Nuclear PDFs and heavy quark(onium) production in proton-nucleus collisions

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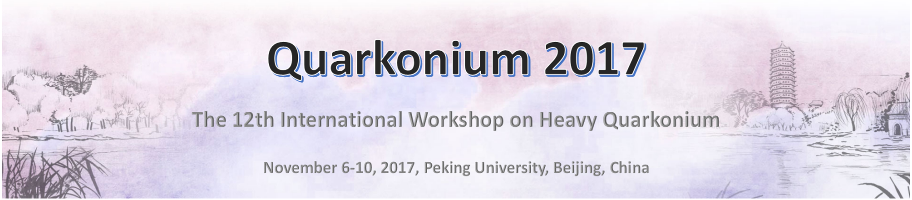

in collaboration with M. Cacciari, A. Kusina, I. Schienbein and H.S. Shao

Part I

Introduction

Expected nuclear effects on (involved in) heavy quark(onium) production in proton-nucleus collisions

- Nuclear modification of the parton densities, nPDF: initial-state effect

Analogous aspects to that of saturation/CGC: see K. Watanabe's talk

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In what follows, I will assume (and then cross check) the dominance of the nuclear modification of PDF over the other effects in the LHC kinematics

Part II

Automating the computation of nuclear PDF effects

An automated code to evaluate the impact of nuclear PDF I

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- Not yet interfaced to a Glauber model
  [no centrality and no combination with other nuclear effects]

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- Last but not least: the automation of the evaluation allows one to study different nPDF sets AND the scale uncertainties: better control of the theory uncertainties

Part III

Results for pA collisions using nCTEQ15 & EPPS16 out-of-the-box

Some J/ψ comparisons [with EPPS16 added later on]

[See R. Arnaldi's, E. Chapon's, J. Sun's talks]

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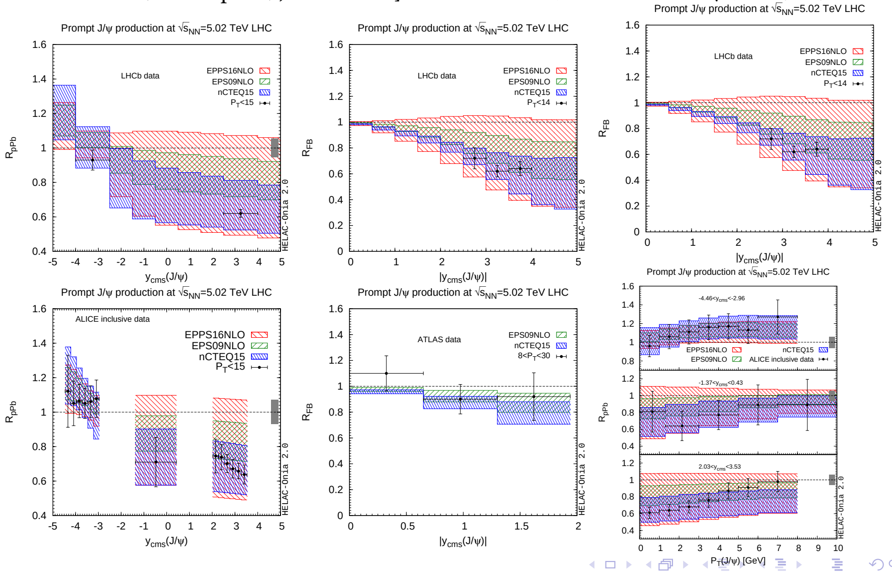

More results: $\Upsilon(1S)$ and ... η_c

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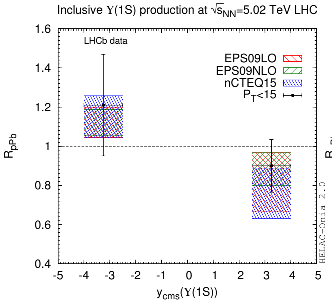

