# Operation and performance of the CMS Resistive Plate Chambers during LHC run II

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On behalf of the CMS collaboration

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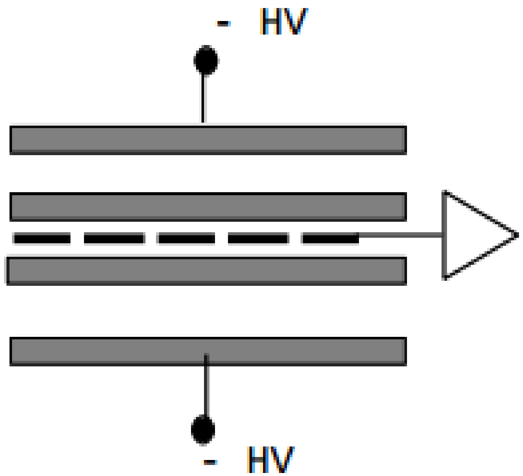
# Overview

- Overview of RPCs within CMS
- Run II in numbers
- Noise and threshold optimization
- Working point calibration and efficiency
- Cluster size
- Summary and conclusions

# Resistive Plate Chambers at CMS




**Resistive Plate Chambers (RPCs)**

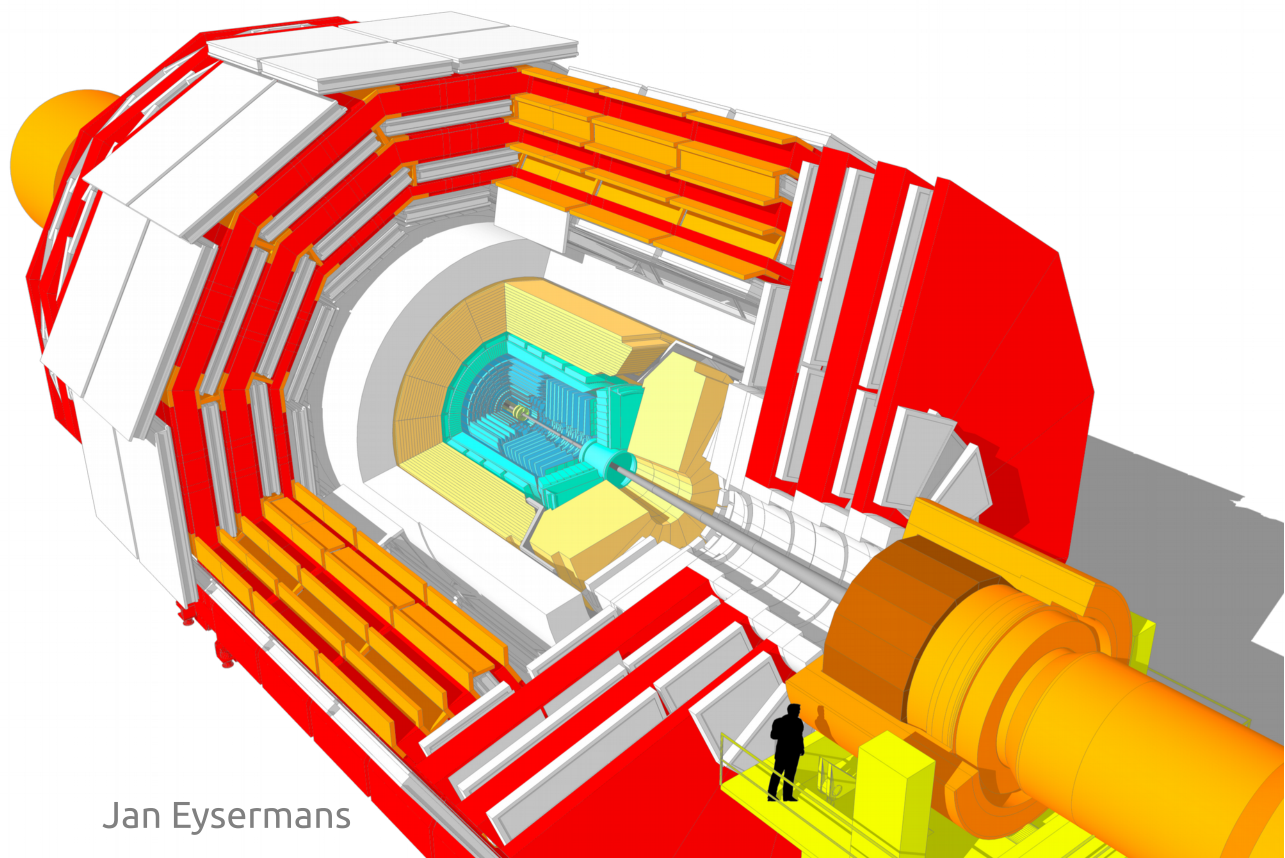
- Double gap gaseous detector operated in avalanche mode
- 2 mm gas gap sandwiched between 2 mm high resistive bakelite plates
- 3 component gas mixture: 95.2% freon, 4.5% isobutane and 0.6% $SF_6$
- Provides redundancy to the CMS muon system (DTs and CSCs) for muon identification, reconstruction and trigger

