How could one see an electroweak pomeron?

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Effects which stem from a contribution of an electroweak pomeron to elastic pp and $\bar{p}p$ scattering are examined. At SSC energies, an electroweak pomeron might lead to the formation of a specific dip in the differential cross section $d\sigma/dt$ at $|t| \in 2$–5 GeV^2. The possible occurrence of this effect at the Tevatron and UNK energies is also discussed.

Nonperturbative effects in standard electroweak theory have recently attracted considerably increased interest. One particular topic of discussion[1–6] is the possibility that processes which do not conserve baryon-lepton $(B+L)$ charge would not be suppressed at energies ~ 10 TeV.

This effect might be closely related to high-multiplicity diffraction events in electroweak theory.[2,3,6] As was stressed in Refs. 4 and 6, an interaction of a diffractive nature may also be characteristic of $(B+L)$-conserving elastic and inelastic amplitudes in electroweak theory. In particular, there is the possibility that the total cross sections for the electroweak interaction of fermions with (anti-) fermions would grow asymptotically as

$$\sigma_W^{tot}(s) \sim \frac{1}{M_W^2} \ln^k(s/M_W^2), \tag{1}$$

where M_W is the mass of the W boson, and $0 \leqslant k \leqslant 2$. The meaning here is that the dynamics of the diffractive regime in electroweak theory would be determined by a pomeron contribution, in a situation analogous to that involving hadrons in quantum chromodynamics.

Although the existence of this effect has yet to be definitively proved, the possibility is extremely interesting, indeed intriguing.

How might one see an electroweak pomeron? In the present letter we show that an interference of the strong and electroweak pomeron amplitudes could lead to an extremely interesting effect in elastic $\bar{p}p$ (pp) scattering: the appearance of a dip of specific shape in the differential cross section $d\sigma/dt$. Its position $|t_{\rm dip}|$ would depend on the energy $\sqrt{s}$. In particular, under certain conditions we would have $|t_{\rm dip}| = 2$–5 GeV^2 at SSC energies and $\sqrt{s} = 40$ TeV. The existence of this dip would thus be a clear indication of the existence of an electroweak pomeron.

To find numerical estimates of the effect of the interference of a strong pomeron and a weak one, we need to parametrize the corresponding amplitudes. The pomeron component of the strong amplitude can be written in the form

$$A_{\rm str}(s,t) = A_1(s,t) + A_2(s,t),$$

where the terms $A_1(s,t)$ and $A_2(s,t)$ describe, respectively, the first ($|t| \lesssim 1$ GeV^2) and second ($|t| \gtrsim 2$ GeV^2) cones in the diffraction cross section for elastic $\bar{p}p$ (pp) scattering. The amplitude $A_1(s,t)$ corresponds to single pomeron exchange:

$$A_1(s,t) = A_1(s,0)\exp[B_1(-is)t] = \frac{i\sigma_{str}^{tot}}{8\pi}[1 - i\rho(s)]\exp[(\alpha' \ln(-is/s_0) + B)t], \quad (2)$$

where α' is the slope of the trajectory of the strong pomeron, $s_0 = 1$ GeV^2, and $\rho(s) = \mathrm{Re}A_1(s,0)/\mathrm{Im}A_1(s,0) \simeq 0.1$–$0.15$ at $\sqrt{s} < 20$ GeV.

For σ_{str}^{tot} we use the dipole model of a pomeron,[7] which describes the data well over a wide energy range up to $\sqrt{s} = 1.8$ GeV:

$$\sigma_{str}^{tot}(s) = a_1 \ln(s/s_0) + a_2, \quad (3)$$

where

$$a_1 \simeq 5.3 \text{ mb}, \qquad a_2 \simeq -6.8 \text{ mb}. \quad (4)$$

In the region of the second cone, the term $A_2(s,t)$ is dominant. From the theoretical standpoint, this term arises from multiple exchanges of a pomeron. Points of importance to the discussion below are that (first) we have $\mathrm{Im}A_2(s,t) < 0$ and (second) the quantity $A_2(s,t)$ falls off exponentially with increasing $|t|$. Phenomenologically, we have

