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PROPOSAL TO TEST TIME INVARIANCE IN THE REACTION $n + p \rightarrow \gamma + d$

by

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INTRODUCTION

Because of the observation of the failure of CP invariance in the decay of the K^0_2, there has been renewed interest in time invariance. It is known to high accuracy that the strong interactions are invariant under parity transformation. Assuming CPT invariance, any failure in C must be compensated in T. From antiproton annihilation, C is known to be good to 1% in strong interactions[1], and T to at least 1%[2], if not 0.1%[3]. For the electromagnetic interactions the situation is not clear. The electromagnetic interaction of leptons is known to be invariant under C, P, and T, but for the hadrons the tests are poor. There have been recent discussions by Lee et al.[4,5] and by Henley and Jacobson[6], and several experimental tests have been proposed.

Recently Barshay[7] has proposed a test of time invariance where one might observe a large effect. He suggests that one tests detailed balance in the reactions:

$$\gamma + d \rightarrow n + p \quad (A)$$

$$n + p \rightarrow \gamma + d \quad (B)$$

In reactions (A) one observes a bump in the total cross section at a γ-ray energy of 300 MeV. It is due to the virtual production of an N*. Barshay suggests that the reactions be compared in this region; it is equivalent to a neutron energy of 600 MeV. Reaction A has been studied by several groups; the most recent experiment was at the Bonn synchrotron[8]. Although there is, at present, a disagreement on the value of the absolute cross section, there is reasonable agreement on the differential cross section, which is fortunately where any effect might be produced. There are no published experiments on reaction (B) for neutrons of a few hundred MeV.

EXPERIMENTAL METHOD

We propose to investigate reaction (B) using the monokinetic neutron beam of the CERN synchrocyclotron[9]. The beam has an estimated intensity of 4×10^5 neutrons/sec. The energy spread should be 7 MeV at an energy of 595 MeV. It has been suggested that the external proton beam of the synchrocyclotron has an energy spread of 20 MeV, and this would produce a similar spread in the neutron energy. For the proposed experiment the energy spread of the neutron beam should not exceed 7 MeV. It may, therefore, be necessary to reduce the energy spread of the proton beam with slits in the extraction channel of the synchrocyclotron.

For 600 MeV neutrons on a hydrogen target, the possible reactions are the following:

$n + p \rightarrow n + p$	25 mb	
$n + p \rightarrow n + n + \pi^+$	2 mb	
$n + p \rightarrow p + p + \pi^-$	2 mb	
$n + p \rightarrow n + p + \pi^0$	3.4 mb	
$n + p \rightarrow n + p + \gamma$	$\sim$ 40 μb	(for $E_\gamma > 150$ MeV)
$n + p \rightarrow \pi^0 + d$	1.5 mb	} ratio of 56
$n + p \rightarrow \gamma + d$	27 μb	

It will be imperative to distinguish clearly between the last two reactions. This is not easy because the π^0, when it decays, usually produces a high-energy γ-ray which travels approximately along the π^0-path. Fig. 1 shows the angle and energy of the deuterons produced by these reactions. The shaded regions illustrate the spread in energy and angle caused by a 10 MeV spread in the neutron beam energy. It is necessary to measure both the energy and angle of the deuteron; we aim to have an experimental resolution which is less than a quarter of the separation of these shaded areas.

To reduce the background from the other reactions we must detect the γ-ray as well. Fig. 2 shows the proposed experimental lay-out. The γ-ray will be detected by a lead glass Cerenkov counter. To increase the count rate we shall shave 11 separate counters. We hope to achieve 25% energy resolution at 200 MeV γ-ray energy[10].

To measure the energy of the deuteron we intend to use a magnetic spectrometer. A field length of 17 kg metres seems necessary; the gap should be 40 cms high and 1.4 m wide. Some alteration in these parameters could be tolerated, but a large reduction in the aperture would decrease our estimated count-rate. To determine the angle and energy of the deuteron, we propose to use thin-walled sonic spark chambers. We hope that 1 mm space resolution can be achieved. To reduce multiple scattering, the material traversed by the deuteron between SC1 and SC4 must not exceed 70 mg/cm^2 of aluminium together with 4 metres of helium gas. The total momentum resolution of the spectrometer must be better than 1½%.

Although we do not need an absolute cross section, we will be able to estimate it, using the reaction $n + p \rightarrow \pi^0 + d$. Isotopic spin analysis shows that the cross section for this reaction is half that for the reaction $p + p \rightarrow \pi^+ + d$. The inverse reaction, $\pi^+ + d \rightarrow p + p$, is at present being investigated at the synchrocyclotron. One could also use the elastic neutron-proton scattering as a monitor, but the cross section is know to only 10%[11].

