Workshop on ET-LF TM Tower Integration

IJCLab in Orsay (Paris)

March 25th -27th, 2025

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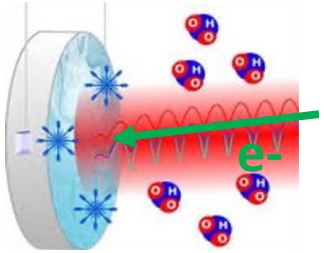
LNF-INFN

ET Activities @ LNF-INFN

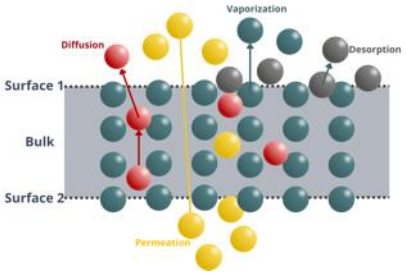
WP1: Frost mitigation and Electrostatic Charging *(MaSSLab)*

The final goal of this WP is to validate the use of low energy electrons as a mitigation method for frost formation and as a neutralization method for mirrors' electrostatic charging.



WP2: Material Properties *(Vacuum Group @LNF in collaboration with MaSSLab and EGO/Virgo)*

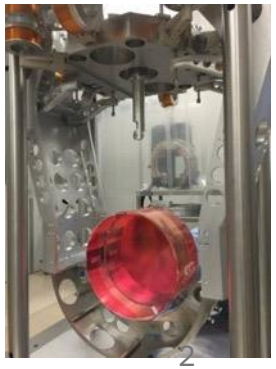
The aim of this WP is the characterization of the materials involved in the tower vacuum system containing the mirrors. The investigation of the outgassing properties will define the level and quality of vacuum surrounding the mirror surfaces.



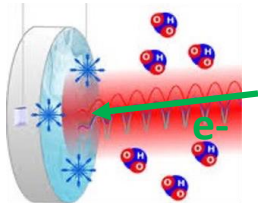
WP3: Passive mitigation method for electrostatic charging

(MaSSLab in collaboration with the Vacuum Group @ LNF, EGO/Virgo)

The aim of this WP is to carry out a R&D activity to develop a passive mitigation strategy for the electrostatic charging generated by low energy electrons coming from ion pumps, propagating along the beampipes and finally impinging on the test masses.



Status of Activities:
Frost mitigation and Electrostatic Charging

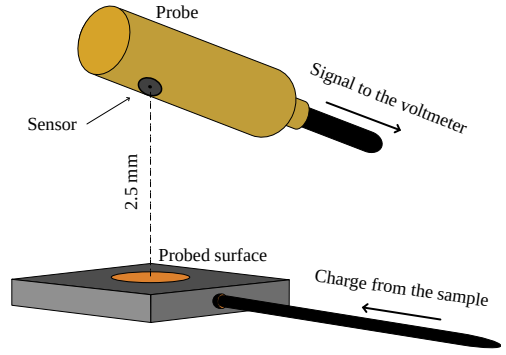


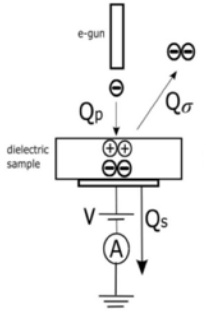
Electrostatic charging neutralization by low energy electron irradiation:

- Proof of concept (Spallino et al., **PRD 2021**; Spallino et al., **PRD 2022**).
- Experimental validation at RT and LT (T~10 K) by developing a capacitive method for small prototypical samples (10 x 10 mm^2) of metals, semiconductors and thin insulator layers (~20 nm) (Spallino et al., **Vacuum 2025**).

Frost mitigation by Electron Stimulated Desorption (ESD):

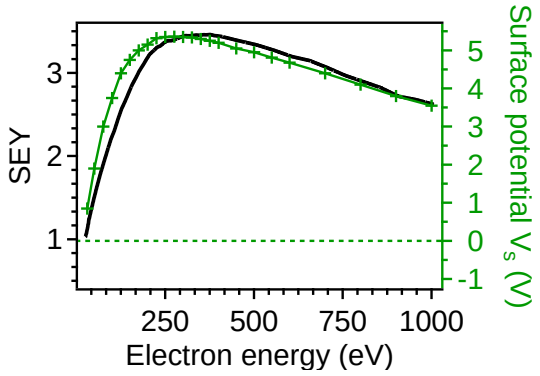
- Efficient process already known in literature (Spallino et al., **PRD 2021**).





