New observables in quarkonium production: the case of double J/ψ production

J.P. Lansberg

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work done in collaboration with Hua-Sheng Shao (CERN)

The current situation in one slide ...

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- Colour-Singlet Model (CSM) back in the game

[large NLO and NNLO correction to the P_T spectrum ; but not perfect → need a full NNLO]

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- One of these is quarkonium-pair production

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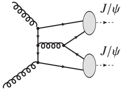

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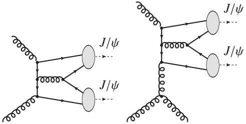

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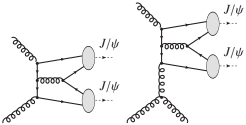

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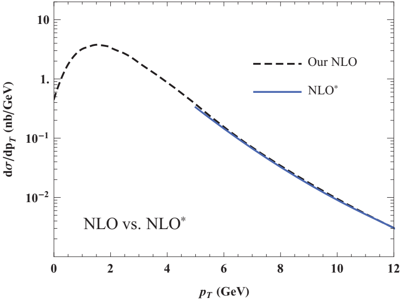

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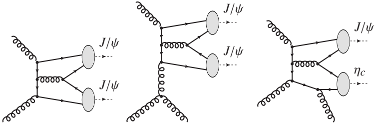

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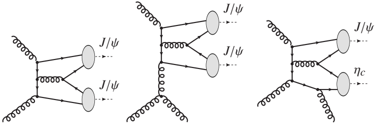

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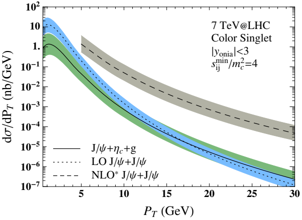

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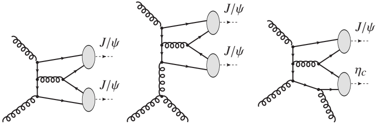

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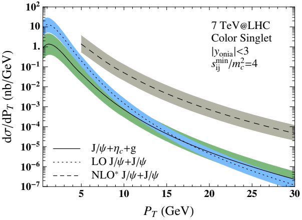

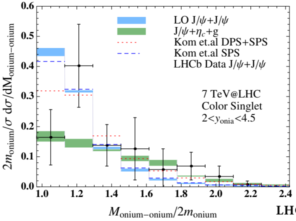

LHCb PLB 707 (2012) 52

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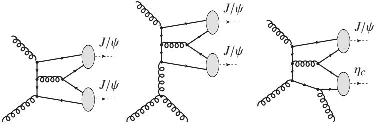

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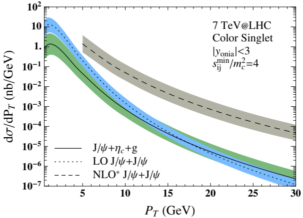

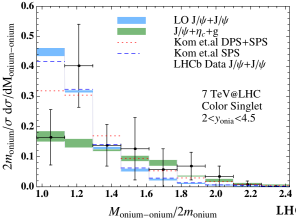

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- $\sigma^{central}_{LO\ SPS} = 4.83$ nb; $\sigma^{central}_{NLO\ SPS} = 5.34$ nb; $\sigma^{LHCb}_{measured} = 5.1 \pm 1.0 \pm 1.1$ nb: that's it at low P_T?

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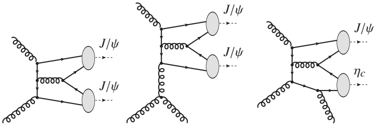

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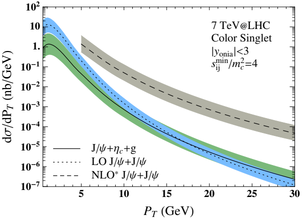

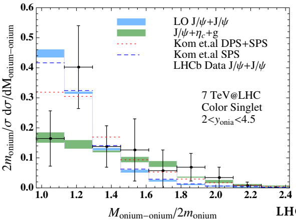

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- Large enhancement at high P_T

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On the importance of QCD corrections : P_T enhanced topologies

