course, that the parentage of the true ground state is the normal free particle state. The interpretation of their result is now clear. Compressional modes relative to a highly excited "ground state" are unstable if they have sufficient admixture of low-energy states, similar to those considered here.

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REGENERATION AND MASS DIFFERENCE OF NEUTRAL K MESONS*

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A very significant feature of the Gell-Mann–Pais particle mixture theory[1,2] is the regeneration of the $K1$ from the $K2$ neutral meson. We examine the three possible types of regeneration and give the results of an experiment that exhibits the expected transformations as demanded by the theory. The experiment also allows an estimate of the difference between the masses of $K1$ and $K2$.

One of the three types of regeneration has been described previously[3]: A plate inserted into a parallel beam of $K2$ particles produces a parallel beam of $K1$ particles. This phenomenon, which we will henceforth call transmission-regeneration, is in striking contrast with other known processes whereby a particle transforms into another one: a parallel beam of charged pions obviously cannot produce a parallel beam of neutral pions by interacting with a plate.

Here we point out another process that typically follows from the theory, namely the regeneration by diffraction. Because the $\bar{K}^0$ and the K^0 waves are diffracted by a nucleus with different amplitudes, the diffracted wave contains $K1$ as well as $K2$ particles. Thus $K1$ mesons are regenerated by a nucleus with a typical diffraction angular distribution.

Regeneration of $K1$ can also occur by interaction of $K2$ with single nucleons. The angular distribution of this nucleon-regeneration is broad, not essentially different from that obtained in K-nucleon scattering, and therefore it is not a crucial consequence of the particle mixture theory.

All three of these components will emerge from a plate traversed by a parallel beam of $K2$'s. The angular distribution should permit one to recognize each component separately.

Case[4] and Good[5] have shown that the intensity of the transmitted component is a very sensitive function of the mean life τ_1 of the $K1$ and of the difference δm between the masses of $K1$ and $K2$. The mass difference appears in the final expression because of the phase difference it introduces between the $K1$ and the $K2$ waves, an effect which was first noted by Serber[6] in connection with K^0 production. Moreover, Good pointed out that the intensities of both the transmitted and "scattered" component (in the forward direction) are proportional to $|f_{21}^0|^2$, f_{21}^0 being the amplitude of the regenerated $K1$, at zero angle, in a $K2$-nucleus collision. Good's "scattered" component must be identified with the diffracted component described above. Thus the intensity ratio of the transmitted wave to diffracted wave is a function only of δm and τ_1. We derive here in a more concise way the expression for this ratio.

The computation of the expected transmitted and diffracted intensities can be greatly simplified by neglecting, from the start, the regeneration of $K2$ from $K1$. As the number of $K1$'s is always less than one thousandth of the number of $K2$'s, this approximation is very good. We consider then a plane wave of $K2$ particles, of wavelength λ, crossing our plate, which contains N nuclei per cubic centimeter. If each nucleus produces $K1$'s with a forward amplitude f_{21}^0, an infinitesimal thickness dx of the plate at depth x

(x in the direction of the incoming $K2$ beam; $x = 0$ and $x = L$ denote the limits of the plate) produces a $K1$ wave amplitude $iN\lambda f_{21}{}^0 dx$ which arrives at the end of the plate with the amplitude

$$da_1 = iN\lambda f_{21}{}^0 dx \, \exp\left(-ik_2 x - ik_1(L-x) - \frac{L-x}{2v\gamma\tau_1} - \frac{L}{2u}\right).$$

