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Search for Parity Violation in the 2.010 MeV Transition in ^{41}Ca after Polarized Neutron Capture

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SEARCH FOR PARITY VIOLATION IN THE 2.010 MEV TRANSITION IN ^{41}CA AFTER POLARIZED NEUTRON CAPTURE

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Polarized states were produced in ^{41}Ca by capture of polarized thermal neutrons. The asymmetry coefficient A in the angular distribution of the 2.010 MeV ($3/2^{+}$-$7/2^{-}$) γ-ray was measured $A=(1.1\pm3.2)\cdot10^{-4}$.

1. INTRODUCTION

Recently, parity violating effects in the γ-decay of nuclei have been detected experimentally by several groups [1-4]. According to the theory of universal weak interaction the parity violation is due to the contribution of a weak nucleon-nucleon interaction to the nuclear forces [5]. Caused by the influence of this small parity nonconserving weak force a nuclear level is no longer described by a definite parity quantum number. Thus it is possible that electric and magnetic radiations of the same multipole order arise simultaniously in a γ-decay. These radiations interfere causing (i) a circular polarization of γ-rays from unpolarized nuclei or (ii) an asymmetry in the γ-distribution from polarized nuclear levels.

So far circular polarizations have been observed in ^{181}Ta, ^{175}Lu, ^{41}K and ^{180}Hf ranging from $6\cdot10^{-6}$ to $3\cdot10^{-3}$ [1-4]. The search for an γ-asymmetry from polarized ^{114}Cd nuclei has been performed by several authors with ambiguous results [6-9]. In this paper preliminary results are given for the case of ^{41}Ca. The nuclei where polarized by the capture of polarized thermal neutrons in ^{40}Ca.

2. THEORETICAL REMARKS

If conservation of parity is violated in nuclear forces the angular distribution $W(\theta)$ of γ-radiation from nuclear states polarized by capture of thermal neutrons may be written as [10]

$$W(\theta) = 1 + P \cdot A \cdot \cos\theta. \qquad (1)$$

The angle between the direction of nuclear orientation and γ-emission is θ and P is the polarization of the neutron beam. The asymmetry coefficient A is proportional to the ratio of the parity nonconserving nuclear matrix element <pnc> to the parity conserving element <pc>.

$$A = 2 \cdot G_1(J_i) \cdot F_1(LLJ_fJ_i) \frac{\langle pnc \rangle}{\langle pc \rangle} \qquad (2)$$

The factor $G_1(J_i)$ is the parameter of nuclear orientation of the initial level with spin J_i [10]. The coefficients $F_1(LLJ_fJ_i)$ are tabulated by Waspra et al.[11]. If the initial level is the compound state, $G_1(J_i)$ can easily be calculated. However, if the initial state is an arbitrary level populated by γ-decay of the compound state the depolarization by proceeding γ-rays has to be considered.

In general the current-current hypothesis predicts an asymmetry of the order 10^{-6}. It is possible, however, to obtain enhancements of many orders of magnitude. The condition therefore is, that the parity forbidden transition is favoured by selection rules, or that the parity allowed decay is hindered by such rules. Thus M-radiation are interesting for investigation. According to the perturbation theory it is favourable that levels with the same spin but different parity have similar energy.

The 2.010 MeV M2-transition seems suitable for an investigation of parity symmetry [12].
There is another state with the same spin but opposite parity about 70 keV below this level (fig. 1). By a comparison with the experimental results in ^{41}K Bock gave an estimation for the expected parity violation [13]: The parity violation in ^{41}K may be caused by mixing of the $3/2^+$ one hole ground state with

the $3/2^-$ one hole two particle level at 1.58 MeV. A similar configuration is found in the $3/2^-$ (one hole, to particles) state and the $3/2^+$ (one particle) state in ^{41}Ca (fig. 1). Due to the perturbation theory the mixing is proportional to the inverse of the level distance. Thus one may expect a parity violation of the order of $4\cdot 10^{-4}$ in ^{41}Ca which is about 20 times larger than the experimental value in ^{41}K [3].

The $3/2^+$ 2.010 MeV level of ^{41}Ca was populated and oriented by thermal polarized neutron capture in natural Ca. By polarized capture the compound state is oriented to 100%. By cascade decay the polarization is transferred to the 2.010 MeV level. Since the cascades are not known in detail a calculation can only be made with the help of a statistical cascade model [14]. The estimations yield $G_1(3/2) \approx 0.2$ for the polarization of this level. This value, however, is rather uncertain. For the F-coefficient the tables [11] yield $F_1(22\ 7/2\ 3/2) = 0.447$ and one obtains

$$A = 0.18\ \frac{\langle pnc \rangle}{\langle pc \rangle} \qquad (3)$$

3. EXPERIMENT AND RESULT

A beam of polarized neutrons of $6\cdot 10^6\ s^{-1}$ was produced by total reflexion (fig. 2) [9]. A target of natural Ca was exposed to the beam. The capture γ-rays from ^{41}Ca were detected by NaI counters (7.5 × 7.5 cm), which were installed at angles $\theta = 0^o$ and 180^o to the direction of the neutron polarization. For measuring A the neutron spin was reversed every 2 s and the (n,γ)-spectra from the two counters were stored in four quarters of a 400-channel analyzer according to the direction of the neutron polarization. Simultaniously the interesting line at 2 MeV was discriminated and the counts were registered. It was not possible to resolve the intensive 1.942 MeV and the 2.010 MeV radiation. In addition there is another unresolvable line at 2.001 MeV [14]. So only 10% of the line which can be clearly seen on the multichannel analyzer belong to the transition under investigation.