Capacitive setup developed for experimental validation

- **Electrons can neutralize both positive and negative charges by properly tuning their energy → ESD feasible in principle.**
- **There is a strict correlation between neutralization parameters and SEY: by studying SEY features of any coating, it is possible to extract operational parameters to discharge it.**
- **It is possible to induce a stable and homogeneous surface potential.**



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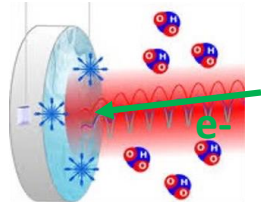
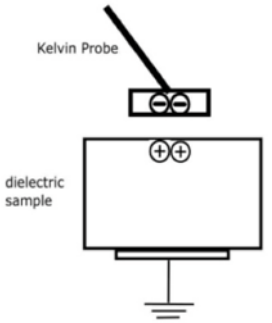


Electrostatic charging neutralization by low energy electron irradiation:

- Experimental validation at RT and LT (T~10 K) on more realistic small samples by capacitive method (→ waiting for materials coming from collaboration)
- Experimental studies on charge distribution and neutralization for big realistic samples (1-inch, thick insulators) → implementation of a dedicated setup equipped with a Kelvin probe (system currently under test).

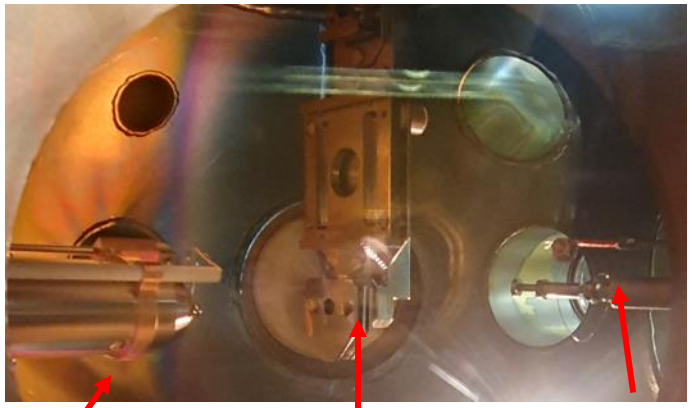
Frost mitigation by Electron Stimulated Desorption (ESD):

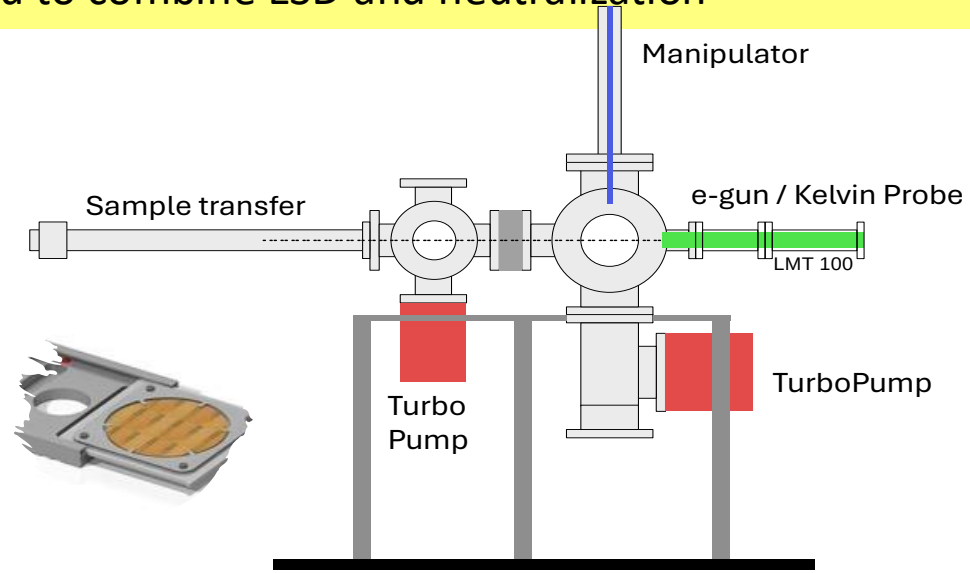
- First tests on H_2O/Si and Cu to combine ESD and neutralization



Kelvin probe scheme under test for charging neutralization

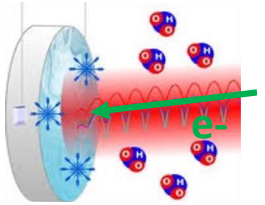
Chamber inner view





Setup overview

Mid-term Perspective:
Frost mitigation and Electrostatic Charging



Preliminary XPS and Raman investigations carried out in our lab on prototypical small have shown that, within the detectability limit of these experimental techniques, electron irradiation below few hundreds' eV does not induce observable structural defects on the substrate.

Laboratory based experiments

- **More investigation are needed, especially on realistic and specific materials.**

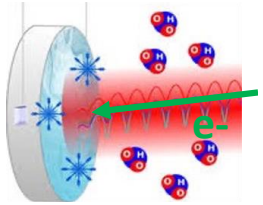
  → WHAT is the effects induced by electron irradiation on optics?

