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Small RPC gap assembly

Summer Student Project Report
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Abstract

During the summer of 2023, I was given the opportunity to do a summer internship with the Resistive Plate Chamber (RPC) group of the Compact Muon Solenoid (CMS) collaboration at the European Center for Nuclear Research (CERN) in Geneva, Switzerland. During my stay at CERN, I have worked on two main projects. The First project was working on the construction of the Improved Resistive Plate Chamber (iRCP) and quality control test for the phase-2 upgrade of the Large Hadron Collider (LHC), also known as High Luminosity LHC (HL-LHC). The second project was working on going beyond what we have and improving more on the Resistive pate chamber, where we built a 1mm glass gap RPC with a new gas injection system with an equal gas flow distribution. During my stay at CERN, I also participated in the data acquisition and analysis for the test beam operation of July 2023 at the Gamma Irradiation Facility (GIF++) facility, CERN. This report summarises the work done and results obtained during my stay at CERN.

In the first chapter, 1, An overview of the compact magnetic solenoid (CMS) project is presented with details about the resistive plate chamber(RPC). Subsequently, the improved resistive plate chamber (iRPC) and the difference between the existing CMS RPC and the newly designed iRPC are briefly discussed in this chapter. Details are provided on the construction program for the improved resistive plate chamber (iRPC) in the context of the HL-LHC upgrade as well as the working principle of the iRPC and Front-End Board (FEB) of the new improved chambers.

The beginning of chapter two gives an overview of the 1mm gap and the new gas injection system. Where we go into detail on what are the main goals that we want to reach after finishing the project. Following that, we are going to focus on the making of the 1mm gap. Where I talk about what are the benefits of building a 1mm gap, what improvement we will reach, some of the big problems that we face, and what we can do to improve the construction of the 1mm gap. Moving on, we dive into solving the inlet gas problem, where we suggest three main solutions and show how each solution performed after going through many gas tightness tests. In the attempt to solve the gas inlet problem, we have faced some minor challenges which are mentioned in this chapter. At the end, we are going to talk about how we got everything together in building the RPC, all the important components in a resistive plate chamber (RPC), and how to maintain the quality of these parts.

The final chapter talks about gas calibration in the view of making a mixing station. I would like to thank Salvatore Buontempo for giving me the chance to be part of the CERN CMS RPC family. I especially would like to thank Mehar Ali Shaw for introducing me to the RPC family showing me around and always being helpful in times of stress. And of course to my teacher and supervisor in

developed, as the existing system would be inadequate for this task. The new front-end electronics must be capable of registering signals with charges as low as 10 fC, all while ensuring fast and reliable signal detection in the high radiation environment anticipated in RE3/1 and RE4/1 during the HL-LHC phase .

Consequently, the FEB holds immense significance in the iRPC upgrade, serving as the readout system for the new chamber[3]. This underscores that the detector's performance is heavily reliant on the performance of the electronics system. The front-end electronics utilized by the iRPCs are based on the PETIROC ASIC (as shown in figure 8), developed by OMEGA, and is known as CMS RPCROC. The CMS RPCROC comprises a 32-channel Application Specific Integrated Circuit (ASIC) equipped with a broadband fast preamplifier and a fast discriminator in SiGe technology. The ASIC boasts an overall bandwidth of 1 GHz and a gain of 25, with each channel offering both charge measurement and a trigger output for signal arrival time measurement. The new Printed Circuit Boards (PCBs) enable the reading of each strip from both ends, enabling the determination of the signal's position along the strip using the Time Difference of Arrival (TDoA) method. Thanks to its outstanding time resolution (20–30 ps), it can accurately determine the position along the strip with a fine resolution of approximately 200 ps or 1.7 cm.

Table 1.1: Comparison between existing RPC and new iRPC chambers. source: [8]

	RPC	iRPC
Gas gap & electrode width, [mm]	2	1.4
High Pressure Laminate, [mm]	2	1.4
Resistivity [Ωcm]	$(1.0 - 6.0) \times 10^{10}$	$(0.9 - 3.0) \times 10^{10}$
Strip pitch, [cm]	2.0 − 4.0	0.6 − 1.2
Electronics threshold, [fC]	150	30
φ coverage, [degree]	10	20
Total thickness, [mm]	32	25

Figure 9: Schematic circuit of a PETIROC ASIC board.

2 The 1mm gap

The enhanced design of the iRPCs, in contrast to the existing RPCs, will help to increase their rate capability and resilience in demanding radiation environments. Fig, 10 illustrates the schematic layout of the iRPC. By reducing the electrode thickness from 2 to 1.4 mm, the recovery time of the electrodes diminishes, and the efficiency of extracting the pickup charge from the avalanche charge is increased. In a similar vein, decreasing the gas gap thickness from 2 to 1.4 mm curtails the rapid growth of pickup charge in ionization avalanches and lowers the operational high voltage, rendering the system more robust with reduced chances of aging. Furthermore, the electronic threshold can be lowered from 150 to 50 fC. This reduction in threshold enhances sensitivity, resulting in a decrease in charge.

