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Young Scientists:

The Time Of Flight (TOF) system of the ALICE experiment

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Abstract. The double-stack Multigap Resistive Plate Chamber (MRPC) is the detector chosen for the large Time-Of-Flight system of the ALICE experiment at CERN LHC. The TOF barrel has to cover an area of 160 m^2 and has to be highly segmented (160.000 readout pads of 2.5×3.5 cm^2) in order to keep the occupancy at the 15% level. In this article recent results on several prototype MRPCs are presented, with particular emphasis on the study of the uniformity of these devices.

1 Introduction

ALICE (A Large Ion Collider Experiment) [1] is one of the four experiments at the CERN Large Hadron Collider (LHC). ALICE will study Pb-Pb collisions at a centre-of-mass energy of 5.5 TeV per nucleon pair. The aim of the experiment is to investigate the behaviour of nuclear matter at extreme densities and temperatures. In particular ALICE will study the QCD phase transition of nuclear matter into a deconfined state of quarks and gluons, i.e. the QGP (Quark-Gluon-Plasma) state, with partial chiral symmetry restoration and quark masses reduced to the small bare ones.

Particle identification is a key element to study the QGP. The event-by-event hadron identification will allow to measure, with high statistics, the shape of the p_t distributions of π, K and p, their average p_t and the $\pi/K/p$ ratios. It will provide information on possible thermodynamical instabilities during the phase transition, on the degree of thermal equilibrium and on expansion dynamics. Moreover the kaon identification will provide information on:

- the level of s-quark density, which is expected to be large due to the partial chiral symmetry restoration in a QGP;
- the identification of the $\phi \to K^+K^-$ decays. The measurement of the ϕ resonance provides more stringent constraints on the origin of the observed flavour composition, as compared to the K/π ratio.
- the open charm decays. The detection of open charm will be very important for cross-section normalization, necessary in the study of J/Ψ suppression, one of the basic QGP probes.

The Time of Flight detector [2,3], presently under construction, will allow hadron identification in the momentum range from 0.5 GeV/c up to a few GeV/c.

The TOF surrounds the whole ALICE central barrel (see Fig. 1), equivalent to an area of 160 m^2. In the ALICE experiment up to 8000 primary charged particles will be produced per unit of rapidity, therefore a high segmentation is required. In particular, Monte Carlo simulations [2, 3, 4] indicate that, in order to have an occupancy of about 15%, 160000 individual channels of 2.5×3.5 cm^2 read-out pads are necessary.

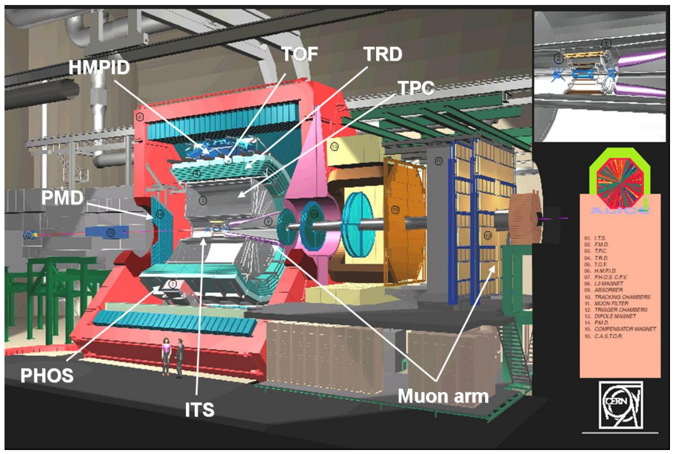

Fig. 1. Layout of the ALICE detector

2 The TOF system

The TOF detector is internal to the ALICE solenoid, it has a polar acceptance $|\theta - 90°| < 45°$ and full coverage in ϕ. The inner radius of the TOF cylinder is 3.70 m from the beam axis.

