

Rencontres Accélérateurs 2016

20 septembre 2016

GANIL (Caen)



Société Française
de Physique

DIVISION ACCÉLÉRATEURS



IN2P3

Institut national de **physique nucléaire**
et de **physique des particules**

Les ACCELERATEURS à l'IN2P3

Etat des lieux, Vision & Perspectives

Jean-Luc Biarrotte

IN2P3, one of the 10 CNRS institutes

CNRS

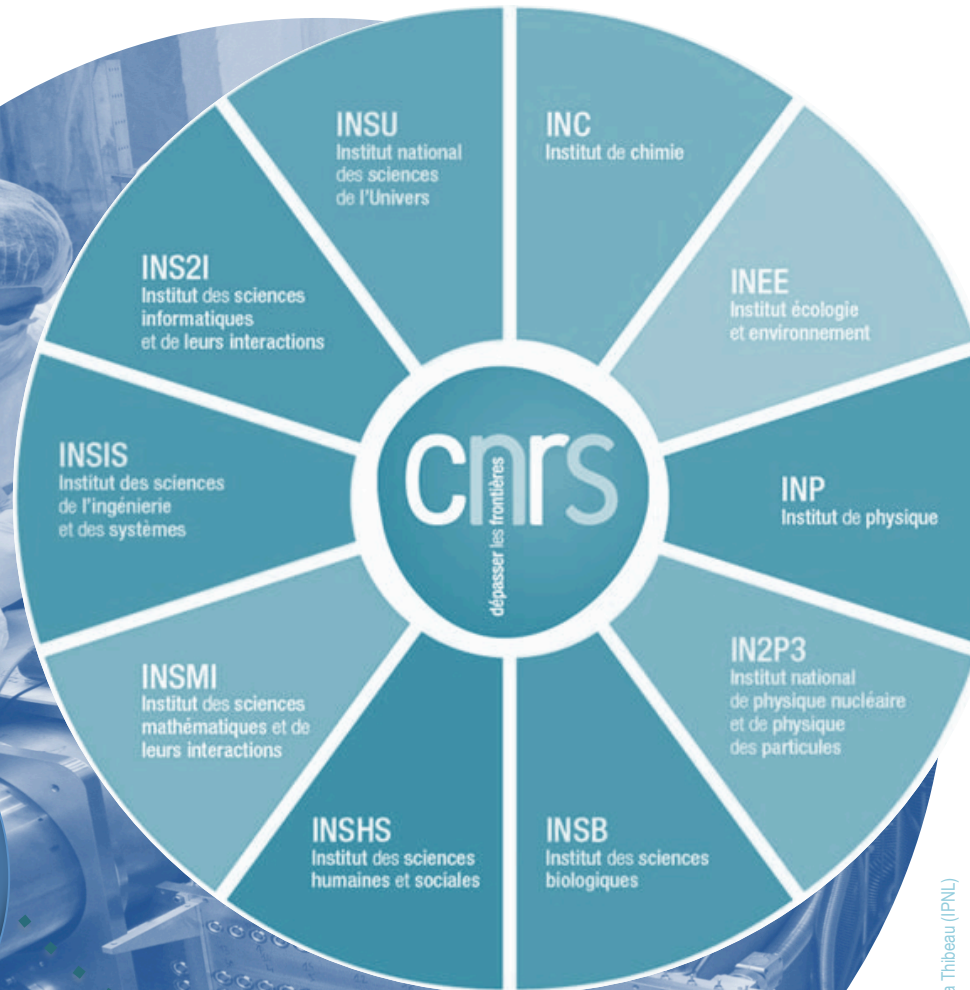
10 institutes

(3 national: INSMI, INSU, IN2P3)

1 100 research units
(95% in partnership)

**34 000 researchers,
engineers, technicians**

**€ 3.3 billion
budget**



IN2P3: mission & key figures

National mission of animation & coordination

Nuclear physics, particle physics, astroparticles, associated technologies & applications

About 25 laboratories and platforms

About 30 research programmes

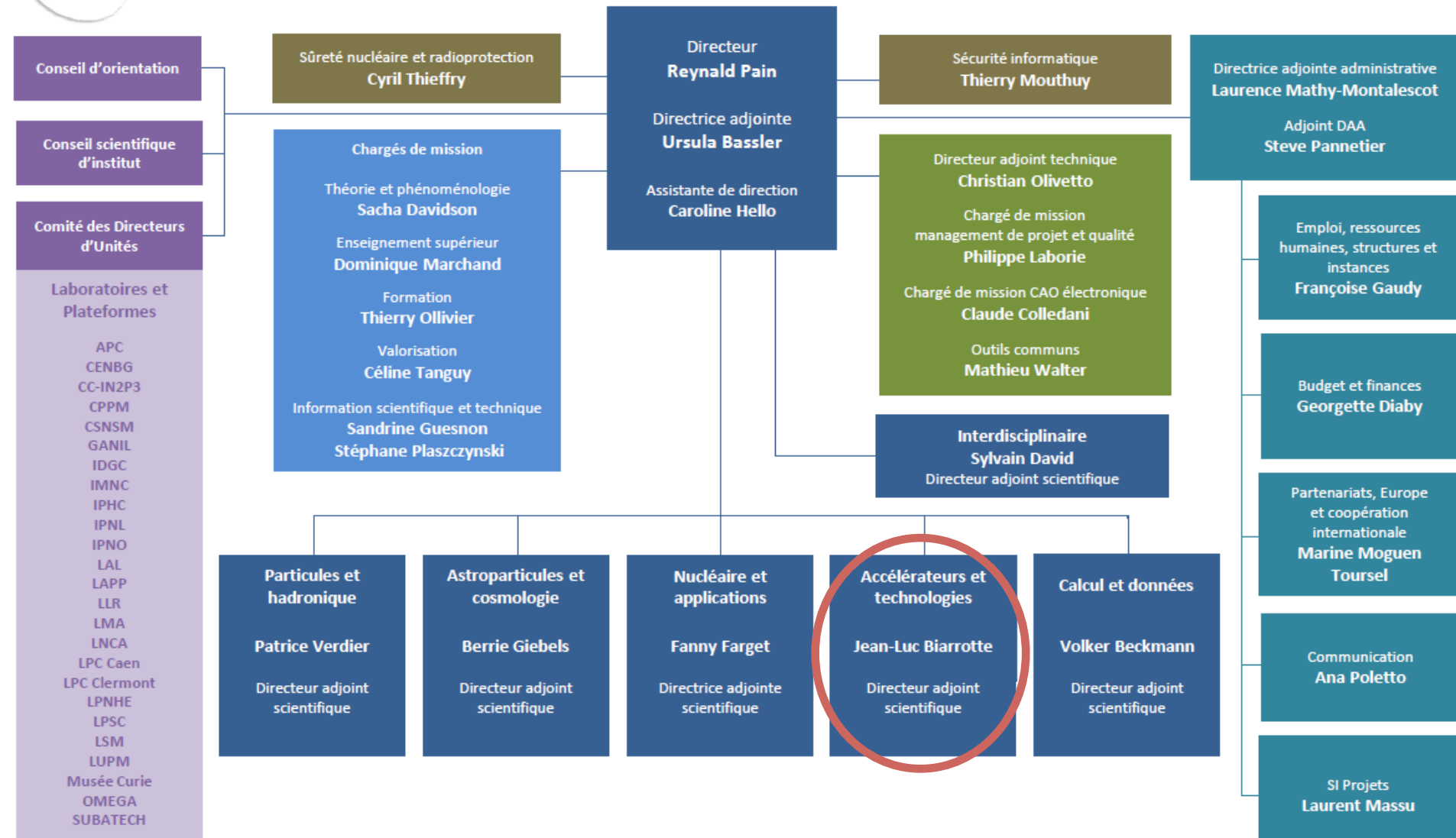
« Study & Understand »
« *Research & Develop* »

About 3 000 researchers, engineers and technicians

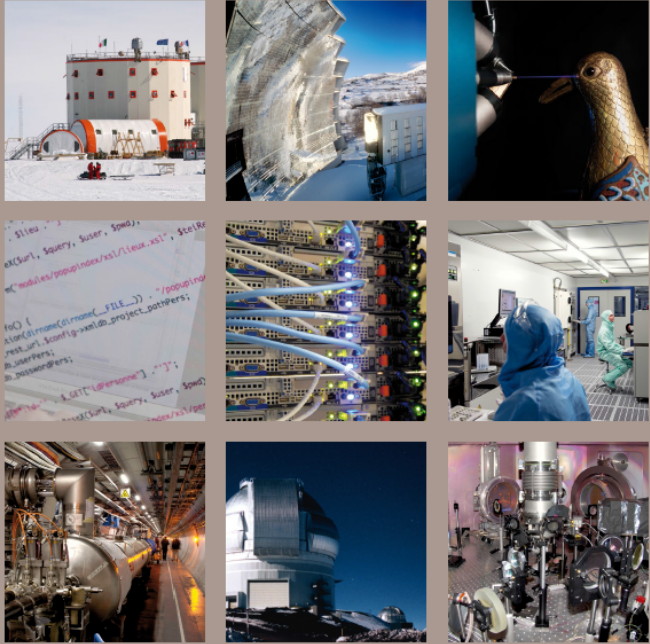
IN2P3: new structure



Organigramme de l'IN2P3
1^{er} août 2016



Accelerator-based science: FR roadmap



**STRATÉGIE NATIONALE
DES INFRASTRUCTURES DE RECHERCHE**
ÉDITION 2016

www.enseignementsup-recherche.gouv.fr



Physique nucléaire et des hautes énergies

CERN – LHC



Organisation Européenne pour la Recherche Nucléaire –
Grand Collisionneur Hadronique/European Organization
for Nuclear Research - Large Hadron Collider

GANIL-SPIRAL2



Grand Accélérateur National d'Ions Lourds –
Système de production d'Ions Radioactifs en Ligne de 2^e génération

FAIR



Facility for Antiproton and Ion Research

Sciences de la matière et ingénierie

ESRF



Source Européenne de Rayonnement Synchrotron/
European Synchrotron Radiation Facility

