Meson Production in Au+Au Collisions at $\sqrt{s_{NN}} = 3.0$ GeV at STAR

Benjamin Kimelman (For the STAR Collaboration)

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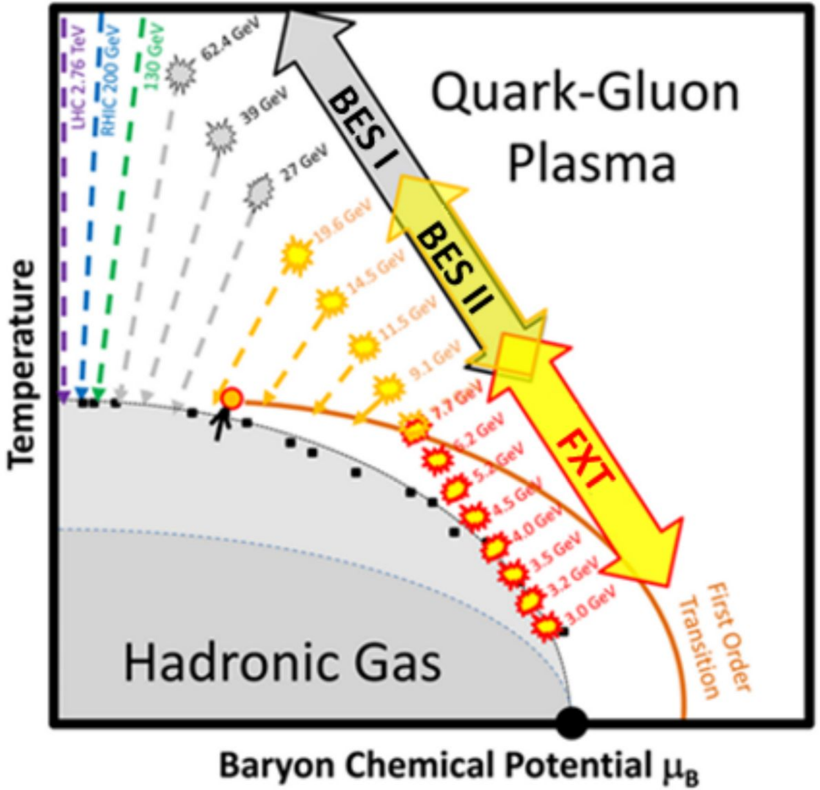
Motivation

- Study QCD phase diagram and properties of QCD matter
- Determine location on QCD phase diagram
- Understand different particle production mechanisms



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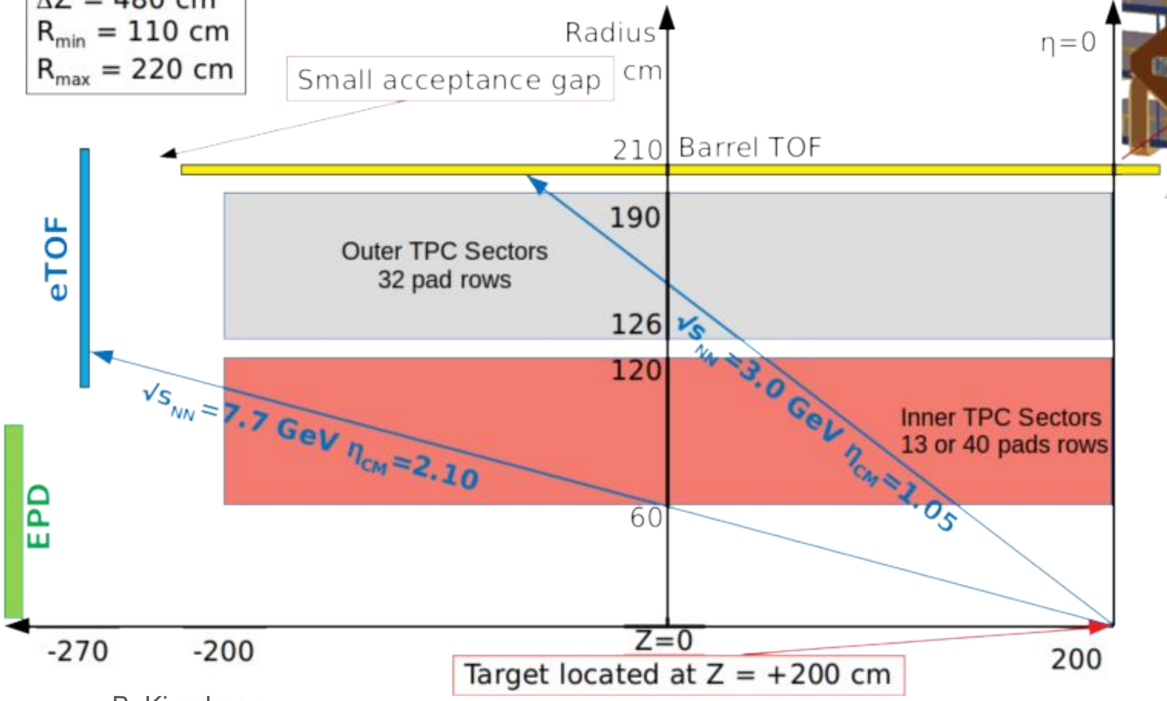
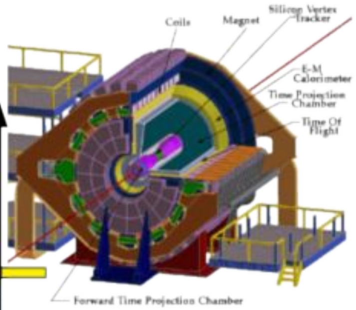
STAR Fixed-Target Geometry

