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IONIZATION LOSSES OF THE ENERGY OF FAST ELECTRONS IN THIN FILMS

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IT is known that the energy losses, due to ionization, of fast charged particles in dense media at high values of $p/\mu c$ (p is the momentum and μ is the mass of the particle) remain practically constant due to the density effect. Garibyan[1] showed that if a particle passes through a sufficiently thin plate then its electric field remains the same as it was in vacuum. Therefore, in such a plate the particle ionizes in a manner as if there is no screening action of the medium, i.e., there is no density effect.

Earlier calculations[1] showed that for this to happen the plate thickness a should satisfy the inequality

$$a \ll \frac{2v\Omega}{\sigma} \ln \frac{v\varkappa_0}{\sqrt{1-\beta^2}\,\Omega}, \qquad (1)$$

where v is the velocity of the particle; $\beta = v/c$; $\sigma = 4\pi Ne^2/m$ (the plasma frequency); Ω is the frequency above which the dielectric constant of the medium can be given by the formula $\epsilon(\omega) = 1 - \sigma/\omega^2$; κ_0 is a quantity inversely proportional to the distance beyond which the macroscopic approach is applicable.

In plates of this thickness one should expect a logarithmic increase of the ionization losses with increase of the particle energy. The presence of such an increase of the ionization losses may be used to measure the energies of very fast particles in those cases when other methods are not practicable.

This method can obviously be used to determine the energies of particles in monoenergetic beams, although in principle it can also be used for single particles. In the latter case a large number of thin plates must be used to measure the particle energy, so that the total energy losses can be measured sufficiently accurately and with minimum fluctuations. Then, as pointed out earlier,[2] the distance between the thin plates should be much smaller than the quantity in the right-hand part of the inequality (1). This condition is necessary to ensure that the field of the particle is not distorted by the polarization of the medium not only in the first plate but in all the subsequent ones.

EXPERIMENTAL SECTION AND RESULTS

Measurements were carried out using the linear accelerator of the Physico-technical Institute of the Ukrainian Academy of Sciences. The experimental setup is shown in Fig. 1. Electron beams of energies 20.5, 40, 47.5, 88 MeV were in turn focused on a target consisting of a scintillation film of 10^{-6} cm thickness deposited on an aluminim substrate of $10\,\mu$ thickness. In all the measurements the current passing through the target reached $0.01\,\mu$A. The beam intensity was measured with a secondary-emission monitor. The monitor was calibrated by means of a Faraday cylinder and had a constant secondary-emission coefficient in the range of electron energies used in the present work. The scintillation film was prepared from a plastic polystyrene-based scintillator by the usual method of deposition on a substrate.

From Eq. (1) we deduced the following critical values of the thickness a_0 of the polystyrene film for different values of the electron energy:

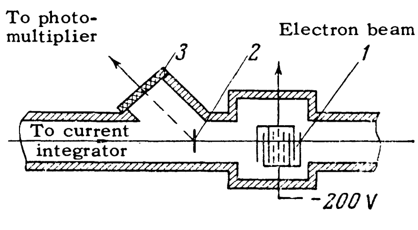

FIG. 1. Schematic representation of the experimental setup: 1) secondary-emission monitor; 2) target; 3) vacuum window.

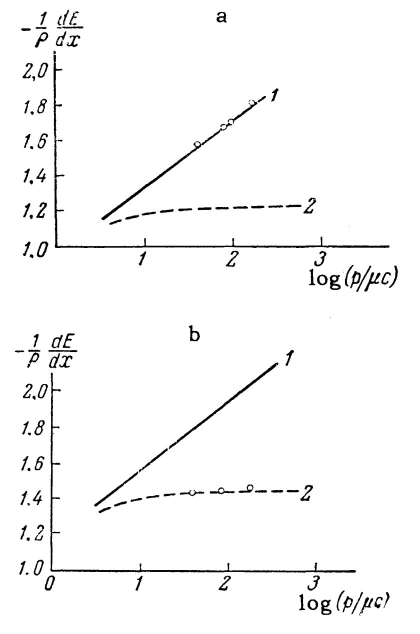

FIG. 2. Theoretical curves and experimental values of energy losses in polystyrene films of thicknesses 10^{-6} cm (a) and 2×10^{-3} cm (b). 1) Theoretical curve without allowance for the density effect; 2) theoretical curve with allowance for the density effect. The circles denote the results of measurements. The ordinate axis gives the specific luminescence in relative units.

$p/\mu c$	10	40	100	200
$10^6 a_0$, cm	31.7	37,5	39.5	45.0

In the present work the film thickness was $\approx 10^{-6}$ cm, in accordance with the condition (1). In a control experiment measurements were also made on thick films (2×10^{-3} cm).

As a measure of the electron energy loss in the film we took its specific luminescence, i.e., the luminescence of the film per one transmitted electron. The luminescence was recorded with an FÉU-29 photomultiplier and a calibration was initially obtained which showed that the luminescence was proportional to the beam intensity. Moreover, it was found that the specific luminescence decreased somewhat at the beginning of the irradiation but remained constant afterwards. Because of this the samples in each series of measurements were subjected to a preliminary irradiation until a specific luminescence, constant in time, was reached for a given electron energy (in practice for a current of 0.01 μA this took about 30 min).

Figure 2 shows the results of measurements and the theoretical curves [3] for films of 10^{-6} cm and 2×10^{-3} cm thicknesses. The experimental data are made to fit the theoretical curves at points corresponding to an electron energy of 40 MeV. The standard error in the measurements was 1%.

As shown by Fig. 2a, the experimental data for thin films agree satisfactorily with a curve which is based on the assumption that there is no density effect. From Fig. 2b we see that the experimental results for thick samples fit the curve which allows for the polarization effect.

Thus we have shown that the ionization losses in thin films rise logarithmically with increase of the electron energy.

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ELASTIC ππ SCATTERING AT HIGH ENERGIES

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An investigation of the analytic properties of the scattering amplitude as a function of the angular momentum has made it possible to establish a connection between the cross sections of particle interaction at high energies [1,2,3]. In particular, a relation exists between the differential cross sections of elastic ππ, πN, and NN scattering:

$$(d\sigma / d\Omega)^2_{\pi N} = (d\sigma / d\Omega)_{\pi\pi} (d\sigma / d\Omega)_{NN}. \qquad (1)$$

This relation enables us to find the differential cross section of ππ scattering, provided we know $(d\sigma/d\Omega)_{\pi N}$ and $(d\sigma/d\Omega)_{NN}$, measured at identical total energies in the corresponding center-of-mass systems.

An obvious modification of relation (1) for the case when the cross sections for πN and NN scattering are measured at the different energies, leads to the formula