Perspectives de production de J/ψ et Υ au LHC

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Outline

Introduction

What we understand:

1. why QCD corrections do matter at mid- and high-P_T
2. why χ_c's and χ_b's do matter...

What we seem to understand:

3. that QCD corrections do matter for the polarisation, but why ?
4. that Colour Octet Dominance is challenged at low/mid P_T in pp
5. what the leading mechanism for ψ production at low P_T is

What we do not understand:

6. ψ production at very large P_T
7. Other features not understood

What we expect from the LHC

8. More observables !

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  -without any intermediate b quark decay

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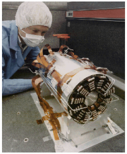

The study to separate prompt from non-prompt events is done thanks to a silicon microvertex detector

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- **Direct production:** the gluons produce the J/ψ:
  -without any intermediate b quark decay: $gg \to B\bar{B} \to J/\psi + X$ **rejected**
  -without any other intermediate $\mathcal{Q}'$: $gg \to \chi_c g \to J/\psi + \gamma + X$ **rejected**
  One needs to see the γ emitted by the χ_c.

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
P.Artoisenet, J.P.L, F.Maltoni, PLB 653:60,2007
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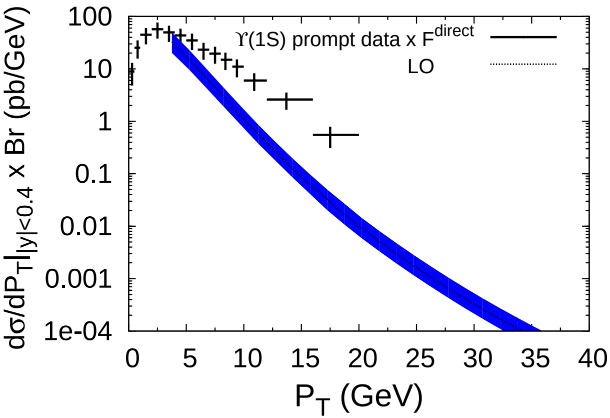

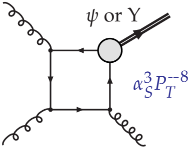

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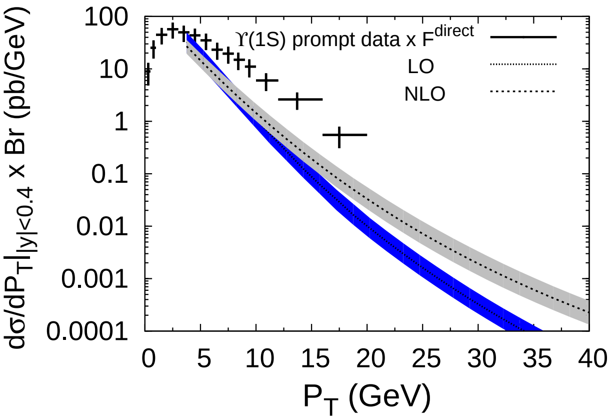

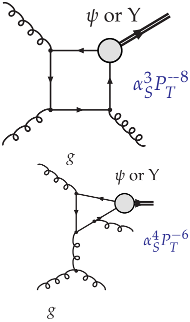

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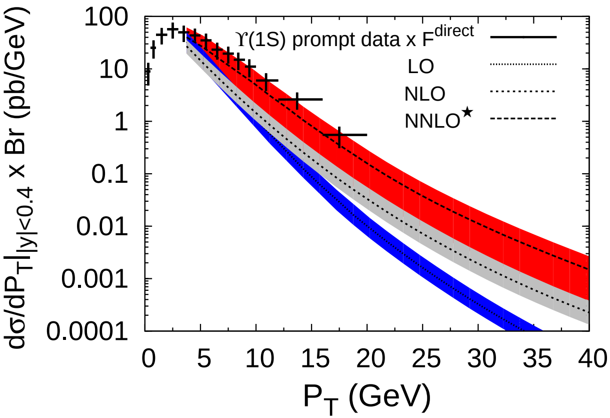

