of the mean dc electron velocity: they are restored with a relaxation time of a few plasma periods. The plasma is turbulent and far from neutral, electric fields other than $\bar{E}$ are continually excited. Electron motion is damped because electrons and ions collide in bunches rather than individually. The collision frequency is the inverse of the relaxation time, say ω_{pe}/K where K is perhaps 10.

With the appropriate collision term in the equation of motion of the electrons, their mean velocity $\bar{u}$ becomes steady when

$$m\omega_{pe}\bar{u}/K = e\bar{E},$$

giving a current density $\rho\bar{u} = Ke\rho\bar{E}/m\omega_{pe} = K\epsilon_0\omega_{pe}\bar{E}$ and a real conductivity $K\epsilon\omega_{pe}$. This is of the order of mhos per meter for a density 10^{12} per cc, much smaller than typical conductivities calculated from individual collisions (see Spitzer[5]). It applies at low frequencies (less than ω_{pe}/K) only.

Radiation from bunches of charge accelerated by the two-stream mechanism is more intense than Bremsstrahlung (owing to coherence). Boundary conditions permitting, it may account for noise received from ionized media. Hoyle[6] describes qualitatively a mechanism for noise production by interestreaming charges.

The mechanism may wreck some ambitious schemes for channeling electrons through ions or vice versa[7,8] and it is of value in thermonuclear work where rapid heating is both desired and observed.[9] It may be the answer to the Langmuir paradox (see Gabor et al.[10]), and the rapid growth of collective instabilities, compared with the poor interaction through close collisions, would suggest that coarse-grained turbulence (rather than micro-randomness of particle motion) is the closest one can get to a "thermo"-nuclear regime.

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ENERGY vs MOMENTUM RELATION FOR THE EXCITATIONS IN LIQUID HELIUM*

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Cohen and Feynman[1] have pointed out that the elementary excitations in liquid helium may be studied by scattering monoenergetic cold neutrons from the liquid. At temperatures below 2°K, the most important scattering process is that in which the neutron creates a single excitation in the liquid. In this case, the energy and momentum of the excitation are given by the change of energy and momentum suffered by the neutron in the scattering.

Thermal neutrons which have been passed through a polycrystalline filter may be used instead of monoenergetic neutrons in this experiment. In this case, the sharp cutoff in the neutron spectrum transmitted by the filter serves as an energy marker. If the predominant scattering process is the creation of a single excitation, the energy spectrum of the scattered neutrons should also possess a sharp cutoff, but at a lower energy.

Palevsky, Otnes, Larsson, Pauli, and Stedman[2] have done an experiment of this type. They find that at a helium temperature of 1.4°K, the shape of the cutoff is preserved in the scattered beam. At 4.2°K, no indication of a sharp cutoff is seen in the scattered beam. This indicates that the scattering process proposed by Cohen and Feynman is essentially correct. These authors have obtained a number of points on the energy-momentum curve for the excitations.

This note is to report preliminary results of a similar experiment in progress at Los Alamos. A beam of thermal neutrons from the Los Alamos Omega West Reactor was filtered through 16 in. of beryllium, and allowed to strike a target of liquid helium 10 in. in diameter and 3 in. high. The energy spectrum of neutrons scattered through an angle θ was measured with a

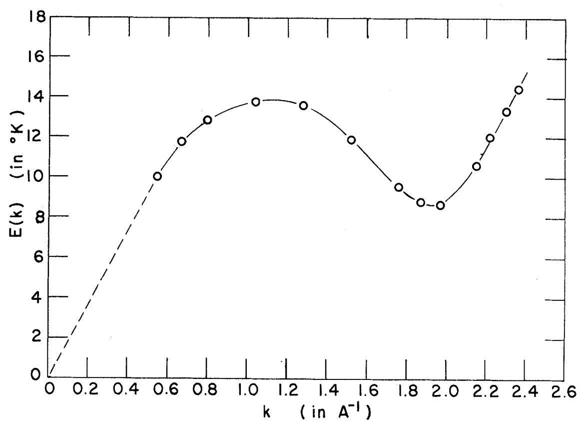

FIG. 1. Energy vs momentum for the excitations in liquid helium. The dotted portion of the curve corresponds to a first sound velocity of 240 m/sec. The minimum in the "roton" region occurs at $k = 1.93 \pm 0.04\ A^{-1}$, $E(k) = 8.6 \pm 0.2$°K.

