
# Latest results of Longevity studies on the present CMS RPC system for HL-LHC phase

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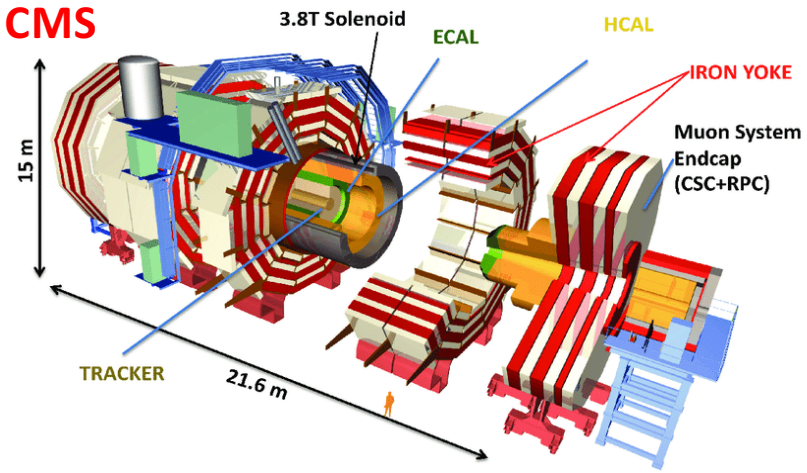
**On behalf of the CMS Muon Group**

**RPC2022: XV Workshop on Resistive Plate Chambers and related detectors, 26-30 Sep 2022, CERN**

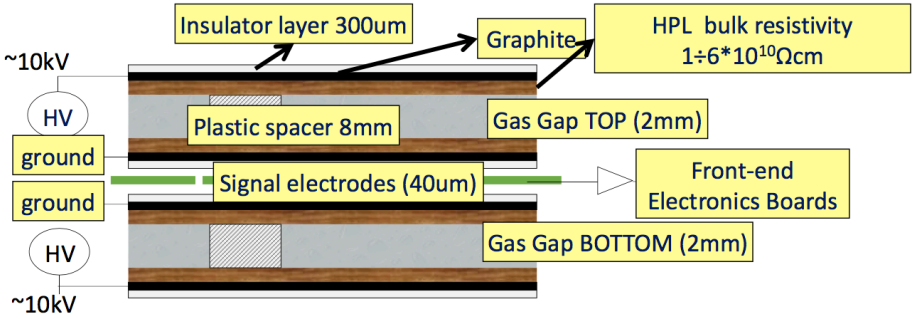
# The CMS-RPC System @ HL-LHC

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*




- ***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 present RPC system at **HL-LHC** (5 x$10^{34}$ $cm^{-2}s^{-1}$) .

***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.**

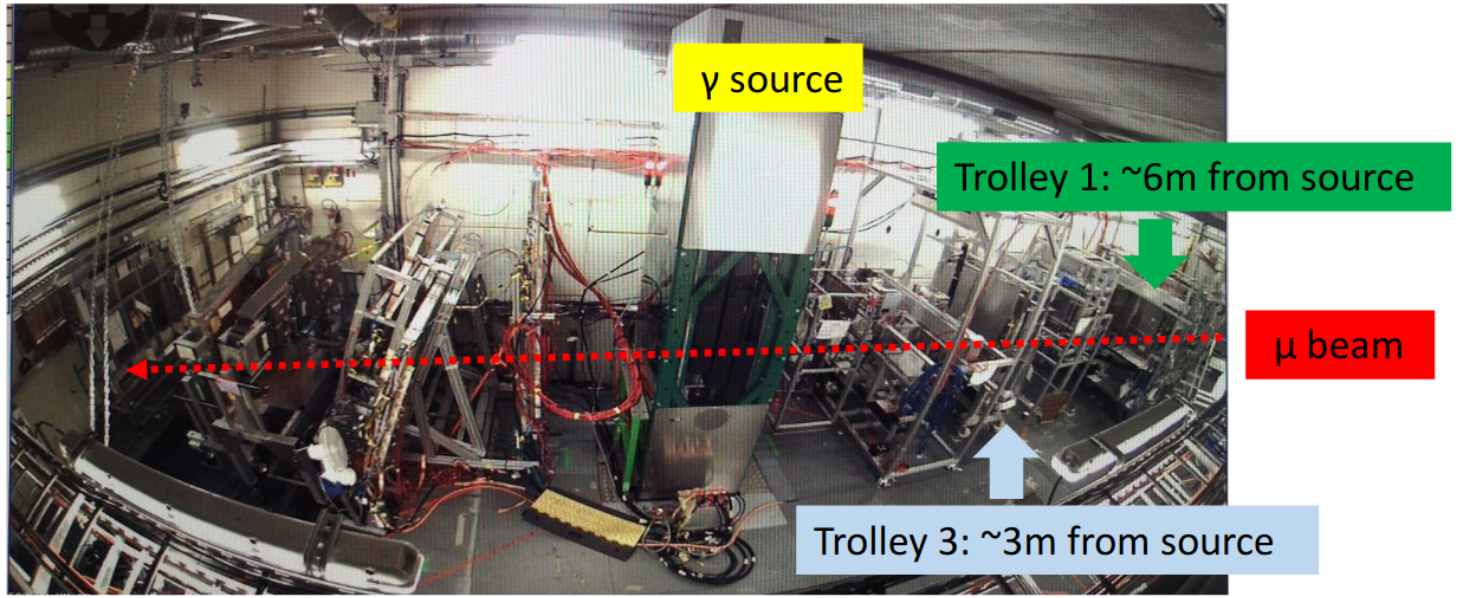
- 14 TBq $^{137}$Cs source (662 keV gammas)
- Muon Beam (3-4 times per year)
  Energy up to 150 GeV
- Unified control and monitor of the environmental parameters:
  - Temperature
  - Humidity
  - Pressure
- Gas parameters monitoring:
  - gas composition
  - gas flow
  - gas temperature
  - gas humidity
  - gas pressure
- Gamma Filters:
  System of movable attenuators allow to test the detector in different irradiation conditions.

