J/Ψ production in hadron collisions: two parton showers contribution

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E.L. & Siddikov:

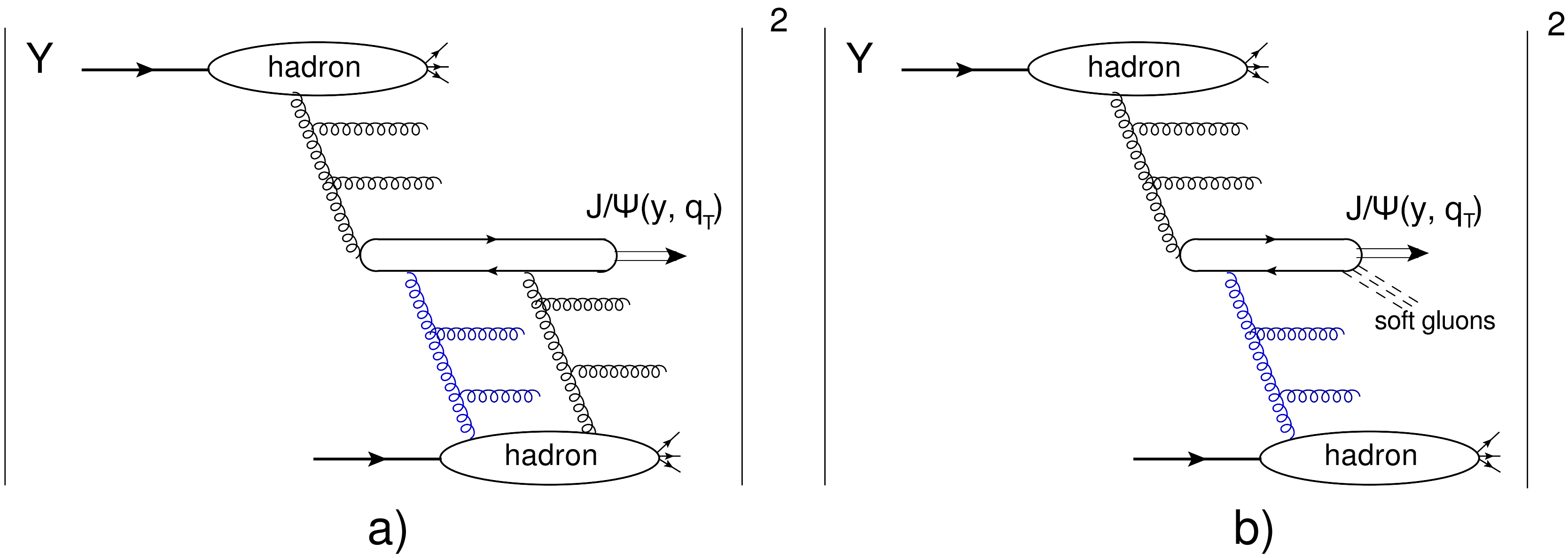
“J/ψ production in hadron scattering: three-pomeron contribution,” Eur. Phys. J. C **79** (2019) no.5, 376; [arXiv:1812.06783 [hep-ph]];

“J/ψ production in hadron scattering: multiplicity distribution ” in preparation.

Outline:

- Motivations.
- Main ideas and formulae
- The value and energy dependence of the cross section.
- Rapidity distribution.
- p_T spectra.
- Multiplicity dependence.

