ALICE-PUB-2001-08

The Multigap RPC: The Time-of-Flight Detector for the ALICE experiment

M.C.S. Williams for the ALICE collaboration

EP Division, CERN, 1211 Geneva 23, Switzerland

Abstract

The selected device for the ALICE Time-of-Flight is the Multigap Resistive Plate Chamber. This detector, consisting of a stack of glass plates, has a time resolution between 60 and 80 ps. We discuss the principle of operation of this detector and present the latest results from the ongoing R&D program.

Key words: resistive plate chambers, ALICE, time of flight, particle identification

---

1 Introduction

The Multigap Resistive Plate Chamber (MRPC) was developed 6 years ago [1]. It consists of a stack of resistive plates, spaced one from the other with equal sized spacers creating a series of gas gaps. Electrodes are connected to the outer surfaces of the stack of resistive plates while all the internal plates are left electrically floating. The devices described here for Time-of-Flight purposes have small gas gaps (between 200 and 300 μm).

There are two features of the MRPC which are important to note: (a) the internal plates take the correct voltage initially by electrostatics and are kept at the correct voltage due to the flow of electrons and ions generated in the avalanche process; (b) even though there are many gaps, there is a single anode and cathode read-out electrode. Avalanches in any of the gaps induce the signals on these electrodes.

It is often questioned whether the electrically-floating internal sheets of glass will remain at the correct voltage. In an ideal case shown schematically in fig. 1a, the voltage across each gap is the same. Since each gap has the same width, on average each will produce the same number of avalanches from the

Preprint submitted to Elsevier Preprint *22 March 2001*

through-going flux of charged particles. This implies that the flow of electrons and ions into the resistive plates bounding a particular gas gap will be the same for all gaps. Each intermediate plate will receive a flow of electrons (and negative ions) into one surface balanced by a flow of positive ions into the opposite surface. Thus the net charge to an individual intermediate plate is zero; this is a stable state. However, let us now consider the case where one of the intermediate plates has an ‘incorrect’ voltage (as shown schematically in fig. 1b where the voltage on plate 3 has shifted from -9 kV to -10 kV). Using the labelling shown in the figure, this shift of voltage decreases the field in gap b and increases the field in gap c. Thus the flow of electrons from gap b into plate 3 will be reduced, and the flow of positive ions from gap c will be increased; i.e. there will be a net flow of positive charge that will make the voltage on plate 3 more positive. This is just what is needed, thus one finds that the voltages are automatically adjusted to give equal gain in all gaps.

2 The ALICE Time-of-Flight system

Two years ago [2] small MRPCs (3 × 3 cm^2 active area) were tested and had a time resolution of 65 ps with an efficiency of more than 98 %. In addition there were negligible tails to the time distribution.

The Time-of-flight system for the ALICE experiment will be a 7 m long barrel of radius 3.7 m. This 160 m^2 area will be divided into 160,000 read-out channels, each with an active area of 10 cm^2. Although it is possible to construct this TOF system using 160,000 individual cells, it is much easier if the detector consists of larger devices that are segmented with read-out pads. The chosen design for ALICE consists of strips each with an active area of 1.2 m × 7 cm. Each strip has 96 read-out pads arranged in 2 rows of 48. Each pad reads out an area of 2.5 × 3.5 cm^2. The TOF system will consist of 1600 such strips.

The strip was chosen so that the MRPCs could be orientated to point to the interaction point (in the rz plane) and so reduce edge effects. It also allows a differential signal to be derived from the MRPC and fed to the front-end electronics. Even though the front-end electronics is single-ended, a differential signal from the chamber substantially lowers the noise. The reason is that the signal return is direct to the cathode rather than through the ground (which is shared by all other read-out pads).

3 Tests of strips of 1.2 m length

Even though small test cells of 10 cm^2 have an excellent performance, it is not obvious that much larger devices will be equally good. As stated above all the intermediate resistive plates are electrically floating and one can imagine that a 'bad' region somewhere along the strip could adversely affect the whole strip. Nonetheless it has been found that it is relatively straightforward to construct strips that are uniformly good.

The cross-section of a typical strip is shown in fig. 2. We have built MRPC strips with both 5 and 6 gaps and with gap widths between 200 and 280 μm. We have varied the thickness of the internal glass plates in the range 400 μm to 1.1 mm and the external glass plates in the range 1.1 mm to 2.6 mm. The edge of the internal glass plates defines the edge of the active area. Nylon fishing line creates the space between the glass plates. This runs across the width of the strip every 2.5 cm; it is aligned from one gap to the next and is positioned at the boundary between pads. The voltage is applied to the exterior glass surfaces using carbon tape [3] with a surface resistivity of 200 kΩ/square. A layer of Mylar 350 μm thick is used to insulate the voltage layer from the pick-up pads. Either a positive and negative high voltage was applied respectively to the anode and cathode carbon layer, or a negative high voltage was applied to the cathode carbon layer with the anode carbon layer at ground.

