Status Report of the Setup for Ageing and Degradation Studies of MPGDs at the São Paulo University

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Goals

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Contribute to the study of **aging and degradation of MPGDs** through **controlled experiments** and **high-sensitivity surface analyses**, enabling the investigation of **processes in their early stages**.

This approach aims to provide insights that benefit both **future** and **current** experiments, particularly the **ALICE-TPC**.

Importance of aging for future experiments

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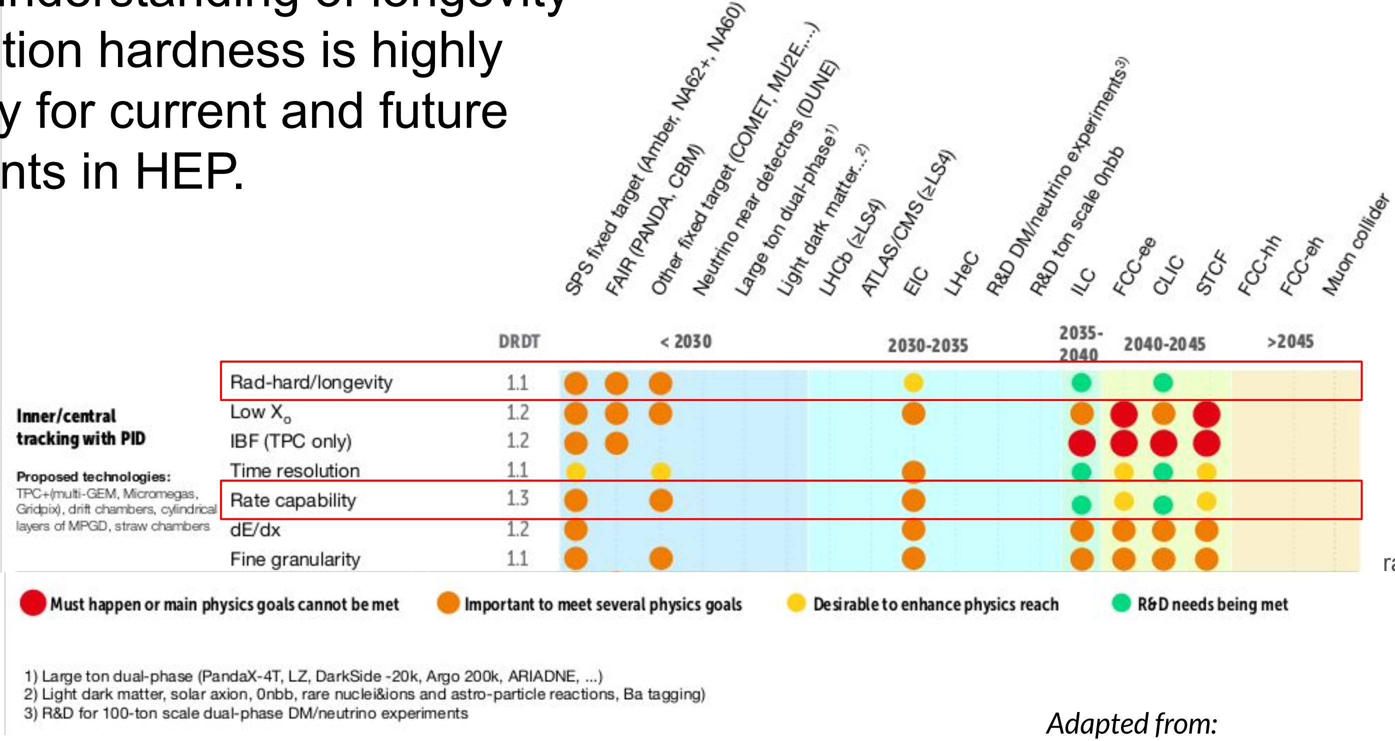
A better understanding of longevity and radiation hardness is highly necessary for current and future experiments in HEP.



Rate capability is linked to rad-hard/longevity

Adapted from:
R&D Roadmap of the European Committee for Future Accelerators (ECFA) 2021

Importance of aging for future experiments

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Growing demand for information regarding the robustness of materials and susceptibility to aging of MPGDs

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Implementation of the HEP instrumentation R&D roadmap in the USA

Petra Merkel

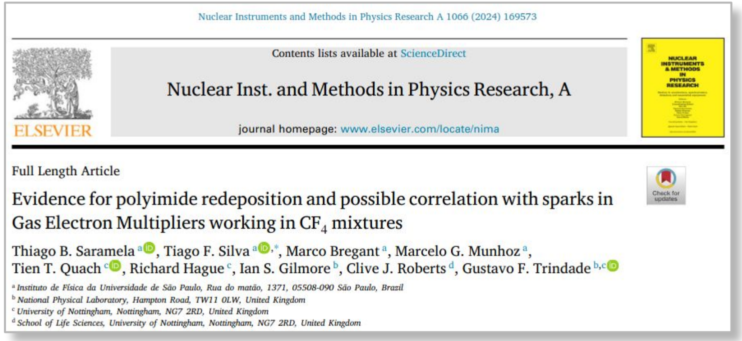
Fermilab, PO Box 500, 60510-0500, Batavia, IL, USA

3.6. RDC 6: Gaseous detectors

- Advance gas TPC readout to performance limits, enabling new experiments: maximize sensitivity by achieving 3D single electron counting, minimize background by developing radio-pure MPGDs, develop matching, highly scalable front-end electronics and readout systems, develop on-detector AI/ML and trigger-driven, highly multiplexes readouts.
- Advance MPGDs for high-background environments: develop cylindrical and exotic-shape tracking layers, develop picosecond timing layers, improve radiation hardness, rate capability, robustness against sparking and aging.
- Establish MPGD development, prototyping and production facility in the US.

Previous results on GEM surface analysis

- Surface analysis revealed polyimide residuals and by products deposits on the electrode surface
  - Possible correlation with sparks
- Chromium diffusion into the electrodes
  - Possible thermal anisotropy
- Migration of polyimide additives
  - Possibly due to electric fields


Nuclear Instruments and Methods in Physics Research A 1066 (2024) 169573

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Full Length Article

Evidence for polyimide redeposition and possible correlation with sparks in Gas Electron Multipliers working in CF_4 mixtures

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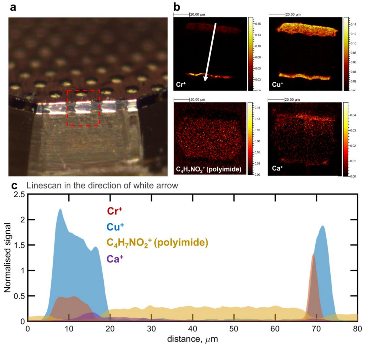

