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Abstract:

The polarization of protons elastically scattered from deuterium has been measured at four energies between 10 and 20 MeV incident proton energy. The asymmetry is seen to become negative for large angles at 19.1 MeV and for small angles at 11.0 and 13.2 MeV.

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Recent measurements of proton polarization in elastic proton-deuteron scattering at incident particle energies of 22 MeV[1], 30 MeV[2], 40 MeV[3], and 50 MeV[4], have provided angular distributions for the scattered particles, each characterized by a considerable negative polarization in the region of the minimum of the elastic scattering cross-section. Lower energy data on the other hand, from the Wisconsin[5] and Washington[6] laboratories in the range 1 to 10 MeV, exhibit positive polarization at all angles, and show double peaking of the angular distribution about a shallow minimum.

The purpose of the present work was to investigate the intermediate region between these two sets of results, and to examine in some detail the behavior of the polarization at large angles as a function of energy.

Protons with a polarization in the region of 100% are produced as recoil protons from the bombardment of liquid-nitrogen-cooled hydrogen by the α-particle beam of the 88" cyclotron at Berkeley. Polarized protons of energies up to 65 MeV are readily available; but the present experiment was performed at energies

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†On leave from the University of Birmingham, England

of 11.0 MeV, 13.2 MeV, 15.7 MeV, and 19.1 MeV. At each energy the protons were scattered from a gaseous deuterium target held at a pressure of one and a half atmospheres, and the observed asymmetries in the angular distribution of scattered particles enabled the polarizations due to the scattering process itself to be calculated. The polarization of the incident beam could be considered unity in all cases.

Throughout the experiment eight detectors consisting of CsI crystals mounted on Dumont 6363 photomultiplier tubes were available to record simultaneously asymmetries at four scattering angles. For the lowest energy considered (11.0 MeV), however, only the four forward counters were used because of the limited angular range over which particles can reach the detectors. Pulses from the detectors were routed to separate quadrants of two 400-channel pulse height analyzers, and from these final spectra were obtained. Sample spectra obtained at 15.7 MeV incident proton energy and at an angle of 20 degrees are shown in fig. 1. It will be seen that the proton peak is clearly resolved from that due to recoil deuterons. At several of the energies considered, the recoil deuterons enable asymmetries of the associated backward protons to be deduced, thus providing consistency checks on some experimental data at backward angles. Such points are shown on the data as open triangles. A spin precession solenoid was used to rotate proton spins through 180 degrees at each of the energies mentioned.

The uncertainties in the measurements taken are seldom greater than a few per cent, after consideration of both background and statistics. Background in all cases was reduced to a minimum, and at backward angles crystals as thin as 0.005 inch were made for this purpose. These thin crystals efficiently reduced the background from gamma conversion and were thick enough to stop low energy protons at those angles for which they were designed.

The results obtained are shown in figs. 2 and 5. In each case the asymmetry in the second scattering is plotted as a function of center of mass angle.

An interesting feature of the data is that the polarization becomes negative at backward angles in the vicinity of 19 MeV incident proton energy. The position of the observed minimum in the asymmetry distribution is near 110° center of mass. (See fig. 5) Indeed between 11.0 MeV and 19.1 MeV a marked change occurs in the shape of the angular distribution, for which the authors have no quantitative explanation. It should be noted, however, that the value of the minimum in the p-d elastic scattering cross section drops by an order of magnitude in this energy range[7)], and that this minimum occurs at a similar center of mass angle to that of the minimum in the asymmetry distribution. The expected $\frac{1}{E}$ dependence of the differential cross section would have produced a decrease of only a factor of two.

A. De-Shalit[8)] has recently suggested that minima in the elastic scattering cross section are closely related to the zeros of the complex scattering amplitude f(z), and that the nearer these zeros lie to the real axis, the deeper are the observed minima, and the more pronounced will become the variation in the polarization in this angular region. The present results appear to be in agreement with this qualitative picture.