  → WHAT is the best way to monitor the effects (studies on optical properties and/or noise induced effects: crystallization status, optical defects, scattering centers, scattering losses, mechanical losses,...)?

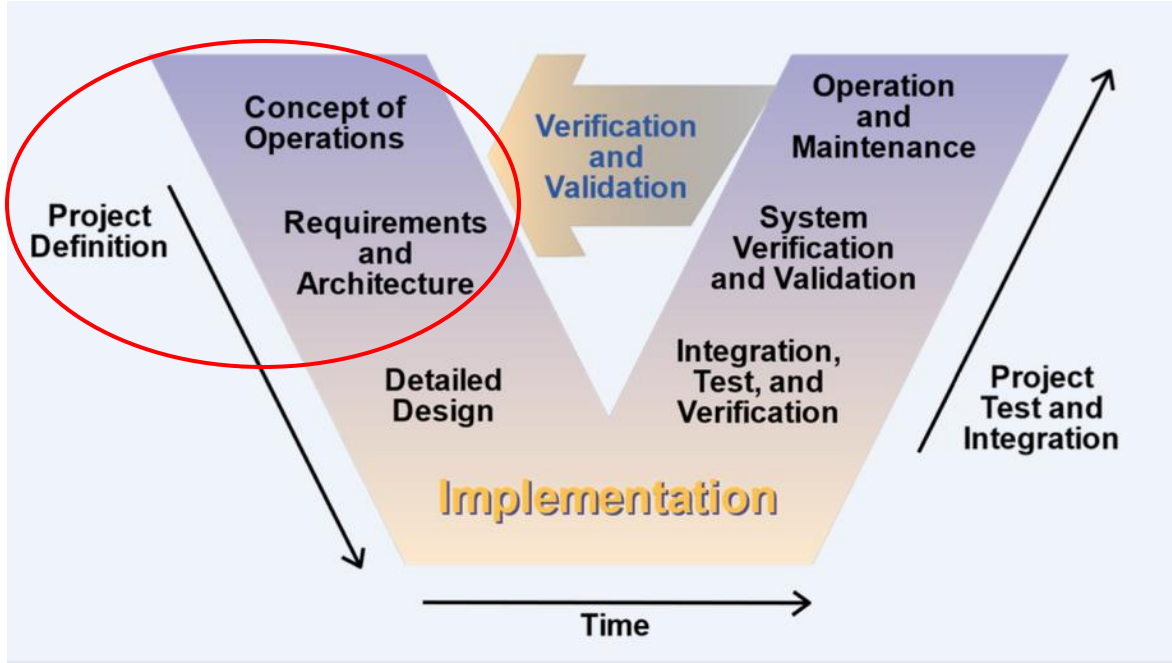
Work in progress within the ET-Italia collaboration (*Core Optics and Coating* group) but we are opened to inputs and suggestions!

Frost mitigation and Electrostatic Charging

Final goal → Integration



In principle, electron irradiation to mitigate charging is compatible with cryogenics and will work at RT as well.



Frost mitigation and Electrostatic Charging

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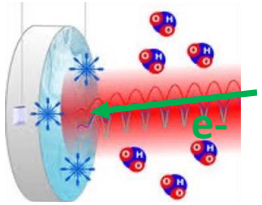
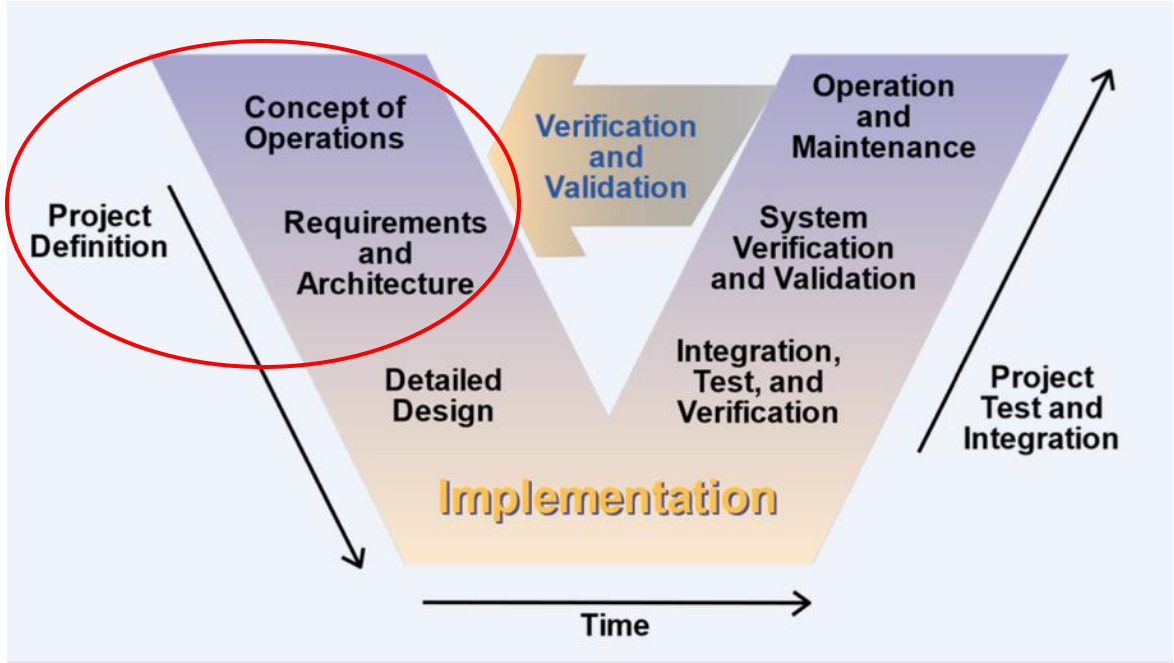


