TOWER-VACUUM

workshop ET@TO

Jun 15-16, 2022

A.Buggiani, J.Gargiulo, A.Paoli, A.Pasqualetti, D.Sentenac, T.Zelenova, … ***contributors welcome***

Summary

Tower Vacuum

Highlights and possible activities

- Static charge accumulation on optics (Virgo) study and lab. activity;
- Shields for Ion pumps (study and lab. activity)
- In-vacuum contamination due to residual gas (studies, lab. activity);
- Control the concentration of dust particles on chambers walls (studies, tests, industry)
- Conditioning of in-vacuum surfaces (studies, tests, industry)
- Gas damping effects (simulations);
- **Outgassing measurements;**

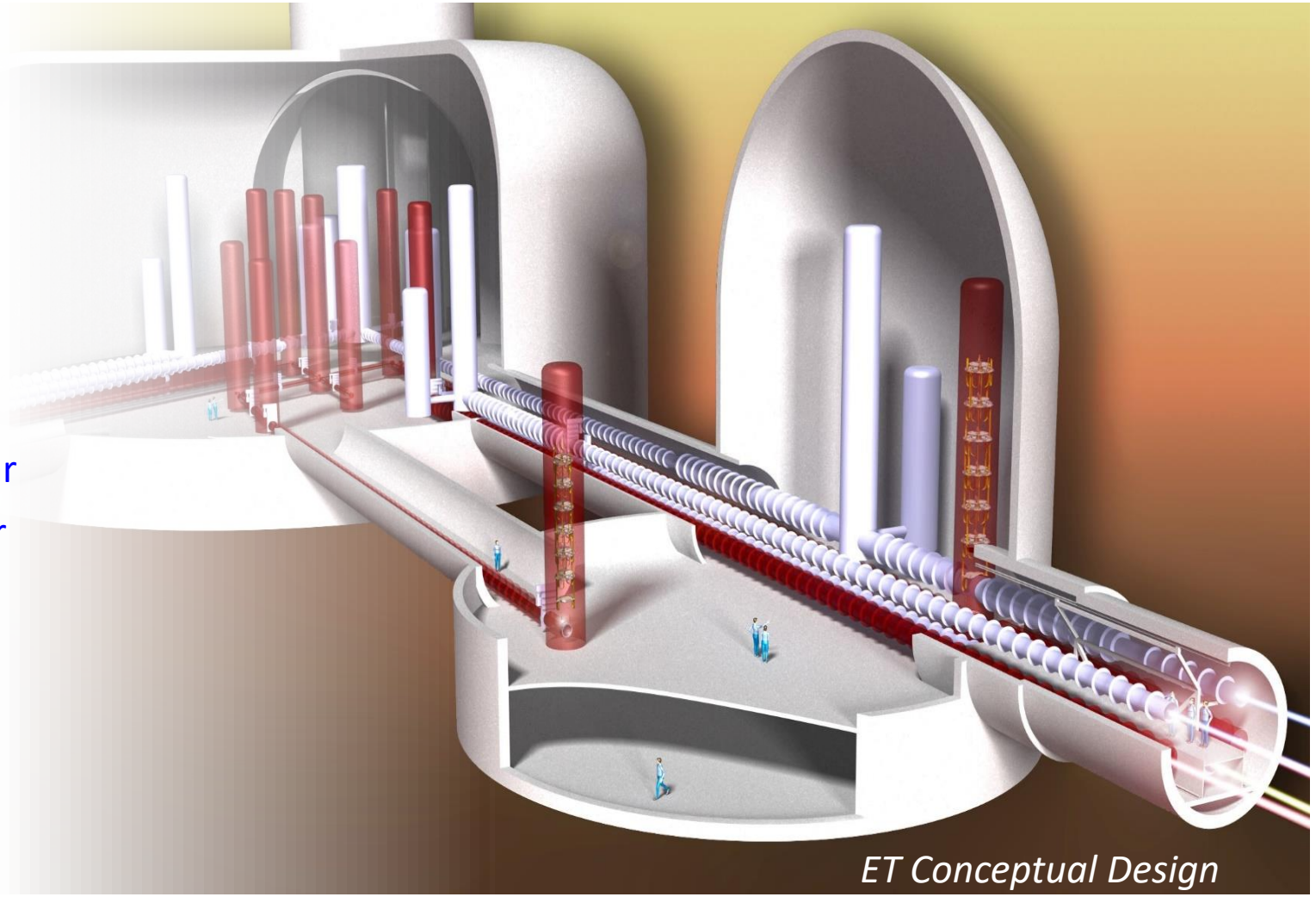
Tower Vacuum (WPIV.1)

ET opera sotto vuoto per limitare vari disturbi.
2 diversi sistemi da vuoto (‘Test Masses’ , fasci laser) di dimensioni eccezionali

In via preliminare:

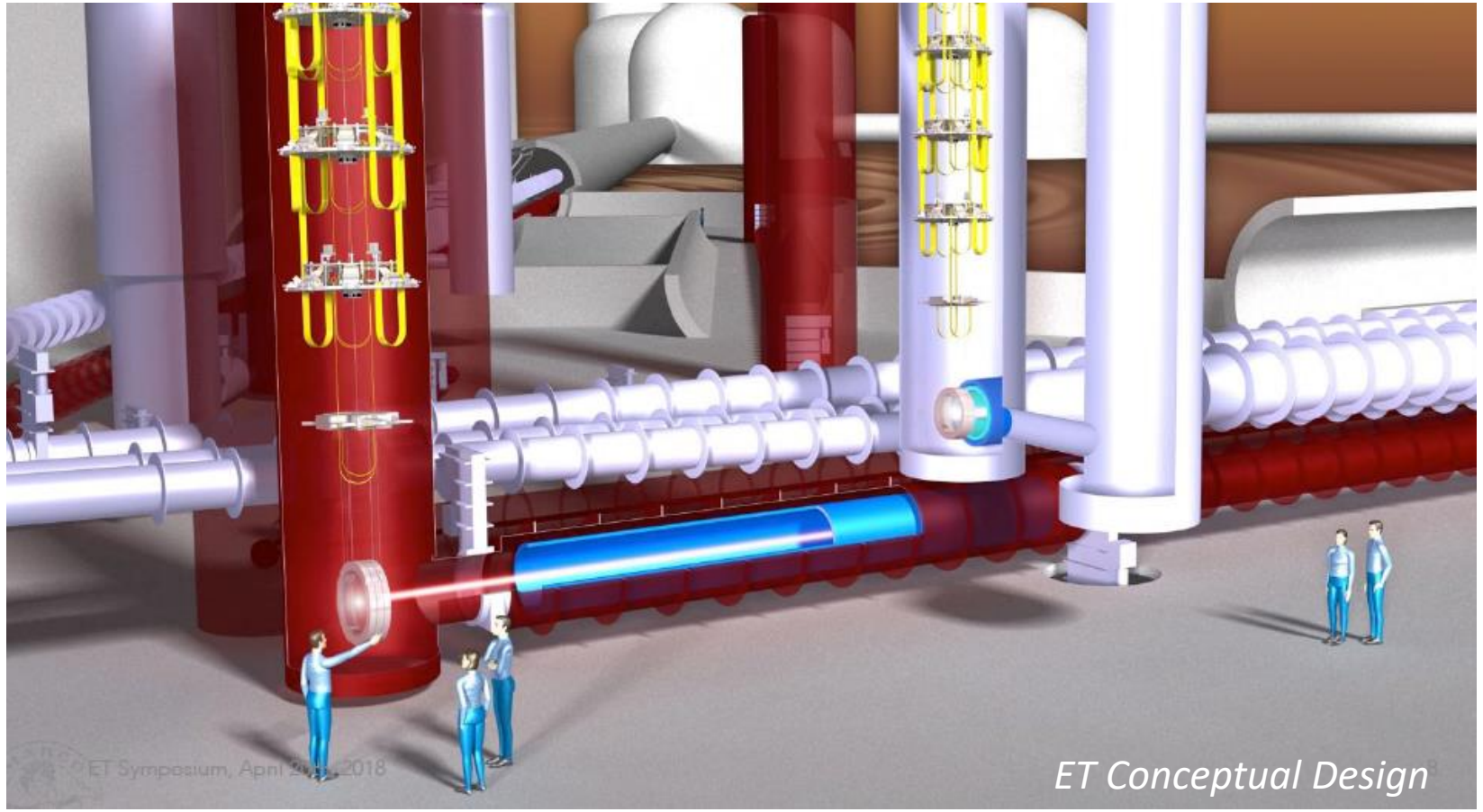
HF $H_2 \leq$ 5E-10 mbar, $H_2O + N_2 \leq$ 5E-11 mbar

