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Electron Drift Velocities of Ar-CO_2-CF_4 Gas Mixtures

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Abstract

The muon spectrometer for the D0 experiment at Fermi National Accelerator Laboratory uses proportional drift tubes filled with an Ar-CO_2-CF_4 gas mixture. Measurements of drift velocity as a function of electric field magnitude for 90%-5%-5% and 90%-4%-6% Ar-CO_2-CF_4 mixtures are presented, and our operational experiences with these gases at D0 is discussed.

I. Introduction

The WAMUS (Wide Angle MUon Spectrometer) [1] system for the D0 experiment [2] at Fermilab uses proportional drift tubes (PDTs) and an Ar-CO_2-CF_4 gas mixture chosen for its high drift speed. As part of the effort to calibrate the D0 muon system, we used a WAMUS chamber prototype in a cosmic ray test stand to study how the drift distance in the PDTs varies with the measured drift time. From these studies we derived empirical relations for the drift distance as a function of drift time. These relations are used to reconstruct muons observed in $p\bar{p}$ collisions.

To calculate the drift velocity of the gas as a function of the electric field strength, we combine the drift time-to-distance function with knowledge of the electric field within the drift tubes. The electric field is calculated using the POISCR software package developed at CERN [3]. Given the geometry of the drift tubes and the applied potentials, this program determines the field by numerically solving the electrostatic boundary value problem. We varied the high voltage applied to the PDTs and studied the drift velocity for electric field intensities between about 300 and 600 V/cm.

II. Experimental Apparatus

A cross section of a WAMUS chamber is shown in Figure 1. It consists of three layers of drift tubes formed from interlocking aluminum extrusions as shown. The tubes are approximately 10 cm × 6.4 cm in cross section. Each tube has a sense wire in the center and 5 cm wide cathode pads above and below the wire.

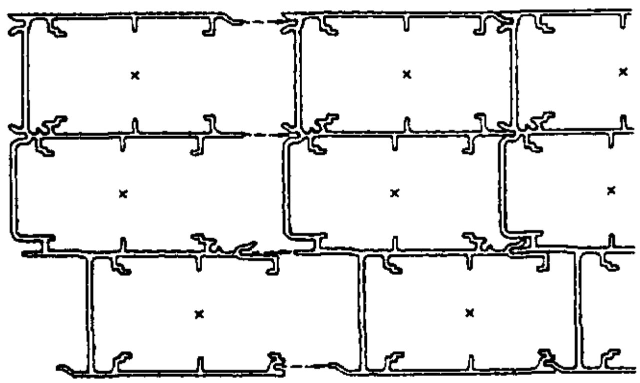

Figure 1: Cross section of a WAMUS PDT chamber. Wire positions are indicated by the ×s. The cathode pads are not shown.

The WAMUS prototype used in this study was three drift tubes wide by 554 cm long. A pair of proportional wire chambers (PWCs), each with 128 parallel wires spaced 1 mm apart, were mounted above and below the chamber. These were used to measure the position of cosmic rays along the PDT drift direction with a resolution of 290 μm. A coincidence between signals from phototubes attached to scintillators above and below the PWCs provided a trigger for the readout electronics. The drift tube electronics are double buffered and two drift times were recorded for each event.

III. Data Sample

Each cosmic ray event consisted of hits in the PWCs and two digitized drift times per drift tube. To reduce backgrounds from noise, multiple tracks and delta rays, events were required to have hits in each PWC on either a single wire or two adjacent wires, first drift times above pedestal in each layer of the chamber, and second drift times below

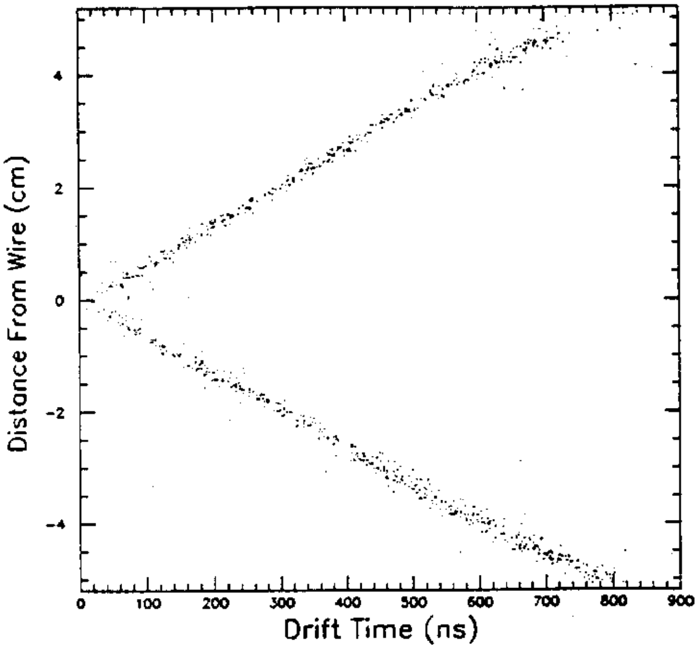

Figure 2: The distance of the cosmic ray from the wire at tube midplane, as measured by the PWCs, versus the PDT drift time. The gas mixture is 90-4-6 and the pad and wire voltages are +2.0 kV and +4.26 kV respectively.

pedestal. We considered only events with cosmic rays at normal incidence to the PDT wire planes, and further required that the line defined by the hits in PWCs be within 5° of vertical. Data was taken with the gas at atmospheric pressure plus 6 in of oil, corresponding to an absolute pressure of 751 torr.

