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Upgrade**

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High-Rate Glass Resistive Plate Chambers For LHC Muon Detectors Upgrade

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Abstract—The limitation of the detection rate of standard bakelite resistive plate chambers (RPC) used as muon detector in LHC experiments is behind the absence of such detectors in the high η regions in both CMS and ATLAS detectors. RPCs made with low resistivity glass plates ($10^{10} \Omega \cdot \text{cm}$) could be an adequate solution to equip the high η regions extending thus both the trigger efficiency and the physics performance. Different beam tests with single and multi-gap configurations using the new glass have shown that such detectors can operate at few thousands Hz/cm^2 with high efficiency ($> 90\%$).

I. INTRODUCTION

RESISTIVE Plate Chambers (RPC) are excellent detectors due to their simplicity, high efficiency and cost-effectiveness. Large RPC can be built easily and for this reason they are extensively used in HEP experiments as muon detectors. RPC can also be used as a powerful tool in many applications where an excellent time measurement is required. The RPC does not suffer as other gaseous detectors do, from discharge problems thanks to the high resistivity of its plates (either Bakelite or Glass). However, this same propriety is the cause of the detector's main limitation: It does not support high rates of particles. The high resistivity of the RPC electrodes prevents the charge of the avalanches created by the crossing charged particles to be absorbed quickly. This delays the restoration of the electric field before the next avalanche. The rate limitation is the reason behind the absence of RPC detectors in the high η region of CMS and ATLAS experiments where the expected particles rate is higher than $1 \text{ kHz}/\text{cm}^2$. This rate goes beyond the RPC detection capability. The absence of RPC in the high η region results in trigger performance degradation and affects the physics performance. For instance, Higgs search in the ZZ channel with one or both Z decaying into two muons in the forward regions is one of the physics channels that is affected by the absence of RPC in the high η region. A promising technology has been identified which allows RPCs capable of high rate detection to be produced. It consists of using a special glass doped with metallic elements. This reduces significantly the glass resistivity without affecting the glass surface quality and also without aging consequences when it is exposed to strong irradiation sources. Many RPC, single and multi-gap, using this new kind of glass were built. The detectors were tested in different places and conditions. The results obtained so far

with these detectors justify to propose this High-Rate GRPC as a good solution to instrument the high η regions of both CMS and ATLAS detectors.

II. HIGH-RATE GLASS RESISTIVE PLATE CHAMBERS

The difference between the High-Rate GRPC (HRGRPC here after) and the standard Glass RPC is the nature of the glass. The doped glass used in the HRGRPC was developed by the Tsinghua University[1] following a new process. This results in a low-resistivity silicate glass ($< 10^{10-11} \Omega \cdot \text{cm}$) that facilitates the absorption of the avalanches charges created by the passage of charged particles in the RPC. This value is to be compared with the $10^{12-13} \Omega \cdot \text{cm}$ resistivity of the common borosilicate glass (float glass) which is commonly used in building the standard GRPC detectors. The reduction of the resistivity is sufficient to allow the new GRPC to reach high detection rate exceeding few thousands Hz/cm^2 . Several single-gap and multi-gap HRGRPC were built and extensively tested.

A. Single-gap HRGRPC

Single-gap GRPCs with two sizes: $20 \times 8 \text{ cm}^2$ and $30 \times 30 \text{ cm}^2$ were built using the low-resistivity glass. All have glass plates of 07-1.1 mm thickness and separated by ceramic spacers of 1.2 mm height (Figure1). Colloidal graphite was used for the coating with surface resistivity of about $1 \text{ M}\Omega/\text{square}$. The gas mixture used to operate them is similar to the one used in the CMS Bakelite RPC with slightly different proportions of the usual gases (93% TFE, 5% CO_2 and 2% SF_2). In 2010, two small-size chambers were built and tested with the CERN-PS pion beam. They were found to be quite efficient ($> 90\%$) at a particles rate exceeding $20 \text{ kHz}/\text{cm}^2$. The trigger rate was estimated using a set of scintillators-photomultipliers with an overlapping surface smaller than the detectors active surface. However, to validate these encouraging results and to generalize it to large-surface detectors, four $30 \times 30 \text{ cm}^2$ detectors were built in 2011 using the same low-resistivity glass. A test beam was organized at DESY in January 2012. A continuous electron beam with intensity as high as $9 \text{ kHz}/\text{cm}^2$ was obtained.

