
Accelerators for the Future

2020-2030 French Strategic Plan for Nuclear Physics, Particle Physics, Astroparticle Physics and associated Technologies & Applications.

Report of the GT07 working group:

PARTICLE ACCELERATORS & ASSOCIATED INSTRUMENTATION

Photo: Christophe Barué (GANIL)

Authors
Jean-Luc Biarrotte (CNRS/IN2P3), Rodolphe Clédassou (CNRS/IN2
Brigitte Cros (CNRS/LPGP), Angeles Faus-Golfe (CNRS/IJCLab),
Luc Perrot (CNRS/IJCLab)

Institut national de
physique nucléaire et
de physique des particules

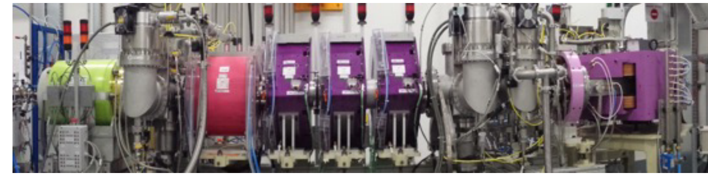
GT07: Accelerators for the Future

J.L. Biarrotte, <u>A. Faus-Golfe,</u> L. Perrot, B. Cros

https://indico.in2p3.fr/event/19783/

19-22 October 2021

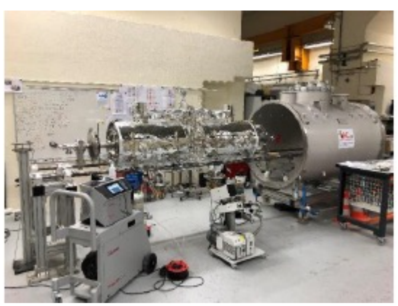
Outline

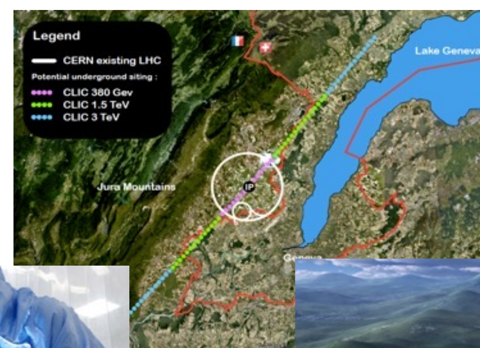


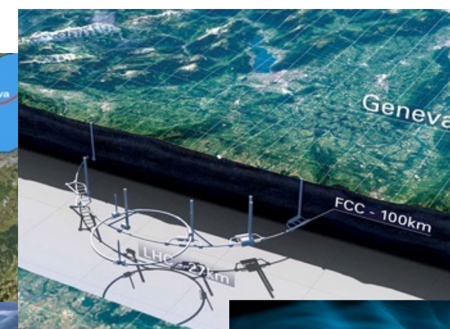
- ❑ **Introduction and general framework**
- ❑ **Accelerator Science Drivers**
- ❑ **Accelerator R&D at IN2P3:** *the present picture*

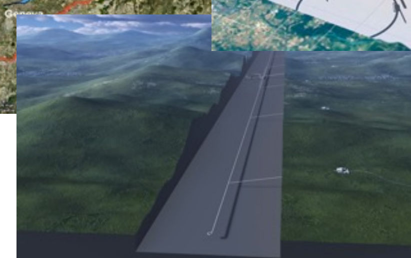
- ❑ **Stable & Radioactive Heavy-Ion production & acceleration** *(SRHI)*
- ❑ **Superconducting RF Cavities & high-power Proton Linacs** *(SCPL)*
- ❑ **Laser Plasma Acceleration & high-energy Colliders** *(LPAC)*
- ❑ **Innovative Electron and Light Sources** *(IELS)*

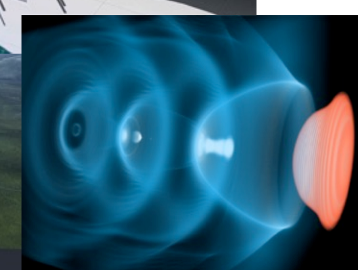
- ❑ **Transverse aspects**
- ❑ **Conclusions**









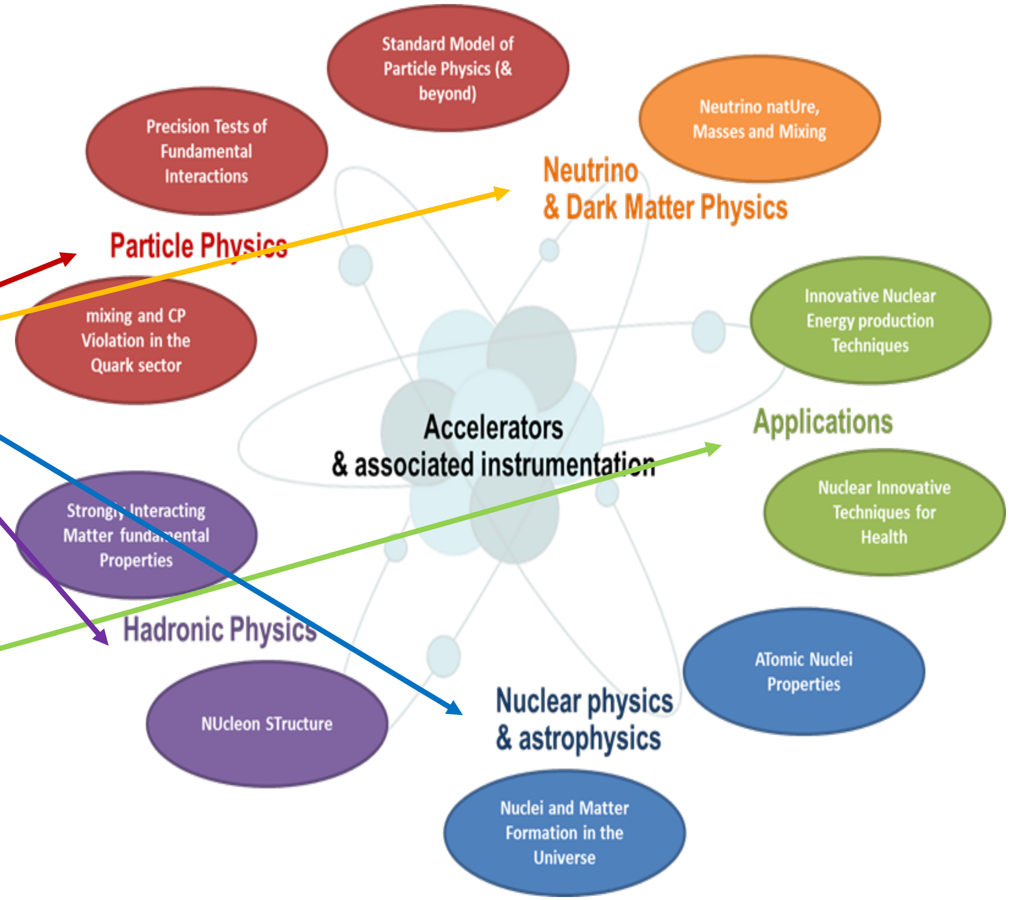


Introduction and general framework

The **mission** of **IN2P3 accelerator teams** is to **focus** their main effort on: the **design, development and construction** of **particle accelerators** able to address the **IN2P3 research programs**, and on the **associated R&D**

- ***Top priorities*** should go to the development of **GANIL, CERN**, and **other world-class accelerator** facilities addressing **IN2P3 science**

- ***Lower priority*** make accelerator technologies available to other **scientific users** and to specific **societal needs**



Accelerator Science Drivers

- **SD#1** – Push accelerator development towards **higher beam energies** → to address the issues of the next generation **high-energy colliders** and beyond.

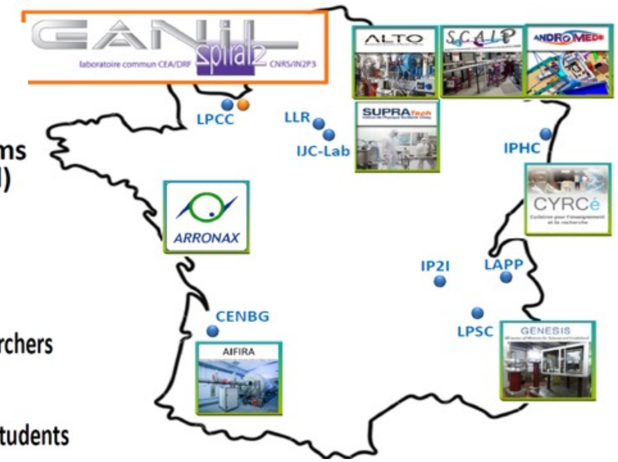
- **SD#2** – Push accelerator development towards **enhanced beam intensities & luminosities** → to be able to track rare events more efficiently, like at **ISOL factories** for nuclear physics, at **high-precision frontier colliders** for particle physics or at **long baseline facilities** for neutrino physics.

- **SD#3** – Push accelerator development towards **higher beam quality, efficiency & reliability** → to increase the general performance of accelerator-based research infrastructures (including their energy efficiency and their cost).

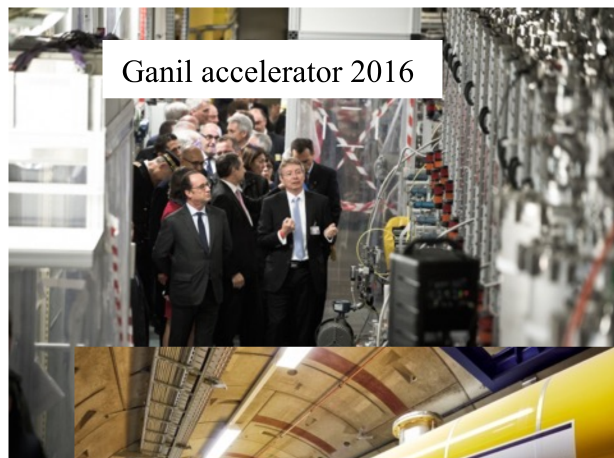
Accelerator R&D at IN2P3 – *present picture*

- About **200 FTE IN2P3** involved in **accelerator projects**: R&D, development and construction
  → most of them at IJCLab + GANIL
  → ~150 FTE in 9 operation platforms

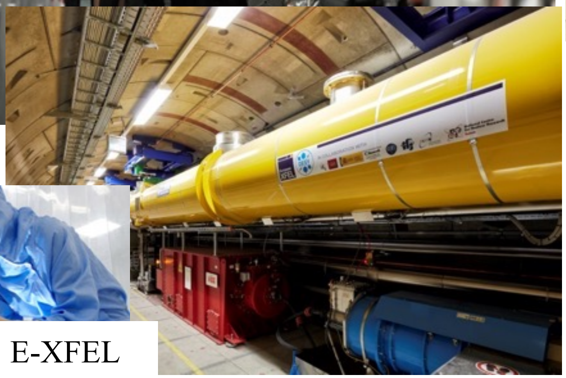
9 labs involved
9 platforms (1 national)
1 GDR
~65 researchers (~15 HDR)
~25 PhD students

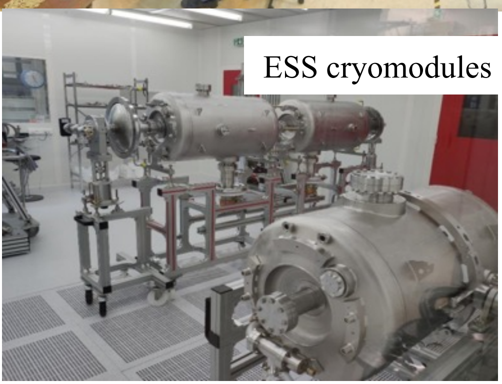


- Forefront expertise, together with CEA/IRFU, in particular on **Superconducting Accelerators**
  → For about 20 years, major in-kind contributions to the construction of LHC, SPIRAL2, E-XFEL, ESS & others


Ganil accelerator 2016


LHC 2004




ESS cryomodules


E-XFEL

R#1: In the **coming years**, **IN2P3 accelerator teams** should **reinforce** their involvement in the **exploratory R&D** → Increasing the human resources effort on these activities from 20% of the **available FTE** (present situation) to about **30-40%** is a suitable target.

