FERMILAB-Proposal-0579

Study of Polarization of Inclusively - Produced Neutrons

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SUMMARY

The polarization of neutrons produced by the proton beam incident on a Be target may be studied using scattering from a heavy element at an angle where the nuclear and electromagnetic amplitudes are comparable (Schwinger scattering). This scattering has an analyzing power of up to 100%.

Whereas polarization in elastic scattering of hadrons at Fermilab energies ($\geq$ 100 GeV) has been shown to be quite small, it has also been found, surprizingly, that inclusively-produced Λ's are polarized by up to 30%. It is of obvious interest to explore the possible polarization of other baryons such as neutrons. The M3-beam in the meson lab provides an ideal opportunity for such a study by varying the production angle (0.5 - 4 mr) and examining the polarization using Schwinger scattering as an analyzer.

The scatterer, 1/2 λ of U, would be located about 675 ft from the production target, just beyond a 1/16" collimator. The scattered neutrons would be detected by a PWC system behind an Fe converter plate and followed in turn by an ionization calorimeter all at about 1350 ft (under the meson detector building mezzanine). A second phase of the experiment would employ a double scattering to calibrate the polarization - analyzing power of the Schwinger scattering. This would involve the same equipment plus an additional collimator and would run the full length of the M3 wonder building. About 800 hours would be required for setup and data collection.

I. Physics

A. Relationship to Other Reactions.

The polarization in the reactions $p+p \rightarrow \vec{\Lambda} + X$ and $p + Be \rightarrow \vec{\Lambda} + X$ has been measured and found to be substantial in the range $0.2 \leqslant x \leqslant 0.7$; in fact when expressed in terms of $P/\sin \theta_{c.m.}$, the polarization rises to over half the saturation value.[1]

The polarization of the recoil proton in the reaction $p+C \rightarrow X+\vec{p}$ and $p+p \rightarrow \vec{p}+X$ has been measured in CO by the Indiana group. In the first reaction the proton (knocked out of the carbon nucleus) was seen to be polarized, however the polarization of the proton from pp is consistent with zero on the basis of the preliminary analysis of those data (private communications from H. Neal). These experiments were done at $x \simeq 0.9$, in contrast with the Λ experiments.

The proposed neutron measurements would be done over the range of x similar to the Λ measurements, $0.2 \leqslant x \leqslant 0.8$. More importantly, the physics of the $pp \rightarrow \vec{n}x$ reaction is much more similar to the $pp \rightarrow \vec{\Lambda}x$ than to $pp \rightarrow \vec{p}x$ because the neutron production cannot proceed via Pomeron exchange whereas the proton production at the large values of x studied is most probably dominated by Pomeron exchange (see Figure 1).[2] We therefore do not believe that the proton experiment should be a guide to the potential interest in this proposed experiment.

B. Theoretical Interest

Recently there has been growing interest in polarization

I. Introduction

The E-8 group has found that Λ's are polarized with $P \simeq 0.3\, p_\perp$, over the range $0.4 < y < 0.7$, when produced inclusively by 400 GeV protons incident on a Be target[1] (Figure 1). Neutrons are produced much more copiously, and might be similarly-or more, or less - polarized. Ulimately a theory of strong interactions based on the quark model and Q.C.D. must be able to predict such polarization phenomena.

Neutrons scattered by heavy elements at very small angles are strongly polarized due to the interference between the (almost totally imaginary) nuclear amplitude and the spin-flip electromagnetic amplitude. As originally noted by Schwinger[2] and emphasized for Fermilab beams by Rosen[3] and in general by Leader[4], the polarization in this process is given by

$$P = (2q/1+q^2)(1 + \rho^2)^{-1}$$

where $q = p_\perp/p_{\perp\circ}$, and $p_{\perp\circ} = \frac{4\pi\alpha Z\mu}{m\sigma_T(nA)}$ (Figure 2).

For n-U elastic scattering, $p_{\perp\circ} \cong 2$ MeV/c, and $\rho \cong 0$. For analysis of polarized beams, this is also the analyzing power (modified by a factor $\langle|\cos\varphi|\rangle$).

The M3 neutron beam has been produced by protons incident on the meson laboratory Be production target at a vertical pitch angle of 0.5-1.75 mr (Figure 3). If the neutrons are polarized on production, this would have not been observed or relevant in any past experiments (e.g. np elastic scattering (E248)) as they would be horizontally polarized and these experiments studied scattering (or production) in a horizontal plane. Furthermore, the bending (M2) and sweeping magnets in M3 with vertical fields would have precessed the beam through some arbitrary vertical angle.

The new flexibility in the meson lab makes possible targeting tangent to M1 or M6, thus varying the M3 production angle by up to ~3 mr horizontally. Hence a range of neutron production angles is available in the M3 beam.

Experimental Details:

Configuration: The meson production target is beryllium of 1/16" (square) cross section. A 1/16" diameter collimator at 675 ft subtends 5×10^{-11} sr and an angle of $\pm 4\mu$ rad. A scatterer of 1/2 λ of U at that point produces scattered beam at 1350 ft, and a 3/16"-1/4" diameter plug (i.e. rod 3/16"-1/4" diameter, 4 ft long) would block the unscattered flux. A detector behind this plug would detect neutrons scattered from U through angles from θ = 12-15μ rad ($q \cong 2$ at 300 GeV) to an arbitrary maximum (e.g. $\theta \cong 60\mu$ rad depending on the sensitive detector area) where the angles are uncertain by $\pm 12\mu$ rad (maximum) due to the finite target and first collimator size (Figure 4).

Detector: The detector would be, in sequence, an anticoincidence counter, a 1 inch Fe converter, an x-y pair of PWC planes, and an ionization calorimeter (Figure 5). Experience with E248 has demonstrated that the position resolution of the neutron vertex may be found to ± 1 mm(FWHM); the E4 calorimeter has an energy resolution of about 12% (FWHM). Each event would be recorded as a vertex coordinate (x,y) and an energy. About 10% of the incident neutrons will convert in the iron converter plate.

Rates: The beam flux through a 1/16" collimator at 600 ft is about 10^5 neutrons per pulse, (depending on targeting angle and protons on target.) At 300 GeV about 1.5×10^{-2} of these are scattered into the angular acceptance of the detector (15 to 60 μ rad.); this fraction falls at lower energy, where the analyzing power of the scattering rises. With the 10% conversion efficiency of the detector, about 100 scattered neutrons per pulse would be detected. This would provide about 500,000 events per (20 hr) day. For these parameters, the analyzing power of the scattering averaged over the scattering angle ranges from .4 to .9 (the lower value at the higher energy where the flux is greatest.) Hence in one week (~ 100 hours) it should be possible to measure the polarization of the neutron beam to about 1% in each of 5 energy bins between 100 and 400 GeV. Four weeks (400 hours) would permit exploration of 4 production angles, permitting a scan of x, $p_\perp$ space for the scattered neutrons for 1,2,3, and 4 mr production angles (out to $p_\perp$ = 1.6 GeV/c at 400 GeV).