JPL, H.-S.Shao PLB 751 (2015) 479

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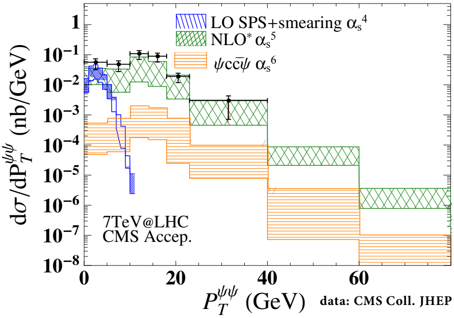

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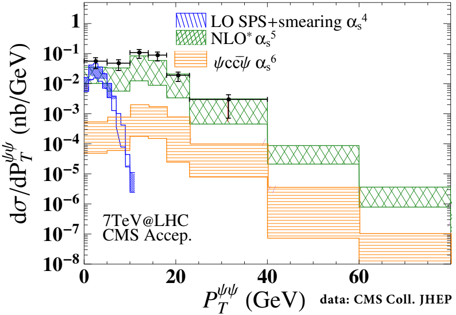

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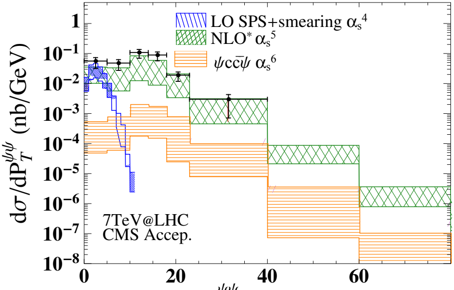

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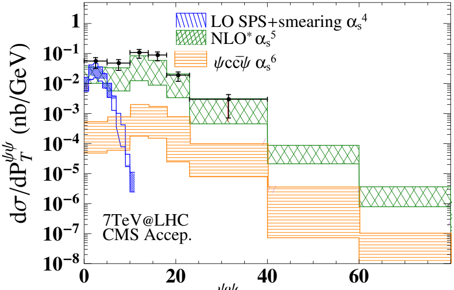

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- We do not expect NNLO (α_s^6) contributions to matter where one currently has data

[the orange histogram shows one class of leading P_T α_s^6 contributions]

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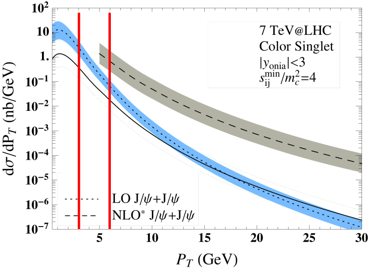

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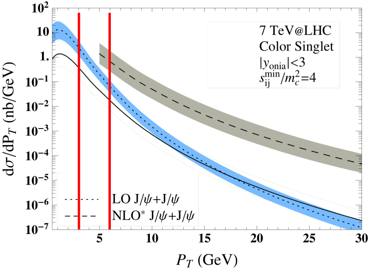

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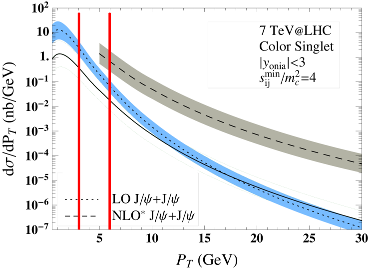

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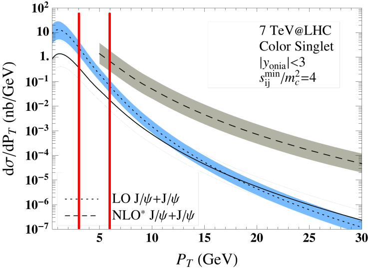

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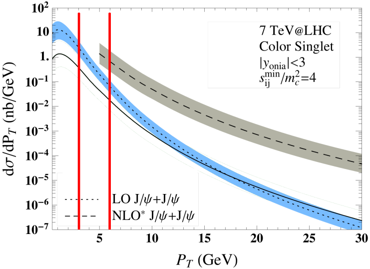
- As we will also see, this was foreseeable (this should not have been a puzzle at all)



