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ASYMMETRY IN p-n AND p-p SCATTERING FROM TARGETS BOMBARDED WITH 285-Mev POLARIZED PROTONS

Hugh Bradner and Robert E. Donaldson

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ABSTRACT

Asymmetries in neutron and proton production have been observed in the quasi-elastic scattering of 285-Mev 65 ± 4% polarized protons by carbon, lithium, and beryllium targets. The neutrons and protons were counted in coincidence with their recoil protons. The neutron data give quasi-elastic asymmetries that differ somewhat from antisymmetry about 90° cm. The proton asymmetries are much smaller than the asymmetries from a free hydrogen target.

INTRODUCTION

In the preceding paper results on double charge-exchange asymmetry were presented. This paper gives the results of a different approach to the n-p polarization problem and also the p-p polarization problem.

As mentioned in a previous paper,[1] in a p-n collision, if the incident protons have a polarization P_p, the left-right asymmetry in the counting rate of the neutrons is related to P_{pn} by the equation

$$e = \frac{L-R}{L+R} = P_p P_{pn} ,$$

where e is the asymmetry, L and R are the neutron counting rates at equal angles to the left and right, and P_{pn} is the polarization in a p-n collision in which the initial nucleons are unpolarized. In this experiment the polarized proton beam developed by Chamberlain, et al.[2] was used as the first scattered beam. Neutrons and protons ejected from the second target were then counted in coincidence with their recoil protons (quasi-elastic coincidence).

APPARATUS

Experimental Arrangement

The polarized proton beam was obtained by scattering the internal proton beam of the 184-inch cyclotron on a Be target, and by bringing this beam out into the experimental area by the method described in Reference 2. This beam has a polarization of 65.0 ± 4 percent, an energy of 285 ± 15 Mev, and a flux of approximately 10^5 protons per second entering the bombardment area.

Counters and targets

Figure 1 shows the general arrangement of the target and counters in the bombardment area.

The counters were all plastic scintillators. Counters 1 and 3 were rectangular in shape, 3 by 3 by 0.25 in. and 6.5 by 6.5 by 7/16 in., respectively. Counters 2 and 4 were cylindrical, 2 in. in diameter by 7 in. long and 5.5 by 4 in., respectively. The angle between telescopes 1, 2 and 3, 4 was kept at 85° in the laboratory system. This angle is the approximate relativistic nucleon-nucleon scattering angle. The distances between the second scatterer and the telescopes were altered for different angles of observation in order to obtain an optimum ratio of counting rate to background. The solid angle subtended by the 1, 2 telescope was varied between 0.2×10^{-2} and 0.8×10^{-2} steradian, and that subtended by the 3, 4 telescope was varied between 0.03 and 0.3 steradian. The counter phototubes were surrounded by soft iron and μ metal to shield against stray magnetic fields. It was shown that the shielding eliminated any effect of the magnetic field on the photomultipliers.

The targets were thin slabs, of vertical dimension greater than that of the incident beam. The thin dimension was oriented perpendicular to the incident beam in order to allow the scattered particles to get out of the target. The targets had the following composition and dimensions; carbon, 1-15/16 by 11/16 by 9 in.; beryllium, 2 by 5/16 by 4 in.; lithium, 3 by 0.25 by 3 in.

Electronics

Figure 1 shows the coincidences demanded from the four counters. The output of each of the four counter photomultipliers was amplified by distributed amplifiers and then split into two channels. The signals from the first of the two channels (from each of the four counters) were mixed directly into fast-coincidence circuits of 10^{-8} sec resolution in the four possible combinations of pairs. The signals from the other channel were further amplified and fed into two 10^{-8}-sec coincidence circuits with outputs 4 and 2 delayed in time by one rf cycle (6×10^{-8} sec). The delayed circuits gave a simultaneous measurement of accidental events. The outputs of the 10^{-8}-sec coincidence circuits were then amplified by linear amplifiers, shaped by variable gates, and mixed appropriately (see Fig. 1) into coincidence circuits of 10^{-6} sec resolution time.

