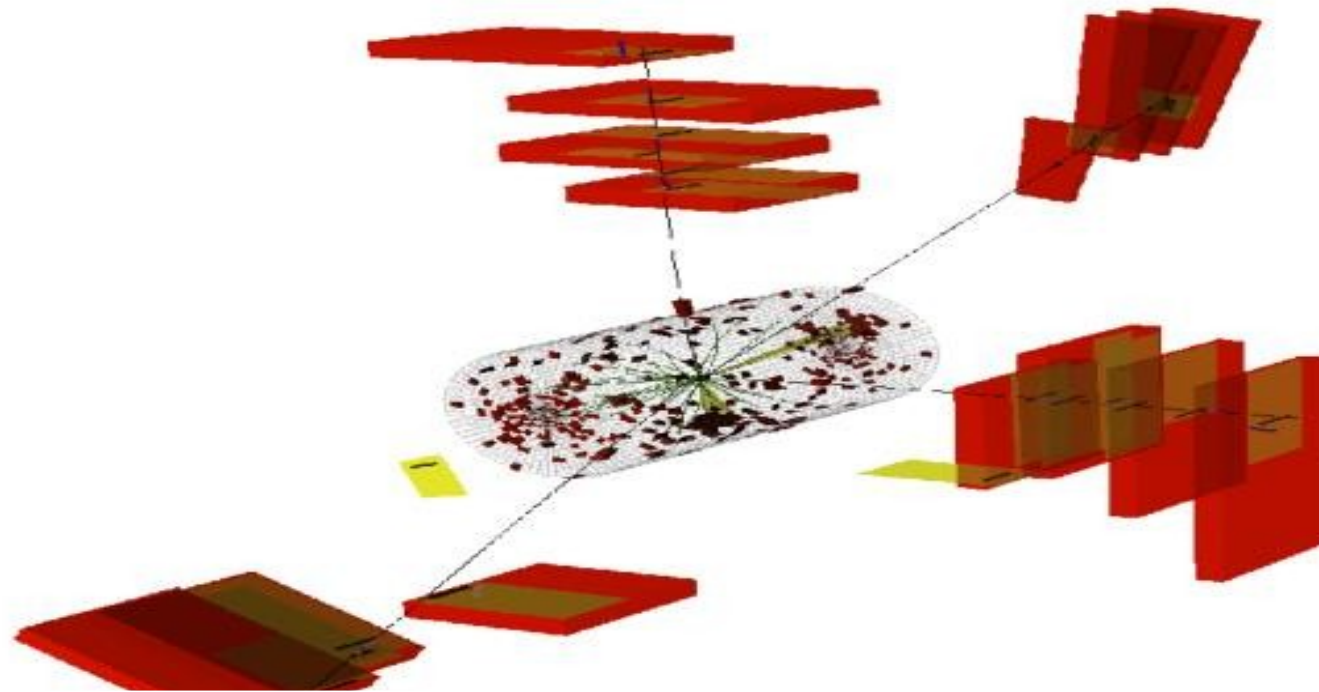




Long-term aging studies on Resistive Plate Chambers (RPC) of the CMS muon system for HL-LHC

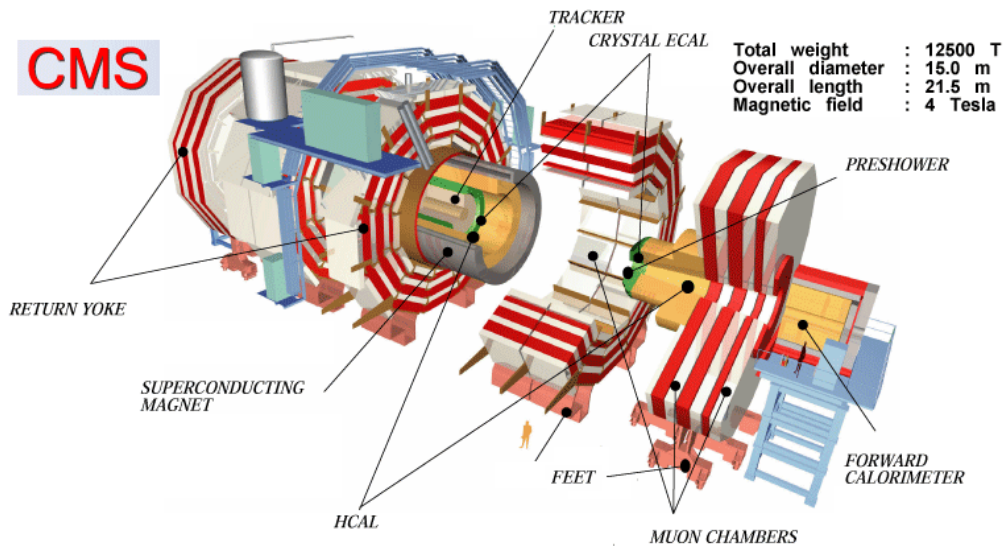


Priyanka (Panjab University, Chandigarh)
On behalf of the CMS Collaboration

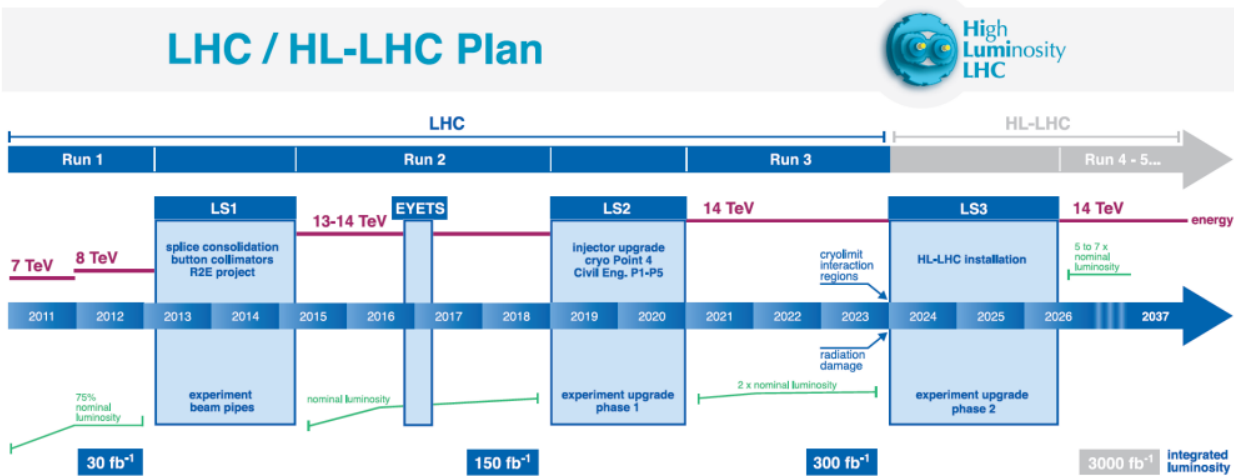
**DAE-HEP 2018: XXIII DAE-BRNS High Energy Physics Symposium,
10-14 Dec 2018, Chennai (India).**



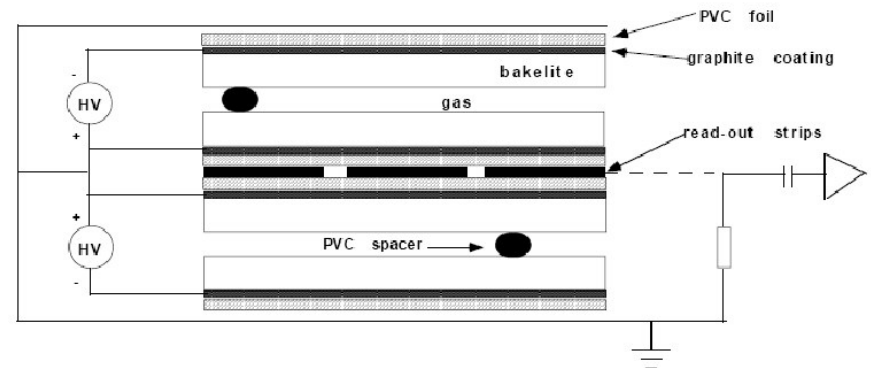
The CMS-RPC system @ LHC



- RPC system covers $0 < |\eta| < 1.9$
- 1056 chambers:
480 in *Barrel* & 576 in *Endcap*
- Working in avalanche mode
- Double gas-gaps RPC
- 2 mm gas gap and electrodes thickness
- HPL bulk resistivity: $= 1 - 6 \cdot 10^{10} \Omega\text{cm}$
- RPC information used in the muon trigger, reconstruction and identification
- **High and stable RPC performance during LHC operation**



- 150 fb⁻¹: by 2018 Run 2
- 300 fb⁻¹: by 2023 Run 3
- 3000 fb⁻¹: by 2037 High-lumi LHC (HL-LHC)

