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Sixth Joint Meeting of the Nuclear Physics Divisions of the APS and JPS
Supported in part by:

Rapidity Dependent Production of $\pi^{\pm}$, $K^{\pm}$, p, & $\bar{p}$ in BES-II Au+Au Collisions at STAR

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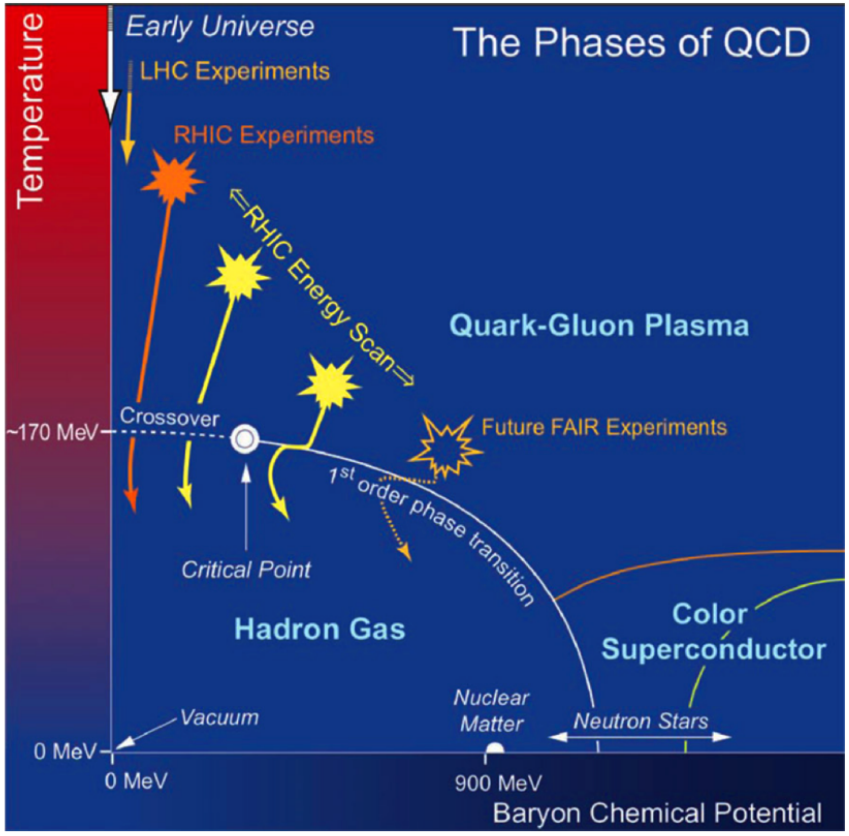
For the STAR Collaboration
DNP 2023 (Waikōloa Village, HI)

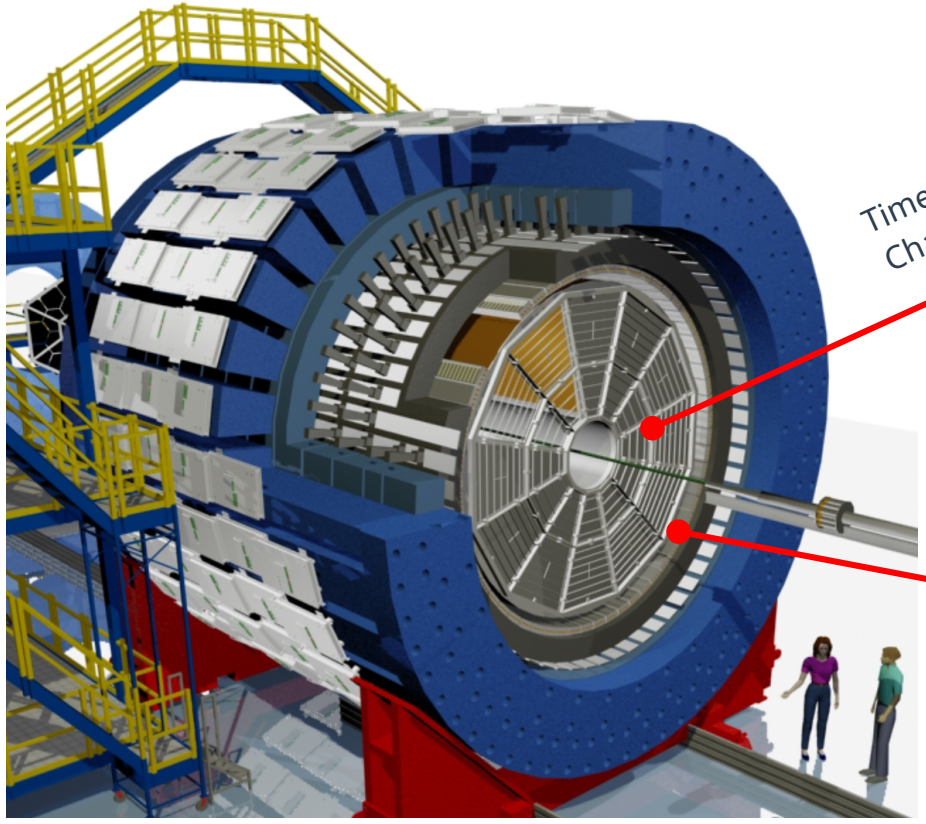
Why Measure Light Hadrons?

- Measure **$\pi^{\pm}$, $K^{\pm}$, p**, & **$\bar{p}$** across p_T and rapidity
  - Chemical Freeze-out
  - Rapidity Dependence of Chemical Potentials (μ_B & μ_S)
  - Updated Feed-Down Estimation for Protons
- Beam Energy Scan II (BES-II)
  - Collider: $\sqrt{s_{NN}}$ = 7.7, 9.2, 11.5, **14.6**, 17.3, **19.6**, **27** GeV
  - FXT: $\sqrt{s_{NN}}$ = 7.7, 9.2, 11.5, 13.7, 3.0, 3.2, 3.5, 3.9, 4.5, 5.2, 6.2, 7.2 GeV
  - Extend BES-I Results Beyond Mid-Rapidity
  - Where are we on the QCD phase diagram at chemical freeze-out & how does that change with rapidity?



