EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

TRACK LOCALIZATION BY MEANS OF A DRIFT CHAMBER*)

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1. INTRODUCTION

The accurate localization of the trajectory of a particle is of obvious importance. Fast non-visual localization techniques are especially desirable for on-line information processing. Spark chambers have achieved accuracies of a few tenths of a millimetre. Proportional chambers are capable of similar performance. We present here a method which should permit improving on these figures, though the presently achieved accuracy is about ±0.1 mm.

A drift space was added to a proportional chamber. The electrons liberated in the gas of the drift space move under the influence of a uniform electric field, pass through a grid into the proportional chamber, and are detected there. The time taken to cross the drift space gives a measurement of the position. This method of coordinate determination should have an accuracy limited by: 1) the inherent width of the track due to δ rays and scattering; 2) diffusion of the electrons in their flight; 3) timing inaccuracies. At present the latter two effects dominate.

2. DESCRIPTION OF APPARATUS

Figure 1 is a schematic drawing of the chamber. The drift space is 3 cm high × 12 cm × 12 cm. The proportional chamber is 1.4 cm high, with the wires in the centre. A grid with a transparency of 90% separates the two sections. The proportional chamber was first constructed with the wires spaced at 1 cm intervals and was later reconstructed with 2 mm spacing.

The beam passed through the drift space, leaving a trail of ions and electrons. The electrons moved perpendicular to the beam under the influence of the drift space field, passed through the grid, and were detected in the proportional chamber. Scintillation counters 2 mm high defined the beam and provided the zero of time. The time from T_0 until signals appeared in the proportional chamber was digitized. In order to determine the space resolution that could be obtained, the chamber was divided into three parts. When the wire spacing was 1 cm, 3 adjacent wires in the centre of the chamber were used as detectors. With the 2 mm spacing, 3 groups of 5 wires in parallel were used. The resolution was determined by measuring the width of the distribution of the quantity ΔT defined as:

$$\Delta T = \frac{T(1) + T(3)}{2} - T(2) ,$$

where T(i) is the time of flight to the (i) detector. Number 2 is the middle detector. Thus, the single chamber was treated as though it were 3 independent chambers.

Each wire or set of wires had a amplifier whose output went to a discriminator, the output of which provided the stop signal for a time-to-pulse height converter. The start signal was given by the scintillation counters coincidence. The output pulses from the time-to-amplitude converters were digitized and recorded on magnetic tape.

3. RESULTS

The space resolutions were determined by measuring the time resolutions and the drift velocities. The drift velocities were measured by displacing the chamber a known distance in the beam and measuring the corresponding changes in drift time. The best time resolutions were 5 nsec (Fig. 2). The timing electronics was stable to 2 nsec. The variations in time due to fluctuations in amplitude of the signal are not known, but they were minimized by running the proportional chambers at gains high enough to saturate the amplifiers. The gas mixture used for these tests was 3% propane-97% argon.

With the chamber wires spaced at 1 cm, the best spatial resolution obtained was about 0.3 mm for tracks near the grid. For tracks 2.5 cm from the grid the resolution went to 0.5 mm. These and subsequent resolutions are full width at half-maximum. The figures above are for a drift field of about 70 V/cm and for protons about 100 MeV.

For the chamber with the wires spaced at 2 mm, the resolution near the grid was 0.18 mm and at 2 cm distance, the resolution was 0.4 mm for 100 V/cm drift field. The drift velocity was 2.5×10^6 cm/sec. When the drift voltage was increased to $\sim$ 600 V/cm the resolution near the grid was about 0.2 mm and 0.25 at 1.4 cm. The drift velocity was 4×10^6 cm/sec. Increasing the voltage to 800 V/cm reduced the drift velocity by $\sim$ 10% without changing the resolution significantly.