We estimate the count rate for the reaction $n + p \rightarrow \gamma + d$ as follows:

Hydrogen target:	0.14 g/cm^2 i.e. 10^{23} protons/cm^2
Neutron beam:	4×10^5 per sec.
γ-ray counters:	200 msr (total)
Cross section:	2 μb/sr
Count rate:	1.6 10^{-2} per sec.or 1 every minute

We need 3% statistics in each gamma-ray counter. Since the counters subtend different solid angles, we need a total of 20,000 counts, i.e. data taking will last 330 hours. In addition we need time to study the characteristics of the neutron beam and to test the system. We therefore request a total of 100 shifts spread out over a period of about a year.

The following people have agreed to take part in the experiment, W. Hirt (ETH), P. Skarek (CERN), C. Serre (Univ. of Grenoble), and U. Trinks (Univ. of Bonn).

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DEUTERON ENERGY AND ANGLE

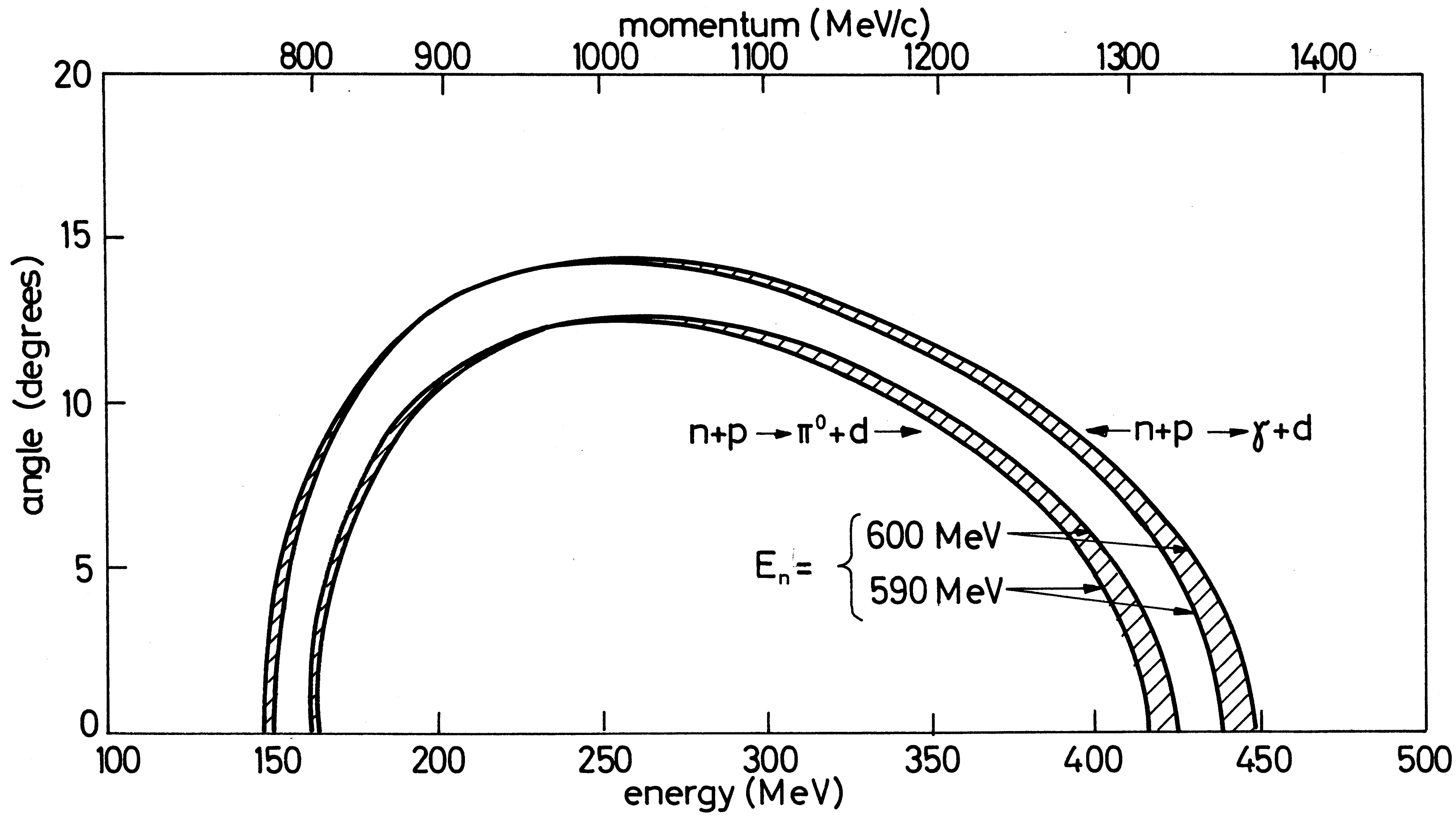

FIG.1

EXPERIMENTAL LAY-OUT

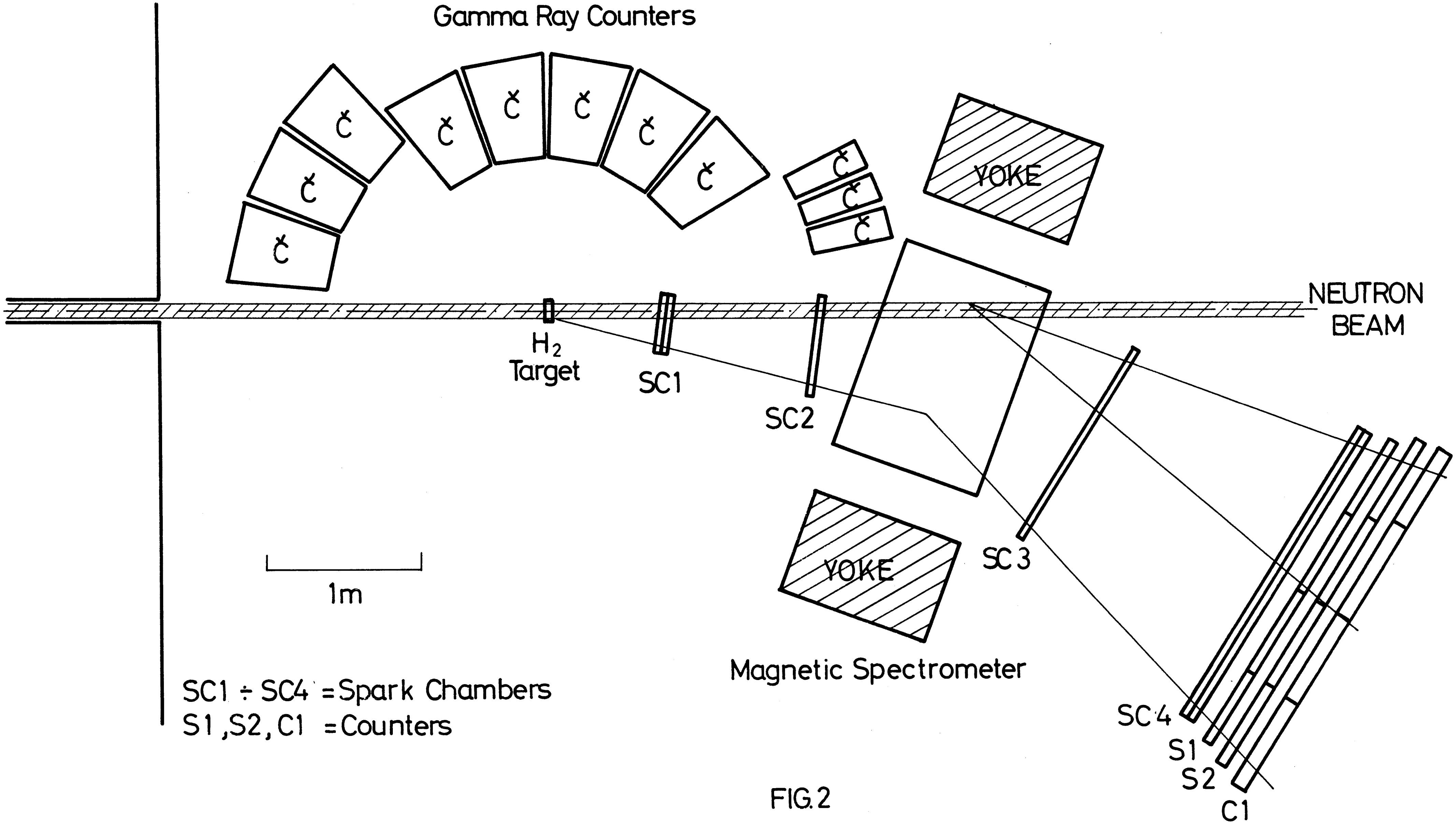

FIG.2