First results of the new endcap TOF commissioning at BESIII postprint

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Abstract

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Full Text

First Results of the New Endcap TOF Commissioning at BESIII

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Abstract: The upgrade of the current BESIII Endcap TOF (ETOF) has been carried out using Multi-gap Resistive Plate Chamber (MRPC) technology. The installation of the new ETOF was completed in October 2015. This paper reports the first results of the MRPC commissioning at BESIII.

Keywords: BESIII, Endcap TOF, MRPC, Collision results
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1. Introduction

The BESIII experiment [?] studies e+e− collisions in the -charm energy region at the Beijing Electron and Positron Collider II (BEPCII) [?]. Particle identification is a fundamental tool in data analysis, as it helps disentangle specific processes within high-multiplicity events. The original ETOF system [?], which primarily identified pions and kaons, consisted of two disks with 48 plastic scintillating counters covering the polar angle region 0.83<|cos |<0.96, as shown in [Figure 1: see original paper]. Each counter comprised fast scintillator blocks (BC204) read out by fine-mesh photomultiplier tubes (Hamamatsu R5924). The time resolution measured by the ETOF detector was 138 ps for pions [?], which cannot fully satisfy the higher precision requirements of physics analyses. Two main factors contribute to the relatively poor ETOF time resolution: multiple scattering of particles in the thick aluminum endcaps of the main drift chamber [?], and uncertainties in the particle impact positions on the scintillators.

The multi-gap resistive plate chamber (MRPC) [?] is a new type of gaseous detector featuring excellent time resolution, high detection efficiency, and relatively low cost. It has been successfully employed as a TOF detector in several experiments, including ALICE at the LHC [?][?] and STAR at RHIC [?][?]. From 2011 to 2013, an R&D program was conducted to develop prototype MRPCs for the BESIII ETOF upgrade. Test beam results demonstrated a time resolution better than 50 ps for 800 MeV pions, verifying the physics design [?][?]. The segmentation of the MRPC can also be made sufficiently fine to effectively suppress multi-hit events at BESIII, as discussed in Ref. [?]. In 2012, the decision was approved to replace the existing BESIII ETOF with MRPCs.

2. New ETOF Detector

The new ETOF detector comprises 72 modules, with 36 modules on each end, as shown in [Figure 2: see original paper] (left). Adjacent modules are staggered to avoid dead regions. The effective areas of the MRPC rings have an inner radius of 501 mm and an outer radius of 822 mm. Each MRPC is divided into 12 strips with readout from both ends, representing a twelvefold increase in readout granularity compared to the original ETOF, where each plastic scintillator module was read out by only one PMT from the inner end. The readout strip lengths in each MRPC module range from 9.1 cm to 14.1 cm, with a width of 2.4 cm and a separation of 3 mm, as illustrated in [Figure 2: see original paper] (right).

The gas system consists of 36 independent lines, 18 per end, with each line serving two modules in series. The gas mixture of Freon:SF6:C4H10 (90:5:5) is used and controlled by the MKS 2179A&247D system. The high-voltage system contains nine pairs of positive and negative channels, with each pair split to supply four modules and controlled by the BESIII slow control system.

3. Readout Electronics and Online DAQ System

The MRPC readout electronics system consists of front-end electronics (FEE) boards, Calibration-Threshold-Test-Power (CTTP) boards in NIM crates, Time-to-Digital (TDIG) converter modules, fast control modules, and CLOCK modules in VME crates that operate in pipeline mode with a clock frequency of approximately 40 MHz.

Each MRPC is matched to one FEE module with twenty-four channels based on NINO [**?**], which features time-over-threshold (TOT) measurement. The timing accuracy is better than 15 ps RMS for each channel when the input charge exceeds 100 fC [**?**]. The FEE boards, along with connectors and cables, are mounted on the surfaces of the aluminum boxes of the MRPC modules. Connectors (50-pin QSS-025-01-l-D-RA-MTI) and shielded differential cables (SQCD-025) are used to connect the FEE and TDIG [**?**]. The CTTP board, housed in a NIM crate, provides power, threshold, and test signals for the FEE, and also receives and transmits the OR differential signals from the FEE to the ETOF trigger subsystem.