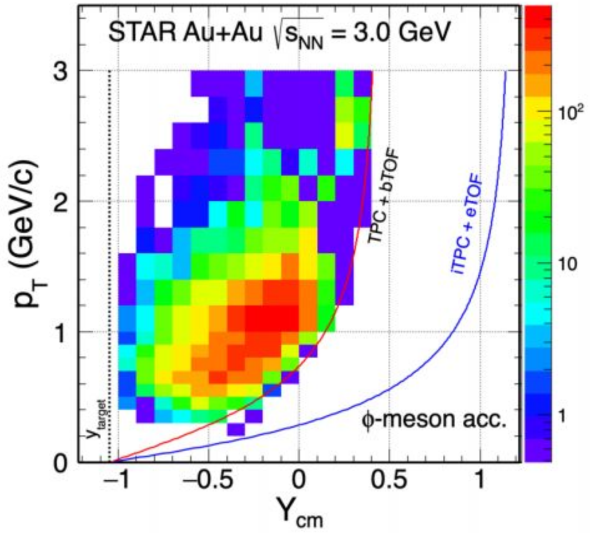
eTOF:
Z = -270 cm
ΔZ = 480 cm
R_{min} = 110 cm
R_{max} = 220 cm



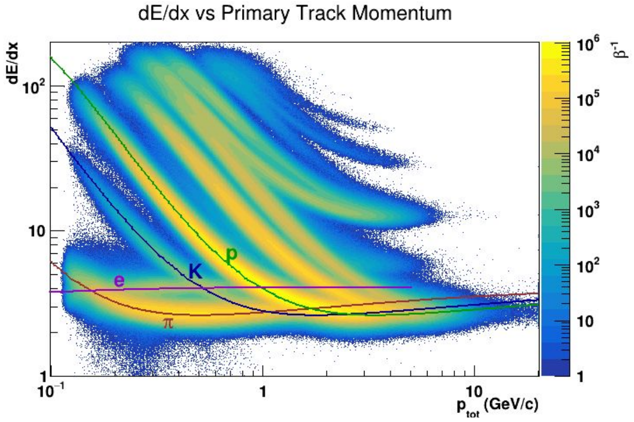


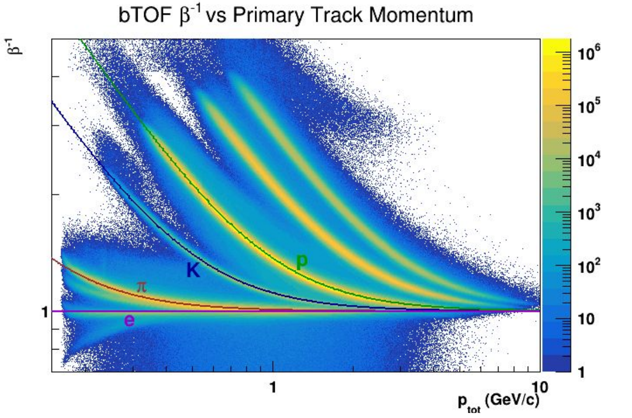
- Target located at z=200 cm
- Target is 0.25 mm thick (1% interaction probability) and held 2 cm below center of beam axis