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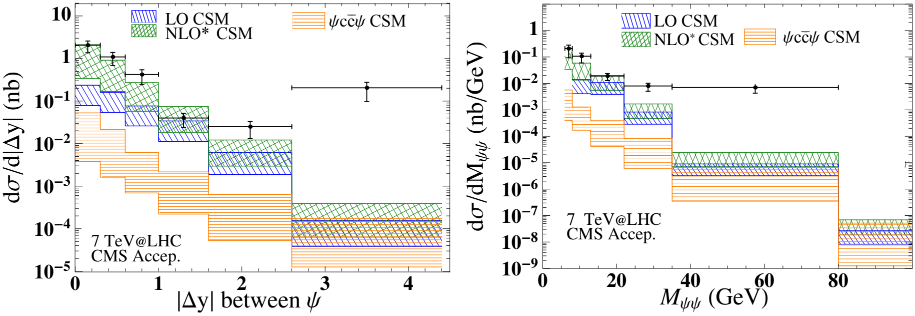

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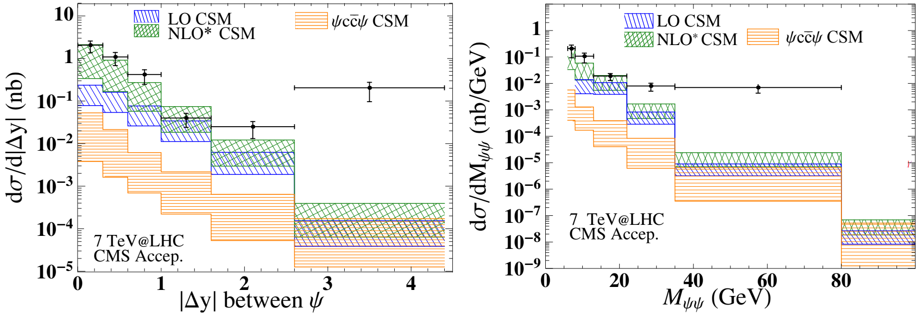

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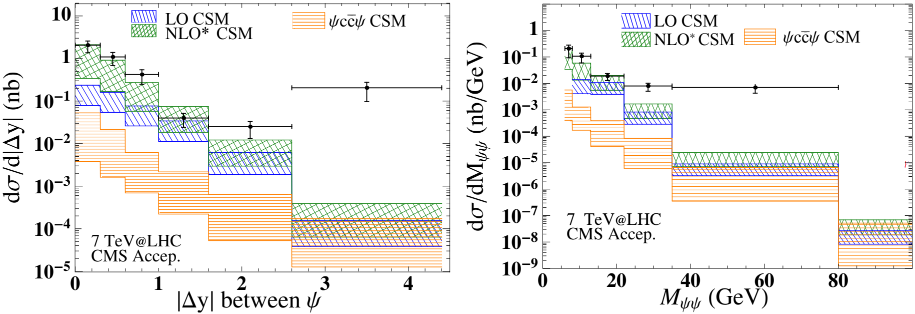

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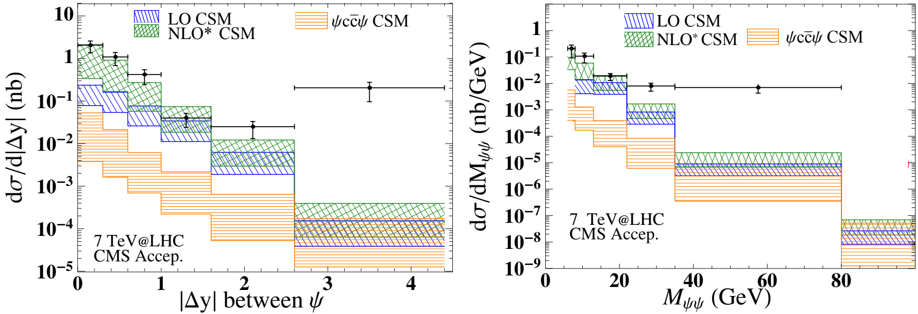

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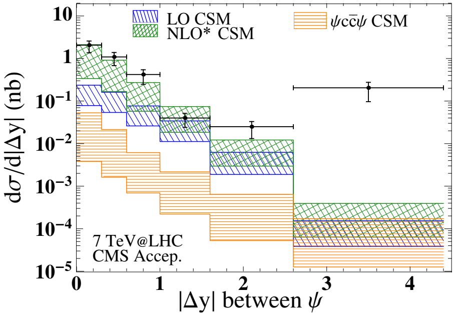

