After the first quarkonium data at $\sqrt{s} = 7$ TeV: where do we stand ?

J.P. Lansberg
Paris Sud XI - IPNO

Winter Workshop on Recent QCD Advances at the LHC
February 13-18 2011
Les Houches, France

Outline

What we understand:

1. why QCD corrections do matter at mid- and high-P_T

What we seem to understand:

2. The CSM predictions account correctly for the yield
3. Colour Octet Dominance is challenged at low/mid P_T in pp
4. QCD corrections do matter for the polarisation

What we do not understand:

5. ψ production at very large P_T

What we already have from the LHC

6. LHC data which are public so far
7. Polarisation impact on acceptance
8. First comparisons of theory with LHC data
9. "Not-so-global" fits with LHC data

What we expect from the LHC

10. More observables !

Part I

What we understand

QCD corrections for Υ at the Tevatron

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J.Campbell, F. Maltoni, F. Tramontano, Phys.Rev.Lett. 98:252002,2007
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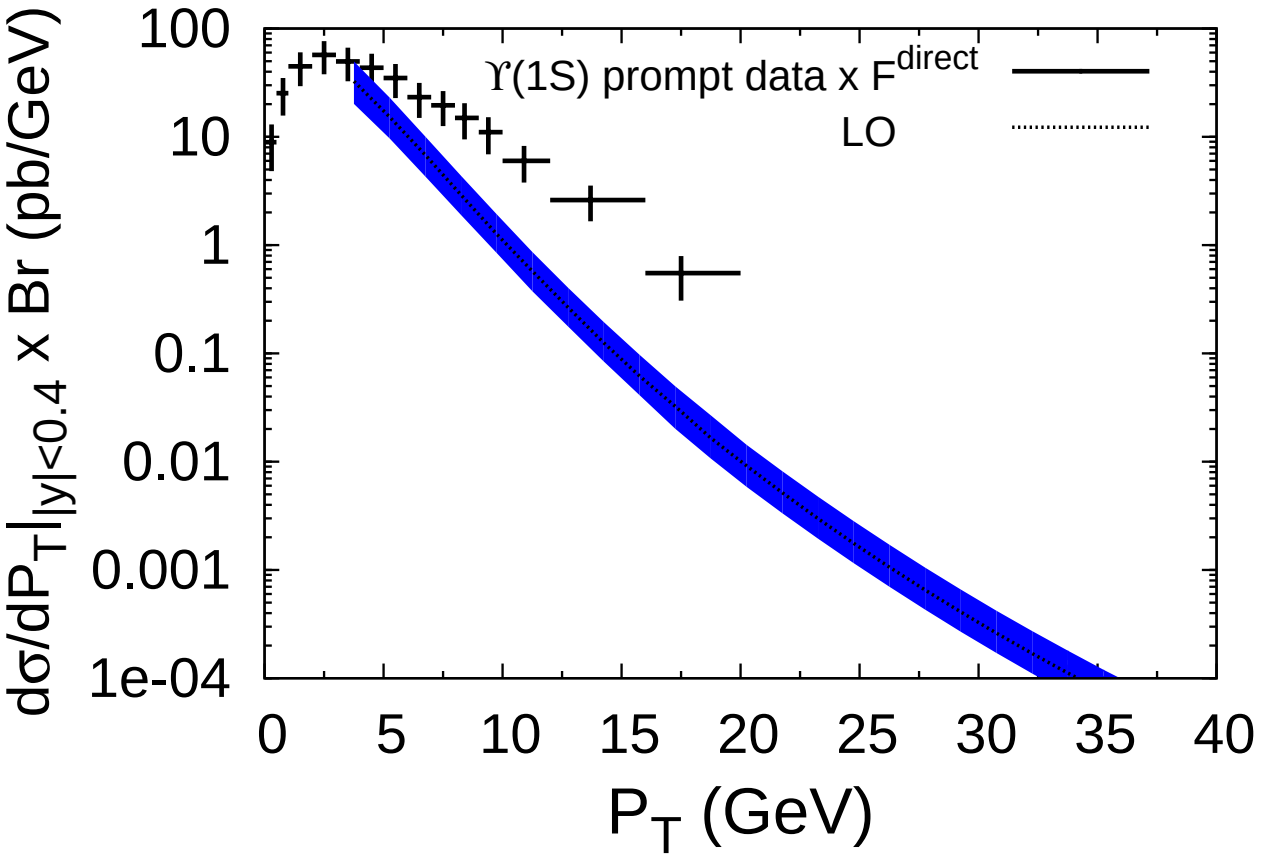

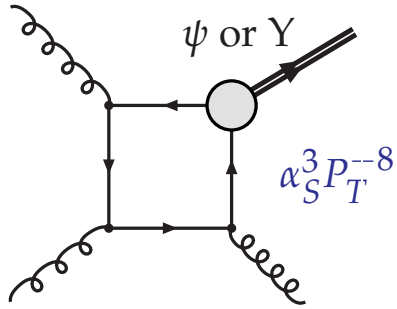

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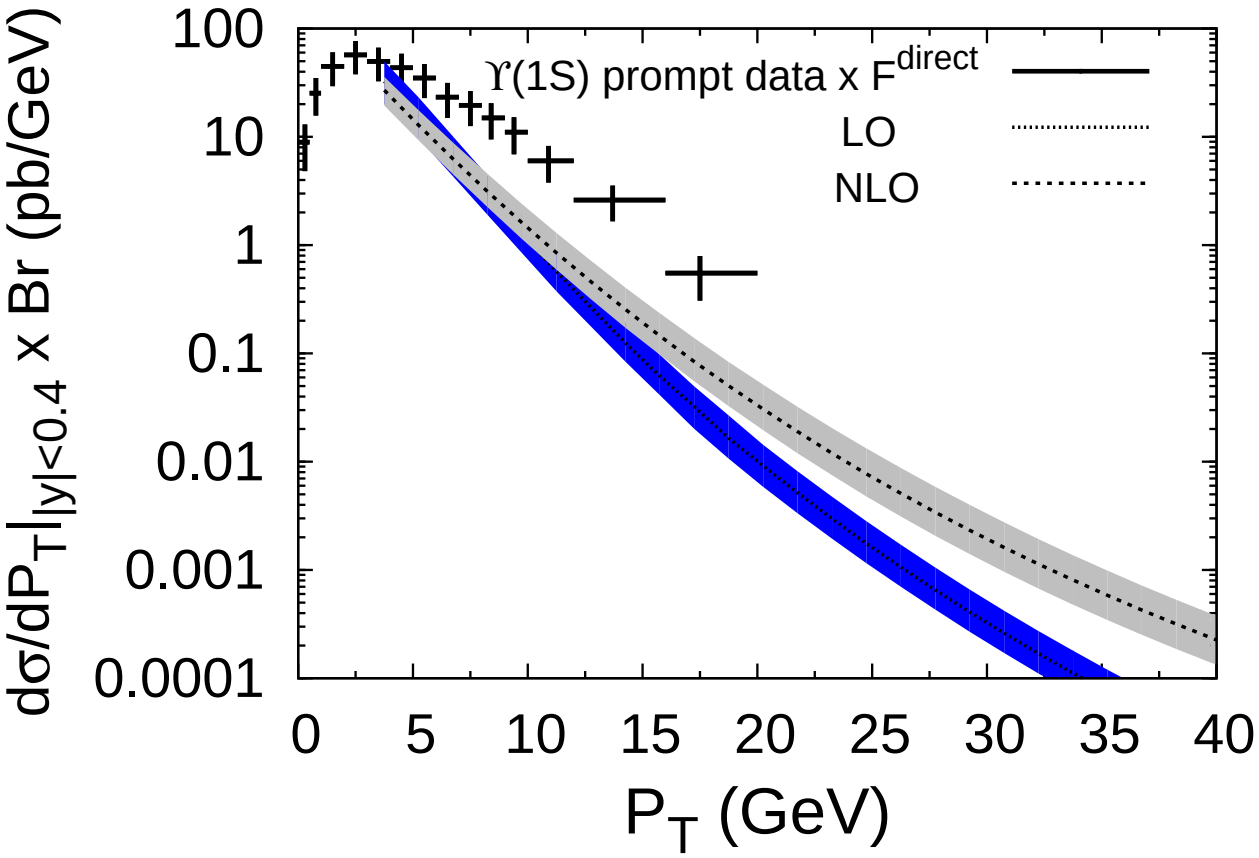

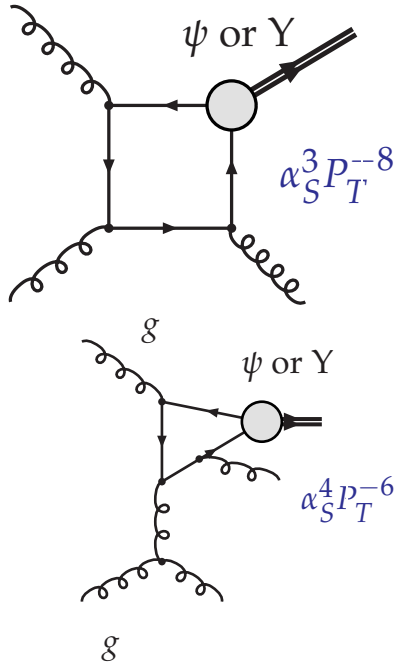

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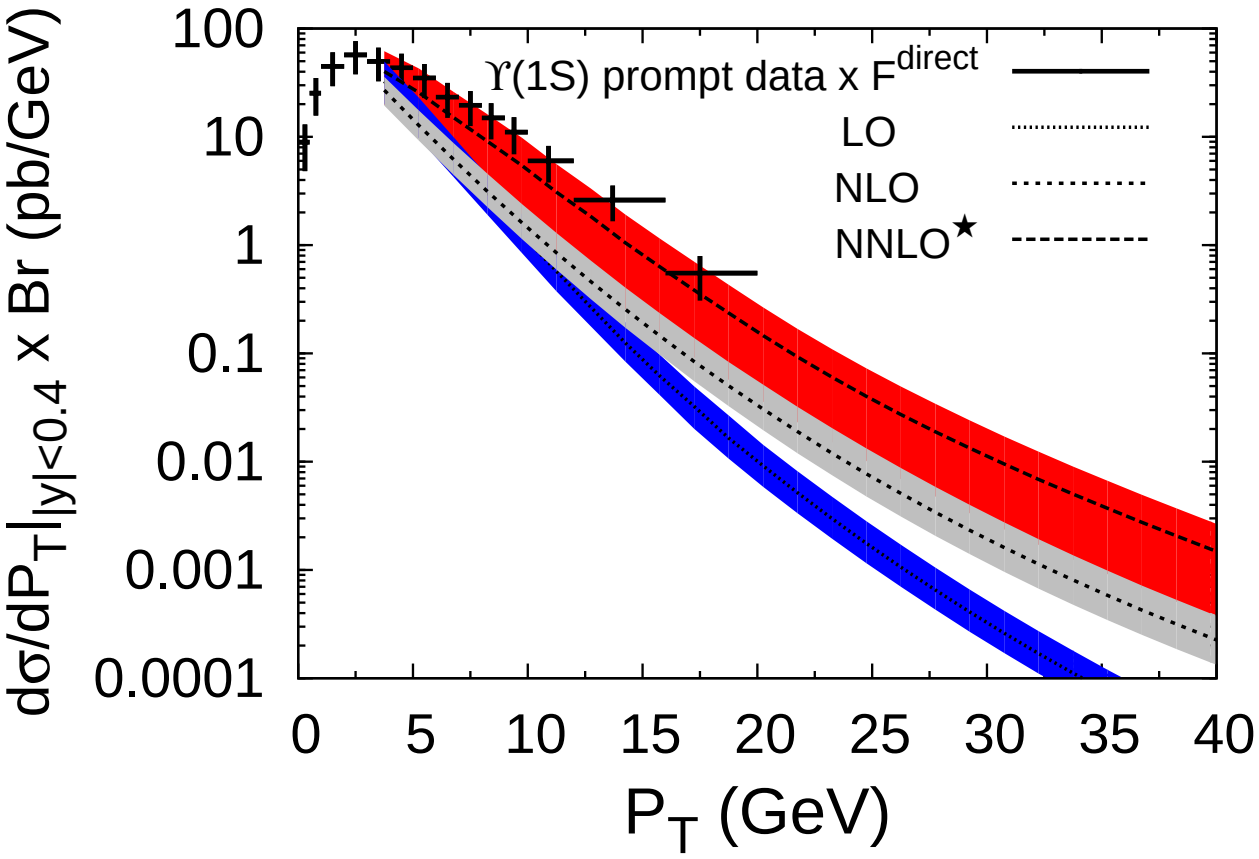

