Development of Hybrid Resistive Plate Chambers

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Abstract: Among the several outstanding issues associated with the RPCs, the loss of efficiency for the detection of particles when subjected to high particle fluxes, and the limitations associated with the common RPC gases can be listed. In order to address the latter issue, we developed novel RPC designs with special anode planes coated with high secondary electron emission yield materials such as Al_2O_3 and TiO_2. The proof of principle was obtained for various designs and is in progress for the rest. The idea was initiated following the achievements on the development of the novel 1-glass RPCs.

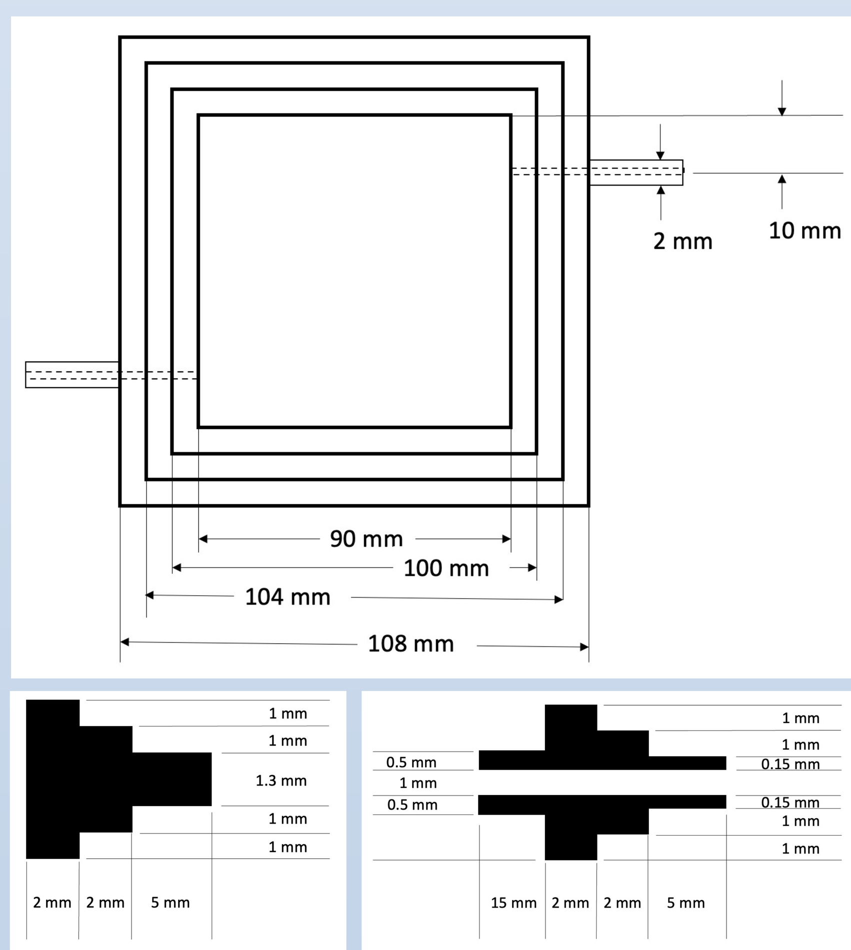
Here we report on the construction of various different RPC designs, and their performance measurements in laboratory tests and with particle beams; and discuss the future test plans which include the long-term performance tests of the newly developed RPCs, investigation of minimal gas flow chambers, and the feasibility study for the large size chambers.

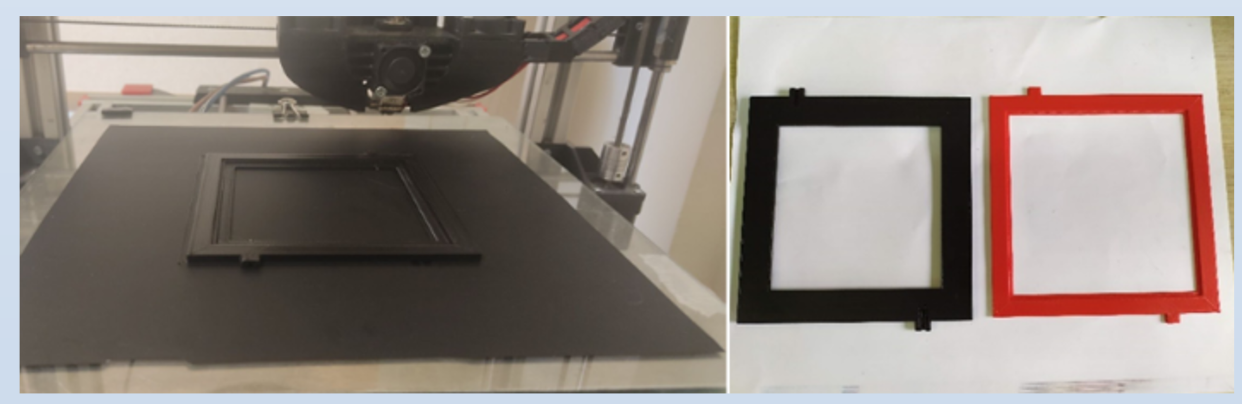
Construction of the RPCs: Several 10 cm × 10 cm chambers were made with 2 mm thick glass plates and a single readout pad of size 9 cm × 9 cm.

