Theory of the Odderon in QCD

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Some recent work:

J.Bartels, L.N.Lipatov, and G.P.Vacca, Phys.Lett.B477:178-186,2000
J.Bartels, M.A.Braun, and G.P.Vacca, Eur.Phys.J.C20:323-331,2001
J.Bartels, M.A.Braun, and G.P.Vacca, hep-ph/0304160

H.G.Dosch, C.Ewerz, V.Schatz, Eur.Phys.J.C24:561-571,2002

Why Should One Be Interested In The Odderon?

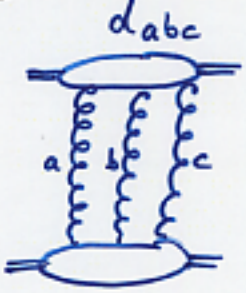
- Experimental Data: Difference in $\frac{d\sigma}{dt}$ between pp and $p\bar{p}$:
  Dip region near $t = -1.35$ GeV^2.
  Difference should be explained by an Odderon.
- pQCD predicts Odderon in hard processes.
  How can we test it?
  Does it survive in soft scattering processes?
- This Odderon is part of BFKL dynamics:
  'gluonic bound state with the quantum numbers of the photon'
  If we want to understand this part of QCD, we cannot avoid looking also for the pQCD Odderon.

This talk:

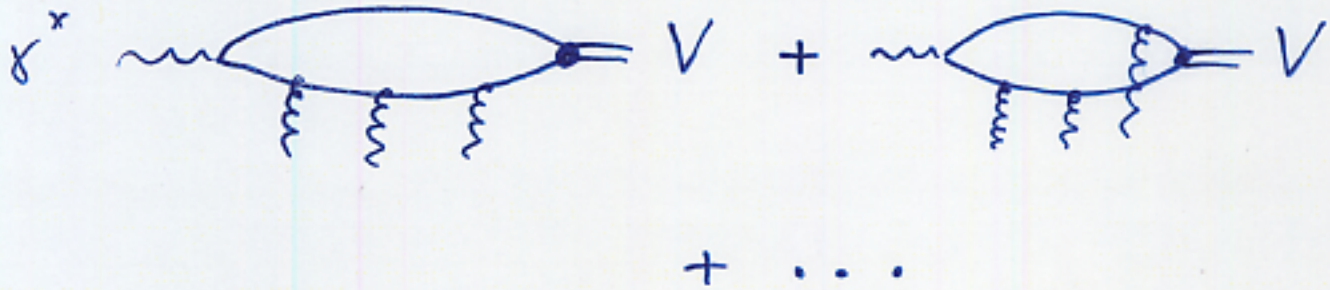
- Review of the pQCD Odderon
- Recent proposals for searching for this Odderon
- Future Tests (NLC; Tevatron, LHC)

The Odderon in pQCD
(a): three gluon exchange

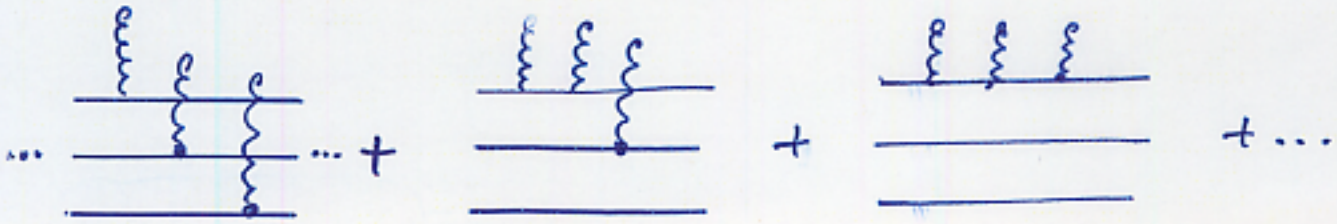
Needs a coupling via d_{abc} color tensor:



Simplest model: (photon $\rightarrow$ meson) - impact factor:
(J.Czyzewski, J.Kwiecinski, L.Motyka, M.Sadzikowski, Phys.Lett.B 398 (1997), 400)



More complicated: coupling to the proton:
(M.Fukugita, J.Kwiecinski, Phys.Lett.B 83 (1979) 119)



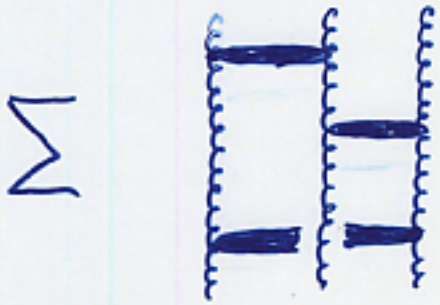
Recent phenomenology on elastic pp scattering
(Dosch, Ewerz, Schatz, Eur.Phys.J.C24:561-571, 2002):

$\frac{d\sigma}{dt}$ for pp and for $p\bar{p}$.
Three gluon exchange, several options for the odderon-proton coupling.

