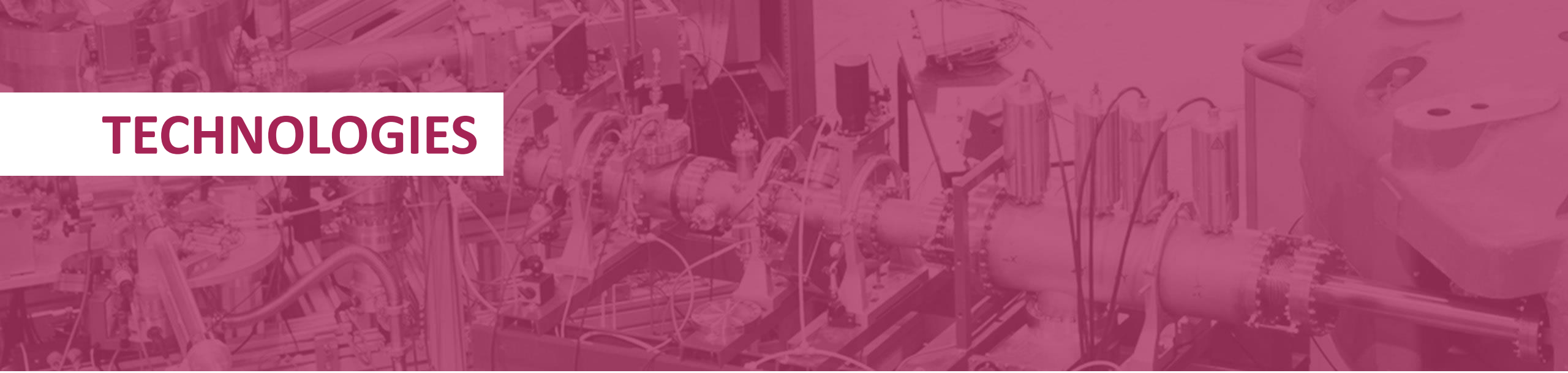

IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY
I2BC
Institut de Biologie Intégrative de la Cellule
UNIVERSITÉ PARIS SUD
ICMMO
Andromède
INVESTISSEMENTS D'AVENIR
IPHC
Institut Pluridisciplinaire Hubert CURIEN
STRASBOURG
IAS
Institut d'Astrophysique Spatiale
Orsay
ORSAY PHYSICS
TESCAN ORSAY HOLDING
De la nucléosynthèse à la chimie prébiotique
TEXAS A&M UNIVERSITY
CSNSM

https://andromede.in2p3.fr

Andromede is an interdisciplinary platform of the IJCLAB (UMR 9012) which contribute to the scientific and technical skills development of Paris Saclay University.

It is open to the academic and industrial world in the fields of nuclear physics; biology, biochemistry; astrophysics and astro-chemistry; molecular chemistry; and chemistry and physics of materials.



TECHNOLOGIES

// Accelerator and ion source

The ion beams are accelerated at high energy by a 4MV NEC Pelletron® accelerator. The voltage can be adjusted from 500 kV to 4 MV. The terminal of this accelerator is designed to receive two kinds of ion sources, an electron cyclotron resonance (ECR) source and a liquid metal ion source (LMIS). **The accelerator delivered proton to nanoparticle beams.**

TEAM

SERGE DELLA NEGRA

CNRS Research Director, Scientific Manager of the Andromede platform
Expertise: Nuclear physics, particle-matter interaction, surface analysis, mass spectrometry, ion sources, applications in chemistry, biology and astrochemistry.

ISABELLE RIBAUD

CNRS Engineer of the Research Division of IPNO, Specialties: Experimental Biology and Quality Control, Development of Multi-Technical Surface Analysis Experiments with Andromede.
Interim Operational Manager !

FRANCOIS DAUBISSE

University Paris-Saclay Assistant Engineer. Accelerator's operator, set up of experiments, source tests for new beams, maintenance

DOMINIQUE JACQUET
MARIN CHABOT
CNRS Research Directors, Physicists

Andromede gathers a team of 20 researchers on its site of the Faculty of Orsay.

ANDROMEDE

Equipex-ANR-10-EQPX-23

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

November 2016

STELLA

nucleosynthesis
Carbon burning

3-4 MV, $C^{1,2,3,4+}$

AGAT

April 2017

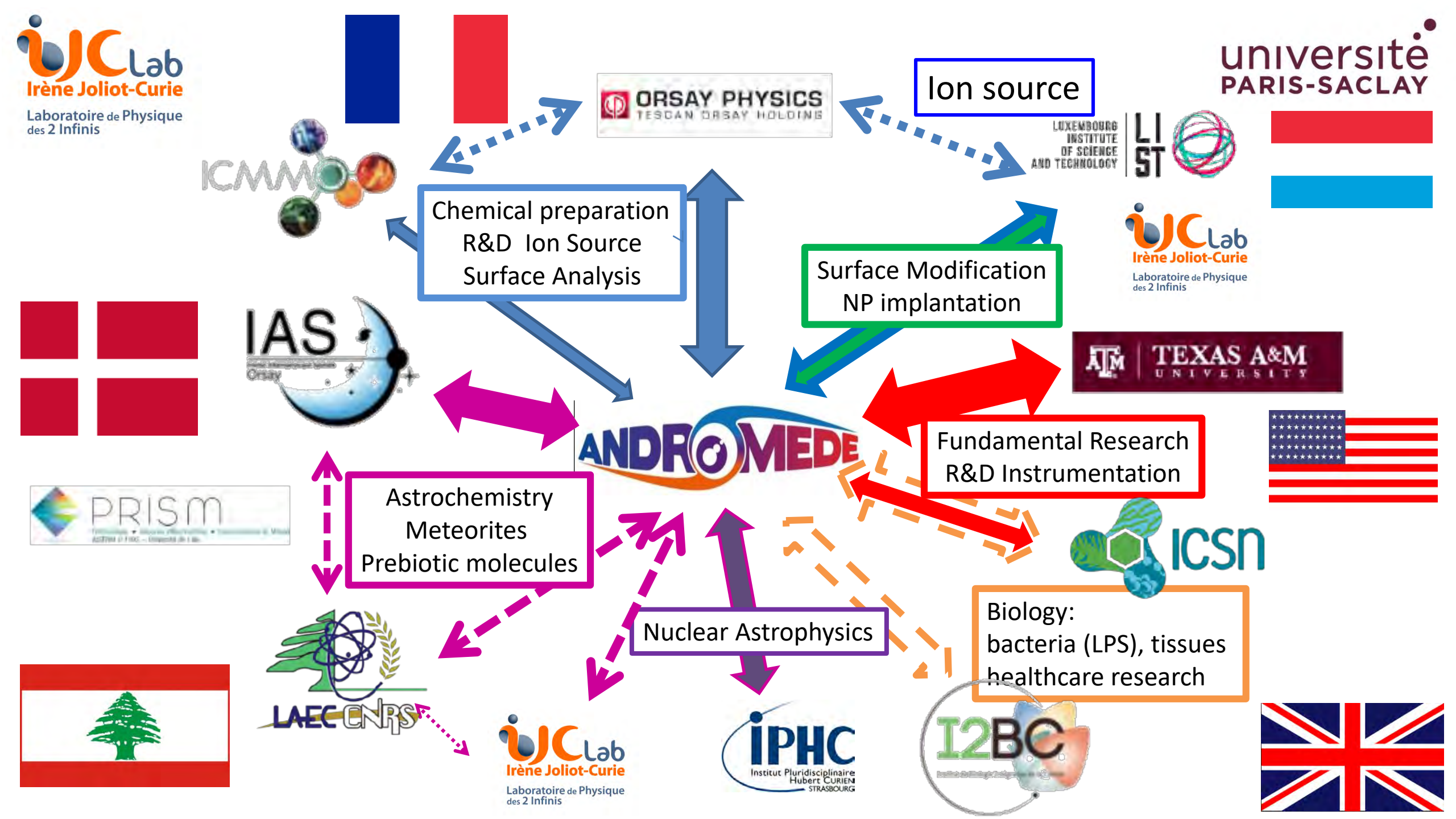
Molecular Fragmentation
Atomic molecules collision

3-4 MV, $CH_{1,2,3,4}^{+}$, $C_2H_{1-6}^{+}$

June 2017

Ionic Imaging
Biology,Health, Exobiology

4 MV, SF_5^{+}, C_{60}^{3+}, Au_n^{+}, Au_{400}^{4+}


IJCLab
Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis
ORSAY PHYSICS
TESCAN ORSAY HOLDING
Ion source
université PARIS-SACLAY
LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY
LIST
ICMMO
Chemical preparation
R&D Ion Source
Surface Analysis
Surface Modification
NP implantation
IJCLab
Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis
IAS
Orsay
TEXAS A&M UNIVERSITY
ANDROMEDE
Fundamental Research
R&D Instrumentation
PRISM
Astrochemistry
Meteorites
Prebiotic molecules
ICSN
Biology:
bacteria (LPS), tissues
healthcare research
Nuclear Astrophysics
LAEC CNRS
IJCLab
Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis
IPHC
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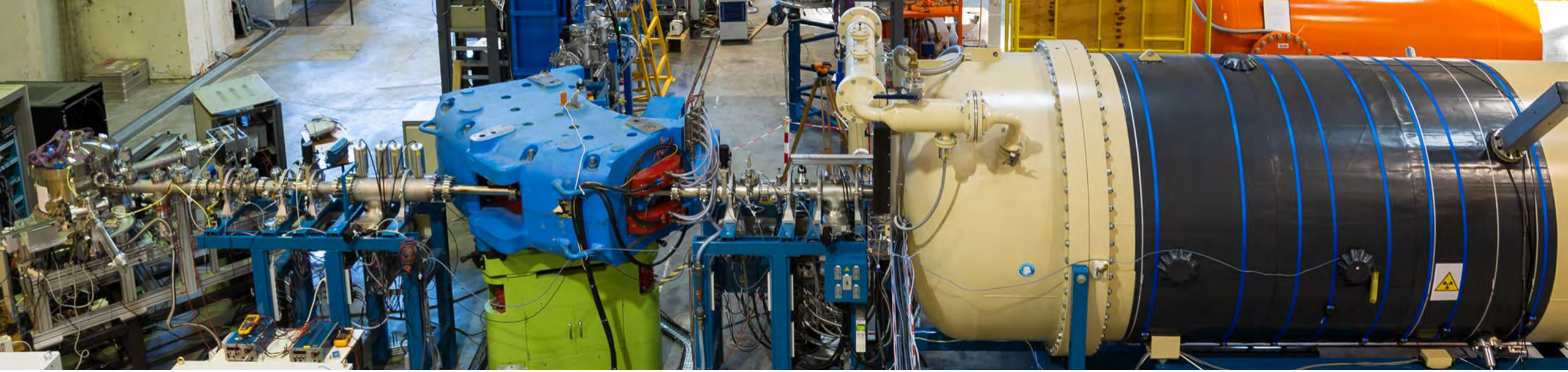
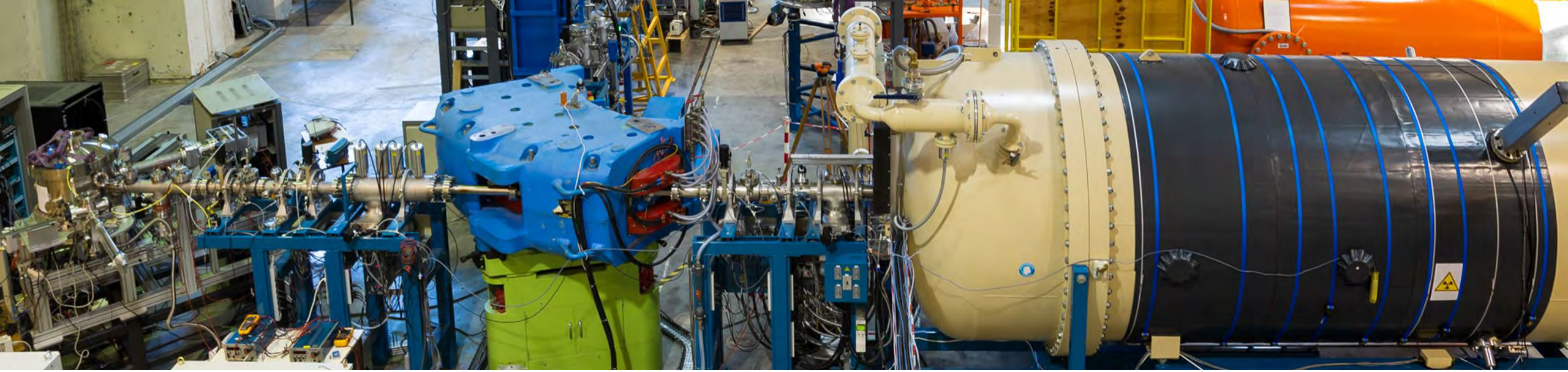
I2BC



Fundamental Research

the wide range of ions, delivered by Andromede, permits to adress many fields of fundamental researches: very low energy nuclear physics, astrochemistry molecule-gas interaction, nanoparticle-solid interaction



MULTIDISCIPLINARY RESEARCH/APPLICATIONS

In the field of nanotechnologies and surfaces, Andromede responds to the great need of very high resolution surface analysis tools both in mass spectrometry and in ion imaging. Access to the chemical characterization of a nanometric volume is envisaged.

APPLICATIONS

BIOLOGIE, HEALTH, IONIC IMAGING

The use of nanoparticle beam (Nanoparticle Probe in Biology (NPB)) as a probe in biology is the results of research on particle-matter-secondary emission interaction conducted at IPNO in the last
few decades. The offer of analysis was then opened to bio-organic surfaces with the emergence of metallic cluster beam and molecular beams.