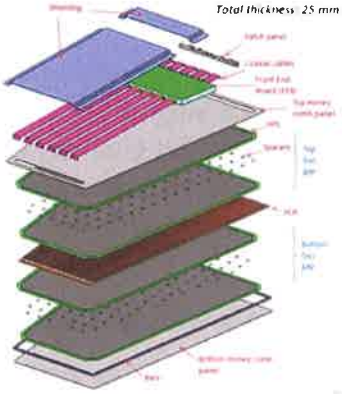

Figure 10: Schematic layout of the iRPC chamber.

iRPC requirements for HL-LHC		
Specification	RPC	iRPC
$\lvert\eta\rvert$ coverage	0–1.8	1.9–2.4
Max. expected rate (safety factor 3 included)	600 Hz/cm^2	2 kHz/cm^2
Max. integrated charge (safety factor 3 included)	~ 0.8 C/cm^2	~ 1 C/cm^2
High Pressure Laminate thickness	2 mm	1.4 mm
Number and thickness of gas gap	2 and 2 mm	2 and 1.4 mm
Resistivity ($\Omega\cdot$ cm)	1–6×10^{10}	0.9–3×10^{10}
Charge threshold	150 fC	50 fC

Figure 11: A comparison between some main characteristics of the current PRCs and the iRPC's.

As you can see from Table 1, lowering the resistivity of the electrode contributes to the higher rate capability since the rate capability is inversely proportional to the resistivity of the electrodes. Reduction of the avalanche charges is also a key to enhancing the higher rate capability. One way to obtain smaller avalanche charges is to reduce the gas volume by reducing gas gap thickness. The smaller charges certainly reduce the probability of aging due to the high-rate background guaranteeing the longevity of the RPCs. However many advantages of the smaller charges can be only achieved by a lower digitization threshold.

Based on the results we got from reducing the thickness of the RPC gap, many improvements would help us with the fundamental particles. To increase the efficiency of the RPC we need to find a way to build a 1 mm gap. Of course, there are many challenges that we can face when we come to building a 1 mm gap. One of the major improvements we will reach in building a 1 mm gap is having a high response device and an equal gas flow distribution inside the cap.

3 The making of a small 1mm RPC gap

In this part of the report, I will talk about how we built the 1 mm gap and what procedure did we take. Our main goal was to build a 30cm x 30cm glass gap but it is so risky to go straight and build a 30cm x 30cm glass gap without knowing what challenges we have. Therefore the plan was to build a 20cm x 20cm polycarbonate gap first and then see what challenges we face and what we can do to surpass these challenges.

3.1 Polycarbonate 20 cm x 20 cm gap

For every experiment, there is a plan and in our plan first, we gather the components of the gaps, then clean these components, and after cleaning these components have a certain procedure we take to build the gap and then after finishing building the gap we check what step was good and what step could be better. The components of the gap consist of a 20cm x 20cm polycarbonate plate, we have chosen this material because it was easy to find, and it was easy to cut and manipulate, four pieces of side spacers that are made out of Bakelite material two pieces measuring 20 cm and another two pieces measured 120 cm so we can create the inlet and outlet of the gas system. We have used isopropane to clean the plates. Another component that is responsible for having a volume inside the gap is the button spacers we use for the button spacers washer. We used black silicone adhesive to glue the parts together and four lead bricks to press on the components of the gap after gluing it to ensure that there was no space left, after that, we started the procedure. We used a red pen to mark the position of the button spacers and the side spacers but in our first try, we have done a mistake where we made a rectangle instead of a square for the button spacers. After making sure that every component was available for us, and that the procedure was clear, we started experimenting. First, we placed the bottom plate where we had the red marks on it and then we applied black silicone adhesive to the bottom of the places of the spacers. After that, we installed the side spacers and bottom spacers, and then applied black silicone adhesive above the spacers and then we installed the upper plate. After installing the upper plate, we put four lead bricks on the gap that presses the components together so we ensure that there are no gas leaks.

Another issue we had was having the 120 mm side spacer moving. Therefore we have different sizes of slots inlets and outlets for the gas as you can see in Fig. 12.