LF $H_2 \leq$ 5E-9 mbar, $H_2O + N_2 \leq$ 5E-10 mbar

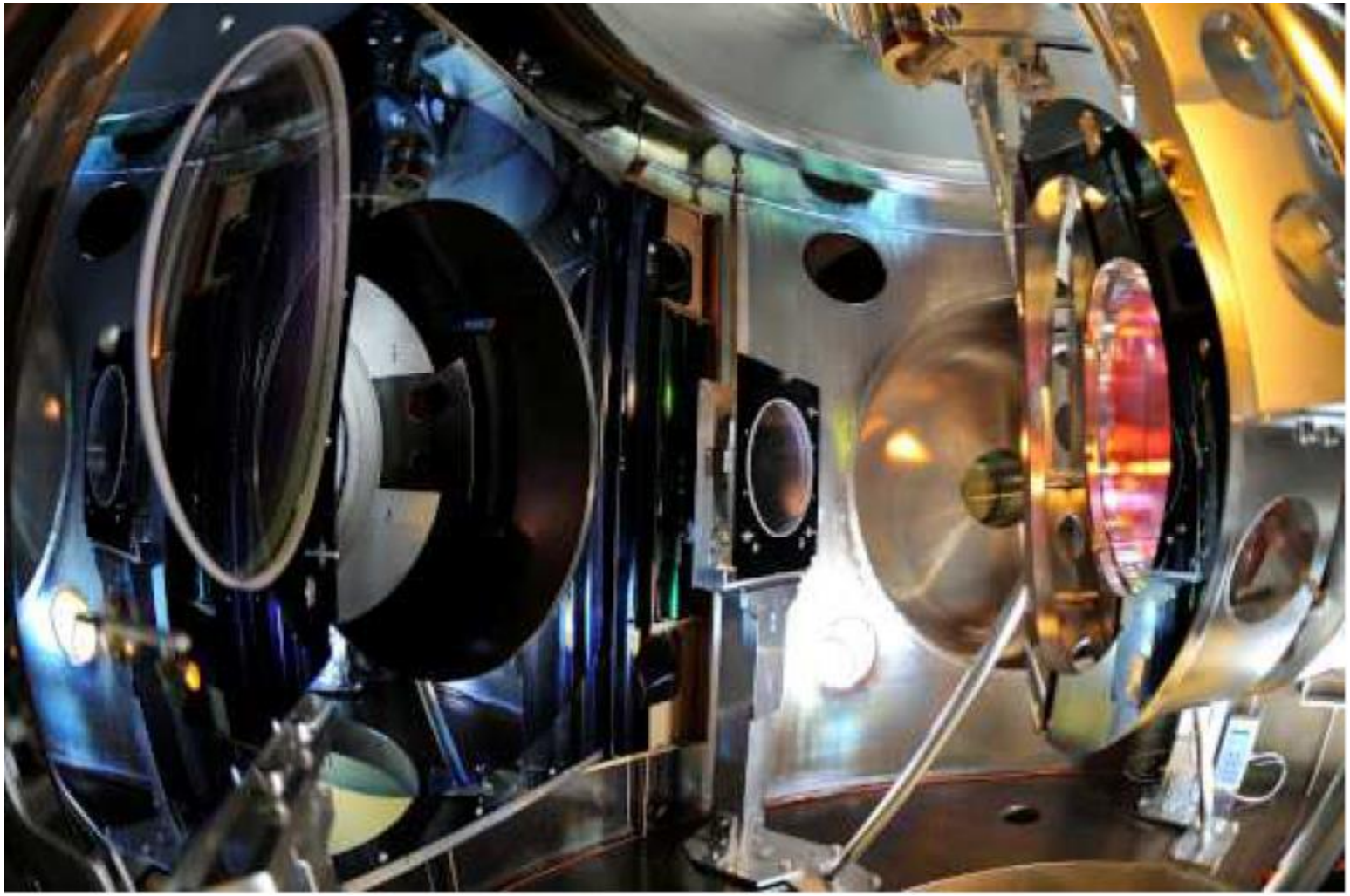


Interfaces with:

- Cryostat and Cryopumps
- Pipe Arm Vacuum
- Civil Infrastructure
- Optical layout of the interferometer
- Suspension system
- TCS system
- Stray Light Control
- Interferometer controls



Topic: Static charge (VIRGO)

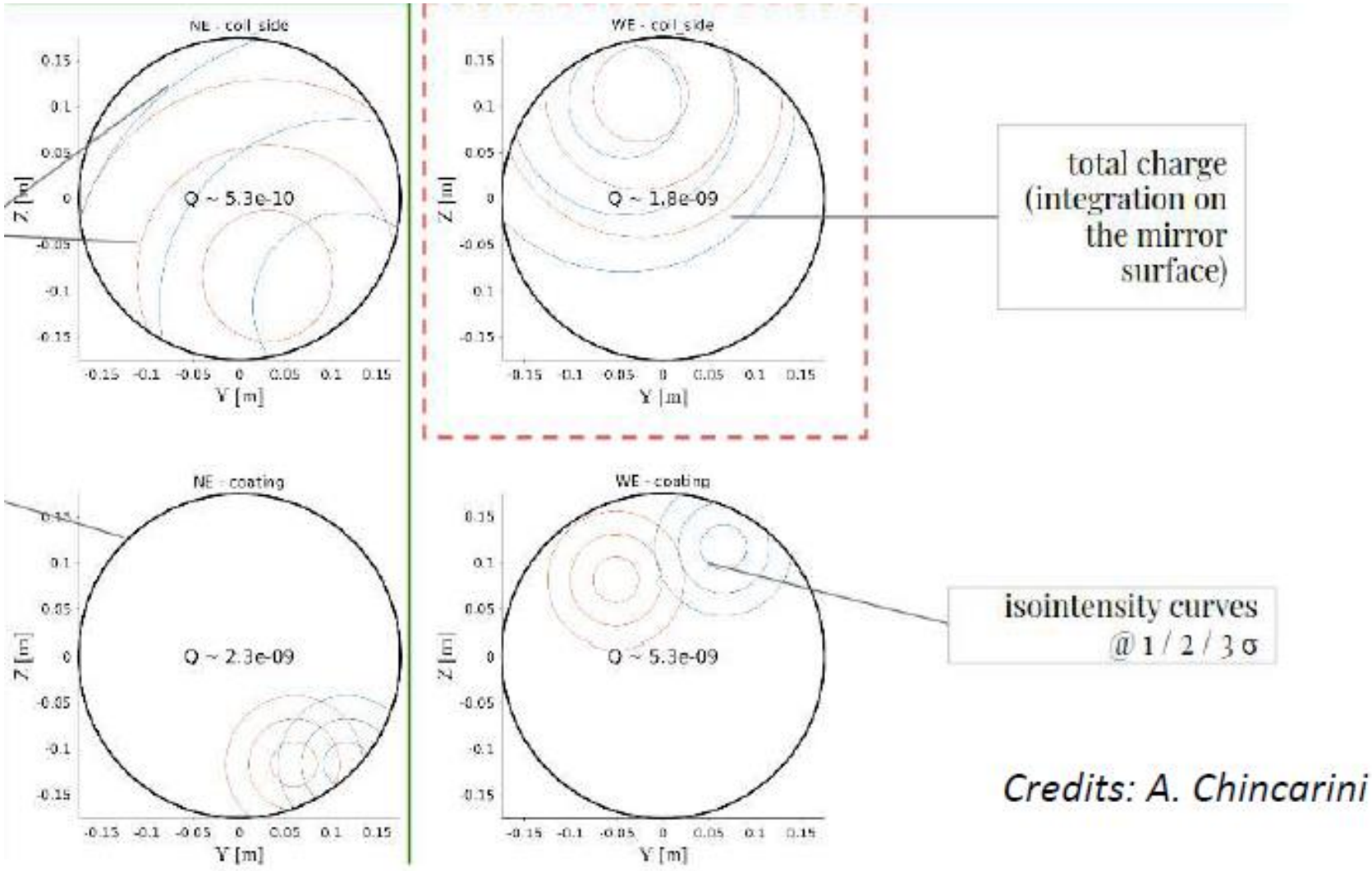


Static charge on TMs estimated at level of E-9 C, not uniform in magnitude and sign.

A related noise effects emerged during the commissioning phase in 2018 , then disappeared with a modification of the coils driving board.

May come back after future sensitivity improvements: a charge neutralization method is needed

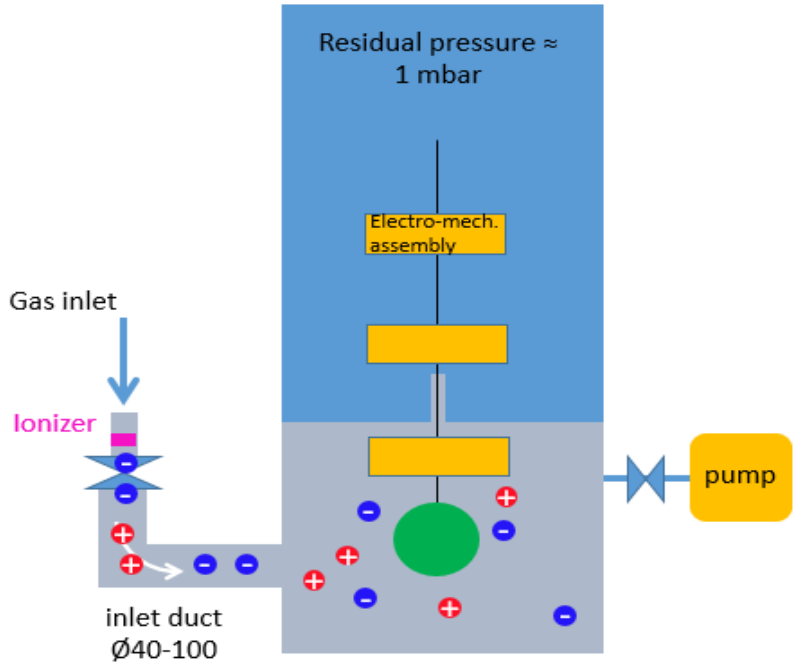
Activity: static charge simulation (VIRGO)



Credits: A. Chincarini

Neutralization process (VIRGO)