Notice that the $K2$ wave has traveled to depth x before producing the $K1$ wave, which then travels from x to L; u is the collision mean free path, which is the same for $K1$ and $K2$, because both particles are a half-and-half mixture of K^0 and $\bar{K}^0$; v is the velocity of the particles; γ is the Lorentz factor; $\hbar k_1$ and $\hbar k_2$ are the momenta. Let us call $\Lambda = v\gamma\tau_1$ the decay mean free path of the $K1$'s and introduce the dimensionless quantities $l = L/\Lambda$ and $\delta = (m_2 - m_1)c^2/(\hbar/c_1)$. By integration with respect to x we obtain, for the transmitted intensity,

$$|a|^2 = \frac{4|f_{21}{}^0|^2 N^2\Lambda^2\lambda^2}{1+4\delta^2} |e^{-i\delta l} - e^{-l/2}|^2 e^{-L/u}. \quad (1)$$

On the other hand, the nuclei, incoherently from each other, regenerate $K1$'s by diffraction with a differential cross section $d\sigma_{21}/d\omega = |f_{21}|^2$. The number of diffraction-regenerated $K1$'s in the infinitesimal thickness dx at x, in the forward direction, surviving through the thickness $L - x$ is

$$d\left(\frac{dn_1}{d\omega}\right)^0 = |f_{21}{}^0|^2 N \exp\left(-\frac{L-x}{v\gamma\tau_1} - \frac{L}{u}\right) dx,$$

which is integrated to give

$$\left(\frac{dn_1}{d\omega}\right)^0 = |f_{21}{}^0|^2 N\Lambda(1 - e^{-l})e^{-L/u}. \quad (2)$$

The ratio between (1) and (2) is

$$R = 4N\Lambda\lambda^2 |e^{-i\delta l} - e^{-l/2}|^2 / [(1 - e^{-l})(1 + 4\delta^2)]. \quad (3)$$

To observe these regeneration processes, we have inserted a plate in the Berkeley 30-inch propane chamber. The chamber was placed in a beam of $K3$ particles which traversed the instrument lengthwise and perpendicular to the plate. The experimental setup will be described in more detail in a later article. Here we give only a brief description.

A beam of 1.1-Bev/c negative pions impinged on a five-foot hydrogen target. The 670-Mev/c K^0 produced in the target travelled a distance of 22.5 feet before arriving at the 30-inch propane chamber, so that approximately one $K2$ crossed the chamber per 10^{11} protons in the Bevatron beam. About 200 000 pictures were taken, half of them with a 1.5-inch iron plate to enhance the diffracted wave relative to the transmitted wave, and the other half with a 6-inch iron plate which yields an intense transmitted wave.

We limited the analysis to those two-prong events in which the positive prong could be recognized to be a meson on the basis of ionization and momentum. We also required that the decay occur within two mean lives from the plate and that the primary momentum be equal, within the errors, to the beam momentum. The $Q(\pi, \pi)$ distribution of these selected events shows a marked peak around the expected value of 220 Mev, which fact proves the regeneration of $K1$. As a further selection, we keep only those events for which Q differs by no more than 1.4 standard deviations from the peak value.

By measuring the vector momenta of the two prongs, we determine the angle θ between the $K1$ and the incident $K2$ beams, within an error of about 2 degrees.

The angular distributions are shown in Fig. 1. The diffraction curve has been computed with an optical model method[7] using the known cross sections for K^+ and K^- with protons and nuclei.[8] The curve is quite close to the black-sphere distribution. Figure 1 clearly shows a diffraction component and a superimposed transmission peak. Most of the transmission peak is confined to angles smaller than 2.5 degrees ($\cos\theta > 0.999$), which is just what we expect from an infinitely narrow peak measured with our errors. The mere presence of such a large transmission peak is a proof that the mass difference is smaller than, say, $5\hbar/\tau_1$.

