Proc. 8th Int. Conf. Quarks and Nuclear Physics (QNP2018)
JPS Conf. Proc. **26**, 024006 (2019)
https://doi.org/10.7566/JPSCP.26.024006

Development and Production of High Rate MRPC for CBM TOF

Yi WANG[1*], Qiunan ZHANG[1], Pengfei LYU[1], Dong HAN[1], Baohong GUO[1], and Yuanjing LI[1]

[1]*Key Laboratory of Particle and Radiation Imaging (Tsinghua University), Ministry of Education, Beijing 100084, China*
**E-mail: yiwang@mail.tsinghua.edu.cn*

(Received December 26, 2018)

The Compressed Baryonic Matter (CBM) is a physics experiment aiming to investigate rare probes of the dense phase of strongly interacting matter with unprecedented accuracy by designing all components of the experiment for an interaction rate of 10 MHz. The CBM Time Of Flight (TOF) detector needs Multi-gap Resistive Plate Chambers (MRPCs) with high rate capability reaching 25 kHz/cm^2. A new kind of high rate MRPC built with newly developed low resistive glass sheets has a rate capability up to 70 kHz/cm^2, meeting the requirement of CBM. The glass has a resistivity in the order of 10^{10} $\Omega\cdot$ cm. It can be used to build high rate MRPCs with different structures. The final version of the high rate MRPC for CBM is called MRPC3a, which has been put into mass production. Performance of MRPC3a is studied via a cosmic ray test system in Tsinghua University. Test results show that MRPC3a has excellent performance with the time resolution better than 90 ps at efficiency higher than 95%. The mini-CBM (mCBM) TOF wall and the Solenoidal Tracker at RHIC (STAR) end-cap TOF (eTOF) are two detectors that firstly adopt MRPC3a. The application of MRPC3a on STAR eTOF shows time resolution better than 100 ps by preliminary analysis and the mCBM TOF wall is ready for beam test. The working gas mixture for MRPC3a in the eTOF is different from the standard working gas mixture in the CBM. But the performance of MRPC3a is stable when working without SF_6 in the eTOF.

KEYWORDS: CBM, low resistive glass, high rate MRPC, eTOF, mCBM

1. Introduction

Quantum Chromodynamics (QCD) is a basic dynamical theory describing the strong interaction. QCD matter has many different phases [1]. Since the phase boundary and the critical points are under study, the phase transition of the strongly interacting matter becomes one of the main research topics. The Compressed Baryonic Matter (CBM) experiment in Fig. 1 is a future high rate fixed target experiment for the study of the phase transition at large baryon densities with unprecedented accuracy. This is achieved by designing all the components of the experiment for an interaction rate of 10 MHz [1]. The identification of the charged hadron in this system is realized via the Time Of Flight (TOF) method. The CBM TOF collaboration designed a 120 m^2 TOF wall composed of Multi-gap Resistive Plate Chambers (MRPCs) and the rate of center area can reach 25kHz/cm^2. So a high rate MRPC is crucial for the CBM TOF wall since the common rate capability of float glass MRPC just reaches a few hundred Hz/cm^2.

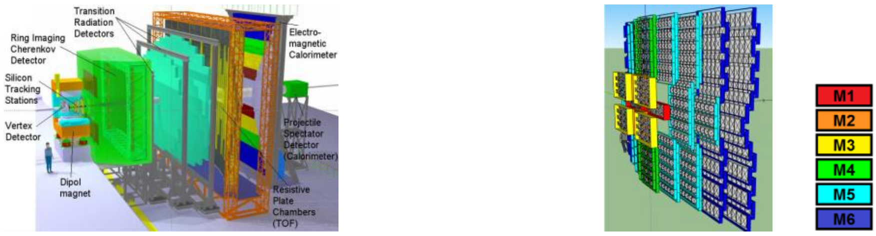


Fig. 1. Left: the design of CBM experiment. Right: the schematic layout of the TOF wall. There are 5 modules in different colors. They consist of MRPCs with different rate capabilities ranging from 0.5 kHz/cm^2 to 25 kHz/cm^2 [2].

