Analyzing Power Measurements in Elastic proton-proton Scattering at 24 and 400 GeV

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ABSTRACT

Recent measurements of the analyzing power, A, in proton-proton elastic scattering at 24 GeV/c out to $P_\perp^2 = 7.1$ (GeV/c)^2 at the AGS clearly show that A is nonzero and increasing at high $P_\perp^2$. An experiment to extend these measurements to 400 GeV and 3 TeV out to $P_\perp^2 = 8$ (GeV/c)^2 at the UNK accelerator in Protvino, USSR is also discussed.

I will report on recent results and future plans of an experimental program for measuring spin parameters in pp elastic scattering. This particular program began at the Argonne ZGS[1,2] in the 1970's, continued at the Brookhaven AGS[3-5] in the 1980's, and will continue at UNK in Protvino, USSR in the 1990's.

The focus here will be on the analyzing power, A, for pp elastic scattering at high $P_\perp^2$. To measure A, one needs either a polarized beam or polarized target. The measurements discussed here use a polarized target with the polarization transverse to the scattering plane.

The analyzing power measures the change in the scattering rate when the polarization is reversed:

$$A = \frac{1}{P}\left[\frac{d\sigma(\uparrow) - d\sigma(\downarrow)}{d\sigma(\uparrow) + d\sigma(\downarrow)}\right] \tag{1}$$

The target polarization direction is either ↑ or ↓ and its magnitude is P.

A detailed description of the experimental setup at Brookhaven has been given elsewhere[5] , hence only a brief outline will be given here. This experiment was a collaboration of the University of Michigan, Brookhaven, Texas A & M, TRIUMF, and King Fahd University in Saudi Arabia.

Our target material was radiation doped frozen ammonia (NH_3). The target itself was a 1 K ^{4}He evaporation refrigerator with a 5 T superconducting split coil magnet supplied by Oxford Instruments. Polarization of the free hydrogen was achieved using the Dynamic Nuclear Polarization method[6,7] . With this new target we could take about four times the beam intensity (2×10^{11} protons/pulse) of previous runs and the average target polarization was 85% (vs. 50% for our previous target). These effects combined to improve our errors in A by a factor of about three over what we could achieve with our previous target.

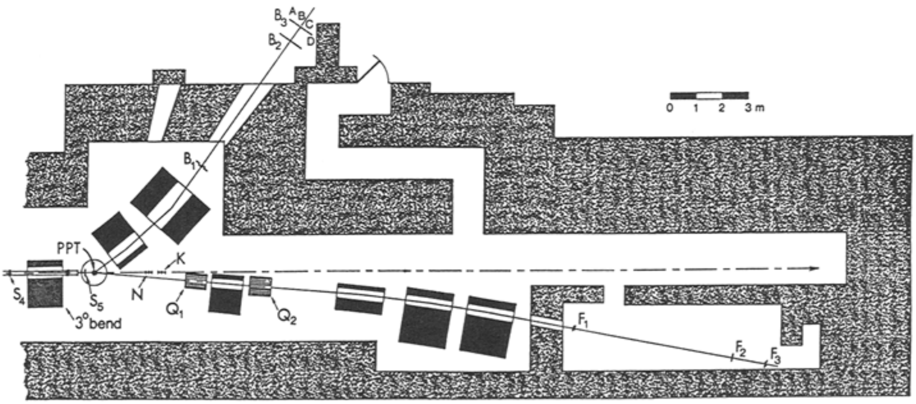

Fig. 1 Diagram of the BNL experiment. The N and K counters were intensity monitors, while the S_4 and S_5 segmented wire ion chambers monitored the beam's position, size and angle.

The double arm spectrometer is shown in Fig. 1. Elastic events are selected by collimation, bending magnets, and a 6 fold coincidence between 3 forward (F) and 3 recoil (B) hodoscopes in the spectrometer. Other relevant hardware were two focusing quadrupoles (Q_1 and Q_2) which doubled our forward arm acceptance to about 10^{-3} sr and a 3° bending magnet just before the PPT which allowed us to go to higher $P_\perp^2$ without drastically altering our spectrometer geometry.

Elastic cross sections drop sharply with increasing $P_\perp^2$; for example, $(d\sigma/d\Omega)_{cm}$ is 1.6 nb/sr at $P_\perp^2 = 6$ $(GeV/c)^2$, and it drops by another factor of three at $P_\perp^2 = 7$ $(GeV/c)^2$. With such small cross sections, we needed the luminosity of 2×10^{34} cm^{-2} s^{-1} to get good statistics.

The new data in the $P_\perp^2$ range of 3.2 to 7.1 $(GeV/c)^2$, is given in Fig. 2 along with data from our earlier 28 GeV/c run[4] and 24 GeV/c data from CERN.[9] The errors shown include statistical errors as well as a 3% relative error in the target polarization. The data was corrected for accidental coincidences and background from scattering off bound protons in NH_3. This was measured by performing a run where our target material was teflon (CF_2) which contains no hydrogen.

