New development of bakelite-based Resistive Plate Chamber

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Introduction:

The proposed India-based Neutrino Observatory (INO) is being planned with the aim to determine precisely the oscillation parameters using atmospheric neutrinos[1]. In INO, Resistive Plate Chamber has been chosen as the active detector for the detection of muons (produced through the interaction of neutrinos) in a 50 kton Iron CALorimeter (ICAL). The Resistive Plate Chamber (RPC) , first developed by Santonico et al. [2] are being used extensively in high energy physics and neutrino physics experiments. RPC is a gas-filled detector utilizing a constant and uniform electric field produced by two parallel electrode plates made of a material of high bulk resistivity (10^{10}-10^{12}-Ω-cm,e.g. Glass, Bakelite) separated by insulating spacers. The large area RPCs are used in experiments like BELLE, BaBar, BESIII, and several LHC experiments (ALICE, ATLAS, CMS etc.) mainly for a) relatively low cost of materials used in making RPCs, b) robust fabrication procedure and handling and c) good time and position resolutions. RPCs are used in neutrino experiments like OPERA where its excellent time resolution and tracking capabilities are exploited.

Bakelite RPC detector of various sizes from 10cm X 10cm to 1m X 1m have been fabricated, characterized and optimized for efficiency and time resolution, and are reported earlier[3-5].

Surface Resistivity Measurement :

The Schematic of electronic setup made to measure the surface resistivity of the bakelite surface and silicone coated surface is shown in Fig.1. This setup may also be used to measure the surface resistivity of graphite coated surface.

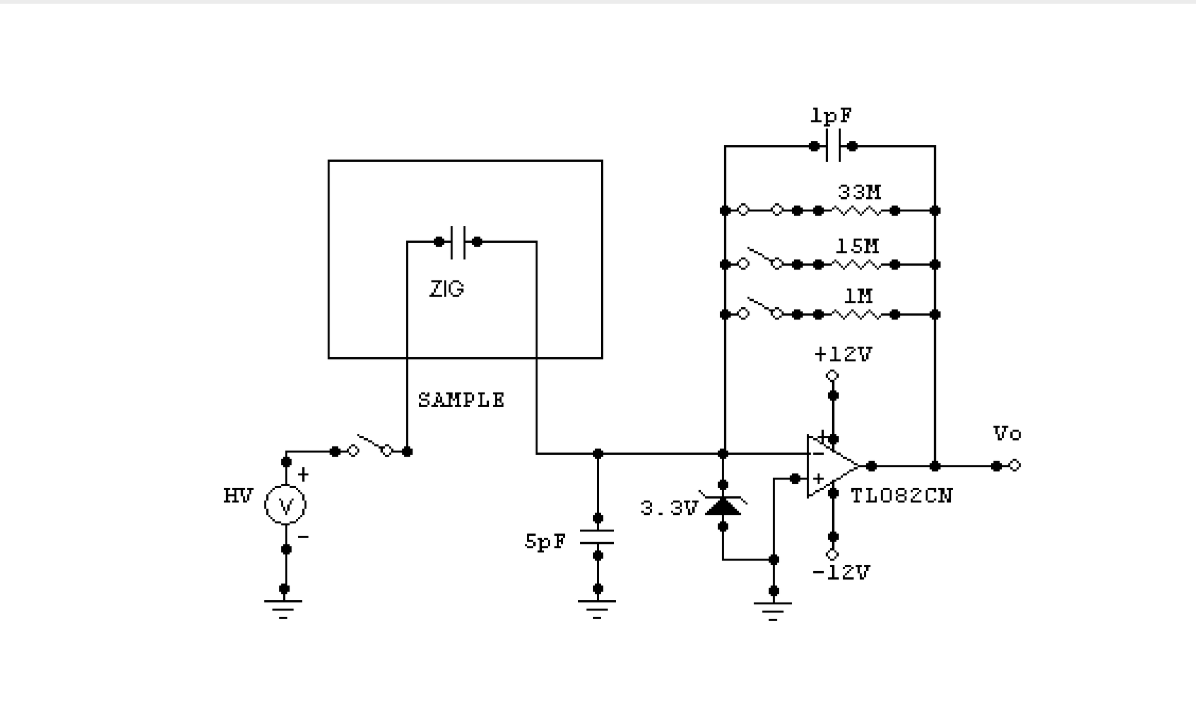

FIG. 1: Schematic of the experimental setup for surface resistivity measurement.

