Detailed simulation of Drift Tubes

T. Rovelli[a] and V. Tano[a]

[a]INFN and Physics Department, University of Bologna,
Via Berti Pichat 6/2, 40127 Bologna, Italy

A detailed simulation of a drift tube for barrel muon chambers of the CMS experiment at LHC has been performed. Drift parameters and the effects of a magnetic field on a drift tube have been studied.

1. Introduction

The aim of this work is to provide a new method for the simulation of an elementary drift cell which is more accurate than the traditional programs used in the past. These simulation tools are optimized for barrel muon chambers of the CMS experiment at LHC [1].

In order to compare the results of the simulation with experimental data, the dimensions and the materials of a prototype constructed by the Padova and Bologna groups have been used for the simulation of drift tube. The prototype has been tested on a CERN SPS muon beam in August 1995 [2].

2. Cell description

Fig. 1 shows a scheme of drift tube with a rectangular cross section. The tube is 1.1 cm high,

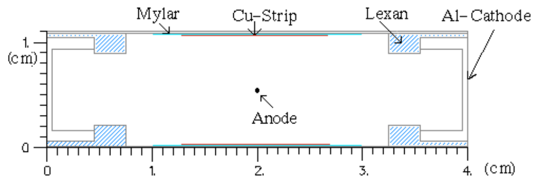


Figure 1. Drift cell prototype.

4 cm wide and about 1 m long. The cathode is made out of Aluminium and it is insulated from Aluminium ground planes by Lexan strips. The anode is a stainless steel wire stretched in the middle of the cell and it has a 50 μm diameter. Above and below the anode there are two Copper strips to improve the shape of the electric field. Cu-strips are 14 mm wide and are insulated from Aluminium ground planes by Mylar. The gas mixture is Ar-CO_2 (85-15).

3. Simulation

The simulation of the cell has been done combining two programs: *Garfield*[3] and *Poisson*[4].

Garfield is a program for bidimensional drift chambers, it calculates and plots the electrostatic field, drift lines of electrons and ions and the current on the sense wire due to the passage of a charged particle through the chamber. Cell regions are described only by infinite planes or wires. Moreover *Garfield* cannot calculate the potential on a dielectric material. This problem can be solved using another program: *Poisson*; it requires an input file with the definition of cell regions and boundary conditions and it calculates numerical solution of any two dimensional Poisson's or Laplace's equations. The goal of simulation is to combine *Poisson* accurancy with *Garfield* versatility.

The two programs have been combined in the following way to simulate the potential on dielectric: *Poisson* calculates the potential every 100 μm on the dielectric material and *Garfield* gets in input the result of *Poisson* calculation. In this way *Garfield* replaces the dielectric with many equidistant (100 μm) ideal wires, each one at the correct potential.

In order to minimize the total number of wires required, Cu-strips are also described with many equipotential wires at a distance greater than the one used for dielectric material [5].

4. Muon cell simulation results

Using these simulation tools the following items have been studied:

- Deviation of drift time from linearity varying the voltage difference between strips and cathode
- Drift time as a function of crossing angle and of impact point of a particle through the chamber
- Behaviour of the chamber in a magnetic field and maximum drift time as a function of magnetic field.

4.1. Deviation of drift time from linearity

In a condition of linearity the drift time is proportional to the distance from the sense wire.

The deviation of drift time from linearity as a function of high voltage conditions has been studied. The high voltage difference between sense wire and cathode is: $\Delta V_{wc} = V_{wire} - V_{cathode} = 5400$ V. Three different values of voltage on the strips have been set.

Deviations from linearity have been calculated as deviations of simulated drift times from a straight line. This line passes through two values of simulated drift times, at about 0.8 and 1.2 cm from the anode. The drift time difference between simulated time and linear time as a function of impact point has been calculated. The result is shown in Fig. 2. There are small deviations from linearity along the whole cell, but the high voltage condition that better reproduces linearity is the one with $V_{cathode} = - V_{strip}$.

4.2. Inclined tracks

We studied the effects of a particle crossing the chamber inclined with respect to the drift lines direction.

In Fig. 3 the drift lines are shown; vertical lines are isochronous. Little asymmetries of drift lines are due to a small asymmetry of regions described in *Poisson* and *Garfield*. Of course electrons produced by ionization in the bottom region of the cell reach the sense wire before than electrons produced in the middle of the cell.