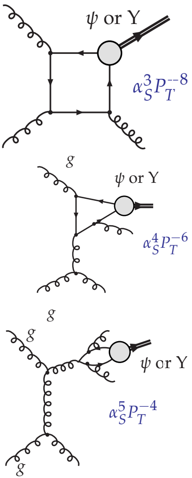

+ double t-channel gluon exchange at α_S^5

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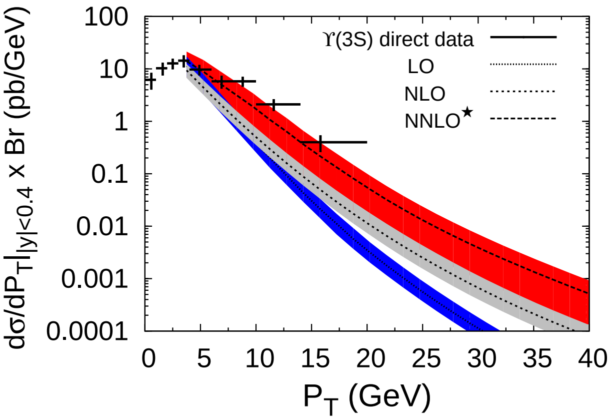

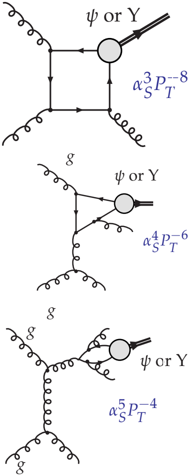

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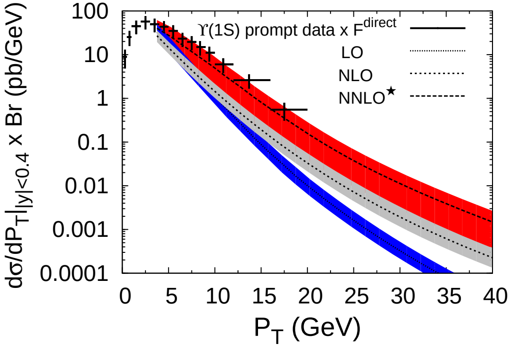
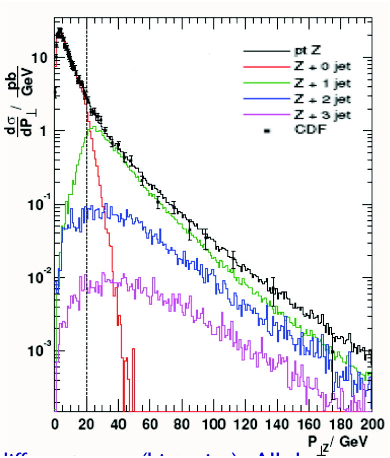
Analogy with the P_T spectrum for the Z^0 boson





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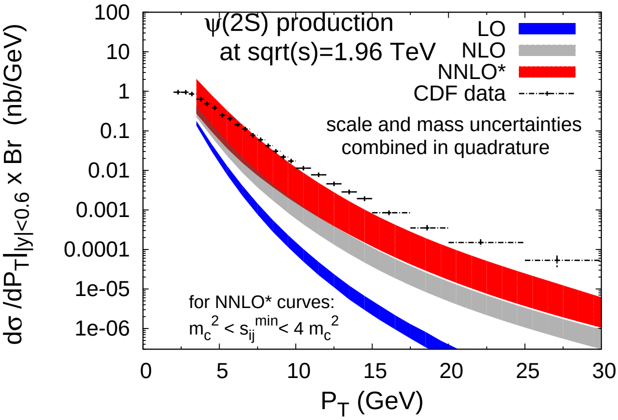

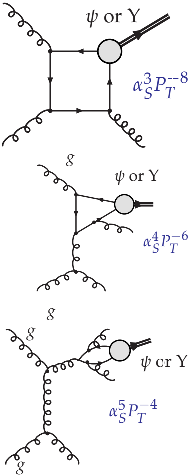

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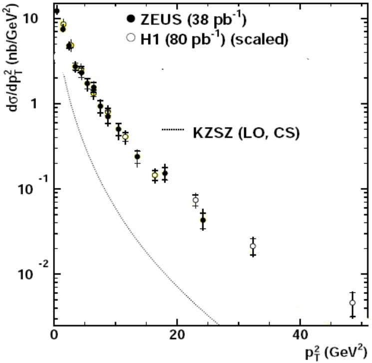
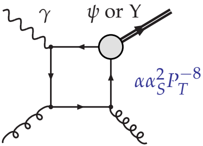
QCD corrections J/ψ photoproduction at HERA

