Phenomenological interpolation of inclusive J/ψ production to proton-proton collisions at $\sqrt{s}$ =2.76 TeV and 5.5 TeV

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Abstract

J/ψ production is one of the key measurements in heavy-ion collisions at the LHC. It is expected to provide means to discriminate between different scenarii, ranging from full suppression by colour screening to enhancement by charm quark pair recombination. In 2010, the LHC delivered Pb-Pb collisions at the center of mass energy per nucleon pair of 2.76 TeV. The knowledge of the J/ψ cross section in p-p collisions at the same energy is crucial for a correct interpretation of the data.

We perform an interpolation of the inclusive J/ψ cross section to p-p collisions at 2.76 TeV (and 5.5 TeV), based on the available experimental data. First, we describe the energy dependence of the J/ψ cross section at mid-rapidity. Second, we study the rapidity dependence of J/ψ production and provide estimates for the cross section in the forward rapidity regions of interest for the LHC experiments. Third, we develop the tools to extrapolate the transverse momentum distributions.

In our approach, we adopt both phenomenological and pQCD-driven techniques and, where possible, we combine them. Our study is documented in arXiv:1103.2394 [nucl-ex]; it is meant to be complementary and provide an useful cross-check to the measurements performed during the recent p-p data-taking campaign at 2.76 TeV at the LHC.

Motivation and strategy

What we want to do:

Provide interpolated values for the inclusive J/ψ differential cross sections in p-p collisions at 2.76 TeV and 5.5 TeV, to be used as reference for heavy ion analysis

How we do it:

- Three steps
  - Energy interpolation of mid-rapidity cross section using the available data
  - Study of the rapidity dependence and estimates for forward cross sections
  - Study of the transverse momentum dependence
- Consider both phenomenogical approach and pQCD predictions; where possible, combine them

Mid-rapidity cross section

Fit to the available experimental data on inclusive cross section:

- PHENIX @ 200 GeV
- CDF @ 1.96 TeV
- ALICE @ 7 TeV

Phenomenological approach

- Power law:

$$\left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=0}(\sqrt{s}) = a(\sqrt{s})^b$$

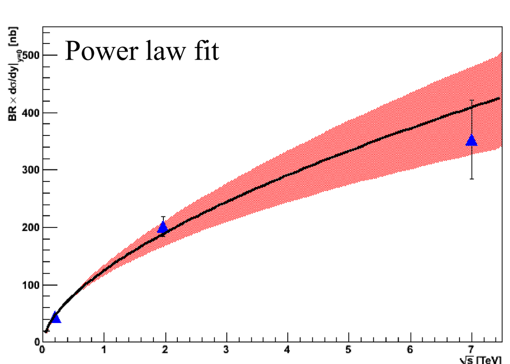
pQCD-driven approach

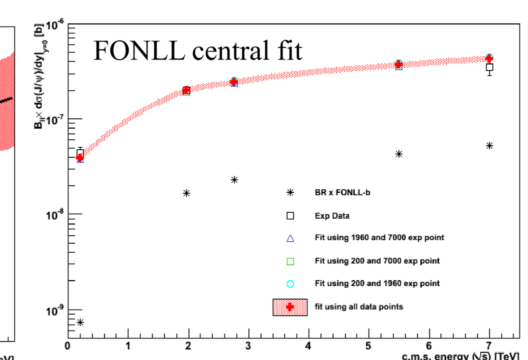
- Leading Order Colour Evaporation Model

$$\left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=0}(\sqrt{s}) = \alpha \left.\frac{d\sigma^{CEM}_{J/\psi}}{dy}\right|_{y=0}(\sqrt{s}) + 2BR_{B->J/\psi}\left.\frac{d\sigma^{FONLL}_{beauty}}{dy}\right|_{y=0}(\sqrt{s})$$

