Quarkonium inclusive production: negative NLO cross sections, scale fixing and high-energy resummation

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Part I

Introduction

Approaches to Quarkonium Production

For an up-to-date review, see JPL. arXiv:1903.09185 [hep-ph] (Phys.Rept. 889 (2020) 1)

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+ extensions: Improved CEM, Soft Gluon Factorisation, Soft Colour Interaction, ...

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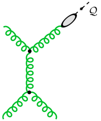

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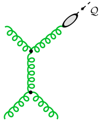

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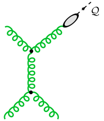

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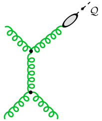

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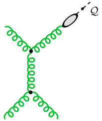

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- Low predictive power, yet overshoots the data at large P_T; issues with the χ_c's

Basic pQCD approach: the Colour Singlet Model (CSM)

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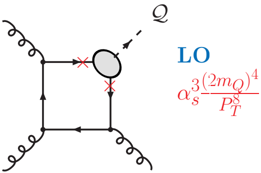

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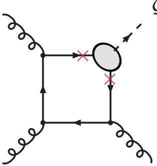

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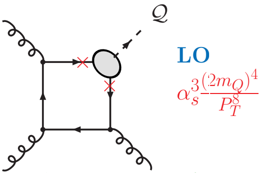

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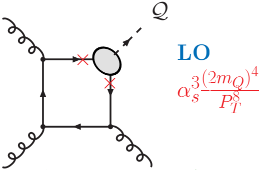

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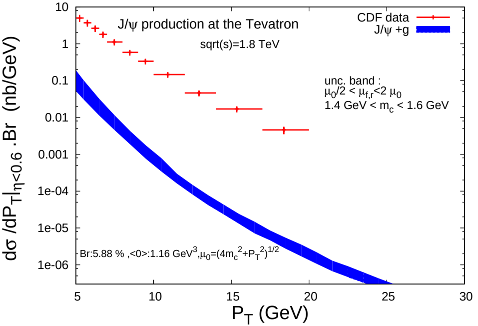

CDF, PRL 79:572 & 578,1997

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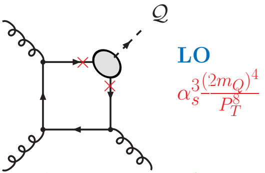

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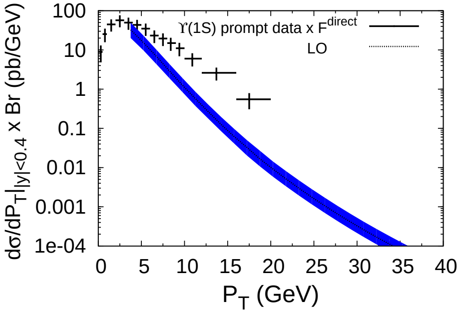

CDF, PRL 88:161802,2002

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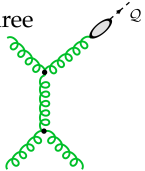

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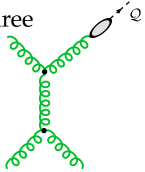

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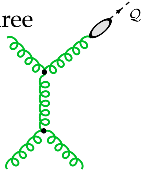

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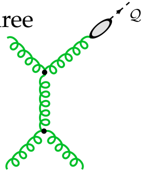

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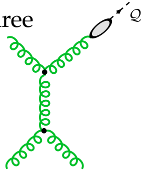

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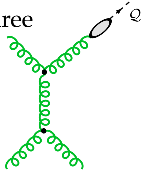

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✗ Cannot describe both the high-P_T and P_T-integrated hadroproduction yields

Part II

Impact of QCD corrections to the C(S,E,O)M*

*See section 2 of Phys. Rept. 889 (2020) 1 for collinear factorisation

General structure of NLO corrections (example for $\gamma p \to J/\psi X$)

Singularities at NLO [and how they are removed]:

Slide borrowed from Y. Yedelkina

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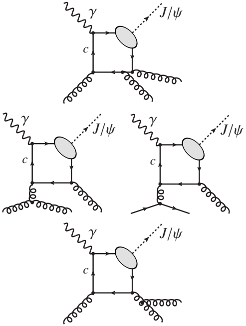

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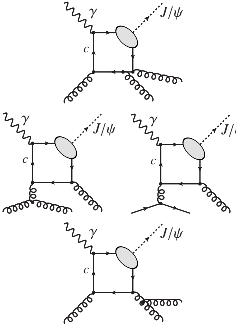

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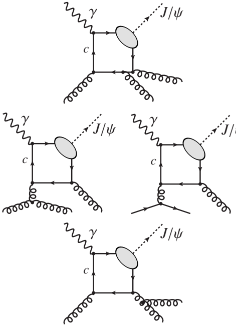

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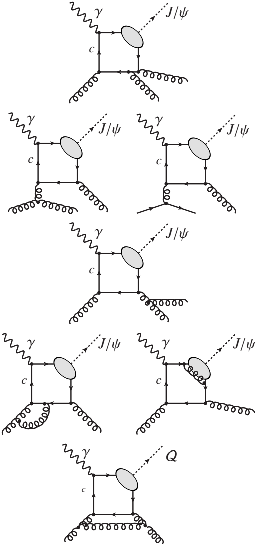

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  - Ultraviolet divergences: [removed by renormalisation]
  - Infrared divergences: [cancelled by real Infrared contribution]

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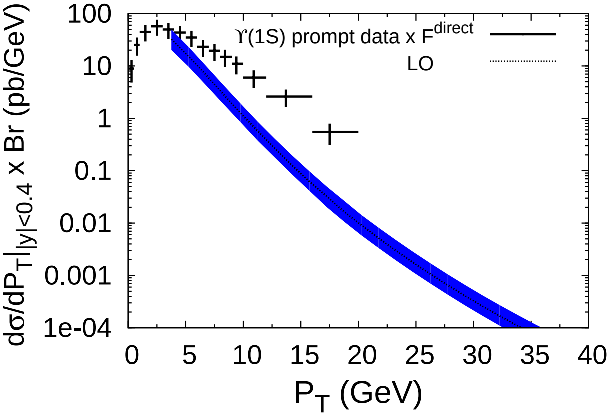

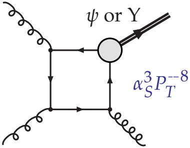

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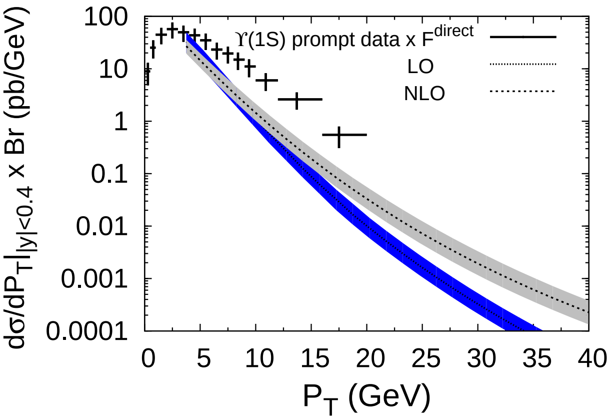
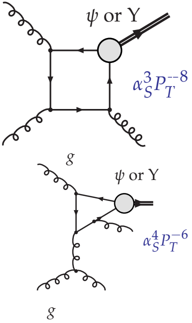
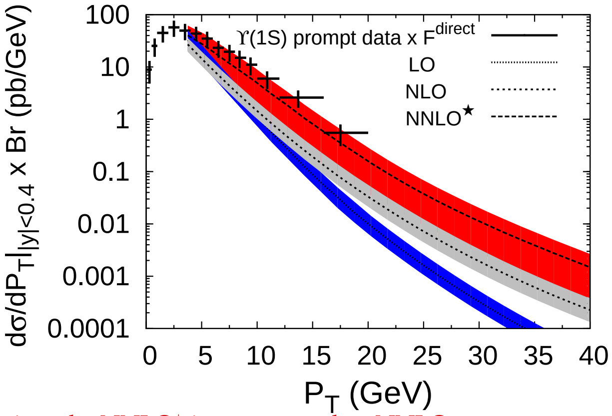
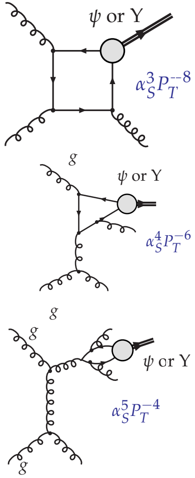




