Longevity study & HF production in CMS-RPC

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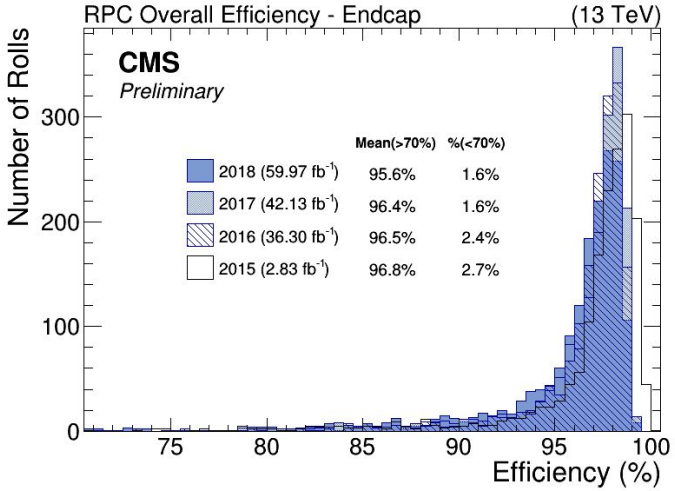
CMS-RPC Performance

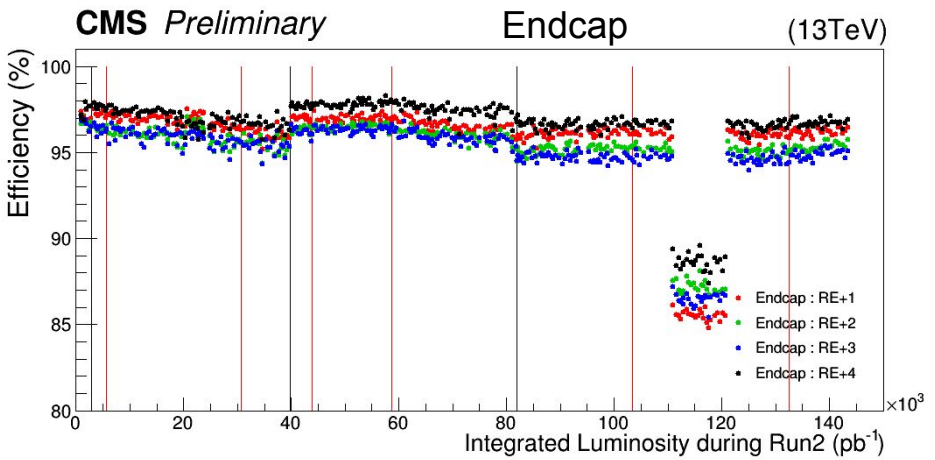
After ~ 9 years operation → ~ 185 fb^{-1} integrated luminosity (156 fb^{-1} only Run 2)

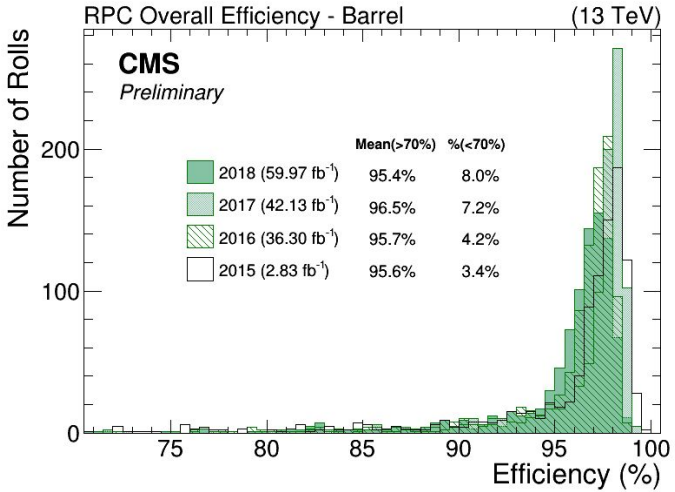
~ 2.3 mC/cm^2 for Barrel and ~7.5 mC/cm^2 for endcap

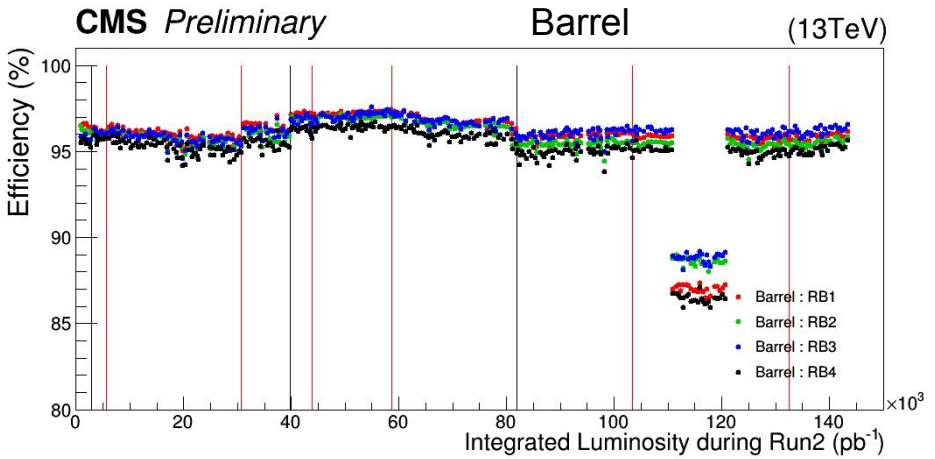
CMS-RPC **performance is high, efficiency >95 % and stable**

→ more details in Mehar Ali Shah's poster: "*CMS RPC system performance during RUN-2 and summary*



