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Transverse polarization induced by final-state interactions in $\Sigma^{\pm} \to \Lambda e \nu$

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The final baryon transverse polarization induced by electromagnetic final-state interactions is calculated for the processes $\Sigma^{\pm} \to \Lambda e \nu$. We find that this induced T-odd effect is of the order of 10^{-4}.

In a recent paper,[1] a study of the electromagnetic final-state interactions on the transverse polarization of the outgoing baryon in quasielastic neutrino reactions has been made. The effect was proportional to the interference between the amplitude of the process and its absorptive part. We distinguished between the inelastic intermediate contribution, which was bounded using two types of positivity conditions, and the elastic one, which was calculated exactly in terms of the form factors involved in the hadronic vertices.

We found that this elastic contribution was negligible compared to the bounds on the inelastic contribution. However, there is an interesting case in which the elastic contribution is the only possible one: the β decay of certain hyperons with the subsequent analysis of the transverse polarization of the outgoing baryon. In this paper we shall be concerned with the processes

$$\Sigma^{\pm} \to \Lambda e^{\pm} \nu, \tag{1}$$

in which the mass difference between the initial and the final baryons is small enough to limit the intermediate hadronic states of the absorptive part to a single Λ state.[2] The corresponding diagrams of the amplitude and its absorptive part, to first order in the electromagnetic coupling constant α, are shown in Fig. 1.

In addition, there are two more reasons to consider the processes (1). First, the Λ polarization can be measured from its decay and second, the momentum transfer $(p - p')^2$ has a high value compared to normal β decay and the effects due to an intrinsic T violation could be important, as we shall discuss below.

The direction of the normal to the decay plane is defined as

$$\vec{n} = \frac{\vec{k}' \times \vec{k}}{|\vec{k}' \times \vec{k}|}$$

in the Σ rest system. To obtain the induced transverse polarization of the outgoing Λ we make use of the calculation performed in Ref. 1 with straightforward modifications consisting essentially in a "crossing" of an ingoing neutrino (antineutrino) of momentum k into an outgoing antineutrino (neutrino) of momentum $-k$. The charged-lepton mass has been neglected, as in Ref. 1.

The analytical expression for this induced transverse polarization is

$$P_T(T_e, T_\Lambda) = \frac{\alpha G^2 (M_{e\Lambda}{}^2 - M_\Lambda{}^2)}{8\pi M_{e\Lambda}{}^2 \sum_{\lambda\sigma'\lambda'} |T_{\lambda\sigma'\lambda'}(\Sigma^{\pm} \to \Lambda e \nu)|^2} \times \int d\Omega_l \frac{1}{q_\gamma{}^2} \mathrm{Im}[L^{\mu\nu\rho}_{(\Sigma^{\pm})} H_{\mu\nu\rho}], \tag{2}$$

where T_e and T_Λ are the kinetic energies of the

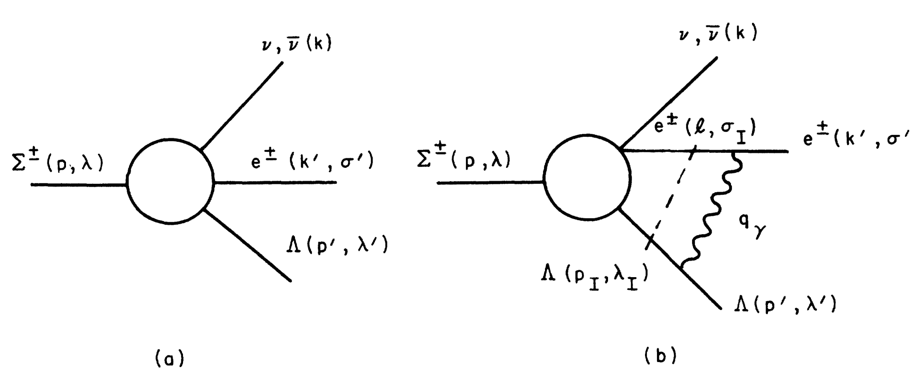

FIG. 1. (a) Amplitude and kinematics for processes (1). (b) Absorptive part of amplitude (a) to first order in α.

