Production of $e^+e^-$ in U+U and Au+Au as Measured by STAR

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Outline

✧ Using $e^+e^-$ to probe the medium

✧ Vector meson modification in the medium & lifetime measurement of the medium

✧ Measurements in U+U @ $\sqrt{s_{NN}} = 193$ GeV

✧ Measurements in RHIC Beam Energy Scan

✧ Outlook

✧ Summary
EM Probes

ฆExcellent Probe
ฆMinimal final state interactions
ฆGenerated at all stages of the collision
ฆChronological Phases [Early to Latest]
ฆHigh Mass Region [HMR]
ฆDrell-Yan
ฆ$J/\psi + \gamma$ Suppression
ฆIntermediate Mass Region [IMR]
ฆHeavy flavor modification
ฆQGP (thermal) radiation
ฆLow Mass Region [LMR]
ฆVector meson modification
ฆPossible link to chiral symmetry restoration
LMR: Spectral Functions

- Spectral functions modified in the medium
  - Successful description of data @ SPS & RHIC energies
- Possible link to chiral symmetry restoration
  - Spectral Functions + QCD Sum Rules + Weinberg Sum Rules + IQCD
Lifetimes

- Lifetime of the fireball
  - Proportional to ‘excess’ in LMR

- ‘Excess’ Au+Au data
  - Greater at more central collisions
  - In agreement with model lifetime trends
Experimental Controls

◊ From RHIC to SPS
  ◇ Beam Energy Scan Program: 7.7 - 62.4 GeV
  ◇ Ties RHIC to SPS
  ◇ Sufficient data \([\text{Au+Au} @ \sqrt{s_{NN}} = 19.6, 27, 39, 62.4 \text{ GeV} ]\)
  ◇ Change \(\sqrt{s_{NN}}\), maintain colliding species & total baryon density

◊ Systematically study the LMR excess yield
  ◇ As a function of \(\sqrt{s_{NN}}\)
  ◇ Versus fireball lifetime

◊ Higher energy densities + number of participants
  ◇ \(\text{Au+Au} \rightarrow \text{U+U} @ \sqrt{s_{NN}} = 193 \text{ GeV}\)
    ◇ Energy density expected to be up to 20% higher than \(\text{Au+Au}@\sqrt{s_{NN}} = 200 \text{ GeV}\)
  ◇ Longer fireball lifetime?
  ◇ Higher excess yield in the LMR?
Data

- Time Projection Chamber (TPC) and Time of Flight (TOF)
- Large acceptance ($p_T^e>0.2\text{ GeV/c}, |\eta^e|<1$, & $|Y_{ee}|<1$)

<table>
<thead>
<tr>
<th>Species</th>
<th>$\sqrt{s_{NN}}$ [GeV]</th>
<th>Events (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au+Au</td>
<td>200</td>
<td>730 (min. bias)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ 220 (central)</td>
</tr>
<tr>
<td>Au+Au</td>
<td>62.4</td>
<td>67</td>
</tr>
<tr>
<td>Au+Au</td>
<td>39</td>
<td>130</td>
</tr>
<tr>
<td>Au+Au</td>
<td>19.6</td>
<td>36</td>
</tr>
<tr>
<td>Au+Au</td>
<td>27</td>
<td>70</td>
</tr>
<tr>
<td>U+U</td>
<td>193</td>
<td>270</td>
</tr>
</tbody>
</table>
Electron Identification

$\text{Au+Au @ } \sqrt{s_{NN}} = 62 \text{ GeV}$

- Uses the TOF’s precise timing
  - Remove slower hadrons
  - Extends and improves the TPC’s PID reach
- High-purity detection of electrons
  - Integrated purity $> 95\%$
Minimum-Bias Yields

- Different collision systems
- In good agreement with model(s) that incorporates $\rho$ spectral function broadening

**STAR, PRL113 22301 2014**

PHSD: O. Linnyk et al., PRC 85 024910 2012

S. Yang, Quark Matter 2015
20% higher energy density compared with Au+Au

Model, which incorporates the broadening of the $\rho$ spectral function, is consistently in agreement in the LMR as a function of $p_T$
Centrality Dependence: U+U

- 20% higher energy density compared with Au+Au
- Model, which incorporates the broadening of the $\rho$ spectral function, is consistently in agreement in the LMR as a function of centrality
Different initial conditions by changing energy density (species + $\sqrt{s_{NN}}$)

In good agreement with a model that incorporates a broadened $\rho$ spectral function
**Model**: Normalized integrated excess yield in the LMR is proportional to the lifetime of the system for $\sqrt{s_{NN}} = 17.3 - 200$ GeV

- Increase of yields
  - At higher energies with respect to lower energies
  - At central collisions compared to peripheral collisions

- Measurements are consistent with model calculations that report longer lifetimes for more central collisions
Future $e^+e^-$ Studies

- BES-I investigated LMR emission & proportional to lifetime (w/ constant total baryon density)
- BES-II continue to probe LMR and investigate the lifetime and $\rho$ spectral function dependence on total baryon density
  - If near critical point, possible increase in excess yields compared to the expected excess yield
- BES-II may allow for meaningful measurements of IMR
- Overlaps & spans $\sqrt{S_{NN}}$ that connects many experiments
Future $e^+e^-$ Studies (cont.)

<table>
<thead>
<tr>
<th>Au+Au @ $\sqrt{s_{NN}}$ [GeV]</th>
<th>Events (M)</th>
<th>Au+Au @ $\sqrt{s_{NN}} = 200$ GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.7</td>
<td>100</td>
<td>Similar stat. uncert. as Au+Au @ $\sqrt{s_{NN}} = 200$ GeV</td>
</tr>
<tr>
<td>9.1</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>11.5</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>14.5</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>19.6</td>
<td>400</td>
<td></td>
</tr>
</tbody>
</table>

- **inner Time Projection Chamber**
  - Reduction in statistical uncertainties
  - Quantity + acceptance increase
  - Reduction in systematic uncertainties
  - Cocktail + purity improvement

- **end-cap Time Of Flight**
  - Matches the reach of iTPC
  - Measure rapidity dependence → study total baryon density dependence

Summary

♢ STAR has an established LMR $e^+e^-$ program measuring the invariant mass
  ◇ Measurements as a function of $\sqrt{s_{NN}}$
  ◇ Measurements as a function of $p_T$
  ◇ Measurements as a function of centrality
  ◇ Measurements as a function of collision species
♢ Our measurements agree with models, which include a broadened $\rho$ spectral function
  ◇ Measurements are consistent with a model that indicates a longer medium lifetime for collisions that are more central and have a higher $\sqrt{s_{NN}}$
♢ Outlook
  ◇ BES-II offers an opportunity to build and extend the current program
  ◇ Continue to study the relationship between excess yields and fireball lifetimes
  ◇ Statistics may allow for IMR measurements
Thank you
Backup