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A single Time-of-Flight tray based on multigap resistive plate chambers for the STAR experiment at RHIC

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Abstract

The STAR experiment at RHIC plans to implement a 60 m^2 Time-of-Flight (TOF) system. The Multigap Resistive Plate Chamber (MRPC) is a suitable candidate for the STAR TOF system due to its time resolution of order of 60 ps with efficiencies in excess of 97%. We obtained this result with modules composed of 6 gas gaps of 220 μm and pad area of 20 cm^2. In this paper, we report on the performance of this MRPC module and present the current status of the construction and installation into STAR of a prototype tray.

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Keywords: Resistive plate chambers; Time-of-Flight; Particle identification; Gaseous detector; MRPC; STAR

1. Introduction

The main goal of the STAR Time-of-Flight (TOF) system is to provide information that extends the hadronic particle identification capabilities of the experiment. The STAR detector consists of several detector sub-systems in a large solenoidal magnet of 0.5 T. The Time Projection Chamber (TPC) [1] is 4.2 m long, with a 50 cm inner radius and a 2 m outer radius. The STAR experiment plans to implement a 60 m^2 TOF system [2]. It consists of a highly-segmented cylindrical detector immediately surrounding the TPC and it is to be arranged in 120 trays. Each individual tray is 2.4 m long, 21.3 cm wide and 8.5 cm deep ($z \times \phi \times r$). Since 1998, we have been developing Multigap Resistive Plate Chambers (MRPC) [3] suitable for the STAR experiment. Following the decision of the ALICE experiment at CERN to build a MRPC system for the TOF [4], members of the STAR collaboration who participated in the development efforts at CERN submitted a Letter of Intent to the STAR management and DOE for an MRPC TOF system in STAR [5]. Then we launched a major effort to develop these devices during the years 2000 and 2001. We built and tested many prototype MRPCs

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at the Proton Synchrotron at CERN. The goal of these tests was to build a module with a time resolution better than 100 ps and suitable design according to the TOF tray dimensions.

2. Design of the multigap RPC module

The MRPC is basically a stack of resistive plates arranged in parallel. The utility of resistive plates is to quench the streamers so that they do not initiate a spark breakdown. The intermediate plates create a series of gas gaps. Electrodes are applied to the outer surfaces of the two outer plates. A strong electric field is generated in each subgap by applying a high voltage across these external electrodes. All the internal plates are electrically floating; they initially take the voltage as defined by electrostatics, but are kept at the correct voltage by the flow of electrons and ions produced in the gas by avalanches. A charged particle going through the chamber generates avalanches in the gas gaps. Since plates are resistive they are transparent to signal induced by avalanches, thus a signal induced in the pickup pad is the sum of signals from all the gas gaps. We built a series of chambers using glass resistive plates with a resistivity of $5 \times 10^{12}\,\Omega$ cm. In this paper, we report results obtained with chambers with six gas gaps of 220 μm. We operate these devices in avalanche mode, with a non-flammable gas mixture which contains 90% of tetra-fluoroethane ($C_2H_2F_4$), 5% of iso-Butane and 5% of SF_6.

The dimensions of the current module are 94 mm × 212 mm × 12 mm and the active area is 61 mm × 200 mm. A cross-section view of the module is shown in Fig. 1a. The electrodes are made of graphite tape with a surface resistivity of 400 kΩ/square which covers the entire active area. The outer and inner glass plates are 1.8 and 0.55 mm thick, respectively. They are kept parallel by using 220 μm diameter nylon fishing-line. The signal is read out with a 1 × 6 array of copper pickup pads, each pad with an area of 63 mm × 31.5 mm, and the distance between pads is 3 mm. The pickup pad layers are separated from the outer electrodes by 0.35 mm of Mylar. Fig. 1b shows the readout pad array.

