

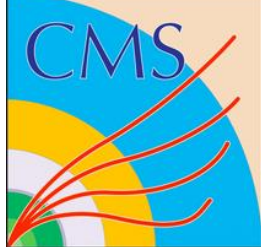


Longevity studies on the CMS-RPC system

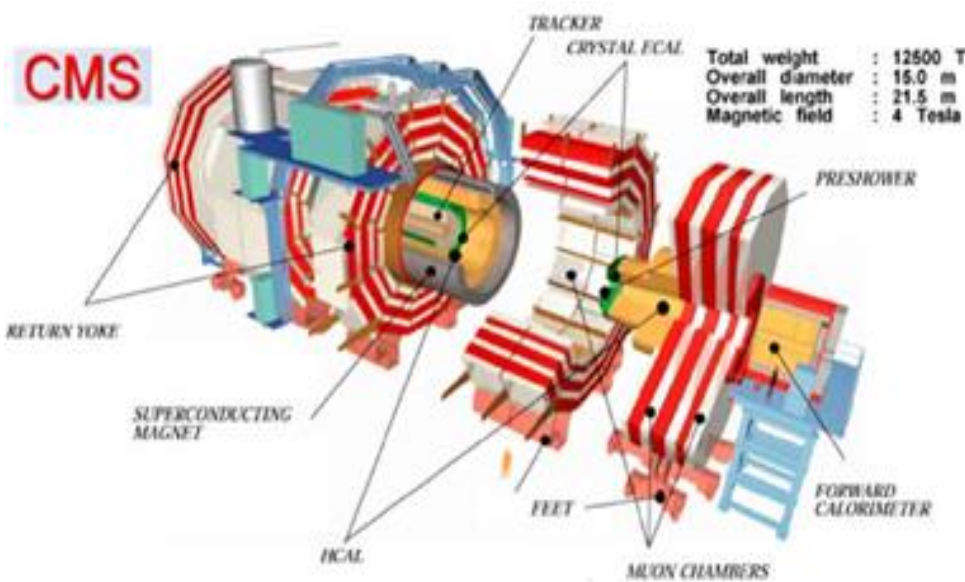
**Andrea Gelmi (INFN & Università di Bari)
On behalf of the CMS Muon Group**

XIV Workshop on Resistive Plate Chambers and Related Detectors

Puerto Vallarta (Mexico), 19-23 Feb 2018



The CMS RPC system @ LHC



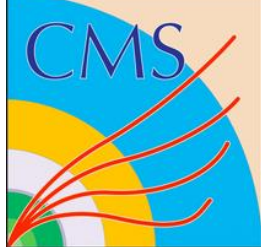
- *RPC system covers $0 < |\eta| < 1.9$*
- *1056 chambers:
480 in **Barrel** & 576 in **Endcap***

- *Working in avalanche mode*
- *Double gas-gaps RPC*
- *HPL bulk resistivity: $\rho = 1 - 6 \cdot 10^{10} \Omega\text{cm}$*
- *2 mm gas gap and electrodes thickness*

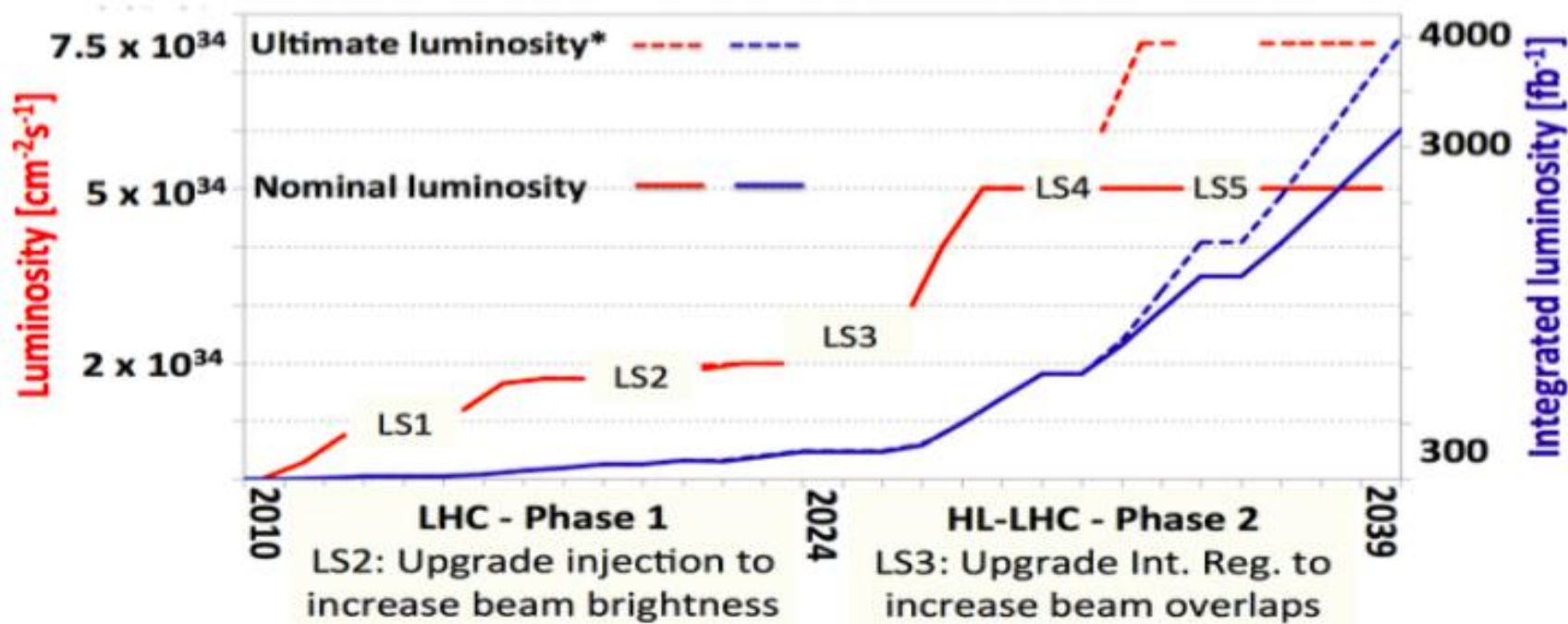
- *RPC information used in the muon trigger, reconstruction and identification*
- ***High and stable RPC performance during LHC operation***

More details:

“The CMS RPC detector performance, calibration and stability”, Mehar Ali Shah

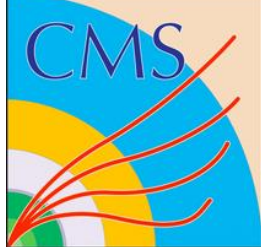


The CMS RPC system @ HL-LHC



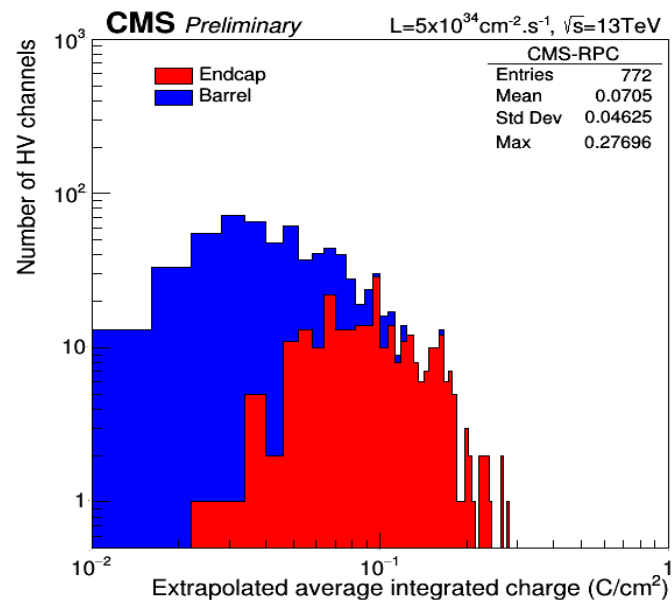
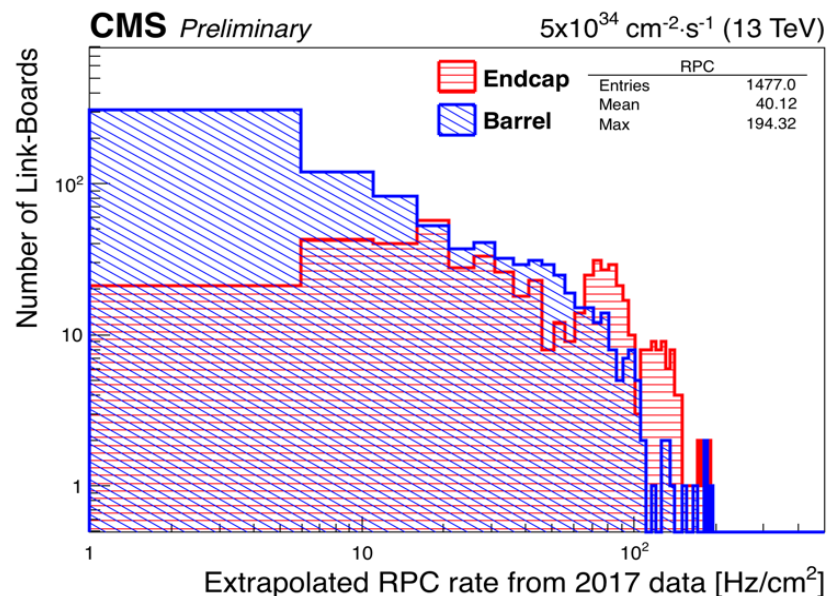
The RPC system has been certified for **10 years of LHC** (at nominal luminosity of $10^{34} \text{ cm}^{-2}\text{s}^{-1}$) at maximum rate of **300 Hz/cm²** and for an integrated charge of **50 mC/cm²**.

The detectors must to maintain excellent performance up to 3 times the expected **HL-LHC** conditions (luminosity of $5 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$) → **LONGEVITY STUDIES**



Expected conditions at HL-LHC

2017 LHC collision data has been used to estimate the expected **background rates** and the **integrated charge** at **HL-LHC** (luminosity of $5 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)



Expected rate

Max rate: $\approx 200 \text{ Hz/cm}^2$

$\cong 600 \text{ Hz/cm}^2$ (safety factor of 3)

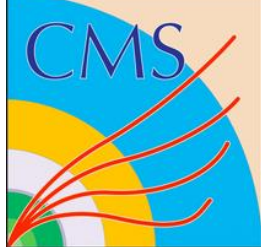
➤ Barrel chambers factor 2 less

Expected integrated charge

Max integrated charge: $\approx 280 \text{ mC/cm}^2$

$\cong 840 \text{ mC/cm}^2$ (safety factor of 3)

➤ Barrel chambers factor 2 less



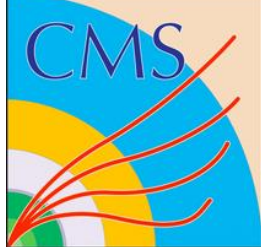
Gamma Irradiation Facility (GIF++)

To certify the RPC system at HL-LHC conditions a new LONGEVITY STUDY started @ ***Gamma Irradiation Facility (GIF++) CERN in 2016:***

- ***^{137}Cs source***
 - *$\sim 13 \text{ TBq}$*
 - *Filter system (ABS source attenuation)*
 - *Photons Energy spectrum 0-662 keV*
- ***Muon beam***
 - *Energy up to 100 GeV, 10^4 muons/spill*
 - *3-4 times per year*
- ***Main parameters under control***
 - ***Environmental parameters***
 - *Temperature, Humidity, Pressure*
 - ***Gas parameters***
 - *gas composition,*
 - *gas flow,*
 - *gas Temperature, Humidity, Pressure*



GIF++ allows to test real size detectors in a similar background condition as in CMS



Longevity setup & procedure



- *Monitoring of the currents*
- *Daily measurements*
 - *Current & rate with background*
- *Weekly measurements*
 - *Current and rate at different background conditions and without background*
- *Test beam: 3-4 times per year*
 - *Performance measured with muon beam in several background conditions*

Setup @ GIF++:

- *2 RE2 chambers (Irrad & Ref)*
- *2 RE4 chambers (Irrad & Ref)*

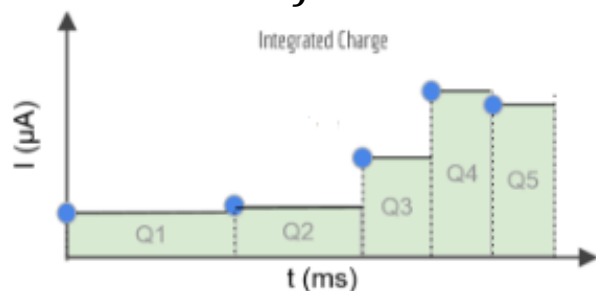
- *Max background rate is expected in the endcap region*
- *Two different types of chambers because the RE4 production has been performed later (2012-2014)*
- *Two chambers continuously irradiated, two used as reference*



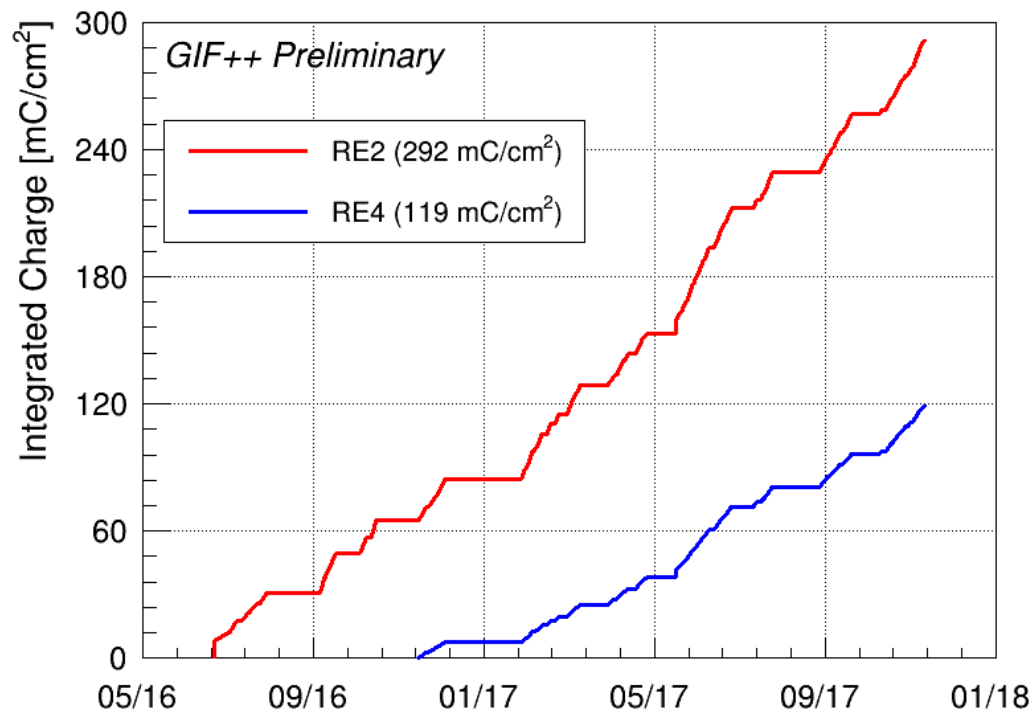
Longevity test status

Expected integrated charge @ HL-LHC
840 mC/cm²

$$Q_{RPC} = \sum_{j=1}^n i_j \Delta t_j$$



Expected integrated charge @
 HL-LHC without safety factor



RE2

- July 3, 2016
- Gas flow ~ 10 l/h
(2 gas volumes/h)
- $Q_{Int} = 292 \text{ mC/cm}^2$

