Collaboration Meeting
WG3 10.12.2024

Measurements of F^- in irradiated straw tubes

Mattia Verzeroli[1], Maria Cristina Arena[2], Katerina Kutznezova[4], Beatrice Mandelli[5], Gianluca Rigoletti[5]

EP-DT
Detector Technologies

1. Université Claude Bernard Lyon I
2. Università degli Studi di Pavia
4. UF/INP
3. CERN

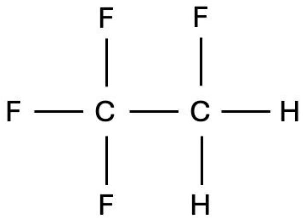
Outline

- Introduction:
  - F- Gases at LHC experiments;
  - F- production.
- Ion Selective Electrode measurements:
  - Technique introduction;
  - Previous tests.
- Dedicated Setup @904;
- Measurements:
  - Overview of the measurements;
  - Data selection and data analysis;
  - Measurement results.
- Conclusion.

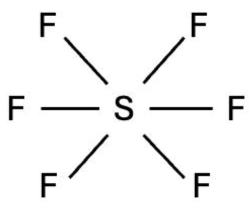
F-gases at LHC experiments

Fluorinated gases are used in several LHC experiment gaseous detectors

R134a
GWP: 1430

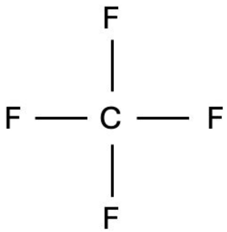


SF_6
GWP: 23500



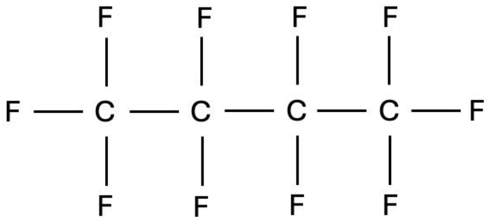
ATLAS RPC | **ALICE** TOF, MID | **CMS** RPC

CF_4
GWP: 6630



CMS CSC | **LHCb** MWPC, RICH2

C_4F_{10}
GWP: 8860



LHCb RICH1

EU fluorinated gases regulation:

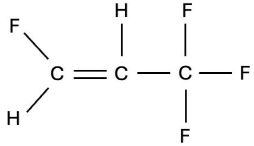
(2014)

- Limiting the availability;
- Banning the use of F-gases where alternatives are available.

The **research on new eco friendly gas mixture** is ongoing, together with other strategies.

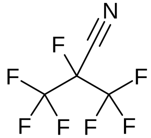
However
some of the promising alternatives still F-gases

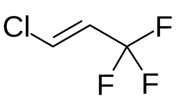
2023, ECOgas@GIF++
2024, M. Verzeroli et al.
2024, G. Proto et al.
...



HFO-1234ze
GWP: 7

NOVEC 4710
GWP: 2100



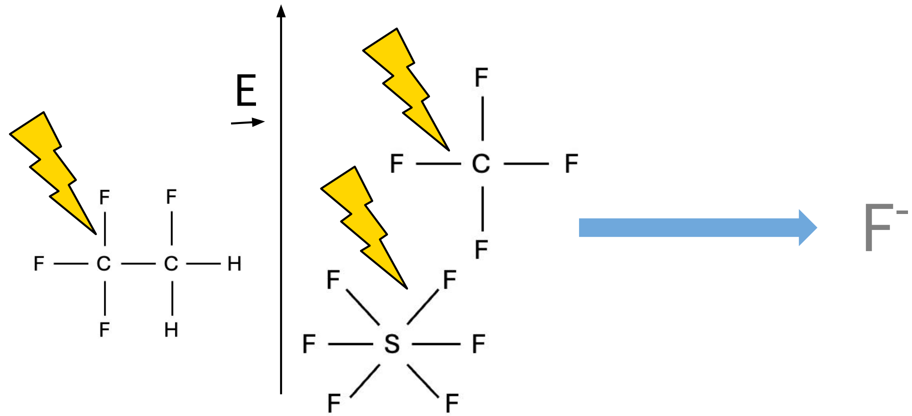


HFO-1233zd
GWP: 2100

F^- Production

It is essential to <u>investigate the production of F^- impurities</u> not only in the newly proposed environmentally friendly gases but also in the ones currently in use, to establish a clear and direct comparison between them.

The combination of the electric field and high irradiation fragments F-gases in the detector's gas gap.



The **effect of F^- impurities** is strictly <u>connected to the detector's design</u>:

RPC

Free F^- can react with the water vapour forming hydrofluoric acid:
-> <u>Detector's gap and gas system damages.</u>

Increasing ageing effects

CSC

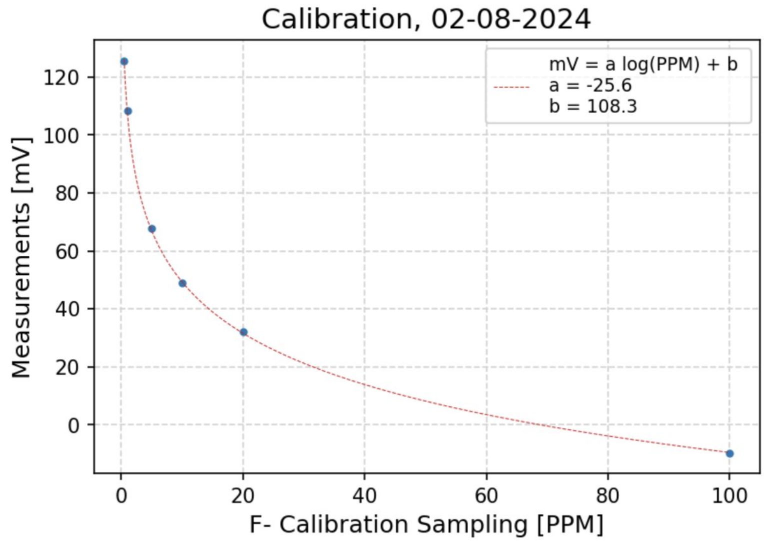
Free F^- can react with the wire deposit, and remove it:
-> <u>Wire cleaning effect.</u>

