

Semiexclusive production of vector mesons in proton-proton collisions with electromagnetic dissociation of protons

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Outline

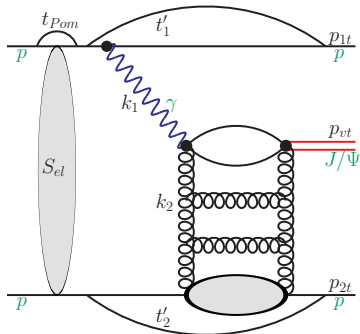
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- **Anna Cisek, Wolfgang Schäfer, Antoni Szczurek**

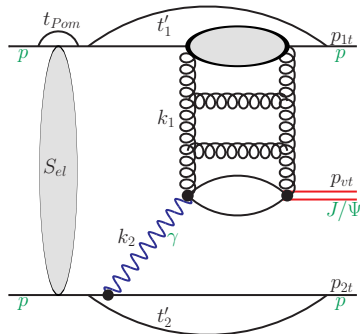
Introduction

- Exclusive production of heavy vector mesons in proton-proton collisions has been studied in rapidity range $y \sim 2.0 - 4.5$
- Large rapidity gaps: no exchange of charge or color. t -channel exchanges with the Regge intercept $\alpha(0)$ or spin $J \geq 1$.
- We often have to deal with diffractive reactions which include **excitation of incoming protons**. Instead of fully inclusive final states: gap cross sections, or even only vetos on additional tracks(!) from a production vertex.
- Inelastic state of mass M_X populates a rapidity interval $\Delta y \sim \log(M_X^2/m_p^2)$.
- A background for exclusive production – or a possible signal when looking for large p_T vector mesons with a gap.

Diagram for exclusive production of vector meson in proton-proton collisions

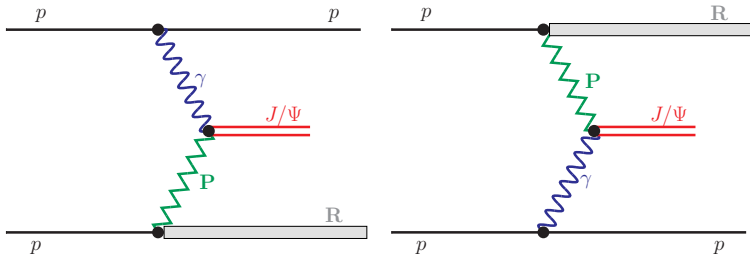


photon-Pomeron



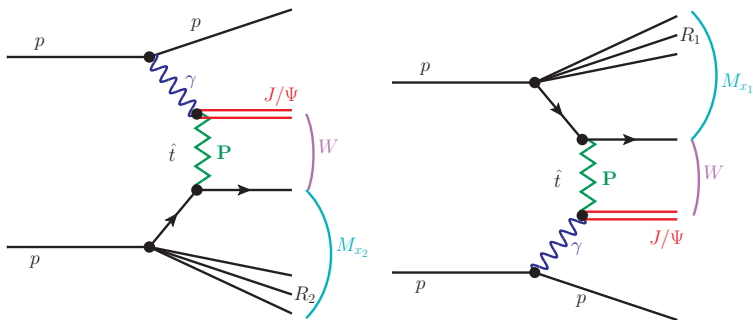
Pomeron-photon

Diffractive resonance with strong dissociation



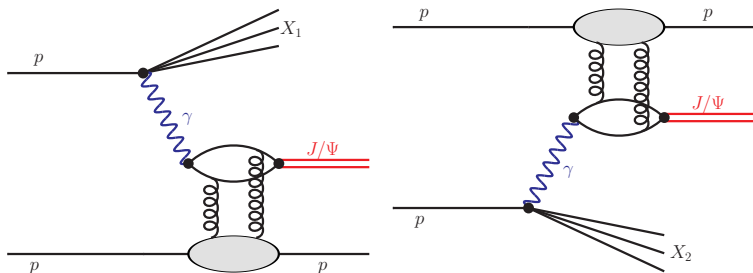
- low $p_T \rightarrow$ Dissociation into nucleon resonances/low mass continuum states. Dominated by $N^*(1680)$, $J^P = \frac{5}{2}^+$, $N^*(2220)$, $J^P = \frac{9}{2}^+$, $N^*(2700)$, $J^P = \frac{13}{2}^+$.
A model by L.L. Jenkovszky, O.E. Kuprash, J.W. Lämssa, V.K. Magas and R. Orava (2011).
- large $p_T \rightarrow$ Incoherent diffractive photoproduction of J/ψ off partons. Large diffractive masses are possible here.

