Measurement of the production cross-section of J/ψ and ψ(2S) mesons at high transverse momentum in pp collisions at √s = 13 TeV with the ATLAS detector

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on behalf of the ATLAS collaboration
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Introduction

Analysis goal

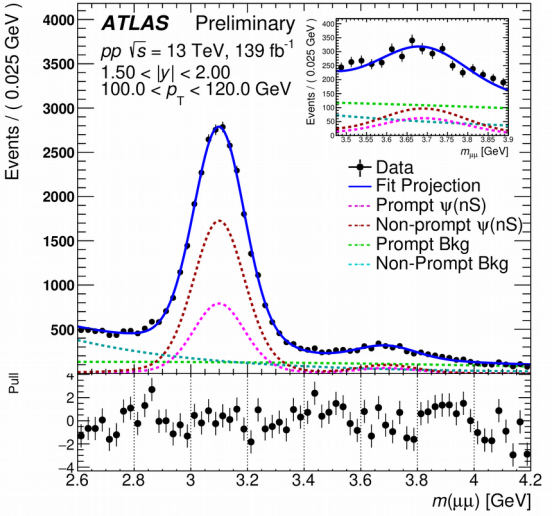
- Perform the measurement of J/ψ and ψ(2S) production cross-sections;
- Separately for prompt and non-prompt contributions;
- Measure ψ(2S) to J/ψ production ratios;
- Reach highest possible transverse momentum;
- 12 bins in p_T between 60 GeV up to 360 GeV, 3 bins in rapidity;
- Broaden the scope of comparison between theory and experiment.

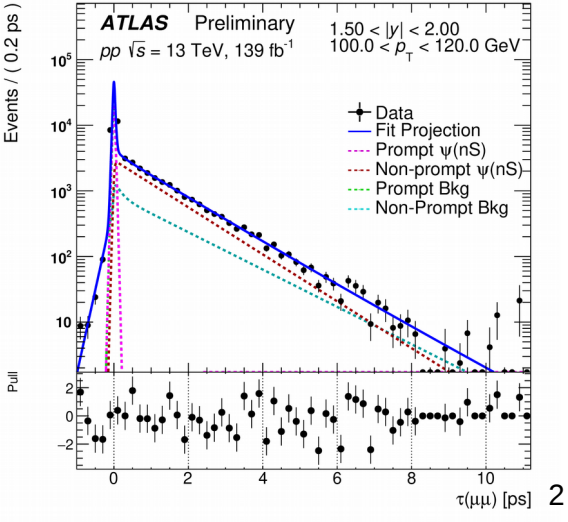
Strategy

- Full Run 2 statistics of LHC pp collisions at √s=13 TeV with ATLAS detector;
- Integrated luminosity L = 139 fb^{-1};
- Use a single-muon trigger, with p_T > 50 GeV;
- Select charmonium candidates as pairs of oppositely charged muons.
- Perform 2-dimensional unbinned maximum-likelihood fits to mass and pseudo-proper decay time (Formula 1) to extract yields. The transverse distance L_{xy} between the primary vertex and the dimuon vertex is used to calculate the pseudo-proper decay time:

$$\tau = \frac{m_{\mu\mu}}{p_T} \cdot \frac{L_{xy}}{c} \qquad (1)$$

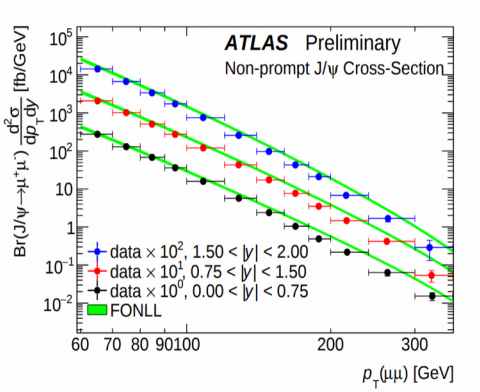
  where $m_{\mu\mu}$ and p_T are respectively the mass and the transverse momentum of the dimuon.
- Apply corrections for acceptance, efficiency and bin migration.