Particle Identification

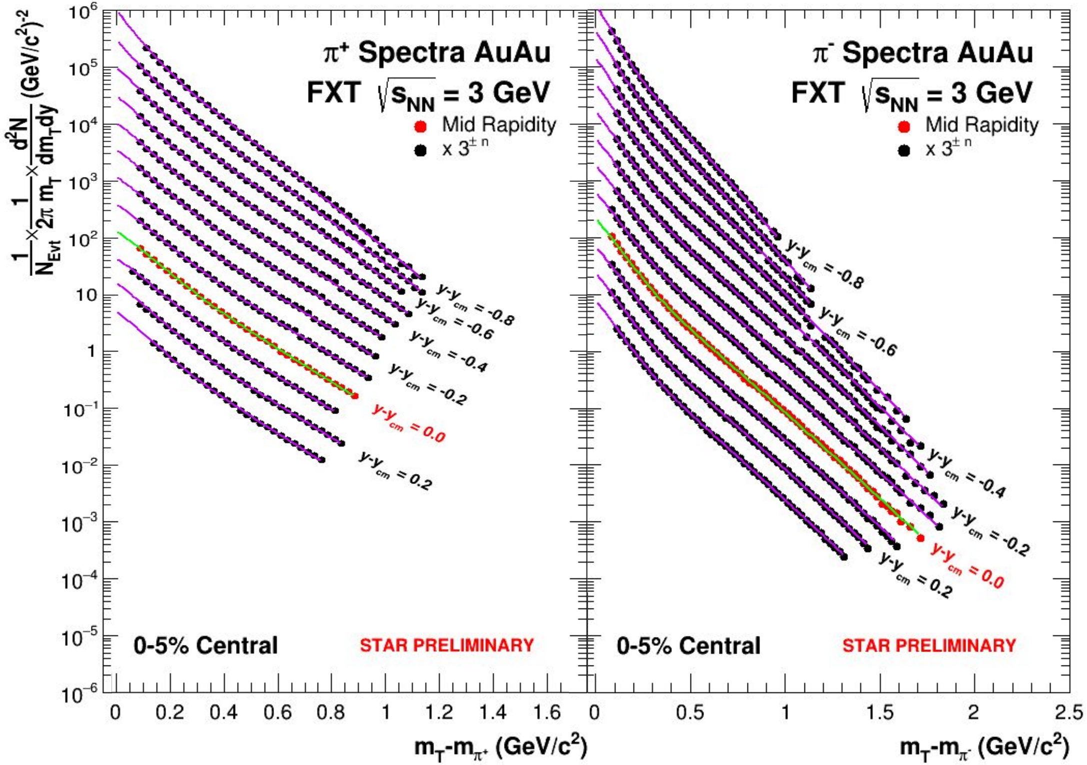


- Pions and Kaons are identified using a combination of information from the TPC (dE/dx) and the barrel ToF (m^2 or $1/\beta$)
- In each rapidity and m_T-m_0 bin, distributions of the TPC and bToF distributions are fit in order to extract the raw yields of particles
- Tracking and acceptance efficiencies, obtained by embedding simulated tracks into real data, are then applied to data along with an efficiency accounting for bToF matching





π Spectra

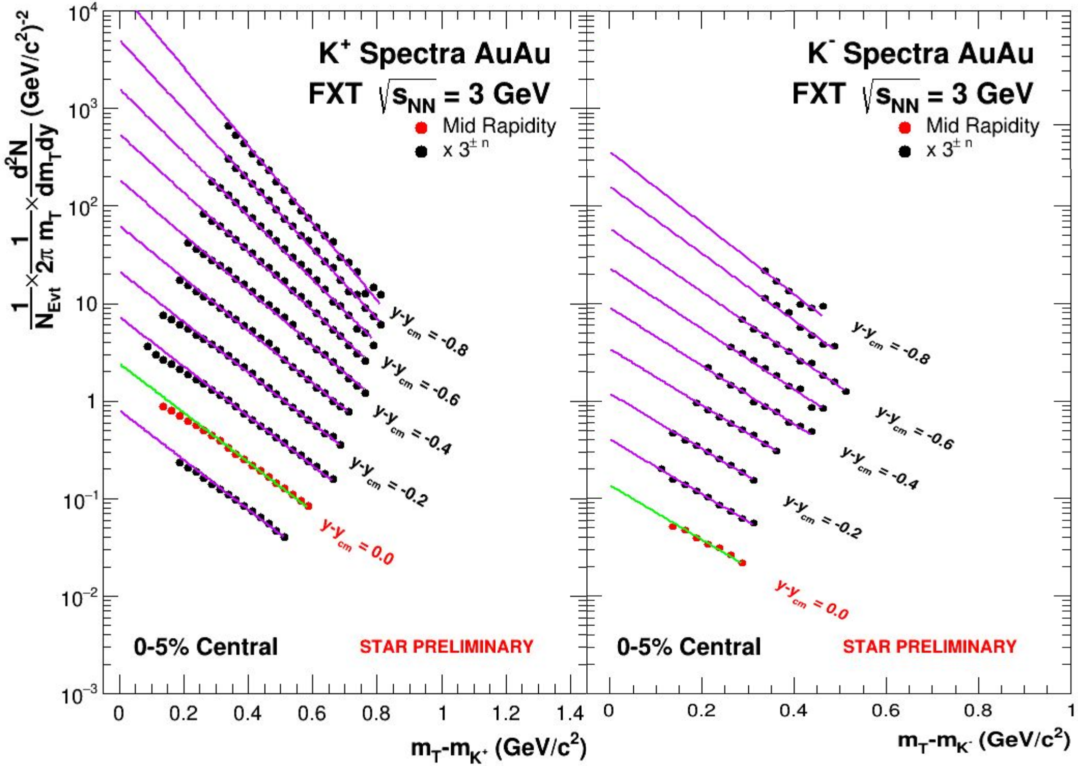


- Pion yields extracted from fitting dE/dx from TPC and 1/β from barrel ToF
- Pion spectra described well by double thermal function[1], which describes thermal production at high m_T-m_0 and production from Δ resonance at low m_T-m_0

$$\frac{1}{2\pi m_T}\frac{d^2N}{dm_T dy} = A m_T e^{-(m_T-m_0)/T}$$

[1]J. Klay et al. (E895 Collaboration), Phys. Rev. C 68, 054905 (2003)

