

CMS Muon Condition Data Automation

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Abstract

CMS Muon Condition Data Automation project implies processing raw data coming from the “CMS non-physics event bus” such as detector currents and rates, environmental parameters, and gas flows, performing in-built analysis studies in the data-streaming by making correlations between detector and condition parameters and preparing final format data for being easily displayed on front-end frameworks such as CMS OMS (Online Monitoring System), RPC General Webpage or others.

The summer student project is devoted to creating the graphical front layer and the navigation layers of the CMS RPC General webpage which aims at being a single-entry point to various RPC field areas, including the visualization of RPC condition data during the operation data-taking period, provided by the Muon condition data automation.

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1 Introduction

The Compact Muon Solenoid (CMS) experiment [1] utilizes four different gaseous detector technologies to build its powerful Muon system [2] focused on delivering muon triggering and identification, as well as charge and transverse momentum measurement: Drift Tubes (DT), Cathode Strip Chambers (CSC), Resistive Plate Chambers (RPC) and the gas electron multiplier (GEM), recently installed in the detector during the second, long-shutdown (LS2) maintenance period.

The CMS RPC system is composed in total of 1056 double-gap chambers. Each chamber consists of 2 or 3 double gaps with 2 mm gas gap width each and a copper strip readout plane located between the top and the bottom single gaps [2]. High voltage (HV) is applied to the graphite electrodes, coated on High Pressure Laminate (HPL), called bakelite, with bulk resistivity in the range of $1\text{--}6 \times 10^{10} \Omega\text{cm}$.

The RPC are operated in avalanche mode with a 3-gas-component mixture of 95.2% Freon ($C_2H_2F_4$), to enhance the ionization caused by incident particles, 4.5% Isobutane (iC_4H_{10}), used to clean the signal, controlling the secondary ionization and 0.3% SF_6 used as a electronegative gas to reduce the streamer formation. The barrel region of the CMS RPC system is divided

into 5 separate wheels (named W0, W $\pm$ 1 and W $\pm$ 2), while a total number of 4 stations (named RE $\pm$ 1, RE $\pm$ 2, RE $\pm$ 3, RE $\pm$ 4) construct each endcap region [2]. Each barrel wheel is divided into 12 sectors in azimuthal angle ϕ , while every endcap station into 36 sectors. The CMS RPC are used mainly as triggering detectors, given their designed and calibrated excellent time resolution of < 2 ns and lower absolute number of adjacent fired strips in a single muon hit, called cluster size, below 3.

The RPC General webpage should collect all information about the CMS RPC detector relevant to different historical periods in the detector evolution such as construction, operation, and calibration.

2 Ideology

The RPC General webpage should serve as a single-entry point to all detector related problematics and various field areas.

The Construction period is the first phase in the life cycle of the RPC detector which covers entirely the chamber mass production. The RPC ConstructionDB is the tool, realized in APEX, responsible for storing all chambers, chamber components and validation tests in the dedicated database schema. The RPC General webpage will host the RPC Construction database in an “iframe” inside the Construction navigation.

The second phase in the life cycle of the detector is the Operation period. Upon construction, all chambers were transported, finally validated, and installed in the big CMS detector. Since 2009 the RPC muon chambers have been operational both in collision and cosmic data taking regimes. Here comes the crucial role of the muon condition data automation which collects all non-physics data, mentioned in the abstract, and performs on-the-fly data analysis using streaming techniques. The results of the various analysis are presented on the second navigation level below Operation. Among those are RPC Currents, RPC Rates, RPC Integrated Charge, RPC Known Problems, RPC OMS. Every single area is broken down to smaller tasks presented on the third navigation layers (Fig. 1).

Important phase in the life cycle of the RPC detector is the Calibration period. At annual basis, calibration runs like HV scans and Noise rate scans are taken to define the best working points of the detector.

R & D is a continuous process which starts before the mass production of the detector and runs permanently for studies on performance improvement, aging, simulation, new eco-friendly gas mixtures.

