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THE PRELIMINARY STUDY OF PRESSURIZED DRIFT TUBES AS A DETECTOR FOR PRECISION MUON TRACKING

G.D.Alekseev, S.A.Baranov, Yu.E.Bonushkin, G.A.Shelkov, B.Fialovski, G.V.Karpenko, N.N.Khovansky, Z.V.Krumstein, V.L.Malyshev, Yu.V.Sedykh, V.V.Tokmenin

The pressurized cylindrical drift tubes are proposed as a detector for precision muon tracking. Such a detector is suitable where high individual coordinate accuracy (well below 100 microns) is needed and it helps to decrease remarkably a number of detecting layers. The preliminary results include an accuracy versus gas pressure dependence obtained with the system of stainless steel tubes of 0.2 mm wall thickness, 20 mm in diameter and 40 cm long operated in the self-quenching streamer mode, using Ar/CH4/C4H10=75/8/17 gas mixture.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Изучение дрейфовых трубок повышенного давления в качестве точного детектора для мюонных систем

Г.Д.Алексеев и др.

Цилиндрические дрейфовые трубки повышенного давления предложены в качестве точного детектора для мюонных систем. Такой детектор необходим в случае потребности в координатной точности лучше 100 микрон, он также позволяет значительно уменьшить число детектирующих слоев. Предварительные результаты включают зависимость разрешения от давления, полученную на системе трубок из нержавеющей стали с толщиной стенок 0,2 мм, 20 мм в диаметре и длиной 40 см, которые работали в самогасящемся стримерном режиме на газовой смеси Ar/CH4/CH10=75/8/17.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

1. Introduction

The investigation of an accuracy versus gas pressure dependence was done with the system of stainless steel tubes 20 mm in diameter operating in self-quenching streamer mode at different voltages. The tubes were exposed at the electron beam of Serpukhov accelerator.

The main idea of the study is to measure the achievable coordinate accuracy with a tube of relatively large diameter. The results obtained with «straw» tubes [1] indicate that with small diameter (few mm) and in streamer mode of operation one can improve accuracy with pressure roughly as $1/p$. At such a diameter the statistics of primary ionization has an important contribution to an accuracy. With increasing diameter (few cm) the diffusion plays increasing role and one could try to minimize it varying mode of operation, readout scheme, etc.

Coming from analogy with «straw» tubes let us call this detector "bamboo" tubes because of bigger diameter and more regidity.

This detector was proposed [2,3] as a good candidate for precise muon tracking for spectrometers with ironless muon systems.

The present study is performed following the JINR research plan item «Development of detectors for installation to be used with future colliders» and as a part of common R&D of Laboratory of Nuclear Problems JINR (Dubna) and Max Plank Institute (Munich) on precise muon tracking.

2. Experimental Setup

Bamboo tubes were 40 cm long, 20 mm in diameter with stainless steel wall 0.2 mm thick and gold-plated tungsten wire 50 microns in diameter, strung with 400 ġ. The chamber includes 4 parallel tubes, the forth one is shifted by 8 mm (fig.1). The tubes are blown in parallel from a common volume which also contains high voltage circuit.

The measurements were done making use of very high intensities 2*10**4 and 1*10**4 1/s per cm of anode wire for 10 and 15 GeV electron beam, respectively. Tracks were selected by coincidence of two scintillators and three unshifted tubes. XP1020 photomultiplier (S1) provided good timing signal for start in drift time measurements.

Tubes were operated in the self-quenching streamer mode with signal average amplitude ranged

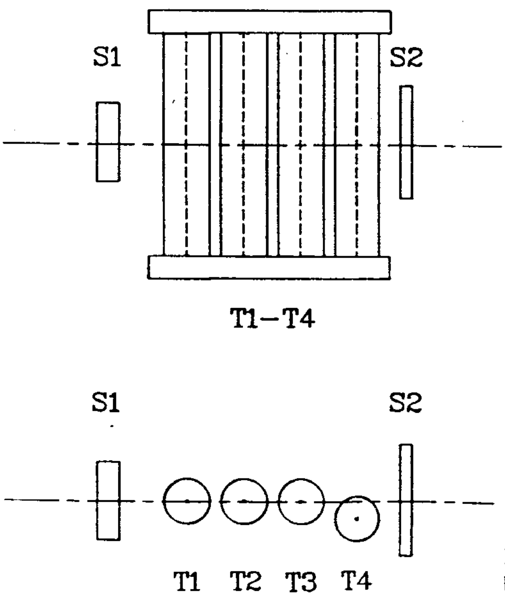


Fig. 1. Layout of setup: *T1*—*T4* are «bamboo» tubes, *S1*—*S2* are scintillators

from 50 to 150 mV on 50 Ohm impedance. Current preamplifiers we used had the gain equal to 20. After passing 50 m long cables the signals from 4 tubes and timing photomultiplier *S*1 were shaped (shaper threshold was set equal to 30 mV) and connected to the input of LeCroy TDC model 2228 A, which sensitivity was set equal to 170 psec/bin.

We used gas mixture Argon/Methane/Isobutane = 75/8/17 which provides an average drift velocity about 45 microns/ns.

