NEPTUN-A Spectrometer for measuring the Spin Analyzing Power in p-p elastic scattering at large $P_\perp^2$ at 400 GeV (and 3 TeV) at UNK.[1]

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We are constructing the NEPTUN-A spectrometer for measuring the Spin Analyzing Power in $p + p_\uparrow \rightarrow p + p$ at $P_\perp^2 = 2$ to 10 $(\mathrm{GeV/c})^2$ at 400 GeV (or at 3 TeV) when the UNK accelerator in Protvino, Russia, becomes operational. The spectrometer consists of a 55 m long recoil arm with 3 horizontally bending magnets to guide the recoil protons onto a fixed 37° line. Then two vertical dipole magnets bend the protons up by 12° for momentum analysis. The momentum will be measured to an accuracy of 0.1 % using chambers. In order to accept a large solid angle, the spectrometer contains a strong-focusing pair of quadrupoles looking at the polarized proton jet target. The forward arm consists of scintillator hodoscopes for measurement of the forward vertical angle. Acceptances and event rates are calculated. The status of the spectrometer is reported.

INTRODUCTION

We had measured the one-spin Analyzing Power in p-p elastic scattering up to the large $P_\perp^2$ value of 7.1 $(\mathrm{GeV/c})^2$ at the incident momentum of 24 GeV/c at the Brookhaven AGS some years ago (1). As shown in Fig. 1, that analyzing power data exhibited interesting structure with a dip around 3.5 $(\mathrm{GeV/c})^2$ and then it began to rise to about 20 % at the largest measured $P_\perp^2$ value of 7.1 $(\mathrm{GeV/c})^2$.

Perturbative QCD predictions (2) required this analyzing power to approach zero at a large enough $P_\perp^2$ and at a large enough incident energy. Apparently, such a prediction is at variance with our experimental result, but one could argue that the energy is not large enough.

Our group then decided to pursue the goal of measuring the one-spin analyzing power at even larger $P_\perp^2$ values and at larger incident energies. A new "Mark II" polarized hydrogen gas jet (refer to the talk by V. G. Luppov of our group in these conference proceedings) is being developed for use as an

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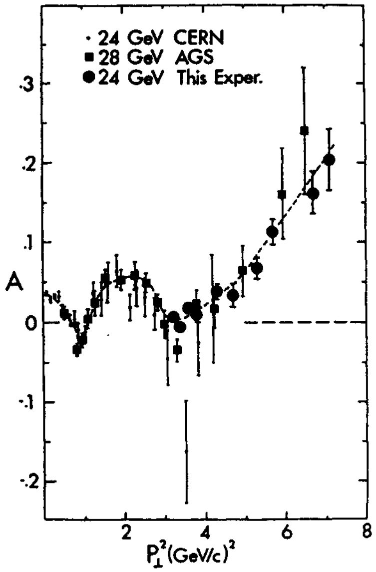

FIG. 1. Analyzing Power in p-p elastic scattering at 24–28 GeV/c.

internal target in the UNK ring. The NEPTUN-A collaboration [2] was formed for measuring the analyzing power at $P_\perp^2$ of 2–10 $(GeV/c)^2$ at 400 GeV/c and perhaps later at 3 TeV (if UNK II gets built). (For information on NEPTUN and other experiments looking at the same target, refer to the talk by V. L. Solovianov in these proceedings.)

RELEVANT KINEMATICS

The kinematics of p-p elastic scattering for $P_\perp^2$ values of 2–10 $(GeV/c)^2$ at 400 GeV/c determined the ranges of the momenta and angles of the forward and recoil protons. Table 1 shows these ranges that we are interested in measuring.

EXPERIMENTAL SET-UP

It was decided, early on, that because the forward protons have too high a momenta [> 390 (GeV/c)] and too close to the beam [< 10 mrad], its

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[2] The present NEPTUN-A collaboration consists of about 50 physicists from the University of Michigan, MIT, IHEP(Protvino), and JINR(Dubna)– with spokesperson Prof. A. D. Krisch of Michigan, and Prof. V. L. Solovianov of IHEP as spokesperson for the Russian contingent.

