Material Surface Science Laboratory @ LNF: research activity and laboratory resources

ET Italia: 1° Workshop on Coatings

30th May 2024

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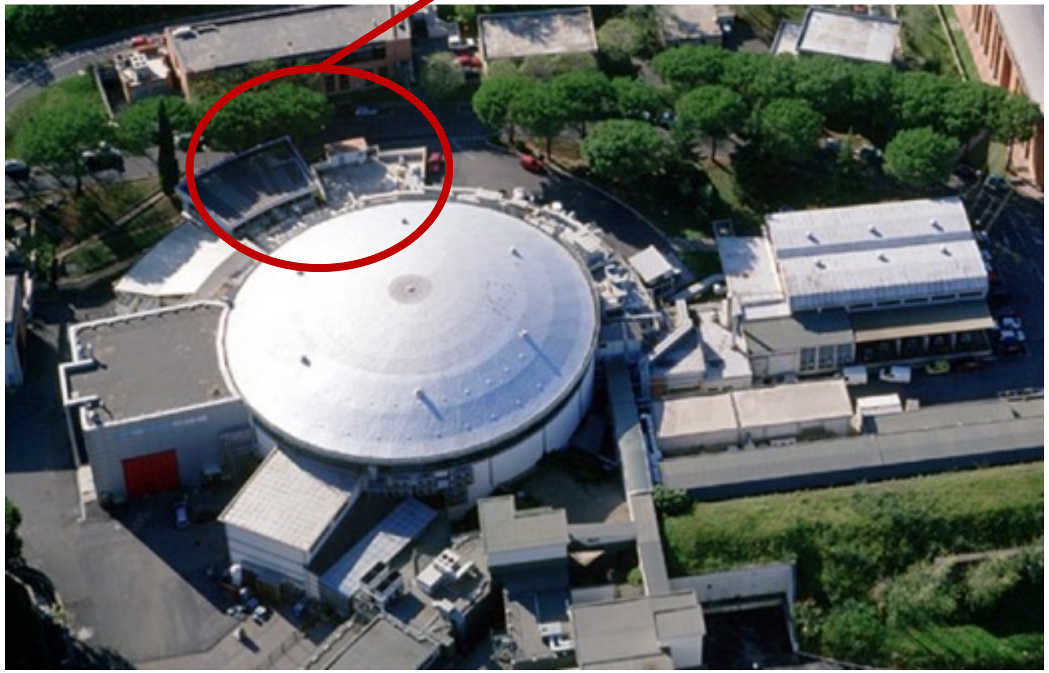
LNF-INFN

INFN LNF

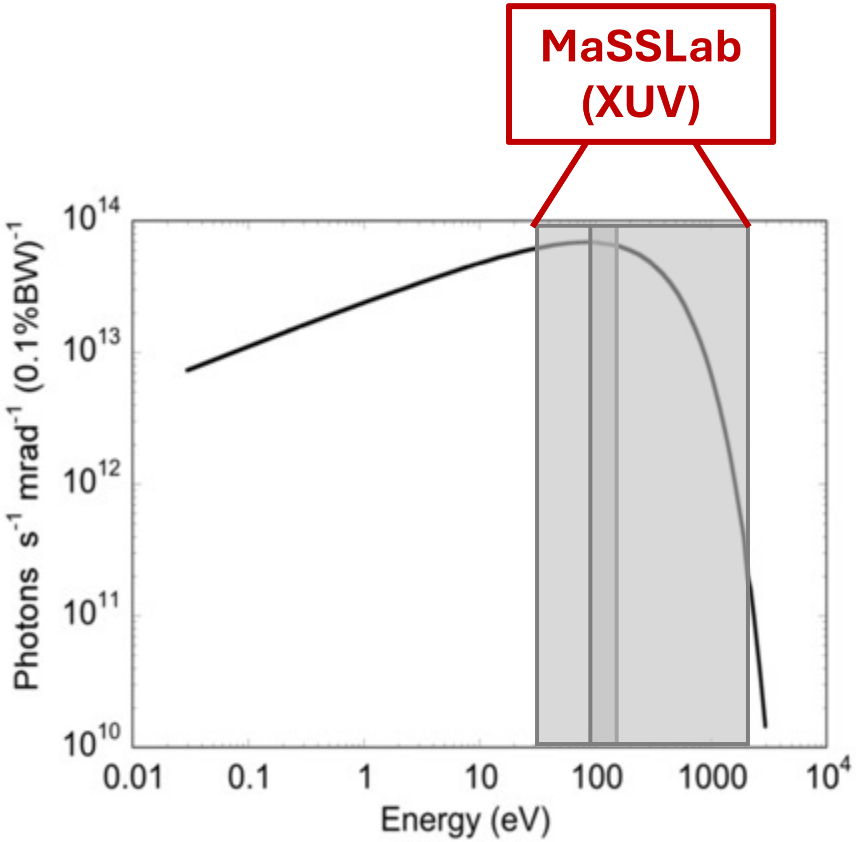
Istituto Nazionale di Fisica Nucleare

Where we are

DAΦNE-L synchrotron light laboratories

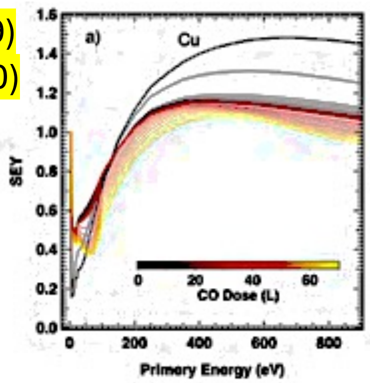


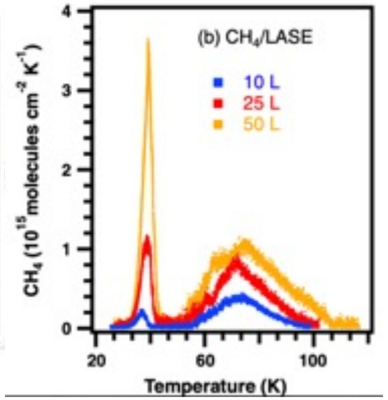
DAΦNE collider in Frascati



Research Activities

L. Spallino et al. Appl. Phys. Lett. (2019)
L. Spallino, J. Vac. Sci. Technol. B (2020)
L. Spallino et al., Phys. Rev. Accel. Beams (2020)

