$\Upsilon J/\psi$ Production at LHC

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Contents

Introduction

- $pp \to \mathcal{Q}_1\mathcal{Q}_2 + X \Rightarrow$ info on $\mathcal{Q}$ structure
- Different production mechanisms: LO CS, NLO CS, LO CO, DPS, etc
  - $2J/\psi$:
    $$\sigma_{CS} = 4\,\text{nb}, \qquad \sigma_{DPS} = 2\,\text{nb}$$
  - $2\Upsilon(1S)$:
    $$\sigma_{CS} = 8.7\,\text{pb}, \qquad \sigma_{DPS} = 0.4\,\text{pb}$$
- How about $\Upsilon J/\psi$?

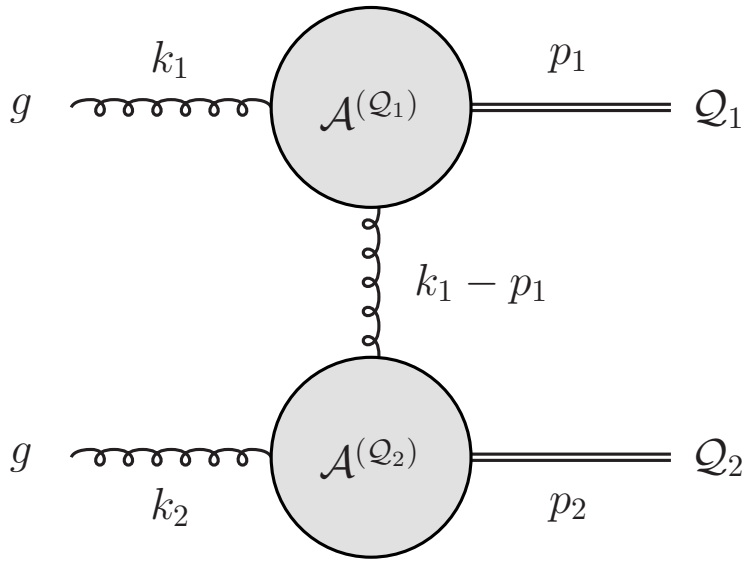
$$\sigma_{CS}^{J/\psi\Upsilon} \ll \sigma_{CS}^{\Upsilon\Upsilon} \ll \sigma_{CS}^{J/\psi J/\psi}$$

LO CS is forbidden $\Rightarrow$ clean mode to study other subrocesses

LO CS, discussion

- $\Upsilon J/\psi$ production at LO CS is forbidden by C-parity conservation
- Can be produced via radiative decays of $\chi_b\chi_c$

$$\hat{\sigma}(\Upsilon\psi) = \sum_{J_c J_b} \mathrm{Br}(\chi_{bJ_b} \to \Upsilon\gamma)\mathrm{Br}(\chi_{cJc} \to J/\psi\gamma)\hat{\sigma}(\chi_{bJ_b}\chi_{cJ_c})$$



$+perm$

- peaks at $p_T = 0$
- equivalent gluon $\Rightarrow$ $\hat{\sigma}(\chi_{bJ_b}\chi_{cJ_c}) \sim (2J_b+1)\Gamma(\chi_{bJ_b})(2J_c+1)\Gamma(\chi_{cJ_c})$
- The ratios are

$$\chi_{b2}\chi_{c2} : \chi_{b2}\chi_{c0} : \chi_{b0}\chi_{c2} : \chi_{b0}\chi_{c0} \approx$$

