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R. Sultanov,[a] A. Akindinov,[a] R. Beyer,[b] J. Dreyer,[b] X. Fan,[b] R. Greifenhagen,[b] B. Kämpfer,[b] R. Kotte,[b] A. Laso Garcia,[b] D. Malkevich,[a] L. Naumann,[b,1] V. Plotnikov,[a] M. Prokudin,[a] S. Shirinkin,[a] and D. Stach.[b] on behalf of CBM-TOF collaboration

[a] *Institute for Theoretical and Experimental Physics, Moscow, Russia*
[b] *Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany*

E-mail: L.Naumann@hzdr.de

Abstract: For precise start time determination a Beam Fragmentation T_0 Counter (BFTC) is under development for the Time-of-Flight Wall of the Compressed Baryonic Matter Spectrometer (CBM) at FAIR/Darmstadt. This detector will be located around the beam pipe, covering the front area of the Projectile Spectator Detector. The fluxes at this region are expected to exceed $10^5 \text{cm}^{-2}\text{s}^{-1}$. Ceramic RPCs could be use because of their high rate capabilities and radiation hardness of material. Efficiency $\geq 97\,\%$, time resolution $\leq 90\,\text{ps}$ and rate capability $\geq 10^5 \text{cm}^{-2}\text{s}^{-1}$ were confirmed during many tests with high beam fluxes of relativistic electrons. We confirm the stability of these characteristics with low resistive Si_3N_4/SiC floating electrodes for a prototype of eight small RPCs, where each of them contains six gas gaps. The active RPC size amounts $20{\times}20\,\text{mm}^2$ produced on basis of Al_3O_2 and Si_3N_4/SiC ceramics. Recent test results obtained with relativistic electrons at the linear accelerator ELBE of the Helmholtz-Zentrum Dresden-Rossendorf with new PADI-10 Front-end electronic will be presented.

Keywords: RPC, ceramic composite electrodes, high rate capability, signal cross-talk

[1] Corresponding author.

Contents

1 Introduction

Within the framework of the Facility for Antiproton and Ion Research (FAIR), which is currently under construction at Darmstadt/Germany, a determined effort is being made to implement the CBM spectrometer [1]. Important prerequisites of high energy heavy ion experiments are the start-time and the reaction-plane determination. For the CBM Time-of-Flight Wall at FAIR the use of resistive plate chambers (RPC) for the BFTC with low resistive radiation hard ceramics electrodes and small chess-board like single cells is under consideration [2]. This detector should cover the inner solid angle range of the spectrometer with an area of about $120{\times}120\,\mathrm{cm}^2$ in front of the Projectile Spectator Detector. It is planned to arrange approximately 4000 RPC cells of $20{\times}20\,\mathrm{mm}^2$ size around the beam tube with a central hole of $40{\times}40\,\mathrm{cm}^2$ to detect the arrival time and the position of the charged relativistic beam fragments and hence, to determine the reaction time and reaction plane of an event. Due to the expected high fluxes, the detector is fixed in terms of both efficiency and time resolution. The small size of the detector cells is mandatory to minimize the occupancy in a single cell guaranteeing a double hit probability of less than 2 % [3]. Also the crosstalk between adjacent detector cells should not exceed 2 %. Tests with the BFTC-minimodule of 8 RPC cells have been performed with high fluxes of electrons at the ELBE accelerator during two beam-times in 2017 in order to adopt the BFTC-prototype construction and signal readout scheme for operation with the PADI ASIC [4].

