Summer Student Internship

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Table of Content

1. Introduction of RPC Phase 2 Upgrade Project

CMS is a general purpose experiment measuring proton-proton and heavy-ion collisions at the Large Hadron Collider (LHC) at CERN which produced many scientific results [1]. One of the most significant discoveries was the discovery of the 126 GeV Higgs Boson in 2012. However it still in need of improvement, which is why the CMS Phase 2 Upgrade Project is starting.

The CMS is made of a barrel yoke that is subdivided into 5 wheels and two endcaps. This project focuses on the endcaps and the Resistive Plate Chambers (RPCs) are located there. RPC stations in the barrel and endcaps have one RPC chamber per station. RPCs are chambers that are operated in high electric field and use High Pressure Laminate (HPL) electrodes. They are mainly used for accurate timing and fast triggering [1]. Which in turn allows in particular the identification of the corresponding bunch crossing. One of the important upgrades on the RPCs is replacing the off-detector electronics. Moreover, two new RPC layers will be added and this increases efficiency. Below are images of the model on the endcap with RE ±3/1 and RE ±4/1 RPC detectors, respectively in figures 1 and 2.

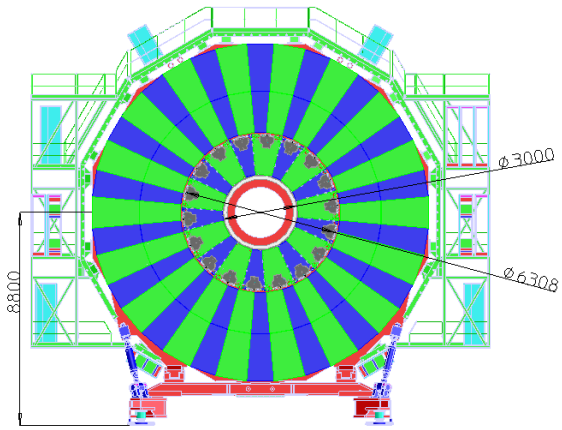

Figure 1: Model of the RE −3/1 endcap

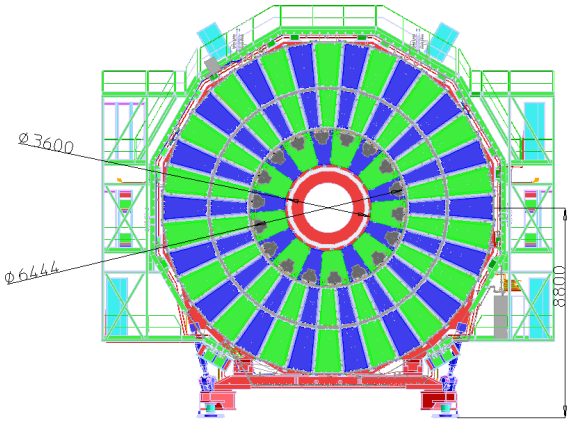

Figure 2: Model of the RE −4/1 endcap

2. Software Used: PTC Creo Elements/Direct Modeling

Creo Elements/Direct Modeling is one of the most intuitive modeling systems. It can work with large assemblies, parts, and surfaces. In the tasks below, the program was used to view the model of the RPCs within the endcap. The program allowed sharing/copying of parts, creating assemblies, creating 2D drawings from 3D models, and more.

3. RE ±3/1 Mounting

3.1) Document

A document was created on the steps on mounting the RE ±3.1 on the yoke. The brackets used for assembly were studied by analyzing each part and why it was design the way it is. For the RE ±3.1 detectors, an eRPC Yoke Mounting Brackets were used as shown in figure 3 (note that the left and right yoke brackets are similar but mirrored).

