A high time resolution multi-gap resistive plate chamber

LI Cheng, WU Jian, WANG Xiao-Lian, CHEN Hong-Fang, XU Zi-Zong, SHAO Ming, YE Shu-Wei, RUAN Li-Juan, HUANG Sheng-Li

(Department of Modern Physics, University of Science and Technology of China, Hefei 230027)

Abstract Research on a single cell Multi-gap Resistive Plate Chamber (MRPC) was carried out for the Time Of Flight detector (TOF) R and D of the STAR experiment. The property of the single chamber was tested with the test beam facility T10 at CERN in Geneva. The MRPC was scanned with the test beam to get the efficiency and time resolution at different position of the active area. The HV plateau was also measured. The time resolution is 65 ps which satisfies the requirement of STAR. The working mechanism of the MRPC is also explained.

Keywords TOF , MRPC, Time Resolution

CLC numbers O571.1

1 INTRODUCTION

In high energy nuclear and particle experimental physics, a detector with good time resolution is critical for event triggering and particle identification. Thus it is an important component of detecting system in these fields over the world. The time of flight (TOF) detector with excellent time resolution is a sub-detector used to identify final state particles coming from collisions in order to select valid events and analyze physics of interest. The traditional candidate of such TOF is a scintillation crystal-based detector coupled with photomultiplier tube (PMT) which occupies relatively large space and is considerably expensive. The new generation accelerator experiments such as ALICE experiment at the Large Hadron Collider (LHC) at CERN and the STAR experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven demand for a cheaper TOF with ideal time resolution to cover large detecting area. The STAR experiment requires a time resolution around 100 ps to separate $K/\pi/p$ in certain momentum range.[1]

The Resistive Plate Chamber (RPC) is a parallel plate chamber with resistive electrodes. These resistive electrodes quench the steamers so that they do not initiate a spark breakdown. It can be operated in both avalanche mode and steamer mode. A common design of RPC has a gas of 2 mm and resistive plates of Bakelite or glass.[2,3] Compared with RPC and other gas detectors which typically have a time resolution of the order of 10^3 ps, The typical time resolution of Multigap RPC (MRPC) is around 10^2 ps which will greatly improve the particle identification power of TOF detector. Zeballos *et al.* raised the idea of MRPC[4,5] to keep the advantages of RPC and substantially

Manuscript received date: 2001-08-29

improve the timing. Fig.1 is the side view of a MRPC. The detector is made of 6 glass plates (bulk resistance $\sim 10^{12}\Omega\,\mathrm{cm}$) creating 5 gaps within which there is non-flammable multi-molecular gas mixture at atmospheric pressure to quench sparks and streamers. The thickness of each gap is normally around 0.2 mm. There are electrodes on the 2 outer surfaces of the glass plates to be the cathode and anode. The cathode is connected to the negative high voltage (HV) and the anode outputs the induced signal. When a charged particle passes through the gaps of the cell, it creates electron and positive ion pairs. The electrons multiply themselves in each gap quickly by avalanching in the high electric field created by the HV. All the intermediate glass plates are electrically floating and transparent to the avalanche signals. The net flow of current is zero inside the glass plates. The system is self-stabilizing with equal gain in all gaps. The intermediate glass plates take correct voltage due to electrostatics and are kept at correct voltage with flow of positive ions and electrons generated by the avalanche. Induced signals on external anode and cathode are analogue sum of avalanches in all the five gaps. For the same length of gas gap, the time resolution of MRPC is much better than that of a RPC.