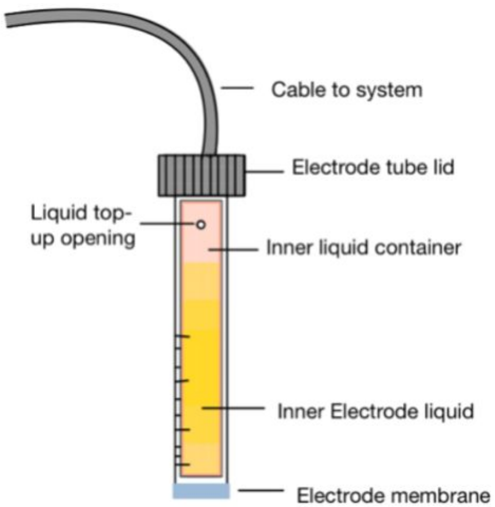
Reducing ageing effects

Ion Selective Electrode Measurements

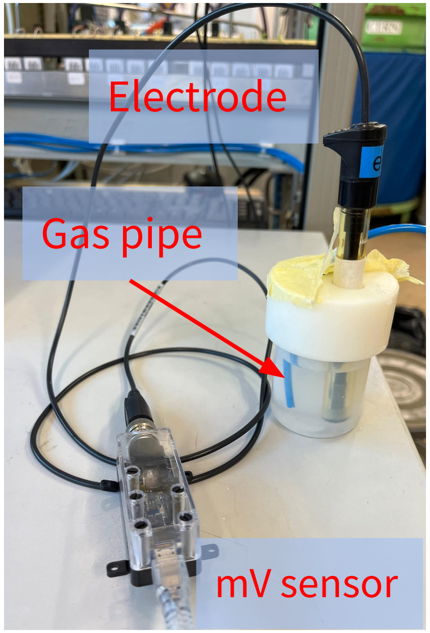
Potentiometric technique that allows to measure the concentration of F^- in a specified solution of water + TISAB (Total Ionic Strength Adjustment Buffer)

- Real-time measurements;
- Wide concentration measurements range;
- Inexpensive and easy to operate.





Example of ISE setup



This measurements are not trivial, several parameters need to be fixed:

- Gas flow to the sampling bottle;
- Gas pressure;
- Volume of the sampling solution;
- Periodic calibration;
- …

And you need to operate with an high irradiation!

Ion Selective Electrode Measurements

NEW

Where is it possible to find such high background irradiation conditions?

- LHC experiments
- GIF++ Facility
- **Dedicated set up @ 904**

LHC experiments
- "Parasitic" measurements;
- Long sampling time needed (~months).

GIF++ Facility
- Quite low statistic: -> less detectors;
- No free access to setup;
- Long and repeated measurements needed.

Dedicated set up @ 904
- Lower irradiation background;
- Long and repeated measurements needed.

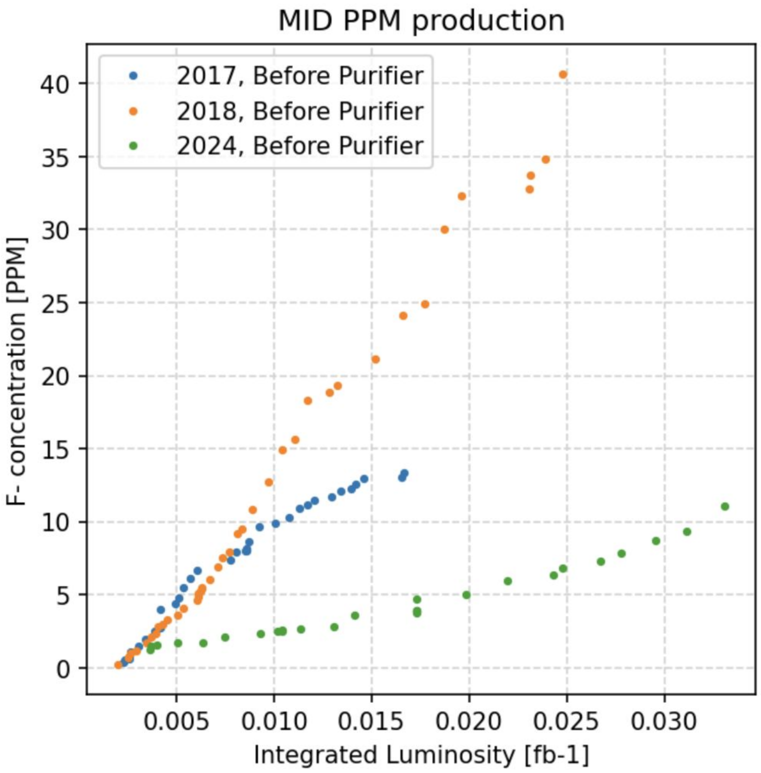
LHC experiments
- F^- as a function of Luminosity and Integrated Charge;
- Comparison with previous run (starting from 2017 RUN2);
- Excellent statistic -> sampling all detectors.

GIF++ Facility
- F^- as a function of Gas Mixture, Integrated Charge and Background Irradiation;
- Setup could be used to improve the actual measurements method.

Dedicated set up @ 904
- F^- as a function of Gas Mixture and Integrated Charge;
- Short Pipes and Controlled Environment;
- Used with Straw detectors, but possibility to extend it to other technologies.