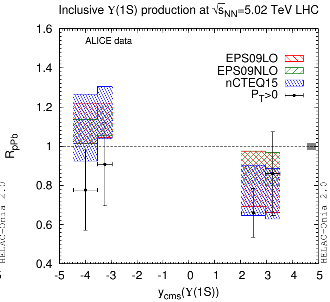

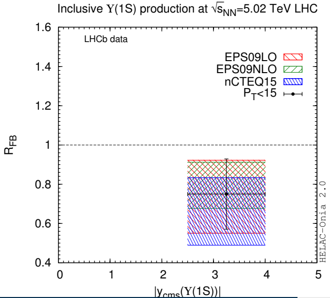

Our 8 TeV predictions in J.L. Albacete, *et al.*. arXiv:1707.09973

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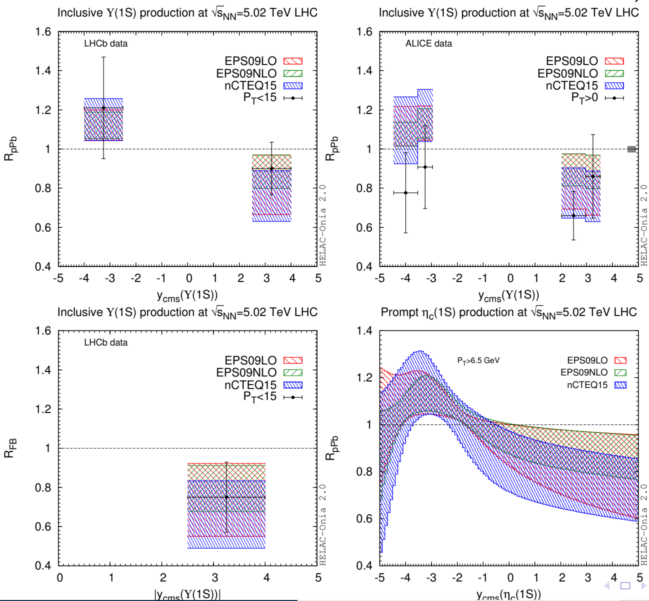

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Part IV

First step toward the inclusion of HF *pA* data in a fit: the reweighting*

*From now on, all nPDF uncertainties are 68%CL

Reweighting: the principle behind

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1. Convert Hessian error PDFs into replicas

$$f_k = f_0 + \sum_i^N \frac{f_i^{(+)} - f_i^{(-)}}{2} R_{ki},$$

2. Calculate weights for each replica

$$w_k = \frac{e^{-\frac{1}{2}\chi_k^2/T}}{\frac{1}{N_{\rm rep}} \sum_i^{N_{\rm rep}} e^{-\frac{1}{2}\chi_k^2/T}}, \qquad \chi_k^2 = \sum_j^{N_{\rm data}} \frac{(D_j - T_j^k)^2}{\sigma_j^2}$$

3. Calculate observables with new (reweighted) PDFs

$$\langle \mathcal{O} \rangle_{\rm new} = \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} w_k \mathcal{O}(f_k),$$

$$\delta \langle \mathcal{O} \rangle_{\rm new} = \sqrt{\frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} w_k \left(\mathcal{O}(f_k) - \langle \mathcal{O} \rangle\right)^2}.$$

* N is the # of eigensets, N_{rep} is the # of constructed replicas
* f_0 is the "central-value" of the nPDF vector (*i.e.* of functions of x) in $N_{\rm flavour}$ dimension
* $f_i^{(\pm)}$ ($i \in [1:N]$) is the "upper/lower value" function of a given eigenset i
* R_{ki} is a number randomly choosen for each set of (k, i) (thus fixed for all $N_{\rm flavour}$) according to a standard Normal distribution
* f_k is the constructed vector
* T is the tolerance factor (for 68% CL: 13 for nCTEQ15; 19 for EPPS16)

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- Global data (or theory) uncertainties can be dealt with adjusting T_j^k
- When a replica k describes well the data, it gets a higher weight w_k thanks to a smaller χ_k^2
- The nPDF are then modified –reweighted– since the initial set of replicas is altered. If replicas closer to (further from) the central value are favoured, the nPDF uncertainty is reduced (enlarged). nPDF uncertainties for any flavour can easily be redrawn
- Any other observables can also be redrawn ($pA\ d\sigma$, R_{pA}, R_{FB}, ...)