$$4/3 : 1 : 1 : 3/4$$

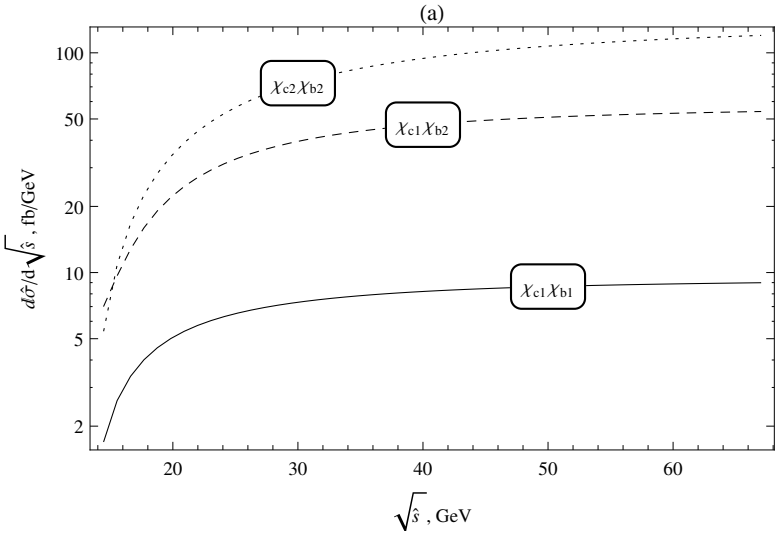
- production of $\chi_{c,b1}$ is suppressed

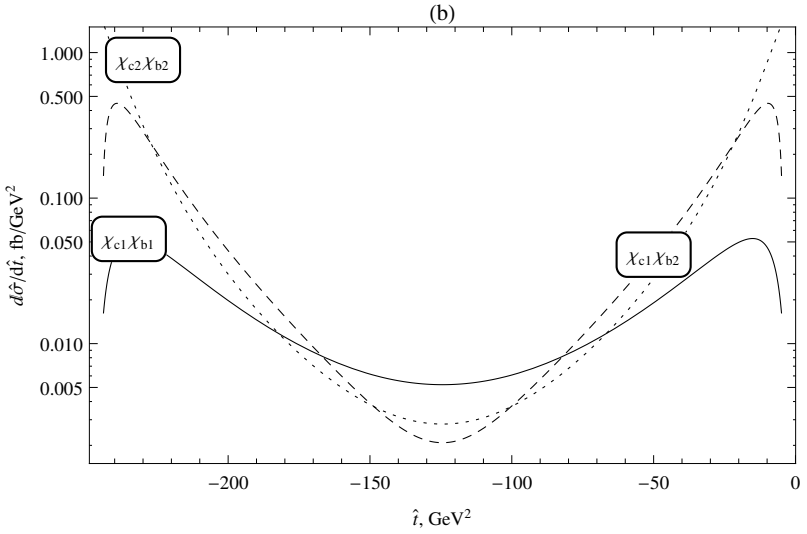
LO CS, results

- Partonic cross sections (in fb) at $\hat{s} = \hat{s}_0 = 2(M_{\chi_c} + M_{\chi_b})^2$

$\mathcal{Q}_1/\mathcal{Q}_2$	χ_{c0}	χ_{c1}	χ_{c2}
χ_{b0}	16.3	14.8	21.4
χ_{b1}	2.1	4.6	3.8
χ_{b2}	21.4	19.6	29.2

  The ratios agree with naive expectations
- Distributions of the partonic cross sections