Determines the strength of the coupling: $\alpha_s = 0.3$.
Equally good fits.

The Odderon in pQCD: Odderon Solutions

Theoretical basis: BKP equation (generalizion of BFKL equation).
Bound state of three reggeized gluons, pairwise interactions.
Interest in solution with highest intercept
(same as: 'lowest energy in reggeon space'):



Interesting history:

1) search for lowest energy solution with completely symmetric wave function.
Result: positive energy, intercept less than one:

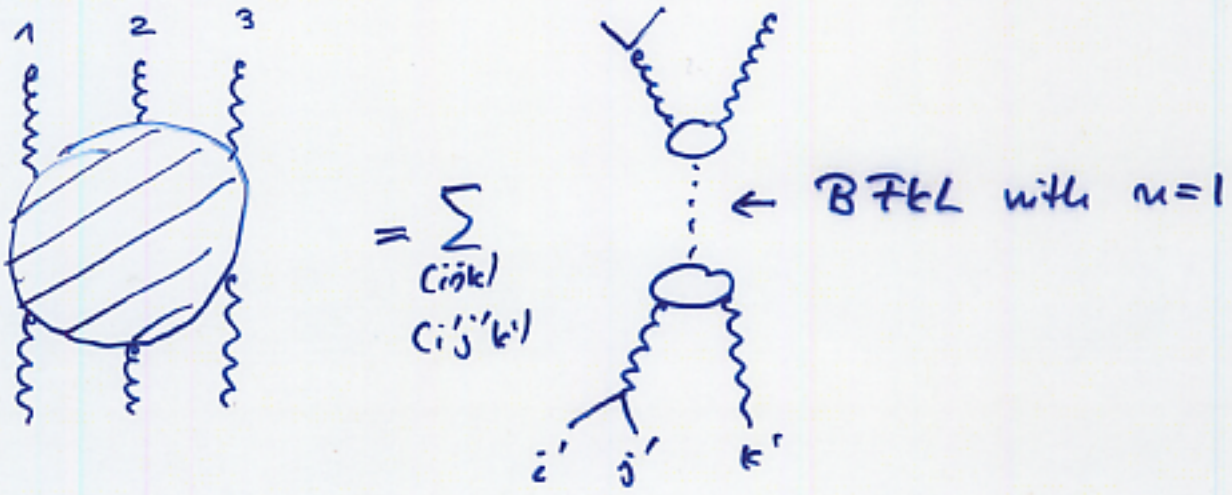
$$\alpha_{odderon}(0) = 1 + \omega_{odderon} = 1 - 0.247\alpha_s N_c/\pi,$$

Also: solution decouples from (photon $\rightarrow$ meson) impact factor.

2) new solution (mixed symmetry) with intercept equal to one.
Structure matches the (photon $\rightarrow$ meson) impact factor.

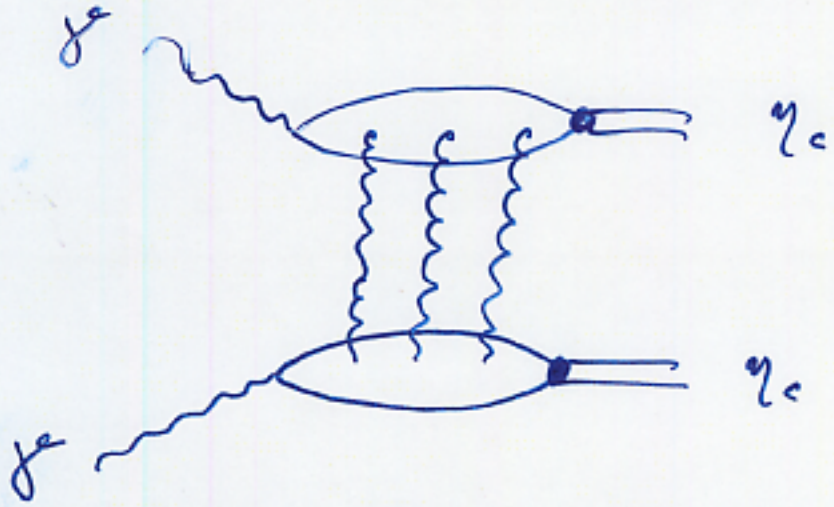
$$\alpha_{odderon}(0) = 1 + \omega_{odderon} = 1$$

Structure of the new solution:
BFKL-solution with $n = 1$



Interpretation: antisymmetric bound state of f and d-reggeons.
State of 'mixed symmetry'.