The TOF is divided into 18 azimuthal sectors, as shown in Fig. 2. Each sector is made of five modules of three different types (see Fig. 3). Each module consists of two separate volumes: a gas region containing the Multigap Resistive Plate Chambers (MRPCs) and a second one containing the Front End Analogue (FEA) cards.

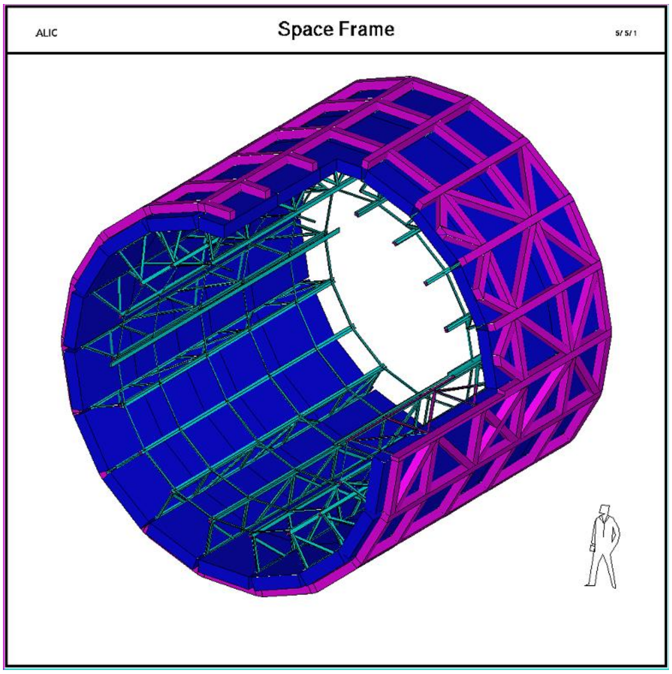

Fig. 2. Time of Flight (TOF) detector layout on the ALICE spaceframe structure

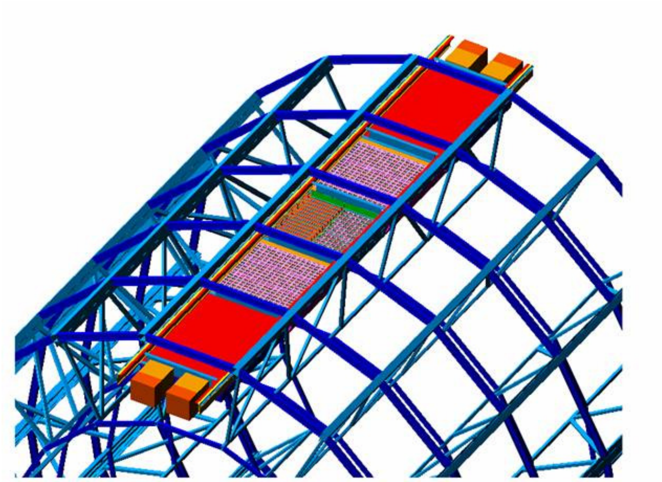

Fig. 3. A detail of one sector with 5 modules: one central, two intermediate and two external. The three types of modules have different lengths and contain different numbers of MRPC strips: there are 15 MRPCs in the central module, 19 in the intermediate and outer ones

The MRPC strips (each of 120×7.4 cm^2 active area) will be placed orthogonally with respect to the beam direction (z-axis) and tilted in such a way as to be perpendicular to the particle trajectory from the interaction point in the r-z plane[1]. To minimize the dead area, adjacent strips inside the modules will be overlapped by about 2 mm.

[1] r is the track projection in the longitudinal view.