- FONLL prediction for bare charm (central, lower, and upper value of uncertainty band)

$$\left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=0}(\sqrt{s}) = \alpha \left.\frac{d\sigma^{FONLL}_{charm}}{dy}\right|_{y=0}(\sqrt{s}) + 2BR_{B->J/\psi}\left.\frac{d\sigma^{FONLL}_{beauty}}{dy}\right|_{y=0}(\sqrt{s})$$

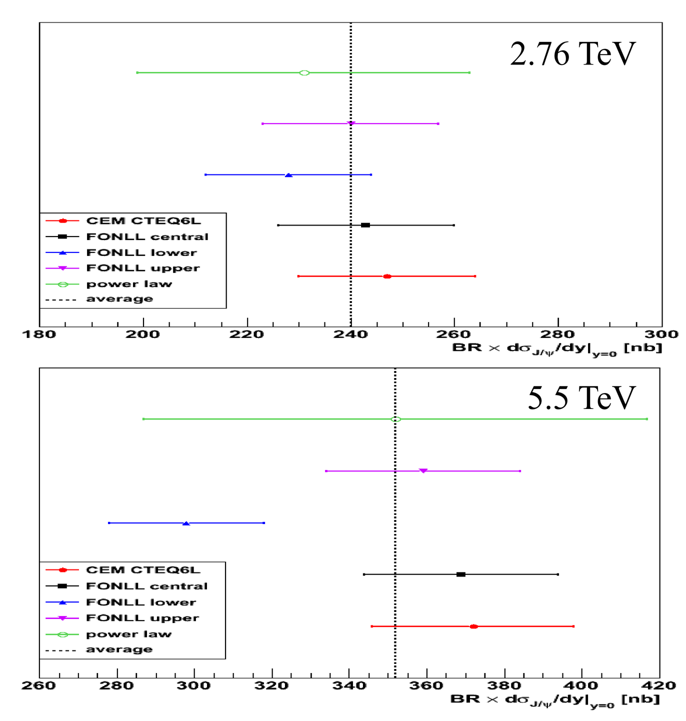




Energy dependence of inclusive J/ψ cross section at y=0, as fitted by a power law and by the FONLL predictions for bare charm. The fit stability has been verified by removing one by one the available experimental points

Fit type	Power law	CEM CTEQ6	CEM MRST01	FONLL central	FONLL upper	FONLL lower
χ^2	1.4	2.4	8.1 (discarded)	1.8	1	0.1
DF	1	2	2	2	2	2

Fit quality for different fitting functions



Interpolated values for the J/ψ inclusive cross section y=0 at 2.76 and 5.5 TeV, for different choices of the fitting function

Final values and uncertainties

Weighted average of power law, CEM and FONLL (average) fit results

Two error components:

- Fit uncertainty: largest relative fit uncertainty is retained
- Spread of results obtained with different fits: full envelope of results as systematic error band

