NOTAS DE FÍSICA

VOLUME X

Nº 3

ON THE DECAY $\Sigma^0 \rightarrow \Lambda^0 + \gamma$ IN THE CHARGE-INDEPENDENT PION INTERACTION

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1962

Notas de Física - Volume X - Nº 3

ON THE DECAY $\Sigma^{o} \rightarrow \Lambda^{o} + \gamma$ IN THE CHARGE-INDEPENDENT PION INTERACTION * **

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(Received September 1, 1962)

ABSTRACT. $\Sigma^{o} \Lambda^{o}$ anomalous magnetic moment is calculated in the charge independent pion baryon interaction. The life time for the radiative decay $\Sigma^{o} \rightarrow \Lambda^{o} + \gamma$ is found to be $\sim 1.46 \times 10^{-18}$ S for the same $\Sigma^{o} \Lambda^{o}$ parity while it is $\sim 0.33 \times 10^{-18}$S in the case of the opposite parity.

* Supported in part by the Conselho Nacional de Pesquisas of Brazil.

** Published in Nuovo Cimento, vol. 22, 1293 (1961).

Σ^o is known to radiate rapidly into Λ^o and a photon with a lifetime $\tau < 10^{-10}$ S. The decay is possible due to the anomalous $\Sigma^o \Lambda^o$ magnetic momentum generated by the pion and K meson-cloud around these particles, e.g.

$$\Sigma^o \rightarrow \pi^{\pm} + \Sigma^{\mp} + \gamma \rightarrow \Lambda^o + \gamma, \quad \Sigma^o \rightarrow K^- + p + \gamma \rightarrow \Lambda^o + \gamma,$$

$$\Sigma^o \rightarrow K^+ + \Xi^- + \gamma \rightarrow \Lambda^o + \gamma.$$

The knowledge of this anomalous magnetic momentum is also important for the associated decay $\Sigma^o \rightarrow \Lambda^o + e^+ + e^-$ which has been proposed for the determination of the $\Sigma\Lambda$ parity [(1)].

The pion interaction in the charge-independent form and consequently in the Doublet Approximation [(2)] of Tiomno, Gell--Mann and Pais does give rise to an anomalous $\Sigma^o \Lambda^o$ magnetic and hence the decay $\Sigma^o \rightarrow \Lambda^o + \gamma$ contrary to the implied forbiddenness in Pais's paper [(3)]. The magnetic moment contributions being due to the isovector pion and Σ currents (in the usual charge--independent scheme) is expected to be of the order of magnitude of the nucleon magnetic moments where the main contribution is known to come from the isovector part [(4)].

The charge independent strong interaction of pions and baryons is written as

$$iG_1 \bar{N}_1 \tau \gamma_5 N_1 \cdot \pi + iG_4 \bar{N}_4 \tau \gamma_5 N_4 \cdot \pi + G_2(\bar{\Sigma}^+ \Gamma \Lambda^o \pi^+ + \bar{\Sigma}^o \Gamma \Lambda^o \pi^o + \bar{\Sigma}^- \Gamma \Lambda^o \pi^-) + h.c. +$$

$$+ iG_3 \left[(\bar{\Sigma}^o \gamma_5 \Sigma^- - \bar{\Sigma}^+ \gamma_5 \Sigma^o) \pi^+ + (\bar{\Sigma}^+ \gamma_5 \Sigma^+ - \bar{\Sigma}^- \gamma_5 \Sigma^-) \pi^o + \right.$$

$$+ (\bar{\Sigma}^- \gamma_5 \Sigma^o - \bar{\Sigma}^o \gamma_5 \Sigma^+) \pi^- \Big] , \qquad (1)$$

