Accelerator Physics at IJCLab-ORSAY

Achille Stocchi

Orsay-IJCLab / Frascati-LNF
Twin laboratories
& EPS Historic Sites

Just 3 Slides to introduce the new laboratory

IJCLab : a New European Laboratory. Created in 2020

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

A new European Laboratory.

by the merging of 5 Laboratories in Orsay-France

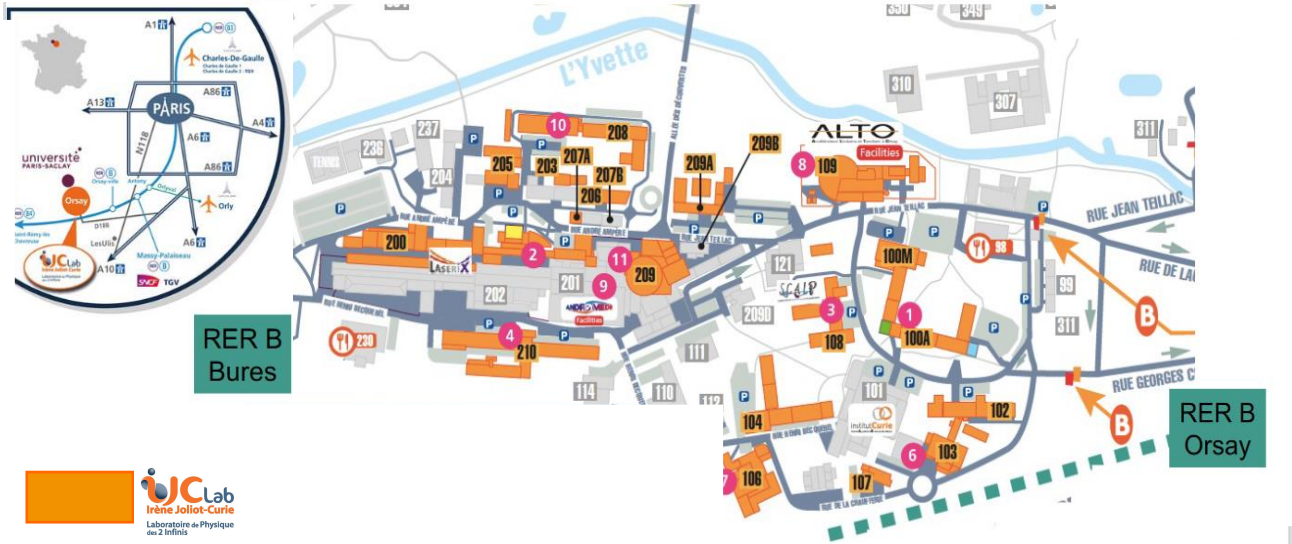
CSNSM *Centre de Sciences Nucléaires et de Sciences de la Matière*
IPN *Institut de Physique Nucléaire*
IMNC *Imagerie Modélisation en Neurobiologie et Cancérologie*
LAL *Laboratoire de l'Accélérateur Linéaire*
LPT *Laboratoire de Physique Théorique*

IJCLab(*)

~ **530** Permanents (Researchers, IT)
~ **200** PHD, PostDoc, contracts
~ **100** Short visiting/interships

(*) *CNRS/IN2P3, University Paris-Saclay University de Paris*

IJCLab is occupying a large part of the Orsay Campus (~50000m²)



7 Research Poles
31 research teams and 2 services

1 Engineering Pole
4 Departments with 11 Services

1 Administration Pole
3 Divisions + 1 Service

8 Support Services

5 Platforms (with external users)
+ several technical platforms

IJClab

7 Pôle Scientifiques

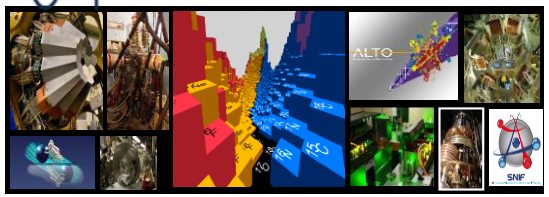
The ensemble of all the themes of "the physics of the two infinities" with the presence of strong historical/existing poles, of emerging poles and of activities at the interfaces

A2C Astroparticles, Astrophysics & Cosmology

~ 64

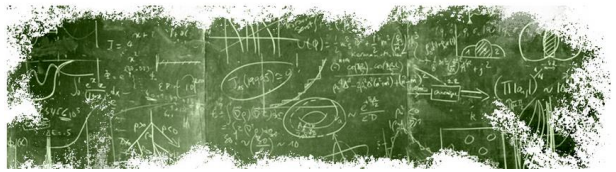
PHYSIQUE NUCLÉAIRE NUCLEAR PHYSICS

~ 67



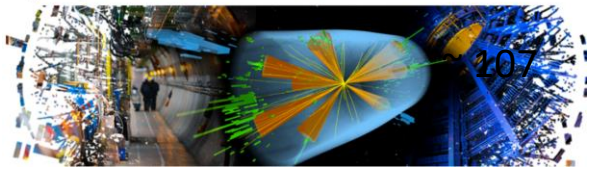
Théorie

~ 52



PHE Physique des Hautes Energies High Energy Physics

~ 107

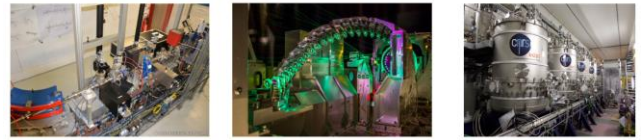


Santé

~ 23

Accelerator Physics

~ 87



Including RF and cryogenic services

Energie et Environnement

~ 40

~ 120 PhD

IJClab : Technical Skills

1 Pôle Ingénierie 4 Départements

~180 staff members

4 Departments :

Electronics / Computing
Instrumentation / Mechanics

with 10 Services

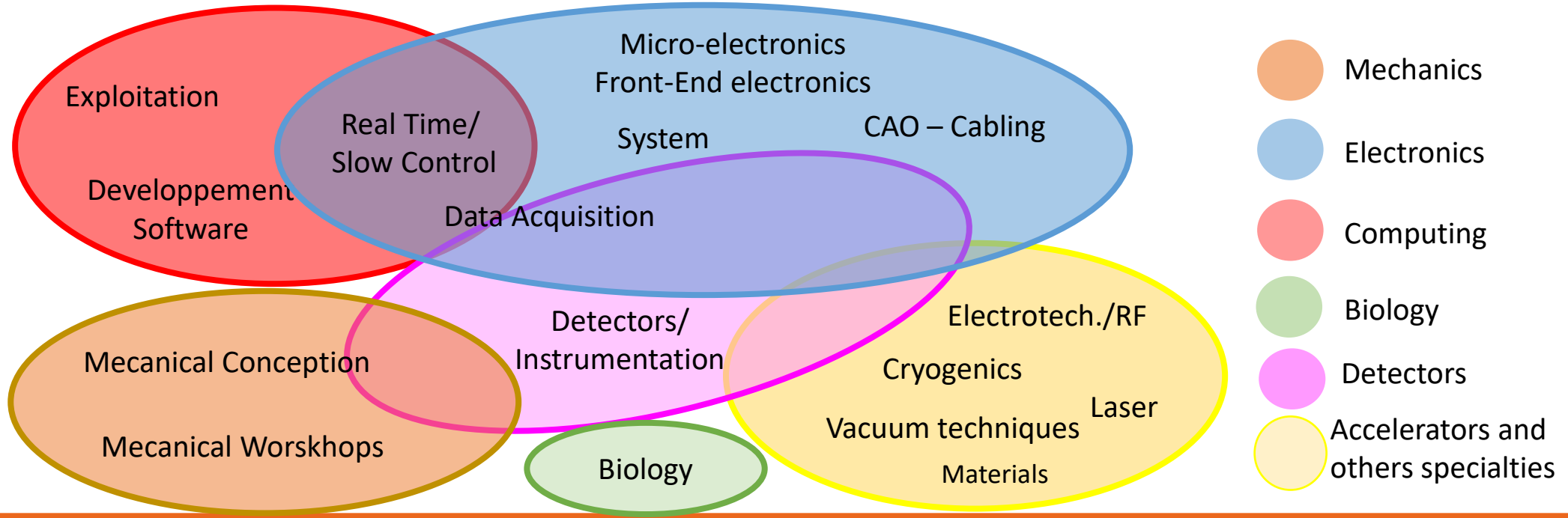
Services in accelerator Pole

- **RF**
- **Cryogenics**

~30 staff members

Technical staff with technical skills/expertise
essential pillars for the laboratory to design, draw and build instruments.

