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Alignment correlation term in mass A = 8 system and G-parity irregular term

T. Sumikama[1,a], T. Iwakoshi[1], T. Nagatomo[1], M. Ogura[1], Y. Nakashima[1], H. Fujiwara[1], K. Matsuta[1], T. Minamisono[1], M. Mihara[1], M. Fukuda[1], K. Minamisono[2], and T. Yamaguchi[3]

[1] Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan
[2] TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, V6T 2A3, Canada
[3] Department of Physics, Saitama University, Saitama 338-8570, Japan

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Abstract. The pure nuclear spin alignments of ^{8}Li and ^{8}B were produced from the nuclear spin polarization applying the β-NMR method. The alignment correlation terms in the β-ray angular distribution of the mirror pair ^{8}Li and ^{8}B were observed to limit the G parity irregular term in the weak nuclear current. The significant deviation due to the forbidden matrix elements between the alignment correlation terms and the β-α correlation terms was observed. The determination of the alignment correlation terms was essential to extract the G-parity violating induced tensor term without the influence of the forbidden term in the vector current.

PACS. 11.30.Er Charge conjugation, parity, time reversal, and other discrete symmetries – 23.40.Bw Weak-interaction and lepton (including neutrino) aspects – 27.20.+n $6 \le A \le 19$

1 Introduction

The β-α angular correlation terms of the mirror pair ^{8}Li and ^{8}B were measured in 1975 and 1980 by Tribble *et al.* [1] and McKeown *et al.* [2] to limit the G-parity violating induced tensor term. The results were consistent with non existence of the induced tensor term. While strong interaction induces only the G-parity conserved current into the weak nucleon current, a small but finite G-parity irregular current may be caused by the asymmetry between the up and down quarks such as the mass difference. However, it is difficult to set more accurate limit to the induced tensor term only from the β-α angular correlation terms due to serious contribution from the second-forbidden matrix elements. The other approaches are necessary in the mass $A = 8$ system. Since some terms of the forbidden matrices contribute in opposite directions to the alignment correlation term, we have a good chance to determine the induced tensor term and these forbidden matrices at the same time.

2 G-parity irregular term

In the present study, we observed the alignment correlation terms in the β-ray angular distributions from spin aligned ^{8}Li and ^{8}B to extract the induced tensor term $g_{\rm II}$ precisely. The β-ray angular distribution from purely aligned ^{8}Li and ^{8}B is given by

$$W(E,\theta) \propto pE(E-E_0)^2 \times B_0(E)\left[1+\mathcal{A}\frac{B_2(E)}{B_0(E)}\mathrm{P}_2(\cos\theta)\right], \qquad (1)$$

where $\mathcal{A}$ is the alignment, E and E_0 are the β-ray energy and end-point energy, respectively, p is the β-ray momentum, θ is the β-ray ejection angle and P_2 is the Legendre polynomial. The difference δ between the alignment correlation terms B_2/B_0 of ^{8}Li and ^{8}B is formulated by Holstein [3] as

$$\delta = \left(\frac{B_2(E)}{B_0(E)}\right)_{^8\mathrm{Li}} - \left(\frac{B_2(E)}{B_0(E)}\right)_{^8\mathrm{B}} = -\frac{2E}{3M_n}\left[\frac{b}{Ac}-\frac{d_{\rm II}}{Ac}+\frac{3}{\sqrt{14}}\frac{f}{Ac} +\sqrt{\frac{3}{28}}\frac{g}{A^2c}\frac{E_0-E}{M_n}\right], \qquad (2)$$

where b is the weak magnetism, c is the Gamow-Teller term, $d_{\rm II}/Ac = g_{\rm II}/g_{\rm A}$ is the ratio of the induced tensor term to the axial-vector coupling constant, f and g is the second forbidden matrix elements of the vector current, M_n is the nucleon mass and A is the mass number. All

[a] Conference presenter; *Present address*: RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan; e-mail: sumikama@riken.jp. Thanks for the Special Postdoctoral Researcher Program of RIKEN.

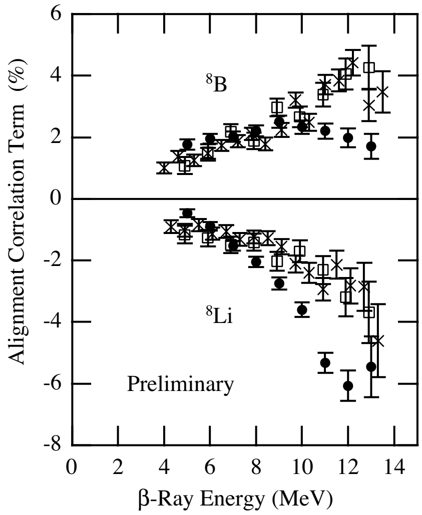

Fig. 1. The alignment correlation terms. The full circles are from the present result and and the open squares and the crosses are from the β-α correlation terms in refs. [1] and [2], respectively, which are multiplied by $-2/3$.

