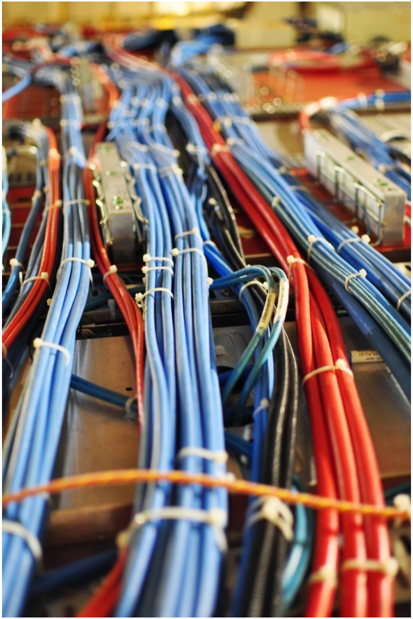
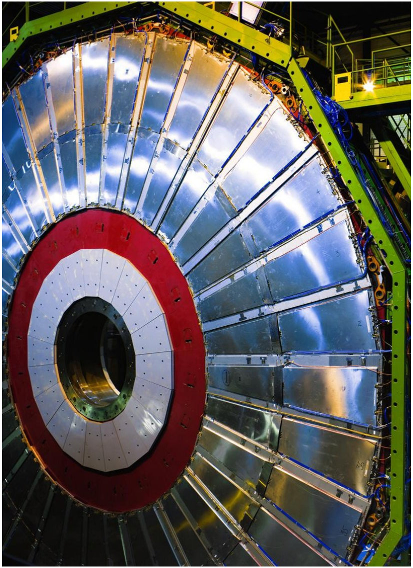


2A. Operation of the RPC detector

Piet Verwilligen

INFN Sezione di Bari

Capita Selecta in HEP
Vrije Universiteit Brussel
April 9-10, 2014



Resistive Plate Chamber detector

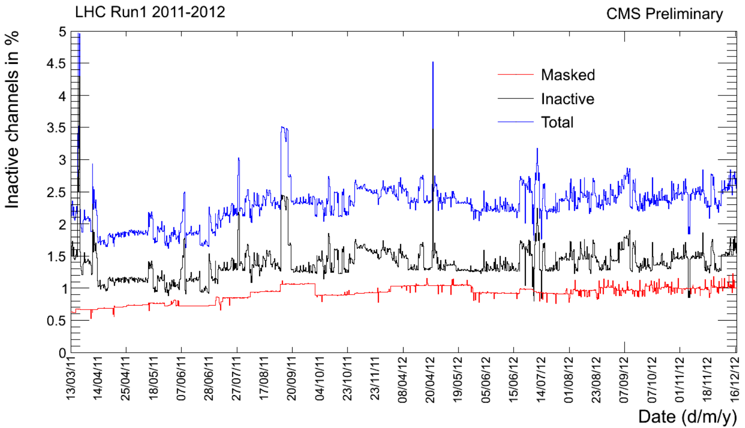
Overview

- RPC R&D done 1993 – 2003. First RPCs produced in 2003, first RPCs installed in 2007 and ready for beam in 2008.
- Performed long cosmic - ray running in 2008 – 2009. Now 3 years of Run experience with *pp* collisions 2010–2012
- **Phase I (2010-2020) ::** RPC System designed to run for 10 years and to operate at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- **Phase I (2020-2030) ::** RPC System will be running for another 10 years beyond design specification ($\mathcal{L} = 5 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$)

Run-I experience crucial for

- **Fine tuning** of operation procedures, finding optimal working point and detector performance
- Investigate the **Longevity** of the system and understand the possible issues for operating the detector another 20 years
  - monitor the stability of the performance (efficiency, cluster size, intrinsic noise, currents)

