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COMPARISON OF THEORETICAL PREDICTIONS FROM THE IMPACT PICTURE WITH THE RECENT UA4 DATA

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Abstract

The theoretical predictions of the proton-antiproton elastic scattering cross section is compared with the recent UA4 data in the Coulomb interference region at the centre-of-mass energy of 541 GeV. The agreement is excellent. A plot of the ratio of the experimental data to the theoretical prediction shows an oscillation of about 2.9%. Further experimental studies are needed to ascertain whether this oscillation is actually present.

For more than twenty years, the impact picture phenomenology\(^1,2\) has been proven to be a very successful theoretical framework for the description of pp and \(p\bar{p}\) elastic scattering at high energies. It predicts in a natural way, the correct rise of the total cross section \(\sigma_{\text{tot}}\) and of the integrated elastic cross section \(\sigma_{\text{el}}\), as well as the correct shape of the differential cross section \(d\sigma/dt\). The most recent improvement of this theoretical approach has allowed in 1984\(^3\) the final determination of all the relevant parameters which characterize the real and the imaginary parts of the nuclear elastic amplitude \(a^N(s,t)\), their energy dependence up to supercollider energies, and their \(t\)-dependence up to large \(t\) values. Since then, these accurate predictions have been repeatedly verified by collider experiments, not only at the CERN-ISR\(^3\) but also at the CERN \(SppS\) \(^4\) and at the highest FNAL\(^5\) energy \(\sqrt{s} = 1.8\) TeV. Detailed theoretical predictions have also been presented for the centre-of-mass energy in the range of the future colliders LHC and SSC\(^6\), which we hope will not be left unexplored.

One important test of any reliable theoretical picture is its ability to describe the differential cross section \(d\sigma/dt\) near the forward direction, more precisely in the Coulomb interference region, where it is very sensitive to the real part of the hadronic amplitude. This type of measurement allows the determination of the ratio of the real to imaginary parts of the forward amplitude \(a^N(s,t = 0)\)

\[
\rho = \frac{\text{Re } a^N(s,t = 0)}{\text{Im } a^N(s,t = 0)},
\]

which was predicted to be about 0.13\(^5\) at energies of CERN \(SppS\) collider. For a more significant confrontation of our prediction with the data, we gave a plot of \(d\sigma/dt\) in the Coulomb interference region\(^6\) shown as the curve in fig. 1. Shortly after that, the UA4 Collaboration\(^7\) published their data based on two days of running, in some disagreement with our prediction and from which they extracted the value \(\rho = 0.24\pm0.04\), at variance with the theoretical prediction\(^8\). Two years ago the E710 at FNAL\(^9\) released the experimental

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value $\rho = 0.140 \pm 0.069$ at $\sqrt{s} = 1.8$ TeV, not very accurate but in agreement with our prediction $\rho = 0.128$ at that energy. In view of the uncertainty of the UA4 result, a new proposal was accepted for a more accurate determination of $d\sigma/dt$ in the Coulomb interference region at the CERN SppS collider. Last year we published a table of our predicted values, which corresponds to the curve in fig. 1 and were already available in 1984.

Also shown in fig. 1 is the new experimental data from the UA4 Collaboration. The event rate $dN/dt$ is proportional to $d\sigma/dt$ up to a normalization constant that was fixed for a best agreement with the theoretical prediction in the entire $t$-range. It is seen that these data give an excellent confirmation to the theoretical prediction. In particular, the new data give the following values for $\rho$ and the slope $B$ of the forward peak

$$\rho = 0.135 \pm 0.007 \quad \text{and} \quad B = (15.4 \pm 0.1) \text{ GeV}^{-2}.$$  \hspace{1cm} (2)

to be compared with the 1984 theoretical values of

$$\rho = 0.13 \quad \text{and} \quad B = 15.6 \text{ GeV}^{-2}.$$  \hspace{1cm} (3)

Thus this new piece of experimental data contributes a new success of our theoretical approach.

A careful examination of fig. 1 shows that there is a slight oscillation of the experimental data around the more smooth theoretical prediction: the data are somewhat above the theoretical curve for $|t|$ near 0.03 (GeV/c)$^2$, and somewhat below for $|t|$ near 0.1 (GeV/c)$^2$. In order to show this small oscillation more clearly, it is instructive to plot the ratio of the experimental to theoretical results. This is shown in fig. 2. This ratio is obviously very close to 1, as expected, but the oscillation mentioned above is more clearly seen.

There is no obvious explanation of this oscillation of a few per cent. For example, it is unlikely that it is related to the exchange of any Regge trajectory. Since the highest Regge

trajectory is about half a unit below the Pomeron, its relative contribution is roughly the inverse of the centre-of-mass energy in GeV, or 0.2%. In the absence of any explanation, accurate measurements at the Tevatron collider, LHC and SSC, in this Coulomb interference region, are highly desirable, and probably essential in clarifying the presence or absence of this oscillation. If this oscillation is verified in the future to be actually present, then we may look forward to interesting and unexpected new physics.

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Figure captions

Fig. 1 Comparison of the theoretical prediction of ref. [4] and the new experimental measurement by UA4[11] at $\sqrt{s} = 541$ GeV in the small-$t$ region.

Fig. 2 The ratio of the experimental to theoretical results.
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UA4 $\sqrt{s} = 541$ GeV

Fig. 2