The next link on the first navigation level is dedicated to Plots which are an important product of the work of a physicist. Storing approved plots is essential as those can be easily displayed and retrieved when writing new articles and proceedings.

Finally, the last highlight in the first navigation level goes to Documents and useful links which will undoubtedly be one of the most visited links.

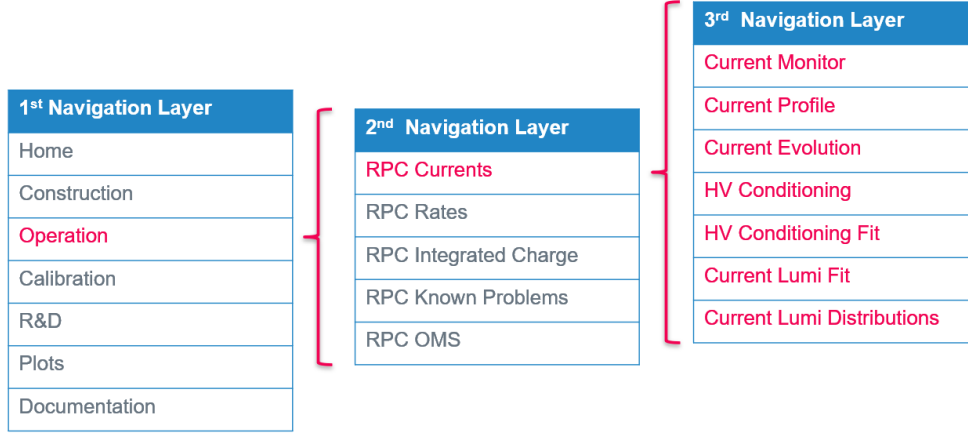


Figure 1: CMS RPC Website navigation levels. The pages which are indicated in red are fully functional with the latest supporting libraries.

3 Methodology

Initially, a research on the latest web development frameworks was carried out. According to the survey, the most popular front-end development frameworks by 2023 are *React*, *Angular*, and *Vue.js*. Similarly, for back-end development *Django*, *Express.js*, and *Node.js* libraries are used. Out of these choices, *Angular* 16 and *Node.js* 16.17.1 were selected to carry out the project given that a patch of the Operation pages of the website was developed back in 2019 using *Angular* 8.

As a first step, the previously developed Operation pages such as Current Monitor, Current Profile, Current Evolution, HV Conditioning, HV Conditioning Fit, Current Lumi Fit, and Current Lumi Distributions were upgraded to Angular 16.

As for the backend development framework, *Node.js* was upgraded to its latest version 16.17.1. Next, the supporting libraries such as *plotly*, *npm* and *bootstrap* were upgraded to their latest versions.

The definitions of Typescript arrays and variables were updated according to their latest versions. The first navigation layer of the website was created with Angular 16 and the Operation pages were re-positioned in the new navigation menu. Next, the App-routing module of the Angular platform that governs the navigation was created.

A sidebar was initialized to all hierarchy levels to access any page. The first navigation layer was placed on the homepage of the website. Furthermore, the CMS logo was placed on the grey color top navigation bar which is displayed on every page (Fig. 2). Finally, the breadcrumbs which display the hierarchy level on each page were updated.

4 Results and Analysis

The CMS RPC Website consists of three navigation levels. The first navigation includes Construction, Operation, Calibration, Research & Development, Plots, and Documentation.

4.1 Homepage

The homepage of the CMS RPC Website is still under construction. The scope of this page is to provide a general overview of the website and the first navigation level is displayed for easier access.

