Odderon Searches in Exclusive Vector Meson Production in pp Collisions

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Overview

Motivation

Formalism

Implications

Based on results obtained with A. Bzdak, J-R. Cudell and L. Szymanowski

Puzzle of Odderon

High energy scattering in QCD $\longrightarrow$ 2 color neutral reggeons with intercepts around 1: Pomeron ($C = +1$) and Odderon ($C = -1$)

Pomeron: Total cross sections and diffraction
Odderon: Difference between cross sections for AB and $A\bar{B}$ and exclusive processes

Searches for odderon at HERA: $\gamma p \to p\pi^0$, $\gamma p \to \eta_c$, $\gamma p \to \eta_c X$,
asymmetries in diffractive charm and pion pair production $\longrightarrow$ no signal found

Some weak evidence for odderon in elastic pp and $p\bar{p}$ scattering at CERN-ISR at $\sqrt{s} = 53$ GeV in the dip region $|t| \sim 1.5$ GeV^2

Odderon is important element of the theory
The first reggeon beyond Pomeron that fulfills BKP equation; **[Bartels, Kwieciński, Prszałowicz]**;
relevant for considerations of integrability

Unitarisation corrections to odderon are known **[Kovchegov,Szymanowski,Wallon,Hatta, McLerran, Iancu, Itakura]**

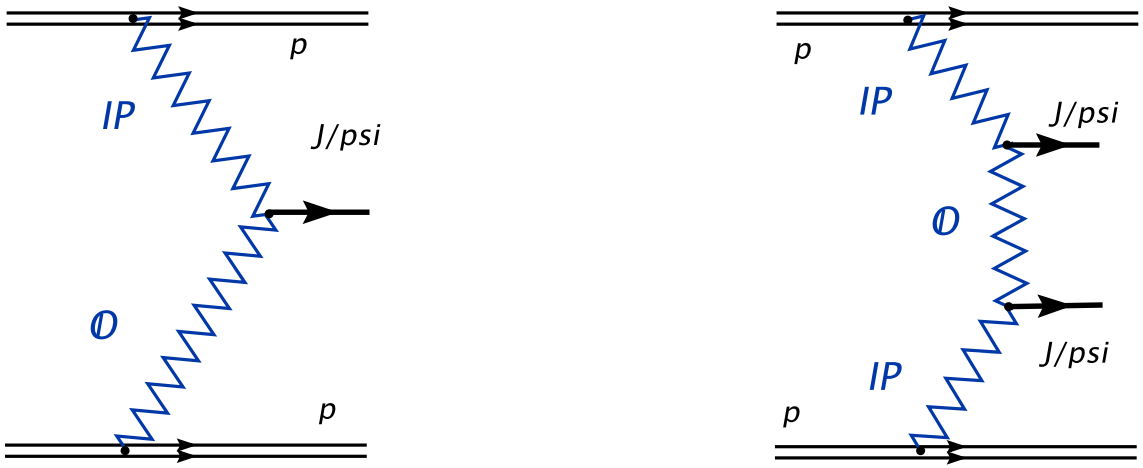
Proposal of measurement

Exclusive production of vector mesons: **[Schäfer, Mankiewicz, Nachtmann, Ewerz]**

$pp \to p\bar{p}\,V$ (or $pp \to p\bar{p}\,V$) with $V = J/\Psi, \Upsilon$

C-parity conservation requires the odderon exchange (or the photon)

Alternatively: $pp \to p$ gap V gap V gap p

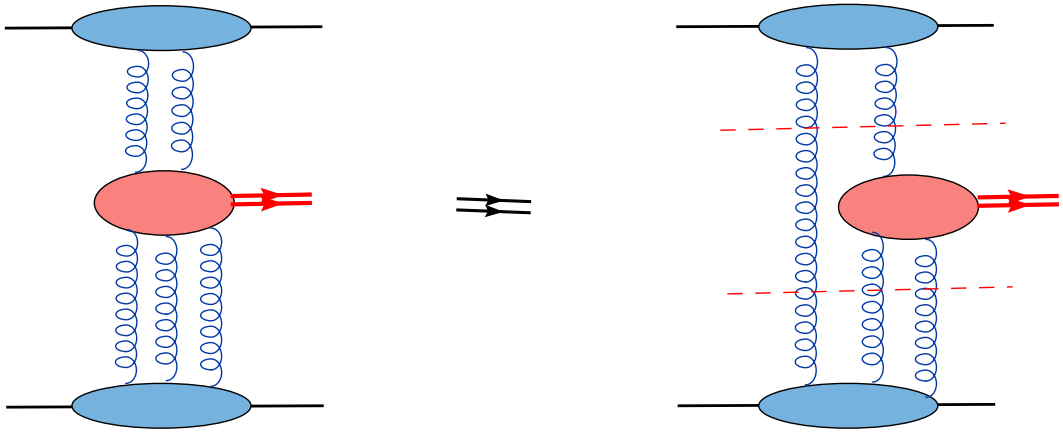


Formalism

Basic tool – QCD at high energy $\longrightarrow$ eikonal couplings, discontinuities

