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ON THE DETERMINATION OF THE PARITY OF HYPERONS AND K-MESONS

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A b s t r a c t

Possible ways for determining relative parity of hyperons and K-mesons in the reactions with polarized proton beams were considered.

The determination of the intvinsic parity of K-mesons and hyperons is one of the most important problems of the physics of elementary particles. Since the parity is not conserved in all weak interactions including the decays of strange particles the intrinsic parity of hyperons and K-mesons may be determined only in the study of strong interactions responsible for their production and mutual transformations.

Recently some ways for the determination of parity of strange particles based upon the study of the reactions involving hyper-nuclei and of those involving strange particles near the threshold /I-6/ have been suggested.

Other possibilities are pointed out in this note.

I. Consider the reaction /I/

$$p + He^4 \to He^4 + Y + K \qquad /I/$$

with a polarized proton beam. The matrix of reaction /I/ is of the form

$$\mathcal{M} = a + \vec{\sigma}\cdot\vec{b} \qquad /2/$$

where the quantities a and $\vec{b}$ are the functions of the momenta of the initial and final states. The spins of a hyperon and K-meson are assumed to be I/2 and 0 respectively.

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i/ Note that in /I/ helium may be replaced by ~~changed for~~ any nucleus with zero spin. e.g. C^{I2}.

Using usual methods /7/ we obtain the following expression for the differential cross section of reaction /I/ involving the polarized proton beam

$$\sigma = \sigma_0 \left(1 + \vec{P}_0 \cdot \frac{2\,\mathrm{Re}\, a^* \vec{b} + i\, \vec{b}^* \times \vec{b}}{a a^* + \vec{b} \cdot \vec{b}^*}\right). \qquad /3/$$

Here σ_0 is the cross section of process /I/ in case when the incident beam is unpolarized, whereas $\vec{P}_0$ is the initial proton polarization. On the other hand, hyperon polarization in reaction /I/ with the unpolarized protons is

$$\vec{P} = \frac{2\,\mathrm{Re}\, a^* \vec{b} + i\, \vec{b} \times \vec{b}^*}{a a^* + \vec{b} \cdot \vec{b}^*}. \qquad /4/$$

The product of intrinsic parities of a proton, hyperon and K-meson may take two values $I_p I_Y I_K = \pm 1$. In the first case the matrix M is a scalar, i.e., the quantity $\vec{b}$ is an axial vector and may be presented in the form

$$\vec{b} = b_1 \vec{k} \times \vec{k}' + (\vec{k} \cdot \vec{k}' \times \vec{k}'') (b_2 \vec{k} + b_3 \vec{k}') \qquad /5/$$

where $\vec{k}$, $\vec{k}'$ and $\vec{k}''$ are the momenta of a proton, hyperon and K-meson I/ respectively. The quantities a and b_i are arbitrary functions of scalar products constructed from the vectors $\vec{k}$, $\vec{k}'$ and $\vec{k}''$.

In the second case M is a pseudoscalar, i.e. the quantity $\vec{b}$ is a vector

$$\vec{b} = (\vec{k} \cdot \vec{k}' \times \vec{k}'') b_1' \vec{k} \times \vec{k}' + b_2' \vec{k} + b_3' \vec{k}'. \qquad /6/$$

I) Here and further the momenta $\vec{K}$ and $\vec{K}'$ are not parallel to each other.

The quantity a is a pseudoscalar

$$a = (\vec{k}\cdot\vec{k}'\times\vec{k}'')\,a'. \qquad /7/$$

a' and b'_i are arbitrary scalar functions.

If the momenta of a proton, K-meson and hyperon lie in the same plane then the triple scalar product $(\vec{k}\cdot\vec{k}'\times\vec{k}'')$ vanishes and if $I_p I_Y I_K = 1$

$$\vec{b} = b_1\,\vec{k}\times\vec{k}' \qquad /5'/$$

while if $I_p I_Y I_K = -1$

$$\vec{b} = b_2'\,\vec{k} + b_3'\,\vec{k}' \qquad /6'/$$

and

$$a = 0 \qquad /7'/$$

Then, as can be easily seen from /3/ and /4/, the expression for the differential cross section takes the form

$$\sigma = \sigma_0\,(1 \pm \vec{P}_0\cdot\vec{P}) \qquad /8/$$

where there is /+/ if the complete intrinsic parity does not change, and /-/ - otherwise.

Polarized proton beams are obtained in the scattering of unpolarized beams by nuclei and their polarization is orthogonal to the momentum of the scattered protons. Choosing the z-axis in a direction of vector $\vec{K}$, and the y-axis in that of $\vec{P}_0$, write /8/ as follows

$$\sigma = \sigma_0\,(1 \pm P_0 P \cos\varphi'). \qquad /9/$$

Hence, the azimuthal asymmetry of the hyperon distribution is

$$\varepsilon = \pm P_0 P \qquad /10/$$

Thus, the measurement of the azimuthal asymmetry in reaction/I/ with the polarized protons makes it possible to define the sign of $I_p I_Y I_K$ uniquely, if the sign of the polarization P arising as a result of the reaction with the unpolarized protons [I)] is known. The sign of P may be determined by studying the pion asymmetry from the decay of polarized hyperons. As it follows from the previous arguments in the determination of the azimuthal asymmetry it is necessary to choose such events when all the particles ~~lie in the~~ same plane. One may perform the integration over the angle between the directions of the momenta of a proton and K-meson.

Another reaction of the considered type is

$$p + He^4 \rightarrow {}_\Lambda H^4 + p + K^+ \qquad /II/$$

when the spin of a pypernucleus ${}_\Lambda H^4$ is zero. However, reaction/I/ considered above does not require such an assumption. Moreover, its study would enable to determine the relative parity of different hyperons.

2, Consider the reaction/3/

$$p + He^4 \rightarrow {}_\Lambda He^5 + K^+ \qquad /I2/$$

Suppose the spin of the hypernucleus ${}_\Lambda He^5$ to be I/2. Since in this case only two vectors /relative momenta of the initial and final states /are available then, as is from /2/-/4/, the cross section of the reaction /I2/ with the polarized proton beam is of the form /8/. Therefore the measurement of the azimuthal asymmetry of K-mesons makes it possible to determine the relative parity/ΛK/ if the sign of polarization of the hypernucleus ${}_\Lambda He^5$ in reaction/I2/

I) The magnitude and sign of the polarization Po are supposed to be known from previous experiments on double proton scattering.

with the unpolarized protons is known. These conclusions refer also to the reactions with the polarized antiproton beam. For example, to the reaction

$$\tilde{p} + He^4 \rightarrow {}_{\Lambda}H^3 + K^0 \qquad /13/$$

if the spin of ${}_{\Lambda}H^3$ is I/2.

In conclusion let us point out that reactions /I/ and /II/ when all the particles lie in the same plane as well as reactions /I2/ and /I3/ are the processes of the type

$$1/2 + 0 \rightarrow 1/2 + 0. \qquad /14/$$

For such processes the differential cross section always has the form /8/, that makes it possible to use them for the unique determination of the internal parity. Here there are two possibilities :

I. Polarized target with spin I/2 and a beam of spinless particles /8-9/.

2. Polarized beam of particles with spin I/2 and a spinless target.

The latter possibility has been considered in this note.

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