Diffractive partonic with strong dissociation



- dissociative production of vector mesons at large p_T probes the perturbative QCD Pomeron. (Ryskin, Forshaw et al.). An alternative to the “jet - gap - jet” type of processes.

Diagrams representation of the electromagnetic excitation



- The schematic diagrams representation of the electromagnetic excitation of one (left panel) or second (right panel) photon
- Anna Cisek, Wolfgang Schäfer, Antoni Szczurek
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Diffractive production with electromagnetic dissociation

- The important property of these processes is that the $p\gamma^* \rightarrow X$ transition is given by the electromagnetic structure function of protons

The cross section for such process can be written as:

$$\frac{d\sigma(pp \rightarrow XVp; s)}{dyd^2\mathbf{p}} = \int \frac{d^2\mathbf{q}}{\pi q^2} \mathcal{F}_{\gamma/p}^{(\text{in})}(z_+, \mathbf{q}^2) \frac{1}{\pi} \frac{d\sigma^{\gamma^* p \rightarrow Vp}}{dt}(z_+, s, t = -(\mathbf{q} - \mathbf{p})^2) + (z_+ \leftrightarrow z_-)$$

$$z_{\pm} = e^{\pm y} \sqrt{\mathbf{p}^2 + m_V^2} / \sqrt{s}$$

- Generalization of the Weizsäcker-Williams flux to dissociative processes.
- Must in principle add contributions of longitudinal photons. Negligible for heavy mesons as long as $Q^2 \ll m_V^2$

Diffractive production with electromagnetic dissociation

The flux of photons associated with the breakup of protons is calculable in terms of the structure function of protons

$$\mathcal{F}_{\gamma/p}^{(\text{inel})}(z, \mathbf{q}^2, M_X^2) = \frac{\alpha_{\text{em}}}{\pi} (1-z) \theta(M_X^2 - M_{\text{thr}}^2) \frac{F_2(x_{Bj}, Q^2)}{M_X^2 + Q^2 - m_p^2} \cdot \left[\frac{\mathbf{q}^2}{\mathbf{q}^2 + z(M_X^2 - m_p^2) + z^2 m_p^2} \right]^2$$

where

$$Q^2 = \frac{1}{1-z} \left[\mathbf{q}^2 + z(M_X^2 - m_p^2) + z^2 m_p^2 \right]$$

$$x_{Bj} = \frac{Q^2}{Q^2 + M_X^2 - m_p^2}$$

Structure function of protons

Useful fits to F2

- H. Abramowicz, E. M. Levin, A. Levy and U. Maor Phys. Lett. **B269**, (1991) 465

$$F_2(x, Q^2) = \frac{Q^2}{Q^2 + m_0^2} (F_2^{\mathcal{P}}(x, Q^2) + F_2^{\mathcal{R}}(x, Q^2))$$

Useful fits to F2

- R. Fiore, A. Flachi, L. L. Jenkovszky, A. I. Lengyel and V. K. Magas - Phys. Rev. **D70**, 054003 (2004)

$$\begin{aligned} \mathcal{I}m\alpha(s) &= s^\delta \sum_n c_n \left(\frac{s - s_n}{s} \right)^{\text{Re}\alpha(s_n)} \cdot \theta(s - s_n) \\ \text{Re } \alpha(s) &= \alpha(0) + \frac{s}{\pi} PV \int_0^\infty ds' \frac{\mathcal{I}m\alpha(s')}{s'(s' - s)} \end{aligned}$$

