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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

PROPOSAL FOR A DIRECT DETERMINATION OF THE Σ-N-K PARITY

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I. INTRODUCTION

A polarized proton target has been developed by a Saclay group.(3) A hydrogenic compound is kept at 1° K in a high-magnetic field (~20 kgauss), inside a microwave cavity; one out of 16 protons is free and polarized up to 50%. The density of the compound is 2.0 gr/cm^3; therefore, one has about the same density of free (and polarized) protons as in liquid hydrogen. The polarization of the free protons may be directly measured by recording the signal of nuclear magnetic resonance of the compound. It can be reversed by changing either the magnetic field, or the microwave frequency by less than 1%.

This is a joint proposal from target constructors and high energy physicists for an experiment to determine the Σ-N-K parity. This experiment is considered as a first step of general research programme using polarized targets at CERN. The work should be done through a collaboration among Saclay and CERN physicists.

II. PRINCIPLE OF THE EXPERIMENT

It now seems well established that the Σ^o and Λ^o hyperons have the same parity 1). Helium bubble chamber data strongly favours the choice of an <u>odd</u> (Λ^o-N-K) parity, although the even parity alternative cannot be excluded at present [2]. A direct determination of this important quantity seems to be of considerable interest. The present measurement also appears to be a necessary step to the application of the same method to the more difficult case of the Ξ^- hyperon.

The method discussed here is based on a theorem due to Bohr. No hypothesis has to be made about the actual structure of the particles involved. Its validity solely follows from the assumption of angular momentum and parity conservation in the production process. The experiment consists essentially of the measurement of the differential cross-section at about 90° in the c.m. for producing Σ^+ on polarized protons, in the reaction

$$\pi^+ + p \rightarrow \Sigma^+ + K^+, \qquad (1)$$

at about 1 GeV of incident π^+ kinetic energy. The particular energy and the particular reaction chosen were based on the requirement that in a similar experiment but performed on an unpolarized proton target the produced hyperon be highly polarized. Bohr's theorem links the intrinsic parity ε of the (Σ-N-K) system, the proton polarization $\vec{P}_p$, and the polarization of the Σ^+ hyperon $\vec{P}_\Sigma$ (as produced on <u>unpolarized protons</u>) to the differential cross-section:

$$\left(\frac{d\sigma}{dr}\right)_{pol} = \left(\frac{d\sigma}{dr}\right)_{unpol} (1 + \vec{P} \cdot \vec{P}_\Sigma). \qquad (2)$$

A possible experimental arrangement is discussed, keeping in mind the limitations introduced by the use of a polarized target.

1. At present the target size is quite small, about 1 cc. The cryostatic system around it as well as the structure of the magnet considerably limits the geometry of the detectors around it.

2. The polarized protons are only 3% of the nucleons present in the compound. The geometrical cross-section of the element with $Z \neq 1$ is about 11 times that of the free protons. A very effective rejection of events, due to the bound nucleons, must be provided.

These problems appear solvable with the large abundance of π^+'s available. The extension of the same method to the reaction

$$K^- + p \rightarrow \Xi^- + K^+$$

requires K^- beam, at least one order of magnitude stronger than the one available at present, or a target of much larger size. A target about one order of magnitude larger than the one discussed at present seems quite feasible.

III. THE EXPERIMENTAL ARRANGEMENT (Fig. 1)

A target of $\sim 1 \times 1 \times 1$ cm^3 is placed at the centre of a 5 cm gap of a magnet. The diameter of the pole pieces is of the order of 30 cm. A 1 GeV π^+ beam is reduced by collimation to 1 cm^2 and this image is focused on the target by two quadrupole lenses. An incident flux of 10^5 π^+/pulse over 1 cm^2 is assumed. It may be pointed out that there is no spark chamber in the beam and very probably rates several times the one assumed here are quite acceptable.

