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V. V. Ammosov[1], V. A. Gapienko[1], O. P. Gavrishchuk[2],
N. A. Kuzmin[2], A. A. Semak[1], Yu. M. Sviridov[1],
S. Ya. Sychkov[2], E. A. Usenko[2],
A. I. Yukaev[2], V. G. Zaets[1]

PROPERTIES OF A SIX-GAP TIMING RESISTIVE PLATE CHAMBER WITH STRIP READOUT

[1]Institute for High Energy Physics (IHEP), Protvino, Russia
[2]Joint Institute for Nuclear Research (JINR), Dubna, Russia

Аммосов В. В. и др. E13-2009-86

Свойства 6-зазорной временной резистивной плоской камеры со стриповым считыванием информации

Стеклянная 6-зазорная резистивная плоская камера со стриповым съемом информации была испытана на пучке ускорителя У-70 ГНЦ РФ (Институт физики высоких энергий). Получено временное разрешение ~ 45 пс при эффективности более 98%. Координатное разрешение вдоль стрипа составило ~ 1 см.

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

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Properties of a Six-Gap Timing Resistive Plate Chamber with Strip Readout

Six-gap glass timing resistive plate chamber with strip readout was tested using IHEP U-70 PS test beam. The time resolution of ~ 45 ps at efficiency larger than 98% was achieved. Position resolution along strip was estimated to be ~ 1 cm.

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

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1. INTRODUCTION

For the first time a use of Multigap Resistive Plate Chamber (MRPC) as a high resolution timing detector for time-of-flight (TOF) system has been proposed by ALICE TOF group [1]. As a result of their many years R&D work the ALICE TOF system based on ten-gap glass RPCs having readout pads (3.5×2.5 cm^2 each) has been created [2]. At the R&D stage the resolution of ~ 50 ps has been achieved with the ALICE MRPCs. So high resolution is due to the usage of narrow (0.25 mm) gap with the high strength electric field inside and a summing of signals from several gaps.

Results of the ALICE TOF group have served as a starting point for numerous developments of TOF detectors with high granularity and large active area. First TOF system based on four-gap glass MRPCs [3] was realized in already completed HARP experiment at CERN. Big pad with size of 24×10 cm^2 and consisting of eight strips of 3×10 cm^2 each were chosen as a signal electrode for the HARP MRPCs. Outputs from eight strips were summed electronically. Timing resolution of the HARP TOF system was about 170 ps. Currently the TOF systems based on MRPC are used or under development in the HADES [4], FOPI [5], STAR [6] experiments.

The purpose of the present work was an investigation of the time property of six-gap glass RPC equipped with strip readout. Such a detector could be good candidate for the TOF system in new experiments like PANDA [7], MPD [8], SPIN [9]. Strip readout instead of pads allows reducing considerably number of channels of front-end electronics and also amounting of introduced matter.

Early the results from study of MRPC with strip readout were described in [10, 11]. In work [10] wide (25 mm) strip, and in work [11] — narrow (2.54 and 3.44 mm) strips were used. Already when we have got the data presented in the present work, there were simultaneous papers [12, 13] in which the data on usage of 25 mm wide strips in ten-gap and six-gap glass MRPC were published.

2. MRPC DESCRIPTION

A schematic cross section of the tested by us MRPC is shown in Fig. 1. The chamber consists of two identical triple gap stacks with anode readout strips in

