# ACCELERATOR AND MAGNET INFRASTRUCTURE FOR COOPERATION AND INNOVATION

A technology infrastructure to strengthen European excellence in the field of particle accelerators and superconducting magnets

European Commission

Horizon 2020
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# ACCELERATORS AND BIG MAGNETS FOR RESEARCH: A EUROPEAN EXCELLENCE

# ACCELERATOR AND MAGNET BASED RESEARCH INFRASTRUCTURES POSITION EUROPE AT THE FOREFRONT OF SCIENCE

European research laboratories originally devoted to particle and nuclear physics have set up large scale Technological Facilities that have become seminal for the realization of major Research Infrastructures in many scientific domains. Examples include the LHC at CERN in France/Switzerland where the Higgs boson was discovered, FAIR at GSI Darmstadt and SPIRAL-2 at GANIL Caen for nuclear physics, W7X in Germany and ITER in France for the field of nuclear fusion, the European XFEL in Germany, the world's largest X-ray laser, and the ESS in Sweden, which will be the world's most powerful neutron source, for the fields of material, chemical and biological sciences, ISEULT in France for brain imaging, and many other smaller scale but leading-edge infrastructures, projecting Europe to an undisputed position of scientific worldwide leadership.

European Technological Facilities and associated industries are also contributing to the construction of research infrastructures in the world, for instance in Japan  the JT60 tokamak and IFMIF-EVEDA for fusion, and in US the LCLSII light source and the PIP-II particle physics accelerator, capitalizing on their participation to similar European projects.

# THE CONCEPT OF THE ACCELERATOR AND MAGNET EUROPEAN TECHNOLOGY INFRASTRUCTURE : THE AMICI PROJECT

The construction of so many RIs has been made possible thanks to the collaboration between the different European Technological Facilities (TFs) that have developed high technology systems built to unparalleled quality standards, spanning all the necessary activities of research, development, fabrication, assembly and verification and the association of Industry for mass production.

The ensemble of these TFs together with the ecosystem they have generated with industry can be viewed as an overall Accelerator and Magnet European Technology Infrastructure distributed among several centers. The goal of the AMICI* (Accelerator and Magnet Infrastructure for Cooperation and Innovation) H2020 project was to propose a new, efficient and sustainable collaboration/production model by means of Cooperation and Innovation.

Federating and profiling the different Technological Facilities in Europe through the coordination of an AMICI consortium will contribute to render the competences and Technical Platforms of the Technological Facilities for the realization of the large future Research Infrastructures complete and complementary, therefore enabling large synergetic gains.

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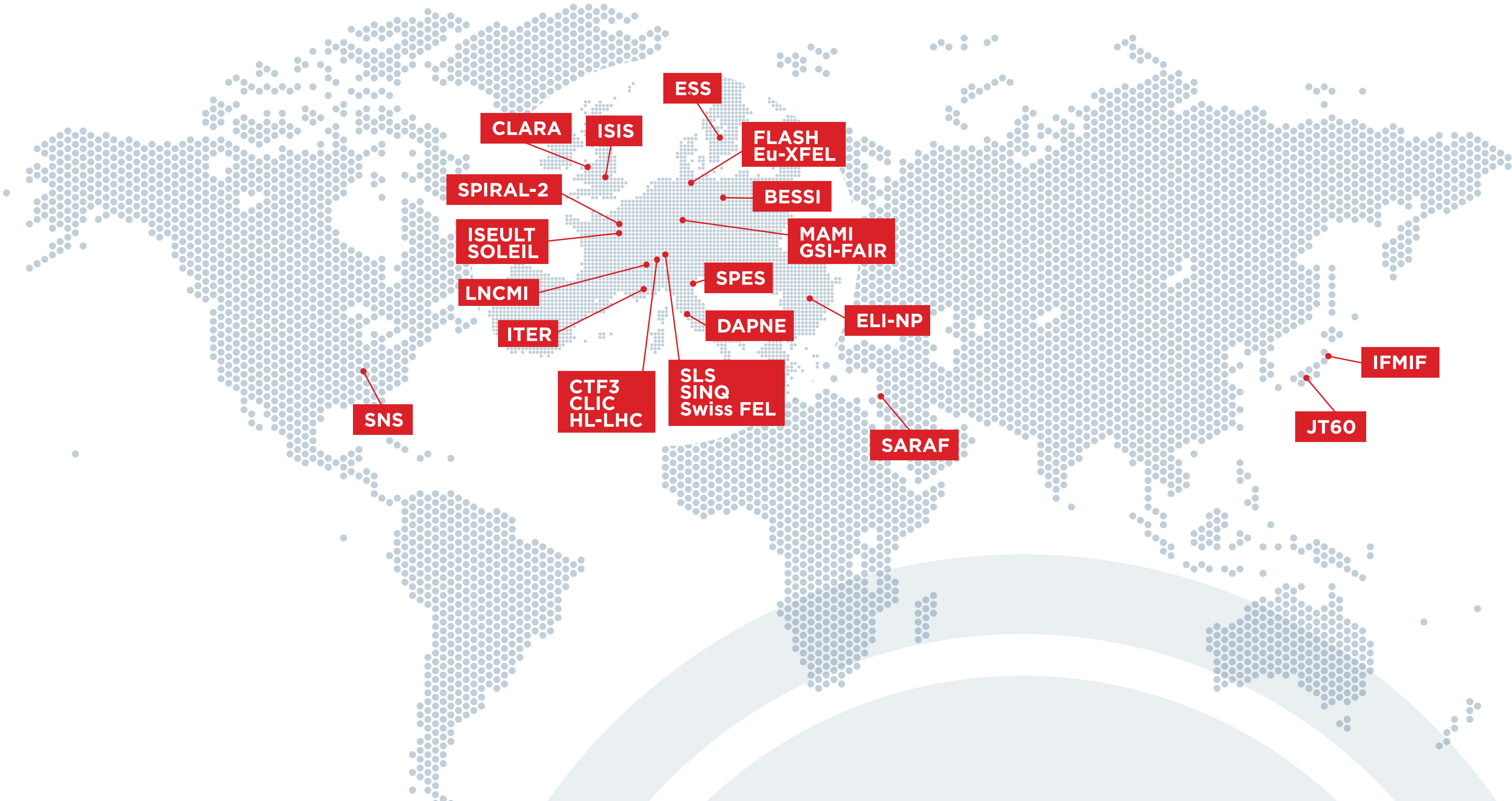
ESS
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IFMIF
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CTF3
CLIC
HL-LHC
SLS
SINQ
Swiss FEL
JT60
SARAF

# THE AMICI TECHNOLOGY INFRASTRUCTURE

While **Research Infrastructures** are facilities aimed at conducting top-level research activities in a given scientific field, the **Technology Infrastructure** is a network of facilities based on the same technologies serving different domains of research.

The AMICI accelerator and SC magnet **Technology Infrastructure** includes several **Technological Facilities**, located at European research laboratories, that are dedicated to the development of accelerator components and superconducting magnets, available to collaborations with industrial partners.

AMICI Technology Infrastructure entails numerous **Technical Platforms**, i.e. installations which can be used to develop, fabricate, test and measure technological components of accelerators. These platforms are sophisticated R&D platforms for key technologies and large-scale facilities for assembly, integration and verification.

The technological facilities employ large concentrations of dedicated, highly-skilled personnel and have established long-term relationships with industry.