→ At the present stage, can the method be integrated in design of the overall system? and HOW?

→ WHAT is the impact at cryogenic conditions?

Strong interaction with ET community is needed



Is there an available mock-up system where to plan test on:

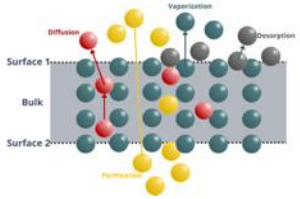
→ frost/neutralization mitigation methods by using electrons;
→ effects on optics under realistic conditions;

If it is not, a mock-up system should be designed/realized.

Mandatory R&D plan

→ cold electron gun
→ a charging monitoring system

Status of Activities: Materials properties

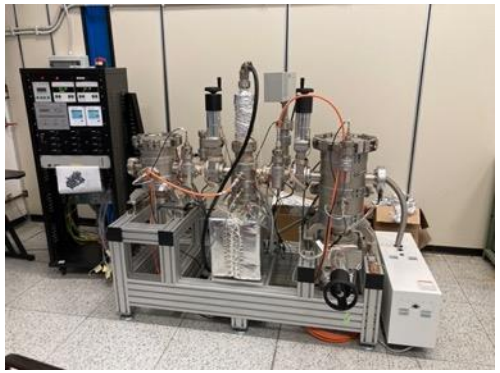


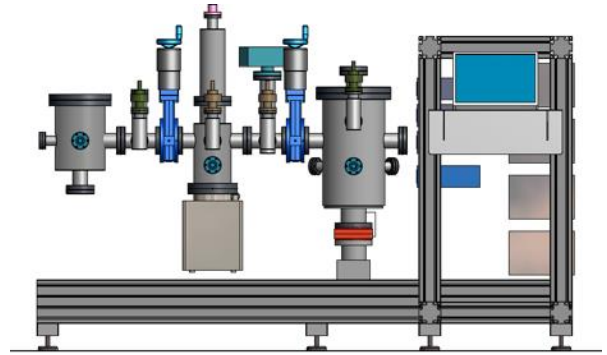
The aim of this WP is the characterization of the materials involved in the tower vacuum system containing the mirrors. The investigation of the outgassing properties will define the level and quality of vacuum surrounding the mirror surfaces.

LNF «LATINO» - Outgassing Facility - fully operating.

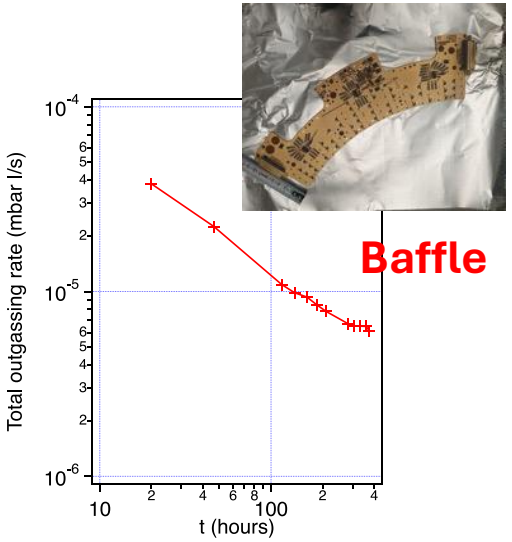
LNF-Virgo/EGO networking for materials' characterization.

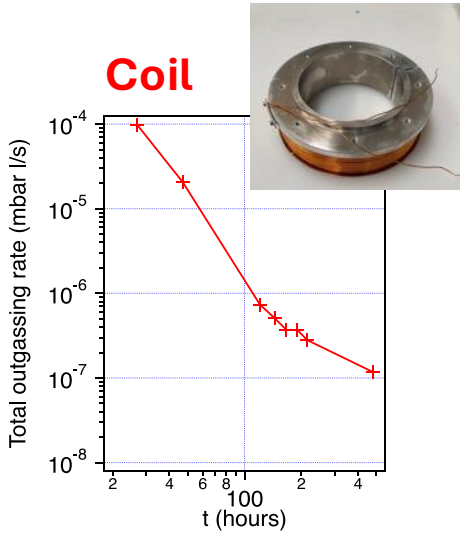
First tests on samples provided by Virgo/EGO to be in line with measurement methods and procedures





Two Chamber for samples (ϕ 200 x 260mm and ϕ 250 x 450mm)
Background ≈10^{-13} mbar/l s cm^2; two RGA analyzer





We are ready to carry out measurements' campaigns.

