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The Compact Muon Solenoid Experiment

CMS Performance Note

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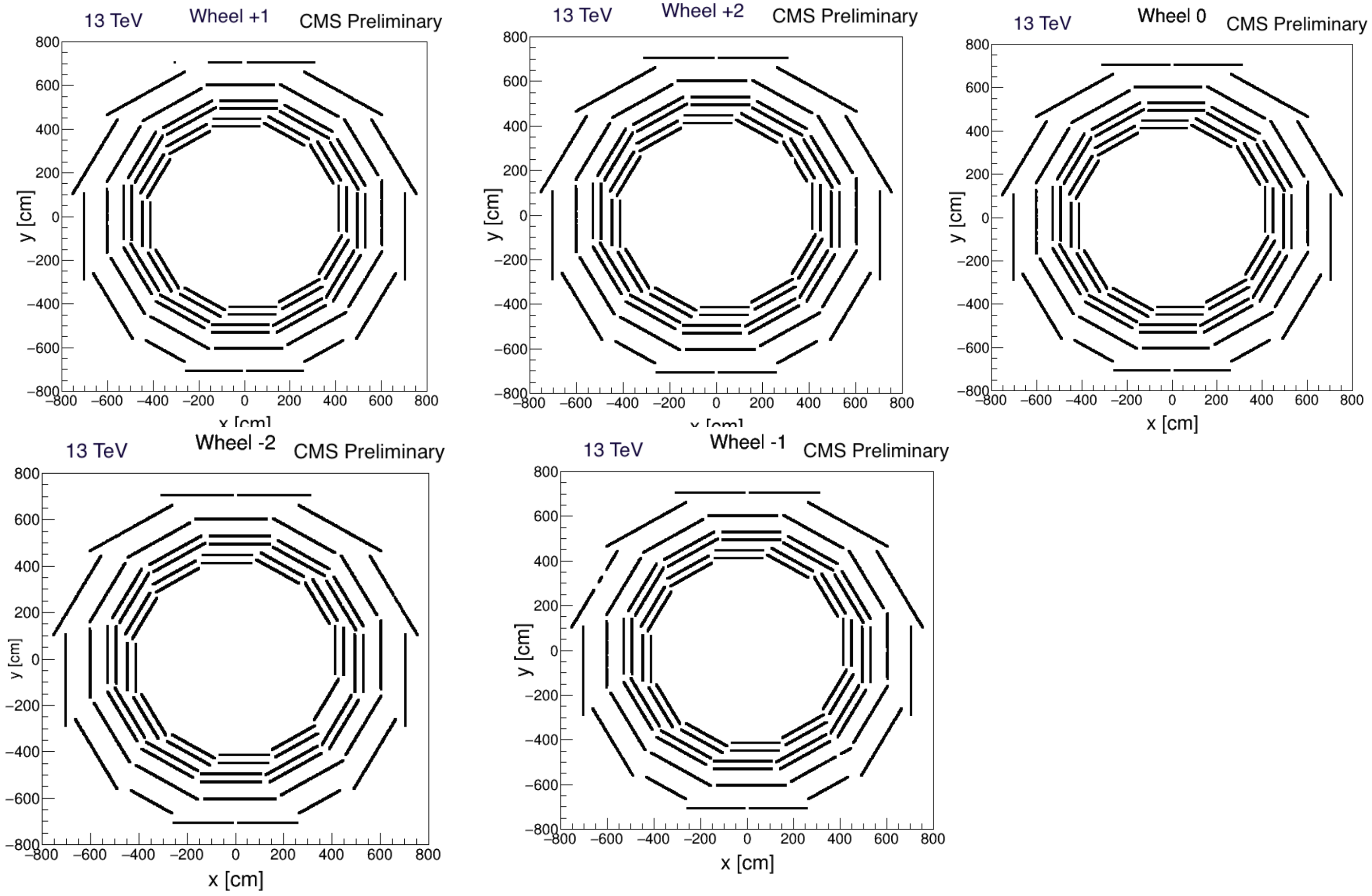
Resistive Plate Chambers commissioning and performance results for 2015

CMS Collaboration

Abstract

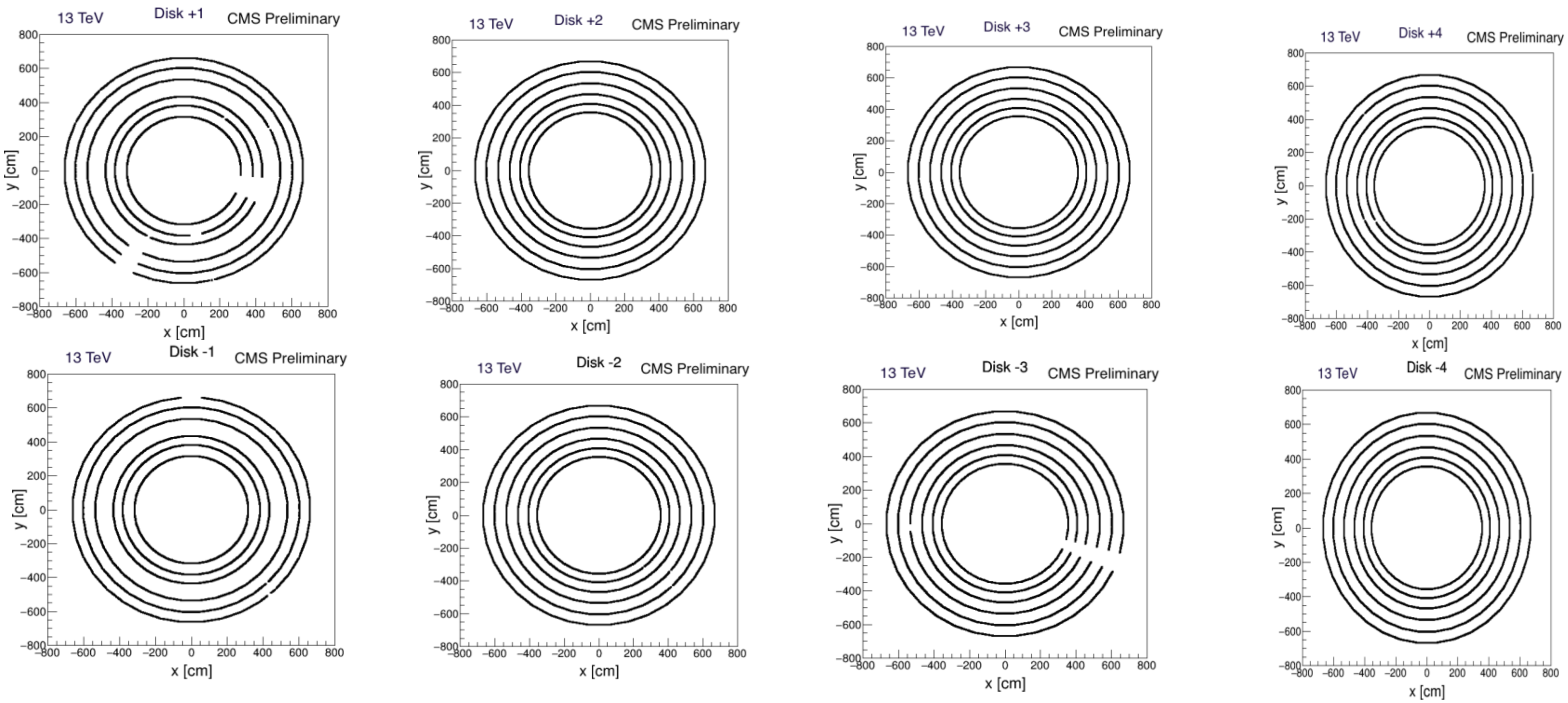
The Resistive Plate Chamber (RPC) detector system at the Compact Muon Solenoid experiment at the LHC confers robustness and redundancy to the muon trigger. During the first long shutdown of the LHC (2013-2014) the CMS muon RPC system has been upgraded with 144 double-gap chambers on the forth forward stations. A total of 1056 double-gap chambers cover the pseudo-rapidity region up to 1.6. The main detector parameters 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 (13 TeV and 25 ns bunch spacing). Resistive Plate Chambers (RPC) performance results for 2015 with pp collisions at 13 TeV are presented. These results include the occupancy, efficiency of newly installed detectors after applying new working point, history plots for the RPC relevant variables such as: Cluster Size, Efficiency, percentage of inactive detector during operation and Rates and overall system noise. RPC variables are studied as function of relevant parameters such as the averaged instantaneous luminosity of the LHC. RPC Background rates measured during 2012 and 2015 with luminosity of $4.5*10^{33}$ $cm^{-2}s^{-1}$ and 50 ns bunch spacing are presented and compared.

BARREL OCCUPANCY



The plots represent the cross-sectional view of the barrel wheels of the RPC system. The black points show the position of the reconstructed hits in the middle of the strips. The results are based on the analysis of the collision data taken since September 2015 to the end of the year at sqrt (s) =13 TeV at 3.8T. The empty spots correspond to the inactive signal electrodes.

ENDCAP OCCUPANCY



The plots represent the cross-sectional view of the 1st , 2nd , 3rd and newly installed 4th positive and negative RPC stations in the forward regions of the CMS (Endcaps). The black points show the position of the reconstructed hits in the middle of the strips. The results are based on the analysis of the collision data taken since September 2015 to the end of the year at sqrt (s) =13 TeV at 3.8T. The empty spots correspond to the inactive signal electrodes.

RPC efficiency

The RPC efficiency values are calculated using the segment extrapolation method explained in [*]
The analysis is based on the 2015D RPCMonitor stream data taken during the 2015 proton-proton collisions at sqrt(s) = 13 TeV and B = 3.8 T and 25 ns bunch spacing.

The analyzed runs are selected to be longer than 1 hour.

The low luminosity runs are also excluded from the analysis.

