Probing the hadronic phase via the measurement of resonances in Au+Au collisions at 19.6 GeV from STAR BES-II

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Outline

• Motivation
• The STAR detector
• Signal reconstruction
• Results
  ➢ Transverse momentum spectra
  ➢ $p_T$ integrated yield (dN/dy)
  ➢ $K^{0}/K$ ratio
  ➢ Hadronic phase lifetime
• Summary
Why $K^0$ Resonance

- Lifetime comparable to that of the hadron gas phase.
- Modification of resonance yields due to interplay of rescattering and regeneration

$K^0/K$ ratio can be used to probe these effects in heavy ion collisions

<table>
<thead>
<tr>
<th>Resonance</th>
<th>Quark content</th>
<th>Decay Channel</th>
<th>$t$ (fm/c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K^*0$ (896)</td>
<td>$d\bar{s}$</td>
<td>$\pi^- K^+$ (B.R= 0.66)</td>
<td>4.16</td>
</tr>
</tbody>
</table>

The STAR Detector and Data Set

Data Set:
System: Au+Au 19.6 GeV (BES-II)
# of events: ~710 M

Tracking:
TPC

Particle Identification:
TPC & TOF
Particle Identification

Au+Au 19.6 GeV

(Using TPC)

(Using TOF)
Signal Reconstruction

- Signals are extracted using invariant mass method. Invariant mass: $m^2_{inv} = E^2 - p^2$ where, $E^2 = (E_\pi + E_K)^2$ and $p^2 = (p_\pi + p_K)^2$

- Combinatorial background is estimated using pair rotation method.

- Fitting function: $\frac{Y}{2\pi} \times \left[ \frac{\Gamma_0}{(M - M_0)^2 + \frac{\Gamma_0^2}{4}} \right] + 1^{st}$ order polynomial (residual background)

<table>
<thead>
<tr>
<th>0-10% centrality, 1.0 &lt; $p_T$ (GeV/c) &lt; 1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.6 GeV</td>
</tr>
<tr>
<td>BES-I</td>
</tr>
<tr>
<td>BES-II</td>
</tr>
</tbody>
</table>
• $K^0$ reconstruction efficiency is estimated based on single particle efficiency
Levy Tsallis function is used to extrapolate yield at low and high $p_T$ regions.

**p_T Integrated Yield**

\[ \frac{dN}{dy} \text{ increases with centrality and collision energy} \]

**BES-I result:** arXiv:2210.02909


The statistical errors are reduced by a factor of 3 in BES-II compared to BES-I.
K*⁰/K Ratio

H. Albrecht et al., Z. Phys. C, 61:1–18,1994 (e+e)

$K^{*0}/K$ Ratio

- $(K^{*0}/K)_{\text{central}} < (K^{*0}/K)_{\text{peripheral}}$
- $(K^{*0}/K)_{\text{central}} < (K^{*0}/K)_{\text{pp/ee-reference}}$
- $(\phi/K)$: independent of centrality
- Thermal model explains the $\phi/K$, but overpredicts the $K^{*0}/K$ in central collision

Favors dominant hadronic rescattering in central collisions
Lower Limit of Hadronic Phase Lifetime

\[ \Delta t = \tau^{-1}_{\text{chem}} \]

Here, \( \Delta t \) = lower limit of hadronic phase lifetime (\( t_{\text{kin}} - t_{\text{chem}} \))

\[ \tau = \text{Lifetime of } K^* \]

- Errors are the quadratic sum of statistical and systematic errors
- Here, \( (K^0/K)_{pp} = 0.34 \pm 0.01 \)
- No clear energy dependence within the current uncertainties at RHIC
Summary

- $K^*0$ resonance production in BES-II Au+Au collisions at 19.6 GeV is presented

- $K^*0/K$ ratio indicates dominance of hadronic rescattering over regeneration in central Au+Au collisions

- The lower limit of hadronic phase lifetime increases with centrality, and no clear energy dependance is observed within current uncertainties for RHIC measurements.
Outlook

- $K^{*0}$ resonance measurement using high statistics data collected in STAR BES-II program
- Constraints on the hadronic phase lifetime
- Explore more differential measurements (e.g. rapidity dependence)
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Thank You
• Thermal model parameters: $T_{ch} = 153.9$ MeV, $\mu_s = 43.2$ MeV, $\mu_B = 187.9$ MeV