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MASTER

PROGRESS IN RESEARCH

January 1, 1979 - December 31, 1979

by the

University of Texas at Austin Members of the

P-7 (LASL), TAMU, UTEXAS, COLLABORATION ON

MEDIUM ENERGY MEASUREMENTS OF n-p PARAMETERS

January, 1980

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Austin, Texas

MASTER

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I. INTRODUCTION

The purpose of this report is to summarize our progress in Medium Energy Research during 1979. The research has been supported by the U.S. Department of Energy Contract No. EY-76-C-05-2972, TASK C. The group, all from The University of Texas at Austin, consists of P. J. Riley, Professor of Physics, Charles Hollas, Research Scientist, and two Physics graduate students, Charles Newsom and Ron Ransome. Our research program is one principally involving medium energy neutron experiments at LAMPF. It is a collaborative effort involving The University of Texas, Texas A & M University, and Los Alamos Scientific Laboratory. The aim of the experimental program is the determination of the nucleon-nucleon amplitudes at medium energy. The required data include both elastic and inelastic experiments, and in addition the measurement of polarization and spin correlation parameters. The progress reported here is progress involving the collaborative research program as a whole. We have tried to emphasize the research work that The University of Texas group was most concerned with.

An unusually large fraction of 1979 was spent on actual experimental runs at LAMPF, all involving polarization measurements. Overall, we believe that the measurements have been very successful, and will provide significant new nucleon-nucleon data. The early part of 1979 was spent in preparation for experiment 360, "The Measurement of the Polarization Transfer Coefficients D_t and A_t' at 800 MeV for the Reactions $d(\vec{p},\vec{n})2p$, $^{6}Li(\vec{p},\vec{n})^{6}Be$, and $^{9}Be(\vec{p},\vec{n})^{9}B$." Following a tune-up run during March 5-9, the first experimental data were taken during April 12-23. For all but two days of this time period the spin of the LAMPF polarized proton beam was aligned vertically, allowing the D_t measurements to be made. During the period May 17-June 11, final experimental measurements were carried out on experiment 66, "Neutron-Proton Polarization Measurements Using a Polarized Target: Phase II. The n-p Spin Correlation Observable, $C_{NN}(\theta)$." Further experimental runs were made with the LAMPF polarized proton beam from June 12-25, the beam time being divided between experiment 360 and experiment 402, "A Measurement of the Polarization Transfer Coefficients $D_t(0^o)$ in the Reaction $p\vec{p}\rightarrow x\vec{n}$ at 800 MeV." The incident polarized proton beam was aligned vertically, allowing measurement of the D_t polarization transfer for both experiments. During July and August, development work and tests were carried out using both the EPB and Line B beam lines on the recoil proton polarimeter to be used for experiments 194, "p-p D, R, and A Measurements," 403, "A Measurement of the Triple Scattering Parameter D_t for the Charge Exchange Region of np Scattering," and 492, "Polarimeter Calibrations and Search for Energy Dependent Structure in pp Elastic via Cross Section, Analyzing Power, and Wolfenstein Parameter Measurements."

During the fall shut-down of LAMPF, a superconducting spin-precession solenoid was installed in the line B beam transport system of LAMPF, allowing simultaneous usage of longitudinally polarized protons in area BR and vertically aligned protons in lines EPB and C. Using this solenoid, concluding measurements were made on experiment 360 during the period Dec. 14-24, during which time the A_t' transfer coefficients were measured. During the same time period, December 14-24, the first experimental measurements were carried out on experiment 194 using the proton recoil polarimeter in line EPB for D_t measurements. Immediately following this experimental run, the recoil-polarimeter was moved into area BR for experiment 403, to be run during January 5-20, 1980.

Charles Hollas, Charles Newson, and Ron Ransome all spent 1979 in residence at Los Alamos, Charles Newsom with the support of an Associated Western

Universities (AWU) Fellowship. Ron Ransome also received an AWU Fellowship, starting October 1, 1979. Peter Riley spent the months of June, July, and August in residence at Los Alamos, and visited there approximately once per month during the remainder of the year. Charles Hollas spent the early part of 1979 with preparations for experiment 360. Later, he became involved in an analysis of the singlet and triplett contributions to the total cross sections differences $\Delta\sigma_T$ and $\Delta\sigma_L$ in $\vec{p} - \vec{p}$ scattering. He submitted a contributed paper on this work to the 8th International Conference on High Energy Physics and Nuclear Structure, Vancouver, Canada, August, 1979. This paper was selected for oral presentation at the meeting. During the Fall of 1979, he spent most of his time assisting in the final development of the recoil proton polarimeter to be used for experiment 403. During this work, he designed and built a neutron monitor telescope system, QPAN (Quick Polarization Analyzer for Neutrons), which was subsequently used very successfully in both experiments 360 and 403 for monitoring the spin direction of the incident neutron beam, and for optimizing the magnet settings of the neutron spin precession magnets EURYDICE and POLLUX. During 1979 Charles Hollas also served both as the Nucleon Physics Working-Group Chairman, and as a member of the LAMPF Technical Advisory Committee (TAP).

1979 was Ron Ransome's first year in full-time residence at Los Alamos. During the early part of 1979 he assisted in preparations for experiment 360. During the spring he became involved with work on the proton recoil polarimeter, especially with the programming aspects necessary to operate the polarimeter in conjunction with the multiwire proportional chamber spectrometer (MWPC) system. He has become an expert in programming and file manipulation on the PDP RSX 11 D operating system and with the LAMPF "Q" data acquisition programs. He has been largely responsible for writing and developing software for final data analysis of polarimeter data. We expect that his Ph.D. thesis work will be based on the measurements of Experiment 403. Most of Charles Newsom's time during 1979 has been spent in analyzing data for experiment 65 (on which his Ph.D. thesis is based), "Neutron Proton Polarization Measurements Using a Polarized Proton Target: Phase I. The n-p Polarization Observable P(θ)." He has also been assisting in the analysis of data for experiment 66, and has been helping during experimental runs. In August, he submitted a contributed paper to the 8th International Conference on High Energy Physics and Nuclear Structure, Vancouver, Canada, entitled "N-P Analyzing Power at LAMPF Energies." This paper was selected for oral presentation at the meeting. Charles Newsom has spent most of the past few months in writing his Ph.D. thesis, which should be completed during February, 1980.

II. EXPERIMENTAL RESEARCH.

1. Analysis of the Singlet and Triplet Contributions to the Total Cross Section Differences $\Delta\sigma_T$ and $\Delta\sigma_L$ in $\vec{p}-\vec{p}$ Scattering Between 1 and 3 GeV/c.

Measurements of total cross section differences for proton-proton scattering in pure spin states, both transverse, $\Delta\sigma_T=(\sigma\uparrow\downarrow-\sigma\uparrow\uparrow)$[1] and longirudinal, $\Delta\sigma_L=(\sigma\rightleftarrows-\sigma\rightrightarrows)$[2] have exhibited momentum dependent structure for proton lab momenta between 1 and 2 GeV/c. These data are illustrated in Fig. 1(a) with Δ and ∇. The structures, especially that in $\Delta\sigma_L$, have been the source of much discussion and have been interpreted[3,4] as indicating a $^3F_3$ dibaryon resonance near 1.5 GeV/c.

These cross section differences, and the spin averaged total cross section, σ_{tot}^T, can be expressed in terms of the imaginary part of the three helicity amplitudes evaluated at t = 0[5].

$$\sigma_{tot}^T = \frac{\pi}{q^2}\,\mathrm{Im}[\phi_1(0)+\phi_3(0)], \tag{1}$$

$$\Delta\sigma_T = \frac{-2\pi}{q^2}\,\mathrm{Im}[\phi_2(0)], \tag{2}$$

$$\Delta\sigma_L = \frac{2\pi}{q^2}\,\mathrm{Im}[\phi_1(0)-\phi_3(0)]. \tag{3}$$

Here q is the center of mass proton momentum; ϕ_1, ϕ_2, ϕ_3 are three of the five independent helicity amplitudes with the partial wave expansions[6]

$$\phi_1(0) = \sum_{J\ \mathrm{even}} \{(2J+1)R_J+JR_{J-1,J}+(J+1)R_{J+1,J}-2\sqrt{J(J+1)}\,R^J\}, \tag{4}$$

$$\phi_2(0) = \sum_{J\ \mathrm{even}} \{-(2J+1)R_J+JR_{J-1,J}+(J+1)R_{J+1,J}-2\sqrt{J(J+1)}\,R^J\}, \tag{5}$$

$$\phi_3(0) = \sum_{J\ \mathrm{even}} \{(J+1)R_{J-1,J}+JR_{J+1,J}+2\sqrt{J(J+1)}R^J\}$$

$$+\sum_{J\ \mathrm{odd}} (2J+1)R_{JJ}. \tag{6}$$

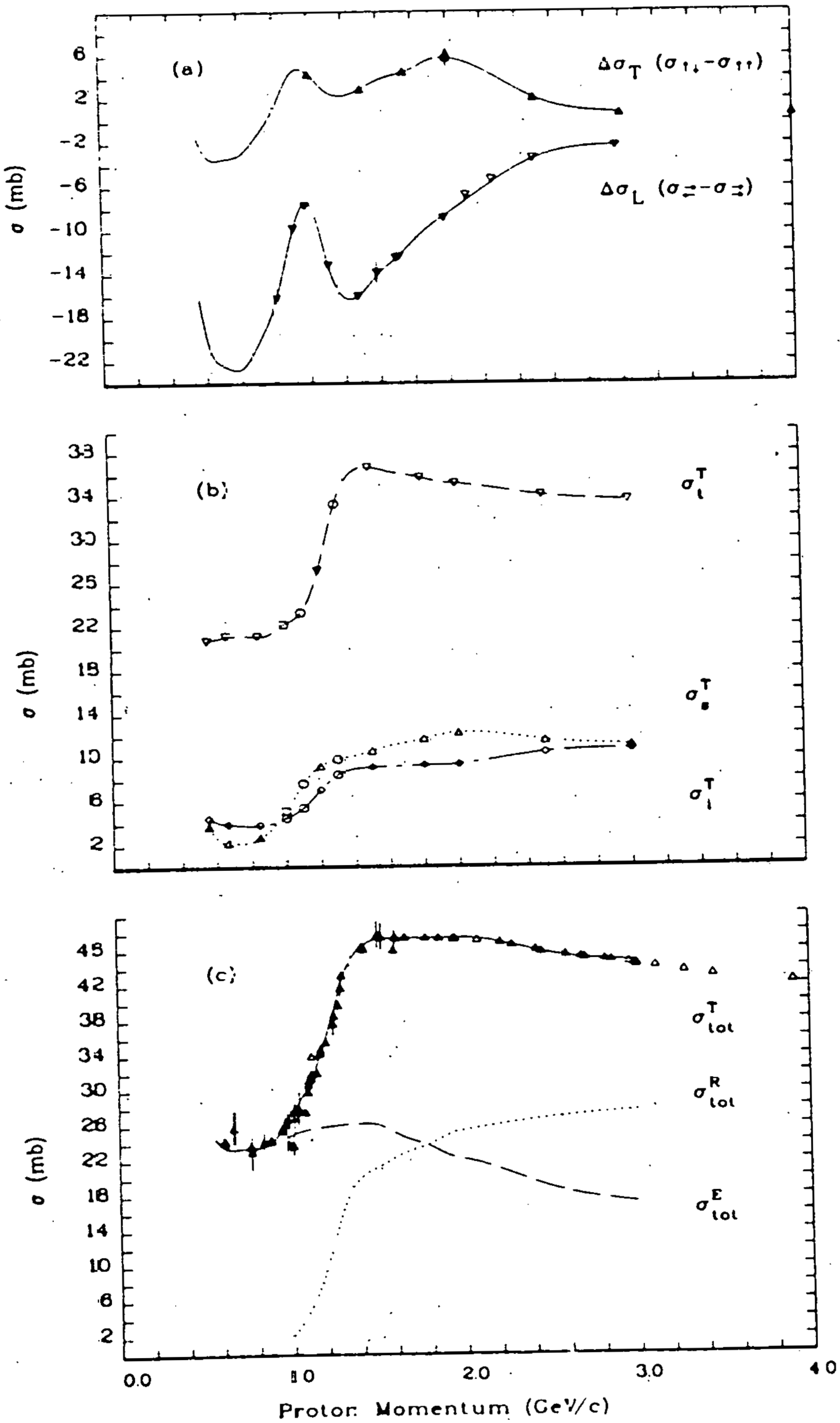

Fig. 1.

The momentum dependence of (a) the cross section differences $\Delta\sigma_T$ and $\Delta\sigma_L$. The data are from Refs. 1 and 2, the curves are described in the texts. (b) the singlet σ_s^T, triplet σ_t^T and triplet-interference σ^T cross sections, as described in the text. (c) the spin averaged total cross sections, σ_{tot}^T (Δ), σ_{tot}^E (chain-dot) and σ_{tot}^R (dashed).

With appropriate groupings, the three observables can be expressed in terms of three partial cross sections σ_s^T, σ_t^T and σ_i^T,

$$\sigma_{tot}^T = \sigma_s^T + \sigma_t^T, \tag{7}$$

$$\Delta\sigma_T = 2\,(\sigma_s^T - \sigma_i^T), \tag{8}$$

$$\Delta\sigma_L = 2\,(\sigma_s^T + 2\sigma_i^T - \sigma_t^T), \tag{9}$$

where σ_s^T is the singlet contribution

$$\sigma_s^T = \sum_{J\ \mathrm{even}} \sigma_J, \tag{10}$$

σ_t^T is the triplet contribution

$$\sigma_t^T = \sum_{J\ \mathrm{even}} (\sigma_{J-1,J} + \sigma_{J+1,J}) + \sum_{J\ \mathrm{odd}} \sigma\ , \tag{11}$$

and σ_i^T is the contribution of spin-triplet term of even J and their interference I.

$$\sigma_i^T = \sum_{J\ \mathrm{even}} \left(\frac{J}{2J+1}\,\sigma_{J-1,J} + \frac{J+1}{2J+1}\,\sigma_{J+1,J} - I\right). \tag{12}$$

The partial cross sections are defined in terms of the amplitudes

$$\sigma_j = \frac{\pi}{2q^2}\,(2j+1)\; 2\mathrm{Im}(R_j), \tag{13}$$

$$\sigma_{j\pm1,j} = \frac{\pi}{2q^2}\,(2j+1) 2\mathrm{Im}(R_{j\pm1,j}), \tag{14}$$

$$I = \frac{\pi}{2q^2}\, 2\,\sqrt{j(j+1)}\; 2\mathrm{Im}(R^j). \tag{15}$$

Using the data of Ref. 1 and 2 and σ_{tot}^{T} from Ref. 7 and 8, the points in Fig. 1(b) have been extracted for momenta at (or near) which data for the three cross sections exist. The points below .9 GeV/c have been calculated from the phase shifts of an analysis by Bugg et al.[9] of a data base which contains extensive spin dependent observables. Additional points at 1.0, 1.1, and 1.3 GeV/c plotted as open circles, were obtained by estimating values which yield a smooth momentum dependence for σ_s^T, σ_t^T, and σ_i^T, and reproduce the values of σ_{tot}^T and $\Delta\sigma_L$.

