σ_t is made by the scattering length a_{33}, for which the solution obtained for the dispersion relations of Chew et al. is apparently satisfactory. Deviations of the experimental points from the theoretical curve in the region close to the threshold (up to 180 Mev) indicate that E1 does make a definite contribution to the total cross section.

The variation of σ_t with the energy, obtained in the present work, is in good agreement with the variation of the cross section as obtained by Koester and Mills,[3] but the absolute values given by the latter for σ_t are 30% less.

In conclusion we thank I. A. Erofeev for help in the measurements and for the processing of the experimental data, and to V. I. Gol'danskiĭ and A. M. Baldin for valuable advice.

[1] Vasil'kov, Govorkov, and Kutsenko, Приборы и техника эксперимента (Instruments and Measurement Engg.) in press.

[2] Vasil'kov, Govorkov, and Gol'danskiĭ, J. Exptl. Theoret. Phys. (U.S.S.R.) **37**, 11 (1959), Soviet Phys. JETP, this issue, p. 7.

[3] L. J. Koester and F. E. Mills, Phys. Rev. **105**, 1900 (1957).

[4] Chew, Goldberger, Low, and Nambu, Phys. Rev. **106**, 1345 (1957).

[5] McDonald, Peterson, and Corson, Phys. Rev. **107**, 577 (1957).

Translated by J. G. Adashko
57

THREE-ELECTRON DECAY OF THE MUON

I. I. GUREVICH, B. A. NIKOL'SKIĬ, and L. V. SURKOVA

Submitted to JETP editor April 17, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **37**, 318-319 (July, 1959)

In measuring the asymmetry of the angular distribution of the electrons from $\pi \rightarrow \mu \rightarrow e$ decay, we observed an event in which three relativistic electrons escaped from a stopped muon. A microprojection of this event is shown in Fig. 1. All three electrons from the muon decay have a large dip angle, and therefore accurate measurements of grain density are not significant. Nevertheless the grain density was close to that of relativistic particles, and consequently they have in each case an energy above 1 Mev. The muon was stopped in the last pellicle of an emulsion stack, and all decay electrons escaped from the emulsion stack.

The recorded part of the electron tracks consisted of $L_{e_1} = 455\mu$, $L_{e_2} = 562\mu$, and $L_{e_3} = 455\mu$.

An additional argument for the energy of all the electrons being sufficiently large is the rectilinearity of their trajectories in the recorded part of the track. The muon track was 598-μ long, while the average track length for muons from $\pi \rightarrow \mu$ decay is 602μ in R-NIKFI emulsion. The angles between the electrons are $\theta_{12} = 8.6°$, $\theta_{13} = 10.6°$, and $\theta_{23} = 10.5°$. From the microprojection it is evident that the event is not a three-particle decay of the muon ($\mu \rightarrow 3e$), since in that case the electrons would have to be coplanar with zero total momentum. It is not possible to interpret the observed event as the decay of a muon into an electron and a photon with a subsequent conversion of the latter at the point of decay into an electron-positron pair (Dalitz effect). In such a process the photon and consequently also the components of the pair must escape to the side opposite from the decay electron.

The present event can be interpreted as a decay $\mu^+ \rightarrow e^+ + e^+ + e^- + \nu + \tilde{\nu}$. In this interpreta-

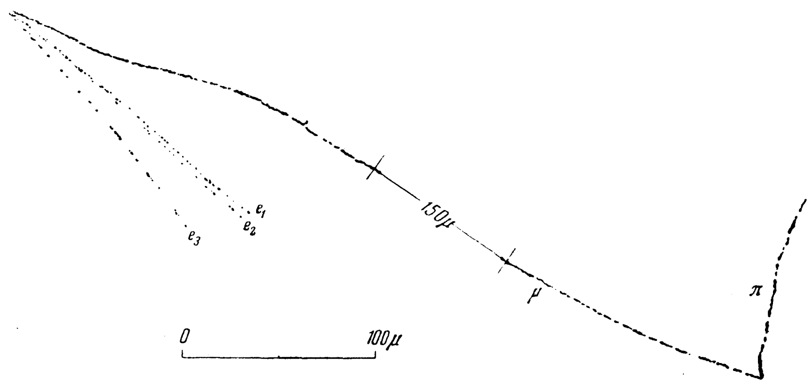

FIG. 1. Microprojection of the three-electron decay of a muon.

tion the question remains open whether we are dealing with the conversion of a virtual or a real photon into an electron-positron pair. One of the possible explanations is the decay $\mu^+ \to e^+ + \nu + \tilde{\nu} + \gamma$ with subsequent conversion of the photon into a pair.

The present event was observed in scanning about 50,000 muon decays. Thus the relative probability of a "three-electron" decay of a muon may be estimated as $p(3e)/p(e) \leq 2 \times 10^{-5}$. If the data of other authors, who have observed a large number of μ-e decays and have not discovered the "three-electron" decay, are considered, then the estimated probability of such a process must be reduced to a few times 10^{-6}. The reliability of this number is not great, since only one case of "three-electron" decay has been observed, and therefore it is impossible to absolutely exclude the possibility of an accidental superposition of tracks.

The probability $p(3e)/p(e)$ of the order of 10^{-6} can be obtained by assuming a second-order radiative process: emission of a virtual photon during the escape of the electron with its subsequent conversion into an electron-positron pair. The energy of such an electron-positron pair may be estimated from the angle formed by the tracks of the pair, which is about 8°, approximately the same for all three possible pairs of electron tracks, and is equal to 15 Mev.

