# Measurement of the $J/\psi$ and $\psi(2S)$ cross section in pp collisions at $\sqrt{s} = 13$ TeV

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# Outline




# Introduction

# Introduction: Prompt and Non prompt production

Let's take a $J/\psi$ for the example.

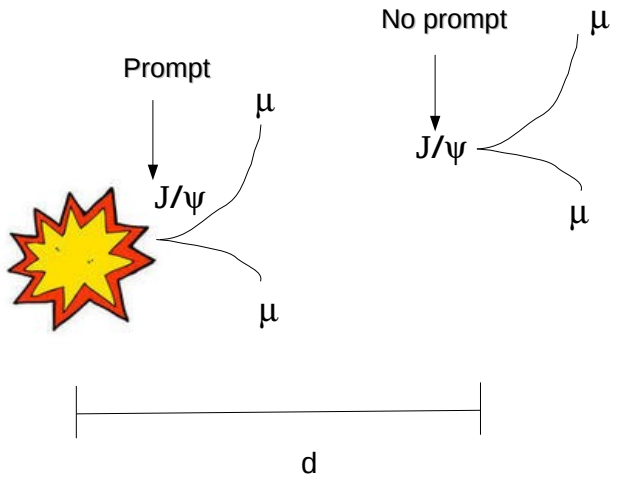



Figure: Prompt and no-prompt production of $J/\psi$.

# Introduction: How is it possible?

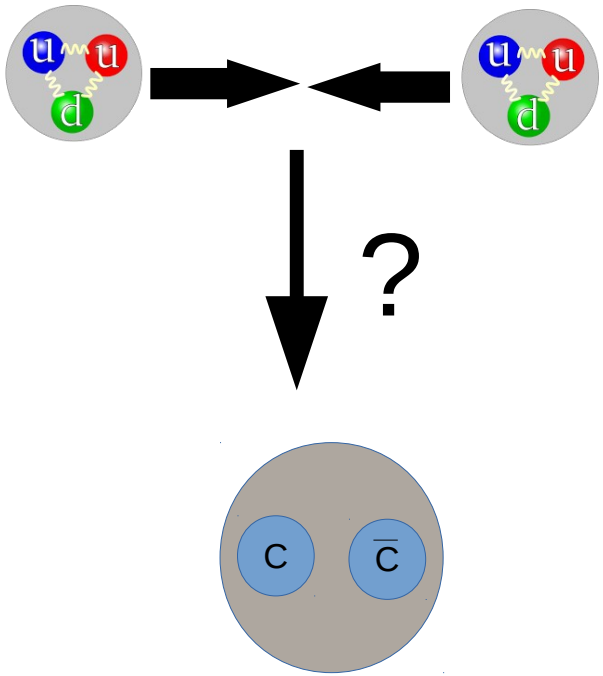
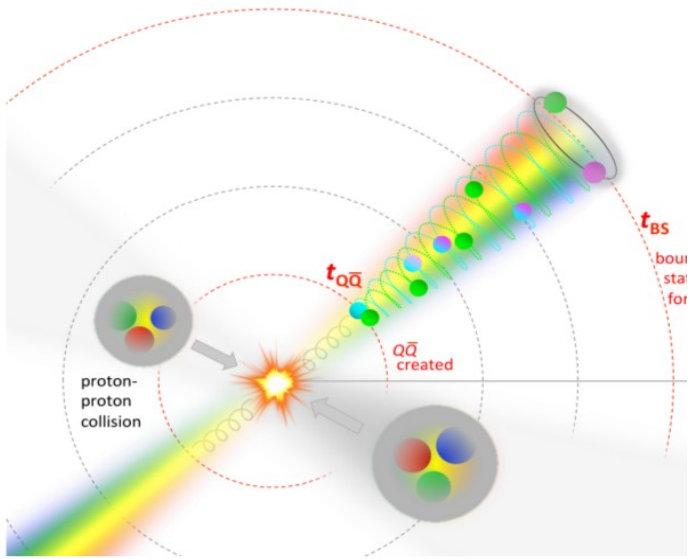



Figure: $J/\psi$ from proton-proton collision.

# Introduction: Explaining production

- NRQCD factorization: Short-distance (Color Singlet Model) and long-distance (Color Octet Model).




