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a Polarized ^{3}He Target and 52 MeV Deuterons

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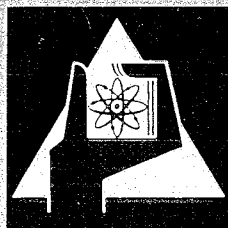March 1969 KFK 947

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Investigation of the reaction ^{3}He(d,p)^{4}He with
a polarized ^{3}He target and 52 MeV deuterons[*]

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Introduction

In recent years general interest was paid to the investigation of
polarization phenomena in low and high energy physics. Polarization
in the entrance channel obtained by the use of polarized beams or
targets provides enlarged insight in details of nuclear forces and
structure. In addition to polarized hydrogen targets optical pumped
polarized ^{3}He targets are use in nuclear reaction studies.

At several deuteron energies up to 10 MeV the angular distribution
of the proton asymmetry was investigated in the reaction
^{3}He(d,p)^{4}He (1). Measurements of the proton polarization which were
carried out with an unpolarized entrance channel at the same energies
supplied further information (2). For theoretical interpretation the
optical model and the method of invariant amplitudes has been used
by several authors (3), (4), (5). From these low energy experiments
one has been able to conclude, that between the asymmetry A and the
polarization P, the relation P=-A is to be taken as a fairly good
approximation. In order to extend the data available to higher
energies an experimental investigation of the ^{3}He(d,p)^{4}He reaction
was carried out at the Karlsruhe isochronous cyclotron. The reaction
was induced by 52 MeV deuterons. The proton asymmetry was measured
at center of mass angles between 30.5 and 74.2 degrees.

Polarization of the ^{3}He target by optical pumping.

The design of our polarized ^{3}He target is based on the techniques of
optical pumping as described by Walters et al. (6). The metastable
$^3S_1$-state of ^{3}He is the basic state of the optical pumping cycle.
Circularily polarized radiation of 10830 Å from a ^{4}He gas discharge
lamp is used for pumping. In a suitable environment such as a very
clean pyrex glass bulb and in the absence of appreciable magnetic
field gradients high polarization of up to 0,25 can be achieved.
But such high polarizations can be only obtained at gas pressures
of one mm Hg and lower. For nuclear physics experiments a higher
pressure and extremely thin glass walls are desirable. The polarization
is then always below the above stated value.

The targets used in our experiments were pyrex glass vessels in the
shape of bulbs of 5-6 cm diameter. The walls were 30-50μ thick. They
were filled with carefully purified [3]He gas at a pressure of 6-8 mm Hg.
The degree of polarization was evaluated by means of optical
absorption measurement using the relations given by Shearer (7).
The polarization achieved was 0,1 typically. Details of our optical
pumping system will be discussed with respect to the use of [3]He gas
as a target in nuclear reaction studies in a separate publication.

The experimental setup

The 52 MeV deuteron beam of the Karlsruhe isochronous cyclotron was
focused on the target cell which was located in the center of the
scattering chamber. Fig. 1 shows the setup. The optical pumping
and polarization measurement device was outside of the evacuated
scattering chamber. Two detector systems, consisting of thin
NaJ-crystals coupled to photomultipliers were located at positions
symmetrical to the primary beam axis. Slits were used near the
scattering chamber and in front of the NaJ-crystals to define the
effective volume of the target. The dimensions of the slits had to
be choosen very carefully to eliminate all charged particles
created in the walls of the glass cell by the primary deuteron beam.
The background was reduced to a sufficiently low level by the
additional use of neutron shields made from lead and paraffin wax.
The total charge of the deuteron beam was collected in a Faraday cup.
Two detectors at small forward angles allowed to monitor the position
of the primary beam. The magnetic field of 60 G was produced by
Helmholtz coils mounted outside of the scattering chamber. The
magnetic field direction was perpendicular to the reaction plane.
In Fig. 2 the schematic diagramm of the electronics used is shown.
The energy signals E_R and E_L of the two counters were amplified and
summed. A discriminator was used to prevent low energy signals from
reaching the input of the two dimensional analyzer. For the purpose
of particle identification timing signals t_R and t_L were derived
from the two detectors. The special time of flight method described
in (8) allowed particle identification by the use of energy and
timing signals. The corresponding energy and timing signals were
registered in a two dimensional 4096 channel analyzer.