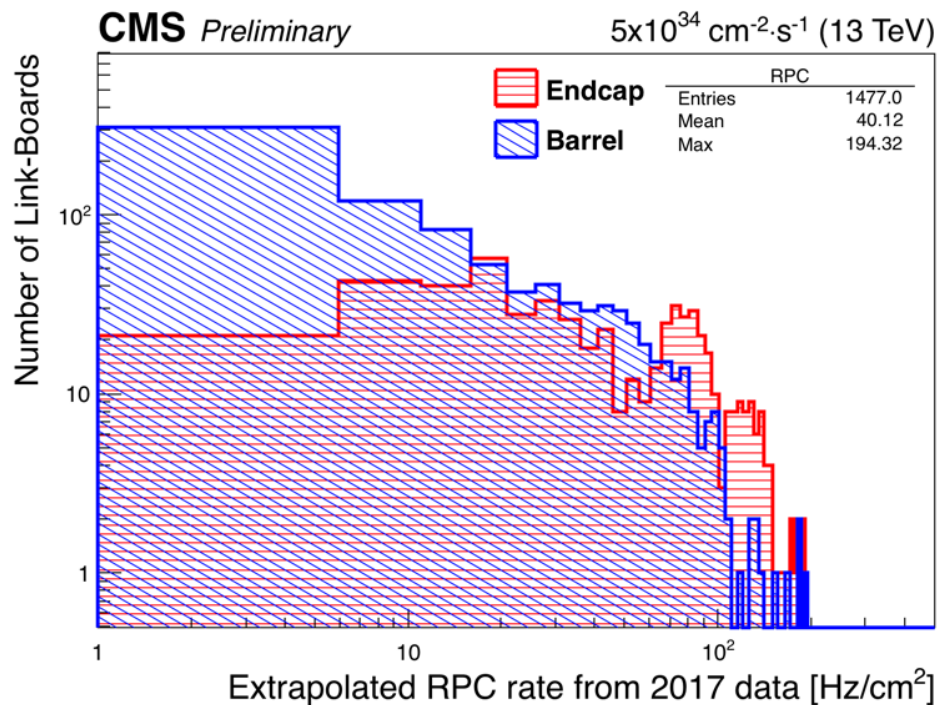


- RPC certification for **10 years of LHC** ($10^{34} \text{ cm}^{-2}\text{s}^{-1}$).
- **HL-LHC** ($5 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$) **LONGEVITY STUDIES**



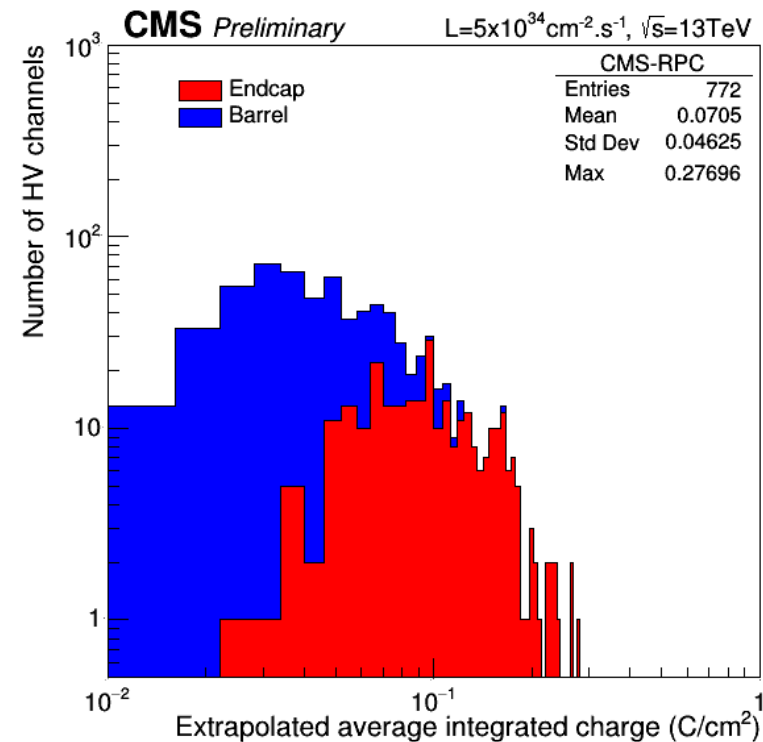
Expected Conditions in the RPC system at HL-LHC

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



Expected Rate :

- ❖ Max. Rate :
 $\sim 600 \text{ Hz}/\text{cm}^2$ (including safety factor of 3)



Expected Integrated Charge :

- ❖ Max. integrated charge :
 $\sim 840 \text{ mC}/\text{cm}^2$ (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.

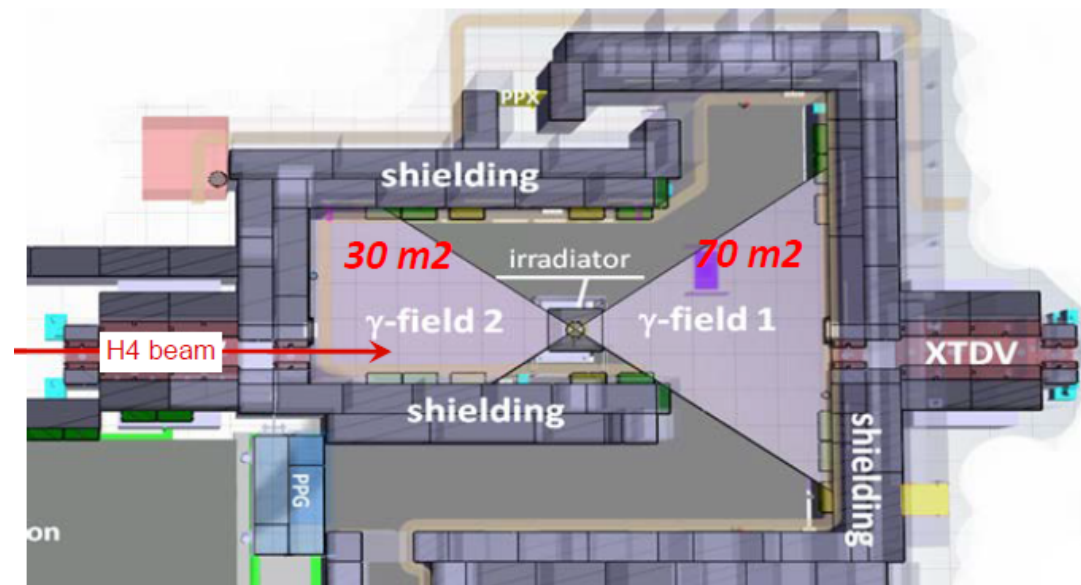
- ❖ 14 TBq ^{137}Cs source (662 keV gammas)

- ❖ Gamma filters: Systems of movable attenuators allows to test the detectors in different irradiation conditions

- ❖ Muon beam
 - ↳ Energy up to 100 GeV, 10^4 muons/spill.
 - ↳ 3-4 times per year

- ❖ Unified control and monitor of the environmental parameters:
 - ↳ Temperature,
 - ↳ Humidity,
 - ↳ Pressure.

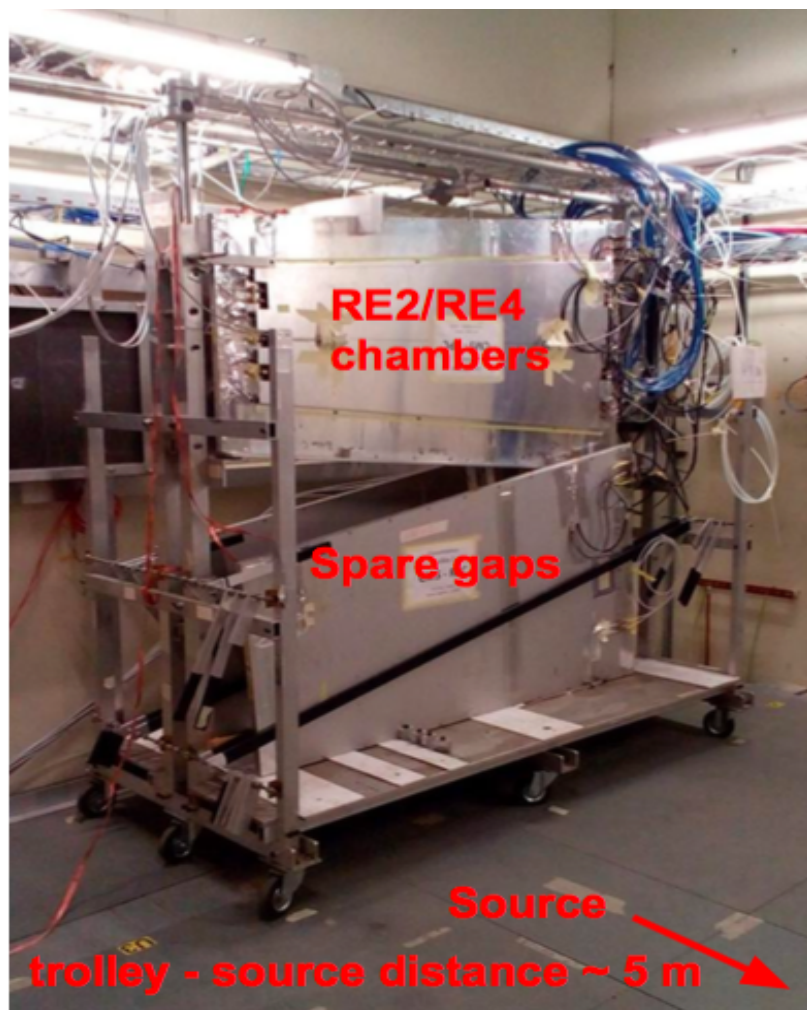
- ❖ Gas parameters monitoring:
 - ↳ gas composition,
 - ↳ gas flow,
 - ↳ gas Temperature,
 - ↳ gas Humidity,
 - ↳ gas Pressure.



