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# STUDY OF DRIFT TUBES WITH FIELD SHAPING ELECTRODES IN THE BEAM OF SERPUKHOV ACCELERATOR

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## Abstract

Antipov Yu. et al. Study of Drift Tubes with Field Shaping Electrodes in the Beam of Serpukhov Accelerator: IHEP Preprint 94-58. - Protvino, 1994. - p. 10, fig. 6, refs.: 6.

The design of the drift tubes with flat and wire field shaping electrodes is described. The physical characteristics of the tubes are studied with gas mixture $90\% Ar + 10\% CO_2$. The comparison of two drift tube options is presented.

## Аннотация

Антипов Ю.М. и др. Исследование характеристик дрейфовых трубок с полеформирующими электродами на пучке Серпуховского ускорителя: Препринт ИФВЭ 94-58. - Протвино, 1994. - 10 с., рис. 6, библиогр.: 6.

Описаны конструкции дрейфовых трубок с полеформирующими электродами двух модификаций — в виде пластин и в виде проволок. Изучены физические характеристики трубок на газовой смеси 90% Ar+10% $CO_2$. Приведено сравнение характеристик двух модификаций трубок.

# Introduction

Modern physical facilities used in high energy physics collider experiments have very large sizes ($\sim$ 1000 $m^3$) and a great number of registration channels ($10^5$ – $10^6$). The essential part of these facilities is a large area muon tracking system with high space resolution. For example, the SDC [1] facility proposed for the SSC collider had to have a muon tracking system with the total area of about $10^4$ $m^2$ and the coordinate accuracy $\leq$ 250 mkm.

Because of relative simplicity in manufacturing and high reliability, drift tubes are certainly very attractive when designing such muon tracking systems. For example, the muon spectrometer SAMUS of the D0 facility [2] consists of about 6000 "classic" drift tubes based on the stainless steel round tubes 30 mm in diameter with one anode wire along the axis of each tube. But the "classic" drift tube is characterized by the fast decrease of electric field strength (as $1/r$, where $r$ is the tube radius), so the electron drift velocity saturation is practically impossible for the tubes with the diameter larger than 30 mm. Moreover, the two-track resolution of the "classic" drift tube with the "standard" read out electronics can not be less than the tube diameter. Field shaping electrodes inside the drift tube allow one to overcome the above difficulties.

## 1. Drift tubes with flat field shaping electrodes

The drift tubes with flat field shaping electrodes were proposed in 1992 by the specialists of SSCL to be used in the central muon system of the SDC facility [1]. These drift tubes were made of an aluminium round tube profile with anode wire stretched along the profile axis and two flat electrodes mounted at the T-like ledges inside the tube (fig.1a). The electrodes were isolated from the ledges by dielectric plastics. The high voltage potential applied to the flat electrodes is close to that of the anode wire. These electrodes allow one to concentrate the electric field lines coming out from the anode wire in the narrow (about 10 mm wide) region along the tube axis (fig.1b). The electric field strength sufficient for the drift velocity saturation can be achieved in such a tube. For example, the mean electric field strength in the 90 mm inner diameter SDC drift tubes at voltages 6.5 kV applied both to the 90 mkm anode wire and field shaping electrodes is about 1000 V/cm (fig.1c). This value corresponds to the plateau of the drift velocity dependence on the electric field strength for the gas mixture $90\% Ar + 10\% CO_2$. The variation of the drift field is less than 10% within the distance from the anode wire 0.8 cm to 4.2 cm.

In our opinion this drift tube option has some disadvantages:

1. The effective thickness of the above mentioned tubes is more than two times larger than that of the "classic" tubes because of much thicker wall (1.6 mm against 0.7–1.0 mm for standard aluminium tubes) and the presence of T-like ledges.

2. When extruding the aluminium profile its twist can take place. For the drift tube with flat field shaping electrodes such a twist causes irregular nonuniformitiy of physical characteristics along the drift tube length.

3. Uncontrollable changes of the surface charge collected on the plastics inside the tube with flat field shaping electrodes can lead to uncontrollable changes in the electric field and therefore to worsening the coordinate accuracy.

4. The special aluminium profile made with high accuracy is much more expensive than a standard aluminium tube.

## 2. Drift tubes with wire field shaping electrodes

In 1992 we proposed [3] another drift tube design (fig.2a) based on thin wall (1 mm thick) aluminium round tube with one anode wire and four additional wires for electric field shaping. The potential $U_f$ applied to field shaping wires is approximately equal to the potential $U_a$ at anode wire. The condition $U_f = U_a$ is the most preferable because it minimizes the required number of connectors, cables, HV power supplies and thus, higher reliability could be achieved.

