ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

ИНСТИТУТ ТЕОРЕТИЧЕСКОЙ И ЭКСПЕРИМЕНТАЛЬНОЙ ФИЗИКИ
АКАДЕМИИ НАУК СССР

B.N. Valuyev, B.V. Geshkenbein

D - 531

ON DETERMINATION OF RELATIVE PARITY OF Σ° AND Λ

ЖЭТФ, 1960, т 39, вып 4, с1046-1048.

Дубна 1960

B.N. Valuyev, B.V. Geshkenbein

D – 531

716/5 pr.

ON DETERMINATION OF RELATIVE PARITY OF Σ° AND Λ

Abstract

The correlation between the polarizations of Σ^0 and Λ^0 particles and an electron-positron pair in the reaction $\Sigma^0 \to \Lambda^0 + e^+ + e^-$ is treated depending upon the relative parity of Σ^0 and Λ^0. The correlations for positive and negative relative parity are essentially different. If it is possible to get polarized Σ^0 particles, the measurement of the above correlation may turn out to be a comparatively convenient way for determining the relative parity of Σ^0 and Λ^0.

In papers [1,2] it was pointed out that the reactions $\Sigma^0 \to \Lambda^0 + \gamma$, $\Sigma^0 \to \Lambda^0 + e^+ + e^-$ may be used for determining the relative parity of Σ^0 and Λ particles. The conversion coefficients have been calculated for the positive $(+)$ and negative $(-)$ relative parity. The difference between them is 12 – 13%.

The calculated spectrum of Λ- particles turned out to be sensitive to the parity in the range of small momenta, but, unfortunately, small momenta are less probable.

The determination of the correlation between the linear photon polarization and the polarization of Σ^0 and Λ^0 suggested in [2] consists in the necessity of measuring the photon polarization, what is likely to be difficult (see, e.g., an analysis made in [3]).

In the present note the correlation between an electron-positron pair and the polarizations of Σ^0 and Λ - particles in the reaction $\Sigma^0 \to \Lambda + e^+ + e^-$ are considered. As was shown in [4], a pair of internal conversion 'remembers' well the direction of the gamma-quantum polarization. Therefore, a considerable correlation between Σ^0 and Λ polarizations and the orientation of a pair should be expected.

We calculate the density matrix for the Λ- particle generated in the reaction depending upon the variables characteristic of a pair orientation.

The matrix element for the process under consideration may be written as (see [2], the notations are also explained there)

$$\mathcal{M}_{\pm} = \Gamma^{(\pm)}_{\mu} \Omega_{\mu}\, \delta^4(p-q-r-s), \quad \text{where}$$

$$\Gamma^{(+)}_{\mu} = f^{(+)}(k^2)\sqrt{\frac{M_\Sigma M_\Lambda}{p_0 q_0}}\, \bar{\Lambda}(q)\sigma_{\mu\nu}\frac{k_\nu}{M}\Sigma(p)$$

$$\Gamma^{(-)}_{\mu} = f^{(-)}(k^2)\sqrt{\frac{M_\Sigma M_\Lambda}{p_0 q_0}}\, \bar{\Lambda}(q)\gamma_5\sigma_{\mu\nu}\frac{k_\nu}{M}\Sigma(p)$$

$$\mathcal{L}_\mu = e\sqrt{\frac{m^2}{r_0 s_0}}\,\bar{u}(r)\gamma_\mu v(s)$$

$$K = p - q \quad ; \qquad K^2 = \vec{K}^2 - K_0^2$$

In the expressions for $\Gamma_\mu^{(\pm)}$ the terms proportional to K_μ, are omitted, since they do not make a contribution due to the gauge invariance. ($K_\mu \mathcal{L}_\mu = 0$). Also are omitted the terms $\sim K^2$, which make a small contribution. The accuracy allowed may be estimated, it is found to be $\gtrsim$ 1%. Therefore, $f^{(+)}(K^2)$ is assumed to be $f^{(+)}(0)$.

In the rest system of a Σ^0- particle its polarization state is described by the density matrix

$$\rho_\Sigma = \frac{1}{2}\left(1 + \vec{\sigma}\vec{P}_\Sigma\right).$$

The state of the generated Λ- particle is described by the density matrix

$$\rho_\Lambda = \mathcal{M}\rho_\Sigma\mathcal{M}^+$$

where $\mathcal{M}$ is taken in the rest system of a Σ^0- particle. As a result of simple calculations, by neglecting the terms $\frac{\Delta^2}{M_\Lambda^2}$ we obtain the expression for $\rho_\Lambda^{\pm}$ (with an accuracy up to a common factor):

$$\rho_\Lambda^{(+)} = \frac{|f^{(+)}|^2}{r_0 s_0'}\,\frac{M_\Sigma}{M_\Lambda}\Big[-2[\bar{s}\bar{r}]^2 - K^2\vec{K}^2 + \Big\{2[\bar{s}\bar{r}]^2\big(\bar{P}_\Sigma - 2\bar{n}(\bar{n}\bar{P}_\Sigma)\big) +$$

$$+ K^2(\bar{K}\bar{P}_\Sigma)\bar{K} + \frac{K^2}{M_\Lambda}(r_0 \mp s_0)\big(\bar{P}_\Sigma[\bar{s}\bar{r}]\big)\Big\}\vec{\sigma}\Big]\,\frac{\delta^4(r+s-K)}{K^4}$$