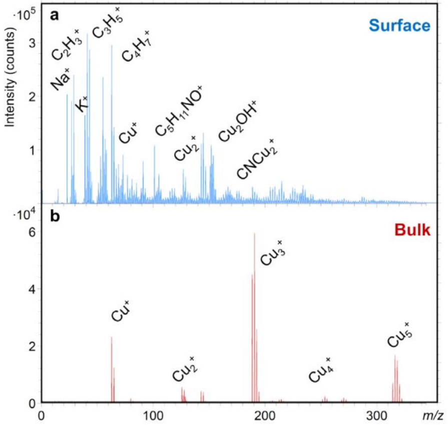

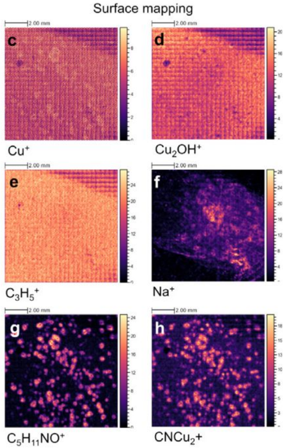

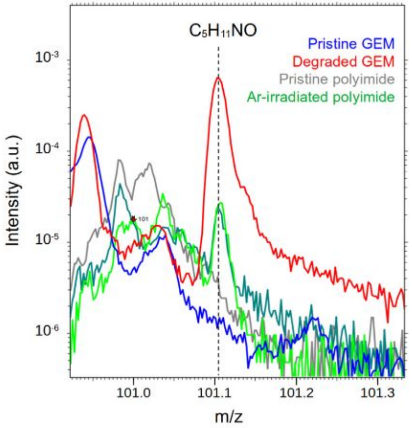

The setup for aging studies of MPGDs

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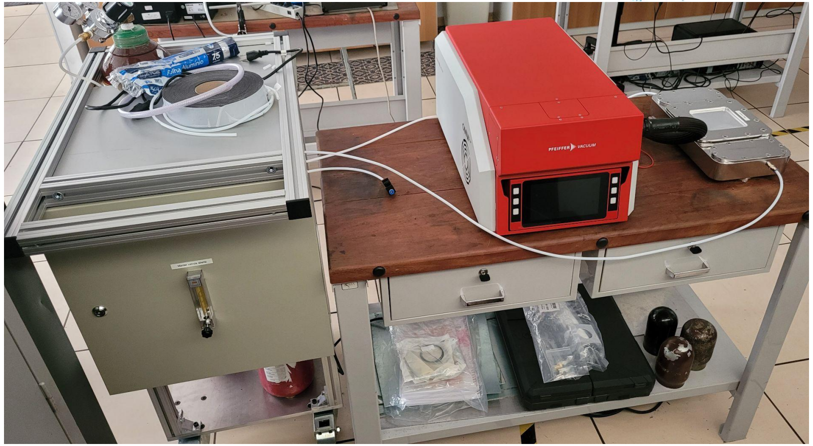
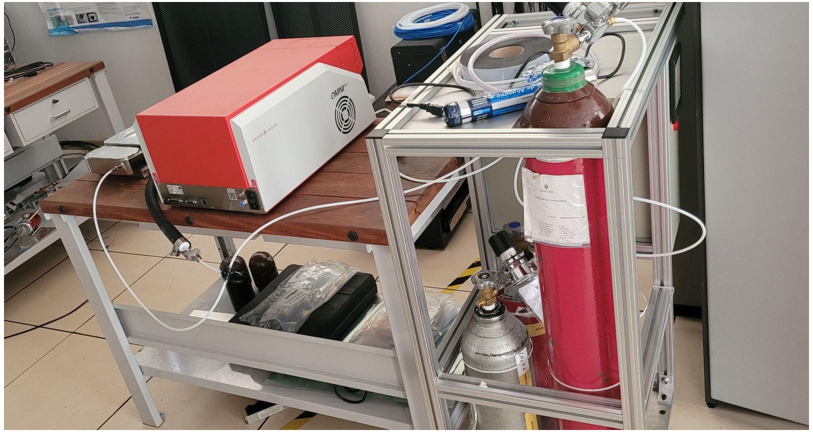
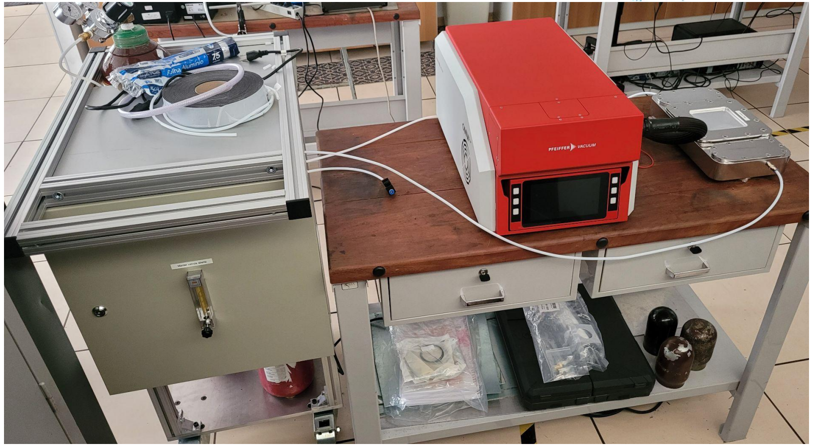
- **Topics to study:**
  - Influence of gas mixture
  - The role of humidity in the classical aging process
  - Evaluate possible release of hydrogen content molecules from the polyimide and their influence in the aging process
  - Exploit high-sensitivity surface analysis techniques to study early stages of aging and degradation

