DEVELOPMENT OF HIGH TIME RESOLUTION MULTIGAP RPCS FOR THE TOF DETECTOR OF ALICE

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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 close to 50 ps. We discuss the principle of operation of this detector and present the latest results from the ongoing R&D program.

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 of 250 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 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

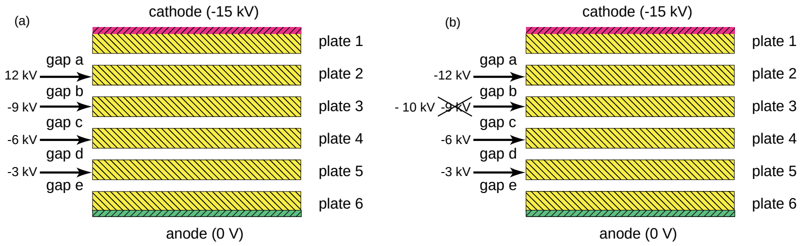

Figure 1. Schematic representation of MRPC stack. Normal operation is shown in the left-hand diagram with the electric field the same in each gap. See the text for a description of the feedback mechanism, which ensures that the voltage restablizes if it deviates from the correct value

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 ALICE experiment [3] is designed to study heavy ion interactions at the CERN LHC. The Time-of-flight system[4] 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 boundary effects between pickup pads. A strip also allows both sides of the detector to be accessed; thus allowing a differential signal to be derived from the anode and cathode electrodes 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 relevent

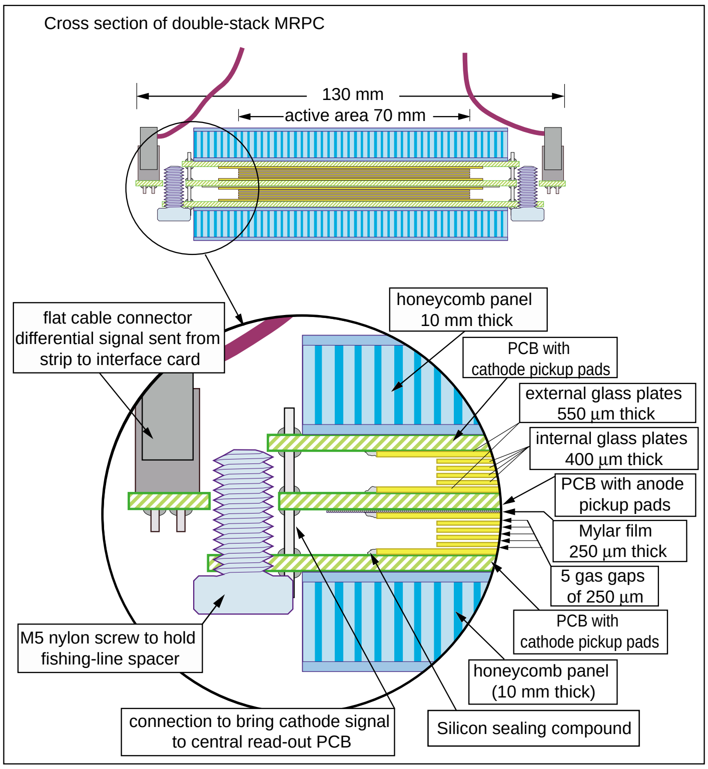

Figure 2. Cross section of ALICE TOF MRPC strip

cathode pad rather than through the ground (which is shared by all other read-out pads).

3 ALICE TOF MRPC strips

The cross-section of the final design of an ALICE TOF strip is shown in fig. 2. This is a 10 gap MRPC, arranged into 2 stacks of 5 gaps. The gap size is 250 μm; this gap is created by nylon fishing line that runs across the width of the glass plate. This fishing line crosses the stack every 2.5 cm and is aligned such that the fishing line is in exactly the same position in all gaps. The internal resistive sheets are 400 μm thick glass sheets, while the outer plates of each stack are 550 μm thick glass. All the glass is ‘soda-lime’ float

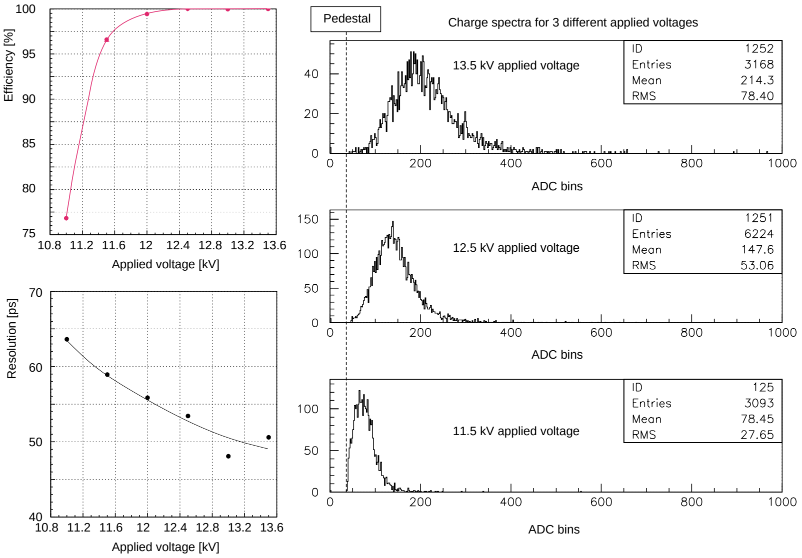

Figure 3. Performance of ALICE TOF strip. The Efficiency and time resolution versus applied voltage are shown on the left-hand side; charge spctra for three applied high voltages are shown on the right-hand side.

glass produced by Glaverbel[a]. The high voltage is applied by a resistive layer on the outer layers with a resistivity of 5 MΩ/square. This resistive layer is acrylic paint loaded with metal oxides[b].