R#2: In order to **reinforce the visibility and attractiveness of accelerator science in France**, IN2P3 accelerator teams should:
→ increase their scientific production with **peer-reviewed publications**
→ increase their **involvement in academics** (HDR) & **education** and **attract students** to do internships & PhD in IN2P3 laboratories,
→ develop more joint projects with **industrial partners** *(CIFRE, LabCom...)*

The on-going **structuration effort** of the French accelerator community should also be pursued → **national coordination**

(Master-Projects, Research teams, Platforms, GdR APPEL, ARCO@IJCLab, EquipexPACIFICS, etc.)

Accelerator R&D at IN2P3 – *targeting a bright future*

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MAIN GOAL:

KEEP & REINFORCE THE FRENCH INTERNATIONAL LEADERSHIP !

R#2: In … **ator**
science … uld:
→ incre … **ns**
→ incre … nd
attract … laboratories,
→ devel … **industrial partners** *(CIFRE, LabCom...)*

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

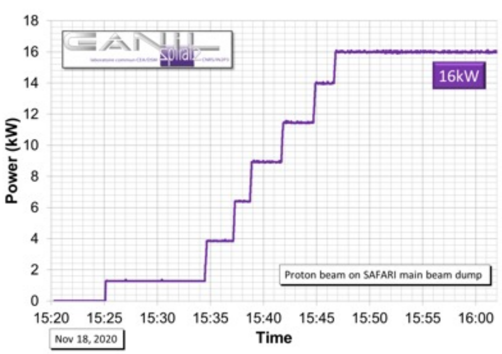
Stable & Radioactive Heavy-Ion production & acceleration (SRHI)

The main objectives for **SRHI** research program:

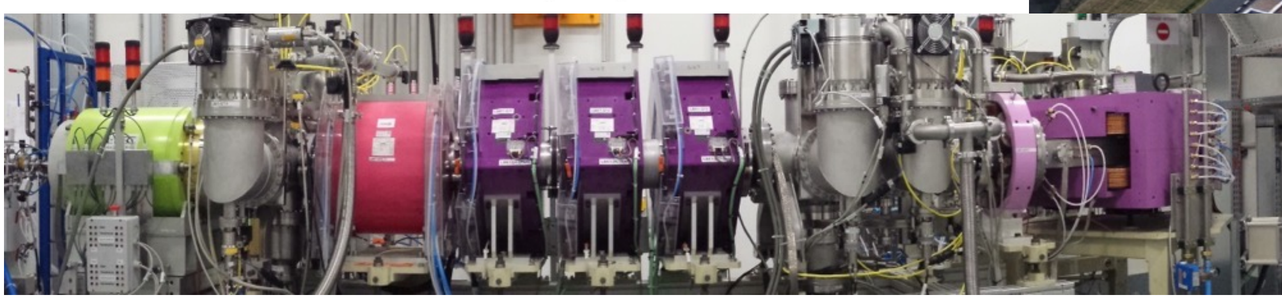
- Better understand and master the physics processes able to **produce stable and radioactive ions** with the **highest** possible **intensities** and **purities** and to identify and develop the best corresponding technologies

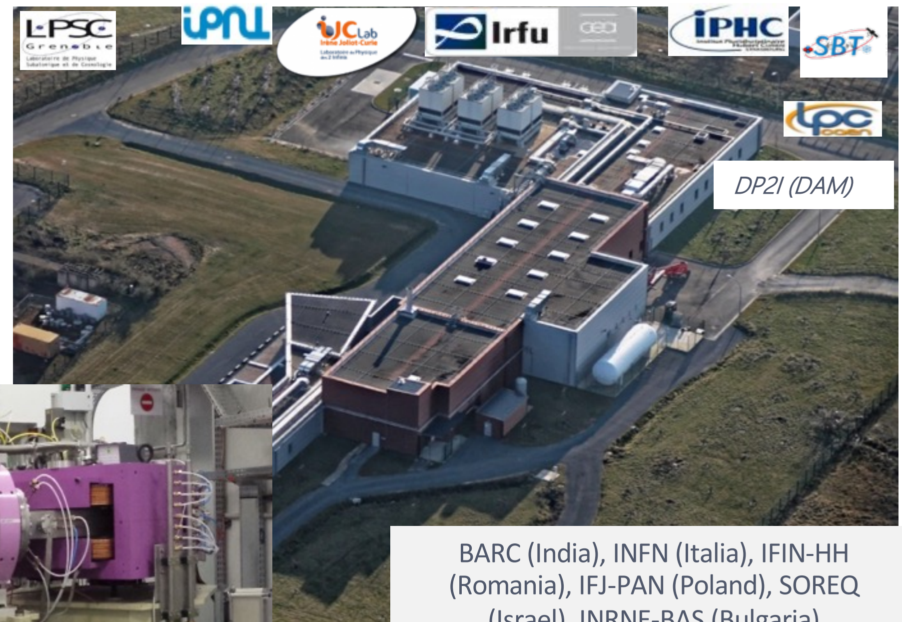
- Strongly support the **development of the GANIL** accelerators complex our French national research infrastructure for fundamental nuclear physics.

18/11/2020 : Power rise - 16kW



Accélérateur SPIRAL2 - Source PHOENIX

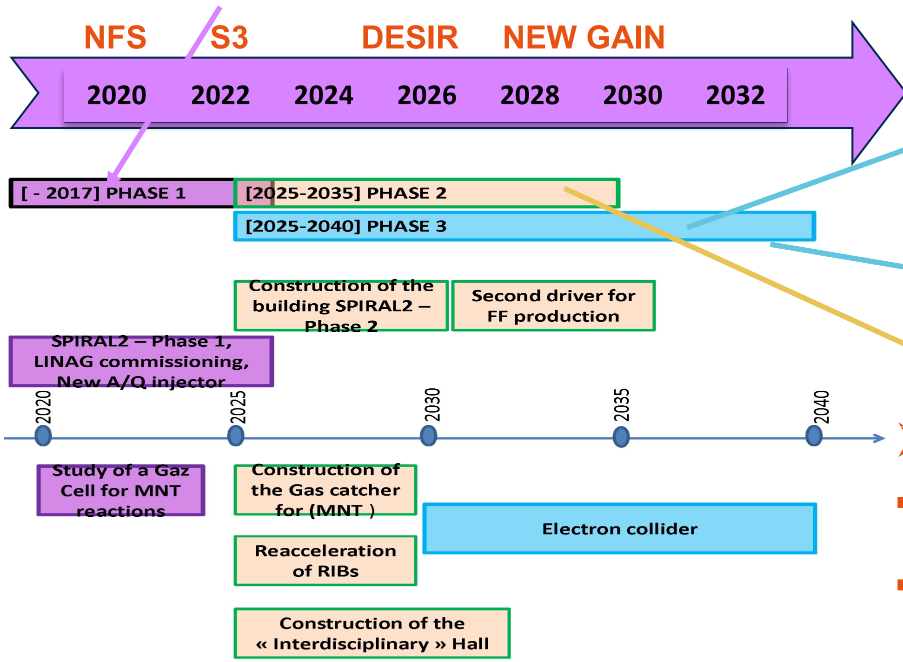


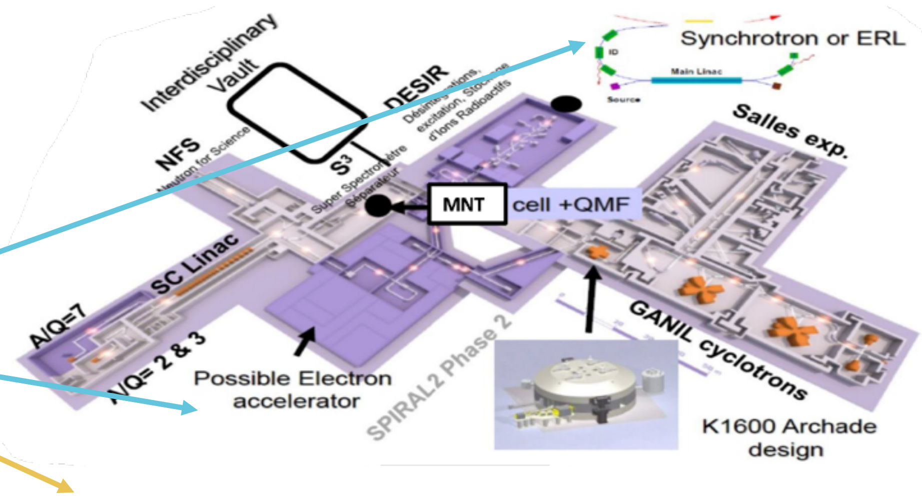


BARC (India), INFN (Italia), IFIN-HH (Romania), IFJ-PAN (Poland), SOREQ (Israel), INRNE-BAS (Bulgaria)

R#3: The **SPIRAL2 LINAC** will produce, in its energy range, the **most powerful beams** worldwide over a large variety of ions, providing to GANIL a unique potential to increase its **international competitiveness** in nuclear physics and associated applications. It is therefore of **very high priority to complete the construction of "SPIRAL2 phase 1"** as planned, including the **new heavy-ion injector.**

➢ **"SPIRAL2 phase 1"**





➢ **"GANIL future"** (GT02 & Michel Spiro committee):

- **Neutron rich Physics**: modest photo-fission RIB facility with electron scattering: ERL...
- **Interdisciplinary research and applications** : compact neutron source CANS, high-power irradiation station for R&D radioisotopes, demonstration of AB-NCT for cancer therapy...

