Timing Studies of Bakelite Multi-gap Resistive Plate Chamber

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INTRODUCTION

The Multi-gap Resistive Plate Chamber (MRPC)[1] is an advanced form of Resistive Plate Chamber (RPC) detector where the gas gap is divided into sub-gaps. MRPCs are known for their good time resolution and detection efficiency for charged particles. They have found suitable applications in several high energy physics experiments like ALICE in LHC, CERN, Geneva, Switzerland and STAR in RHIC, BNL, USA. As they have very good time resolution and are of low cost, they can be suitable replacement for very expensive scintillators used in Positron Emission Tomography Imaging. The MRPCs that are being used nowadays are developed with glass electrodes. We have made an attempt to develop 6-gap **oil-free bakelite** MRPC. The outer electrodes are of dimensions 15 cm × 15 cm × 0.3 cm and the inner electrodes are of dimension 14 cm × 14 cm × 0.05 cm. The performance of the detector has been studied measuring the efficiency, noise rate and time resolution with cosmic rays. Details of the development procedure and performance like efficiency, time resolution have been presented here.

MOTIVATION

1. Probable application in Medical Physics like Positron Emission Tomography.

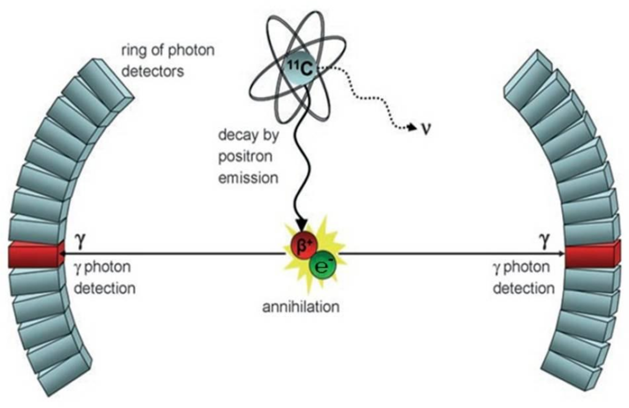

Figure 1: Working principle of TOF-PET Imaging.

MRPCs can be suitable replacement for the present day scintillators used in PET Imaging because:-

- They have good time resolution (10 ps) (Depends on the number of gas gaps).
- They are of low cost and easy to fabricate and operate.
- They can easily be fabricated over a large area.

We have developed two nearly identical 5-gap glass MRPCs to establish the basic working principle of PET imaging. (presented in DAE-BRNS HEP 2016 symposium , India[2].)

2. Why bakelite ?

- Unlike glass, bakelite sheets do not break easily.
- Testing, handling and shifting of bakelite based modules are much more easier than the glass modules.
- Bakelite RPCs can be easily operated in "streamer mode" unlike glass RPCs reducing the number of electronics channels used and hence the overall cost in an experiment.
- The used bakelite sheets do not need any kind of oil coating[3, 4].