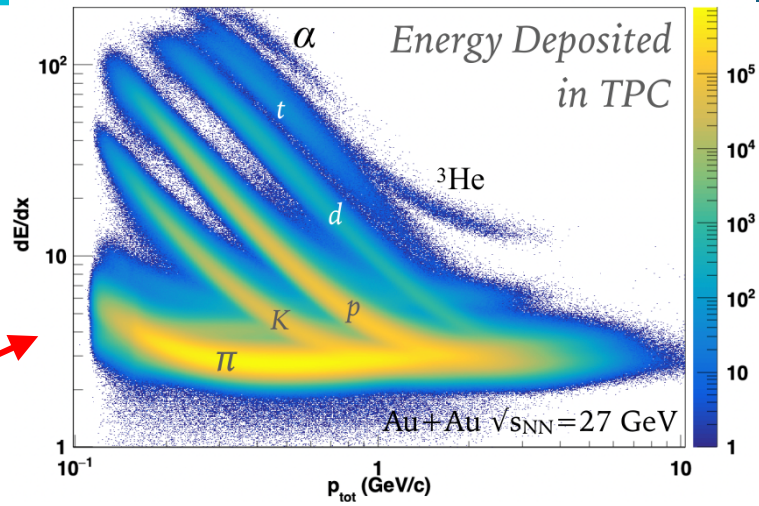
Particle Identification in STAR

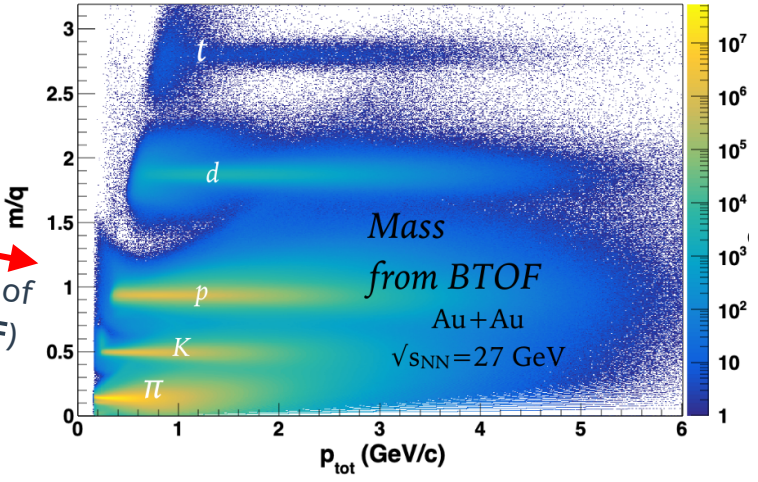
Solenoidal Tracker At RHIC (STAR)



Time Projection Chamber (**TPC**)

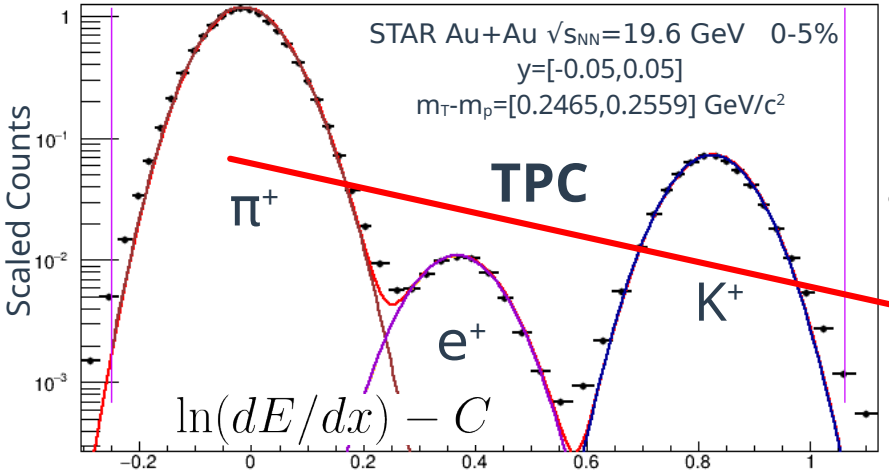
Barrel Time of Flight (**BTOF**)

