Measurements of $J/\psi \rightarrow e^+e^-$ with ALICE at the LHC

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Outline

• Motivation

• The ALICE detector at the LHC
  - $J/\psi \rightarrow e^+e^-$ reconstruction

• Results:
  - pp collisions at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 2.76$ TeV
  - Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
  - Prospects for p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

• Conclusions
Motivation (1)

- **pp collisions:**
  - Test of QCD-based models (CEM, CSM, NRQCD) in a new energy domain
  - Measure the beauty production cross section ($J/\psi \leftarrow B$) at low $p_T$
  - Reference for Pb-Pb collisions

- **p-Pb collisions:**
  - Understand Cold Nuclear Matter (CNM) effects (e.g. Nuclear Parton Shadowing)
Motivation (2)

- **Pb-Pb collisions:**
  - $c\bar{c}$ pairs produced at the early stage of the collision → sensitive to the full QGP history
  - $J/\psi$ suppression via Colour Debye Screening
    → historical QGP signature

- **Regeneration mechanisms**
  new QGP signature at LHC energies → can counteract suppression

- **Study of beauty production via displaced $J/\psi$**
The ALICE detector at the LHC

J/ψ → μ+μ- at forward rapidity → see L. Palomo's talk

Acceptance for inclusive J/ψ → e⁺e⁻ measurements: down to $p_T = 0$ at mid- rapidity

TRD, EMCAL → electron PID + trigger

ITS → vertexing + tracking
TPC → tracking + electron PID

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**J/ψ → e⁺e⁻ reconstruction**

- Kinematic cuts: $|y^{J/ψ}|<0.9$, $p_T>0.85 - 1.0$ GeV/c, $|\eta|<0.9$
- Tracking: Inner Tracking System (ITS) + Time Projection Chamber (TPC)
  - Removal of electrons from gamma conversion
- PID:
  - Energy loss measurements $dE/dx$ in TPC
- Good impact parameter resolution in the transverse plane ($\sim60\mu$m for $p_T=1$ GeV/c)
- allows the study of J/ψ detached from primary vertex, coming from B hadrons decays ($c\tau_B \sim 500\mu$m)
Results in proton-proton collisions
Inclusive J/ψ cross section in pp

- down to $p_T = 0$
- kinematical coverage complementary to the one of CMS and ATLAS
- pp at $\sqrt{s} = 2.76$ TeV → reference for Pb-Pb analyses
Non-prompt J/ψ fraction in pp at $\sqrt{s} = 7$ TeV

- Separation of prompt and non-prompt J/ψ in 4 $p_T$ bins using the pseudoproper decay length:

$$X = \frac{c \cdot L_{xy} \cdot m_{J/\psi}}{p_T^{J/\psi}}, \quad L_{xy} = \frac{\bar{p}_T^{J/\psi}}{p_T^{J/\psi}}$$

- Prompt and non-prompt J/ψ yields measured also as a function of charged particle multiplicity (→ see Renu Bala's talk on Thursday)

- Non-prompt J/ψ fraction $f_B$ measured for $p_T > 1.3$ GeV/c

$$f_B = 0.149 \pm 0.037 \text{(stat.)}^{+0.018}_{-0.027} \text{(syst.)}^{+0.025}_{-0.021} \text{(syst.pol.)}$$
Prompt J/ψ in pp at $\sqrt{s} = 7$ TeV

Good agreement for prompt J/ψ cross section with NRQCD calculations

$\frac{d\sigma_{\text{prompt J/ψ}}}{dy} = 5.89 \pm 0.60 \text{(stat.)}^{+0.88}_{-0.90} \text{(syst.)}^{+0.03}_{-0.01} \text{(extr.)}^{+1.01}_{-0.99}(\lambda_{\text{HE}}=1) \mu b.$
Non-prompt J/$\psi$ in pp at $\sqrt{s} = 7$ TeV


- Non-prompt J/$\psi$ and beauty production cross sections extrapolated down to $p_T = 0$ at mid-rapidity, using FONLL predictions [M. Cacciari et al., JHEP 07, 033 (2004).]
  - total beauty cross section from FONLL extrap.:
    \[
    \sigma(pp \rightarrow b\bar{b} + X) = 282 \pm 74(\text{stat.})^{+58}_{-68}(\text{syst.})^{+8}_{-7}(\text{extr.}) \text{ fb}
    \]
Results in Pb-Pb collisions
J/ψ → e⁺e⁻ analysis in Pb-Pb