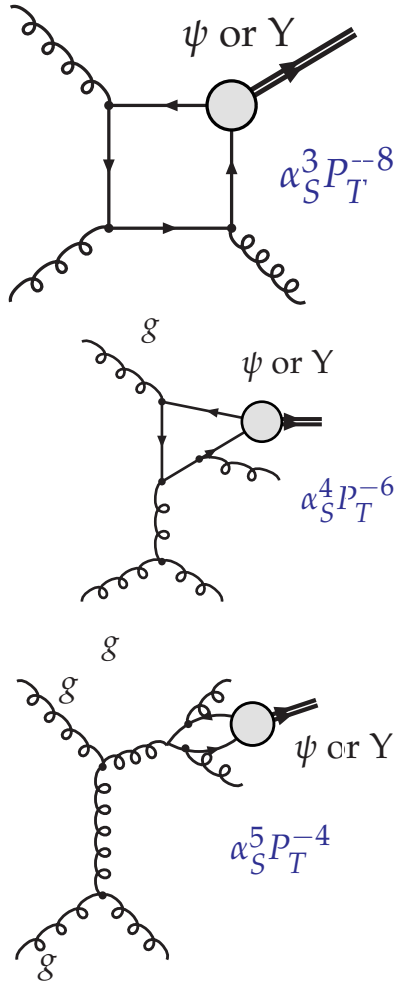

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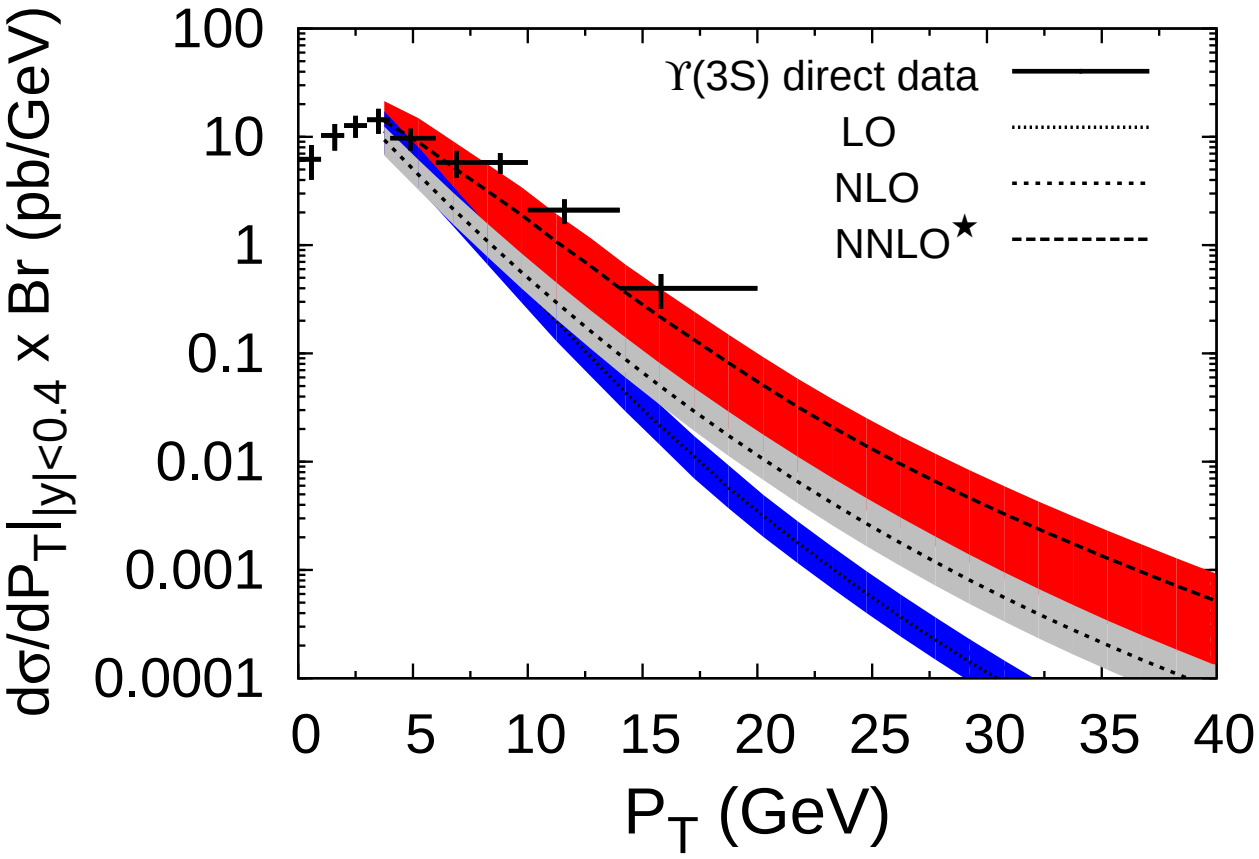

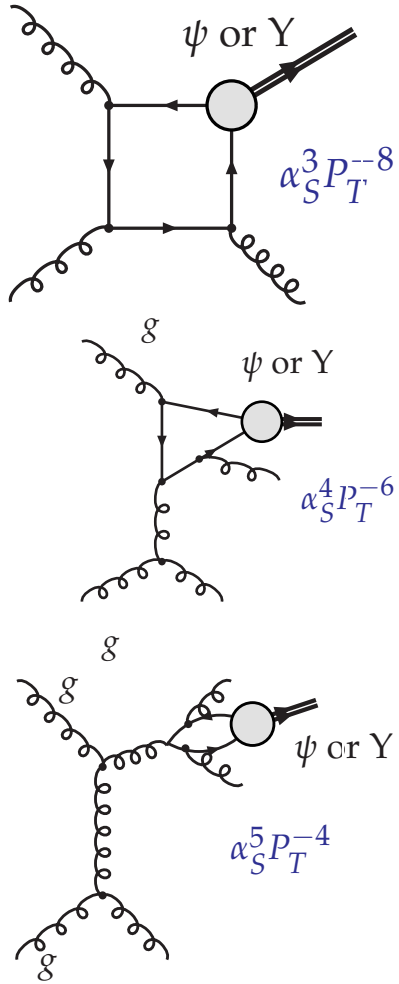

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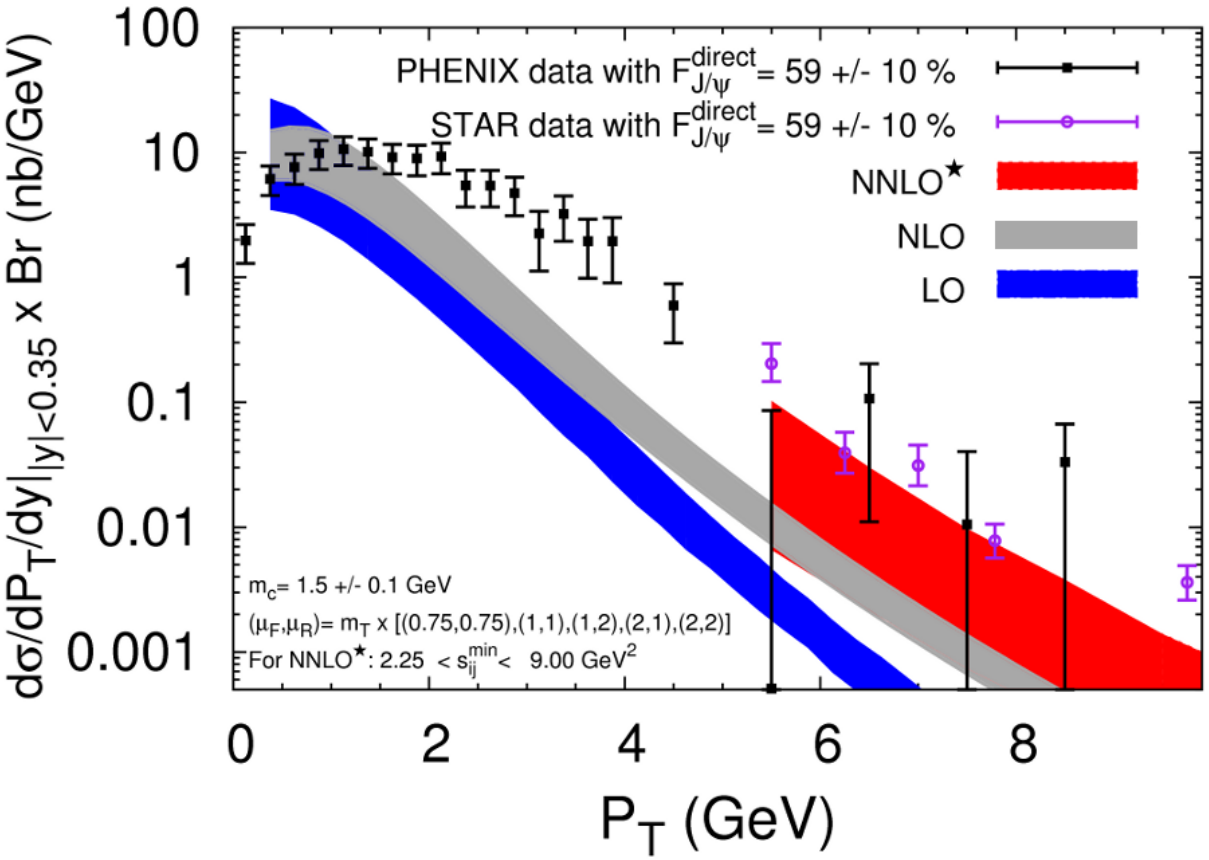
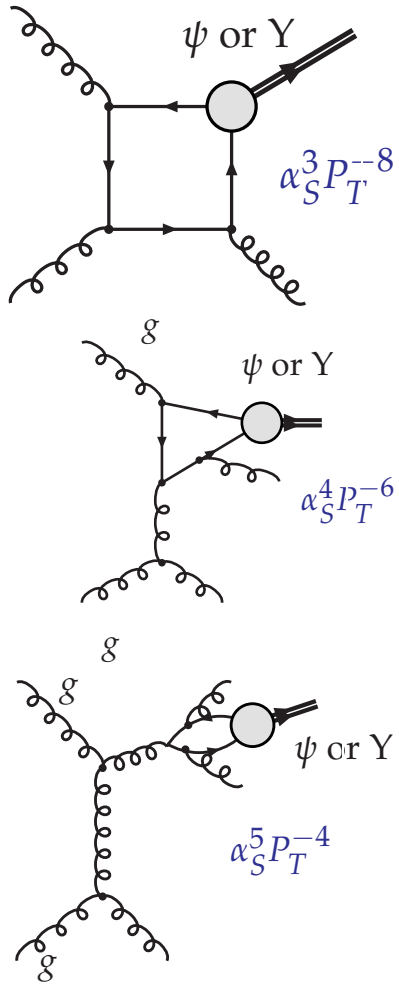
QCD corrections for J/ψ at RHIC

JPL, PLB695:149-156,2011.





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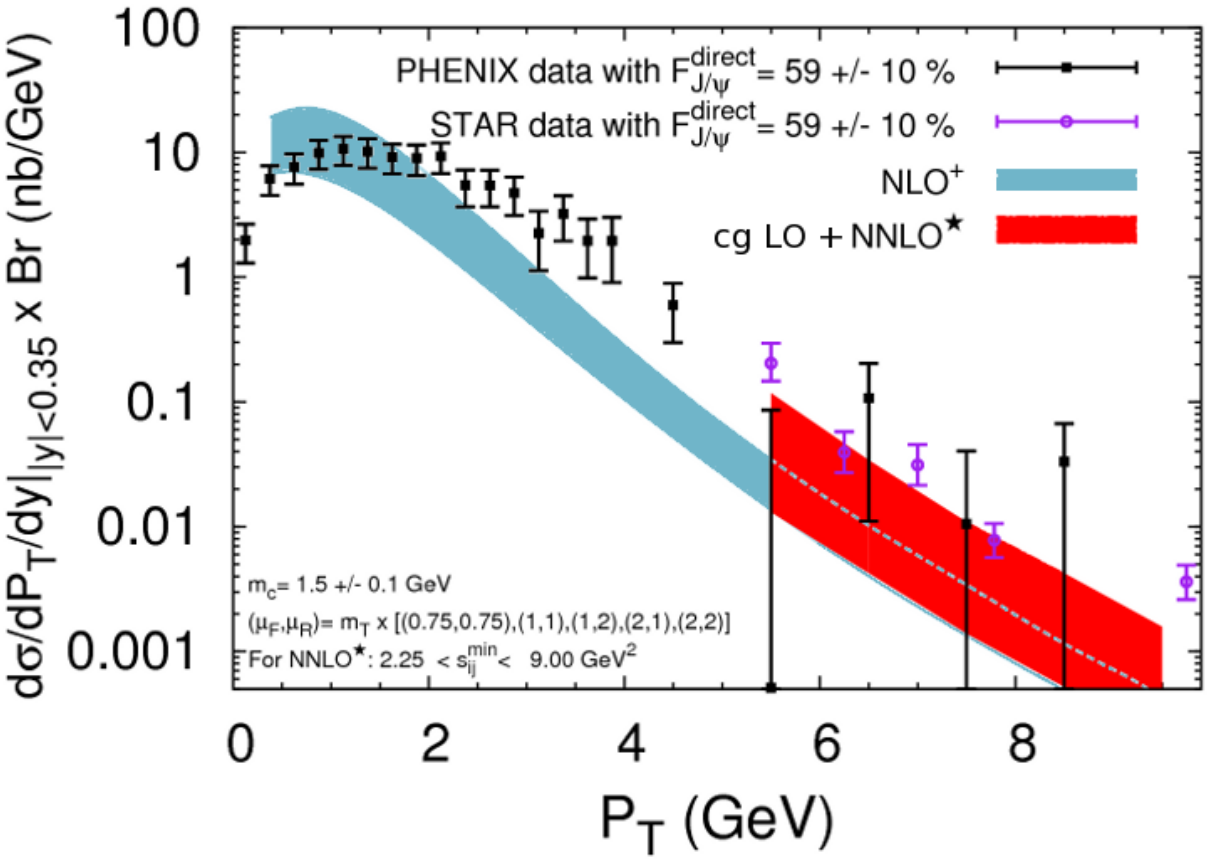

