ISOTENSOR MUON CAPTURE IN NUCLEI

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It has been shown by Kisslinger[1] that the study of muon capture in nuclei provides a sensitive test of one of three possible lepton-number schemes, namely, that in which there is a single lepton number, which is +1 for e^-, ν_e, μ^+, $\bar{\nu}_\mu$, and −1 for e^+, $\bar{\nu}_e$, μ^-, ν_μ, since such an assignment permits the reaction $\mu^- + {}^A Z \to e^+ + {}^A(Z-2)$ to occur. This reaction is particularly interesting for Nuclear Physics since it can proceed only through the N^*-components of the nuclear wave function. The most likely mechanism for the fundamental process, $\mu^- + p + p \to e^+ + n + n$, is shown in figure 1. That in figure 2 is, in fact, forbidden in nuclei if the isotensor vector current is conserved ; the process shown in figure 3 is expected to be much smaller than the first since the amplitude is of higher order in the strength of the N^*-component of the nuclear wave function, which is approximately 0.01. If we note the strength of this component by a_Δ and the strength of the $\mu^- N^* e^+ N$-coupling by g, then the current operator corresponding to figure 1 is crudely

$$J_o \sim a_\Delta g \exp\left[i\underline{k}.(\underline{x}_1 + \underline{x}_2)/2\right] \tau_1^- \tau_2^- \quad , \quad \underline{J} \sim 0 \quad .$$

in obvious notation with $\underline{k}$ the lepton momentum transfer. If we further assume that the positron is emitted with well-defined energy, the expression for the capture rate becomes

$$\Lambda(\mu^- \to e^+) = (2\pi)^{-1} |\underline{k}|^2 |\varphi_\mu|^2_{av} \langle N_i | J_o^+ J_o | N_i \rangle \quad ,$$

where φ_μ is the muon wave function. This expression is readily calculable to order Z^{-1} independent of the wave function $\Psi(N_i)$. The result is

$$\langle N_i | J_o^+ J_o^+ | N_i \rangle = (1/2) |a_\Delta|^2 g^2 Z(Z-1) \left[(1-F(|\underline{k}|/2))^2 - (Z-1)^{-1} F(|\underline{k}|/2)(1-F(|\underline{k}|/2))\right]$$

where $F(|\underline{k}|/2)$ is the isovector (two-body) correlation function of the nucleus ($F(0) = 1$). For a Fermi gas this relation is exact. For ordinary muon capture, the capture rate is given by

$$\Lambda(\mu^- \to \nu_\mu) = (2\pi)^{-1} |\underline{\nu}|^2 |\varphi_\mu|^2_{av} (G_V^2 + 3G_A^2 + G_P^2 - 2G_A G_P) Z[1 - F(|\nu|)]$$

where $\underline{\nu}$ is the neutrino momentum. Taking $|a_\Delta|^2 \sim 0.005$, $|\underline{\nu}| \sim 80$ MeV/c , $|\underline{k}| \sim 60$ MeV/c , and $Z = 29$ the branching ratio becomes

$$\Lambda(\mu^- \to e^+) / \Lambda(\mu^- \to \nu_\mu) = 1.2 \times 10^{-4} (g/G_V)^2 .$$

The experimental upper limit[2] for this branching ratio is 3.8×10^{-3}. This is consistent with the most recent experimental upper limit for isotensor electromagnetic couplings[3]. More detailed calculations[4] evaluating the Feynman diagram directly seem to agree with this heuristic estimate to within an order of magnitude

[1] L.S. Kisslinger, Phys. Rev. Letters, 26 (1971) 998 ; 28(E) (1972) 869

[2] D. Bryman et al., to appear in Bull, Am. Phys. Soc. (April 1972)

[3] J. Bleckwenn et al., Phys. Letters, 35B (1972) 265

[4] M. Rho and M. Shuster, to be published.

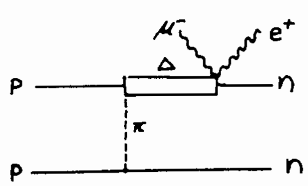

Fig.1

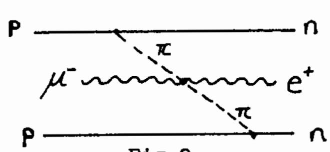

Fig.2

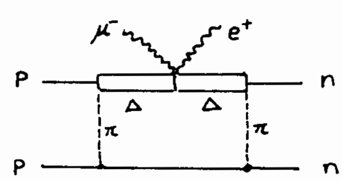

Fig.3

Proceedings, First European Conference on Nuclear Physics, Aix-en-Provence, France, June 25 - July 1, 1972