

Cosmic-Ray Test and Temperature Effects of MRPC

YUE Qian¹⁾ LI Yuan-Jing CHENG Jian-Ping WANG Yi

LI Jin LAI Yong-Fang LI Qing-Hua TANG Le

(Department of Engineering Physics, Tsinghua University, Beijing 100084, China)

Abstract A cosmic-ray test system has been built for testing the performance of MRPC modules. Some methods have been studied to improve the time resolution of the cosmic-ray test based on this testing system. The time resolutions of about 84ps and 75ps can be achieved for MRPC and its reference time, respectively. The temperature effects of MRPC have also been researched and some useful results are obtained.

Key words cosmic-ray test, MRPC, time resolution, reference time

1 Introduction

Multi-gap Resistive Plate Chamber (MRPC)^[1-3] has been chosen to be the detector for the proposed TOF projection of RICH-STAR experiment due to its excellent time resolution and low cost^[4,5]. Large area detector can be realized by arraying many detector modules with a small size and this is also an important advantage for MRPC to be used as STAR TOF detector. More than twenty of MRPC modules from China have been assembled to run as a TOF tray on STAR detector and some primary and important physics results have been obtained based on the data from these detectors. According to the size of each module, thousands of this kind of MRPC modules should be produced for covering the whole STAR TOF detector space. It will be important to design a method to test all of these MRPC modules efficiently before assembling in a short time.

Cosmic-ray particles can be used as incident beam to make a rough test for these modules conveniently even through more precise measurement can be done by test beam from accelerator. So in this article we will describe such a cosmic-ray testing system that we have completed for this purpose^[6,7] and present some testing results.

2 Experimental setup

The cosmic-ray testing system^[8] is used to select cosmic-ray events and also provides reference time for timing measurement of each MRPC module. We built a cosmic-ray telescope system as trigger to choose the effective cosmic-ray event. The telescope system consists of three scintillation counters with five photo multiplier tubes (PMTs) coupled to three scintillators respectively as shown in Fig. 1. The types of these five PMTs are R7621 (Hamamatsu), XP2020 (Philips), XP2020 (Philips), R2083 (Hamamatsu) and R2083 (Hamamatsu) for PMT1 to PMT5 respectively. All the outputs from four (except PMT1) of these PMTs will be sent to the Time-Digital Converter (TDC, CAEN V775) as the start time of one cosmic-ray event. The coincident output of PMT1 and PMT5 will be used as the common STOP signal of TDC after delay and the gate signal of ADC. So we can use the average arriving time of these 4 PMTs as the reference time to decrease the time jitter of signal from single PMT, and this method can improve the precision of reference time for MRPC. The pre-amplifier of each signal channel of MRPC gives two outputs: one is sent to the Analog-Digital Converter (ADC, CAEN V265) for charge measurement and the other one passes through a low threshold discriminator to TDC for

time measurement. There are six channels for each MRPC module. The data acquisition is realized by VME bus system^[6, 7].

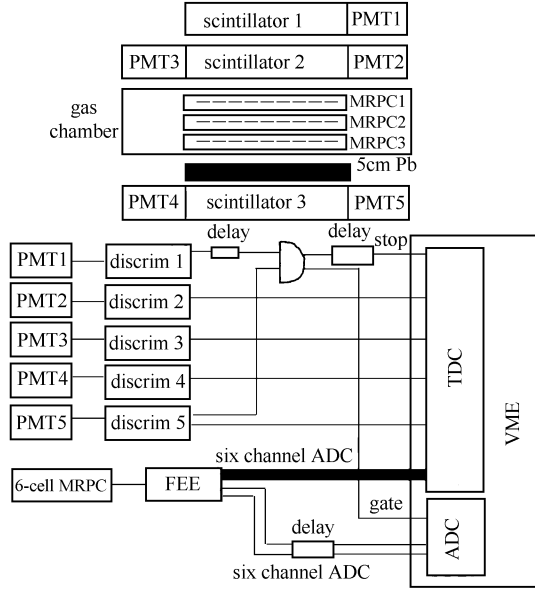


Fig.1. The schematic diagrams of the cosmic-ray test system and the electronics system.

3 Data taking and processing

Due to the small event rate for the cosmic-ray test system, it will take a long time to complete a good enough testing for one MRPC module. We have tried two kinds of testing methods for different goals.

(1) In order to do the rough measurement as fast as possible, three MRPC modules have been measured at the same time without 5cm thick lead brick to cut off the low energy cosmic-ray particles. Three MRPC modules work independently, i. e. data from anyone of the three MRPC can be processed just as the other two do not exist. This could make us to measure three or even more MRPC modules at the same time and this is just limited by the electronics channels of ADC and TDC. From this measurement, several such important parameters as the dark current, the noise of each MRPC channel and the efficiency of MRPC can be achieved and the time resolution of each MRPC channel can be obtained.