PROCEDURE

The position of the beam was found by means of x-ray film, and the target was then placed in the center of the beam. Photographs were taken periodically to monitor possible changes in the beam position. All the counter angles were measured with a transit centered at the target position. The estimated angular error was of the order of 0.1°, and intentional misalighments of this amount gave errors in asymmetry of less than 1 percent.

The counters were plateaued by raising the photomultiplier voltages until the coincidence counting rate for a pair of counters remained a constant when the output pulses from either counter were attenuated by a factor of two.

The incident beam was monitored by an argon-filled ionization chamber.

An absorber that rejected protons of energy less than $0.7\ E_o \cos^2\theta$ was placed in front of Counter 1, where E_o was the energy of the polarized proton beam and θ was the angle of the 1, 2 telescope. This absorber reduced the accidental singles rate in Counter 1 and increased the efficiency for counting fast protons by increasing their pulse heights. The proton-proton coincidence counting rate was found to be independent of this absorber; thus no quasi-elastic events were excluded by the absorber. The value $0.7\ E_o \cos^2\theta$ was chosen in order to measure separately the proton asymmetry obtained without using the recoil particle in coincidence, and to compare with the results of a similar experiment by Chamberlain et al.[2] The observed asymmetries agreed with those observed by Chamberlain, within the statistical errors. When absorbers of greater thickness than the proton range were placed in front of Counter 1, the remaining counting rate decreased by the amount expected from nuclear attenuation alone, thus indicating that neutrons were being counted.

Background counts were determined by removing the target.

RESULTS

Figure 1 shows the events measured. Figures 2 and 3 show the asymmetries observed for neutrons from carbon, lithium, and beryllium. It should be noted that for center-of-mass angles greater than 90° the neutrons were defined by the telescope with poor angular resolution.

Figures 4 and 5 show the p-p quasi-elastic asymmetries obtained for carbon, lithium, and beryllium.

The polarization can be calculated by the relation $e = 0.65 P_{pn}$.

The p-n asymmetries for Li, Be, and C differ somewhat from being antisymmetric fore and aft. There is a positive asymmetry at 90° c.m., discussed in the preceding paper, and the asymmetries for Be are higher in the backward direction.

The p-p quasi-elastic polarization is considerably smaller at all angles than the p-hydrogen polarization.[2]

A similar p-n experiment has been done by Chamberlain et al.,[3] with a liquid deuterium target. The n-p polarization they obtain from deuterium agrees, within statistics, with our results from carbon.

ACKNOWLEDGMENTS

The authors are indebted to Dr. Edward Teller, who initiated the experiments, Dr. Luis W. Alvarez for continued support and advice during the experiments, and Dr. Louis Wouters, who furnished equipment that he was constructing for a p-n-p experiment. They are deeply indebted to Mr. Richard Blumberg, Dr. Frank Crawford, Jr., Miss Claire E. Johnson, Mr. H. Brook Knowles, Mr. Vern Ogren, and Dr. M. Lynn Stevenson for assistance during the experiments, and Dr. Warren Heckrotte, Dr. Malvin Ruderman, Dr. Stephen Tamor, and Dr. Lincoln Wolfenstein for interesting discussions on polarization. The authors also wish to thank James Vale and the 184-inch cyclotron crew for their cooperation during the bombardments.

REFERENCES

1. H. Bradner and R. Donaldson, Phys. Rev. 95, 1701 (1954)
2. O. Chamberlain, E. Segrè, R. Tripp, C. Wiegand, and T. Ypsilantis, Phys. Rev. 93, 1430 (1954)
3. O. Chamberlain, R. Donaldson, E. Segrè, R. Tripp, C. Wiegand, and T. Ypsilantis, Phys. Rev. 95, 850 (1954)

LEGENDS FOR FIGURES

Fig. 1. Experimental setup showing counter arrangement and events recorded. Solid angle subtended by the 1, 2 counter was approximately 0.2×10^{-2} to

