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Negative K-meson Production Threshold*

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Negative K-meson Production Thereshold

Gell-Mann and Pais[1] were the first to consider the peculiar behaviour of θ^0-mesons. From the point of view of the associated production of K-mesons and hyperons (well verified by experiments)[2], the small probability of two hyperon production in a nucleon-nucleon collision[3] suggests that the isotopic spin of K-mesons equals 1/2. This is in agreement with the Gell-Mann[4] classification: under charge conjugation the θ^0 particle does not go over into itself, i.e. θ^0 and $\tilde{\theta}^0$-particle are not identical. However if the weak interaction, responsible for the decay of the θ^0-particle, is taken into account, the transitions $\theta^0 \rightleftarrows \tilde{\theta}^0$ become possible. This circumstance led Gell-Mann and Pais to conclude that the θ^0-particle is a mixture of two particles θ_1^0 and θ_2^0 -possessing different charge parities and different decay schemes. Pais and Piccioni[5] as well as Booth et al[6] proposed concrete variants of an experiment designed to verify the idea that θ^0-particles are a two particle mixture.

In the present note some remarks are made concerning the properties of charged K-mesons. These remarks follow directly from the considerations of Pais and Piccioni. To our knowledge they were not yet published explicitly in the literature. Considering them we propose a variant of the Pais - Piccioni experiment which might be simpler than other variants already discussed.[5],[6],[7].

Let us consider the production of negative K-mesons. According to Gell-Mann[4], the threshold for production of these particles (or $\tilde{\theta}^0$-particles) in collisions of π-mesons with nucleons or nucleons with nucleons exceeds considerably the threshold for the production of K^+_0-mesons (or θ^0-mesons). This is due to the rule of conservation of "strangenesses", according to which a K^+(or θ^0) can, while a K^- (or $\tilde{\theta}^0$) cannot, be produced together with a hyperon. Therefore, the K^--meson can be produced directly only together with an other K-meson of opposite "strangeness". The threshold for the production of K^+(or θ^0) mesons, for instance, in nucleon-nucleon collisions, is about 1580 MeV, while the threshold for the production of K^--meson - 2500 MeV. However taking into account the Gell-Mann - Pais -Piccioni effect, we can see easily that K^--mesons may be obtained with the help of nucleon (or π-meson) beams with energies lower than the threshold for the direct production of K^--mesons, i.e. lower than the threshold for K-particle pair production. This results from the possibility of the creation of K^--mesons at energies lower than the threshold for K-meson pair production, according to transitions of the following type:

$$\theta^0 \xrightarrow[\text{effect}]{\text{Gell-Mann-Pais}} \tilde{\theta}^0 \xrightarrow[\text{nuclear scattering}]{\text{Charge exchange}} K^-$$

The threshold for the indirect production of K^--mesons in "thick, voluminous" targets is thus lower than the threshold for their direct production.

It is characteristic of the proposed experiment variant that the very observation of K^--mesons below the threshold for K-meson pair production indicates the correctness of the idea of two particle mixture.

Experimental arrangements[5,6,7] designed to investigate time changes of the θ^0-meson beam properties by observing decays of short-living θ_1^0 or Λ^0-particles require cloud or bubble chambers. As the K^--mesons possess longer life-time, their observation, corresponding to the proposed experiment variant, is possible at large distances from a specially constructed proton-synchrotron target. From the technical point of view the method is quite usual (magnetic deviation, focusing) and was already often used, for example, in experiments on nuclear interactions of K^--mesons at rest.

In one of the possible experimental arrangements we can measure the ratio K^-/K^+ (or the ratio K^-/π^-) of the number of created K^- and K^+ mesons as a function of the target size. One may use for example cylinders with diameters equal to their heights. It is clear, that the ratio K^-/K^+, obtained for a given energy of the primary proton beam (lower than the threshold for the direct production of K^--mesons) ought to increase with increasing target size. Apart from informations about some characteristics of the decay of θ_1^0 and θ_2^0 mesons, on may, in principle, obtain from the experiment also some information about the charge exchange process.

One can expect, that the upper limit of the ratio K^-/K^+ for energies lower than the threshold for the production of K - meson pairs equals:

$$(K^-/K^+) \lesssim (\theta^0/K^+) \times 1/4 \times \delta_{opt}/\lambda_{\tilde{\theta} \to K^-}$$

where θ^0/K^+ is the ratio of the number of neutral to the number of positive K -mesons directly produced; $1/4$ is the maximum "number" of $\tilde{\theta}^0$-particles, which may appear as a result of the Gell-Mann-Pais-Piccioni effect from one θ^0-particle; δ_{opt} is the target thickness* in g/cm^2; $\lambda_{\tilde{\theta} \to K^-}$ is the mean free path for the charge exchange process. The order of magnitude of the ration K^-/K^+ appears to be about 0.01.

When bombarding a "thick, voluminous" target with protons of energy higher than the threshold for the production of K - meson pairs, the Gell-Mann-Pais-Piccioni effect can increase considerably the K^--meson flux. As noticed by M. Podgoretzky this may be of practical interest in experiments requiring high value for the K^-/π^+ ratio.

One may notice also the relatively great probability of a "change of sign" of K^+-mesons, by successive nuclear interactions $K^+ \to \theta^0 \to \tilde{\theta}^0 \to K^-$. When bombarding a "thick, voluminous" target with a beam of $K^{\pm}$-mesons, the ration of the number of charged mesons, scattered with change of sign, to the number of charged mesons scattered without "change of sign" will be, as in the previous case, of the order of magnitude of 0.01.

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* It is clear, that the target thickness δ_{opt} should be less $(\approx 1/3\, \lambda_{K^-})$ than the aborption path λ_{K^-} of the produced K^--mesons.

L i t e r a t u r e

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