ASTRO-CHEMISTRY, COSMO-MATERIALS, ION IMAGING

The availability of cluster beams and high energy nanoparticles make it possible to simultaneously determine the elemental and molecular composition of a complex surface such as meteorites.
These analyses of cosmo-materials by mass spectrometry and ion imaging can be supplemented
by simulation to obtain analogs in the laboratory.

APPLICATIONS

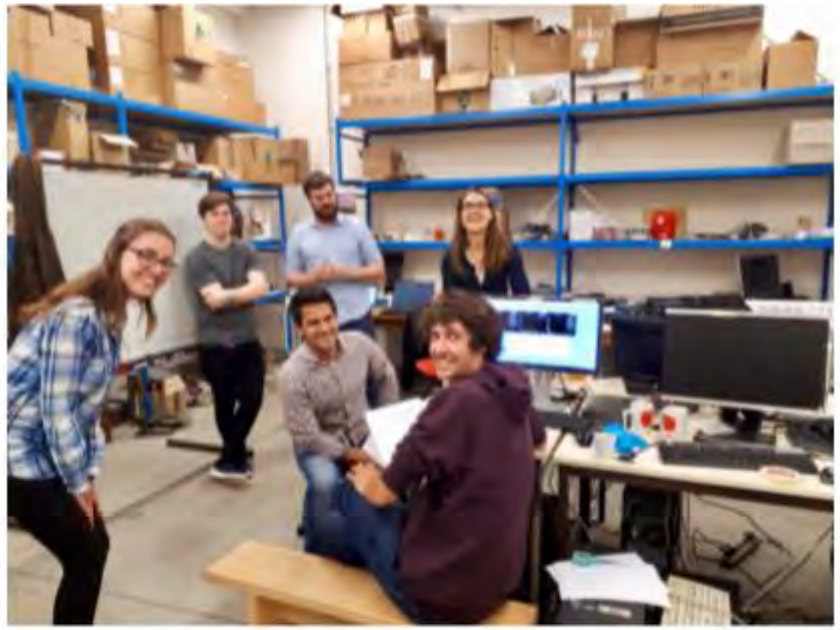
IMPLANTATION IN MATERIALS

Andromede provides the scientific community molecular beams of methane, fullerenes and metal clusters for studying the behavior of materials under irradiation. The scientific fields studied are the modification of materials under irradiation or implantation, the aging of materials, study of solid physics, microelectronics, cosmo-materials and earth sciences.

The Andromeda platform has two sets of ion source development. a filtered NAPIS ionic column dedicated to R & D around LMIS, LICIS and vacuum electro-spray type sources for the production of cluster beams or molecular beams with great brightness. TANCREDE beam line for ion beam developments with ECR type sources.
These two systems are available for all new developments with our support and the contribution of our expertise on these kinds of source.

Nuclear astrophysics experiments at Andromede
Fusion cross sections

D. Curien, IPHC, Strasbourg
for the STELLA collaboration

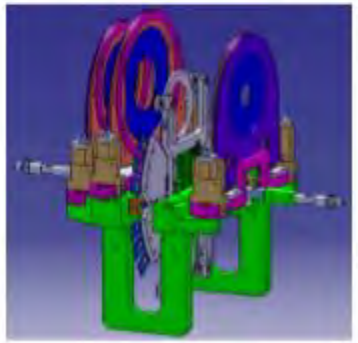


Contact : Sandrine.Courtin@iphc.cnrs.fr

STELLA (Stellar Laboratory)

A toolbox for the measurement of fusion reactions of astrophysics interest

Argonne NATIONAL LABORATORY



- Si detectors
- $LaBr_3$ detectors
- Rotating target system
- Andromede facility, University of Paris-Sud - Orsay
- ^{12}C up to 10 µA

M. Heine et al., NIM, A 903 (2018) 1–7

Contact : Sandrine.Courtin@iphc.cnrs.fr

Collaboration STELLA

IPHC Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

GANIL SPIRAL2

UNIVERSITY of York

SOLIDUM PETIT IN PROFUNDIS UNIVERSITAS ARHUSIENSIS

UNIVERSITY OF SURREY

Results of the first run

Runs on $^{12}C+^{12}C$ (206-2017, 2019), 1 under analysis :
Fusion measured down to astro. energies, down to σ ~ 100 pb
(important result for nuclear astrophysics)

- 4 articles (refereed journals)
- 6 proceedings
- 2 'brèves' IN2P3
- 24 invited talks at international conferences such as INPC, Nucleus-Nucleus, Fusion, Nuclear Physics in Astrophysics, HIAS, Cluster …
- 1 series of courses. The technique used for STELLA at Andromede is now the standard for direct measurements of fusion X sections for astrophysics
- 1 PhD (G. Fruet, sept. 2018)

Contact : Sandrine.Courtin@iphc.cnrs.fr

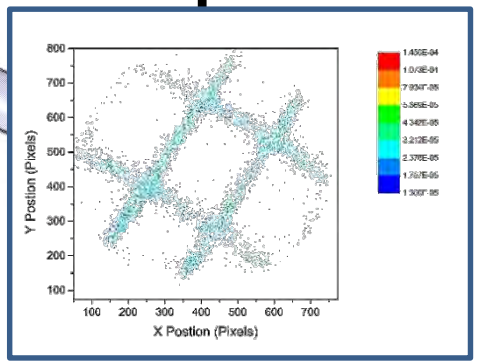
Nanoparticle-Solid Interaction

Andromede
IN2P3 research plateform
https://andromede.in2p3.fr

EVE

Nanoscale ion imaging

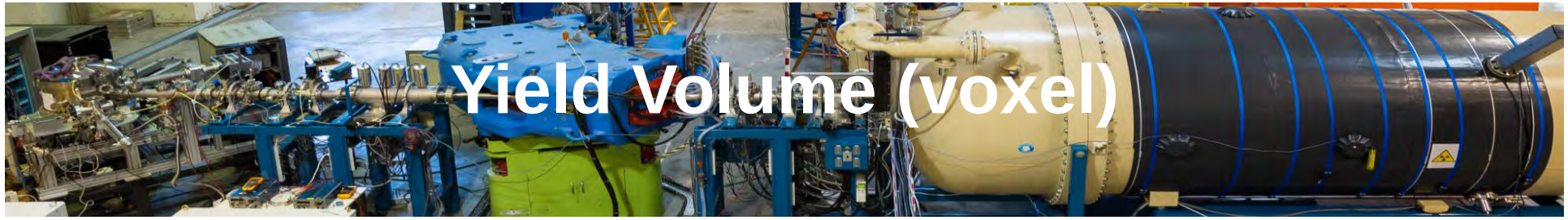
Electron or
Proton Emission
Microscope



TOF Mass spectrometer

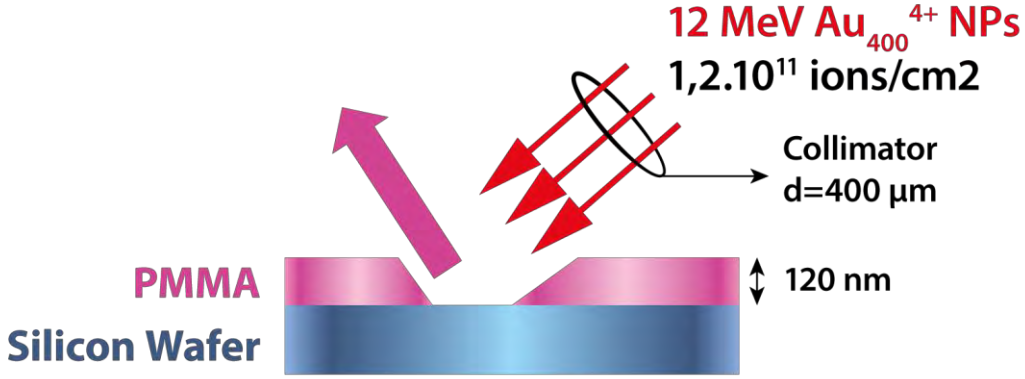
Primary Ions

Secondary Ions



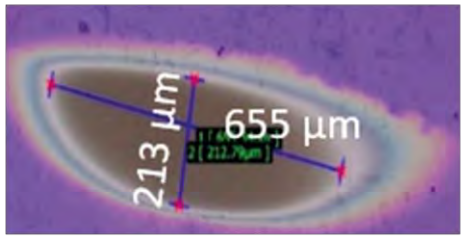
Yield Volume (voxel)

What is the volume of emission ?

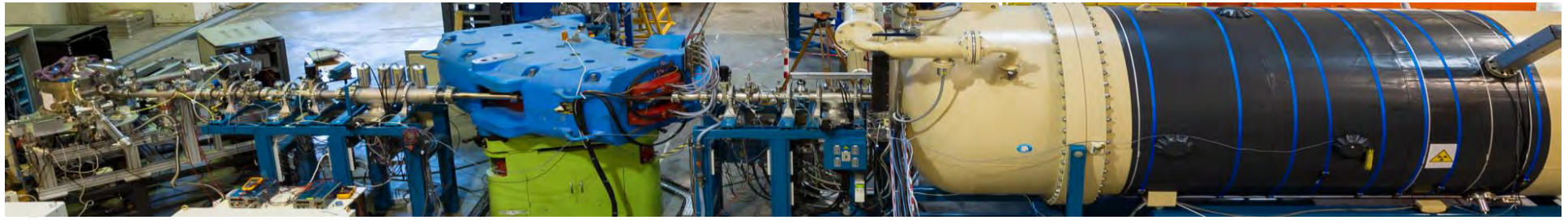


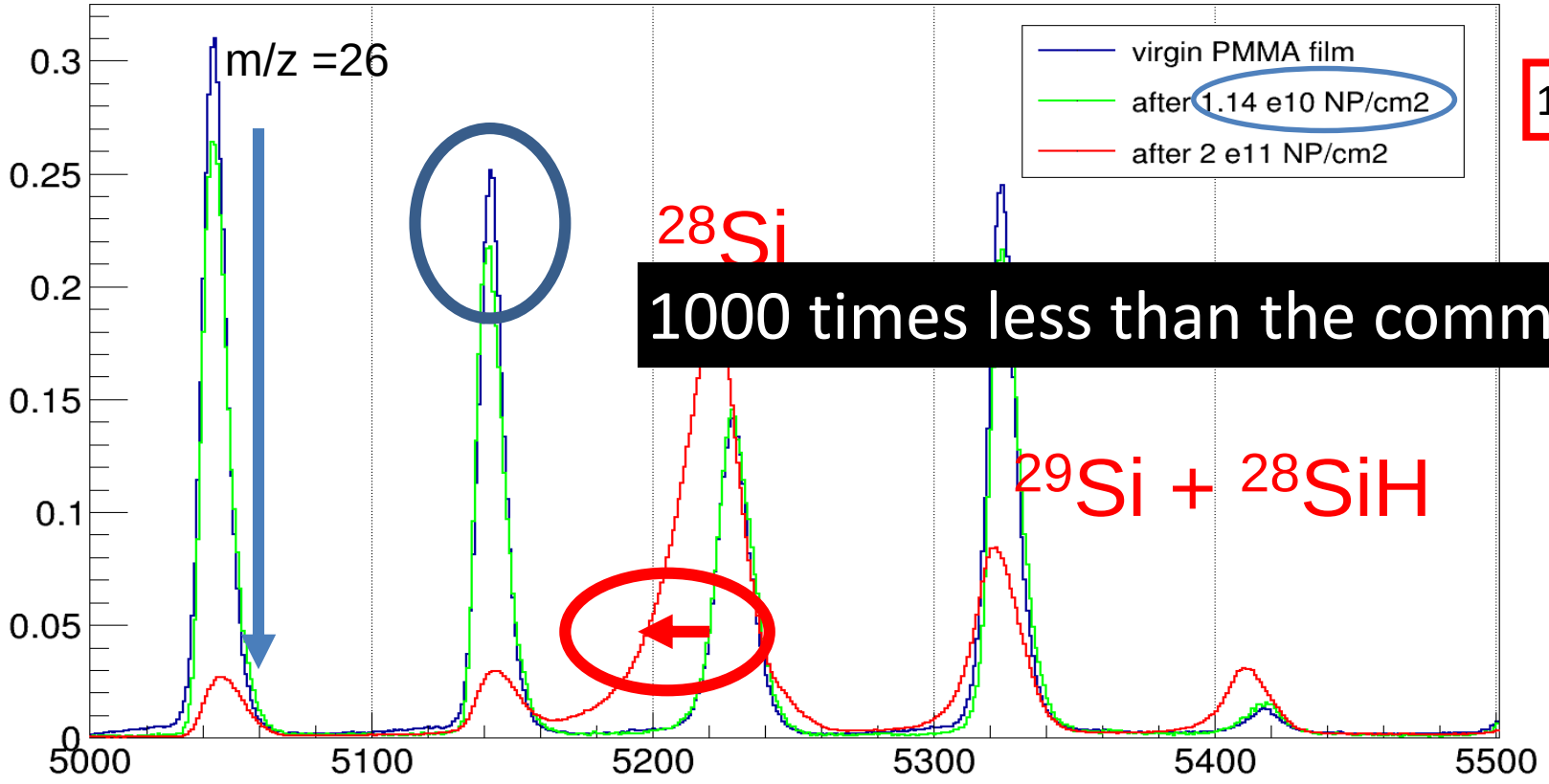
Controlled parameters:

- ✓ Incident ions number
- ✓ Material thickness
- ✓ Sputtered Volume



3D Confocal microscopy image





10^{13} ions/cm^2

1000 times less than the commercial probes

Yeld Volume (voxel)

