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CONTROL AND READOUT ELECTRONICS OF THE TIME-OF-FLIGHT SYSTEM OF THE MPD

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This paper devotes to the control and readout electronics for the time-of-flight (TOF) system of the Multi Purpose Detector (MPD). The TOF system is based on Multigap Resistive Plate Chambers (MRPC) with a long strip readout. The readout electronics uses the NINO ASIC. The board with preamplifier has the control block, which functionals are monitor voltage, thresholds, electronics temperature and gas temperature. The examples of methodological studies of RPC are presented. The electronics of a cosmic rays stand for research and mass testing of detectors for the MPD experiment at the NICA collider is described.

Keywords: MRPC, Time of Flight, NINO, MPD, NICA

1. Introduction

The Multi Purpose Detector (MPD) facility [1] is proposed for studying barionic matter in its hot and dense state on the planning at the Nuclotron-based Ion Collider fAcility (NICA) [2]. The MPD consists of a barrel part and two endcaps located inside the magnetic field. The barrel part is a shell-like set of various detector systems surrounding the interaction point and aimed at reconstruct ions and identifying both charged and neutral particles in the pseudorapidity region of $|\eta| \leq 1.3$.

The Time of Flight system (TOF) of MPD is one of the elements for particle identification. The TOF has to provide time resolution better than 100 ps. As a detector of TOF system is selected Multigap Resistive Plate Chambers (MRPC) with a long strip readout [3]. The MRPC consists of a stack of resistive plates separated one from the other with equal size spacers creating a series of gas gaps [4]. Float glass plates are used as resistive plate electrodes. The MRPC operates at high gain in avalanche mode. As a readout electrodes are designed a long narrow strip. And signal is read from both sides. The signals from MRPCs have to be amplified and discriminated as fast as possible without loss. Leading and trailing times of the discriminated signal must be digitized and measured with accuracy much better than the time resolution of the detector. Readout electronics for the MPD-TOF will consist of the front-end electronics (FEEs) and data acquisition system (DAQ). As FEEs is used electronics based on NINO application-specific integrated circuit (ASIC) [5]. Electronics of DAQ is developed on HPTDC chip [6].

The barel TOF will consist of 14 sectors with total number of FEEs channels of 13440. In order to have optimal time resolution during experiment one needs monitoring. The FEEs have to monitor voltage, thresholds, electronics temperature and gas temperature.

2. Front-end electronics for the TOF MPD

2.1. Front-end board design

The main front-end board (Fig. 1) has been developed at the Laboratory of High Energy Physics [7]. The board includes a preamplifier-discriminator and a control block. The preamplifier-discriminator has 24 channels based on NINO ASIC. The NINO ASIC had to satisfy the following requirements: differential input; optimized to operate with 30 – 100 pF input capacitance; LVDS differential output; output pulse width dependent on the charge of the input signal; fast amplifier to minimize time jitter(a peaking time less than 1ns); threshold of discriminator adjustable in the range 10 – 100 fC; eight channels per ASIC.

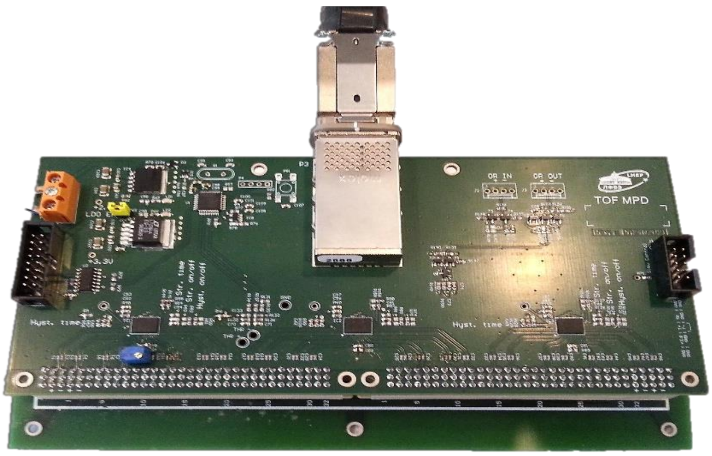

Figure 1. 24-ch NINO based front-end board with Molex's CXP connector as an output and intermediate board

The front-end board is specially adapted for the two-side strip readout in MRPC. Connecting FEEs to the strips of MRPCs takes place through a specialized adapter boards. Adapter board is developed using coupled-microstrip lines technique. Impedance of differential pairs input is designed to match to the impedance of the MRPC readout strip (55Ω).

