Measurement of the J/ψ cross section in pp collisions at $\sqrt{s} = 13$ TeV

Heber Zepeda Fernández
Advisor: Dr. Alberto Sánchez Hernández
CINVESTAV, CMS
http://inspirehep.net/record/1447964

May 25, 2016

Outline

Introduction

Introduction: J/ψ production

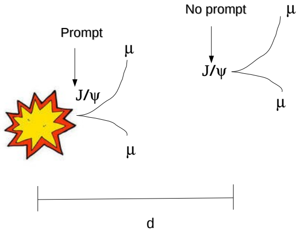


Figure : Prompt and no-prompt production of J/ψ.

Introduction: How is it possible?

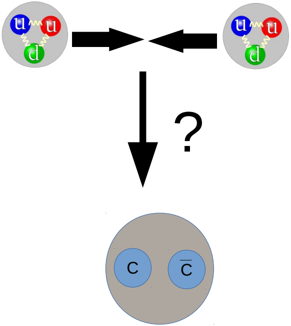


Figure : J/ψ from proton-proton collision.

Introduction: Explaining production

Several models:

- Color-Singlet Model

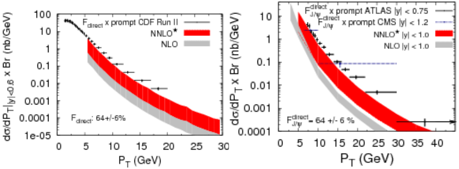
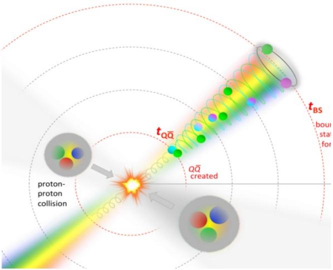


Figure : NLO and NNLO*CS contributions at (left) $\sqrt{s} = 1.96$ TeV and (right) $\sqrt{s} = 7$ TeV. Taken from **Journal of Physics G: Nuclear and Particle Physics, 38, Number 12.**

Introduction: Explaining production

- NRQCD factorization: Short-distance (Color Singlet Model) and long-distance (Color Octet Model).
- Fragmentation function aproach: 1.- All information incoming state and 2.- $Q\bar{Q} \rightarrow$ quarkonium; phenomenological.



The two steps of quarkonium production. The initial $Q\bar{Q}$ in $t_{Q\bar{Q}}$ and the final state t_{BS} is the bound state.

Introduction: High energy (7 TeV) at LHC: CMS

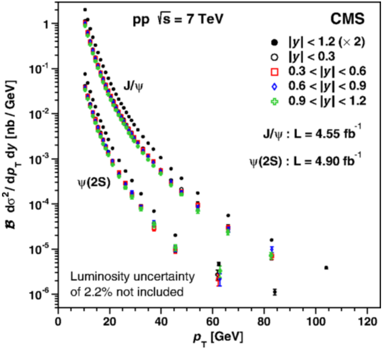
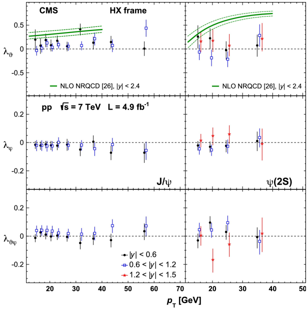


Figure : The J/ψ and $\psi(2S)$ differential p_T cross sections times the dimuon branching fractions for four rapidity bins and integrated over the range $|y| < 1.2$. Taken from **Phys. Rev. Lett. 114, 191802**

Introduction: J/ψ is not polarized.



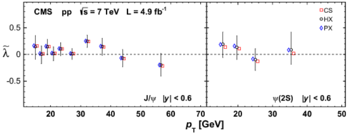


Figure : Left: Polarization parameters for prompt. Right: Values of λ parameter of polarization. Taken from **Phys. Lett. B 727 (2013)**

Models fail to describe simultaneously J/ψ differential cross-section and polarization measurements.

The Compact Muon Solenoid (CMS)