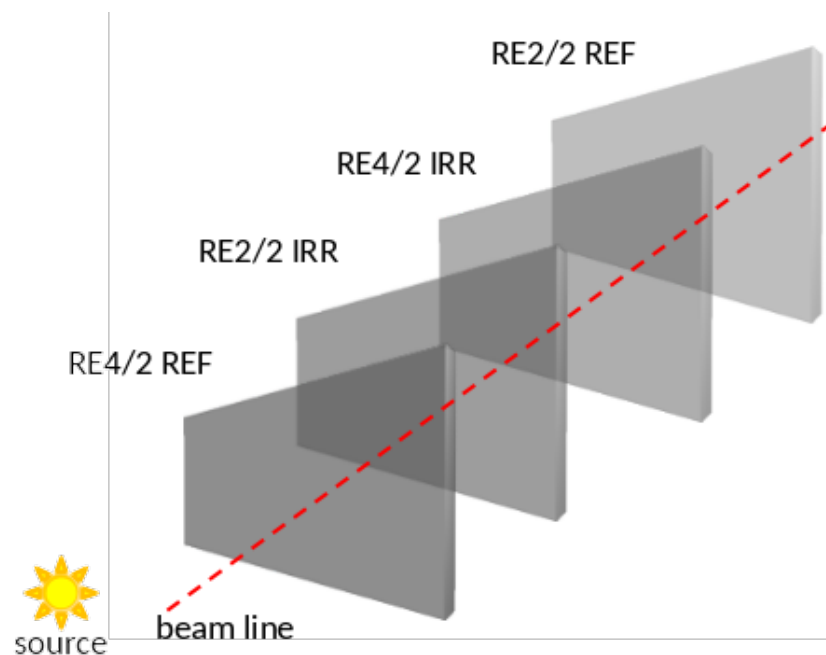
Longevity Setup & Procedure

❖ Setup @ GIF++:

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



- Two different types of chambers from old and new production (RE4 production done in (2012-2014))
- Two chambers continuously irradiated, two used as reference.



❖ Daily measurements:
Current & rate with background.

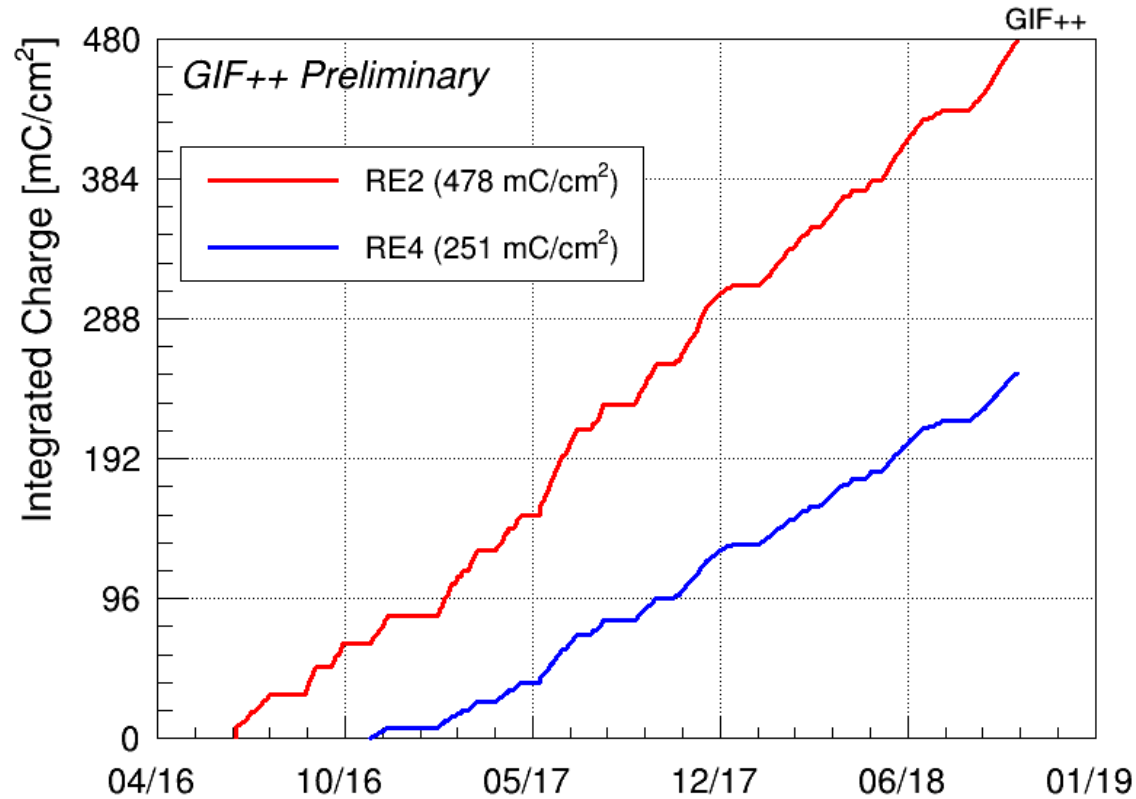
❖ Weekly measurements:
Current and rate at different background conditions and without background.

❖ 3-4 time per year:
Argon resistivity measurements.

❖ 3-4 times per year Test beam:
Performance measured with muon beam at several background conditions.



Longevity Test Status



❖ **Expected Integrated Charge @ HL-LHC**
840 mC/cm²

❖ **Uniform Irradiation**
→ **Average Integrated Charge :**

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

$$I = \frac{i_{Bot} + i_{TN} + i_{TW}}{S_{Bot} + S_{TN} + S_{TW}}$$

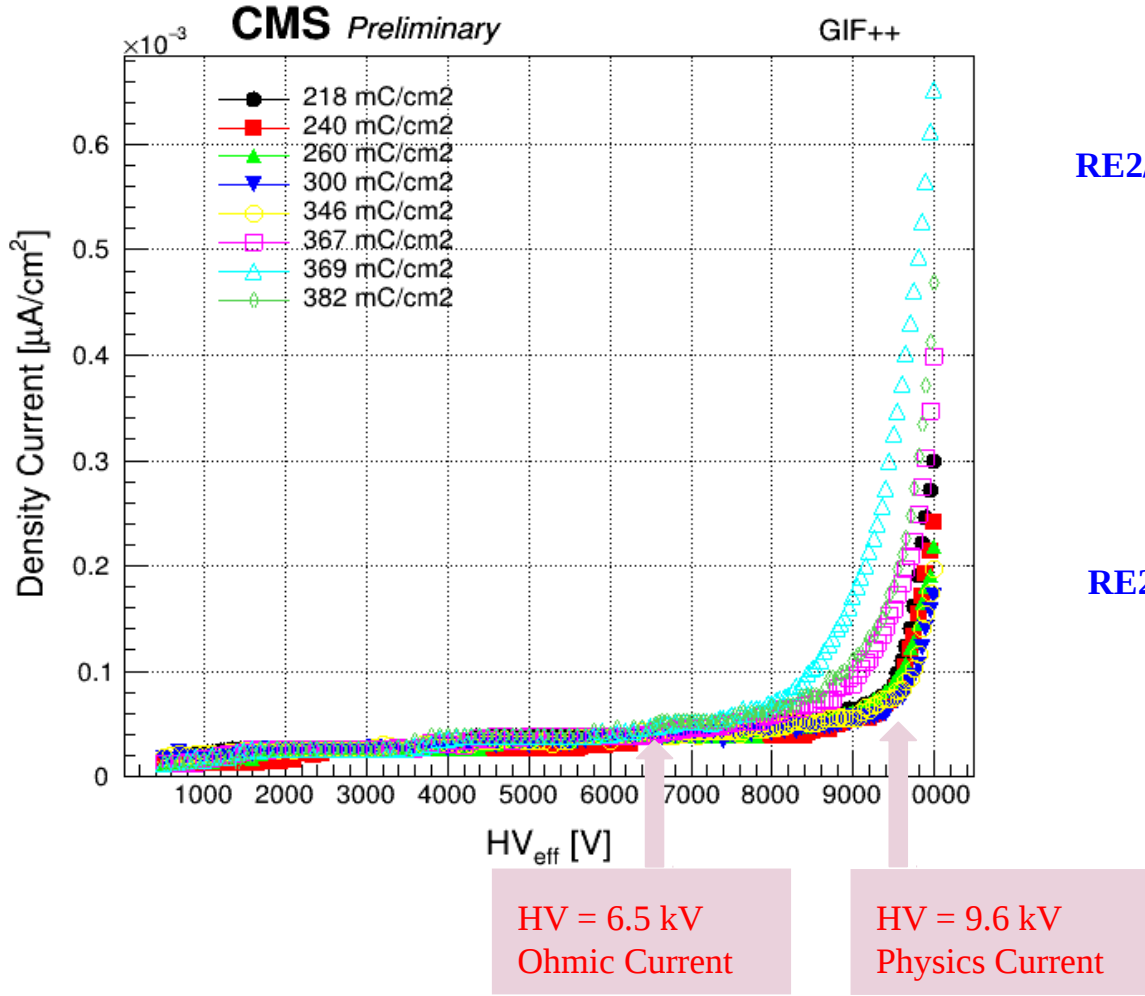
RE2 IRR :
→ July 3, 2016
→ $Q_{Int} = 478 \text{ mC/cm}^2$
57%