QCD corrections to the CSM for Υ at colliders

J.Campbell, F. Maltoni, F. Tramontano, Phys.Rev.Lett. 98:252002,2007
P.Artoisenet, J.Campbell, JPL, F.Maltoni, F. Tramontano, Phys. Rev. Lett. 101, 152001 (2008)



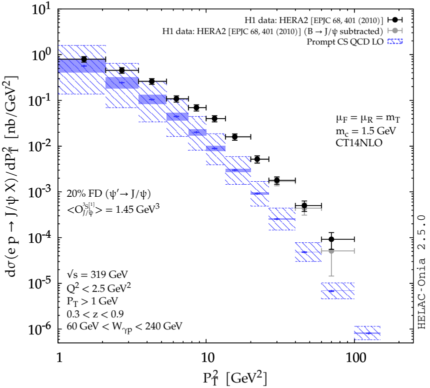


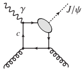
Attention: the NNLO* is not a complete NNLO

See a recent study by H.S. Shao JHEP 1901 (2019) 112

QCD and QED corrections in photoproduction

C.Flore, JPL, H.S. Shao, Y. Yedelkina, PLB 811 (2020) 135926





$\gamma + g \rightarrow \psi + g @ \alpha\alpha_s^2$ [LO]

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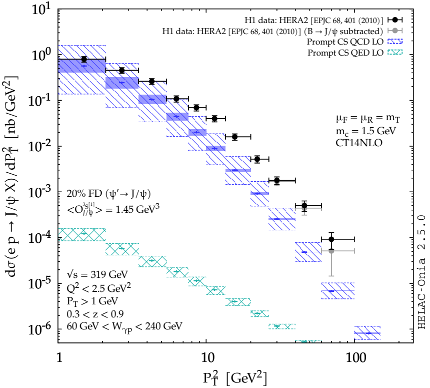

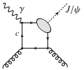

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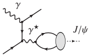

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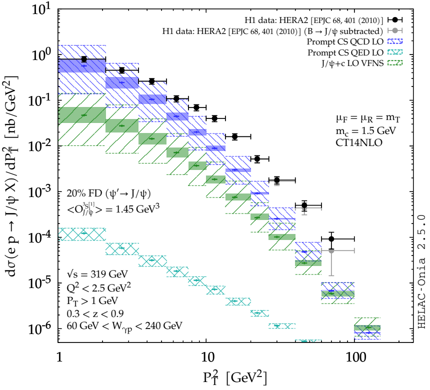

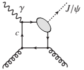

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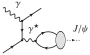

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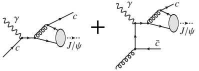

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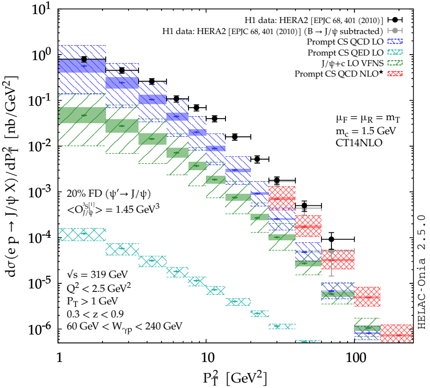

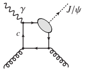

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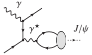

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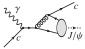
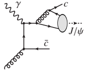
 + 

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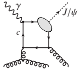
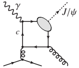
 + 

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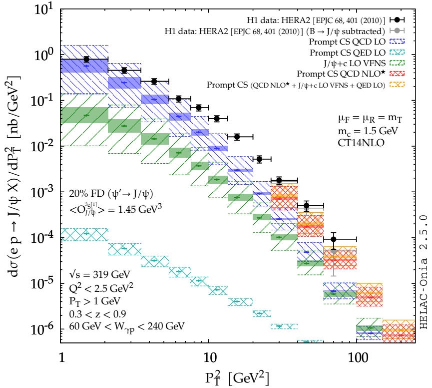
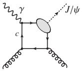
QCD and QED corrections in photoproduction

C.Flore, JPL, H.S. Shao, Y. Yedelkina, PLB 811 (2020) 135926





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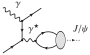

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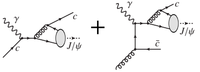

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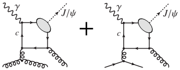

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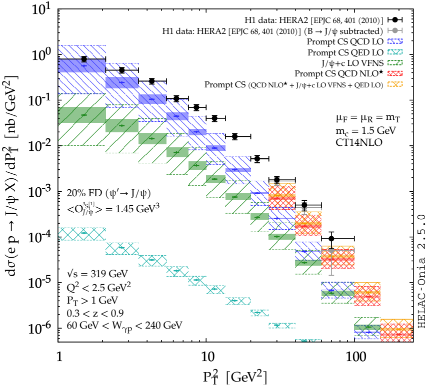

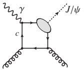

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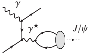

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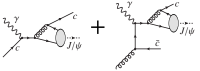

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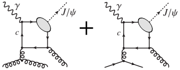

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- LO QCD does a good job at low P_T
- LO QED much harder but small normalisation [will matter at EIC]
- J/ψ+charm: starts to matter at high P_T [will also matter at EIC]
- NLO$^{(\star)}$ close the data, the overall sum nearly agrees with them
- Agreement when the expected $B \to J/\psi$ feed down (always overlooked) is subtracted

→ CSM accounts for the data

COM at NLO in hadroproduction: even more complicated

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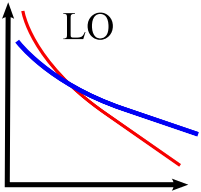

ψ data: a little less hard than the blue curve

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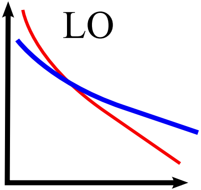

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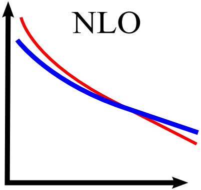

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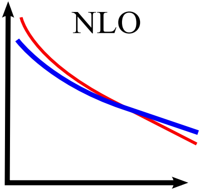

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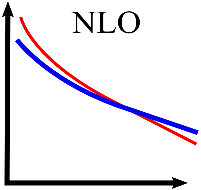

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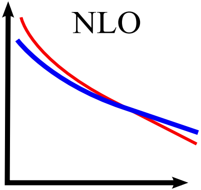

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- Polarisation: ${}^1S_0^{[8]}$: unpolarised; ${}^3S_1^{[8]}$ & ${}^3P_J^{[8]}$: transverse

QCD corrections to the CEM P_T dependence

JPL, H.S. Shao JHEP 1610 (2016) 153

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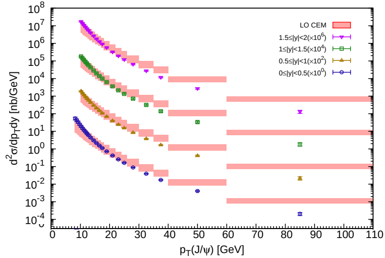

Part III

P_T-integrated cross sections up to NLO

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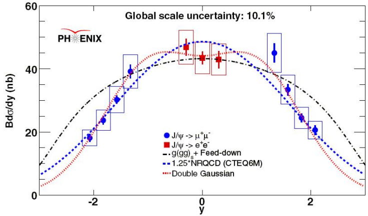

No CSM curve, why ?

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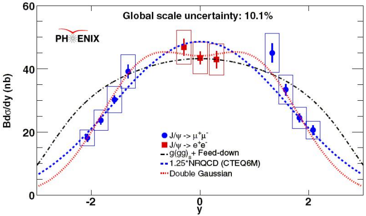

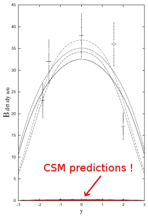

PHENIX, PRL98 232002,2007/ CSM: Cooper *et al.*, PRL 93:171801,2004

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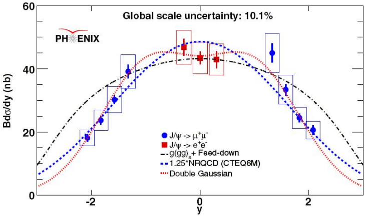

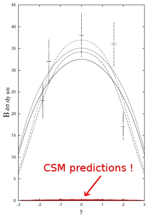

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section in the singlet and octet channel. In the color singlet channel, the J/ψ production cross section at α_s^2 order is given by:

$$\sigma_1^{pp \to J/\psi}(s) = \sigma_1^{pp \to \chi_0}(s) BR_{\chi_0}, \quad + \sigma_1^{pp \to \chi_2}(s) BR_{\chi_2}. \quad (9)$$