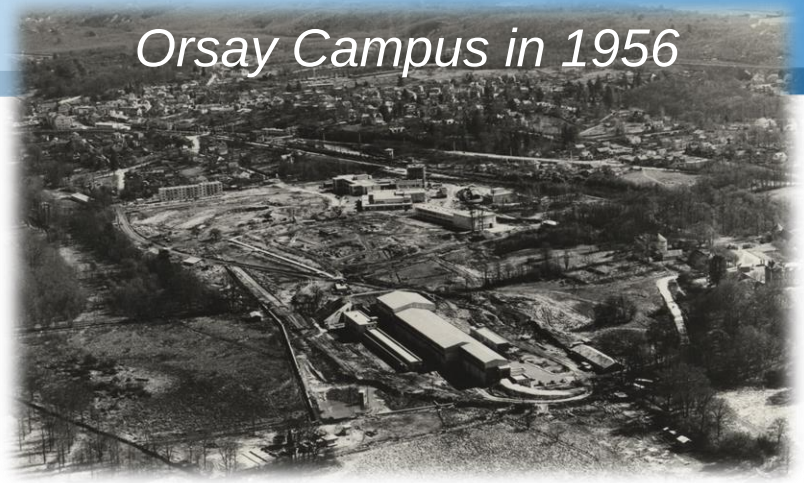
- Technical services are fuelled by the challenges of research (R&D and projects)
- The proximity of technical and research teams (integrated teams)
- The ability to combine and make coexist versatility and specialization



I now move to talk on

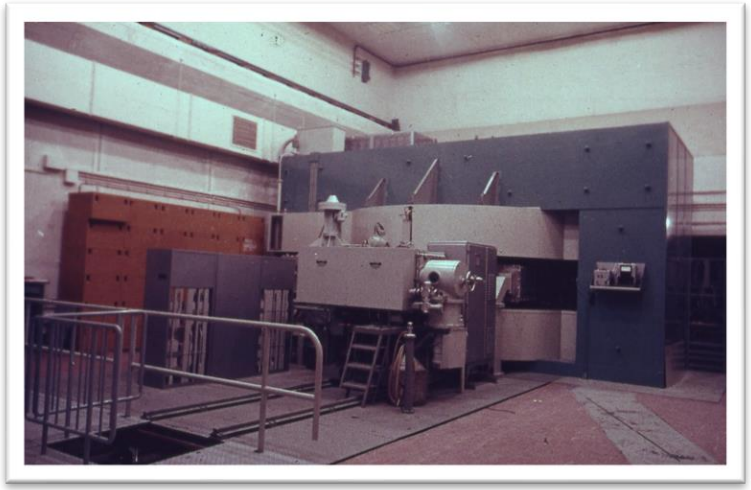
Accelerator Physics at IJCLab-ORSAY

Electrons, Protons, Ions beams

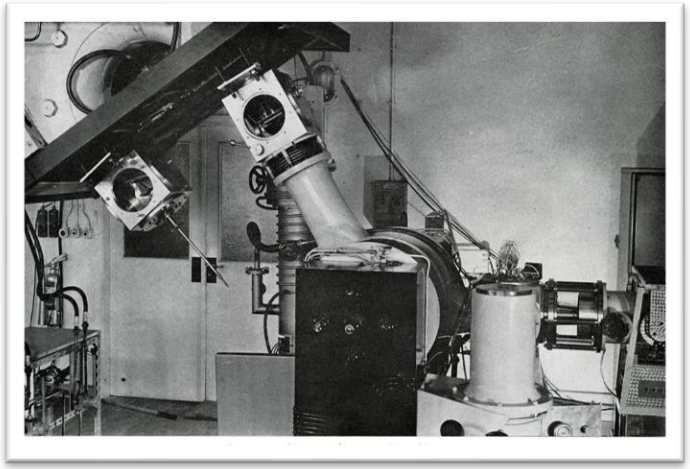


LAL 1956 : The Linear electron Accelerator

IPN 1958 : First Beam with a synchrocyclotron



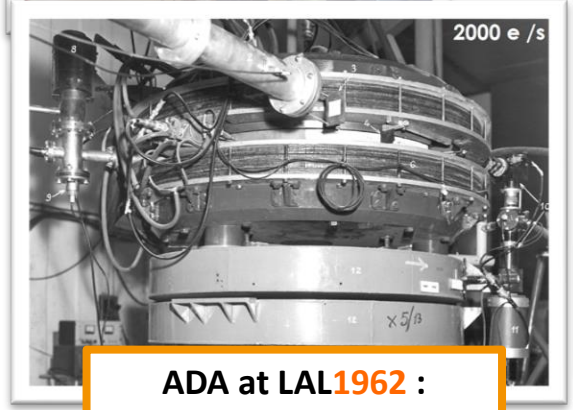
CSNSM 1965 : mass spectrometry at SC Orsay



Accelerator Physics in Orsay – following

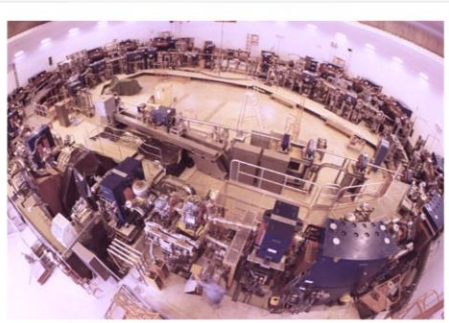
Electrons

Protons - Ions



ADA at LAL1962 :
First Collider e^+e^-

ACO ~ 1965



DCI (Dispositif de Collisions dans l'Igloo), ~1970

Lure → Soleil

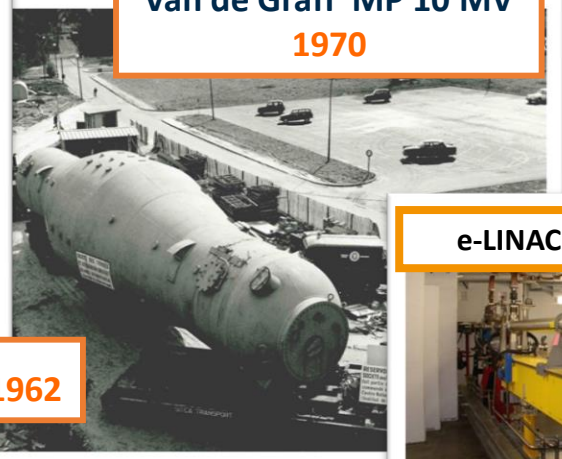
LEP/CERN

AGOR/KVI

CPO/Orsay

Ganil

LHC/CERN



Van de Graff MP 10 MV
1970

4 MeV 1962

CEV 1965

LINAC ALICE 1969

The heavy ion revolution

e-LINAC ~2005

10 µA 50MeV (LEP injector)

TODAY : 4 International Research Platforms : ALTO

- **15 MV Tandem** (from proton to aggregates)
- **electron linac** Radioactive beams by photofission