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: Explaining production

Several models:

- Color-Singlet Model

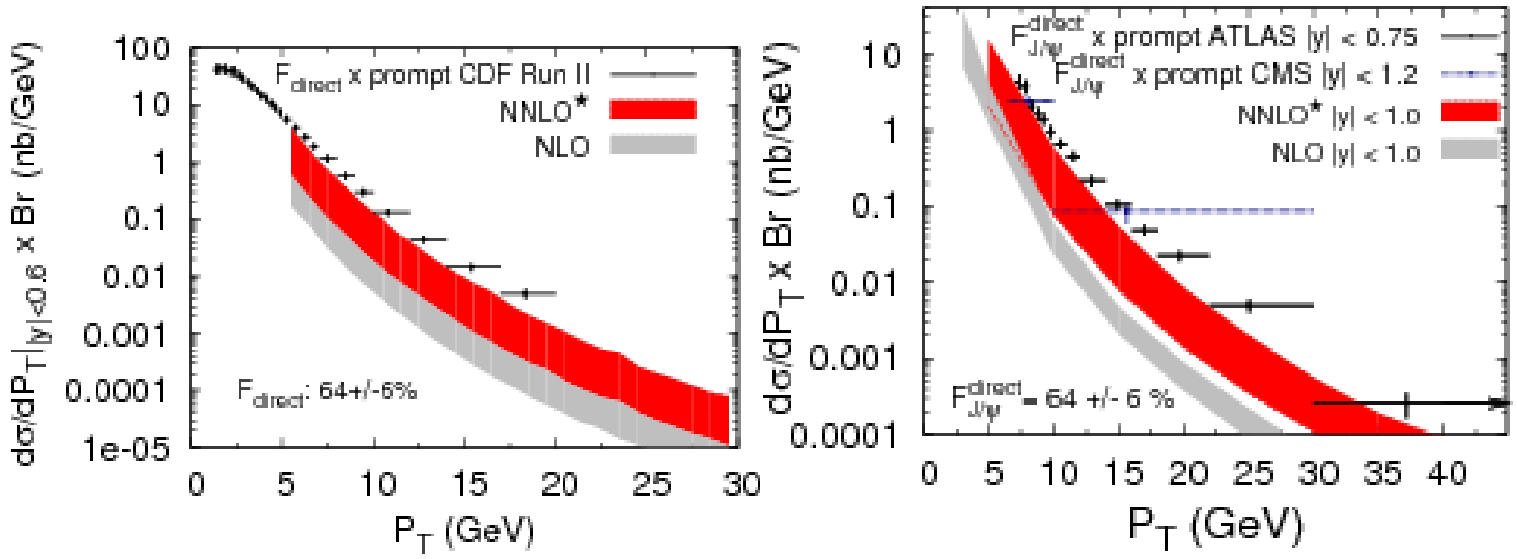



Figure: NLO and NNLO*CS contributions at (left)$\sqrt{s} = 1.96$ TeV and (right) $\sqrt{s} = 7$ TeV. Taken from **Journal of Physics G: Nuclear and Particle Physics, 38, Number 12.**