In fig. 2 it will be seen that the asymmetry at 11.0 MeV becomes negative at small angles, a result which is also suggested by the 13.2 MeV data of fig. 3. The former values were checked by interchanging counters and phototubes from one side of the beam to the other. The effect, however, remained unchanged despite this manipulation, so it seems unlikely to be instrumental in origin, and therefore requires some explanation.

It has been suggested in the past by Cassells[9] and others that extreme changes in polarization can occur in the region of interference between Coulomb and nuclear scattering amplitudes, and such a region in this case would lie between 15° and 30° center of mass. As the counters placed at 20° and 340° in the laboratory for the 11.1 MeV experiment accept particles over an angular range of ±3°, it is possible for them to see a portion of the interference region. At higher energies of course, the interference region moves to smaller angles and chances of observing it with our apparatus become less with increasing energy.

There already exists some scant evidence of a Coulomb-nuclear interference minimum at 9.7 MeV incident energy in p-d elastic scattering[10], and it may be that this fact suggests a solution to the present anomaly. Clearly, there is need for both elastic scattering and polarization data at small angles, and it is hoped to obtain the latter at Berkeley in the near future.

From the results of the present experiment it is clear that the deuteron tensor polarizations obtained by Young and Ivanovich[11] cannot predict the observed 11.0 MeV distribution of asymmetry, nor is it reasonable to assume zero vector polarization at this energy.

In the absence of a complete basic theory of the three-nucleon system, and in the knowledge that the impulse approximation can have no applicability to this energy region[12], the above results are presented as useful data with which to test the predictions of present and future models of the nucleon deuteron interaction in this energy range.

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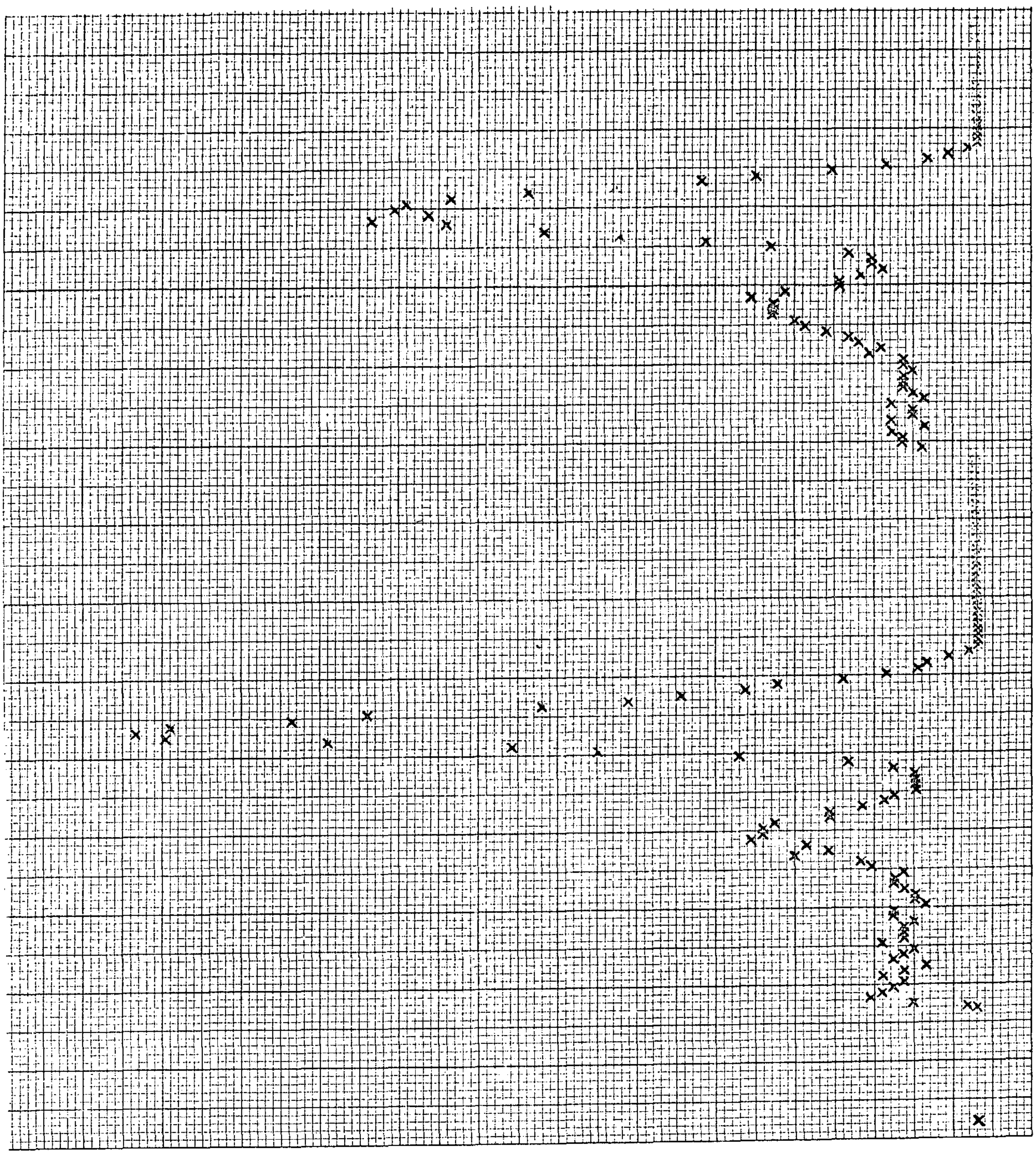
Figure Captions