XFEL



European X-ray Free Electron Laser

ESS



European Spallation Source

EMIR



Fédération des Accélérateurs pour les Études
des Matériaux sous Irradiation

SOLEIL



Source Optimisée de Lumière d'Énergie
Intermédiaire du LURE

LULI-APOLLON

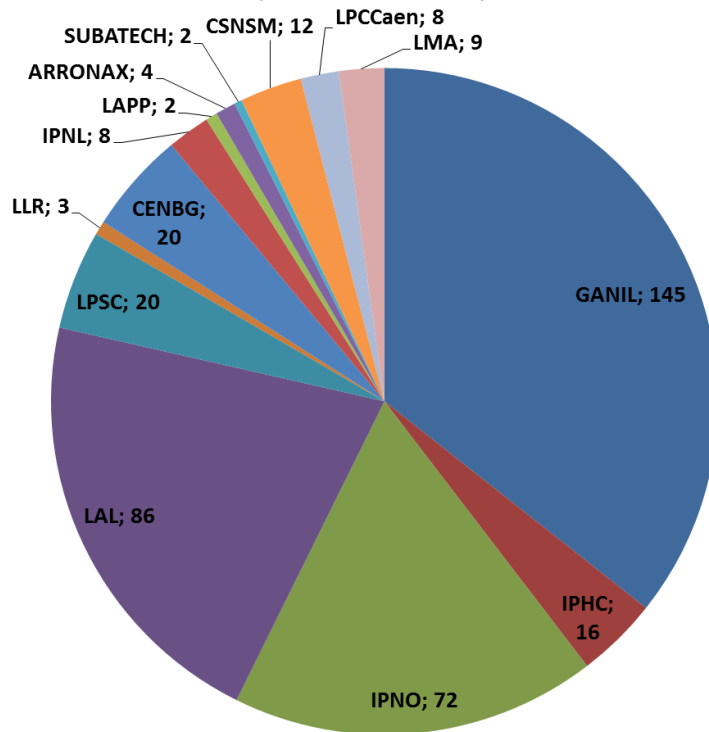


Laboratoire d'Utilisation
des Lasers Intenses

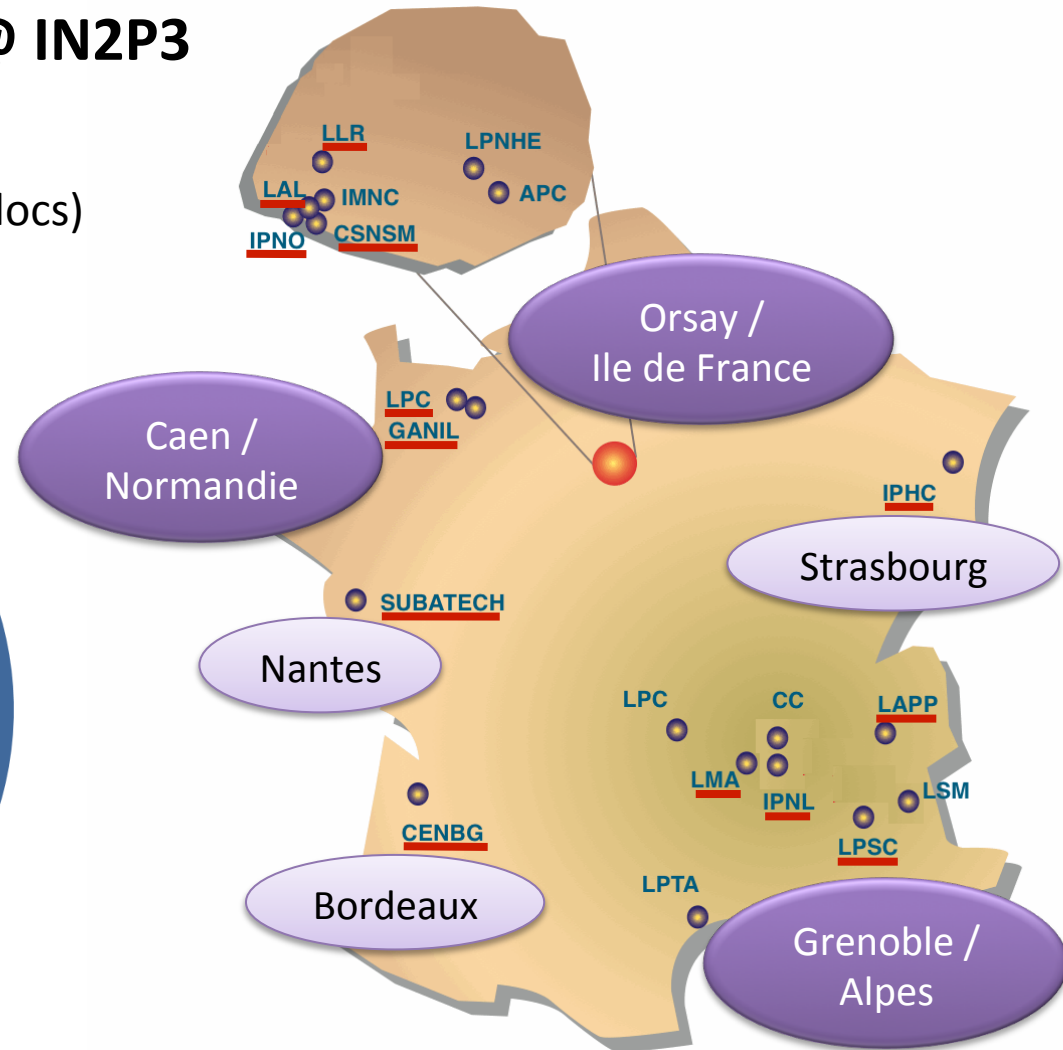


Accelerators & Technologies @ IN2P3

- ❑ 6 main laboratories poles
- ❑ About 70 researchers (incl. IR & post-docs)
- ❑ About 400 FTE (incl. GANIL)



FTE on Accelerators & Technologies - labs

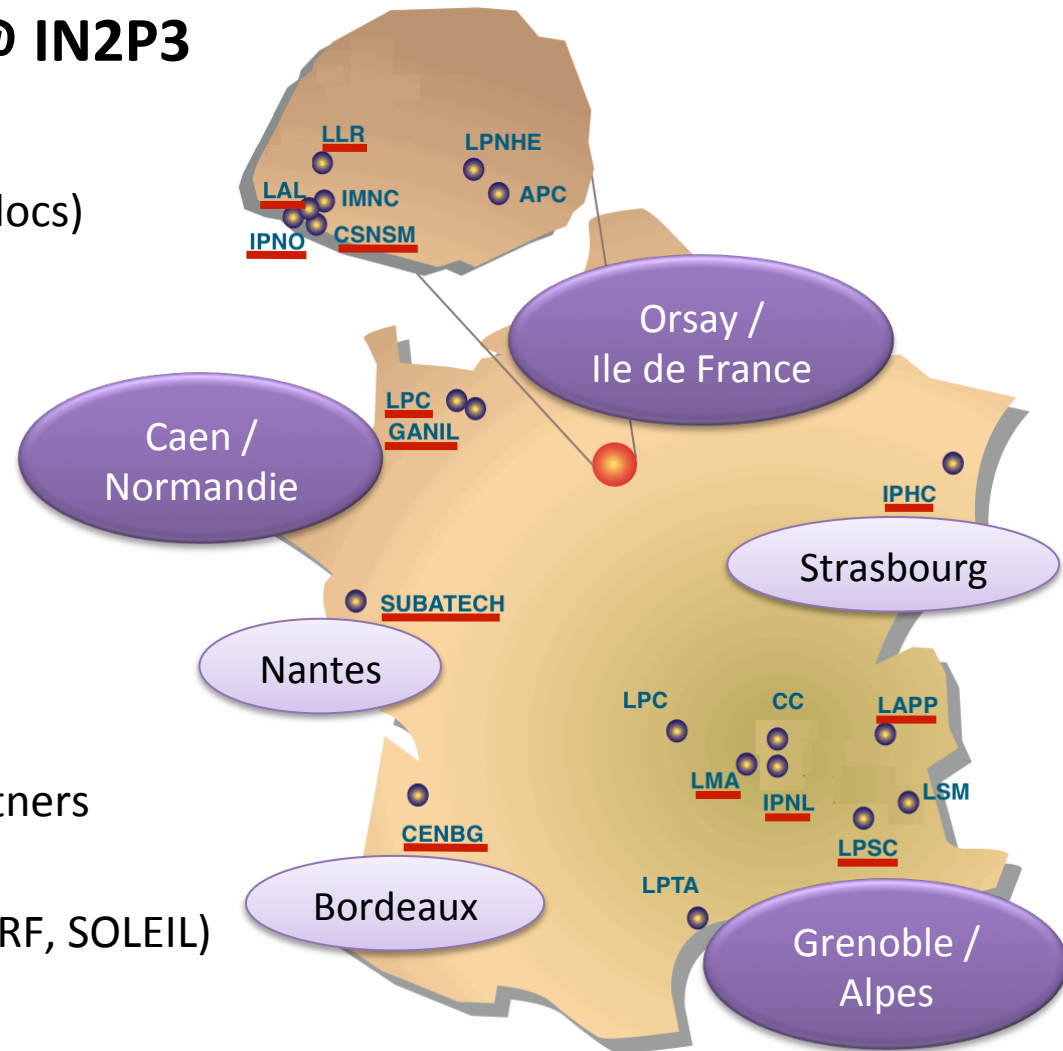


Accelerators & Technologies @ IN2P3

- 6 main laboratories poles
- About 70 researchers (incl. IR & post-docs)
- About 400 FTE (incl. GANIL)

Strong links with:

- CEA/IRFU
- French universities & other CNRS institutes (e.g. INP)
- CERN
- Other European and international partners (e.g. DESY, GSI, INFN, SCK*CEN)
- French accelerator civil companies (ESRF, SOLEIL)
- Industries (e.g. GIS with Thalès TED)



Driving forces

- Push towards **higher intensity/luminosity**
 - ✓ Particle sources and injectors
 - ✓ High-current/low emittance beams
 - ✓ High-power RF systems
- Push towards **higher energy, higher gradients**
 - ✓ Superconducting RF technology
 - ✓ Next generation colliders (ILC, CLIC, FCC)
 - ✓ Laser/plasma acceleration
- Push towards **higher reliability**
 - ✓ Increase competitiveness & efficiency
 - ✓ Specific requirements for some applications (ADS)
- Make accelerators **available to societal needs**
 - ✓ Cancer treatment (radiotherapy, radioisotope prod.)
 - ✓ Transmutation of nuclear wastes by ADS
 - ✓ Compact accelerators for interdisciplinary applications

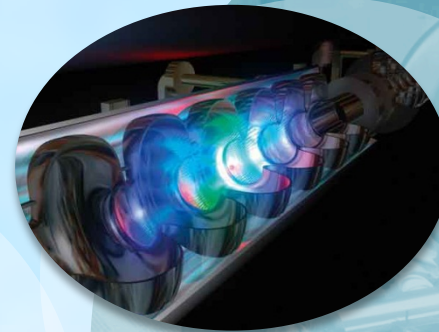
Strategies

- Sustain an **ambitious accelerator R&D** on selected areas
 - ✓ Close interaction with CEA & other partners
 - ✓ Participation in European R&D programs
- Develop forefront **technological platforms**
- Participate to **world-class accelerator project** development & construction
- Propose **innovative accelerators** for applications
 - ✓ e.g. compact X-ray sources...
- Develop **partnerships**
 - ✓ with major players (e.g. CERN, DESY...)
 - ✓ with emerging countries in the field (e.g. ELI-NP project in Romania)
 - ✓ with industries