K Spectra

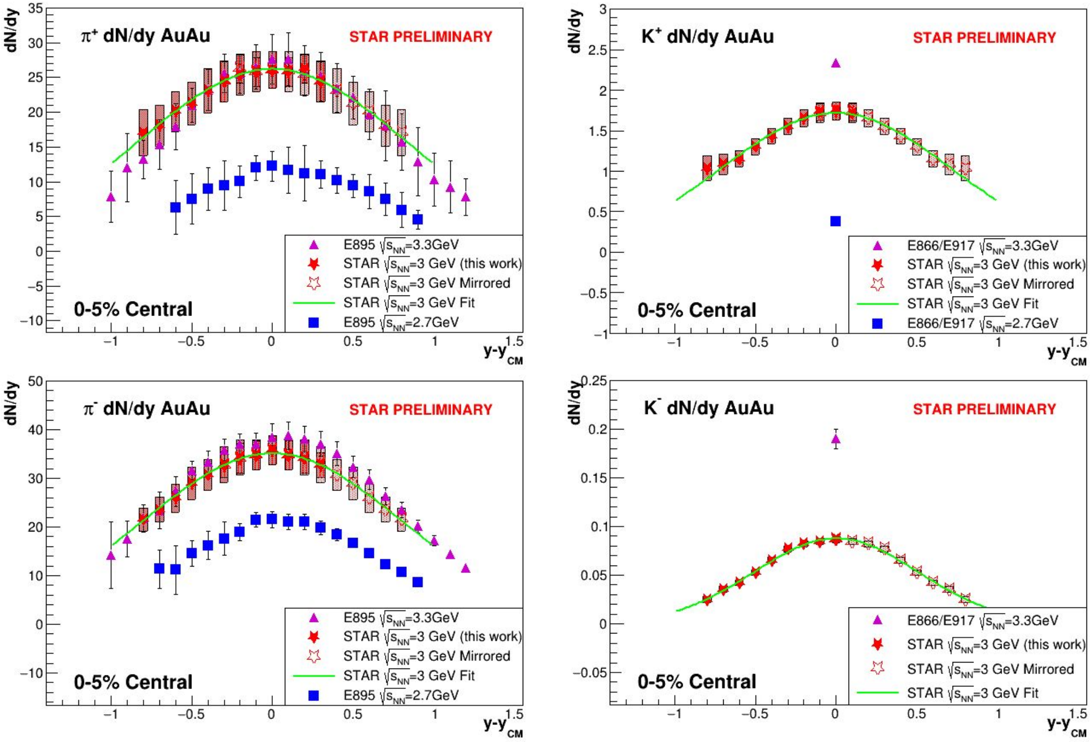


- Kaon yields extracted from fitting dE/dx from TPC and 1/β from barrel ToF
- Kaons described well by m_T exponential function

$$\frac{1}{2\pi m_T}\frac{d^2N}{dm_T dy} = Ae^{-(m_T-m_0)/T}$$

Pion and Kaon Rapidity Densities, 0-5% Most Central Collisions

- Yields obtained from integrating fits of spectra and are then fit with a Gaussian
- Yields agree well with results from E895[1] and E866/E917[2] from the AGS



[1]J. Klay et al. (E895 Collaboration), Phys. Rev. C 68, 054905 (2003)
[2]L. Ahle et al. (E866 and E917 Collaborations), Phys. Lett. B490, 53 (2000)

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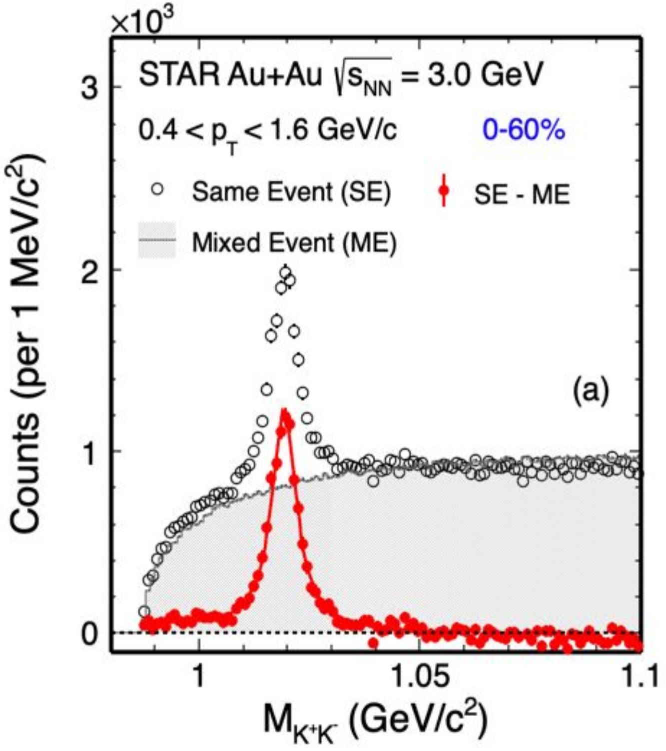
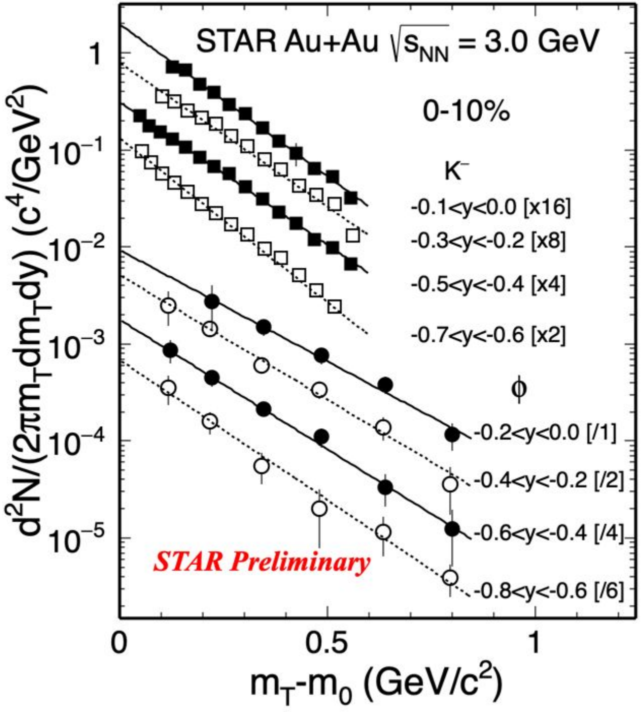
ϕ-meson signal and m_T Spectra

$\phi \rightarrow K$+ K- (hadronic channel)