$$A_2(s,t) = -\lambda A_1(s,0)\exp[(c_1 \ln(-is/s_0) + c_2)t], \quad (5)$$

where $\lambda = (4.5$–$10) \times 10^{-3}$. For the constants c_1 and c_2 we consider two extreme cases, corresponding to $(B_2)_{\min}$ and $(B_2)_{\max}$ ($B_2 = c_1 \ln s/s_0 + c_2$):

$$\text{I)} \quad (B_2)_{min}: \qquad c_1 = 00.4 \text{ GeV}^2, \qquad c_2 = 0.85 \text{ GeV}^2, \quad (6a)$$

$$\text{II)} \quad (B_2)_{max}: \qquad c_1 = 0.28 \text{ GeV}^2, \qquad c_2 = 0.40 \text{ GeV}^2. \quad (6b)$$

[The parameter $A_2(s,t)$ cannot be determined more accurately from the corresponding experimental data.]

Following the arguments of Ref. 6, we assume that an electroweak pomeron amplitude can be found from the strong amplitude through a change of scale: $s_0 \to M_W^2$. A fact of fundamental importance is that the typical transverse momenta in electroweak interactions are $p_T \lesssim p_W \sim M_W$. It follows that the slope of the cone satisfies $B_W \sim M_W^{-2}$. Accordingly, we have

$$A_W(s,t) = \kappa \frac{s_0}{M_W^2} A_1\left(s\frac{s_0}{M_W^2}, 0\right)\exp(B_W t) \simeq i\frac{\kappa}{8\pi}\frac{s_0}{M_W^2}[a_1 \ln(-is/M_W^2) + a_2], \quad (7)$$

where the constant κ is in the interval[6] $0.01 \lesssim \kappa \lesssim 1$.

We need to know the particular energy E_0 at which the asymptotic behavior in (1) or (7) sets in. As in Ref. 6, we assume that E_0 lies in the interval 2 TeV $\lesssim E_0 \lesssim 10$ TeV. It is interesting to note that the lower limit on E_0 is close to the Tevatron energy.

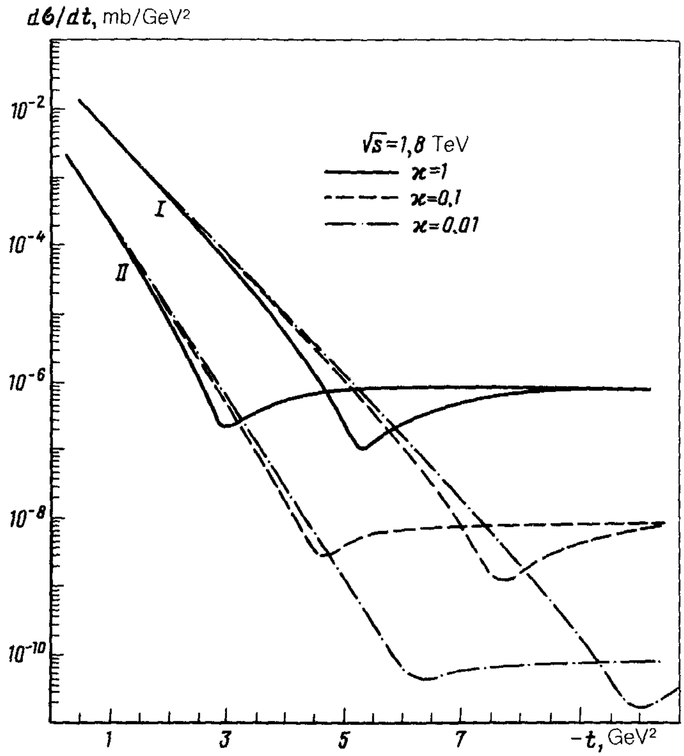

FIG. 1. Differential cross section for elastic pp scattering at $\sqrt{s} = 40$ TeV according to calculations for two cases of $B_2(s)$. I—$(B_2)_{\min}$; II—$(B_2)_{\max}$. The solid, dashed, and dot–dashed lines show the cross sections for $\kappa = 1$, $\kappa = 0.1$ and $\kappa = 0.01$, respectively.

