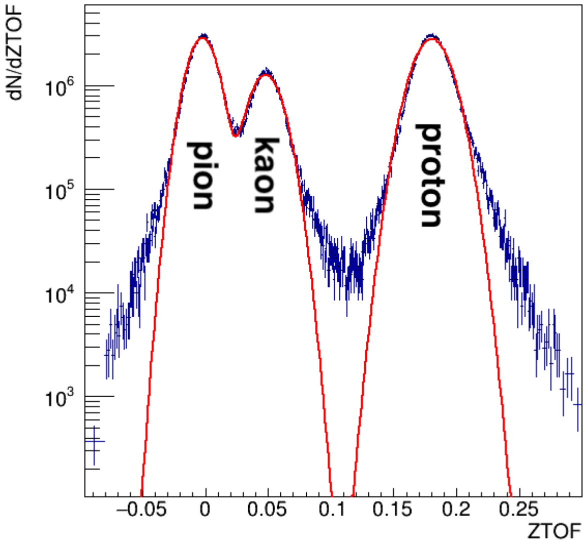
$$Z_{TPC} = \ln\left(\frac{dE/dx_{measured}}{dE/dx_{predicted}}\right)$$

- **Fit Modified Time of Flight**

$$Z_{TOF} = \beta^{-1}_{measured} - \beta^{-1}_{predicted}$$



π^- dE/dx Example Fit
y = [-0.05, 0.05]
m_T-m_0 = [0.25,0.275]



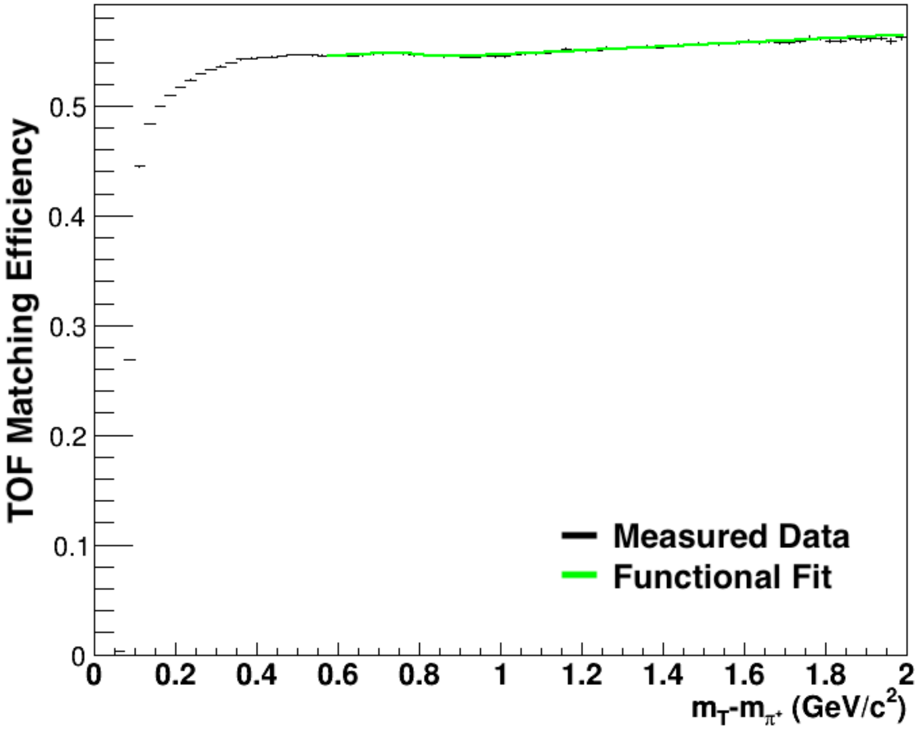
TOF Example Fit
y = [-0.05, 0.05]
m_T-m_0 = [1.325,1.35]

Corrections to Spectra

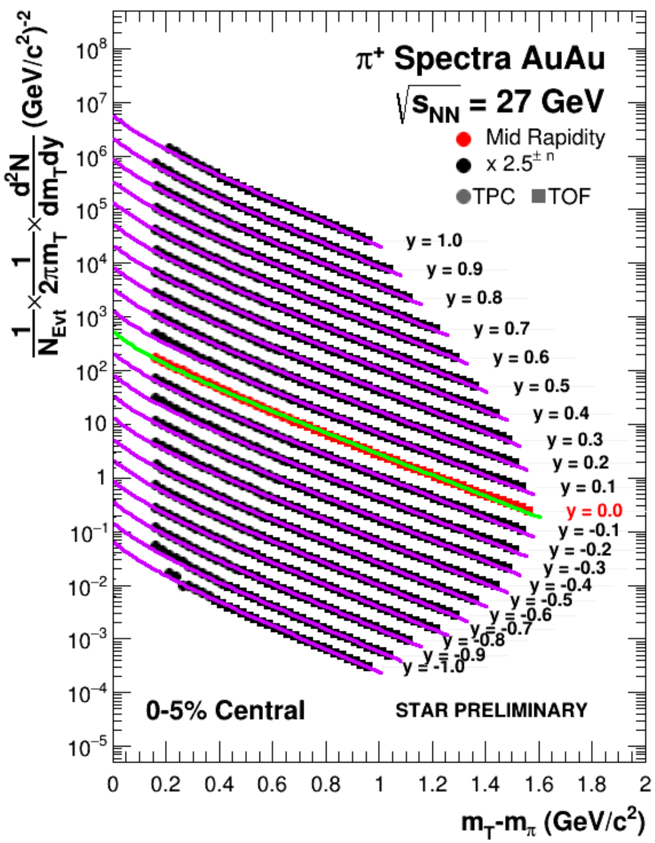
- TOF Matching Efficiency
- TPC Tracking Efficiency
- Energy Loss in TPC
- Knockout Protons
- Muon Contamination