*The detailed descriptions of the 10 AMICI Technological Facilities are available in the annex.*

# THE AMICI TECHNOLOGICAL FACILITIES WITH THEIR TECHNICAL FIELDS OF EXPERTISE

## BEAM

Creating, manipulating and controlling charged particle beams is the core goal and challenge of particle accelerator technology. The Technical Platforms under this category consist mostly of particle source test benches, beam test facilities including beam diagnostics. It also includes vacuum, metrology and electronics laboratories closely associated to beam dynamics and beam stabilization.

## MAGNET

Magnet technology, be it normal conducting, permanent and superconducting magnets, is the key technique to high-energy beam transport. The Technical Platforms under this category consist of SC conductor measurement laboratories, coil winding workshops, magnetic measurement laboratories. It also includes impregnation, insulation and furnace facilities for the development of $Nb_3Sn$ and High-Tc coils.

## CAVITY

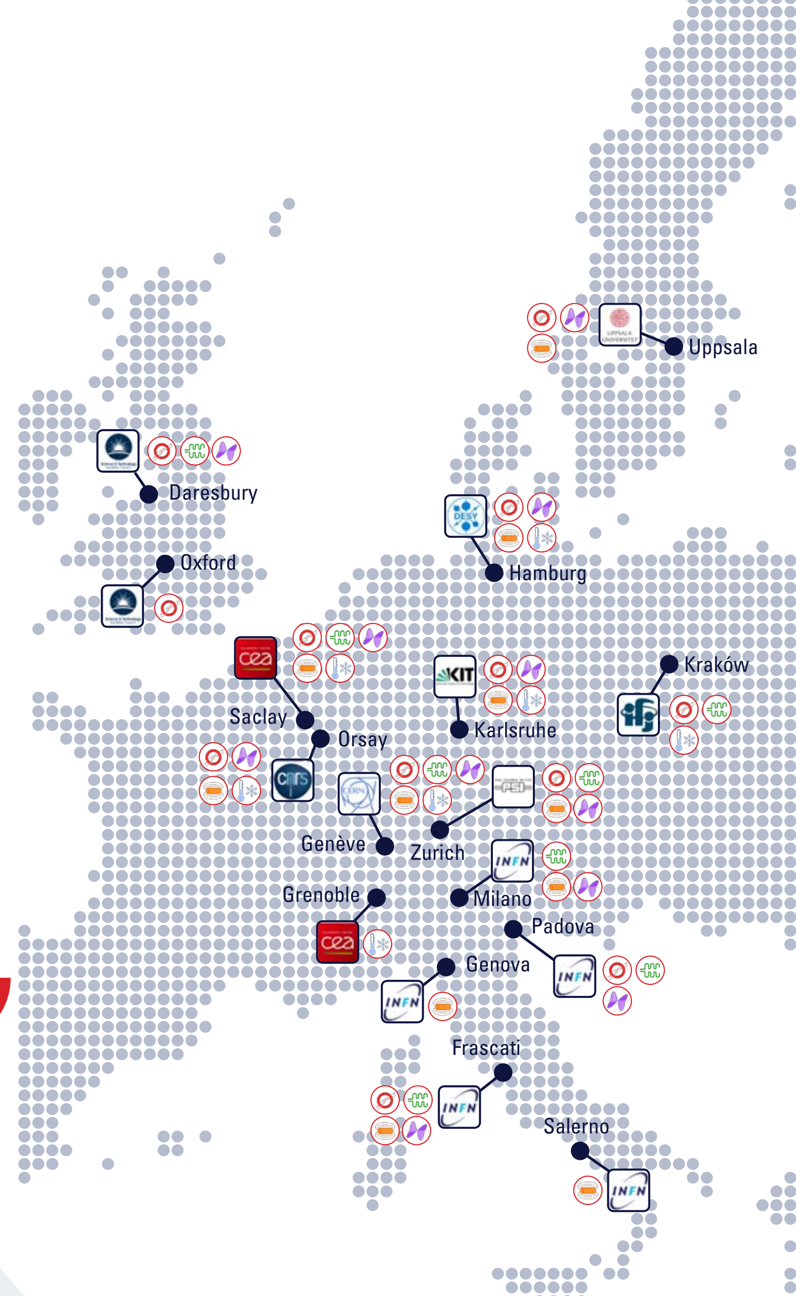
Cavity technology, be it room temperature or superconducting, is the key technique to beam RF acceleration. The Technical Platforms under this category consist of chemistry and surface preparation laboratories, furnace and thermal treatment equipment, welding workshops, RF surface investigation and characterization or any other laboratories used for RF-cavity fabrication and preparation. They also include assembly platforms, such as clean rooms and assembly hall, needed for cryomodule integration.

## CRYOGENICS

Cryogenics has become over the past few decades the key technology enabling the construction of superconducting accelerators and fusion reactors. The Technical Platforms under this category consist of integrated SC-coils cold test facilities, liquid Helium and Nitrogen test cryostats and laboratories to test material mechanical properties at low temperature.

## RADIO-FREQUENCY

Radio-Frequency encompasses basic RF design for cavities, couplers and power sources, their low-level control and measurement, their high-power characterization, be it room temperature or superconducting, and the needed power-source technologies. The Technical Platforms under this category consist of the low-power and high power RF test stations for normal and superconducting RF structures, including vertical and horizontal test cryostats, low-level electronics laboratories and equipment needed for cavity RF tuning.



# ACHIEVEMENTS OF THE AMICI PROJECT

**The goal of the AMICI project was to define the conditions of the coordination of the European Technological Facilities in the area of accelerators and superconducting magnets in order to harmonize their operation and increase their efficiency, adapt to the development of present and future European RIs, open them more to the industry and establish a fruitful co-innovation ecosystem for the benefit of both European science and European industry.**

- The different TPs have been mapped with their characteristics and functionalities
- The global landscape of future accelerator and magnet based RIs has been analyzed
- Key Technological Areas for the construction of future RIs have been identified and the necessary developments in TFs determined
- A survey of potential markets for societal applications has been done, showing that innovation activities between AMICI Partners and Lateral Markets, in order to develop accelerator-related societal applications, have favored the healthcare sector, with some representation in the security sector whilst opportunities for potential developments in the energy sector are comparatively unexplored. The possible role of TFs in their deployment identified
- Relations with industry has been analyzed and barriers for a stronger engagement between TFs and industry identified, in particular communications, cost of access, IP and transparency. Some propositions to overcome these barriers were made, which would need cultural changes to be embedded and supported over extended periods of time and resulting in a transition from a primarily RI-driven model to a broader ecosystem supporting enhanced partnership with Industry,
- A new European Standard “Helium cryostats – protection against excessive pressure” has been developed to be submitted to the European Committee for Standardization CEN. This could be seen as an example of procedure that could be applied to other cases.
- A possible structure and content for a common data base for materials and components has been proposed, which would allow sharing the knowledge acquired within the TFs
- The conditions for the involvement of the industry in the prototyping phase has been investigated, showing that industry should be associated as earlier as possible to the design, allowing industry setting the basis for future products beyond the scopes of the specific prototyping activities, and respecting a subsidiary principle, i.e. favoring developments in industry when possible.
- Conditions for the sustainability of the TFs have been analyzed showing that support from the European science and technology funding agencies is crucial and that a better coordination of efforts, avoiding unnecessary duplication but covering, in an optimized and cost-efficient way, all significant needs for the technology developments required by the new frontline Research Infrastructures would be welcome.
- Founded on a collaboration agreement between core AMICI partners, a networking model between the main stakeholders (Industry, National Laboratories, Universities and Research Infrastructures) has been proposed which would guaranty the sustainability of the European TI, contribute to overcome the identified barriers between TFs and industry and establish an ecosystem that would maintain Europe at the forefront of science and innovation,
- The benefit and conditions of apprenticeship has been evaluated both for industry personnel trained at the Technology Infrastructure and for scientific staff trained at company sites. The importance of well-understood and functional System Engineering and Quality Assurance plans was recognized as another powerful mean to improve the quality of industrial products and services received by the Technology Infrastructure for the construction of Research Infrastructures.”