Ion Selective Electrode Measurements

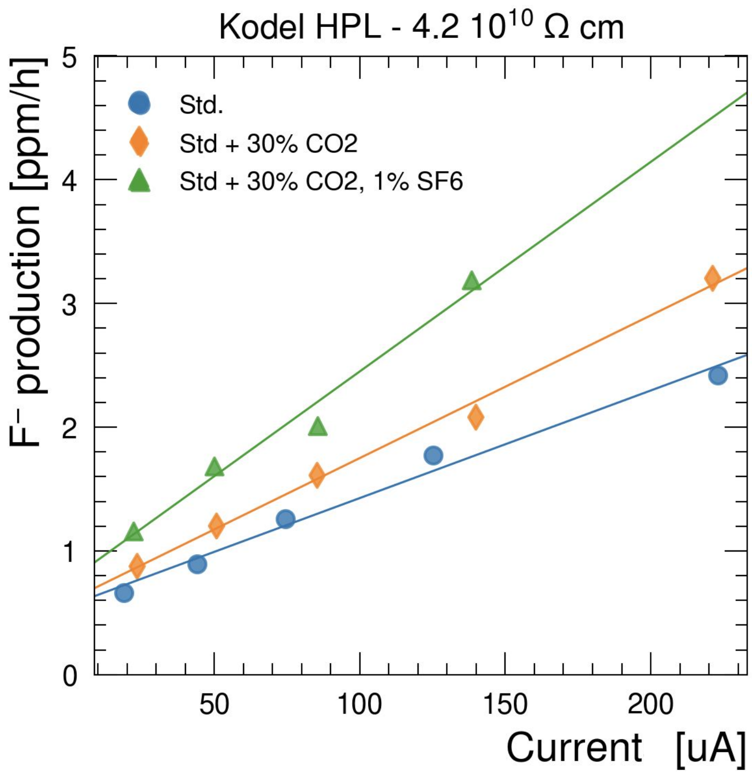
LHC experiments:
ALICE MID example



- Accumulated F^- over months of irradiation
- Good accuracy: sampling of the common exhaust of the 72 RPCs

M. Verzeroli, RPC2024
B. Mandelli, JINST

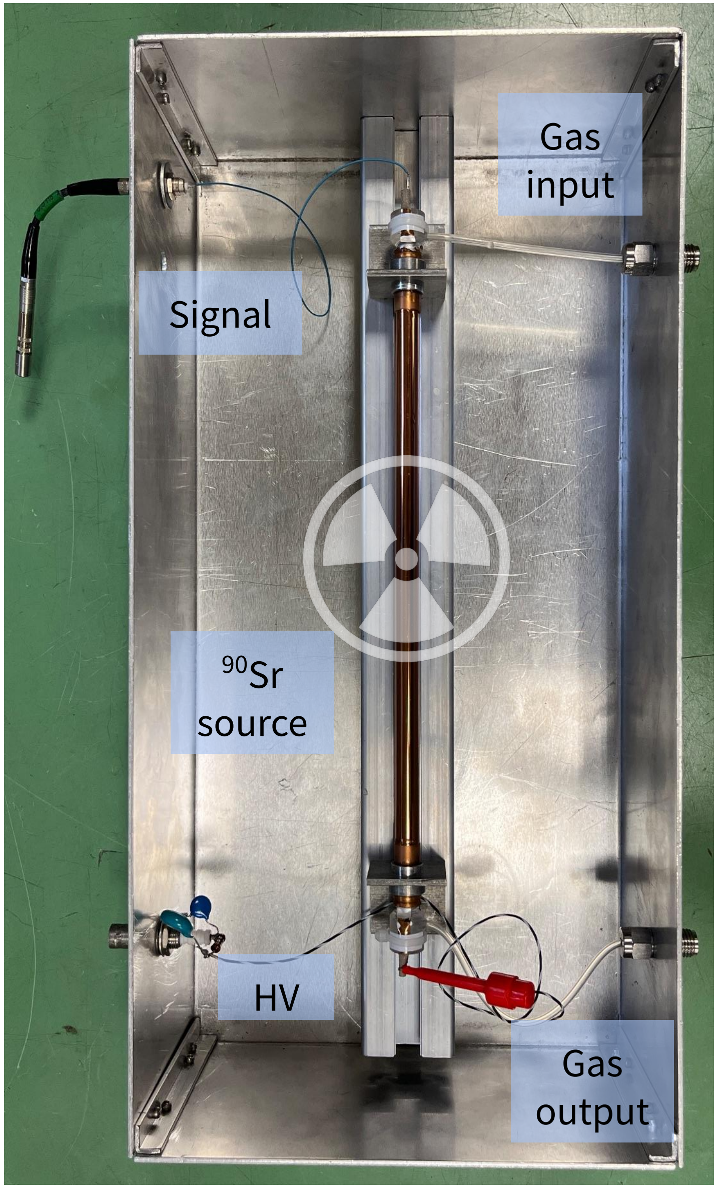
GIF++ facility
EPDT RPC example



- Measurements for different background irradiation
- Measurements for different gas mixtures

M. C. Arena, Stability 2023
G. RIgoletti, NIMA

Dedicated setup @ Bld. 904



Straw detector:

- Selected for small gas volume and thin, transparent envelope to the source;
- ∅ 1 cm, Length 21 cm;
- Provided by StrawTrackerRD team;
- Operated at 2140 V for the studied 40% Ar-based gas mixture.

^{90}Sr source;

- 235 MBq.