The three partial cross sections each exhibit an increase above 0.9 GeV/c, with the largest increase occuring in the triplet contribution σ_t^T. These increases are caused by the sharp rise in the spin averaged (σ_{tot}^T) cross section near 1.2 GeV/c (Fig. 1 [c]) which is primarily due to the increases in the cross sections for the three pion production reactions $pp \rightarrow pp\pi^o$; $pn\pi^+$; and $d\pi^+$. It is suggestive that the structures observed in $\Delta\sigma_T$ and $\Delta\sigma_L$ between 1 and 2 GeV/c are caused by the momentum dependence of pion production from the initial singlet and triplet partial waves.

A separation into the elastic (σ_s^E, σ_t^E, σ_i^E) and inelastic, or reaction (σ_s^R, σ_t^R, σ_i^R) contributions to the three partial cross sections of Fig. 1 (b) can be obtained by noting that the spin averaged total cross section is the sum of the elastic and reaction spin averaged total cross sections ($\sigma_{tot}^T = \sigma_{tot}^E + \sigma_{tot}^R$); that each of the partial cross sections is the sum of elastic and reaction contributions ($\sigma_x^T = \sigma_x^E + \sigma_x^R$, with x = s, t,i); and that relation 7 holds for the total elastic ($\sigma_{tot}^E = \sigma_s^E + \sigma_t^E$) and total reaction ($\sigma_{tot}^R = \sigma_s^R + \sigma_t^R$) cross sections. Within these constraints the separation is obtained from values of the spin averaged total inelastic (or elastic) cross sections and assumed values for σ_s^R and σ_i^R. The spin averaged total inelastic cross sections are well determined from threshold to near 1.3 GeV/c and are taken from Ref. 7. Above this momentum values for σ_{tot}^R have been taken from Ref. 10. In the following, σ_i^R has been fixed to be 5/21 σ_t^R. The factor 5/21 results from the ratio of (2J+1) values included in these cross sections when J⩽3. The use of only this factor implies that pion production from the even triplet partial waves is the same as from the odd triplet partial waves. This is an over-simplification, but the exact behavior of σ_i^R is not important for the discussion that follows.

The momentum dependence illustrated by the dashed curve in Fig. 2(a) for the singlet reaction cross section σ_s^R was obtained from the results of the analysis of single pion production by Mandelstram[11] from threshold to 1.2 GeV/c. Above 1.2 GeV/c the momentum dependence was taken to be essentially that of σ_s^T. With this curve, and the curves for σ_s^T, σ_t^T and σ_i^T, and σ_{tot}^R illustrated in Fig. 1 (b,c), all the remaining curves of Figs. 1,2 are determined via the above relationships. The curves in Fig. 1 (b) represent smooth interpolations between the points. Note that the sharp rise in the resulting inelastic triplet cross sections (σ_t^R) in Fig. 2(a) coincides with that of the total triplet cross sections (σ_t^T) in Fig. 1(b). The elastic singlet (σ_s^E) and triplet (σ_t^E) cross sections illustrated in Fig. 2(b) show no dramatic momentum dependence. Small increases do occur in the regions where the inelastic cross sections are increasing rapidly, perhaps reflecting the unitarity coupling of the elastic and inelastic channels as indicated in the calculations of Kloet and Silbar.[12]

This particular separation into elastic and inelastic contributions is not unique, and implies that pion production from the initial singlet partial waves occurs earlier than that from the initial triplet, which overtakes the

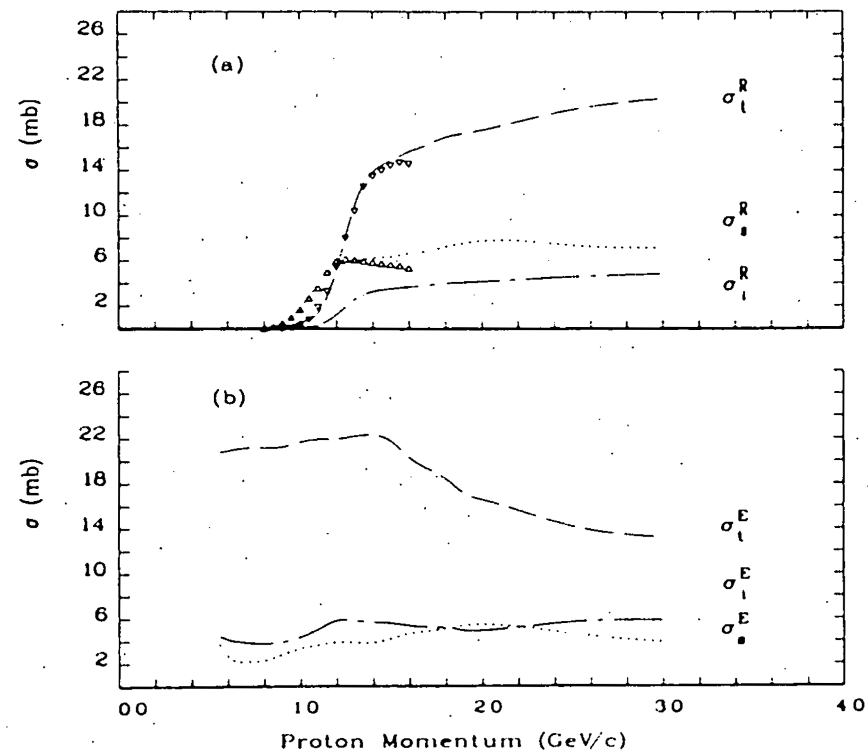

Fig. 2.

The momentum dependence of (a) the inelastic cross sections σ_s^R (dashed), σ_t^R (chain-dot) and σ_i^R (chain-dash). The symbols ∇ and Δ are results from Ref. 13. (b) the elastic cross sections σ_s^E (dashed), σ_t^E (chain-dot) and σ_i^E (chain-dash).

singlet near 1.2 GeV/c and subsequently becomes greater. The recent calculation of single pion production by Green and Sanio[13] does not agree with such behavior, rather predicts both singlet and triplet cross sections rise together. However, the calculations of Kloet and Silbar[12] do indicate the singlet production occuring earlier than the triplet. Mandelstam's [11] analysis requires the production from singlet partial waves to occur earlier. The results of Mandelstam's analysis are illustrated in Fig. 2(a) with the symbols Δ for singlet and ∇ for triplet initial partial waves. The agreement is quite good with the proposed present inelastic contributions until above 1.4 GeV/c, where the assumptions by Mandelstam of nonenergy dependence of the transition amplitudes and the limitation to only $^1D_2$ and $^3P_{0,1,2}$ partial waves is no longer expected to be valid.[14]

In Mandelstam's model, the pion production takes place through an intermediate nucleon-delta (N-Δ) system in an "s- or p- state," where Δ is the T=3/2, $J^\pi=3/2^+$ pion-nucleon resonance of mass 1232 MeV. The "s-state" production refers to the (N-Δ) system in an L=0 relative angular momentum state and has spin and parity either 1^+ or 2^+. Only the 2^+ can be formed by the initial proton-proton system, and that only from the $^1D_2$ partial wave. The "p-state" production refers to the (N-Δ) system in an L=1 relative angular momentum state and has possible total angular momenta and parity of 0^-, 1^-, 2^-, 3^-. Only initial triplet partial waves of ℓ=1 or 3 can form this system. In his analysis, Mandelstam reduced the number of free parameters by excluding the ℓ=3 initial partial waves and absorbed their contributions into that form the ℓ=3 initial partial waves. Subsequent analysis,[15] including additional data using the same model, distributed the triplet contributions.

A crucial test of the momentum dependence of the inelastic cross sections of Fig. 2(a) would lie in a complete energy-dependent phase-shift analysis which includes the $\Delta\sigma_T$ and $\Delta\sigma_L$ data and constrains the elasticities to reproduce the cross sections proposed here. Arik and Williams[16] have performed an analysis at 1.26 and 1.66 GeV/c, but the elasticities at 1.26 GeV/c were constrained to those of Amaldi et al.;[17] at 1.66 GeV/c the elasticities in the low partial waves were allowed to vary. The resulting inelastic singlet and triplet cross sections at 1.66 GeV/c were 6.57 and 16.3 mb respectively. Bugg[18] has performed additional phase shift analyses on the data at 0.99 and 1.10 GeV/c of Ref. 9. With $\Delta\sigma_L$ included in the data base, the resulting inelastic singlet and triplet cross sections are 1.52 and 0.06mb at 0.99 GeV/c, and 4.07 and 1.40 mb at 1.1 GeV/c. These values are in excellent agreement with the present analysis.

In summary, the structures observed in $\Delta\sigma_T$ and $\Delta\sigma_L$ between 1 and 2 GeV/c are due to increases in the singlet, triplet, and triplet interference cross sections occurring at differing momenta. Theoretical calculations should attempt to reproduce these cross sections as illustrated in Fig. 1(b) rather than the cross section differences which are very sensitive to small changes in the momentum dependence of the sharp increases in the cross sections.

A separation into elastic and inelastic contributions to the singlet and triplet cross sections has been proposed which easily accomodates the data and is in close agreement with the analysis of Mandelstam[11] for single pion production, and in agreement with phase shift analyses[16,18] at 0.99, 1.10 and 1.66 GeV/c. With the proposed interpretation of the data, no resonant behavior is required to describe the structures observed in $\Delta\sigma_T$ and $\Delta\sigma_L$

between 1 and 2 GeV/c. These structures result primarily from pion production through the (N-Δ) system in a relative angular momentum state of L=0 being initiated at lower momenta than when the (N-Δ) is in a relative angular momentum state of L=1.

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2. N-P Analyzing Power at LAMPF Energies.

The experiment described here has the object of providing new data on the free n-p analyzing power, A_y (θ) at energies up to 800 MeV. Prior to the recent TRIUMF[1] experiments, below 500 MeV, the previous data in this energy range were obtained by quasi-free p,n scattering.[2,3] Free n-p analyzing power data[1,4,5,6] above 500 MeV is sparse with errors typically greater than 0.1.

The experiment was performed in the Nucleon Physics Laboratory at the LAMPF accelerator with the experimental setup shown in Fig. 3. An unpolarized neutron beam was produced at 0 degrees when 800 MeV protons were scattered from a beryllium target. The resultant neutron energies varied from 300 to 800 MeV (Fig. 4). The neutrons were then scattered from a polarized proton target with both outgoing particles detected. The time of flight and position of the scattered neutrons was detected in an array of NE110 plastic bar scintillators with an efficiency of about 15%. The outgoing charged particles were momentum analyzed in a magnetic spectrometer. Particle identification was determined by calculating

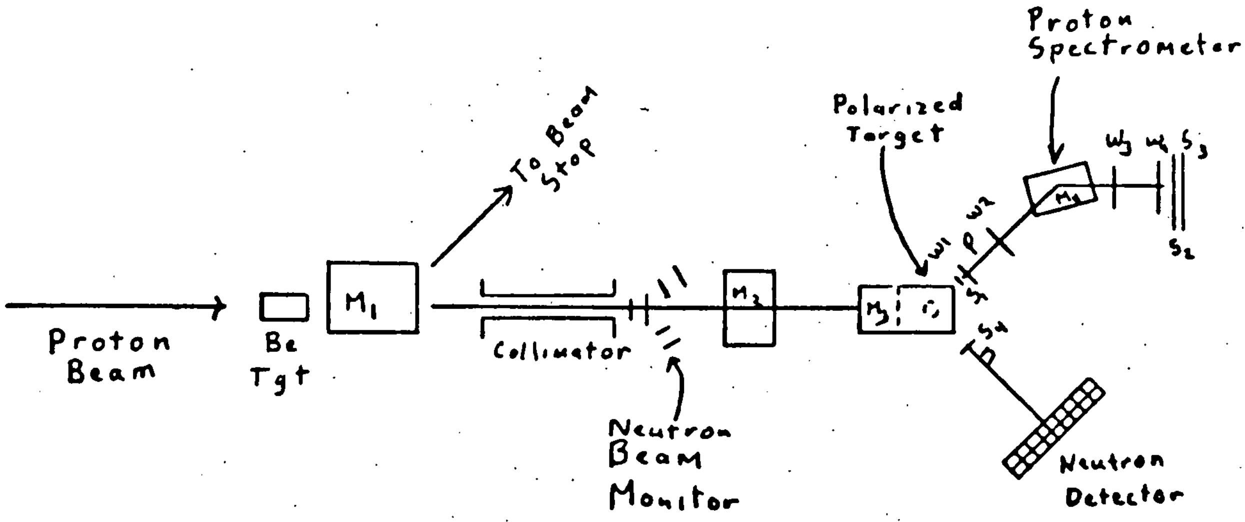

FIGURE 3
Experimental Setup

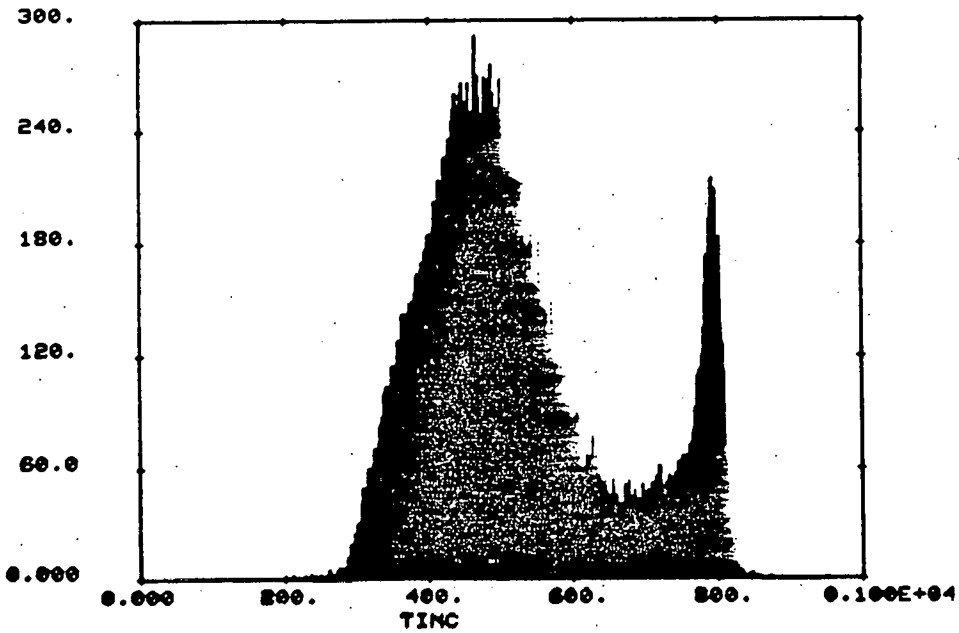

FIGURE 4.
Incident neutron Energy

the mass from the measured time of flight and momentum. Bending effects in the proton trajectory due to the field of the polarized target magnet were calculated using the measured momentum. Elastic signal events of this type provided 6 kinematic quantities, which allowed determination of the incident neutron energy by use of either the proton or neutron angles. In addition, the 5 nanosecond pulsed structure of the incoming proton beam allowed us to measure the incident neutron time of flight to within a modulus of 5 ns. For elastic events the 2 arm energy determination enabled us to remove this rf time of flight uncertainty, giving a third indication of the energy. Differences in these 3 measurements gave criteria for separation of elastic events from accidental and inelastic events. Areas of poor resolution in one method were usually offset by better resolution in another and when the final energy was determined by a weighted average of the three methods, the resolution ranged from 30 to 50 MeV.