Beam Line: An essential element in the beam line is the Fixed-Variable Collimator, originally built for E4 several years ago. It will require refurbishing or replacing so that it may be remotely positioned and read out by the experimenters. Other beam line elements in M3 may remain as they have been with the exception that the parallel jaw collimators should be remotely translateable in addition to their present mode. With a beam defined this tightly it is necessary to aperture the beam carefully before and after the defining collimator to minimize collimator punch- though and other halo effects. This has been done in the past only at the expense of inordinate access time which could be eliminated by a remote capability. The beam must be transported in vacuum, before and after scattering, save for gaps at the collimators (as has been customary).

An essential element in the beam is a bending magnet of at least 51.3 kg-m to precess the spin. From the M2 magnets already in the beam a determinable precession of the beam already occurs. The controlled magnet would be set to bring this spin precession to a half integral number of rotations, and to then reverse the spin by 180° periodically to cancel systematic errors due to apparatus asymmetries. A second magnet, preferably mounted to rotate (with its axis of rotation along the beam axis), should also be provided for spin precession when the beam is produced at some horizontal angle to M3. It should be noted that $\int Bdl$ of 51.3 kg-m will precess the neutron spin 180° independent of neutron momentum.

Calibration: Although the Schwinger effect is based on known electrodynamics plus the negligible real nuclear amplitude, it would be gratifying to check it and to thus calibrate the analyzing power of the scatterer. This can be done with a double scattering experiment, where the first scattering produced a polarized beam and the second scattering, in the same material, analyzes it. The orientation of components is indicated in Figure 6. The first scattering is again a 1/2 λ U target at 675 ft following a 1/8" collimator. A second 1/8" collimator at 1350 ft, offset from the beam by 1/4" accepts beam scattered through 30μr. A second, identical scatterer just beyond the second collimator scatters neutrons which are then detected at 1800-2000 ft, toward the far end of the M3 wonder building (Figure 6).

The rates in this experiment are low; only 3×10^{-4} of the primary beam is scattered through the second collimator, and of this 4×10^{-2} is elastically scattered by the second target outside the halo of the first-scattered beam (into an angular interval from 30 to 120 μr). With 5×10^{5} neutrons/pulse through the first collimator, about one double-scattered neutron per pulse is detected. Here also the average polarization and analyzing power are reduced by going to larger angles, so that $\bar{P}$(first scatter) $\cong$ 0.4, and $\bar{P}$(Second scatter) $\cong$ 0.2. A run of 100 hours would permit a 1% determination of the asymmetry, hence a 10% verification of the Schwinger effect.

These rates are deliberately vague; besides uncertainty in the M3 flux (depending on the protons targeted on M3), the exact flux and polarization varies with neutron energy. Hence, since $(d\sigma/d\Omega)\ 0° \propto p^2$, the double-scattered flux is sharpened in momentum by p^4. Increasing the scattering angle x 2 increases each of 3 solid angles x 4 so that rates increase rapidly and the polarization decreases as the scattering angles are increased. From a purely statistical argument, it appears tempting to open the solid angles much larger and measure a tiny polarization to great precision. On the other hand, systematic uncertainities and the subjective desire to see a large asymmetry argue for smaller angles. The numerical example above is an attractive compromise.

This polarization calibration exercise would require a total of 200 hours, including tuning. It could precede or follow the running of the other parts of the experiment.

Auxilliary Observations: Depending on results of this experiment it may be interesting to explore larger $p_\perp$ by repeating the experiment in the M4 beam line, where production angles up to 7-8 mr would be available.

If significant polarization is found, (and the results of E440 indicate it may be), the possibility of using the neutron beam of good intensity (10^7 per pulse was used in E248 with reasonable parameters) as a source of polarized nucleons for explicit study of polarization phenomena is obvious. Examples include the study of $\Delta\sigma_L$ and $\Delta\sigma_T$ in np total cross sections using a polarized target, the spin dependence of elastic scattering, the spin dependence of large $p_\perp$ and jet production phenomena, etc.

In this connection it should be noted that the Schwinger scattering provides a remarkably effective polarimeter for scattered neutrons, although the small solid angles involved may limit its general applicability.

Requested Running Time and Facilities:

We request 400 hours for data collection, 200 hours for the polarization calibration, and 200 hours for setup and debugging, including beam alignment. This time could be distributed to accomodate others users in view of the requested variations in M3 production angle.

We request that Fermilab furnish all beam elements, and the PREP electronics. Michigan will provide the detector system and on-line computer.

APPENDIX

A. Parameters and relationships for neutron-uranium scattering at 300 GeV

Neutron-uranium total cross section at 300 GeV:	$\sigma(nU)=3.3\mathrm{x}10^{-24}\mathrm{cm}^2$
Differential n-U elastic scattering cross section at 0°:	$\left(\frac{d\sigma}{d\Omega}\right)_O(nU)=1.55\mathrm{x}10^{-17}\mathrm{cm}^2/\mathrm{sr}$
Neutron interaction mean free path in uranium:	$\lambda(nU)=120\ \mathrm{g/cm}^2$
Fraction of incident neutron flux scattered per sterad. by a 1/2 λ U scatterer:	$\frac{0.3}{\sigma}\left(\frac{d\sigma}{d\Omega}\right)_O=1.4\mathrm{x}10^6\ \mathrm{sr}^{-1}$
Transverse momentum for maximum polarization in n-U elastic scattering:	$p_{\perp\circ}=\frac{4\pi\alpha z\mu}{m\sigma(nU)}=2.0\ \mathrm{MeV/c}$
Scattering angle corresponding to $p_{\perp\circ}$ for 300 GeV neutrons:	$p_{\perp\circ}/300 = 6.67\ \mu\mathrm{rad}$
Relative scattering angle:	$q = p_{\perp}/p_{\perp\circ}$
Reference solid angle for 300 GeV neutrons:	$\delta\Omega_O=\pi(p_{\perp\circ}/300)^2=1.4\mathrm{x}10^{-10}\mathrm{sr}$
Fraction of incident neutrons scattered into solid angle subtended by q from a 1/2 λ U scatterer:	$\frac{0.3}{\sigma}\left(\frac{d\sigma}{d\Omega}\right)\delta\Omega_O q^2=2\mathrm{x}10^{-4}q^2$

B. Parameters for proposed experiment

1. Polarization in inclusive neutron production (numbers correspond to 300 GeV neutrons) (Figure 4).

Angle subtended by first collimator from production target:	4μ rad, 0.6q
Angular range subtended by detector from first scatterer; direct beam blocked:	15 μ rad-60μ rad 2.25q-9q
Fraction of incident neutron flux scattered into acceptance of detector:	$1.5x10^{-2}$

2. Calibration and verification of Schwinger scattering (300 GeV) (Figure 6).

Angles subtended by first collimator from production target:	8μ rad, 1.2q
Angle subtended by second collimator from first scatterer:	8 μ rad, 1.2q
Fraction of flux through first collimator scattered by 1/2 λ scatterer into second collimator:	$3x10^{-4}$
Angle subtended by detector from second scatterer:	30-120 μ rad, 4.5-18q
Fraction of flux through second collimator incident on detector, outside unscattered beam:	$4x10^{-2}$
Fraction of beam incident or first collimator double scattered into detector:	$3x10^{-4} \times 6x10^{-2} = 1.8x10^{-5}$

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4. N.H. Buttimore, E. Gotsman, and E. Leader, "Spin Dependent Phenomena Induced by Electromagnetic-Hadronic Interference at High Energies" Westfield College, London, (to be published in Phys. Rev.).
   E. Leader, "Usefulness of Spin-Dependent Electromagnetic Hadronic Interference Experiments" Phys. Lett. 71B, 353 (1977).

