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- TITLE -

Spin Effects in High-$P_\perp^2$ $p+p \rightarrow p+p$ at 800 to 900 GeV

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- SUMMARY -

We propose to study the spin-orbit Analyzing Power, A, in p+p → p+p at large $P_\perp^2$. We propose to run at Fermilab around Fall 1987 and scatter a high intensity unpolarized proton beam of 800 to 900 GeV from a Polarized Proton Target; we would measure the difference between the $d\sigma/dt$ when the target spin is up and when it is down.

Our main goal is to see if the unexpected large values of A recently found at the 28 GeV AGS in proton-proton elastic scattering persist to Fermilab energies. The large A value of 24 ± 8% at $P_\perp^2 = 6.5$ $(\text{GeV/c})^2$ was not only unexpected but also seems difficult to reconcile with the A = 0 prediction of conventional models of strong interactions, such as perturbative QCD. The validity of perturbative QCD is believed to improve with increasing energy and with increasing $P_\perp^2$, and this proposed Fermilab experiment would increase the incident energy by about a factor of 30.

The experiment would be done using a Polarized Proton Target (PPT) employing radiation-doped NH_3 beads and a "local" cooling power of about 130 mW at 1/2°K. Such a target could be used with a beam intensity of 3 to 6 10^{10} protons per second, which is 1.5 to 3.0 10^{12} protons per pulse with Fermilab's 50 sec rep rate. This high beam intensity would allow good measurements out to about $P_\perp^2 = 10$ $(\text{GeV/c})^2$ where the p+p → p+p cross section is quite small.

We propose to run in an underground target station such as P-West, which is ideally suited for such a high-$P_\perp^2$ elastic scattering experiment. We would use a double-arm spectrometer consisting of magnets with considerable bending power and high resolution scintillation hodoscopes and wire chambers. The hodoscopes should operate successfully in the somewhat hostile environment caused by some 10^{12} protons per pulse. The resulting good resolution on both angle and momentum for both the forward and recoil protons should provide adequate discrimination against inelastic events and events from the non-hydrogen protons in the PPT. We would further improve the resolution by using a 2.5 mm diameter beam and "rastering" it in a 15 mm × 10 mm (HxV) pattern across the PPT on each pulse. An additional improvement would come from 10° of vertical bending on the recoil arm. Using this large bend together with 2 mm resolution vertical wire chambers and the tiny rastered beam will give very good momentum resolution which should strongly discriminate against "non-elastic" events. We would significantly increase the solid angle and further reduce the background by using a quadrupole pair on the recoil arm to make the diverging protons approximately parallel.

- PHYSICS JUSTIFICATION -

The proposed experiment would study spin effects in proton-proton elastic scattering at the highest possible energy and $P_\perp^2$. Experiments[1] in the late 1970's using the Argonne ZGS polarized proton beam found very large spin-spin effects in large-$P_\perp^2$ p+p → p+p near 12 GeV as shown in Fig. 1. These results were very difficult to reconcile with current theories of strong interactions, but during the past 8 years these results have come to be accepted as an inexplicable aberration.

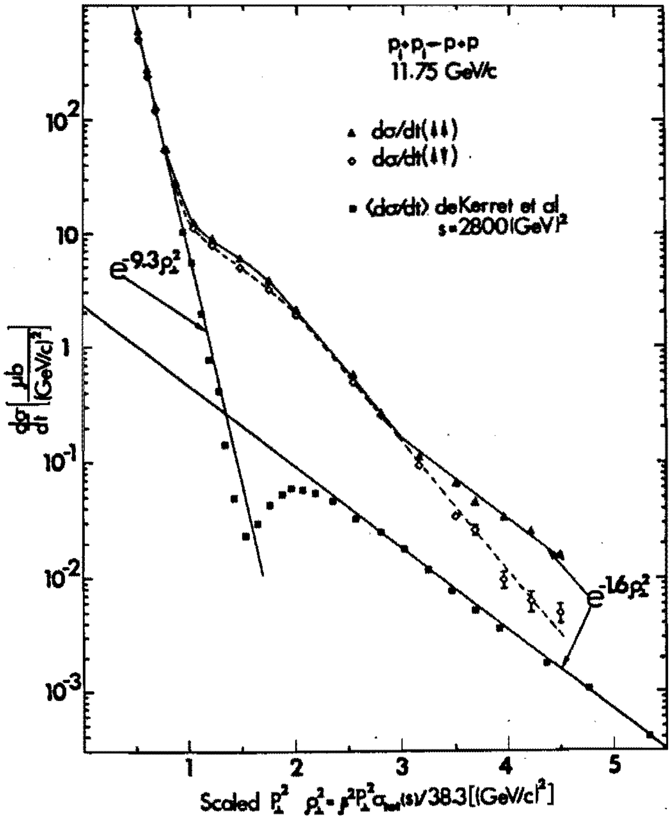


Fig. 1 Spin-Spin Effects in p+p→p+p at 12 GeV

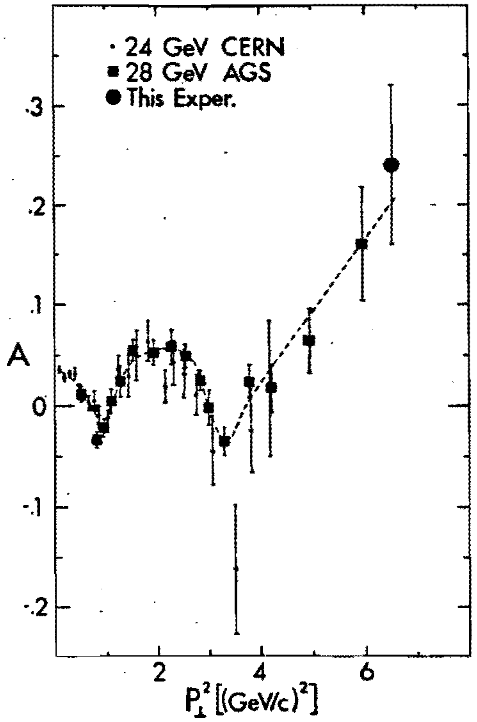


Fig. 2 One-Spin Effects in p+p→p+p at 28 GeV

Recent experiments[2] at the Brookhaven AGS have found large and surprising values of the Analyzing Power, A, in 28 GeV p+p → p+p at large $P_\perp^2$ as shown in Fig. 2. This unexpected one-spin effect was not predicted by Perturbative Quantum Chromodynamics (PQCD) and has led to some consternation within the high energy theory community. As discussed in a recent Physics Today Search and Discovery News article[3], some theorists believe that both the energy [28 GeV] and the transverse momentum [$P_\perp^2 = 6.5\ (\mathrm{GeV}/c)^2$] are too small for PQCD to be applicable. Other theorists believe the PQCD should start to be applicable in this range of E and $P_\perp^2$ and that these surprising spin results indicate that one must question PQCD's overall applicability to exclusive hadronic processes.

