# High Counting Rate Timing Resistive Plate Chamber

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**Abstract:** ***Timing resistive plate chamber with thickness of 70~mg/cm$^2$ is constructed as alternative to plastic scintillation detector in particle physics. Chamber gives high rate capability up to 1MHz per cm$^2$ in sensitive area 10 cm$^2$. To avoid contamination and damage under strong ionization the gas forced jet device and cleaning circulation system including nuclear filtres are applied. Chamber consists of anode which is 5 µm-polyimid film coated cuprum and gold and cathode which is 330 µm silicium plate with diamand-like film on surface. Gap between cathode and anode is 0.2 mm. Fast preamplifier is connected to anode. Signal from preamplifier feeds constant fraction discriminator with time reference of 20 ps. Negative power supply is connected to cathode. Time between signal from plastic scintillation detector and resistive plate chamber is measured with time reference of 20 ps. Four-component gas mixture of noble gases containing 73%$C_2H_2F_4$, 20%Ar, 5%$CO_2$ and 2%$SF_6$ is circulated through chamber. Test of chamber is performed with radioactive source $^{90}$Sr($^{90}$Y). Time resolution 270 ps is obtained at maximum possible counting rate.***

**Keywords:** neutron detector, resistive plate chamber, high timing resolution, SiC, gas mixture

## 1. Introduction

High counting rate timing resistive plate chamber is a perspective detector for an application in the particle and nuclear physics. It has a time resolution of less than 1 ns and high rate capability up to 10$^5$ см$^{-2}$ с$^{-1}$. Recently, a such chamber have been developed [1]. It consist of a ceramic cathode coated by aluminum and ceramic anode which is coated by aluminum on the one side and by semiconducting layer of SiC on the other side. The resistive semiconducting layer placed between the anode and cathode quenches an streamer during a avalanche development under the action of an ionizing particle in gas. Using the gas mixture 85%$C_2H_2F_4$ + 5%$C_4H_{10}$ + 10%$SF_6$ it is possible to get a short signal with a large pulse height. A gas in the chamber is under a condition of an extremely high electric field intensity. Therefore, a good uniformity of an electrode surface and a gas purity is claimed for a stable operation of the detector. An ionisation produced by an ionizing particle induces an avalanche which tries to transform into a streamer. However, a high electric field intensity in the semiconducting layer leads to an abrupt discharge in this layer . It causes a falling of a gap field intensity and, as a result, decaying a discharge. A streamer energy is dissipated in a small region of the silicium carbide surface layer in a volume 10$^{-5}$ мм$^3$. A strict requirements is applied to a quality of a surface to prevent a damage of it. A radiation resistance of SiC is equals 10$^5$ W cm$^{-3}$ , a heat capacity of it is equals 5 W cm$^{-3}$ K$^{-1}$ and an electric strength 6MW cm. Applying the SiC surface coating the upper limit of a rate capability of 10$^5$ с$^{-1}$ cm$^{-2}$ is achieved [2]. However, a microstructure of the SiC surface is not enough smooth and has a characteristic size of crystall in several micrometers. As a result, the detector operation is not stable. Unlike existing detectors, a coating of diamond-like film on the silicium plate surface is used in this detector. The surface of cathode and anode is uniform and smooth. It has a characteristic size of crystall in several nanometers. The diamond-like surface has a high radiation resistance and heat resistance. It has a large energy of the cohesion.

## 2. Detector Design

An internal design of the narrow gap timing resistive plate chamber is shown in the figure 1.