# Longevity Setup & Procedure

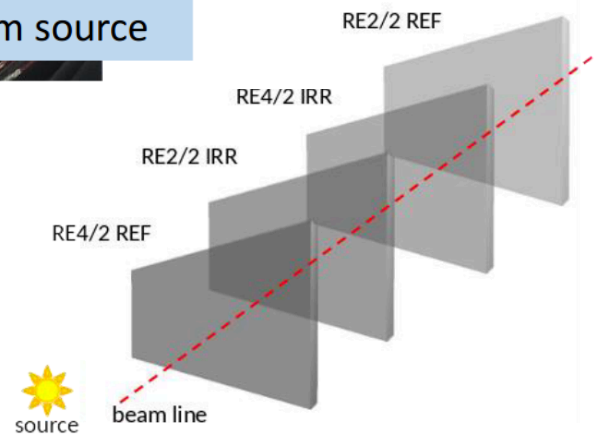
**Setup @ GIF++ since July 2016:**

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

- Two chambers are continuously irradiated & two used as reference.

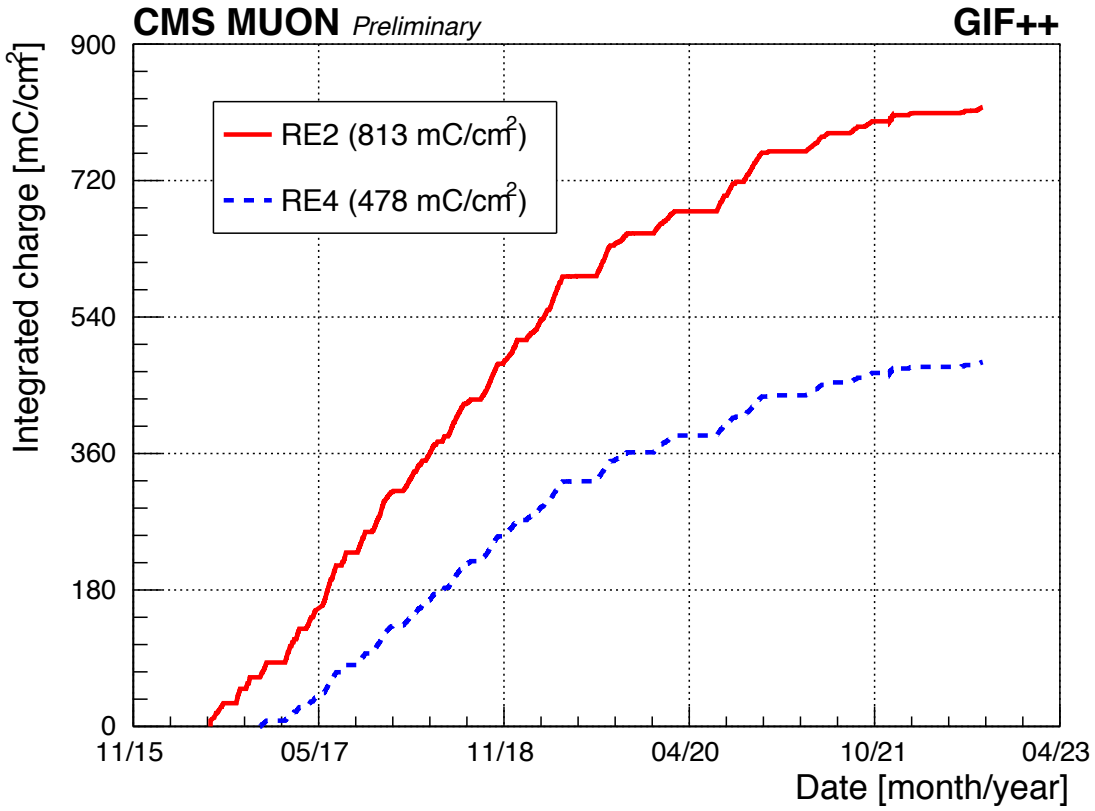



- The max. background rate expected in endcap region
- Two different types of chambers from old and new production (RE4 produced in 2012- 2014)




- 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

# Longevity Status




✓ Expected Integrated charge @HL-LHC
840 mC /cm²

✓ Average Integrated charge:

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

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

**RE2**

- IRR. In 3 July 2016
- $Q_{int}$ : 813 mC /cm²

**97 %**

**RE4**

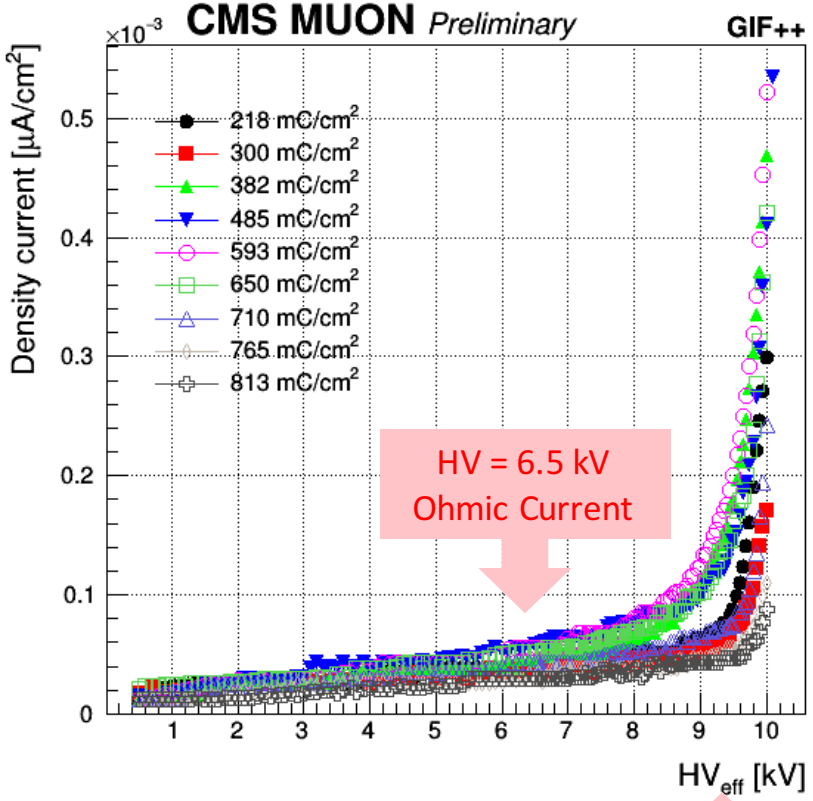
- IRR. In 25 Nov. 2016
- $Q_{int}$ : 478 mC /cm²

