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SYSTEM FOR FAST BEAM SPILL ONTO THE INTERNAL TARGET OF THE IHEP ACCELERATOR

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For the operation of bubble chambers in charged particle beams a comparatively low intensity is required - up to 10 particles in the acceleration pulse, with a duration of less than 1 microsecond.

In the IHEP accelerator, particle pulses of short duration are generated by rapidly spilling the accelerated beam onto an internal target. This is achieved by the well known method[/1/] consisting of producing a magnetic field which increases with time in a special bending magnet located in a straight section. The special feature of the system described here is that it involves the use of a slow C-shaped iron magnet having a magnetic field rise time of about 0.5 millisecond, in conjunction with a feed-back system directing the accelerated beam away from the target after a given number of particles have passed through the bubble chamber. To obtain the necessary intensity in the chamber, it is sufficient to train only a small part of the accelerated beam onto the target. In this way, by using a comparatively slow pulsed magnet it is possible to obtain a number of particles in the chamber which remains stable from one cycle to the next for a time interval not exceeding 1 millisecond. The use of the slow magnet considerably simplified the technical solution used for this system. The pulsed magnet, which is 1 m long, consists of bonded sheets of electrical steel 0.5 mm thick. Measurements showed that when a stainless-steel vacuum chamber with walls 0.4 mm thick was placed in the magnet gap, the drop in the magnetic field inside the chamber was no more than 5% at the frequency of 1 kHz. The data obtained are in good agreement with the calculated results obtained using the technique described in reference /2/. This enabled the magnet to be located outside the vacuum chamber.

Figure 1 is a block-diagram of the fast spill system. During the interval between the acceleration cycles the energy is accumulated in the condensor battery C_1. When switch T_4 is triggered the battery discharges into the magnet winding. The triggering moment of T_4 is determined by a pulse synchronised with the accelerator operation. The current decay in the magnet is obtained by triggering the switch T_3 with a pulse from the system that controls either the number of particles in the channel or the intensity of the particles spilled onto the target. The pulse from the output of this system reaches the triggering unit of the thyristor switch T_3. When T_3 is triggered, the opposing voltage of an additional capacitor C_2 is switched into the magnet circuit. This considerably shortens the current decay time in the magnet and consequently increases the speed at which the beam is directed away from the target. Figure 2 shows a pulse oscillogram of the current in the magnet (lower trace) and the pulse of secondary particles generated on the target (upper trace).

The relationship between the deflecting power of the magnet and the beam displacement at the azimuth of the target was calculated taking into account the actual characteristics of the accelerator's magnetic field, using the technique described in /3/. As an example, figure 3 shows the shape of the distorted orbit in the region of the target when a pulsed magnet of 1,5 k-oersteds/m was switched on. Figure 4 shows the dependence of the beam displacement, at the azimuth of the target, on the betation oscillation frequency. By using two magnets azimuthally displaced in relation to each other by a distance which is a multiple of a quarter of a betatron oscillation wavelength, it is possible to obtain the necessary deviation for any azimuthal position of the target by suitably selecting the currents in the magnets.

The radial operating range of the targets in the IHEP accelerator is ± 5 cm. To reduce the power requirements of the pulsed magnet to a minimum, the fast spill onto the target is effected in two stages. In the first stage, the accelerated beam is directed to the target by means of a slow system for exciting local inhomogeneity of the magnet field in the accelerator magnet units /4/. This system is switched on in advance and produces the required beam displacement on the azimuth of the target. Next, by means of the pulsed magnet the orbit is quickly distorted and the beam brought on to the target. To obtain the necessary intensity in the chamber it is sufficient to displace the beam rapidly by an amount less than the beam's diameter, i.e. several millimetres. The remaining part of the beam is subsequently trained on the other targets.

The fast particle spill system was investigated in a π^- meson beam of 40 GeV/c (channel 4B). A set of scintillation counters was installed in the channel together with an electronic system, their purpose being to produce the pulse which provided the signal for cutting off the current in the bending magnet after the first, second, fourth etc. particle recorded on the monitor, and to enable studies to be made of the time distribution of the particles in the channel. To study metering efficiency, a bubble chamber with an inlet window measuring 100 x 100 mm was installed at the end of the channel (the beam dimensions in the chamber region are 30 x 80 mm).