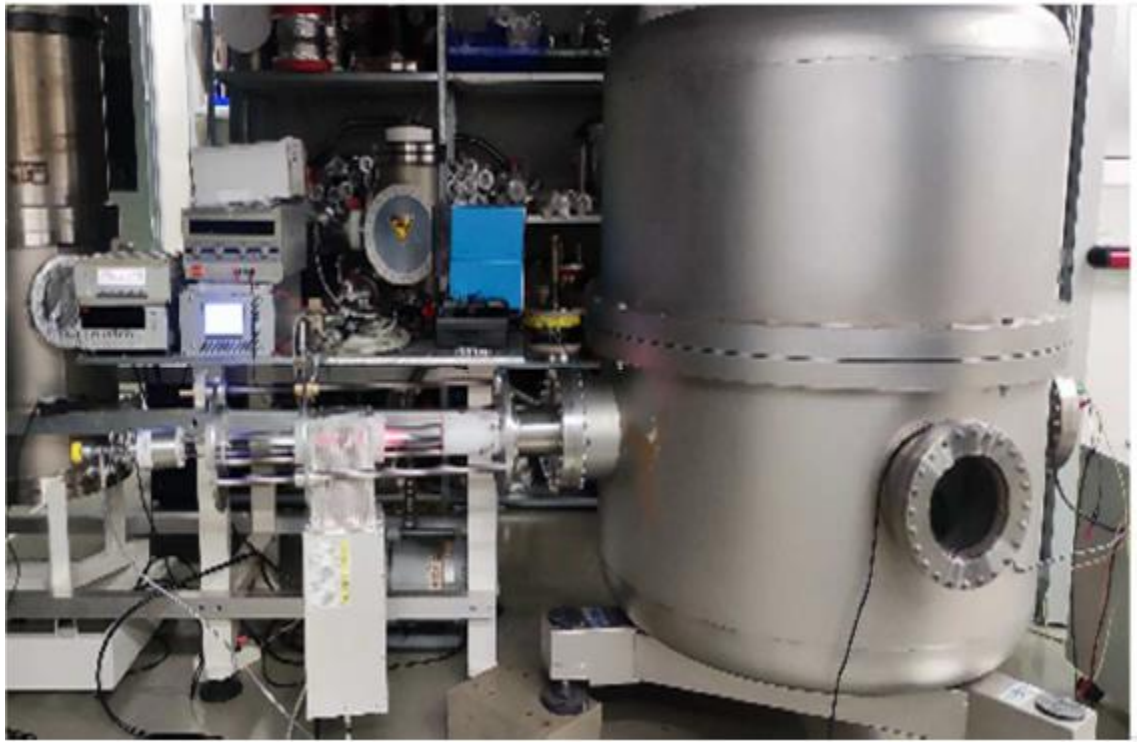
- 1st step= venting up to ≈ 1 mbar, 2nd step= neutralization process (N_2 1 ppm purity);
- Ionization is produced externally and then conveyed into the chamber by the general gas flow;

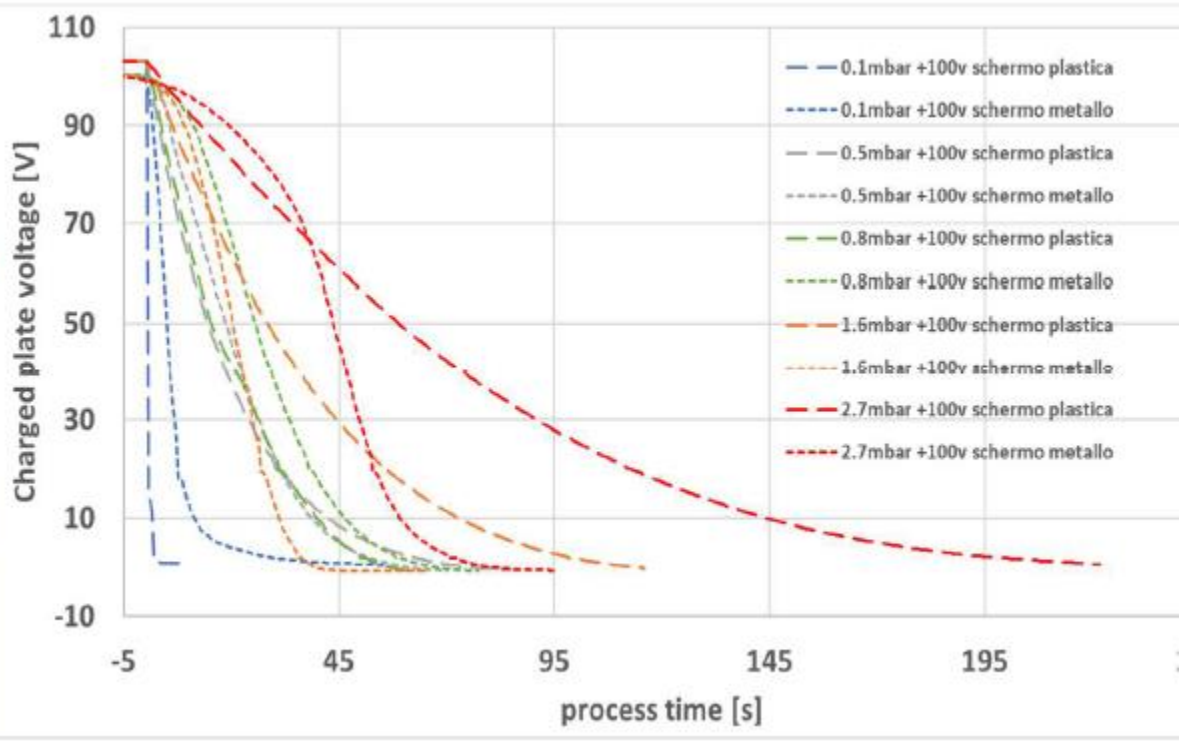


Similar to the routinary operation done in cleanroom with commercial tools: positive and negative charges (ions, electrons) are conveyed by the gas flow around the optic and drawn by the unbalanced charges on surfaces. Here applied under (low) vacuum 'without opening the tower chamber'.

Activity: neutralizer device setup (VIRGO)

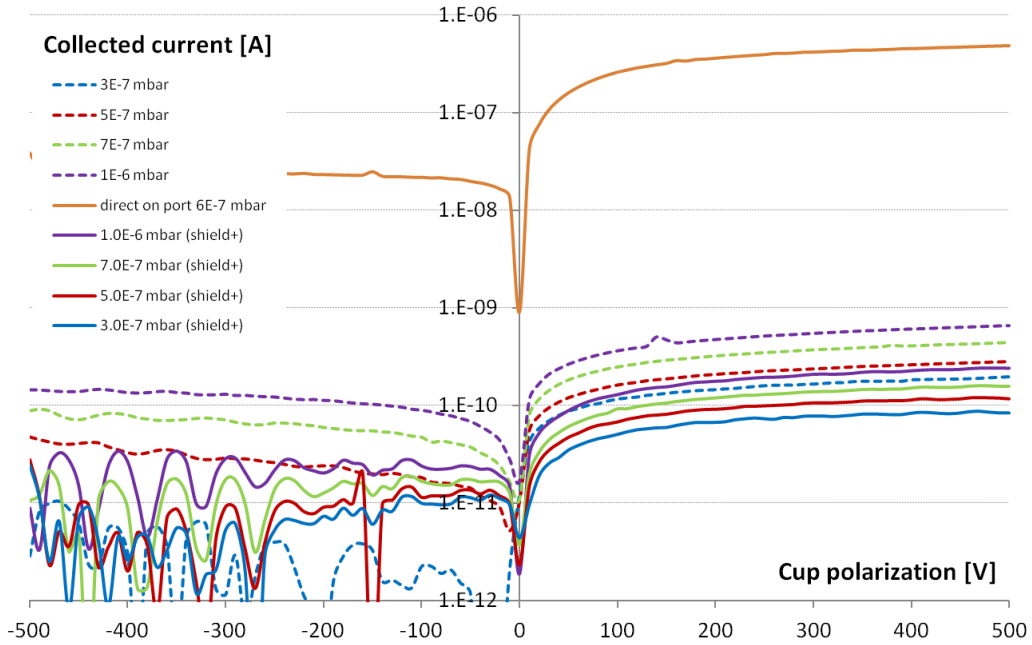
- prototypes under test @ site lab.

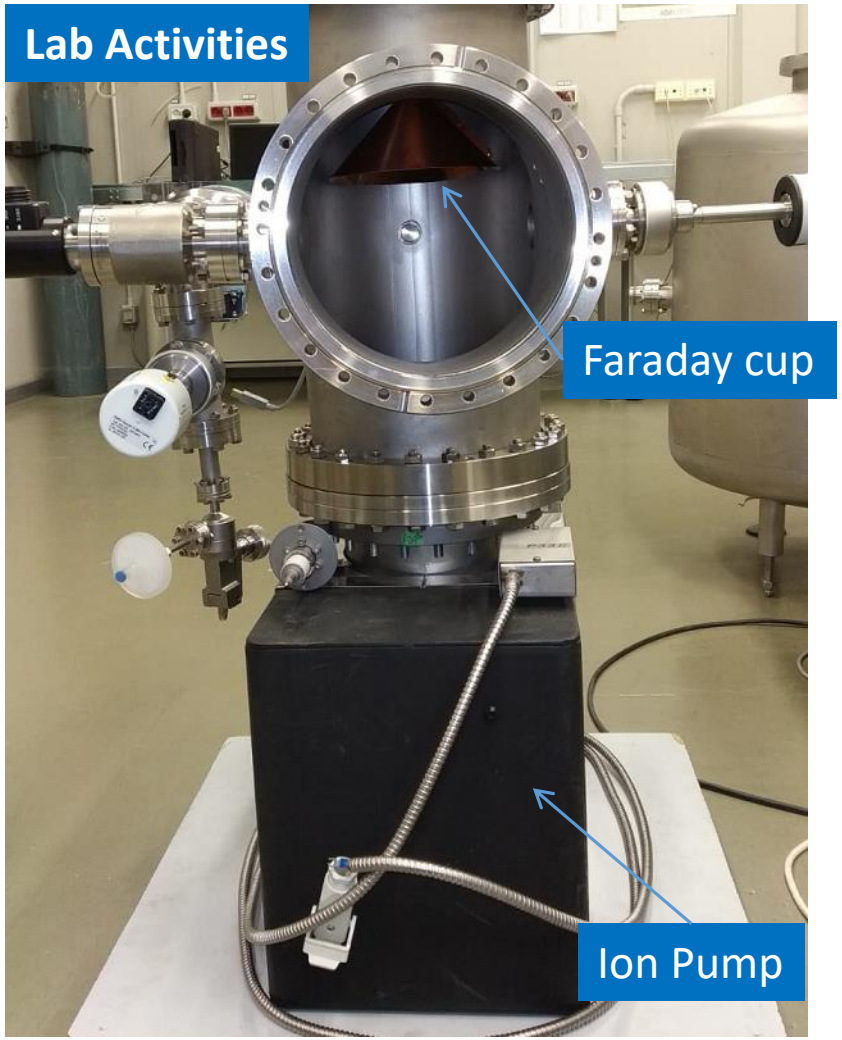




Activity: shields for Ion pumps

Mitigation of potential charging sources (studies, simulation, laboratory activities)





Static charge neutralization for ET

- Next talk by L. Spallino (WPIV.3 ET-ISB)

Topic: in-vacuum contamination

- ET's core optics are a cutting-edge components of the interferometer. The coatings will be characterized by low losses, low absorption and low scattering properties. A single monolayer of molecules deposited on surface could affect their performances.

