TABLE 2

Single-pronged stars		Double-pronged stars		Triple-pronged stars	
particle symbol	energy in mev (range in μ)	particle symbol	energy in mev (range in μ)	particle symbol	energy in mev (range in μ)
p	>21	α	11	p	19
p	11	p	9,5	p	16
H	6	α	11		0,9—1,2
α	13	H (d,T)	4,5—5.5	W	W
f	(17)	α	9	H	6
f	(8.5)	H (d,T)	8,5—9,5	H	1
f	(5,5)	f	(22)	H	3- -2
f	(3)	H	2—3	—	—
—	—	f	(15)	—	—
—	—	f	(4,5)	—	—

nucleus, there arose, on the average, not more than one single charged particle, the mean energy of the charged particles being 5-10 mev.

In such a light nucleus as Be, the particles which receive the energy in the initial act in the distribution of the rest pion between the nucleons, cannot undergo a large number of collisions with the rest of the nucleus. Consequently, in the energy spectrum of the particles emitted in the disintegration of the nucleus, one can make a direct judgement on the spectrum of primary particles.

Among the particles which are emitted from the star in Be and C, there are absent tritons with energy > 10 mev. Consequently, fast tritons are not observed in the primary acts in a significant number of cases. The data obtained do not agree with the model in which the pion is absorbed by a system similar to He^4, as a result of which a neutron is formed with energy ~ 95 mev and a triton with energy ~ mev.[4] This model also contradicts the fact that absorption of the pion by beryllium fairly frequently fails to result in the emission of charged particles.

A differeet model was proposed by Menon,[5] in which the pion was absorbed by a group of He^4 with a subsequent uniform distribution of energy among the four nucleons (three neutrons and a proton). From the point of view of this model, the absence in σ-stars in Be and C of a large number of tracks of protons with energy 20-40 mev remains unexplained (mean energy of the emitted protons does not exceed 10 mev).

The energy released in the emission of charged particles in the disintegraiion of a Be nucleus is equal on the average to 10-15 mev. Almost ten times more energy is released in the emission of neutral particles than in the emission of charged particles.

The resultant experimental information on σ-stars in Be and C testifies to the fact that 1 or 2 neutrons receive a large part of the energy of the rest pion. In such a light nucleus as Be, they rarely undergo collisions and thus retain an appreciable part of the energy without transmitting it to charged particles.

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The Disintegration and Mass Difference of Heavy Neutral Mesons

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IN the researches of Pais, Gell-Mann and Piccioni[1,2] there were forecast very interesting characteristics of the behavior of heavy neutral mesons θ which are formed in a pair with Λ -particles, for example, by the reaction $\pi^- + p = \Lambda + \theta$. Along with θ, there ought to exist antiparticles $\bar{\theta}$; in this case, only the $\bar{\theta}$ and not the θ, are capable of bringing about the creation of Λ -particles in the interaction with nucleons through the reaction $\bar{\theta} + N = \Lambda$ (the momentum and energy can be given off to a pion or to the nucleus, into whose formation the nucleon enters). Strict laws of conservation of electric charge and of the number of heavy particles ("the nuclear charge")[3] do not forbid the interconversion $\theta \leftrightarrows \bar{\theta}$.

In the scheme of Gell-Mann[4], this conversion cannot be completed quickly under the action of a strong interaction. If the conversion $\theta \leftrightarrows \bar{\theta}$ could take place quickly, then the process

$$N + N = \Lambda + \theta + N = \Lambda + \bar{\theta} + N = \Lambda + \Lambda$$

would be possible according to a scheme with the virtual formation of θ, with a threshold much lower in comparison with the process of creation $N + N = N + \Lambda + \theta$. Experiment shows that the process $N + N \to \Lambda + \Lambda$ is not realized.[5]

As a consequence of the invariance of the laws of nature relative to charge conjugation (the operator P) the eigenstates of p have a definite mass and a definite period of decay in a vacuum, symmetric

$$\theta_s = (\theta + \bar{\theta}) / \sqrt{2}, \qquad P\theta_s = + \theta_s$$

and antisymmetric

$$\theta_a = (\theta - \bar{\theta}) / \sqrt{2}, \qquad P\theta_a = - \theta_a.$$

The creation of θ must be regarded as the creation of a mixture of particles θ_s and θ_a, so related that a linear combination of the wave funciions of θ_s and θ_a describes θ at this particular moment. Later, in flight, as a consequence of the difference in the masses of θ_s and θ_a, their phase relation changes; as a consequence of the different decay times of θ_s and θ_a, their amplitude ratio changes. As a result, at a certain distance from the point of creation of θ, the linear combination of θ_s and θ_a no longer contains only θ but also $\bar{\theta}$. The appearance of $\bar{\theta}$ in the beam could be discovered by the nuclear interaction $\bar{\theta} + N = \Lambda$. The quantity of $\bar{\theta}$ changes with distance according to a decaying sinusoid, whose period depends on the mass difference of θ_s and θ_a.

In the present note it is observed that a similar periodicity ought to be observed in the decay $\theta \to \mu + \pi + \nu$ and also considerations are made on the order of magnitude of the mass difference of θ_s and θ_a.