Control block of the front-end board consists of a microcontroller, temperature sensors, low dropout linear regulators, RS-485 full-duplex interface via bus. Microcontroller is used to control +2.5 V regulator, threshold and temperature acquisition from the board and the gas space. The distribution board was developed to connect several amplifiers with a low voltage source. Also, the distribution board provides to allow all amplifiers to communicate with the TCP server through RS-485 full-duplex interface. 20 FEE boards are connected in parallel by the 20 pins twisted-pair cable to one distribution board, where the power channels from the LV source and the signal lines are distributed to the buses. The scheme of organizing control and powering of the front-end boards is presented in Fig. 2.

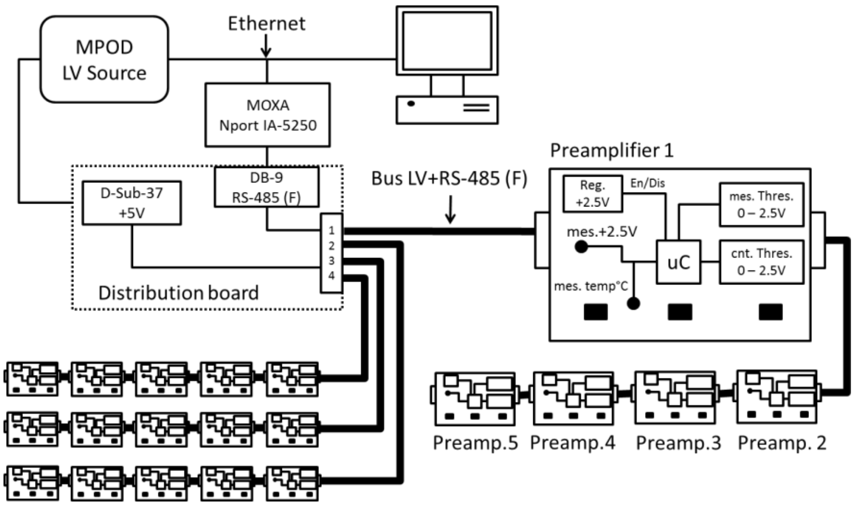

Figure 2. Powering Preampilfier boards and connection scheme

An interesting feature of MRPC is the ability to use each detector as a trigger. Front-end electronics have OR logic circuit which links all NINO. OR logic circuit is used to obtain Trigger OUT signal in LVDS format. The FPGA has been selected as a device for implementing the trigger logic. Trigger OUT signal is transmitted to FPGA through twisted pair. And scheme in the FPGA allows to select cosmic rays in different directions. The first test trigger logic was performed on the BM@N detectors. Efficiency of trigger logic was 94.58%. Though it was developed for the cosmic test setup for mass testing of MRPC (Fig. 3).