# The Compact Muon Solenoid (CMS)

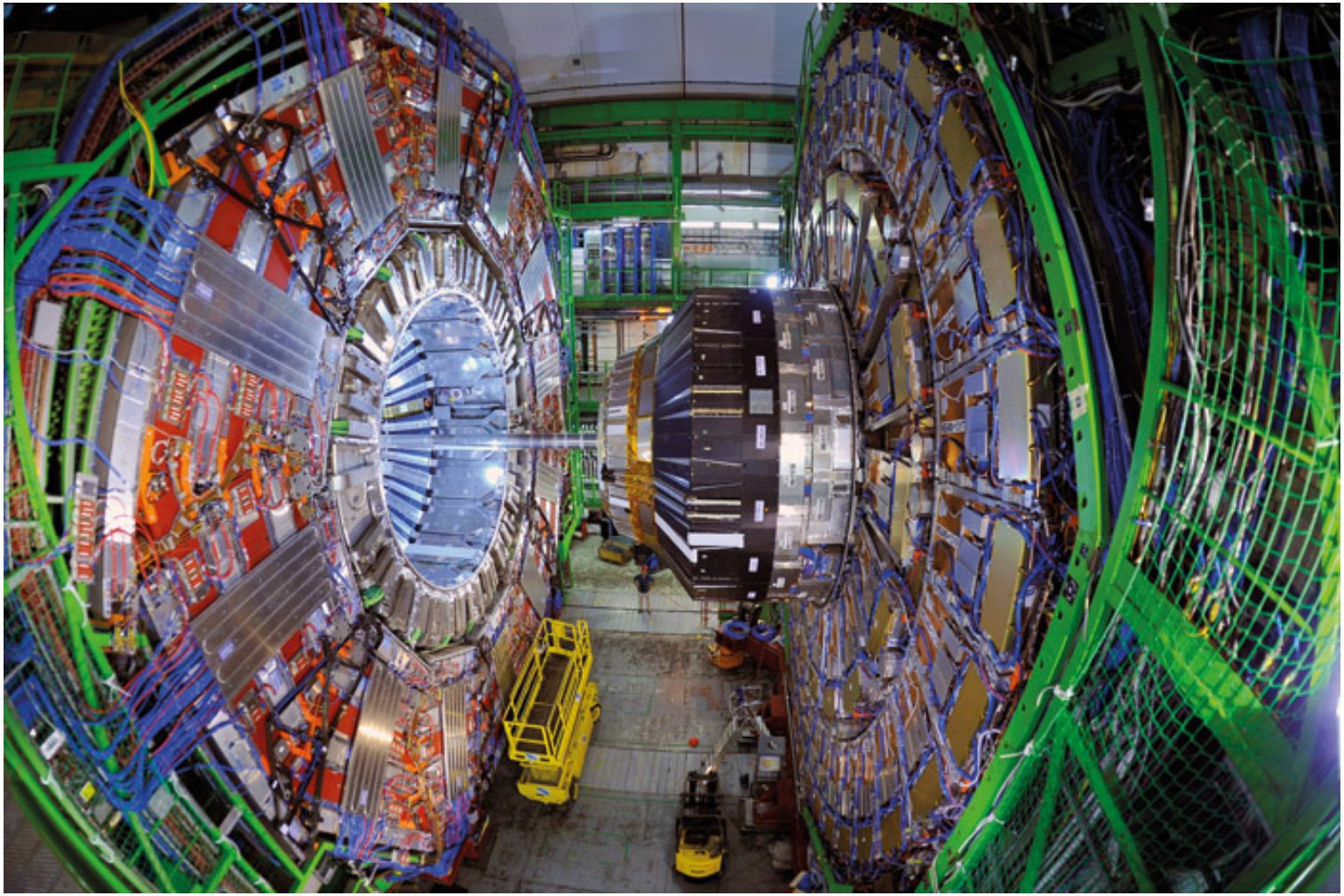


Figure: The incredible CMS detector

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

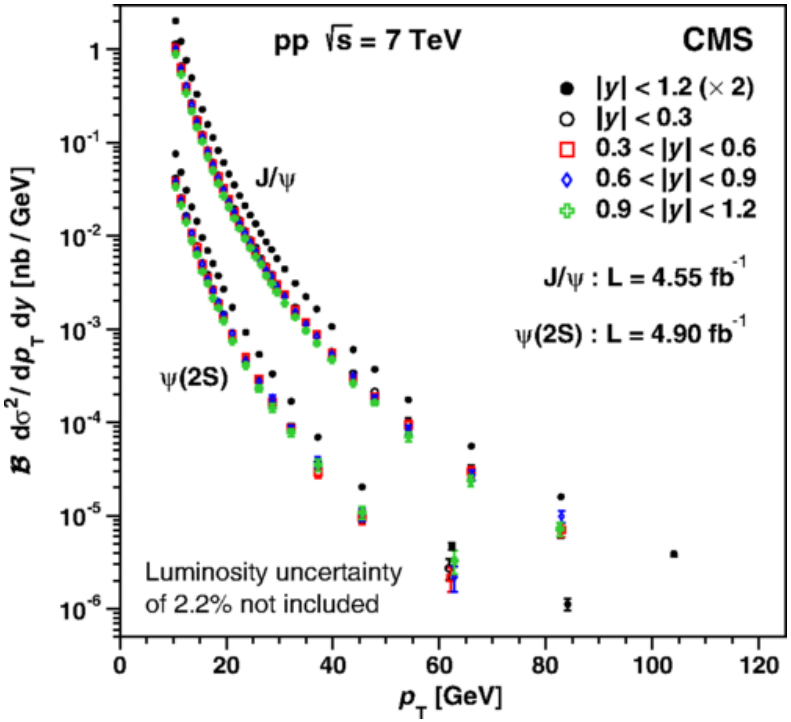



Figure: The $J/\psi$ and $\psi(2S)$ differential $p_T$ cross sections times the dimuon branching