KERNFORSCHUNGSZENTRUM

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Institut für Experimentelle Kernphysik

Search of Parity Mixing in ^{181}Ta by Measurement of the Circular Polarisation of γ-Rays

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SEARCH OF PARITY MIXING IN ^{181}TA BY MEASUREMENT OF THE CIRCULAR POLARISATION OF γ-RAYS

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von

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Zusammenfassung

Es wurde die zirkulare Polarisation der 482 keV-γ-Strahlung des ^{181}Ta gemessen.
Unser Resultat ist $P = -(6.0 \pm 2.5)\ 10^{-6}$.
Diese Zahl wurde korrigiert auf apparative Asymmetrien und Bremsstrahlung.

Abstract

The circular polarization of the 482 keV-γ-radiation of ^{181}Ta was measured.
Our result is $P = -(6.0 \pm 2.5)\ 10^{-6}$.
This number is corrected for instrumental asymmetries and bremsstrahlung.

A weak parity violating nucleon-nucleon force is predicted by the current-current hypothesis |1| of weak interaction. Parity mixing in nuclear states can be detected by measuring the circular polarization of γ-rays emitted from unpolarized sources.

Recently E. Bodenstedt et al. |2| published a circular polarization $P = -(32 \pm 8) \times 10^{-6}$ for the 482 keV γ transition in ^{181}Ta. This result disagrees with the value given by Lobashov et al. |3|, i.e. $P = -(6 \pm 1) \times 10^{-6}$.

To measure polarization we used Compton forward scattering from a magnetized iron cylinder |4|. The magnetization was changed every second; the dead time between the beginning and the end of a switching process was 0.14 s. The detector consisted of a NaI (Tl)-crystal (5 cm × 5 cm), a 2 m long light guide and a magnetically shielded RCA 8053 venetian blind-type photomultiplier which is less affected by magnetic fields than tubes of box and grid structures. The magnetic stray field at the position of the multiplier was less than 10^{-6} Oe. A ^{181}Hf source was used; 1 g of HfO_2 enriched to 90% ^{180}Hf was mixed with 6 g of graphite powder to reduce the contribution of external bremsstrahlung to the polarization and irradiated in the FR2 reactor in Karlsruhe. The ^{181}Hf activity of approximately 30 Ci was limited by the neutron flux of the reactor (10^{14} $cm^{-2}s^{-1}$).

Because of the high photon intensity we could not count individual pulses, but used the Lobashov method of 'integral detection of γ-quanta intensity |3|'. The main part of the electronic system was developed by Tönnies and Burchard. The current at the output of the photomultiplier was amplified, integrated over time intervals of 0.8 s, and read out every second on scalers by a digital voltmeter. Two scalers accumulated the data corresponding to the two polarities of the magnetization in the scattering magnet. The data were punched on tape every 2000 s and analysed with the aid of a computer program |5|.

Reversing the magnetization one obtains the effect $\delta = 2(N_- - N_+)/(N_- + N_+)$ which is proportional to the circular photon polarization: $\delta = P \cdot E$.

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The analysing efficiency E was determined by investigating the circularly polarized bremsstrahlung of a ^{32}P source (β-endpoint energy 1710 keV). The experimental results for δ are listed in table 2. Theoretical results for δ were obtained by averaging the internal bremsstrahlung spectrum given by Lewis and Ford |6| and the bremsstrahlung polarization |7| over all photon energies. The analysing efficiency E was written in the form E = E(482 keV) • f(k), where k is the photon energy and f(482 keV) = 1. The function f(k) describing the energy dependence of E was calculated as in ref. 4 . The factor E(482 keV) was then adjusted so as to make the theoretical and experimental values δ equal. In this way the result E(482 keV) = 0.035 was obtained.