2. The development of the low resistive glass

According to a direct current (DC) model as depicted in eq. (1) [3], the rate capability Φ of MRPC is related to q, ρ, and d:

$$V_{drop} = V_{ap} - V_{gap} = q\Phi\rho d \, , \qquad (1)$$

where V_{drop} is the voltage drop caused by the current I in the resistive plates, V_{ap} is the High Voltage (HV) on the chamber, V_{gap} is the HV on the gaps, q is the charge produced in the chamber. ρ is the bulk resistivity of the plates and d is their total thickness. In order to increase the Φ and keep the V_{drop} low so that MRPC works at the set HV, the possible ways are reducing d, q, and ρ. While the rate capability of thin float glass MRPC is no more than 3 kHz/cm^2 [4], which only meets the requirement of CBM TOF outer region. The reduction of q will result in small signals and high requirement on electronics. So low resistive glass electrode becomes an effective solution. The low resistivity glass needs shorter time for avalanche charge collected on the glass surface to dissolve, resulting in high rate capability. The key challenge for CBM TOF is the development of MRPC with rate capability above 25 kHz/cm^2, which becomes possible due to the development of a new low resistive glass. The resistivity of the glass is in the order of 10^{10} Ω · cm as shown in Table I. It is about 1% of that of the float glass [5].

Table I. The parameters of the low resistive glass performance.

Performance	Parameter
Bulk resistivity	10^{10} Ω · cm
Standard thickness	0.7mm, 1.1mm
Thickness uniformity	20 μm
Surface roughness	< 10 nm
Maximal dimension	32 cm × 30 cm
Dielectric constant	7.5-9.5
DC measurement	Ohmic behavior stable up to 1 C/cm^2

Two MRPC prototypes based on such low resistive glass were produced and tested by the beam in ELBE, Dresden-Rossendorf, Germany, to examine their performance under high rate. As shown in Fig. 2, the efficiency is still higher than 90% and the time resolution is about 80 ps at 70 kHz/cm^2 rate [6].

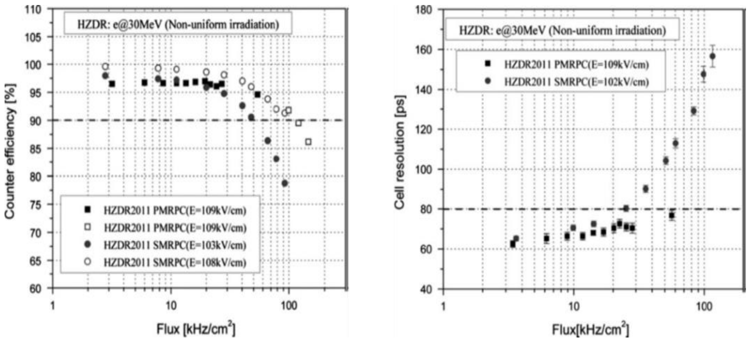


Fig. 2. Measured efficiencies and time resolutions for different runs as a function of the average particle flux determined with reference scintillators [6].

3. Development and performance of the high rate MRPCs

The MRPC3a is the low resistive MRPC firstly used for the two physics experiments the Solenoidal Tracker at RHIC (STAR) [7,8] and the mini-CBM (mCBM). The detailed structure of MRPC3a is shown in Fig. 3. It has two stacks. Each stack has 4 gas gaps of 0.25 mm wide created by fishing line between each two plates and there are 32 readout strips on each PCB. Between the mylar layers and the glass sheets, there are conductive layers coated on the glass as HV electrodes. The honeycombs are used to smooth the chamber.

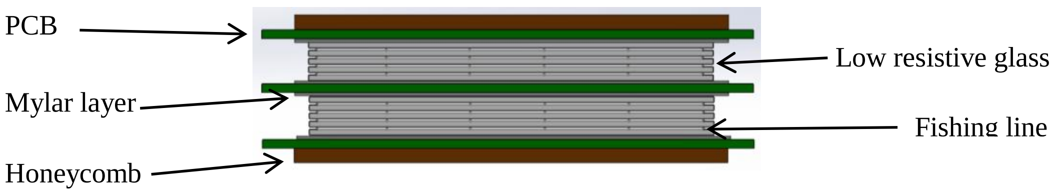


Fig. 3. The structure of MRPC3a.

