

Polarization in pp elastic scattering at small $|t|$ *

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We have measured the polarization parameter for proton-proton elastic scattering at $p_0 = 6$ GeV/ c for $|t| < 0.5$ (GeV/ c)² using the polarized proton beam at the Argonne Zero Gradient Synchrotron. These data, together with all previous measurements in this t region, are well fitted by the empirical relation $P = (0.481 \pm 0.010)(-t)^{1/2} \exp(2.291 \pm 0.085)t$.

The determination of the proton-proton elastic-scattering polarization parameter for $|t| < 0.1$ (GeV/ c)² is difficult in a polarized-target experiment. This kinematic region is of interest because of the structure observed in the differential cross section at $|t| \approx 0.1$ (GeV/ c)² and because elastic-scattering models may be sensitive to the functional dependence of the polarization as it rises from the necessary zero in the forward direction. With the advent of the polarized proton beam at the Argonne Zero Gradient Synchrotron (ZGS), a good determination of the small-angle elastic-scattering polarization parameter was possible.¹ The data reported here extend the existing measurements at $p_0 = 6$ GeV/ c to smaller $|t|$ and decrease the errors at several points. Taken together, the data from three experiments^{1,2} yield a good empirical fit to the elastic-scattering polarization for $|t| < 0.5$ (GeV/ c)².

The apparatus used for this experiment was a single-arm magnetic spectrometer, which is described in detail in Ref. 3. The extracted proton beam from the Argonne Zero Gradient Synchrotron (ZGS) was incident on a 10-cm liquid-hydrogen target. The beam polarization was vertical and normal to the scattering plane. The typical beam polarization was 70% and the usual intensity was 5×10^8 protons per accelerator pulse. The direction, size, and position of the incident beam were determined by wire proportional chambers read out in an integrated mode. The relative beam intensity was measured by two three-scintillation-counter telescopes located in the vertical plane. The incident polarization was measured by a double-arm scintillation-counter telescope oriented at 70° to the proton beam which viewed a thin polyethylene target. The analyzing power of this polarimeter was determined to be 0.051 ± 0.002

by calibration against an absolute elastic-scattering polarimeter located in another beam line. The magnetic spectrometer had an angular acceptance of order 10^{-4} sr. An event was defined by the coincidence of three scintillation counters located at the end of the spectrometer.

This experiment actually measured the analyzing power, which is defined by the equation

$$\alpha = \frac{1}{P_B} \frac{N_{\uparrow} - N_{\downarrow}}{N_{\uparrow} + N_{\downarrow}}, \quad (1)$$

where P_B is the beam polarization and N_{\uparrow} (N_{\downarrow}) is the number of spectrometer coincidences normalized to the incident intensity for the initial beam polarization up (down). Since the spectrometer was located on the left, looking downstream, of the incident proton beam, this equation is in accord with the usual sign convention. Corrections due to multiple scattering and nuclear absorption and uncertainties in the absolute acceptance had no effect on the analyzing-power measurement. The beam polarization was reversed every pulse to minimize systematic errors. Target-empty data runs were taken at every point. For $|t| > 0.25$ (GeV/ c)², the target-empty counting rate was 25% of the target-full rate; at smaller $|t|$, the target-empty subtraction increased, reaching 84% of the target-full rate at $|t| = 0.02$ (GeV/ c)². This large target-empty effect was mainly due to beam halo interactions in the septum wall of the first spectrometer magnet. A detailed analysis, using information from a momentum hodoscope in the spectrometer with a resolution of 0.5% (full width at half maximum), was done to estimate the inelastic background due to pion production. Over the entire $|t|$ range covered by this experiment, the inelastic contamination was negligible.

Since the analyzing power and the polarization

TABLE I. The polarization parameter for pp elastic scattering at $p_0 = 6$ GeV/c. The errors shown are point-to-point only and do not include a 6% normalization uncertainty.

$-t$ [(GeV/c) ²]	Polarization
0.020	0.072 ± 0.030
0.025	0.100 ± 0.018
0.030	0.086 ± 0.011
0.035	0.093 ± 0.010
0.040	0.090 ± 0.010
0.050	0.102 ± 0.014
0.070	0.114 ± 0.004
0.116	0.125 ± 0.003
0.158	0.135 ± 0.006
0.211	0.127 ± 0.003
0.421	0.124 ± 0.003

parameter are equal for elastic scattering by time-reversal invariance, we have used the latter term in Table I for consistency with the previous literature. Figure 1 indicates our data points superimposed on a line resulting from an empirical fit to all existing data for $|t| < 0.5$ (GeV/c)². No attempt has been made in the fitting process to force agreement in the normalization between our data and those from Refs. 1 and 2. Despite this, the empirical formula

$$P = (0.481 + 0.010)\sqrt{-t} \exp(2.291 \pm 0.085)t \quad (2)$$

yields a χ^2 of 38.0 for 33 degrees of freedom. The error bars shown are point-to-point errors only; they do not include the normalization uncertainty of 6%.

These results change slightly the parametrization of the spin amplitudes at small $|t|$ reported in Ref. 1. Using the notation of Halzen and Thomas,⁴

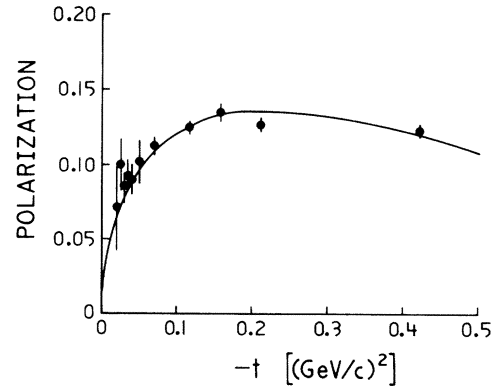


FIG. 1. The polarization parameter for pp elastic scattering at $p_0 = 6$ GeV/c. The error bars shown represent point-to-point errors only; they do not include a normalization uncertainty of 6%. The solid line shows the empirical fit given in the text.

which describes the scattering in terms of three natural-parity (N_i) and two unnatural-parity (π, A) t -channel amplitudes, we can estimate the component of the spin-flip amplitude N_1 orthogonal to the nonflip N_0 in the complex plane as

$$N_{1\perp} \approx \frac{1}{2} P (d\sigma/dt)^{1/2} \\ = 2.2\sqrt{-t} \exp(6.1t) [\text{mb}/(\text{GeV}/c)^2]. \quad (3)$$

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