

High counting rate, differential, strip read-out, multi gap timing RPC

**M. Petrovici^{*},^a M. Petriș,^a V. Simion,^a D. Bartoș,^a G. Caragheorghopol,^a,
F. Constantin,^a L. Rădulescu,^a J. Adamczewski-Musch,^b I. Deppner,^c K. Doroud,^d
N. Herrmann,^c S. Linev,^b P. Loizeau,^c and M.C.S. Williams,^e**

^a*National Institute for Physics and Nuclear Engineering, Bucharest, Romania*

^b*Gesellschaft für Schwerionenforschung, Darmstadt, Germany*

^c*Physalisches Institut der Universität Heidelberg, Germany*

^d*CERN, Geneva, Switzerland*

^e*INFN, Bologna, Italy*

E-mail: mpetro@nipne.ro

Based on single ended strip structure, symmetric, multi gap RPC, developed by us more than a decade ago, the time-of-flight barrel of FOPI experiment at GSI-Darmstadt was designed, constructed and is currently in operation. Motivated by the requirements of the next generation experiments in terms of very good time resolution in high counting rate and multiplicity environment, a new architecture of differential, strip structure, symmetric, multi gap timing RPC was developed. The results on efficiency, two dimensions position resolution, time resolution and performance in high counting rate environment using low resistivity glass electrodes are reported.

XI Workshop on Resistive Plate Chambers and Related Detectors

5-10 February, 2012

Laboratori Nazionali di Frascati dell'INFN - Frascati (Rome) - Italy

^{*}Speaker.

1. Introduction

With the aim to enhance the particle identification performance of the FOPI device, more than a decade ago, we proposed a completely novel symmetric multigap RPC concept, read out via multistrip anodes, similar to Pestov counters [1, 2, 3, 4]. The first prototype had 16 readout strips of 300 mm length with a pitch of 2.54 mm and the second 12 readout strips of 900 mm length with a pitch of 3.44 mm. During the preparation of the paper [3], where we reported time resolution of 70-80 psec, $\sim 95\%$ efficiency and a non-Gaussian tail of 1%, we learned that Coimbra group has build and tested a detector of $160 \times 10 \text{ cm}^2$ of similar structure with two anode strips of 50 mm width [5]. As a conceptual difference, our design is able to measure the position across the strips with an accuracy better than the strip width. Intense R&D activities following the first promising results, on both sides, detector [6] and front end electronics [7, 8] finalized with the construction of the FOPI RPC time-of-flight barrel [9, 10] successfully running in the last 4 years. The first large area multi gap timing RPC based on many wide strips (3.2 cm pitch) was developed for muons detection in extensive air showers, as well as for looking for unexpected cosmic events, within the Extreme Energy Events (EEE) Project [11].

Next generation experiments such as CBM [12] at FAIR aim to select rare probes in high multiplicity environment at collision rates up to 10^7 events/sec. Hadron identification in such conditions is a real challenge requiring intensive R&D activities for developing very good time and position resolution and high granularity detectors at reasonable cost. The low polar angles region of CBM-TOF detector will be exposed at counting rates of the order of 20 kHz/cm^2 . Being a fixed target experiment aiming to measure collisions up to Au+Au at 25 A-GeV the hit density varies from $6 \cdot 10^{-2}/\text{dm}^2$ at the outer regions to $1/\text{dm}^2$ for the most inner zone of the detector. Therefore, an occupancy smaller than 5% requires very high granularity. Promising results in terms of performance of standard single ended strip structure RPC or differential architecture strip RPC based on low resistivity glass electrodes of Pestov type were obtained already a few years ago [13, 14]. In order to increase the granularity, the longitudinal strip architecture was replaced by a transverse strip architecture, the performance in terms of efficiency and time resolution being presented at the last RPC2010 Workshop [15]. Based on these promising results new prototypes were developed; their characteristics and in-beam test results are presented in this contribution.