In view of this unclear theoretical situation we feel that it is especially appropriate to seek further experimental guidance by extending the parameter range for these high-$P_\perp^2$ spin experiments as much as possible. Thus, later this year we plan to extend our 28 GeV AGS measurements up to $P_\perp^2 = 7.2$ $(\mathrm{GeV}/c)^2$ and we may later extend them to $P_\perp^2 = 8.0$ $(\mathrm{GeV}/c)^2$ by adding additional magnets.[4] However it is very difficult to increase the $P_\perp^2$ range by a large factor because all hadronic exclusive cross sections drop so rapidly with increasing $P_\perp^2$. As shown[5] in Fig. 3 the most violent exclusive events ever observed were proton-proton elastic scattering at about $P_\perp^2 = 16$ $(\mathrm{GeV}/c)^2$ in the 1963 AGS thesis experiment[6] of one of us. In 23 years no experiment has exceeded this $P_\perp^2$ value in any exclusive hadronic measurement.

Thus it seems especially important to extend the energy range of these high-$P_\perp^2$ spin measurements. The availability of Fermilab's new Tevatron makes it possible to extend this energy range by a factor of about 30 from 28 GeV to 800 or 900 GeV.

There have been 3 previous multi-hundred-GeV measurements of A in $p + p \rightarrow p + p$ but none have extended into the large-$P_\perp^2$ region where the spin effects seem so interesting.

1. The Chamberlain group[7] measured A at 100 and 300 GeV at Fermilab out to $P_\perp^2 = 2.0$ $(\mathrm{GeV}/c)^2$.

2. The Indiana group[8] measured A from 20 to 210 GeV at Fermilab out to $P_\perp^2 = 1.0$ $(\mathrm{GeV}/c)^2$.

3. The Fidecaro group[9] made a measurement of A in $p + p \rightarrow p + p$ at 150 GeV at the CERN SPS out to almost $P_\perp^2 = 3$ $(\mathrm{GeV}/c)^2$.

All three of these experiments were limited to the $P_\perp^2$ range of 3 $(\mathrm{GeV}/c)^2$ or less, where spin effects appear to be quite small above 100 GeV. Recent improvements in polarized target technology allow the use of much higher intensity proton beams, which permit precise measurements of A out to $P_\perp^2$ of at least 7 $(\mathrm{GeV}/c)^2$. This is the $P_\perp^2$ region where A is quite large at 28 GeV. The main goal of our proposed experiment is to see if this large and unexpected spin effect in hard proton-proton elastic scattering persists to Tevatron energies.