Results

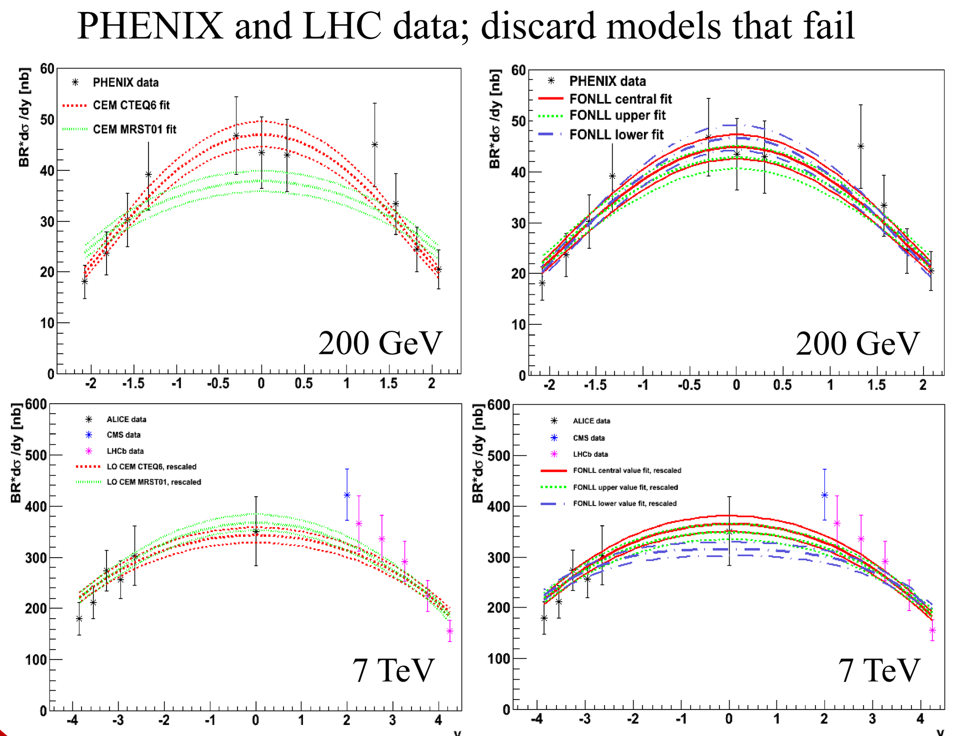
$$BR_{ll}\left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=0}(\sqrt{s} = 2.76\,TeV) = 240^{+7}_{-12}(syst.) \pm 33\,(fit)\,nb$$

$$BR_{ll}\left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=0}(\sqrt{s} = 5.5\,TeV) = 352^{+20}_{-54}(syst.) \pm 65\,(fit)\,nb$$

Rapidity dependence

pQCD approach

Step 1: test the models' rapidity shape against the PHENIX and LHC data; discard models that fail



Step 2:

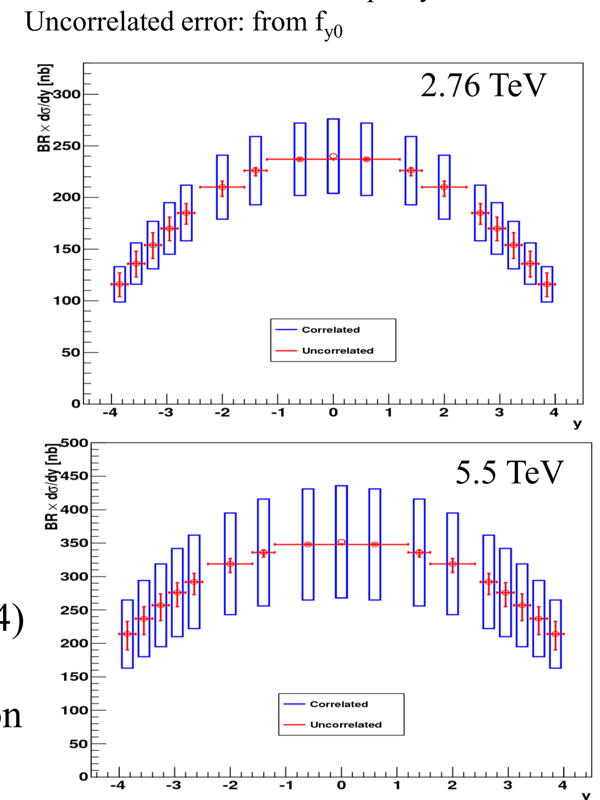
- for each model, and for many y_0 values, compute

$$f_{y_0} = \left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=y_0} \Big/ \left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=0}$$

at 2.76 and 5.5 TeV.