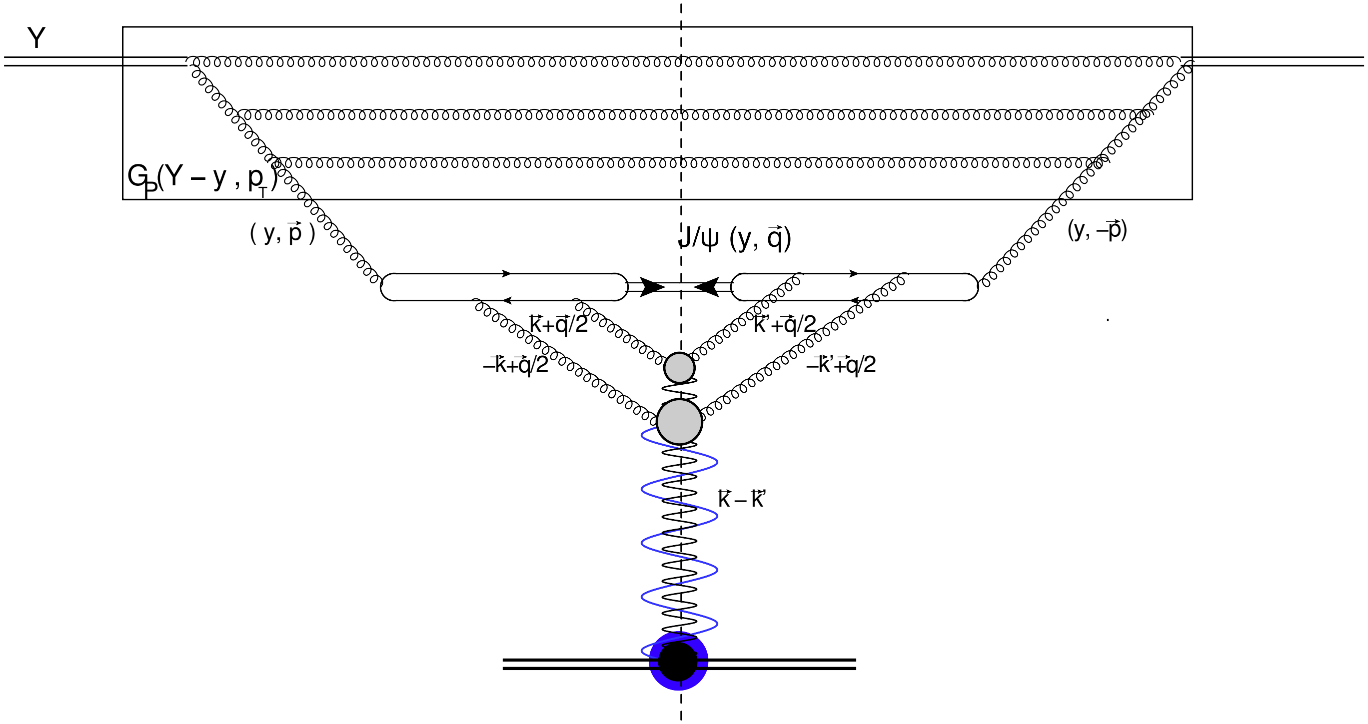
Motivations:



- **L. Motyka and M. Sadzikowski (2015)**

Main formulae:

- $$\frac{d^2\sigma\left(Y,q_T\right)}{dy\,d^2q_T} = \frac{4\,C_F^3\bar{\alpha}_S^3}{(2\pi)^6}\int d^2k_T\,d^2p_T\,d^2Q_T\,G^{\mathrm{cut}}_{I\!P}\left(Y-y,\,p_T,\,0\right)\times$$
$$\times\quad I\left(k_T,q_T\right)\,I\left(k'_T,q_T\right)\,G^{\mathrm{cut}}_{I\!P}\left(y,\,k_T+\frac{1}{2}q_T,Q_T\right)\,G^{\mathrm{cut}}_{I\!P}\left(y,\,-k_T+\frac{1}{2}q_T,Q_T\right)$$



- $$\frac{d\sigma\left(Y,Q^2\right)}{dy} = 16 \int \frac{d^2 Q_T}{(2\pi)^2}\, S^2_h\left(Q_T\right)\; x_g\, G\left(x_g, p^{max}_T\right)$$
$$\times \int_0^1 dz \int_0^1 dz' \int \frac{d^2 r}{4\pi}\,\frac{d^2 r'}{4\pi} \left\langle \Psi_g\left(p^{max}_T; r, z\right)\, \Psi_{J/\psi}\left(r, z\right)\right\rangle \left\langle \Psi_g\left(p^{max}_T; r', z'\right)\; \Psi_{J/\psi}\left(r', z'\right)\right\rangle$$
$$\times \left(N\left(y; \frac{\vec{r} + \vec{r}'}{2}\right) - N\left(y; \frac{\vec{r} - \vec{r}'}{2}\right)\right)^2$$

