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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Supported in part by
Motivation

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

- 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 (m² or 1/β)
- In each rapidity and mₜ⁻m₀ 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

B. Kimelman
(for the STAR Collaboration)
- 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 \(m_T-m_0\)

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

Kaon yields extracted from fitting dE/dx from TPC and \(1/\beta\) from barrel ToF

Kaons described well by \(m_T\) exponential function

\[
\frac{1}{2\pi m_T} \frac{d^2 N}{dm_T dy} = Ae^{-(m_T-m_0)/T}
\]
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\textsuperscript{[1]} and E866/E917\textsuperscript{[2]} from the AGS


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$\phi$-meson signal and $m_T$ Spectra

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

- Kaons and $\phi$ described well by $m_T$ exponential function

$$\frac{1}{2\pi m_T} \frac{d^2 N}{dm_T dy} = Ae^{-(m_T-m_0)/T}$$
Rapidity distribution of K- and $\phi$-meson and the Gaussian extrapolation in $y_{CM}$ for various centrality regions. Solid symbols are measured data, open ones are reflection.
Coulomb potential from positive interaction region modifies particle spectra\cite{1}

$\pi^+$ 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\cite{1}

\cite{1} D. Cebra et al., arXiv:1408.1369 [nucl-ex]

\[ R_f(E_f) = \frac{E_f-V_C}{E_f+V_C} \left( \sqrt{(E_f-V_C)^2-m^2} - A^+ \frac{e^{(E_f-V_C)/T_\pi}}{T_\pi+1} \right) \]

\[ V_C: 23.6 \pm 0.04 \text{ MeV} \]

\[ R_{init}: 0.5831 \pm 0.00023 \]

\[ T_\pi: 81.0 \text{ MeV} \]

\[ T_P: 199.0 \text{ MeV} \]

Statistical Uncertainty only 0.5\% Central

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The Kaon Ratio

- The K⁻/K⁺ ratio shows the importance of K⁺ production in association with the Λ (N + N → N + Λ + K⁺).
- Results at √s_{NN} = 3.0 GeV follow the trend seen in SIS, AGS, SPS, and RHIC data.

References:

K/\pi^+ ratio proposed by NA49 as a possible signal of onset of deconfinement

- STAR measurements from BES-I agree with SPS results
- Result at $\sqrt{s_{\text{NN}}} = 3.0$ GeV (this work) agrees well with AGS data


- 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 $\Lambda$, 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.
- $\phi/K$ ratio rules out GCE and favors CE with $r_c \sim 3.2^{+0.2}_{-0.3} \text{ fm}$, 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.