THE ANALYZING POWER FOR p-p SCATTERING AT 180 MeV

J. Sowinski, M. Minty, C. Whiddon, W.W. Jacobs, E.J. Stephenson, J. Templon and S. Vigdor
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

A detailed and precise knowledge of the N-N interaction at intermediate energies is essential since the 2-body interaction forms the basis for the microscopic many-body theory of nuclear reactions. Unfortunately the quality and quantity of the data in the IUCF energy range are found to be quite lacking when compared to this important role. (A recent review of the status of intermediate energy N-N data can be found in Ref. 1.) Problems in this data base are highlighted by variations in the predicted observables from single energy solutions (such as Arndt's C200) versus predictions from global solutions (such as SM86).[2] It is also typical for the predictions of different authors' phase shift solutions for a given observable to differ by more than the error bars generated from the corresponding fits.

The most precise measurements of the analyzing power for p-p scattering in the energy range 100-200 MeV are at 141 MeV from Harwell.[3] These data disagree with the SM86 phase shift solutions substantially in normalization and to some extent in shape. This is rather unsettling if one wants to use p-p scattering as the analyzer in a polarimeter or to normalize other analyzing powers. One such application of accurately known p-p analyzing powers is the determination of absolute beam and target polarizations in the charge symmetry breaking (CSB) experiment which are needed to extract the n-p scattering observables $A(\theta)$ and $C_{NN}(\theta)$ with reliable normalizations.[4] Due to the precision of the measured n-p observables ($\delta A \sim 0.001$), it would be nice to determine an absolute normalization to a high degree of accuracy. A normalization accurate to about 1% could be accomplished by using p-p scattering induced by an unpolarized proton beam to determine the target polarization. Then since the CSB $\vec{n}$-$\vec{p}$ data provide a direct measure of the ratio of neutron to proton polarizations, to the extent that charge symmetry holds (believed accurate to $< 1\%$ in angle regions where the n-p analyzing power is large), the neutron beam polarization can be determined. The present experiment, #273, was proposed to provide p-p analyzing power measurements of sufficient accuracy at an energy chosen to match that of the secondary proton beam in the PNF to perform such a normalization. A long-term goal is to accumulate high precision measurements of N-N observables, both n-p and p-p at the same energy using modern techniques. This experiment and the CSB determinations of $A(\theta)$ and $C_{NN}(\theta)$ in n-p scattering[4] would be the first of such measurements.

The present p-p analyzing power angular distribution measurements were performed in the 64" scattering chamber with a gas cell as a target. A standard double slit system, constructed from copper and tantalum, was used to define the interaction region and symmetric left-right arms were used to help cancel systematic errors. Each arm consisted of three detectors. The scattered protons were stopped in 10.2 cm. long by 5.7 cm. diameter NaI detectors. A plastic scintillator delta-E detector was positioned behind each slit in order to insure that only charged particles coming through the slit system would be counted. This eliminated a large background in the NaI's observed in early test runs.

A number of diagnostic devices were used to reduce possible systematic error contributions arising from the second-order effects of beam misalignment and differences in polarization between the two beam spin states. The beam polarization was continuously monitored with a high energy transmission polarimeter based on p-^{12}C elastic scattering at 20° (developed by the spin transfer group[5]) during the p-p data acquisition. In addition to the spin up and down polarized beam states the nominally unpolarized state was also used in order to help determine false asymmetries and measure polarization differences between spin up and down. Signals from a beam position monitor, provided by the Cooler diagnostic group, were used to keep the beam centered on the polarimeter with a computer controlled feedback loop driving a beam-line steering magnet. Similarly, signals from a split ionization chamber in the gas cell were used to keep the beam centered on the primary target with a second feedback loop. With these measurement techniques this class of second-order effects should be minimized and information will be available to correct for them.

The high energy polarimeter was assumed to have an analyzing power of 0.92+/-0.02, based on earlier calibration performed in conjunction with the spin transfer experiments. In order to obtain a more accurate absolute normalization, analyzing power measurements were taken on p-^{4}He elastic scattering near θ_{lab}=20° which will provide a polarization standard for calibrating the high energy polarimeters. The p-^{4}He analyzing power gets quite close to 1 at this angle and hence can be determined quite accurately (and absolutely) by measuring the spin transfer coefficients. These spin transfer measurements will be made at a later date as part of experiment #290.

A p-p scattering spectrum taken at 25° is shown in Fig. 1. The region immediately below the peak appears to be dominated by slit-edge scattering. A "punch-through" peak from protons degraded by the lip of the tantalum slit can be seen well below the main peak. A channel by channel calculation of the measured asymmetry is constant across the whole spectrum, indicating that almost all events observed originate from free p-p scattering. An empty gas cell run does reveal a small amount of background in the region of the free scattering peak which grows stronger at more forward angles. Empty gas cell runs were taken at each angle so that a careful background subtraction can be made. As a check of the subtraction procedure, data were also taken by detecting the two protons in coincidence, once with both detectors at 43.7° and again with one detector at 15° (the angle with the largest empty-cell background) and the other at the conjugate angle of about 73°. The results from this data with very little background can then be compared to results from background subtracted singles data.

