E13-2012-69

V. A. Gapienko [*], O. P. Gavrishchuk, A. A. Golovin [*],
N. A. Kuzmin, E. A. Ladygin, Yu. P. Petukhov, A. A. Semak [*],
Yu. M. Sviridov [*], S. Ya. Sychkov, E. A. Usenko, A. I. Yukaev

TEST OF STRIP READOUT MRPC EQUIPPED WITH AMPLIFIER DISCRIMINATOR BASED ON THE NINO CHIP

Submitted to «Nuclear Instruments and Methods»

---

[*] Institute for High Energy Physics (IHEP), Protvino, Russia

Гапиенко В. А. и др. E13-2012-69
Испытание МРПК со стриповым съемом информации
с использованием усилителя-дискриминатора NINO

Использование широких стрипов вместо падов в качестве электродов для считывания информации в многозазорных резистивных плоских камерах (МРПК) позволяет значительно уменьшить количество каналов накамерной электроники. Поскольку стрип является волновой линией, требуется правильное согласование с нагрузкой на его конце, что создает определенные проблемы в применении уже существующей накамерной электроники, в которой метод коррекции время–ширина реализован для съема информации с помощью падов. В работе приведены результаты использования двух различных усилителей-дискриминаторов, созданных на основе чипа NINO для съема информации с помощью стрипов шириной 25 мм в шести- и десятизазорных временных МРПК. Измерения проведены на ускорителе У-70 в ИФВЭ (Протвино).

Работа выполнена в Лаборатории физики высоких энергий им. В. И. Векслера и А. М. Балдина ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 2012

Gapienko V. A. et al. E13-2012-69
Test of Strip Readout MRPC Equipped with Amplifier Discriminator Based
on the NINO Chip

The use of wide strips instead of pads as readout electrodes in a multigap resistive plate chamber (MRPC) helps to reduce essentially a number of FEE channels. However, a strip being a transmission line, requires correct matching with an end terminator that leads to a certain problem in applying already existing FEE in which the time–width correction method is realized to read pads. Here we describe our attempts to use two different amplifier discriminators based on the NINO chip to read 25 mm wide strips in six- and ten-gap timing MRPCs. Tests have been carried out at the IHEP U-70 PS (Protvino).

The investigation has been performed at the Veksler and Baldin Laboratory of High Energy Physics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 2012

1. INTRODUCTION

Glass MRPC with a pad readout is a detector with high time resolution and good detection efficiency. The pad readout can provide any required granularity of the timing detector. MRPC with pads have been chosen to construct time-of-flight (TOF) system in such experiments as ALICE [1], HARP [2], STAR [3], and PHENIX [4]. However, if the expected multiplicity of particles in the events is not very big, it should be more reasonable to use a readout with strips instead of pads to reduce the number of the FEE channels. This can be very useful in case of a large area TOF system. There are a few already published papers [5–7] describing the performance of the MRPC equipped with wide strips.

Ten-gap MRPC with the readout system segmented into six double-ended strips of 25 mm width each was tested by cosmic rays and at the accelerator [5]. Signals were read out from the both ends via FEE based on MAXIM 3760 chip. The mean time formed from the time measured at two ends of one strip was corrected for the slewing effect by using the correlation between the measured time and charge. The resolution reached in the test was about 70 ps.

Results from the beam test of the six-gap single stack MRPC equipped with a strip of 25 mm wide and 180 cm long are presented in [6]. In that beam test the strip was read out at each end with the standard ALICE FEE card and digitized by high performance TDC (HPTDC). The output signal of NINO chip is the time-over-threshold (TOT) pulse whose leading edge provides with the time of the hit while its pulse width is proportional to the input signal charge [8]. HPTDC ASIC designed at CERN for the ALICE TOF measures the time of leading and trailing edges of the TOT signal [9]. Thus a correction for the slewing effect can be done with the time–width correlation instead of using the time–charge dependence. In [6] the authors have mentioned the problem observed for the TOT method: the FEE input resistivity was not consistent with the impedance of the strip line in the MRPC that resulted in the appearance of reflected signals. As a result, the correction for the slewing effect was not easy because of not a simple correlation between the time and pulse width (see Fig. 9 in [6]). The measured values of the time resolution in the paper mentioned above were between 65 and 80 ps.

The goal of our previous test [7] of the six-gap MRPC equipped with the 25 mm wide strips was to reach the resolution value which is typical for MRPCs with the pad pick-up electrodes. In that beam test the FOPI FEE1 amplifier discriminators [10] read out the both ends of the strip. The time–charge correction method was applied to compensate time slewing. The best resolution of ~ 45 ps was achieved at the efficiency higher than 98%. Neither the time resolution nor the efficiency dependence on the coordinate along the strip of 30 cm long has been observed. The general conclusion is that MRPC with wide strips has demonstrated as high timing resolution and efficiency as a chamber with the pad readout.

