hard sphere for the positive one. We note that our results agree well with the predictions of the bubble model of negative carriers in neon [6], and also with the results obtained by others [2, 7, 8].

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TRANSITION EFFECT IN IONIZATION LOSSES OF HIGH-ENERGY PARTICLES

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Attempts have been made recently [1 - 3] to use the relativistic growth of the charged-particle ionization losses in the gas of a proportional counter to identify high-energy particles. An experimental verification of this possibility in [2] has revealed that for some unknown reasons the relativistic growth of the ionization losses at $\gamma = E/mc^2 \gtrsim 100$ is smaller than the expected one and amounts to 45% of the minimum value of the energy loss at $\gamma = 2000$, as against the 60% predicted by a theory that takes the density effect in gases into account [4]. It was shown in [3] that the experimentally measured ratio of the ionization losses of electrons and pions with momenta $P = 370$ MeV/c ($\gamma \simeq 740$ and 2.8, respectively) is at best 1.45 instead of the expected 1.78. Such a discrepancy between experiment and theory is unexpected, because in the case of solids the theoretical predictions are confirmed by experiment with accuracy ±1% [5]. It is important to ascertain the causes of such a discrepancy, since a weakening of the relativistic growth of the ionization loss creates additional difficulties in the problem of particle separation by masses, which is made complicated enough by the fluctuations of the energy losses.

The purpose of the present paper is to find a possible mechanism that explains the decrease of the ionization losses of relativistic particles in gas counters and to discuss methods that make a reduction of this effect possible.

A charged particle enters the gas of a proportional counter through the entrance window or through the counter wall; the thickness of either exceeds 25 μ. At such thicknesses, the particle field has time to become screened because of the polarization of the atoms in the medium, for only at thicknesses $\lesssim 10^{-5} - 10^{-4}$ cm can the particle ionize without the density effect [6]. On penetrating farther into the counter gas, the particle field is not immediately transformed into that of a particle in a gas. At a certain distance the particle "remembers its past," as it were, and continues to ionize with the field it possessed in the dense matter. Consequently, the ionization due to the particle can be lower on trajectory segments close to the entrance window than at large distances from the window.

In fact, it is known that the corresponding transformation of the field of the particle with frequency ω occurs over a path length called the formation zone in the theory of transition radiation [7]

$$Z_m(\gamma, \omega, \theta) = \frac{\frac{c}{\omega}}{1 - \beta\sqrt{\epsilon - \sin^2\theta}}, \qquad (1)$$

Here $\epsilon(\omega)$ is the dielectric constant of the medium and θ is the emission angle1). Assuming the particles to be extremely relativistic, we can put $\theta \simeq 0$ in (1). In the frequency region where ϵ differs little from unity, putting $\epsilon(\omega) = 1 + \delta(\omega)$, we obtain

$$Z_m(\gamma, \omega) = \frac{4 \cdot 10^{-5}}{\hbar\omega\,(\mathrm{eV}) \left[\frac{1}{\gamma^2} - \delta(\omega)\right]} (\mathrm{cm}). \qquad (2)$$

For the gases usually employed in counters (argon, methane, etc.) we have $\delta \sim 10^{-4}$ at optical frequencies (cf., e.g., [8]); at frequencies much higher than the natural frequencies of the atoms we have $|\delta| \sim 10^{-5}$ and less, as follows from the expression $\epsilon = 1 - (\omega_0/\omega)^2$ ($\omega_0 = [4\pi Ne^2/m]^{1/2}$ is the plasma frequency), while in the region of the vacuum ultraviolet and soft x-radiation the value of δ depends strongly on $h\omega$ and $\delta \sim 0$ in certain definite frequency regions2). Thus, at $\gamma \gg 1$ and at the frequencies responsible for the ionization of the gas atoms, the denominator of (3) can be so small that Z_m becomes of the order of a centimeter or even larger. Owing to the foregoing transition effect, the ionization of the particle over such path lengths after its emergence from the solid matter may be small, thus decreasing the relativistic loss growth at $\gamma \gg 1$.

Since it is difficult to develop a theory that takes into account the exact fields of the particle and the atom ionization levels, qualitative estimates can be obtained in the following manner. We assume that the particle ionization increases linearly3) starting with the edge of the window, up to a certain distance $t_{eff}(\gamma)$. The energy loss at distances larger than t_{eff} is equal to the theoretical energy loss with allowance for the density effect in the gas, while on emerging from the solid matter the loss is equal to that in the gas without the density effect, but decreased by the same factor as the energy loss in the solid matter of the window is decreased by the density effect [4].

An estimate made with the aid of the experimental data of [2] at $\gamma \simeq 10^3$, with allowance for the errors, yields $t_{eff} \sim 5 - 15$ cm. In the case of the experiment of [3], t_{eff} exceeds the counter thickness L = 1.2 cm. If the transition effect does indeed exist, then the ratio of the ionization of electrons and pions with momenta 374 MeV/c should be 1.5, in agreement with the 1.45 observed in [3], and not 1.78 as expected from the theory without allowance for the transition effect.

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1)Generally speaking, formula (1) holds true for a medium with real ϵ. In the case of complex $\epsilon = \epsilon_1 + i\epsilon_2$, it remains in force if $\epsilon_2 \ll \epsilon_1$ and $\theta \ll 1$.

2)An experimental value $\delta \sim 10^{-3}$ is given in [9] for the region $\hbar\omega = 4 - 9$ eV. We found no other reports of direct measurements of δ at $\hbar\omega \simeq 5 - 1000$ eV.

3)The assumption that the ionization varies linearly is equivalent to the assumption made in [10] that the maximum impact parameter varies exponentially.

The foregoing suggests immediately a method for decreasing the transition effect. The counter walls must be made so thin, $\sim 10^{-4} - 10^{-5}$ cm, that the relativistic growth of the ionization loss is not suppressed in them. This can be done by placing the counter in additional pressure chambers or by constructing multisectional counters with thin intermediate walls.

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COHERENT EXCITATION OF ATOMS PASSING THROUGH A CRYSTAL

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It was suggested in 1965 that nuclei [1] or atoms [2] can be excited coherently when they pass through a single crystal.

Our article is devoted to experimental results demonstrating that this effect is observed when He^+ ions pass through a single-crystal silver film.

The physics of this phenomenon is considered in sufficient detail in [1] and reduces, in the roughest approximation, to resonant excitation of the atoms (or nuclei) when the transition frequency $\nu_{tr} = (E_{exc} - E_{gnd})/h$ coincides with the frequency $\nu_0 = v_0/a_0$ of "collision" of the atom (nucleus) passing through the crystal with the crystal atoms (v_0 is the particle velocity and a_0 is the distance between the atoms in the crystal).

For the hydrogen-like atom He^+, whose levels are 0 eV ($n = 1$), 40.80 eV ($n = 2$), 48.37 eV ($n = 3$), 51.0 eV ($n = 4$), ..., such a resonance occurs on passage through a single-crystal silver film ($a_0 = 4.07$ Å) for a transition from the ground state $n = 1$ to the excited state with $n = 4$, at an energy $E_{He^+} = 526$ keV. By the same token, the He^+ beam passing through the silver film should contain, in addition to the ions excited as a result of various incoherent processes (single collisions, pickup of electrons by He^{++} ions, etc.), also a certain admixture of coherently excited ($n = 1 \to n = 4$) He^+ ions.

On leaving the film, the excited He^+ ions will radiate. The $n = 4 \to n = 3$ transition lies in the visible region ($\lambda = 4685$ Å). It can be readily separated by optical spectrometry devices (spectrometer, interference filter) from the

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