Construction of LMRPC modules for STAR-MTD

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1 Introduction

Data taken over the last several years have demonstrated that the Relative Heavy Ion Collider (RHIC) has created dense and rapidly thermalizing matter [1].The next objective at RHIC is to study properties of this partonic matter in detail in terms of color degrees of freedom and the equation of state. The precise measurement of transverse momentum distributions of quarkonia at different centralities, collision systems, and energies will serve as a thermometer of QGP. A large-area and cost-effective Muon Telescope Detector (MTD) at mid-rapidity for the STAR was proposed. The MTD will be constructed with LMRPC instead of small pad read-out MRPC. With this design the number of electronic channels can be reduced effectively and the hit position along the strip can be obtained by the time differences of two ends of the strips. Fig.1 shows the STAR detector and Fig.2 shows that the MTD on STAR. It is evident from the simulations that protons are reduced by a much larger factor than pions and kaons. Shown in Fig. 3 is the combined acceptance and efficiency for primary muons, pions, kaons and protons. It indicates that the MTD can detect muons of $pT \geq 2$ GeV/c at a level of 45% while less than 1% of the overall hadrons are accepted taking into account the relative yields of pions, kaons, and protons. This illustrates that the MTD detector can reject hadrons effectively. A rejection factor of 50-100 can be obtained based on the simulations shown in Fig. 3 while maintaining an efficient trigger (*>80%)* for prompt muons*.* MTD also allows an effective cut for rejecting the backgrounds for the dimuon candidates. To achieve the phyiscs goal, it is required that the MTD has good time resolution (less than 100ps), good spatial resolution and low noise (less than 100K). The MTD consists of 120 LMRPCs and all of modules will be constructed in Tsinghua University, University of Science and Technology of China and Variable Energy Cyclotron Centre in India.

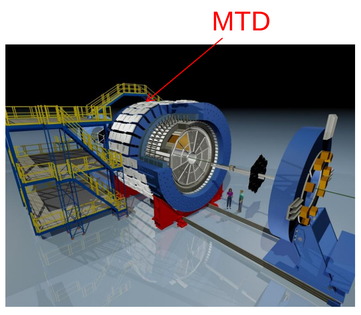

Fig.1 STAR detector

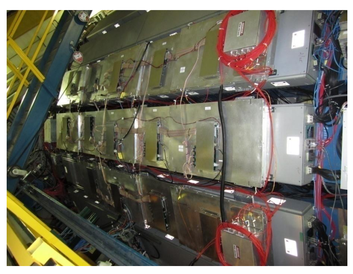

Fig.2 MTD on STAR

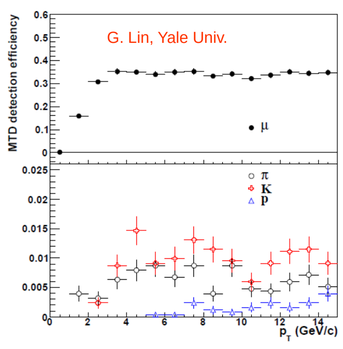

Fig.3 MTD efficiency to muon, pion and hadrons

2 LMRPC prototype design

Different from the conventional muon detector, STAR-MTD is a novel detector utilizing the new Time-of-Flight (TOF) system with precise timing and hit position. The MTD covers more than 50% in azimuth and $|\eta| < 0.8$ in pseudorapidity, behind the return iron bars for the STAR magnetic..The STAR-MTD will be constructed with long strip multi-gap resistive plate chamber (LMRPC). The first prototypes [2,3] were developed in 2007. They have been running 3 years in STAR and many important results were obtained [4,5]. In 2011, two new MTD prototypes with wider strips and fewer gaps were developed. The two prototypes have nearly the same structure but only the number of gas-gap is different. One prototype has 6 gas-gaps and the other only 5 gaps. Fig.4-6 show the picture and the structure of the prototype.