**CMS RPC system**

- 480 barrel chambers
- 576 endcap chambers
- Coverage up to $|\eta| < 2.4$

**Readout**

- ~ 137,000 copper readout strips
- Strip pitch ~ 2 cm
- Covering area ~ 4000 $m^2$
- Strips aligned in $\eta$ direction
- Electronic controllable threshold



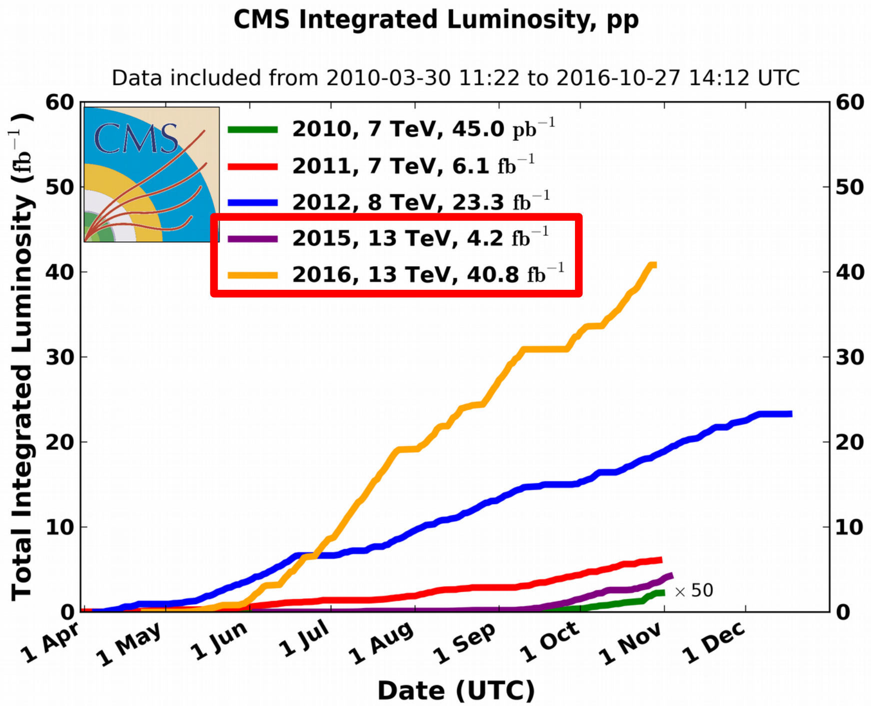
# Run II – some numbers

**LHC Run II**

- Started in 2015 after Long Shutdown 1 (LS1)
- Center of mass energy of 13 TeV
- Very good LHC performance delivering record luminosity

**RPC Run II**

- Good and stable operation
- Successful commissioning of RE+/-4
- Active chambers ~ 98%
- Planned hardware interventions during winter shutdowns