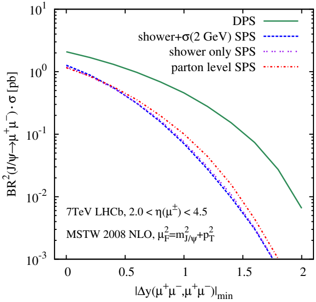

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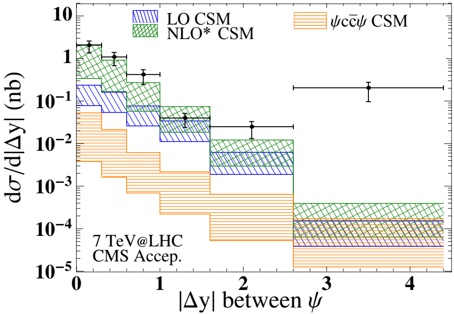

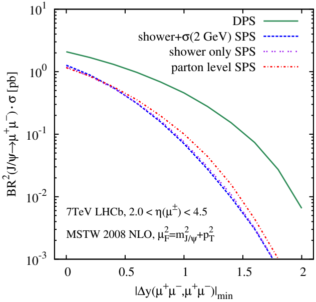

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  → We will come back to this later **Z. He, B. Kniehl PRL 115, 022002 (2015)**

On the importance of double parton scatterings at large Δy I

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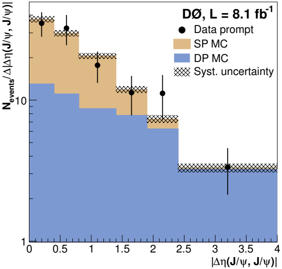

D0 Coll. PRD 90 (2014) 111101

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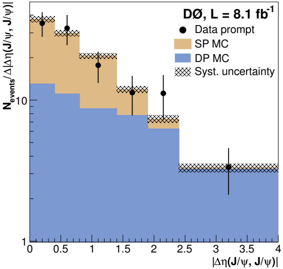

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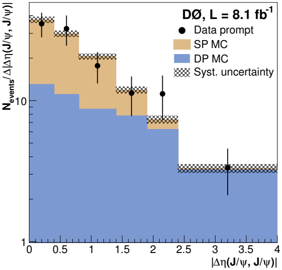

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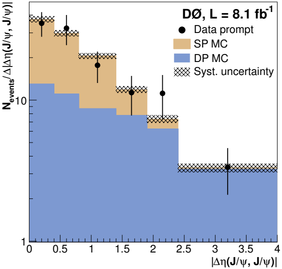

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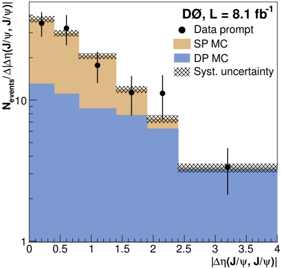

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- A natural question arises: using $\sigma^{\rm DPS} = \frac{\sigma_\psi \sigma_\psi}{\sigma_{\rm eff}}$ and $\sigma_{\rm eff} = 4.8 \pm 2.5$ mb, can one account for the large Δy CMS data ?

On the importance of double parton scatterings at large Δy II

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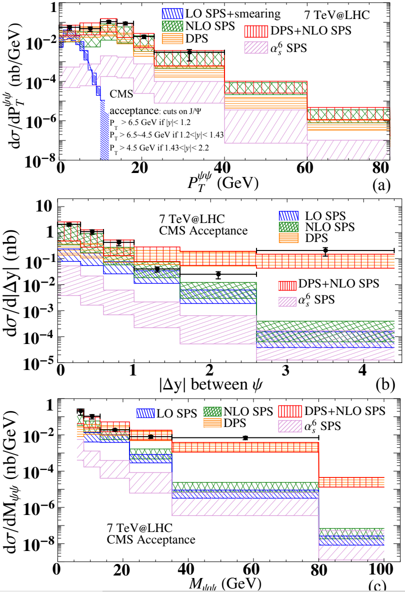

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C.H. Kom, A. Kulesza, W.J. Stirling PRL 107 (2011) 082002

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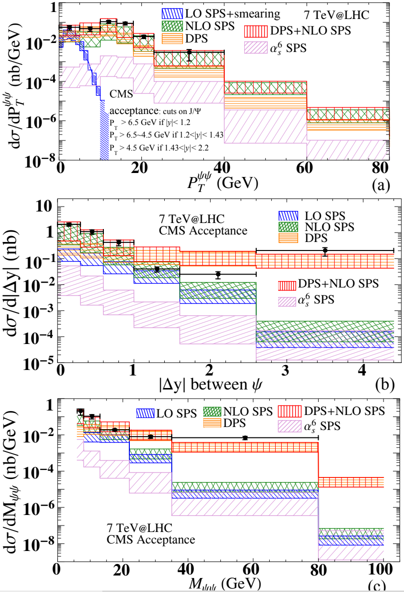