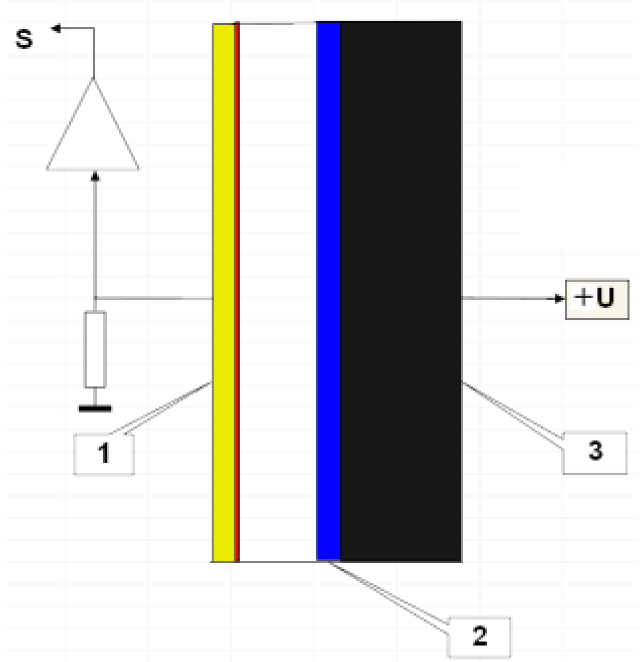


**Figure 1:** An internal design of timing resistive plate chamber:

1- The anode based on the 5-µm capton coated by copper and gold;
2 - The diamond-like film on the sic surface;
3 - The cathode based on the 330--µm crystal of silicium.

The detector consists of an anode and cathode. The anode is based on the high-strength strong stretched 5-µm capton film coated by copper and gold. The cathode is based on the 330-µm pure silicium plate with a coating of a refractory, radiation resistance, semiconducting silicium carbide. The diamond-like film is created on the surface of cathode. The cathode serves as well as a semiconducting element with a specified resistivity of the value 10$^4$ Ω. A gas gap between anode and cathode is equals 0,2 mm. The safe gas mixture of

73%$C_2H_2F_4$, 20%Ar, 5%$CO_2$ and 2%$SF_6$ forcibly circulates in the gap with filtering by the special facility. In contrast to earlier have applied gas mixtures this one has a low escaping tendency to a polymerization. Argon provides a gas gain due to a secondary ionization. Carbon dioxide quenches photons. Freon limits an avalanche size. Sulfur hexafluoride enhances an electrical strength and restricts a discharge time. A key feature of detector is a large energy of an cohesion of the semiconducting coating of electrodes.

A gas purification system is shown in the figure 2.