# AMICI PARTNERS CONTRIBUTE TO BUILDING EUROPEAN RESEARCH INFRASTRUCTURES

The AMICI partners contribute to the construction of numerous European and international Research Infrastructures (RI). This is possible due to the sustainable use of infrastructure set-up and commissioned for selected RIs. As an example, the successful collaborative construction of the European XFEL required distributed infrastructure at in-kind partners. The needed invest led to extremely valuable Technical Platforms which immediately after finishing XFEL construction could foster the ESS related R&D and are now used during construction phase. Technical platforms are adopted and extended when needed. Participation in several projects following in series helps with respect to sustainability.

Nevertheless, science development and decision making processes can lead to deemphasized use and periods during which knowledge increase and even conservation can become challenging. Therefore all AMICI partners strongly contribute to the development and construction of RIs.

| PROJETS | CEA | CERN | DESY | INFN | IFJ PAN | CNRS | STFC | UU | PSI | KIT |
|---|---|---|---|---|---|---|---|---|---|---|
| **CLIC-CTF3** | | • | | • | | • | • | • | • | |
| **ELI-NP** | | | | • | • | • | • | | | |
| **ESS** | • | • | • | • | • | • | • | • | • | • |
| **European X-FEL** | • | | • | • | • | • | | • | • | • |
| **HL LHC** | • | • | | • | • | | • | • | | • |
| **IFMIF** | • | | | • | | | | | | • |
| **JT-60SA** | • | | | | | | | | | • |
| **Spiral2** | • | | | | • | • | | | | |
| **SwissFEL** | | • | • | • | | | • | | • | |

**The projects listed above are only a few examples of the prestigious Research infrastructures built using some of the AMICI facilities**

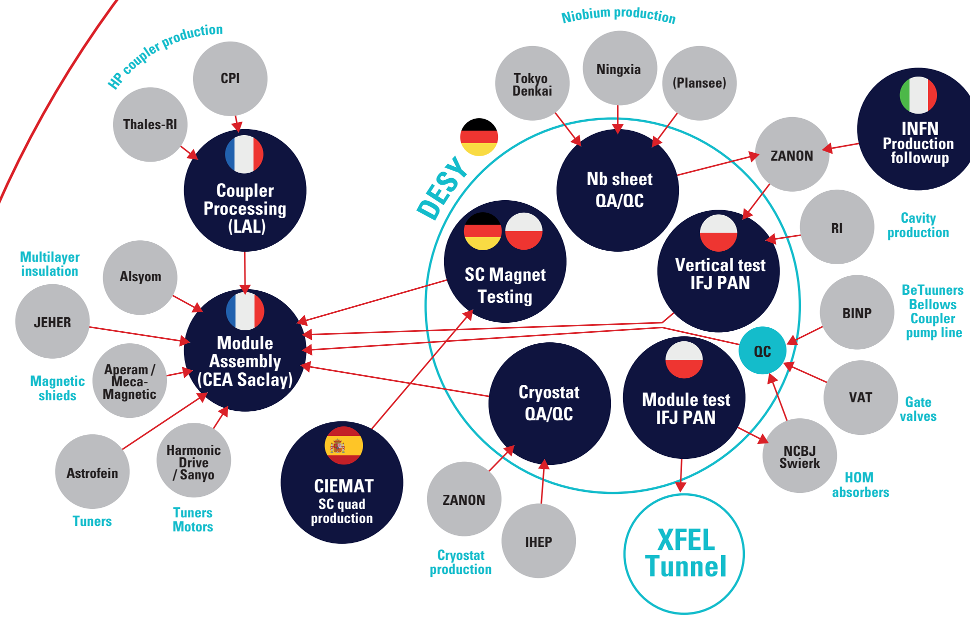
European XFEL

# SUCCESSFUL COLLABORATIONS AROUND THE EU-XFEL RESEARCH INFRASTRUCTURE

## FIELD OF THE PROJECT: LIGHT SOURCE

The European XFEL is a research facility of superlatives: It generates ultrashort X-ray flashes—27 000 times per second and with a brilliance that is a billion times higher than that of the best conventional X-ray radiation sources. Smaller, faster, more intense: The European XFEL is opening up areas of research that were previously inaccessible. Using the X-ray flashes of the European XFEL, scientists will be able to map the atomic details of viruses, decipher the molecular composition of cells, take three-dimensional images of the nanoworld, film chemical reactions, and study processes such as those occurring deep inside planets.

**https://www.xfel.eu/**




**The construction of the European XFEL was only possible in collaboration of institutes at different sites across nine countries. Many of them are now partners within AMICI.**

**Thanks to the European XFEL project a number of sophisticated and valuable new Technical Platforms exist. These platforms can now be offered to research partners and/or companies providing accelerator components to research facilities worldwide.**

In recent years DESY's cooperation with industrial vendors in the field of SRF technology was further emphasized. The companies Research Instruments and Ettore Zanon, both producing superconducting cavities for different research projects worldwide, are time and again customers in the existing Technical Platforms. The European XFEL project helped to qualify both companies in the complete procedures related to production and surface treatment for large series productions.

**Companies involved in the European XFEL acquired new skills which enabled them to develop new business opportunities.**

Cooperation started at a time when the companies were already prequalified through the very successful mechanical production of a large number of cavities, but knowledge transfer was still needed. This transfer included training of personnel which was partly done at DESY. Since then both companies are perfectly aware of the capabilities offered by the operated Technical Platforms. In consequence requests were made to share the use of DESY infrastructure. This holds especially for R&D projects, small series production, and testing of cavities which requires workshops, assembly areas, cryogenic temperatures and dedicated radiofrequency sources, but also shielded test areas. Larger projects are the quality inspection of niobium sheets needed for cavity production, or the testing of series cavities for ESS.

# SUCCESSFUL COLLABORATIONS AROUND THE ESS RESEARCH INFRASTRUCTURE

**AMICI BRINGS TECHNICAL CAPACITY AND COST AND TIME SAVING TO THE LARGE RESEARCH INFRASTRUCTURES**

The Research Infrastructures will not have enough Technical Platform capacity to develop and build their own future accelerators and magnet systems and the European Technological Infrastructure therefore constitutes a necessary contributor to the technical development for, and build-up of, the future accelerator and magnet systems for the large international and national infrastructures for research in High Energy Physics, Nuclear Physics, Synchrotron Radiation Science, Spallation Neutron Science, New Energy Sources, Environmental Research and others.

