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Prototype with the basic architecture for the CBM-TOF inner wall tested in close to real conditions

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Prototype with the basic architecture for the CBM-TOF inner wall tested in close to real conditions

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Abstract.
Two dimensional position sensitive timing MGMSRPC prototypes were developed for the low polar angles of the CBM - TOF wall. Four MGMSRPC counters were arranged in a staggered geometrical configuration along the z direction, with overlap along and across the strips, in order to define a basic architecture for the inner zone of the CBM-TOF wall. This configuration was tested with mixed electron-pion beam at CERN-PS and with reaction products resulted from the heavy ion induced reactions at SIS18 - GSI Darmstadt and SPS - CERN. The performance of the basic architecture in conditions close to the ones expected for their operation in the inner zone o the CBM - TOF wall at SIS100/FAIR will be presented.

1. Introduction

The Compressed Baryonic Matter (CBM) experiment is a fixed target experiment at the future experimental Facility for Antiproton and Ion Research (FAIR), with the aim to investigate the high net-baryon density matter in nucleus-nucleus collision in an energy range between 2 - 14 GeV/u at SIS100 accelerator. Due to the high interaction rates up to 10^7 interaction/s, at which the experiment is designed to run, the detectors of the innermost part of the experimental setup will be exposed to high counting rate and multiplicity environment.

The Time Of Flight (TOF) subsystem is one of the core detectors of the CBM experiment. The TOF wall in conjuction with Silicon Tracking System (STS) is foreseen to identify charged hadrons, i.e. pions, kaons and protons, in the acceptance of the system (the angular range covered by the STS detector of 2.5^0-25^0). It covers an active area of about 120 m^2, approximately rectangular in shape. A full system time resolution of at least 80 ps is needed, including all possible contributions, such as electronics jitter and the resolution of the time reference system.

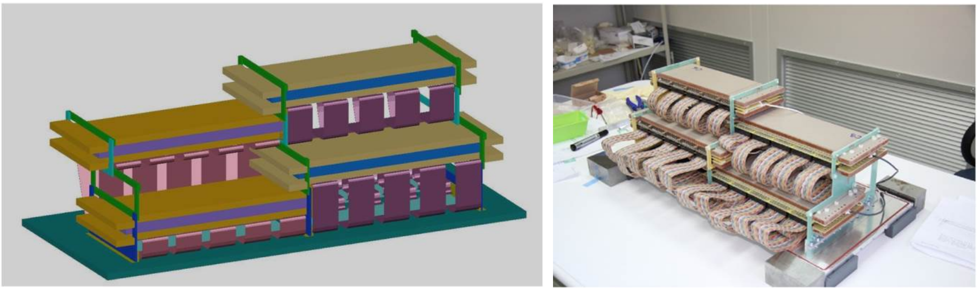

Figure 1. Sketch of the basic architecture of a module based on four staggered MGMSRPCs - left side. Photo of the four staggered MGMSRPC counters mounted on the back flange of the tight gas box - right side.

This requires a single channel time resolution better than 60 ps. At the same time the detection efficiency should be at least 95%. This performance should be maintained up to a counting rate which, very close to the beam pipe, exceeds 30 kHz/cm^2 [1]. The size of a readout channel should match an occupancy less than 5%.

Our activity has been focused on the development of a Multi-gap, Multi-strip Resistive Plate Counter (MGMSRPC) prototype for high counting rate and multiplicity environment, as it is anticipated to be in the inner zone of the CBM-TOF [2]. The double stack counter has a 10 gap structure, 5 on each stack. The gap size is 140 μm. The resistive electrodes are made from low resistivity glass, ($\sim 10^{10}$ Ωcm)[3], provided by our Chinese collaborators from CBM. The use of materials with lower resistivity than that of float glass (of $\sim 10^{12}$ - 10^{13} Ωcm, currently used in the RPC construction) is one of the way to increase the rate capabilities of RPC counters. The narrow strip pitch of 2.54 mm, combined with a strip length of 4.6 cm confers a high granularity. The in-beam test performed at the CERN PS accelerator with a mixed electron - pion beam of 6 GeV/c momentum, showed a very good performance in terms of efficiency and time resolution. The readout of each strip at both ends allows to obtain the position information along the strip with a position resolution of a few millimeters and the charge sharing based on a mean cluster size of 3 strips gives position information across the strips with a position resolution of 450 μm, better than the digital one (pitch/$\sqrt{(}12)$ [2].