Fig.1. SCHEMATIC DRAWING OF THE APPARATUS

PHOTOMULT.

NaJ-CRYSTAL

SLIT

SLIT

MONITOR

He-TARGET

Θ

Θ

52 MEV DEUTERONS
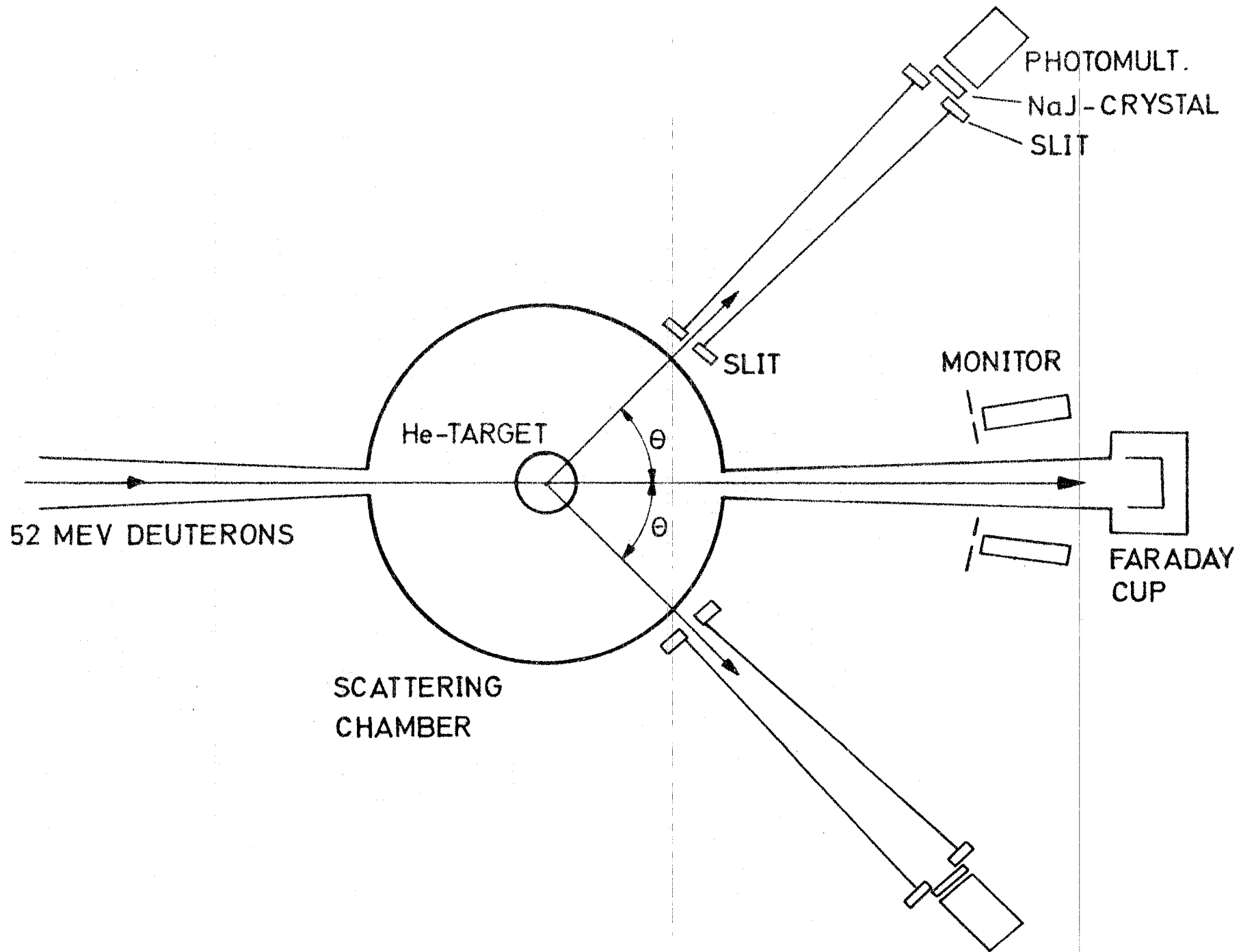