The four chambers were tested together with a similar GRPC built in identical way but with the standard (float) glass.

Each of the five chambers was housed in an aluminum cassette (Figure 2). An electronic readout card with readout pads of 1 cm^2 separated by 425 microns was used to read out the chambers. This is the same electronics used to read

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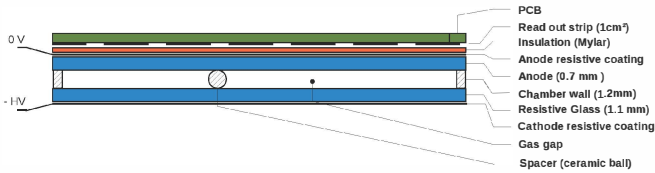


Fig. 1. Cross-section of a GRPC with its associated readout electronics.

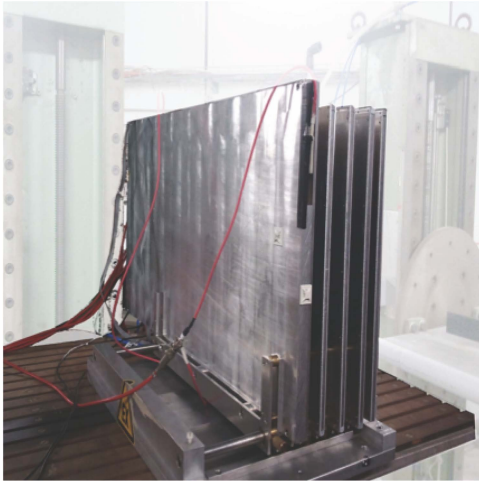


Fig. 2. The test setup at DESY with 4 HRGRPC and 1 standard GRPC.

out the GRPC chambers used in the SDHCAL prototype [2] developed within the CALICE collaboration. The electronics board was put into contact with the detector by fixing it in one of the cassette's walls. To study the efficiency one of the 5 chambers, tracks built using the fired pads from at least three of the others were used. However, electron interactions with the cassettes material may increase artificially the detector efficiency estimated in this way. Hence, only tracks with one cluster per detector and not more than 4 pads per cluster were used to build the candidate tracks. The impact of this on the studied chamber is then determined and fired pads in a 2 cm radius around the impact are looked for.

The efficiency and the pad multiplicity which is defined as the average number of pads fired when a single particle crosses the chamber were studied for different high voltage values of one of the HRGRPC.

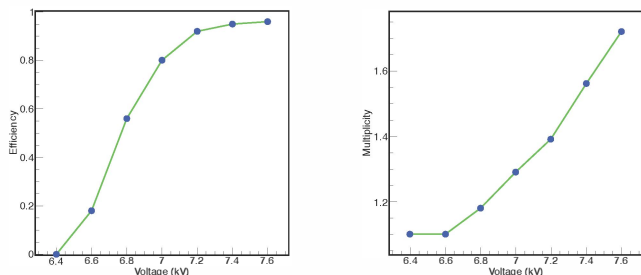


Fig. 3. Left: HRGRPC efficiency vs HV. Right: HRGRPC pad multiplicity vs HV.

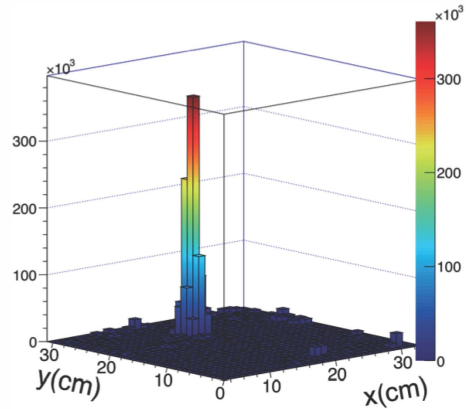


Fig. 4. Beam profile as seen in the first HRGRPC of the setup with respect to the beam.

