PROCEEDINGS OF SCIENCE

Strip MRPC for the MPD/NICA Time-of-Flight System

V.A. Babkin*†, M.G. Buryakov, V.M. Golovatyuk, S.P. Lobastov, M.M. Rumyantsev, A.V. Schipunov, A.V. Shutov, I.V. Slepnev.

Joint Institute for Nuclear Research, Joliot-Qurie St., 6, 141980 Dubna, Russia

E-mail: vbabkin@cern.ch

The Multi-Purpose Detector (MPD) [1] is developed in order to study properties of hot and dense baryonic matter in collisions of light and heavy ions. The MPD will be installed at the NICA collider [2]. Identification of charged hadrons of transitional pulses (0.1 – 2 GeV/s) is carried out via time-of-flight (TOF) measurements. It has been decided to use MRPCs with strip readout as a basic element of the TOF detector. Chambers with the required parameters have been created and the compatible electronics have been improved.

Technology and Instrumentation in Particle Physics 2014,
2-6 June, 2014
Amsterdam, the Netherlands

*Speaker.

†On behalf of the TOF group of the MPD/NICA collaboration.

PoS(TIPP2014)289

1. Introduction

At the NICA accelerator, there will be colliding beams of ions from protons to gold Au^{+78} in the energy range $\sqrt{s_{NN}}$ = 4 – 11 GeV for heavy ions and $\sqrt{s_{NN}}$ = 4 – 20 GeV for protons with the luminosity $L = 10^{27} m^{-1} c^{-1}$. The MPD has to provide high precision measurements of all properties of particles produced in the nucleus collisions. One of the main purposes of the detector is to identify the types of particles. Several systems of the detector are involved in this process. One of them is the time-of-flight system (TOF).

In most recent experiments in high energy physics involving time-of-flight systems (such as the ALICE (LHC) and STAR (RICH)) multi-gap resistive plate chambers (MRPC) [3] were used as bases for TOFs, they are simple and not expensive in terms of production as well as stable in operations.

2. Design of MRPC prototypes

Full-scale strip MRPC prototypes were developed and produced for the barrel part of the time-of-flight system. The readout electrodes of these prototypes were designed as thin narrow strips. The active region area of the MRPC was determined by the size of the glass and it amounts 590×290 mm^2. Three different strip MRPCs were assembled for the first test run. A single-stack MRPC prototype was assembled for the first test run at the Nuclotron beam having 5 gas gaps with the thickness of 250 μm and 24 strips with the size of 600×10 mm^2.

For the second run the design of the strip detector was changed and two prototypes were assembled: a single-stack prototype having 6 gas gaps of 220 μm and 48 strips of 600×5 mm^2 and a double-stack MRPC with 12 gas gaps of 220 μm (6 per a stack) and the same strips that the single-stack prototype had. An important feature of double-stack prototype is that the internal strips of two different stacks are separated by 5-mm panel of Honeycomb. This is made to ensure that the construction is symmetric, and speed of signals on the anode and cathode are the same. In other words, to prevent the dispersion of the signal.

3. Readout electronics

To amplify the differential signal accepted from the MRPC's pads and strips, a 24-channel amplifier based on the NINO chip was used [5], which was specially designed for the time-of-flight system of ALICE and now is the most common amplifier for time-of-flight MRPCs. This amplifier has a fast output signal (rise time <1 ns) and small jitter of the output signal (<10 ps), which is provided by the low noise level of the amplifier. Another characteristic feature of the NINO chip is the possibility to change input resistance in order to match it with the readout electrodes. A discriminator with the minimal triggering threshold of about 25 fC is imbedded into the NINO chip. The discrimination threshold was set at 75 fC for all the conducted experiments. The output signal from the discriminator is LVDS-standard differential signal. The leading edge of the pulse corresponds to the time of its passing through the threshold, and its width corresponds to the amplitude of the input pulse, which allows one to make time-over-threshold correction.

32-channel time-to-digital converters (TDC32VL) based on HPTDC chip were developed and produced for digitization of LVDS signals and data acquisition. First experiments on the MRPC time resolution evaluation showed that large integral nonlinearity occurs with TDC operating in the mode of 24.4 ps per bin. This nonlinearity causes strong degradation of time distribution. The contribution of this nonlinearity and the method to eliminate it has already been shown in the HPTDC Manual [6], as well as in other publications [7, 8]. The method of uniform filling the time gap with random events (code density test) was used for calibration (consideration of nonlinearity) of VME TDC32VL module. Minor differential and strong integral nonlinearity in terms of time were observed distracting the measured value for 8 bins (∼200 ps) from the real time, which deteriorated significantly the time resolution of the electronics. Calibration matrices were developed for further data processing for each channel of the TDC allowing for elimination of the integral nonlinearity contribution. Native time resolution of a TDC32VL channel made up about 20 ps after applying the calibrations.