For determining the asymmetry coefficient A the relative counting rate differences E was measured for each counter

$$E = \frac{N(0^\circ)-N(180^\circ)}{N(0^\circ)+N(180^\circ)} \qquad (4)$$

where $N(\theta)$ ($\theta = 0$ or 180°) is the counting rate at an angle θ between the direction of the neutron spin and the γ-emission.

Table: Experimental result for the 2.010 MeV ($3/2^+ - 7/2^-$) decay in ^{41}Ca

Measured effect	E	$= (0.7\pm2.0)10^{-5}$
Corrected for 75% neutron polarization	E_{cor}	$= (0.9\pm2.8)10^{-5}$
Asymmetry coefficient A (corrected for background and unresolved lines)	A	$= (1.1\pm3.2)10^{-4}$
Parity violating matrix element (equ. 3)	$\frac{\langle pnc\rangle}{\langle pc\rangle}$	$= (0.6\pm1.7)10^{-3}$

In the table the experimental results for a measuring period of two weeks are shown. Our asymmetry coefficient $A = (1.1\pm3.2)10^{-4}$ indicates no parity violation. However, the statistical accuracy is rather low. The upper limit of a parity violation $\frac{\langle pnc\rangle}{\langle pc\rangle} = (0.6\pm1.7)10^{-3}$ is nearly 6 times larger than the expected value from the estimations of Bock. In spite of this we are stimulated to publish our result because of several reasons: (i) the theoretical estimations are crude, (ii) the parity violation may be high (see measurement of Jenschke and Bock [4] $\frac{\langle pnc\rangle}{\langle pc\rangle} \approx 3\ 10^{-3}$ for ^{180}Hf. By using polarized beams with higher fluxes and high counting rate techniques it is possible to improve our results.

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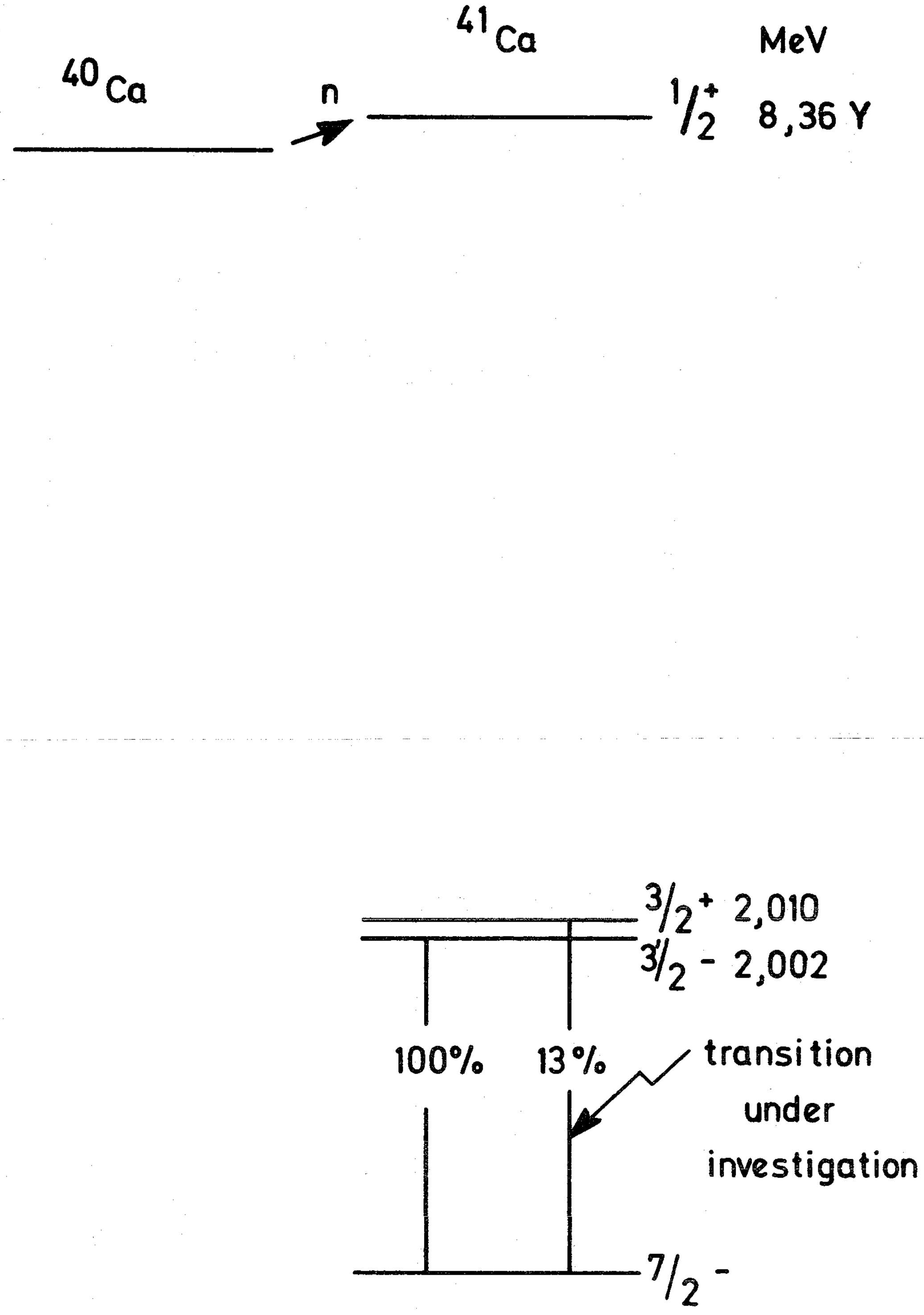