A strip as a pick-up electrode differs from a pad not only by the fact that a signal arriving to one end of a strip is by a factor of 2 smaller than a signal gathered from a pad. A strip works as a transmitting line. If a pulse arrives to the end of the strip whose load does not correspond to the line impedance, it is reflected. Then the reflected signal runs along the strip to the opposite end to be reflected again, and so on up to the complete attenuation. The main goal of the presented work was to test the strip readout in case when the time–width correction is applied instead of the time–charge correction method. Our efforts were focused on using the ultrafast NINO chip [11] developed for the ALICE TOF detector.

2. CHAMBER CONSTRUCTION

For the tests we have used two double stack MRPCs. The chambers were built identically. The difference between them was only in the number of gaps: the first chamber had six gaps, the second one — ten gaps. The gap width in both chambers was 300 μm. The schematic cross section of six-gap MRPC is shown in Fig. 1. The chamber consists of two identical stacks with readout strips in between. Each stack is formed by four glass plates, sized $300 \times 300 \times 0.85$ mm, with the $2 \cdot 10^{12}$ $\Omega \cdot$cm bulk resistivity. The gap between the glasses was fixed by spacers — usual fishing lines, which ran directly through the RPC working area.

Graphite conductive coating with surface resistivity of ~ 1 M$\Omega/\Box$ was painted to outer surfaces of external glass plates of each stack to distribute both the high voltage (HV) and its separate ground and thus to form the uniform electrical field in the stack sensitive area of 290×290 mm. Signal pulses were

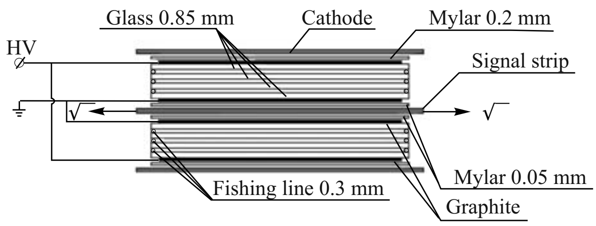

Fig. 1. Schematic cross section of the six-gap MRPC

taken from the both ends of anode strips of 25 mm wide and 300 mm long each. Spacing between the strips was 1 mm.

The entire MRPC assembly was put into a gas-tight aluminum box which was blown through by the gas mixture of 93% $C_2H_2F_4 + 5\%\ C_4H_{10} + 2\%\ SF_6$.

3. BEAM TEST SETUP

The both MRPCs were tested at the IHEP U-70 PS. The beam consisted in general of positively charged hadrons having momentum of ~ 3 GeV/c with intensity of beam $100 \div 300$ Hz/cm^2. The scheme of the MRPC test setup is given in Fig. 2. The system of four scintillation counters was used for beam monitoring and getting the reference time. Beam counters $S1$ and $S2$ being each a scintillation cubic and photomultiplier (PM) selected the 1×1 cm beam spot on the MRPC plane. Each of two timing counters $T1$, $T2$ and $T3$, $T4$ consisted of the scintillation bar ($1 \times 1 \times 5$ cm) viewed at both ends with PM's $T1$, $T2$, $T3$ and $T4$. The timing counters were placed symmetrically, one before and another behind the MRPC. Signals from timing PMs ran to constant fraction discriminators. The time averaged over four PMs, $T0 = (T1+T2+T3+T4)/4$, was taken as the reference relatively to which the MRPC time response was studied. The time difference $T12 - T34 = ((T1 + T2) - (T3 + T4))/4$ was measured for each test run to control the measurement stability. The distribution on $T12 - T34$ was fitted with a Gaussian to define the resolution of the reference time. The jitter of the reference time determined as $50 \div 55$ ps was subtracted quadratically from the measured MRPC time jitter.

The MRPC was mounted in some mechanical frame to move the chamber relatively the beam line in horizontal and vertical directions with the accuracy of ~ 0.5 mm. The data from two-coordinate proportional chambers (PC1 and PC2) were used to find a place where a charged particle crosses the MRPC, and thus to study changes of the resolution and efficiency in the region close to the strip edge.