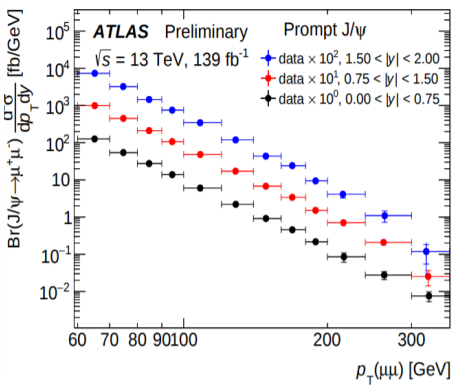




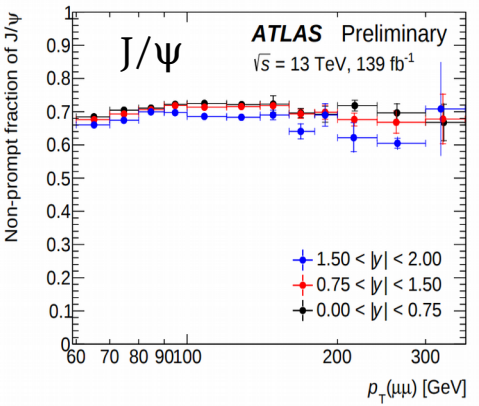
Results

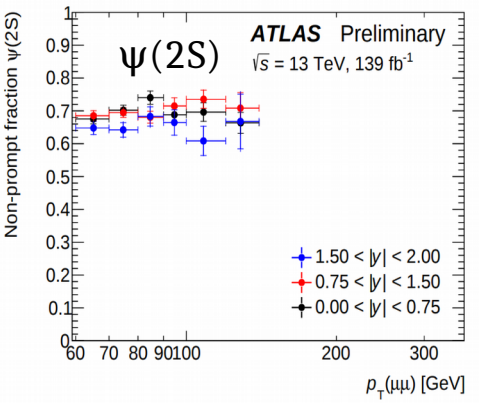
- After the 2D fit procedures are performed, double-differential cross sections are calculated for prompt and non-prompt J/ψ and ψ(2S).
- Non-prompt production results are compared with FONLL and gives good agreement at the lower p_T, but with FONLL predicting somewhat higher cross-sections at high-p_T.



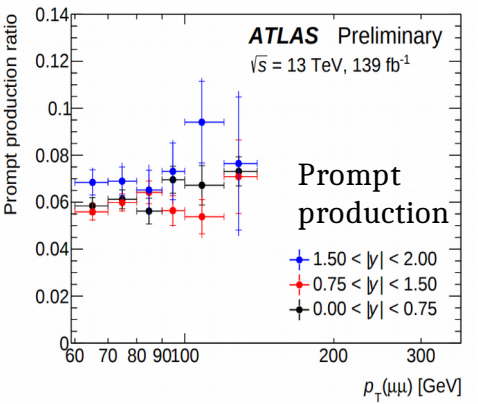


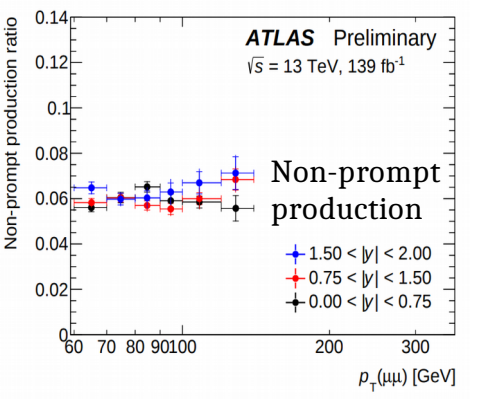
Non-prompt production fraction of J/ψ and ψ(2S)





