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Multistrip multigap symmetric RPC

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Abstract

The characteristics of a symmetric multigap resistive plate chamber with multistrip readout electrode, recently developed by us, continued to be investigated. Studies of the time resolution, efficiency, average charge and dark rate as a function of applied voltage and the influence of the angle of incidence of the detected particle on these observables have been performed. Different type of discriminators have been tested.

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1. Introduction

Recently we reported on a novel concept of a symmetric multigap glass resistive plate chamber with multistrip anodes, read out at both ends [1,2]. The principle configuration, experimental setups used for ^{60}Co source and in-beam tests and the results concerning the time resolution and efficiency have been presented in detail in our previous publication [2].

This paper contains the results of detailed investigations of this new type of GRPC using protons of 1.5 A GeV at the SIS of GSI. The next chapter presents the measured time resolution, efficiency, average charge and dark rate as a function of applied voltage. The position dependence of the time resolution along the counter is presented and discussed in Chapter 3. Chapter 4 describes the results on time resolution and efficiency for an angle of incidence of 55° relative to the orthogonal direction to the counter and the influence of different type of discriminators on the observed time resolution. The conclusions are presented in Chapter 5.

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2. Time resolution, efficiency, average charge and dark rate

For these studies we prepared three type of prototypes of which characteristics can be followed in Table 1. The three prototypes have had similar configuration. The central strip structure readout board divides the counter in two identical halves. It is 0.6 mm thick with strips on both sides, the corresponding strips being connected at the outer left and right end. Each half-houses three plates separated by 2 gaps of 0.3 mm, defined by fishing rod placed between the plates. Both outermost conductive plates are connected to the negative HV. All non-conductive electrodes were floating.

For the long prototypes (I and II in Table 1) the whole ensemble was held together by a support structure of extruded polycarbonate which guarantees the mechanical stability as well as an enforced gas flow through the gaps. For the wide counter (III) the electrodes' structure was held together by four horizontal bars, across the electrodes, centered relative to the fishing rods used as spacers. Such a discrete mechanical support relative to the continuous one in case of extruded material brought to much lower dark counting rate and better parallelism of the electrodes, with a direct influence on the position dependence of the time resolution (see next chapter). The gas containers are stainless steel tubes (I and II) or box (III), respectively. The readout board with the signal strips, the high voltage and the gas in- and outlet are led through the lateral flanges. As counting gas we used the standard mixture of 85% $C_2F_4H_2$, 10% SF_6 and 5% C_4H_{10} (isobutane) flushed at normal pressure.

As an example, Fig. 1 shows the measured dark rate, efficiency, time resolution and average charge as a function of high voltage, for prototype I RPC. If one considers the effective surface of the counter (four operated strips $\sim 123\ \mathrm{cm}^2$), the dark rate increases from $3.6\ \mathrm{Hz/cm}^2$ at 5.8 kV to about $6\ \mathrm{Hz/cm}^2$ at 7 kV. Already at 6.2 kV the counter efficiency is larger than 95%. As far as concerns the time resolution, there is observed a slight difference between the two measured middle strips most probable due to different electronic channels. In the average it improves as a function of HV from about 90 ps at 5.8 kV to 67 ps at 7 kV. The exponential grows of the charge value as a function of applied voltage can be followed in the last plot of Fig. 1.

3. Position dependence of the time resolution

In order to study the position dependence of the time resolution along the counter, we exposed the counter to the beam in different regions, the size of the exposed region for a given position being selected by a finger plastic scintillator ($10 \times 5 \times 80\ \mathrm{mm}^3$) perpendicular to the strips' direction. This type of measurement was done using RPC prototype II, assembled before these new series of tests, with a dark rate of about 1.5 lower than the one corresponding to prototype I, mentioned in the previous section, assembled 8 months earlier, continuously used for ^{60}Co source or in-beam tests.

Table 1
The main characteristics of the three prototypes of RPC used in the investigations described in the present paper

Proto-type	Length (mm)	Width (mm)	Pitch (mm)	Gap (mm)	Resistive electrodes	Cathode	No. of strips	Spacers (μm)
I	900	41	3.44	1.14	1 mm glass	2 mm Al	12	300
II	900	41	3.44	1.14	1 mm glass	1 mm glass covered by Cu foil	12	300
III	200	189	3.0	1.0	1 mm glass	1 mm glass covered by Cu foil	60	300

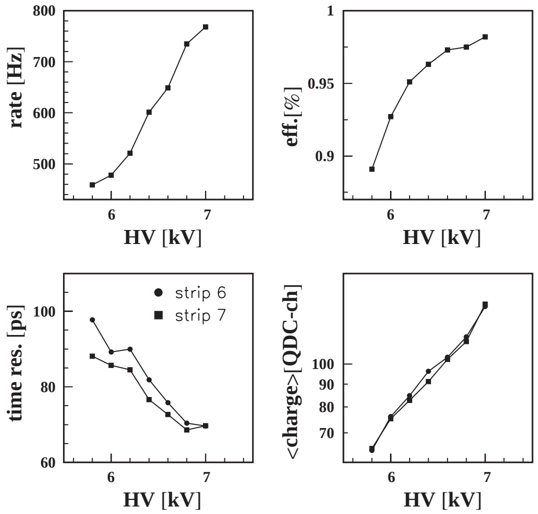

Fig. 1. The dark rate, efficiency, time resolution and average charge as a function of high voltage for Prototype I RPC.