2. Description of detector configuration

As it was mentioned in the introduction, we designed and built the new prototypes based on a complete symmetric architecture relative to median plane. This can be followed in the zoomed zone of Fig.1. Among other advantages, such a structure allows to use lower absolute values of the applied voltages as far as this is applied on both, the cathode and anode electrodes. The high voltage and read-out electrodes have the same strip structure. The strip configuration was maintained the same as in the case of previous prototypes [15], i.e. 2.54 mm pitch, 1.1 mm strip width and 1.44 mm gap width. Three such prototypes, each of them with an active area of $46 \times 180 \text{ mm}^2$ were built. The difference among them is the following: RPC1 has the strip structured high voltage electrode in contact with a resistive layer deposited on the last float glass electrode, for RPC2 the strip structured high voltage electrode is in direct contact with the last float glass electrode. Both

RPC1 and RPC2 are based on float glass resistive electrodes of 0.55 mm thickness and have 2×7 $140 \mu\text{m}$ gas gaps. RPC3 is based on low resistivity glass electrodes [16] of 0.7 mm thickness, 2×5 $140 \mu\text{m}$ gas gaps and the same pitch size, the high voltage electrode strips being in direct contact with the last glass electrode. Each RPC prototype has 72 strips. A photo of the in-beam set-up is presented in Fig.2. In order to access the position information along the strips for some runs one of the RPC was positioned orthogonal relative to the other two. Signals delivered by the RPC strips at both ends were amplified and discriminated by differential front end electronics based on NINO chips [17] and sent to 32-channels V1290A CAEN TDCs. Signals from 15 strips of each counter were recorded.

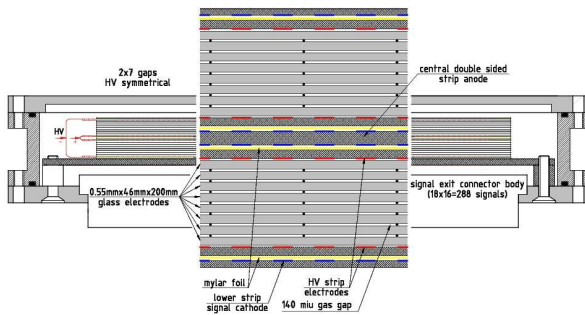


Figure 1: Schematic drawing of a complete symmetrized RPC structure, easy to be followed in the zoomed zone of the figure

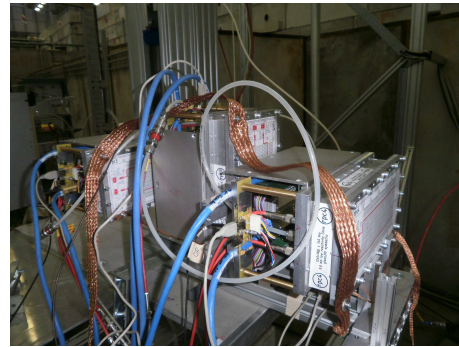


Figure 2: In-beam position of the three RPC prototypes, see the text. The middle one is rotated by 90° for position resolution measurement along the strip direction

As it will be seen in the next chapter, the results obtained with these prototypes in terms of time resolution, position resolution along and across the strips are excellent. However, the number of channels required to equip the most forward polar angles of the CBM TOF Wall with RPC cells of this type is quite high ($\sim 140,000$ electronic channels), with direct consequence on the cost. In order to reduce the cost, a new prototype was designed and built. The strip structure of the electrodes has 7.112 mm pitch (5.588 mm strip width and 1.524 mm gap width) and 96 mm length. It is based on low resistivity glass electrodes [16] of 0.7 mm thickness, 2×5 $140 \mu\text{m}$ gas gaps. Two such cells of $96 \times 280 \text{ mm}^2$ active area covered by 40 strips were constructed. They were staggered having an overlap of 6 mm along the strips and introduced in the same gas box, see Fig.3. A highly integrated new version of mother boards using NINO chip are used for signal processing. An idea on integration of the electronics can be followed in Fig.4 where a photo of the back plane housing box with the electronics can be followed. Signals from 64 strips were recorded. Time-over-Threshold (ToT) information delivered by NINO chip was used for slewing correction and position information across the strips.