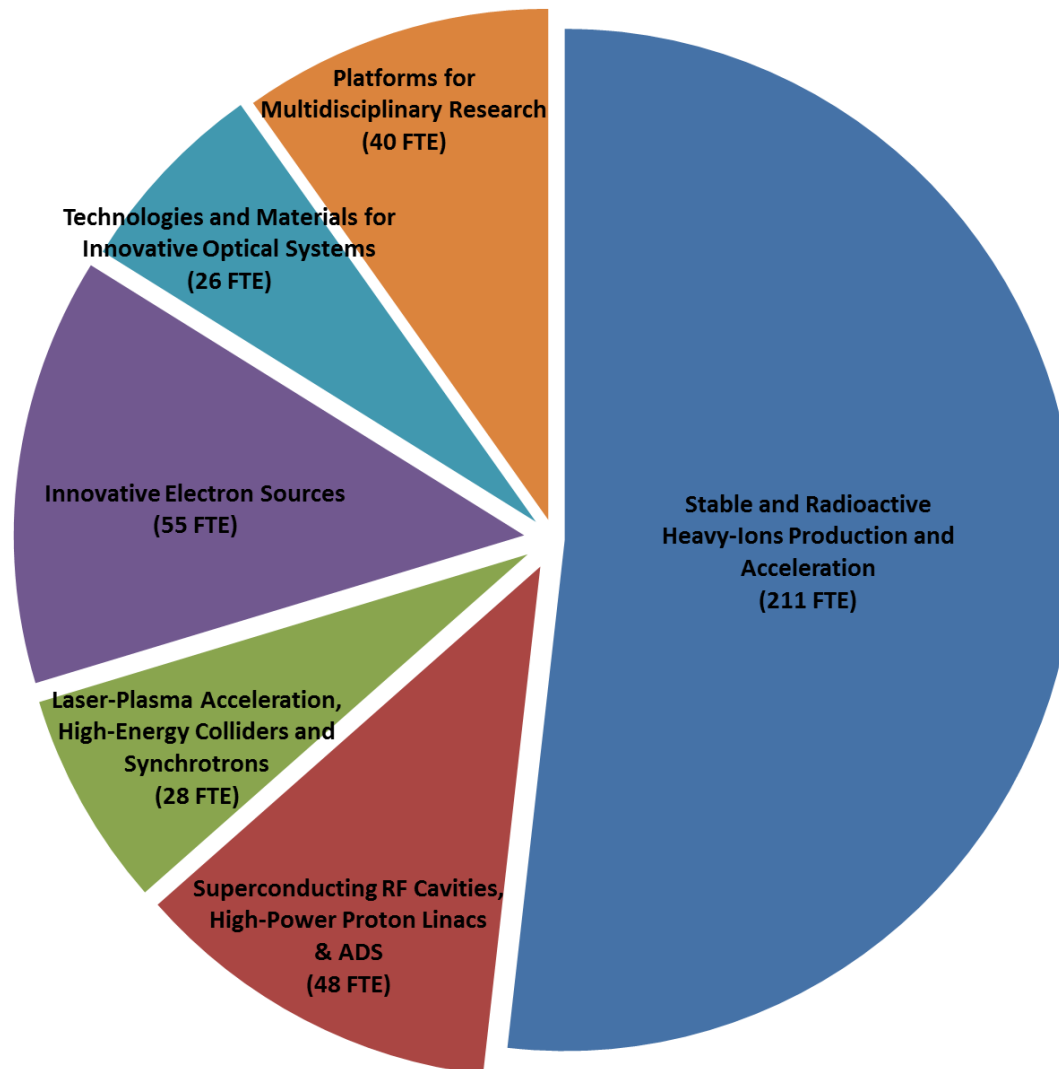
ACCELERATOR RESEARCH & DEVELOPMENTS

- Superconducting accelerating cavities and cryotechnology
- Ion and electron sources
- Radioactive beams
- Plasma acceleration, laser/beam interactions
- Beam dynamics, final focus
- Beam instrumentation
- Related technologies (RF, vacuum...)



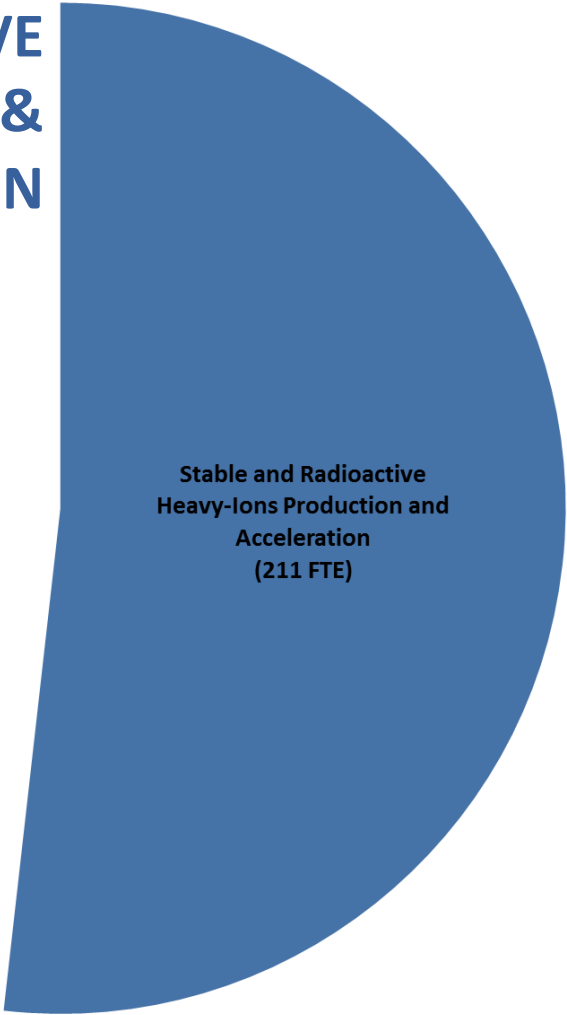
INTENSE BEAMS LASERS SUPERCONDUC
ION SOURCES PLATFORMS CRYOTECHNOLOGY

Accelerator & Technology R&D programs



STABLE & RADIOACTIVE HEAVY-IONS PRODUCTION & ACCELERATION

- ❑ **Leading labs**
GANIL, IPNO
- ❑ **Other labs:**
LPSC, CENBG, IPHC, CSNSM, LPC Caen, IPNL
- ❑ **Accelerator operation & platforms**
GANIL-SPIRAL1, ALTO
- ❑ **Facility construction**
SPIRAL2, S3, DESIR, SPES
- ❑ **Research & Developments**
R&D ion sources
R&D radioactive beams

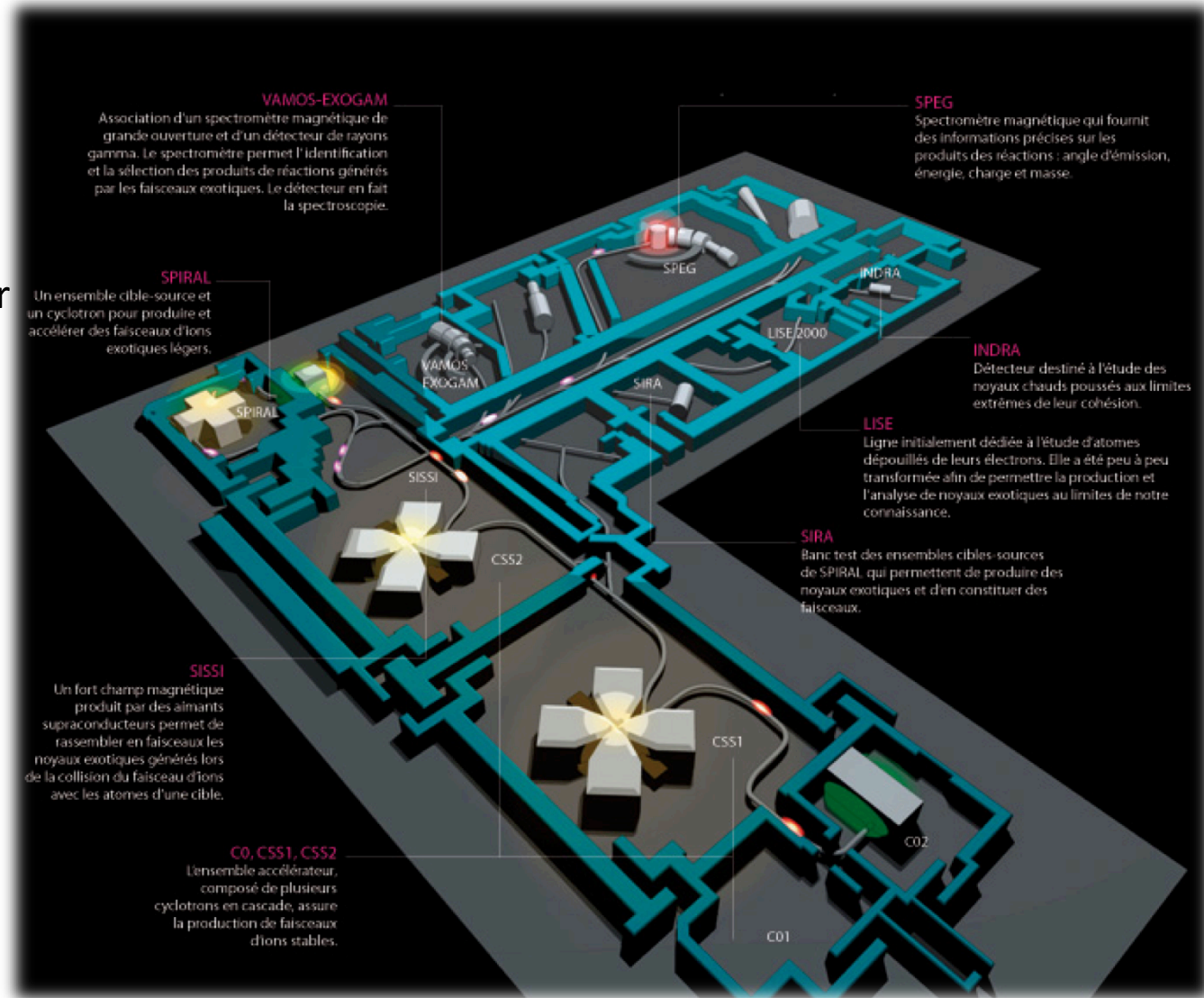


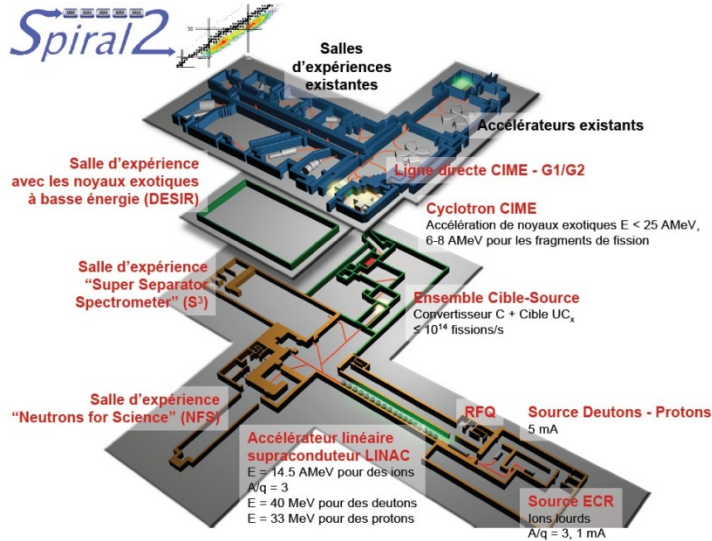
Stable and Radioactive
Heavy-Ions Production and
Acceleration
(211 FTE)



Grand Accélérateur National d'Ions Lourds (CEA/CNRS)

- Main French accelerator complex for nuclear physics
- Cyclotrons complex (CSS1, CSS2, SPIRAL...)
- Several experimental areas & instruments (VAMOS, LISE...)
- Recent upgrade of SPIRAL1
- Major upgrade SPIRAL2 under construction





SPIRAL-2 project

(Système de production d'Ions Radioactifs en Ligne de 2^{ème} génération)