After putting lead bricks in the gap we waited 24 hours for the glue to polymerize. In this part, we applied the silicone adhesive on a piece of paper so we could check if the silicone adhesive was polymerized. Unfortunately, our first try at building a 1 mm gap had many problems and one of these issues was that the two plates were not aligned together perfectly as you can see in Fig. 31. The way of solving this problem was to have side strips made out of polymer material that guide the position of the two plates when using the lead bricks (Pb) to press the plates together. Another issue we had was that the average thickness of the gap size was 1.6 mm which is pretty far away from 1 mm as you can see in Fig. 14. One of the procedure for building the gap was similar to the first gap. What we did differently in this gap is that we had a paper that had equal measurements of the button spacers in the right place as you

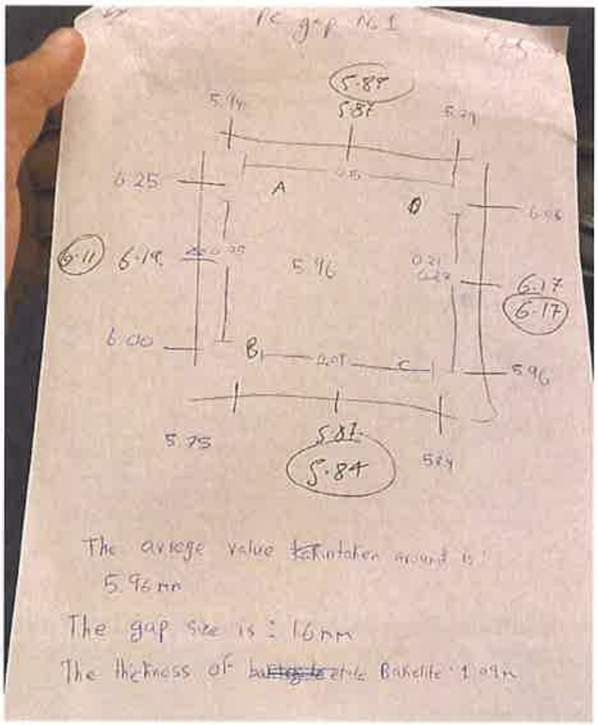

Figure 14: The measurement of the gap size by using an electronic vernier caliper.

7 — can see Fig.13. As we learned from the first gap we have added side polymer strips that hold the two plates in position, so that the plates will be aligned together as you can see in Fig 15. Another thing that we did differently in this gap was using epoxy glue that has low viscosity. As a result, we had a perfectly aligned gap and an average gap size of 1.1 mm, which is close enough to 1 mm. After we had solved all the major problems that we could have faced in building a 1 mm gap we proceeded with our plan to build a 30cm x 30cm glass 1 mm gap.

3.2 Glass 30 cm X 30 cm gap.

After finishing building the 20cm x 20cm polycarbonate gap and finding all the challenges and mistakes we could have made we started building the 30cm x 30cm glass gap.

3.2.1 Cleaning the glass plates

Before we started the experiment we gathered all the equipment together. The glass gap was made out of the same components that we used for the polycarbonate gap. Using Bakilite side spacers and button spacers, epoxy glue, the only thing that is different is using glass

Here we took that area of the two probes. We first measure the radius by using an electronic vernier caliper. And then calculated the area as following:

weight

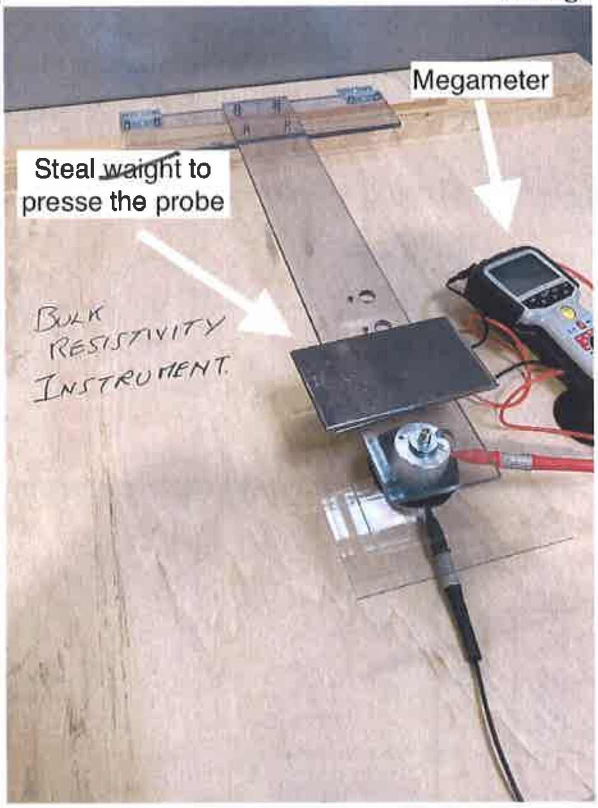

Figure 20: Bulk resistivity instrument.

$$A = \pi . r^2$$

$$D = 2.r$$

$$r = \frac{D}{2}$$

$$r^2 = \frac{D^2}{4}$$

Therefor:

$$A = \pi \frac{D^2}{4}$$

The area A = 20cm^2