The arrangement of the field shaping wires inside the tube ($D_X, D_y$ parameters on fig.2a) must be optimized for the concrete gas mixture, tube and wires diameters. A detailed description of the optimization procedure will be given elsewhere.

The drift field lines and the electric field strength along the X-axis simulated by GARFIELD code [4] for the drift tube with the inner diameter 50.6 mm, $D_X = 11$ mm, $D_y = 32$ mm, $U_a = U_f = 3.5$ kV are shown in fig.2b,c.

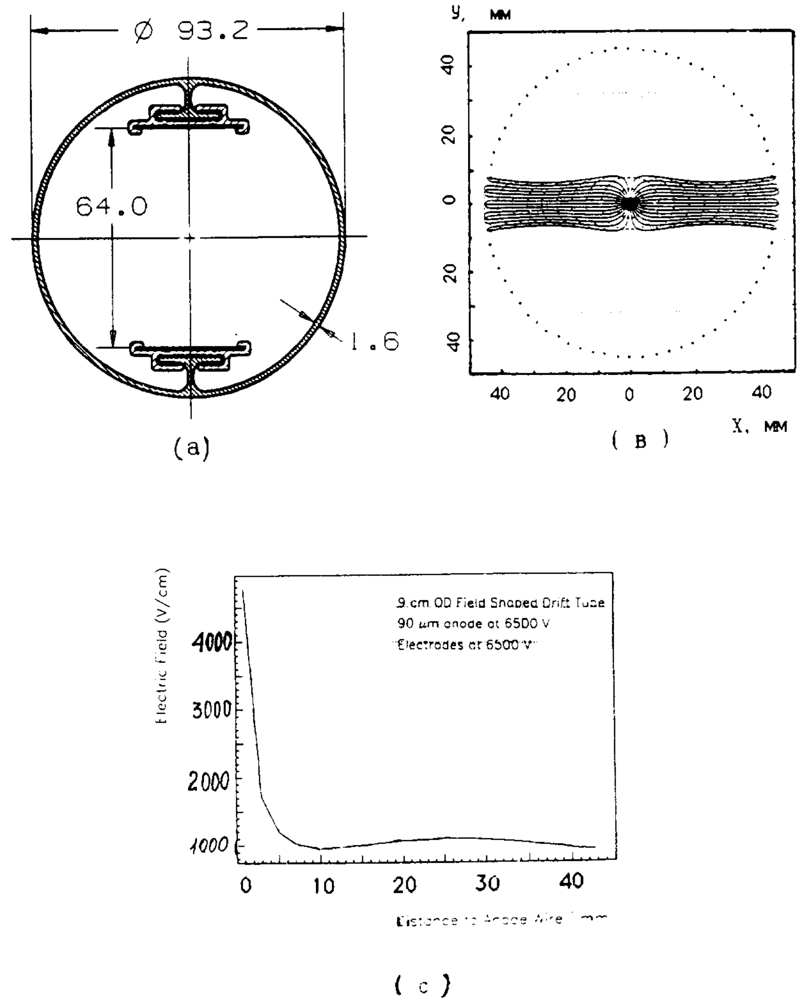
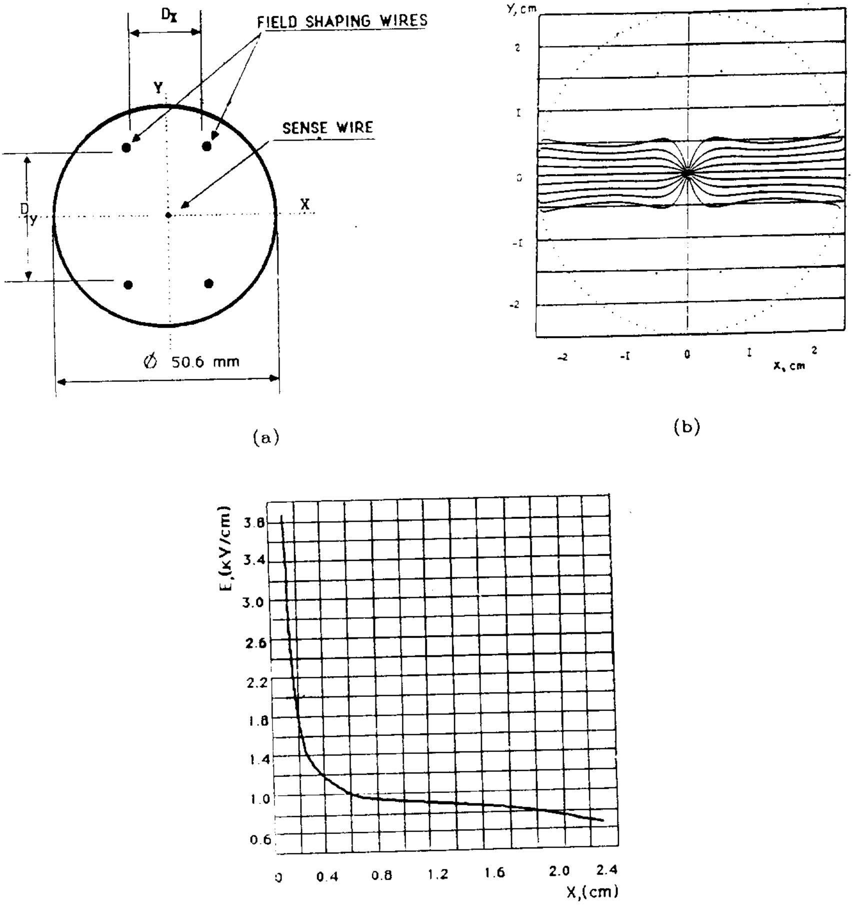


