

Development of a time resolution and position sensitive Multi-Gap Multi-Strip RPC for high counting rate experiments

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Abstract. A full differential strip readout multi-gap RPC was developed to meet high counting rate and high multiplicity requirements of a high collision rate experiments as Compressed Baryonic Matter at the future FAIR facility. The Multi-Gap, Multi-Strip Resistive Plate Chamber (MGMSRPC) is a completely symmetric two stack structure with time resolution around 50 ps and a detection efficiency better than 95%. A very good efficiency and time resolution at counting rates exceeding the CBM-TOF requirements is obtained using low resistivity ($\sim 10^{10} \Omega\text{cm}$) glass electrodes.

1. Introduction

Next generation experiments such as the Compressed Baryonic Matter (CBM) [1] at the future Facility for Antiproton and Ion Research (FAIR) [2] in Darmstadt will be confronted with the selection of rare probes in high multiplicity environment (up to 1000 tracks/event) at collision rates up to 10^7 events/s. Hadron identification in such a limiting environment is a real challenge. In the current design of the CBM experimental set-up the hadron identification is based on Time-of-Flight (ToF) measurements provided by a wall of Multi-gap Resistive Plate Chambers (MRPC). The low polar-angle region of a fixed target experiment like CBM will be exposed to high counting rates up to 25 kHz/cm^2 and high multiplicities. Therefore, a high counting rate and high granularity detector is required for this particular region.

2. Multi-Gap, Multi-Strip Resistive Plate Chamber

Fall of 1999 we proposed a new multi-gap resistive plate chamber architecture with readout on a multi-strip electrode - MGMSRPC (Multi-Gap, Multi-Strip Resistive Plate Chamber) [3]. The prototype was a double stack, multi-gap symmetric structure with 2×2 gas gaps of $300 \mu\text{m}$ thickness each. The resistive electrodes are made of commercial float glass with a resistivity of the order of $\sim 10^{13} \Omega\text{cm}$. The counter was based on a single ended standard readout with the signals picked up only from the central anode. The readout on 16 strip lines (2.54 mm strip pitch) placed on both sides of the anode allows in addition to a very good time resolution the access to position information on both orthogonal directions that define the readout electrode plane: along and across the strips. The time of flight is obtained as the mean of the time information measured at the both ends of a strip. In this way, the dependence of the time information on



the position along the strip is canceled. The difference of the times measured at the two ends gives the position information along the strip. The transverse position is reconstructed applying the centre of gravity method to the signals induced on adjacent strips around the particle track. The functionality of the two designed and constructed prototype versions (300 mm and 900 mm strip length), was first tested with a ^{60}Co radioactive source in the detector laboratory. A typical ^{60}Co time resolution of about 90 ps was obtained [3]. The in-beam test performed with minimum ionizing particles at SIS18 accelerator of GSI Darmstadt demonstrated a very good performance: a time resolution of 70 ps for an efficiency larger than 95% [4]. Based on this new architecture, the upgrading of the FOPI ToF barrel was done, extending the kaon identification from 0.5 GeV/c to 1.3 GeV/c for beam energies up to 2 AGeV and 1 m flight path [5]. The successful commissioning of FOPI ToF barrel showed that large area detectors based on such an architecture is feasible.

3. High Counting Rate, High Multiplicity MGMSRPC

Our recent R&D activity has been focused on development of a MGMSRPC prototype for high counting rate environments, as it is anticipated to be in the most inner zone of the CBM-ToF wall. The classical timing multi-gap RPCs using float glass as resistive electrodes keep their performance up to about 1 kHz/cm² counting rate [6]. To extend the rate capability, the drop of the potential of the glass electrode should be restored faster. The solutions are the use of electrodes with lower resistivity, thinner resistive electrodes or build counters with smaller gap size in order to reduce the avalanche charge per gap.