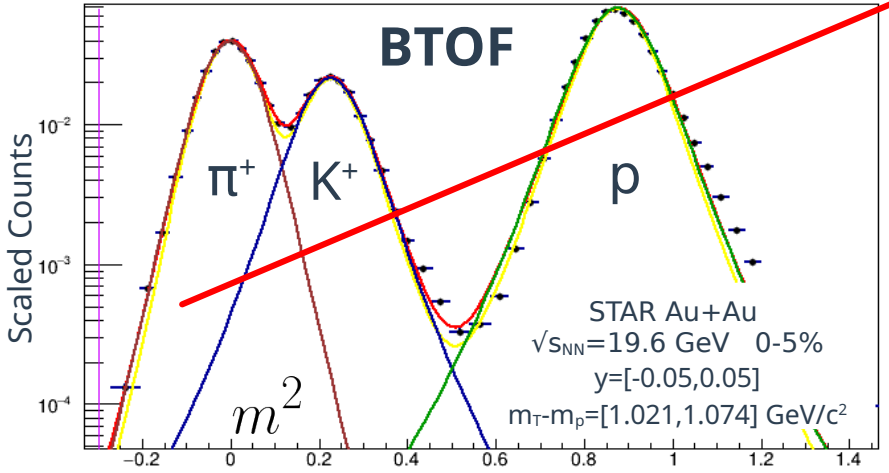


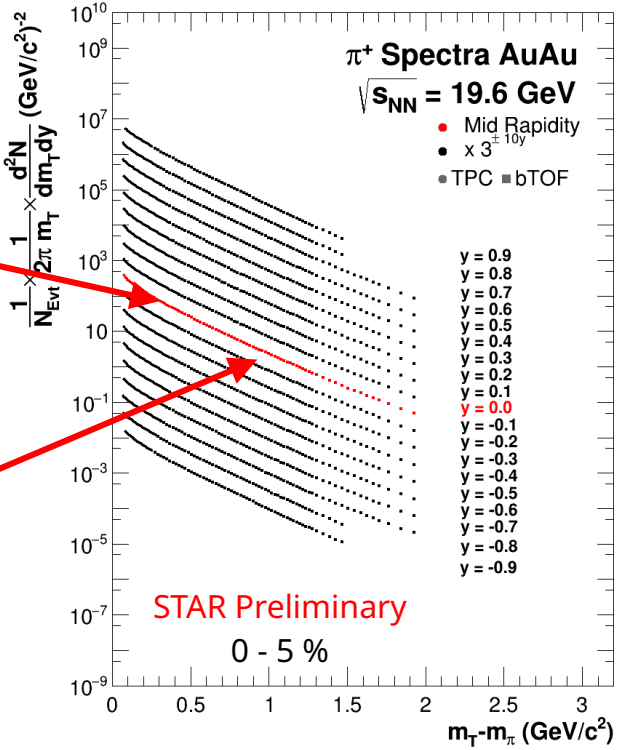


Yield Extraction

- Gaussian Fits of ln(dE/dx) from TPC
- Student-T Fits of m^2 from BTOF

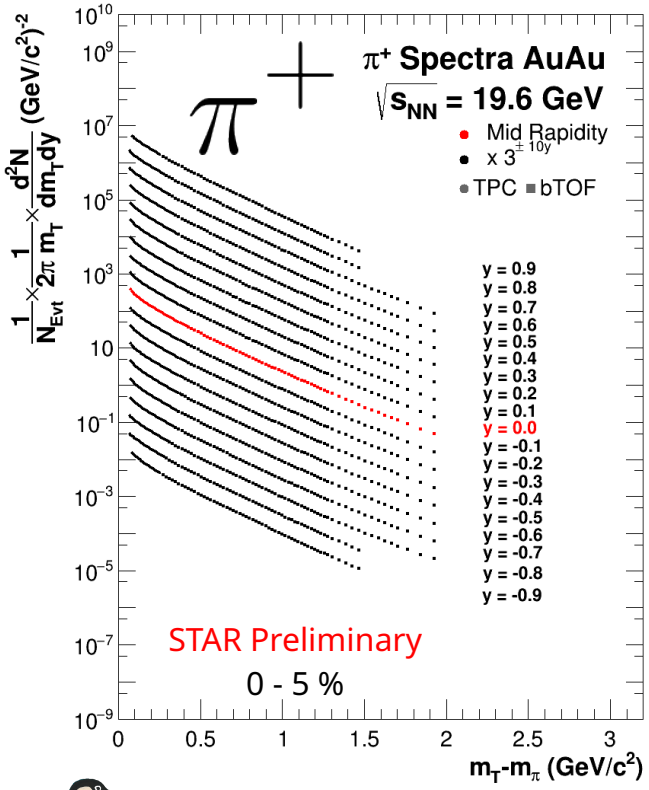


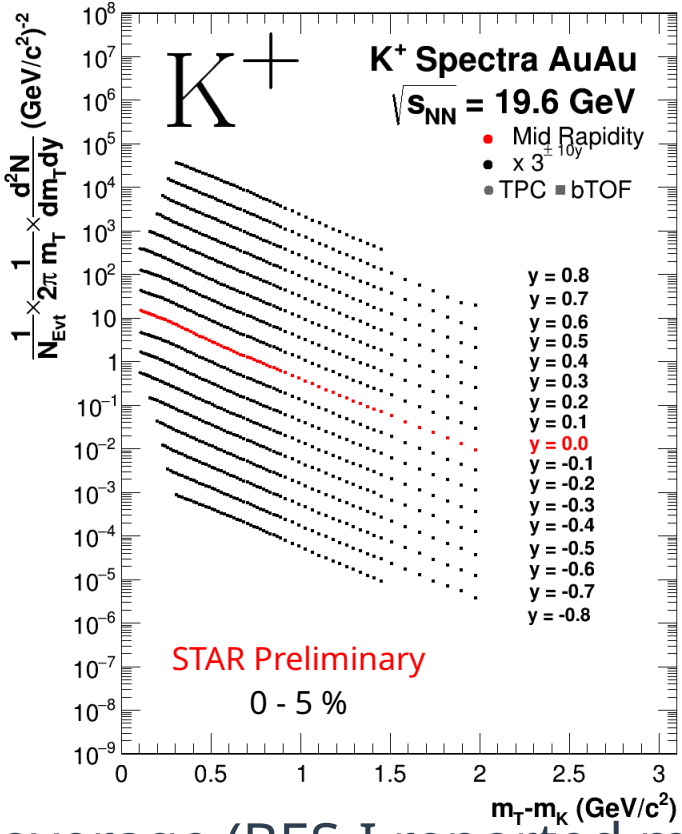


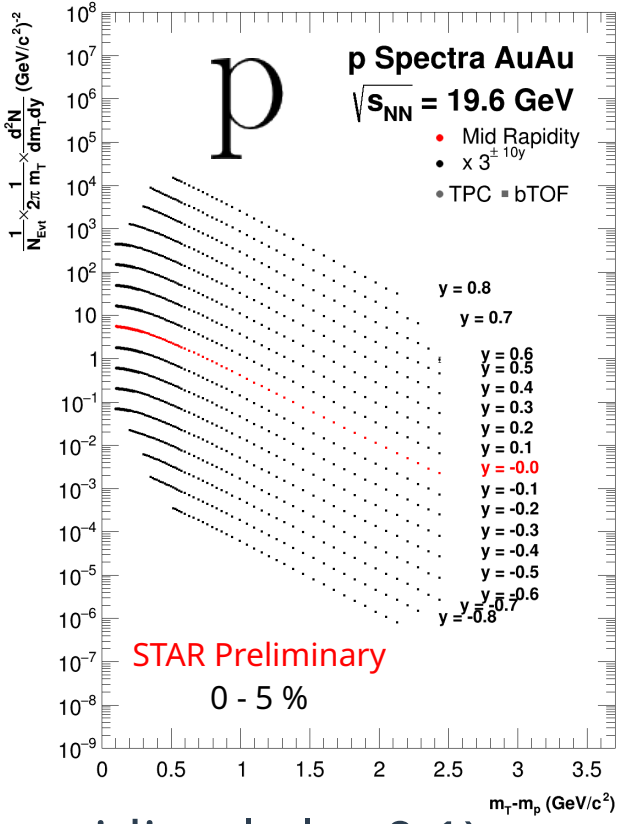


$$m_T - m = \sqrt{p_T^2 + m^2} - m$$

Rapidity Dependent Spectra



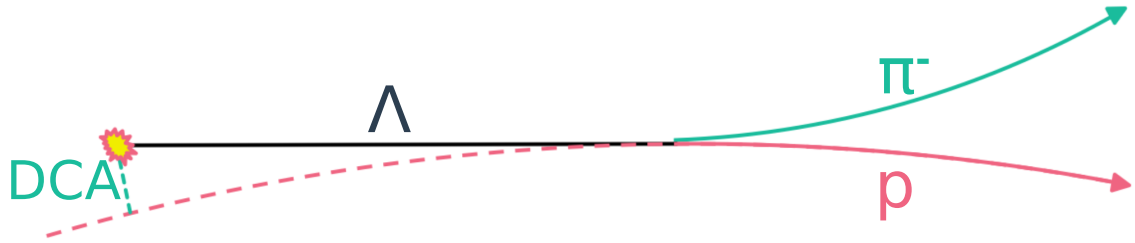


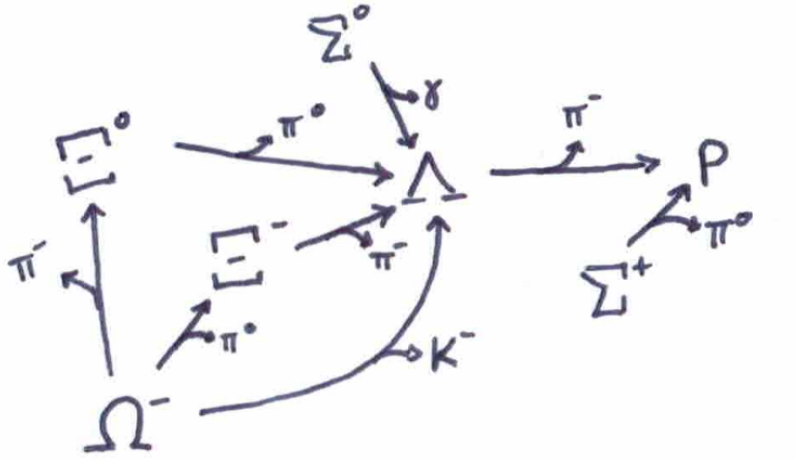


