Effect of surface roughness on the performance of RPC: A simulation study

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Introduction

The Resistive Plate Chambers (RPCs) [1] will be used as the active detectors inside the iron calorimeter for the proposed INO experiment [2]. RPC is a gas-filled detector having parallel plate capacitor geometry and one of the possible options for the electrodes to be used for INO-RPCs is the locally made bakelite. Typically, the resistivity of the material of electrode is in the range of $10^{10} - 10^{12}\ \Omega - \mathrm{cm}$ and a large voltage gradient of 10 kV/mm is applied across the electrodes. We have developed a framework for simulating the response of the RPC to an incident minimum ionizing particle like cosmic muon. For this work, we consider a 0.3 mm single-gap RPC, having 2 mm thick bakelite electrodes. A mixture of $C_2F_4H_2$, $i - C_4H_{10}$, SF_6 gases in 85 : 5 : 10 ratio respectively are used for the detector. A DekTek 117 Profilometer is used to scan the surface profile for three different grades of bakelite material which are

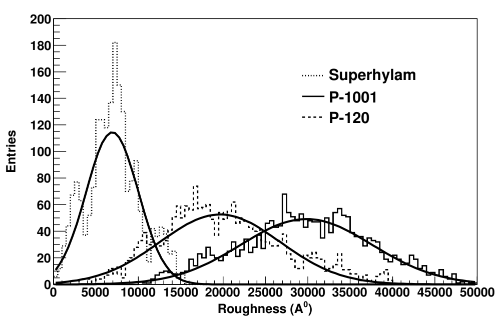

FIG. 1: The surface roughness profile of three different grade bakelites.

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TABLE I: Variation in roughness for three different grade bakelite materials.

Grade	Long Range Variation (μm)	Short range Variation (μm)
P-120	0.84±0.12	0.64±0.06
Superhylam	0.49±0.17	0.17±0.02
P-1001	0.88±0.09	0.63±0.13

P-120, Superhylam and P-1001. The distribution of measured surface heights centered at zero by proper shifting of the mean of distribution is shown in figure 1. The surface heights measured by the profilometer has the following feature: (a) when the measured heights are binned in $\sim 1\mu m$ scale, then the RMS of the distribution is termed as "long-range variation". For this distribution the shape of the variation of surface heights along the direction of scan shows fluctuations in long range scale and (b) the distribution of measured heights when binned in $\sim 0.1\mu m$ scale, then it shows small scale fluctuating behavior along the the direction of measurement, and RMS of this small scale distribution is called the "short-range variation". The RMS values of the distributions represent the roughness of the materials and the average values of the roughness for three different grades of bakelites are listed in Table I.

Monte Carlo simulation

In this work, we have simulated the response of a minimum ionizing particle passing through the detector by including primary ionization, avalanche development and formation of induced current considering the space charge effect. The Monte Carlo procedure followed here is similar to the one used in Ref. [3] and, additionally, we have introduced the surface roughness of electrodes for further

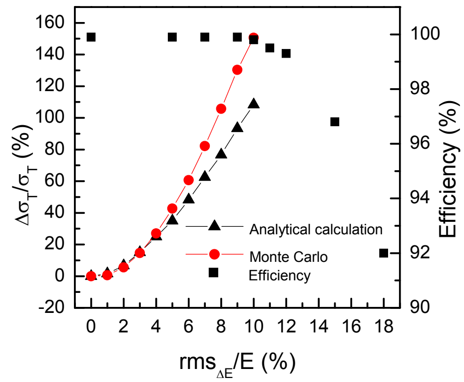

FIG. 2: The variation of efficiency as well as time resolution of the timing RPC due to the variation in electric field, arises due to the non-uniformity of the surface of the RPC electrodes.

study. The distribution of the surface heights is Gaussian in nature, as shown in figure 1. We have incorporated this Gaussian distribution of surface fluctuations in the simulation and sigma of the distribution is the measure of the roughness. The fluctuation of the width of the gas gap will have an impact on the field inside the RPC. It is assumed that the perturbation in the field is only due to the non-uniformities in the gap size g and under this assumption, the RMS variation of field becomes equal to the RMS variation of gap. Since the time resolution σ_T is the second moment of RPC time response, it is expected that σ_T will have an impact due to the fluctuations of the voltage across the gas gap. Description of the detail procedures will be available in Ref. [4].

Results

Considering all the physics processes, we obtained ~80 ps time resolution and 99% efficiency at the 20 fC threshold for the 0.3 mm single-gap timing RPC, for a smooth surface. Then we simulated the effect of the rough surface of the RPC electrodes on its performance. The variation of the simulated time resolution(σ_T) values are compared with the analytically calculated values [5] as shown in figure 2. It is observed that a total 4% fluctuation in the gas gap i.e., $\sim 8.5\mu m$ average roughness at each plate causes $\sim$ 25% variation in time resolution and this result is compatible with the analytically obtained values. It is noticeable from the figure 2 that above 5% fluctuation of the field, the Monte Carlo results show larger variation in time resolution compared to those of the analytical calculations. The efficiency of the detector remain 100% upto 10% gap fluctuation, thereafter decreases gradually as shown in figure 2. There is a 10% decrease in efficiency for 20%($60\mu m$) overall variation in surface profile.

Summary and Conclusions

We present a Monte Carlo method which simulates the physics processes when a charged particle passes through a RPC. We show the results for a 0.3 mm single-gap timing RPC. Our main motivation was to analyze the effect of non-uniformity of the surface on the performance of RPC. It is observed that the time resolution of the detector is worsened by 25% for $12\mu m$ bakelite roughness, which is in agreement with the analytical calculations. The efficiency worsens by 10% for $60\mu m$ roughness.

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