Referring to the data for the 6-inch plate, 29 events occur in the interval for $\cos\theta$ between 0.998 (3.5°) and 1, which should contain the total number T of the transmitted $K1$'s and a part D of the diffracted ones. Knowing the diffraction angular distribution we can compute D from the 31 particles in the 0.980 to 0.998 interval, assuming that that region contains only diffracted $K1$'s. A nucleonic background will actually be present in this interval, which we ignore for the moment. We thus obtain $D = 12$, which gives $T = 17$. For comparison with formula (3), we note that $(dn_1/d\omega) = 1.18(D/\omega)$, where the factor 1.18 is equal to the ratio of the intensity at zero degrees to the average intensity within ω, ω being the solid angle in the peak interval, that is, $2\pi \times 0.002$. It is convenient to compare $T/1.18D$

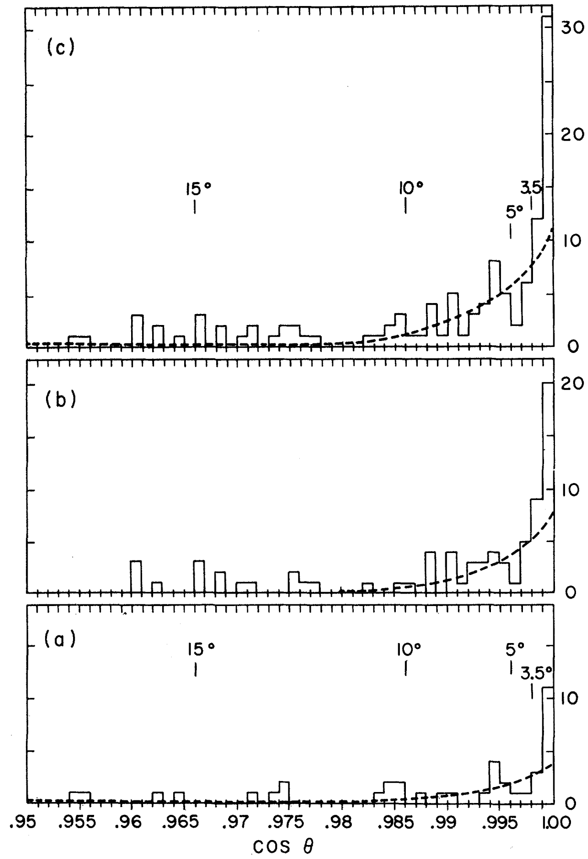

FIG. 1. Histograms of number of $K1$ decay events per 0.001 interval of $\cos\theta$ (θ is the angle between the direction of the primary $K2$ beam and the regenerated $K1$). (a) Data for the 1.5-inch plate; (b) data for the 6-inch plate; (c) combined data for the two plates. The curves are diffraction angular distributions normalized in the 0.980 to 0.998 interval for $\cos\theta$.

with R/ω, which is plotted in Fig. 2 versus the mass difference, in units of $\hbar/\tau_1$. We obtain $T/1.18D = 1.2 \pm 0.53$, which gives $\delta m = 0.85^{+0.4}_{-0.25}$. With a probability of 95%, $\delta m < 1.4$.

In the same way, we find from the thin plate alone $\delta m = 0$ ($\delta m < 4.5$ with 95% probability) and from the combination of thin and thick plate $\delta m = 0.85^{+0.3}_{-0.25}$ ($\delta m < 1.5$ with 95% probability).

If we correct for nucleonic or any other background, we would obtain a larger value for R, hence a smaller value for δm. For instance, assuming a uniform background from $\cos\theta = 0.96$ to $\cos\theta = 1$, the compounded data for both plates yield $\delta m = 0$ ($\delta m < 1.1$ with 95% probability). In view of a remark by Okun' and Pontecorvo,[9] this result indicates that decay rates for $\Delta S = 2$ are 10^5 times slower than for $\Delta S = 1$.