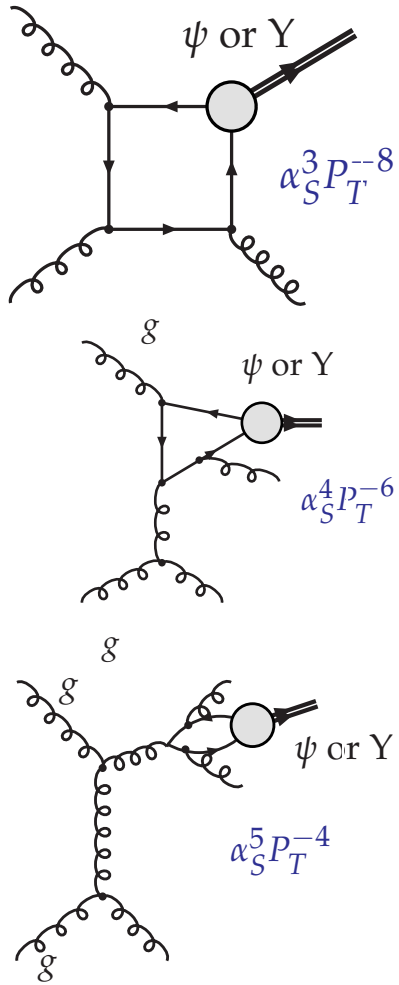

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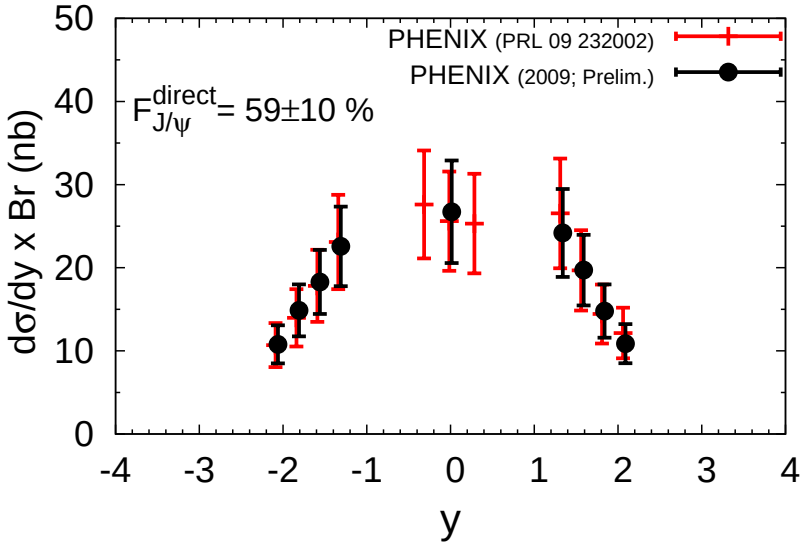
Part II

What we seem to understand

the CSM predictions account for the yield ($\frac{d\sigma}{dy}$)

S. J. Brodsky and JPL, PRD 81 051502 (R), 2010



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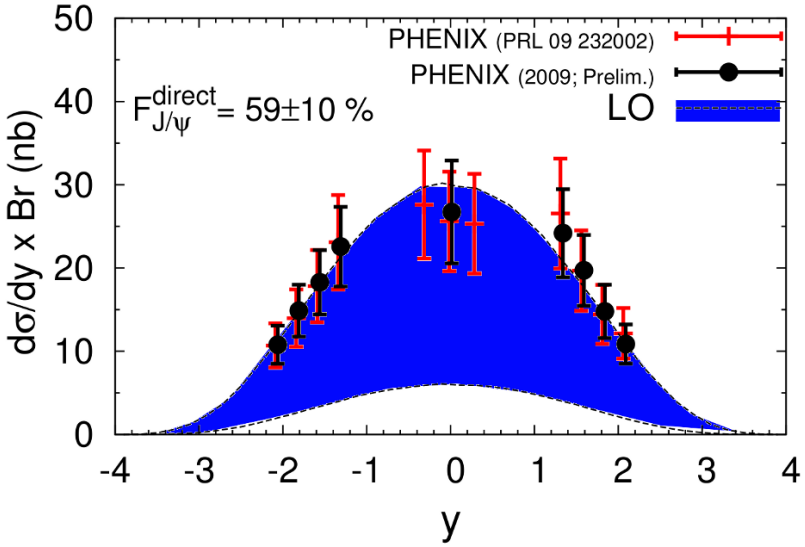

LO: $gg \to J/\psi g$ (nothing new !, back to 1981 !)

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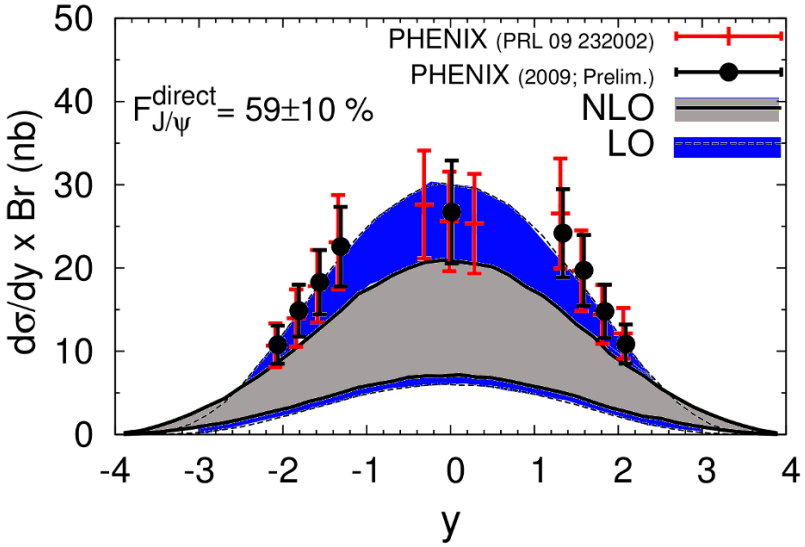

NLO: $gg \to J/\psi$, $gq \to J/\psi gq$, ...

using the matrix elements from J.Campbell, F. Maltoni, F. Tramontano, PRL 98:252002,2007

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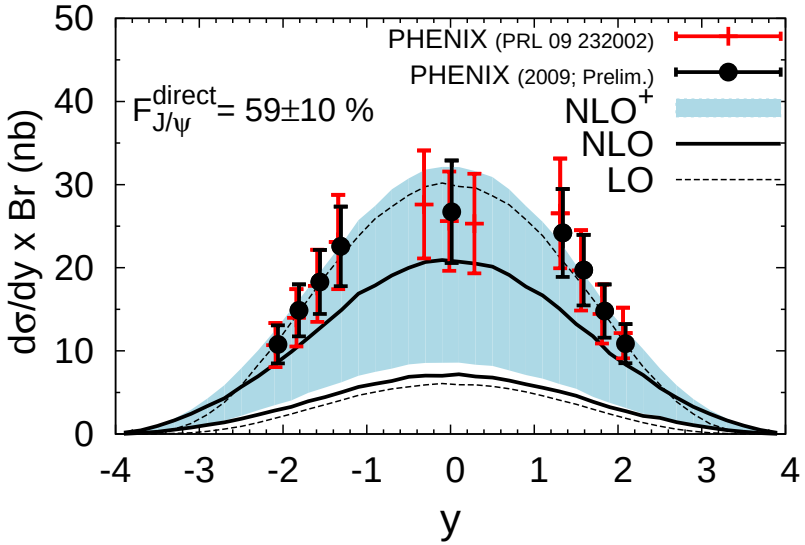

NLO$^+$: adding one new LO contribution $cg \to J/\psi c$

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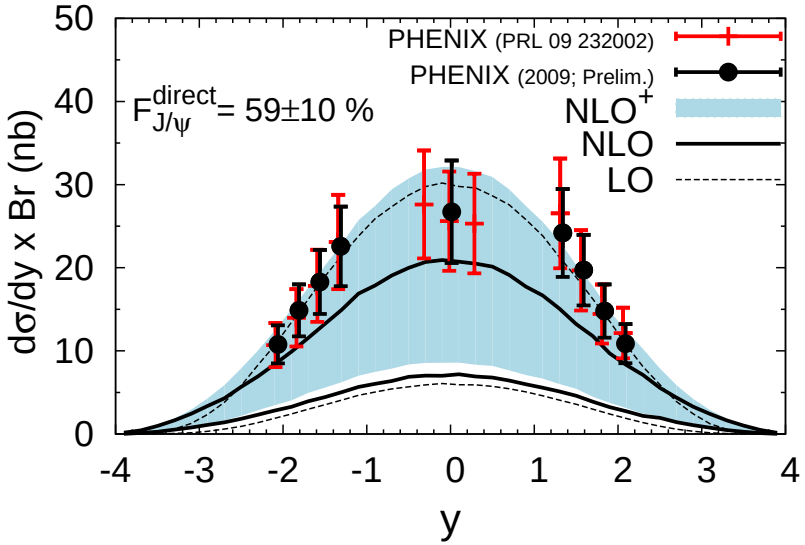

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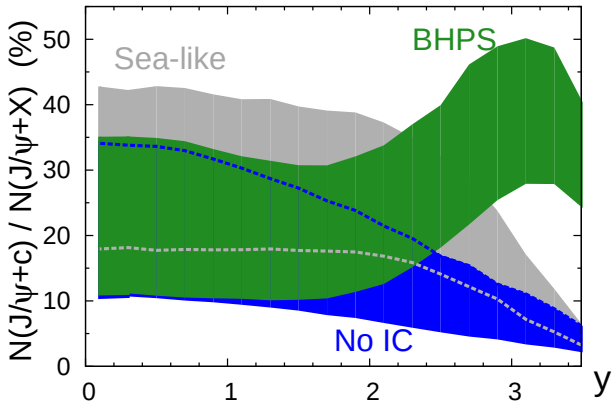


Could be studied via azimuthal correlation $J/\psi + e, \mu$;
10-40% of the direct signal

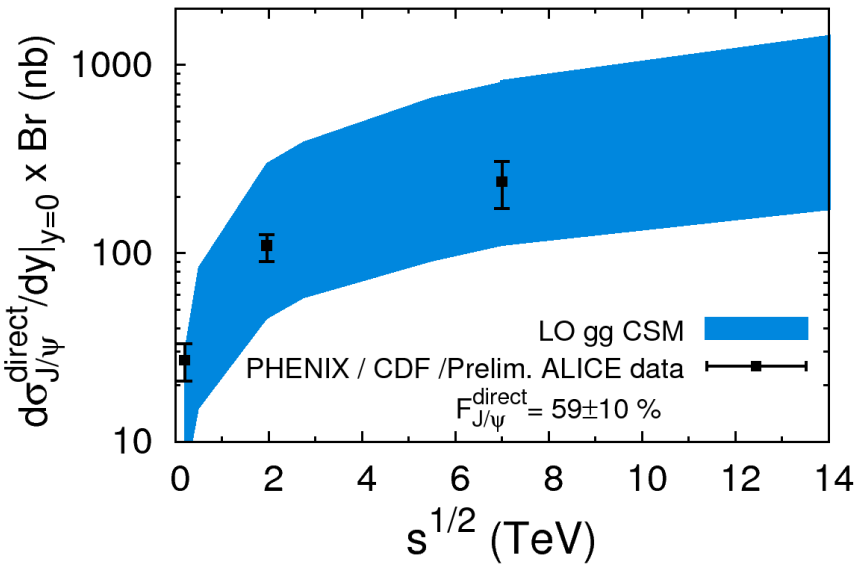
the CSM predictions account for the yield ($\frac{d\sigma}{dy}$)

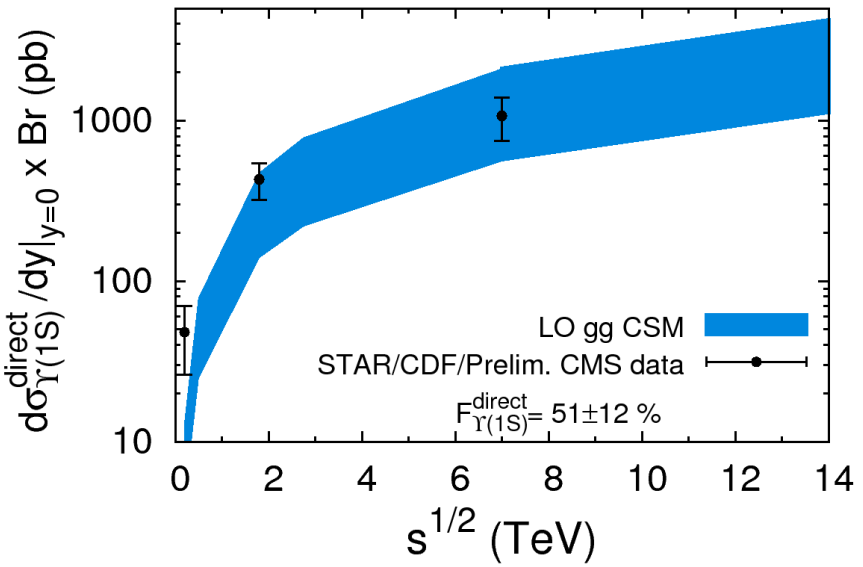
JPL, PoS(ICHEP 2010), 206 (2010)