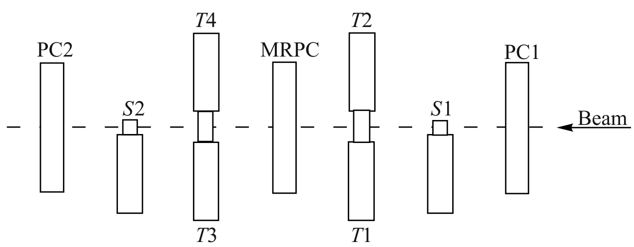

Fig. 2. Sketch of experimental test setup: $S1$, $S2$ — beam counters; $T1$, $T2$ and $T3$, $T4$ —- timing counters; RPC — tested chamber; PC1, PC2 — two-coordinate proportional chambers

4. EXPERIMENTAL RESULTS

4.1. Six-Gap MRPC with ALICE FEE. In [7] we got the high time resolution and efficiency with six-gap MRPC. In the presented work, firstly, we tried to test the same MRPC after replacing the FOPI FEE1 amplifier with the ALICE FEE card. Outputs of the ALICE FEE cards were connected with a multichannel HPTDC (MTDC64 [12]) via the twisted pair flat cables of 25 m long. Figure 3, *a*

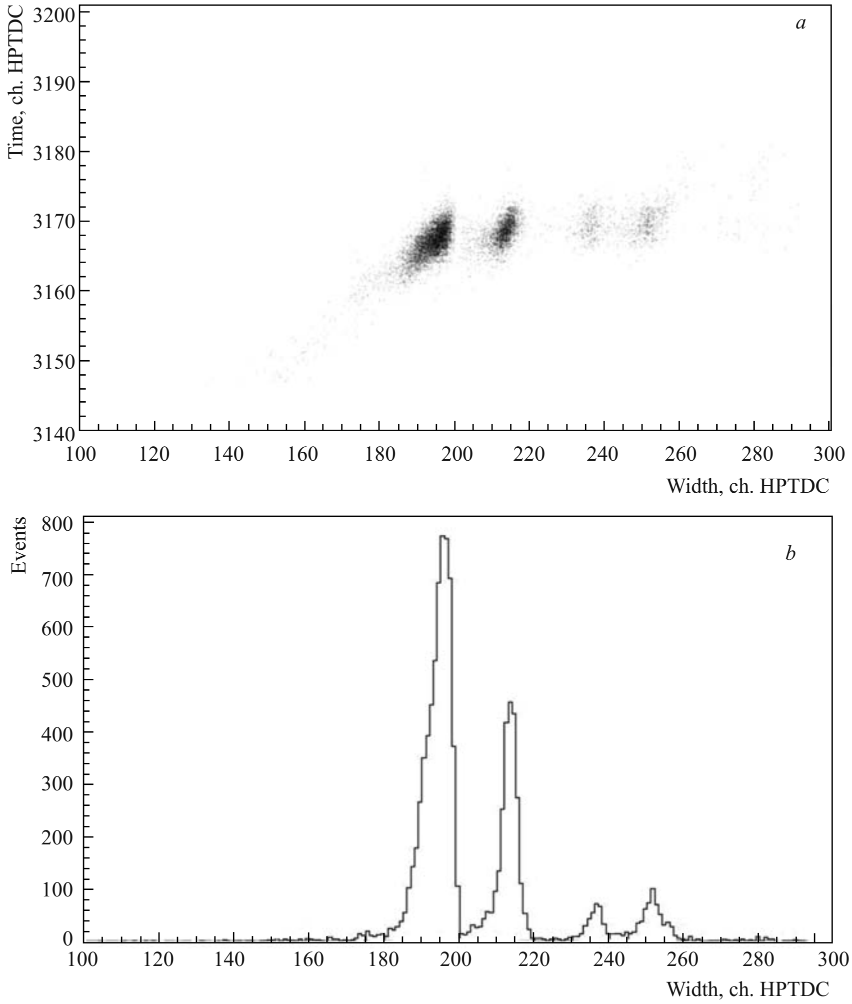

Fig. 3. *a*) Time–width plot for the TOT pulse; *b*) distribution of the TOT signal width. Six-gap MRPC with the ALICE TOF FEE. No matching between strip impedance and the FEE input resistivity

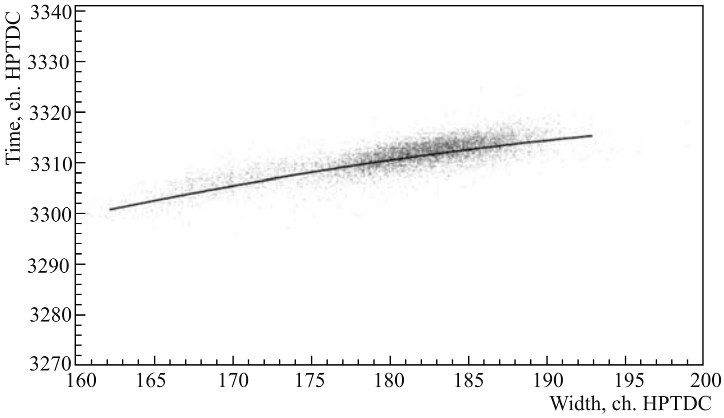

Fig. 4. The time–width correlation plot for six-gap MRPC with the ALICE FEE. All ends of strips are terminated with 25 Ω resistors. The solid curve is a polynomial approximation of the data