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

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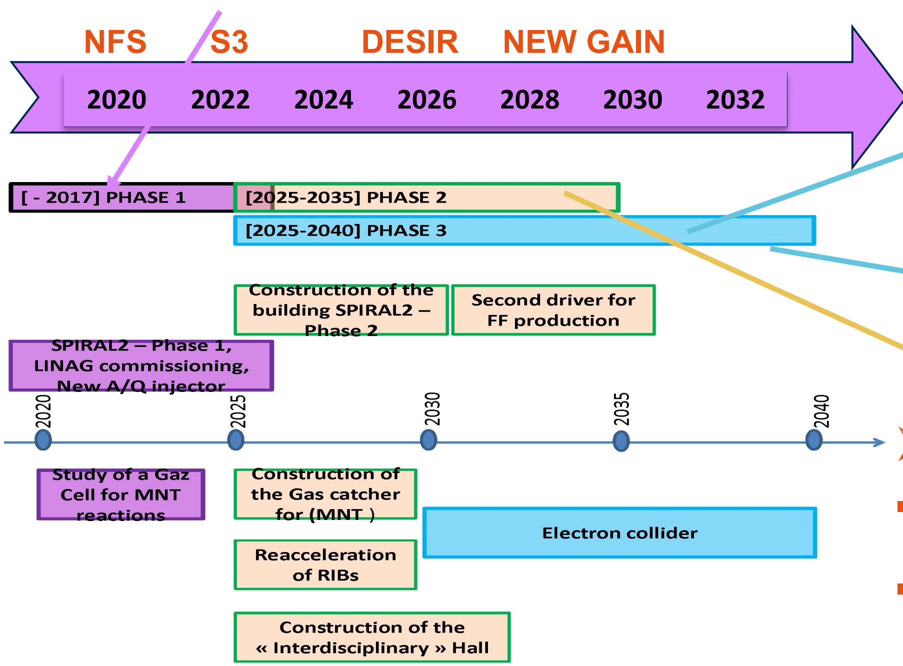
- **"SPIRAL2 phase 1"**



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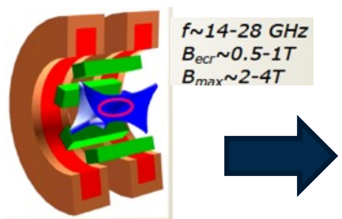
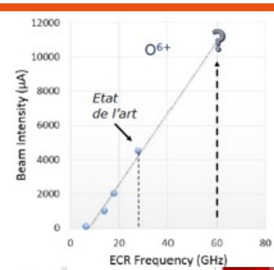
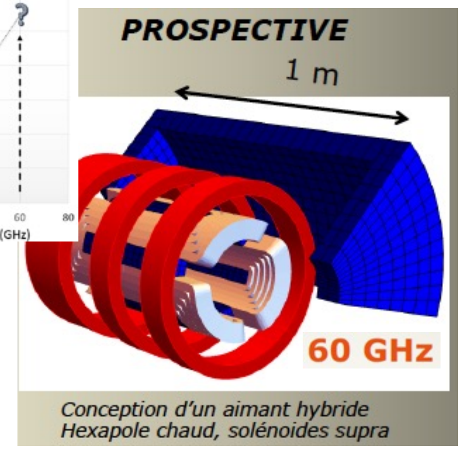
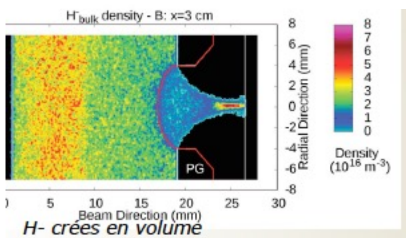
R#4: The development of **intense multi-charged heavy-ion ECR sources** is a priority R&D area to be strongly pursued. **Focus** should be maintained in particular on the development of **high-field high-frequency sources** and on a better understanding of the ionization process occurring inside the **ECR plasma**.









Other related R&D:

- **Irradiation targets and thin foils** (GANIL, IJCLab)
- Optimization of **Target-Ion-Source** (TIS) (GANIL IJCLab)
- Post-Acceleration efficiency and **charge boosters** (LPSC, GANIL)

R#5: IN2P3 teams are developing **very diverse** and **innovative R&D** projects in the field of **radioactive ions production** for nuclear physics. These crucial activities should be strongly supported in the long term but should also try to better **focus** on the **most promising** and **priority developments.**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Superconducting RF Cavities & High-Power Proton LINACs (SCPL)

Superconducting RF Cavities & High-Power Proton LINAC (SCPL)

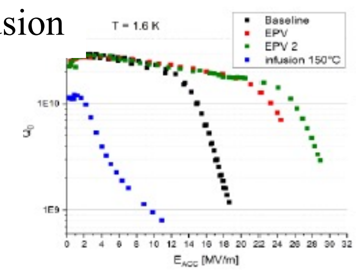
The main objectives for **SCPL** research program:

- Better understand the physics of SRF regime to **optimize** the **performance** of **Nb** or other **new materials** in terms of accelerating gradient and quality factor (cost)

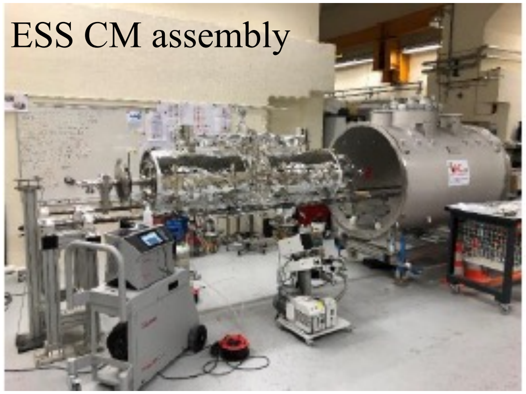
- Better understand the physics of high-intensity hadron beams to improve **simulation tools** and **stability** and **control** during operation

- Improve **reliability** and **efficiency** of the critical technologies for future high-power linacs

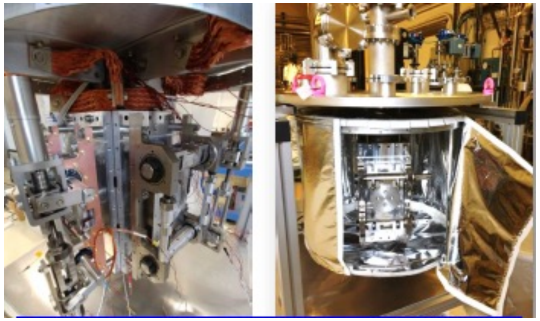
N-infusion



ESS CM assembly



ISO 5 cleanroom with 4 RF test stands, RF power source and equipment adapted for mass production (8 couplers conditioning in a raw)



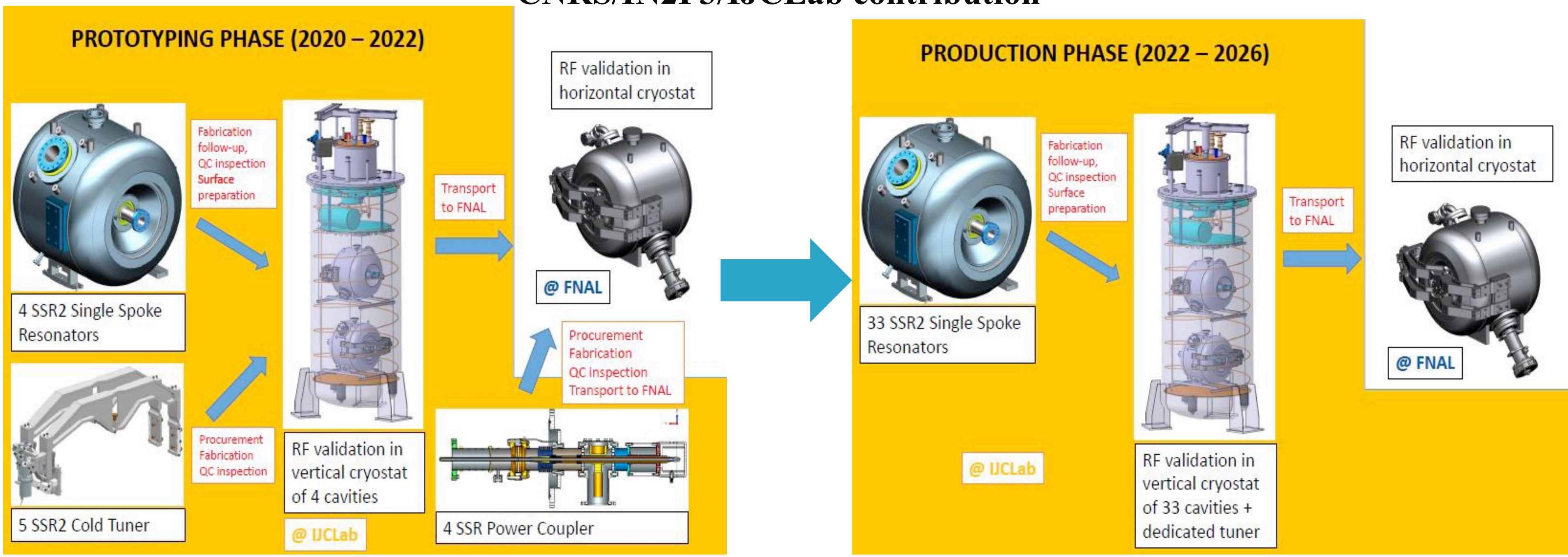
LN2 cryostat & insert (T=77K), testing of four FACTS

Fast Active Cold Tuning System (FACTS) & Piezo tuning sytem

R#6: The contribution to the construction of **PIP-II** should become a **top priority** in the **5** next years for IN2P3. This contribution is indeed fully coherent with the world-leading expertise of IJCLab teams on **spoke cavities** and will allow further enhancing their skills and international visibility in the field of SRF technology R&D

- **International LBNF/DUNE project PIP-II** → world's most intense beam of neutrinos with 1.2 MW proton beam

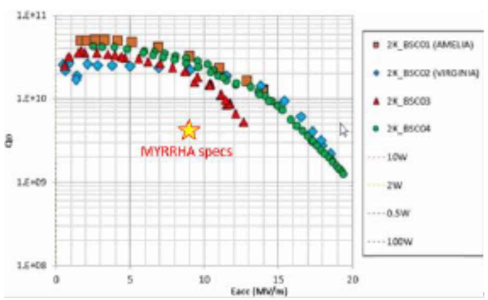
CNRS/IN2P3/IJCLab contribution



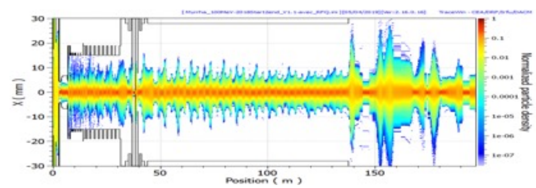
R#7: IN2P3 teams should pursue and reinforce their **innovative R&D** on **high-power linac reliability**, in particular on the demonstration of fault-recovery procedures (possibly using machine learning methods). In this context, a participation to the **construction** of **MINERVA (MYRRAH)**, which will be a unique full-scale test-bench to explore, develop and demonstrate these reliability-oriented concepts, is **highly recommended**.