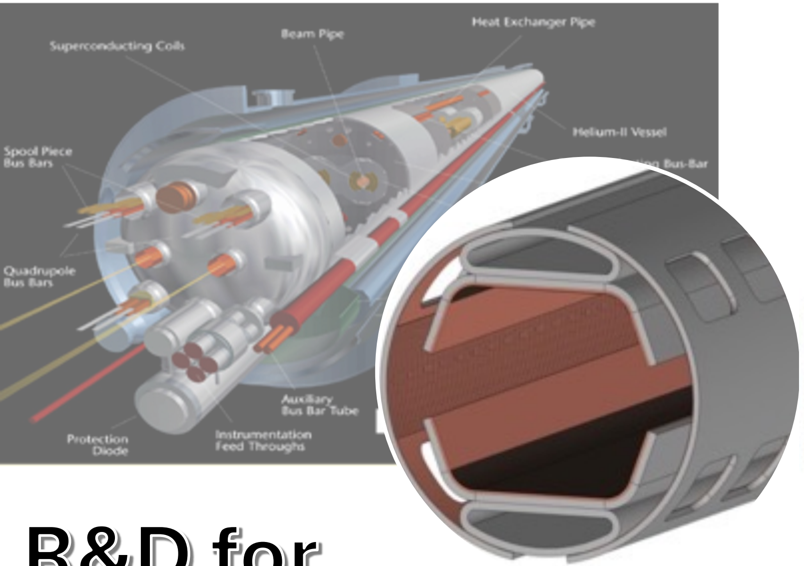




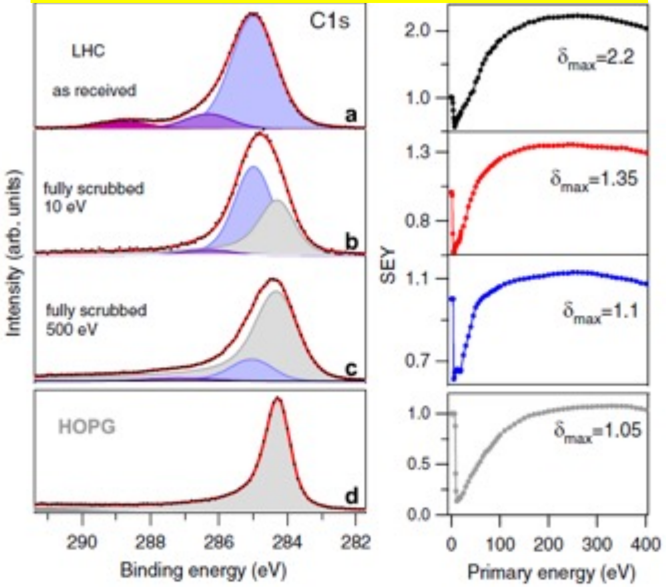
Secondary Electron Emission from UHV vacuum chamber surface → Electron Cloud Instabilities

Condensed gases on porous surfaces → Vacuum Instabilities

Studies at Cryogenic temperature (10 K)



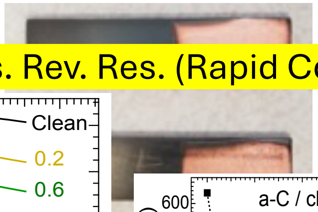
R. Cimino et al., Phys. Rev. Lett. (2012)

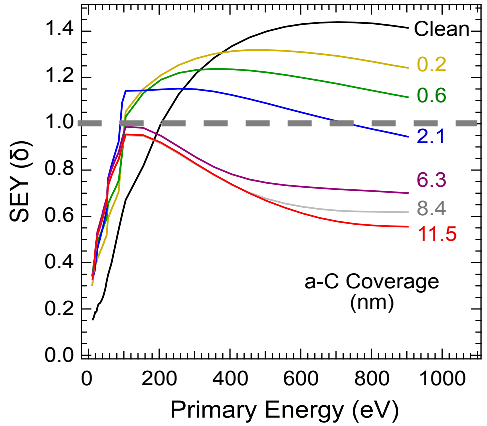


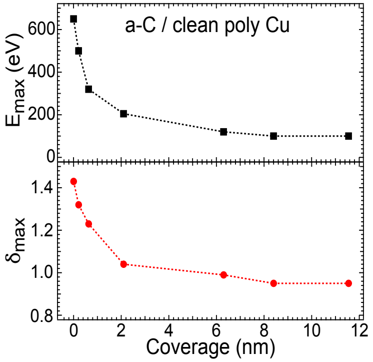
Surface conditioning with electrons

R&D for accelerators

M. Angelucci et al., Phys. Rev. Res. (Rapid Comm.) (2021)





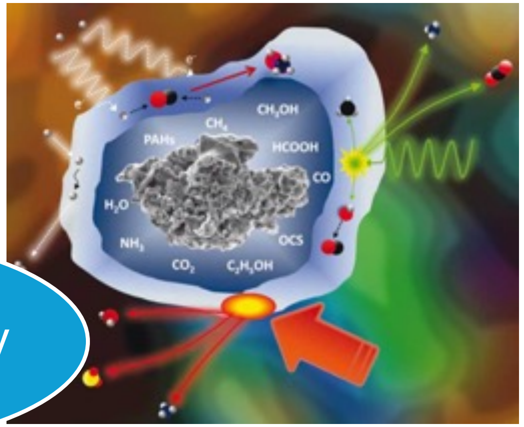


Studied for electron cloud and multipacting mitigation

Multidisciplinary Activities

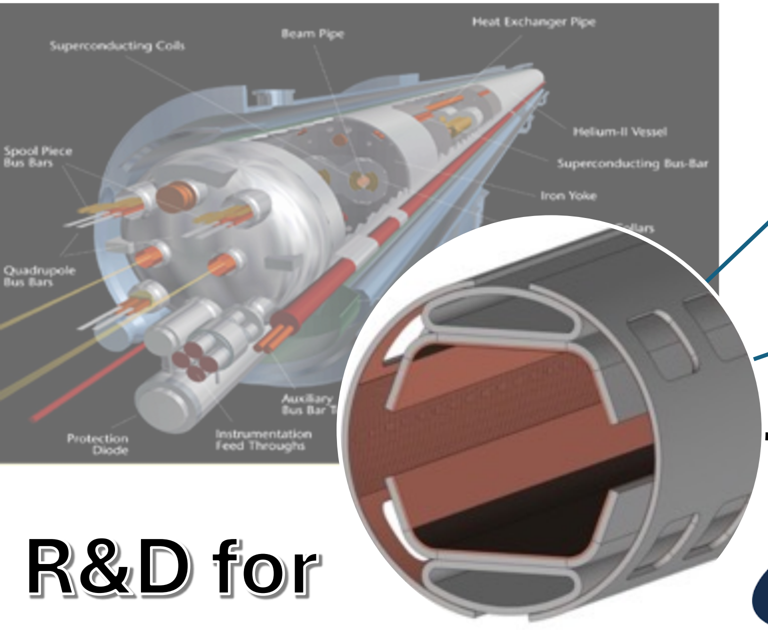
Multipacting

Space and Satellites



Astrochemistry

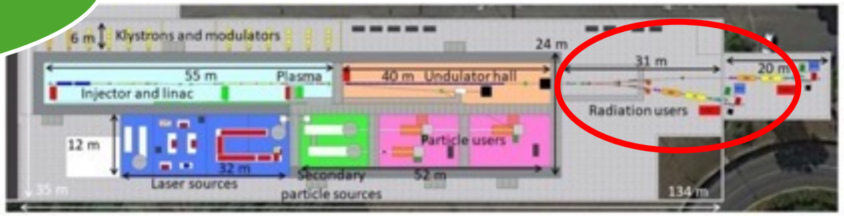
Thermal and non thermal desorption of condensed gases on interstellar medium.



R&D for Accelerators

Eupraxia@Sparc_Lab

Vacuum system and beamlines



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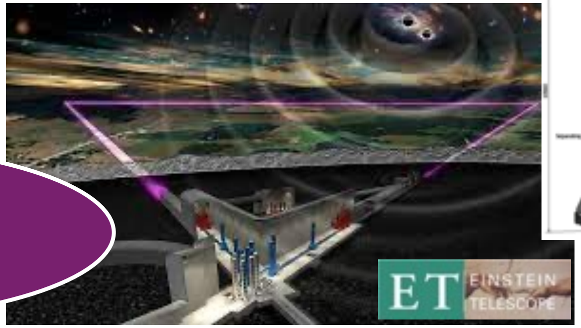
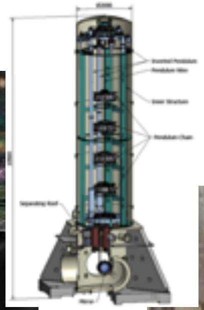
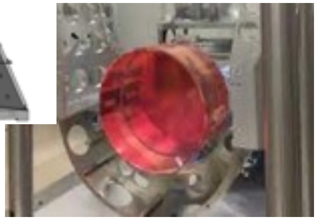
Einstein Telescope







Cyogenic vacuum of towers and beampipes vacuum

Synergies between dynamic vacuum issues in accelerators and GW instrumentations

Common standard vacuum issues

- Installations and running of huge vacuum and cryogenic systems
- Joints, flanges, valves etc. R&D
- Pumps and diagnostic (gauges, mass spectrometers and related R&D)
- Vacuum calculations
- R&D on new materials, material's coatings and/or surface treatments to reduce surface degassing to limit vacuum pumps and contain vacuum costs!

