Aging study on Resistive Plate Chamber of the CMS muon detector for HL-LHC

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On behalf of the CMS Muon Group

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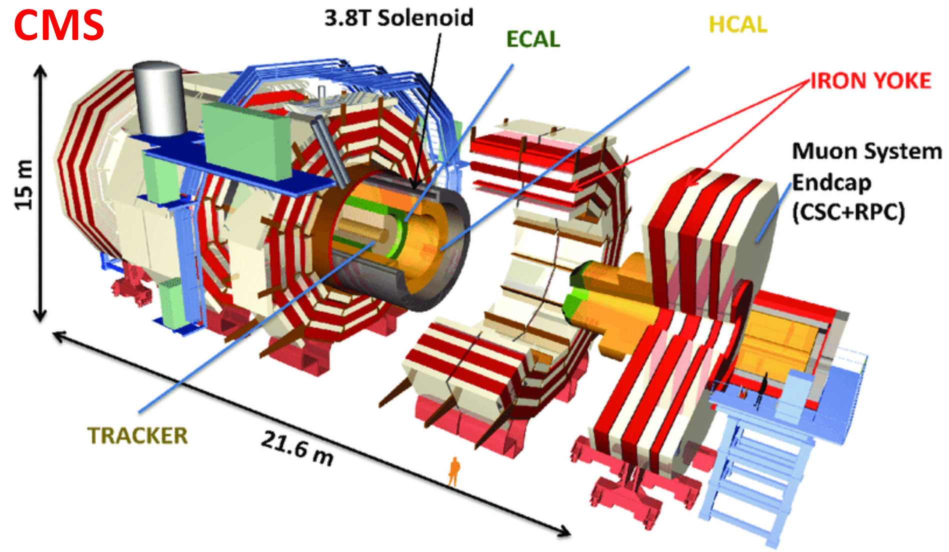
The CMS-RPC system @ HL-LHC

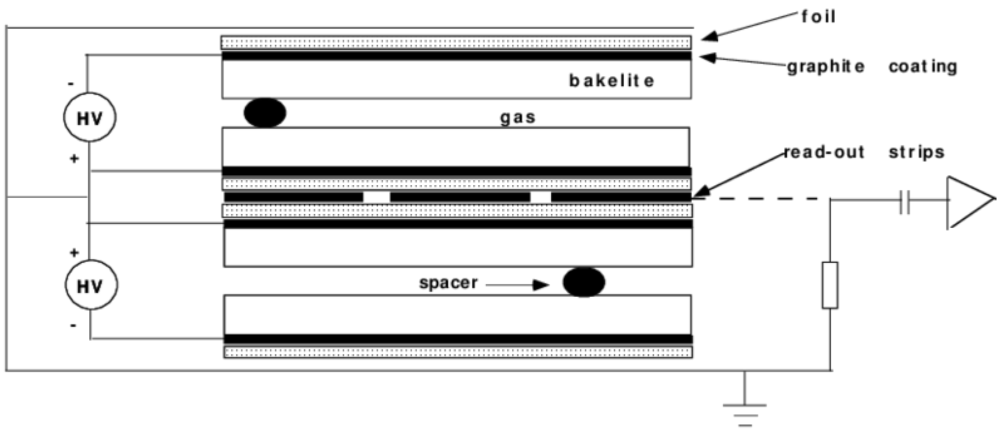
Aim: Validation of the present RPC system in view of the HL-LHC phase



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

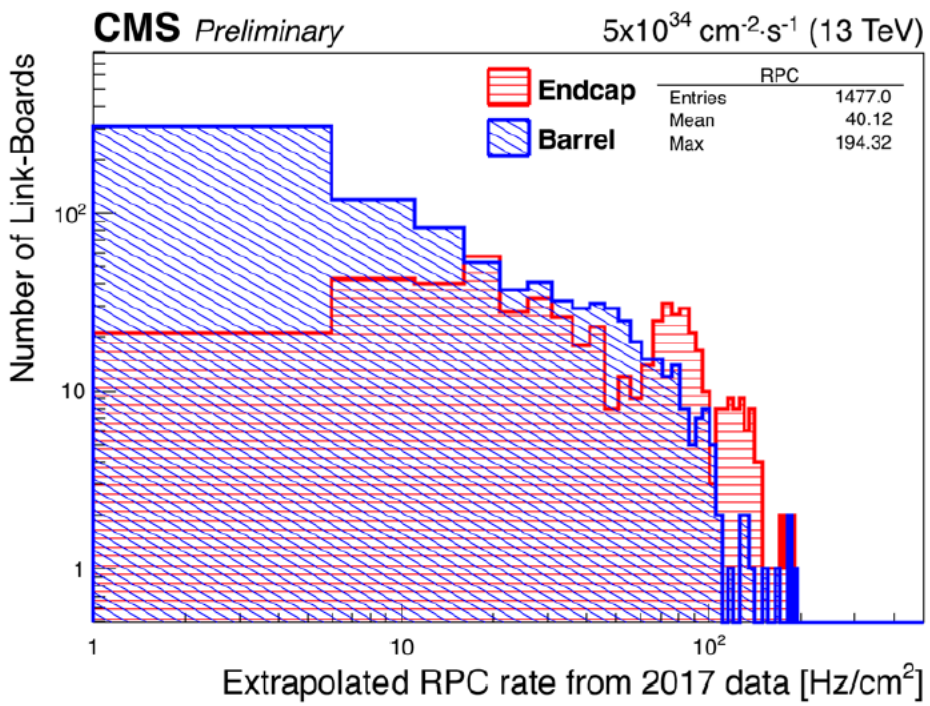
- ➢ *Working in avalanche mode*
- ➢ *Double gas-gaps RPC*
- ➢ *2 mm gas gap and electrodes thickness*
- ➢ *HPL bulk resistivity: $\rho = 1 - 6 \cdot 10^{10}\ \Omega cm$*

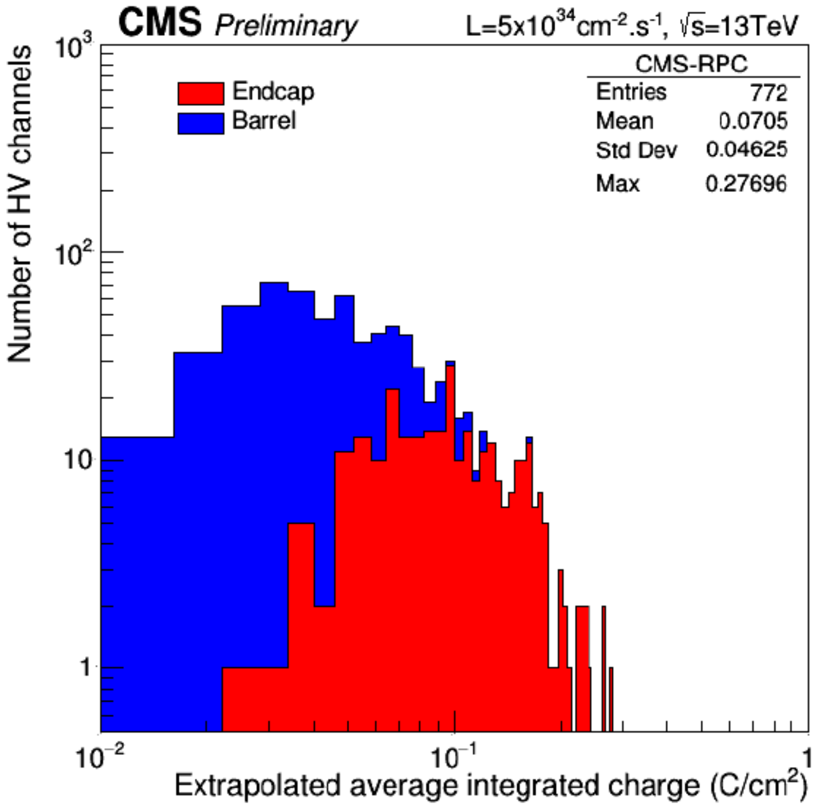
- ❑ RPC information's used in the muon trigger, reconstruction and identification
- ❑ ***High and stable RPC performance during LHC operation***
- ❑ RPC's are certified for **10 years** of LHC (at nominal luminosity of 10^{34} cm^{-2}s^{-1}) with high and stable performance
- ❑ **Longevity studies** are necessary to check the behavior of the RPC system at **HL-LHC** (5 x10^{34} cm^{-2}s^{-1}) .