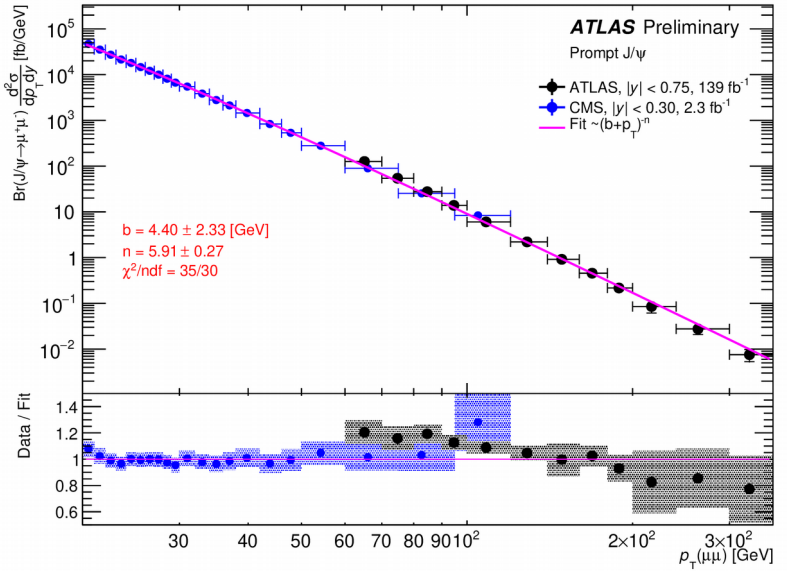
Ratio of ψ(2S) production with respect to J/ψ, for prompt and non-prompt production





Summary

- For J/ψ and ψ(2S) charmonium states, the cross-sections are measured separately for prompt and non-prompt production mechanisms.
- The results show similar p_T-dependence for prompt and non-prompt differential cross sections, with non-prompt fractions close to constant for both J/ψ and ψ(2S) in this range of transverse momenta.
- Where they overlap, results for prompt production are consistent with similar results obtained by the CMS collaboration.



- The results for non-prompt production are compared with the predictions of the FONLL model with default set of parameters.
- These predictions are consistent with the present measurement at the low end of the p_T range, but exceed the experimental values at large transverse momenta.
- *References*:

[1] ATLAS Collaboration, Measurement of the production cross-section of J/ψ and ψ(2S) mesons at high transverse momentum in pp collisions at √s=13 TeV with the ATLAS detector, ATLAS-CONF-2019-047.

[2] CMS Collaboration, Measurement of quarkonium production cross sections in pp collisions at √s=13TeV, Phys. Lett. B780(2018) 251.

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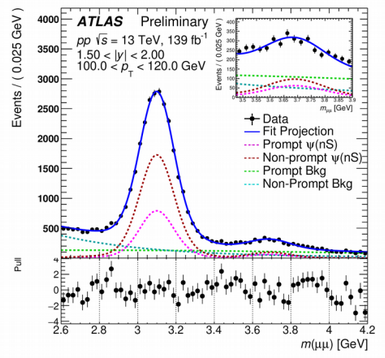
Fit model

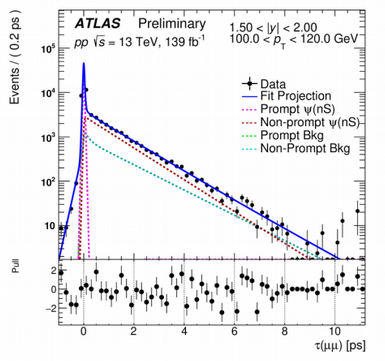
The fit model PDF is described by a sum of terms, with each term factorized into a function f_i of charmonium mass m and a function h_i of pseudo-proper decay time τ, with m−τ correlations allowed in one of the terms:

$$PDF(m,\tau) = \sum_{i=1}^{7} \kappa_i f_i(m) \cdot (h_i(\tau) \otimes R(\tau)) \cdot C_i(m,\tau).$$