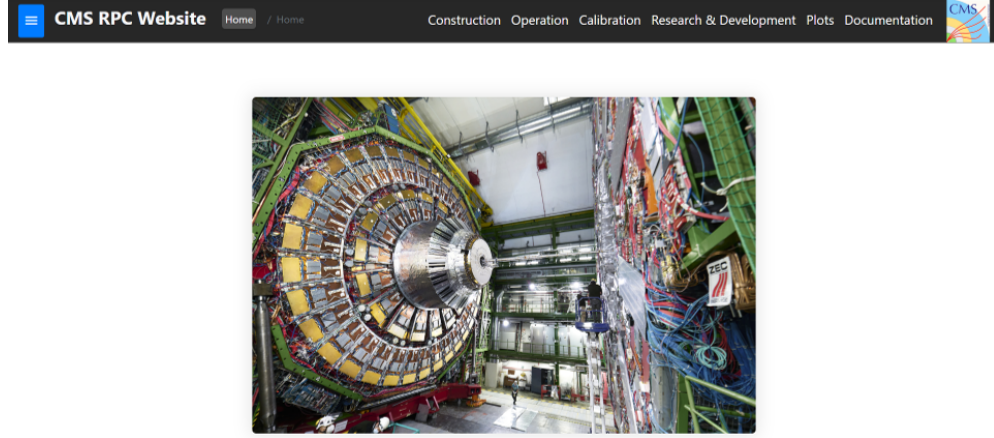


Figure 2: Homepage of the CMS RPC website.

4.2 Operation

The Operation page consists of two sub-navigation levels. RPC Currents, RPC Rates, RPC Known Problems, ML Current Predictions, and RPC OMS form the second navigation level. Various RPC Current studies such as Current Monitor, Current Profile, Current Evolution, HV Conditioning, HV Conditioning Fit, Current Lumi Fit, and Current Lumi Distributions are presented on the third navigation level under RPC Currents (Fig. 3). Operations monitored through these pages are fully functional with their latest supporting libraries (Figures 4, 5, 6, 7).

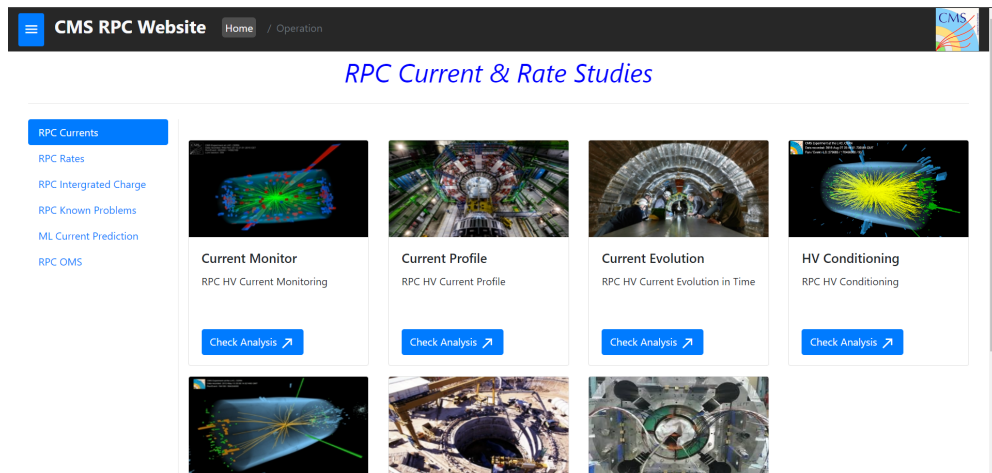


Figure 3: The sidebar menu on the left presents the second hierarchy navigation of the RPC Operation. The grid layout on the right presents the third hierarchy level of the RPC Currents.

4.2.1 RPC Currents studies

In the following, several examples of plots generated by *Plotly.js* upon specifying conditions in a dedicated search engine are presented.