The performance of MRPC3a is shown in Fig. 4. It can be seen the efficiency stays at 97%. The cluster size is the average number of fired strips in each event. It maintains a proper value of 1.6. Assuming an equal performance with the reference counter, we have a time resolution of the MRPC3a of about 50 ps [9].

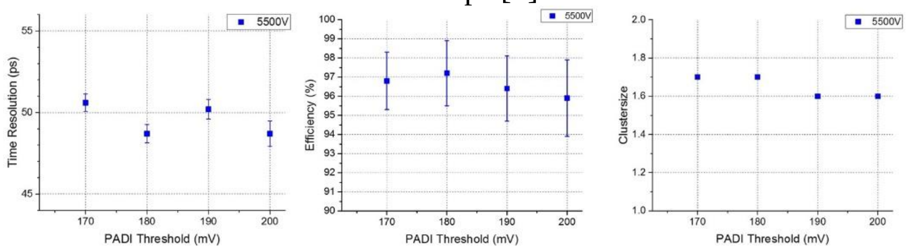
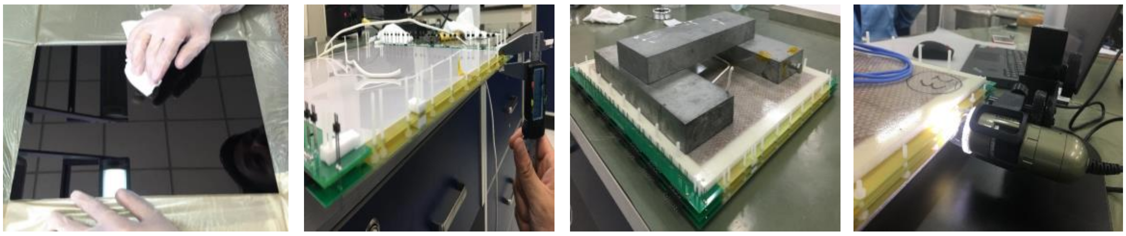


Fig. 4. Time resolution (around 50 ps), efficiency (97%) and cluster size (1.6 to 1.7) of MRPC3a under different FEE (PADI) electronics thresholds [9].

The MRPC3a has been put into mass production. The mass production was carried out in the manufacture base of NUCTECH Ltd. with strict procedures as shown in Fig. 5. Firstly, the raw materials were checked to make sure they were clean and smooth. Then they were assembled together and the HV connections were made. Some irons blocks were used to smooth the assembled MRPCs. The gas gap uniformity was first checked by the digital microscope by taking photos of the gas gap width from the sides. The width of each gas gap was measured automatically with micron grade accuracy. Then all MRPCs would go through HV test with 90% $C_2H_2F_4$, 5% iso-C_4H_{10} and 5% SF_6. MRPCs with dark current no more than 50 nA at $\pm$5600 V are qualified.



A) Preparations of materials | B) Assembly and HV production | C) Flattening MRPC with iron blocks | D) Gas gap uniformity test by microscope

Fig. 5. Mass production process of MRPC3a.

4. Status of STAR end-cap TOF (eTOF) and mCBM TOF

The mass production of MRPC3a for the STAR eTOF and the mCBM TOF has been finished. 34 MRPCs were tested by cosmic rays as samples. The test results in Fig. 6 shows that their efficiency higher than 95% and time resolution better than 90 ps. The standard gas mixture for MRPC3a is 90% $C_2H_2F_4$, 5% iso-C_4H_{10} and 5% SF_6. It is used in the mCBM. The gas mixture in the eTOF is 95% $C_2H_2F_4$ and 5% SF_6. During the cosmic test, MRPC3a can work in both gas mixtures of eTOF and CBM [10].