The relative size of the elastic signal was measured by fitting the coplanarity histogram (Fig. 5) with a gaussian shape and a quadratic background. The asymmetries were then calculated by 2 methods. In the first method the gaussian component is assumed to be a constant fraction of the elastic signal. In the second method, the signal was deemed to be the yield minus the calculated background. Consistency between the two methods was excellent.

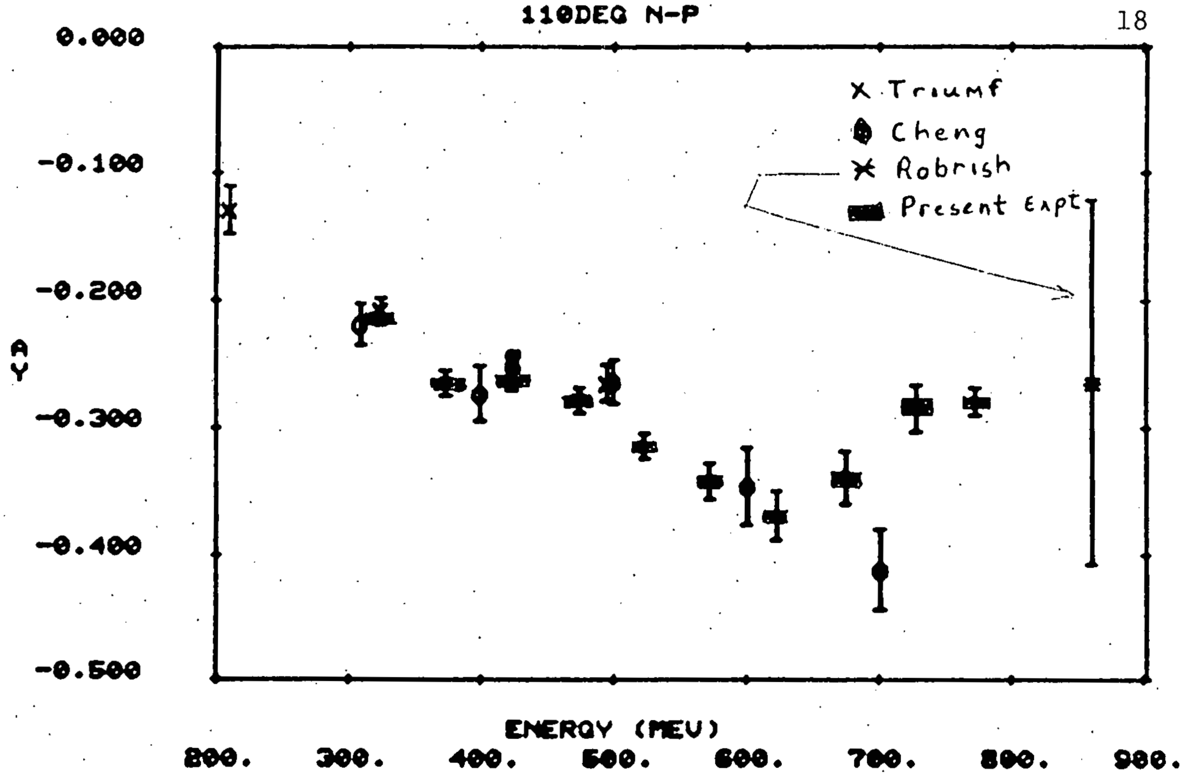

FIGURE 6
110^{0} (cm) n-p Analyzing Power

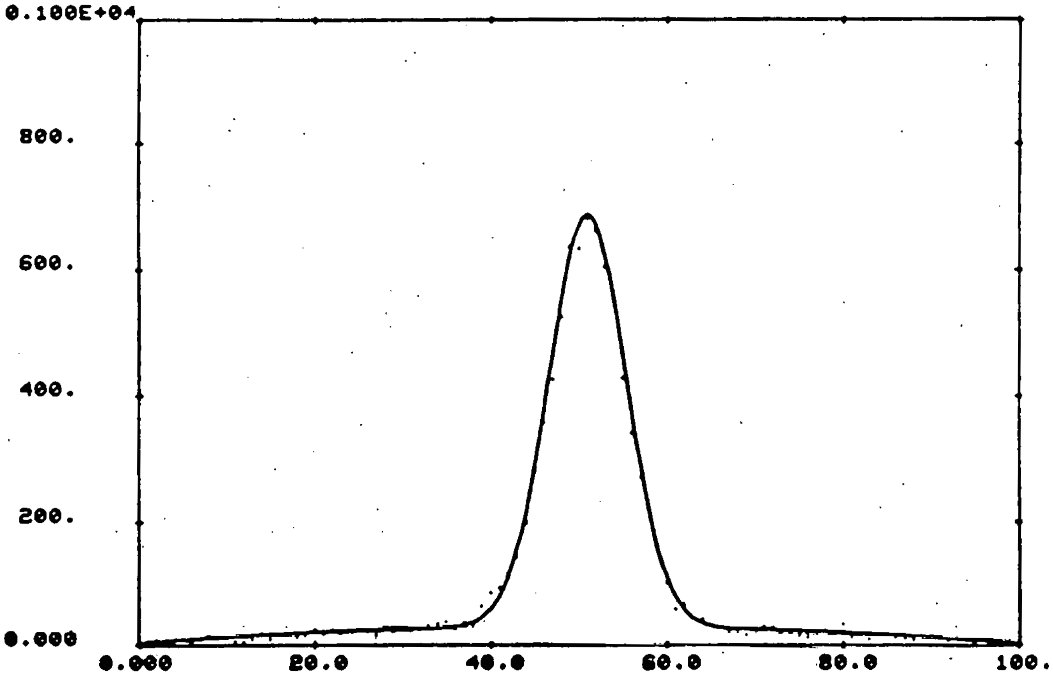

FIGURE 5
Coplanarity Histogram solid line represents a gaussian with a quadradic background fil.

The polarization of the target was determined from 2 independent methods. In the standard method, we measured the thermal equilibrium polarization signal present at 1.0 degree Kelvin in a 25 KGauss field by an NMR method. This method has an inherent uncertainty of typically 5%. In the second method, we performed a p-p A_y scattering experiment and related the measured asymmetry to the measured p-p analyzing power of Bevington et al.[7]. This method calibrated our NMR technique to about 2%. Results from a preliminary analysis of the p-p calibration were in good agreement with the NMR measurement. Drifts in the equipment were determined by measuring thermal equilibrium polarizations at intervals throughout the experiment. Typical drift corrections to the analyzing power were less than 1%, while the average polarization of the target was about 80%.

In the present experiment, the measurements in the energy range 400 to 800 MeV were made simultaneously at a single spectrometer angle. Systematic errors from energy to energy were minimized, and thus, the overlap of this experiment with the TRIUMF data provided an excellent check of our calibration techniques.

The data shown in Fig.6 demonstrates the energy dependence of A_y for n-p scattering at 110 degrees (cm). A broad minimum is observed in the data at about 650 MeV. However, the data point of Cheng for 110 degrees (cm) at 700 MeV is in disagreement with our data and gives no indication of a minimum at 650 MeV. Existing data above 700 MeV is of insufficient precision to indicate the observed structure, but is nevertheless consistent with it. A similar structure in the p-p polarization data[7,8] at 35 degrees (cm) suggests that the observed energy dependence in the n-p data is a reflection of the T = 1 contribution to the n-p interaction.

Angular distributions in A_y at 7 different energies were measured from 60 to 160 degrees (cm). Figures 7, 8, and 9 show the 575, 625, and 800 MeV data. The data in the lower energy range are in good agreement with the TRIUMF[1] and Cheng[2] results, thus giving us confidence in the higher energy behavior.

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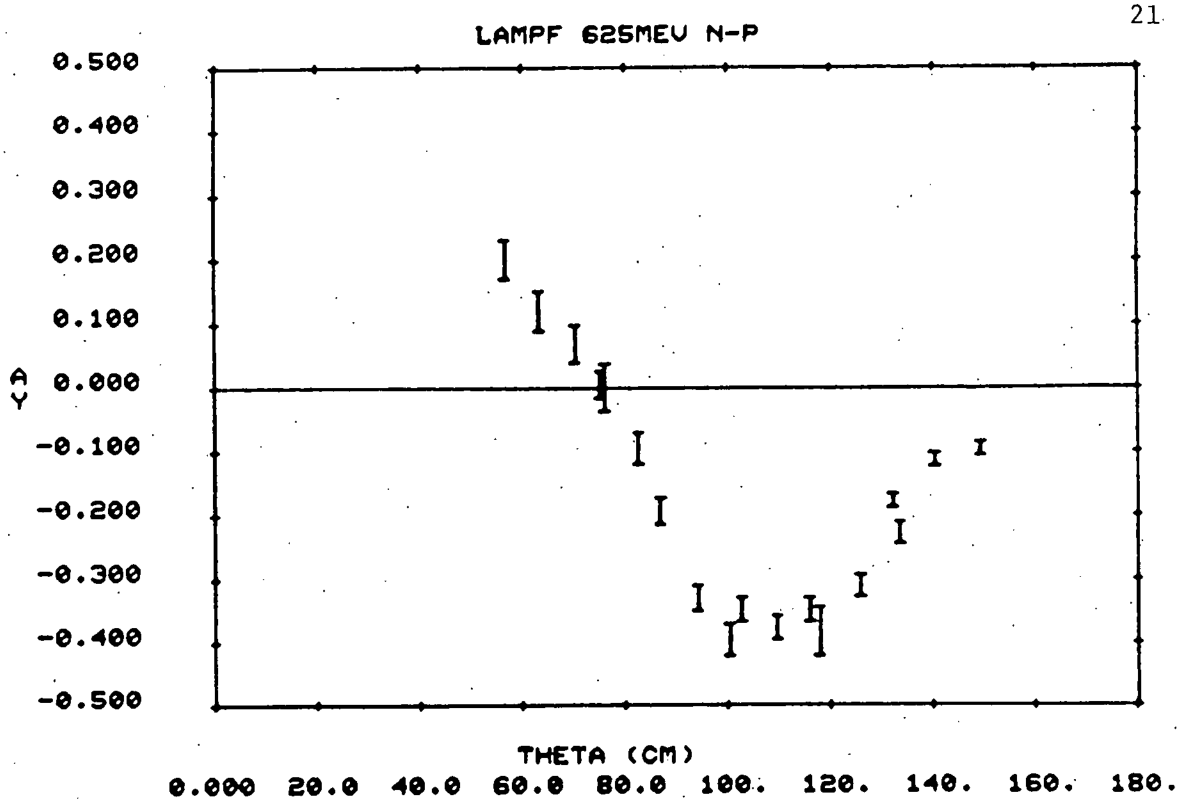
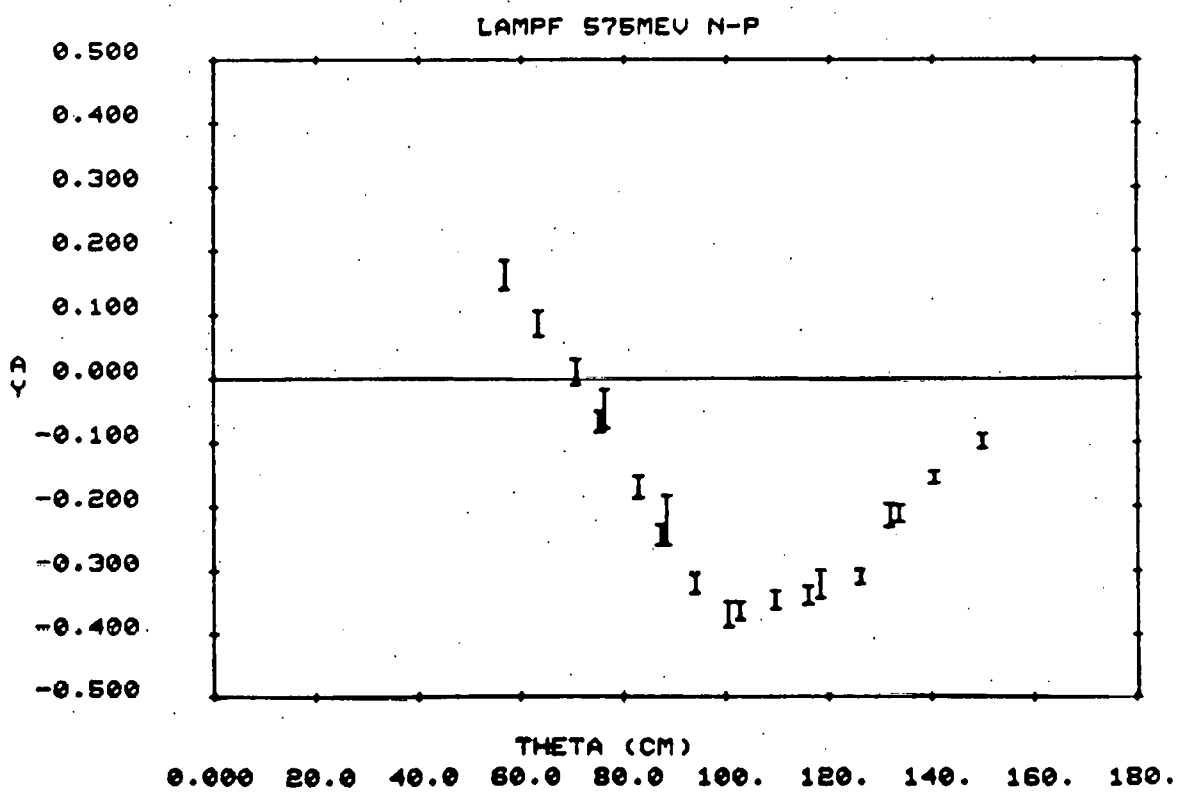

LAMPF 625MEV N-P
0.500
0.400
0.300
0.200
0.100
0.000
-0.100
-0.200
-0.300
-0.400
-0.500
A
Y
THETA (CM)
0.000
20.0
40.0
60.0
80.0
100.
120.
140.
160.
180.