→ The yield vs. $\sqrt{s}$ (here only LO curves)

- Unfortunately, very large th. uncertainties: masses, scales (μ_R, μ_F), gluon PDFs at low x and Q^2, ...
- Good agreement with RHIC, Tevatron and LHC data

(multiplied by a constant F^{direct})





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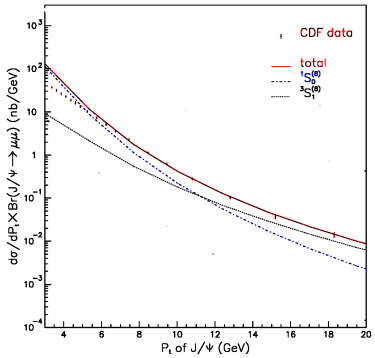
- **Constraints from the P_T dependence in pp**
  - NLO yield for CO channel overshoot data at low P_T



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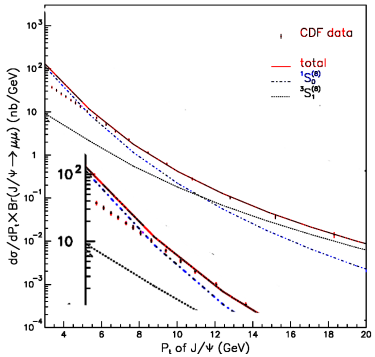

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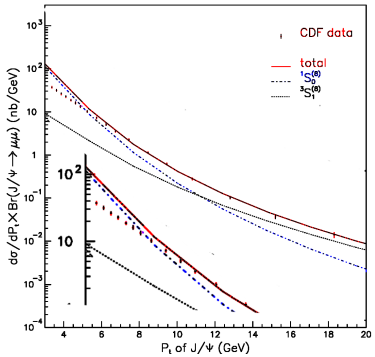

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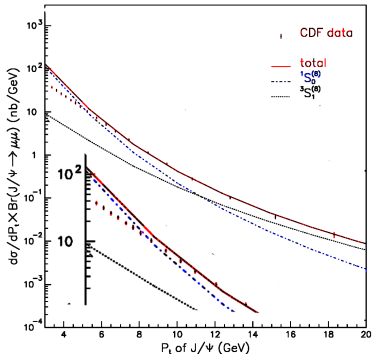

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  - $e^+e^- \to J/\psi gg$ **CS** at NLO + rel. corr. : 0.4-0.7 pb

no space for CO ($^1S_0$ or ^3P_J) in B-factory data

Y.Q.Ma,*et al.*,PRL102 (2009)162002;B.Gong, J.X.Wang, PRL102 (2009) 162003; Z.G. Hue *et al.*, PRD81 (2010) 054036

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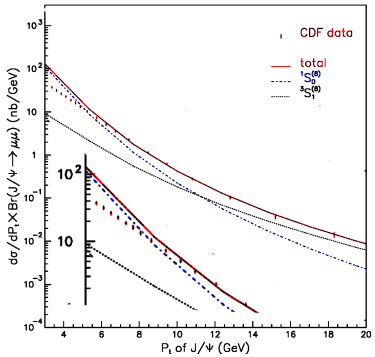

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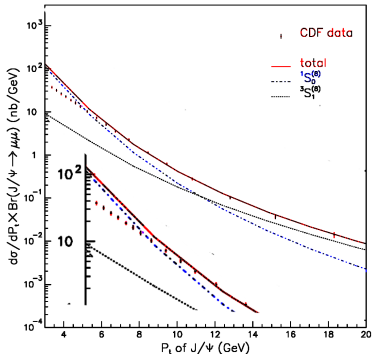

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(Academical) reduction by a factor of 2-3 of the LDMEs, IF one ignores the CSM

- Actually, the reduction is much stronger and thus in $p-p$ collisions the CS dominates over CO at low/mid P_T

Y. Zhang *et al.*, PRD81:034015,2010.

Υ & ψ polarisation at $\mathcal{O}(\alpha_S^4)$ & $\mathcal{O}(\alpha_S^5)$

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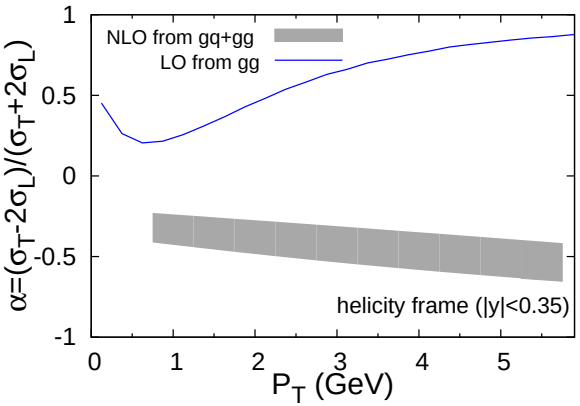

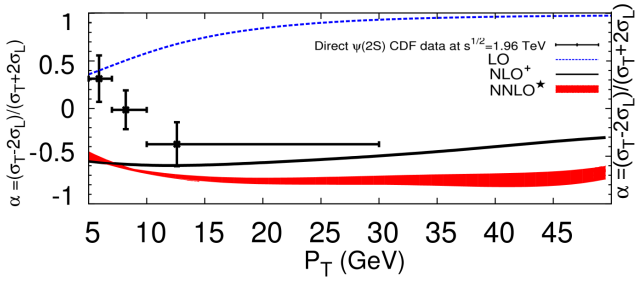

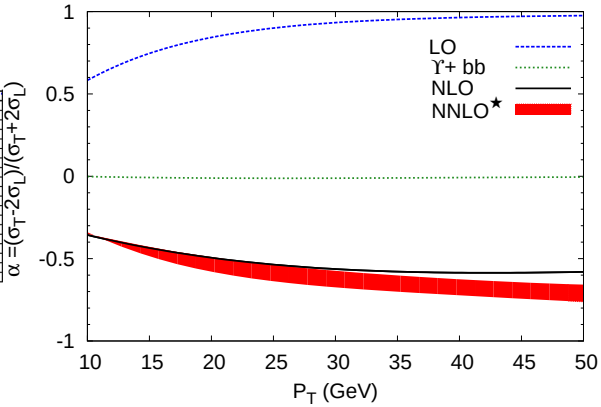

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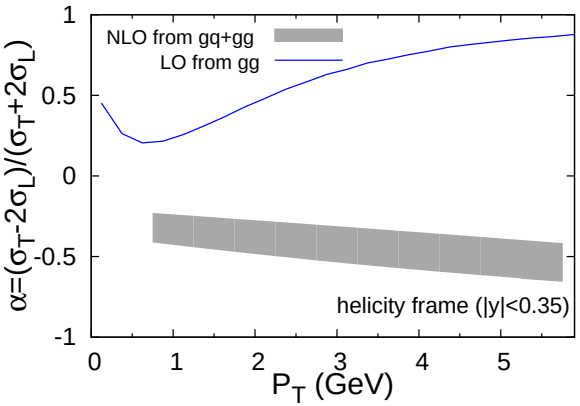
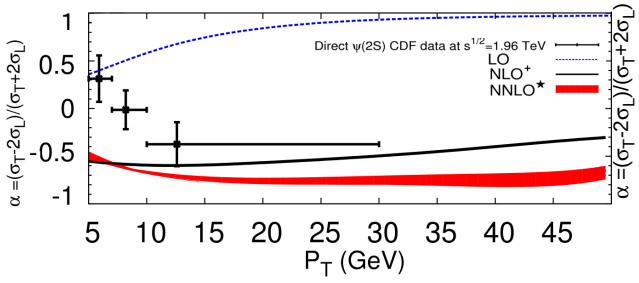
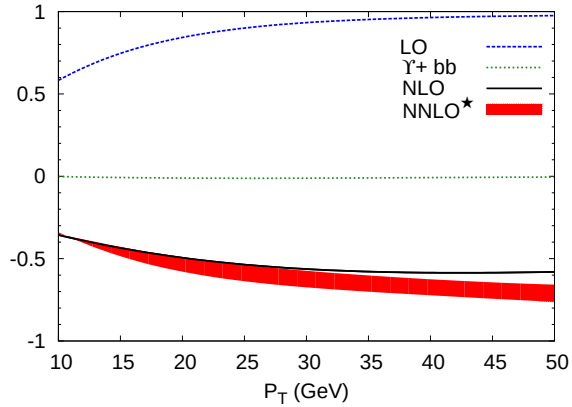






→ Complete modification of the polarisation at NLO

(also at NNLO*)

→ Yield from k_T factorisation is also longitudinal (in the helicity frame)

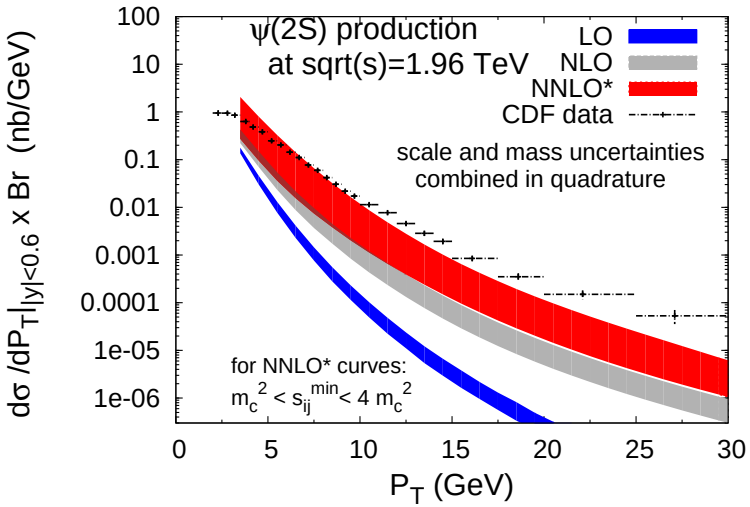
→ **This is not yet explained by simple arguments**

(although reasonable)

Part III

what we do not understand

ψ production at very large P_T



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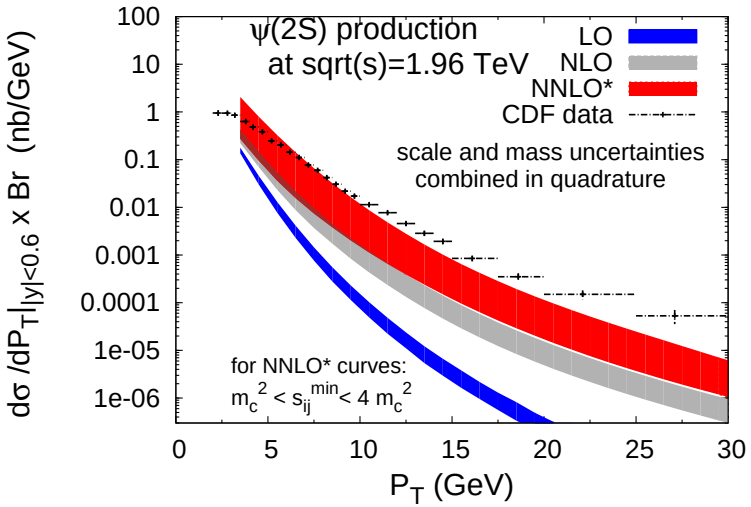

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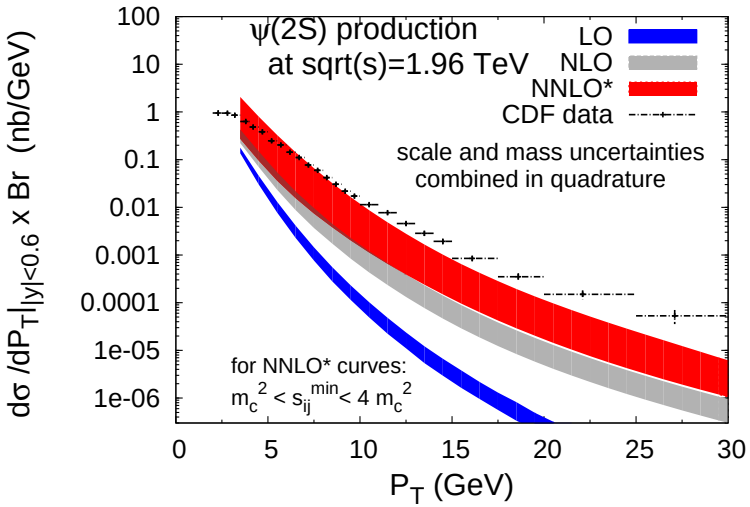

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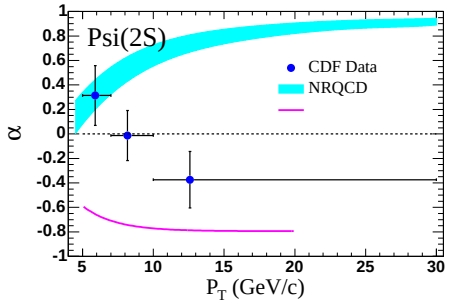