3. Measurements and Results

We measured a spatial resolution at absolute pressures from 1 to 7 atm for several operation voltages (average signal amplitudes) at each point.

The value $(T1+T3)/2-T2$ was monitored during the run, where T is the drift time, as well as the correlation in time for different pairs of unshifted tubes. The typical correlation plot for drift times of two tubes is given in Fig.2.

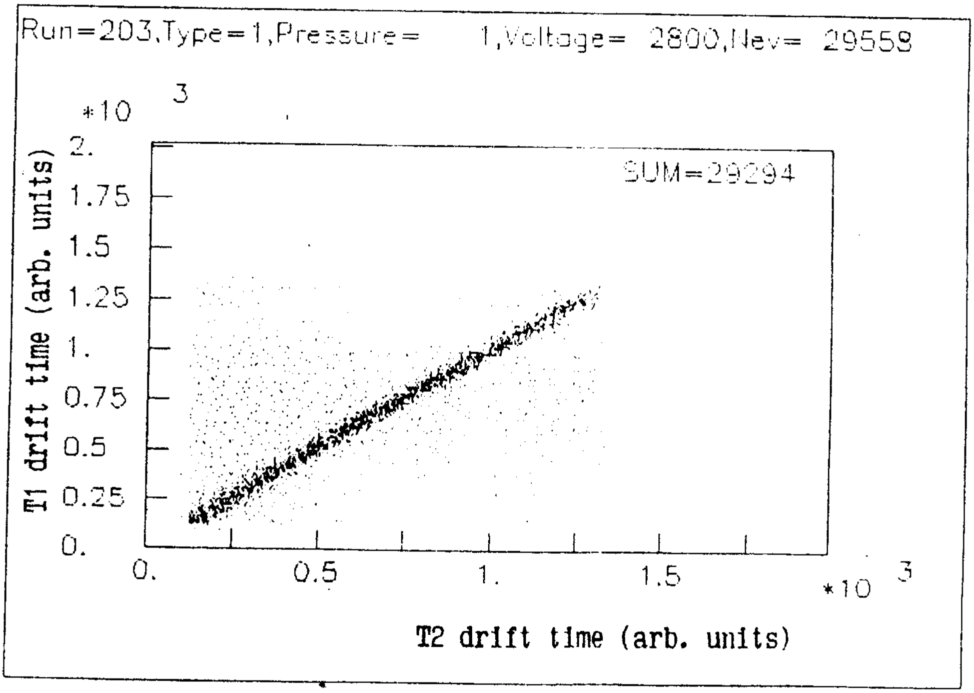
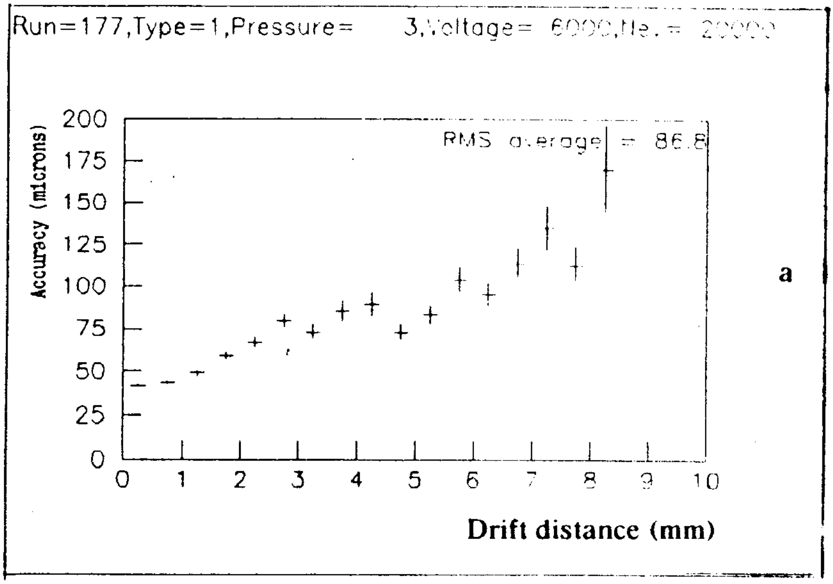