Fig. 8


LAMPF 575MEV N-P
0.500
0.400
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0.100
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-0.100
-0.200
-0.300
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Y
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140.
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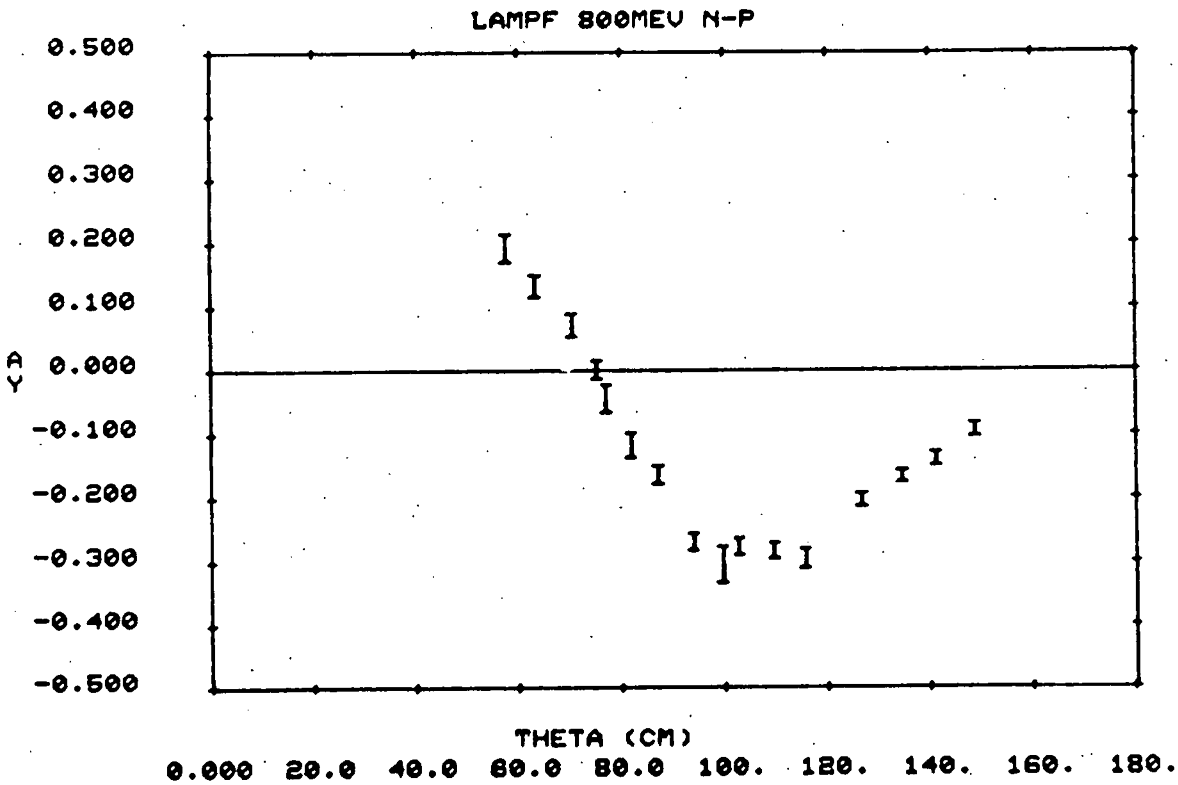
180.

Fig. 7


LAMPF 800MEV N-P
0.500
0.400
0.300
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0.100
0.000
-0.100
-0.200
-0.300
-0.400
-0.500
A Y
THETA (CM)
0.000 20.0 40.0 60.0 80.0 100. 120. 140. 160. 180.

FIGURE 9.

3. Progress on Data Analysis for Experiment 66.

The purpose of this experiment was to measure the spin correlation parameter A_{yy} in np scattering. Data were accumulated in late 1978-early 1979 and preliminary results are now available. The experimental arrangement used was very similar to that for experiment 65 except that the polarized neutron beam was obtained by quasifree $pd \to \vec{n}x$ at 20°. The experimental layouts for both experiment 66, which used the 20° neutron line, and for experiment 360, on the 0° beam line, are shown in Fig. 10.

Two dipole magnets, CASTOR and POLLUX were used in the incident neutron beam line to precess the incident neutron polarization through 180°, from the spin-up to the spin-down configuration. The characteristics of the neutron beam are a polarization of 20% and an energy spread of 75 MeV centered at an energy of 675 MeV. It was found that the lower energy neutrons also had about the same polarization. The asymmetry in the scattering of these neutrons from polarized protons was measured over the c.m. angular range 80-165°. Measurements were made for the four initial spin states.

An indication of the consistency of the results can be had by extracting the analyzing power as well as A_{yy} from the data. In Fig. 11(a) is shown the A_y extracted at 110° c.m., compared to the energy dependence of this parameter measured in experiment 65. Tbe agreement is very good. Also shown are the predictions of Arndt's phase shift analysis code. Some discrepancy at 600 and 800 MeV is evident.

The results for A_{yy} for 107-165° at 670 MeV are shown in Fig. 11(b). The results of the two predictions are also shown--that of Arndt at the same energy and the predictions from David Bugg based on recent TRIUMF

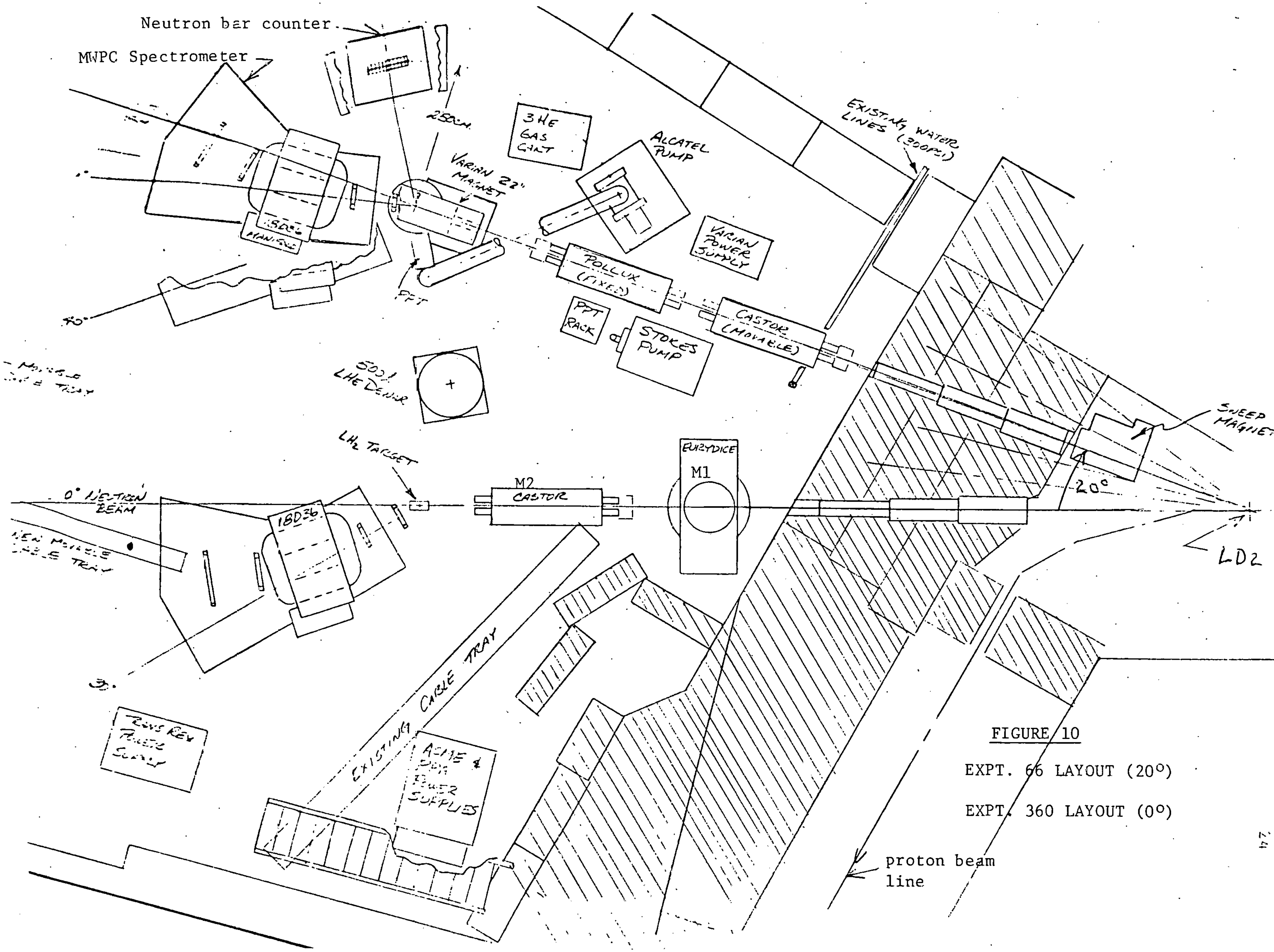


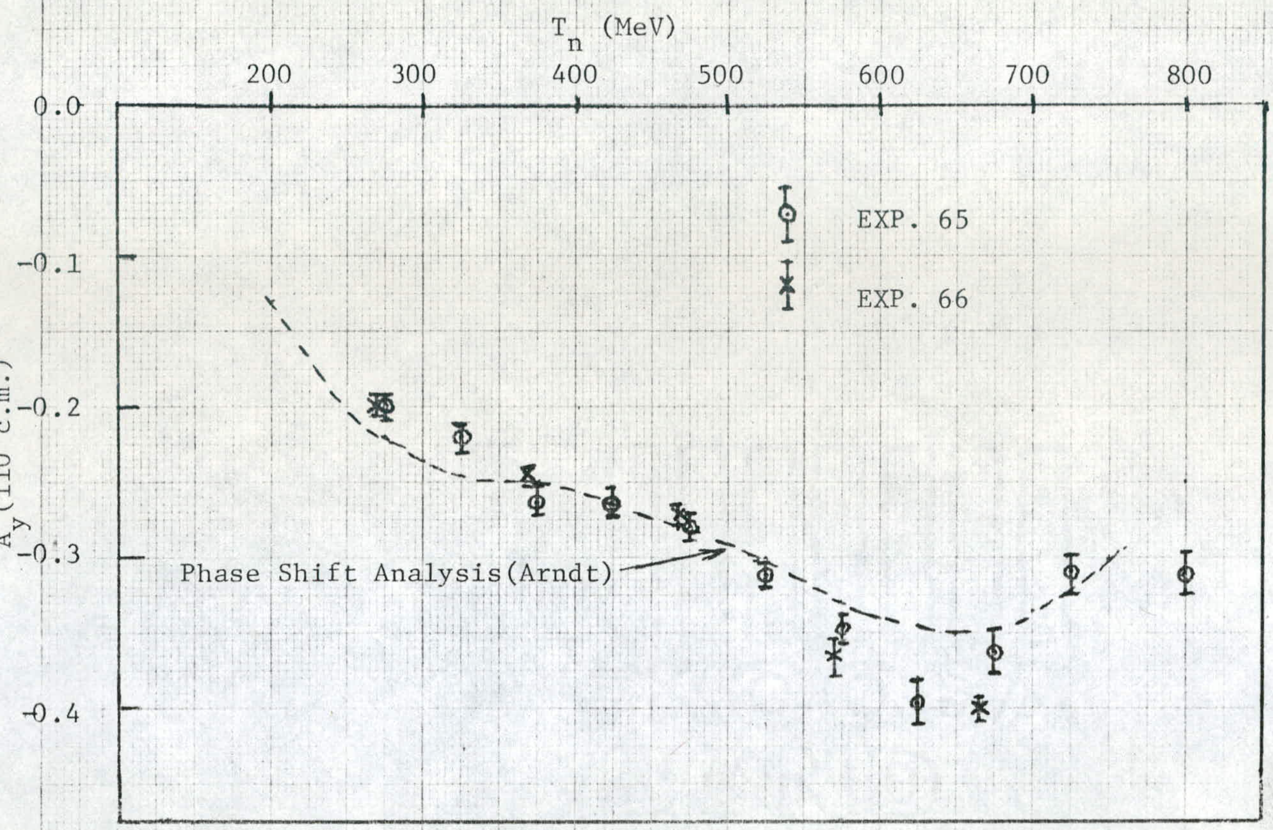
FIGURE 10

EXPT. 66 LAYOUT (20°)

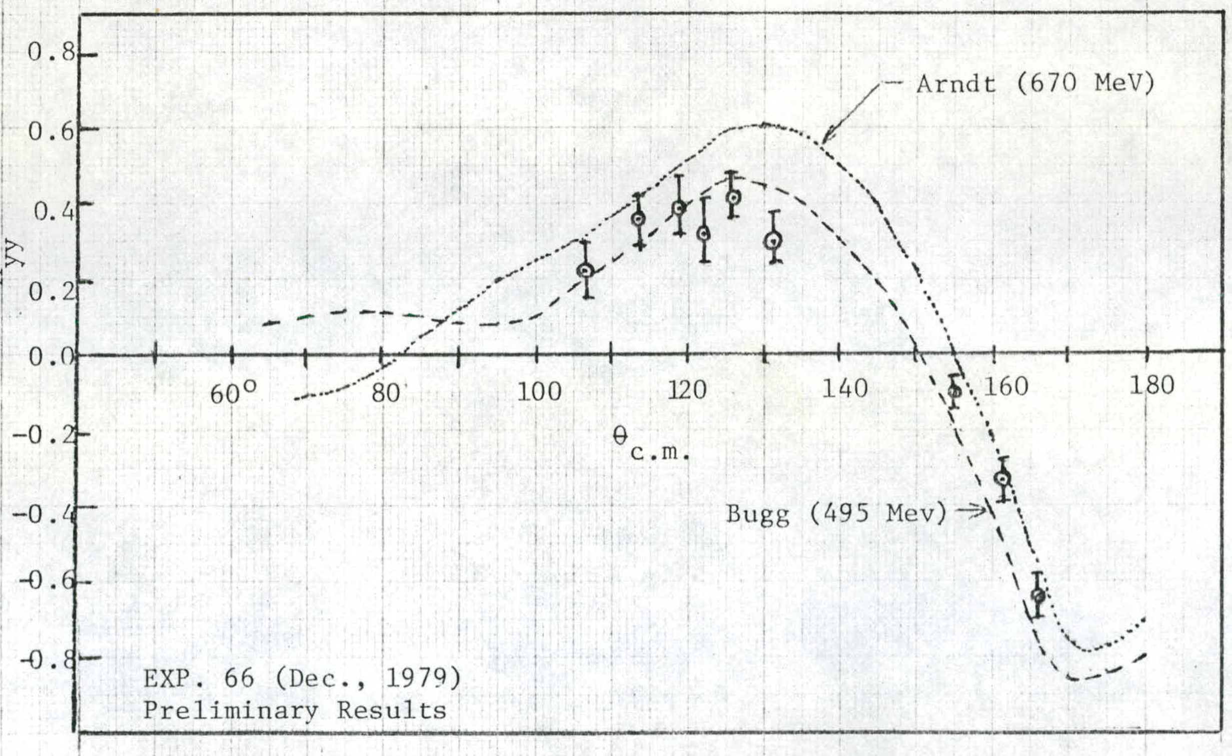
EXPT. 360 LAYOUT (0°)

FIGURE 11

(a) $A_y(110^o c.m.)$ versus Incident Neutron Energy



(b) $A_{yy}(\theta c.m.)$ for 670 MeV Incident Neutrons



measurements at 495 MeV. It is apparent that A_{yy} at the two energies are very similar in shape and magnitude. Arndt's phase shift solution will undoubtedly improve after the inclusion of these results.