RE4 IRR :
→ Nov 25, 2016
→ $Q_{Int} = 251 \text{ mC/cm}^2$
30%



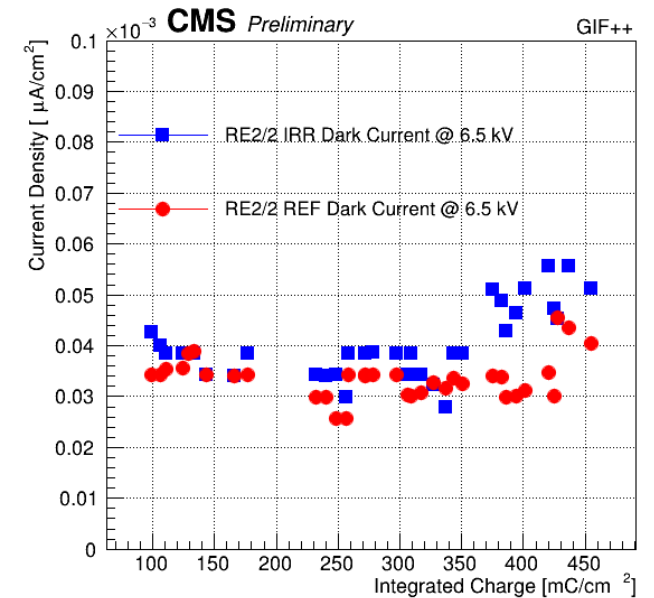
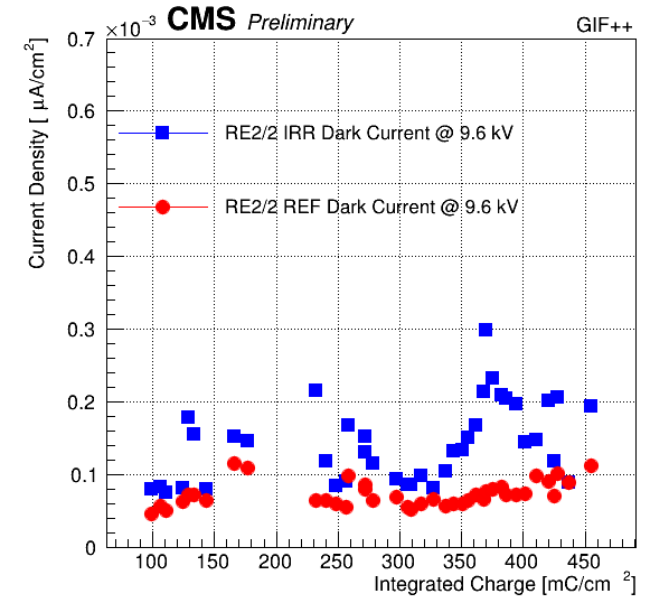
Dark current

RE2/2 IRRADIATED dark current

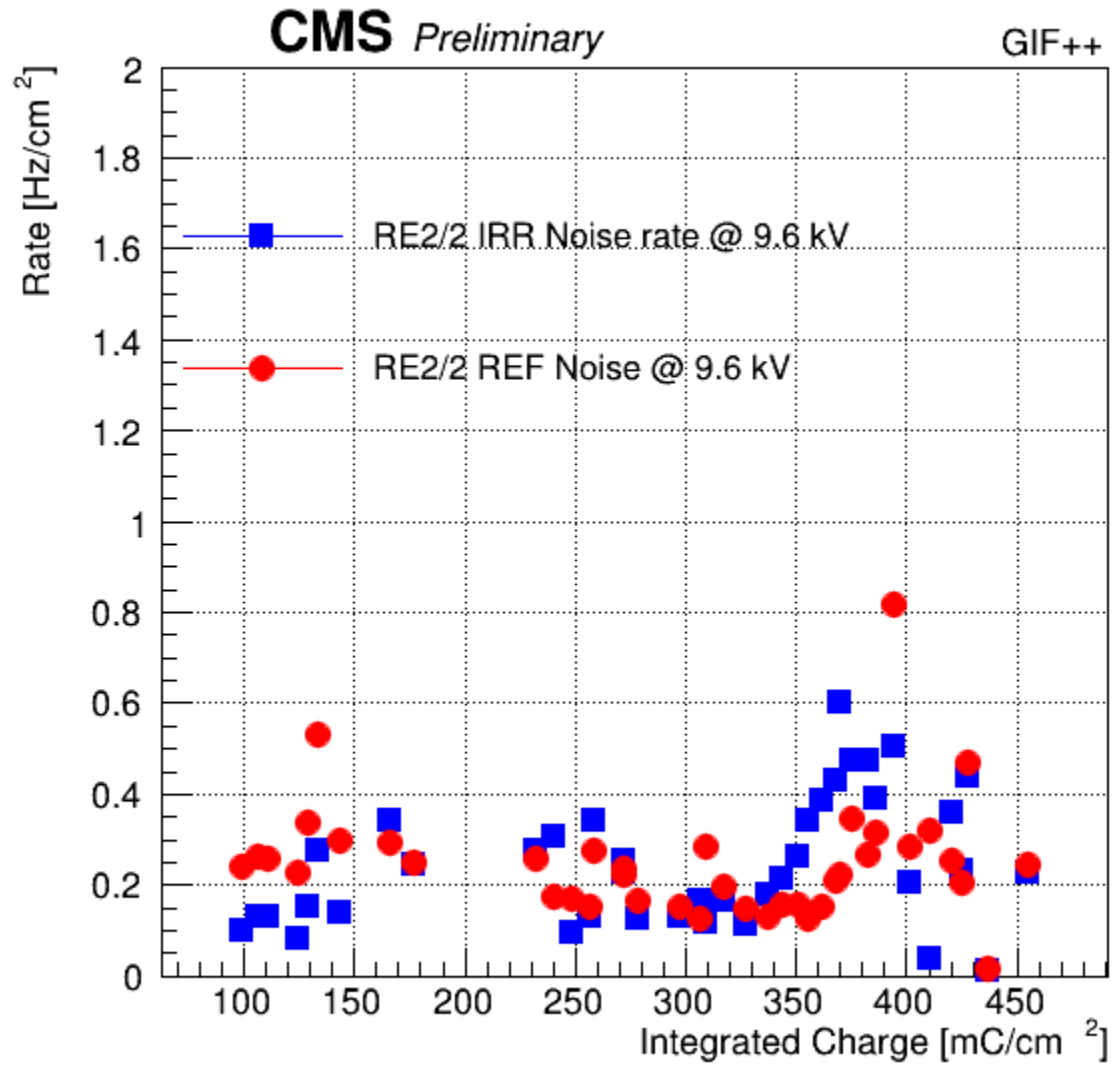


RE2/2 IRR & REF PHYSICS Current

RE2/2 IRR & REF OHMIC Current



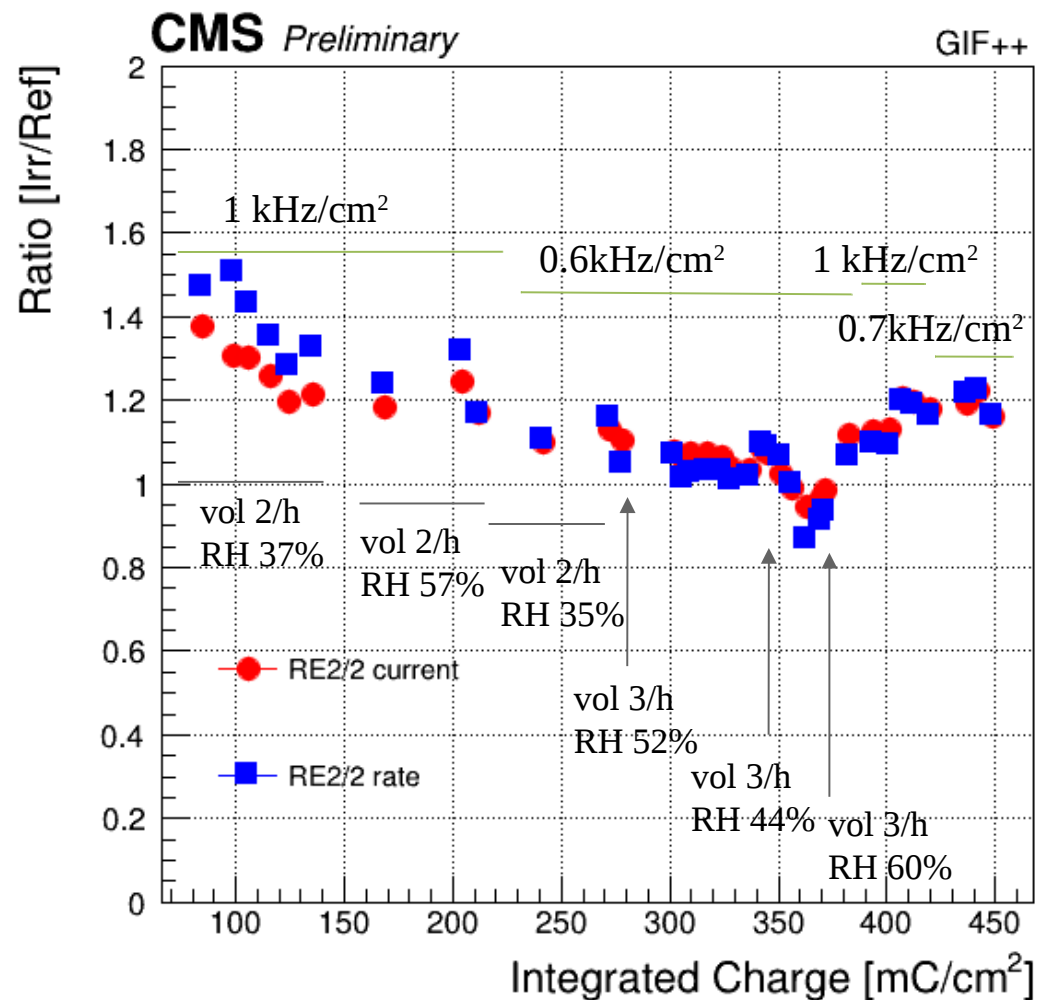
★ Dark currents (ohmic and physics) are almost stable.