**57 %**

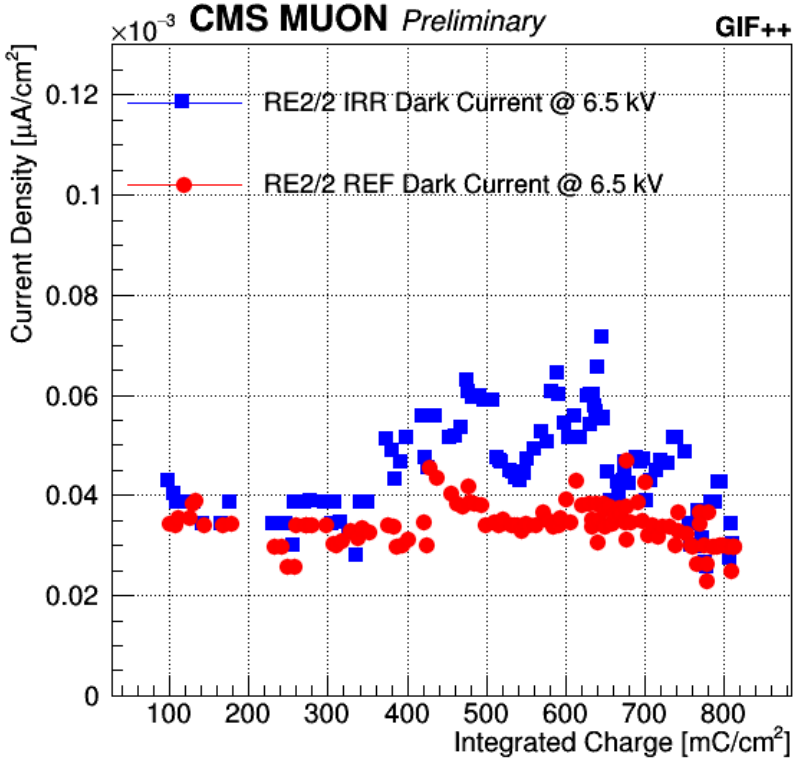
# Detector Parameters Monitoring

# Dark Current

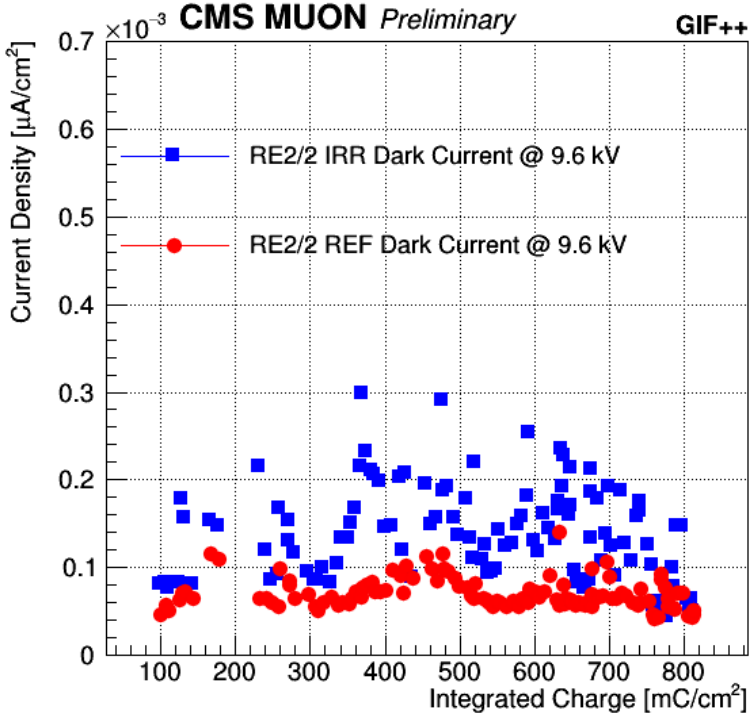
RE2/2 Irradiated dark current




RE2/2 IRR. & REF **ohmic** current



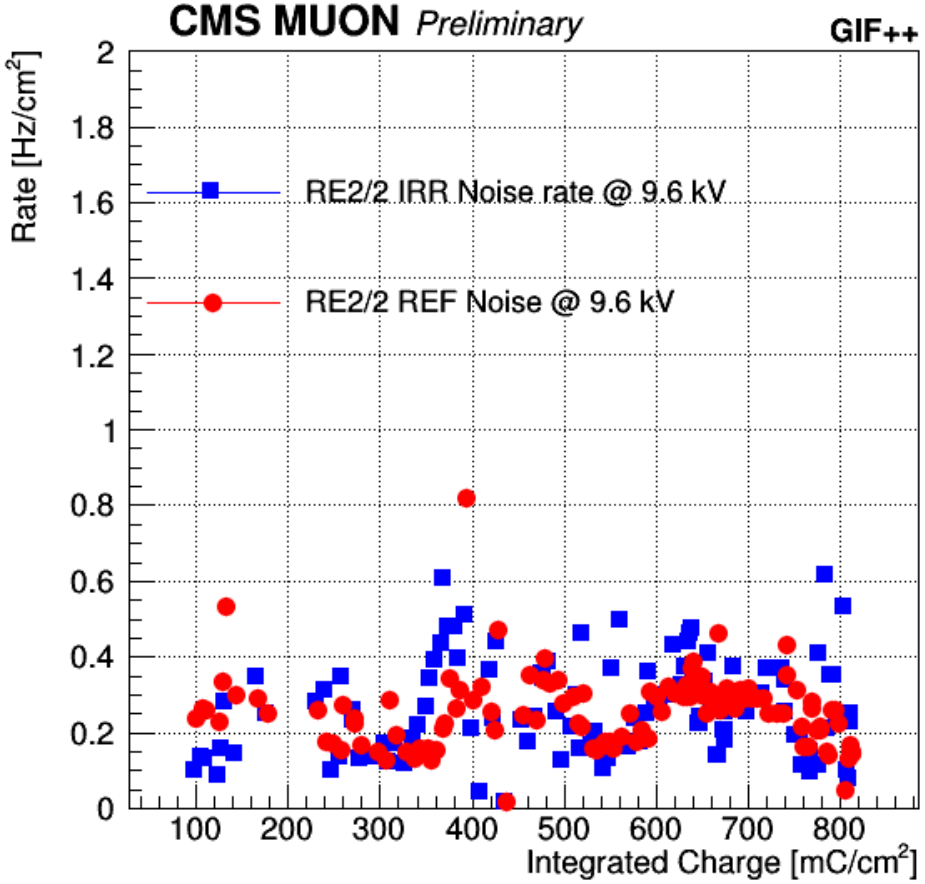

RE2/2 IRR. & REF **total** current




- **Ohmic and total** current almost stable with time and after collecting 813 mC/cm² of IC & in agreement with values before the irradiation for irradiated (IRR). & reference (REF). chambers.