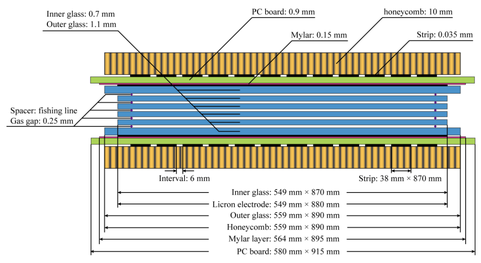

Fig.4 Structure of the LMRPC prototype

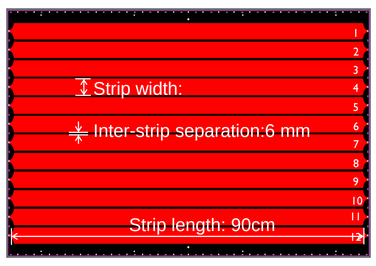

Fig.5 Structure of the readout strips

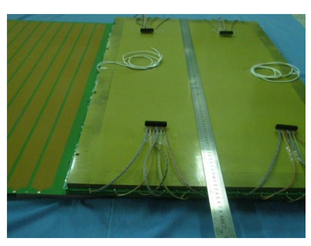

Fig.6 Picture of the LMRPC prototype

The prototype is both much larger than those MRPCs in STAR-TOF system [6] and the read-out is double-ended. It has an active area 52×87 cm2 and the signals are read out from 12 strips, which are 3.8cm wide and 87cm long with intervals of 0.6cm. There are five gas gaps of about 0.25mm defined by nylon fishing-line of this diameter. The inner and outer floating glass plates are 0.7mm and 1.1mm thick separately. The volume resistivity of the glass plates is about 10^{12}-$10^{13}\Omega$·cm. The electrodes are made of colloidal graphite with a surface resistivity of ~5MOhm/square which covers the entire active area. We use a nonflammable gas mixture which contains 95% tetra-fluoro-ethane and 5% iso-butane. When a charged particle goes through the chamber the avalanche generates in the gas gaps. The induced signal on the strips is the average of possible avalanches from all gas gaps.Fig.7 shows the raw signal of the LMRPC, the high voltage is ±6.3kV. It can be seen the amplitude is about 5mV and its rising time is less than 1ns. It is smaller than the raw signal of STAR-TOF MRPC module.

Fig.7 Raw signal of LMRPC

Fig.8 Layout of the cosmic ray test system

3 Cosmic test results

Fig.8 shows the layout of the cosmic ray test system. The cosmic-ray test system used for the tests of the STAR-MTD LMRPC prototypes is similar to the one used for the tests of the STAR-TOF MRPC prototypes, which is shown in Fig. 8. Three 20 cm × 5 cm × 5 cm scintillators and two 4 cm × 2 cm × 1 cm scintillators were used to trigger on cosmic rays. Two of the larger scintillators and one of the smaller scintillators are above the module, and the rest are below the module. PMT0 through PMT4 were used for basic coincidence triggering and to provide the reference time. The two small scintillators are used to measure the efficiency of the module – the width of the area subtended by the small scintillators is smaller than the width of an LMRPC strip. The 5-gap STAR-MTD LMRPC prototype was tested in the cosmic-ray test system with a working gas mixture consisting of 95% Freon and 5% iso-Butane. The efficiency and time resolution versus the electric field in the gas gap, E, is shown in the left of Fig. 9. The electric field, E, is equal to the applied high voltage (total voltage drop between HV anode and cathode) divided by the total thickness of the gas gaps (5 × 0.025cm). The efficiency of the module reached 98% and the time resolution was around 70 ps. We also measured the noiseof all the strips at the standard working point (HV = ±6.3 kV, E = 100.8 kV/cm), which is shown in the right of Fig. 10. The noise are all less than 0.3Hz/cm^2.

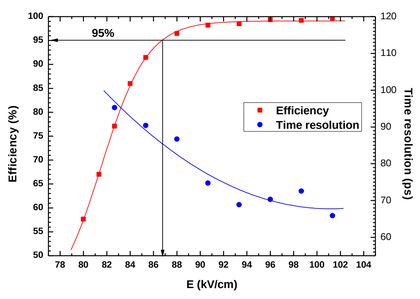

Fig.9 Efficiency and time resolution change with HV

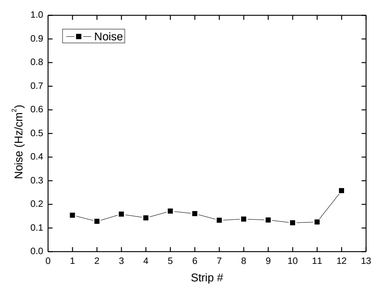

Fig.10 Noise of each strip of one module

4 LMRPC mass production

The QC criterions of acceptance for the STAR-MTD LMRPC modules are shown as follows:
1) The efficiency of the module should be better than 90%.
2) The module should not have more than 1 strip which has a time resolution worse than 120ps.
3) The noise of each channel should be less than 1 Hz/cm^2.
The milestone s of LMRPC production is shown in Fig.11. All of modules will be produced in two years. MRPC assembling was carried out in clean room. The temperature and moisture of the clean room can be controlled and its cleanness reaches 100K degree. The temperature is 22±5ºC and the moisture is kept less than 40%. Fig.12 and 13 show the technicians were assembling and packing LMRPC modules . 52 LMRPC has been assembled in Tsinghua. Fig.14- 16 show time resolution, streamer ratio and noise of 52 LMRPC modules. It can be seen that theses modules meet the requirement. The production goes smoothly and will be finished by the end of this year.

