[2] T. D. Lee and C. N. Yang, Phys. Rev. **104**, 254 (1956).
[3] W. Pauli, Nuovo cimento **6**, 204 (1957).
[4] J. Weneser, Phys. Rev. **105**, 1335 (1957).

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ON THE DETERMINATION OF THE PARITY OF THE K MESON

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THE determination of the parities of K mesons and hyperons has for some time been one of the central problems of the experimental physics of elementary particles. Since the strong interactions conserve strangeness and the weak interactions do not conserve parity, we can speak only of the relative parity of K mesons and hyperons, i.e., of the signs of $P_K P_N P_\Lambda$, $P_K P_N P_\Sigma$, and so on. We discuss below an experiment which provides a possibility of determining the sign of $P_K P_N P_\Lambda$.

Let us consider the capture of a slow K^- meson from an S state by a proton, according to the reactions

$$K^- + p \rightarrow \Lambda^0 + \pi^0 + \pi^0, \qquad (1)$$

$$K^- + p \rightarrow \Lambda^0 + \pi^+ + \pi^-. \qquad (2)$$

Since parity is conserved in the strong interactions, the parity of the system $\Lambda + 2\pi$ must be equal to the parity of the system K + p. Let us consider the two possibilities.

1. Suppose $P_K P_N P_\Lambda = +1$. In this case the transition amplitudes for the two reactions have the forms

$$A_1 = -(a + bp^2 + cq^2)/\sqrt{2} + \cdots,$$

$$A_2 = (a + bp^2 + cq^2) + d\mathbf{pq} + \cdots.$$

Here $\mathbf{q}$ is the difference of the momenta of the two π mesons and $\mathbf{p}$ is the sum of their momenta, equal to the momentum of the Λ particle. The energies released in the reactions (1) and (2), if the K meson had zero kinetic energy, are 47 and 38 Mev, respectively, and the maximum momenta p and q are of the order of μ_π (we use units $\hbar = c = 1$). If we assume that the dimensions of the region in which the strong interaction occurs are of the order of $1/m_p < r < 1/\mu_\pi$, then we can suppose that $pr < 1$ and $qr < 1$ and confine ourselves to terms independent of p and q. In this case

$$A_1 = -a/\sqrt{2}, \quad A_2 = a \qquad (3)$$

and we find that the angular distributions in the reactions (1) and (2) are spherically symmetric, the Λ particle is not polarized, and consequently the angular distribution of the π mesons coming from its decay is isotropic. If the energies released in the reactions (1) and (2) were the same, then from Eq. (3) we would get for the cross-sections of reactions (1) and (2)

$$\sigma_2/\sigma_1 = 2. \qquad (4)$$

Inclusion of the effect of the difference of the masses of $\pi^\pm$ and π^0 in changing the volume in phase space gives instead the ratio

$$\sigma_2/\sigma_1 = 1{,}34. \qquad (5)$$

2. Suppose $P_K P_N P_\Lambda = -1$. In this case the transition amplitudes must have the forms

$$A_1 = -a\sigma\mathbf{p}/\sqrt{2}, \quad A_2 = a\sigma\mathbf{p} + b\sigma\mathbf{q}, \qquad (6)$$

where $\boldsymbol{\sigma}$ is the vector of the Pauli matrices. Again we have retained the lowest powers of p and q in the expressions for A. Calculating the angular distribution, including effects of the possible polarization of the Λ particle, we get

$$d\sigma_1(p, q, \zeta) = {}^1/_4 |a|^2 p^2 d\rho_f, \qquad (7)$$

$$d\sigma_2(p, q, \zeta) = {}^1/_2 \{p^2 |a|^2 + q^2 |b|^2 + 2\mathrm{Re}\,(a^*b)\,\mathbf{pq} + 2\,\mathrm{Im}\,(a^*b)\zeta\,[\mathbf{p} \times \mathbf{q}]\}\, d\rho_f, \qquad (8)$$

where $\boldsymbol{\zeta}$ is a unit vector in the direction of polarization of the Λ particle, and $d\rho_f$ is the density of states.