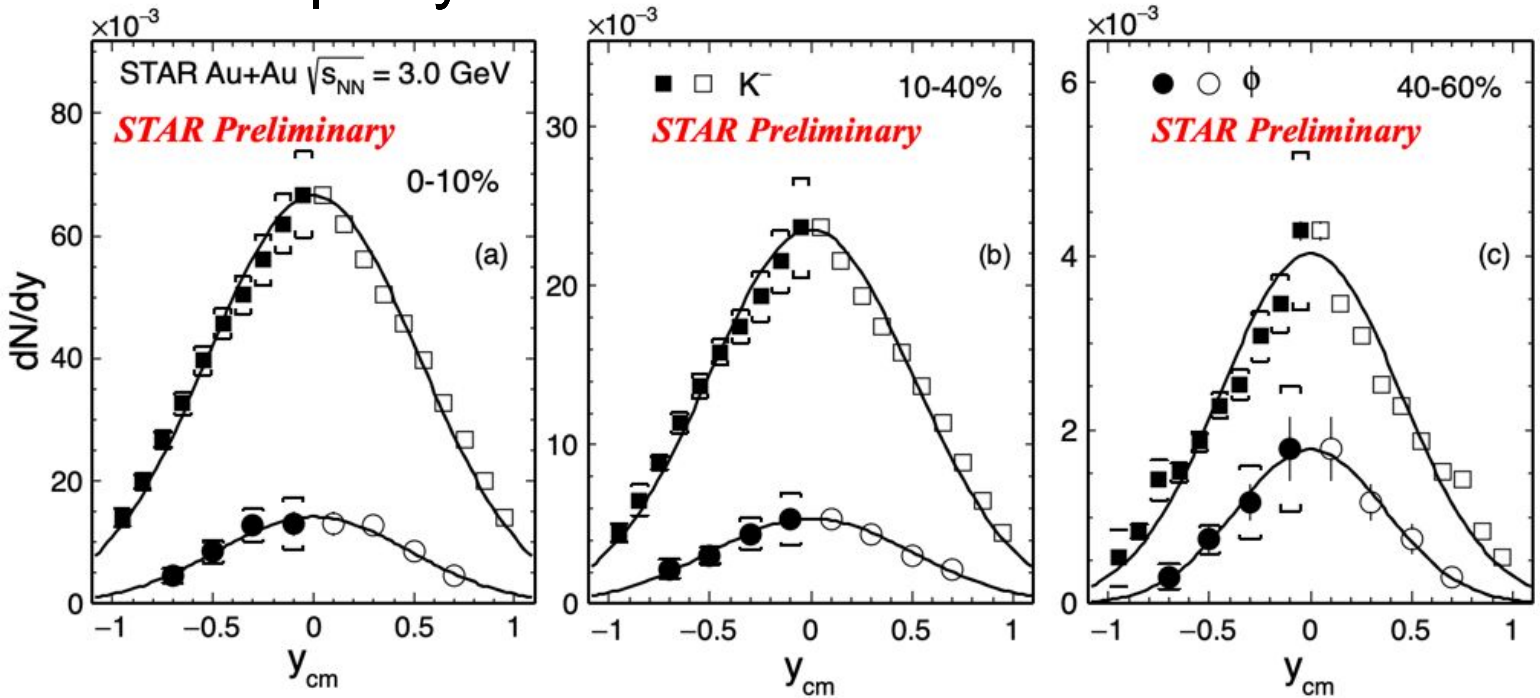




- Kaons and ϕ described well by m_T exponential function

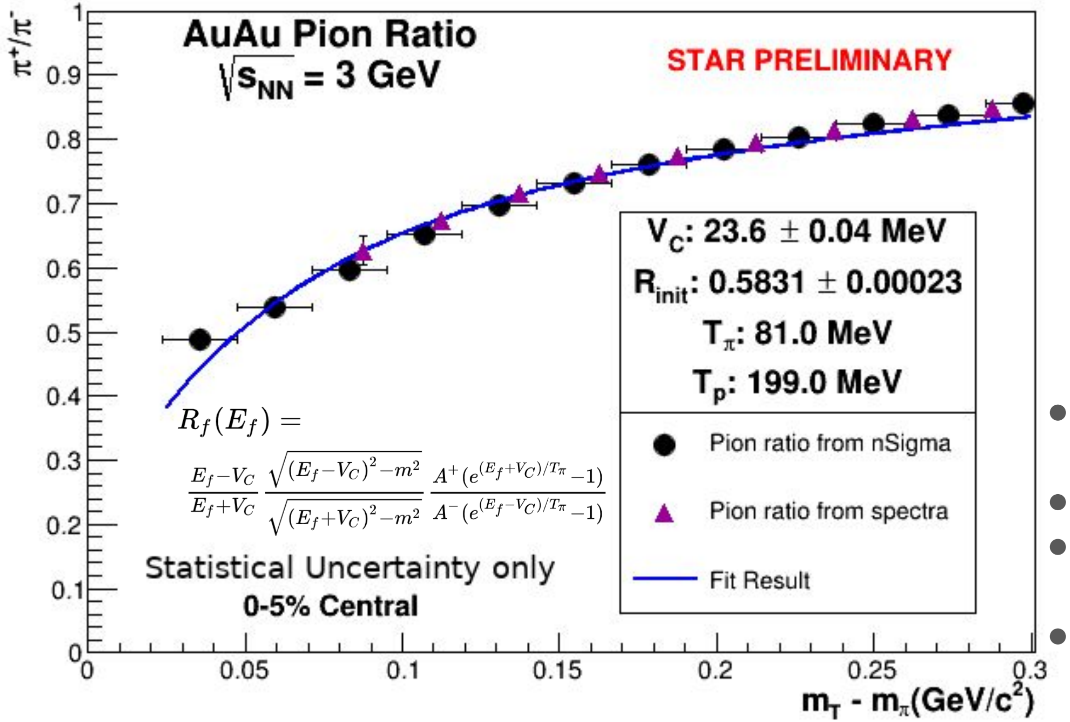
$$\frac{1}{2\pi m_T}\frac{d^2N}{dm_T\,dy} = Ae^{-(m_T-m_0)/T}$$