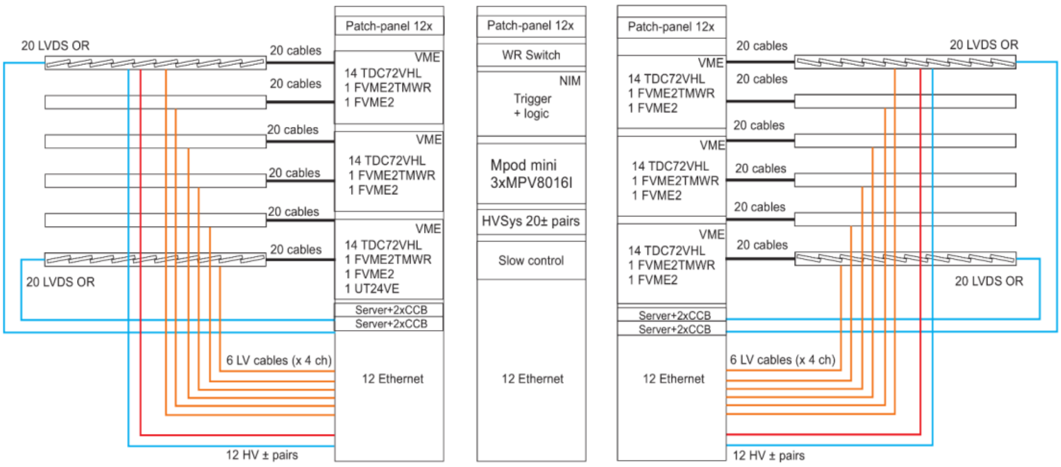

Figure 3. The scheme of the cosmic test setup

Three amplifiers connected to one VME64x time-to-digital converter TDC72VHL based on HPTDC chip. VME module is used for digitizing LVDS signals coming from the output of the NINO amplifier. Time-sampling of the TDC72VHL is less than 25 ps . Then the data is collected on the PC for the future analysis.

The FEE boards were tested at the BM@N experiment at LHEP JINR in December 2016 and March 2017. The dependence of time resolution and efficiency on the applied high voltage for different NINO discriminator thresholds are presented in Fig. 4. The best time resolution for the tested MRPC is 40 ps with efficiency higher than 98% [8].

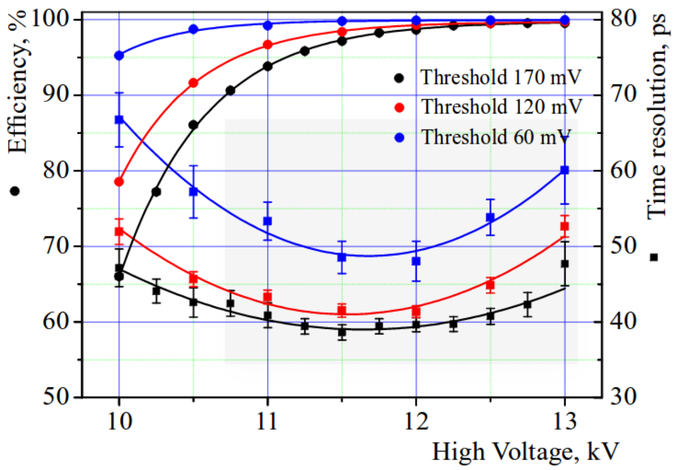

Figure 4. Voltage dependence of the time resolution and efficiency

2.2. Differentieal preamplifier

The secondary front-end prototype (Fig. 5) has been developed for methodological research. The FEE board has 12 channels based on ADA4960 and ADA4937. The board can be used with MRPC with long strips or pads. The differential input was designed to have different impedance. LEMO connector is used as an output. The output analog signal goes through the coaxial cable to an oscilloscope or a sampling ADC (for example, DRS4 used in Cherenkov detector modules for start and L0 trigger detectors of MPD and BM@N experiments [9]).

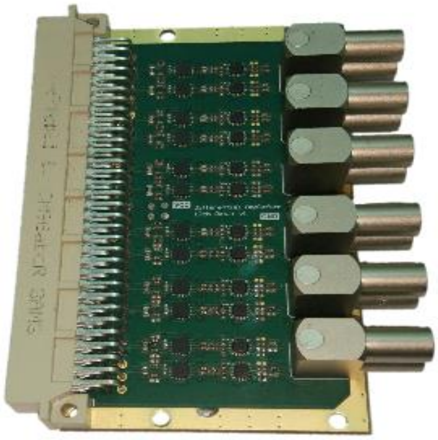

Figure 5. Differential preamplifier board based on the chips ADA4960 and ADA4937

3. Methodological research of resistive plate chambers

3.1. Crosstalk in MRPC

Specific of MRPC with long strips is the existence of crosstalk between the strips. Simulation of propagation of signal through strip was conducted to assess the influence of crosstalk on signal reading quality (Fig. 6). Dependence of the signal amplitude on the distance from the signal source are presented in Fig. 7. The signal source is the signal produced from the strip on which the charge from the avalanche was induced.