4. Testing the prototypes at the accelerator beam

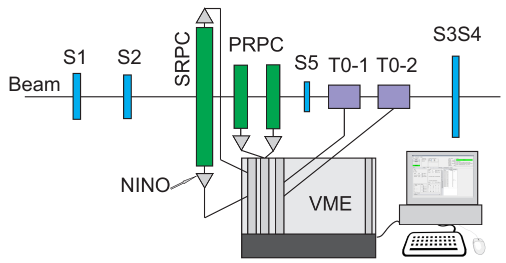

Figure 1: Layout of the experimental setup. S1–S5 – a scintillation counters; T0-1, T0-2 – start detectors; PRPC – pad MRPC prototypes; SRPC – strip MRPC prototypes.

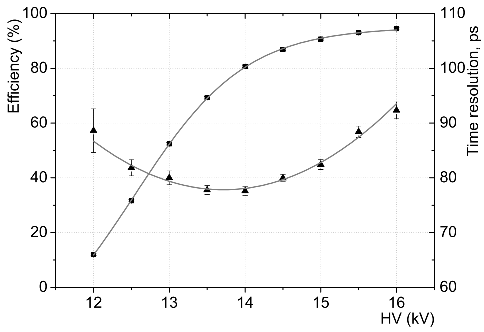

Figure 2: Time resolution and efficiency for first single stack MRPC prototype.

Tests of the prototypes were carried out at the Nuclotron deuteron beam at LHEP JINR in December 2012 and March 2013. The deuteron beam with the energy of 1 GeV/n was injected into Building 205 and was sent to the experimental setup (Fig. 1). A scintillation telescope made up of C1-C5 counters was used for trigger signal obtaining. Also, the C5 counter with the size corresponded to the FFD prototypeŠs effective surface was placed right before T0-1. The following MRPC prototypes were tested: two identical double-stack pad prototypes (PRPC) and three full-sized strip prototypes (SRPC). The detector T0 was used as a start detector in all experiments and had the time resolution of 37 ps with TDC32VL [9]. This value was used later on for calculation of the time resolution of MRPCs.

The dependencies of efficiency and time resolution from the applied voltage for a single-stack chamber with a 10 mm-wide strip were measured in the experiment in December 2012. Fig. 2 demonstrate the dependencies of the efficiency and time resolution of the first one stack strip MRPC prototype versus voltage. The efficiency of the first prototype of the strip MRPC made up 80% at the best time resolution and it did not exceed 93% even at the voltage increased up to 16 kV. Such degradation of the time resolution at the low efficiency was associated with the contribution of the signal reflection from the edge of the strip. The reflection was caused by bad matching of the

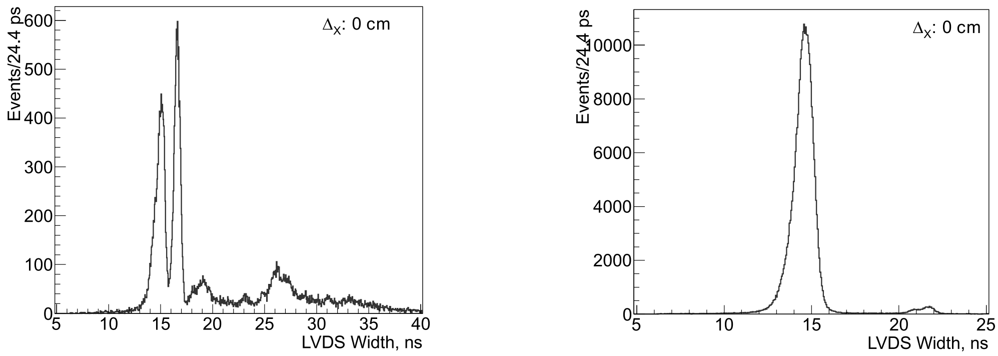

Figure 3: The width LVDS signals spectra from the strips with width of 10 mm(left) and 5 mm (right).

strip (which impedance is about 75 Ohm, according to the calculations and measurements) with cable and amplifier. An 8-cm long ribbon twisted pair cable with the impedance of 110 Ohm was used. For this reason the splitting was observed for the width spectrum of the output LVDS signal. As a consequence, the information on the actual pulse height was distorted. Such splitting may be caused by interference of the reflected signal with the trailing edge of the main pulse. It is supported by the fact that the position of the second width peak and its value depends on the coordinate of the particle passing the detector along the strip (Fig. 3 (left)).

A similar problem arose during the work with the MRPC with a long strip [10]. In order to the avoid splitting of the width spectrum, the strip is matched with the amplifier by adjusting the input impedance of the amplifier. According to the manual, the input impedance of the amplifier can be changed within the range of 20 – 100 Ohm. In our case, such method hardly influenced to the width spectrum and it was decided to change the design of the detector and the way of the signal acquisition due to the main reflection occurred in the point of strip-cable.

Two new MRPC prototypes with 5 mm strip readouts were tested at the Nuclotron beam in March 2013. As pulse generator tests demonstrated, this constructions was well matched with the signal transmission line.Figure 3(right) shows the relative absence of the width spectrum splitting with such strips configuration.