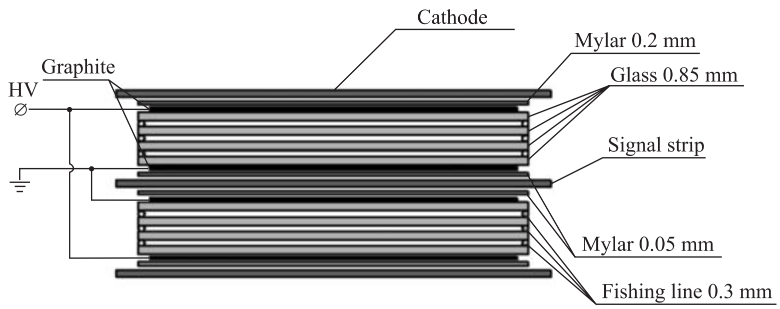

Fig. 1. Schematic cross section of the six-gap MRPC

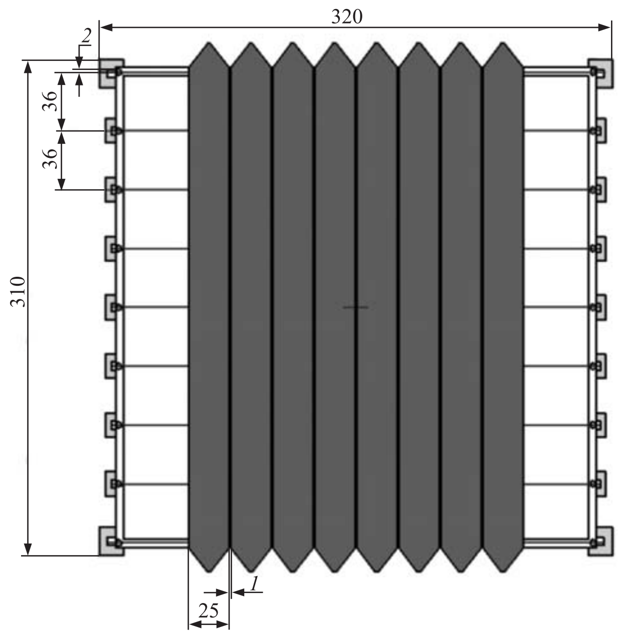

Fig. 2. Anode strip readout structure

between. Each stack is formed by four glass plates, sized $300 \times 300 \times 0.85$ mm^3, with $2 \cdot 10^{12}\ \Omega \cdot \mathrm{cm}$ bulk resistivity. The gap sizes of 0.3 mm between glass plates were fixed by spacers of an insulator — usual fishing line, which ran directly through the RPC working area.

A graphite conductive coating with surface resistivity of $\sim\ 1\mathrm{M}\Omega/\square$ 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 uniform electrical field in a stack sensitive area of 290×290 mm^2. Two internal glass plates of each stack are electrically floating. Signal pulses were taken from the eight anode strips with 300 mm length, 26 mm pitch and 25 mm width (Fig. 2). The impedance of anode strip line was measured and equal to 20Ω.

The entire MRPC assembly was put into gas-tight aluminum box which was flowed through by the gas mixture of 93% $C_2H_2F_4 + 5\%$ $C_4H_{10} + 2\%$ SF_6. A material budget of the chamber thickness is $\sim 8.5\%$ X_0.

3. BEAM TEST SET-UP

The MRPC was tested in the test area of beam line 6 at the IHEP U-70 PS. The beam consisted in general of positive hadrons having momentum of few GeV/c.

System of four scintillating counters based on the FEU-87 photomultipliers (PMT) was used for beam monitoring and to get reference time for MRPC. Scheme of layout in test area is shown in Fig. 3. Beam counters S_1 and S_2 with $1 \times 1 \times 1$ cm^3 scintillator selected the 1×1 cm^2 beam spot on the MRPC plane. Two timing counters T_{12} and T_{34} each consistsed of $1 \times 1 \times 5$ cm^3 scintillator viewed at both ends with PMTs. Signals from the timing PMTs were fed to constant fraction discriminators. Trigger signal was defined as coincidence of signals from all counters: $S_1 \cdot S_2 \cdot T_1 \cdot T_2 \cdot T_3 \cdot T_4$.

