ing in the equations for ρ_j and S_j the terms linear in S_j and ρ_j, we get

$$\begin{aligned} & S_j + (\mathbf{v}_j^0 \nabla) S_j \\ & + \int G(|\mathbf{r}-\mathbf{r}'|) \sum_i \rho_i(\mathbf{r}')\, d\mathbf{r}' - (\hbar^2/4m_j^*)\Delta\rho_j = 0, \quad (6) \\ & \rho_j + (\mathbf{v}_j^0 \nabla)\rho_j + (1/m_j^*)\Delta S_j = 0. \end{aligned}$$

For solutions of ρ_j and S_j of the form $\sim \exp[i(\mathbf{k}\cdot\mathbf{r}) - i\omega t]$ these equations lead to the following dispersion relation

$$1 = k^2 G(k) \sum_j \frac{1}{m_j^*} \left\{(\omega - \mathbf{v}_j^0\cdot\mathbf{k})^2 - \frac{\hbar^2 k^4}{4m_j^{*2}}\right\}^{-1}. \quad (7)$$

From (7) it follows that in the limit as $\mathbf{k} \to 0$ the frequency ω_0^* depends on the effective mass of the quasi particles which, generally speaking, differs from the ordinary mass of the particles.

In the case where $\epsilon(p) = p^2/2m$, (7) goes over into the well-known dispersion law.[1] To evaluate m_j^* it is sufficient to know the dependence of the total energy (kinetic Fermi, exchange, and correlation energy) of one particle on its momentum. In the case of a dense electron gas $\epsilon(p)$ can be evaluated by the method given in Ref. 2.

The method proposed here is suitable to find the spectrum of the plasma oscillations of electrons in a periodic field, for the case of one band.† If we understand by $\epsilon_{0j}(p_0)$ the energy of an electron in a periodic field, then Eq. (7) is equivalent to the corresponding equation in the paper by Wolff.[3]

[1] D. Pines, Phys. Rev. **92**, 626 (1953).

[2] M. Gell-Mann and K. A. Brueckner, Phys. Rev. **106**, 364 (1957); M. Gell-Mann, Phys. Rev. **106**, 369 (1957).

[3] P. A. Wolff, Phys. Rev. **92**, 18 (1953).

Translated by D. ter Haar
90

†The method developed to find the dispersion equation is easily generalized to cover the case of many bands.

CREATION OF POSITIVE PIONS BY NEGATIVE PIONS

Iu. P. DOBRETSOV and B. A. NIKOL'SKII

Academy of Sciences, U.S.S.R.

Submitted to JETP editor October 29, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 510-511 (February, 1958)

THE creation of pions by pions has been studied by a number of authors.[1-6] All these analyses refer to the creation of pions in the nucleus as a whole; one may assume, however, that at these incident energies, the pions are created on the individual nucleons of the nucleus. The effect of the nucleus manifests itself in this case through a second-order interaction between pions of the final state and the nucleons of the nucleus. This circumstance considerably complicates the interpretation of experimental data, and therefore we can only obtain from it the qualitative character of the creation of pions by pions.

In the present article we consider the creation of positive pions in nuclear emulsion under the action of negative pions having an energy of 340 ± 30 Mev.

The emulsion stack consisting of 60 layers of NIKFI type R emulsion, of 23 mm total thickness and 100 mm diameter was placed in the 370-Mev negative pion beam of the synchrocyclotron of the Joint Institute for Nuclear Research. In passing through the emulsion, the incident pions lost up to 60 Mev by ionization. Thus the present results describe the creation of pions under the influence of negative pions having an energy $E_0 = 340 \pm 30$ Mev. The method chosen to find cases of positive pion production consists in area scanning the emulsion and counting $\pi^+ \to \mu^+ \to e^+$ decays. Then the positive pions were followed to their creation point. This search method effectively allowed us to count the production of pions leaving a path of up to 6 cm, i.e., an energy up to 70 Mev.

In following positive pion tracks, 56 stars caused by negative pions were found. In 21 of these stars the emission of the positive pions was accompanied by the emission of a second meson identified by the grain density gradient along the track. It is evident that these events must be attributed to the formation of the positive pion. The emission of a second pion was not found in the remaining stars, but these events can again be attributed to the formation of positive pion followed by the absorption of the negative pion by the nucleus, or the emission of a neutral pion. This conclusion is supported by data on the absorption of pions by nuclei at these energies.[7]

The energy of the created positive pions was determined from their range in the emulsion; the energy of the negative pions (in stars with two pions) was determined from the grain density.