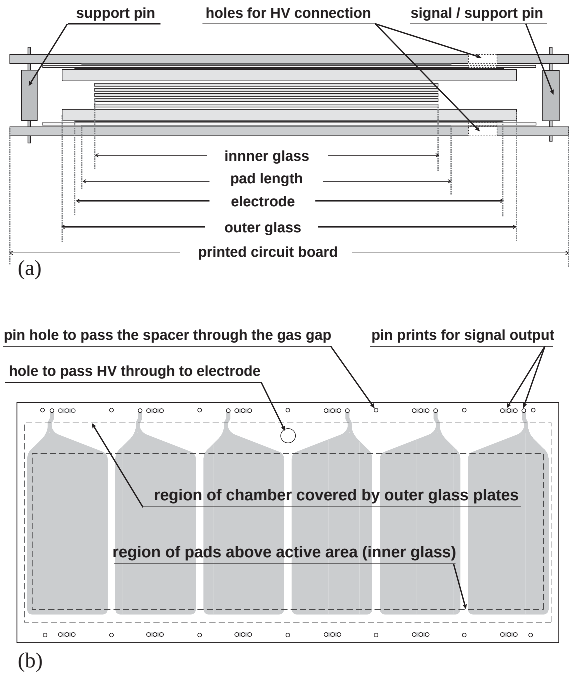

Fig. 1. (a) Cross section of the 6 × 220 μm multigap RPC module for TOF. (b) Top view of the printed circuit board with a 1 × 6 readout pads array. The PCB is 94 mm × 212 mm area. The projection of the glass layers on the readout pads is also shown.

3. Results from the test beam

We tested these chambers in the PS T10 beam line at CERN. The tests were done with a beam spot of $\sim 4\,cm^2$. Most of these tests were performed with a 7 GeV/c pion beam. The PS spill length was 0.25 s and we had one or sometimes two or three spills every 15 s. The signal from the pads was amplified by Maxim 3760 fast current amplifier connected to a custom built discriminator, based on the AD96685 comparator. We apply the same absolute value of voltage to each electrode, positive voltage to the anode and negative voltage to the cathode. Fig. 2a shows a typical pulse height distribution obtained at ±7.5 kV; the equivalent mean charge is around

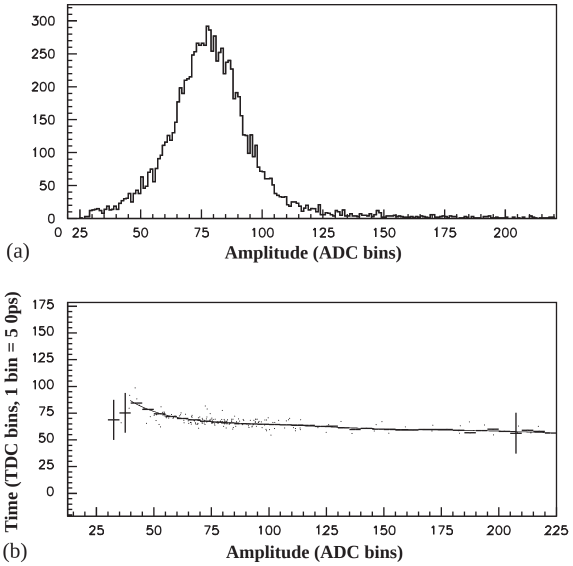

Fig. 2. (a) A typical pulse height distribution from a 6 gaps multigap RPC at ± 7.5 kV. (b) Time-to-Amplitude correlation. The vertical scale is the RPC time minus the average time of two reference scintillators. Superimposed is the curve fitted to the data.

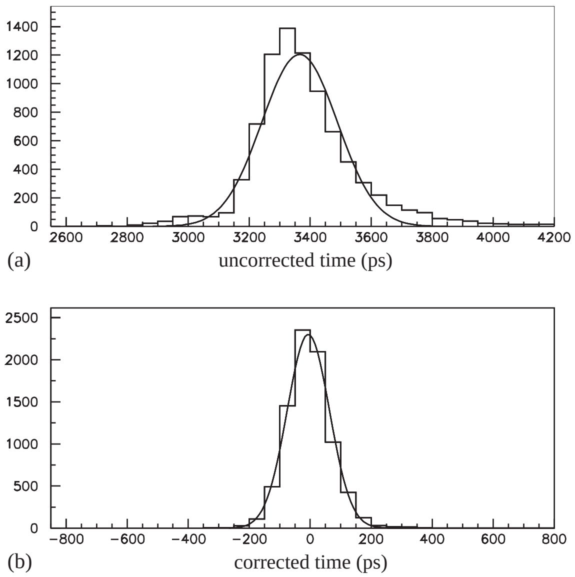

Fig. 3. (a) The raw time, and (b) the Time-to-Amplitude corrected time distributions for a six-gap MRPC at ± 7.5 kV.