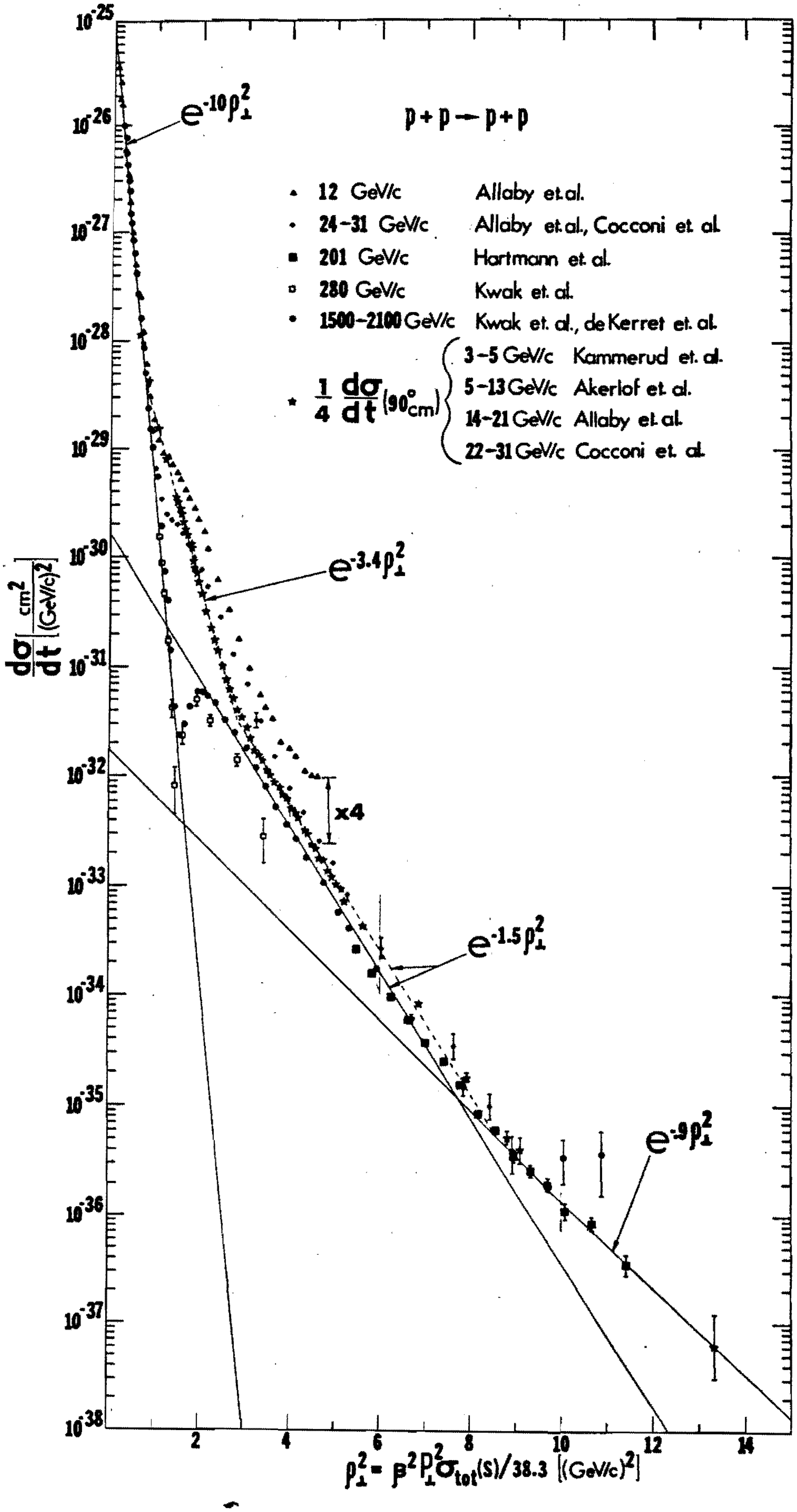


Fig. 3 Differential Cross Section for p-p Elastic Scattering Plotted Against Scaled $P_\perp{}^2$ Variable

- EXPERIMENTAL APPARATUS -

We would scatter a high intensity 800 to 900 GeV unpolarized extracted proton beam from a Polarized Proton Target and use a high-resolution double arm spectrometer to detect proton-proton elastic scattering events in the $P_\perp^2$ range of about 2 to 10 $(GeV/c)^2$.

Polarized Proton Target

The Polarized Proton Target will probably be one of the University of Michigan targets. Our conventional target has a 4 cm long by 2.9 cm diameter target flask which contains ammonia (NH_3) beads which are cooled to 0.5°K by a ^3He evaporation refrigerator. This cryostat is placed in the 2.5 T field of our conventional iron magnet, which is uniform to about 1 part in 10^4 in both time and space over the entire volume of the target flask. Polarizing transitions are driven by a 70 GHz microwave system and the polarization of the free protons is measured with a 107 MHz NMR system. We developed a technique to operate this target with an average proton beam intensity of $3\ 10^{10}$ per second by using radiation-doped NH_3 beads and by using a ^3He-^4He mixture as the circulating fluid in the ^3He cryostat. The NH_3 beads are given a dose of about 10^{17} electrons/cm^2 using the MIT Bates Linac. The average target polarization is then about 55% when used in a beam of about $3\ 10^{10}$ protons per second.

We are now planning a further upgrade to allow operation of a Polarized Proton Target at even higher beam intensity. We have ordered a 140 GHz microwave tube from Varian which will be delivered this Spring. We are planning a 5 T high-uniformity superconducting solenoid to match this 140 GHz frequency. With 5 T we can get a target polarization of 55% or more[10] by operating at 1°K, while with 2.5 T this polarization requires 0.5°K operation. Fortunately it is easy to obtain a much larger cooling power at 1°K where a ^4He evaporation refrigerator is quite efficient. For temperatures near 0.5°K the evaporation of ^3He is required since the ^4He vapor pressure goes rapidly to zero below 1°K. If this new cryostat works as planned we should be able to use average beam intensities of 1 to 2 10^{11} per second which should allow us to extend our $P_\perp^2$ range well beyond our present maximum value of 6.5 $(GeV/c)^2$.

Realistically the new 5 T PPT magnet may not be ready by Fall 1987 and we would probably begin the run with our present 2.5 T / 70 GHz PPT. As demonstrated at the AGS this is certainly adequate for measurements up to about $P_\perp^2 = 7\ (GeV/c)^2$.

Extracted Proton Beam

To allow precise measurements at very large $P_\perp^2$ where $d\sigma/dt$ is quite small we propose to use as high a beam intensity as possible. There are three factors which will limit our maximum intensity:

1. The overall and local cooling power of our present polarized target cryostat limits us to an average intensity of about $3\ 10^{10}$ protons per second ($1.5\ 10^{12}$ protons per 50 sec pulse). If the 5 T / 140 GHz planned PPT operates as expected then our cooling power limit should increase to about 1 to 2 10^{11} protons per sec (5 to 10 10^{12} protons per 50 sec pulse).

2. Accidental coincidences become more serious at high beam intensity. However, we have recently used 100 to 300 MHz logic, added more sophisticated accidental monitoring logic, hardened the photomultiplier tube voltages, and increased shielding and bending, so that we can easily operate with instantaneous beam rates of a few 10^{11} protons per second. Unless the Tevatron duty factor becomes less than 10%, accidentals should not be a serious problem.

3. The maximum beam allocated to this experiment by the Fermilab management may vary with time. For the smaller $P_\perp^2$ points we could easily make precise measurements with 5% of the total beam (~ 5 10^{11} protons per pulse). At the maximum $P_\perp^2$, if our upgraded PPT works, we would benefit from having 3 to 5 10^{12} protons per pulse.

In view of these high intensities it is clearly wise to use an underground target lab such as Proton West where earth serves as radiation shielding. We feel that placing the PPT in the most upstream cave of Proton West as shown in Fig. 4 seems sensible. We will discuss this in more detail in the spectrometer section.