The expected Conditions at HL- LHC

- LHC collision data in 2017 has been used to estimate the expected background rates & integrated charge at HL-LHC (5×10^{34} $cm^{-2}s^{-1}$).





Expected Rate :

- Max. Rate : ~ 200 Hz/cm^2

~ 600 Hz/cm^2 (including safety factor of 3)

Expected Integrated Charge :

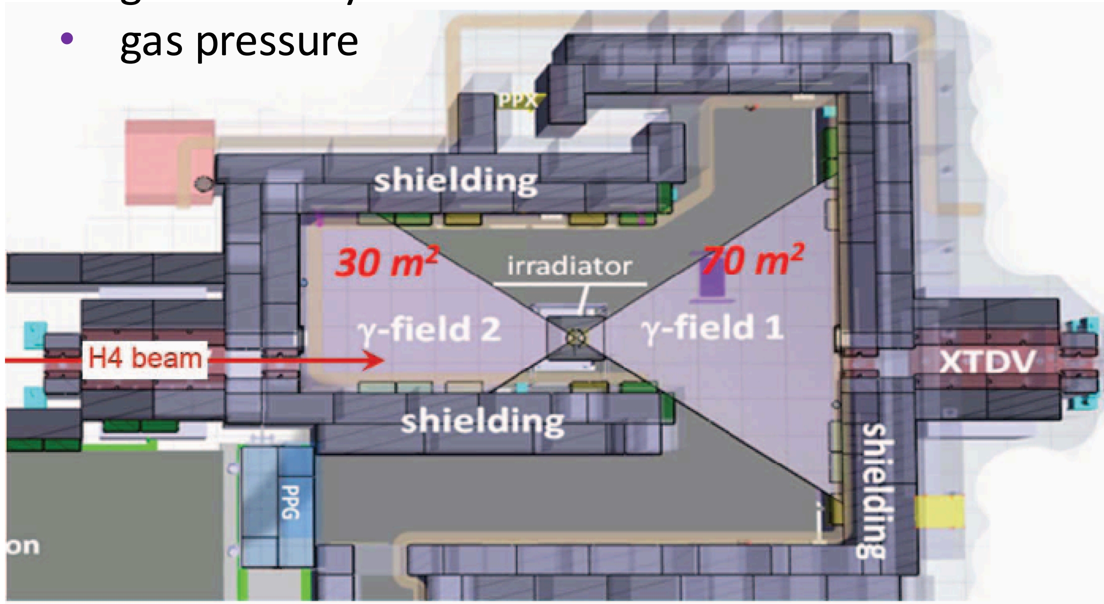
- Max. integrated charge : 280 mC/cm^2

~ 840 mC/cm^2 (including safety factor of 3)

Gamma Irradiation Facility (GIF++)

GIF++ is a facility that allows to test real size detectors in a similar background condition as in CMS.

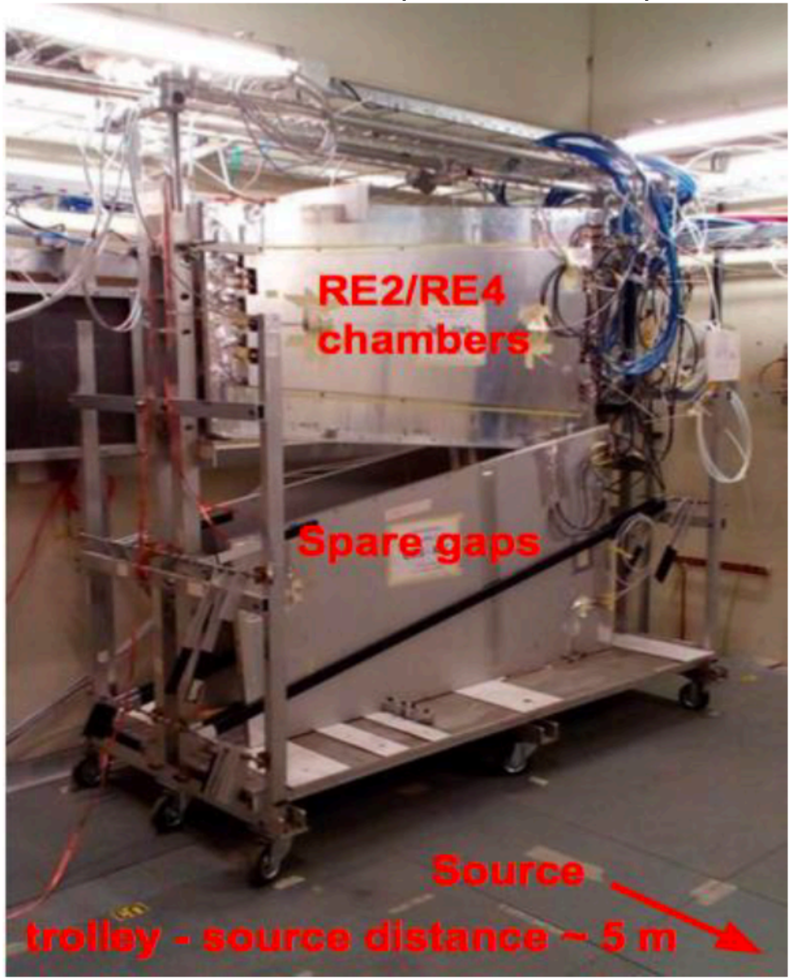
- ❑ 14 TBq ^{137}Cs source (662 keV gammas)
- ❑ Gamma Filters:
  System of movable attenuators allow to test the detector in different irradiation conditions.
- ❑ Muon Beam (3-4 times per year)
  Energy up to 100 GeV
- ❑ Unified control and monitor of the environmental parameters:
  - Temperature
  - Humidity
  - Pressure
- ❑ Gas parameters monitoring:
  - gas composition
  - gas flow
  - gas temperature
  - gas humidity
  - gas pressure



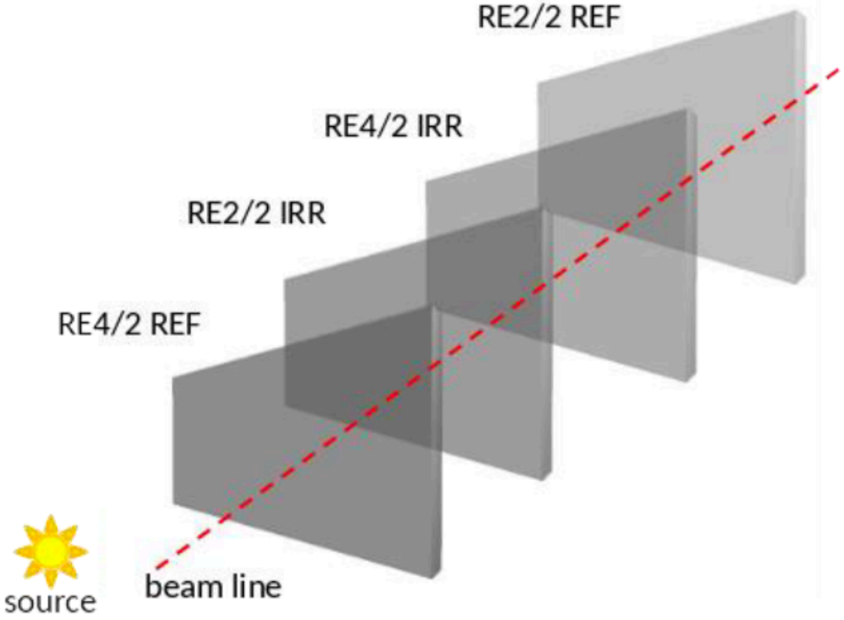
Longevity Setup & Procedure

Setup @ GIF++ since July 2016:

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



- The max. background rate expected in endcap region
- Two different types of chambers from old and new production (RE4 produced in 2012- 2014)
- Two chambers are continuously irradiated & two used as reference.



