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V. Ammosov, V. Gapienko, A. Ivanilov, A. Semak,
Yu. Sviridov*, E. Usenko, V. Zaets

COMPARISON OF TIMING PROPERTIES OF GLASS MULTIGAP RPCs WITH 0.3 AND 0.6 MM SUBGAP WIDTH

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*) Corresponding author, E-mail: yu_sviridov@mx.ihep.su

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Abstract

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Two glass RPCs with symmetrical read-out scheme — (2×(2×0.3mm)) and (2×0.6mm) — were constructed and tested at CERN PS T10 beam. Specially developed electronics was used. Electronics resolution convoluted with measured charge spectra at operating point was estimated as about 65 ps. The best time resolutions obtained at low counting rate were 75 ps for the 0.3 mm subgap and about 125 ps for the 0.6 mm one, after slewing corrections. The rate capability of the (2×0.6mm) counter was found to be much worse than for the (2×(2×0.3mm)) one.

Аннотация

Аммосов В., Гапиенко В., Заец В. и др. Сравнение временных характеристик стеклянных многозазорных РПК с шириной зазора 0.3 и 0.6 мм: Препринт ИФВЭ 2002-14. – Протвино, 2002. – 9 с., 7 рис., библиогр.: 9.

Были изготовлены и оттестированы на пучке T10 ЦЕРН две стеклянные резистивные плоские камеры (РПК) с симметричной схемой считывания (2×(2×0.3мм)) и (2×0.6мм). Использовалась специально разработанная электроника. Разрешение электроники, усредненное по измеренным спектрам в рабочей точке, оценивается в 65 псек. Минимальные временные разрешения, полученные при низкой загрузке, после время-амплитудной коррекции составили 75 псек для зазора 0.3 мм и 125 псек для зазора 0.6 мм. Загрузочная способность счетчика (2×0.6 мм) оказалась значительно ниже, чем для счетчика (2×(2×0.3мм)).

INTRODUCTION

In the recent years significant progress was achieved in developing RPCs working in avalanche mode at atmospheric pressure, as TOF detectors [1]. From the point of view of counters design, the following direction was formulated:

– using narrow (sub-millimeter) gas gaps to obtain excellent time resolution;

– summing signals of several such subgaps to have high efficiency, good charge spectrum and to reject tail of delayed signals.

Multigap counters having 5–6 subgaps as narrow as 0.21 mm are under investigation as candidates for the ALICE TOF system [2]. Other groups are developing 4-gaps counters with subgap width 0.3 mm [3].

But up to now there is not enough information about the dependence of RPC time resolution on gas gap width. Time resolution of about 70 ps was obtained for (5×0.22 mm) multigap glass chamber [2] and about 50 ps — for the (2×(2×0.3 mm)) small counters [3]. In [4], about 100 ps resolution was obtained for the four-gaps counter with 0.3 mm gap width; for the double-gap counter with 0.6 mm wide subgaps, the measured time resolution was 180-200ps [5].

The only reserved study of the time resolution dependence on gas gap width was made in [6]. The time resolutions of about 120, 170 and 230 ps were measured for the 0.3, 0.4 and 0.6 mm gas gaps, respectively. It was found, that for this range of gap width, time resolution can be presented as a linear function of gap width with the slope of 40 ps/100 μm.

In the course of our work on the HARP experiment [7] TOF system we have studied two options of glass RPCs, one having 4 subgaps 0.3 mm wide and the other — 2 subgaps 0.6 mm wide. The construction of counters having less number of wider subgaps is obviously simpler and less expensive. We studied what will be the retribution of this approach in terms of operational characteristics of the counter. Though the decision in HARP was made in favour of the 0.3 mm wide gap [8], we believe that our results have nevertheless more general interest.

1. COUNTERS DESIGN AND FRONT END ELECTRONICS

Basing on our previous experience, we used as most promising the symmetrical read-out scheme. That is, in case of 0.6 mm gap, the read-out electrode was placed between two such subgaps. In case of 0.3 mm gap, read-out electrode was placed between two (2×0.3 mm) double-gaps, thus forming (2×(2×0.3 mm)) structure. This approach provides better read-out efficiency (the ratio between measured charge and the avalanche charge inside gas gap) and requires lower voltage than fully serial multigap counters.