The data process procedure has been described in several articles^[8]. Four PMT time signals (i. e. PMT2 to PMT5) will be used as the reference time. So the time information of one signal from any MRPC channel can be corrected using the following equation:

$$t_{\text{mrpc}} = t - \frac{1}{4}(t_2 + t_3 + t_4 + t_5), \quad (1)$$

Where t is the measured time of any MRPC channel and $t_2 \cdots t_5$ is the measured times of PMT2 \cdots PMT5. t_{mrpc} is the time difference between the MRPC and the reference time, the time jitter was canceled by this way. The distribution of the reference time and the MRPC time from one channel are shown in Fig. 2 and Fig. 3. The resolutions of these two time distributions are 102.0ps and 148.5ps, respectively.

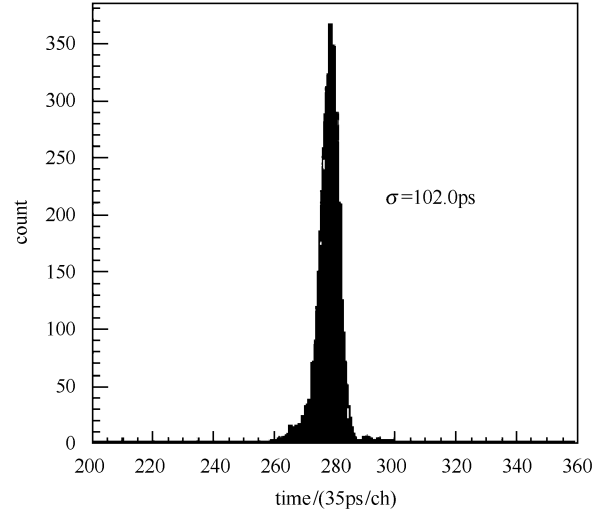


Fig.2. Reference time resolution $(t_2 + t_3 - t_4 - t_5)/4$ from 4 PMTs.

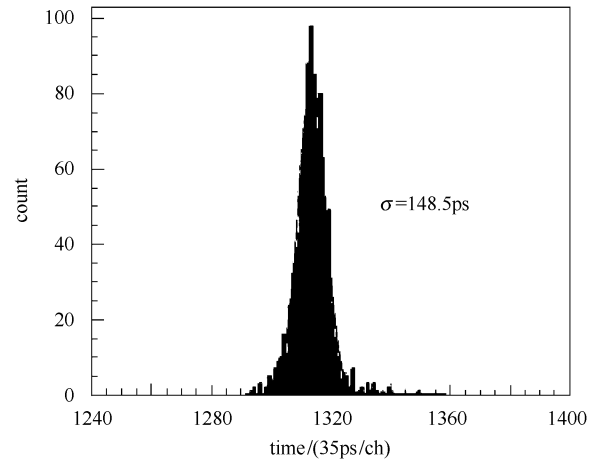


Fig.3. Time resolution of one MRPC channel.

(2) The time resolution of MRPC is not satisfactory very well for the STAR TOF requirement. This is not due to the intrinsic property of MRPC, but due to the test system. So, in order to improve the timing measurement of MRPC we tried to add the cosmic-ray direction selection and energy selection for choosing "good" cosmic-ray events. Several steps have been taken. A piece of 5cm-thick lead brick has been added to the "telescope" test system to select higher energy cosmic-ray particles (Fig. 1). Also, we can choose the correspond-

ing overlapping channels from these three MRPCs to make the cosmic-ray direction cut by software. For example, we can treat one event as a good one when this event has the effective output from all of the 3rd channels of three MRPCs, and so on. This will be cost little more time because of the lower efficiency of the whole detection system. Experimental data have been taken for offline analysis.

This data analysis procedure means to do the direction selection for cosmic-ray particles. Only the particles passing through all the scintillators and the same channel of all the MRPCs can be chosen as an effective event. After these selections, the reference time distribution and the time distribution from the same channel of MRPC as part (1) mentioned are shown in Fig. 4 and Fig. 5. The time resolutions are 74.6ps and 112.6ps respectively and the results are much better than that without these selections.

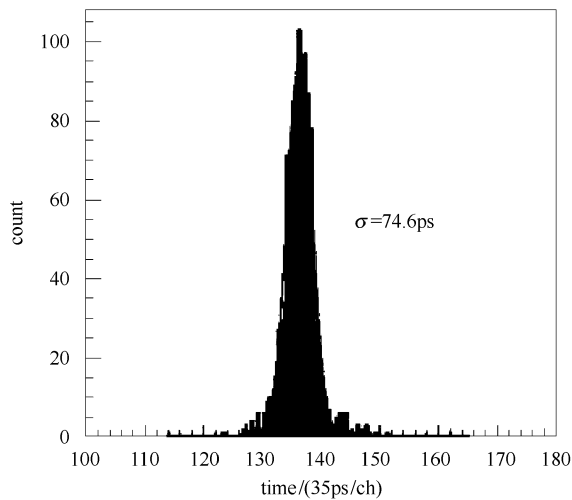


Fig.4. Reference time resolution of $(t_2 + t_3 - t_4 - t_5)/4$ after selections.

