G-10 read out panel (1m x 1m) as an option for RPCs in INO

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Introduction:

India-based Neutrino Observatory (INO) is a proposed experimental project primarily to study atmospheric neutrinos and to make precision measurement of the neutrino oscillation parameters. The experiment will consist of a 50 kt magnetized Iron Calorimeter (ICAL) with 2m x 2m RPCs (Resistive Plate Chamber) as the active detector elements. About 30,000 RPCs having about 4 million read out channels will be needed for the INO experiment, which will be interleaved within 4 cm gaps of the magnetized iron plates [1].

When a charged particle such as a muon passes through the chamber it ionizes the gas and charges move towards their respective electrodes. The electrodes are transparent to the signal (the electrons), which are picked up by external metallic strips. The signal is carried by coaxial cable (50 Ohm impedance) from read out to pre-amplifier. We are using positive HMC (Hybrid Micro Circuit) and negative HMC pre-amplifier (provided by TIFR-INO group) for the respective signals. The two stage voltage sensitive pre-amplifier board has 8 channels. Each stage has a gain of ~10. So, the total gain is ~100. The operating voltage required for pre-amplifier board is ± 6 V. The trigger is generated by taking the telescopic coincidence of two scintillator paddles of same dimension (40 x 18 x 1 cm^3) kept above and below the RPC such that they cover 5 strips.

We have been using polycarbonate based readout panel with a thickness of around 5 mm obtain from TIFR-INO group. This panel has an aluminium ground plane and copper strips for signal. There are 32 strips of width 28 mm with a characteristic impedance of ~50 **Ω**.

In this paper, we report our test measurements with a 1 m x 1 m G-10 based readout plane, as an alternative, having a thickness of ~0.8 mm with 32 copper strips each of width ~3 cm, each 1 m long, which were fabricated locally. Using a, 1 mm G-10 read-out plane, effectively reduces the RPC thickness by 80%, which is very crucial in an allotted space of 40 mm for inserting the RPCs. Fig 1 below shows the G-10 Readout.

Figure 1:1 m x 1m G-10-Readout with 32 read out strips (strip dimensions: 3 cm x 100 cm)

The characteristic impedance of the copper strips in the G-10 readout is calculated using the formula [2]:

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}}} \frac{1}{\left[\frac{w}{h} + 1.393 + 0.677 * \ln\left(\frac{w}{h} + 1.444\right)\right]}$$

$$where: \varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \times \left[\frac{1}{\sqrt{1 + 12h/w}}\right]$$

w = Width of the strips (w = 28 mm)
h = Thickness of the dielectric (h = 0.8 mm)
ε_r = Dielectric constant of the strip (ε_r= 4.2)

The calculated impedance is found out to be 4.87 Ω or ~5 Ω.

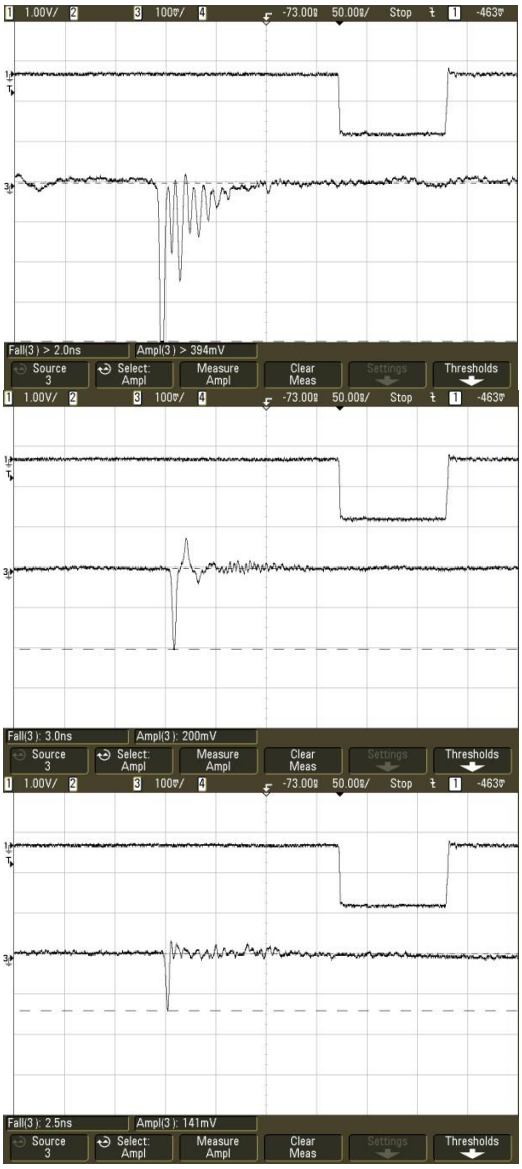

Figure 2: (Top), Coaxial cable soldered directly on readout strip and other end of read out strip is without termination. **(Middle),** Coaxial cable soldered directly on readout strip with 50 Ω in series, 5 Ω in parallel and no termination at the other end of the strip. **(Bottom),** Coaxial cable soldered directly on readout strip with 50 Ω in series, 5 Ω in parallel and a 5 Ω resistance at the other end of the strip.

To match the impedance with the readout panel, following combinations are tried and results are observed in the oscilloscope, which are shown in Fig-2 (signal is shown as a sharp negative pulse and scintillator paddle trigger is shown as a square pulse). The signal is transmitted through coaxial cable from the read out to the pre-amplifier.The input impedance of the pre-amplifier is also 50 Ω. For maximum signal transmission, impedance should be matched with electronics. The ringing observed in Fig-2 (Top) is because of impedance mismatch at both the ends of the readout strips. In Fig-2 (Middle), we can see that the ringing is significantly reduced; but some reflection is seen due to the absence of termination at the other end of the strip. In Fig-2 (Bottom), we see significant reduction in ringing as well as reflection because the other end of the strip is terminated by a 5 Ω resistor. The pulse rise time is ~2.5 ns and the amplitude is ~140 mV after amplification (Fig-2: Bottom) and is as expected in such applications.

Conclusions:

We have been able to match the impedance of the copper strips in the G10 readout by using a 50 Ω resistor in series, 5 Ω in parallel to connect pre-amplifier electronics with a 50 Ω coaxial cable and a 5 Ω resistance at the other end of the strip. The G-10 readout shows promise to be used for the RPCs in the INO project. It would be advantageous since the thickness of the RPCs can be reduced by 8 mm, compared with polycarbonate honeycomb based readout. It would further make handling of RPCs in a gap of 40 mm between the 56 mm thick iron plates of the ICAL detector, easier. The G-10 readout plane is quite flat and remains in better contact with RPC than the polycarbonate plane, thus ensuring a better signal quality. 1 m x 1m glass RPCs with G-10 readout (X-plane and Y-plane) will also be assembled for muon tomography programme being pursued in NPD.

References:

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