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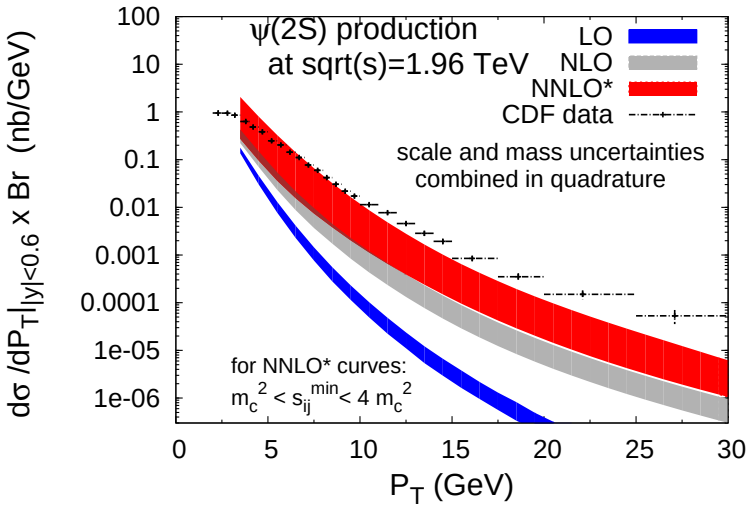

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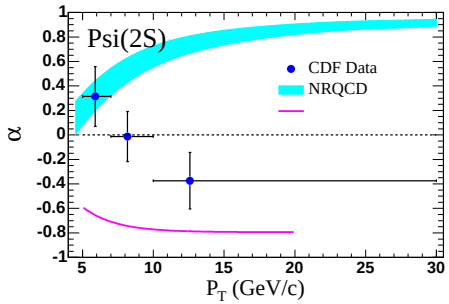
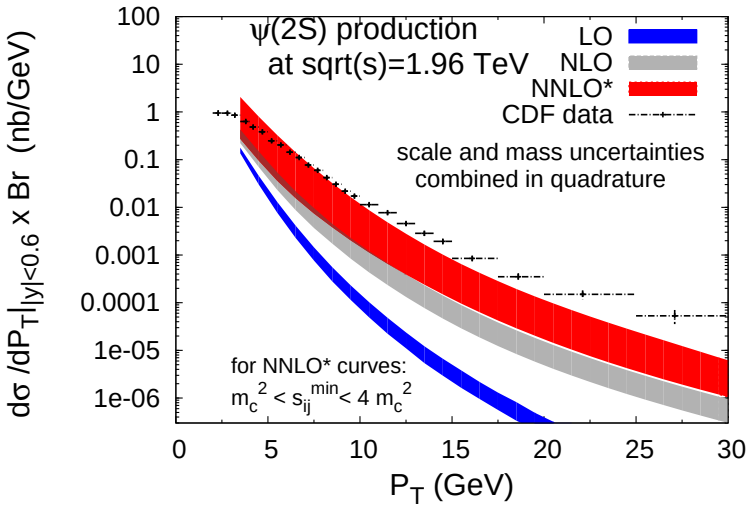


- Could be the data ...

ψ production at very large P_T



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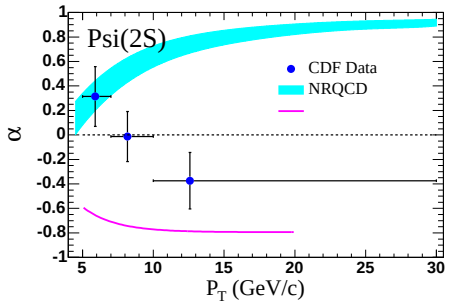

- Could be the data ...
- Let's wait for the LHC data for prompt $\psi(2S)$ or **direct** J/ψ

Part IV

LHC data at $\sqrt{s} = 7$ TeV

LHC data which are public so far

- CMS: **arXiv:1011.4193 [hep-ex] , arXiv:1012.5545 [hep-ex]**
  - J/ψ $d\sigma/dP_T$ in 3 y bins: $|y| < 1.2$, ..., $1.6 < |y| < 2.4$
  - Extraction of the prompt signal (*i.e.* excluding B feed down)
  - $\Upsilon d\sigma/dP_T$ for $1, 2, 3S$ in 2 y bins $|y| < 1$, $1 < |y| < 2$ ($\rightarrow d\sigma/dy$)

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- LHCb: **LHCb-PUB-2010-011 + talk by De Capua**
  - $J/\psi\ d\sigma/dP_T$ in 5 y bins: $2.5 < |y| < 3.0$,..., $3.5 < |y| < 4.0$
  - Extraction of the prompt signal in these 5 bins
  - Signal for χ_c
  - Signal for Υ's

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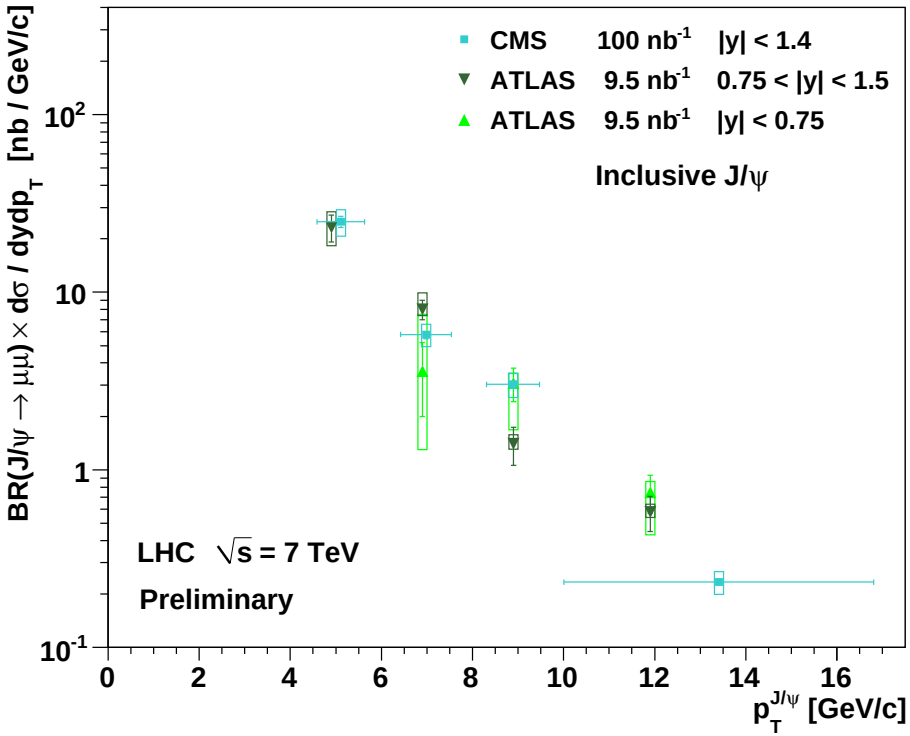
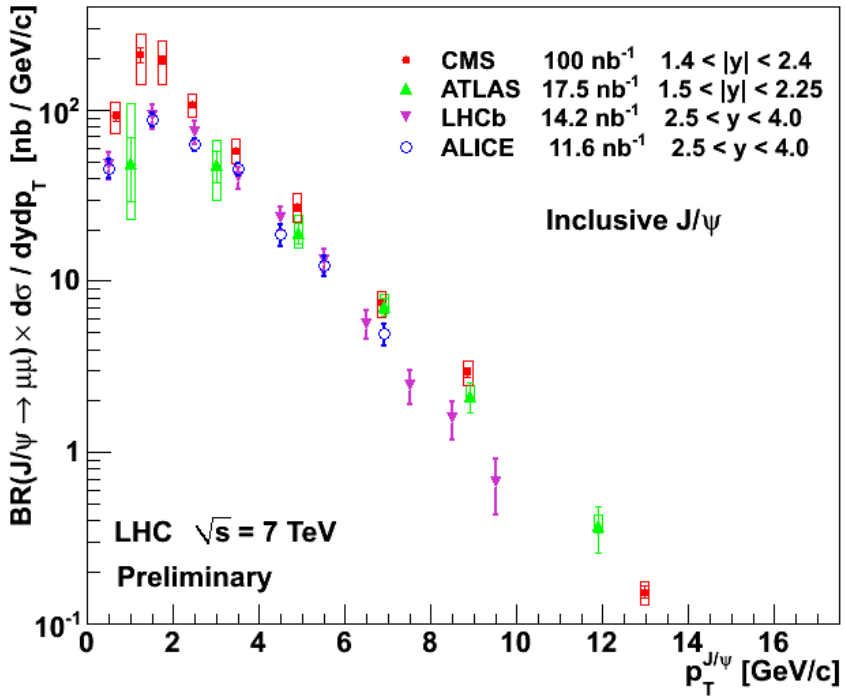
- ALICE:
  - $J/\psi\ d\sigma/dy$ in the central region and for $2.5 < |y| < 4.0$
  - $J/\psi\ d\sigma/dP_T$ in 1 y bin: $2.7 < |y| < 3.8$

Comparison data-data

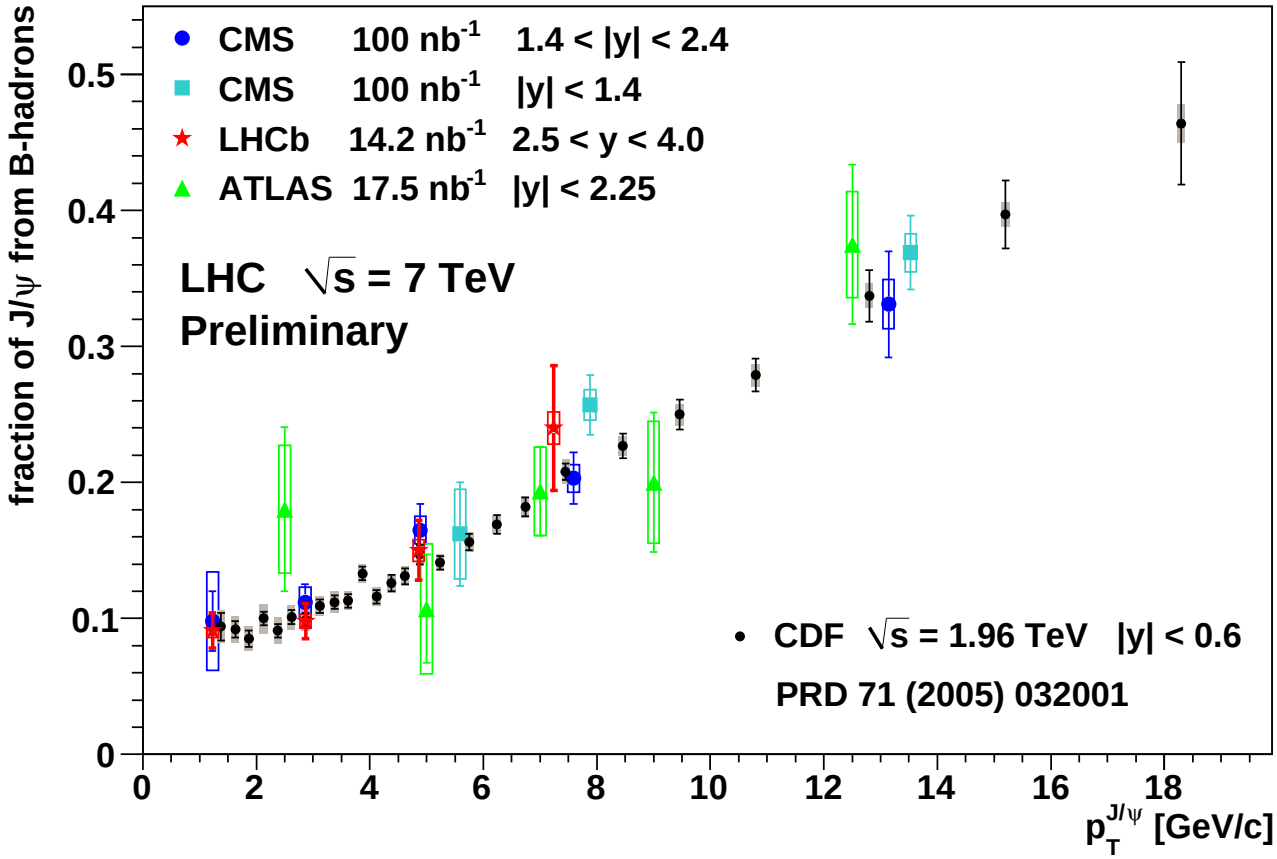
Plots courtesy of E. Scomparin, H. Woehri, C. Lourenço, collaborative work CMS, LHCb, ATLAS and ALICE





b-feed down extraction

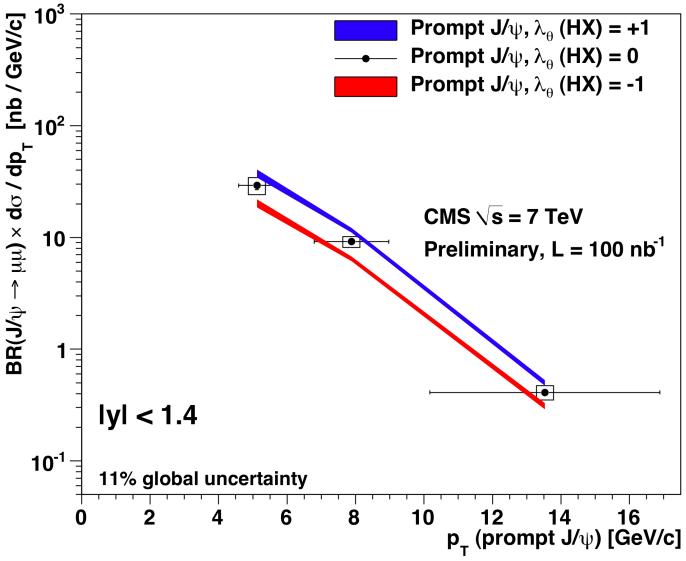
Plot courtesy of H. Woehri, collaborative work with colleagues from LHCb, ATLAS and ALICE shown by C. Lourenço at Quarkonium2010

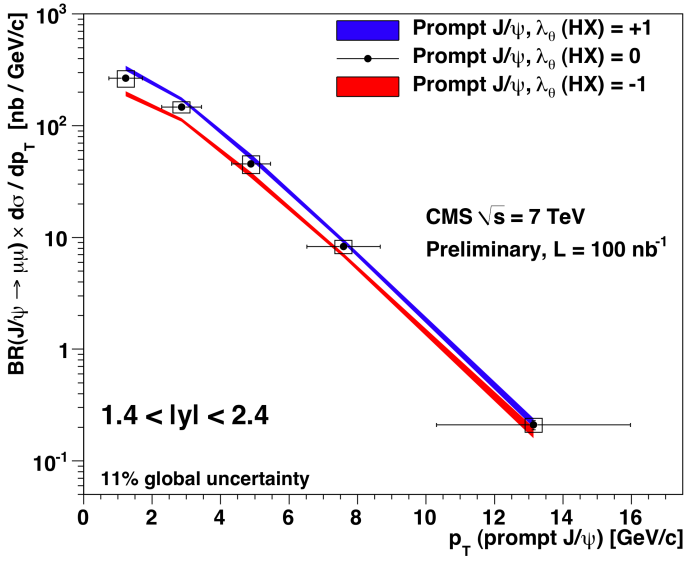


→ There does exist a y dependence of $f_B^{J/\psi}$,
see Stephano's talk (pg 22 !)