Fig. 1. (a) The cross-section of the drift tube with flat field shaping electrodes.
(b) Drift field lines for 90 mm inner diameter drift tube with voltages at anode and electrodes 6.5 kV.
(c) The electric field strength vs the distance from the anode wire.



(a) (b)

(c)

Fig. 2. (a) The cross-section of the drift tube with wire field shaping electrodes.
(b) Drift field lines for voltages at anode and electrodes 3.5 kV.
(c) The electric field strength vs the distance from the anode wire.

## 3. Study of the drift tubes characteristics

The results of the experimental study of the flat field shaping electrodes drift tubes with 43 mm and 73 mm inner diameters and the wire field shaping electrodes drift tube with 50.6 mm inner diameter are presented. The length of the tubes was 40 cm. The characteristics of a long (7.4 m) drift tube with wire field shaping are presented in [5]. The anodes of all drift tubes were made of the 50 mkm gold-plated tungsten wire, the field shaping wires were made of stainless steel of 200 mkm diameter. All quoted results were obtained with the "standard" $90\% Ar + 10\% CO_2$ gas mixture.

The read-out electronics included preamplifiers and comparators which provided a possibility to register up to 4 hits per event from each drift tube [6]. The shaping time was about 40ns, the threshold sensitivity could be varied. The presented results were obtained with 1.5 mkA threshold. The time-digital convertor had an accuracy of 0.3 ns/count with integral nonlinearity $\leq 0.2\%$ in the range up to 1000 ns.

The studies were made in the 40 GeV/c $\mu-$ and $\pi-$mesons beam of the Serpukhov accelerator. Three identical drift tubes were studied simultaneously with the experimental setup that is schematically shown in fig.3. It included three scintillation counters and two sets of proportional chambers. The proportional chambers define the particles coordinates in the drift tubes with an accuracy of 0.3 mm. The dependencies of the drift time versus the distance from the sense wire and deviations from the linearity for the three drift tubes options are presented in fig.4. It is seen that in all the tubes options the time-coordinate dependence is practically linear in the whole coordinate range.

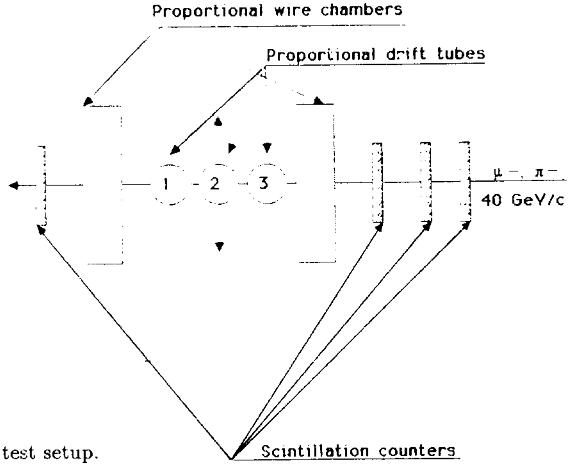


Fig. 3. The schematics of the test setup.