The LO CSM accounts for the P_T-integrated yield

S. J. Brodsky and JPL, PRD 81 051502 (R), 2010; JPL, PoS(ICHEP 2010), 206 (2010); NPA 910-911 (2013) 470

→ The yield vs. $\sqrt{s}$, y

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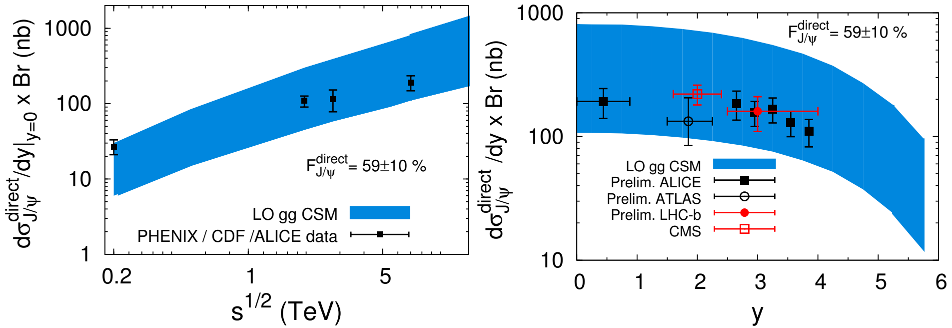

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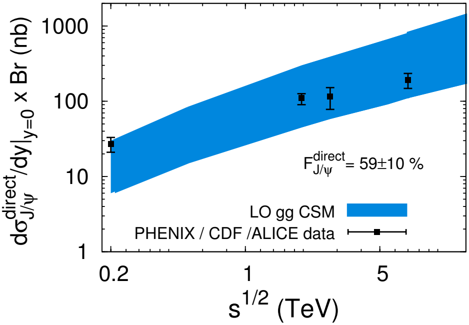

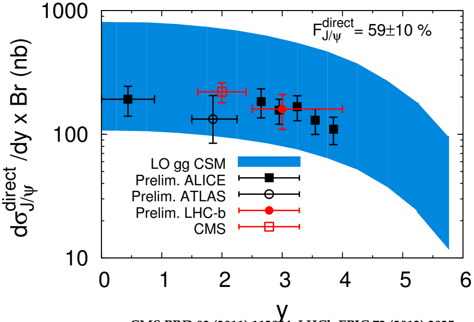

CMS PRD 83 (2011) 112004; LHCb EPJC 72 (2012) 2025

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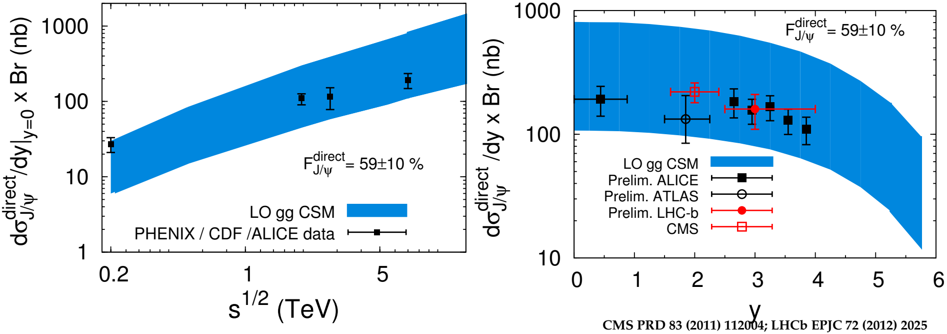

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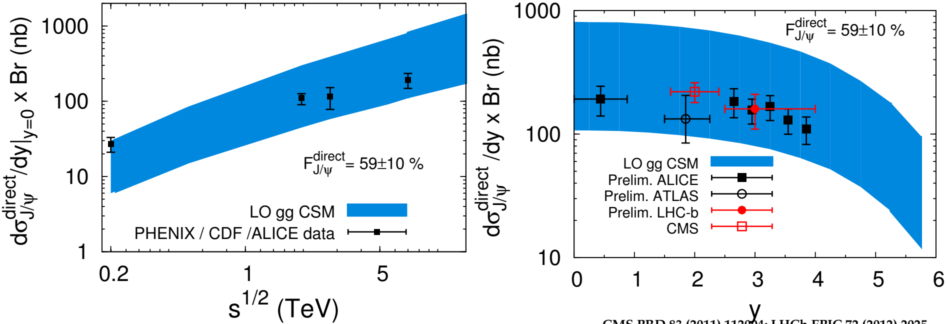

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- Earlier claims that CSM contribution to $d\sigma/dy$ was small were based on the incorrect assumption that $\chi_{c,b}$ feed-down was dominant

NLO CSM at RHIC

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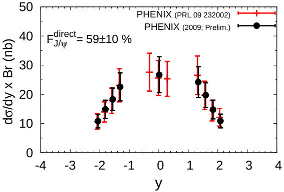

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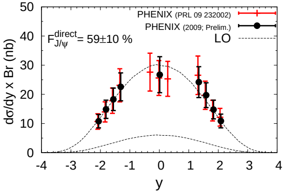

LO: $gg \to J/\psi g$ (nothing new !)

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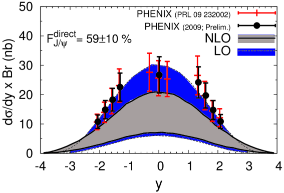

NLO: $gg \to J/\psi gg, gq \to J/\psi gq, ...$

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

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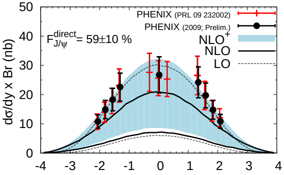

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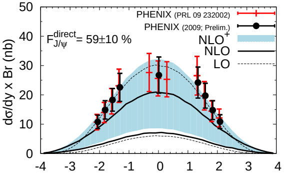

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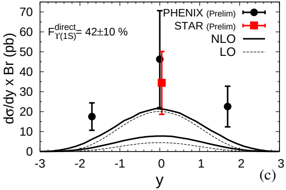

† Sorry: I should update these plots (updated data and feed-down fraction)

NLO NRQCD up to RHIC II

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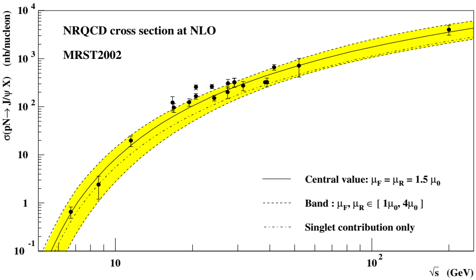

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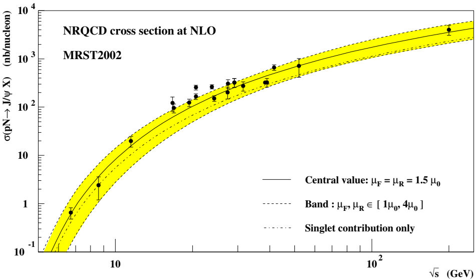

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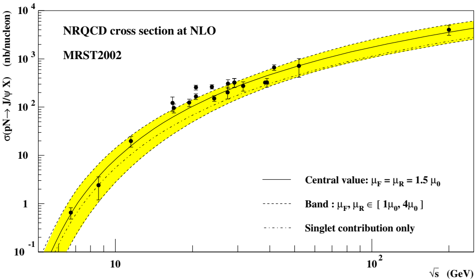

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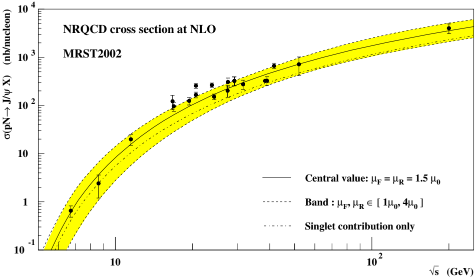

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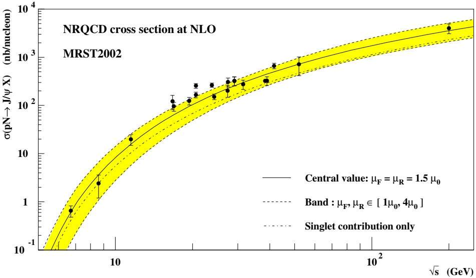

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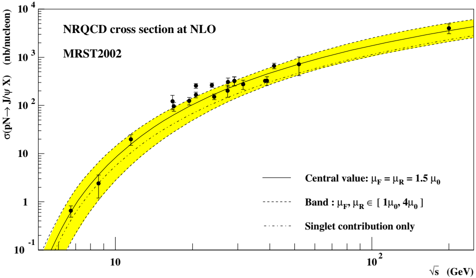