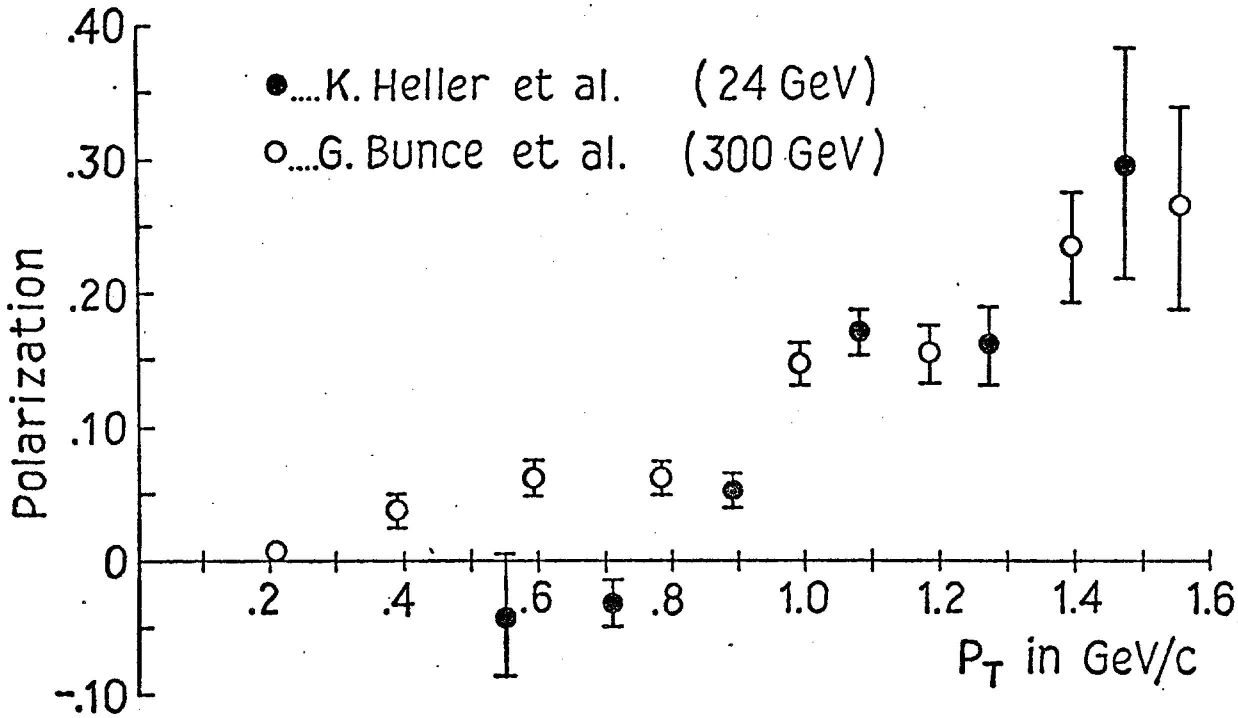

Figure 1. Data on the polarization of Λ's from the E8 group (reference 1).

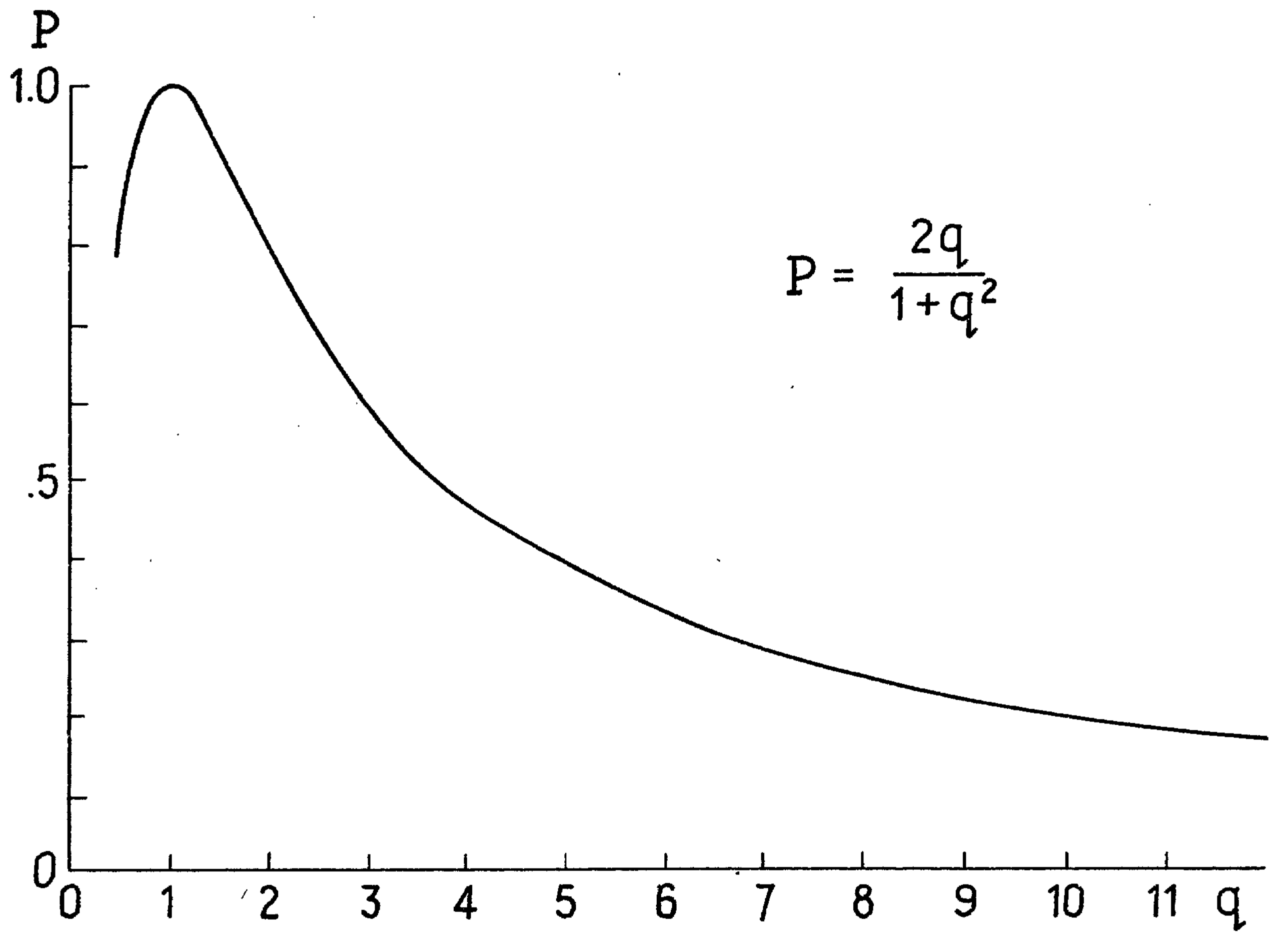

Figure 2. The function $P = 2q/(1+q^2)$ relating polarization to elastic scattering in Schwinger scattering