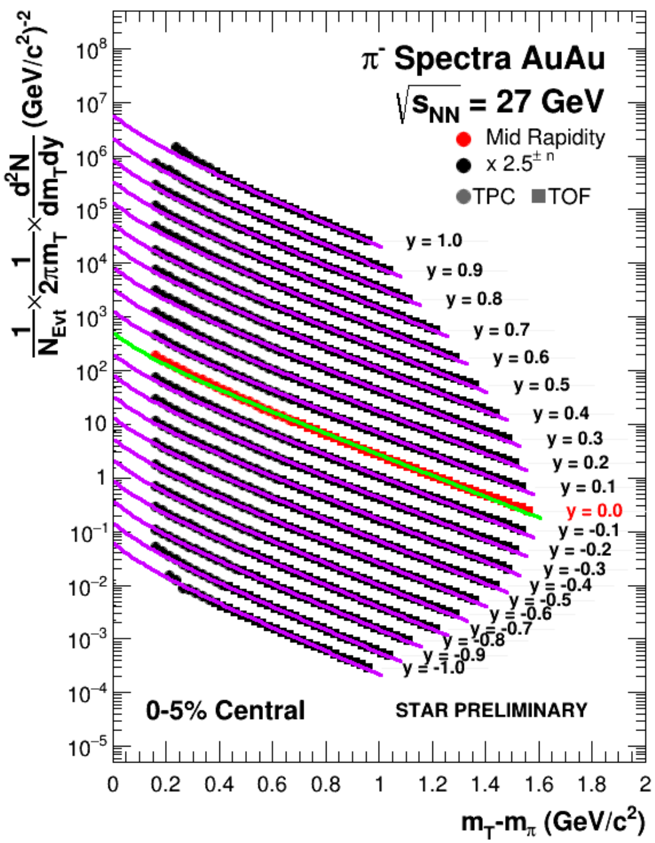
- Feed-Down

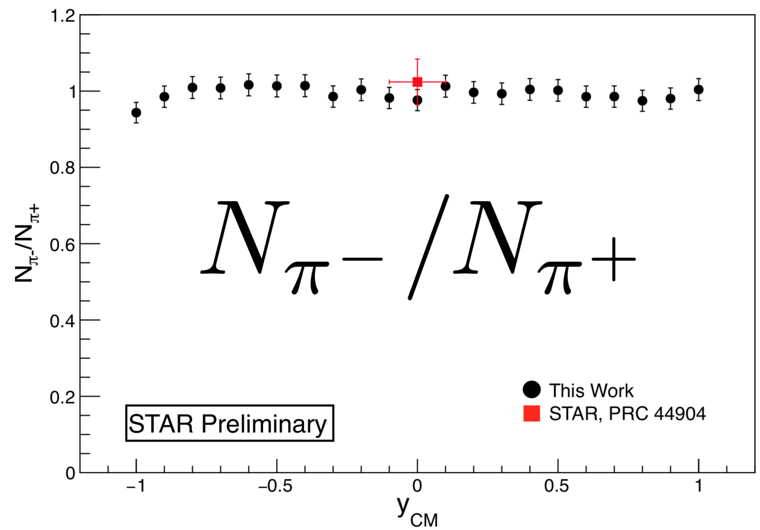
π^+ at Midrapidity



Pion Spectra and Ratio







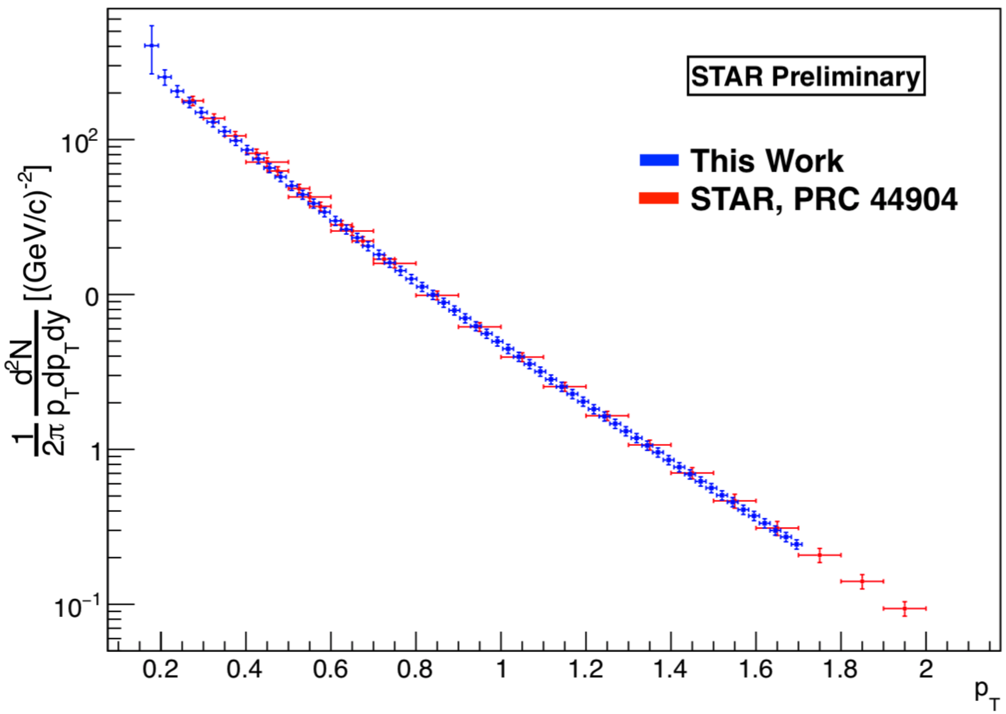
- **Spectra fit over a wide range of rapidities**
- **Pion ratio consistent with published results at mid-rapidity**