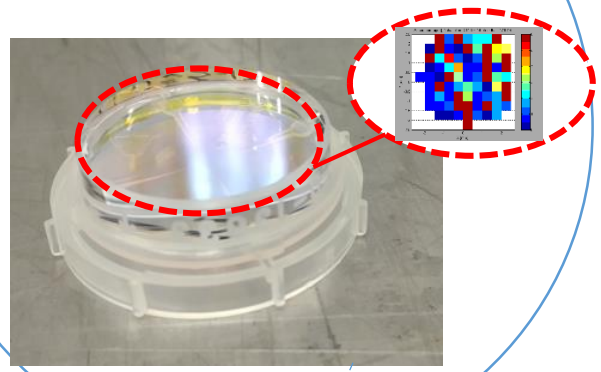
VIRGO mirror: optical absorption ≈0.3 ppm

LOW-VOLATILE MOLECULES PRESENT IN RESIDUAL GAS MAY DEPOSIT ON OPTICAL SURFACES BUILDING UP A LAYER OF CONTAMINATION

TO BE KEPT UNDER CONTROL

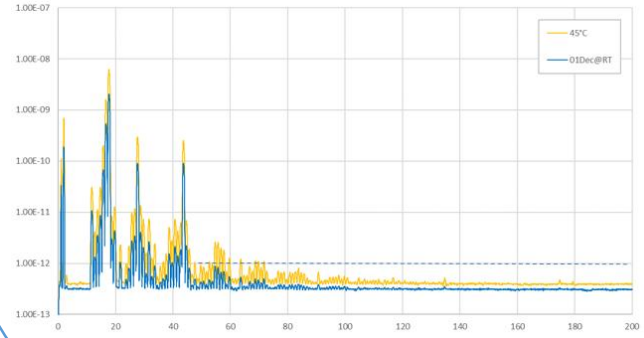
In-vacuum contamination

OPTICAL LOSSES MEASUREMENTS

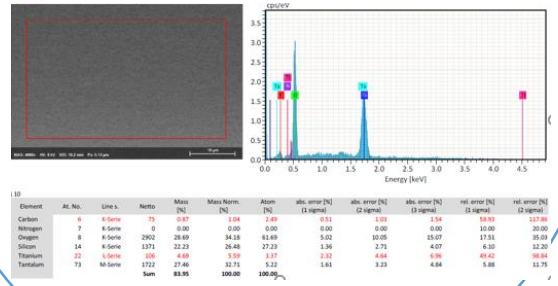


No clear correlation between the detected contaminant level in the gas and the optical losses

RESIDUAL GAS ANALYSIS



SEM for GROSS contamination identification



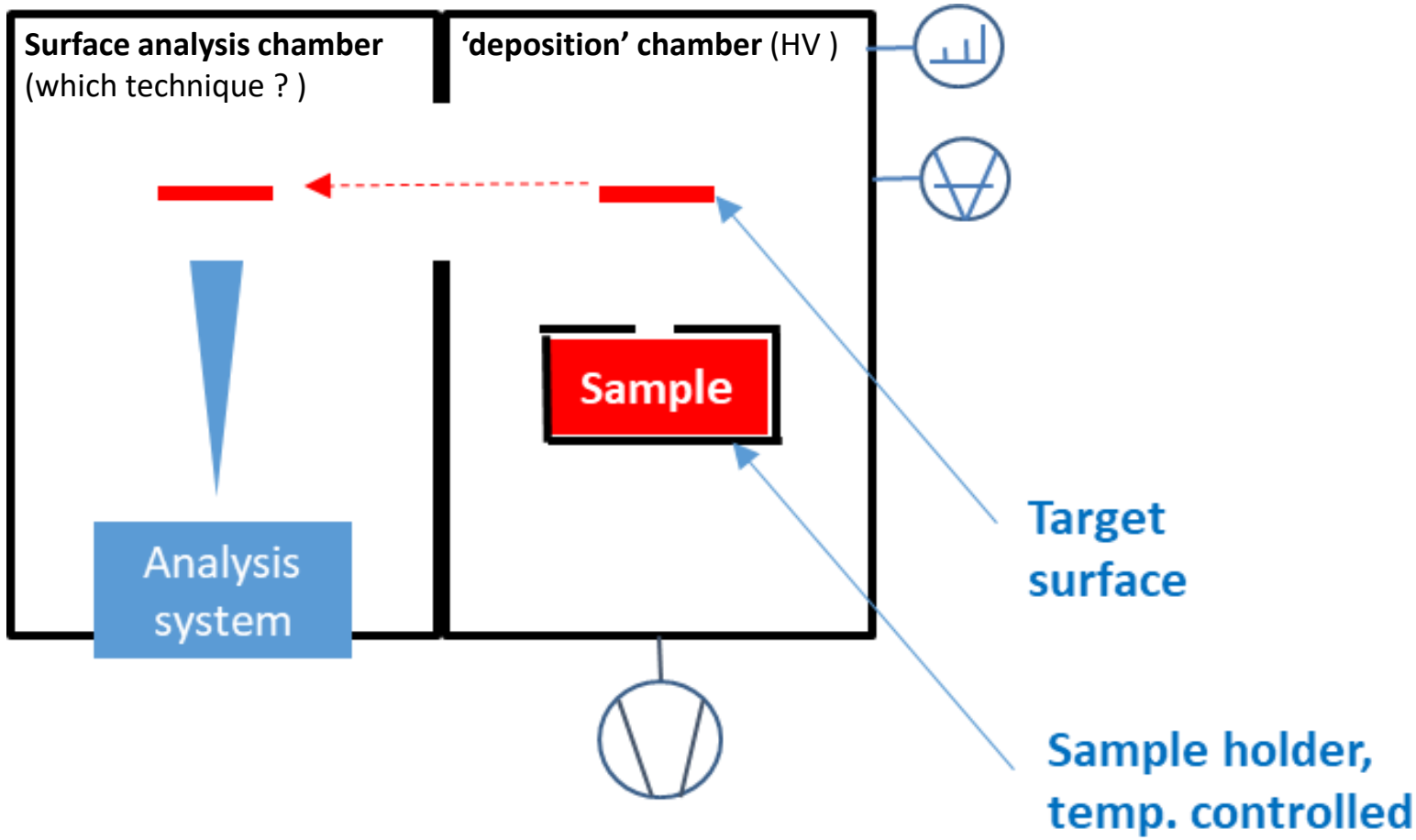
MISSING

1. **Identification of deposited species**
2. **Quantification of deposited quantities**

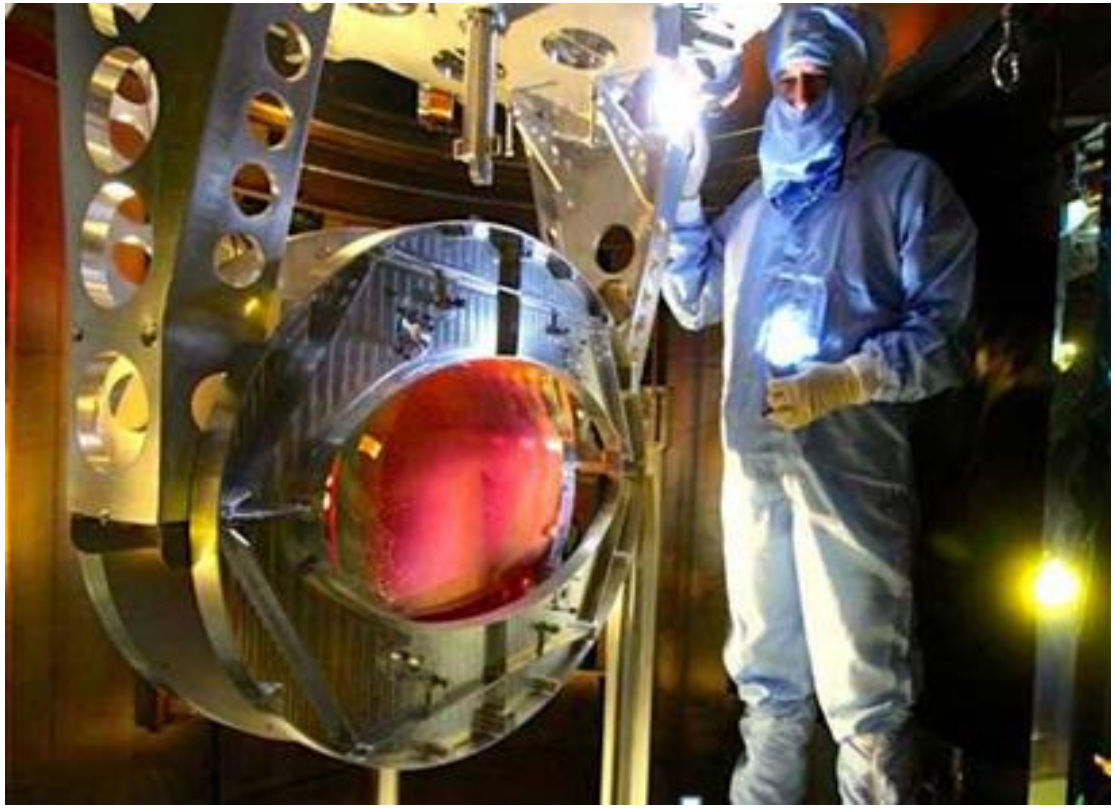
Activity: realize a ‘standard’ for the in-vacuum contamination assessment

Surface analysis:

a. - performed under vacuum just after the exposition to the contaminant
b. - sensitive to a single monolayer of deposit
c. - the target media can be chosen as wanted to ease the analysis