35 %

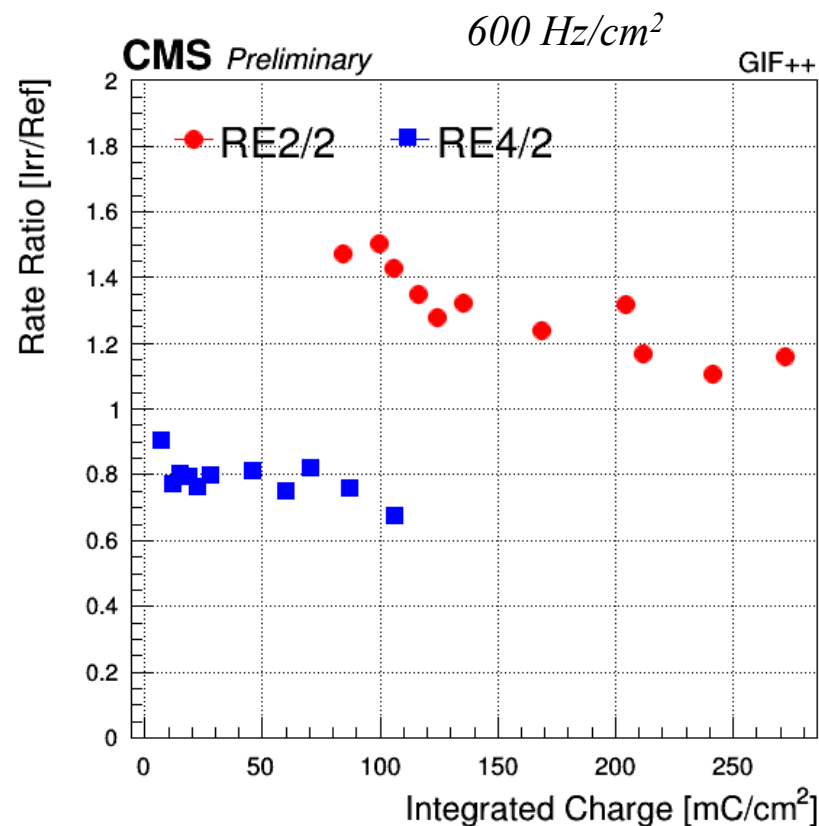
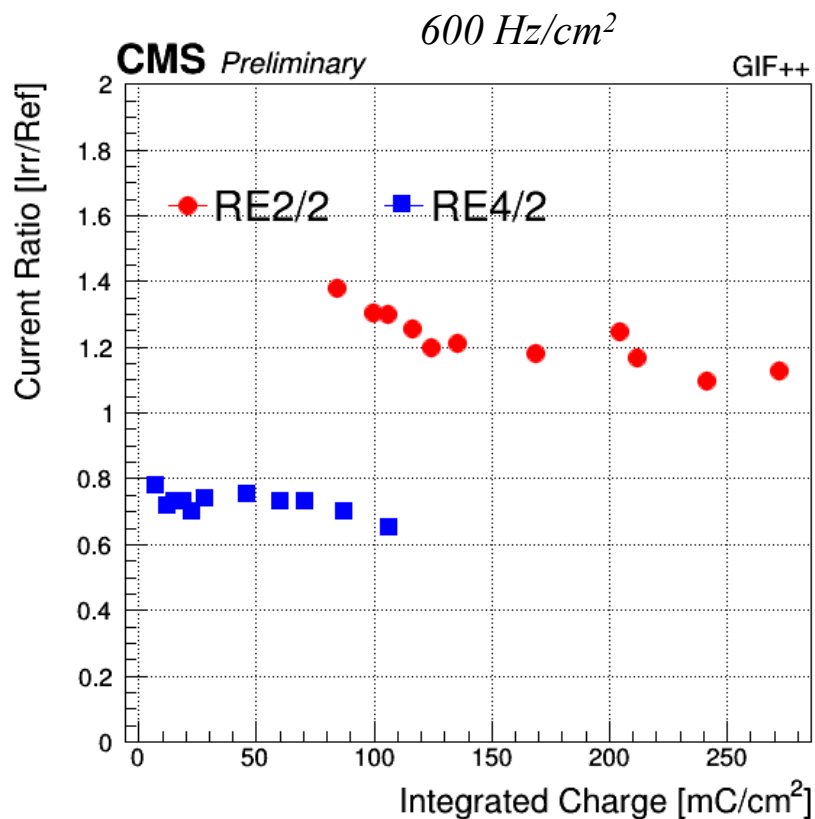
RE4

- November 25, 2016
- Gas flow ~ 10 l/h
(2 gas volumes/h)
- $Q_{Int} = 119 \text{ mC/cm}^2$

14 %



Rate and Currents monitoring with background

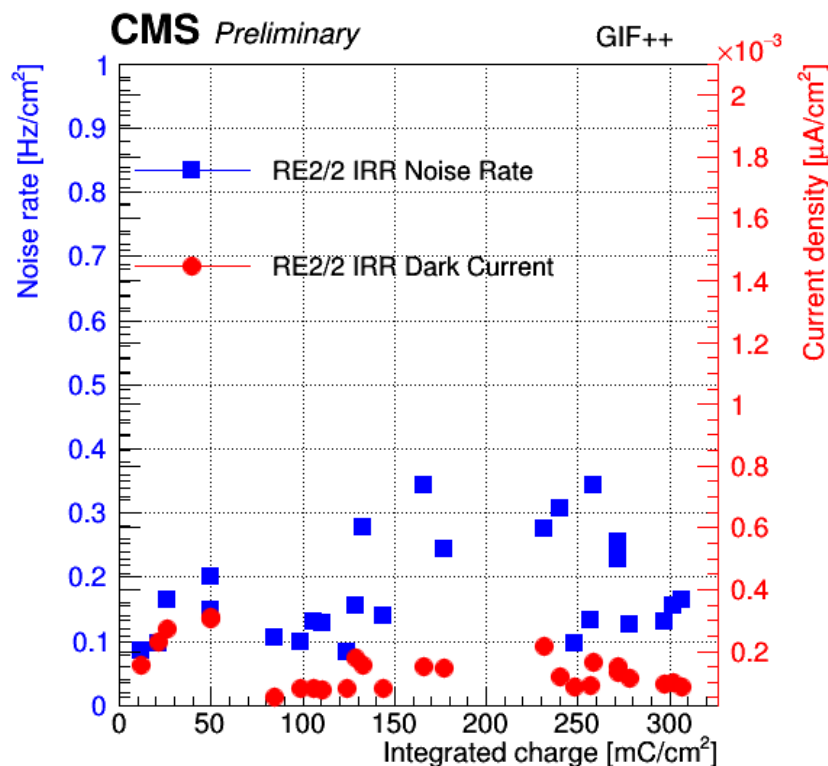


The relative current (left) and rate (right) of the irradiated chamber with respect to the reference chambers are almost stable up to 31 % of the expected HL-LHC integrated charge

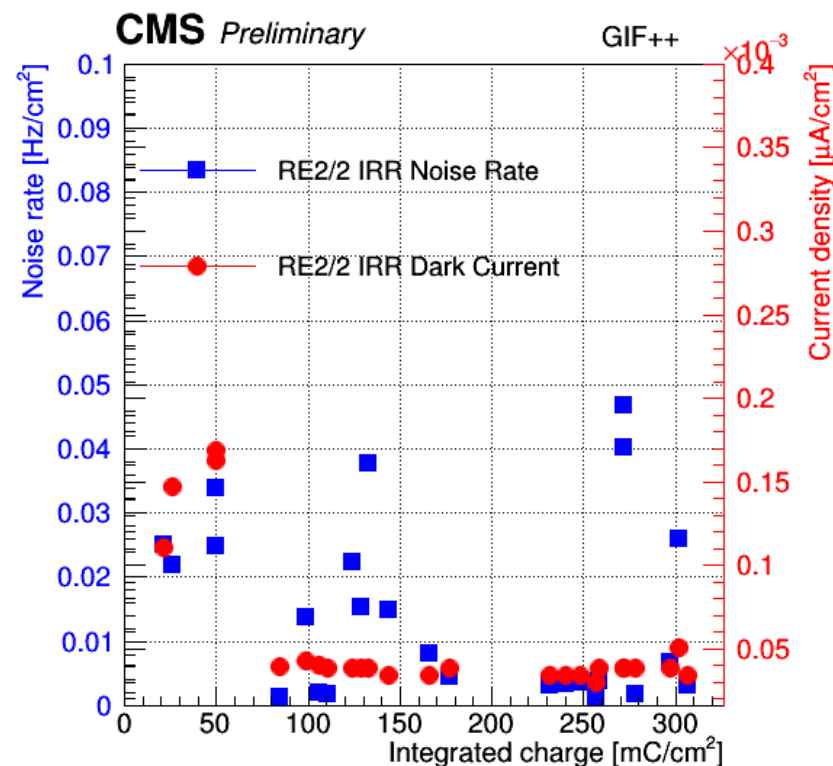


Rate and Currents monitoring without background

RE2/2 IRR @ $HV = 9.5 \text{ kV}$



RE2/2 IRR @ $HV = 6.5 \text{ kV}$



*Noise rate and dark current (without background) are periodically monitored in order to spot variations of the quality of the electrodes: **stable so far.***