# Noise Rate

RE2/2 IRR. & REF Noise rate




- Noise rate is 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

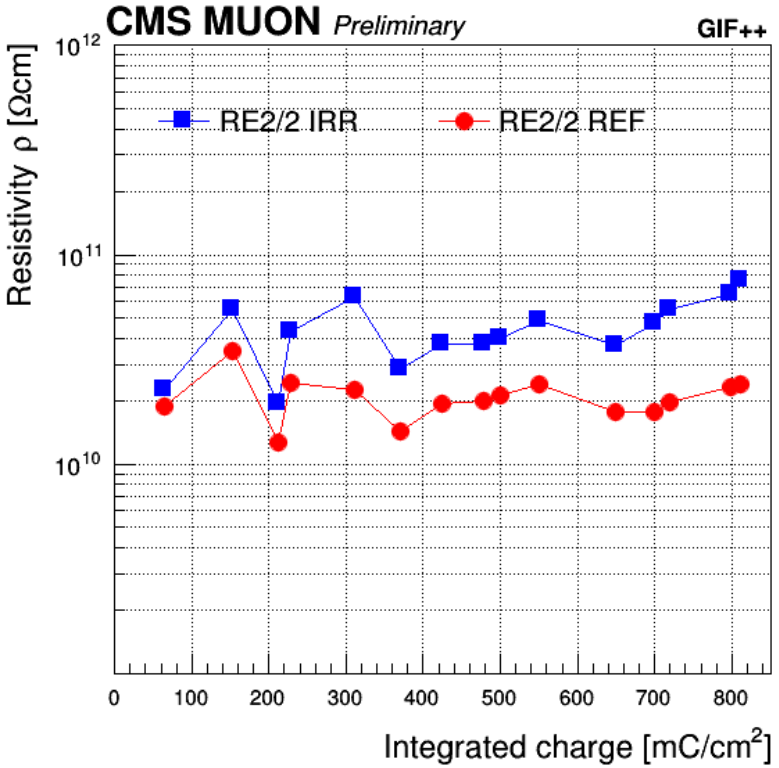
$$\rho = \frac{R \times S}{L}$$

- 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

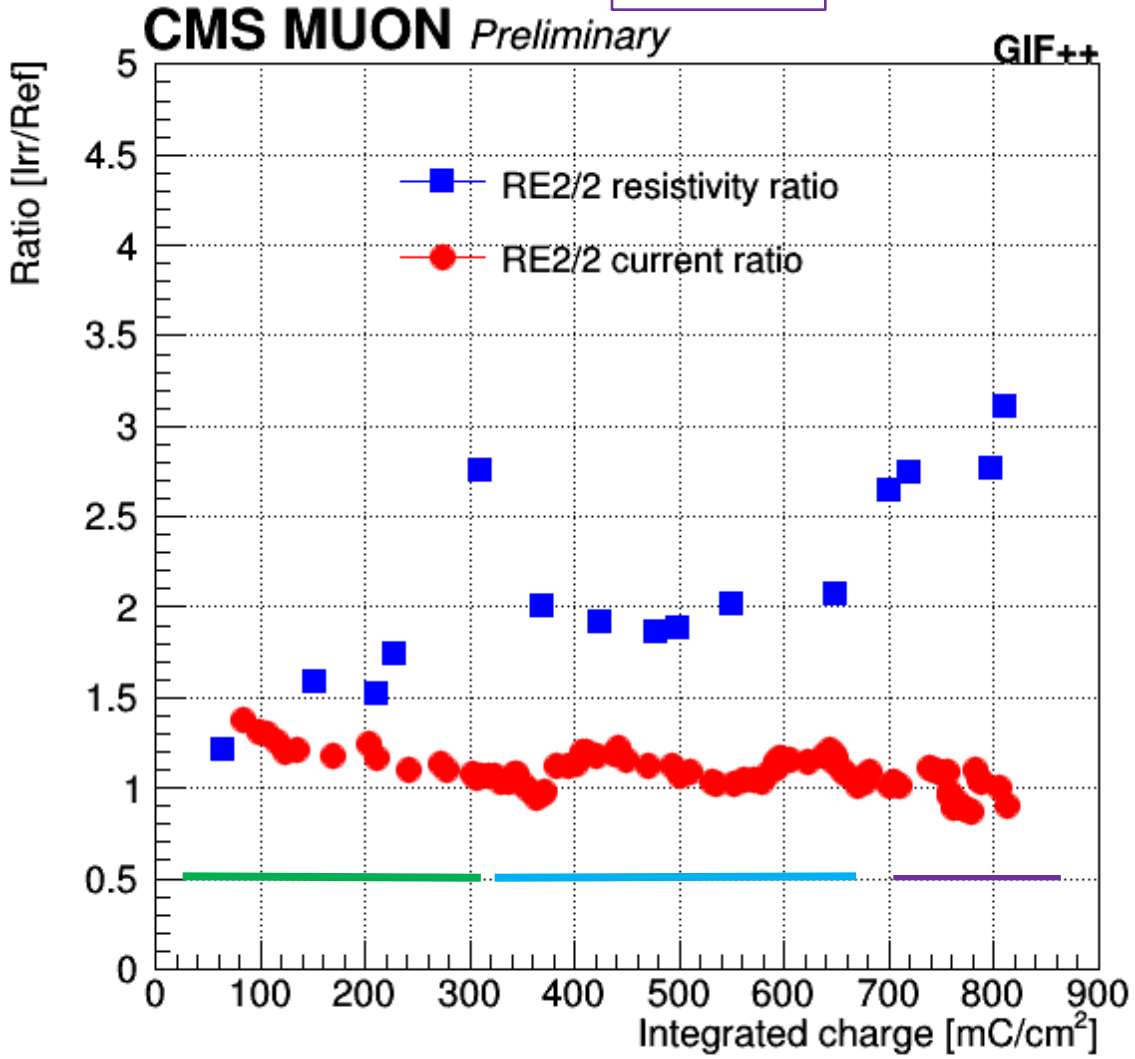
$$\rho_{20} = \rho \times e^{\alpha(T-20)}$$