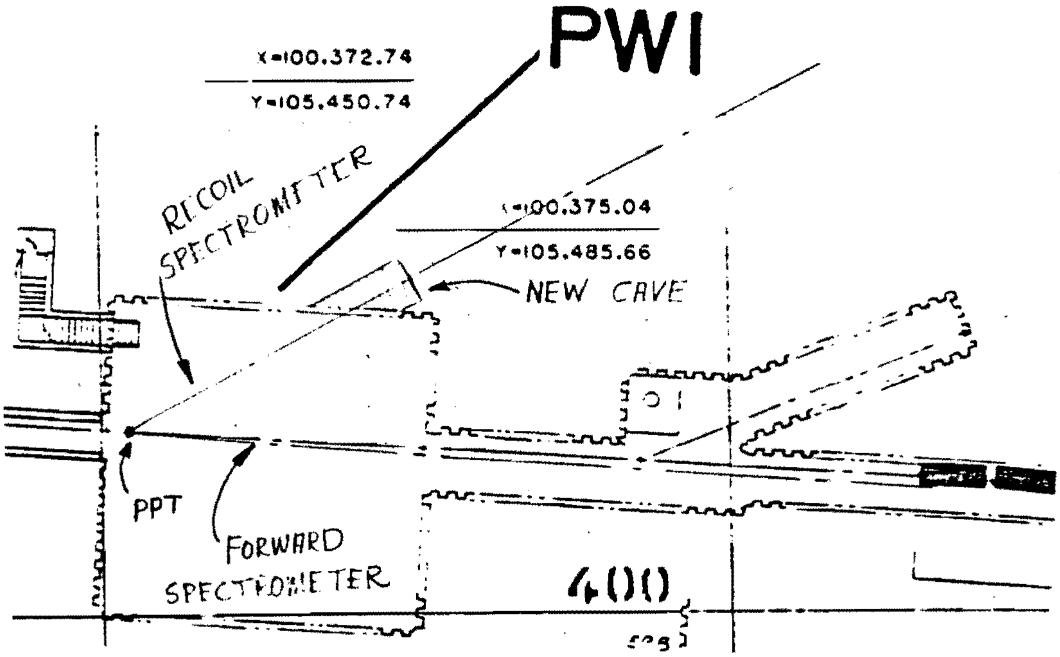


Fig. 4 Proton West Cave

We would plan to operate at the normal Tevatron energy of 800 to 900 GeV. Some proposed properties of the extracted beam at our PPT are:

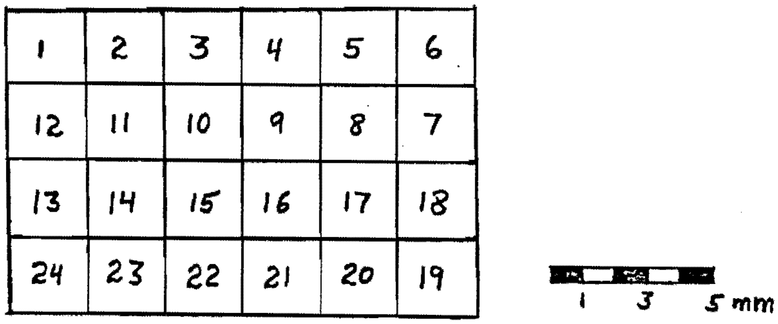
1. Intensity: 5 10^{11} to 5 10^{12} protons per 50 sec pulse.

2. Beam spot size: 2.5 mm × 2.5 mm (H×V) FWHM.

3. Beam divergence: 0.05 mrad × 0.05 mrad (H×V) FWHM.

4. Rastering:

We wish to eliminate local overheating in our PPT, while still maintaining a small beam size to give precise vertex position identification. Therefore we propose to use small upstream bending magnets to "raster" the beam across the area of our PPT during each 30 sec long beam pulse. This idea, which has been used at SLAC, is similar to the way the electrons are swept across a TV screen. Our present plan is to use a 15 mm × 10 mm (H×V) effective beam spot on our PPT with a 2.5 mm × 2.5 mm instantaneous spot size. Thus the raster pattern might look like:



1	2	3	4	5	6
12	11	10	9	8	7
13	14	15	16	17	18
24	23	22	21	20	19

Fig. 5 Possible Raster Pattern

We would propose to move the beam in this pattern using one horizontal and one vertical dipole bending magnet placed about 100 m upstream of our PPT. Then the maximum horizontal and vertical field required would be

$$\int B \cdot dl = \frac{15\ \mathrm{mm}}{100\ \mathrm{m}}\ (900\ \mathrm{GeV/c})1313.22 = 177\ \mathrm{KG\text{-}inch}$$

This rastering would introduce maximum angles of ± 0.075 mrad which is larger than the beam's angular divergence of ± 0.025 mrad. Thus we may want a second magnet pair to realign the beam's angle, just upstream of the PPT. Since there are 24 positions in the raster pattern and the total raster time is about 30 sec, the sweep time in the magnets is modest. We have had considerable experience with much faster response times in our servo system which keeps the beam well centered on our PPT by compensating for variations in the AGS extracted beam's angle and energy with a millisecond response time.

5. Servo and Position Monitoring System:

We would probably install fast position detectors to keep the beam properly centered on the desired raster position using the same horizontal and vertical raster magnets. This servo system would compensate for small variations in the energy and angle of the extracted Tevatron beam. We would use these same position detectors to monitor the horizontal and vertical position and size of the beam. We would probably use segmented wire ion chambers (SWIC's) as we now do. The digitized information from these SWIC's would be used together with our spectrometer to give high precision information about the kinematics of the elastic events, especially the recoil protons' momenta, which will be measured by the vertical bend.

Spectrometer

We would use a double arm spectrometer to detect events in which the high intensity 800 to 900 GeV extracted proton beam is elastically scattered from our polarized proton target. The spectrometer was designed to have the following properties:

1. The spectrometer should have good angular and momentum resolution on both the scattered and recoil protons to discriminate against non-elastic events and events from the non-hydrogen protons in the PPT.
2. The spectrometer should be "hardened" to allow operation with beam intensities of 5 10^{11} to 5 10^{12} protons per pulse.
3. The spectrometer should have as large a solid angle as possible to maximize the event rate for the very rare hard collisions at large $P_\perp^2$.
4. The spectrometer should be as fully "on-line" as possible to provide instantaneous data analysis and instantaneous information about unanticipated problems with the experiment.
5. The spectrometer should be flexible to allow necessary improvements to reduce background or to extend the $P_\perp^2$ range.

The proposed spectrometer uses fine-grain scintillation counter hodoscopes as the basic detectors. Wire chambers will be added to the 45 m long recoil arm to provide very precise momentum resolution. The momentum analysis and the steering of the forward scattered and the recoil protons are provided by a series of dipole bending magnets. To increase the solid angle in the recoil arm, focusing is provided by a pair of quadrupole magnets. In both the forward arm and the recoil arm the bending for steering is horizontal while the main bending for momentum analysis is vertical. Because of the difficulty of bending and momentum analyzing the 800 to 900 GeV forward scattered protons we propose to use a very long lever arm to allow significant spatial separation with only small bend angles. Thus the spectrometer is about 300 m long. The upstream part of the spectrometer was shown in Fig. 4, and the magnets required are listed in Table 1.