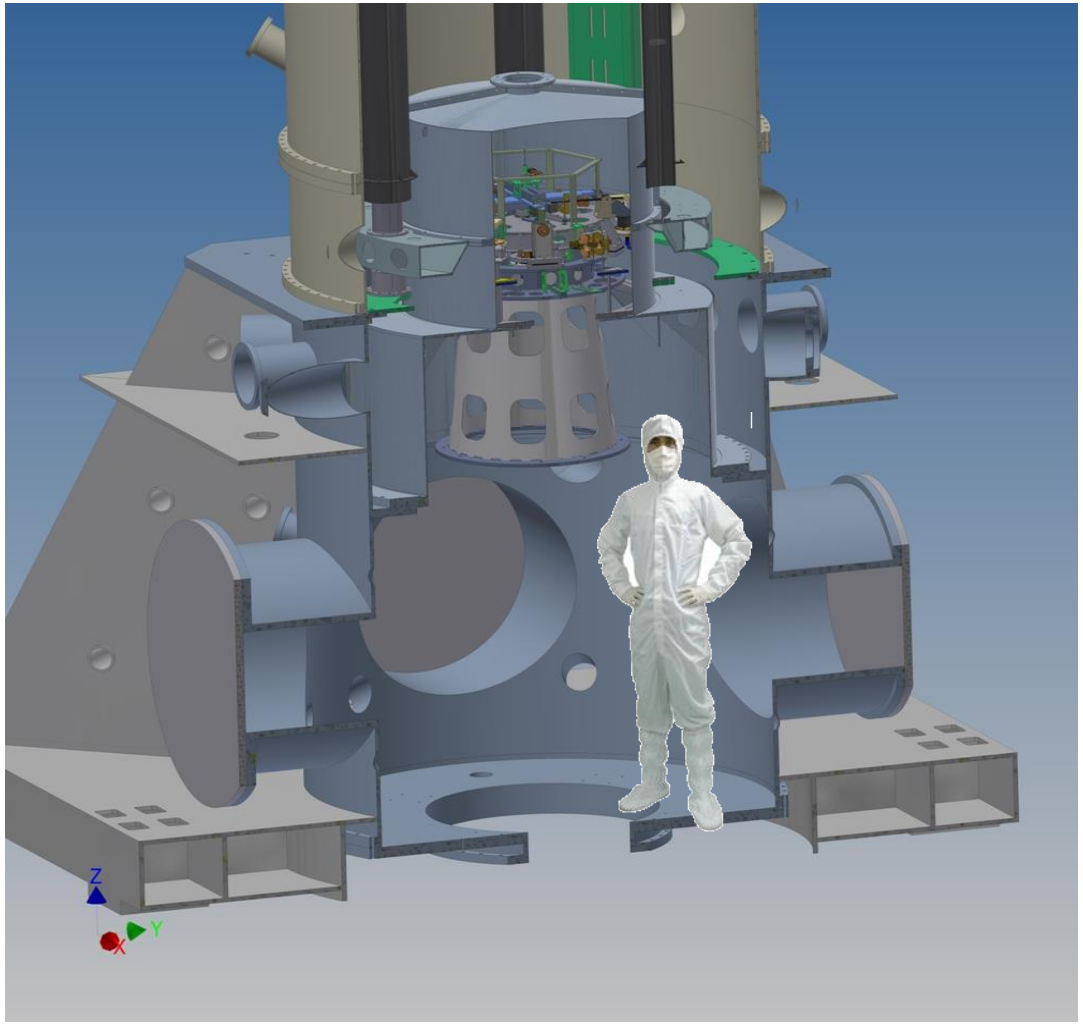


Topic: dust particles control



- la ‘Torre’ deve lavorare anche in modalità ‘camera bianca’ durante gli interventi di assemblaggio e manutenzione

Activity: cleanroom design

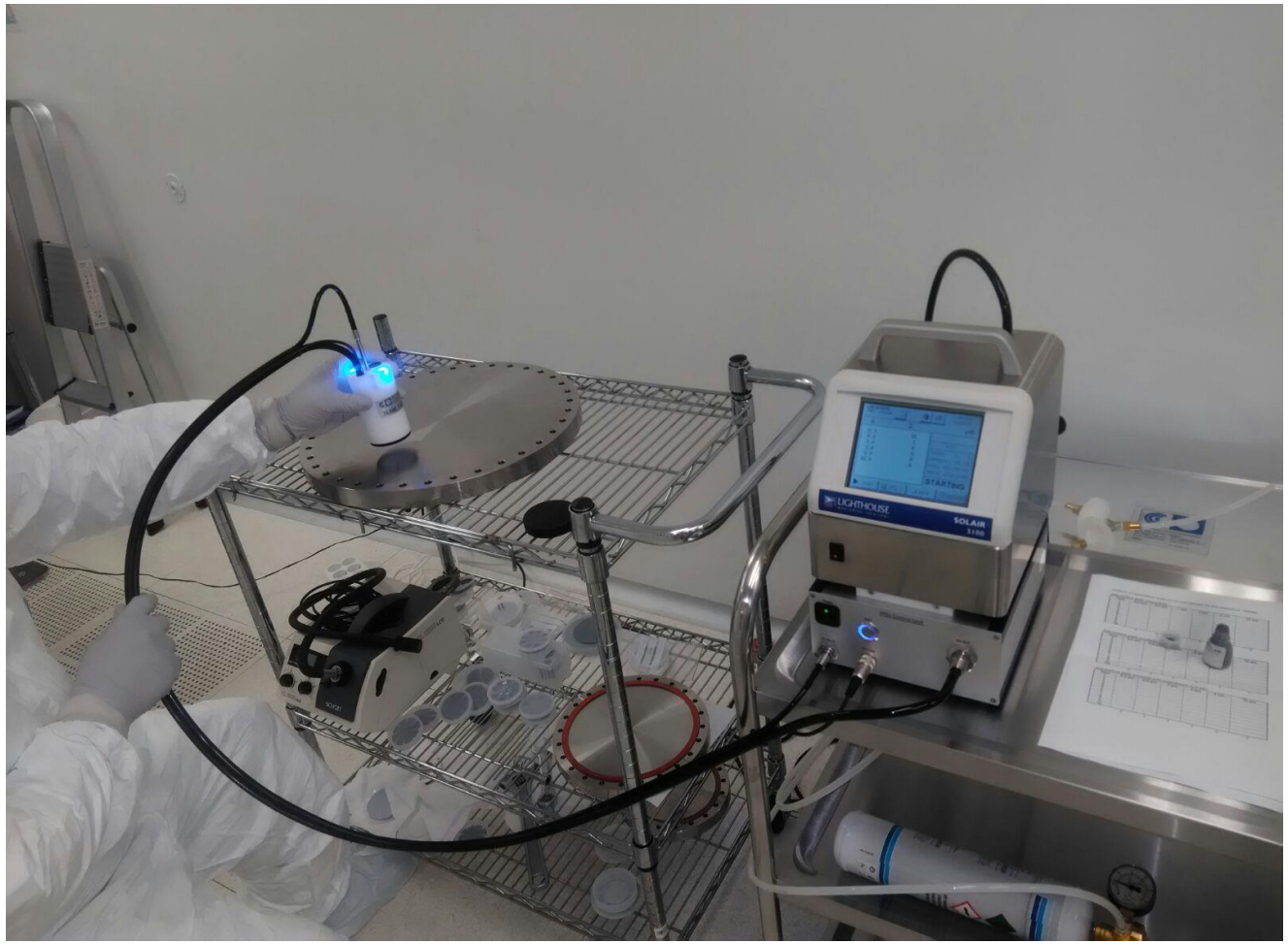


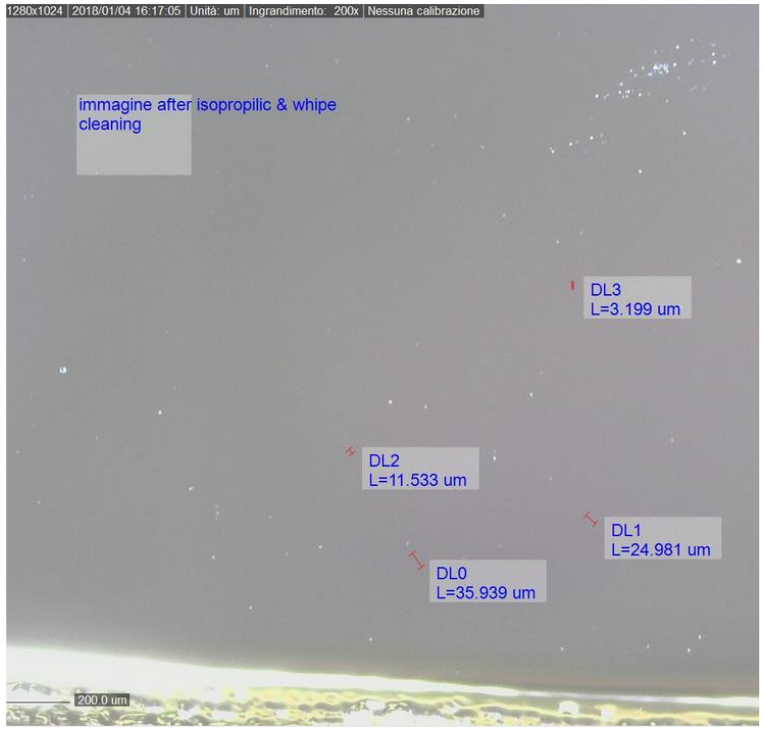
- *Per le torri di ET serve una progettazione specifica, integrata con le necessità per l'uso in alto-vuoto, che includa:*
- *geometria, scelta dei materiali di base , studio CFD dei flussi di aria nei vari scenari operativi , sistemi di monitoraggio della concentrazione di particelle su superfici, ...*
- *le superfici delle camere da vuoto di ET avranno tra i requisiti una determinata 'classe di contaminazione da particelle' (assente per le camere 2G)*

attività di ingegneria e metodi da industria dei semiconduttori.