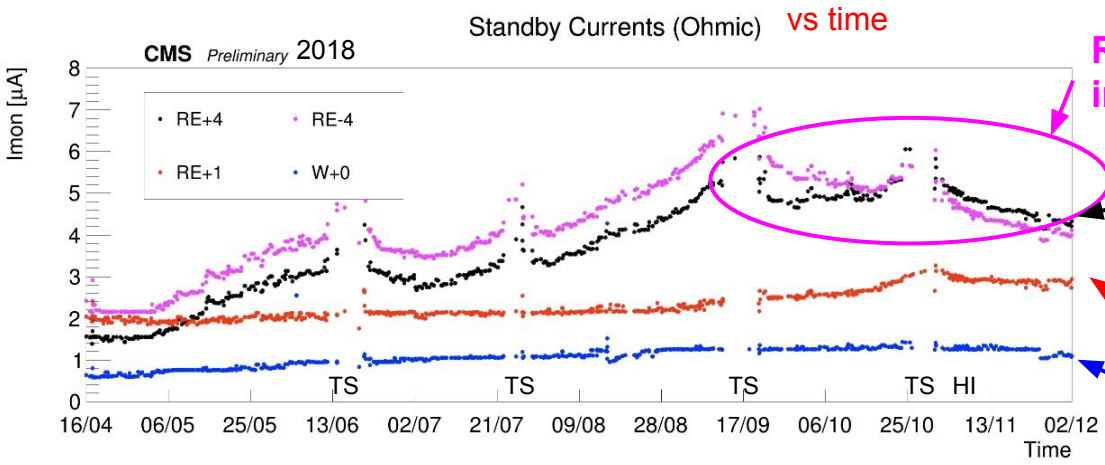




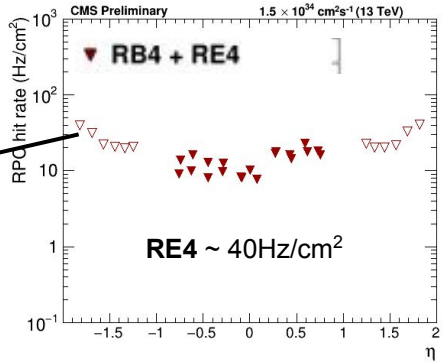


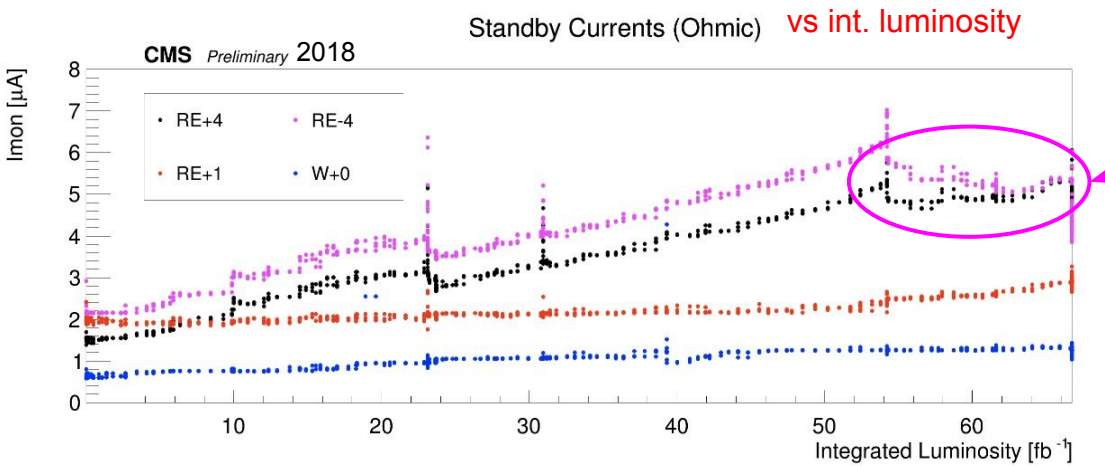
Ohmic current monitoring

- **Ohmic current increase** in the furthermost parts of the detector (Endcap RE4)
- **Ohmic current decrease** when there is no beam (TS) or the luminosity is very low (HI)

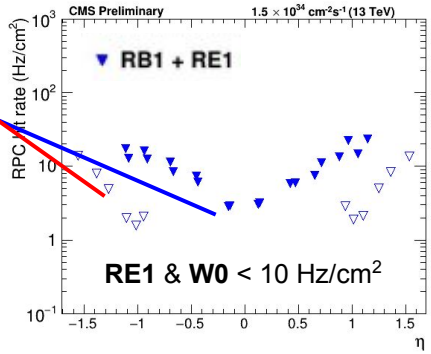


RE-4 gas flow increase





RE-4 gas flow increase



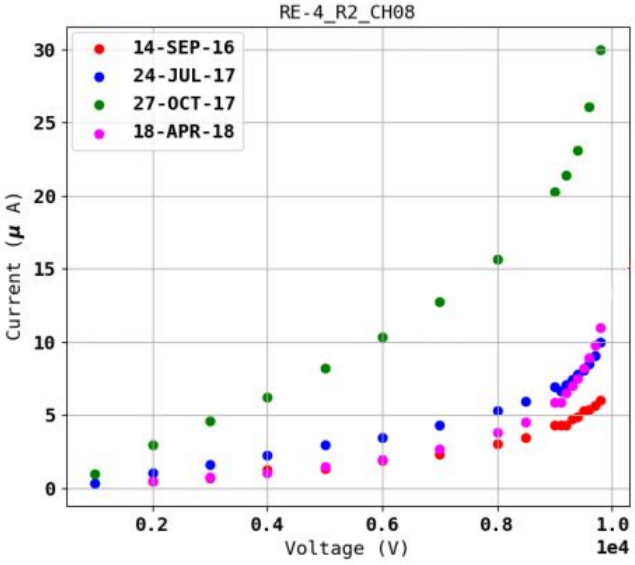
$$i_{ohmic} = L_R * \kappa + i_0$$

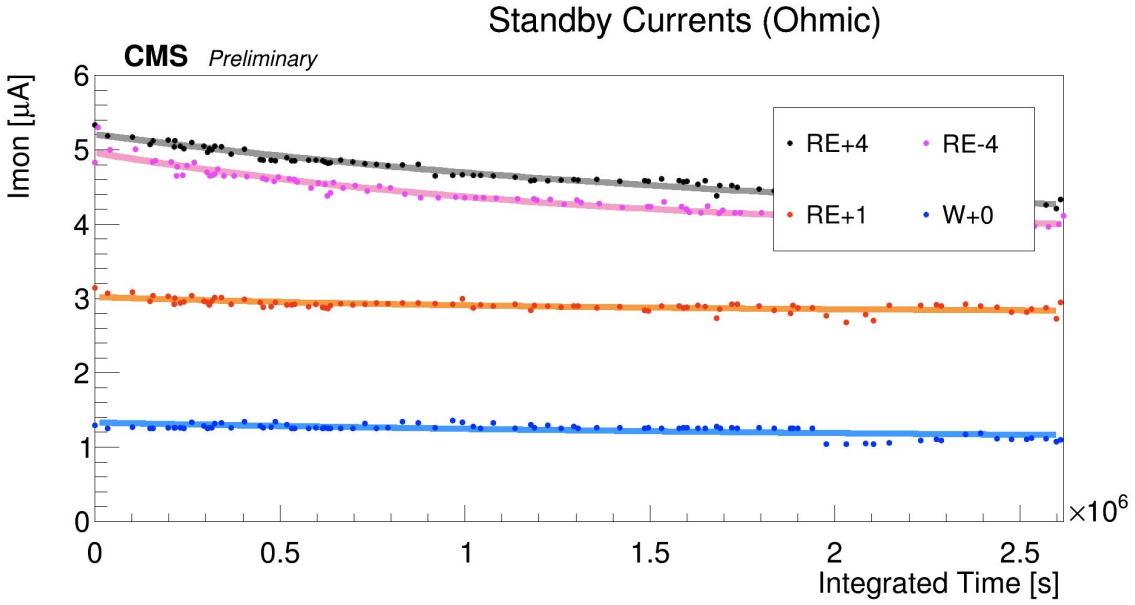
$$\frac{di_{ohmic}}{dL_R} = \kappa$$

- **Ohmic current** is influenced by the **background** and **gasflow**
- **Ohmic current** is **linear** as a function of the integrated luminosity

Ohmic current recovery

- **Ohmic current decay** is observed when there is no beam (TS) or the luminosity is very low (HI)
- Increase of the gas flow in RE-4 seems to have accelerated the recovery (see slide no. 3)