Table 1. Magnets Required

Magnet	Dist. of L from PPT L (Meters)	GAP (inches) H	W	L	OUTER SIZE (inches) H	W	L	Max B_0 (KiloGauss)	Amps	(Tons)	Comments
MF_1	10	0.8	6	157	23	18	168	16	1400	8	R-1 0.6" Septum built for E-6
MF_2	30	2	12	100	46	37	110	16	1400	21	Polarimeter Magnet from AGS
MF_3	40	2	12	100	46	37	110	16	1400	21	Polarimeter Magnet from AGS
MF_4	63	1.5	5	239	14	25	244	17.9	4600	13	B-2 Main Ring Magnet Vertical Bend
MF_5	70	1.5	5	239	14	25	244	17.9	4600	13	B-2 Main Ring Magnet Vertical Bend
MF_6	77	1.5	5	239	14	25	244	17.9	4600	13	B-2 Main Ring Magnet Vertical Bend
Q_1	1.1	5	5	36	35	35	45	4.8 KG/inch	1200	3.5	5Q36 Quadrupole
Q_2	2	5	5	18	28	28	26	4.8 KG/inch	1200	2	5Q18 Quadrupole
H_1	4	6	18	72	44	81	94	18.6	2400	35	18 VI 72 Dipole
H_2	9.5	6	15	30	42	88	51	20.0	1300	18	15 VI 30 Dipole
V_1	12	6	18	72	44	81	94	18.6	2400	35	18 VI 72 Dipole Vertical Bend

In designing the spectrometer it is necessary to know the range of kinematic variables in our desired range of $P_\perp^2 = 2$ to 10 $(\mathrm{GeV}/c)^2$. At 900 GeV some of these are:

	Scattered Proton		Recoil Proton	
$P_\perp^2$ $(\mathrm{GeV}/c)^2$	Angle [mrad]	Momentum [GeV/c]	Angle [mrad]	Momentum [GeV/c]
2	1.573	898.9	923.9	1.772
6	2.731	896.8	651.5	4.040
10	3.535	894.6	532.5	6.229

Some noteworthy features which can be seen from this table are:

1. The forward angle is very small and it will be non-trivial to separate the forward scattered protons from the unscattered beam protons.

2. The momenta of the forward scattered protons vary very little and very precise momentum analysis here will be simultaneously difficult and of limited value.

3. The recoil momenta and angles are very similar to their values at much lower incident energy. Thus the recoil arm offers the best opportunity to have good angle and momentum resolution.

Forward Spectrometer Arm

The forward arm of the spectrometer would be 300 m long as shown in Fig. 6. The 4 m long "R-1" septum magnet (MF_1) helps to separate the scattered protons from the unscattered beam by bending them by an angle of 0 to 2.0 mr away from the beam. The scattered protons are then bent by 1.3 mr in a 2.5 m long C-magnet (MF_2). They are then bent by about 1.0 mrad by a second 2.5 m C-magnet (MF_3) and realigned into the downstream part of the spectrometer. The protons then enter the three standard ring magnets (MF_4, MF_5, MF_6) in the downstream part of P-West Cave where they are bent vertically up by an angle of 10.0 mrad. The protons then pass through a 200 meter long evacuated beampipe which must be cut in the earth. The final detectors would be placed in a small "pit" built at the end of the beampipe. Unfortunately the upstream end of the beampipe may have to be drilled through an iron beamstop; missing this beamstop would require considerably more upstream bending.

The forward arm detectors will be scintillation counter hodoscopes. The final detectors F_3 and F_4 will be about 5 cm × 30 cm in size (H×V) at a distance of 300 m from the PPT. They will be respectively horizontal and vertical hodoscopes of 5 and 30 channels each, and thus of 1 cm resolution. The F_1 and F_2 detectors will be just downstream of the final bending magnet at a distance of about 80 meters from the PPT. They will be hodoscopes about 2 cm × 10 cm in size, again with 5 by 30 channels.