(*) http://iopscience.iop.org/article/10.1088/1748-0221/8/11/P11002/meta

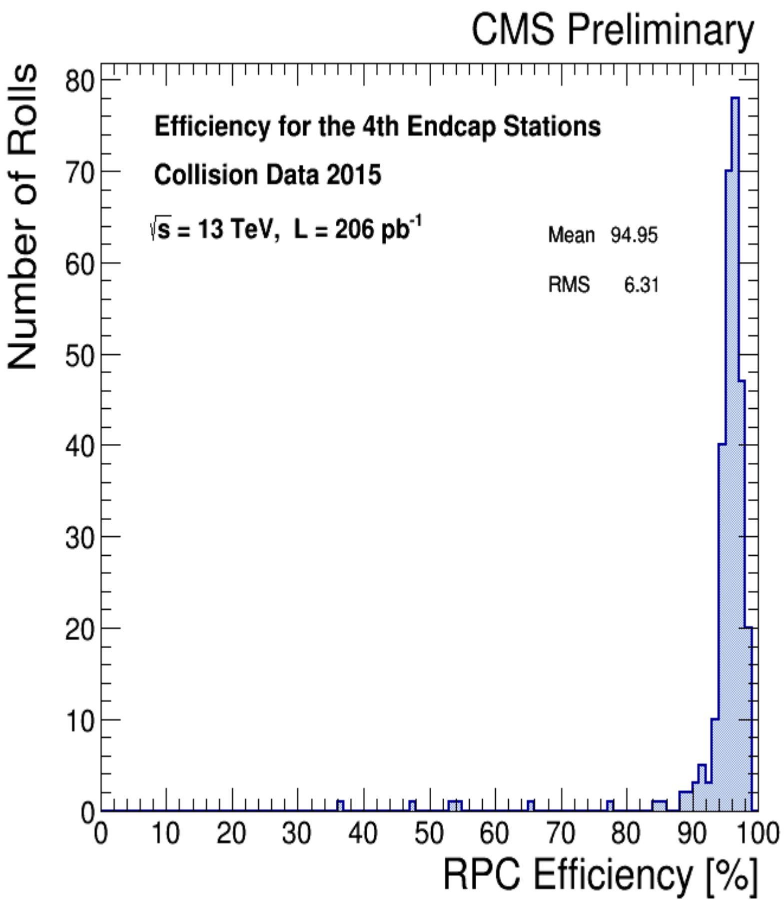
Efficiency of 4th EndCap Stations

During the first long shut down the CMS Muon system was upgraded with 144 newly installed RPC chambers in the 4th endcap stations.
The overall efficiency distribution is obtained using the 2015 collision data at sqrt(s) = 13 TeV and B=3.8T.

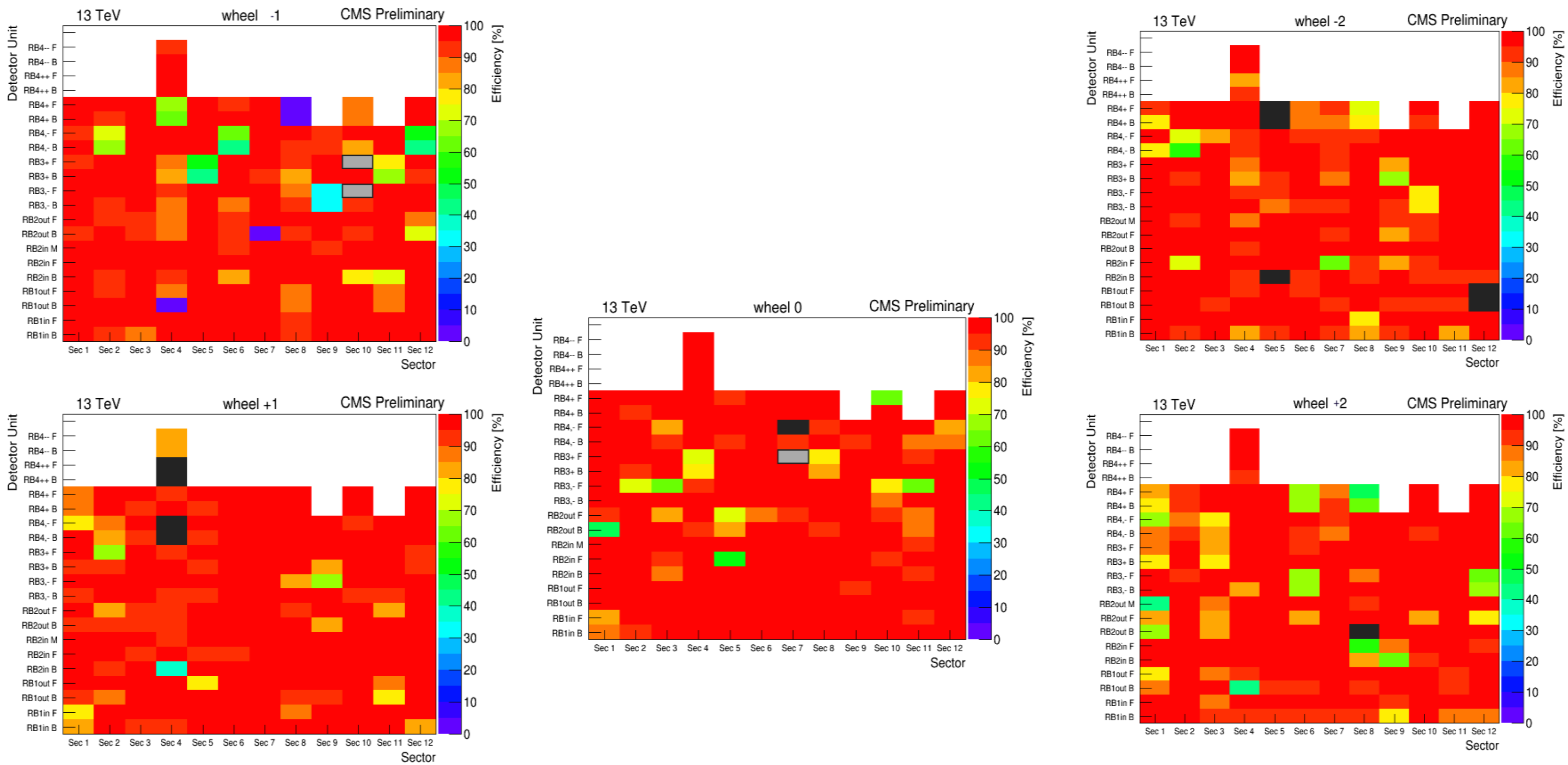
The efficiency distribution shown on the plots is obtained after the new HV working points have been deployed on 08-10-2015. The improvement of a about 0.7% is observed after the setting of the new WPs.

Few chambers with low efficiency in the distribution correspond to known hardware problems.

RE4 efficiency distribution average value ~95%



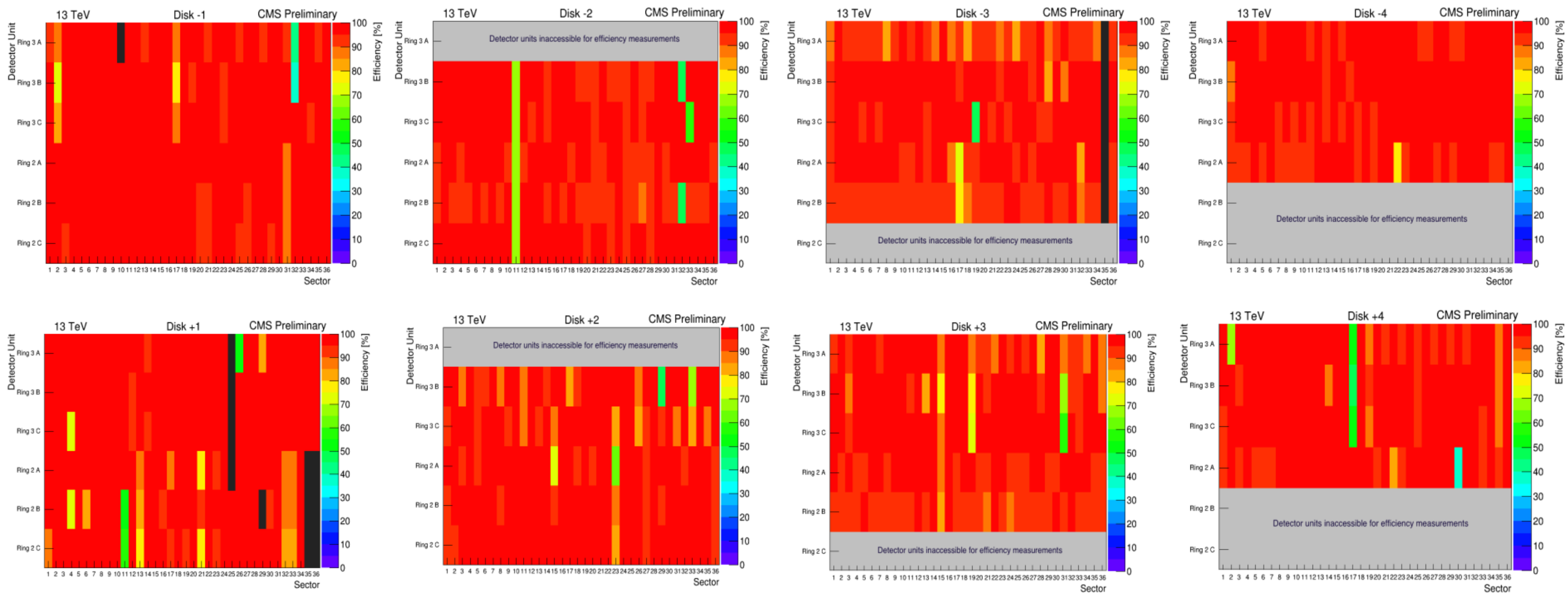
2-D Efficiency for Barrel Wheels
13 TeV, 2015D, 3.8 T



The plots represent the efficiency of all Barrel RPCs. The X-axis corresponds to the sector number – there are 12 sectors per barrel wheel. The RPC chambers are subdivided in 2 or 3 eta partitions. The Y-axis corresponds to the names of the detector unit. The analysis is based on the data taken during the 2015 proton-proton collisions. The black entries correspond to the detector units which are switched off due to known hardware problems and the gray ones correspond to the detector units which are excluded from efficiency calculation because the software algorithm is not effective for them due to geometrical constrains. Blue and green colors correspond to the lower efficiency values measured for detector units which are partially masked.