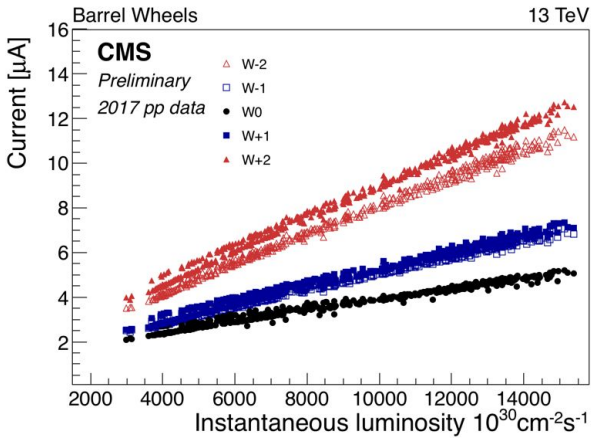


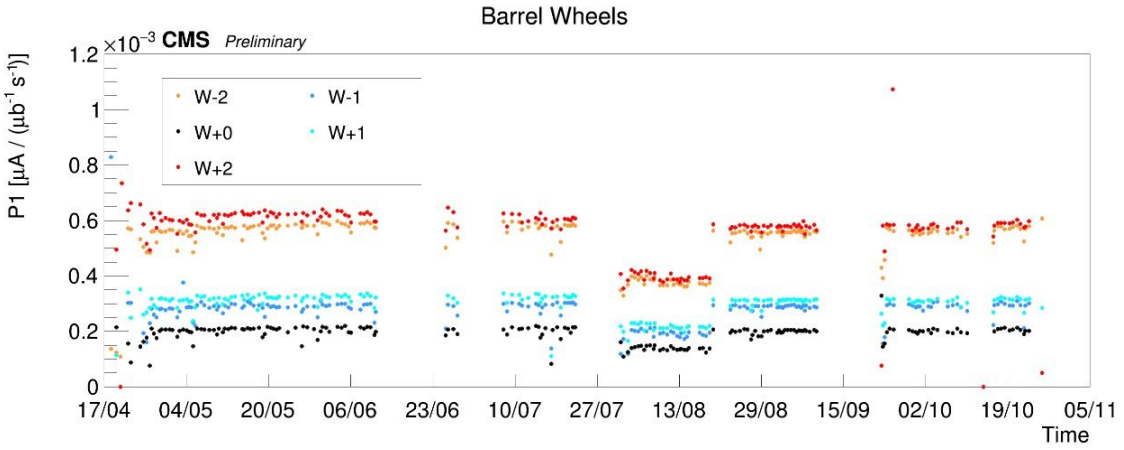


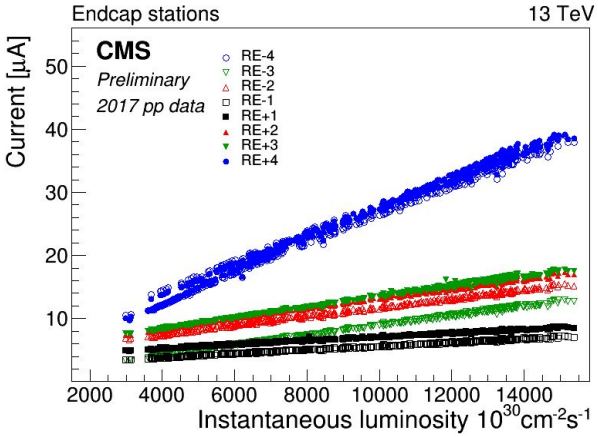
An **exponential function** has been used to fit the recovery period: i = p0 + p1 * exp(-p2 * x)

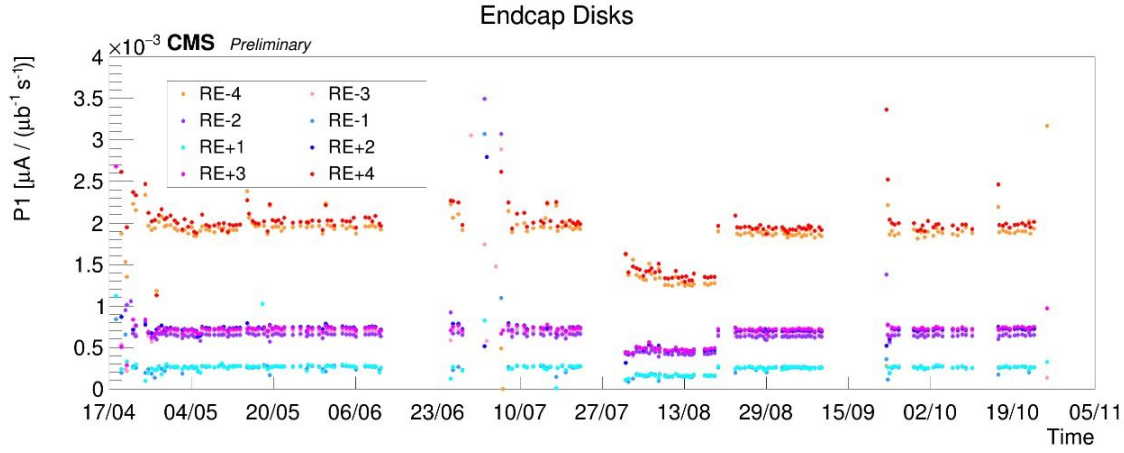
Physics Current Monitoring

Physics current can be evaluated by the linear dependence of current vs luminosity, subtracting the offset, leaving: i = p1 * L









Physics current is stable and not affected by the ohmic current increase

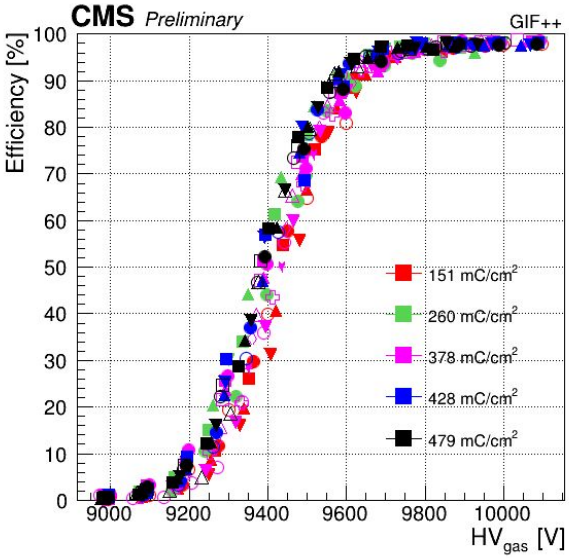
GIF++ Irradiation

CERN Gamma Irradiation Facility (GIF++) allows to test real size detectors with background (14 TBq ^{137}Cs source) and muon beam

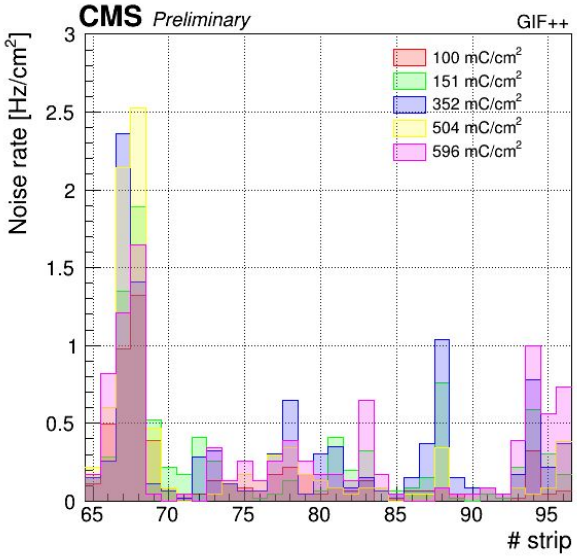
Few spare RPC chambers are under gamma irradiation @ GIF++ for the CMS-RPC system certification @ HL-LHC. After having collected ~ 600 mC/cm^2 from 2016:

- **stable performance**
- **stable noise rate**
- **stable ohmic current** → different operation & background (rate, particles, energies) with respect to CMS