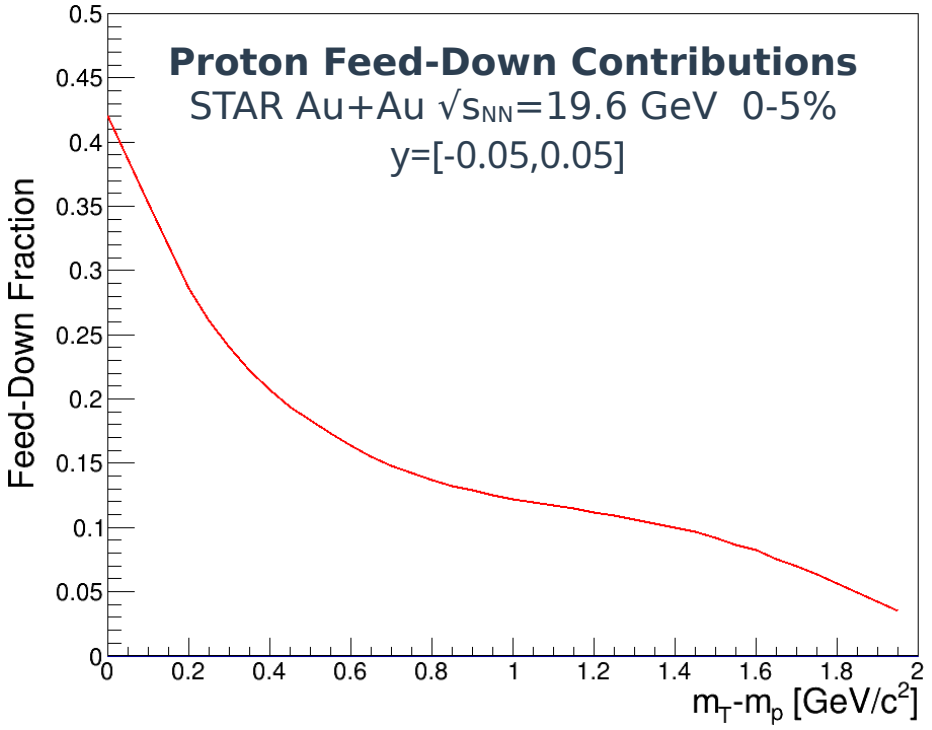
- Wide Rapidity Coverage (BES-I reported mid-rapidity, $|y| < 0.1$)
- Spectra fit at low & high m_T-m_0 to extract dN/dy

Feed-Down Corrections to the Proton Spectra

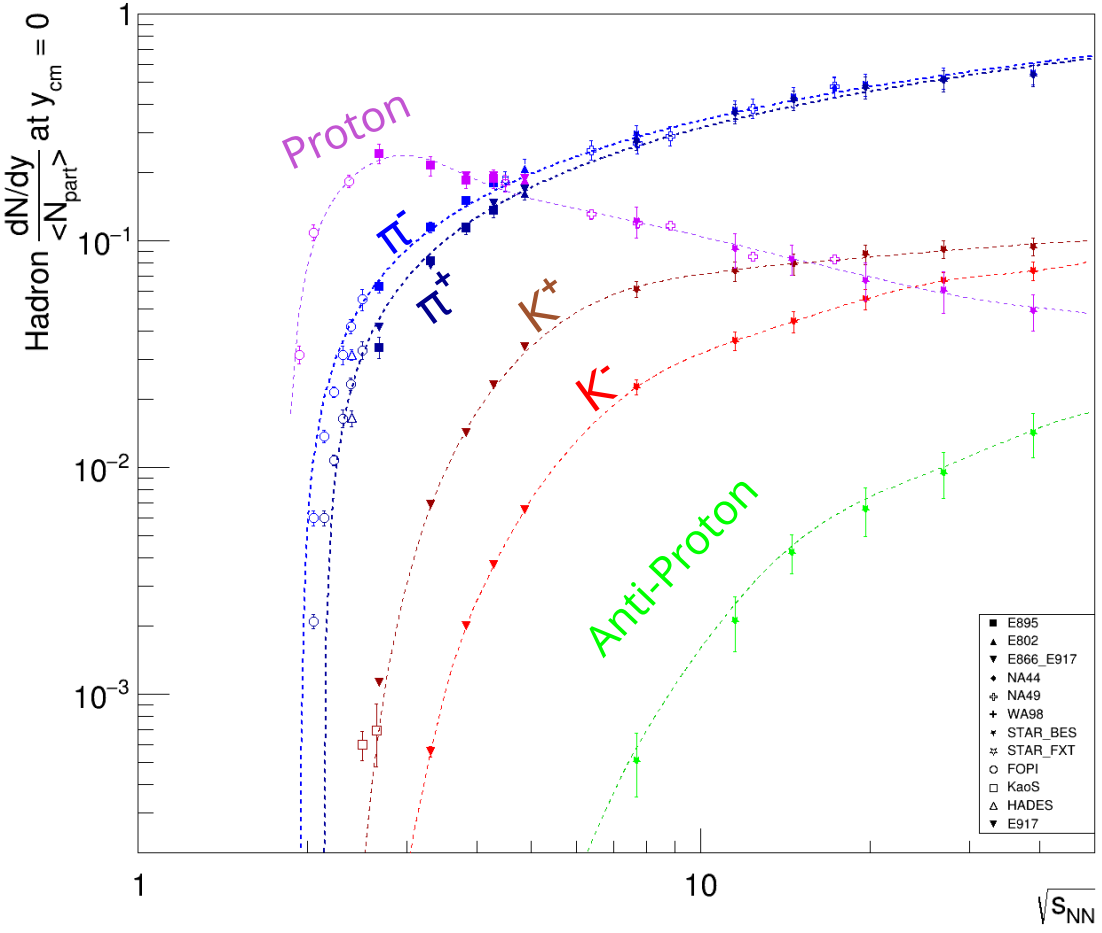
- Improvement on BES-I (not feed-down corrected)
- Decays of weak hyperons to protons, extrapolated back to vertex
- Mixture of measurement and model to estimate rapidity dependence
- 15% for protons at y = 0, $\sqrt{s_{NN}}$ = 19.6 GeV







