$$(E_{exc} - E_{gr})/\hbar = \omega = 2\pi/T = (2\pi/a_0)(2E_{He^+}/m_{He})^{1/2}$$

It is best to choose very thin plates of mica, so that the energy lost by the traveling He^+ ions is small. This may determine the narrowness of the He^+ ion beam energy region at which coherent excitation takes place.

[1] V. V. Okorokov, YaF 2, No. 5 (1965), Soviet JNP, in press.

SELF-ACCELERATION OF IONIZING PARTICLES IN AN ELECTRIC FIELD OF A POLARIZING IONIZATION LOOP

G. A. Askar'yan
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 21 June 1965

An ionizing particle or a bunch of particles traveling through a medium leaves behind it an ionization trail. Polarization of this trail in an external field may produce a stronger edge field, capable of accelerating the particles inducing the ionization [1]. In the present paper we consider the conditions for the acceleration of particles by means of such a field of an ionization "loop," both in the presence and in the absence of breakdown.

We consider first the case of non-breakdown polarization, when the cascade does not have time to develop within the time when the strong edge field is crowded out. Let us assume that a bunch of N particles passes through a medium, leaving behind it an ionization loop of radius ρ with electron volume concentration $n_e \simeq (N/\pi\rho^2)(dn_1/dx)$, where dn_1/dx is the ionization produced by each particle on a unit path in the medium (for example, for gases at a pressure p we obtain $dn_1/dx \simeq 10^2 p/\beta^2 cm^{-1}$, where $\beta = v/c$ is the relative velocity of the ionizing particles, which for simplicity will be assumed singly-charged).

To intensify the external field behind the particle bunch it is necessary that the plasma of the ionization loop distort the external field rapidly and strongly. The condition for the crowding out (i.e., strong distortion) of the field is the presence of a polarization $P = n_e ex = n_e ekEt \simeq E/4\pi$, where $k = e/m\nu$ is the mobility and ν is the collision frequency of the electrons. The time t of crowding out of the external field by the plasma produced is in this case $t \simeq 1/\sigma$ with $t > 1/\nu$, where the conductivity is $\sigma = n_e e^2/m\nu$. (In the case of "dielectric" screening $t \sim 1/\omega_p$, where ω_p is the plasma frequency). In the case of interest to us, that of screening by conduction current, $t \simeq m\nu\pi\rho^2/Ne^2(dn_1/dx)$ and does not depend on the pressure, since $\nu \sim p$ and $dn_1/dx \sim p$, with $t \sim \rho^2/N$.

The permissible distance X_0 from a bunch of ionizing particles to the front of the intensification of the external field by the plasma trail is defined in such a way that when $X_0 \lesssim \rho$ the field intensity at the bunch is close to the field intensity E at the end of an elongated plasma trail of length l, and can exceed by many times the intensity E_0 of the external field: $E/E_0 \simeq l/\rho \gg 1$ when $l \gg \rho$ for the spherically-rounded-off end of a cylindrical trail and $E/E_0 \simeq (a/b)^2$ for a spheroidal trail with semi-axes a and b. To ensure strong distortion of the field within a time $t \sim X_0/v$, it is then necessary to have $m\nu\pi\rho^2/Ne^2(dn_1/dx) \simeq X_0\beta c$. This relation can be ensured by choosing the number of particles $N \simeq \beta mc\nu\pi\rho^2/X_0e^2 \times (dn_1/dx)$. For example, when $X_0 \simeq \rho \simeq 3$ cm, we find that for $\nu \simeq 10^{11}$ sec^{-1} (pressure $p \sim 1$ atm) and $\beta \lesssim 1$ the necessary number of particles in the ionizing accelerated bunch is $N \sim 10^{12}$. It is interesting to note that $N \sim \beta^3$ and is practically independent of the pressure, if we disregard the broadening of the end of the plasma trail under the influence of the transverse component of the electric field. Even from these estimates we see that it is possible, at least in principle, to accelerate ionizing bunches of particles in a medium with an electric field without increasing the ionization concentration in the trail to breakdown values.