Unconventional GWO issues

Cryosorption on cold optics (frost):

- KAGRA GWO suffers from gas cryosorbed on the mirror surface inducing detrimental effects on the optics.

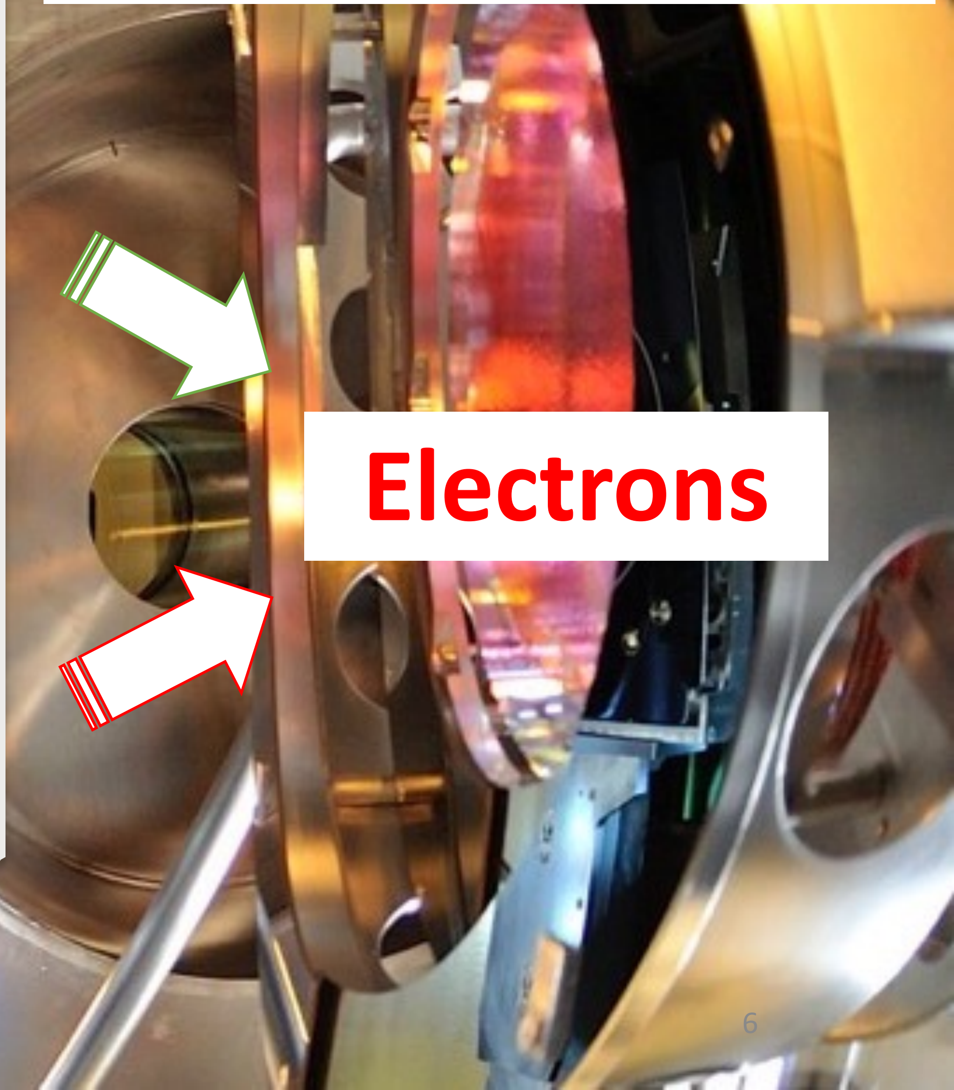
→ Warming up should be avoided (time consuming)

Electrostatic charge of mirrors

- Both VIRGO and LIGO optics undergo to inhomogeneous electrostatic charging of variable (or unknown) sign that may induce unwanted noise.

→ procedures are undertaken for neutralization with positive/neg ions (Not applicable at LT)

See presentation of tomorrow!



ET ITALIA @ LNF (Gr II)

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 – Latino @ LNF in collaboration with MaSSLab & 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.

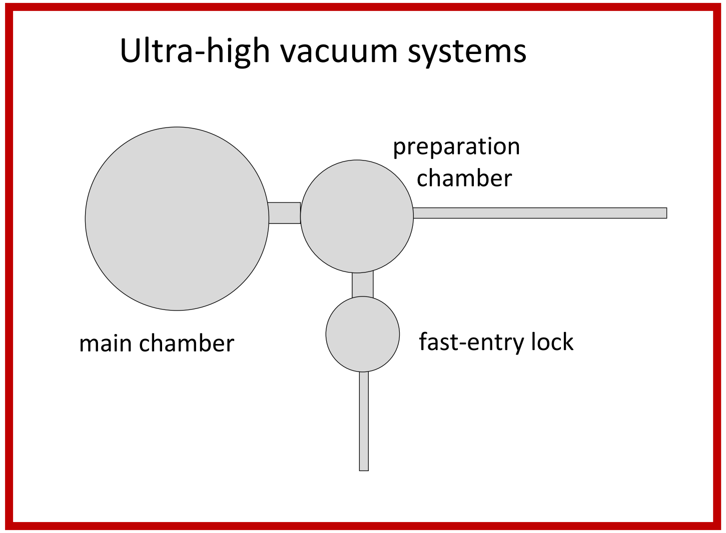
WP3: Passive mitigation method for electrostatic charging

(MaSSLab in collaboration with EGO/Virgo & IFAE and Vacuum Group @ LNF)

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 .