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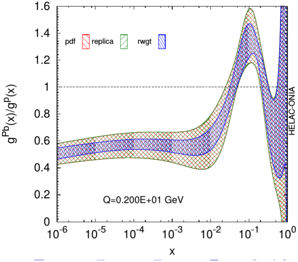

Used data sets

	D^0	J/ψ	$B \to J/\psi$	$\Upsilon(1S)$
μ_0	$\sqrt{4M^2_{D^0} + P^2_{T,D^0}}$	$\sqrt{M^2_{J/\psi} + P^2_{T,J/\psi}}$	$\sqrt{4M^2_B + \left(\frac{M_B}{M_{J/\psi}} P_{T,J/\psi}\right)^2}$	$\sqrt{M^2_{\Upsilon(1S)} + P^2_{T,\Upsilon(1S)}}$
p+p data	LHCb (1)	LHCb (2; 3)	LHCb (2; 3)	ALICE (4), ATLAS (5), CMS (6), LHCb (7; 8)
R_{pPb} data	ALICE (9), LHCb (15)	ALICE (10; 11), LHCb (16; 12)	LHCb (12)	ALICE (13), ATLAS (14), LHCb (17)

[1] LHCb, R. Aaij et al., JHEP **06**, 147 (2017), 1610.02230.
[2] LHCb, R. Aaij et al., Eur. Phys. J. **C71**, 1645 (2011), 1103.0423.
[3] LHCb, R. Aaij et al., JHEP **06**, 064 (2013), 1304.6977.
[4] ALICE, B. B. Abelev et al., Eur. Phys. J. **C74**, 2974 (2014), 1403.3648.
[5] ATLAS, G. Aad et al., Phys. Rev. **D87**, 052004 (2013), 1211.7255.
[6] CMS, S. Chatrchyan et al., Phys. Lett. **B727**, 101 (2013), 1303.5900.
[7] LHCb, R. Aaij et al., Eur. Phys. J. **C72**, 2025 (2012), 1202.6579.
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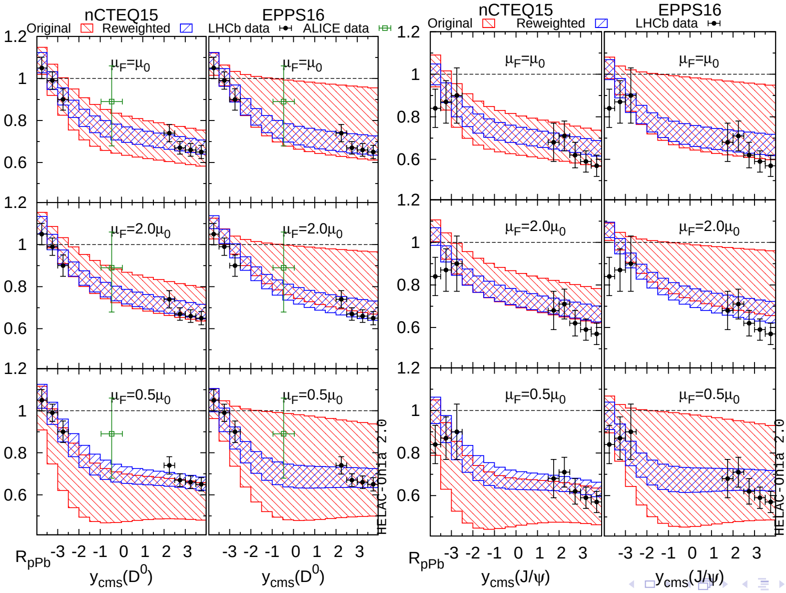
[9] ALICE, B. B. Abelev et al., Phys. Rev. Lett. **113**, 232301 (2014), 1405.3452.
[10] ALICE, J. Adam et al., JHEP **06**, 055 (2015), 1503.07179.
[11] ALICE, B. B. Abelev et al., JHEP **02**, 073 (2014), 1308.6726.
[12] LHCb, R. Aaij et al., (2017), 1706.07122.
[13] ALICE, B. B. Abelev et al., Phys. Lett. **B740**, 105 (2015), 1410.2234.
[14] The ATLAS collaboration, (2015), ATLAS-CONF-2015-050.
[15] LHCb, R. Aaij et al., (2017), 1707.02750.
[16] LHCb, R. Aaij et al., JHEP **02**, 072 (2014), 1308.6729.
[17] LHCb, R. Aaij et al., JHEP **07**, 094 (2014), 1405.5152.

