Energy Dependence of the Dip in pp Elastic Scattering and the Pomeron Periphery

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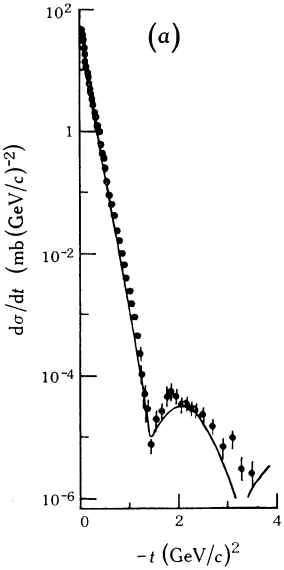
Abstract

It is shown that, at ISR (intersecting storage ring) energies, the energy dependence of the dip in the differential cross section for pp elastic scattering can be explained by the dual absorptive model with a peripheral pomeron.

The first observation of a pronounced minimum in the differential cross section for pp elastic scattering at momentum transfers $t \approx -1 \cdot 3$ $(\mathrm{GeV}/c)^2$ was made by Bohm *et al.* (1974). However, the question of the energy dependence of this structure remained open for some time. Recently Kwak *et al.* (1975) have observed that the position of the dip in the cross section depends upon the reaction energy: at c.m. energies of $s = 529$ and 3844 $(\mathrm{GeV})^2$ the dip occurs at $t = -1 \cdot 44 \pm 0 \cdot 02$ and $-1 \cdot 26 \pm 0 \cdot 03$ $(\mathrm{GeV}/c)^2$ respectively, i.e. the position of the dip moves inwards with energy. As yet no theoretical model has been able to provide an adequate quantitative explanation of this phenomenon. In this note we give a description of the structure of pp elastic scattering according to the dual absorptive model of Harari (1970, 1971), assuming that the pomeron is peripheral in nature.

The first applications of the most conventional Regge ideas to pp elastic scattering were made by Rarita *et al.* (1968) and Austin *et al.* (1970). However, such models do not lead to a dip in $\mathrm{d}\sigma/\mathrm{d}t$ as observed at ISR (intersecting storage ring) energies. The Chou–Yang model (Chou and Yang 1968; Durand and Lipes 1968) only gives a qualitative explanation of pp elastic scattering, and does not include an energy dependence. Henzi and Valin (1973) and Buras and Dias de Deus (1974) have tried to explain the differential cross-section curve using geometrical scaling but the agreement obtained in the vicinity of the dip is not good. In fact, contrary to the experimental results, their model predicts that the differential cross section at the dip will decrease with an increase in energy. Gotsman and Maor (1975) have tried to improve this geometrical model by parameterizing the data with a more complicated form, but they are still unable to explain the dip structure quantitatively. On the other hand, Ng and Sukhatme (1973) and Pajares and Schiff (1973) have been able to explain several characteristics of high energy pp elastic scattering by employing Gribov's reggeon calculus (Gribov and Migdal 1968*a*, 1968*b*; Baker 1973), while many features have been explained by Saleem *et al.* (1975) using the dual absorptive model with a peripheral pomeron. However, these models predict a dip at $t = -1 \cdot 3$ $(\mathrm{GeV}/c)^2$ which stays fixed with energy. Phillips and Barger (1973) have made an



Figs 1*a*–1*e*. Comparison of the present theoretical results (curves) with the experimental data for pp elastic scattering differential cross sections, plotted against $-t$, for:
(*a*) $s = 529$ (GeV)^2,
(*b*) $s = 949$ (GeV)^2,
(*c*) $s = 2016$ (GeV)^2,
(*d*) $s = 2809$ (GeV)^2,
(*e*) $s = 3844$ (GeV)^2.

empirical study of pp elastic scattering in terms of two exponential amplitudes plus interference and have obtained a good fit to the data. In the present paper we use the dual absorptive model with a peripheral pomeron to fit the data for $|t| < 2\,(\mathrm{GeV}/c)^2$.