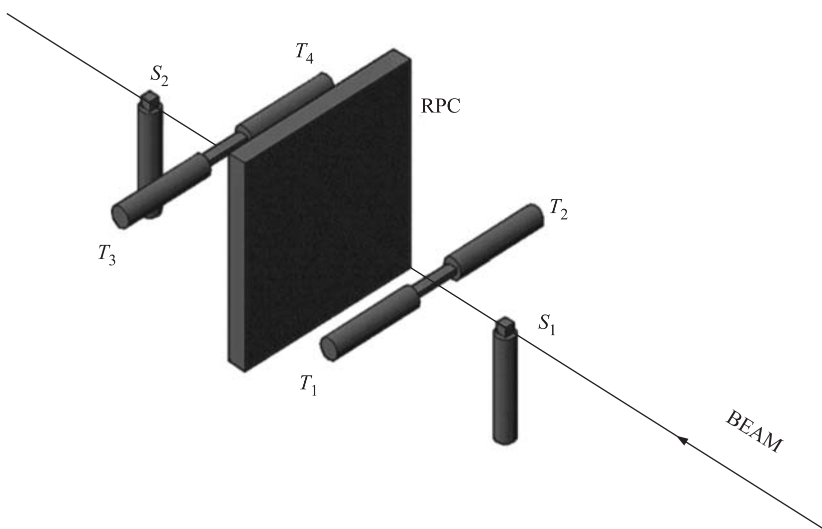

Fig. 3. Scheme of the experimental set-up in test area

Signals from both ends of MRPC strips were transferred by the $50\,\Omega$ coaxial cables to the 4-channel RPC FEE1 amplifier-discriminator boards [14], developed in the FOPI experiment and having a bandwidth of 1 GHz, amplification up to 100. FEE1 has analogue and digital outputs. The own rise time of an analogue branch is ~ 350 ps. All output MRPC signals and signals from timing PMTs were transferred by 25 m of $50\,\Omega$ coaxial cables to counting room for time and charge digitization with TDC LeCroy 2228A (47 ps/count) and with QDC LeCroy2249A CAMAC modules.

4. RESULTS

Time averaged over four timing photomultipliers, $T_0 = (T_1+T_2+T_3+T_4)/4$, was taken as a reference time relatively to which the MRPC time response was studied. Accuracy of T_0 determination can be measured via difference between times of two timing counters $T_{12} = (T_1 + T_2)/2$ and $T_{34} = (T_3 + T_4)/2$. Approximation of $(T_{12}–T_{34})$ distribution with Gaussian gives (see Fig. 4) $\sigma \sim 104$ ps what automatically means that T_0 is determined with accuracy of 52 ps.

Discrimination of MRPC signal with constant threshold leads to time-charge dependence. Figure 5, a demonstrates time-charge slewing observed for one of

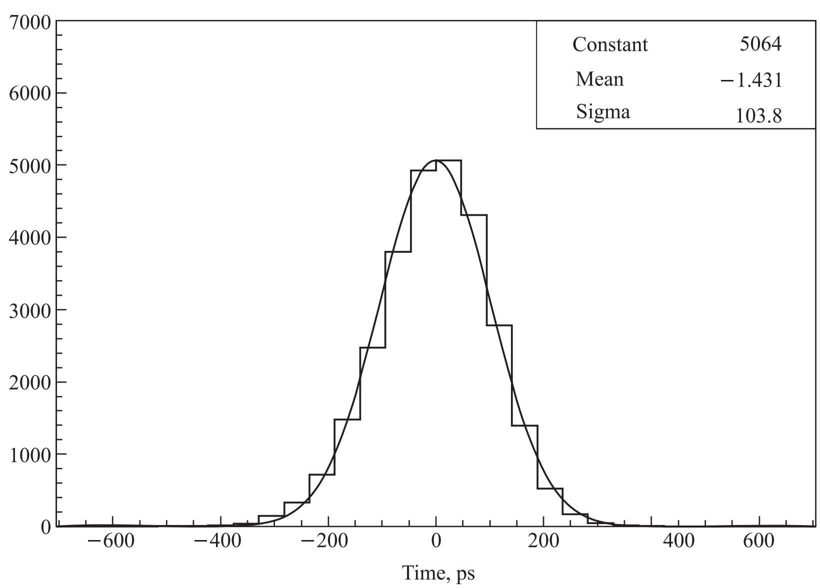

Fig. 4. Distribution of time difference between two timing counters $(T_{12}–T_{34})$