TABLE 1. Momenta of some Forward and Recoil scattered protons at 400 GeV/c.

$P_\perp^2(GeV/c)^2$	$P_F(GeV/c)$	@	θ_F	$P_R(GeV/c)$	@	θ_R
2	398.9	@	0.20°	1.77	@	52.9°
6	396.8	@	0.35°	4.05	@	37.2°
10	394.6	@	0.46°	6.27	@	30.3°

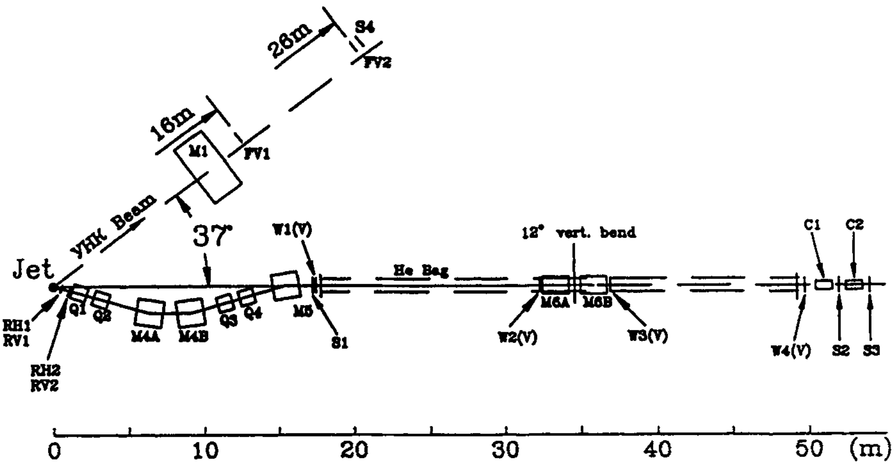

FIG. 2. Top view of the NEPTUN-A spectrometer setup.

momentum would not be measured. Because of the vicinity to the beam, and because of the unknown aspects of the beam halo, we decided to use fast small scintillation counters to detect the vertical angle of the forward scattered protons, with the horizontal angular acceptance overmatching the corresponding recoil arm acceptance.

We decided to concentrate on measuring the momentum *vector* of the recoil protons very accurately by using a 55-m long magnetic spectrometer (see Fig. 2). First, the angle of the recoil proton will be measured with vertical and horizontal solid state detectors RV1,RH1, and RV2,RH2. The about-median value of 37° was chosen for the axis of the spectrometer, with three horizontal bending magnets M4A, M4B and M5 steering the recoil protons of interest onto the axis. Two long field-free regions before and after the two vertically bending magnets M6A and M6B bending up by 12° total were then allotted for the placement of wire and proportional chambers for measuring the tracks to within 1 mm. We then expect to measure the momentum of the recoil proton to an accuracy of about 0.1 %. Note that all magnets are symmetrically placed as much as possible for simplicity and ease of surveying.

To obtain a large solid angle acceptance of the recoil protons, particularly in the vertical plane, a pair of strong-focusing quadrupoles are inserted close to the target.

For particle identification, a pair of threshold Cherenkov counters at the end of the spectrometer line will be used in classifying the higher momenta recoil particles. Lower momentum recoil particles will be identified by time-of-flight through the scintillators S1·S2·S3.

Interaction region

The fixed target interaction region is defined by the transverse beam size of (recently proposed) 5 mm vertical by 10 mm horizontal proton beam interacting with the Mark-II polarized jet which will travel down with transverse widths of 10 mm and 20 mm along beam. Thus the longitudinal interaction length is 20 mm.

Sideways, the interaction region will appear to be 15-19 mm width for the recoil arm and about 10 mm width for the forward arm.

TRANSPORT beam optics

For each $P_{\perp}^2$ point, by geometrical considerations from a (mid)point target, one obtained first the angles of bend for the central ray in each bending magnet, from which the fields were then calculated. The quadrupoles were placed with their axis on the central ray and their positions adjusted using the TRANSPORT program[3].