The sputtered Volume has been measured with Dextrat XT A from Brucker Nanosurface division

The total ejected volume is: 11200 µm^3 of PMMA for 1.2 10^{10} Au_{400}^{4+} ions

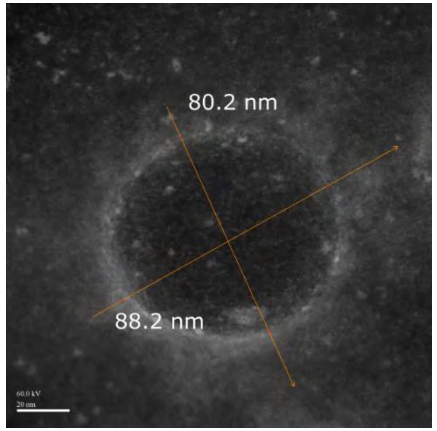
Max. ejection voxel ~10^6 nm^3

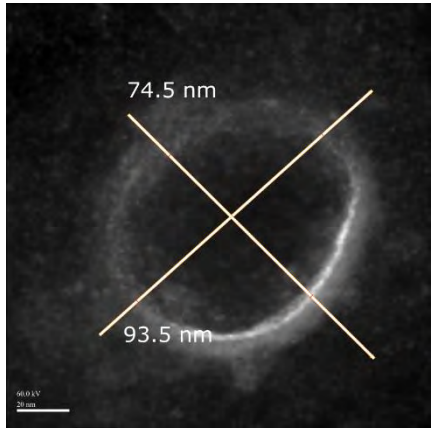
➡ Typical size (R,h)~ 100 nm, 30nm

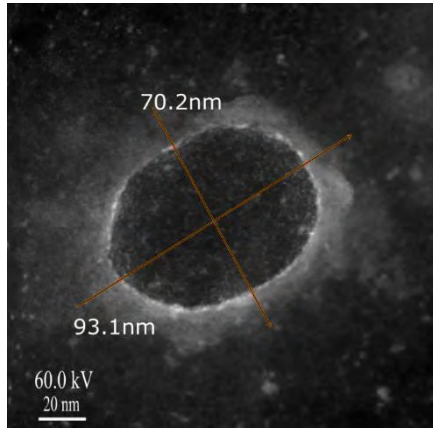
Profile measurement is possible
with the EPEM localisation >>> 3D ion imaging

Track diameter

What is the track diameter ?
Graphene 6 ML







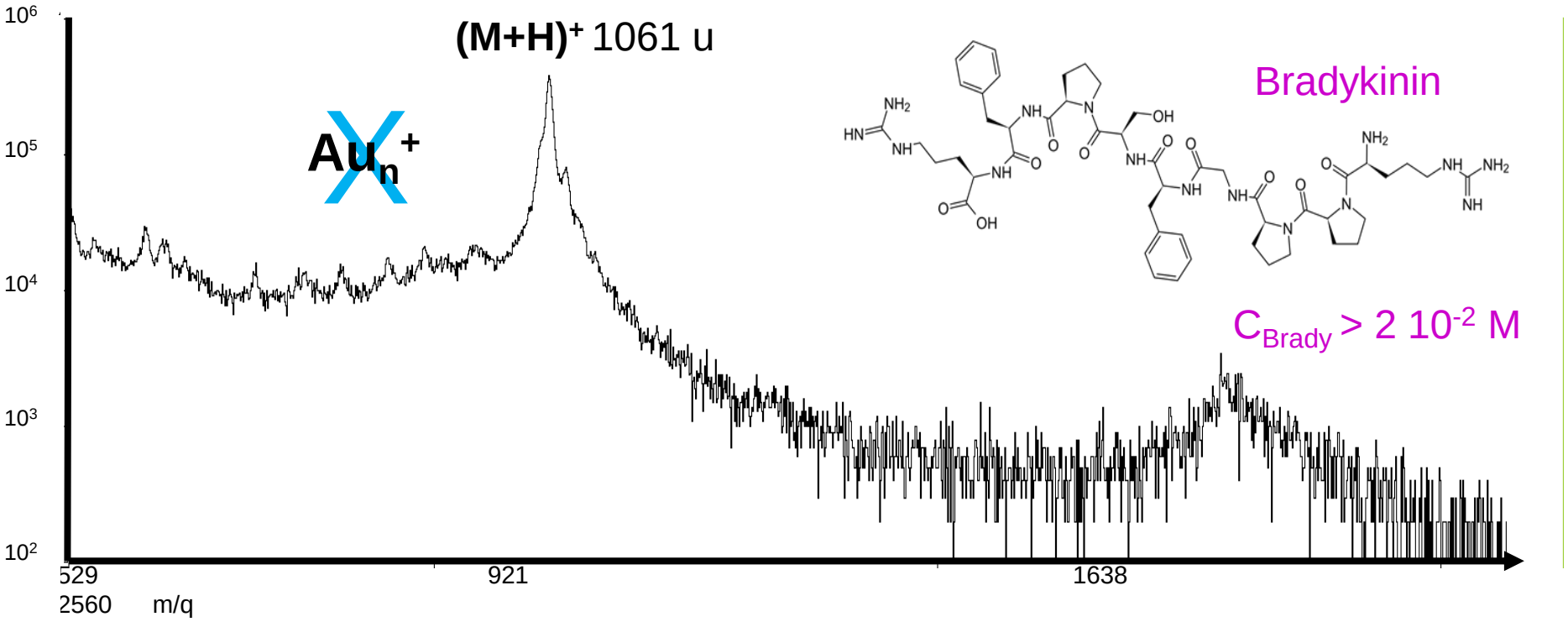
region	Diameter1 (nm)	Diameter 2(nm)
1	80.2	88.2
2	74.5	93.5
3	70.2	93.1

Nion UltraSTEM 200 operated at 60 keV,
Beam settings: 30 pA current, 34 mrad half angle convergence, 350 meV energy spread
In coll. With Luiz Galvao-Tisei and Fuhui Shao from LPS, Orsay

Secondary Ion Emission

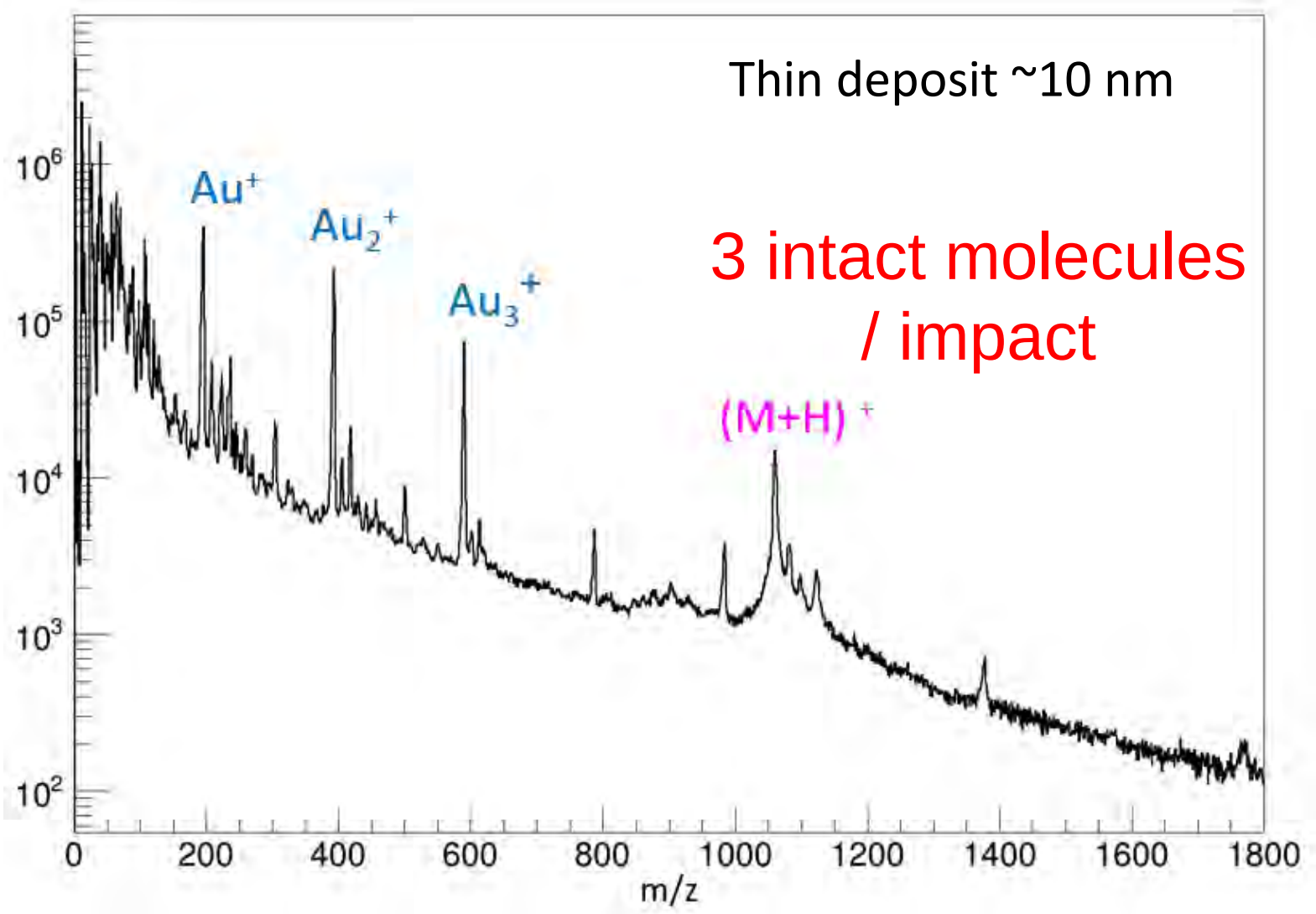
Thick deposit

5 intact molecules /impact



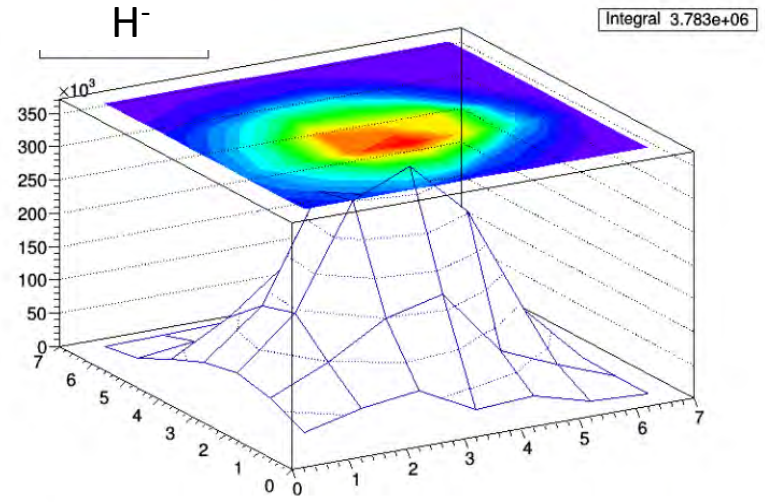
Au_{400}^{4+} 12 MeV : Emission efficiency 1000 times higher than commercial probes