ET-ISB Division IV Vacuum and Cryogenics

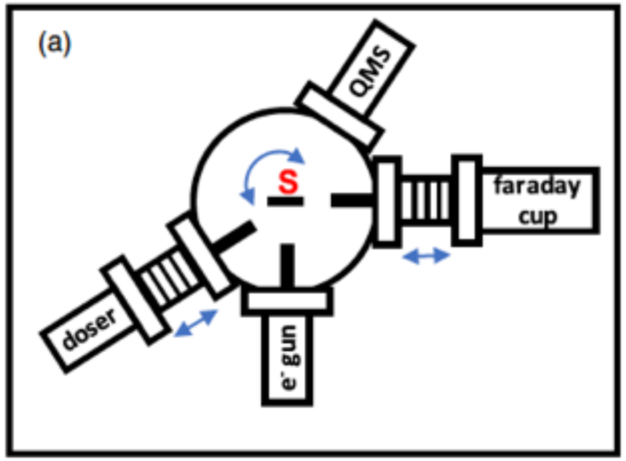
Experimental stations at MaSSLab



2 UHV systems ($P \sim 1 \times 10^{-10}$ mbar) equipped with a cryogenic manipulator ($T_{sample} \sim 10 - 300$ K)

a UHV system ($P \sim 1 \times 10^{-10}$ mbar) for measurements at RT

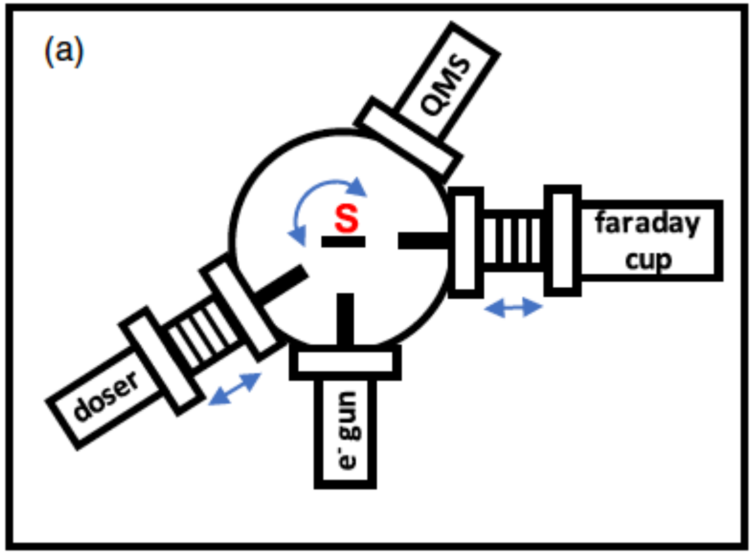
Main chamber

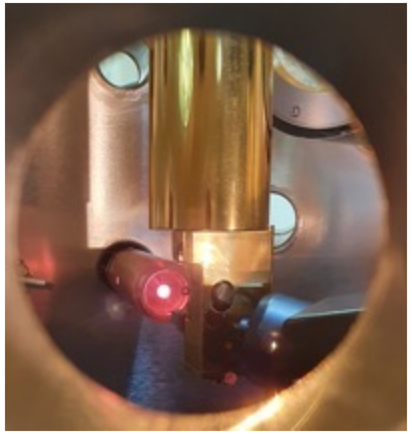


Common elements of the main chambers:

- Set-up for SEY measurements, TPD and electron irradiation
- Gas line and Quadrupole Mass Spectrometer (QMS)

Experimental stations at MaSSLab

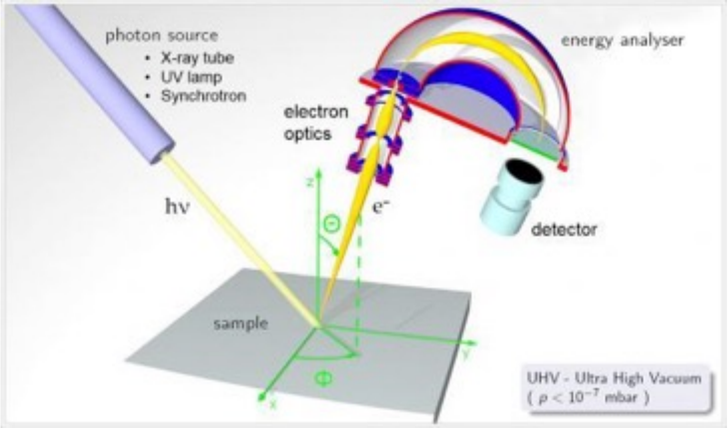




LE Chamber:
+ Atomic Hydrogen Source (under test)

RT Chamber:
+ XPS set-up (Al and Mg nonmonocromatic sources)

HE Chamber:
- + XPS set-up (Al and Ag monocromatic and Al and Mg nonmonocromatic sources)
- + Electron flood gun

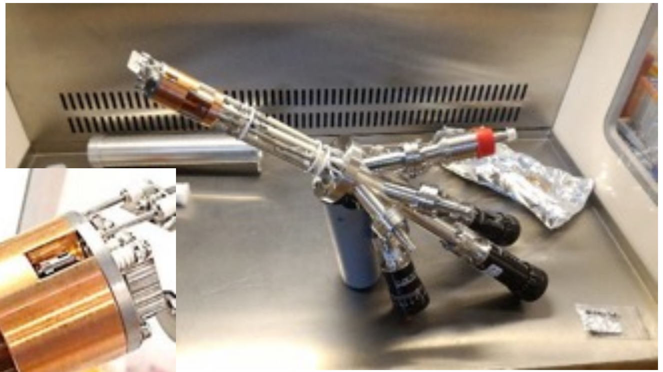


Experimental stations at MaSSLab

LE and RT Preparation Chamber:
Sputtering and thermal heating

HE Preparation Chamber:

- Sputtering and thermal heating
- Electron beam evaporator



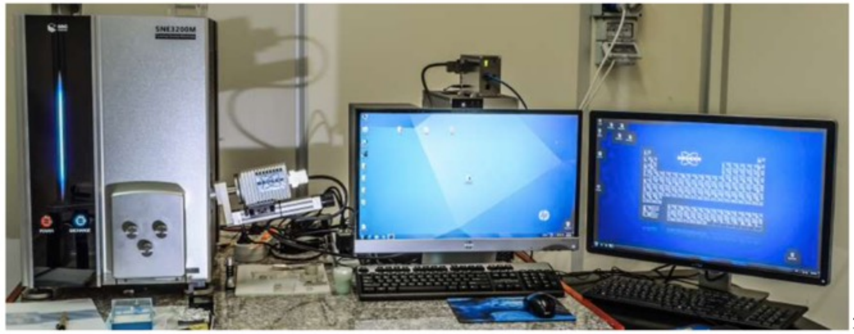
Experimental stations at MaSSLab

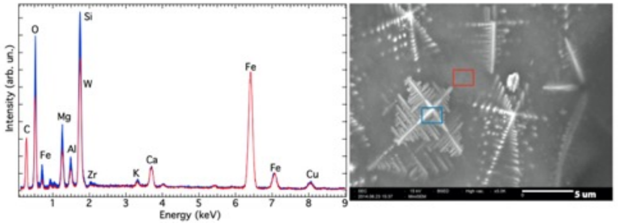
More in lab

- Raman microscope (fundamental at 532 nm) that can be coupled to the UHV chamber by optical fiber (coupling to be implemented)

- Furnace for chemical vapour growth of materials on substrates

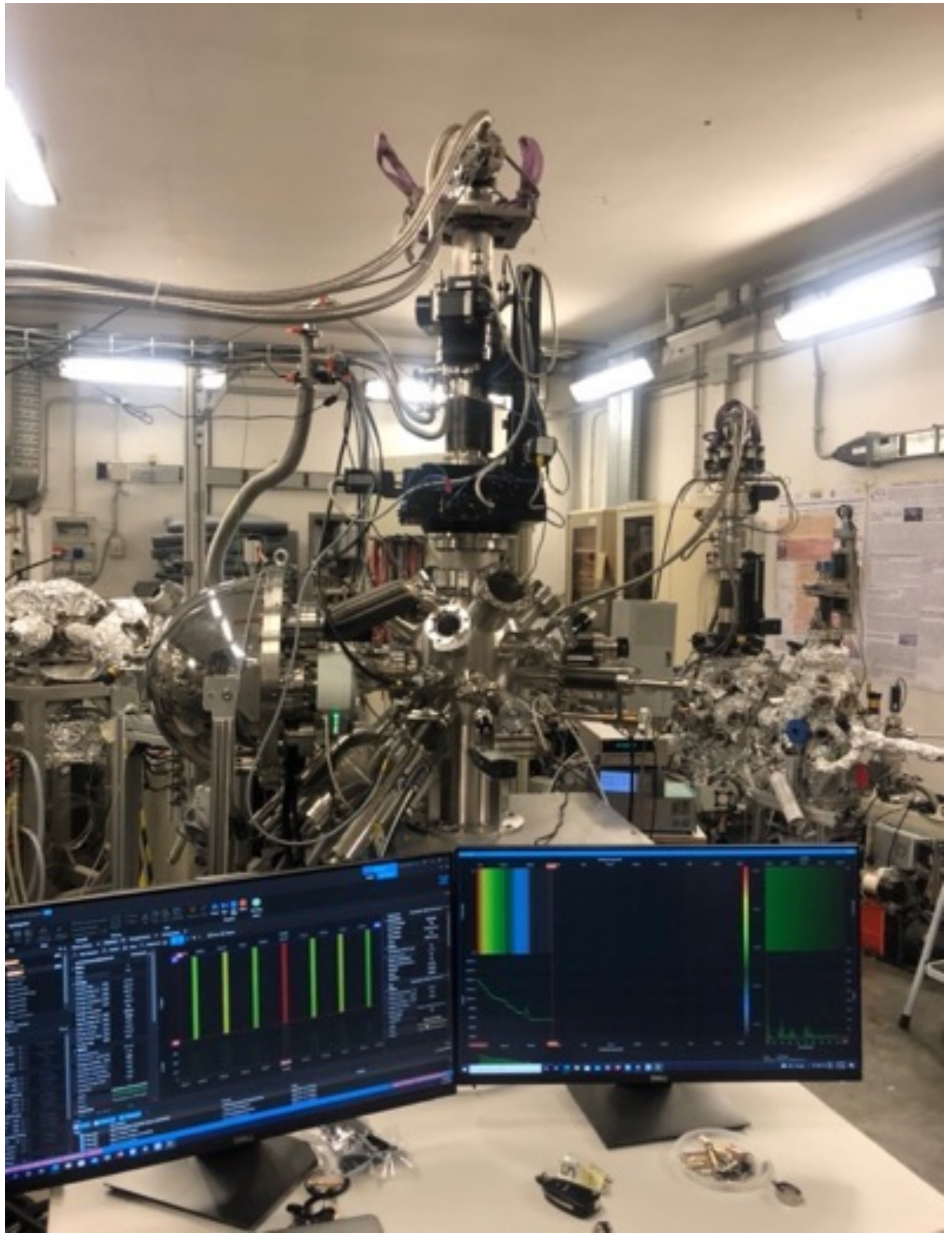
- SEM + EDS for surface characterization