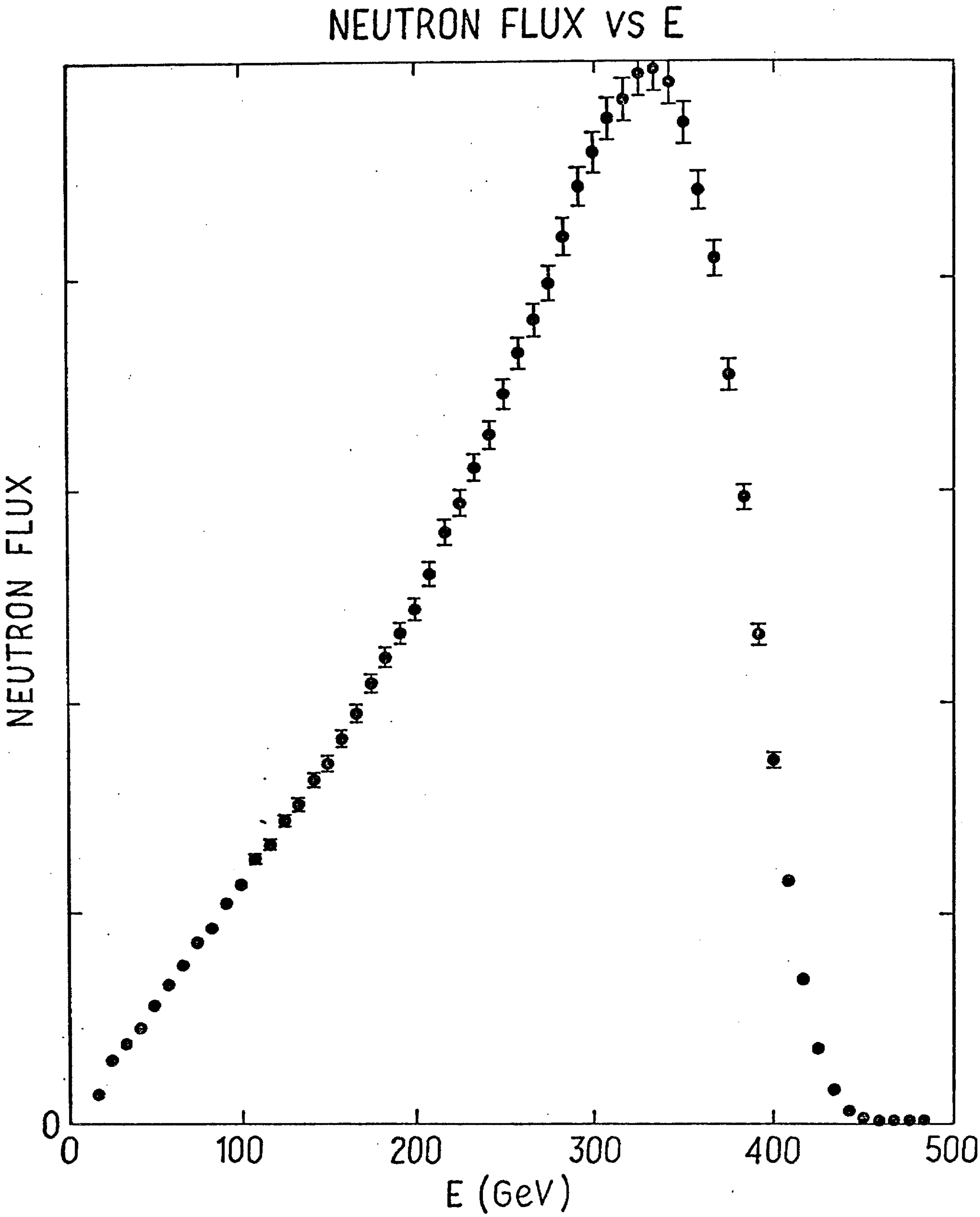

Figure 3. The M3 neutron spectrum recorded during E248.

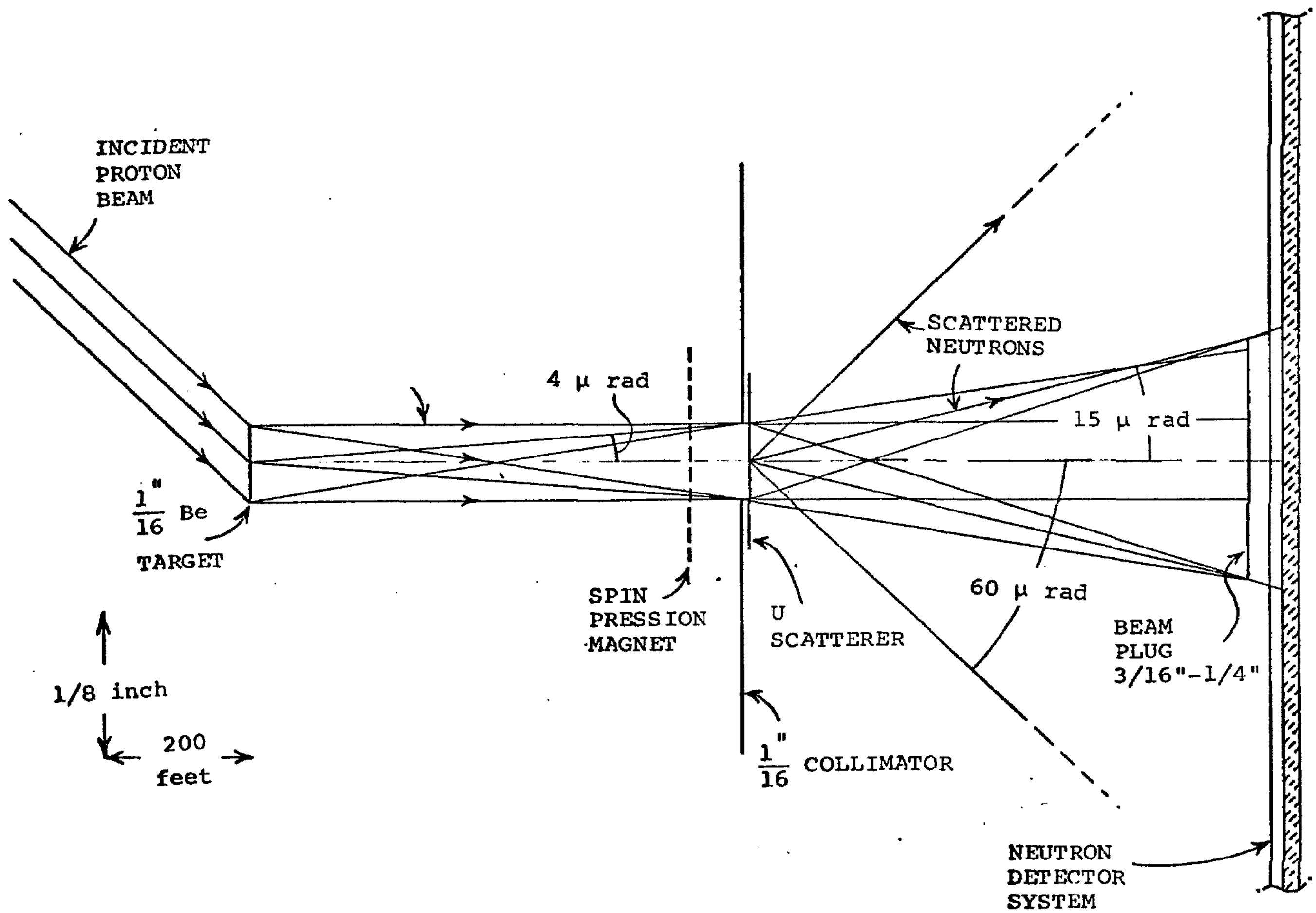

Figure 4. The configuration for determining the polarization of inclusively-produced neutrons.

