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In the analysis of the problem of the conservation of parity in strong interactions we proceed from the fact that the law of conservation of combined parity is a fundamental law of the symmetry in nature and is fulfilled in all the interactions and the conservation of spatial parity in some interactions follows from additional requirements of invariance. One can come to these conclusions if one assume that properties of space–time with respect to the reflections exhibit in the behaviour of those particles which in the given stage of development are considered to be elementary. Then, one may conclude from the non–conservation of parity in weak interactions that the space–time has no property of symmetry with respect to the reflection of space coordinate and one has to investigate the conservation of parity in each interaction.

As it was shown in [1,2] the non–conservation of parity in strong interactions may be expected in those processes in which k–mesons and hyperons interact. The processes of the formation of k–mesons and hyperons play an important part at very high energies. The contribution from K–meson–hyperon forces to the processes of the interactions of π –mesons with nucleons increases with increasing energy. Therefore the high energy reactions are of great interest from the point of view of conservation of parity in strong interactions. It should be noted that at very high energies the processes of the production of two, three of more particles play a predominant role.

In the present paper we treat the processes the final states of which contain N particles ($N \geqslant 3$), namely, we examine what asymmetries in the distribution of produced particles testify to the non–conservation of parity in strong interactions. Let us investigate in what reactions and between what particles the appearance of such asymmetries will be more probable, and also state the cases in which the asymmetry due to the decay of a hyperon as one of N–particles in the final state will testify to the non–conservation of parity in strong interactions.

Consider the reaction of the type:

$$a + b \longrightarrow c_1 + c_2 + \cdots + c_N$$

in the final state of which there are N particles, the spins of particles being arbitrary. The cross section of such a process is written in the form

$$\sigma = A + \sum_{i<k} B_{ik} (\vec{n}_i \vec{p}_k) + \sum_{i<k<\ell} C_{ik\ell} (\vec{n}_{ik} \vec{p}_\ell)$$

where $\vec{k}$ is the momentum of the initial particle, $\vec{p}_i$ $(i = 1, \ldots N-1)$ are the momenta of particles in the final state (in the center of mass system), $\vec{n}_i = \vec{k} \wedge \vec{p}_i$, $\vec{n}_{ik} = \vec{p}_i \wedge \vec{p}_k$.

The coefficients A, B_{ik}, $C_{ik\ell}$ are the scalar functions k^2, p_i^2 ; $(\vec{k}\,\vec{P}_i)$ and $(\vec{P}_i\,\vec{P}_k)$ while the terms in the cross section which contain $(\vec{n}_i\,\vec{P}_k)$, or $(\vec{n}_{ik}, \vec{P}_\ell)$ are not invariant with respect to the operation of the reflection of spatial coordinates. The vector $\vec{k}$ is directed along the axis z, the directions of the vectors $\vec{p}_i$ $(i=1,\dots N-1)$ are described with the angles ϑ_i, φ_i, where ϑ_i is the angle between $\vec{k}$ and $\vec{P}_i$, φ_i is an asimuthal angle which should be calculated from the fixed plane determined by the vectors $\vec{k}$ and $\vec{P}_s$, where $\vec{P}_s$ is the momentum of any final particle. The coefficients A, B_{ik}, $C_{ik\ell}$ are even functions of the angles φ_i ; $(\vec{n}_i\,\vec{p}_k)$ and $(\vec{n}_{ik}\,\vec{p}_\ell)$ are odd functions φ_i. It is easy to show that the term A of the cross section which conserves the parity give no asymmetry in the particle distribution with respect to the fixed plane, on the contrary the terms of the type B_{ik} $(\vec{n}_i\,\vec{P}_k)$ or $C_{ik\ell}\,(\vec{n}_{ik}\,\vec{p}_\ell)$ which do not conserve the parity give the asymmetry in the distribution of particles with respect to the fixed plane.

Thus, once the parity is not conserved in strong interactions it should appear asymmetries with respect to any plane going in the direction of the momentum of an incident particle and the direction of the momentum of any but quite definite final particle: a) in the distribution of some other definite final particle or b) in the summary distribution 2,3.... (N–2) of other final particles. It should be noted that if the parity is not conserved it should appear asymmetries with respect to the planes going in the directions of any two final particles in the distribution of the initial particle as well as in the distribution of other final particles.

We investigate the question in what processes and with respect to the distribution of what particles one may expect the appearance of asymmetries related to the non–conservation of parity in strong interactions. On the basis of our arguments about the role of k–meson–hyperon interactions it should be expected the appearance of desired asymmetries in the distribution of those baryons and mesons among which there are strange particles. Then, in my opinion, the appearance of these asymmetries in the distribution of those particles which has been produced in central collisions is more probable and on the contrary, the appearance of asymmetries in the distribution of those particles the part of which has been produced in peripheral interactions or has received the small momentum transfer in the reaction under consideration is less probable. For example, in the process $\pi^- + d \to \Lambda^0 + K^- + p$ it is quite difficult to expect the desired asymmetry (if it is not performed like a two–stage process, as in the paper /4/) since the role of one of final particles in the production of strange particles is rather small. The appearance of the asymmetry in the k–meson distribution with respect to the plane constructed by the incident π –meson and hyperon in the reaction of the type /3/

$$\pi^- + p \to \Lambda^0 + K^0 + (N'\pi) \quad , \quad \pi^- + p \to \Sigma^- + K^+ + (N'\pi)$$

(where $N'\pi$) is any number of π –mesons, their summary electrical charge equals zero) is also unlikely (though more probable than in $\pi^- + d \rightarrow \Lambda^0 + K^0 + p$) since the presence of π – mesons in the final state is not necessary.

