Performance of a six gap MRPC built for large area coverage


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1. Introduction

We have constructed an MRPC with an active area of $82 \times 158$ cm$^2$. This has six gas gaps each of 300 $\mu$m width. This chamber was one of the many built for the EEE project [1–3]; this project needs large area detectors to detect muons in extensive air showers initiated by incoming particles with extremely high energy. A 2-D position resolution of $\sim 1$ cm is needed so that the direction of the muons can be determined. The performance of these chambers measured with cosmic rays has already been published [4,5]; in this paper we employ TDCs with better time resolution and measure the performance at a test beam at CERN to better understand the performance of this device. We also give details concerning the construction of this device.

2. Description of the MRPC

The detector is a multigap resistive plate chamber with six gaps, each of 300 $\mu$m width (MRPC 6/300). We define the thickness of the MRPC 6/300 as the distance between the anode and cathode pickup electrodes and is 14.1 mm in this case. It consists of a stack of resistive (glass) plates, with voltage applied only to the external surfaces; these are coated with a special resistive paint, Licron 1755. In this paper we employ TDCs with better time resolution and measure the performance at a test beam at CERN to better understand the performance of this device. We also give details concerning the construction of this device.

We have constructed an MRPC with an active area of $82 \times 158$ cm$^2$. It has six gas gaps each of 300 $\mu$m width. The performance of this chamber measured at a CERN test beam is presented. Details concerning the construction are also given.
Avalanches are then generated due to the high electric field. The resistive plates terminate the avalanche development in each gap. Since these glass plates have high resistivity they act as dielectric plates for the fast signal produced by the movement of electrons in the gas avalanches. The induced signal on the pickup electrodes is the sum of all gas avalanches in all of the gas gaps.

There are 24 readout strips, each 2.5 cm wide and 180 cm long. They are mounted on a vetronite sheet with an area of $90 \times 180 \text{cm}^2$ as shown in Fig. 2. Readout strips are mounted on both sides of the stack of glass plates (i.e. cathode and anode readout strips). The signal induced by a charged particle traversing the chamber is read out at both ends of the strip. The hit coordinate along the strip is obtained by the time difference of the signals at the two ends.

### 3. Assembly procedure

The schematic cross-section along one edge of the MRPC is shown in Fig. 3. The chamber construction procedure is the following:

1. Twenty-four readout strips are fabricated on the vetronite sheet. Each strip is a length of self-adhesive copper tape 25 mm wide. A 7 mm gap is left between strips.
2. Plastic (M5) screws are mounted along each edge of the vetronite sheet. These screws will be used to hold the nylon fishing line that acts as a 300 µm spacer.
3. A honeycomb panel is attached to the vetronite sheet using double-sided adhesive tape.
4. The first (outer sheet) of glass is placed on top of the vetronite and a connection is made to the Licron coating, so that a high voltage can be applied. This is shown in Fig. 4. A mylar film (160 µm thick) with a cut out (to create some space for the connection) is first placed on the vetronite sheet. Copper tape is put into this cut out with a small pad of carbon tape to make the connection between the Licron coating and copper.
5. The fishing line is stretched across the surface of the glass, and around the plastic screws along the edges as shown in Fig. 5. This fishing line acts as a spacer between glass plates and creates the gas gap with a width equal to its diameter, 300 µm.
6. Five internal glass sheets (each separated by a layer of fishing line) are then stacked up. All these glass plates need special care so that they can be placed into position. We used a vacuum lifting device specially built for this operation.
7. The top piece of glass is again of the external type coated with Licron. A high-voltage connection is made in a similar fashion as the lower external glass (however, the opposite corner is used).
8. The MRPC is completed by adding the mylar film and then the vetronite sheet with its readout strips and another 15 mm thick honeycomb.
9. The top and bottom honeycomb panels are fastened together using standoffs and screws. The MRPC chambers are designed to be used horizontally; however, for the chamber that we tested in the T10 test beam we needed to add some ‘feet’ to stop the glass sheets sliding out when the chamber was placed vertically. We built some special inserts to support the weight of the glass sheets in the chamber foreseen to be mounted vertically.
Twisted pair cable is soldered to the two ends of the anode and cathode readout strips and connected to the inner surface of two pcbs mounted at the two ends of the chamber. The front-end electronics is plugged onto the outer surface of these pcbs.

The MRPC is then placed in an aluminium box that is eventually sealed to make a gas-tight enclosure as shown in Fig. 5.

4. Beam test set-up

For the tests in the beam and also when used in the EEE project, these MRPCs are read out using the front-end cards built for the ALICE-TOF detector. Each card has 24 channels and ultra-fast NINO asics are employed [6]; the threshold was set to detect signals with an input charge of 100 fC. We tested this large MRPC in the T10 test beam by mounting it on a movable support system downstream of some ALICE-TOF modules that were the main focus of the time spent at the test beam. We used the data acquisition system and HPTDCs designed for the ALICE TOF; these TDCs have 25 ps bins. The experimental set-up in the T10 beam line of the CERN PS East Hall is shown in Fig. 6.