Secondary Ion Emission

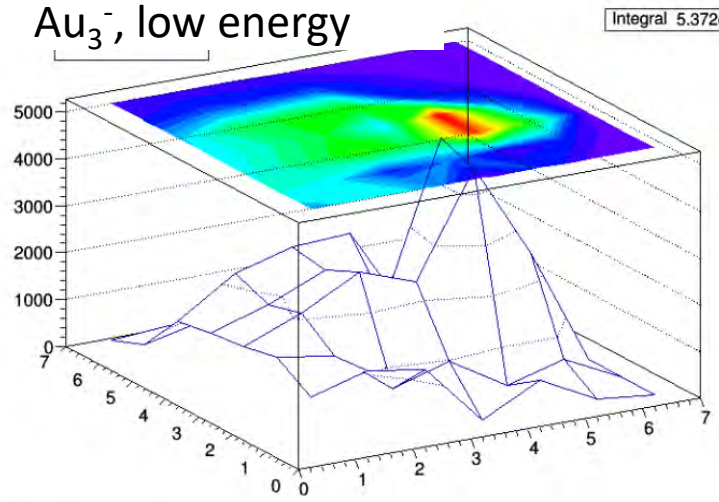


Characteristics of the Secondary Ion Emission

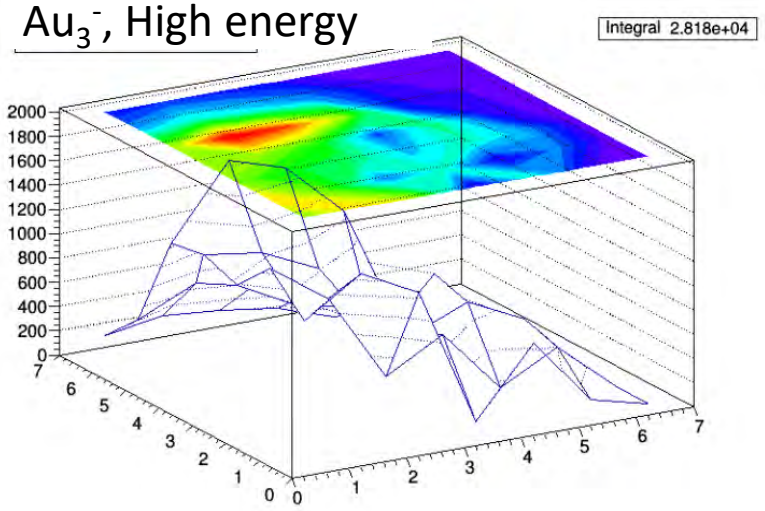
H^-



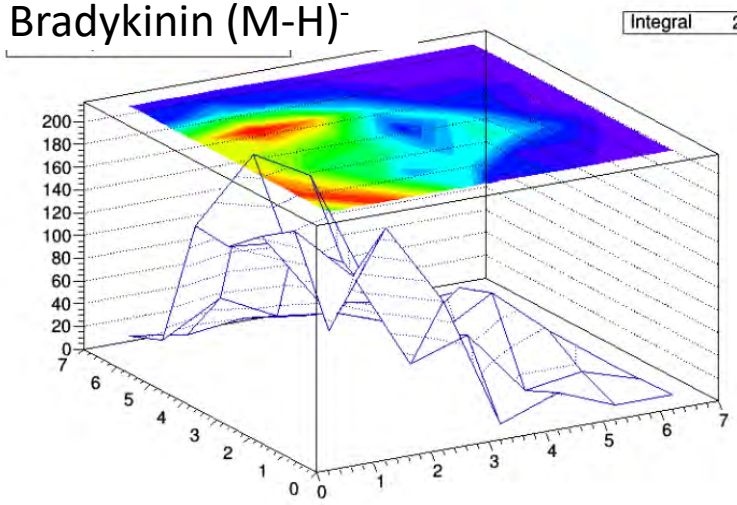
Au_3^-, low energy



Au_3^-, High energy



Bradykinin $(M-H)^-$



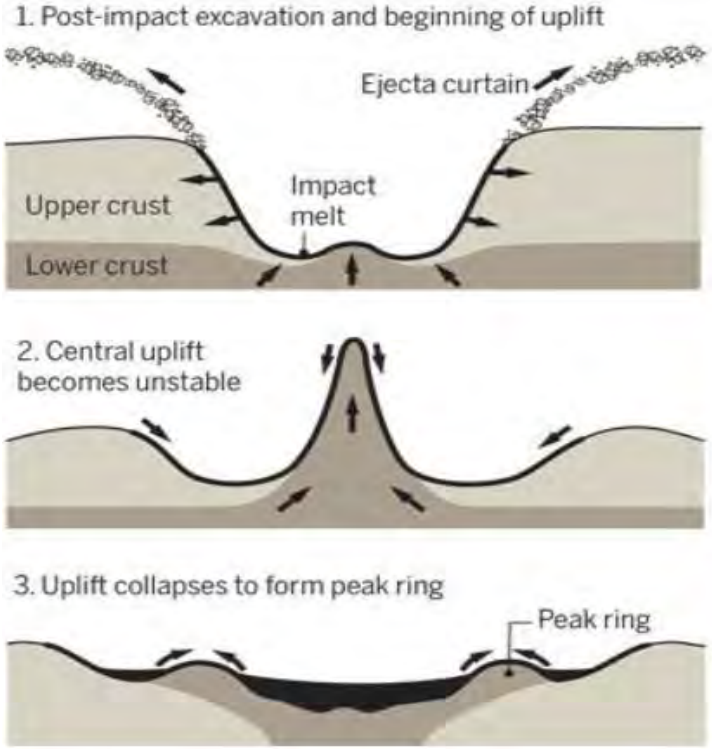
Characteristics of the Secondary Ion Emission

Probing ground zero

In April, scientists will drill into Chicxulub crater, where an asteroid impact 66 million years ago led to one of Earth's biggest mass extinctions. They hope to reach a buried peak ring, Earth's only preserved example.

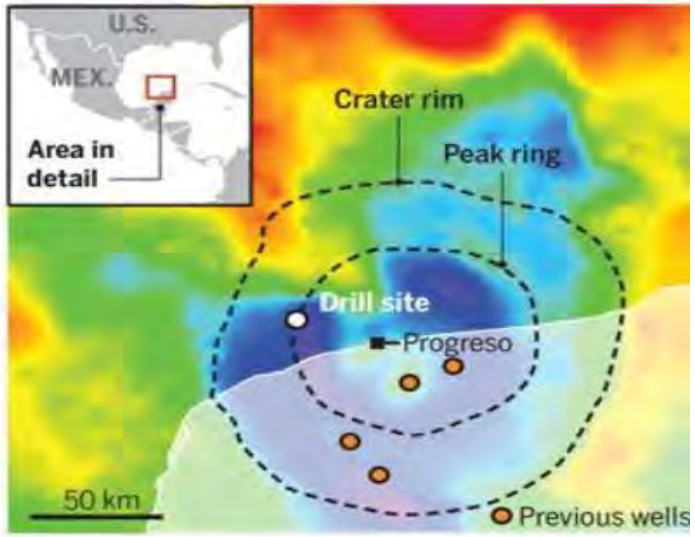
Making the mounds

Impact shocks could make rocks behave like fluids, piling deep crustal rocks on top of rocks of shallower origin.



Buried treasure

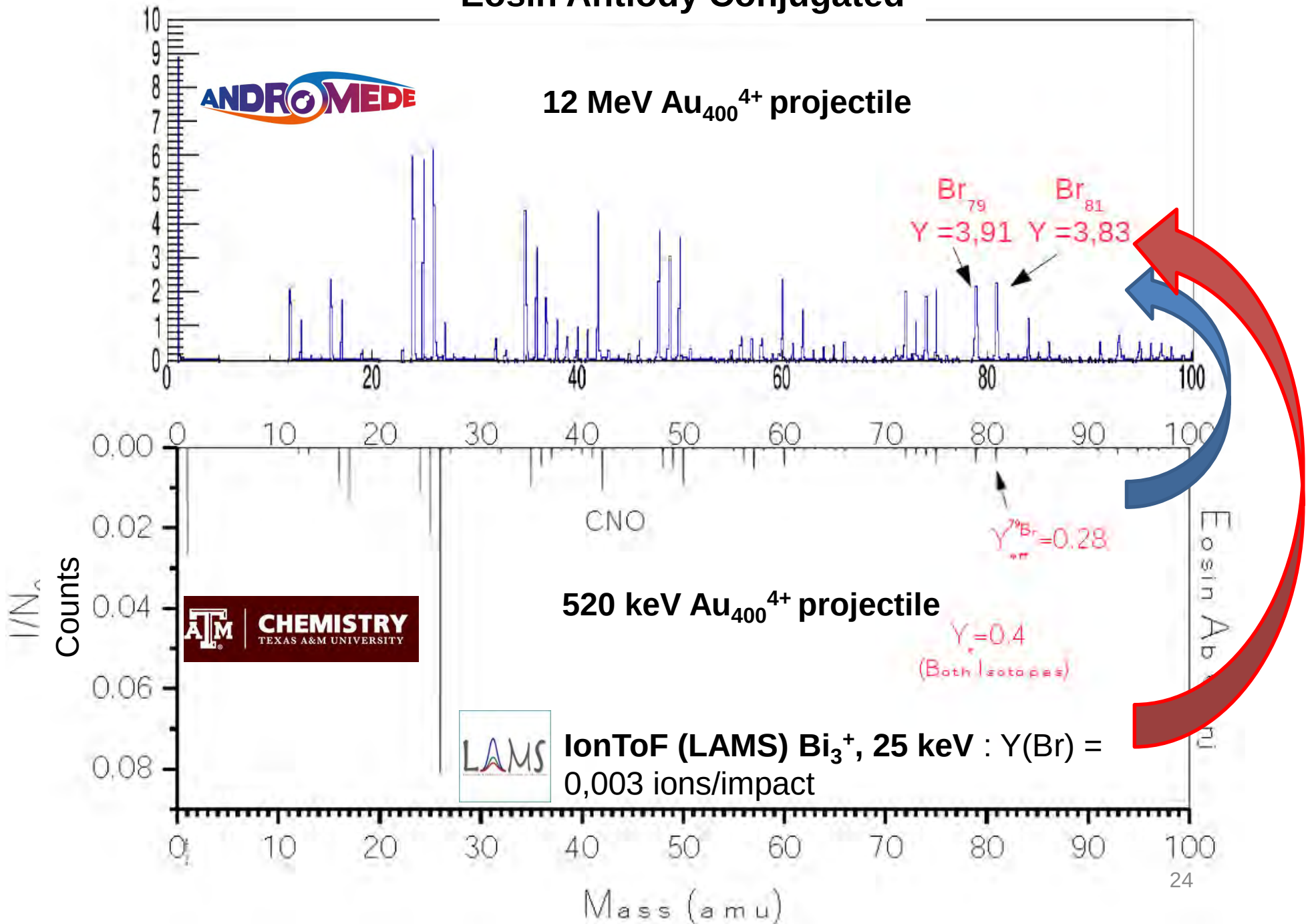
Offshore from Progreso, Mexico, scientists will drill into the crater's peak ring, partially seen in geophysical remote sensing data (below). Onshore wells have been drilled into the crater before, but few were cored and none reached the peak ring.



Andromede is crucial for achieving a major objective, nanoscale co-localization of tagged proteins in cell membranes. Is it possible ?

Comparison with other techniques:
keV Bismuth clusters IONTOF V
Pegase 500 keV Nanoparticles beams

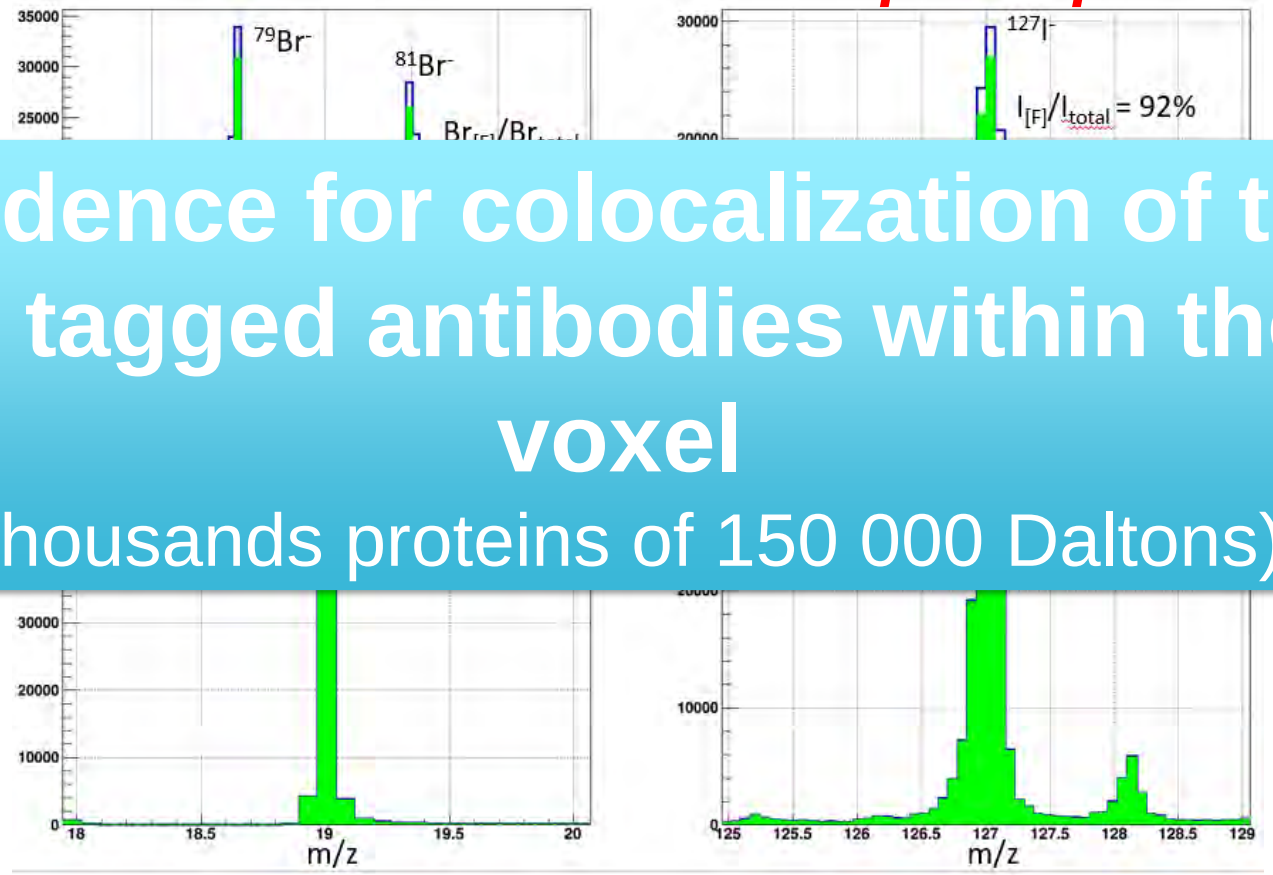
Eosin Antiody Conjugated



Colocalization - Coemission

Br^- and I^- peaks in coincidence with F^-

*A mean value of **3 F^- emitted per impact***



Evidence for colocalization of the 3 tagged antibodies within the voxel

(thousands proteins of 150 000 Daltons)