4. Measurement of the Polarization Transfer Coefficients D_t and A_t' at 800 MeV for the Reactions $^2H(\vec{p},\vec{n})X$, $^1H(\vec{p},\vec{n})X$ and $^9Be(\vec{p},\vec{n})X$

Measurements of polarization transfer coefficients in $(\vec{p},\vec{n})$ reactions are of interest to determine whether these mechanisms can be used for the production of a polarized neutron beam at medium energies. The values of the polarization transfer coefficients can also provide information relating to n-p scattering phase shifts and to pion exchange models. Using the LAMPF polarized proton beam incident on a liquid deuterium target, we have carried out measurements of the polarization transfer parameters D_t and A_t' at 0^o. 0^o neutron momentum spectra for protons incident on deuterium and hydrogen are shown in Fig. 12.

The outgoing neutron polarization was measured with an analyzer consisting of a liquid hydrogen radiator and a multiwire proportional chamber (MWPC) spectrometer.[1] The conceptual experimental measurements of D_t and A_t' are shown in Fig. 13, where the symbol $\odot$ indicates vertical polarization, and the symbol $\rightarrow$ is used to designate longitudinal polarization. A layout of the experimental area is shown in Fig. 10. After passing through the LD_2 target, the incident polarized proton beam is deflected through 60^o and transported to a shielded beam dump. Neutrons emerging at 0^o are collimated, and after passing through a clearing magnet M1, encounter a liquid hydrogen radiator placed upstream of the MWPC spectrometer. The spectrometer was positioned at a nominal angle of 30^o (110^o c.m.) where the n-p analyzing power is known to be a maximum. The value of the n-p analyzing power for

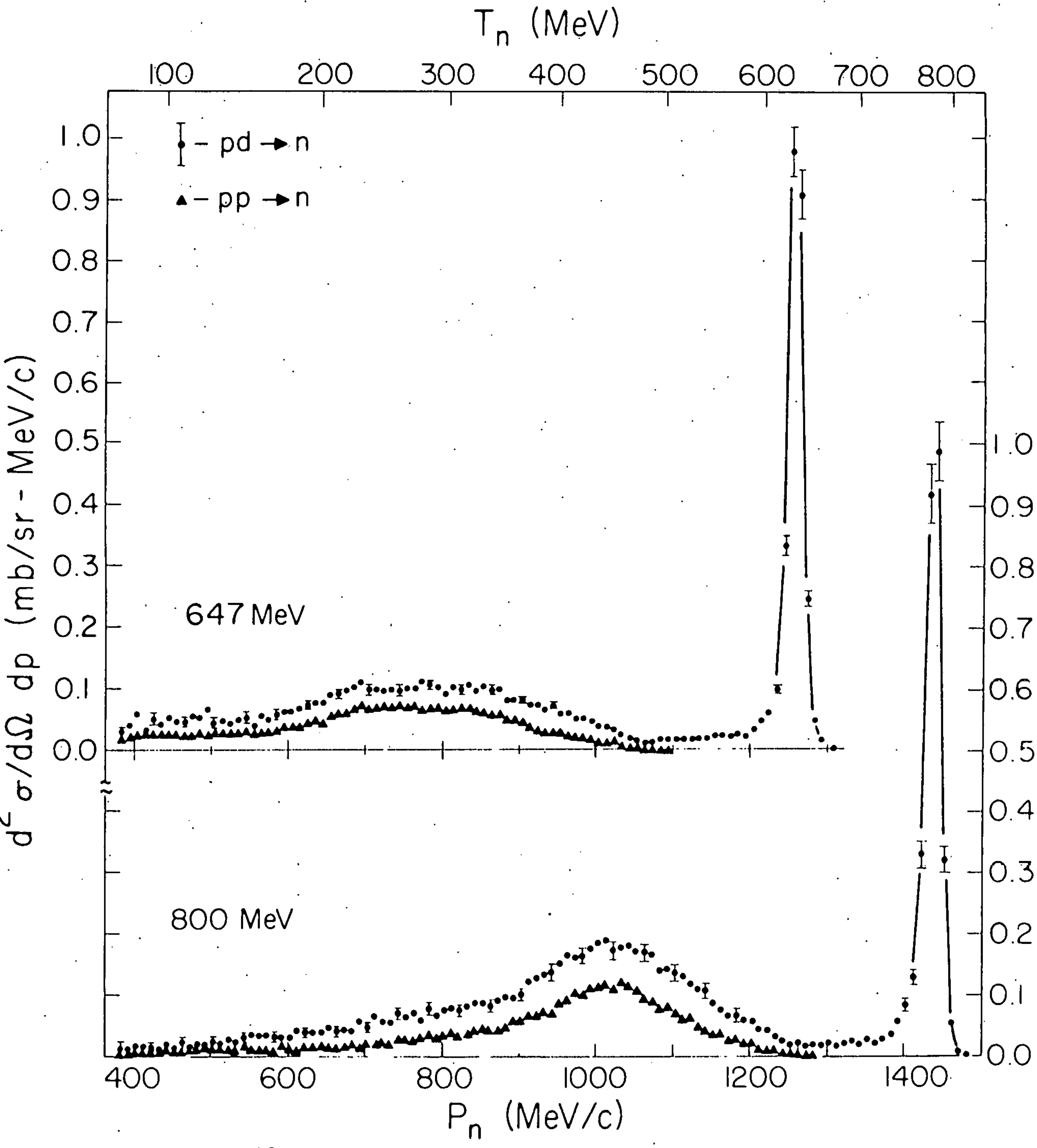
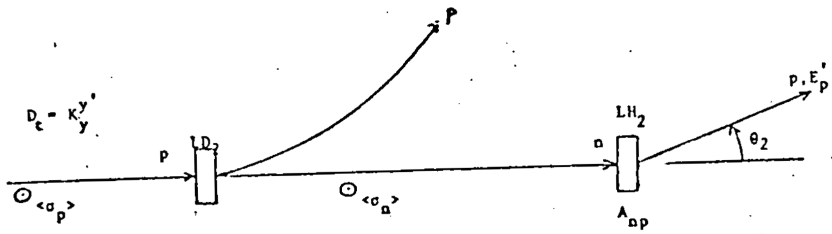
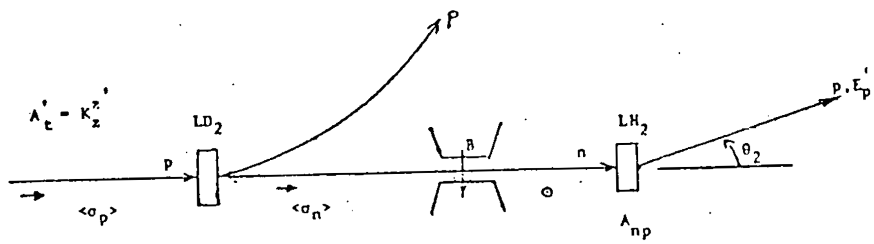

Tn (MeV)
100 200 300 400 500 600 700 800
- pd → n
- pp → n
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0
d²σ/dΩ dp (mb/sr - MeV/c)
647 MeV
800 MeV
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0
400 600 800 1000 1200 1400
Pn (MeV/c)

FIGURE 12.



$$D_t(0°,\ E_n) = \frac{\varepsilon(\theta_2,\ E_p')}{\langle\sigma_p\rangle\ A_{np}(\theta_2, E_n)}$$



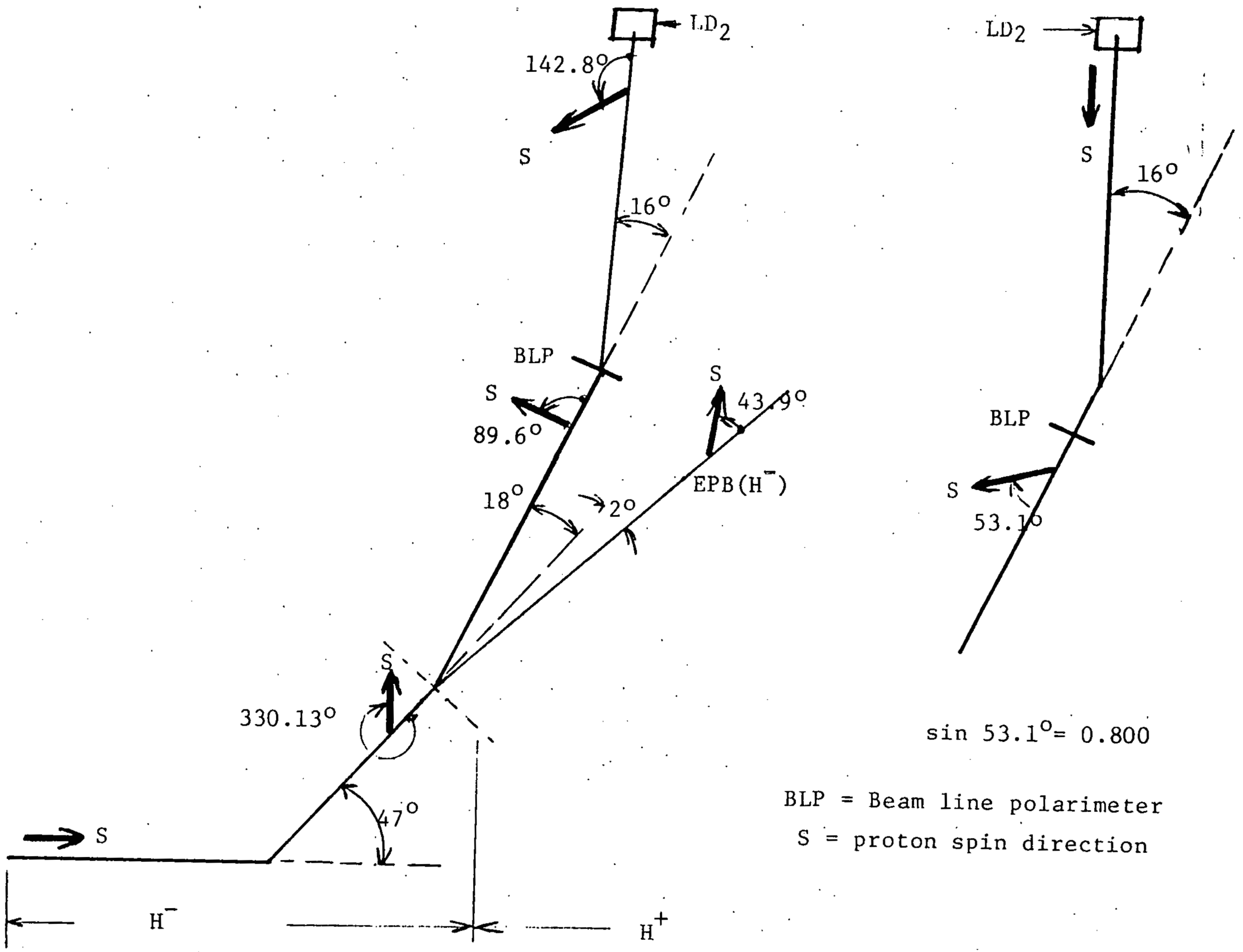
$$A_t'(0°,\ E_n) = \frac{\varepsilon(\theta_2,\ E_p')}{\langle\sigma_p\rangle\ A_{np}(\theta_2, E_n)}$$

Figure 13. Conceptual experimental measurements of D_t and A_t' for the reaction d $(\vec{p},\vec{n})$2p. The symbol [⊙] indicates vertical polarization, and the symbol [→] is used to indicate longitudinal polarization.

800 MeV incident neutrons at 110^{o} c.m. was taken to be 0.31 ± 0.02 from previous measurements in this laboratory.[2] The basic technique used to deduce the polarization of the incident neutron beam was to measure the spectrum of protons scattered elastically near 30^{o} into the acceptance of the MWPC spectrometer for a given incident polarized proton spin orientation. Spin reversal (from up to down for D_t and from parallel to anti-parallel for the A_t' work) was accomplished by reversing the spin of the incident polarized proton beam at the accelerator ion source every three minutes. During an experimental run, separate recoil spectra were built up for spin-up and spin-down (or parallel and anti-parallel) events, and asymmetries were computed from the spectra as a function of incident neutron energy. The proton beam polarization was measured using a double-arm beam line polarimeter; typical proton polarization was 0.78.

The $A_t'(0^{o})$ measurement was complicated by the spin precession of H^-, H^+, and neutrons in the vertical bending magnet fields. The precession of the incident H^- and H^+ beam between the accelerator and the LD_2 target is indicated in Fig. 14. Since a 16^{o} bending magnet was located between the beam line polarimeter and the LD_2 target, the H^+ beam, when aligned parallel to the beam axis at the LD_2 target, was aligned at 53.1^{o} with respect to the beam axis at the beam line polarimeter, which could, therefore, be used to monitor the beam polarization just as in the D_t measurements.

During preliminary A_t' measurements the polarized beam was aligned at the LAMPF ion source to give longitudinal polarization at the LD_2 neutron production target. This alignment necessitated that line B be the sole users of the polarized beam. During the Fall shut down of LAMPF, a superconducting spin precession solenoid was installed in line B immediately downstream of the Line EPB split to precess the polarized beam by 90^{0},



sin 53.1° = 0.800

BLP = Beam line polarimeter

S = proton spin direction

For H^+, $\theta_{rot} = 3.32\ \theta_{Bend}$

For H^-, $\theta_{rot} = -7.024\ \theta_{Bend}$

FIGURE 14.

from vertical to transverse. The succeeding bend of 32^o in line B precessed the spin by 106.2^o so that the polarized beam reached the neutron production target with its spin 16.2^o away from a pure longitudinal configuration. Since cosine $16.2^o = 0.96$ the misalignment was not serious, and other users of the polarized beam were able to use the beam with a vertical spin alignment.