4. DISCUSSION

The main contribution to the width of the resolution seems to have been the diffusion of electrons during their drift. The radius of diffusion of a swarm of electrons is proportional to $\sqrt{Dt} = \sqrt{Dx/v}$, where D is the diffusion coefficient of electrons in the gas, t the drift time, x the distance, and v the drift velocity. From kinetic theory it can be shown[1]) that the following relation holds:

$$D/v = \frac{3kT}{2FcE} ,$$

where kT is the mean agitation energy of the electrons, c is the electronic charge, E is the applied field, and F is a quantity which depends on the mean free path and velocity distribution of the electrons. In an argon-organic gas mixture, the quantities T and F, once the inelastic thresholds have been reached, are slow functions of the electric field, and thus we would expect D/v to fall roughly as 1/E. Thus, for a given gas mixture, we would expect the width of the electron cloud to fall as $\sqrt{1/E}$. Indeed we found that, as the field was increased from 100 to 600 V/cm, the resolution for long drifts improved markedly. This has to be pushed to still higher fields and longer drift distances. Other gas mixtures should be studied to find lower electron temperatures.

We probably also had timing variation due to the fact we used a standard amplitude discrimination rather than a circuit that would determine the centre of the pulse. When minimum ionizing particles rather than 4 times minimum were used, the resolution worsened, and there was a displacement in time of 10 nsec.

Improvements in the electronics, higher drift fields, and work on different gas mixtures should lead to better resolution. Inherent widths due to δ rays could be eliminated by pulse-height analysis with rejection of those tracks that deposit large energies in the chamber.

Acknowledgements

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REFERENCE

1) R.N. Varney and L.H. Fischer, in Methods of Experimental Physics (Ed. Bederson and Fife) (Academic Press, New York, 1968), Vol. 7B, p. 29-77.

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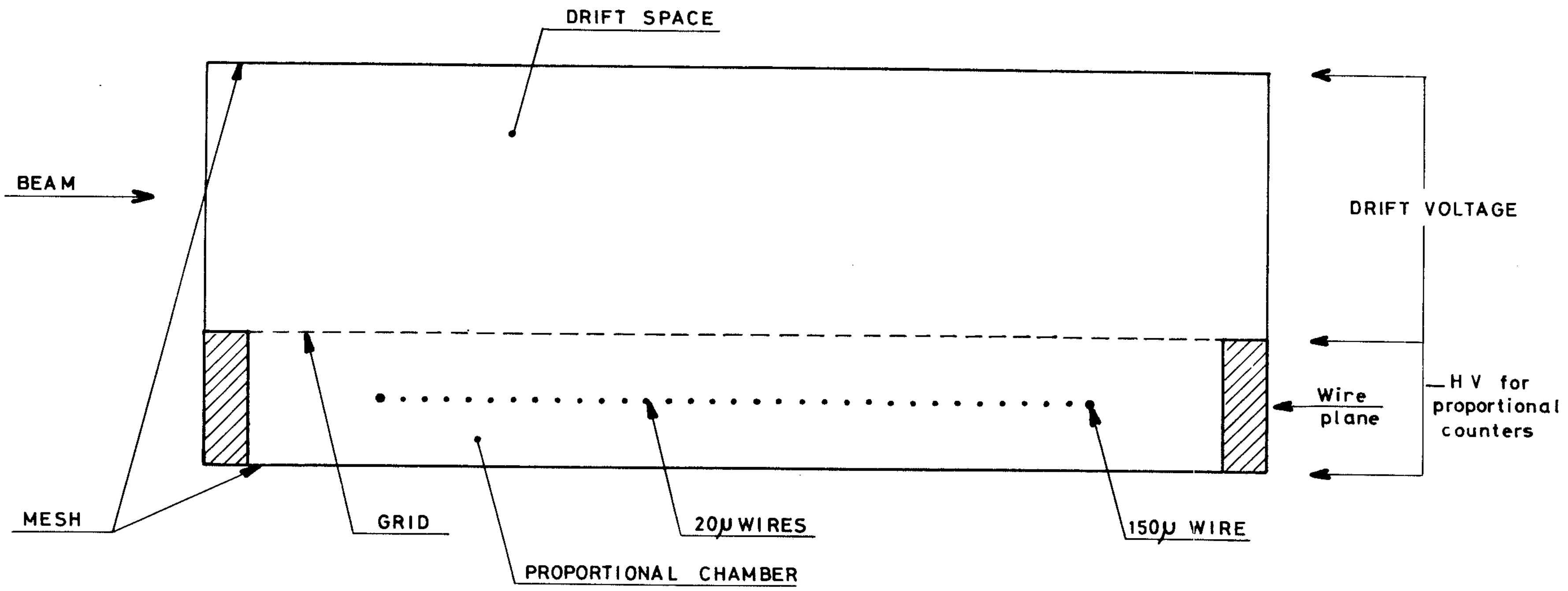
Figure captions

Fig. 1 :	Schematic design of the drift chamber. Electrons liberated by the beam drift through the grid and are detected in the proportional chamber.
Fig. 2 :	An example of the time spectrum, ΔT, as defined in the text.