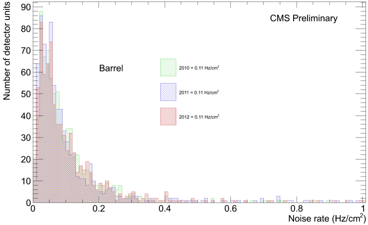
Inactive Channels

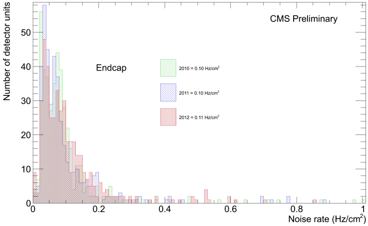


Percentage of inactive channels stable between 2% and 2.5%

- Masked strips: mainly caused by noisy chambers due to electronic board failure (inside the chambers, not accessible since 2009).
- Inactive strips: mainly caused by failures of HV/LV channels. Some of them recovered soon after the beam dump

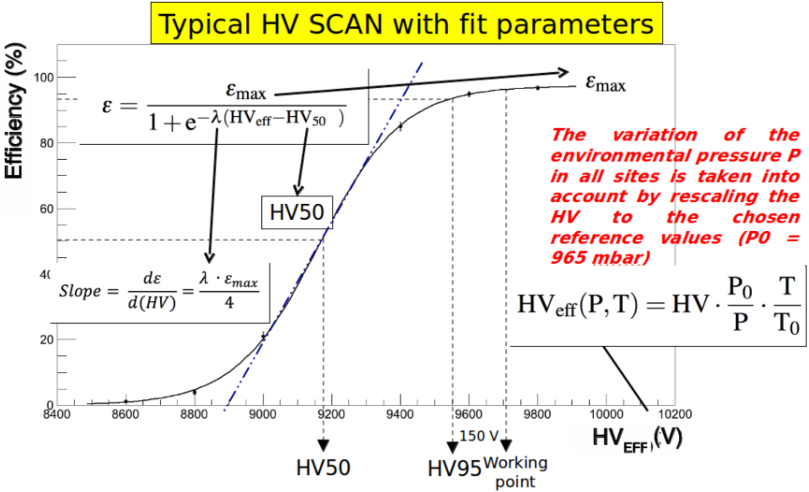
Noise





- CMS continued data taking during inter fill periods of LHC (Cosmic + Background runs)
- For Noise measurements runs selected just before proton fills
- Result is hits due to Cosmic muons and due to noise in chamber / electronics
- Average noise lower than CMS requirements ()
- Average noise stable during three years of operation

HV working point determination with HV Scan



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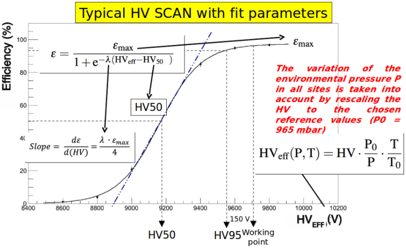
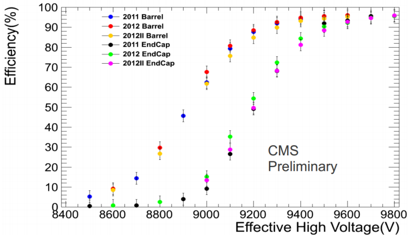
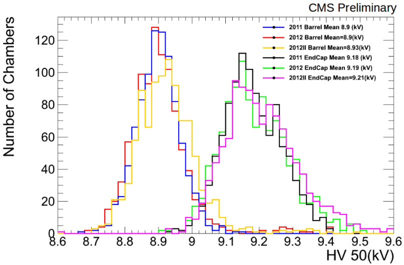






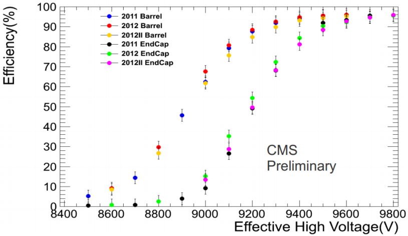
- 3 HV Scans performed:
- oct 2011, jun 2012, dec 2012
- **Efficiency Plateau** is stable
- **HV Turn On** compatible
- **HV50** distribution comparable
- No ageing spotted so far

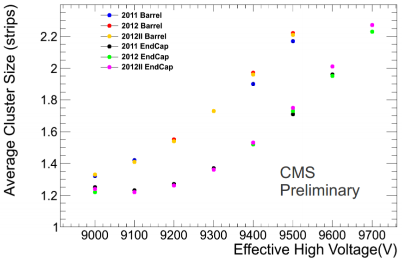
HV working point determination with HV Scan