- **MYRRHA** ADS demonstrator **– MINERVA Phase 1:** 100 MeV Acc + ISOL (2016-2026)

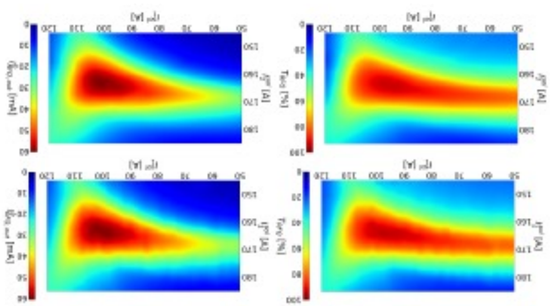
CNRS/IN2P3/IJCLab-LPSC-IPHC contribution



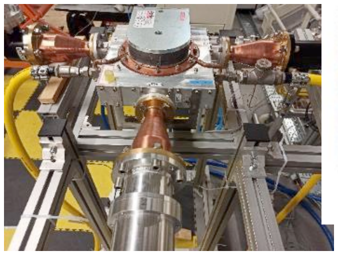
Vertical tests of the Spoke cavities



Beam horizontal transverse density

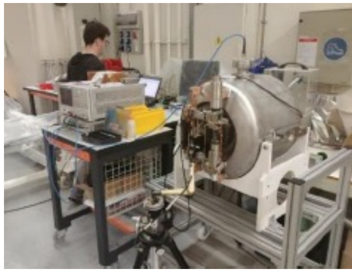


Comparison between the experimental data (top) and the model predictions (bottom) for the RFQ transmission (left) and the beam current measured at the exit of the RFQ (right) during a solenoids scan with Teal = 130 mm.

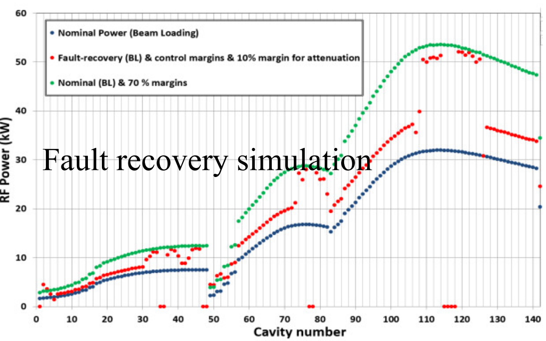


Vacuum vessel delivered @ SUPRATECH

Elementary brick



Test at 300K of the tuning system

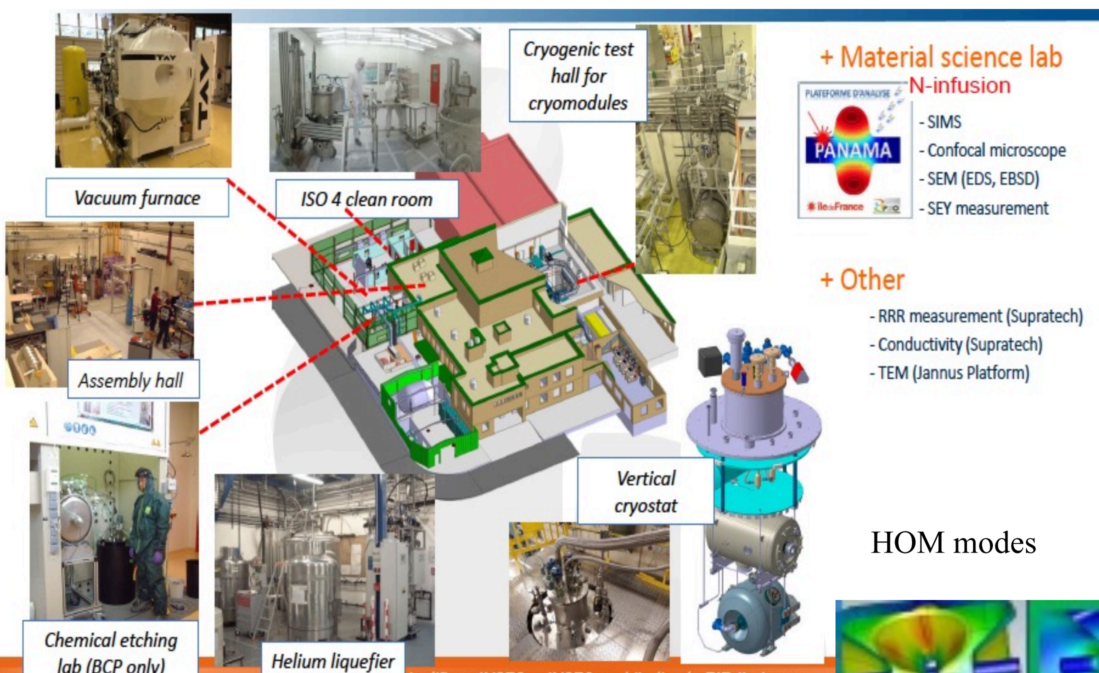


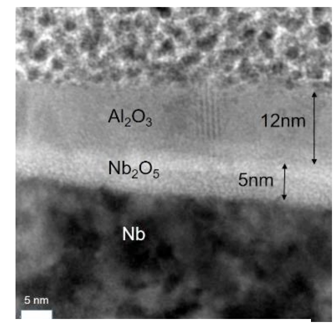
Fault recovery simulation

Superconducting RF Cavities & High-Power Proton LINAC (SCPL)

R#8: The R&D on **SRF cavities** and **associated ancillaries** (couplers, tuners) is a **priority area** to be strongly pursued. This is crucial in view of future IN2P3 high-priority projects, like **FCC or ILC**, in which IN2P3 teams will need to ensure a key role in the construction phase in close partnership with industrial partners. Based on their flagship SRF expertise, the IN2P3 teams should develop a **more prioritized and focused R&D roadmap.**

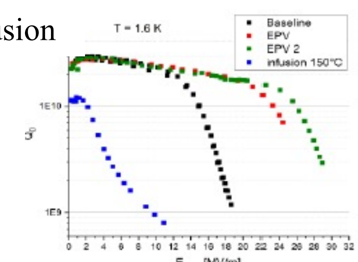
SUPRATECH platform at IN2P3 - IJCLab





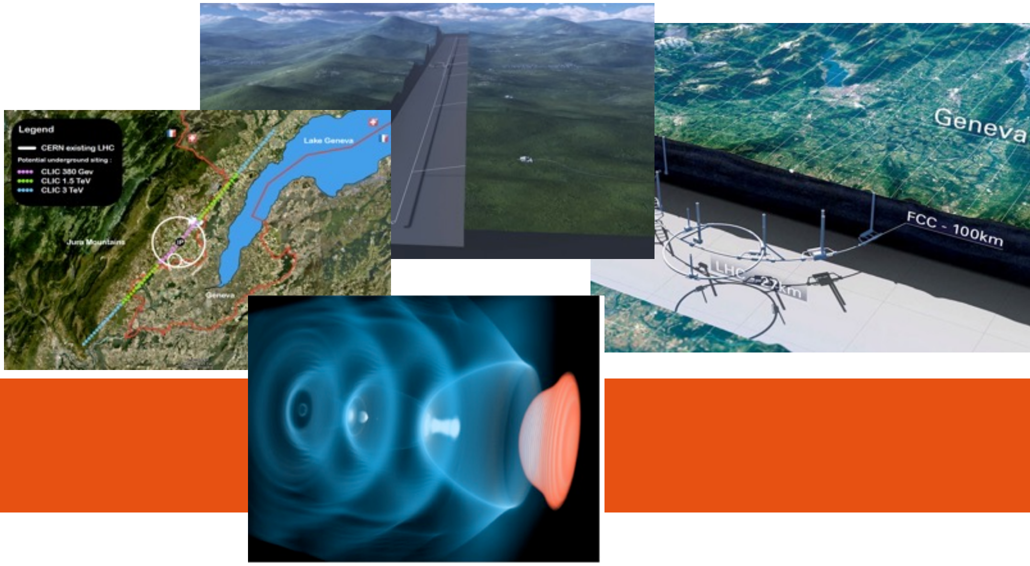
Production of thin film by ALD

N-infusion



HOM modes

MYRRHA FPC
Power 80 KW CW
@ 352 MHz



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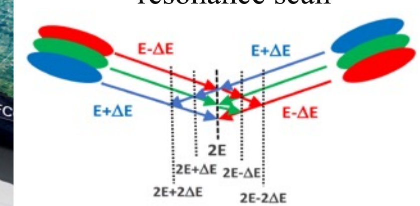
Laser Plasma Accelerators & High-Energy Colliders (LPAC)

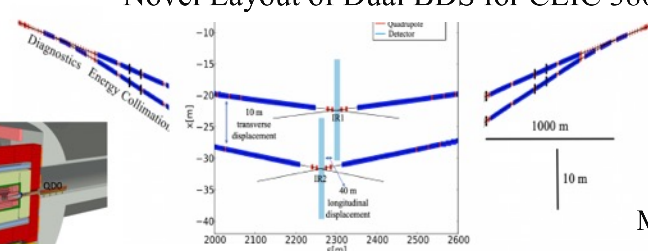
The main objectives for the **LPAC** research program:

- Better understand and master the **accelerator and beam physics of high-energy colliders** and to identify and develop the most appropriate technologies
- Strongly support the developments of the **CERN colliders projects**
- Explore **advanced innovative accelerator concepts** able to push the high-energy and high-precision frontiers present limits

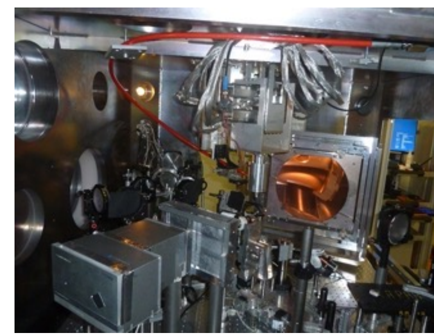
Monochromatization without crab crossing and integrated resonance scan



