Di-electron Continuum Production from
\( \sqrt{s_{NN}} = 200 \text{GeV} \) p+p and Au+Au Collisions at STAR

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Outline

- Motivation
- STAR detector and electron identification
- Background subtraction
- Di-electron production in $p+p$ and $Au+Au$ collisions
- Transverse mass spectra at IMR
- Summary and outlook
Motivation(1)

- **Low mass region (LMR):**
  - ✓ in-medium modifications of vector mesons
  - ✓ chiral symmetry restoration

- **Intermediate mass region (IMR):**
  - ✓ thermal radiation expected to have significant contribution
  - ✓ dominated by charm in p+p, but the contribution is expected to be modified in Au+Au

- **High mass region (HMR):**
  - ✓ heavy quarkonia
  - ✓ Drell-Yan contribution

**Dileptons:** Clean probe
✓ no strong interaction - direct information of the medium in heavy ion collisions
**Motivation(2)**

Different slope in $m_T$ spectra in low and intermediate mass at SPS energy

- **hint of partonic thermal dileptons**
  
  $q\bar{q} \to \ell \bar{\ell}$

What about at RHIC energy?

**Experimental observables**

- production cross section vs (mass, $p_T$)
- elliptic flow in the future

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Quark Matter 2011, Annecy

J. Zhao
**STAR detector**

- **Time Projection Chamber**  
  \(0 < \phi < 2\pi, |\eta| < 1\)  
  Tracking – momentum  
  Ionization energy loss – \(dE/dx\) (particle identification)

- **Time Of Flight detector**  
  \(0 < \phi < 2\pi, |\eta| < 0.9\)  
  Timing resolution <100ps - significant improvement for PID

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Electron Identification

- Clean electron PID in p+p and Au+Au collisions with a combination of TPC dE/dx and TOF velocity
  - Electron purity ~99% in p+p collision, ~97% in Au+Au MinBias collision.
  - Hadron contamination contribution to the correlated background is small, and has been included in the systematic uncertainties (Au+Au).

\[
\log\left(\frac{dE/dx}{B_e}\right) \quad n\sigma_e = \frac{B_e}{\sigma_e}
\]
Background Reconstruction

- Conversion electrons removed from pair reconstruction

- Background
  - a. Low mass region
    - Like Sign – acceptance corrected
    - Cross pair and Jet contribution
  - b. Mass > 0.75 GeV/c^2
    - Mixed Event
    - Like Sign

- Systematic errors
  - acceptance uncertainty < 0.1 %
  - normalization uncertainty < 0.1%

\[ B_{\text{LikeSign}} = 2 \sqrt{N_{++} \cdot N_{--}} \cdot \frac{B_{\text{Mix}}^{+ \rightarrow -}}{2 \cdot \sqrt{B_{\text{Mix}}^{+ \rightarrow +} \cdot B_{\text{Mix}}^{--}}} \]

\( N : \text{same Event} \), \( B_{\text{mix}}^{\text{mix}} : \text{mixed Event} \)

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J. Zhao
Signal/background ratio: mass(ee) ~ 0.5 GeV/c^2

~ 1:10  for p + p collisions
~ 1:200 for Au + Au minbias collisions
~ 1:250 for Au + Au central collisions
Di-electron production in $p + p$ collisions

~ 107M events!

Poster 102, B. Huang

- Consistent with hadron cocktails
- Charm cross section from STAR $p + p$ measurement\([1]\)
- Provide baseline for $Au + Au$ collisions

[1] Yifei Zhang, Friday 16:00.
Di-electron production in Au + Au collisions

Data show a hint of enhancement at LMR compared to the hadron cocktails w/o ρ.

- ρ contribution not included in the cocktail
- charm = PYTHIA*$N_{bin}$ (0.96 mb)
  real contribution in Au+Au is an open question
- $\pi^0(\pi^\pm)$, φ from STAR
- η, ω, J/ψ from PHENIX
- Green box: syst. errors on data
- Yellow band: syst. errors on cocktail

~ 270M Au+Au MinBias events

Quark Matter 2011, Annecy
Clearer LMR enhancement in central collisions compared to minbias collisions

- $\rho$ contribution not included in the cocktail

- charm = PYTHIA*$N_{\text{bin}}$(0.96mb) overpredicts the data at IMR indicating charm modifications in central Au+Au collisions

Di-electron production in Au + Au collisions

~ 150M Au+Au Central (0-10%)
**LMR Enhancement**

### Minbias (value ± stat ± sys)

<table>
<thead>
<tr>
<th>STAR</th>
<th>Central (value ± stat ± sys)</th>
</tr>
</thead>
<tbody>
<tr>
<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>1.40 ± 0.06 ± 0.38 (w/ ρ)</td>
<td>1.54 ± 0.09 ± 0.45 (w/ ρ)</td>
</tr>
</tbody>
</table>

### PHENIX

<table>
<thead>
<tr>
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<th>4.7 ± 0.4 ± 1.5</th>
<th>7.6 ± 0.5 ± 1.3</th>
</tr>
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</table>

**Enhancement factor in 0.15<\text{M}_{ee}<0.75 \text{ GeV/c}^2**

Note: Acceptance difference etc.
Low mass vector mesons

Poster 102, B. Huang ($\omega$)
Poster 103, C. Markert ($\phi$)

- $\omega$ measurements via di-lepton channel in $p+p$ and $Au+Au$ at STAR
- $\phi$ is in progress