Lowest order diagrams for the odderon and pomeron exchange

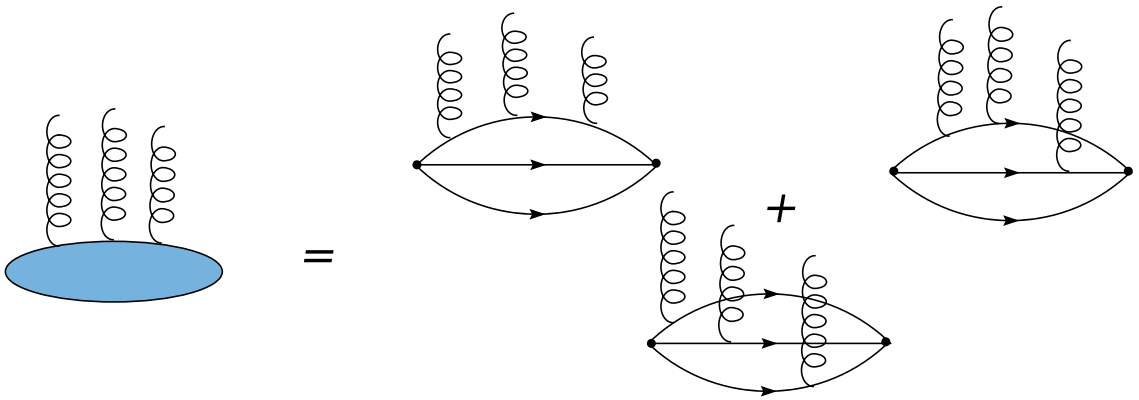
Amplitude and impact factors



Impact factors

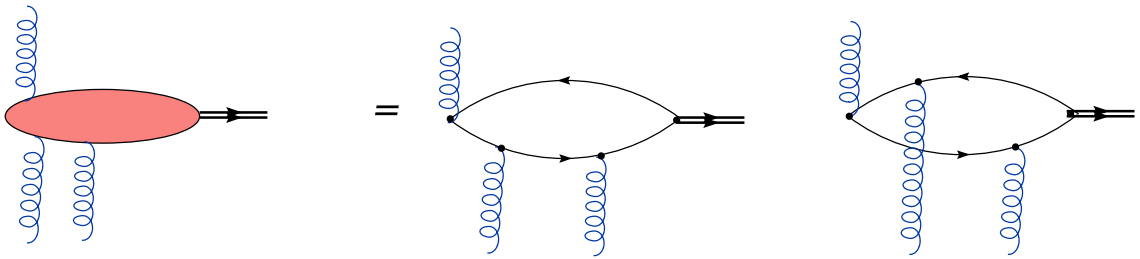
Proton impact factor – Fukugita-Kwieciński model

$\longrightarrow$ Antisymmetric wave function in color indices + scale $m_\rho/2$



$3g \to J/\Psi$ impact factor

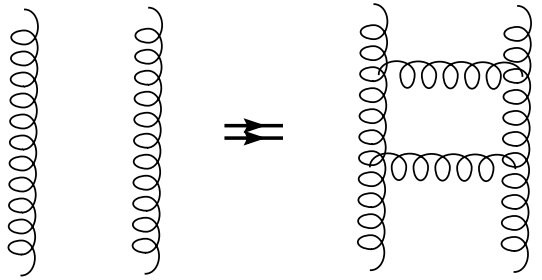
$\longrightarrow$ standard QCD calculation (with non-relativistic wave function)



Evolution & gap survival

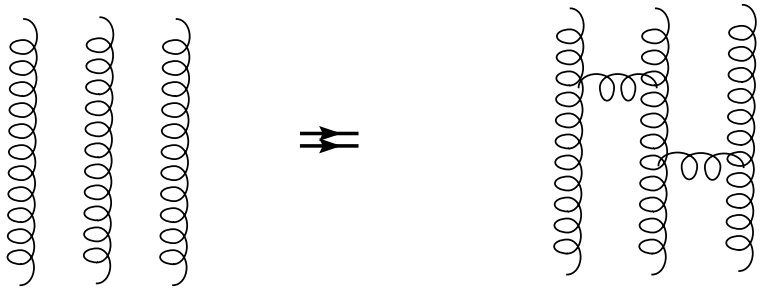
Higher order corrections $\longrightarrow$ ladder diagrams for the Pomeron