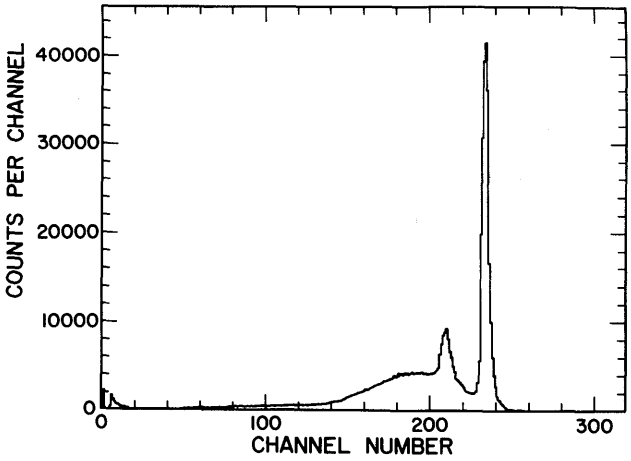

Figure 1. NaI energy spectrum for p-p scattering at 25°.

Preliminary data from an online analysis are shown in Fig. 2. The statistical errors are about ±0.002 or roughly the size of the plotted points. The error bars are conservatively drawn to be ± one half the size of the calculated change in analyzing power from

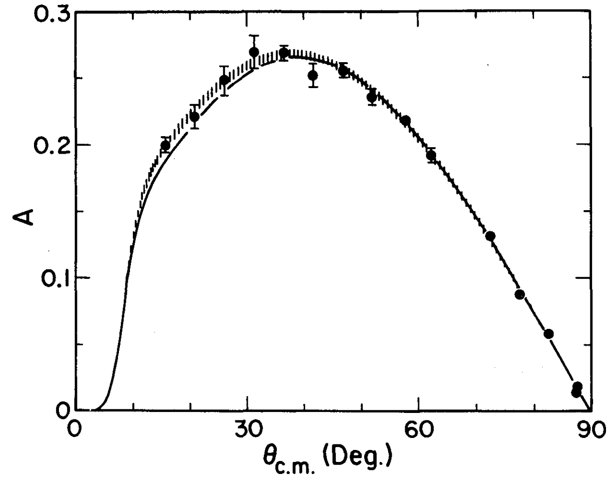

Figure 2. The analyzing power for p-p scattering at 180 MeV. The solid curve is Arndt's global phase shift solution SM86. The vertical bars represent Arndt's C200 single energy solution with error estimates.

background subtraction. This is done because of the preliminary stage of the analysis and also to illustrate the size of the background corrections. The normalization of the data is taken from the high energy polarimeter calibration as described above. The curve is the prediction of Arndt's SM86 global solution,[2] while the vertical bars represent the C200 single-energy solution with error estimates. The difference in the two curves can be traced to the $^1D_2$ phase shift parameter. These data should also further constrain the ε_2, $^3P_1$ and $^3F_2$ parameters.

1) H. Spinka, in Nuclear Physics with Stored, Cooled Beams, ed. P. Schwandt and H.O. Meyer, (AIP, New York, NY, 1985) p. 198

2) R.A. Arndt, J.S. Hyslop III, and L.D. Roper, Phys. Rev. D 35, 128 (1987).

3) G.F. Cox et al., Nucl. Phys. B4, 353 (1967).

4) See contributions to this report, p. 8.

5) 1985 IUCF Scientific and Technical Report, p. 125.

TENSOR POLARIZED DEUTERON CAPTURE BY THE HYDROGEN ISOTOPES

W.K. Pitts[†], H.O. Meyer, L.C. Bland, J.D. Brown[§], R.C. Byrd[¶], M. Hugi[††],
H.J. Karwowski[‡], P. Schwandt, A. Sinha[+], J. Sowinski, and I.J. van Heerden[‡‡]
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

It is with great relief that we announce the end of E234, a measurement of the angular distribution of the cross section $\sigma(\theta)$, vector analyzing power A_y, and tensor analyzing power A_{yy} for the $^1H(\vec{d},\gamma)^3He$ and $^2H(\vec{d},\gamma)^4He$ reactions. Preliminary results have been reported at the Lake Louise conference[1] and the final results for the $^1H(d,\gamma)^3He$ reaction have been submitted to the Physical Review. The analysis of the $^2H(d,\gamma)^4He$ reaction is nearly complete, and these results will also soon be submitted for publication.

The interest in these reactions is due to the sensitivity of the tensor analyzing power to the D-state component of ^3He and ^4He. Since the D-state is mixed with the dominant S-state component by the tensor force, A_{yy} is linked to the tensor force in nuclei.[2] In the case of ^3He, a Faddeev calculation of the $^1H(d,\gamma)^3He$ reaction with the Reid soft-core potential showed that 95% of the tensor analyzing power A_{yy} was due to the D-state of ^3He.[3] A_{yy} vanished when the Malfliet-Tjon potential (which does not have a tensor