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Latest results on the performance of the multigap resistive plate chamber used for the ALICE TOF

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Abstract

For the identification of particles in the momentum range 0.5–2.5 GeV/c, the ALICE experiment uses a Time Of Flight array consisting of Multigap Resistive Plate Chambers (MRPC) in the form of long strips. The design of the detector elements is as follows : double stack MRPCs with glass resistive plates and 5 gas gaps of 250 μm per stack. The latest results on the performance of these MRPCs are presented. Typical values of time resolution σ are better than

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50 ps, with an efficiency of 99.9% and a long, more than 1.5 kV, streamer-free plateau.

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Keywords: Resistive plate chambers; MRPC; ALICE; Time of flight; Time resolution; Particle identification

1. Introduction

One of the techniques used by ALICE for identification of charged particles is the measurement of their time of flight, which combined with the particle momentum and track length, measured by the magnetic spectrometer, gives the particle mass. The time of flight detector of ALICE is a cylindrical array with 3.7 m inner radius and 7.2 m length, covering the whole barrel region [1]. Good time resolution, of 100 ps or less, is required for 3σ π/K separation in the 0.5–2.5 GeV/c momentum range, extending up to 4 GeV/c for protons. To cope with the high multiplicity expected at heavy ion collisions high segmentation is required. To keep the occupancy at the $\sim 12\%$ level readout cells of 9 cm^2 are used; the whole system has an area of $\sim 150\,m^2$ and 160 000 readout channels. The detector chosen is the multigap resistive plate chamber (MRPC) [2], which combines the required performance with an affordable cost. The first tests in 1999 of small, single-cell MRPCs with five 220 μm gaps gave very encouraging results (time resolution of 70 ps) [3]. An intense period of R&D followed, during which the parameters influencing the detector performance were studied and optimised [4].

2. The ALICE TOF detector

The detector element for the ALICE TOF is a long MRPC strip ($120 \times 7.4\,cm^2$ active area) with 96 readout pads of $2.5 \times 3.7\,cm^2$ arranged in two rows. The whole time of flight (TOF) array consists of 18 sectors of 20° in φ; each sector is divided in five modules, each containing 15–19 strips, tilted in such a way as to be perpendicular to particles from the interaction point in the $r\varphi$ plane.

The MRPC strip, a cross-section of which is shown in Fig. 1, consists of 2 stacks of 5 gaps, thus a total of 10 gaps of 250 μm. The resistive plates are commercial ‘‘soda-lime’’ glass, 400 μm thick for the internal and 550 μm for the external plates; the distance between them is kept fixed with spacers made of nylon fishing line. The anode is in the middle and the two cathodes are on the external surfaces; a differential high voltage is applied. For the readout a differential signal is obtained from anode and cathode pickup pads. The frontend electronics used is a recently developed 8 channel ASIC, consisting of an ultra-fast amplifier, discriminator and stretcher [5]. For the readout, a high-resolution, 25 ps bin TDC is used that measures both the leading and trailing edge of the pulse [6].

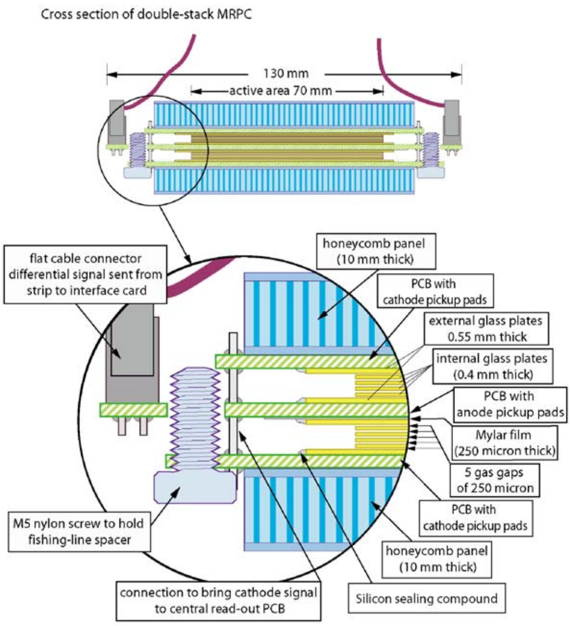

Fig. 1. Cross-section of the MRPC strip for the ALICE TOF.

3. Performance

The MRPC performance is studied at the T10 beam line of the East Hall of the CERN PS, with 6 GeV/c pions. All tests have been performed with a gas mixture of 90% $C_2H_2F_4$, 5% SF_6 and 5% C_4H_{10}; studies of other gases are presented in [7]. A $1\,cm^2$ beam spot is selected by the trigger scintillators; fluxes of $\sim 100\,Hz/cm^2$ are used.