Calculations predicted the efficiency of the assembled single-stack chamber are to be about 90%. Therefore, the double-stack MRPC was assembled with the same stacks as for the single-stack chamber described above. The results on the efficiency and time resolution of the single-stack and double-stack strip MRPC prototypes obtained from March's run are shown in Fig. 4.

As it was expected, the efficiency of the single-stack prototype made up 92%. In this case the best time resolution was in the limit of 70 ps. The efficiency of 99.9% and time resolution of about 65 ps were achieved for the double-stack version.

An important feature of the two-ends strip readout is possibility to position the particle passing along the strip quite precisely. By the using of the time difference between arrivals of signals from the left and the right ends of the strip, it is possible to reconstruct the point of the particle transit. The coordinate resolution of this method of positioning was measured and made up of about 5 mm.

The degradation of the pulse front edge might occur due to the non-symmetric location of strips in the double-stack SRPC and as a result the time resolution might decrease. To prove this

PoS(TIPP2014)289

effect, the dependence of the time resolution in the point of the particle transit through the strip was measured(Fig. 5). It is shown that the time resolution remains almost the same with the coordinate being changed, i.e. dispersion has little influence on the signal.

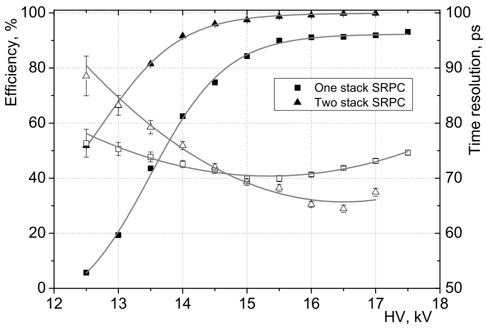

Figure 4: Test results for the MRPC prototypes with 5-mm wide strip.

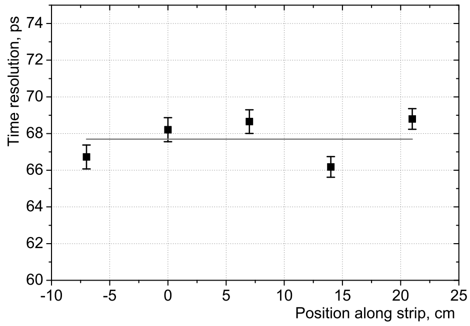

Figure 5: Time resolution of the double-stack SRPC as a function of the coordinate of a particle's flight.

5. Conclusions

The optimization of the full-sized MRPC prototype design was fulfilled for the time-of-flight system of the MPD. Two experiments at the Nuclotron beams allowed us to reveal imperfections of the detectors design and to develop the MRPCs improved for these conditions.

The results obtained for the double-stack MRPC with the strip readout meet the requirements to the time-of-flight system of the MPD. Further investigations will be aimed to the optimization of the readout and front-end electronics. The matching will be performed for strips of various configurations, which will allow to reduce the total number of the electronics channels.

References

[1] Kh.U. Abraamyan, et al., *The MPD detector at the NICA heavy-ion collider at JINR*, Nucl. Instr. Meth. Phys. Res. A 628 (4) (2011) 99.

[2] A.N. Sissakian and A.S. Sorin, *The nuclotron-based ion collider facility (NICA) at JINR: new prospects for heavy ion collisions and spin physics*, Journal of Physics G: Nuclear and Particle Physics 36 (2009) 064069.

[3] A. Akindinov, et al., *The multigap resistive plate chamber as a time-of-flight detector*, Nucl. Instr. Meth. Phys. Res. A 456 (2000) 16.

[4] V.A. Babkin, et al., *Time-of-Flight System for the MultiPurpose Detector (MPD)*, Bulletin of the Russian Academy of Sciences: Physics 75 (9) (2011) 1277.

[5] F. Anghinolfi, et al., *NINO: an ultra-fast and low-power front-end amplifier/discriminator ASIC designed for the multigap resistive plate chamber*, Nucl. Instr. Meth. Phys. Res. A 533 (2004) 183.

[6] J. Christiansen. *High performance time to digital converter (HPTDC)* , Digital Microelec. Group, CERN, HPTDC manual version 2.2 for HPTDC version 1.3.

PoS(TIPP2014)289

[7] Daniel McDonald, *Calibration of the STAR Time-of-Flight Detector for Particle Identication*, MS degree thesis, Houston, Texas, December 2010.

[8] P. Antonioli, S. Meneghini, *A 20 ps TDC readout module for the ALICE. Time of Flight system: design and test results*, in procidings of *9th Workshop on Electronics for LHC Experiments*, Amsterdam, The Netherlands, 29 Sep - 3 Oct 2003, 311.

[9] V.I. Yurevich, et al., *Fast Forward Detector for MPD/NICA Project: Concept, Simulation, and Prototyping*, PEPAN, Letters 10 (3) (2013) 414.

[10] K. Doroud, et al., *MRPC-PET: A new technique for high precision time and position measurements*, Nucl. Instr. Meth. Phys. Res. A 660 (2011) 73.