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AGEING EFFECTS IN DRIFT CHAMBERS

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ABSTRACT

We have observed a degradation of efficiencies of large drift chambers. The effect is caused by deposits on the anode wires and, in our case, became significant after $\sim 10^{17}$ charges per cm of anode had been collected. The deposits are expected to be some sort of hydrocarbons. However, silicon could be identified as one of the components.

These effects, which have also been seen in proportional counters, should be taken into account when designing detectors in which a large number of charges per unit length of the anode wire is expected.

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1. INTRODUCTION

In the NA11 experiment performed at the CERN SPS [1], 48 large drift chambers are used for the measurement of the trajectories of charged particles. The frames of these chambers were made from Vetronite plates^{*)} and from aluminium plates with Vetronite printed boards glued to them. The wires in different planes are at angles of 0° , $\pm 14^\circ$, or $\pm 30^\circ$ with respect to the vertical direction. The structure of an individual drift cell is identical for all chambers; it is presented in fig. 1.

The chambers operate with an argon + ethane mixture (50% of each) and voltages of -2.0 kV on the field wires, 0 to -2.0 kV on the cathode wires (with the gradient increased near the field wires), and +1.55 to +1.85 kV on the anodes. The system has been in operation since 1979 and works satisfactorily. Some of its parameters have already been described elsewhere [2]. Up to now, the total running time has been about 150 days, mainly with a negative beam, of 175 GeV/c and about 2×10^6 particles/s, which hit one or two wires in the drift chambers and had a vertical dimension of ~ 1 cm.

2. DEGRADATION OF THE CHAMBER EFFICIENCIES

We have noticed a decline in the efficiencies after operating in the beam region of the drift chambers for some time, even in the case of very low intensities (thus avoiding space-charge effects); fig. 2 shows efficiency curves for some of the chambers measured on-line for low-intensity beam tracks.

The integrated number of charges per unit length at an anode wire in the beam region is estimated to be around 10^{17} . This has been calculated assuming that the average gas amplification in the beam region is about 5×10^3 . (The initial value of the gas amplification in the beam region was 10^4 , which is in agreement with the initial inefficiencies of the chambers as measured in a high-intensity beam. This value is very much reduced with respect to the mean value of $\sim 2 \times 10^5$ owing to the space charge created in the beam area.)

We should mention that in the outer regions of these drift chambers the efficiencies were still high and the plateau curves did not change. We did not see an increase in noise or dark currents.

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The inefficiencies of the chambers were also studied off-line from the data obtained with a defocused beam of low-intensity (size about $10 \times 10 \text{ cm}^2$ and about 3×10^4 particles/s). The inefficiencies for a particular plane were determined by requiring a signal from this plane corresponding to a trajectory reconstructed from the signals of the other chambers. Figure 3 presents the average inefficiencies in the beam region of some selected planes as a function of running time.

We also studied the inefficiencies as a function of the position of a track with respect to the anode wires. In fig. 4 we show the most characteristic distributions; they were very often asymmetric and the inefficiencies were usually lower for tracks passing near the field wires.

The size of the affected areas was investigated on-line by sweeping the beam across the chambers. At the end of our studies, they had dimensions of about 10 cm in the x and about 5 cm in the y direction. For a particular plane the size was very much dependent on the "history" of the plane (running time, position of the beam, etc.).

3. DEPOSITS ON THE WIRES

One of the chambers affected was opened and inspected: on the cathode wires no deposits were seen, but on the anodes whitish-grey deposits, which extended over a few cm, could be noticed in the beam region.

Samples of the anode and cathode wires were investigated under the Electron Scanning Microscope (ESM)^{*)} at CERN. The cathodes did not show any significant changes; on the anode wires [gold-plated tungsten, $20 \mu\text{m}$ diameter^{**)}], however, a lot of deposits were seen (fig. 5). The deposits showed significant asymmetries, which could explain the dependence of the efficiencies on the track positions with respect to the anode (fig. 4): they were mostly built up on that side of the anode towards which most of the primary electrons drifted ("focusing effect"). The deposit fibres usually start with a non-uniformity on the anode wire (high amplification -- from this point of view the piece of wire shown looks rather bad), which may be responsible for creating the particular structure of the deposits. However, the effect of ageing was observed on wires of different materials and qualities.