Figure 2 shows a plot of PDT drift distance, as measured by the PWCs, versus drift time. Data from the three layers and adjacent tubes in each layer are superimposed. A data sample similar to the one shown in Figure 2 was collected for four different tube voltages: (1.7,3.96), (2.0,4.26), (2.3,4.56) and (2.6,4.8) where the first and second numbers are pad and wire potentials in kV respectively. The difference between the pad and wire voltages was kept nearly constant in order to maintain a constant pulse height.

IV. Calculating the Electric Field and Drift Velocity

The shape of the aluminum extrusion varies slightly from layer to layer, so the electric field for tubes in each layer was modeled separately. Figure 3 shows the geometry used in the POISCR program for one of the layers, and the calculated equipotential lines for a given choice of pad and wire voltages. The minor simplifications made to the actual tube geometry for the purposes of POISCR program had a negligible effect on the field calculations. Figure 4 shows the magnitude of the electric field at the midplane of a tube as a function of distance from the wire.

Empirical fits of drift distance as function of drift time were made using the data from the tube regions farthest

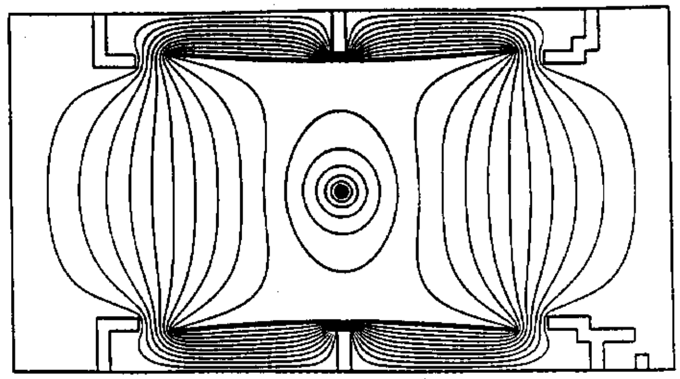

Figure 3: Electrostatic equipotential lines for a PDT with the pads at +2.3 kV and the wire at +4.56 kV.

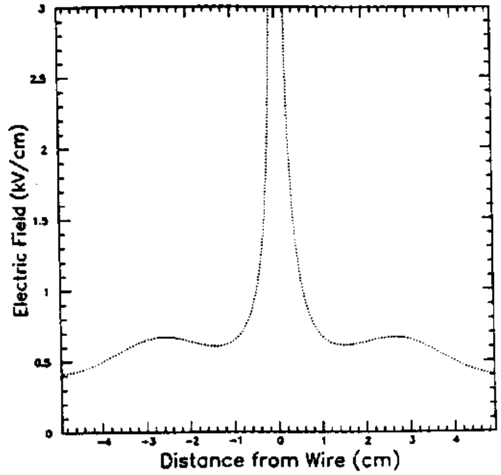

Figure 4: Electric field magnitude along the tube midplane for the same pad and wire potentials as Figure 3.

from the wire, where the electric field decreases from its local maximum. In these regions the drift distance is well described by a parabolic function of the drift time. To remove apparently spurious hits that still remained in the data after the above cuts were applied, an iterative procedure was used in fitting where at each iteration hits far from the fitted curve were discarded. The drift velocity is then given by the derivative of the time-to-distance function.

Figure 5 shows the calculated drift velocity for the two gas mixtures as a function of the applied electric field. The error bars shown include the statistical errors in the empirical fits, the error due to the uncertainty in the alignment of the PWCs with respect to the chamber, and the estimated uncertainty due to the spread in the incident angles of the cosmic rays.

For electric fields greater than 600 V/cm, the drift velocities appear to saturate at about 74 μm/ns for the 90-4-6 gas and 62 μm/ns for the 90-5-5 gas.

V. WAMUS Operational Experience

The WAMUS system has been operated successfully using both the 90-5-5 and 90-4-6 gas mixtures. Average PDT

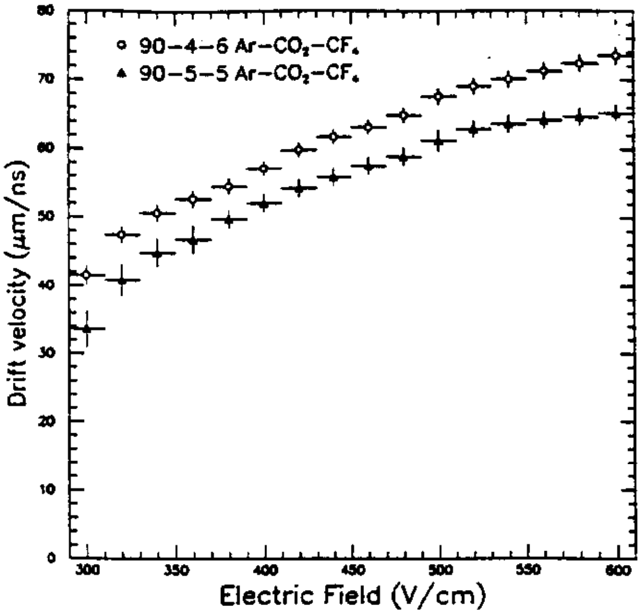

Figure 5: Drift velocity as a function of electric field magnitude for the gases studied. Averaged gas pressure was 751 torr.

resolution is 900 μm. Recently, an aging problem involving tar-like deposits on the anode wire has been encountered, but indications are that it is caused by outgassing from the cathode pad materials and not by the presence of CF_4 gas. The cathode pads are constructed from copper-clad Glasteel (polyester and epoxy based plastic sheets with a glass fiber mat).

REFERENCES

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