It is easy to work out the number of (Σ^+K^+) pairs produced on hydrogen per pulse:

$$N(\Sigma^+K^+) = (\text{atoms H/cm}^2) \times (\pi^+/\text{pulse}) \times \sigma(\Sigma^+K^+) =$$

$$= (6 \times 10^{23} \times \frac{1}{16}) \times (10^5) \times (3 \times 10^{-28}) = 1.1\ (\Sigma^+K^+)/\text{pulse}.$$

About 25% of the K mesons are emitted in the laboratory between 34° and 24°, corresponding to c.m. angles of 90° ± 15°. For this angular interval the Σ^- polarization has been measured by Cork et al. (4), and found to be $P_{\Sigma^+} = .8 \pm .2$. About 5% of them escape within the pole pieces, above the beam axis and they are electronically selected by a K^+ detector. The magnetic field of the magnet bends the K's in such a way that they emerge almost parallel, irrespective of the emission angle. The K^+ detector recognises the K's by measuring the range, velocity, and the decay time distribution. The over-all detection probability is estimated to be of the order of 0.4. Consequently, $0.25 \times 0.05 \times 0.4 = 5 \times 10^{-3}$ of the K^+'s, namely one every 200 machine pulses are detected. On the indicative basis of 40,000 pulses a day, about 10 events/hour are then expected. Of course the number of counts of the K detector will be much larger because:

a) K^+ produced on bound nucleons, via one of the following channels,

$$\pi^+ + (p) \rightarrow \Sigma^+ + K^+ \qquad \pi^+ + (n) \rightarrow \Lambda^0 + K^+$$

$$\pi^+ + (n) \rightarrow \Sigma^0 + K^+ \qquad \pi^+ + (n) \rightarrow \Lambda^0 + K^+ + \pi^0 \; ;$$

b) interactions with no strange particle produced, in which a pion or a proton enters into the K detector and is counted as a K.

This last background is most probably quite negligible for the kind of detector proposed.

IV. DISCUSSION

The success of the proposed experiment depends to a large extent on the possibility of discriminating effectively against events produced on bound nucleons. Very approximately, one may say that the cross-section for producing K^+ increases proportionally to the geometrical cross-section. This would indicate a rate of K^+'s from bound nuclei about one order of magnitude larger than the ones produced on hydrogen. The rejection against inelastic events could, in principle, be infinitively effective by increasing the angle and energy resolution on the detected K^+'s. In order to provide a good measurement of these two quantities, the K detector has two spark chambers, one, thin-plated, for determining the direction of the particle entering the detector, and another, with copper plates, to measure the K^+ range. Multiple scattering effects in the target limit the angular resolution to about 1°. A momentum resolution of about 5% is expected from the range determination. We are not able to estimate exactly the fraction of the events due to complex nuclei which are compatible with the reaction (1) on hydrogen. Order of magnitude estimates can be made:

a) from published bubble chamber data;

b) by a Monte Carlo calculation taking into account the Fermi motion effects.

Both types of estimate seem to indicate a background level which could be as large as the hydrogen effects. This fact, however, essentially reduces the size of the effect to be observed and does not introduce any other spurious effect provided the bound nucleons are not polarized. Now, the large majority of the complex nuclei of the compound have spin zero. For the remaining ones, a polarization inferior to 1% is expected. The size of the effect expected, taking into account possible inelastic contributions, is summarized in Fig. 2, where errors indicated refer to about 100 hours of effective measurement at the rate of 10^5 π^+/pulse and one PS pulse every two seconds. It appears that with this amount of running time, the two parity cases will be 15 standard deviations apart for an inelastic contribution equal to the hydrogen effects; in the rather pessimistic assumption of an inelastic contribution twice the hydrogen one, this separation will become 11 deviations.

REFERENCES

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4) B. Cork et al. Phys. Rev. 120, 1000 (1960)