Fit Function: Bose-Einstein

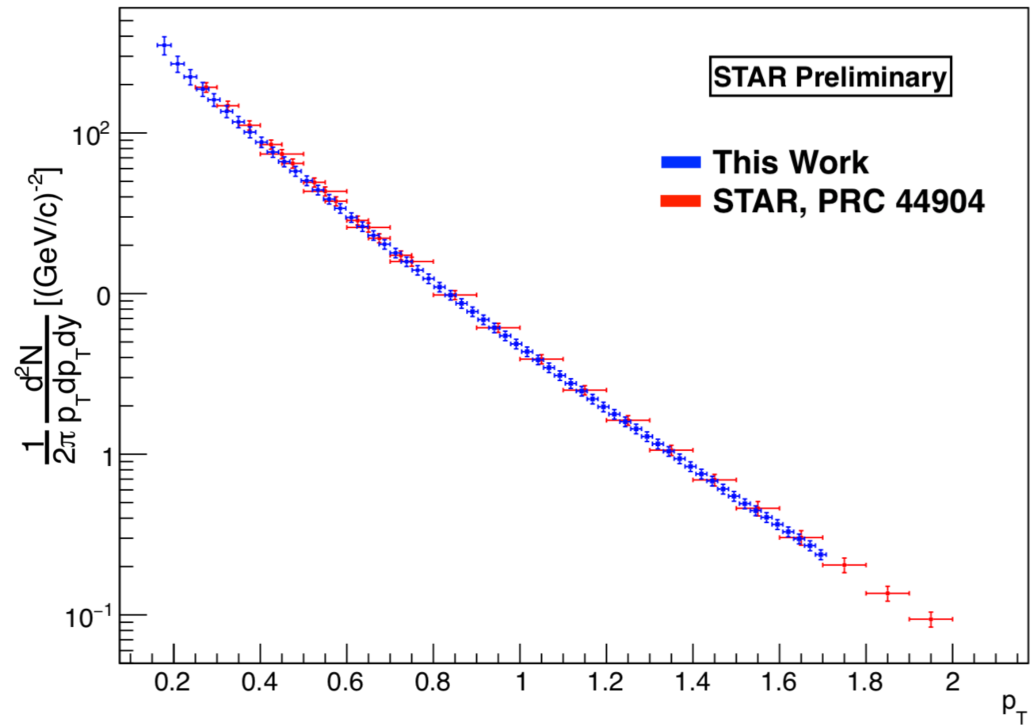
$$f_{\mathrm{BE}}(m_T - m_0) = A\frac{1}{\exp(m_T/T) - 1}$$