A particularly illustrative example of this is ESS for which practically all components of its Research Infrastructure currently are being built up and tested at a large number of European Technological Facilities. It has been estimated* the extra time and extra cost that would have been required for the ESS accelerator if one would have had to employ and train all the physicists, engineers and technicians needed for the build up on the ESS site in Lund the laboratory premises and technical infrastructure required for the design, prototyping, test and industrial ordering for the accelerator project. The conclusion is that this would have required about 7 additional years and about 77 MEUR additional funding, including the funds needed for the salary costs of the extra personnel, for its completion. The nominal total construction time and total nominal cost of the current ESS accelerator project is ca 12 years and ca 570 MEUR, respectively.

** Private communication with Mats Lindroos, head of the ESS accelerator division*

EUROPEAN SPALLATION SOURCE

**FIELD OF THE PROJECT: NEUTRON SOURCE**

The European Spallation Source is under construction in the city of Lund, in southern Sweden. The facility's unique capabilities will both greatly exceed and complement those of today's leading neutron sources, enabling new opportunities for researchers across the spectrum of scientific discovery, including materials and life sciences, energy, environmental technology, cultural heritage and fundamental physics.

**https://europeanspallationsource.se/**

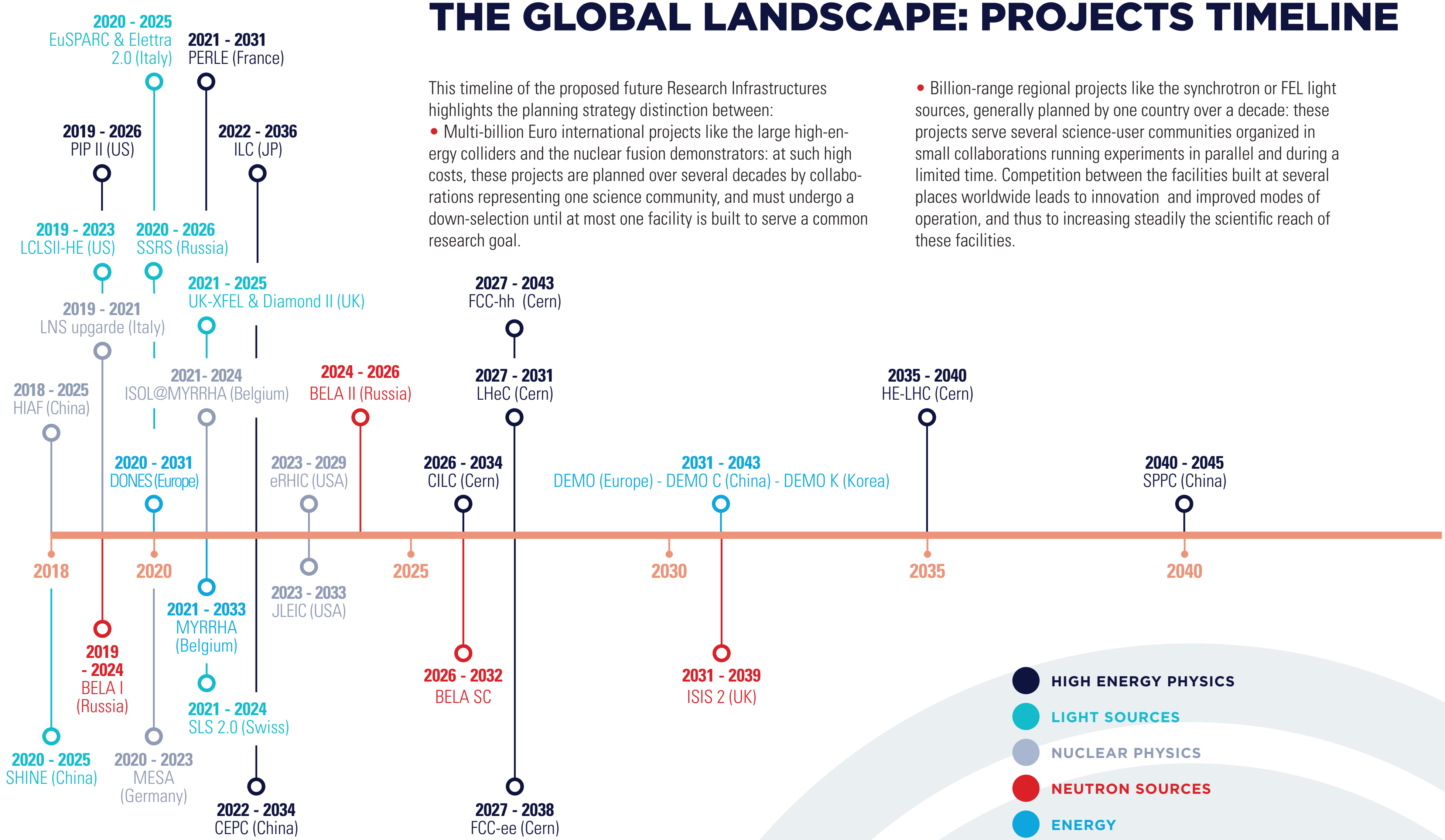
# THE GLOBAL LANDSCAPE OF ACCELERATOR AND SC MAGNETS PROJECTS (NON MEDICAL)


Research Infrastructures based on Accelerators and large Superconducting Magnets are enabling scientific instruments to advance and push the limits of pure human knowledge and of societal welfare. Motivated by the successful operation of the existing Research Infrastructures and building on engineering progress, more powerful facilities are under study. The map illustrates the rich Global Landscape of the proposed Research Infrastructures worldwide serving a wide range of applications from science to technology, spanning fundamental, applied and technological research.

# THE GLOBAL LANDSCAPE: PROJECTS TIMELINE

This timeline of the proposed future Research Infrastructures highlights the planning strategy distinction between:

- Multi-billion Euro international projects like the large high-energy colliders and the nuclear fusion demonstrators: at such high costs, these projects are planned over several decades by collaborations representing one science community, and must undergo a down-selection until at most one facility is built to serve a common research goal.
- Billion-range regional projects like the synchrotron or FEL light sources, generally planned by one country over a decade: these projects serve several science-user communities organized in small collaborations running experiments in parallel and during a limited time. Competition between the facilities built at several places worldwide leads to innovation and improved modes of operation, and thus to increasing steadily the scientific reach of these facilities.



# GLOBAL LANDSCAPE OF FUTURE MEDICAL ACCELERATORS (PROTON-THERAPY)

Radio-medecine uses particles like photons (X-rays and gamma-rays), electrons, protons, neutrons, various atomic nuclei to  penetrate living tissue, for non-invasive imaging of internal organs, or at higher energies selectively destroy malignant tissue. This map illustrates the worldwide landscape of proton-therapy medical accelerators, based on state-of-the-art cyclotrons or synchrotrons, whose construction is scheduled in 2020-2023 at oncology centers.
Besides radio-medicine, health applications of superconducting magnets encompass mainly the magnetic resonance imaging (MRI) scanners when coupled to radio-frequency antennas, and compact gantry systems around hadron-therapy facilities. Health application of accelerators encompasses also the production of radio-nuclides used for disease diagnostics and treatment.