Activity: dust particles monitor

Concentration of dust particles on the walls of vacuum chambers = d*ifferent solutions are needed to contol the fabrication process and to monitor the operative phase*



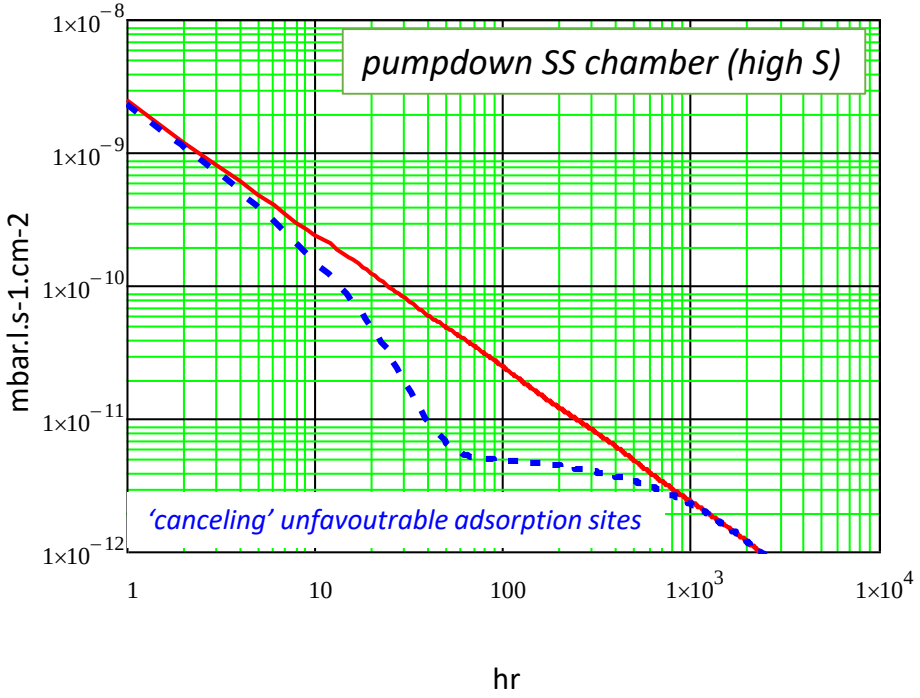


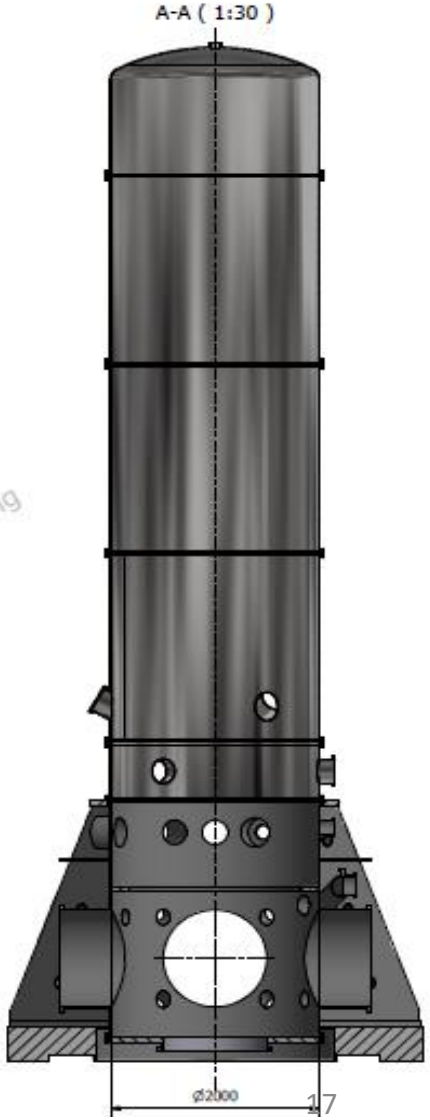
Topic: Surfaces conditioning

Vacuum materials recharge water, air ... at each venting, the released 'slowly' when back in vacuum (e.g., 2-3 weeks), according to the characteristics of the surface

- with so many towers, during the commissioning phases, the impact on the duty cycle of the experiment shall be high
- favorable coatings or surface treatments could be employed
- Surfaces should have also favorable optical properties (stray light control)

Speeding up the pumpdown process of unbaked chambers





Activity: surface conditioning study

- Coatings applicable to large areas (> 10 m^2), normally via vapor deposition under vacuum.
- State of the art (normally with costs)
- selection and test of some commercially available coatings: e.g., hydrophobic amorphous silicon ''functionalized'' (industry, lab activity)

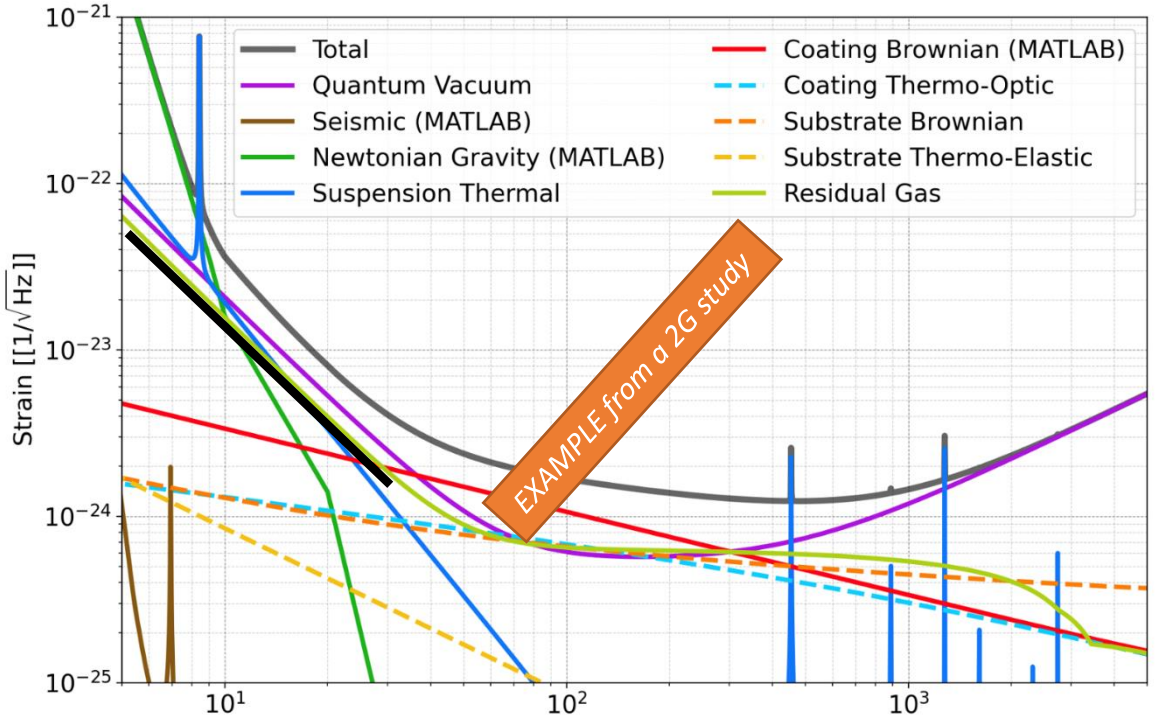
Other ideas ?

Gas damping model for TMs

Noise due the collisions of molecules on the TMs

Model already implemented for the TM in a large ‘unconstrained’ volume [1].

The case of constrainment by other elements (PAY structure) has already been calculated by LIGO and others [2] and noise could higher. Normally, there will be other possible effects to explore (e.g. non-uniform outgassing ...)



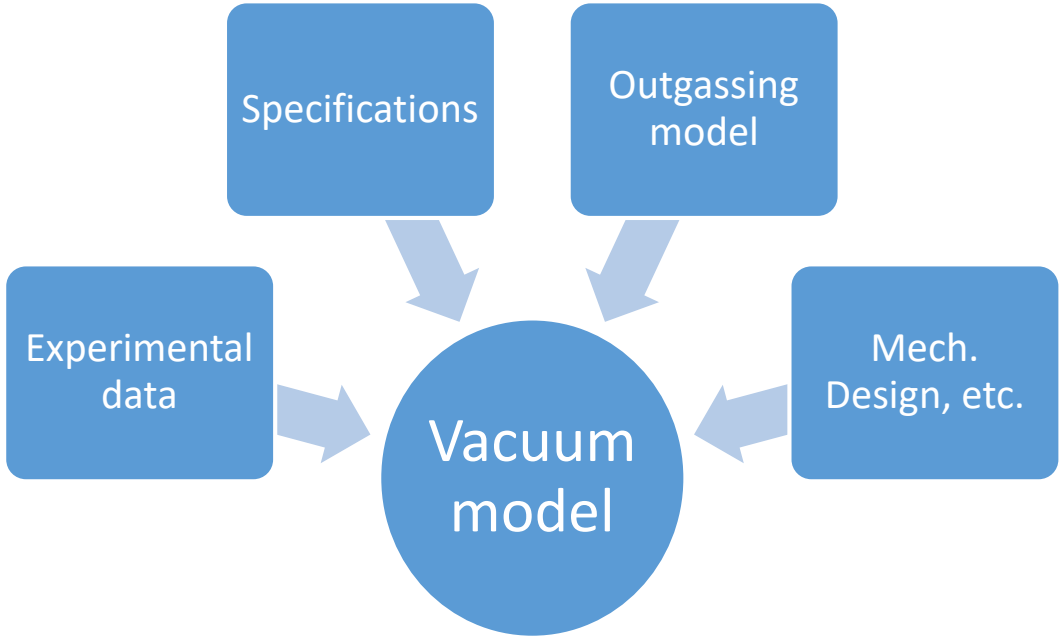
Courtesy: Virgo Collaboration

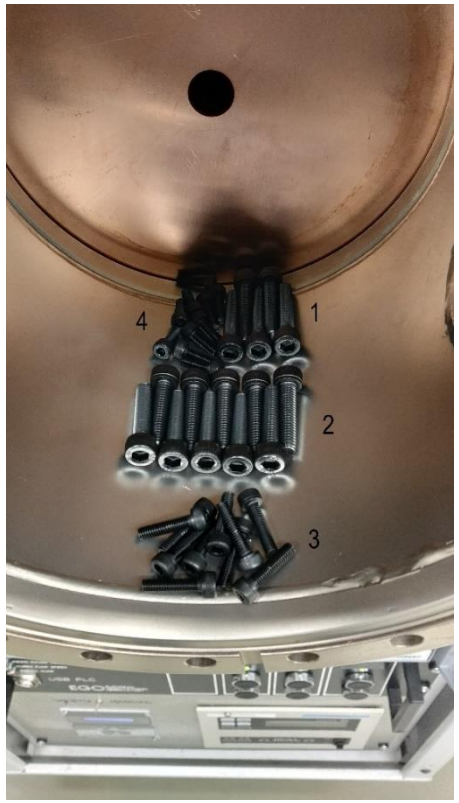
[1] xxx
[2] xxx

Outgassing measurement activity

- Talk by Julien G.

tgassing of materials





Test of 'blackened screws' for DET

Good vacuum level and estimation of the outgassing budget → Essential for the good operation of the interferometer.