The spin precession of the 0^o neutron beam emerging from the neutron production target in the subsequent 15^o bending magnet of approximately 50^o was compensated for by an equal and opposite field in the clearing magnet M1. The neutron beam was then spin-precessed into the vertical plane by an additional magnet M2, (POLLUX), positioned between M1 and the LH_2 radiator. Asymmetries were then deduced as in the D_t measurements.

In order to optimize the neutron spin precession in M1 (EURYDICE), and M2 (POLLUX), a neutron monitor system (QPAN - Quick Polarization Analyzer for Neutrons) was installed between M2 and the LH2 radiator target. QPAN consists of a two-arm telescope with a tapered copper absorber between the scintillators to ensure that only high momentum neutrons are detected. A veto counter is used to reject charged particles in the incident beam, and a four inch thick polyethylene slab is used as an n-p converter. The system has a rather large efficiency, and can be quickly rotated through 90^o to provide information on the neutron spin in either the horizontal or vertical planes. QPAN greatly facilitated the experimental measurements, and allowed us to optimize neutron spin precessions in M1 and M2 rather accurately.

The most serious complication which arose in the asymmetry measurements was caused by inelastic processes in the radiator leading to a proton in the final state, primarily pion associated protons from the reactions

$np \to pn\pi^0$, and $np \to pp\pi^-$. These inelastic events made polarization transfer measurements difficult for the lower energy (pion associated) incident neutrons. During preliminary measurements neutrons in coincidence with elastically scattered recoil protons were detected in a large volume neutron detector placed at the conjugate angle relative to the MWPC spectrometer (55^o laboratory). These events (approximately 10-15% of the total events) provided an unambiguous rejection of inelastic processes in the radiator target. Unfortunately, statistical errors were too great to allow the evaluation of asymmetries based on this fraction of the data. However, it was found possible to remove most the inelasticities by using for all events the incident neutron flight time (to a modulus of 5 nsec). The experimental results for $D_t(0^o)$ for deuterium and for hydrogen are shown in Figs. 15 and 16, respectively. For the quasielastic $\vec{p}d \to \vec{n}X$ peak of the neutron spectrum, the value of D_t is -0.143 ± 0.026. For the lower energies, a smooth peak in the polarization transfer is found, the maximum occurring near the Δ peak observed in $\vec{p}'N' \to \vec{n}\Delta$. The values of D_t appear to be in dis-agreement with predictions of B. Ver West based on his one pion exchange model of pion production. The behavior of D_t for hydrogen is strikingly similar in shape; in fact, only two of the data points for hydrogen are in disagreement with the deuterium data, those at 775 MeV/c (below the pion associated peak) and at 1300 MeV/c (above the pion associated peak). The D_t analysis for Be has not yet been completed; preliminary values of $D_t(o)$ for Be are small, and consistent with a null result.

The $A_t'(0)$ measurements were completed for deuterium and for beryllium on December 24, 1979, and have not yet been analyzed off-line. Measure-ments were also carried out for ^6Li, although it is not certain that the incident polarized proton beam was passing cleanly through the steel lithium target holder. Unfortunately, helium compressor failure occurred

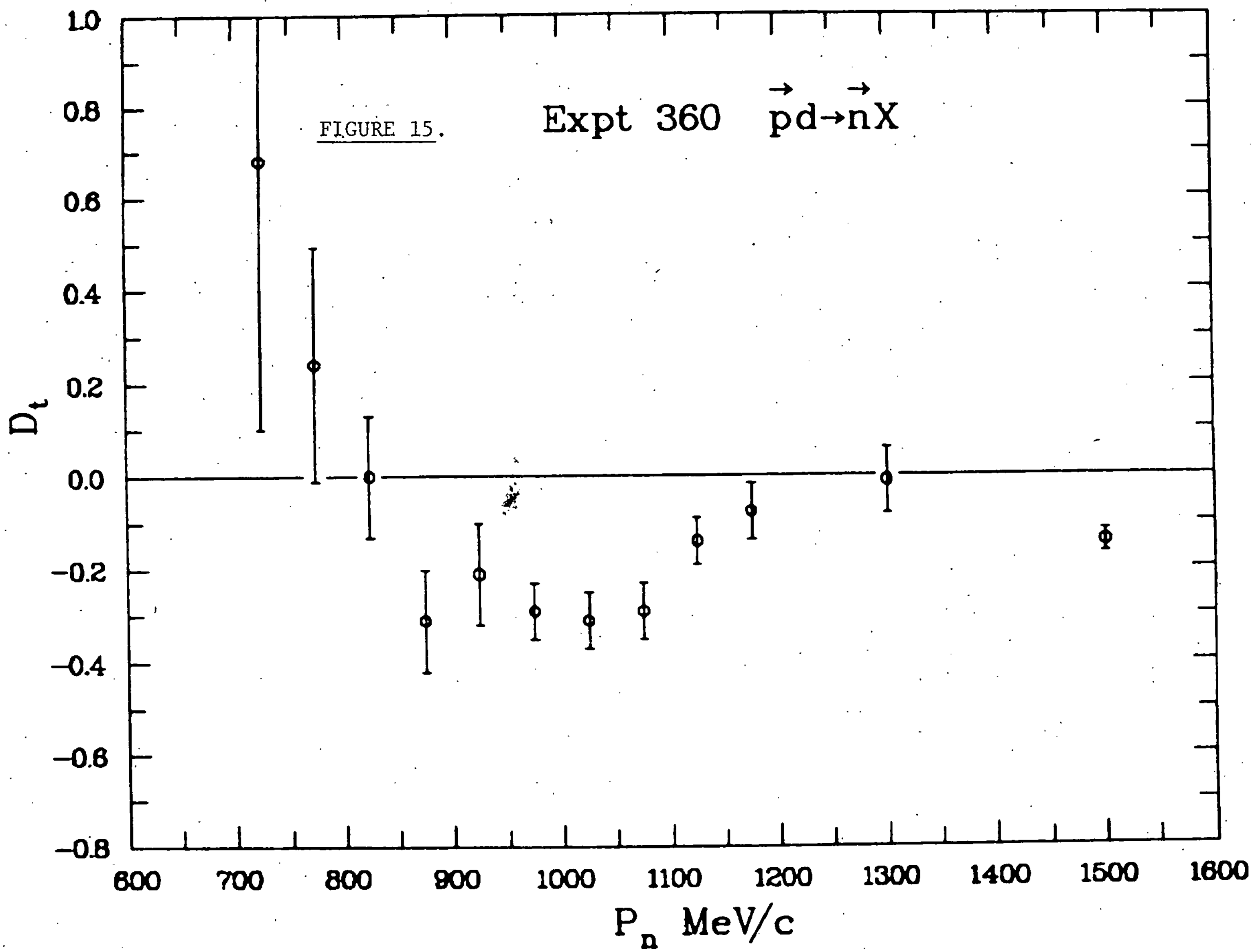

Expt 360 $\vec{p}d \rightarrow \vec{n}X$
D_t
P_n MeV/c
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
600
700
800
900
1000
1100
1200
1300
1400
1500
1600

FIGURE 15.

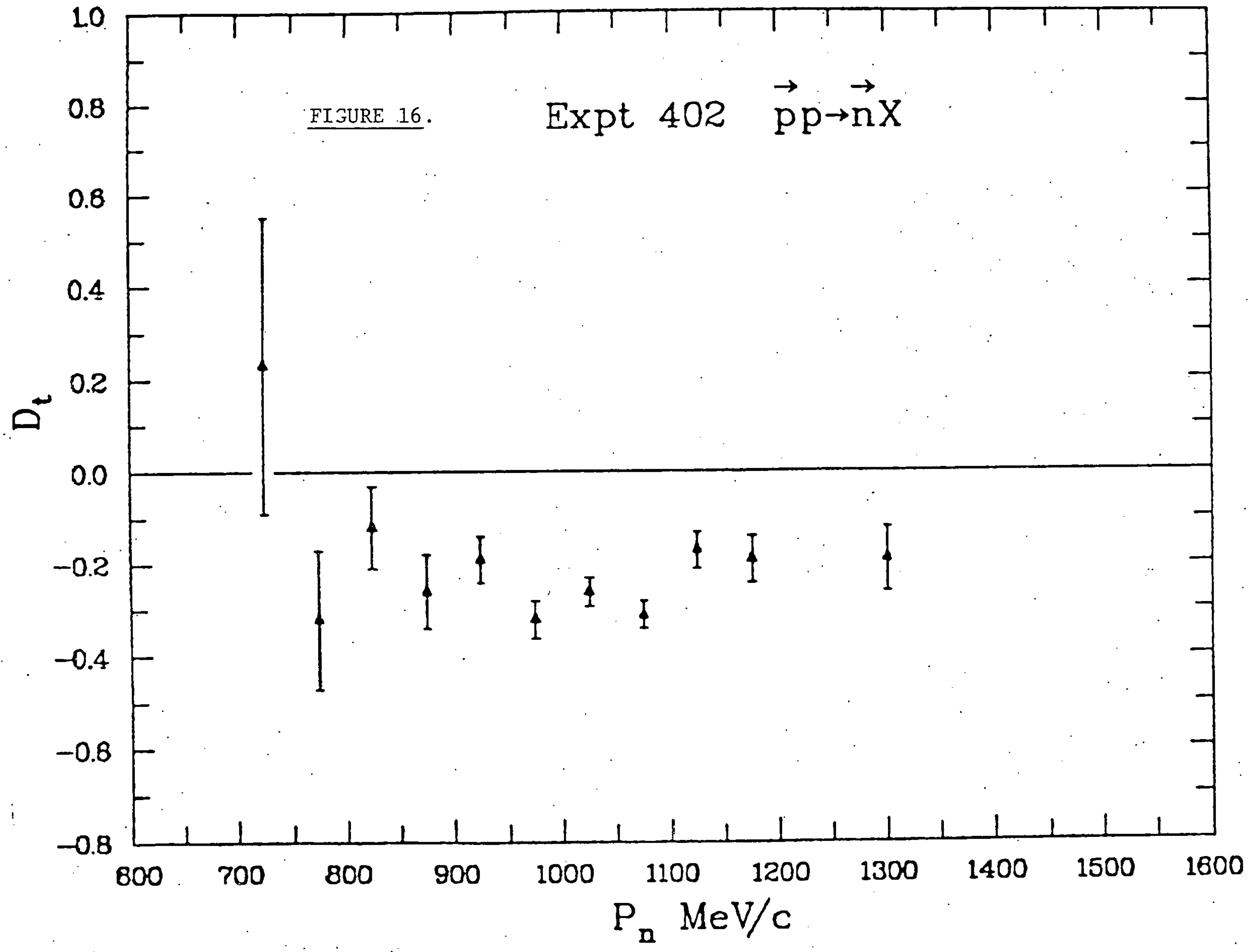
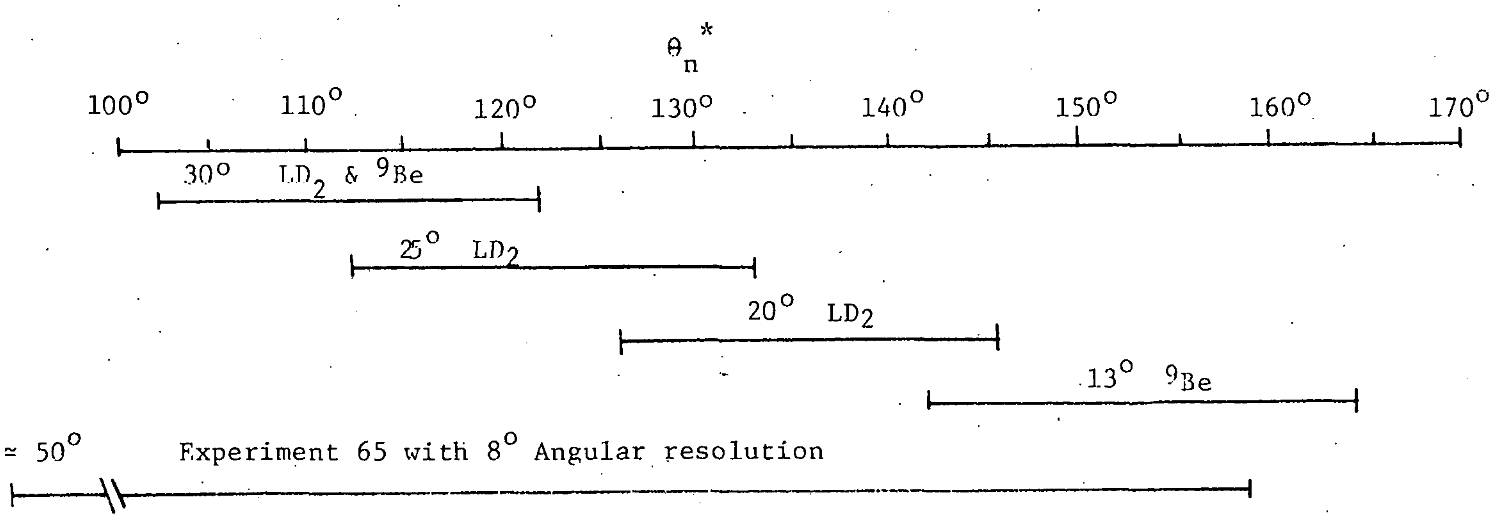

Expt 402 $\vec{p}p \rightarrow \vec{n}X$
1.0
0.8
0.8
0.4
0.2
0.0
−0.2
−0.4
−0.8
−0.8
D_t
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
P_n MeV/c

FIGURE 16.

during the change over from LD2 to a LH2 neutron production target, so that it was not possible to carry out A_t' measurements with hydrogen. The on-line analysis gave the following results for the high momentum neutron peak:

^2H	$A_t' = 0.57 \pm 0.02$
^9Be	$A_t' = 0.44 \pm 0.04$
^6Li	$A_t' = 0.50 \pm 0.04$

The polarization transfer is very small for the pion associated peak at lower momenta for all targets. The sign convention is that used by D. Bugg and others.[5] The positive sign of A_t' indicates that the spin direction of the outgoing neutron is antiparallel to that of the incident proton. Relative measurements were also made of the n-p analyzing power, A_y, by changing the angle of the MWPC spectrometer away from the nominal angle of 30° where the analyzing power has its maximum value. Measurements were carried out at laboratory spectrometer angles of 25°, 20°, and 13°; the c.m. neutron angular ranges are indicated below. Preliminary comparisons with the results of experiment 65 indicate excellent agreement. The measurements will be binned into 2° angular bins, giving A_y data with rather good angular resolution.