Nuclear, Health physics, Irradiation

ALTO Platform

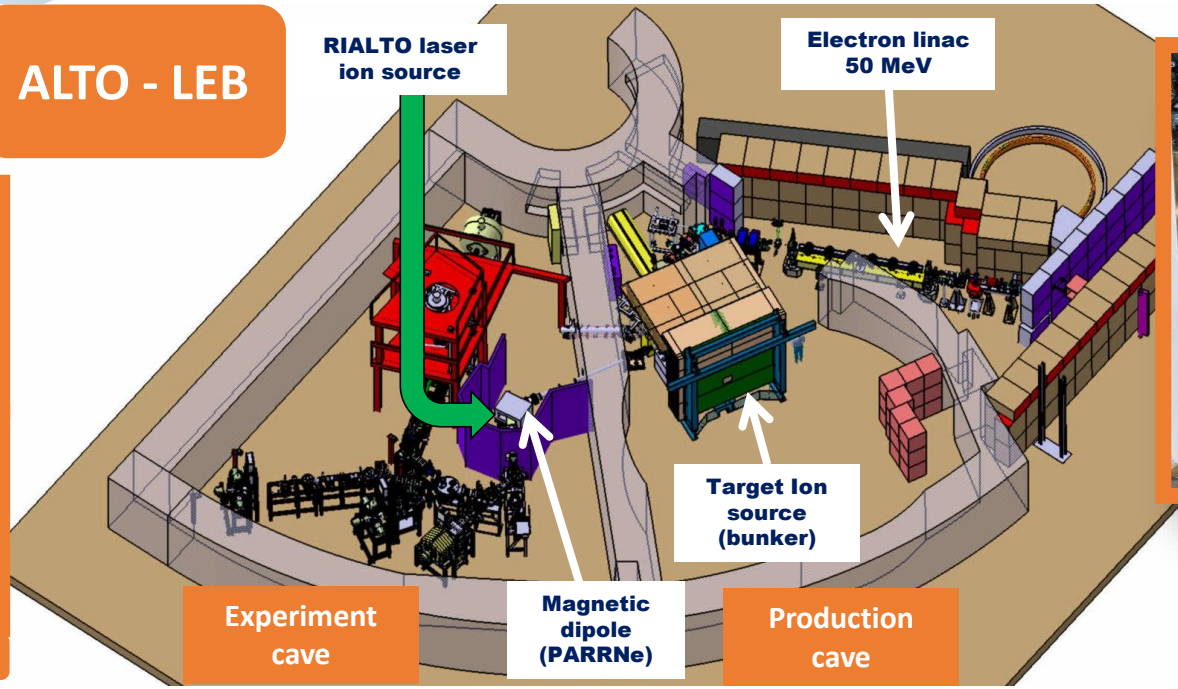
15 permanents technical staff

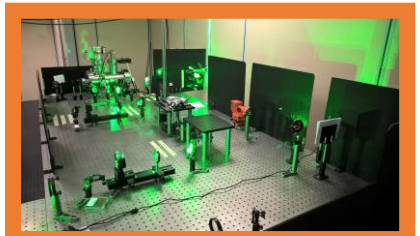
Equipment	~60M€
Running Cost	~0.6M€/year
Publications	~20/year
Thesis on going	~10
Beam availability	~3000h/year
External Users	~300/year

ALTO Low Energy radioactive Beams (LEB)

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

ALTO - LEB





RIALTO

Electron linac

ECS

World's first ISOL photofission facility (~10^{11} f/s)

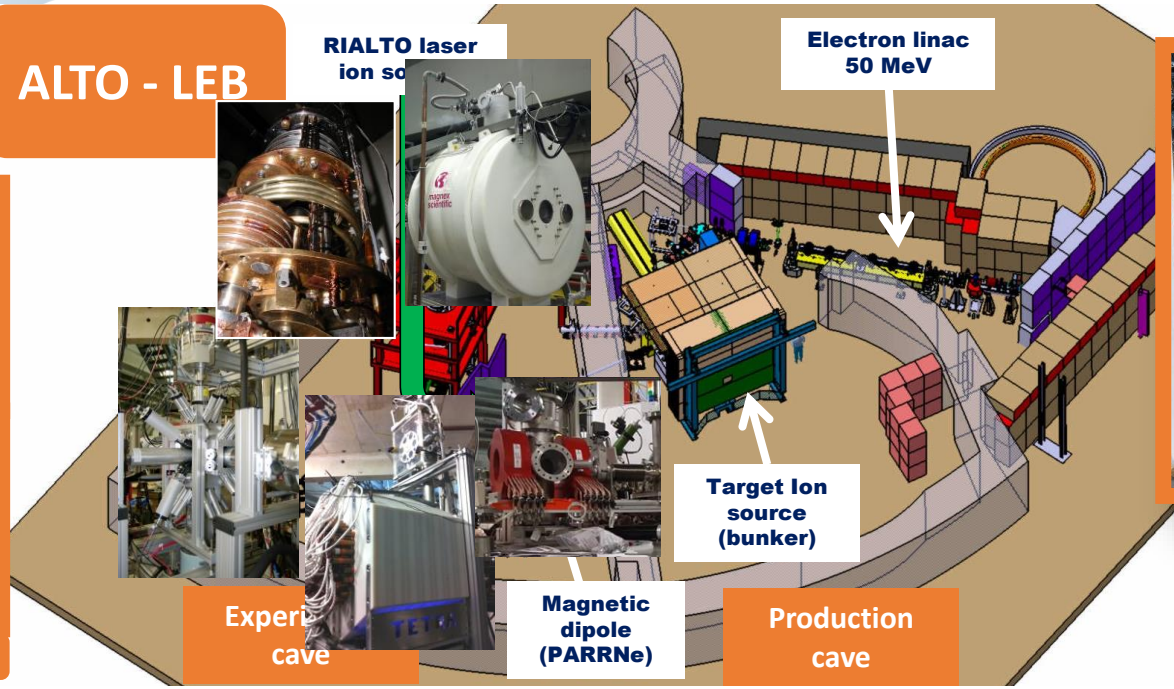
- electron beam **50 MeV** & **10 µA**
- UCx target (~70g, ~140 pellets)
- **RIALTO : laser ion source** → Z selection
- magnetic dipole → mass separation (M/ΔM = 1500)

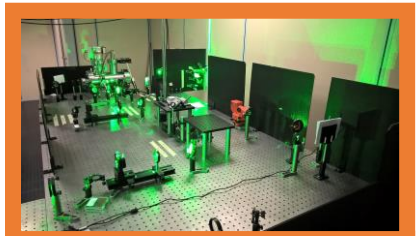
+ SIHL (Off line separator)

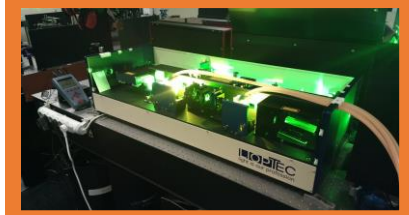
+ carburation laboratory

ALTO Low Energy radioactive Beams (LEB)

ALTO - LEB







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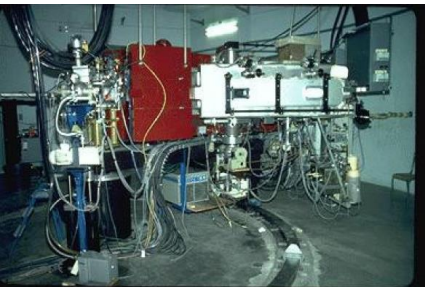
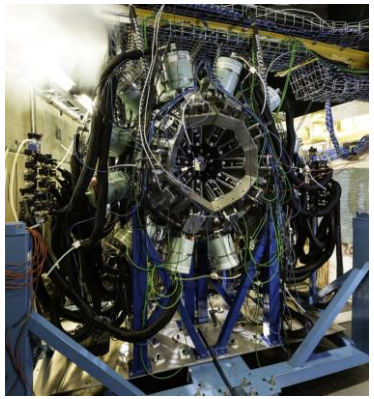
ALTO **H**igh **E**nergy stable **B**eams (HEB)



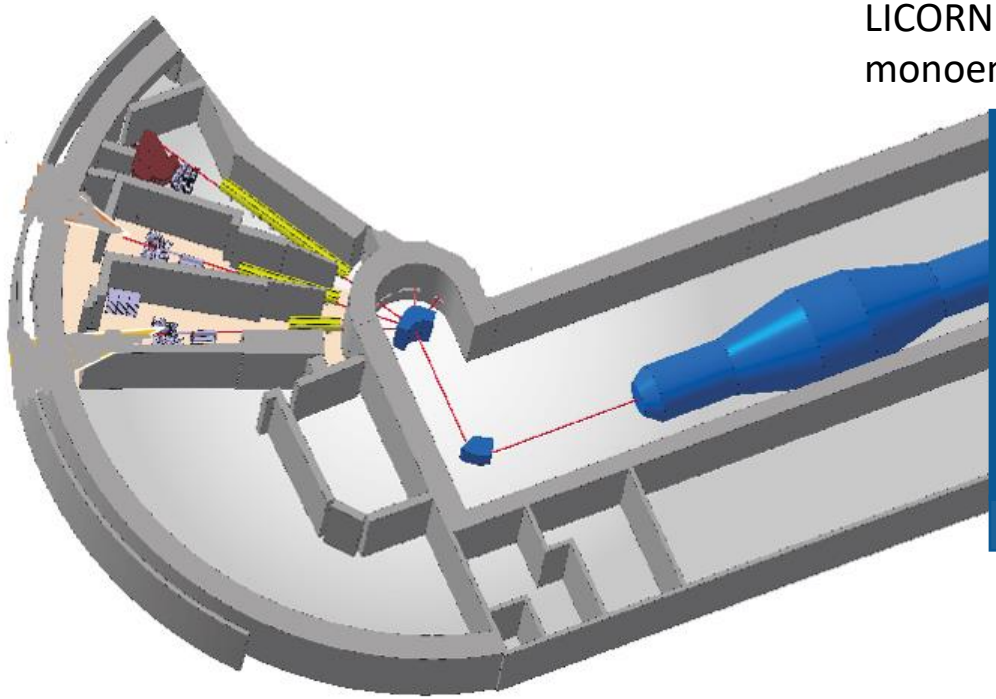


Standart beams of the Tandem : H, ^{3}He, ^{4}He, ..., ^{7}Li , ^{14}C, ... up to **^{127}I**