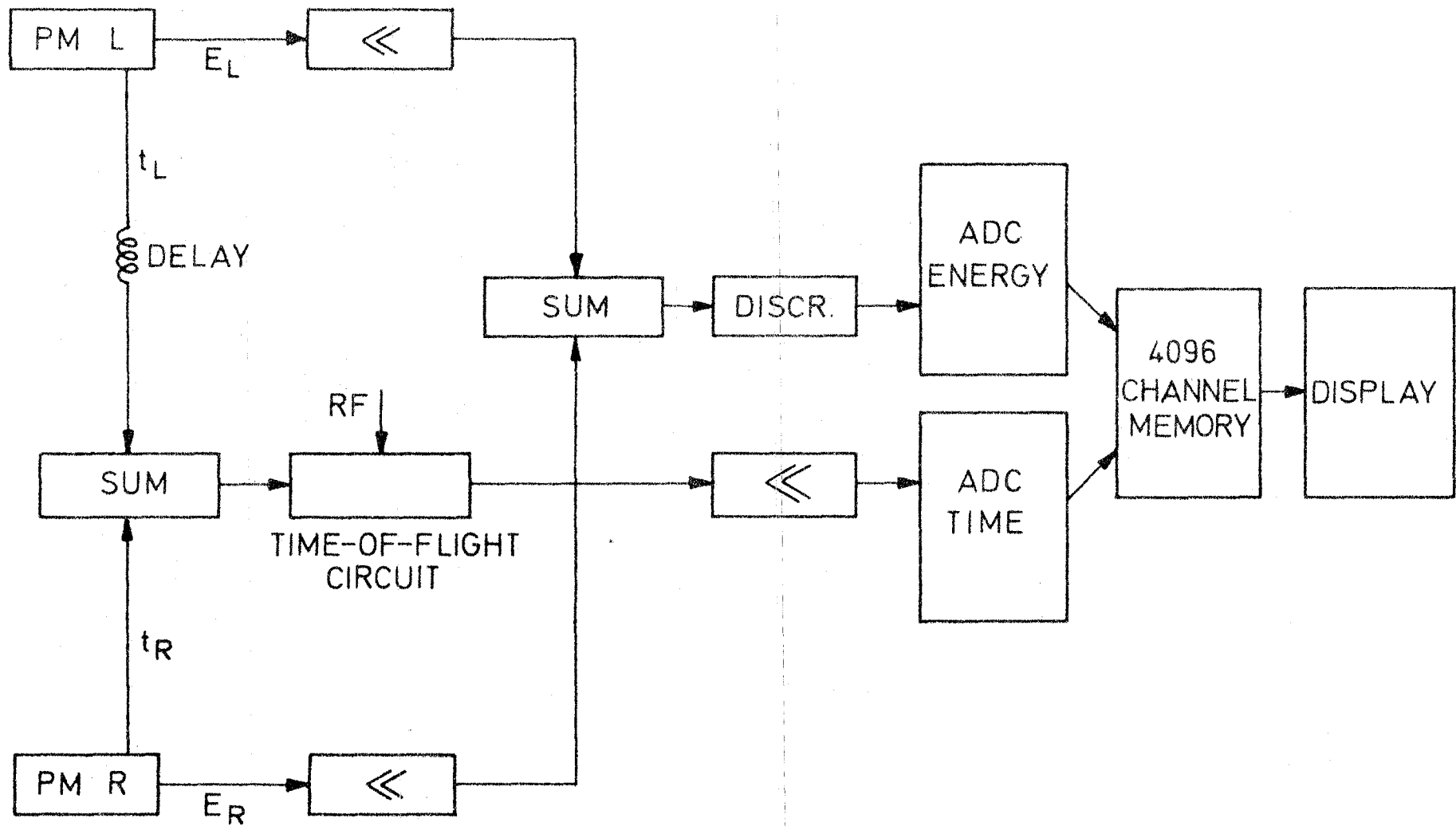SCATTERING
CHAMBER

FARADAY
CUP

Fig.2. SCHEMATIC DIAGRAM OF THE ELECTRONIC SET-UP.