Search: The Process $\gamma^*\gamma^* \to \eta_c\eta_c$

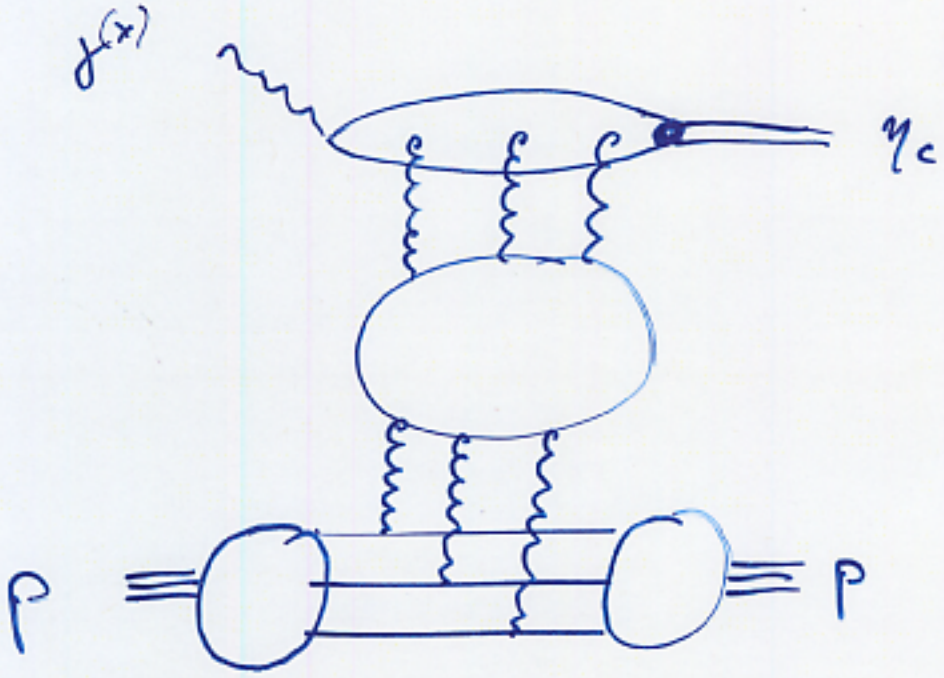


Estimated cross section: 40 fb

For $\gamma^*\gamma^* \to \eta_c X$: 120 fb.

L.Motyka, J.Kwiecinski, Phys.Rev.D 58 (1998) 117501.

Search: The Process $\gamma^{(*)}p \to \eta_c p$



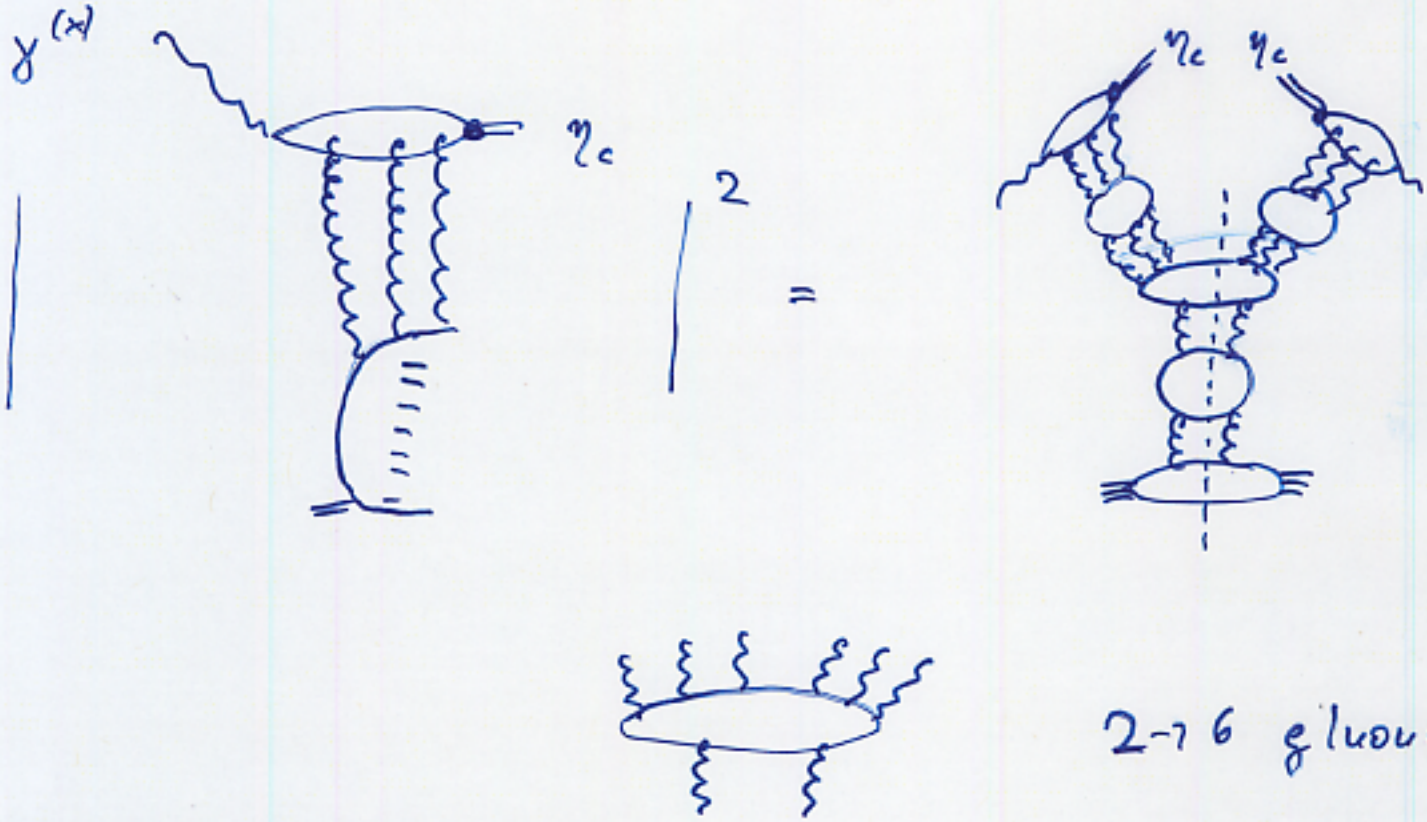
Dip structure in $\frac{d\sigma}{dt}$.

