Comparison of CMS RPC performance during LHC Run1 and Run 2

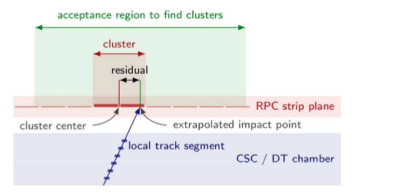
Mehar Ali Shah (National Center for Physics Pakistan)
E mail: mashah@cern.ch
On behalf of CMS RPC DPG

Abstract

The Resistive Plate Chamber (RPC) detector system at the Compact Muon Solenoid experiment at the LHC confers robustness and redundancy to the muon trigger. A total of 1056 double-gap chambers cover the pseudo-rapidity region |η|≤1.6 . All ancillary system (high voltage, low voltage, environmental, gas, and cooling) are constantly and closely monitored to achieve operational stability and high quality data in the harsh conditions of the second run period of the LHC (√s = 13 TeV and 25 ns bunch spacing). Data from these ancillary systems are stored in the online database in order to analyze and tune detector performance. First results of overall detector stability with 2015 data and comparisons with data from the first LHC run period (√s = 8 TeV and 50 ns bunch spacing) are presented.

RPC Efficiency Stability

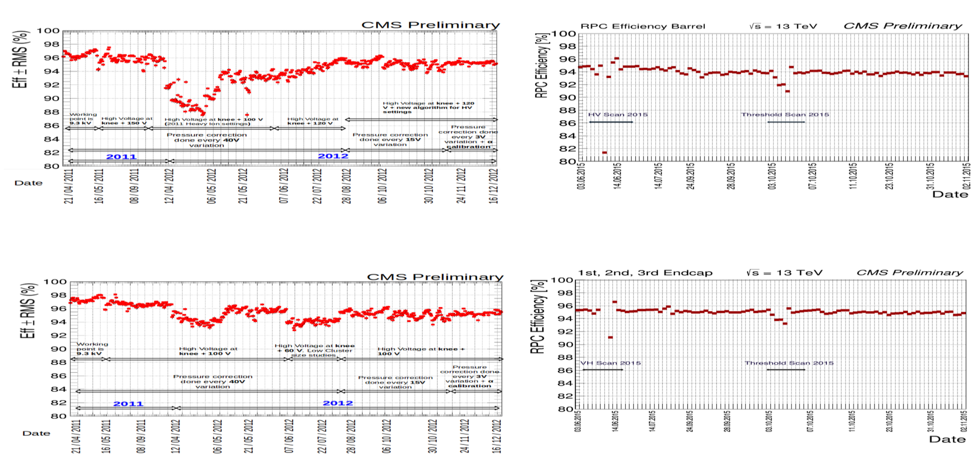
Segment extrapolation method: a DT/CSC segment of high quality, associated to a stand-alone muon track, is extrapolated to RPC strip plane. For each extrapolated impact point, the RPC efficiency is computed looking at RPC Hits in a range of +/- 2 strips from the extrapolated point. Detailed explanation can be found here [3]



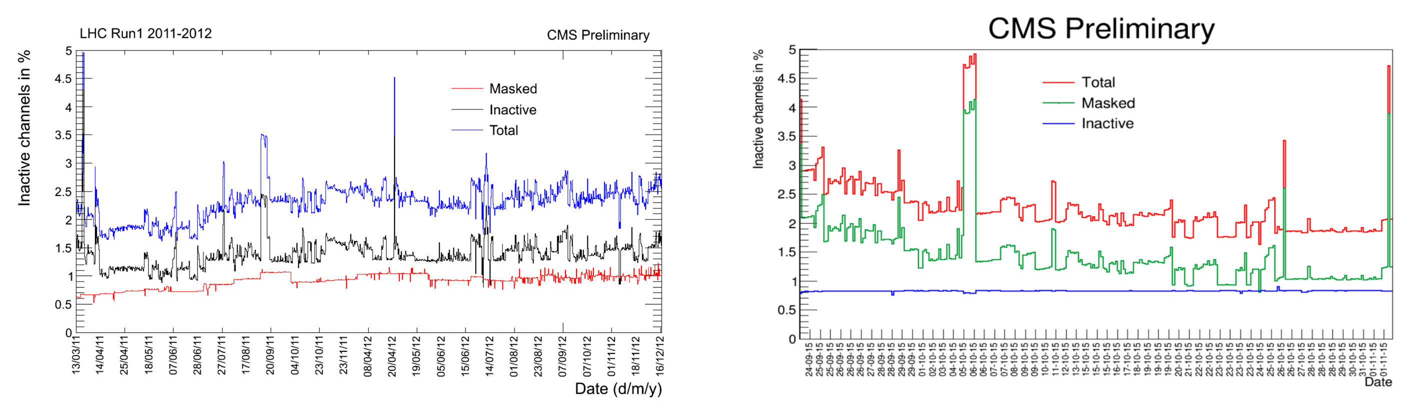
The plot to the left represents the history of the overall RPC efficiency for the Barrel and endcap for the 2011 and 2012 physics data taking. Efficiency is affected by the several HV settings and pressure corrections applied on these settings during 2011 and the beginning of 2012. HV applied to every RPC detector was corrected to compensate for pressure changes in the CMS cavern. An extra alpha factor was applied to account for the different response of every RPC chamber to the changes in pressure. The efficiency at the end of 2012 was kept lower than at 2011 to maintain a lower cluster size and therefore a slightly lower but more stable trigger rate.