Novel Layout of Dual BDS for CLIC 380 GeV



CLICdet with QD0 outside detector

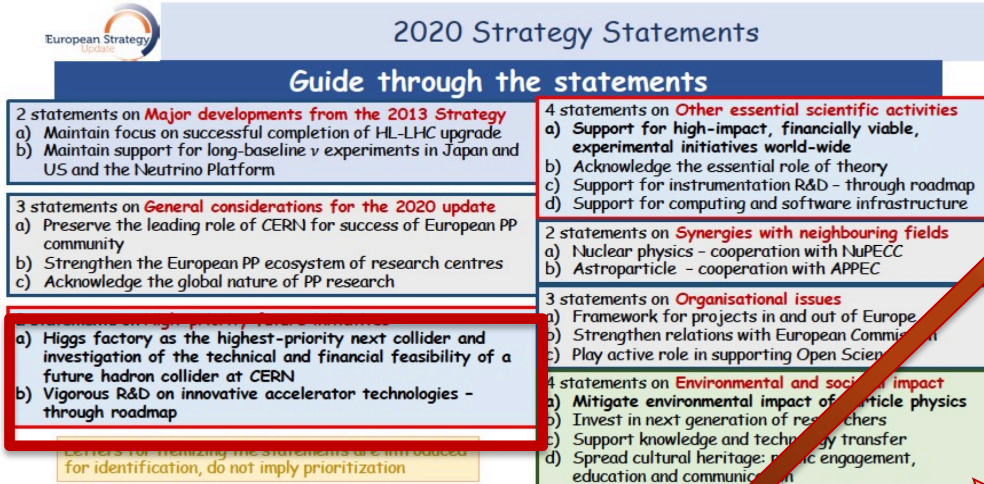


Supercritical H_2 gas jet interaction - PHELIX laser (GSI)

Multi-PW beams of Apollon CILEX

Laser Plasma Accelerators & High-Energy Colliders (LPAC)

➤ EPPSU: the e⁺e⁻ Higgs factories is the highest priority in HEP


European Strategy Update

2020 Strategy Statements

Guide through the statements

2 statements on Major developments from the 2013 Strategy
a) Maintain focus on successful completion of HL-LHC upgrade
b) Maintain support for long-baseline ν experiments in Japan and US and the Neutrino Platform

3 statements on General considerations for the 2020 update
a) Preserve the leading role of CERN for success of European PP community
b) Strengthen the European PP ecosystem of research centres
c) Acknowledge the global nature of PP research

a) Higgs factory as the highest-priority next collider and investigation of the technical and financial feasibility of a future hadron collider at CERN
b) Vigorous R&D on innovative accelerator technologies – through roadmap

for identification, do not imply prioritization

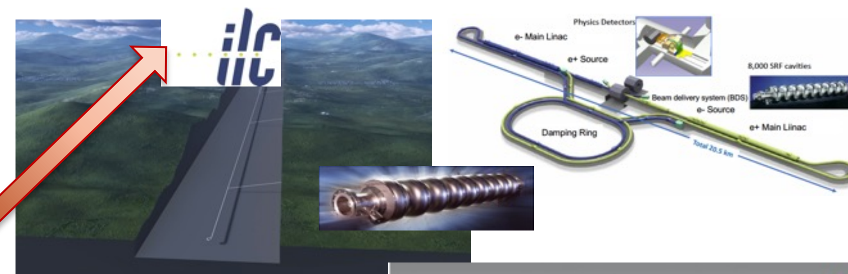
4 statements on Other essential scientific activities
a) Support for high-impact, financially viable, experimental initiatives world-wide
b) Acknowledge the essential role of theory
c) Support for instrumentation R&D – through roadmap
d) Support for computing and software infrastructure

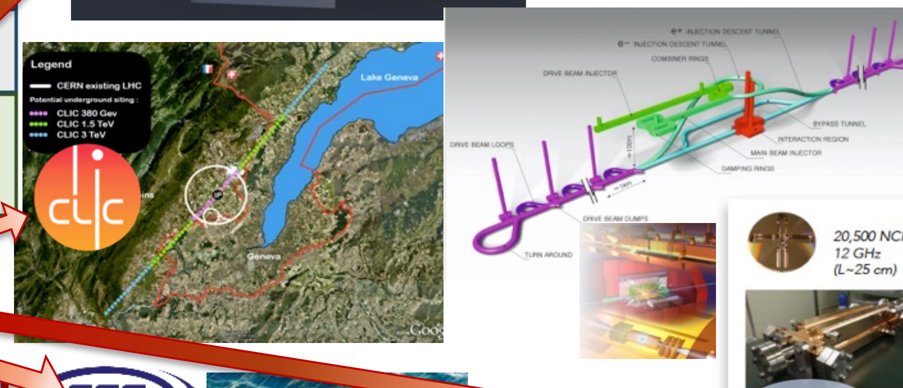
2 statements on Synergies with neighbouring fields
a) Nuclear physics – cooperation with NuPECC
b) Astroparticle – cooperation with APPEC

3 statements on Organisational issues
a) Framework for projects in and out of Europe
b) Strengthen relations with European Commi...
c) Play active role in supporting Open Scien...

4 statements on Environmental and soci... impact
a) Mitigate environmental impact of ...ticle physics
b) Invest in next generation of res...chers
c) Support knowledge and techn...gy transfer
d) Spread cultural heritage: p...c engagement, education and communic...n

Note: H. Abramowizc ESG January 2020.





➤ Technology View on Relative Timelines

Timeline	~5	~10	~15	~20	~25	~30	~35
Lepton Colliders – Linear and Circular:							
SRF-LC/CC	Proto/pre-series	Construction		Operation		Upgrade	
NRF–LC	Proto/pre-series	Construction		Operation		Upgrade	
Hadron Collier – Circular:							
14~16T Nb_3Sn		Short-model R&D		Prototype/Pre-series		Construction	
12~14T Nb_3Sn	Short-model R&D		Proto/Pre-series	Construction		Operation	
9~12T Nb_3Sn	Model/Proto/P re-series		Construction		Operation		Upgrade
6~8T NbTi	Proto/ Pre-series	Construction		Operation		Upgrade	

Note: LHC experience: NbTi, 10 T R&D started in 1980's and 8.3 T Production started in late 1990's, after ~ 15 years

A. Yamamoto, 190513b/updated 190618a

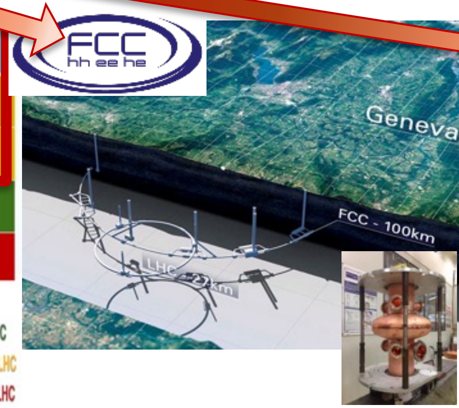
➤ Higgs Factories

Higgs Factories	Readiness	Power-Eff.	Cost
ee Linear 250 GeV			
ee Rings 240GeV/tt			
μμ Collider 125 GeV			*
ALIC 125 GeV		?	?

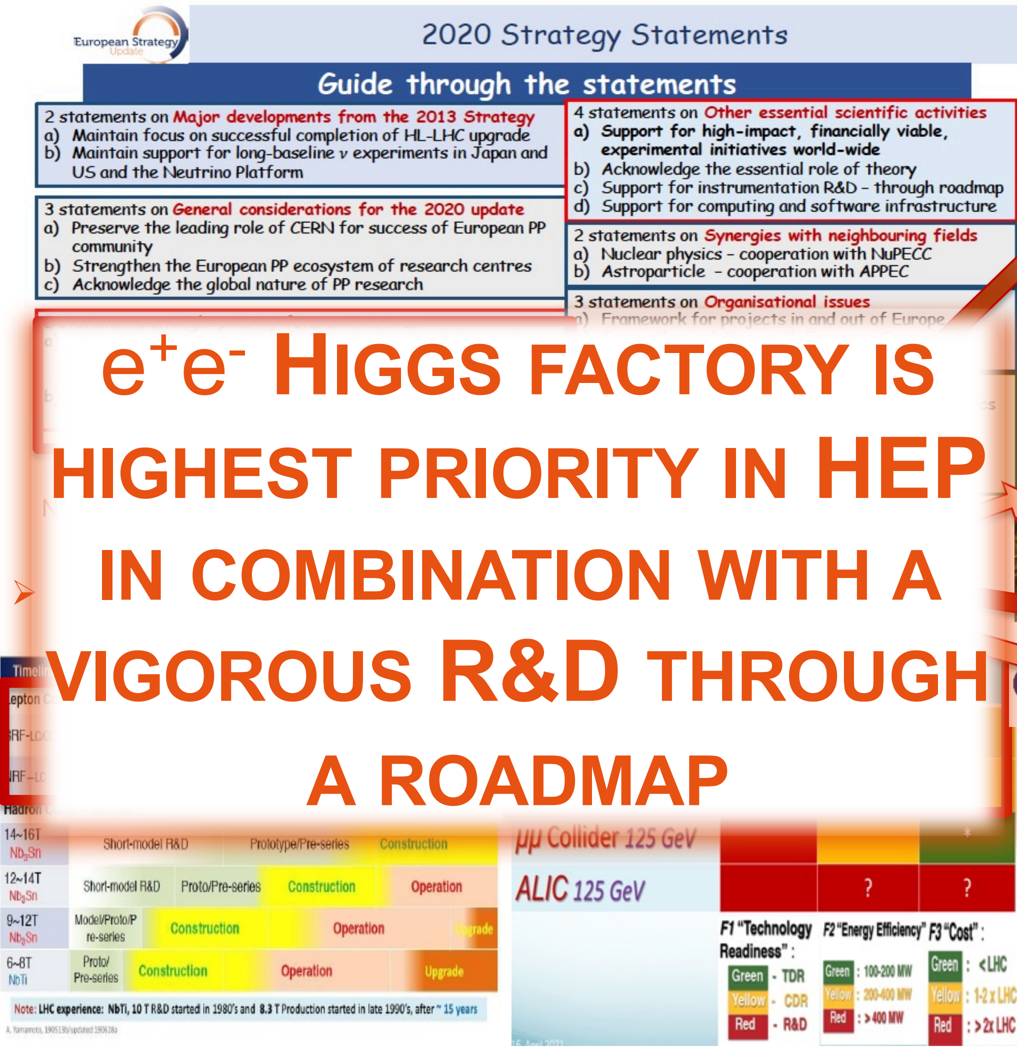
F1 "Technology Readiness": Green - TDR, Yellow - CDR, Red - R&D

F2 "Energy Efficiency": Green : 100-200 MW, Yellow : 200-400 MW, Red : > 400 MW

F3 "Cost": Green : < LHC, Yellow : 1-2 x LHC, Red : > 2x LHC



- **EPPSU**: the **e⁺e⁻ Higgs factories** is the **highest priority** in **HEP**



e⁺e⁻ HIGGS FACTORY IS HIGHEST PRIORITY IN HEP IN COMBINATION WITH A VIGOROUS R&D THROUGH A ROADMAP

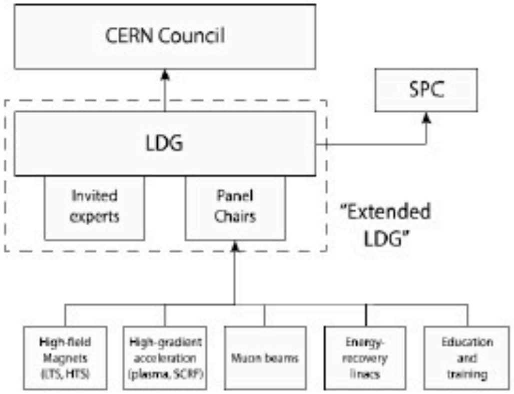
Higgs factory technology is ready, but with different degrees of maturity