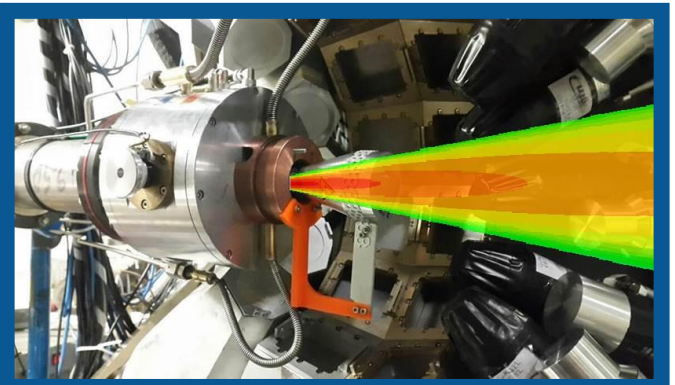
- standard operation **< 1 MV** et **14.5 MV**

- Pulsed beam: pulse width **1 - 2 ns**; repetition rate : **100 ns - 100 µs**

- New ion sources→ intensity x5 → difficult beams (Mg, Ca)



LICORNE: Unique, naturally directional quasi-monoenergetic neutron source 10^{8} n/s/steradian



LICORNE

TODAY : 4 International Research Platforms : ANDROMEDE

Several MeV protons, multicharged atomic ions, gold molecules and nanoparticles

Nuclear/A2C, Health physics, Irradiation

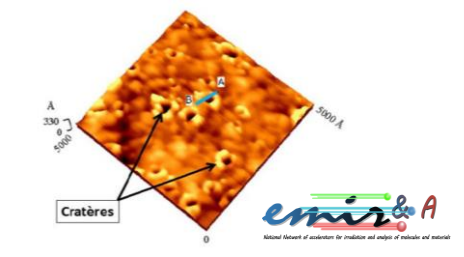
Andromede Platform

2 permanents technical staff

Equipment	~3M€
Running Cost	~0.05M€/year
Publications	~3/year
Thesis on going	~6
Beam availability	~1200h/year
External users	~40/year

Andromede, a facility dedicated to interdisciplinary research

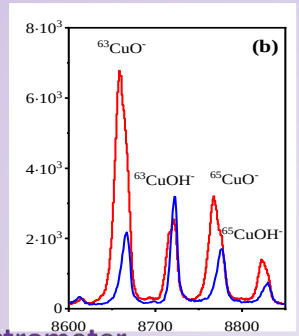
Ion Beam Analysis, Irradiation



Clusters-Solid Surfaces Interaction

Sciences Accelerator

Vacuum and surfaces



EVE Mass Spectrometer
Ionic Imaging
Material modifications

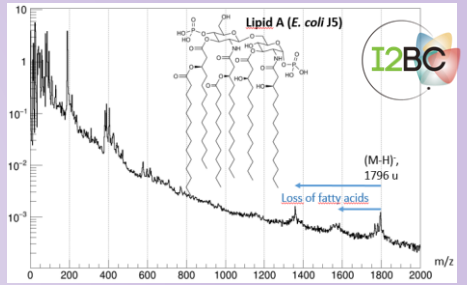
....

Heritage (IPANEMA)

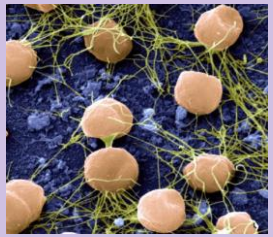
Exobiology (IAS)

Biochemitry , Ionic imaging, Health

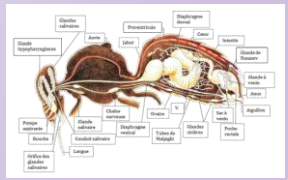
Bacteria



Archea

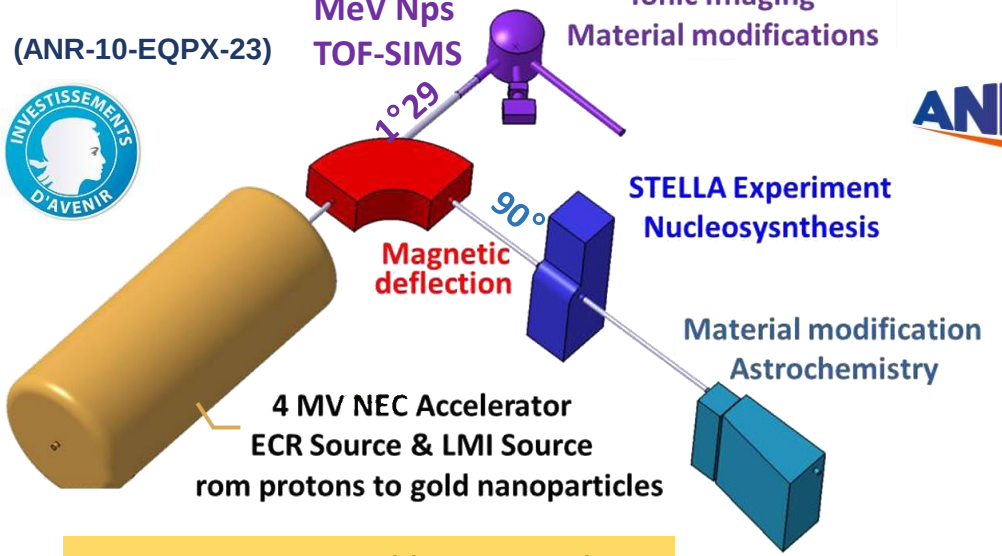


MolyBee Project
Metal and Health



(ANR-10-EQPX-23)

MeV Nps
TOF-SIMS



STELLA Experiment
Nucleosysnthesis

From protons to gold nanoparticles

IPHC

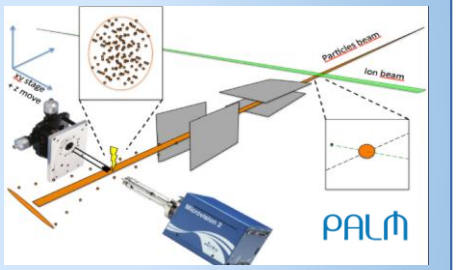
STELLA

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

ISMO

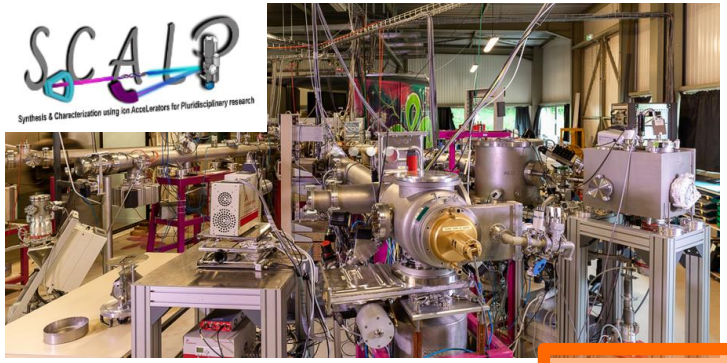
IRAMIS

NanoCr



Emerging topic

TODAY : 4 International Research Platforms : SCALP



Synthesis and **C**haracterization using ion **A**cce**L**erators for **P**luridisciplinary research