Due to the error transformation, part of the sigma of t_{mrpc} (112.6ps) comes from the reference time jitter whose resolution is 74.6ps. After subtracting this error, the time resolution for MRPC module is about 84ps.

4 Temperature effect

When MRPC modules are assembled onto the STAR detector, it will run in a complex environment. Because the amplifiers near MRPC modules heat the work gas of MRPC, it will be important to study the temperature effect of MRPC.

A big enough box was used as the gas chamber for MRPC in order to prevent the temperature of the MRPC from

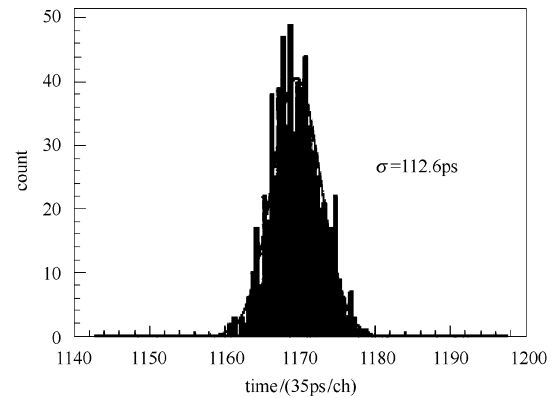


Fig.5. Time resolution of one MRPC channel after event selections.

being affected by continuous flowing of Freon and iso-butane gas mixture. The heating system can be controlled precisely to ensure the long-term temperature stability at a certain temperature point. So, the temperatures of MRPC and the work gas should be the same after a long time. Fig. 6 shows the noise change of three MRPC neighboring channels with its temperature. The result shows that the noises of MRPC channels increase almost exponentially. It means that our MRPC should work at a temperature-controllable environment and the temperature should be less than 35°C. Table 1 shows the time resolution of three MRPC channels at the temperature of 24°C, 32°C, 37°C respectively without the selection of direction and energy of the cosmic ray.

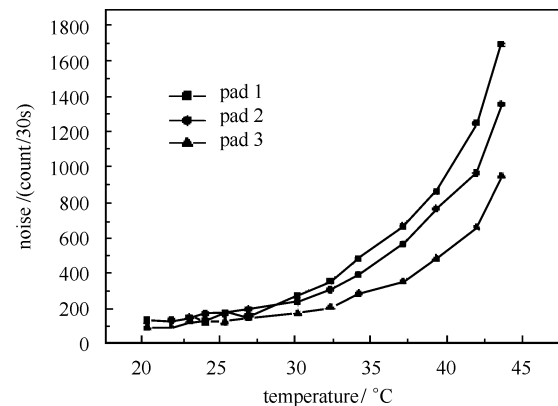


Fig.6. The relationship between noise and temperature for three different channels.

Table 1. The time resolution of three MRPC channels for different temperatures.

temperature	24°C	32°C	37°C
channel 1 (ps)	158.6 ± 22.5	164.9 ± 10.8	155.7 ± 8.7
channel 2 (ps)	147.4 ± 8.4	163.8 ± 8.6	190.7 ± 10.6
channel 3 (ps)	142.6 ± 8.4	158.8 ± 7.3	192.6 ± 8.4

From the results, we can see that the time resolutions of channel 2 and channel 3 become worse when temperature increases, and at the same time channel 1 does seem not to obey this conclusion. More researches are needed for this topic to be understood further.

5 Conclusion

MRPC has been chosen as the TOF detector of RICH-STAR experiment. Thousands of these detectors will be produced and tested before assembly. The cosmic-ray testing has been approved better enough to check the rough quality of MRPC modules. A cosmic-ray test system has been assembled for this kind of MRPC testing. Three scintillators have

been made into one telescope system for the timing of incident cosmic-ray particle and five PMTs for the decreasing of time jitter of the trigger signals. The direction selection of incident cosmic-ray particles is also possible in this testing system. Different methods have been studied to improve the measurement of time resolution that can be obtained by this testing system. The results show that the time resolution for MRPC is about 84ps when the reference time resolution is about 75ps. This is better enough to make the cosmic-ray testing for the quality control of MRPC modules. The environment temperature can affect the MRPC properties like noise and time resolution, so the temperature control for MRPC is necessary. Our experiment has given some hints for the temperature effect on the time resolution of MRPC modules.

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MRPC 宇宙线测试及温度效应

岳骞¹⁾ 李元景 程建平 王义 李金 来永芳 李清华 唐乐

(清华大学工程物理系 北京 100084)

摘要 建造了一套 MRPC 单元的宇宙线测试系统. 在数据处理过程中实现对入射宇宙线的方向选择. 实验结果表明:MRPC 的时间分辨可以达到约 84ps, 对应的触发系统参考时间分辨可以达到约 75ps. 对 MRPC 的温度特性进行了研究, 得到了一些初步结论.

关键词 宇宙线测试 MRPC 时间分辨 参考时间