DETECTOR SPECIFICATIONS

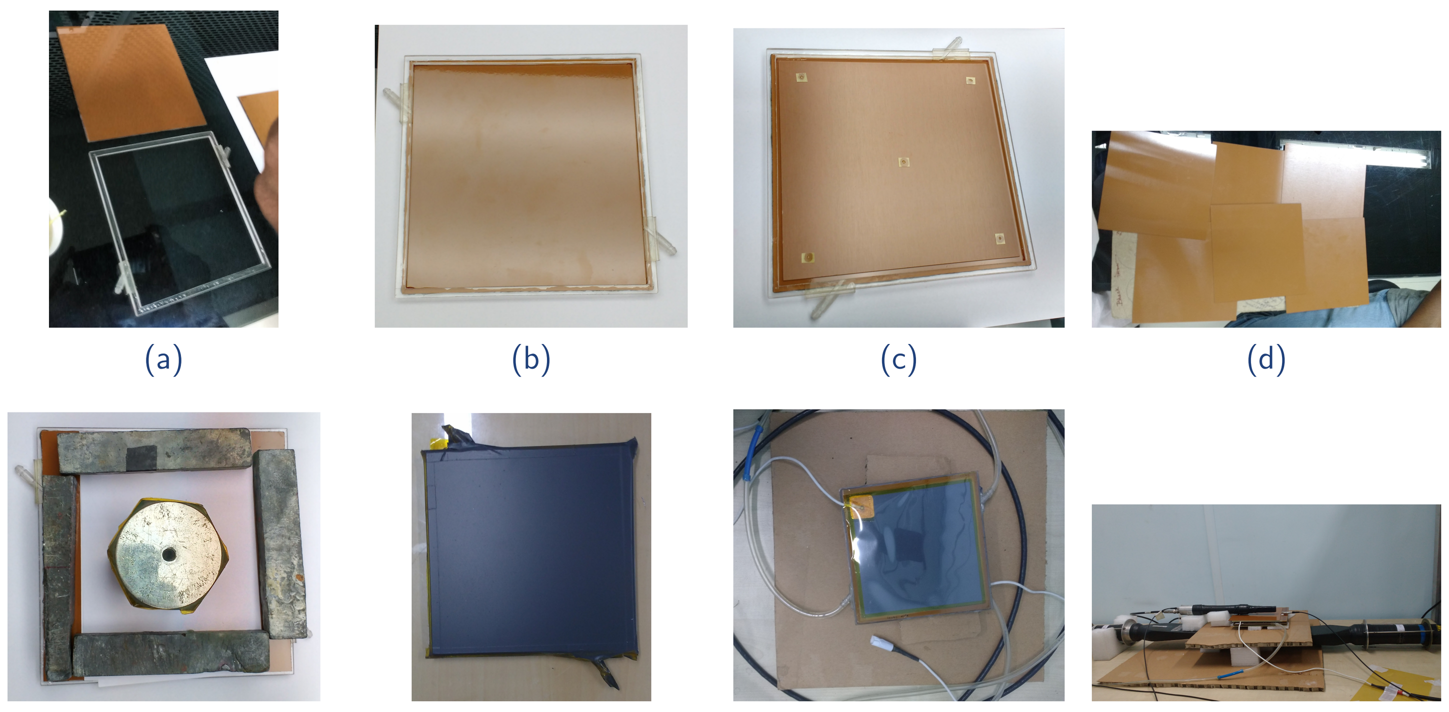

Figure 2: Various steps of development of bakelite MRPC (a) shows the bottom electrode plate and the side spacer with two attached gas nozzles - one for gas input and another for gas output (b) shows the side spacer with the gas nozzles has been glued to the bottom electrode plate (c) shows five button spacers glued on the button electrode plate (d) shows the intermediate bakelite electrodes each of ∼500 μm thick. These intermediate electrodes were stacked one over the other on the button electrode plate with the help of the button spacers. (e) finally the whole chamber is closed by gluing the top electrode on the last intermediate electrode. Few weights have been placed on the chamber to ensure that the electrode plates should cling properly with the spacers. (f) the outer surface of the top and bottom electrodes was pained with semi-conducting paint. (g) the electrical and the gas connections have been done. The painted surface of the electrodes were also properly insulated and isolated from the outer environment with the help of mylar sheets. (h) MRPC under test with cosmic rays with one finger and two paddle scintillators.

Total area of the MRPC	∼ 15 cm × 15 cm
Active area of the MRPC	∼ 14 cm × 14 cm
Number of outer electrodes	2
Number of inner electrodes	5
Dimensions of the outer electrodes	∼ 15 cm × 15 cm × 0.30 cm
Dimensions of the inner electrodes	∼ 14 cm × 14 cm × 0.050 cm
Thickness of each button spacer	∼ 0.024 cm
Thickness of the side spacer frame	0.40 cm
Total number of gas nozzles	2
Total number of gas gaps	6
Thickness of each gas gap	∼ 0.025 cm

Table 1: Specifications of the MRPC.