RE2/2 IRR & REF NOISE RATE

★ **Noise rate almost stable.**

Current & Rate with background

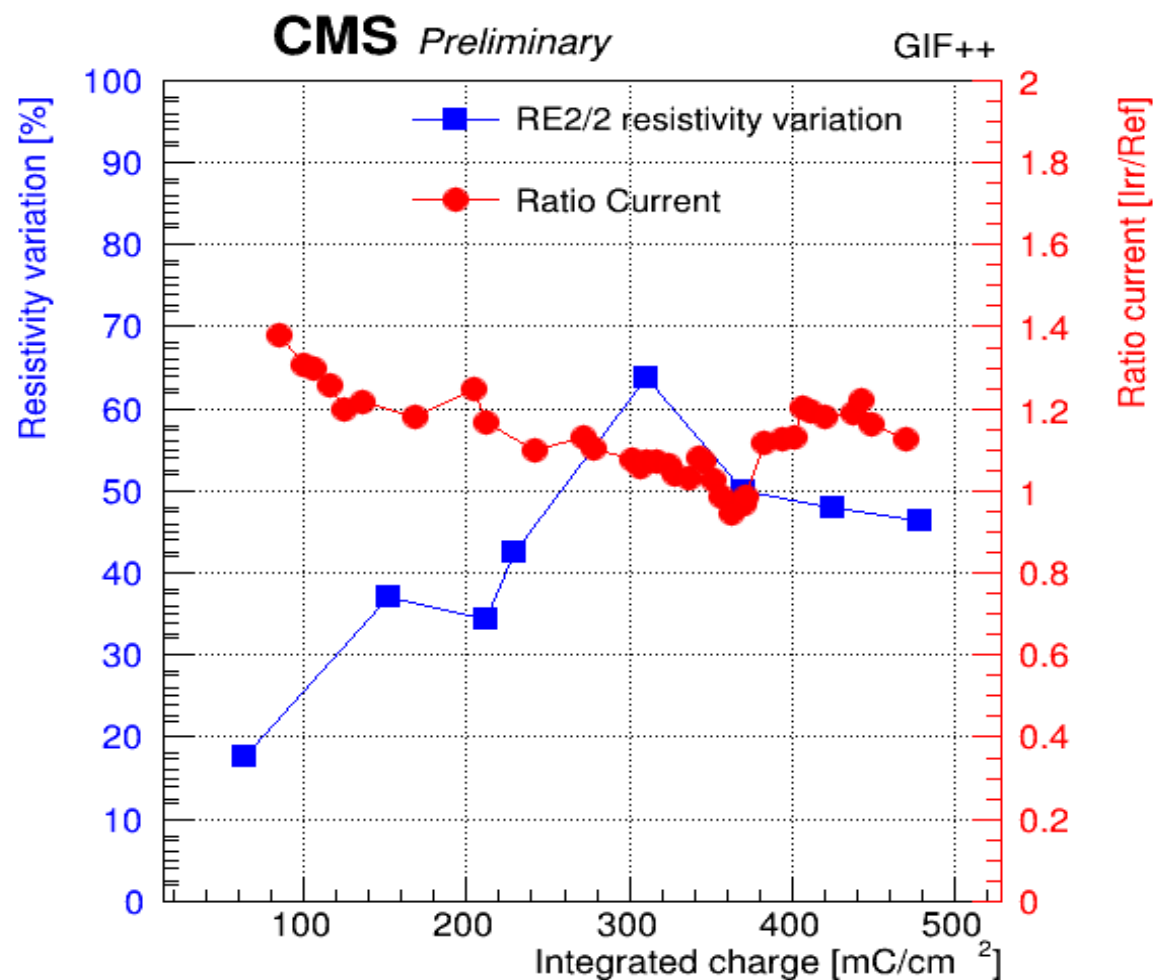


RE2/2

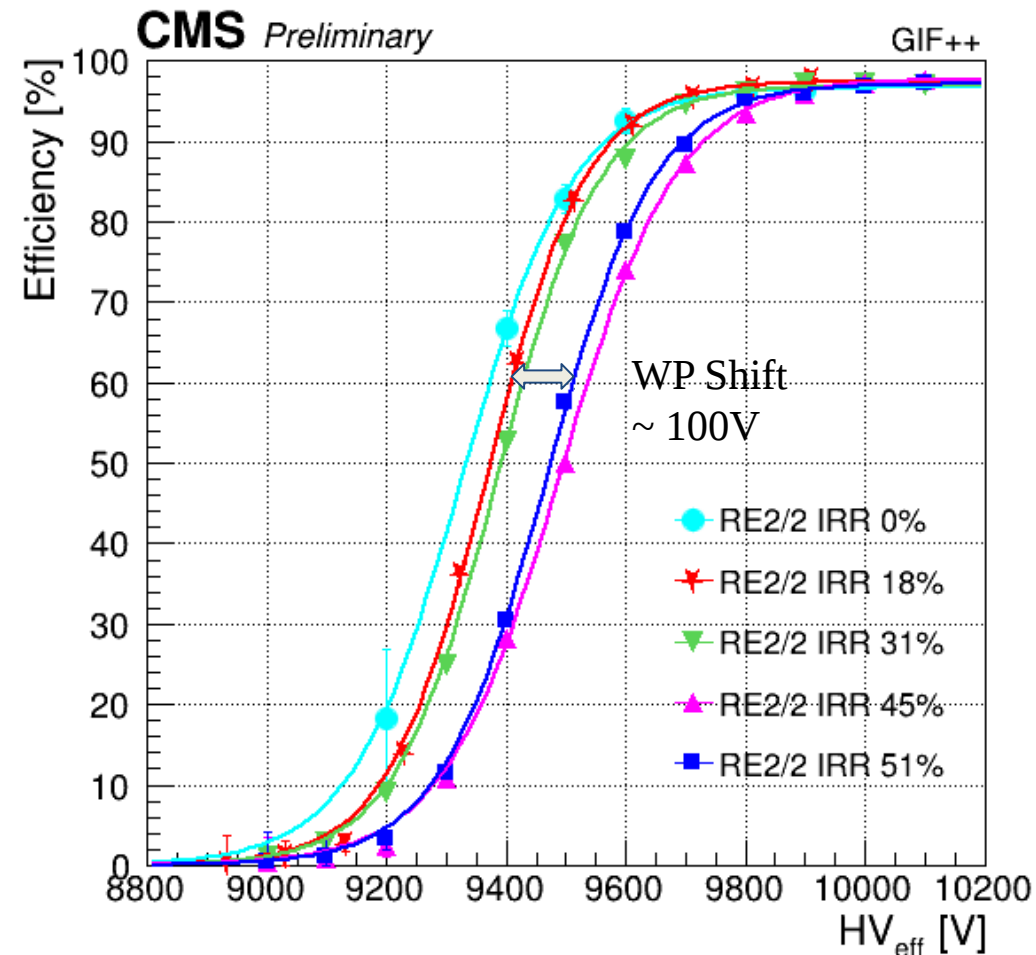
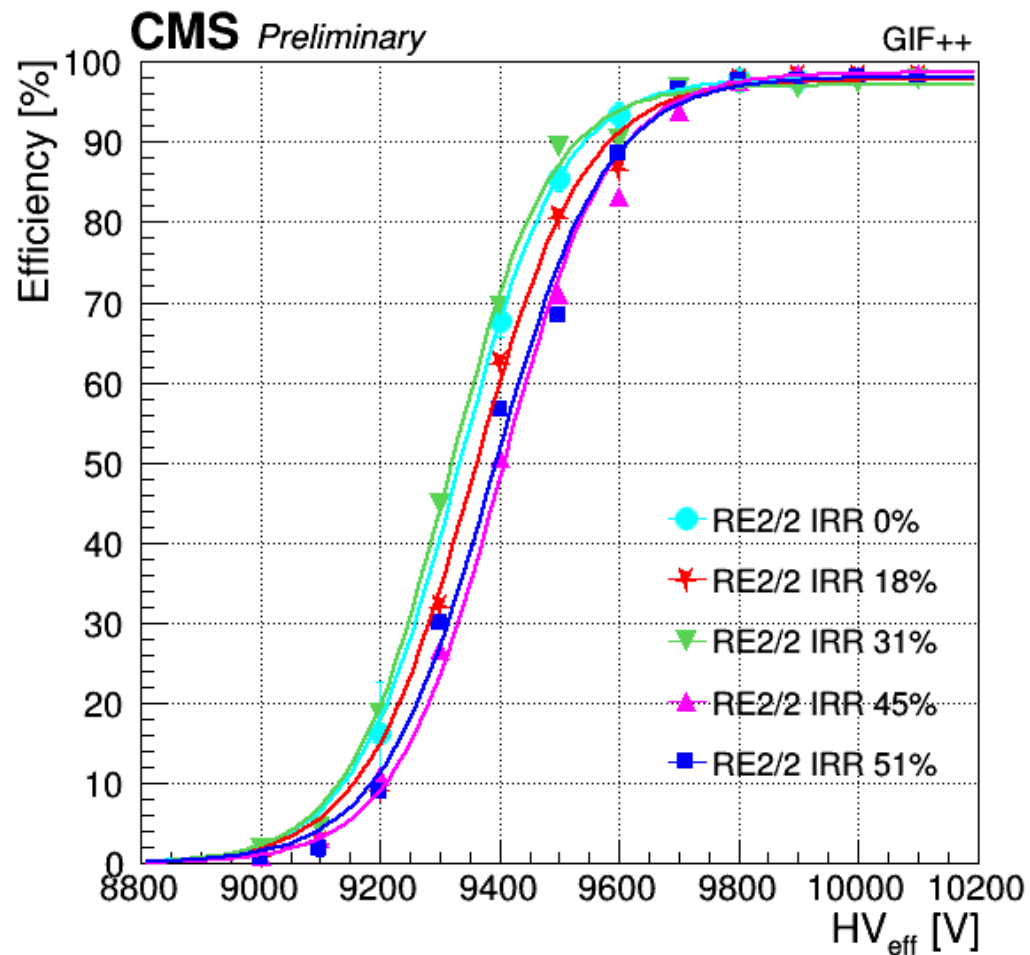
- ★ Background current & rate decrease correlated to the resistivity increase.
- ★ Background current & rate increase (or stable) since when running at 60% RH and 3 vol/h.