To be added: e.g. *ALICE D^0 data published in PRC, ...*

Reweighting results: D and J/ψ

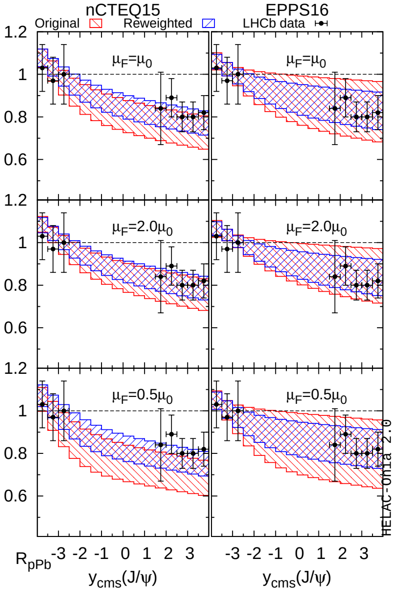


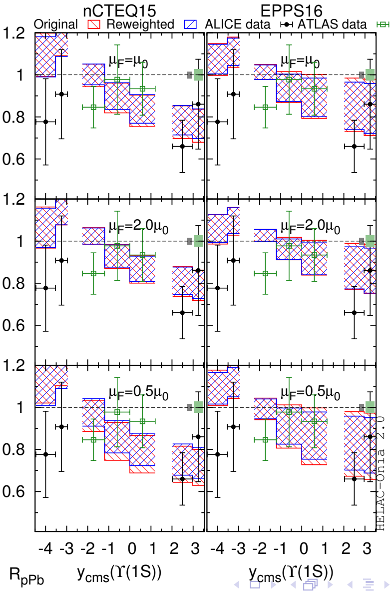
Changing the scale has two effects:

1) the uncertainty tends to increase at low μ_F

2) since the shadowing suppression (in/de)creases for (de/in)creasing μ_F, the reweighted nPDF from data shifts within the original uncertaities

Reweighting results: J/ψ from B and Υ





Compared to the D and J/ψ cases,

1) the scales uncertainties are smaller, but

2) the data are not yet as precise

Results of the reweighting process

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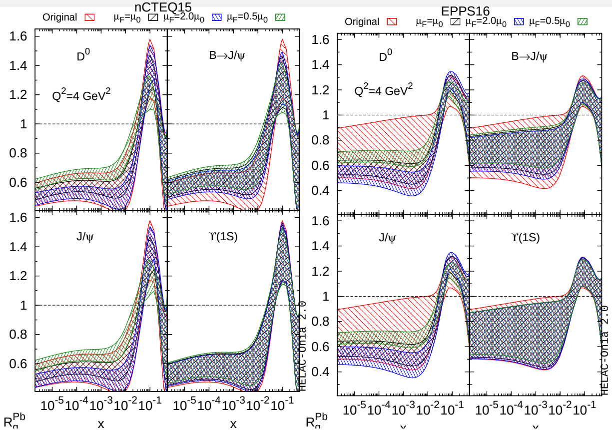

