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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 $\Sigma^0 \rightarrow \Lambda \gamma$.

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The decay $\Sigma^0 \rightarrow \Lambda \gamma$ 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 $\Sigma^0 \rightarrow \Lambda \gamma$ is ($\sigma_{\mu\nu} \gamma_5$ is not second-class¹)

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

The average helicity of the Λ or γ produced in the decay of an unpolarized Σ^0 is then²

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

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

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

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

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

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 $\Sigma^+ \rightarrow p \gamma$ (multiplied by $\cot \theta_C$), then one finds

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

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

Several authors⁴ have suggested measurements of parity violation resulting from interference between the processes

$$\Sigma^0 \rightarrow \Lambda \gamma_{-e^+e^-} \text{ and } \Sigma^0 \rightarrow \Lambda Z_{-e^+e^-}.$$

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

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¹This 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.

²R. E. Behrends, Phys. Rev. **111**, 1691 (1958).

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⁴H. S. Mani and H. S. Sharatchandra, Phys. Rev. D **10**, 2849 (1974); J. Schechter and M. Singer, Nuovo Cimento **26A**, 117 (1975); E. S. Abers and M. Sharif, Phys. Rev. D **16**, 2237 (1977); M. A. Pérez, *ibid* **19**, 400 (1979).