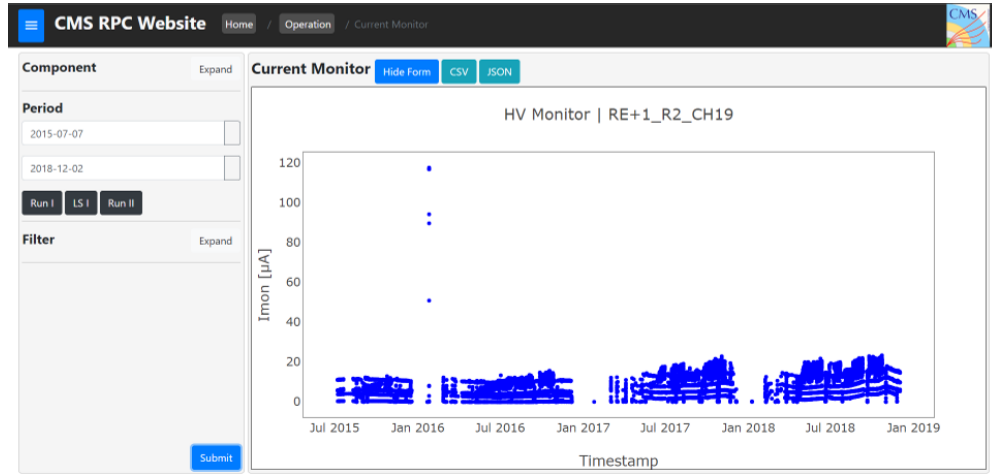


Figure 4: CMS RPC Current Monitor study

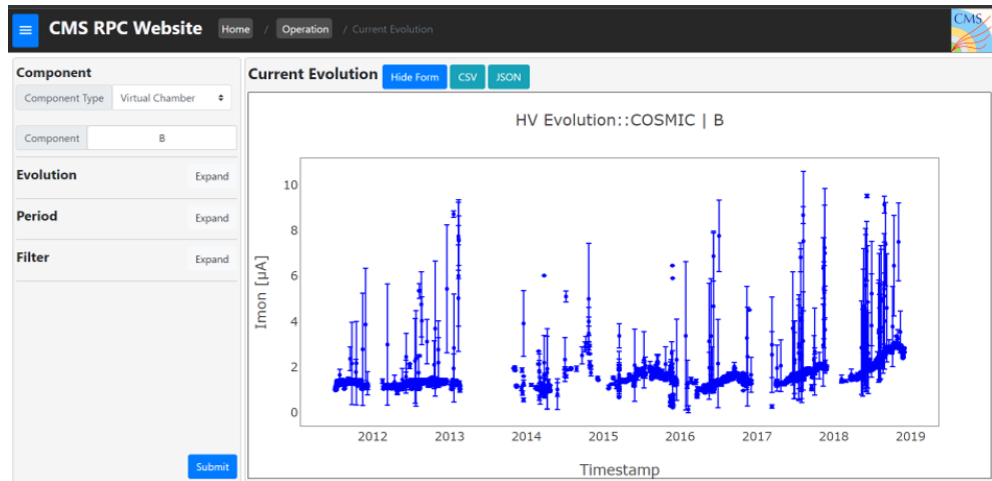


Figure 5: CMS RPC Current Evolution study

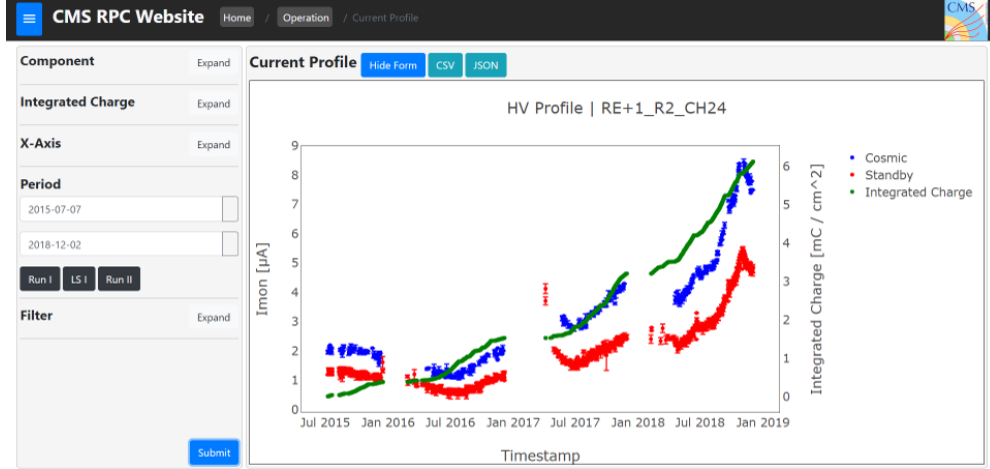


Figure 6: CMS RPC Current Profile

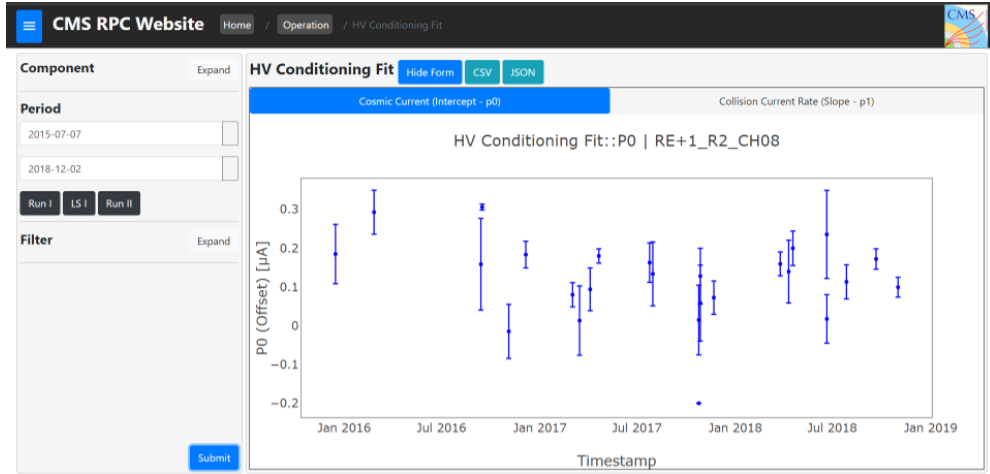


Figure 7: CMS RPC HV Conditioning Fit study

During the process of generating graphs, as shown above, the user has the luxury of selecting the respective component of the RPC Chamber, the time period, and filtering the output by inputting several conditions to the variables. The generated graphs can be downloaded in CSV and JSON formats. The updated *Plotly.js* libraries provide functionalities like zoom-in, zoom-out, crop, and selecting specific graphs to be displayed from the legend. Furthermore, the computing time to generate the plots is greatly reduced due to the latest *Node.js* and *Angular* versions which control the server side and the client side.

4.3 Breadcrumbs

The updated breadcrumbs provide links back to each navigation level and guide the user along the website. The user has the luxury of navigating back to any hierarchy level from the current page according to their preference.

4.4 Sidebar

The sidebar is another feature of the website which is still under construction. The user can explore the hierarchy of the navigation layers of the entire website from one place without navigating back to the Homepage. The sidebar is displayed as a fall-down menu such that the area of the web pages is preserved.

5 Conclusion

For my summer student project "CMS Muon Condition Data Automation", I contributed to the development of the CMS RPC General Webpage. I created a gitlab project inside the cms-rpc project where I designed the Homepage and the navigation tree of the website. I linked an old patch of the RPC Currents studies to the new RPC General Webpage and upgraded all *Angular* and *Node.js* libraries to their latest versions to make the site functional.

References

- CMS Collaboration. "The CMS Experiment at the CERN LHC". in: *JINST* 3 (2008), S08004. DOI: 10.1088/1748-0221/3/08/S08004
- CMS Collaboration. *The CMS muon project: Technical Design Report*. Tech. rep. Geneva: CERN, 1997. URL: <https://cds.cern.ch/record/343814>