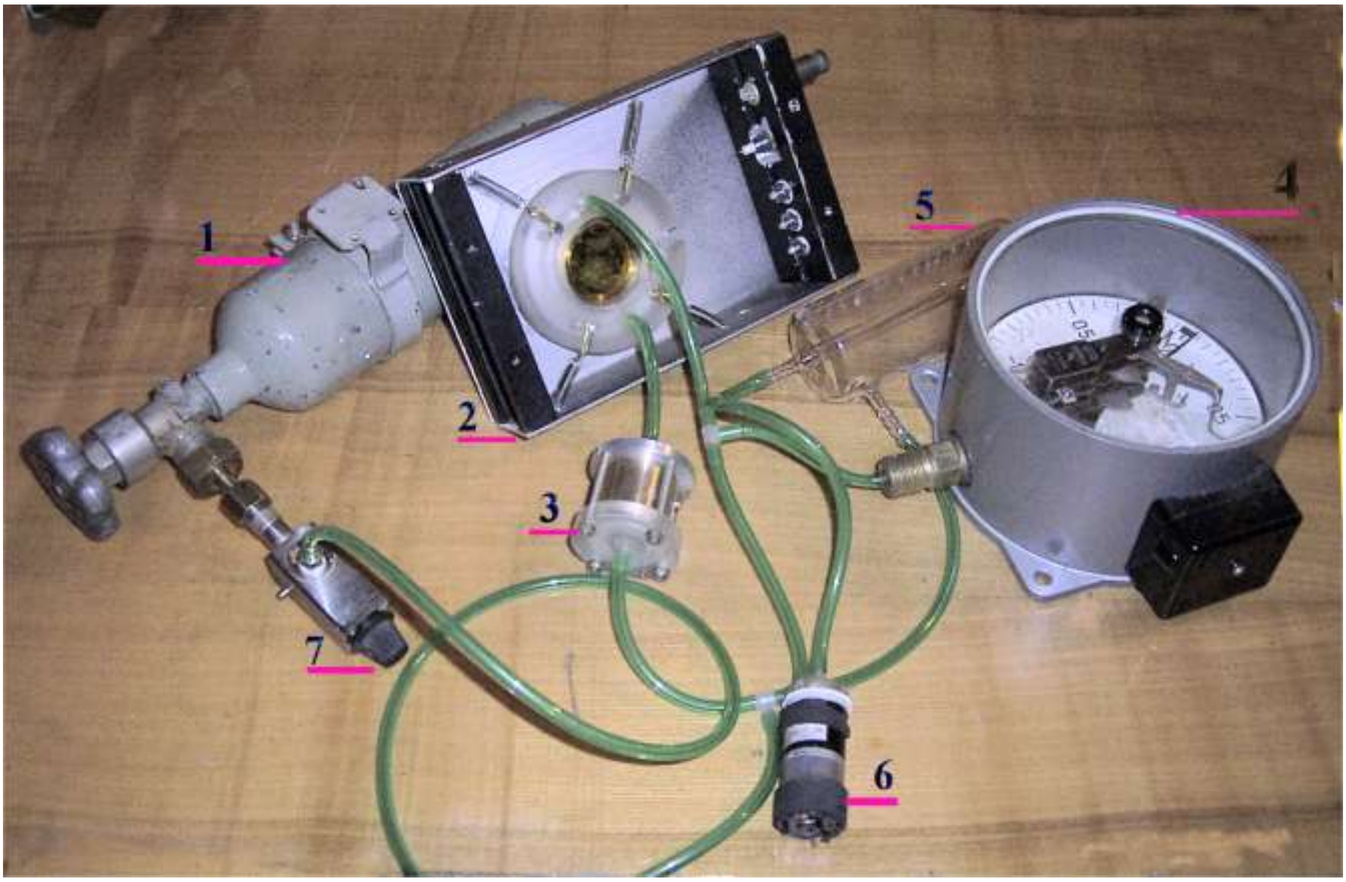


**Figure 2:** A gas purification system:

1 - a gas bottle;
2 - a time resistive plate chamber;
3 - a lot of filters;
4 - a manovacuumeter;
5 - a gas receiver;
6 - a pump
7 - a gas valve.

It is used to avoid an accumulation of charges and a deposition of pollutions on electrodes which causes an detector ageing. The gas purification system consists of a pump, a gas valve, a manovacuumeter, a gas bottle filled by the mixture made in advance and a lot of filters. An internal design of the lot of filters is shown in the figure 3.


**Figure 3:** A lot of filters

1 - a conductive boss with the output tube olive and nuclear membrana;
2 - a dielectric boss with the input tube olive and ion chamber anode contact;
3 - an ion chamber cathode;
4 - a nanometer filter;
5 - an ion chamber anode;
6 - a nuclear membrana.

A nanometer filter traps the claster aggregations of a size more than 1 μm. A high ion concentraton of aggregations result in a polymerization in the detector. Charged aggregations are traped in the ion chamber of lot of filters. Clasters in several ten nanometers are traped by the nuclear membrana. A loss of a gas circulation under condition of the ~ $10^9$ $cm^{-3}$ $c^{-1}$ ion concentration leads to a catastrophic polymer deposition on electrods and a detector damage.

## 3. Test Facility and Data Acquisition System

A data acquisition system for testing of the timing resistive plate chamber is shown in the figure 4.

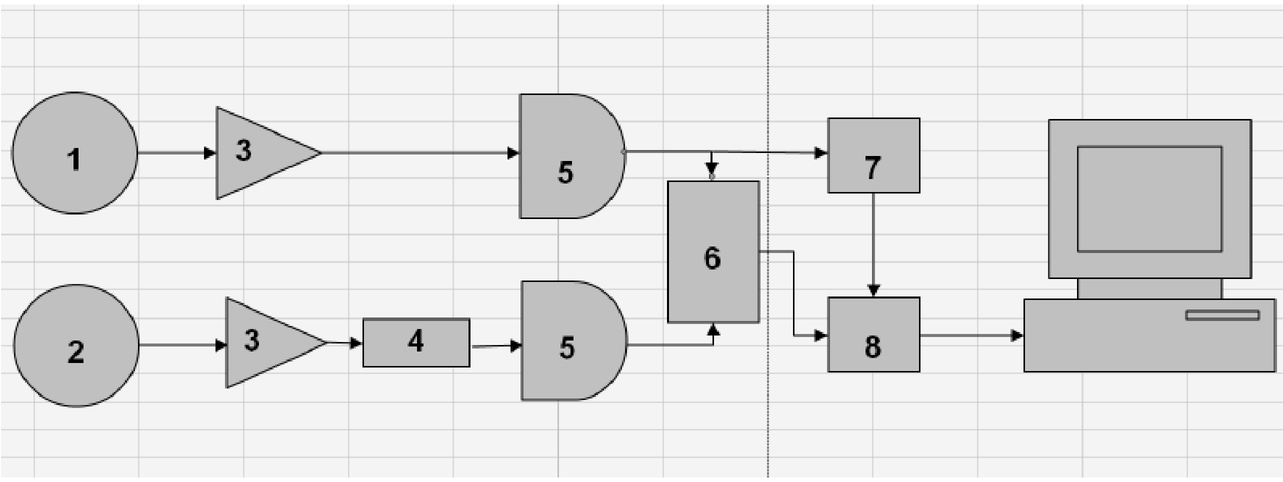


**Figure 4:** A data acquisition system for testing of the timing resistive plate chamber:

1 - a scintillation detector;
2 - the timing resistive plate chamber;
3 — preamplifiers;
4 — a delay line;