Material/devices proposed to be used in the tower vacuum system?

Networking with other outgassing facilities for database?

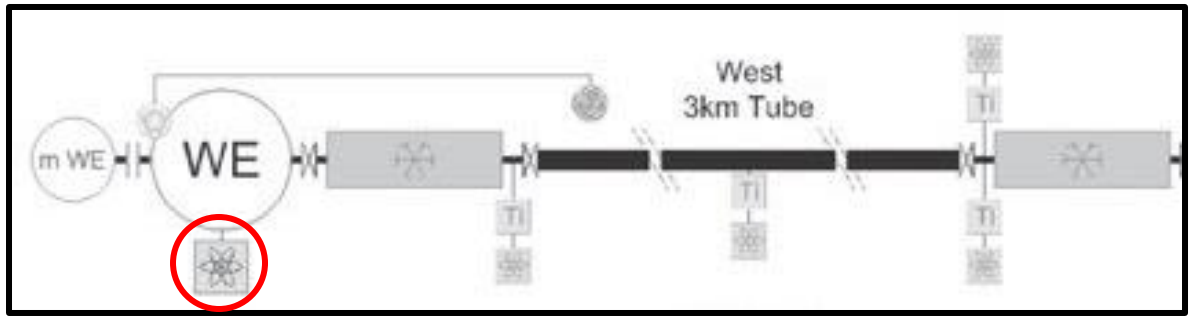
Status of Activities:
Passive mitigation method for electrostatic charging

Limit free electron imping on optics

From the Virgo experience: Electrons coming from Ion pumps

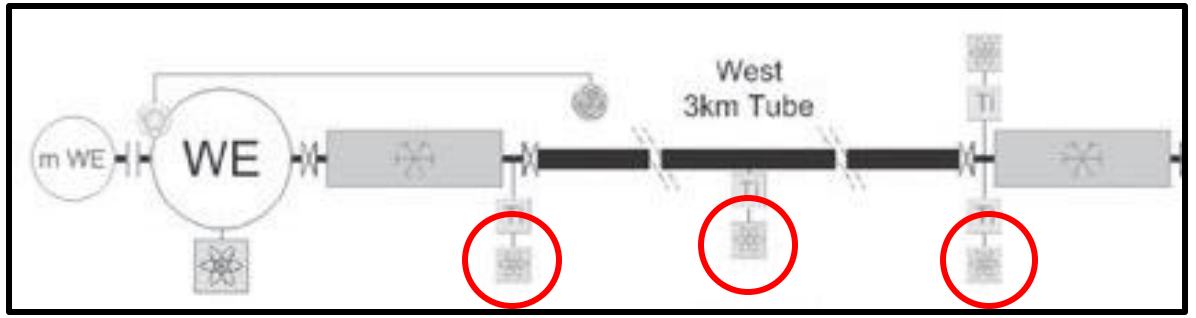
Studies on the emitted electrons from ion pumps

