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# A prototype of a high rating MRPC*

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**Abstract** Six-gap resistive plate chamber (MRPC) prototypes with semiconductive glass electrodes (bulk resistivity $\sim 10^{10}$ $\Omega\cdot$cm) were studied for suitability in time-of-flight (TOF) applications at high rates. These studies were performed using a continuous electron beam of 800 MeV at IHEP and an X-ray machine. Time resolutions of about 100 ps and efficiencies larger than 90% were obtained for flux densities up to 28 kHz/cm$^2$.

**Key words** MRPC, bulk resistivity, high rate, time resolution

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## 1 Introduction

An MRPC (Multigap Resistive Plate Chamber) has a good performance and low noise. Its intrinsic time resolution can reach 60—80 ps, and it has been adopted to construct the time-of-flight (TOF) detector for the STAR experiment at RHIC[1, 2]. The MRPC TOF system can improve the particle identification capability in the high momentum range and will improve RHIC STAR in its K/Pi and K/p separation power to 1.7 and 3 GeV/$c$, respectively. MRPC can potentially be widely used in other experiments, but the MRPC developed at present use thin float glass. The bulk resistivity is about $10^{12}$—$10^{13}$ $\Omega\cdot$cm. This kind of MRPC can only bear lower particle rates (less than 200 Hz/cm$^2$), and can not meet the requirement of other high-rate experiments (for example, CBM-TOF). CBM-TOF requires particle rates up to 50—100 kHz/cm$^2$[3, 4].

Usage of electrodes made of semiconductive glass with low bulk resistivity seems to be a promising way to adapt MRPC to the high-rate environment of the upcoming CBM experiment[5]. To address this issue, we developed a six-gap MRPC with resistive electrodes made of semiconductive glass which has a bulk resistivity of the order of $\sim 10^{10}$ $\Omega$·cm. Tests performed in electron beams yielded an efficiency above 90% and a time resolution within 120 ps at background rates up to 28 kHz/cm$^2$ produced with photons from an X-ray generator. This kind of MRPC can be used to construct a TOF system in a high rating environment. In this paper, the performance of conductive glass is presented and beam test results of the MRPC are also presented.

## 2 Low-resistive silicate glass for MRPC electrodes

The MRPC rate capability is limited by the time interval needed for a localized discharge to dissolve from the glass electrode. With all the other parameters of MRPC being fixed, this time is determined by the bulk resistivity of glass[6, 7]. An MRPC made of conventional float glass is unacceptable for the high rate system. Recently, there was no commercially available window glass with a bulk resistivity of less than $10^{12}$ $\Omega\cdot$cm. There are three known types of semiconductive glasses depending on the base material selected for their production: phosphate, silicate and borosilicate glasses. These glasses are characterized by electron conductivity and contain the oxides of transition elements. They have a black color and are opaque to visible light. Compared to window glass, the technology of semiconductive glass produc-

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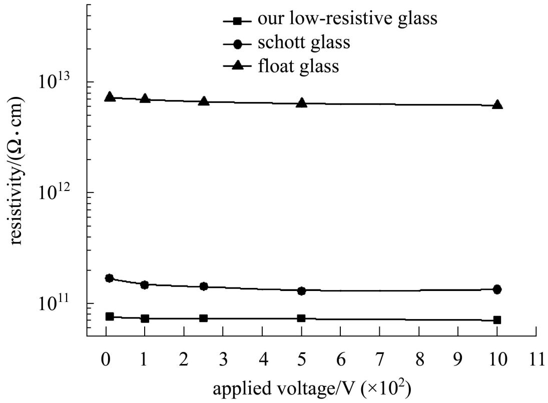


Fig. 1. Resistivity of the sample of silicate glass as a function of the applied voltage.