Applying appropriate constraints, one obtained the required quadrupole field gradients. The maximum half-widths of the beam envelope in both transverse horizontal and transverse vertical directions were then calculated from the program about every meter along the principal axis. This calculation was then repeated for a finite size target (e.g. for half-sizes of 10 mm (h) x 3 mm (v)) and the beam envelopes were plotted for both horizontal and vertical directions, as in Fig. 3. Note that the plot contained both horizontal (X - direction up) and vertical (Y-direction down) envelopes for different half-size of targets. The magnet apertures were about 20 cm bores for the quadrupoles and 20 cm gap and 40 cm width for the benders, and so most of the limiting half apertures were about 10 cm. Vertical dashed lines show roughly the positions of the wire and proportional chambers.

EVENT RATES AND BACKGROUNDS

The circumference of UNK tunnel is 21 km, so cycle time is 70 μs. Since the number of protons stored in one cycle is expected to be about 6 10^{14}, the

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[3] Program obtained courtesy of Dr. David C. Carey of Fermilab.

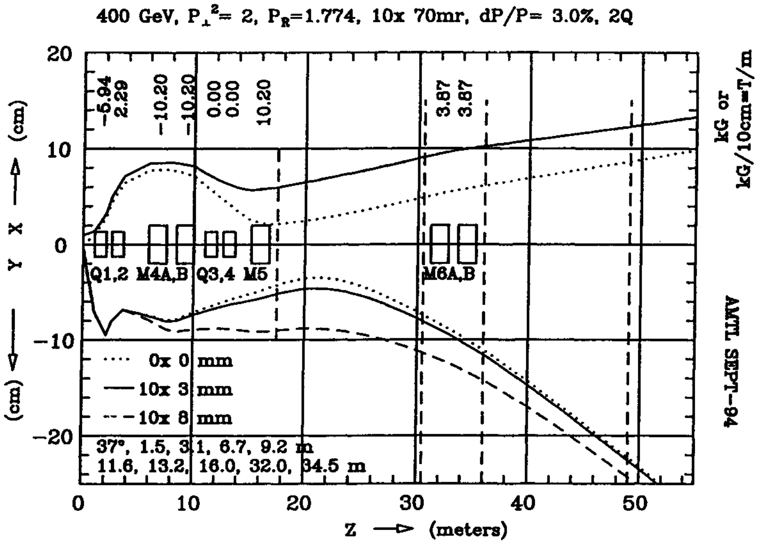

FIG. 3. TRANSPORT beam envelopes for transverse horizontal (X) and vertical (Y) directions at different longitudinal positions for some half-target sizes.

beam intensity should be 8.6 10^{18} per second. As the initial target thickness of Mark-II jet is expected to be 10^{13} cm^{-2}, the target luminosity, L is 8.6 10^{31}. The event rate for elastic scattering is obtained from the formula:

$$\text{Rate } (Events/hr) = L \quad \frac{d\sigma}{dt} \quad \Delta t \quad \frac{\Delta\phi}{2\pi} \quad \epsilon \quad 3600 \quad s/hr.$$

At $P_\perp^2 = 2 \ (GeV/c)^2)$, with a detection efficiency $\epsilon \sim 1$, and azimuthal angular acceptance $\Delta\phi \sim \frac{140\ mrad}{sin\ 52.8^\circ} \simeq 0.175$, one obtains the Event Rate $= 8.6 \ 10^{31} \ 42\frac{nb}{GeV^2} \ 0.17(GeV^2) \ \frac{0.175}{2\pi} \ 1 \ 3600 \ 10^{-33} \ \frac{cm^2}{nb} = 62 \ events/hr.$

We expect to obtain larger luminosities from both the beam and the target in time. Because of the low event rates, one has to be careful about the backgrounds especially in the forward arm, where the counters are close to the beam line. Preliminary estimates show that the one-arm forward background rate is of order 1 kHz. The single count rates will be much more than this, although an accurate assessment is not possible without obtaining beam halo measurements.

REFERENCES

1. D. G. Crabb et al., Phys. Rev. Letters, **65**, 3241 (1990).
2. S. J. Brodsky et al., Phys. Rev. **D20**, 2278 (1979); G. R. Farrar et al., Phys. Rev. **D20**, 202 (1979).