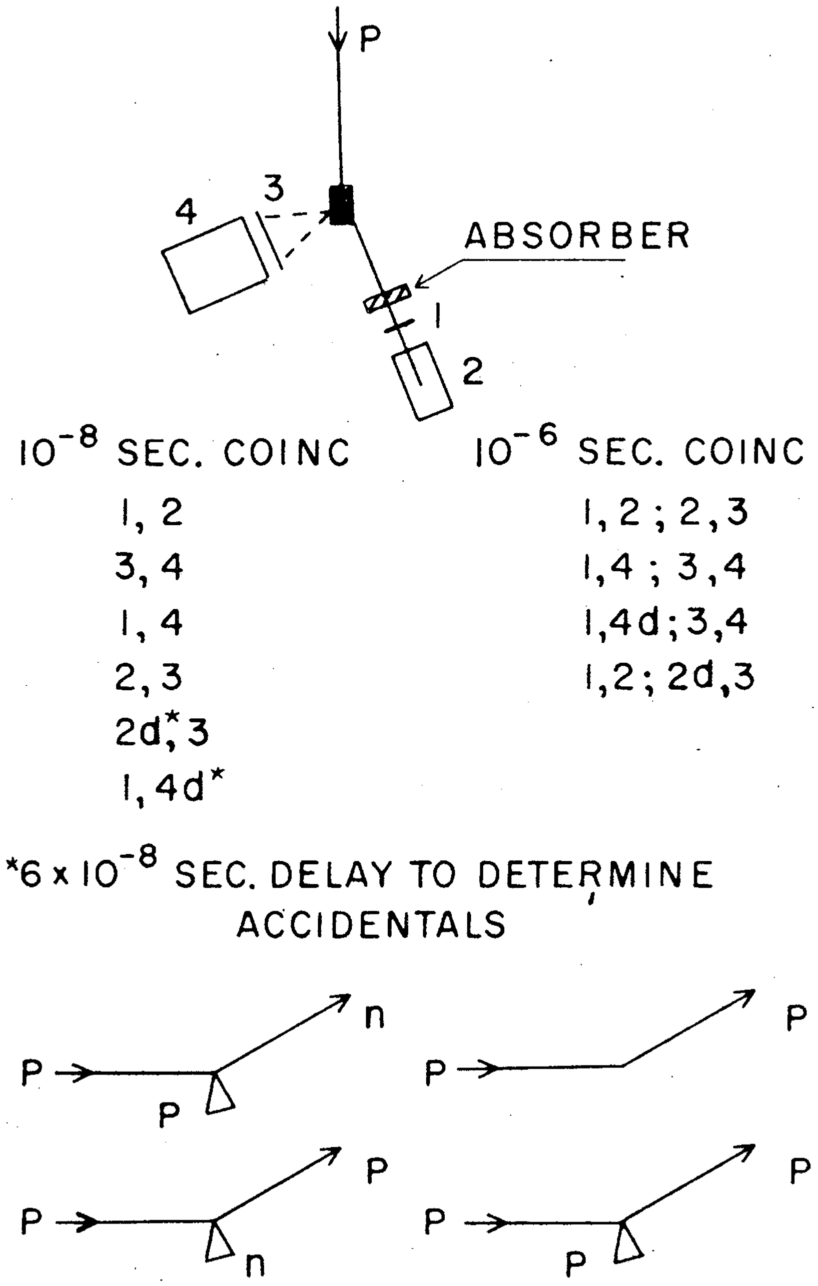
0.8×10^{-2} steradian; that of 3, 4 was approximately 0.03 to 0.3 steradian.

Fig. 2. Assymetry e plotted as a function of the center-of-mass neutron angle for proton-neutron quasi-elastic scattering off carbon. The errors shown include only counting statistics.

Fig. 3. Asymmetry e plotted as a function of the center-of-mass neutron angle for proton-neutron quasi-elastic scattering off lithium and beryllium. The errors shown include only counting statistics.

Fig. 4. Asymmetry e plotted as a function of the center-of-mass proton angle for the proton-proton quasi-elastic scattering off carbon. The errors shown include only counting statistics.