The number of particles in the pulse depends on the arrangement of beam and target in relation to each other, the condenser charge voltage and the metering level.

Figure 5 shows the distributions of the number of particles in the pulse from one cycle to the next. The continuous curve relates to operation without metering, and the dashed curve to operation with metering from the first particle. In the case of metering from the second particle this distribution becomes wider and moves towards the larger number of particles. The distributions given relate to operation without the additional condenser which reduces the current decay time in the magnet.

Figure 6 shows the distribution when the cut-off is made from the first particle and when the additional condenser is switched on. The time distribution of the particles in the pulse is given in figure 7. The pulse duration is 500 - 600 μ-sec, which is fully acceptable for large bubble chambers. No particles are observed outside this background range.

All of the distributions shown were obtained with counters. They are in good agreement with measurement results from the bubble chamber. Figure 8 is an example of the particle photographs taken in the chamber. Measurements showed that the load factor of the chamber and the background prevailing when operating with the above system are fully satisfactory for the performance of the experiments.

References

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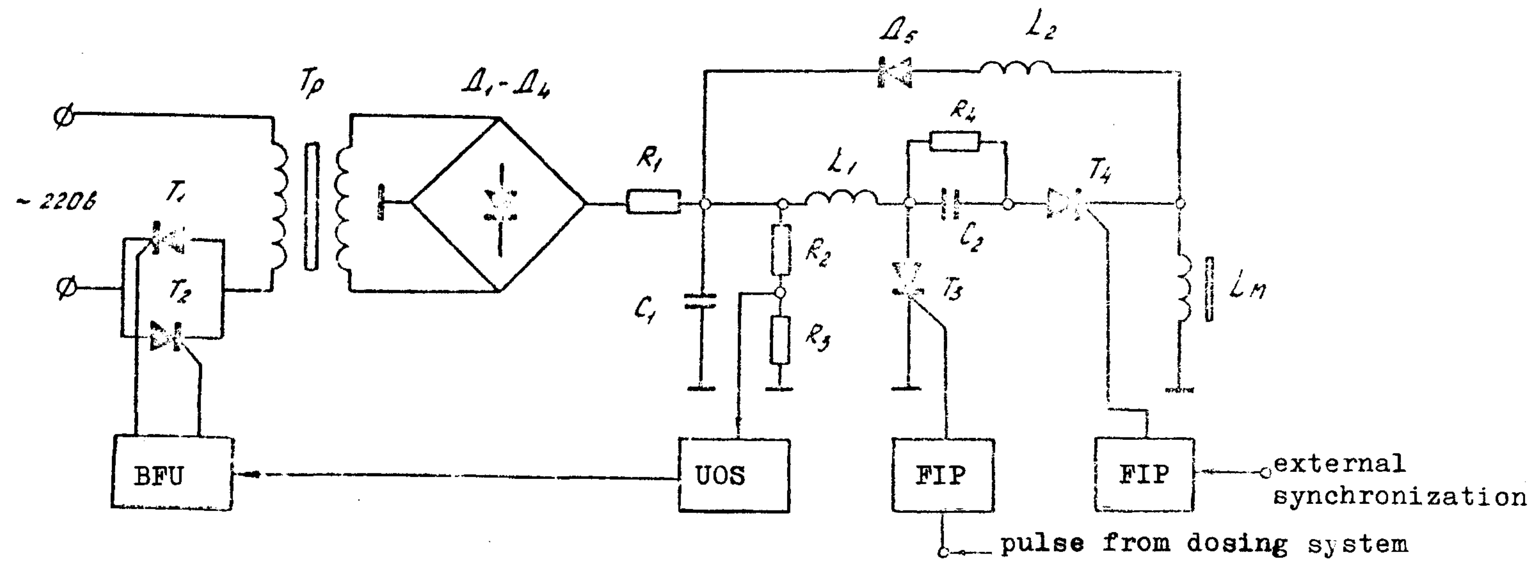


Fig. 1. Block diagram of the fast spill system
BFU - phase control unit
UOS - feed-back amplifier
FIP - triggering-pulse shaper.