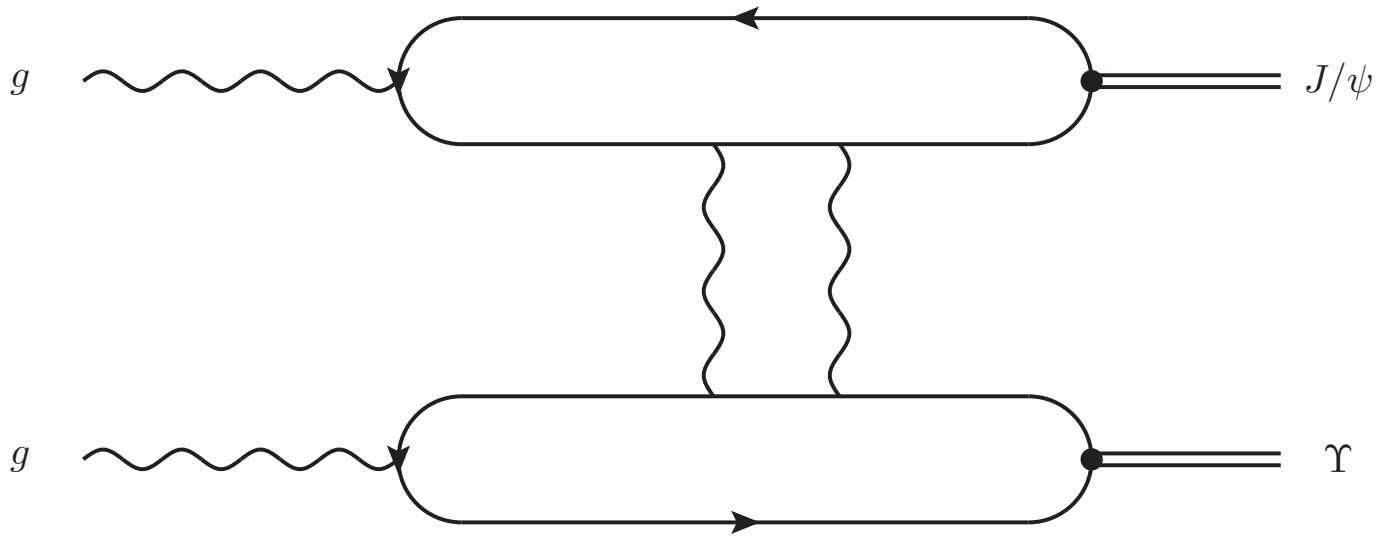


NLO

Furry theorem can be skipped at

- NLO

[V. Kiselev et al, Yad.Fiz.49, 1681 (1989)]



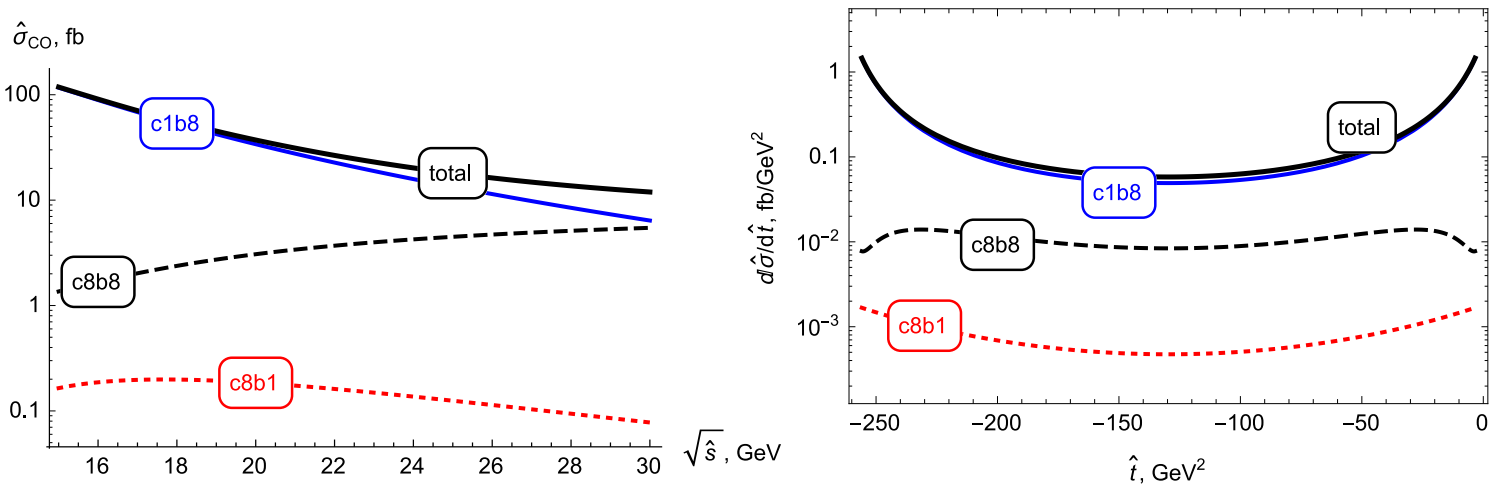
$$\hat{\sigma} \sim F^2(\hat{t}), F(\hat{t}) \sim \int d^2k \frac{J_A J_B}{\mathbf{k}^2(\mathbf{k}-\mathbf{q})^2}$$