Fig. 5. Asymmetry e plotted as a function of the center-of-mass proton angle for the proton-proton quasi-elastic scattering off lithium and beryllium. The errors shown include only counting statistics.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3
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1
2
10^{-8} SEC. COINC
1, 2
3, 4
1, 4
2, 3
2d*, 3
1, 4d*
10^{-6} SEC. COINC
1, 2 ; 2, 3
1, 4 ; 3, 4
1, 4d ; 3, 4
1, 2 ; 2d, 3
*6 x 10^{-8} SEC. DELAY TO DETERMINE ACCIDENTALS
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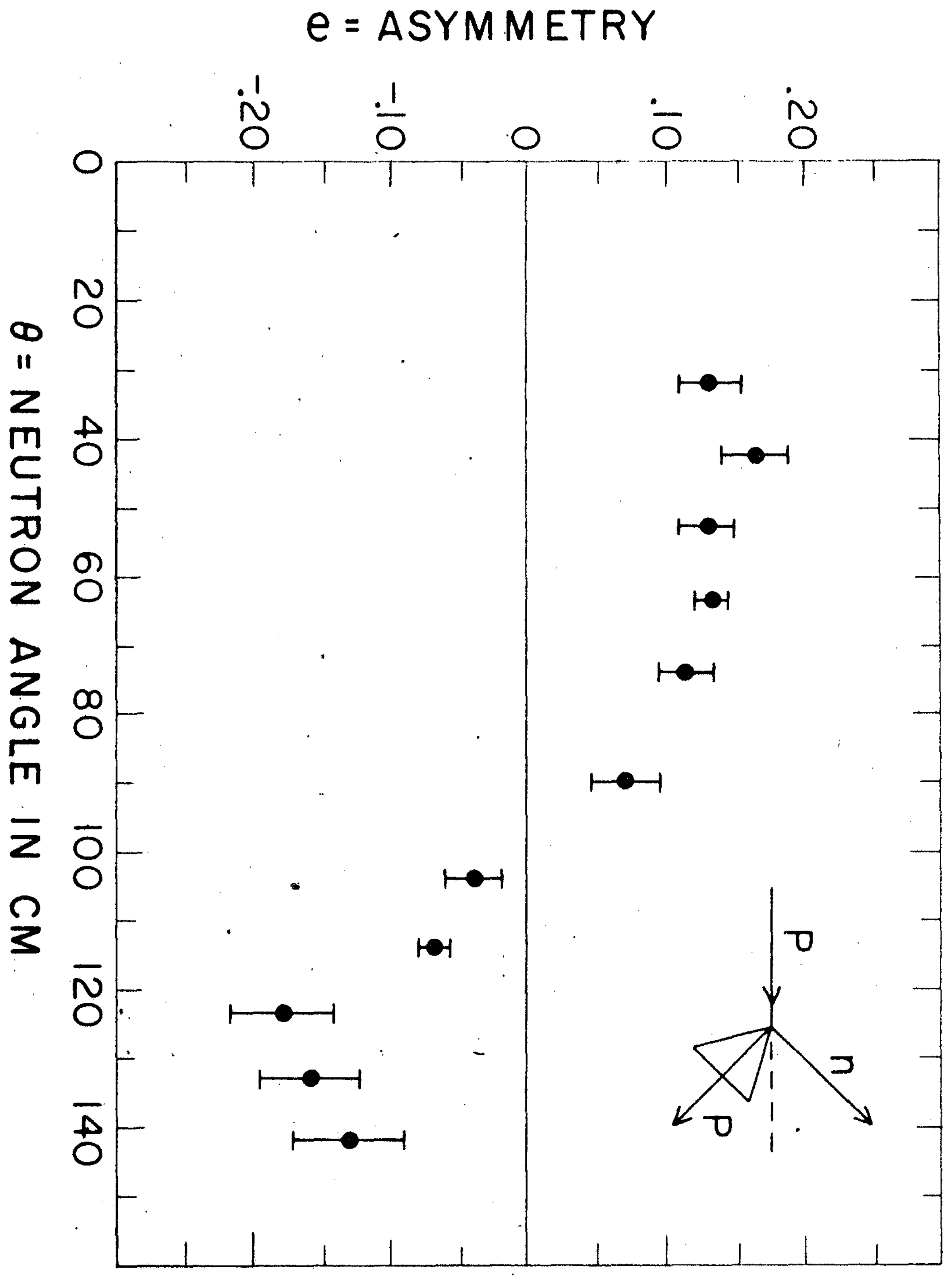
n
P
P
P
P
P
P
n
P
P
P