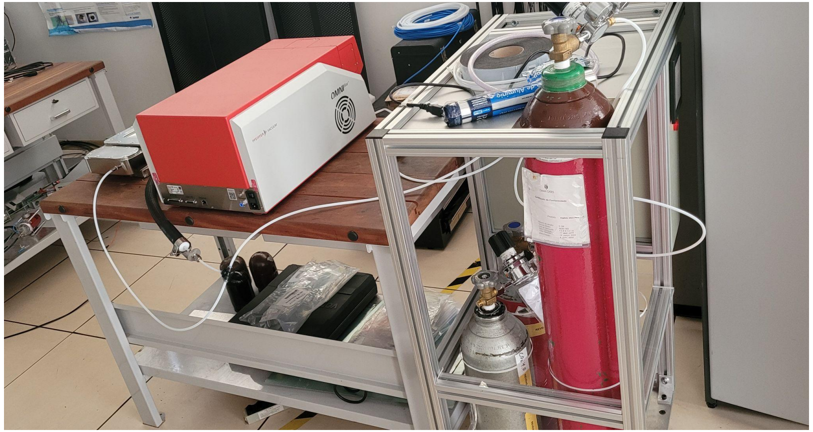




The setup for aging studies of MPGDs

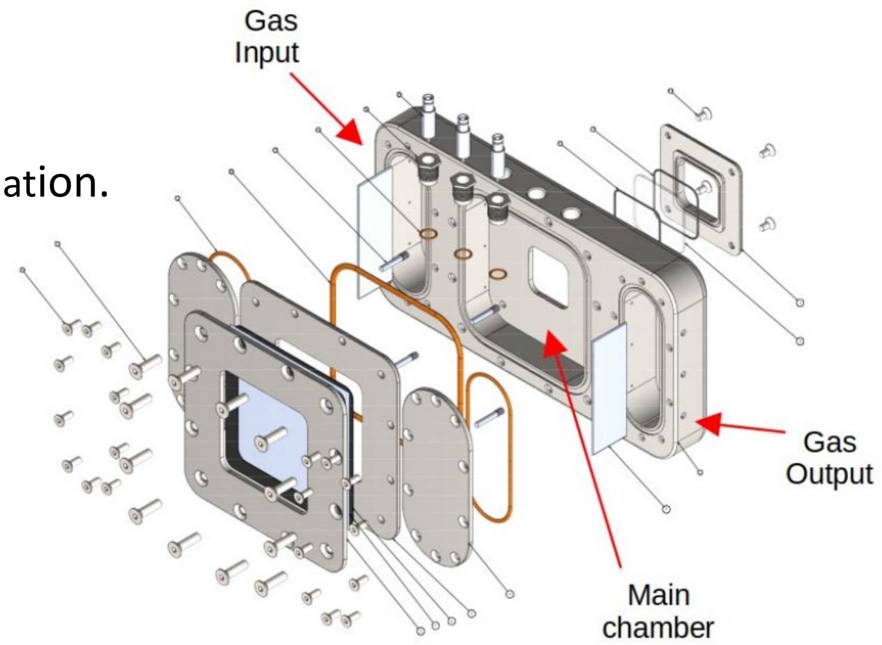
- Setup target the as clean as possible environment for GEM degradation
  - Polished stainless steel chamber
- Reduced humidity levels
  - Teflon tubing
- Gas flow, mixtures, and pressure controls for flexibility of test
  - Four mass flow meters and a pressure controller
- Gas composition monitoring with ppm level of impurity traceability
  - Mass spectrometry for gas analysis at the ambient pressure





The setup - the degradation chamber

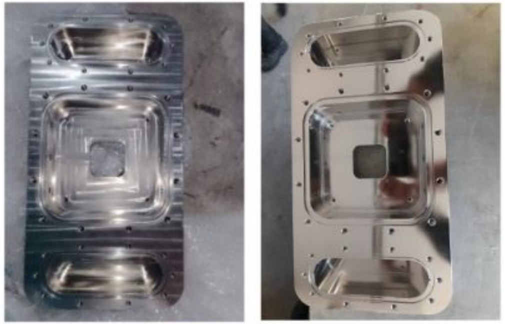
- **Stainless steel chamber**
  - Clean ambient and avoid degassing.
- **Inlet/Filtering Chamber**
  - Filed with purifying materials.
  - Removal of eventual H_2O and O_2 contamination.
- **Outlet/Monitoring chamber**
  - Environmental sensors:
  - Temperature and pressure.
  - Gas quality monitoring:
  - H_2O, O_2 and $\mathbf{H_2}$.
- **Both attached to the GEM chamber**
  - To avoid tubes.



The setup - the degradation chamber

Production

Polishing



Sealing

Testing

The setup - gas flow and pressure control

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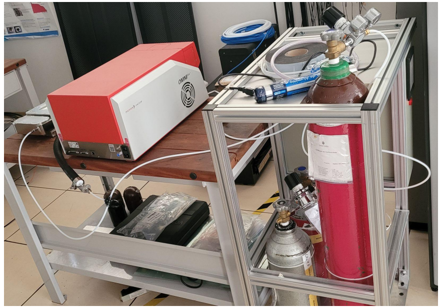
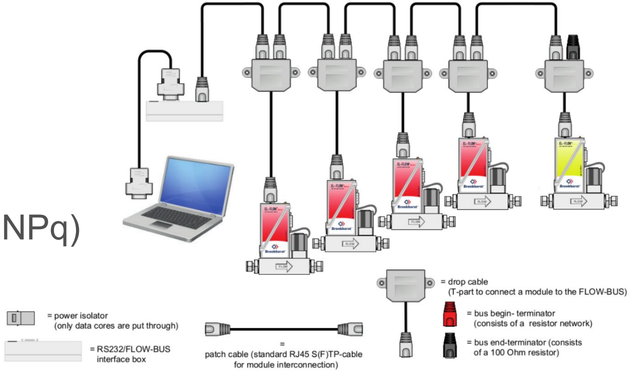
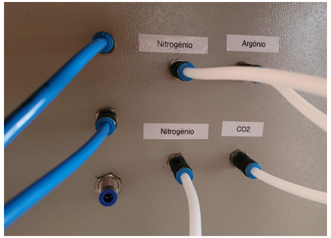
- Gas flow controller:
    - Model: F-201CV-500-RBD-33-K
    - Gas volume control capability: 0,16 ml_n/min - 25 l_n/min
    - Operating pressure: Vacuum - 64 bar
    - Seals: Kalrez®(FFKM)
- Pressure controller:
    - Model: P-702CV-1K1A-RBD-33-K
    - Pressure control capability: 0,35 – 1,1 bar
    - P-max: 3,1 bar
    - Burst pressure: 4,2 bar
    - Back pressure control







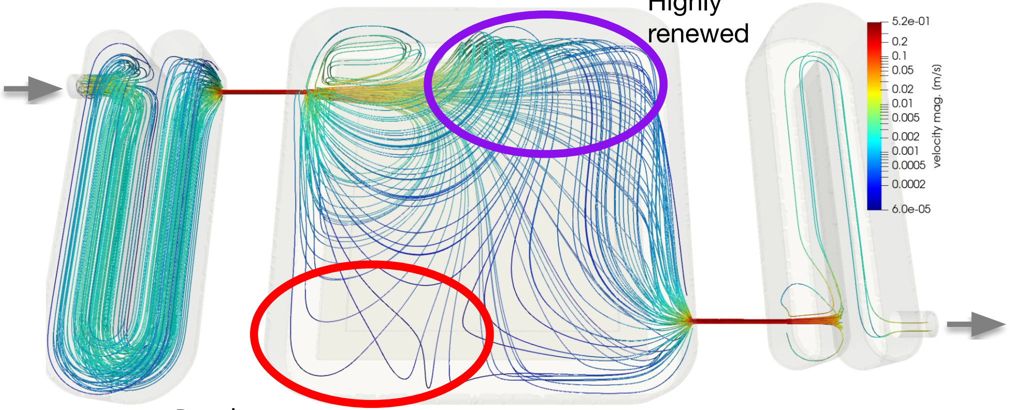
Project with contributions from:

Willian Wallace Ribeiro Alves da Silva (DR-CNPq)
Eduardo dos Santos Palermo (MS-CNEN)
Renan Ferreira de Assis (LAMFI-USP)

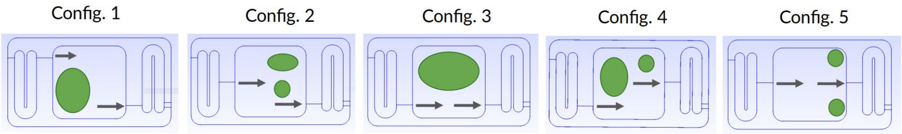
The setup - gas flow simulations

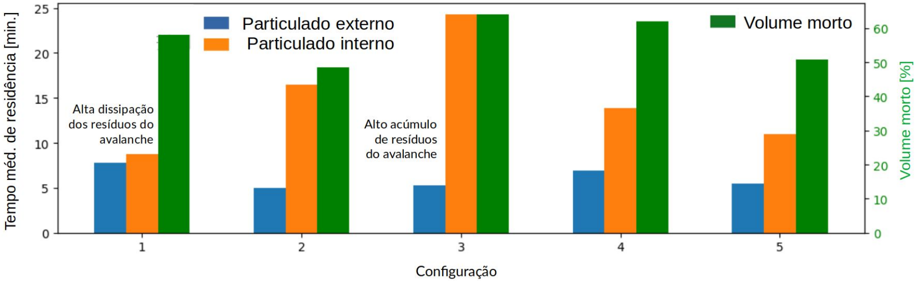
The flow is not homogeneous in the GEM chamber, effect will be position-dependent?

Highly renewed



Poorly renewed (dead volume)





The choice of inlet and outlet position influence the residence time and dead volume sizes.

The setup - gas content monitoring

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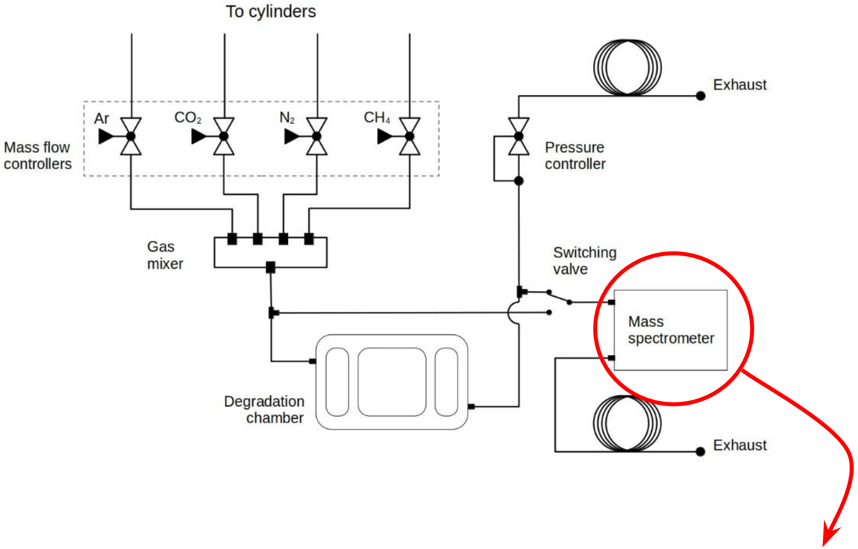
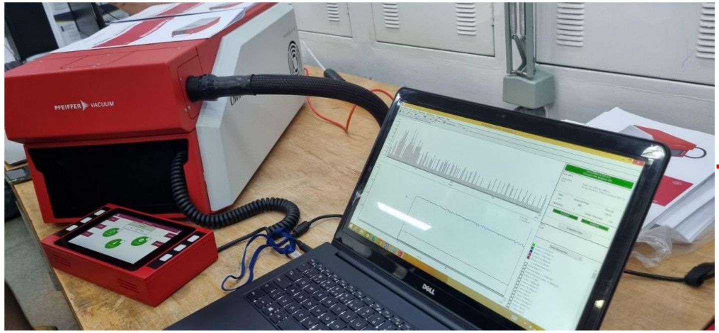




Online gas analysis by molecular mass spectroscopy with ppm sensitivity to trace contaminants or material outgas

Technical info:

- Manufacturer: Pfeiffer Vacuum
- Model: OmniStar® GSD 350 O2
- Mass range: 1 - 200 amu
- Operating temperature: 10 - 40ºC
- Contribution to neighbor mass: <20 ppm
- Min. detection limit.: C-SEM (ppm) <1 ppm
- Max. escape pressure.: 1 atm
- Max. inlet pressure: 1,2 atm
- Filament: Tungsten
- Capilar heating: up to 200 ºC