As it is seen, in both cases the total gas width was equal to 1.2 mm, to have high efficiency (we have found in course of preparatory studies, that 1 mm total gas thickness gives about 2% lower efficiency).

Glass electrodes were made of 1 mm thick window glass with sensitive area of 130×200 mm^2. Glass volume resistivity was measured to be about 7×10^{12} Ω cm. Uniform gap width was provided by fishing lines with 0.3 and 0.6 mm diameters, respectively, placed with ≃40 mm step between glass plates and fixed with epoxy drops in few points. High voltage was distributed on external surfaces of each substructure (0.6 mm subgap or (2×0.3 mm) double-gap) using carbon film. Assemled glass stacks were put into gas tight aluminum boxes.

We used gas mixture $C_2H_2F_4/iC_4H_{10}/SF_6$ in flow rate composition 90/5/5.

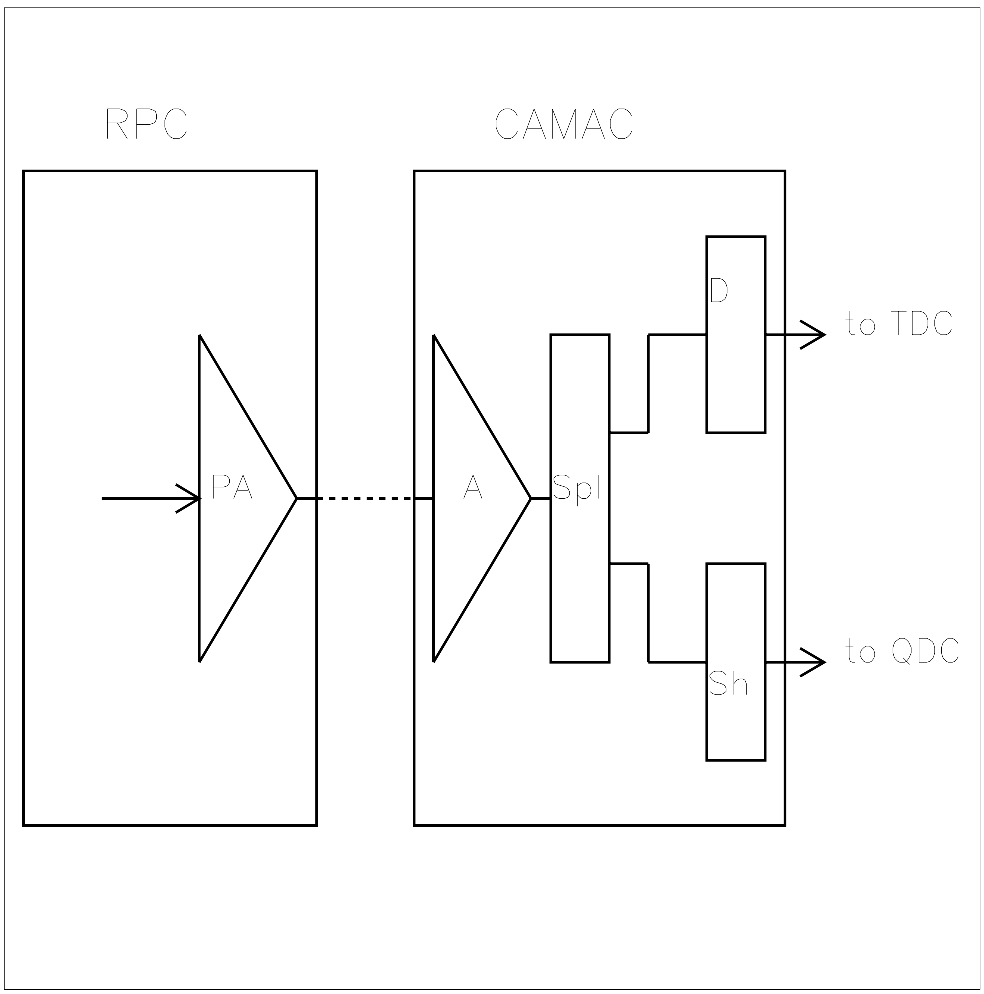

Fig. 1. Block-scheme of electronics: PA — preamplifier, A — amplifier, Spl — splitter, D — discriminator, Sh — analog shaper.