Fig. 2 shows the efficiency, time resolution and streamer probability as a function of the high voltage; the efficiency reaches 99.9%, the resolution σ is in the 40 ps range and the plateau for streamer free operation exceeds 1.5 kV. Fig. 3 shows typical time distributions before slewing corrections ($\sigma = 91$ ps) and after applying slewing corrections ($\sigma = 48$ ps). After subtracting quadratically the jitter of the start signal, 30 ps, provided by the average of four photomultipliers coupled to fast scintillators, a σ of 38 ps is derived. It should be noted that the factors contributing to the quoted resolution are: 20 ps due to the frontend electronics and cables; 20 ps due to the readout electronics (TDC); 14.4 ps due to the $1\,cm^2$ beam spot ($50\,ps/\sqrt{12}$); 25 ps due to the intrinsic MRPC resolution. It will be difficult to reduce the time resolution much below 40 ps.

A key element for the performance of the MRPC is the shape of the charge distribution. As shown in Fig. 4, this is almost Gaussian, due to the superposition of avalanches from many gaps. It allows setting the threshold at a finite value without efficiency loss; this in turn gives reduced cross-talk between pads. The absence of a tail of very large pulses suggests saturation in the avalanche growth due to space-charge effects [8].

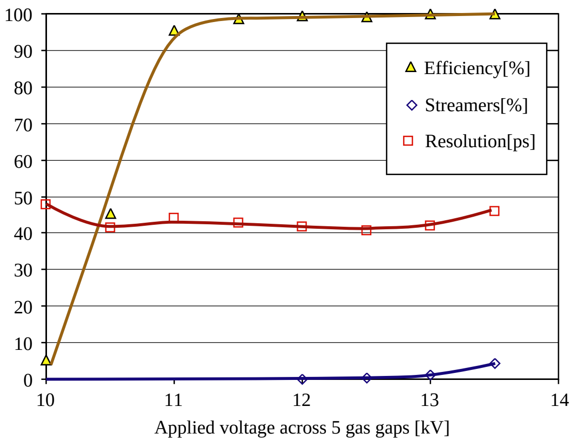

Fig. 2. Efficiency, time resolution and streamer probability of MRPC versus applied voltage.

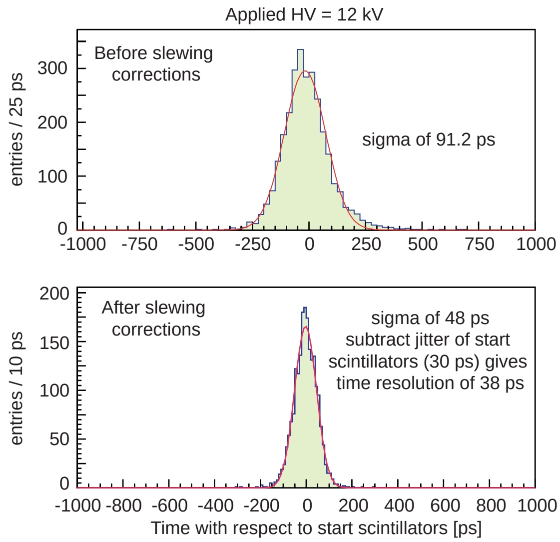

Fig. 3. Time distribution of MRPC before and after slewing corrections.

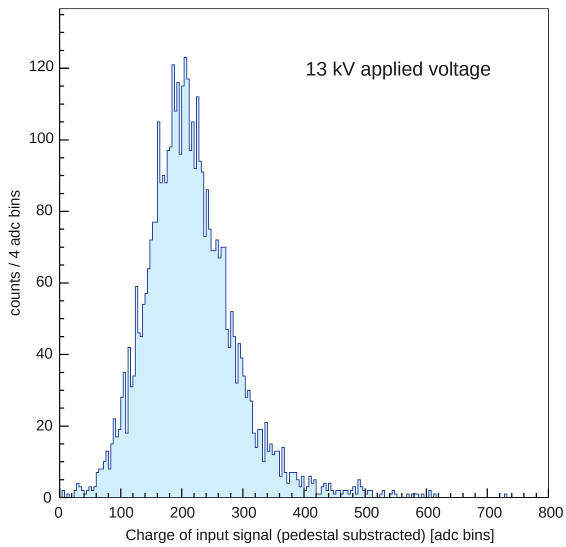

Fig. 4. Charge distribution from a 10 gap MRPC at 13 kV.

Fig. 5 shows a cosmic ray measurement of the total charge of the 10 gap MRPC as a function of the applied voltage; for comparison, the total charge is shown also for a 2 mm gap RPC tested with a mixture containing $C_2H_2F_4$ and another mixture with C_2HF_5. For the MRPC the gain changes slowly with voltage (factor of 5 for 2 kV) and the average total charge is ~ 2 pC at 12 kV, an order of magnitude smaller than the average charge of the 2 mm gap RPC.