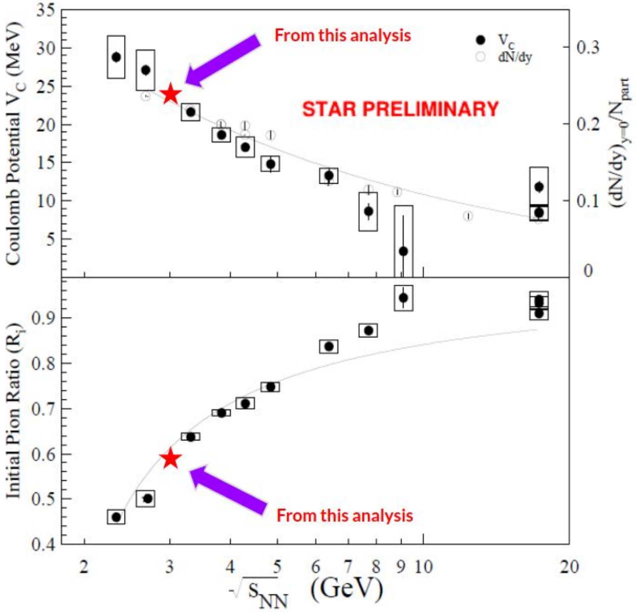
ϕ-meson Rapidity Densities



Rapidity distribution of K- and ϕ-meson and the Gaussian extrapolation in y_{CM} for various centrality regions. Solid symbols are measured data, open ones are reflection

Pion Ratio

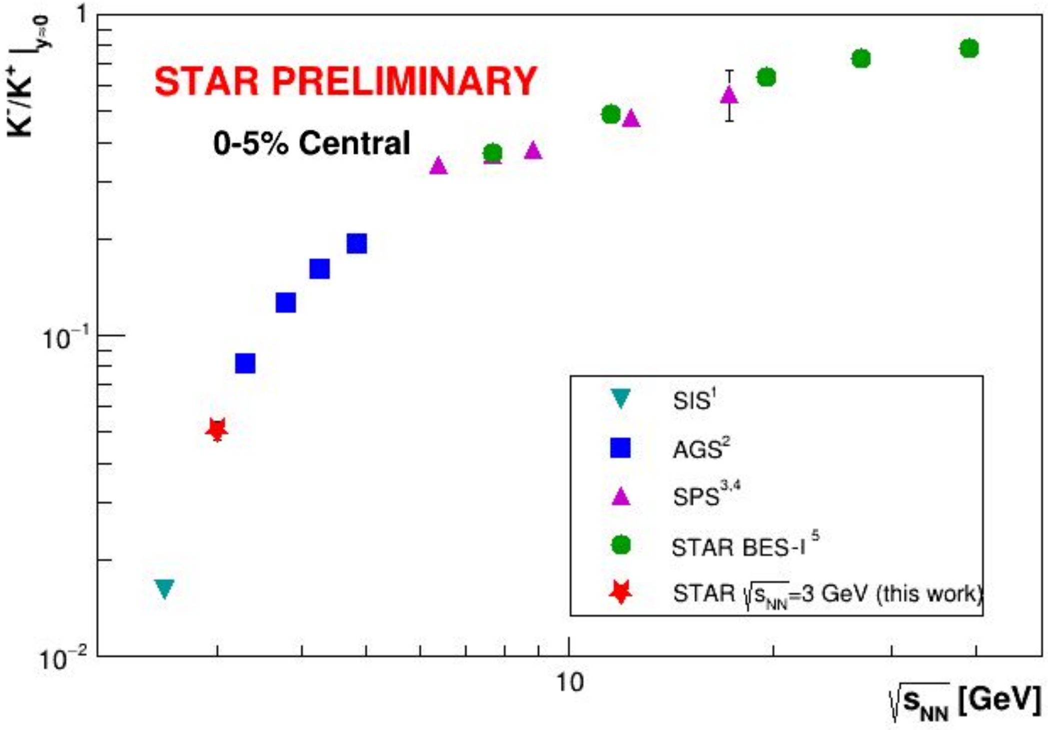




- Coulomb potential from positive interaction region modifies particle spectra[1]
- $\pi^\pm$ most sensitive hadron due to low mass
- Model does excellent job of describing shape of observed data
- Results follow trend observed across SIS, AGS, and SPS experiments[1]

[1]D. Cebra et al., arXiv:1408.1369 [nucl-ex]