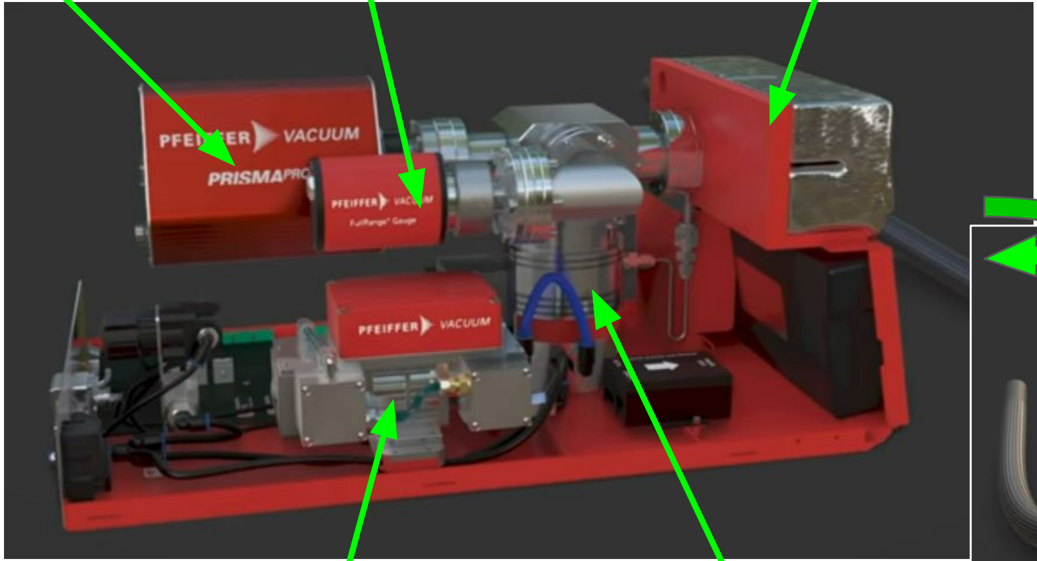
Mass spectrometry gas analyzer

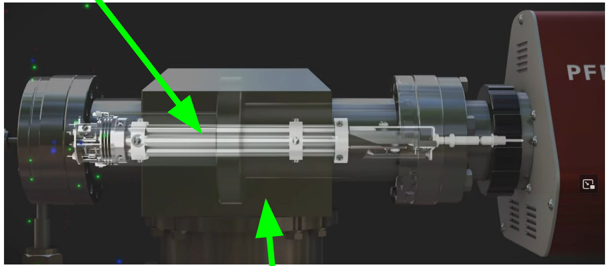
Quadrupole mass spectrometer

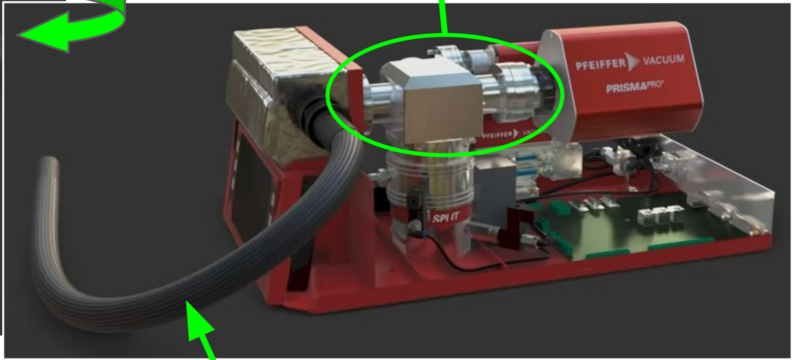
Pressure gauge

Differential pumping chamber

Quadrupole electrode





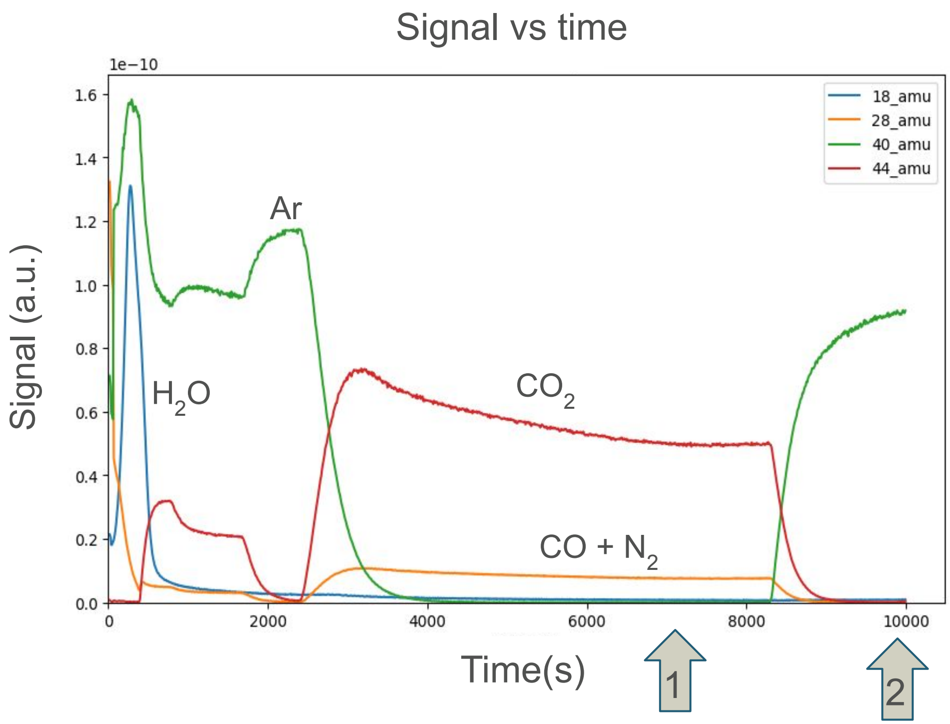


Diaphragm pump

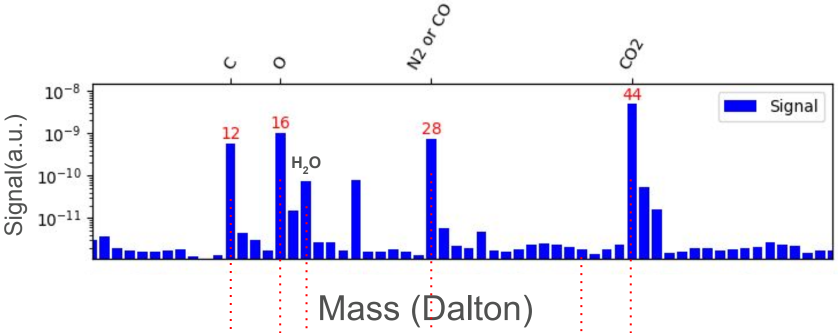
Molecular turbo pump

Gas inlet

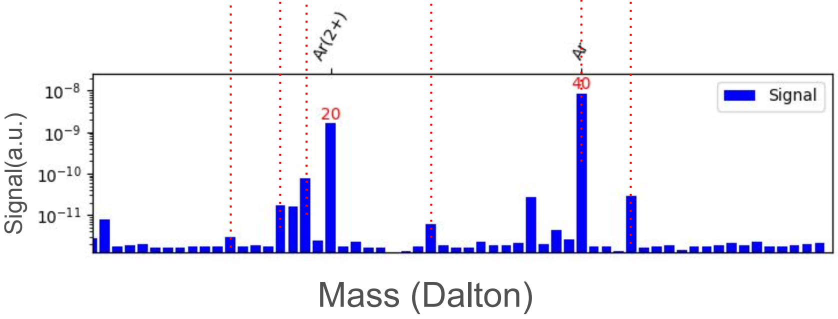
Mass spectrometry gas analyzer



1: CO_2



2: Ar



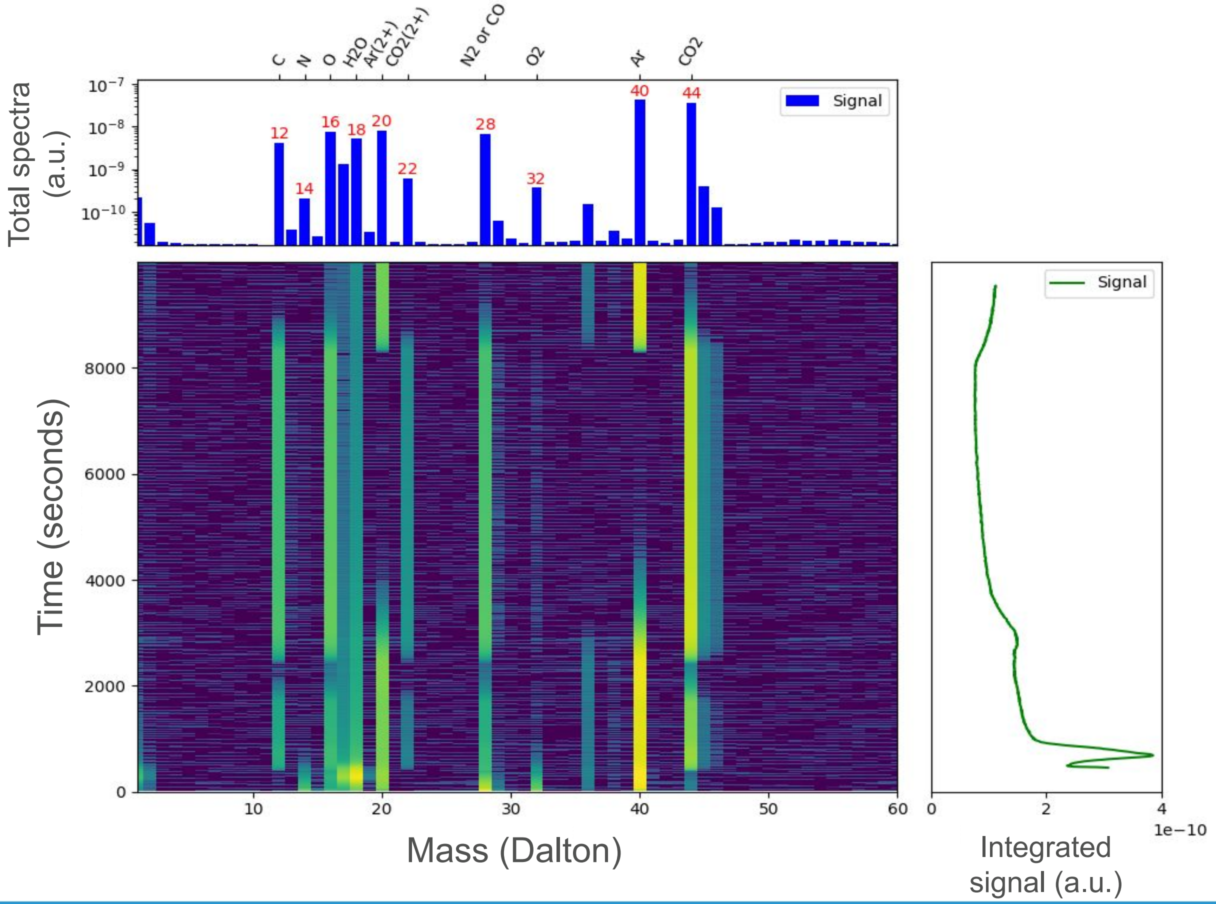
*CO and O as fragments of CO_2 by electron impact in the spectrometer.

Mass spectrometry gas analyzer

Simultaneous measurement of all masses

Signal correlation to resolve ambiguities

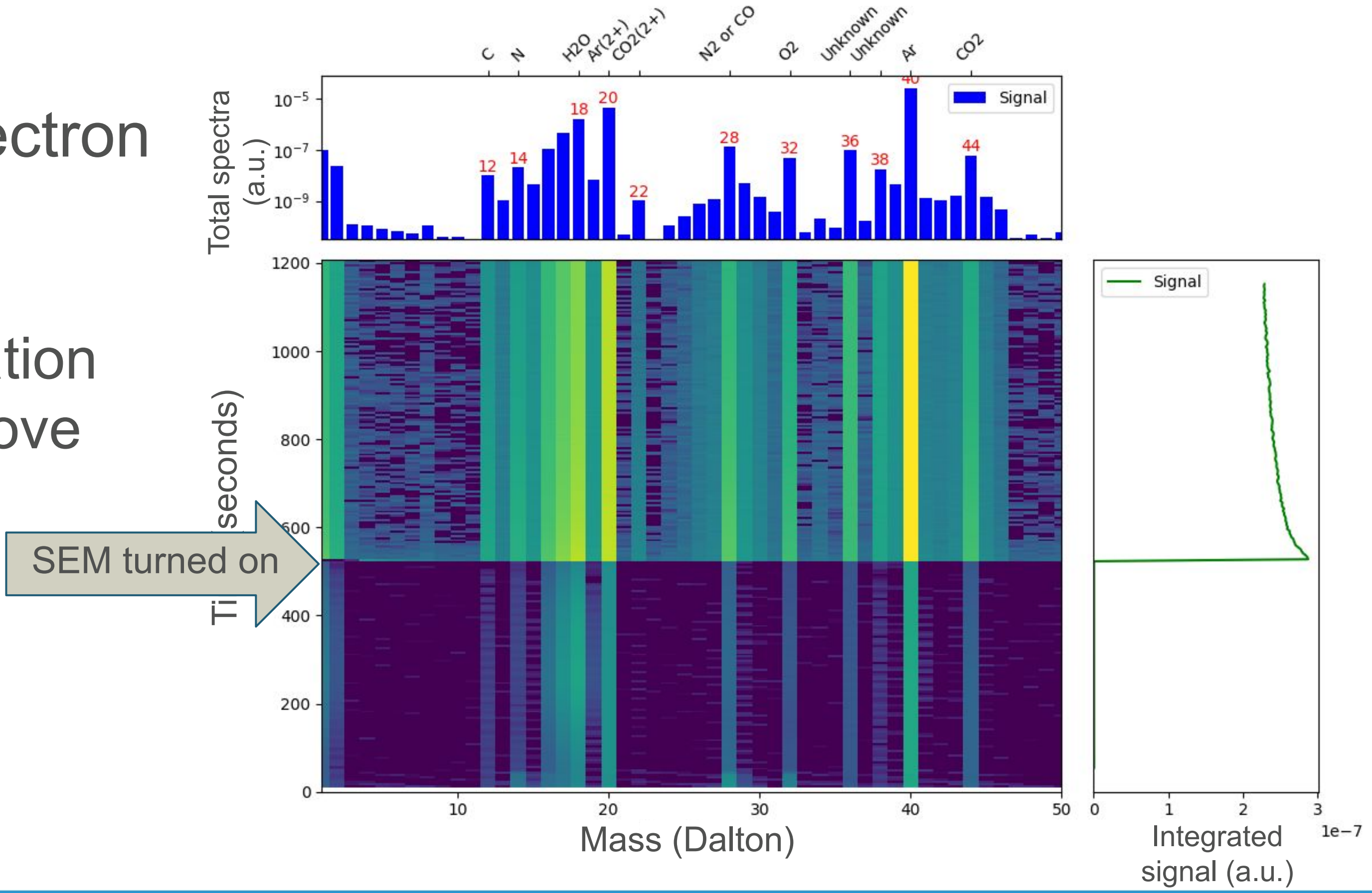