P. Artoisenet *et al.***Phys. Rev. Lett. 102, 142001 (2009)**
M.Kramer Nucl.Phys.B459:3 1996
e.g. **H1,arXiv:1002.0234**





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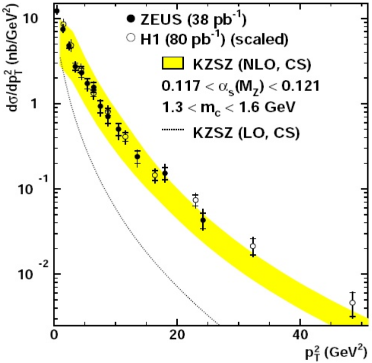
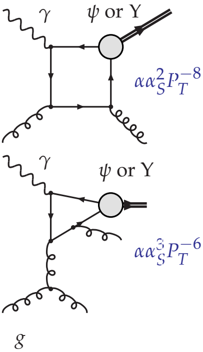
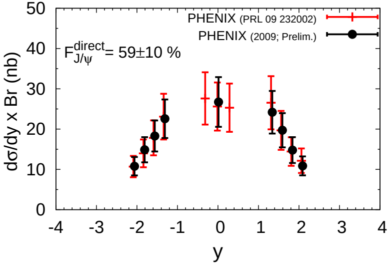




What about the CSM predictions for $\frac{d\sigma}{dy}$?

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



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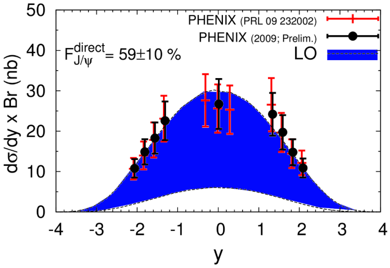

LO: $gg \to J/\psi g$ (nothing new !, back to 1981 !)

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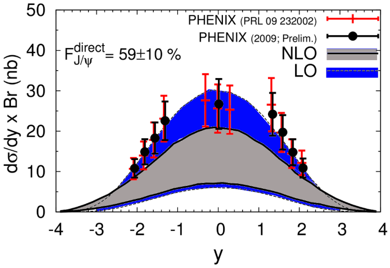

NLO: $gg \to J/\psi, gg\ gq \to J/\psi gq$, ...

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

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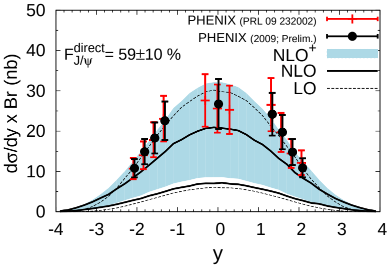

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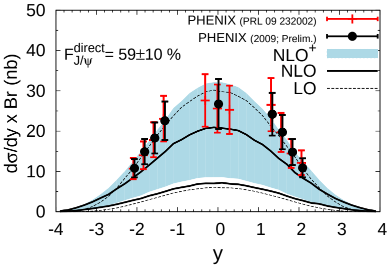

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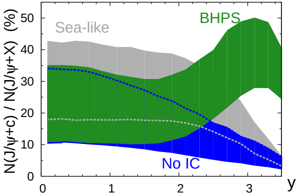

Could be studied via azimuthal correlation $J/\psi + e, \mu$; 10-40% of the direct signal

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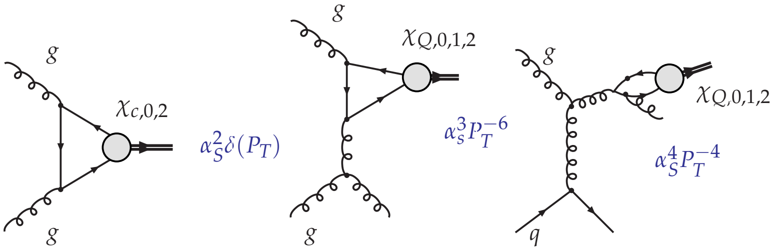

