Possible IJCLab's contribution to the R&D for the Einstein Telescope Vacuum

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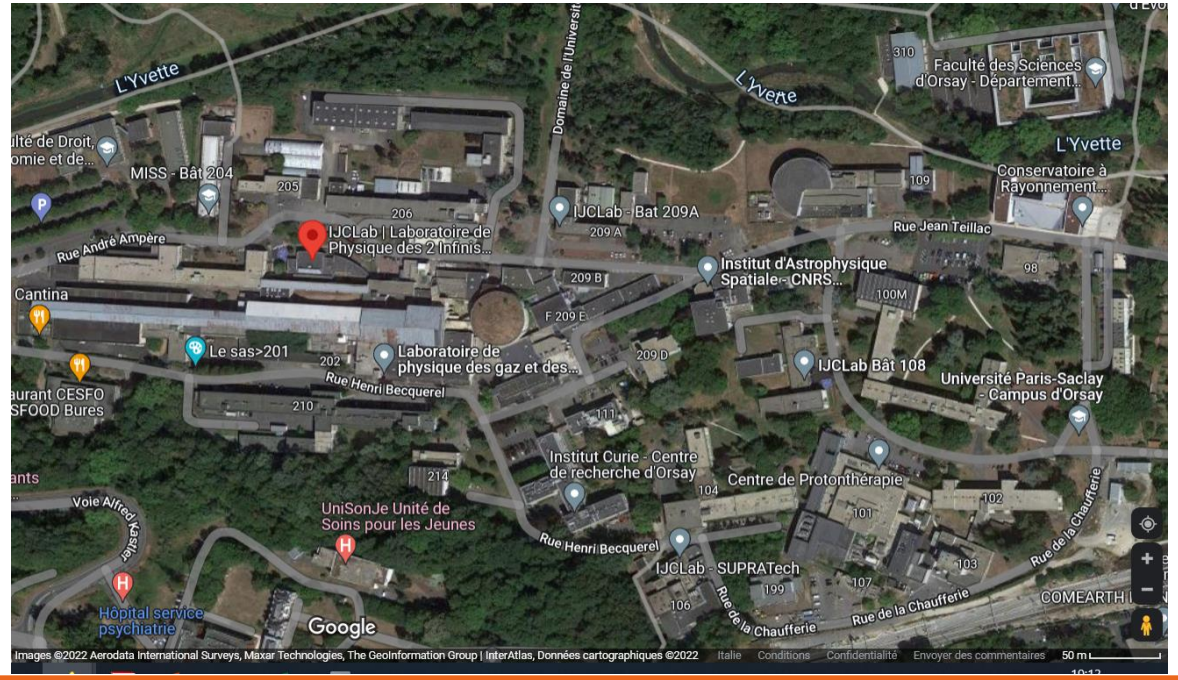
September 30, 2022

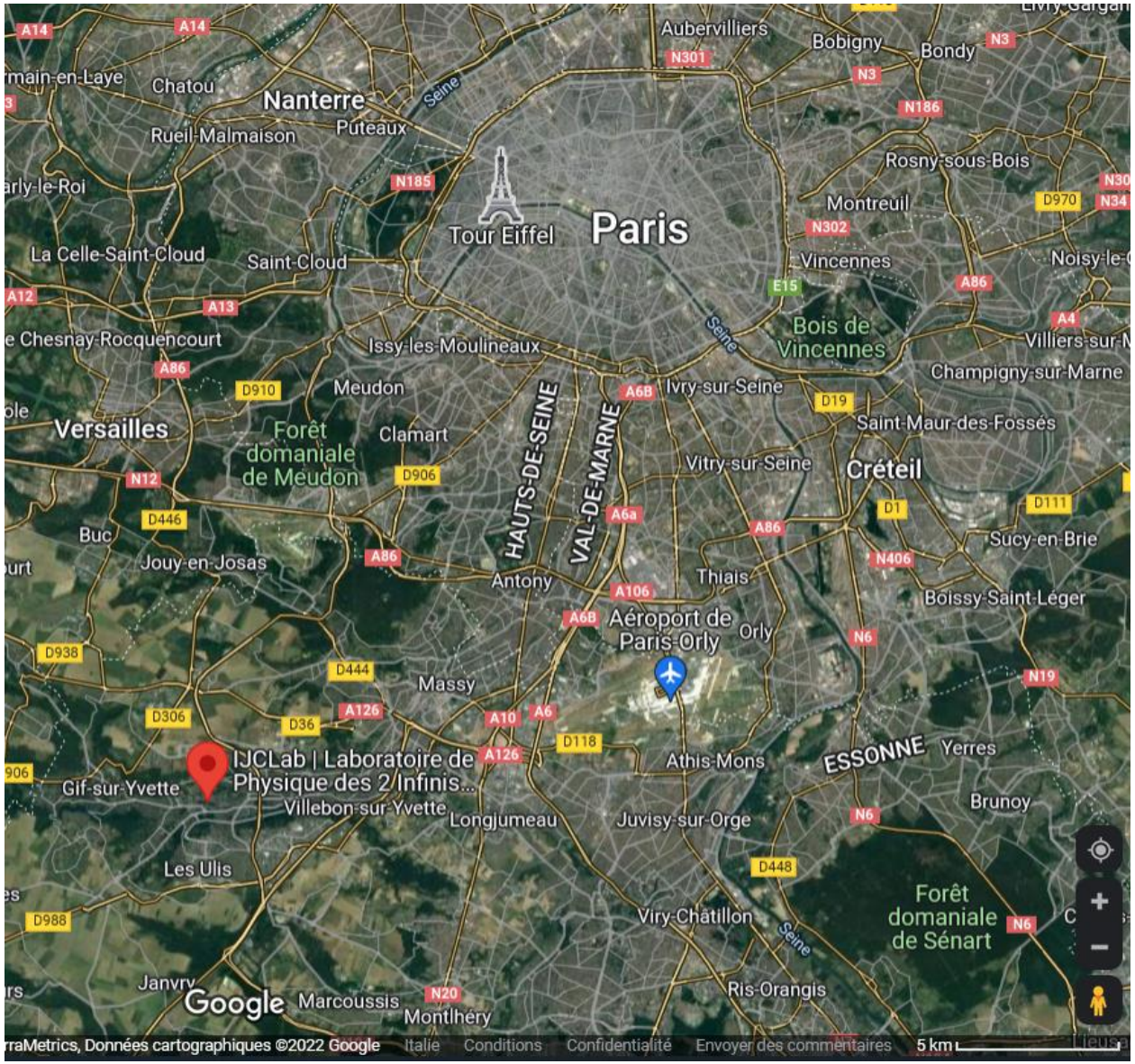
Outline

- Presentation of IJCLab
- Instrumental platforms of interest at IJCLab
- Proposal for IJCLab contribution for vacuum studies in ET tower
- Conclusion and perspectives

IJCLab = Laboratoire de Physique des deux infinis Irene Joliot Curie

30 km South of Paris
in the campus of the Paris-Saclay University





IJCLAB https://www.ijclab.in2p3.fr/en/ijclab-2/overview/

- In 2020 : a merger of 5 laboratories of ORSAY valley (LAL, IPNO, CSNSM, LPT, IMNC)

- 7 scientific poles:
  - Nuclear Physics
  - High-Energy Physics
  - **Astroparticles, astrophysics and cosmology**
  - Energy and environment
  - Health physics
  - Theoretical physics
  - **Accelerator Physics :**
    - ALEA : Laser-plasma acceleration
    - BIMP : Beam Dynamic & diagnostics
    - **MAVERICS : Materials Science, Vacuum & SRF**
    - **Vacuum & Surface Plateforms : Materials Characterization and UHV studies**
    - RF Technology service
    - **Cryogenics service : Design and operation of cryogenic systems for accelerators**

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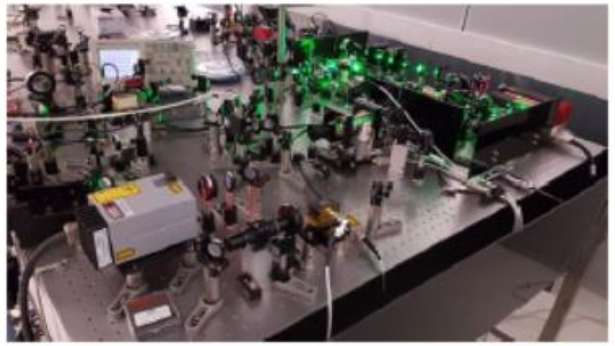
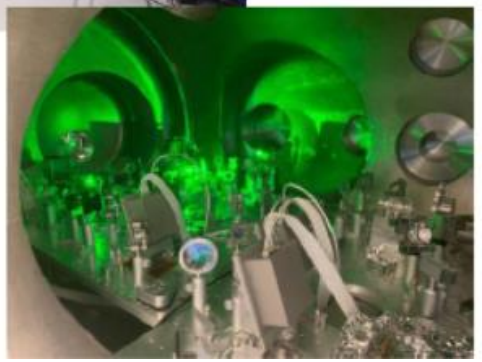
4