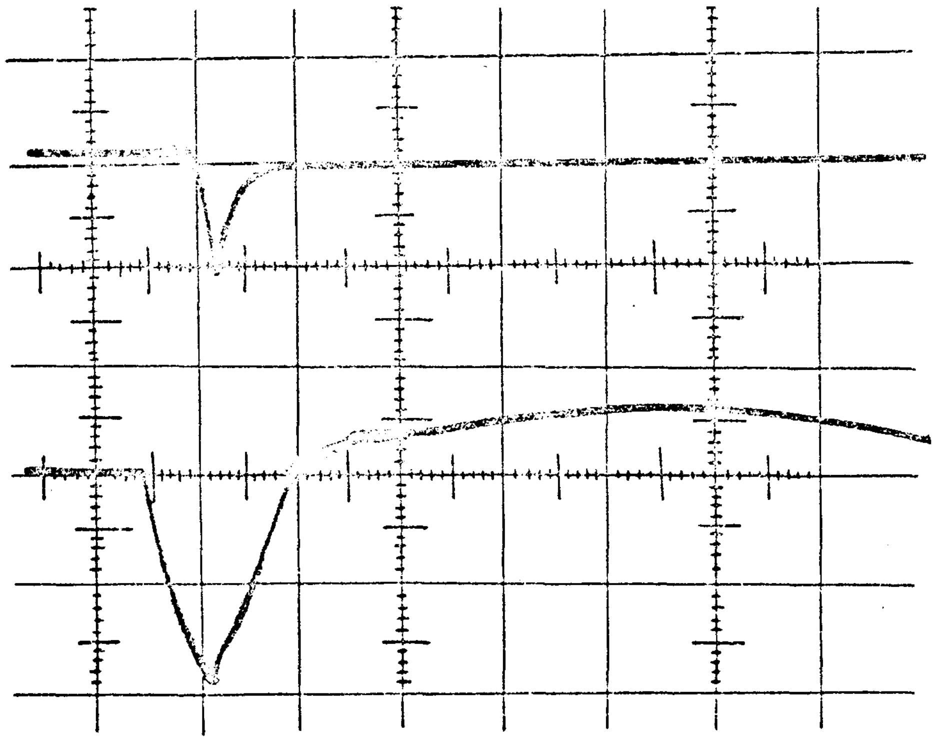


Fig. 2. Oscillogram of the signal from the particle monitor (upper trace)
Oscillogram of the current pulse in the magnet (lower trace)
Time scale: 500 microseconds per division.

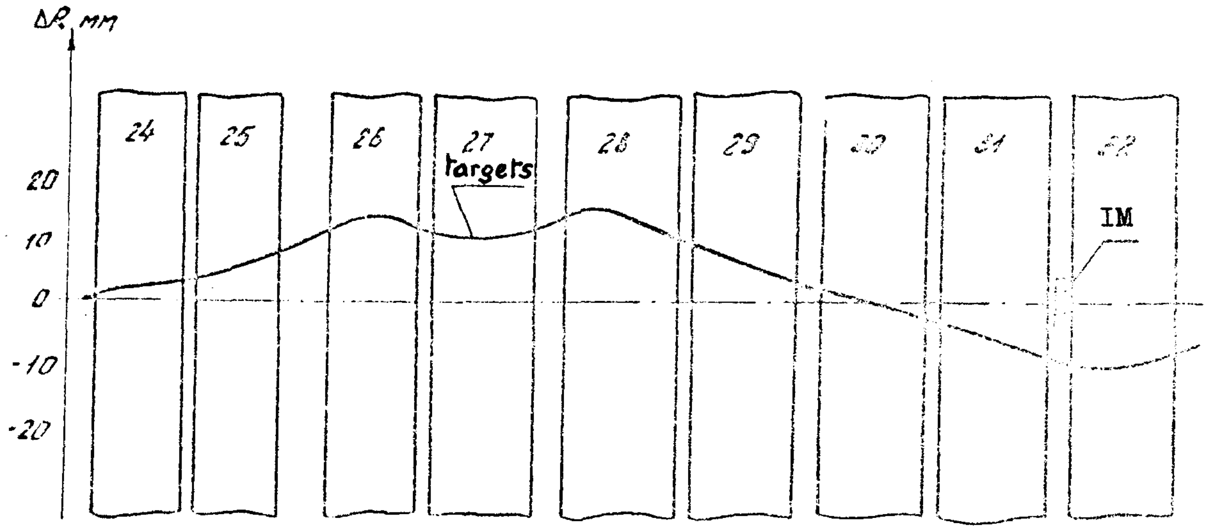


Fig. 3. Section of the disturbed orbit. IM = pulsed magnet.