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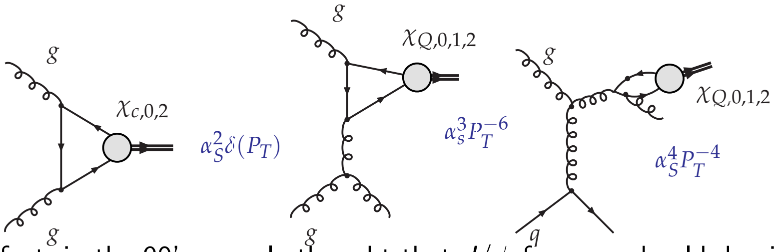
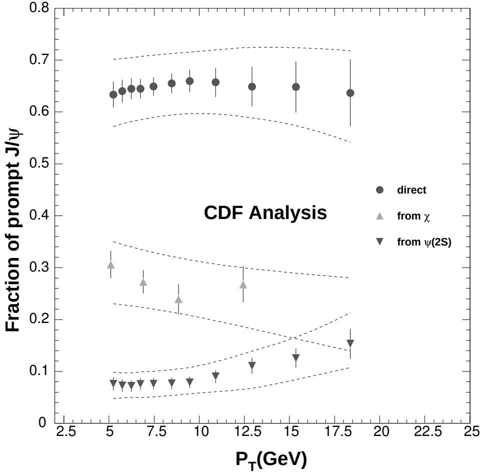


→ In fact, in the 90's, people thought that J/ψ from χ_c should dominate, because of the latter argument

Impact of χ_c's and χ_b's



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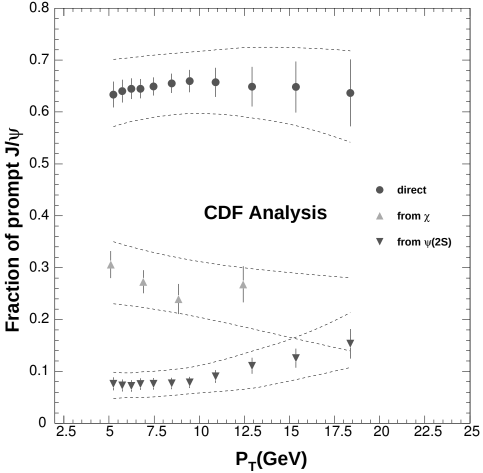

→ About 40 % of $\Upsilon(1S)$ are from χ_b

CDF, Phys. Rev. Lett. 84, 2094 (2000).

Part II

What we seem to understand

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

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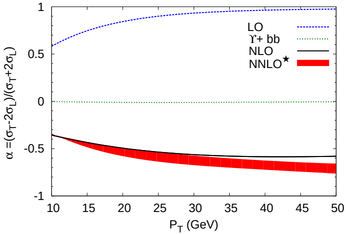

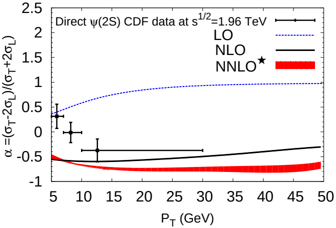

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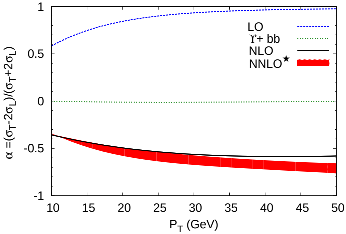

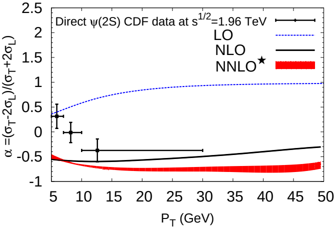

→ Complete modification of the polarisation at NLO (also at NNLO*)

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

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

(although reasonable)

So far, the most fashionable solution: Colour Octet Dominance

Color Octet Mechanism: physical states can be produced by coloured pairs

NRQCD: Bodwin, Braaten, Lepage, 1995; Cho, Leibovich,...

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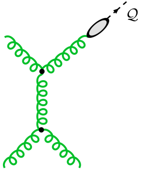

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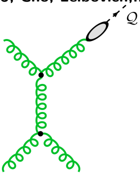

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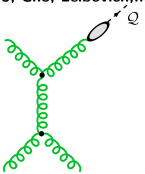