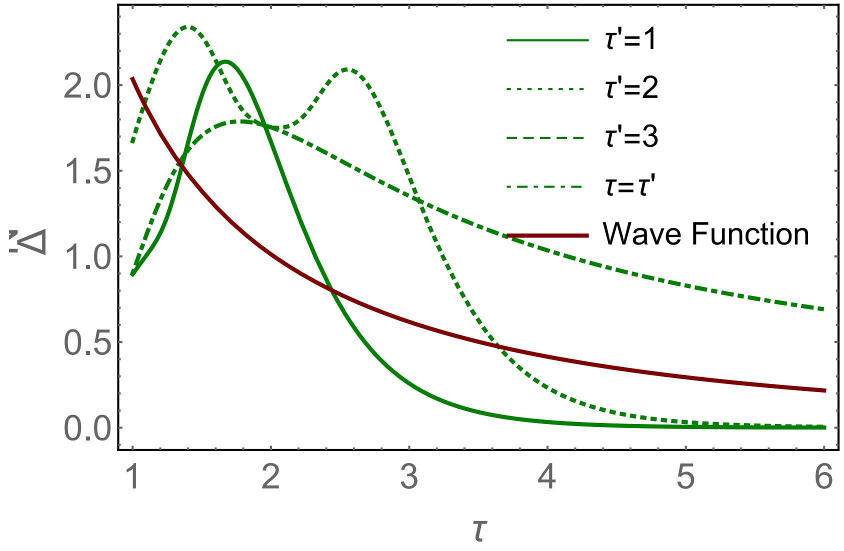
- $$\frac{d\sigma\left(Y,\, Q^2\right)}{dy\, d^2 q_T} =$$
$$4 \int \frac{d^2 Q_T}{(2\pi)^2}\, S^2_h\left(Q_T\right)\;\; x_g G\left(x_g,\, M_{J/\psi}\right)$$
$$\times \int_0^1 dz \int_0^1 dz' \int \frac{d^2 r}{4\pi}\,\frac{d^2 r'}{4\pi}\, d^2 b\; e^{-i\vec{q}_T\cdot\vec{b}} \left\langle \Psi_g\left(r, z\right)\; \Psi_{J/\psi}\left(r, z\right)\right\rangle \left\langle \Psi_g\left(r', z'\right)\; \Psi_{J/\psi}\left(r', z'\right)\right\rangle$$
$$\times \left(N\left(y;\, b - \frac{1}{2}\left(r - r'\right)\right) + N\left(y;\, b + \frac{1}{2}\left(r - r'\right)\right) - N\left(y;\, b + \frac{1}{2}\left(r + r'\right)\right) - N\left(y;\, b - \frac{1}{2}\left(r + r'\right)\right)\right)^2$$

The main ideas

1 **The main contribution stems from the vicinity of the saturation scale where we know the solution to the non-linear equation:**

- $$N\left(r^2, Y\right) = N_0\left(r^2\, Q_S^2(Y)\right)^{\bar{\gamma}} = N_0 \tau^{\bar{\gamma}}$$

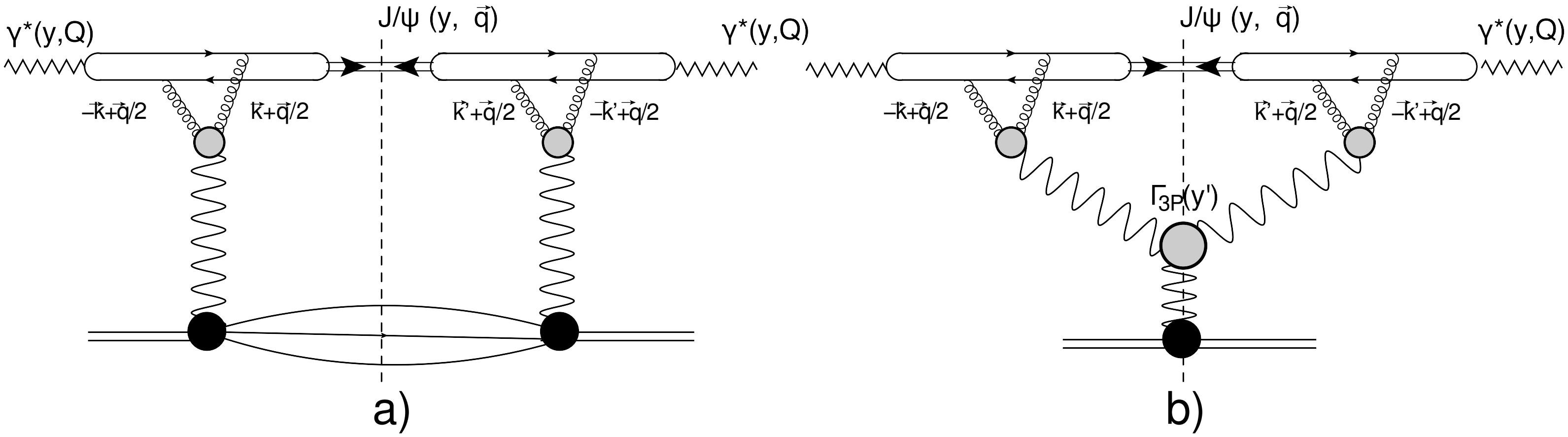
On LO $\bar{\gamma} = 0.63;\;\; Q_s^2 \;=\; e^{\lambda\, Y} Q^2\,(Y = Y_0, b)$