The appearance of asymmetries corresponding to the non–conservation of parity in the distribution of those 'n' final particles ($2 \leq n \leq N - 1$) the productions of (n–1) any particles from which is forbidden in accordance the law of conservation of strangeness or of number of baryons or of electrical charge is more probable. The production of such n–particles is considered to be inter-conditional there are among them no particles which would be produced incidentally in peripheral interactions.

Let us consider the reactions of the type:

$$\pi^- + p \rightarrow \underline{\Sigma^+ + K^0 + \pi^-} + (N'\pi^0), \qquad \pi^- + p \rightarrow \underline{\Lambda^0 + K^+ + \pi^-} + (N'\pi^0),$$

$$\pi^- + p \rightarrow \underline{n + K^0 + \bar{K}^0} + (N\pi), \qquad \pi^- + p \rightarrow \underline{\bar{\Lambda}^0 + p + n + K^-} + (N\pi),$$

$$\pi^+ + p \rightarrow \underline{\Lambda^0 + K^+ + \pi^+} + (N'\pi^0), \qquad K^- + p \rightarrow \underline{K^- + n + \pi^+} + (N'\pi^0).$$

$$K^+ + p \rightarrow \underline{\Lambda^0 + K^+ + K^+} + (N'\pi), \qquad p + p \rightarrow \underline{p + n + \pi^+} + (N'\pi^0)$$

$$p + p \rightarrow \Lambda^0 + K^+ + p + (N'\pi), \qquad p + p \rightarrow \underline{\Sigma^+ + K^0 + p} + (N'\pi)$$

which is of great interest from the point of view of conservation of parity in strong interactions. The underlined terms are the set of three(or four)particles, the production of any two(or three) from which is forbidded in accordance with the laws of conservation and the obtaining of the desired asymmetries in its distribution is more probable.

The reactions in which the quantum numbers S_1 and S_2 introduced in [5] are not conserved are of interest, in this case $S = S_1 + S_2$. Pais assumed [6] that in these reactions the parity may be not conserved. The reactions:

$$\pi^- + p \rightarrow \underline{\Sigma^- + K^0 + \pi^+} + (N'\pi^0), \qquad \pi^- + p \rightarrow \underline{p + K^- + K^0} + (N'\pi),$$

$$\pi^- + p \rightarrow \underline{\Sigma^+ + K^+ + \pi^- + \pi^-} + (N'\pi^0), \qquad \pi^+ + p \rightarrow \Sigma^+ + K^+ + (N\pi),$$

$$\pi^+ + p \rightarrow \underline{K^+ + \bar{K}^\circ + p} + (N'\pi) , \qquad K^- + p \rightarrow \Sigma^+ + \pi^- + (N'\pi^\circ)$$

$$K^+ + p \rightarrow \underline{p + K^\circ + \pi^+} + (N'\pi^\circ) , \qquad K^+ + p \rightarrow \underline{\Lambda^\circ + K^\circ + K^\circ + \pi^+ + \pi^+} + (N'\pi^\circ)$$

$$p + p \rightarrow \underline{\Sigma^+ + K^+ + n} + (N'\pi) , \qquad p + p \rightarrow \underline{p + K^+ + \bar{K}^\circ + n} + (N'\pi)$$

serve as an example. The terms underlined here represent the sets of particles which are of interest.

It should be note that if in the investigation of asymmetry in the distribution of one of secondary particles with respect to the plane constructed by an initial particle and other(quite definite) secondary particle, the other particles are not analysed then in this case we arrive essentially at the summation of asymmetries from various processes. If the parity is not conserved asymmetries from various reactions can strengthen each other or weaken but it is quite clear that if such an asymmetry will be discovered it will testify to the non–conservation of parity in strong interactions) at least in one of summarized reactions).

In /2/ it is shown that if in the reaction of the type $\pi^- + p \rightarrow \Lambda^\circ + K^\circ$ the longitudinal polarization of Λ°–hyperon will be discovered then it will testify to the non–conservation of parity in k–meson and hyperon production. If in the final state in additional to the hyperon there are two or more particles then when the parity is conserved in strong interactions the longitudinal polarization of hyperon can appear. However, in the case of conservation of parity if only the cases in which any other particle is detected in a given direction (or other correlations) are not selected then the longitudinal polarization of hyperon does not lead to the asymmetry in the distribution of the momenta of π –mesons of decay on the plane of the hyperon production. The longitudinal polarization will lead us to the asymmetry in the distribution of π –mesons from the hyperon decay with respect to the plane perpendicular to the hyperon production plane and will testify to the non–conservation of parity in strong interactions in that case if we shall not select hyperons by means of their correlation with directions of any other final particles, hyperons themselves being considered at the fixed angle of production as well as at any angle. of production. Thus, the asymmetry in hyperon decays will testify to the non–conservation of parity in hyperon production in the case only if the averaging over the angles of production of other final particles will take place in the summation cf some cases.

We conclude that the discovery of the non–conservation of parity in strong interactions would confirm the initial conceptions and would give also the possibility to analyse more deeply a number of phenomena: the choice between possible modifications in the systematics of the elementary particles, the test of the hypotheses of the charge invariance, clearing up of the role of k–meson–hyperon forces in the nuclear forces et al.

References

1. V.G. Soloviev, JETP, 33, 537, 796 (1957),
   Nucl. Phys. 6, 618 (1958).

2. V.G. Soloviev, 'Possible test of the conservation of parity in production of k–mesons and hyperons' Preprint, JINR, P–147, February 1958.

3. V.G. Soloviev, JETP, 36, 628 (1959).

4. Horwitz H., D. Miller, J. Murray, M. Schwartz, H. Taft,
   Bull. Am. Phys. Soc. 3, 363 (1958).

5. A. Pais, Phys. Rev. 110, 574 (1958).

6. A. Pais, Phys.Rev. Lett. 1, 418 (1958).

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