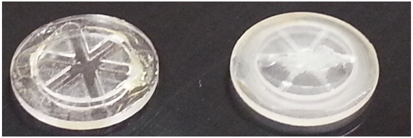
- HV Scan to optimize working point and to monitor ageing

Period	Int Lumi	Int Charge
11/2011	$40\,pb^{-1}$	Few μC
06/2011	$5.5\,fb^{-1}$	$< 1\,mC$
12/2012	$27\,fb^{-1}$	$\sim 3\,mC$

- Barrel – Endcap difference in turn on curve due to different production (Italy – Korea)
- larger spacer size by $10\mu m \Rightarrow$ HV50 shift of 300V







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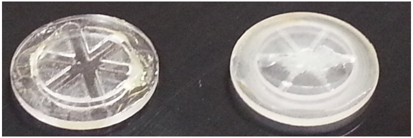
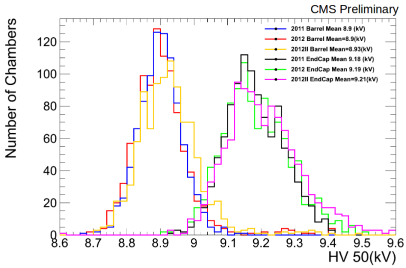
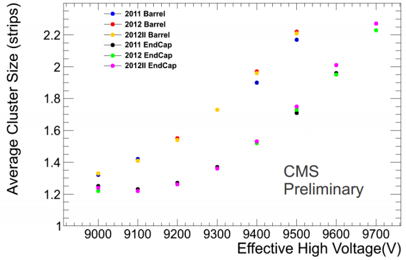
06/2011	5.5 fb^{-1}	< 1 mC
12/2012	27 fb^{-1}	~ 3 mC

- Barrel – Endcap difference in turn on curve due to different production (Italy – Korea)
- larger spacer size by 10μm $\Rightarrow$ HV50 shift of 300V







Corrections to the HV working point

- Assuming[†] avalanche processes in gas depend only on the density ($pV = nRT$)

$$HV_{\text{eff}} = HV_{\text{app}} \cdot \frac{p_0}{p} \cdot \frac{T}{T_0}$$

- but overcorrects the density effect, therefore reduce the correction:

$$\Delta HV = HV_{\text{app}} - HV_{\text{eff}} = HV_{\text{eff}} \cdot \left(\frac{p}{p_0} \cdot \frac{T_0}{T} - 1 \right)$$

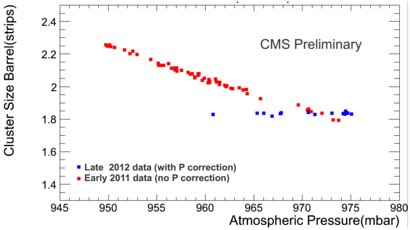
- with a factor α:

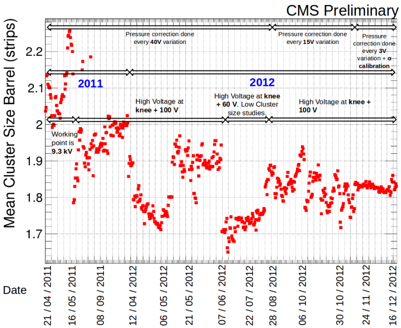
$$\Delta HV = \alpha \cdot HV_{\text{eff}} \cdot \left(\frac{p}{p_0} \cdot \frac{T_0}{T} - 1 \right)$$

- thus:

$$HV_{\text{app}} = HV_{\text{eff}} \cdot \left(1 - \alpha + \alpha \cdot \left(\frac{p}{p_0} \cdot \frac{T_0}{T} \right) \right)$$

† Not only the gas density depends on the temperature, also the **bakelite resisistivity** depends on the temperature.