Fig. 1. Typical spectra obtained with the two forward counters at 20° and 340° (Lab.) respectively are shown. The proton peak is clearly resolved from that due to recoiling deuterons. The ordinate relates to the number of counts and the abscissa to the channel number.

Figs. 2 to 5. Asymmetries in the angular distribution of polarized protons scattered from deuterium at 11.0, 13.2, 15.7, and 19.1 MeV are shown. The polarization is seen to go negative at large angles in the 19.1 MeV distribution.



XBL671 403

Fig. 1.

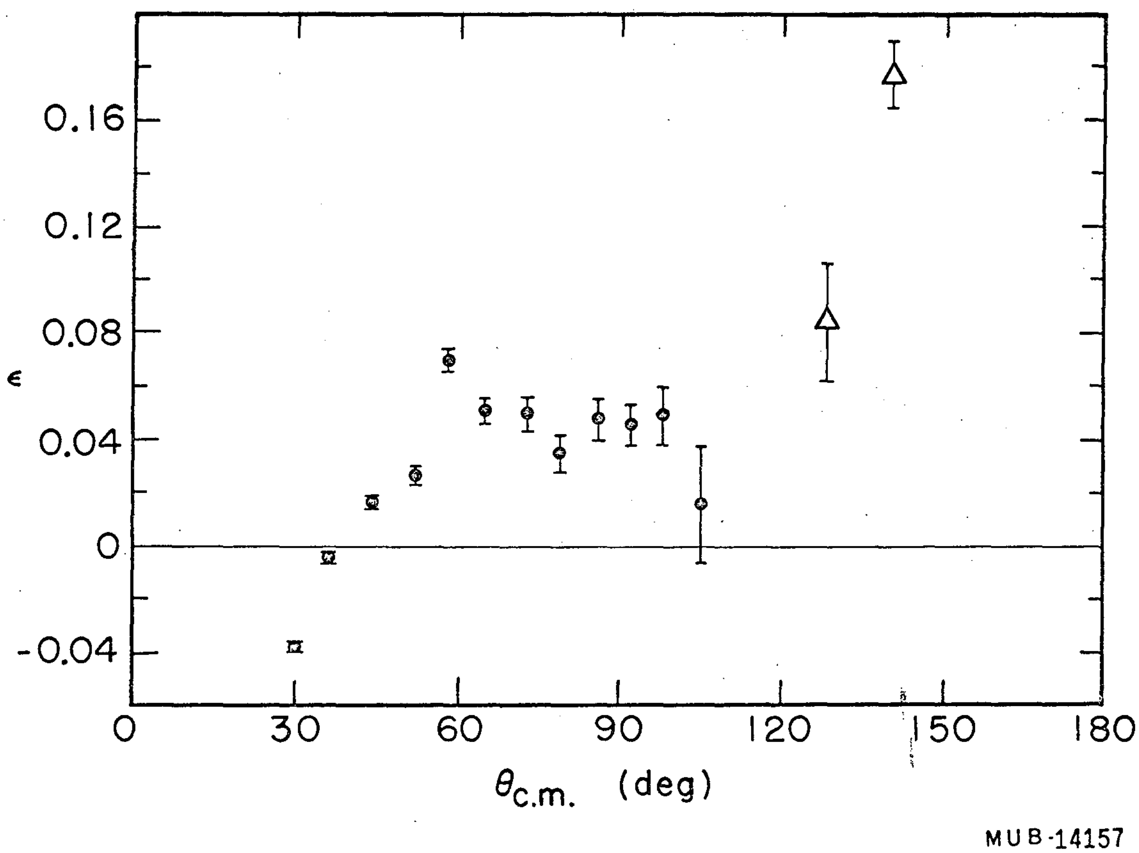


Fig. 2.