DRIFT CHAMBER

FIG.1

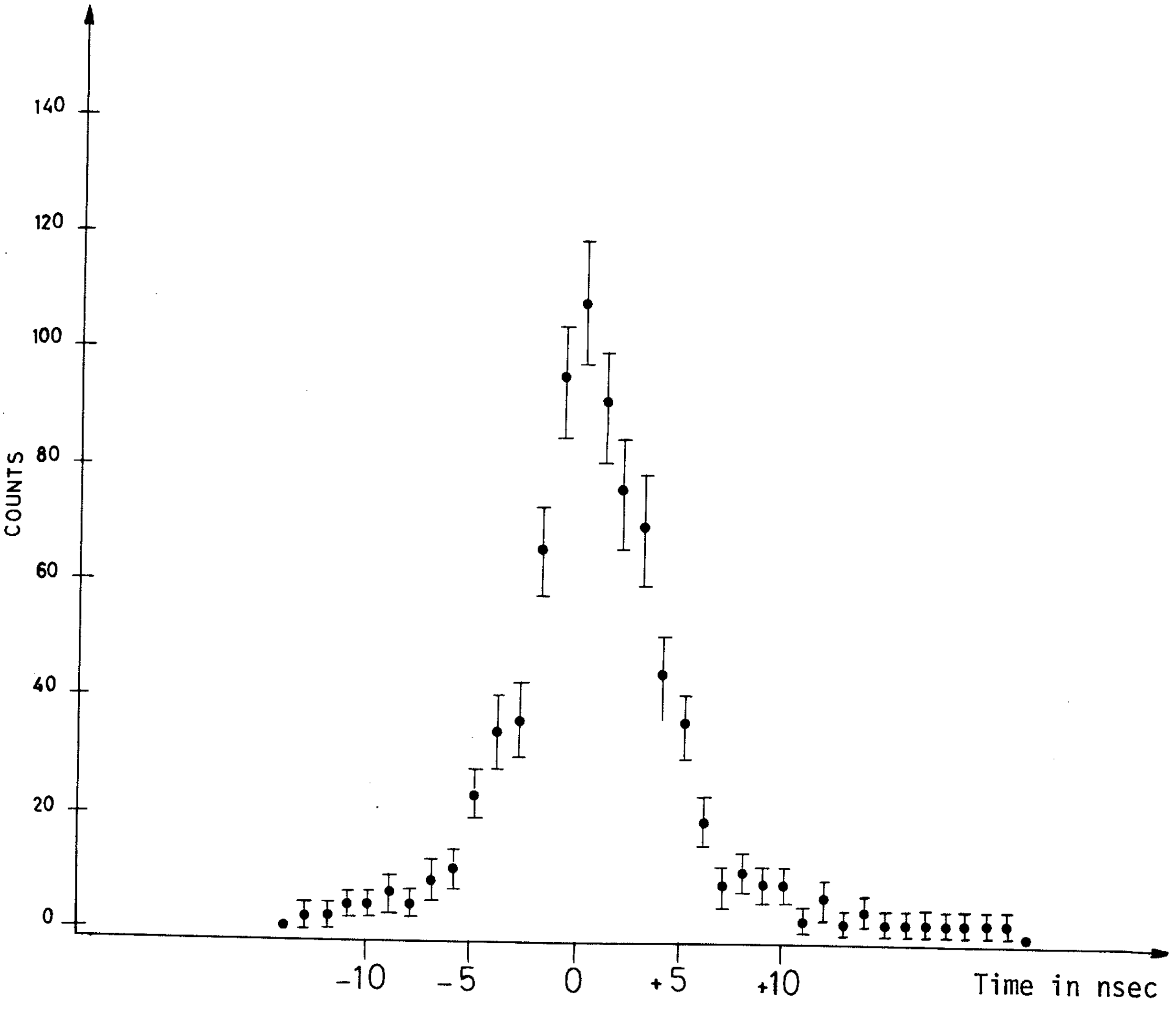


FIG.2