- Inclusive J/ψ analysis:
  - $|y|<0.9$, $p_T>0$
  - $R_{AA}$ measured in three centrality classes:

$$R_{AA} = \frac{d^2N_{AA}/dp_T\,dy}{N_{coll} \times d^2N_{pp}/dp_T\,dy}$$

- Fraction of non-prompt J/ψ studied for $p_T>2$ GeV/c as a function of centrality

- Outlook:
  - $R_{AA}$ as a function of transverse momentum
  - $R_{AA}$ for prompt and non-prompt J/ψ
**Inclusive J/ψ R_{AA} vs centrality**

- Indication for reduced suppression for most central collisions w.r.t. PHENIX (similar behaviour at forward rapidity → see Lizardo Palomo's talk)

- Models which consider the (re)combination of deconfined charm pairs from the QGP are in agreement with data albeit with large uncertainties of the charm cross section

- p-Pb results are necessary to measure gluon shadowing in the Pb nucleus

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Non-prompt J/ψ fraction (1)

- Non-prompt J/ψ fraction measured in Pb-Pb for $2<\rho_T<10$ GeV/c in three different centrality classes.

- Pseudopropert decay length and inv. mass distributions with the projection of the maximum likelihood fit superimposed.
Non-prompt J/ψ fraction (2)

- No significant dependence of fraction of non-prompt J/ψ $f_B$ on centrality

- $f_B$ in centrality class 0-80% measured at low $p_T \rightarrow$ ALICE $p_T$ coverage complementary to the one of CMS

- Evidence of similar trend of $f_B$ as a function of $p_T$ in pp and Pb-Pb
Prospects for p-Pb collisions

- Minimum-bias (~50μb⁻¹) + TRD triggered (trigger on single electron) events (~1.4nb⁻¹)
- Good detector performances for both tracking and PID
- Good quality measurements expected soon
Conclusions

- pp collisions:
  - Inclusive J/ψ cross section measured at mid rapidity down to $p_T = 0$ at $\sqrt{s} = 7$ TeV and at $\sqrt{s} = 2.76$ TeV → unique at LHC
    - Cross section measured at $\sqrt{s} = 2.76$ TeV used as reference for Pb-Pb
    - Prompt and non-prompt J/ψ separated down to $p_T = 1.3$ GeV/c at $\sqrt{s} = 7$ TeV; non-prompt J/ψ and beauty production cross sections also measured down to $p_T = 0$
- Pb-Pb collisions
  - Nuclear suppression factor $R_{AA}$ measured at mid-rapidity for $p_T > 0$ as a function of centrality:
    - Indications of (re)generation of J/ψ from deconfined charm quarks (confirmed also by results at forward rapidity)
    - Analysis of p-Pb collisions will help to understand Pb-Pb results
  - Non-prompt J/ψ fraction measured for $p_T > 2$ GeV/c as a function of centrality:
    - No significant dependence on centrality
    - Suggestion of a similar trend of non-prompt J/ψ fraction $f_B$ as a function of $p_T$ for pp and Pb-Pb
    - Outlook: $R_{AA}$ for prompt and non-prompt J/ψ at low $p_T$ soon
Back-up
Systematics on non-prompt J/ψ fraction

<table>
<thead>
<tr>
<th>Centr.</th>
<th>$F_{\text{Bkg}}(x)$</th>
<th>$^{(*)}R(x)$</th>
<th>$^{(*)}\text{MC }p_T$</th>
<th>Mass (Bkg)</th>
<th>$^{(*)}\text{Mass (Sig)}$</th>
<th>$^{(*)}\chi_B(x)$</th>
<th>Tot.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10%</td>
<td>±22%</td>
<td>±15%</td>
<td>±4%</td>
<td>±6%</td>
<td>±4%</td>
<td>±4%</td>
<td>28.2%</td>
</tr>
<tr>
<td>10-40%</td>
<td>±10%</td>
<td>±10%</td>
<td>±4%</td>
<td>±3%</td>
<td>±3%</td>
<td>±3%</td>
<td>15.6%</td>
</tr>
<tr>
<td>40-80%</td>
<td>±5%</td>
<td>±5%</td>
<td>±4%</td>
<td>±1%</td>
<td>±1%</td>
<td>±2%</td>
<td>8.5%</td>
</tr>
</tbody>
</table>

- Pseudoproper decay length background shape $F_{\text{bkg}}(x)$ under the signal region
- Resolution function $R(x)$ for prompt J/ψ description
- $p_T$ spectra to describe prompt and non-prompt J/ψ to get the “corrected” $f_B$
- Invariant mass:
  - $m_{ee}$ signal shape
  - $m_{ee}$ background shape
- MC-truth pseudoproper decay length distribution for non-prompt J/ψ ($\chi_B(x)$)
- Primary vertex (negligible)

(*) contributions correlated with centrality

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