Possible Violation of the $\Delta S = \Delta Q$ Selection Rule in Leptonic Decays of $\Sigma^+$-Hyperons


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We have found a possible example of the rare decay $\Sigma^+ \rightarrow n \mu^+ \nu$, which violates $\Delta S = \Delta Q$. The positive decay track of the $\Sigma^+$ comes to rest in the hydrogen bubble chamber and decays into an $e^+$. This track has all the characteristics of a stopping $\mu^+$. The decay neutron fortuitously scatters twice, producing two recoil protons. The only other possible interpretation of the event is $\Sigma^+ \rightarrow n \gamma (\pi^+ \rightarrow \mu^+ \nu)$, where the $\pi^+ \rightarrow \mu^+ \nu$ decay produces no deflection ($\theta < 0.1$ rad) and no significant change in curvature. Using the $p$-wave radiative decay predictions of BARSHAY et al.¹ we calculate that the integrated branching ratio for such "accidental" events is

$$\Gamma(\Sigma^+ \rightarrow n \gamma (\pi^+ \rightarrow \mu^+ \nu))/\Gamma(\Sigma^+ \rightarrow n \pi^+) = 1.6 \times 10^{-6}.$$ 

Most of the contribution to this "accidental" branching ratio comes from radiative decays where the $\pi^+$ mesons have ranges less than 1 mm ($p_{\pi} < 20$ MeV/c). If one excludes those $\mu$'s with ranges less than 1.2 cm the above "accidental" branching ratio becomes $5.5 \times 10^{-7}$. With this figure we estimate that we should have seen $6.5 \times 10^{-2}$ events of this type thusfar in our experiment. The neutron momentum does not help in deciding between the two hypotheses. We therefore assign a confidence level of 7% for the radiative hypothesis. For the leptonic hypothesis we obtain an estimate of the branching ratio,

$$\Gamma(\Sigma^+ \rightarrow n \mu^+ \nu)/\Gamma(\Sigma^+ \rightarrow n \pi^+) = 5 \times 10^{-5}.$$ 

If one further accepts the $\Sigma^+ \rightarrow n \mu^+ \nu$ event reported by BARBARO-GALTIERI et al.² and the $\Sigma^+ \rightarrow ne^+ \nu$ event reported by NAUENBERG et al.³, one obtains the $\Delta S = -\Delta Q$ leptonic branching ratio

$$[\Gamma(\Sigma^+ \rightarrow n \mu^+ \nu) + \Gamma(\Sigma^+ \rightarrow ne^+ \nu)]/\Gamma(\Sigma^+ \rightarrow n \pi^+) = (4 \pm 3) \times 10^{-5}.$$ 

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It should be pointed out that in bubble chamber experiments the radiative background simulating a muonic decay is not negligible. Up to now 0.1 event of this type should have been found in all these experiments.

1. Introduction

During the past few years a number of experiments has been performed to search for the presence of $\Delta S = -\Delta Q$ transitions in weak interactions. The present theoretical description of semileptonic interactions hadron $A \rightarrow$ hadron $B +$ lepton $l +$ neutrino $\nu$ considers a phenomenological Lagrangian of the type

$$\mathcal{L}_{\text{weak}} = \frac{G}{\sqrt{2}} (I^\mu_A I^\mu_B + J^\mu_A J^\mu_B) + \mathcal{L}_{\text{non-lept.}}$$

in which the leptonic current is of the form

$$I^\mu_A = \bar{\nu} \gamma^\mu (1 + \gamma_5) \nu + \bar{\nu} \gamma^\mu (1 + \gamma_5) \nu$$

and the hadron current is assumed to be of the simple form

$$J^\mu_A = \cos \theta (J^1_A + i J^5_A) + \sin \theta (J^2_A + i J^3_A)$$

the latter being a member of an $SU(3)$ octet of currents. An octet of currents has the properties $\Delta I = \frac{1}{2}$ for $\Delta S = 1$, $|\Delta S| < 2$, and $\Delta S = \Delta Q$. If $\Delta S = -\Delta Q$ transitions would exist, first one would expect the presence of $\Delta I = \frac{1}{2}$ currents and second one would have to understand the observed absence of $\Delta S = 2$ transitions. The $\Delta S = \Delta Q$ selection rule has been tested experimentally in three reactions. The following 90% confidence limits have been placed on the $\Delta S = \Delta Q$ rates.

$$\frac{\Gamma (\Sigma^+ \rightarrow l^+ n \nu_e)}{\Gamma (\Sigma^- \rightarrow l^- n \nu_e)} < 0.10$$

$$\frac{\Gamma (K^+ \rightarrow \pi^+ \pi^- \nu_e)}{\Gamma (K^+ \rightarrow \pi^+ \pi^- e^- \nu_e)} < 0.02$$

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