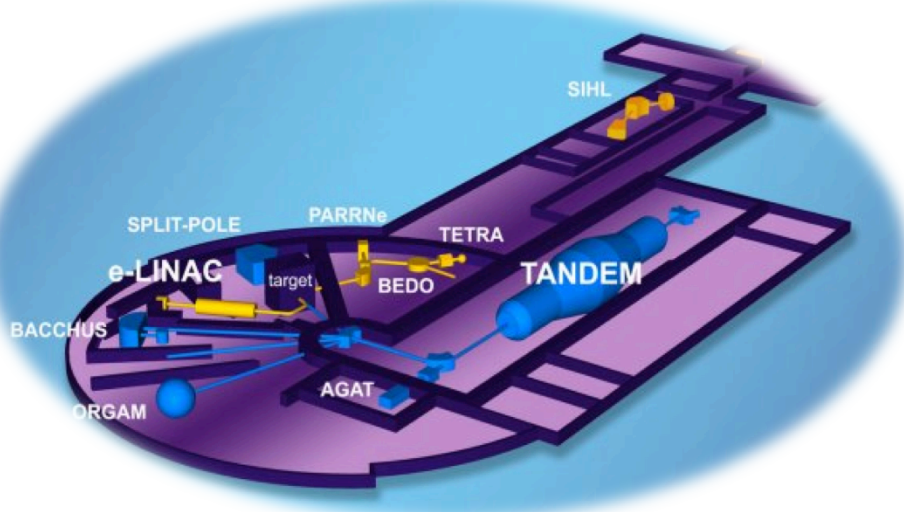
- Phase 1 = 200kW ion SRF linac + 2 experimental halls (NFS, S3)
- Presently in commissioning phase
- Phase 1+ -> DESIR experimental hall
- Phase 2 (on-hold) -> ISOL production building

IN2P3 contribution to SPIRAL-2

- Accelerator design & commissioning (GANIL, IPNO)
- Heavy-ion injector (LPSC, GANIL)
- High-energy SRF cryomodules (IPNO, LPSC, GANIL)
- Cryogenic plant & distribution (IPNO, GANIL)
- Beam instrumentation & dump (IPNO, IPHC, LPSC, IPNL)
- S3 & DESIR (CENBG, CSNSM, IPNO, IPHC, LPC, GANIL)
- R&D for SPIRAL2 phase 2 (IPNO, IPHC, LPSC, LPC, GANIL)



ALTO, heavy-ion R&D



ALTO platform (IPN Orsay)

(Accélérateur Linéaire et Tandem à Orsay)

- 15 MV tandem -> stable beams
- 50 MeV e-linac -> exotic beams (photofission)
- Beam lines & instrumentation
- Carburation lab
-> R&D on Target Ion Sources systems

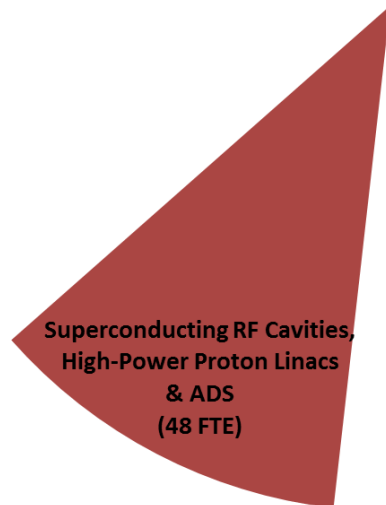
R&D on stable & radioactive ion beams

- R&D on high-frequency high intensity ECR sources:
Phoenix sources, 60GHz prototype... (LPSC, GANIL, IPHC)
- R&D on ISOL Target Ion Sources systems (IPNO, GANIL)
- R&D on charge breeding systems incl. contribution to SPES (LPSC, GANIL, LPC)
- R&D on radioactive beam manipulation (CENBG, CSNSM, GANIL, IPHC, IPNO, LPC)



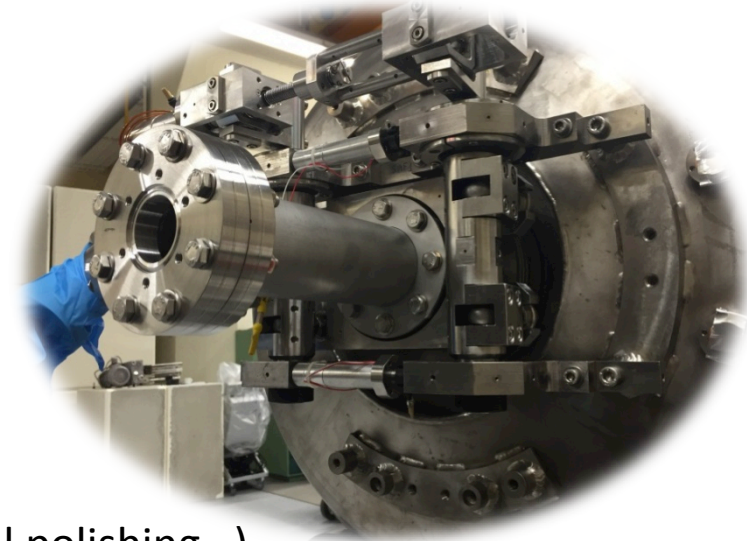
SUPERCONDUCTING RF CAVITIES, HIGH-POWER PROTON LINACS & ADS

- ❑ **Leading labs**
IPNO, LPSC
- ❑ **Other labs:**
LAL, CSNSM, IPHC, GANIL, SUBATECH
- ❑ **Accelerator operation & platforms**
SUPRATECH
- ❑ **Facility construction**
ESS, FAIR, IPHI
- ❑ **Research & Developments**
R&D SRF reliability
R&D SRF high gradient high Q_0
R&D MYRRHA & ADS incl. GENEPI-3C
R&D HI Diag&Control
R&D CERN-SPL
R&D ESSnuSB



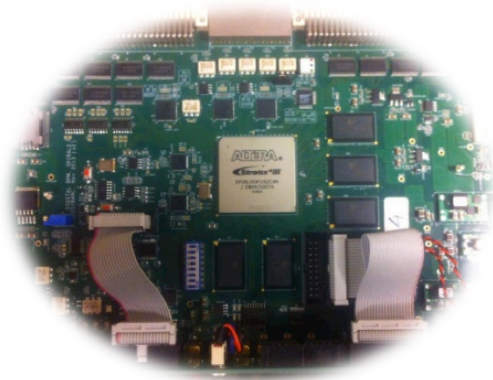
R&D on Superconducting RF (IPNO, LAL, LPSC)

- Low-beta cavity design (Spoke, QWR)
- Power couplers design incl. R&D multipacting
- Cryomodule design (e.g. CERN-SPL module)
- R&D on high gradients (SRF multi-layer thin films)
- R&D on Qo improvement (heat treatments, mechanical polishing...)
- R&D on magnetic shielding, Cold Tuning Systems, quench detection...



R&D on high-intensity instrumentation (IPNO, LPSC)

- R&D on beam diagnostics (BPM, WS, 4D emit..)
- R&D on digital LLRF



SUPRATECH platform (IPN Orsay)

- ❑ 85m² ISO4 clean room
- ❑ Surface treatment lab
- ❑ Helium liquifier (70l/h) & 2K pumping
- ❑ Heat treatment station
- ❑ Cryogenic test halls & temperature sensor calibration station
- ❑ 80kW 700 MHz IOT & 2.8MW 350MHz klystron
- ❑ PANAMA platform for material characterization (IPNO, LAL, CSNSM)



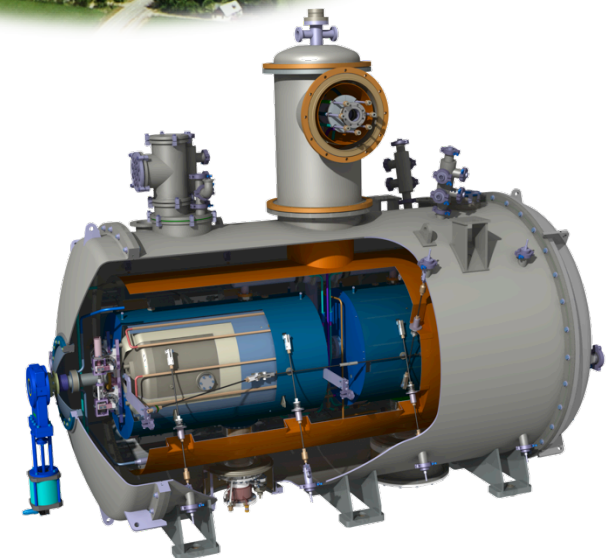
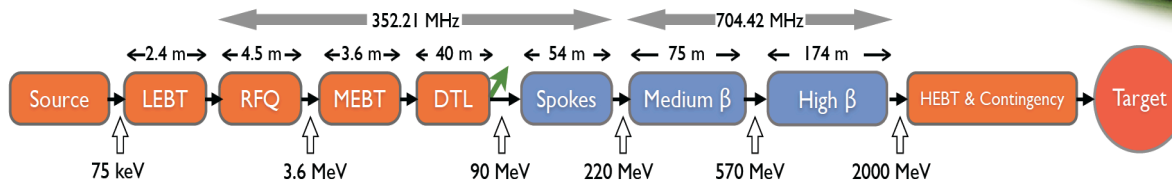
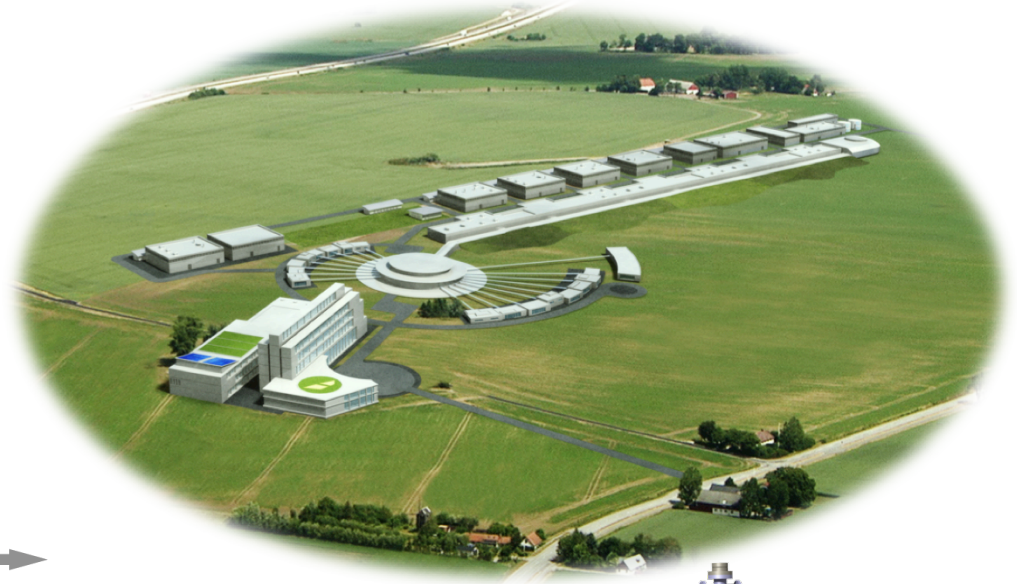
SUPRATECH platform (LAL Orsay)

- ❑ 70m² ISO5 clean room
- ❑ 5MW 1.3 GHz RF station



European Spallation Source (ESS, Lund, Sweden)