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We checked these with FDC

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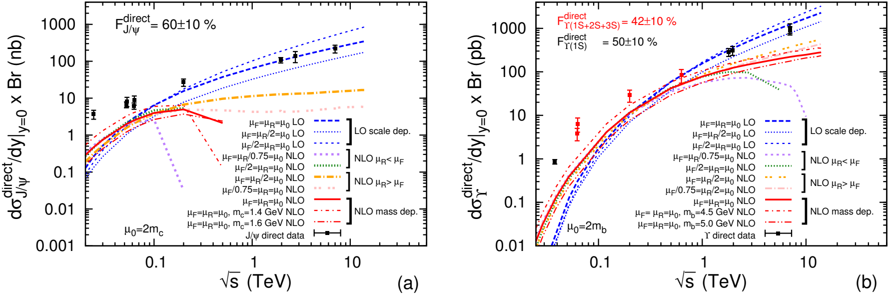

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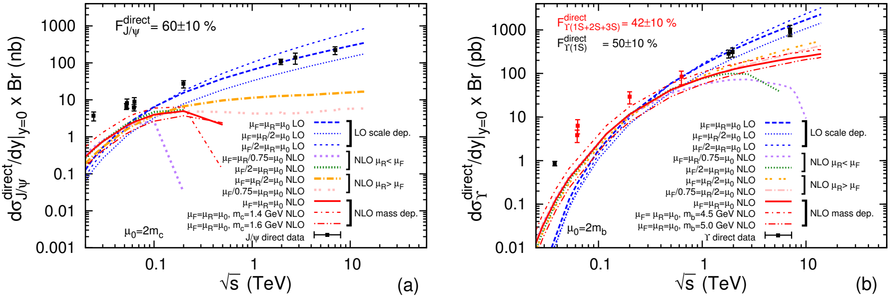

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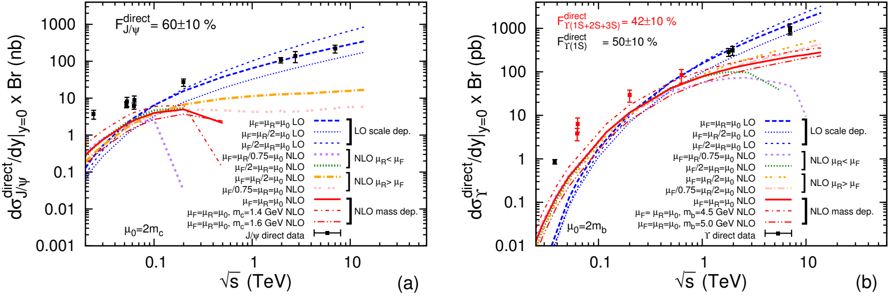

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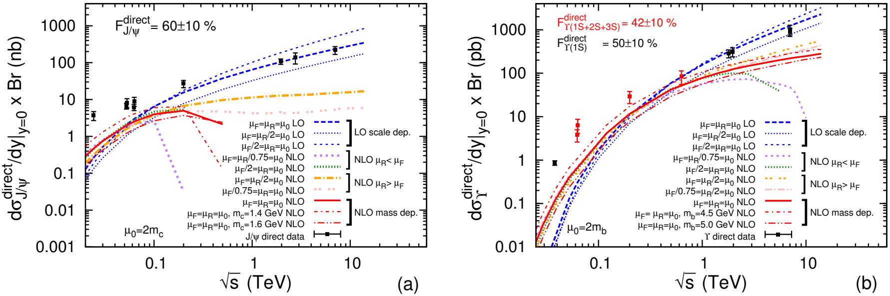

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Is it due to ISR, FSR ? Is NRQCD simply not holding at low P_T ?

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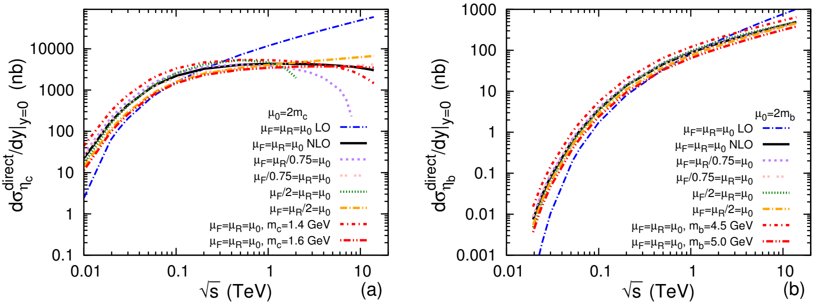

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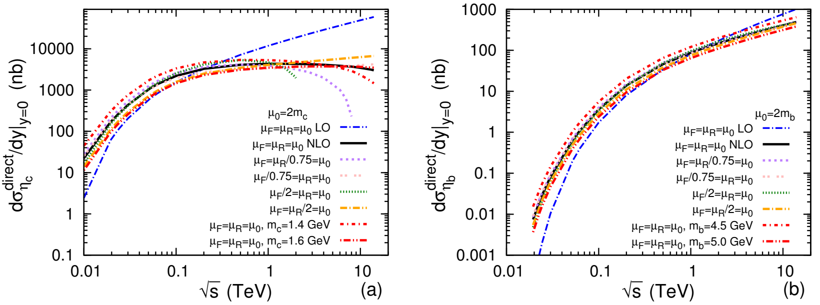

Problem of negative NLO quarkonium cross sections

[Y. Feng, JPL, J.X. Wang, Eur.Phys.J. C75 (2015) 313]; JPL, M.A. Ozcelik, EPJC 81 (2021) 6, 497; A. Colpani Serri, Y. Feng, C. Flore, JPL, M.A. Ozcelik, H.S. Shao, Y. Yedelkina PLB 835 (2022) 137556

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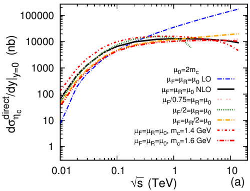

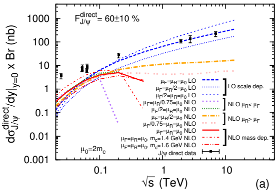

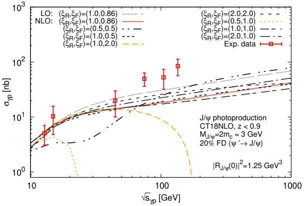

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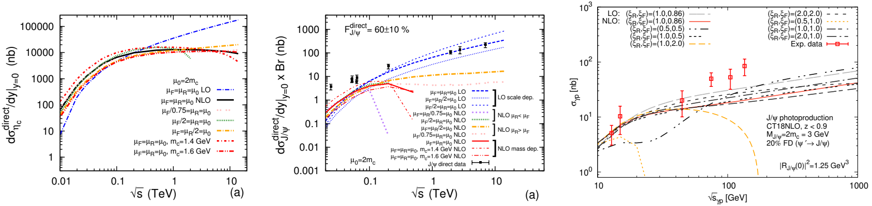

Origin: process-dependent subtraction of collinear divergences vs universal DGLAP PDF evolution

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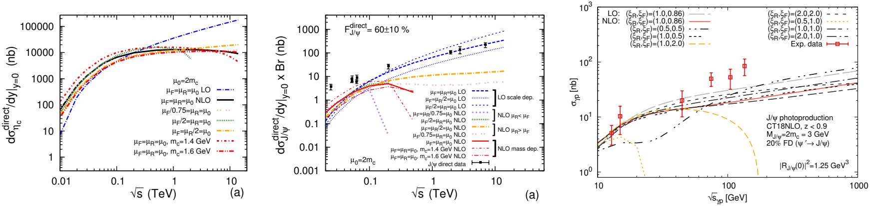

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Diagnosis: $\hat{s} \to \infty : \; \hat{\sigma}_i^{NLO} \propto \alpha_s(\mu_R) \left(\bar{c}_1^i \log \frac{M_Q^2}{\mu_F{}^2} + c_1^i \right), A_i = \frac{c_1^i}{\bar{c}_1^i}, \boxed{A_g = A_q < 0}$

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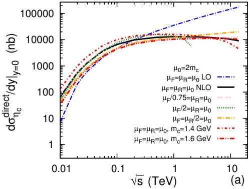

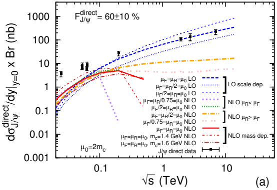

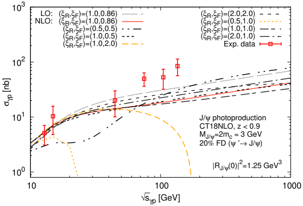

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J.P. Lansberg, M. Nefedov, M.A.Ozcelik, JHEP 05 (2022) 083 + arXiv:2306.02425 [hep-ph]