The FEE signals are fed into TDIG modules, each of which utilizes high-performance TDCs [**?**] for precise time measurements. The L1 trigger is sent via the fast control module to the TDIGs. The CLOCK module receives the synchronized clock from the master and fans out 18 clocks to feed modules within the same VME crate.

The BESIII data acquisition system employs multi-level buffering, parallel processing, high-speed VME readout, and network transmission techniques. Additionally, the running status—including event rate, noise level, time spectra, and hitmaps—is monitored by a computer program to provide real-time information for the entire system. A data quality monitoring system [**?**] has been developed based on offline software to monitor data quality in real time. It can reconstruct a fraction of the acquired data sampled randomly from the online data flow, making detector performance available within a few minutes after a physics run begins.

4. First Results with Collision Data

The installation process lasted approximately two months, from August 1st to October 7th, 2015. The new ETOF has been commissioned together with BESIII since January 2016. Physics data-taking commenced after debugging of the ETOF trigger subsystem. The preliminary results are described and discussed in the following sections, with Bhabha events used for calibration.

4.1 Raw Time Distribution

As shown in [Figure 3: see original paper], a typical time distribution demonstrates that the MRPCs and electronics are functioning properly. The time window is set to 1600 ns, the same as that used for the barrel TOF. The hits in the region before the leading edge of the peak at approximately 600 ns can reflect the noise level, which will be quantified in the following section.

4.2 Noise Rate Measurements

The single-channel rate is estimated using standalone files with a random clock trigger set at a rate of 60 Hz during normal data-taking. Since the TDIG has multi-hit capability, the number of hits in each readout channel is counted at each event and divided by the TDIG time window. At the nominal threshold value of 150 mV, the noise background distribution is shown in [Figure 5: see original paper], yielding an average rate of 9.0 Hz/cm^2.

4.3 Event Start Time (EST) Distribution

The trigger cycle is 24 ns, which equals the duration of 3 or 4 bunches. The TDC from ETOF measures the time interval from the trigger start time to the arrival time of the MRPC signal. This time may differ from the interval between the collision time and the signal time in the detector. The interval between the trigger time and the collision time is called EST, calculated only by offline data analysis [?]. The BTOF or ETOF is the best choice for calculating EST, since it is near the tracker system and has the highest time measurement precision. The EST distribution calculated by ETOF is shown in [Figure 5: see original paper].

4.4 Time Resolution

Time calibration is carried out by comparing the measured time t_meas against the predicted time t_pred. The measured time t_meas is obtained from the TDC subtracting EST, electronics offset, and correction time caused by time-amplitude correlation effects. The predicted time t_pred is calculated by the tracker system using the Kalman Filter method. Time resolutions of 69 ps for one-end ([Figure 6: see original paper] left) and 60 ps for two-ends ([Figure 6: see original paper] right) are determined by fitting the t_meas - t_pred distribution with a Gaussian function. [Figure 7: see original paper] shows the time resolutions for one-end and two-ends of MRPCs versus strip. The one-end resolution represents the result from either the left or right channel in one strip, while the two-ends resolution represents the combined result from both left and right channels in one strip.

4.5 Detection Efficiency

The detection efficiency is determined by the ratio of hits in one end or strip to the number of tracks passing through the strip. As shown in [Figure 8: see original paper], the average efficiency for two-ends is approximately 97.5%, which satisfies the design requirement of >96%.

5. Conclusions

During the commissioning of the new ETOF, all hardware has maintained stable operation. The noise rate has been measured to be 9.0 Hz/cm², reflecting a low noise level. After calibration with Bhabha events, very promising time resolutions of 69 ps and 60 ps have been obtained for one-end and two-ends of MRPCs, respectively. The average detection efficiency for two-ends is approximately 97.5%. These preliminary results indicate that the BESIII ETOF upgrade has been successful.

Acknowledgments

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Note: Figure translations are in progress. See original paper for figures.