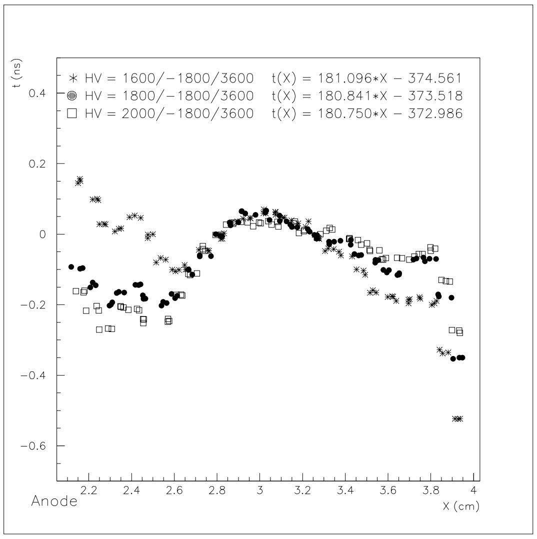


Figure 2. Deviation of drift time from linearity.

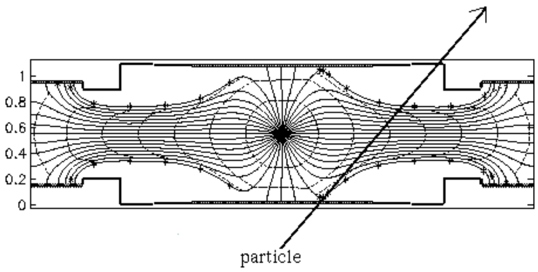


Figure 3. Scheme of a particle passing through the cell. Drift lines and isochronous are shown.

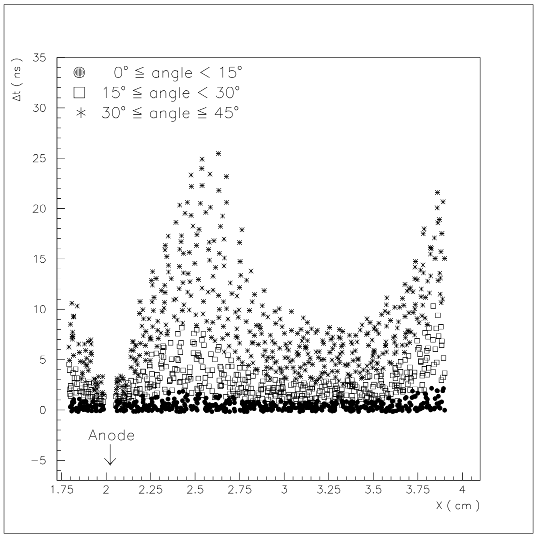
In Fig. 4 differences between drift time of the first electron on the sense wire and drift time of an electron produced in the middle of the cell are shown. High voltage condition is: HV = V_{strips}/ $V_{cathode}$/V_{wire} = 1800/-1800/3600. These differences are shown as a function of impact point and as a function of crossing angle. Differences are larger close to the cathode and in the region at about 0.5 cm from the anode. In these regions the shape of the electric field is not so uniform. Notice that differences for angle below 15° are not remarkable.

4.3. Behaviour of the cell in a magnetic field

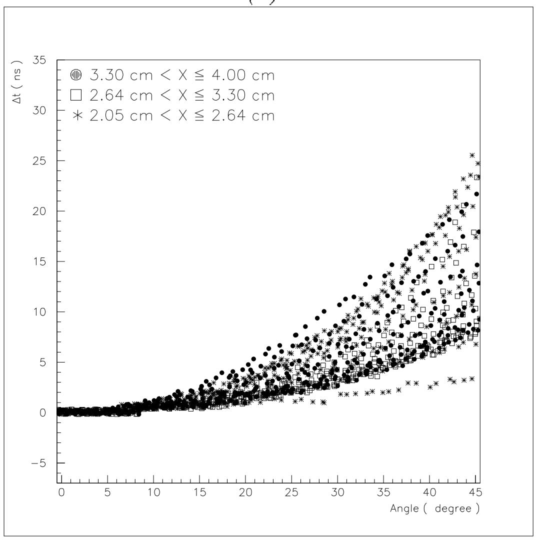
Using the above described simulation tools, it is possible to simulate simple uniform magnetic field. Fig. 5 shows the drift lines in three different situations: without a magnetic field, with a magnetic field orthogonal and longitudinal to the electric field. The distortion of drift lines is due to the longitudinal component to the wire, but both the components change drift velocity. Maximum drift time as a function of total magnetic field B has been studied. Maximum drift time is the drift time of an electron produced in ionization close to the cathode. To compare simulated with experimental data, the same conditions of August 1995 test beam during which the chamber was inclined of 24° respect to the beam direction have been reproduced. The relation between the longitudinal component to the wire B_{wire}, and the orthogonal component to the wire B_{norm} is:

$$B_{wire} = \tan 24° \times B_{norm}. \quad (1)$$

High voltage is: HV = 1500/-1500/3300 V. According to the design of CMS, the longitudinal component of the magnetic field present in the barrel chambers should be of the order of 0.3 T, but it can reach values up to 1.0 T in some boundary regions between barrel and endcaps. Notice that maximum drift time has little variations for values of the magnetic field below 0.5 T. From the Fig. 6 a discrepancy of about 30 ns between simulated and experimental data is self-evident. This discrepancy can be explained by a detected air infiltration in the chamber during test beam operations. Adding Nitrogen and Oxygen in the gas mixture of Ar-CO_2 (85-15), in the percentage of 0.6% and 0.15%, experimental and simulated data bring into agreement. A decrease of



(a)



(b)

Figure 4. Differences between the drift time of the first electron on the sense wire and the drift time of the electron produced in the middle of the cell as a function of (a) impact point, (b) crossing angle.

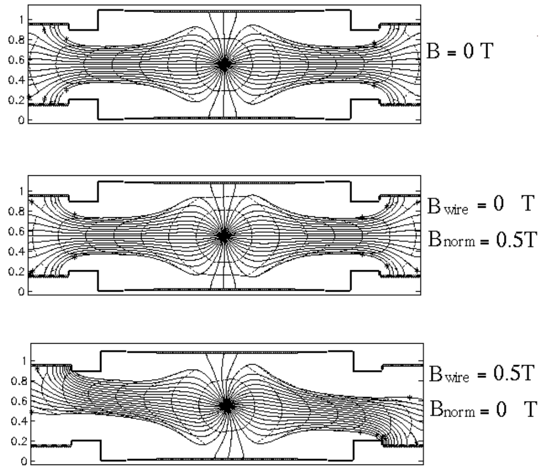


Figure 5. Drift lines map given by *Poisson* and *Garfield*.

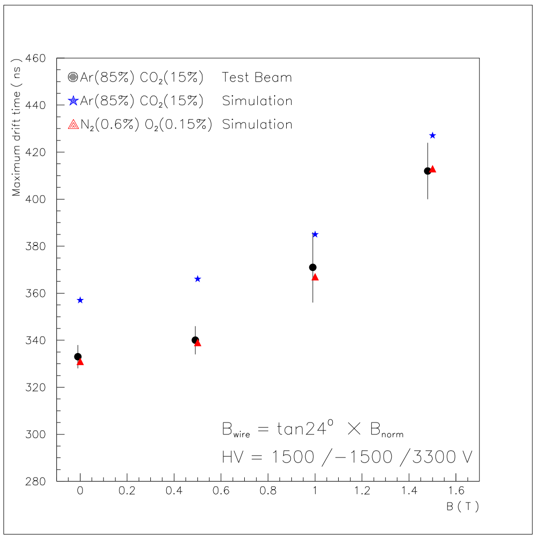


Figure 6. Maximum drift time as a function of total magnetic field B.

simulated drift time is almost entirely due to Nitrogen addition; instead addition of Oxygen does not cause a sensible variation of drift times.

5. Conclusions

The two programs *Garfield* and *Poisson* can be used together for the simulation of drift tubes. This allows the study of cell parameters as, for example, the drift times and the electrostatic field. In this work simulation has been used also to check experimental results.

REFERENCES

1. CMS Technical Proposal, CERN/LHCC 94-38, 15 December 1994.
2. Ivano Lippi, *Performance of the Drift Tubes for the Barrel Muon Chambers of the CMS Detector at LHC*, San Miniato Conference, 22 May 1996, these proceedings.
3. R. Veenhof, *Garfield, a Drift Chamber Simulation Program User's Guide*, CERN Program Library W5050, 1996.
4. C. Iselin, *Solution of Poisson's or Laplace's Equation in Two-Dimensional Regions*, CERN Program Library T604, 1984.
5. T. Rovelli, *Simulation of the CMS Barrel Muon Chambers*, CMS TN/95-106, 1995.