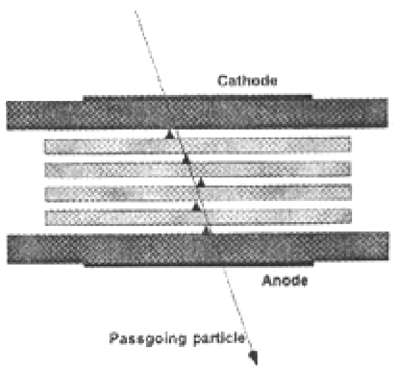

Fig.1 Cross section of a MRPC and the development of avalanche

2 EXPERIMENTS AND RESULTS

In order to acquire required time resolution and enough signal amplitude to meet the demand of TOF of STAR, the single cell MRPC is designed to have five gaps and is separated by six layers of glass plates. There are 2 types of glass plates used in the cell construction. The five gaps of 0.22 mm wide are constructed with 4 layers of 0.64 mm glass plates inserted into two layers of 2.0 mm ones. Kapton polyimide film (product of Dupont company) is put outside the active area as the spacer to offer the 0.22 mm gaps between the glass. The thin glass used has a bulk resistance of $5.2\times10^{12}\,\Omega\mathrm{cm}$ while the thick glass corresponds to $4\times10^{12}\,\Omega\mathrm{cm}$. All the edges of the glass are polished to avoid sparking due to the high voltage between the gaps. Copper tape electrodes are put at the center of the outer surface of the top and bottom glass and cover an active area of 3.0 cm×3.0 cm while each thin glass plates has an area of 4.0 cm×4.0 cm. The HV applied is from 12000V to 13500 V. The gas used is a mixture of 90% freon 134 A, 5% iso-C_4H_{10} and 5% SF_6 at atmospheric pressure and flows across all the gaps at a speed of 20 mL/min.

The MRPC was tested with the T10 test beam facility at CERN. A four-fold telescope system is used to get the start time for the MRPC. The telescope system is composed of 4 PMTs with corresponding plastic scintillators. The average of the 4 PMTs' offers the offline start time to the MRPC, thus the sigma contribution from the telescope system was reduced up to a factor of 2 at about 30 ps. Besides the intrinsic time variance of the cell, there are some other contribution to the overall time resolution of the system. Fig.2 is the time-amplitude distribution of the signals measured. The X-axis is the signal amplitude of the MRPC in ADC count and the Y-axis corresponds to reference time in TDC count. The TDC count comes from the difference between the stop time offered by the signal from the MRPC and the start time provided by the telescope system. As there is a long delay line in the telescope system, the start time comes actually later than the stop time, thus makes the reference TDC count negative. The most important information here is the time difference instead of the absolute value of time, so the origin of the coordinate is not shown in the figure. It can be clearly seen that a signal with high amplitude normally corresponds to an early signal. This needs to be corrected to get the correct time resolution. In fact a polynomial formula is used to fit the distribution. The form of the formula is

$$T = C_0 + C_1A + C_2A^2 + C_3A^3 + C_4A^4 + C_5A^5 + C_6A^6$$

where $C_0 - C_6$ are constants calculated from the fit, T and A correspond to TDC and ADC counts respectively.

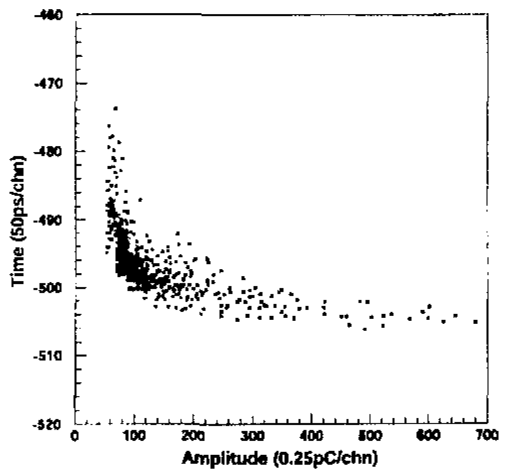

Fig.2 Time-amplitude relation of the signal from MRPC

The time distribution after T-A correction can be seen in Fig.3. As each TDC channel corresponds to 50 ps, thus the result is 70 ps for the MRPC but it still includes time jitter from the telescope system. The time resolution of the telescope system is separately measured and subtracted from the overall time resolution value. The final time resolution of the MRPC is around 65 ps. But this value was measured at the center of the MRPC. The knowledge of the whole active region need also be collected. With the test beam, it is possible to scan the MRPC step by step to look at its response. Fig.4 shows the results of track scan. The HV applied is 13 kV. The open squares are efficiency while the solid is the time resolution. In most of the active area that is from −1.5 cm to 1.5cm, the efficiency is around 95% for MIP (Minimum Ionization Particle) and the time resolution is around 65 ps. At about ±1.5 cm which is the boundary of the active area, the edge effect can be clearly seen. The efficiency drops sharply and the time resolution becomes degraded. As the final design of TOF of STAR will be multi-cell MRPC, this edge effect can be corrected by weighting signals on neighboring cells. The high voltage efficiency plateau was also measured. Within the range between 12.5kV and 13.5kV, the MRPC works well with efficiency around 95% for (Minimum Ionization Particle). The overall results satisfactorily suit the request of STAR physics goal.[1]