Mid-Rapidity Production of Hadrons in Central Heavy-Ion Collisions



- π^+ π^- separation at low $\sqrt{s_{NN}}$ due to Δ resonance
  - Neutron rich initial conditions
- Previous STAR proton yields $\sqrt{s_{NN}}$ = [7.7, 27] GeV were not feed-down corrected
- Necessary to feed-down correct the protons

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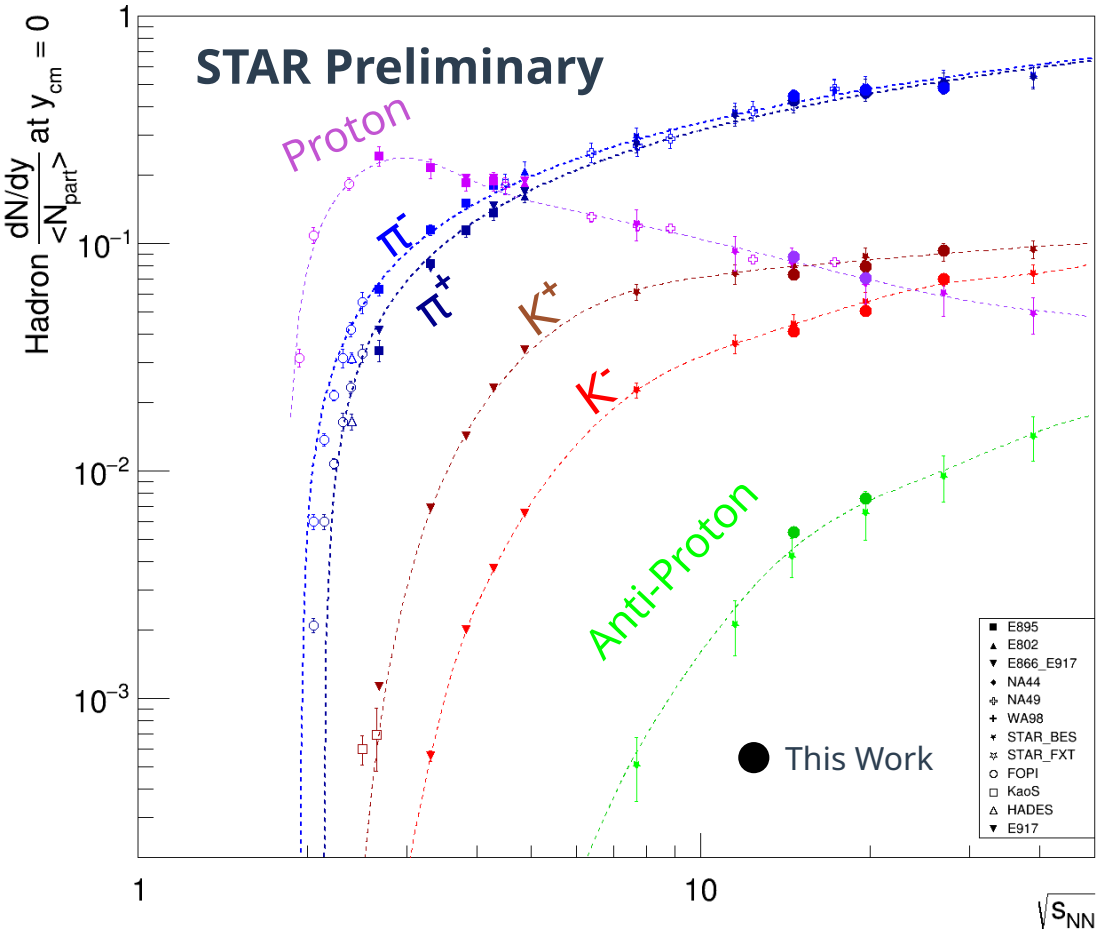