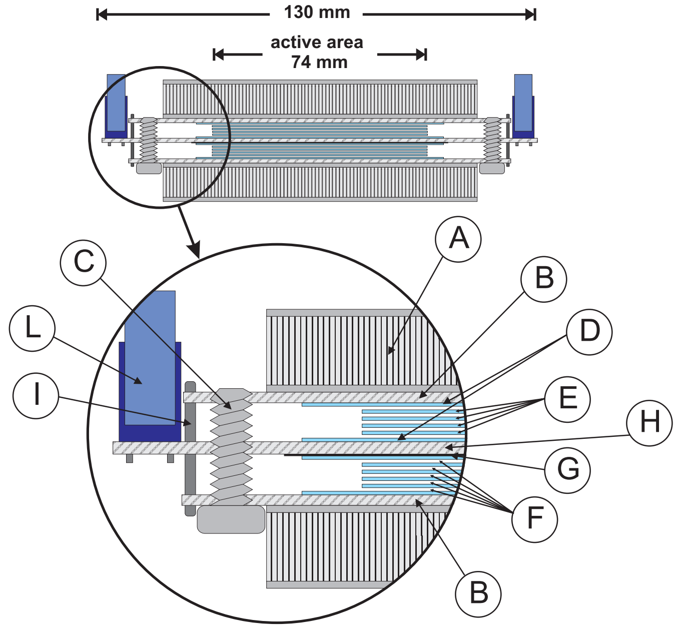

Fig. 4. Cross-section of the double-stack MRPC of the ALICE-TOF system. A: 10 mm thick honeycomb panel; B: PCB with cathode pick-up pads; C: M5 nylon screw to hold the fishing-line spacer; D: 550 μm thick external glass plates; E: four 400 μm thick internal glass plates; F: five gas gaps of 250 μm; G: 250 μm thick mylar film; H: central PCB with anode pick-up pads; I: pin to bring cathode signals to central read-out PCB; L: flat-cable connector (for MRPC signal transmission to the front-end electronics)

3 The double-stack MRPC

The double-stack MRPC represents an evolution of the detector developed in [5] and consists of two stacks of equally spaced resistive plates, creating a series of gas gaps. High voltage is applied to the outer surfaces of the stack of resistive plates while all the internal plates are electrically floating. In this way the internal plates take voltage given by electrostatics and they are kept at the correct voltage values by the flow of positive ions and electrons created in the avalanches.

Two external and one central printed circuit boards (PCBs) contain the cathode and anode readout pads. Each stack has 5 gas gaps of 250 μm; this distance is guaranteed by a fishing-line spacer held around a series of nylon screws, fixed in pre-drilled holes in one of the two external PCBs.

Due to the stack structure, the avalanches produced in different gaps by through-going particles ionizing the gas are independent and the signal is the sum of all gaps. A cross-section of the MRPC is shown in Fig. 4.

During last year, a first prototype of fishing-line stretching machine was built (see Fig. 5) and used to run the spacer across the surface of the glass plates, around the screws. This machine is very useful to automate, simplify and speed up the MRPC assembling procedure. In fact it takes only a few minutes to place each fishing-line layer.

Fig. 5. Photograph of the first prototype of fishing-line stretching machine

Fig. 6. Photographs of the MRPC during the assembly. The upper picture shows an open MRPC strip. The lower picture shows the positioning of the central PCB, with two external glasses glued on both sides of it

The resistive plates are made of 'soda-lime' glass manufactured by Glaverbel[2]; the internal plates are 400 μm thick while the outer plates are 550 μm thick. The external surface (facing the PCB) of the outer plate, painted with a resistive coating of few $M\Omega/\Box$ (acrylic paint loaded with metal oxides),[3] is used to apply the voltage. Figure 6 shows a MRPC during the assembly.

To guarantee a good mechanical rigidity, two honeycomb panels are glued on the external PCBs. Connecting pins are soldered across the 3 PCBs in order to bring the cathode signals from the external PCBs to the central one (providing the anode signals). Moreover these pins are also used to keep the stacks compressed. The connectors used to transmit the differential signals to the front-end electronics are soldered on the central PCB.

Due to the geometry of this detector, the voltage is applied differentially to the resistive coatings.