- Daily measurements:
  Current & rate with background
- Weekly measurements:
  Current and rate at different background conditions and without background
- 3- 4 times per year:
  Argon Resistivity measurements
- 3- 4 times per year Test beam:
  Detector performance measurements with muon beam at several background conditions

WebDCS GIF++

- Daily measuring Current & rate.
- Applied HV correction

Gas parameters:

Flow $C_2H_2F_4$:	89.0164 l/h
Flow iC_4H_{10}:	4.20694 l/h
Flow SF_6:	0.280462 l/h
Mixture $C_2H_2F_4$:	95.200834721138 %
Mixture iC_4H_{10}:	4.4992181173553 %
Mixture SF_6:	0.29994716150687 %
iC_4H_{10} BINOS:	4.50992 l/h
MFC Humidity:	5.91402
Pressure gas box 102:	5.80738 mbar

Environmental parameters:

Pressure box 201 Upstream:	976.072 mbar
Temperature box 201 Upstream:	21.506 degC
Humidity box 201 Upstream:	30.24 %
Pressure:	967.942 mbar
Temperature inside bunker:	21.238 degC
Rel. humidity inside bunker:	33.4462 %
Pressure box 202 Downstream:	700 mbar
Temperature box 202 Downstream:	101.382 degC
Humidity box 202 Downstream:	0 %

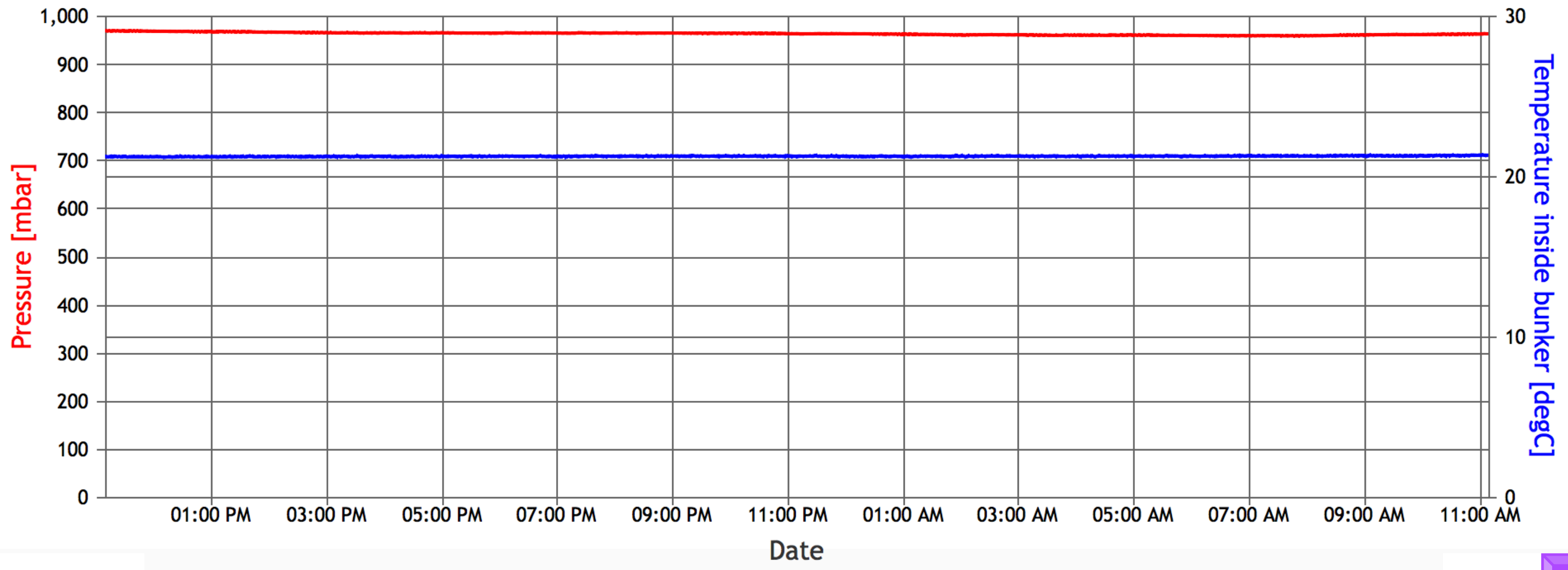
WebDCS GIF++

Monitoring | HVscan | Longevity | Stability | Hardware | Settings

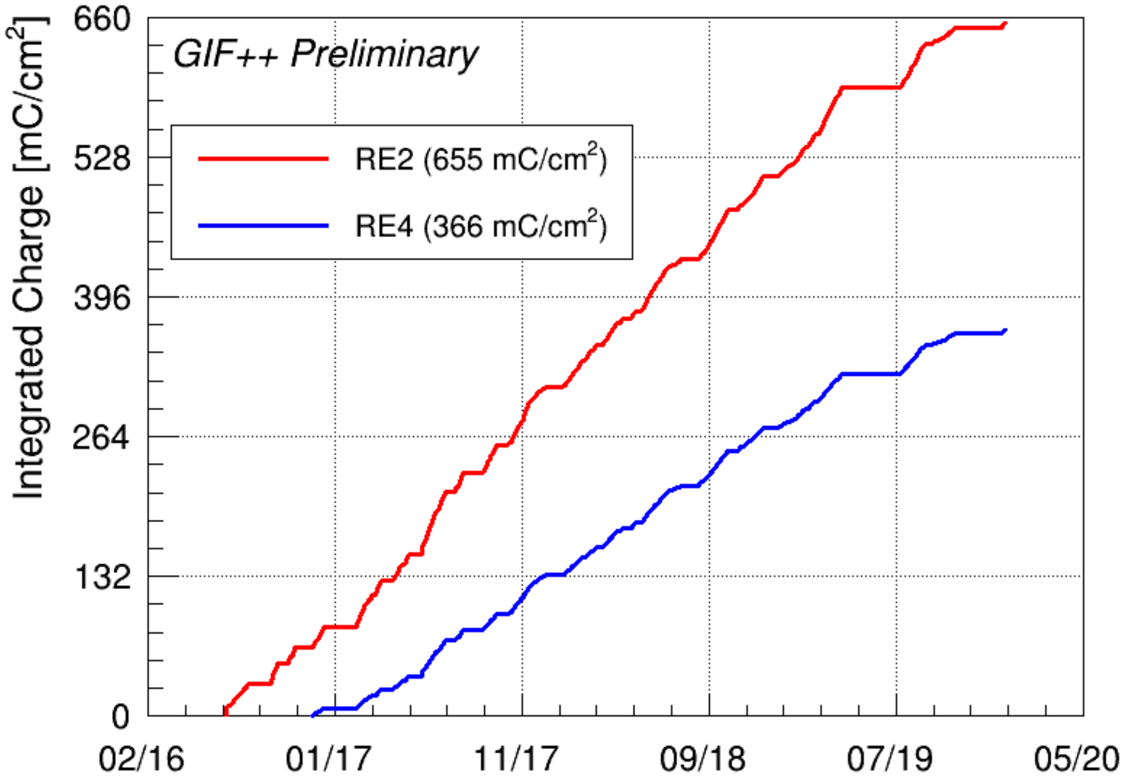
Plot monitoring history

Start time: 2020/02/09 11:09
End time: 2020/02/10 11:09
Parameter left: Pressure (red)
Parameter right: Temperature inside bunker (blue)