5 — a constant fraction discriminator;
6 — a time-to-amplitude converter;
7 — an analogous linear gate;
8- — an amplitude-to-digital converter;

A constant fraction discriminator provides a time reference of the electronics better or ~ 20 ps. The logic signal from the constant fraction discriminator is fed to the «Stop» input of the time-to-amplitude converter. The logic signal from the scintillator is fed to the «Start» input of the time-to-amplitude converter. The output signal from the time-to-amplitude converter is fed to the amplitude-to-digital converter with the 20-ps time quant and 160-ns time range. The analogous linear gate is triggered by the scintillator and selects a 5-ns time interval for an enable processing of the amplitude-to-digital converter. The data is written to the computer disk on-line via the CAMAC controller.

## 4. Detector Test Results

The $^{90}Sr(^{90}Y)$ electron source with the average energy of 1.05 MeV and the emission rate of $F = 10^8$ $e^-/s$ is used for a measurement. The timing resistive plate chamber of the $D$ = 36 mm sensitive diameter is arranged at the distance of the $L$ = 10 mm from the source. An effective electron flux which falls on the chamber and gives a background counting rate is determined by the formula

$$f = \frac{F}{\pi^2} \cdot Arctg^2 \frac{D}{2L} = 3{,}29 \cdot 10^7 e^- s^{-1} \quad , (1)$$

The rectangular plastic scintillator of the side size of $D_1$=40 mm and the 5-mm thickness is placed in the distance $L_1$ = 100 mm from the source. An effective electron flux which falls on the plastic scintillator and gives the useful counting rate is calculated by the formula:

$$f_1 = \frac{F}{4\pi} \cdot \frac{D_1^2}{L_1^2} = 1.27 \cdot 10^6 e^- s^{-1} \quad , (2)$$

An applying of the analogous linear gate with the 5-ns time interval gives a possibility to suppress a random coincidence background. The background is due to a chamber noise and inclined electron tracks.

The measured time-of-flight spectrum at the chamber power supply of 900V is shown in the figure 5.