3. In-beam tests

Detailed tests done in our laboratory in Bucharest showed a negligible noise and dark counting rate of all the prototypes described in the previous chapter. The in-beam tests of the first three prototypes were performed at PS-CERN, using a pion beam of 6 GeV/c. Two pairs of plastic

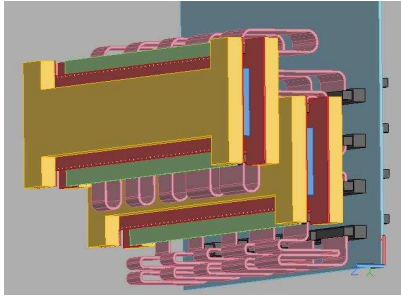


Figure 3: Schematic presentation of the geometrical configuration of the two RPC cells introduced in a common gas box

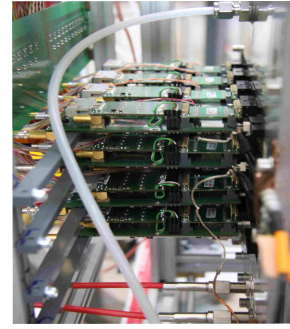


Figure 4: Photo of the back plane gas box, housing two RPC cells, with the electronics motherboards based on NINO chip

scintillators, with $1 \times 1 \text{ cm}^2$ overlap, were used as active collimators and 2 plastic scintillators, with $2 \times 2 \text{ cm}^2$ overlap, were used as time reference. Two channels of each TDC were used for recording the signals of the reference plastic scintillators. Three different gas mixtures were tested, i.e. $85\% \text{C}_2\text{F}_4\text{H}_2 + 5\% \text{SF}_6 + 10\% \text{iso-C}_4\text{H}_{10}$, $90\% \text{C}_2\text{F}_4\text{H}_2 + 5\% \text{SF}_6 + 5\% \text{iso-C}_4\text{H}_{10}$ and $95\% \text{C}_2\text{F}_4\text{H}_2 + 5\% \text{SF}_6$. The high counting rate tests were performed at COSY-Jülich with protons of 2.5 GeV/c. Besides the new prototype based on two RPC cells of 7.112 mm strip pitch, in the beam line was installed also RPC3, used as reference. The RPCs were flushed by $85\% \text{C}_2\text{F}_4\text{H}_2 + 10\% \text{SF}_6 + 5\% \text{iso-C}_4\text{H}_{10}$ gas mixture.

3.1 Cluster size

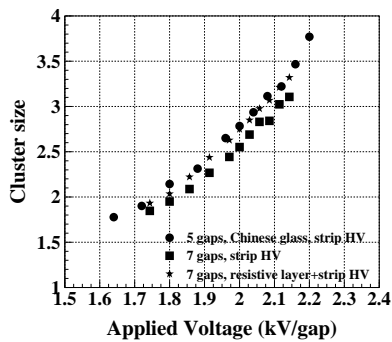


Figure 5: Cluster size for the three 2.54 mm strip pitch RPCs as a function of applied voltage

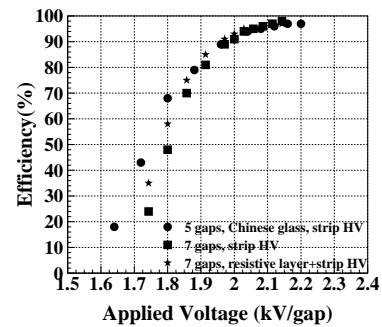


Figure 6: Efficiency for the three 2.54 mm strip pitch RPCs as a function of applied voltage

In Fig.5 the cluster size as a function of applied voltage per gap is presented for RPC1, RPC2 and RPC3. The RPC2, in which the strips of the high voltage electrodes are in direct contact with the float glass electrodes, systematically shows a lower cluster size of about 0.25 strips. At $\sim 2.1 \text{ kV/gap}$ where an efficiency large than 95% is reached, the cluster size is ~ 3 strips, i.e. 7.5 mm.

3.2 Detection efficiency

The efficiency of each RPC is calculated as the number of events with hits in a valid time

window and ToT information divided by the number of triggers. The results are presented in Fig.6. At lower voltages, before reaching the efficiency plateau, systematically RPC3 based on low resistivity glass has higher efficiency than RPC1 based on float glass with the the strips of the high voltage electrode in contact with a resistive layer applied on the last glass electrode. RPC2, where the high voltage strips are in direct contact with the glass electrode, has the lowest efficiency. However, at 2.1 kV/gap all prototypes have an efficiency of $\sim 97\%$.

3.3 Time resolution

The time resolution was measured using the plastic scintillators as reference time or the time difference between two RPCs considering that they have the same time resolution. In Fig.7 is presented the time resolution of RPC1 as a function of applied voltage, for three gas mixtures, using the plastic scintillator as reference time. The isobutane improves the time resolution by $\sim 15\%$, at 2.1 kV/gap the time resolution being better than 50 psec. Fig.8, where the time resolution for different runs using the time difference between RPC3 and RPC2 is presented, confirms the previous result.