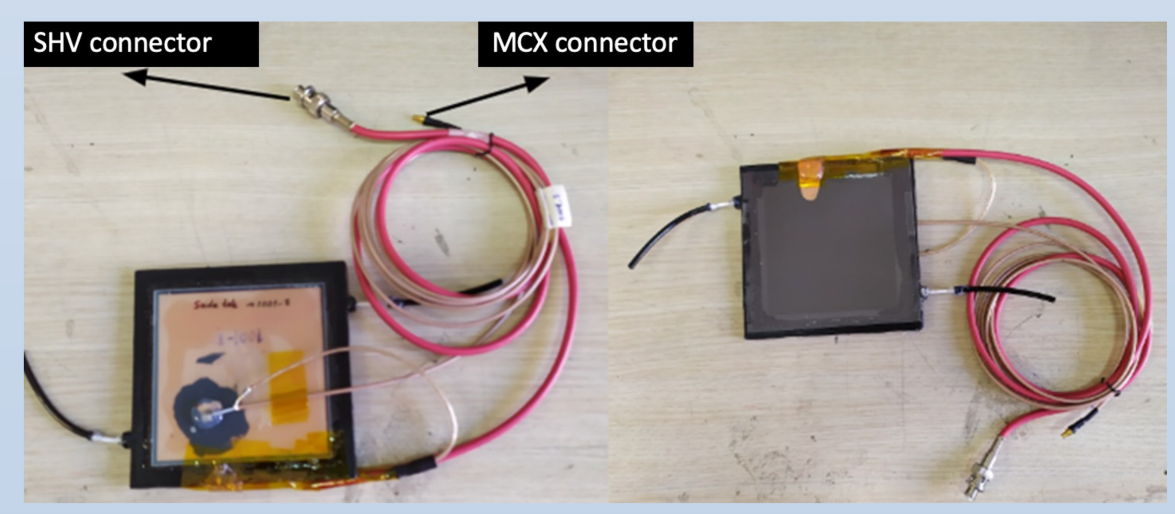
The 5 mm rim of the glass plates were masked and a mixture of a high resistivity and a low resistivity artist paints was applied with airbrush gun to yield 1 – 5 MΩ/□.

The RPC frame was 3D-printed and the glass plates and the pad boards were glued with two-component epoxy. The gas gap was 1.3 mm.

Sketches of the RPC frames are shown on the right (not to scale), as well as the pictures of 3D printing, pad boards and the assembled RPCs.