Experimental stations at MaSSLab

- Electron guns (Secondary Electron Yield, conditioning, charging)
- Kelvin Probe
- XPS/UPS
- TDS (10-300 K or 300-1000 K)
- QMS
- CVD
- Raman
- LEED/Auger
- SEM
- EDS



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ET-ISB Division IV Vacuum and Cryogenics

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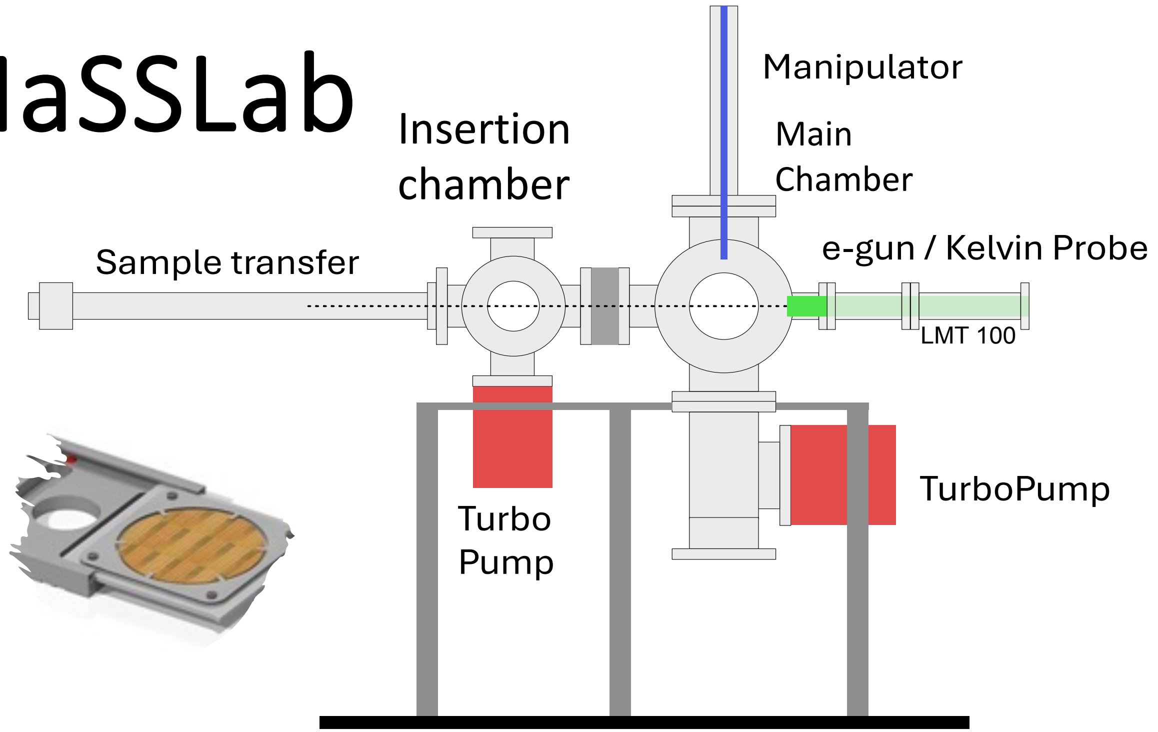
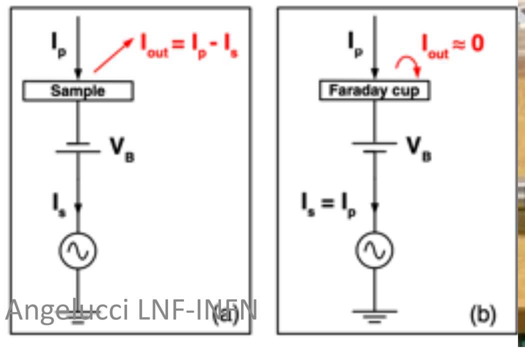
Experimental stations at MaSSLab

Implementation during 2024



The system will be composed by:

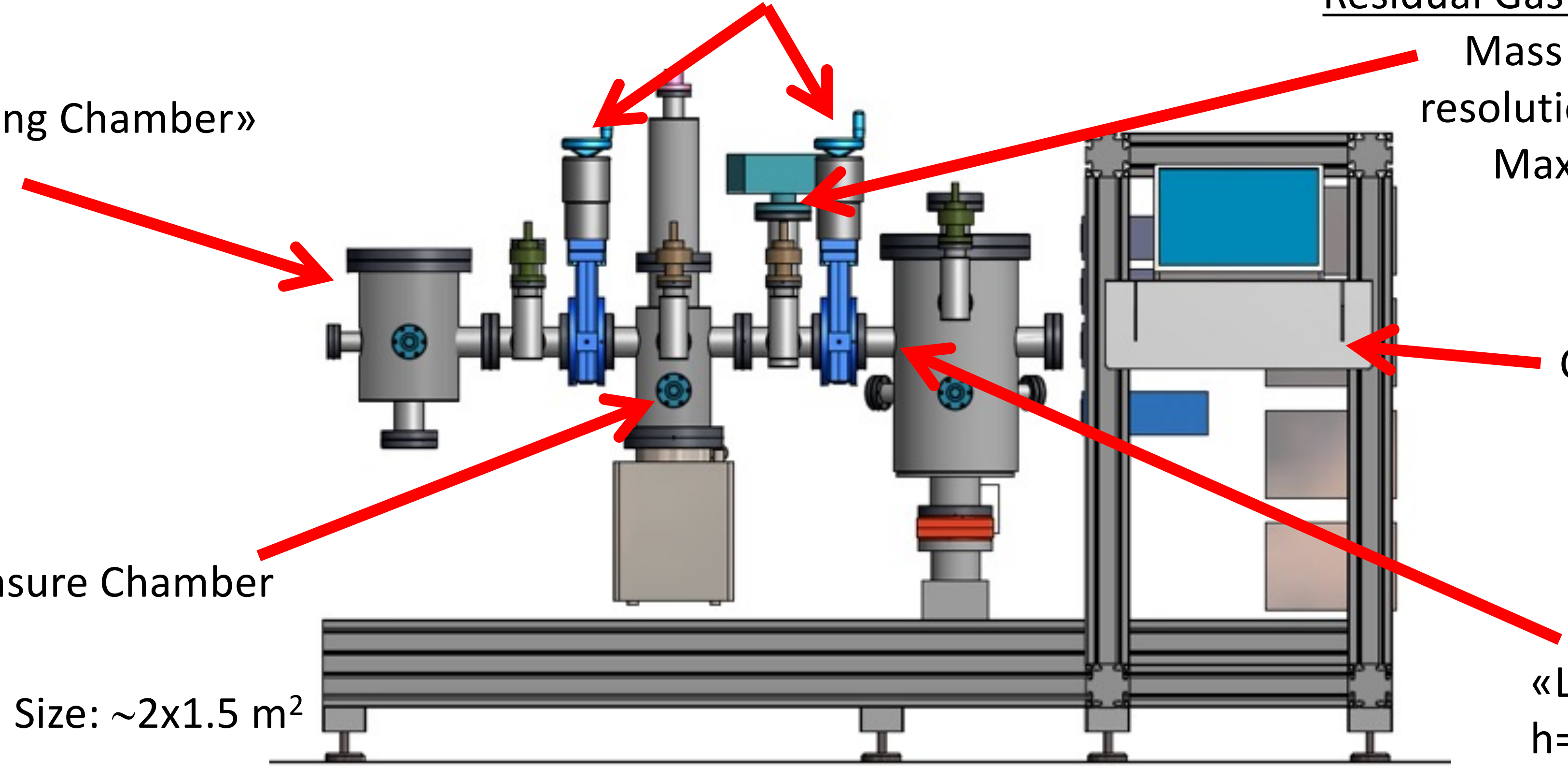
- a UHV chamber equipped with:
  - Electron gun (from Kimball)
  - Kevin Probe from (KP technologies)
  - 4-axis manipulator remotely controlled, with a **specific sample holder for 1” sample**
- An UHV insertion chamber with:
  - **A magnetic transfer equipped with a specific sample grabber**
- **Picoammeters for primary and sample current measurements**
- **Sample holder.**



WP2: Material Properties

(Vacuum Group – Latino @ LNF in collaboration with MaSSLab & EGO/Virgo)

LATINO «OUTGASSING RATE SYSTEM» AT LNF-INFN



G. Delle Monache Gr. II

LATINO (Laboratory in Advanced Technologies for INnOvation) is a cofunded project (INFN-Regione Lazio) - Call "Open Research Infrastructure"

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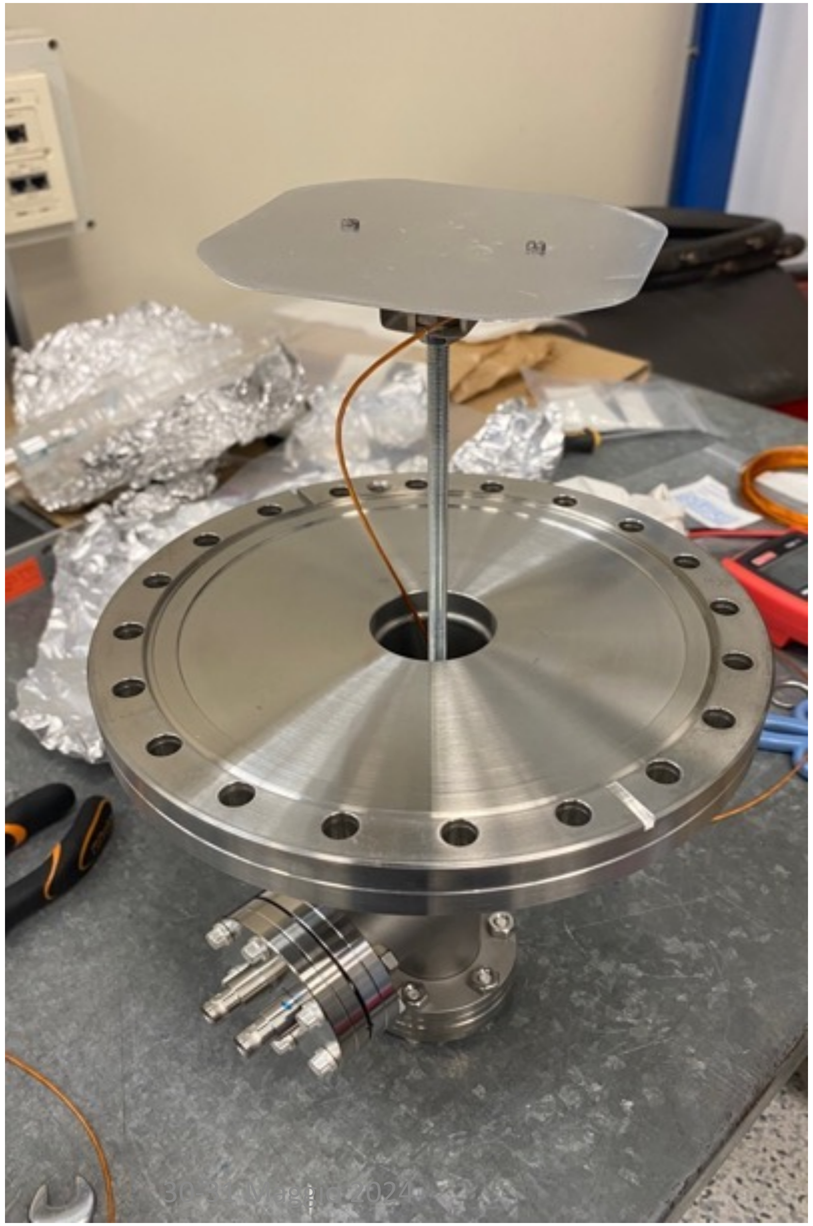
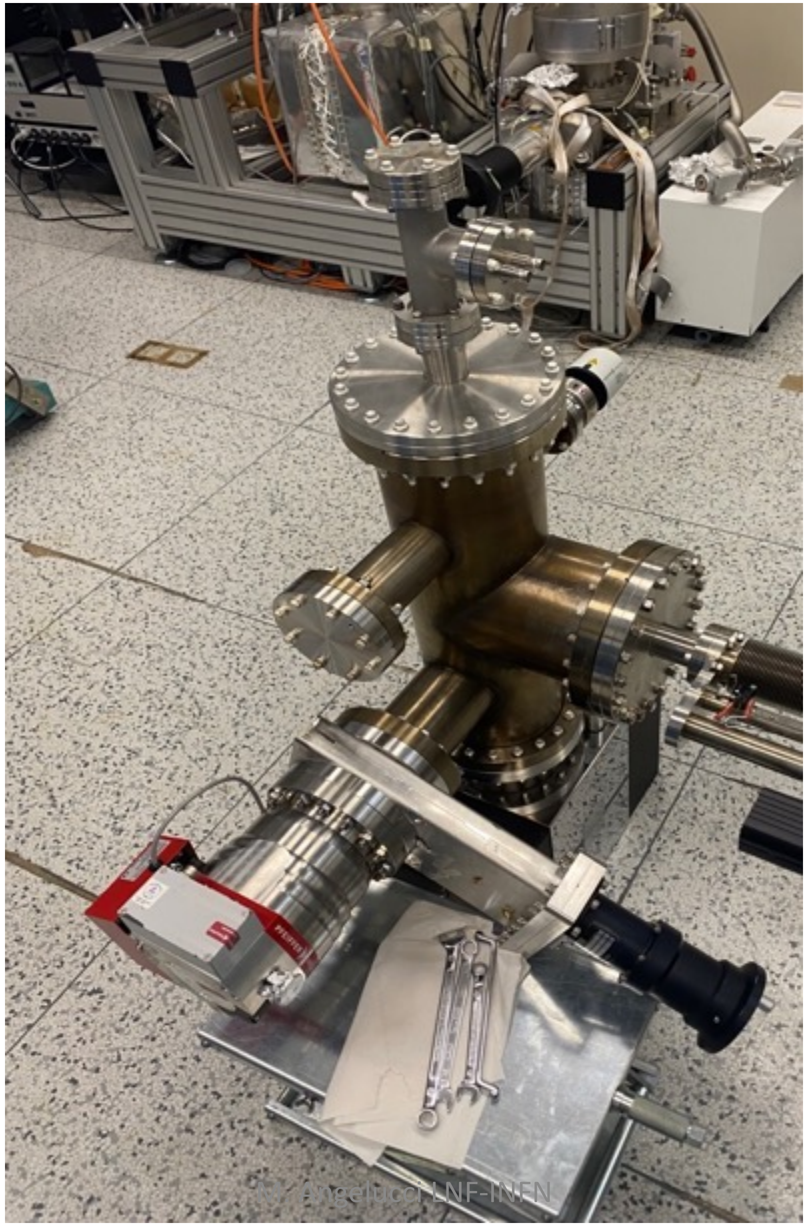
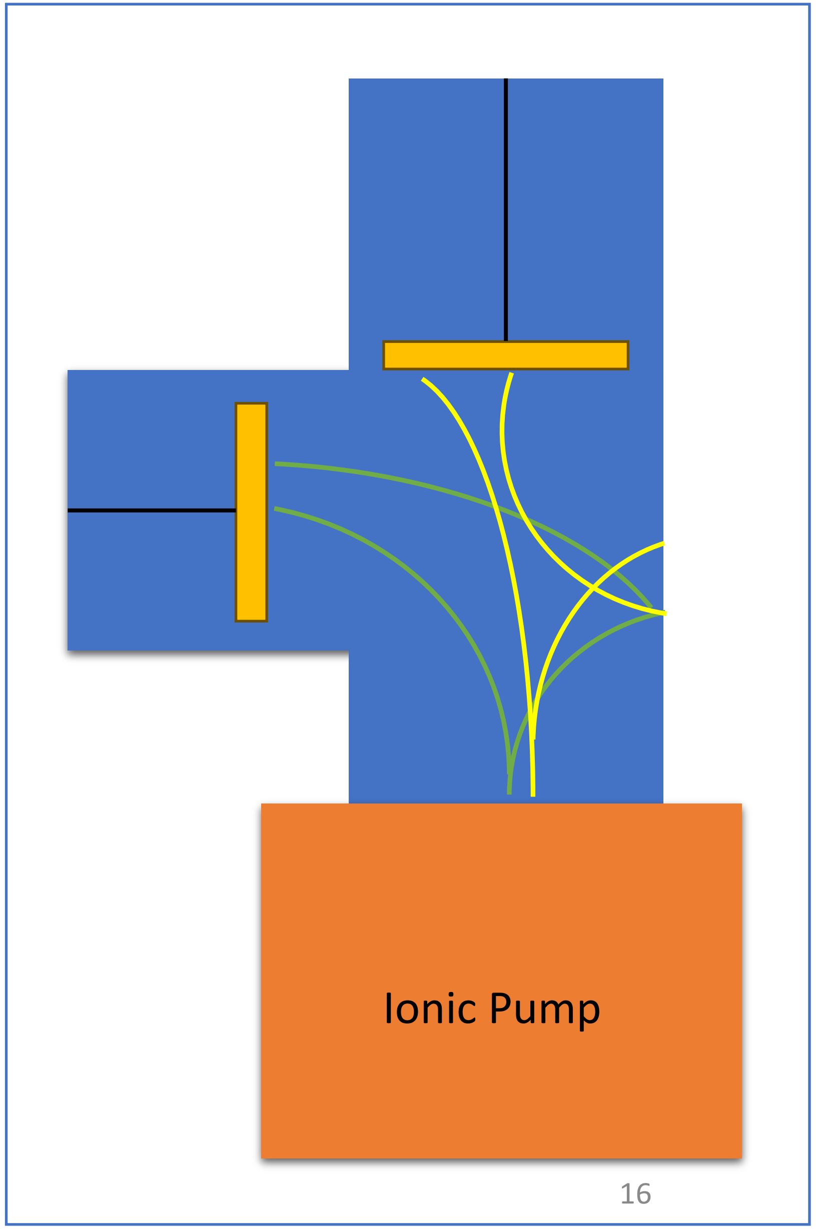