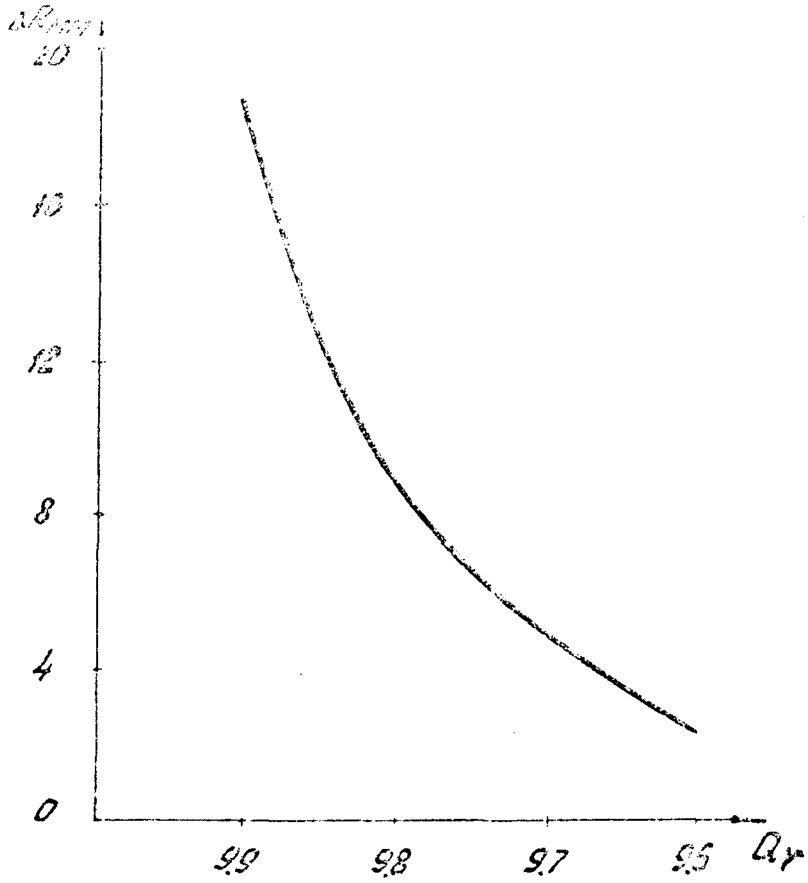


Fig. 4. Dependence of beam displacement in the region of the target Q_r .