To investigate instrumental asymmetries the γ radiation of ^{46}Sc sources (≈ 70 Ci) was used which was not expected to show measurable polarization. The ^{181}Hf and ^{46}Sc sources were exchanged every three days. The results are given in table 1. All measurements were done with a 1 mm thick lead shield around the NaI crystal to reduce the contribution of bremsstrahlung. During the second run an additional lead filter of 3 mm thickness was placed between the source and the scattering magnet. The 46 Sc data of the first run exhibit a non-vanishing effect. To explain this fact the influence of the magnetic stray field on the NaI crystal and photomultiplier was measured and effects $\delta \leq 10^{-7}$ were found. Furthermore, we have investigated spurious asymmetries resulting from a left-right asymmetry in Compton scattering |8|. Misalignments ≤ 3 mm of the source and the crystal led to negligible perturbations in our case. In addition we measured the ^{46}Sc effect as a function of magnetization M and found the effect to be proportional to the derivative $\frac{dM}{dH}$. The instrumental asymmetry could be reduced finally by increasing the magnet current by a factor of 2 (run 2).

The bremsstrahlung yield was studied with the aid of ^{198}Au sources (β endpoint energy 962 keV, γ-ray energy 412 keV) and ^{177}Lu sources (β endpoint energy 497 keV, γ-ray energies 208, 250 and 321 keV); the sources were diluted with graphite to lower external bremsstrahlung. The results of these control experiments are given in table 2.

The ^{177}Lu effects are in good agreement with recent results obtained by Vanderleeden |9|. For comparison, the contribution of internal bremsstrahlung (IB) to δ was calculated with the formulas given by Lewis and Ford |6, 7|. Furthermore, the contribution of external bremsstrahlung to δ was computed and found to be of the same order of magnitude as the IB contribution. On the other hand, the experimental values are not much higher than the theoretical IB results (see table 2). This discrepancy might arise from the fact that the formulas we have used are valid only for $\alpha \cdot Z \ll 1$.

If we take the theoretical IB contributions to correct our ^{181}Ta-results for the bremsstrahlung asymmetry (this procedure is justified by the ^{177}Lu-control experiment), we get a weighted average

$$\delta = -(1.9 \pm 0.8) \times 10^{-7}$$

which corresponds to a polarization

$$P = -(6.0 \pm 2.5) \times 10^{-6}.$$

The error is the standard deviation.
The statistical error of the ^{46}Sc control experiment was taken into account, but systematic errors were neglected.

The result agrees with that given by Lobashov et al., but disagrees with the value obtained by Bodenstedt et al.

The authors thank Prof. H. Schopper for his interest in this work and Mr. J. Müller for preparation of the sources.

Note added in proof

The results of two other groups have come to our knowledge recently.

H. Diehl, G. Hopfensitz, E. Kankeleit and E. Kuphal report
$P = -(13 \pm 7) \times 10^{-6}$.
J.C. Vanderleeden and F. Boehm give $P = -(3.8 \pm 1.3) \times 10^{-6}$.

Table 1

	$\delta \times 10^7$	
	run 1	run 2
$\delta(^{181}\mathrm{Ta})$	-1.27 ± 0.86	-1.04 ± 1.15
$\delta(^{46}\mathrm{Ti})$	$+2.04 \pm 0.58$	$+0.75 \pm 0.62$
difference	-3.31 ± 1.04	-1.79 ± 1.31
correction for bremsstrahlung	$+1.2$	$+0.3$
δ(corrected)	-1.9 ± 0.8	

Table 2

source	lead filter between source and magnet	lead filter between magnet and detector	effect δ	
			exper.	theor. (IB)
$^{32}\mathrm{P}$	0 mm	1 mm	$-(1.4 \pm 0.1) \times 10^{-2}$	determination
	0 "	2 "	$-(1.8 \pm 0.1) \times 10^{-2}$	of E
$^{198}\mathrm{Au}$	0 mm	1 mm	$-(8.7 \pm 0.8) \times 10^{-6}$	-5.6×10^{-6}
$^{177}\mathrm{Lu}$	0 mm	1 mm	$-(19.8 \pm 1.3) \times 10^{-6}$	-22×10^{-6}
	1 "	1 "	$-(33 \pm 4) \times 10^{-6}$	-30×10^{-6}
	2 "	1 "	$-(46 \pm 4) \times 10^{-6}$	-42×10^{-6}
	3 "	1 "	$-(57 \pm 4) \times 10^{-6}$	-60×10^{-6}
$^{181}\mathrm{Hf}$	0 mm	1 mm	---	-1.2×10^{-7}
	3 "	1 "	---	-0.3×10^{-7}