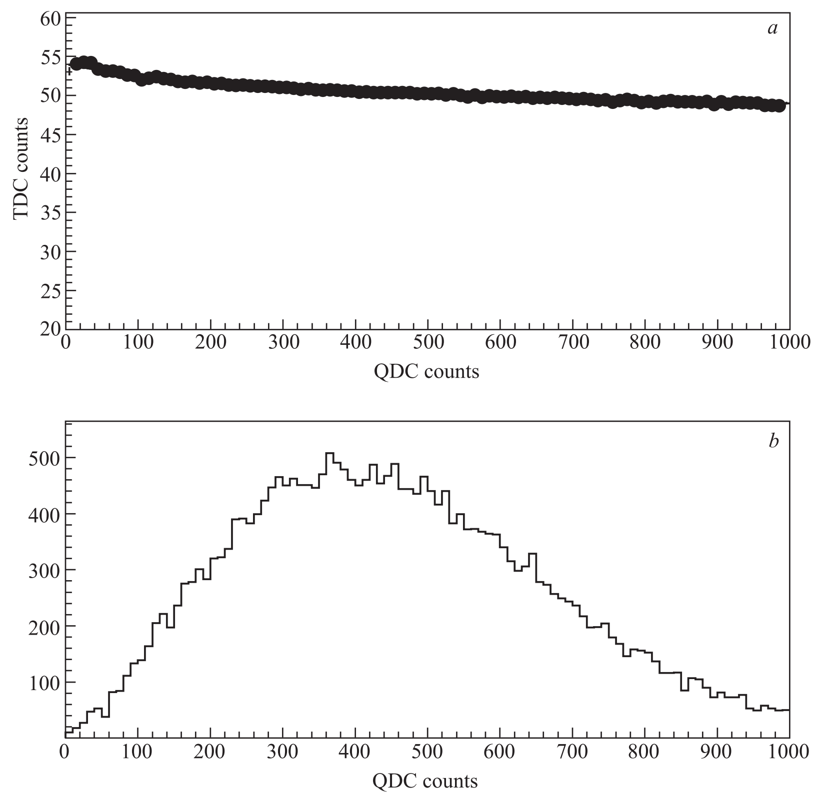

Fig. 5. *a*) Time-charge slewing and *b*) distribution of charge of MRPC signals

strip ends. Distribution on charge for the same channel is presented in Fig. 5, *b*. To avoid the slewing effect and thus to improve the resolution the values of time were corrected for time-charge dependence independently for both ends of a strip.

MRPC response time, $T_{\rm mrpc,}$ was defined as $T_{\rm mrpc} = (T_{\rm mrpc1} + T_{\rm mrpc2})/2$, where $T_{\rm mrpc1}$ and $T_{\rm mrpc2}$ are the time counts from both ends of a strip. It is expected that there is strong correlation between these two signals. However, usage of the information from both ends of a strip allows to have the MRPC response time which does not depend on coordinate position of a hit along a strip.

Figure 6 shows distributions of response time of MRPC, $T_{\rm mrpc}$: *a*) before and *b*) after doing time-charge slewing correction. Subtraction of time resolution of T_0 from corrected time results in own MRPC time resolution of 44 ps. The data were obtained at HV = 9 kV.

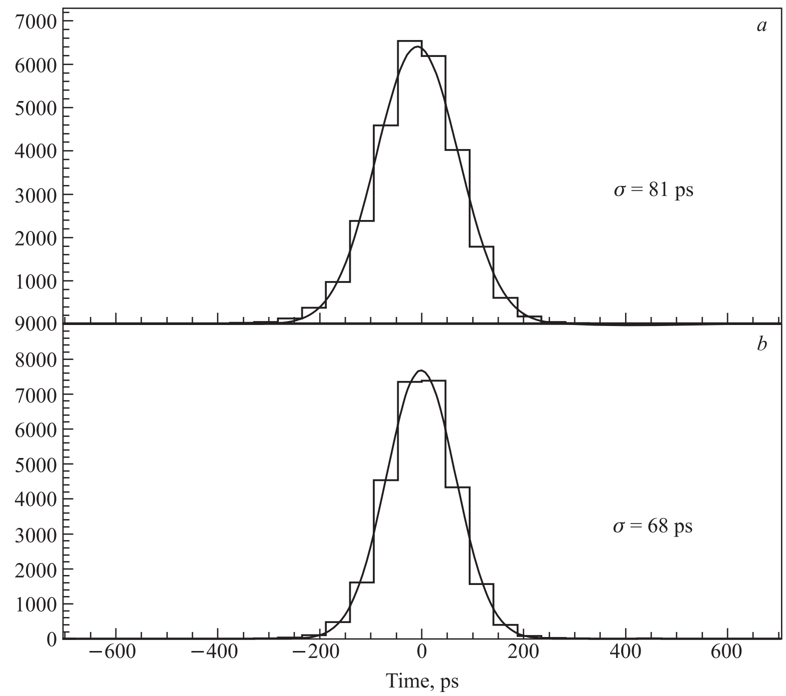

Fig. 6. Distribution of mean time $T_{\rm mrpc}$: *a*) before slewing correction, *b*) after slewing correction

The chamber was considered inefficient in two cases — when there was no signal at least from one end of a strip or when a MRPC response time appeared outside of $3 \cdot \rm RMS$ from average value. Dependences of the MRPC resolution and its efficiency on HV applied to the chamber are shown in Fig. 7. It is seen that the chamber has a wide plateau on efficiency at level more than 98 %. The best time resolution is reached at $\rm HV = 9$ kV.

