Weak effects in Σ^0 decay

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It is pointed out that weak interactions should admix a small parity-violating $E1$ component into the $M1$ electromagnetic decay $\Sigma^0 \to \Lambda\gamma$.

The decay $\Sigma^0 \to \Lambda\gamma$ is dominantly an $M1$ electromagnetic transition. Strangeness-conserving weak interactions should, however, admix a small $E1$ component into the decay, leading to $\langle\vec{\sigma}\cdot\vec{p}\rangle \neq 0$ for the Λ and γ even from an unpolarized Σ^0. The most general amplitude for $\Sigma^0 \to \Lambda\gamma$ is ($\sigma_{\mu\nu}\gamma_5$ is *not* second-class[1])

$$\bar{u}_\Lambda \sigma_{\mu\nu}(1+\delta\gamma_5)u_\Sigma(p_\Sigma - p_\Lambda)_\nu \epsilon_\mu^\gamma . \quad (1)$$

The average helicity of the Λ or γ produced in the decay of an unpolarized Σ^0 is then[2]

$$\langle\hat{\sigma}\cdot\hat{p}\rangle = \frac{N_L - N_R}{N_L + N_R} = \frac{2\delta}{1+\delta^2}. \quad (2)$$

If the Σ^0 is polarized, then the angular distribution of the outgoing γ with respect to the initial Σ^0 spin direction is

$$\frac{dW}{d\Omega} \propto \left(1 - \frac{2\delta}{1+\delta^2}\hat{\sigma}_\Sigma \cdot \hat{p}_\gamma\right) . \quad (3)$$

The parameter δ is a measure of the strength of the nonleptonic strangeness-conserving part of the weak-interaction Hamiltonian. W and Z exchanges between free quarks in the Σ^0 and Λ give

$$\delta \simeq 4\times 10^{-5} . \quad (4)$$

Quantum-chromodynamics effects do not appear to modify this result significantly,[3] although diagrams consisting of weak vertex corrections to gluon exchange could be important. If the weak amplitude is taken to be equal to that in $\Sigma^+ \to p\gamma$ (multiplied by $\cot\theta_C$), then one finds

$$\delta \simeq 2\times 10^{-5} . \quad (5)$$

A measurement of these small $\Delta S = 0$ weak-interaction effects should help to clarify the structure of the nonleptonic weak Hamiltonian.

Several authors[4] have suggested measurements of parity violation resulting from interference between the processes

$$\Sigma^0 \to \Lambda\gamma_{\to e^+e^-} \text{ and } \Sigma^0 \to \Lambda Z^0_{\to e^+e^-} .$$

This effect should be entirely swamped (except perhaps for very small Λ momenta) by the $E1$ admixture into the photon-mediated decay $\Sigma^0 \to \Lambda\gamma_{\to e^+e^-}$ discussed here.

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[1]This coupling to the photon can arise from $\gamma_\mu\gamma_5$ couplings between the quarks, and therefore does not correspond to a second-class effect, which should be (essentially) absent in a gauge theory.

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