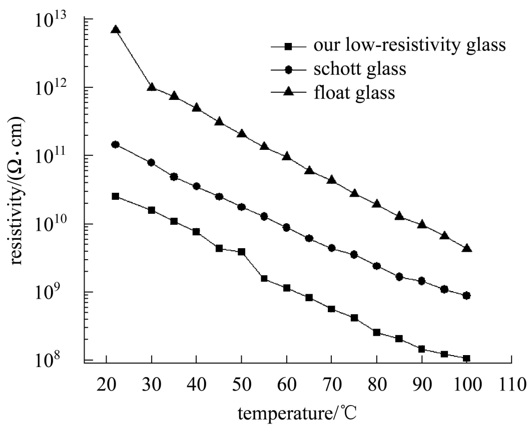


Fig. 2. Resistivity of the sample of silicate glass as a function of temperature measured at an applied voltage of 1 kV. The bulk resistivity of the silicate glass (black line) is of the order of $10^{10}$ Ω·cm at normal temperature and drops to the order of $10^8$ Ω·cm when the temperature is increased to 60℃.

tion is more complicated, and the resulting glass resistivity is sensitive to the chemical composition of the raw material and glass melting procedure. For this test, we produced some samples of silicate glass in the form of moulding with sizes of 210 mm×61 mm and a thickness of about 0.7 mm. After the glasses being ground and polished, the bulk resistivity was measured. The resistivity of one of the samples (silicate glass) is shown in Fig. 1 as a function of the applied high voltage and in Fig. 2 as a function of temperature, with applied HV = 1 kV. The bulk resistivity is about $10^{10}$ Ω·cm at an applied voltage of 1 kV volts. These two figures show that the resistivity of our semiconductive glass is about one percent that of conventional float glass and a tenth of SCHOTT semiconductive glass.

## 3 MRPC detector layout

The basic design features of the tested MRPC prototype with electrodes made of silicate glass is depicted in Fig. 3. The MRPC consists of a stack of planar electrode plates of high resistivity which are kept by spacers at fixed distances of typically 0.22 mm. Carbon resistive tapes were used to apply high voltage to the stack. Its surface resistivity is about 100 k Ω/square. The electrode plates are made of 0.7 mm thick silicate glass and the spacers are made of nylon fishing line. Bipolar high voltages were applied on two electrodes of MRPC. For the readout a differential signal is derived from the anode and cathode pickup pads. The readout strips is shown in Fig. 4. The detector is 212 mm long and 94 mm wide, and it consists of six channels. The pickup strip of each channel is about 18 cm$^2$. The assembly was made under strict clean conditions, which are essential to avoid permanent discharges. The working gas contains 95% tetrafluorethane and 5% iso-butane.

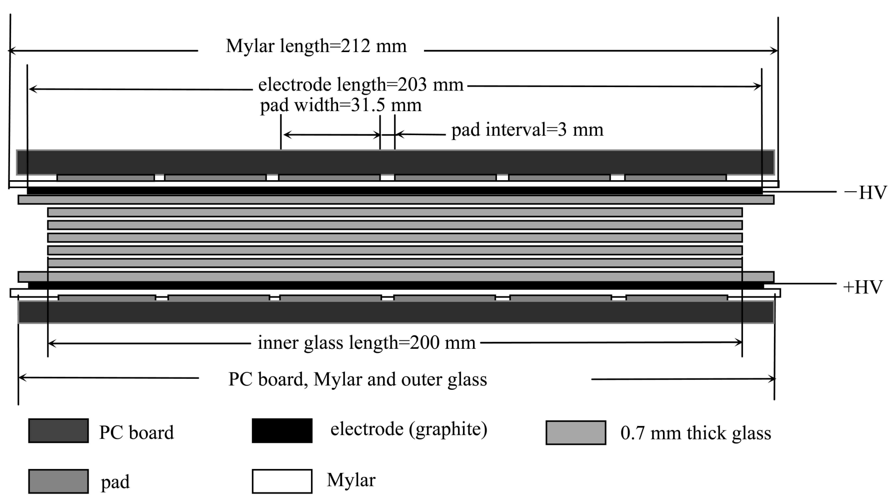


Fig. 3. Schematic drawing of MRPC with electrodes made of silicate glass.