Gas Composition	R134a : iso-butane :: 85 : 15
Gas Flow Rate	∼ 0.21 litre/hour
Master Trigger Rate	∼ 0.008 Hz/cm^2

Table 2: Gas used during test.

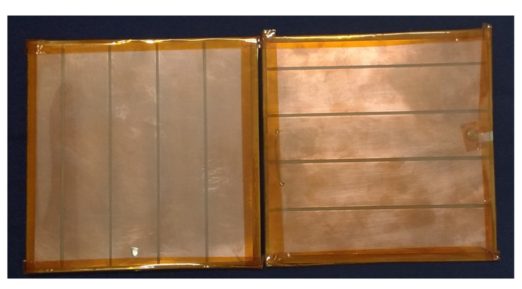

Figure 3: The pick up panel.

The master trigger was obtained from the coincidence of the three scintillators- two paddle scintillators and one finger scintillator.

COSMIC RAY TEST RESULTS

MRPC - 1 WITH SCINTILLATORS

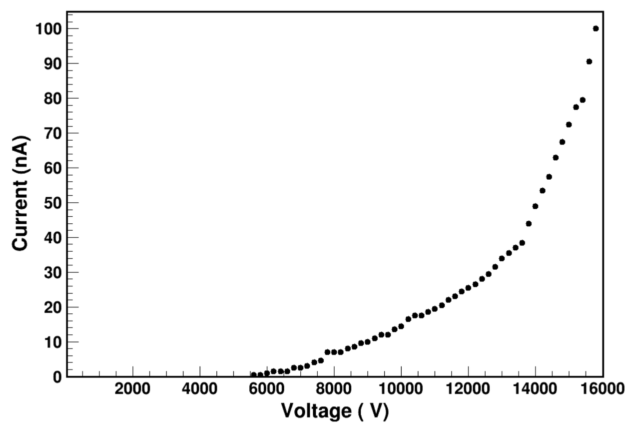

Figure 4: IV characteristics of bakelite MRPC-1.

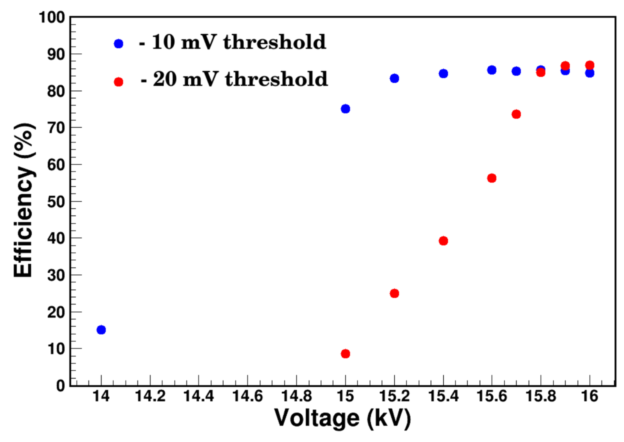

Figure 5: Measured efficiency of the bakelite MRPC-1 as a function of applied voltage.

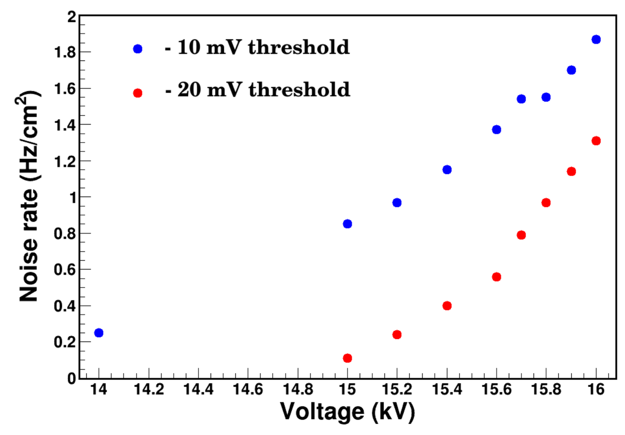

Figure 6: Noise rate of the bakelite MRPC-1 as a function of applied voltage.