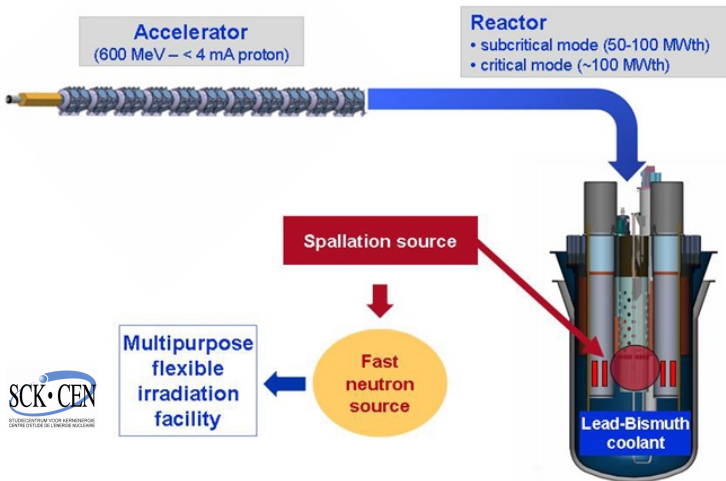
- 5MW high-power proton SRF linac
- 2 GeV, 62.5mA pulsed @4% dc
- Construction has started
- First beam planned in 2019



IN2P3 contribution to ESS (IPN Orsay)

- R&D on spoke and elliptical cryomodules
- In-kind = Spoke cavities, power couplers & cryomodules
- + associated cryogenic distribution and C&C



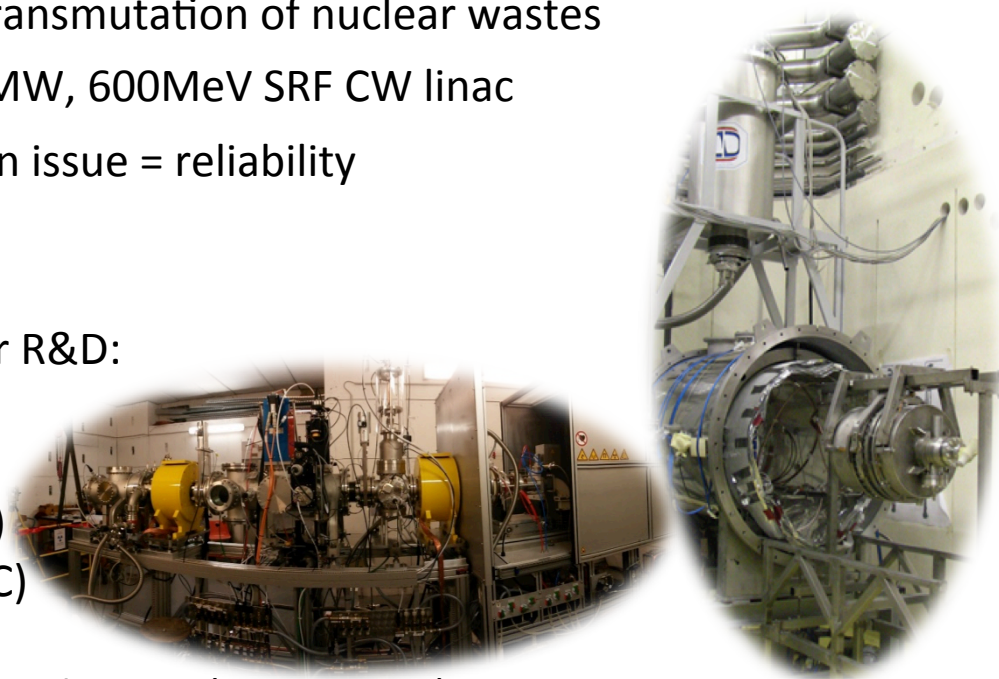


Multipurpose hYbrid Research Reactor for High-tech Applications (SCK*CEN, Mol, Belgium)

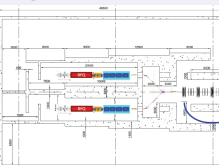
- Demonstration of the ADS concept at high power
-> transmutation of nuclear wastes
- 2.4MW, 600MeV SRF CW linac
- Main issue = reliability

IN2P3 contribution to MYRRHA

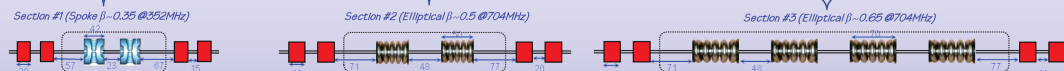
- European coordination of ADS accelerator R&D: EUROTRANS, MAX, MYRTE... (IPNO)
- Accelerator design (IPNO)
- Construction of MYRRHA front-end (LPSC)
- R&D on space-charge compensation (LPSC)
- R&D on spoke cryomodule (IPNO)
- R&D on innovative fault-tolerant systems incl. LLRF (IPNO, LPSC)



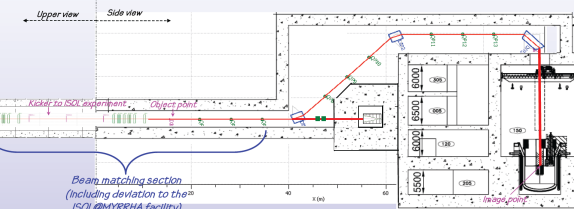
INJECTOR BUILDING



SUPERCONDUCTING LINAC TUNNEL



REACTOR BUILDING



GUINEVERE experiment (SCK*CEN, Mol, Belgium)

(Generator of Uninterrupted Intense Neutrons at the lead Venus REactor)

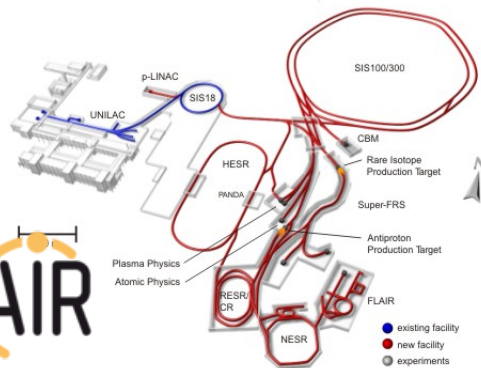
- Low-power ADS mock-up for sub-critical reactor studies
- GENEPI-3C 200keV deuteron accelerator designed & constructed by LPSC (+ IPNO, IPHC, LPC Caen), coupled to reactor since 2011



IPHI (CEA Saclay)

(Injecteur de Protons de Haute Intensité)

- 100mA 3MeV proton injector demonstrator
- IN2P3 contribution on: LLRF systems, beam transport and beam instrumentation (IPNO), beam dump (LPSC)



FAIR (GSI, Darmstadt, Germany)

(Facility for Antiproton and Ion Research in Europe)

- Major upgrade of the GSI facility
- IN2P3 contribution: RF power chain for the p linac (IPNO)



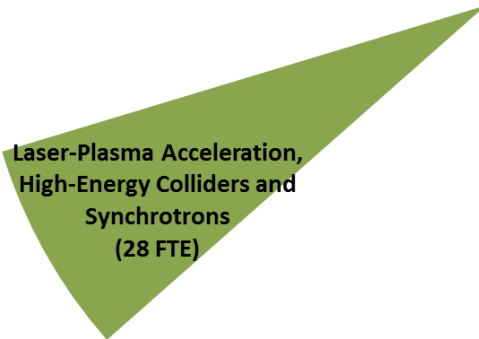
LASER-PLASMA ACCELERATION, HIGH-ENERGY COLLIDERS, SYNCHROTRONS

Leading labs

LAL

Other labs:

IPHC, LAPP, LLR, LPSC, IPNO, IPNL



Laser-Plasma Acceleration,
High-Energy Colliders and
Synchrotrons
(28 FTE)

Accelerator operation & platforms

N/A

Facility construction

N/A

Research & Developments

R&D LPA electrons

R&D LPA ions

R&D Future Linear Colliders

R&D SuperKEKB - BEAST

R&D LHC upgrade (UA9)

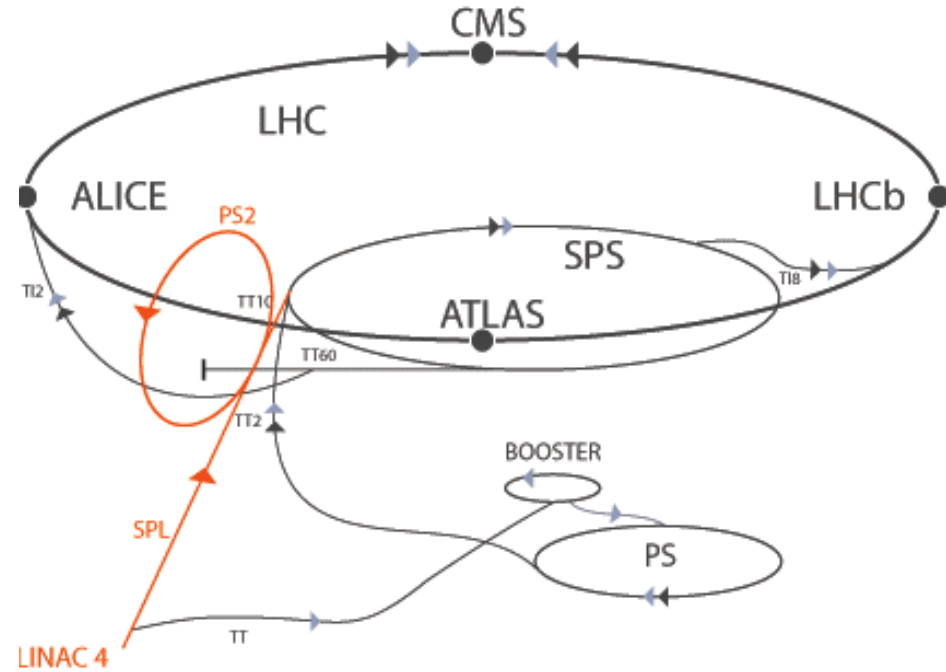
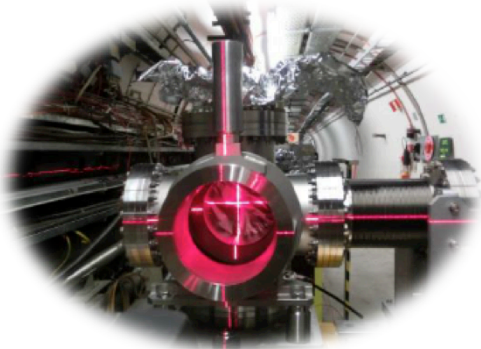
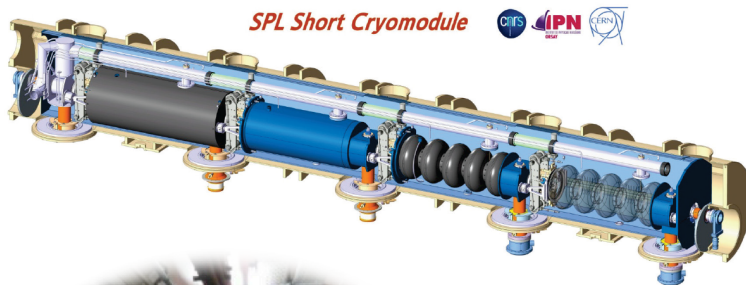
R&D FCC

R&D JEDI



The LHC complex (Large Hadron Collider)

- World-leading facility for particle physics
- Linac2 + Booster + PS + SPS + LHC
- LHC complex upgrade on-going for luminosity increase: High Luminosity LHC