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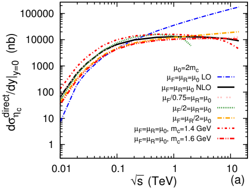
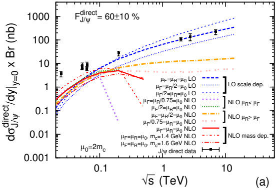
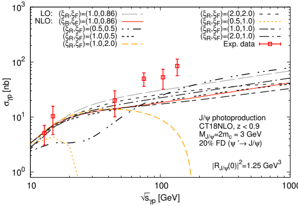
Problem of negative NLO quarkonium cross sections

[Y. Feng, JPL, J.X. Wang, Eur.Phys.J. C75 (2015) 313]; JPL, M.A. Ozcelik, EPJC 81 (2021) 6, 497; A. Colpani Serri, Y. Feng, C. Flore, JPL, M.A. Ozcelik, H.S. Shao, Y. Yedelkina PLB 835 (2022) 137556







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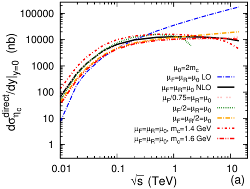

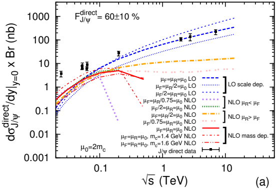

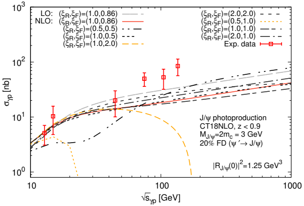

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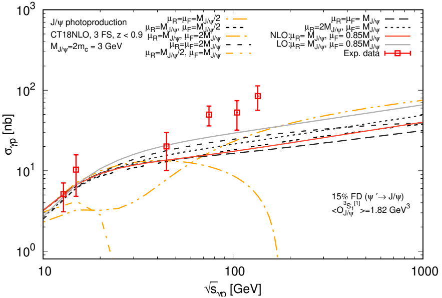
Cure: Scale fixing or resummation (HEF)

Photoproduction as an illustration



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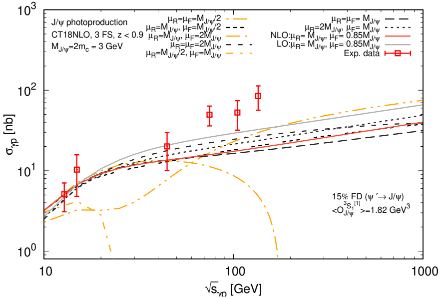

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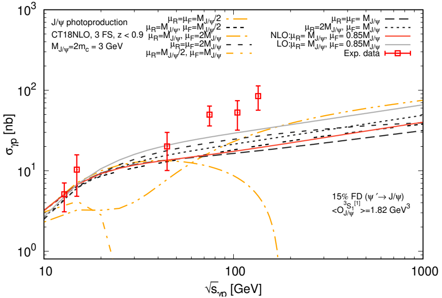

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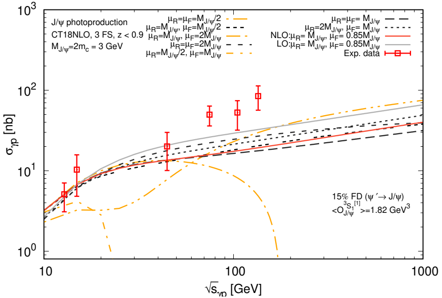

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J.P. Lansberg, M.A. Ozcelik: Eur.Phys.J.C 81 (2021) 6, 497

- 2 possible sources of negative partonic cross sections: loop corrections (interference) and from real emission (subtraction of IR poles)

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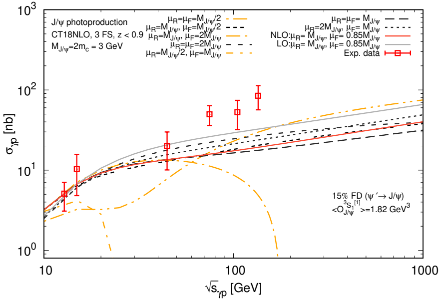
Negative cross-section values



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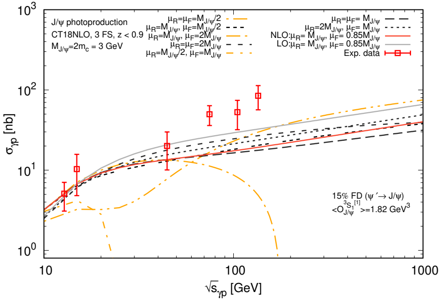

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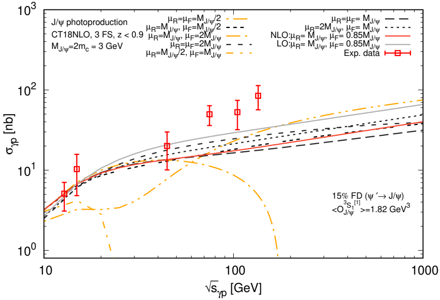

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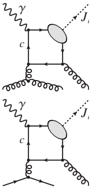
- If large $\mu_F \to \hat{\sigma} < 0 \to \sigma < 0$: over-subtraction from AP-CT into the PDFs

A scale prescription for μ_F

J.P. Lansberg, M.A. Ozcelik: Eur.Phys.J.C 81 (2021) 6, 497;



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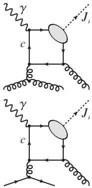

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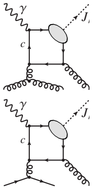

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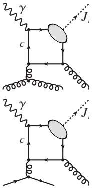

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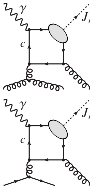

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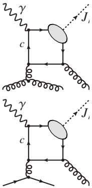

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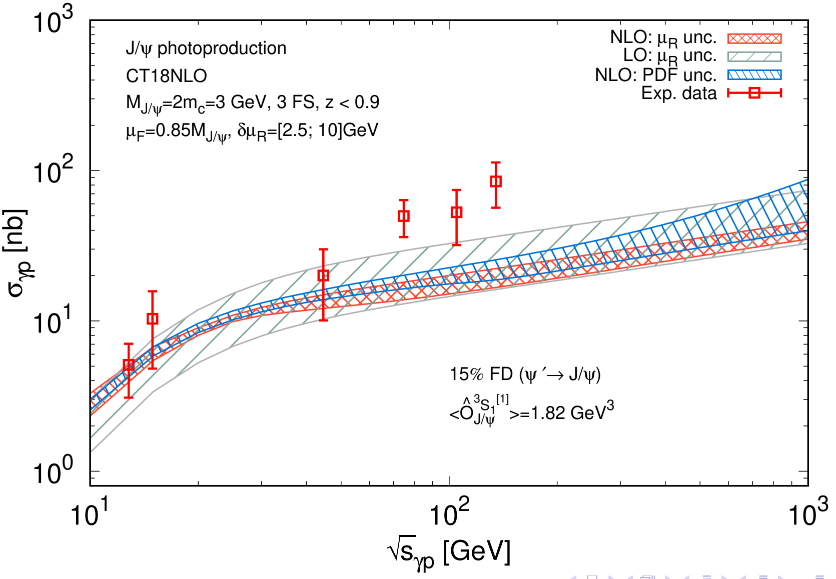
Results with $\hat{\mu}_F = 0.85M$



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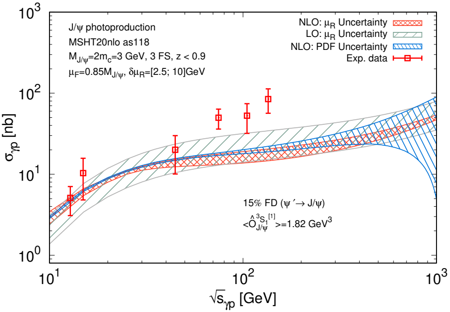