2 Instrumentation

The BFTC-minimodule represents a gas volume with a support structure for 8 RPCs inside, which consists of a plastic (POM) frame with assembled RPCs on it. Each quadratic RPC with 6 gas gaps of $250\,\mu$m consists of a stack of three separate counter cells. The central electrodes at floating potential are made of low resistive Si_3N_4/SiC ceramic composite, while all anodes and cathodes are metallic electrodes on a high resistive Al_2O_3 backing. To reduce the dark current of the detector, all electrode edges are grooved with Rogowski shapes [5]. The RPCs are fixed on a PCB board inside the detector box which serves the following functions: high voltage distribution for all 8 RPCs from a single input and primary readout and converting the RPC signal from single ended to differential mode (100 Ω) for signal transmission to the PADI-10. The signal amplification amounts to 1.5 and shaping of the signal is performed in the readout scheme, so a typical output pulse has no overshoot and its length amounts to 5.5 ns at the base level. This ensures a readout without pileup at high counting rates, expected at the BFTC region [3]. The current design of the board assures that the high voltage lines are placed in the inner layer of the PCB, to minimizes the cross-talks via the HV line. The board with the upper cover of the gas tight box and with assembled RPCs is shown in figure 1.

Figure 1. Top - The PCB readout board with HV distribution (HV capacitors) and preamplifier/shaper circuits fixed on the upper cover of the detector box; Bottom - RPCs of the prototype inside the box. On the photo four RPCs (white quadrat with black belt) are seen.

The detector was tested with a high flux of single relativistic electrons of energy ≥ 30 MeV with a dedicated test facility at ELBE [6–8]. As readout electronics for the RPC signals PADI (versions 6 and 10 at first and second beam-time, correspondingly), ASIC and VFTX TDC were used, while a CAEN TDC was used for the trigger scintillators. A trigger logic was realized in CAEN FPGA module V1495. Since the VFTX TDCs were working with external clock, the accelerator RF signal was fed into the second VFTX TDC.

3 Results

The arrival time of the RPC signal is determined as difference between leading edge of the RPC signal and the reference signal. Characteristic time spectra for the leading and trailing edge distributions and for the amplitude dependend Time-over-Threshold (ToT) behavior are shown in figure 2 for the RPC cell # 4 at 92 kV/cm. The leading edge distribution shows a steep rise and the trailing edge distribution a steep fall of the time signal, while the ToT spectra exhibits a double peak structure. The correlation between ToT and timing allows a the walk correction of the timing distribution. The optimal value of the signal amplitude threshold at the PADI ASIC input was determined by a noise scan and amounts 180 mV.

The detector efficiency in dependence on the high voltage studied with the PADI-10 FEE is shown in figure 3 and compared with former measurements. One can see that both setups with PADI read-out do not exhibit a working plateau, reaching at maximum 89 % registration efficiency. In previous measurements with MAXIM3760 preamplifiers a wider efficiency plateau with a maximum value of 97 % has been obtained.

For cross-talk probability determination the BFTC-minimodule cells were placed one-by-one in the beam center with a narrow trigger while the signals were read out from all eight RPC cells. A maximum cross-talk probability of 1.2 % has been obtained for all other seven channels. This measurement is affected by the fact, that the beam diameter of 5 cm (FWHM) is larger than the cell size of 2 cm. Thus, there is a chance that a soft electron, after series of rescatterings, hits both neighboring channels and still passes the trigger condition. A typical time resolution of the RPC as function of the applied electric field is shown in figure 4. After calibration of the VFTX TDC the RPC time was corrected for time-walk effect and fitted with a Gaussian. The start time resolution of 80 ps and electronic jitter of 90 ps the RF signal used as reference were quadratically subtracted from the width of the Gaussian fit.

4 Conclusion

The BFTC-minimodule of the current design of the inner board demonstrated a stable operation together with the PADI-10 preamplifier: no excitation of the readout chain or refracted signals in the RPCs time spectra's were observed, the ToT spectra indiscrete with proper shape and, the cross-talk probability is very low. This means that the design can be fixed and used for future modules, as well as for the (already started) development of the module-prototype of size 20×20 cm^2 for a test run with heavy ion beam at the upgraded SIS18 at GSI/FAIR. The most probable reason for the low registration efficiency is related to the short signals which are not correctly processed by the VFTX TDC. To check whether this is the case, an external signal stretcher and other preamplifiers will be tested under high rates as well as with cosmic rays.