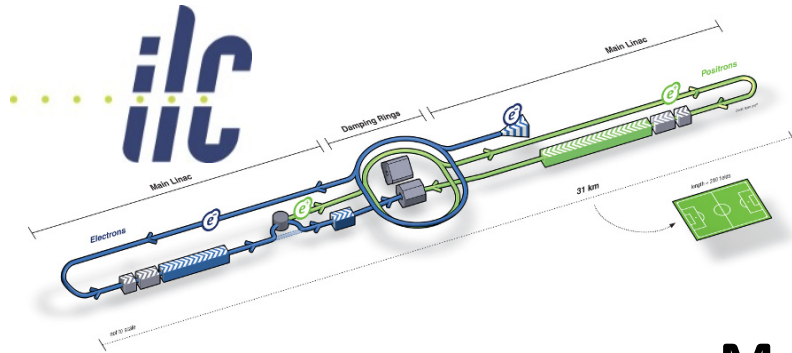


IN2P3 contribution to LHC upgrade

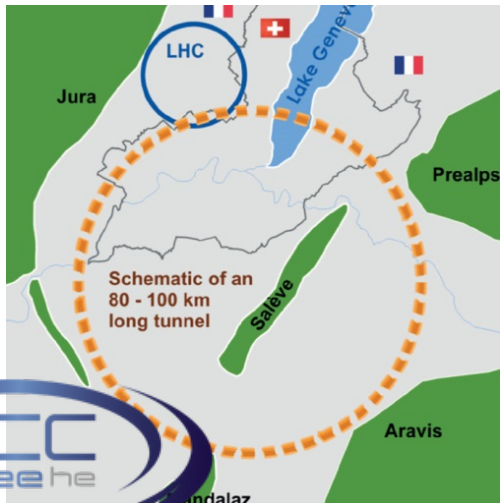
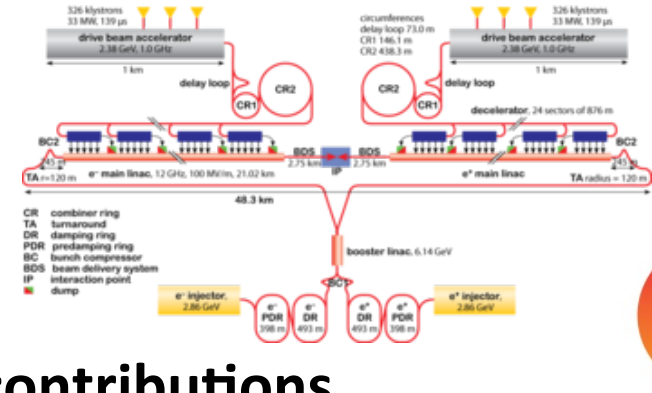
- Participation to LINAC4 construction (LAL, LPSC)
- PS magnets windings (LPSC)
- R&D on SC cryomodules for SPL (IPNO)
- R&D on cristal collimation - UA9 experiment (LAL)
- HL-LHC contributions under discussion



ILC (International Linear Collider)



CLIC (Compact Linear Collider)



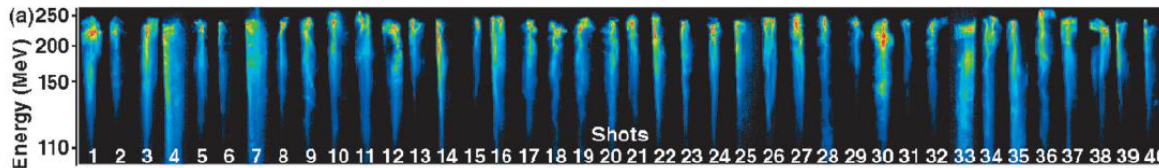
Main IN2P3 contributions

- ❑ R&D on intense positron sources for ILC and CLIC: Compton-based, hybrid scheme (LAL, IPNL)
- ❑ R&D on beam active stabilisation @ATF2 & CTF3 (LAPP)
- ❑ R&D on nano-beam control & diagnostics at the IP for ILC and CLIC @ ATF2 (LAL)
- ❑ Participation to SuperKEKB & Belle-II commissioning: luminosity & background monitoring at IP (LAL, IPHC)
- ❑ Optical design of the collimation insertion for FCC h-h: participation to the EuroCirCol DS (LAL, IPNO)

FCC (Future Circular Collider)



PRL 101, 085002 (2008)

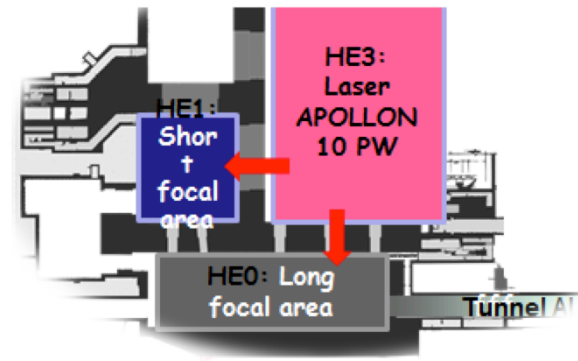


Laser Plasma acceleration

- ❑ Acceleration by high-gradient laser wakefield
- ❑ Potential for dramatic decrease of accelerator dimensions
- ❑ State-of-the-art with Ti-Saph laser (100TW, 30fs): electron acceleration up to ~1 GeV

R&D on LP acceleration (LLR, LAL, CENBG)

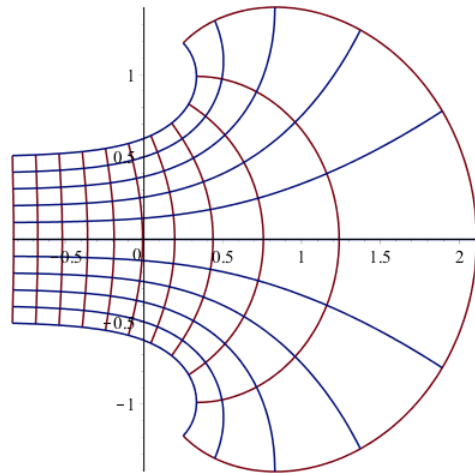
- ❑ R&D ion acceleration at high repetition rate (CENBG)
- ❑ R&D electron acceleration & beam characterisation (LLR, LAL)
- ❑ Contribution to EuPRAXIA European design study (LLR)
- ❑ Contribution to the construction of the CILEX platform (LLR, LAL) (Centre Interdisciplinaire Lumière Extrême, CNRS/CEA/Soleil/UPS)
- ❑ R&D on external injection around LASERIX & PHIL (LAL)



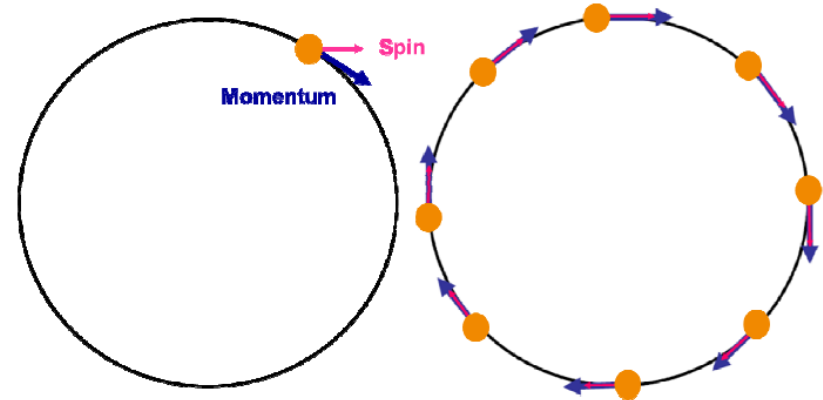
JEDI (FZ Juelich)

(Jülich Electric Dipole moment Investigation)

- Measurement of the permanent Electric Dipole Moments of charged particles (e.g. protons, deuterons, helium)
- Stored in an electrostatic storage ring



Left: a polarized charged particle (beam) in a storage ring



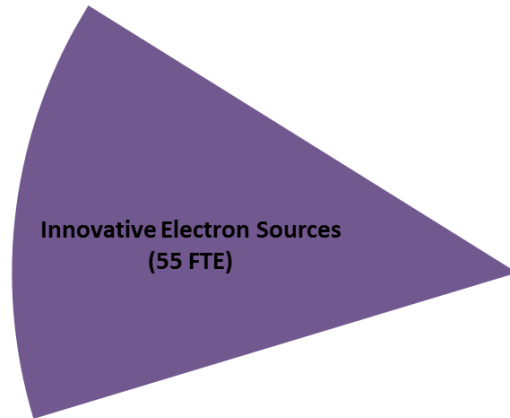
Right: fixing the horizontal spin along the momentum direction

IN2P3 contribution (LPSC)

- Participation to the design of the storage ring
- Detailed design of electrostatic deflectors



INNOVATIVE ELECTRON SOURCES



- Leading labs**
LAL
- Other labs:**
CENBG
- Accelerator operation & platforms**
PHIL
- Facility construction**
X-FEL, THOM-X, LCLS2
- Research & Developments**
R&D short bunches
R&D LUNEX5
R&D SPEEP



PHIL (LAL Orsay)

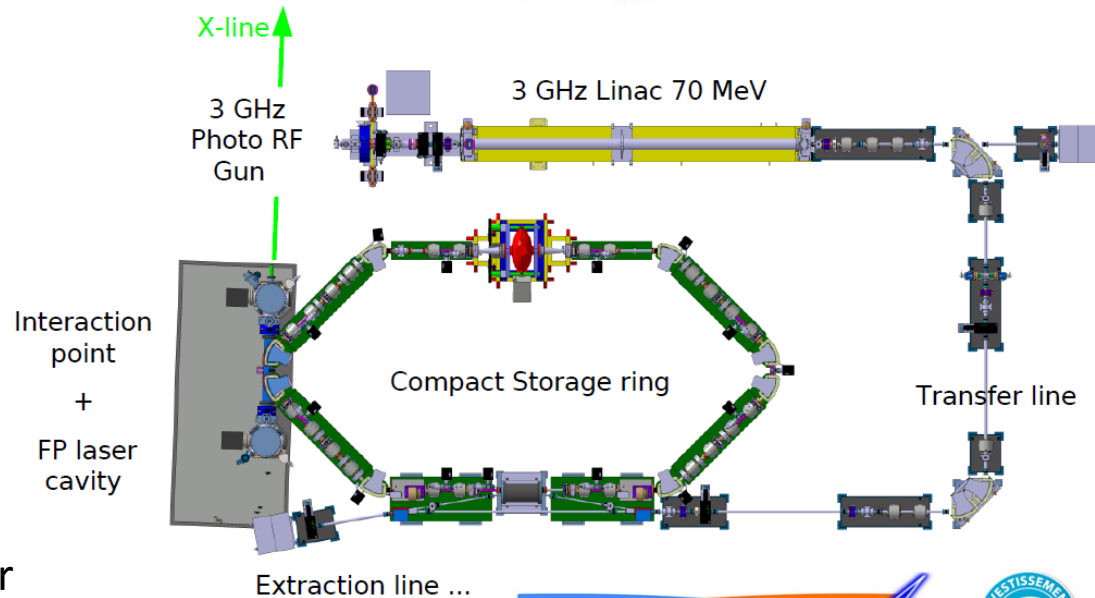
(Photo-Injector au Lal)

- Test bench for high brilliance photo-guns
- 3GHz klystron
- Picosecond UV laser Nd:YLF
- Beam lines & instrumentation



ThomX project (LAL Orsay)

- Compact & intense X-ray source based on Compton backscattering (small enough to be installed in an hospital or museum)
- 3Ghz photo-gun + linac + compact electron storage ring
- Laser + Fabry-Perot optical resonator
- Under construction