Ion irradiation / implantation and *in situ* characterization techniques (TEM, IBA)

Energy, nuclear materials, Health physics, Irradiation physics and chemistry

SCALP Platform

7 permanents technical staff

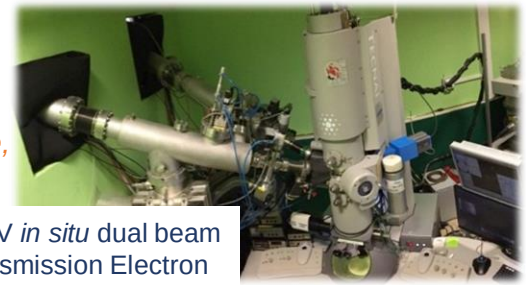
Equipment	~6M€
Running Cost	~0.2M€/year
Publications	~20/year
Thesis on going	~3
Beam availability	~1500h/year
External users	~20/year

The JANNuS platform

Physics and materials science with ion beams

✓ **Ion beam modification of materials**
ion deposition, implantation and irradiation

✓ **Characterization of materials**
chemical composition, crystallographic structure, defects, nano-precipitates, impurities,…



200 kV *in situ* dual beam Transmission Electron Microscope (TEM)

71 chemical elements available

energy range 100 eV to 11 MeV

LN_2 to 1000°C

50 kV SIDONIE isotope separator

190 kV IRMA ion implanter and 2 MV ARAMIS Tandem-VdG, connected together

JANNUS SCALP

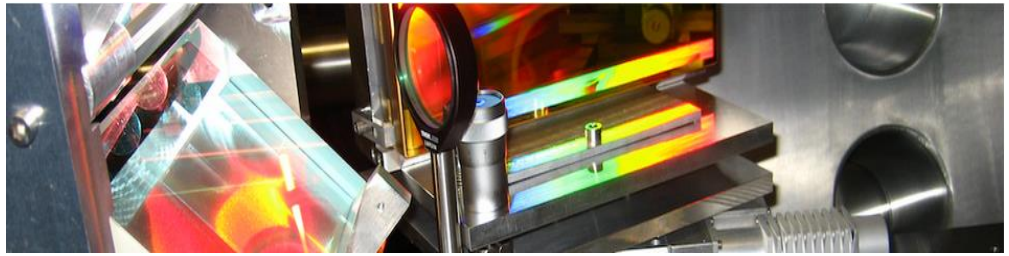
- **Ion beam analysis** : RBS, Channelling, ERDA, PIXE, including *in situ* RBS-C with few hundred keV ions
- ***In situ* dual ion beam Transmission Electron Microscopy**
  with a large diversity of ions available, a controlled dosimetry and dynamical observation - unique in the world ; equipped with STEM, EDX, EELS, EFTEM analytical techniques
- **Scanning Electron Microscopy** (equipped with EDX)
- **Atomic Force Microscopy**
- **Preparation of specimen** (cutting, mechanical and ion polishing)

Founding member of EMIR&A

French Accelerators federation for Irradiation and Analysis of Materials and Molecules

On-going extension of the experimental hall (+280 m²) for new beam lines

TODAY : 4 International Research Platforms : LaseriX



LASERIX : laser platform providing **coherent, intense and brief** (50fs to 10 ps) **sources in the near-infrared** (800 nm) **and EUV** (30 to 90 eV) domains. Will be completed including the electron photo-injector (PHIL).

Accelerator (mainly laser-plasma), Optics, QED tests

LaseriX Platform

2 permanents technical staff

Equipment	~5.5M€
Running Cost	~0.25M€/year
Publications	~5/year
Thesis on going	~3
Beam availability	~1200h/year
External users	~5/year

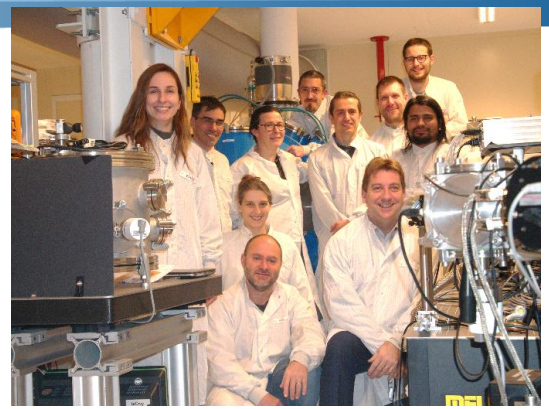
LASERIX

Equipment :

40fs - 40TW laser @10Hz (potential 300TW @0.4Hz)

Three XUV beamlines fully equiped (diagostic, interaction chambers) :

- Femtosecond HHG (High-order Harmonic Generation) beamline
- High energy X-ray laser beamline
- High intensity seeded X-ray beamline



Main activities :

- R&D on intense sources (laser, XUV) and diags
- Applications : Plasma physics, material studies, irradiation, spectral and time-resolved experiments in XUV-NIR regions, beam manipulation…
- Formation for CPA lasers (Practicals)

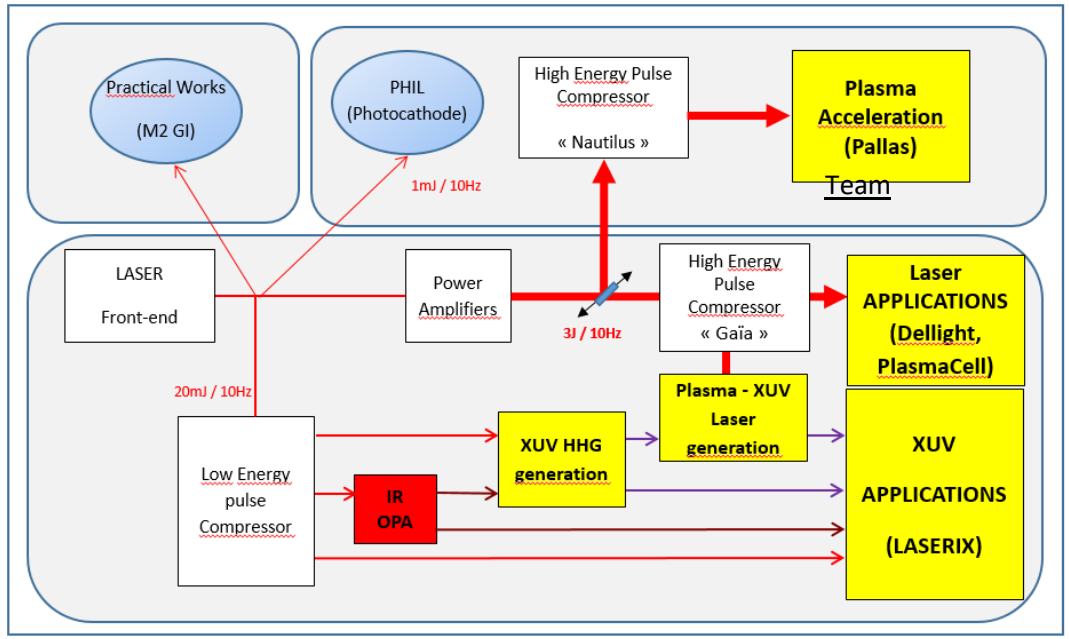
New research area/projects :

QED (Dellight) : high field vacuum perturbation

Plasma acceleration (**PALLAS**) : prototyping of a reliable fully controlable compact laser based e- accelerator (150-200MeV)

Main collaborations :

- LOA : UHI lasers, XUV sources and e- acceleration (LAPLACE project)
- ISMO : XUV sources, diagnostics and applications
- SOLEIL : X-ray sources and manipulation
- APOLLON : UHI Lasers, laser diagnostics, e- acceleration



Platforms for Accelerators research themes/technologies

Opening to Materials, atomic physics, detectors

SUPRATECH

R&D on the superconducting cavities for future high-energy and high-power particle accelerators **(**prepare, package, assemble & test of the superconducting RF cavities).

SupraTech Platform	
Equipment	~6M€
Running Cost	~0.3M€/year
Publications	~3/year
Thesis on going	~3

SEE NEXT SLIDE

SIMS

Confocal microscope

RX Diffractometer

Vacuum and Surfaces Platform

(in construction)

Specialized vacuum technology and characterization of material for accelerators. Investigation of material properties, including analyses of their surface to work in ultravacuum, or for superconducting RF acceleration.

