The Possible β Decay of Hyperions and *K* Mesons

M. MARKOV AND V. STAKHANOV
The P. N. Lebedev Institute of Physics, Academy of Sciences, USSR

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At the present time it is apparently possible to consider it established that the Λ^0 particle can enter into the composition of complex nuclei on a par with the nucleons. It is not known to what degree the properties of hyperions and nucleons are related*. In every case there are certain bases for considering a Λ^0 particle as a nucleon which exists in a certain excited state, with all the resultant consequences[1]. For example, such a nucleon could be beta active:

$$\Lambda^0 \rightarrow P + e^- + \nu. \qquad (1)$$

The aim of the present writing is to turn attention on the fact that due to the high upper limit for the disintegration energy, one should expect a short τ_β compared to the observed lifetime of Λ^0 particles, as in the case of $\tau_\pi(\Lambda^0 \rightarrow \pi^- + P)$.

Indeed, the lifetime of the free neutron is about 10 minutes, while the beta spectrum endpoint in this case is $E_0 \sim m_e c^2$. In the case of beta decay of Λ^0 particles, the beta spectrum endpoint is about 350 $m_e c^2$, and the probability of beta decay is approximately proportional to E_0^5. Thus, in deriving the probability of deta decay of Λ^0 particles, there appears a factor of the order of magnitude 10^{10}, which leads to a relatively short lifetime for the Λ^0 particle with respect to beta decay.

The detailed computation[1] shows that in the case of vector** variation (under the assumption that the Λ^0 particle is like the neutron, with $G \sim 10^{-44}$ erg cm^3), τ_β turns out to be $\sim 10^{-9}$ seconds. The Λ^0 particle, as is known, decays into a π^- meson and a proton, with a lifetime of about 10^{-10} seconds. At present, there are known many instances of the decay of a Λ^0 particle into a π^- meson and a proton, and, apparently, unrecorded cases of beta decay. This is evidence that either the Λ^0 particle does not appear as a particle in this case, according to its characteristics when near a nucleon, or else it possesses a higher spin which causes beta decay to be a forbidden transition. Some well-established correlating data point to a high spin for the Λ^0 particle.

The considerations indicated above may also be applied in the case of *K* mesons[2], if, for example, the spin of the latter is equal to zero and their decay can occur with the emission of Fermi particles. Here, the lifetime with respect to such decay will compete with the decay of *K* mesons to π mesons. At the same time the decay of *K* mesons with the emission of weakly interacting Fermi particles (μ mesons and electrons) would indicate the use of a low spin (0 or 1) by the *K* particles.

Data available in the literature appear to indicate the possibility of the decay of *K* mesons with the emission of Fermi particles[3].

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* The possibility is not excluded that the analogy between a Λ^0 particle and a nucleon is still a weak one, since the Λ^0 particle, for example, interacts weakly with a π field, but interacts strongly with nucleons through other fields (θ field, etc.).

** Pseudoscalar variant gives $\tau_\beta \sim 10^{-7}$ seconds.

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Multiple Meson Production at Energies of 1-2.2 Bev

S. Z. BELEN'KII AND A. I. NIKISHOV
P. N. Lebedev Institute of Physics Academy of Sciences, USSR

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In a recent work[1] a study was made of the interaction of protons with neutrons of high energies obtained by means of a Cosmotron. The interaction was studied in a Wilson chamber filled with hydrogen. The authors investigated 154 three-prong stars. Not a single five-prong star was registered. Analysis of the results obtained showed conclusively that, during collisions of high energy nucleons, multiple production of mesons, namely the production of double mesons, takes place in a considerable number of cases. The authors give the following data for the ratio of the number of cases of the production of a single negative π meson (−) and the number of cases of the production of a double π meson: one positive (+) and one negative (−) or one negative (−) and one neutral (0):

$$(pp-):(pn+-):(pp-0)=0.8:3.2:1. \qquad (1)$$

Since not a single case of the production of five-prong stars was observed which could be interpreted as the origination of triple mesons ($pp--+$), the authors[1] concluded that the number of three-prong stars, resulting from the formation of triple mesons, is negligibly small.

In the same work a comparison is given of the results obtained with Fermi's statistical theory of the multiple production of particles[2].