	12_amu	14_amu	16_amu	17_amu	18_amu	20_amu	22_amu	28_amu	32_amu	40_amu	44_amu
12_amu	1	-0.2	0.99	-0.29	-0.29	-0.89	0.98	0.19	-0.21	-0.89	1
14_amu	-0.2	1	0.091	0.31	0.3	0.18	-0.2	0.92	1	0.18	-0.21
16_amu	0.99	0.091	1	-0.18	-0.18	-0.87	0.97	0.3	-0.098	-0.87	0.99
17_amu	-0.29	0.31	-0.18	1	1	0.48	-0.28	0.2	0.34	0.46	-0.29
18_amu	-0.29	0.3	-0.18	1	1	0.48	-0.28	0.2	0.34	0.46	-0.29
20_amu	-0.89	0.18	-0.87	0.48	0.48	1	-0.86	-0.17	0.2	1	-0.87
22_amu	0.98	-0.2	0.97	-0.28	-0.28	-0.86	1	0.19	-0.21	-0.87	0.99
28_amu	0.19	0.92	0.3	0.2	0.2	-0.17	0.19	1	0.92	-0.17	0.19
32_amu	-0.21	1	-0.098	0.34	0.34	0.2	-0.21	0.92	1	0.2	-0.22
40_amu	-0.89	0.18	-0.87	0.46	0.46	1	-0.87	-0.17	0.2	1	-0.88
44_amu	1	-0.21	0.99	-0.29	-0.29	-0.87	0.99	0.19	-0.22	-0.88	1