fractions for four rapidity bins and integrated over the range $|y| < 1.2$. Taken from **Phys. Rev. Lett. 114, 191802**

# Before the unknown, the known.

It was necessary to re-discovered.

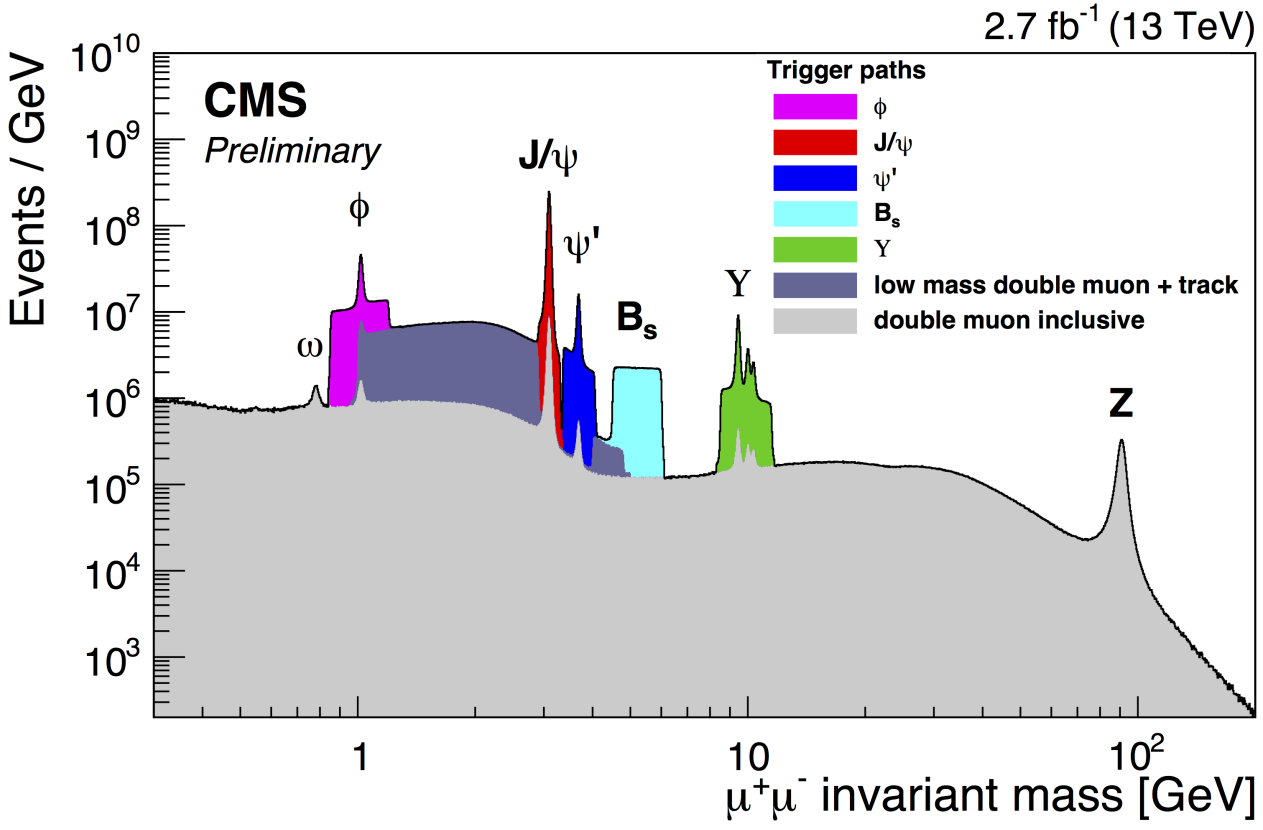



Figure: Different masses can be reconstructed using CMS tracking.