The method chosen for counting positive pions in order to determine the production cross section and the angular and energy distribution of created pions, requires the introduction of a correction for edge effect, depending upon the finite size of the emulsion stack. In order to include the edge effect, every counted event of positive pion formation was assigned a statistical weight $\kappa_i = 1/p_i$, where p_i is the probability for finding a pion track of the given length and distributed in a certain way in the emulsion stack. The computation of κ_i is described in detail in Ref. 8.

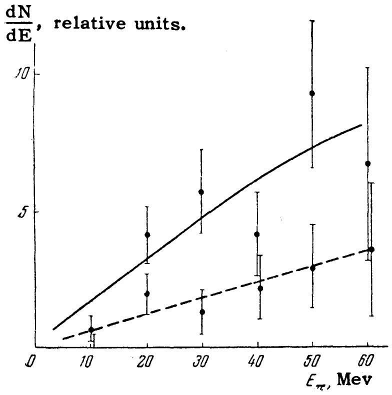

Fig. 1. Energy distribution for the creation of positive pions. The dotted curve indicates the distribution of positive pions emitted from stars in which the emission of a second pion was noted.

Figures 1 and 2 show the energy and angular distribution for the creation of positive pions. It may be seen from these figures that the distribution of positive pions accompanied and not accompanied by the emission of a second meson from the nucleus are similar. This is an additional argument for believing that almost all the observed positive pions are created.

Determinations of the relative momentum of the two pions emitted from the same nucleus, disclose no visible correlation between the two final state pions. This is only a qualitative conclusion however. A reliable determination of the momentum distribution function for the pions requires a considerably more accurate experiment.

The cross section for creation of slow positive pions ($E_{\pi^+} = 0 - 60$ Mev) by negative pions of 340 ± 30 Mev in photoemulsion nuclei was found to be

$$\sigma = (2.1 \pm 0.8) \cdot 10^{-27} \text{cm}^2.$$

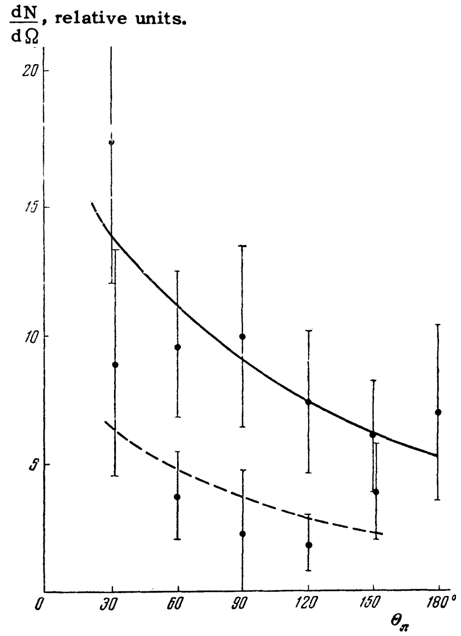

Fig. 2. Angular distribution for the creation of positive pions. The dotted curve indicates the distribution of positive pions emitted from stars in which the emission of a second pion was noted.

In conclusion the authors would like to express their gratitude to Professor I. I. Gurevich for discussing the results, to S. A. Ali-Zade, L. V. Sukrov, A. P. Mishakov, and L. A. Smirnov for helping with the experiment, to D. M. Samoilovich for developing the emulsion.

[1] V. V. Krivitskii and A. A. Reut, Paper delivered at the All-Union Conference on Physics of High-Energy Particles, Moscow, May, 1956.

[2] M. Blau and M. Kaulton, Phys. Rev. **96**, 150 (1954).

[3] M. Blau and A. Oliver, Phys. Rev. **102**, 489 (1956).

[4] W. F. Fry, Phys. Rev. **91**, 1576 (1953).

[5] Blau, Caulton, and Smith, Phys. Rev. **92**, 516 (1953).

[6] N. A. Mitin and E. L. Grigor'ev, Dokl. Akad. Nauk SSSR **103**, 219 (1955).

[7] B. A. Nikol'skii and L. M. Barkov, Usp. Fiz. Nauk **61**, 341 (1957).

[8] Alpers, Barkov, et al., J. Exptl. Theoret. Phys. (U.S.S.R.) **30**, 1025 (1956), Soviet Phys. JETP **3**, 914 (1957).

Translated by M. A. Melkanoff
91