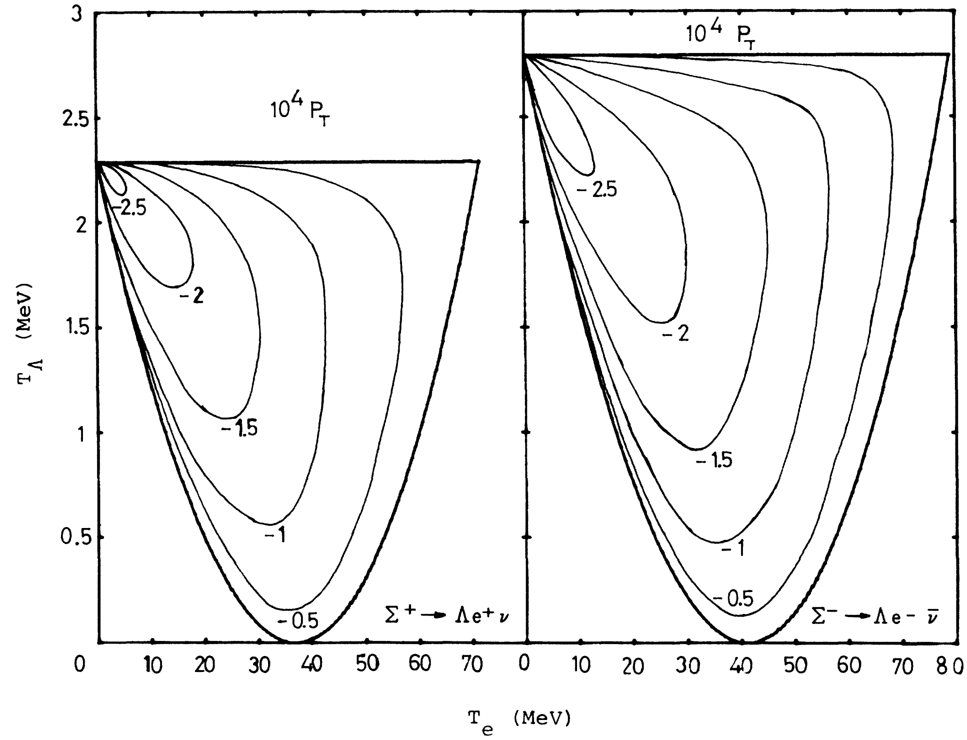

FIG. 2. Level curves of the Λ transverse polarization induced by final-state interactions.

electron and the Λ, respectively, in the Σ rest system; $d\Omega_I$ is the element of solid angle in the direction of the intermediate electron momentum in the center of mass of the $e\Lambda$ system whose invariant mass is $M_{e\Lambda}$. The tensors $L^{\mu\nu\rho}$ and $H_{\mu\nu\rho}$ are defined as[3]

$$L^{\mu\nu\rho}_{(\Sigma\pm)} = \mathrm{Tr}[(-1 \mp \gamma_5)\not{k}\gamma^\nu \not{l}\gamma^\mu \not{k}\gamma^\rho] + 0(m_e{}^2),$$

$$H_{\mu\nu\rho} = \sum_{\lambda\lambda_I} (\langle\Sigma,\lambda|J^w_\nu|\Lambda,\lambda_I\rangle\langle\Lambda,\lambda_I|J^{\mathrm{em}}_\mu|\Lambda,\uparrow\rangle \times\langle\Lambda,\uparrow|J^w_\rho|\Sigma,\lambda\rangle - \langle\Sigma,\lambda|J^w_\nu|\Lambda,\lambda_I\rangle\langle\Lambda,\lambda_I|J^{\mathrm{em}}_\mu|\Lambda,\downarrow\rangle \times\langle\Lambda,\downarrow|J^w_\rho|\Sigma,\lambda\rangle),$$

where $\uparrow$ ($\downarrow$) means that the final Λ is polarized along (against) the normal to the decay plane defined above.

The phenomenological input in Eq. (2) is from the form factors involved in the currents of $H_{\mu\nu\rho}$, which we have fixed as follows: For the Λ electromagnetic form factors we have taken the same expression as in the neutron case with the experimental value for its magnetic moment. For the weak form factors we have used the predictions of the conventional Cabibbo model.[4] The experimental values of its parameters have been taken from Ref. 5. We have ignored the induced pseudoscalar form factor whose contribution is zero in the limit of vanishing electron mass, and we have assumed the pseudotensor form factor to be zero as imposed by T invariance, charge symmetry, and exact SU(3) symmetry simultaneously. The q^2 dependence has been taken as in the electromagnetic case for the weak vector form factors and of the dipole form

$$F_A(q^2) = F_A(0)/[1 - q^2/(0.95\ \mathrm{GeV})^2]^2$$

for the weak axial-vector form factor. Numerical results are shown in Fig. 2, in which we can see that these induced T-odd effects are of the order of 10^{-4}.