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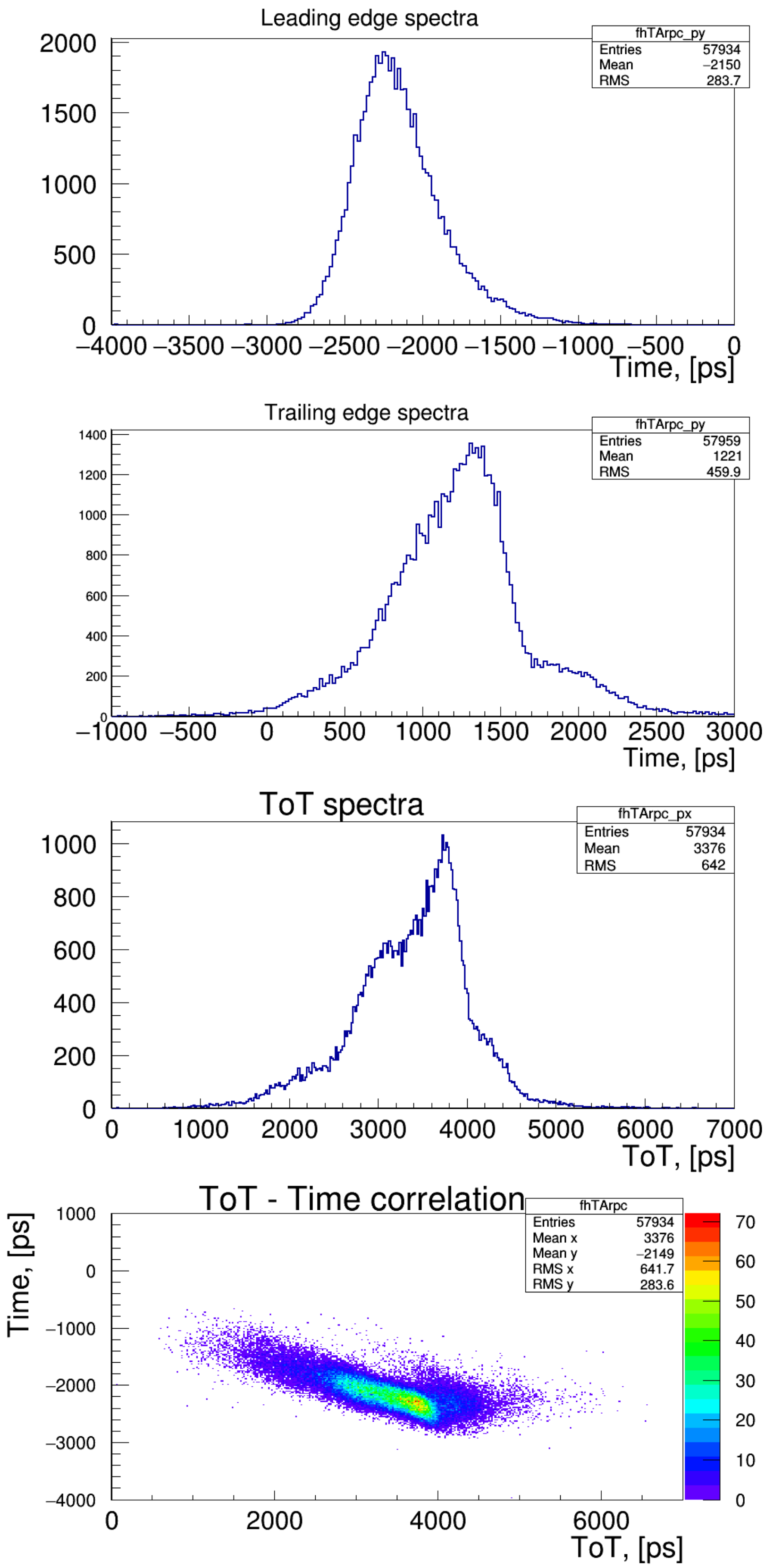

Figure 2. Spectra from top to bottom: leading edge distribution, trailing edge distribution, Time-over-Threshold (ToT) distribution, ToT-to-time correlation.

