

## OBSERVATION OF CHARGED RELATIVISTIC PARTICLES IN A LUMINESCENT CHAMBER

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Luminescent chamber photographs of cosmic ray  $\mu$  meson tracks have been obtained with ionization close to minimum. The density of the tracks of these  $\mu$  mesons was measured.

**E. K. ZAVOĬSKIĬ** and his co-workers<sup>1-3</sup> recorded in a luminescent chamber the tracks of relatively slow protons, mesons and  $\alpha$  particles. Recently, Jones, Perl, Reynolds, et al.<sup>4</sup> obtained tracks in luminescent chambers of fast cosmic ray particles, but they did not show quantitatively that the tracks recorded were those of particles with minimum ionization density. The clarity of the tracks in these experiments far exceeded those achieved in Zavoĭskiĭ's luminescent chamber.

The present work was undertaken for the purpose of observing singly-charged minimum ionization particles in a luminescent chamber, with high sharpness of imaging, and for a quantitative determination of the density of such tracks. A knowledge of the minimum value of the density of tracks in the chamber enables one to establish an absolute calibration of ionization density for all tracks observed in it.

A schematic diagram of the equipment is shown in Fig. 1. The working volume of the chamber is the crystal  $K_1$  [NaI(Tl) crystal 7 cm in diameter, with a thickness actually used  $\sim 1$  cm]. The objective  $O$  of the "Yupiter" type projects an image of the luminous track of a particle on to the input photocathode  $\Phi$  of the multi-stage electron optical converter EOC, which has the maximum coefficient of amplification of brightness of imaging.<sup>2,3,5,6</sup> The long magnet winding  $K$  produces the longitudinal magnetic field which is needed for focusing the electron image in the EOC. The EOC is operated in a "slaved" pulse mode on the first, second and last electron optical stages. The image of each track in the crystal is "held" on the luminescent screen  $S_1$  of the first stage for  $\sim 100 \mu\text{sec}$ .<sup>7</sup> If during this time a gating pulse arrives at the input of the control circuit (CC), the image is "accepted" from the screen  $S_1$ , passes to the output luminescent screen  $S_{\text{out}}$  and is photographed by the automatic photographic apparatus PA. In Fig. 1 we also show the shape of the control pulses which go from the circuit CC to the EOC and to the relay for

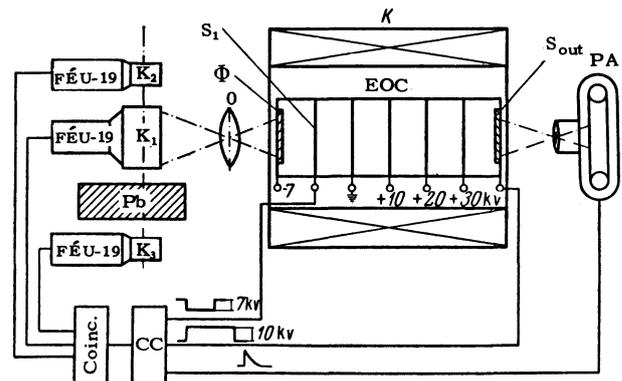


FIG. 1

moving the plates of the photographic apparatus.

Most of the photographs were obtained in this synchronized type of operation of the EOC, in which the gating pulse to the input of CC came directly from the FÉU-19 photomultiplier "looking at" the working volume of the luminescent chamber. About 1,000 track photographs were obtained in this way. In 125 of these, there are visible well-focused single tracks most of which passed through the whole working volume of the chamber in directions close to the vertical. Five such tracks were recorded per minute on the average, apparently belonging to relativistic cosmic-ray mesons (Fig. 2a). In addition, there were recorded several stars and showers (Fig. 2b).

To measure the track density for minimum ionizing particles, a special experiment was done in which relativistic particles were selected by a telescope system of three counters ( $K_1$ ,  $K_2$ ,  $K_3$ ) connected in coincidence (Fig. 1). A  $115 \text{ g/cm}^2$  lead absorber was placed between  $K_1$  and  $K_3$ . The gating pulse to the CC came from the coincidence circuit (Coinc). The coincidence circuit (Coinc) operated once every 2 - 2.5 hours. With the absorber thickness used in this experiment we could record only particles with an ionization differing by no more than a factor of  $1\frac{1}{2}$  from minimum. If we consider that the cosmic radiation at sea level consists predominantly of  $\mu$  mesons, it is

