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E.L. & Siddikov:
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)

$J/\Psi$ production in hadron collisions: two parton showers contribution
Main formulae:

\[
\frac{d^2 \sigma (Y, q_T)}{dy \ d^2 q_T} = \frac{4 C_F^3 \alpha_S^3}{(2\pi)^6} \int d^2 k_T \ d^2 p_T \ d^2 Q_T \ G_{\text{cut}}^\text{IP} (Y - y, p_T, 0) \times \\
\times I (k_T, q_T) I (k'_T, q_T) \ G_{\text{cut}}^\text{IP} \left( y, k_T + \frac{1}{2} q_T, Q_T \right) \ G_{\text{cut}}^\text{IP} \left( y, -k_T + \frac{1}{2} q_T, Q_T \right)
\]
\[
\frac{d\sigma (Y, Q^2)}{dy} = 16 \int \frac{d^2 Q_T}{(2\pi)^2} S_h^2 (Q_T) \ x_g \ G (x_g, p_{T_{\text{max}}}) \\
\times \int_0^1 dz \int_0^1 dz' \int \frac{d^2 r}{4\pi} \frac{d^2 r'}{4\pi} \langle \Psi_g (p_{T_{\text{max}}}; r, z) \ \Psi_{J/\psi} (r, z) \rangle \langle \Psi_g (p_{T_{\text{max}}}; r', z') \ \Psi_{J/\psi} (r', z') \rangle \\
\times \left( N \left( y; r + r' \right) - N \left( y; r - r' \right) \right)^2
\]

\[
\frac{d\sigma (Y, Q^2)}{dy \ d^2 q_T} = \\
4 \int \frac{d^2 Q_T}{(2\pi)^2} S_h^2 (Q_T) \ x_g \ G (x_g, M_{J/\psi}) \\
\times \int_0^1 dz \int_0^1 dz' \int \frac{d^2 r}{4\pi} \frac{d^2 r'}{4\pi} \ d^2 b \ e^{-i\vec{q}_T \cdot \vec{b}} \langle \Psi_g (r, z) \ \Psi_{J/\psi} (r, z) \rangle \langle \Psi_g (r', z') \ \Psi_{J/\psi} (r', z') \rangle \\
\times \left( N \left( y; b - \frac{1}{2} (r - r') \right) + N \left( y; b + \frac{1}{2} (r - r') \right) - N \left( y; b + \frac{1}{2} (r + r') \right) - N \left( y; b - \frac{1}{2} (r + r') \right) \right)^2
\]
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 \( \bar{\gamma} = 0.63 \); \( Q_s^2 = e^{\lambda Y} Q^2 \left( Y = Y_0, b \right) \)

\[ \Delta = \int d\phi \left( N \left( \frac{1}{2}(r + r') \right) - N \left( \frac{1}{2}(r' - r') \right) \right)^2 \rightarrow \text{Solution to non-linear BK equation} \]

in the leading twist approximation.
The non-pertubative info from $\gamma^* + p \rightarrow J/\Psi$ diffractively.

Values and W dependence

<table>
<thead>
<tr>
<th>Theoretical estimates</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sqrt{s} \approx 1.96$ TeV</td>
<td>2.1-2.6 $\mu$b</td>
</tr>
<tr>
<td>$\sqrt{s} \approx 7$ TeV</td>
<td>3.8-5.6 $\mu$b</td>
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</tbody>
</table>
The rapidity distribution.

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

\[
y^* = - \ln \left( \sqrt{\frac{M_{J/\psi}^2 + q_T^2}{s}} \right)
\]

\[
x_g G \left(x_g, r^2 \right) \propto \left( Q_s^2 \left(x_g \right) r^2 \right)^{\bar{\gamma}} \left(1 - x \right)^5, \quad x_g = e^{-y^* \pm y}
\]
The transverse momenta spectra.

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

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

\[
\frac{d^2\sigma}{d^2p_T} \sim \frac{1}{p_T^{4+4\gamma}} \rightarrow \frac{1}{(p_T^2 + \Lambda_c^2)^{2+2\gamma}}
\]

\(J/\Psi\) production in hadron collisions: two parton showers contribution
Multiplicity distribution.

The saturation momentum $Q_s$ is the solution to the equation:

$$Q_s^2 = \frac{2 \frac{\pi^2}{3} \bar{\alpha}_S}{C_F} \left( \frac{x_g G (x_g, Q_s)}{\pi R_h^2} \right)$$

Conjecture:

$$Q_s^2 \sim \frac{n}{\bar{n}} Q_s^2 (n = 1)$$
Three kind of experiment

1. Experiment $\propto n$

\[
\begin{array}{c}
Y \rightarrow \bar{n} \quad \bar{n} \\
Y/2 \rightarrow \Delta \eta \\
0 \rightarrow \bar{n} \\
\end{array}
\]

\[
\begin{array}{c}
Y \rightarrow J/\Psi(y, q) \\
Y/2 \rightarrow \Delta \eta \\
0 \rightarrow \bar{n} \\
\end{array}
\]

2. No data

\[
\begin{array}{c}
Y \rightarrow \bar{n} \quad \bar{n} \\
Y/2 \rightarrow \Delta \eta \\
0 \rightarrow \bar{n} \\
\end{array}
\]

\[
\begin{array}{c}
Y \rightarrow J/\Psi(y, q) \\
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\]

$J/\Psi$ production in hadron collisions: two parton showers contribution

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3. Data are shown:

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

$J/\Psi$ production in hadron collisions: two parton showers contribution
Conclusions

- We believe that the production of two parton showers is the dominant mechanism for $J/\Psi$ 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.