Special calculations by the Fermi theory for the corresponding energies (1.7 bev = average energy of the neutron beam and 2.2 bev = the maximum energy of the beam) were carried out by Yang and Christian (cited in reference 1). These calculations led to the following result:

for the energy of 2.2 bev

$$(pp-):(pn+-):(pp-0)=12.2:3.1:1, \qquad (2)$$

for the energy of 1.7 bev

$$(pp-):(pn+-):(pp-0)=20.5:3.3:1. \qquad (3)$$

From a comparison of Eqs. (1) and (3) it is evident that the experimental ratio of the number of cases of double meson production to the number of cases of single meson production is approximately 20 times as great as the value predicted by Fermi's statistical theory. It should be noted that into the Fermi theory enters a quantity, determined from theory only by the order of magnitude --- namely, the volume Ω in which the energy of the colliding nucleons is concentrated and the formation of particles takes place. It is possible to choose a value for this volume such as to obtain an experimental value for the ratio of the cases of the production of double and single mesons. However, a simple calculation will show that at the same time we will obtain a very large value for the number of five-prong stars. In fact, when in the selection of the volume Ω, proposed by Fermi, the ratio of the number of five-prong stars to the number of three-prong stars is equal to $1/300_{T}$, which does not contradict the experiment[1], then a change in the volume Ω, giving rise to an inevitable increase in the probability of the production of two mesons simultaneously, will at the same time lead to an increase in the ratio of the number of five-prong stars to the number of three-prong stars. This ratio becomes 3/10, which sharply contradicts the investigation[1] in which not even one five-prong star was observed out of 154 cases of three-prong stars.

From the above it is evident that the statistical Fermi theory in its general form does not agree with experiment. The authors of reference 1 point out that certain properties of the multiple production of mesons during the collisions of nucleons can be qualitatively explained by the presence of excited states of nucleons. Studies on the scattering of π mesons on nucleons indicate the existence of intermediate states of nucleons with an angular momentum of 3/2 and an isotopic spin of 3/2. In the investigations of Tamm and his co-workers[3] intermediate (isobaric) states of nucleons were used for the construction of the phenomenological theory of the interaction of nucleons and mesons. Previously, ideas were also put forward that the formation of mesons partly or even entirely proceeds through the intermediate states of nucleons[4].

In the present investigation an attempt was made to include the isobaric states into the statistical theory of the multiple formation of particles. We have assumed that during the collision of nucleons particles can be produced with a mass of $1.32\, M_0$, where M_0 is the mass of the nucleon (this value gives the best agreement with the experiments on the scattering meson-nucleon[3]), an isotopic spin of 3/2 and an ordinary spin of 3/2. We have also assumed that the probability of the formation of such particles is determined by the statistical weight. The life-duration of the "isobaric particle" is very small (of the order of the time of nuclear collisions), and it breaks up very rapidly into a nucleon and a meson.

We will designate by N the nucleon, by N' the isobaric state of the nucleon and π- meson.We will consider the following states originating during the collision of nucleons: NN (elastic scattering), $N'N$, $NN\pi$ (formation of a single π meson), $NN'\pi$, $N'N'$, $NN\pi\pi$ (formation of double π mesons), $N'N'\pi$, $N'N\pi\pi$, $NN\pi\pi\pi$ (formation of triple mesons). When computing the statistical weight of the different states, we start with a general formula of the following type (see reference 1):

$$S(n) = \left[\frac{\Omega}{(2\pi\hbar)^3}\right]^{n-1} \frac{dQ(E)}{dE}. \tag{4}$$

here $\Omega = \Omega_0(2M_0c^2/E)$, Ω_0 is the volume, equal to $4/3\ \pi(\hbar/\mu c)^3$ (μ is the mass of the meson), E is the total energy of two colliding nucleons in a center-of-mass system, $Q(E)$ is the volume in the momentum space corresponding to the total energy E, n is the number of all the particles in a given state. In the calculations the conservation of energy and momentum is taken into account, but the conservation of the moment of the quantity of motion is neglected. The identity of the particles is also taken into account.

If as a result of the collision two heavy particles are produced (the states NN, $N'N$, $N'N'$), then Eq. (4) can be reduced to the following:

$$S_{NN'} = g_N g_{N'} \frac{\Omega}{(2\pi\hbar)^3} \frac{\pi}{c^3}(M_0c^2)^2 \tag{5}$$

$$\times \left\{\frac{(E^2 + M_2^2 - M_1^2)^2}{4E^2} - M_2^2\right\}^{1/2} E.$$

g_N and $g_{N'}$ are the numbers of the states for N and N' dependent on the ordinary spin. M_1 and M_2 are the masses of the heavy particles, the quantities E, M_1 and M_2 are measured in the units M_0c^2.