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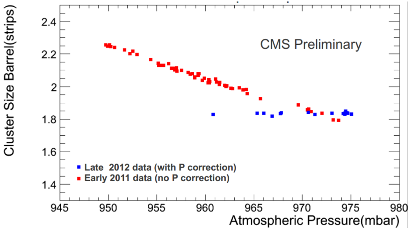
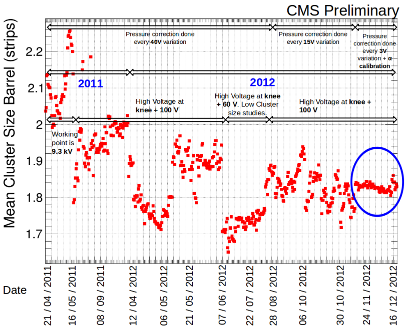
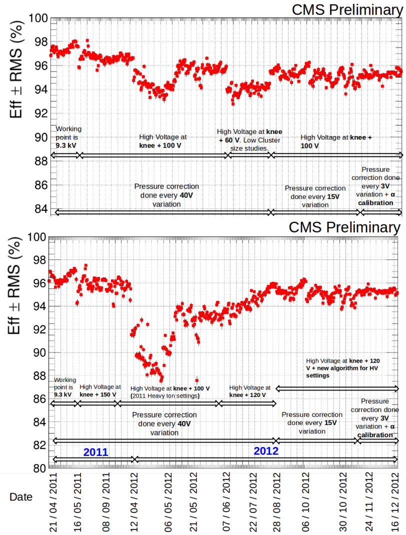




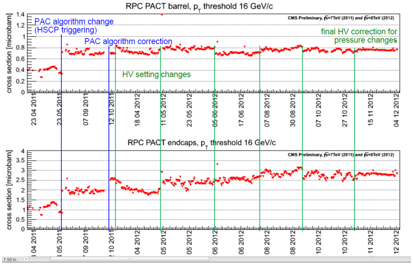
RPC Efficiency



RPC Trigger cross section

$$\text{trigger cross section} = \frac{\text{trigger rate}}{\text{Instantaneous Luminosity}}$$

- Clustersize variations due to atmospheric pressure changes
- Wider clustersize leads to higher trigger rates (straighter patterns)
- change in PAC Trigger Algorithm to trigger on Heavy Stable Charged Particles



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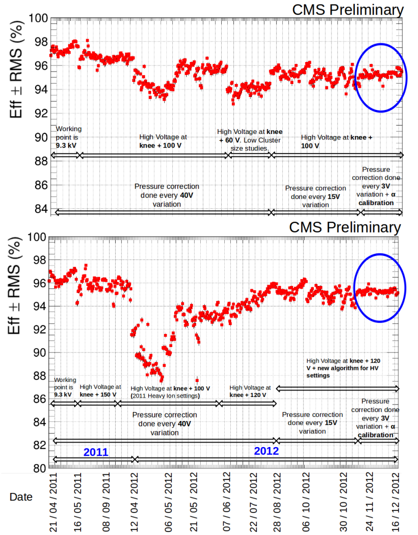

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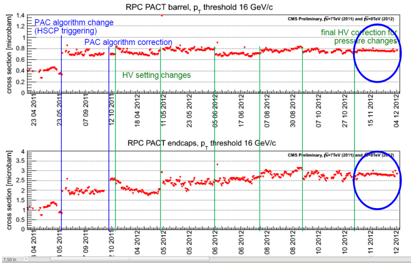
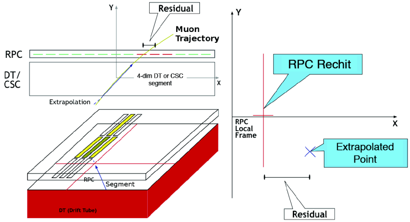
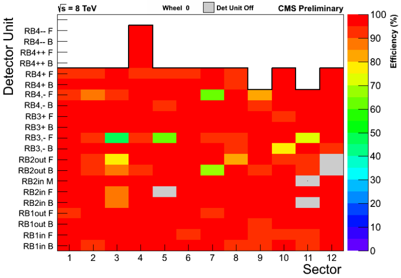


