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Neutron–proton elastic scattering at high energies and small momentum transfers

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Abstract. It is shown that the most recent measurements of differential cross-section at small momentum transfers, integrated and total cross-sections, and the slope of np elastic scattering from 100 to 400 GeV/c are successfully fitted by using the simple Regge pole model proposed by the authors several years ago.

Keywords. Neutron-proton elastic scattering; Regge pole model; differential cross-section; total cross-section.

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Recently, Arefiev *et al* (1984) have studied neutron–proton elastic scattering for incident neutron momenta 100–400 GeV/c in the NA-6 experiment at CERN SPS. The t-range covered by this experiment is $6{\cdot}10^{-6} < |t| < 5{\cdot}10^{-1}$ (GeV/c)^2. The choice of this t region was motivated due to the following reasons:

(i) This experiment extends the investigation of np scattering previously limited to $|t| > 0{\cdot}14$ (GeV/c)^2 (De Haven *et al* 1979), to smaller $|t|$ values by five orders of magnitude.
(ii) np scattering allows a direct measurement of the hadronic amplitude for $|t| < 10^{-2}$ (GeV/c)^2.
(iii) For very small momentum transfers $|t| < 10^{-4}$ (GeV/c)^2, electromagnetic effects should be seen in np scattering. These are due to the interaction between the magnetic moment of the neutron and the proton charge. This interaction, called Schwinger scattering, should cause a steep rise of the differential cross-section towards $t = 0$, which at high energies could not be verified experimentally before.
(iv) The measurement of the optical point allows the determination of the total np cross-section.

The differential cross-section data at average incident laboratory momenta $\langle p \rangle = 155{\cdot}4$, $257{\cdot}2$ and $342{\cdot}4$ GeV/c and for $|t| < 0{\cdot}08$ (GeV/c)^2 are shown in figure 1, while the differential cross-section in the normalisation interval 200–400 GeV/c with $\langle p \rangle = 309{\cdot}5$ GeV/c and in the t range $10^{-4} < |t| < 0{\cdot}33$ (GeV/c)^2 is exhibited in figure 2. Figure 3 shows the local slope parameter in various t intervals as a function of laboratory momentum p. Figure 4 shows the slope parameters measured in np scattering by various groups (Arefiev *et al* 1984; Engler *et al* 1973; Bohmer *et al* 1975; De Haven 1978].

The total cross-section is deduced in this experiment from the optical point using

$$A = \frac{1}{16}\sigma_T^2(1+\rho^2).$$

The ratio ρ of the real-to-imaginary part of the hadronic amplitude crosses zero around 300 GeV/c in *pp* scattering. Assuming an analogous behaviour in np scattering and

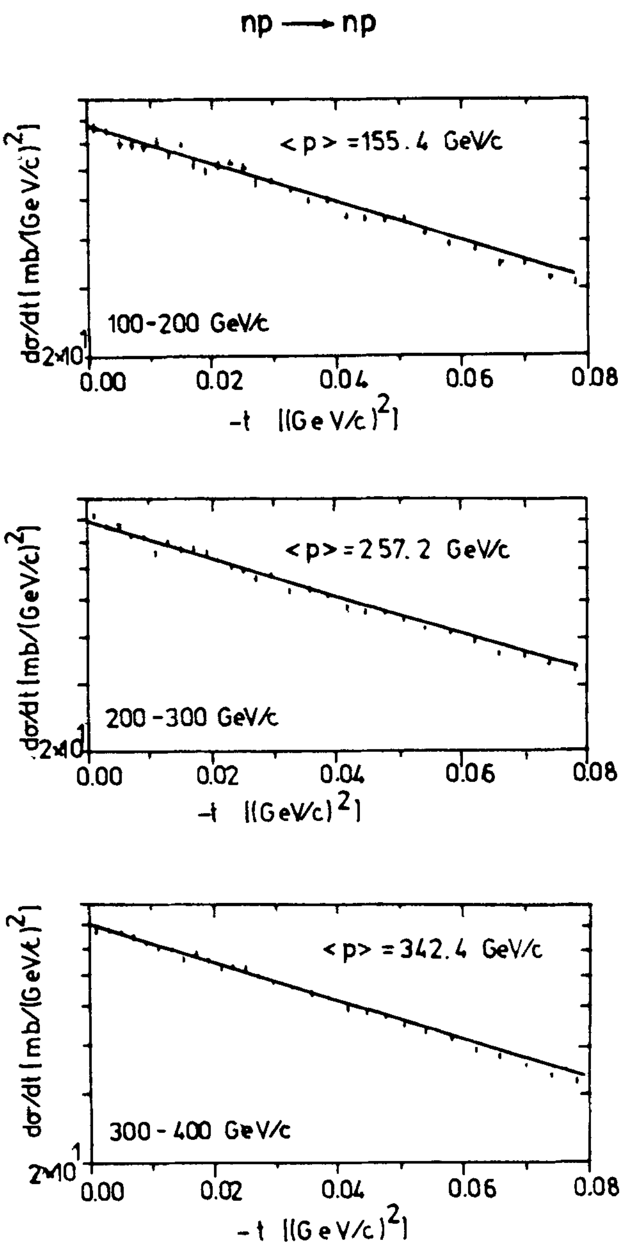

Figure 1.