**1.** USA: 1 Cycl, 1 SC Cycl, 1 Syn & 2 SC Syn Cycl
**2.** Argentina: 1 Cyclotron
**3.** Egypte: 1 Cyclotron
**4.** Italy: 1 Cyclotron
**5.** Switzerland: 1 Cycl + 1 SC Syn
**6.** Belgium: 1 Cyclotron
**7.** Netherland: 1 Cyclotron
**8.** Norway: 2 SC Cyclotron
**9.** Russia: 1 Synchrotron
**10.** India: 1 Cyclotron
**11.** China: 1 SC Cycl, 1 Cyclo & 2 Synch 1c-ion synchrotron
**12.** S Korea: 1 C-Ion Synchrotron
**13.** Singapore: 1 SC Cyclotron
**14.** Australia: 1 Synchrotron

# THE ROLE OF THE KEY TECHNOLOGICAL AREAS FOR FUTURE MAJOR PROJECTS

This table illustrates the criticality of KTAs for the major Research Infrastructures of the global landscape, regarding the following criteria:

- Being widely needed for the future projects.
- Presenting a high development potential allowing to meet the needs of future challenging machines.
- Presenting a high development potential allowing to reduce the construction and/or operation costs of future machines.

| | Particle sources | Magnet and Vacuum systeme | High Field SC magnets | Normal Conducting RF structures | Superconducting RF cavities | RF power sources | Cryogrnics | Instrumentation |
|---|---|---|---|---|---|---|---|---|
| **ILC** | ● | | | | ● | ● | ● | ● |
| **FCC** | ● | ● | ● | | ● | | ● | ● |
| **PIP-II, MYRRHA** | | | | | ● | ● | ● | ● |
| **JLEIC** | ● | | ● | ● | | ● | | ● |
| **eRHIC, LHeC** | | | | | ● | | ● | ● |
| **DIAMOND2, SLS2** | | ● | | | | ● | | ● |
| **LCLS-HE, SHINE** | | ● | | | ● | | ● | ● |
| **DONES** | ● | ● | | ● | ● | ● | ● | ● |
| **DEMOs** | ● | | ● | | | ● | ● | |
| **PERLE** | | | | | ● | ● | | ● |
| **BELA, compact neutron sources** | ● | | | ● | | | | ● |

# THE ROLE OF AMICI TECHNOLOGICAL FACILITIES FOR KTA'S DEVELOPMENT

This table illustrates the matching of Key Technology Areas with the Technological Facilities that constitute the current AMICI Technology Infrastructure: for the checked entries, scientists at Technological Facilities recognize running cutting-edge technical developments aimed at breakthroughs in performance, cost or reliability of the given KTA.

| | Particle sources | Magnet and Vacuum systeme | High Field SC magnets | Normal Conducting RF structures | Superconducting RF cavities | RF power sources | Cryogrnics | Instrumentation |
|---|---|---|---|---|---|---|---|---|
| **CEA** | ● | | ● | ● | ● | | ● | |
| **CERN** | | ● | ● | ● | ● | | ● | ● |
| **DESY** | | ● | | ● | ● | ● | ● | ● |
| **INFN** | ● | | ● | ● | ● | | | |
| **IFJ-PAN** | | ● | ● | | | | ● | ● |
| **CNRS** | ● | ● | | ● | ● | | | ● |
| **STFC** | | ● | | ● | ● | | ● | ● |
| **UU** | | | | ● | | ● | | |
| **PSI** | ● | ● | ● | ● | | ● | | ● |
| **KIT** | | ● | ● | | | ● | ● | ● |

# SUPERCONDUCTING RF CAVITIES

The past two decades have seen the advent of superconducting RF cavities in most of the accelerators recently built or under construction, resulting from the dramatic breakthroughs in the accelerating field (from 5 MV/m to 30 MV/m) and cryogenic consumption at roughly constant fabrication cost and unsurpassed operation efficiency. After LEP200 operational success, the usage of niobium based SRF technology became widespread and almost unavoidable for circular and linear accelerator projects using electron, proton and heavy ion beams in pulsed or CW mode or operation. It also opened up new operation modes included beam recirculation and beam energy recovery, and new applications like SRF electron guns and transverse deflection. Furthermore, some advances are still the result of recent R&D demonstrating that higher performances are to be expected in the medium term future.

### ADVANCES: SURFACE TREATMENTS, NEW MATERIALS, PARTICLE-FREE ASSEMBLY AND ROBOTICS, COST REDUCTION

- High Q0 / high gradient SRF structures, requesting special furnaces, and other demanding infrastructure.
- Surface preparation of SRF cavities requesting innovative sophisticated surface modification methods like Nitrogen doping or infusion.
- New fabrication techniques using large grain bulk niobium or coated cavities with higher Tc material.
- SRF electron sources of high demand for future CW FEL operation.
- Optimized cryostat design for particle-free assembly and robotics, and cost reduction.

# RADIO-FREQUENCY POWER SOURCES

The electrical power consumption of future accelerators will be driven to a large part by their RF systems. A significant part of the initial investment and running cost of the large scale machines will be determined by the purchasing cost and the efficiency of their RF sources. Increasing the efficiency of existing RF systems to higher levels means several millions euros saved per year on the electricity bill. The upcoming large scale accelerators are expected to require RF power in the range of 10 to 100 MW (for comparison, the Large Hadron Collider (LHC) has a total RF drive of 5 MW). This is particularly true for electrons colliders, circular (e.g. FCC-ee or CEPC) or linear (e.g. ILC or CLIC), High power hadron Linacs (e.g. PIP2) and Accelerator Driven Systems (e.g. MYRRHA).

### ADVANCES: HIGH EFFICIENCY FOR KLYSTRONS AND MODULATORS, SOLID STATE AMPLIFIERS

- Modulators: today's modulator are already operating with very high efficiency (85-92%) almost independent of their output power (kW-MW), Voltage (1-100kV), and pulse length. For short pulses (<500 µs), the modulator rise time becomes an important factor in the system efficiency and this is where further developments, such as the Stacked Multi-Level (SML) design, are expected to make a significant difference.
- Klystrons: Current State of the art Klystrons can deliver a maximum efficiency of approximatively 65%. The limiting factor is the electron bunch profile as it approaches the output cavity of klystrons, as well as the velocity of the lowest electron leaving the output gap. With the advance of modern beam dynamics tools, number of novel electron bunching mechanisms such as the Core Oscillation Method (COM), the Bunching, Alignment and Collecting (BAC) method and the Core Stabilisation Method (CSM), have shown an improve on the efficiency through numerical investigations.
- Solid State Amplifiers (SSA): SSAs promise cost efficient RF power generation and the advantages of modular systems. This imply an effective combination of the single units (of 1 kW) to reach high power values (> 100kW). A promising solution is to use combiner cavities that combine all the output of single units in one stage. The difficulty still to match hundreds of input antennas and minimise the reflected power due to manufacturing tolerances of the electronics or to failed units.

# CRYOGENICS

Cryogenics is a base technology for the numerous worldwide research facilities that utilize large superconducting (SC) magnets or SC particle accelerators, be it with superconductive radio-frequency cavities or high-field magnets. The rarity and potential shortage of helium gas, as the most used cooling liquid for the large facilities, call for critical advances in reducing the overall helium and raising efficiency, as well as alternative cryo-cooling technologies. Industry, especially European firms, and research laboratories are leading these developments. European PED certification is not fully adapted to the peculiar risk and technical solutions of the Helium cryostats used in accelerators.

### ADVANCES: HIGH EFFICIENCY, CRYO-COOLERS, CRYO-SAFETY

- Higher efficiency cryo-plants through improved performance sub-system components such as heat exchangers, turbines, instrumentation and process control optimisation.
- Cryo-coolers adopting development technologies employed from space industry applications and possibly new cryogenic fluid mixtures.
- Safety specifically for accelerator equipment, by developing dynamic models for improving mitigation of cryogenic incidents and new European standards to certify cryostat design and fabrication.