2-D Efficiency for EndCap

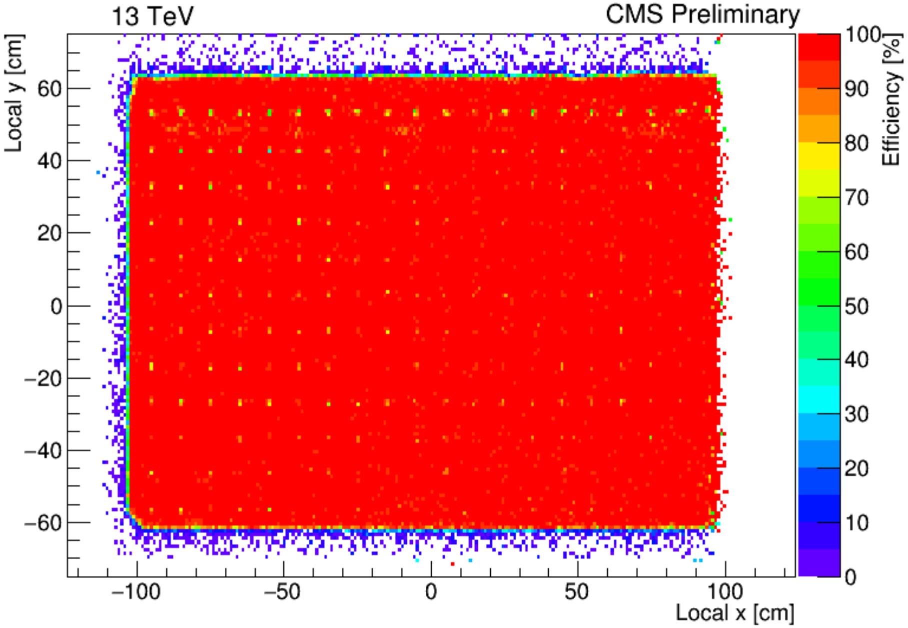
13 TeV, 2015D, 3.8 T

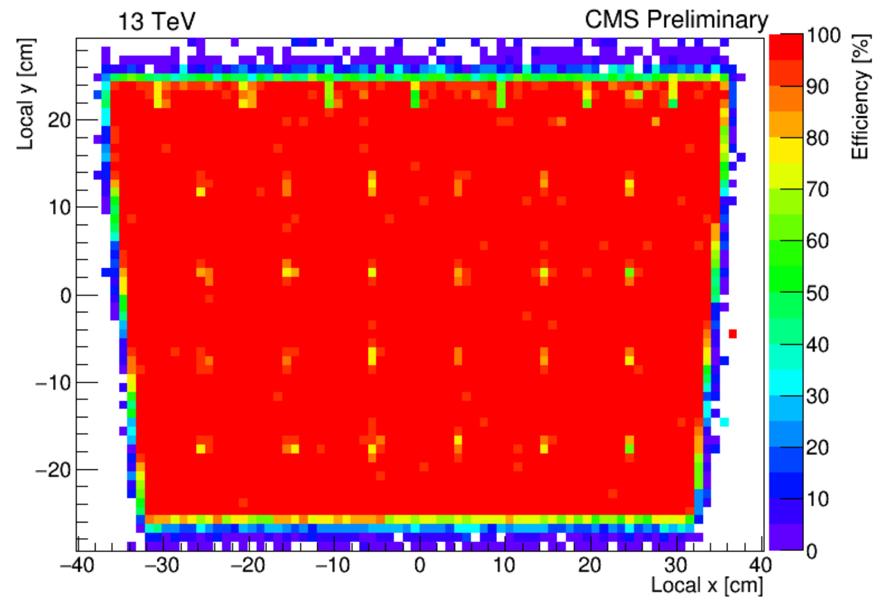


The plots represent the efficiency of the RPCs installed on the four positive and negative endcap stations. The X-axis corresponds to the sector number – there are 36 sectors per ring. The endcap RPC chambers are subdivided in 3 eta partitions. The Y-axis corresponds to the ring number and the names of the detector units. The analysis is based on the data taken during the 2015 proton-proton collisions. The black entries correspond to the detector units which are switched off due to known hardware problems and the gray ones correspond to the detector units which are excluded from efficiency calculation because the software algorithm is not effective for them due to geometrical constrains. Blue and green colors correspond to the lower efficiency values measured for detector units which are partially masked.

Muongraphy Plots

2015-D



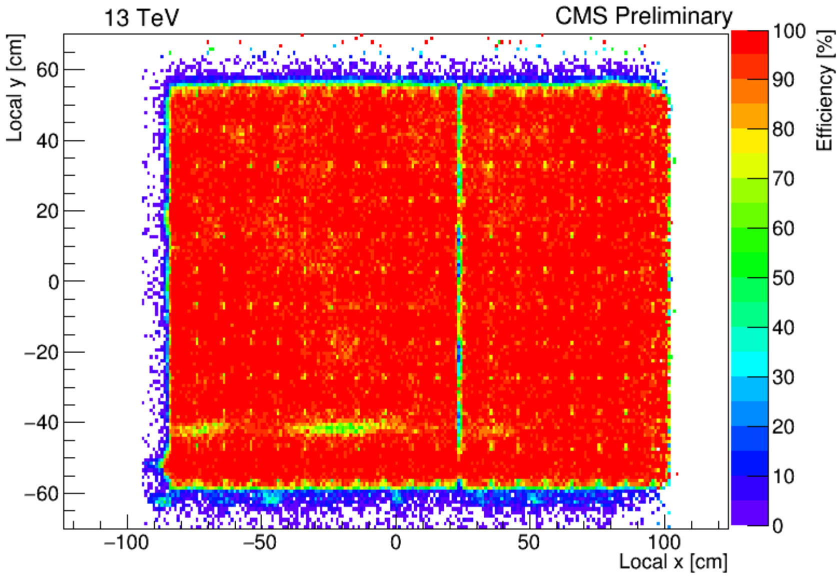


The plots represent the efficiency vs the local impact point on the RPC surface for one of the barrel (left) and one of the endcap (right) detector units, namely W+1_RB1out_S12_Forward and RE-1_R2_CH10_B. The lower efficiency spots are due to the dead regions induced by spacers on a 10 × 10 cm^2. The Y axes is along the strip length. Due to the geometrical issues there are not extrapolated hits in the area corresponding to x >= 98 cm on the left plot and because of this the efficiency is not calculated for it.

Muongraphy

(Example for Leaky Chamber)

2015D



The plot represents the efficiency vs the local impact point on the RPC surface. The showed example is for one of the barrel RPC from the first layer in Wheel -1 (W-1_RB1in_S08_Backward) which was working with no problems during RUN1, but a gas leak problem appeared in beginning of the 2015 data taking (01.02.2015.). Despite the problem the efficiency of the considered RPC is still high enough. The lower efficiency spots are due to the dead regions induced by spacers on a 10 × 10 cm^2. The vertical green line on the right plot corresponds to a masked readout strip.

Efficiency History Plots

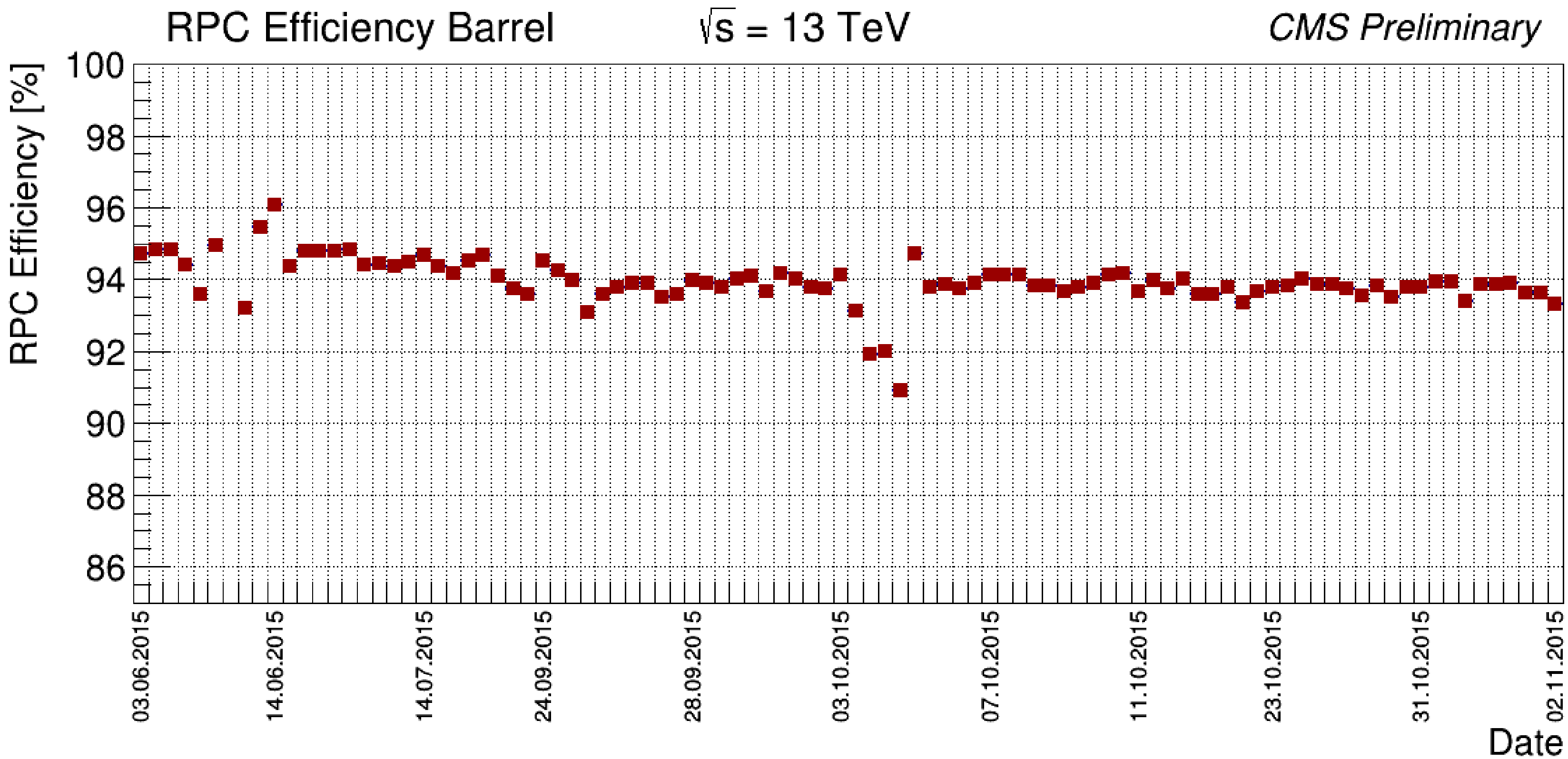
The RPC efficiency values are calculated using the segment extrapolation method explained in [*]
The analysis is based on the RPCMonitor stream data taken during the 2015 proton-proton collisions at sqrt(s) = 13 TeV