Tsallis Blast-wave (TBW) fit:
$<\beta>=0$ in $p+p$,
$<\beta>=0.47$ in 0-80% $AuAu$.
Z. Tang et al., arXiv:1101.1912
Transverse mass spectra

- p + p result consistent with PYTHIA charm
- $m_T$ slope parameter in Au+Au is higher than that in p + p
  - hint of thermal di-lepton production and/or charm modification
- Inclusive di-lepton slope in Au+Au at RHIC is also higher than that (charm/DY subtracted) from SPS

A + A: Minbias collisions

RHIC Au + Au 200 GeV / SPS In + In 17.2 GeV

SPS data: charm/DY subtracted - PRL 100, 022302 (2008)
STAR data: inclusive di-electron, statistical error only
First di-electron measurement from 200GeV $p + p$ and $Au + Au$ collisions at STAR

Low mass region:
- Enhancement in $Au + Au$ central collisions compared to the cocktail $\rho$ in-medium modifications? – call for theory calculations in STAR acceptance

Intermediate mass region:
- Inclusive di-electron $m_T$ slope parameter is higher in $Au + Au$ compared to $p + p$
  - modification of charm and/or thermal radiation contribution?
- Need more precise measurement to constrain charm and QGP thermal radiation contributions

Outlook: STAR Heavy Flavor Tracker and Muon Telescope Detector - charm contribution!

MTD: Poster 129, L. Ruan
BACKUP
**Systematic check**

Different photonic rejection

Different background subtraction

Included in systematic uncertainties
Photon conversion removal

- Conversion electrons are removed from signal pair reconstruction.

- Difference between w/ and w/o photon conversion rejection to the final signal is less 10% at M>0.2GeV/c^2 (included in the systematic errors)

Low material budget in run9 and run10
Efficiency

Au + Au $\sqrt{s_{NN}} = 200 GeV$

MinBias

Central

STAR Preliminary

Efficiency vs. Mass($e^+e^-$) (GeV/c^2)
Background Reconstruction

Like Sign:

1: \( B_{\text{LikeSign}} = 2\sqrt{N_{++} \cdot N_{--}} \cdot \frac{B^\text{Mix}_{++}}{2 \cdot \sqrt{B^\text{Mix}_{++} \cdot B^\text{Mix}_{--}}} \)

2: \( B_{\text{LikeSign}} = a(N_{++} + N_{--}) \cdot \frac{B^\text{Mix}_{++}}{(B^\text{Mix}_{++} + B^\text{Mix}_{--})^b} \)

\[ a = \frac{\int_0^\infty 2 \cdot \sqrt{N_{++} \cdot N_{--}} \ dmdpT}{\int_0^\infty (N_{++} + N_{--}) \ dmdpT}, \quad b = \frac{\int_0^\infty 2 \cdot \sqrt{B^\text{Mix}_{++} \cdot B^\text{Mix}_{--}} \ dmdpT}{\int_0^\infty (B^\text{Mix}_{++} + B^\text{Mix}_{--}) \ dmdpT} \]

MixEvent:

- normalize mixed likeSign ++ and -- to same event ++ and --

\[ A_+ = \int_{N.R.}^{\infty} \frac{N_{++}}{B^\text{Mix}_{++}} \ dmdpT, \quad A_- = \int_{N.R.}^{\infty} \frac{N_{--}}{B^\text{Mix}_{--}} \ dmdpT \]

\[ B^\text{mix}_{++} = \int_0^\infty A_+ B^\text{mix}_{++} \ dmdpT, \quad B^\text{mix}_{--} = \int_0^\infty A_- B^\text{mix}_{--} \ dmdpT, \]

- normalize mixed unlikeSign (combinatorial background)

\[ B^\text{combinatorial}_{++-} = \frac{2\sqrt{B^\text{mix}_{++} \cdot B^\text{mix}_{--}}}{\int_0^\infty B^\text{mix}_{++-} \ dmdpT} \]

PHENIX PRC 81, 034911 (2010)
Cocktail with $\rho$

![Graphs showing dN/dM for Au+Au 200 GeV MinBias with and without $\rho$.](image)

**Without $\rho$**
- $\pi^0$, $\eta$, $\eta'$, $\omega$, $\phi$
- $J/\psi$, $\psi'$, $b\bar{b}$, $Dy$

**With $\rho$**
- $\pi^0$, $\eta$, $\eta'$, $\rho$, $\omega$, $\phi$
- $J/\psi$, $\psi'$, $b\bar{b}$, $Dy$

Data/Cocktail

Quark Matter 2011, Annecy  
J. Zhao
Enhancement in Central collisions

The fit of charm cocktail to the data gives:
0.62 ± 0.14 mb

PYTHIA setting for charm:
V6.416
MSEL=1,
PARP(91)=1.0 (kt),
PARP(67)=1 (parton shower level)
Systematic error

*MinBias*

- Normalization
- Hadron contamination
- Acceptance
- LikeSign calculation
- Photon rejection
- Total Sum

![Graph showing systematic error in MinBias](image)
Cocktail

 Inputs:

- flat rapidity (-1,1) flat $\Phi$ (0, 2$\pi$)
- $p_T$: in $p+p$, use Tsallis function fit for all measured particles in $Au+Au$ for measured $\pi^0, J/\psi$ use Tsallis function fit, and use $m_T$-scaling for $\eta, \omega, \phi, \eta$`

Zebo Tang et al, PRC 79, 051901(R) (2009)

Considered minbias centrality definition difference between PHENIX (0-93%) and STAR (0-80%)