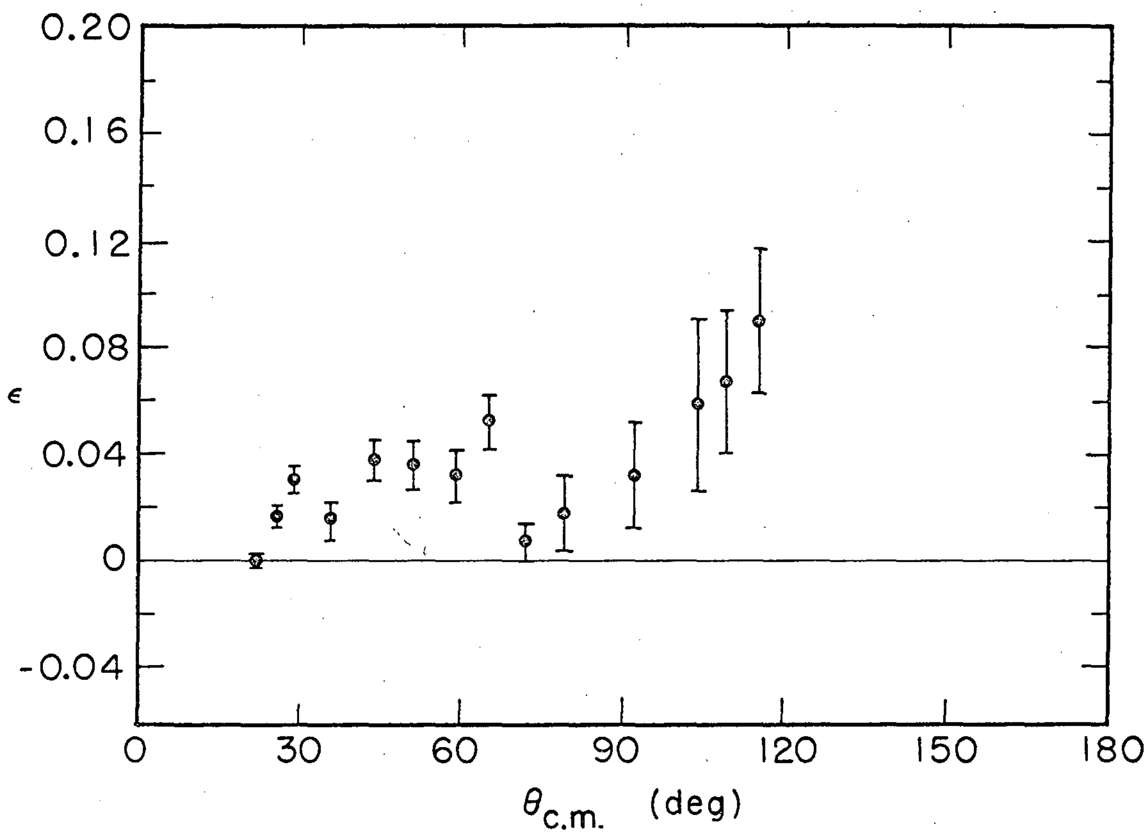


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Fig. 3.