- 2016 delivered integrated luminosity: 40.8 $fb^{-1}$
- 2016 recorded integrated luminosity: 37.82 $fb^{-1}$
- **CMS luminosity loss: 3.25 $fb^{-1}$**

- RPC lumi loss contribution ~ 155 $pb^{-1}$, mainly due to the following occurrences:
  - channel readout problems
  - failure of HV power supply problem

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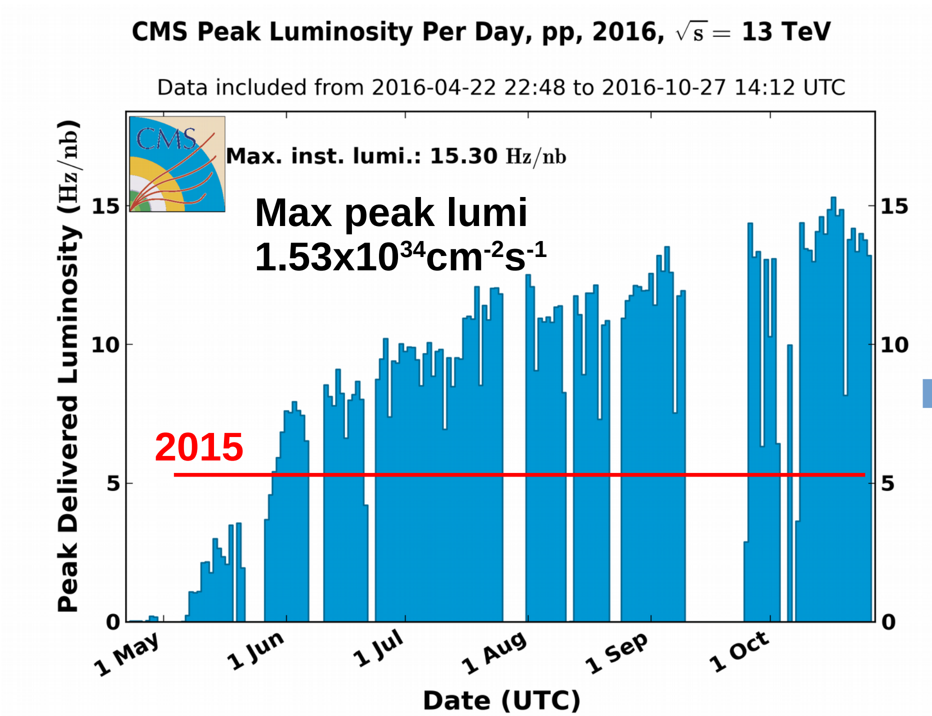
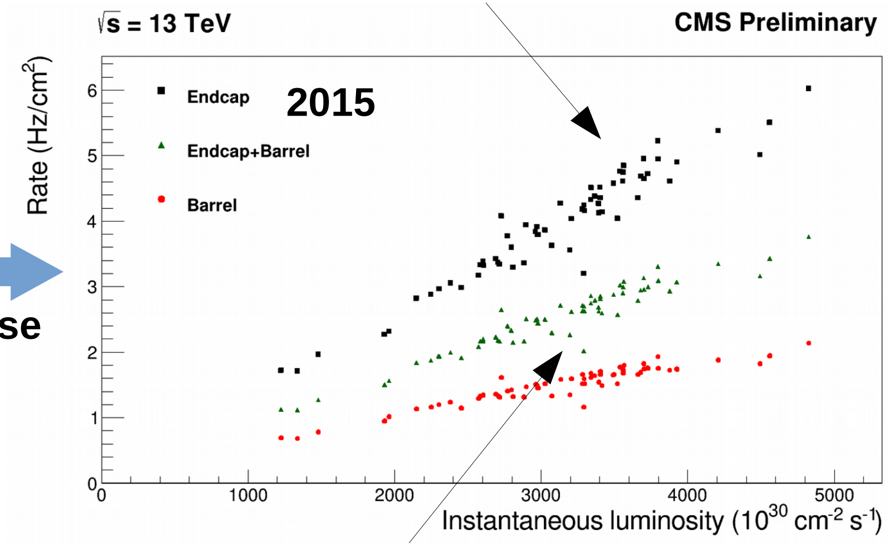