Generate plot



Longevity Status



RE2

- IRR. In 3 July 2016
- Q_{int} : 655 mC /cm^2

78 %

RE4

- IRR. In 25 Nov. 2016
- Q_{int} : 366 mC /cm^2

44 %

✓ Expected Integrated charge @HL-LHC 840 mC /cm^2

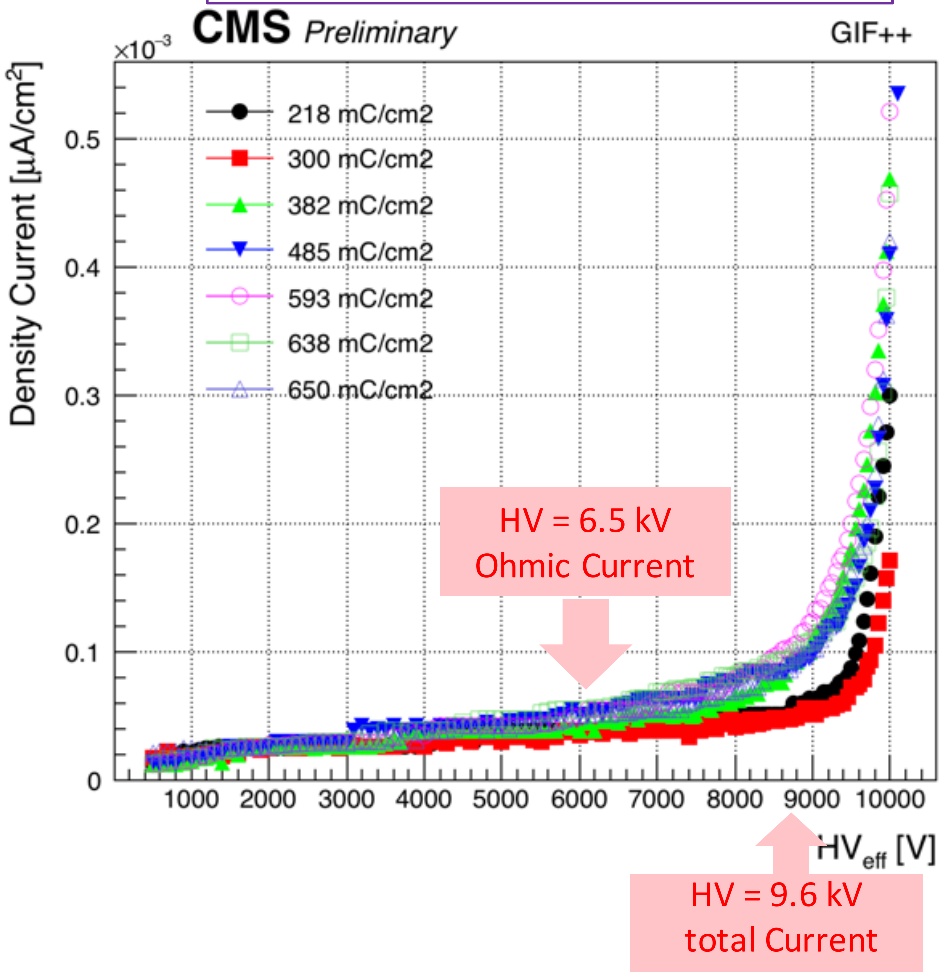
✓ Average Integrated charge:

$$J_{mon} = \frac{I_{mon}^{TW} + I_{mon}^{TN} + I_{mon}^{BOT}}{A_{TW} + A_{TN} + A_{BOT}}$$

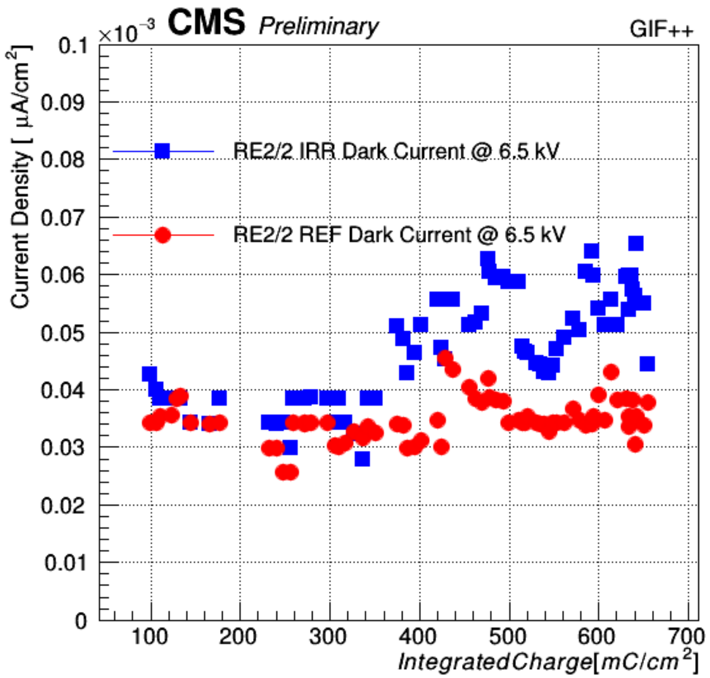
$$Q_{int} = \int_{t_i}^{t_f} J_{mon}\,dt$$

