J/ψ and ψ(2S) production in pp and PbPb collisions at 5.02 TeV with ATLAS

Sebastian Tapia Araya, for the ATLAS Collaboration

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Why measure the Quarkonia:

Charmonia bound states of c and c\(^-\) quarks, could be a unique probe to study the hot, dense system created in nucleus-nucleus (A+A) collisions.

T. Matsui and H. Satz PLB 178 (1986) 416

However, the full picture is much more complicated

- Color-Screening: melting
- Color-exchange: absorption
- Medium induced energy loss
- Regeneration via statistical recombination
- Feed-Down of excited charmonium states and B-hadrons
Method

Reconstructed dimuons in Invariant Mass $2.6 < M_{\mu\mu} < 4.2$ GeV

Trigger PbPb
- L1 Trigger: Single MU4 (PbPb)
- High Level Trigger: 2 muons, $p_T > 4$ GeV

Trigger pp
- L1 Trigger: Double MU4
- High Level Trigger: 2 muons, $p_T > 4$ GeV

Measurements of prompt and non-prompt $J/\psi$ and $\psi(2S)$
Kinematic Range: $9 < p_T < 40$ GeV and $|y| < 2$, centrality 0-80%
Perform weighted 2D unbinned maximum likelihood fit
- dimuon Invariant mass and lifetime
- Per-dimuon weight: trigger and reconstruction efficiency; acceptance
- Parametrize signal, background and non-prompt fraction
Simultaneous Fit Method

pp projections

pseudo-proper decay time

\[ \tau = \frac{L_{xy} m_{\mu\mu}}{p_T} \]

\( L_{xy} \) = projection of decay length on the transverse plane

<table>
<thead>
<tr>
<th>i</th>
<th>Type</th>
<th>Source</th>
<th>( f_i(m) )</th>
<th>( h_i(\tau) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( J/\psi ) S</td>
<td>P</td>
<td>( \omega_i CB_1(m) + (1 - \omega_i) G_1(m) )</td>
<td>( \delta(\tau) )</td>
</tr>
<tr>
<td>2</td>
<td>( J/\psi ) S</td>
<td>NP</td>
<td>( \omega_i CB_1(m) + (1 - \omega_i) G_1(m) )</td>
<td>( E_1(\tau) )</td>
</tr>
<tr>
<td>3</td>
<td>( \psi(2S) ) S</td>
<td>P</td>
<td>( \omega_i CB_2(m) + (1 - \omega_i) G_2(m) )</td>
<td>( \delta(\tau) )</td>
</tr>
<tr>
<td>4</td>
<td>( \psi(2S) ) S</td>
<td>NP</td>
<td>( \omega_i CB_2(m) + (1 - \omega_i) G_2(m) )</td>
<td>( E_2(\tau) )</td>
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<tr>
<td>5</td>
<td>Bkg</td>
<td>P</td>
<td>flat</td>
<td>( \delta(\tau) )</td>
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<tr>
<td>6</td>
<td>Bkg</td>
<td>NP</td>
<td>( E_3(m) )</td>
<td>( E_4(\tau) )</td>
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<tr>
<td>7</td>
<td>Bkg</td>
<td>NP</td>
<td>( E_5(m) )</td>
<td>( E_6(</td>
</tr>
</tbody>
</table>
Invariant dimuon mass and lifetime

Simultaneous Fit Method

PbPb projections

Weights: Acceptance, trigger and reconstruction efficiency
As can be seen, the data are in very good agreement with the theoretical prediction within the uncertainties.
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Non-prompt fraction of J/ψ in pp 5.02 TeV vs. \( p_T \) for \(|y|\) slices

\[
\mathcal{f}_{\text{NP}}^{\psi(nS)} = \frac{N_{\psi(nS)}^{\text{NP}}}{N_{\psi(nS)}^{\text{NP}} + N_P}
\]

**ATLAS** Preliminary

\( pp \sqrt{s} = 5.02 \text{ TeV}, \int L dt = 25 \text{ pb}^{-1} \)

J/ψ Non-Prompt Fraction

- 0.00 < |\( y \)| < 0.75
- 0.75 < |\( y \)| < 1.50
- 1.50 < |\( y \)| < 2.00

Strong \( p_T \) dependence

No significant |\( y \)| dependence
Non-prompt fraction of J/ψ in pp 5.02 TeV, 13 TeV and 1.96 TeV

Good agreement between the different energies
$R_{AA}$ vs. $p_T$

Integrated $y$ and centrality

Prompt

$R_{AA} = \frac{N_{AA}}{\langle T_{AA} \rangle \sigma_{pp}}$

non-Prompt

Increasing $R_{AA}$ as a function of $p_T$

Flat along the $p_T$ range
$R_{AA}$ vs. $|y|$  
Integrated $p_T$ and centrality

**Prompt**

Integrated $p_T$ and centrality

**non-Prompt**

Integrated $p_T$ and centrality

No significant $|y|$ dependence
J/ψ is strongly suppressed in most central collisions
Suppression of $\psi(2S)$ to $J/\psi$ vs $N_{\text{part}}$

Prompt

non-Prompt

Stronger suppression of $\psi(2S)$ with respect to the $J/\psi$

Consistent with 1
Conclusions

pp collision

- Measurement of the J/ψ and ψ(2S) production Cross Section for prompt and non-prompt component.
- Measurement of non-prompt fraction.

First measurement of quarkonia production in PbPb with ATLAS

- Per-event Yields of prompt and non-prompt production of J/ψ for different centrality classes.
- non-prompt fraction for different centrality classes.
- $J/\psi R_{AA}$ as a function of $p_T$, $|y|$ and $N_{\text{Part}}$. For prompt and non-prompt component.
- ψ(2S) to J/ψ double ratio as a function of $N_{\text{Part}}$. For prompt and non-prompt component.
Additional Slides
Centrality vs. Fcal

ATLAS Preliminary

Pb+Pb, 5 μb⁻¹, \( \sqrt{s_{NN}} = 5.02 \text{ TeV} \)

\[ \Sigma E_T^{FCal} \text{ TeV} \]
Per-event-yields prompt and non-prompt $J/\psi$

$\frac{1}{N_{\text{evt}}} \frac{dN}{dy}$ vs $p_T$ for prompt $J/\psi$, $|y| < 2.0$

$\frac{1}{N_{\text{evt}}} \frac{dN}{dy}$ vs $p_T$ for non-prompt $J/\psi$, $|y| < 2.0$

Poster by Jorge
Simultaneous Fit Method

\[ \text{PDF}(m, \tau) = \sum_{i=1}^{7} \kappa_i f_i(m) \cdot h_i(\tau) \otimes g(\tau), \]

The composite PDF terms are defined as follows:

- \textit{CB} - Crystal Ball;
- \textit{G} - Gaussian;
- \textit{E} - Exponential;
- Resolution function \( g(\tau) \) is a double Gaussian function;
- \( \delta \) - delta function.