RPC → response

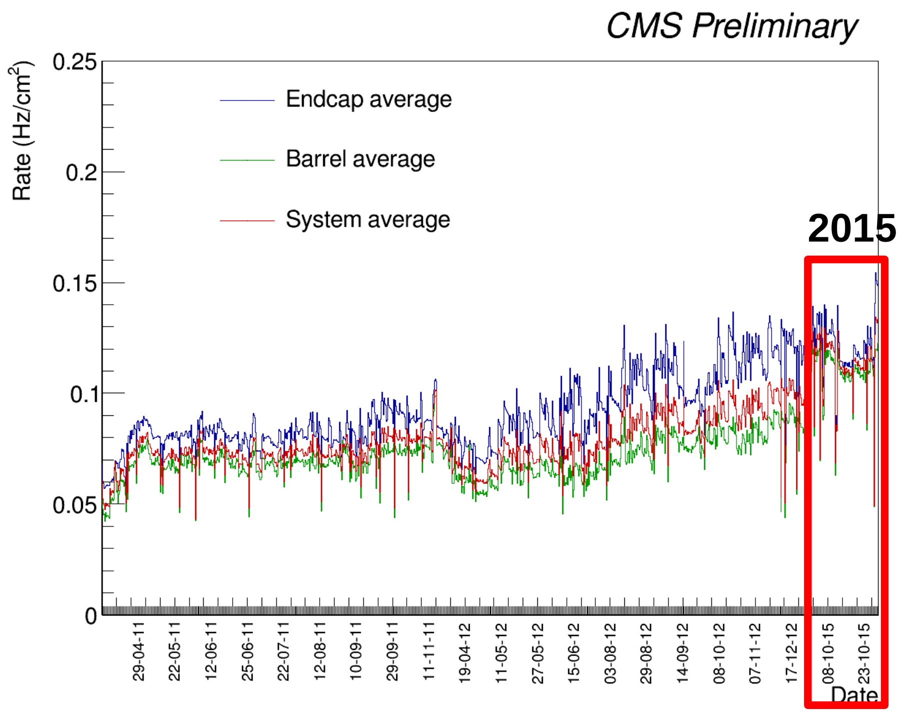
**Background rate and current ~ linear with instantaneous luminosity**




**Extrapolation towards higher instantaneous luminosity**

# Noise rate

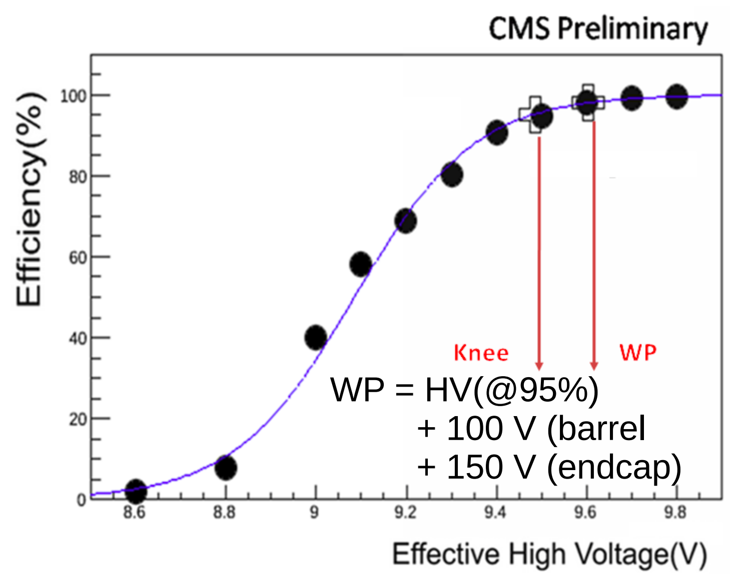
- High noise rate and background radiation can affect the performance of muon reconstruction and identification
- CMS noise rate requirement: lower than 5 $Hz/cm^2$
- **Continuous monitoring** of the noise rate:
  - during cosmic runs between the collision runs
  - Run II noise rate increased due to lumi and residual radiation
  - However still well below the criterium
- **Threshold optimization** to control the noise levels:
  - Adapt the electronic channel threshold (*)
  - Mask the unrecoverable noisy channels
  - Run II 2015: 2-2.5% of all the channels inactive (similar results for 2016)