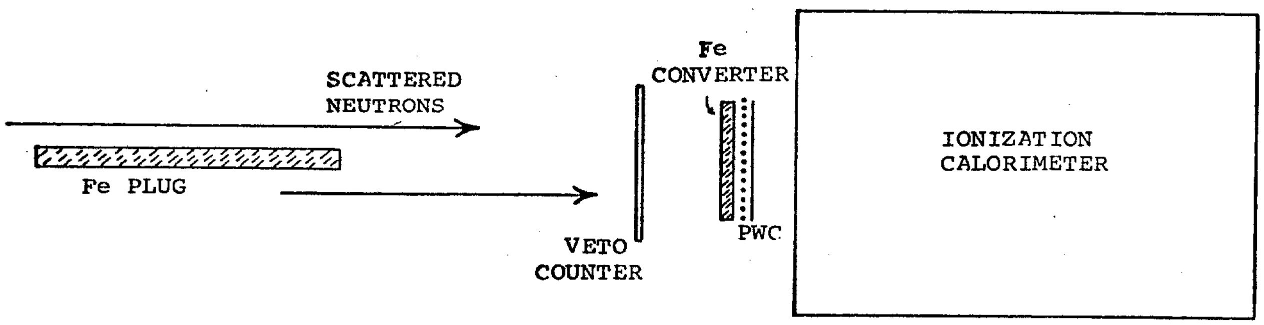

Figure 5. Schematic representation of the detector system.

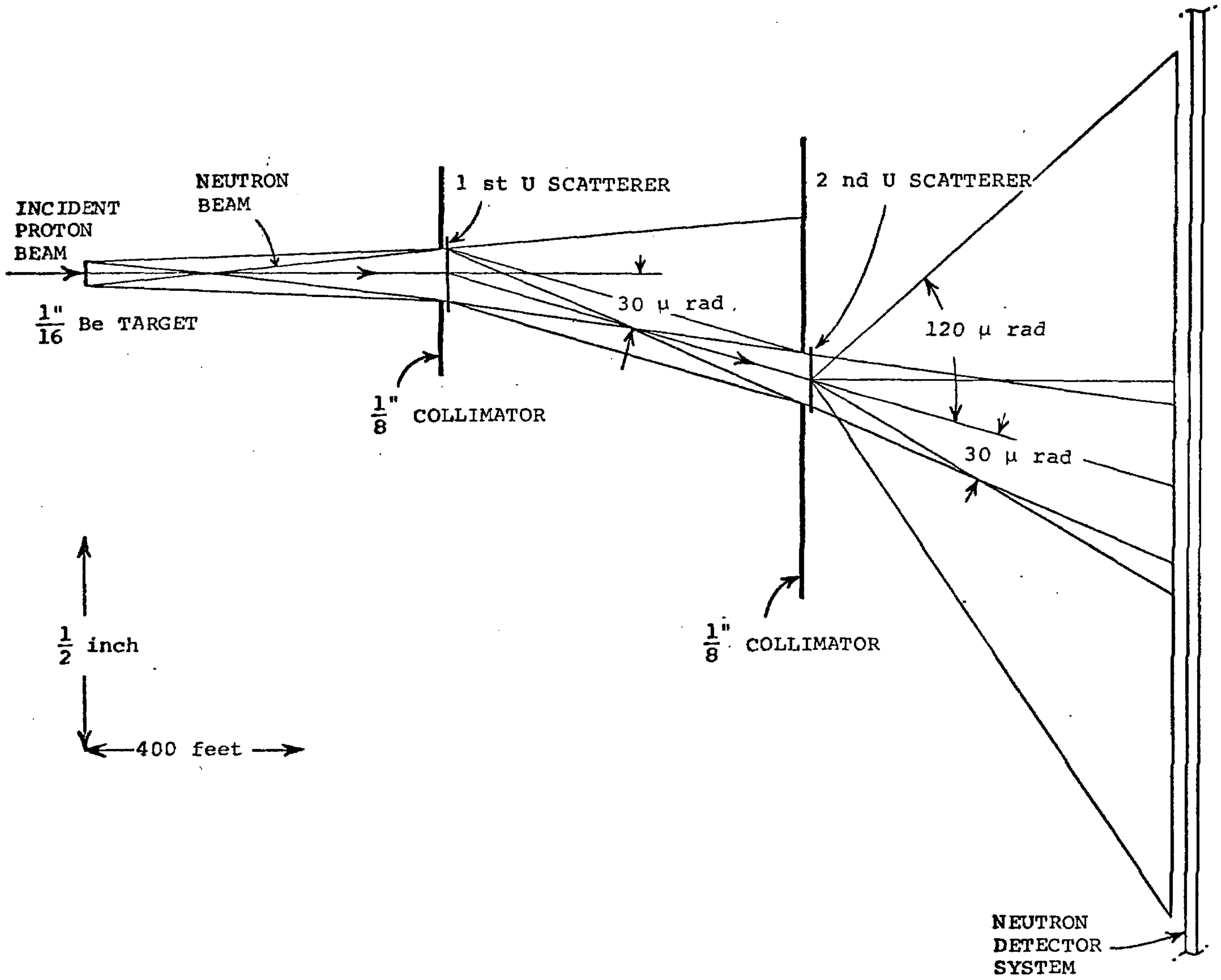

Figure 6. The configuration for verifying the Schwinger scattering with a double scattering experiment.

Addendum P-579

Addendum to

Study of Polarization of Inclusively-Produced Neutrons

P-579

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in inclusive reactions from the point of view of the quark structure of hadrons and QCD. Recent theoretical studies have noted that polarizations such as seen in inclusive Λ production should fall to zero as $p_\perp$ increases into the regime where asymptotic freedom takes hold, e.g. where $p_\perp \geqslant 4$ GeV/c. As $\vec{p}(\Lambda)$ is increasing with $p_\perp$ from 0 to 2 GeV/c this QCD prediction will require a reversal of the trend seen so far. In this context the more copious neutron production ($\sigma(pA \to nX) \simeq 1/3\ \sigma$ inelastic) is all the more interesting.

It may be recalled that a particular event in the fall from grace of Regge theory was the strong polarization seen in $\pi^- p \to \pi^\circ n$, in spite of the good general agreement of the differential cross section with Reggeized ρ exchange. Perhaps polarization studies may prove a more sensitive probe of QCD at easily-accessible energies than other processes.