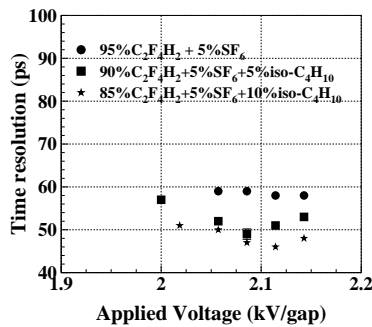


Figure 7: Time resolution of RPC1 as a function of applied voltage for the 3 gas mixtures mentioned on the figure

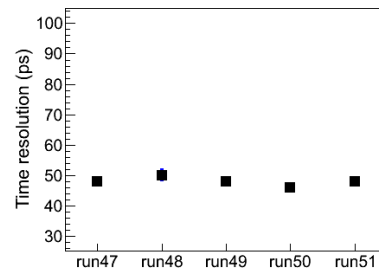


Figure 8: Time resolution using the time difference between RPC3 and RPC2 under the hypothesis that both counters have the same time resolution

3.4 Position resolution

As far as each strip is read-out at both ends, using the time difference one could access the position information along the strip. In order to extract the resolution, we conditioned the position spectrum by the strip number of RPC prototype rotated by 90° , as shown in Fig.2. The obtained position resolution along the strip direction is presented in Fig.9 for two strips using the condition on 5 orthogonal strips of the reference counter. A position resolution of ~ 4.5 mm is obtained. The position information across strips was obtained using the runs where all three prototypes had the same orientation. In Fig.10 are presented the results obtained using the residuals distribution relative to the track reconstructed using the position information of all three counters. The hit position in each counter was obtained using a Gaussian Pad Response Function. The position resolution depends on the type of glass and the way in which the high voltage is applied, i.e. directly on the glass electrodes or via a resistive layer. It ranges between $220 \mu\text{m}$ and $450 \mu\text{m}$. The RPCs were operated at 2.1 kV/gap.

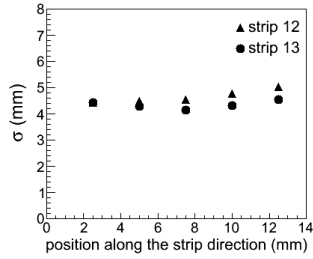


Figure 9: Position resolution along two strips using the condition on the orthogonal strips of the reference counter

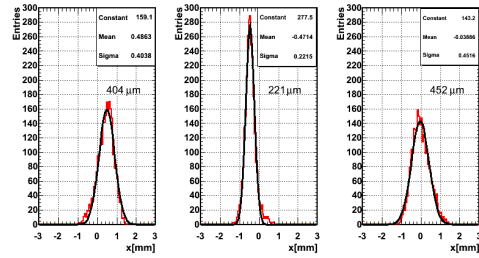


Figure 10: Position resolution across the strips for RPC3, RPC2 and RPC1 using residual distributions relative to the track determined by all three counters

3.5 High counting rate performance

The counting rate performance of the 7.112 mm pitch prototype, based on two overlapping cells can be followed in Fig.11 and Fig.12. Fig.11 shows the time resolution obtained using the time difference between the overlapped zones while Fig.12 shows the time resolution and efficiency using the RPC3 as reference counter. Even at 100,000 particles/cm²·sec, the time resolution remains better than 80 psec and the efficiency higher than 90%.

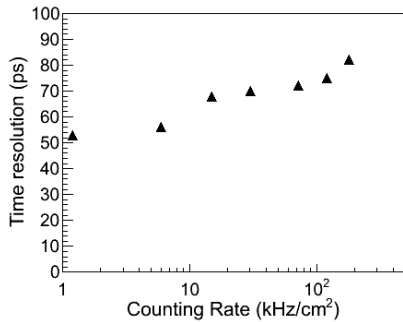


Figure 11: Time resolution obtained using the two overlapped RPC cells as a function of counting rate

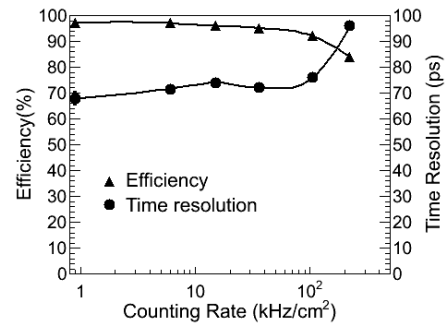


Figure 12: Efficiency and time resolution (using RPC3 as reference counter) as a function of counting rate

4. Conclusions

Based on the results presented in this contribution it can be concluded that differential, strip read-out, multi gap timing RPC, based on low resistivity glass electrodes, is the way to go for high counting rate and high granularity, as required by the next generation experimental devices. Test for multi-hit performance and high counting rates all over the counter will be performed in the near future.