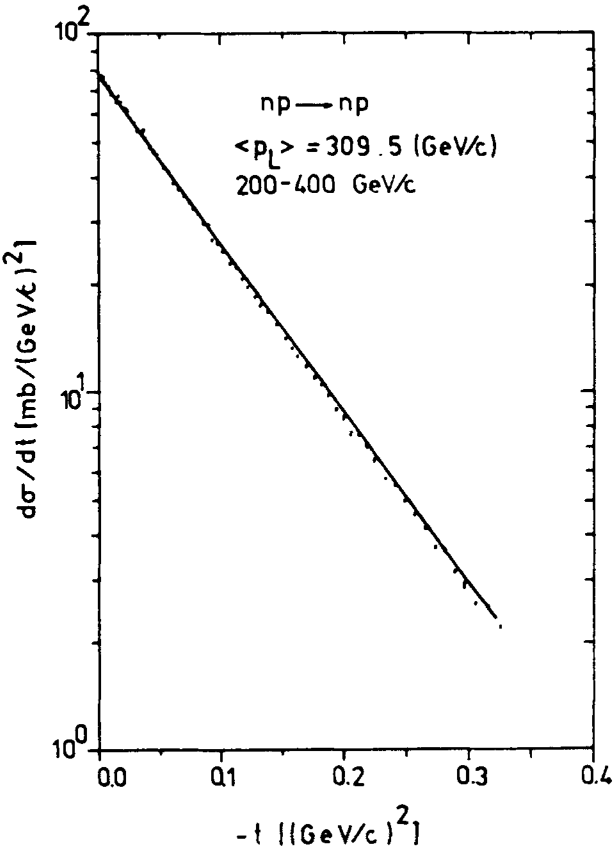

Figure 2.

Figures 1 and 2. Fit of the differential cross-section for the reaction $np \to np$ at $p = 155{\cdot}4$, 257·2, 342·2 and 309·5 GeV/c. Experimental data have been taken from Arefiev *et al* (1984).

therefore neglecting ρ^2, it was found that

$$\sigma_T^{np} = 39{\cdot}6 \pm 0{\cdot}6\,\text{mb at } \langle p \rangle = 310\,\text{GeV/c}.$$

This value deduced from the optical point is consistent with direct measurements of σ_T^{np} and σ_T^{pp}.

The total elastic np cross-section above 100 GeV/c had not been measured prior to this experiment which gave:

$$\sigma_{el}^{np} = 7{\cdot}05 \pm 0{\cdot}22\,\text{mb at } \langle p \rangle = 310\,\text{GeV/c}.$$

Combined with σ_T^{np} this gives a ratio

$$\sigma_{el}^{np}/\sigma_T^{np} = 0{\cdot}178 \pm 0{\cdot}006,$$

which is in good agreement with the pp data at ISR energies (Baksay *et al* 1978).

We shall now show that the simple Regge pole model for neutron–proton elastic scattering at high energies proposed by us (Saleem and Aleem 1979) gives very satisfactory results when compared to these measurements. In this paper it has been shown that at high energies where the pomeron dominates, the two scattering amplitudes

$$N_0 = f(t)\,\xi(t)\,s^{\alpha(t)}\sqrt{mb}\ \mathrm{GeV}$$

$$N_1 = \sqrt{-t}\,g(t)\,\xi(t)\,s^{\alpha(t)}\sqrt{mb}\ \mathrm{GeV}$$

govern the behaviour of the scattering process. The differential cross-sections at