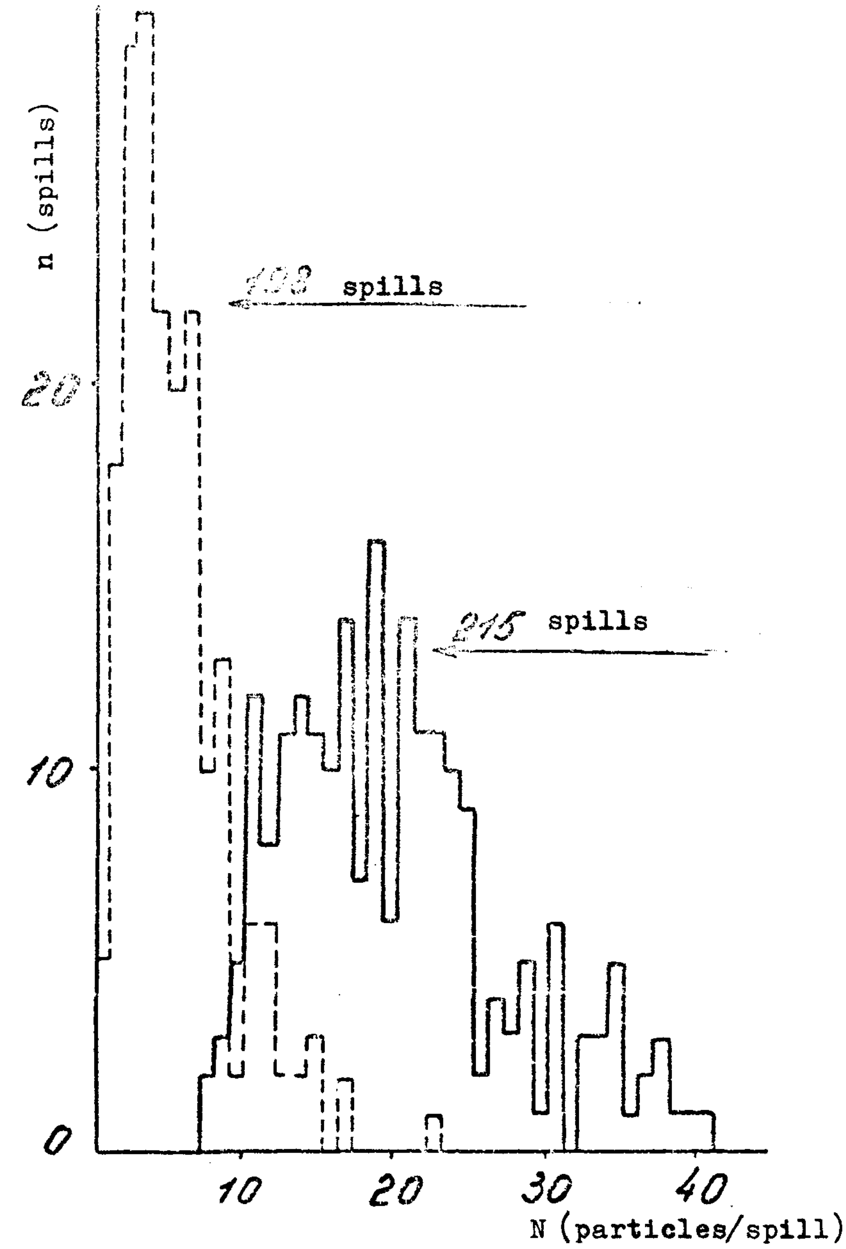