The reason for the 10 gaps is (a) to increase the efficiency and (b) to enhance the shape of the charge spectrum. In fig. 3 we show the performance of a typical strip. The efficiency has a plateau of 99.98 %, which is remarkable since the path length of the through-going charged particle through the gas is only 2.5 mm.

For Pb-Pb heavy ion collisions we expect an occupancy of 12 % with the pad size of 2.5×3.5 cm^2; it is therefore important to keep the probability of two pads firing for a single through-going particle as low as possible. A major contribution is at the boundaries between pads and we want to make this boundary region as small as possible. The double-hit probability depends on (a) the shape of the charge spectrum and (b) the size of the 'charge-

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[a] VERTEC thin glass, vertec@glaverbel.com

[b] DETEC di Orietti M.L., viale E. Thovez 16/a, 10131 Torino, Italy

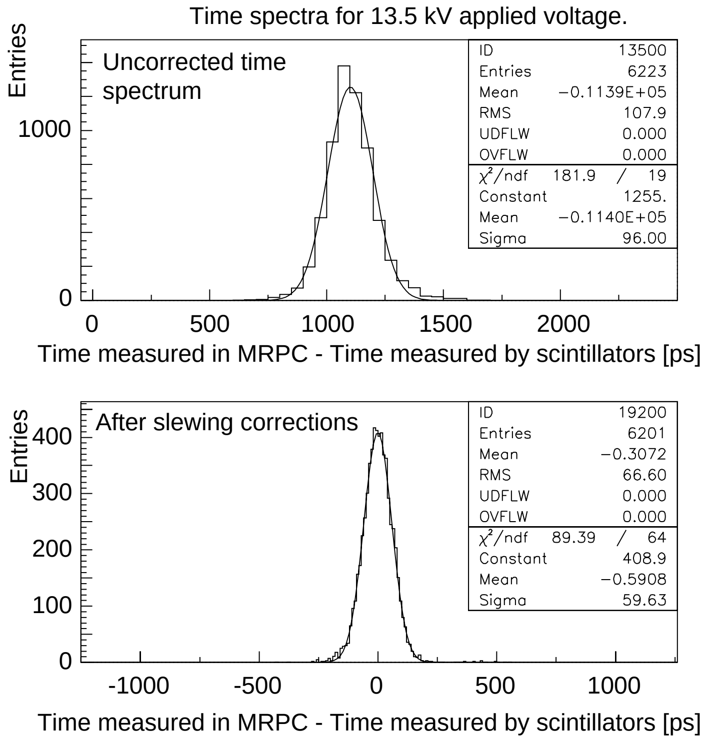

Figure 4. Time spectra at 13.5 kV applied voltage. The spectra show the time difference between the ‘hit’ time in the MRPC strip and the reference scintillators. The lower histogram is after a slewing correction has been applied. The upper histogram is before any correction. The measured width of 59 ps in the lower plot includes the 30 ps of jitter of the scintillators. When this is subtracted we get 51 ps.

footprint’. In fig. 3 the charge spectra have an almost ‘gaussian’ shape, which aids the reduction of the double hit probability. We have studied the effect of the resistive layer on the size of ‘charge-footprint’ and found a substantial increase in size for a resistive layer of 200 kΩ/square.

During September 2001 we built 18 ALICE-TOF strips, each with an active area of 1.2 m × 7 cm. This was a batch to evaluate problems related to mass production. We learned many things concerning the details of the assembly, but the main result was that these 18 strips had similar performance.

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 (MAXIM 9691). 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. Typical time spectra are shown in fig. 4 before and after the time-slewing correction.

4 Summary

We have shown that the Multigap Resistive Plate Chamber has the performance that more than satisfies the requirements for the ALICE TOF. Even though this type of detector is easy to build and uses readily available materials ('soda-lime' float glass and nylon fishing line), the performance equals all other TOF technologies.

The ALICE-TOF array will consist of strips, each with an active area of 7 cm × 1.2 m. Each strip will be divided into 96 readout channels. We have built a batch of 18 strips and found acceptable uniformity of performance; typical measurements have been shown here. We have found a commercially produced fast-amplifier that can be used and forms the base-line of the electronic chain.

References

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4. ALICE Technical Design Report of the Time of Flight System, CERN/LHCC 2000-012 ALICE TDR 8, 16 February 2000