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The deposits are expected to be mostly hydrocarbons produced on the anodes from negative ions of CH-combinations [3,4] created in the process of gas discharge from C_2H_6 [5]. Unfortunately, the apparatus for X-ray fluorescent analysis^{*)} connected to the ESM used was limited in the detection of hydrogen and carbon; hence hydrocarbons were not directly seen. However, in all cases silicon was found to be present. The source of this element is still unknown to us; it could potentially come from, for example, gas, fibre glass, O-rings, silicon oil, etc. From the quality of the photographs taken with and without gold evaporated on the sample, it looks as if the deposits are good insulators. Owing to the very small quantities, we have not been able to perform a more complete analysis of these deposits.

A small drift chamber, with the structure shown in fig. 1 and operating under the same conditions, was exposed to electrons from a strong β source (^{90}Sr , ~ 1 mC/cm of an anode). After two weeks of operation of this chamber (at that period 10^{16} - 10^{17} charges per cm of an anode wire were collected) we could see deposits on the anode wire similar to those seen in fig. 5a and which also contain silicon. We note that recently similar effects have also been seen by others [6].

To restore the efficiencies of the drift chambers we have cleaned the wires; we have found that brushing with acetone is a good method to remove most of the deposits.

4. CONCLUSIONS

The local drop in efficiency observed has drawn our attention to the problem of the ageing of wire detectors.

The ageing effects, already known to exist for MWPCs and which can lead to the shrinkage of plateaus and breakdowns, have been explained as being caused by deposits on cathodes and were cured by the addition of some alcohol to the gas mixtures [7]. However, the process of gas amplification can also create deposits on anodes, which can significantly change pulse-height spectra [3,4] and thus also detection efficiencies, as has been demonstrated in the present work.

^{*)} Microanalyser EDX-EDAX 9100/60.

The possible changes in the characteristics of wire detectors can be particularly disturbing when they work in the linear mode (for example, dE/dx measurements). They must be taken into account when designing detectors which accumulate a large number of avalanches per unit length of an anode, e.g. for a time projection chamber (TPC) [8] and a high-density projection chamber (HPC) [9]. Considering a TPC detector with a diameter of 3 m and 200 wires in every dE/dx sector, and assuming a continuous current of 1 μA uniformly distributed over all wires (signals plus background at a gas amplification of $\sim 10^3$), we come to the conclusion that the limit of "unaffected linear operation"*) , estimated by some authors for an Ar + 10% CH₄ mixture to be equal to 10^{14} - 10^{15} charges per cm of the anode [4], may be reached already in about 100 days of running (!?).

The ageing effects are dangerous because they have not yet been well understood and the sources of some deposited elements are still unknown. This implies that further studies for better qualitative and quantitative description of the phenomenon are necessary.

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*) Within this limit the energy resolution of a 5.9 keV line from a ⁵⁵Fe source should not be worse than 20%.

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Figure captions

- Fig. 1 : Geometry of an individual drift cell of the chambers. Dimensions are in mm.
- Fig. 2 : Efficiencies as a function of the anode voltage of some of the drift chambers in the beam region measured at low intensities (~ 500 particles/s).
- Fig. 3 : Average inefficiencies of some of the drift chambers in the beam region as a function of running time.
- Fig. 4 : Two typical distributions of chamber inefficiencies as a function of the position of a track with respect to the anode wire.
- Fig. 5 : Deposits on an anode wire (20 μm diameter, gold-plated tungsten) of a drift chamber:
- a) as in the beam region after $\sim 10^{18}$ charges per cm of anode,
 - b) ~ 5 cm out of the beam region (ESM, magnification 2500 $\times$).

Fig. 1

Fig. 2

Fig. 3

Fig. 4

a)

b)

Fig. 5