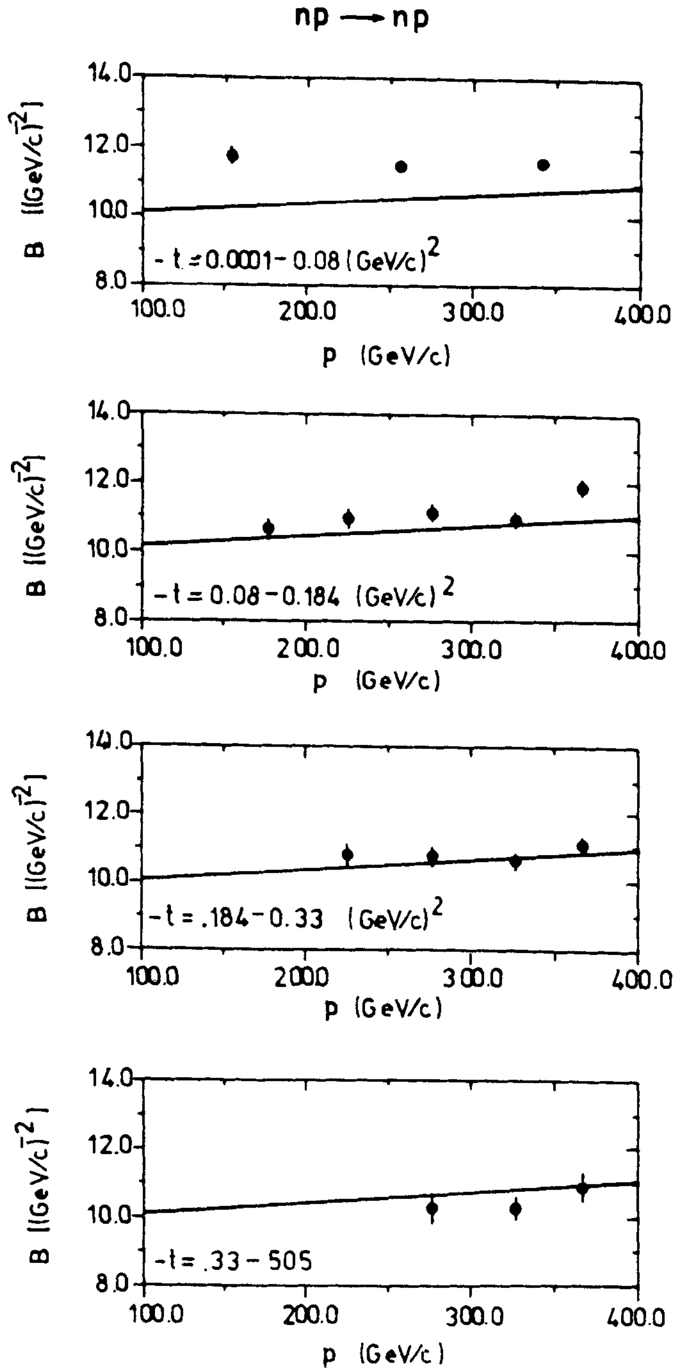

Figure 3.

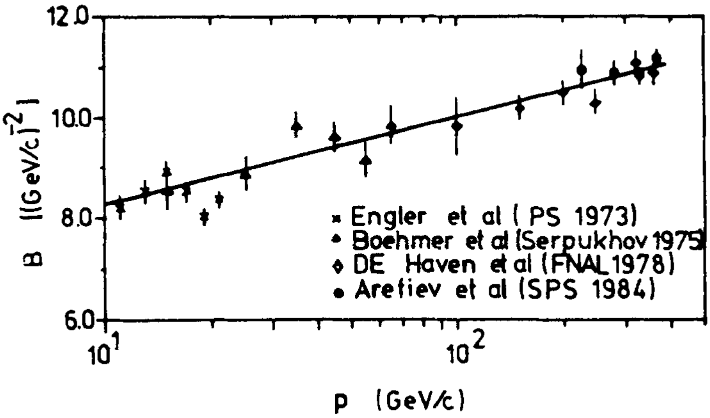

Figure 4.

Figures 3 and 4. Fit of the slope parameter at various momenta and in different t intervals. Experimental data have been taken from Arefiev *et al* (1984).

$p = 155{\cdot}4$, $257{\cdot}2$, $342{\cdot}2$ and $309{\cdot}5$ GeV/c and the slope parameters at various momenta and in different t intervals are shown in figures 1, 2 and 3, 4. The agreement between the predictions of the model and the experimental data is very good except for the slope parameter diagram for the t-interval 0·0001–0·08 $(\mathrm{GeV/c})^2$.

At $p = 310$ GeV/c, the total elastic cross-section σ_{el} and total cross-section σ_T have been calculated as 7·24 and 39·88 mb respectively, and are also in good agreement with experiment. The ratio comes out as 0·181 which is excellent agreement with the experimental value of $0{\cdot}178 \pm 0{\cdot}006$.

If this model is valid, the measurements of polarisations P at this momentum should yield zero. Such a measurement has not been made. If P has a non-vanishing spectrum at this momentum, the model would have to be improved by introducing one or more of Regge trajectories such as ρ, and A_2.

It may be pointed out that our model does not take into effect very small momentum transfers, $|t| < 10^{-4}$ $(\mathrm{GeV/c})^2$, and is restricted to hadronic amplitudes.

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