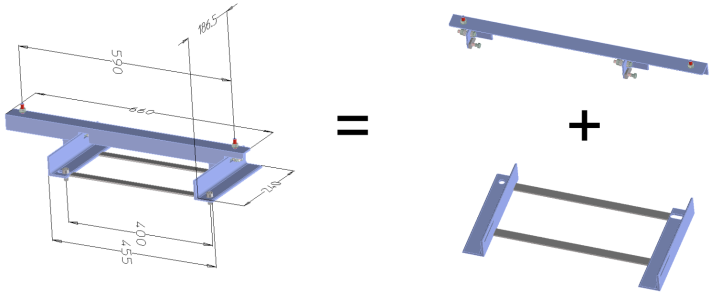

Figure 3: Yoke bracket used for the assembly of the RE ±3.1 detectors

Figure 4: Bellievele Washer

The two parts of the bracket are connected via a screw that has a Bellivele washer shown in figure 4. The Bellivele Washer (M8) is designed to absorb heavy loads and vibrations by acting as a spring. In the L bracket, it is used to help ease adjustments of the angle of the brackets. If lower screw was tighted and the top screw was loosened, the detector will tilt downward towards the center and vice versa. Moreover, due to the elliptical hole, the detector will be able to move up and down. These features are designed within the bracket to ensure that the RPCs are attached correctly and that adjustments can be easily made if necessary.

The bracket is attached to the yoke through one circular hole and one elliptical hole to allow motion flexibility of around 20mm. A bracket needs to be attached starting from the circular hole, moving to the elliptical one in the order above. Below in figure 5 is the final image with the brackets attached.

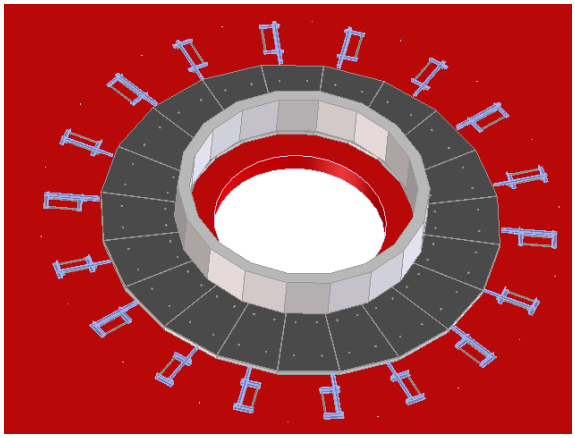

Figure 5: Left and right yoke brackets attached.

RE3/1 contains ‘on yoke’ and ‘off yoke’ detectors. The brackets on the detector should be attached off site so that it is ready to be attached to the yoke. The figures 6 and 7 below show the type of brackets attached on the detectors.

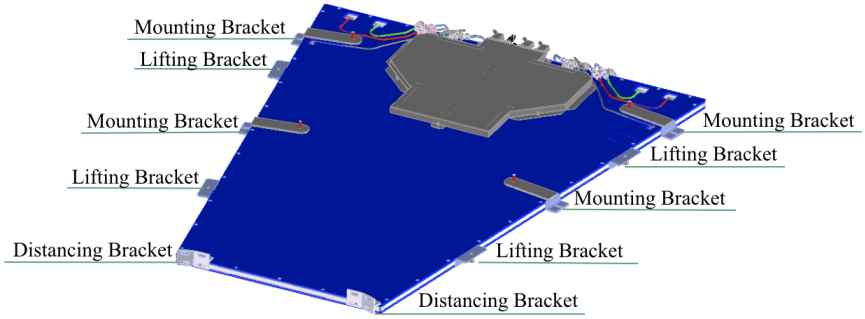

Figure 6: On-yoke detector with all brackets attached.

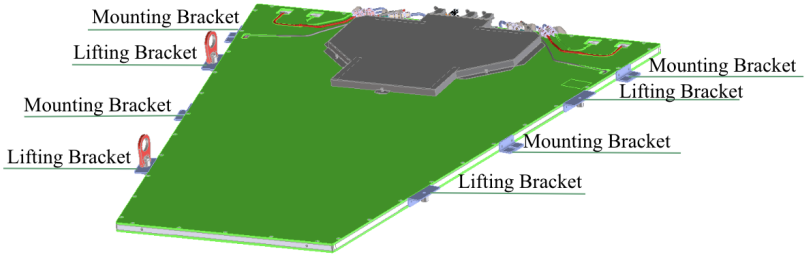

Figure 7: Off-yoke detector with brackets attached

Note that the inner RPCs have a lifting bolt (size M8) that helps transfer them on a crane, it is movable and the RPCs can be transferred horizontally and vertically. An example of a lifting bolt is shown on the left.