Setup for degazing rate measurement

Setup for desorption and SEY measurement

Supratech

Clean room ISO4

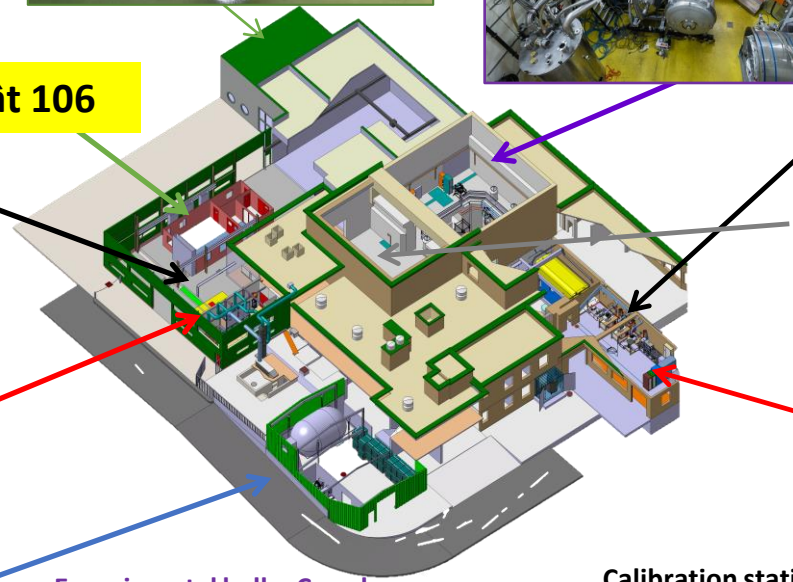
New integration zone

Experimental hall

Helium pumping units

Vacuum oven

Bât 106



Integration hall

Surface treatment room

RF power sources

Helium gas recovery and compression hall helium gas compression associated with a helium liquefier

+

Experimental hall « Cryodrome »

Bât 102

+

Calibration station

+

Clean rooms RF couplers and conditioning bench

Bât 208

Two dedicated services on RF and Cryogenic

RF Technology.

R&D programs to further push the performances of all systems of the RF chain

- RF power sources (reliability, efficiency)
- Low level RF systems for control of the acceleration (phase, amplitude, frequency)
- RF components (design and optimization of room temperature and superconducting RF structures, power couplers, frequency tuning systems, RF-guns for particle generations, RF beam diagnostics).

RF Technology : 20 persons
15 permanents 5 non permanents
11 engineers / 9 technical staff

Cryogenics.

The cryogenic technology for accelerators

- design and operation of superconducting modules (cryomodules)
- cryogenic metrology and specific instrumentation
- Measurement/characterization of material at cryogenic temperatures, heat exchange at low temperature, cryo-generators
- cryogenic targets for nuclear physics.

Cryogenic: 9 persons
7 permanents 2 non permanents
7 engineers / 2 technical staff

Accelerators Physics– research themes

IELS (Innovative electron and light sources)

Electron/laser interactions, and development of high performing optical devices (Fabry-Perot cavities) to store very high average power in pulsed mode [X-ray or g by Compton back-scattering]

→ **X or g sources, of high brilliance**, for health science (**ThomX),** nuclear physics (gamma factory) particle physics (polarimetry measurements).

LPAC (Laser Plasma Acceleration & high-energy Colliders)

R&D programs oriented towards future accelerators

- Nanobeam in IP / high intensity positron sources (**FCC-ee, ILC, SuperKEKB**)
- Collimations studies with crystal (**UA9**)
- Dynamic vacuum/surface properties of vacuum chamber materials (**LHC, FCC**)
- Prototype laser plasma injector in the range 150-200 MeV at 10 Hz, (**PALLAS**)
- Demonstrator of a multi-turn 10 MW ERL (**PERLE @ Orsay**).

SCPL (Superconducting RF Cavities & High-Power Proton Linacs):

Development of high power proton linac

✓ **Research programs** :

- beam physics modelling to improve the reliability and efficiency of the critical technologies future MW-class accelerators
- superconducting RF science to push the performances of superconducting cavities

✓ **Construction programs**. Contributions to **ESS, MYRRHA, PIP-2**

3 teams/2 Services
15 permanents
16 PHD
2 PostDoc
2 Emeriti
48 Engineers

SRHI (Stable & Radioactive Heavy-Ion production & acceleration):

Studies/Mastering the physics processes to produce stable and radioactive ions with the highest possible intensities and purities. Development of Penning traps

GANIL (low-energy RIB using ISOL technics) .

DESIR facility at GANIL in 2026

ALTO-LEB

Projects in Accelerator Physics

Within France, most of these projects are done with **other IN2P3 laboratories** and with strong contributions from **IRFU/CEA-Saclay**

~100 FTE in Accelerator Physics

~20 FTE **ESS** Strong contributions (cavities and cryomodules). *Finishing in 2022*
~10 FTE **Myrrha** in the projects since the beginning – now in Minerva
~25 FTE **ThomX** in site project – now commissioning *Construction finished*
~ 5 FTE for R&D activities in this domain.
~ 5 FTE **PIP II** starting contribution
~10 FTE Activities in **Future Colliders** (LHC, SuperKeKB, FCC, ILC …)

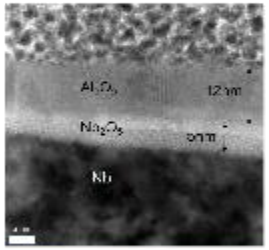
→ Two strong axes for present → future with manpower rapidly increasing

PALLAS – Laser Plasma in situ experiment with LaseriX laser
PERLE - ERL @Orsay with international collaborators

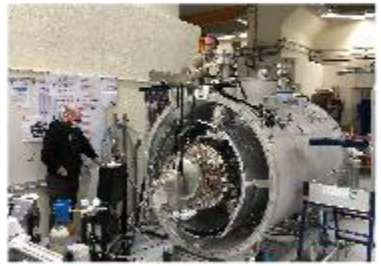
Human and Financial Resources Plan
in progress also accordingly to the ESPP Accelerator Roadmap

Accelerators Physics– very selected hightlights – last months

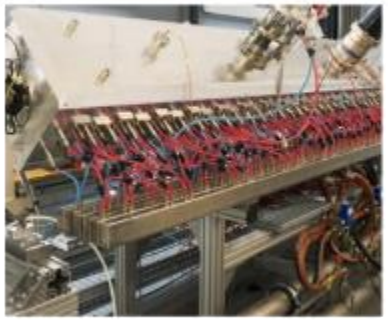
SRF: Thin films (Al_2O_3, Y_2O_3, MgO): SEY measurement and MET analysis



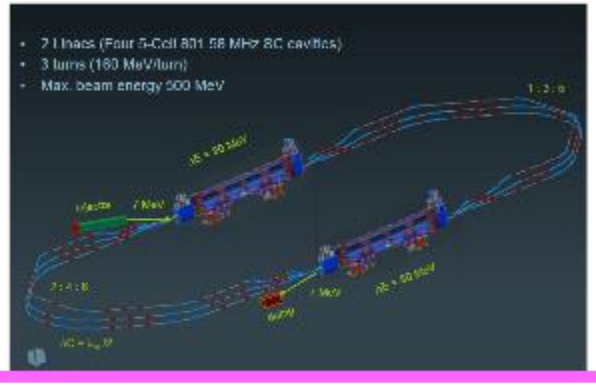
5 spoke cryomodules (over 13 in total) of the CNRS contribution to the European Spallation Source (ESS): validated and delivered @ Lund

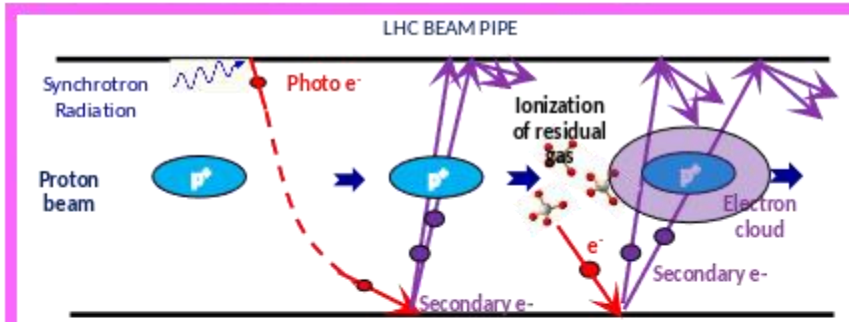


First beam with the RFQ @ Louvain-la-neuve: major contribution of IJCLab with the RFQ low level RF !