# BEAM INSTRUMENTATION

Beam instrumentation is the accelerator artificial intelligence: it keeps particle beams alive and bring them to their required performance level. As an analogy, beams stored during one day on powerful circular accelerators travel the same distance as the orbit of Pluto (about 30 billion kilometers), while keeping their sub-millimeter orbit and size characteristics. Beam instrumentation includes beam diagnostics, i.e. instruments that sense the electro/optical signals of charged particles and monitor their evolution
front-end systems, i.e. ultra-fast electronics systems that process these signals and dynamically generate corrective actions
control systems, i.e. specialized software suites that command and regulate the operation of the many technical individual constituents and systems cooperating collectively to stabilize the accelerator operation, from the beam source to beam delivery.

### ADVANCES: OPTICAL AND RF DIAGNOSTICS, DIGITAL AND FAST ELECTRONICS, FEEDBACK ALGORITHMS

- Non-invasive diagnostics based on RF or optical signals, particularly for high intensity beams.
- Longitudinal diagnostics for ultra-short bunches based in RF structures, electro-optics or Terahertz detectors.
- Digital conversion of electric or light signals with high resolution and large bandwidth.
- Ultra-fast electronics based on parallel developments in computer industry and high-speed communications
- Innovative feedback algorithms in control systems improved with AI.

# PARTICLE SOURCES

Ion sources determine the research potential of the accelerator or post-accelerator facilities. The essential parameters are the ion species, the ion current intensity and the polarization. Proton accelerators (e.g. LHC, SNS, ESS, etc…) are using high intensity H+ or H- ion sources, while heavy ions accelerator are based on the widest range of stable ions from helium to heavy stable ions (e.g. lead or uranium). Radioactive ions beams are using secondary sources including a target. Fusion reactors are using MeV-energy intense ion sources (e.g. D-) for neutral injection as a plasma heating mechanism. For spatial (e.g. ion thruster) and industry (e.g. ion beam lithography) application, compactness and reliability are crucial properties of the ion sources. There is also a strong interest in material science for ion traps producing highly charged ions at rest. For electron sources, the new generation of CW FELs calls for high current high repetition rate (10 kHz-1 MHz) RF photo-injectors, a possible new application of superconducting RF cavities. Pushing the intensity of positron sources is mandatory for colliders, together with polarization, and for very low energy positron beams used in anti-matter research and material science. Creating low-emittance energetic muon beams would open the way for a new generation of lepton colliders.

### ADVANCES: HIGH INTENSITY HEAVY IONS, POSITRON SOURCES, POLARIZED BEAMS

- Electron Cyclotron Resonance (ECR) ion source breakthroughs in intensity can be expected by increasing the microwave RF frequency (up to 45 GHz) and using superconducting coils (up to 11 T) to match the resonance condition. On the other hand, the standard ECR sources (0.8 T, 2.45 GHz) can increase their power efficiency, ease of operation and compactness by using permanent magnets for spatial and industry applications.
- Electron Beam ion sources (EBIS) are more efficient for highly charge heavy ion sources. A large range of studies are in progress to improve their reliability and ease of operation.
- The creation of electron-positron pairs in matter is the basic mechanism for the positron sources; hence thermal effects on the solid target limit the beam intensity. New schemes are proposed using intense photon radiation from laser collision or undulators, preferably superconducting, or atomic crystals, followed by photon conversion on thin targets. Some schemes are amenable to producing polarized positron beams, others are considered to produce muon pairs.

# MAGNETS AND VACUUM SYSTEMS

Warm magnet technology is indeed basic for guiding particle beams along accelerators, with a widespread group of laboratories and industries capable of producing and testing conventional magnets in large series. However, new promising beam transport techniques have recently been discovered or implemented successfully (e.g. ultimate-brilliance synchrotron-radiation storage rings (DLSR), fixed-field alternating gradient accelerators (FFAG), beam channels for plasma acceleration) that extend the design and manufacturability needs for warm magnets, be they resistive magnets or permanent magnets, beyond their current state of the art. In many cases, small aperture vacuum chambers with high pumping speed and low desorption are required to implement these techniques.

### ADVANCES: SPECIAL FUNCTION MAGNETS, PERMANENT MAGNETS, SMALL VACUUM CHAMBERS

- Manufacturing of combined function magnets with complex magnetic polar pieces.
- Permanent magnets introducing high permeability material like Neodymium or Praseodymium.
- Coating of small aperture vacuum chambers using the Non-Evaporable-Getter (NEG) technology and which reduces electron secondary-emission yield.
- Surface treatment of vacuum chamber to reduce secondary electron emission yield.

# HIGH FIELD SUPERCONDUCTING MAGNETS

Large and powerful high-field superconducting magnets are routinely used in science, research and technological development (RTD) and in medical diagnostics, using Magnetic Resonance Imaging (MRI), the latter representing the biggest current market for superconductivity. In addition, superconductors bring potentially large energy savings in power applications, with demonstrations of power cables, transformers, motors or current limiters already have been made. There is a strong drive on new superconductor developments to increase the power of hadron colliders and MRI for scientific research, and for tokamaks for the next demonstrators by raising the magnetic field strength in large volumes using new innovative superconducting materials, such as $Nb_3Sn$ or High Temperature Superconductors (HTS), and developing cable and coil innovative cooling technologies.

### ADVANCES: NB3SN AND HIGH-TC CONDUCTORS, CRYO-COOLING, COST REDUCTION

- Development and use of ultimate performance $Nb_3Sn$ conductors, the most mature option so far, to overcome cost and coil fabrication issues.
- Development and use of HTS conductors still needing R&D on material science to electromechanical engineering.
- Innovative conductor and cold mass cooling methods to increase the operating temperature margin.
- Reinforcement of the conductor mechanical strength to take on much higher internal magnetic forces.

# NORMAL CONDUCTING RF STUCTURES

Radio Frequency acceleration technology (normal conducting) was introduced 90 years ago (e.g. drift tube linacs) and is still the standard reference for acceleration, used in the majority of particle accelerators worldwide. There are irreplaceable in the front-end injection systems of proton and ion linear accelerators (e.g, Radio-Frequency-Quadrupole). Normal-conducting RF cavities are characterised by a large variety of designs (single cell, multi-cell, TE-mode, TM-mode, RFQ, etc.), operating frequencies (from the kHz to the multi-GHz range), operating modes (CW or pulsed, tunable or fixed frequency, coupled or stand-alone, etc.), and of construction technologies (Cu-plated or full copper, bolted, welded or brazed). The availability of simple designs using conventional fabrication techniques makes normal-conducting RF accessible to small universities and laboratories without the need for specialised infrastructure. Conversely, sophisticated designs reaching challenging parameters and/or large-scale productions require specific technological infrastructure for the manufacturing and for the processing of the cavities.