The analyzed runs are selected to be longer than 1 hour.

The low luminosity runs are also excluded from the analysis.

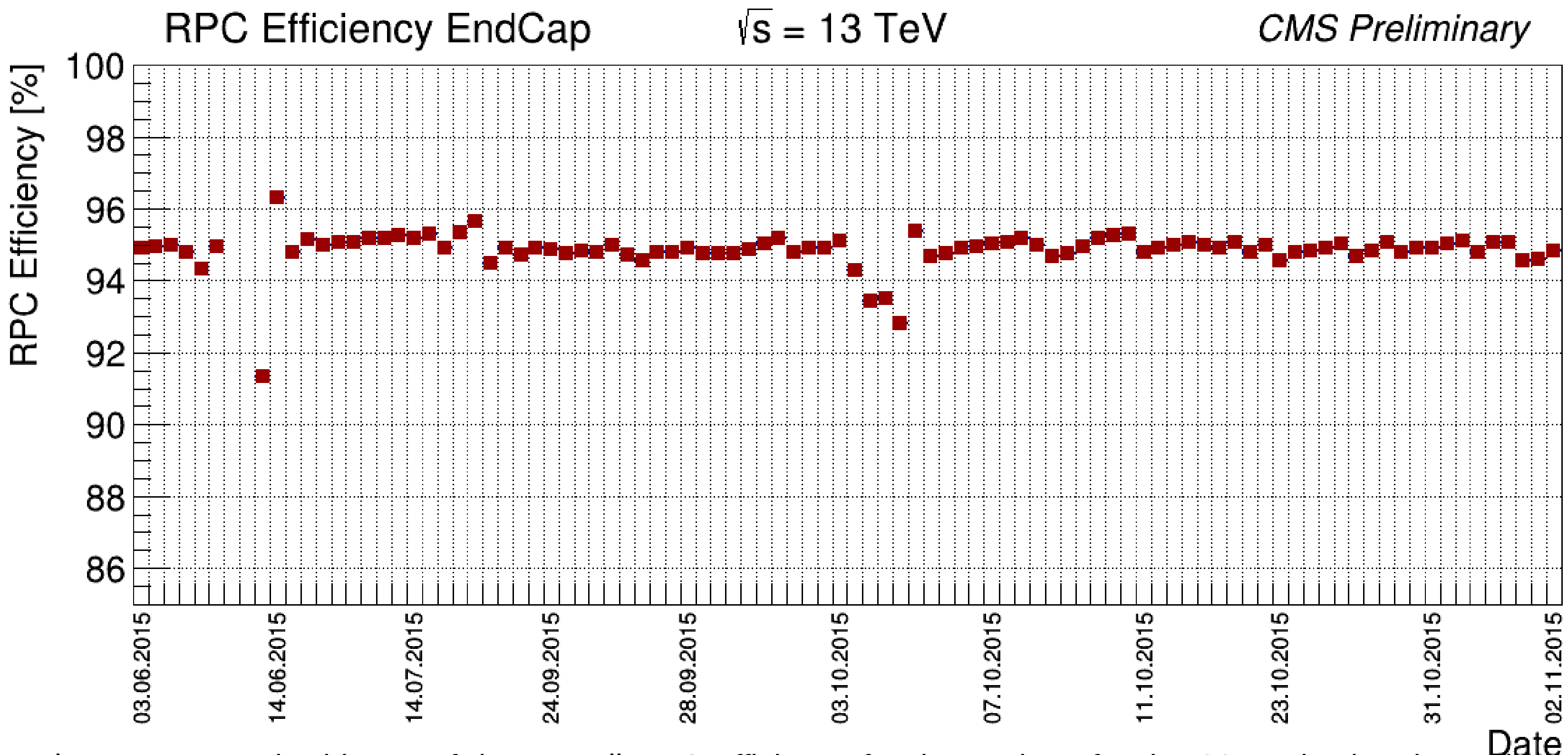
(*) http://iopscience.iop.org/article/10.1088/1748-0221/8/11/P11002/meta

Barrel Efficiency History Plot



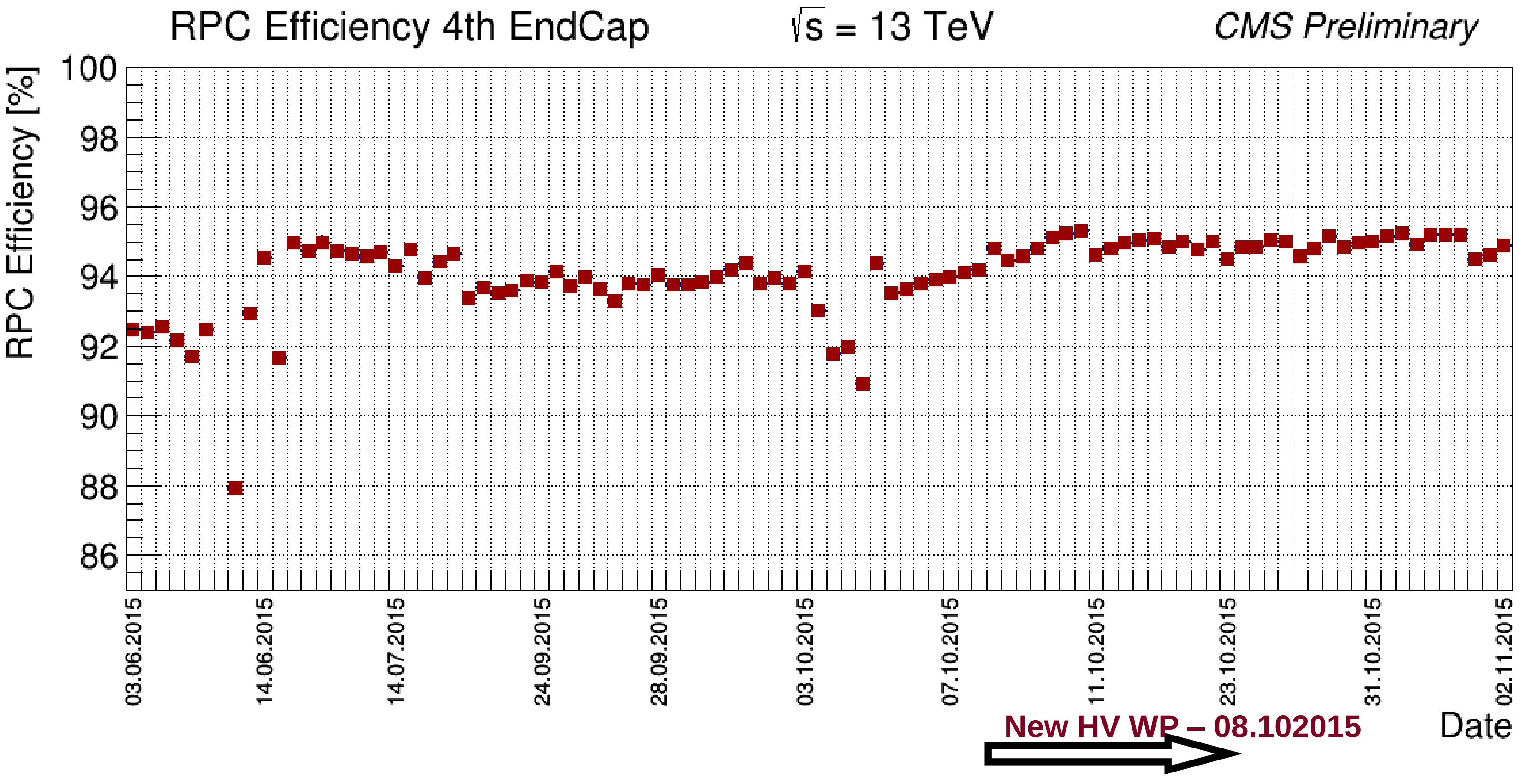
The plot represents the history of the overall RPC efficiency for the Barrel for the 2015 physics data taking. The fluctuation in the middle of June are due to the performed HV scan. The fluctuations in the beginning of October are due to the performed threshold scan. The RPC efficiency depends on the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