Structure function of protons

Useful fits to F2

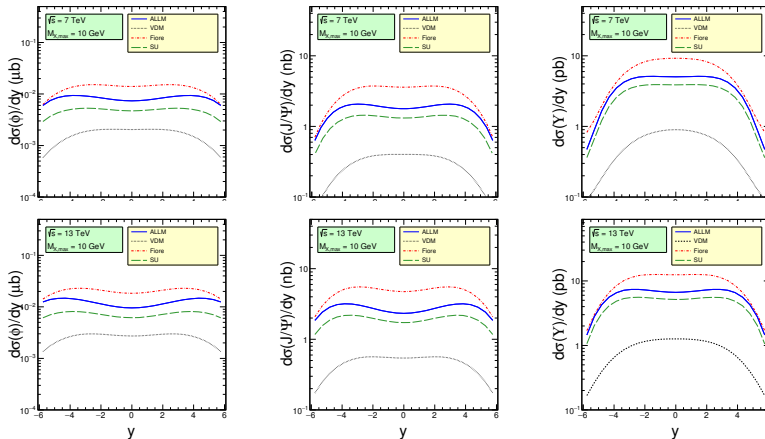
- A. Szczurek, V. Uleshchenko
Eur. Phys. J. **C12** (200) 663-671

$$F_2^N(x, Q^2) = F_2^{N,VDM}(x, Q^2) + F_2^{N,part}(x, Q^2)$$

$$F_2^{N,VDM}(x, Q^2) = \frac{Q^2}{\pi} \sum_V \frac{M_V^4 \cdot \sigma_{VN}^{tot}(s^{1/2})}{\gamma_V^2 (Q^2 + M_V^2)^2} \cdot \Omega_V(x, Q^2)$$

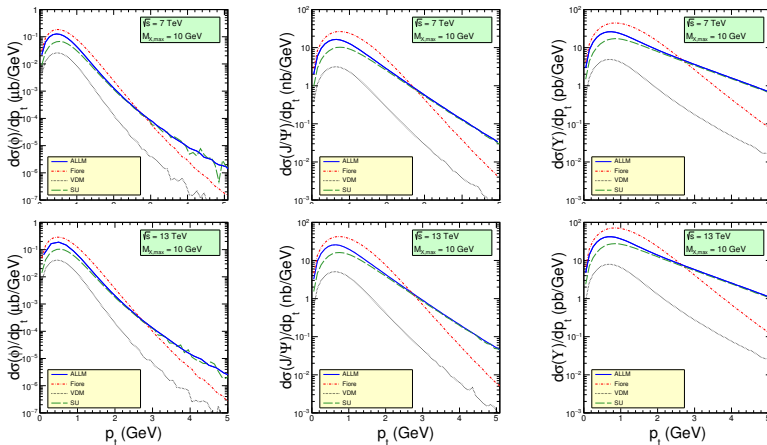
$$F_2^{N,part}(x, Q^2) = \frac{Q^2}{Q^2 + Q_0^2} \cdot F_2^{asympt}(\bar{x}, \bar{Q}^2)$$

Rapidity distribution- different structure function of proton



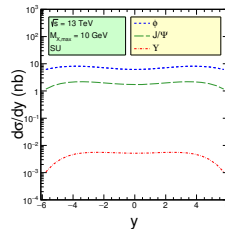
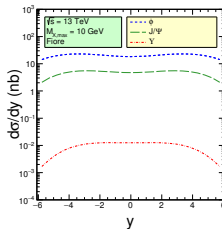
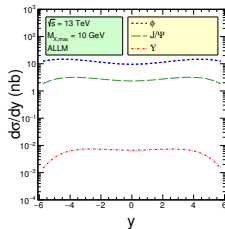
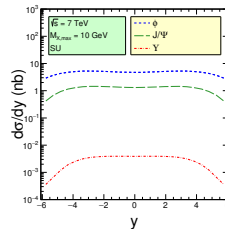
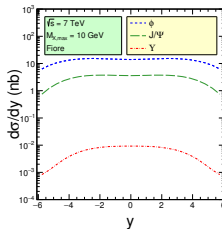
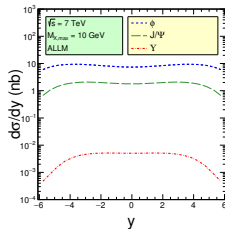
● preliminary results