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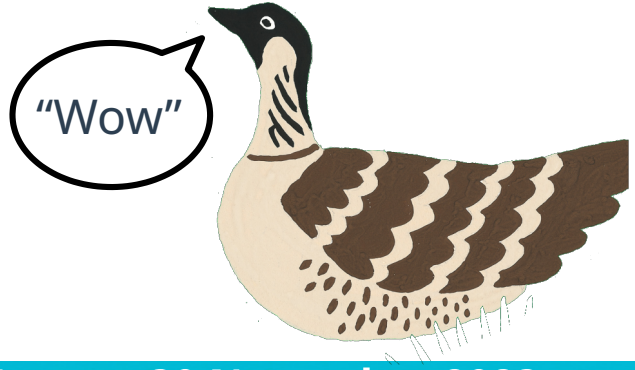
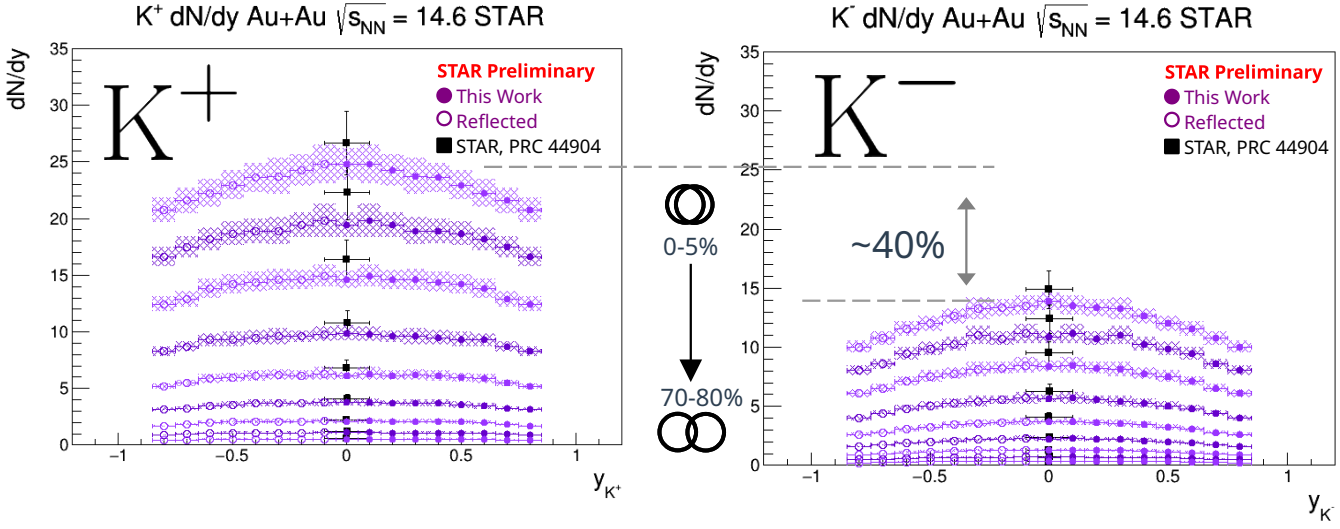


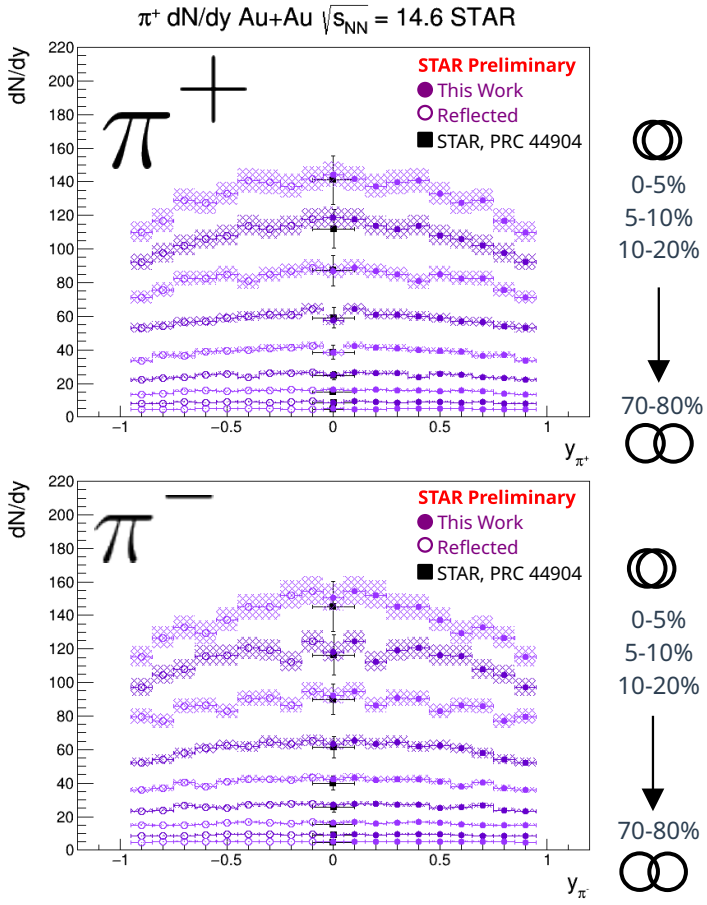
Rapidity Density Distributions @ $\sqrt{s_{NN}}$=14.6 GeV