The set-up consists of a jig with two aluminium bars having V-shaped sections and soft-padded conducting edges at the bottom, which are placed on the surface under measurement. The bars, forming the opposite sides of a square shape, were mounted on a G-10 insulating plate having very high resistivity (>10^{14}/Square). A current to voltage converter circuit, made out of TL082CN FET input OPAMP, with provisions to cover 3 decades of surface resistivity measurement (~10^{10} - 10^{12}Ω/Square), was made. Measurements were done on the inner surfaces of the Bakelite electrodes (silicone coated or uncoated) before assembly of the RPCs. A DC bias voltage -600 volt was applied on the jig, and the leakage current (~nA/pA) owing across the terminals of the jig through the Bakelite surface was measured. The surface resistivity was obtained from the leakage current and the applied bias voltage.

The variation of surface current and surface resistivity with the applied voltage for different coated and uncoated Bakelite electrodes are shown in Fig. 3.

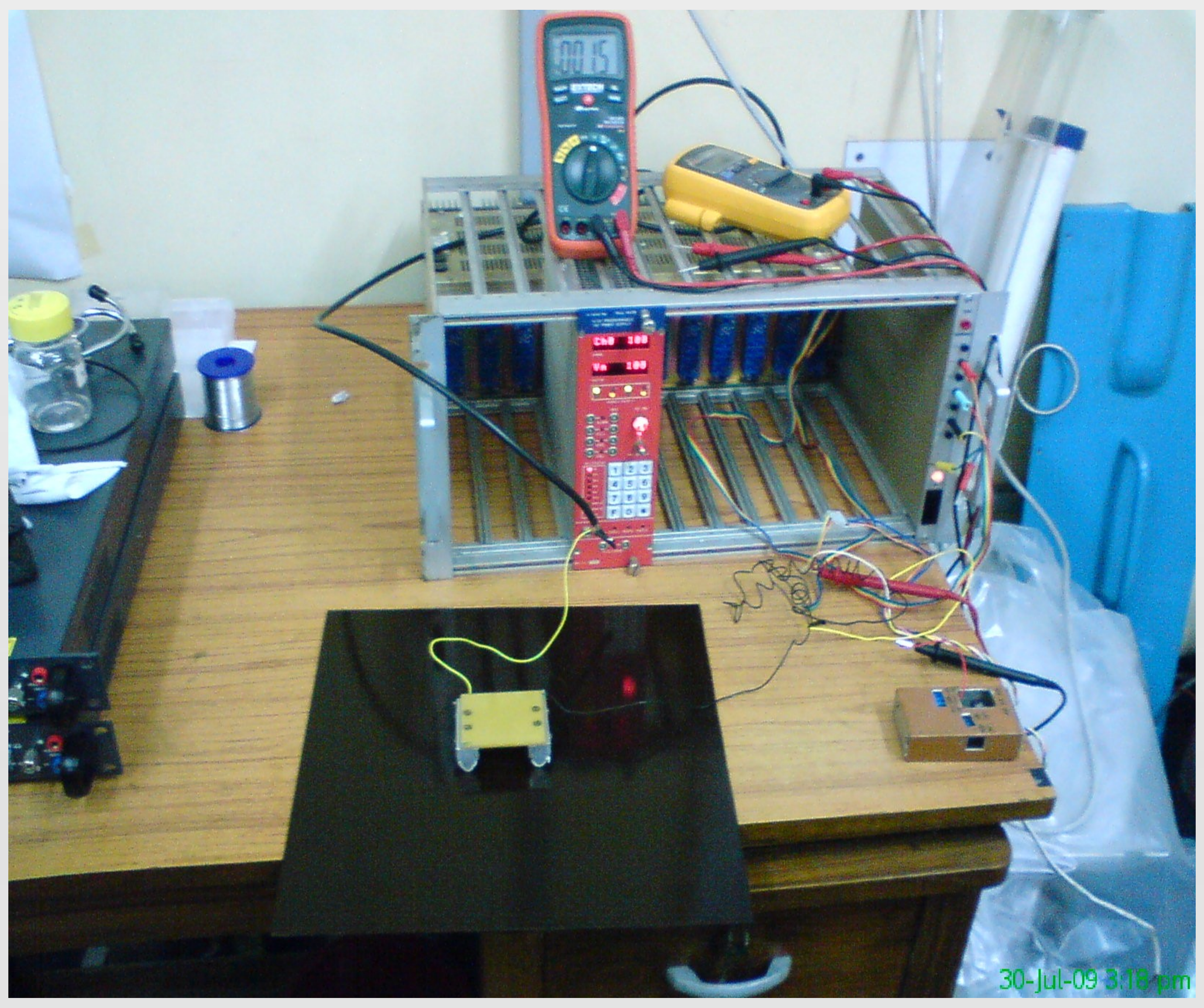

Fig.2: Experimental setup for surface resistivity measurement..