Some instrumental platforms of interest at IJCLab

CALVA : dedicated platform for GW detectors

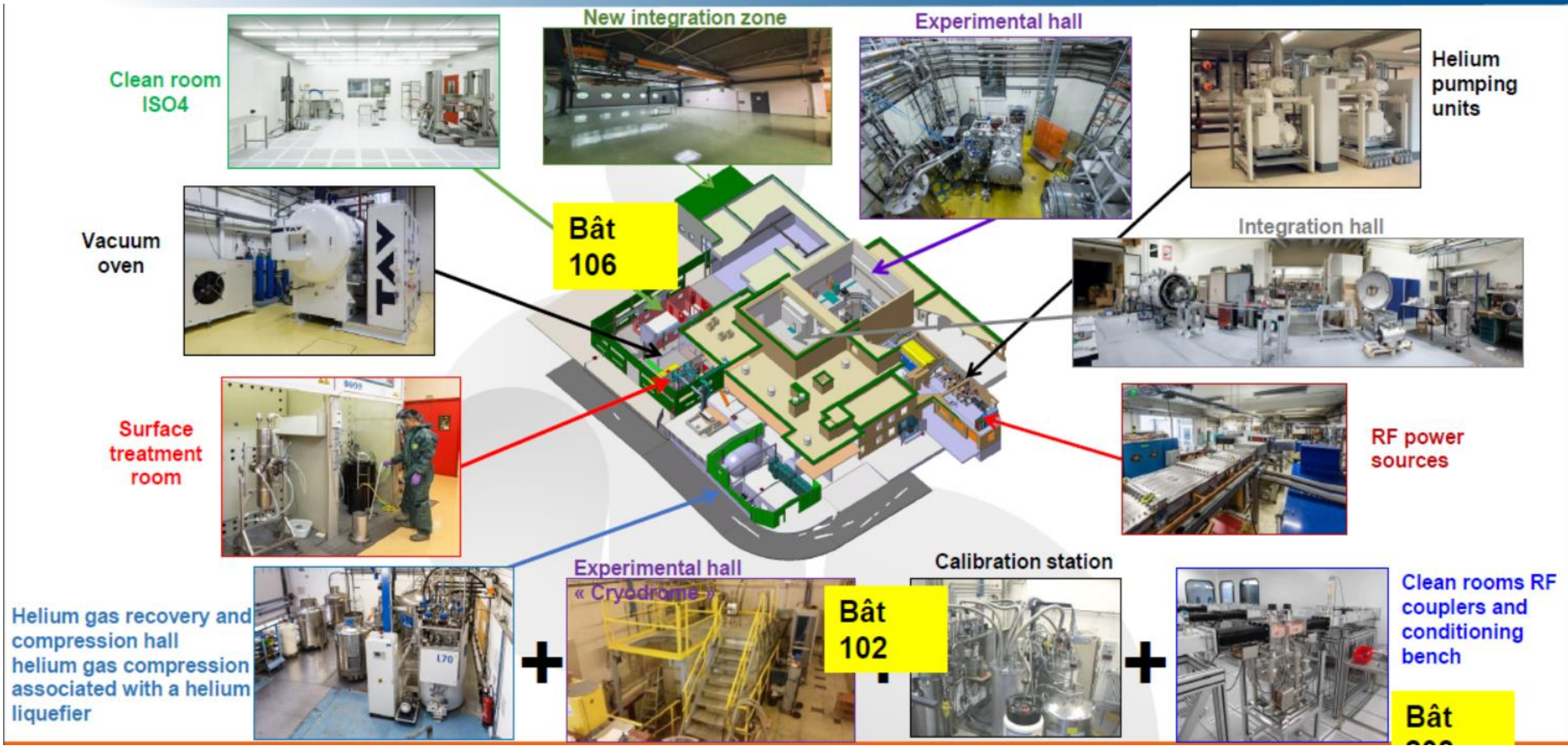
- First developed to test new technics to acquire control of suspended cavities for GW interferometers
  - Laser injection in in-vacuum 50m long cavity with suspended mirrors
  - Virgo electronics and software to ease integration
  - Control strategy development
- Test now new optical design for squeezing technic - in common with LKB, LMA, LAPP – 2 ANRs (Exsqueez/Qfilter)
  - Frequency dependent squeezing allow to beat the standard quantum limit observed in GW detectors
  - Need knowledge on non linear optics (LKB), low loss optics (LMA), low noise electronics (LAPP) and low noise control of cavities (IJCLab)
  - Prepare in-vacuum system – study also possible implementation in Advanced Virgo
  - Test possible schemes for 3rd generation of GW detectors
  - Test low noise wavefront corrections
- Host 2 PhDs, 20+ internships (L2 to M2) in the last 10 years





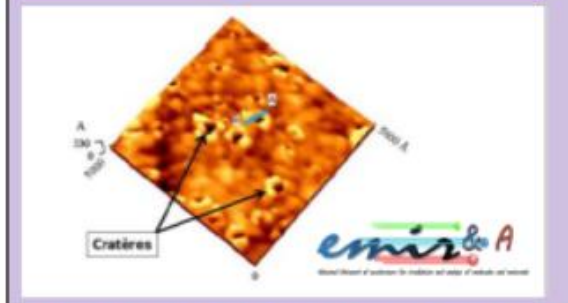
Driven by the GW team

SUPRATECH : dedicated to R&D on Superconducting RF Cavities for future high energy particle accelerators



ANDROMEDE platform : a facility dedicated to interdisciplinary research

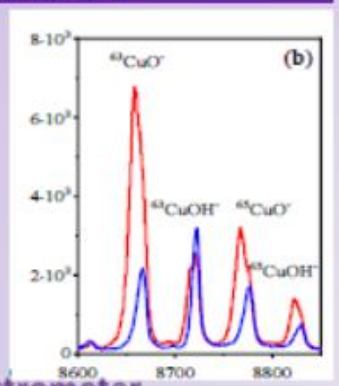
Ion Beam Analysis, Irradiation



Clusters-Solid Surfaces Interaction

Sciences Accelerator

Vacuum and surfaces



EVE Mass Spectrometer
Ionic Imaging
Material modifications

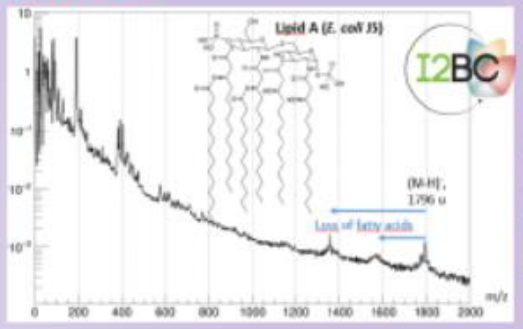
....

Heritage (IPANEMA)

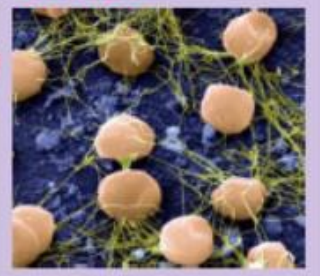
Exobiology (IAS)

Biochemitry , Ionic imaging, Health

Bacteria



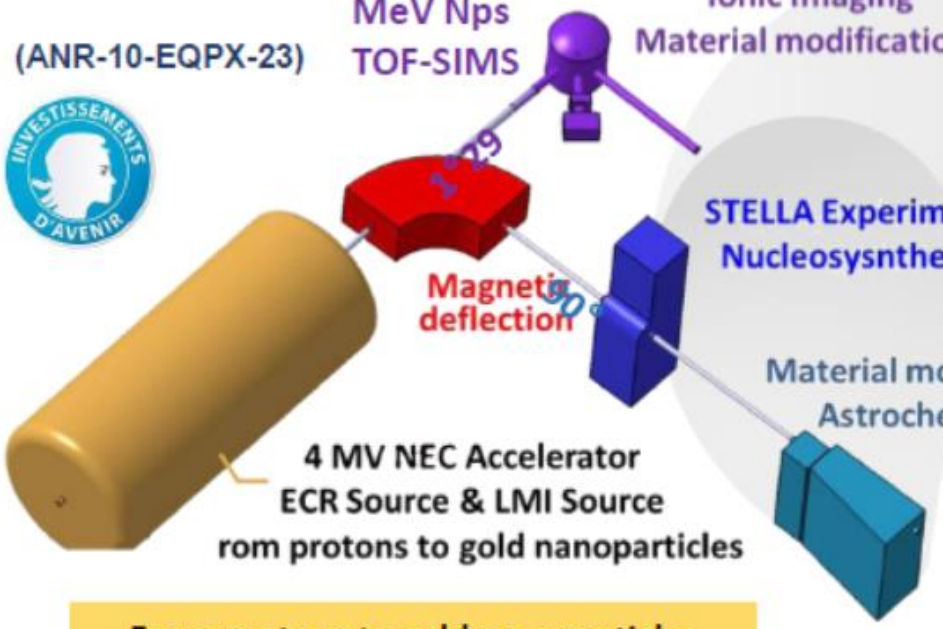
Archea



MolyBee Project
Metal and Health

(ANR-10-EQPX-23)

MeV Nps
TOF-SIMS



STELLA Experiment
Nucleosysnthesis

Material modification
Astrochemistry

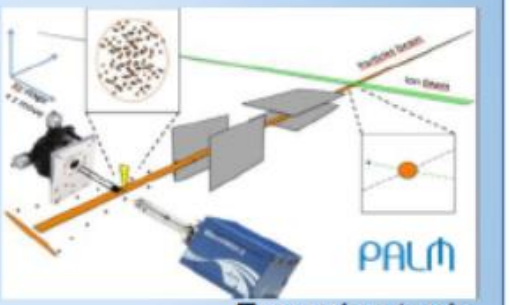
4 MV NEC Accelerator
ECR Source & LMI Source
rom protons to gold nanoparticles

From protons to gold nanoparticles

iPHC
STELLA

$^{12}C+^{12}C$
$^{12}C+^{16}O$
$^{16}O+^{16}O$

ismo
IRAMIS
NanoCr



Emerging topic

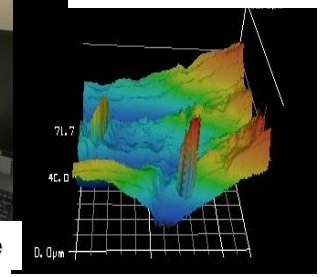
Vacuum&Surfaces platform

Dedicated to characterization and surface analysis of materials used in accelerator technology + UHV studies

Confocal Microscope

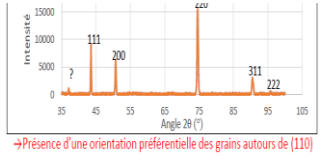
VKX200 de Keyence

surface roughness



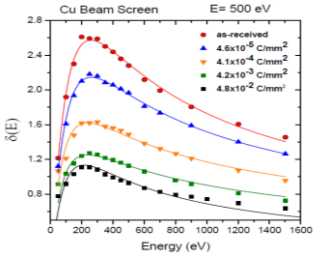
X-ray diffractometer

Surface Structure and Texture



→Présence d'une orientation préférentielle des grains autours de (110)

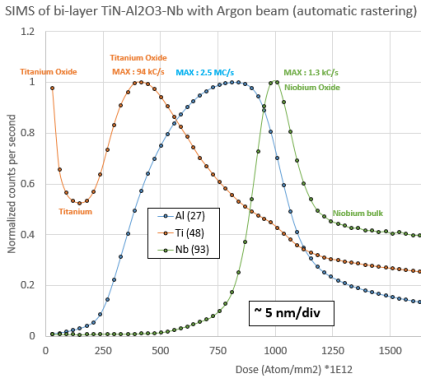
Secondary Electron Yield (SEY)



Thèse S. Bilgen

Secondary Ion Mass Spectrometry (SIMS)