The plots to the right represents the history of the overall RPC efficiency for the Barrel and Endcap for the 2015 physics data taking. The fluctuation in the middle of June are due to the performed HV scan. The fluctuations in the beginning of October are due to the performed threshold scan. The RPC efficiency depends on the atmospheric pressure in the cavern. In order to compensate this dependence automatic corrections to the applied HV have been applied during the data taking.

Efficiency history 2011, 2012 at 8 TeV | **Efficiency history 2015 at 13 TeV**



RPC Inactive Channels



2011 | **2012** | **2015**

During 2011, 2012 and 2015 percentage of inactive channels is stable around 2%
Masked strips: mainly caused by noisy chambers due to of electronic board failure (located inside the chambers).
Inactive strips: mainly caused by failures of HV/LV channels. Some of them recovered soon after the beam dump.

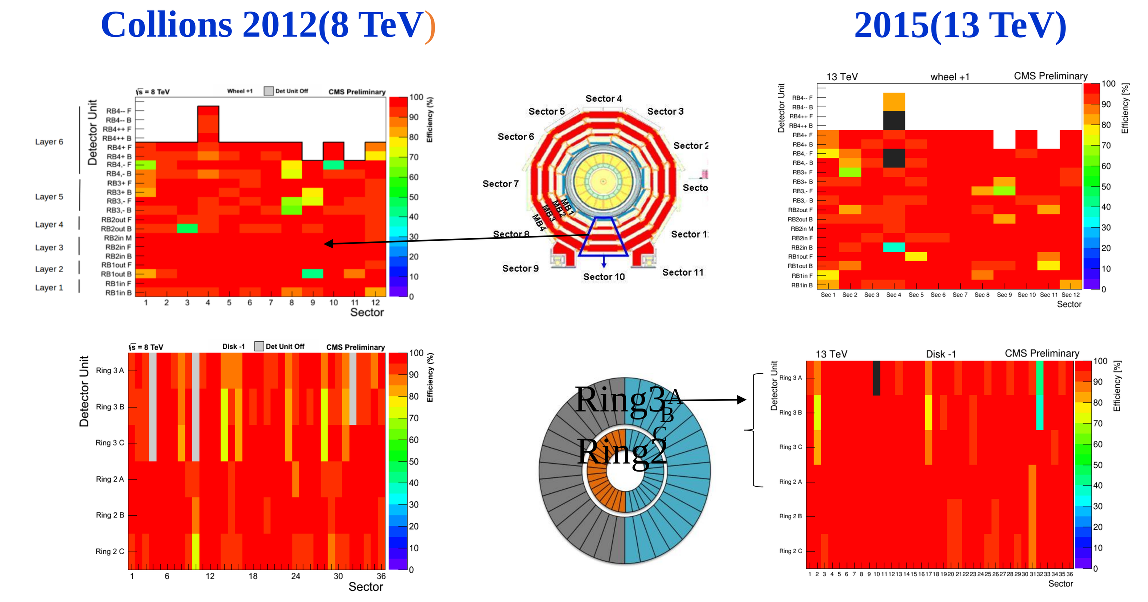
The observed peaks related to the bigger number of masked strips caused by the temporary hardware problems, which were successfully resolved.