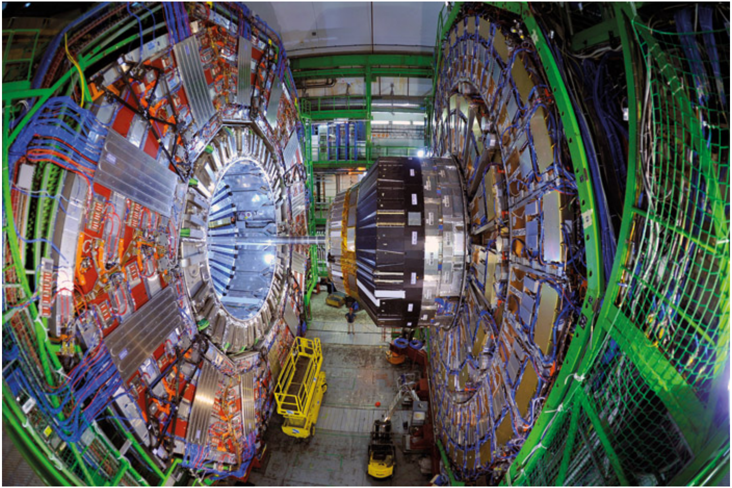
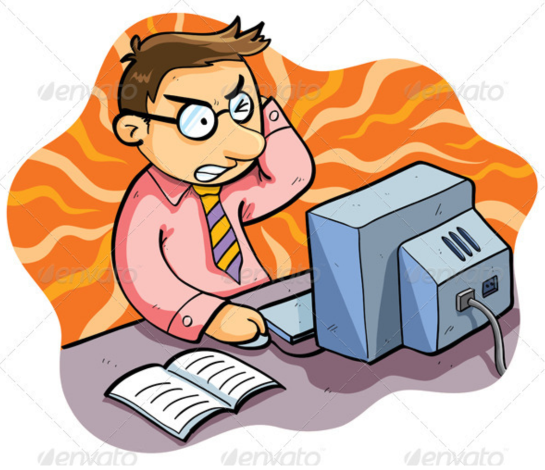


Figure : The incredible CMS detector

Measurment of the cross section

Measurment of the cross section



Before everything

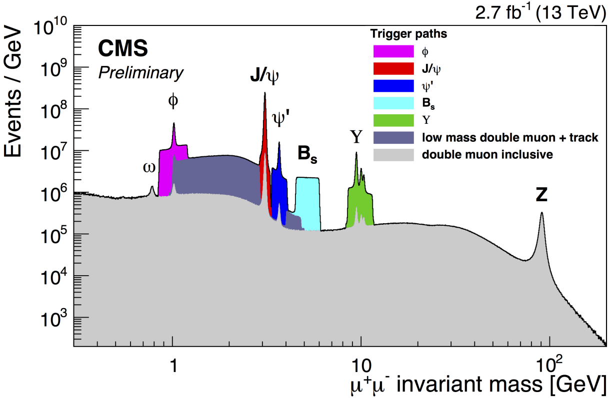


Figure : Different masses can be reconstructed using CMS tracking.

Cross section

The differential cross section is given by:

$$Br(J/\psi \to \mu\mu) \cdot \frac{d^2\sigma}{dp_T dy} = \frac{N^{c\bar{c}}(p_T, y)}{\mathcal{L}\Delta y \Delta p_T} \left\langle \frac{1}{\epsilon(p_T, y)\mathcal{A}(p_T, y)} \right\rangle, \qquad (1)$$

The measurement:

- 2.4 fb^{-1}
- $20 < p_T(J/\psi) \sim 120$ GeV and $|y| < 1.2$ (increasing 0.3).

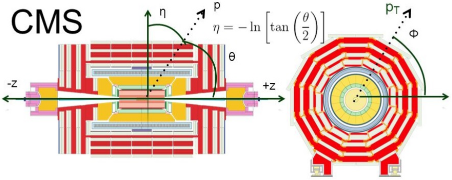


Figure : Barrel region

Measurement of the yields $N(c\bar{c})$

- The yields: using an unbinned extended maximum likelihood fit.

$$F(m_{\mu\mu}) = \mathbf{n_{Sig}} \cdot \mathbf{M_{Sig}}(\mathbf{m}_{\mu\mu}) + \mathbf{n_{Bkg}} \cdot \mathbf{M_{Bkg}}(\mathbf{m}_{\mu\mu}). \quad (2)$$

- Lifetime to separate prompt and non prompt.

$$ct = L_{xy} \cdot m_{J/\psi}/p_T, \qquad L_{x,y} = \frac{\mathbf{u^T}\sigma^{-1}\mathbf{x}}{\mathbf{u^T}\sigma^{-1}\mathbf{u^T}} \quad (3)$$

- The lifetime $\mathcal{L}(ct, \sigma_l)$ pdf is given by:

$$\mathcal{L}(ct, \sigma_l) = \mathrm{n_{sig}} \cdot (f_{NP}(ct, \sigma_{ct,i}) \cdot L_{NP}(ct, \sigma_{ct,i}) + (1 - f_{NP}) \cdot L_{PR}(ct, \sigma_{ct,i})) + n_{Bkg} \cdot L_{Bkg}(ct, \sigma_{ct,i}), \quad (4)$$

  - $L_{PR}(ct)$: Delta function (G) convolved with G.
  - $L_{NP}(ct)$: Exponential decay convolved G.
  - $L_{Bkg}(ct)$: Sum of two G + exponential decay conv. with the G.