Each pad was connected to a fast amplifier and discriminator. The amplifier is a transimpedance amplifier with 560 MHz bandwidth (MAXIM 3760). This is followed by a discriminator based on a fast ECL comparator (AD 96685). For these tests we measured the leading-edge, the time-over-threshold and also the total charge of the signal. The leading edge was produced using a fixed threshold discriminator; there is a dependence on the pulse height of the signal. We corrected for this time-slewing using the ADC value or the time-over-threshold. Both techniques gave similar results.

During 2000, seven strips with 96 read-out pads of active area 1.2 m $\times$ 7 cm were built and tested. Individual cells were tested with a beam spot of $\sim 1.5 \times 1.5$ cm^2. In fig. 3 we show the time resolution and efficiency measured for 17 read-out cells distributed along one of these strips. Other strips had similar good uniformity.

Even though we have spacers every 2.5 cm it is hard to believe that the gap spacing is better than 10 μm. In order to study the dependence of operating voltage on gap width, we built three strips of six gaps, each with a different gap width (220 μm, 250 μm and 280 μm). The efficiency, time resolution and time-walk versus voltage are shown in fig. 4. The time-walk shown in fig. 4 is after correcting for time-slewing (where the slewing correction was calculated for the 18 kV data).

4 Discussion

We find that changing the size of the gas gap by ± 30 μm results in very little change in operating voltage. Thus it is not too surprising that strips of 1.2 m in length have a very uniform response. A reason for this insensitivity could be as follows: at a given applied voltage a device with a smaller gas gap will have a higher electric field; this higher field will result in an increase in the Townsend coefficient; thus the gain will be higher. However the avalanche grows in size with the distance it travels; thus a smaller gap results in a smaller distance and thus the gain is lower. It seems that we are working in a regime where these effects cancel. A similar insensitivity to gap size has been discussed previously by Y. Giomataris [4] where he has been studying gas gaps of 100 μm with the micromegas device. The very small shift in absolute time with voltage (especially with the 220 μm chamber) gives us confidence that the timing of this device will not be overly sensitive to changes in high voltage, pressure and temperature. Further studies are in progress. We have identified a commercial amplifier that has a very good performance with the chamber. This amplifier is now the base-line front-end for the ALICE TOF detector.

References

[1] E. Cerron Zeballos, I. Crotty, D. Hatzifotiadou, J. Lamas Valverde, S. Neupane, M.C.S. Williams and A. Zichichi, Nucl. Instr. Meth. A374(1996)132.

[2] M.C.S. Williams et al., Nucl. Phys. A, Vol 661(1999)707.

[3] Nisshin T-9149 Carbon tape, Kokosai Kinzoku Yakuhin Co. Ltd, Tokyo, Japan.

[4] Y. Giomataris, Nucl. Instr. Meth. A419(1998)239.