Two dimensional plots energy versus time were obtained as illustrated in (8).

By applying a delay line in the path of one of the time signals the two dimensional spectra of the two detectors were shifted against each other. In this way a sum spectrum was obtained where both single spectra did not overlap in their essential parts.

The measurement and the discussion of the errors.

The asymmetry which is to be measured $A(\theta)_{LR}$ is given by the expression:

$$A(\theta)_{LR} = \frac{1}{p} \cdot \frac{\sigma(\theta)_L - \sigma(\theta)_R}{\sigma(\theta)_L + \sigma(\theta)_R}$$

p is the target polarization. $\sigma(\theta)_L$ and $\sigma(\theta)_R$ are the differential cross sections for the production of the protons at the angle θ to the left and right half of the scattering plane.

The left half of the scattering plane is defined by the momentum of the reaction proton, the momentum of the incoming deuteron and the target polarization vector forming a left handed system in this sequence. To obtain this asymmetry A_{LR} independent from apparative asymmetries measurements were made for opposite target polarization directions. For each direction an asymmetry a_{LR},

$$a_{LR} = \frac{1}{p} \cdot \frac{L(\theta) - R(\theta)}{L(\theta) + R(\theta)}$$

was measured. For the evaluation of A_{LR} the two experimental values a_{LR} were averaged.

belonging to

L(θ) and R(θ) are the counting rates of the protons the left and right detector. The described method supplies correct values for the asymmetry A_{LR}, if three conditions are fulfilled.

Firstly, during each pair of runs, which corresponds to opposite target polarization directions the position and the direction of the primary beam are not allowed to change. This condition was controlled by the two monitors. Furthermore the shape of the two dimensional spectra turned out to be very sensitive to the beam geometry. The spectra were used as a second independent control of

beam stability.

Secondly, the apparative asymmetry should not be affected by reversing the polarization of the target. The here used procedure to reverse the target polarization is not able to affect the primary beam or the reaction protons. This special feature arises because the direction of the target polarization is determined only by the direction of the circularly polarized pumping light.

Thirdly, the two detectors and the electronics have to register the protons with probabilities which do not change with time. This was assured by summing both the energy signals and the timing signals from the two detectors. Fig. 2 shows, that the critical parts of the electronics were common to both detectors. In this circuit the dead time is determined only by the common part of the electronics. Hence, the dead time is identical for both counting rates, and dead time corrections can be omitted.

