CERN-TH/5862
CPT-90/P.2428

EXPERIMENTAL CONFIRMATION OF THE IMPACT-PICTURE PREDICTIONS FOR $\bar{p}p$ ELASTIC SCATTERING AT FNAL COLLIDER

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Abstract : Theoretical predictions on the basis of the impact picture for $\bar{p}p$ elastic scattering are compared with recent experimental results from FNAL at the center-of-mass energy of 1.8 TeV. At this energy, the theoretical predictions for σ_{tot} and $\sigma_{\text{el}}/\sigma_{\text{tot}}$ are 74.8 mb and 0.230 while the experimental results are (72.1 ± 3.3) mb and 0.23 ± 0.02 respectively. The data also confirm the predictions for the elastic differential cross section.

September 1990

¹ Work supported in part by the U.S. Department of Energy under Grant no. DE-FG02-84ER40158.

Over twenty years ago, it was realized that a useful approach to the theoretical understanding of hadronic scattering at high energies is to study the asymptotic behaviour of Feynman diagrams for relativistic quantum gauge field theories. With this approach, the low-order diagrams [1] show features similar to the droplet model of Yang and collaborators [2], but these features are modified with the inclusion of higher-order diagrams [3]. In 1970, the unexpected result was found that the total cross sections and the integrated elastic cross sections must increase indefinitely in the limit of extremely high energies [4]. By incorporating this rising total cross section into the optical model, some phenomenological data analysis has been carried out beginning in the early seventies [5]. The predictions [5,6] of this impact-picture phenomenology have been repeatedly verified by experiments [7]. This development has been summarized in a recent book [8].

Three years ago detailed theoretical predictions were presented for the center-of-mass energy range from 0.5 to 40 TeV, including those for CERN collider, FNAL collider, LHC and SSC [9]. The purpose of this letter is to compare these predictions with recent FNAL data.

The $\bar{p}p$ and pp elastic scattering are described by the following amplitudes

$$a(s, t) = a^N(s, t) \pm a^C(t) \quad (1)$$

where upper sign is for $\bar{p}p$ while the lower one is for pp , $a^N(s, t)$ is the hadronic amplitude and $a^C(t)$ is the $\bar{p}p$ Coulomb amplitude. The Coulomb amplitude is of course

$$a^C(t) = 2\alpha s \frac{G^2(t)}{|t|} \exp[\mp i\alpha\phi(t)] \quad (2)$$

where α is the fine structure constant, $\phi(t)$ is the West-Yennie phase [10] given by

$$\phi(t) = \ln(t_0/|t|) - \gamma \quad (3)$$

with $t_0 = 0.08 \text{ GeV}^2$ and $\gamma = 0.577$ is the Euler constant. We use

$$G(t) = [(1 - t/m_\pi^2)(1 - t/m_\pi^2)]^{-1} \quad (4)$$

as the proton electromagnetic form factor. From the impact picture [4-6] the hadronic amplitude at high energies is given by

$$a^N(s, t) = is \int_0^\infty J_0(b\sqrt{-t})(1 - e^{-\Omega_0(s, b)}) b db \quad (5)$$

where

$$\Omega_0(s, b) = S_0(s) F(b^2) \quad (6)$$

since the Regge background is negligible at the energies under consideration. The energy dependence is given by the crossing symmetric function

$$S_0(s) = s^c / (\ln s)^c + u^c / (\ln u)^c \quad (7)$$

which comes from the high energy behaviour of quantum field theory [3,4]. In (7) u is the third Mandelstam variable. The t -dependence of $a^N(s, t)$ is controlled by $F(b^2)$ whose Fourier transform is taken to be [6]

$$\tilde{F}(t) = f[G(t)]^2 [(a^2 + t)/(a^2 - t)]. \quad (8)$$

The values of the parameters are [6]

$$\begin{aligned} c &= 0.167 & c' &= 0.748 \\ m_1 &= 0.586 \text{ GeV} & m_2 &= 1.704 \text{ GeV} \\ a &= 1.953 \text{ GeV} & f &= 7.115 \text{ GeV}^{-2} \end{aligned} \quad (9)$$

The normalization is such that

$$\frac{d\sigma}{dt} = \frac{\pi}{s^2} |a(s, t)|^2 \quad (10)$$

so that the amplitude is dimensionless.

Very recently, two and half years after the predictions of ref. [9], FNAL presented some of the Tevatron measurements of the $\bar{p}p$ total and elastic cross sections at 1.8 TeV [11]. While the theoretical predictions are 74.8 mb for the total cross section and 0.230 for the ratio of the integrated elastic cross section to the total cross section, these recent measurements give $(72.1 \pm 3.3) \text{ mb}$ and 0.23 ± 0.02 respectively. We show in fig. 1 our theoretical curves together with the data from FNAL and CERN $\bar{p}p$ colliders. The t -dependence of the elastic cross section is shown in fig. 2. It is seen that the experimental data once again confirms the theoretical prediction.

Since future measurements at FNAL of the real part of the forward elastic amplitude a^N involves interference with the known Coulomb amplitude, the differential cross section in the small t -region is shown in fig. 3.

It may be worth emphasizing that the t -dependence in fig. 2 is *not* a straight line. This is to be contrasted with the claim of Block and Cahn [13]. Indeed, since they give a total cross section of 96 to 98 mb at 2 TeV, these recent data rule out their model.

ACKNOWLEDGMENTS

One of us (JS) thanks Roy Rubinstein for very informative discussions. Another (TTW) is grateful to John Ellis, Maurice Jacob and many other members of the Theory Division for their kind hospitality at CERN.

Fig. 1

FIGURE CAPTIONS

Fig. 1 The total cross section σ_{tot} in barns, the ratio σ_{el}/σ_{tot} of the integrated elastic cross section to the total cross section, and the ratio ρ of the real to imaginary parts of the forward amplitude for pp and $\bar{p}p$ scattering as functions of the center-of-mass energy $\sqrt{s}$. The curves are the predictions from ref. [9], the data points are from refs. [7, 11].

Fig. 2 $d\sigma/dt$ for $\bar{p}p$ elastic scattering at $\sqrt{s} = 1.8\text{TeV}$. The curve is the prediction from ref. [9], the data points are from ref. [12].

Fig. 3 Predictions from ref. [9] for $\bar{p}p$ elastic scattering at several energies in the small- t region (solid curve $\sqrt{s} = 1\text{TeV}$, dashed curve $\sqrt{s} = 1.4\text{TeV}$, small dashed curve $\sqrt{s} = 1.8\text{TeV}$). One expects $\rho = 0.128$ for these three energies.

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Fig. 3

Fig. 2