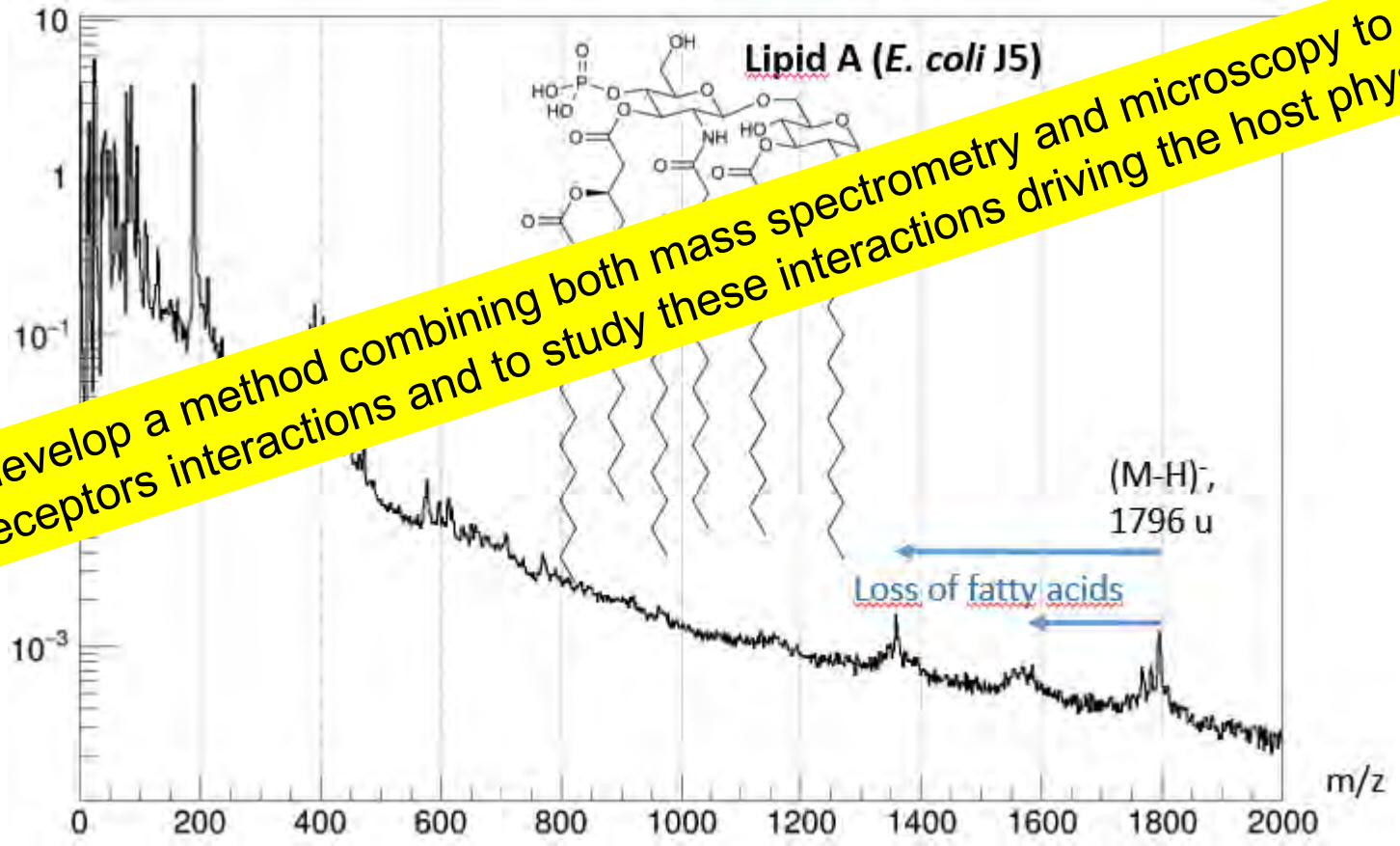
F^- and I^- peaks in coincidence with $^{79}Br^-$

A mean value of 4 $^{79}Br^-$ emitted per impact.

Lipopolysaccharides analysis

Feasibility study

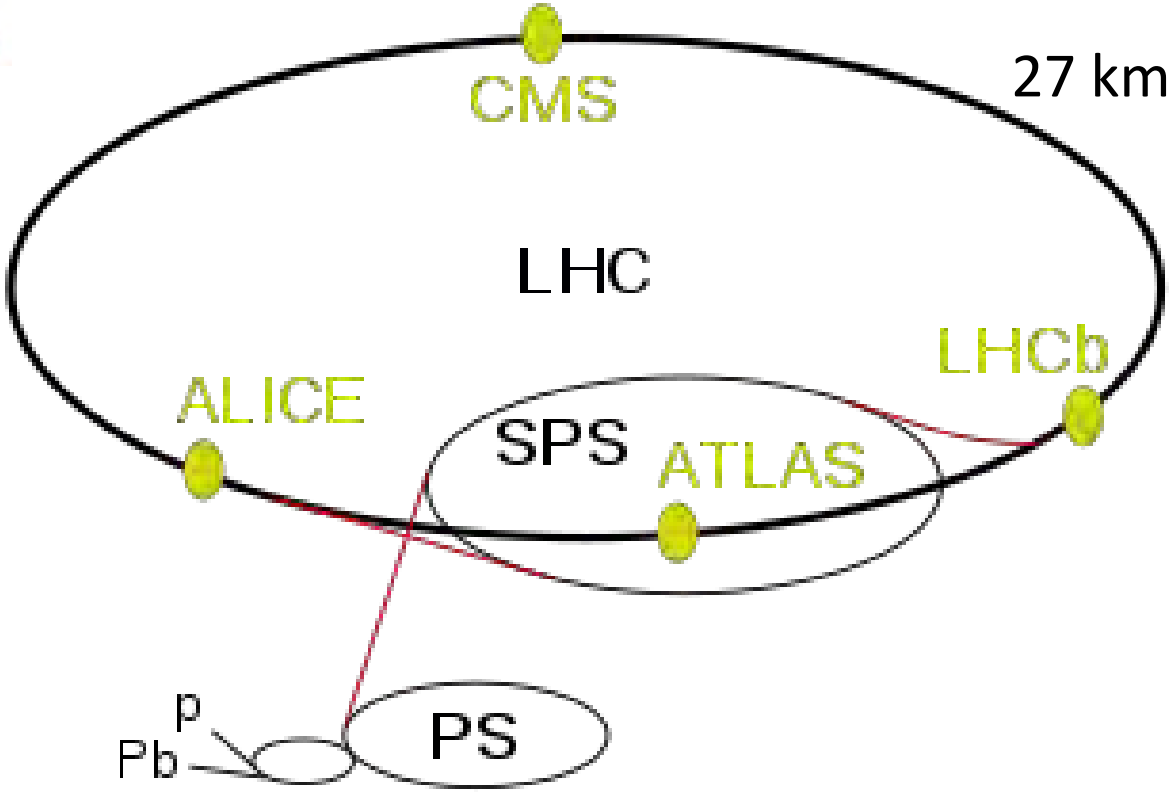
Now, it is possible to develop a method combining both mass spectrometry and microscopy to localize in tissue and cell endotoxins-receptors interactions and to study these interactions driving the host physiological responses



Emission yield : Y (lipid A) ~ 30%

Surface analysis-Collaboration IJCLAB

CERN's accelerator complex



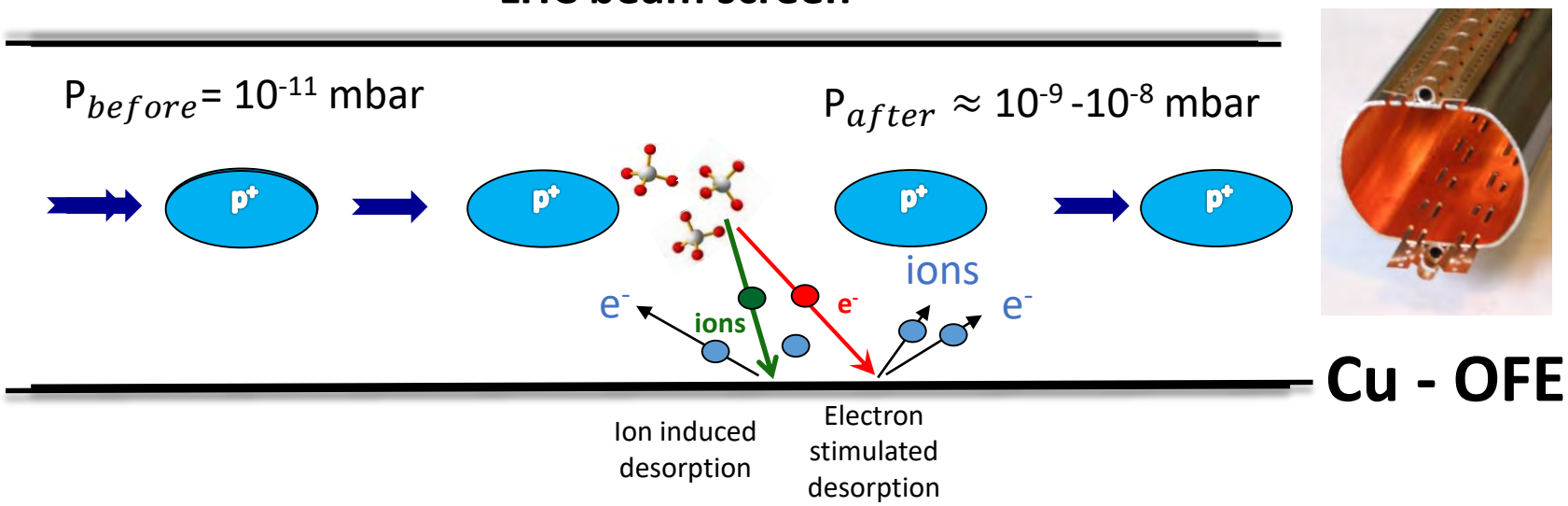
Cu-OFE

Large Hadron Collider (**LHC**) - the world's largest and most powerful particle collider

https://fr.wikipedia.org/wiki/Grand_collisionneur_de_hadrons

Surface analysis-Collaboration IJCLAB

LHC beam screen



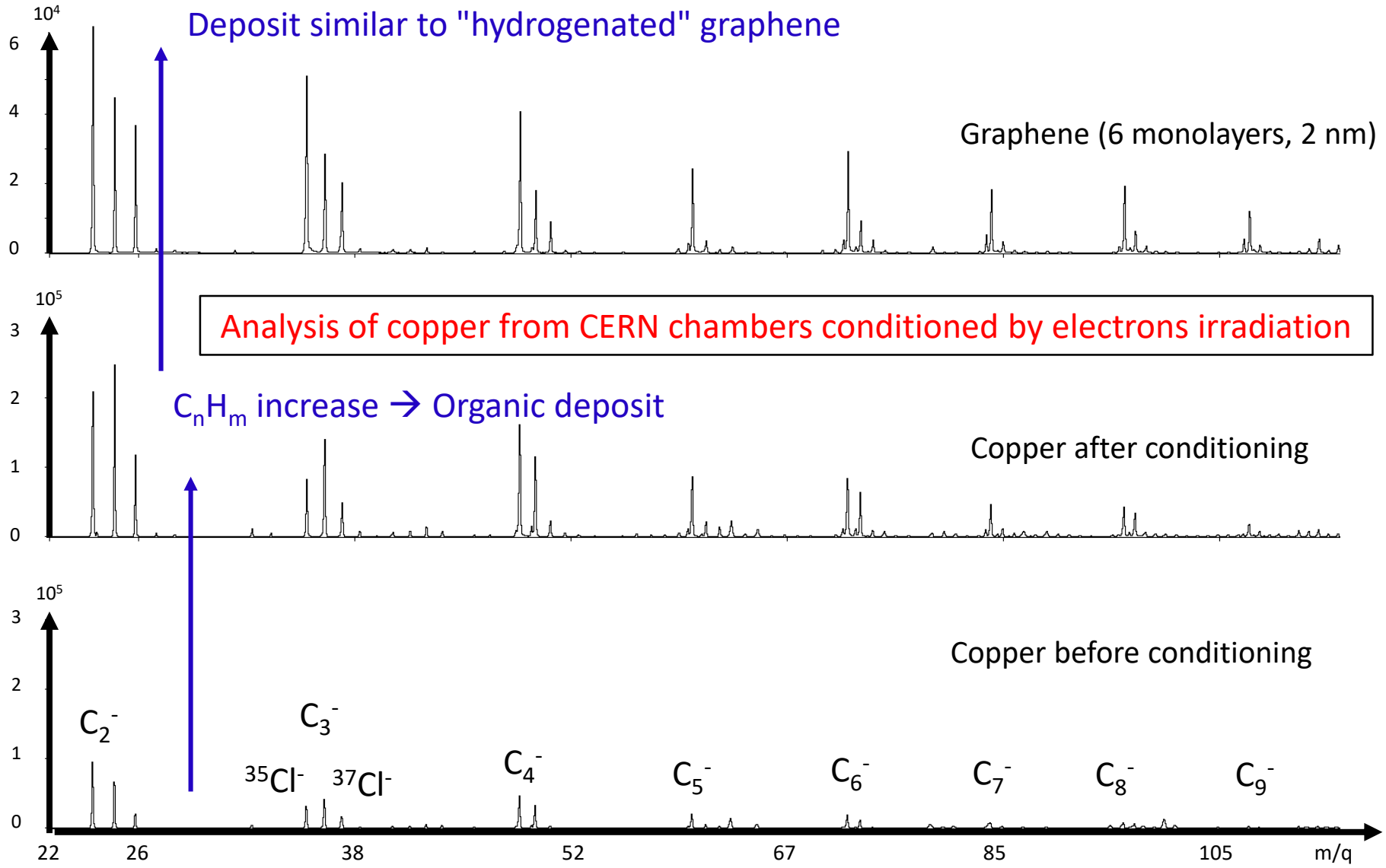
Cu - OFE

The beam emittance increases, the luminosity deteriorates and the beam becomes instable.

