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RESTRICTIONS FOR ASYMMETRY AND POLARIZATIONS OF RECOIL IN MUON CAPTURE

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A B S T R A C T

Using the helicity formalism, we discuss muon capture by targets of spin-zero. Owing to the definite neutrino helicity, three independent observables define a complete experiment. The precise relation between asymmetry α and longitudinal polarization P_L of recoil, $\alpha = 1 + 2jP_L$, comes only from rotational invariance. When time-reversal invariance is inserted, there is an additional restriction between the average polarization P_{av} and the longitudinal polarization P_L. On the basis of the experimental result $P_{av} = 0.43 \pm 0.10$ for ^{12}C, we predict

$$P_L = -(0.99^{-0.04}_{+0.01}).$$

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It seems that the measurement of angular distributions and polarizations of recoils, in nuclear muon capture, is already a new field to explore. This can settle old questions, as universality of β decay and μ capture form factors and, in particular, if the G-T relation for the pseudoscalar coupling constant is satisfied. A measurement of the average polarization (see below) of the recoil nucleus in the process $\mu^- + {}^{12}C \rightarrow {}^{12}B + \nu$ has been made by the Louvain-Saclay group [1] and the result compared with the theory of Devanathan et al. [2)-3)]. A value of $g_P = (12 \pm 5) g_A$ is obtained, when all other form factors are fixed to their canonical values. The same group plans to measure other observables in the same process.

The purpose of this note is to show, without any explicit form of the nuclear muon capture interaction, what are the relations between the different observables which are accessible experimentally. We only use rotational invariance and the defined helicity of the neutrino. For the time being, we restrict ourselves to targets of spin zero in order to avoid the problems of the hyperfine interaction in the initial state. Apart from that, the results are completely general, in particular, they are valid for any spin of the final nuclear state.

Although stated in another language, the kind of restrictions in which we are interested are well known [4] for hyperon decays, such as the asymmetry parameters in $\Lambda \rightarrow p\pi^-$. In some sense, our process is similar to this case, at least for the purpose of counting different amplitudes. The initial state $(\mu\ N_i)$ in muon capture is bound and has a definite angular momentum. In the final state, both particles N_f and ν have spin, but the helicity of the neutrino is $-\frac{1}{2}$. If time-reversal invariance is imposed, the absence of final state interactions in muon capture gives the reality condition without any problems.

We consider the reaction

$$\mu^- + N_i\ (J_i = 0) \rightarrow N_f\ (J_f = j) + \nu \qquad (1)$$

in the rest frame of the initial state. This corresponds, in the final state, to the c.m. system, with the recoil momentum $\vec{p} = -\vec{\nu}$. We characterize the physical states in the helicity basis, and we expand them in terms of basis states of the irreducible representations of the rotation group. The moving reference