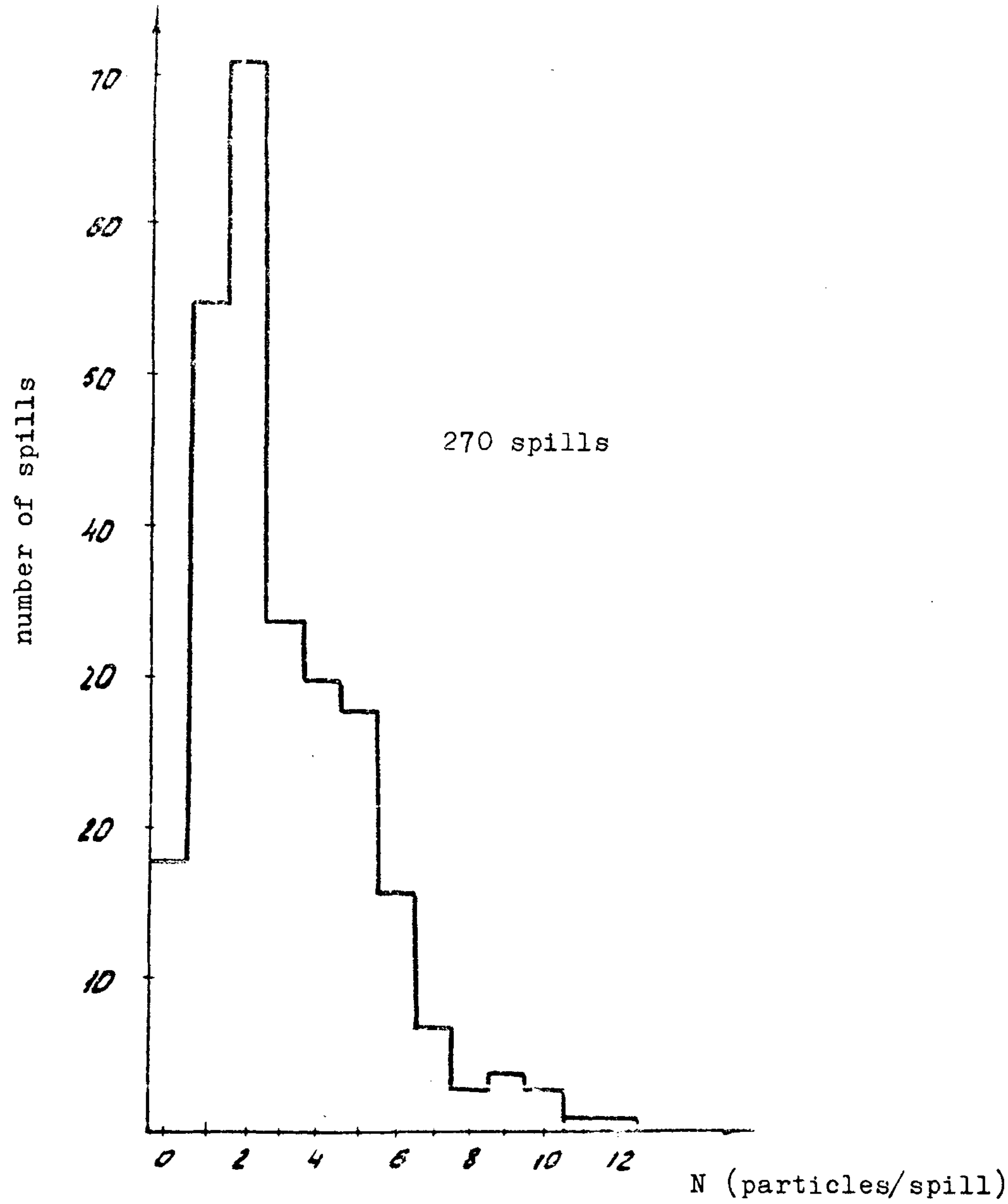