Detectors should be initially attached in one of the following order:

- Starting from the bottom and moving up left and right
- Starting from one of the sides (left or right) and moving downwards
- Starting from the top and moving on only one side

This is to avoid the effect of gravity on the movement of the detectors this will help attach every detector. The detectors are raised by a crade (crane should only hold the detector from two points), one 'on yoke' detector is placed and attached on both left and right yoke brackets. Note that the 'on yoke' detectors are only attached to the yoke through four points (through the yoke brackets). The other end of the detectors is supported by the distancing brackets.

Once one detector is attached, the same process is repeated for another alongside 'on yoke' detector. Then one 'off yoke' detector is attached on top of the two 'on yoke' detectors and are connected together by the distancing brackets. Alternate between 'on yoke' and 'off yoke' detectors in the same method above. Adjust the angles of the detectors as needed, general movement range of the detectors is around $\pm$ 2mm. Finally the final detector is placed after needed adjustments which results in figure 8 below.

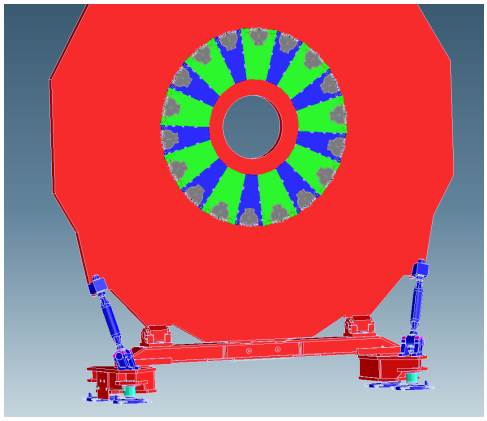

Figure 8: Final detector placement of the RE $\pm$3/1

4. RE $\pm$4/1 Mounting

4.1) Design/Drawing

One of the tasks within this program was to create a drawing of a bracket used to connect the RPCs in RE $\pm$4/1. Drawings of separate parts of this bracket and a drawing of the final assembly was created. Below in figure 9 is an example of the assembly drawing that was done.