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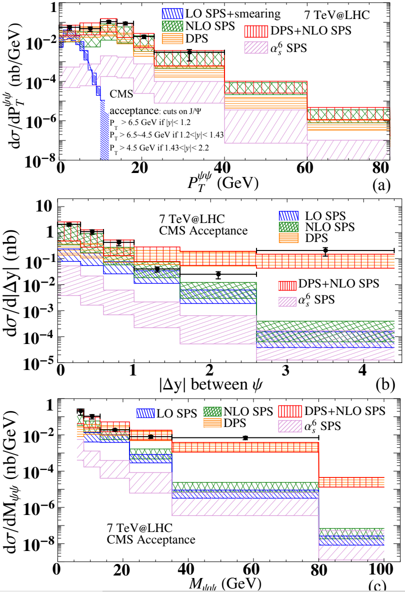
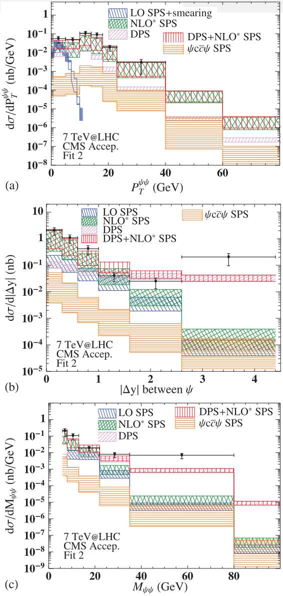


Our fit of the double parton scatterings



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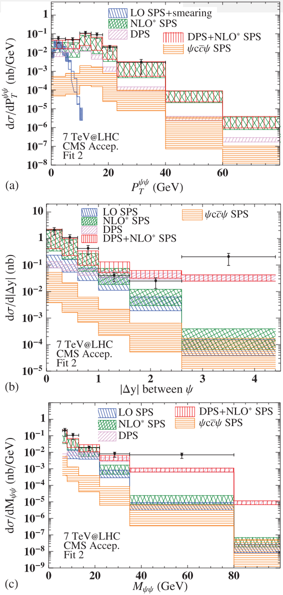

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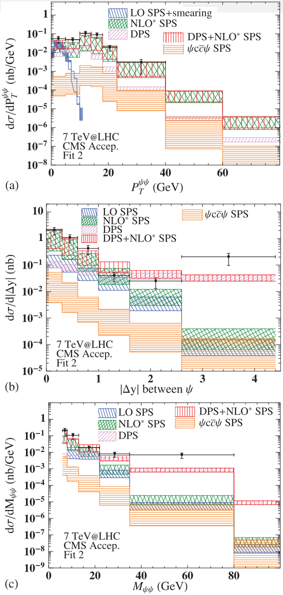

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	$\sigma_{\rm eff}$ [mb]	$\chi^2_{\rm d.o.f.}$	d.o.f.
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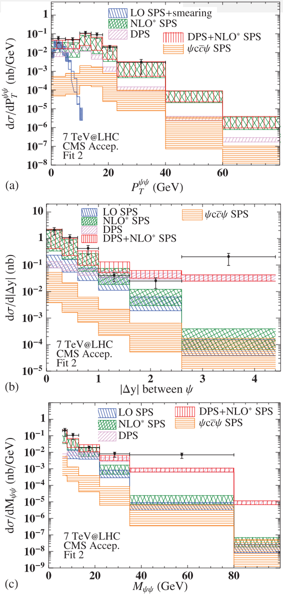

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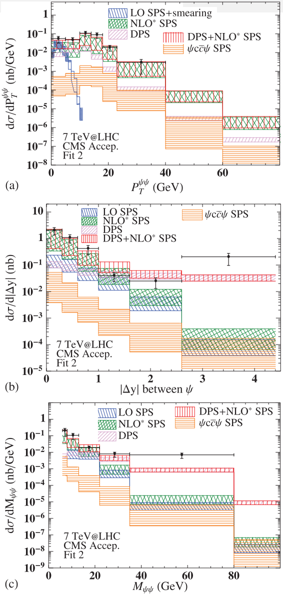