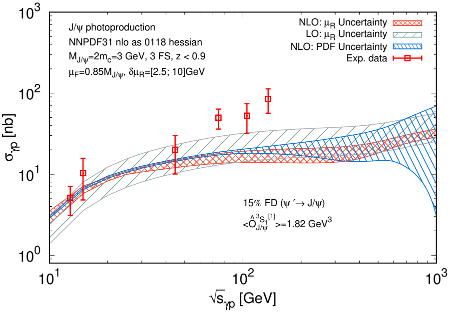

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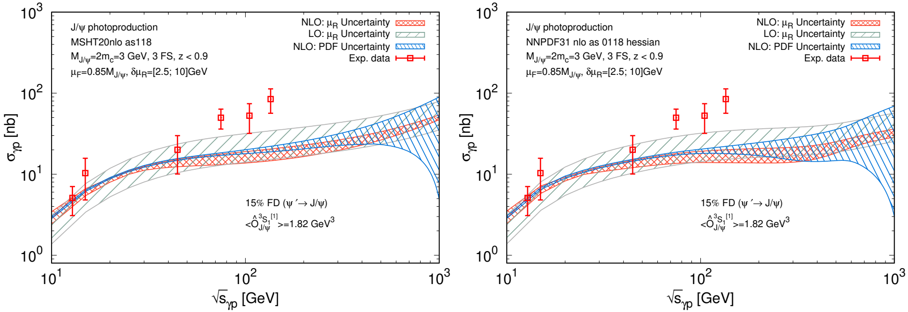

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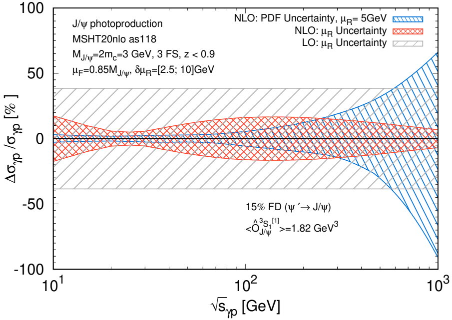

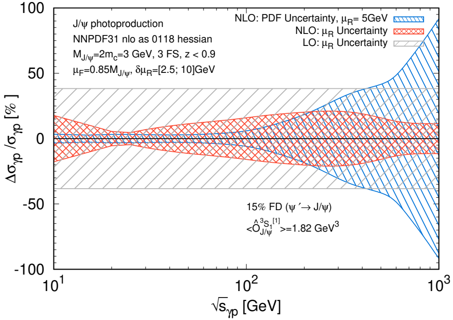

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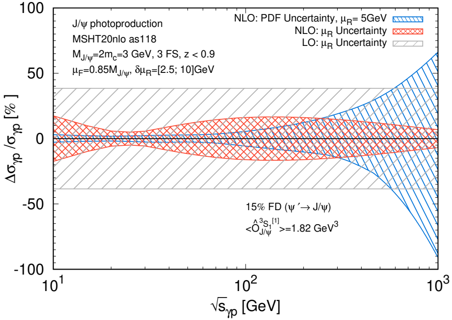

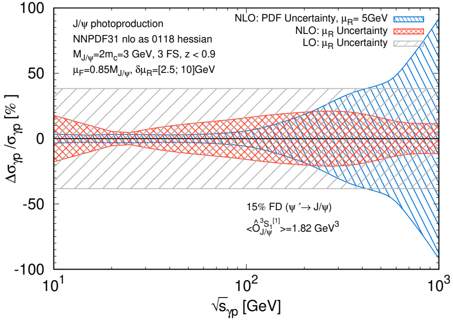

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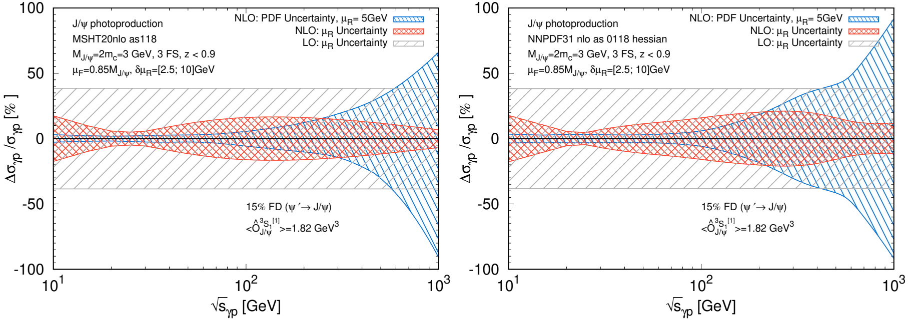

High-Energy Factorisation (HEF) and the leading-log approximation

The leading-log approximation (LLA): $\sum_n \alpha_s^n \ln^{n-1}\left(\frac{\hat{s}}{M_{\mathcal{Q}}^2}\right)$ [Collins, Ellis, 91'; Catani, Ciafaloni, Hautmann, 91',94']

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$\mathcal{H}^{[m]}$ known at LO in α_s [Hagler *et.al*, 2000; Kniehl, Vasin, Saleev 2006] for $m = {}^1S_0^{(1,8)}, {}^3P_J^{(1,8)}, {}^3S_1^{(8)}$. These are tree-level "squared matrix elements" of the $2 \to 1$-type process:

$$R_+(\mathbf{q}_{T1}, q_1^+) + R_-(\mathbf{q}_{T2}, q_2^-) \to Q\bar{Q}[m].$$

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$$\hat{\sigma}_{ij}^{[m],\,\mathrm{HEF}}(z,\mu_F,\mu_R) = \int_{-\infty}^{\infty} d\eta_\mathcal{Q} \int_0^{\infty} d\mathbf{q}_{T1}^2 d\mathbf{q}_{T2}^2\, \mathcal{C}_{gi}\left(\frac{M_T}{M}\sqrt{z}e^{\eta_\mathcal{Q}}, \mathbf{q}_{T1}^2, \mu_F, \mu_R\right)$$
$$\times\, \mathcal{C}_{gj}\left(\frac{M_T}{M}\sqrt{z}e^{-\eta_\mathcal{Q}}, \mathbf{q}_{T2}^2, \mu_F, \mu_R\right) \mathcal{H}^{[m]}(\mathbf{q}_{T1}^2, \mathbf{q}_{T2}^2) + \mathrm{NLL} + \mathcal{O}(z),$$

$\mathcal{H}^{[m]}$ known at LO in α_s [Hagler *et.al*, 2000; Kniehl, Vasin, Saleev 2006] for $m = {}^1S_0^{(1,8)}, {}^3P_J^{(1,8)}, {}^3S_1^{(8)}$. These are tree-level "squared matrix elements" of the $2 \to 1$-type process:

$$R_+(\mathbf{q}_{T1}, q_1^+) + R_-(\mathbf{q}_{T2}, q_2^-) \to Q\bar{Q}[m].$$

The resummation factors $\mathcal{C}$ are the solution of the LL **BFKL** equation
with the collinear divergences subtracted

High-Energy Factorisation (HEF) and the leading-log approximation

The leading-log approximation (LLA): $\sum_n \alpha_s^n \ln^{n-1}\left(\frac{\hat{s}}{M_Q^2}\right)$ [Collins, Ellis, 91'; Catani, Ciafaloni, Hautmann, 91',94']

Defining $z = \frac{M_Q^2}{\hat{s}}$, one can face large $\ln 1/z$ when s becomes large
The resummation of such logs can be done through HEF.
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The resummation factors $\mathcal{C}$ are the solution of the LL **BFKL** equation
with the collinear divergences subtracted
$\mathcal{O}(z)$ terms (without $\ln 1/z$) cannot be captured by HEF (see later)

High-energy factorisation for photoproduction

$$\hat{\sigma}_{\mathrm{HEF}}(\eta) \propto \int_0^{1+\eta} \frac{dy}{y} \int_0^{\infty} d\mathbf{q}_{T1}^2 \mathcal{C}\left(\frac{y}{1+\eta}, \mathbf{q}_{T1}^2, \mu_F, \mu_R\right) \mathcal{H}(y, \mathbf{q}_{T1}^2) + \mathrm{NLLA} + O(1/\eta)$$

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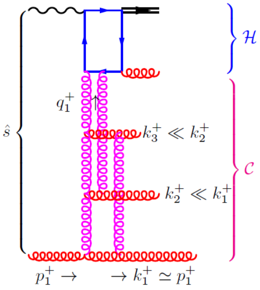
Physical picture in the **LLA** for photoproduction:

- Here one resums $\sum_n \alpha_s^n \ln^{n-1}(1+\eta)$ $[\eta = (\hat{s} - M_{\mathcal{Q}}^2)/M_{\mathcal{Q}}^2]$



Glauber exchanges($k_+ k_- \ll \mathbf{k}_T^2$) form the **Reggeised gluon** in the t-channel.