2. A basic architecture for the inner zone of the CBM-TOF wall

Based on the positive results mentioned in the previous section, in order to decrease the number of electronic channels, a new prototype with the strip pitch equal with 7.4 mm and a strip length of 96 mm was designed and built. This new prototype has an active area of 96 x 300 mm^2, constrained by the layout of low resistivity glass plates. Two identical detectors were mounted in a tight gas box in a staggered geometry along the strips [2].

The high counting rate performed at COSY facility in Jülich, with a proton beam of 2.5 GeV/c momentum showed a very good behavior of the efficiency and time resolution as a function of counting rate [2, 4]. Up to 100 kHz/cm^2 the time resolution remains better than 70 ps and the efficiency higher than 90%. However, it should be mentioned that the detector was exposed on an area limited to the beam spot size, of about 1 cm^2.

A continuous coverage of the active area of the TOF wall requires a staggered arrangement of MGMSRPCs, with overlaps of the counter active areas on both x and y directions inside the units of the CBM-TOF wall called modules, as well between the modules themselves.

In order to configure a basic structure with such a geometry, two new identical counters were added to the previous structure. The four identical counters inside the gas tight box overlap

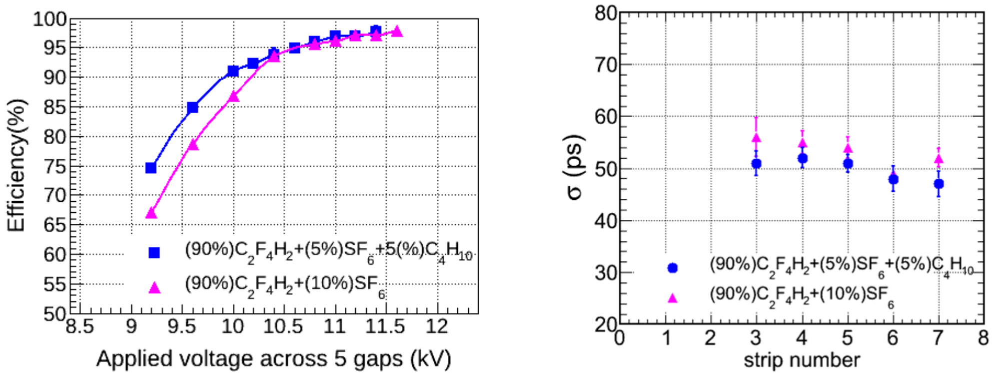

Figure 2. Working curve - left side and time resolution - right side of the prototype for a gas mixture of 85% $C_2H_2F_4$+ 5% iso-C_4H_{10}+10% SF_6 and a gas mixture without isobutane.

their active area on 16.5 mm along the strips and 17.5 mm across the strips. The arrangement of the MGMSRPCs inside the box and the cables routing is shown on the left side of Fig. 1. The right side of Fig. 1 shows a photo of the four counters mounted on the Al back plate of the box. The lateral and the front walls of the gas box are made of 10 mm thick honeycomb sheets sandwiched between two glass fiber epoxy plates of 0.4 mm which are covered on the inner side by a 0.13 mm PCB. The aluminum back plate of 12 mm thickness holds the mechanical support structure of the counters. All signals are transported through this plate via connectors on PCBs glued on the rectangular openings milled into the plate. The architecture of this prototype is designed as close as possible to a real module, the basic unit in the modular configuration of the TOF wall. A motherboard with 8 channel NINO chip [5] mounted on was used as front-end electronics (FEE) for signal processing. All FEE cards are connected on the outer side of the back plane of the housing. V1290A CAEN TDCs were used for signal digitization.

3. In-beam tests of the basic architecture prototype

3.1. In-beam test with minimum ionizing particles

The prototype performance was first tested at CERN-PS with a mixed beam of electrons and pions of 2 - 10 GeV/c momentum, in a low counting rate. The test allowed the estimation of the efficiency and the time resolution. The working curve of one of the RPC counters, shown in Fig. 2 - left side, reaches an efficiency of 97% in the plateau region. The obtained time resolution, after slewing corrections, is arround 50 ps.

The MGMSRPC performance was also investigated for two different gas mixtures flushed through the counters. A slight improvement, in both efficiency and time resolution, can be observed when 5% of isobutane is used. The effect of improving the efficiency for applied voltages lower than those corresponding to the efficiency plateau could be due to the larger average number of ionization clusters per mm produced in the gas mixture containing isobutane than in the mixture without isobutane [6]. The improvement in the time resolution is due to the quenching effect of the UV photons in the mixture containing isobutane, preventing the generation of secondary avalanches which decreases the time resolution.

3.2. In-beam test with exposure of the whole active area to reaction products

Further in-beam tests in conditions closer to the ones expected for the CBM experiment were performed with reaction products at GSI-SIS18 and CERN-SPS accelerating facilities.

