Aging studies for the CMS RPC system

Jan Eysermans[1] on behalf of the CMS muon group

[1]Facultad de Ciencias Físico-Matemáticas, Benemérita Universidad Autónoma de Puebla

jan.eysermans@cern.ch

Abstract

Aging effects are studied for the CMS RPC system which can manifest during the HL-LHC running period. A dedicated consolidation program is set up using the CERN Gamma Irradiation Facility ++, where RPC detectors are exposed to a high gamma flux for a long term period equivalent to the HL-LHC operational time. Based on the past operational experience, the high background conditions are estimated and the RPC are tested under such circumstances. Several parameters are monitored as function of integrated charge and dedicated test beam periods allows to measure the detector efficiency as function of the background rate. In this work, an overview of the measurements which are performed for these studies is given. After having collected a significant amount of the total irradiation, no aging effects nor degradation of the RPC detectors has been observed. These results suggest that the RPC system is capable to handle the HL-LHC conditions.

1. CMS RPC Muon system

The Resistive Plate Chambers (RPC) at the Compact Muon Solenoid (CMS) experiment at the CERN Large Hadron Collider (LHC) provide redundancy to the muon trigger system and contributes to the muon reconstruction and identification. The key parameters are[1]:

- double gap gaseous detector with 2mm high resistive bakelite electrodes;
- operated in avalanche mode (low streamer probability);
- 480 barrel chambers and 576 endcap chambers with a coverage up to $|\eta| < 1.9$;
- humidified closed loop gas mixture (95.2% $C_2H_2F_4$, 4.5% i-C_4H_{10}, 0.3%SF_6).

2. Motivation of longevity studies

The increase of the luminosity during the High-Luminosity LHC (LH-LHC) up to 5×10^{34} cm^{-2}s^{-1} at a center-of-mass energy of $\sqrt{s}$ = 14 TeV will be a challenge for the RPC system which would affect the muon identification and reconstruction in the following ways:

- **Performance**: increase of background rate which can lead to (partial) detector saturation and degradation of the performance;
- **Aging**: continuous irradiation can induce non-recoverable aging effects inside the RPC gap materials which can alter the material properties (e.g. bakelite resistivity).

Both effects can lead to a degradation of the performance with a lower muon detection efficiency. Therefore it is necessary to estimate the impact of these effects under the HL-LHC conditions up to an integrated luminosity of 3000 fb^{-1}.

Based on Run-I and II collision data, the maximum rates and integrated charge for the entire RPC system can be estimated, which is shown in the following table[2]. A conservative safety factor of 3 needs to be applied to cover all the uncertainties and to cope with e.g. the center of mass energy increase.

	Run-I+II	HL-LHC	HL-LHC (+safety factor)
Maximum rate (Hz/cm^2)	≈ 40	200	600
Max. Integrated charge (mC/cm^2)	4	280	840

During Run-I and II data taking, no detector degradation nor aging effects were observed so far.

3. Methodology

In order to provide answers to the above questions, a dedicated consolidation study was set up at the CERN Gamma Irradiation Facility ++ (GIF++):

- 14 TBq Cs-137 intense gamma source with controllable attenuation;
- 100 GeV muon beam (several weeks per year);
- controlled environment with T $\approx 21°$C, humidity ≈ 45 % and gas monitoring system.

The setup consists of two endcap chambers of type RE2 and RE4 which are continuously irradiated. Also two non-irradiated chambers of the same type are installed to be used as reference.

Periodic measurements are performed on both the irradiated and reference chambers:

- continuous monitoring of the current and daily rate scans (irradiated chambers only);
- weekly noise scan and high voltage scan without radiation to monitor the Ohmic behavior;
- high voltage scans around the working point for different gamma fluxes;
- during test beam periods the chamber efficiency is measured;
- few times per year measurement of the bakelite resistivity.

From these measurements the detector performance and stability as function of integrated charge can be monitored.

4. Preliminary results

The longevity campaign has been started in July 2016 for the RE2 type chamber whereas the RE4 type has only been included in October 2016 due to gas limitations. The evolution of the charge collection up to now is shown in Fig. 1. The RE2 type has reached around 23% of the aimed charge collection whereas the RE4 type only has collected 8%.