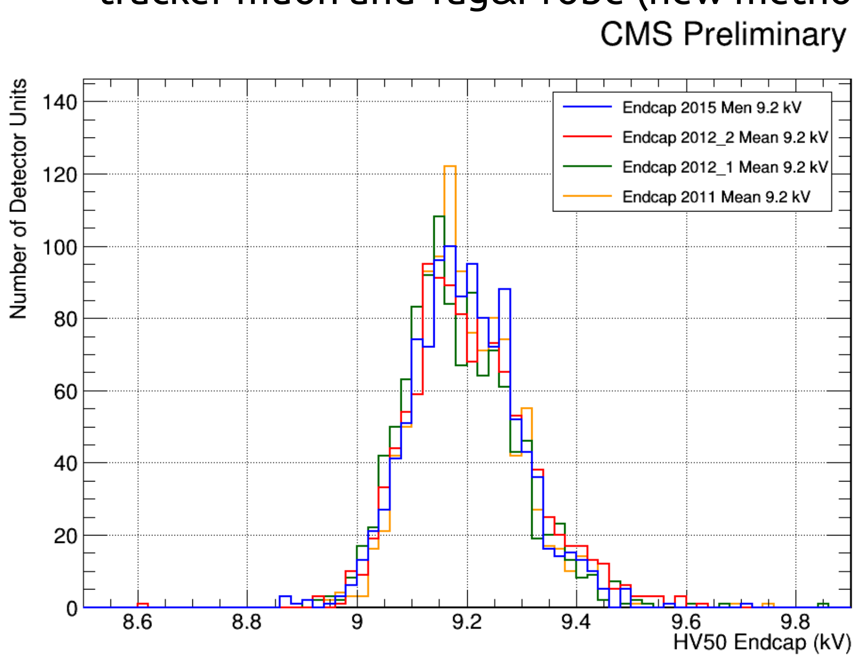



(*) threshold variations are limited due to efficiency and cluster size requirements

# Working point calibration

- CMS requirement: muon hit efficiency > 95%
- Regular Working Point (WP) calibration needed in terms of **High Voltage scan**
- Measure efficiency as function of HV and extract the working point:
  - segment extrapolation from other muon detectors (DTs and CSCs)
  - tracker muon and Tag&Probe (new method)