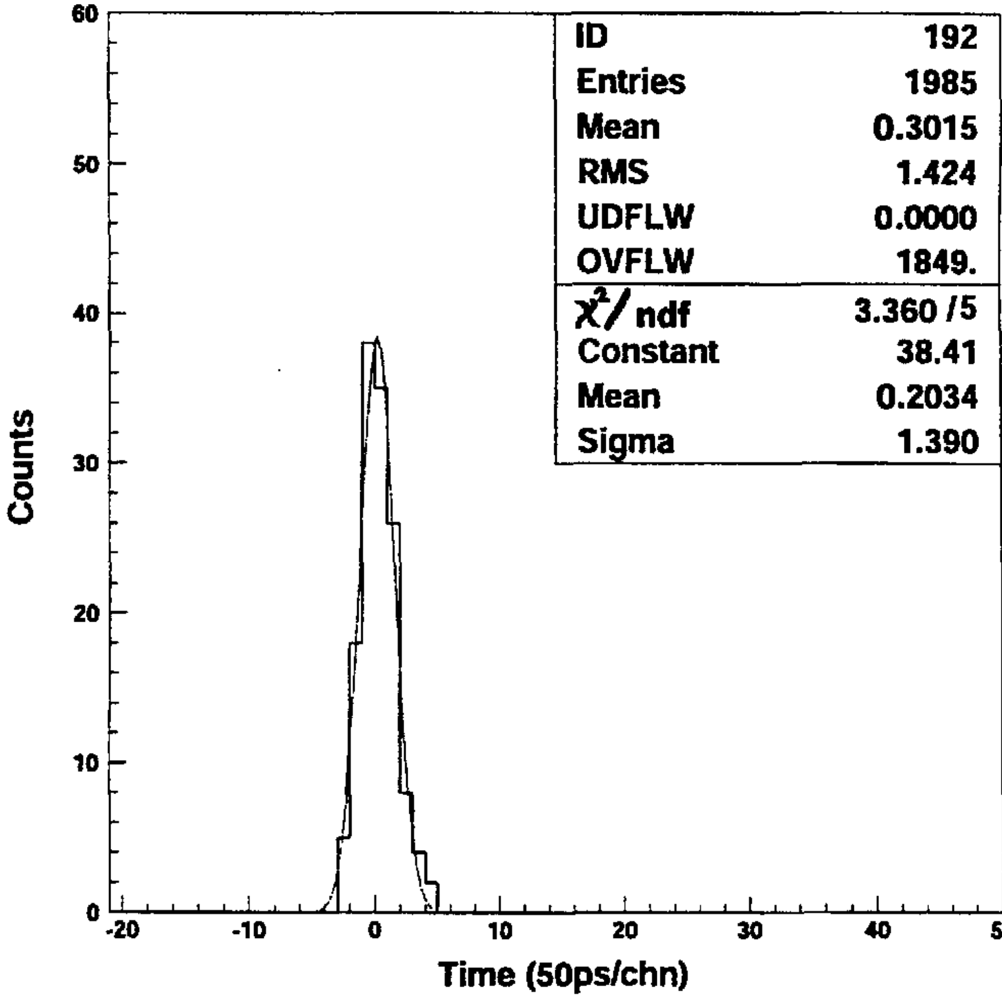

Fig.3 Time distribution of the MRPC after T-A correction

3 SUMMARY

The 5-gap MRPC configuration that has been designed has both good time resolution and high detection efficiency for MIP. It meets the critical time resolution requirement of TOF of STAR. This makes the design and final construction of a full scale TOF of STAR possible.