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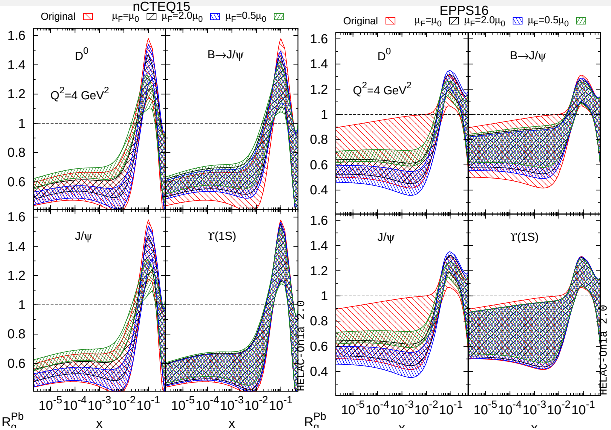

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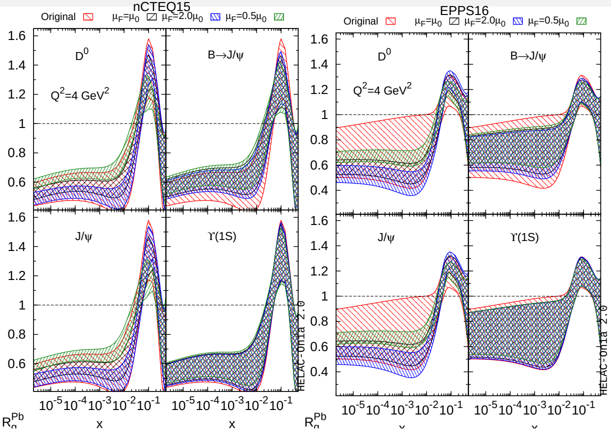

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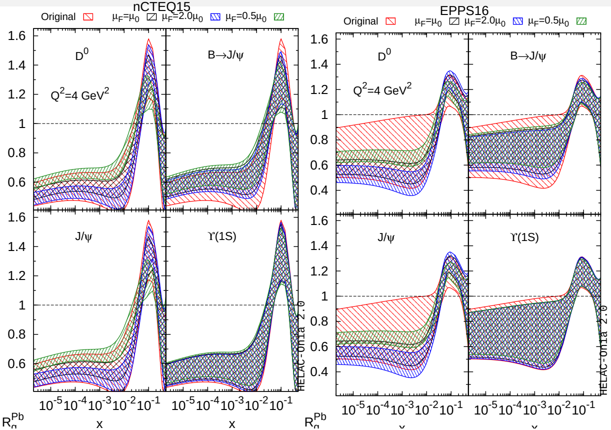

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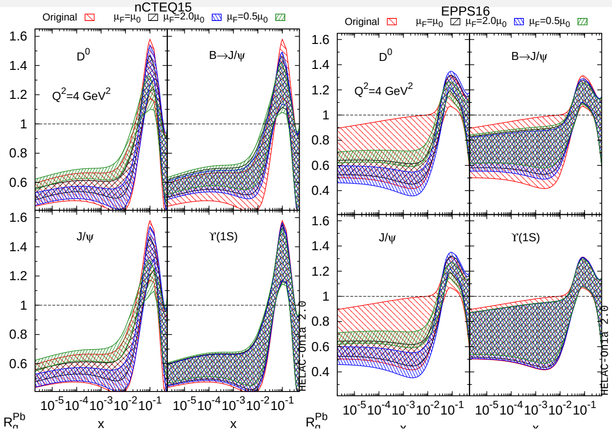