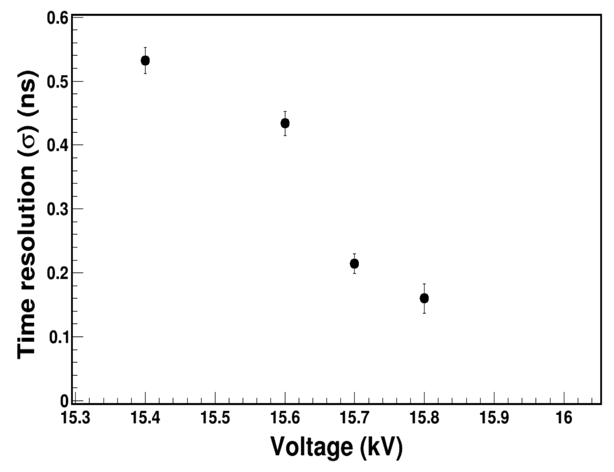

Figure 7: Variation of time resolution of bakelite MRPC-1 with applied voltage.

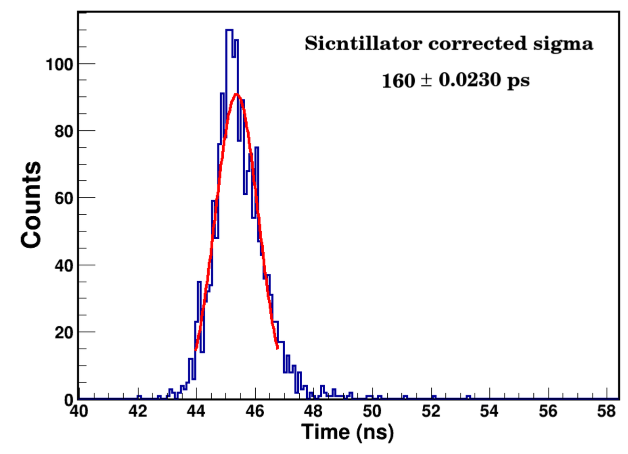

Figure 8: TDC spectra of bakelite MRPC - 1 at 15.8 kV of applied voltage.

- **The efficiency of the detector was obtained to be ∼85%.**
- **The maximum noise rate of the detector was found to be ∼1.85 Hz/cm^2 at 16 kV of applied voltage and 10 mV of signal threshold.**
- **The best time resolution obtained is ∼160 ps at an applied voltage of 15.8 kV.**

MRPC - 2 WITH SCINTILLATORS

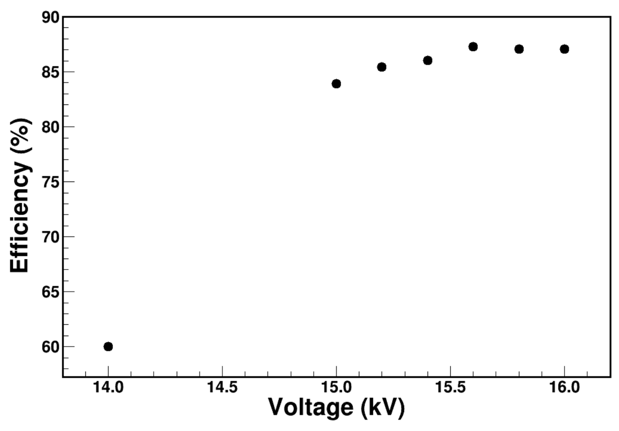

Figure 9: Measured efficiency of the bakelite MRPC-2 as a function of applied voltage.