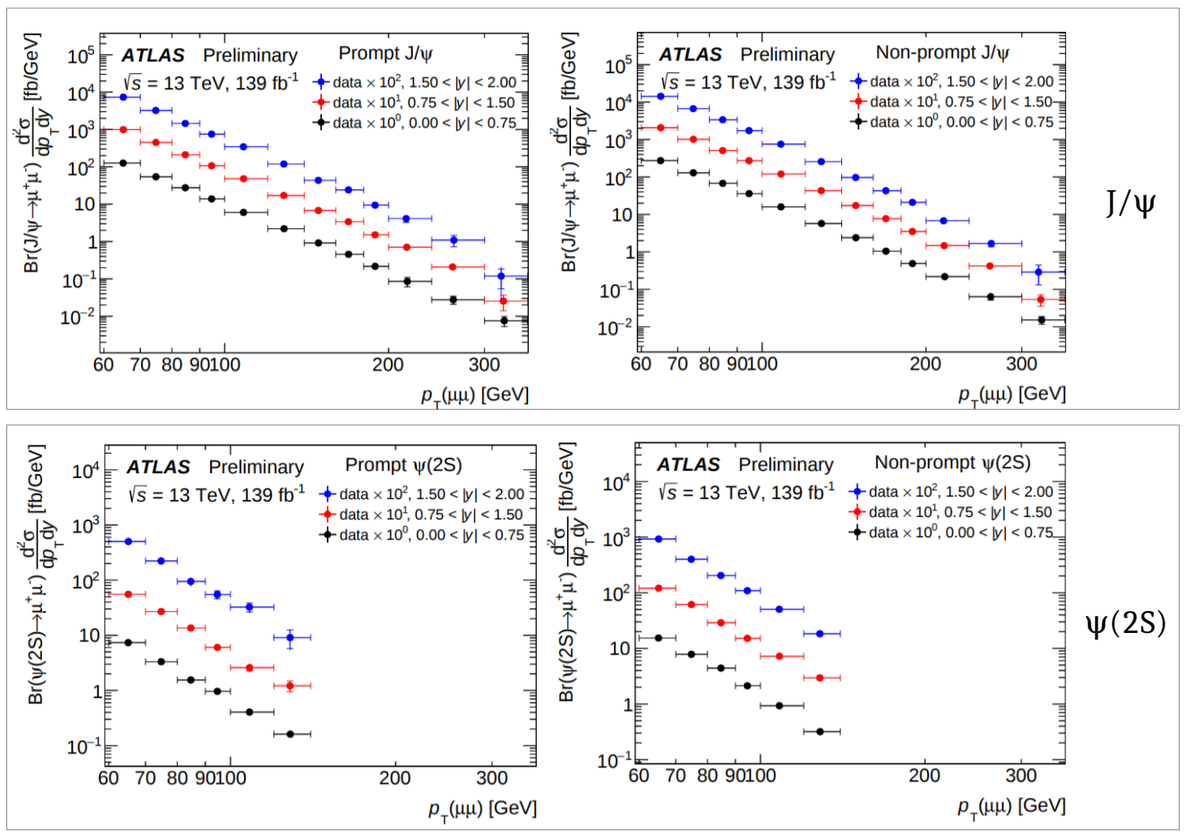


i	Type	P/NP	$f_i(m)$	$h_i(\tau)$	$C_i(m,\tau)$
1	J/ψ	P	$\omega G_1(m) + (1-\omega) CB_1(m)$	$\delta(\tau)$	$BV(m,\tau,\rho)$
2	J/ψ	NP	$\omega G_1(m) + (1-\omega) CB_1(m)$	$E_1(\tau)$	1
3	$\psi(2S)$	P	$\omega G_2(m) + (1-\omega) CB_2(m)$	$\delta(\tau)$	1
4	$\psi(2S)$	NP	$\omega G_2(m) + (1-\omega) CB_2(m)$	$E_2(\tau)$	1
5	Bkg	P	B	$\delta(\tau)$	1
6	Bkg	NP	$E_4(m)$	$E_5(\tau)$	1
7	Bkg	NP	$E_6(m)$	$E_7(\|\tau\|)$	1

Notations: G – Gaussian; CB – Crystal Ball; E – Exponential; B – Bernstein polynomials; BV – Correlation term of the bivariate Gaussian distr.