Dark Current

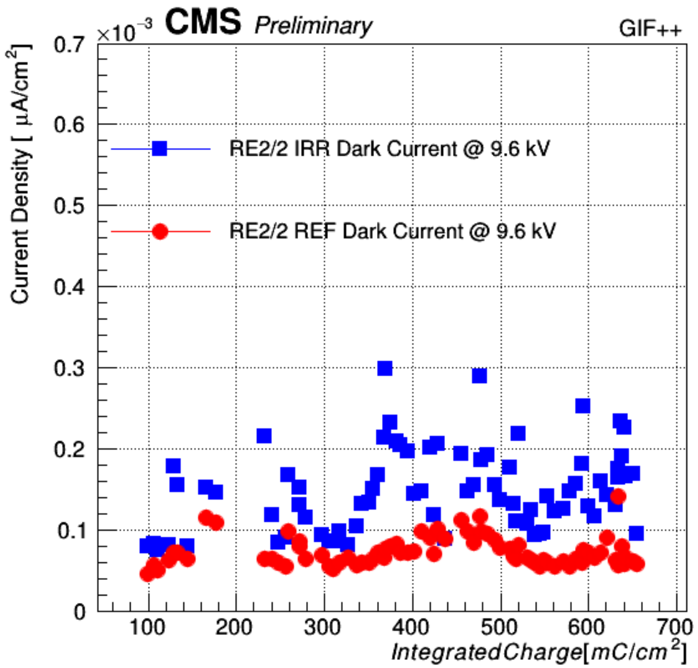
RE2/2 Irradiated dark current



RE2/2 IRR. & REF ohmic current



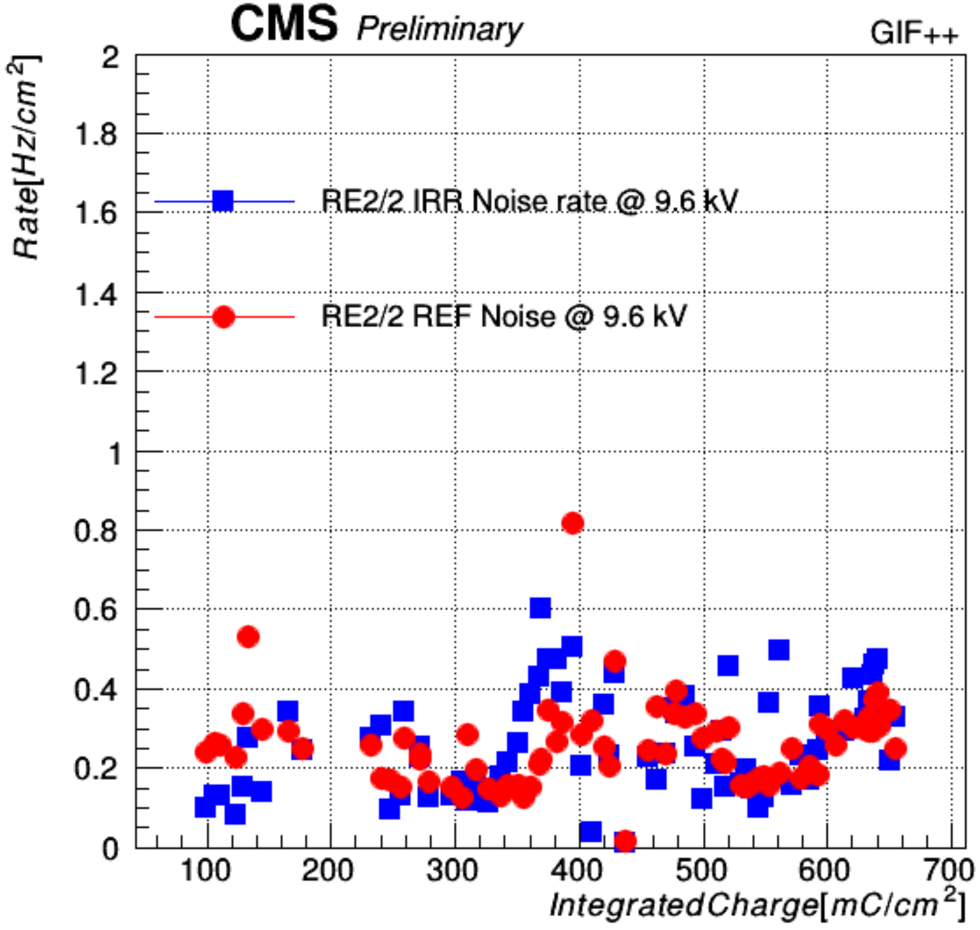
RE2/2 IRR. & REF total current



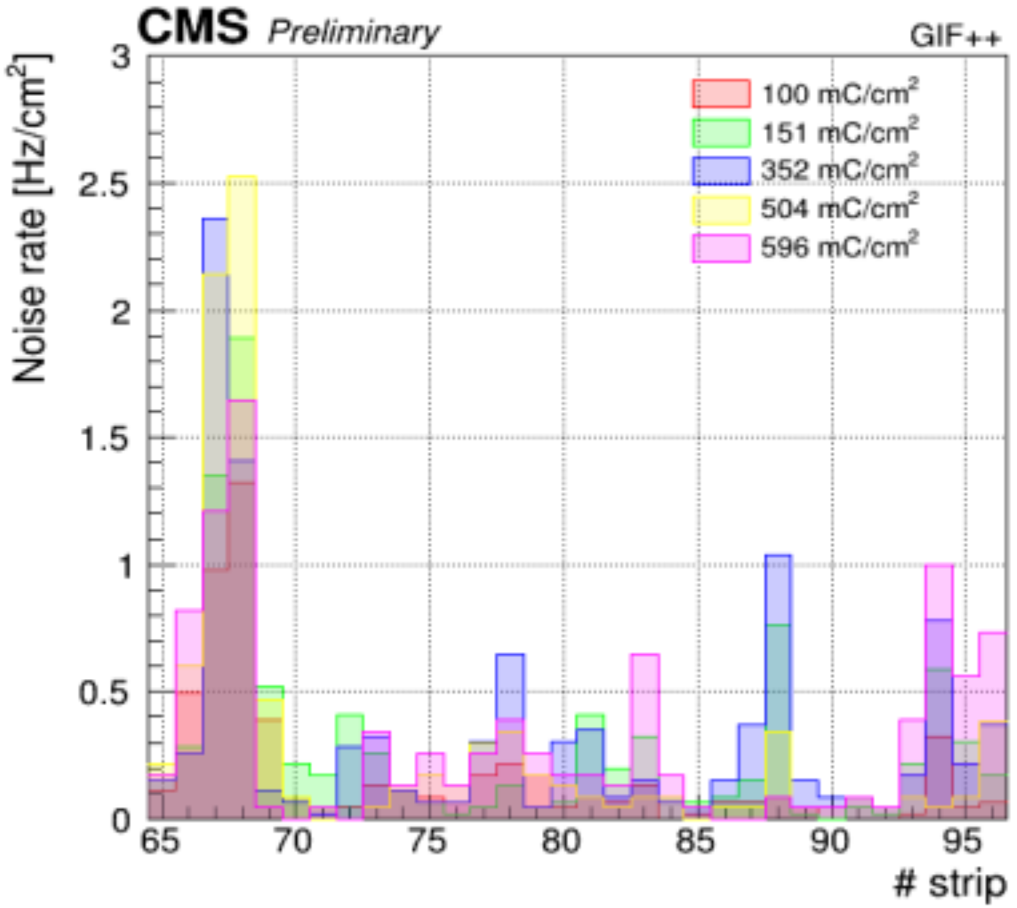
- **Ohmic and total** current almost stable with time and after collecting 650 mC/cm^2 of IC & in agreement with values before the irradiation for IRR. & REF. chambers.

Noise Rate & Strip profile

RE2/2 IRR. & REF Noise rate



RE2/2 IRR. Strip profile



- Noise rate & strip profile are almost stable with time.
- **Average noise rate** less than 1 Hz/cm^2

Resistivity measurement

- The resistivity is periodically measured at GIF++.
- The resistivity of the plates can be determined by running the detector filled with pure Argon in a self-sustaining streamer regime.
- By measuring the current as a function of the applied high voltage we can measure the resistance of the HPL plates, and hence their resistivity

$$\rho = \frac{R \times S}{L}$$

- Where: R is the measured resistance , S corresponds to the HPL surface, L is the electrode thickness.

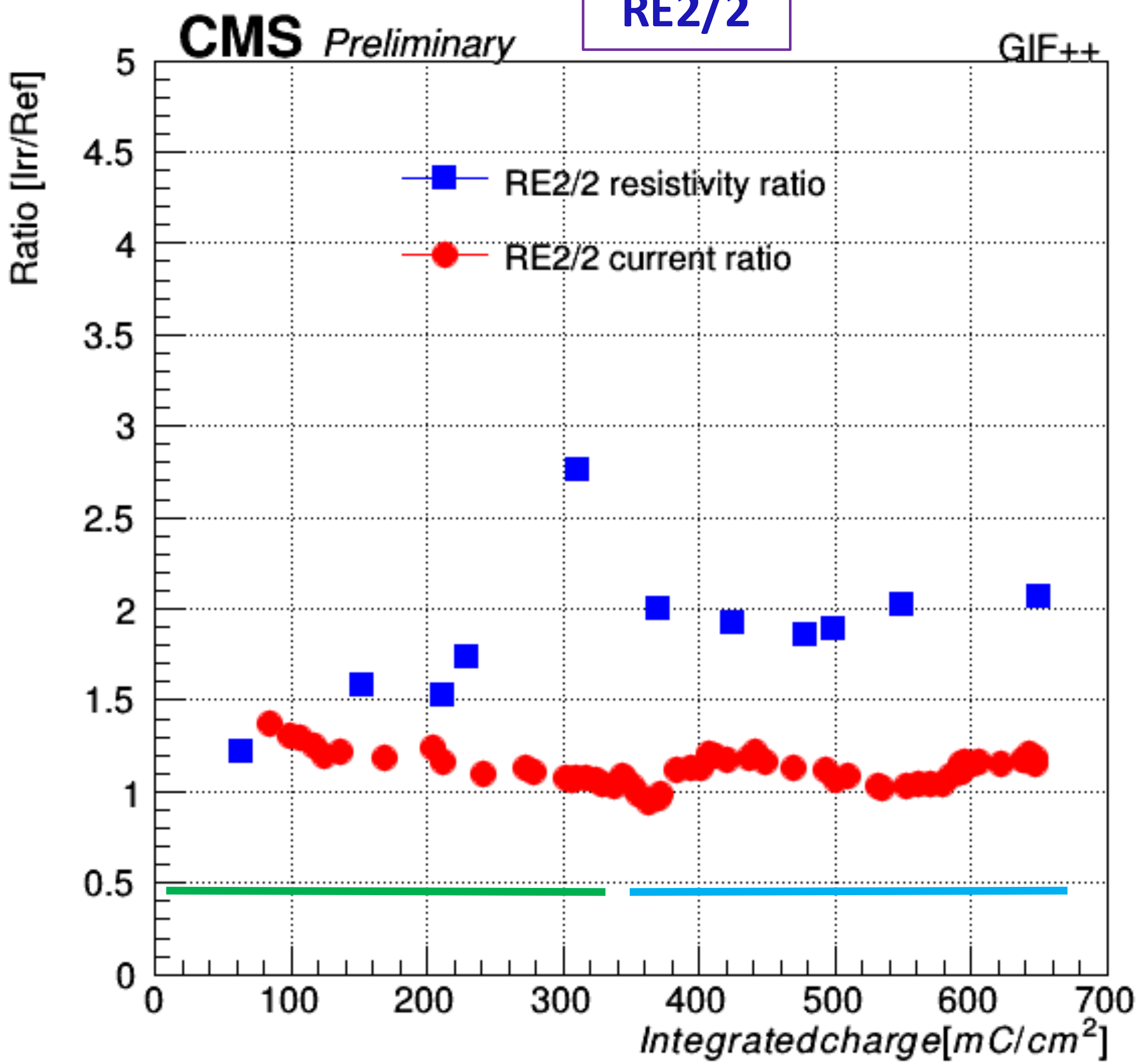
- The measured resistivity values are normalized at 20°C