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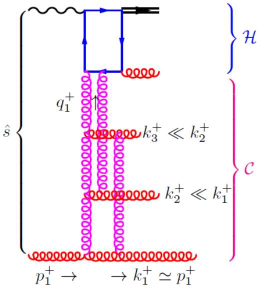

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$$\gamma_{gg}(N, \alpha_s) = \underbrace{\underbrace{\frac{\hat{\alpha}_s}{N}}_{\text{DLA}} + 2\zeta(3)\frac{\hat{\alpha}_s^4}{N^4} + 2\zeta(5)\frac{\hat{\alpha}_s^6}{N^6} + \dots}_{\text{LLA}}$$

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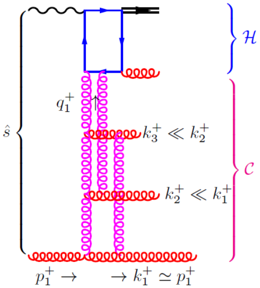

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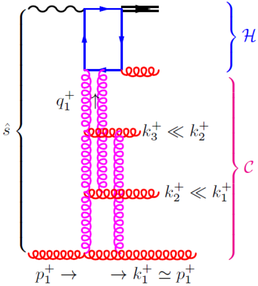

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- Note: the coefficient function $\mathcal{H}$ should be calculated at NLO for **NLLA**,

Consistency check

J.P. Lansberg, M. Nefedov, M.A.Ozcelik, JHEP 05 (2022) 083

HEF expanded up to NLO in α_s should reproduce the $A_1^{[m]}$ NLO coefficient

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$$\hat{\sigma}_{gg}^{[m],\,\mathrm{HEF}}(z \to 0) = \sigma_{\mathrm{LO}}^{[m]} \left\{ A_0^{[m]} \delta(1-z) + \frac{\alpha_s}{\pi} 2C_A \left[A_1^{[m]} + A_0^{[m]} \ln \frac{M^2}{\mu_F^2} \right] \right.$$
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From HEF, up to NNLO, one has

State	$A_0^{[m]}$	$A_1^{[m]}$	$A_2^{[m]}$	$B_2^{[m]}$
$^1S_0$	1	$\mathbf{-1}$	$\frac{\pi^2}{6}$	$\frac{\pi^2}{6}$
$^3S_1$	0	1	0	$\frac{\pi^2}{6}$
$^3P_0$	1	$\mathbf{-\frac{43}{27}}$	$\frac{\pi^2}{6} + \frac{2}{3}$	$\frac{\pi^2}{6} + \frac{40}{27}$
$^3P_1$	0	$\frac{5}{54}$	$-\frac{1}{9}$	$-\frac{2}{9}$
$^3P_2$	1	$\mathbf{-\frac{53}{36}}$	$\frac{\pi^2}{6} + \frac{1}{2}$	$\frac{\pi^2}{6} + \frac{11}{9}$

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Perfect match for NLO and prediction for NNLO !

NLO: JPL, M.A. Ozcelik, EPJC 81 (2021) 6, 497

Matching HEF and NLO CF (illustration for η_Q)

The HEF works only at $z \ll 1$ and does not include corrections $O(z)$, while NLO CF is exact in z but only NLO up to α_s. **We need to match them.**

- Simplest prescription: just subtract the overlap at $z \ll 1$:

$$\sigma^{[m]}_{\text{NLO+HEF}} = \sigma^{[m]}_{\text{LO CF}} + \int_{z_{\min}}^{1} \frac{dz}{z} \left[\check{\sigma}^{[m],ij}_{\text{HEF}}(z) + \hat{\sigma}^{[m],ij}_{\text{NLO CF}}(z) - \hat{\sigma}^{[m],ij}_{\text{NLO CF}}(0) \right] \mathcal{L}_{ij}(z)$$

- Or introduce **smooth weights**:

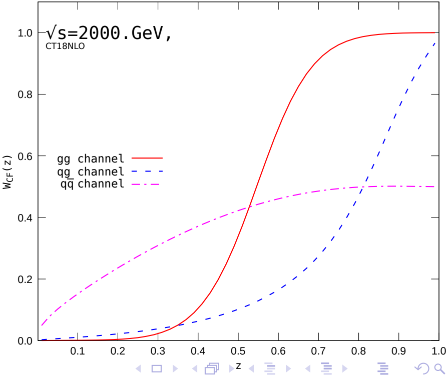
$$\sigma^{[m]}_{\text{NLO+HEF}} = \sigma^{[m]}_{\text{LO CF}} + \int_{z_{\min}}^{1} dz \left\{ \left[\check{\sigma}^{[m],ij}_{\text{HEF}}(z) \frac{\mathcal{L}_{ij}(z)}{z} \right] w^{ij}_{\text{HEF}}(z) + \left[\hat{\sigma}^{[m],ij}_{\text{NLO CF}}(z) \frac{\mathcal{L}_{ij}(z)}{z} \right] (1 - w^{ij}_{\text{HEF}}(z)) \right\},$$

Inverse error weighting method (illustration for η_Q)

In the InEW method [Echevarria, *et.al.*, 2018] the weights are calculated from the **parametric estimates of the error** of each contribution and combined as such:

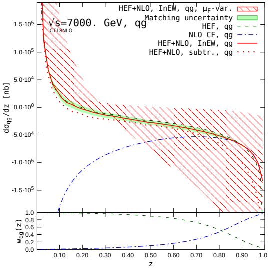
$$w^{ij}_{\rm HEF}(z) = \frac{[\Delta\sigma^{ij}_{\rm HEF}(z)]^{-2}}{[\Delta\sigma^{ij}_{\rm HEF}(z)]^{-2} + [\Delta\sigma^{ij}_{\rm CF}(z)]^{-2}},$$

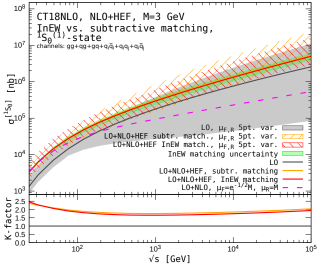
- For $\Delta\sigma_{\rm CF}$, we take the NNLO $\alpha_s^2 \ln \frac{1}{z}$ term of $\hat\sigma(z)$ predicted by HEF,
- For $\Delta\sigma_{\rm HEF}$, we take the $\alpha_s O(z)$ part of the NLO CF result for $\hat\sigma(z)$.
- In both cases, stability against $O(\alpha_s^2)$ (constant in z, unknown) corrections is checked



Matched results
η_c hadroproduction

J.P. Lansberg, M. Nefedov, M.A.Ozcelik, JHEP 05 (2022) 083 and 2306.02425





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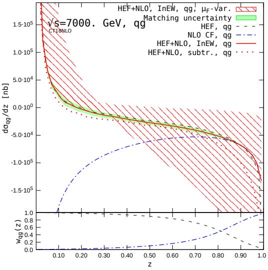
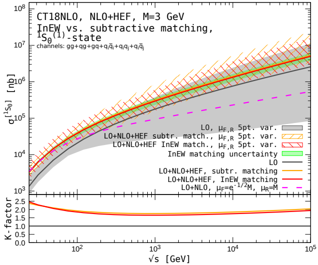
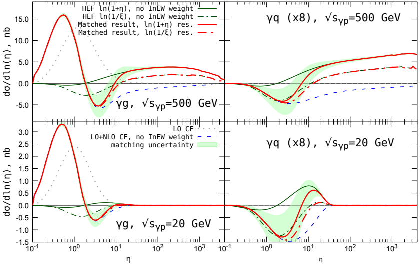
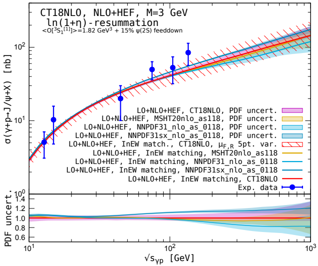




J/ψ photoproduction





Part IV

Summary and outlook

The current situation in one slide ...

For an up-to-date review, see JPL. arXiv:1903.09185 [hep-ph] (Phys.Rept. 889 (2020) 1)

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

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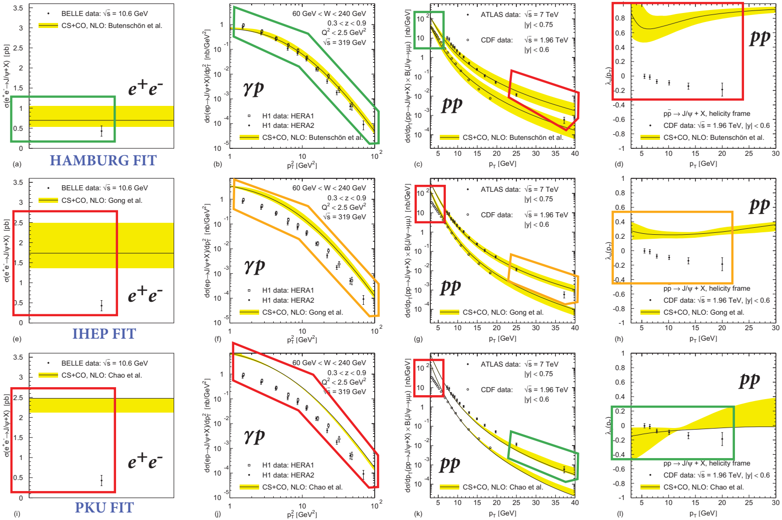
All approaches have troubles with *ep*, *ee* or *pp* polarisation and/or the η_c data

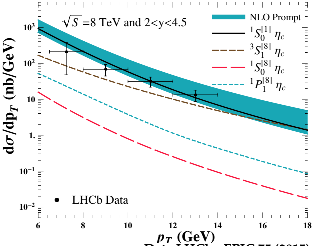
Universality of NLO NRQCD fits ?