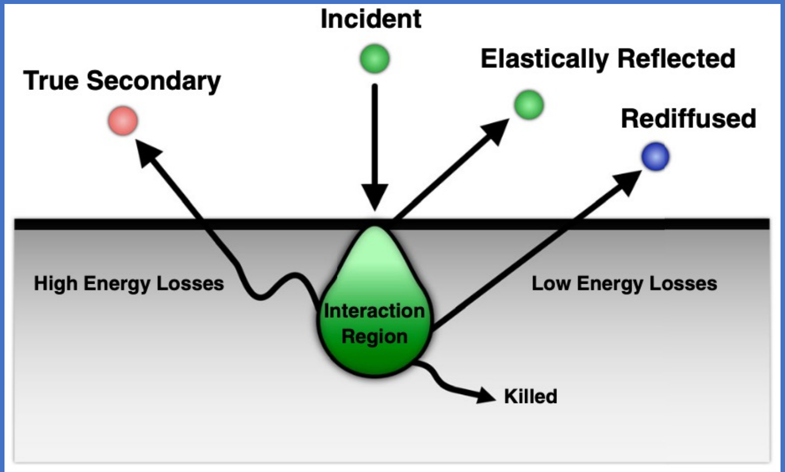




(BK – Slides)

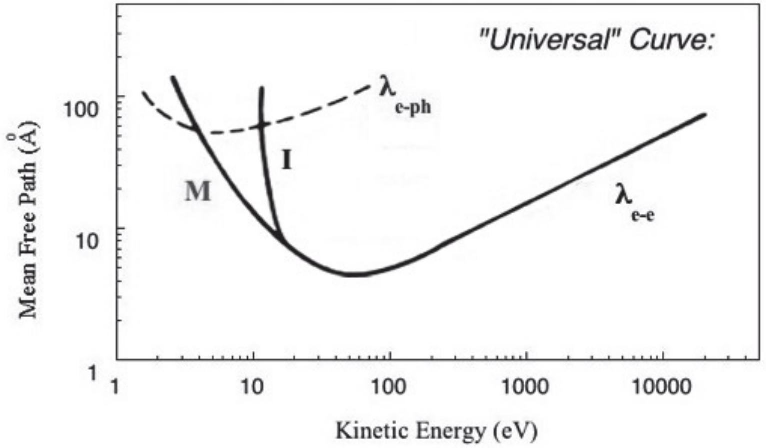
Secondary Electron Yield

Secondary Electron emission



Three-step process:

- Production of SE at a depth *z*
- Transport of the SE toward the surface
- Emission of SE across the surface barrier

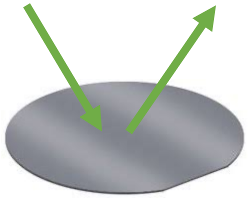


Electron mean free path up to ~10 nm

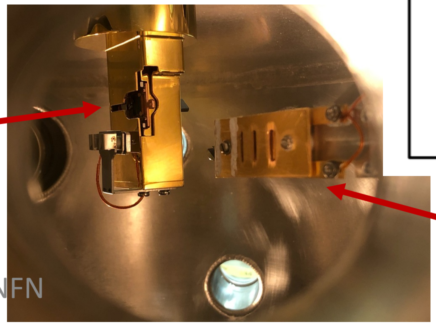
SEY is an intrinsic surface property of materials

