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Search for Weak-Electric Moment in the Beta-Disintegration of the $A = 12$ Isobars

M. STEELS, L. GRENACS, J. LEHMANN, L. PALFFY and A. POSSOZ

Institut de Physique Corpusculaire, University of Louvain, Louvain-la-Neuve, Belgium

By comparison of counting rates of beta-particles from polarized and inversely polarized ^{12}B nuclei the decay asymmetry was measured as a function of the electron kinetic energy. The preliminary result for the slope of the decay asymmetry, normalized to complete vector polarization, is: $\Delta A_1 = -1.7 \pm 2.3.$ 10^{-3} MeV^{-1}. The theoretical prediction based on the assumption that the whole lifetime asymmetry in the decay of ^{12}B–^{12}N mirror nuclei is due to the divergenceless second class induced tensor current is: $+3.5.\ 10^{-3}$ MeV^{-1}.

Operating the spin inversion of ^{12}B by transverse pulse technique the magnetic moment of ^{12}B was measured: $|\mu(^{12}B)| = (1.09 \pm 0.05)\mu_N$.

Introduction

The *G*-irregular currents,[1] whose presence in the hadronic axial current would lead to odd interferences in mirror beta-transitions, were invoqued for the explanation of the observed lifetime asymmetry in mirror Gamow-Teller transitions.[2] Correlation experiments were proposed to separate the part of the asymmetry due to nuclear effects (unequal configuration mixings in the intervening mirror states, etc.) from the odd interference effect due to the (presumed) *G*-irregular currents.[3] The *ft*-ratios depend on nuclear effects in first order, except possibly for the case of the isobars $A = 8$,[4] while correlations are in first order independent of these effects. We have undertaken the measurement of the angular distribution of beta-rays from polarized $A = 12$ mirrors. Only one kind of irregular current can be detected by this experiment,[3] the induced tensor $\sigma_{\mu\nu}q_\nu\gamma_5$ called "weak-electricity",[5] the axial counterpart of the regular "weak-magnetism" $\sigma_{\mu\nu}q_\nu$ which was detected precisely in the $A = 12$ multiplet.[6]

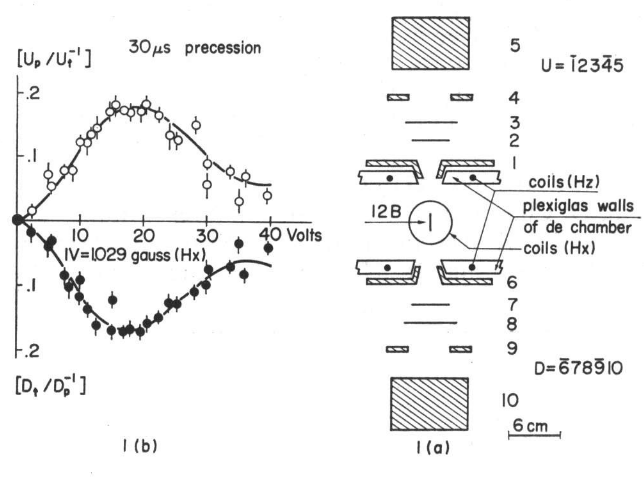

Fig. 1. (a) The scintillator counter telescopes and the reaction chamber.
(b) Precession curves of ^{12}B in a transverse magnetic field of 30 μs duration. To 1 volt of the power generator corresponds 1.029 gauss transverse field (H_x).