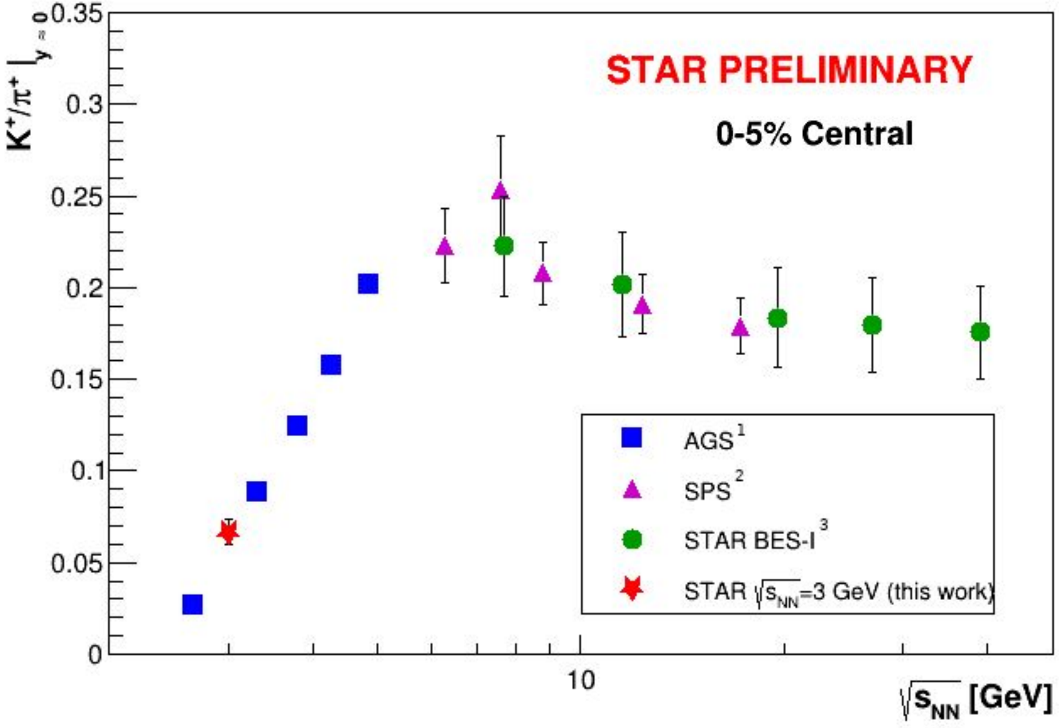
Kaon Ratio



- K^-/K^+ ratio shows importance of K^+ production in association with the Λ $(N + N \rightarrow N + \Lambda + K)$
- Results at $\sqrt{s_{NN}}$= 3.0 GeV follows trend seen in SIS, AGS, SPS, and RHIC data

[1]A. Forster et al. (KaoS Collaboration), J. Phys. G 28, 2011 (2002)
[2]L. Ahle et al. (E866 and E917 Collaborations), Phys. Lett. B490, 53 (2000)
[3]C. Alt et al. (NA49 Collaboration), Phys. Rev. C 77, 024903 (2008)
[4]S. Afanasiev et al. (NA49 Collaboration), Phys. Rev. C 66, 054902 (2002)
[5]L. Adamczyk et al. (STAR Collaboration), Phys. Rev. C 96, 044904 (2017)

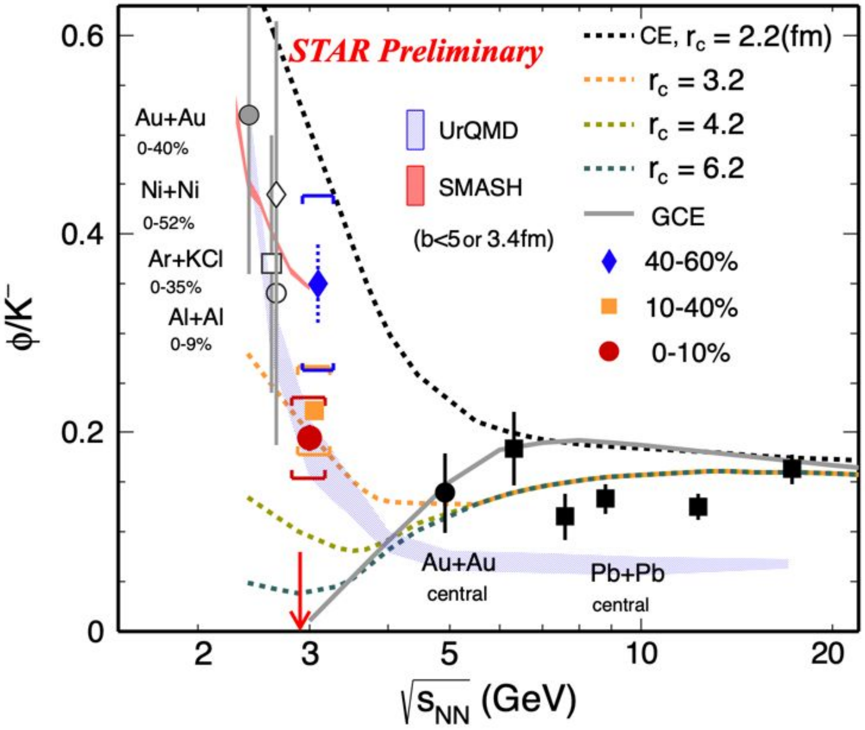
K/pi Ratio



- K^+/π^+ ratio proposed by NA49 as a possible signal of onset of deconfinement
- STAR measurements from BES-I agree with SPS results
- Result at $\sqrt{s_{NN}}$=3.0 GeV (this work) agrees well with AGS data

[1]L. Ahle et al. (E866 and E917 Collaborations), Phys. Lett. B476, 1 (2000)
[2]C. Alt et al. (NA49 Collaboration), Phys. Rev. C 77, 024903 (2008)
[3]L. Adamczyk et al. (STAR Collaboration), Phys. Rev. C 96, 044904 (2017)