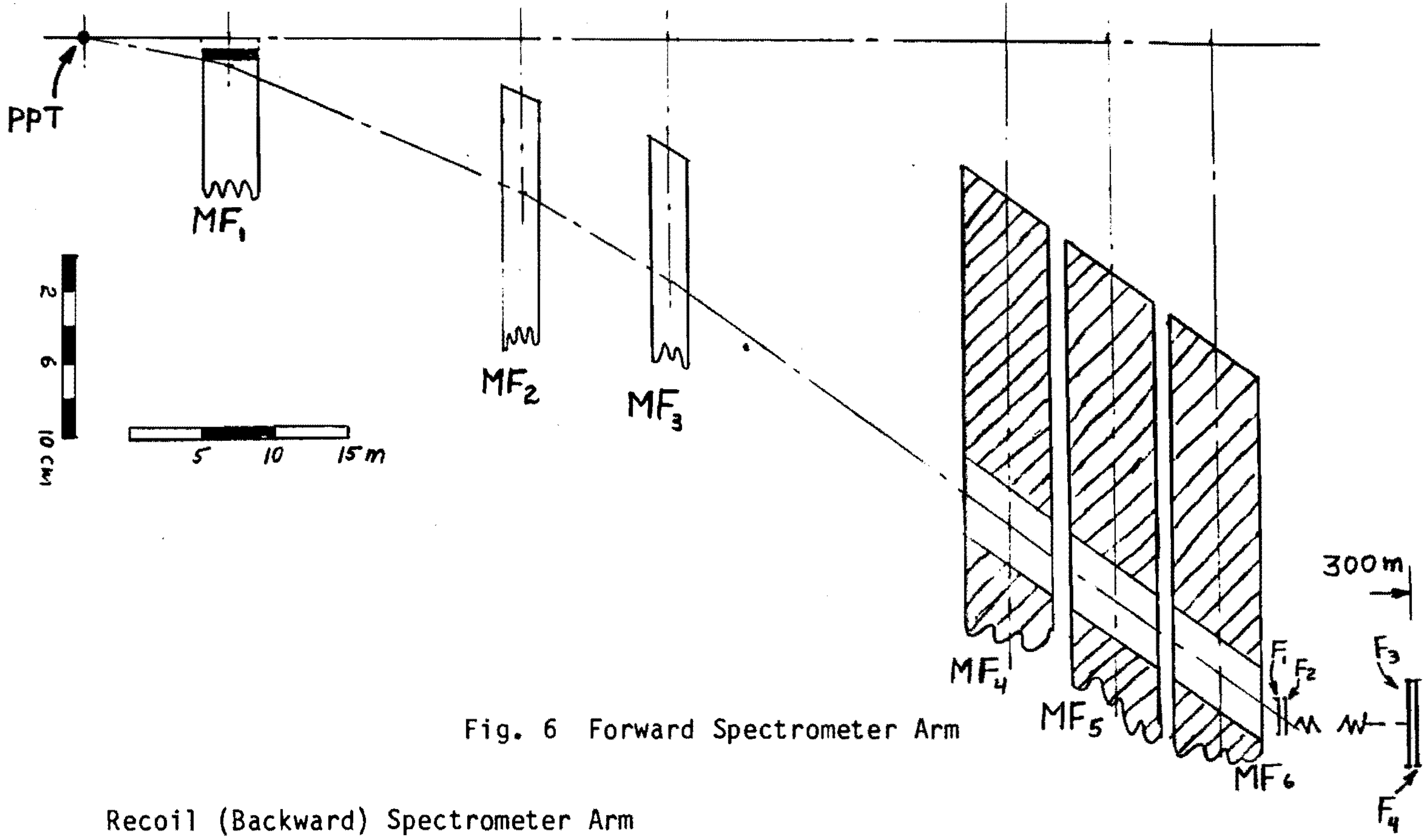


Fig. 6 Forward Spectrometer Arm

Recoil (Backward) Spectrometer Arm

The strongest effort to tag elastic events cleanly will occur in the recoil arm. This backward spectrometer will be 45 m long and will have high resolution detectors and 10° of vertical bending to provide very precise momentum analysis of the recoil protons whose momentum range is 1.8 to 6.2 GeV/c. The details of the recoil spectrometer are shown in Fig. 7. Unfortunately, a small excavated extension in the P-West cave will be required as shown in Figs. 4 and 7. We will now discuss some of the properties of the recoil spectrometer.

1. Solid Angle Matching:

The ratio of the Recoil (Backward) to Forward Jacobians is huge for 900 GeV proton-proton elastic-scattering. This quantity

$$J_B : J_F \equiv \frac{\partial\Omega_{\text{Recoil}}}{\partial\Omega_{\text{cm}}} : \frac{\partial\Omega_{\text{Forward}}}{\partial\Omega_{\text{cm}}}$$

varies between 2.5 10^5 at $P_\perp^2 = 2$ $(\text{GeV/c})^2$ and 2.0 10^4 at $P_\perp^2 = 10$ $(\text{GeV/c})^2$. This means that the very tiny lab solid angle subtended by the 5 cm × 30 cm F_4 detector at 300 m ($\sim 10^{-7}$ sr) is matched into recoil detectors which would be about 3 m × 12 m at 45 m for $P_\perp^2 = 2$ $(\text{GeV/c})^2$ $(\Delta\Omega_{\text{lab}} > 2\ 10^{-2}$ sr). Such huge detectors are clearly rather unattractive; moreover beamports for such detectors would present significant construction, radiation and practical problems. A special problem would be the cost of the large aperture downstream bending magnets for such a recoil arm.