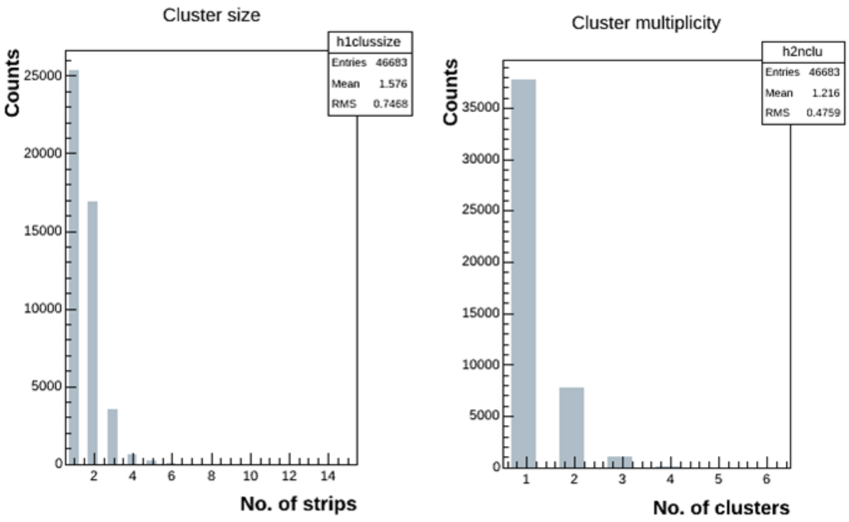

Figure 3. Cluster size - left side - and hit multiplicity - right side - distributions for one of MGMSRPC counter.

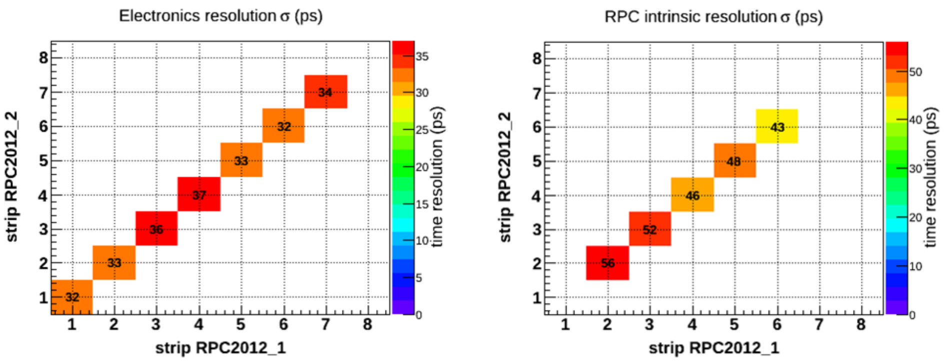

Figure 4. Time resolution of the electronic channels involved in the estimation of the resolution of the individual strips - left side. Intrinsic time resolution of the individual readout strips after quadratic subtraction of the electronic resolution - right side.

The prototype was tested using reaction products produced by an Ar beam of 18A GeV incident on a Pb target at H4 beam line of CERN SPS-facility, in a multi-hit environment. As can be seen in Fig. 4 - left side, the average cluster size is 1.6 strips per hit. The right side of Fig. 4 shows an average hit multiplicity of 1.2 hits per event.

The time of flight distribution was obtained as the coincidence between two RPCs which overlap along the strips. The intrinsic RPC time resolution after slewing corrections and quadratic subtraction of the electronic resolution is shown in Fig. 4 - right side. The value of the intrinsic time resolution for single hit events with one strip cluster size shown in Fig. 4 confirms the performance obtained in the test with minimum ionizing particles.

A high counting rate test of this prototype was performed at the SIS18 accelerator of GSI Darmstadt. The whole prototype surface was exposed to charged particles produced by Ni beam of 1.7A GeV on a 1 mm thick Pb target up to the highest intensity per spill delivered by SIS18. The detector was operated in a standard gas mixture of 85%$C_2H_2F_4$+ 5%iso-C_4H_{10}+10% SF_6