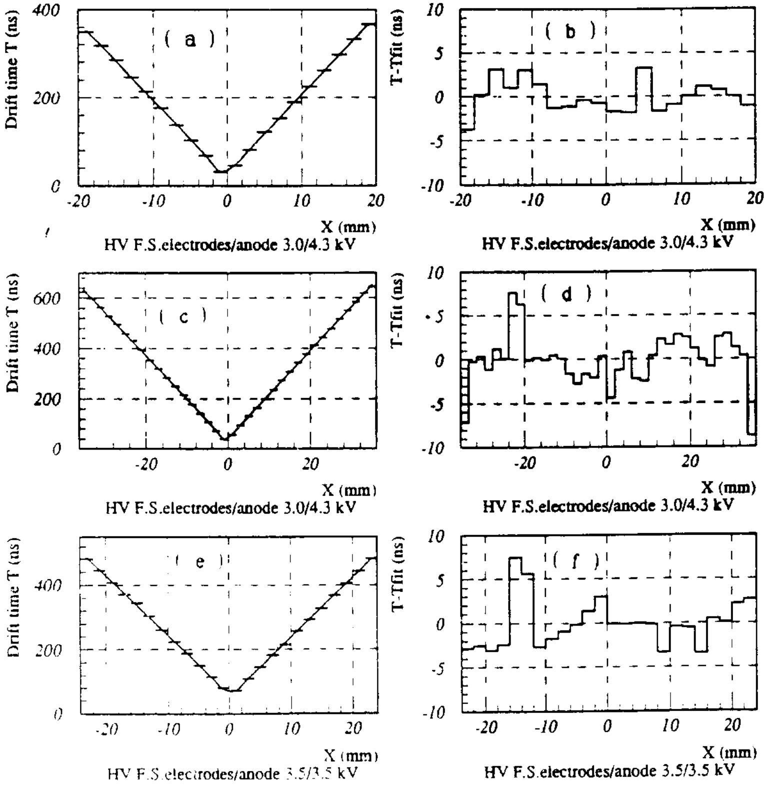


Fig. 4. Measured time-coordinate relations and deviations from linearity for:
a, b – the 43 mm drift tube with flat field shaping electrodes;
c, d – the 73 mm drift tube with flat field shaping electrodes;
e, f – the 50.6 mm drift tube with wire field shaping electrodes.

The spatial resolution of the drift tubes is better than that defined by proportional chambers. So we determined the drift tubes resolution $\sigma(X)$ using the drift tubes themselves:

$$\delta(t) = (t_1 + t_3)/2 - t_2, \quad \sigma(X) = V \cdot \sigma(t)/sqrt(1.5),$$

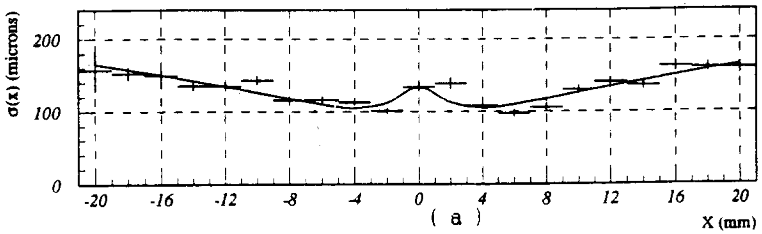
where $t_1, t_2, t_3$ — measured drift times in three identical drift tubes, $V$ — the drift velocity, X — the distance from the anode wire. The dependencies of coordinate resolution $\sigma(X)$ obtained by this method are shown in fig.5. Except the narrow region $X \sim 3-5$ mm near the anode wire, the $\sigma(X)$ dependence can be presented as $\sigma(X) = sqrt(D \cdot X + C^2)$, where $D$ is the diffusion coefficient, $C$ is the constant term about $70 - 100$ mkm. At $X = 10$ mm the contribution from the diffusion term $sqrt(D \cdot X)$ is about 100 mkm.

When studying the two-track resolution drift tube 2 could be shifted perpendicularly to the beam direction (fig.3). The two-track resolution was studied with a single track but in two separate shifted tubes. The signals from anode wires of tubes 2 and 3 were summed electrically and sent to the common preamplifier. The shift value $\delta X$ when read-out electronics begins to register effectively two signals from the common preamplifier defines the two-track resolution (fig.6). In our case it was about 2 mm for all studied drift tubes options and was mainly defined by the shaping time of the preamplifier.