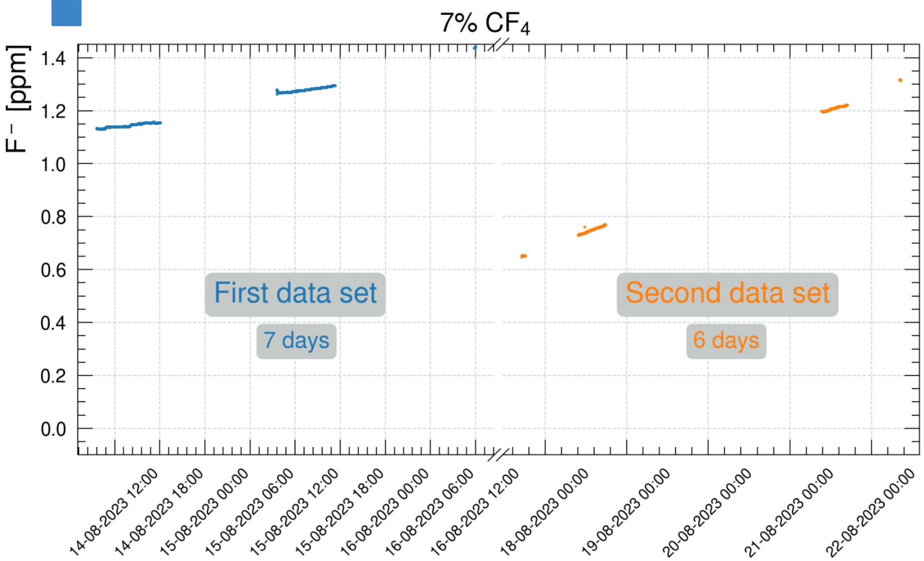
Sampling bottle:

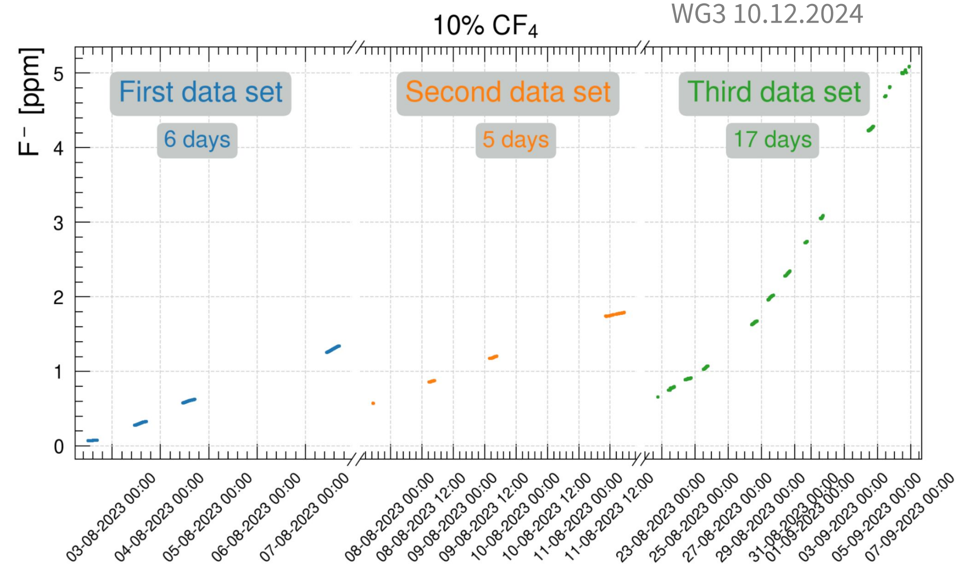
- 20 ml solution;
- Fixed 0.6 ln/h flow;
- Pipes length short as possible.

Measurements performed in collaboration with EP-DT-FS and CMS CSC group in the contest of the Summer Students project.

The **goal** is to use the straw detector to investigate the F^- production in CMS CSC gas, focusing on the CF_4 contribution to this production, and to prepare for the comparative measurements within searches for CF_4 alternatives.

Overview of the measurements





7% CF4: 2 data sets;
10% CF4: 3 data sets.

EP/DF/FS + CMS CSC Summer Students

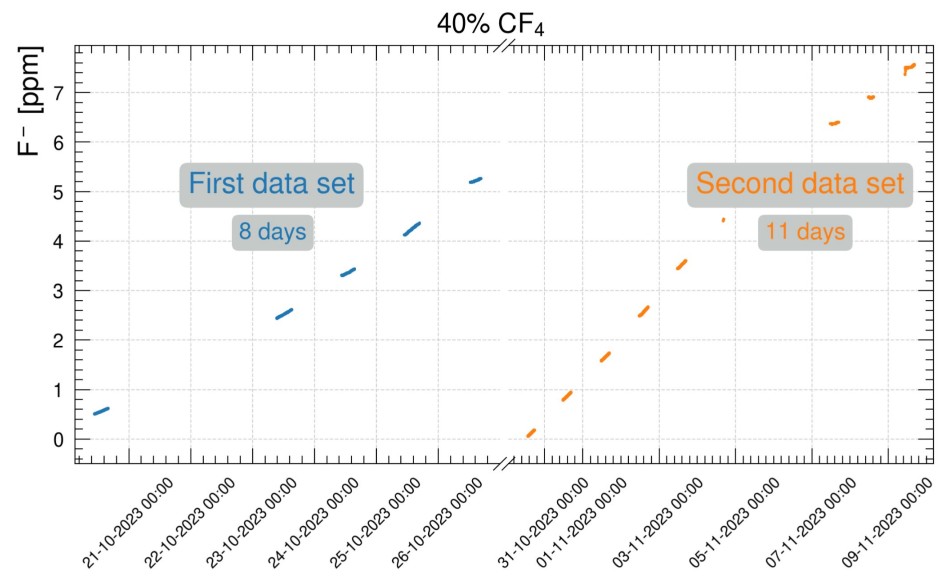
40% CF4: 2 data sets.