Endcap Efficiency History Plot



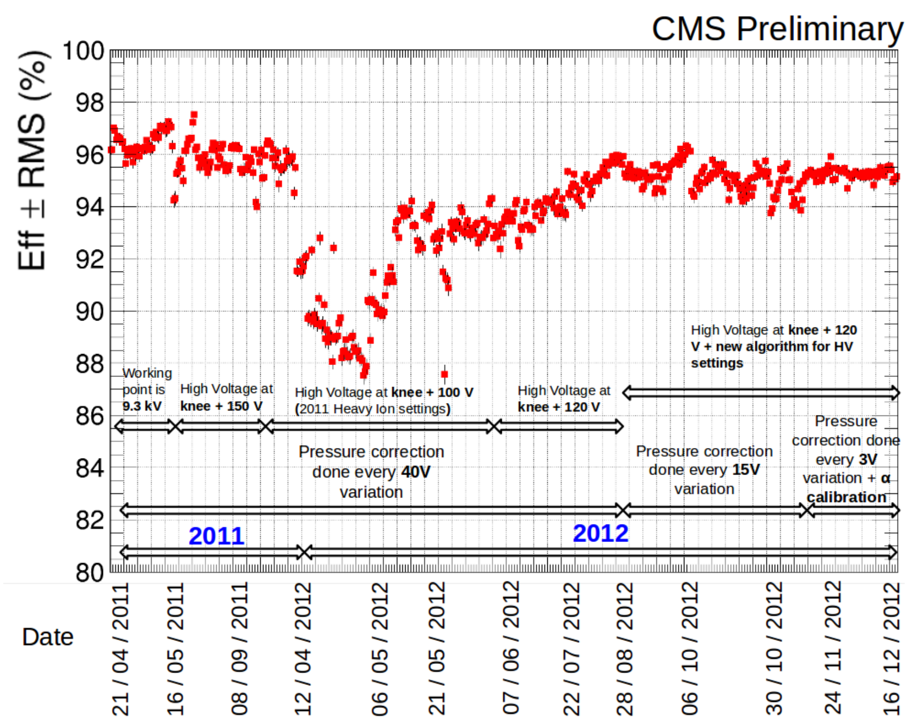
The plot represents the history of the overall RPC efficiency for the Endcap for the 2015 physics data taking. The fluctuation in the middle of June are due to the performed HV scan. The fluctuations in the beginning of October are due to the performed threshold scan. The RPC efficiency depends on the atmospheric pressure in the cavern. In order to compensate this dependence automatic corrections to the applied HV have been applied during the data taking. The automatic pressure corrections were deactivated only for the HV scan runs. Since the main contribution in the number of the extrapolated and observed hits are coming from the first two endcap stations the efficiency fluctuations observed for the RE4 (please, see the next slide) in the beginning of the year do not affect the stability of the efficiency of the whole endcap system.

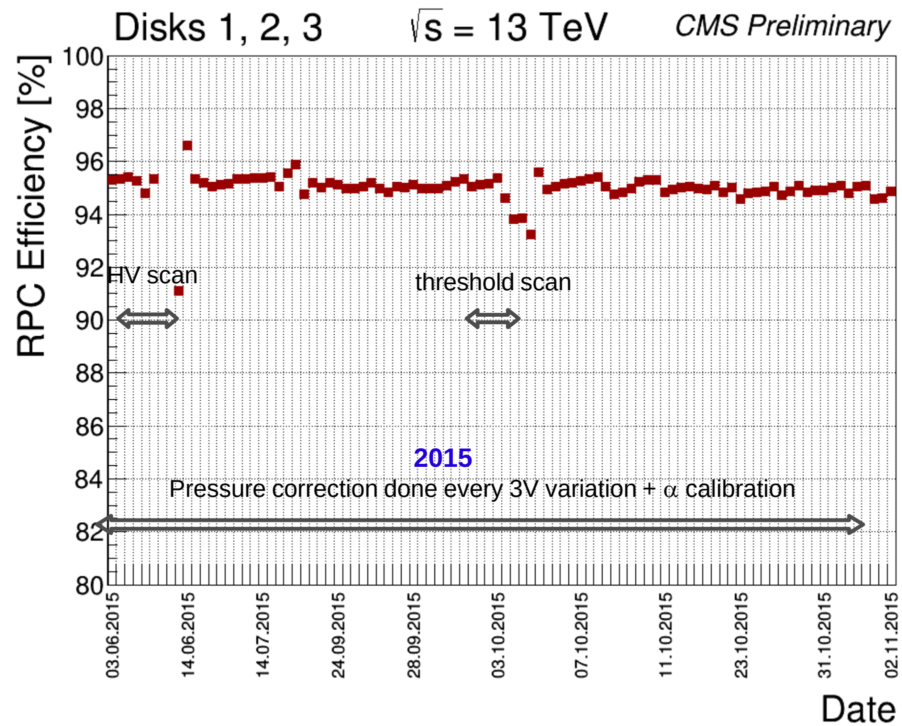
RE4 Efficiency History Plot



The plot represents the history of the overall RPC efficiency for the newly installed RPCs on the forth positive and negative endcap stations 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. After the deploying of the new HV working points (08.10.2015) the system performance is improved and the efficiency is higher. 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. The automatic pressure corrections were deactivated only for the HV scan runs.

Endcap Efficiency History Plot



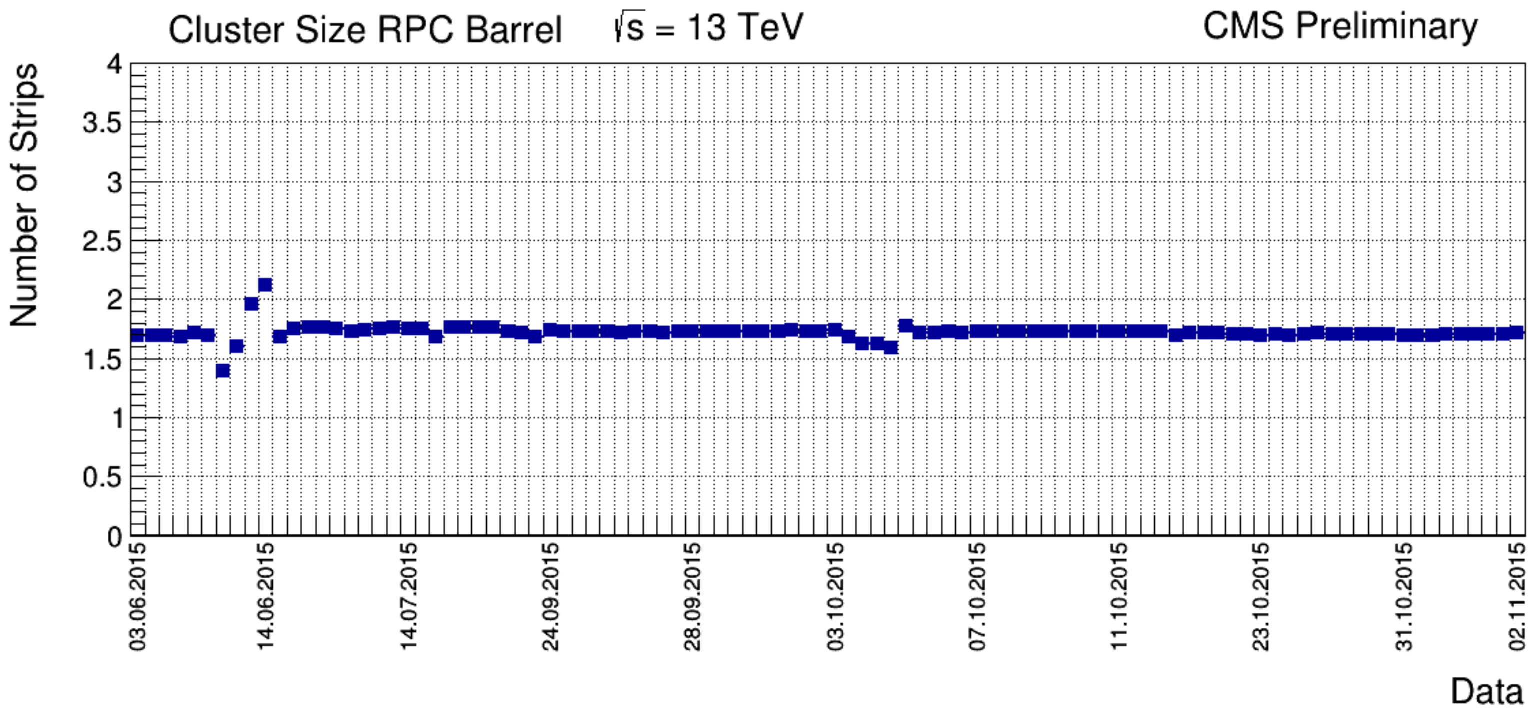


The plot on the right represents the history of the RPC efficiency for the first three endcap stations (run1 system) evaluated with the 2015 physics data taking. The fluctuation in the middle of June are due to the performed HV scan. The fluctuations in the beginning of October are due to the performed threshold scan. The effective HV depends on the environmental parameters, where the dominant effect is due to the atmosferic pressure variation. A variation of about 10 mbar produces a HV eff difference of about 100V [**]. In order to compensate this dependence automatic corrections to the applied HV have been applied during the data taking. The automatic pressure corrections were deactivated only for the HV scan runs.The plot on the left represents the efficiency measured during Run1 data taking period.