LDG: Accelerator R&D Roadmap

CERN and the national laboratories in Europe (LDG) are charged by Council to define a Roadmap for Accelerator R&D

Topics:

- High-field magnets
- High-gradient accelerations (plasma, SCRF)
- Muon beams
- Energy recovery linacs
- Education and training



Panel chairs:

	High Field Magnets Low Temp & HTS	High Gradient Acceleration (plasma)	Muon Collider	ERL	High Gradient Accelerating Structures (sc & nc)
chair	Pierre Vedrine, IRFU	Ralph Assmann, DESY & INFN	Daniel Schulte, CERN	Max Klein, Liverpool	Sebastien Bousson, IJCLab
co-chair	Luis Garcia-Tabares Rodriguez, CIEMAT	Edda Gschwendtner, CERN	Nadia Pastrone, INFN	Andrew Hutton, JLAB	Hans Weise, DESY

Timeline

- **September 2020 Council**: presentation of process and outline structure
- **December 2020 Council**: presentation of panel composition and process scope
- **September 2021 Council:** presentation of LDG interim progress report for feedback
- **December 2021 Council:** presentation of final roadmap report

LDG: Accelerator R&D Roadmap

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IN2P3 IS PARTICIPATING ACTIVELY IN THE PROCESS IN MAINLY ALL PANELS

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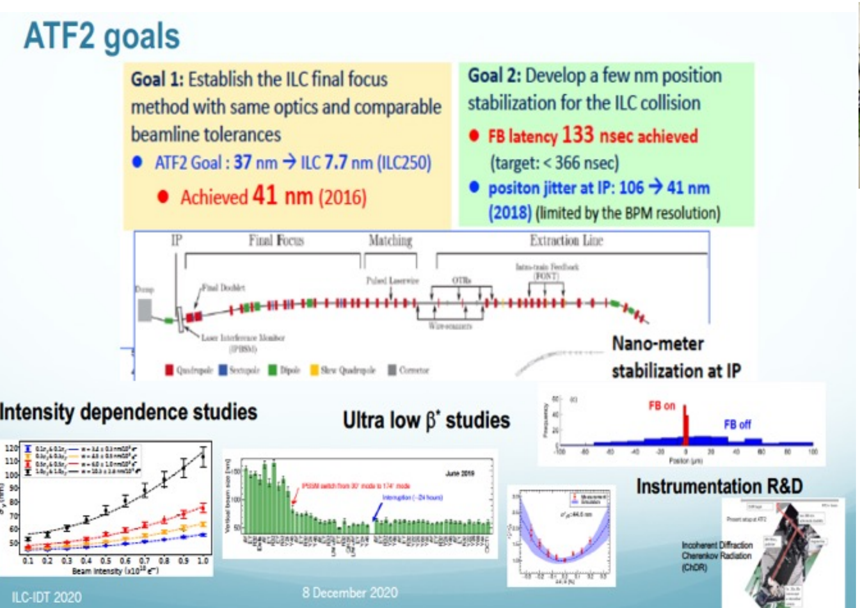
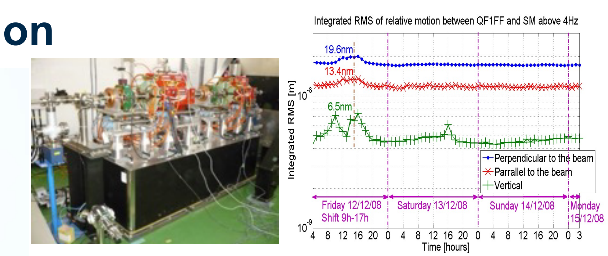
  on of process and
  ucture
- **r 2020 Council**:
  on of panel
  on and process
- **2021 Council:**
  f LDG interim
  t for
- **l Council:**
  nal

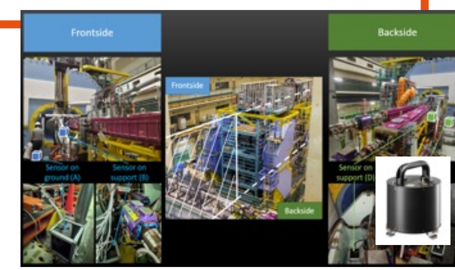
R#9: It is vital for the IN2P3 HEP accelerator community to ensure an appropriate **contribution to the design, construction** and **upgrade of high-energy** and **high-precision colliders**, in strong cooperation with **CERN** and with other institutes. IN2P3 teams, who have developed a series of **'niche' expertise** in the field, should in particular reinforce their participation to the on-going international conceptual studies and associated R&D programs for next-generation colliders, with a **specific priority** on the development of the FCC project.

- **IRs Nanobeam sizes and stabilization**

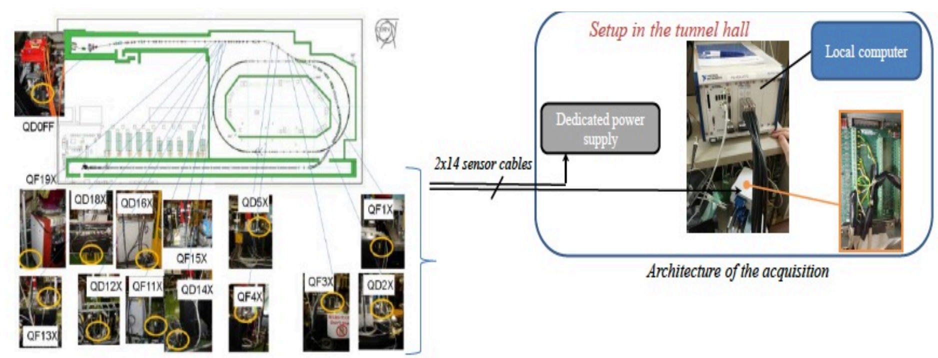




Coherence study at ATF2

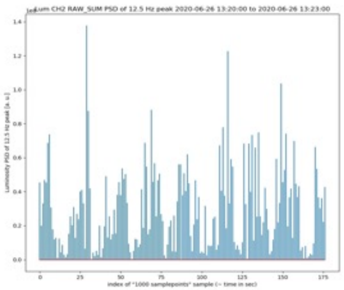


4 seismic sensors (2 each side)
BELLE II

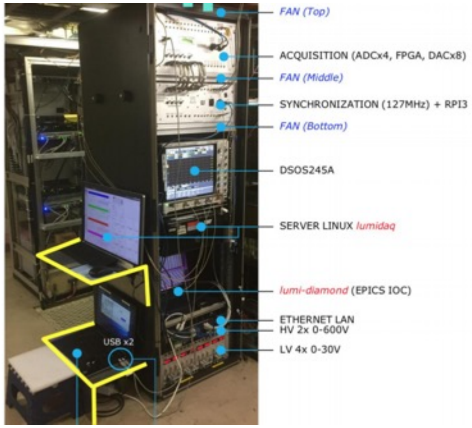


Laser Plasma Accelerators & High-Energy Colliders (LPAC)

Fast Luminosity monitoring

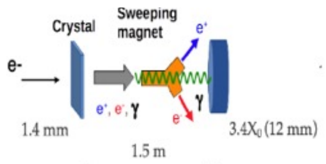


Power Spectral Density component at 12.5 Hz reconstructed during 3 minute scan: injections are visible lasting 10 seconds every 20 seconds !

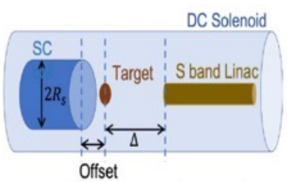


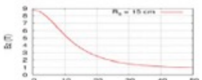
High-Intensity e^+ sources

Hybrid target

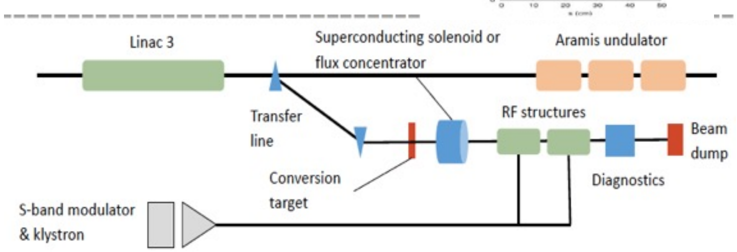


AMD based on SC solenoid



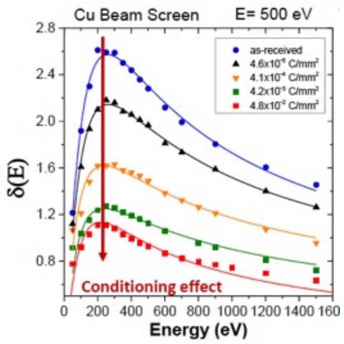


e+ production test in SwisFEL

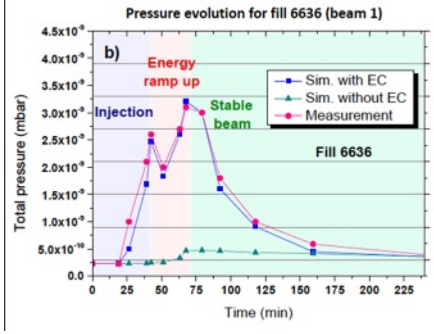


Dynamics Vacuum and Material studies

SEY measurements

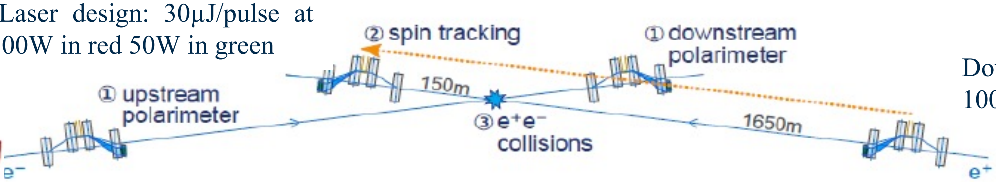


LHC measurements versus DYVACs simulations



e^+e^- Polarimetry

Upstream Laser design: 30μJ/pulse at 1.8 MHz, 100W in red 50W in green

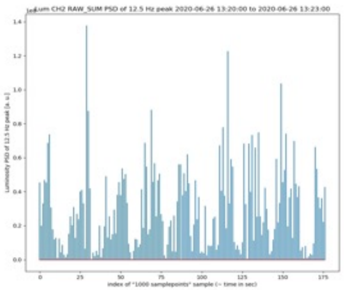


Downstream Laser design: 100mJ at 2KHz

Compton polarimeter + Spin tracking + e^+e^- collision data

Laser Plasma Accelerators & High-Energy Colliders (LPAC)