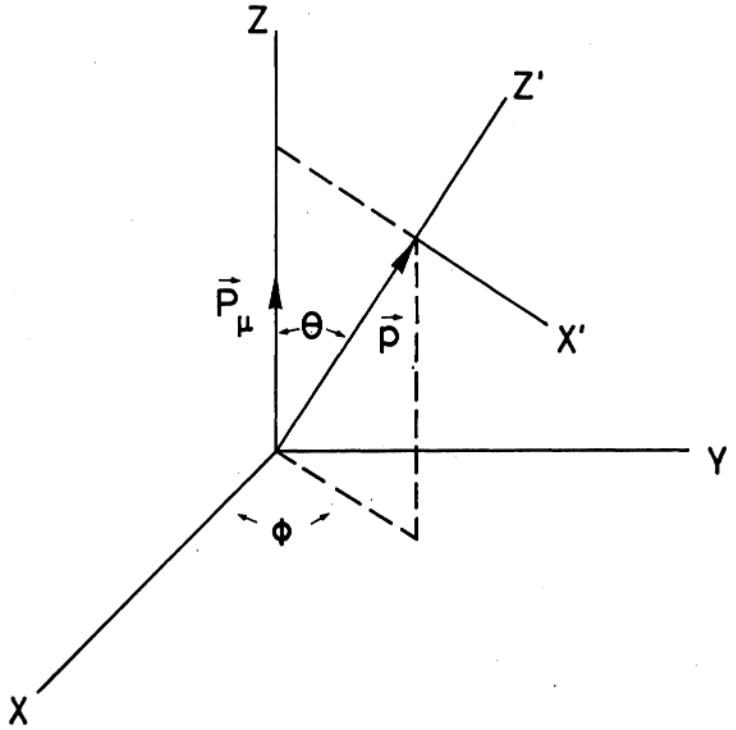

FIG.1

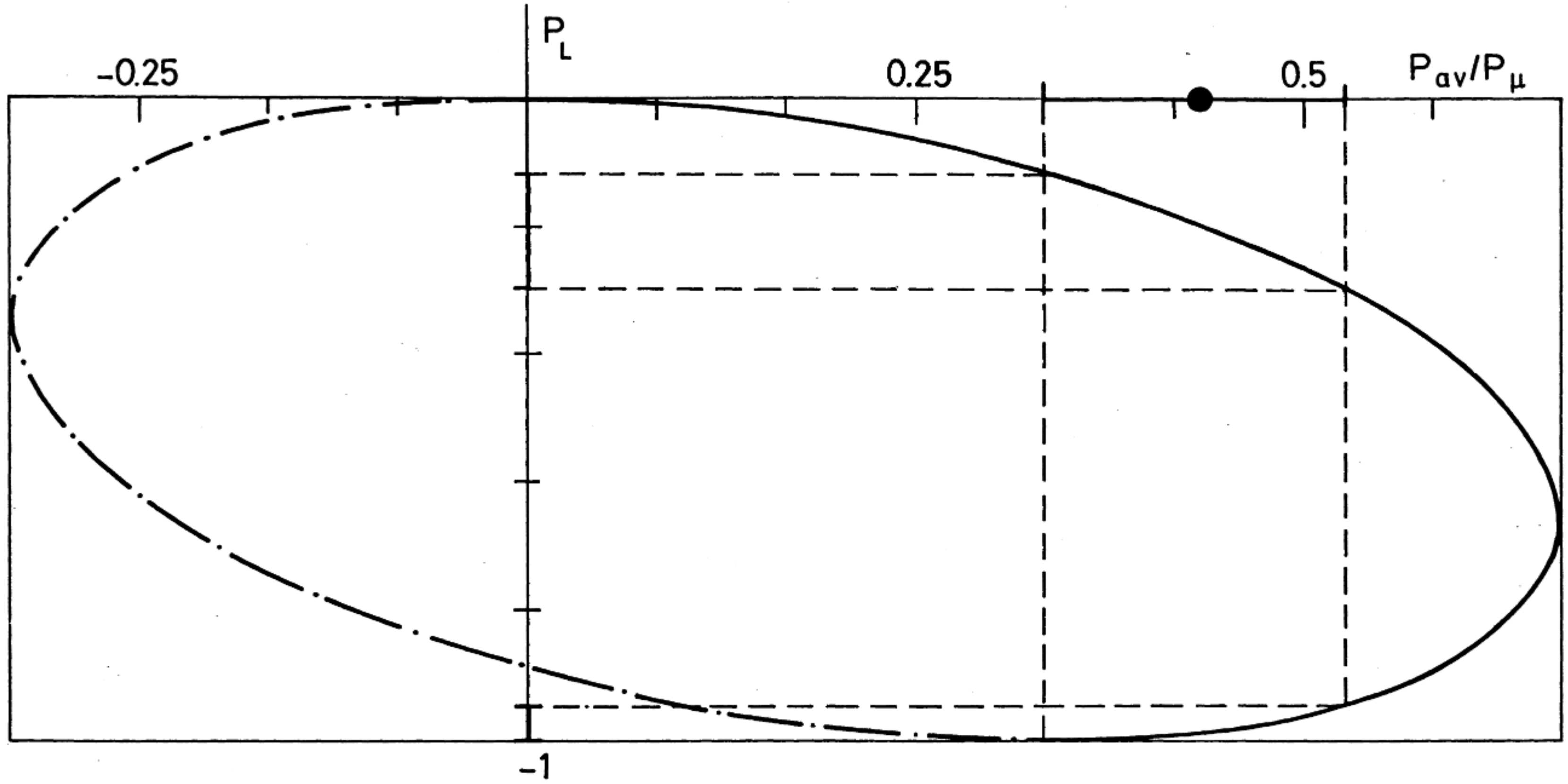

FIG. 2