Fig. 1

22381-1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-.10
-.20
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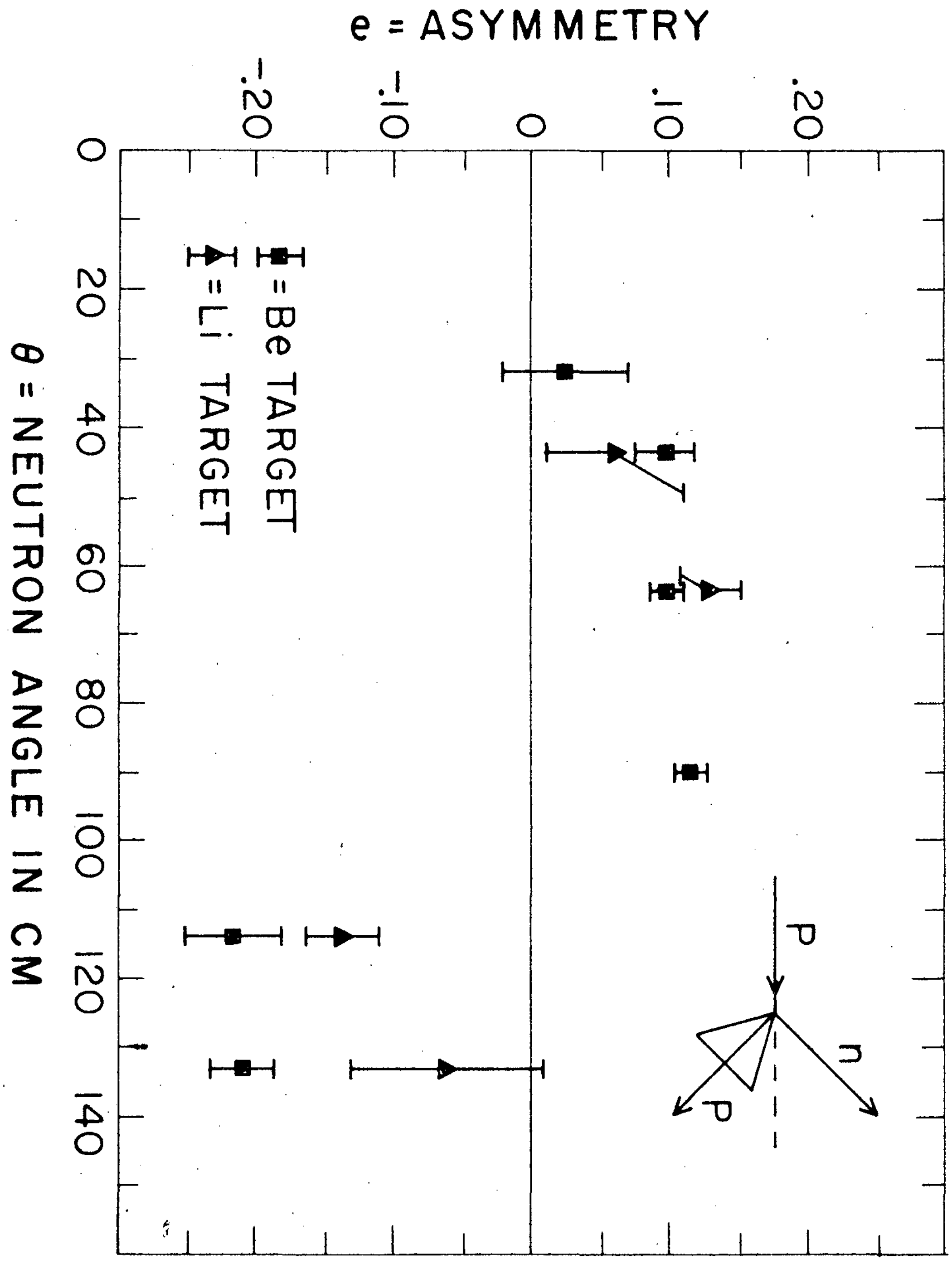
40
60
80
100
120
140
θ = NEUTRON ANGLE IN CM
P
n
P