$$\hat{\sigma}_{NLO}(\hat{s}_0) = 21\,\text{fb}$$

CO

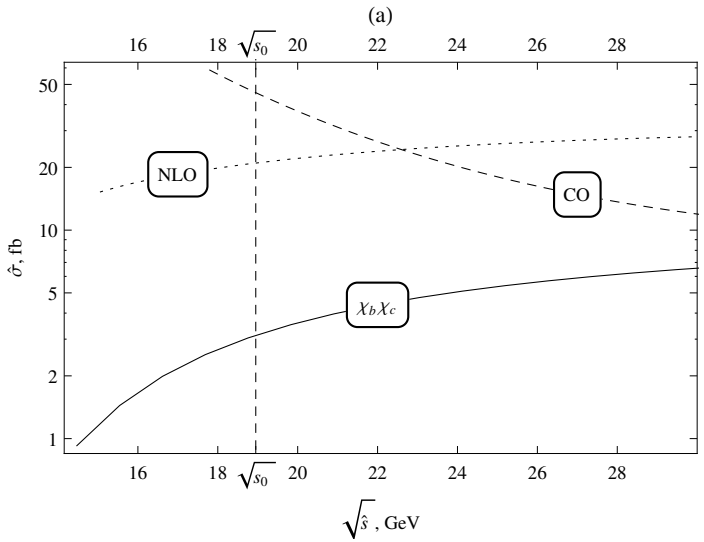
[P. Ko,JHEP 1101, 070 (2011), arXiv:1007.3095.]

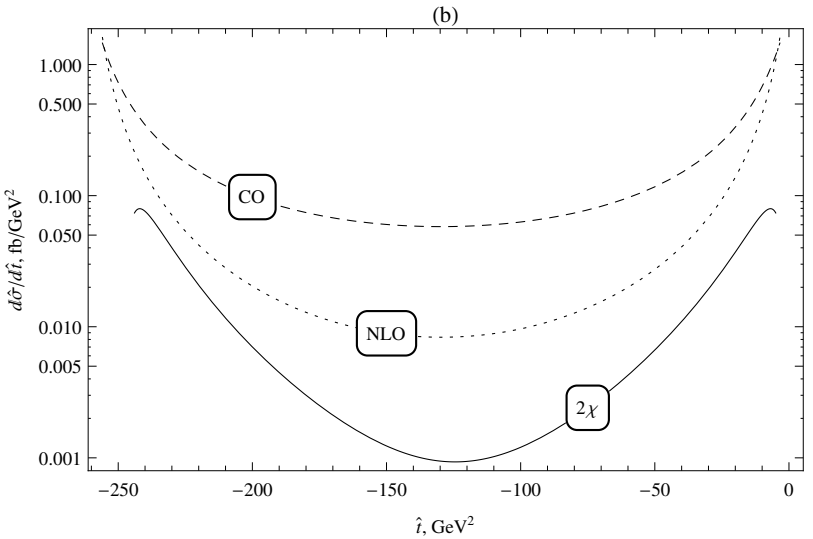
Colour octet components $c\bar{c}[^3S_1^{[8]}]$, $b\bar{b}[^3S_1^{[8]}]$ were taken into account



$$\hat{\sigma}_{CO}(\hat{s}_0) = 50\,\text{fb}$$

Distributions





- In all kinematical region 2χ channel is suppressed
- From analysis of angular distributions one can separate CO and NLO channels

Hadronic Cross Sections

- From presented above partonic cross sections one can obtain hadronic ones. At LHCb ($\sqrt{s} = 8$ TeV, $2 < y_{\Upsilon, J/\psi} < 4.5$)