Surface conditioning by the electron flux decreases the emission of secondary electrons

Surface modification
Desorption and conditioning mechanisms

Surface analysis-Collaboration IJCLAB



Surface analysis Collaboration IJCLAB

Before e- irradiation

After e- irradiation

C_6^-

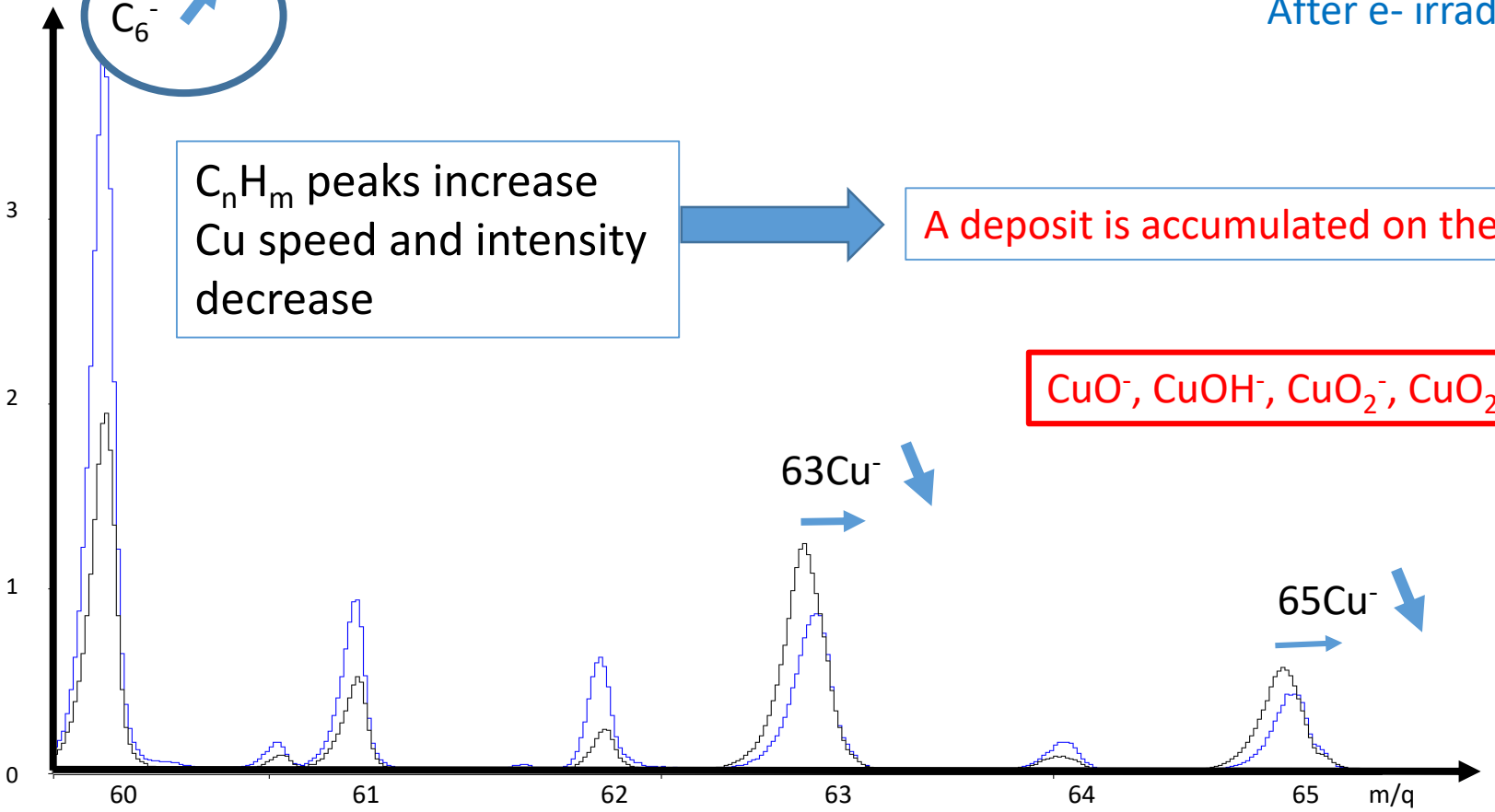
C_nH_m peaks increase
Cu speed and intensity decrease

A deposit is accumulated on the surface

CuO^-, $CuOH^-$, CuO_2^-, CuO_2H^- disappear

63Cu⁻

65Cu⁻



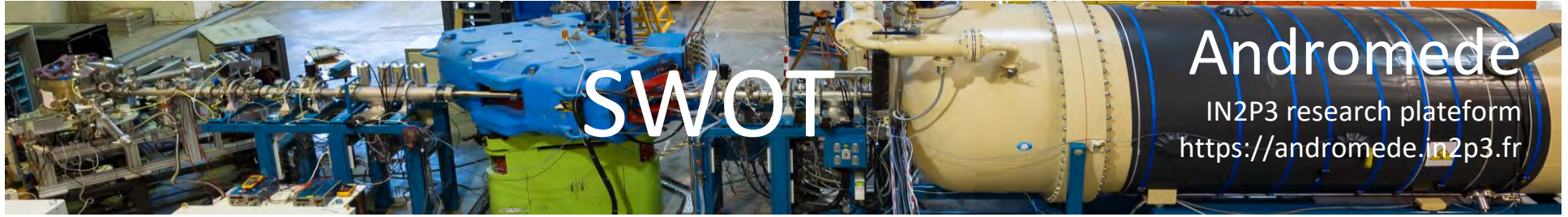
https://andromede.in2p3.fr

Andromede set-up is **unique world-wide**, with its capability to perform molecular analysis at the nanoscale with detection limits that are near a single molecule (for MW below 1,500 Da). Yet to be implemented is a molecular imaging capability which promises again to **be unequalled.**


Andromede team
STELLA Exp2019 - ELOG - 016, cosmic - Mozilla Firefox
General infos about stella campeign starts 02/04/2019

Acknowledgments

Thank you for your attention !



SWOT

Andromede
IN2P3 research plateform
https://andromede.in2p3.fr

STRENGTHS

- New Platform/low maintenance machine for 5 next years
- Strong multidisciplinary expertises : nuclear physics, vacuum and surfaces, materials science, physics and astro-chemistry, biology
- Originality of beams (atomic, aggregates, nanoparticles)
- Unique performance of nanoparticle beams: ion emission efficiency / impact analysis (chemical environment, co-localization, 3D ion imaging, etc.)
- Complementarity of our platform with local, national and international ones

WEAKNESSES

- Strategic Human Resources Plan
  - thesis and post-doc supervision
  - strategy for future project submission
- Operating and maintenance funding
- Chronic dwindling of human and financial resources
- recognition for multidisciplinary Platforms
-

OPPORTUNITIES

- Unique international research infrastructure
- Local, national and international partnerships
- Lab unification /Technical support IJCLab
- University Paris-Saclay / interdisciplinary programs focus on training /Meet My Platform
- SATT/ R&D and technology transfer
- Openness of the EMIR federation to the scope of analysis IBA

THREATS

- Sustainability of the platform due to mainly unpaid collaborations
- Change of ASN rules
- Barriers to delivering programs that would no longer be free in the academic community

Back up

Publications related to Andromède, Nanoparticles beams and feasibility studies

Andromede : 1

Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 51(décembre 2015) Volume 365, Part A, Pages 367-370

Stella : 4

Nucl.Instrum.Meth.A, 2018, 903, pp.1-7.

Agat : 2

A&A 628, A75 (2019)1-14

Instrumentation : 3

Rev. Sci. Instrum. 84, 103706 (2013)

Ion-Solid Interaction : 4

The Journal of Chemical Physics 146, 054305 (2017); doi: http://dx.doi.org/10.1063/1.4975171

Biological surface Analysis: 6 publications

Scientific Reports ***volume 9****, Article number: 1928 (2019)*

Astrochemistry : 3

Life 2019, 9, 44; doi:10.3390/life9020044

Oral Presentation:

Permanents, Postdocs, doctorants

2019 : SMAP 2019 keynote (T.L.Lai), IBA2019 (T.L. Lai- I. Ribaud), SIMS22(S. Della Negra)

2018: SNEAP2018 invited talk (S. Della Negra)

2017 : SIMS21 (S. Della Negra), (T.Fu), Pittcon 2017 (T. Fu)

2016 : SIMSEUROPE2016 (T. Fu)

2015 : SIMS20 invited talk (S. Della Negra)

2015 : 16th International Conference on Ion Sources (O. De Castro)

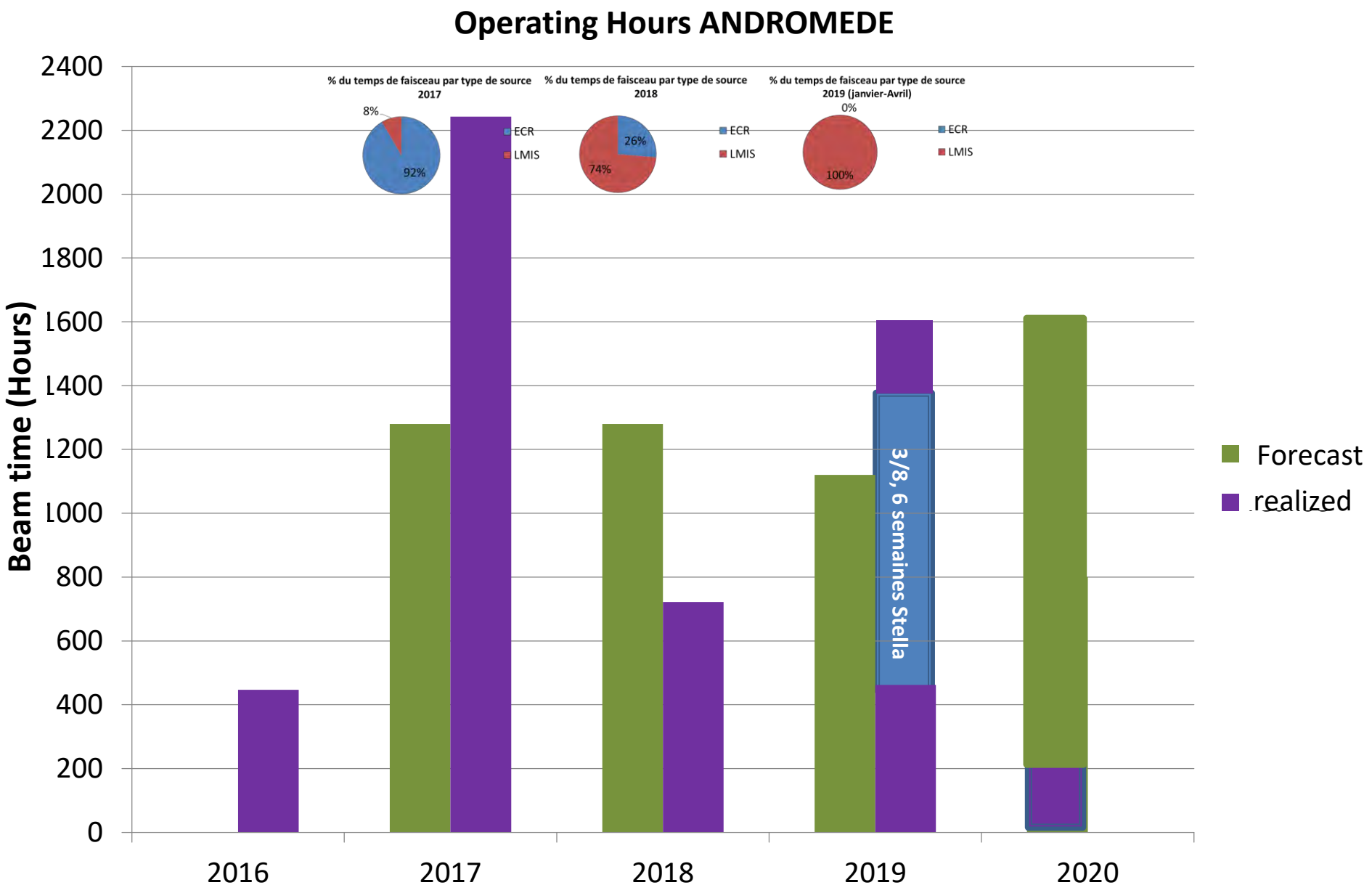
2014 : 9TH INTERNATIONAL CONFERENCE ON CHARGED PARTICLE OPTICS (O. De Castro) (M.S. Verruno), Desorption 2014 (M. Eller) (M. Noun)

2013 : PASI2013 (M.Eller), 61 ASMS (M. Noun)

Internship and practical work in the Master2 large instruments (S. Kazamias)
2017 2018
4 practical work, 1 intern.
1 BTS Biology Intern in 2017

Theses 7 including 1 in progress within the framework of the PHENIICS doctoral school
international co-supervision or joint supervision

IN2P3 Bio Network I. Ribaud
GDR I. Ribaud
.


Operating Hours ANDROMEDE
Beam time (Hours)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2016
2017
2018
2019
2020
% du temps de faisceau par type de source 2017
8%
92%
ECR
LMIS
% du temps de faisceau par type de source 2018
26%
74%
ECR
LMIS
% du temps de faisceau par type de source 2019 (janvier-Avril)
0%
100%
ECR
LMIS
3/8, 6 semaines Stella
Forecast
realized

Estimated ANDROMEDE service costs

Particle beam production : **1280 h/year**

Personal costs

Nom	Prénom	ETP (%)	Grade	Coût exploitation
Ribaud	Isabelle	30	IR	23 472,00 €
Daubisse	François	100	AI	63 257,00 €
Maintenance: 2 months		30	IR	3 912,00 €
		70	AI	7 379,98 €
				Sub-total : 98 020,98 €
Personal environment				Sub-total: 78 416,79 €
				Total: **176 437,77 €**

Operating costs:

- 40 000 € + 20 000 € (estimates of fluid and electricity costs)

Accelerator depreciation: (3 M€ / 120 months)

- 250 000 € (8 months of operation + 2 months of maintenance)

Estimated costs of ANDROMEDE services

Types of services	Actual Costs	Prices[1]	
		Internal (excluding HR)	**External**
Irradiation	380 €/h	300 €/h	475 €/h
Irradiation + Analyses[2]	Irradiation prices + scientific expertise		

[1] + 20% margin in the case of laboratory direct debit (under discussion)

[2] The fees for scientific expertise (ion beam analyses + analysis report) will be calculated later and will be subject to a quote

Note: An inventory of the different calculation and deduction policies on the services of the old laboratories is in progress. Once the rate and the sampling base will be fixed by the management of the IJCLab, the file for the validation of the rates will be sent to the DR4.