RPC Efficiency Map

2D Wheel efficiency map

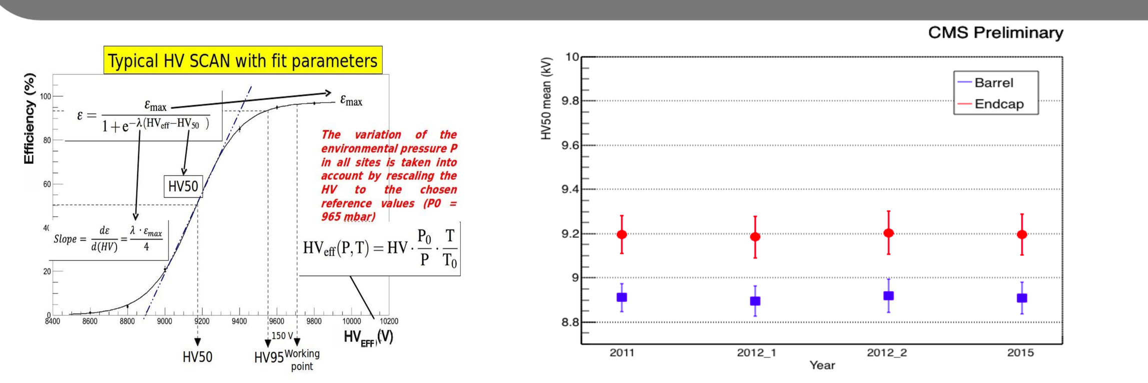
Collisions 2012(8 TeV) | **2015(13 TeV)**

The plots represent the efficiency of wheel+1 in Barrel and Disk-1 in Endcap of CMS. The X-axis corresponds to the sector number (12 in wheels and 36 in disks). The RPC chambers are subdivided in 2 or 3 eta partitions. The Y-axis corresponds to the names of the detector unit. The efficiencies are calculated using the segment extrapolation method explained in [3]. The black entries correspond to the detector units which are switched off due to known hardware problems in 2015 and grey were off during 2012. Blue and green colors correspond to the lower efficiency values measured for detector units which are partially masked.

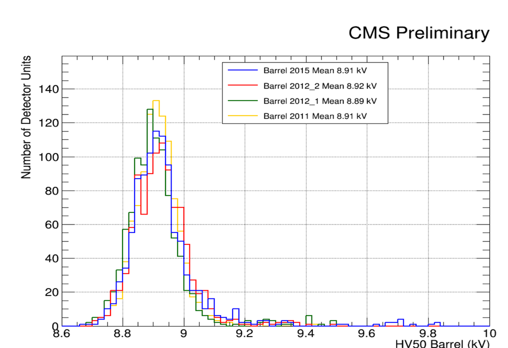


Average RPC efficiency is > 94% after 1 year of LHC running as we decided to operate the detector at lower WP. We are not operating in the limit of the operation of the RPC. In case it is needed we may increase the applied HV at WP.
During 2015, the RPC system was running with a very stable efficiency!!