- $$\Delta = \int d\phi \left(N\left(\tfrac{1}{2}(\vec{r} + \vec{r'})\right) - N\left(\tfrac{1}{2}(\vec{r} - \vec{r'})\right)\right)^2 \rightarrow$$ **Solution to non-linear BK equation**

in the leading twist approximation

2 The non-pertubative info from $\gamma^* + p \to J/\Psi$ diffractively.



Values and W dependence

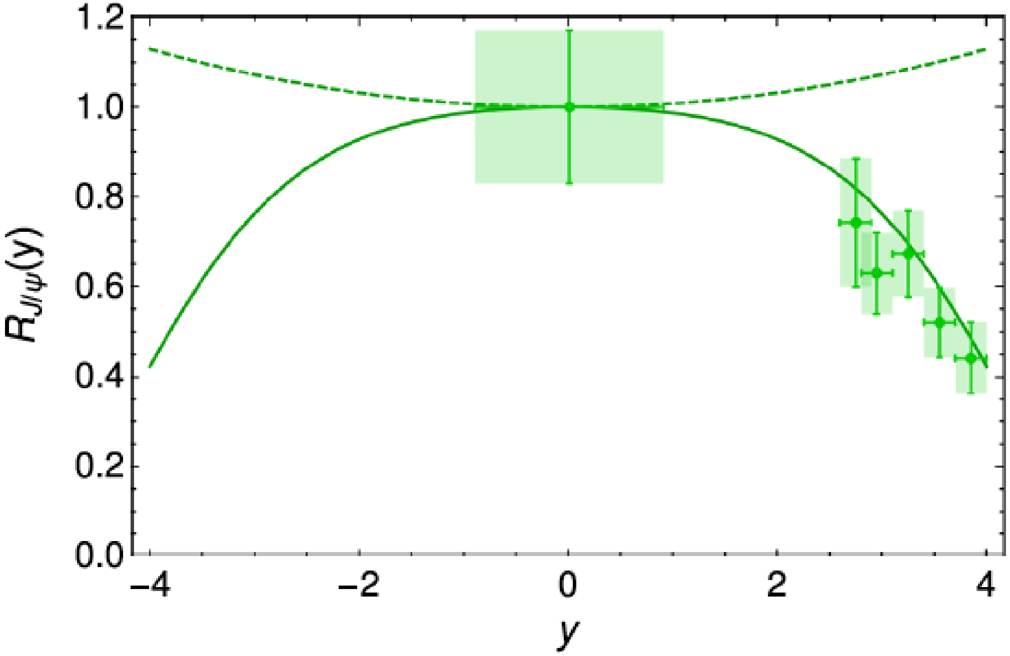
	Theoretical estimates	Experiment
$\sqrt{s} \approx 1.96$ TeV	2.1-2.6 μb	2.38 μb CDF
$\sqrt{s} \approx 7$ TeV	3.8-5.6 μb	5.8 μb ALICE

The rapidity distribution.