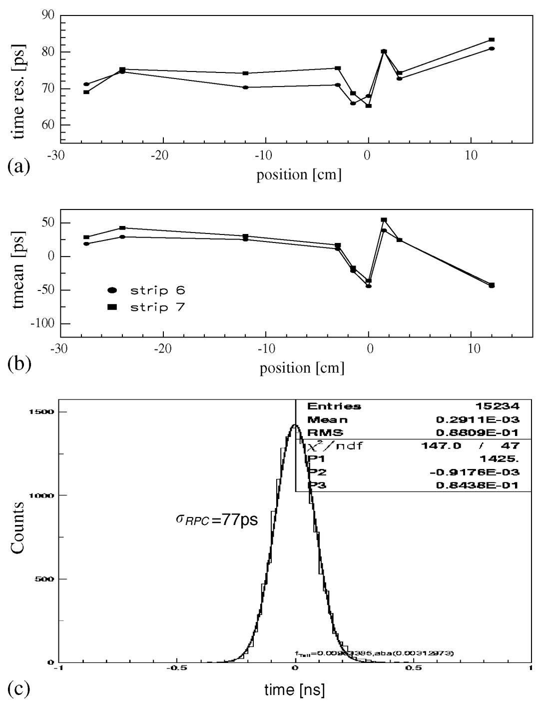

Fig. 2. Timing performance as a function of position along the counter for Prototype II RPC.

Timing performance as a function of position along the counter can be followed in Fig. 2. While the position dependence of the time resolution, represented in Fig. 2a, shows a variation of about 15 ps, the mean value shows variations of about 100 ps, see Fig. 2b. Linearizing the mean time position dependence over the whole measured length one obtains a time resolution of 77 ps (see Fig. 2c). The two measured middle strips show very similar results. Although such position dependence of the counter performances can be corrected, these counters delivering an accurate position information, for large area TOF detectors it is desirable to reduce such dependences at minimum possible. This was the reason to use for prototype III a more refined mechanics for packing the electrodes' stack, decreasing the probability of electrodes' bending. Dedicated ^{60}Co source measurements, in which the whole counter volume was exposed, shown indeed that this is the main effect in the observed position dependences and confirmed us the possibility to reduce it.

4. Time resolution and efficiency for inclined trajectories

For a real experimental configuration for MIPs measurements, based on such counters, many of the incident particles have an inclined trajectory relative to the orthogonal direction to the electrodes' plane. For this test we used prototype III—Box RPC, tilted relative to the beam direction by 55°. The corresponding time spectra is represented in Fig. 3a. A time resolution of 65 ps was obtained relative to 80 ps for the normal incidence, at 6.4 kV. A 2% increase in the efficiency was also observed. This result is expected due to an increase in the counter thickness by a factor of 1.74.

5. Electronic tests

The results presented in the previous chapters were obtained using CES-510 discriminators. For Pestov spark counters [3] were developed special discriminators [4]. Using these type of discriminators for our RPCs, we observed a small change in the time resolution, from 65 to 72 ps (see Fig. 3b). We tested also a new type of discriminator, based

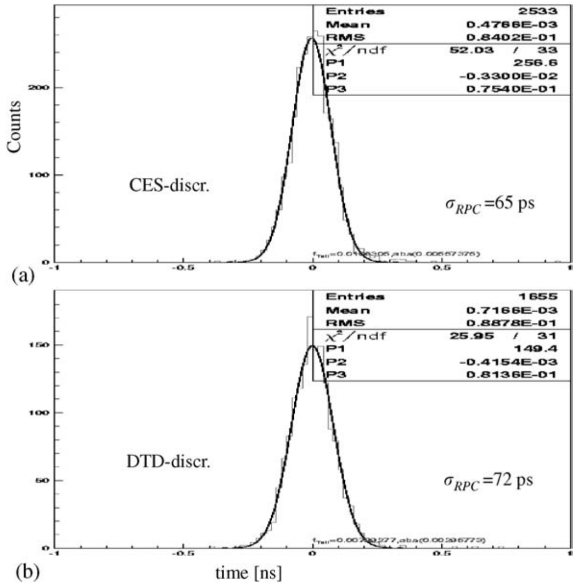

Fig. 3. Time resolution for inclined trajectories using (a) CES-510 discriminator and (b) DTD.

on Motorola CHIP, specially developed by HADES Collaboration at GSI-Darmstadt for high time resolution measurements with diamond detectors (CVD) [5]. An improvement of about 20 ps in the time resolution relative to the CES-510 discriminators was observed.

6. Summary and outlook

We successfully continued the tests of various prototypes of a new configuration of multistrip multigap symmetric resistive-plate chambers recently developed by us. All three prototypes show a time resolution better than 80 ps above 6.4 kV, an efficiency larger than 96% and very low dark rate. Delivering a very good position resolution, the position dependence of the counterperformances can be corrected. After such corrections, the time resolution remains at the above-mentioned values over the whole detector. The reason for this dependence was investigated and better mechanics of the electrodes' packing shown that it can be decreased at an acceptable limit which make unnecessary the position corrections. For the inclined trajectories of the incident particles the detector response in terms of time resolution and efficiency, improves. The best time resolution was obtained using discriminators based on Motorola comparators, while the DTD gave a time resolution of about 10% worse that the one obtained using CES-510 discriminators.

These new results support our conclusions from the previous paper [2] that these multistrip GRPCs are a promising new line of development of high resolution, large-area gas TOF detectors. Their performance in a multihit environment remains to be studied.

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