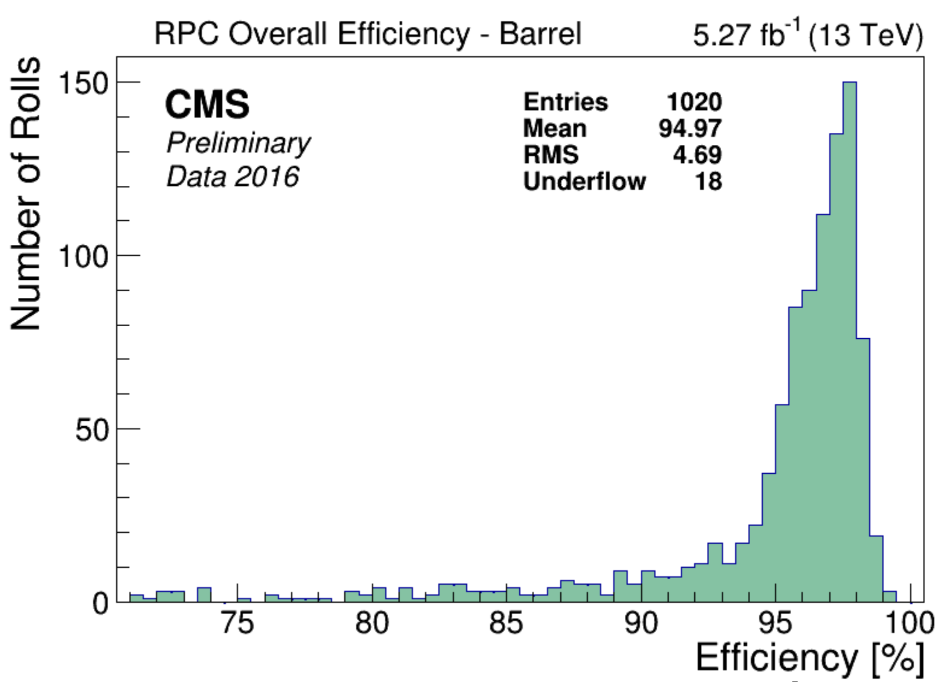


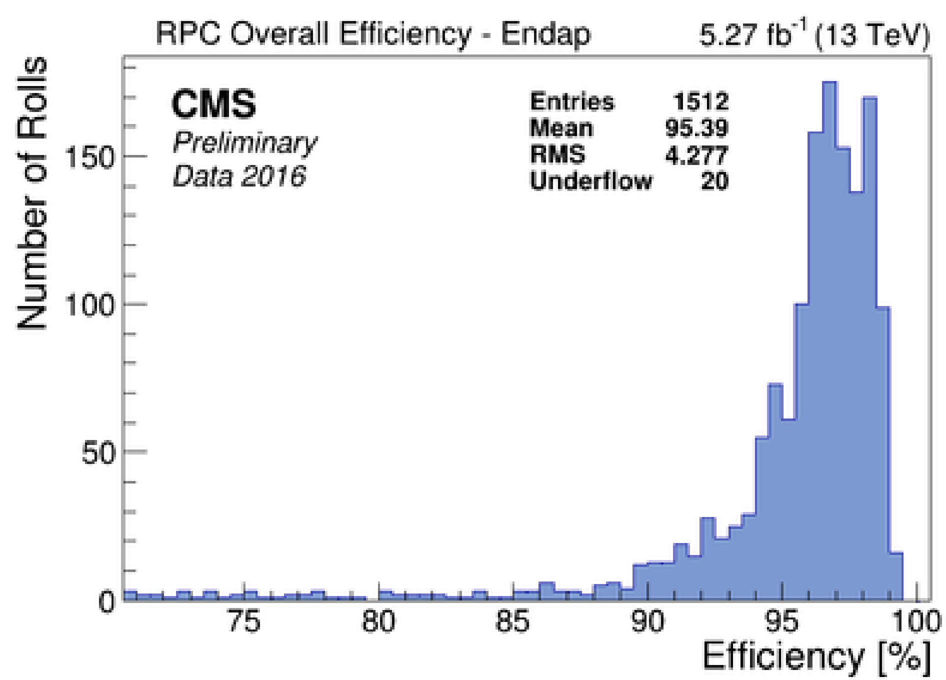




- HV scan done at least once per year at the start of the LHC run during calibration runs
- Results are consistent and stable over the years
- no effect of detector performance degradation spotted

# Working point calibration

- WP calibration done at LHC startup in 2016 and new working points have been applied
- Average efficiency measured after collecting 5.3 $fb^{-1}$
  - overall efficiency in barrel and endcap ~ 95%
  - small fraction with lower efficiency: chambers are OFF, masked strips or Single Gap mode