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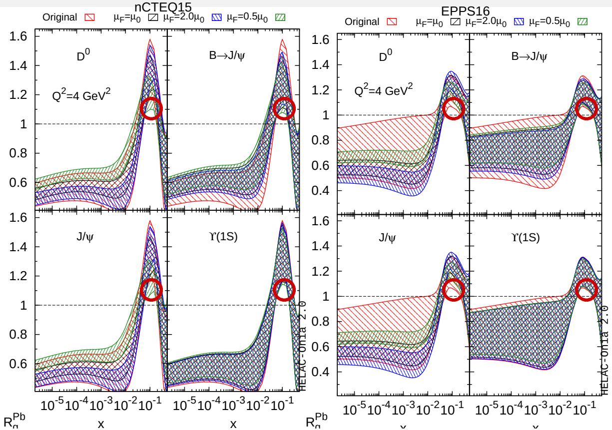
- Non-prompt J/ψ are really promising if improved data can be obtained

Results of the reweighting process



- Global coherence of the data constraints: necessary condition to assume a shadowing-only approach
- First clear experimental observation on gluon SHADOWING at low x; Visible reduction of the EPPS16 uncertainties; confirmation of the extrapolation done in nCTEQ15
- The scale ambiguity for D and J/ψ production is now the dominant uncertainty
- Non-prompt J/ψ are really promising if improved data can be obtained
- Confirmation of the existence of a gluon anti-shadowing : $\boxed{R_g(0.05 \lesssim x <\lesssim 0.1) > 1}$

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- Heavy-flavour leptons could be added to the list as well as other differential data [no drastic change expected with the current data]

Probing the Quark-Gluon Plasma with Collective Phenomena and Heavy Quarks 27 August - 21 September 2018

Torsten Dahms, Laura Fabbietti, Jean-Philippe Lansberg, Jean-Yves Ollitrault

will start with a 3-day topical workshop (August 27 to 29, 2018)

Registration form and further information at
http://www.munich-iapp.de/programmes-topical-workshops/2018/heavy-ion/

MIAPP requires attendance for at least two weeks to support the participants

The registration deadline is November 27, 2017

Submission of proposals/application for programme participation:

www.munich-iapp.de

Part V

Backup

Fitting the pp data [~ tuning our partonic amplitude to the data]

JPL, H.S. Shao Eur.Phys.J. C77 (2017) 1

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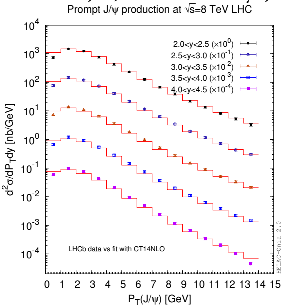

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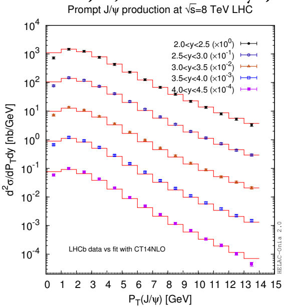

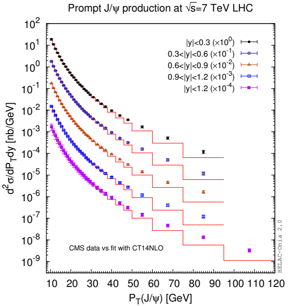

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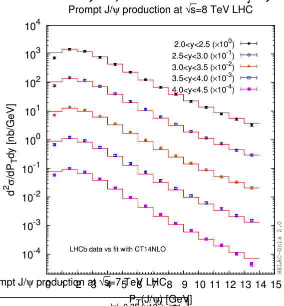