TECHNOLOGIES

// R&D ion sources

In addition to the accelerator platform, ionic columns equipped with the ECR source and the NAPIS source are available to test source developments and to produce new beams. These devices are also available for analysis and material modifications in the low energy range (a few keV)

Promotion: DR4 - University of Paris Sud and SATT
Patent under evaluation and Polyions maturation project with SATT in collaboration with ICMMO

TECHNOLOGIES

*// Ion beams and characteristics - **Source ECR Microgan***

The ions produced by this source are selected at the accelerator terminal by a Wien filter.

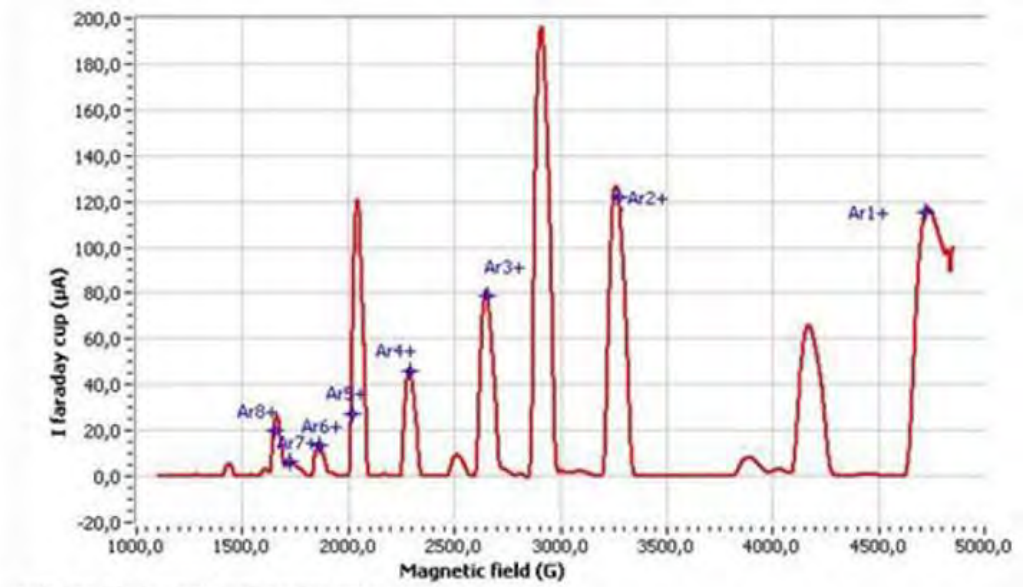


Illustration 12: Ar spectra with oxygen gas support

Ions multichargés d'Argon

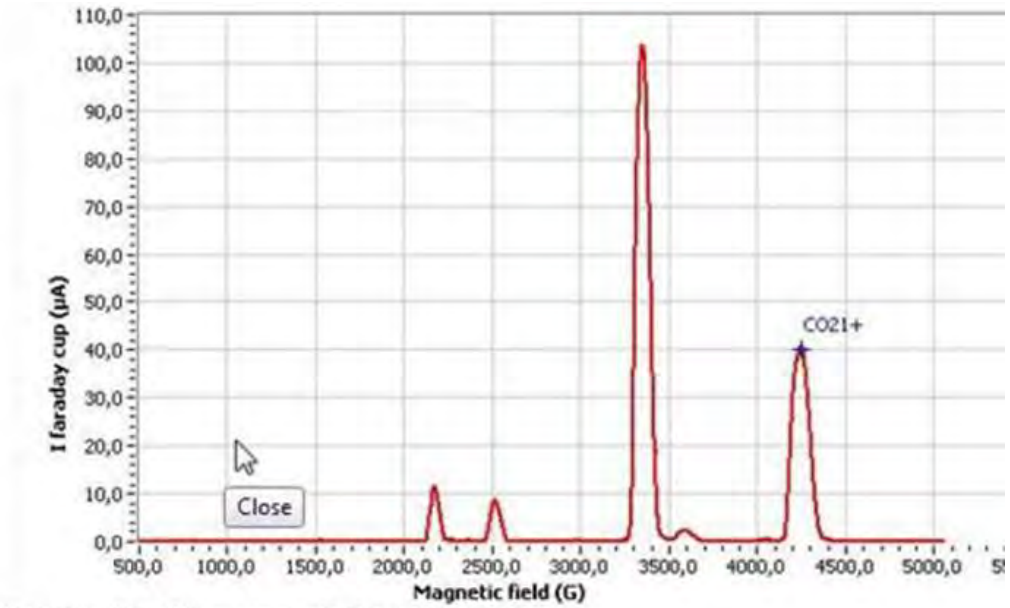


Illustration 21: CO_2^+ spectrum with flat magnetic field

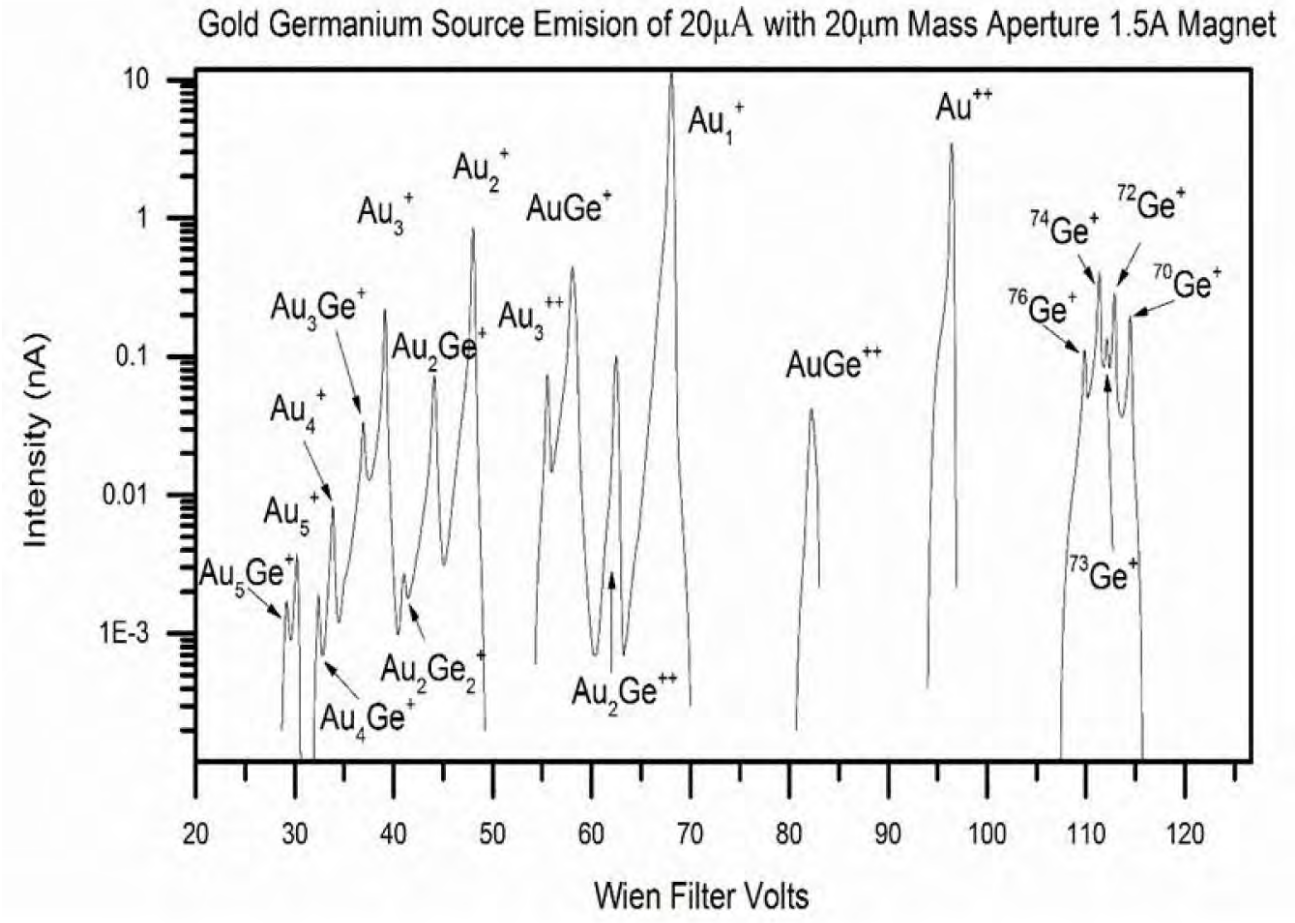
Ions moléculaires

TECHNOLOGIES

// Ion beams and characteristics

– Sources LMIS NAPIS

The NAPIS column is equipped with a LMIS (Liquid Metal Ion Source) providing beams of metallic atomic ions, clusters and nanoparticles.



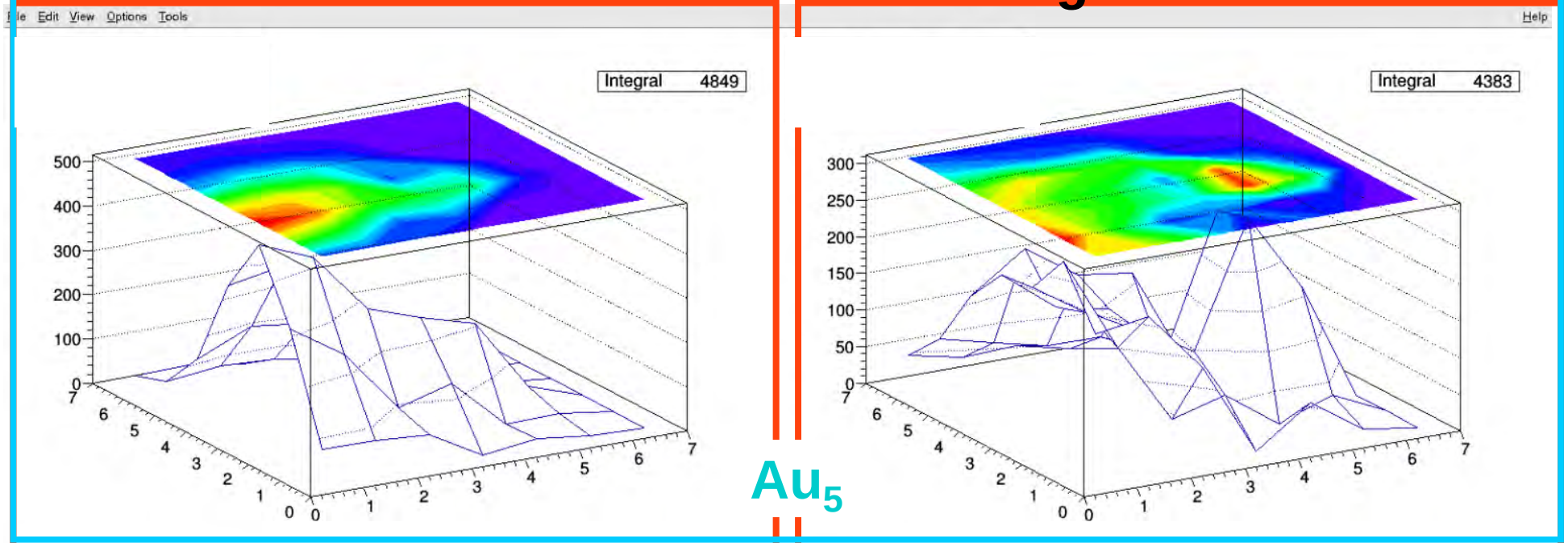
Available beams

Andromede
IN2P3 research plateform
https://andromede.in2p3.fr

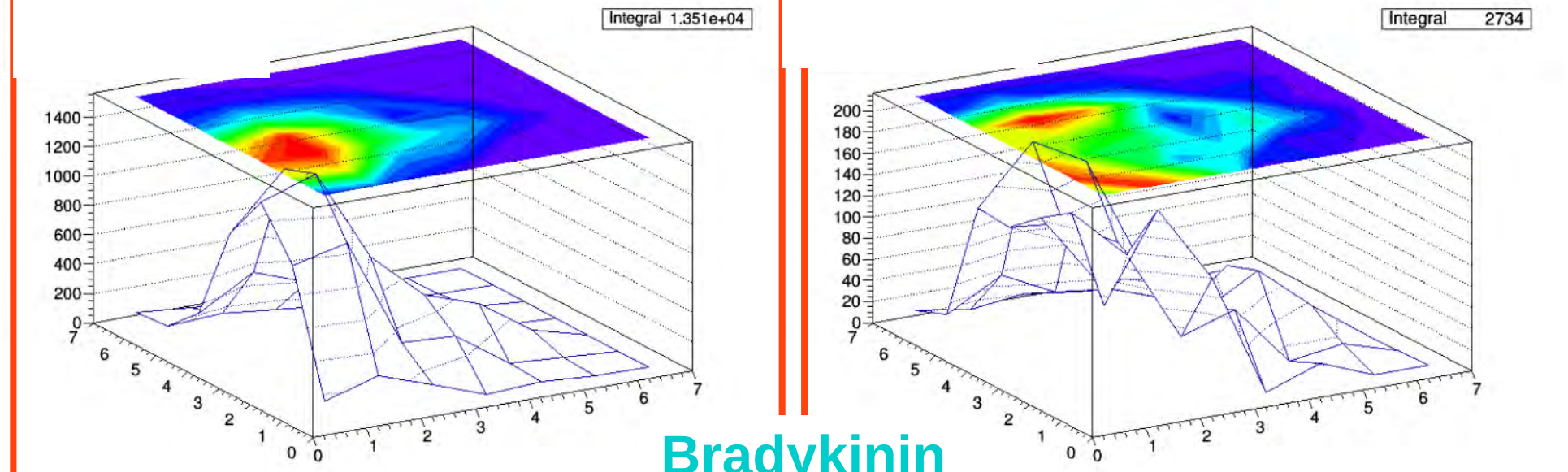
Ions	Energy (MeV)	Intensity (nA) @the exit of the acc.	beam size (µm) & Intensity (pA) In the centre of MSI EVE chamber	
Ar^{q+}, q=1- 8	1-32	100-1000		
SF_5^+	1, 2, 3, **3.65**	150 (1000)	**50**	**300**
Au^{2+}	1, 2, **3**	6 (10)		
Au^+	"	20(40)	**10**	**1000**
Au_2^+	"	2(4)		
Au_3^+	"	1.5 (3)	**10 (200)**	**150 (3nA)**
Au_5^+	"	0.2	**20**	**20**
Au_{400}^{4+}	4-16MeV	0.4 (.5-1)	**100 (400-800)**	**< 10**
Au_n^{q+}, n = 120, 1600 atoms		0.1-1-0.4	**400 (800)**	**10**
Future beams for MSI Experiment				
C_{60}^{q+}, q= 1-3		10-100		