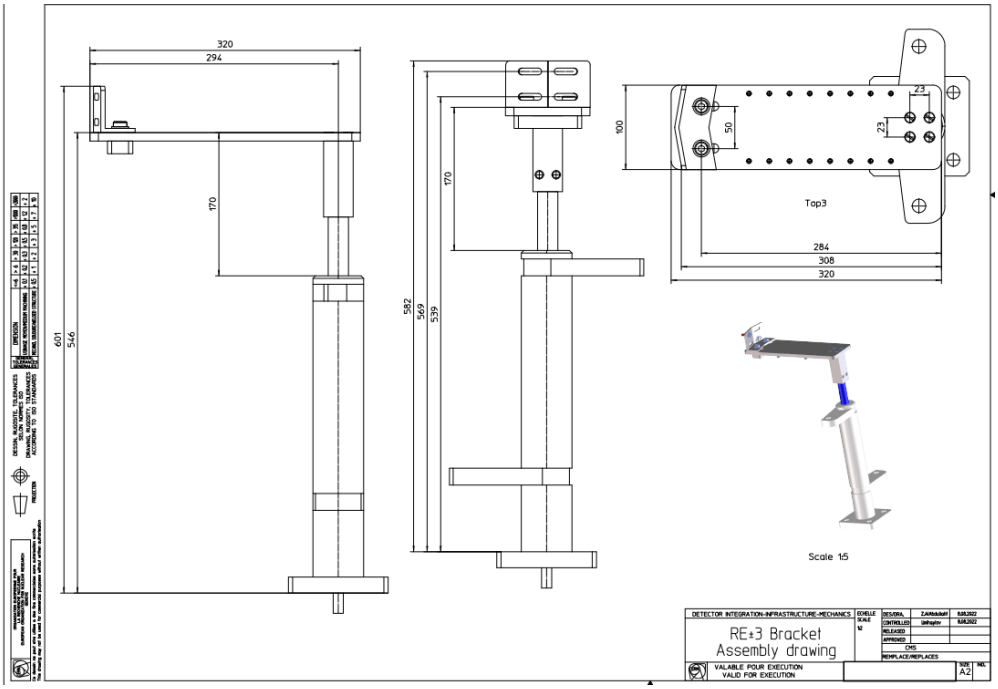

Figure 9: Assembly drawing of the outer main bracket for the RE ±4/1

4.2) Document

For the RE ±4/1 assembly, two general brackets are needed: Big Radius and Small Radius. The big radius bracket is shown on figure 10. It holds the 'on yoke' detectors from the outer points and connects them to the 'off yoke' detectors. Each 'on yoke' detector connects with two big radius brackets that should be assembled off-site.

The threaded rod connection with threst of the bracket is designed in a way that allows the post to rotate clockwise and anticlockwise but constrains vertical movement which in turn allows the detector to rotate around that point. The bracket has multiple elliptical holes in its design which allows the RPCs attached to them to tilt within 20mm movement range.

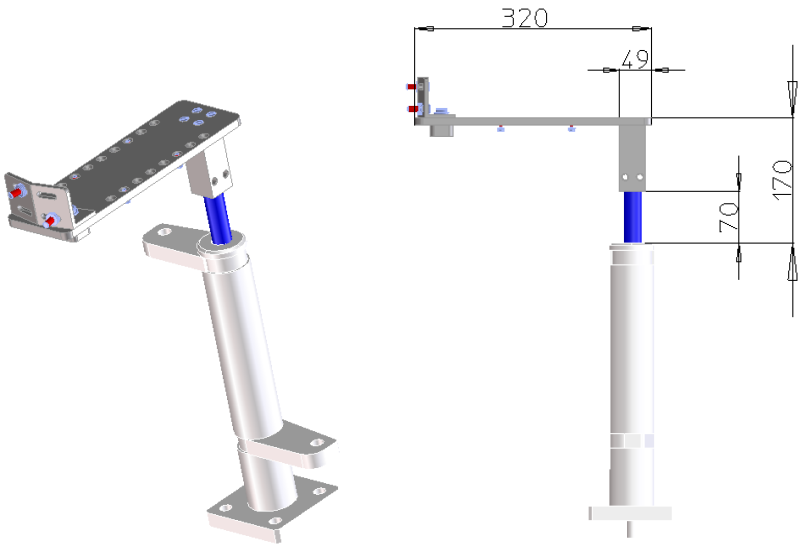

Figure 10: Dimensions of the main bracket of RE ±4/1

The small radius brackets are designed in two ways, one with a short post and one with a long post. The short post holds the 'off yoke' detectors and the long the post holds the 'on yoke' detectors, these brackets are shown in figure 11 and should be assembled offsite.