For completeness, we will compare these induced T-odd effects with the effects of a possible intrinsic T violation of weak interactions assuming, as in a Cabibbo model,[6] the presence of "second-class" currents out of phase by 90° from "first-class" currents. Actually, in neutron β decay, the charge-symmetry condition forces the second-class current form factors (the scalar and the pseudotensor) to be imaginary if we do not assume T invariance. In the exact-SU(3) limit this result holds for processes (1). Therefore, this model on T violation consists essentially in the simultaneous assumption of charge symmetry and exact SU(3) symmetry. Obviously, these effects become im-

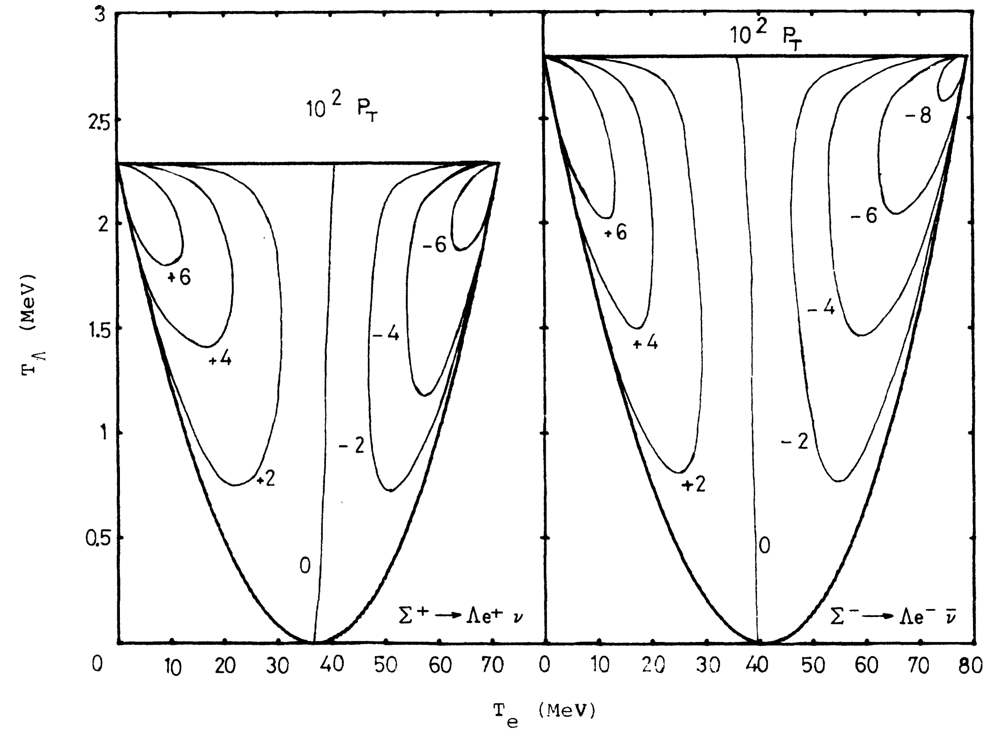

FIG. 3. Predictions of the Cabibbo model of T violation.

portant when q^2 can reach high values as in the case of processes (1), owing to the considerable mass difference between the Σ and the Λ compared to neutron β decay, as we mentioned before.

In order to estimate these effects, we have fixed the second-class current form factors in the following way. The pseudotensor form factor has been taken equal in magnitude to the weak-magnetism one but 90° out of phase, and the induced scalar form factor has been assumed to be zero according to the octet Cabibbo hypothesis.

The results are shown in Fig. 3. We see that these T-violation effects are considerably larger than the final-state interaction ones. Therefore, we conclude that any experimental discrepancy from the values of Fig. 2 would be direct evidence of T violation not attributable to a final-state-interaction effect.

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[1]A. Méndez, Nucl. Phys. B126, 417 (1977).

[2]Notice, however, that in the case of Σ^- decay there is another possible intermediate state, the Σ^0, but we neglect its contribution because the phase space available for the process $\Sigma^- \to \Sigma^0 e\nu$ is considerably smaller than for the process $\Sigma^- \to \Lambda e\nu$.

[3]Our convention for γ matrices is the same as that of J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics* (McGraw-Hill, New York, 1964).

[4]N. Cabibbo, Phys. Rev. Lett. 10, 531 (1963).

[5]L. M. Chounet, J. M. Gaillard, and M. K. Gaillard, Phys. Rep. 4C, 199 (1972).

[6]N. Cabibbo, Phys. Lett. 12, 137 (1964).