2. Proposed Setup and Costs

A. Collimators

In the Fermilab estimate of costs of this experiment (\$200,000) about 2/3 was ascribed to the cost of the requested collimators. We believe that this cost may be totally avoided, as indicated on Appendix A. We will undertake to make the necessary modifications to the "Fixed-Variable Collimator" and to provide the required second such collimator. We will further either live with the existing parallel-jaw collimators or (if time permits) make the necessary modifications ourselves. (Our idea had been to attach motorized drives to the existing horizontal or vertical screws. I still believe that this can be done for a couple hundred dollars per collimator, not \$40,000 as apparently estimated by Fermilab.) If this cannot be done, we will live with the surveying as provided by the lab.

B. Magnets

The proposal suggested that some magnetic field may be necessary to cancel the $\int Bd\ell$ of the first elements of the M3 beam line shared with M2. It now appears that the neutron production angle from the proton beam will be in the horizontal plane, hence the neutron polarization (if any) will be vertical and will be unaffected by the M2 bends shared with M3.

There is currently a 5 - 1.5 - 120 bending magnet in E201 (400 ft) in M3. For P579 this magnet would be mounted on edge (B horizontal) and pulsed to $\int Bd\ell$ = 51.3 kG-m (16.2 kG) to reverse the (vertical) spin. When pulsed to half this value the spin vector would lie along the neutron beam hence no transverse polarization would be possible.

For the portion of the experiment designed to verify the Schwinger effect a spin rotation following the first scattering at 600 ft. would be necessary. There is currently a 240 in. magnet in the 1000 ft enclosure (Encl. 204) which had been in M3. It could be replaced in the beam for this experiment and would be sufficient for this purpose (see Appendix B).

In our proposal we suggested the desirability of reversing these magnets between successive pulses. It is probable that we could do as well by simply ramping the magnets between some

B1 and a higher B2. The required fields are modest, and the only asymmetry introduced into the experiment would be that due to differences in the charged-particle sweeping between the two different field values. We believe that the very small beam aperture makes this problem readily managable.

C. Interaction with E 533

It may be that P579 could be run before the E533 program is completed; if so it is desireable to explore the compatibility of the two setups. It appears to us that the two are indeed generally compatible. The magnets and collimators as they exist in the upstream beam enclosures have been mentioned.

As the original writing of P 579 did not consider E533, the P579 detector was sited in the detector building for the polarization measurements. At this time there seems no strong reason not to locate the detector (calorimeter, PWC system, and upstream shield) near the end of the M3 Wonder Building tunnel, well beyond the entire E533 spectrometer. Their vacuum tank need only be broken and terminated in a thin window ~ 50 ft. inside the north end of the M3 Wonder Building. All of our scattering angles are comfortably small enough to fit within their blue box vacuum pipe.

For that portion of P579 where a second scatterer is used (Schwinger effect calibration) we note that a 30 ft. section of the red 4 ft. Cherenkov counter pipe immediately under the mezzanine could be unbolted and moved to one side to make room for the second scatter plus collimator. Only vacuum windows and some supplemental vacuum plumbing would be needed from the

Laboratory

D. Targeting

From conversations with Jonckherre we have learned that the M1-2-3-4 meson target will still permit targetting over a horizontal range of ±3 mr following the changes made during the Mesopause. The vertical pitch angle will be small and variable (~0.5 - 1.5 mr). We would hope to use the horizontal aiming to vary the $p_\perp$ of the produced neutrons; if the central beam is aimed midway between M1 and M2-3; a ± 3 mr aiming could vary the production angle from ~0 to ~4 mr, corresponding to $p_\perp \sim 1.6$ GeV/c at 400 GeV. We find therefore that the parameters of M3 and its production configurations are quite suitable for P579 as proposed.

We enclose in Appendix B sketches of the M3 beam-line as it exists for E533 and as we propose it for P579. We would be able to run in late spring, 1979

3. Follow-On

Our proposal represents a complete pair of experiments: demonstration and study of the Schwinger Effect and study of polarization of inclusively - produced neutrons up to modest $p_\perp$. We recognize that the greatest theoretical interest may come not from these measurements but from future experiments for which P579 is a necessary antecedent. We identify here some possibilities.

A. $p+Be \rightarrow \vec{n}+X$ at large $p_\perp$.

If the M3 neutron beam is polarized it would be possible to extend the measurements to twice the $p_\perp$ (θ prod. ~ 8 mr) by setting up in M4. While we expect less polarization in M3, the much greater neutron fluxes there make measurements much easier for an exploratory experiment.

B. Polarization in $\vec{n}+p \to \pi+X$

Just as polarization of inclusively-produced neutrons should fall to zero for large $p_\perp$, so also should the dependence of inclusively-produced pions at large $p_\perp$ on the transverse polarization of incident neutrons.

If M3 is polarized, a moderately high flux (cf. E 533) could be used to bombard a target and a simple spectrometer used to study the flux of secondaries near x=0, $p_\perp \geqslant 4$ GeV/c. As the transverse neutron polarization is flipped the flux of secondaries would be studied for any dependence on beam polarization.[3]

A second experiment would be a strong-weak equivalent to the recent SLAC longitudinally polarized electron experiment. Here neutrons would be longitudinally-polarized and the dependence of secondary ("deep inelastic") produced particles on longitudinal polarization (parity violation) could be sought. This would be a natural companion to the previous experiment; it is trivial to flip the neutron polarization to lie along any of six directions (up, down, left, right, fore, aft) and to flip between them from pulse to pulse.

C. Dependence of $\sigma(np)$ on polarization

A simple pair of experiments would be a repeat of E4 with a polarized beam and polarized target and to flip the polarization to seek differences in the total cross sections,

$\sigma(n\uparrow p\uparrow) - \sigma(n\uparrow p\downarrow)$ and $\sigma(\vec{n}\vec{p}) - \sigma(\vec{n}\overleftarrow{p})$.

D. A litany of "conventional" polarization measurement, such as polarization in elastic scattering, could easily be carried out, if polarization exists in M3 and/or M4. The exceptional analyzing power of the Schwinger Effect makes neutrons particularly attractive high energy probes of polarization phenomena.

In view of this, we suggest that P579 should properly preceed a major installation effort for a polarized proton beam from Λ-decay.

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4. H.E. Haber and G. Kane, UM HE 78-11 "Detection of Intermediate Vector Bosons and High Energy Weak Interactions from Decay of Hadron Resonances."

