MEASUREMENTS OF A AND A_{nn} IN PP ELASTIC SCATTERING

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ABSTRACT

The spin analyzing power A in 24 GeV/c proton-proton elastic scattering was measured for $P_\perp^2$ between 3.5 and 7 $(\text{GeV/c})^2$. This measurement was made using the new Michigan high cooling power 5T-1K polarized proton target and a high intensity unpolarized proton beam at the Brookhaven National Laboratory Alternating Gradient Synchrotron. The experiment aimed to further confirm a large and rising analyzing power in the large $P_\perp^2$ region. New results are reported; less recent data on the spin-spin correlation parameter A_{nn} are also reviewed.

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We measured the analyzing power, A, at $P_{lab} = 24$ GeV/c for $P_\perp^2$ between 3.5 and 7 $(\text{GeV/c})^2$ in our on-going investigation of spin effects in p-p elastic scattering at the Brookhaven AGS. This experiment used a high intensity unpolarized proton beam and the new Michigan polarized proton target.

The size and position of the beam were monitored with segmented wire ion chambers at several different positions along the beam line. The beam intensity on the target was monitored by an ion chamber, a secondary emission counter, and counter telescopes in the vertical scattering plane. The beam intensity averaged about $2 \cdot 10^{11}$ protons per pulse. When running polarized beam,[1] the beam polarization was measured with two double-arm spectrometers looking at a liquid hydrogen target located upstream of the polarized target, as shown in Fig. 1.

The new Michigan polarized proton target[2] uses the technique of dynamic nuclear polarization to polarize the free protons in the target material at a temperature of 1 K in a 5 T magnetic field. The old target operated at 0.5 K and 2.5 T. The change to 1 K increases the available cooling power, which is needed to operate the target in such a high intensity beam, while the change to 5 T is required to maintain the Boltzmann factor $\mu B/kT$. For this run, we used frozen ammonia (NH_3) beads as the target material. We produced radicals in the frozen ammonia by irradiation with electrons at the MIT Bates Linac; these radicals are fully electron polarized at this temperature and field. The electron polarization is then transferred to the protons by using 140 GHz microwave. The proton polarization was measured with a 213 MHz NMR system. Target polarization was vertical, which is transverse to the scattering plane, and was typically reversed every three hours. The peak polarization measured was 96%, while the average polarization for the entire three month run was 85%. This is nearly a factor of two improvement over the old target.

Elastic events were detected by the double-arm spectrometer shown on the right side of Fig. 1. The two arms are matched for elastic kinematics, with an acceptance of

$$\Delta P_\perp^2 \approx 1 \ (\text{GeV/c})^2 \text{ and } \Delta\phi \approx 2^\circ. \quad (1)$$

The spectrometer gives a clean signal of elastic events, rejecting most of the backgrounds from quasielastic and inelastic processes. We experimentally estimated the quasielastic scattering from non-hydrogenous nuclei in the target and the inelastic background by substituting Teflon (C_2F_4) beads for the ammonia beads. The resulting background events were presumed to have an analyzing power of zero and were treated as a dilution of the elastic analyzing power.

The normalized event rates, $N(ij)$, are given, for the possible spin states of the beam ($i =\uparrow$ or $\downarrow$) and target ($j =\uparrow$ or $\downarrow$), by

$$N(ij) = \frac{E(ij)}{I(ij)}, \tag{2}$$

where $E(ij)$ is the number of elastic events corrected for quasielastic background, and $I(ij)$ is a relative beam intensity obtained by averaging the beam monitors. A and A_{nn} are given by the following equations:

$$\begin{aligned} A_{nn} &= \frac{1}{P_B P_T} \frac{N(\uparrow\uparrow) + N(\downarrow\downarrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)} \\ A_B &= -\frac{1}{P_B} \frac{N(\uparrow\uparrow) - N(\downarrow\downarrow) + N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)} \\ A_T &= -\frac{1}{P_T} \frac{N(\uparrow\uparrow) - N(\downarrow\downarrow) - N(\uparrow\downarrow) + N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)}, \end{aligned} \tag{3}$$

where P_B and P_T are beam and target polarizations respectively. When running polarized beam, the fact that $A = A_B = A_T$ serves as a good test for systematic errors.

Preliminary results for A are shown in Fig. 2 along with earlier data;[3] the new data for $P_\perp^2 = 3.5$ and 7 $(\mathrm{GeV/c})^2$ have yet to be analyzed. The new errors are substantially reduced compared to earlier runs, due to the improved target polarization and high beam intensity. The most recent results[4] for A_{nn}, at $P_\perp^2 = 18.5$ $(\mathrm{GeV/c})^2$, are plotted with earlier data in Fig. 3.

QCD should allow perturbative calculations of p-p elastic scattering at high energy and momentum transfer. The simple quark-interchange model,[5] for example, predicts $A = 0$ and $A_{nn}(90^\circ_{cm}) = \frac{1}{3}$, at high enough energy and momentum transfer. This clearly does not agree with the data in Figs. 2 and 3. However, the simplifying assumptions of the quark-interchange model make suspect its direct applicability to spin experiments.

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References

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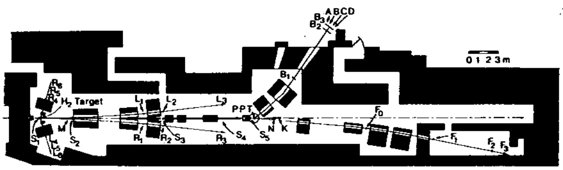

Fig.1 Experimental layout.

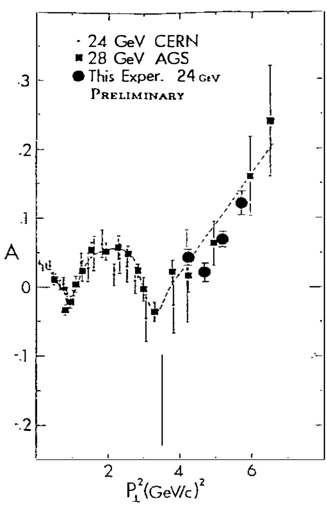

Fig.2 Compilation of A data.

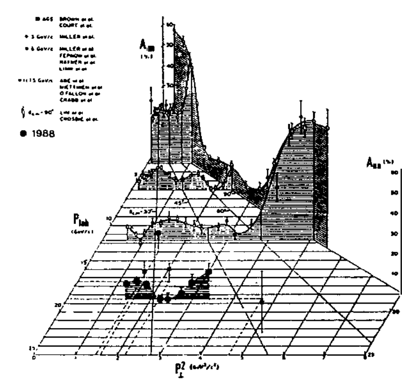

Fig.3 Compilation of A_{nn} data.