A Monte Carlo simulation method for Resistive Plate Chamber

Tapasi Ghosh* and Subhasis Chattopadhyay
Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata-700064, India

Introduction

Resistive Plate Chamber (RPC) is a gas detector constructed with two highly resistive parallel plates with resistivity $10^9 - 10^{12}\ \Omega - cm$ with large voltage gradient (5 KV/mm). A Monte Carlo simulation method has been developed for studying the response of the charged particles in RPC. For the whole study , it is considered that the RPC is working in avalanche mode with gas mixtures $C_2F_4H_2 : i - C_4H_{10} : SF_6$ of the ratio 96.7:3:0.3 [1]. The efficiency, time resolution has been estimated.

Primary Ionisation and Avalanche development

When a charged particle passes through the gas inside the detector, it looses its energy mainly by the inelastic collision with the atomic electrons. In this process, the energy of the incident charged particle is transferred to the atom either by excitation or ionisation of the atom. The charge deposition is characterized by the average number of clusters per unit length and the probability distribution for the number of electrons per cluster. The numbers are calculated by using Heed [2]. For RPC operating in avalanche mode an average of 7.5 clusters/mm are created for minimum ionising particles. The distance between the clusters are exponentially distributed, so that the probability to find the first cluster between position x and $(x + dx)$ is $P(x) = \frac{1}{\lambda}e^{-x/\lambda}$ [3]. To simulated the primary ionisation by Monte Carlo method we first divide the gas gap (2 mm thick) inside RPC into 20 steps, so Δx (= 0.1 mm) which corresponds to time steps of $\Delta t = \Delta x/v$, where v is the drift velocity as provided by Magboltz [5]. Then the primary clusters are distributed along gas gap at distances following an exponential distribution with mean 7.5 clusters/mm. This mean value is calculated by Heed [2]. Next, the primary electrons are put to each cluster following a cluster size distribution as shown in Fig. 1. Each primary electron will start an avalanche due to electric field intensity. There are mainly two processes recombination and attachment which hinder the process of avalanche development. The avalanche multiplication is characterized by Townsend coefficient α and the attachment coefficient η. These parameters calculated by Imonte [4] used. Here, for trigger RPCs

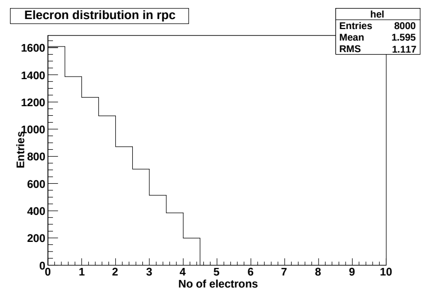

FIG. 1: Electron distribution for each cluster.

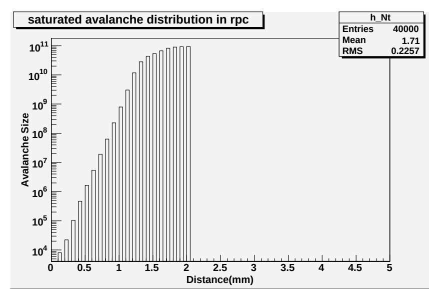

FIG. 2: Avalanche is saturated considering space-charge effect.

*Electronic address: tapasi@veccal.ernet.in

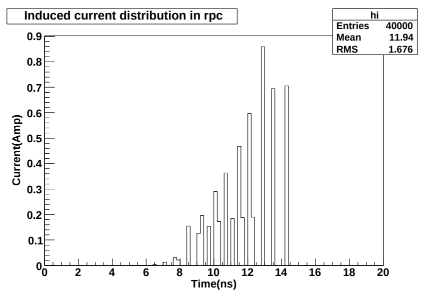

FIG. 3: Current induced by the avalanche at RPC electrode.

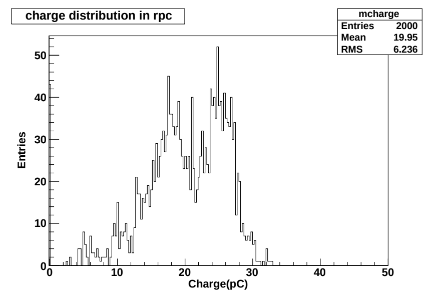

FIG. 4: Charge spectrum for all the particles.

with E = 50 KV/cm, $\alpha = 13.3$/mm and $\eta = 3.5$/mm. While simulating avalanche production, if number of electrons exceeds a specified value N_{sat} the avalanche growth is stopped and N_{sat} electrons propagate upto the end of gas gap as shown in Fig. 2. This procedure simulates the space-charge effect.

Induced current and Time Resolution

Finally, the movement of the avalanche electrons in the electric field inside the gas gap will induce a current signal on the RPC electrodes. The negative and positive ions also induce a signal, however we have neglected this as the signal is small due to ions slow drift velocity. The current signal Fig. 3 induced on an electrode is given by $i(t) = \frac{E_w.v}{V_w} e_0 N(t)$, where e_0 is the electron charge, $\frac{E_w}{V_w}$ is the weighting field which depends on the geometry. For our trigger RPC having two glass plate of thickness b and gas gap thickness d, $\frac{E_w}{V_w} = \frac{\epsilon_r}{2b+d\epsilon_r}$. Here ϵ_r is the relative permittivity of glass. Finally, adding up all the currents for each particle over all the time steps a charge spectrum is obtained as shown in Fig. 4.
We have also simulated the time resolution of the RPC from the RMS value of the time spectrum as shown in Fig. 5.

In conclusion, we show that the response of a charged particle inside the RPC has been simulated. The efficiency of the detector is upto 99 % with implementing all the physics

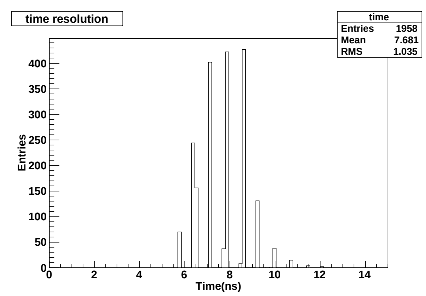

FIG. 5: Time response of the detector. The rms value will give the time resolution.

issues related to the passage of the charged particle inside matter. The time resolution of the detector is also estimated.

References

[1] Werner Riegler *et al.* Nucl. Instr. Math. A **500**, (2003) 144.
[2] I. Smrinov, Heed, program to compute energy loss of fast particles in gases, Version 1.01, CERN.
[3] W. Blum, L. Ronaldi, particle Detection with drift Chambers, Springer, Berlin, 1993, ISBN 3-540-56425-X.
[4] S. Biabi, Imonte, program to compute gas properties, Version 4.5.
[5] S. Biabi, Magbolz, program to compute gas transport parameters, Version 2.2, CERN.