Noise rate $< 0.5 \text{ Hz/cm}^2$

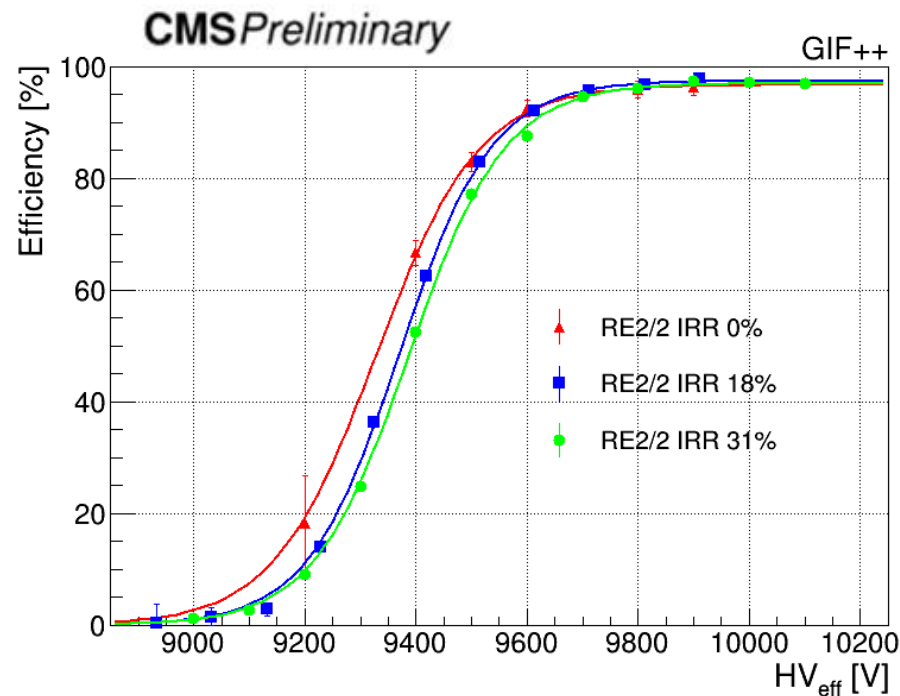
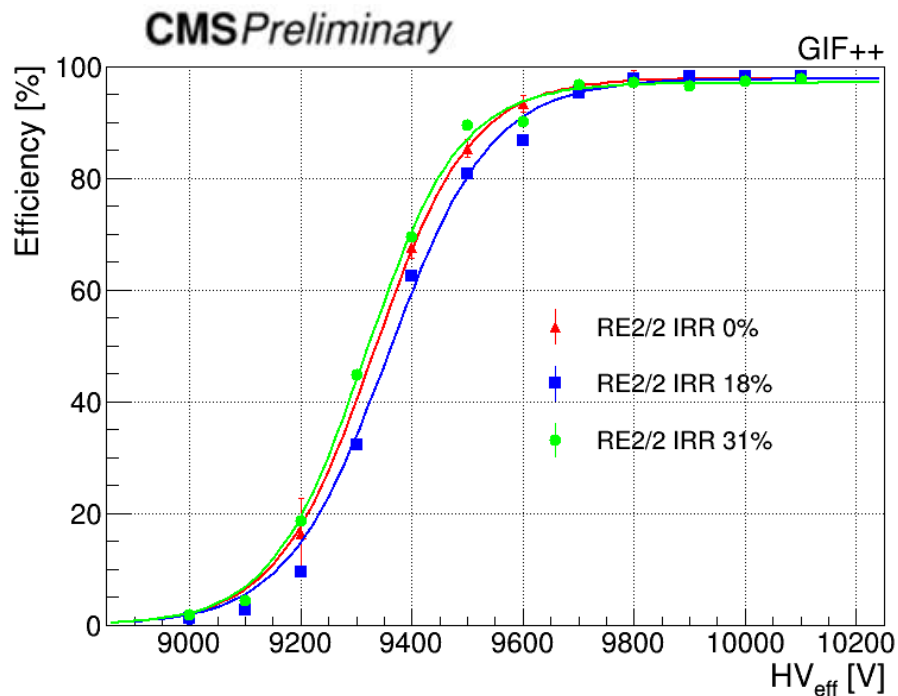
Dark current $< 4.5 \text{ } \mu\text{A}$



Test beam: Efficiency vs HV

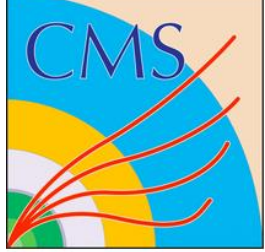
RE2/2 IRR Source OFF

RE2/2 IRR 600 Hz/cm²



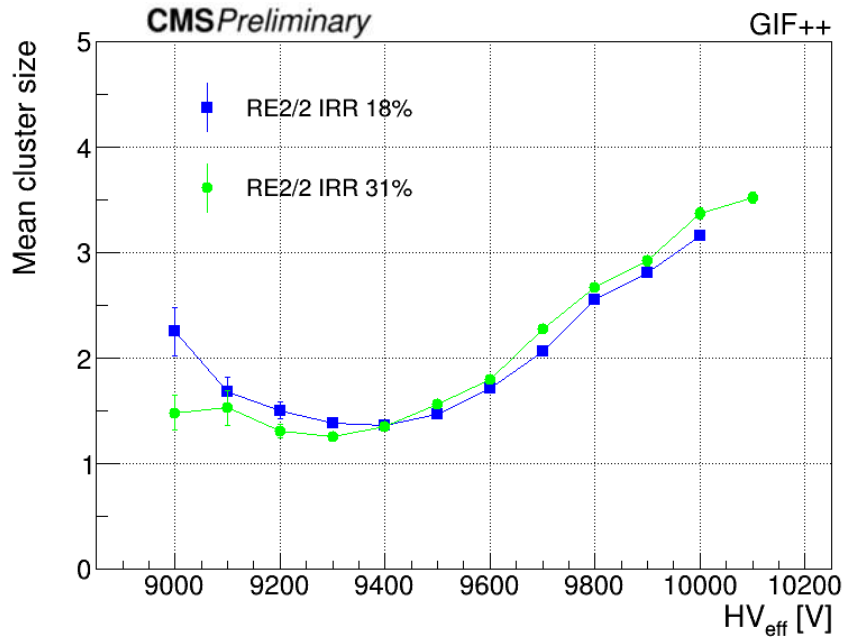
Efficiency vs HV_{eff} as measured w/o background. Three irradiation periods have been considered up to 31 % of the expected HL-LHC integrated charge