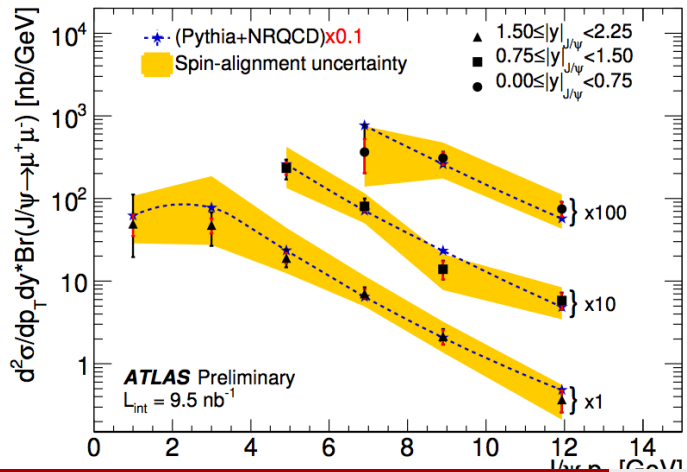
Polarisation impact on acceptance

Plots shown by C. Lourenço at Quarkonium2010

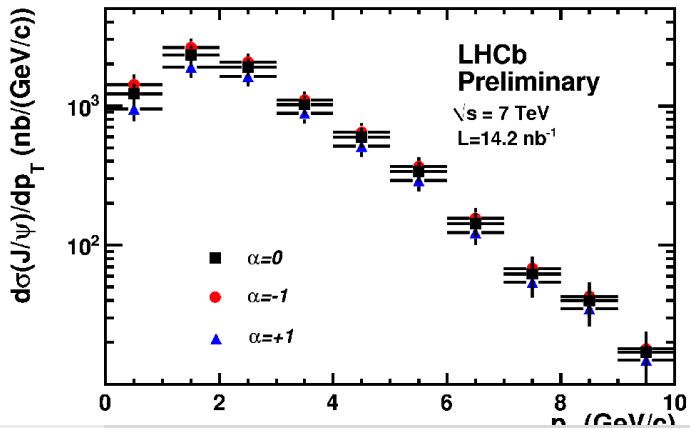




Plot shown by D. Price at Quarkonium2010

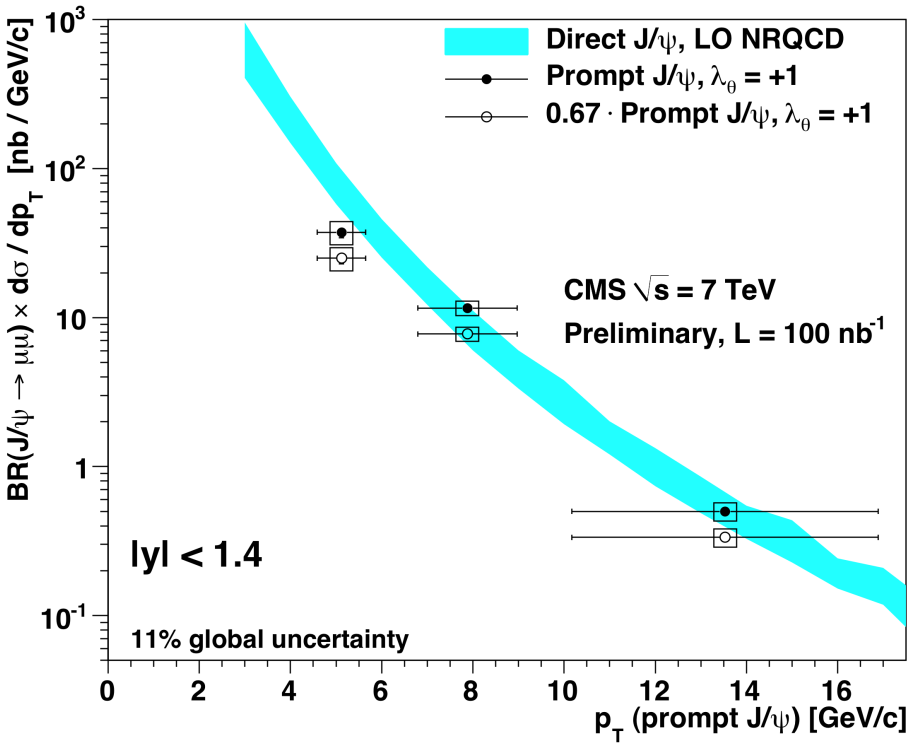


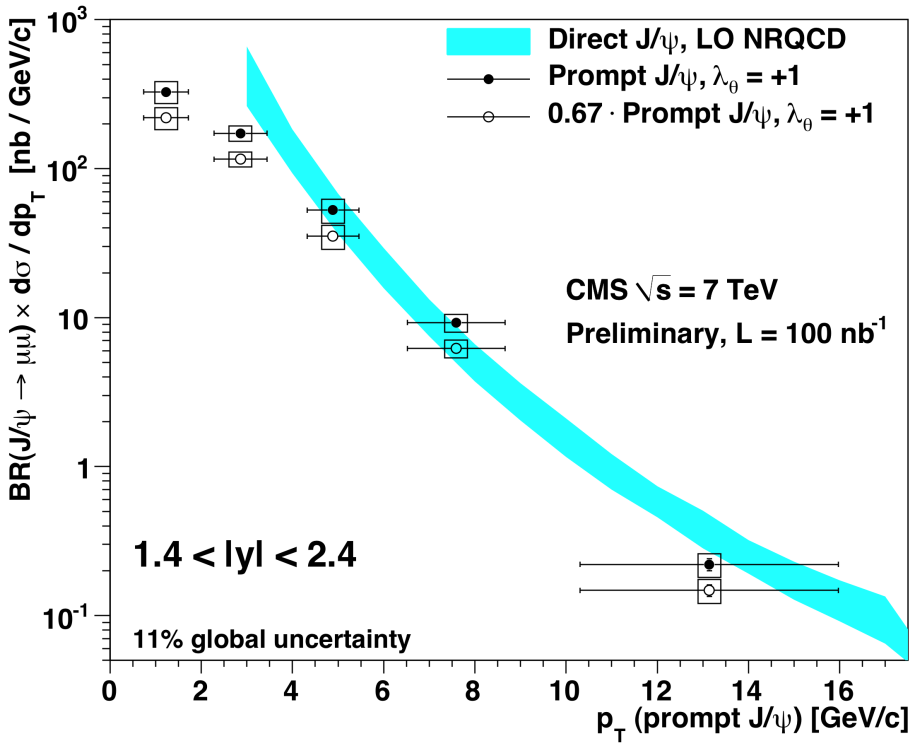
Plot shown by P. Robbe at Quarkonium2010



Comparison of the data with different models: Colour Octet Dominance

Plots by C. Lourenço shown at Quarkonium2010





Theory curves by P. Artoisenet.

Comparison of the data with different models: Colour Evaporation Model

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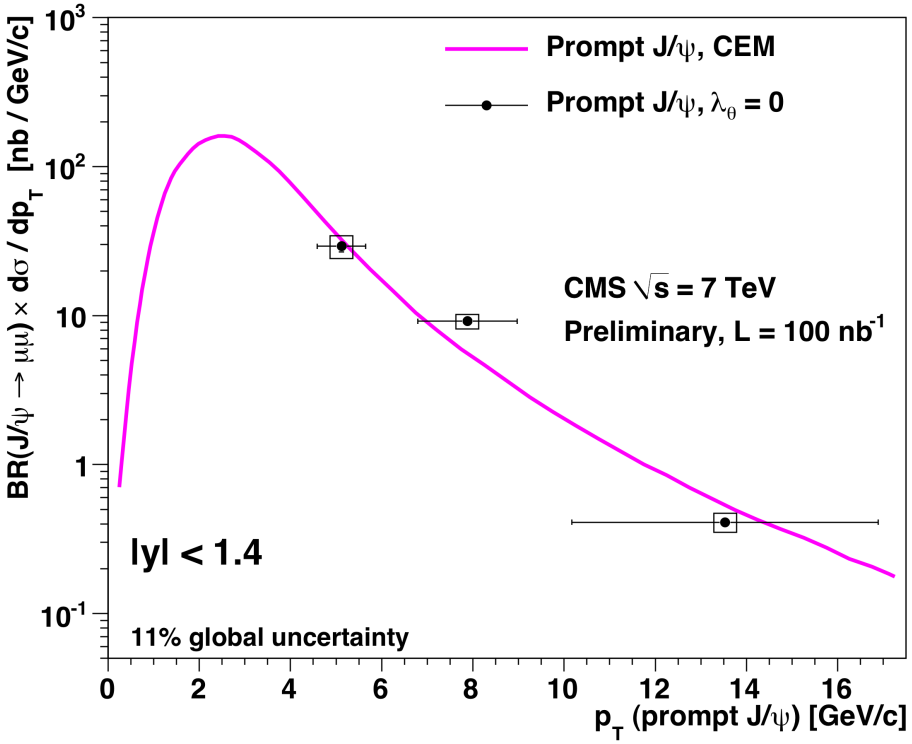

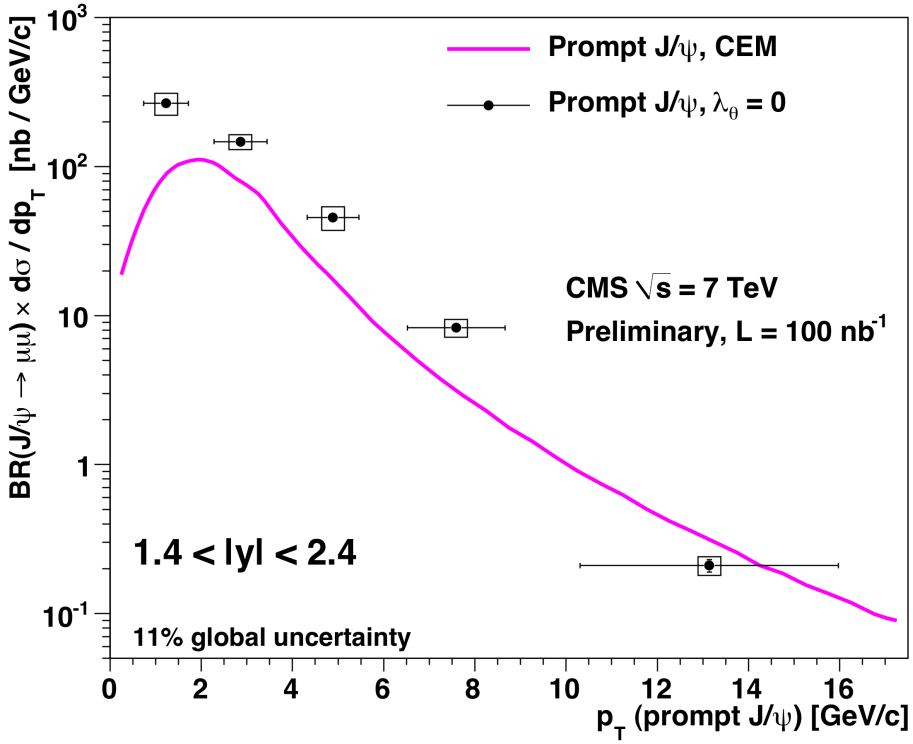

Theory curves by R. Vogt.