Two pairs (P1–P2 and P3–P4) of crossed scintillators were used to provide the trigger. The downstream pair (P1–P2) has a 1 x 1 cm² area. The upstream pair (P3–P4) defines a 2 x 2 cm² area. A 5 x 5 cm² scintillator (P5) was added to the trigger to ensure that the particles passed through the MRPC chamber being tested. To provide an accurate time reference, we used two scintillator bars (2 x 2 x 10 cm³) orthogonal to each other; these were read out at each end with photomultipliers (S1–S4) and discriminated by Constant Fraction Discriminators. The time resolution of one of these scintillator bars with respect to the other (i.e. \((\text{time}_{\text{S1}} + \text{time}_{\text{S2}})/2 - (\text{time}_{\text{S3}} + \text{time}_{\text{S4}})/2\)) had a sigma of 60 ps. We used the mean of all four times as the time reference (i.e. \((\text{time}_{\text{S1}} + \text{time}_{\text{S2}} + \text{time}_{\text{S3}} + \text{time}_{\text{S4}})/4\)); the expected time resolution from this mean is 30 ps; thus, we subtracted 30 ps quadratically from the measured sigma when quoting the time resolution of the MRPC.

The gas mixture was 98% of Freon (C₂F₄H₂) and 2% of SF₆, with a continuous flow of 5 l/h. DC/DC converters provided high voltage to the chambers; they produce a voltage up to 10 kV (or 10 kV for the negative polarity) with an input voltage between 0 and 5 V. The DC/DC converters were mounted onto the MRPC chamber; thus, no high-voltage cables were needed.

5. Results and discussion

We centred the beam in the middle of one of the strips and measured the efficiency versus high voltage as shown in Fig. 7. This efficiency is obtained from the OR of the strip and its two neighbours. The voltage is the total voltage across the six gas gaps (applied as positive voltage to the anode and negative voltage to the cathode).

The soft knee of the efficiency plateau shown in Fig. 7 is probably due to the 7 mm space between the readout strips; this should be reduced for future chamber production.

The strip was read out at each end; thus, the mean time \((\text{time}_{\text{end1}} + \text{time}_{\text{end2}})/2\) is independent of the position of the hit along the strip direction. A typical time distribution is shown in Fig. 8. There is time slewing in the discriminators since they have a fixed threshold; the input charge of the signal from the

chambers was encoded into the width of the LVDS pulse sent to the TDCs. The TDCs measured the time of both edges of the pulse (leading and trailing) and thus the width could be used to correct for slewing. The variation of the time measured by the MRPC as a function of the width of the signal (i.e. input charge) arriving at the TDC is shown in Fig. 9. This plot shows the problem that we had with this device. The input impedance of these cards was set at 50 Ω adjusted to match the impedance of the readout pads of the ALICE-TOF MRPCs for which the card was designed; the strips in this chamber have a characteristic impedance around 100 Ω. This mismatch resulted in reflection of the signal. This had the effect of generating a long tail of long pulses; all the widths greater than 18 ns shown in Fig. 10 are produced by these reflected pulses. In some positions along the strips, this tail became very dominant and it was difficult to make slewing corrections and thus the time resolution was worse than expected; this will be shown later. The time distribution after this slewing correction is shown in Fig. 10. The time resolution we quote is obtained, as specified above, by taking the sigma and subtracting 30 ps quadratically to remove the effect of jitter of the scintillators used as a time reference. The time resolution as a function of high voltage is shown in Fig. 11. A voltage of ±8.5 kV (17 kV total) was used for the remaining investigations. However, it should be noted that excellent time resolution can be obtained with the voltage in
the range of 15–19 kV; this shows the inherent stability of the MRPC.

We can obtain the position of the hit along the direction of the strip from the time difference of the hit time at each end of the strip. We wanted to measure the position resolution and its dependence on the position of the hit. We thus moved the MRPC in 2 cm steps from one end of the strip to the other. A mechanical system was used with the position read out by a ruler mounted on the underside of the ‘moving frame’; it was difficult to position the chamber more accurately than 1 mm. The time difference versus the chamber position is shown in Fig. 12. A linear fit has a slope of 112.4 ps/cm; the deviation from this linear fit is shown in Fig. 13 where the time difference is converted to distance using the slope; there is a non-linearity of about 6 mm. A typical time difference distribution (obtained from data taken near the middle of the strip length) is shown in Fig. 14. The sigma of this distribution is 94 ps that corresponds to 8 mm. However, the position resolution worsens significantly towards the two ends of the strips (as shown in Fig. 15).

We calculated the time resolution for all positions along the strip. This is shown in Fig. 16. In general the time resolution is between 65 and 70 ps; however, there are some points between

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**Fig. 12.** Time difference versus position of MRPC support frame.

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**Fig. 13.** Deviation from the linear fit shown in Fig. 12.

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**Fig. 14.** Typical distribution of time difference (i.e. $t_{\text{end1}} - t_{\text{end2}}$). The time difference is converted to distance using the slope shown in Fig. 12.

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**Fig. 15.** Position resolution versus position along the strip.

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**Sigma = 94 ps**

**position resolution =**

$94 \text{ ps} / 112 \text{ ps cm}^{-1}$

$= 0.84 \text{ cm}$
70 and 80 ps that are clearly different. This is caused by the mismatch between the characteristic impedance of the readout strips, cables connected to the strips and the input impedance of the front-end electronics. This mismatch causes the signal to be reflected and thus creates an afterpulse in the front-end electronics. The input charge is encoded into the pulse width and thus these reflections can severely disturb the charge measurement; we believe that the next generation of chambers that we build with correctly matched impedances will have time resolutions between 65 and 70 ps for all points along the strip.

6. Conclusion

The MRPCs discussed here have been built using low-technology construction techniques; this was a deliberate choice since many of the chambers were assembled by high school children. As an example: the pickup strips are made by sticking copper tape onto a vetronite board. Nonetheless the performance of this device is excellent.

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References