- $$\frac{d\sigma_{J/\psi}(y)/dy}{d\sigma_{J/\psi}(y)/dy|_{y=0}} = \left(\frac{Q_s^2(y^*-y)\left(Q_s^2(y^*+y)\right)^2}{Q_s^2(y^*)\left(Q_s^2(y^*)\right)^2}\right)^{\bar{\gamma}} + \left(\frac{Q_s^2(y^*+y)\left(Q_s^2(y^*-y)\right)^2}{Q_s^2(y^*)\left(Q_s^2(y^*)\right)^2}\right)^{\bar{\gamma}}$$

$$y^* = -\ln\left(\sqrt{\frac{M^2_{J/\psi}+q_T^2}{s}}\right)$$

- $$x_g G\left(x_g, r^2\right) \propto \left(Q_s^2(x_g)\, r^2\right)^{\bar{\gamma}} (1-x)^5, \qquad x_g = e^{-y^* \pm y}$$

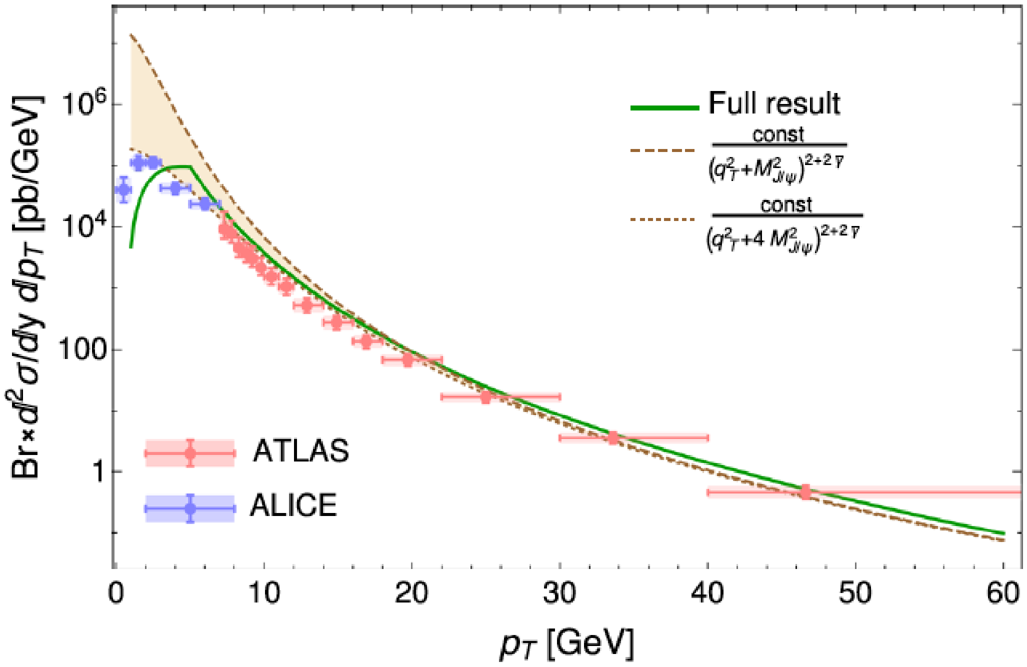


The transverse momenta spectra.

Main contributions : $|b| \sim |r + r'| \sim 1/p_T, \quad |r| \sim |r'| \sim m_c^{-1} \gg p_T^{-1}$

$|b| \sim |r - r'| \sim 1/p_T, \quad |r| \sim |r'| \sim m_c^{-1} \gg p_T^{-1}$

- $$\frac{d^2\sigma}{d^2 p_T} \sim \frac{1}{p_T^{4+4\bar{\gamma}}} \longrightarrow \frac{1}{\left(p_T^2 \; + \; \Lambda_c^2\right)^{2+2\bar{\gamma}}}$$



Multiplicity distribution.