Characterization of Pick-up panel:

Capacitive read out strips for the RPCs were made out of 16-conductor ribbon cable (20 mm wide and 1 mm thick), which is commercially available. The cables, cut in proper size, were placed side by side and glued to a mylar sheet of thickness 0.1µm, cut out according to the size of the RPC. 15 conductors of each ribbon cable, forming a readout strip, were shorted and connected to a signal transmission cable, and the 16th conductor grounded for strip isolation. 2 mm layer of foam was pasted on the mylar sheet, with a ground plane placed on the opposite foam surface. Two sets of read-out strips for the X- and Y-axes were made. Characteristics of the pickup pulses, impedance of the strips, efficiency and time resolution of the RPC were studied.

The Impedance Analysis of the pick up panel is done using Instek LCR meter. The Inductance of the ribbon cable is L~ 11600pH/cm. The capacitance of each strip is measured using LCR meter. Then the impedance is measured using the formula:

$$z=\sqrt{L/C}$$

The measurement is repeated three times and the average impedance and standard deviation are calculated. The impedance is plotted with standard deviation. Almost ~10% variation in impedance can be seen across the strips.

Result:

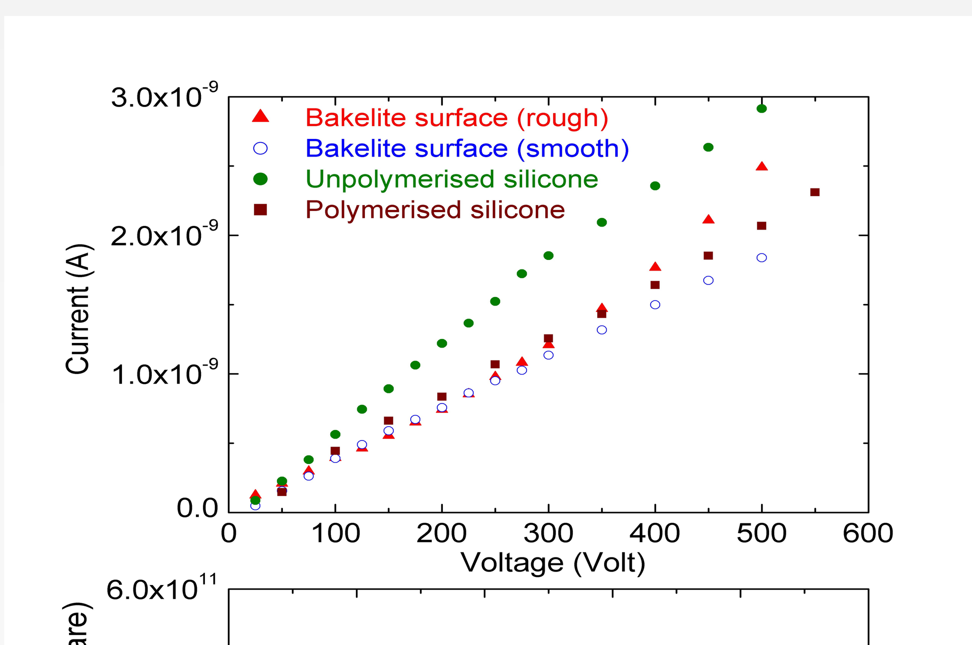

FIG. 3: (a) The surface current & (b) the surface resistivity versus the applied voltage for different samples.

Result(Cont'd):

The I-V plots for the surface resistivity of uncoated Bakelites having two different surface textures (rough and smooth) shows a non-linear trend for the rough surface, resulting in an apparent reduction of surface resistivity at higher bias voltage. This is likely to be correlated with the relatively high occurrence of microdischarge across the surface due to the roughness. In addition, comparison of the two different grades of silicone coating (unpolymerized and polymerized) on the Bakelite electrode surface shows that 1) the surface resistivity is less by a factor of 2 for the coated surface compared to the uncoated surface, and 2) the surface resistivity for the polymerized silicone coating is 1. 5 times higher than that for the unpolymerized variety.