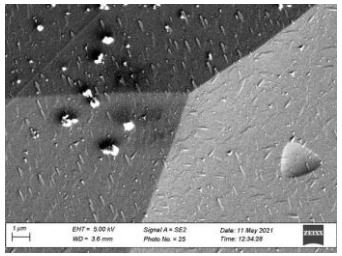
Compact SIMS Hiden Analytical



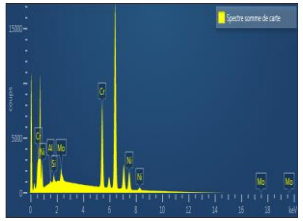
Profile of bi-layer TiN/Al2O3/Nb

Thèse S. Birra

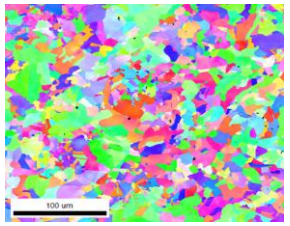
Scanning Electron Microscope



Composition (EDS)



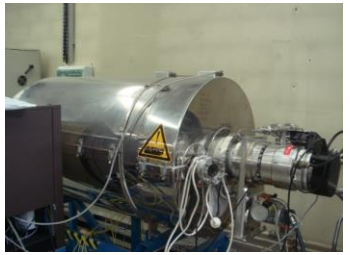
Structural (EBSD)



outgassing rate

NEG coating chamber (Ti,Zr,V)

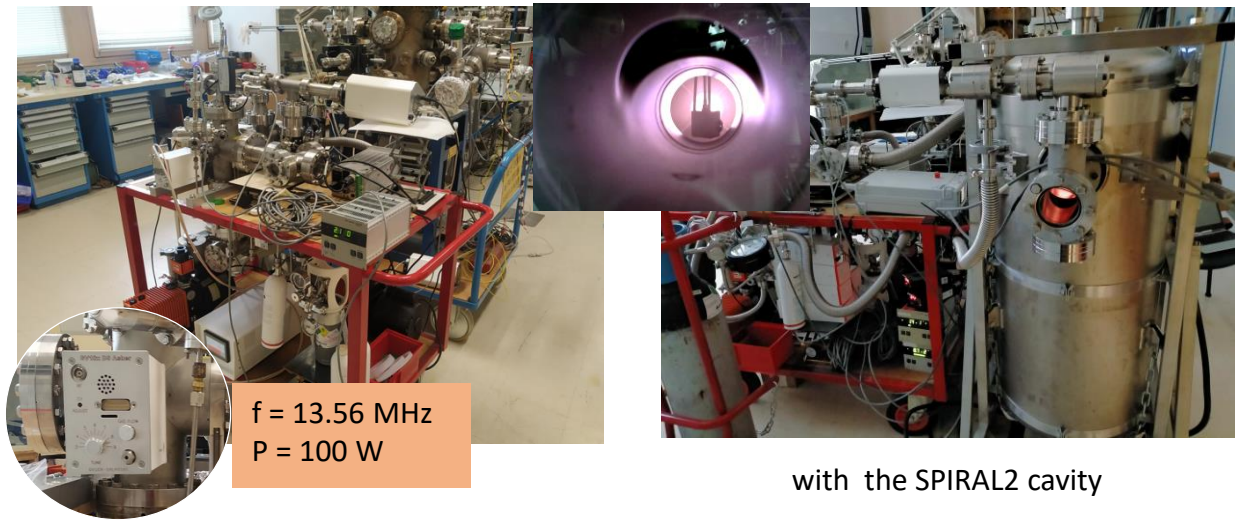
Heat treatment (H2)



molecular desorption energy

Vacuum&Surfaces platform : new equipment

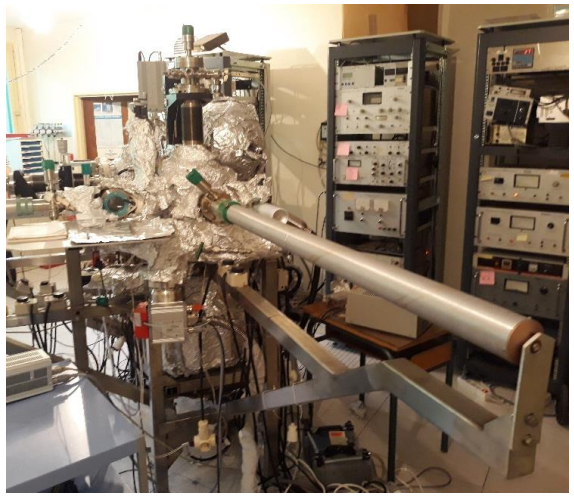
➢ Plasma cleaning set-up



f = 13.56 MHz
P = 100 W

with the SPIRAL2 cavity

➢ Recovery of a multi-technical analysis set-up (ISIS from ICMMO)



2022

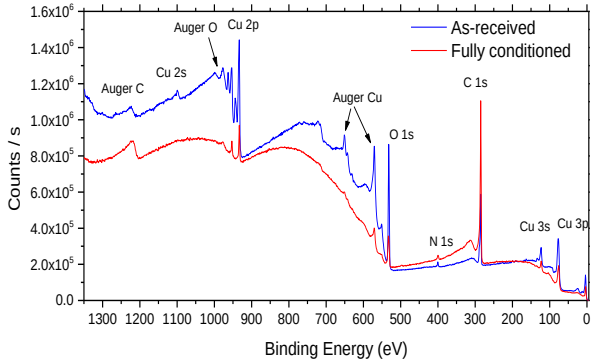
SEY
XPS
LEED
RGA
ion gun
@ RT / 1000 K

Funding : EQUIPEX+ PACIFICS

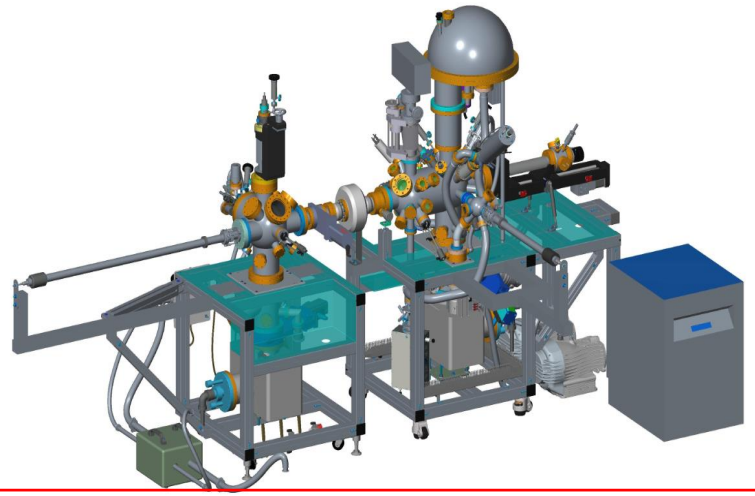
Particle Accelerators Initiative for Future Innovative and Challenging Systems

➢ Routine XPS

2022/2023



➢ Multi technical set-up – Surface analysis at cryogenic temperature

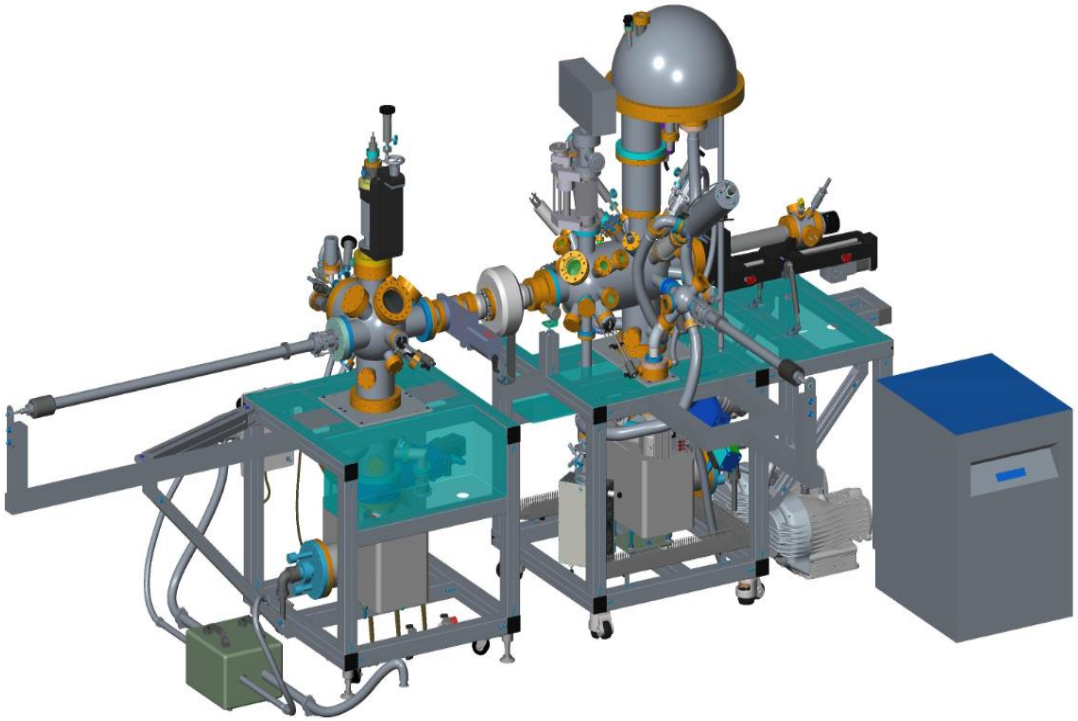


SEY
XPS
RGA
ion gun
@ 10K

New multitechnical set-up – Surfaces analysis at cryogenic temperature

Dedicated to the analysis of materials for accelerators : SEY measurements coupled with XPS analysis at 10K (e- gun, ion gun, RGA…)

It could be used to investigate some issues related to GW mirrors (charging effets, cleaning processes…)