Comparison to Published Data

π^+ at Midrapidity

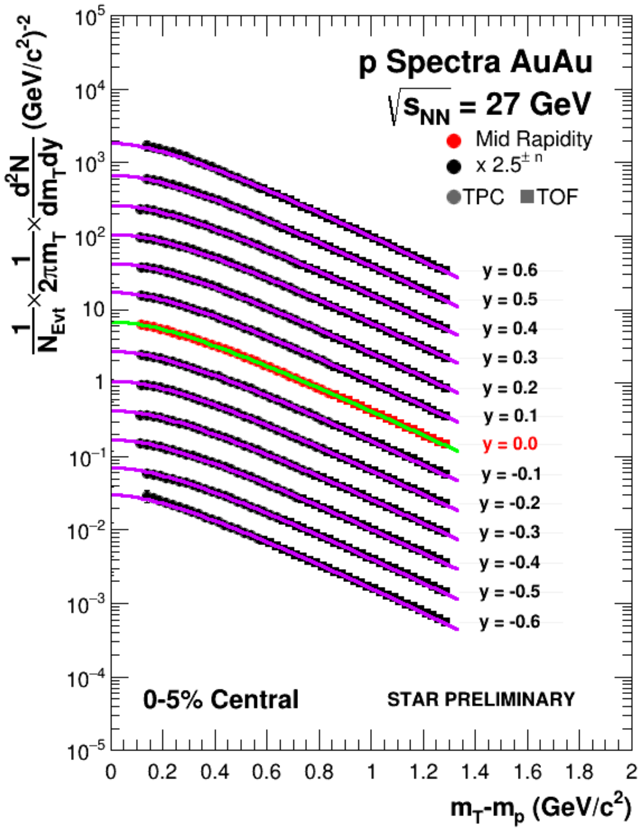


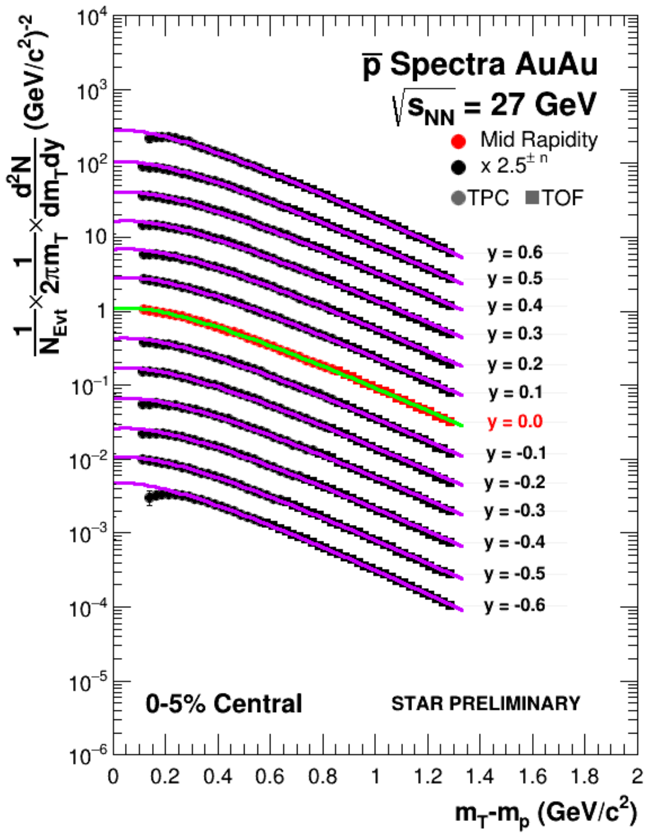
π^- at Midrapidity

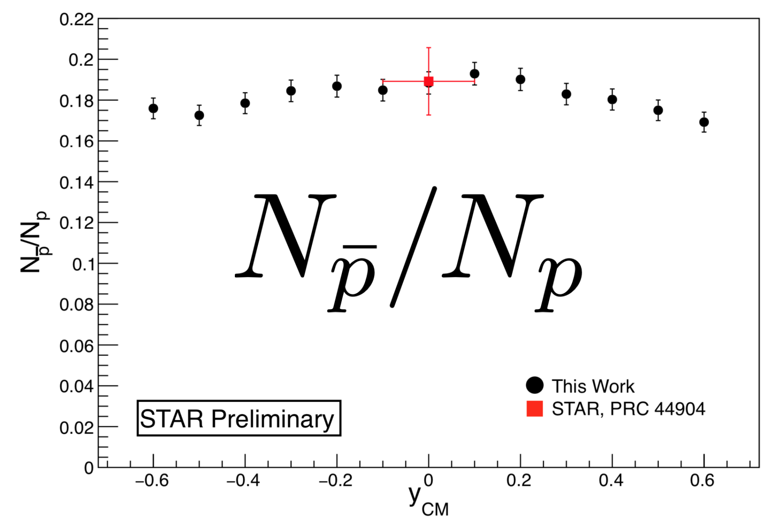


- **Pion mid-rapidity spectra are consistent with published data**

Proton Transverse Mass Spectra







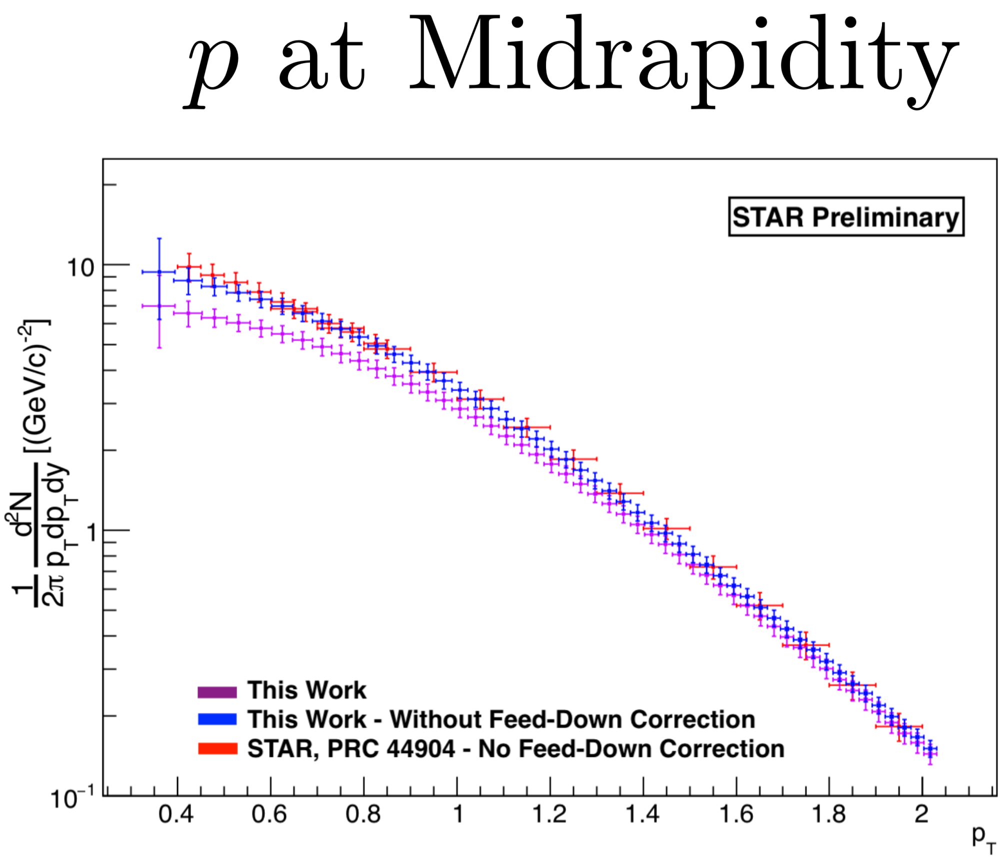
Fit Function: Blast Wave Model [Schnedermann, et al. PRC 48]

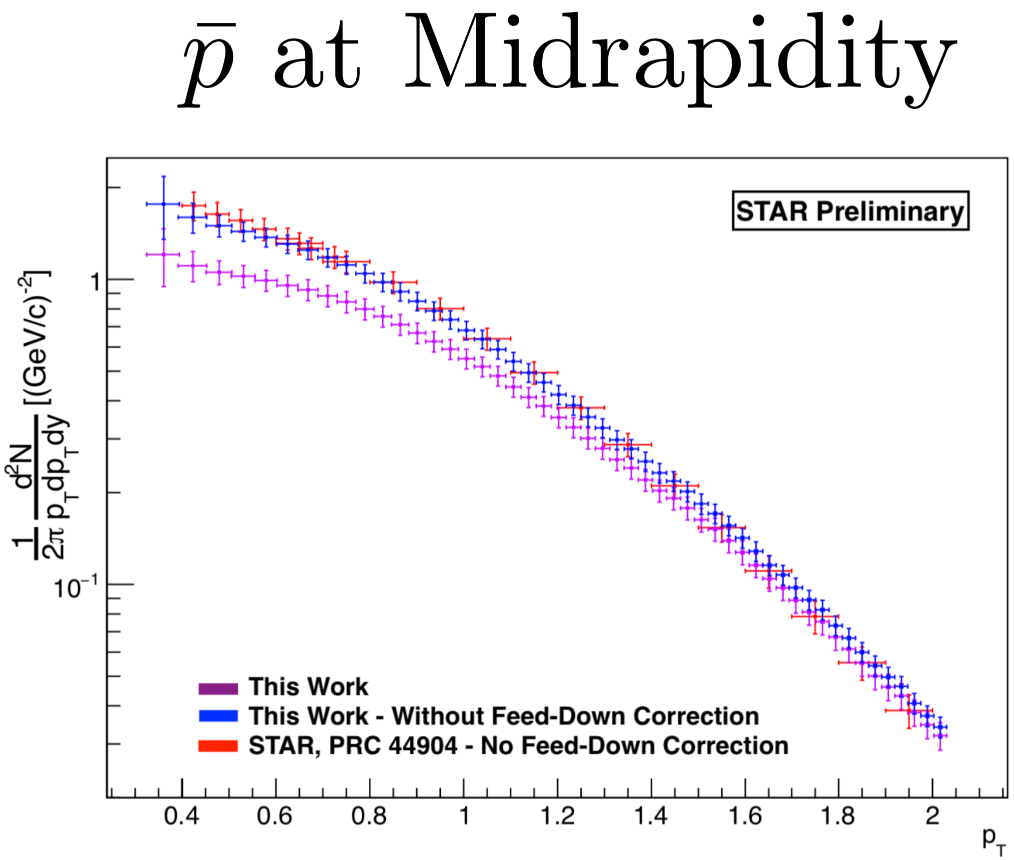
$$\frac{d^2N}{m_T dm_T dy} = A\int_0^R r\,dr\,m_T \times I_0\left(\frac{p_T \sinh\rho(r)}{T_{Kin}}\right) K_1\left(\frac{m_T \cosh\rho(r)}{T_{kin}}\right)$$