Acknowledgments

We acknowledge V.Aprodu, L.Prodan, A.Radu for their skilful contribution to the construction

of detectors. This work was supported by WP18-HP2 of FP7-2274431, WP19-HP3 of FP7-283286, CAPACITAȚI/Modul3-42EU and PN09370103 financed by Romanian National Authority for Scientific Research.

References

- [1] M. Petrovici et al, *Two times double gap strip lines read-out RPC IFIN-HH Scientific Report 1999* (2000) 59
- [2] M. Petrovici et al, *Development of Multistrip Glass Resistive-Plate Counters (GRPC) GSI Scientific Report 2001 2002-1* (2002) 216
- [3] M. Petrovici et al, *A large-area glass-resistive plate chamber with multistrip readout Nucl.Instr. and Meth.Phys.Res. A487* (2002) 337
- [4] M. Petrovici et al, *Multistrip Multigap Symmetric RPC VI Workshop on Resistive Plate Chambers and Related Detectors, Coimbra, Portugal, 26-27, November, 2001, Nucl.Instr. and Meth.Phys.Res. A508* (2003) 71
- [5] A. Blanco et al, *A Large Area Timing RPC Preprint LIP 01-04* (2001)
- [6] A. Schuttauf et al, *Performance of the multistrip-MRPCs for FOPI Nucl.Phys.(Proc.Suppl) B158* (2006) 52
- [7] K. Koch et al, *A new TAC-based multichannel front-end electronics ... with very high time resolution IEEE Trns. Nucl.Sci. NS-52* (2005) 745
- [8] M. Ciobanu et al, *A Front-End Electronics Card Comprising a High Gain/High Bandwidth Amplifier and a Fast Discriminator for Time-of-Flight Measurements IEEE Trns. Nucl.Sci. NS-54* (2007) 1201
- [9] M. Kiš et al, *Strip Readout RPC Based on Low Resistivity Glass Electrodes Nucl.Instr. and Meth.Phys.Res. A646* (2011) 27
- [10] M. Kiš et al, *Performance of FOPI MMRPC Barrel in Recent Heavy-Ion Experiments RPC2012 - XI Workshop on Resistive Plate Chambers and Related Detectors February 5-10, 2012, Frascati* (2012)
- [11] M. Abbrescia et al, *Multigap Resistive Plate Chambers for EAS study in the EEE Project Proceedings of the 30th International Cosmic Ray Conference, Mexico City, Mexico, 2007 Vol. 5 (HE part 2)* (2008) 1565
- [12] CBM Collaboration, *Compressed Baryonic Matter Experiment Technical Status Report* (2005)
- [13] D. Bartoş et al, *High granularity, symmetric differential readout - timing multigap RPC 2008 NSS/MIC, Book Series:IEEE Nuclear Science Symposium Vol 1-9* (2008) 1933
- [14] M. Petriş et al, *Strip readout RPC based on Low Resistivity Glass Electrodes Romanian Journal of Physics 56* (2011) 349
- [15] M. Petriş et al, *Toward a high granularity, high counting rate differential readout RPC X Workshop on Resistive Plate Chambers and Related Detectors, GSI Darmstadt, February 9 - 12, 2010, Nucl.Instr. and Meth.Phys.Res. A661* (2012) S129
- [16] Wang Yi, *Aging test of high rate MRPC RPC2012 - XI Workshop on Resistive Plate Chambers and Related Detectors February 5-10, 2012, Frascati* (2012)
- [17] F. Anghinolfi et al, *NINO: an ultra-fast and low-power front-end amplifier/discriminator ASIC designed for the multigap resistive plate chamber Nucl.Instr. and Meth.Phys.Res. A533* (2004) 183