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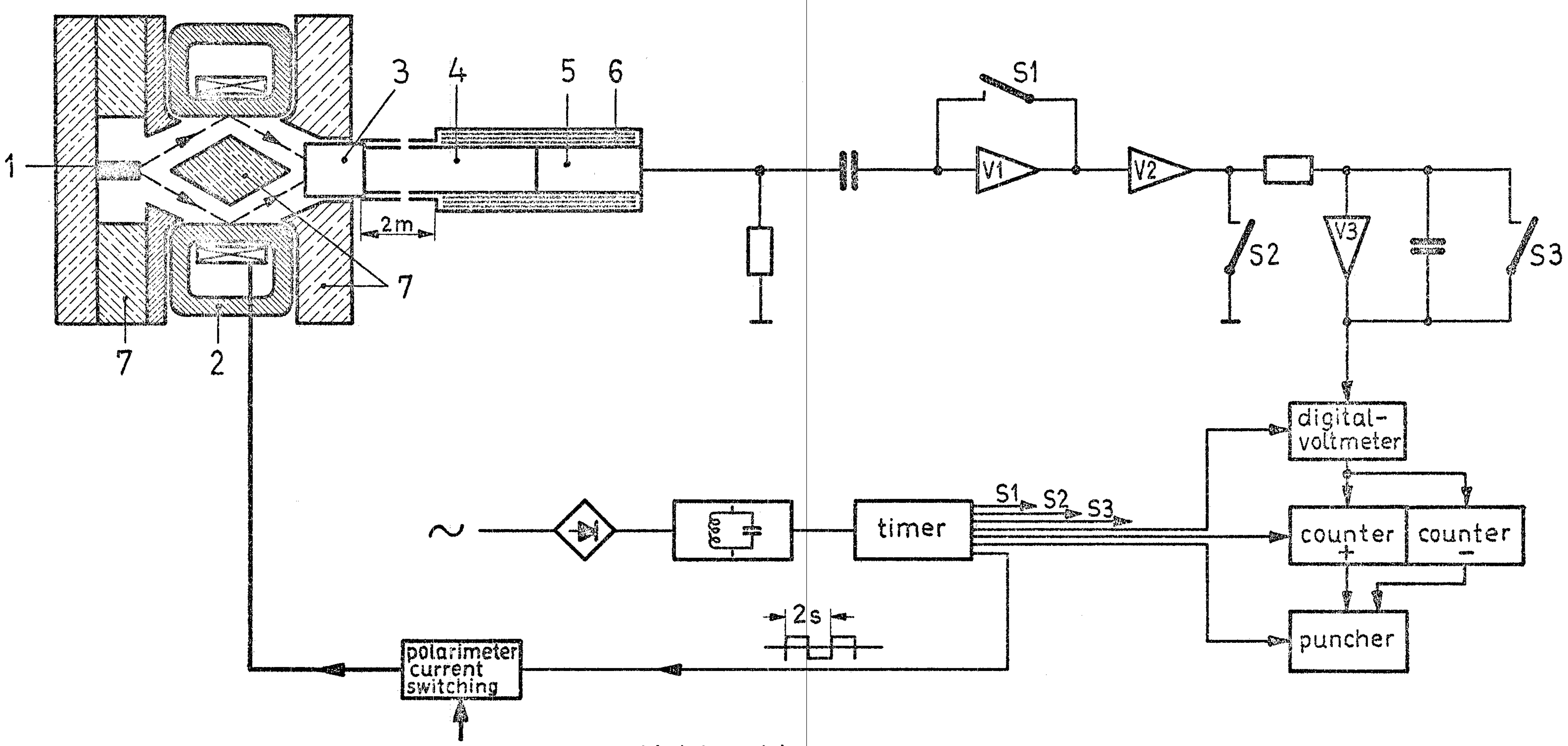

1 source
2 scattering magnet
3 NaI (Tl) crystal

4 light guide
5 photomultiplier tube
6 mu-metal
7 lead shield

Fig. 1. Experimental arrangement