T_{kin} : temperature at kinetic freeze-out

- **Spectra fit over a wide range of rapidities**
- **Proton ratio consistent with published results at mid-rapidity**

Comparison to Published Data





- **Proton midrapidity spectra are consistent with published data**
- **Addition feed-down corrections applied**

From Proton Ratios to the Baryon Chemical Potential

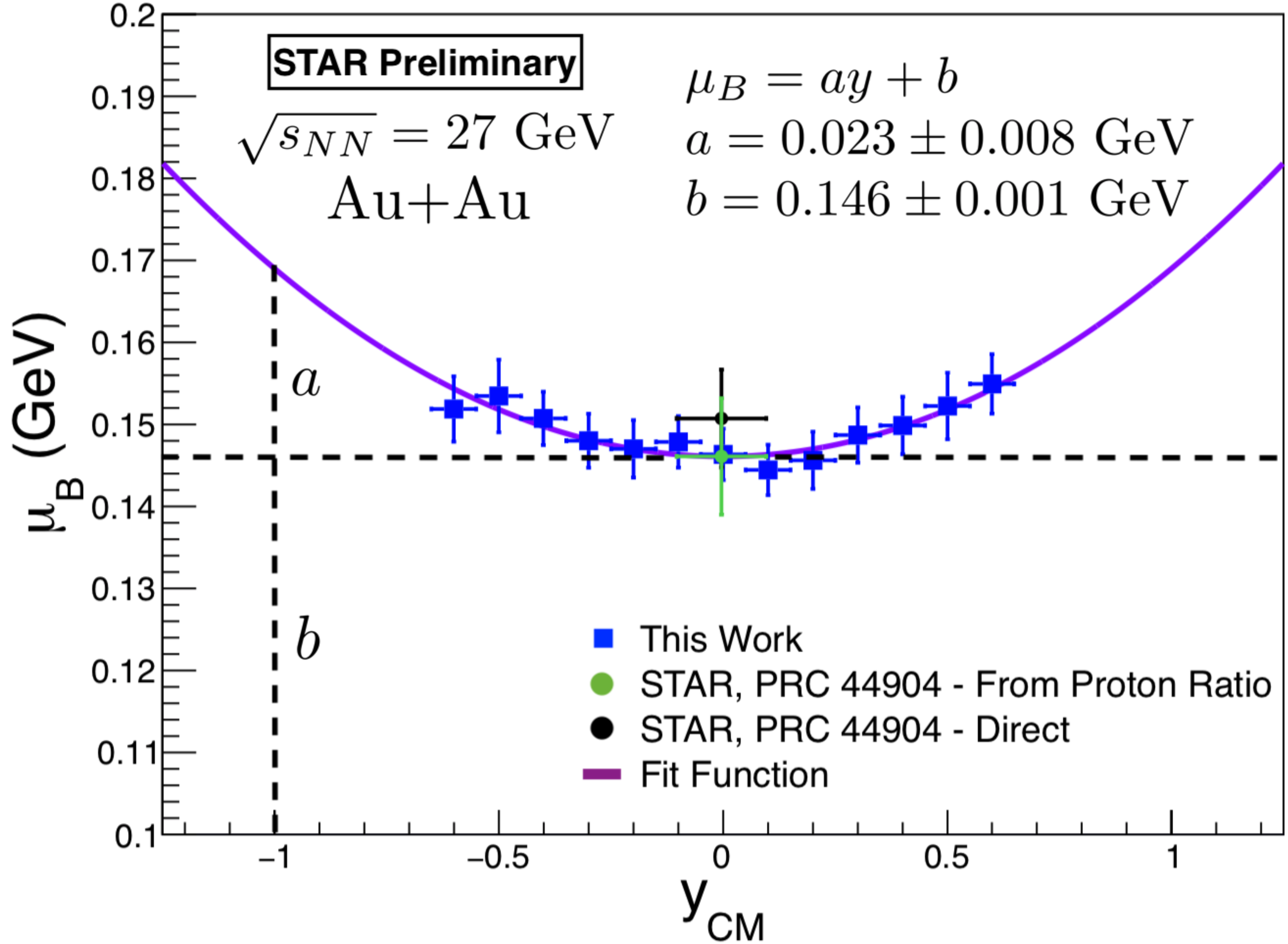
$$\frac{N_{\bar{p}}}{N_p} = e^{-\frac{2\left(\mu_B + \mu_Q\right)}{T_{ch}}}$$