crystal spectrometer. Results obtained to date are given in Table I, and are plotted in Fig. 1.

The theories of Landau,[3] Feynman and Cohen,[4] and Brueckner and Sawada[5] all predict an excitation spectrum which first rises linearly from the origin with slope equal to the velocity of first sound (phonon region), then passes through a maximum, next a minimum (roton region), and then rises again. The experimental points fall on a curve of this general type. The following comments apply to the experimental results.

(1) Although not much data was obtained in the phonon region, the following comparison may be made. A straight line joining the origin and the first measured point has a slope corresponding to a sound velocity of 240 ± 20 m/sec. Recent measurements[6] of the velocity of first sound in helium give a value of 237 m/sec.

(2) The maximum in the excitation spectrum occurs at $k = 1.10 \pm 0.04\ A^{-1}$, $E(k) = 13.8 \pm 0.2$°K. The spectrum appears to be quite symmetric about the maximum.

(3) The minimum in the spectrum occurs at $k = 1.93 \pm 0.04\ A^{-1}$, $E(k) = 8.6 \pm 0.2$°K. The spectrum is not symmetric about the minimum.

(4) At wave numbers greater than $2.3\ A^{-1}$, the cutoff in the scattered neutron spectrum becomes progressively more smeared out. This effect is expected theoretically, since in regions where the slope of the excitation curve exceeds the slope of the phonon branch, the excitations are unstable with respect to breakup into a phonon and an excitation closer to the minimum of the curve. The smearing of the cutoff is thought to result from the shortened lifetime of these excitations.

We plan to make additional measurements in the region of the minimum and at high wave numbers. We also intend to look for possible variation of the shape of the spectrum with the temperature of the helium target. Calculations of the specific heat, normal fluid density, and second sound velocity from the experimentally determined excitation spectrum are in progress.

Table I. Excitation spectrum of liquid helium. Momenta are expressed in terms of wave numbers k, where $p = \hbar k$. Energies have been divided by Boltzmann's constant.

Scattering angle	Helium temperature (in °K)	Wave number (in A^{-1})	Excitation energy (in °K)
20°	1.14 ± 0.03	0.55 ± 0.03	10.0 ± 0.30
25°	1.14 ± 0.03	0.67 ± 0.03	11.73 ± 0.25
30°	1.17 ± 0.05	0.80 ± 0.02	12.83 ± 0.20
40°	1.13 ± 0.02	1.04 ± 0.02	13.75 ± 0.15
50°	1.15 ± 0.03	1.28 ± 0.02	13.62 ± 0.15
60°	1.14 ± 0.02	1.52 ± 0.02	11.90 ± 0.15
70°	1.14 ± 0.02	1.76 ± 0.02	9.57 ± 0.15
75°	1.13 ± 0.01	1.87 ± 0.02	8.79 ± 0.15
80°	1.13 ± 0.01	1.97 ± 0.02	8.65 ± 0.15
90°	1.40 ± 0.04	2.15 ± 0.02	10.63 ± 0.15
95°	1.20 ± 0.03	2.22 ± 0.02	12.05 ± 0.15
100°	1.22 ± 0.01	2.30 ± 0.02	13.35 ± 0.15
105°	1.48 ± 0.05	2.36 ± 0.02	14.4 ± 0.20

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OBSERVATION OF UNPOLARIZED Λ's PRODUCED BY 1.5-Bev π^- INTERACTIONS IN Pb, Fe, AND C †

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Bubble chamber groups at the Cosmotron[1] and at the Bevatron[2] have observed an "up-down" asymmetry in the decay of Λ's produced by the reaction $\pi^- + p \rightarrow \Lambda + \theta^0$. This note reports the search for asymmetries among 138 Λ events produced by interactions of 1.5-Bev π^- mesons in lead, iron, and carbon.