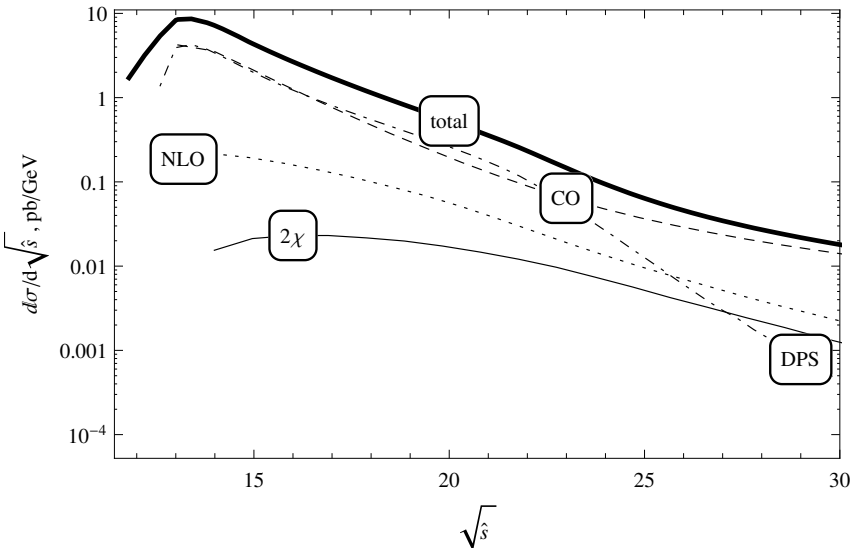
$$\begin{aligned} \sigma_{SPS}\left(pp \to \chi_b \chi_c + X \to \Upsilon J/\psi + X\right) &= 0.2\ pb, \\ \sigma_{SPS}\left(pp \to \Upsilon J/\psi + X, NLO\right) &= 1.5\ pb, \\ \sigma_{SPS}\left(pp \to \Upsilon J/\psi, CO\right) &= 11.1\ pb. \end{aligned}$$

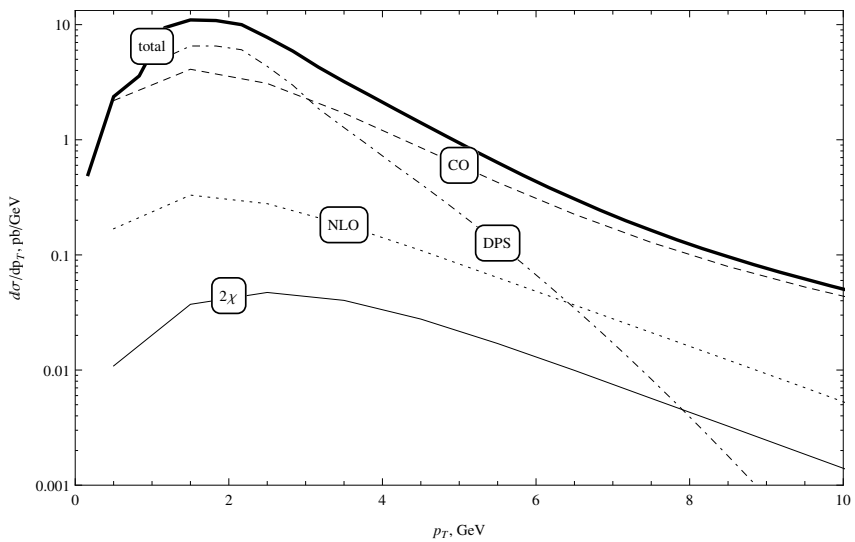
- At LHC energies Double Parton Scattering channel is significant

$$\sigma_{DPS} = \frac{\sigma_{SPS}\sigma_{SPS}}{\sigma_{eff}} = 12.5\,\mathrm{pb}$$

- One can separate contributions of different channels from distributions' analysis

Distributions





- CO and DPS channels give main contributions in all kinematical region
- 2χ channel is suppressed

Conclusion

- Inclusive hadronic production of $J/\psi\Upsilon(1S)$ pair is considered
- CS ($\chi_b\chi_c$), CO, NLO and DPS mechanisms were taken into account
- Main contributions come from DPS and SPS CO reactions
- Inclusive $\Upsilon J/\psi$ production can be used to study CO matrix elements and DPS distribution functions
- More details can be found at

  A.K Likhoded, A.V. Luchinsky, S.V. Poslavsky, arXiv:1503:00246 [hep-ph]

Thank you for your attention!