6 MRPC3as have been installed on the STAR eTOF and they are running now. The preliminary results show that the time resolution is better than 100 ps, providing (π,K)/p separation up to 3 GeV/c as shown in Fig. 7. More careful calibration and analysis are under research. Another 25 MRPC3as for the mCBM have been installed and they are ready for beam tests.

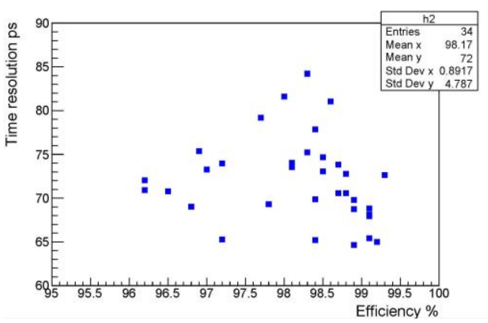


Fig. 6. Test results of 34 mass produced MRPCs.

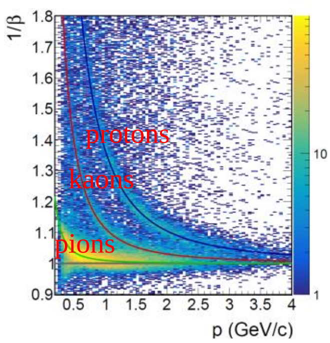


Fig. 7. The preliminary result of PID of eTOF.

5. Conclusion

The experiment results show that the high rate MRPC equipped with low resistive glass has an excellent performance. The bulk resistivity of the glass is in the order of $10^{10}\ \Omega\cdot\mathrm{cm}$, which is two orders of magnitude smaller than that of float glass. So the rate capability of the MRPC gets improved. The MRPC has 2 stacks to reduce the HV requirement, reduce the insulation requirement and increase the efficiency. The maximum rate capability of the low resistive MRPC is 70 kHz/cm^2 with 93% efficiency [11].

MRPC3a is a kind of high rate MRPC. It makes full use of limited glass sheet dimension and became the candidate for the high rate region of the CBM TOF. It can work well in both gas mixtures of eTOF and CBM TOF. The first stage mass production of 73 MRPC3as had been completed. Cosmic test results of the samples show the efficiency higher than 95% and time resolution better than 100 ps. The time resolution of the eTOF is also better than 100 ps and mCBM TOF will have beam test.

For better performance and smaller data file, low noise and low crosstalk structure are necessary for the high rate MRPC and a new kind electrode is under research. The eco gas mixture with smaller global warming potential (GWP) for high rate MRPC is also under research due to the GWP of SF_6 is more than 23000 [12].

Acknowledgement

The work is supported by National Natural Science Foundation of China under Grant No.11420101004, 11461141011, 11275108, 11735009. This work is also supported by the Ministry of Science and Technology under Grant No. 2015CB856905, 2016 YFA0400100.

References

[1] N. Herrmann et al.: TOF TDR, http://repository.gsi.de/record/109024.
[2] I. Deppner, Development of a fully differential Multi-gap Resistive Plate Chamber for the CBM Experiment. (2013).
[3] G. Aielli et al., Nucl. Instr. Meth A. **456** 82 (2000).
[4] W. Zhu et al., Nucl. Instr. Meth A. **735** 277 (2014).
[5] Y. Wang, et al., Chinese Physics C. **33** (2009) 374.
[6] J. Wang et al., Nucl. Instr. Meth A. **713** 40 (2013).
[7] The STAR Collaboration, the CBM Collaboration eTOF Group, arXiv:1609.05102 (2016).
[8] I. Deppner et al., arXiv preprint arXiv:1807.02070 (2018).
[9] Y. Wang et al., JINST. **11** C08007 (2016).
[10] Q. Zhang et al., JINST. **14** p01003 (2019).
[11] W. Zhu et al., Science China Technological Sciences. **56** 2821 (2013).
[12] Y. W. Baek et al., Nucl. Instr. Meth A. **927** 366 (2019).