$$\rho_{20} = \rho \times e^{\alpha(T-20)}$$

- where α= represents the temperature-dependent coefficient, ρ and ρ_{20} is the resistivity measured and normalized at 20°C , and T is the environmental temperature

Resistivity & current

RE2/2



- Resistivity ratio and Current ratio of IRR & REF chambers
- Running with CMS RPC gas conditions: Resistivity increase observed due to the low humidity and gas flow with respect to the high background rate (600 Hz/cm^2) ➔ Current Ratio decrease
- Running with new gas conditions: Revocable effect mitigated with the gas humidity increase to 60 % and gas flow 3 V/h➔ almost stable resistivity
- **Resistivity value** almost stable and within the range 1-6 *10^{10} Ωcm.

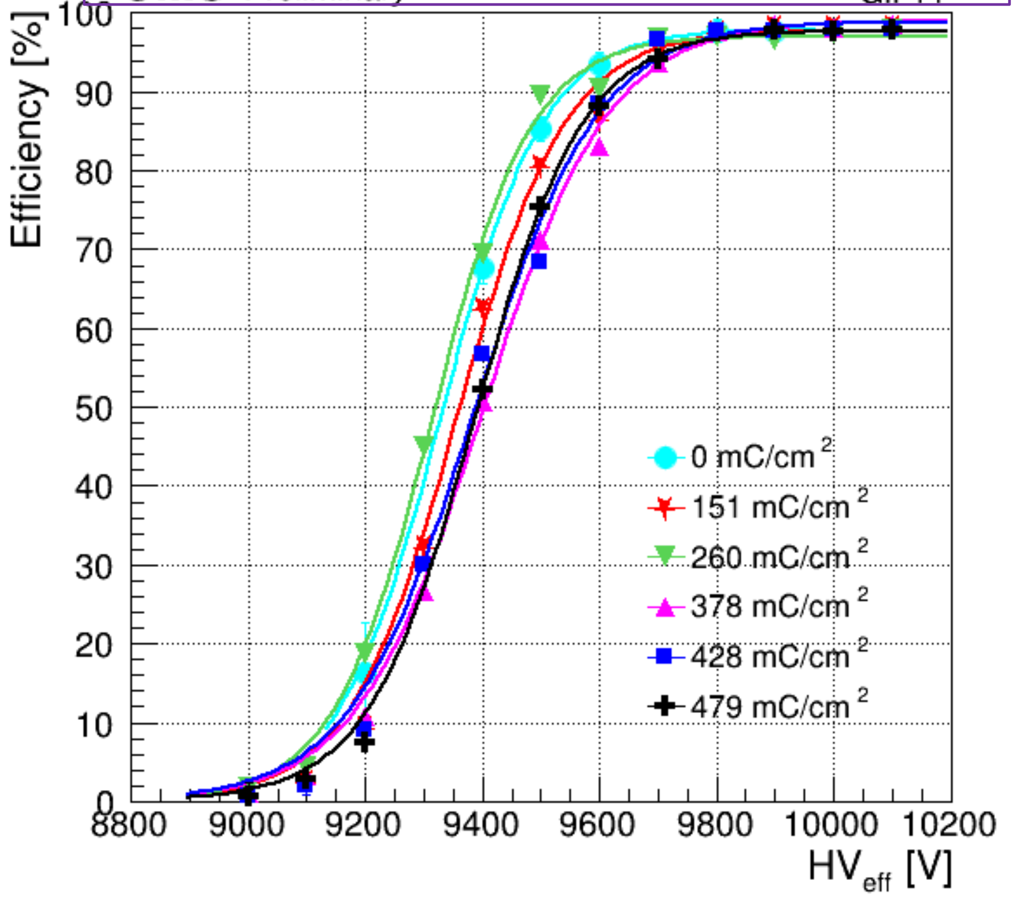
—— CMS RPC gas conditions (max ~ 40 Hz/cm^2): RH 40% & ~1 gas vol/h