The data shown in Fig. 7 were obtained for a case when the beam passed through the strip centre. However, there were no significant changes neither in efficiency nor in the time resolution if the chamber was installed so that the beam passed through a strip more close to its end. Figure 8 shows $T_{\rm mrpc}$ distribution for case when beam passed through strip centre (Fig. 8, *a*) and, in comparison, when beam crossed strip 10.5 cm far from its centre (Fig. 8, *b*). Results of Gaussian fits are also shown in the figure.

The distribution on difference between values of time measured at two ends of the same strip ($T_{\rm mrpc1}$–$T_{\rm mrpc2}$), is presented in Fig. 9. This difference allows

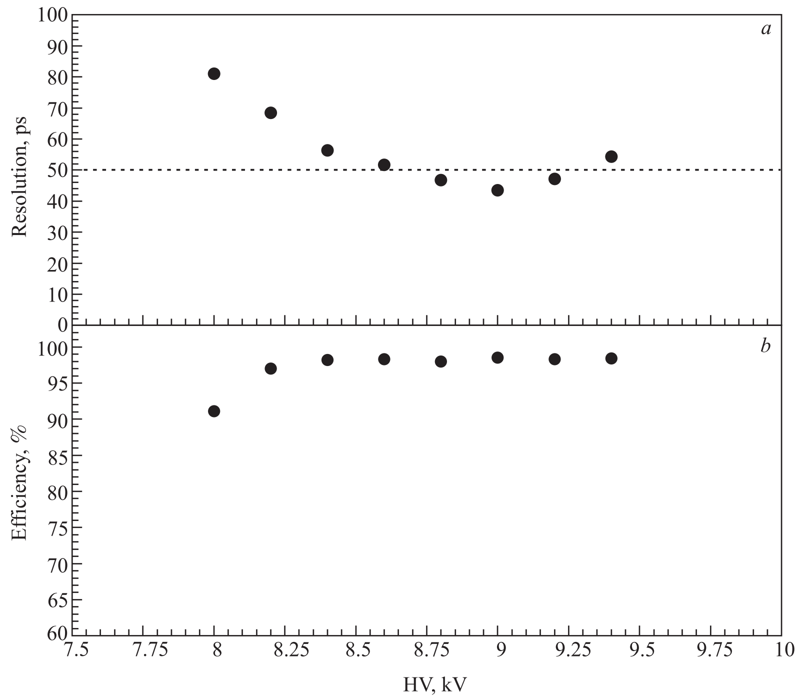

Fig. 7. Time resolution and efficiency of MRPC versus high voltage

getting a coordinate of hit along a strip. The RMS of this distribution is ~ 37 ps. It translates into coordinate accuracy of better than 1 cm if to take into account measured speed of signal propagation of ~ 55 ps/cm.

If MRPC is used together with outside tracking detectors which can provide with coordinate information at reasonable for MRPC accuracy then only signals from one end of strips can be used. It allows reducing by two times the number of channels of electronics. For $\mathrm{HV} = 9$ kV it was found that timing resolution for one end strip readout is ~ 48 ps. Taking into account time uncertainty due to the beam spot one can obtain $\sigma \sim 45$ ps. It confirms that signals from two ends of the same strip are strongly correlated and gives an opportunity to use only one end of a strip keeping the same time resolution.