Measurement of the yields $N(c\bar{c})$

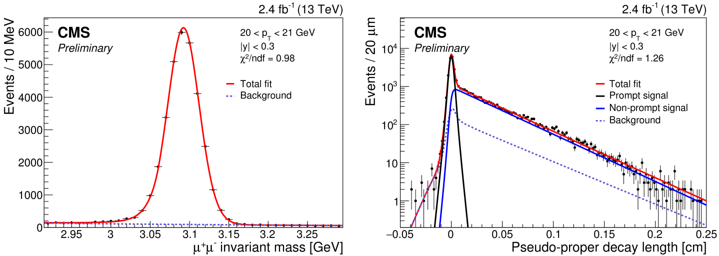


Figure : J/ψ mass (left) and lifetime (right).

Acceptance and efficiency

- Acceptance

We used Monte Carlo simulation.

$$\mathcal{A}(p_T, y) = \frac{N^{gen}_{|kin}(p_T, y)}{N^{gen}(p_T, y)}. \tag{5}$$

- Efficiency

We used data.

$$\epsilon_{\mu\mu}(p_T, y) = \epsilon(p_{T1}, \eta_1) \cdot \epsilon(p_{T2}, \eta_2) \cdot \rho(p_T, y) \cdot \epsilon^2_{tk} \tag{6}$$

- All efficiencies from data.
- $\epsilon(p_{T_i}, \eta_i) = \epsilon_{reco} \cdot \epsilon_{L1L2} \cdot \epsilon_{L3}$, from TnP technique.
- $\epsilon_{\mu\mu}$ = Reconstructed / Accepted.

Systematic uncertainties

- Uncertainties in the estimation of the yield.
- Statistical.
- Non-prompt fraction statistical.
- Acceptance statistical.
- ρ statistical.
- Conditional single efficiencie.
- L3 scale factor.
- Single efficiency.
- Non-prompt fraction systematical.
- Yield systematic.
- ρ Systematical.

Measurement of cross section

We have all the numbers of

$$Br(J/\psi \to \mu\mu) \cdot \frac{d^2\sigma}{dp_T dy} = \frac{N^{c\bar{c}}(p_T, y)}{\mathcal{L}\Delta y \Delta p_T} \left\langle \frac{1}{\epsilon(p_T, y)\mathcal{A}(p_T, y)} \right\rangle, \quad (7)$$

So, we can calulate the cross section of the $J/\psi \to \mu\mu$:

Measurement of cross section: Non-Prompt fraction

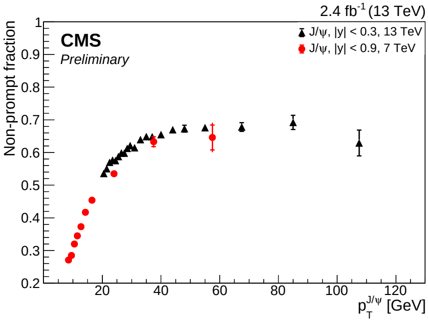


Figure : Comparison of the non-prompt fraction of J/ψ as function of dimuon p_T for 13 TeV and 7 TeV. The inner error bars represent the statistical uncertainty while the total errors show the statistical and systematic uncertainties.

Measurement of the Cross section

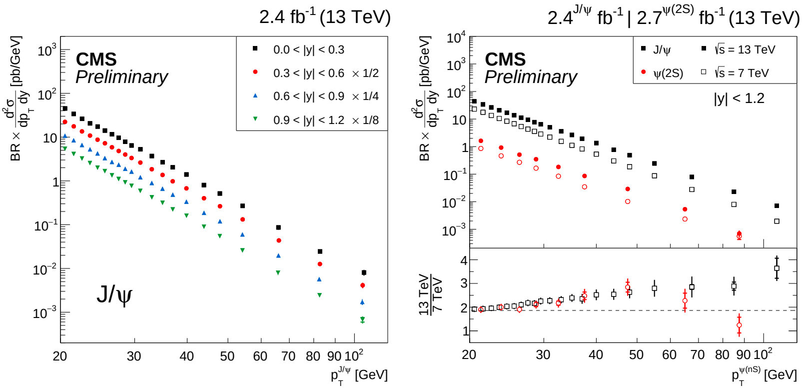


Figure : Prompt cross sections times branching ratios for the J/ψ (left). Comparison of 7 TeV and 13 TeV cross sections.

Conclusions

- The differential production of J/ψ cross section have been measured in pp collisions at $\sqrt{s} = 13$ TeV with the CMS detector at the LHC.
- This measurement has been performed in central rapidity region ($|y| < 1.2$) as function of p_T in several rapidity region.
- We studied the p_T from 20 GeV to 120 GeV.
- We could make the ratios of cross sections measured at 13 TeV and 7 TeV.

References

CMS-PAS-BPH-15-005,
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Thanks

References

CMS-PAS-BPH-15-005,
*http : //inspirehep.net/record/*1447964