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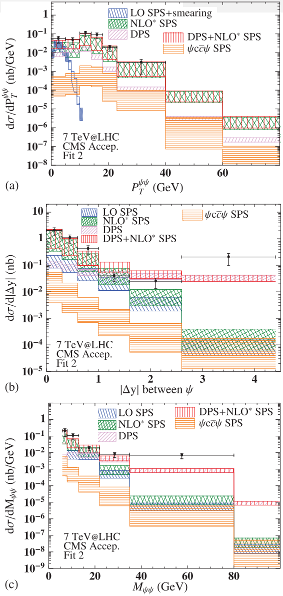
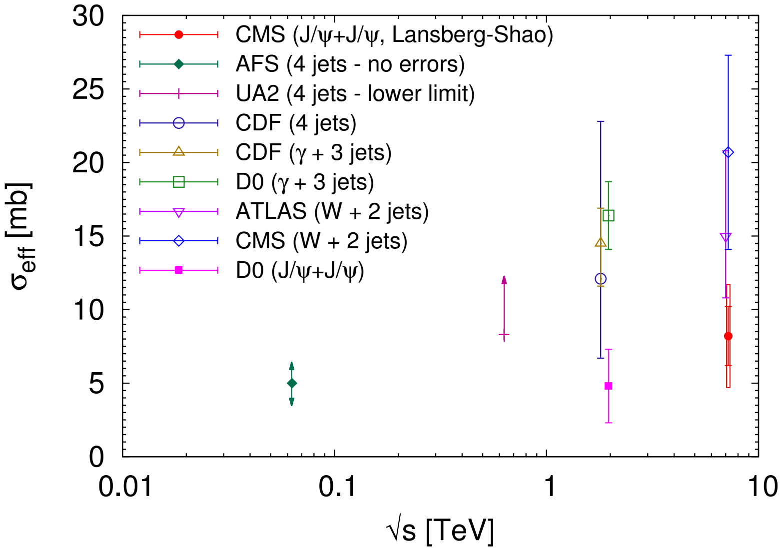
- Best agreement with Fit 3 confirming the consistency: $\sigma_{\rm eff} = 4.8 \pm 2.5$ mb vs $\sigma_{\rm eff} = 5.3 \pm 1.4$ mb



Our fit value for σ_{eff} : $8.2 \pm 2.0 \pm 2.9$ mb



On the (non-)importance of colour-octet channels

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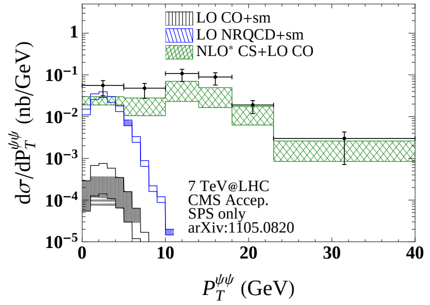

Single J/ψ LDME fit: M. Butenschoen, B. Kniehl arXiv:1105.0820, PRD 84 (2011) 0515

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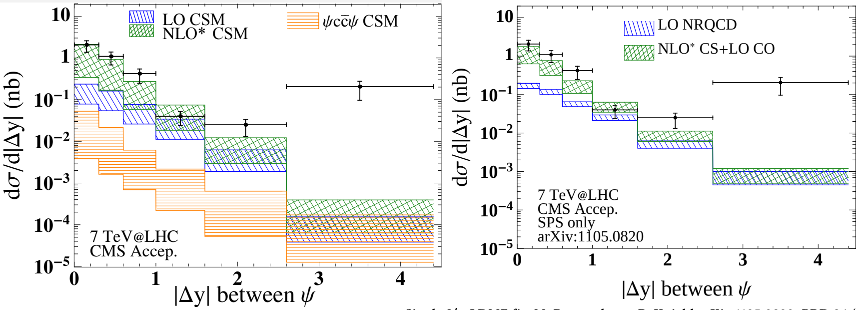

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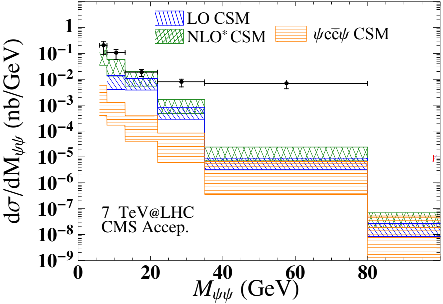