- Associated K+ production

$$p + N \rightarrow \Lambda + K^+ + N$$
$$uud \qquad uds \quad u\bar{s}$$

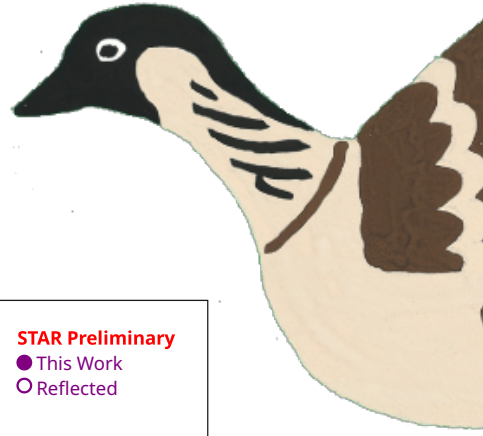
- Kaon Ratio related to μ_S

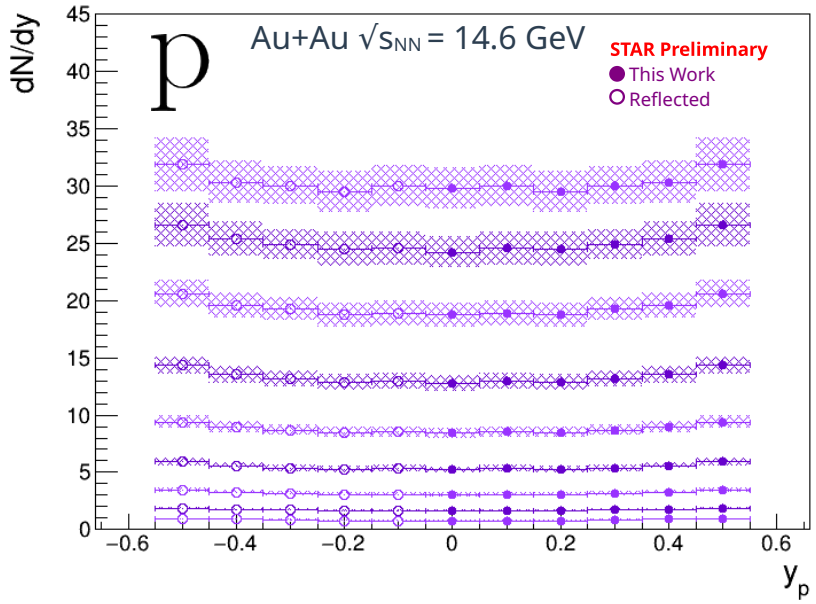


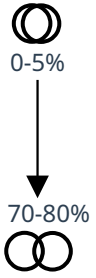


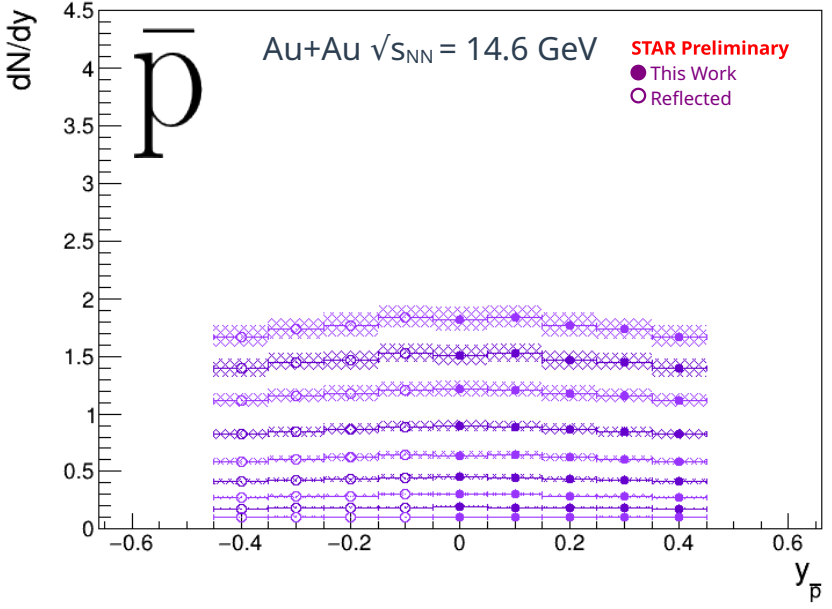
Rapidity Density Distributions @ $\sqrt{s_{NN}}$=14.6 GeV

- **Participant protons slowed toward mid-rapidity**
  - Interactions with medium
  - y_{beam} = 2.75 (14.6 GeV)
- **Proton ratio relates to μ_B**