shows the time versus the pulse width both digitized with MTDC64 operated in the 100 ps/count mode. The data in Fig. 3, *a* look like a set of separated spots (ellipses). This is due to the existence of the reflected signal walking along a strip several times before its complete attenuation. In the ALICE FEE the TOT pulse has turned out to be very sensitive to the structure of the input pulse trailing edge. The width of the TOT pulse (see Fig. 3, *b*) jumps every time when the next reflected signal arrives to the NINO input. The number of spots in Fig. 3, *a* depends on the input charge and on the FEE threshold.

Impedance of the strip line in the six-gap MRPC was measured as $\sim 20\ \Omega$. To suppress the reflection, all the strips were ended with terminating resistors. Figure 4 shows the time–width plot obtained for the case of terminated strips. No splitting of the pulse width is seen in this figure. The data were approximated by a polynomial function (the solid curve in the figure), and this function was used to correct the data for the time slewing. The best resolution achieved with the six-gap MRPC plus the ALICE FEE was ~ 110 ps only. One of the ideas why better result was not reached is that the amplitude of the pulse at the input of the ALICE FEE is not high enough after loading of the $25\ \Omega$ resistors at the strip end. This suspicion is conditioned by the fact that the best resolution has been observed at the knee of the efficiency dependence on HV but not on its plateau.

4.2. Ten-Gap MRPC with HADES TRB FEE. For the further tests we replaced both the amplifier and the MRPC. The ALICE FEE was replaced with the HADES TRB (Trigger and Readout Board) [13]. TRB is a multipurpose electronic module playing the key role in the HADES Data Acquisition System. For us, it was important that TRBv2 coupled with TOF AddOn board [14] could be used as FEE for our MRPCs after simple input circuit adaptation. The amplifier discriminator on the TOF AddOn board also employs NINO ASIC. However, in contrast to the ALICE FEE each input signal on the AddOn board is linked to two circuits. The final output signal of the AddOn amplifier is a superposition of signals from these two branches. The first circuit contains a fast amplifier and a shaper. It provides the final pulse with a leading edge. The second circuit amplifies, integrates and shapes a signal to provide the final output TOT pulse with a trailing edge. After integration of the primary pulse in the second circuit the width of the output TOT signal becomes insensitive to the structure of the input signal. As a result, there is no necessity to load a strip with the resistor matching the strip impedance. Digitization of the TOT signal in TRB is carried out with HPTDC chip operated in the 100 ps mode.

Taking into account that the signal splits in the AddOn board into two NINO channels, we intentionally increased the input charge by using the ten-gap MRPC instead of the six-gap chamber. Figure 5 shows a typical time–width plot observed with the ten-gap MRPC and TRB. The plot contains no break in the pulse width, and that is why the time slewing can be easily corrected by the third-order polynomial function fitted to the time–width dependence. The obtained time resolution is given in Fig. 6 as the function of high voltage. The data on the resolution indicate an obvious problem: instead of constant improvement with rise of HV and then smooth degradation after passing through the minimum, the resolution demonstrates a nontrivial behavior.

The problem of the integral nonlinearity in digitization with the HPTDC chip was described earlier in [9]. To verify that a strange behavior of the measured resolution takes place due to the HPTDC chip, we have tested our HPTDC modules operated in the 100 ps mode with a pulse generator. A pulse splits into