Our first chambers developed for high counting rate experiments were based on resistive electrodes made from a special glass, with a resistivity of the order of 10^{10} Ωcm , known as Pestov glass [7]. The first prototype built using 300 mm length x 46 mm width glass of 2 mm thickness [8] had the same inner structure as the MGMSRPC prototype described in Section 2. A second prototype was built with a strip differential readout [9]: the signals are picked up from both the central anode and the outermost cathodes. This new architecture was developed being aware that the pick-up of external noise and the effect of internal cross talk between transmission lines corresponding to different strips are reduced once the counter has a differential structure and is correspondingly operated. All prototypes developed further have a differential read-out, the signals being processed by an amplifier/discriminator based NINO ASIC chip [10]. The in-beam test of both prototypes was performed with 28-30 MeV electron beam at ELBE facility in Dresden. The obtained time resolution for single-ended readout MGMSRPC was around 60 ps in conditions of a 1 kHz/cm² uniform illumination of the detector [8]. The results obtained in the in beam test for the differential architecture showed that the time resolution remains at about 80 ps up to 16 kHz/cm² (the maximum counting rate reached during these tests) [9].

The region of small polar angles of the CBM-ToF subsystem has to cope, besides of high counting rate, also with a high multiplicity which requires a high granularity detector. For this particular region of the ToF wall a new RPC prototype with a readout electrode with much shorter strips, of 46 mm length instead of 300 mm as the previous prototypes had, was designed and constructed. The counter has a 2 x 5 gap structure with a gap size reduced to 140 μm . A 40 ps time resolution was measured in the in-beam test at the SIS18 accelerator of GSI Darmsadt and reported in reference [11].

The prototypes developed so far have been supplied only with negative potential applied on cathodes. The next step was to build a completely symmetric structure (see Figure 1) with high voltage electrodes for both negative and positive polarities in order to reduce at half the potential applied on each high voltage electrode [12]. The strip geometry was maintained the same as in the case of previous high granularity prototype, (i.e. 2.54 mm pitch, 46 mm length). Three such prototypes were built: the first two (RPC1 and RPC2) are based on float glass resistive electrodes of 0.55 mm thickness and have 2x7 140 μm gas gaps. The difference between

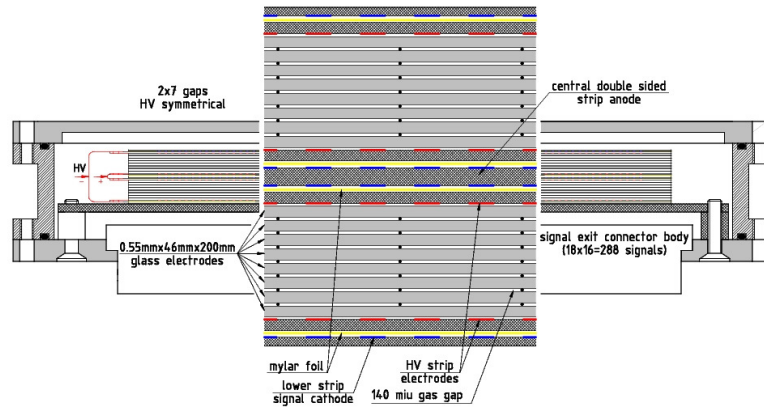


Figure 1. Schematic drawing of the full differential MGMSRPC structure.

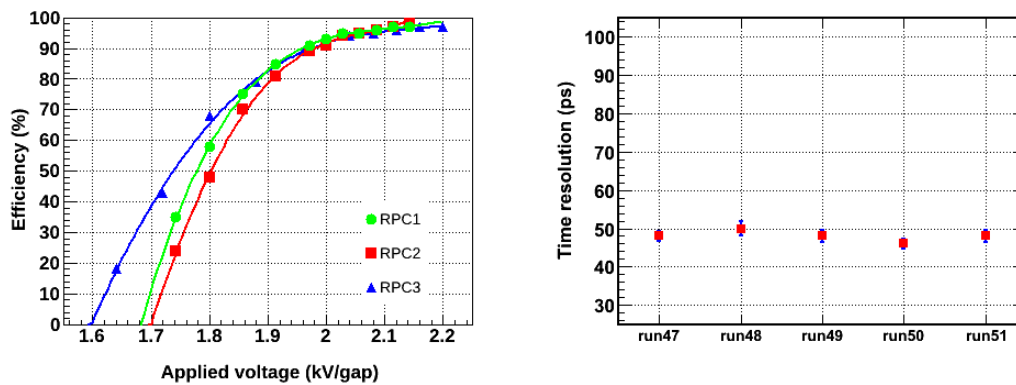


Figure 2. Efficiency for the three detectors as a function of applied voltage - left side. Time resolution using the time difference between RPC3 and RPC2 under the hypothesis that both counters have the same time resolution - right side.