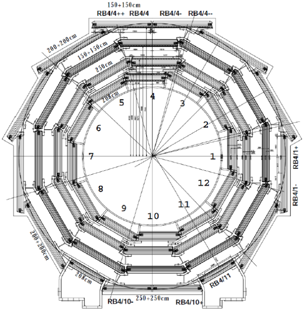
Efficiency Measurement per detector unit



Efficiency Measurement

- Use redundancy of Muon System to measure Efficiency
- **Track segment** of CSC or DT pointing to RPC detector
- Use track segments associated to a real muon passing through CMS
- Average RPC efficiency 95% after 3 years of running





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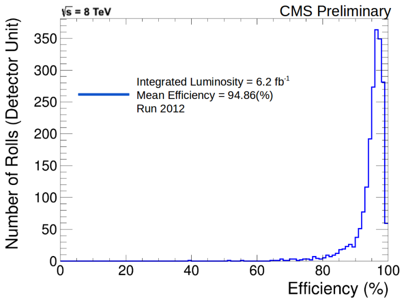

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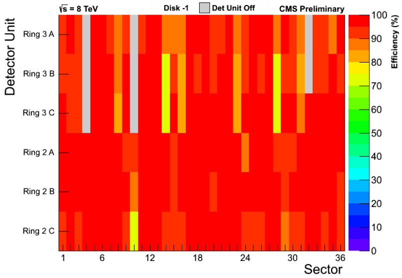
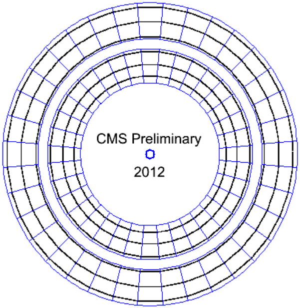
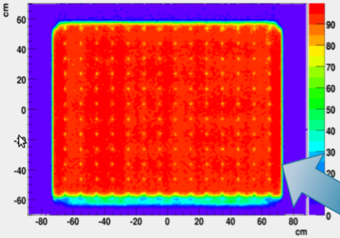
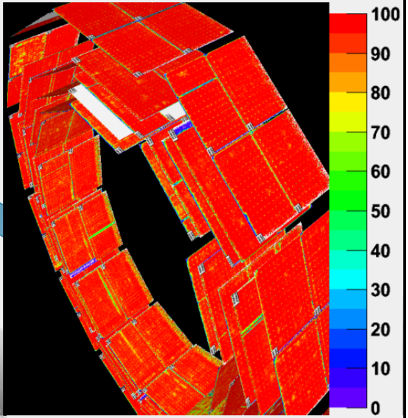




MuonRadiography



CMS 2011 Preliminary $\sqrt{s} = 7$ TeV



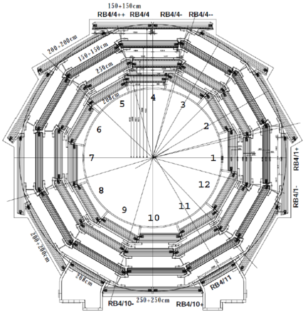
Muon Radiography: the chamber efficiency can be studied in details, with a resolution of ≈ 1 cm2. Spacers, border effects can be easily spotted. For few chambers, the stability in time of inefficient zones is under observation. **No degradation observed up to now.**

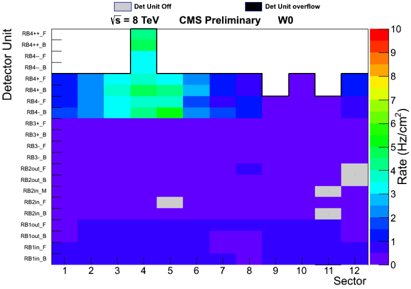
- **RPC Montitor Stream** with reduced event content to keep CSC, DT & RPC hits
- Use high statistics of 2011 run and 2012 B,C,D runs ($\gtrsim 5\,\mathrm{fb}^{-1}$)
- Monitor inefficiency zones in time (work ongoing) important for ageing studies

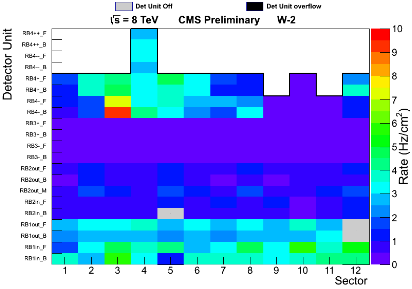
Background Measurement per detector unit