- Mes. Of Number of emitted electrons
- Emission configuration
- …

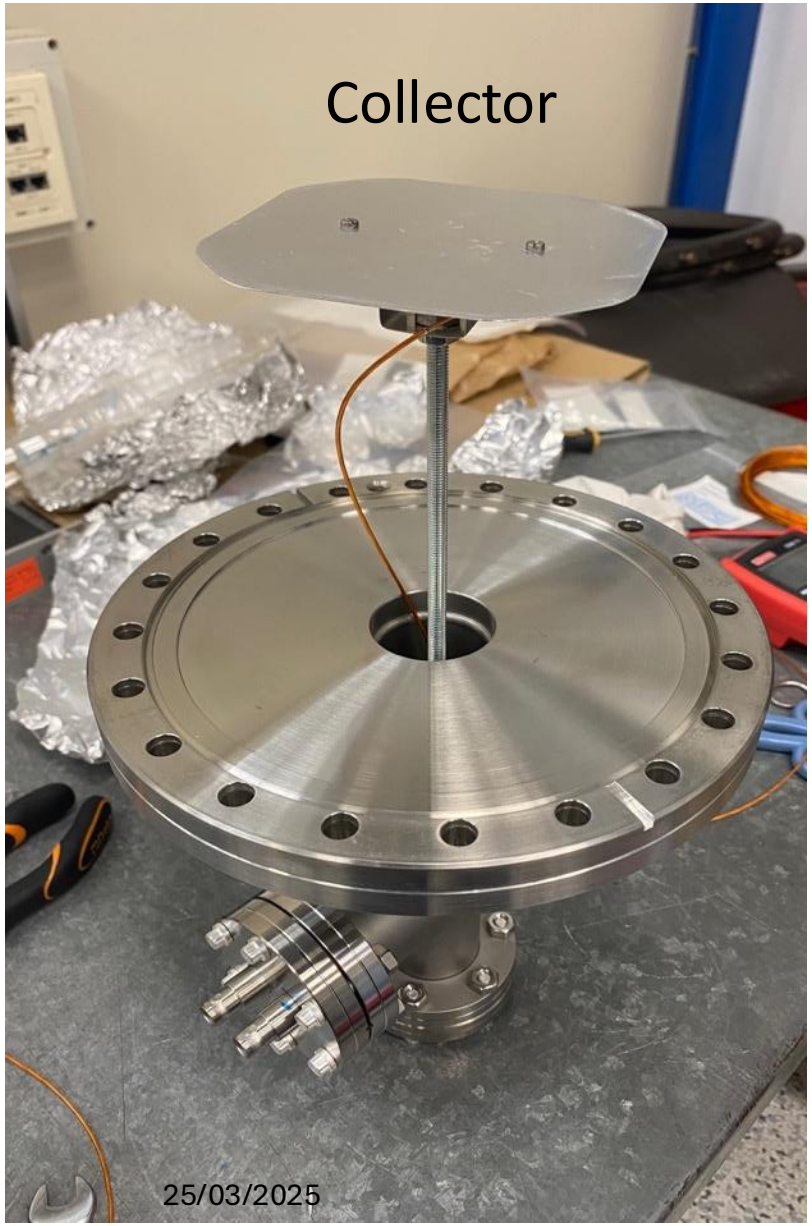


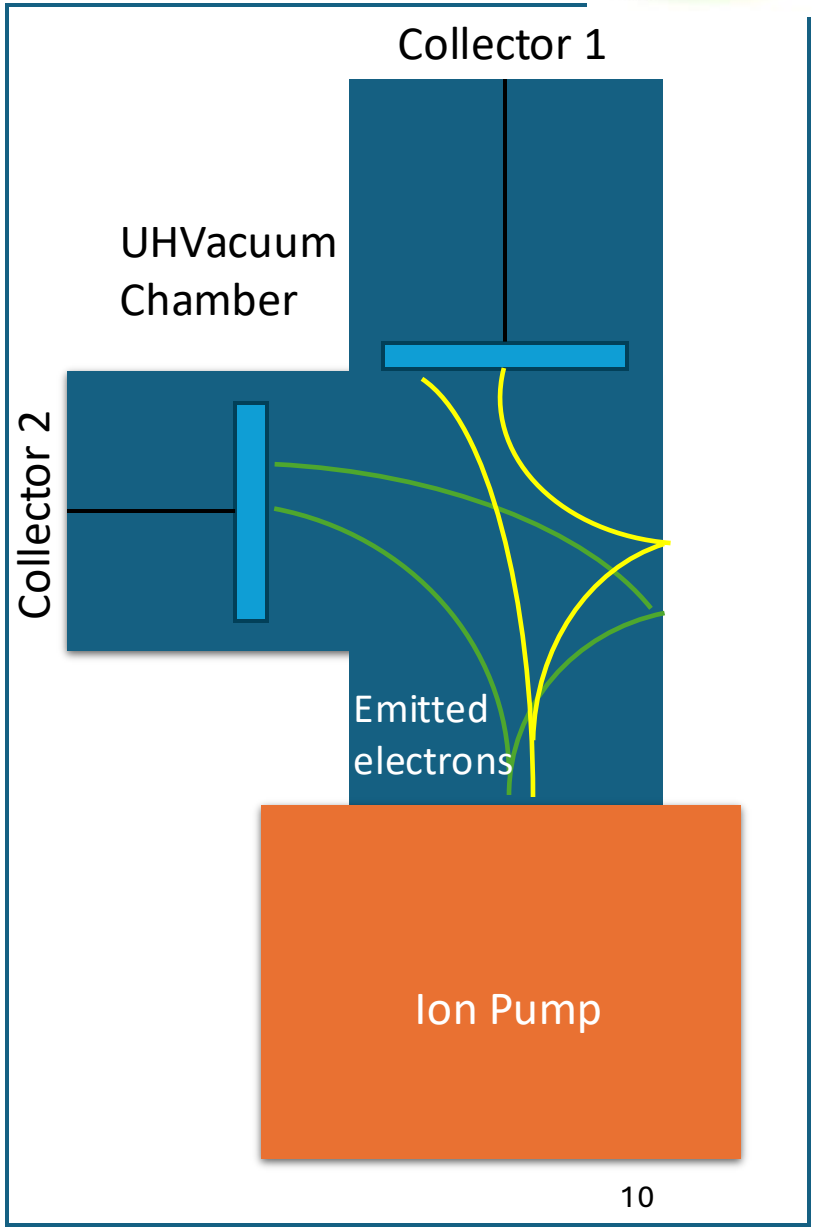
Studies on the electron's propagation along the beampipe