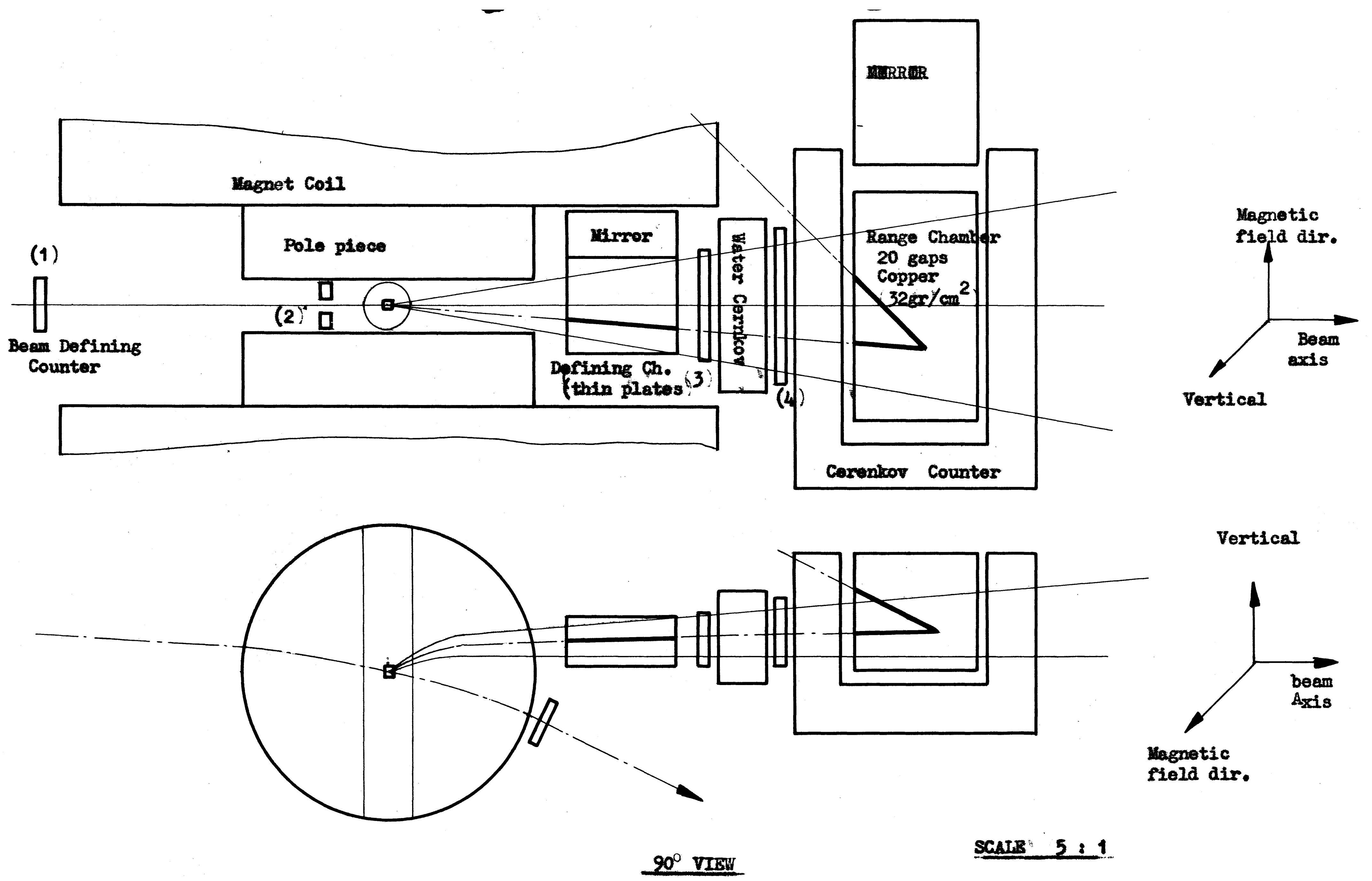
MIRROR
Magnet Coil
Pole piece
Mirror
(1)
Beam Defining
Counter
(2)
Defining Ch.
(thin plates
(3)
Water Cernkov
(4)
Range Chamber
20 gaps
Copper
32gr/cm^2
Cerenkov Counter
Magnetic
field dir.
Beam
axis
Vertical
Vertical
beam
Axis
Magnetic
field dir.
90° VIEW
SCALE 5 : 1