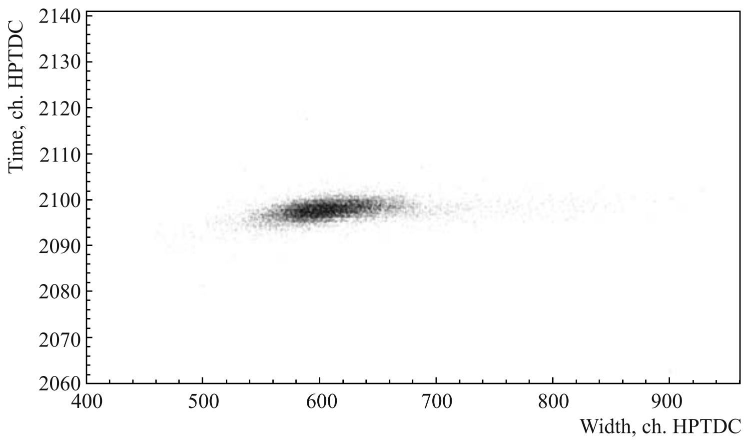

Fig. 5. A typical time–width plot for the case when AddOn was used

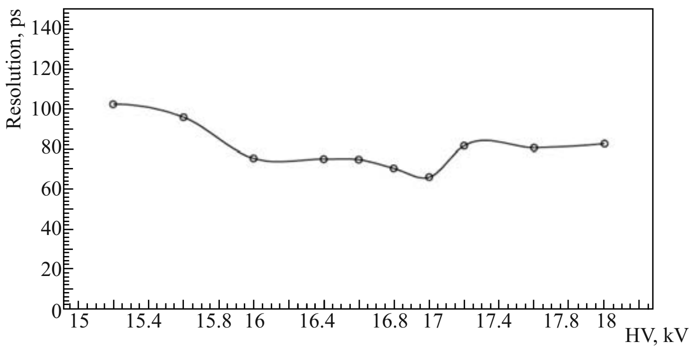

Fig. 6. Time resolution of ten-gap MRPS as a function of high voltage in the case when TRB FEE and HPTDC were used

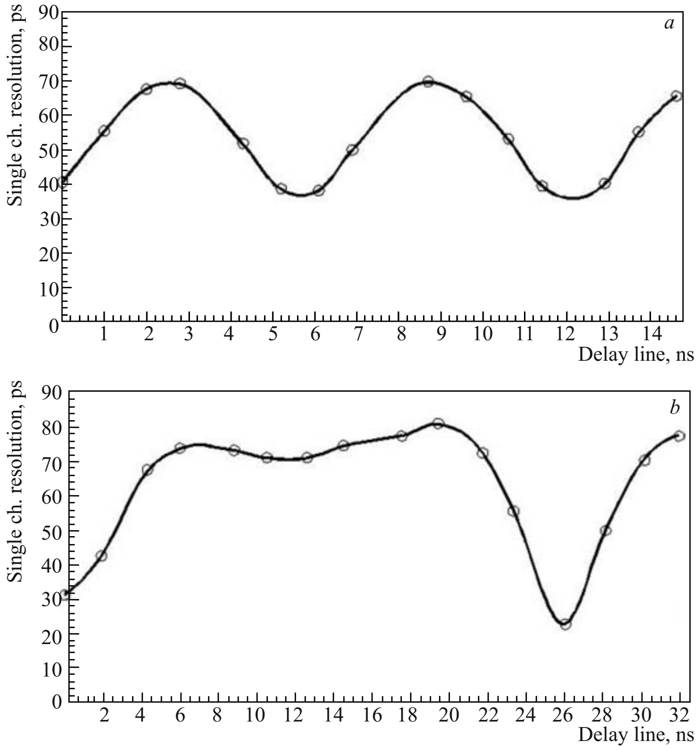

Fig. 7. Jitter in time difference between two channels measured as a function of time delay of one input signal relative to the other one: *a*) MTDC64; *b*) TRB HPTDC

two HPTDC inputs and the resolution (jitter) was measured depending on time difference between two pulses. The RMS of the measured time difference distribution divided by $\sqrt{2}$ is an achievable time resolution. The jitter was found to be not stable but it is some kind of a periodic function. The similar nonlinearity was observed for the both HPTDC modules used in our tests. Variation in the time resolution measured for the MTDC64 module versus the delay between signals is given in Fig. 7, *a*. Figure 7, *b* shows instability in the resolution found for the HPTDC from TRB. A different period of RMS variation is caused by a different clock rate of HPTDCs — 160 MHz for MTDC64 and 40 MHz for TRB HPTDC.

4.3. Ten-Gap MRPC with HADES TRB FEE and LeCroy TDC. Having been pressed by time, during our tests we had no opportunity to improve the situation with the HPTDC. Nevertheless, we intended to prove that the time–width correction works for the strip readout as well as the time–charge one does. For this, we excluded HPTDC from our setup. Using LVDS-NIM convertor and two NIM discriminators the TOT signal was split into two NIM pulses: the front edge of the first NIM pulse corresponds to the front edge of the TOT signal, the front edge of the second NIM pulse corresponds to the TOT trailing edge. Then both NIM pulses were delayed by ~350 ns and digitized with TDC LeCroy 2228A module having 50 ps LSB. The delay was needed as TDC had to be used in the «common start» mode. An additional time jitter contributed by the convertor, discriminators and cables was measured as $\sim$ 25 ps. Thus, digitization of the TOT signal was performed with two channels of the LeCroy TDC instead of one channel of HPTDC.