The authors are pleased to thank I. S. Shapiro for interesting discussions.

Translated by J. Heberle
58

HYDRODYNAMICS OF SOLUTIONS OF STRANGE PARTICLES IN HELIUM II NEAR THE λ POINT

D. G. SANIKIDZE

Institute of Physics, Academy of Sciences, Georgian S.S.R.

Submitted to JETP editor April 21, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **37**, 320-321 (July, 1959)

We have derived the equations for the hydrodynamics of solutions of strange particles in helium II in the immediate vicinity of the λ-transition point. In contradistinction to the usual set of equations, from the point of view considered here (compare reference 1) ρ_s is not a given function of p, T, and the concentration c, but is determined from these equations themselves which also describe the process by which ρ_s approaches its equilibrium value. As in the paper by Ginzburg and Pitaevskii[1] the superfluid part of the liquid is described by a complex function $\psi(x, y, z, t) = \eta e^{i\varphi}$ defined in such a way that

$$\rho_s = m|\psi|^2, \qquad \mathbf{v}_s = (\hbar/m)\nabla\varphi$$

(m is the mass of a He^4 atom).

The derivation is analogous to the one used by Pitaevskii[2] in deriving the equations for the hydrodynamics of pure helium II near the λ point. We shall, therefore, not give the calculations but write down the final result:

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\Delta\psi + \left[\left(\frac{\partial\varepsilon}{\partial\rho}\right)_{\rho_s, S, c} + \left(\frac{\partial\varepsilon}{\partial\rho_s}\right)_{\rho, S, c} - \frac{Z}{\rho}c\right]m\psi$$
$$- i\Lambda\left[\frac{1}{2}\left(-\frac{i\hbar}{m}\nabla - \mathbf{v}_n\right)^2 + \left(\frac{\partial\varepsilon}{\partial\rho_s}\right)_{\rho, S, c}\right]m\psi; \qquad (1)$$

$$\partial\rho/\partial t + \operatorname{div}(\rho - m|\psi|^2)\mathbf{v}_n + (i\hbar/2)(\psi\Delta\psi^* - \psi^*\Delta\psi) = 0; \qquad (2)$$

$$\partial(\rho c)/\partial t + \operatorname{div}(\rho c\mathbf{v}_n + \mathbf{g}) = 0; \qquad (3)$$

$$\frac{\partial}{\partial t}\left\{(\rho - m|\psi|^2)v_{ni} + \frac{i\hbar}{2}\left(\psi\frac{\partial\psi^*}{\partial x_i} - \psi^*\frac{\partial\psi}{\partial x_i}\right)\right\}$$
$$= -\frac{\partial}{\partial x_k}\left\{(\rho - m|\psi|^2)v_{ni}v_{nk} + \frac{\hbar^2}{2m}\left(\frac{\partial\psi}{\partial x_i}\frac{\partial\psi^*}{\partial x_k} - \psi\frac{\partial^2\psi^*}{\partial x_i\partial x_k} + \text{c.c.}\right) + p\delta_{ik} - \eta\left(\frac{\partial v_{ni}}{\partial x_k} + \frac{\partial v_{nk}}{\partial x_i} - \frac{2}{3}\delta_{ik}\operatorname{div}\mathbf{v}_n\right)\right\}; \qquad (4)$$

$$\frac{\partial S}{\partial t} + \operatorname{div}\left[S\mathbf{v}_n + \frac{1}{T}\left(\mathbf{q} - \frac{\mathbf{g}Z}{\rho}\right)\right] = \frac{R}{T}. \qquad (5)$$

The dissipative function of the liquid is

$$R = \frac{2\Lambda}{\hbar}\left|\left[\frac{1}{2}\left(-\frac{i\hbar}{m}\nabla - \mathbf{v}_n\right)^2 + \left(\frac{\partial\varepsilon}{\partial\rho_1}\right)_{\rho, S, c}\right]m\psi\right|^2 + \frac{1}{2}\eta\left(\frac{\partial v_{ni}}{\partial x_k} + \frac{\partial v_{nk}}{\partial x_i} - \frac{2}{3}\delta_{ik}\frac{\partial v_{nl}}{\partial x_l}\right)^2 - \mathbf{q}\frac{\nabla T}{T} - \mathbf{g}T\nabla\frac{Z}{\rho T}.$$

The impurity current **g** and heat current **q** are expressed by the usual equations.[3]

In the case of small gradients of ρ_s Eqs. (1) to (5) go over into the following ones:

$$\mathbf{v}_s + \nabla\left\{\frac{v_s^2}{2} + \left(\frac{\partial\varepsilon}{\partial\rho}\right)_{\rho_s, S, c} + \left(\frac{\partial\varepsilon}{\partial\rho_s}\right)_{\rho, S, c} - \frac{Z}{\rho}c - \frac{\hbar\Lambda}{2m\rho_s}\operatorname{div}\rho_s(\mathbf{v}_s - \mathbf{v}_n)\right\} = 0, \qquad (6)$$

$$\partial\rho/\partial t + \operatorname{div}(\rho_s\mathbf{v}_s + \rho_n\mathbf{v}_n) = 0, \qquad (7)$$

$$\partial(\rho c)/\partial t + \operatorname{div}(\rho c\mathbf{v}_n + \mathbf{g}) = 0, \qquad (8)$$