Transverse momentum distribution- different structure function of proton



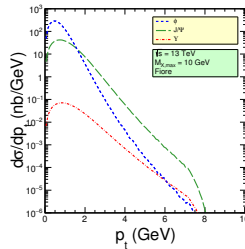
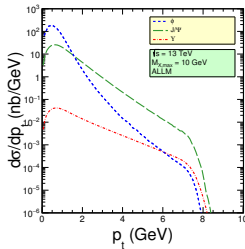
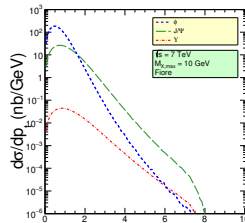
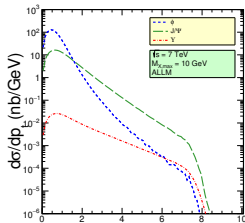
● preliminary results

Rapidity distribution - meson comparison



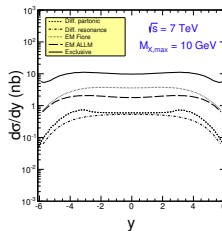
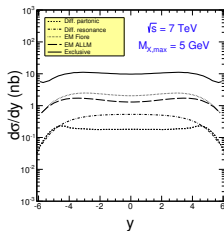
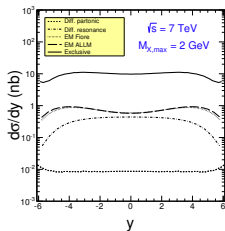
● preliminary results

Transverse momentum distribution



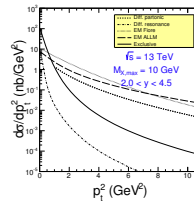
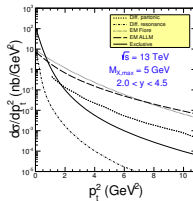
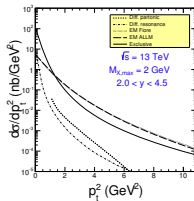
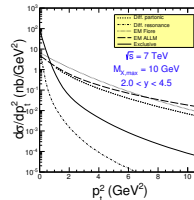
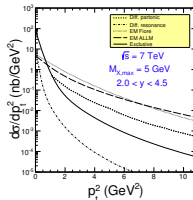
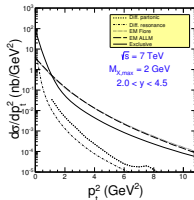
- preliminary results

Rapidity distribution, $\sqrt{s} = 7$ TeV - different mechanism comparison



- Rapidity distribution of J/ψ mesons produced when one of the protons is excited due to photon or Pomeron exchange. Both contributions (one or second proton excitation) are added together. We also show a reference distribution for the $pp \rightarrow ppJ/\psi$ exclusive process with parameters taken from Anna Cisek, Wolfgang Schäfer, Antoni Szczurek: JHEP 1504 (2015) 159.
- Anna Cisek, Wolfgang Schäfer, Antoni Szczurek Phys. Lett. **B769** (2017) 176

Transverse momentum - mechanism comparison



- Anna Cisek, Wolfgang Schäfer, Antoni Szczurek
Phys. Let. **B769** (2017) 176

Conclusions

- In γ -Pomeron fusion reactions in proton-proton scattering, electromagnetic dissociation is of the same size as strong, diffractive dissociation. It even dominates in some regions of the phase space.
- Electromagnetic dissociation is calculable from F_2 data. Resonance excitation is important at low excited masses.
- Diffractive dissociation requires modelling, there is only little data to constrain it. The resonance contribution is concentrated at very small t , similar to the coherent elastic contribution