them is that RPC1 has the strip structured high voltage electrode in contact with a resistive layer deposited on the last float glass electrode while in case of RPC2 the strip structured high voltage electrode is in direct contact with the last float glass electrode. The third one, RPC3 is based on low resistivity glass electrodes ($2.5 \times 10^{10} \Omega \text{cm}$) [13] of 0.7 mm thickness and have 2×5 140 μm gas gaps. The in-beam test of the prototypes (RPC1, RPC2, RPC3) was performed at T10 beam line of CERN-PS, using pions of 6 GeV/c momentum. The measured efficiency at an applied electric field of 150 kV/cm was of 97% for all three detectors. A 50 ps time resolution for different runs measured over a time period of 6 hours is shown in Figure 2. This result confirms the stability of the counters, gas flow and electronics. A 4.5 mm position resolution along the strip lines was measured. The obtained transverse position resolution was of 400 μm [12].

For the regions where a lower granularity is required, a new prototype with the strip pitch equal with 7.1 mm and a strip length of 96 mm was designed and built. This new prototype has the active area defined by the low resistivity glass plate [13] size of 96 x 300 mm^2 . Two identical detectors were mounted in a tight gas box in a staggered geometry along the strips (Figure 3-left side), a basic architecture of the disposal of the RPC cells similar with a proposed real one for the inner zone of the TOF wall. The detectors were tested in a high counting rate

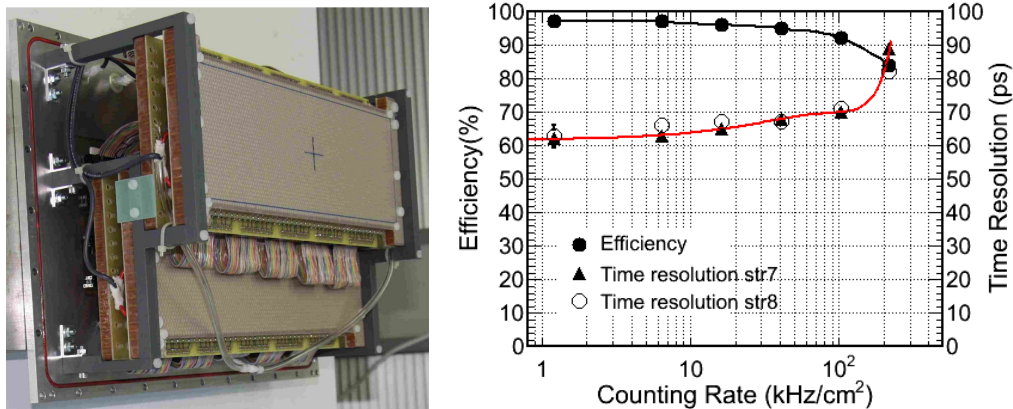


Figure 3. Photo of the two staggered RPC cells mounted on the back flange of the tight gas box - left side. Efficiency and time resolution as a function of counting rate - right side.

at the COSY facility in Jülich. As can be seen in Figure 3-right side, the efficiency is still larger than 90% and the time resolution is better than 70 ps at 100 kHz/cm² counting rate [12]. The next step is to complete the basic architecture of the inner zone with the staggering of the RPC cells across the strip direction for an uniform coverage of the full active area.

4. Conclusions

The obtained results in terms of efficiency, time and position resolutions and counting rate performance recommend the proposed high granularity MGMSRPC architecture based on low resistivity glass as a solution for large area detectors in high collision rate experiments.

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