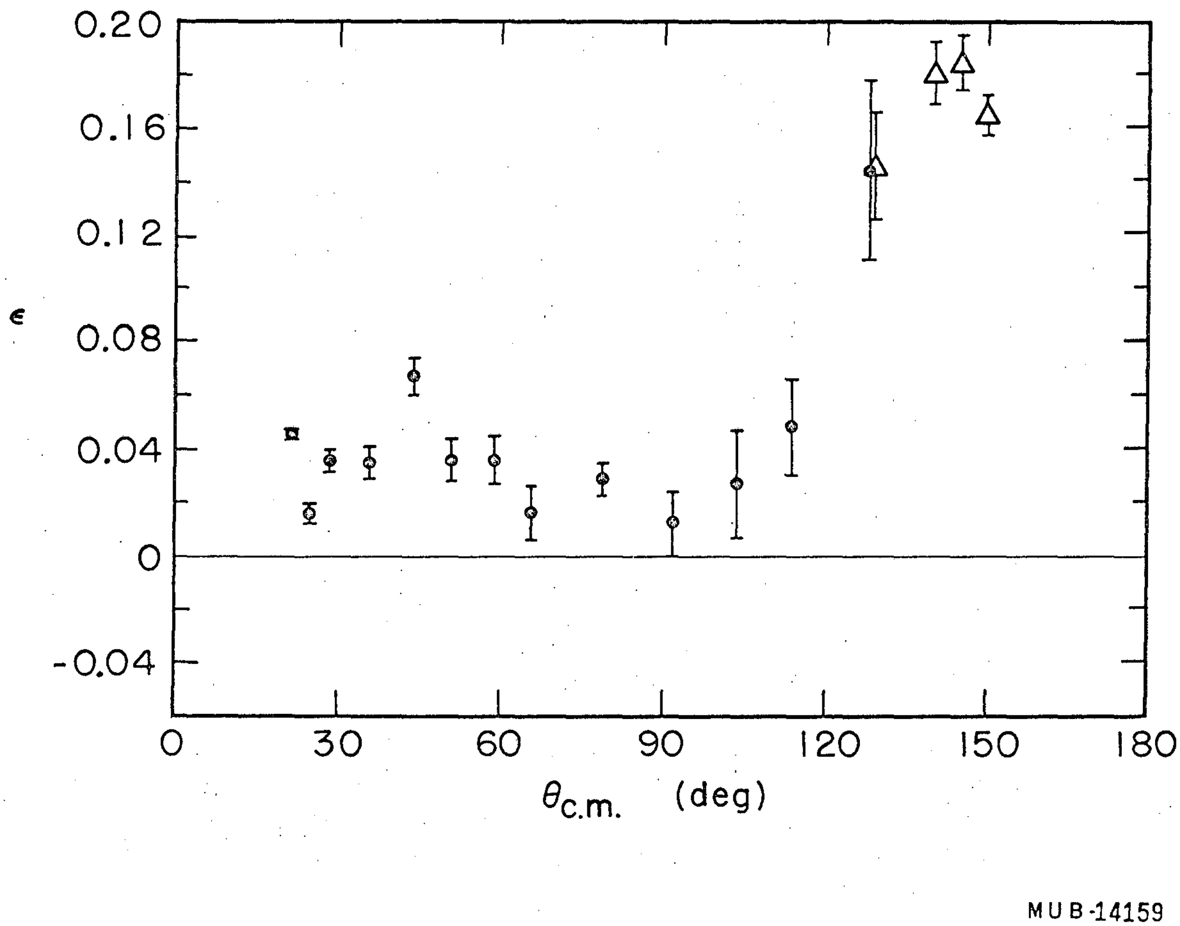
0.20
0.16
0.12
0.08
0.04
0
-0.04
ϵ
0
30
60
90
120
150
180
θc.m. (deg)
MUB-14159