We see from Eq. (7) that as before the cross-section of reaction (1) is isotropic and does not depend on the polarization of the Λ particle, but unlike the case $P_K P_N P_\Lambda = +1$ the matrix element is now proportional to p and the probability for emission of low-energy Λ particles is sharply reduced. The cross-section for reaction (2) is in this case anisotropic and depends on the polarization of the Λ particle. Generally speaking, the Λ particle will be polarized in the direction normal to the plane in which the products of the reaction are emitted. In virtue of the nonconservation of parity in the decay, this has as a result that the numbers of π mesons produced in the decay of the Λ particles and emerging upward and downward relative to the plane of the reaction will be different. The angular distribution of the two π mesons and the Λ particle in reaction (2) turns out to be proportional to $1 + \alpha \cos \vartheta$ (ϑ is the angle between **p** and **q**), where

$$\alpha = 2\mathrm{Re}\,(a^*b)\,pq/(p^2\,|a|^2 + q^2\,|b|^2).$$

If we average Eqs. (7) and (8) over angles and energies, we find that the ratio of the total number of charged π mesons to the total number of neutral π mesons is given by

$$\sigma_2 : \sigma_1 = 1.34\,(1 + \overline{q}^2\,|b|^2/2\overline{p}^2\,|a|^2).$$

The use of reactions (1) and (2) for the determination of the sign of $P_K P_N P_\Lambda$ is made difficult by the fact that the cross-section for these reactions makes up only a fraction $2 - 3 \times 10^{-3}$ of the total cross-section for inelastic interactions of K^- mesons with protons. Another important difficulty comes from the fact that in order to get an unambiguous interpretation of the distributions obtained for the reactions (1) and (2) one must make sure that the K^- meson was captured by the proton from an S state.

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PHOTOGRAPHIC METHOD OF DETECTION OF DENSE SHOWERS OF CHARGED PARTICLES

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THE emission spectrum of the majority of phosphors used for detection of charged particles coincides, as a rule, with the spectral region of maximum sensitivity of photosensitive materials ($\lambda = 3500 - 4500$ A). This fact can be used for detection of showers of charged particles (in particular, electron-nuclear showers initiated in high-energy nuclear processes) by direct contact photography of scintillations.

The method can be used in practice if the density of particles is sufficient to produce an amount of light energy per unit surface of emulsion E which is larger than the sensitivity threshold of the material ϵ_T. If a shower of density σ constant within radius R falls upon luminiscent layer of thickness H and density ρ then, neglecting the absorption of light in the phosphor, we have

$$E_{\max} = 0.5\,\sigma\,\alpha\,(\partial E/\partial H)\,\rho\,\{H + R - \sqrt{H^2 + R^2}\},$$

where $\partial E/\partial H$ is the specific ionization loss of shower particles in the luminiscent medium and α is the relative energy yield of luminiscence. Assuming that $\partial E/\partial H = 2$ Mev g^{-1}cm^2, $\rho \sim 1$ g/cm^2, $\alpha \sim 0.1$,[1] $\epsilon_T \sim 300$ units GOST[2] (which corresponds to $\sim 3 \times 10^9$ ev/cm^2), $R \sim 0.1$ cm (for electron-nuclear showers produced in lead[3]), and $H \gg R$ we obtain $N_T \sim 10^4$ for the minimum number of shower particles necessary for photographic detection. Production of such a shower requires a "primary" of $\sim 10^{12}$ ev. The detector might be therefore useful for study of interaction of high-energy cosmic ray particles with matter.

Various luminiscent materials were investigated for their applicability in the proposed detector. Besides the inorganic phosphors NaI, KI and CsI (Thallium activated), plastic scintillators (antracene, terphenyl in polystyrene) which are convenient for use in large-area detectors were tested. Showers were simulated by a collimated electron beam (collimator diameter 3 mm) from radioactive sources (P^{32} and Sr^{90}). The beam was directed perpendicularly to the surface of scintillator. The photographic film (35 mm motion picture film with sensitivity of ~ 350 GOST) was placed in close contact with the scintillator. The most effective position for film without anti-halation backing was between two layers of scintillator. The lowest value of the threshold attained using this method was $\sim 1.5 \times 10^4$ particles. Short-wavelength luminiscence proved to be most active.

Photometric measurements showed that the image density increases with particle density according to the characteristic curve of emulsion.[2] Previous calibration of the detector permits it, therefore, to find the density and the number of particles in a shower. Large latitude of modern high-speed emulsions ($\sim 10^3$) together with the possibility of simultaneous use of several layers of different sensitivity makes it possible to obtain a practically unlimited range of measurement. The experiment shows, furthermore, that the recorded mark is not greatly diffused in comparison with the beam section (within a few tenths of a millimeter). This makes it possible to determine the position of the shower and the particle distribution with a good accuracy.