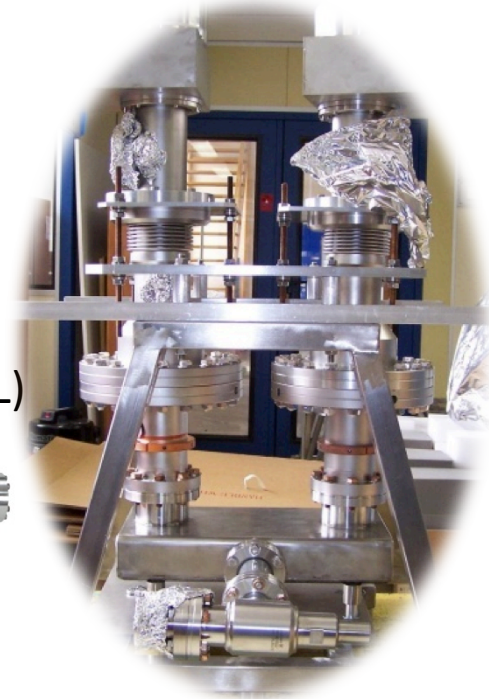


European XFEL (DESY, Hamburg, Germany)

(X-ray Free Electron Laser)



- ❑ New generation light source w/ extremely intense Xray production
- ❑ 20 GeV electron 1.3GHz SRF linac (100 12m long modules)
- ❑ IN2P3 contribution: conditioning & delivery of 800 RF couplers (LAL)



Related activities on couplers (LAL)

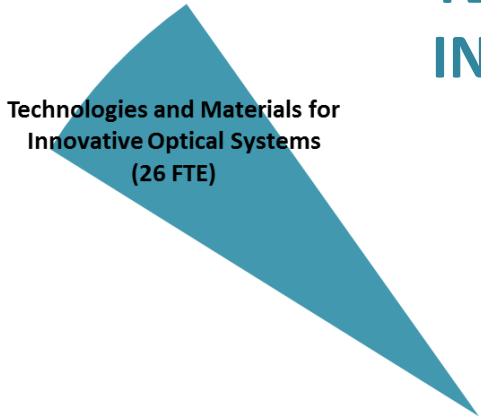
- ❑ Contribution to LCLS2 couplers production with SLAC
- ❑ R&D for the LUNEX5 project (5th generation FEL) with SOLEIL

Other R&D activities

- ❑ R&D ETALON / DRUM – short bunch (sub-ps) production (using Laserix) & longitudinal profil measurement by Smith-Purcell coherent radiation (LAL)
- ❑ R&D SPEEP – laser-excited pulsed plasma electron source (CENBG)



TECHNOLOGIES & MATERIALS FOR INNOVATIVE OPTICAL SYSTEMS



Technologies and Materials for Innovative Optical Systems
(26 FTE)

- Leading labs**
LMA, LAL
- Other labs:**
N/A
- Accelerator operation & platforms**
LMA platform
- Facility construction**
ELI-NP, THOM-X
LIGO, VIRGO, LSST, DKIST, KAGRA
- Research & Developments**
R&D Mighty Laser
R&D optical thin films



R&D on thin optical films (LMA)

- R&D on low loss coatings
- R&D on metrology
- R&D on materials
- Large platform

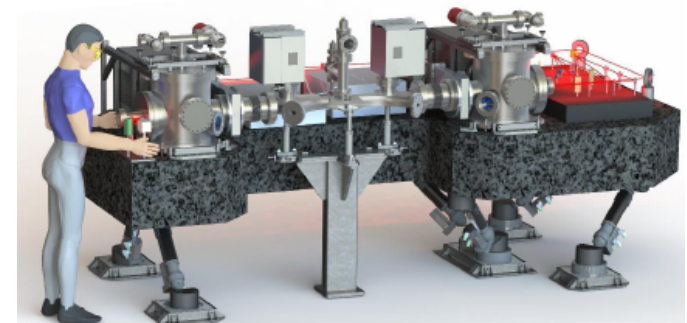


Contribution to interferometers & telescopes projects (LMA)

- Interferometers: VIRGO, LIGO...
- Telescopes: LSST, DKIST...

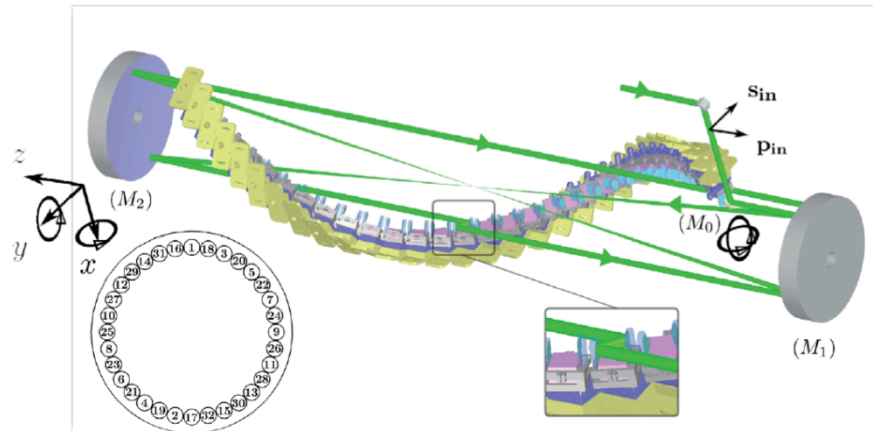
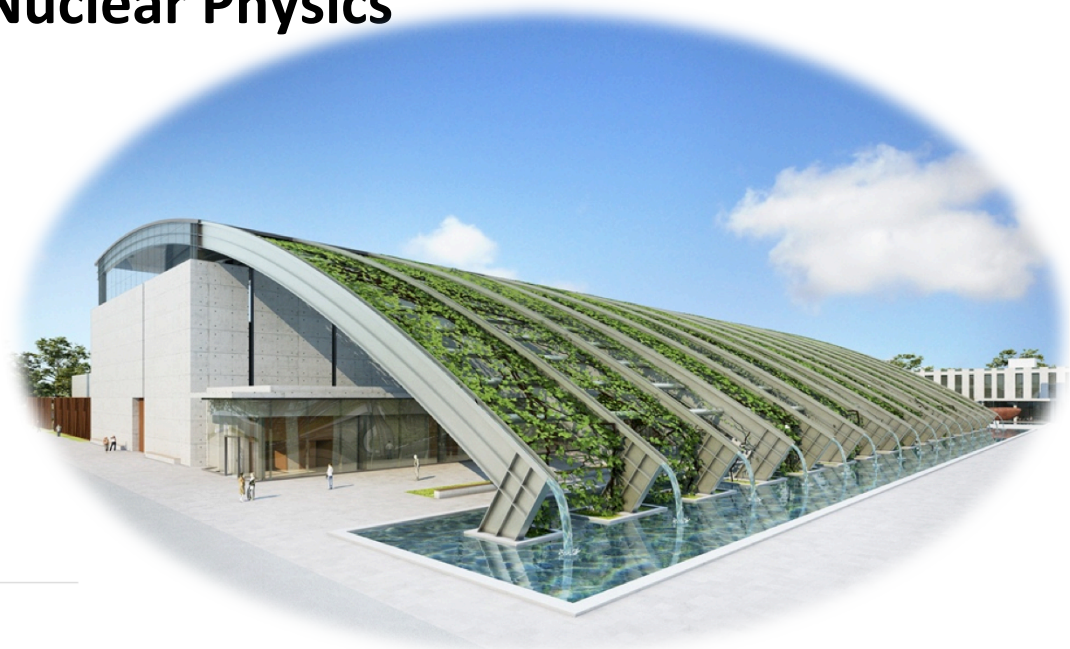
R&D on laser optical systems (LAL)

- R&D Mightylaser on High Q Fabry-Perrot cavities
- ThomX interaction cavity & associated X-ray line (LAL)



Extreme Light Infrastructure – Nuclear Physics (Bucharest, Romania)

- Very intense Compton γ -ray source ($E_\gamma > 19$ MeV)
- 700 MeV warm electron linac
- Two 10 PW lasers
- Under construction



IN2P3 contribution to ELI-NP (LAL Orsay)

- Beam/laser interaction point
- Design, alignment, synchronisation & commissioning of the optical setup





PLATFORMS FOR MULTI-DISCIPLINARY RESEARCH

- Leading labs**

N/A

- Other labs:**

CENBG, CSNSM, IPHC, IPNL, IPNO,
LAL, LPSC, SUBATECH + ARRONAX

- Accelerator operation & platforms**

AIFIRA, ANAFIRE, ARRONAX, CYRCE,
GENEPI2, SCALP

- Facility construction**

ANDROMEDE, PRAE





AIFIRA platform (CENBG Bordeaux)

(Applications Interdisciplinaires des Faisceaux d'Ions en Région Aquitaine)

- 3.5MV electrostatic accelerator
- High spatial resolution beam lines

ANAFIRE platform (IPN Lyon)

(ANALysis and Ion beams for Radiobiology and the Environment)

- 4MV Van de Graaf
- 400kV ion implanter



SCALP platform (CSNSM Orsay)

- ARAMIS 2MV tandem accelerator
- IRMA 190kV ion implanter
- 200 kV Transmission Electron Microscope
- SIDONIE 50kV isotope separator



ANDROMEDE project (IPN Orsay)

(New instrument for mass spectrometry analysis of nano-particles)

- 4MV Van de Graaf
- Under construction

PRAE project (LAL, IPNO)

(Platform for Research and Applications with Electrons)

- 70 MeV electron beam – design phase
- Application: nuclear physics, radiotherapy...



ARRONAX (Nantes)

(Accélérateur pour la Recherche en Radiochimie en Oncologie à Nantes Atlantix)

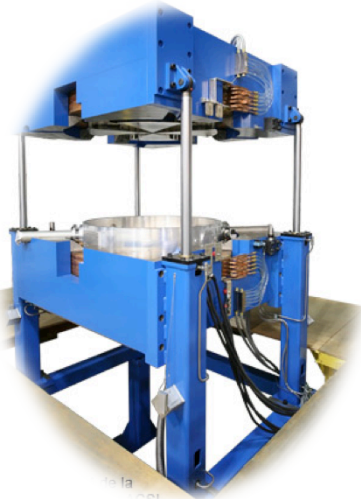
- 70 MeV cyclotron
- Radio-isotope production



CYRCé platform (IPHC Strasbourg)

(Cyclotron pour la Recherche et l'Enseignement)

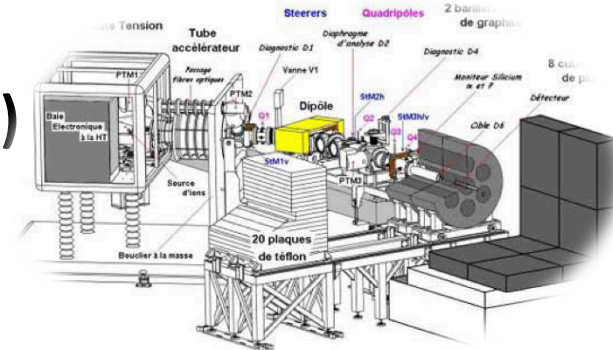
- 24 MeV cyclotron
- Radio-isotope production
- Imaging platform



PEREN-n platform (LPSC Grenoble)

(Plate-forme d'Etude et de Recherche sur l'Energie Nucléaire - neutronique)