Fig. 1: Simplified decay scheme for ^{41}Ca with γ-transition under investigation

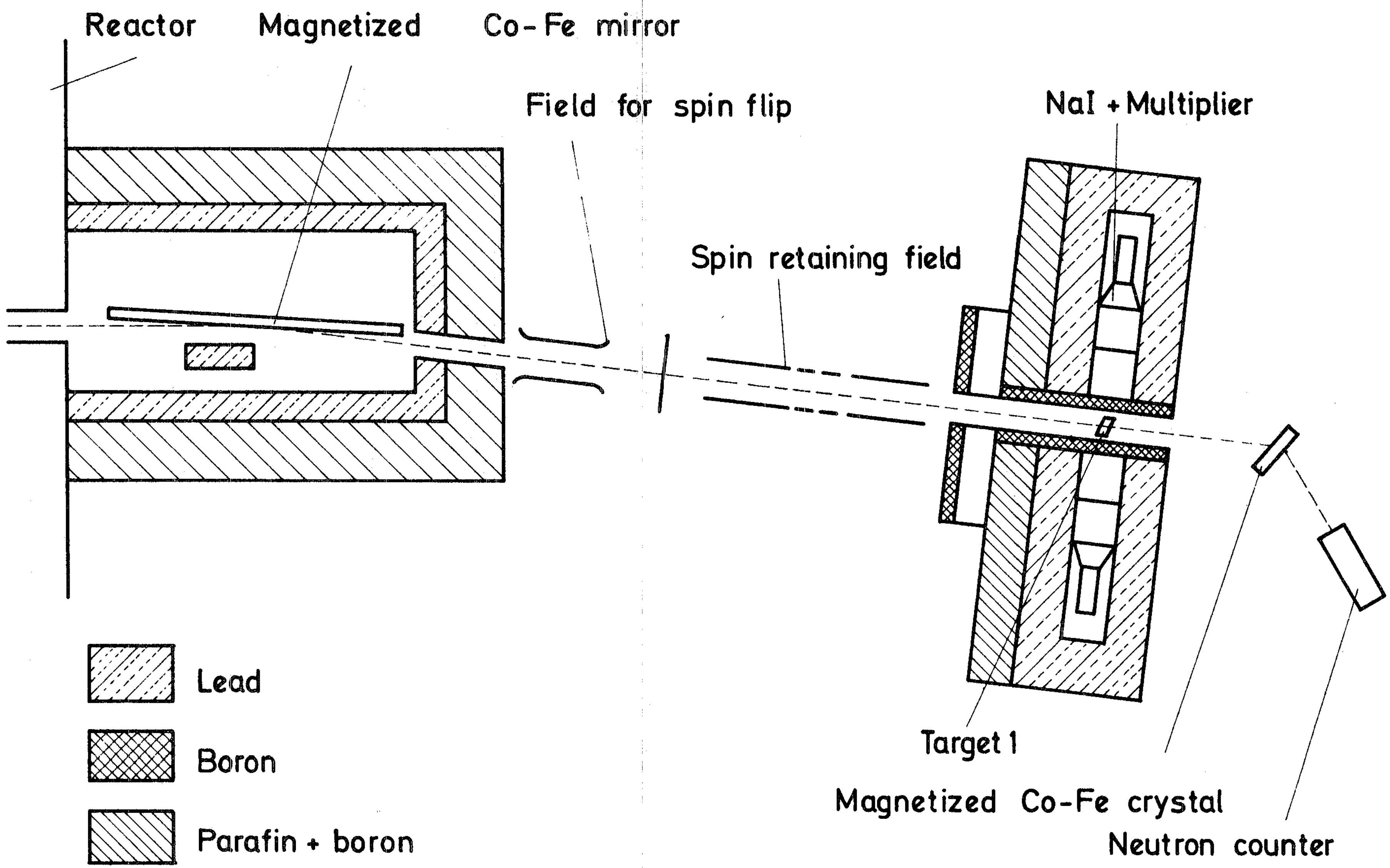

Fig. 2: Experimental arrangement for producing polarized neutrons and for measuring the γ-asymmetry