4 The experimental set-up

The experimental set-up was located at the PS-T10 beam line of the CERN Proton Synchrotron. As illustrated in Fig. 7 it consisted of:

- a small MRPC (SMRPC), made of a single stack of glasses defining 5 gaps, each of 230 μm with 10 cm^2 active area, which acts as pre-trigger providing the start to the TDCs and the gate to the ADCs;
- three tracking chambers (TC1, TC2, TC3), each consisting of 2 planes (10×20 cm^2) of strips with 4 mm pitch, to provide information on the position of the beam. The precision of the TCs is about 1 mm in both the coordinates;
- two pairs (P1-P2 and P3-P4) of crossed scintillators, whose coincidence defines a 1 cm^2 area and provides the trigger;
- two fast scintillator bars ($2\times2\times10$ cm^3), each equipped with two photomultipliers (S1, S2, S3 and S4), discriminated by Constant Fraction Discriminators, to provide an accurate time reference;
- the device under test (DUT), i.e. up to 5 MRPC strips, closed in an aluminium box with external dimensions of 19.5 cm $\times$ 48 cm $\times$ 129 cm.

The chambers were filled with a gas mixture of 90% $C_2F_4H_2$, 5% SF_6 and 5% C_4H_{10}. The measurements have been made using a 7 GeV/c beam of negative particles (π and μ).

A mechanical frame was used to move the aluminium box with relative millimetric accuracy. This allowed to position the beam on different pads by remote control.

5 Results

During autumn 2002, seventeen double-stack MRPCs were tested at the T10 beam line. Particular care was devoted