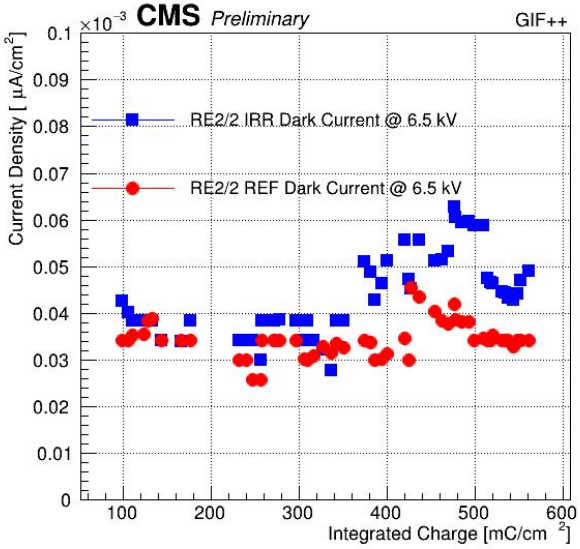
Efficiency vs HV
@ different IC



Noise rate profile
@ different IC



Ohmic current
@ different IC

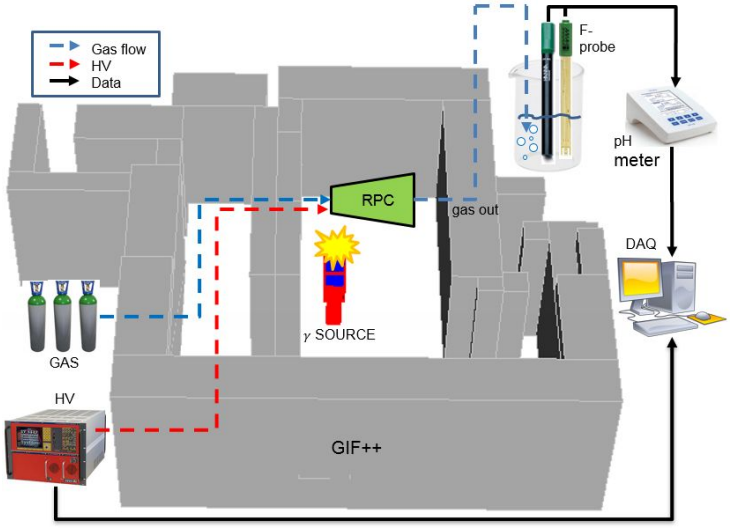


HF measurements @ GIF++

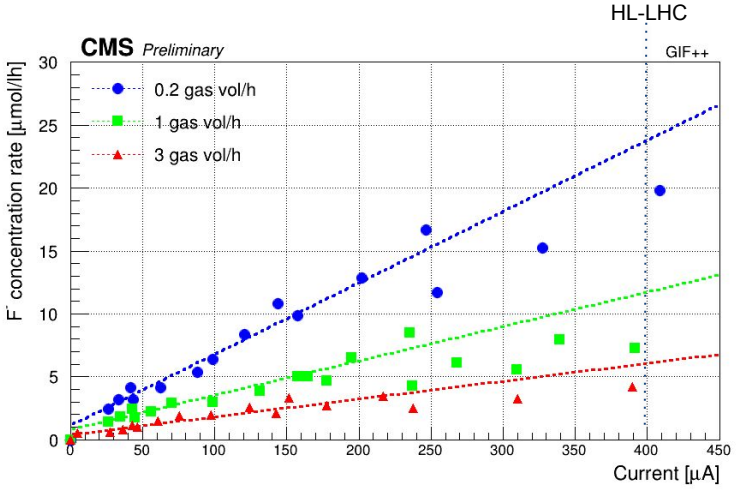
Hydrogen Fluoride (HF) if not removed may represents a possible cause for inner detector surface damaging and relative ohmic current increase, due to its electrical conductivity and high chemical reactivity

GOAL:
Study the HF production rate as a function of the background rate and as a function of the detector gas flow

DETECTOR:
CMS-RPC RE4/2 spare
2 mm electrodes and gas gap thickness
Total gaps surface 23388.5 cm^2
CMS-RPC gas mixture



An ion-selective electrode (ISE), is a transducer (or sensor) that converts the activity of a specific ion dissolved in a solution into an electrical potential (G. Aielli et all. "*Fluoride production in RPCs operated with F- compound gases*" & R. Guida et all. "*HF production in CMS-Resistive Plate Chambers*")

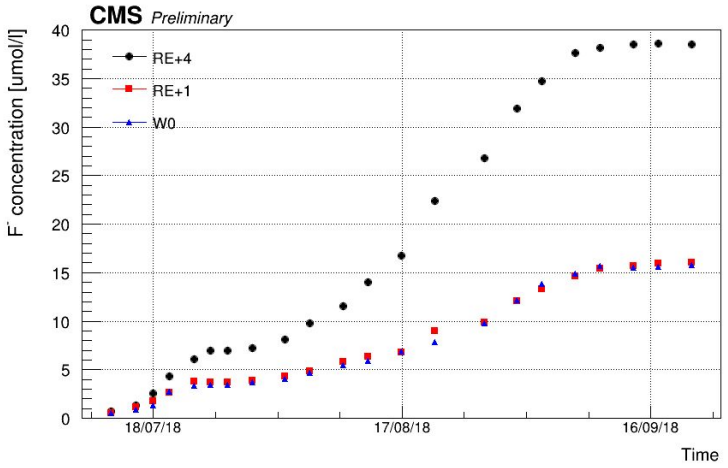


- **HF concentration rate depends linearly on the background**
- **HF concentration rate slope depends on the gas volumes exchanges**

HF measurements @ CMS

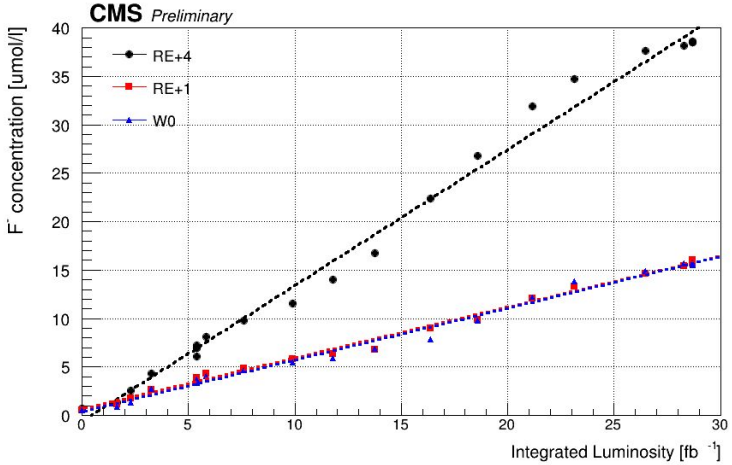
HF measurements performed during run II (July - October 2018) @ CMS:

- Endcap **RE+4** → ~1.1 gas vol/h → ~ 40Hz/cm^2 @ 1.5*10^{34} cm^{-2}s^{-1}
- Endcap **RE+1** → ~0.7 gas vol/h → < 10Hz/cm^2 @ 1.5*10^{34} cm^{-2}s^{-1}
- Barrel **W0** → ~0.6 gas vol/h → < 10Hz/cm^2 @ 1.5*10^{34} cm^{-2}s^{-1}



HF accumulated from gas exhaust vs time:

- HF accumulated, gas flow and background rate in RE+1 & W0 are similar
- RE+4 with respect to RE+1 & W0 has:
  - ~ 2 times the HF accumulated
  - ~ 4 times the background rate
  - ~ 2 times the gas flow



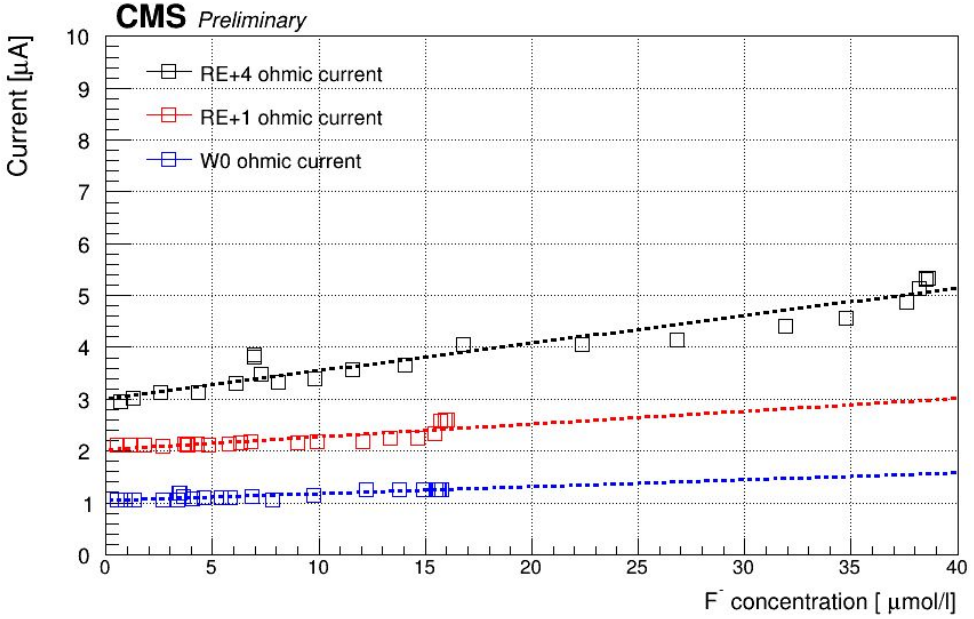
The **HF accumulated** follows a linear trend with respect to the integrated luminosity

$$HF = L_R * \kappa + HF_0$$

$$\frac{dHF}{dL_R} = \kappa$$

HF & Ohmic current @ CMS

Both the ohmic current and the HF concentration have a linear correlation with respect to the integrated luminosity



$$\frac{di_{ohmic}}{dL_R} = \kappa_1$$

$$\frac{dHF}{dL_R} = \kappa_2$$

$$\frac{di_{ohmic}}{dHF} = \kappa_3 = \frac{\kappa_1}{\kappa_2}$$

- **The ohmic current and the HF concentration are linearly dependent**
- W0 & RE+1: lower background → lower HF production → lower ohmic current increase
- RE+4: higher background → higher HF production → higher ohmic current increase

HF trapped in the gap may form a thin conductive layer that increase the ohmic current → it is necessary to fine tune the gas flow as a function of the background rate so that the HF is efficiently removed

Conclusions

- After ~ 9 years of operation (~ 185 fb-1), **CMS-RPC performance remains stable**
- An ohmic current increase was observed

- GIF++ irradiation tests show stable detector performance and parameters
- HF production has been studied @ GIF++ as possible cause of ohmic current increases:
  - **HF concentration rate depends linearly on the background, and the slope depends on the gas flow**

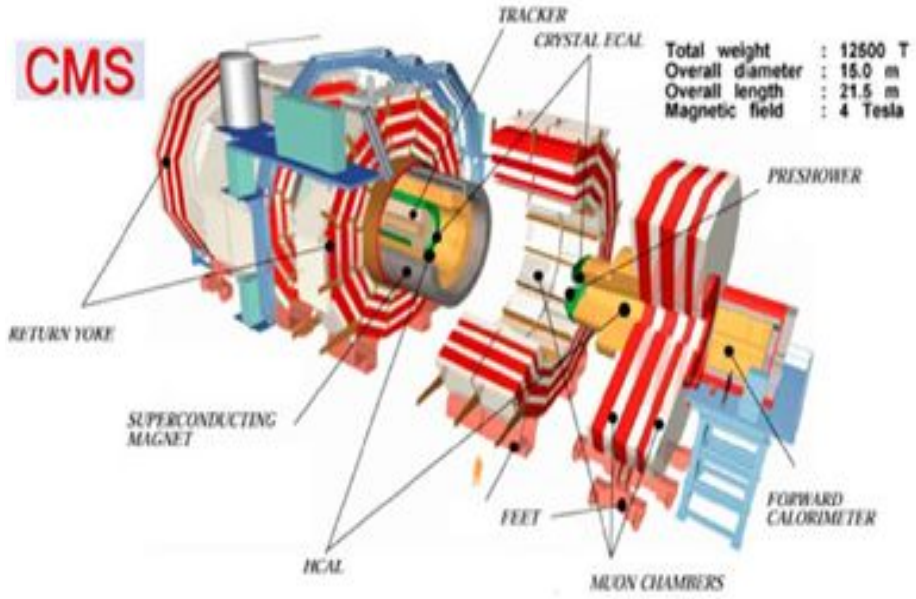
- HF measurements have been performed @ CMS, confirming the GIF++ results
- **Ohmic current is linearly dependent on the HF accumulated**
- **HF trapped in the gap can be the reason of the ohmic current increase**

- **For a good detector performance, it is necessary to fine tune the gas flow so that the HF is efficiently removed**

BACKUP

Contact: andrea.gelmi@cern.ch, osvaldo.miguel.colin@cern.ch

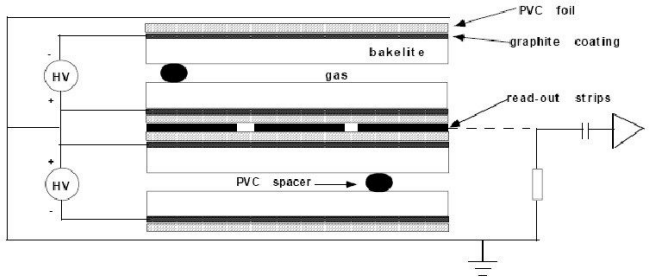
CMS-RPC



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

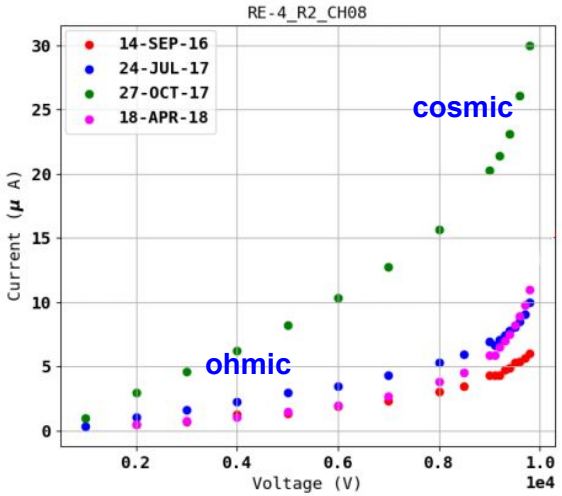


The CMS RPC gas mixture:

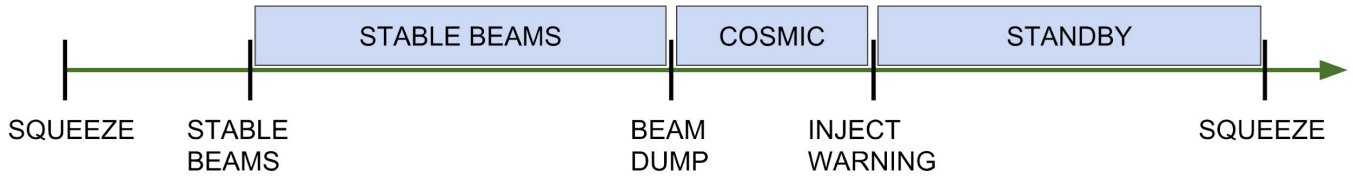
95.2% $C_2H_2F_4$ (tetrafluoroethane) → ***active gas***
0.3% SF_6 (sulphur hexafluoride) → ***electronegative gas***
4.5% C_4H_{10} (isobutane) → ***quencher gas***

DEFINITIONS

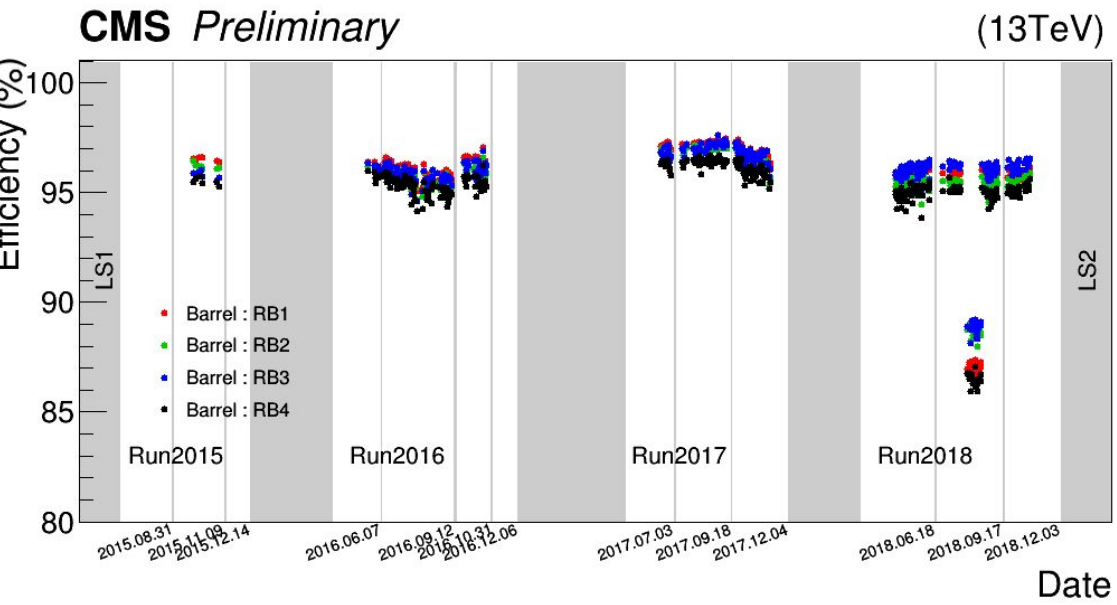
Ohmic current is defined as current with no beam, up to around 7000V, in the range where there is no gas amplification contribute and the current follows the ohmic law.
The ohmic current values are monitored at 6500 V, between Inject Warning and Squeeze.

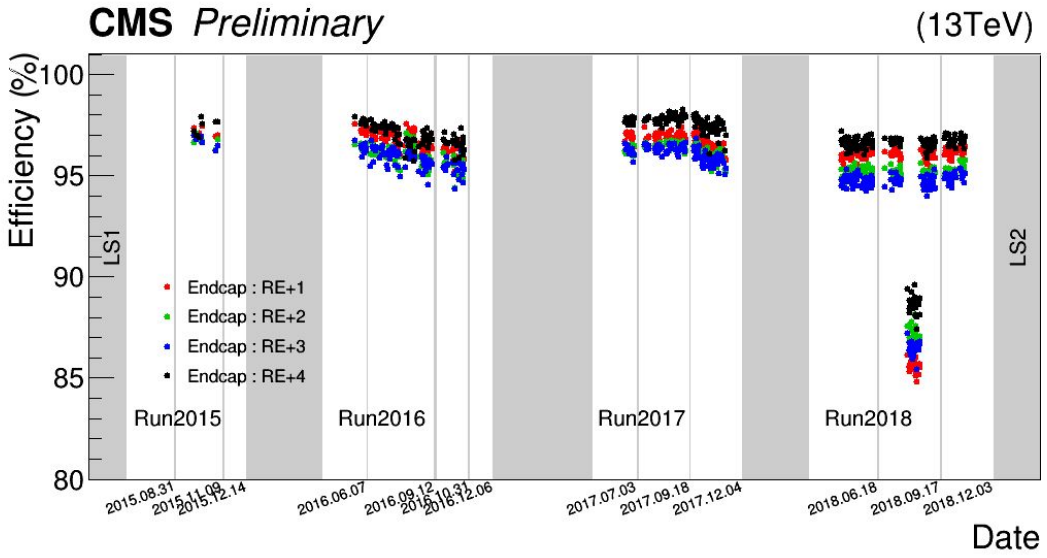


Cosmic current is defined as current with no beam, at working point voltage, in the region of the gas amplification. The cosmic current values are monitored between Beam Dump and Inject Warning.



CMS-RPC EFFICIENCY MONITORING





Efficiency history by date of barrel rolls.

The x-axis is date and the y-axis is average efficiency of each LHC fills.

Gray lines are technical stops(TS) and large lines are year end technical stops(YETS) in each years.

Each point correspond to average efficiency per station of a LHC fill. Data points with low statistics or temporary problems are removed.

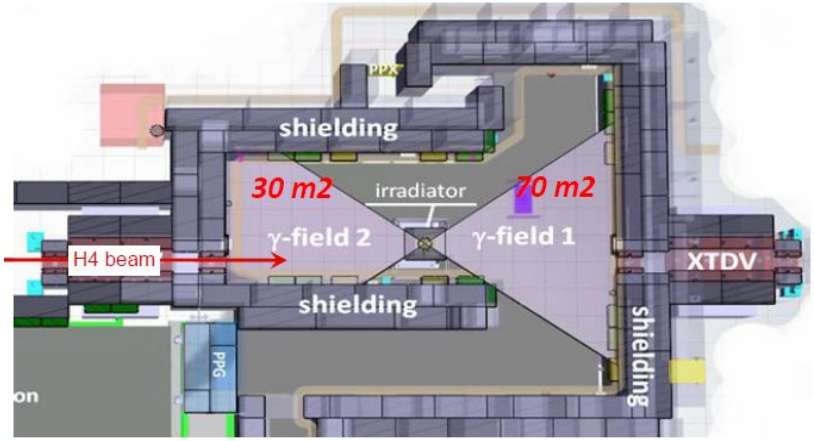
Efficiency was obtained using the Tag-and-Probe method with single muon triggered dataset. Probe muons are reconstructed using the tracker muon algorithm which is independent to RPC system, requiring at least one segment to be matched in local x position within 3cm and pull ≤ 3. Probe muons are also required to have at least 10GeV in transverse momentum.

Change of efficiency correspond to the changes of applied high voltage working point and gas mixture changes.

