Measurement of A and A_{NN} in $p_\uparrow$ $p_\uparrow$ Elastic Scattering at 18.5 GeV/c*

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As part of a continuing study of spin effects in pp-interactions, we have measured the analyzing power, A, and the spin correlation parameter, A_{NN}, in $p_\uparrow$ $p_\uparrow$ elastic scattering in the $p_\perp^2$ range 1.4 to 3.35 $(GeV/c)^2$.[1] The experiment was carried out using a polarized proton beam at the AGS at Brookhaven National Laboratory together with a polarized proton target. The intensity, polarization, and reliability of the polarized proton beam have improved significantly since the first commissioning in 1984. These improvements have allowed a systematic study at a single energy with good precision, rather than the more scattered measurements possible in the earlier runs.

The parameters for the accelerated beam and extracted beam to the experiment are shown in Table I.

Table I
Polarized Beam Parameters

18.5 GeV/c	Intensity		Polarization	
	Peak	Average	Peak	Average
Accelerated	2.5 10^{10} pppp	2.10^{10} pppp	52%	43%
Extracted to D Line		1.2 10^{10} pppp		41%

The experimental layout is shown in Fig. 1. The polarized protons enter from the left and first strike the liquid hydrogen target of the high energy polarimeter. The polarimeter measures the left-right asymmetry in proton-proton elastic scattering at $p_\perp^2 = 0.3$ $(GeV/c)^2$ where an analyzing power of 3.9 ± 0.3 % is used to calculate the beam polarization.

The polarized protons continue on to interact in the polarized proton target from which elastic scattering events are detected in the double arm spectrometer. Six magnets and an eight channel hodoscope system ensure that elastic events are selected cleanly with little background.

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$$A_B = -\frac{1}{P_B}[\frac{N(\uparrow\uparrow)+N(\uparrow\downarrow)-N(\downarrow\uparrow)-N(\downarrow\downarrow)}{N(\uparrow\uparrow)+N(\uparrow\downarrow)+N(\downarrow\uparrow)+N(\downarrow\downarrow)}]$$

$$A_T = -\frac{1}{P_T}[\frac{N(\uparrow\uparrow)-N(\uparrow\downarrow)+N(\downarrow\uparrow)-N(\downarrow\downarrow)}{N(\uparrow\uparrow)+N(\uparrow\downarrow)+N(\downarrow\uparrow)+N(\downarrow\downarrow)}]$$

where P_B and P_T are the beam and target polarizations respectively.

The results are shown in Fig. 2. Both A and A_{NN} show considerable structure. The A data are similar to data at lower energies[4] where the value of A peaks at around $p_\perp^2 = 1.5$ (GeV/c)^2, falls to a minimum then rises again. In the older data there appear to be variations in peak width and value of the minimum. The quality of the data made it difficult to quantify any systematic variations. In the current data it is clear that the value of A is negative at the minimum. However, comparing these data with those at 24 and 28 GeV/c[5] it appears that A in this $p_\perp^2$ region is varying with energy, in that the peak value of A is considerably suppressed, dropping from $\sim$ 15% at 18.5 GeV/c to $\sim$ 5% at 24 and 28 GeV/c. Moreover, the peak width increases, delaying the onset of the minimum to about $p_\perp^2 = 3.5$ (GeV/c)^2.

The A_{NN} data are plotted again on the three dimensional graph shown in Fig. 3. It is not clear how the structure of these data correlates with the structure of the older data from the ZGS. We note that the rise of A_{NN} to 60% around 12 GeV/c has never been satisfactorily explained, although there have been many attempts. The most recent is from Brodsky and de Teramond[6]. However, two general statements have been made on the trend of the data: one is the apparent oscillation in A_{NN} at 90°cm has been linked to the oscillation of the 90°cm pp differential cross-section around the general s^{-10} dependence[7]; second is that the peaking towards 90°cm at fixed momentum is due to particle identify effects[8].

It is clear from Fig. 3 that a least two sets of measurements of A_{NN} are necessary to address the validity of these two statements. One is a continuation of the 90°cm measurement from 12.75 GeV/c and the second is to extend a fixed momentum measurement to large values of θcm. The simultaneous measurement of A for the second case may give some insight into whether perturbative QCD is applicable in this $p_\perp^2$ region. Though PQCD predicts that A = 0, it is clearly not the case at 28 GeV/c and $p_\perp^2 = 6.5$ (GeV/c)^2.

The polarized target consists of a conventional evaporation refrigerator, using a $^3He/^4He$ mixture as the coolant, operating at 0.5K in a 2.5T field. The target materials used during the course of the experiment were radiation doped ammonia (NH_3)[2] and chemically doped ethylamine-borane ammonia (EABA)[3]. The performance of these materials are summarized in Table II.

Table II

Target Material Performance

Material	Polarization	
	Maximum	Average
NH_3	55%	44%
EABA	80%	65%

The ammonia gave rather disappointing values of polarization as past experience with a number of samples had shown a much better performance. However, the beam intensities were such that EABA could be used without serious radiation damage problems arising. The majority of the data was taken with EABA. The measurement of background events from non-hydrogenous material was made by replacing the polarizable material with teflon (CF_2).

The beam position and size at both the hydrogen and polarized target were monitored continuously by segmented wire ion chambers S_1, S_2, S_3, S_4 while the relative beam intensity was measured with an ion chamber, secondary emission chamber, and three counter telescopes M, N, and K. The absolute beam intensity was calculated from an aluminum foil irradiation.