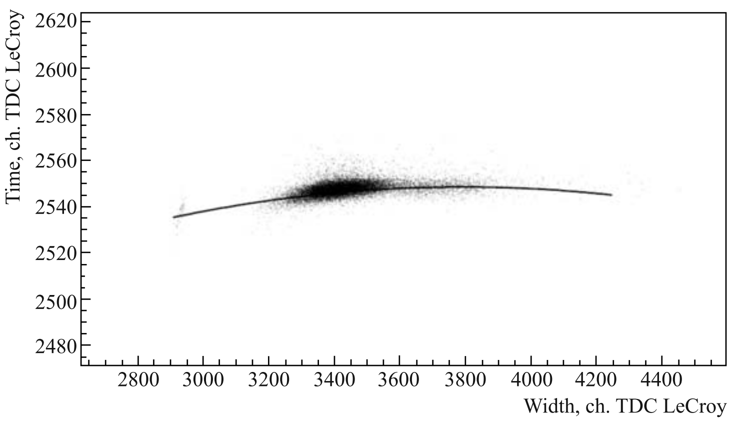

Fig. 8. An example of the time–width correlation. The solid curve is the result of approximation with a polynomial function. Ten-gap MRPC, TOT signals were digitized by the LeCroy 2228A module

The time–width correlation measured by means of the LeCroy TDC is shown in Fig. 8. The solid curve in the figure is the result of approximation with a polynomial function. The efficiency and time resolution obtained after correction for the slewing are given in Fig. 9 as the functions of high voltage. The resolution better than 55 ps and efficiency above 98% were reached at $\mathrm{HV} = 16.2$ kV.

Due to capacitive coupling between the pick-up electrodes, the charge induced on one electrode produces the crosstalk signal in neighboring channels. To prove

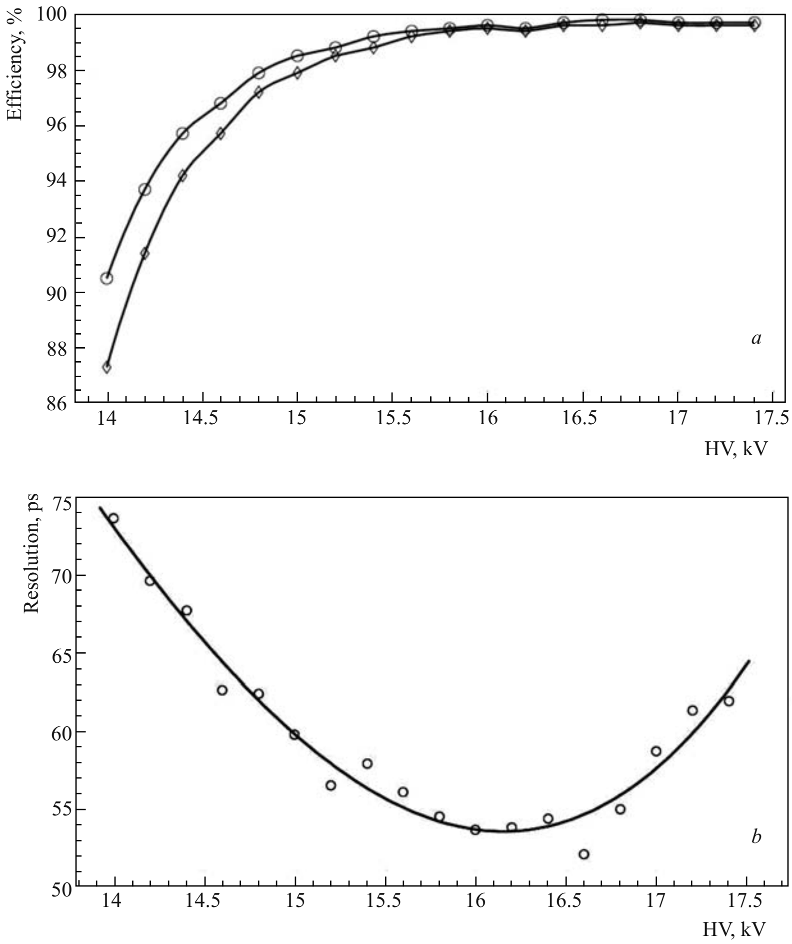

Fig. 9. Efficiency (*a*) and resolution (*b*) versus HV for case when TOT signal was digitized by the LeCroy 2228A module. Efficiency is shown for each of the two ends of a strip. The resolution is for the time averaged over the time from two opposite ends

