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

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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).

| State | J/ψ (1S) | χ_c (1P) | ψ′ (2S) |
|-------|----------|----------|---------|
| m (GeV/c²) | 3.10     | 3.53     | 3.68    |
| r₀ (fm)   | 0.50     | 0.72     | 0.90    |

| Υ (1S) | χ_b (1P) | Υ′ (2S) | χ_b′ (2P) | Υ″ (3S) |
|--------|----------|--------|-----------|--------|
| 9.46   | 9.99     | 10.02  | 10.26     | 10.36  |
| 0.28   | 0.44     | 0.56   | 0.68      | 0.78   |

A. Mocsy
Eur.Phys.J.C61,2009
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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- At higher $p_T$
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The difference between these results can be explained by various mixes of competing effects:
- Sequential melting
- Shadowing or saturation
- Regeneration

PHB PbPb $\sqrt{s_{NN}} = 2.76$ TeV
- CMS: $6.5 < p_T < 30$ GeV/c, $|y| < 2.4$
- ALICE: $2.5 < y < 4.0$ (Preliminary - HP 2012)

AuAu $\sqrt{s_{NN}} = 200$ GeV
- PHENIX: $|y| < 0.35$
- PHENIX: $1.2 < |y| < 2.2$
- STAR: $p_T > 5$ GeV/c, $|y| < 1.0$ (Preliminary)

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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

Muon

HCAL

|η| < 2.4

|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

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

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

$J/\psi$

$\rho, \omega, \phi$

$\psi(2S)$

$\rho_{T} > 4 \text{ GeV/c}$

$m_{\mu\mu} (\text{GeV/c}^2)$
Dimuon spectrum in 2011 PbPb

CMS Preliminary
PbPb $\sqrt{s_{NN}} = 2.76$ TeV
$\gamma(1,2,3S)$

Open Bottom: Fri 15:40
(Parallel 6A: Mihee Jo)

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

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

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

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

$J/\psi$, $\rho$, $\omega$, $\phi$, $\psi(2S)$

$\rho^\mu > 4$ GeV/c

$E_{T} \mu > 1$ GeV/c

$M_{\mu\mu}$ (GeV/c$^2$)

Events/(GeV/c$^2$)
Prompt/non-prompt J/ψ

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

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

**Inclusive $J/\psi$**

- Prompt $J/\psi$
- Non-Prompt $J/\psi$ from B decays

**This Talk !!!**

- 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

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

Open bottom (Fri.)

6A: Mihee Jo

CMS Preliminary

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

- $|y| < 2.4$
- Cent. 0-100%
- $6.5 < p_T < 30$ GeV/c

Data
- total fit
- bkgd + non-prompt background

CMS Preliminary

$N_{J/ψ}$: $8525 \pm 177$
- $\alpha = 35 \pm 1$ MeV/c²
- $L_{int} = 150 \mu$b⁻¹

PAS CMS-HIN-12-014
2011 prompt J/ψ results
$R_{AA}$ of prompt $J/\psi$ vs $N_{\text{part}}$

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

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

- Prompt $J/\psi$

$|y| < 2.4$

$6.5 < p_T < 30$ GeV/c

$N_{\text{part}}$
$R_{AA}$ of prompt $J/\psi$ vs $N_{\text{part}}$

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

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

$|y| < 2.4$
$6.5 < p_T < 30$ GeV/c

- Suppressed by factor 5 in most central

CMS-HIN-12-014
$R_{AA}$ of prompt J/$\psi$ vs $N_{\text{part}}$

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

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

No strong dependence on rapidity

PAS CMS-HIN-12-014

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

6.5 < $p_T$ < 30 GeV/c

N_{\text{part}}

• No strong dependence on rapidity
$R_{AA}$ of prompt $J/\psi$ vs $N_{\text{part}}$

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

PAS CMS-HIN-12-014

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

2011

- Hint of less suppression at lower $p_T$

$|y| < 2.4$

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

$3 < p_T < 6.5 \text{ GeV/c}$

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

$1.6 < |y| < 2.4$
2011 $\psi(2S)$ results
Raw yields ratio ($\psi(2S) / J/\psi$) in PbPb is ~2 times smaller than pp.
$\psi(2S)$ PbPb and pp

1.6 < |y| < 2.4 and 3 < $p_T$ < 30 GeV/c

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

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
Back up