ϕ/K Ratio



HADES: Phys. Lett. B 778, 2018.403-407, Phys. Rev. C. 80.025209. (2009)
E917: Phys. Rev. C. 69.054901 (2004)
NA49 : Phys. Rev. C 78, 044907 (2008), Phys. Rev. C 77, 024903 (2008), Phys. Rev. C 66, 054902 (2002)
P. Braun-Munzinger: Nucl. Phys. A 772, 167 (2006)
K. Redlich: Phys. Lett. B 603, 146 (2004)
UrQMD: J. Phys. G: Nucl. Part. Phys. 43 (2016) 015104 (14pp)
SMASH : Phys. Rev, C 99, 064908 (2019)

- Precision measurement: ~5σ larger than zero for 0-10% and 10-40% central collisions.
- Grand Canonical Ensemble clearly underestimates the measured data.
- Data favors the Canonical Ensemble with strangeness correlation length $r_c \sim 3.2^{+0.2}_{-0.3}\ fm$ in 0-10% centrality.
- Transport models with resonance decays can reasonably describe the data.
- A significant change in the strangeness production, EoS of dense baryon matter

Summary and Outlook

- Many meson observables have been measured and agree well with results from experiments at similar energies
- Pion ratio allows us to extract Coulomb potential, which is consistent with previous analyses
- Kaon ratio demonstrates importance of associated production with the Λ, which suggests unique strangeness production mode
- Kaon to pion ratio is consistent with previous measurements and lays groundwork for measurements at higher energies of possible onset of deconfinement
- ϕ/K ratio rules out GCE and favors CE with $r_c \sim 3.2^{+0.2}_{-0.3}\ fm$, and further demonstrates change to strangeness production and EoS of dense baryon matter
- Studies at higher fixed target energies will build from this analysis and shed light on various particle production mechanism and EoS

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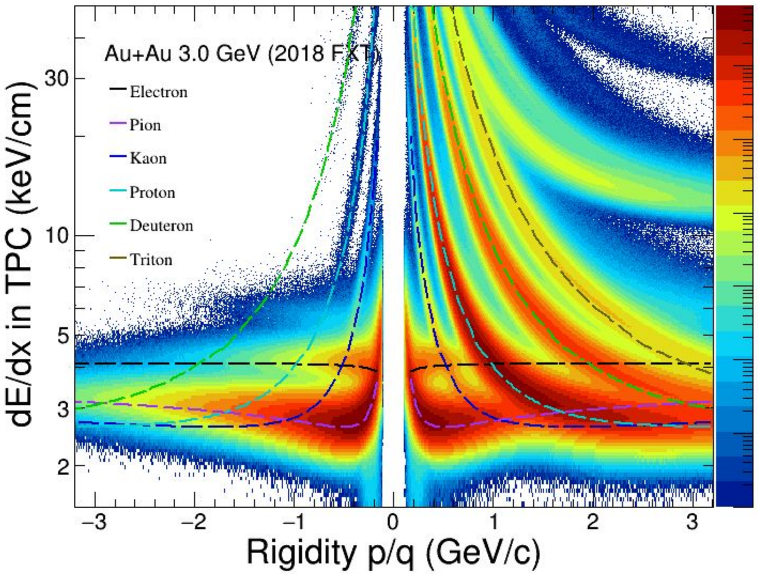
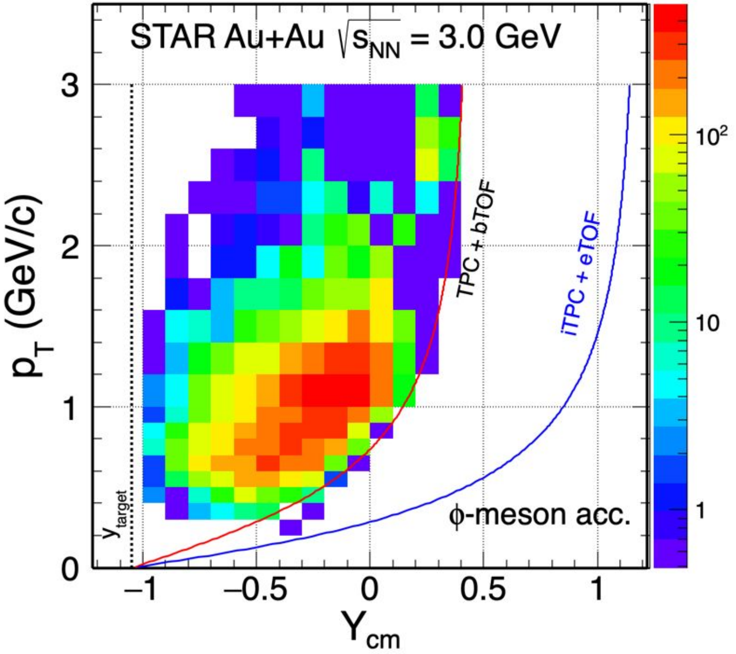


Au+Au 3.0 GeV (2018 FXT)
Electron
Pion
Kaon
Proton
Deuteron
Triton
dE/dx in TPC (keV/cm)
Rigidity p/q (GeV/c)



STAR Au+Au $\sqrt{s_{NN}}$ = 3.0 GeV
p_T (GeV/c)
Y_{cm}
TPC + bTOF
iTPC + eTOF
y_{target}
ϕ-meson acc.