Differential cross sections

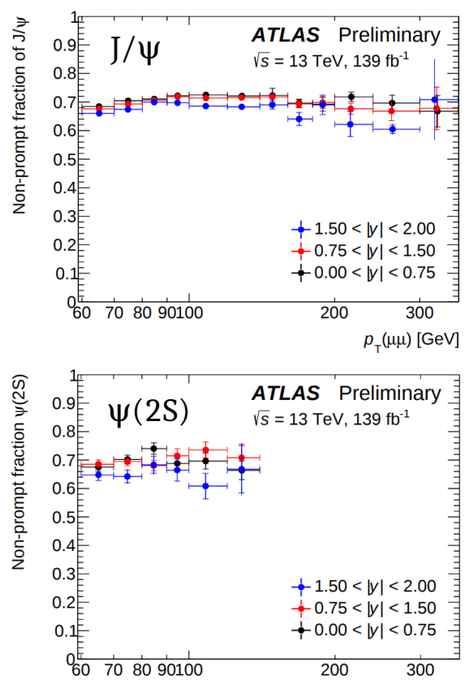


J/ψ

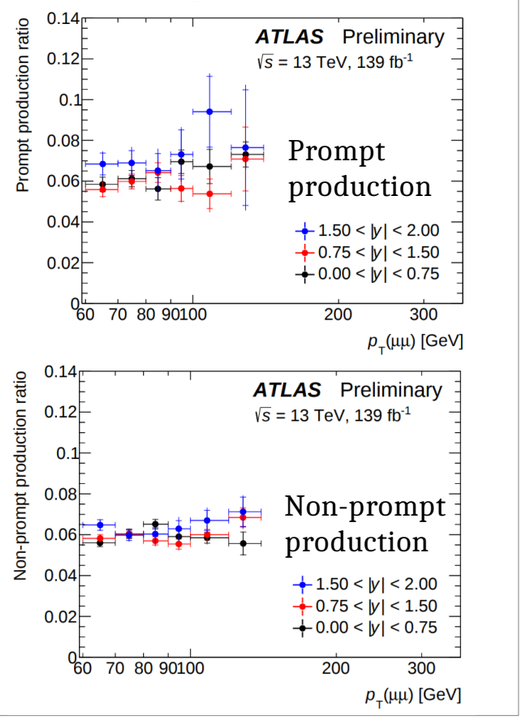
ψ(2S)

Production fractions

Non-prompt production fraction of J/ψ and ψ(2S)