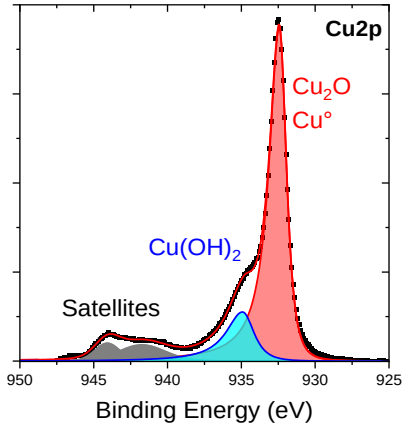


Specification, design under discussion

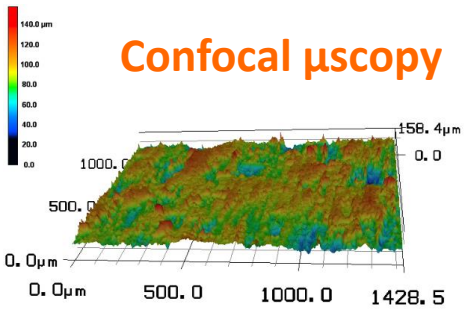
Possibility for benchmark analysis

Surface Analysis

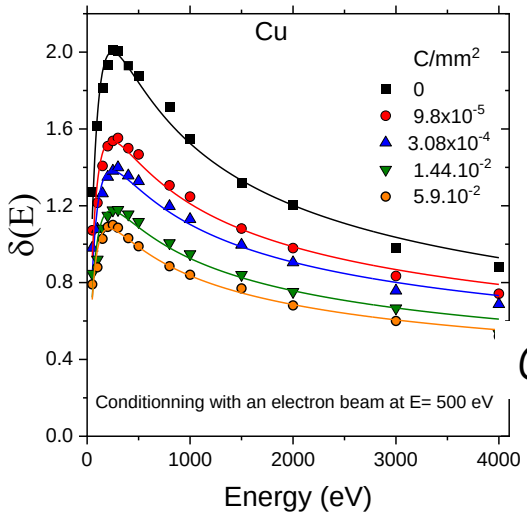
XPS



Confocal µscopy

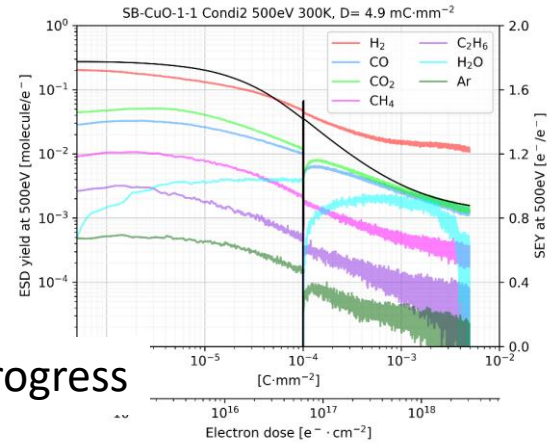


Secondary Electron Yield

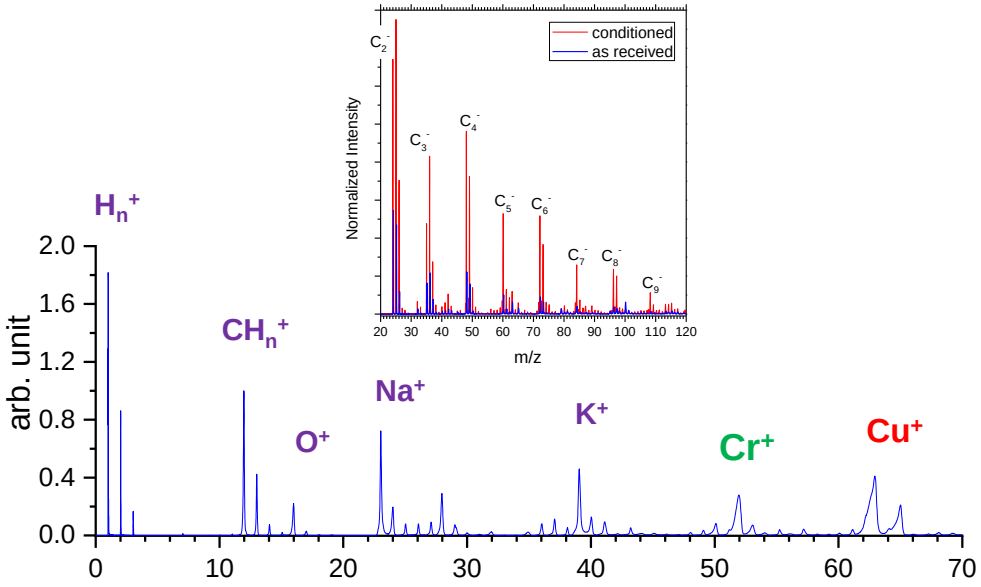


@ 10K in progress

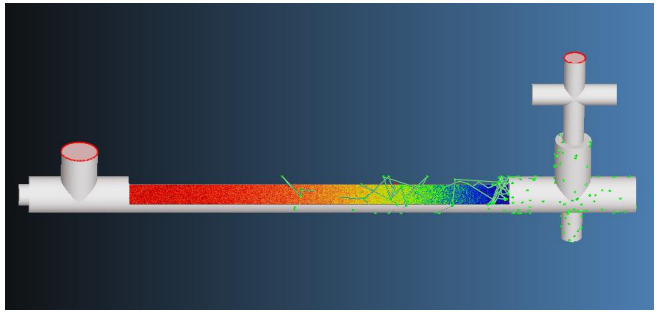
Electron Stimulated Desorption



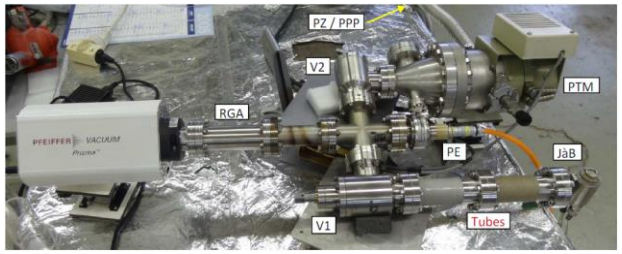
MeV ToF SIMS

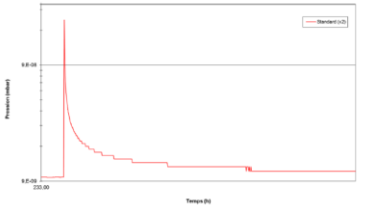


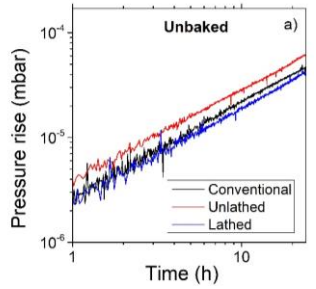
Molflow calculation



Outgassing rate





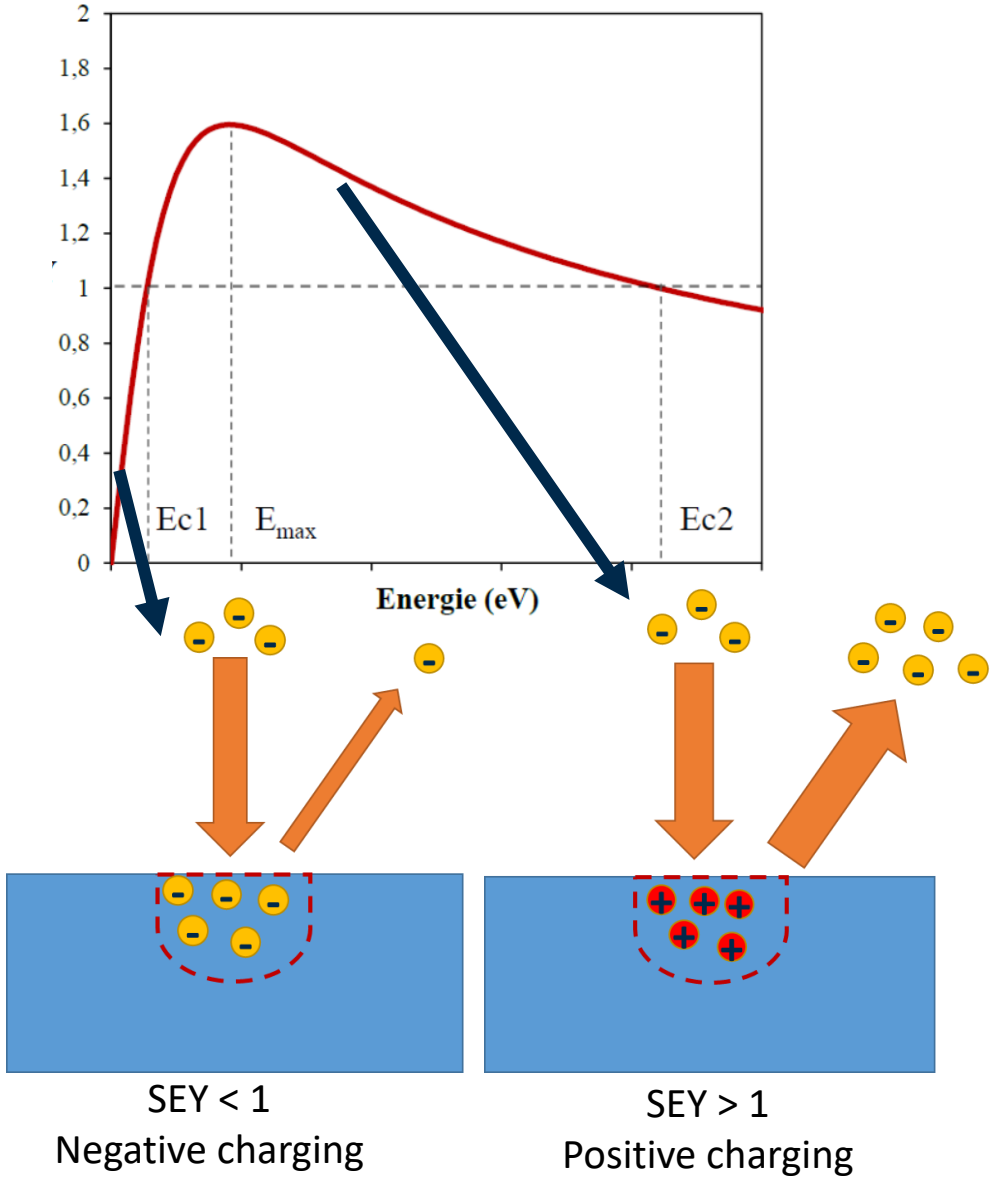


Proposal for IJCLab contribution for vacuum studies in ET tower

- Charging effects in insulators (mirrors)
- Frosting on mirrors / Contamination of mirrors : new cleaning processes

These issues also represent interesting topics in the field of materials for accelerators (similar centre of interest)