Fig. 2

22449-1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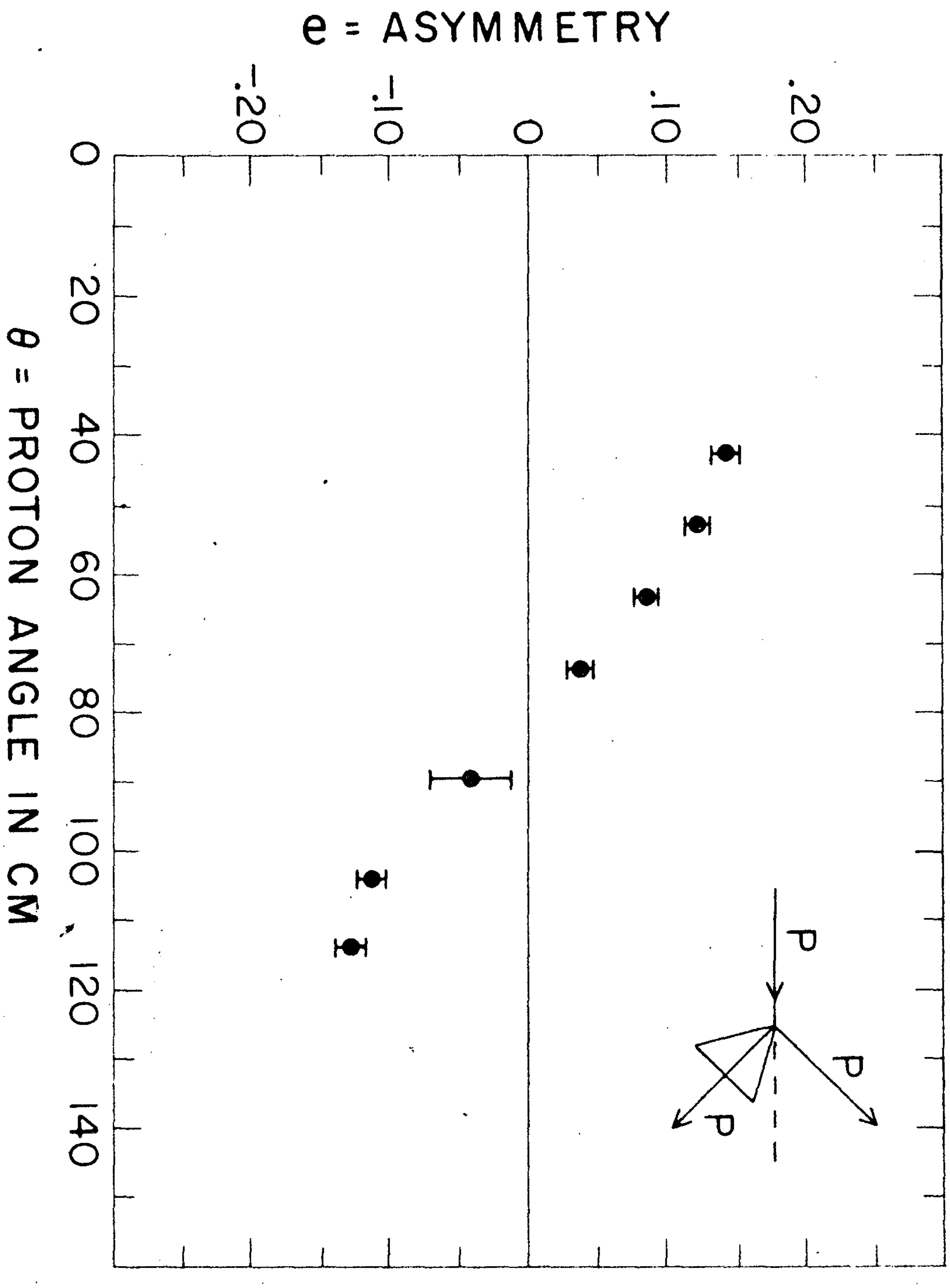
▲ = Li TARGET
P
n
P