Fig. 4.

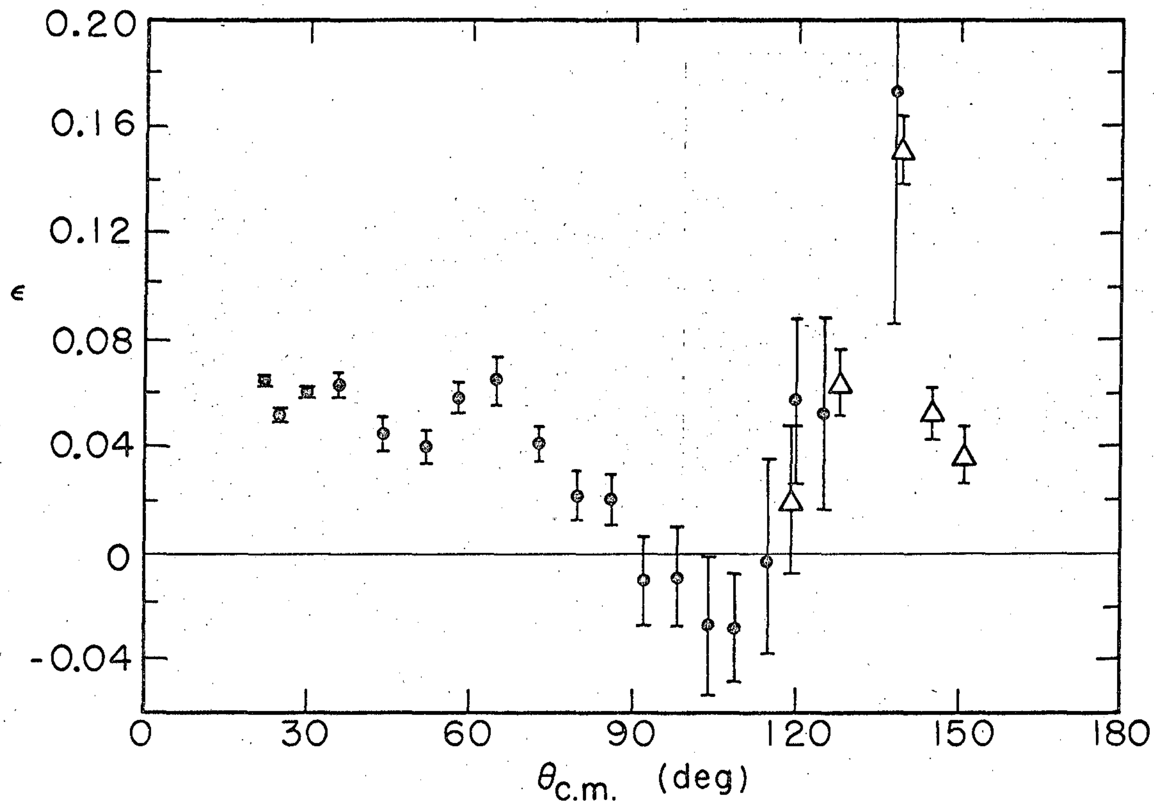

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Fig. 5.