- **Performance stable**
- **No shift in the Working Point (WP)**

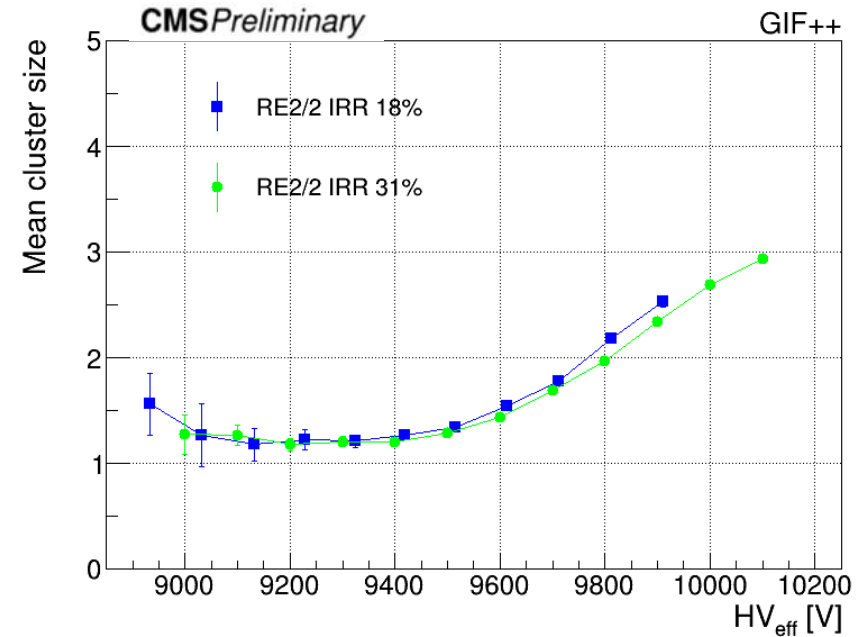


Test beam: Cluster size vs HV

RE2/2 IRR Source OFF



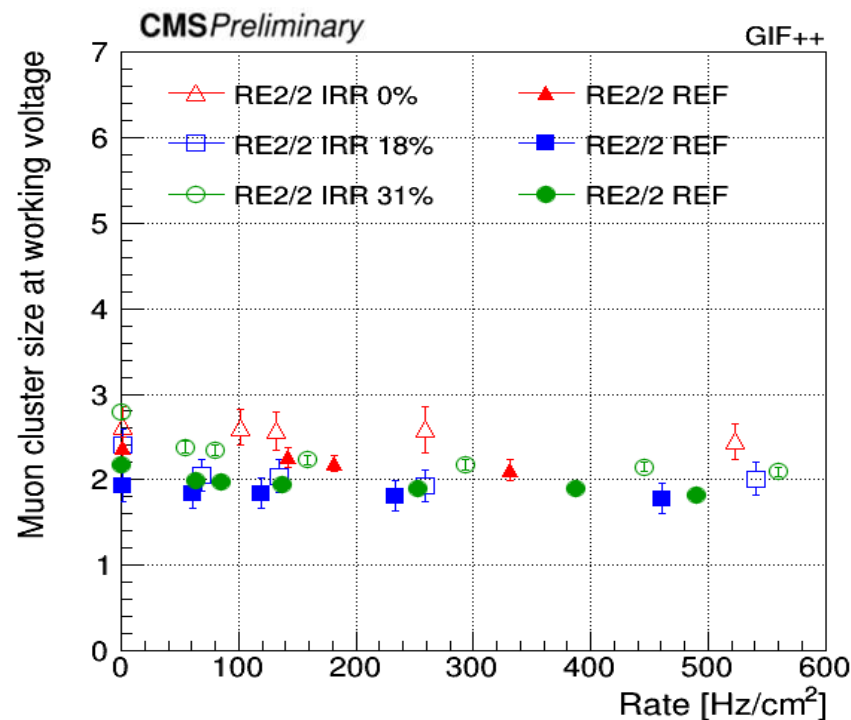
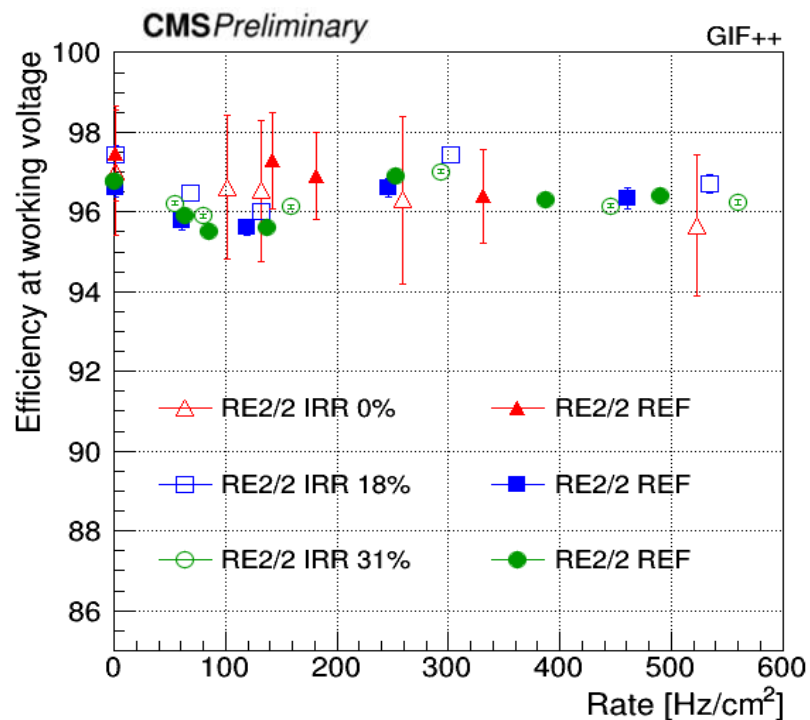
RE2/2 IRR 600 Hz/cm²



Muon cluster size (defined as the number of fired strip per hit) vs HV_{eff} as measured w/o background. Two irradiation periods have been considered up to 31 % of the expected HL-LHC integrated charge.



Test beam: Efficiency & cluster size vs Rate



Efficiency and muon cluster size at the working point as a function of the background rate

A decrease of about 2% of the efficiency at the highest expected background rate (600 Hz/cm²)

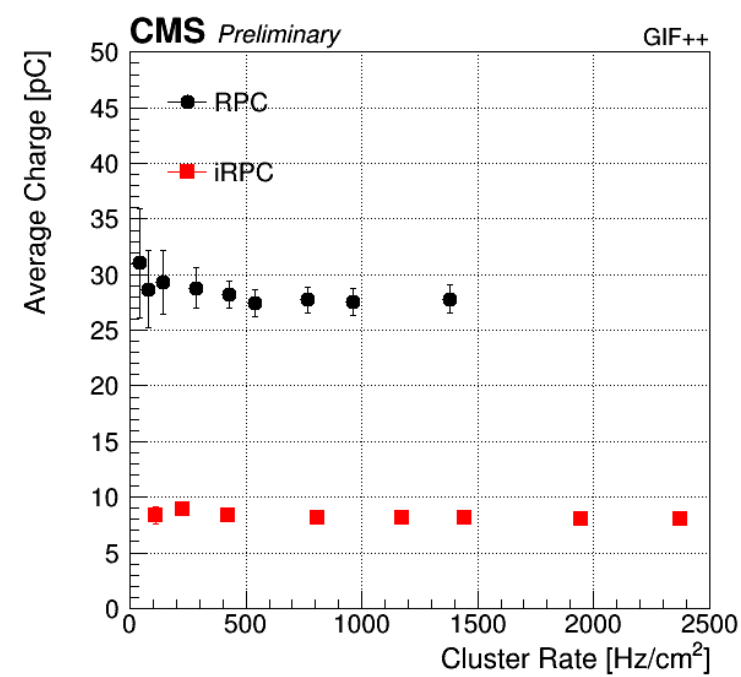
Irradiated detector shows stable behavior with increasing integrated charge 12



iRPC longevity studies

Longevity test recently started on large size prototype of improved RPC for the RE3/1 and RE4/1 Endcap stations.

iRPC must maintain the performance for entire HL-LHC period.



$$q = \frac{\text{current}}{\text{gamma cluster rate}}$$

iRPC expected Rate $R \cong 2 \text{ kHz/cm}^2$
 iRPC expected charge $q \cong 8 \text{ pC}$
 Effective time @ nominal luminosity $T = 6 \cdot 10^{10} \text{ s}$