# Measurement of the cross section

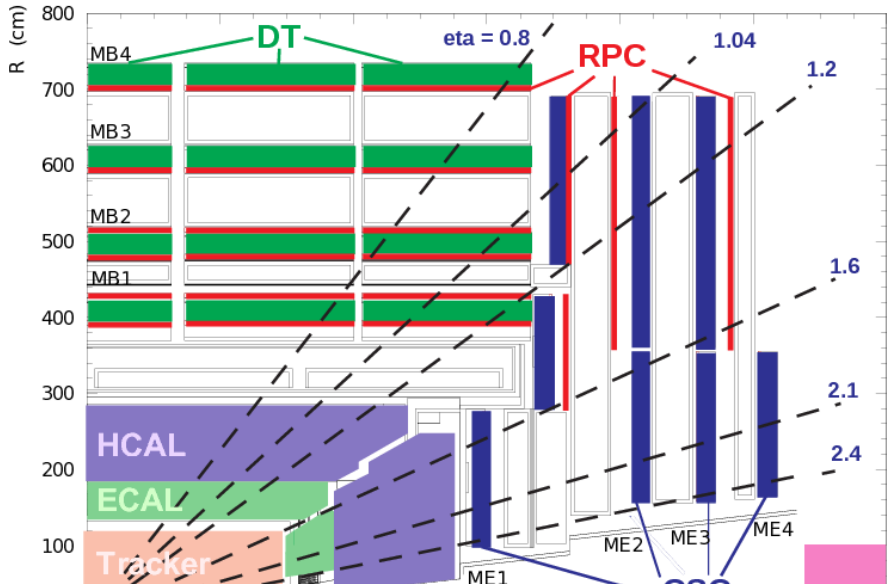
# Cross section

The differential cross section is given by:

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

The measurement:

- 2.4 $fb^{-1}$ for $J/\psi$ and 2.7 $fb^{-1}$ for $\psi(2S)$
- 20 GeV $< p_T \sim$ 120 GeV and $|y| < 1.2$ (increasing 0.3) for both particles.



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

- Mass fit: Different PDF function for $J/\psi$ and $\psi(2S)$.
- Lifetime fit: To separate Prompt and No-Prompt.