(**) (http://iopscience.iop.org/article/10.1088/1748-0221/8/03/P03017/pdf)

Barrel Cluster Size History

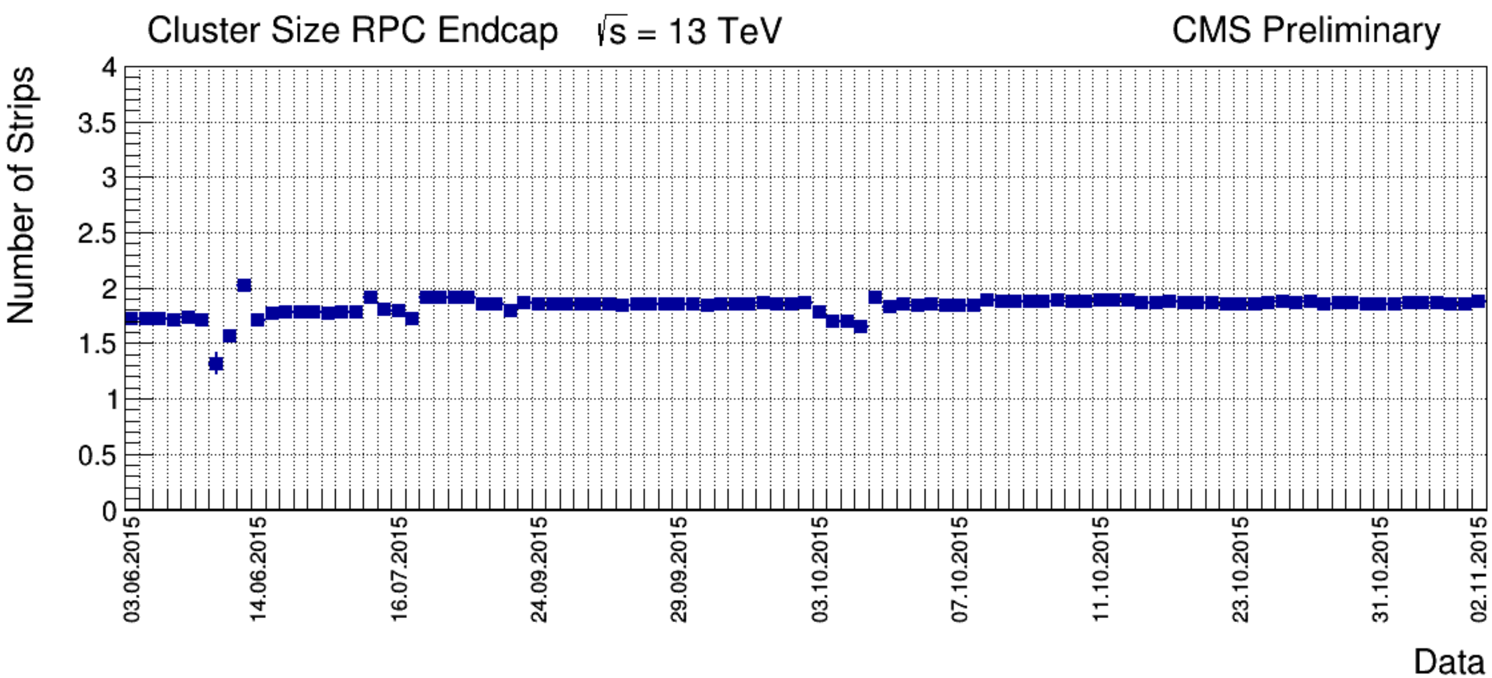
Collisions 2015 at 13 TeV



The plot represents the history of the Mean Cluster Size for the Barrel 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 details about the expected values of cluster size can be found (CERN/LHC 97-32 (https://web.physik.rwth-aachen.de/~hebbeker/cms_muon_tdr.pdf)).

EndCap Cluster Size History

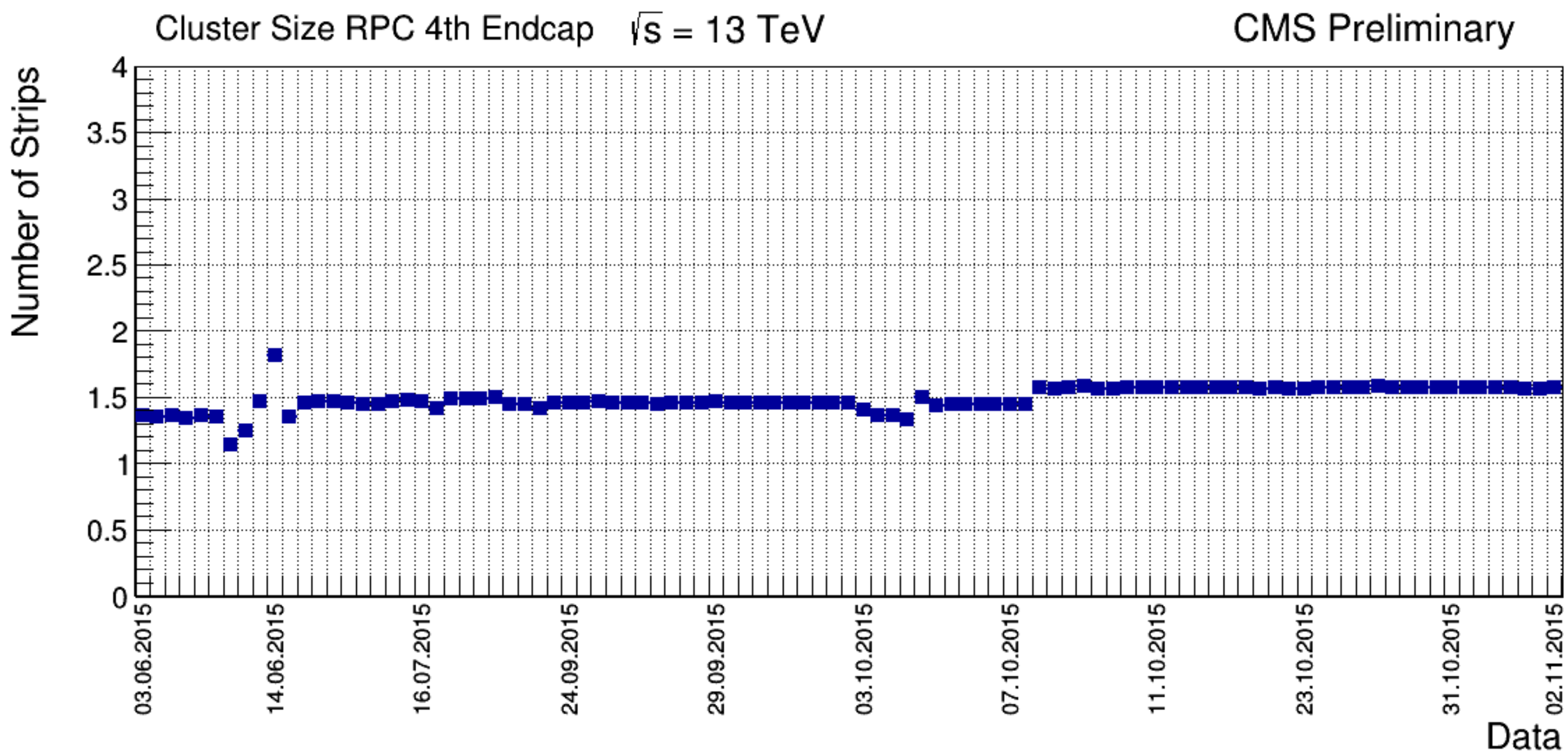
Collisions 2015 at 13 TeV



The plot represents the history of the Mean Cluster Size for the 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 details about the expected values of cluster size can be found (CERN/LHC 97-32 (https://web.physik.rwth-aachen.de/~hebbeker/cms_muon_tdr.pdf)).

RE4 Cluster Size History

Collisions 2015 at 13 TeV



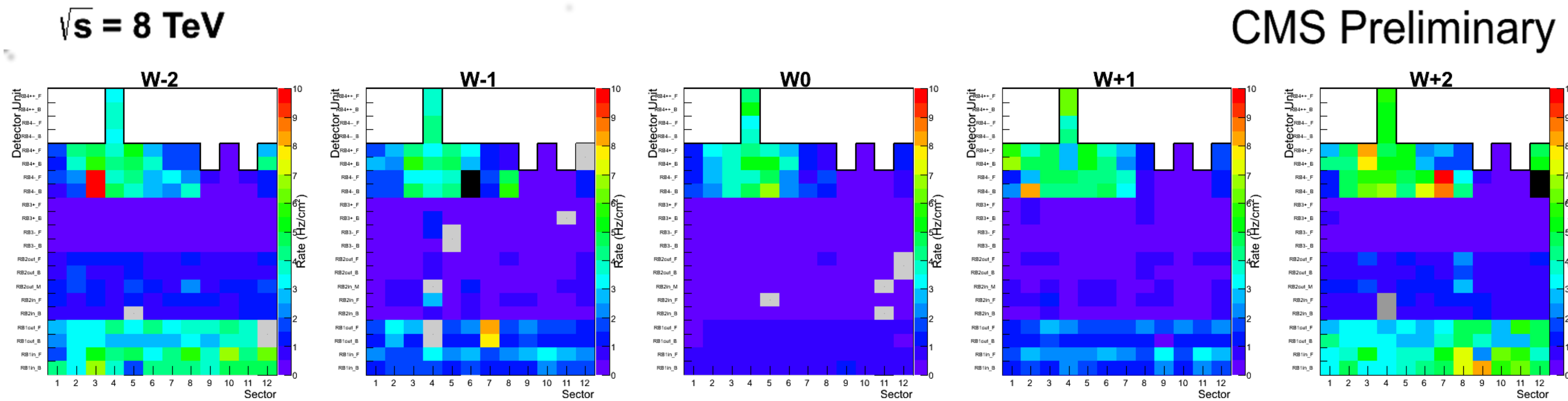
The plot represents the history of the Mean Cluster Size for the newly installed RPC chambers on the 4-th Endcap stations. The fluctuation in the middle of June are due to the performed HV scan. The fluctuations in the beginning of October are due to the performed threshold scan. The details about the expected values of cluster size can be found (CERN/LHC 97-32 (https://web.physik.rwth-aachen.de/~hebbeker/cms_muon_tdr.pdf)).