June - November 2023

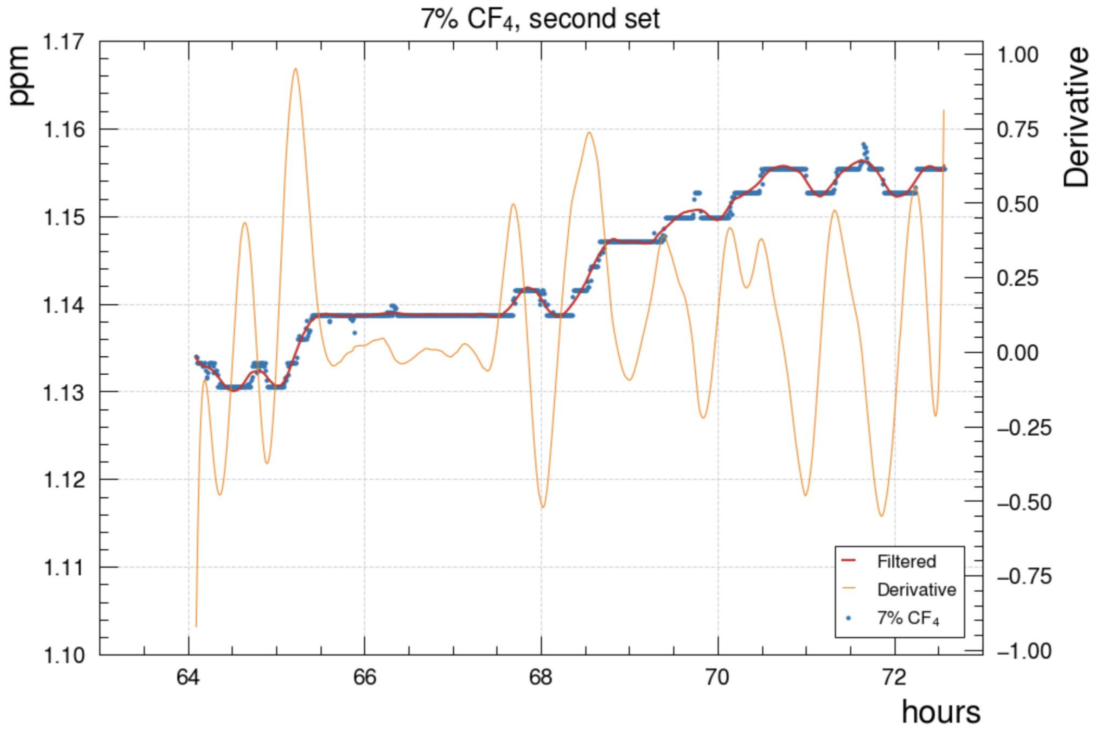
CMS CSC Student

Gas mixture:
$Ar/CO_2/CF_4$

With Ar 40% and variable $\%CO_2$ and $\%CF_4$



Data selection and analysis



After ~8 hours of measurements, not stable ppm increase:

- Change in gas flow;
- Change in temperature and pressure;
- Evaporation of the solution bottle;
- Electrode calibration non optimal;
- Difference in bubble surface;
- …

-> Not all the data shows a good reliability and a <u>data selection need to be performed.</u>

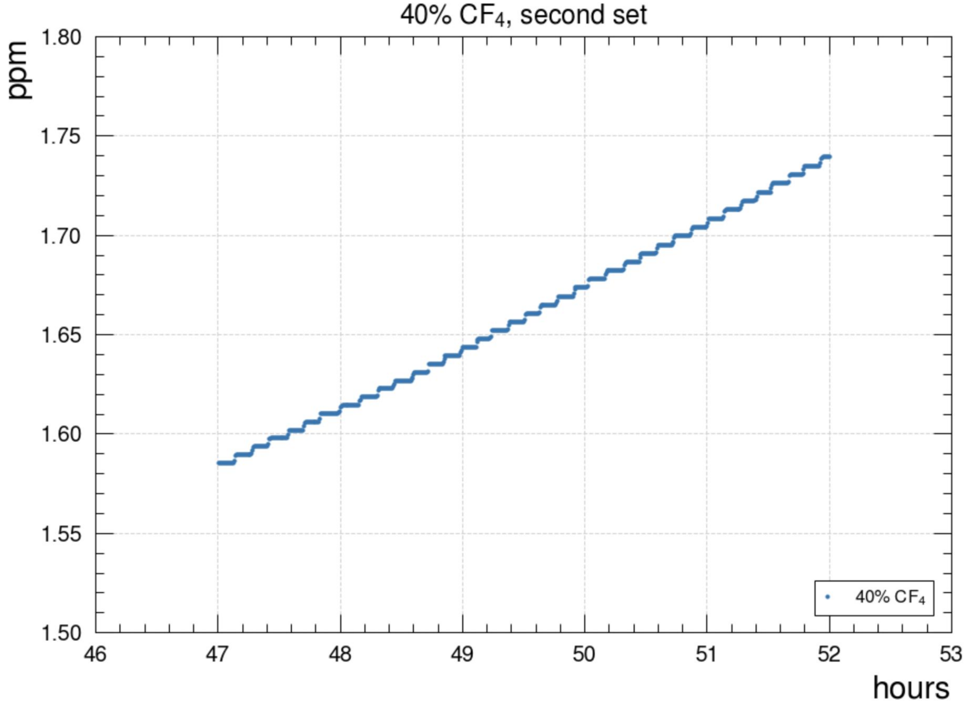
26 independent measurements -> <u>13 selected</u>

Quite tricky measurements due to the amount of possibly systematic and environmental related errors…

Data selection and analysis

For the data selection, the following step were considered:

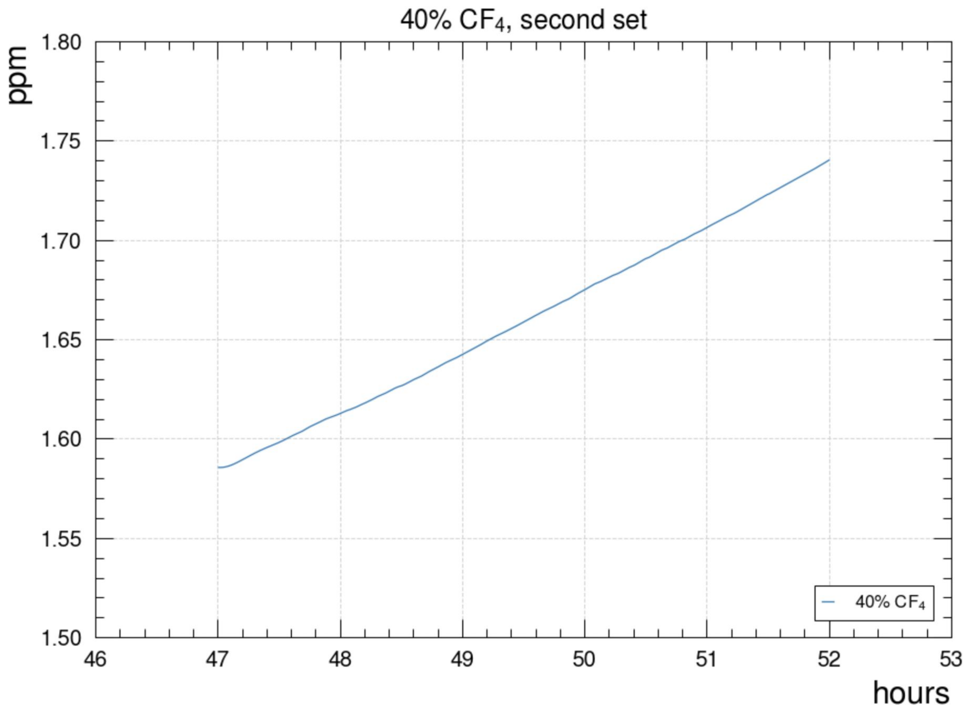
1. Data smoothing with Savitzky-Golay filter (python-based);
2. Computation of the data derivative;
3. Selection of the bigger data interval were the derivative is stable (±0.1);
4. Linear fit performed on this interval.



Data selection and analysis

For the data selection, the following step were considered:

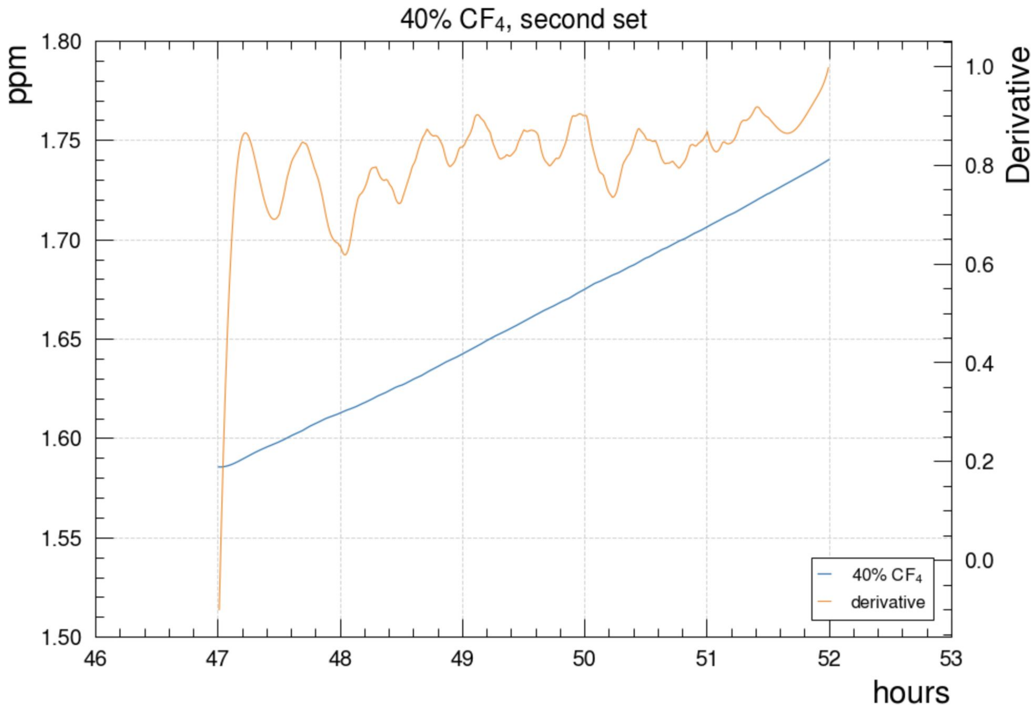
1. Data smoothing with Savitzky-Golay filter (python-based);
2. Computation of the data derivative;
3. Selection of the bigger data interval were the derivative is stable (±0.1);
4. Linear fit performed on this interval.



Data selection and analysis

For the data selection, the following step were considered:

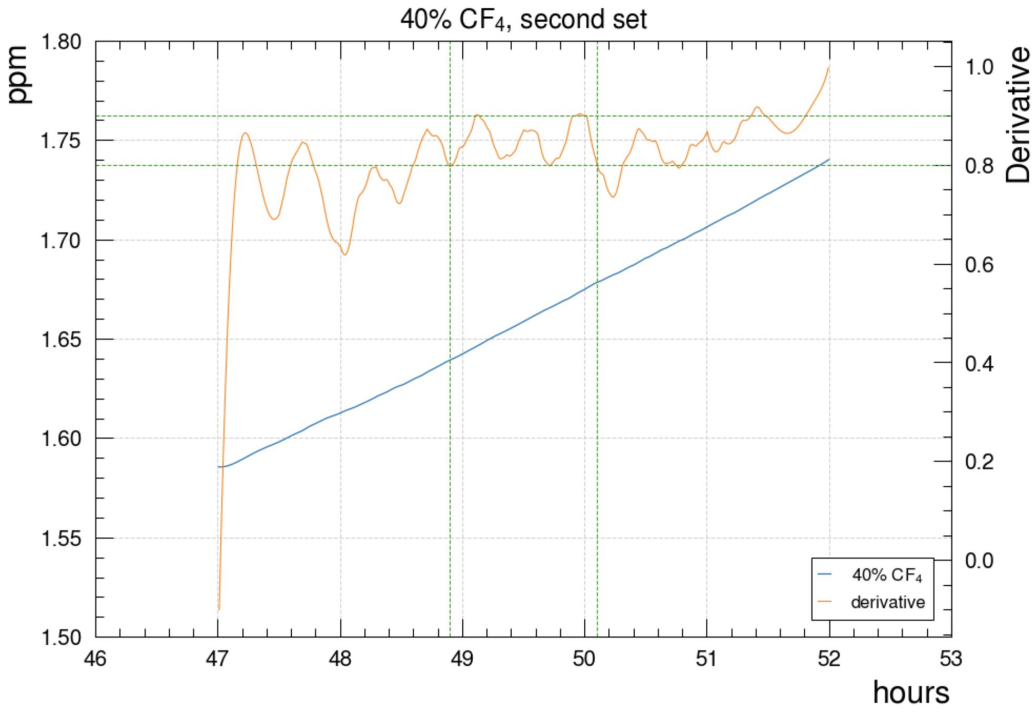
1. Data smoothing with Savitzky-Golay filter (python-based);
2. Computation of the data derivative;
3. Selection of the bigger data interval were the derivative is stable (±0.1);
4. Linear fit performed on this interval.