If during the collision three particles are formed (the states $NN\pi$, $NN'\pi$, $N'N\pi$) then with the aid of reference 5 it is not difficult to obtain the following formula:

$$S_{NN'\pi} = g_N g_{N'} \frac{\Omega^2 (M_0c^2)^5}{96\pi^4\hbar^6c^6} \tag{6}$$

$$\times \int_0^{p_{\text{max}}} \frac{B^{1/2}}{(A^2 - p^2)^2} \left[\left(1 - \frac{4A^2}{A^2 - p^2}\right) B + {}^3/_2\, A\, \frac{dB}{dA}\right] p^2 dp,$$

where

$$A = E - E_1; \quad E_1^2 = p^2 + \mu^2;$$

$$B = (A^2 - p^2 - M_1^2 - M_2^2)^2 - 4M_1^2M_2^2,$$

$$p_{\text{max}}^2 = E_{1\ \text{max}}^2 - M_1^2,$$

$$E_{1\ \text{max}} = \frac{E^2 + \mu^2 - (M_1 + M_2)^2}{2E}.$$

The weight of the state $NN\pi\pi$ can be obtained from the calculation of Yang and Christian cited in reference 1. The states $N'N\pi\pi$ and $NN\pi\pi\pi$ are very unlikely, and their phase weight is evaluated only approximately. For energies of 1.75 bev and lower, the role of these states is negligibly small.

In the calculation of the statistical weights it is also necessary to take into account the conservation of charge and of isotopic spin. Since the colliding particles are a neutron and a proton, therefore the initial state represents a mixture of states with isotopic spins $T = 1$ and $T = 0$; moreover, the contribution of both these states is equal. When making computations it is necessary to calculate the number of states corresponding to the given

End States		Statistical Weight in %			
		1.75 bev		1.46 bev	
pp—	*NNπ*	8.4	10.4	8.4	11.4
	NN′	2		3	
pn+—	*N′Nπ*	11	28.5	6.5	20
	N′N′	16.5		13.5	
	NNππ	1			
pp—0	*N′Nπ*	2.5	5	1.5	3.2
	N′N′	2		1.7	
	NNππ	0.5			

values of the isotopic spin and the total charge (see reference 2). However, for comparison with experiment, the distribution of particles according to charge is essential. Such a distribution can often be found on the basis of the conservation of isotopic spin in utilizing the methods of group theory[6].

By carrying out the respective calculations,it is possible to find the statistical weights for the end states with different distributions of charge between the particles. The data for the end states $(pp\,-)$, $(pn\,+\,-)$, $(pn\,-\,0)$, which are of interest to us, are compiled in the Table.

From the above Table it follows that the ratios $(pp\,-)$: $(pn\,+\,-)$: $(pp\,-\,0)$ at an energy of 1.75 bev are equal to 2.1 : 5.7 : 1 and at an energy of 1.46 bev these are 3.5 : 6.3 : 1. As is shown by the calculation , at 2.2 bev these ratios are 1.4 : 5 : 1. The experimental value of these ratios, as has already been pointed out, is 1 : 3.2 : 1. However, the authors[1] themselves stress that even the ratios 2.4 : 7.6 : 1 do not contradict experiment. In our calculation the probability of the production of five-prong stars was found to be negligibly small.

Thus, the calculation of the multiple production of mesons at energies of the order of 2 bev by the statistical theory, but taking into account the isobaric states gives an entirely satisfactory agreement with experiment. We are postponing the discussion of the angular and energy distributions until the subsequent communication.

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A Study of the Energy Levels of the Lithium Nucleus by the Method of Magnetic Analysis

L. M. KHROMCHENKO AND V. A. BLINOV
Radio Institute of the Academy of Sciences, USSR

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IN this work the energy spectrum of the lithium nucleus was investigated by the method of magnetic analysis of the products of nuclear reactions, which has been described previously[1]. The method used gave the possibility of obtaining lines visible to the eye on a photoplate, at the position of the localization of discrete groups of particles. Such a spectrogram was then studied with the aid of a microphotometer. The length of the whole photoplate and half of its width was covered with a filter of aluminum foil, whose thickness could be varied. Its thickness was calculated to be such that protons would pass through, but that particles having a shorter path would be completely filtered out. When the type of particles, the value of the magnetic field and the geometry of the instrument are known, it is possible to determine definitely the energy of the particles of the group under investigation from the position of the line on the photoplate.

In our experiments a layer of lithium oxide, (obtained by burning metallic lithium in air) was deposited on a copper foil having a thickness of approximately 0.5 μ. The target was bombarded with a monoenergetic beam of deuterons with an energy up to 4.7 mev. The experiments were carried out at three energies of the bombarding deuterons, from 3.7 to 4.7 mev. As in the previous experiments[1,2] carried out by this method, the total spectrum of the element studied was obtained at the same time on one and the same photoplate. The energy of the primary deuterons was determined by the elastic recoil from the nuclei present in the target.

The reproductions of the photoplates obtained during the irradiation of the lithium oxide with deuterons are given in Fig. 1. The microphotograms of these plates are shown in Figs. 2 and 3. In Fig. 2 the upper curve was obtained on the half of the plate without the filter, and the lower curve on the filtered half. As is evident from the Figures, in addition to the deuterons elastically recoiled from Cu^{64}, 0^{16}, C^{12}, and Li^7, we have