Mass spectrometry gas analyzer - SEM

Secondary **E**lectron **M**ultiplier

Signal amplification (1000x) to improve detection limit



Mass spectrometry gas analyzer - Mass range

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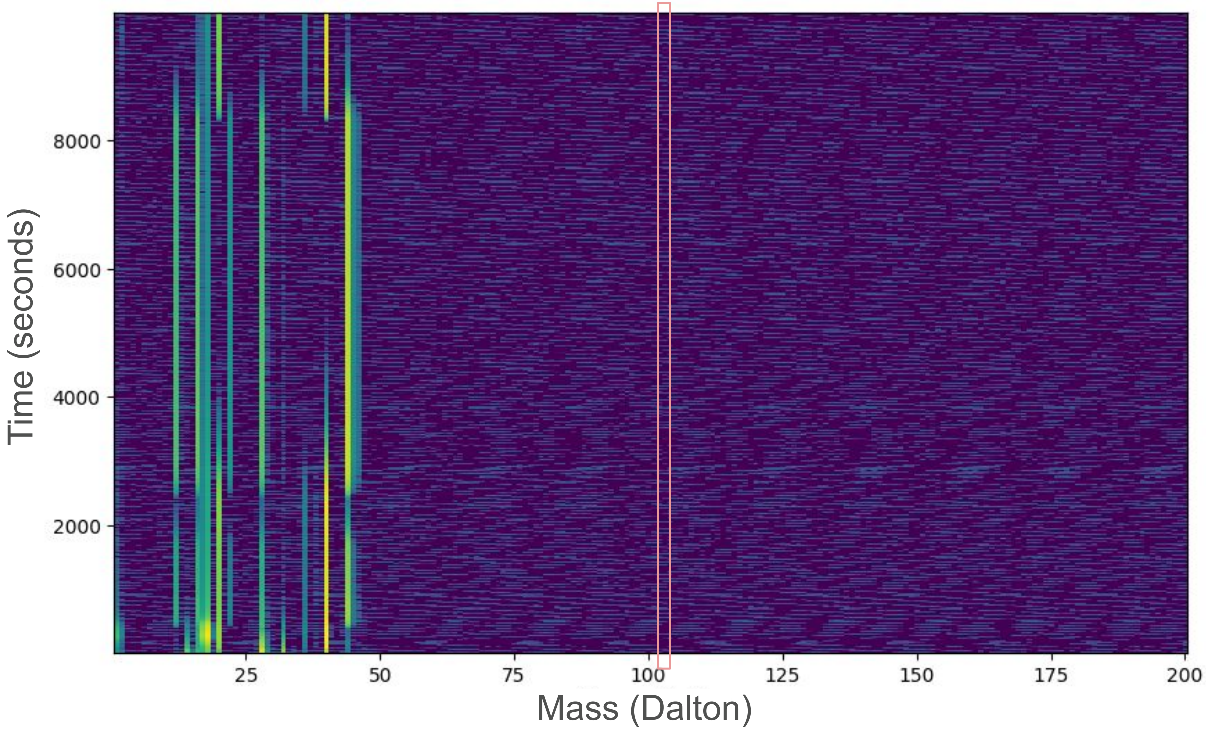
Mass range of
1 to 200 amu

Enable the detection of large hydrocarbon molecules such as $C_5H_{11}NO$ (101 amu)



GEM sample preparation - An ALICE-TPC oriented experiment

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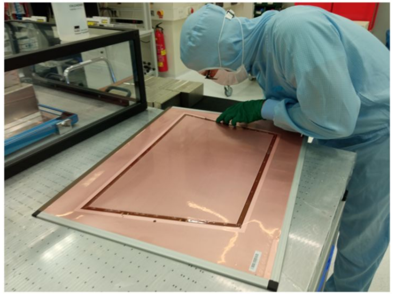
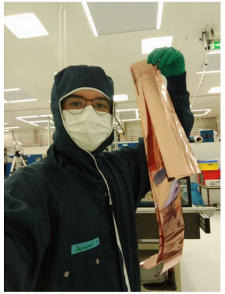
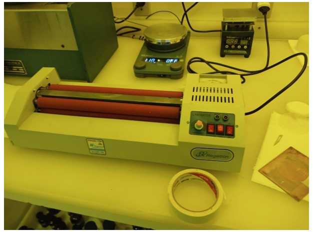
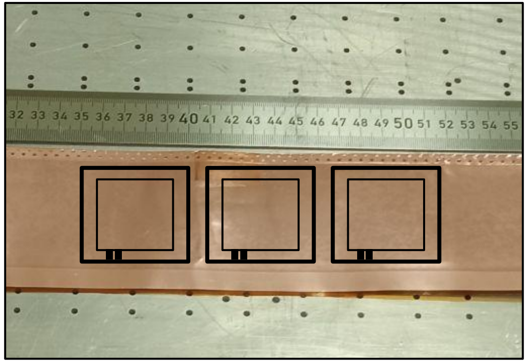
Sample production:

- ALICE-TPC GEM foils
  - 3 cm x 3 cm
- Chemical etching and frame gluing in our lab