Fig. 5. Distribution of the number of particles in the pulse, when operating without metering (continuous bars) and with metering of the first particle. Operation without condenser C_2, which reduces the current decay time in the magnet.



<u>Fig. 6</u>. Distribution of the number of particles when metering from the first particle. Operation with condenser C_2.

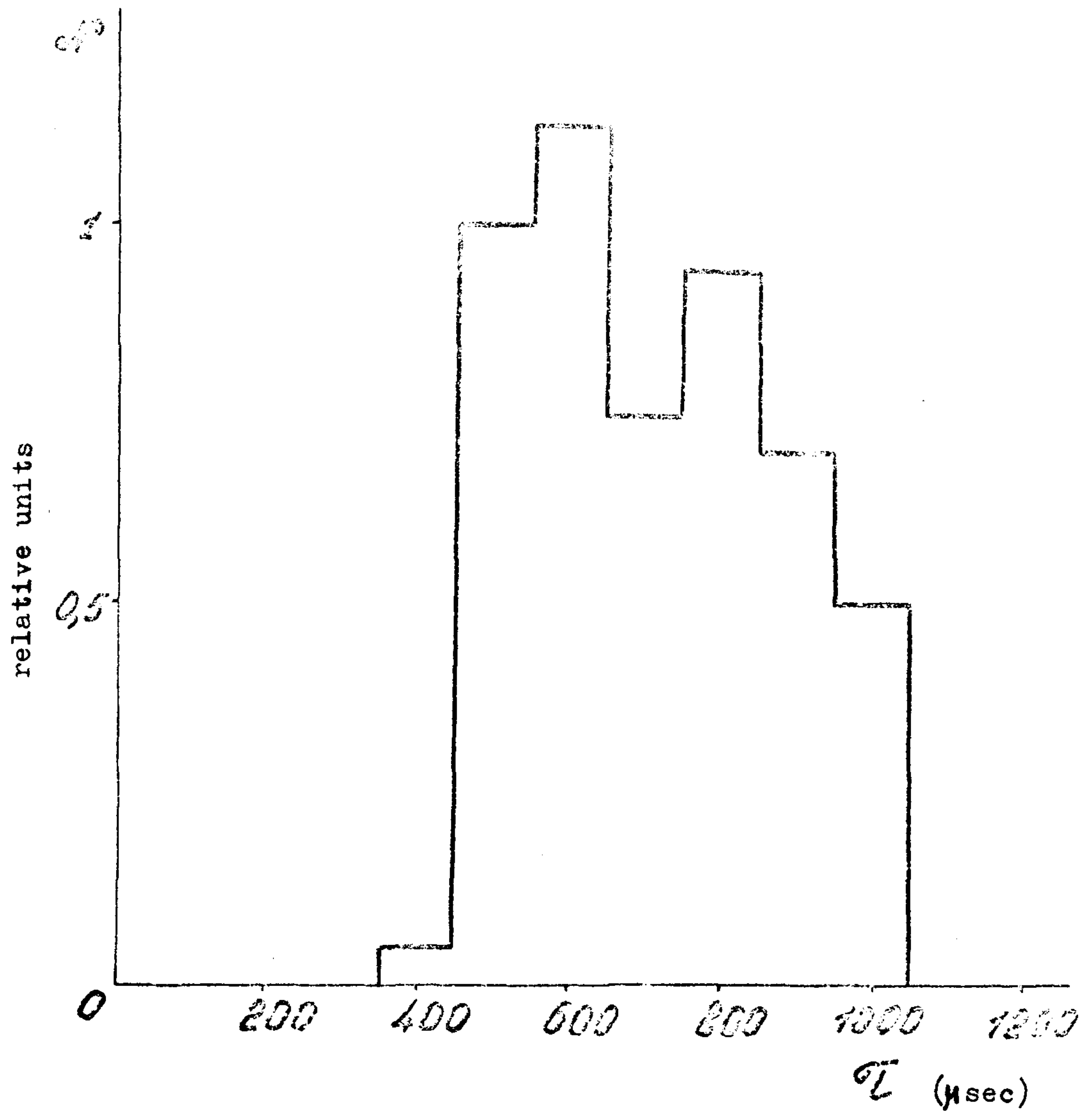


Fig. 7. Time distribution of the particles in the pulse.

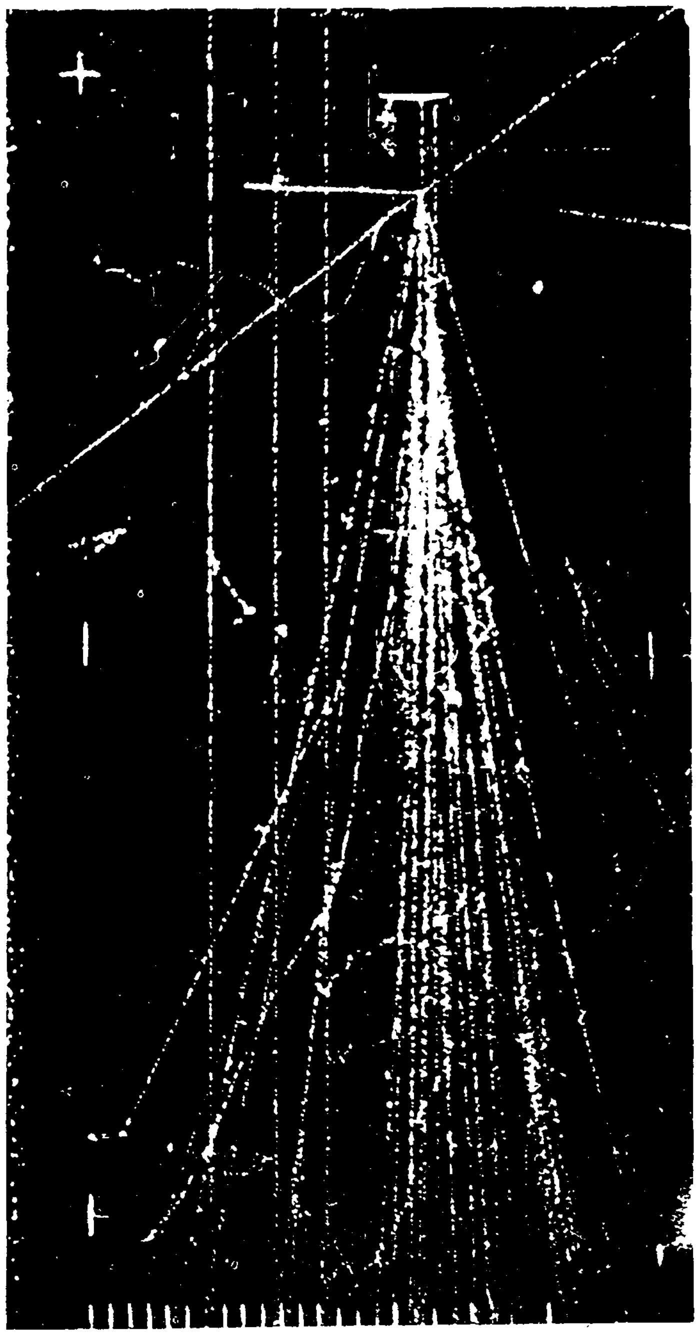


Fig. 8. Bubble chamber photograph of particle tracks.