Study of timing properties of single gap high-resistive bakelite RPC

S. Biswas a,∗, S. Bhattacharya b, S. Bose b, S. Chattopadhyay a, S. Saha b, Y.P. Viyogi c

a Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata-700 064, India
b Saha Institute of Nuclear Physics, 1/AF Bidhan Nagar, Kolkata-700 064, India
c Institute of Physics, Sachivalaya Marg, Bhubaneswar, Orissa-751 005, India

Abstract
The time resolution for several single gap (2 mm) prototype Resistive Plate Chambers (RPC) made of high resistive (ρ ∼ 10^{10} - 10^{12} Ω cm), 2 mm thick matt finished bakelite paper laminates with silicone coating on the inner surfaces, has been measured. The time resolution for all the modules has been found to be ∼ 2 ns at the plateau region.

Key words: RPC; Streamer mode; Bakelite; Cosmic rays; Silicone; Time resolution
PACS: 29.40.Cs

1. Introduction
Performances of several single gap (2 mm) prototype Resistive Plate Chambers (RPC) [1] made of high resistive (ρ ∼ 10^{10} - 10^{12} Ω cm) bakelite paper laminates produced and commercially available in India has been carried out in recent times [2]. A thin silicone coating has been applied to the inner electrode faces of the detectors to make the surfaces smooth. Such high resistive electrodes are being explored since the detectors are one of the candidates of the proposed neutrino oscillation experiment in the India-based Neutrino Observatory (INO) [3]. One of the requirements for the INO RPC is to have a time resolution ∼ 2 ns or better.

The silicone coated chambers, operated in the streamer mode using argon, tetrafluoroethane (R-134a) and isobutane in 34:59:7 mixing ratio, prepared by a gas mixing and flow control unit [4] have been tested with cosmic rays. The results of the long term test (with efficiency > 90%, counting rate of ∼ 0.1 Hz/cm²) and some other aspects such as crosstalk, dependence on threshold value, the effect of external humidity etc. of these silicone coated RPCs have been reported earlier [5]. In this article, we would like to present the timing characteristics of such single gap (2 mm) silicone coated RPCs.

∗ Email address: saikatb@veccal.ernet.in (S. Biswas).

Fig. 1. Schematic representation of the time resolution measurement setup. A common start Phillips Scientific 7186 Time to Digital Converter (TDC) was used.

2. Test setup and method of calculation
The time resolution of the RPC was measured in the same cosmic ray test bench described in Ref. [2]. The cosmic ray telescope was constructed using three scintillators, two placed above the RPC and one below. The individual time resolution of each RPC was estimated as follows. The triple coincidence of the signals obtained from the three scintillators was taken as the START signal (master trigger) for the TDC. The STOP signal was taken from a single RPC strip. Fig. 1 shows the schematic of the time resolution measurement setup.

The distribution of the time difference between the master trigger and the signal from one RPC strip is shown in Fig. 2. Time calibration was measured as 0.1 ns/channel. From the time difference spectrum, the full width at half maximum (FWHM) and the corresponding standard deviation (σ_{ij}), where i and j refer to scintillators and the
RPC, were obtained by fitting a Gaussian function. The same $\sigma_{ij}$ were obtained similarly for the 3 different pairs of the scintillators I, II and III. The intrinsic time resolutions of the RPC and the scintillators were obtained from the individual standard deviations $\sigma_i$, $\sigma_j$, which were extracted by solving the equations: $\sigma_{ij}^2 = \sigma_i^2 + \sigma_j^2$. Time resolution (FWHM) of the individual scintillators were obtained as: 3.20 ± 0.07 ns (scintillator I), 3.39 ± 0.08 ns (scintillator II) and 1.98 ± 0.02 ns (scintillator III), where the quoted uncertainties include statistical and fitting errors. The extracted time resolution (FWHM) of the RPC at 8 kV operating voltage for a typical run was: 2.48 ± 0.08 ns.

3. Results

The average signal arrival time ($T$), taken as the mean position of the fitted Gaussian peak in the time difference spectrum (such as in Fig. 2) and the time resolution (FWHM) $\tau$ of the RPC as function of the applied high voltage (HV) for the two 30 cm × 30 cm RPCs are shown in Fig. 3. The measured values of $T$ include the delays introduced in both the START and STOP channels by the electronics shown in Fig. 1. The time resolution for both the modules improves and the average signal arrival time decreases with the increase of HV which is common to any gas filled detector. At the plateau region, the time resolution has been found to be $\sim 2$ ns.

One of the modules was tested for a long period (more than 130 days) at a constant high voltage of 8 kV and showed nearly constant values of the time resolution ($\sim 2$-3 ns) and the average signal arrival time ($\sim 55$ ns) as shown in Fig. 4. One of the modules was tested for a long period (more than 130 days) at a constant high voltage of 8 kV and showed nearly constant values of the time resolution ($\sim 2$-3 ns) and the average signal arrival time ($\sim 55$ ns) as shown in Fig. 4.

Finally the time resolution between two RPCs was measured by taking the START signal from one RPC operated at constant voltage (8 kV), while the voltage of the other RPC was varied. The results are shown in Fig. 5. In this case, the average time resolution is found to be $\sim 3$ ns in the plateau region.
4. Conclusions and outlook

In conclusion, a systematic study on the timing properties of silicone coated RPCs made of bakelite paper laminates, commercially available in India has been performed. The measured time resolution of those RPCs have been found to be $\sim 2$ ns which is comparable to any single gap glass or linseed oil coated bakelite RPC. The study of the effect of continuous HV on the time resolution has also been performed. In the long term operation of the detector, 2-3 ns time resolution is obtained.

5. Acknowledgement

We would like to thank Mr. Ganesh Das of VECC for fabricating the detectors.

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