Enhancement of three gluon exchange by factor 5.

Estimated cross section: 1.5 pb for photoproduction, 40 fb for $Q^2 = 25$ GeV^2.

J.Bartels, M.A.Braun, G.P.Vacca, Eur.Phys.J.C20 (2001) 323.

Search: The Process $\gamma^{(*)}p \to \eta_c X$



New vertex in pQCD: $P \to OO$

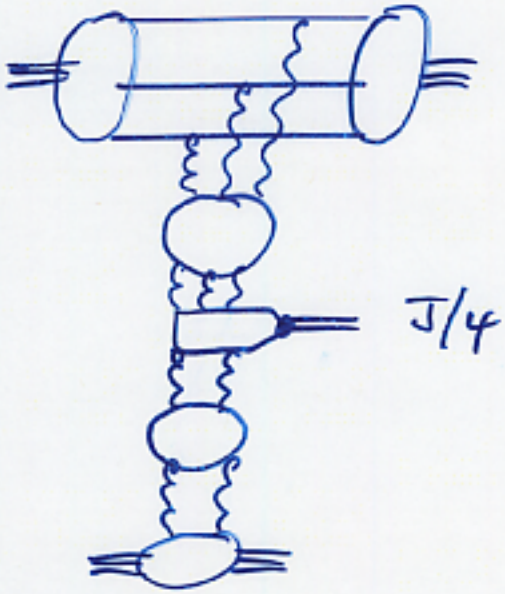
J.Bartels, C.Ewerz, JHEP 9909 (1999) 026.

Advantage: larger cross section, less uncertainty in coupling to proton.

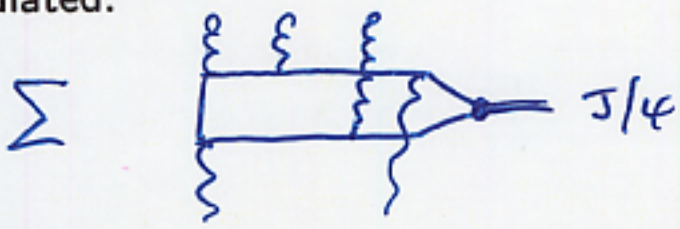
Estimated cross section: 60 pb for photoproduction,
1.5 pb for $Q^2 = 25$ GeV^2.

J.Bartels, M.A.Braun, G.P.Vacca, hep-ph/0304160.

Double Diffractive J/ψ Production



Vertex to be calculated:



Another (nonperturbative) calculation: estimated cross section: 0.1 - 1 μb.

A.Schafer, O.Nachtmann, L.Mankiewicz, Phys.Lett.B272 (1991) 419.

Summary

- The pQCD Odderon is part of BFKL dynamics: bound state of three gluons.
- Look for odderon in $\gamma^*\gamma^* \to \eta_c\eta_c$ (NLC).
- Look for odderon in $\gamma^* p \to \eta_c X$ (HERA).
- Look for odderon in double diffractive $p\bar{p} \to X + J/\psi + X$ (Tevatron, LHC).
- Estimate the cross section for diffractive $p\bar{p} \to X + J/\psi + X$.