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

State Research Centre of Russian Federation
Institute for High Energy Physics
142281 Protvino Moscow region Russia

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

Abstract

Two glass RPCs with symmetrical read-out scheme — (2×(2×0.3mm)) and (2×0.6mm) — were con-
structed 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.

Key words: glass RPC, time resolution.
PACS 29.40.Cs.
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 130×200mm². Glass volume resistivity was measured to be about 7×10¹² Ωcm. 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. Assembled glass stacks were put into gas tight aluminum boxes.

We used gas mixture C₂H₄F₄/iC₄H₁₀/SF₆ in flow rate composition 90/5/5.

Specially developed electronics consisted (Fig. 1) of the on-counter preamplifier (PA) and remote Splitter-Shaper-Discriminator (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.

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 cm² area on the RPCs. Time resolution of RPCs was obtained by measuring ∆T 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 ∆T distributions for both counters are shown on Figures
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 ps for the (2×0.6 mm) counter and 125 ps for the (2×0.3 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/cm², 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/cm². 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.

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 obtain σ₀ ≈ 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 obtains resolutions of 40 ps and 80 ps for the 0.3 mm and 0.6 mm subgaps, respectively.

What can be expected for σ₀ vs gap width dependence? It is known that time resolution is proportional to the rise time of the detector signal T_r, which in turn in our case is proportional to 1/αν_d. Here α is effective first Townsend coefficient and ν_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 measurements of α and ν_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 αν_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 σ₀.6/σ₀.3≃2, taking into account uncertainties 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 ps and 125 ps for the (2×(2×0.3 mm)) and (2×0.6 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.

ACKNOLEDGEMENTS

The authors would like to thank M.C.S.Williams and ALICE TOF group for continuous support.
REFERENCES

1. W.Klempt, Nucl. Instr. Meth., Vol. A433, 1999, 542.

2. A.Akindinov et al., Nucl. Instr. Meth., Vol. A456, 2000, 16.

3. P.Fonte et al., Nucl. Instr. Meth., Vol. A449, 2000, 295.

4. A.Akindinov et al., ITEP preprint 20-99, Moscow, 1999.

5. A.Akindinov et al., ITEP preprint 45-98, Moscow, 1998.

6. P.Fonte et al., CERN preprint CERN-EP/99-68, Geneva, 1999.

7. HARP proposal. http://harp.web.cern.ch/harp

8. M.Bogomilov et al., The RPC time-of-flight system of the HARP experiment, presented by J.Wotschack at the 6th Int. Workshop on RPCs and Related Detectors, Coimbra, Portugal, 2001: http://doc.cern.ch/DTP/dtp-2001-029/files/MainFile/

9. Talk of W.Riegler at the 6th Int. Workshop on Resistive Plate Chambers and Related Detectors, Coimbra, Portugal, 2001. http://www-lip.fis.uc.pt/~rpc2001/pdf/riegler.pdf
Fig. 1.  Block-scheme of electronics: PA — preamplifier, A — amplifier, Spl — splitter, D — discriminator, Sh — analog shaper.
Fig. 2. FEE resolution in dependence on input charge.
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.
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.
Fig. 7. Average charge dependence for two counters on counting rate.