Benchmark analysis : charging effect in insulators

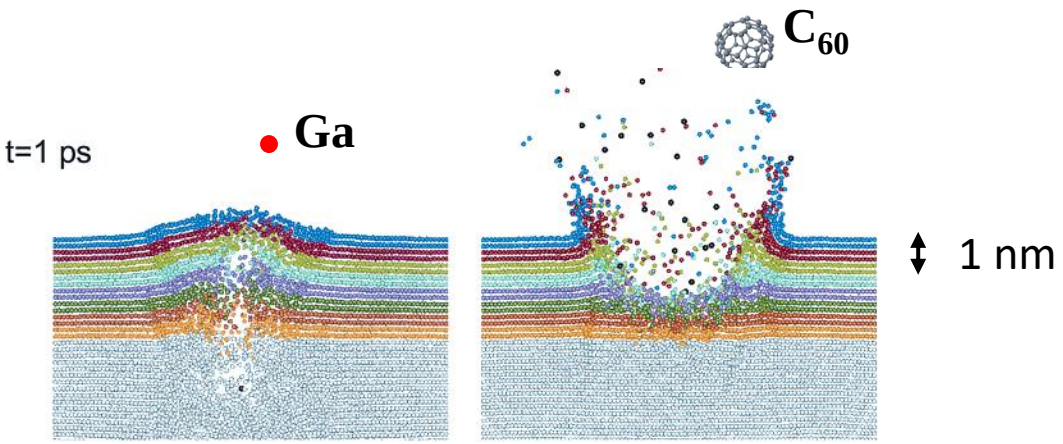


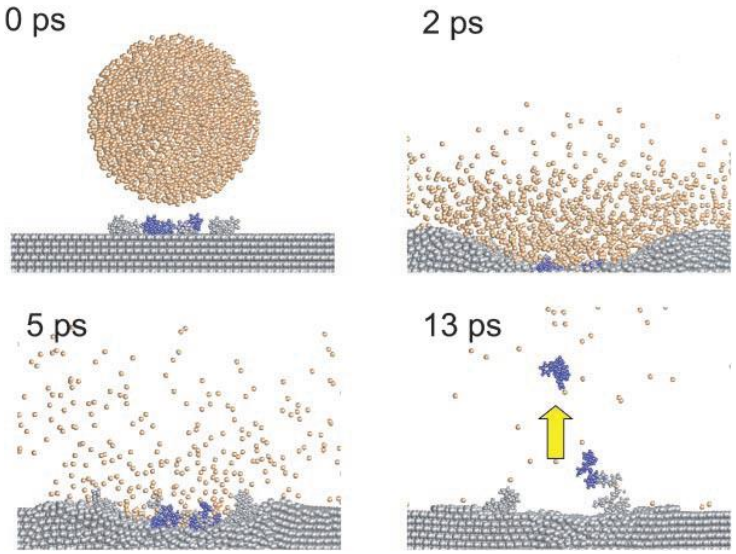
Neutralization of electrostatic charge on mirrors in GW detectors

- Electron gun (flood gun) to irradiate the surface with low energy electrons (pay attention to C contamination coming from the filament of the e- gun : by using new e- gun based on ECR source* ?)
- UV photon irradiation (for polymers)
- Perhaps positive ion beams/cluster ion beams to neutralize negative charging
- Tools at IJCLab will be available to investigate the charging effect in insulators @10 K with the new set up

**electron cyclotron resonance*

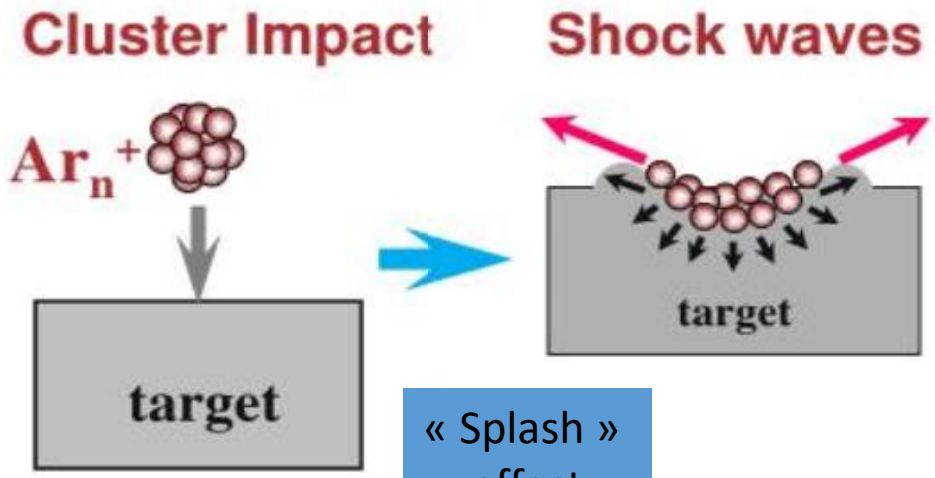
Using the Cluster ion beam cleaning : mirrors cleaning/ice removing?





Postawa Z. et al. J. Phys. Chem. B ***2004****, 108,7831-7838*

Garrison B. J. & Postawa Z. Mass Spectrom. Rev ***2008****, 27, 289-315*



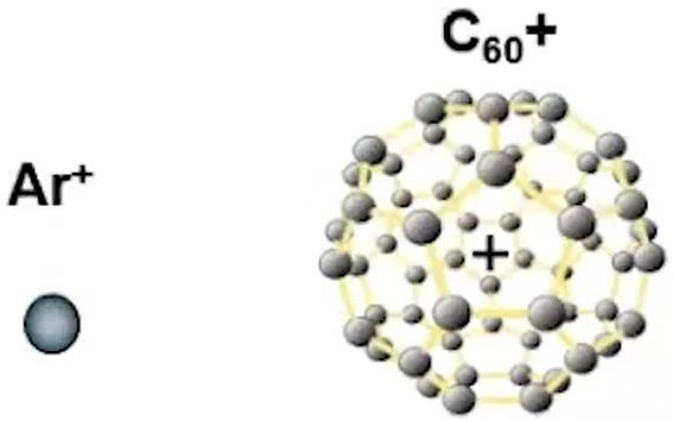
- Gas Cluster Ion Beams (GCIB) impact a surface with very low energy, down to as little as 1 eV per atom.
- At such low energies they sputter material without modifying the surface chemistry, i.e. without breaking bonds

- Cleaning effect without materials damage (unlike single ions)

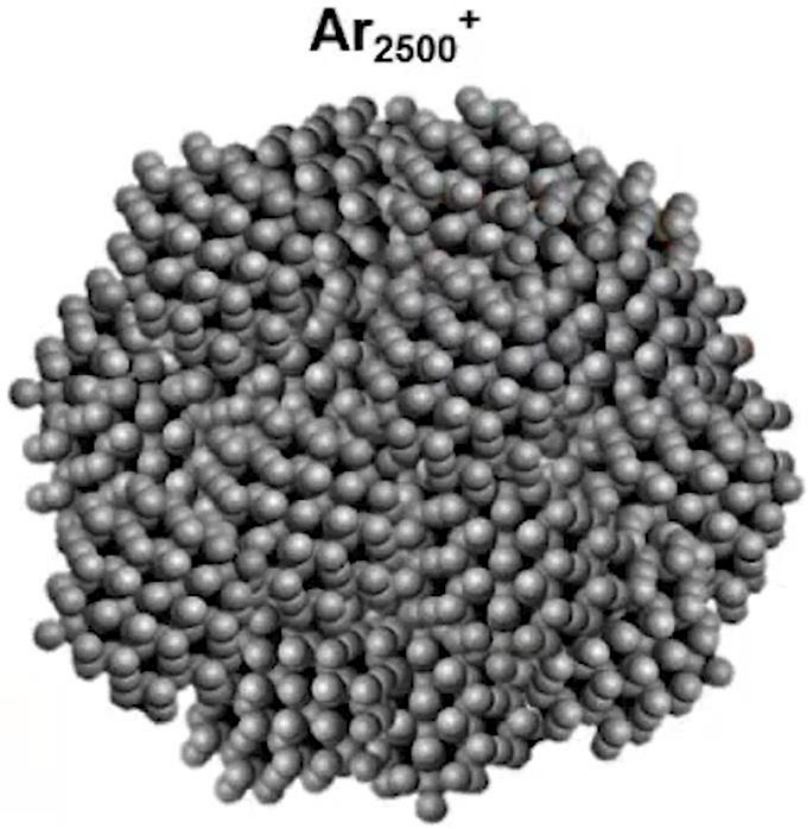
➢ Sputtering of organic layers without destroying the underlying layers (only the extreme surface is impacted)

Cluster ion cleaning : for ice removing?

Cluster ion beam sputtering provides access to quantitative chemical state information below the surface for many organic and polymer materials that would typically be damaged with monatomic Ar ion gun sputtering.



