Eur Phys J A (2005) **24,** s2, 103
DOI: 10.1140/epjad/s2005-04-023-1

EPJ A direct
electronic only

Corrections to the nuclear axial vector coupling in a nuclear medium

G.W. Carter and E.M. Henley

Department of Physics,Box 351560, University of Washington, Seattle, WA 98195-1560, USA

Received: 15 October 2004 / Published Online: 8 February 2005

Abstract. The temporal component of the weak axial vector current in nuclei is increased due to meson exchange currents. We consider further corrections from pions and the sigma mean-field.

PACS. 23.40.-s Beta decay; double beta decay; electron and muon capture – 23.40.Bw Weak interaction and lepton (including neutrino) aspects

The weak axial current j_μ^5 is not conserved in a nuclear medium or nucleus; the space component is reduced whereas the time component, g_A^0 increases by $50-100\%$ [1].

Already in the 1970's it was shown [2] that nuclear exchange currents are responsible for the major part of the increase of g_A^{0*}. A simplistic explanation is that the pion adds an extra γ^5 which makes the space component of $O(p/M)$, whereas the time component becomes of $O(1)$. Pion exchange currents have been examined by several authors [3]. Some aspects of the exclusion principle have been included in pion exchange calculations, e.g., via use of the shell model. However, the theoretical enhancement falls about 10% short of the measurements [4]. There is, to the same order, the one nucleon pion loop contribution. It differs from the free nucleon counterpart by the effect of the Pauli exclusion principle. It is this effect we have examined in order to see whether it might contribute the missing $\sim 10\%$ of g_A^{0*}.

We use the chiral Lagrangian of Carter, et al. [5], treating the σ field in mean field theory.

$$L_1 = -\bar{N} g \left[(\sigma + i\tau \cdot \pi\gamma_5) + \frac{1}{2} g' \gamma^\mu \tau \cdot \mathbf{a}_\mu \gamma_5 \right] N \,, \quad (1)$$

$$L_2 = \frac{1}{2}\frac{D}{\sigma_0^2}\bar{N} \left[\gamma^\mu \tau \cdot \left[\pi \times \Delta_\mu \pi + \gamma_5 (\sigma \Delta_\mu \pi - \pi \Delta_\mu \sigma)\right]\right] N \,, \quad (2)$$

$$\Delta_\mu \sigma = \partial_\mu \sigma + g' \mathbf{a}_\mu \cdot \pi \,, \quad (3)$$

$$\Delta_\mu \pi \approx \partial_\mu \pi - g' \sigma \mathbf{a}_\mu \,, \quad (4)$$

where g' is the coupling to the chiral vector mesons ρ and A_1, and bold characters indicate isospin vectors.

To start with, the nucleon has a momentum $\leq k_F$. Since we need the propagators in the presence of the nucleus, they have to be above the Fermi sea (e.g. $|\mathbf{p}| > k_F$).

The effect of the in-medium sigma field is to reduce the nucleon mass, $M \to M^* \sim 0.8M$. We assume that the pion coupling to the nucleon has a dipole form factor with a cutoff $\Lambda = 0.9$ or 1.1 GeV. The constant D is fixed to fit $g_A = 1.26$ for the free nucleon,

$$g_A \approx \left(1 + D\frac{\bar{\sigma}^2}{\sigma_0^2}\right) \,, \quad (5)$$

where σ_0 is the vacuum expectation value of the σ field, $\sigma_0 = 102$ MeV, and $\bar{\sigma}$ is the mean field result at finite density.

We fnd that $g_A^* = g_A(1+\delta)$, with $\delta = -.13(-.11)$ for $\Lambda = 1.1(0.9)$ GeV. Thus, the omitted effect is indeed of the order of magnitude required (10-15%), but with the wrong sign. These corrections only serve to increase the discrepancy between theory and experiment.

The authors thank Mary Alberg for helpful comments. This work was supported by the U. S. Department of Energy grant DE-FG02-97ER4014.

References

1. See, e.g., D.H. Wildenthal, M. S. Curtin, B. A. Brown: Phys. Rev. C **28**, 1343 (1983)
2. L. Kubodera, J. Delorme, M. Rho: Phys. Rev. Lett. **40**, 755 (1978)
3. See e.g., T-S. Park, H. Jung, D-P. Min: Phys. Lett. B **409**, 26 (1997)
4. E.K. Warburton: Phys. Rev. Lett. **66**, 1823 (1991); Phys. Rev. C **44**, 233 (1991)
5. G.W. Carter, P.J. Ellis, S. Rudaz: Nucl. Phys. A **603**, 367 (1996), [Erratum-ibid., **608**, 514] (1996)