Specially developed electronics consisted (Fig. 1) of the on-counter preamplifier (PA) and remote Splitter-Shaper-Disriminator (SSD) in CAMAC standard. The PA had 100 mV/pC conversion factor and 2 GGz bandwidth. PA output was fed to SSD by coaxial cable about 0.5 m long. SSD provided further signal amplification by 2 and splitted it in two branches. One branch — Shaper — lengthened the tail of the short input pulse for better transition to the remote QDC. The other branch was the discriminator with variable (4 — 10 mV) threshold; output NIM signal of the discriminator was sent to TDC. Measured FEE resolution in dependence on input charge is shown on Fig. 2.

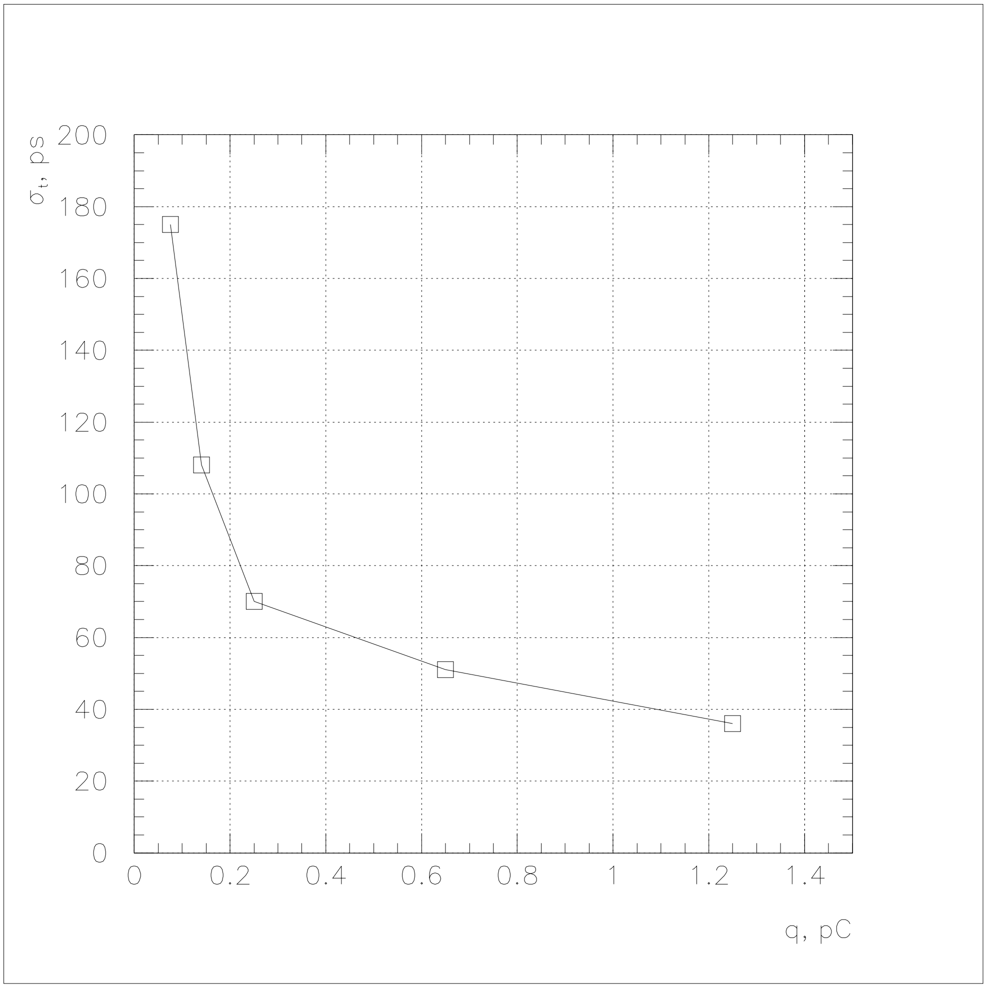

Fig. 2. FEE resolution in dependence on input charge.