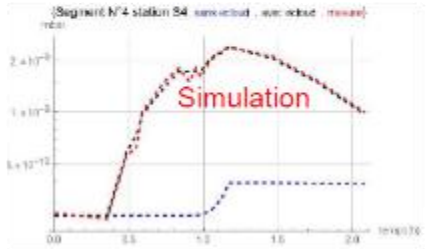


Perle@Orsay – design study - TDR

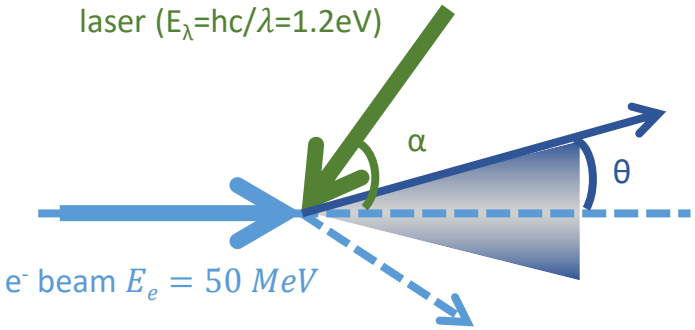




Dynamic vacuum at LHC

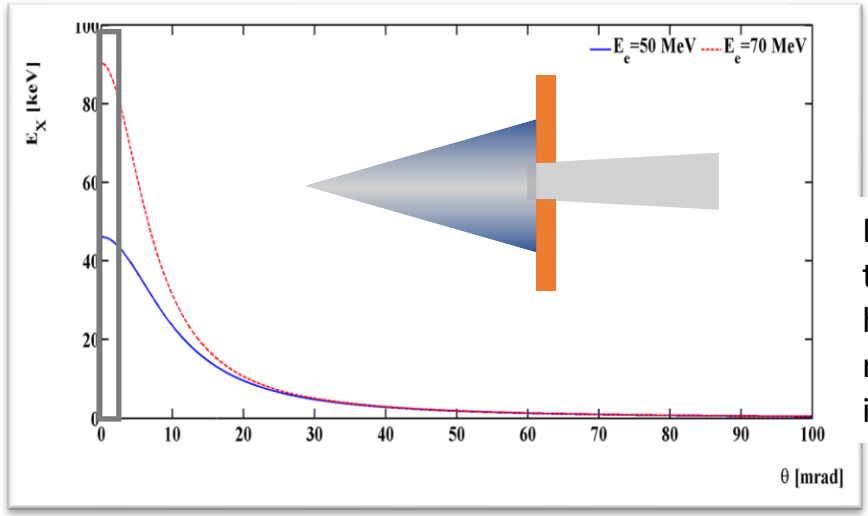


ThomX : a new generation Compact Compton Source



Compton photon

$$E_{X/\gamma} \simeq \frac{4\gamma^2}{1+\gamma^2\theta^2} E_\lambda \approx 45\ keV$$



ThomX Technical Design Report

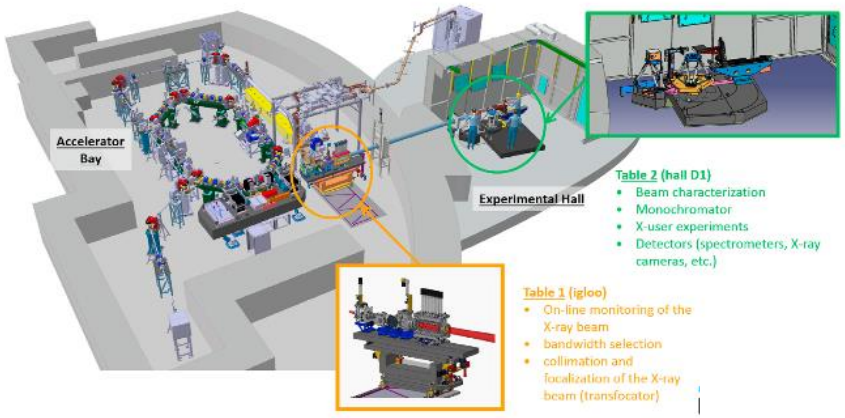
A. Variola [1], J. Haissinski [2], A. Loulergue [3], F. Zomer [2], (eds.)

1 ThomX - Dept. Accelerateurs
LAL - Laboratoire de l'Accélérateur Linéaire
2 LAL - Laboratoire de l'Accélérateur Linéaire
3 SSOLEIL - Synchrotron SOLEIL

TDR 2014

Demonstrator using Compton interaction to produce X-rays to be used for cultural heritage, biomedical, crystallography, radiotherapy, paleontology, using X-ray imaging techniques.

Aimed targeted flux ph/s10^{12}–10^{13}



From design

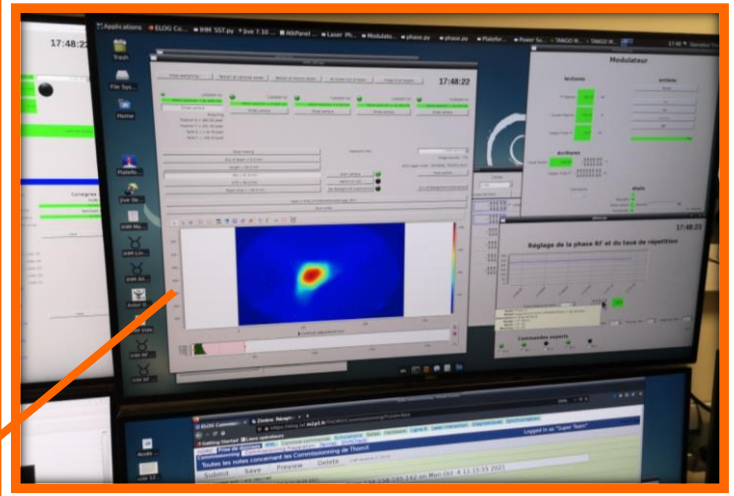
to Reality

~10 years

THOMX : The first electrons in the LINAC !

October 2021 !

