Measurements of prompt and non-prompt J/ψ production at central rapidity in pp at √s = 7 TeV with the ALICE experiment

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Physical Motivations

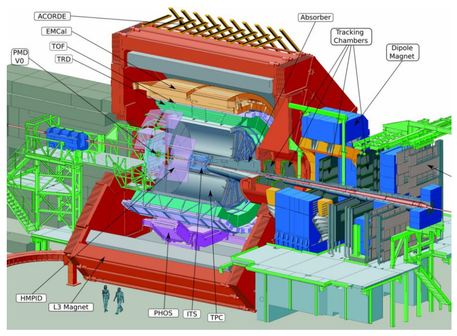
- Understand the J/ψ production mechanism: the measurements in p+p collisions at LHC energies can provide constraints for QCD calculations
- The J/ψ suppression in heavy ion collisions is one of the proposed signals for the study of the hot and dense deconfined quark-gluon medium created. Thus the understanding of the p+p reference is crucial.
- The main theoretical approaches to explain quarkonium production in pp are:
  - ✓ Color Evaporation Model (CEM) - [H.Fritzsch, PLB 67 (1977) 217]
  - ✓ Color Singlet Model (CSM) - [S.D.Ellis, M.B.Einhorn, C.Quigg, PRL 36 (1976) 1263]
  - ✓ Color Octet Model (COM) - [G.Bodwin, E.Braaten, G.Lepage, PRD51 (1995) 1125]

J/ψ production mechanism at LHC

J/ψ production at LHC is dominated by:
- prompt J/ψ: direct J/ψ+ J/ψ from higher mass resonances.
- Non-prompt J/ψ coming from Beauty hadrons decays.

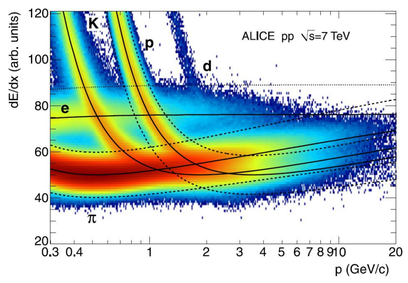
Measurements of prompt and non-prompt J/ψ components:
- ✓ direct comparison with prediction of NRQCD for prompt production
- ✓ allows to extract the beauty production cross section

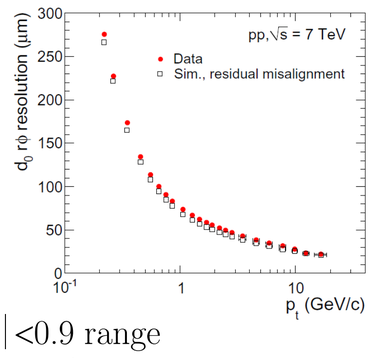
J/ψ → e⁺e⁻ in ALICE



- J/ψ analysis in ALICE is performed:
  - in the dimuon channel J/ψ → μ⁺μ⁻ at forward rapidity (-4 < y < -2.5)
  - in the dielectron channel J/ψ → e⁺e⁻ at central rapidity ((|y| <0.9)

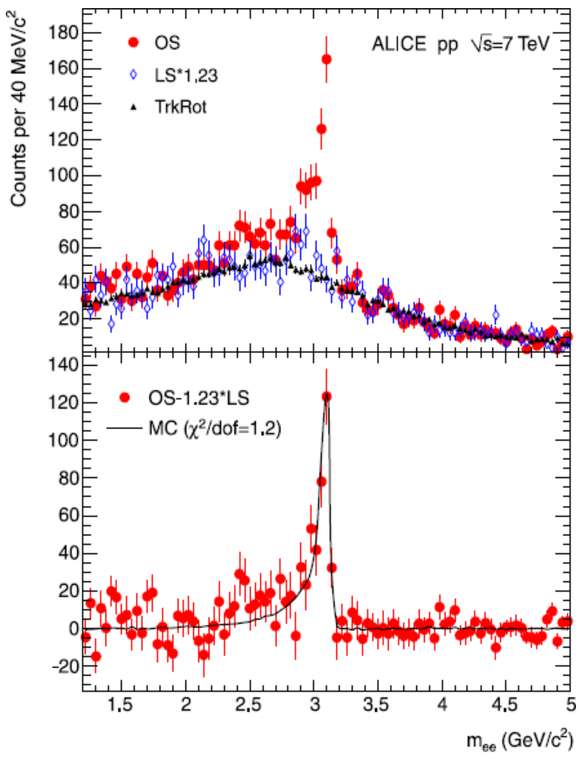
J/ψ analysis in central barrel is based on ITS (made by six layers of silicon detectors) and TPC:





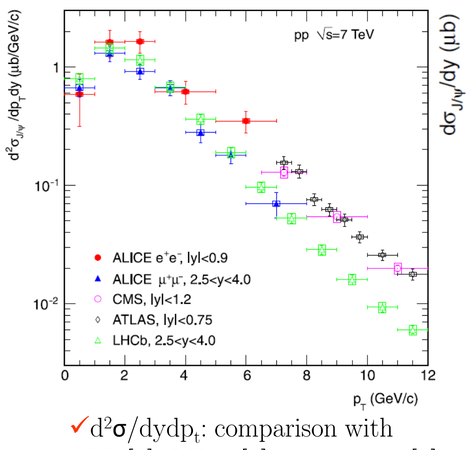
- ✓ Full azimuthal coverage in the |η|<0.9 range
- ✓ Momentum resolution ~7% at 10 GeV/c when combining ITS and TPC
- ✓ PID done via specific energy loss (dE/dx) allows the separation of electrons
- ✓ Rejection of electrons from photon conversions in the detector material
- ✓ Very good resolution for the measurement of secondary vertices from beauty decays (B→J/ψ+X) thanks to the SPD (composed by the two innermost layers of ITS)

Inclusive J/ψ production cross section



- 350 M minimum bias proton-proton events (L_{int}=5.6nb^{-1})
- Single track selection:
  - ✓ standard track quality tracks
  - ✓ at least one hit in one of the two SPD's layers
  - ✓ $p_t(e^{\pm})$>1 GeV/c
- PID cuts (only TPC in this analysis [1]):
  - ✓ 3 σ band electron inclusion
  - ✓ 3 (3.5) σ band proton (pion) exclusion
  - ✓ rejection of electrons tagged from conversion
- Signal extraction:
  - ✓ Like-sign ($N^{++}+N^{--}$) scaled to match with unlike-sign between 3.2-5 GeV/c²
  - ✓ Bin counting in 2.92-3.16 GeV/c²

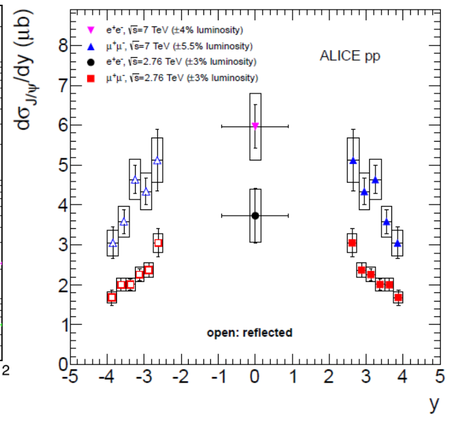
- Transverse and rapidity dependence of J/ψ cross section:



✓ $d^2\sigma/dydp_t$: comparison with CMS[2], LHCb[3] and ATLAS[4] results

✓ p_t spectrum distribution at mid-rapidity is harder than the same at forward rapidity

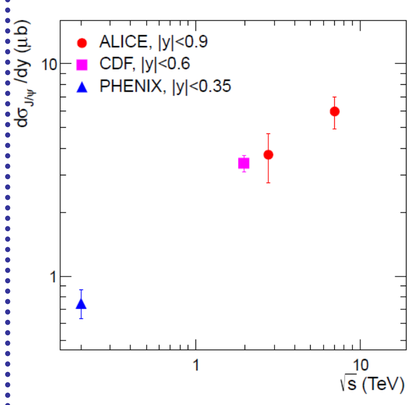
✓ At mid-rapidity CMS and ALICE cover complementary p_t ranges



✓ dσ/dy[5] measured by ALICE at mid and forward rapidity: comparison of results at √s=2.76TeV and √s=7 TeV

✓ vertical bars show statistical errors while boxes represent systematic uncertaintes

- √s dependence of J/ψ cross section:



✓ Kinematic coverage of the ALICE experiment is unique at LHC (down to pt = 0 at central rapidity) → This allows a comparison with similar results from lower energy collider experiments[5]

Separation of prompt and non-prompt J/ψ: unbinned likelihood fit

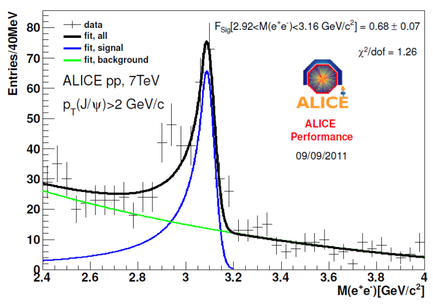
- Basic idea: J/ψ from B is likely to be displaced from the primary vertex where B-hadrons are produced (displaced J/ψ)
- Analysis is based on a simultaneous 2D fit of
  1. the invariant mass spectrum
  2. an "impact parameter" to separate prompt from detached J/ψ, e.g. pseudo- proper decay time (à la CDF[5])