Both detectors were tested at T10 CERN PS beam of 7 GeV/c pions using ALICE TOF group environment and DAQ. Trigger counters defined 1×1 cm^2 area on the RPCs. Time resolution of RPCs was obtained by measuring ΔT between RPC signal and the time mark, provided by scintillation counter with 40 ps resolution, also written to TDC. In the results presented further, the resolution of start counter is quadratically subtracted.

2. EXPERIMENTAL RESULTS

Time resolution of RPCs was obtained off-line after slewing correction. The examples of charge spectra, arrival time - charge correlation plots and corrected ΔT distributions for both counters are shown on Figs 3 and 4. Time–charge correlation plots were fitted with appropriate polinom and the corrected time distributions were obtained with respect to this fitting function. These ΔT distributions were fitted with Gaussian, and the standard deviations of the obtained fit are refered further on as time resolutions.

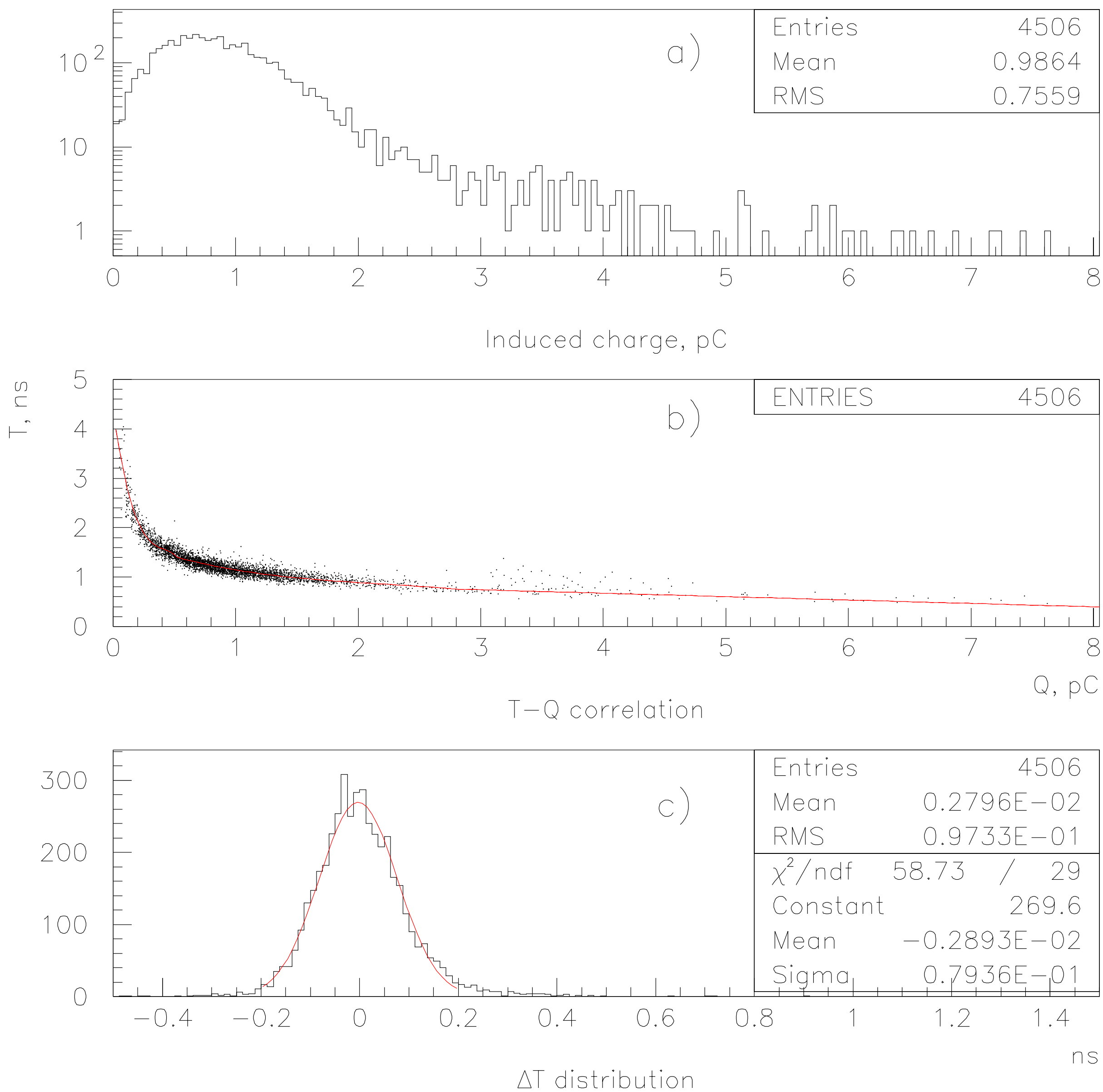

Fig. 3. Charge spectrum, arrival time - charge correlation plot and corrected time distribution for the 0.3 mm subgap counter. HV=6.4 kV.