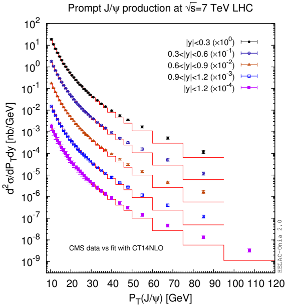

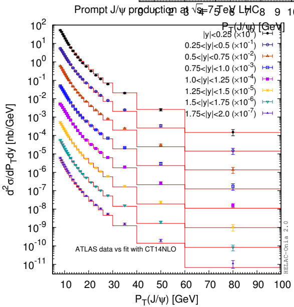

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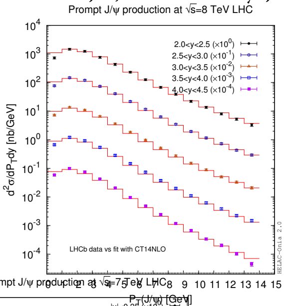

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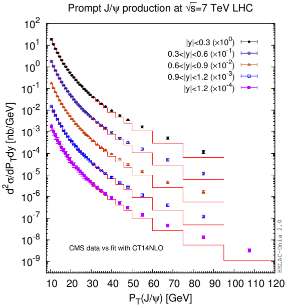

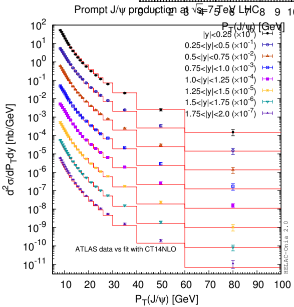

More *pp* fits ...

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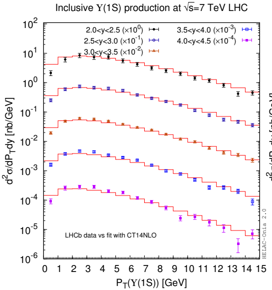

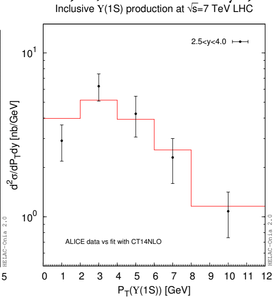

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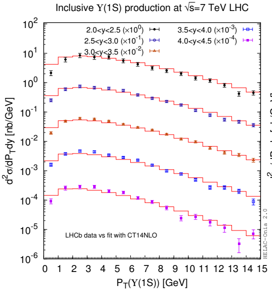

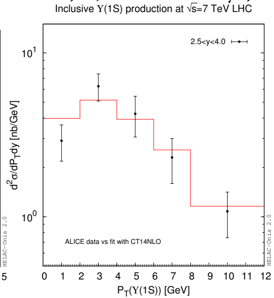

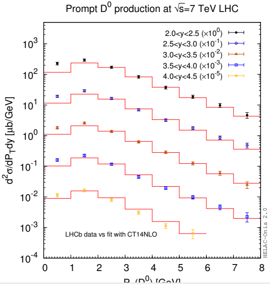

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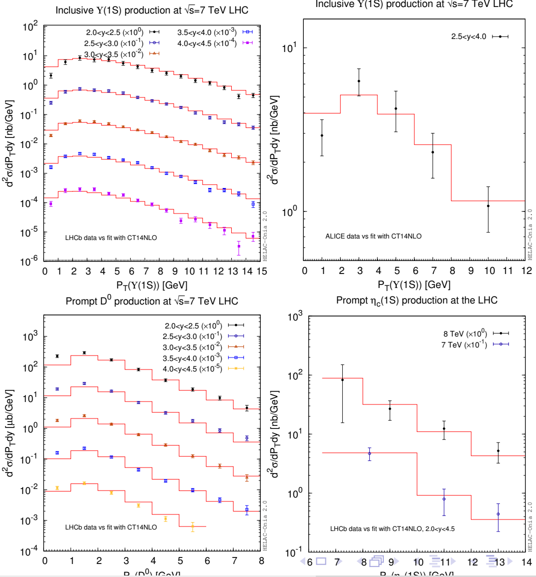

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Nota: These fits do not tell us anything about the HF production mechanisms; they "just" provide us efficient and controlled inter/extra-polations of the differential xsection in the space $\{x_1, x_2, y, P_T\}$