Appendix A

P 579

Lawrence W. Jones

Neutron Polarization
Proposal Cost Work Sheet Detail

As Submitted May, 1978			Revised Aug., 1978	Est. Cost to Fermilab
Equipment				
Magnets:	1)	51.4 kG-m, B vertical, [to correct upstream $\int Bd\ell$] at Encl. 201.	Not necessary	0
	2)	±51.4 kG-m, B ⊥ n beam production plane, at Encl. 201	Existing M2B3 mounted on edge ($\vec{B}$ horizontal)	Rigging, mount $1000
	3)	±51.4 kG-m; <u>or</u> 0-102.8 kG-m at ~1000 ft. (Encl. 201)	Existing 20 ft magnet replaced in beam	Rigging, $200
ver Supplies:		For the above magnets it would be very desireable to be able to reverse one magnet on a pulse-to-pulse or minute-to-minute basis.	Reversal not necessary. Provide ramping; program to alternate two ramps	0
Special Vacuum Work:		Transport M3 beam in vacuum, except for collimators and targets up to 1300 ft (phase 1) and up to 2000 ft (phase 2).	Existing E553 vacuum system adequate	0
Collimators:	1)	Standard Parallel-jaws 4 ft collimators at 400 (Encl. 201) and 1000 ft (Encl. 204) <u>modified</u> to permit remote translation moving both pairs of jaws together	No FNAL modifications required	0

2)	A muon spoiler (or equivalent) <u>long</u> collimator (⩾ 6 feet) at Encl. 201 of 1/8" aperture <u>modified</u> to permit remote translation	Provided by Michigan	0
3)	Fixed-variable collimator at Encl. 202 repaired, mounted stably, with operable remote read out, remote control.	Repaired, modified at Michigan (this collimator may require rebuilding from scratch; it is currently lost at Fermilab)	0
4)	A second collimator such as the fixed-variable collimator with a round aperture 1/8"-1/4", ⩾ 5 ft long, translateable.	Provided by Michigan	0
5)	A third collimator with 4" dia. round aperture, ⩾ 5 ft long, translateable.	Provided by Michigan	0

Portacamp:	One large portacamp, air conditioned should be adequate	Suggest E439 Portacamp.	
Rigging:	No lab rigging required beyond moving the 6-ton calorimeter to the beam line	Must displace 30 ft. of E533 red pipe under mezzanine and reconnect vacuum	$1000
	Research Services		
Targets:	Two Uranium targets, each ⩾ 2 inches square, each 1.25 inches thick. Prefer 8 target plates; 2 of 1/4 inch, 4 of 1/2 inch, 2 of 1 inch thickness.	Have one from E4, E438. Obtain second from Argonne.	0

Alignment and Surveying:	Standard survey of M3 beam line required to 2000 ft to about 0.100 inch precision. Final alignment must be done with the beam.	Align collimators to 0.01 inches by Survey Crew	$3000
PREP:	~5 nim bins with standard discriminators, coincidence, etc. units.	Existing Prep; about 60K$ new cost. Amortize over 5 years	$12,000
Computing:	On line computing, data acquisition with Michigan H.P. 2100-2115 system. Off line analysis during exp't. at Fermilab (Off line analysis at Michigan following completion of experiment.)		$5,000
			$22,200

Experimenter Supplied Equipment:

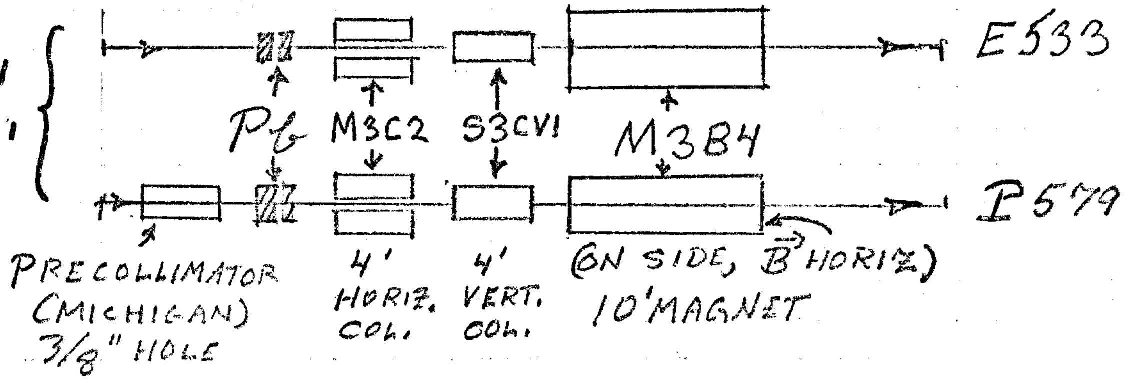
Standard scintillation counters
Small PWC system
E4 calorimeter (6 tons, including stand.)
On line computer system.

APPENDIX B

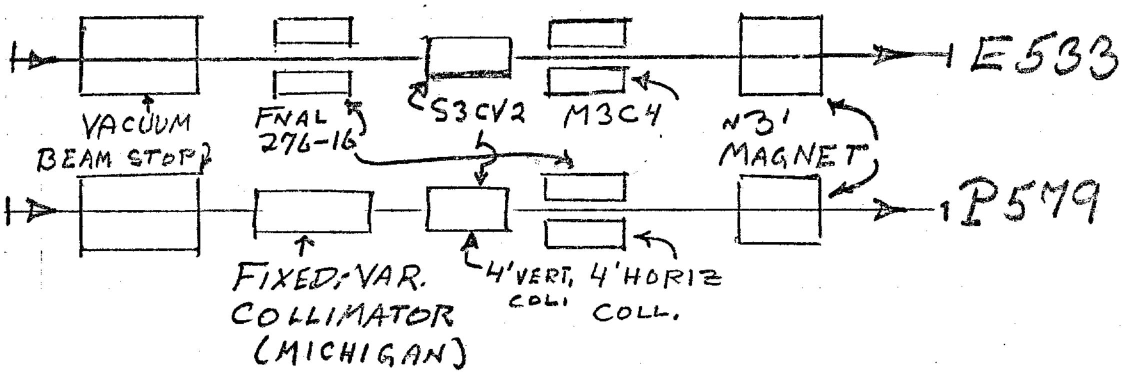
M3 BEAM ENCLOSURE

UPSTREAM

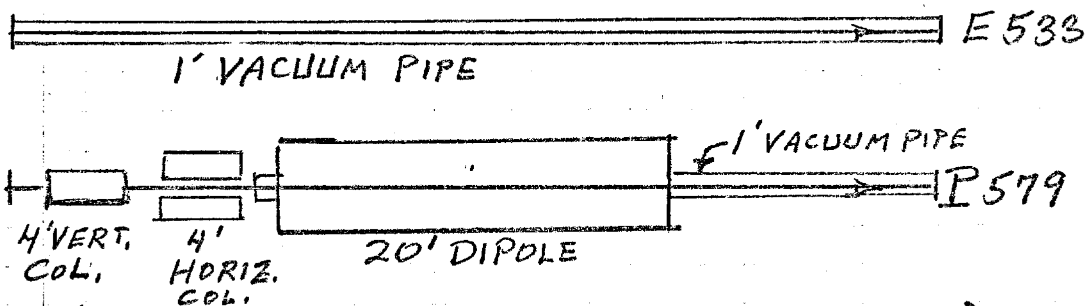
ENCL. 201
363'-414'



ENCL. 202
614'-695'



ENCL. 204
1003'-1055'