Comparison of the data with different models: Colour Singet Model

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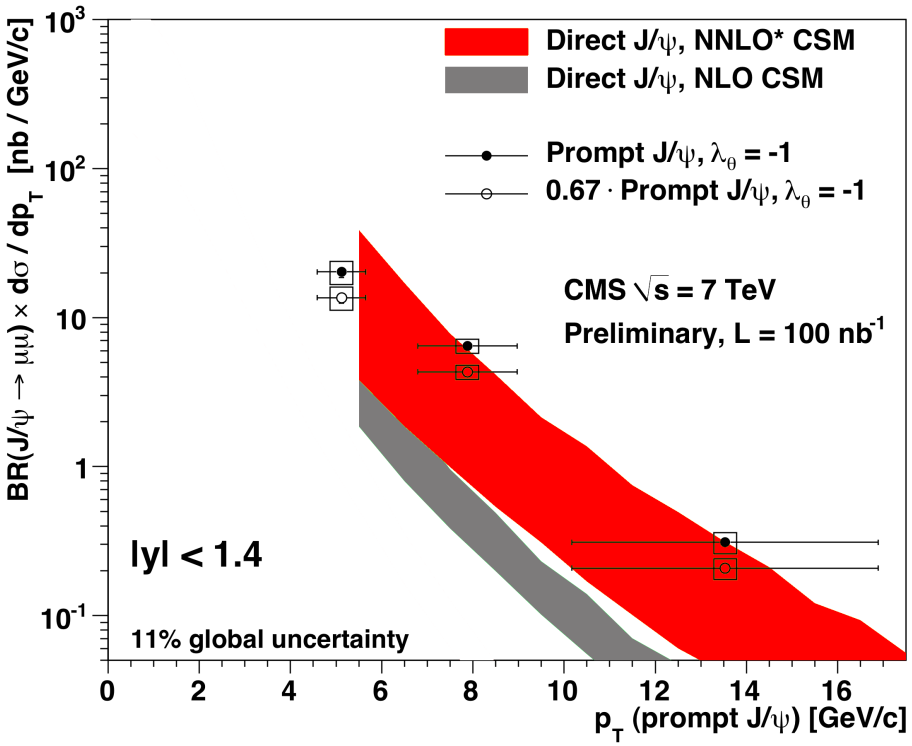
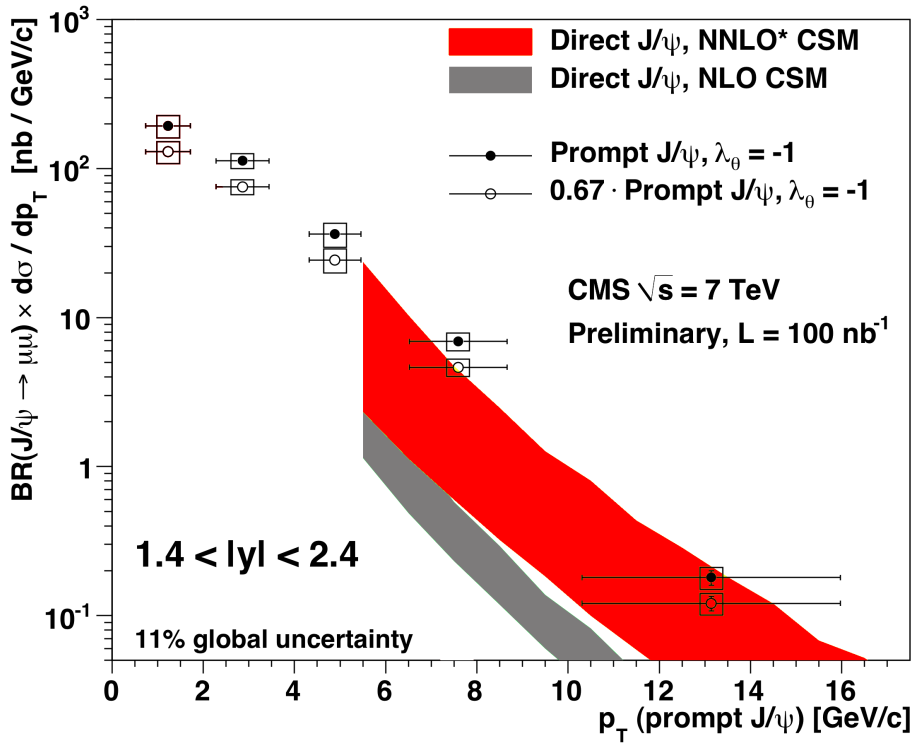
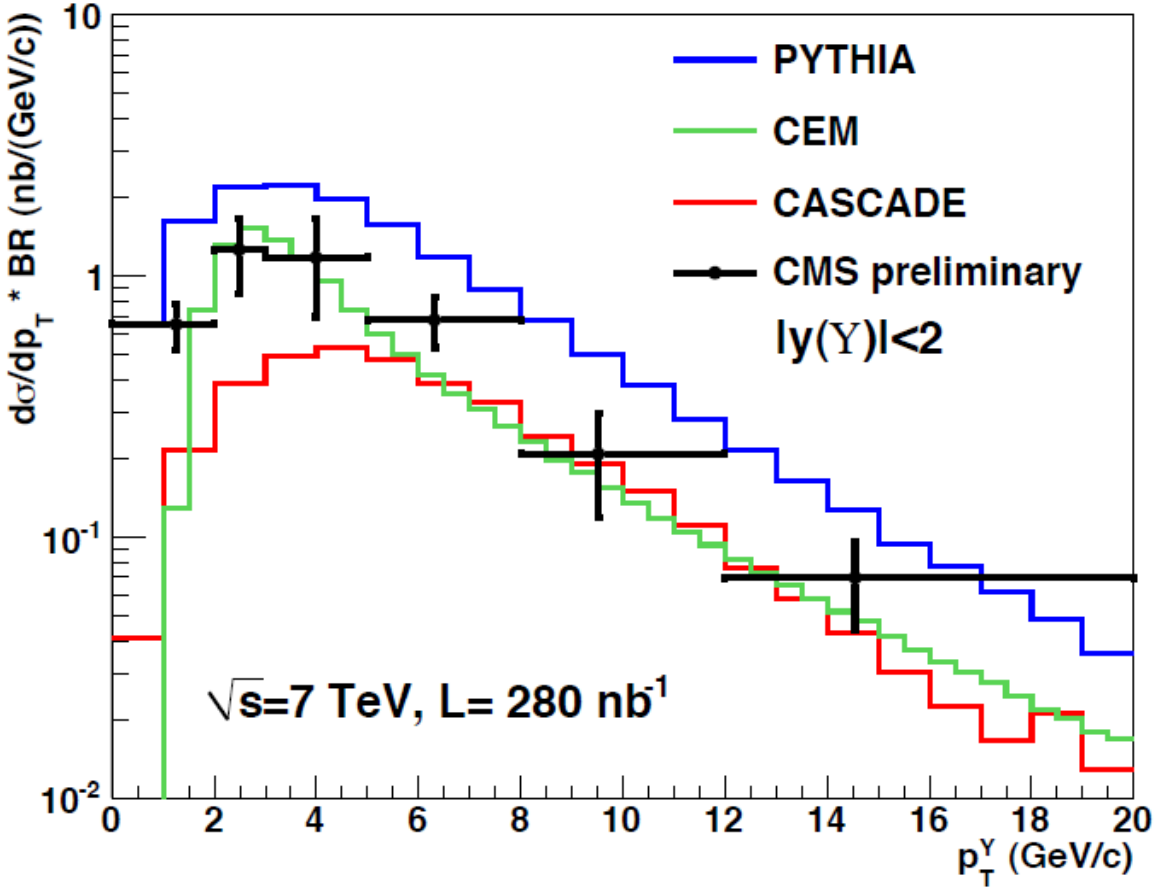




Theory curves by JPL

Comparison of the Υ data with different models

Plot shown by T. Dahms at Quarkonium2010



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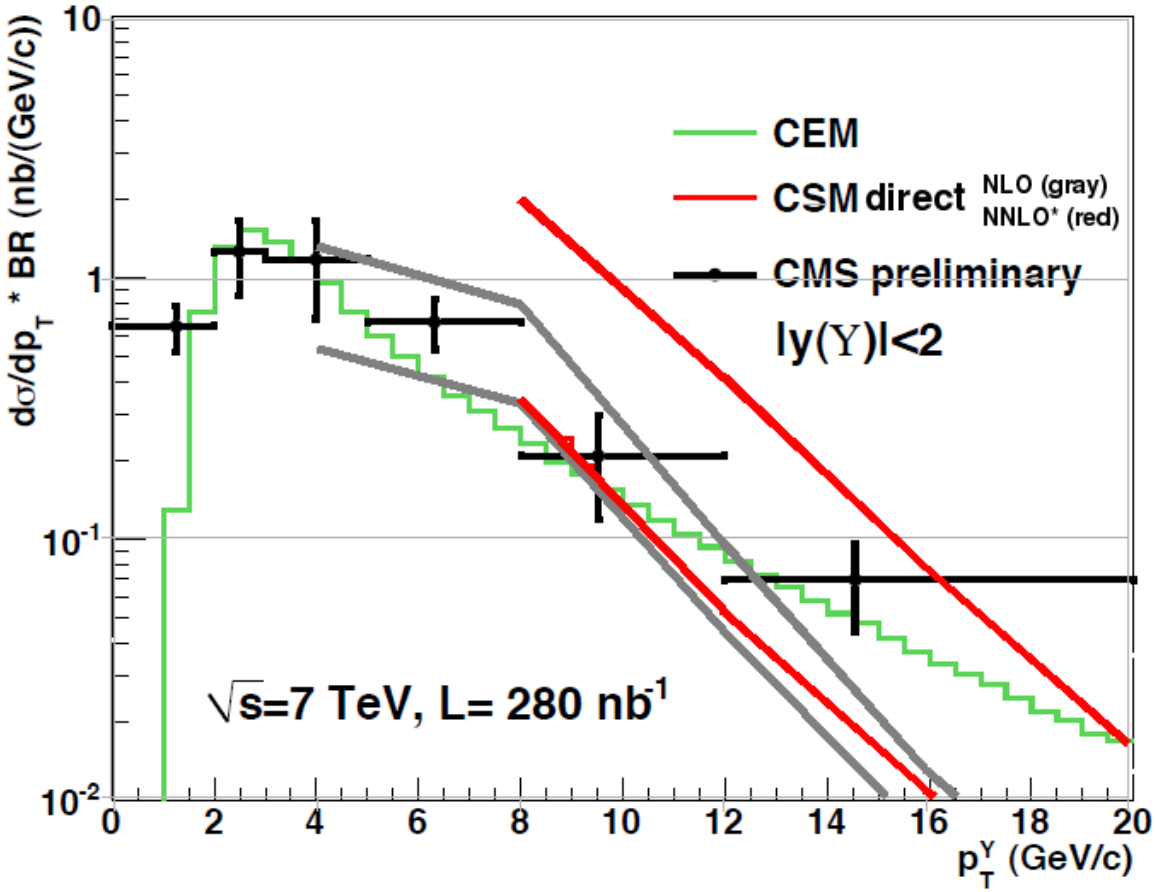

Comparison with Color Singlet Model: NEW !

P.Artoisenet, J.Campbell, JPL, F.Maltoni, F. Tramontano, Phys. Rev. Lett. 101, 152001 (2008)

Impact of Octets ? "Not-so-global" fits with LHC data

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QWG Yellow Report, hep-ph/0412158

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- To be complete: these studies also ignored e^+e^- constraints (slide 9)

Part V

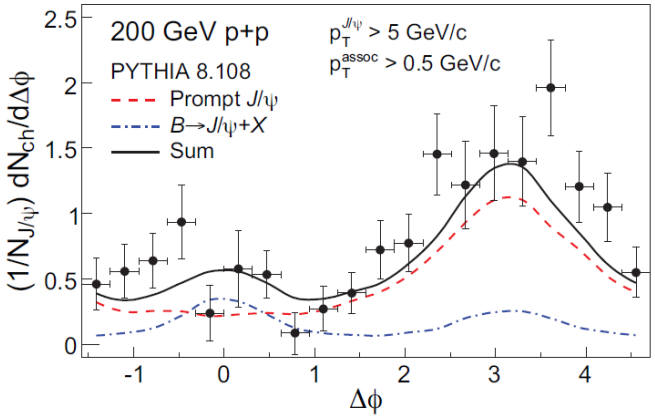
what we expect from the LHC:

Part V

what we expect from the LHC: new measurements

New observables

- $J/\psi+$ hadron azimuthal correlations **STAR Collab., Phys.Rev.C80:041902 (R),2009.**



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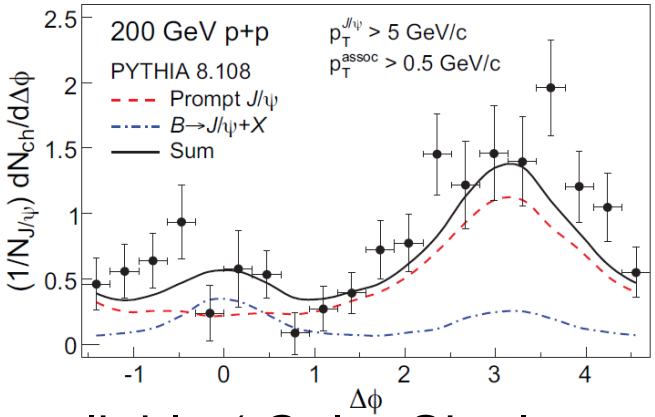

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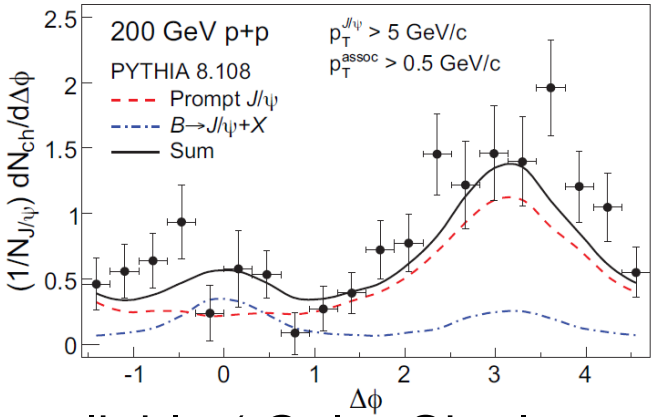