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

$$T_{ch} = 159.9 \pm 2.1 \text{ MeV}$$
$$\mu_Q = -12.9 \text{ MeV}$$

- **Statistical equilibrium model**
- **T_{ch}: fixed chemical temperature**
  - Average of Grand Canonical Ensemble and Strange Canonical Ensemble Results [STAR, PRC 44904 (2017)]
- **μ_Q: fixed charge chemical potential**
  - Model prediction using T_{ch} above [Mekjian, Phys Lett B. 651 (1993)]
- **Antiproton to proton ratio is Gaussian, so μ_B is quadratic in y**

Baryon Chemical Potential



Conclusions

- **BES-II is collecting high statistics data sets**
- **Light particle spectra consistent with published data at midrapidity**
- **Extended range beyond mid-rapidity**
- **Exhibited rapidity dependence of the baryon chemical potential**

References

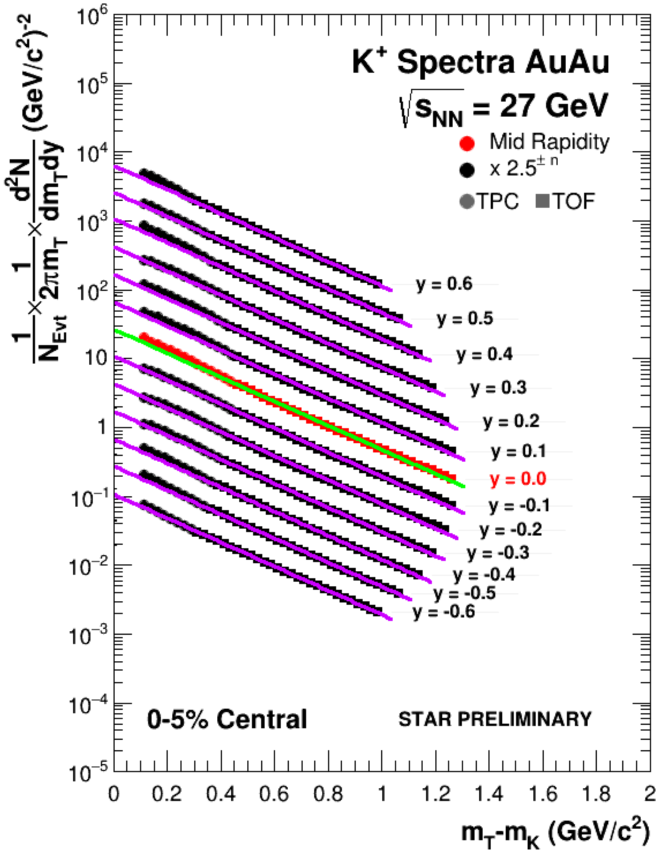
[1] STAR, "Bulk Properties of the Medium Produced in Relativistic Heavy-Ion Collisions from the Beam Energy Scan Program" Phys. Rev. C 96 44904 (2017)

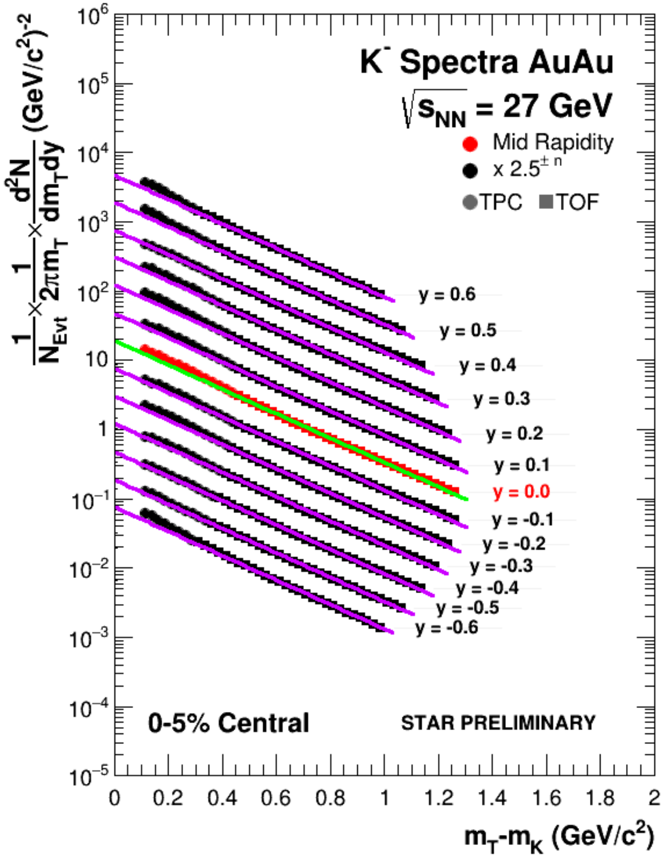
[2] Schnedermann, Sollfrank, and Heinz. "Thermal phenomenology of hadrons from 200A GeV S+S collisions". Phys. Rev. C 48 p2462-2475 (1993)

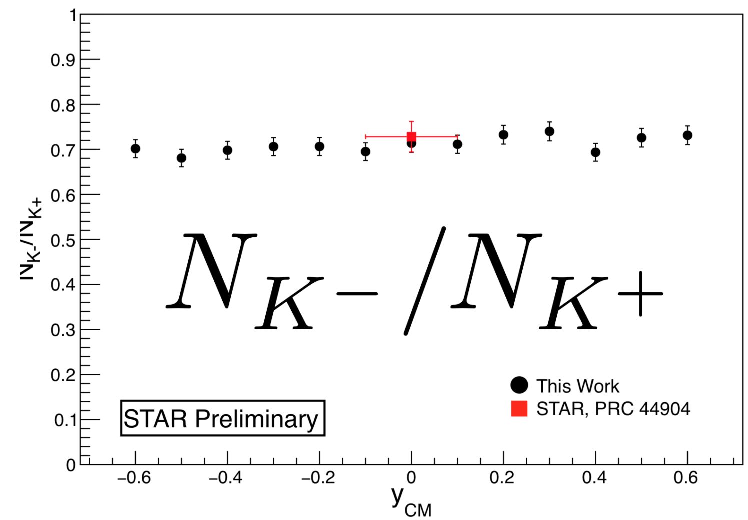
[3] Mekjian, Aram. "Properties of baryonic, electric and strangeness chemical potentials" Phys. Lett. B 651 p33-38 (2007)