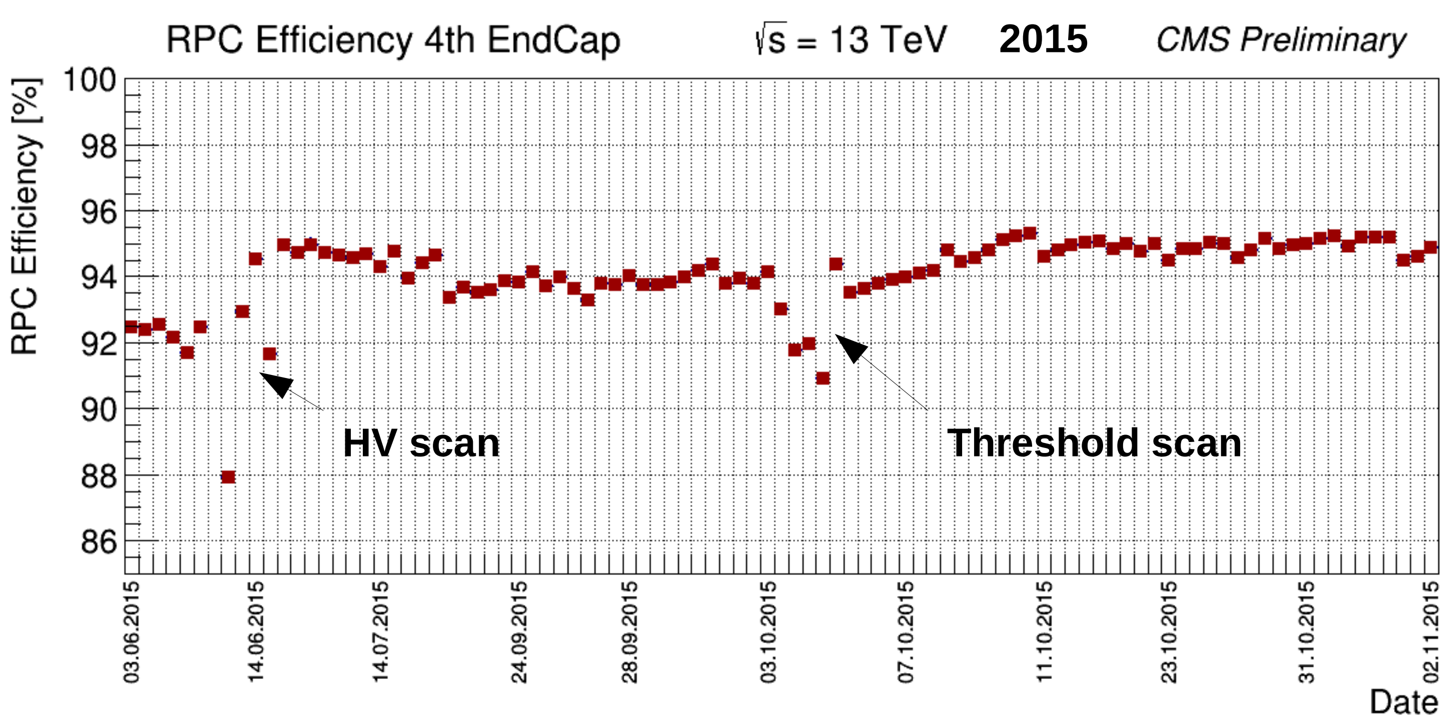

**(segment extrapolation)**

# Efficiency over time

- Stability of the detector performance: measure chamber efficiency in time
- Efficiency depends on gas pressure variations, online high voltage correction applied:

$$HV = HV_{eff}(1 - \alpha + \alpha p/p_0) \qquad \text{with } p_0 = 965 \text{ mbar}, \ \alpha = 0.8$$

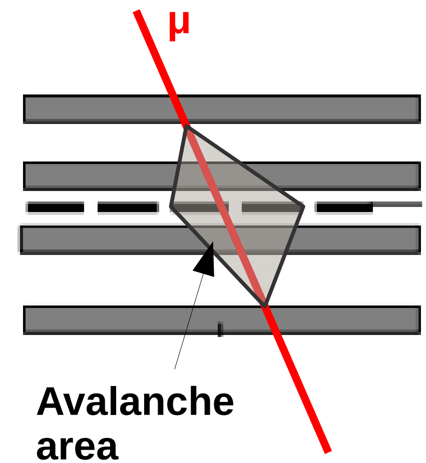
- During 2016: temperature decrease of ~ 0.5 °C observed → considering the implementation of temperature correction