Introduced 2004



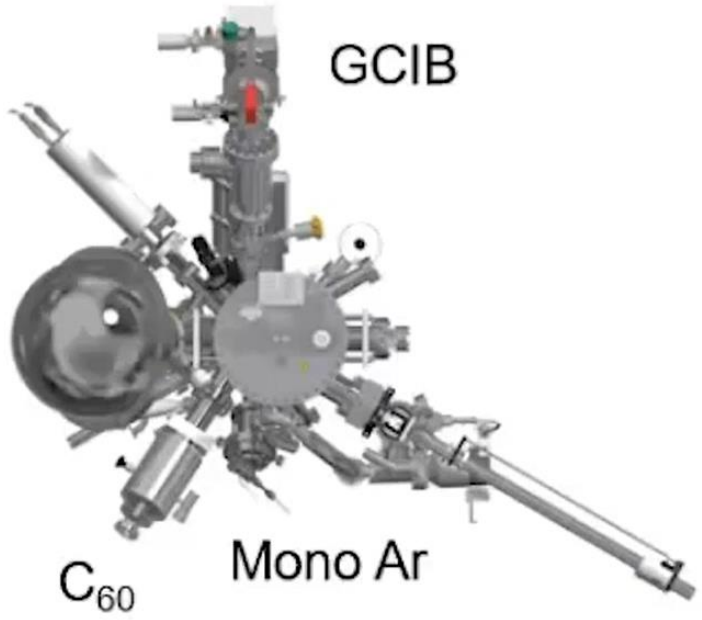
Introduced 2010

Cluster beam of Ar_n (1<n<3000) : Surface cleaning without contamination

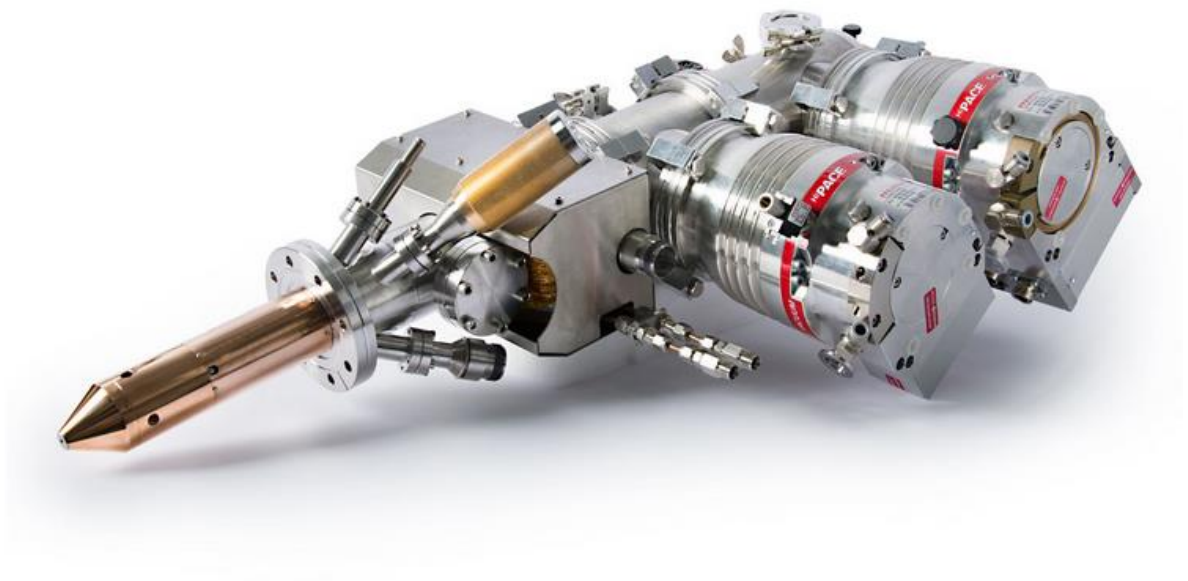
An example of cluster ion beam gun

Ion Gun Options on PHI *VersaProbe* Systems

- **Standard monatomic Ar ion gun**
  - 5 V to 5 kV
  - Floating column provides high current / low voltage ion beams
  - Provides low-energy ions for dual-beam charge neutralization
- **Optional C_{60} ion gun**
  - Beam voltage 10 to 20 kV
  - Mass filtered ion beam
- **Optional argon cluster ion gun (GCIB)**
  - Tunable cluster size up to ~2500 argon atoms
  - Beam voltage 2.5 to 20 kV
  - Mass filtered ion beam
- **Cluster size measurement tool now available**



An other example of cluster ion gun

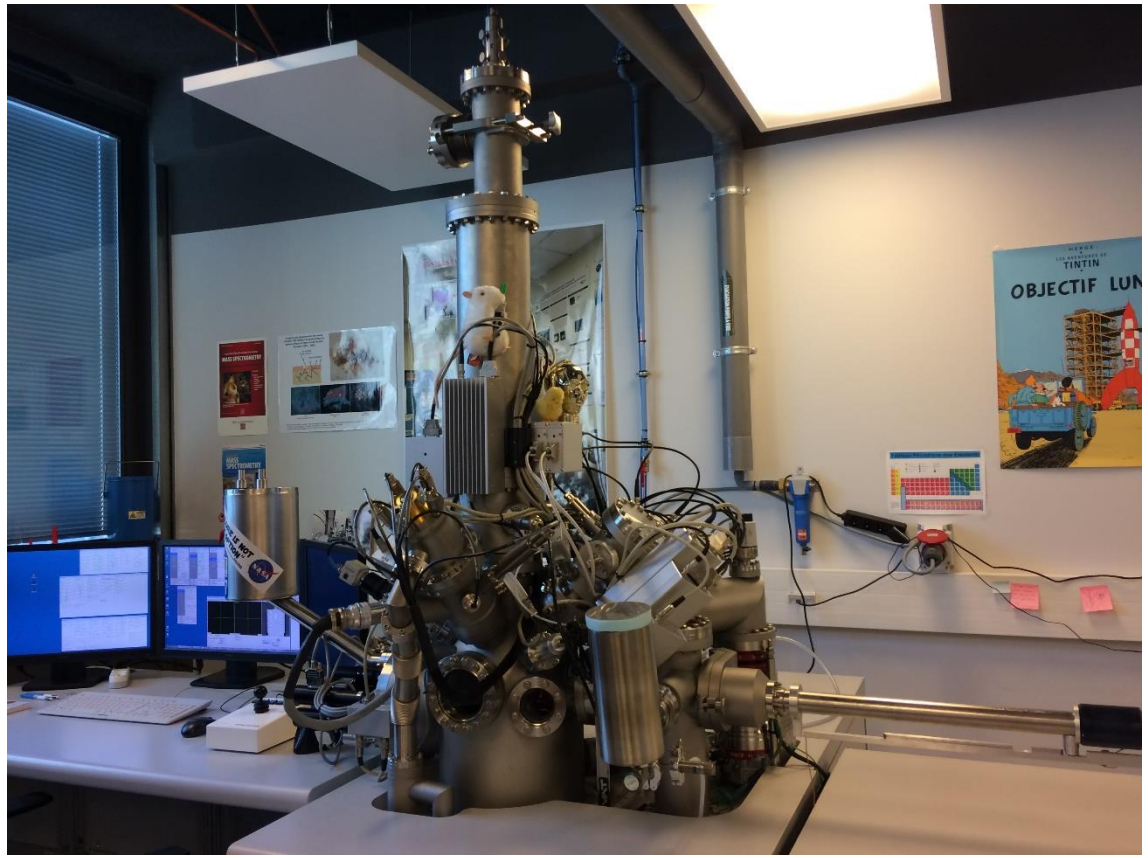


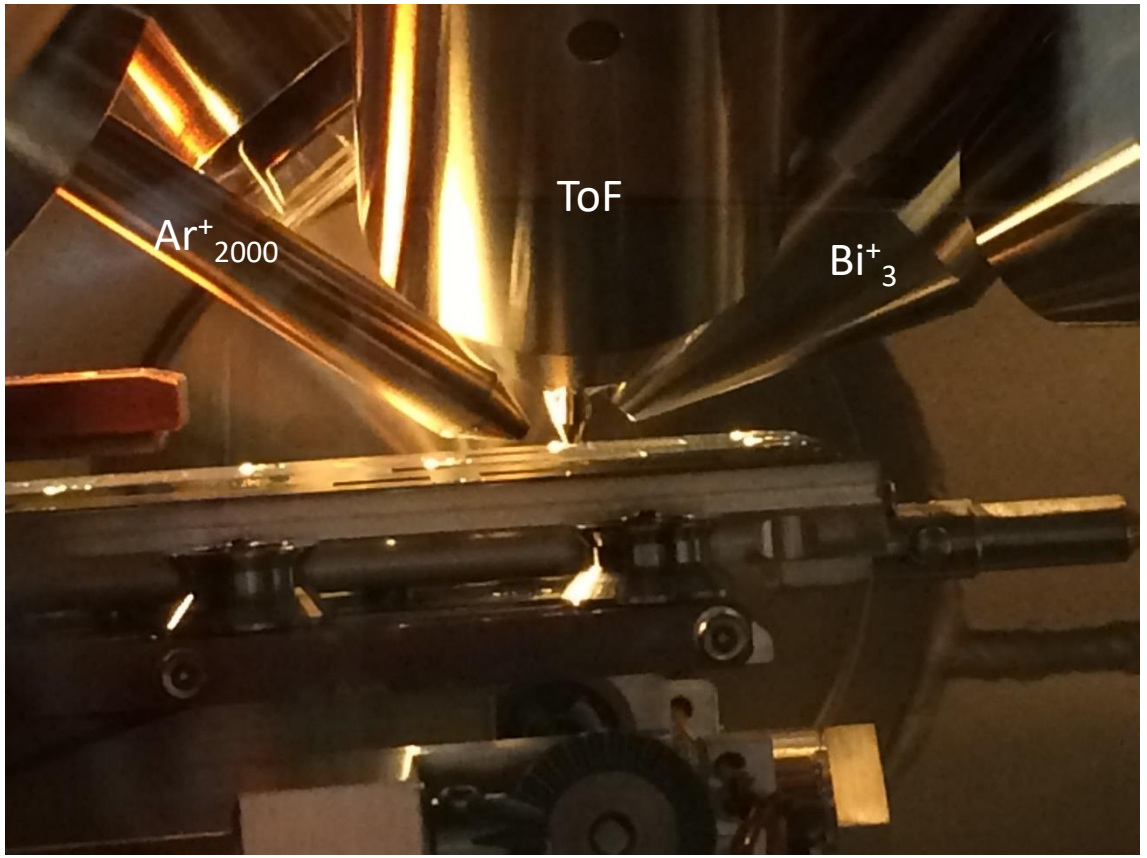
GCIB 10S

IONOPTIKA
- 10 keV argon cluster ion source
- Selectable clusters from Ar1 to > Ar3000

An example of application of cluster ion beam cleaning before surface analysis : test for Cu

ToF SIMS_IonToF_Jussieu





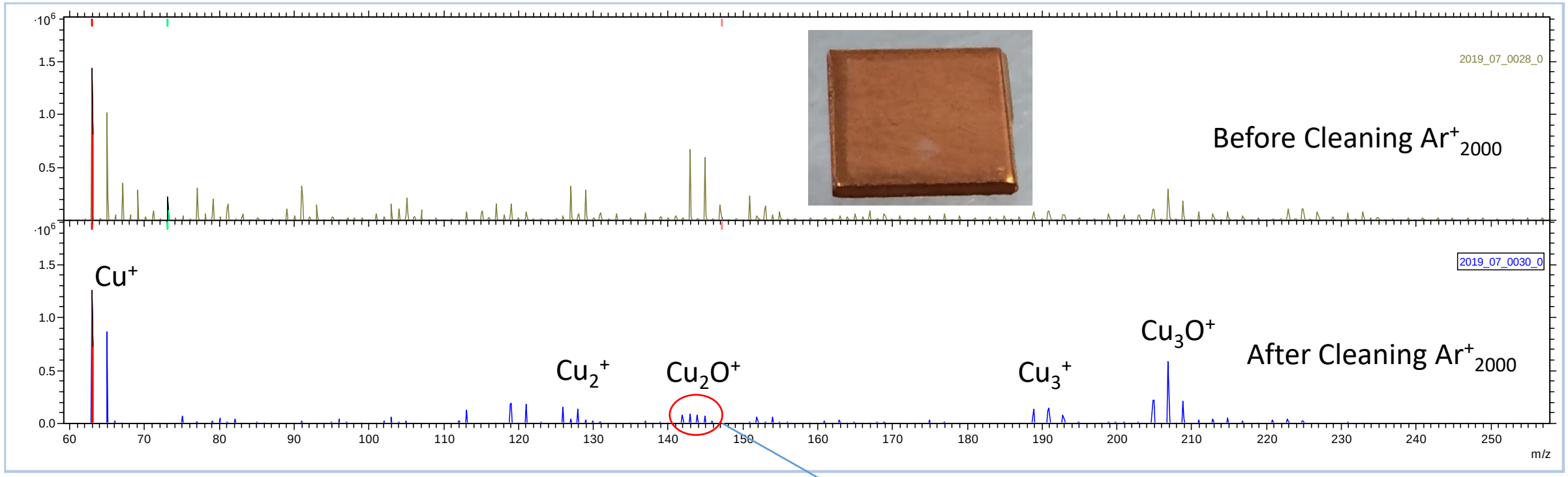
Conditions of analysis : 10 keV, beam diameter= 2-4 µm

