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The multigap resistive plate chamber as time-of-flight detector for the STAR experiment at RHIC

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Abstract

The Multigap Resistive Plate Chamber (MRPC) is a suitable candidate for the Time-of-Flight system for the STAR[1] experiment at RHIC[2] at the BNL[3]. A time resolution of 50 ps with an efficiency of 98 % has been measured with MRPCs composed of 6 gas gaps of 220 μm. Results obtained during the year 2000 are reported here.

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

Resumen

La cámara de multiplacas resistivas (MRPC) es un detector candidato apropiado para el sistema de Tiempo-de-Vuelo del experimento STAR en el colisionador RHIC del laboratorio BNL. La MRPC presentada aquí esta compuesta de 6 espacios de gas de 220 μm, con ella se ha obtenido una resolución en la medida del tiempo de 50 ps con una eficiencia de detección de 98 %. Los resultados presentados aquí corresponden a los tests realizados durante el año 2000.

Palabras Clave: Cámara de placas resistivas; Tiempo-de-Vuelo; Identificación de partículas; Detector gaseoso; MRPC; STAR

1. Introduction

The STAR experiment at RHIC consists of several detector sub-systems in a large solenoidal magnet of 0.5 Tesla. STAR is a large experiment that was designed to measure the thousands of particles per event at mid-rapidity expected in central Au+Au collisions at 100 GeV/N/beam. The physics potential of the STAR detector will be enhanced with the improved particle identification provided by a segmented Time-of-Flight (TOF) system. To achieve this, the TOF system must measure the time of flight of as many particles as possible in the central region with a time resolution better than 100 ps for a flight path from 2.2 m to 2.9 m depending on pseudorapidity, η. A highly segmented and cylindrical detector immediately surrounding the 4.3 m

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[1] *Soleinoidal Tracker at Rhic, www.bnl.gov/rich/star.html*

[2] *relativistic Heavy ion Collider; www.bnl.gov/rhic/*

[3] *Brookhaaven National Laboratory; www.bnl.gov/*

long STAR Time Projection Chamber (TPC) can meet this requirement. Particle identification (PID) in the STAR TPC is done using the fact that pions, kaons, and protons are not minimum-ionizing in the energy range of the STAR acceptance and thus exhibit different energy losses while traversing these detectors. In PID via Time-of-Flight, the absolute time interval between the occurrence of an event and the arrival of a particle at a specific location of the TOF system is measured. Tracking information from the TPC provides the momentum of a particle, and a total path length from the collision vertex to the measurement location. The total path length so measured by the TPC and the time-of-flight lead to a velocity, β, for each track, which, when compared to the track momentum, predicts a mass for each track. If the time can be measured to better than ~ 100 ps, then such analysis allow the direct particle identification of hadrons with high efficiency to significantly higher momenta than possible from TPC dE/dx alone.

This TOF detector must be capable of operating in a 0.5 Tesla magnetic field. In the original design of the TOF detector for STAR, scintillators were proposed. These were to be arranged in 120 trays and cover an area of 60 m^2. Each individual tray is 2.4 m long, 21 cm wide and 8.5 cm deep (z x phi x r). Although this scintillator detector will certainly work, the cost of mesh-dynode phototubes required for operation in the magnetic field is prohibitive. Since 1998 the Rice University TOF group has been developing Multigap Resistive Plate Chambers (MRPC) suitable for the STAR experiment, and following the decision of the ALICE experiment at CERN to build a MRPC system for the Time-of-Flight [2], a major effort was launched to develop these devices from the year 2000 in collaboration with the ALICE TOF group. We built and tested many prototypes of MRPCs at the Proton Synchrotron (PS) at CERN. The goal of these tests was to build a device with a time resolution better than 100 ps and with cell and detector dimensions appropriate for the STAR detector at RHIC..