5. CONCLUSION

The six-gap glass timing resistive plane chamber sized by 30×30 cm^2 with $2 \times (3 \times 0.3\ \mathrm{mm})$ gas-gap structure and strip readout was built and tested. Readout

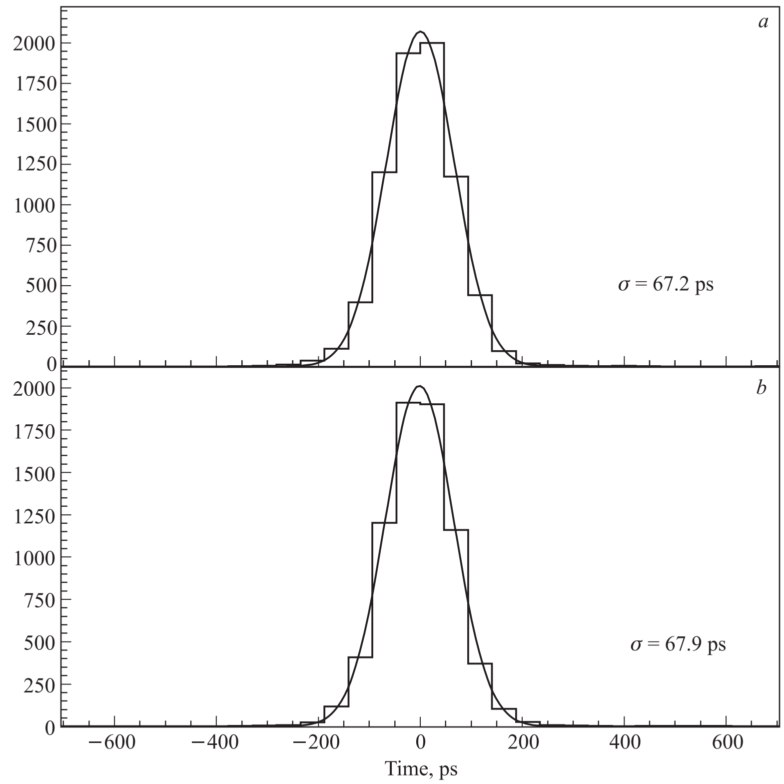

Fig. 8. Distribution of mean time T_{mrpc}: *a*) beam passed through centre of strip, *b*) beam was 10.5 cm far from the strip centre

system of eight anode strips with 30 cm length and 25 mm width placed between two glass stakes was used. Signals were picked up from both ends of each strip. MRPC properties were measured in hadron beam of IHEP U-70 PS. The best time resolution of $\sim$ 45 ps both for single-end strip signal and for half-sum of signals from both strip ends with efficiency more than 98% was achieved. The coordinate resolution along a strip, deduced from resolution of time difference of signals from two ends of the same strip is estimated to be $\sim$ 1 cm.

Our results are in good agreement with the data published in [12, 13]. In [12] beam test of the ten-gap RPC, having strips of 25 mm width, was resulted in the time resolution of $60 \div 70$ ps and the coordinate resolution along a strip of 1 cm. In [13] the time resolution of 70 ps was reached for the six-gap RPC with 25 mm width and 180 cm length strips using differential readout.

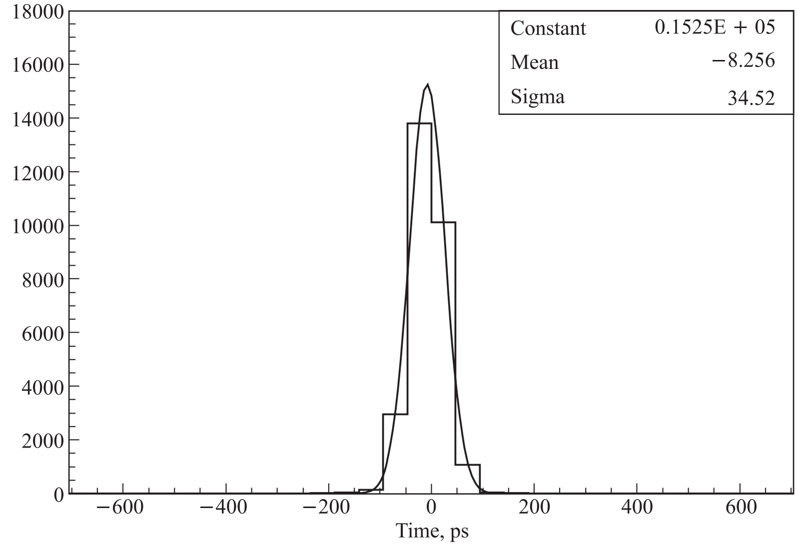

Fig. 9. Difference in time measured at the opposite ends of the same strip, T_{mrpc1}–T_{mrpc2}

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141980, г. Дубна, Московская обл., ул. Жолио-Кюри, 6.
E-mail: publish@jinr.ru
www.jinr.ru/publish/