System-size and energy dependence of di-electron excess invariant-mass spectra at STAR

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Outline

- Motivation
- STAR experiment
- Electron Identification
- Di-electron measurements
  - Di-electron mass spectra within STAR acceptance in U+U@193 GeV
    - Transverse momentum dependence
    - Centrality dependence
  - Energy and system-size dependence of acceptance corrected yield
    - AuAu@19.6, 27, 39, 62.4, 200 GeV
    - UU@193 GeV
- Summary
Di-lepton production

Di-leptons – penetrating probe
- Do not suffer strong interactions
- Bring direct information of the medium created in heavy ion collisions

Different physics of interest
- **Low Mass Region** (LMR, $M_{ll} < M_\phi$)
  - In-medium modifications of vector meson
- **Intermediate Mass Region** (IMR, $M_\phi < M_{ll} < M_{J/\psi}$)
  - QGP thermal radiation
  - Semi-leptonic decays of correlated charm
- **High Mass Region** (HMR, $M_{J/\psi} < M_{ll}$)
  - Drell-Yan process
  - Heavy quarkonia
Di-electron physics @ STAR

- **UU@193 GeV**
  - Energy density is higher by 20% than that in AuAu@200 GeV.
  - Longer medium life time?
  - Higher excess yield in the low mass region?

- **Beam Energy Scan Program**
  - Systematically study energy dependence of LMR excess
  - Systematically study the low mass excess yield versus medium life time.

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D. Kikola, G. Odyniec, and R. Vogt, *PRC* 84 (2011) 054907

R. Rapp, H. van Hees, arXiv:1411.4612

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STAR detector

- **Time Projection Chamber**
  - $|\eta|<1$, $0<\phi<2\pi$
  - Main detector: tracking, momenta, and energy loss

- **Time Of Flight**
  - $|\eta|<0.9$, $0<\phi<2\pi$
  - Rejects slow hadrons, enables clean electron identification at $p < 3 \text{ GeV/c}$
Clean electron identification with a combination of TPC and TOF

\[ n\sigma_e = \frac{1}{R} \log \left( \frac{(dE/dx)_{measured}}{(dE/dx)_{electron}} \right) \]
U+U @ 193 GeV results

- Significant enhancement w.r.t cocktail at ρ-like mass region (0.3-0.76 GeV/c²) 
  \[ 2.1 \pm 0.1\text{(stat.)} \pm 0.2\text{(sys.)} \pm 0.3 \text{ (cocktail)} \]

- The charm contribution to the total cocktail is significant in the ρ-like mass region (48.5%).
  \[ \sigma_{c\bar{c}} = 797 \mu b, \sigma_{b\bar{b}} = 3.7 \mu b, \sigma_{DY} = 42 nb \]

  Model shows good agreement with data within uncertainty.

Cocktail simulation: STAR, PRC 92 (2015) 024912

STAR preliminary
Model calculation consistently describes the LMR excess in all $p_T$ bins.

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Model calculation consistently describes the LMR excess in all centrality bins.

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Excess yield in ρ-like mass region:
• Increase faster than $N_{\text{part}}$ scaling
• Sensitive to medium dynamics

Data - Cocktail
Mass Region: 0.30-0.76 GeV/c²

AuAu@200 GeV: STAR, PRL 113 (2014) 022301
Acceptance-corrected excess mass spectra are well described by a $\rho$ broadened spectral function in various collision systems and energies.
Energy and system-size dependence of integrated excess yield

The normalized excess yields of UU@193 GeV and AuAu@200 GeV
- Increase from peripheral to central collisions.
- In central collisions are higher than those at lower energies.

Indicate longer medium lifetime in central UU@193 GeV and AuAu@200 GeV collisions.

AuAu@200 GeV, 19.6 GeV: STAR, PLB 750 (2015) 64
InIn@17.3 GeV: NA60, Eur. Phys. J. C 59 (2009) 607

The normalized excess yield in LMR is proportional to the medium life time (HG + QGP) for \( \sqrt{S_{NN}} = 17.3-200 \) GeV
- Nearly constant total baryon density
- Emission rate dominated around \( T_c \)
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STAR preliminary

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- Systematically study di-electron continuum from $\sqrt{s_{NN}} = 7.7 - 19.6$ GeV
- Inner Time Projection Chamber (iTPC) upgrade: reduce systematic and statistical uncertainties
- Distinguish models with different $\rho$-meson broadening mechanisms (Rapp’s method vs. PHSD)
- Study the total baryon density effect on LMR excess yield in BESII
Summary

- The di-electron production is systematically studied in UU@193 GeV for the first time.
- The LMR excess at all collision systems can be consistently described by a $\rho$ broadened spectral function scenario.
- The excess yield in $\rho$-like mass region has a strong centrality dependence and increases faster than $N_{\text{part}}$ scaling in UU@193 GeV and AuAu@200GeV.
- The measurements indicate that the lifetime of medium created in central UU@193GeV and AuAu@200GeV collisions is longer than those in peripheral collisions and at lower energies.
Backup
InIn@17.3 GeV: NA60, AIP Conf. Proc. 1322 (2010) 1

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Theory lifetime:
- 200 GeV
- 193 GeV
- 62.4 GeV
- 39 GeV
- 27 GeV
- 19.6 GeV
- 17.3 GeV
Theoretical temperature and lifetime

<table>
<thead>
<tr>
<th>Collision Energy (GeV)</th>
<th>Temperature (MeV)</th>
<th>Lifetime (fm/c)</th>
</tr>
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<tbody>
<tr>
<td>AuAu@19.6</td>
<td>227</td>
<td>7.7</td>
</tr>
<tr>
<td>AuAu@27</td>
<td>230</td>
<td>8.0</td>
</tr>
<tr>
<td>AuAu@39</td>
<td>237</td>
<td>8.2</td>
</tr>
<tr>
<td>AuAu@62.4</td>
<td>272</td>
<td>9.2</td>
</tr>
<tr>
<td>AuAu@200</td>
<td>328</td>
<td>10.5</td>
</tr>
<tr>
<td>UU@193 10-40%</td>
<td>357</td>
<td>12.3</td>
</tr>
<tr>
<td>UU@193 0-10%</td>
<td>392</td>
<td>16.2</td>
</tr>
</tbody>
</table>