Let us examine now the extent to which the breakdown-induced increase in the plasma-trail concentration can be effectively utilized to reduce the necessary number of particles in the accelerated bunch. In the case of cascade breakdown processes with $t \gg 1/\nu$, the polarization is

$$P = n_e(0)x + \int_0^x (x - \xi)\,dn(\xi) = \int_0^x n(\xi)\,d\xi$$

but $n(\xi) = n(0)e^{\alpha\xi}$, where $\alpha = eE/I$ is the linear coefficient of multiplication and I is the energy per pair of produced ions. Integrating, we obtain

$$P(x) \simeq en_e(0)\alpha^{-1}(e^{\alpha x} - 1)$$

whence we obtain from the same conditions ($P \sim E/4\pi$ and $x \simeq keT$) a relation for the required value of $n_e(0)$:

$$n_e(0)\{e^{ekE^2t/I} - 1\} \simeq E^2/4\pi I \qquad (t \simeq X_0/v)$$

It is easy to satisfy the condition $\alpha x \gg 1$, i.e., $\exp(\alpha x) \gg \alpha x$, especially if large edge fields $E > E_0$ are taken into account, so that the required number of particles $n_e(0)$ and N can be reduced by several orders of magnitude.

Large edge accelerating fields ($E >$ MV/cm), and high velocities of the accelerated particles make it possible to neglect multiple scattering of the particles along the acceleration path even at pressures of ~ 1 atm. If the transverse bunch dimensions change little, the potential rise of the accelerated particles is

$$U \simeq \int_0^L E\,dl \simeq E_0/\rho \int_0^L l\,dl \simeq E_0L^2/2\rho$$

for the field at the rounded end of a cylindrical plasma trail. For example, if $E_0 \simeq 30$ kV/cm, $\rho \sim 3$ cm, and the section length is $L \sim 3$ meters we obtain $U \simeq 500$ MV. An advantage of the proposed acceleration method is that the process is non-potential, making it possible to effect acceleration through electrodes of alternating polarity from a single source of not very high voltage, in view of the possibility of controlling the edge field over a wide range by selecting the properties of the gas in the individual accelerating sections.

It is obvious that these devices, which employ pulsed non-stationary processes, have a maximum efficiency if they are used in conjunction with accelerators that deliver compact plasmoids of pre-accelerated particles in sections of spark chambers 1).

[1] G. A. Askar'yan, JETP Letters 1, No. 3, 44 (1965), Translation 1, 97 (1965).

1) Contributing to conservation of the bunch dimensions during the acceleration is the magnetic field due to the time variation of the edge field (since this field counteracts the transverse field component), or an external magnetic field, and also the self-phasing processes of the longitudinal drift of the bunch particles from the weak-field to the strong-field region and vice versa.

CONCERNING THE DIFFERENCE BETWEEN ν_μ AND ν_e

V. V. Ushakov
Khar'kov State University
Submitted 21 June 1965

It is known [1] that the main experimental support for the hypothesis that the muonic and electronic neutrinos are different is the absence of the $\mu \to e + \gamma$ decay, which must result from the $\mu \to e + \bar{\nu} + \nu$ interaction. We consider below two questions: 1) Has it been proved that a neutrino-antineutrino pair is emitted when the meson decays, and consequently that the lepton charges of the negative muon and the electron are equal? 2) Do the results of the CERN experiment [2] and the absence of the $\mu \to e + \gamma$ decay require the existence of two types of neutrinos?

1. Figure 1 shows the spectrum of the μe transition as given by Rozenson [3], while Fig. 2 indicates all the allowed decays. For the first and second schemes of Fig. 2, the theory [4] yields a spectrum in the form

$$W(x) \sim [(1 - x) - (2/9)\rho(1 - 3x)]x^2 \qquad (1)$$

which agrees with experiment when $\rho = 3/4$. If two identical neutrinos are emitted (third scheme) it is necessary to have $\rho = 0$. This variant includes also the fourth case, where the hypothetical particle $\bar{\gamma}_\nu$ in the second channel must be assigned a lepton charge -2, a spin 1, and a right-hand polarization (left-hand for μ^+e^+ transition). Its rest mass is determined in the following manner. The spectrum of the electrons in the first channel should satisfy formula (1) for $\rho = 0$. Such a curve was drawn through the experimental points ($x \leq 0.7$), and then subtracted from the experimental curve. The remainder should give a mono-energetic line. It follows from Fig. 1 that $m_{\gamma\nu} \approx 0$. The reduction of the data of other papers [5,6] yields ~ 7% for the probability of the decay $\mu \to e + \gamma_\nu$.

The introduction of the quantum γ_ν of polarized "neutrino light" makes it possible to explain why the interaction constant g_e in β decay is smaller than G_μ, the constant calculated