As example,

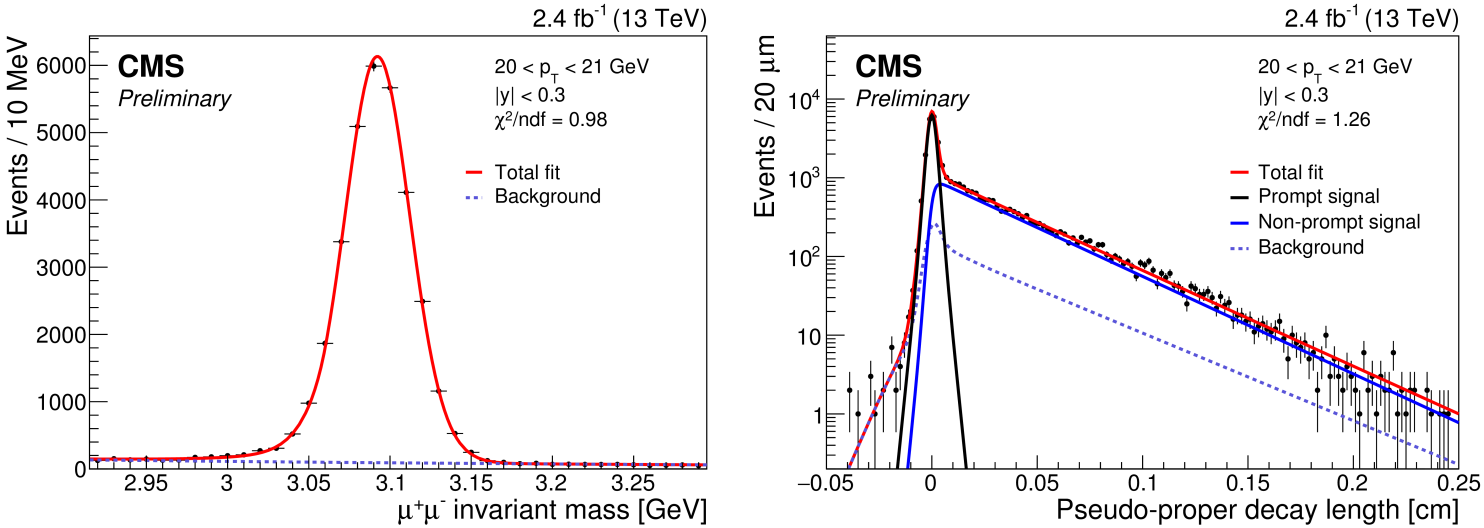



Figure: Mass fit (left) and lifetime fit (right) for *J/psi* in a particular $y$ and $p_T$ bin.

# Acceptance and efficiency

- Acceptance

We used Monte Carlo simulation.

$$\mathcal{A}(p_T, y) = \frac{N^{gen}_{|kin}(p_T, y)}{N^{gen}(p_T, y)}. \tag{2}$$

- Efficiency

We used data.

$$\epsilon_{\mu\mu}(p_T, y) = \epsilon(p_{T1}, \eta_1) \cdot \epsilon(p_{T2}, \eta_2) \cdot \rho(p_T, y) \cdot \epsilon^2_{tk} \tag{3}$$

- 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.
  - MC.
  - Statistic of sample.
- Reconstruction efficiency.
  - Single muon efficiency.
  - Dimuon orrelation ($\rho$).
- Rapidity integrated range.


# Measurement of cross section

We have all the numbers of

$$Br(\psi \to \mu\mu) \cdot \frac{d^2\sigma}{dp_T dy} = \frac{N^{c\bar{c}}(p_T, y)}{\mathcal{L}\Delta y \Delta p_T} \left\langle \frac{1}{\epsilon(p_T, y)\mathcal{A}(p_T, y)} \right\rangle, \tag{4}$$

So, we can calulate the cross section:


# Measurement of cross section: Prompt $J/\psi$ and $\psi(2S)$

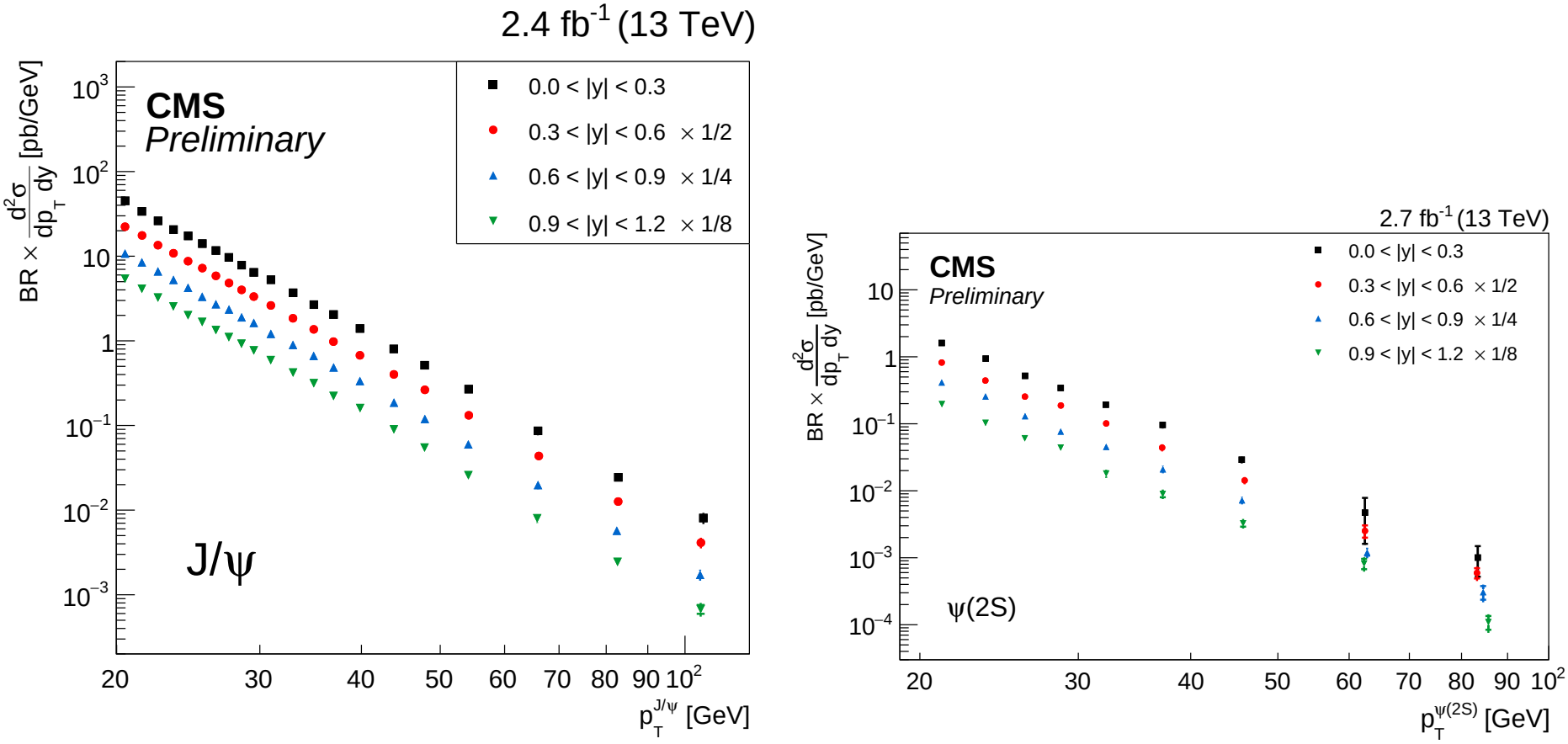
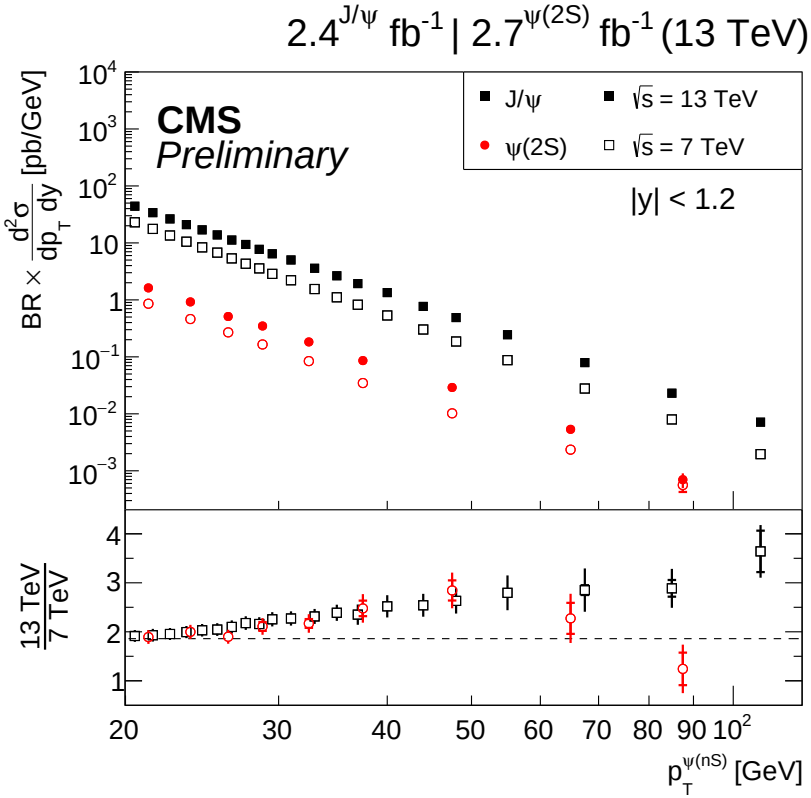



Figure: Prompt cross section times branching ratios for the $J/\psi$ (left) and $\psi(2S)$(right) in several rapidity ranges for the barrel trigger.