Resistivity & current

Resistivity and Current measurements are coherent



- ❖ **Resistivity** increase observed due to the too low humidity and gas flow with respect to the high background rate.
- ❖ **Recoverable effect** mitigated with the gas **RH increase at 60 %**.



Efficiency vs HV_{eff} measured without background

★ Stable performance: stable WP and efficiency

Efficiency vs HV_{eff} measured with background (600 Hz/cm²)

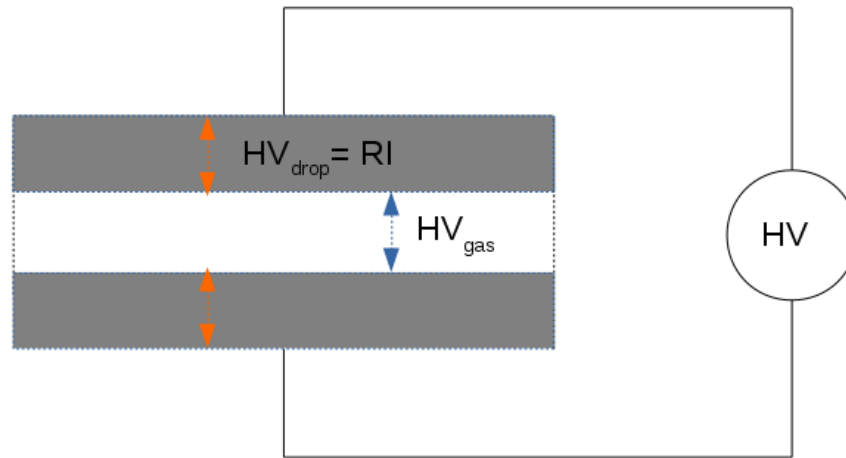
★ Stable performance
★ WP shift of ~ 100 V at 45% and 51% of integrated charge

HV correction

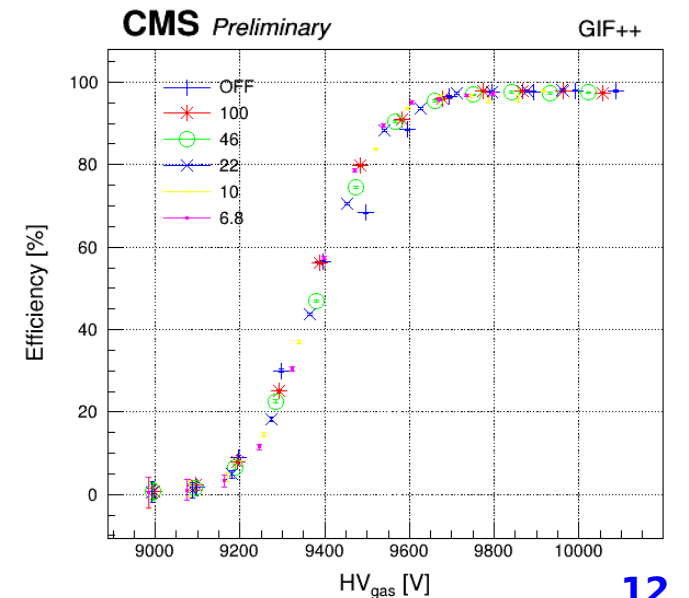
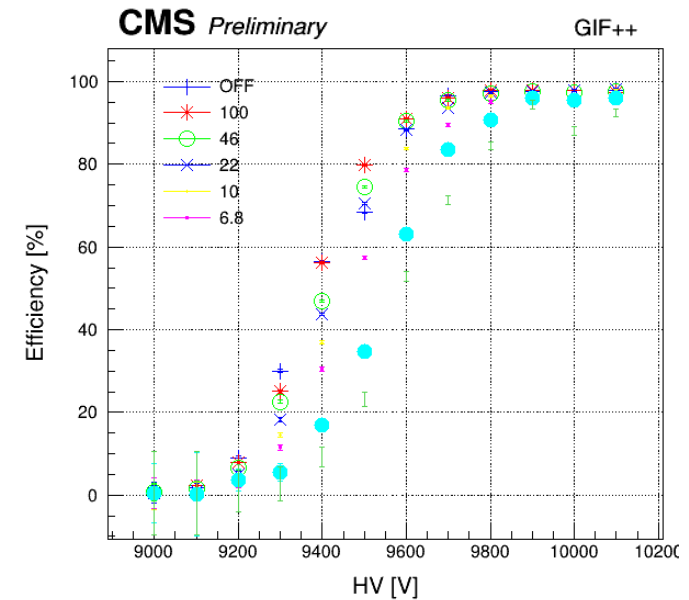
- ❖ The voltage applied to the electrodes (**HV**) is reduced by the voltage drop (**RI**), and the effective voltage applied to the gas (HV_{gas}) is defined as:

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

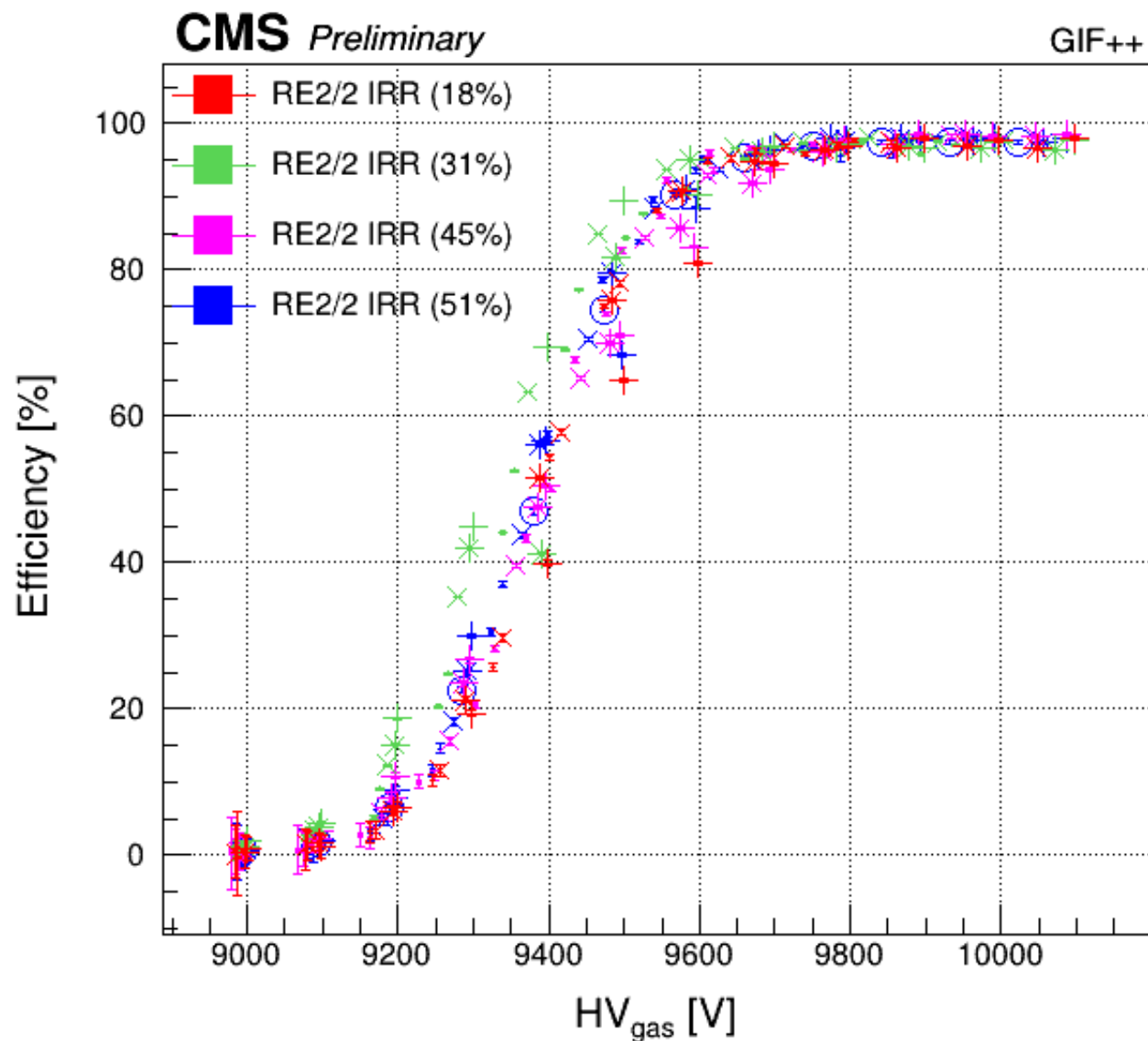
Where **R** is the electrodes resistance and **I** is the current produced by the ionizing particles.



