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7.9 Polarizations of ^{12}B in Muon Capture Reaction and Induced Pseudoscalar Weak Interaction

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Muon capture reaction is a unique probe for studying the induced pseudoscalar term in the weak charged nucleon currents due to large muon mass and momentum transfer. Recently we studied nuclear polarizations of ^{12}B in the muon capture in ^{12}C to investigate the strength g_P of the induced pseudoscalar form factor of a nucleon[1)] by taking into account effects of the first order core polarization on the one-body current matrix elements and also the exchange currents. We found that these effects are rather large for nuclear polarizations of ^{12}B. They are regarded as the same first order effects in the perturbation theory. Since each of the first order effects is large, examination of the second order effects on the polarizations is required as a next step.

In this note we investigate the induced pseudoscalar form factor by studying the second order effects on the nuclear polarizations of ^{12}B. We studied the second order core polarization effect on the one-body current matrix elements, and the first order core polarization effect on the exchange current matrix elements (cross term), both of which are regarded as the second order effects. To make our calculation more realistic and accurate, we revised formulation of the core polarization which was used in the previous work[1)]. The unperturbed nuclear hamiltonian H_0 includes the two body interaction between nucleons upto the 0p-shell, and the corresponding unperturbed states are obtained by diagonalizing the hamiltonian H_0. Details of the formulation will be given in a separate paper. The intermediate states entering the perturbation theory are restricted to the configurations with $2\hbar\omega$ excitation in the second order calculations, due to the limitation of the computer capacity. In this formulation, the energy denominator is not simply an integral multiple of $\hbar\omega$. In numerical calculation, the 0p-shell wave function of Hauge and Maripuu[2)] and the Sussex interaction[3)] for the core polarization are used.

To confirm validity of our restriction of the configurations, we estimated the contribution of $4\hbar\omega$ excited intermediate states on the second order calculations by adopting the simple jj-coupling model ($0p_{3/2}$ closed shell and 1p-1h states for the initial and final states, respectively). As a result, we found that inclusion of $4\hbar\omega$ excited intermediate states affects the calculated polarizations little, while it affects the muon capture rate seizably.

Experimentally the average polarization[4)] P_{AV}^{exp} and the ratio[5)] of the average polarization to the longitudinal polarization $R^{exp} = (P_{AV}/P_L)^{exp}$ are available. The latter experimental data are expected to be relatively free from the systematic errors compared with the former. The measured values P_{AV}^{exp} and R^{exp} contain contributions from the excited states as well as the one from the ground state of ^{12}B. Following the method of Ref.6), we can obtain $P_{AV}^{exp}(1^+)$ and $R^{exp}(1^+)$ of the ground state, which depend upon the partial muon capture rates. If we adopt the data measured by the ETH group[7)], we have

$$P_{AV}^{exp}(1^+) = 0.462 \pm 0.053 \quad \text{and} \quad R^{exp}(1^+) = -0.499 \pm 0.044. \tag{1}$$

These are shown in Fig.1 and Fig.2 by the shaded region, respectively. If we adopt the data by the Saclay group[8)], we have

$$P_{AV}^{exp}(1^+) = 0.481 \pm 0.056 \quad \text{and} \quad R^{exp}(1^+) = -0.524 \pm 0.048. \tag{2}$$

The theoretical values of $P_{AV}(1^+)$ are shown in Fig.1 as a function of g_P/g_A. The dashed curve shows sum of the contributions of the impulse approximation with 0p-shell nuclear wave functions and the first order effects. The second order effects increase the value of $P_{AV}(1^+)$ by 1.3 to 2.5 percent for g_P/g_A = 7 to 13. The solid curve in Fig.1 shows the result including the effects upto the second order. Most of the difference between the dashed and solid curves comes from the cross term, and the second order core polarization effect on the one-body current matrix elements is very small. The theoretical values of $R(1^+)$ are shown in Fig.2 as a function of g_P/g_A. The solid and dashed curves are with and without the second order effects as in Fig.1. As in the case of $P_{AV}(1^+)$, the cross term is the main contribution of the second order effects. Net second order effects increase the absolute value of $R(1^+)$ by 1.8 to 2.7 percent for g_P/g_A= 7 to 13. Consequently, the strength of g_P is limited to

$$g_P/g_A = 10.6 \begin{smallmatrix} +\ 2.3 \\ -\ 2.6 \end{smallmatrix} \text{ from } P_{AV}(1^+) \quad \text{or} \quad 9.5 \pm 1.7 \text{ from } R(1^+), \tag{3}$$

if the values of eq.(1) are adopted, and

$$g_P/g_A = 9.7 \begin{smallmatrix} +\ 2.5 \\ -\ 2.9 \end{smallmatrix} \text{ from } P_{AV}(1^+) \quad \text{or} \quad 8.6 \pm 1.9 \text{ from } R(1^+), \tag{4}$$

if the values of eq.(2) are adopted.

Inclusion of the second order effects increases the central value of g_P/g_A by 0.4 to 0.5. Although we obtain different values of g_P/g_A by 0.9 depending on whether we adopt eq.(1) or (2), these values are not inconsistent with the naive prediction of PCAC.

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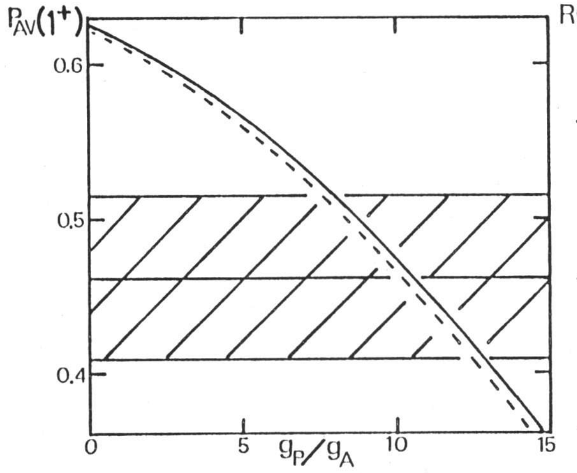

Fig. 1. The average polarization $P_{AV}(1^+)$ of ^{12}B.

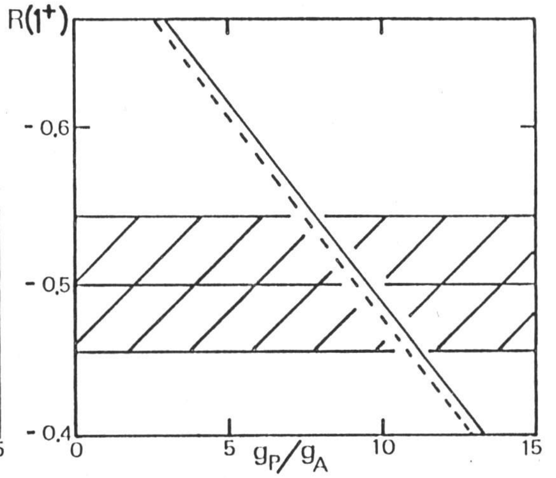

Fig. 2. The ratio $R(1^+)$ of the average polarization to the longitudinal polarization of ^{12}B.

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