Characterisation of a new RPC prototype using conventional gas mixture

A. Sena, S. Chatterjeea, S. Das, S. Biswas

aDepartment of Physics, Bose Institute, Kolkata-700091, INDIA

Abstract

Resistive Plate Chamber (RPC) is a well-known gaseous detector in the field of High Energy Physics (HEP) experiments for its good tracking capability, high efficiency, good time resolution, and low cost of fabrication. The main issue in RPC is its limitation in the rate handling capability. Several experimental groups have developed sophisticated techniques to increase the particle rate capability and reduce the noise rate of this detector. In this article, we discussed a new method for linseed oil coating in case of bakelite RPC detector to achieve good efficiency and the results obtained using a conventional gas mixture.

Keywords: RPC, Gaseous detector, Cosmic ray, Efficiency, Noise rate

1. Introduction

HEP experiments have been using RPCs for triggering and tracking for their high efficiency and good time resolution. RPCs are also being used in several cosmic ray experiments to cover large detection area [1,2]. Future heavy-ion experiments e.g. CBM will use RPCs for muon detection [3]. RPC is a gaseous detector made up of resistive electrode plates e.g. bakelite, glass, ceramic, etc [4,5,6].

In bakelite RPC linseed oil coating [7] is introduced in the BaBar experiment. The coated linseed oil formed stalagmite, that subsequently forms the conducting paths through the gas gap, around the spacers and the discharge permanently damages the detector. The formation of stalagmite is due to the polymerization of uncured linseed oil droplets present on the surface [8]. However, lot of R&D is performed and the solution is found out for this issue [9].

A new technique of linseed oil coating [11] is introduced in the bakelite plates in which one can check visually whether there is any uncured oil present inside the gas gap. With this new technique one RPC prototype was built and tested with 100% C2H3F4 gas. In this article the test results of the RPC prototype with conventional C2H3F4 and i-C4H10 mixture is presented.

2. Detector description and experimental set-up

The detector is built with two 27 cm x 27 cm bakelite plates of thickness 2 mm and having bulk resistivity of ∼ 3 × 10^10 Ω cm (at 22°C). Four edge spacers, two gas nozzles, one button spacer made of polycarbonate (resistivity ∼ 10^15 Ω cm) and having thickness of 2 mm are used to make the gas gap. The surface resistivity of the outer graphite surface of the electrode plates are measured to be ∼ 510 kΩ/cm and 540 kΩ/cm.

The signal is read out from the copper strips of dimension 2.5 cm × 27 cm. The strips are covered with 100 µm thick mylar foils to isolate them from the graphite layers. The details of the fabrication of the chamber is described in [11].

Three scintillation detectors of dimensions 10 cm × 10 cm (SC1), 10 cm × 2 cm (SC2), 20 cm × 20 cm (SC3) are used to generate the trigger for the detector. All the scintillators are operated at +1550 V and -15 mV threshold is applied to the leading edge discriminator (LED). The RPC signal from the pick-up strip is first fed to a 10x fast amplifier and then the output goes to the LED. Suitable thresholds are applied to the LEDs to reduce the noise. From the LED, one output goes to the scalar to count the number of the signal from the RPC which is known as the noise count or singles count of the chamber. The other output from LED goes to the dual timer where the discriminated RPC signal is stretched to avoid any double counting of the pulses and also to apply the proper delay to match the signal with the trigger. The output of the dual timer is taken to the coincidence with the trigger and this is defined as the 4-fold signal. The window of the cosmic ray test set-up is of area 10 cm × 2 cm. The block diagram of the set-up is shown in Figure 2.

3. Result

The chamber is tested with cosmic rays in avalanche mode. The detector is purged with Tetrafluoroethane (C2H3F4) and Isobutane (i-C4H10) gas mixture in 90/10 volume ratio. The leakage current through the RPC module is measured as a function of the applied high voltage (HV) and shown in Figure 1.
The efficiency of the RPC module for the cosmic rays is defined as the ratio of the 4-fold counts to the 3-fold coincidence trigger count of the plastic scintillator telescope for a fixed duration and the noise rate of the RPC, is defined as the number of counts per unit area of the strip per second. The efficiency and noise rate are studied by varying the applied HV. The RPC is tested with -20 mV and -25 mV threshold settings to the LED. An efficiency and the noise rate are very low for this gas mixture compared to the 100% C$_4$H$_2$F$_4$ used earlier for the same detector [11]. An efficiency of greater than 90% is found from 10 kV onwards with a maximum noise rate of 120 Hz/cm$^2$ at -20 mV threshold.

4. Summary

A linseed oil-coated RPC prototype of dimension 27 cm × 27 cm is fabricated using indigenous resistive bakelite plates. The linseed oil coating is done before making the gas gap. Before building the detector, electrode plates are checked visually whether the oil is cured properly or if any uncured oil is present on the surface.

The detector is tested with Tetrafluoroethane (C$_4$H$_2$F$_4$) and Isobutane (i-C$_4$H$_{10}$) in 90/10 volume ratio. Both the current and noise rate are very low for this gas mixture compared to the 100% C$_4$H$_2$F$_4$ used earlier for the same detector [11]. An efficiency of greater than 90% is found from 10 kV onwards with a maximum noise rate of 120 Hz/cm$^2$ at -20 mV threshold.

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References

[1] G. Aielli et al., Nucl. Instrum. Methods. A 562 (2006) 92.
[2] Q. Zhang et al., Nucl. Instrum. Methods. A 583 (2007) 278.
[3] A Kiseleva et al., Indian J. Phys. 85 (1) 211-216 (2011).
[4] A. Sen et al., 2020 JINST 15 C06055.
[5] G.C. Trinchero et al. Nucl. Instrum. Methods. A 508 (2003) 102.
[6] A. Laso Garcia et al., 2012 JINST 7 P10012.
[7] B. Hong et al., Journal of the Korean Physical Society. Vol. 48, No. 4, April 2006, 515.
[8] C. Lu, Nucl. Instrum. Methods. A 602 (2009) 761.
[9] J. Va’vra, Nucl. Instrum. Methods. A 515 (2003) 354.
[10] F. Anulli et al., Nucl. Instrum. Methods. A 508 (2003) 128.
[11] A. Sen et al., Nucl. Instrum. Methods. A 1024 (2022) 166095.