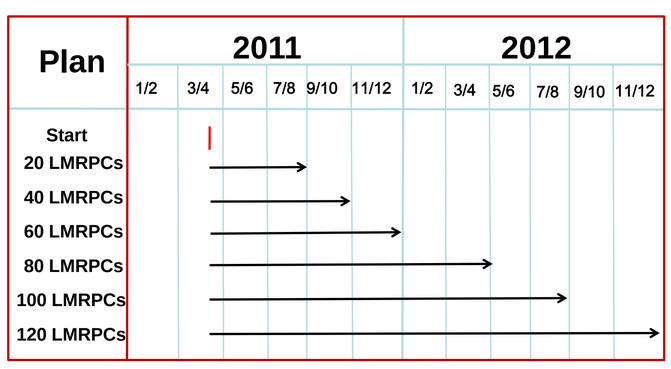

Fig.11 Milestone s of LMRPC production

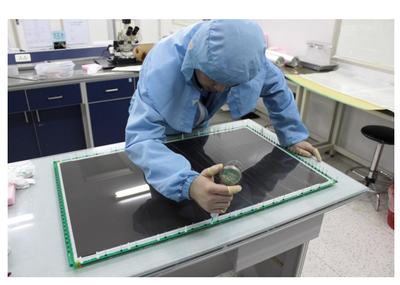

Fig.12 Technicians are assembling modules

Fig.13 Technicians are packing modules

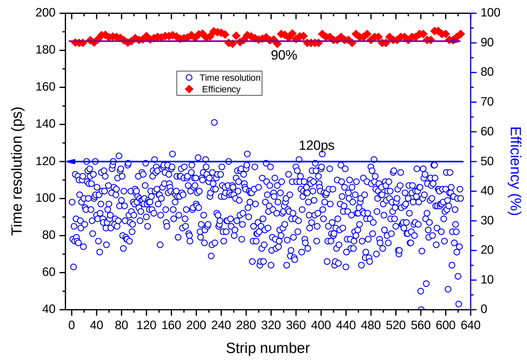

Fig.14 Time resolution of 52 modules, average is 96ps

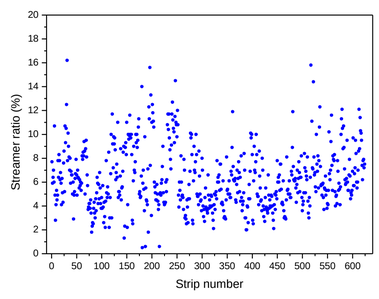

Fig.15 Streamer ratio of 52 modules, average is 6.3%

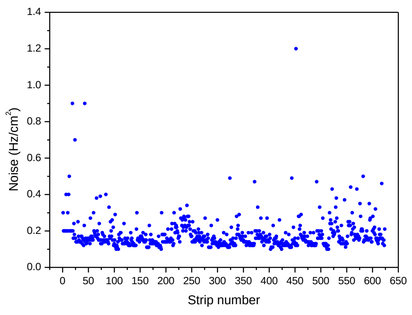

Fig.16 Noise of 52 modules, average is 0.18Hz/cm^2

5 Conclusions

STAR-MTD is an important upgrade for STAR experiment. It will provide excellent muon trigger and identification capabilities at mid-rapidity in the high-luminosity. The MTD will directly address many of the open questions and long-term goals during the RHIC II era by advancing our knowledge of Quark Gluon Plasma (QGP) properties and it also provides a promising device for future quarkonia studies and primordial dilepton measurements at RHIC. The MTD was constructed with 120 LMRPC detectors.The 5-gap STAR-MTD LMRPC module has efficiency up to 98% and the time resolution is in the range of 70 ps. The noise level of such modules is quite low. The production goes smoothly in Tsinghua. 52 LMRPC modules have been built and they all have passed QC. In the next few months, 120 LMRPC modules in total will be produced.

6 Reference

[1] J. Adams et al., Nucl. Phys. A 757, 102 (2005).
[2] Y. Sun et al., Nucl. Instr. and Meth. A 593, 307 (2008).
[3] Xiaobin Wang., Chinese Physics C, 2009,33(2):114-118
[4] L Ruan et al., J. Phys. G: Nucl. Part. Phys. 36 (2009) 095001
[5] L Ruan et al., STAR Muon Telescope Detector Proposal:
[6] Y. Wang et al., Nucl. Instr. and Meth. A 613(2010) 200.

Acknowledges

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