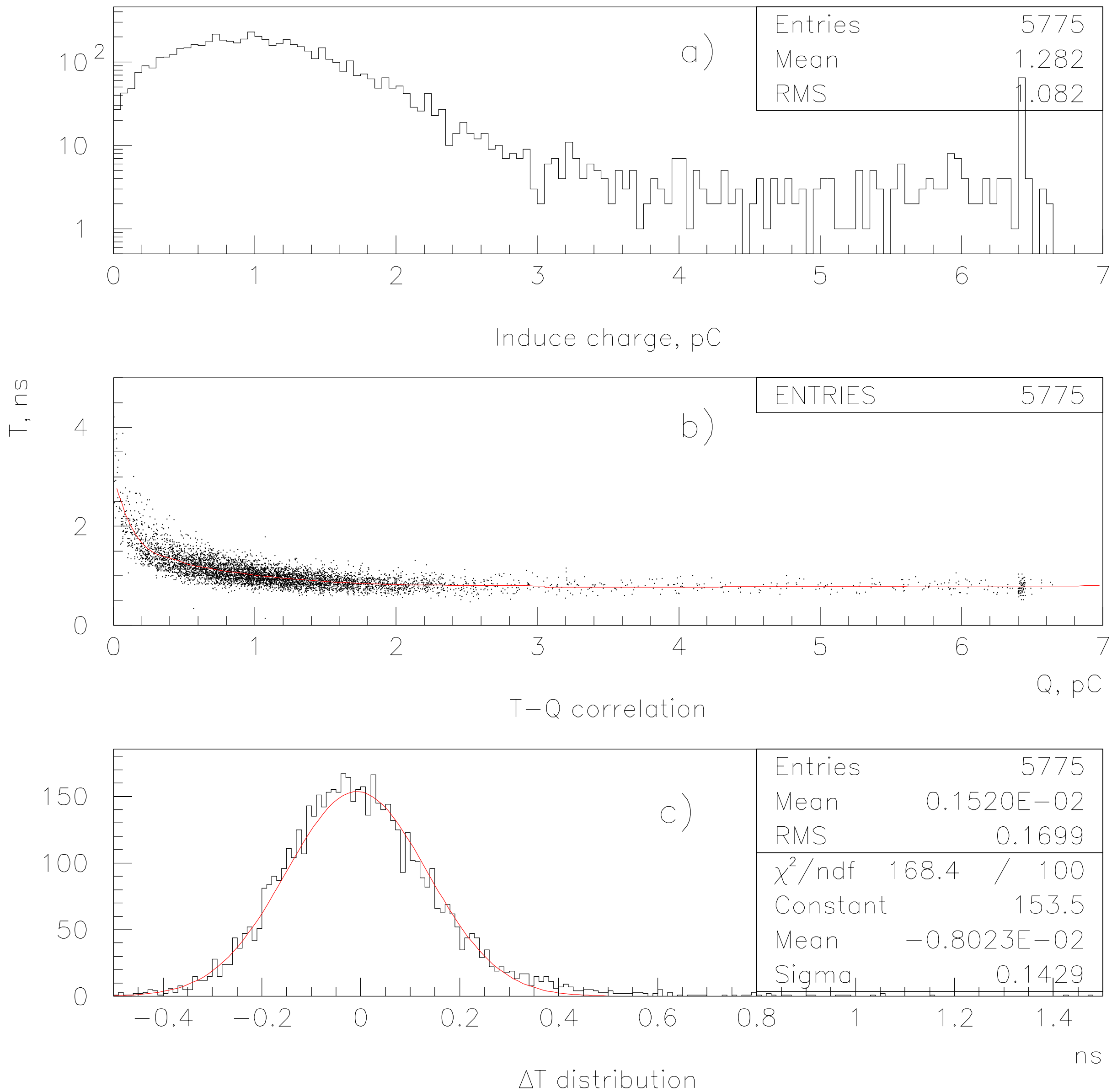

Fig. 4. Same as Fig. 3, for the 0.6 mm subgap counter. HV=5.4 kV.

The results are shown on Fig. 5 as a function of applied HV. Discrimination threshold was set at 4 mV. Total efficiency for the both counters was about 99% in operating region. For both counters, two read-out pads were studied differing in area ten times. For the small pads, the best measured time resolutions are 75 ps for the 0.3 mm subgap and about 140 ps for the 0.6 mm one. These resolutions were achieved