where $N_1 = \begin{pmatrix} p \\ n \end{pmatrix}$ $N_4 = \begin{pmatrix} \Xi^o \\ \Xi^- \end{pmatrix}$ and $\Gamma = 1$ or $i\gamma_5$. The doublet approximation is obtained by assuming (Λ, Σ and N having same parities) $\Gamma = i\gamma_5$, $G_2 = G_3 = G$, neglecting the mass difference between Σ and Λ and writing the m as two doublets [5] $N_2 = \begin{pmatrix} \Sigma^+ \\ Y^o \end{pmatrix}$. $N_3 = \begin{pmatrix} Z^o \\ \Sigma^- \end{pmatrix}$ where $Y^o = (\Lambda^o - \Sigma^o)/\sqrt{2}$ and $Z^o = (\Lambda^o + \Sigma^o)/\sqrt{2}$. The strong interaction can then be written as [6]

$$i\Big[G_1 \bar{N}_1 \tau \gamma_5 N_1 + G(N_2 \tau \gamma_5 N_2 + \bar{N}_3 \tau \gamma_5 N_3) + G_4 \bar{N}_4 \tau \gamma_5 N_4\Big] \cdot \pi . \qquad (2)$$

The interaction with the electromagnetic field is written as

$$H_{em} = - ie \left(\frac{\partial \pi^{*}_{+}}{\partial x_\mu} \pi^+ - \pi^{*}_{+} \frac{\partial \pi^+}{\partial x_\mu} \right) A_\mu + e^2 \pi^{*}_{+} \pi^+ A_\mu^2 ,$$

$$H'_{em} = - ie (\bar{p} \gamma_\mu p + \bar{\Sigma}^+ \gamma_\mu \Sigma^+ - \bar{\Sigma}^- \gamma_\mu \Sigma^- - \bar{\Xi}^- \gamma_\mu \Xi^-) A_\mu .$$

The latter one can also be written in the form

$$H_{em} = - ie \Bigg[\bar{N}_1 \gamma_\mu \left(\frac{1 + \tau_3}{2} \right) N_1 + \bar{N}_2 \gamma_\mu \left(\frac{1 + \tau_3}{2} \right) N_2 +$$

$$+ \bar{N}_3 \gamma_\mu \left(\frac{-1 + \tau_3}{2} \right) N_3 + \bar{N}_4 \gamma_\mu \left(\frac{-1 + \tau_3}{2} \right) N_4 \Bigg] A_\mu .$$

The last two terms in this form can be combined to give the form $- e \cdot \bar{\Sigma} \gamma_\mu \rho_3 \Sigma A_\mu$, where ρ are the isospin matrices for isospin one.

The anomalous magnetic moment λ calculated from the Feynman graphs shown in the Fig. 1 is given by the following:

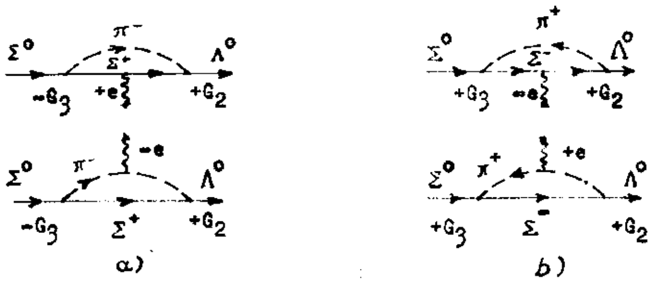

Fig. 1 - Feynman graphs contributing to the $\Sigma^0 \Lambda^0$ anomalous magnetic moment.

For the same Σ and Λ parities II = + (pion assumed pseudoscalar)

$$\lambda_+ = - \left(\frac{G_2 G_3}{4\pi} \right) \left(\frac{e}{2M} \right) \cdot \frac{1}{\pi} f(\eta) ,$$

where $\eta = m_\pi / M$ and

$$f(\eta) = 1 - \eta^2 \ln \eta + \frac{\eta^4 - 2\eta^2}{\sqrt{4\eta^2 - \eta^4}} \cos^{-1} \left(\frac{\eta}{2} \right) .$$

We neglect the mass difference of Σ^0 and Λ^0.