Fast Luminosity monitoring



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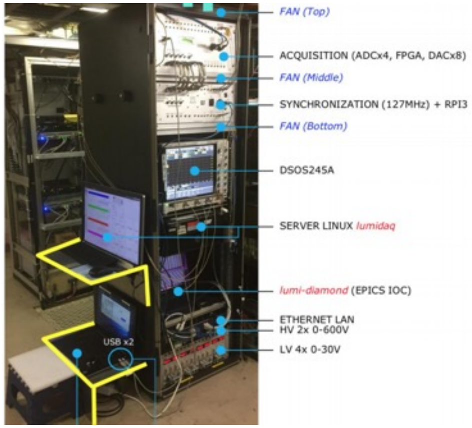

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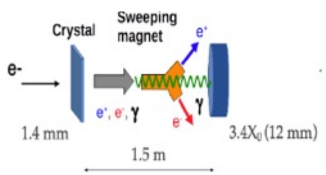
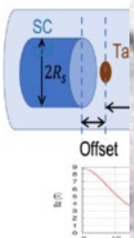
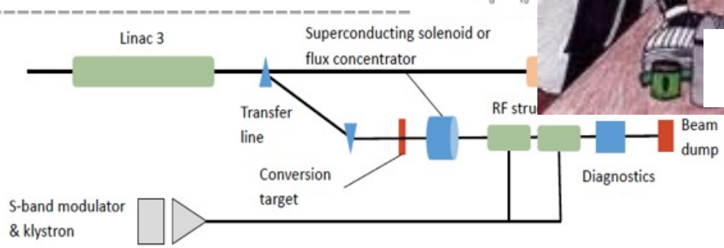
Hybrid target

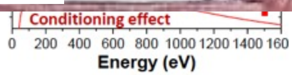


AMD based on



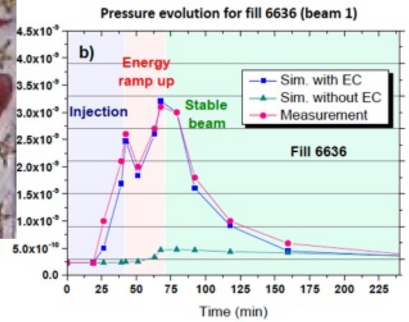
e+ production test in SwisFEL





terial studies

measurements versus Cs simulations



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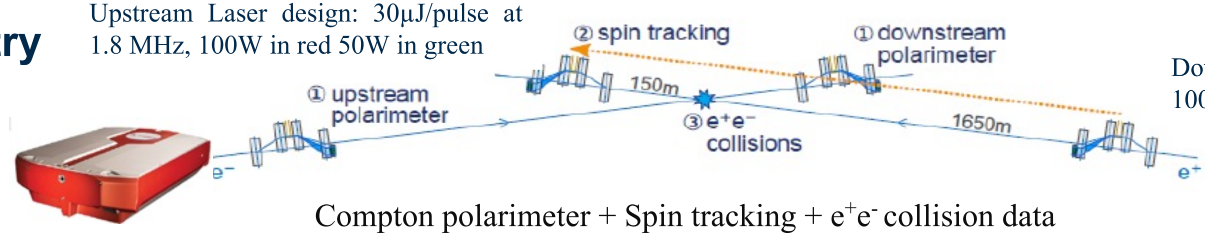


Downstream Laser design: 100mJ at 2KHz

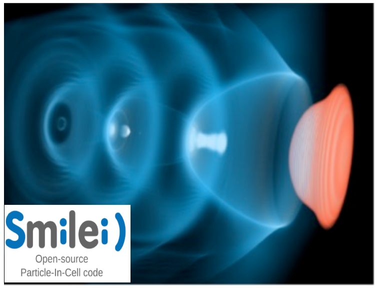
Compton polarimeter + Spin tracking + e^+e^- collision data

Institut national de physique nucléaire et de physique des particules

Laser Plasma Accelerators & High-Energy Colliders (LPAC)

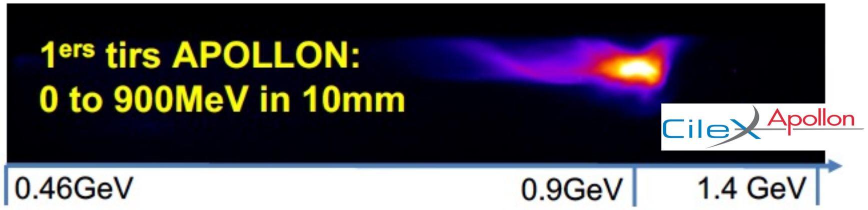
R#10: Laser-driven acceleration is presently making fast progress with the advent of PW class laser drivers. 10 GeV energy range for electrons and 100 MeV for protons are within reach of **emerging experimental facilities** like **APOLLON** and **exploratory programs** should be actively pursued. The building of a prototype for multistage acceleration of electrons at the GeV level with at least **10 Hz repetition rate** aiming at demonstrating the reliability of this technology, such as the **PALLAS** project, is of **high priority**. It will allow fostering French collaboration at the national level and serve as a dedicated test facility in the frame of the European EuPRAXIA initiative.

- **Modelling and simulations**



Fast simulations for optimisation
Reliable for tolerance studies

- **Explore limits of frontier facilities**



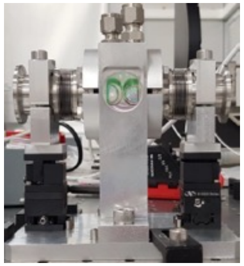
Supercritical H_2 gas jet interaction - PHELIX laser (GSI)

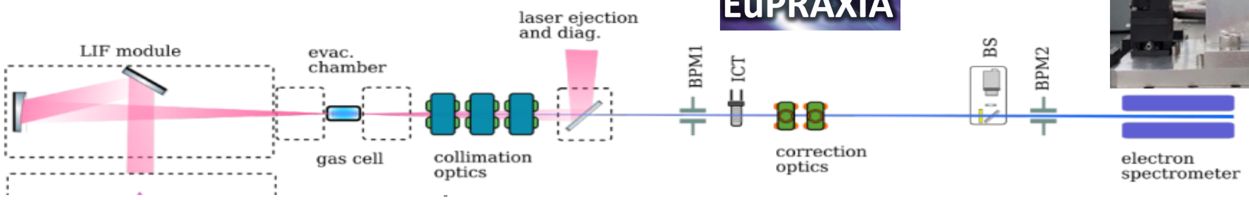
- **Build demonstrators**

PALLAS project

EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS
EuPRAXIA

Plasma cell





Institut national de physique nucléaire et de physique des particules

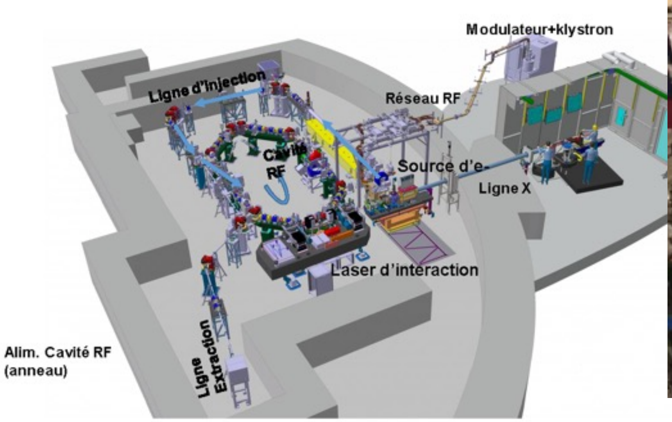
cnrs

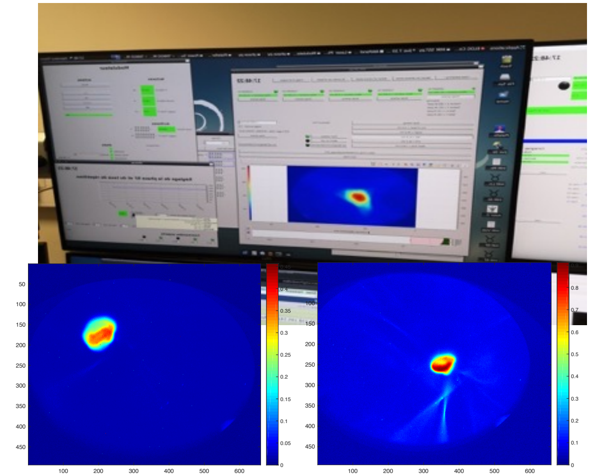
Innovative electron & Light Sources (IELS)

Innovative electron & Light Sources (IELS)

R#11: The IJCLab R&D program on **electrons/laser interaction** and on associated **optical cavities** has developed a unique worldwide renowned expertise that can serve several **innovative applications**. These activities should be pursued with a stronger focus on HEP applications and on R&D for innovative acceleration processes.

- **ThomX ICS demonstrator**

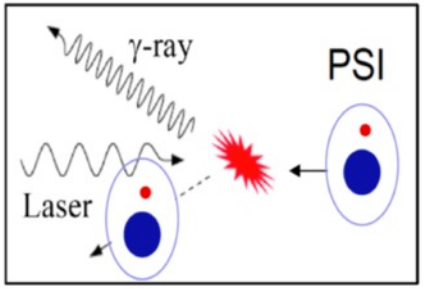


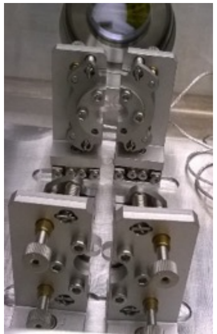


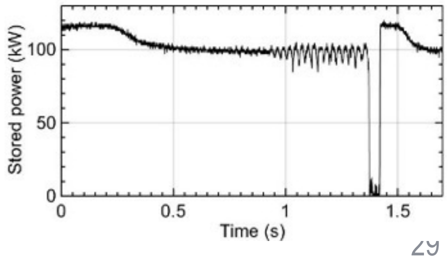
- **e^+e^- Polarimetry** (see LPAC)

- **Gamma factory**

Collisions of a laser beam with ultra-relativistic atomic beam of Partially Stripped Ions (PSI), circulating in the SPS ring.