# Measurement of the Cross section



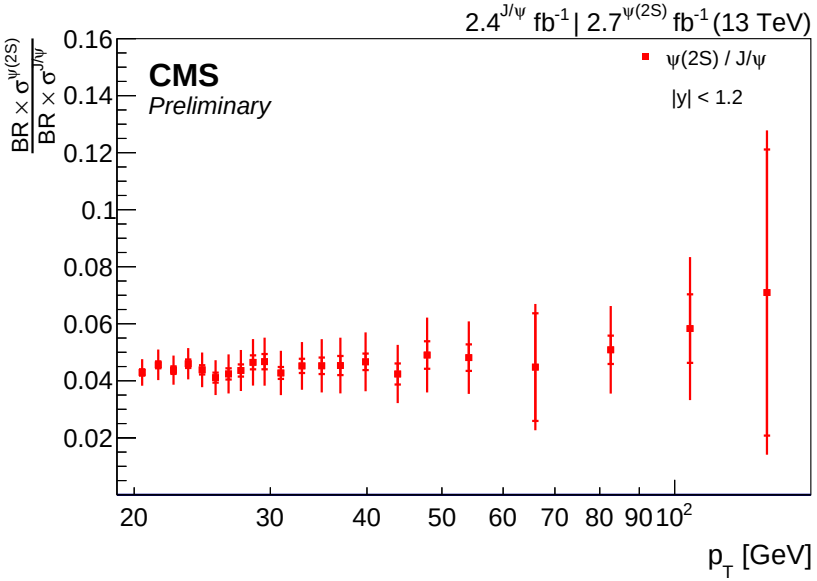
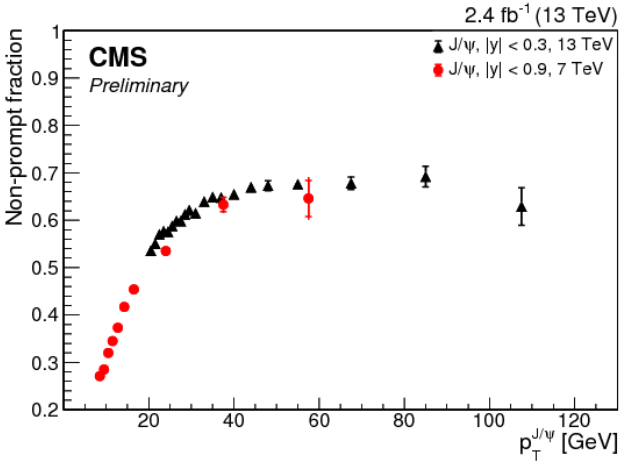




Figure: (left) Prompt cross sections times branching ratios for the $J/\psi$ Comparison of 7 TeV and 13 TeV cross sections. (right) Cross section ratios $\psi(2S)/J/\psi$ (right).

# Measurement of the Cross section



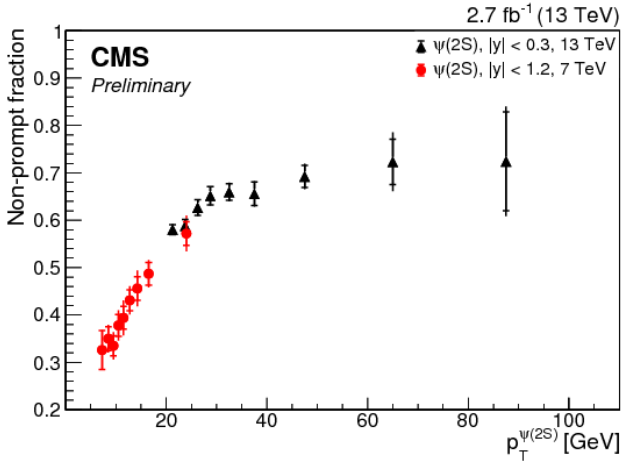




Figure: (Comparison of the non-prompt fraction of $J/\psi$ (left) and $\psi(2S)$ (right) as a function of dimuon pT for 13 TeV and 7 TeV.


# Conclusions

- The differential production of $J/\psi$ and $\psi(2S)$ 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.
- **The complete result will be public in few weeks.**

## References

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

# Thanks

## References

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