The decay of θ into μ, π, ν was noted by Thompson.[6] The constants of interaction, which govern the decay of θ into $\mu^+ \pi^- \nu$ (g_1) and into $\mu^- \pi^+ \nu$ (g_2) did not have to be identical. Carrying out charge conjugation, we find that the decay of $\bar{\theta}$ into μ^+ is characterized by the constant g_2 and into μ^- by the constant g. Here θ_s decays with constant $(g_1 + g_2) / \sqrt{2}$, giving μ^+ and μ^- with equal probability, and θ_a decays with constant $(g_1 - g_2) / \sqrt{2}$, also giving μ^+ and μ^- with equal probability. However, the ratio of the phase of μ^+ to the phase of μ^- in the superposition of states, which is formed upon the decay of θ_a, has a sign opposite to the ratio of the phases for the decay of θ_s into μ^+ and μ^-. Therefore, in the beam of θ-particles (which we ought to regard as a mixture of θ_s and θ_a), the ratio of the probability of decay with formation of μ^+ or μ^- oscillates in dependence on the ratio of the amplitudes and phases of θ_s and θ_a. With the passage of time, the quantity $\mu \pm$ changes in proportion to

$$|(g_1 + g_2) \exp(im_s - w_s) t \pm (g_1 - g_2) \exp(im_a - w_a) t|^2,$$

where m_s, m_a are the masses, w_s, w_a the probabilities of decay (total) of the particles θ_s and θ_a. Thus, even in this process one must expect damped oscillations of the ratio μ^+ / μ^- with a period which depends on the mass difference, similarly to the oscillation of the nuclear interaction noted in Ref. 2.

The difference in masses of θ_s and θ_a depends on the possibility of the interconversion $\theta \leftrightarrows \bar{\theta}$. Such a conversion, accompanied by change in strangeness by two units, is a process of much higher order, and is much weaker in comparison with the decay $\theta \to \pi^+ + \pi^-$. At first glance, then, it follows that the mass difference ought to be significantly smaller than the probability of decay (in the system $\hbar = c = 1$). Actually, the probability of decay is proportional to the square of the matrix element for the process with change in strangeness $\Delta S = 1$, i.e., proportional to g^2, where g is the coupling constant. At the same time, the difference in masses is proportional to the first power of the matrix element for the transtion $\theta \leftrightarrows \bar{\theta}$, with change in strangeness $\Delta S = 2$. Actually, if we write symbolically

$$-i\partial\theta/\partial t = E_0\theta + f\bar{\theta},$$

$$-i\partial\bar{\theta}/\partial t = E_0\bar{\theta} + f\theta,$$

we get $E_s = E_0 + f$, $E_a = E_0 - f$; since we are dealing with the excitation of a created system, then the E_0 for θ and $\bar{\theta}$ are identically equal. According to considerations on the magnitude of ΔS for the conversion $\theta \to \bar{\theta}$, we can expect that $f \sim g^2$, so that $\Delta m \sim \hbar / \tau c^2$ (as was assumed by Pais and Piccioni), where τ is the period of decay $\sim 1.5 \times 10^{-10}$; numerically, we obtain $\Delta m = 10^{-11} m_e$, where m_e is the mass of the electron.

Another approach to the problem of the difference of the masses of θ_s and θ_a is based on the direct consideration of that coupling of the θ-particles with other fields, which determines their decay. If we assume that the spin of θ is zero, then the pair π^+, π^- which are generated in the decay, is found in a state which is even relaive to charge conjugation; only the decay $\theta_s = \pi^+ + \pi^-$ is possible, not the decay of θ_a. The decay of θ_s gives information on the coupling of the field of θ_s with the field of the pions*. According to the usual formulas of perturbation theory, such a coupling must produce a displacement of the level, i. e., a change of the energy of θ_s, along with the decay which produces a broadening of the level. We write down side by side the energy shift and the decay probability:

$$w = 2\pi M^2(E)\frac{dN}{dE}\Big|_{E=E_0}, \quad \Delta E = \int\limits_0^\infty \frac{M^2(E)}{E_0 - E}\frac{dN}{dE}\,dE,$$

$M(E)$ is the matrix element of the transition from the state θ_s into the state of continuous spectrum, i.e., into the pair π^+, π^- with energy E; dN/dE is the density of levels of the continuous spectrum. The integral in ΔE is taken in the sense of the principal value; therefore the immediate neighborhood of E_0 does not determine its values. In order that the integral converge, it is necessary that the falling off of $M(E)$ be sufficiently rapid for $E \to \infty$. To compute ΔE, not knowing the properties of $M(E)$ is impossible. From the expressions that have been given, it is evident only that ΔE is of the same order of magnitude as w; dimensional quantities—the coupling constants, etc. —enter into ΔE and w in the same degrees.

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* Decay into muons, which is less probable, is not considered here.

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Angular Correlation in Cascade Decay of Hyperons

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STUDY of the angular distribution of the decay products of hyperons can give evidence on the spin of the latter. The distribution of pions in the cascade decay $\Xi \to \Lambda \to p$ was considered in Ref. 1. Here we consider the cascade decay $\Sigma^0 \to \Lambda^0 + \gamma \to p + \pi^- + \gamma$. The wave function pertaining to the motion of a proton and a $\pi -$ particle has the following form:

$$\psi_{jm_j}(\mathbf{p},\sigma) = C^{jm_j}_{lm\,1/2\,\sigma}\, Y_{lm}\left(\frac{\mathbf{p}}{p}\right)\chi_\sigma,$$