Data selection and analysis

For the data selection, the following step were considered:

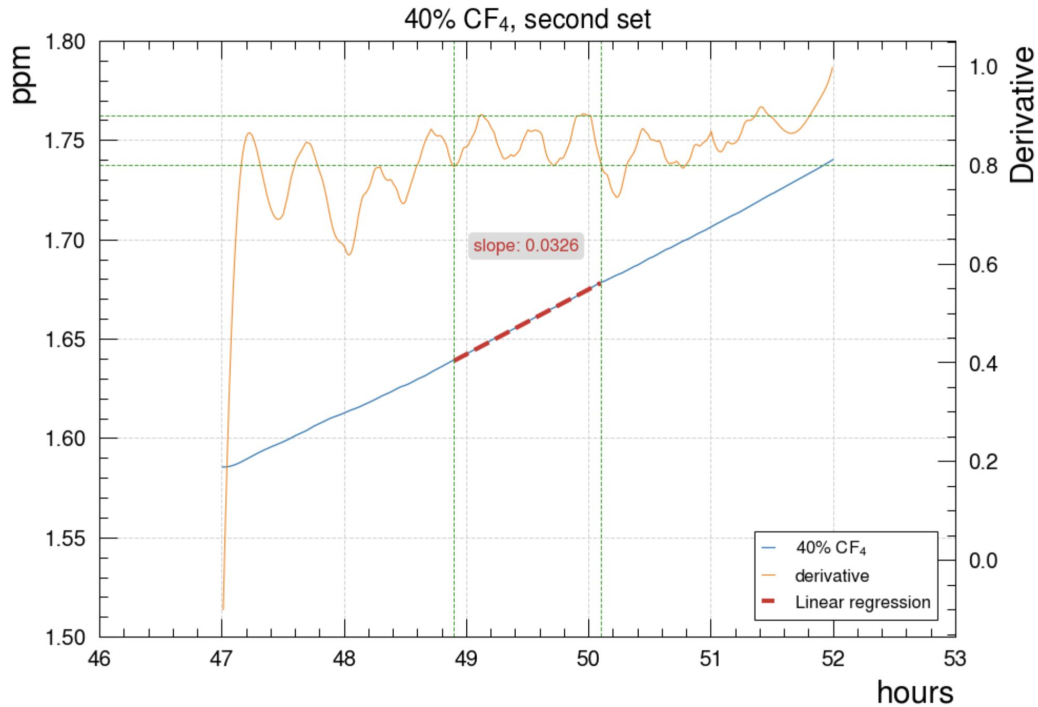
1. Data smoothing with Savitzky-Golay filter (python-based);
2. Computation of the data derivative;
3. Selection of the bigger data interval were the derivative is stable (±0.1);
4. Linear fit performed on this interval.



Data selection and analysis

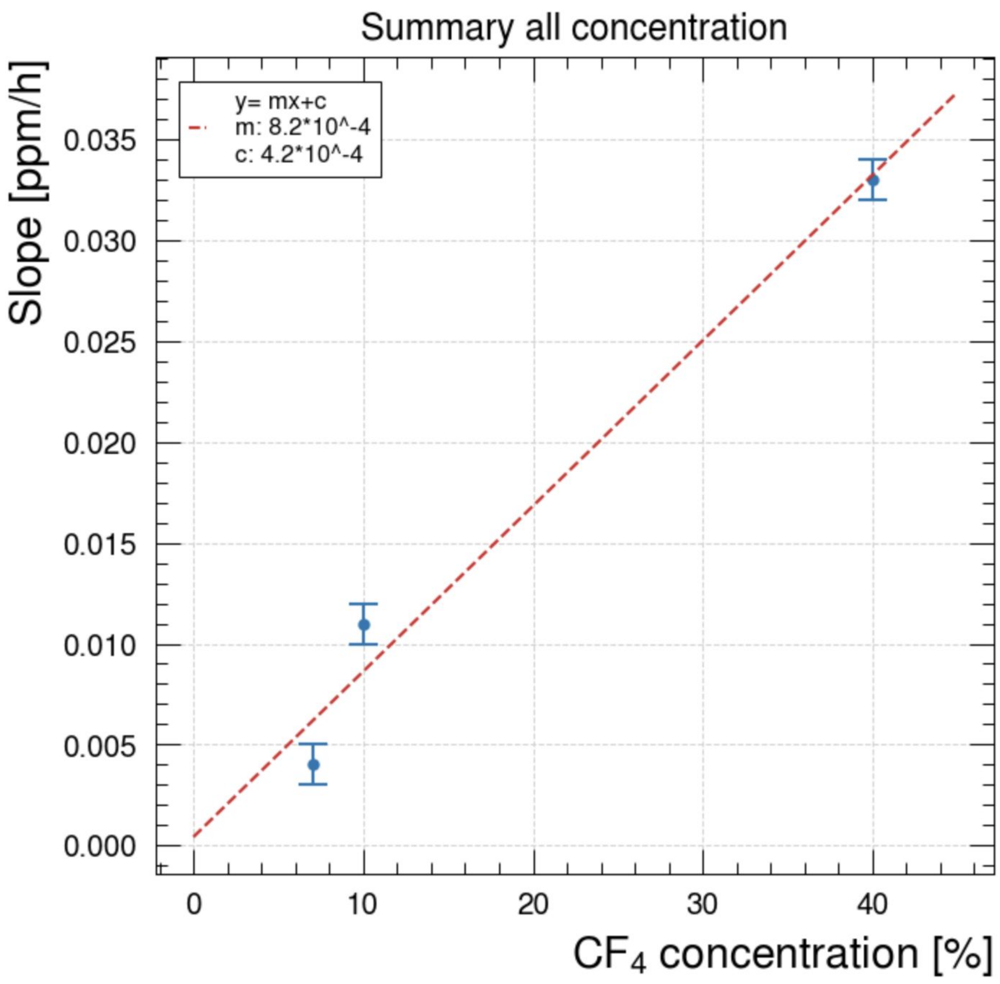
For the data selection, the following step were considered:

1. Data smoothing with Savitzky-Golay filter (python-based);
2. Computation of the data derivative;
3. Selection of the bigger data interval were the derivative is stable (±0.1);
4. Linear fit performed on this interval.



The slope is the ppm/h F^- production, and it is the results of the mean of the slope for fixed CF_4 concentration. Uncertainty is taken as mean standard deviation.

Measurements results



The increase of CF_4 brings to an increase of the ppm rate production:

The measurements suggest a linear trend, but more measurements are needed to confirm it.

Conclusion

- The dedicated new set up was commissioned during Summer 2023;

- Measurements show promising results for the study of the F^- impurities production:
  - Suggest a linear trend in the F^- production as a function of the CF_4 concentration;

- The set up is very flexible: possibility to study also other fluorinated gases (e.g. HFO) and other type of detectors.

Future improvements:

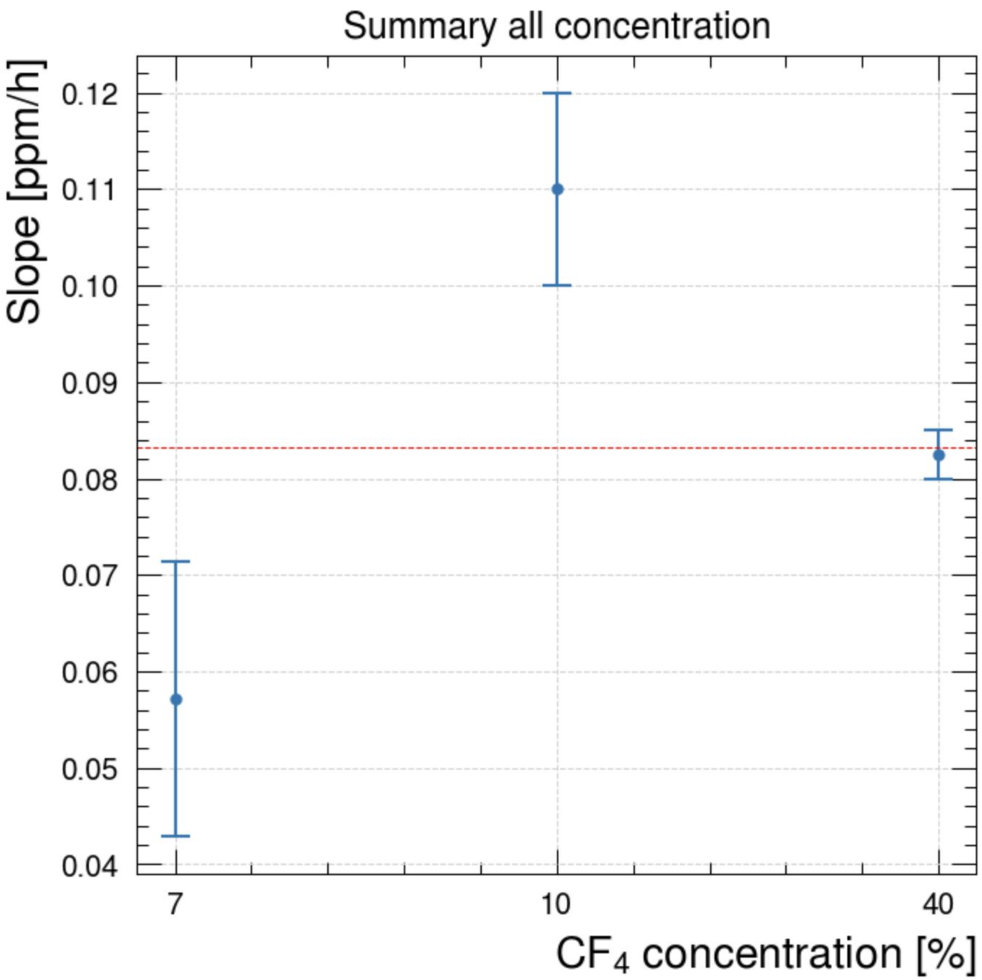
- Increase the sensitivity adding a second straw detector;

- For CSC purpose: more measurements on the range 0-10% CF_4 concentration;

- Study of error sources (such as variation of flow)

Backup

Measurements results



$F^-(\%CF_4) : F^-(\text{total } CF_4) = \%CF_4 : 100$

→ (0.08 ± 0.02) ppm/h

if the detector operated with 100% CF_4