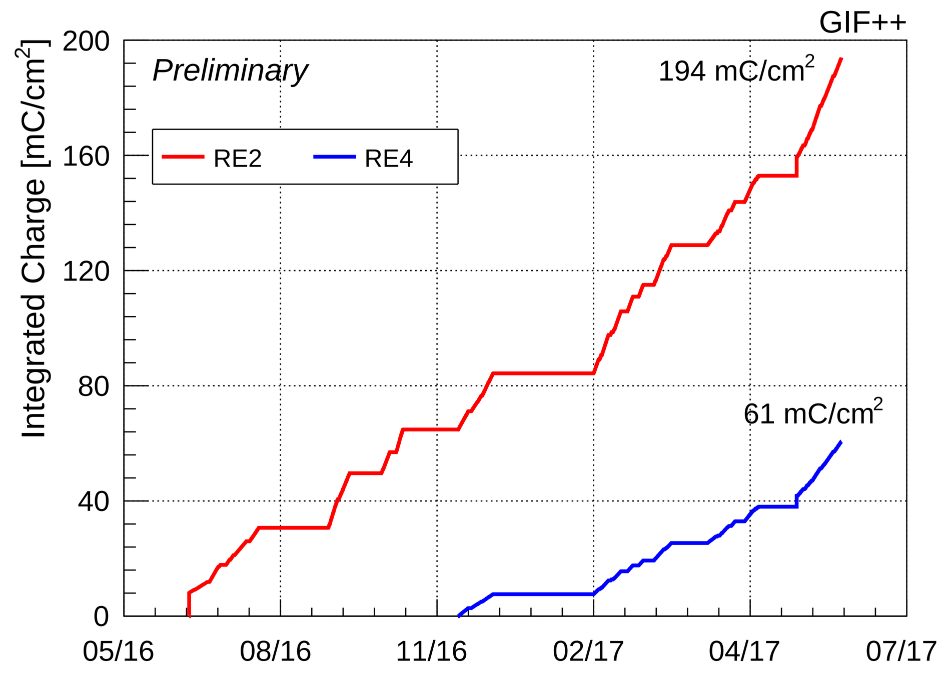

Figure 1: *Integrated charge collected at GIF++ for both RE2 and RE4 chambers.*

Current stability

The stability of the current as function of integrated charge is one of the key parameters to spot any aging effects. The current stability for both RE2 and RE4 is shown in Fig. 2. In order to remove as much as possible the systematic fluctuations related to the gas system, atmospheric variations and external gamma attenuators, the current is normalized to the current of the corresponding reference chamber, taken at the same working point.

From the plot it is clear that a reasonable stable behavior is obtained up to the current values of the integrated charge for both RE2 and RE4. Small variations are accounted for different chamber conditions such as gas flow differences and overpressure.