Model and Parameterization

Harari (1971) has shown that the following set of assumptions is internally inconsistent:

(1) A dominance of the peripheral partial waves at all energies.

(2) An indefinite shrinking of the amplitude dominated by peripheral impact parameters.

(3) A radius which approaches a constant at high energies.

We must therefore abandon at least one of these assumptions. Here we describe a model in which assumption (3) does not apply, i.e. we consider the possibility that the radius $r(s)$ is not constant at high energies but takes the form

$$r(s) \to r_0\{\ln(\ln s)\}^{\frac{1}{2}} \qquad s \to \infty\,.$$

(Several alternative forms of $r(s)$ were tried but this form gave the best fit to the data).

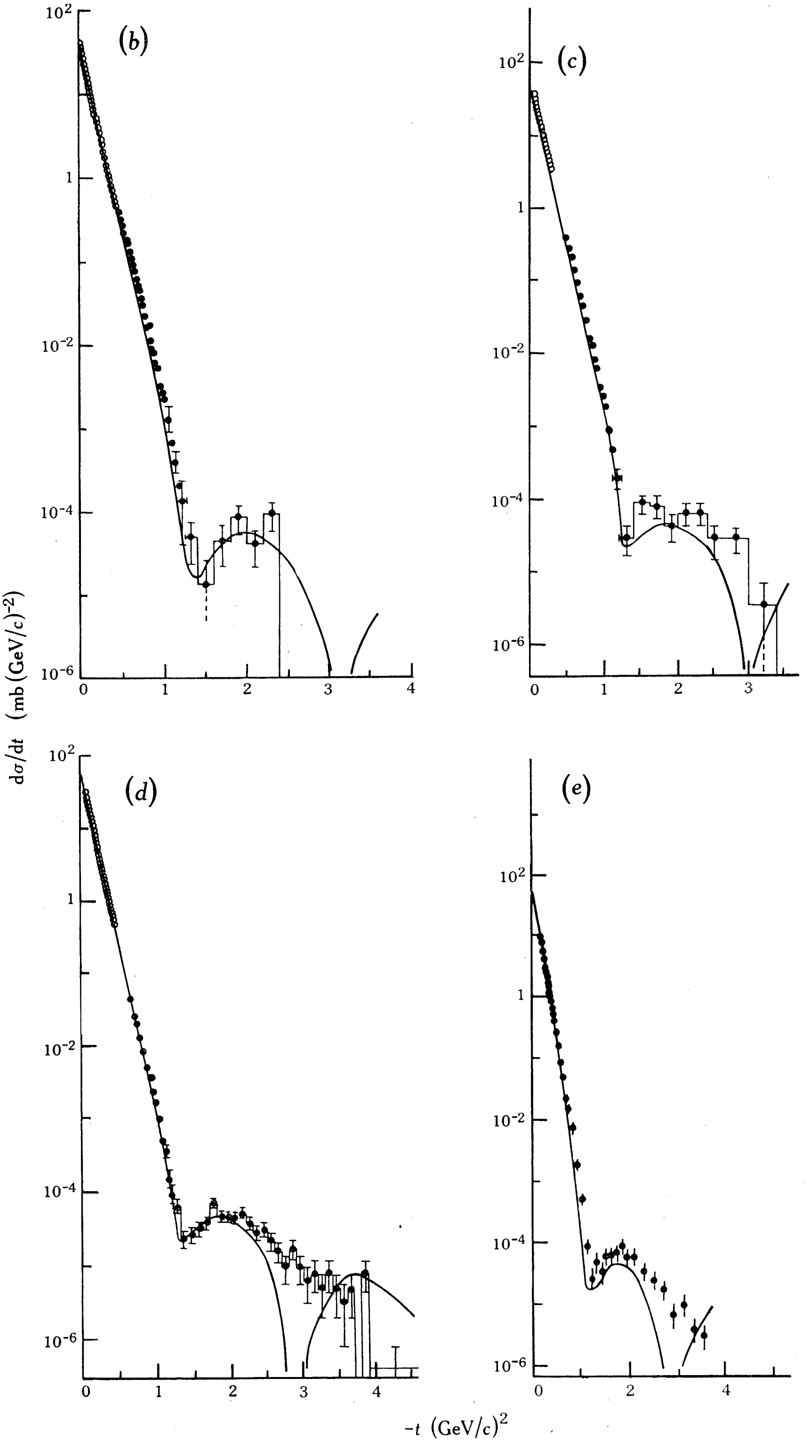
The number of independent helicity amplitudes for pp scattering is five. In general more than one helicity amplitude corresponds to the same value of $\Delta\lambda$ but these amplitudes then differ only in their residue functions. At high energy, as the scattering is dominated by the exchange of a pomeron trajectory $\alpha(t)$, the helicity amplitudes $f_{\Delta\lambda}$ will be of the form