Background Measurement

- Hit counting after discriminators (FEB) in 25 ns window
- No trigger decision involved
- No background discrimination: count all fired strips
  (muons + cosmic muons + noise + neutron background)
- Need correct for $\langle \text{cls} \rangle \approx 1.8$
- Higher background in top sectors barrel and closer to beampipe in endcap







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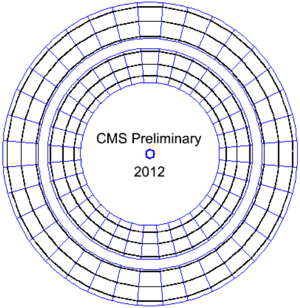
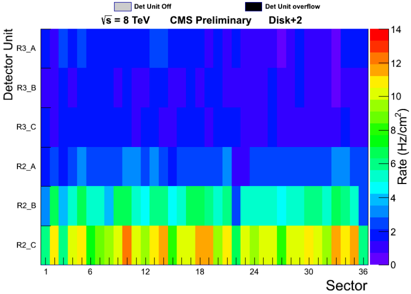
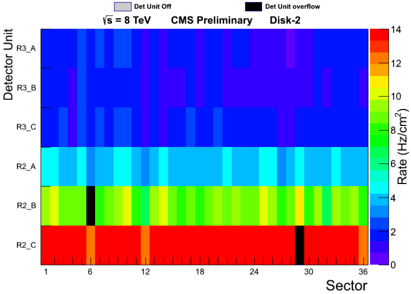
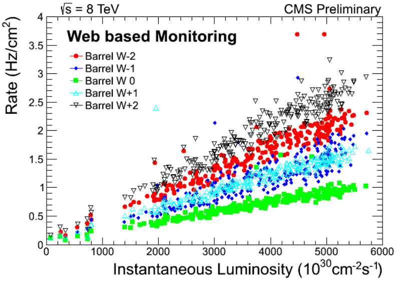




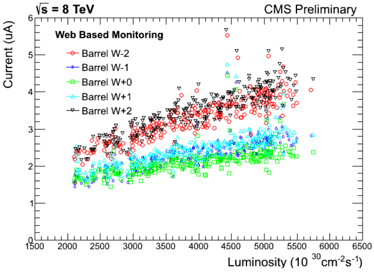


RPC Background measurements

Barrel Average Rate / Inst. Lumi



Barrel Av. Current / Inst. Lumi



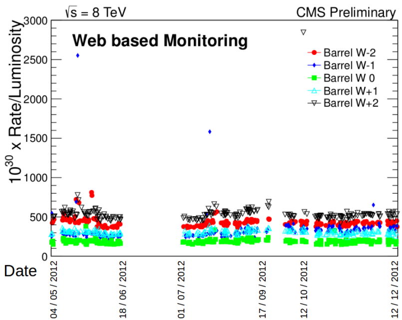
Two ways to observe the effect of the hit rate

- hit counts after discriminator and currents drawn by the chambers
- average current is in agreement with measured rate
  (assuming experimental value of averaged charge per hit of ≈ 20–25 pC)
- ratio current / instantaneous luminosity & hit rate / instantaneous luminosity stable in time

- Careful Measurement of the background hit rates provides input for Phase-II studies
- Extrapolation linear hit rates to $\mathcal{L} = 5 \cdot 10^{34}$ cm^{-2}s^{-1} leads to:
- Maximum rate :: Barrel = 60 Hz/cm^2 Endcap = 150 Hz/cm^2
- Average rate :: Barrel = 15 Hz/cm^2 Endcap = 40 Hz/cm^2
- Current system will be able to deal with those background levels

RPC Background measurements

Barrel Average Rate / Inst. Lumi



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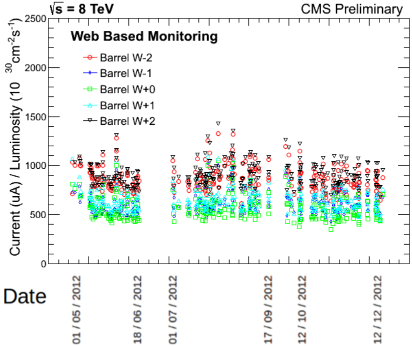