Backup Slides

Kaon Spectra and Ratio





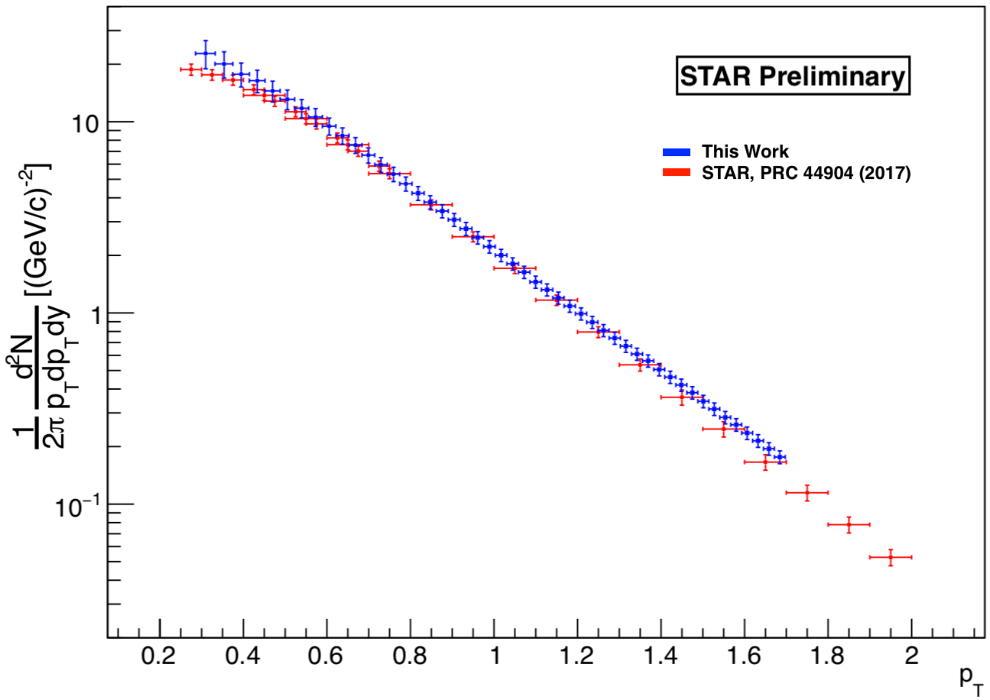


$$f_{m_T}(m_T - m_0) = A\frac{1}{\exp((m_T - m_0)/T)}$$

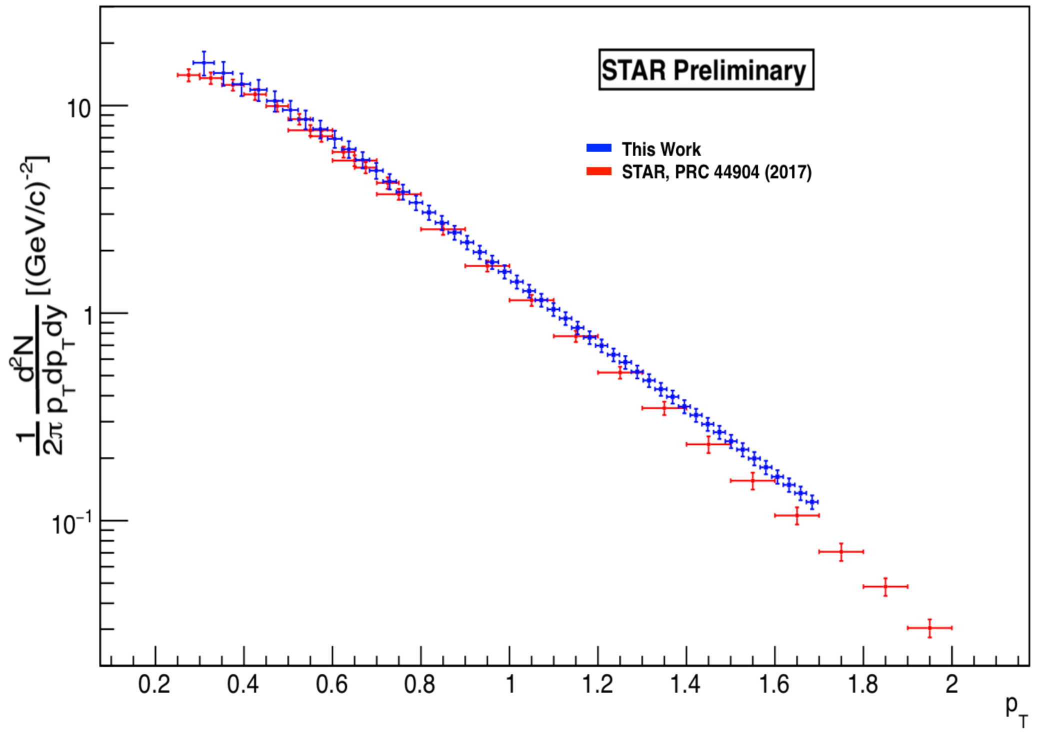
- **Spectra fit over a wide range of rapidities**
- **Kaon ratio consistent with published results at mid-rapidity**