- where $\alpha$= represents the temperature-dependent coefficient, $\rho$ and $\rho_{20}$ 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
- **Running with gas humidity 40 %** and gas flow 3 V/h

—— **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**

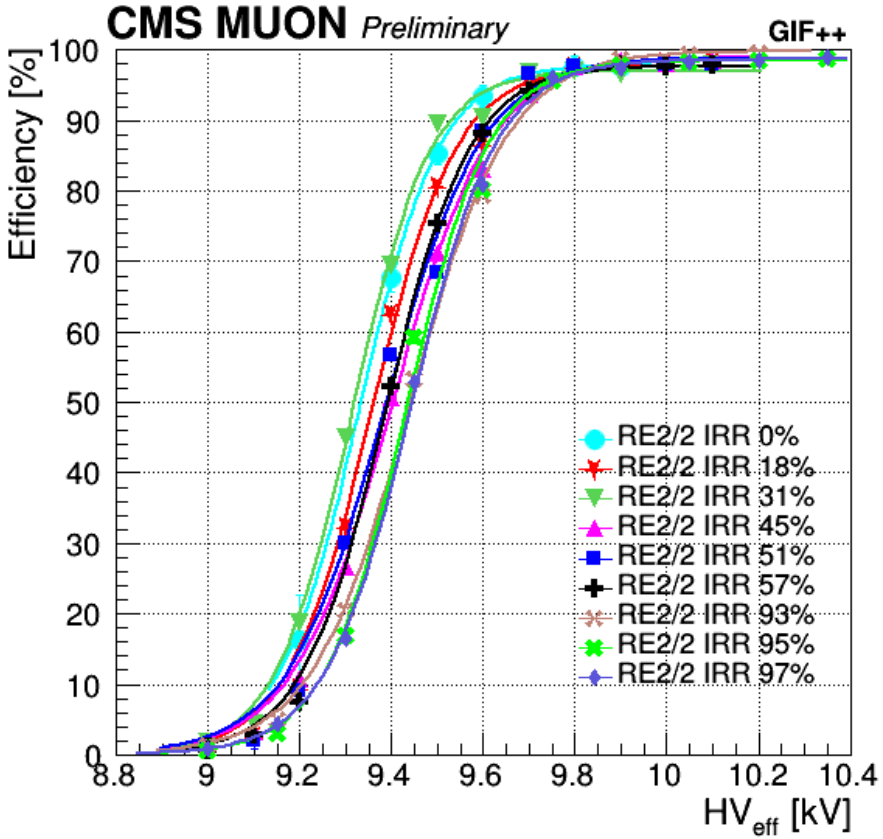
—— **RH 40% & ~3 gas vol/h**

# Detector Performance Monitoring

# Detector Performance Monitoring I

## Efficiency

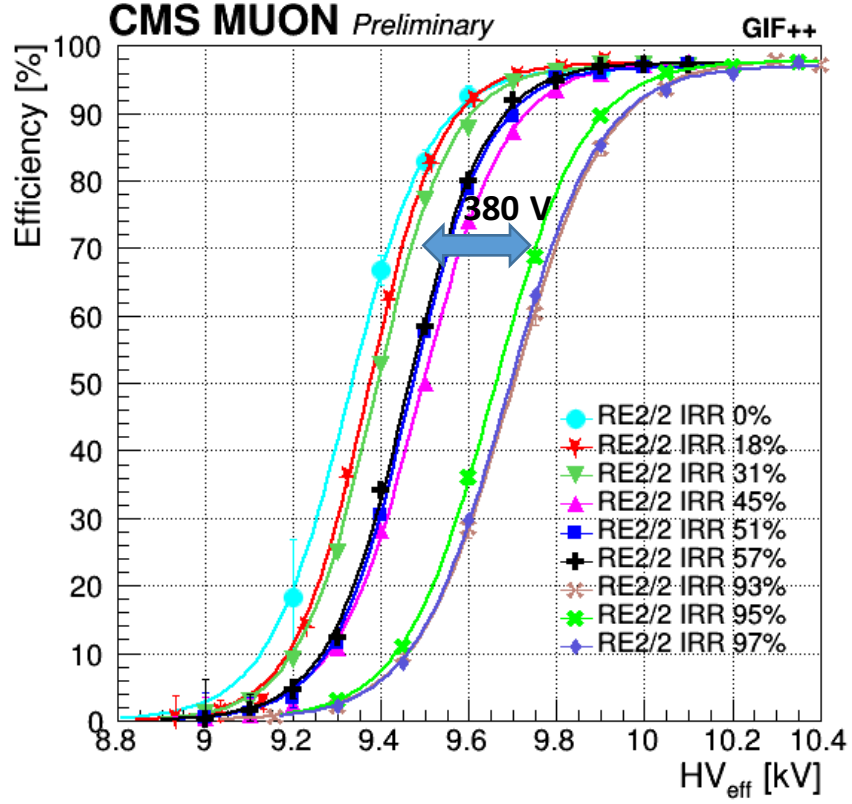
**Without Background radiation & With muon beam**




$$\epsilon(HV_{eff}) = \frac{\epsilon_{max}}{1 + e^{-\lambda(HV_{eff} - HV_{50})}}$$

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

**With Background radiation (600 Hz/cm²) & with muon beam**



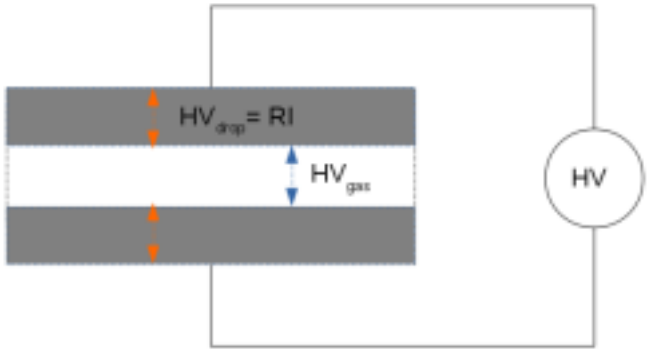

- Efficiency vs. $HV_{eff}$ measured with background (600 Hz/cm²)
- WP shift of ~ 380 V after collecting > 780 mC/cm² of IC