A pp-elastic scattering event in the spectrometer was defined by a sevenfold FB coincidence between the appropriate channels of the $F = F_0F_1F_2F_3$ and $B = B_1B_2B_3$ arms. The normalized event rates N(i,j) in the four possible spin states for beam [$i = \uparrow$ *or* $\downarrow$ (up or down)] and target ($j = \uparrow$ *or* $\downarrow$) were obtained by measuring the quantities:

$$N(i,j) = \frac{Events(i,j)}{I(i,j)}$$

where N(i,j) is the number of elastic events corrected for accidentals and non-hydrogen background and I(i,j) is the relative intensity obtained by averaging the monitors. A and A_{NN} are then obtained from the relations

$$A_{NN} = \frac{1}{P_BP_T}[\frac{N(\uparrow\uparrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow) + N(\downarrow\downarrow)}{N(\uparrow\uparrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow) + N(\downarrow\downarrow)}]$$

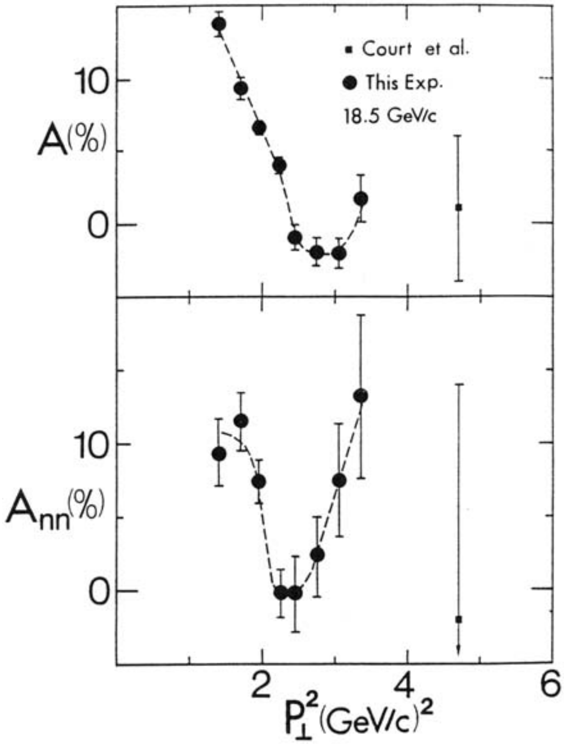

Fig. 2. Plot of the analyzing power, A, and the spin-spin correlation parameter, A_{nn}, as a function of momentum transfer squared for proton-proton elastic scattering at 18.5 GeV/c. The error bars include both statistical and systematic errors. The dashed lines are hand-drawn curves to guide the eye.

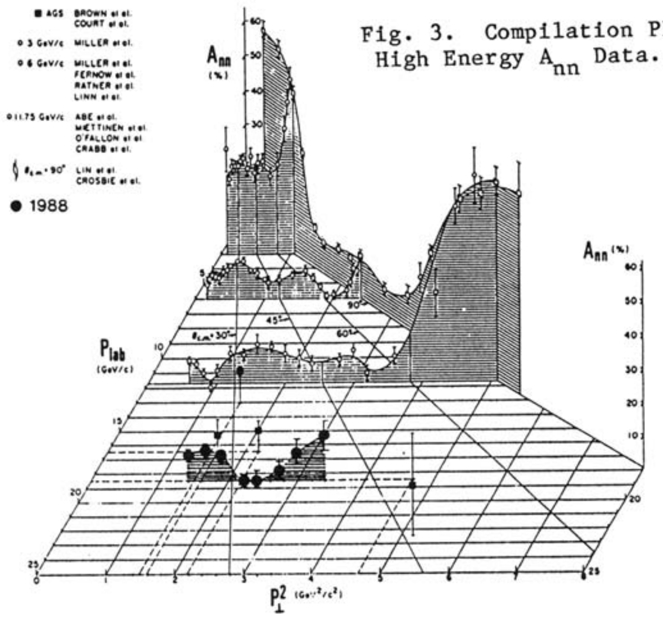

Fig. 3. Compilation Plot of High Energy A_{nn} Data.

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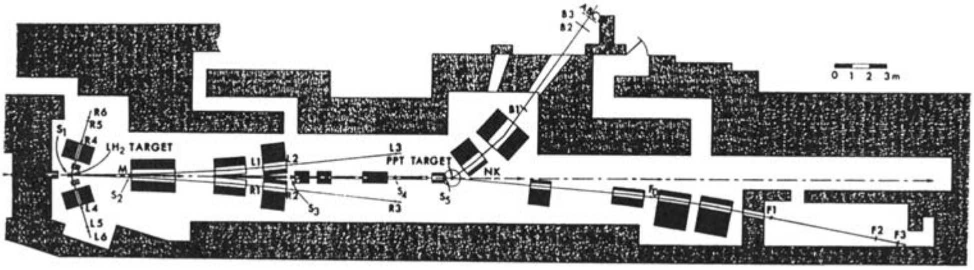

Fig. 1 Layout of the experiment. The high energy polarimeter on the left uses a liquid hydrogen target to measure the left-right asymmetry in p-p elastic scattering. The polarized proton beam then scattered in the vertically polarized proton target (PPT) and the elastic events were detected by the spectrometer which contained magnets for momentum analysis and the F and B scintillation counter hodoscopes. The M, N, and K counters were intensity monitors, while the S_1, S_2, S_4 and S_5 segmented wire ion chambers monitored the beam's position, size and angle.