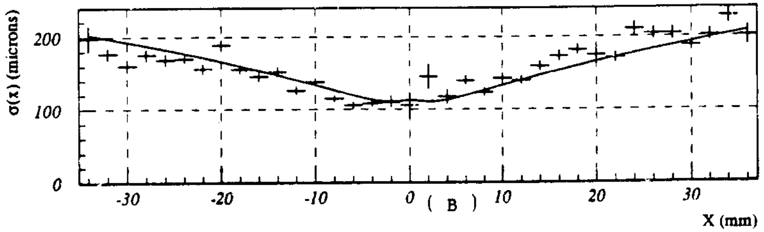
The mean hits multiplicity in our measurements was $\cong 1.2$. It was essentially independent of the tube option and was mainly caused by the registration of high energy $\delta-$electrons.

## Conclusion

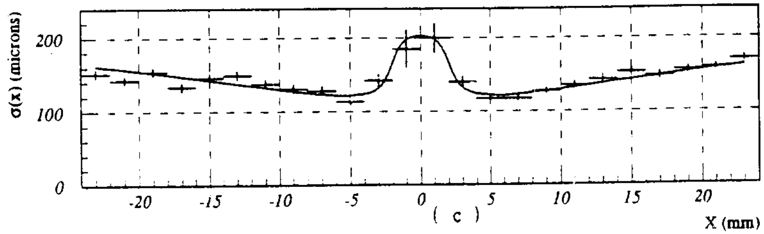
The studied drift tubes with flat and wire field shaping electrodes have shown very close characteristics and can provide coordinate resolution from 100 mkm to 200 mkm depending on the tube radius, the two-track resolution of about 2 mm and the linear time-coordinate dependence almost in the whole coordinate range. We think that the drift tube option with wire field shaping is more preferable because it has no shortcomings mentioned earlier in chapter 1.



HV F.S.electrodes/anode 3.0/4.3 kV



HV F.S.electrodes/anode 3.0/4.3 kV



H.V. F.S.wires/anode 3.5/3.5 kV

Fig. 5. Measured spatial resolution vs coordinate dependencies for:
(a)- the 43 mm drift tube with flat field shaping electrodes;
(b)- the 73 mm drift tube with flat field shaping electrodes;
(c)- the 50.6 mm drift tube with wire field shaping electrodes.

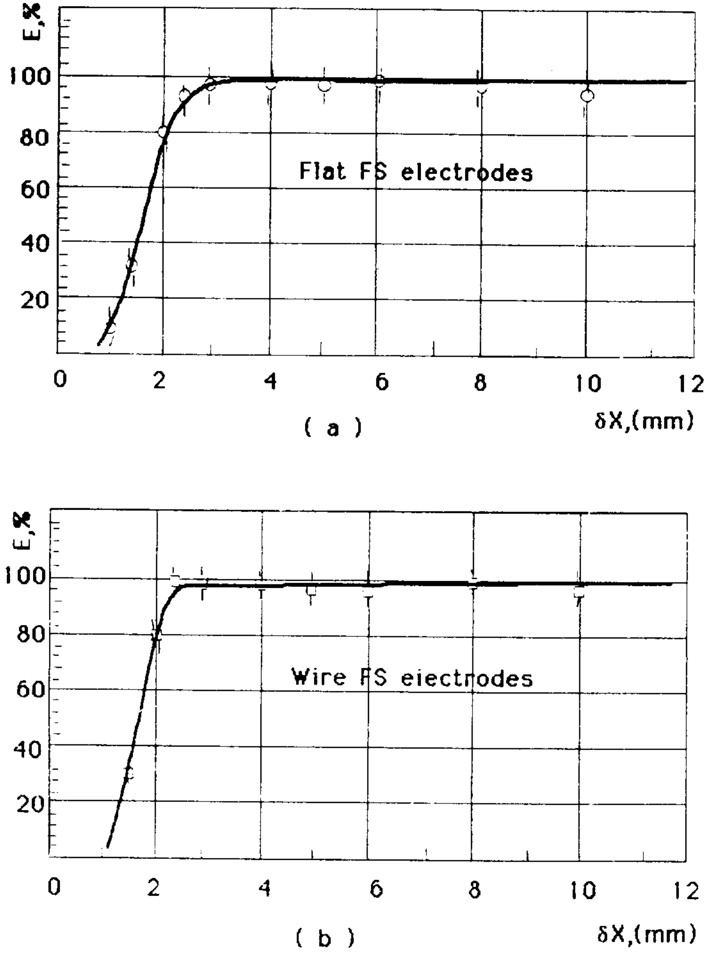


Fig. 6. The second track registration efficiencies for different two-track distancies for drift tubes with flat (a) and wire (b) field shaping.

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