Development of MMRPC in India with timing resolution better than 100 ps

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Introduction: A prototype of Multi-strip Multi-gap Resistive Plate chamber (MMRPC) with active area 40 cm × 20 cm has been developed at SINP, Kolkata using mainly locally available materials. The planning, designing, building and commissioning were performed at SINP, Kolkata. The design of the detector elements is as followed: double stack MRPC with glass resistive plates and two gas gaps of 0.3 mm per stack. The Anode plate was segmented with 2cm wide strip. The response of this MMRPC has been studied using cosmic muons, γ-rays [1] at SINP laboratory and electron beam at ELBE, Dresden. In this report we have discussed the testing of our newly developed MMRPC detector using the electron linac ELBE at Forschunszentrum Dresden-Rossendorf. Using ELBE electron beam the timing resolution (σ) was found to be around 100 ps.

Test Set-up:

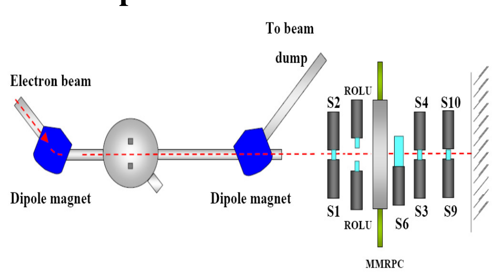

Fig. 1 Experimental set-up for MMRPC testing using electron beam .

The detector test was performed at the radiation physics cave of ELBE. The electron energy was chosen to 29 MeV with a micro-pulse repetition rate of 12 MHz and pulse width of ~ 10 ps. The beam was operated in single-electron per bunch mode and allowed to hit the test set-up straight through a 40 micrometer thick Beryllium window (without using any thick Al foil target in the scattering chamber).

The geometry of the test set-up is shown in Fig. 1. The pulsed electron beam from the Be-window passes through air for 41 cm and then falls on the test set-up. Active collimation was done by plastic scintillators (Bicron BC-408) of dimension 2 × 2 × 0.5 cm^3. Each scintillator was read out by a pair of 2in. Photo Multiplier Tubes, hence delivering signals S1/S2, S3/S4 and S9/S10. As shown in Fig. 1, between scintillator S1/S2 and the MMRPC detector there was a VETO detector ROLU which has four plastic scintillators each read out by a PMT. There was another scintillator placed between MMRPC and S3/S4 for active collimation produces signal S6. Beam profile was estimated using a plastic scintillator (S5) which can be moved using a remote controlled motor to scan both in horizontal and vertical direction. We used a non-flammable gas mixture of 85% R134a Freon ($C_2H_2F_4$), 8.5% Sulphur hexafluoride (SF_6), 6.5% iso-butane (iso-C_4H_{10}) at normal atmospheric pressure as counting gas in the MMRPC detector. The detector was flushed with a flow exchanging the gas volume in every ~ 8 hrs.. FOPI cards were used as Front End Electronics (FEE) [2] for generating timing and amplified signals from MMRPC. Timing signals were shaped properly using leading edge discriminator. The amplified analog signals are used for time-slewing (walk) correction.

Results and Discussion: To find the optimum operational condition of the prototype, the detector efficiency and time resolution were scanned as a function of the applied high voltage using a beam with a flux of 10 Hz/cm^2.

Fig. 2, 3 and 4 are the plot of the absolute efficiency against bias voltage of MMRPC, RF trigger rate and strip number of MMRPC respectively. In this analysis the efficiency for strip 4 and 5 reaches 97% at bias voltages greater than 7 kV. It is also

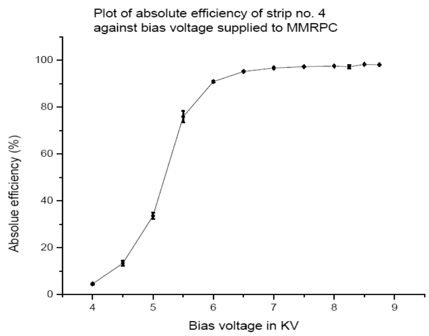

Fig. 2 Plot of absolute efficiency vs. bias voltage.

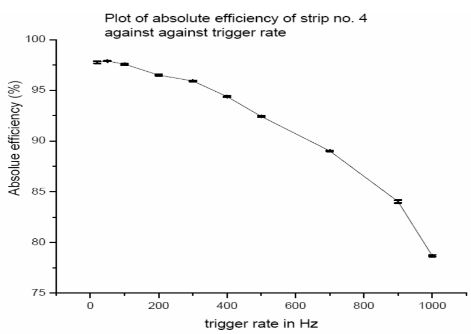

Fig. 3 Plot of absolute efficiency of strip no. 4 against trigger rate.

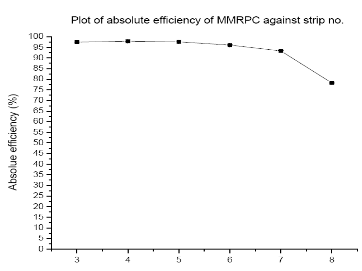

Fig. 4 Plot of absolute efficiency vs. strip number.

clear that efficiency decreases with increasing RF trigger rate. A sufficiently long plateau has been observed allowing the safe detector operation. Therefore, a high voltage of 7.5 kV was used for the further investigation reported below.

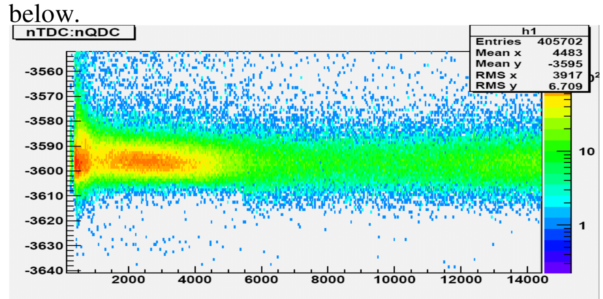

Fig. 5 Walk corrected correlation plot of TOF against its charge distribution.

For time resolution, the measurements of time were considered with reference to the R.F. signal provided by ELBE. It is worthy to mention that similar to the read out of a

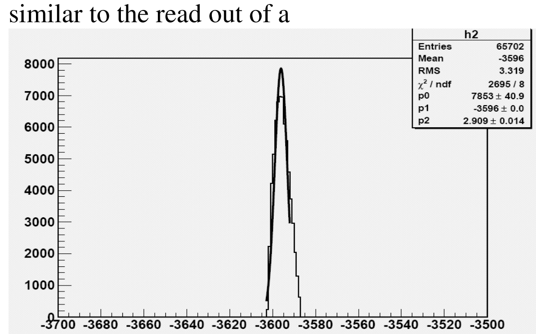

Fig. 6 TOF spectra showing time resolution less than 100 ps.

scintillator by two photomultiplier tubes, the mean timing, (t-left + t-right)/2, of the signals taken from both sides of a MMRPC is independent of the position along the strip. Thus TOF distribution, for the involved strips, was obtained from the arithmetic mean of the time signal delivered from both ends of a strip relative to the RF trigger. Hence, Fig.5 shows a correlation between the TOF of strip 4 against its average charge distribution after walk correction. The time resolution after walk correction was found to be around 75 ps (Fig.6).

References:

[1]] U. Datta Pramanik et. al. accepted in NIMA doi:10.1016/j.nima.2010.10.055

[2] M.Ciobanu et al., IEEE54 (2007) 155