Production of Polarized ^{12}B and Lay-out

The method of production was inspired by the works of the authors of refs. 7, 8 and 9. Recoil ^{12}B nuclei issued in polarized state from the $^{11}B(d, p)^{12}B$ reaction were implanted in Pd lattice (~3 mg/cm^2) where the nuclear polarization is preserved for many lifetimes of ^{12}B by the application of a longitudinal decoupling field $H_z \simeq 35$ gauss. The parameters of the production process are the following ones: 1) the beam energy $E_d = 1.5$ MeV, 2) the ^{11}B target thickness was $\simeq 110$ μg/cm^2 deposited on stainless steel backing, 3) the recoil angle of ^{12}B nuclei was $49° \pm 3°$ (right), 4) the mechanically chopped beam bombarded the target during 25 ms (counting of beta-rays vetoed) and the interval between two successive irradiations was 60 ms (counting period 50 ms). The observed polarization of ^{12}B was $\simeq 9.5\%$ ("up" in the laboratory). The beta-rays were counted by two scintillator counter telescopes (Fig. 1(a)). The thickness of the vacuum, light-tighting and detector materials travelled by the electrons up to the energy detector (5 and 10) was $\simeq 100$ mg/cm^2.

The beta spectrum in the "up" telescope with spin "up" $U_\uparrow(E_\beta)$ was compared to that taken with spin "down" $U_\downarrow(E_\beta)$ (and similarly $D_\uparrow$ compared to $D_\downarrow$). The spin "down" polarization was obtained by the application of a transverse magnetic pulse H_x to nuclei produced in "up" state. The decoupling field H_z was always "on" during the implantation. To obtain the spin-flip the following program was applied: i) after four successive implantation periods (four holes in the chopping wheel transmit the beam) H_z was set to zero with $\tau = 23$ μs (let us call this time t_0), ii) at $t_0 + 500$ μs H_x was applied during 30 μs ($\tau = 10$ μs), iii) at $t_0 + 550$ μs H_z was set back to 35 gauss and finally iv) at $t_0 + 1000$ μs the counting of beta-particles was started for a period of 50 ms. Following the next four successive implantation periods i), ii) and iii) were not applied (the spin remained in "up" state). Figure 1(b) shows the "precession" curves; $U_p(D_p)$ means the counting in the "up" ("down") telescope after the execution of the program i)-iii). The curves are the results of best-fits, the inhomogeneity of H_x was simulated with a damping factor (free parameter). The reversal of the polarization was reached at $H_x = 20.2 \pm 1.0$ gauss. From these measurements the magnetic moment of ^{12}B was deduced: $|\mu(^{12}B)| = (1.09 \pm 0.05)\mu_N$, in accordance with the published results.[8,9)]

The beta-ray spectrum, corrected for background, is shown on Fig. 2(a) ("down" telescope) with the ^{207}Bi conversion-electron spectrum (FWHM $\simeq 25\%$). The ^{207}Bi peak-the maximum intensity of the beta spectrum-the end point of the spectrum furnished the energy calibration points; the error on the energy assignment was $\simeq 100$ keV in the range 1 MeV $\lesssim E_\beta \lesssim 13$ MeV. The background was measured by the counting with the Pd foil removed from the ^{12}B recoil trajectory.

Results

The spectra $U_\uparrow$, $U_\downarrow$, $D_\uparrow$ and $D_\downarrow$ were routed to distinct memory banks of a multichannel pulse-height-analyser. Measurements with and without Pd in the recoil trajectory were alternated periodically. The parameters $\varepsilon_U = U_\downarrow/U_\uparrow - 1$ and $\varepsilon_D = D_\uparrow/D_\downarrow - 1$, shown on Fig. 2(b), were corrected for the corresponding backgrounds, for the contribution of the internal $1^+ \rightarrow 2^+(1.33\%)$ beta-branch and for v/c. The dotted-line curve is the estimated effect due to backscattering (normalized to $\varepsilon = .21$ at 13.4 MeV) in the interior of the reaction chamber. Above $E_\beta \gtrsim 4$ MeV this effect looses its importance, the data points above this energy were fitted by a straight line. The best-fit result is: $\varepsilon(E_\beta) = 0.2082 - (0.0006 \pm 0.0008)$. E_β, (χ^2_{min}(normalized) $= 1.3$). The error on the slope corresponds to 3 standard deviations.