For II = - (7)

$$\lambda_- = + \left(\frac{G_2' G_3}{4\pi} \right) \left(\frac{e}{2M} \right) \frac{1}{\pi} h(\eta) ,$$

where

$$h(\eta) = - \ln \eta + \frac{\eta}{\sqrt{4-\eta^2}} \cos^{-1}\left(\frac{\eta}{2}\right).$$

For $\eta = 0.121$ and

$$\left.\begin{array}{ll} II = + & \lambda_+ = - \left(\frac{G_2 G_3}{4\pi}\right)\left(\frac{0.849}{\pi}\right) \\ \\ II = - & \lambda_- = + \left(\frac{G'_2 G_3}{4\pi}\right)\left(\frac{2.204}{\pi}\right) \end{array}\right\} \text{ in units of } \left(\frac{e}{2M}\right).$$

Thus

$$\lambda_-/\lambda_+ = - 2.595(G'_2 G_2).$$

The corresponding decay probability for the decay is

$$\frac{1}{\tau} = \Gamma = \frac{1}{\pi} |\lambda|^2 \cdot \omega^3 ,$$

where ω is the energy of the photon.

For

$$II = + \qquad \tau_+ = \left(4.38 \Big/ \left(\frac{G_2 G_3}{4\pi}\right)^2\right) \cdot 10^{-18} \text{ s} .$$

For

$$II = - \qquad \tau_- = \left(0.65 \Big/ \left(\frac{G'_2 G_3}{4\pi}\right)^2\right) \cdot 10^{-18} \text{ s} .$$

For

$$\left(\frac{G_2G_3}{4\pi}\right)^2 = \left(\frac{G'_2G_3}{4\pi}\right)^2 \simeq 3 ,$$

the life time is $\sim 1.46\cdot 10^{-18}$ S for the same $\Sigma\Lambda$ parity while it is $\sim 0.33\cdot 10^{-18}$ S in the case the parity is opposite.

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Acknowledgements

The author is grateful to Professor J. Tiomno for suggesting the problem. The author acknowledges gratefully several useful discussions with him and Professor J. Leite Lopes.

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References

1. G. FEINBERG: Phys. Rev., 109, 1019 (L) (1958); G. FELDMAN and T. FULTON: Nucl. Phys., 8, 106 (1958).
2. J. TIOMNO: Nuovo Cimento, 6, 69 (1957); M. GELL-MANN: Phys. Rev., 106, 1296 (1957) and A. PAIS: Phys. Rev., 110, 574 (1958).
3. A. PAIS: Phys. Rev., 112, 624 (1958).
4. We can write the anomalous magnetic moment as $\mu = \mu_s + \mu_v T_3$ where T_3 is the third component of isospin matrix. Then for nucleons $\mu_p = \mu_s + \mu_v = 1.79$; $\mu_n = \mu_s - \mu_v = -1.91$ giving $\mu_s = -0.06$ and $\mu_v = 1.85$ in nuclear magnetons.
5. When the relative parities of various baryons are different, a modified doublet theory can be developed using doublets which are eigenstates of parity. See Notas de Física, vol. 8 - nº 14.

6. It may be remarked that this form of writing the strong interaction is more general than the usual charge-independent theory interaction (1). For if $G_2 \neq G_3$ we obtain for the Λ and Σ interaction an additional term of the form:

$$\Big[(-\bar{\Sigma}^{+} i\gamma_5 \Sigma^{o}\pi^{+} - \bar{\Sigma}^{-} i\gamma_5 \Sigma^{o}\pi^{-}) + \text{h.c.} + (\bar{\Sigma}^{+} i\gamma_5 \Sigma^{+} + \bar{\Sigma}^{-} i\gamma_5 \Sigma^{-})\pi_{o} -$$

$$- (\bar{\Sigma}^{o} i\gamma_5 \Sigma^{o} + \bar{\Lambda}^{o} i\gamma_5 \Lambda^{o})\pi^{o} + (\bar{\Sigma}^{+} i\gamma_5 \Lambda^{o}\pi^{+} - \bar{\Sigma}^{-} i\gamma_5 \Lambda^{o}\pi^{-})\Big] .$$

7. G'_2 being the $\Sigma\Lambda\pi$ coupling constant in this case.

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