2. Detector description

The Multigap Resistive Plate Chamber (MRPC) was developed in 1996 [3,4]. A resistive plate chamber (RPC) is a parallel plate chamber (PPC) with resistive electrodes instead of metallic electrodes used in PPCs. The utility of resistive electrodes is to quench the streamers so that they do not initiate a spark breakdown. By choosing a suitable gas mixture, operation of RPCs either in avalanche or streamer mode is possible [5]. The MRPC is a resistive plate chamber with intermediate resistive plates, which create a series of gas gaps. A cross-section view of the chamber here reported is shown in Fig.1. For these tests we built a series of chambers using glass resistive plates. Electrodes are applied to the outer surfaces of the two outer glass plates. A strong electric field is generated in each subgap by applying a high voltage across these external electrodes. All the internal glass sheets are electrically floating; they take the voltage as defined by electrostatics. We used float glass plates with a bulk resistivity of around 5×10^{12} $\Omega \cdot$cm. The glass plates are kept parallel by using 240 μm diameter nylon fishing-line. The electrodes are made of graphite tape with surface resistivity of 500 kΩ/square which covers the entire active area. We use a non-flammable gas mixture, which contains 90 % of tetra-fluoro-ethane ($C_2H_2F_4$), 5 % of iso-Butane and 5 % of SF_6. We report here results obtained with chambers with six gas gaps of 220 μm. The active area of all these prototypes is 6.5 cm × 19.5 cm. The signal is read out with a 2×6 array of copper pickup pads, each with an area of 31 mm × 30 mm. The distance between pads is 3 mm. We also studied pads of larger area, some results are presented in section 3.

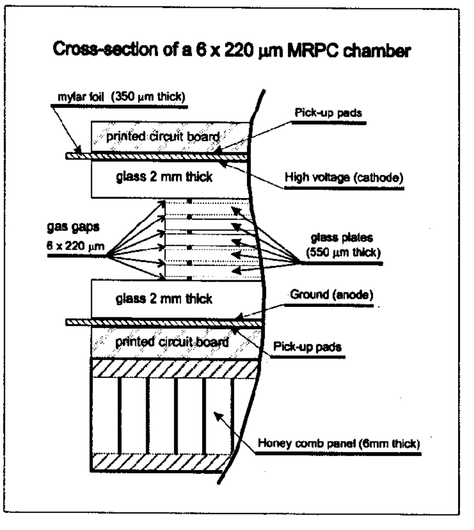

Fig 1. Cross-section of the 6 × 220 µm MRPC prototype for TOF

3. Test beam result

The purpose of these tests at the PS beam facility was to measure the time and efficiency performance of the MRPC. The tests were done with a beam spot of ~ 4 cm^2 and an intensity of 500 Hz/cm^2 during the PS spill of 350 ms. The operation of these chambers is in avalanche mode.

The signal from the pads was amplified by using a fast current amplifier Maxim 3760. This amplifier was connected to a custom built discriminator based on the AD96685 comparator. Figure 2a shows a typical pulse height distribution obtained with an operation voltage of 15.5 kV, in the middle of the plateau curve. The equivalent mean charge for that distribution is around 500 fC. Fig. 2b shows the Time-to-Amplitude (TA) correlation used for the offline correction for slewing [6].

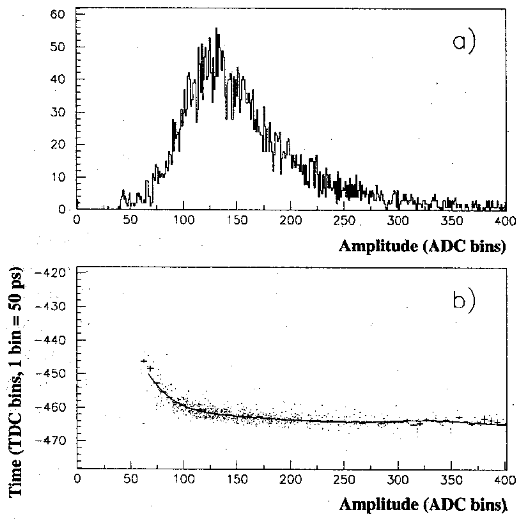

Fig. 2. a) A typical pulse height distribution from a six gaps multigap RPC at 15.5 kV. b) Time-to-Amplitude correlation. The vertical scale is the RPC time minus the average time of two reference scintillators. Superimposed is the curve fitted to the data.