Fig. 3

22450-1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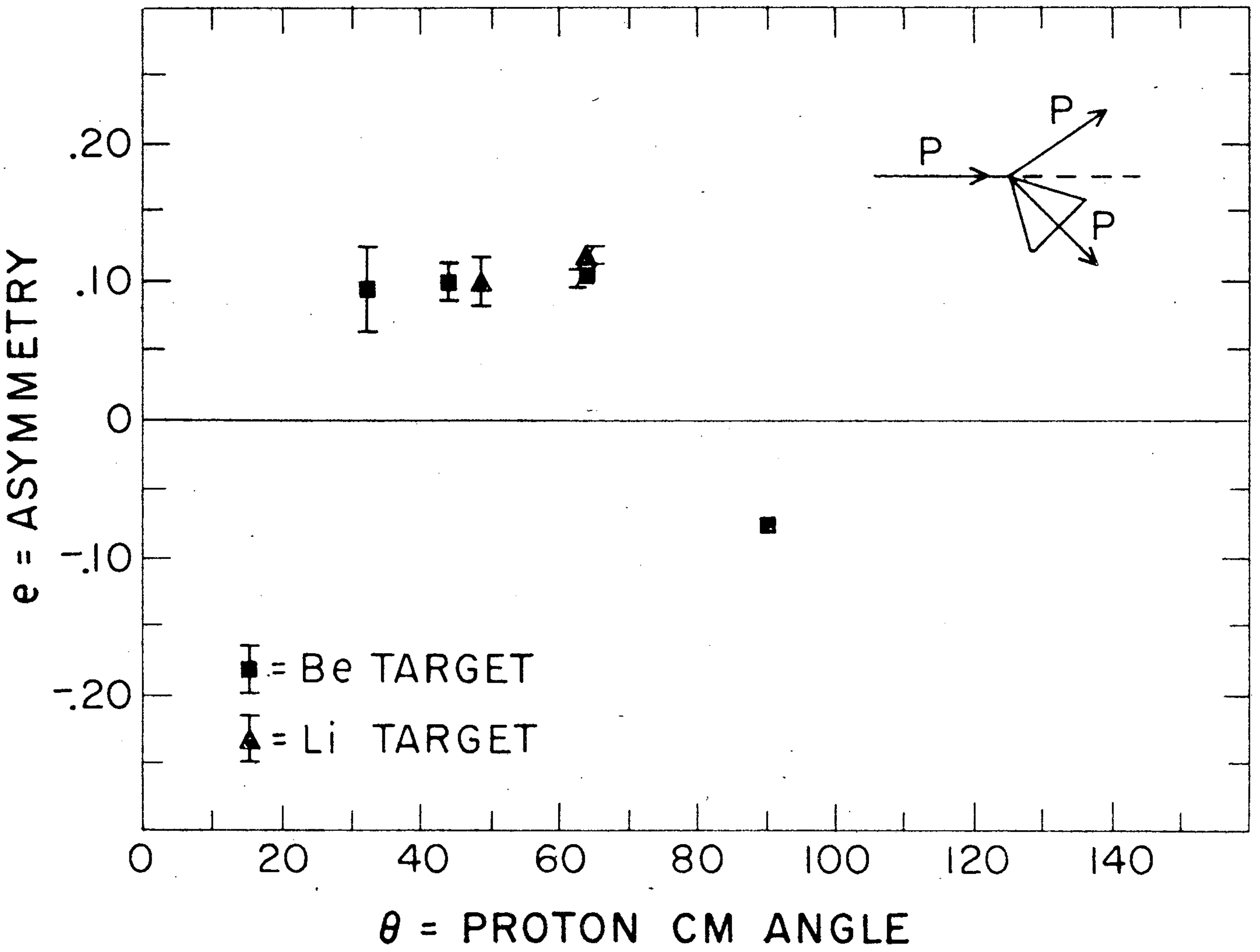
P
P
P

Fig. 4

22451-1



P
P
P
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.10
0
-.10
-.20
= Be TARGET
= Li TARGET
0
20
40
60
80
100
120
140
e = ASYMMETRY
θ = PROTON CM ANGLE

Fig. 5

22749-1