During 01 Aug. 2018 ~ 19 Aug. 2018, there were efficiency drop because of known configuration setting problem.

GIF++

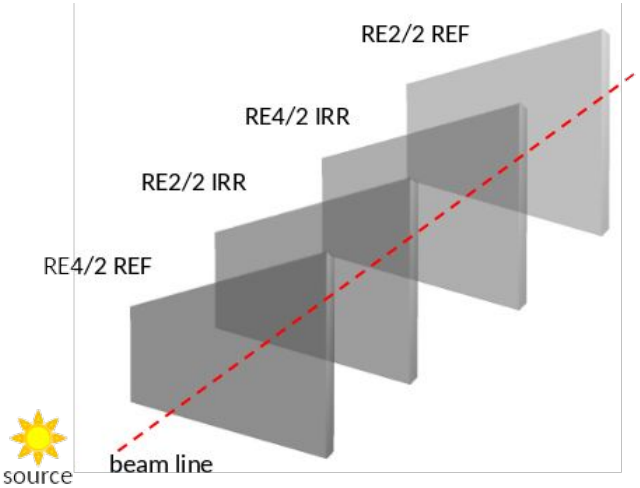
- **GIF++ is a facility that allows to test real size detectors in a similar background condition as in CMS.**
- 14 TBq ^{137}Cs source (662 keV gammas)
- Gamma filters: Systems of movable attenuators allows to test the detectors in different irradiation conditions
- Muon beam
  - ↦ Energy up to 100 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.



GIF++ setup

- **Setup @ GIF++:**
  - ↦ 2 RE2 chambers (Irrad & Ref)
  - ↦ 2 RE4 chambers (Irrad & Ref)

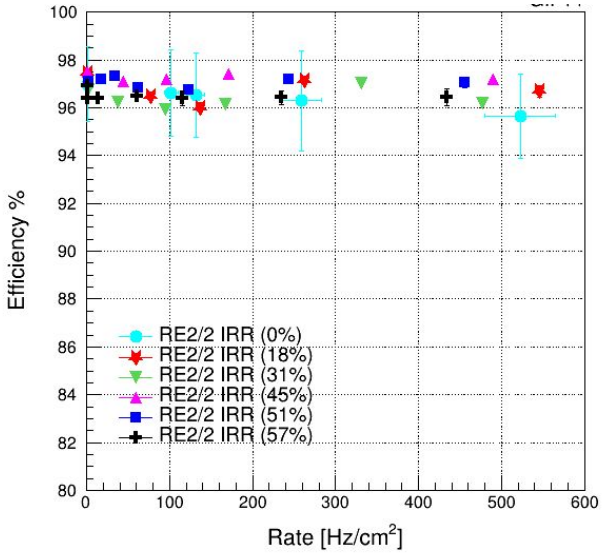
- ➢ Two different types of chambers from old and new production (RE4 production done in (2012-2014)
- ➢ Two chambers continuously irradiated, two used as reference.

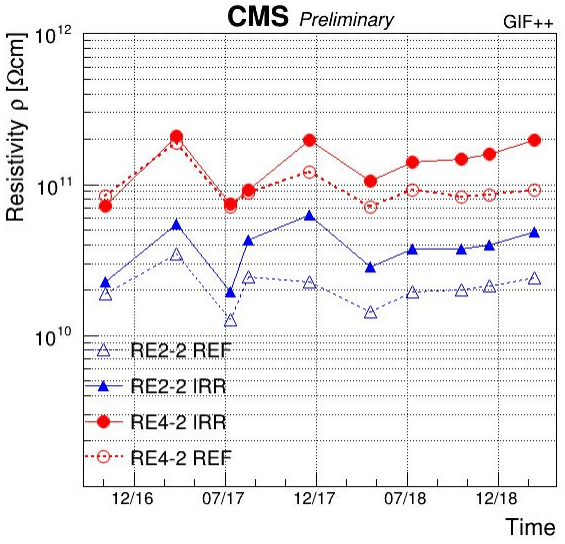


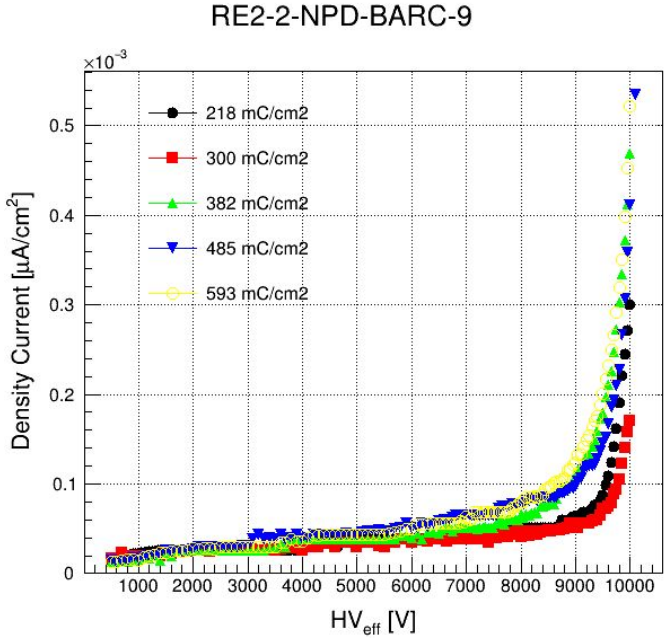
- Daily measurements: Current & rate with background.
- Weekly measurements: Current and rate at different background conditions and without background.
- 3-4 time per year: Argon resistivity measurements.
- 3-4 times per year Test beam: Performance measured with muon beam at several background conditions.