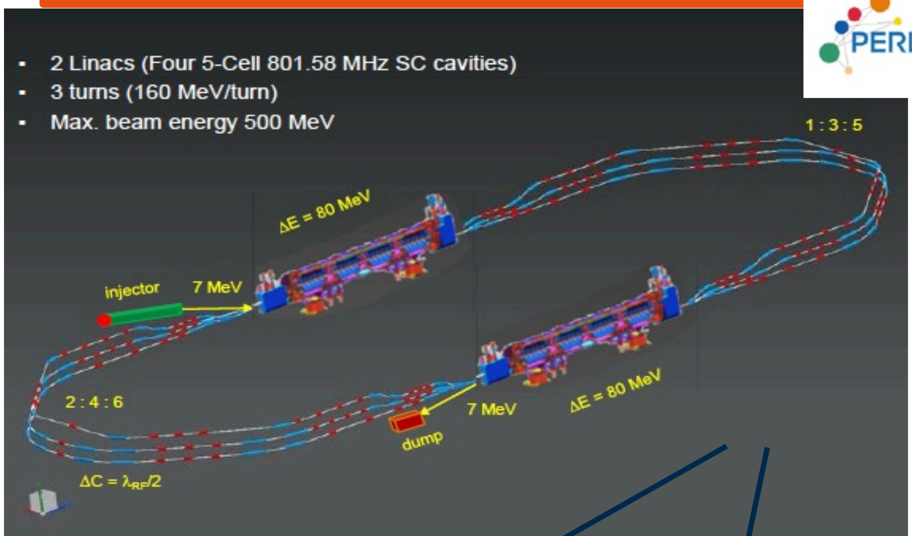


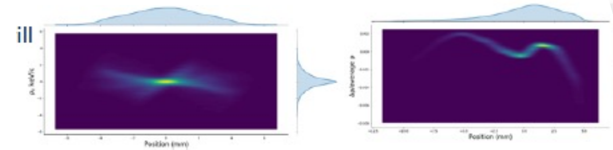




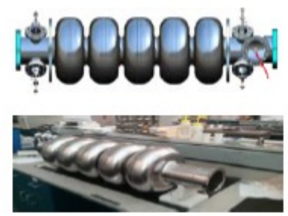
Innovative electron & Light Sources (IELS)

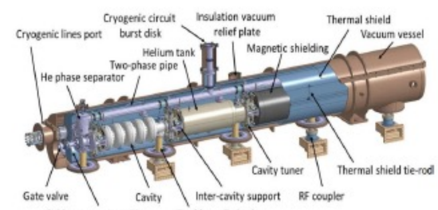
R#12: **ERL** is a very **promising technology** for future electron accelerators. The ambitious **PERLE@Orsay** initiative should be strongly supported, provided that an adequate international participation to the project can be settled.





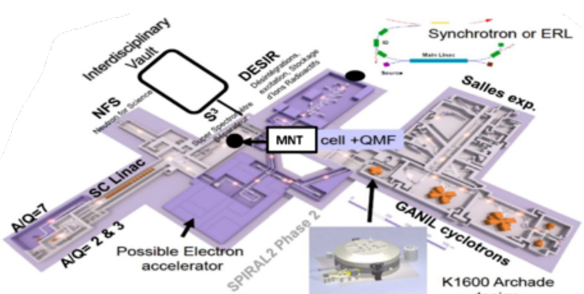
PERLE Injection System

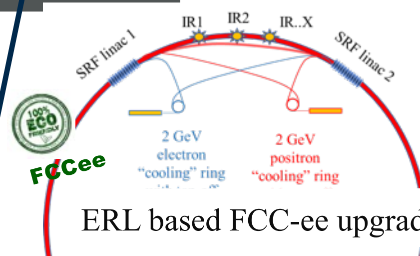




PERLE SRF System

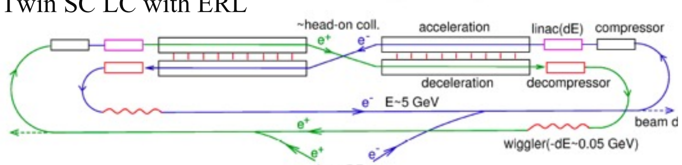
ERL e- scattering post-DESIR

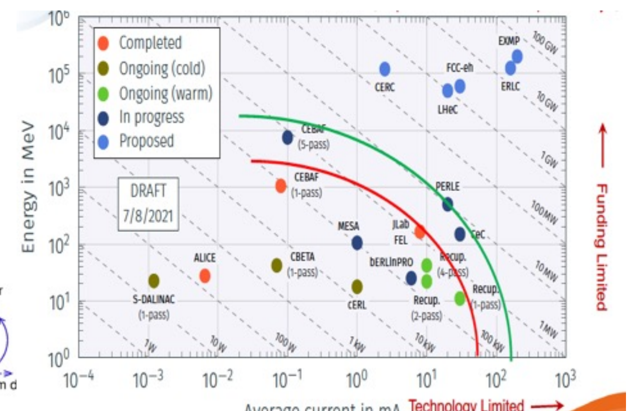




ERL based FCC-ee upgrade

Twin SC LC with ERL





Transverse aspects

Transverse Aspects

R#13: It is of prime importance to guarantee a suited scientific and technical support for accelerators development in terms of **human resources**, infrastructures & platforms and **specific skills** like charged **particle dynamics**, **RF**, **magnetism**, **cryogenics** and **vacuum** among others. It would be also highly valuable to **strengthen** the connection between the **accelerator** and the **detector** IN2P3 communities in order to enhance exchanges of know-how and of innovative technological ideas. This particularly applies to the crucial R&D activities on **beam instrumentation**

Transverse instrumental skills like typically:

- mechanics
- electronics and electro-technics
- IT (code developments, data analysis, control/command,..)
- matter-particle interaction and electromagnetic radiative phenomena
- plasma components & technologies
- optics & laser
- Technology platform supporting accelerator R&D

High-Impact Projects for Accelerator Science at IN2P3

Engage IN2P3 resources to develop at MTP:

- High-visibility **Very Large Research Infrastructures** providing leadership in **accelerator-based science;**
  - *Completion of the construction & commissioning of **SPIRAL2 phase 1** and associated R&D on the production of radioactive ions.*
  - *Design of the **FCC and associated R&D on next-generation HEP colliders**, including ERL options (with **PERLE@Orsay** as a possible demo).*
  - *Prototyping and construction of the **PIP-II linac***
  - *Development of the **MYRRHA-MINERVA** and associated R&D on accelerator reliability*
  - *Development of a CANS demo*

- Active exploratory program for **long term accelerator R&D** and to ensure a major role in **future international projects**.
  - *R&D on **Superconducting RF.***
  - *R&D on **laser-plasma acceleration** for electrons, focused on the development of a plasma accelerator demo (with PALLAS as a possible contribution to EuPRAXIA).*
  - *R&D on **ECR high-intensity ion sources**.*
  - *R&D on **laser-plasma acceleration for ions.***

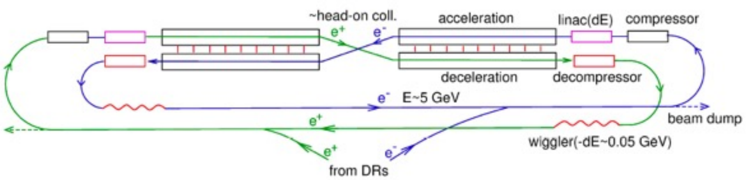
MERCI POUR VOTRE ATTENTION !

Beyond Higgs factories

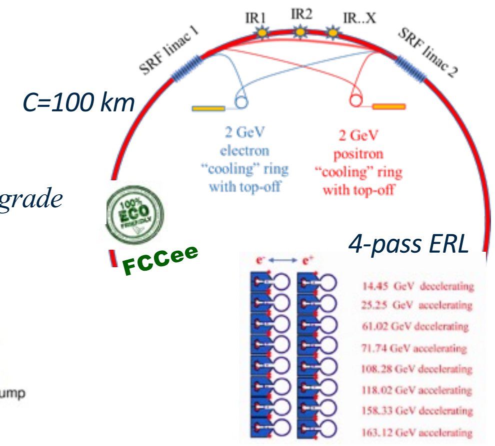
➢ Beyond Higgs factories…

- **Boosting the performances** of Higgs factories
  - **ERLs** for FCCee and ILC
  - **Plasma Injectors**
- **Muon colliders**
- **Advance Linear Collider e+e-**: HEP Energies in PWA
- Dreamt colliders…

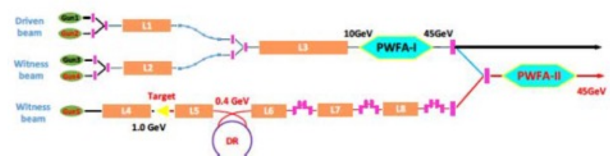
Twin SC LC with ERL



ERL based FCC-ee upgrade



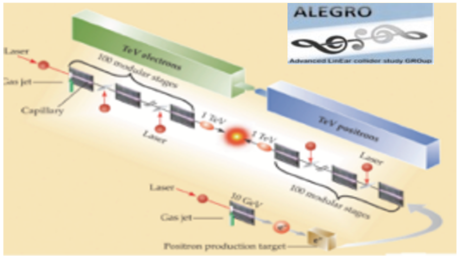
CEPC Injector Alternative: Plasma Accelerator up to 45GeV single stage)~120GeV (cascade)

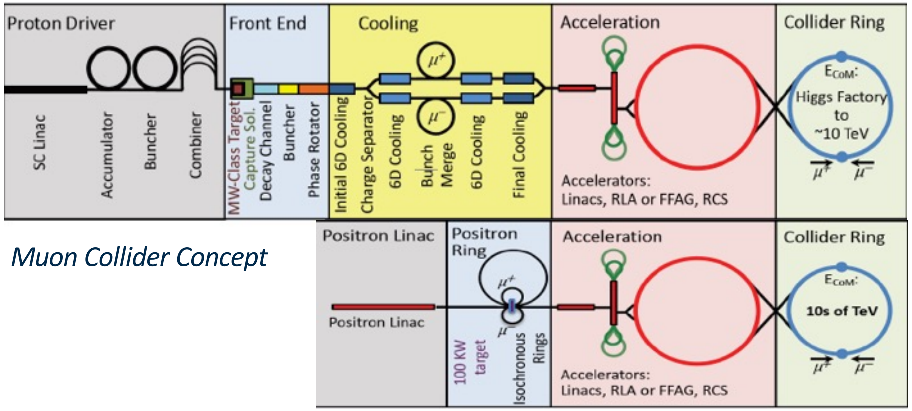


PERLE synergies

PALLAS synergies

e^+ synergies





Muon Collider Concept

CNRS contribution to EupRAXIA

Excellence Center for Laser Acceleration and FEL

Horizon 2020

3 French institutions have signed the EuPRAXIA Consortium Agreement : **CNRS, CEA and Soleil**

French contribution is structured around 2 main facilities and projects

LAPLACE

development of LPA and their applications

- **high repetition rate** (≥100Hz) LPA sources development
- **FEL** LPA-driven development, robust high quality beam LPA development (SOLEIL/LOA)

PALLAS

10 Hz, 150 MeV laser-plasma injector (LPI) test facility devoted to:

- **advanced online control** of LPI
- **plasma target** development for high beam beam quality
- beam transport for **staging**

In addition the following CNRS labs contribute to **EuPRAXIA clusters**

LLR : **multi-PW** driver LPA experimental demonstration at APOLLON, applications to HEP and other field, beam diagnostics and compact beam transport, and theory **simulations** and continuous development of PIC (Smilei)

LULI : **new advanced laser technology development** : Compressor, intensity stabilization, focal spot alignment stabilization, amplification stage, beam transport + bring benefit from its close links with the laser industrials partners to ensure the economic feasibility.

LPGP : R&D of optimised LPI in tailored plasma density profile and of specific **plasma components**, based **on novel discharge schemes** or laser ionised plasmas, suitable for **laser guiding over large propagation distances** and experimental tes