### ADVANCES: HIGH PRECISION FABRICATION AND TUNING, RF BREAKDOWN

- The main ongoing developments for accelerating RF cavities are related to increasing the accelerating gradient to reduce the length the accelerator, and to increase the power efficiency. This latter challenge leads to increasing the operating frequency reducing at the same time the cavity dimensions, thus imposing additional challenges on the manufacturing in terms of precision machining and surface quality.
- Given the pressing need of proton or ion high intensity injectors, the fabrication of RFQs in industry requires sophisticated machining, thermal treatment and firing of ultra-pure copper, with some commonalities with the fabrication of high power RF input couplers and CW RF guns. Consolidating these techniques over time and regions would benefit to the lead time and cost of their fabrication.

# THE RELATIONSHIP WITH INDUSTRY

## CHALLENGES AND OPPORTUNITIES

# INNOVATION: AN INTEGRATED ECOSYSTEM THAT WILL FOSTER INNOVATION

Technology development, test and validation is at the epicenter of both the delivery of inspiring new European Research Infrastructures for fundamental research, and also the development of innovative products, processes and services by leading European companies to generate measurable scientific, economic and societal impact.

The necessary building blocks of world class skills, test infrastructures and commercial expertise are already in place across Europe, both within the National Laboratories and Industry. Indeed, many companies are already making effective use of these facilities to develop their businesses. Preliminary data mapping by AMICI has illustrated a significant overlap of technology development needs between the National Laboratories and Industry. The results from existing collaborations are already being used in application areas such as healthcare and security, with significant potential to address challenges in evolving market sectors around industrial processing, energy and the environment. co-operation, technology development and training opportunities across the European science base.

Industry has conveyed that the current procedures and co-ordination of test and validation infrastructure across the European National Laboratories can inadvertently generate barriers to access. To drive innovation and allow Industry to make valid business cases to support future investment, facilities must have:

- Clear communication of facility capabilities and benefits
- Industry-relevant timescales for responses and scheduling
- Transparent costs
- Fair IP terms to support co-innovation

The AMICI partnership is ideally placed to co-ordinate, promote and expand this concept, taking the building blocks and establishing an integrated ecosystem that will assist in streamlining access processes, standardizing components and procedures, and maximizing exploitation. This strategic transition from a primarily Research Infrastructure-driven model to a broader ecosystem supporting enhanced partnership with Industry represents a significant cultural change and will require support over an extended period of time to become embedded.

These enhancements will more readily allow Industry to identify potential benefits and risks, accurately assess their likely return on investment and provide the best foundations for project success. Enhancing opportunities for Industry, through added value rather than subsidy, inherently strengthens the critical high-technology supply chain, and provides benefits for all in terms of innovation, co-operation, technology development and training opportunities across the European science base.

# SUCCESS STORIES



## COLLABORATION WITH TE2V BRINGS BENEFITS FOR BOTH PARTIES

### The Challenge
Teledyne e2v  recognised that access to an accelerator and radiation test facility would enable them to speed up product development and address more customer requests and STFC required a supported accelerator platform for industrial and academic engagement.

### The Solution
Through collaboration with STFC Daresbury Laboratory, Teledyne e2v has been able to take advantage of the Compact Linac and Linac Test Facility, and expertise of STFC's staff and the support of Teledyne e2v ensures a reliable platform

### The Benefits
Teledyne e2v can assess the impact of new products and system designs against the wider performance and reliability aspirations of its customers and STFC has a reliable, supported platform for academic &industrial engagement.

## INFN/ROLLENG COLLABORATION BRINGS BENEFITS TO BOTH PARTIES

### The Challenge
Rolleng recognised that access to a technology such as Physical Vapour Deposition could improve the value of its main products. The core business of Rolleng is Wire and Tube Rolls production.

### The Solution
Through the collaboration with INFN, Rolleng gained access to the expertise and the PVD lab at INFN-LNL premises. This techniques is suitable to coat the Wire and Tube Rolls and can provide a wide range of different coatings (e.g. hard coatings).

### The Benefits
INFN provides a PVD prototype to Rolleng and a study on hard coatings to apply on the Wire and Tube Rolls and improve their life time. INFN acquired the know how on hard coatings deposited via PVD techniques.

# INDUSTRIALIZATION: FOSTERING COLLABORATION INITIATIVES AND OPPORTUNITIES

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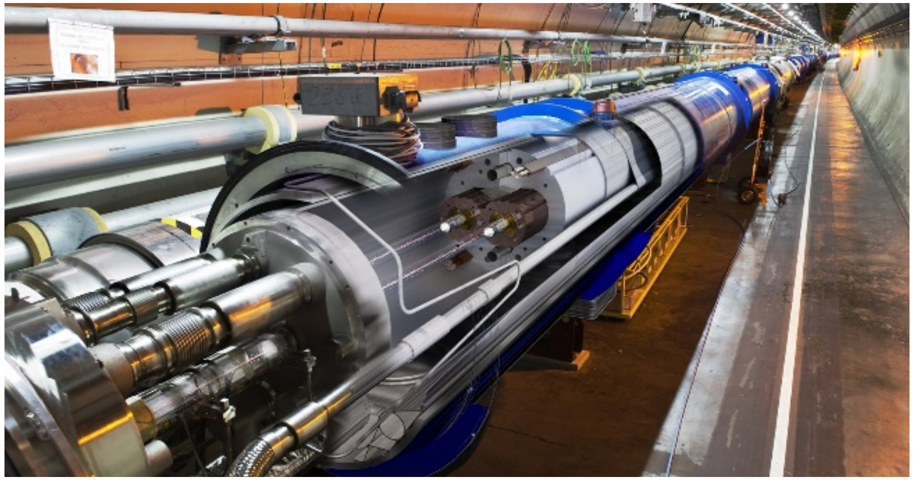
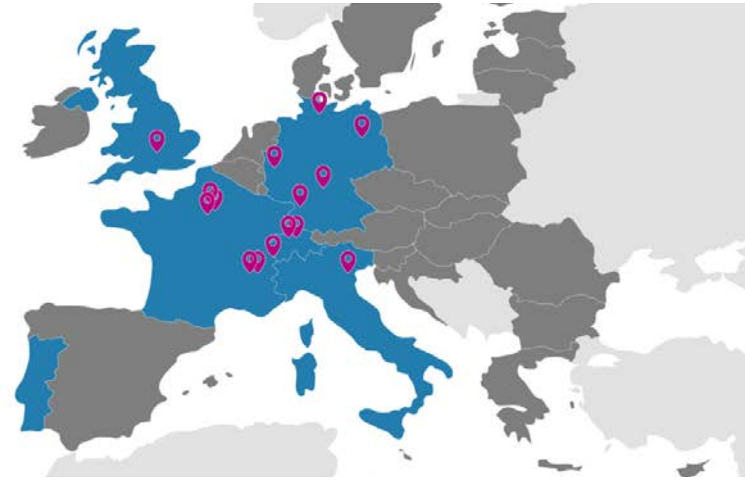
# SUCCESS STORIES





## NEW EUROPEAN STANDARD "HELIUM CRYOSTATS – PROTECTION AGAINST EXCESSIVE PRESSURE"

### The Challenge

Difference of design practices, understanding of risk and technical solutions for cryogenic equipment used in accelerator and magnet devices are source of many difficulties inside international collaborations, and also among labs and industry.

### The Solution

Development of the first European Standard specifically dedicated to the protection of all types of helium cryostats against excessive pressure.

### The Benefits

Harmonisation of the risk assessment, protection concepts and dimensioning of pressure relief devices for helium cryostats to assure acceptable safety levels and to promote cooperation between European Research/Technology Infrastructures and industry.