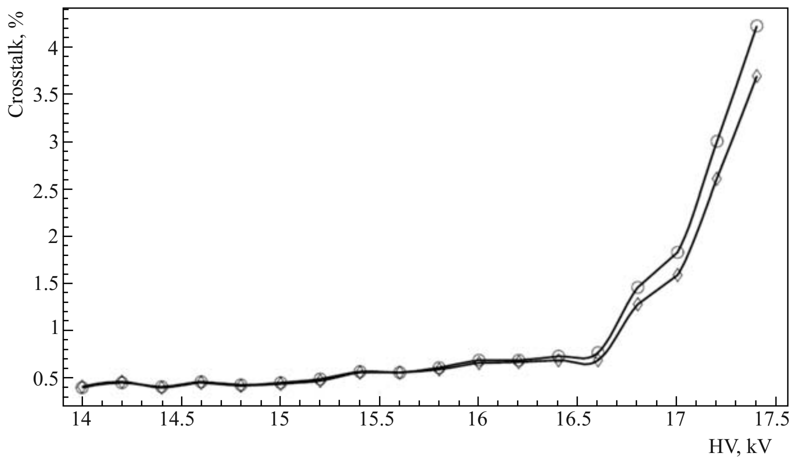

Fig. 10. Fraction of events in which one of adjacent strips located on the left and right sides from the fired strip shows the crosstalk signal

that a long border between two adjacent strips in MRPC does not mean a big crosstalk, we have carried out the following test. To measure the value of crosstalk we centered the beam spot (1×1 cm) in the middle of one of the strips and looked for a probability to get a reply from adjacent channels as a function of HV. Figure 10 shows a fraction of events in which the crosstalk signal was detected in one of two strips being next to the strip fired with the beam. The fraction rises with HV, however, at the voltage below 16.6 kV the crosstalk contribution is less than 1%.

If a charged particle crosses MRPC in the place close to the strip border it induces a charge on two adjacent strips. The charge is shared between two strips and the amplitude of the signal from each of two pick-up electrodes is weaker than in the case when only one strip is fired. Weakening of the amplitude affects the single-strip efficiency and time resolution. To estimate this effect, the beam spot was centered exactly on the border between two strips. In each event the place where the particle crosses the MRPC was found by using the information from proportional chambers PC1 and PC2. The result of scan across two neighboring strips done at HV = 16.2 kV is shown in Fig. 11. The efficiency and time resolution are presented in the figure depending on the distance measured from the border between two pick-up electrodes. Degradation of the time resolution and efficiency for a single strip is obviously seen near the border. The border effect for MRPC with the pad readout system was studied in [15] and several approaches were described how to improve the resolution using information from two adjacent electrodes. The same methods can be also applied for the strip readout.

