Dielectron Production in 200 GeV Au+Au Collisions at STAR

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• Motivation
• Electron Identification / Background Subtraction
• Di-electron production in Au+Au collisions
• Preliminary Trigger Combination Methodology
• STAR MTD / HFT Upgrade
• Summary / Outlook
Motivation

- Dileptons can be used as a probe for all stages of the collision
- No strong force interaction (they stay intact after production)
- Carries information as system evolves in time

- Difficult to measure – Low production rate, low S/B ratio
Motivation

- **Dileptons have a wide mass range over which to study**

<table>
<thead>
<tr>
<th></th>
<th>LMR</th>
<th>IMR</th>
<th>HMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_{ee} &lt; 1.1$ GeV/$c^2$</td>
<td>$1.1 &lt; m_{ee} &lt; 3.0$ GeV/$c^2$</td>
<td>$m_{ee} &gt; 3.0$ GeV/$c^2$</td>
<td></td>
</tr>
</tbody>
</table>
| • *In-medium* vector meson decay, possible link to Chiral Symmetry Restoration | • Thermal Radiation of the QGP
• Semileptonic decays of charm mesons (expected to be modified vs p+p) | • Heavy Quarkonia
• Drell-Yan processes |
We use primarily TOF and TPC in dilepton study
- Provides excellent timing resolution and hadron rejection ability
- Also require E-M Calorimeter for electron-ID
- TOF/TPC allows electron PID down to very low momentum
- Beta and $n\sigma_e$ cuts together allow us to pick out electron region
  - Important for pure eID sample

$$n\sigma_e = \frac{\log \frac{dE}{dx}}{B_e \sigma_e}$$
Electron ID from TPC + BEMC

High pT electron PID:

- **TPC+BTOW:**
  - Associate TPC tracks with BTOW clusters.
  - Cut p/E ~1.0

- **Cut on number of BSMD strips per cluster:**
  - Associate TPC tracks with BSMD clusters.
  - Higher for electron.
• Each electron is mixed with all other electrons in different events over a set buffer size
• Mixing only between events (not within) ensures no useful physics are mixed away
Event Mixing Method

- The Event Mixing background is normalized to the like-sign foreground over a certain mass range.

- Event Mixing is only done within specific event plane, centrality, magnetic field orientation, and z-Vertex bins.
- Then, the event mixing is normalized over a certain mass range (1-3 GeV/c²) to match the original foreground.
Background Reconstruction

For $M_{ee} > 0.75 \text{ GeV/c}^2$:

$$BG_{+-} = \frac{BG_{mix}^{+-}}{2 \sqrt{BG_{++} \cdot BG_{--}}}$$

Event Mixing Method

For $M_{ee} \leq 0.75 \text{ GeV/c}^2$:

$$BG_{+-} = \frac{BG_{mix}^{+-}}{BG_{++}^{mix} + BG_{--}^{mix}}$$

Like-Sign Method

- Conversion electrons are removed prior to pairing (mass-dependent $\phi_v$ cut)
- Systematic errors from normalization and detector acceptance are $< 0.1\%$
Background Subtraction

• **Reconstructing background is difficult due to low S/B ratio**

![Graph showing S/B ratio vs. M_{ee} (GeV/c^2) for different collision types.](image)

<table>
<thead>
<tr>
<th></th>
<th>In p+p</th>
<th>In Au+Au MinBias</th>
<th>In Au+Au Central</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/B @ 500 MeV is:</td>
<td>~ 1/10</td>
<td>~ 1/200</td>
<td>~ 1/250</td>
</tr>
</tbody>
</table>
Dielectron Spectrum in Minimum Bias

- **Data hints at enhancement in the Low Mass Region**
- Cocktail is shown without $\rho$ meson
- Yellow Band is systematics on cocktail
- Green Band is systematics on data
Dielectron Spectrum in Central Data

- Slight difference in LMR enhancement compared to MB Data
- Pythia charm production is over predicted, suggesting charm modification in Central collisions
- Cocktail again does not include $\rho$ meson
- Systematic errors are as before
Comparison to Theory