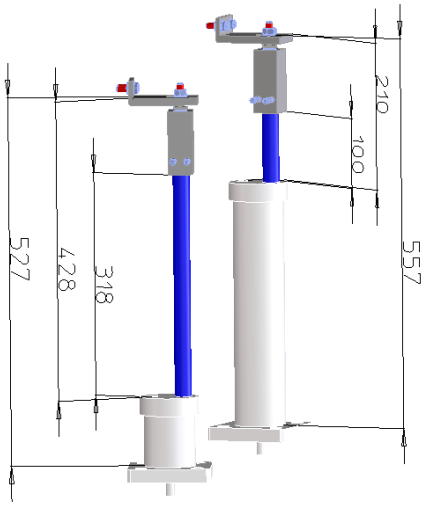

Figure 11: Dimensions of both the inner brackets of RE ±4/1

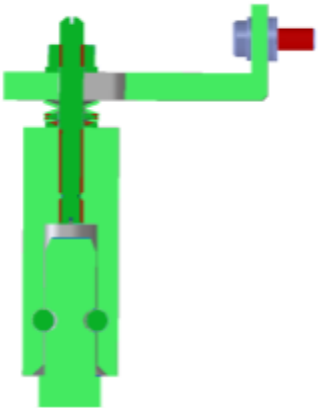

Figure 12: clipping that shows the threaded rod connection

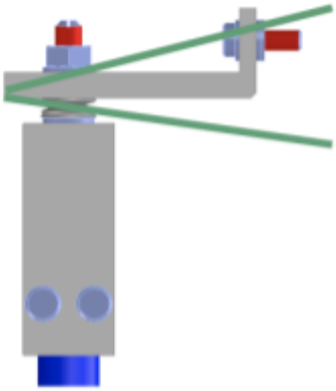

Figure 13: Effect of the belleville washers on the bracket

The connection between the L bracket and the square holder has two main features: the threaded rod and the belleville washers. The threaded rod in figure 12 has a plug piece that is glued into the hole, then the rest on the threaded rod is inserted and glued as well. This is necessary to make sure the connection is fixed. On the other hand, figure 13 shows how the belleville washer design affects the bending movement of the bracket, it should only move in $\pm 1.5^{\circ}$.

The assembly of the long and short rod inner brackets are similar, the difference lies in the shape of the L bracket. For the short rod, the bracket will not have an elliptical hole. This is because the 'on yoke' detector placement should be specific and doesn't need adjustments unlike the 'off yoke' detectors. The final assembly of the short rod bracket is shown below in figure 14.

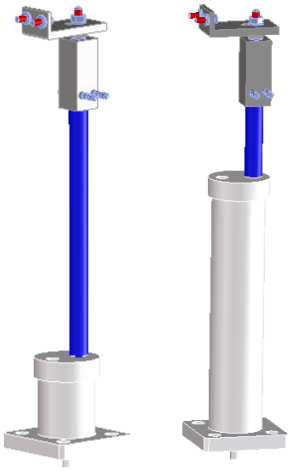

Figure 14: Final assembly of the long (left) and short (right) rod brackets

The white posts should be already attached to the yoke through their square base. To connect the brackets, the rods should be screwed to them. On the inner circle, short rods correspond with long white posts, and long rods correspond to short white posts.

The big radius brackets are also screwed on the white posts as well. All outer brackets are connected together by two flat bars that have elliptical holes on the end to control how close the RPCs are. This is shown in figure 15 below. These flat bars are used to help adjust the location of cables and pipes so that they don't touch other detectors. Figure 16 shows all the brackets attached to the yoke for the RE $\pm$4/1.