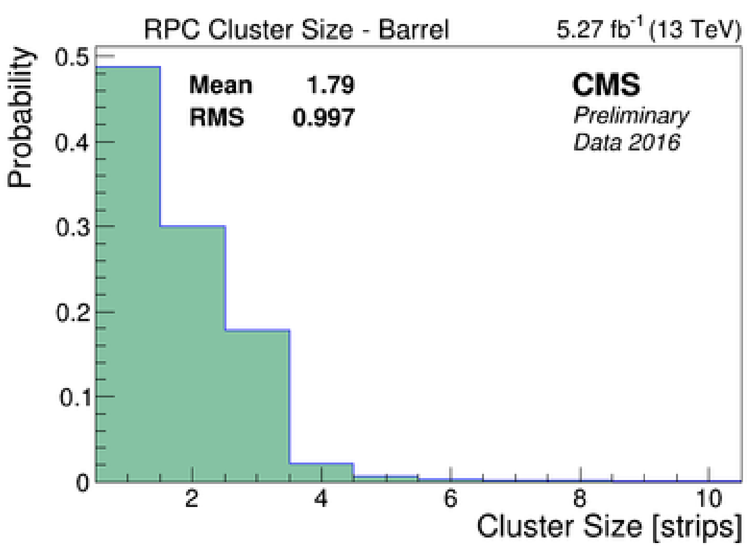


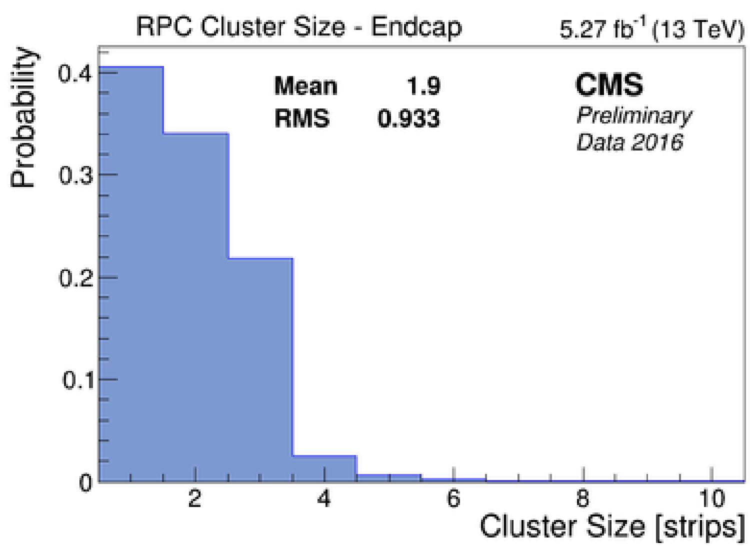
# Cluster Size

- Cluster size = amount of strips fired per muon hit
- Affects position and momentum resolution measurements

  → CMS criteria cluster size <= 2
- From operational point of view, it depends on:
  - avalanche size in the gap related to the HV applied
  - electronic threshold
- Measured mean cluster size for run II < 2 and stable



# Summary

- During run II the CMS RPC system performed very well
- Stable operation without observation of hardware degradation
- Low amount of hardware problems, maintenance during winter shutdowns
- Regular calibrations performed to maintain a good performance
- Continuous monitoring of the performance resulting in a high efficiency, low noise rate and good cluster size

**→ Ready for another year of pp collisions!**

- References:


  - Performance plots: https://twiki.cern.ch/twiki/bin/view/CMSPublic/RPCPlots
  - [CMS Collaboration], CMS, the Compact Muon Solenoid. Muon technical design report, CERN-LHCC-97-32