- Numerical simulation of propagation
- Mes. of Number of propagated electrons
- SEY of beampipes material



Studies on the emitted electrons from ion pumps





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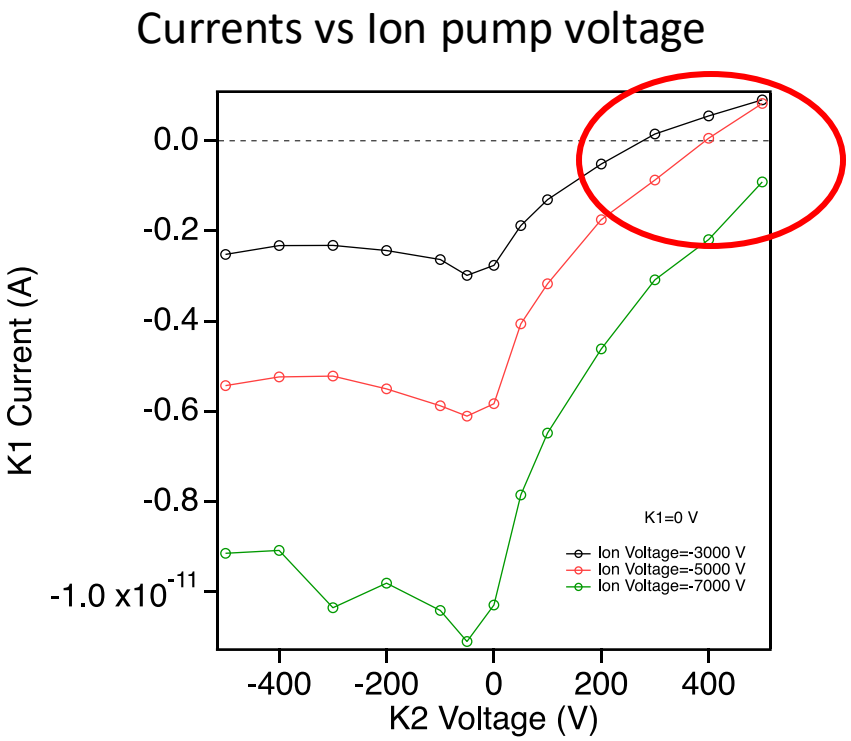
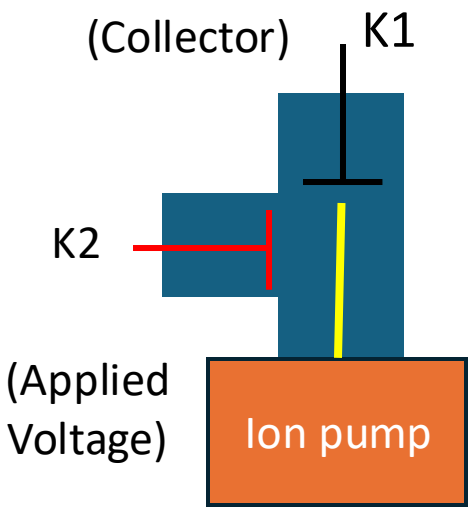
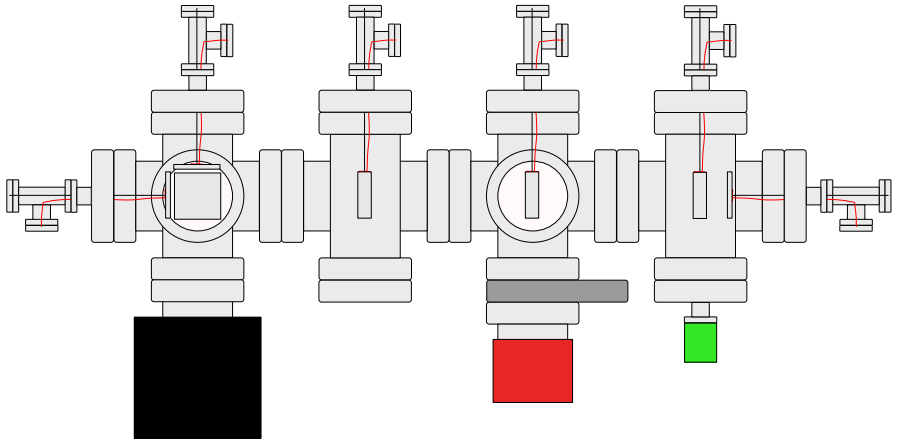
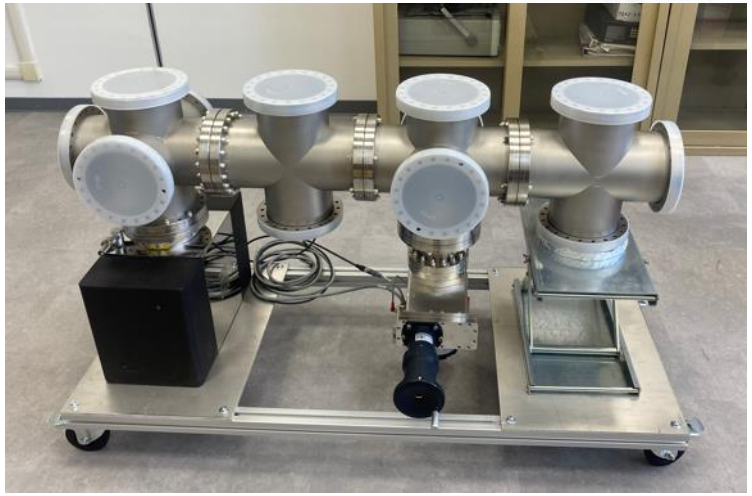