$$f_{\Delta\lambda} = B_{\Delta\lambda}(t)\,J_{\Delta\lambda}(x)\,(s/s_0)^{\alpha(t)}\{-\cot(\tfrac{1}{2}\pi\,\alpha(t))+\mathrm{i}\}\,,$$

where

$$x = r_0\{-t\ln(\ln s)\}^{\frac{1}{2}}\,,$$

r_0 taking the value $3\cdot5\,(\mathrm{GeV}/c)^{-1}$ in this case. The contribution to the differential



Figs 1*b*–1*e*

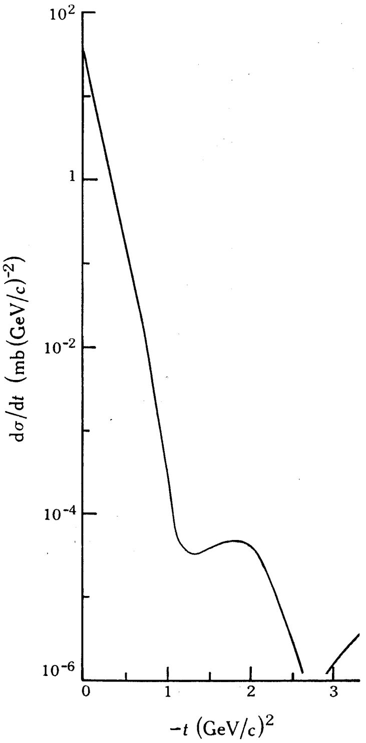


Fig. 2. Predictions of the preent model for the form of $d\sigma/dt$ at $s = 10^4$ (GeV)^2.

cross section may therefore be written as

$$\mathrm{d}\sigma/\mathrm{d}t = \{a(t)\,J_0^2(x) + b(t)\,J_0^2(x) + c(t)\,J_1^2(x) + f(t)\,J_1^2(x) + g(t)\,J_2^2(x)\}$$
$$\times q^{-2}\,s^{2\alpha(t)-1}\operatorname{cosec}^2(\tfrac{1}{2}\pi\,\alpha(t)),$$

where we have taken $s_0 = 1\,(\mathrm{GeV})^2$. We have found that a very good fit to the experimental data is obtained by choosing:

$$a(t) = 0{\cdot}0006, \qquad b(t) = 18\,\mathrm{e}^{8t}, \qquad c(t) = \mathrm{e}^{7t},$$
$$f(t) = 0, \qquad g(t) = 120\,\mathrm{e}^{13t}, \qquad \alpha(t) = 1 + 0{\cdot}05\,t,$$

where the units of the parameters a, b, c and g are mb.

Figs 1a–1e show the differential cross section $\mathrm{d}\sigma/\mathrm{d}t$ plotted against $-t$ for $s = 529, 949, 2016, 2809$ and $3844\,(\mathrm{GeV})^2$. The curves, which represent the theoretical predictions from the model, show that the agreement with experiment is quite good for $-t \leqslant 2{\cdot}0\,(\mathrm{GeV}/c)^2$. Fig. 2 shows the predicted behaviour of $\mathrm{d}\sigma/\mathrm{d}t$ at $s = 10^4\,(\mathrm{GeV})^2$.

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