$$\rho_\Lambda^{(-)} = \frac{|f^{(-)}|^2}{r_0 s_0}\Big[\frac{M_\Lambda}{M_\Sigma}\,\frac{K^2\vec{K}^2}{2} - \frac{3}{2}\Delta^2 K^2 - 2\vec{a}^2 + \Big\{\frac{M_\Sigma}{M_\Lambda}K^2(\bar{K}\bar{P}_\Sigma)\vec{K}$$

$$- 4(\bar{a}\bar{P}_\Sigma)\vec{a} + \Big(2\vec{a}^2 - \frac{1}{2}\,\frac{M_\Sigma}{M_\Lambda}K^2\vec{K}^2 + \frac{K^2\Delta^2}{2}\Big)\bar{P}_\Sigma\Big\}\vec{\sigma}\Big]\,\frac{\delta^4(r+s-K)}{K^4}.$$

Here $n = \frac{[\bar{r}\bar{s}]}{|[\bar{r}\bar{s}]|}$, $\vec{a} = \Big[r_0 + \frac{(\bar{r}\bar{K})}{2M_\Lambda}\Big]\vec{K} - \Delta\vec{r}$

σ_i are the Pauli matrices. Introduce the unit vectors $\vec{\varkappa} = \frac{\vec{K}}{|K|}$, $\vec{\mathcal{N}} \perp \vec{\varkappa}$ and that lying in the plane of a pair, and $\vec{n} = [\vec{\varkappa}\vec{\mathcal{N}}]$). Then, averaging over the rest variables, we obtain the following expressions

$$\overline{\rho_\Lambda^{(+)}} \sim 2.55|f^{(+)}|^2\left\{1 - 1.41(\bar{P}_\Sigma \varkappa)(\sigma\varkappa) - 0.41\left[2(\bar{n}\bar{P}_\Sigma)(\sigma\bar{n}) - (\sigma P_\Sigma)\right]\right\}$$

$$\overline{\rho_\Lambda^{(-)}} \sim 2.88|f^{(-)}|^2\left\{1 - 0.64\left[2(\bar{P}_\Sigma\varkappa)(\sigma\varkappa) - (\sigma P_\Sigma)\right] - 0.68(\sigma\bar{P}_\Sigma) - 0.40\left[2(\bar{P}_\Sigma\bar{N})(\bar{N}\bar{\sigma}) - (\bar{\sigma}\bar{P}_\Sigma)\right]\right\}.$$

One can see that the ratio of the conversion coefficients for $(+)$ and $(-)$ parity is equal to 1.13, what agrees with the calculations made in/1,2/.

Further we have

$$\mathcal{P}_{\Lambda N} = \langle \sigma N \rangle_{\text{average}}, \quad \text{etc.}$$

For the case of $(+)$ parity	For the case of $(-)$ parity
$\mathcal{P}_{\Lambda N} = +0{,}41\ \mathcal{P}_{\Sigma N}$	$\mathcal{P}_{\Lambda N} = -0.44\ \mathcal{P}_{\Sigma N}$
$\mathcal{P}_{\Lambda n} = -0{,}41\ \mathcal{P}_{\Sigma n}$	$\mathcal{P}_{\Lambda n} = +0.36\ \mathcal{P}_{\Sigma n}$
$\mathcal{P}_{\Lambda \varkappa} = -\ \mathcal{P}_{\Sigma \varkappa}$	$\mathcal{P}_{\Lambda \varkappa} = -0.92\ \mathcal{P}_{\Sigma \varkappa}$

Here $\mathcal{P}_{\Lambda N}$, $\mathcal{P}_{\Sigma N}$ etc are the projections of the polarization vector along the direction $\vec{N}$ etc. As is seen from the Table, there is an essential difference between $(+)$ and $(-)$ parties, which may allow to distinguish experimentally these two cases.

The polarization of Σ^0 may be determined, as is known/2,5/ by determining the polarization of Λ- particles in the decay $\Sigma^0 \to \Lambda + \gamma$ ($\bar{\mathcal{P}}_{\Lambda\, average} = -\frac{1}{3}\bar{P}_\Sigma$), whereas the polarization of Λ - by the asymmetry in its decay. A shortcoming in the proposed way of determining the relative parity of Σ^0 and Λ consists in the necessity of having Σ^0 with a sufficiently high polarization (A sufficiently high polarization of a Σ^0 is needed for the suggested way to be favourable from the point of view of statistics). However, there is a possibility that Σ^0 may be obtained considerably polarized in the production in the reaction $\pi^- + p \to \Sigma^0 + K^0$ (for $E_\pi \sim 1$ BeV), as it holds for Σ^+ generated in the reaction $\pi^+ + p \to \Sigma^+ + K^+$.

Thus, a suggested way for determining the relative parity of Σ^0 and Λ^0 may prove practically convenient.

We are grateful to V.I. Ogievetsky and to L.B. Okun for discussion and remarks.

References

1. G. Feinberg, Phys.Rev. 109, 1019 (L), (1958).
2. Feldman and T. Fulton, Nuclear Physics, 8, 106, (1958).
3. E. Carlson, Arkiv for Physik, Band 13, N 1, s. I, (1958).
4. N. Kroll and W. Wada, Phys.Rev. 98, 1355, (1955).
5. R. Catto, Phys.Rev. 109, 610, (1958).

Recieved by Publishing Department
on April 29, 1960.