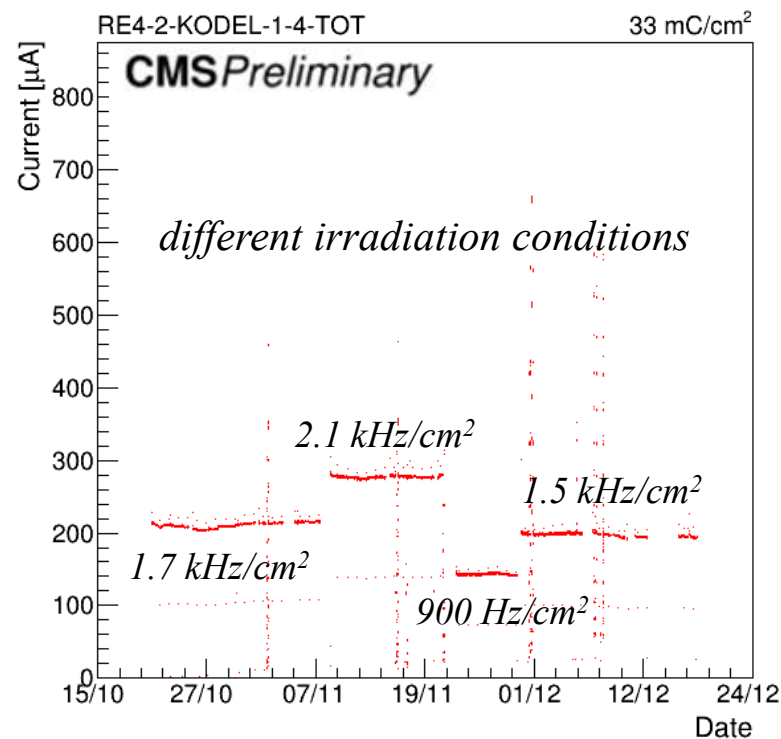
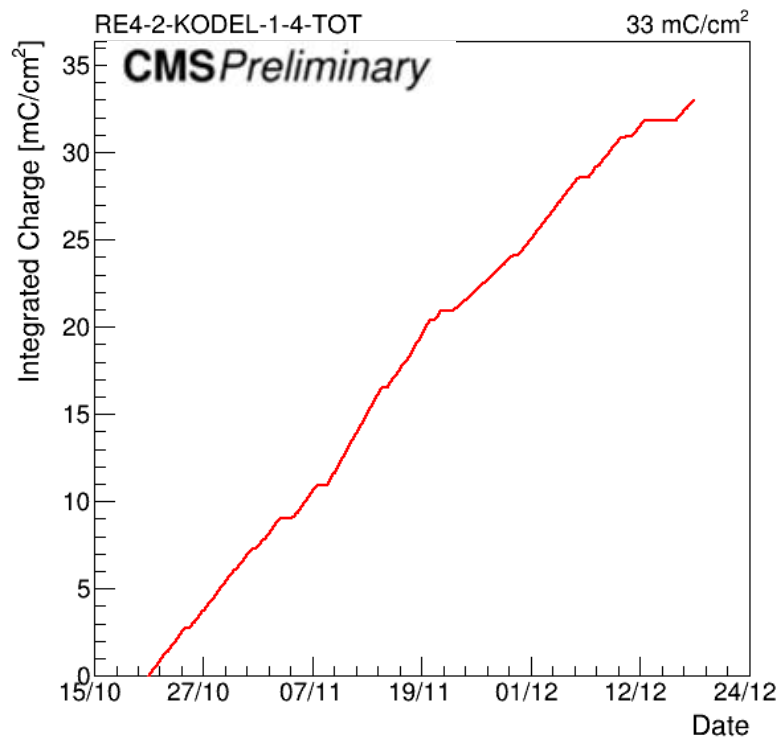
Integrated charge: $Q = R \cdot q \cdot T$

Expected integrated charge similar to the RPC : $\cong 1 \text{ C/cm}^2$
 (safety factor 3 included)

[“RPC upgrade project for CMS Phase II“ , Isabel Pedraza]
 [“ R&D results of iRPC tested at GIF++ for CMS Phase II upgrade “ , Jae Hoon Lim]



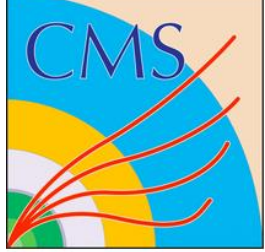
iRPC longevity studies



iRPC

- October 21, 2017
- Gas flow ~ 5 l/h
(1 gas volumes/h)
- 3 %

Main parameters are stable so far



Conclusions

➤ *Longevity studies on CMS RPCs are ongoing at GIF++:*

*The **detectors performance** and the main **detectors parameters** are stable up about 31% of the expected integrated charge (corresponding to HL-LHC without safety factor)*

➤ *We plan to integrated the total expected integrated charge for the HL-LHC in 1.5 years*

➤ *Longevity studies on iRPC are just started @ GIF++*



Thanks

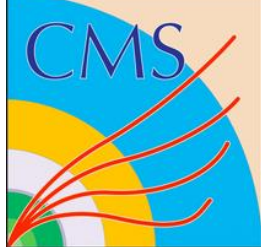
for your attention

Contact:

andrea.gelmi@cern.ch

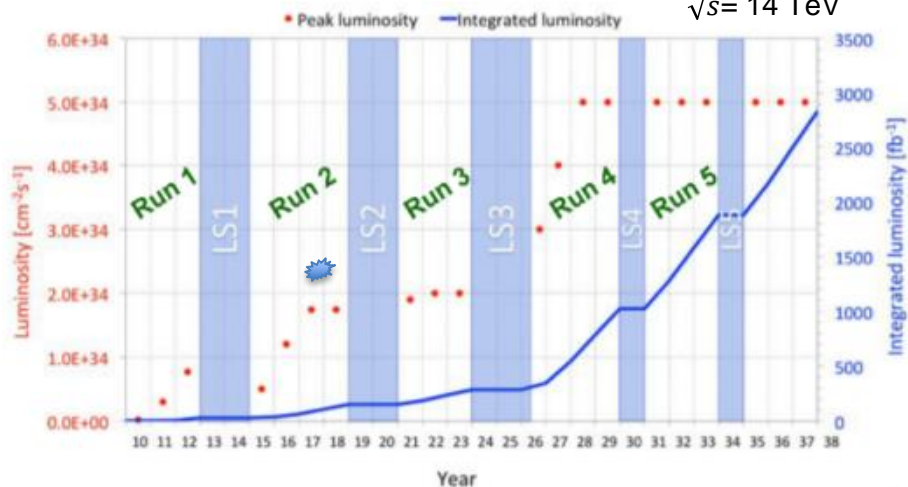


Back up
slide



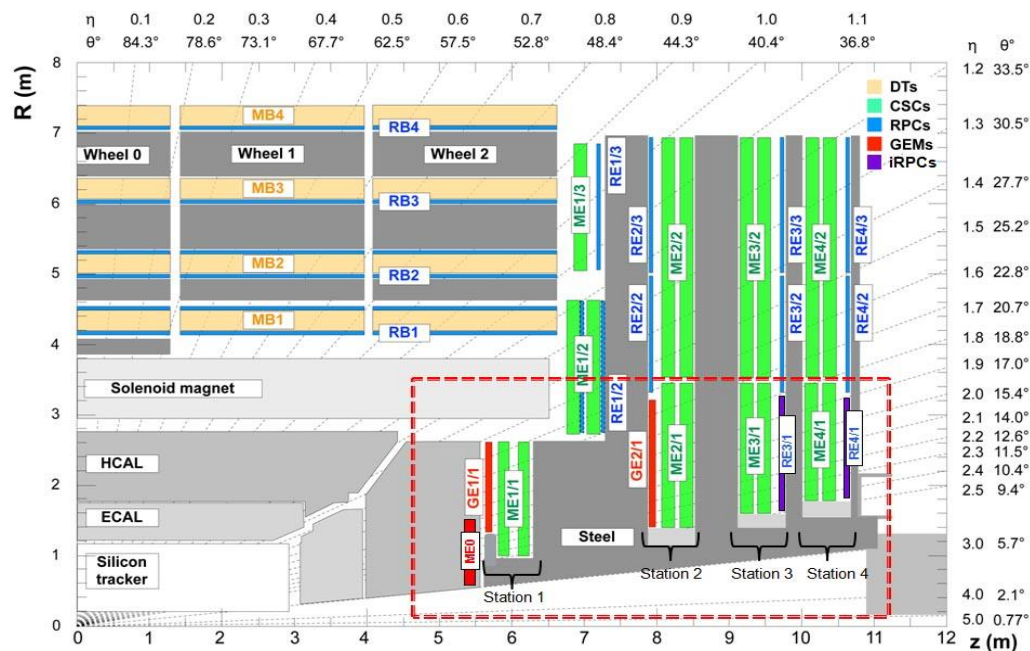
HL-LHC & CMS

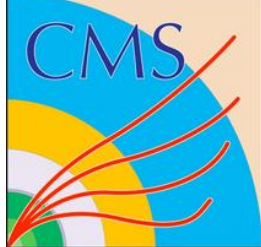
$\sqrt{s} = 14 \text{ TeV}$



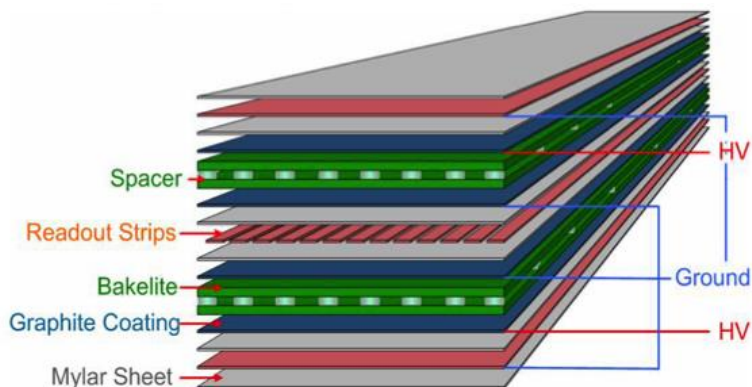
$$\mathcal{L} = \frac{R_{inel}}{\sigma_{inel}}$$

$$\mathcal{L} = \int_0^t L(t') dt'$$



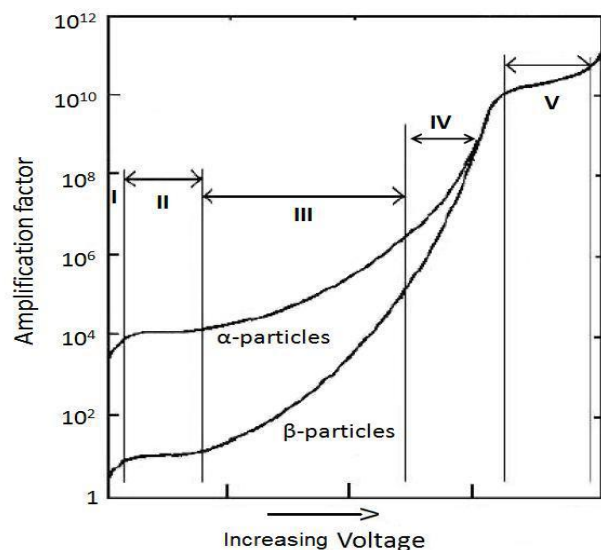


CMS RPC design

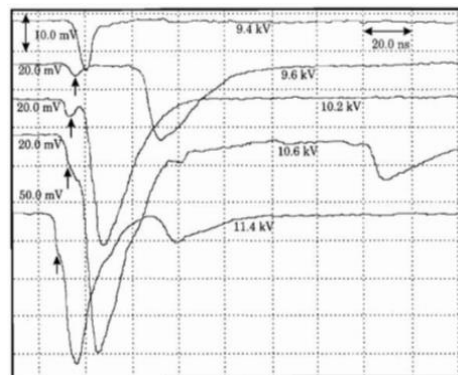


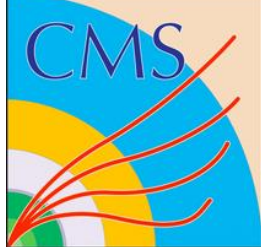
- **Covers** $0 < |\eta| < 1.8$
- **1056 chambers** (480 in Barrel and 576 in Endcap)
- 120000 **electronic channels** and 400 m² of **active area**
- **Double gaps gas chamber:** 2 mm gas width
- **Electrodes:** High Pressure Laminate
- **HPL** bulk resistivity: $\rho = 1 - 6 \times 10^{10} \Omega\text{cm}$
- **Humidified Gas mixture:** $\text{C}_2\text{H}_2\text{F}_4 + \text{isoC}_4\text{H}_{10} + \text{SF}_6$ (40% of H₂O)

95.2%	4.5%	0.3%
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- Close loop with 10% -15% of fresh gas
- Operated in **avalanche mode**



$$S = \left(-\frac{dE}{dx} \right) = \frac{4\pi N_A}{m_e c^2} \rho \frac{Z}{A} \frac{z^2}{\beta^2} \ln \left[\left(\frac{2m_e c^2 \beta^2 \gamma^2}{I} \right) - \beta^2 - \frac{\delta}{2} - \frac{C}{Z} \right]$$





CMS RPC production

Barrel Station



Forward Station

RPC mass production started in **early 2000**:

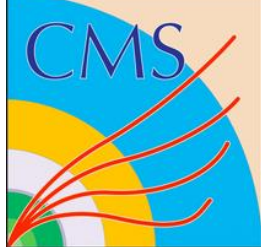
- **HPL:** PanPla (Italy)
- **Gaps:** General Tecnica (Italy) for the Barrel and Korea University for Endcap
- **Chambers** built and tested in several sites in Europe and Asia
- **Detector installation from 2004-2008**