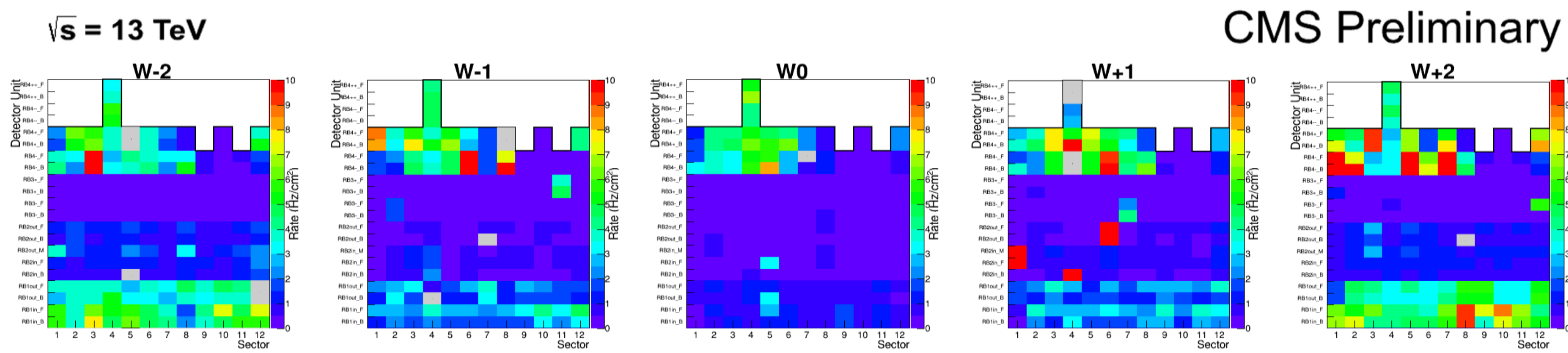
RPC Rate

The RPC hit rate (in Hz/cm^2) is measured for runs at average instantaneous luminosity of $4.5*10^{33}\ cm^{-2}s^{-1}$. The main contribution in the hit rate is caused by the background. Because of this the plots for 2012 vs 2015 with a similar inst. luminosity are compared to search for differences in the background distribution. The higher rate is observed for the higher eta regions and in the top of the stations which is in agreement with the expectation from the previous measurements and MC simulation as it shown in [*]

(*) http://iopscience.iop.org/article/10.1088/1748-0221/8/11/P11002/meta

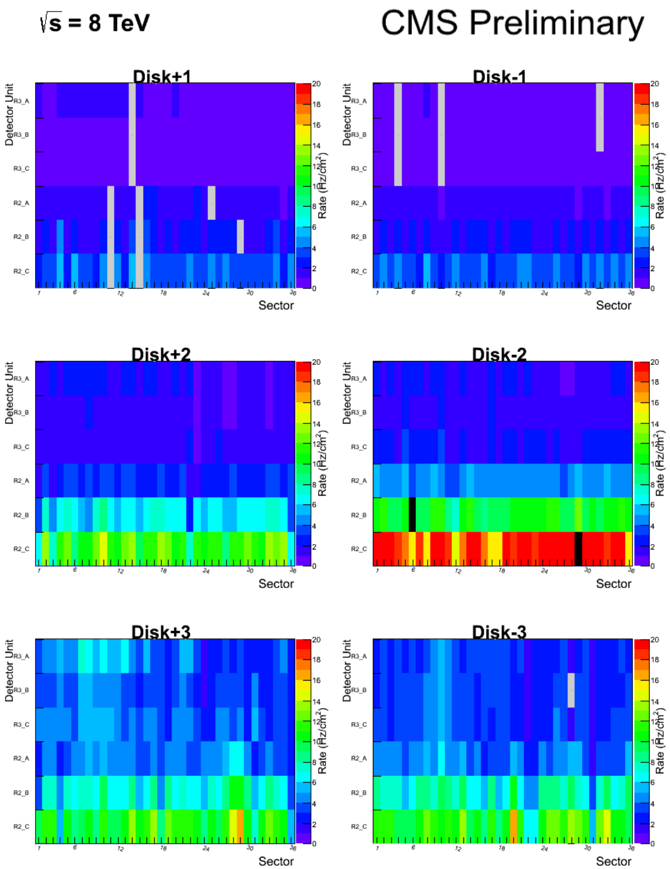
2D Background distribution Barrel 2012 vs 2015

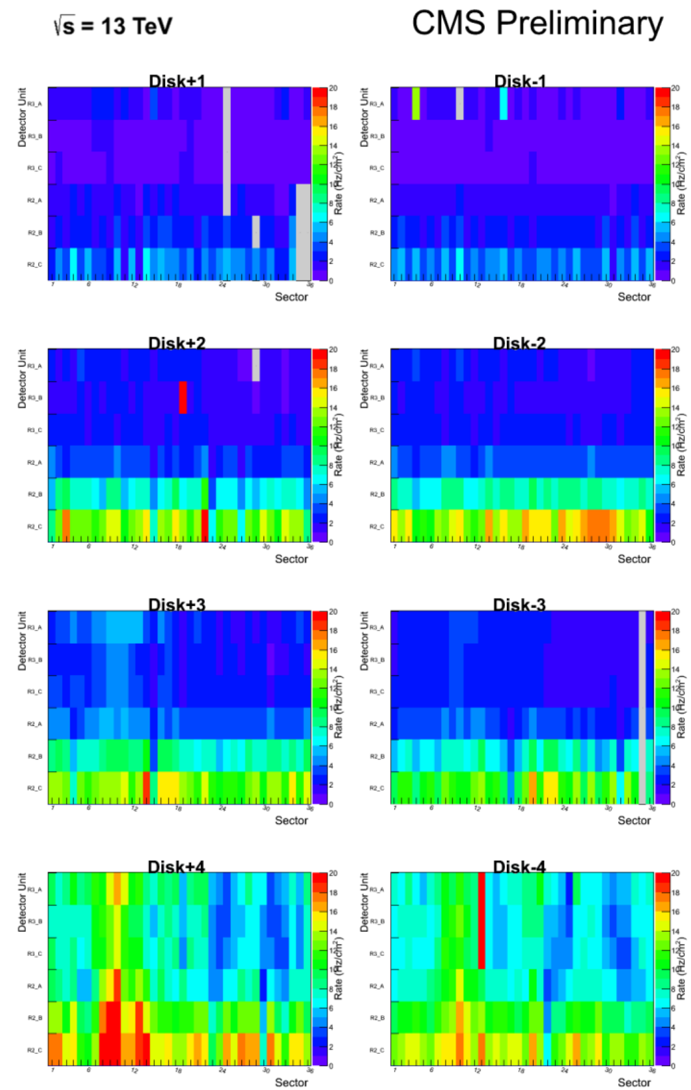




The detector units hit rate (in Hz/cm^2) is shown for a runs at average instantaneous luminosity of $4.5*10^{33}$ cm^{-2} s^{-1}. The highest rate is measured in the innermost (RB1in) stations and in the top sectors (3,4,5) of the outermost (RB4) stations. Detector units switched off are shown in gray, 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. Plots for 2012 (upper row) vs 2015 (down row) with a similar inst. luminosity are compared to search for differences in the background distribution.

2D Background distribution Endcap (2012 vs 2015)