Positive ions

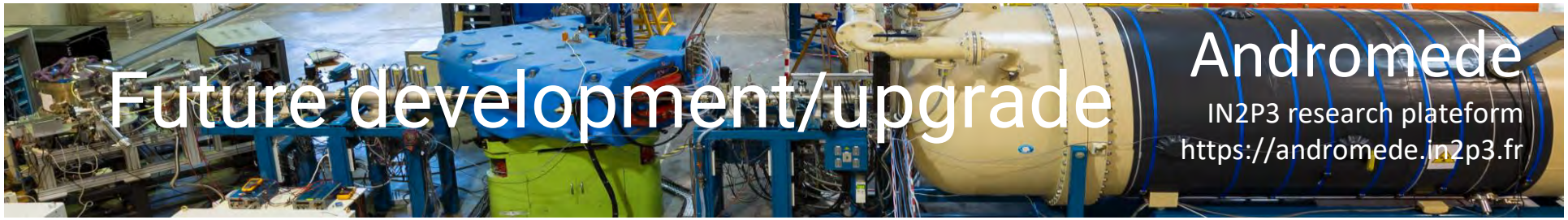
Negative ions-



Au_5



Bradykinin



Very high mass resolution and determination of the molecular structure

Orbitrap Thermo Résolution >240 000

Précision 0.3 ppm

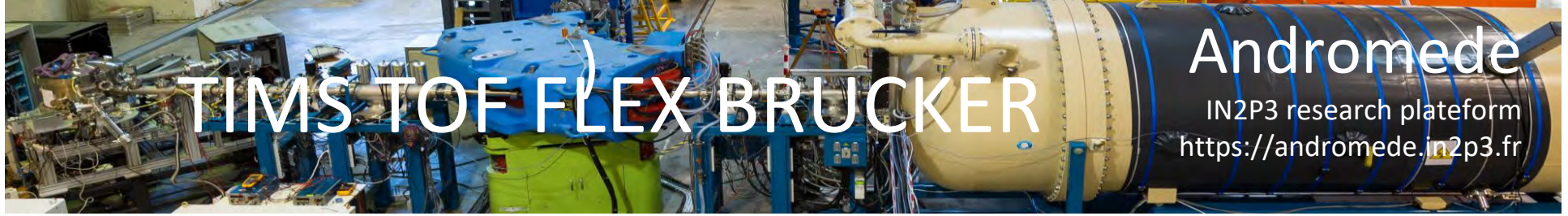
Or

Spectro Brucker Ion mobility+ trap+ OToF

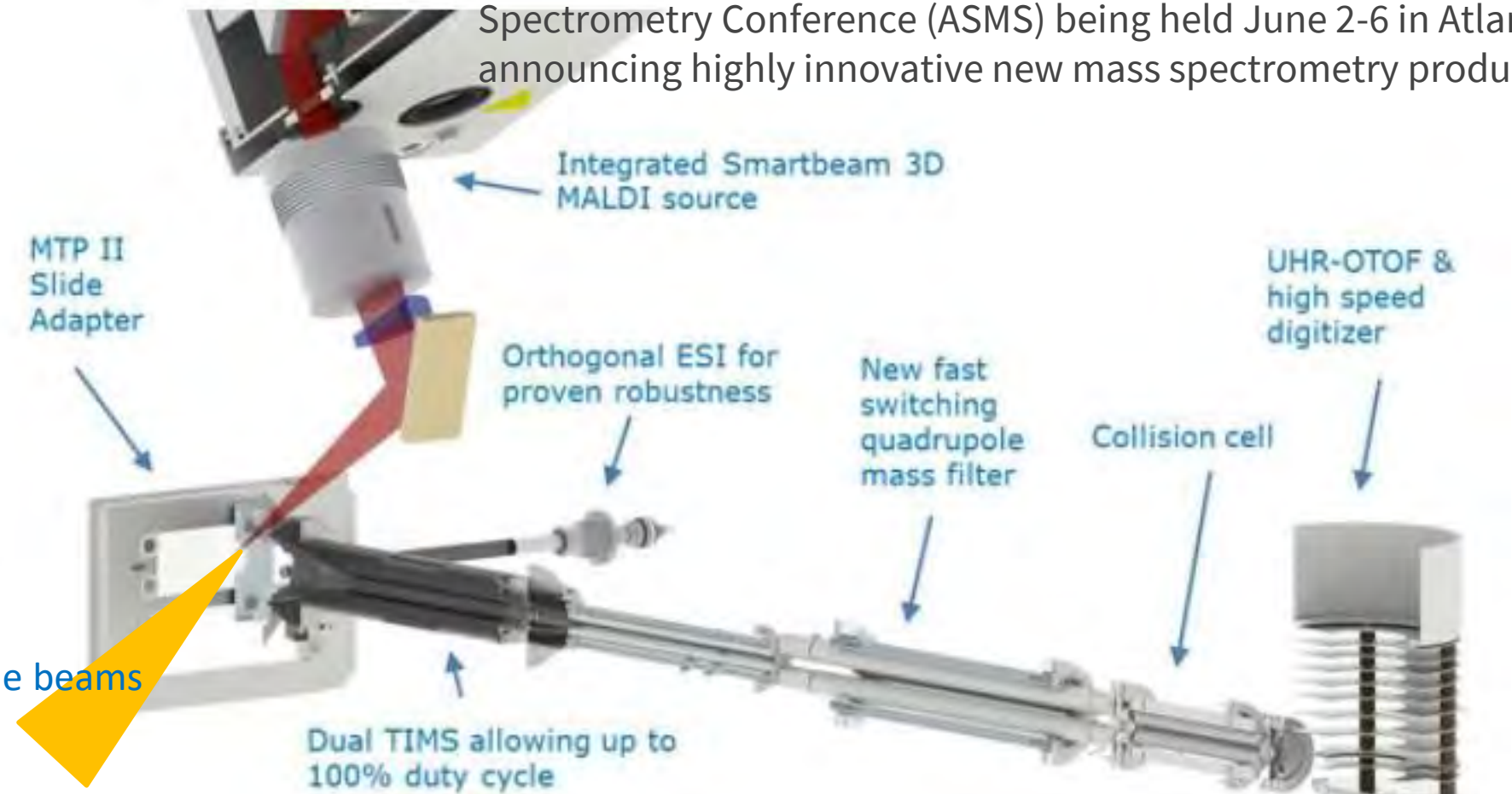
Résolution > 30 000, MS/MS & Software

What is Orbitrap?

The Orbitrap is an ion trap mass analyzer that consists of two outer electrodes and a central electrode, which enable it to act as both an analyzer and detector. Ions entering the Orbitrap are captured through "electrodynamic squeezing," after which they oscillate around the central electrode and in between the two outer electrodes. Different ions oscillate at different frequencies, resulting in their separation. By measuring the oscillation frequencies induced by ions on the outer electrodes, the mass spectra of the ions are acquired using image current detection. Due to its setup, the Orbitrap mass analyzer is actually a Fourier Transform mass analyzer analog of FT-ion cyclotron resonance (ICR) technology, yet with smaller instrument size and easier instrument operation.



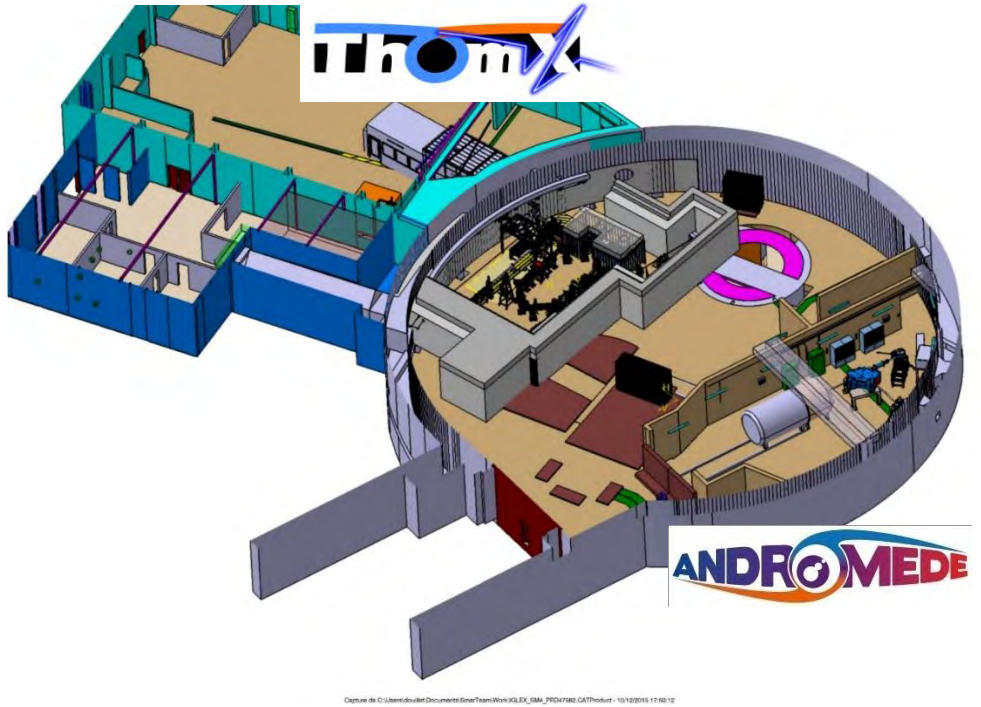
ATLANTA, Georgia – May 31, 2019: At the 67th American Society for Mass Spectrometry Conference (ASMS) being held June 2-6 in Atlanta, Bruker is announcing highly innovative new mass spectrometry products and workflows:



Schematic of the timsTOF fleX

HE Nanoparticle beams

CPER - IGLEX



- Réhabilitation Igloo pour ThomX et Andromède : ***2,1 + 0.3 M€*** : terminé
  11 lots, 15 entreprises,
  non réalisés, : tests en charge 11 k€, faux plancher ThomX 30 k€
  pris sur projet : chemin câbles, contrôle accès
- Marché PSS+radioprotection : ***272 619,86 + 381.728 €***
- Projet Fresque : ravalement façade igloo + peinture : ***500k€***? : 2019-2020
  projet fresque abouti (Beton Puzzle)
- Déménagement Andromède : 80 k€ (NEC) + 5 k€ (BOVIS) : 2020 (prix 2016)

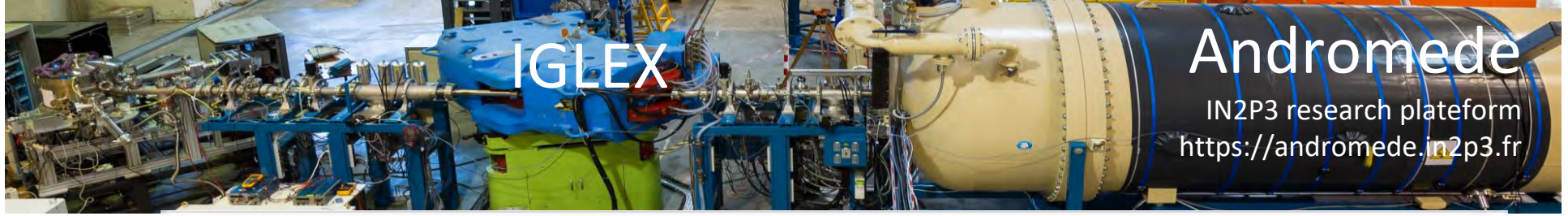
Contrats de plan ÉTAT-RÉGION Bâtir aujourd'hui la France de demain

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

LAL LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

UNIVERSITÉ PARIS SUD

cnrs


IGLEX
Andromede
IN2P3 research plateform
https://andromede.in2p3.fr