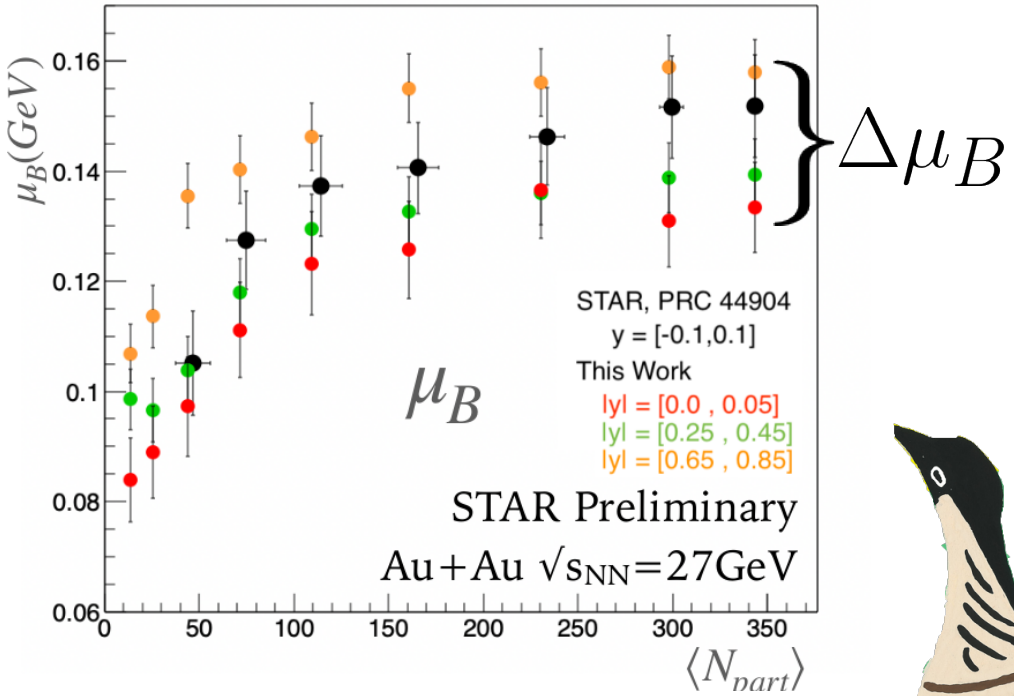




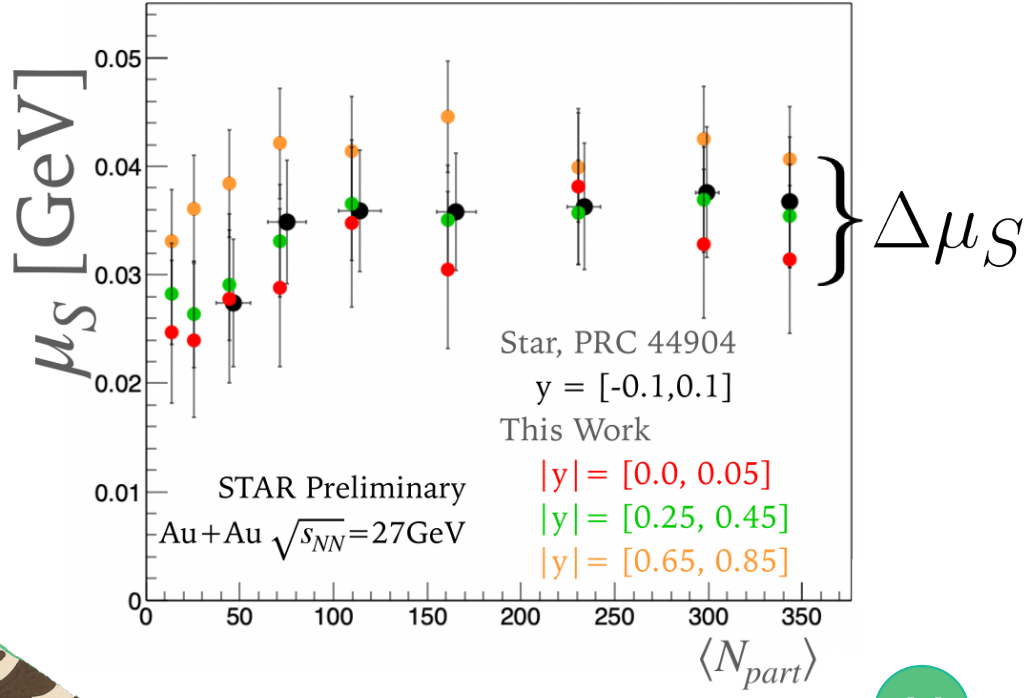


Chemical Freeze-Out (THERMUS) at 27 GeV

- Chemical Equilibrium Model (GCE)
- **$\Delta\mu_B \sim 25$ MeV for $\Delta y = 1$**



- Strangeness Distillation ($\mu_S \neq 0$)
- **$\Delta\mu_S \sim 10$ MeV for $\Delta y = 1$**
- New results were feed-down corrected, while the previous results were not



Conclusions

- **dN/dy of $\pi^{\pm}$, $K^{\pm}$, p, & $\bar{p}$ with p_T spectra**
  - $\sqrt{s_{NN}}$ = 14.6, 19.6, & 27 GeV
  - Extended Rapidity Measurements
  - Improved Feed-Down Estimation
  - Baryon and Strangeness Chemical Potentials ($\sqrt{s_{NN}}$ =27 GeV)
    - $\Delta\mu_B \sim 25$ MeV for $\Delta y = 1$ (baryon stopping)
    - $\Delta\mu_S \sim 10$ MeV for $\Delta y = 1$ (associated production)

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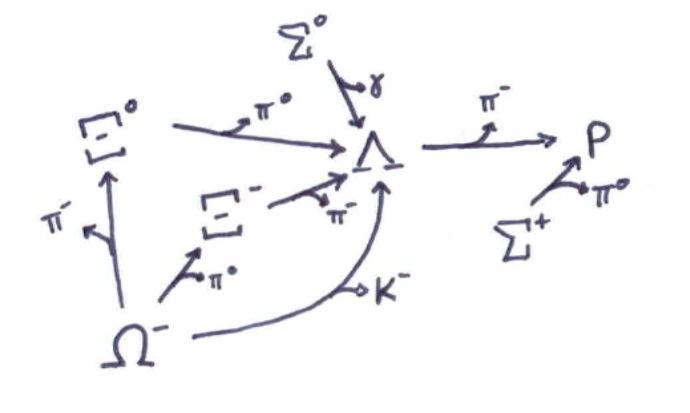
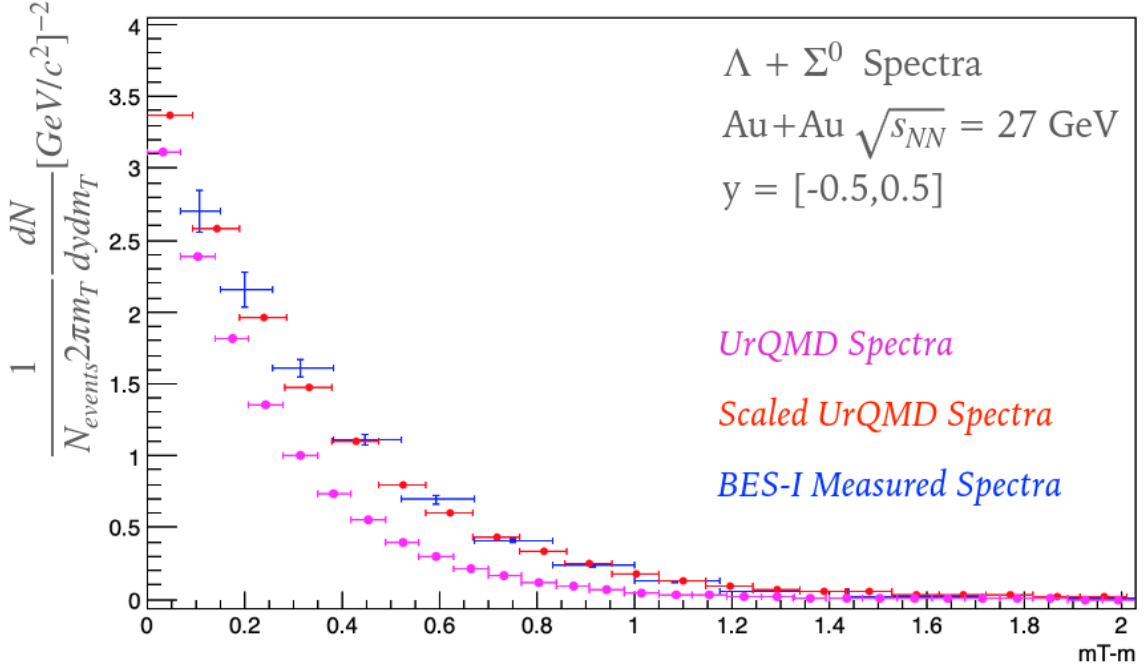
HYBRID FEED-DOWN METHOD





- Scale UrQMD strange spectra to mid-rapidity BES measurements
  - Many analyses need rapidity dependence and BES-I published mid-rapidity strangeness only
  - No measured coverage at low p_T
  - Scale and stretch parameters determined by χ^2 minimization
    - Scale : $d^2N/dm_T dy \rightarrow a \cdot d^2N/dm_T dy$
    - Stretch : $m_T - m_0 \rightarrow b \cdot (m_T - m_0)$
  - Ξ^- and Ξ^0 spectra assumed identical (Ξ^0 not measured)
  - Σ^+/Λ ratio conserved (Σ^+ not measured)

- Strange hadron production in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 11.5, 19.6, 27, and 39 GeV. *Phys. Rev. C 102 34909 (2020)*
  - Ξ^- and Ξ^0 decays into Λ were corrected by data-driven feed-down (23% at low p_T) assuming uncorrelated uncertainties.
  - Σ^0 considered prompt (included in Λ) and Ω^- considered insignificant to Λ production