[2] Glaverbel VERTEC sales, 166 Chaussée de La Hulpe, 1170 Brussels, Belgium

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

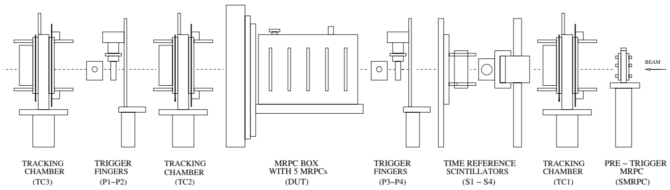

Fig. 7. Schematic layout of the experimental set-up at the T10 beam line

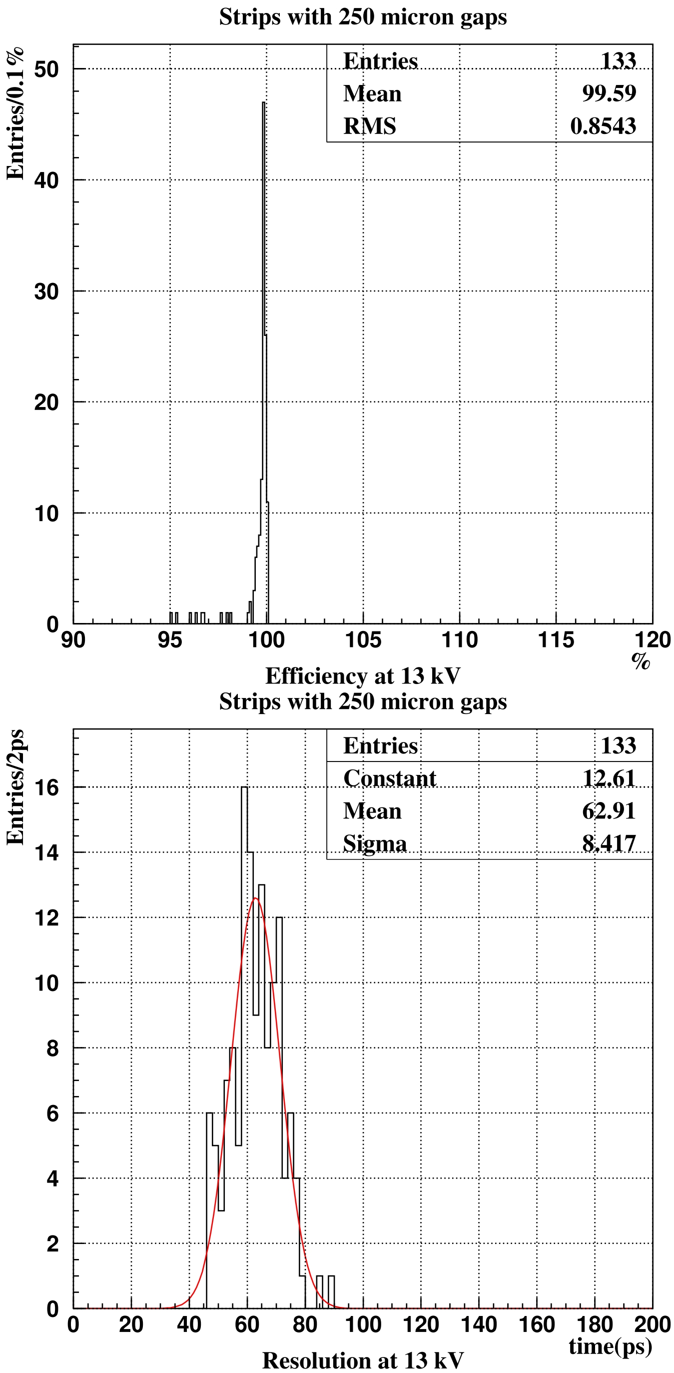

Fig. 8. Efficiency and time resolution distributions for all 17 MRPCs tested in October 2002

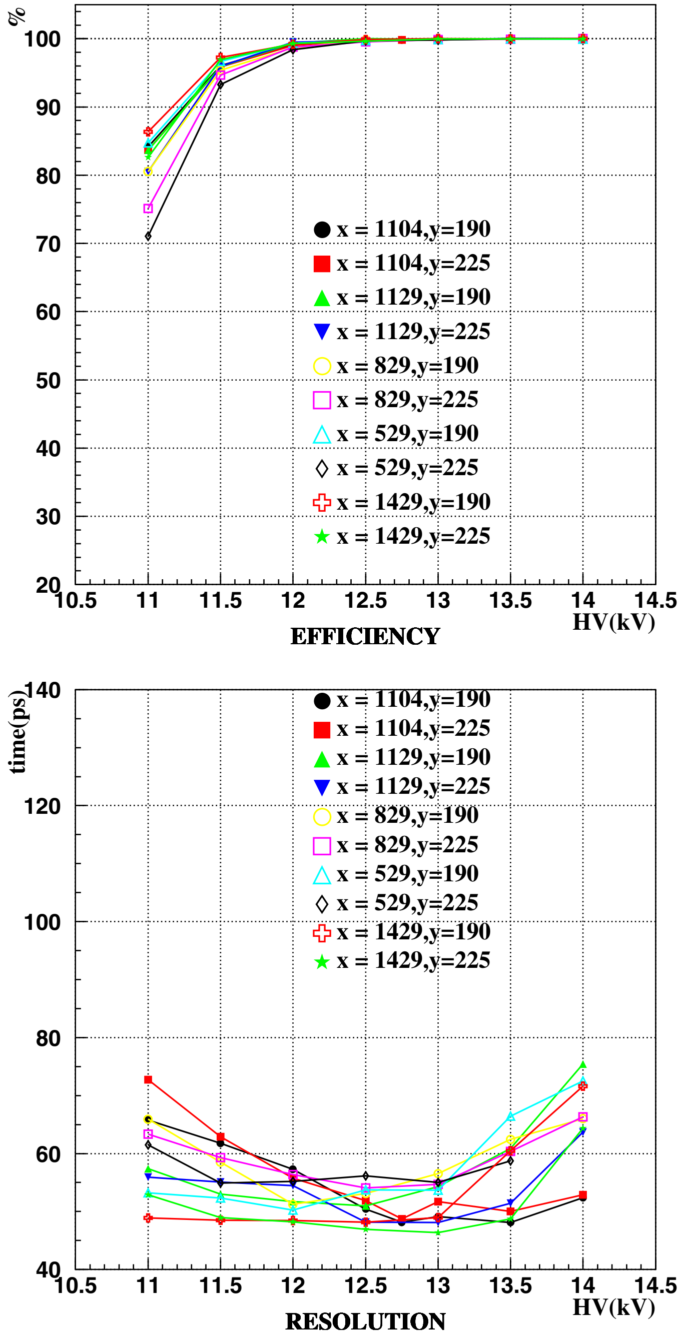

Fig. 9. Example of uniformity study along one MRPC strip in terms of efficiency and time resolution measured in different positions along the strip