$\longrightarrow$ enhancement $\sim x^{-\lambda}$



Bartels-Kwieciński-Praszałowicz (BKP) equation for the odderon

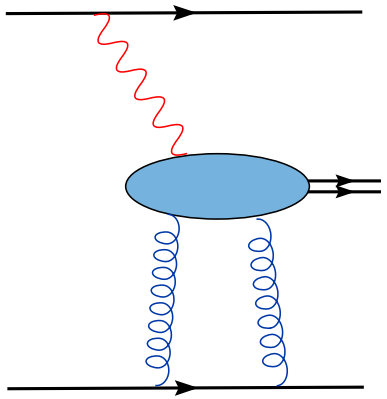
$\longrightarrow$ broadening of the t-dependence, possible pre-asymptotic enhancement



Soft rescattering corrections: impact parameter profile of the scattering similar to $I\!P - I\!P$ fusion. Khoze-Martin-Ryskin estimates for χ_c may be used. However: possible absorption of the odderon

Photon exchange

Instead of the odderon – the photon may be exchanged



Weizsäcker-Williams approximation:
[Khoze,Martin,Ryskin],[Klein,Nystrand]

$$dn_{\gamma/p} \;\propto\; \alpha_{em}\,\frac{dx}{x}\,\frac{dq^2}{q^2}\,F(q^2)$$

$$d\sigma(pp \to pp\,V) \;\simeq\; 2\,dn_{\gamma/p}\,\sigma(\gamma p \to V p)$$

$\sigma(\gamma p \to V p)$ was measured at HERA

WW spectrum and proton form-factor – upper cut-off: $q^2_{max} \sim 0.2$ GeV^2

and lower cut-off $q^2_{min} \sim M_P^2\,M_V^2/s \sim 2.5\cdot 10^{-6}$ to $5\cdot 10^{-8}$ GeV^2

$\longrightarrow$ dominated by small q^2 $\longrightarrow$ peripheral collisions $\longrightarrow$ little rescattering

$\longrightarrow$ soft gap survival $S^2 \sim 0.8 - 1$

Sudakov form-factor – not important for J/Ψ, possibly relevant for Υ

At leading order – no interference between photon and odderon exchange

Uncertainties

Photon contribution is well controlled $\sim 30\%$ of uncertainty

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Odderon exchange:

Details of proton impact factor

High power of strong coupling $\sigma \sim \alpha_s^8$ — but estimates for the photon exchange ($O(\alpha_s^4)$) consistent with HERA data

Evolution and absorption of the odderon – not taken into account yet

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Evolution of the pomeron (DGLAP/BFKL): standard and well controlled

Soft gap survival $S^2 \simeq 0.05$ for Tevatron and $S^2 \simeq 0.025$ for LHC

Results

Photon: t-integrated $\frac{d\sigma}{dy}|_{y=0}$:

$p\bar{p} \longrightarrow p\bar{p}\ J/\Psi$ at Tevatron: ~ 2.5 nb

$pp \longrightarrow pp\ J/\Psi$ at LHC: ~ 12 nb

$pp \longrightarrow pp\ \Upsilon$ at LHC: 0.1 — 0.3 nb

Odderon t-integrated $\frac{d\sigma}{dy}|_{y=0}$:

$p\bar{p} \longrightarrow p\bar{p}\ J/\Psi$ at Tevatron: 0.2 — 3 nb

$pp \longrightarrow pp\ J/\Psi$ at LHC: 0.3 — 5 nb

$pp \longrightarrow pp\ \Upsilon$ at LHC: on the way

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p_T distributions

Photon Weizsäcker-Williams spectrum dominated by $p_T^2 \ll 0.1$ GeV^2

while odderon tends to be much broader in p_T

Pomeron–Odderon fusion gives p_T-distributions of both outgoing proton transverse momenta characterised by a scale $t_0 \sim 0.1$ GeV^2 or larger

Pomeron-Photon fusion gives one proton with very small p_T

Sensitivity to odderon may be improved by measuring protons' p_T:
with both $|t_1| > 0.25$ GeV^2 and $|t_2| > 0.25$ GeV^2 photon contribution decreases 200-500 times and odderon – only 10 times

Recipe for the odderon

1. Measure exclusive $pp \to pp\ J/\Psi$ or $pp \to pp\Upsilon$ and compare to photon contribution

2. Cut on transverse momentum of VM and compare to photon

3. Cut on transverse momenta of two outgoing protons and compare to photon

4. Try to find the excess

5. Estimates of $pp \to p$ gap V gap V gap p are being prepared