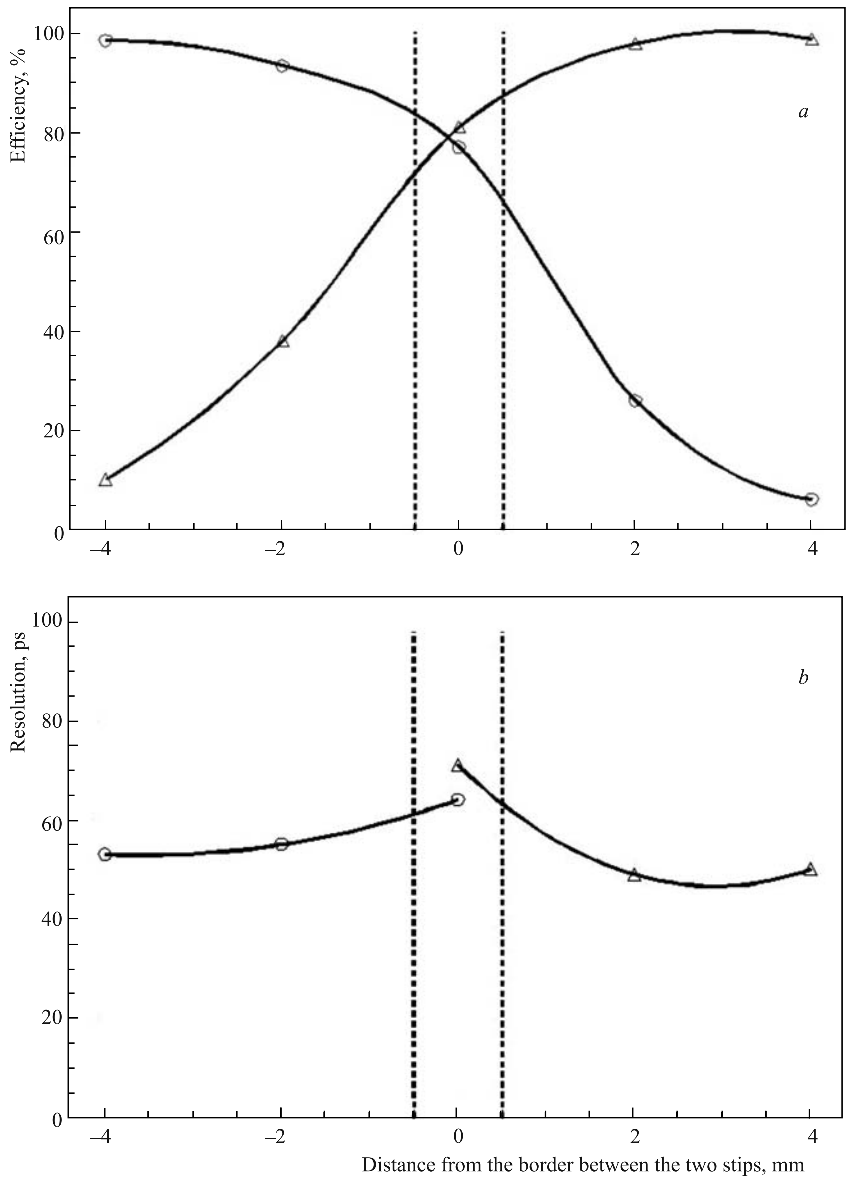

Fig. 11. Changes of efficiency (*a*) and time resolution (*b*) near the border between two adjacent strips

5. SUMMARY

Two timing glass MRPCs equipped with pick-up strips of 25 mm wide and 30 cm long, were tested in the test beam area at the IHEP U-70 PS. To read out strips in the six-gap MRPC, the ALICE amplifier discriminator was used. It has been found that the width of the output pulse produced by the NINO chip is very sensitive to the structure in the trailing edge of the input signal. The existence of the reflection at the end of the strip leads to ambiguity in determination of the input pulse width.

The HADES amplifier discriminator, TOF AddOn, also based on the NINO chip turned out to be free of this drawback. This makes it possible to use the amplifier discriminator without any termination of the strip line. It can be useful for the case when the impedance of the strip line is more than the input FEE impedance. The HADES FEE seems to be more convenient for the MRPC with strips.

Operating with the HPTDC chip, we have faced the problem of its nonlinearity. Having not enough time to fix this problem, we carried out the digitization of the TOT pulse by the LeCroy TDC. The resolution of about 55 ps at the efficiency of above 98% was reached with the ten-gap MRPC and AddOn board FEE. It means that the time–width correction method works as well for the strip readout as the correction for the time–charge slewing does.

REFERENCES

1. *Akindinov A. V. et al.* // Nucl. Instr. Meth. A. 2004. V. 533. P. 74–78.
2. *Ammosov V. et al.* // Nucl. Instr. Meth. A. 2007. V. 578. P. 119–138.
3. *The STAR TOF Collaboration.* 2004. Proposal for a Large Area Time-of-Flight System for STAR.
4. *Velkovska J. et al.* Time-of-Flight of the PHENIX High-Pt Detector. 2005. Conceptual Design Report.
5. *Sun Y. J. et al.* // Nucl. Instr. Meth. A. 2008. V. 593. P. 307–313.
6. *Abbrescia M. et al.* // Nucl. Instr. Meth. A. 2008. V. 593. P. 263–268.
7. *Ammosov V. V. et al.* Properties of a Six-Gap Timing Resistive Plate Chamber with Strip Readout. JINR Commun. E13-2009-86. Dubna, 2009. 10 p.
8. *Anghinolfi F. et al.* // IEEE Trans. Nucl. Sci. 2004. V. 51, No. 5. P. 1974–1978.
9. *Akindinov A. V. et al.* // Nucl. Instr. Meth. A. 2004. V. 533. P. 178–182.
10. *Schuttauf A. et al.* // Nucl. Phys. Proc. Suppl. 2006. V. 158. P. 52–55.
11. *Anghinolfi F. et al.* // Nucl. Instr. Meth. A. 2004. V. 533. P. 183–187.
12. MTDC-64 is a 64-channel, 100 ps time-stamping TDC with PCI-Express interface. http://afi.jinr.ru/MTDC-64.
13. *Fröhlich I. et al.* // IEEE Trans. Nucl. Sci. 2008. V. 55. P. 59–66.
14. *Palka M. et al.* // IEEE Nucl. Sci. Symp. Conf. 2008. Rec. 1. P. 1398–1404.
15. *Akindinov A. V. et al.* // Nucl. Instr. Meth. A. 2004. V. 532. P. 611–621.

Received on June 14, 2012.

Редактор *Т. Е. Попеко*

Подписано в печать 09.08.2012.
Формат 60 × 90/16. Бумага офсетная. Печать офсетная.
Усл. печ. л. 0,93. Уч.-изд. л. 1,26. Тираж 265 экз. Заказ № 57730.

Издательский отдел Объединенного института ядерных исследований
141980, г. Дубна, Московская обл., ул. Жолио-Кюри, 6.
E-mail: publish@jinr.ru
www.jinr.ru/publish/