Predictions have been made for the magnitudes of $D_t(0)$ and $A_t'(0)$ for deuterium. If one simply considers the production of polarized neutrons by knockout in the $d(\vec{p},\vec{n})2p$ reaction, and neglects the D state of the deuteron, then crude arguments give the result that $D_t(0) = -1/3$, since two protons must be left in the singlet state. It has been pointed out by Ohlsen[4] that for the $d(\vec{p},\vec{n})2p$ reaction at 0^o, the expected spin structure is $1 + \vec{1/2} \rightarrow \vec{1/2} + 0$, for which it can be shown that $A_t'(0^o) + 2D_t(0^o) = -1$. The results should apply to the upper few MeV of the neutron spectra, i.e., for the region of the dominant charge exchange peak. The present measurements for the peak region of LD_2 give $D_t(0) = -0.14 \pm 0.026$ and $A_t'(0) = -0.57 \pm 0.02$ and thus are in reasonable agreement with the relationship $A_t'(0) + 2D_t(0) = -1$. Phase shift predictions for A_t' for both free n-p scattering at 180^o [A_t'(np)] equivalent to 0^o in the present work) and for charge exchange scattering for deuterium, [A_t'(CES)] have been made by D. Bugg,[5] and are indicated in Fig. 17. Our measured value of A_t' for deuterium is in rather good agreement with the phase shift predictions for free n-p scattering, and is somewhat less than the extrapolated value for charge exchange scattering. The rough agreement between the values of polarization transfer for LD_2, ^9Be, and ^6Li may provide further evidence that the polarization transfer mechanism at 0^o for all targets is similar to that for the free n-p case. It will be of interest to compare our values with those for free n-p scattering when experimental values for A_t'(np) become available. Bugg's calculation predicts that D_t(CES) = 0, again in fair agreement with out observed results.

From a practical consideration, the rather large value of $A_t'(0)$ for protons on deuterium of 0.57 ± 0.02 demonstrates that the $A_t'(0)$ polarization transfer mechanism should provide a useful source of polarization neutrons

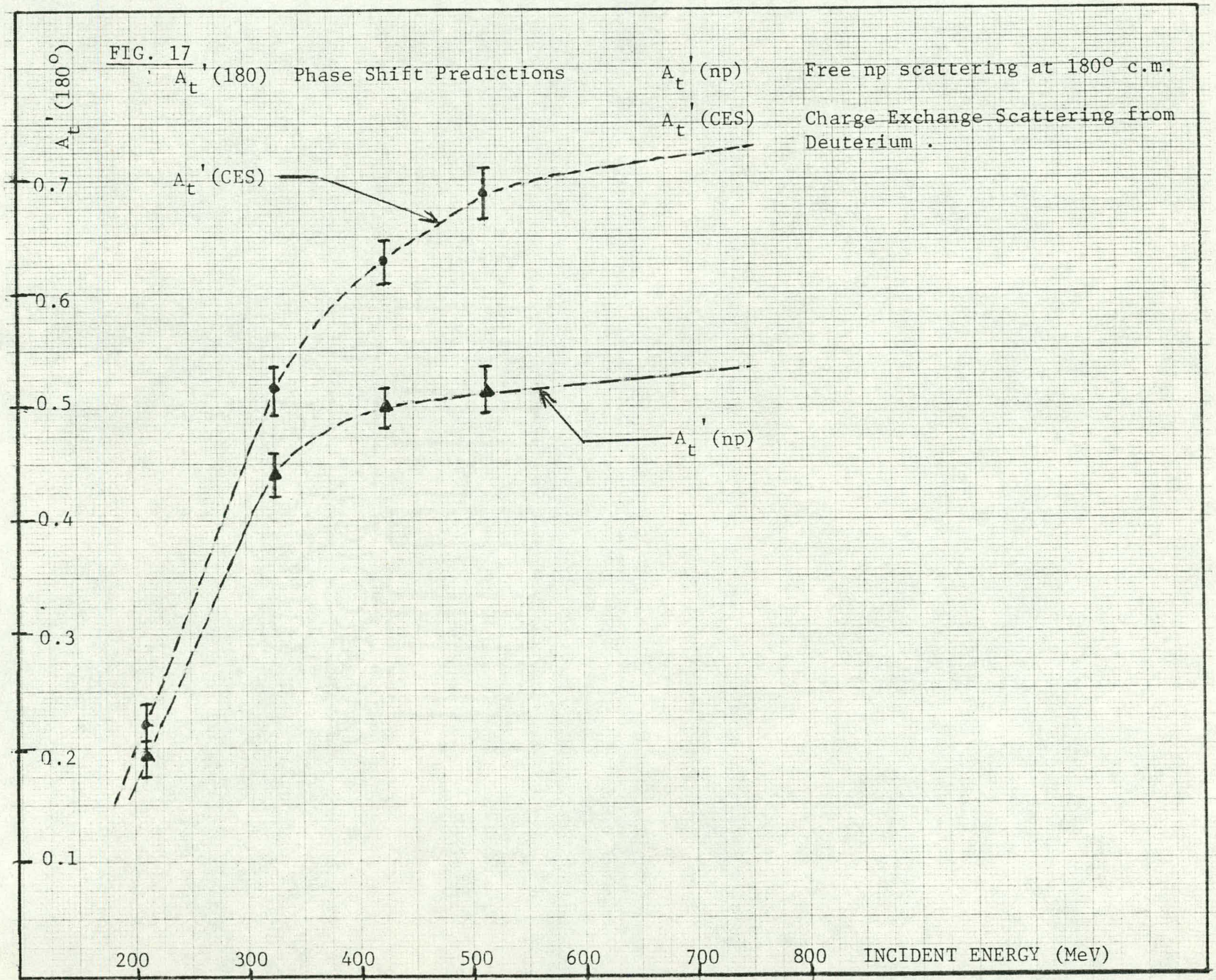


FIG. 17 A_t'(180) Phase Shift Predictions at LAMPF energies. The preliminary results indicate that ^{6}Li and ^{9}Be may also be useful targets for the production of polarized neutrons.

References.

1. G. Glass, et al., Phys. Rev. D 1t, 36, (1977).
2. C. R. Newson, et al., Abstract submitted to this Conference.
3. B. E. Bonner, et al., Phys. Rev. C, 18, 1418, (1978).
4. G. C. Ohlsen, Rep. Prog. Phys. 34, 717, (1972).
5. D. Bugg, private communication, 1979, D. Axen, et al., preprint RL 79-022 (1979).

5. Recoil Proton Polarimeter Development.

The construction and development of the polarimeter was a rather large collaborative effort by some of the members of our collaborative group together with MP-13 and MP-10. Although it was originally designed for use in experiments in EPB, the neutron beam (BR), and at HRS, because of the high anticipated demand for the device, MP-10 is constructing a second one for installation at HRS. From The University of Texas, Ron Ransome and Charles Hollas have played significant roles in the development of the polarimeter. The device is capable of measuring the average polarization of protons produced in a nuclear scattering or reaction. The device is indicated schematically in Fig. 18. It consists of front and back scintillators, and three multi-wire drift chambers before and after a block of analyzer material. The scintillators SF and SB each consist of an upper and lower half, SF1, SF2, SB1, SB2. Each of these measures 24 inches by 12 inches by 3/16 inches thick and is adiabatically coupled at each end to a LAMPF standard photomultiplier tube. Each of XY1 to XY6 are an X-Y pair of multiwire drift chambers with nominal active area 60 cm x 60 cm. Each pair of chambers consists of an X and Y plane of anode wires between three cathode planes. The X and Y planes consist of 0.8 mil sense wires spaced at 0.8 cm apart, alternating with 3 mil field shaping wires. Each anode sense wire is connected to a delay line, each end of which is coupled to a discriminator. The time difference between the two ends of the delay line gives the anode position: $AP = T_{+} - T_{-}$. Interpolation between the sense wires is obtained from the drift time of approximately 20 ns/mm, or $\simeq$ 80 ns for the maximum drift distance of 4 mm. The "left-right ambiguity", the determination of which side of the sense wire the avalanche occurred, is resolved by picking up the image of the avalanche on the adjacent field shaping wires. The wire closest to the avalanche has the larger pulse. Alternate field shaping wires are bussed together to give two pulses known as "odd" and "even." A differential amplifier and a summing amplifier give the two output signals O-E and O + E.

In use, protons enter the polarimeter, and about 15% scatter usefully in the analyzer. The scattering in the analyzer at a given angle θ has an azimuthal asymmetry given by

$$P(\theta,\phi) = \frac{1}{2\pi} [1 + A(\theta) (\sigma_y \cos \phi + \sigma_x \sin \phi)]$$

where $A(\theta)$ is the analyzing power and σ_x and σ_y are the two transverse components of the spin of the incident protons. $A(\theta)$ is a function of both proton energy and scattering angle. Preliminary measurements indicate that the average value of A for carbon is 0.2 at LAMPF energies.

6. Progress on Experiments 194 and 492.

Experiment 194, "P-P D, R, AND A MEASUREMENTS," was written in 1974 with P. R. Bevington as Spokesman. A related proposal, 492, "Polarimeter Calibrations and Search for Energy Dependent Structure in pp Elastic Scattering via Cross Section, Analyzing Power, and Wolfenstein Parameter Measurements," was written in 1979 with M. McNaughton and H. Willard as Spokesmen. Since then, M. McNaughton has effectively become spokesman for both experiments. Because of our mutual interest in the nucleon-nucleon problem, and because both experiments involve usage of the proton recoil polarimeter to be used in Experiment 403, the members of The University of Texas group and B. Bonner of P-7, LASL, have joined the collaborative work on experiments 194 and 492. The importance of experiment 194 is that it should make possible for the first time an amplitude analysis for T = 1 at 800 MeV. The objective of the experiment is to measure the six Wolfenstein parameters as a function of angle for $\vec{p}p \rightarrow \vec{p}p$ at 800 MeV. The experiment is indicated schematically in Fig. 19. A conjugate detector, consisting of a drift chamber and scintillator like those of the recoil polarimeter, is used to detect the recoil proton. A fast clear electronic system, utilizing analog electronics, was devised for the polarimeter to reject events, before interrupting the computer, that do not scatter in the carbon through a significant (3-4^{o}) angle. Since at small angles the trigger rate into the computer sets the limitations on event rates, this system allows the true event rate to be significantly increased. The first experimental running time for experiment 194 took place during December 14-24, 1979, with the incident polarized proton beam aligned vertically. During this

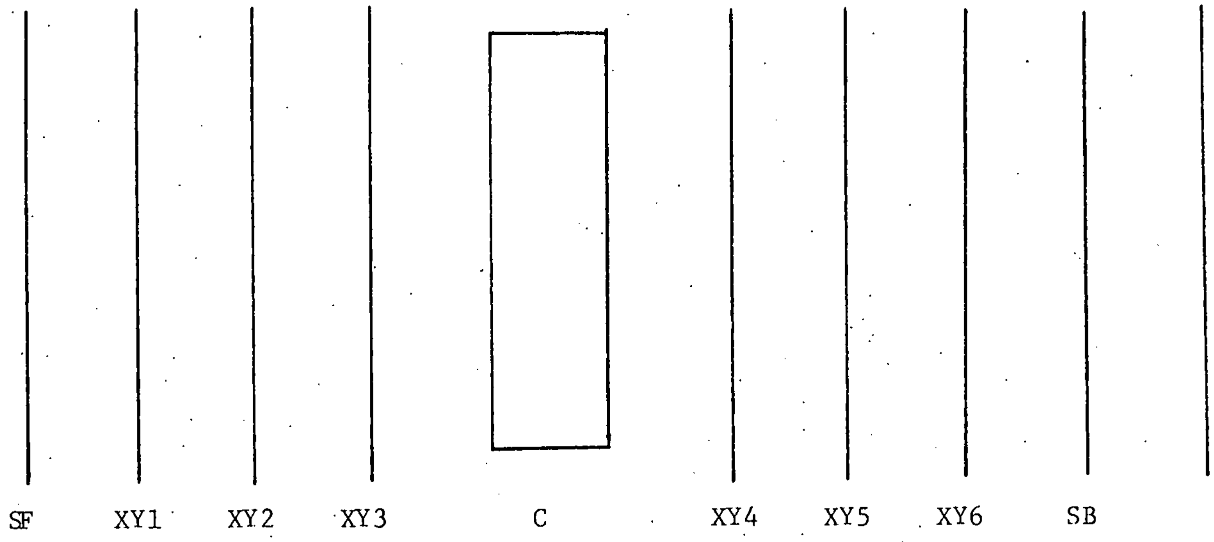


FIG. 18. Schematic of the Proton Recoil Polarimeter

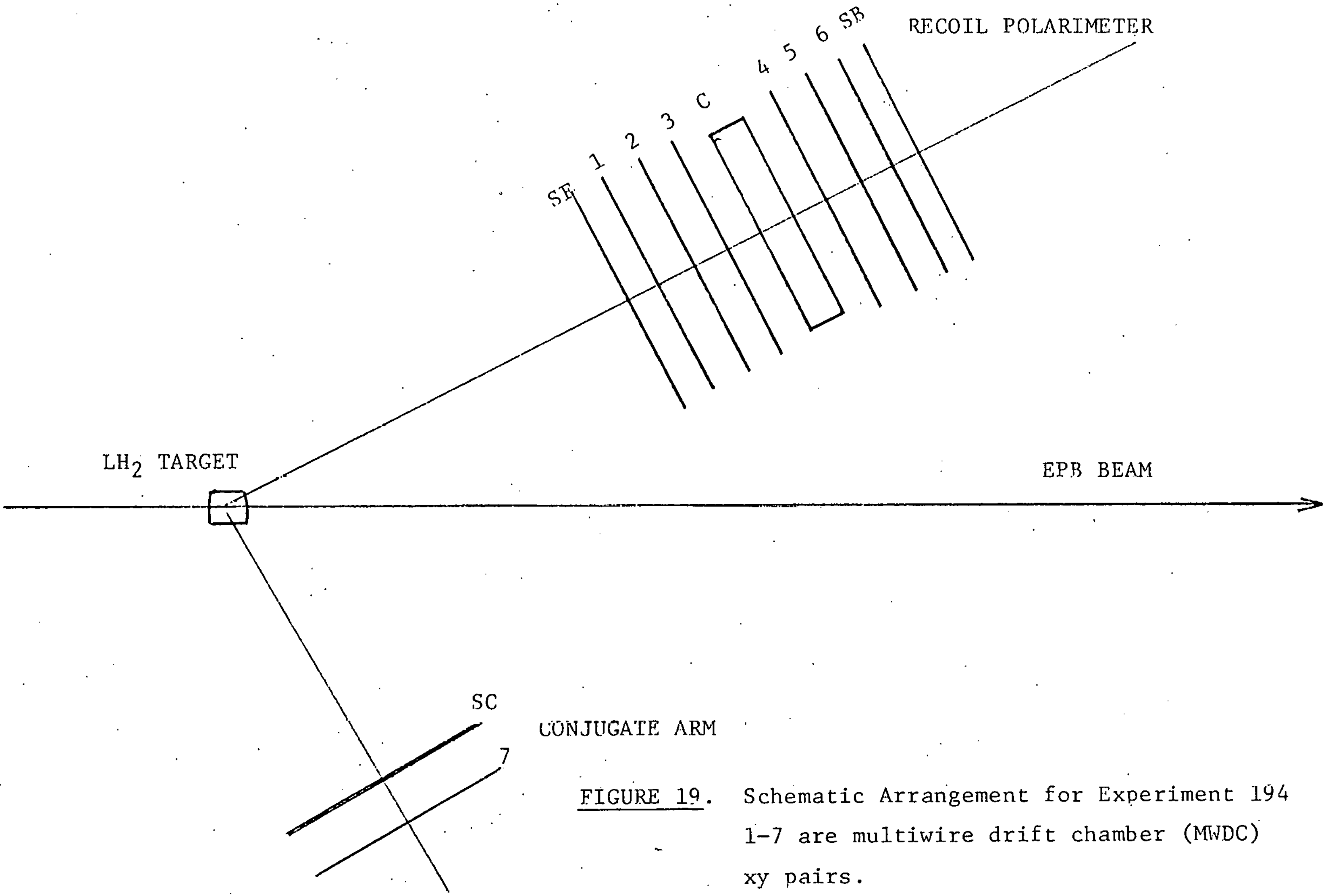


FIGURE 19. Schematic Arrangement for Experiment 194
1–7 are multiwire drift chamber (MWDC) xy pairs.
SF, SB, SC are Scintillators.

time period the polarimeter was calibrated, and measurements of the D parameter were carried out.