Gun : 6MW – 3,0 µs – 1 Hz, EZ = 80 MV/m

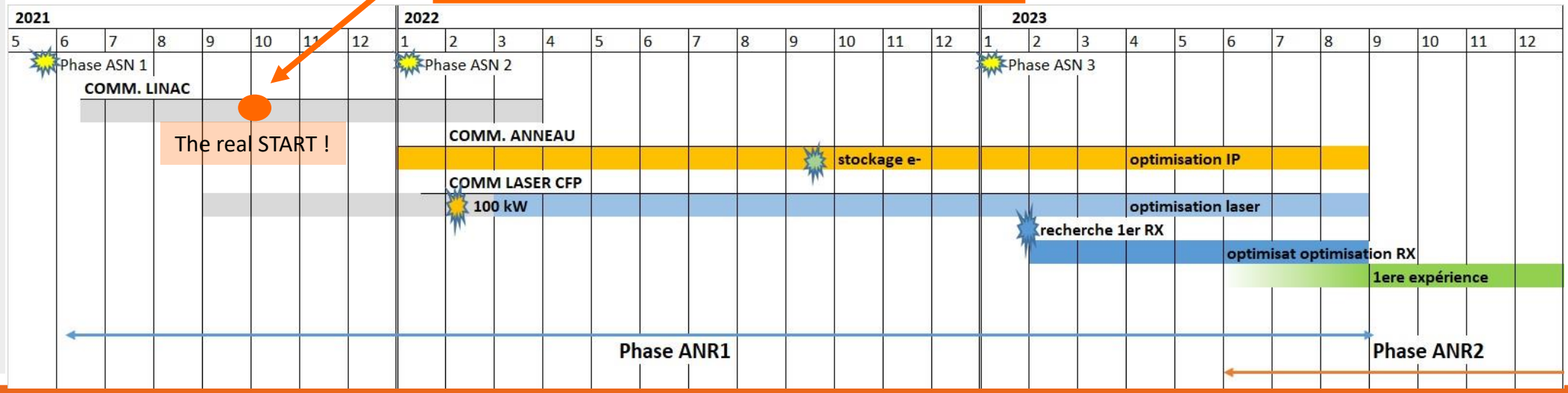


First electrons accelerated in the LINAC

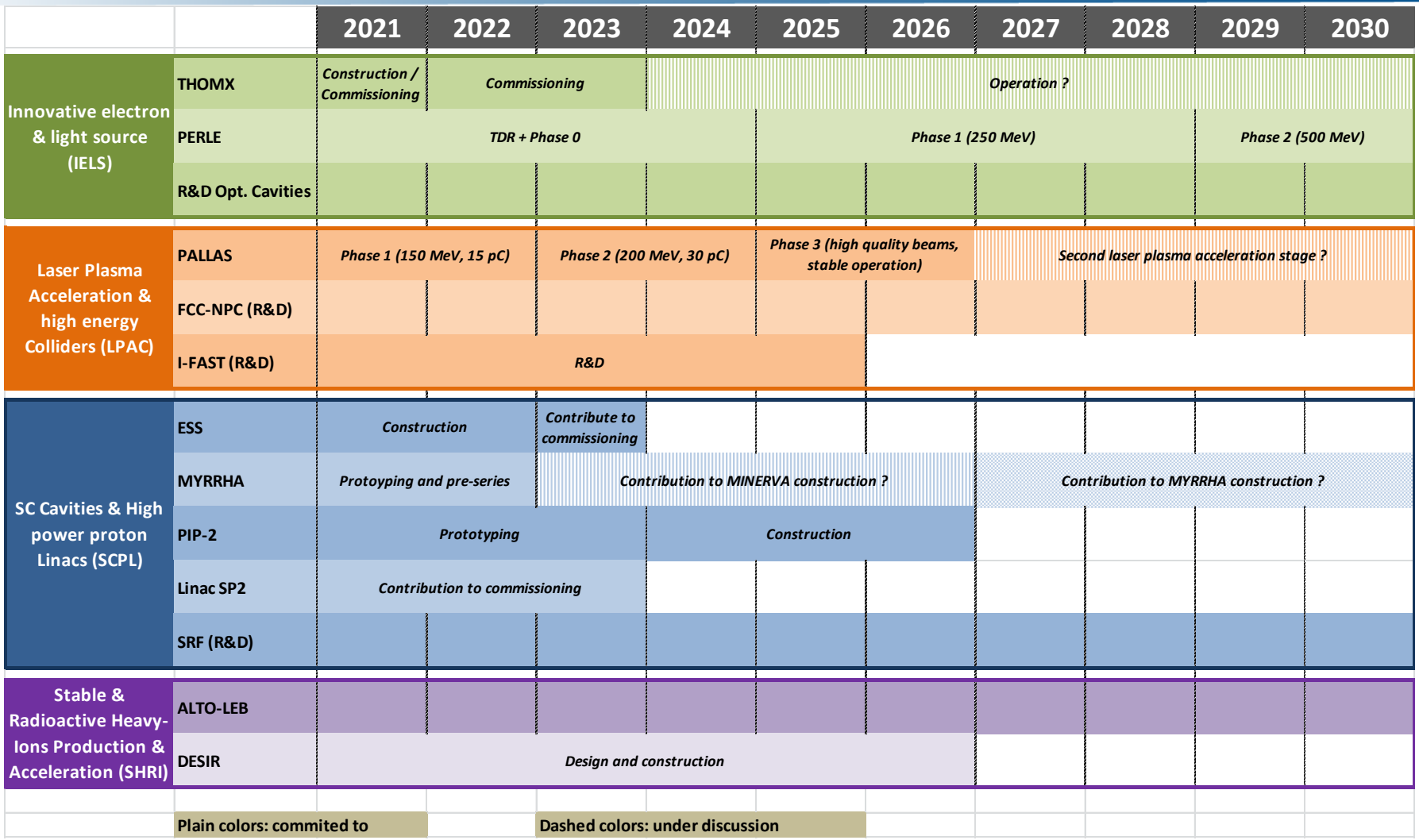
E= 30 MeV , now 50 MeV

(4 MeV at the exit of the gun)

The commissioning plan



Accelerators Physics – Roadmap



As a conclusion : Accelerator Physics –Activities, Priority and Persepectives.

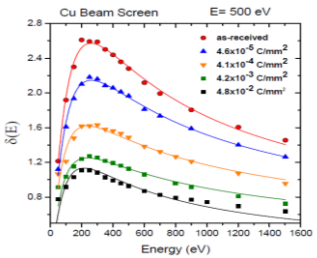
- **Complete ThomX installation and start commissioning**
- **Achieve ESS cryomodules** production in early 2022 and the spoke cryogenic distribution in 2021
- **Start scientific production** on laser plasma acceleration with the completion of **PALLAS phase 1**
- **Conduct** the PERLE TDR phase and shape the scientific/technological/financial to build **PERLE @ Orsay**
- **Perform the first experiments** on **MYRRHA** prototype cryomodule. Prepare future contribution to MINERVA construction
- **Build and install** the **new vacuum and surface platform** (within D3/D4 building)
- **Pursue contributions** to **GANIL** (S3,DESIR,Spiral-2 commissioning, MLLTRap@ALTO). Build new research coll. with GANIL
- **Prepare and test** the **PIP-2 prototypes** (cavity, coupler, tuning system) in 2021/2022 and prepare for the production phase
- **Pursue** the on-going activities on our structured R&D projects: activities for future colliders (**FCC/NPC**), developments on high finesse **optical cavities (Minicav**), **Superconducting RF R&D (SRF),** additive manufacturing for accelerators (**I3DMetal**)

MORE MATERIAL

Equipment of the V&S plateformes (some Examples)

dedicated to characterization and surface analysis of materials used in accelerator technology

Secondary Electron Yield (SEY)



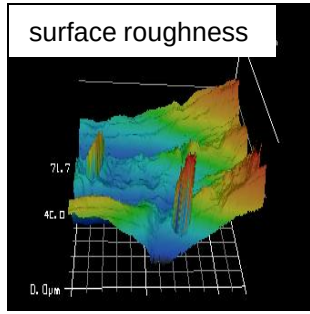
Thèse S. Bilgen

outgassing rate

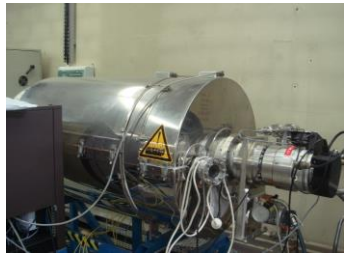
NEG coating chamber (Ti,Zr,V)

Confocal Microscope

VKX200 de Keyence

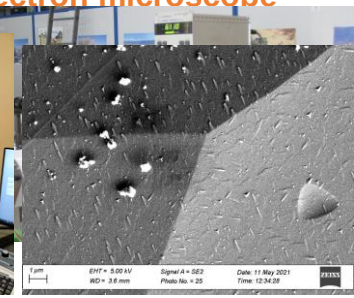


Heat treatment (H2)



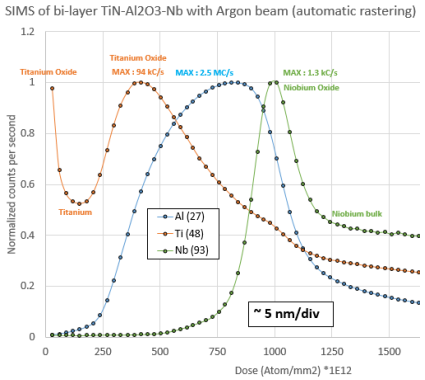
molecular desorption energy

scanning electron microscope



Secondary Ion Mass Spectrometry (SIMS)

Compact SIMS Hiden Analytical

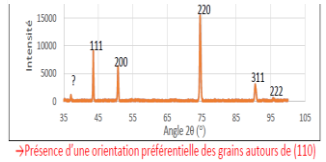


Profile of bi-layer TiN/Al2O3/Nb

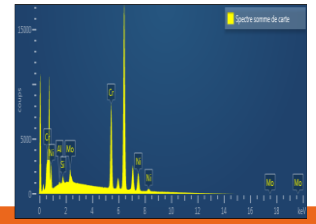
Thèse S. Birra

X-ray difractometer

Surface Structure and Texture



Composition (EDS)



Structural (EBSD)