Detailed measurements of charmonium suppression in PbPb collisions at 2.76 TeV with CMS

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for the CMS Collaboration

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J/ψ in heavy-ion collisions

- One of the most powerful tools to understand the QGP
  - Heavy quarks created at the early stage and with a large momentum transfer in gluon-gluon fusion.
  - Sequential melting
    - By Debye screening.
    - Can play a role to quantify medium properties (as thermometer).

<table>
<thead>
<tr>
<th>State</th>
<th>J/ψ (1S)</th>
<th>χc (1P)</th>
<th>ψ' (2S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m (GeV/c^2)</td>
<td>3.10</td>
<td>3.53</td>
<td>3.68</td>
</tr>
<tr>
<td>r_0 (fm)</td>
<td>0.50</td>
<td>0.72</td>
<td>0.90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Γ (1S)</th>
<th>χ_b (1P)</th>
<th>Γ' (2S)</th>
<th>χ'_b (2P)</th>
<th>Γ'' (3S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.46</td>
<td>9.99</td>
<td>10.02</td>
<td>10.26</td>
<td>10.36</td>
</tr>
<tr>
<td>0.28</td>
<td>0.44</td>
<td>0.56</td>
<td>0.68</td>
<td>0.78</td>
</tr>
</tbody>
</table>

A. Mocsy
J/ψ in heavy-ion collisions

- At lower $p_T$
  - PHENIX observed less suppression at mid-rapidity than at forward rapidity
  - ALICE observed less suppression than PHENIX

- At higher $p_T$
  - CMS measured more suppression than STAR

- At LHC
  - CMS measured more suppression at higher $p_T$ than ALICE at lower $p_T$

Phys. Rev. Lett. 98 (2007) 232301,
arXiv:1107.0532,
arXiv:1202.1383
J/ψ in heavy-ion collisions

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The difference between these results can be explained by various mixes of competing effects:
- Sequential melting
- Shadowing or saturation
- Regeneration
CMS detector

- Calorimeters (Electromagnetic & Hadron)
- Beam Scintillator Counters (BSC)
- Hadron Forward Calorimeter (HF)
- Muon Chamber (DT, RPC)
- Inner Tracker (Silicon Strip & Pixel)
- Muon Chamber (CSC, RPC)

Magnetic Field: 3.8 T

| Module       | |η| Region |
|--------------|------------------|
| Muon         | |η| < 2.4          |
| HCAL         | |η| < 5.2          |
| ECAL         | |η| < 3.0          |
| Tracker      | |η| < 2.5          |
Muon reconstruction

- Excellent muon identification & triggering in muon system.
- Excellent momentum resolution of tracking system.
  - Overall resolution: 1~2 %
Dimuon spectrum in 2011 PbPb

CMS Preliminary
PbPb $\sqrt{s_{NN}} = 2.76$ TeV

$\gamma(1,2,3S)$

$L_{\text{int}}$ (PbPb) = 147 $\mu$b$^{-1}$

$\rho, \omega, \phi$

$\psi(2S)$

$J/\psi$

$p_T^\mu > 4$ GeV/c

$\mu\mu$ (GeV/c$^2$)

Events/(GeV/c$^2$)
Dimuon spectrum in 2011 PbPb

CMS Preliminary
PbPb $\sqrt{s_{NN}} = 2.76$ TeV

$\psi(2S)$

$\psi(1,2,3S)$

Bottomonia: Tue 16:45
(Parallel 2D: Guillermo B. Rangel)

Quarkonia: Thu 11:05
(Plenary IVB: Camelia Mironov)

Z, W: Wed 12:00
(Parallel 4C: Lamia Benhabib)

EWK: Thu 9:45
(Plenary IVA: Raphael de Cassagnac)

Open Bottom: Fri 15:40
(Parallel 6A: Mihee Jo)
Prompt/non-prompt $J/\psi$

- Reconstruct opposite sign muon vertex
- 2-D unbinned maximum likelihood fit of dimuon mass and pseudo-proper decay length ($l_{J/\psi}$)

$$l_{J/\psi} = L_{xy} \frac{m_{J/\psi}}{p_T}$$
Prompt/non-prompt J/ψ

Inclusive J/ψ

- Reconstruct opposite sign muon vertex
- 2-D unbinned maximum likelihood fit of dimuon mass and pseudo-proper decay length ($l_{J/ψ}$)

$$l_{J/ψ} = L_{xy} \frac{m_{J/ψ}}{p_T}$$

This Talk !!!