- Electrostatic screens
- Specific configuration for installation

→ Mock-up system under construction



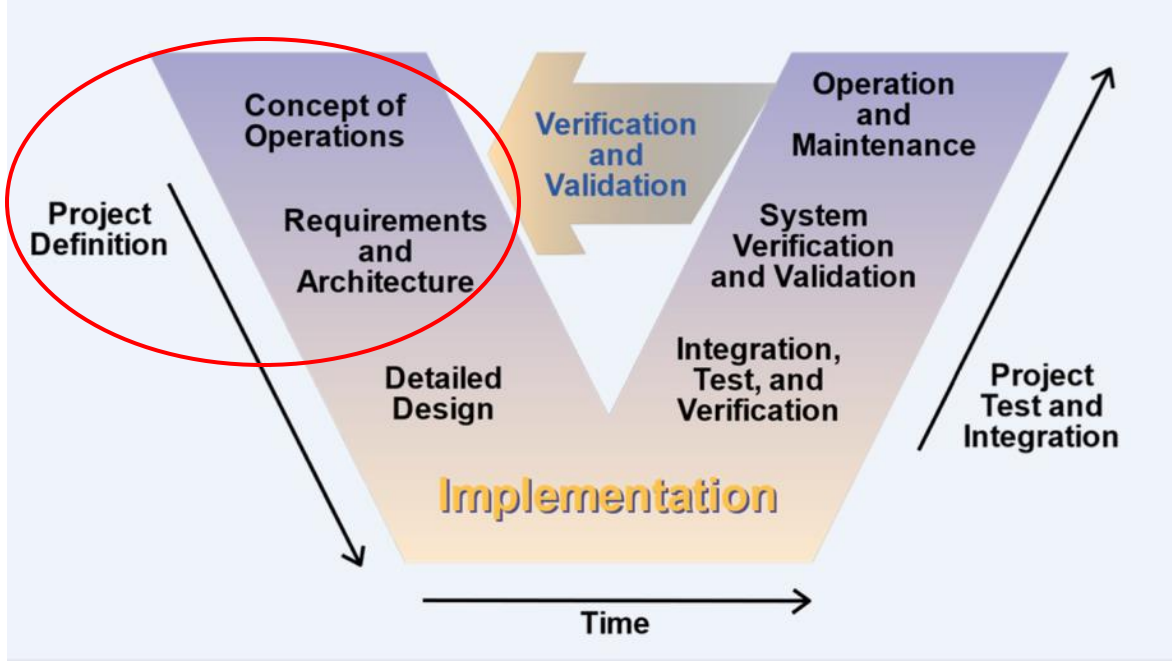


Studies on the emitted electrons from ion pumps

Final goal → Integration

→ At the present stage, can the method be integrated in design of the overall system? and HOW?

Strong interaction with ET community is needed



- R&D activity LNF-EGO/Virgo to test the possibility of integrating an electrostatic ring on selected baffles to mitigate the charges' flow.

- R&D activity on final design of electrostatic screen considering pumping variation...

Summary

We are going on with our work program

We are at a critical point for activities related to frost and charging mitigation by electrons

→ we believe it could be the right time to move towards an advanced phase requiring a well-defined R&D program involving the GWD community.

Even if we are ready, characterizations on outgassing properties of specific materials of interest are in stand-by

→ a collective enterprise could be beneficial to push this activity in different laboratories (EU call?).

The work on passive strategy to mitigate electrostatic charging is promising and in line with time

→ Interaction for integration/R&D

Final goal → Integration

Strong interaction with the community is needed

Mandatory R&D plan