# HV Correction

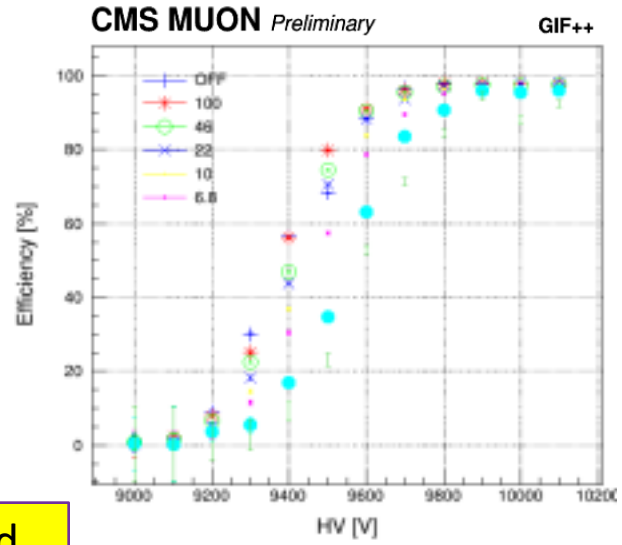
- The voltage applied to the electrodes (**HV**) is reduced by the voltage drop (**RI**), and the effective voltage applied to the gas ($HV_{gas}$) is defined as:

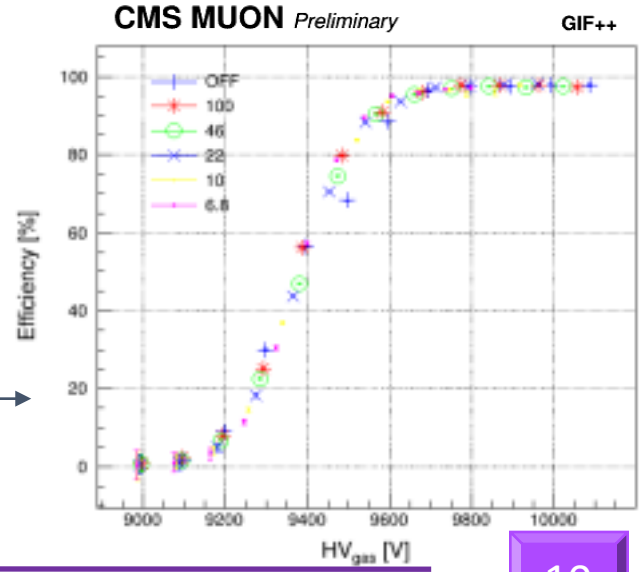
$$HV_{gas} = HV - RI$$

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




Rescale Method

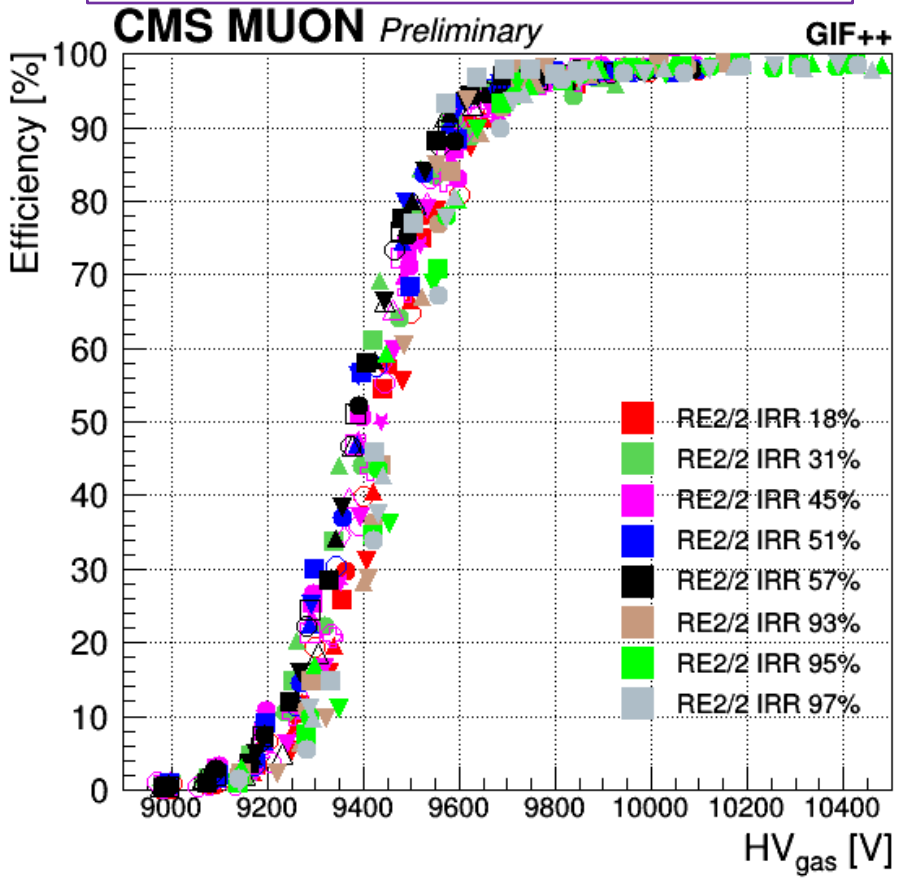


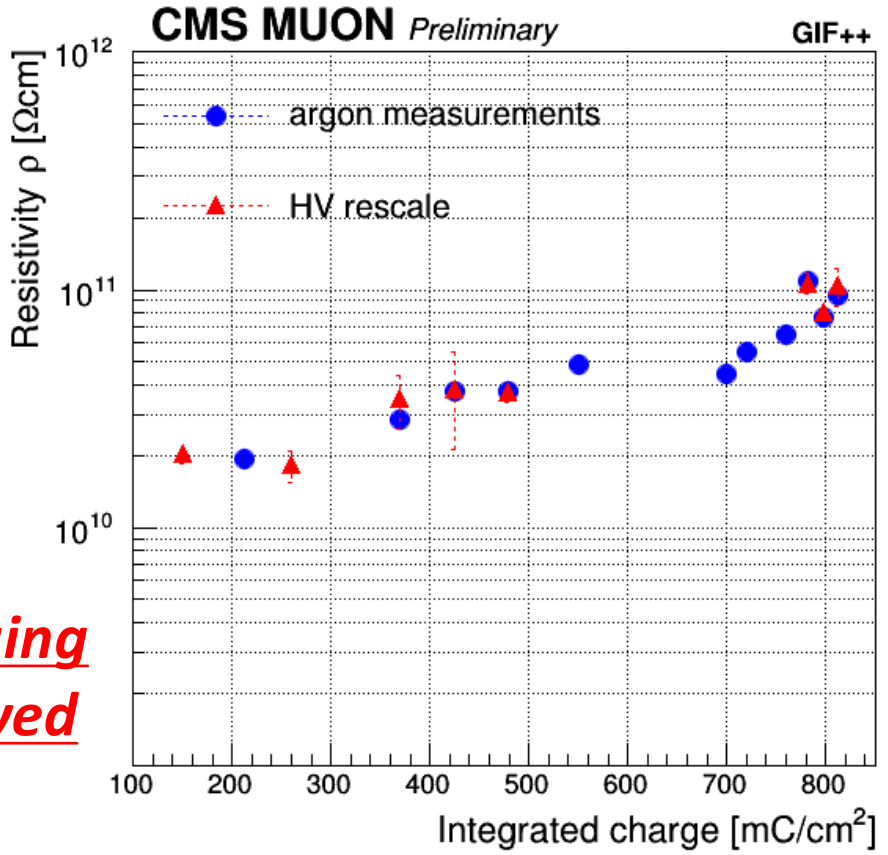

- The efficiency plotted as a function of $HV_{gas}$ does not depends on the background conditions and on the electrodes resistance: the operation regime of the detector is invariant with respect to $HV_{gas}$

# Detector Performance Monitoring II

Efficiency @ different Test Beam




***No Evidence of any aging effect has been observed***

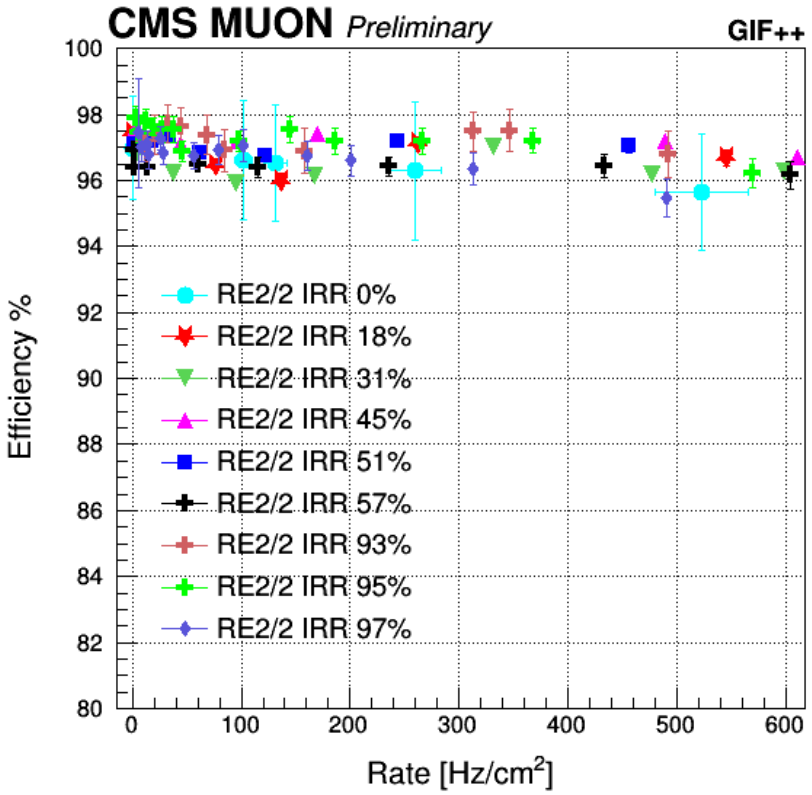



- ✓ Stable Efficiency at different Integrated charge & different background conditions
- ✓ No shift observed vs. time and up to background rate 600 HZ/cm$^2$

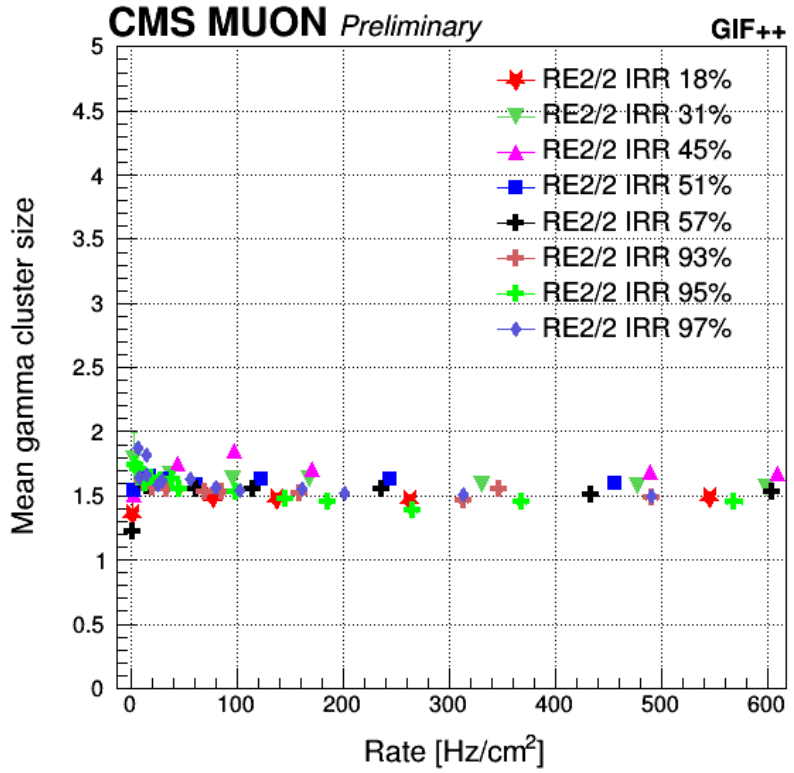
- ✓ Rescale method confirmed by the resistivity measurements