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



Efficiency vs HV gas @ Different TB



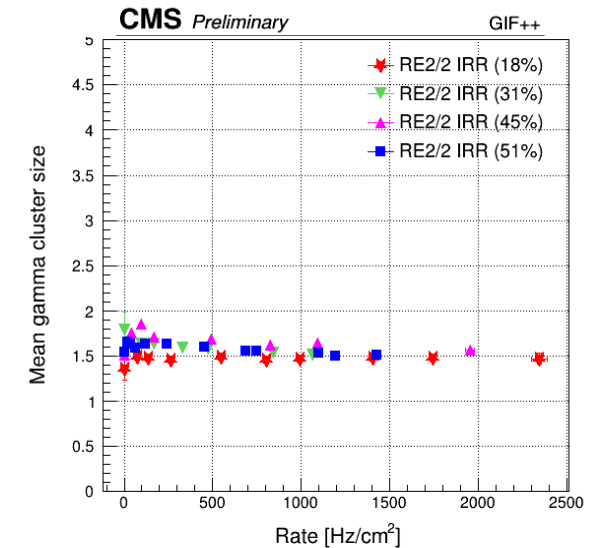
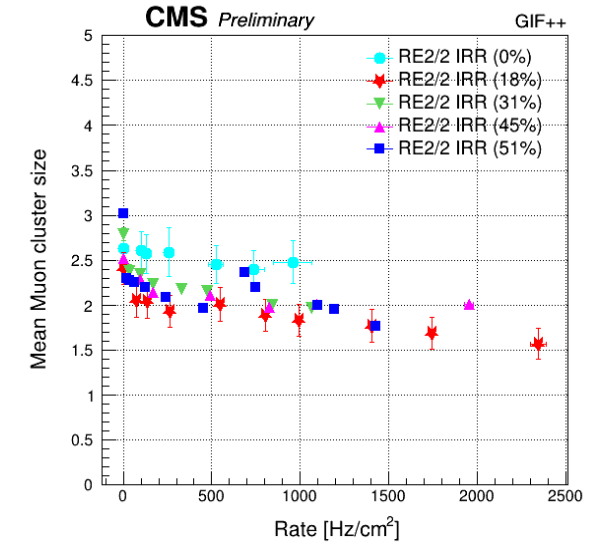
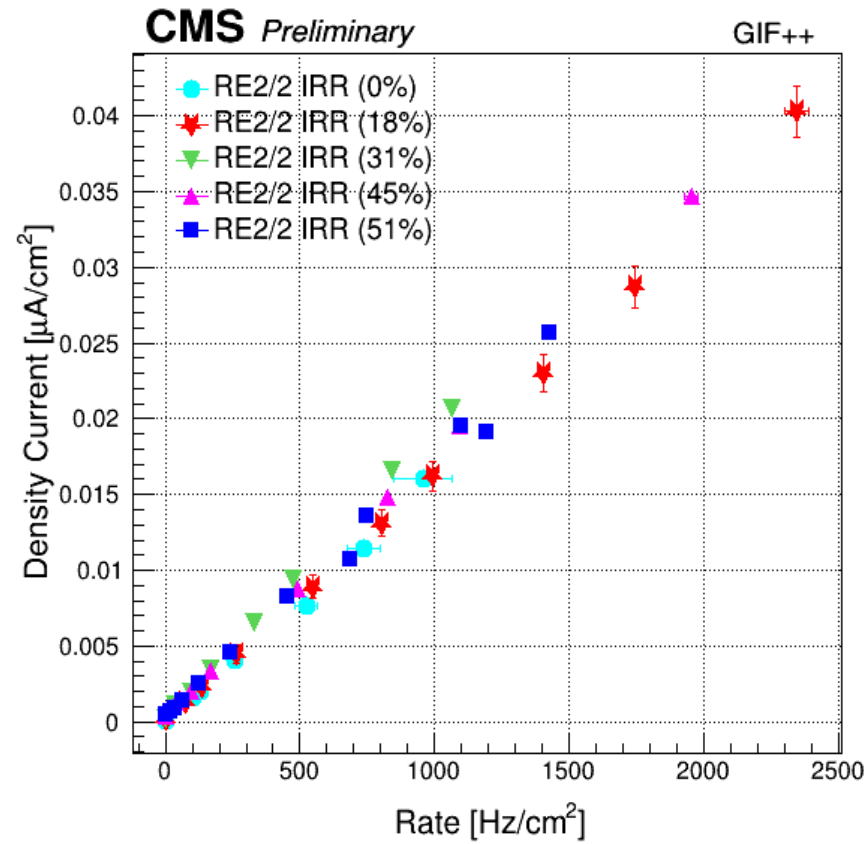
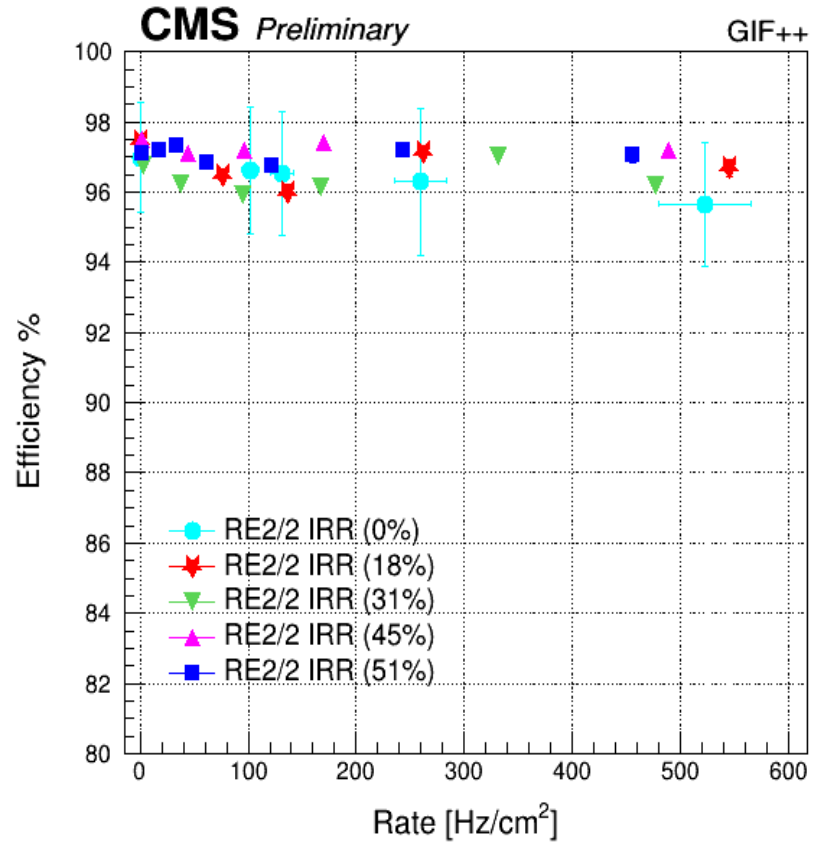
❖ Efficiency at **different ABS** and at **different integrated charge** (different TB) overlap.