PAS CMS-HIN-12-014
Prompt/non-prompt J/ψ

This Talk !!!

- Reconstruct opposite sign muon vertex
- 2-D unbinned maximum likelihood fit of dimuon mass and pseudo-proper decay length ($l_{J/ψ}$)

$$l_{J/ψ} = L_{xy} \frac{m_{J/ψ}}{p_T}$$
2011 prompt $J/\psi$ results
$R_{AA}$ of prompt $J/\psi$ vs $N_{\text{part}}$

$$R_{AA} = \frac{L_{pp} \frac{N_{\text{PbPb}}(J/\psi)}{N_{pp}(J/\psi)} \frac{\varepsilon_{pp}}{\varepsilon_{\text{PbPb}}(\text{cent})}}{T_{AA} N_{MB}}$$

CMS PbPb $\sqrt{s_{NN}} = 2.76$ TeV

- Prompt $J/\psi$

$|y| < 2.4$

$6.5 < p_T < 30$ GeV/c
$R_{AA}$ of prompt $J/\psi$ vs $N_{\text{part}}$

$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{MB}} \frac{N_{\text{PbPb}}(J/\psi)}{N_{pp}(J/\psi)} \frac{\varepsilon_{pp}}{\varepsilon_{\text{PbPb (cent)}}}$$

CMS Preliminary
\[ \text{PbPb} \sqrt{s_{NN}} = 2.76 \text{ TeV} \]

- Suppressed by factor 5 in most central

$|y| < 2.4$

$6.5 < p_T < 30 \text{ GeV/c}$

PAS CMS-HIN-12-014

Dong Ho Moon
Quark Matter 2012, Washington DC
$R_{AA}$ of prompt $J/\psi$ vs $N_{\text{part}}$

\[ R_{AA} = \frac{L_{pp}}{T_{AA} N_{\text{MB}}} \frac{N_{\text{PbPb}}(J/\psi)}{N_{pp}(J/\psi)} \frac{\varepsilon_{pp}}{\varepsilon_{\text{PbPb}(\text{cent})}} \]

CMS Preliminary
$\sqrt{s_{NN}} = 2.76$ TeV

2011

- No strong dependence on rapidity

CMS Preliminary
$\sqrt{s_{NN}} = 2.76$ TeV

Prompt $J/\psi$

- $|y| < 1.2$
- $1.2 < |y| < 1.2$
- $1.6 < |y| < 2.4$

$6.5 < p_T < 30$ GeV/c

60-100 %

0-5 %
$R_{AA}$ of prompt $J/\psi$ vs $N_{\text{part}}$

$$R_{AA} = \frac{L_{pp}}{T_{AA} N_{MB}} \frac{N_{\text{PbPb}}(J/\psi)}{N_{pp}(J/\psi)} \frac{\varepsilon_{pp}}{\varepsilon_{\text{PbPb}}(\text{cent})}$$

- Hint of less suppression at lower $p_T$

CMS Preliminary
$\text{PbPb}\sqrt{s_{\text{NN}}} = 2.76$ TeV

- 2011
2011 \( \psi(2S) \) results
$\psi(2S)$ PbPb and pp

$|y| < 1.6$ and $6.5 < p_T < 30$ GeV/c

Raw yields ratio ($\psi(2S) / J/\psi$) in PbPb is $\sim 2$ times smaller than pp.
Raw ratio ($\psi(2S) / J/\psi$) in PbPb is ~5 times larger than pp.
Double ratio of $\psi(2S)$ & $J/\psi$

\[ \frac{R_{\psi(2S)}^{PbPb}}{R_{\psi(2S)}^{PP}} = \left[ \frac{N_{\psi(2S)}}{N_{J/\psi}} \right]_{PbPb} / \left[ \frac{N_{\psi(2S)}}{N_{J/\psi}} \right]_{PP} \]

3 < $p_T$ < 30 GeV/c

For $p_T > 6.5$ GeV/c, $\psi(2S)$ are more suppressed than $J/\psi$.
Indication that $\psi(2S)$ less suppressed than $J/\psi$ for $p_T > 3$ GeV/c.
(not more than 2$\sigma$ significance, limited by pp statistics)
Summary

- **Prompt J/ψ**
  - $R_{AA}$ measured in finer bins than 2010 results
  - Significant suppression observed
  - No strong dependence on $p_T$ and rapidity

- **ψ(2S)**
  - More suppressed than J/ψ at high $p_T$ and mid-rapidity
  - Less suppressed than J/ψ at lower $p_T$ and forward rapidity
    (but not more than 2σ significance)

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN
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