Mid-Rapidity Comparison to Literature

Kaon Plus at Mid-Rapidity

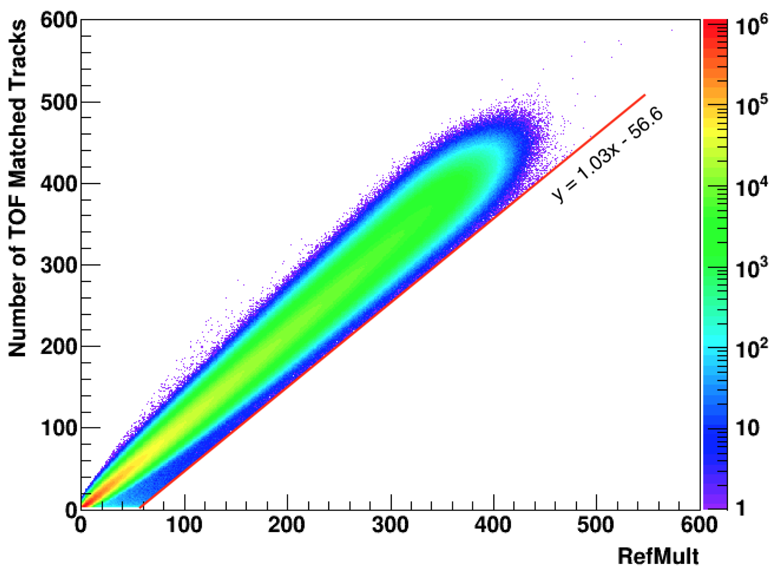


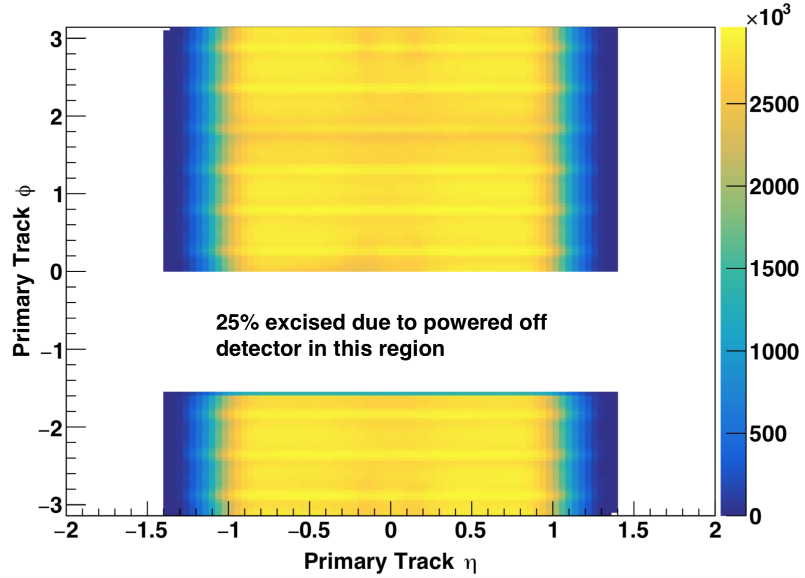
Kaon Minus at Mid-Rapidity

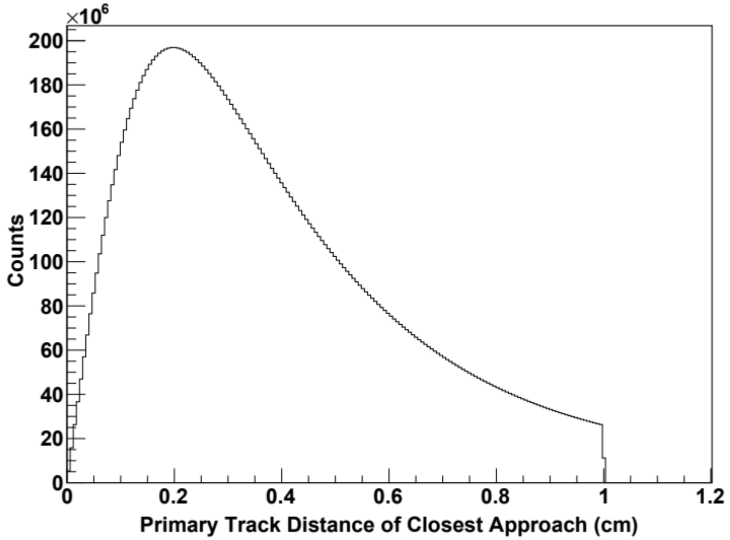


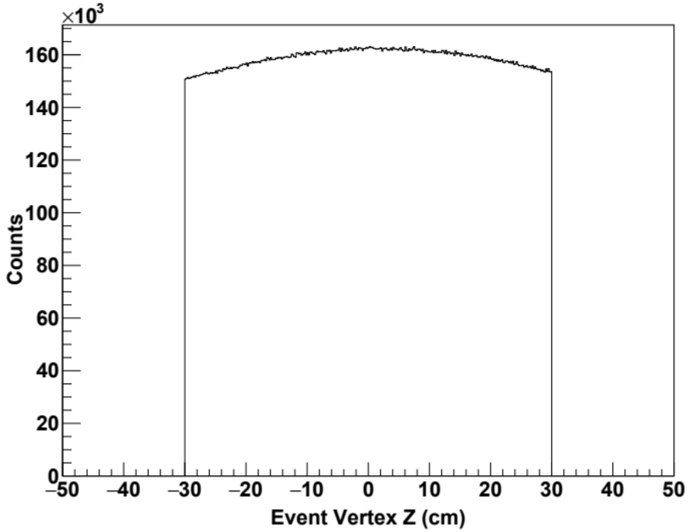
- **Kaon mid-rapidity spectra are consistent with published data**

Detailed Event and Track Cuts









Detailed Event and Track Cuts

Event Cuts:

V_z = [-30cm, 30cm]

V_r < 2cm

bTOF-matched tracks > 3

Minimum-bias trigger ID

RefMult > 295

Track Cuts:

NHitsFit >= 15

NHitsDeDx >= 10

NHitsFit/NHitsMax >= 0.52

gDCA < 1.0 cm

Phi = [-π,-π/2] and [0,π]

bTOF yLocal = [-1.6 , 1.6cm]

bTOF zLocal = [-2.8 , 2.8cm]