Correlated with the small charge of the MRPC signal is its good rate capability. Since the resistivity of the glass plates is high, $10^{13}\,\Omega$cm measured in the lab, the rate capability could be a potential problem. Tests at the Gamma Irradiation Facility [9] have shown no deterioration in performance up to 1 kHz/cm^2 [10]. Fig. 6 shows the efficiency and resolution as a function of the equivalent charged particle flux for fixed applied voltage and for fixed effective voltage (where the voltage drop due to the current flowing through the plates has been taken into account). It should be noted that the ALICE TOF will be exposed to a maximum rate of 50 Hz/cm^2 from Pb–Pb collisions at LHC.

It is essential that the performance of all 1600 elements of the TOF array is uniform. Nine MRPC strips with the final design characteristics have been tested and the results are shown in Fig. 7. All strips can be operated at 12 kV and the

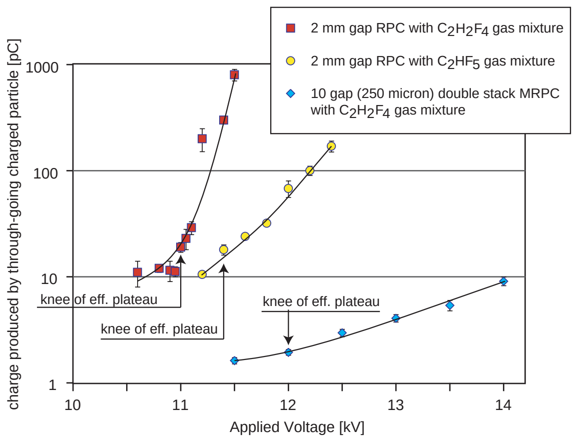

Fig. 5. Total charge versus voltage for a 10 gap MRPC and for a standard, 2 mm gap RPC.

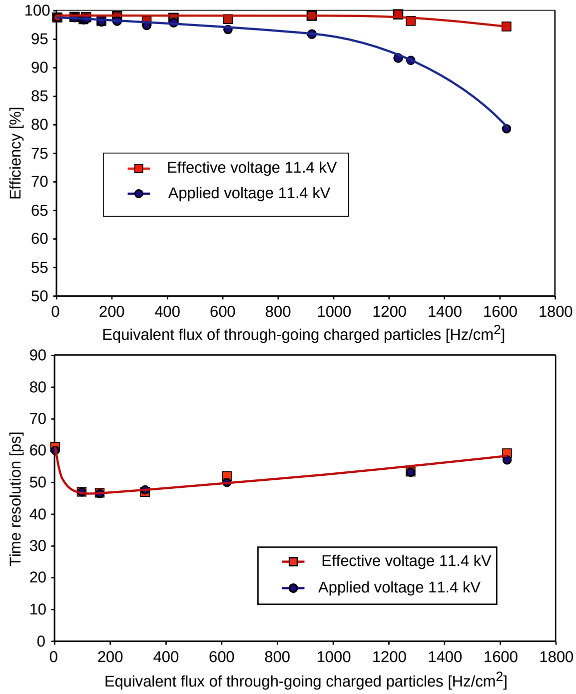

Fig. 6. Efficiency and time resolution versus equivalent flux of charged particles for MRPC tested at the GIF.

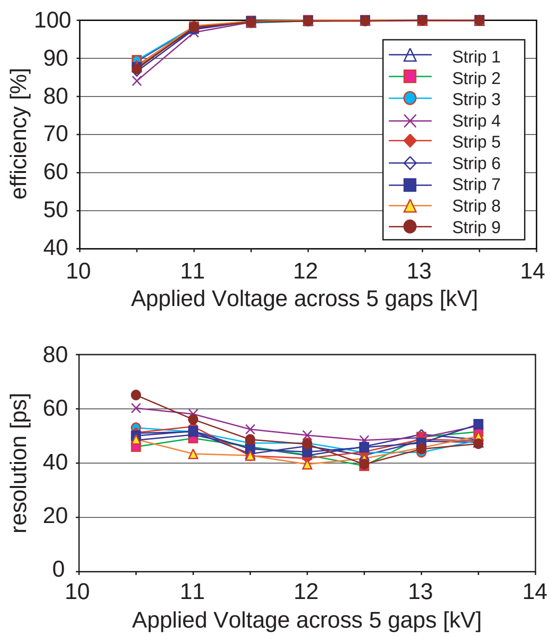

Fig. 7. Efficiency and time resolution versus applied voltage for 9 MRPC strips tested in October 2003.

time resolution has a value between 40 and 50 ps. Therefore the construction technique is satisfactory and the project can go ahead with MRPC mass production.

4. Summary

Multigap resistive plate chambers with 10 gaps of 250 μm completely satisfy the requirements for the ALICE TOF array. They have an efficiency of 99.9%, resolution better than 50 ps, excellent rate capability and uniformity of performance.

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