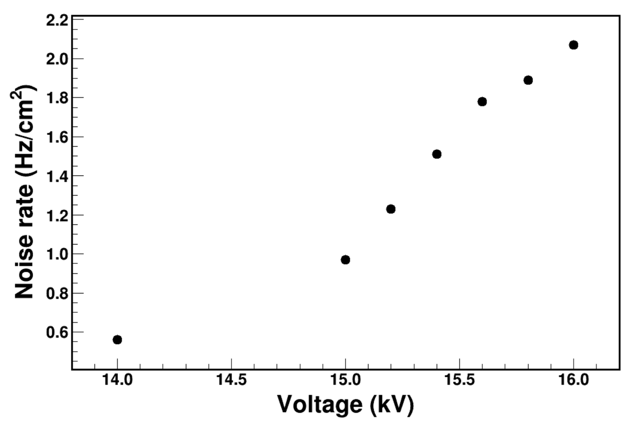

Figure 10: Noise rate of the bakelite MRPC-2 as a function of applied voltage.

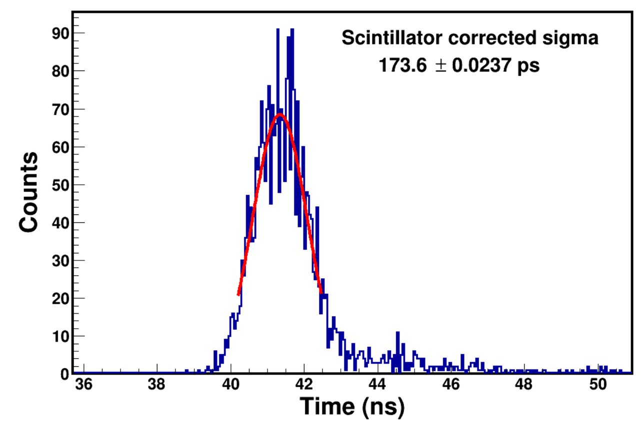

Figure 11: TDC spectra of MRPC-2 at 16 kV applied voltage obtained with scintillator set up.

- **The efficiency of the detector was obtained to be ∼87%.**
- **The maximum noise rate of the detector was found to be ∼2.1 Hz/cm^2 at 16 kV of applied voltage and 5 mV of signal threshold.**
- **The best time resolution obtained is ∼174 ps at an applied voltage of 16.0 kV.**

MRPC - 2 WITH MRPC - 1

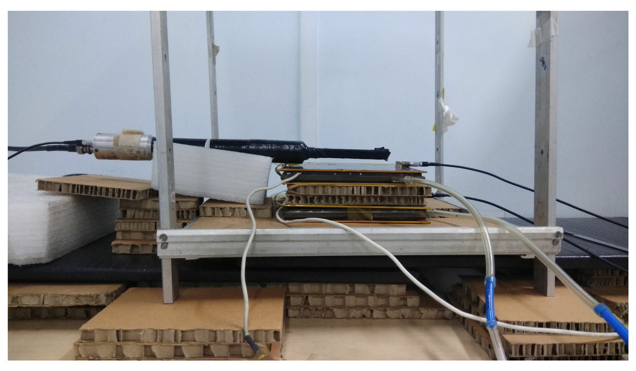

Figure 12: Cosmic ray test set up of both the MRPCs with three scintillators.

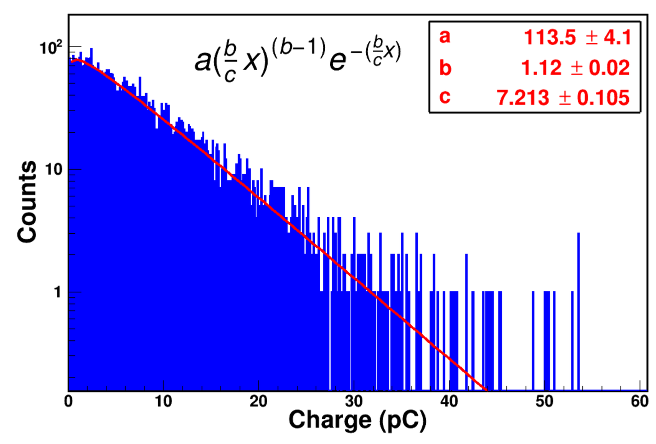

Figure 13: Charge spectra of MRPC-2 at 16 kV applied voltage.