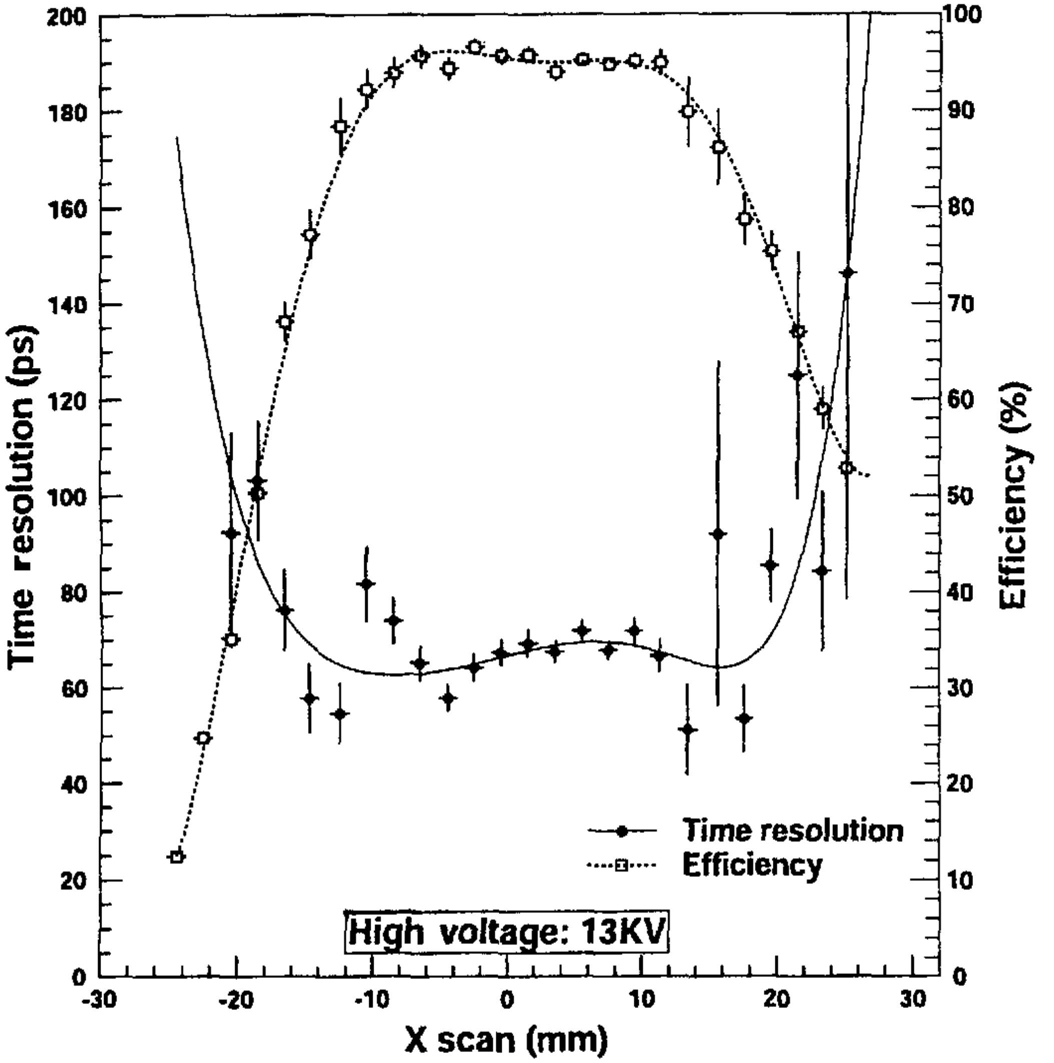

Fig.4 Scanning results of the MRPC at HV 13 kV

Acknowledgement

The authors thank the help from the STAR collaboration for offering the chance to test the MRPC at CERN. Thanks also to Prof. C. Williams and Dr. Lamas for their assistance at CERN.

References

1 Klempt W. Nucl Instr Meth, 1999, **A433**:542
2 Santonico R, Cardarelli R. Nucl Instr Meth, 1981, **187**:377
3 Abe K *et al.* Scientifica Acta, 1998, **13**(2):281
4 Zeballos E C *et al.* CERN PPE/95-166, CERN/LAA-MC 95-23
5 Zeballos E C *et al.* Nucl Instr Meth, 1997, **A396**:93