—— New GIF++ gas conditions (600 Hz/cm^2): RH 60% & ~3 gas vol/h

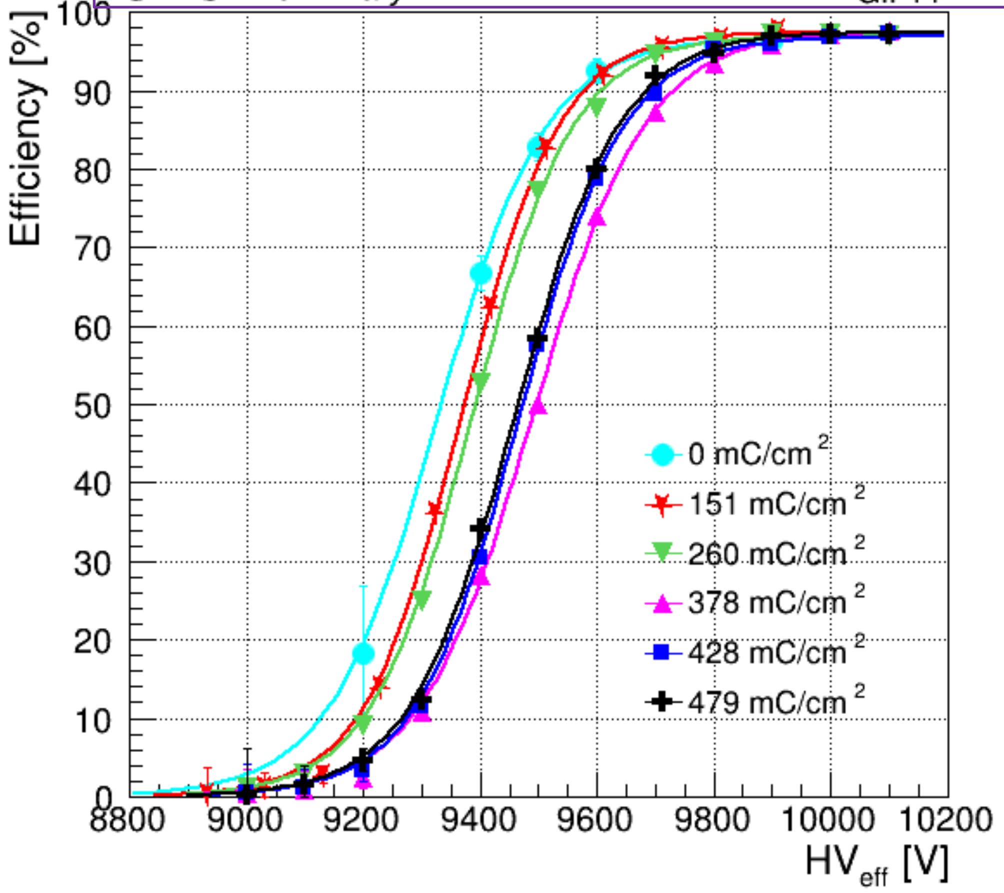
Detector Performance Monitoring

Efficiency

Without Background radiation & With muon beam



With Background radiation (600 Hz/cm^2) & with muon beam



- Efficiency vs. HV$_{eff}$ measured without background
- Stable WP & efficiency

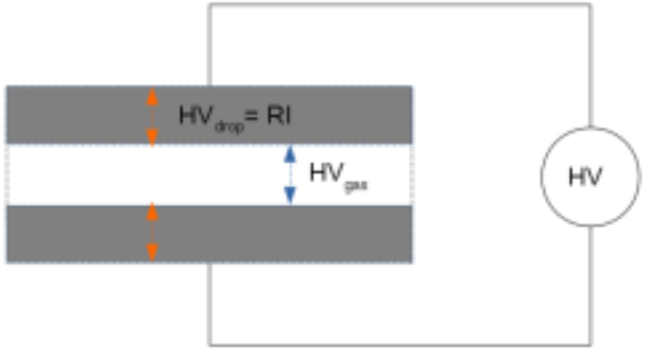
- Efficiency vs. HV$_{eff}$ measured with background (600 Hz/cm^2)
- WP shift of ~ 100 V after collecting > 300 mC/cm^2 of IC

HV correction

- The voltage applied to the electrodes (**HV**) is reduced by the voltage drop (**RI**), and the effective voltage applied to the gas (HV_{gas}) is defined as:

$$\mathbf{HV_{gas} = HV - RI}$$

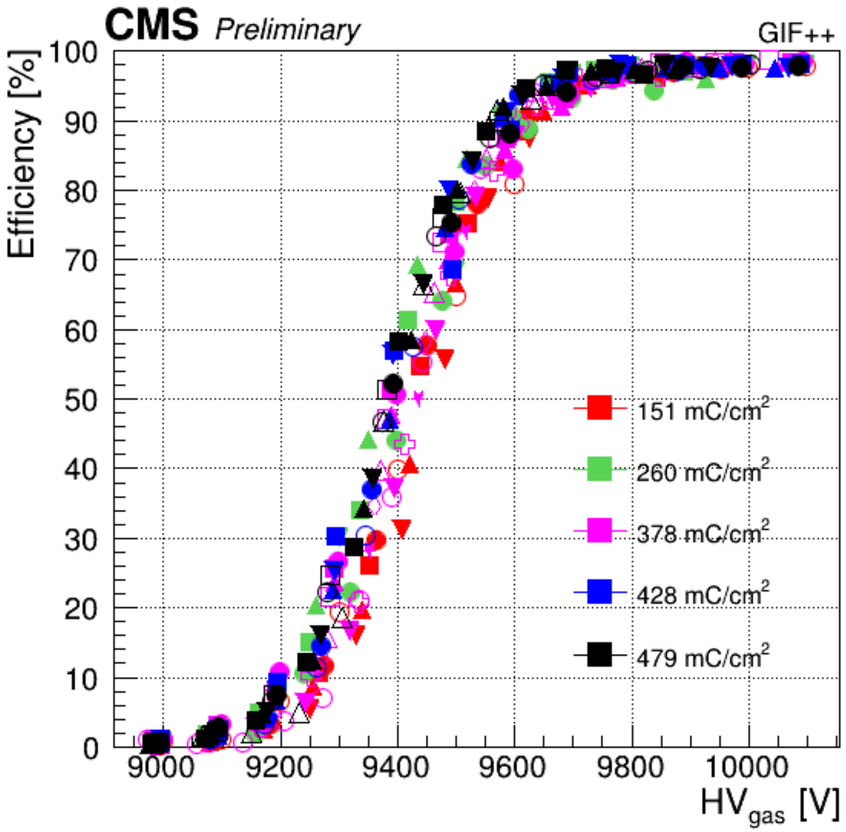
Where **R** is the electrodes resistance and **I** is the current produced by the ionizing particles



- The efficiency plotted as a function of HV_{gas} does not depends on the background conditions and on the electrodes resistance: the operation regime of the detector is invariant with respect to HV_{gas}