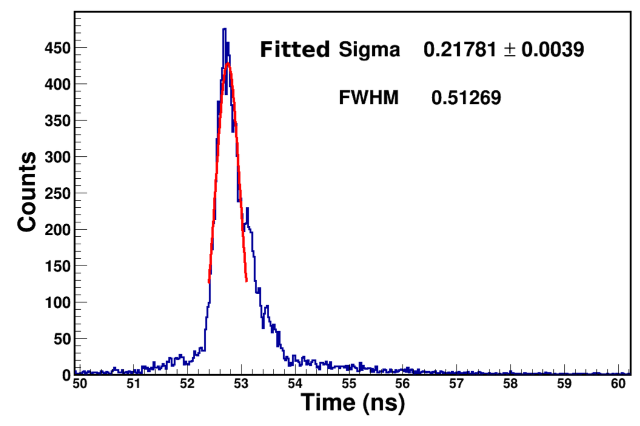

Figure 14: TDC spectra of MRPC-2 at 16 kV applied voltage obtained with w.r.t MRPC-1.

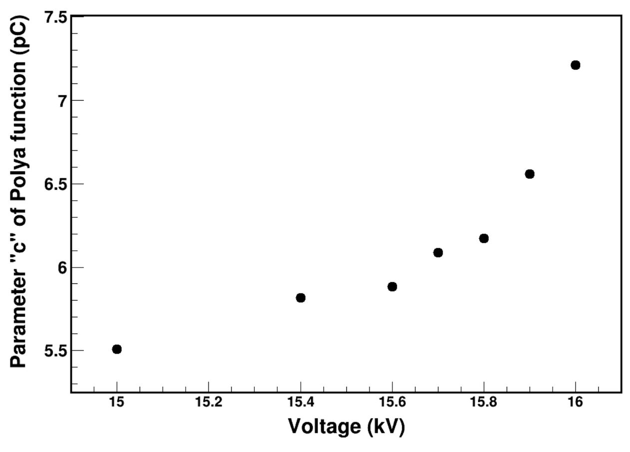

Figure 15: Variation of parameter "c" of Polya function as a function of the applied high voltage.

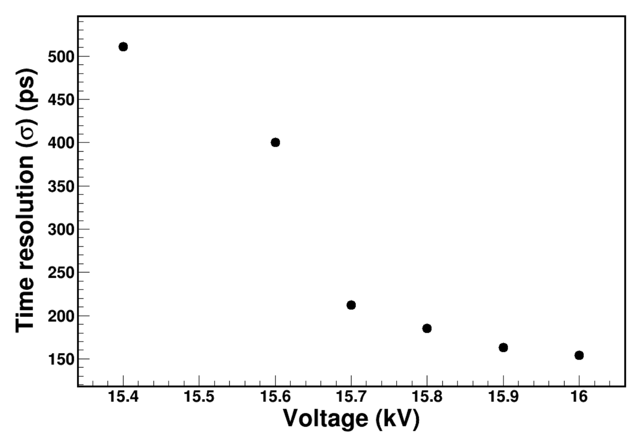

Figure 16: Variation of time resolution of the MRPCs as a function of applied high voltage.

- **The charge spectra of MRPC-2 were obtained at different applied voltages and fitted with "Polya function".**
- **The variation of parameter "c" of Polya function was studied as a function of applied voltage.**
- **The best time resolution of the detectors obtained was ∼154 ps at an applied voltage of 16 kV.**

CONCLUSION AND OUTLOOK

We have successfully developed two 6-gap bakelite oil-free MRPCs. The detectors have been characterized for their efficiency, noise rate and time resolution with a gas mixture of R134a:iso-butane::85:15 (by volume). The efficiency and the best time resolution of the detectors were found to be >85% and ∼154 ps respectively.

As a future work, the detectors have to be tested for their photon detection efficiency and to characterize them with different other gas mixtures with an inclusion of SF_6 to improve their time resolution.

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