- take the average of all models as central value of f_{y0}
- use full envelope as error band (relative error ~1% at y~1, ~10% at y~4)
- multiply by the mid-rapidity cross section

Interpolated J/ψ rapidity distributions
Correlated error: from midrapidity cross section
Uncorrelated error: from f_{y0}



Phenomenological approach

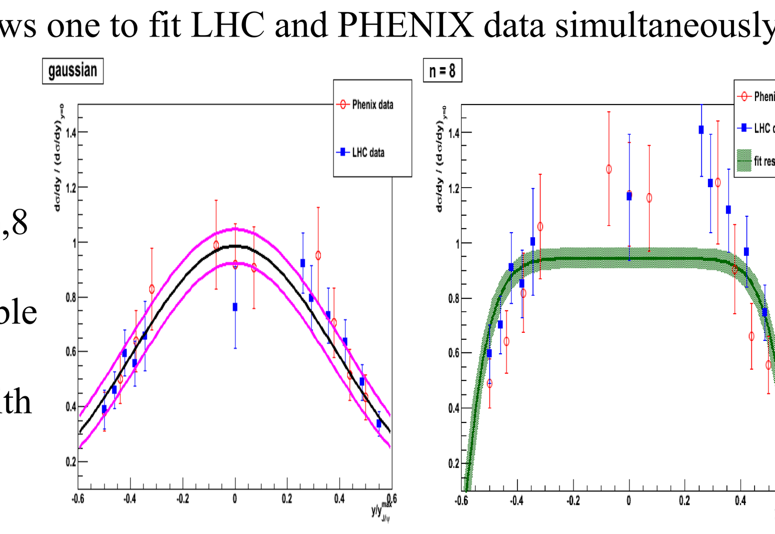
Use scaling variables: for each energy, plot

$$\frac{d\sigma_{J/\psi}}{dy} \Big/ \left.\frac{d\sigma_{J/\psi}}{dy}\right|_{y=0} \quad \text{as a function of} \quad y^{max}_{J/\psi} = \ln(\sqrt{s}/m_{J/\psi})$$

Such procedure allows one to fit LHC and PHENIX data simultaneously

Fitting functions:
- gaussian
- $Ax^n + B$, n = 2,4,6,8

Results are compatible with the pQCD approach, though with larger uncertainties



Transverse momentum dependence

Phenomenological approach based on the p_T distributions measured by:

- PHENIX
- CDF
- CMS
- ALICE
- LHCb

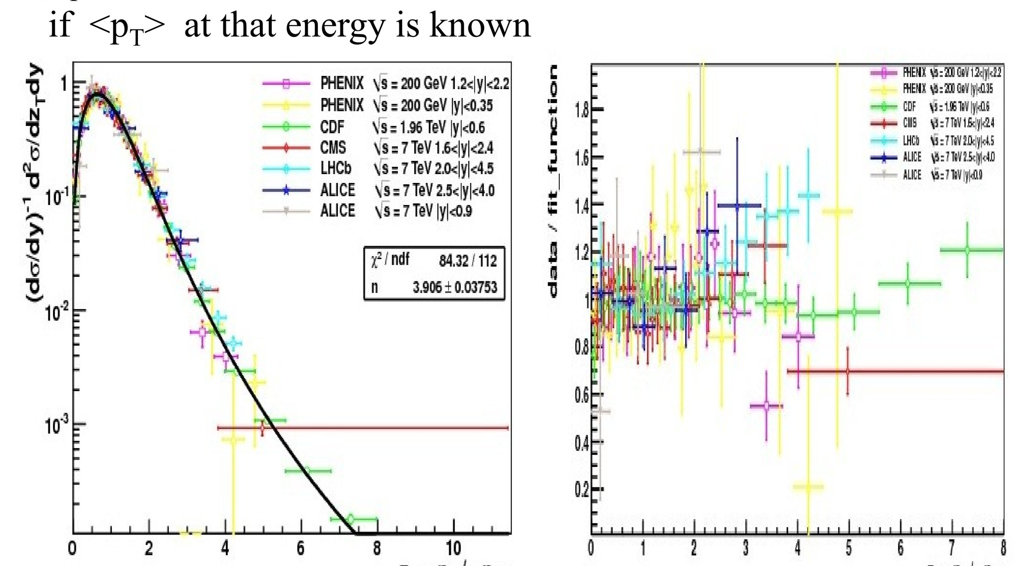
- Compute $\langle p_T \rangle$ for each distribution
- Plot normalised distributions as a function of:

$$z_T = p_T / \langle p_T \rangle$$

- Fit all data simultaneously as:

$$\frac{dN}{dz_T} \propto \frac{z_T}{(1 + a^2 z_T^2)^n}$$

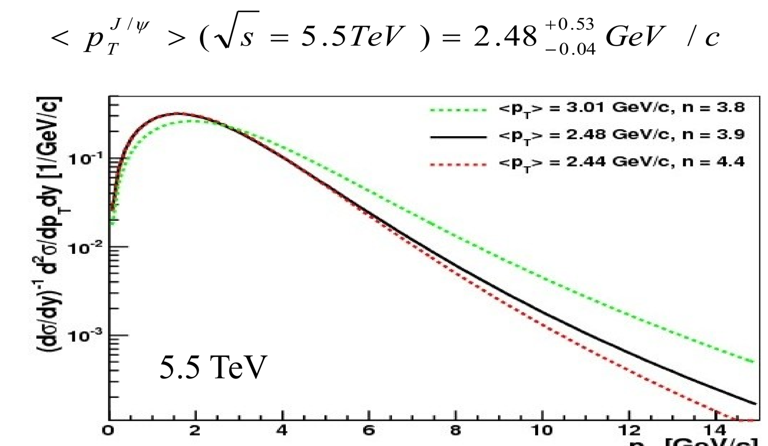
- the *a* parameter can be fixed by requiring $\langle z_T \rangle = 1$
- the *n* parameter is obtained from the fit
- remove datasets one by one to estimate systematic error on *n*
- p_T distribution at any energy can now be obtained, if $\langle p_T \rangle$ at that energy is known

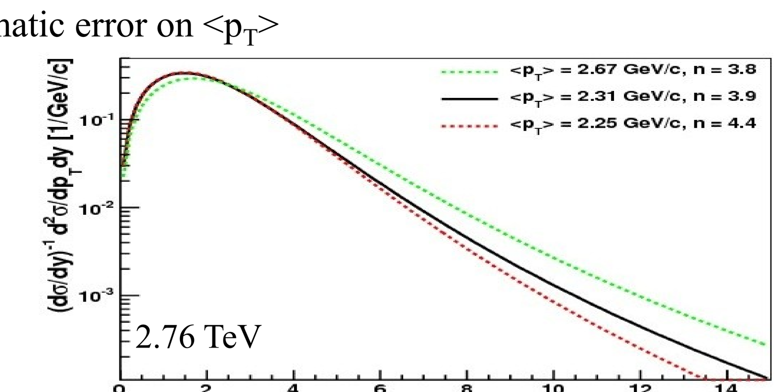


- power law fit to the measured $\langle p_T \rangle$ vs energy (RHIC, Tevatron, LHC)
- obtain interpolated values for $\langle p_T \rangle$ at 2.76 and 5.5 TeV
- remove datapoints one by one to estimate systematic error on $\langle p_T \rangle$
- Results:

$$\langle p_T^{J/\psi} \rangle (\sqrt{s} = 2.76\,TeV) = 2.31^{+0.36}_{-0.06}\,GeV/c$$

$$\langle p_T^{J/\psi} \rangle (\sqrt{s} = 5.5\,TeV) = 2.48^{+0.53}_{-0.04}\,GeV/c$$





J/ψ p_T distributions at 2.76 and 5.5 TeV obtained by feeding the interpolated $\langle p_T \rangle$ values in the universal expression of dN/dz_T

Conclusions

- We provided interpolated values for the J/ψ dσ/dψ in p-p collisions at 2.76 and 5.5 TeV both at mid-rapidity and in forward rapidity bins of interest for the LHC experiments
- We provided interpolated transverse momentum distributions at 2.76 and 5.5 TeV
- Details on our technique can be found in arXiv:1103.2394v1, v2 to come soon including results shown in this poster (using the final data from the LHC experiments)
- Outlook: investigate rapidity dependence of $\langle p_T \rangle$ and p_T distributions