- 250 kV GENEPI-2 deuteron beam
- Fast neutron source



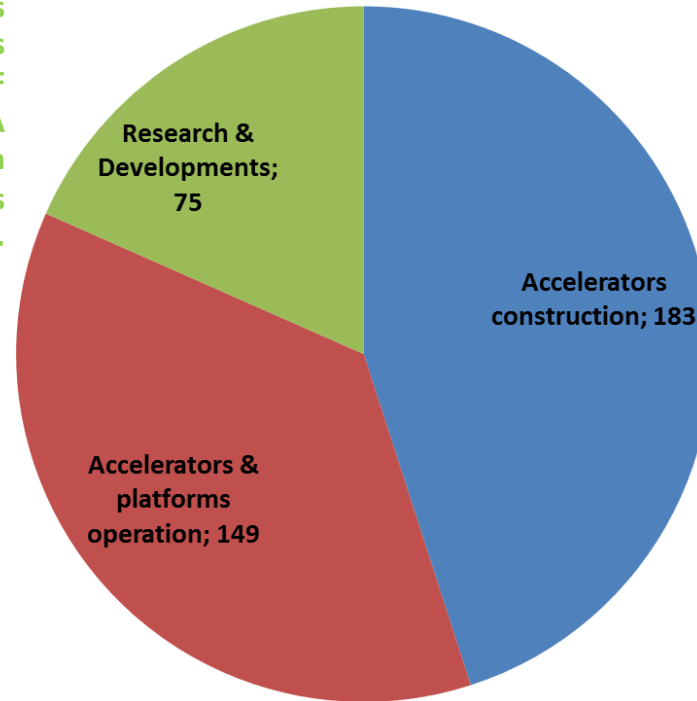
Conclusions and roadmap

Conclusions

- ❑ Accelerator physics and R&D = **healthy disciplin**
- ❑ IN2P3 accelerator teams are involved in **almost all major accelerator projects**
- ❑ Not easy to keep a **good balance between operation, project construction & R&D**

Future colliders
 Ion sources & radioactive beams
 Superconducting RF
 ADS incl. MYRRHA
 Laser-plasma acceleration
 Innovative optical systems
 Etc.

GANIL/SPIRAL1 (Caen)
ALTO (Orsay)
PHIL (Orsay)
SCALP (Orsay)
ANAFIRE (Lyon)
SUPRATECH (Orsay)
ARRONAX (Nantes)
AIFIRA (Bordeaux)
GENEPI2 (Grenoble)
CYRCE (Strasbourg)
 Etc.



SPIRAL2 incl. S3 & DESIR (Caen)
THOMX (Orsay)
ESS (Lund)
XFEL (Hamburg)
ELI-NP (Romania)
FAIR (Darmstadt)
ANDROMEDE (Orsay)
SPES (Legnaro)
IPHI (Saclay)
PRAE (Orsay)
 Etc.

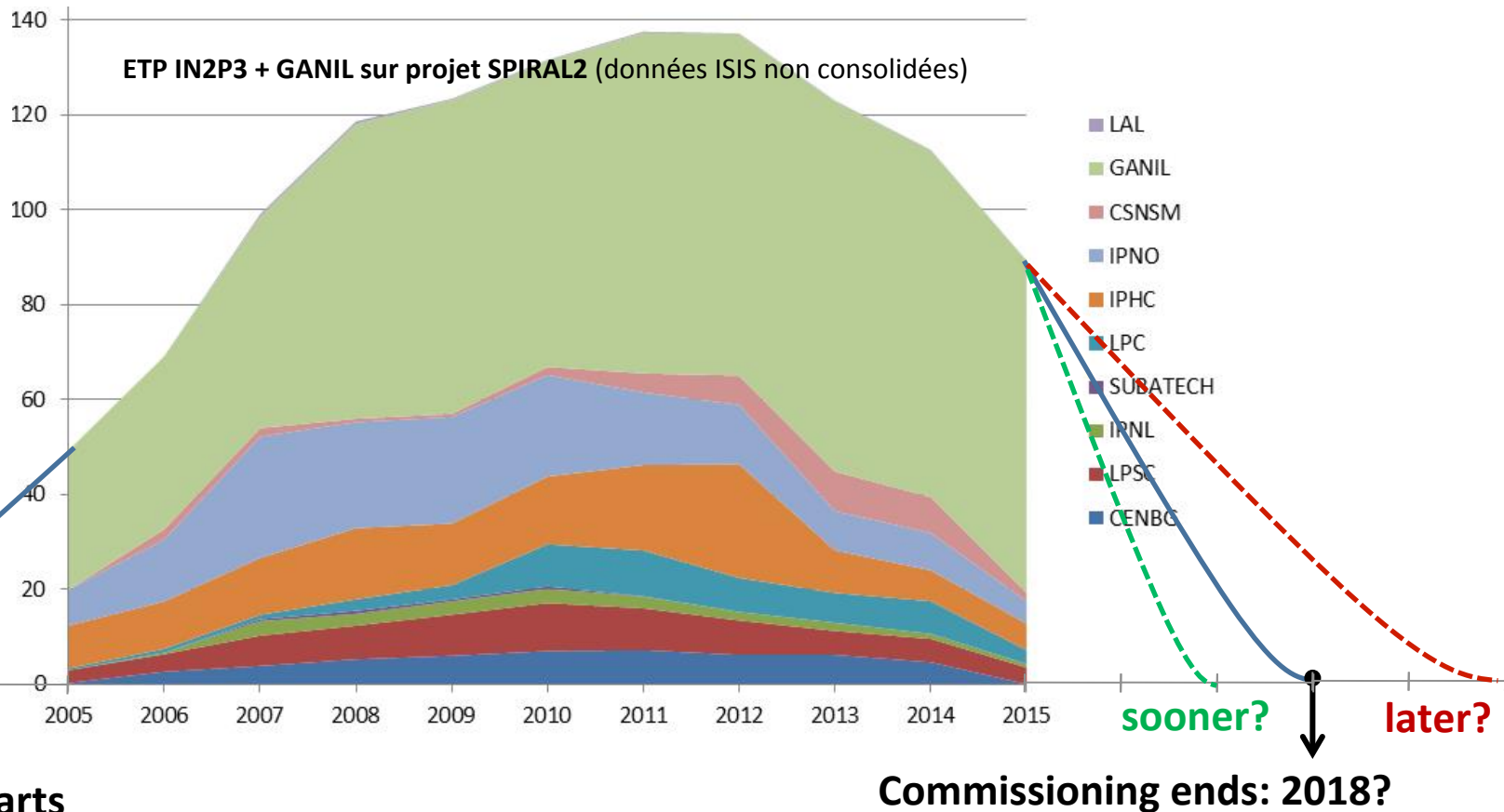
FTE on Accelerators & Technologies - activities



Conclusions and roadmap

Roadmap priorities

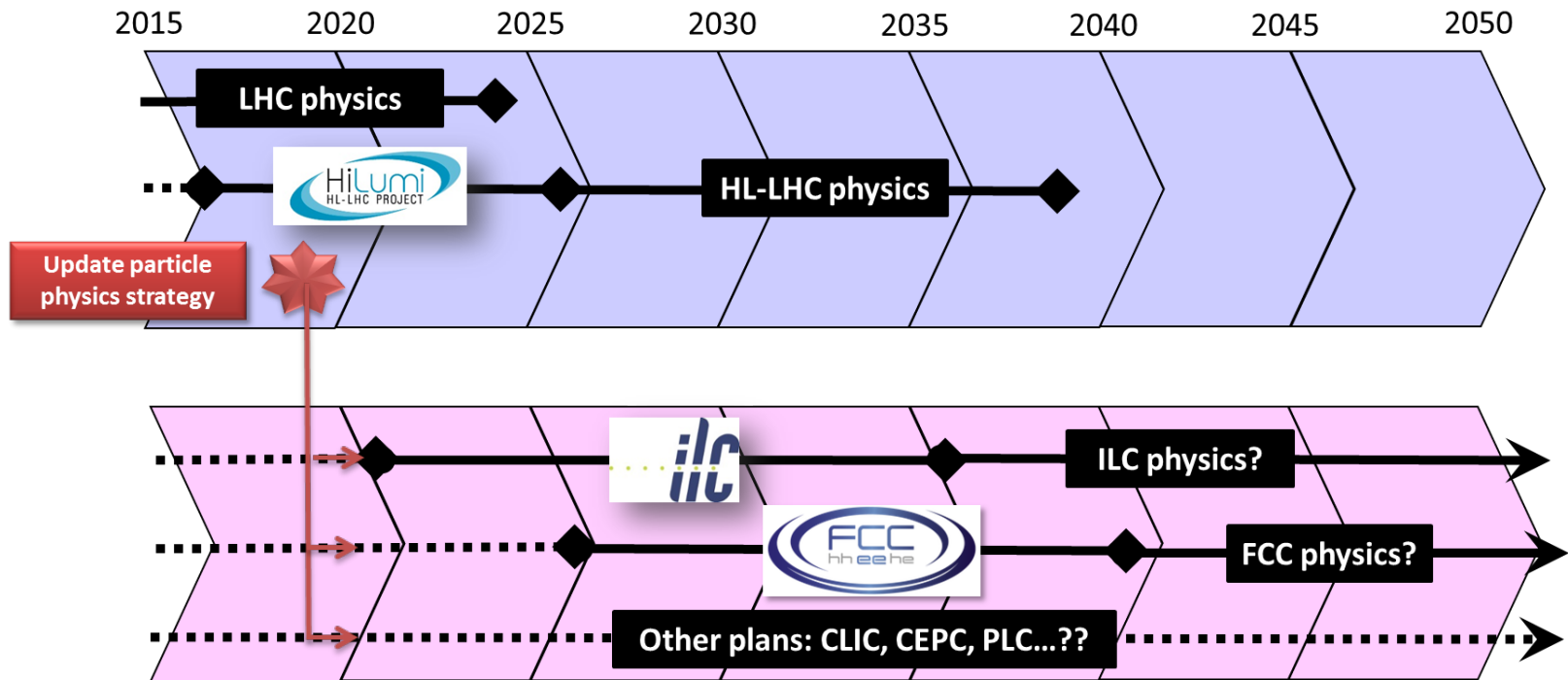
- Achieve SPIRAL-2 and support GANIL to prepare SPIRAL2 upgrades (1+, 1++, 2?)



Conclusions and roadmap

Roadmap priorities

- ❑ Achieve SPIRAL-2 and support GANIL to prepare SPIRAL2 upgrades (1+, 1++, 2?)
- ❑ Support CERN and contribute to next-generation collider projects



Roadmap priorities

- Achieve **SPIRAL-2** and support GANIL to prepare SPIRAL2 upgrades (1+, 1++, 2?)
- Support **CERN** and contribute to next-generation collider projects
- Pursue & achieve contributions to **X-FEL, FAIR and ESS**
- Contribute to **MYRRHA** and ADS systems
- Support emergence of **innovative small/medium scale machines** for multi-disciplinary applications & societal needs (Compton sources e.g. ThomX, medical accelerators, irradiation stations...)
- Push **R&D effort on IN2P3 specific expertises**:
Ion sources, Superconducting RF, High-power proton linacs, innovative electron sources, Laser/beam interaction & associated optical systems
- Explore further new R&D areas for **next-generation accelerators** (plasma acceleration, ERL?) in close partnership with CEA



Merci pour votre attention!