Fig. 1

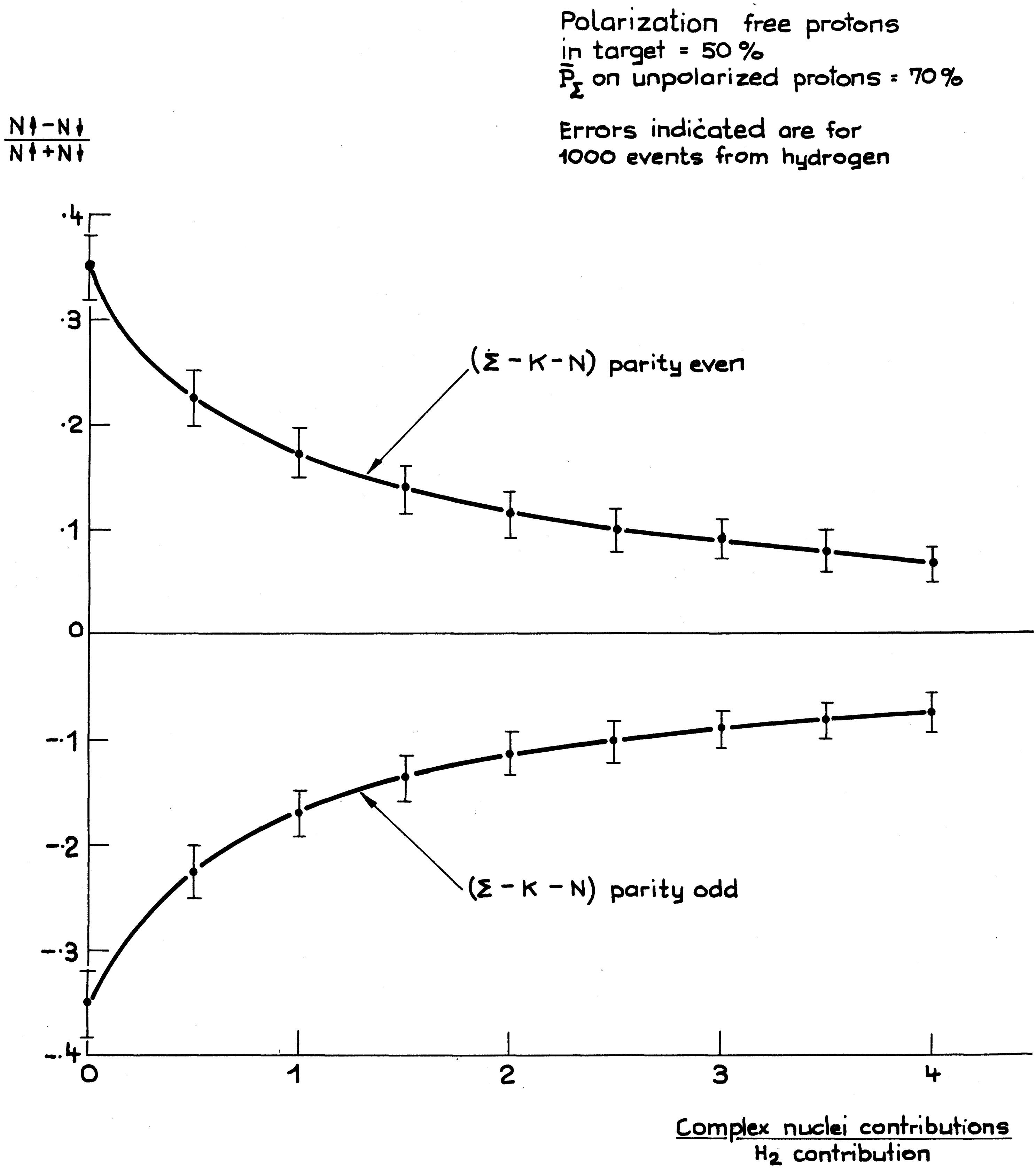
Polarization free protons
in target = 50 %
$\bar{P}_\Sigma$ on unpolarized protons = 70 %
Errors indicated are for
1000 events from hydrogen
$\frac{N\uparrow - N\downarrow}{N\uparrow + N\downarrow}$
·4
·3
·2
·1
0
-·1
-·2
-·3
-·4
0
1
2
3
4
(Σ - K - N) parity even
(Σ - K - N) parity odd
Complex nuclei contributions / H_2 contribution

Fig.2