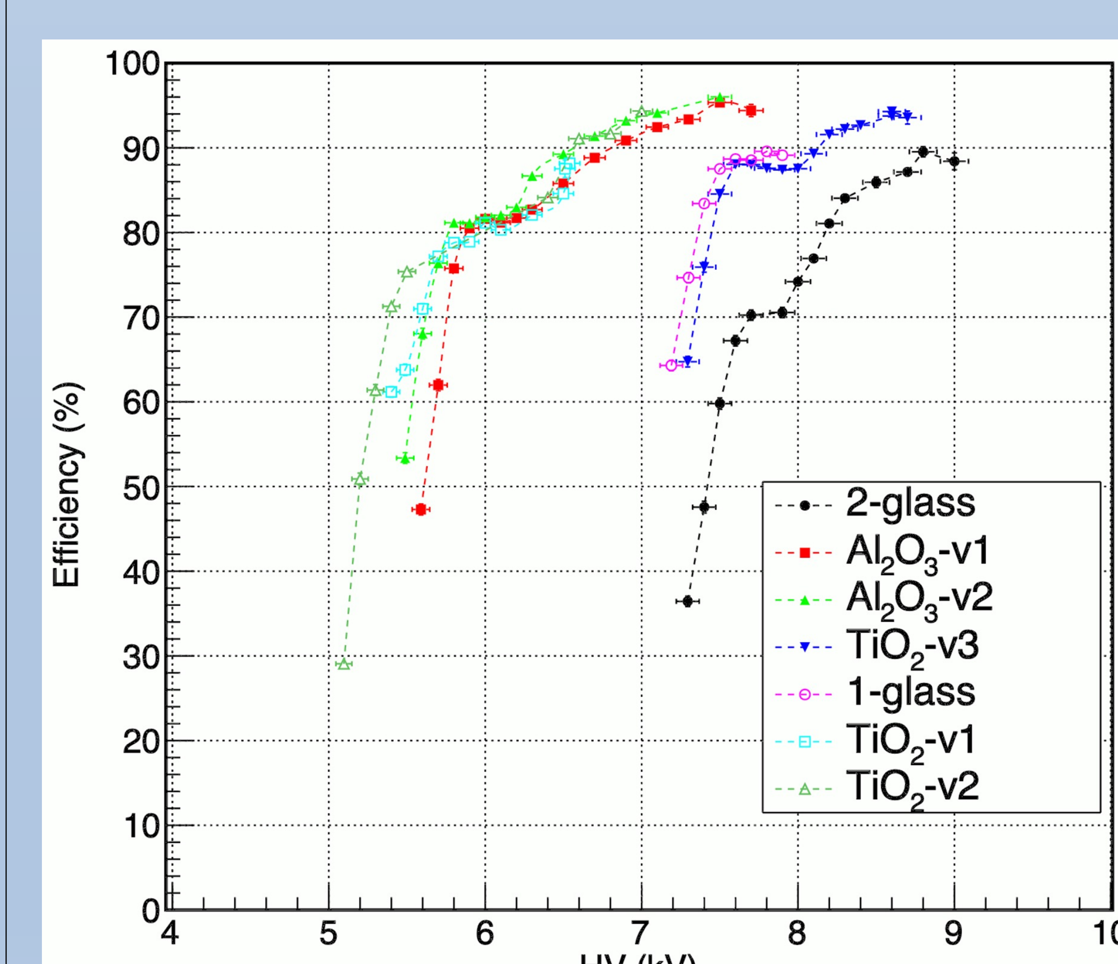




The coating of Al_2O_3 was done with magnetron sputtering at Gazi University Photonics Application and Research Center, Ankara (https://fotonik.gazi.edu.tr/), and the coating of TiO_2 was applied with airbrush gun as a solution in ethanol in the lab.

Beam Tests of the Hybrid RPCs: Following the laboratory tests, the RPCs were tested with FTBF (https://ftbf.fnal.gov/) muons. The list of the RPCs tested is as follows: one standard 1-glass RPC; one standard 2-glass RPC; two 1-glass RPCs with anodes coated with 500 nm and 350 nm Al_2O_3 (Al_2O_3-v1 and Al_2O_3-v2); three 1-glass RPCs with anodes coated with 1 mg/cm^2, 0.5 mg/cm^2 and 0.15 mg/cm^2 TiO_2 (TiO_2-v1, TiO_2-v2 and TiO_2-v3). The gas mixture was R134a (94.5%), isobutane (5.0%) and SF_6 (0.5%); and the gas flow rate was 2-3 cc/min, roughly half of the nominal gas flow that would normally be applied to this size of chambers. Figure on the right shows the efficiency as a function of the applied high voltage.

If one considers the approximate high voltage value at the 90% efficiency crossing as a measure; the standard 2-glass RPC: 8.5 kV; the standard 1-glass RPC and TiO2-v3: 7.5 kV; Al_2O_3-v1, Al_2O_3-v2, TiO2-v1 and TiO2-v2: 6.5 kV are obtained. There is a clear indication of the contribution of the electron multiplication in the coating.



The 1-glass RPC design offers several advantages over 2-glass RPCs such as avalanches with higher collimation and an increased rate capability. It also starts a new chapter where the in-chamber anode plate can be made more functional. By coating the anode plate with high secondary electron yield materials, electron multiplication in the chamber can be enhanced considerably. R&D is underway to fully characterize the newly developed, so-called hybrid RPCs. The hybrid RPCs have the potential to mitigate the limitations associated with the RPC gases and to relax the overall operating conditions. Long-term stability tests and the measurements of the response with alternative gas mixtures are underway.

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