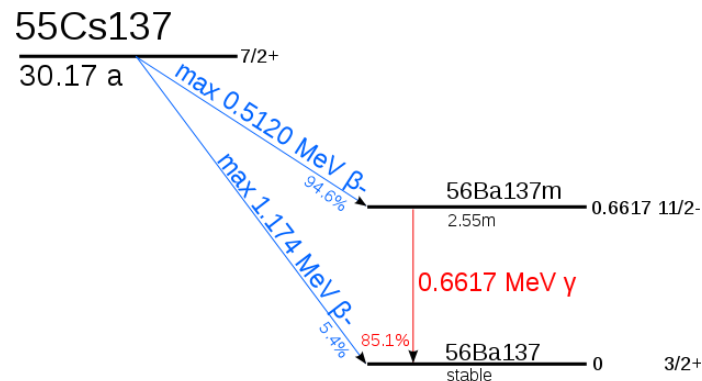
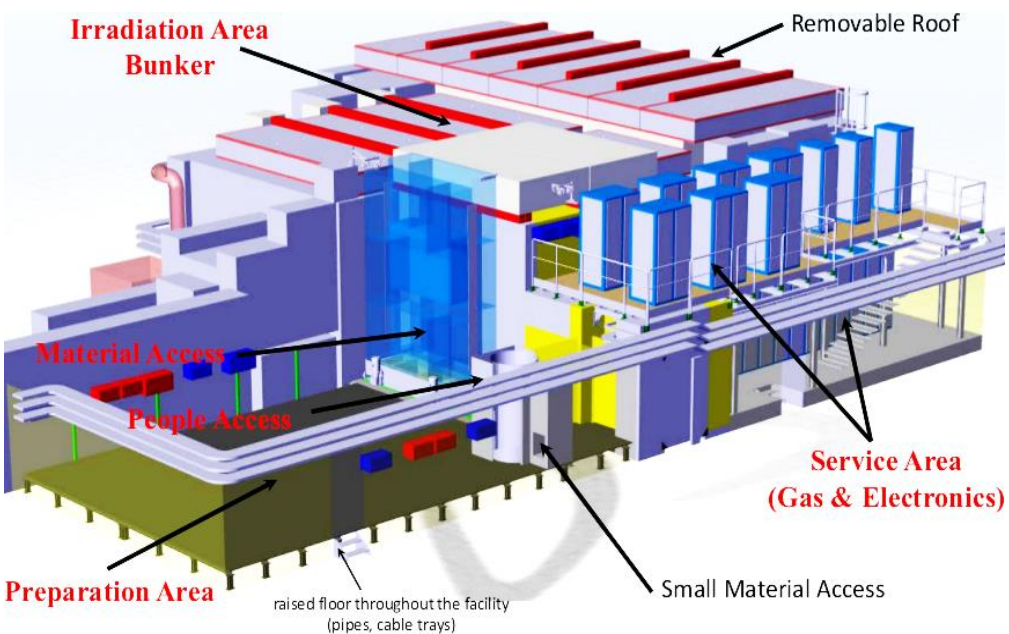
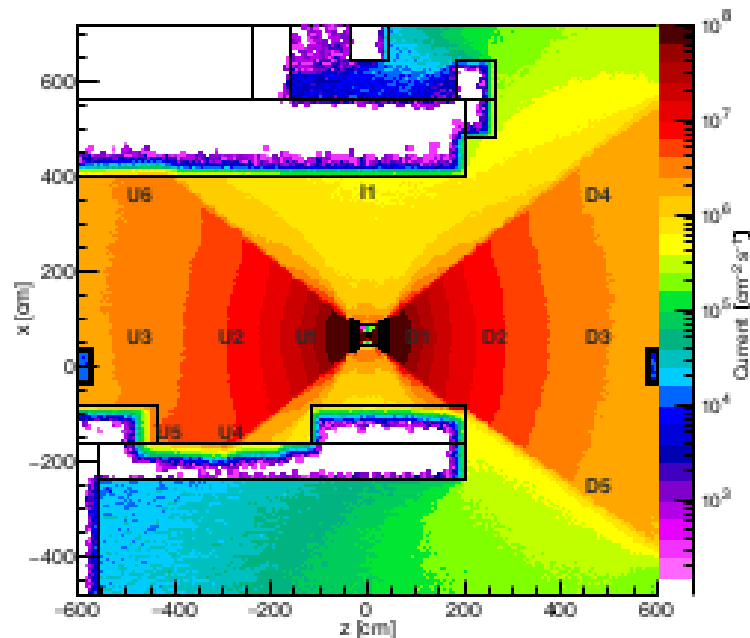
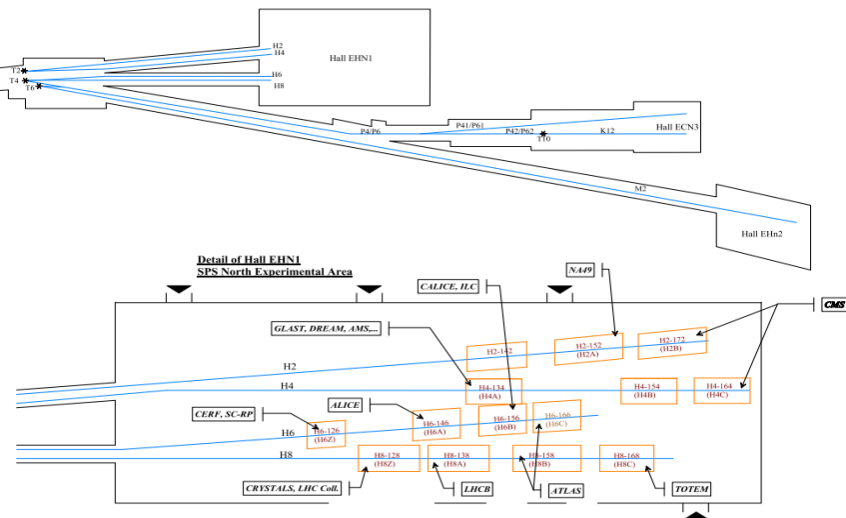
RE4 Station

RE4 stations construction and installation in 2012-14:

- **HPL:** Puricelli (Italy)
- **Gaps:** Korea University
- **Chambers:** India, Belgium and CERN



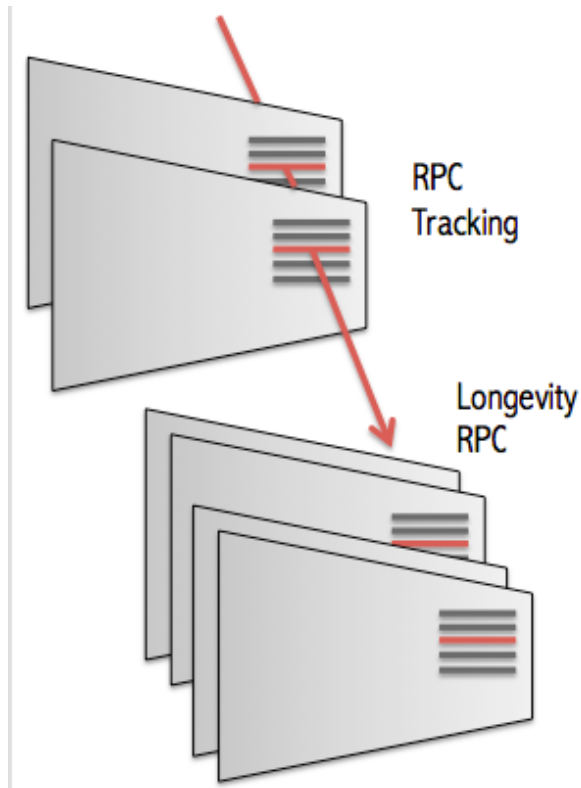
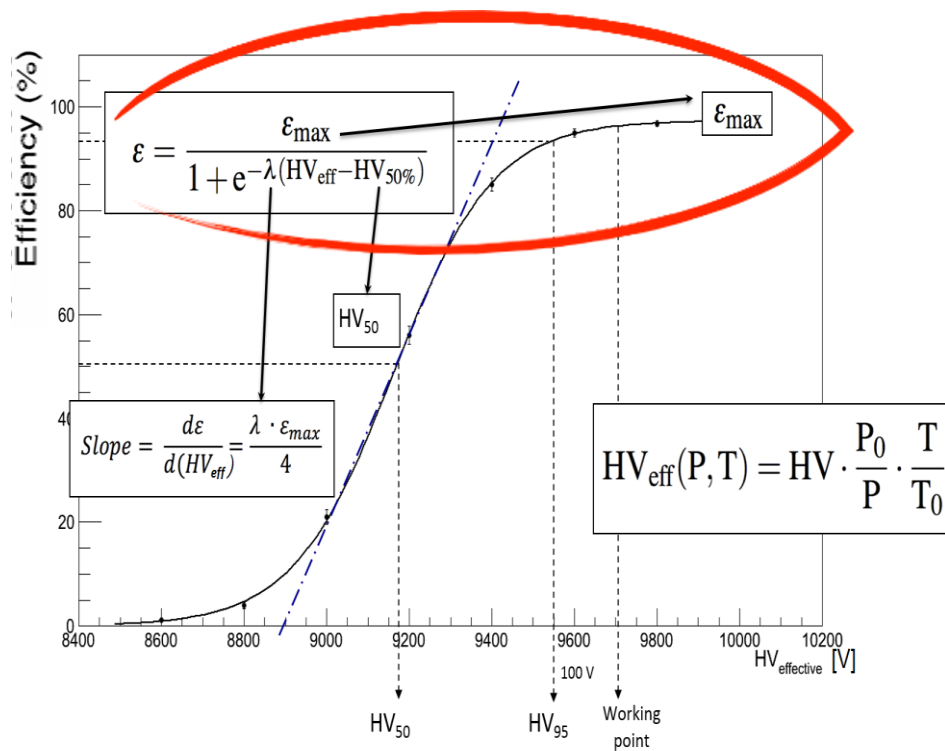
Irradiation Test at GIF++





RPC Efficiency

Detector performance measured with muon beam using additional RPCs for muon tracking



$$\lambda = \frac{1}{HV_{90\%} - HV_{10\%}}$$

HV correction

$$HV_{\text{app}} = HV_{\text{eff}} \left(1 - \alpha + \alpha \frac{P}{P_0} \frac{T_0}{T} \right)$$

$$\begin{aligned} P_0 &= 990 \text{ mbar} \\ T_0 &= 293.15 \text{ K} \\ \alpha &= 0.8 \end{aligned}$$



Rate and Currents monitoring without background