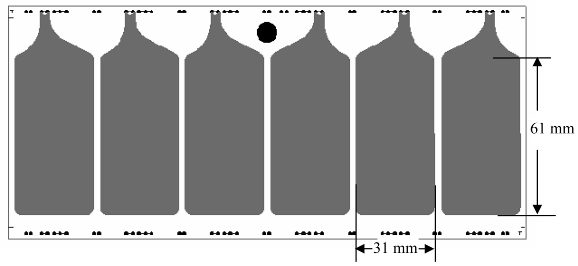


Fig. 4. The geometry of a readout strip. The six strips are distributed equally on a PC board.

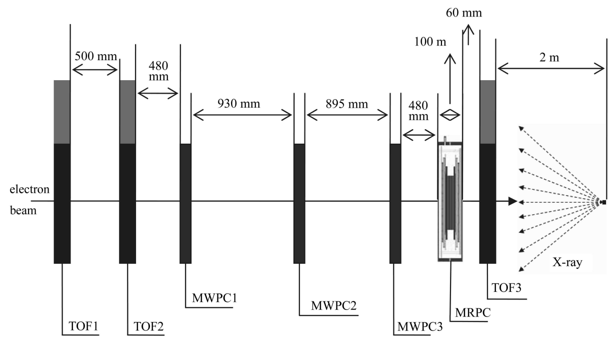


Fig. 5. The experimental system. The high rates up to 45 kHz/cm$^2$ were provided by an X-ray generator.

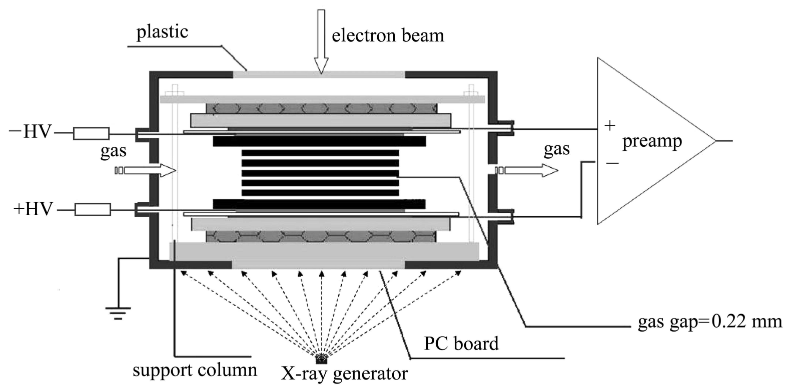


Fig. 6. Schematic view of the detector structure. The detector was enclosed in a metallic shielding box. On the box, there are input and output windows to reduce electron absorption.

## 4 Beam test at IHEP

A beam test experiment was carried out in the test beam facility at the Institute of High Energy Physics (IHEP), CAS in March 2008. The beam mainly contains 800 MeV electrons. The setup of the beam test is shown in Fig. 5. The MRPC was placed in a gastight box and continuous gas flow was piped into the box; this can be seen in Fig. 6.

The coincidence of TOF1, TOF3 and three Multi-Wire Proportional Chambers (MWPC) acted as trigger and common STOP for TDC (Time to Digital Convertor). The TOF2 and TOF3 provided the reference time for MRPC. Three layers of MWPC provided the particle incident position. Precisions of up to the order of 1 μm can be reached. The electron beam was about 6 cm in diameter, the range of the

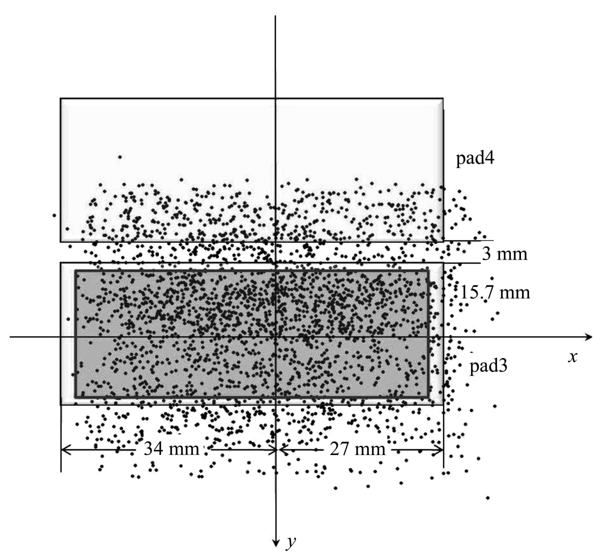


Fig. 7. Position distribution of incident electrons.