Results and discussion

In fig. 3 the results of the asymmetry measurement are displayed. The solid dots show the proton asymmetry of the reaction ^{3}He(d,p)^{4}He as a function of the center of mass angles. The statistical errors are indicated by bars. The asymmetry shows predominantly negative values in the angular region investigated.
The maximum value A_{LR}=-0.38 $\pm$ 0.11 is reached at 56.5 degrees and the asymmetry vanishes near 35 and 75 degrees. For comparison the asymmetry of the deuterons of the reaction ^{4}He(p,d)^{3}He is plotted. The deuteron asymmetry was measured with a polarized proton beam of 65 MeV (9). From time reversal invariance one is able to conclude that the deuteron asymmetry in this reaction is equal to the proton polarization measured with an unpolarized entrance channel in the reaction ^{3}He(d,p)^{4}He. The data given in (9) correspond to a deuteron energy of 54 MeV and allow a comparison between the angular distribution of the proton polarization and asymmetry in the reaction ^{3}He (d,p)^{4}He. The two curves in fig. 3 are only connecting the experimental values.
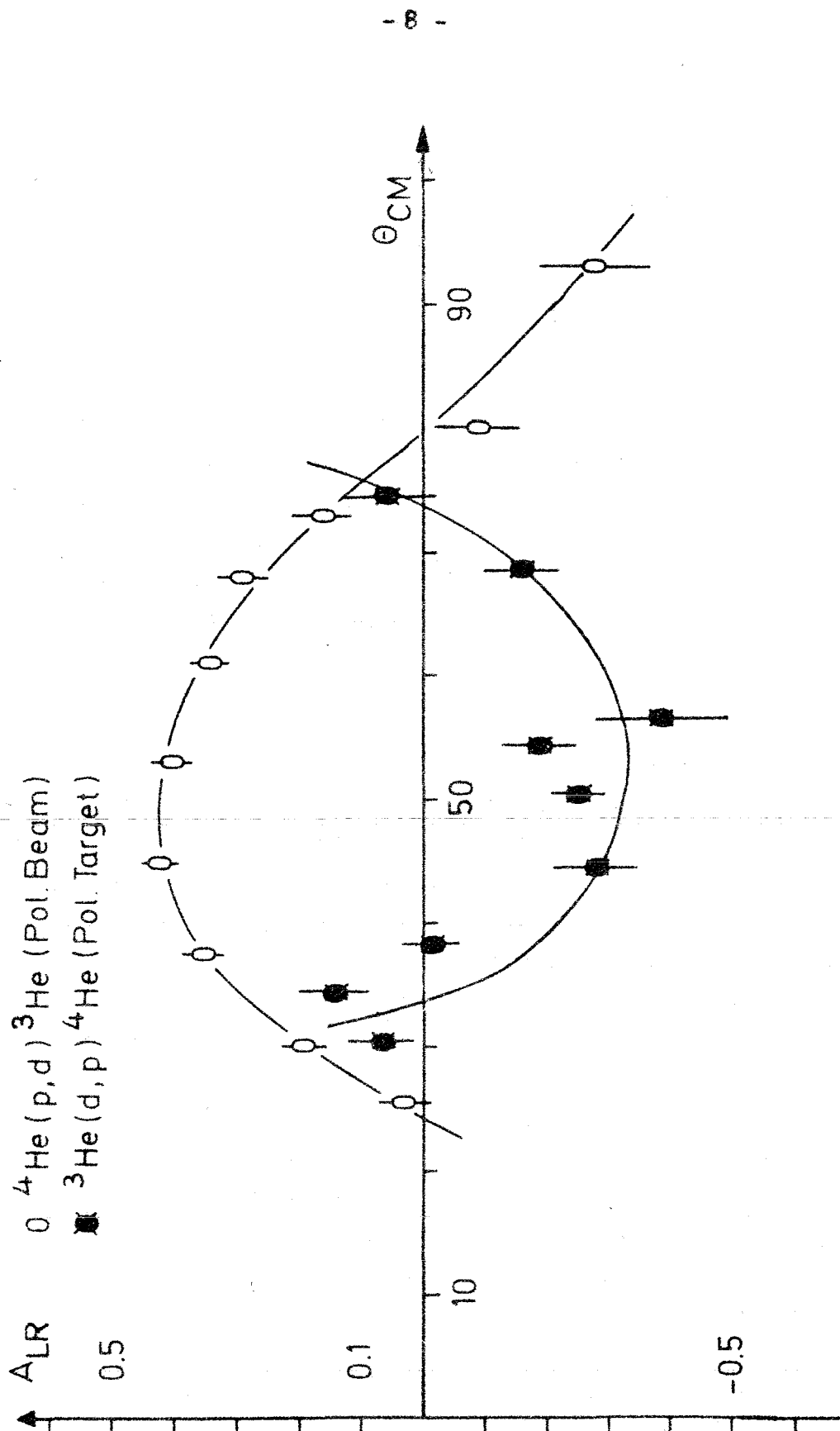
Fig.3. EXPERIMENTAL RESULTS

The main features of these data are the following. The absolute
maximum values of the polarization and of the asymmetry are nearly
the same and the sign of the two quantities are opposite within a
large part of the measured angular range. The relation P= -A can be
only taken as a rough approximation. A comparison with the low
energy data shows, that the deviation of this relation near the zero
crossing points is even more significant at high energies. Several
attempts have been made to explain the low energy data (1), (2) by
theoretical approch. By means of conventional direct reaction
theory it was found (3), that the relation P=-A is only obtained if
tensor forces are active between the proton and the ^{3}He nucleus.
An other investigation using coupled channel methods (4) was even
able to fit the zero crossing points of both distributions. For this
analysis too tensor terms in the potentials were necessary.

The here reported measurement of the proton asymmetry using a
polarized target, which is the first above 10 MeV, adds one more
evidence for the necessity of tensor terms for the description of
nuclear forces.

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