In Fig. 3 the histograms show the time resolution a) before (raw time) and b) after Time-to-Amplitude correction. The distributions are fitted with Gaussians. Comparing the two distributions one observes that the overall time resolution improves and we obtain a variance, σ, of 94 ps and 57 ps for the uncorrected and TA corrected distributions. After subtracting the mean time jitter introduced by two scintillator counters. (4 Photo-Multipliers), we obtain 90 ps and 50 ps respectively.

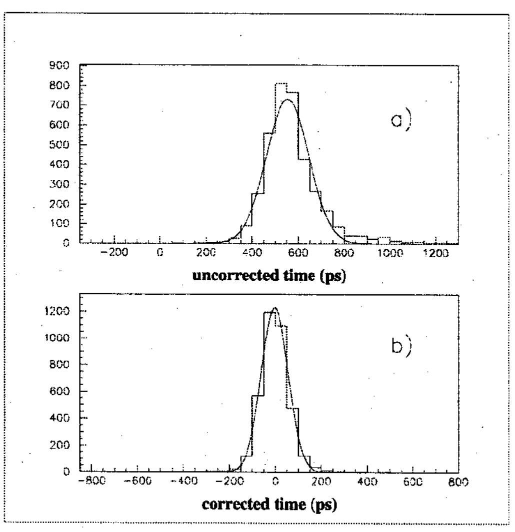

Fig.3. a) The raw time, and b) the Time-to-Amplitude corrected time distributions for a 6 gaps MRPC at 15.5 kV.

The efficiency and the TA corrected time resolution versus voltage are shown in Fig. 4a. An efficiency of 98 % has been measured over a 2 kV region with a time resolution of 55 ps. We have also studied the effect of larger pad size on time resolution (TA corrected). We built a 1x6 array by combining two pads from the 2x6 array into a single pad. The resulting pad size is 65 mm x 30 mm. The signal is picked up from one of the edges of the rectangular pads. The results are shown in Fig. 4b. The time resolution at a point 50 mm from the pickup edge is nearly the same as that of the 31 mm x 30 mm pads of the 2x6 array. The time resolution for positions closer to the pickup edge is 8 to 15 ps worse.

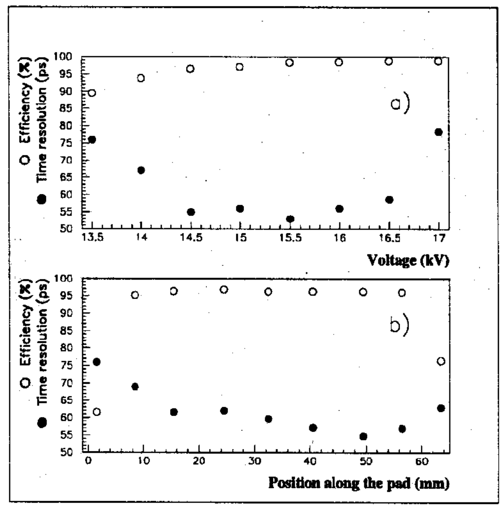

Fig. 4 a) Efficiency and corrected time resolution (σ) versus voltage for a 6 gas gaps MRPC. The pad area is 31mm × 30 mm. b) Efficiency and corrected time resolution (σ) versus position along the pad. The voltage applied was 15.0 kV. The pad size is 65 mm × 30 mm. The signal pickup edge of the pad is at 0 mm in the horizontal scale.

4. Conclusions

The results of the tests performed at the Proton Synchrotron at CERN with the MRPC here described clearly show that efficiencies in excess of 95 % and time resolutions of order of 50 ps can be achieved with this device, and this over a relatively broad high voltage plateau. These excellent results make MRPCs a very suitable candidate for the Time-of-Flight system for the STAR experiment at RHIC.

Acknowledgement

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5. References

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