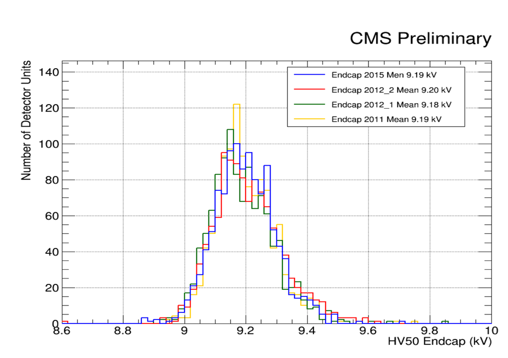
RPC Working Point calibration



HV50 Barrel 2011-12 &2015



HV50 EndCap 2011-12 & 2015



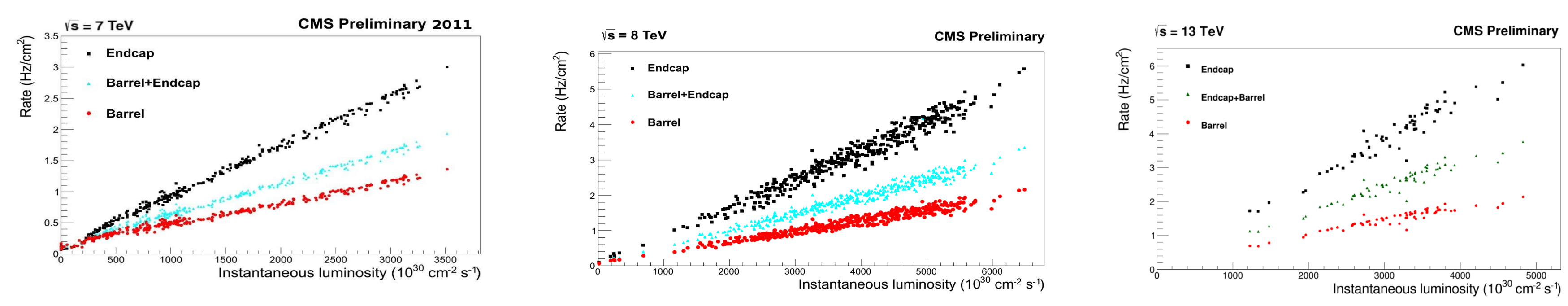
RPC efficiency depends on the applied high voltage. That's why we have performed a HV scan every year to evaluate the optimal working point for every chamber.

HV50 is defined as the high voltage at which the roll reaches 50% of the plateau efficiency. Details can be found in [2] for a full explanation of the HV scan. The width and the peak of the distributions depend mostly on the construction specifications such as spacers sizes and operational conditions. The spacers are the supports that create the RPC gaps in the chambers.

The distributions for 2011, 2012 and 2015 are very similar therefore no obvious ageing effect is observed.

RPC Background (Rate vs Luminosity)

2011, 2012 Barrel average rate vs. inst. luminosity | ***2015 Barrel average rate vs inst. luminosity***



The plots represent the average hit rate vs. instantaneous luminosity, with 2012 pp collisions at 8 TeV and 2015, 13 TeV pp collisions data. The red dots represent the rate measured in Barrel and the black represent the rate measured in Endcap. The green markers relate to the overall rate evaluated for the entire RPC system. The linear behavior can be used to extrapolate the rate for future upgrades.

RPC Rate and Background

Main contribution in measured RPC rate is coming from background, that's why we are using such plots to study the background condition in the cavern. Two plots are shown as an example for 2015 at 13 TeV with their comparison with 2012 at 8 TeV.

The detector units hit rate (in Hz/cm²) is shown for for a run at average instantaneous luminosity of $4.5*10^{33} cm^{-2}s^{-1}$ for a Disk -2 and wheel 0 of barrel. Detector units switched off are shown in gray, while those not used in the background calculations are shown in black. Blue and violet colors correspond to lower rates, while yellow, orange and red colors correspond to high background level.
The comparison shows also the disappearances of the rate asymmetry in Disks -2 Ring 2 after mounting missing shielding on the Non IP side of YE-1 .

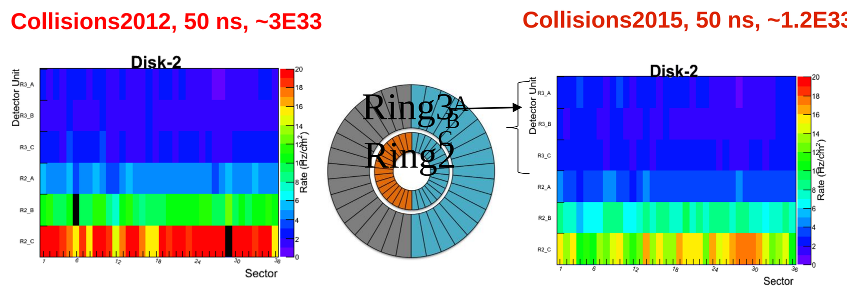
Barrel Higher rate in:
- **outermost stations affected by slow neutron gas**
- **innermost stations affected by HCAL particle leakage**
- **top – bottom asymmetry due to wheels' supports and steel flooring**

Endcap region: higher rate in inner rings i-e higher eta regions

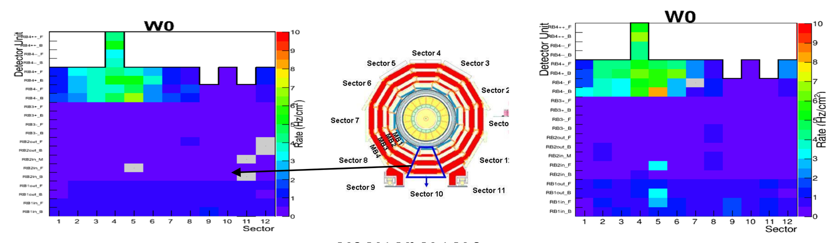
$$\eta \equiv -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$