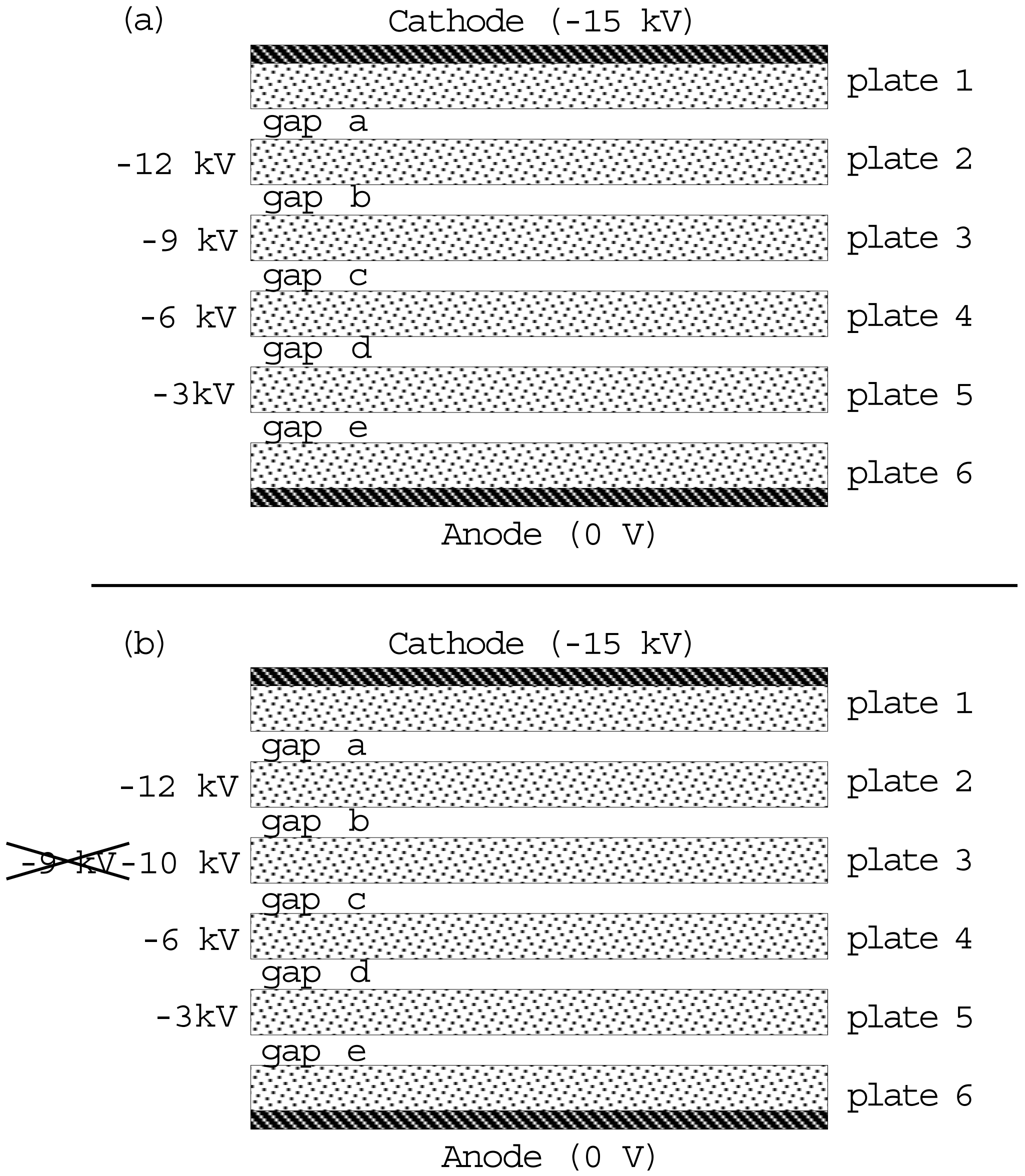


Fig. 1. (a) Schematic representation of MRPC showing distribution of voltage in normal operation. (b) See text for discussion.

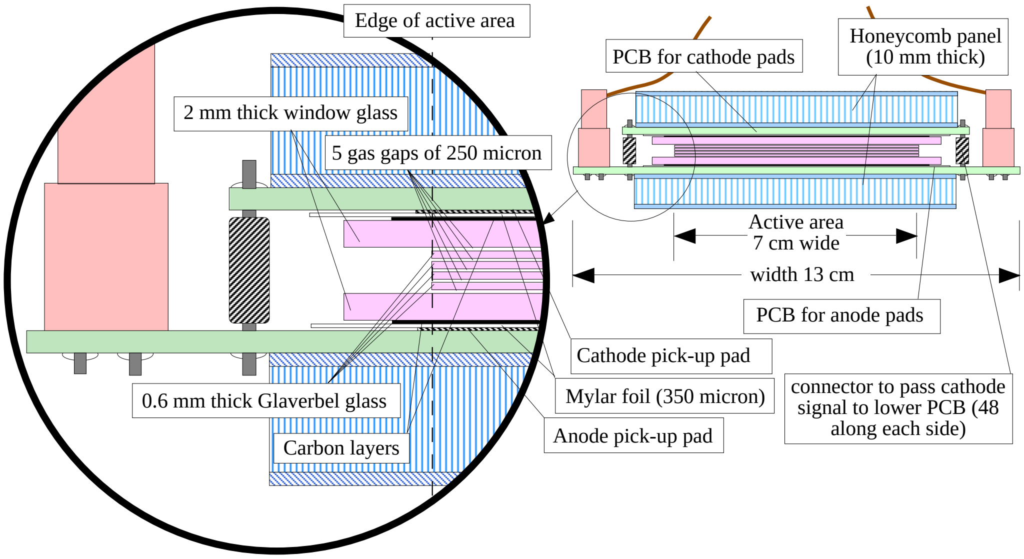
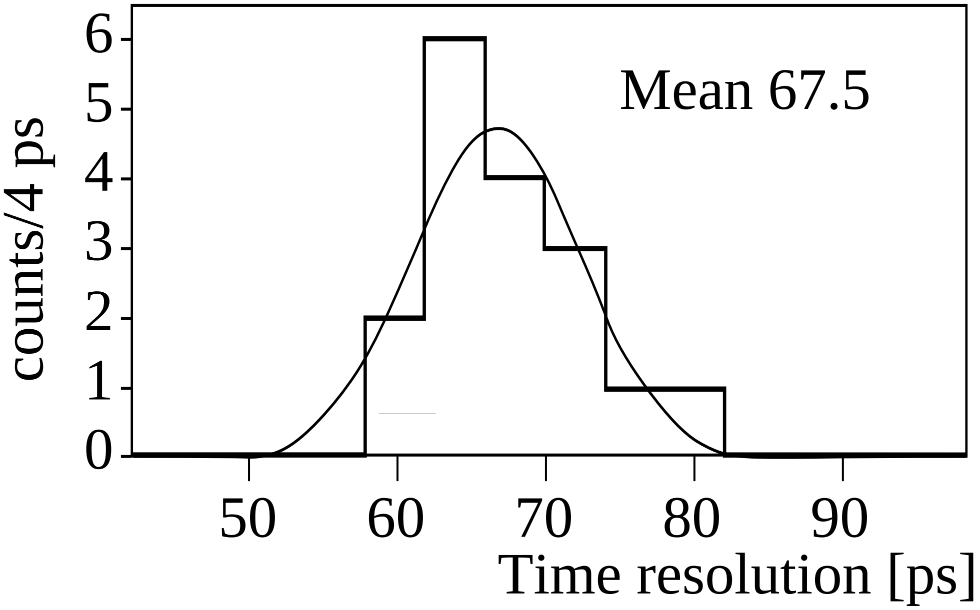