MRPC rate density was about 0—20 Hz. Higher rates in the test chamber were obtained with an X-ray generator which provides a photon spectrum peaking at 45 keV. The position distribution of the incident electrons is shown in Fig. 7. The center of the beam is on Pad3. In order to avoid disturbance of crosstalk events, only electrons located in the inner rectangle area (57 mm × 28 mm) are used to analyze the efficiency and time resolution of MRPC.

### 4.1 Efficiency and time resolution

The efficiency and time resolution as a function of the applied voltage are shown in Fig. 8. The increase of the applied voltage resulted in a higher efficiency and a better time resolution. With an applied voltage above 14.8 kV, the efficiency increased up to a level of around 93%, and the time resolution decreased below 100 ps. For this reason, the operating voltage was set to 14.8 kV at beam test.

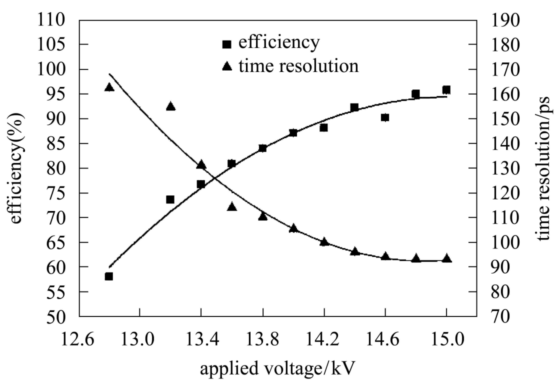


Fig. 8. Efficiency and time resolution as a function of the applied voltage.

### 4.2 Time resolution and efficiency changes with rates

The results of efficiency and time resolution measurements under different rates in the range of 2.37—40 kHz/cm$^2$ are summarized in Fig. 9. The increase in rate from 2.37 to 28 kHz/cm$^2$ leads to a degradation of efficiency from 93.5% to 90%, while the time resolution gradually deteriorates from 90 ps to 120 ps.

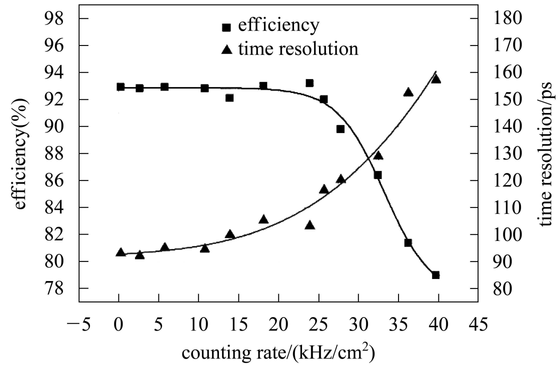


Fig. 9. Efficiency and time resolution as a function of different rates: the rate capability can reach up to 28 kHz/cm$^2$, while keeping the time resolution below 100 ps.

## 5 Conclusions

Simulations predict that the innermost part of the CBM TOF system, proposed to be made up of MRPC cells, will be operating under extreme hit rates of about 50—100 kHz/cm$^2$. To improve the high-rate capability of the MRPC, we have developed a six-gap MRPC with resistive electrodes made of semiconductive glass which has a bulk resistivity of the order of $10^{10}$ Ω·cm. The MRPC was tested with an electron beam and yielded an efficiency above 90% and a time resolution within 120 ps at background rates up to 28 kHz/cm$^2$. At the best applied voltage measured (14.8 kV), the experiment gave an acceptable result: an increase in rate from 2.37 to 28 kHz/cm$^2$ leads to degradations in efficiency (from 93% to 90%) and in time resolution (from 90 ps to 120 ps).

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