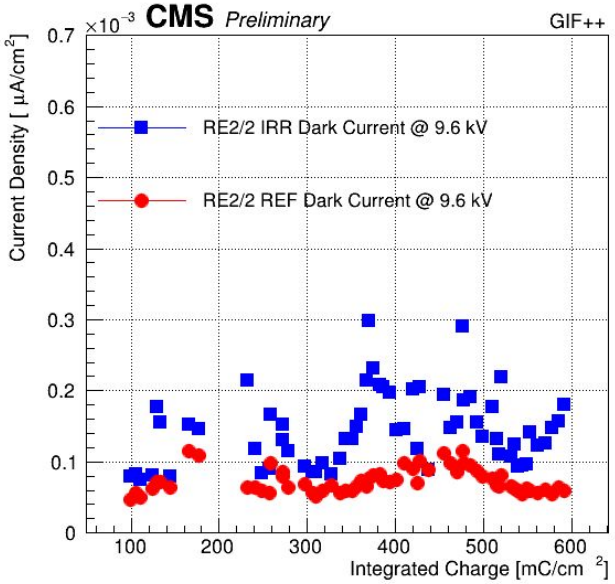
16

PARAMETERS MONITORING @ GIF++









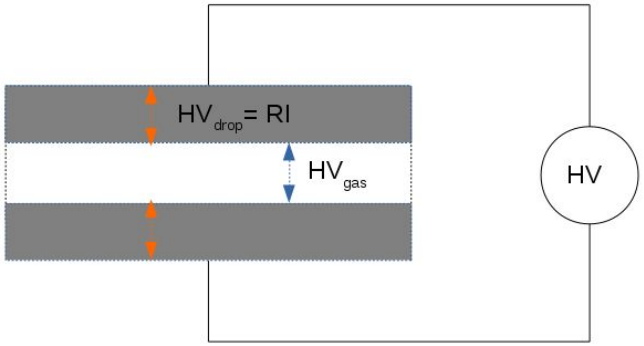
17

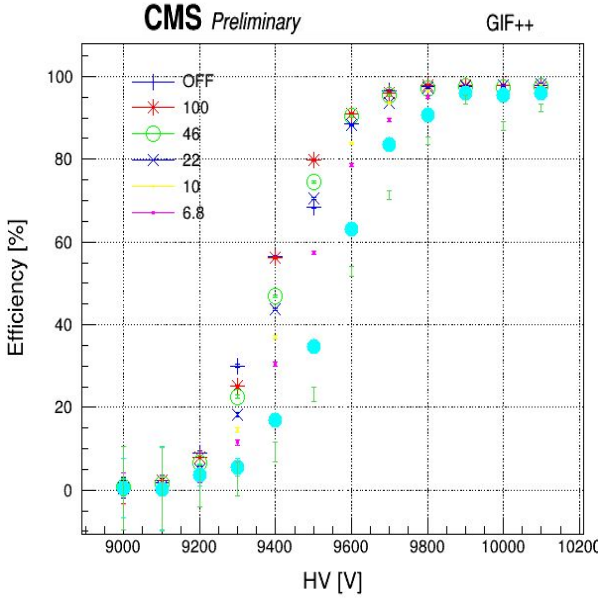
HV correction

- 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:

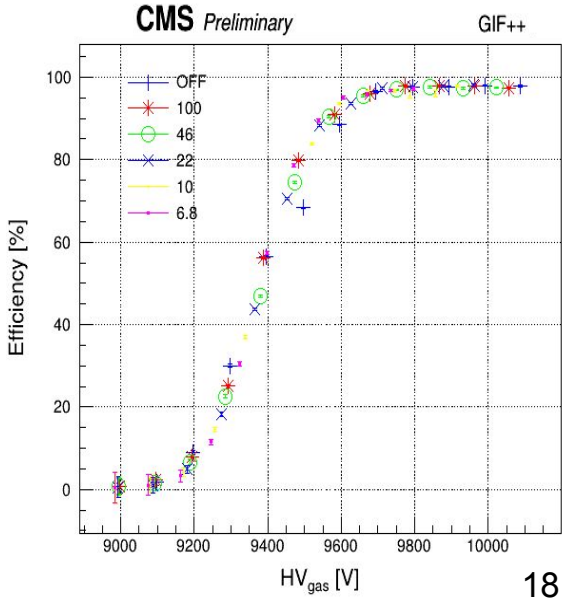
$$HV_{gas} = HV - RI$$

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





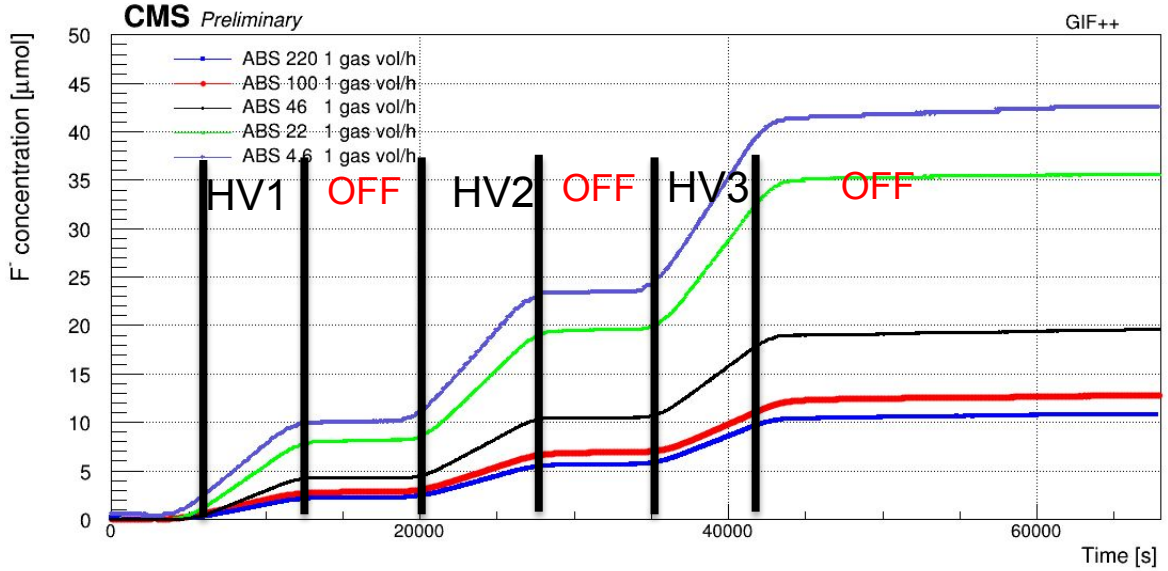
- The efficiency plotted as a function of HV_{gas} does not depends on the background conditions and on the electrodes resistance: the operation regime of the detector is invariant with respect to HV_{gas}



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

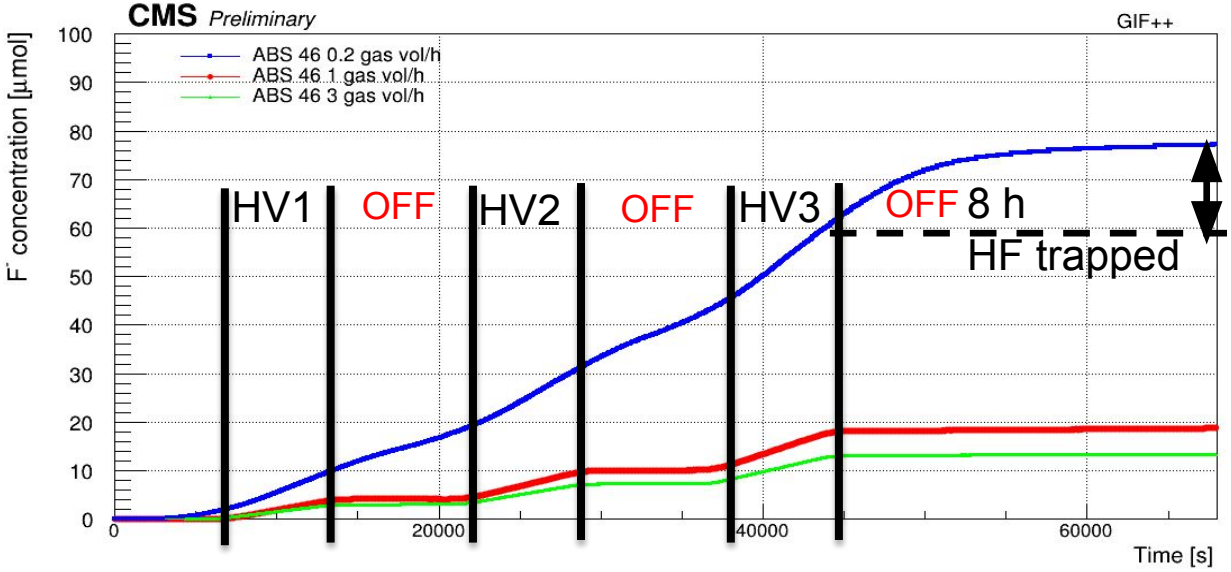
HF vs time

HF concentration at different background & fix gas flow



- ✔ HF concentration increase with background rate (ABS)
- ✔ HF increase with the current (HV)

HF concentration at different gas flow & fix background



- ✔ HF concentration increase with lower gas volume changes
- ✔ HF trapped increase with lower gas volume changes