No Evidence of any aging effect has been observed

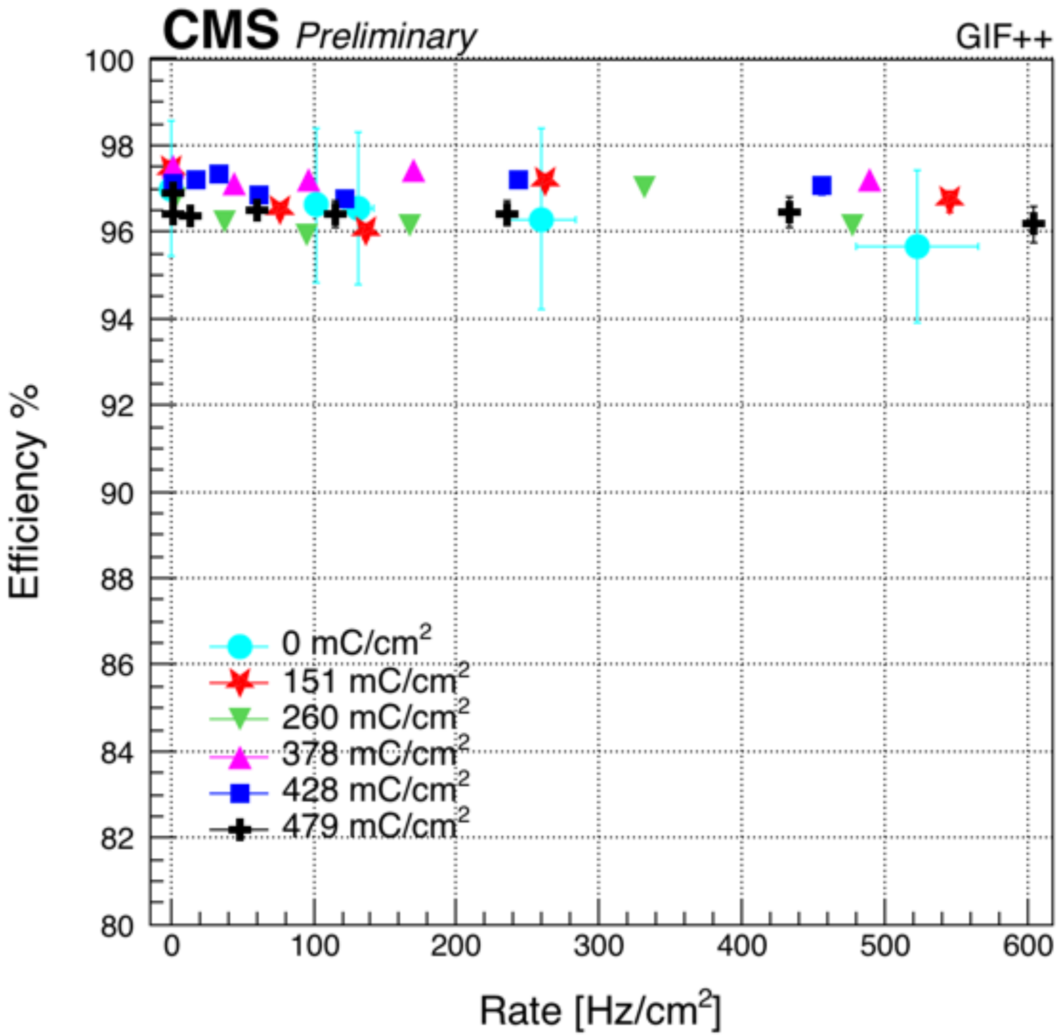
Efficiency @ different Test Beam

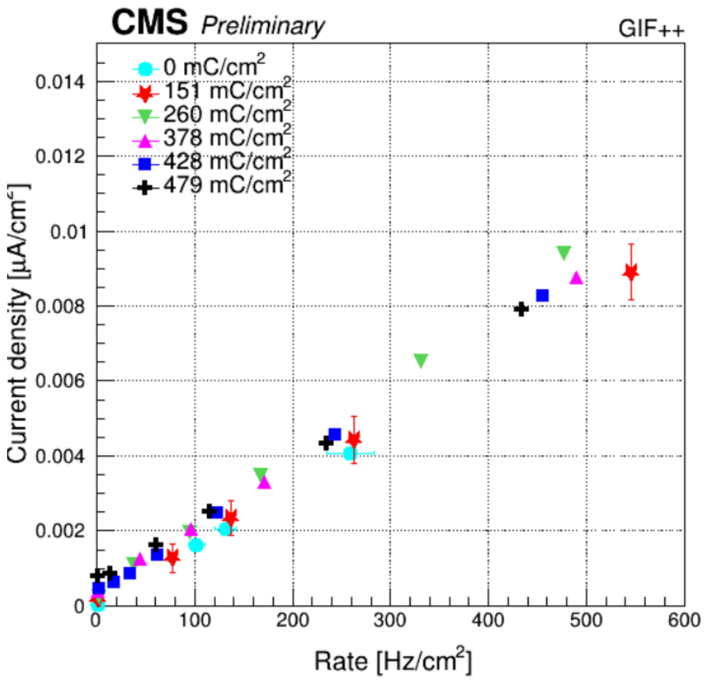


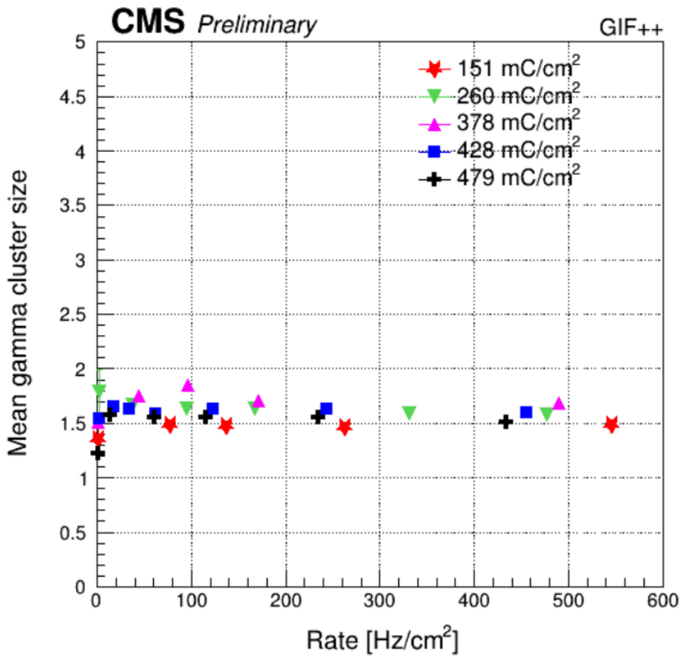
✓ Stable Efficiency at different Integrated charge & different background conditions

✓ No shift observed vs. time and up to background rate 600 HZ/cm^2

Performance @ WP







- Efficiency at WP remains stable in time up to the maximum expected rate (600 Hz/cm^2)

Conclusion

- RPC longevity studies: ongoing @ GIF++ since July 2016
  - 78% of the expected integrated charge at HL-LHC has been collected, additional ~ 1.5 year to complete the test.
  - Stable noise rate and dark current.
  - An increase of electrodes resistivity has been observed, due to the low humidity and gas flow rate with respect to the high background conditions. We recover and mitigate the effect with 60% of gas Humidity and 3 gas volume exchange per hour.
  - Stable performance from different test beams, Efficiency remains stable as a function of Integrated charge and background Rate ➡ New trigger system to measure detector performance with cosmic muons.

No Evidence of any aging effect has been observed

Thank you

Backup

HV correction

- The voltage applied to the electrodes (**HV**) is reduced by the voltage drop (**RI**), and the effective voltage applied to the gas (HV_{gas}) is defined as:

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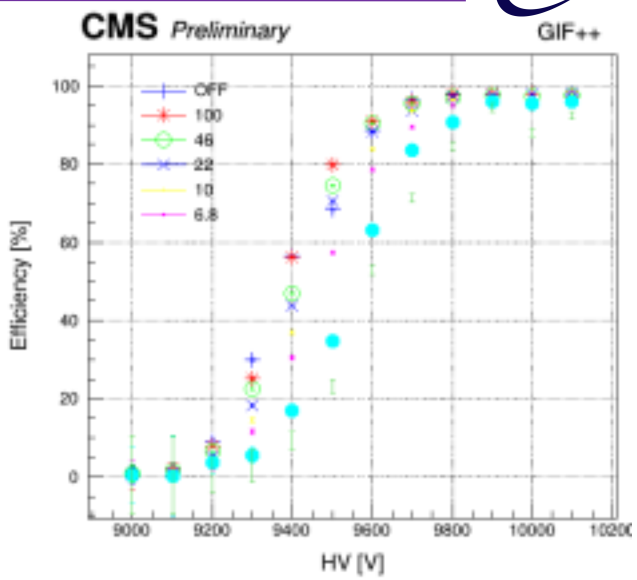
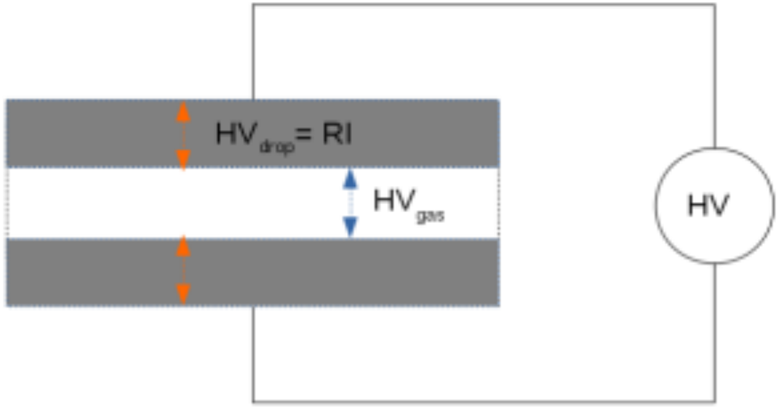
Where **R** is the electrodes resistance and **I** is the current produced by the ionizing particles.





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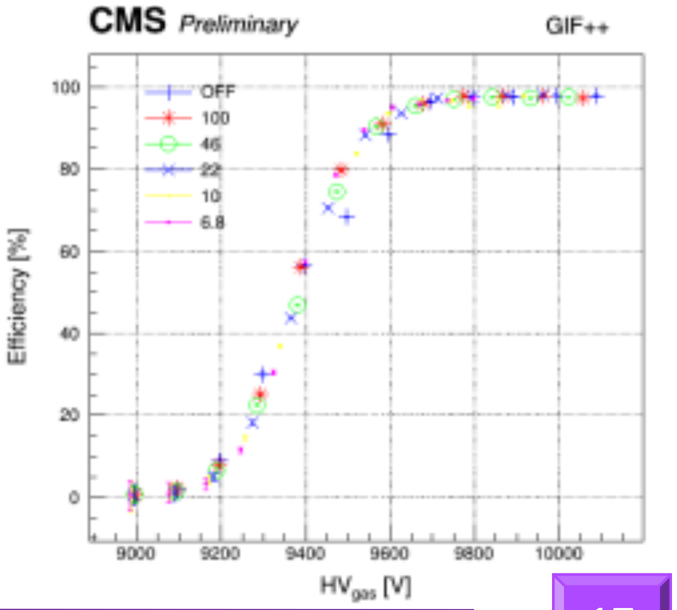

G. Pugliese, *"Aging study for resistive plate chambers of the CMS muon trigger detector"*
G. Aielli, *"Further advances in aging studies for RPCs"*