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A solution for the inner area of CBM-TOF with pad-MRPC

Y. Wang [a], X.J. Huang [a,*], P.F. Lyu [a], D. Han [a], B. Xie [a], Y.J. Li [a], N. Herrmann [b], I. Deppner [b], P. Loizeau [b], C. Simon [b], J. Frühauf [c], M. Kiš [c]

[a] Key Laboratory of Particle & Radiation Imaging (Tsinghua University), Ministry of Education Department of Engineering Physics, Tsinghua University, Beijing 100084, China
[b] Physikalisches Institute, University Heidelberg, Heidelberg, Germany
[c] GSI Helmholtzzentrum fr Schwerionenforschung, GSI, Damstadt, Germany

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ABSTRACT

The Compressed Baryonic Matter (CBM) experiment has decided to use the Multi-gap Resistive Plate Chambers(MRPC) technology to build its Time-Of-Flight (TOF) wall. CBM-TOF requires a rate capability over 20 kHz/cm^2 for inner region. A 10-gap pad-MRPC assembled with low resistive glass is designed to construct this area. The prototypes, which consist of 10×0.22 mm gas gaps and 2×8 20 mm $\times$ 20 mm readout pads, require fewer electronic channels compared to the strip design. A timing resolution of around 60 ps and an efficiency above 98% were obtained in a cosmic test and a beam test taken in 2014 October GSI beam time. The results show that the real-size prototypes fulfill the requirements of the CBM-TOF.

1. Introduction

The Compressed Baryonic Matter (CBM) experiment, which aimed at the exploration of the QCD phase diagram in the region of high baryon densities using heavy-ion collisions, will be one of the four major scientific pillars of Facility for Antiproton and Ion Research (FAIR). The Time-of-Flight (TOF) system is one of the core detectors of the CBM experiment. It will provide particle identification for all charged hadrons produced in beam–target interactions and emitted to polar angles from 2.5° to 25°. The TOF wall, which will be located between 6 m and 10 m from the target depending on the physics needs, is 9 m in height and 13 m in width and covers an active area of about 120 m^2 [1]. To separate hadrons with a momentum up to a few GeV/c, a TOF timing resolution of 80 ps at high efficiency is required according to simulations [2]. In the current design, the TOF wall is divided into four rate regions. The simulated particle flux ranges from 8 kHz/cm^2 to 25 kHz/cm^2 for the innermost region, and falls down to 500 Hz/cm^2 in the outmost region [3], as shown in Fig. 1.

The Multi-gap Resistive Plate Chambers(MRPC) technology, with the advantages of good timing resolution, high detection efficiency and relatively low cost [4], is considered as a good solution that can meet the requirements of CBM-TOF [1]. However, the MRPC assembled with float glass can only achieve a rate capability of hundreds of Hz/cm^2 [5]. Tsinghua University had successfully developed a low resistivity glass with a resistivity on the order of 10^{10} Ω cm [6]. MRPC assembled with this kind of low resistivity glass can keep their performance at a flux rate up to 60 kHz/cm^2 [7]. A simulation study indicated that a MRPC based on low resistivity glass with small readout pads can efficiently cope with a high flux rate of about 20 kHz/cm^2 [7]. Thus pad-MRPC prototypes for the center region of CBM-TOF were designed and produced.

In this paper the structure and the test results of the pad-MRPC prototypes are presented. The cosmic test was performed at Tsinghua. The beam test was performed at 2014 October GSI beam time. Secondary particles from a ^{152}Sm beam hitting on a Pb target were used.

2. Module structure

Real size MRPC prototypes with an active area of 176 mm $\times$ 42 mm which are subdivided into sixteen 20 mm $\times$ 20 mm readout pads with an 2 mm interval between pads were developed and were arranged into a double stack configuration with gas gaps of 10×0.22 mm, defined by nylon fish line. The thickness of outer glass is 1 mm and thickness of inner glass is 0.7 mm. Fig. 2 provides a schematic structure of the

* Corresponding author.
E-mail address: huangxj12@mails.tsinghua.edu.cn (X.J. Huang).

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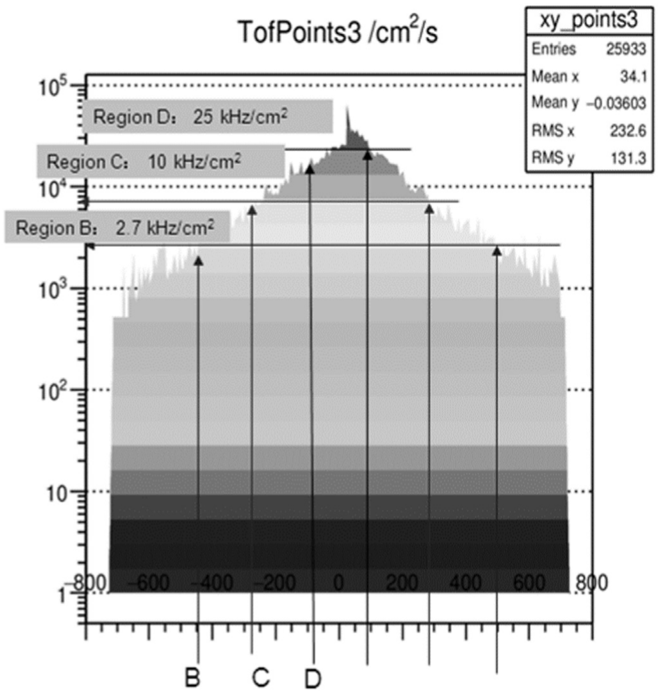

Fig. 1. Simulated particle flux rate on the TOF wall. The TOF wall is separated into four regions with similar flux.