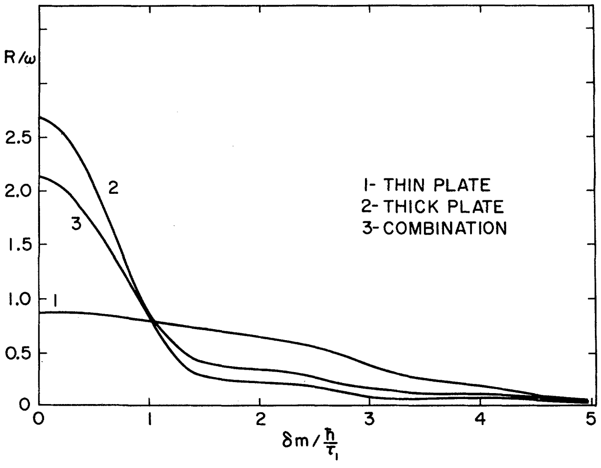

FIG. 2. Calculated intensity of the forward regenerated $K1$'s versus the $K1$-$K2$ mass difference. The ordinate R/ω is the ratio of the transmission-regenerated $K1$'s to the diffraction-regenerated $K1$'s in the interval $\cos\theta > 0.998$.

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COSMIC RADIATION INTENSITY DECREASES OBSERVED AT THE EARTH AND IN THE NEARBY PLANETARY MEDIUM*

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This note reports preliminary experiments which prove that existing theories for the modulation mechanism responsible for rapid decreases of primary cosmic-ray intensity cannot invoke the presence of the earth or its magnetic field.

Forbush first noted sudden intensity decreases in ionization chambers located deep within the atmosphere which followed in the order of 20 to 40 hours some large solar flares.[1] These intensity decreases arose from changes in the secondary radiation produced by primary cosmic rays and were frequently accompanied by substantial geomagnetic field disturbances. It was later shown experimentally that this kind of world-wide decrease was a property of the primary cosmic radiation observed at the earth, and arose neither as a consequence of the geomagnetic storm nor by phenomena which might change temporarily the magnetic cutoff rigidities, such as ring currents around the earth.[2] The changes in the primary spectrum during times of drepressed intensity—namely, a larger decrease for low magnetic rigidity particles than for high rigidity particles—suggested that the modulation was due to interplanetary magnetic fields in the vicinity of the earth.[2] For a typical event, the high rate for reduction of prevailing cosmic radiation intensity at the earth also placed bounds on the requirements for magnetic field intensity and scale size of suitable modulating electromagnetic fields, i.e., intense fields of large scale size, or vice versa.

Several hypotheses have been advanced for this solar-produced modulation of galactic cosmic radiation. On the one hand are models which may be described roughly as heliocentric; namely, where the cosmic radiation intensity in a substantial volume of the inner solar system is reduced by either disordered,[3] or ordered magnetic fields[4,5] of solar origin independent of the presence of the earth and its geomagnetic field. On the other hand are models which depend upon the solid earth and its permanent magnetic field for creating the decrease of cosmic-ray intensity; namely, geocentric models.[6] To decide between these two classes of hypotheses, we ask the question: How far into the interplanetary medium is the full decrease of galactic cosmic-ray intensity observed during a Forbush decrease? Is the pre-existent radiation intensity found at distances beyond which the geomagnetic field could be invoked to account for the Forbush decrease, or is the intensity also reduced in the nearby interplanetary medium as it is at the earth? For all existing models which invoke the presence of the geomagnetic field, a suitable limit for the effective extent of the modulating region is 6 to 10 R_e, where R_e is the radius of the earth.

To answer these questions, we have performed a direct experiment using a cosmic-ray detector carried by the Explorer VI satellite launched August 7, 1959 in an orbit which extended beyond the region of trapped Van Allen radiation and reached a range in excess of $7.5R_e$. In addition to the satellite observations, we measured simultaneously the changes in the nucleonic component at the earth over a wide range of geomagnetic cutoff rigidities. For this purpose we used neutron intensity monitors extending from the geomagnetic equator to high latitudes.

The cosmic-ray detector in the satellite was a triple-coincidence, proportional counter system which measured protons in excess of 75-Mev energy, or electrons in excess of 13-Mev energy. The triple coincidence detector does not respond to bremsstrahlung, such as from electrons trapped in the geomagnetic field. The satellite orbit was an ellipse of apogee approximately 48 800 km and perigee approximately 6600 km, with