Discussion

The prediction of the theory, if the whole lifetime asymmetry (11%) in the $A = 12$ multiplet is due to the conserved weak-electric current (WE) (including the weak-magnetism (WM)), is shown in Table I with the result deduced from this experiment. In this deduction we made the following assumption: the alignment of ^{12}B (if there was any at the instant of

Table I. The slope of the asymmetry parameter A_1 deduced from $\varepsilon(E_\beta)$, $\Delta A_1 \text{MeV}^{-1} \times 10^3$, compared to the theory÷)

	W. E. conserved + W. M.	W. M. only	Experiment+
^{12}B	+3.5	+1.0	−1.7±2.3
^{12}N	−3.9	−1.4	

÷) for the involved coupling constants see ref. 3.
+) normalized to complete vector polarization.

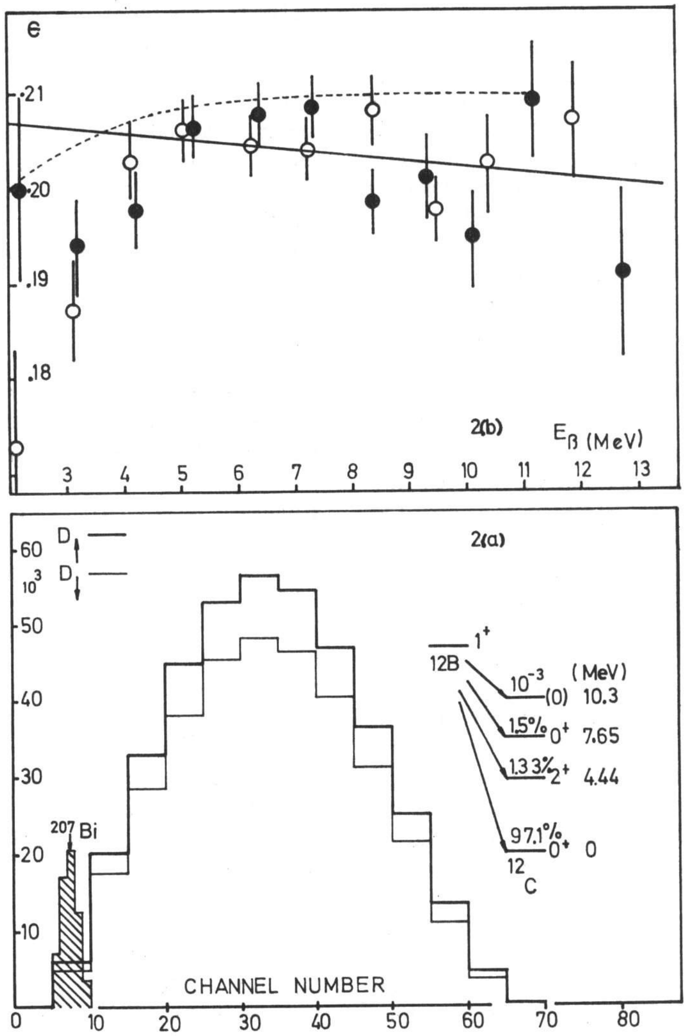

Fig. 2. (a) The beta-ray spectrum taken with the "down" telescope and the ^{207}Bi conversion-electron spectrum.

(b) The parameters ε_U and ε_D versus the beta-ray energy E_β. A slight normalization was made in order to equate ε_U and ε_D in the region of 5 MeV $\leq E_\beta \leq$ 13 MeV. The straight line is the linear best-fit over this energy region.

the reaction) does not survives for a period comparable to $\tau(^{12}B)$. Spin-spin interactions make the relaxation of the alignment (no change in the total energy of the spin) fast compared to the relaxation of the polarization which is operated by the weak spin-lattice interaction; $\tau_1(^{12}B \text{ in Pd}) \gg \tau(^{12}B)$.[10] Moreover, the interactions responsible for the relaxation of the alignment render the envelop of the magnetic substates boltzmanian; hence the polarization is nearly vector type.[11]

With this qualification, the experiment indicates that the contribution of the conserved weak-electric current in the $^{12}B \rightarrow {}^{12}C$ transition is smaller than that of weak-magnetism.

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