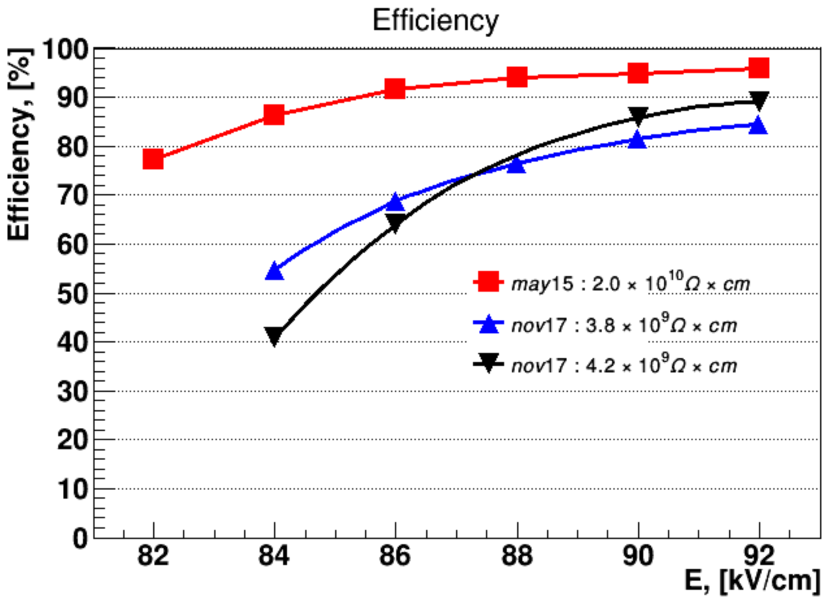

Figure 3. RPC efficiency as function of the field strength for three RPC detectors performed with two readout systems: squares - MAXIM3760+CAEN TDC, triangles - PADI-10. The corresponding bulk resistivities of the ceramic plates on floating potential are given in the legend.

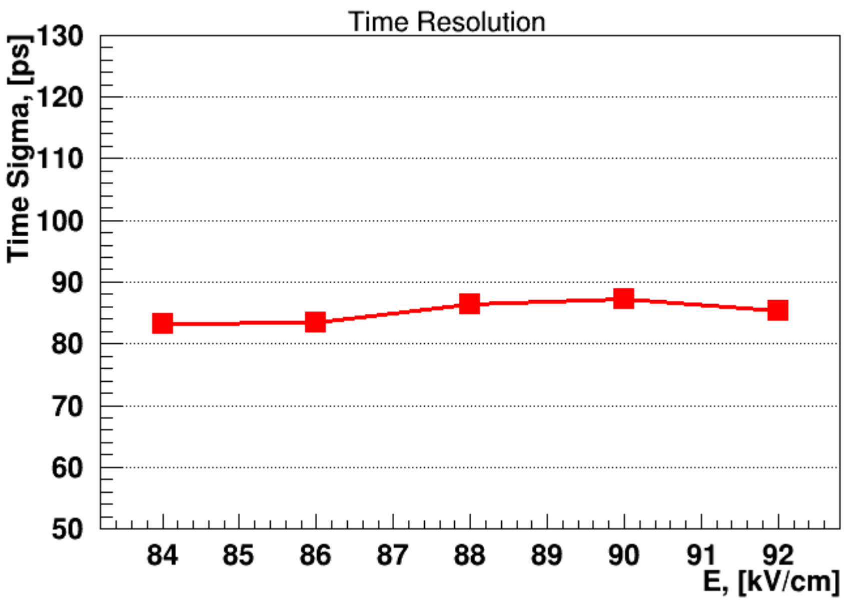

Figure 4. Time resolution of cell # 3 (bulk resistivity $3.8{\cdot}10^9\Omega\cdot$ cm) as function of the applied electric field.