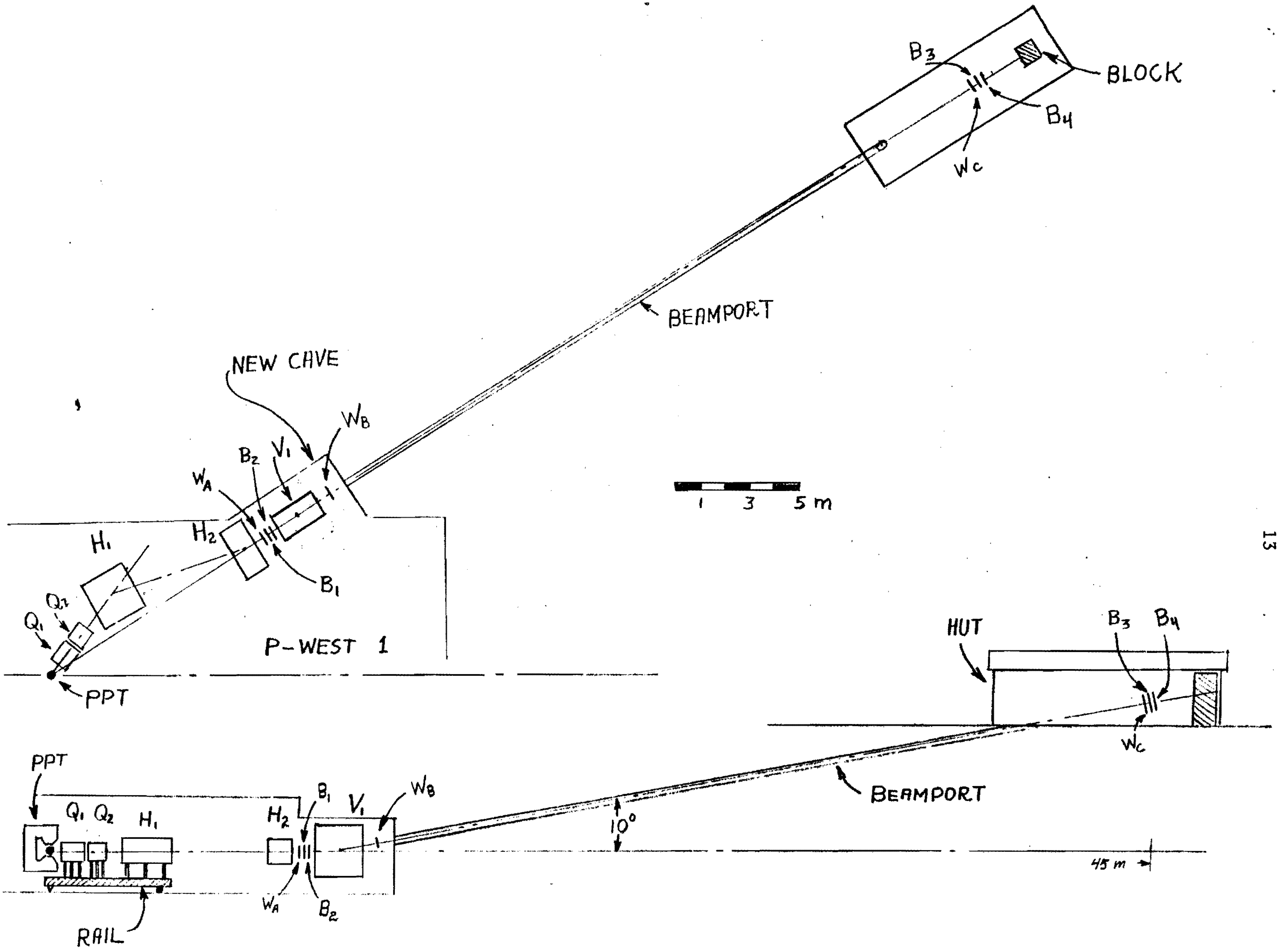


Fig. 7 Recoil (Backward) Spectrometer

2. Focusing Quadrupoles:

We propose to eliminate the above problems while maintaining a large solid angle by installing a pair of focusing quadrupoles close to the PPT. As shown in Fig. 7 the upstream quadrupole will be a 5Q36 (Vertical Focusing) while the downstream quadrupole will be a 5Q18 (Horizontal Focusing). There is also a "kinematic focusing" effect for elastically scattered protons caused by the horizontal bending. Together with this kinematic focusing, this pair of quadrupoles focuses the diverging beam of recoil protons into a vertically and horizontally parallel beam which can be easily managed with small aperture magnets, a small beamport, and small detectors.

3. Steering Magnets and Rail:

To cover the $P_{\perp}^2$ range 2 to 10 $(GeV/c)^2$ we must be able to cover the angular range 924 to 533 mrad (52.9° to 30.5°). It would be very undesirable to have to move the large vertical bending magnets, the detectors, and the beamport through the earth. We therefore plan to mount the pair of quadrupoles and a steering dipole magnet on a rail pivoted about the PPT. The rail would be rotated to the proper angle for each $P_{\perp}^2$ which we measure. The steering magnet would then be adjusted to aim the recoil protons into the smaller downstream horizontal dipole. This downstream magnet would be adjusted to align the protons with the downstream part of the spectrometer which is fixed at an angle of 32°, as shown in Fig. 7.

4. Vertical Bending Magnets and Beamport:

As shown in Fig. 7 the recoil protons are next bent vertically upward by a standard 6 ft. magnet through an angle of 10° into an evacuated beamport which passes upward through the earth and emerges at ground level. The final detectors are at the end of this beamport, in a portable building. The beamport will be about 25 m long and about 30 cm × 50 cm in size (H×V), and must be cut in the earth along with a small extension to P-West cave about 5 m long and 3 m in diameter.

5. Detectors:

As shown in Fig. 7 there are two independent sets of detectors in the recoil arm. The medium resolution scintillation counter hodoscopes would give the fast "trigger". The high resolution wire chambers would give a precise vertical momentum measurement.

There will be three planes of wire chambers:

W_A Just upstream of the vertical bend
W_B Just downstream of the vertical bend
W_C At the end of the spectrometer .

These should each have a resolution of about 2 mm FWHM. The vertical position of the vertex will be known to about 2.5 mm FWHM, by using the rastering technique. The 10° vertical bend with a lever arm of 33 m will give a vertical displacement of 5.82 m. Thus we obtain

$$(\Delta P/_{P})_{d} = \frac{\sqrt{(2\ \text{mm})^2 + (2\ \text{mm})^2}}{5.82\ \text{m}} = \frac{2.83\ \text{mm}}{5.82\ \text{m}} = 4.9\ 10^{-4}$$

Unfortunately there is an additional uncertainty in the momentum introduced by the upstream part of the recoil spectrometer

$$(\Delta P/_{P})_{u} = \frac{\sqrt{(2\ \text{mm})^2 + (2.5\ \text{mm})^2}}{5.82\ \text{m}\ (12\ \text{m}/33\ \text{m})} = \frac{3.20\ \text{mm}}{2.12\ \text{m}} = 15.1\ 10^{-4}$$

The total momentum resolution will thus be approximately

$$\Delta P/_{P} = \sqrt{(4.9\ 10^{-4})^2 + (15.1\ 10^{-4})^2} = 1.6\ 10^{-3}\ \text{FWHM}$$

The downstream recoil hodoscopes, B_3 and B_4, will each be about 30 cm × 60 cm in size (H×V). They will be respectively 10 channels horizontally and 30 channels vertically giving 3 cm and 2 cm resolution. The 3 cm horizontal resolution is matched to the 4 cm horizontal length of the PPT. The upstream hodoscopes, B_1 and B_2, will each be about 15 cm × 15 cm, again respectively with 10 channel horizontal resolution and 30 channel vertical resolution. These hodoscopes will all be constructed of scintillation counters with fast photomultiplier tubes. The larger vertical size of B_3 and B_4 is caused by the fanning-out due to the 10° bend and the momentum variation as we move across the $P_{\perp}^2$ bite.

6. Logic:

We will use fast logic to form a matrix of appropriate coincidences between the forward spectrometer and recoil spectrometer. An elastic event will be denoted by an eightfold coincidence of the type

$$F \cdot B \equiv F_1 \cdot F_2 \cdot F_3 \cdot F_4 \cdot B_1 \cdot B_2 \cdot B_3 \cdot B_4$$

We will use a matrix logic system to hardwire appropriate hodoscope channels with the following goals:

1. Identify elastic events with only a small loss of true elastic events.

2. Exclude most background events due to inelastics and scattering from non-hydrogen protons in the PPT.

Obviously some compromise between these two goals must be made by adjusting the "tightness" of the matrix.