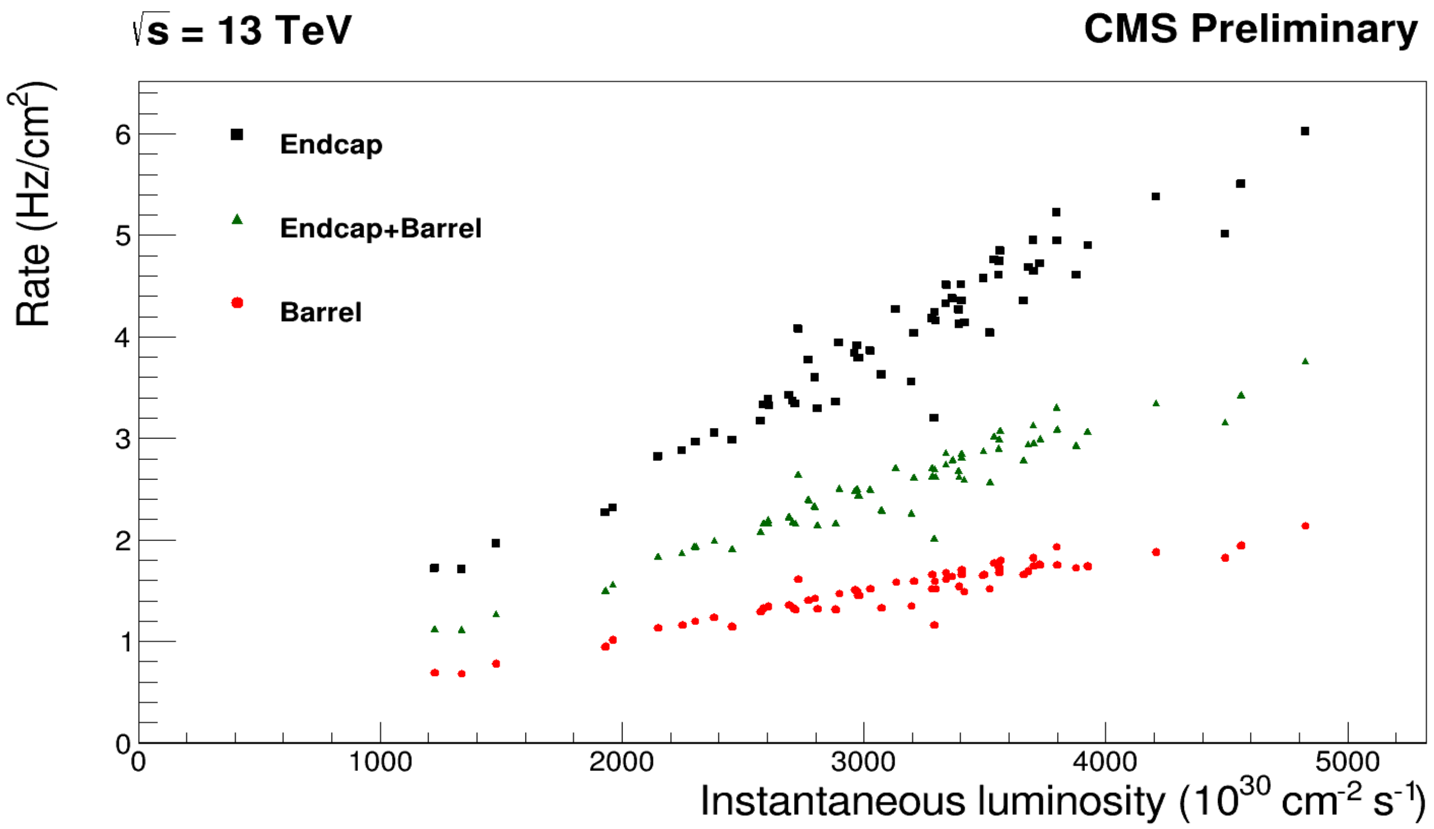


The detector units hit rate (in Hz/cm^2) is shown for a run at average instantaneous luminosity of $4.5*10^{33} cm^{-2}s^{-1}$. Detector units switched off are shown in gray, while those not used in the background calculations are shown in black. Blue and violet colors correspond to lower rates, while yellow, orange and red colors correspond to high background level. Plots for 2012 (left) vs 2015 (right) are compared to search for differences in the background distribution.

Comparison between Background in 2012 & 2015

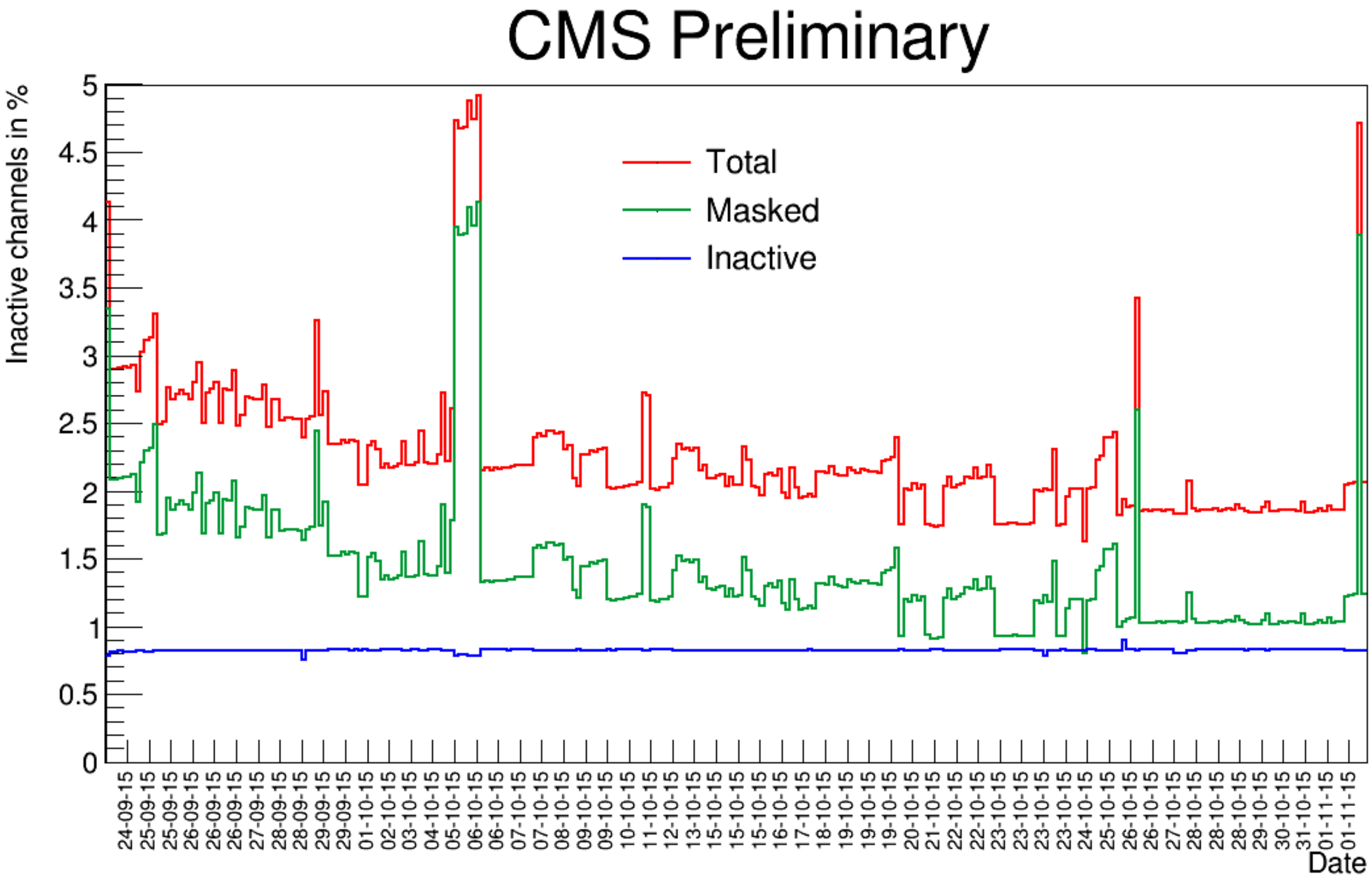
The comparison shows the disappearance of the rate asymmetry observed in 2012 between the inner-most RPC eta partitions in Disk +2 and Disk-2, after mounting the missing shielding. In 2015 data we are observing rate asymmetry in the fourth endcap stations where the rate is higher for the sectors installed between phi 70^{o} and 120^{o}.

RPC Rate vs Luminosity



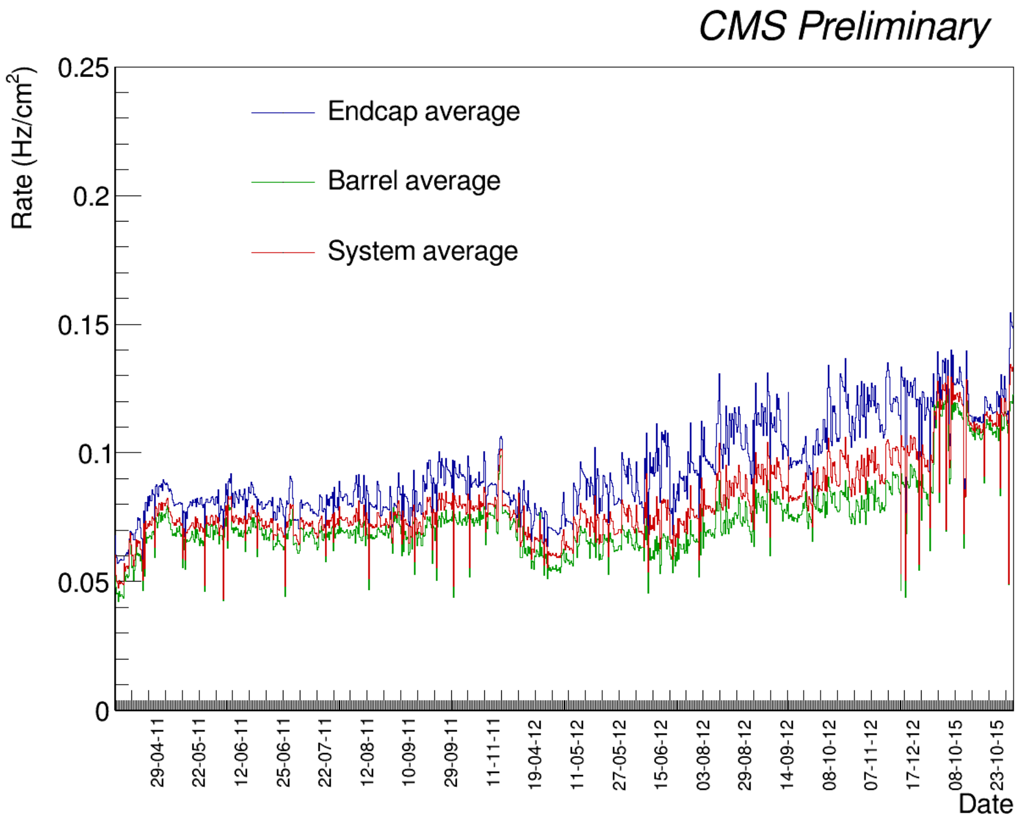
The plot shows the average hit rate vs. instantaneous luminosity, with 2015 13 TeV p-p collisions data. The red dots represent the rate measured in Barrel and the black represent the rate measured in Endcap. The green markers relate to the overall rate evaluated for the entire RPC system.

Inactive channels 2015



The plot represents the fraction of channels not operational during 2015. The blue line represents the number of inactive (non responsive) channels, while the number of the masked strips (green line) changes with a time as they are adjusted per run depending on the performance of the system. The observed peaks related to the bigger number of masked strips caused by the temporary hardware problems, which were successfully resolved.

RPC System Noise 2011-2015



System noise rate: The RPC rate is measured also during the cosmics data taking in between the collisions runs. The plot represents the rate level in barrel, endcap and system average from 2011 to 2015. Fluctuations in the rate are mainly due to post-collisions radiation, threshold value optimization vs efficiency and operating channels number change. Though the blue and the green curves show similar drift behavior, no significant spike correlations are observed . The overall trend show minor increase in the system rate with time, which is well below the official CMS requirement of rate < 5 Hz/cm^2.