Thermal induced outgassing tests

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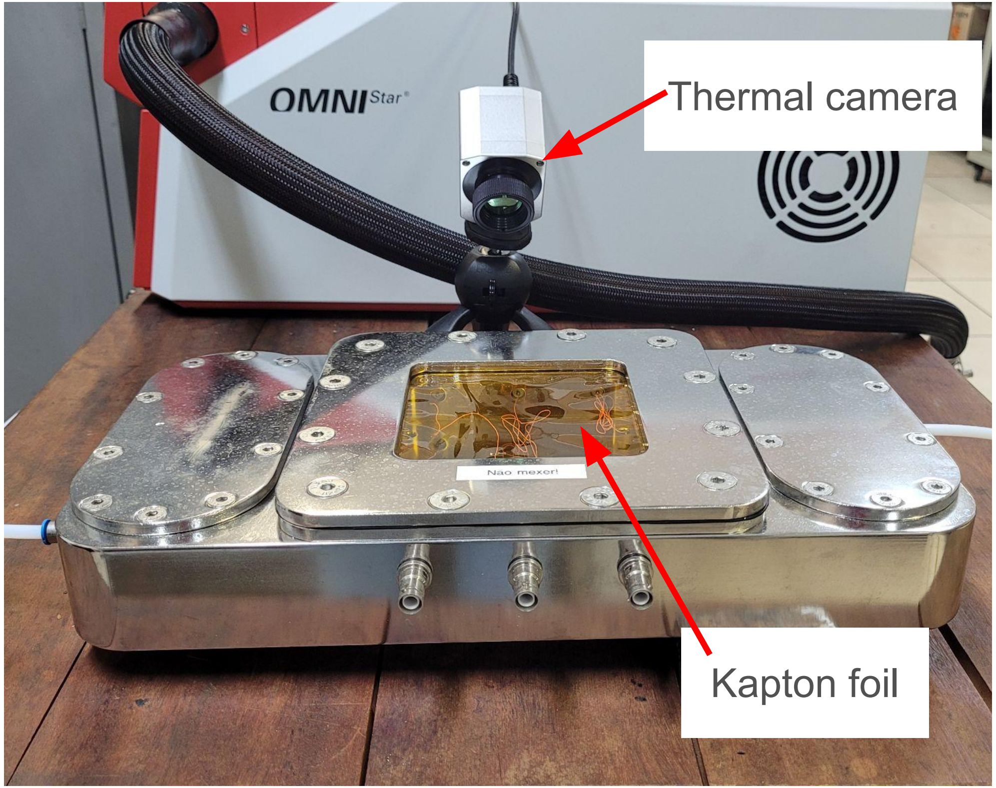
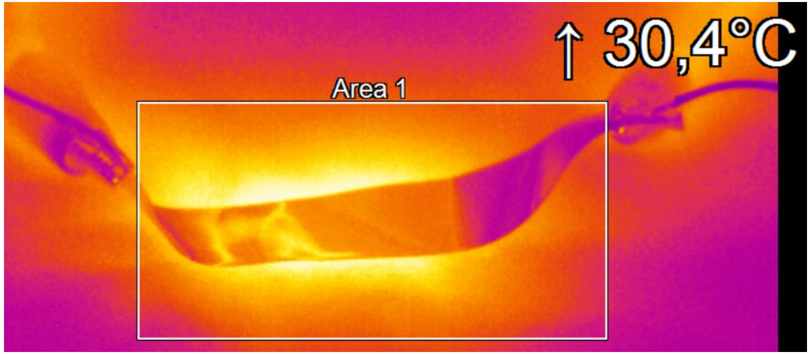
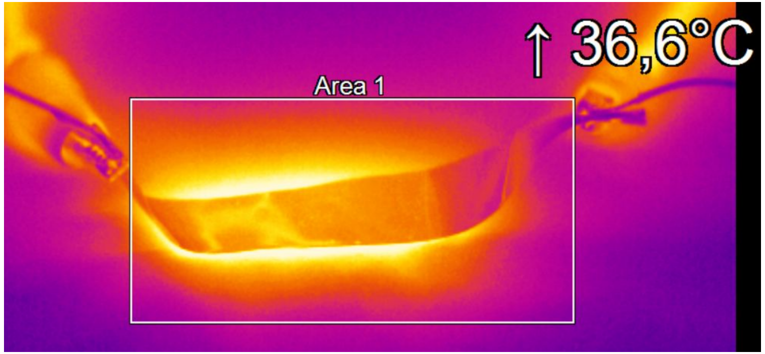
- Degradation chamber mounted with a 50μm thick kapton window (transparent to infrared)
- Infrared camera to monitor temperature



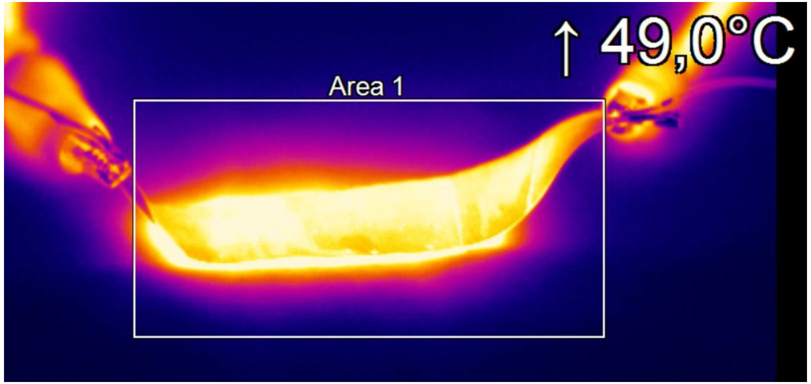
Heating Tests



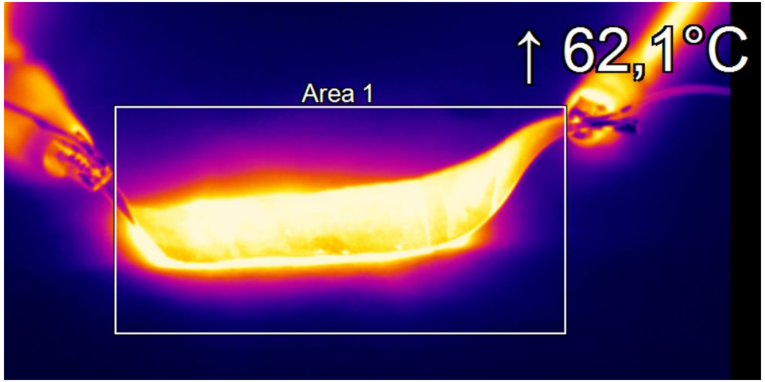
Test with 0A current.



Test with 2A current.



Test with 4A current



Test with 5A current.

Conclusions

The setup has been commissioned

Perspectives

Outgassing studies (search for hydrocarbons)

Production of GEM samples

Aging tests followed by surface analysis