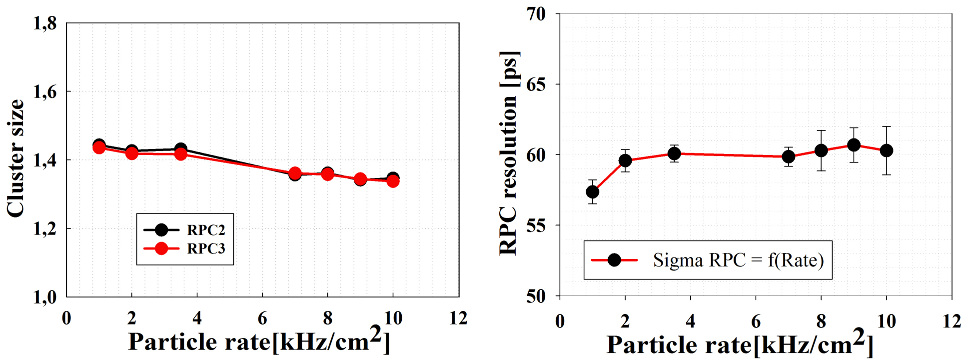

Figure 5. Cluster size - left side - and time resolution - right side - as a function of particle rate.

and at an electric field strength of 157 kV/cm. Signals of 16 strips of each counter were processed by NINO fast amplifiers, their differential outputs being converted by FPGA TDCs [7]. The cluster size as a function of the counting rate is shown in Fig. 5 - left side for two of the four counters. A decrease of about 7% is observed at 10 kHz/cm^2. The time resolution was obtained using the time difference between two MGMSRPC counters overlapped along the strips, or between two MGMSRPCs overlapped across the strips. For the first case, where the overlap is at the edge of the strip, some influence of edge effects is not excluded. After walk correction, a time resolution of ∼70 ps was obtained, including electronics resolution and considering an equal contribution of the two MGMSMRPC counters. For the overlap across the strips a time resolution of ∼60 ps was obtained. The time resolution as a function of counting rate is shown in Fig. 5 - right side. A slight deterioration of the time resolution of about 5% is observed up to 3 kHz/cm^2 counting rate. This value seems to remain unchanged, within the error bars, up to 10 kHz/cm^2, the highest average counting rate on the whole area of the prototype accessed in this experiment.

4. CBM-TOF inner zone design based on MGMSRPCs

The results presented in this paper recommend such an architecture as solution for the inner zone of CBM-TOF wall. A modular structure of the inner zone was designed, the modules being independent units positioned in a mechanically structure called space frame. These modules contain inside MGMSRPC counters, the front-end electronics cards being mounted on the outer side of back plane of the housing. In the current proposed design [8, 1] the CBM-TOF inner zone is covered by eight modules of three types, M1 (2 pieces), M2 (2 pieces) and M3 (4 pieces) disposed in space as it is shown in Fig. 6.

The geometric area of the inner zone is of about 14 m^2 and contains about 300 MGMSRPCs with a total of about 40000 readout channels. The design of the CBM-TOF inner zone was done such to have a full coverage with the lowest possible overlap between counters and modules, in order to minimize the number of readout channels and thus the costs and a proper matching with the design of the outer region of the TOF wall.

5. Conclusions

The prototype with the basic architecture for the inner zone of CBM-TOF wall was tested in close to real operation conditions. The MGMSRPC counters of the prototype have an efficiency of 97% and a time resolution of about 50 ps. Efficiency larger than 90% and time resolution

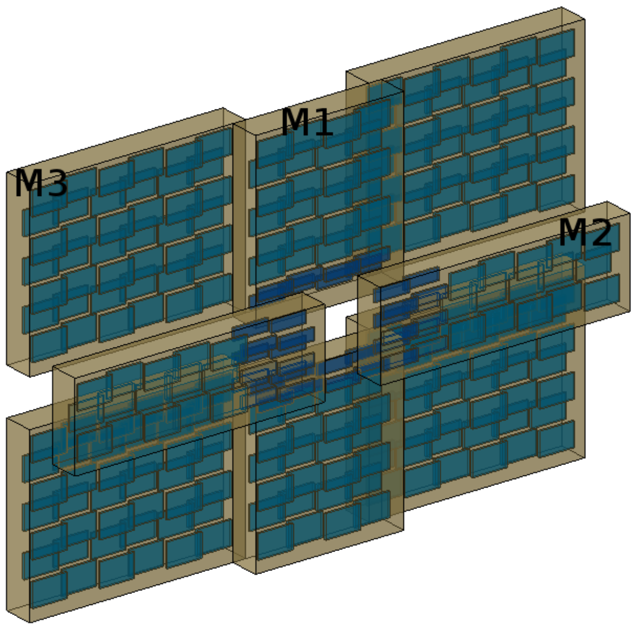

Figure 6. CBM-TOF inner zone modular configuration.

better than 70 ps up to 100 kHz/cm^2 particle flux in a focused beam and up to 10 kHz/cm^2 in exposure of the whole active area were demonstrated.

Further in-beam test with exposure on the whole active area will be dedicated to the evaluation of the prototype performance in both high counting rate and multihit environment.

Acknowledgments
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