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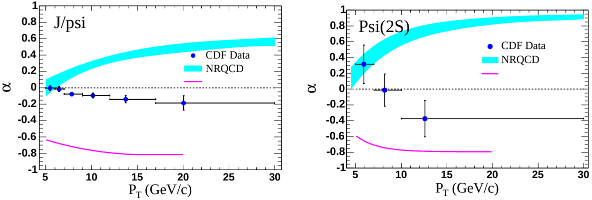
- ✔ Gluon fragmentation then LO in α_S: larger rates
- ➞ When $P_{gluon} \gg$, the gluon is nearly on-shell and transversally pol.
- ➞ NRQCD spin symmetry: $\mathcal{Q}$ has the same polarisation as the gluon
- ✗ Experimentally, **this is clearly contradicted !**

$\alpha = +1 \Leftrightarrow$ Transverse $\alpha = 0 \Leftrightarrow$ Unpolarised $\alpha = -1 \Leftrightarrow$ Longitudinal



CDF, PRL 99: 132001, 2007

Colour Octet Dominance challenged at low/mid P_T in pp ?

- "Approximately taking into account the higher-order effects due to multiple-gluon initial-state radiation, [...] we find that the matrix elements [...] $^{2S+1}L_J = ^1S_0$ and ^3P_J, are significantly reduced." **B.A. Kniehl, G. Kramer, EPJC 6:493,1999.**
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- Analysis of fixed target data (low P_T) also tends to a reduction of the CO LDMEs
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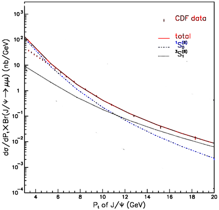

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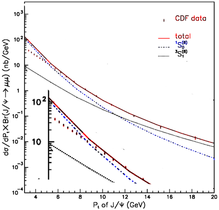

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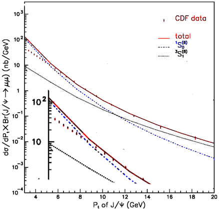

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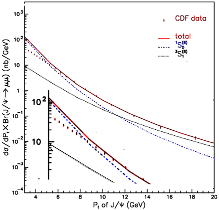

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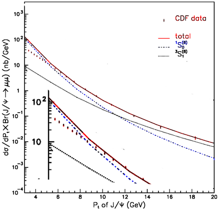

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what the leading mechanism for ψ production at low P_T is.

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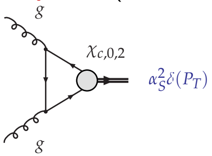

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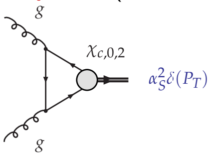

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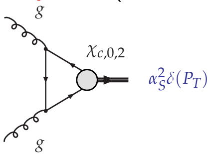

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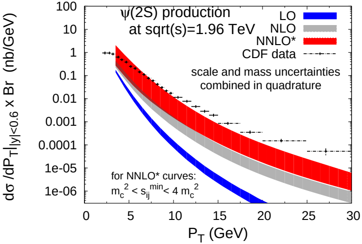
Part III

what we do not understand

ψ production at very large P_T



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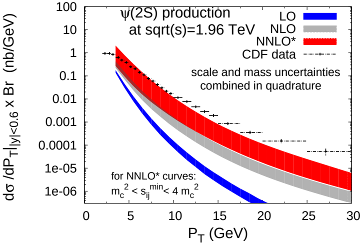

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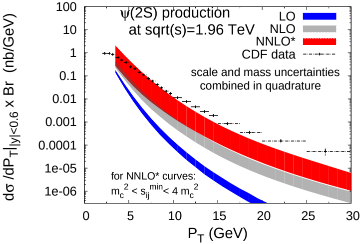

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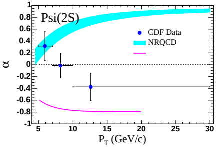

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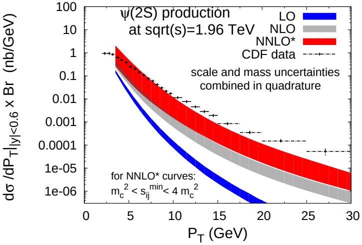

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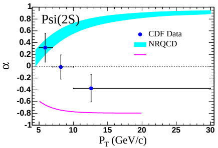

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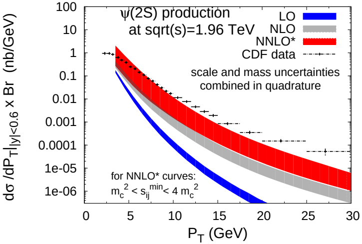

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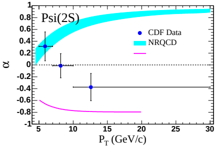