The saturation momentum Q_s is the solution to the equation:

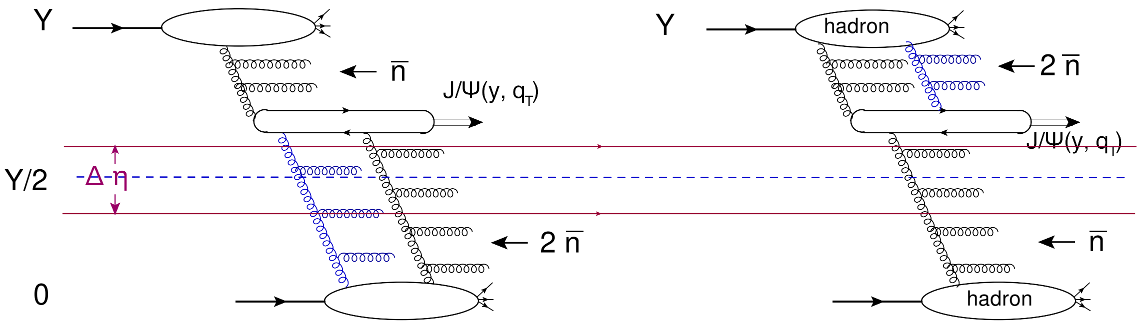
- $$Q^2_s = \frac{2\,\pi^2\,\bar{\alpha}_S}{C_F}\quad\underbrace{\frac{x_g G\left(x_g, Q_s\right)}{\pi\,R^2_h}}_{\text{density of gluons}}$$

Conjecture:

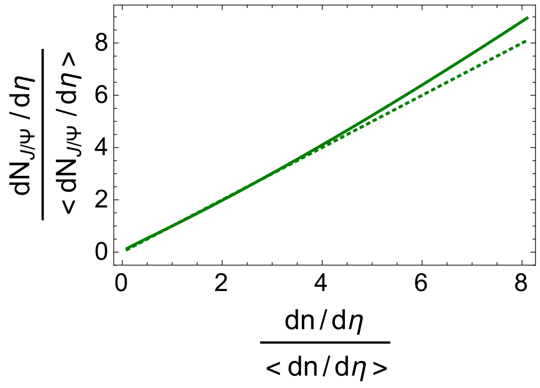
- $$Q^2_s = \frac{n}{\bar{n}} Q^2_s\left(n = 1\right)$$

Three kind of experiment

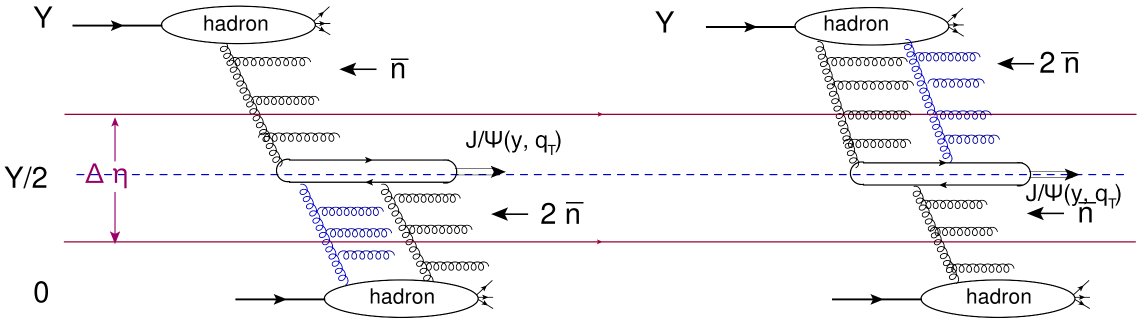
1. Experiment $\propto n$



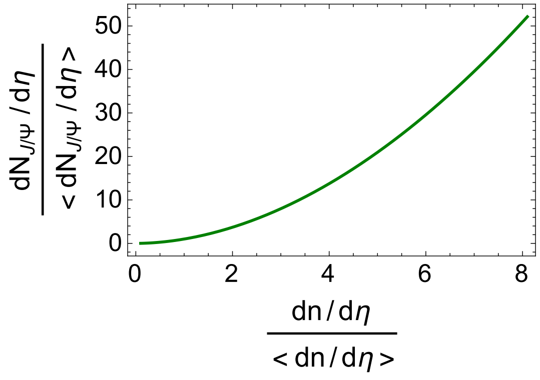
a) b)