For this reason, one might hope to see a low-energy tail of an electroweak pomeron at large values of $|t|$ even at the Tevatron, although that result looks unlikely. The UNK might be more promising in this regard.

The total amplitude in the region of interest here, $|t| \gtrsim 2$ GeV, is thus given by the sum

$$A(s,t) = A_2(s,t) + A_W(s,t) = -i\frac{\lambda}{8\pi}[a_1 \ln(-is/s_0) + a_2]\exp[(c_1 \ln(-is/s_0) + c_2)t]$$

$$+i\frac{\kappa}{8\pi}\frac{s_0}{M_W^2}[a_1 \ln(-is/M_W^2) + a_2], \qquad (8)$$

where the parameters a_1, a_2, c_1, c_2, and λ are defined in (4)–(6).

Figures 1 and 2 show results calculated for $d\sigma/dt$ at the SSC and Tevatron energies, respectively, for three values of κ: $\kappa = 1$, $\kappa = 0.1$, and $\kappa = 0.01$.

It can be seen from these figures that the dip in $d\sigma/dt$ occurs in both cases: (I) $B_2 = (B_2)_{\min}$ and (II) $B_2 = (B_2)_{\max}$, as defined by expressions (6a) and (6b). The

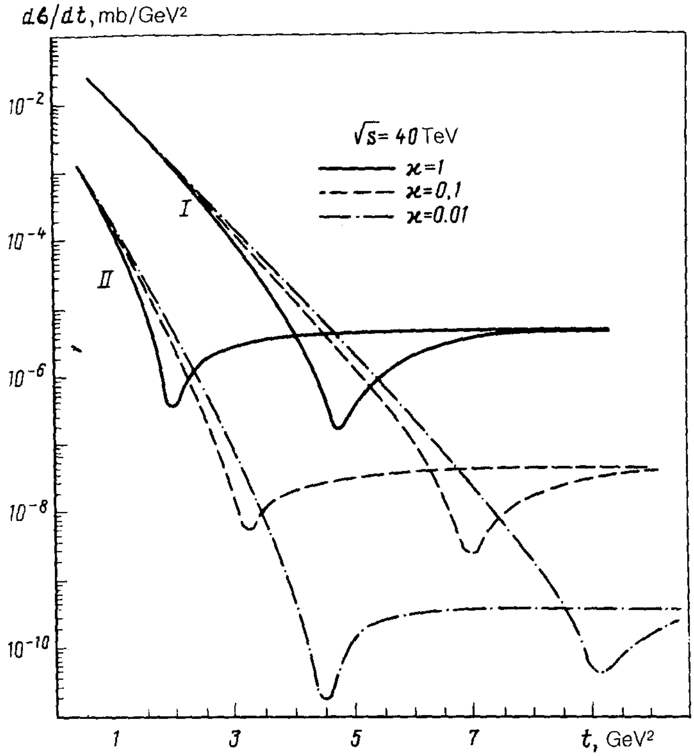

FIG. 2. The same as in Fig. 1, for $\sqrt{s} = 1.8$ TeV.

cross sections near the dip would apparently be large enough to be measured experimentally if $\kappa \gtrsim 0.1$. If $\kappa \lesssim 0.01$, however, the cross section at $|t| \gtrsim 2$ GeV would be so small that observation of the effect might be problematical.

We need to stress the important distinction between a "hybrid" dip and the effect which occurs in a purely strong interaction. Since $B_W(s)$ is small, the cross section increases very slowly beyond the hybrid dip ($|t| > |t_{\rm dip}|$), up to $t^* \sim 0$ (10^2 GeV^2). This behavior is fundamentally different from that observed in the strong interaction, in which the cross section goes through a maximum just after the dip and then falls off exponentially.

In summary, there would be a clear indication of an electroweak pomeron in high-energy ($\sqrt{s} \gtrsim 2$ TeV) elastic $\bar{p}p$ (pp) scattering: There would be a dip in the differential cross section $d\sigma/dt$ at $|t| = 2$–5 GeV^2, beyond which the cross section would rapidly adopt an essentially t-independent behavior.

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