The data clearly indicates that the analyzing power is nonzero and increasing at high $P_\perp^2$. Calculations of A based on perturbative QCD (where quark helicity is conserved) predict that A should be zero. This data certainly shows that even at these energies and $P_\perp^2$'s, non-perturbative effects play a strong role, and present a challenge to any theorist searching for an explanation. While a satisfactory answer is being sought, we plan to forge ahead to see if this effect persists at even higher energies and $P_\perp^2$.

Thus, we are presently designing and constructing an experiment to measure A for pp elastic scattering in the 400 GeV to 3 TeV range, and for $P_\perp^2$ of up to 8 $(\mathrm{GeV/c})^2$.This experiment (designated NEPTUN-A) will take place at the currently under construction UNK accelerator in Protvino, USSR. NEPTUN-A is a collaboration of IHEP in Protvino, JINR in Dubna, MIT, and the University of Michigan.

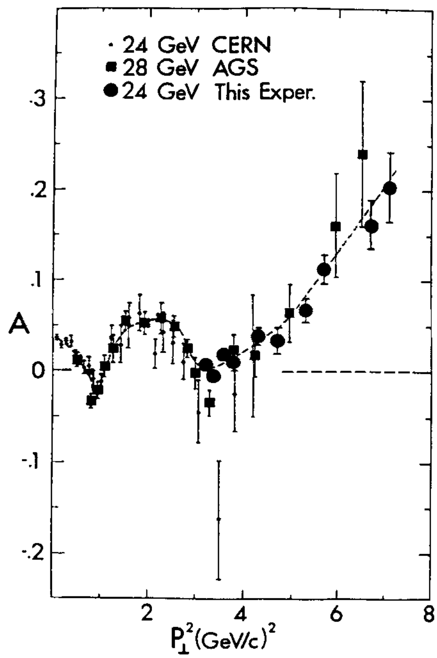

Fig. 2 The analyzing power A as a function of momentum transfer squared $P_\perp^2$. Other data at 28[4] and 24[9] GeV/c are also shown. The dashed curve is a hand-drawn curve to guide the eye.

The NEPTUN-A experimental setup is shown in Fig. 3. It contains a 55 meter long recoil spectrometer with a 12° vertical bend for momentum selection. The planned recoil momentum resolution for this arm is 0.1%, and the planned recoil angle resolution is 0.3 mrad. Minimal information will be needed from the forward arm to separate out the elastic signal; we will detect the forward particle with two forward hodoscopes. This momentum and angle resolution will be achieved using the hodoscopes H_i at the beginning and end of the recoil arm and multi-wire proportional chambers W_i for good particle track position resolution. The information from these detectors will be supplemented with a time-of-flight measurement between the hodoscopes and also by threshold Cherenkov counters for velocity selection. With this extra information, we should be able to distinguish between protons, kaons, and pions. The spin asymmetry in inclusive reactions can then be studied.

The internal gas target will be an ultra-cold spin polarized atomic hydrogen target being built at the University of Michigan. We hope to achieve a target thickness of $10^{14}/\mathrm{cm}^2$ and UNK should eventually have an intensity of 10^{19} protons per sec passing through our target; this would give a luminosity of 10^{33} cm^{-1} sec^{-1}. Our predicted errors in a measurement of A range from 0.2% for $P_\perp^2 = 2$ $(\mathrm{GeV/c})^2$ to 3.8% for $P_\perp^2 = 8$ $(\mathrm{GeV/c})^2$, based on our approved hours of running. Our first run at 400 GeV/c should be in October 1993.

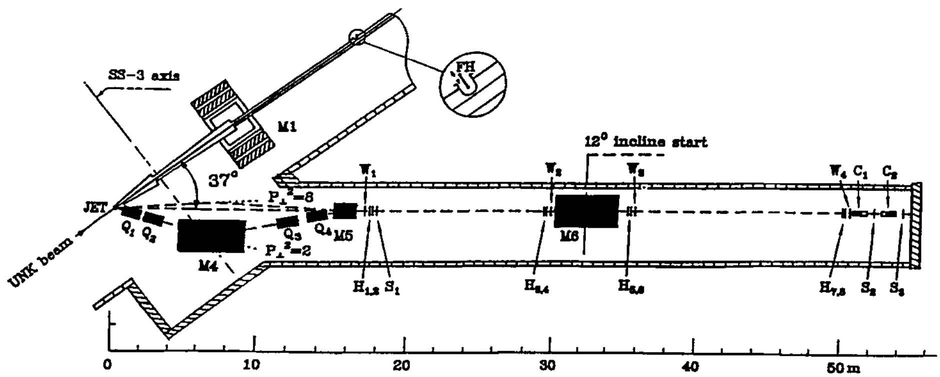

Fig. 3 Diagram of the NEPTUN-A experiment (Top View). The H_i's are scintillation-counter hodoscopes, the W_i's are wire chambers and the C_i's are threshold cherenkov counters. Magnets include pairs of focusing quadrupoles (Q_i's) and dipole bending magnets (M6 vertical and all others horizontal).

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