at 6.2 and 5.4 kV, respectively. Data for the 0.3 mm counter were measured at beam intensity less than 60 Hz/cm^2 during spill of 300 ms duration. Results for the 0.6 mm counter presented on this Figure were obtained at beam intensity of about 140 Hz/cm^2. As it will be seen later, the best measured time resolution for the (2×0.6 mm) counter at counting rate lower than 100 Hz/cm^2, was 125 ps.

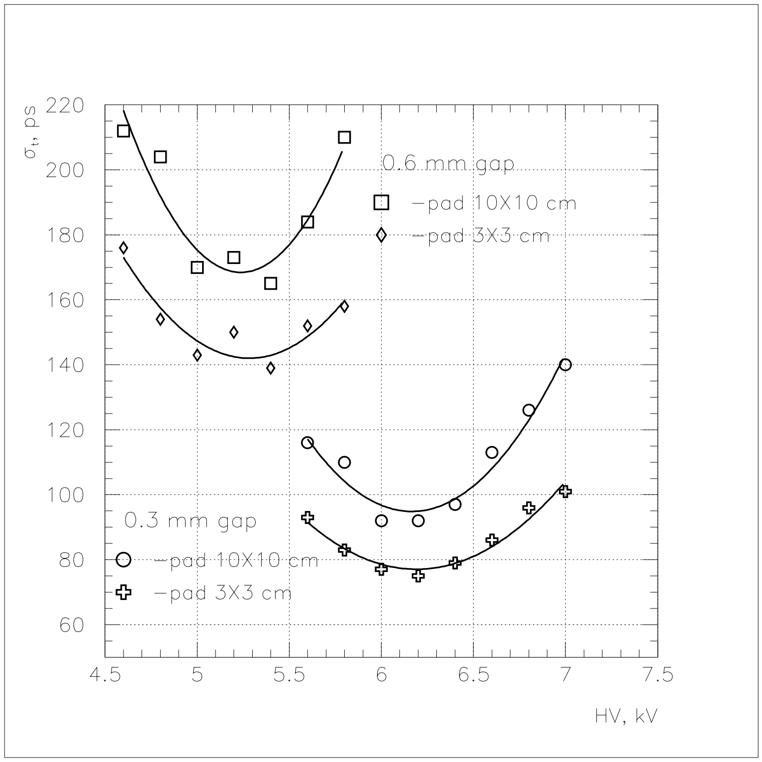

Fig. 5. Measured time resolution for two counters in dependence on applied HV.