• Blue dotted = Hadronic gas medium modification
• Pink dotted = QGP Radiation
• Sum = cocktail + HG + QGP
• HG Medium & QGP Radiation curves from R. Rapp

PHSD = Parton-Hadron-String Dynamics Model
• Off-shell transport model
• Collisional broadening of vector mesons
• Microscopic secondary multiple-meson channels
• sQGP radiation through quasiparticle interaction
Low Mass Region Enhancement

- The LMR enhancement in PHENIX is significantly larger than that of STAR

### Enhancement Factors ($M_{ee}$ integral from 150 – 750 MeV/c$^2$)

<table>
<thead>
<tr>
<th></th>
<th>Min Bias (value ± stat ± sys)</th>
<th>Central (value ± stat ± sys)</th>
</tr>
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<tbody>
<tr>
<td><strong>STAR</strong></td>
<td>1.53 ± 0.07 ± 0.41 (w/o ρ)</td>
<td>1.72 ± 0.10 ± 0.50 (w/o ρ)</td>
</tr>
<tr>
<td></td>
<td>1.40 ± 0.06 ± 0.38 (w/ ρ)</td>
<td>1.54 ± 0.09 ± 0.45 (w/ ρ)</td>
</tr>
<tr>
<td><strong>PHENIX</strong></td>
<td>4.7 ± 0.4 ± 1.5</td>
<td>7.6 ± 0.5 ± 1.3</td>
</tr>
</tbody>
</table>

PhysRevC.81.034911 (PHENIX Coll.)
Applying the PHENIX $\phi$ acceptance in STAR data does not seem to reproduce the LMR enhancement observed by PHENIX.
By combining Min Bias data with high-tower triggers, we can extend our reach into the IMR and high-pT regime.

- Each “NPE-XX” trigger corresponds to a certain energy threshold on the EMC towers.
- By adding the statistics from these towers in a specific way (by combining the prescale factors appropriately), we can still obtain an unbiased spectrum.
- In this manner, we extend our reach to higher energy electrons.
Trigger Combination Simulation

- **Simulation seems to confirm the soundness of the methodology – this is an unbiased sample**

- We simulated e+e- pairs using the a functional fit from real data

- Compares the trigger-combined spectrum to the pure unbiased (generated) spectrum

- Ratios are very (< 0.2%) close to 1
The STAR HFT and MTD Upgrade

STAR HFT: prototype run-13  
complete run-14

STAR MTD: 43 % run-13  
complete run-14
The STAR HFT and MTD Upgrade

J. Zhao, JPG 38, 124134 (2011)

L. Ruan et al., JPG 36 (2009) 095001

search for QGP thermal radiations

Dominated by the correlated pair from charm-decay electrons. Addressed by:

- e-µ correlation with Muon Telescope Detector at STAR from c-cbar
  - S/B=2 ($M_{e\mu}>3$ GeV/c² and $p_T(e\mu)<2$ GeV/c)
  - S/B=8 with electron pairing and tof association
- Accurate D meson measurements
Summary

- In the LMR, we find enhancement in Au+Au collisions compared to cocktail
- STAR LMR enhancement exists, but not as large as that of PHENIX
- Trigger Combination results should allow us to obtain more precise measurements in the IMR + high pT regions
- STAR HFT and MTD (completed 2014) should be able to measure the QGP thermal radiation in the IMR by providing very accurate heavy flavor meson measurements
Backup Slides
Conversion Electron Removal

- Applied mass-dependent $\phi_v$ cuts (where $\phi_v$ is the opening angle of the $ee$ pairs)
Electron Purity

- Select on $dE/dx$ (TPC)
- On $n\sigma_e$ (TOF)
- On $1/\beta - 1$ (TOF)
- On momentum (TOF)
- + Track Quality Cuts (TPC)

![Graph showing electron purity against momentum (GeV/c)](image)