to the study of the uniformity of response of the devices by centering the beam on many different pads, randomly distributed along each MRPC strip. Figure 8 shows the efficiencies and the time resolutions of over 100 pads belonging to the 17 chambers, measured at a fixed high voltage value of 13 kV. The upper histogram shows the distribution of the efficiency values, with a mean of 99.6%, the lower one refers to the distribution of the time resolution values, with a mean of 62.9 ps.

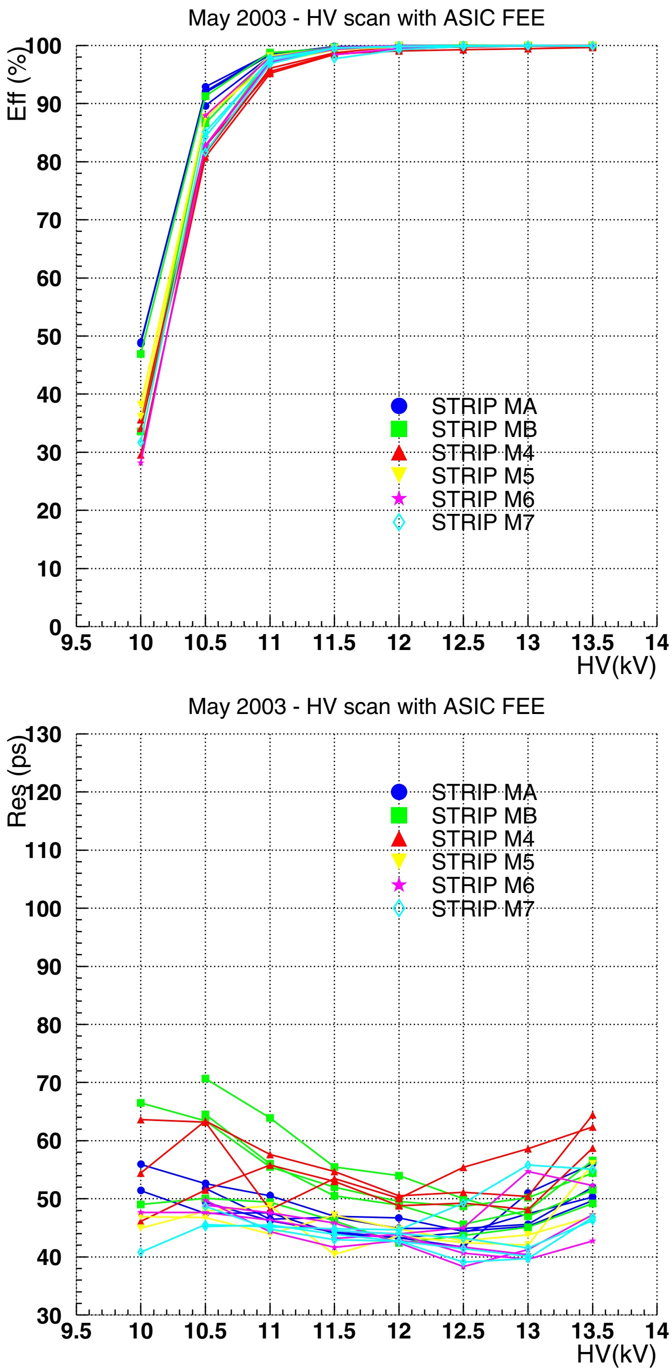

Fig. 10. Results of May 2003 beam test, using the new NINO-ASIC FEE card for different MRPCs

Figure 9 shows an example of high voltage scan along one MRPC: the two plots show, respectively, the efficiency and the time resolution as a function of high voltage, for different beam positions along the strip. It should be noted that each curve corresponds to a different read-out pad.