Fig. 2. Cross section of MRPC strip with 96 pads for the readout.



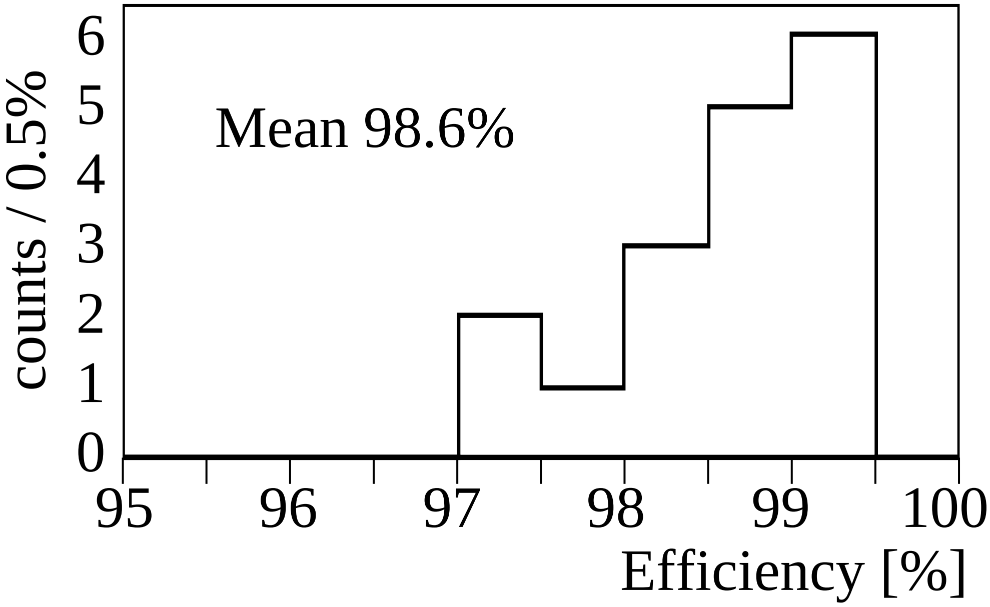


Fig. 3. Time resolution and efficiency distributions.

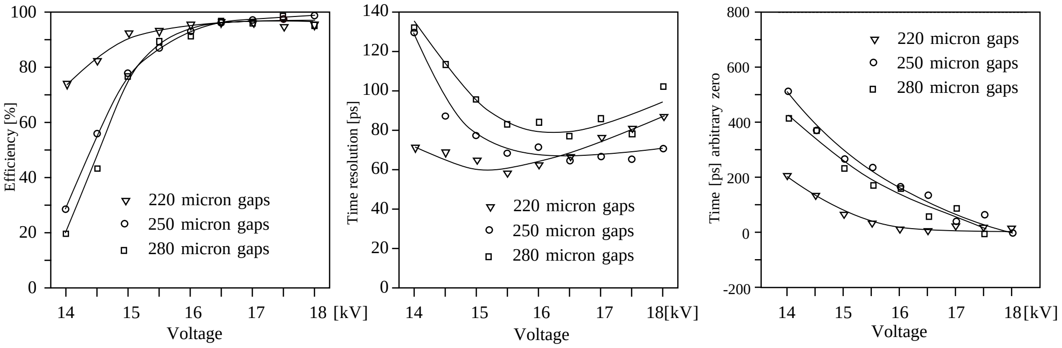


Fig. 4. Efficiency, time resolution and time walk as a function of the high voltage.