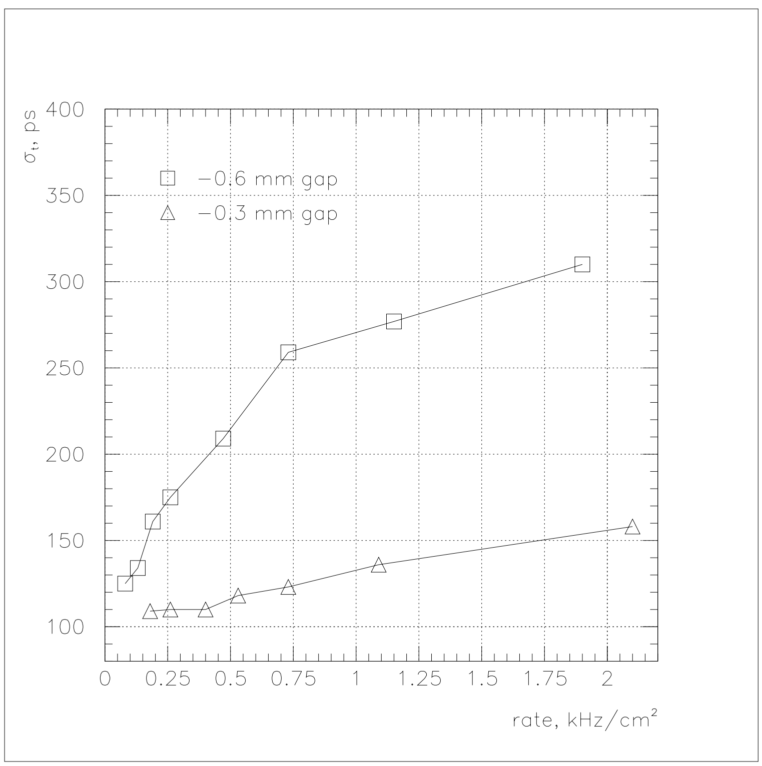

Fig. 6. Time resolution of two counters in dependence on counting rate.

For both counters, ten times larger pads show worse resolution; the difference is about 17 ps for the 0.3 mm subgap and 25 ps — for the 0.6 mm one. The best time resolution was obtained at about 1 pC mean charges for both counters.

Very significant difference was observed in the rate dependence of σ_t for two counters, Fig. 6. The data refer to different pads: it was 100 cm^2 for 0.3 mm subgap and 9 cm^2 for the 0.6 mm one. Degradation of resolution is dramatic for the (2×0.6 mm) counter; there is practically no region of constant time resolution. On the contrary, the (2×(2×0.3 mm)) counter shows much slower resolution degradation. For the rate range up to 2 kHz/cm^2, width of the time distribution for the 0.3 mm subgap is increased on only 50 ps, while this rise is about 200 ps for the 0.6 mm subgap.

On Fig. 7, the dependence of mean measured charges on particle rate is shown for both counters. Average charge for the (2×0.6 mm) counter is decreased about 5 times for the rate range from 0.1 to 2 kHz/cm^2. For the 0.3 mm subgap counter, this dependence is considerably weaker. Such behaviour can be explained by the drop of effective potential difference applied to gas gap due to increased current flow through glass electrodes of high resistivity. Accordingly the counting rate has two-fold influence on the time resolution: decrease in effective electric field strength E in gas gap and decrease in amplitudes of signals. Fig. 7 shows that this effect is more important for the double-gap counter than for the four-gaps one.