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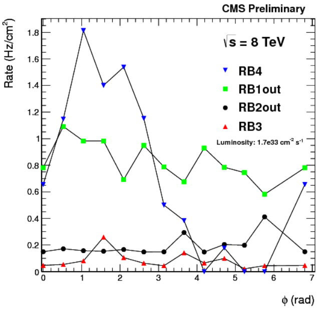
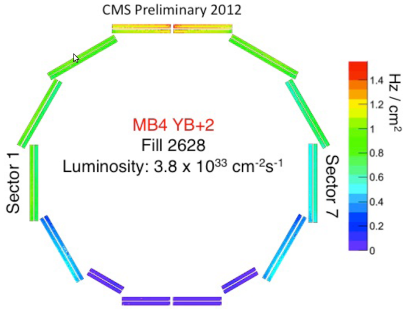
Radiation Asymmetry Barrel

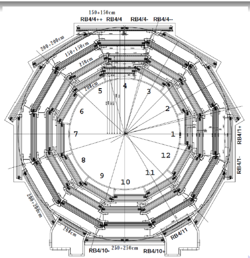
RPC ϕ asymmetry



DT ϕ asymmetry

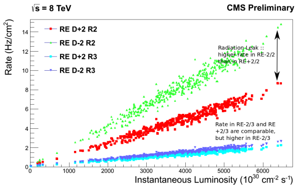


- ϕ asymmetry observed by both RPC and DT
- MB4 and RB4 chambers exposed to *n*-background
- Cavern floor proves to excellent shielding
- Not much difference between chambers in iron feet (S9,11) and chambers close to the floor (S10)



Radiation Asymmetry Endcap

RPC — 8 TeV — 2012



CSC — 7 TeV — 2010

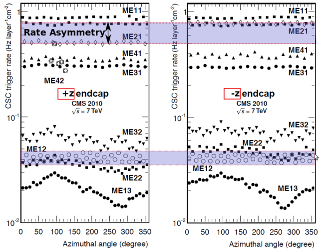
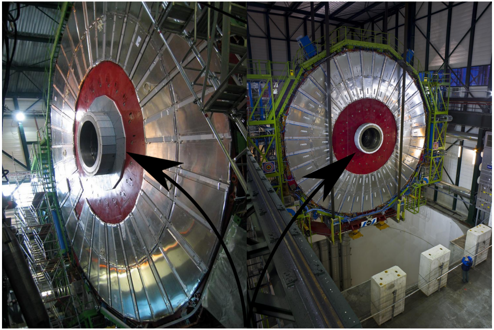


Figure 36: The CSC rate at the luminosity 1.9×10^{32} cm $^{-2}$s $^{-1}$ as a function of the chamber angular position for the minus ($z < 0$) and plus ($z > 0$) endcaps.

- Rate in RE-2/2 > RE+2/2 (and ME-2/1 > ME+2/1)
- Rate in RE-2/3 ≈ RE-2/3 (and ME-2/2 $\lesssim$ ME-2/2)
- Origin found last week when opening YE-1 and YE-2
- Polyethylene tiles have not been installed on the back of disk YE-1
- Will be installed during LS1 (but need to be found first)

RE+2 — RE-2



Conclusions

- The CMS RPC system was performing very reliable during during Run-I (2010-12).
- The CMS RPC system was able to deliver good quality triggers at high efficiency and precise bunch crossing determination
- The CMS RPC system had a contribution to the CMS down time of $\sim 1.5\,\%$
- At the end of Run-I, the fraction of active channels was about 97.5 %
- Most of inactive channels have been already recovered during LS1.

- After 3 years of LHC running the detector performance is within CMS specifications
- We have learned how to operate the RPCs in good conditions provinding stable trigger
- So far no ageing effects have been spotted ::
  - Average efficiency :: 95%.
  - Average cluster size :: 1.8 strips
  - Intrinsic noise :: 0.1 Hz/cm^2
  - From the measured background :: within expectations