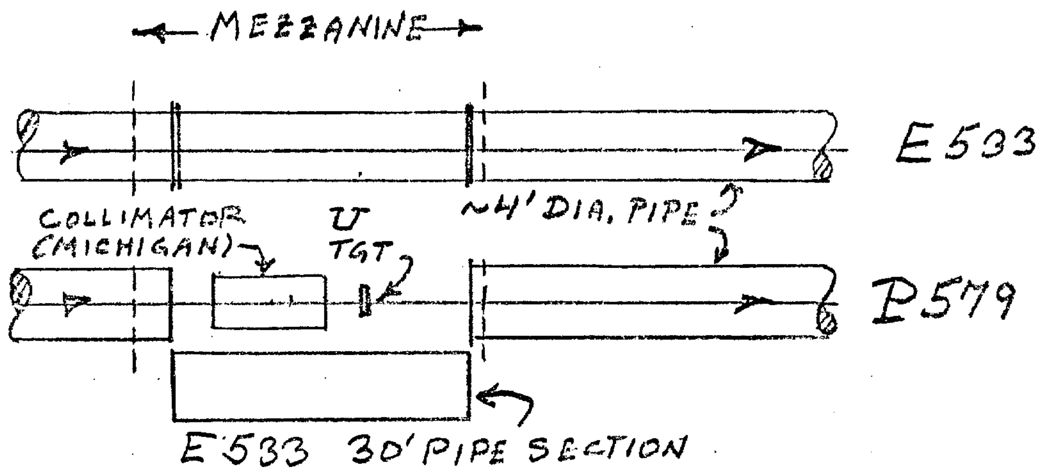
(THESE COMPONENTS EXIST IN THE TUNNEL)

APPENDIX B

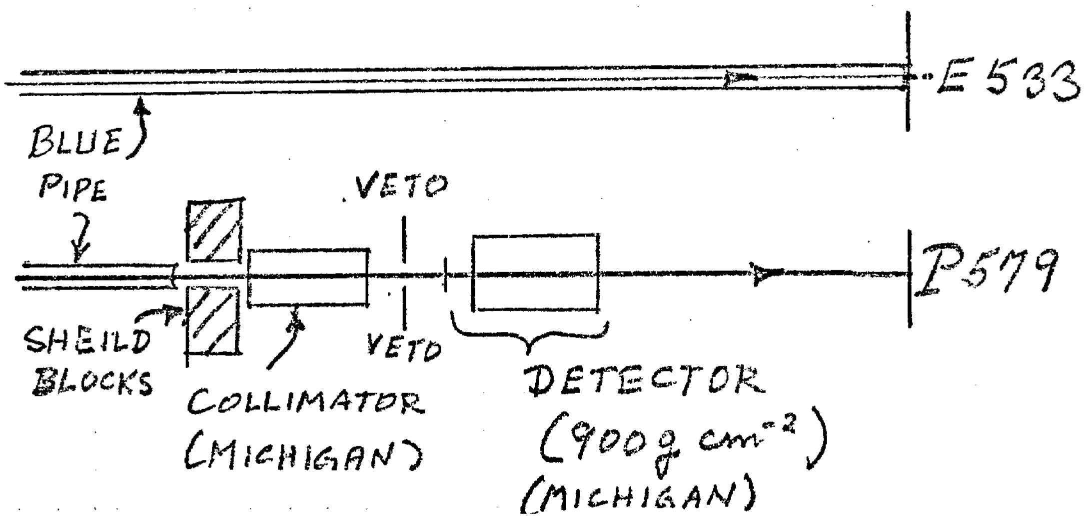
M 3 BEAM LINE

DETECTOR- AND WONDER BLDG.

UNDER MEZZANINE (1350'-1400')



END OF WONDER BLDG 1750'-1780'



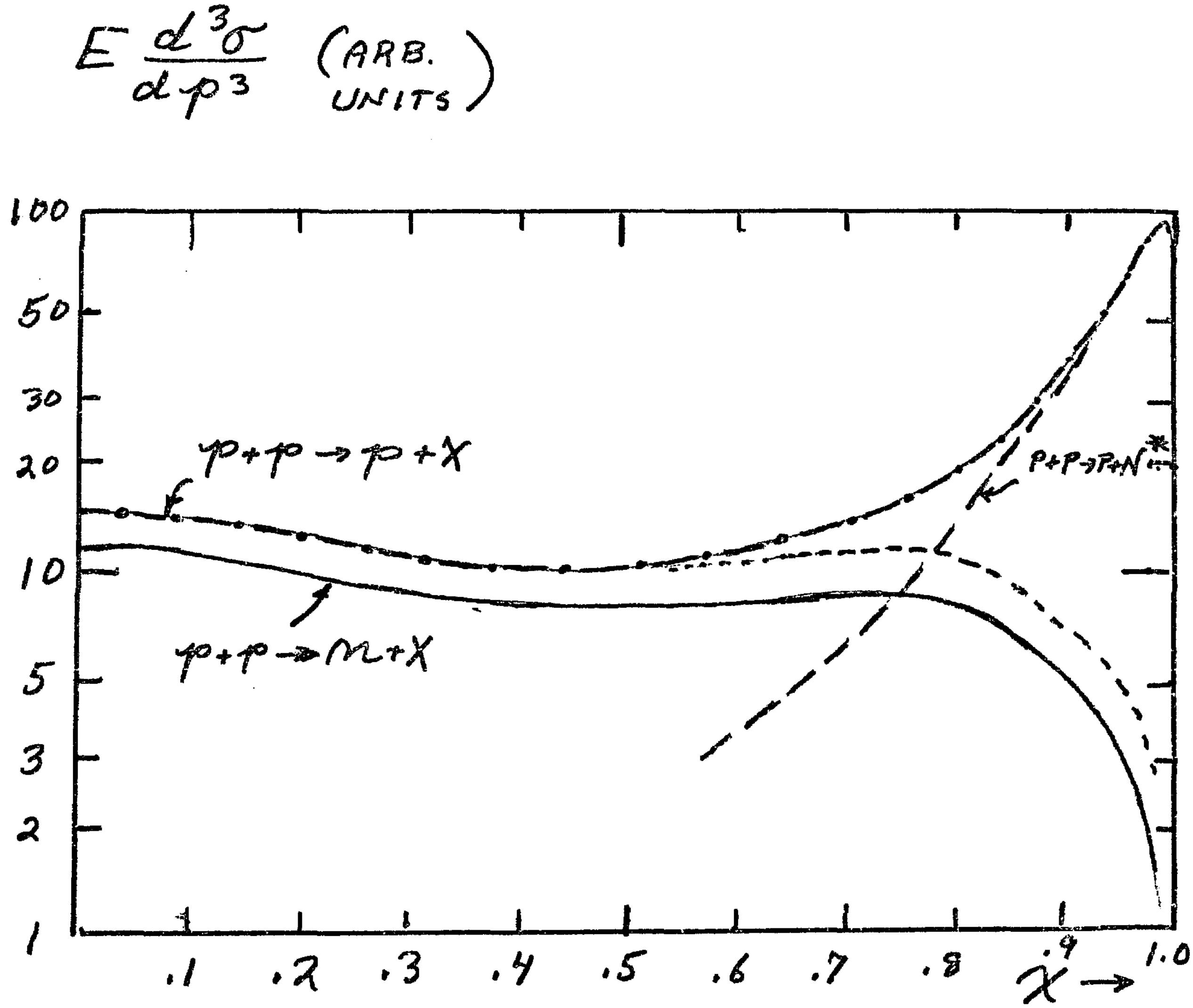


FIGURE 1

$P+P \rightarrow N+X$, N = n or P

(APPROXIMATE, NOT QUANTITATIVE)