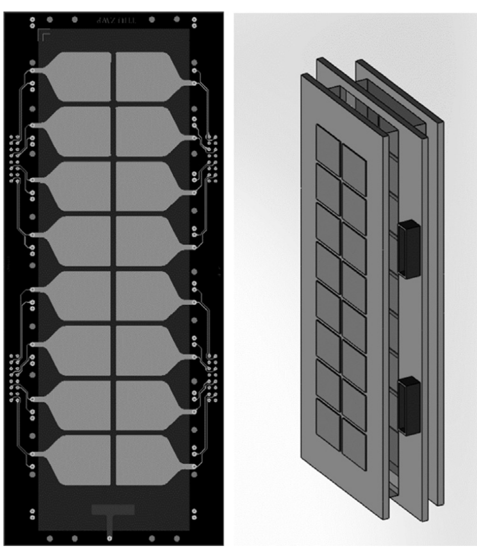

Fig. 2. A schematic structure of the pad readout MRPC.

module. Compared with the thin strip MRPC design for inner region of CBM-TOF, the pad-MRPC has advantages of requiring less electronic channels and supposed to have a smaller cluster size.

3. Detector performance and tests

The MRPC modules with same glass material and same gas gap width were tested at IHEP, March, 2013. The HV scan was taken under a low flux rate. And a timing resolution of 45 ps and a efficiency of 98% was obtained when the applied HV is higher than 5.8 kV [8]. An aging test which measured the performance of the prototypes using cosmic ray while irradiated by X-rays was also taken. No obvious performance degradation was observed after 0.1 C/cm^2 charge was accumulated [9]. The test results of a cosmic test and a beam test taken in the 2014 October GSI beam time will

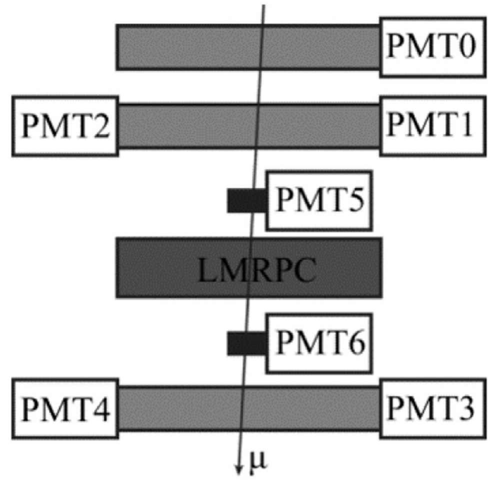

Fig. 3. A schematic view of a cosmic test system.

be presented in this section. A HV of 6 kV was applied and PADI electronics was used in the tests [10].

3.1. Cosmic test

A cosmic test system was set up in our lab at Tsinghua. Fig. 3 left gives a schematic view of the cosmic test system. Where PMT 0 acts as trigger, PMTs 1–4 provide the timing reference and PMT 5, PMT 6 provide the efficiency reference. Three pad-MRPC modules were test in this system. Fig. 4 shows the timing difference between tested module MRPC3 and PMT reference. Each bin represents 25 ps and the reference timing resolution is 63 ps. The MRPC3 timing resolution was thus $\sqrt{(3.577*25)^2 - 63^2} = 63.3$ ps. Table 1 summarizes the performance of the MRPC modules studied in the cosmic test.

3.2. Beam test

The pad-MRPC prototypes were tested in the 2014 October GSI beam time using the secondary particles from a ^{152}Sm beam hitting on a Pb target. Fig. 5 provides the layout of the beam test. The pad-MRPC modules and a thin strip MRPC module BucRef are the target detectors. The coincidence signal of the diamond detector and a target detector is used as the trigger of the DAQ system. And the two PMTs provide the flux rate measurement. A flux rate of

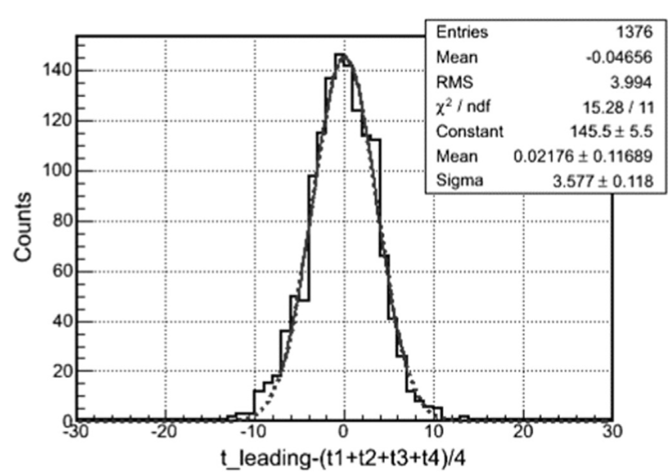

Fig. 4. The timing difference between tested module MRPC 4 and PMT timing reference. The curve is a Gaussian fit to the distribution to obtain the total MRPC+ref timing resolution.

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