0.5 pC. Fig. 2b shows the Time-to-Amplitude (TA) correlation used for the offline correction for slewing [6]. In Fig. 3, the histograms show the

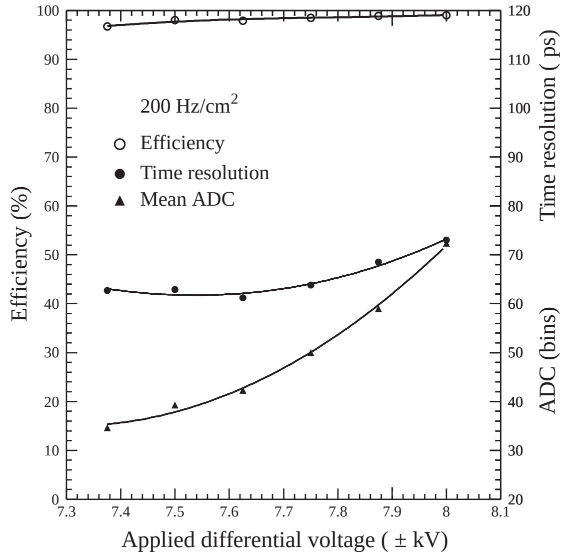

Fig. 4. A typical efficiency plateau curve, average pulse height and corrected time resolution versus voltage for a six-gap MRPC.

time resolution (a) before (raw time) and (b) after TA correction. The distributions are fitted with Gaussians. Comparing the two distributions one observes that the overall time resolution improves and we obtain a σ of 124 and 70 ps for the uncorrected and TA corrected distributions. After subtracting the mean time jitter introduced by two scintillator counters (4 PMTs), we obtain 120 and 60 ps, respectively. In Fig. 4, we show the efficiency, the corrected time resolution and the average pulse height versus applied differential voltage. An efficiency of 97% has been measured for 500 V at 7.4 kV with a time resolution of $\sim$63 ps. The signal is picked up from one of the edges of the rectangular pads shown in Fig. 1b. We scanned many pads and found a dependence of the time resolution on the position along the pad length. The time resolution for positions close to the pickup edge is 5 ps worse. Fig. 5 shows the efficiency, average pulse height and corrected time resolution for different particle rates. These results were obtained in T10 test beam illuminating a $\sim$4 cm^2 area in a spill of 0.25 s every 15 s. Thus direct comparison with the continuous background flux at STAR cannot be made; however, the rate of 10 Hz/cm^2 at STAR is expected to pose

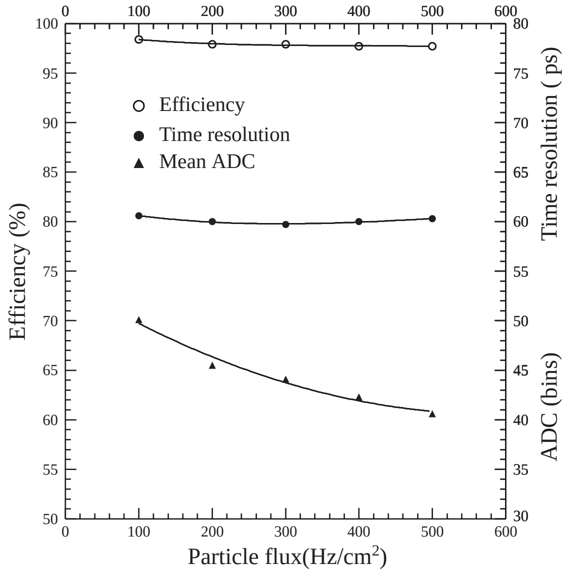

Fig. 5. Efficiency, average pulse height and corrected time resolution versus particle flux for a six-gap MRPC at ±7.625 kV.

no problems. The bunch crossing at STAR is every ~100 ns. Tests of rate capability in the STAR environment conditions will follow.

We also studied pads of smaller area. A typical corrected time resolution of around 50 ps (σ) is obtained with similar prototypes. The pickup pads were of 31 mm × 30 mm area in a 2 × 6 readout array [7].

4. Current status

We plan to install a full size TOF tray in STAR in 2002. It will be equipped with 33 MRPC modules and the readout will consist of 198 channels. These modules have been built at CERN and USTC and the construction of the tray is being finished at Rice. The active area of modules will cover ~95% of the tray, 5% is uncovered due to the distance of few mm from the active area edge of modules to the inner walls of the tray.

5. Conclusions

The excellent time resolution and very good rate capability makes MRPCs a suitable candidate for the TOF system of the STAR experiment. Recently very good results, not reported here, were obtained with front-end electronics developed at Rice University. These encouraging results will be followed by the installation at STAR and data taking next Autumn 2002.

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