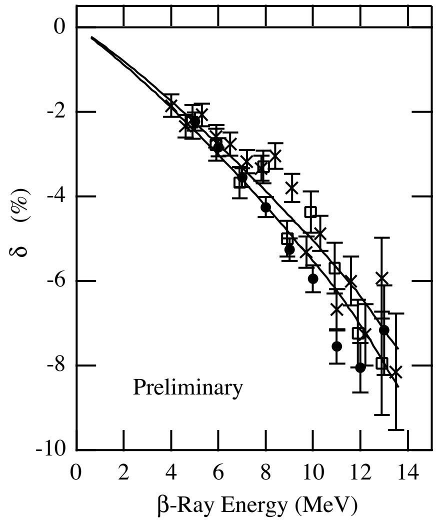

Fig. 2. The difference of the alignment correlation terms. The meaning of the marks is same as in fig. 1. The lines show the weak magnetism term b/Ac with $\pm 1\sigma$ bands [4].

the terms have a dependence of the final-state excitation-energy, where the final state is the first excited state of ^{8}Be, but this dependence is not included in eq. (2) for simplicity. The $g_{\rm II}$ term is given by combining the present alignment correlation term with the weak magnetism [4] and the β-α correlation term [1,2] where the f and g terms contribute in opposite directions to eq. (2).

The present experimental procedure and setup were essentially the same as previous one [5]. The ^{8}Li and ^{8}B nuclei were produced through the nuclear reactions ^{7}Li(d, p)^{8}Li and ^{6}Li(^{3}He, n)^{8}B, respectively. The deuteron and ^{3}He beams were accelerated by the Van de Graaff accelerator at Osaka University up to 3.5 MeV and 4.7 MeV, and were used to bombard a Li_2O and an enriched metal ^{6}Li targets, respectively. The recoil angles of the nuclear reaction products were selected to produce the polarized nuclei. The typical polarization was 7.2% for ^{8}Li and -5.7% for ^{8}B in the direction of $\boldsymbol{k}_{\rm B} \times \boldsymbol{k}_{\rm R}$, where $\boldsymbol{k}_{\rm B}$ and $\boldsymbol{k}_{\rm R}$ are the momenta of a beam and a recoil nuclei, respectively. ^{8}Li and ^{8}B were implanted into Zn and TiO_2 single crystals, respectively, which were placed in an external magnetic field B_0 to maintain the polarization and to manipulate the spin with the β-NMR technique. The c-axis of the single crystals was set parallel to B_0, which is 60 mT for ^{8}Li and 230 mT for ^{8}B. The β-ray asymmetry was observed by two sets of plastic-scintillation-counter telescopes placed above and below the catcher relative to B_0 direction. The polarizations were converted into pure positive and negative alignments with ideally zero polarization by applying the β-NMR technique. The alignment was converted back into polarization to check the spin manipulation. The β-ray angular distribution from the pure aligned ^{8}Li and ^{8}B was observed as a function of β-ray energy.

The alignment correlation terms were preliminarily extracted as shown in fig. 1. The β-α angular correlation terms $p_{\mp}(E)$ in refs. [1,2] are also plotted in the same figure, after multiplied by $-2/3$ to compare it with the alignment correlation terms. Both of these correlation terms have large E^2 contributions from the second-forbidden matrix elements. There is a significant deviation between the alignment correlation terms and the β-α correlation terms due to the forbidden terms of f and g in the vector current and the one of j_2 in the axial-vector current. Among these 3 terms, the contribution of j_2 is unique, since the j_2 term contributes in same direction to the mirror pair of a same correlation term, while the f and g terms contributes in opposite directions to the mirror pair. Main deviation comes from the j_2 term because the alignment correlation terms are lower than β-α correlation terms in the high energy region for both nuclei. The differences δ are shown together with the β-α correlation terms [1,2] and the experimental weak magnetism b/Ac [4] in fig. 2. The dependence of the final-state excitation-energy for b/Ac has been observed experimentally. Small but definite deviation between δ for alignment correlation term and β-α correlation terms was observed. The contribution from f and g was about 8% of b at 10 MeV, while the value extracted from the γ decay width [4] is consistent with zero and the upper limit was half of the present deviation. The induced tensor term was preliminary extracted without the influence of f and g terms as the limit $\left|d_{\rm II}/\bar{b}\right| < 0.06$, where $\bar{b}$ is the energy average of the weak magnetism [4,6]. Detailed analysis is in progress.

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