Bi^+_3 : 250 x 250 μm^2, 50 scans, 128 x 128 $pixel^2$, dose : $3{,}8.10^{11}$ ions/cm^2

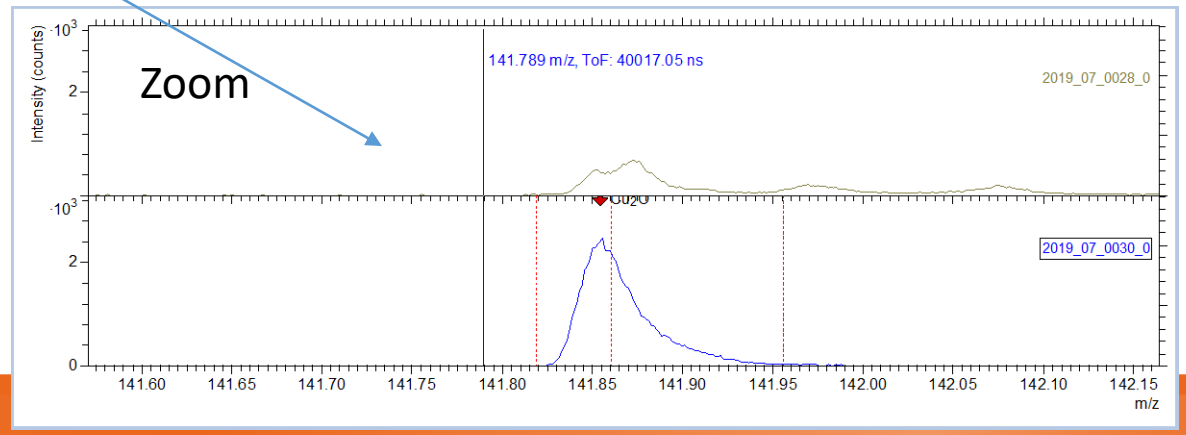
Ar^+_{2000} : 1000 x 1000 μm^2, 20 s, dose : $9{,}7.10^{13}$ ions/cm^2

Application of cluster ion beam cleaning for Secondary Ion Mass Spectrometry – *ToF SIMS*

Mass Spectra : Positive ions



- Contaminants and organic compounds are removed from the surface
  - Cu signal is higher because the contaminant layer was removed



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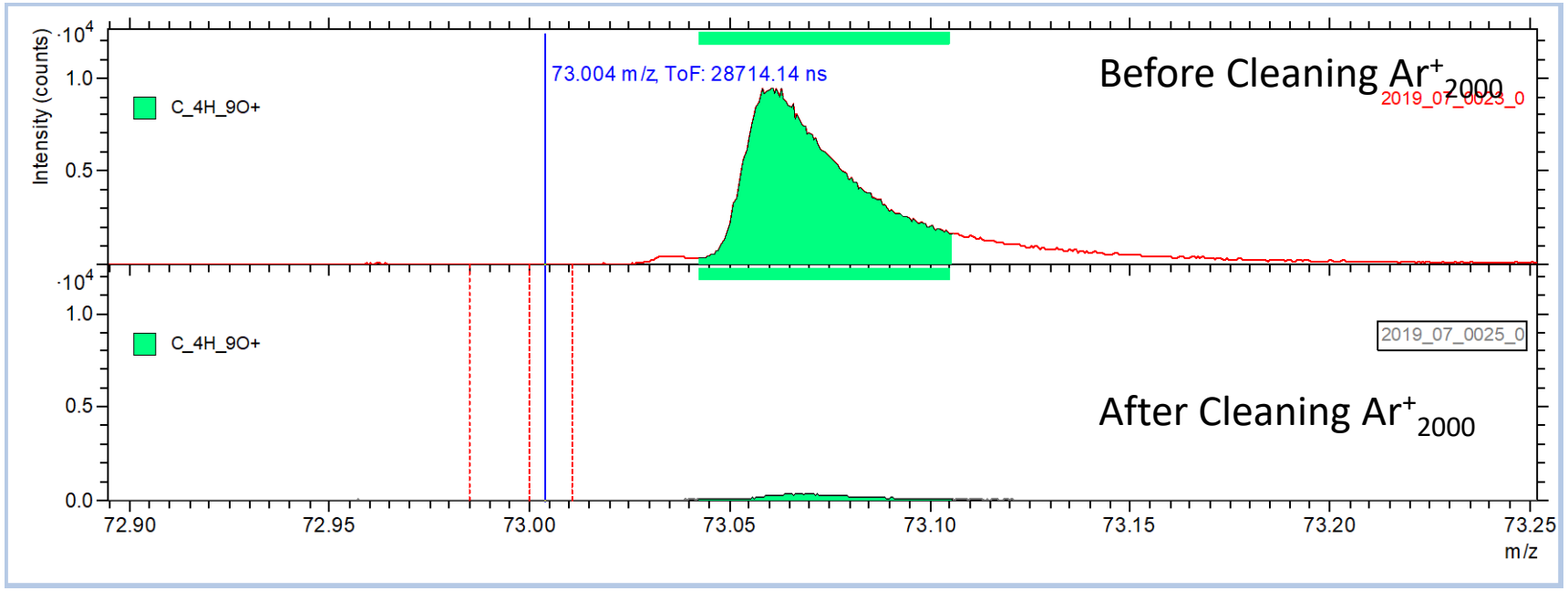
—[O-Si(CH3)2]n—
PDMS (Polydimethylsiloxane)
silicone polymer family



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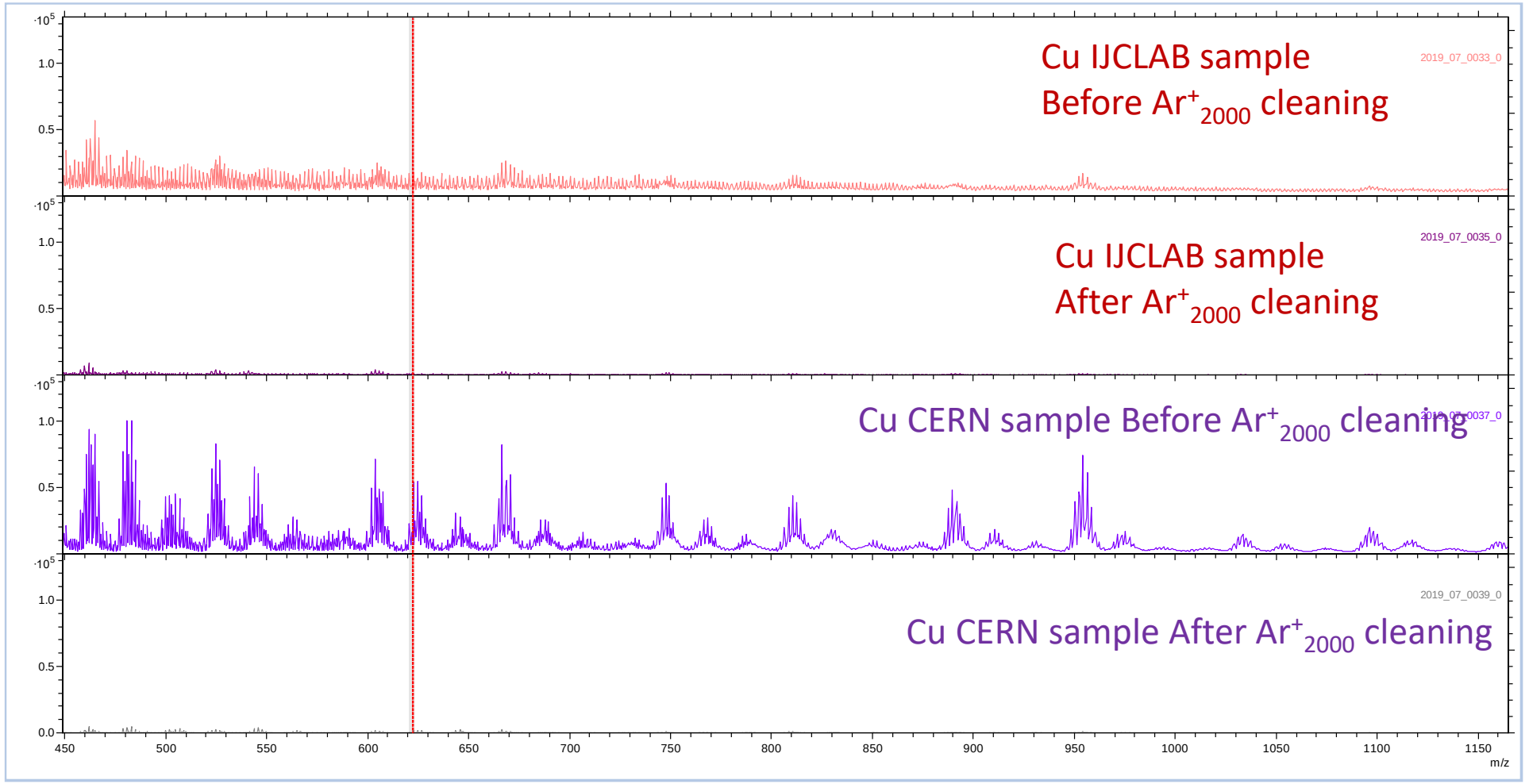
Mass spectra : Negative ions