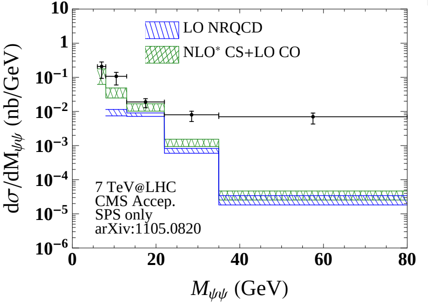

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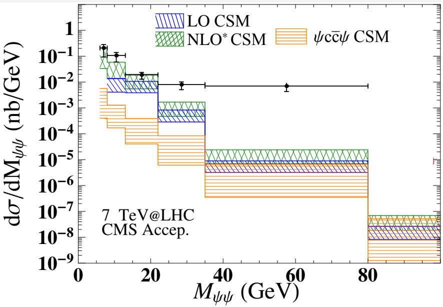

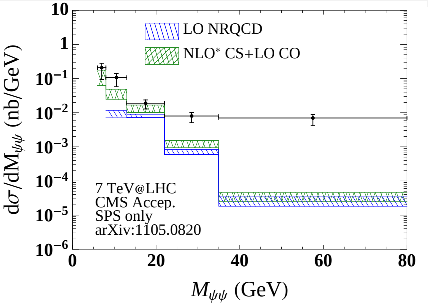

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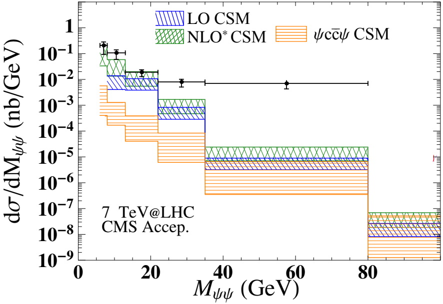

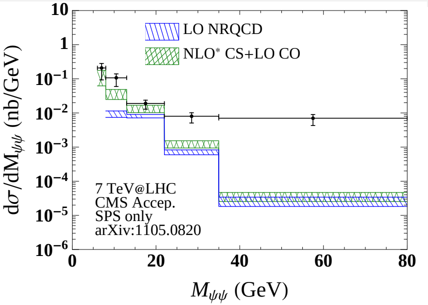

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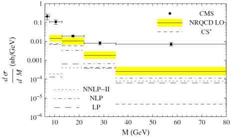
- We disagree "that their inclusion nearly fills the large gap" **Z. He, B. Kniehl PRL 115, 022002 (2015)**



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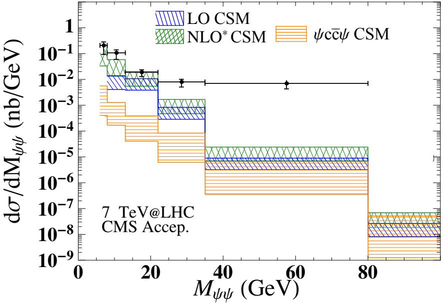

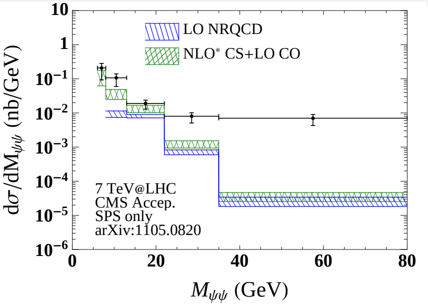

Single J/ψ LDME fit: M. Butenschoen, B. Kniehl arXiv:1105.0820, PRD 84 (2011) 0515

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- Same with other NLO LDMEs, by the PKU group (incl. my co-author), by the IHEP group as well as by Bodwin et al. **PRL 110 (2013) 042002 ; JHEP 1505 (2015) 103; PRL 113 (2014) 022001**
- We disagree "that their inclusion nearly fills the large gap" **Z. He, B. Kniehl PRL 115, 022002 (2015)**
- In terms of $\chi^2_{\rm d.o.f}$:

	LO CO+ NLO* CSM w/o DPS	NLO* CSM w DPS
$\chi^2_{\rm d.o.f}$	3.0	1.9

Another way to see this with 2 CO channels

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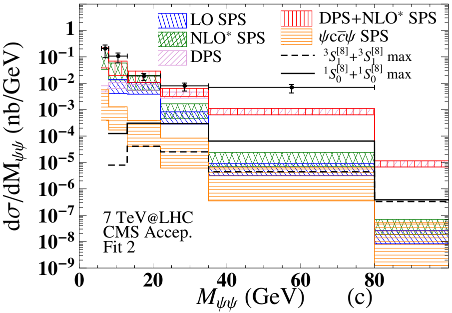

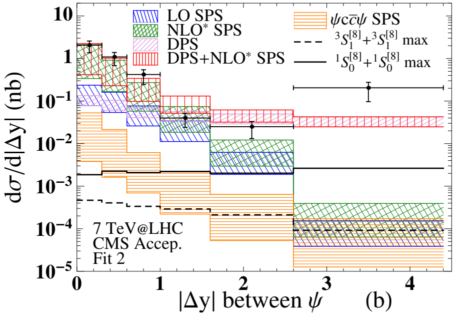

- Using for the upper bound: $\langle \mathcal{O}^{J/\psi}(^3S_1^{[8]})\rangle < 2.8 \times 10^{-3}$ GeV^3 & $\langle \mathcal{O}^{J/\psi}(^1S_0^{[8]})\rangle < 5.4 \times 10^{-2}$ GeV^3

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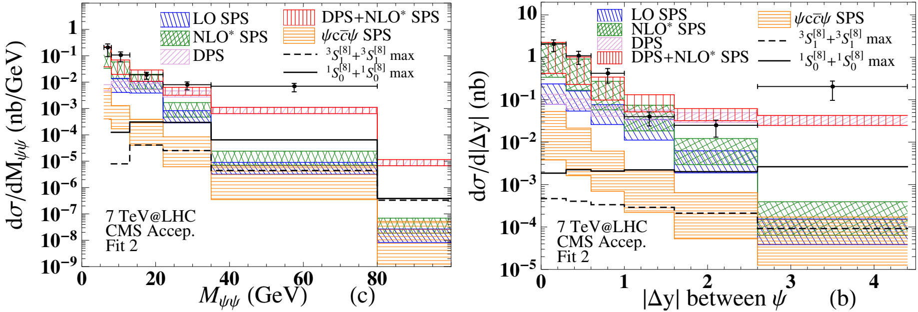

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  (See Mathias' talk and **H. Han *et al.*PRL 114 (2015) 092005**)

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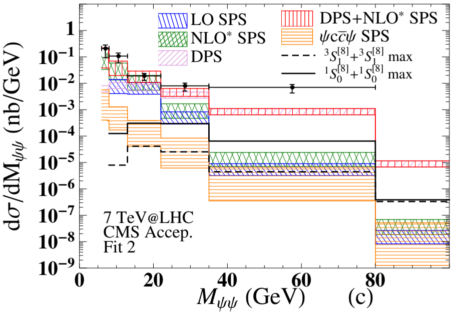

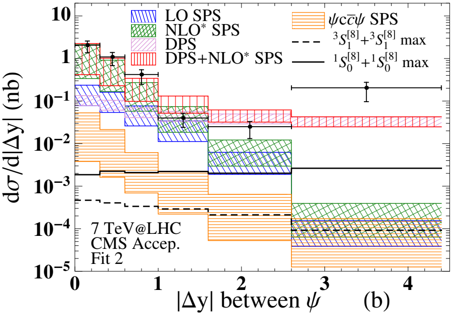

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  (See Mathias' talk and **H. Han *et al.*PRL 114 (2015) 092005**)
- Ignoring all previous constraints and fitting (one channel at a time) the LDME on the CMS data one gets irrealistically large values:
  $\langle \mathcal{O}^{J/\psi}(^3S_1^{[8]})\rangle = 0.42 \pm 0.12$ GeV^3 & $\langle \mathcal{O}^{J/\psi}(^1S_0^{[8]})\rangle = 0.91 \pm 0.22$ GeV^3 !!!

Predictions: excited states

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- Overall :

	(CSM) SPS	DPS
$F^{\psi'}_{\psi\psi}$	45%	20%
$F^{\chi_c}_{\psi\psi}$	small	50%

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- Predictions made for forthcoming LHCb and ATLAS data also for AFTER@LHC

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