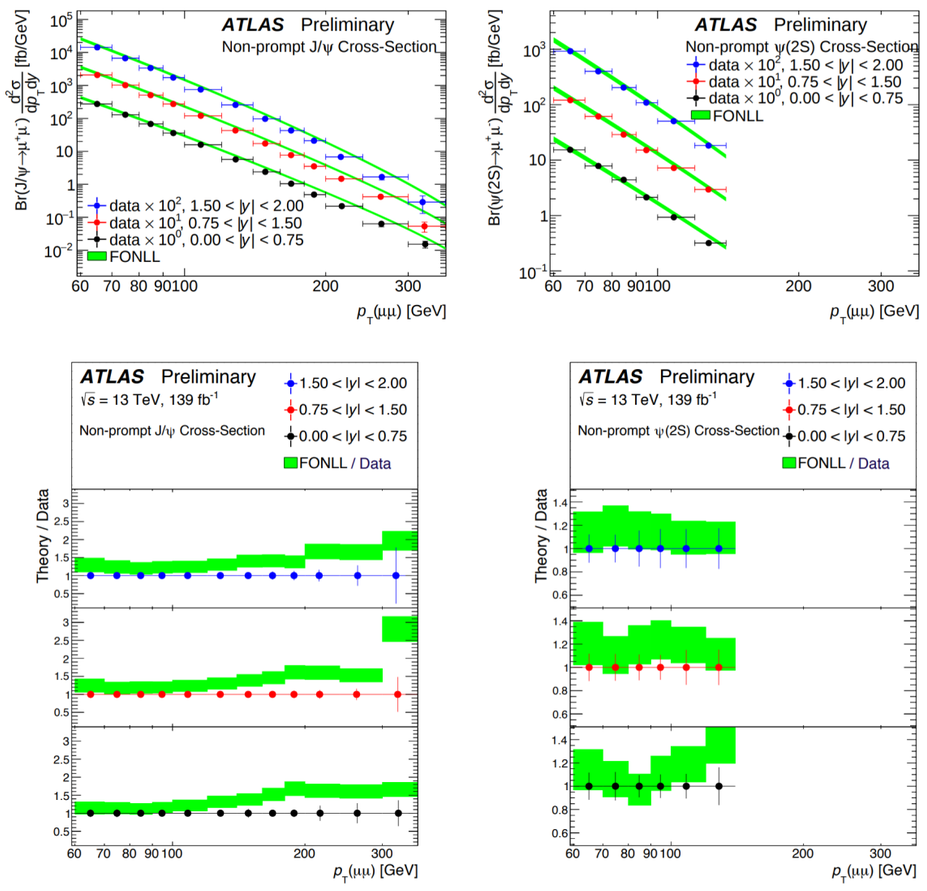


Ratio of ψ(2S) production with respect to J/ψ, for prompt and non-prompt production



The p_T dependence of prompt and non-prompt contributions in the p_T range covered by this measurement is similar, resulting in the non-prompt fractions being close to constant, for both J/ψ and ψ(2S).

The non-prompt differential cross-section overlaid with FONLL predictions



The comparison gives good agreement at the lower p_T, but with FONLL [3] predicting somewhat higher cross-sections at high-p_T.

Summary

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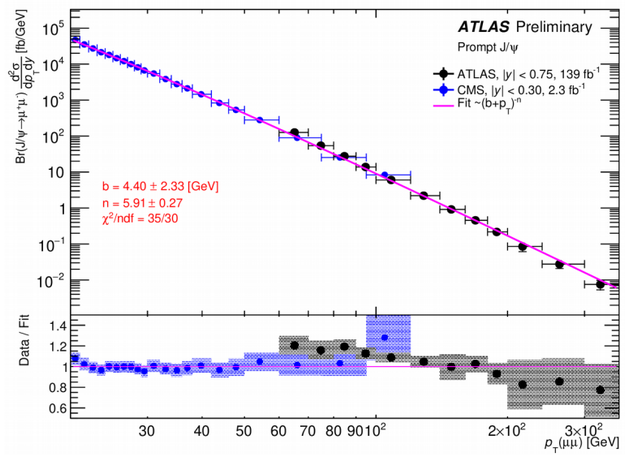

- Where they overlap, results for prompt production are consistent with similar results obtained by the CMS collaboration [4].
- The results for non-prompt production are compared with the predictions of the FONLL model with default set of parameters.
- These predictions are consistent with the present measurement at the low end of the p_T range, but exceed the experimental values at large transverse momenta.

References:

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[2] ATLAS collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, 2008 JINST 3 S08003.
[3] FONLL Heavy Quark Production, M. Cacciari, http://www.lpthe.jussieu.fr/~cacciari/fonll/fonllform.html.
[4] CMS Collaboration, Measurement of quarkonium production cross sections in pp collisions at √s=13TeV, Phys. Lett. B780(2018) 251.

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