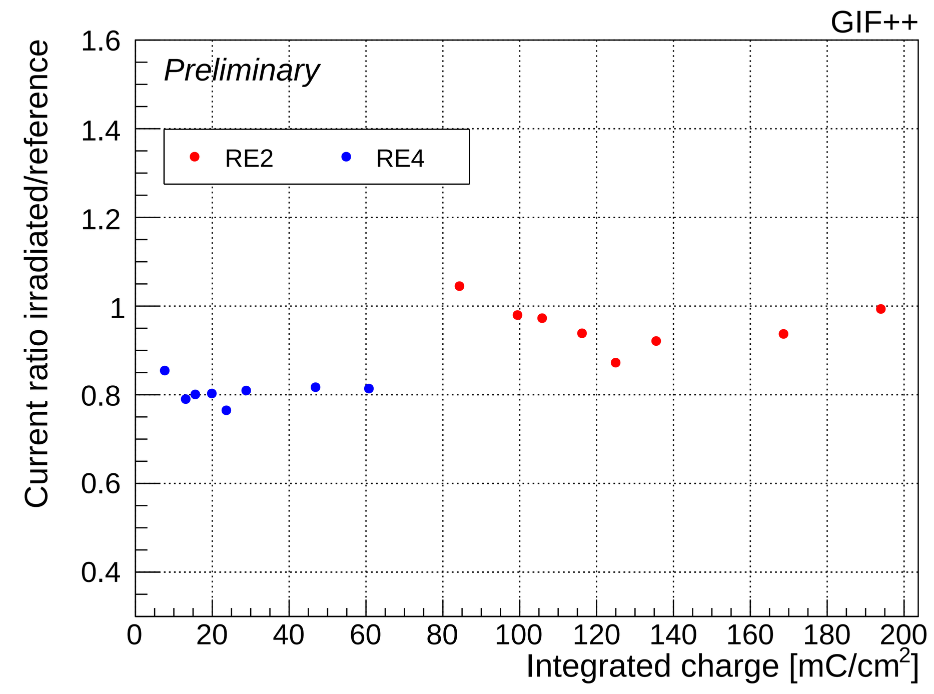

Figure 2: *Current of the irradiated chamber divided by the rate and current of the reference chamber as function of the integrated charge of the irradiated chamber.*

Efficiency and rate capability

The final aim of the longevity studies is to show a high muon detection efficiency at sufficient high rates and stable efficiency up to the aimed charge collection. Dedicated test beam periods allows to measure precisely the muon efficiency for all the chambers under study.

In Fig. 3, the efficiency is shown for both RE2 type chambers at several values of integrated charge and different gamma background rates. No drop of efficiency is observed towards the maximum rate of 600 Hz/cm^2 nor up to an integrated charge of 153 mC/cm^2.

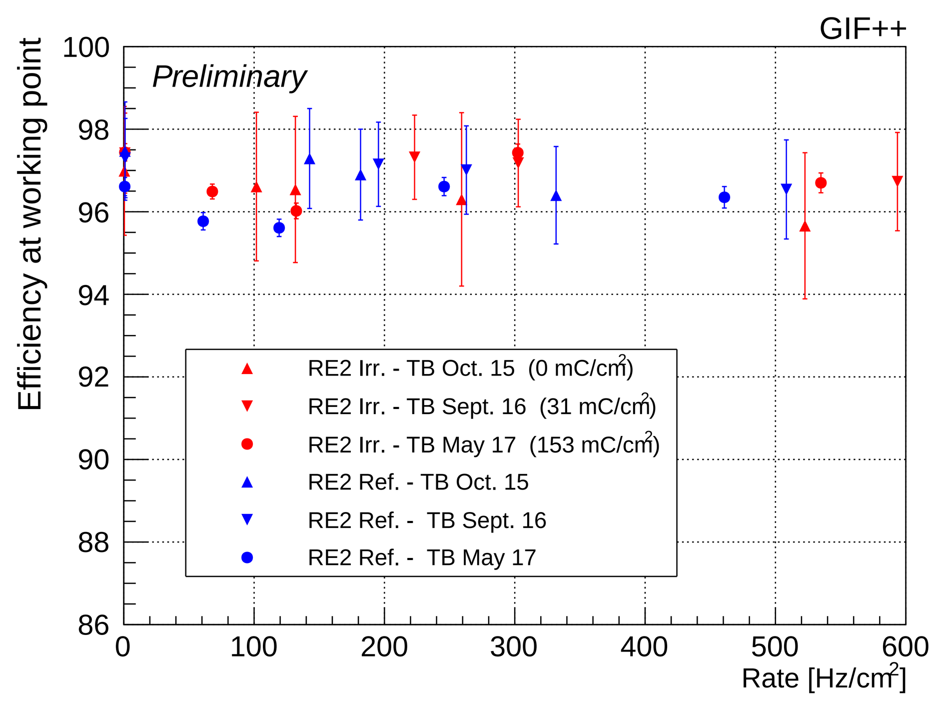

Figure 3: *Efficiency of the RE2 chamber at different values of integrated charge as function of the gamma background rate. The error bars correspond to different tracking algorithms used during the corresponding test beams.*

5. Conclusions

In this poster the motivation, methodology and preliminary results of the CMS RPC aging campaign are presented. Continuous radiation of two RPC types under controlled conditions allows to monitor several detector parameters as function of integrated charge. After collecting of a significant amount of charge, no detector degradation nor aging effects are observed. The chambers tested with a mean background rate up to 600 Hz/cm^2 do not show any evidence of degradation in the detection performance. We conclude from the current study that the current RPC system is capable of reliable operation in the HL-LHC.

References

[1] [CMS Collaboration], CMS, the Compact Muon Solenoid. Muon technical design report, CERN-LHCC-97-32

[2] Study of the CMS RPC detector performance in high radiation background conditions, Poster EPS-HEP2017