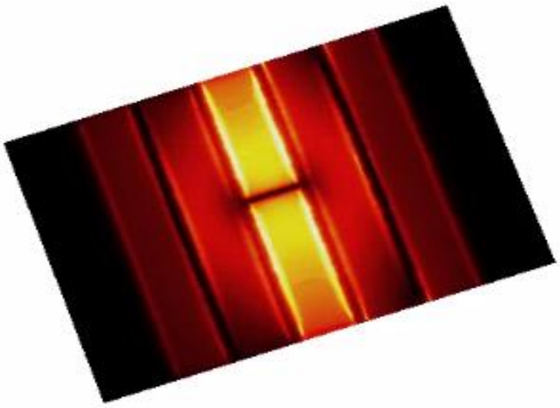

Figure 6. Simulation of propagation of signal through strip

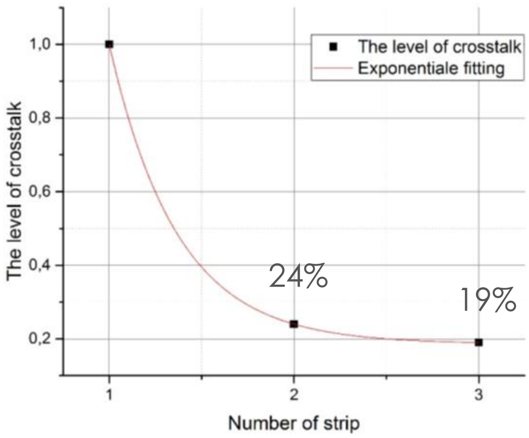

Figure 7. Dependence of the signal amplitude on the distance from the signal source. Counting starts from the source-strip

The differential amplifier was used in the research of crosstalk in the MRPC on test stand. With its, waveforms were obtained in the detector with a long strip. Research of the waveforms confirmed the simulation data.

3.2. Calculation of the efficiency MRPC

MRPC efficiency depends on the efficiency of a single gap. If the efficiency of one of the gap in known, it is possible to calculate a optimal number of gaps of MRPC for reach ~100% efficiency. One of the directions of the MRPC's research is the search for the optimal configuration. For this purpose, the single-gap RPC with the gap of 175 μm was developed and tested. During testing, a differential amplifier was used. Efficiency of detector was 28.2%. 100% efficiency will be achieved at the detector with 14 such gaps. The dependence of the efficiency on the number of gaps is shown in Fig. 8.

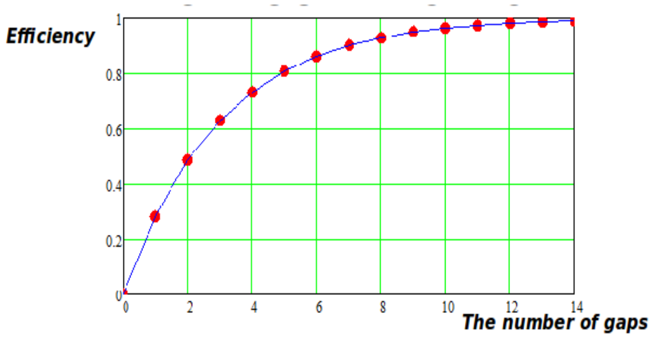

Figure 8. Dependence of the efficiency on the number of gaps

4. Conclusion

The improvement of the front-end electronics design was fulfilled for the time-of-flight system of the MPD. The two experiments at the Nuclotron beams allowed us to check functionality of the FEE design. Time resolution of 40 ps was reached after time-over-threshold correction. The detector provided an efficiency of about 98% at high voltage (12 kV). And two experiments with differential amplifires were carried out on test stand. It has been shown that crosstalk in the MRPC with strips is about 24% of the main signal. And the calculation of the MRPC efficiency with gaps of 175 micron has been represented.

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