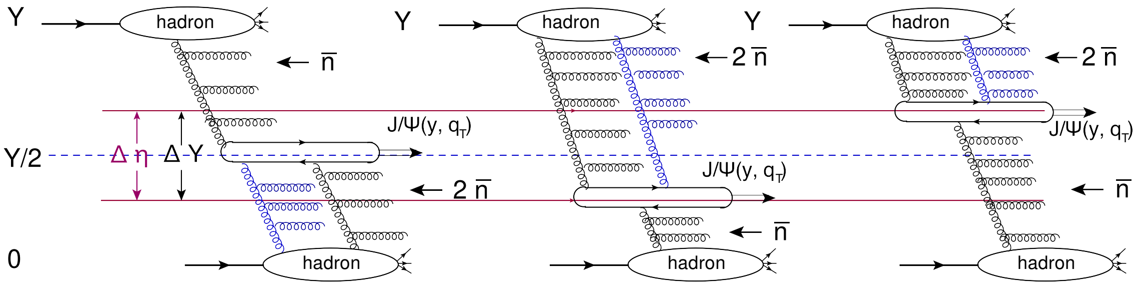
2. No data



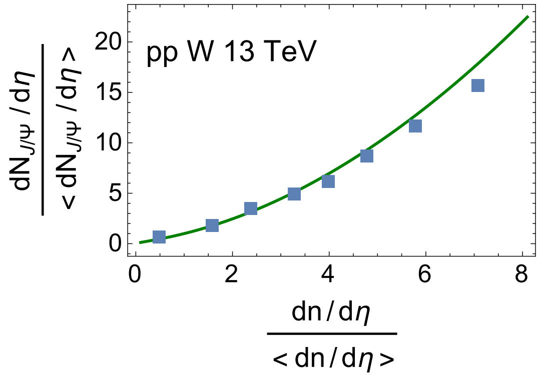
a) b)



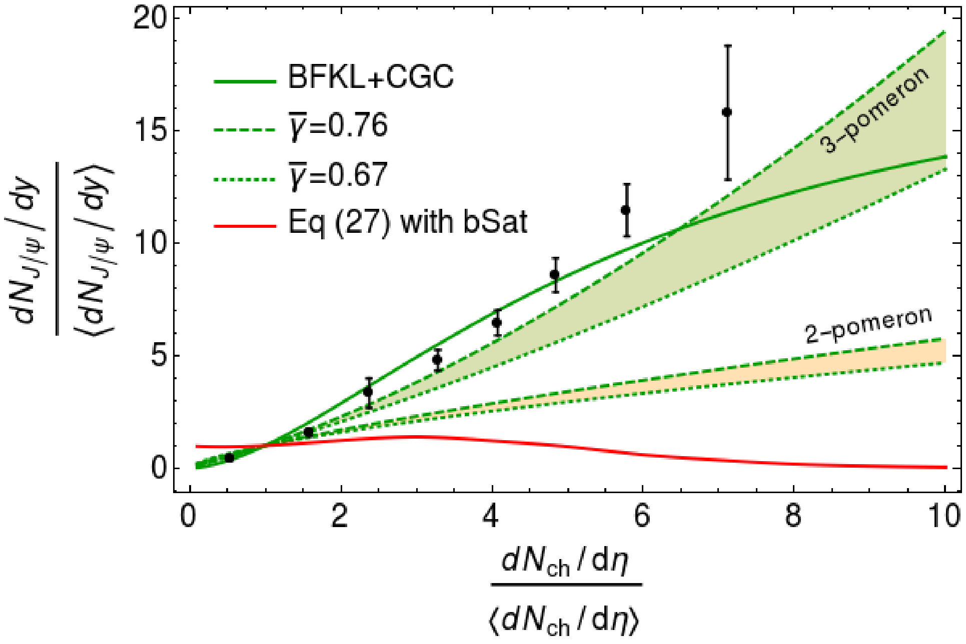
3. Data are shown:



a) b) c)



Alternative approach $\longrightarrow$ **production of many BFKL Pomerons with average multiplicity $\bar{n}$**



Conclusions

- We believe that the production of two parton showers is the dominant mechanism for J/Ψ production in proton-proton scattering;
- Strong multiplicity dependence turns out to be a typical feature of the CGC approach, in which this dependence appears due to dependence of the saturation momentum on the density of produced particles.
- We show that this source leads to the good description of the available experimental data.
- We consider this type of the experiment is very important for recovering of the CGC dynamics and suggest the experiment, for which it is predicted the strong non-linear dependence of the cross section on the multiplicity of produced hadrons in the framework of the CGC approach.