In the HV range between 12 and 13 kV, the mean efficiency is 99.9% and the mean time resolution is 50 ps. All the tested MRPCs showed a very good uniformity and a long streamer-free plateau.

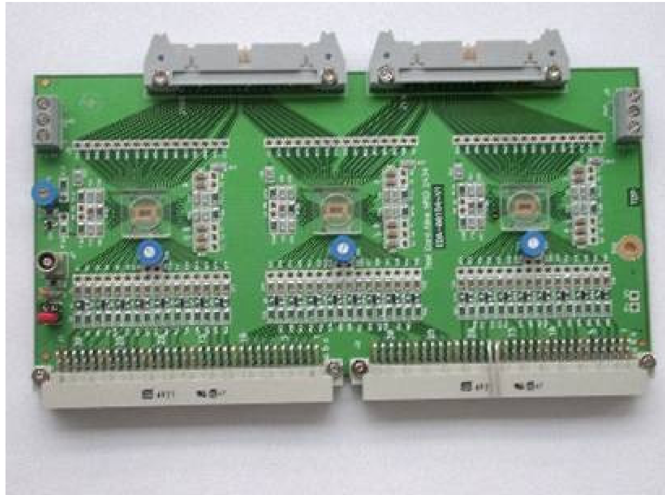

Fig. 11. Photograph of the new FEE card with 3 NINO-ASIC amplifiers/discriminators used to collect data during May 2003 beam test

To collect these data, a front-end electronics based on the commercial MAXIM 3760 amplifier and MAXIM 9691 ECL comparator was used.

To obtain a very good time resolution, a very fast front-end electronics is mandatory. Although the MAXIM 3760 gave good results, this kind of amplifier has the following drawbacks:

- it is a high power device (300 mW per channel);
- its input is not differential;
- it has a low input capacitance (1 pF).

The idea was then to design an ultra fast ASIC amplifier solution. The advantages of this choice are several:

- it has a differential input;
- it has to operate with a large input capacitance (30 pF);
- it is very fast, with a jitter less than 25 ps;
- it has a low input impedance;
- it is a low power device (about 30 mW per channel).

The new NINO-ASIC (see Fig. 11) is an excellent amplifier/discriminator to fully exploit the MRPC intrinsic performances. It was used during a beam test in May 2003, with different MRPC strips. Figure 10 shows the efficiency and time resolution versus high voltage for different chambers. As it can be seen, the uniformity is very satisfactory; in fact the mean efficiency is close to 100% and the mean time resolution is 50 ps in the plateau region.

The ALICE experiment will run for many years and the detectors will be irradiated by a very large number of particles. Hence ageing tests are required to study a possible degradation of the behaviour of the MPRCs. During last year, two detectors (CH1 and CH2) were irradiated at the CERN Gamma Irradiation Facility (GIF), located in the X5 area of the West Hall. This facility allows a device to be irradiated with 662 keV photons from a 740 GBq ^{137}Cs source.

CH1 and CH2 were irradiated for a total equivalent of about 1000 days of Pb-Pb run at 50 Hz/cm^2 [4]. These two MRPCs were tested at the T10 beam line before and after the irradiation at GIF and no ageing effect was observed.

6 Conclusion

All the tests presented herein clearly show that the double-stack MRPC of the ALICE-TOF system is an outstanding detector. This device has a very good uniformity, a long streamer-free plateau, an excellent efficiency of 99.9% and an excellent time resolution of ∼50 ps. Moreover, after a long period of irradiation corresponding to 17 years of ALICE activity, the MRPC has proved to be a radiation-hard device.

[4] According to the present LHC running scenario, Pb-Pb collision runs will last about 1 month per year.

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