- Could be the data ...
- Let's wait for the LHC data for prompt $\psi(2S)$ or **direct J/ψ**

Other features not understood

- $\sigma(\chi_{c1})/\sigma(\chi_{c2})$: Hera-B vs CDF, COM vs CSM vs CEM

NEW: NLO for χ_c's: Y.-Q. Ma, K. Wang, K.-T. Chao, arXiv:1002.3987 [hep-ph]

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Part IV

what we expect from the LHC:

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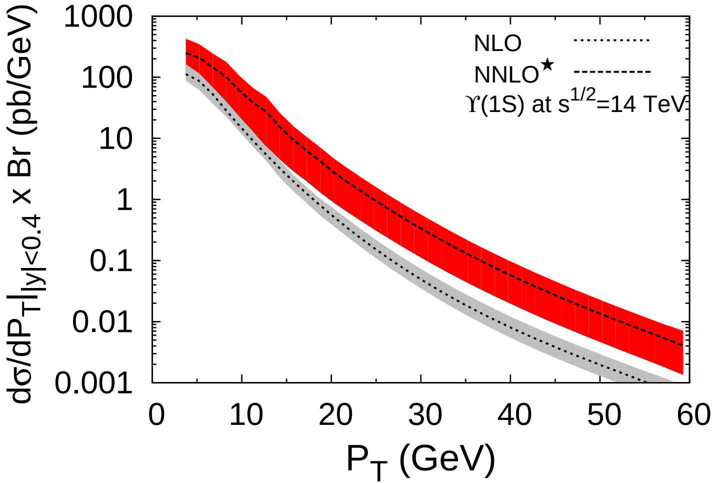
what we expect from the LHC: new measurements

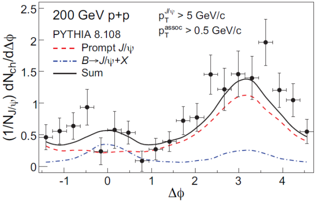
Υ cross section at the LHC

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



New observables

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



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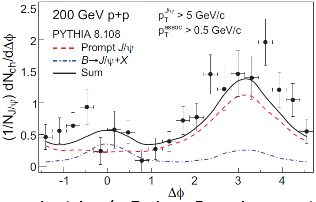

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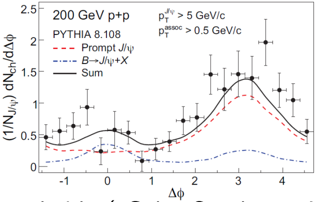

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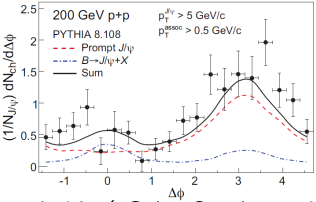

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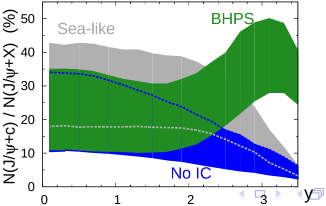
S. J. Brodsky and JPL, PRD 81 051502 (R), 2010



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

plot for RHIC kinematics

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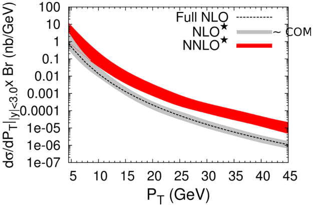

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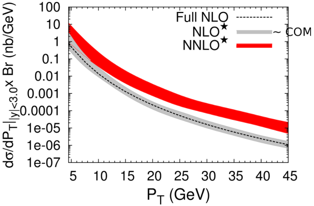

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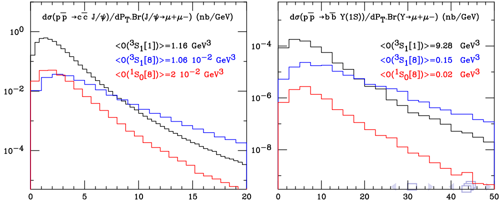
- $J/\psi + c\bar{c}$, $\Upsilon + b\bar{b}$



Part V

Conclusions and Outlooks

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- Prepare yours for a 3 day workshop in École polytechnique devoted to Quarkonium production after ICHEP in Paris (29-31 July 2010)

  www.cpht.polytechnique.fr/quarkonium