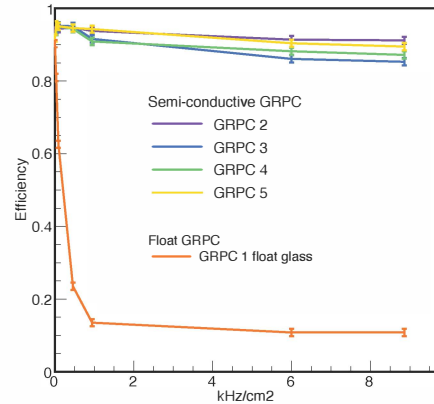


Fig. 5. Beam profile as seen in the first HRGRPC of the setup with respect to the beam.

Figure3 shows that the evolution of the efficiency and multiplicity of these chambers are identical to the ones observed with the float-glass RPC[3]. The efficiency of the five chambers at 7.2 kV was then studied at different rates of particles (Figure5). The rate was estimated from the average number of tracks recorded by a scintillator-photomultipliers counting system in front of the five GRPC and the shape of the beam characterized by the pad occupancy of the first detector as can be shown in Figure4. The divergence of the beam was found to be negligible along the distance separating the first and the last detector (12 cm). Although the efficiency of the standard GRPC is dramatically diminished at rates exceeding few tens of Hz/cm², the four HRGRPC efficiency are slightly reduced and exceed 90% at the highest possible rate of 9 kHz/cm² confirming the previous results observed at CERN.

B. Multi-gap HRGRPC

To achieve high-precision timing measurement for the TOF detector of the future CBM experiment in which particles rates are expected to be very high (few kHz/cm²), several multi-gap GRPC (21×6.1cm²) were developed and extensively tested with different accelerators. With 6 gaps of .22 mm, these

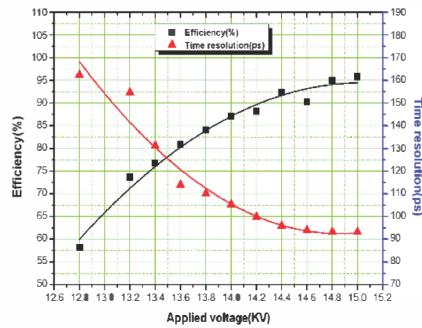


Fig. 6. Efficiency and time resolution of a multi-gap HRGRPC as a function of the applied high voltage obtained at a particles rate of 25 kHz/cm².

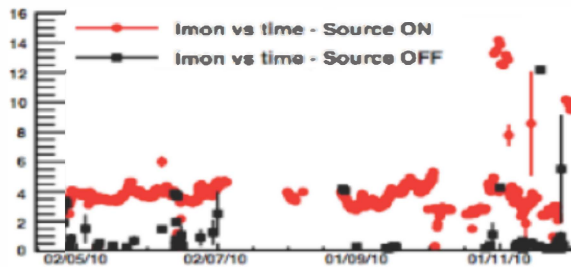


Fig. 7. HRGRPC current vs time with source on (red) and off (black) .

GRPC made with the same low-resistivity glass have shown an excellent performance and efficiencies exceeding 90% at rates up to 25 kHz/cm². These results were obtained using gamma and electron beams and confirmed later with proton beams. To read out the multi-gap GRPC signal, both pick-up pads and strips were used. The time resolution obtained with such detectors was found to be about 90 ps at this high rate as shown in Figure6.

III. HRGRPC IRRADIATION HARDNESS

In order to check the stability of the new glass in a strong irradiation environment the small-size HRGRPC that was tested in 2010 was put in the Gamma Irradiation Facility (GIF) at CERN and exposed to a Gamma source of (¹³⁷Cs) corresponding to about 200 Hz/cm² (equivalent to 400 pC/cm²/s). The monitoring of the HV power-supply current shows a stable operation (Figure7) during long periods of exposure.

More tests are however needed to confirm that aging effects are absent when the HRGRPC are put in conditions equivalent to those to which they will be exposed in the CMS high eta regions.

IV. CONCLUSION

A new kind of RPC detectors using a low-resistivity glass was studied in both single and multi-gap schemes. In both cases the new detector shows high rate capability (> few thousands Hz/cm²). The nice performance of this new detector suggests to use it to complete the high eta region of both CMS and ATLAS detectors. In addition to its simplicity and cost-effectiveness, the new detector could be installed and used without any additional services to the ones already in use for the Bakelite RPC.

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