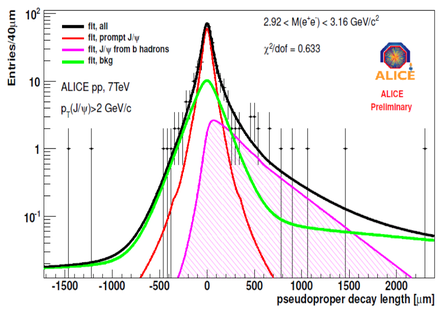
$$x = L_{xy}(J/\psi)\cdot\frac{M_{J/\psi}}{p_T(J/\psi)} \qquad L_{xy}(J/\psi) = \frac{\vec{L}\cdot\vec{p}_T(J/\psi)}{|\vec{p}_T(J/\psi)|} = \frac{(\vec{r}_{vtx}^{\,sec} - \vec{r}_{vtx}^{\,prim})\cdot\vec{p}_T(J/\psi)}{|\vec{p}_T(J/\psi)|}$$

- Simultaneous mass and lifetime fit performed using the log-likelihood function:

$$\ln L = \sum_{i=1}^{N} \ln F(x, m_{ee}) \qquad F(x,m_{ee}) = \underbrace{f_{Sig}\times F_{Sig}(x)\times M_{Sig}(m_{ee})}_{\text{"Signal" part (prompt + secondary)}} + \underbrace{(1-f_{Sig})\times F_{Bkg}(x)\times M_{Bkg}(m_{ee})}_{\text{"Background" part}}$$

- Main ingredients of the fit are:
  - ✓ resolution function R(x) to describe prompt J/ψ "x" distribution → fixed on Monte Carlo
  - ✓ $F_{bkg}(x)$ to describe the "x" distribution of the background → fixed on "x" distribution taken from the sidebands
  - ✓ $\chi_B(x)$ → "x" template distribution for J/ψ from beauty decays





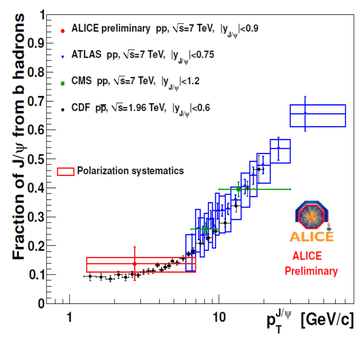
- Likelihood fit performed for p_t >2 GeV/c to extract prompt and non-prompt J/ψ cross section
  - resolution function R(x) to describe prompt J/ψ distribution is candidate's type dependent → candidate were divided in three types:
    FF → both the electron and the positron have hits in the first pixel layer
    FS → one of two legs has a hit in the first layer and the other does not
    SS → none of the legs has a hit in the first layer
  - same cuts used for inclusive analysis, but SS candidates were excluded

$$f_B(p_t > 2GeV/c) = 0.150 \pm 0.041(stat.) \pm 0.018(syst)^{+0.023}_{-0.032}(syst.pol)$$

$$\frac{d\sigma^{prompt}}{dy}(|y|<0.9, p_T > 2GeV/c) = 3.20 \pm 0.35(stat) \pm 0.43(syst)^{+0.82}_{-0.58}(syst.pol)\mu b$$

$$\frac{d\sigma^{non-prompt}}{dy}(|y|<0.9, p_T > 2GeV/c) = 0.56 \pm 0.16(stat) \pm 0.12(syst)\mu b$$

- Fraction of secondary J/ψ measured by ALICE in 1.3<p_T <7 GeV/c: comparison with other LHC experiments (CMS[2], ATLAS[4]) and with CDF[6] results at lower energy :



✓ ALICE reaches lower p_t region for the measurements of f_B → unique measurement at LHC

✓ bars: statistical + systematical errors added in quadrature

✓ polarization uncertaintes shown by boxes

Conclusions and outlook:

- ALICE has measured the inclusive cross section and the fraction of non-prompt J/ψ at mid rapidity, reaching the lowest pt region at LHC
- New results with analysis performed in pt bins (which cover also the measurement of beauty production cross section) will come out soon

References:

[1] K. Aamodt et al. (ALICE Collaboration), Phys. Lett. B704, 442 (2011).
[2] V. Khachatryan et al. (CMS Collaboration), Eur. Phys. J. C71, 1575 (2011).
[3] R. Aaij et al.(LHCb Collaboration), Eur. Phys. J. C71, 1645 (2011).
[4] G. Aad et al. (ATLAS Collaboration), Nucl. Phys. B850, 387 (2011).
[5] B. Abelev et al.(ALICE Collaboration), arXiv:1203.3641v1 (2012).
[6] D. Acosta et al. (CDF Collaboration), Phys. Rev. D71, 032001 (2005).