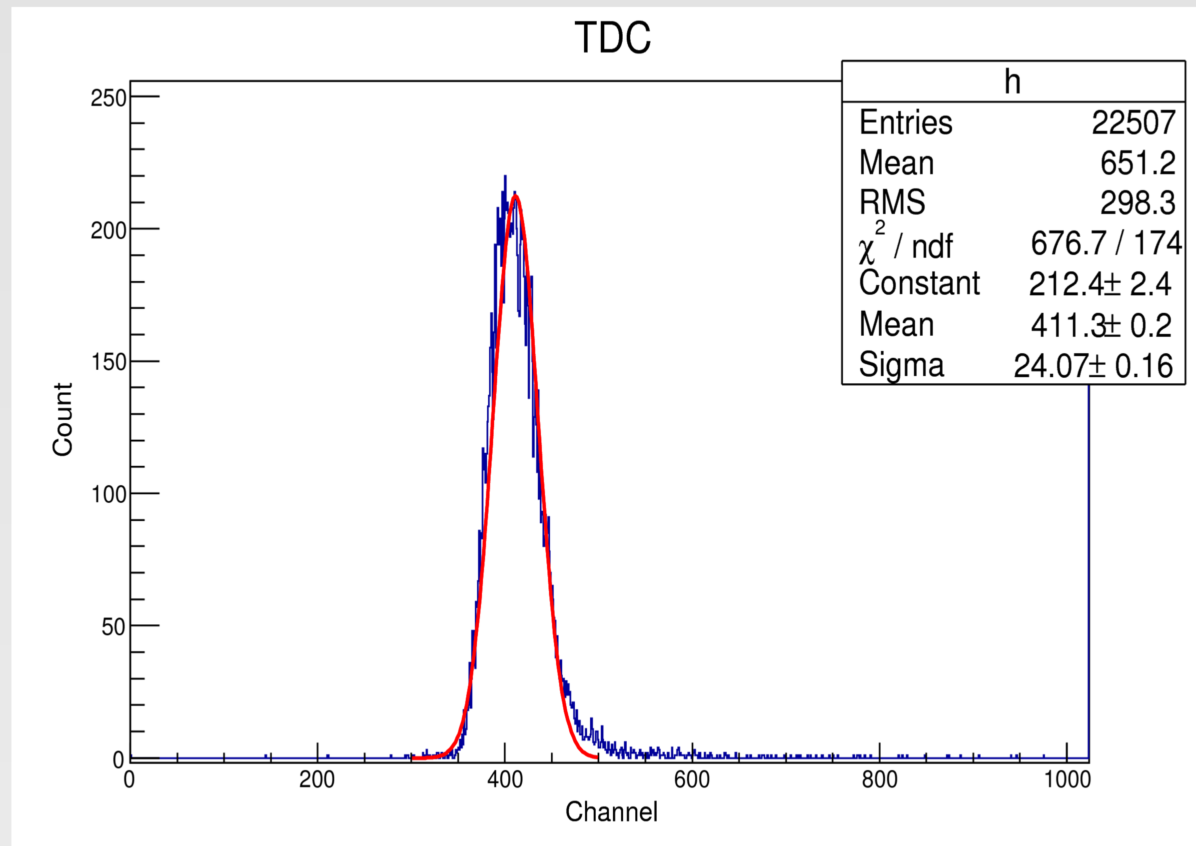

Fig.4. TDC spectra with Ribbon cable pick up panel.

The results of time resolution studies indicate that while the measured efficiency of the RPC remains unaltered, the time resolution is degraded (~2.4ns) as compared to the pick-strips used earlier, which is likely to be due to larger capacitance and variation of the characteristic impedance.

Summary:

·The surface resistivity of Bakelite RPC with rough surface reduces at higher bias voltage.
·The surface resistivity for the unpolymerized silicone coating is lower compared to polymerized, which may help in reduction of space charge effect.
·Compared to the Cu-pick up panel, the time resolution using ribbon cable pick up panel is deprived which may be due to larger capacitance and variation of characteristic impedance.

Acknowledgement:

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Reference:

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