Research areas

H_2O	N_2 and other gases	H_2

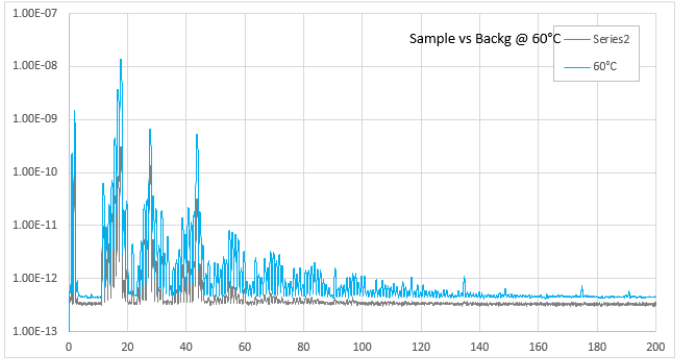
Investigations in reducing the outgassing:

- Water, “air” in thick polymers (> 3mm): ex. PEEK.
- Hydrophobic coatings: behaviour of water or sticky gases during pump-down.
- Hydrogen outgassing in metals.
- Process: Baking, Roughness, etc.

Correlation between the detected HC level and optical losses.

$$Q = C * (P_1 - P_2)$$

‘Throughput method’



Sample/background at 60C (after 4 days at 70C) – 1150V

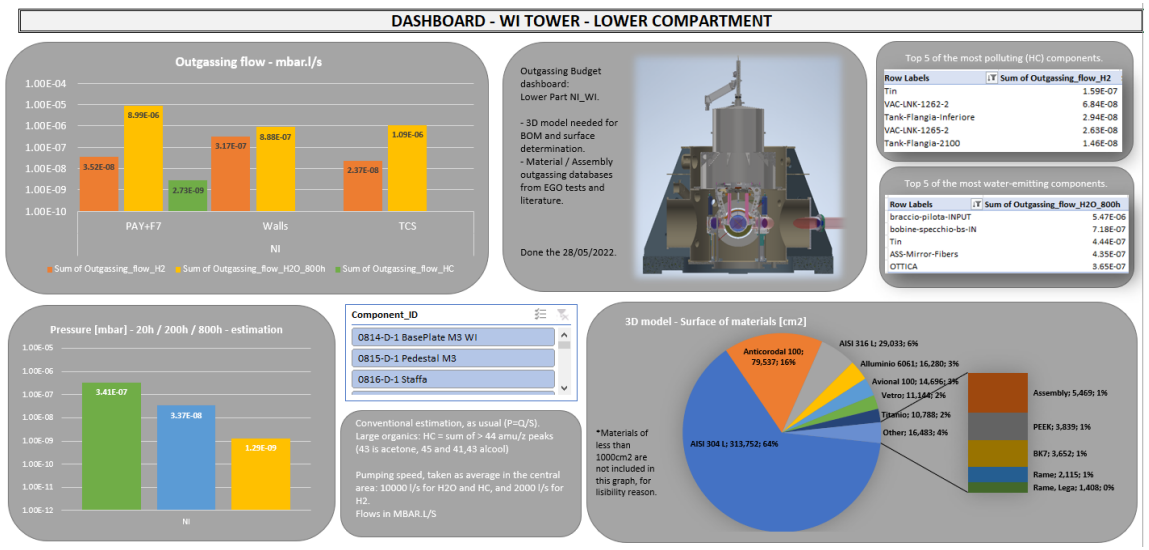
Research areas

Building of the outgassing budget:

For each vacuum chamber, to assess the residual pressure (especially for the low-volatile compounds), and identify the gas species present in the tower, dynamic.

For one compartment, EXAMPLE:

- More than 250 components (including 30 assemblies)
- 20 materials



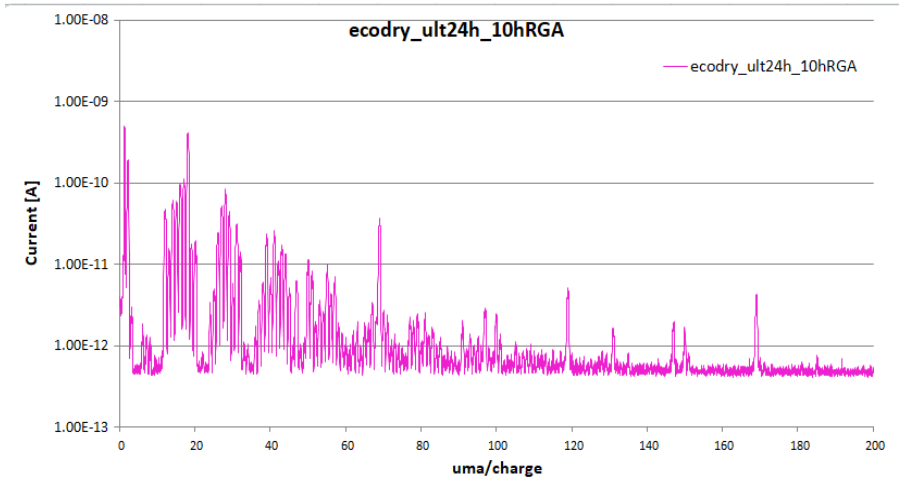
- Risk if no budget:

Accepting too many elements with a medium / strong outgassing while the pumping system is not updated (difficult and high cost), resulting in an ultimate pressure elevation and/or longer pumping time to acceptable pressure level.

Test activity

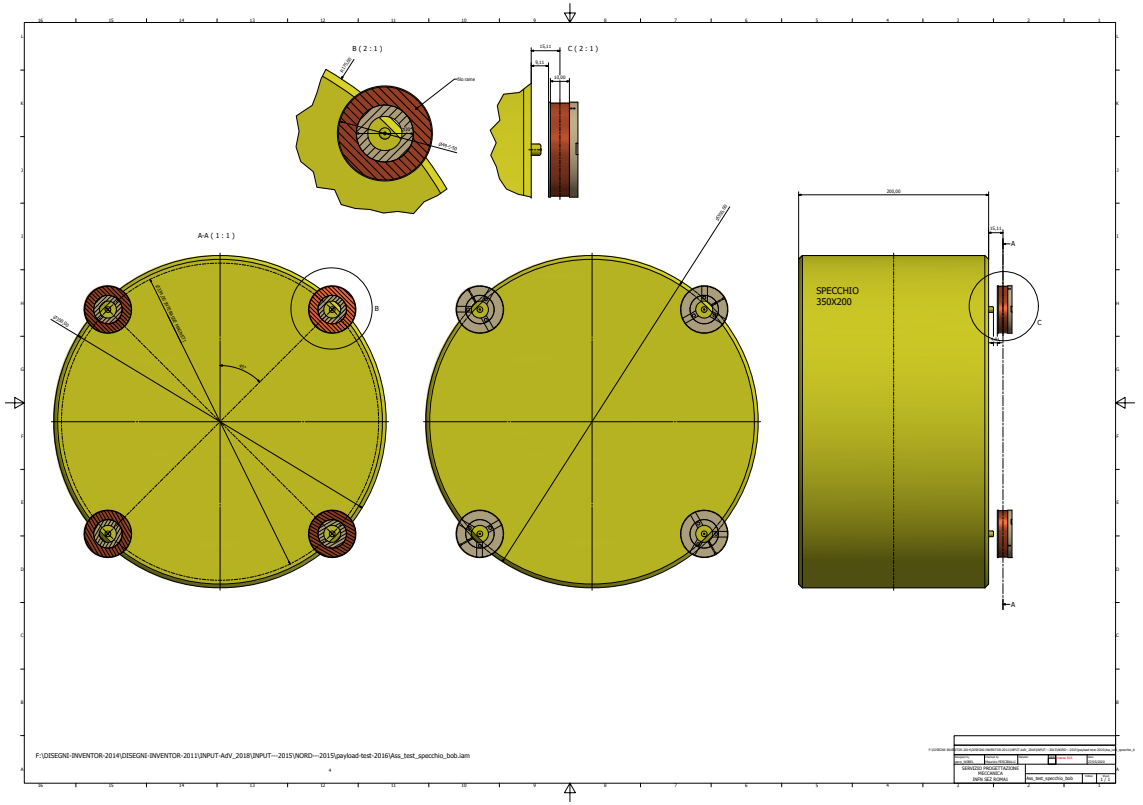
Building new benches for measuring H_2 outgassing by accumulation, H_2O and for thermal desorption.