Incident electrons current (I_p)

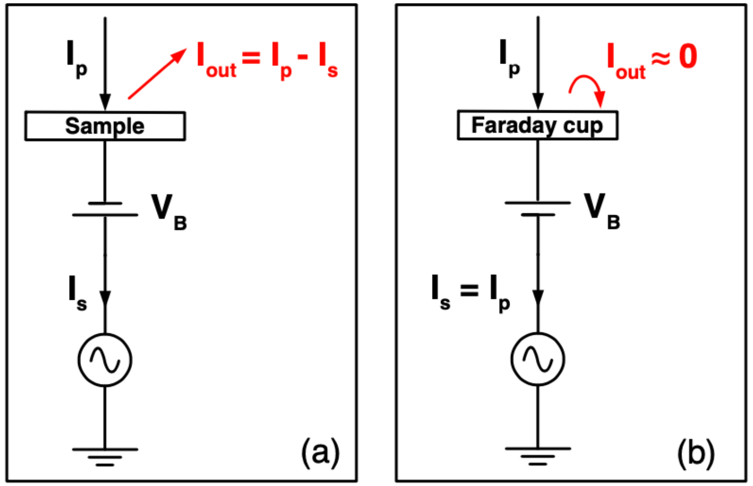
Emitted electrons current (I_{out})



Sample



Farady cup



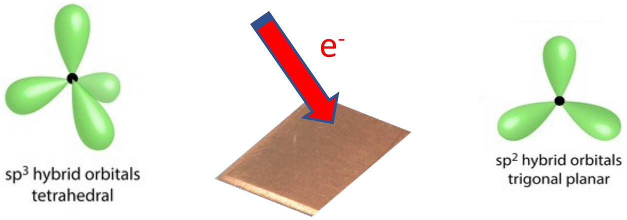
(BK – Slides)

Secondary Electron Yield

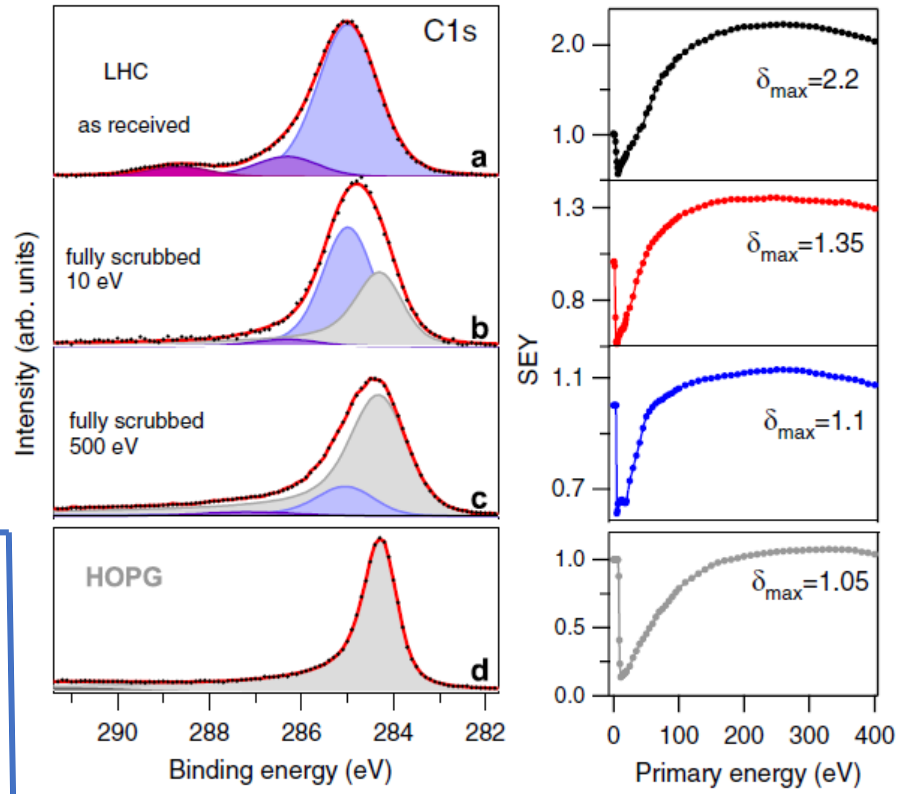
R. Cimino et al., Phys. Rev. Lett. (2012)

$sp^3 \rightarrow sp^2$ carbon surface contamination conversion

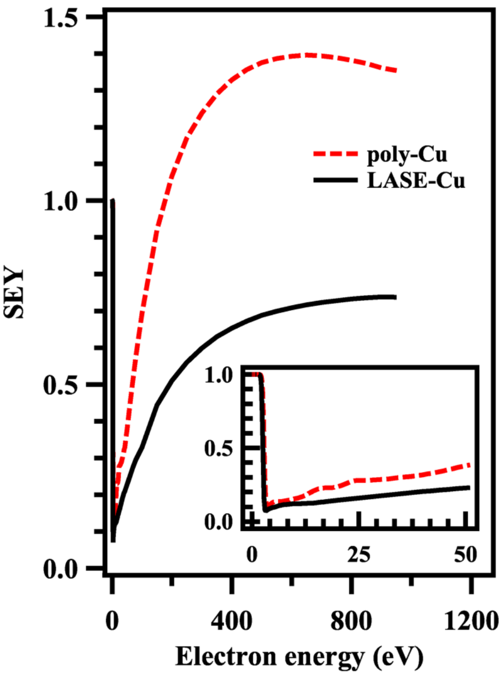
- **SEY depends on the surface chemical state**

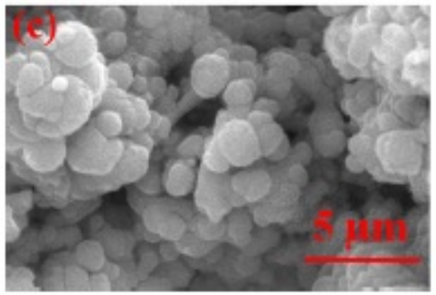


As received LHC-Cu sample

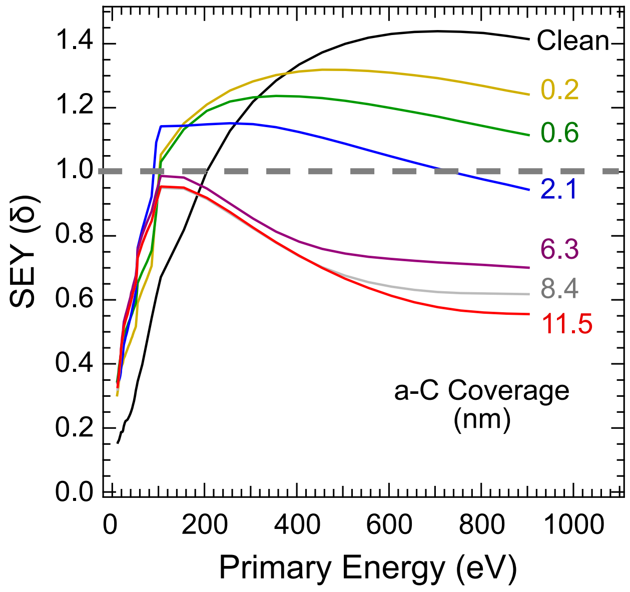


L. Spallino, J. Vac. Sci. Technol. B (2020)





- **SEY depends on the surface morphology**



- **SEY depends on the coverage thickness, even at sub-monolayer coverage**

M. Angelucci et al., Phys. Rev. Res. (Rapid Comm.) (2021)