MRPC detector for the upgrade of BESIII E-TOF

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Published 15 May 2014

An end-cap Time-of-Flight (E-TOF) system with higher granularity and intrinsic time resolution of better than 50 ps will extend the K/pion separation (2 sigma) pT range to 1.4 GeV/c and enhance the physics capability of Beijing Spectrometer (BESIII). A R&D work was carried out aiming at upgrading the current BESIII E-TOF with the Multi-gap resistive Plate Chamber (MRPC) detector. The latest best test for the prototype MRPC, together with the custom designed Front End Electronics (FEE) and TDC boards, was performed at the BEPC E3 line in July 2012. The test results show that time resolution of less than 50 ps can be achieved with such a system.

Keywords: Multi-gap resistive plate chamber; BESIII; End-cap TOF.

1. Introduction

The MRPC detector is a good candidate for large area TOF system with very good time resolution, high efficiency and relatively low cost per channel.^{1,2} It has been widely used as TOF detector in many experiments, such as LHC/ALICE,³ RHIC/STAR.⁴ The BESIII⁵ is a high precision general-purpose detector designed for the high luminosity in the τ -charm energy region at the upgraded Beijing Electron-Positron Collider (BEPCII).⁶ A MRPC-based TOF with 50 ps intrinsic time resolution is estimated to extend the BESIII K/ π separation (2σ) momentum range to 1.4 GeV/c at BESIII end-cap. A proposal was raised to upgrade the current BESIII ETOF with the MRPC technology and readout electronics, aiming at the 50 ps time resolution.

2. Design

In the conceptual design, each BESIII end-cap ring will be fully covered by 36 trapezium MRPC modules, as shown in Fig. 1. The MRPC module to be used on

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Fig. 1. The schematic of BESIII MRPC/ETOF.

Fig. 2. Left: The side-view of the MRPC structure. Right: the readout pattern.

Fig. 3. The setup at BEPC E3 line.

BESIII E-TOF has 12 gas gaps of 0.22 mm thick, arranged in two stacks. Thin floating glass with bulk resistivity $\sim 10^{13} \Omega/\square$ is used as the resistive plate. The signals are picked up by 12 strips with different length and read out from both ends of each strip. The structure of the MRPC is plotted in Fig. 2.

3. Test

The test was performed at BEPC E3 line. The setup of the test is shown in Fig. 3. There MRPC detectors are arranged along the beam line close to each other. The FEE board is custom designed with NINO ASIC chips. The time jitter of the FEE is tested ~ 10 ps. The custom designed far-end electronics is based on HPTDC chips with Leading- and Trailing-edge recording capability. Thus, the TOT (Time-Over-Threshold) of the signal can be used for the slewing correction instead of the traditional T-A correction. The secondary beam contains pions and protons. They can be distinguished clearly by the flight time between scintillators S1 and S2, as shown in Fig. 4.

Fig. 4. The PID with TOF between S1 and S2.

Fig. 5. The slewing correction and the time spectrum.

The MRPC was first tested with pion samples around 600 MeV which can be considered as MIPs. The slewing correction was made with T-TOT correlation. For each MRPC, the other two modules can be used as reference time (T0). Correcting the time circularly until stable correction relation achieved, the time resolution of each MRPC can be solved. Figure 5 shows the slewing correction and the time spectrum before and after the correction.

The performance of the MRPC is also analyzed with proton samples which is the main contents of the beam. Since proton at such momentum is not MIP, the time resolution is much better, as summarized in Table 1.

Table 1. The time resolution achieved with pion and proton samples at different momentum.

Momentum		500 MeV	600 MeV	800 MeV
Pion sample	MRPC #1	56 PS	47 PS	45 PS
	MRPC #2	51 PS	48 PS	40 PS
	MRPC #3	46 PS	48 PS	45 PS
Proton sample	MRPC #1	29 PS	32 PS	36 PS
	MRPC #2	28 PS	30 PS	35 PS
	MRPC #3	31 PS	31 PS	35 PS

Table 2. The time resolution on different incident positions along a selected strip.

MRPC #2 @600MeV		Strip center → Strip end				
Pion		48 PS		49 PS	49 PS	47 PS
Proton	29 PS	27 PS	26 PS	29 PS	31 PS	36 PS

Table 3. The time resolution under different applied High Voltage.

@600 MeV	±7250 V	±7300 V	±7500 V
Pion	48 PS	48 PS	46 PS
Proton	30 PS	29 PS	30 PS

The performance uniformity along the strip is checked by moving one of the MRPC modules along the strip direction. As shown in Table 2, no position dependence is found. Table 3 shows the time resolution under different applied High Voltage, which indicates the stable performance profited from the long plateau of MRPC.

4. Summary

We successfully design, built and test the MRPC prototype with 12 gas gap structure and double-end readout strips for BESIII ETOF. The proposed performance has been achieved. The time resolution including the custom designed electronics is ~50 ps for MIPs. The detector shows stable performance at different position and working HV. The systematic construction project has been approved and will start soon.

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