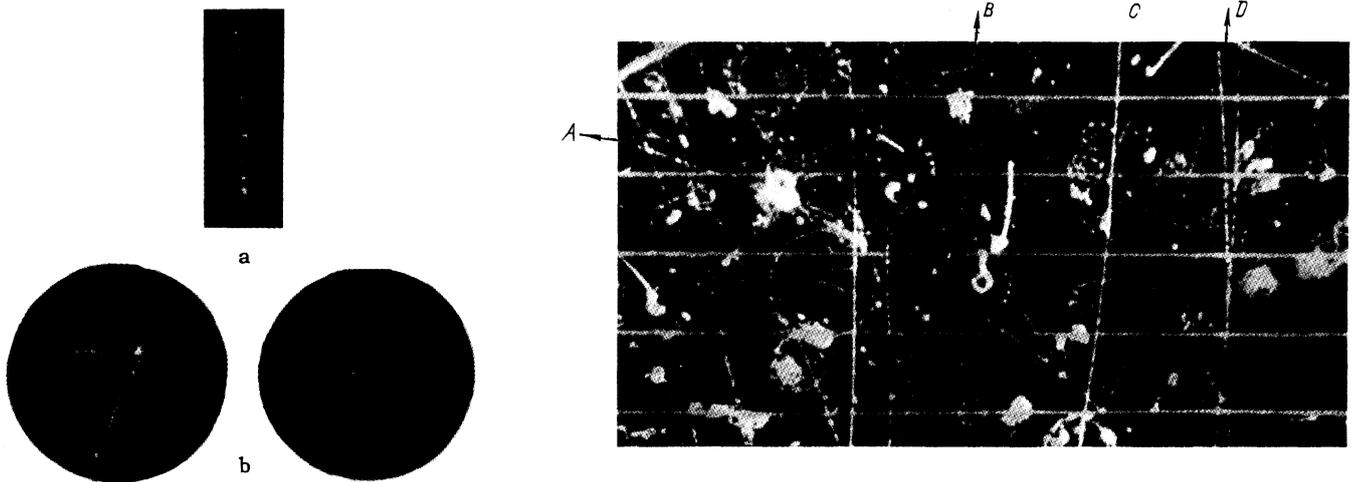


FIG. 2

easy to show that the difference in density of the tracks recorded from minimum did not exceed 10–20%. Under these conditions we photographed and measured on the negative a total track length of 10.4 cm (this corresponds to 41.6 cm in the crystal). In the photographs a track consists of individual points, each of which is formed by a single photoelectron emerging from the input photocathode.\*

The number of “points”  $m$  appearing on the image of 1 cm of track in the crystal, is given by the formula:<sup>2</sup>

$$m = [\gamma k^2 B^2 / 1600 (1 + k)^2 n^2 \epsilon] (dE/dx),$$

$$\gamma = 100 C_{IP} \eta (1 - f) \quad (1)$$

In this expression  $dE/dx$  is the energy loss of the particle per cm path in the luminescent crystal;  $n$ ,  $C_{IP}$  and  $\epsilon$  are, respectively, the index of refraction, the efficiency and the mean energy of photons of the luminescence in the crystal;  $\eta$  is the quantum yield of the photo cathode of the EOC;  $f$  is the coefficient for absorption and scattering of light along the path from the track in the crystal to the photocathode of the EOC;  $B$  and  $k$  are the aperture and magnification of the objective  $O$ . The experiment gave for the density of tracks of minimum ionizing particles a value  $m_{\text{exp}} = 5 \text{ cm}^{-1}$ , from which it follows that the coefficient in formula (1) is  $\gamma_{\text{exp}} = 0.4$  for our chamber. This is half the computed value  $\gamma_{\text{comp}}$ , obtained on the assumption that  $f = 0$ ,  $C_{IP} = 0.08$  and  $\eta = 0.1$ . Thus, because of light losses in the objective and crystal and

\*Neighboring points sometimes may fuse together, forming a “conglomerate.”

possibly also because of a somewhat reduced quantum yield of the photocathode used in the particular EOC employed in this experiment, or because of a reduced quantum yield of the luminescence of the NaI(Tl) crystal which we used, the density of tracks in our apparatus was half as great as the maximum possible.

In conclusion the authors express their gratitude to E. K. Zavoïskiï for valuable advice and discussion, and to L. S. Danelyan and V. V. Sklyarevskiï for providing the crystals.

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