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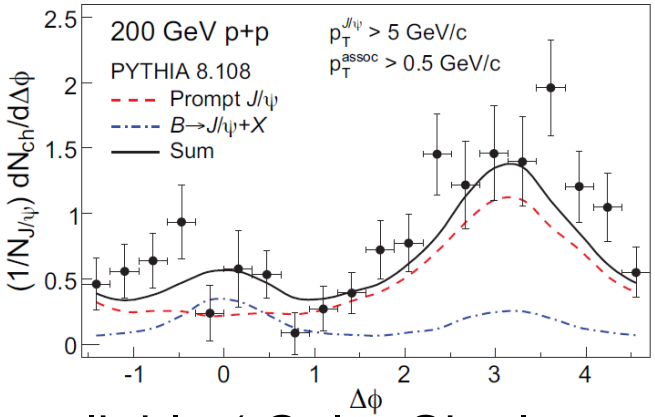

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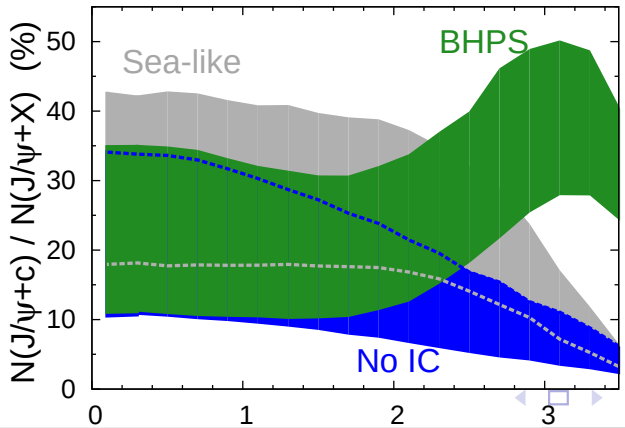
S. J. Brodsky and JPL, PRD 81 051502 (R), 2010



Besides, the rapidity dependence gives info on $c(x)$

plot for RHIC kinematics

New observables

$\rightarrow J/\psi + \gamma$

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R.Li and J.X. Wang, PLB 672:51,2009

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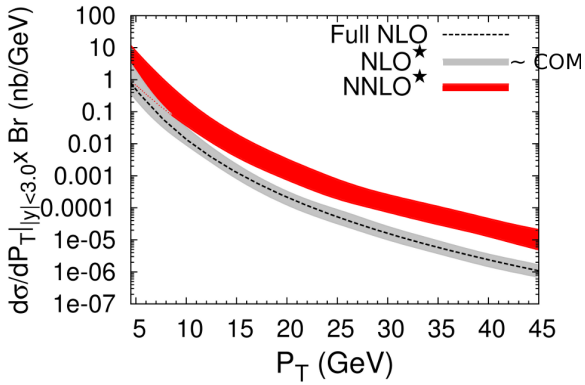

JPL, PLB 679:340,2009.

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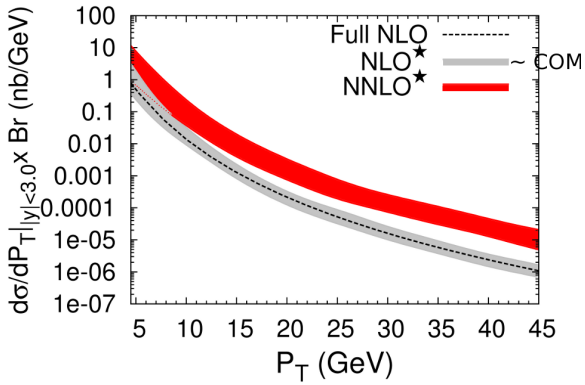

JPL, PLB 679:340,2009.

→ $J/\psi + c\bar{c}$, $\Upsilon + b\bar{b}$

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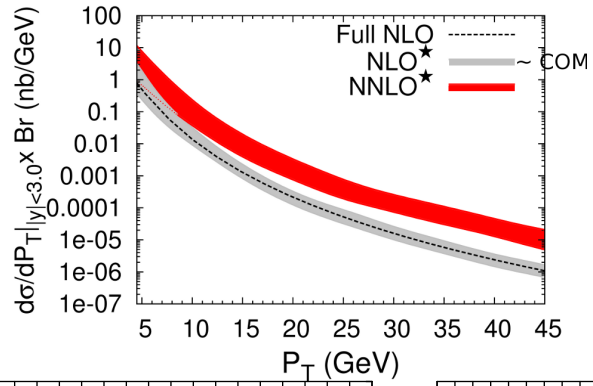

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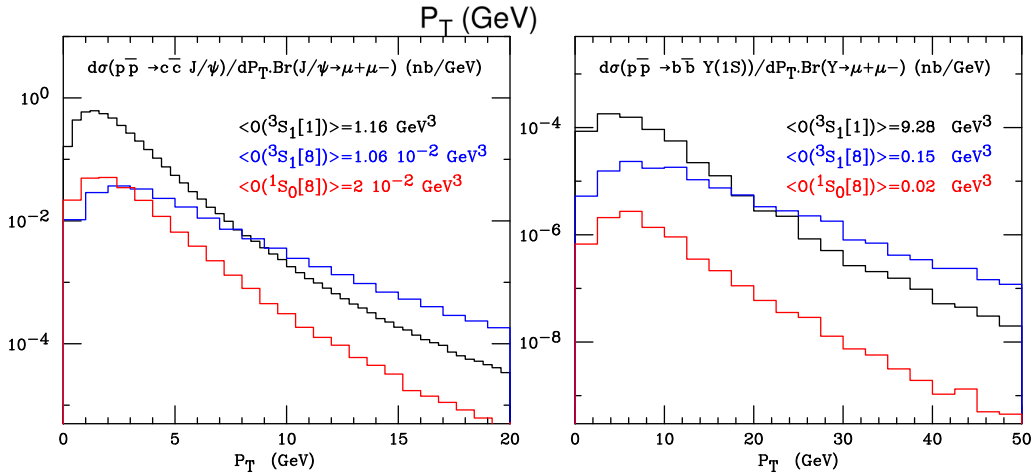


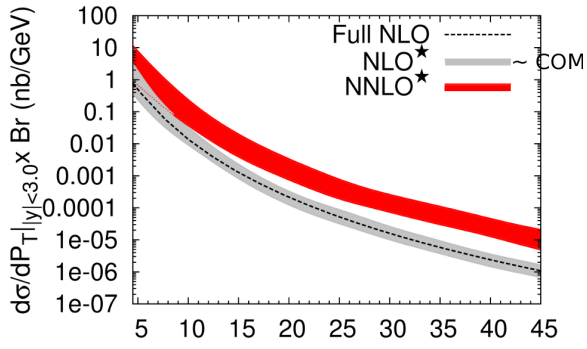
New observables

→ $J/\psi + \gamma$

- CS rate at NLO $\simeq$ conservative (high) expectation from CO

R.Li and J.X. Wang, PLB 672:51,2009

- At NNLO, CS rate clearly above expectation from CO
- Clearly, new info on CS vs CO w.r.t inclusive case !



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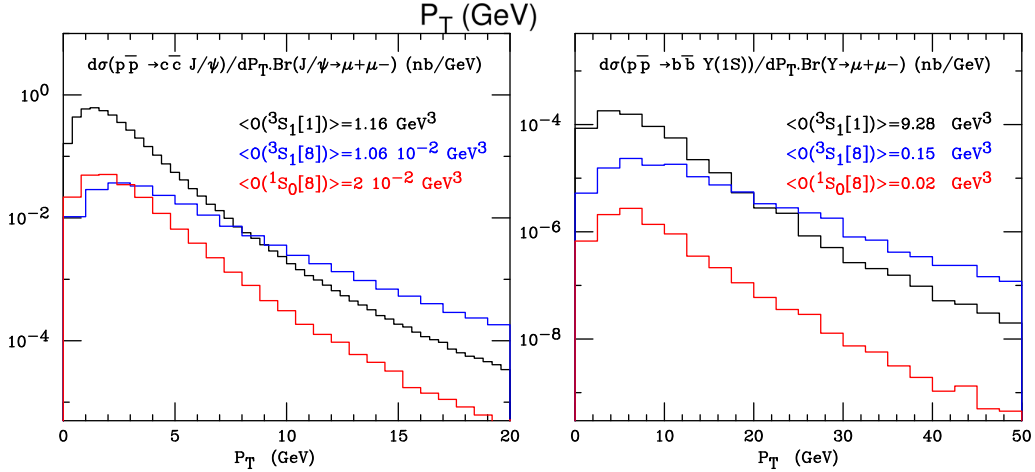

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  - maybe different acceptances, nice cross check

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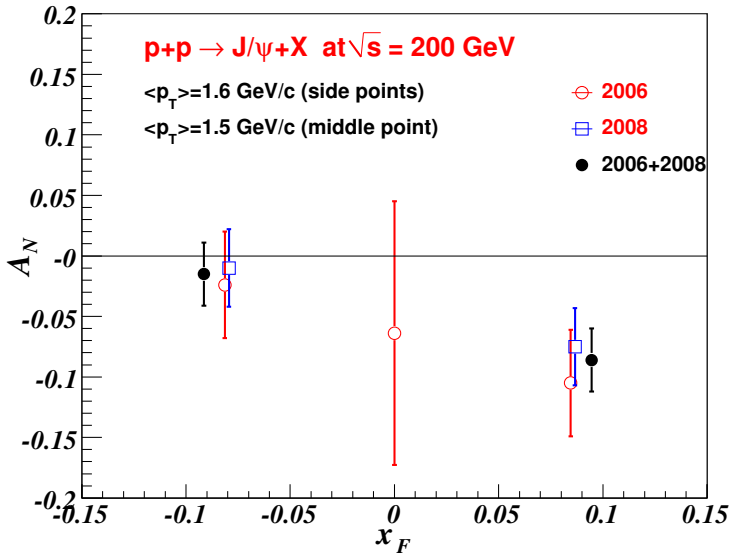

PHENIX, PRD 82, 112008 (2010)

Part VI

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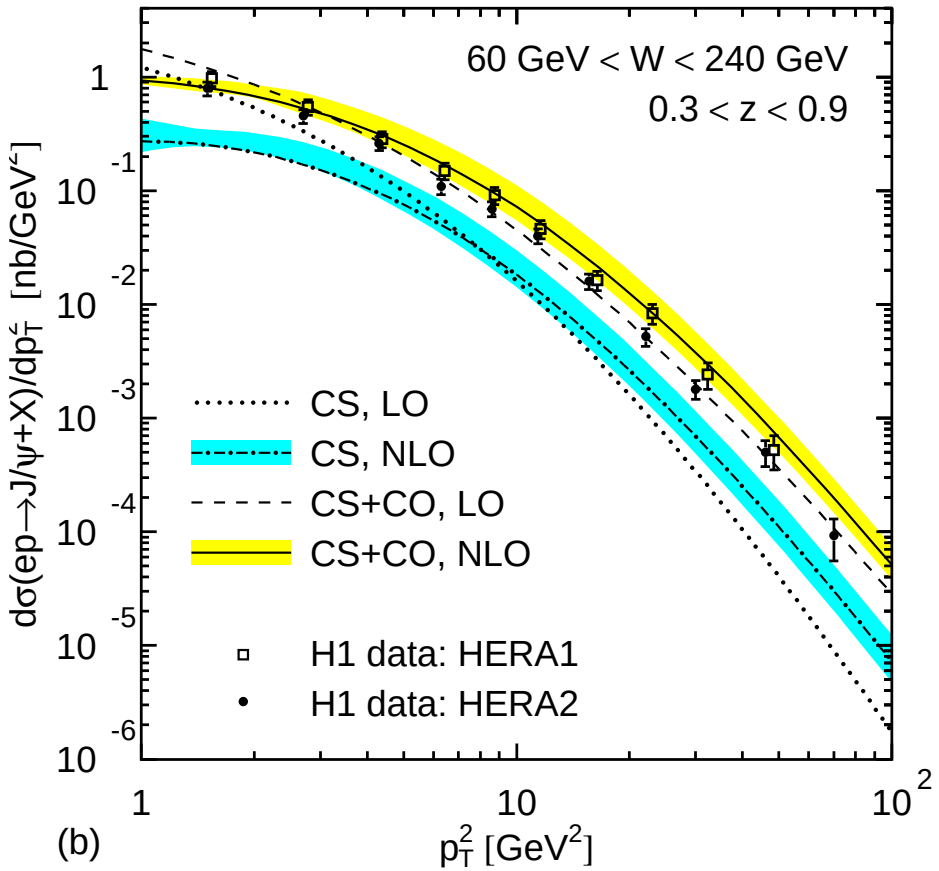
- The time has come for another look with **new observables**
  at the LHC or elsewhere !

Part VII

Backup

HERA: CSM vs COM at NLO

M. Butenschoen, B. Kniehl, arXiv:1009.5662v1 [hep-ph]



→ Equally good (or ... bad) description of large P_T data.