The Λ events were obtained in a multiplate cloud chamber in a 1.5-Bev π^- beam at the Cosmotron[3]. The chamber illuminated volume was 29 in. × 29 in. × $10\frac{1}{2}$ in. Plate assemblies with iron, lead, and mixed lead and carbon plates were used; all plates were $\frac{1}{2}$ in. thick. The π^- kinetic energy spectrum at the cloud chamber was peaked at 1.5 Bev with an estimated half-width at half-maximum of 0.2 Bev. The first step in the identification of a V^0 was the location of a beam-particle interaction coplanar with the plane of the V^0 secondaries. From the space angles of the secondaries with respect to the line of flight of the V^0, the observed ranges of the secondaries, and the ionizations obtained by visual comparison with neighboring beam tracks, 138 V^0 events could be definitely identified as Λ hyperons, and 27 events were consistent with either a Λ or θ^0. In every case there was only one possible choice for the proton secondary consistent with a Λ interpretation so that the proton was identified.

The description of these decays follows the procedure suggested by Lee *et al.*[4] The polarization axis was taken as $P_i \times P_\Lambda$, where P_i = laboratory momentum of the incident π^- and P_Λ = laboratory momentum of the Λ.

The distribution of the pseudoscalar $\cos\theta = (P_i \times P_\Lambda) \cdot P_\pi^* / |P_i \times P_\Lambda|\,|P_\pi^*|$ was examined, where P_π^* = momentum of the π^- secondary in the center-of-mass system of the Λ. If the Λ is polarized in production and parity is not conserved in the decay, the angular distribution of the decay pion for a Λ spin of $\frac{1}{2}$ is $[1 + P\alpha\cos\theta]$, where P = polarization of the Λ at production ($|P| \leq 1$) and α = decay asymmetry coefficient for fully polarized Λ's ($|\alpha| \leq 1$).

Of the 138 Λ's, there were 91 produced in lead, 32 in carbon, and 15 in iron. The events in lead gave $\bar{P}\alpha = (3/N)\sum \cos\theta_i \pm (3/N)^{1/2} = 0.00 \pm 0.18$, where $\bar{P}$ is the average of P over the production solid angle for the sample. A chi-squared test shows less than a 4% chance that these are sampled from the population observed by the bubble chamber groups at the Cosmotron who obtained an average[1] $\bar{P}\alpha = 0.40 \pm 0.11$ for the beam π^- kinetic energy range 0.9-1.3 Bev. (The bubble chamber group at the Bevatron[2] obtained a value $\bar{P}\alpha = 0.44 \pm 0.11$ at 0.99 Bev.) Of the events produced in carbon, 17 were up and 15 down (up= positive $\cos\theta$; down = negative $\cos\theta$); the events in iron yielded 8 up and 7 down. Thus, the Λ's observed in this experiment appear to be largely unpolarized.

Division of the lead events according to the laboratory production angle ϕ showed no asymmetry (35 up, 35 down) for those events with $0 < \phi < 53°$. Of those lead events with $53° < \phi < 90°$, there were 10 up and 4 down giving some indication of asymmetry. (There is less than a 10% chance that this is a fluctuation from a symmetrical binomial distribution.) In addition, however, seven of the Λ's traveled backward in the laboratory, and all these events were down.

An attempt was made to select those events kinematically consistent with the simple interaction $\pi^- + p \rightarrow \Lambda + \theta^0$ (π^- kinematic energy 1.5 Bev; target proton at rest). From the laboratory momentum of the Λ, its angle of emission ϕ was