EVIDENCE FOR A CHANGE OF SLOPE IN
LARGE-\( t \) ELASTIC PROTON-PROTON SCATTERING
AT \( \sqrt{s} = 53 \) GeV

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ABSTRACT

New experimental results are presented on proton-proton elastic scattering in
the range of momentum transfer \( 4 \) GeV\(^2 < -t < 10 \) GeV\(^2\) at the centre-of-mass energy of
\( \sqrt{s} = 53 \) GeV. The data have been obtained using the Split-Field Magnet detector at
the CERN Intersecting Storage Rings. We observe another change of slope of the
differential cross-section near \(-t = 6.5 \) GeV\(^2\).

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We have extended our previous measurements \cite{1} of large-\( t \) elastic proton-proton scattering in the range \( 4 \text{ GeV}^2 < -t < 10 \text{ GeV}^2 \) in order to investigate with better sensitivity the open question whether further diffraction-like minima exist at large values of the momentum transfer. The data have been obtained using the Split-Field Magnet detector (SFM) at the CERN Intersecting Storage Rings (ISR). We report here results obtained at a centre-of-mass energy of \( \sqrt{s} = 53 \text{ GeV} \) for an integrated luminosity of \( 4.87 \times 10^9/\text{mb} \). We observe a new break in the \( t \)-dependence near \( t = -6.5 \text{ GeV}^2 \) followed by an exponential decrease of the cross-section with a slope of \( b = (0.88 \pm 0.13) \text{ GeV}^{-2} \) in the \( t \)-range from 6 to 10 GeV\(^2 \).

The SFM detector has been described before \cite{2}. It consists of two forward telescopes, each equipped with 12 multiwire proportional chambers, 1 m high, 2 m wide, and having 2 mm wire spacing. Each chamber has a vertical and a horizontal wire plane. The average magnetic field is 1.0 T, providing a momentum resolution of \( \Delta p/p = \pm 7\% \) for scattered protons. Events are selected by requiring two charged tracks (one in each telescope) at the trigger level, and by a cut on the deviation from collinearity, after having performed the geometrical reconstruction and a kinematical fit with four constraints. In terms of \( \chi^2 \) this cut corresponds to accepting events at the 1% confidence level.

The value of the differential cross-section at \( t = -10 \text{ GeV}^2 \) is about \( 10^{10} \) times smaller than at \( t = 0 \). A careful study of possible contamination by background is therefore required. We have investigated the collinearity distribution, expressed in terms of \( \chi^2 \), as a function of momentum transfer. A scatter diagram for events selected by the criteria described above is shown in Fig. 1. Attributing events with \( \chi^2 > 9 \) to background, we estimate a residual contamination of less than 5% for accepted events with \( \chi^2 < 9 \) at all \( t \)-values. This residual background has been neglected.
We have determined absolute differential cross-sections by correcting for the t-dependent acceptance of the detector and by applying an over-all normalization factor. The detailed procedure is described in Ref. 2; the acceptance at large t has been improved over the previous experiment [1] and has now a value larger than 40% for \(-t > 3 \text{ GeV}^2\).

The momentum transfer t is measured with a resolution of \(\sigma_t = \pm 0.04 \text{ GeV}^2\) at \(t = -4 \text{ GeV}^2\) increasing linearly to \(\sigma_t = \pm 0.10 \text{ GeV}^2\) at \(t = -10 \text{ GeV}^2\).

The over-all normalization factor is obtained by collecting monitor counts simultaneously with data taking. The monitoring telescope has been calibrated using the van der Meer method [3]; we estimate the systematic uncertainty of this monitor to be \(\pm 5\%\).

The results \(^*)\) are shown in Fig. 2. Describing the differential cross-section by a single exponential with slope \(b\) we observe a succession of changing slopes; \(b_1 = (10.3 \pm 0.02) \text{ GeV}^{-2}\) for \(0.25 < -t < 0.6 \text{ GeV}^2\) \(^{**}\), followed by a narrow minimum at \(-t = 1.34 \text{ GeV}^2\) and a second maximum at \(-t = 1.8 \text{ GeV}^2\); \(b_2 = (1.81 \pm 0.02) \text{ GeV}^{-2}\) for \(2.2 < -t < 6 \text{ GeV}^2\), followed by a break near \(-t = 6.5 \text{ GeV}^2\) and a third slope \(b_3 = (0.88 \pm 0.13) \text{ GeV}^{-2}\) for \(6 < -t < 10 \text{ GeV}^2\) \(^{***}\).

Several authors have predicted a second diffraction-like minimum in the t-range near 4 GeV\(^2\) and an associated change in slope, by using optical models [4], constituent models [5] or exchange models [6]. To our knowledge none has predicted this set of slope values and breaks [7]. Wakaizumi and Tanimoto [8] have shown that a model of multiple scattering of constituents with suitably chosen form factors and wave functions can describe this data. Van Hove [9], using a quark-glue model, predicts a continuous change of slope with \(b = 1.4 \text{ GeV}^{-2}\) at \(t = -8 \text{ GeV}^2\).

\(^*)\) Tables of the differential cross-sections are available from the authors.

\(^{**}\) This value has been obtained at \(\sqrt{s} = 23\) GeV and 62 GeV, see Ref. 2.

\(^{***}\) Restricting the maximum likelihood fit to the range \(7 < -t < 10 \text{ GeV}^2\), we find \(b_3 = (0.39 \pm 0.23) \text{ GeV}^{-2}\).
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REFERENCES

Figure captions

Fig. 1: Scatter diagram of collinearity in terms of $\chi^2$ as a function of momentum transfer. Events with $\chi^2 < 9$ are selected. The residual background contamination is less than 5% at all $t$-values.

Fig. 2: Differential cross-sections as a function of momentum transfer $t$. The error bars represent statistical and systematic errors. An overall scale uncertainty of ±5% has to be added.
Fig. 1

- $t$ (GeV$^2$)

$\chi^2$