High efficiency to remove contaminants

Conclusion and perspectives

IJCLab contribution to the R&D of the ET Tower vacuum

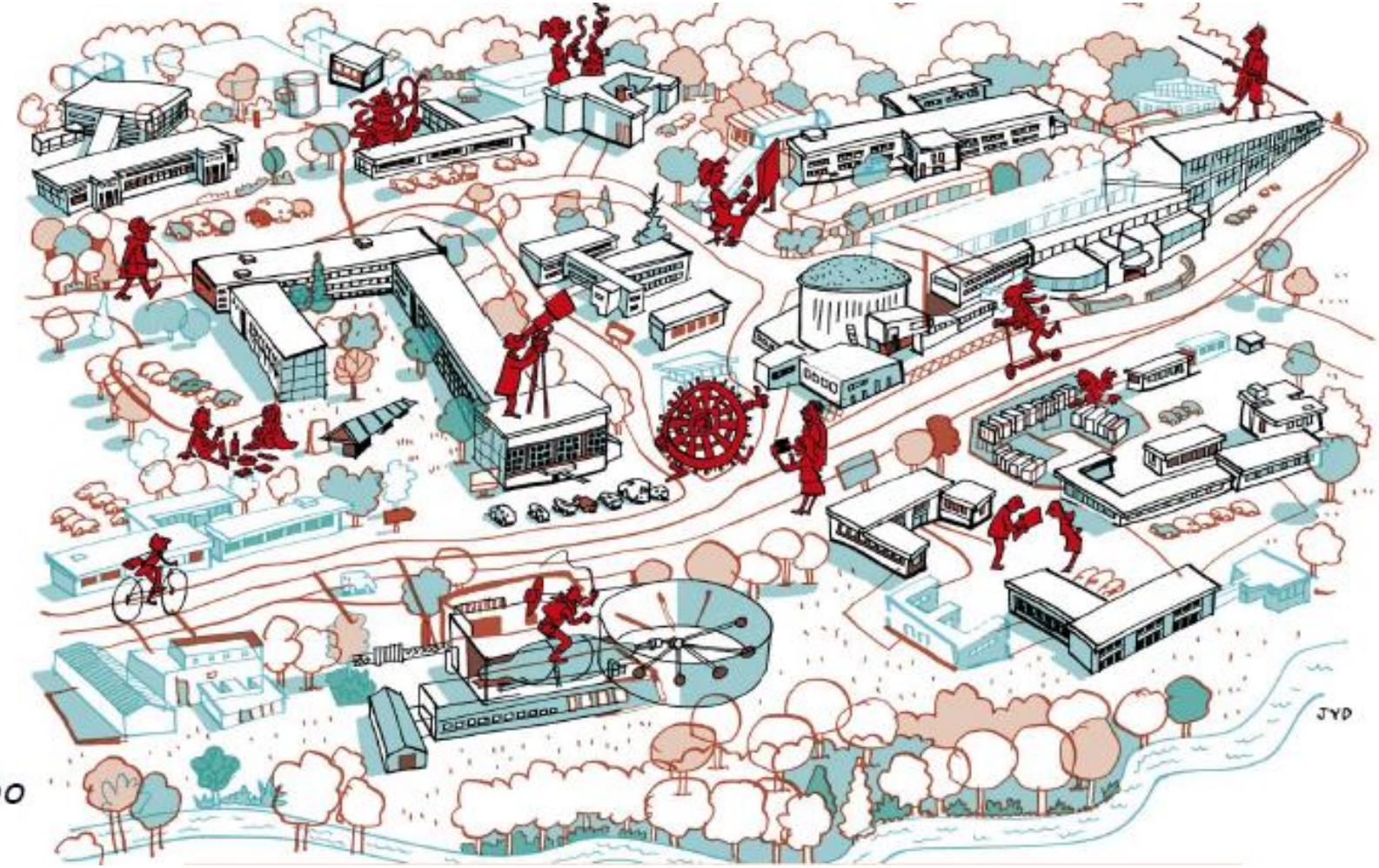
- **Issues concerning mirrors**:

  (i) Neutralization of the Electrostatic charge forming on mirrors (benchmark analysis with other Research teams)

  (ii) Surface cleaning/ice removing by cluster ion beam cleaning
  - expertise in the lab for using cluster ion beams to clean surfaces (ANDROMEDE platform)
  - it is necessary to perform experiments to test the efficiency of this process on materials of interest
  - complementary to other mitigation strategies (UV photons, low energy electrons…*)*

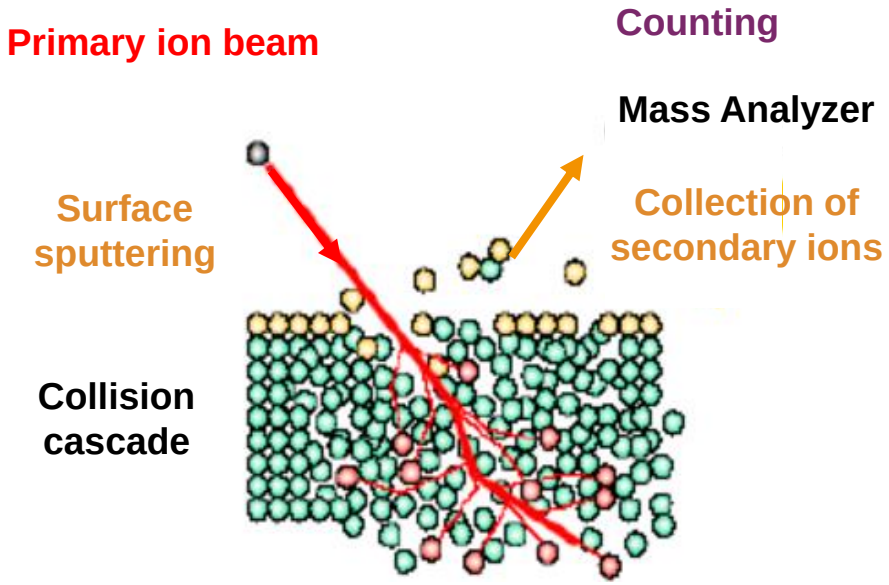
- **Perspectives R&D**:

  Design a multitechnic set up to fit this kind of investigation (we have the funding…)



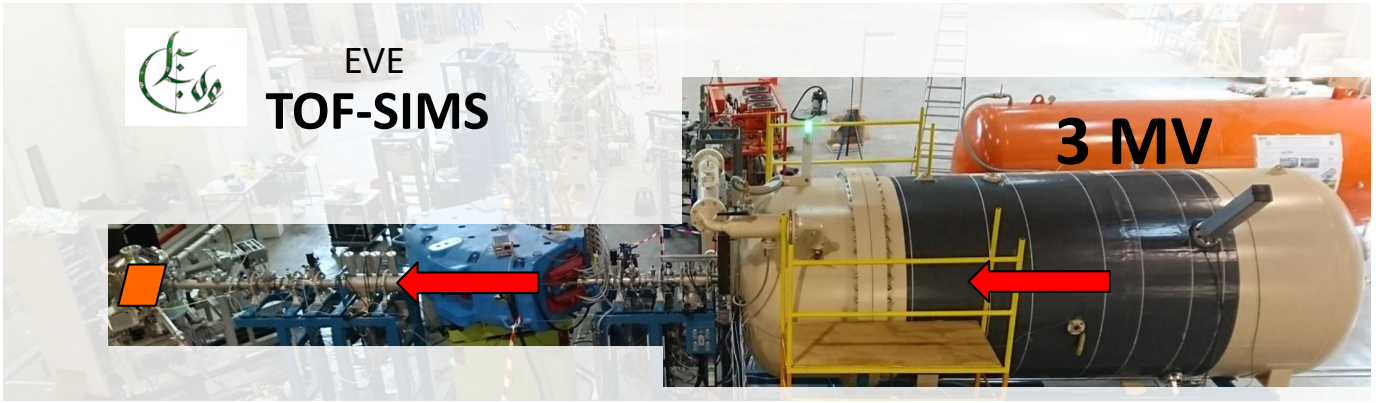
Thanks for your attention

SIMS : Principle



12MeV – Au_{400}^{4+} nanoparticle beam

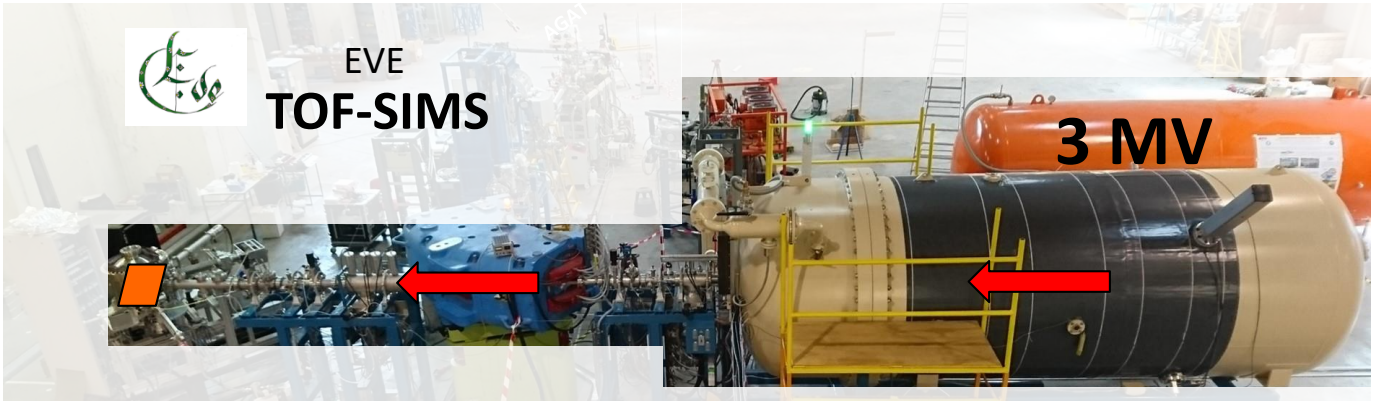
- LMIS source
- Pulsed beam = gold nanoparticles
- Intensity= 3 MeV/q = 12 MeV
- Size = 100 µm diameter
- Current <10 pA
- Line for analysis at 1°29 with 2 collimators to adjust the position at 100 nm precision



Sample

12MeV – Au_{400}^{4+} nanoparticle beam

- ✓ Large multiplicity (10 to 1000 ions detected per impact).
- ✓ Large efficiency detection.
- ✓ It is possible to obtain a Time Of Flight Secondary Ion Mass Spectrum with only one impact.



Sample

12MeV – Au_{400}^{4+} nanoparticle beam

- ✓ Large multiplicity. → **Huge intensity of the signal**
- ✓ Large efficiency detection.
- ✓ It is possible to obtain a Time Of Flight Secondary Ion Mass Spectrum with only one impact. → **Quasi non-destructive analysis**