7. Preparations for Exp. 403.

The original aim of this experiment was to measure the spin flip probability D_t in the charge exchange (CEX) region in neutron proton scattering. From our previous experiments (263, 125) it is known that the cross section in the CEX region has the simple shape of the sum of two exponentials in the momentum transferred. This behavior is almost independent of energy and would appear to be due to two noninterfering mechanisms. Simple one pion exchange is in contradiction to this behavior. It is possible that a knowledge of D_t over this region will severely constrain proposed explanation for the observed effects.

During the past few months we have examined the feasibility of measuring the four other spin transfer coefficients for the CEX region in addition to $D_t(k_y^{y'})$. These are the two spin rotation parameters resulting from transverse initial polarization ($R_t = K_x^{x'}$, $R_t' = K_x^{z'}$) and the two spin rotation parameters resulting from longitudinal initial polarization ($A_t = K_z^{x'}$, $A_t' = K_z^{z'}$). Only three of these four are independent; thus a consistency check is possible.

One property of the recoil polarimeter is its inability to measure the component of polarization parallel to the particle momentum. This precludes direct measurement of A_t' and R_t' (which have the final component of spin parallel to the momentum). This difficulty can be overcome by use of a spin precession magnet. Near 800 MeV the spin of a proton will precess about 3.3 times the bend angle. Thus, for a bend angle of 27^o the spin will precess 90^o, making it completely transverse.

Experiment 403 will incorporate the 18D36 MWPC spectrometer and the proton recoil polarimeter; the final two planes of the MWPC spectrometer will be replaced by the polarimeter in order to maximize the acceptance of the device. The spectrometer will momentum analyze the recoil protons and will precess the proton spins, making possible the measurement of all five transfer parameters D_t, R_t, R_t', A_t, A_t' and the polarization parameter. The measurements are indicated schematically in Fig. 20. The measured quantities are the two transverse components of the spin of the proton entering the recoil polarimeter, σ_{nm} and σ_{sm}, as given by the scattering asymmetries in the recoil polarimeter by the expression:

$$P(\theta,\phi) = \frac{1}{2\pi} [1 + A(\theta) (\sigma_{nm} \cos \phi + \sigma_{sm} \sin \phi)].$$

In addition, from the measured proton trajectory through the MWPC spectrometer system, the quantities θ_H, ϕ_H, θ_B, θ_p are known. The spin of the recoil proton, σ_R, with components σ_{nR}, σ_{sR}, $\sigma_{\ell R}$ is related to the measured quantities by the relationship:

$$\sigma_{nm} = \sigma_{nR} [\cos^2 \phi_H + \sin^2 \phi_H \cos (\theta_p - \theta_B)]$$

$$+ \sigma_{sR} [\tfrac{1}{2} \cos \theta_H \sin 2\phi_H (1 - \cos (\theta_p - \theta_B))$$

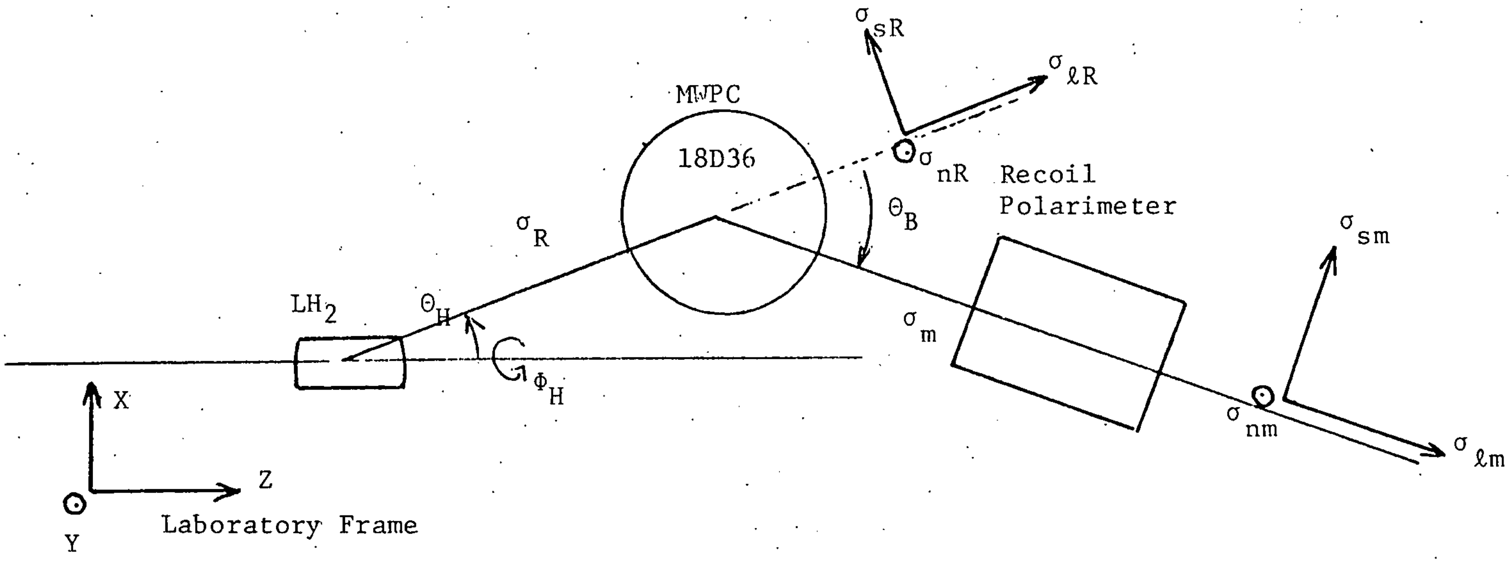
$$- \sin \theta_H \sin \phi_H \sin (\theta_p - \theta_B)]$$

$$+ \sigma_{\ell R}[\cos \theta_H \sin \phi_H \sin (\theta_p - \theta_B) + \tfrac{1}{2} \sin \theta_H \sin 2\phi_H$$

$$(1 - \cos (\theta_p - \theta_B))].$$

$$\sigma_{sm} = \sigma_{nR} [\tfrac{1}{2} \cos \theta_H \sin 2\theta_H (1 - \cos (\theta_p - \theta_B))$$

$$+ \sin \theta_H \sin \phi_H \sin (\theta_p - \theta_B)]$$



σ_R = spin of recoil proton

σ_m = spin of proton after precession and bend

Θ_H = scattering angle of proton

Φ_H = azimuthal angle of scattered proton

Θ_B = bending angle in 18D36

Direction of spin of Neutron Beam at LH_2	Parameters Measured	18D36 Current Settings
$\hat{Z}$	A_t', A_t	2
$\hat{X}$	R_t', R_t, D_t	2
$\hat{Y}$	D_t, R_t' *, R_t*	1

* Indicates those parameters which are zero for $\Phi_H = 0$.

FIGURE 20 Schematic of MWPC - Recoil Proton Polarimeter System.

$$+ \sigma_{sR} [\cos^2\theta_H (\sin^2\phi_H + \cos^2\phi_H \cos(\theta_p - \theta_B)) + \sin^2\theta_H \cos(\theta_p - \theta_B)]$$

$$+ \sigma_{\ell R} [-\cos\phi_H \sin(\theta_p - \theta_B) + \cos\theta_H \sin\theta_H (\sin^2\phi_H + \cos^2\phi_H$$

$$\cos(\theta_p - \theta_B) - \cos(\theta_p - \theta_B))]$$

By making measurements at two different values of bend angle θ_B, (and thus θ_p also) i.e., by changing the 18D36 magnet current, we can deduce the three unknowns,

$$\sigma_{nR},\ \sigma_{sR},\ \text{and}\ \sigma_{\ell R}.$$

Thus in the general case the measured spins σ_{nm} and σ_{sm} will consist of a mixture of the original spin components σ_{nR}, σ_{sR}, and $\sigma_{\ell R}$. Note that for the special case where $\phi_H = 0$, $\sigma_{nm} = \sigma_{nR}$ only, with no mixing of other components. Five settings will be required to separate and measure all five components, as indicated below the figure. The polarization parameter comes from reversing the incident neutron spin and averaging over the initial spin states. An independent measurement of this parameter (actually the analyzing power which is equal to P by time reversal invariance) comes from the asymmetry in counting rates for initial neutron spins up and down.

By optimizing several aspects of the apparatus, our estimated counting rates are such that we should be able to measure all five parameters in the two weeks scheduled in January.

III. CURRENT APPROVED LAMPF PROPOSALS

No. 65 "Neutron-proton Polarization Measurements Using a Polarized Target: Phase I. The N-p Polarization Observable," J. E. Simmons, Spokesman. Data acquisition and analysis are both complete. Ph.D. dissertation of Mr. C. Newsom is based on this experiment.

No. 66 "Neutron-Proton Polarization Measurements Using a Polarized Target: Phase II. The n-p Spin Correlation Observable." J. E. Simmons, Spokesman. Data acquisition on this experiment was completed during June, 1979. Analysis of the data is in progress.

No. 360 "A Measurement of the Polarization Transfer Coefficients D_t and A_t' at 800 MeV for the Reactions $d(\vec{p},\vec{n})2p$, $^6Li(\vec{p},\vec{n})\ ^6Be$, and $^9Be(\vec{p},\vec{n})^9B$," P. J. Riley and J. E. Simmons, Spokesmen. The experimental measurements were completed on December 24, 1979. Analysis of the data is in progress.

No. 402 "A Measurement of the Polarization Transfer Coefficients $D_t(0)$ and $A_t'(0^o)$ in the Reaction $\vec{p}\ p \rightarrow \vec{n}\ X$ at 800 MeV." G. Glass and J. E. Simmons, Spokesmen. $D_t(0)$ measurements on this experiment were completed during June, 1979. We expect to carry out the $A_t'(0^o)$ measurements during 1980.

No. 403 "A Measurement of the Triple Scattering Parameter D_t for the Charge Exchange Region in np Scattering." We expect to carry out these measurements during January, 1980. B. E. Bonner, Spokesman.

No. 366 "Non-Resonant Pion Production in the Reaction $np \rightarrow \pi^- pp$," B. W. Mayes and G. S. Mutchler, Spokesmen. This experiment is scheduled for the time periods Feburary 22 - March 3 and March 18 - 28, 1980.

No. 194/492 "P-P D, R, and A MEASUREMENTS," P. Bevington, Spokesman (194), and "Polarimeter Calibrations and Search for Energy Dependent Structure in PP Elastic Scattering Via Cross Section, Analyzing Power, and Wolfenstein Parameter Measurements," M. McNaughton, Spokesman, (492). Preliminary 194 data were taken During Dec. 14 - 24; an additional run is scheduled for the period March 4 - 17. We hope to begin measurements on Experiment 492 during 1980.

No. 387 "Energy Dependence of the Forward Angle np Differential Cross Section," B. E. Bonner, Spokesman. We expect to be able to carry out this experiment during the beginning of 1981. The present limitation is the low H^- beam intensity available in the chopped beam mode (40 nsec pulsing) at LAMPF.

IV. PAPERS SUBMITTED FOR PUBLICATION DURING 1979

1. C. L. Hollas, "Analysis of the Singlet and Triplet Contributions to the Total Cross Section Differences $\Delta\sigma_T$ and $\Delta\sigma_L$ in $\vec{p}\to\vec{p}$ Scattering Between 1 and 3 GeV/c," submitted for publication in Physical Review Letters.
2. C. L. Hollas, C. R. Newsom, P. J. Riley, B. E. Bonner, G. Glass, "A Test of Charge Symmetry in the $np\to d\pi^0$ Reaction at 795 MeV," submitted for publication in Physical Review C.
3. P. J. Riley, C. L. Hollas, C. R. Newson, R. Ransome, B. E. Bonner, J. E. Simmons, T. S. Bhatia, G. Glass, J. C. Hiebert, L. C. Northcliffe, "Measurement of the Polarization Transfer Coefficients D_t and A'_t at 800 MeV for the Reactions $^2H(\vec{p},\vec{n})$ X and $^9Be(\vec{p},\vec{n})$ X," contributed paper, 8th International Conference on High Energy Physics and Nuclear Structure, Vancouver, Canada, August, 1979.
4. C. R. Newsom, C. Hollas, P. J. Riley, B. E. Bonner, J. J. Jarmer, M. W. NcNaughton, J. E. Simmons, T. S. Bhatia, G. Glass, J. E. Hiebert, and L. C. Northcliffe, "N-P Analyzing Power at LAMPF Energies," contributed paper*, 8th International Conference on High Energy Physics and Nuclear Structure, Vancouver, Canada, August, 1979.
5. C. L. Hollas, "Analysis of the Singlet and Triplett Contributions to the Total Cross Section Differences $\Delta\sigma_T$ and $\Delta\sigma_L$ in $\vec{p}\to\vec{p}$ Scattering between 1 and 3 GeV/c," contributed paper,* 8th International Conference on High Energy Physics and Nuclear Structure, Vancouver, Canada, August, 1979.

*Indicates that this paper was selected for oral presentation at the meeting.

No. 526 "Measurement of Analyzing Powers in $pd \to pd$, $pp \to d\pi$, and $pp \to pp$ Reactions at 520, 600, 650, and 730 MeV," F. Cverna, R. E. Anderson, and N. S. P. King, Spokesman. We hope to carry out these measurements during late 1980.