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WHY ODDERON CONTRIBUTION IS INVISIBLE IN THE HIGH ENERGY TOTAL CROSS SECTIONS

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I suggest an explanation of the fact that the Odderon contribution to the high energy total cross sections is invisible practically while the status of Odderon and Pomeron in pQCD is almost identical.

The Odderon is the C odd partner of the Pomeron. It was introduced in addition to the Pomeron as a phenomenological object which can induce difference between the high energy pp and $p\bar{p}$ cross sections and also a noticeable real part of the forward $p\bar{p}$ amplitude [1]. The modern high energy $p\bar{p}$ data show no contribution of the Odderon into the total cross section, it is $\leq 1/40$ as compare with the Pomeron one [2].

1. I start with discussion of semihard region where pQCD is valid:

$$s \gg |t| \gg \mu^2 \quad (\mu \approx 0.3 \text{ GeV is the QCD scale}) \ . \tag{1}$$

The status of the Pomeron and the Odderon in pQCD is almost identical.

The Pomeron corresponds to a sum of diagrams with C even colorless exchange in t channel; the simplest of these diagrams involve two gluons in t channel (see refs. [3] and other papers). This pQCD (BFKL) Pomeron is related (via unitarity) with the inelastic processes in which the transverse momenta of gluons produced are not too small $p_\perp$ (1), these gluons can be associated with minijets (see e.g. [4]).

The Odderon corresponds to a sum of diagrams with C odd colorless exchange in t channel; the simplest of these diagrams involve three gluons in t channel.

It is expected that both these amplitudes – Pomeron and Odderon – have similar in some features energy dependence (see [5]).

At $\sqrt{s} \approx 1$ TeV the $p\bar{p}$ total cross section is approximately twice as compare with $\sqrt{s} \approx 12$ GeV. The raised part of total cross section relates usually with the pQCD Pomeron. The manifestation of pQCD Odderon here would seem to be natural. However the observed high energy total cross sections are described with Pomeron only; the Odderon contribution is invisible in modern experiments.

Two facts are essential for explanation of this phenomenon:

(i) In the discussed approach the raised part of the cross section can be obtained by factorization relation, i.e. by convolution of the elementary parton cross section with parton densities in protons (structure functions). Since gluon density is the largest one at small x, its contribution into the high energy cross sections is dominant. Next, the Pomeron is coupled with both quarks and gluons. On the contrary, the Odderon is coupled with quarks only, its coupling with gluons (gg-Odderon) is forbidden due to C parity conservation. Indeed, the Odderon is C odd colorless object and gluons have the definite C parity (negative). Therefore the above vertex breaks C parity conservation[1), 2)].

(ii) Besides, at the two gluon colorless exchange the cross sections ratio for scattering on quark and on gluon is small (see e.g.[6]):

$$\sigma_q/\sigma_g = 16/81 \approx 1/5 \ . \tag{2}$$

These facts lead to strong suppression of the Odderon contribution in the raised part of the total cross section.

2. Our experience in high energy phenomena shows that this last statement can be extended on the entire total cross section. To do this, one can use, for example, an approach similar to that developed in refs. [7, 8] for description of diffractive processes at $|t| \lesssim 1\,GeV^2$). There Pomeron and Odderon are described as two gluon and three gluon exchanges in t channel with reggeized nonperturbative gluons.

The problem discussed was investigated in ref. [8]. It was obtained that C odd (Odderon) quark – quark amplitude is suppressed in comparison with C even (Pomeron) one by factor $f_q \approx 1/4$. This suppression however is insufficient to explain data. (In the similar approximation of pQCD the quantity $f_q \sim \alpha_s^2 < 1/4$).

In the papers [7, 8] it was taken into account the quark content of hadrons only. In my opinion it should add contribution of the gluon component of hadron which is not small[3)].

The ratio of Odderon and Pomeron contributions in such model becomes much smaller than $f_q\sigma_{q/g}$ (cf. (2)).

Besides, it is necessary to take into account the ratio $\nu_{q/qg}$ of total quark flux in proton to that of (quark + gluon) for processes with $p_\perp > p_{\perp 0}$ (for definiteness we use $p_{\perp 0} = 1.5$ GeV). For our rough estimate one can write these fluxes as integrals of the corresponding structure functions over x at $x > 4p_{\perp 0}^2/s$. With the structure functions from ref.[9], we obtain that the above ratio varies from 0.25 at $\sqrt{s} = 15$ GeV to 0.07 at $\sqrt{s} = 1000$ GeV.

The product of these factors shows roughly the relative contribution of the Odderon in the high energy pp scattering: (Moreover, perhaps the Odderon contribution decreases as compare with the Pomeron one while energy grows.)

$$\nu_{q/qg}\sigma_{q/g}f_q \sim 0.0012 \div 0.004 \ . \tag{3}$$

This estimate does not contradict to the above phenomenological one [2].

3.Therefore the comparative investigation of the Pomeron and the Odderon seems to be important problem both in the semihard (1) and in soft region. It is useful to separate their contributions in different reactions such

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[1)]Odderon is often represented as 3 gluon system. There are two colorless 3 gluon system, C odd (like Odderon) $d^{abc}g^a g^b g^c$ and C even $f^{abc}gag^b g^c$. Pair of gluons is coupled with C even 3 gluon system only (which can enter into the Pomeron).

[2)]As the energy grows, the effects of shadowing in the gluon subsystem become important at small x. It corresponds to noticeable probabilities of collision of two gluons from one proton simultaneously. This collision can produce Odderon + gluon ($g + g \to O + g$). In this region interaction of the Odderon with gluon system is switched on but it is weaker that interaction of Pomeron with gluon system.

[3)]After that it is necessary to change some parameters in expressions used to preserve main results related to Pomeron.

as the quasidiffractive (small angle) photoproduction of neural mesons at HERA [10, 11, 12]:

$$\gamma p \to V + X; \qquad V = \rho^0, \omega, \varphi, \ldots \Psi, \Upsilon, \ldots, \gamma \text{ (Pomeron)}, \tag{4}$$
$$\gamma p \to P + X; \; \gamma p \to T + X; \qquad P = \pi^0, \eta, \eta', \ldots; \; T = a_2, f, f', \ldots \text{ (Odderon)}. \tag{5}$$

These mesons V, P, T and other hadrons should be separated in rapidity (rapidity gap). The variation of this rapidity gap corresponds to variation of x value. At not too small x Odderon does not interact with gluon system, at smaller x (when shadowing in the Pomeron contribution becomes essential) the interaction of Odderon with gluon system (e.g. with 2 gluons simultaneously) is switched on. These processes are observable at HERA at $p_\perp \sim 3 \div 8$ GeV [12]. The detail investigation of shadowing there seems to be a realistic task.

The comparative investigation of these processes at $p_\perp \lesssim 1$ GeV should give us an information about role of gluon component of proton in models like [7, 8]. (Certainly, at small values of rapidity gap the ω exchange contribution should be taken into account).

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