Plot from M. Butenschön (ICHEP 2012); Discussion in JPL, Phys.Rept. 889 (2020) 1



Further caveats: LDME upper limit from η_c data clearly violated by the 3 fits !

The last piece in the puzzle: the η_c



Data LHCb : EPJC 75 (2015) 311 (plot from H. Han*et al.* PRL 114 (2015) 092005)

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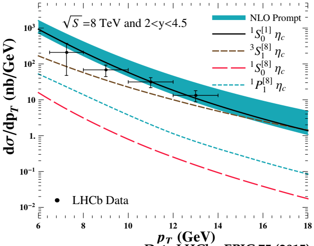

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- η_c x-section measured by LHCb very well described by the CS contribution (Solid Black Curve)

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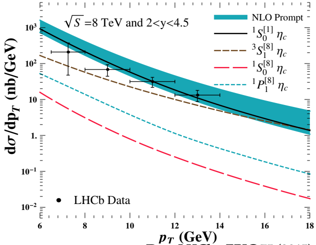

Data LHCb : EPJC 75 (2015) 311 (plot from H. Han *et al.* PRL 114 (2015) 092005)

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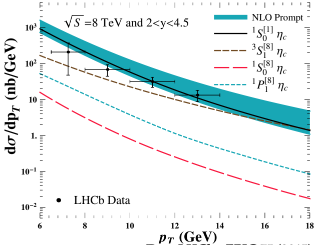

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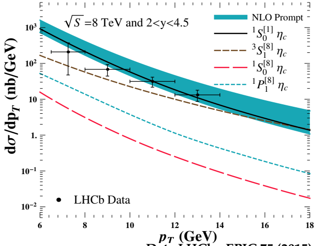

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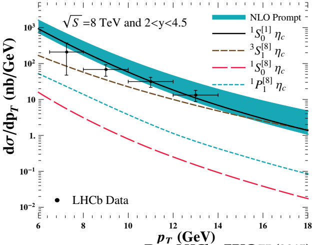

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- Nobody foresaw the impact of measuring η_c yields: 3 PRL published right after the LCHb data came out **(Hamburg) M. Butenschoen *et al.* PRL 114 (2015) 092004; (PKU) H. Han *et al.* 114 (2015) 092005; (IHEP) H.F. Zhang *et al.* 114 (2015) 092006**

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Going further with new observables

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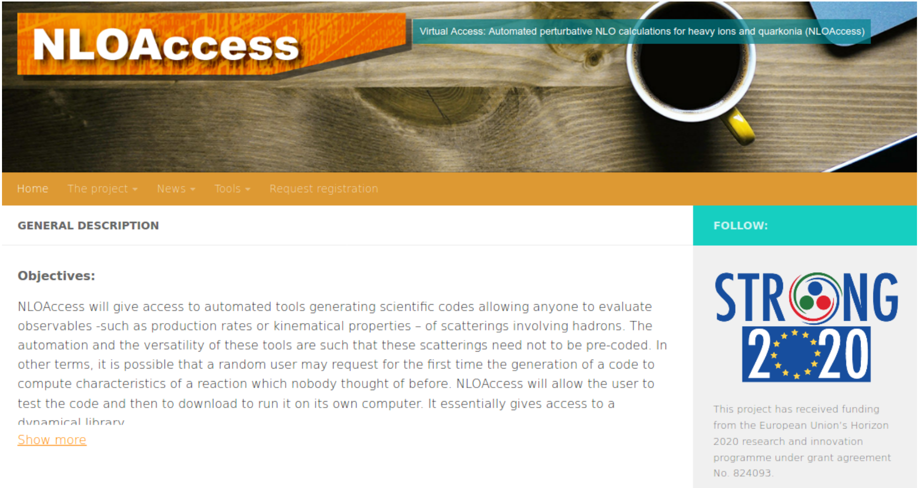
See section 3 of JPL, arXiv:1903.09185 (Phys.Rept. 889 (2020) 1) and section 2.5 of E. Chapon arXiv:2012.14161 PPNP (2021) 103906

Observables	Experiments	CSM	CEM	NRQCD	Interest
J/ψ+J/ψ	LHCb, CMS, ATLAS, D0 (+NA3)	NLO, NNLO*	NLO	LO	Prod. Mechanism (CS dominant) + DPS + gluon TMD
J/ψ+D	LHCb	LO	LO ?	LO	Prod. Mechanism (c to J/psi fragmentation) + DPS
J/ψ+ϒ	D0	(N)LO	NLO	LO	Prod. Mechanism (CO dominant) + DPS
J/ψ+hadron	STAR	LO	--	LO	B feed-down; Singlet vs Octet radiation
J/ψ+Z	ATLAS	NLO	NLO	Partial NLO	Prod. Mechanism + DPS
J/ψ+W	ATLAS	LO	NLO	NLO (?)	Prod. Mechanism (CO dominant) + DPS
J/ψ vs mult.	ALICE,CMS (+UA1)	--	--	--	Initial vs Final state effects ?
J/ψ in jet.	LHCb, CMS	LO	--	LO	Prod. Mechanism (?)
J/ψ(ϒ) + jet	--	--	--		Prod. Mechanism (QCD corrections)
Isolated J/ψ(ϒ)	--	--	--	--	Prod. Mechanism (CS dominant ?)
J/ψ+b	--	--	--	LO	Prod. Mechanism (CO dominant) + DPS
ϒ+D	LHCb	LO	LO ?	LO	DPS
ϒ+γ	--	NLO, NNLO*	LO ?	LO	Prod. Mechanism (CO LDME mix) + gluon TMD/PDF
ϒ vs mult.	CMS	--	--	--	
ϒ+Z	--	NLO	LO ?	LO	Prod. Mechanism + DPS
ϒ+ϒ	CMS	NLO ?	NLO	LO ?	Prod. Mechanism (CS dominant ?) + DPS + gluon TMD

A EU Virtual Access to pQCD tools: NLOAccess

[in2p3.fr/nloaccess]



NLOAccess

Virtual Access: Automated perturbative NLO calculations for heavy ions and quarkonia (NLOAccess)

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GENERAL DESCRIPTION

Objectives:

NLOAccess will give access to automated tools generating scientific codes allowing anyone to evaluate observables -such as production rates or kinematical properties – of scatterings involving hadrons. The automation and the versatility of these tools are such that these scatterings need not to be pre-coded. In other terms, it is possible that a random user may request for the first time the generation of a code to compute characteristics of a reaction which nobody thought of before. NLOAccess will allow the user to test the code and then to download to run it on its own computer. It essentially gives access to a dynamical library

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824093.

HELAC-Onia Web [nloaccess.in2p3.fr/HO/]

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Automated perturbative calculation with HELAC-Onia Web

Welcome to HELAC-Onia Web!

HELAC-Onia ia an automatic matrix element generator for the calculation of the heavy quarkonium helicity amplitudes in the framework of NRQCD factorization.
The program is able to calculate helicity amplitudes of multi P-wave quarkonium states production at hadron colliders and electron-positron colliders by including new P-wave off-shell currents. Besides the high efficiencies in computation of multi-leg processes within the Standard Model, HELAC-Onia is also sufficiently numerical stable in dealing with P-wave quarkonia and P-wave color-octet intermediate states.

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Automated perturbative calculation with NLOAccess

MG5_aMC@NLO

MadGraph5_aMC@NLO is a framework that aims at providing all the elements necessary for SM and BSM phenomenology, such as the computations of cross sections, the generation of hard events and their matching with event generators, and the use of a variety of tools relevant to event manipulation and analysis. Processes can be simulated to LO accuracy for any user-defined Lagrangian, an the NLO accuracy in the case of models that support this kind of calculations -- prominent among these are QCD and EW corrections to SM processes. Matrix elements at the tree- and one-loop-level can also be obtained.

Please login to use MG5_aMC@NLO.

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