❖ **NO any shift observed vs time and up to background rate of 600 Hz/cm²**

No evidence of any aging effect has been observed



Performance @ WP



- ★ Efficiency at WP remains stable in time up to the maximum expected rate (600 Hz/cm²)
- ★ A decrease of about 2% of the efficiency at the highest expected background rate (600 Hz/cm²)



Conclusions

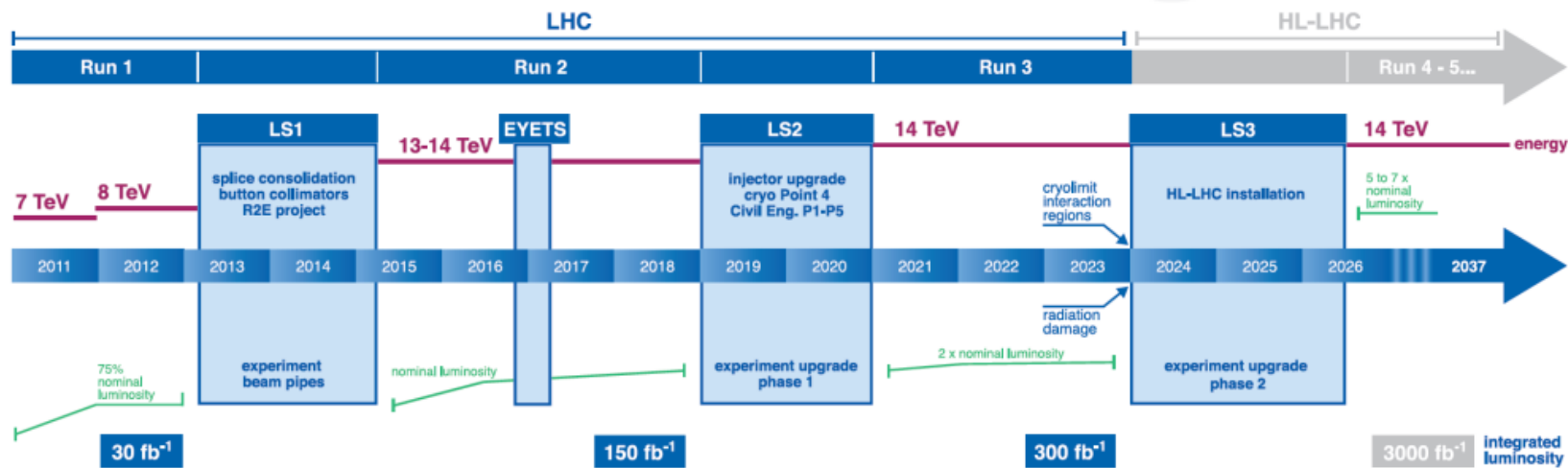
CMS-RPC longevity study is ongoing @ GIF++. **57% (478 mC/cm²)** of the expected Integrated charge at HL-LHC has been collected:

- ❖ Stable noise rate and dark current.
 - ❖ An **increase of electrodes resistivity** has been observed, due to the too low humidity and gas flow rate with respect to the high background rate. Recoverable effect mitigated with **60%** of gas Humidity.
 - ❖ The **efficiency at WP remains stable as a function of the integrated charge.**
- No evidence of any aging effect has been observed.**

BACK UP

RPC System at HL-LHC

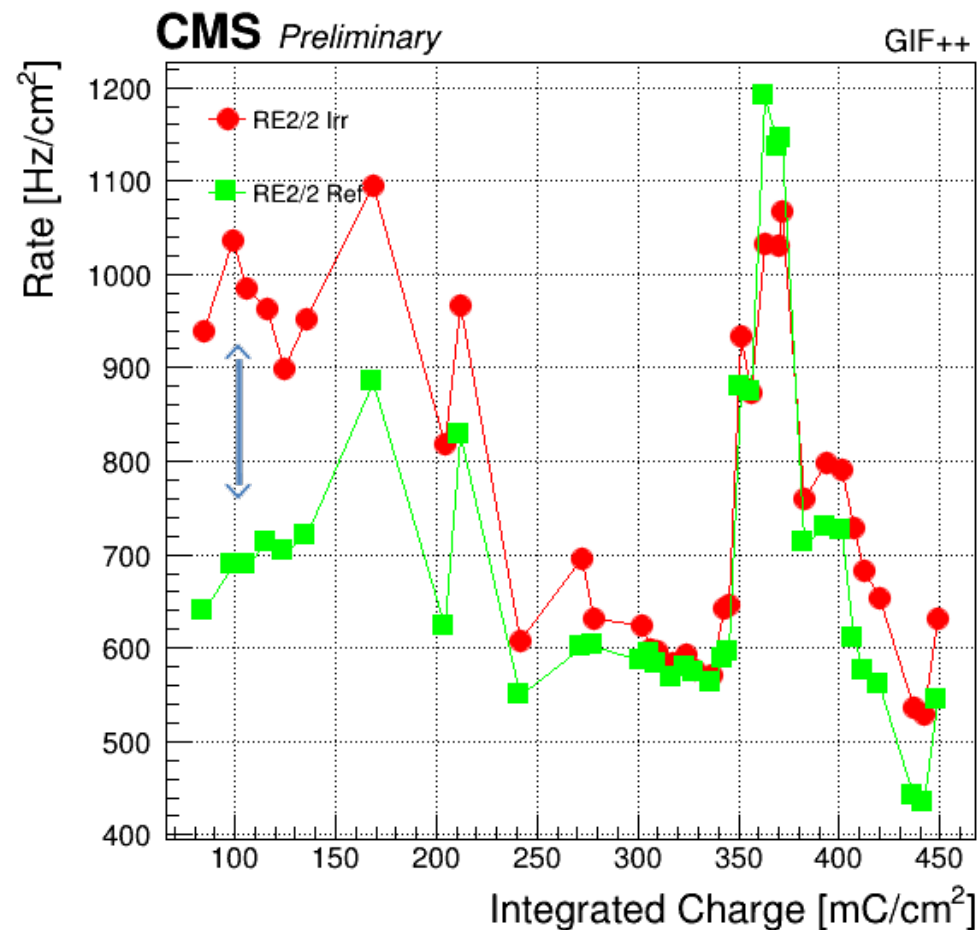
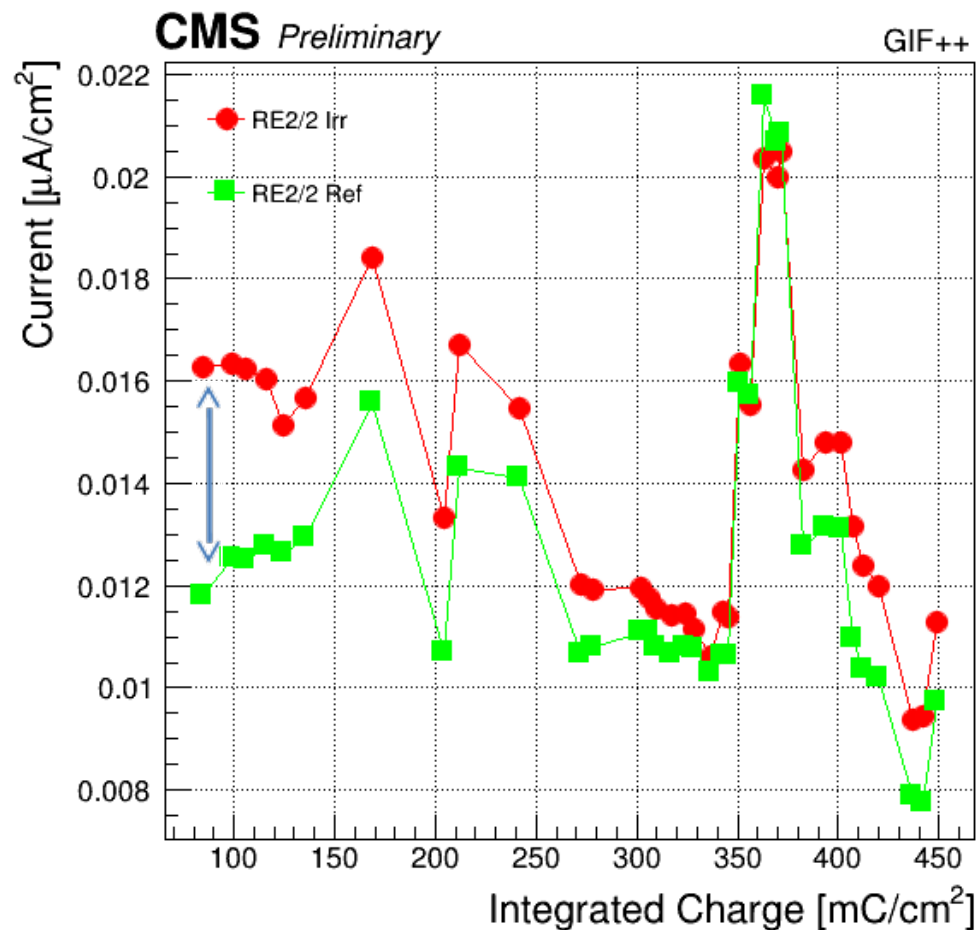
LHC / HL-LHC Plan



- 150 fb⁻¹: by 2018 Run 2
- 300 fb⁻¹: by 2023 Run 3
- 3000 fb⁻¹: by 2037 High-lumi LHC (HL-LHC)

- ❖ RPC's are 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.
- ❖ **Longevity studies** are necessary to check the behaviour of the RPC system at HL-LHC ($5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$).

Current & Rate Monitoring in presence of Background: RE2/2



- ★ Current and rate variations are due to the different irradiation conditions, both chambers follow the same trend.
- ★ **Current & Rate** of the IRR chambers are decreasing with time as compared to the reference chamber.