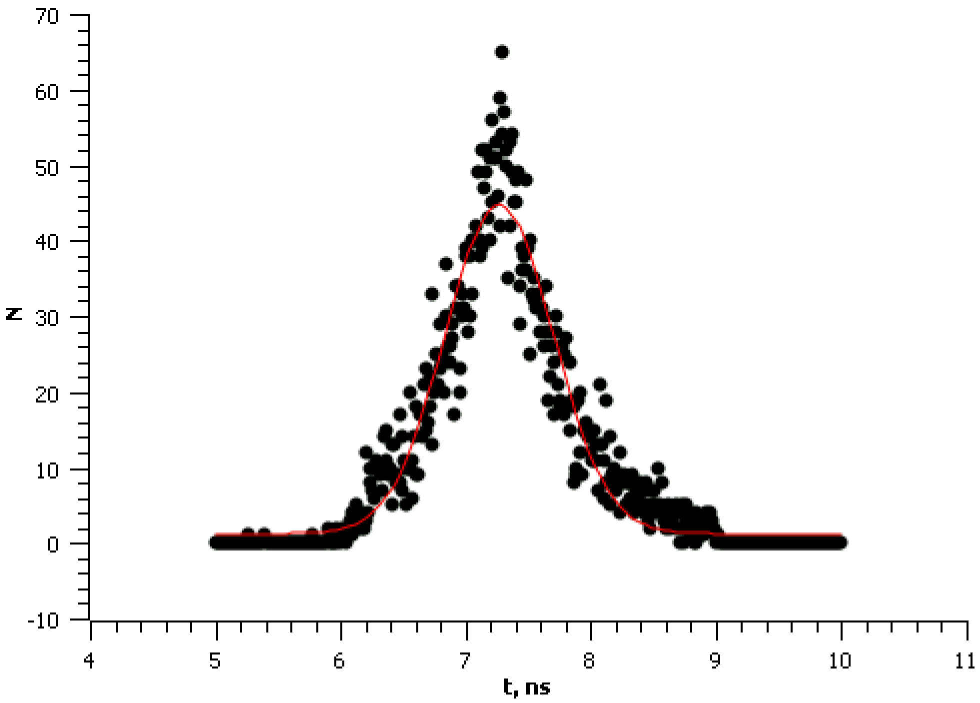


**Figure 5:** A time-of-flight spectrum at the chamber power supply of 900V.

The time-of-flight spectrum at the chamber power supply of 1000V is shown in the figure 6.

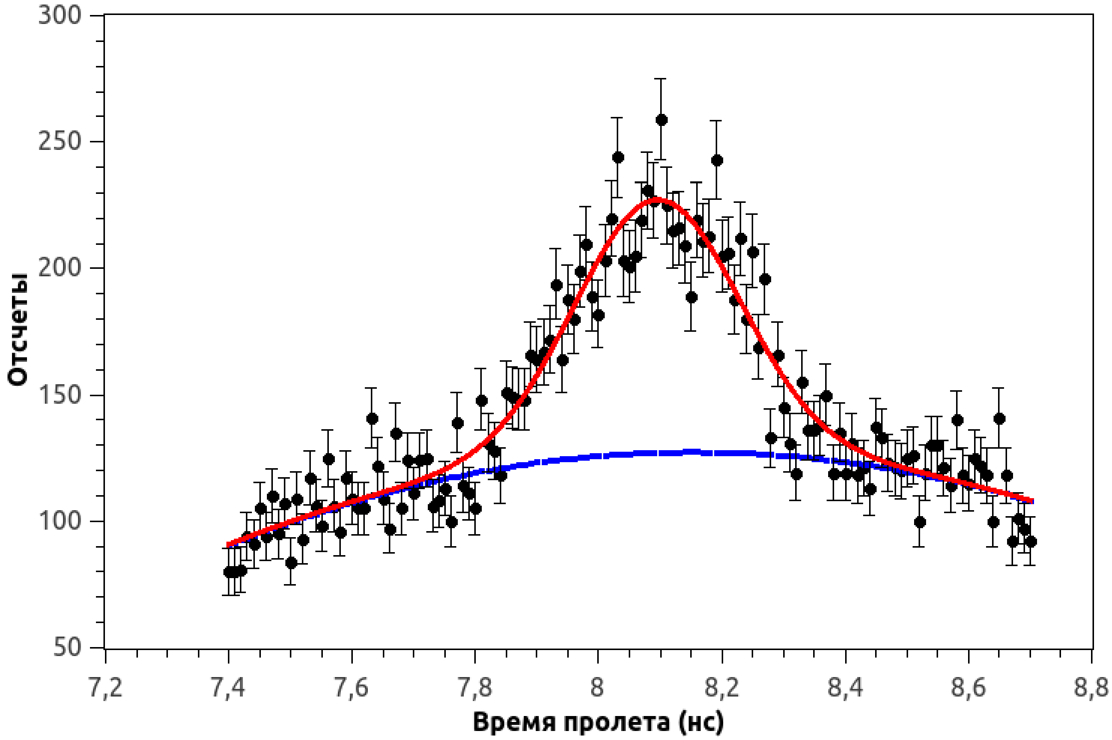


**Figure 6:** A time-of-flight spectrum at the chamber power supply of 1000V.

The time resolution and signal-to-background ratio are calculated with a fitting of the experimental spectra to the gaussian and two order polynom as a background. The timing resistive plate chamber test results are presented in the table 1.

**Table 1:** The timing resistive plate chamber test results.

| No | Power supply, V | Time resolution, ns | Signal-to-background ratio |
|---|---|---|---|
| 1 | 900 | 0,73 | 9,6 |
| 2 | 1000 | 0,27 | 3,8 |

As a result of test measurements the new detector time resolution of 270 ps is obtained under condition of the background electron flux up to $10^6$ $cm^{-2}$ $c^{-1}$.

## 5. Conclusions and Results

1) The timing resistive plate chamber for an operation under condition of an background electron flux up to $10^6$ $cm^{-2}$ $c^{-1}$ is created;
2) The 270-ps time resolution under this condition is obtained;
3) The sentisive area of the detector is equals 10 $cm^2$.

## References

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