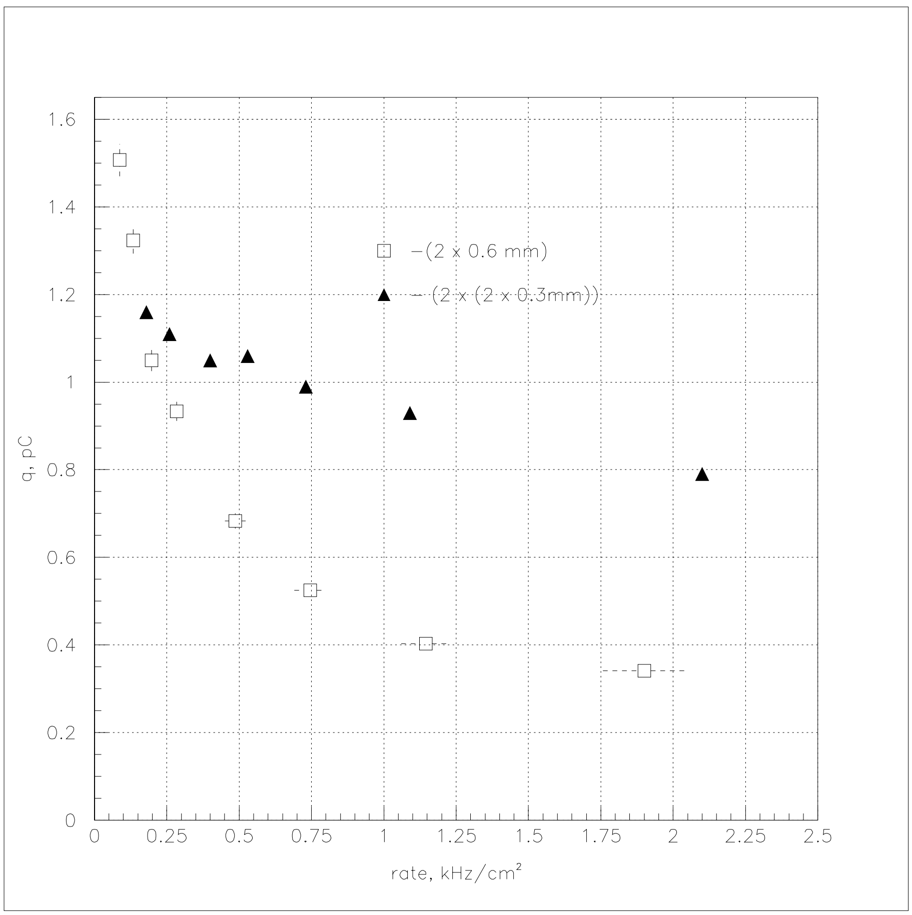

Fig. 7. Average charge dependence for two counters on counting rate.

3. DISCUSSION

As it was said, the best measured time resolutions were 75 ps for the 0.3 mm subgap width and 125 ps — for the 0.6 mm one. Some remarks should be made however.

Keeping in mind very strong dependence of time resolution on the particle rate for the 0.6 mm subgap counter, we can extrapolate measured dependence (Fig. 6) to obtaine $\sigma_t \simeq 100$ ps for this detector at low rate. FEE electronics resolution averaged over measured charge spectra (Fig's 3 and 4) can be estimated approximately as 65 ps. After quadratic subtraction of this estimate from the above values, one obtaines resolutions of 40 and 80 ps for the 0.3 mm and 0.6 mm subgaps, respectively.

What can be expected for σ_t vs gap width dependence? It is known that time resolution is proportional to the rise time of the detector signal T_f, which in turn in our case is proportional to $1/\alpha v_d$. Here α is effective first Townsend coefficient and v_d — electrons drift velocity for the gas mixture used.

Both these quantities are expected to increase with electrical field strength E, which was 10.3 kV/mm for 0.3 mm counter and 8.75 kV/mm for the 0.6 mm one, at points of the best resolution. There are unfortunately no measurments of α and v_d in this region for the gas mixture used. Quite recently [9] the results of simulation of these quantities in dependence on E were reported. According to these data, the product αv_d decreases 1.7 times for the E range from 10.3 kV/mm to 8.75 kV/mm, which seems to be compatible with our estimate $\sigma_{0.6}/\sigma_{0.3} \simeq 2$, taking into account uncertanties in our analysis.

CONCLUSION

Timing characteristics of two multigap Resistive Plate Counters with different subgap width of 0.3 mm and 0.6 mm were measured. The same specially developed FEE was used.

The best measured time resolutions were 75 and 125 ps for the $(2\times(2\times0.3\text{mm}))$ and $(2\times0.6\text{mm})$ counters, respectively. It was found that the later counter is much more sensitive to the particle rate than the former one.

Our results indicate also that the time resolutions achievable for the two counters are about 40 and 80 ps for the 0.3 and 0.6 mm subgaps, respectively.

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