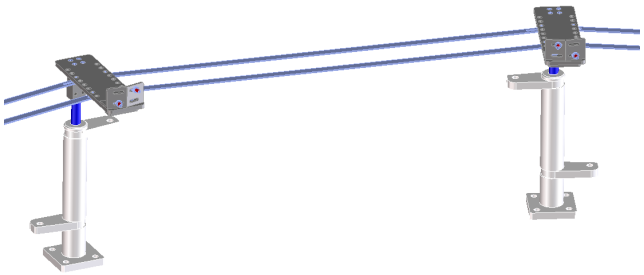

Figure 15: Flat bars connecting the outer backets

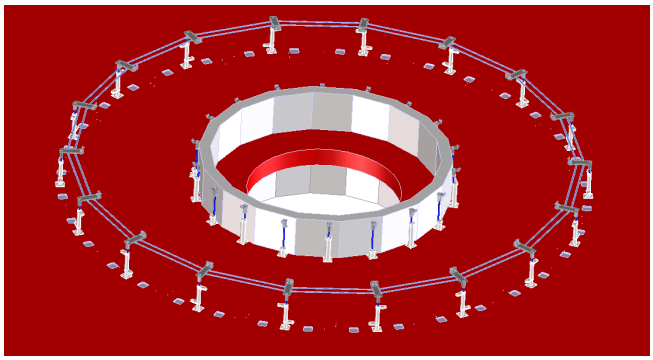

Figure 16: All brackets attacked to the yoke

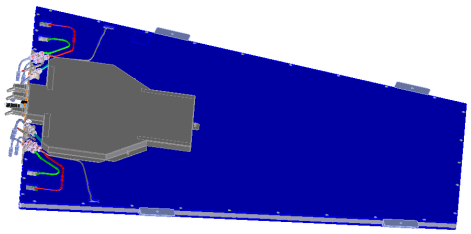

Figure 17: Brackets of the detectors

Each RPC should also have four lifting brackets as shown in figure 17. Notice that there are other detectors and chambers assembled below where the eRPC detectors should be placed. Using the crane, the detectors are lifted and attached to the brackets as seen in figure 18. This process is repeated for two ‘on yoke’ detectors, and one ‘off yoke’ detector in between to result in figures 19 and 20.

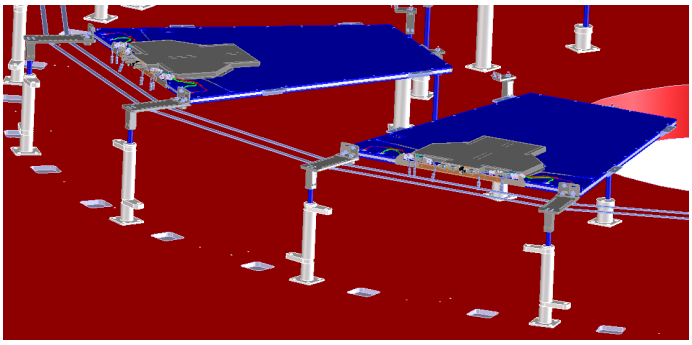

Figure 18: Two ‘on yoke’ detectors attached to the brackets

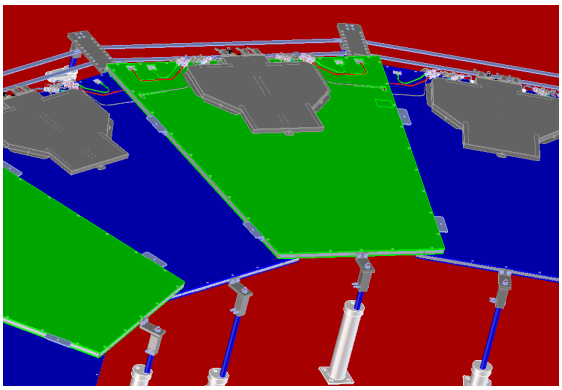

Figure 19: ‘Off yoke’ detectors attached

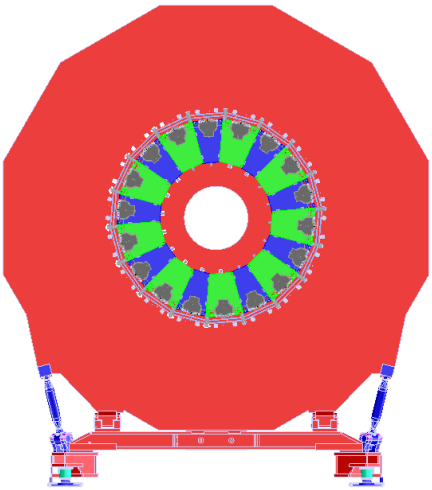

Figure 20: Final assembly results

5. General Remarks and Acknowledgments

This program was an enriching experience that gave an introduction to work life. Visits to different sites were made where I could see real different labs and different work environments. These visits included Atlas, CMS, Data Center, and more.

My greatest gratitude goes to the people who designed and organized the CERN summer student program. Special thanks goes to Mehar Ali Shah and Ivan Mihaylov for supervising my work and helping me understand the material necessary to succeed.

6. Bibliography

[1] Contardo, D., & Ball, A. (2017, September 12). *The phase-2 upgrade of the CMS Muon Detectors*. CERN Document Server. Retrieved August 25, 2022, from https://cds.cern.ch/record/2283189