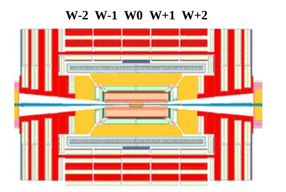
2D disk background map

Collisions2012, 50 ns, ~3E33 | **Collisions2015, 50 ns, ~1.2E33**



2D wheel background map

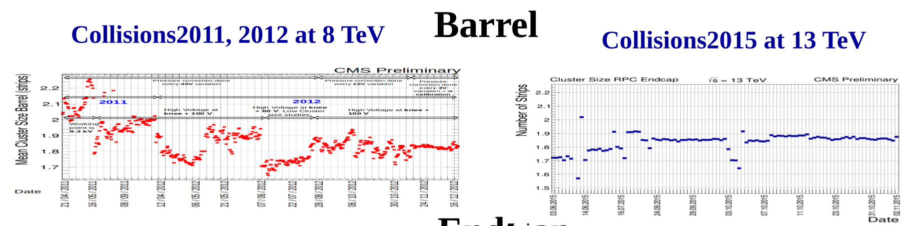




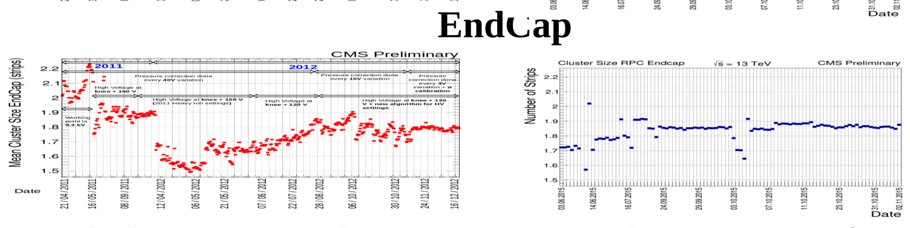
Cluster Size History at 8 TeV and 13 TeV

The plots to the right represents the history of the Mean Cluster Size for the Barrel and Endcap for 2015 physics data taking. The fluctuation in the middle of June are due to the performed HV scan. The fluctuations in the beginning of October are due to the performed threshold scan.

Collisions2011, 2012 at 8 TeV | **Barrel** | **Collisions2015 at 13 TeV**



EndCap



CLS history in 2011 and in start of 2012 affected By the several HV settings and pressure corrections applied on these settings. During 2011 and the beginning of 2012 the HV applied to every RPC detector was corrected to compensate for pressure changes in the CMS cavern. An extra alpha factor was applied to account for the different response of every RPC chamber to the changes in pressure. The CLS at the end of 2012 was kept lower than at 2011 to maintain a lower but more stable trigger rate.

Overall the RPC system has stable cluster size of about 1.8 pitch strip over the years which is in agreement with CMS TDR [1]

Conclusion

CMS RPC system was operating well during RUN 2 (2015). Performance is comparable with RUN1 (2010-12) delivering good triggers and data for physics:

- **At the end of RUN1, the fraction of active channels was about 97.5%. Most of inactive channels have been already recovered during LS1.**
- **At 2015, the fraction of active channels was more than 98.6 %.**

After 1 year of LHC running with increasing instantaneous luminosity and 6 years from the end of RPC construction, the detector performance is within CMS specifications and stable with no degradation observed.

	2012(8 TeV)	2015(13 TeV)
Average efficiency	~ 95%	~ 94 %
Average cluster size	~ 1.8 strips	~ 1.8 strips

From the measured background: no significant issues were found for running up to high luminosity scenarios.

References

[1] CMS Muon Technical Design Report [CERN/LHCC 97-32]

[2] M.Abbrescia et al., "Cosmic ray test of double-gap resistive plate chambers for the CMS experiment", Nucl. Instr. Meth. A550 (2005) 116

[3] The CMS collaboration, The performance of the CMS muon detector in proton-proton collisions at sqrt(s) = 7 TeV at the LHC, Journal of Instrumentation, Volume 8, November 2013 http://iopscience.iop.org/article/10.1088/1748-0221/8/11/P11002

XIII Workshop on Resistive Plate Chambers and related detectors (RPC2016)
Ghent-Belgium
22-26 February 2016