Fig. 2. Correlation plot of drift times for two tubes



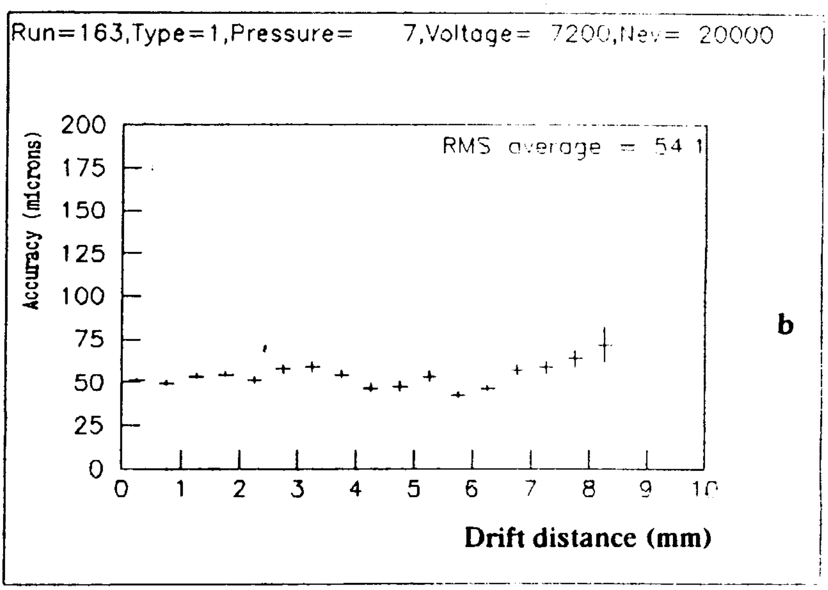


Fig. 3. Accuracy versus drift distance for 3 atm (a) and 7 atm (b)

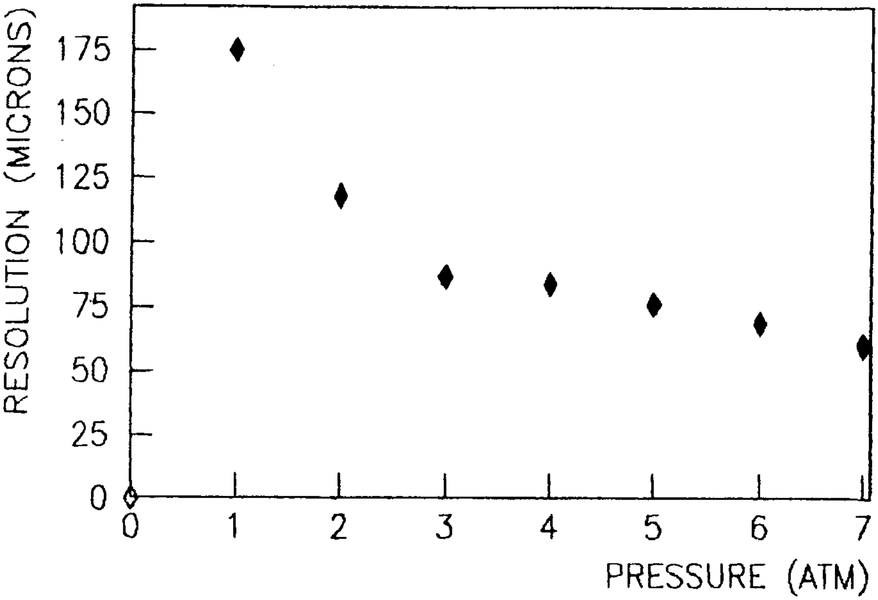


Fig. 4. Average resolution versus absolute pressure

To reject background events in off-line data processing we used simple algorithm: we took 2-dimensional plots of time correlations between the tubes 1 and 2, 1 and 3, 2 and 3 (which look like in fig.2) and rejected all bins with content less than 10% of maximal bin content.

The drift time-to-distance function was calculated for each meaning of pressure-voltage. For that we computed the convolution of drift velocity dependence on electric field [4] with field strength in cylindrical geometry.

Spatial resolution R of a single tube was obtained under assumption of equal accuracy of all tubes from expression:

$$R = \mathrm{sqrt}(2/3)*((r1 + r3)/2 - r2),$$

where «r» is the drift distance from track to the wire. As the beam was quasi-parallel to the axis of setup and had a small divergence (see correlation plot in fig.2) we could easily produce the dependence of spatial accuracy on drift distance. For that purpose the drift distance along the radius of the tubes was cut into small «slices» and for each slice quantity R was computed. An example of obtained spatial resolutions for 15 GeV electrons is presented in fig.3.

Figure 4 shows the behaviour of coordinate accuracy (averaged over the tube radius) with increasing pressure for 15 GeV electrons.

The above data (in figures 3 and 4) are given with voltages providing the best (minimal) mean spatial resolution after the voltage scan at different pressures.

We observed also a remarkable change of signal shape with pressure increase. The duration of signal (at 10% level of amplitude height equal roughly to 100 mV/50 Ohm) decreased from more than 200 ns at normal pressure to less than 50 ns at 8—10 atm. Being a known phenomenon it gives nevertheless an additional argument to the idea of pressurization as it minimizes an occupancy time per wire.

4. Conclusion

The spatial resolution below 100 microns was achieved with fast gas mixture and with tube of relatively big diameter for absolute pressures 2 atm and above. That resolution was obtained at very high counting rate, close to a counting rate limit in streamer mode, so we may hope for even better accuracy at normal conditions.

The resolution improves with pressure, which gives one a simple way to control a necessary level of coordinate accuracy of apparatus and to minimize the number of detecting layers.

Note, that such type of detector was chosen for precise muon tracking by the ASCOT project at LHC, and is being considered as a candidate for muon tracking in united ASCOT/EAGLE project at LHC, and in GEM collaboration at SSC. We expect this results to be of importance to our work on development of muon systems for the future colliders.

Further investigations are required to understand in detail the processes which influence the spatial resolution at high pressure.

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