# Performance @ WP

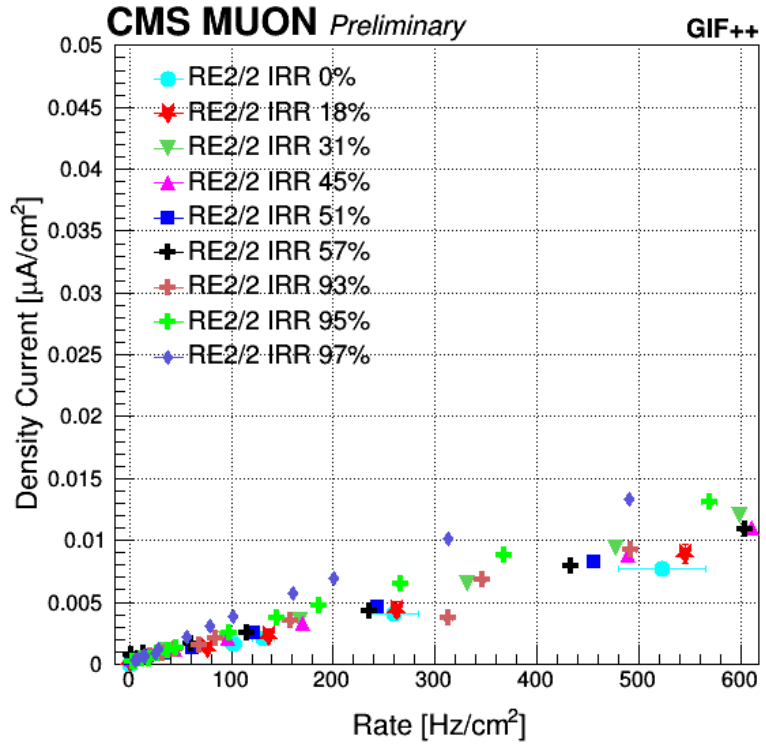
Efficiency vs. Rate @ different Test Beam




Gamma cluster size vs. Rate @ different Test Beam




Current Density vs. Rate @ different Test Beam




- Efficiency at WP remains stable in time up to the maximum expected rate (600 Hz/cm$^2$)
- Stable average charge & Gamma cluster size

# Conclusion

- RPC longevity studies: ongoing @ GIF++ since July 2016
  - 97% of the expected integrated charge at HL-LHC has been collected, expect to finish the test by the end of the year.
  - 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.

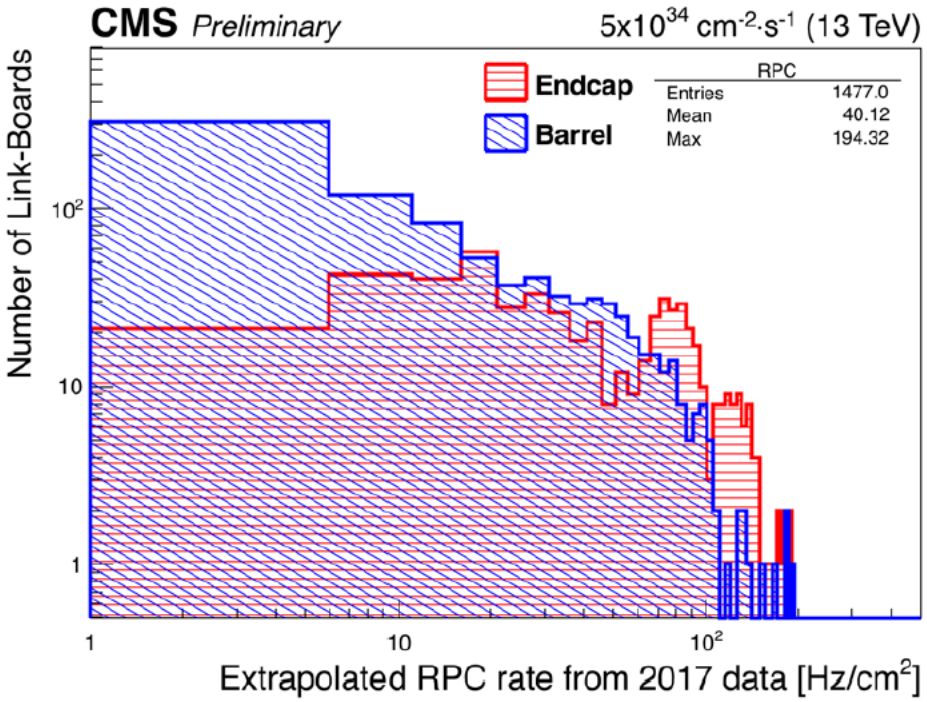
***No Evidence of any aging effect has been observed***


Thank
you

# Backup

# The expected Conditions at HL- LHC

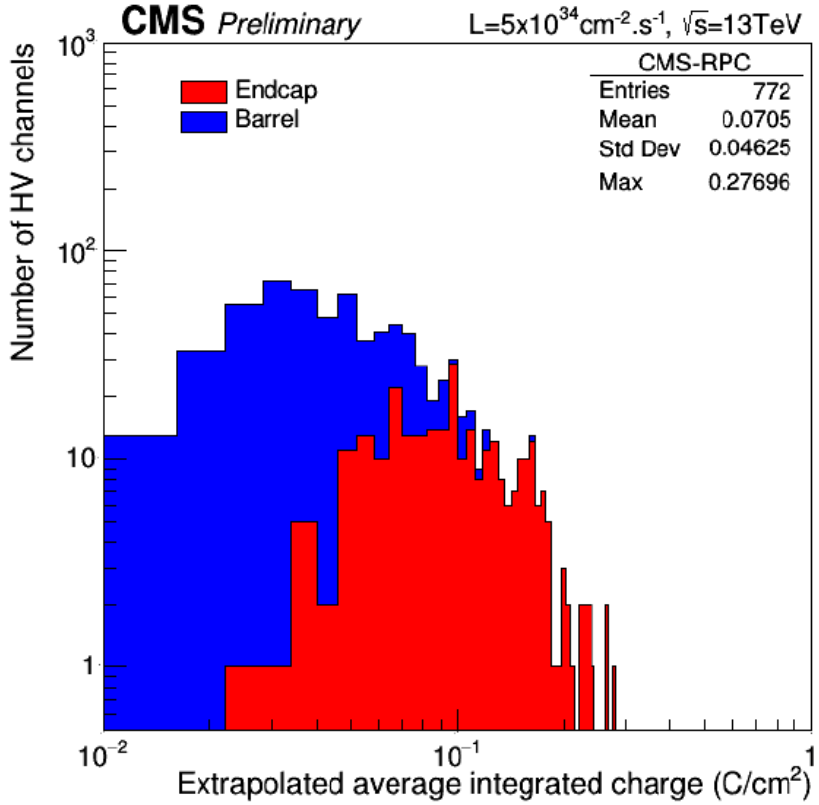
- LHC collision data in 2017 has been used to estimate the expected background rates & integrated charge at HL-LHC ($5 \times 10^{34}$ $cm^{-2}s^{-1}$).




***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)