Vacuum laboratory – Outgassing measurements



Outgassing measurement - Pump

- Spare slides



$d_{coil\text{-}mirror} = 10.11mm$
$r_1 = 25mm$
$r_2 = 15mm$

$S_{coil} = \pi (r_1^2 - r_2^2) = 0.0013\ m^2$

$V_{inj} = 1\ V$

$$V_{mir,coil} = k\frac{h_f}{h_{2f}}V_{int} \quad with \quad k = 0.28$$

$$V_{mir,tot} = \sum V_{mir,coil}$$

$$\sigma_{coil} = \frac{\varepsilon_0}{d}V_{mir,coil}$$

$$\sigma_{tot} = \sum \sigma_{coil}$$

$$Q_{coil} = \sigma_{coil} S_{coil}$$

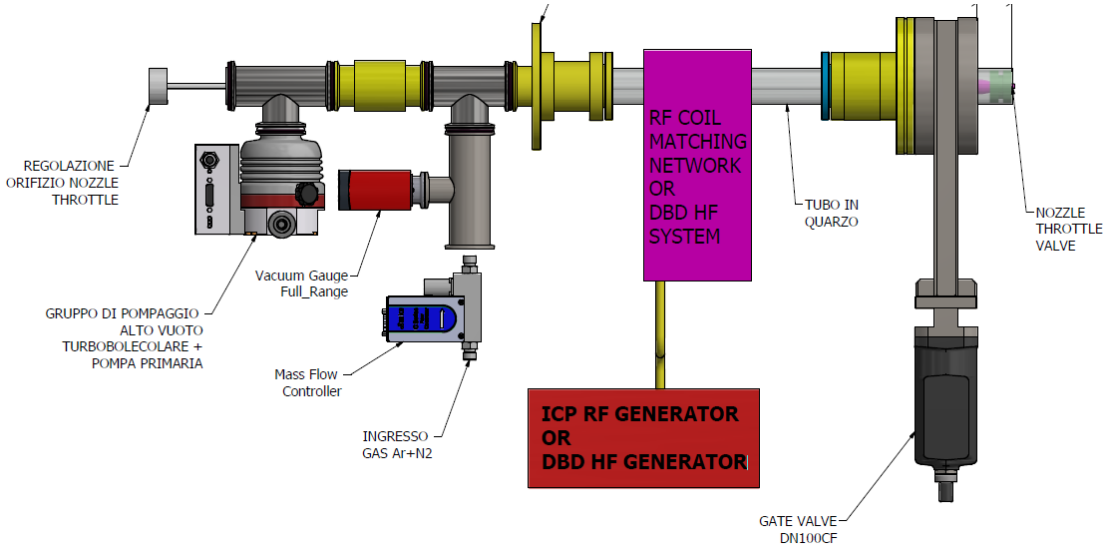
$$Q_{tot} = \sum Q_{coil}$$

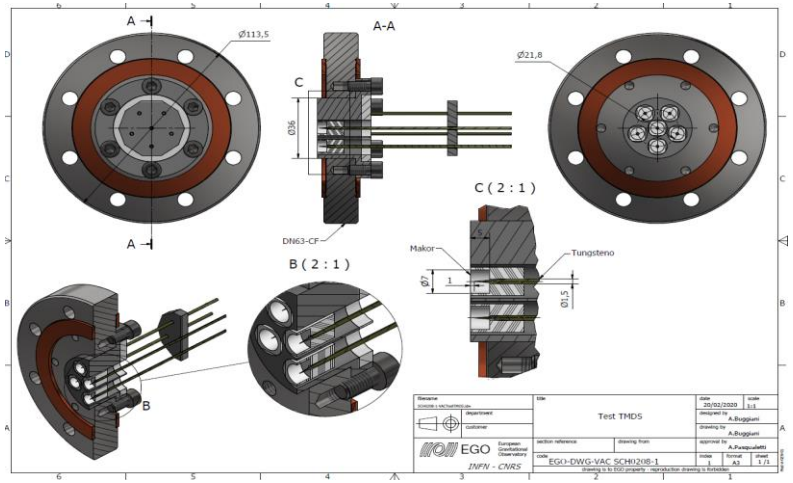
https://logbook.virgo-gw.eu/virgo/uploads/47147_1570536273_Static%20Charge.pdf

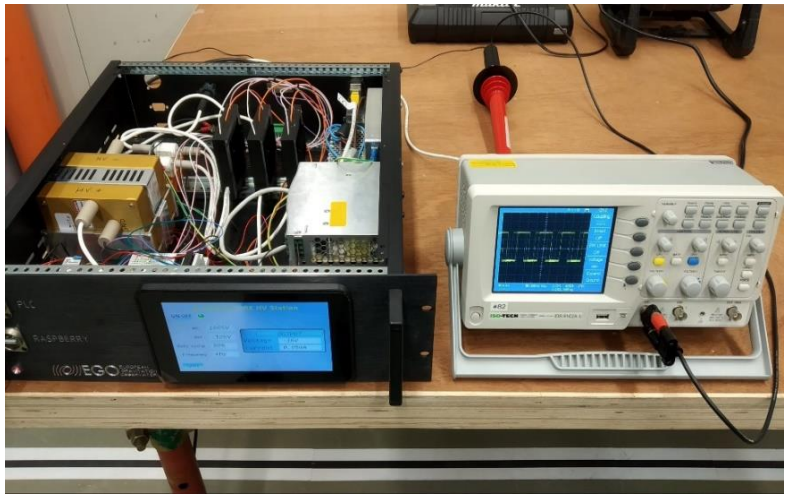
Tower	σ_{tot} (pC/cm²)	Q_{tot} (nC)	$V_{mir,tot}$ (V)	Date of measurements
NE	18	0.22	204	7 Nov 2018
WE	39	0.49	446	7 Nov 2018
WE	46	0.58	524	12 Sept 2019
NI	56	0.71	645	26 Aug 2019
WI	37	0.46	422	26 Aug 2019

Neutralizer prototypes

- Type I: Ionization by alternating current at RF (13.56 MHz) applied to a coil externally mounted on a quartz tube containing N_2 ;
- Type II: follows the LIGO solution and the ‘top gun’ technique as well: ionization by ‘corona’ discharge with HV needles

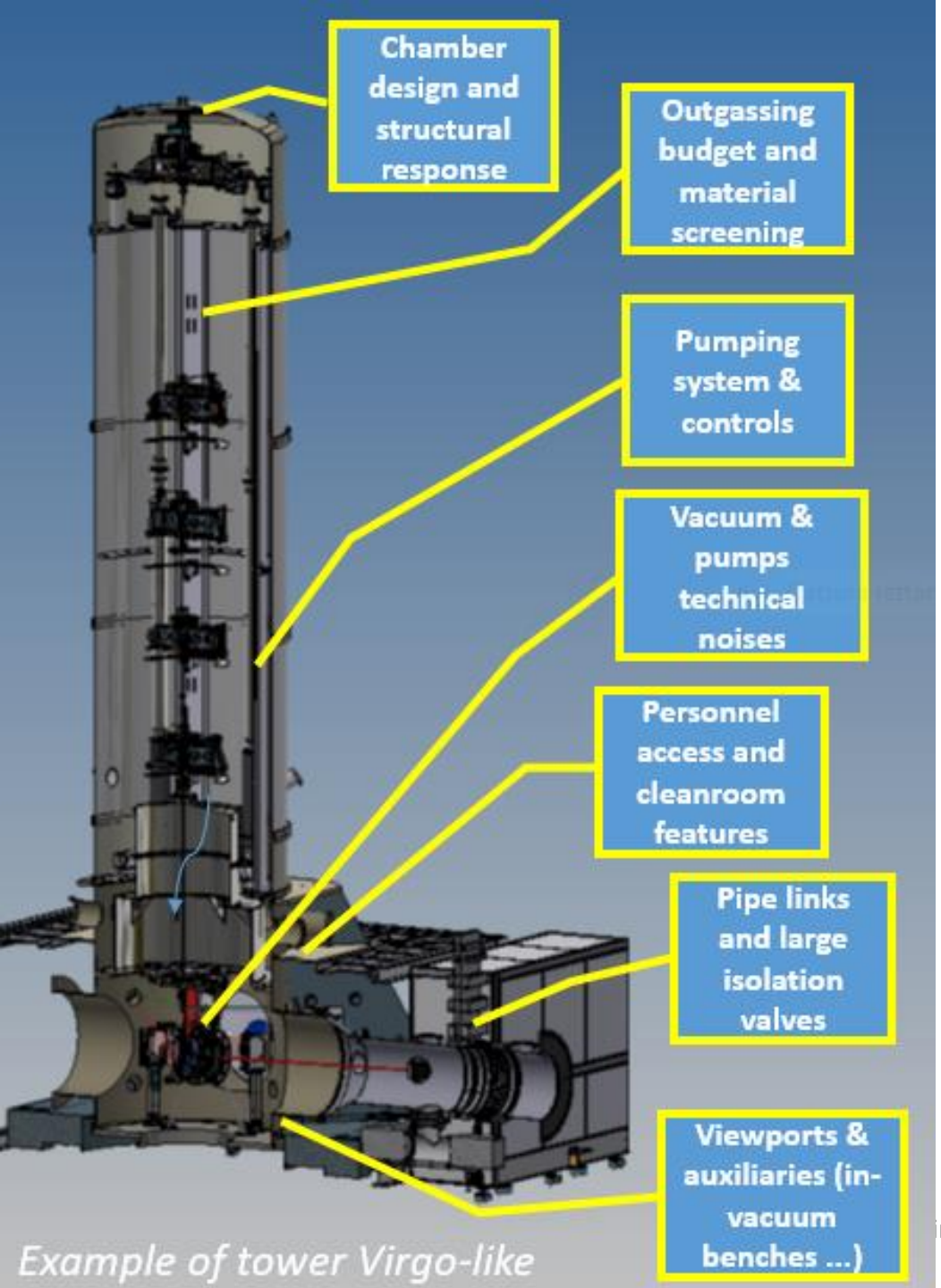






R&D topics (initial ones)

VACUUM CONTAMINANTS CONTROL (Hydrocarbons)
- Study of diagnostics to be applied during the production , qualification and operation of towers - novel cleaning treatment for tower chambers (plasma processing, …)
SPECIALIZED VACUUM TECHNOLOGIES
- Shields for charges dispersed from large Ion pumps - Affordable large metal seals - Large viewports policy and management of ‘breaking risks’
VACUUM-COMPLIANT ‘BLACK’ MATERIALS
coatings or conditioning of the inner - large walls - of towers chambers (and inter-connecting pipes) - performant w.r.t. stray light mitigation - performant w.r.t. UHV (research on physical/chemical treatments for water outgassing reduction)
CONTROL OF DUST PARTICLES IN VACUUM CHAMBERS
- State-of-the-art methods to measure the concentration of dust particles on the walls of chambers



WPIV.1 @ ET-ISB WORK BREAKDOWN

Vacuum requirements

WPIV.1 includes the definition of the requirements, the R&D program for materials qualification and processing, the design and the cost evaluation of

- Towers for the HF interferometer
- Upper part of the cryostat for the LF interferometer
- All the interconnected vacuum chambers
- Vacuum pumps , viewports, valves, gauges and mass spectrometers