The hodoscopes' final 8-fold signal will serve as the trigger for the 3 planes of vertical wire chambers. These wire chambers will therefore not be read very often, but they should significantly reduce the background. We hope that the analysis of the wire chamber data will be fully online, but in any case it should not be very far offline.

7. Background:

Our collaboration is fairly experienced at studying spin effects at high $P_\perp^2$ at the AGS[2] and at high energy at the SPS[9]. This proposed experiment has considerably better resolution than either the AGS or CERN experiment. Based on analytic calculations we estimate that we should have acceptable background levels for proton-proton elastic scattering at 900 GeV at $P_\perp^2$ up to 10 $(\mathrm{GeV}/c)^2$. We are now doing Monte Carlo calculations to make a second independent estimate of the background rates for inelastic events and quasielastic events from non-hydrogen protons in the PPT. We would also experimentally estimate these backgrounds at several $P_\perp^2$ points by taking special background runs with the normal NH_3 PPT beads replaced by Teflon beads which contain no hydrogen protons.

We will experimentally estimate the accidental coincidences using various circuits with suitable extra delays. Based on our recent experience at the AGS we estimate that the accidental coincidence rate will be less than a few %.

8. Miscellaneous

The principle reason for not taking finer grain hodoscopes or wire chambers is that various factors cause smearing of the coplanarity and angular correlation. The multiple scattering in the 4 cm long by 1.5 cm wide PPT would give a smear of 3 mm FWHM at the F_4 counter and at $P_\perp^2 = 6$ $(\mathrm{GeV}/c)^2$ about 6 cm FWHM at the B_4 counter. We plan to use vacuum pipes in both spectrometer arms to minimize additional multiple scattering. The beam's angular divergence of 0.050 mrad FWHM gives a smear of 15 mm FWHM at F_4, which dominates the smearing.

There will be an additional horizontal angular spread due to variations in the $\int B \cdot dl$ of the PPT magnet seen by the recoil protons originating in different parts of the PPT. Much of this spread can be compensated by appropriate adjustments of the quadrupoles.

The computing needs for this experiment will be modest. We expect that all on-line computing will be done using our small computers.

- EVENT RATE AND RUNNING TIME -

We can estimate the event rate by taking the differential cross section from Fig. 3. We use the solid angle subtended by the forward spectrometer and assume that we will capture 50% of the mate recoil protons in the recoil arm. We will assume conservatively a 50% average target polarization (P_T). We would make a separate measurement at each of the $P_\perp^2$ values listed in Table 2. We have calculated the event rates using the equation

$$\text{Events}/_{\text{hour}} = (N_0 \rho t)\left(\frac{3}{17}\right)\left(\frac{\text{Protons}}{\text{pulse}}\right)\left(\frac{\text{Pulses}}{\text{hour}}\right)\frac{d\sigma}{dt}\,\Delta t\,\left(\frac{\Delta\phi}{2\pi}\right)\text{(.5 capture efficiency)}$$

With a $t = 4$ cm long target and an effective density of $\rho = .55$ gm/cm^3 for NH_3 PPT beads, using $N_0 = 6.02\ 10^{23}$ molecules/mole we have for the density of free hydrogen protons in NH_3:

$$\left(\frac{3}{17}\right)(N_0 \rho t) = 2.34\ 10^{23}\ \text{protons/cm}^2$$

The statistical error in the analyzing power, A, is given by

$$\Delta A_{\text{stat}} = \frac{1}{P_T\sqrt{\text{Events}}}$$

We estimate that the total uncertainty in A should be 30% larger to take into account inelastic, non-hydrogen, and accidental backgrounds

$$\Delta A_{\text{TOT}} = 1.3\ \Delta A_{\text{statistical}}$$

In Table 2 we have listed for each $P_\perp^2$ point, the cross-section $d\sigma/dt$, the Δt and $\Delta\phi$ bites subtended by the spectrometer, the proposed intensity, the expected event rate, and the proposed number of hours. We also list the total number of events and the total expected error in the Analyzing Power A. The total number of hours is rather large and probably would not fit into one running period. This may be appropriate, since we may want to modify the experiment based on the early measurements at smaller $P_\perp^2$, before making the larger $P_\perp^2$ measurements.

We could probably be ready to make the first small $P_\perp^2$ measurements during the Fall 1987 Tevatron running period.

Table 2. Event Rate, Intensity, Hours, and Error in Analyzing Power

$P_\perp^2$ $(\mathrm{GeV}/c)^2$	$d\sigma/dt$ $\mathrm{cm}^2/(\mathrm{GeV}/c)^2$	Δt $(\mathrm{GeV}/c)^2$	$\Delta\phi/2\pi$	Intensity (Protons/ Pulse)	$\frac{\text{Events}}{\text{hour}}$	Hours	Events	$1.3\Delta A_{stat}$
2	$6\ 10^{-32}$	.41	.105	$5\ 10^{11}$	$1.1\ 10^{4}$	100	$1.1\ 10^{6}$	± .3%
3	$2\ 10^{-32}$	.47	.083	$5\ 10^{11}$	3200	100	$3.2\ 10^{5}$	± .5%
4	$4\ 10^{-33}$	.59	.072	10^{12}	1400	200	$2.8\ 10^{5}$	± .5%
5	$7\ 10^{-34}$	.65	.064	10^{12}	240	200	$4.8\ 10^{4}$	± 1.2%
6	$1.5\ 10^{-34}$	.73	.058	$2\ 10^{12}$	100	300	$3.0\ 10^{4}$	± 1.5%
8	$1.3\ 10^{-35}$	.85	.051	$3\ 10^{12}$	14	500	9000	± 2.7%
10	$1.5\ 10^{-36}$	.91	.045	$5\ 10^{12}$	2.5	800	2000	± 5.8%

Subtotal	2200 hours
Tuneup Time	200 hours
Total	2400 hours

*Subject to CERN approval.

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