## ORGANISATIONS CONTRIBUTING TO CEN/TC 268/WG6

### National Standardisation Bodies

DIN afnor GROUPE bsi. UNI ENTE ITALIANO DI NORMAZIONE SNV

### Organizations

Air Liquide creative oxygen BILFINGER cea CERN HEROSE INFN KIT Linde PAUL SCHERRER INSTITUT PSI Science & Technology Facilities Council

# TRAINING A NEW GENERATION OF TECHNICIANS AND ENGINEERS : A MAJOR CHALLENGE FOR THE TECHNOLOGY INFRASTRUCTURE

For the future of the field, training activities are mandatory to sustain new development and form the new generation of technicians and engineers. However, for training targeted at industry, companies are ready to send personnel in TI, at their own cost, only if commercial contracts are within 2-3 years future.

Hence the following recommendations:

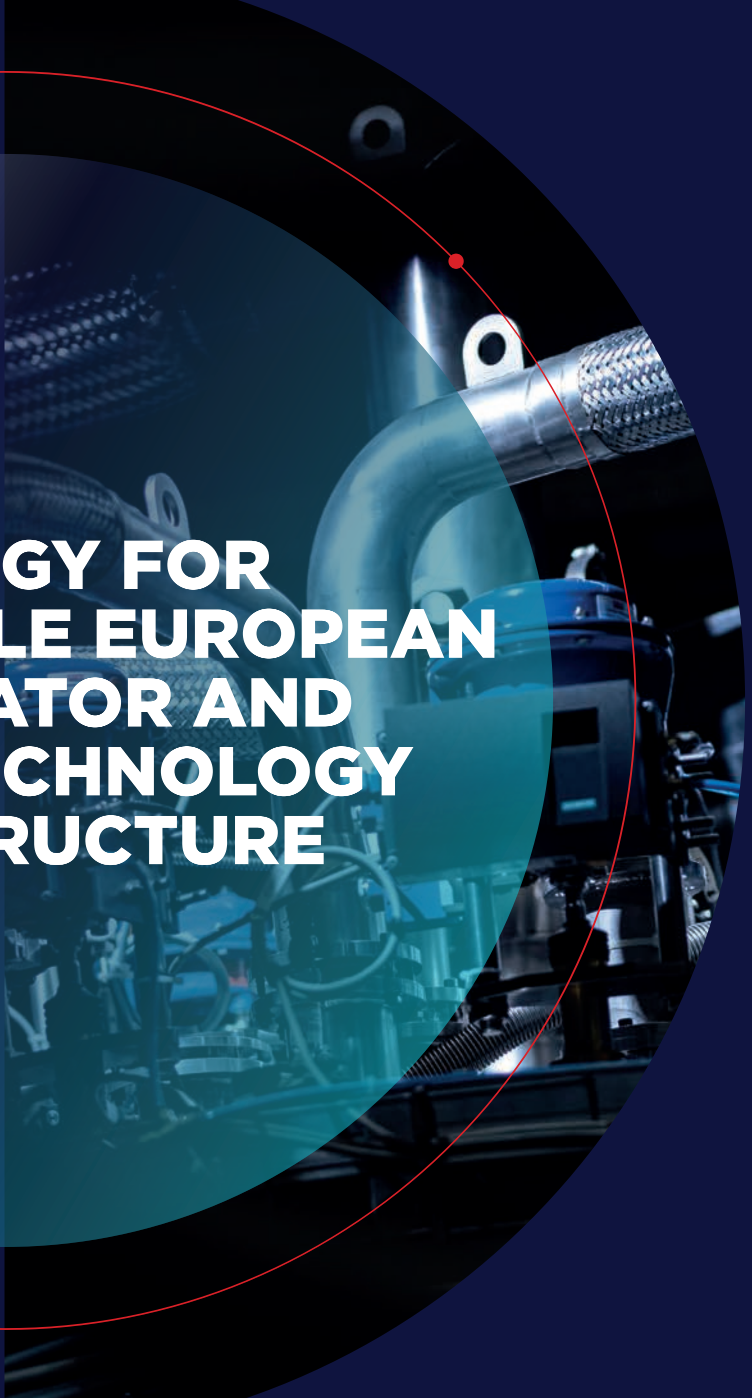
- Establish apprenticeship programs with Technical Universities and Institutes for high qualification technicians.
- Support common programs and exchanges for apprentices among the TI.
- Propose to industry a continuously updated catalog of information and training sessions to key technologies reaching high TRL soon to be industrialized.
- Include that catalog in the industry-oriented existing public funding schemes, and propose the principle of a training certificate.
- For standard competences (e.g. magnetic measurement, vacuum technology, RF technology), training and apprenticeship is already available in the public and private sectors, and no action is required from the TI.

### HARMONIZING SYSTEM ENGINEERING AND QUALITY ASSURANCE PRACTICES

Sustaining pre-existing expertise in industry over the duration of the RI construction and possibly during the gaps in time between several RI construction, entails system-engineering and quality-assurance (QA) methodology enforced at the interface between Industry and TI.

- experts (scientists, engineers and technicians) need to be educated with respect to quality assurance to guaranty successful project management.
- the vast question of 'system engineering and QA' for future RI constructions should be addressed. AMICI could  wor on harmonizing (or defining) the architecture and content of the various plans 'System Engineering and Management plan', 'Quality Assurance plan', Configuration management plan', etc… for the AMICI institute  to manage their (In Kind) Contributions. Such an architecture would in turn guide Industry in their production contract and execution.

# STRATEGY FOR A SUSTAINABLE EUROPEAN ACCELERATOR AND MAGNET TECHNOLOGY INFRASTRUCTURE



# THE IMPORTANCE OF SUSTAINING THE TECHNOLOGY INFRASTRUCTURE IN THE LONG TERM

It is of decisive importance that the European Technological Facilities be sustained. Without that it will not be possible to continue to develop, design and build the new world-leading large Research Infrastructures in Europe required for keeping Europe's leading position within the scientific, technological and economic development in the world. In particular, it should be acknowledged

- that a significant fraction of the advanced scientific research in Europe, on which the further technical and economic development of our Society is critically dependent, is based on the use of large international Research Facilities and that the European Technological Facilities have nowadays become absolutely vital actors for the development, build-up, maintenance and later upgrade of these Research Facilities and
- that the European Technological Facilities make it possible for modern European industry to develop the qualitatively new technologies required by the Research Infrastructures, that soon constitute the basis also for many new practical applications in Society, and also to develop certain new technologies that are directly intended for practical applications in Society, like e.g. for medical or industrial applications.
- It will, at the same time, be necessary for the European Technological Facilities to better coordinate their efforts and avoid unnecessary duplication such that they together cover, in an optimized and cost-efficient way, all significant needs for the technology developments required by the new frontline Research Infrastructures in Europe and in the world.
- Furthermore, their collaboration with European Industry needs be organized in a more coherent way, in particular regarding handling of Intellectual Property and transfer of knowledge to Industry, in order to enhance the role of Industry as qualified producer of the innovative instrumentation and infrastructure required for the future development of new Research Infrastructures as well as of Society at large.

It is the aim and purpose of AMICI to facilitate a development in this direction by acting as a coordinating and supporting common platform for the European Technological Facilities.

# THE AMICI COLLABORATION: PROPOSED STRUCTURE FOR COORDINATING AND SUPPORTING THE EUROPEAN TECHNOLOGICAL FACILITIES

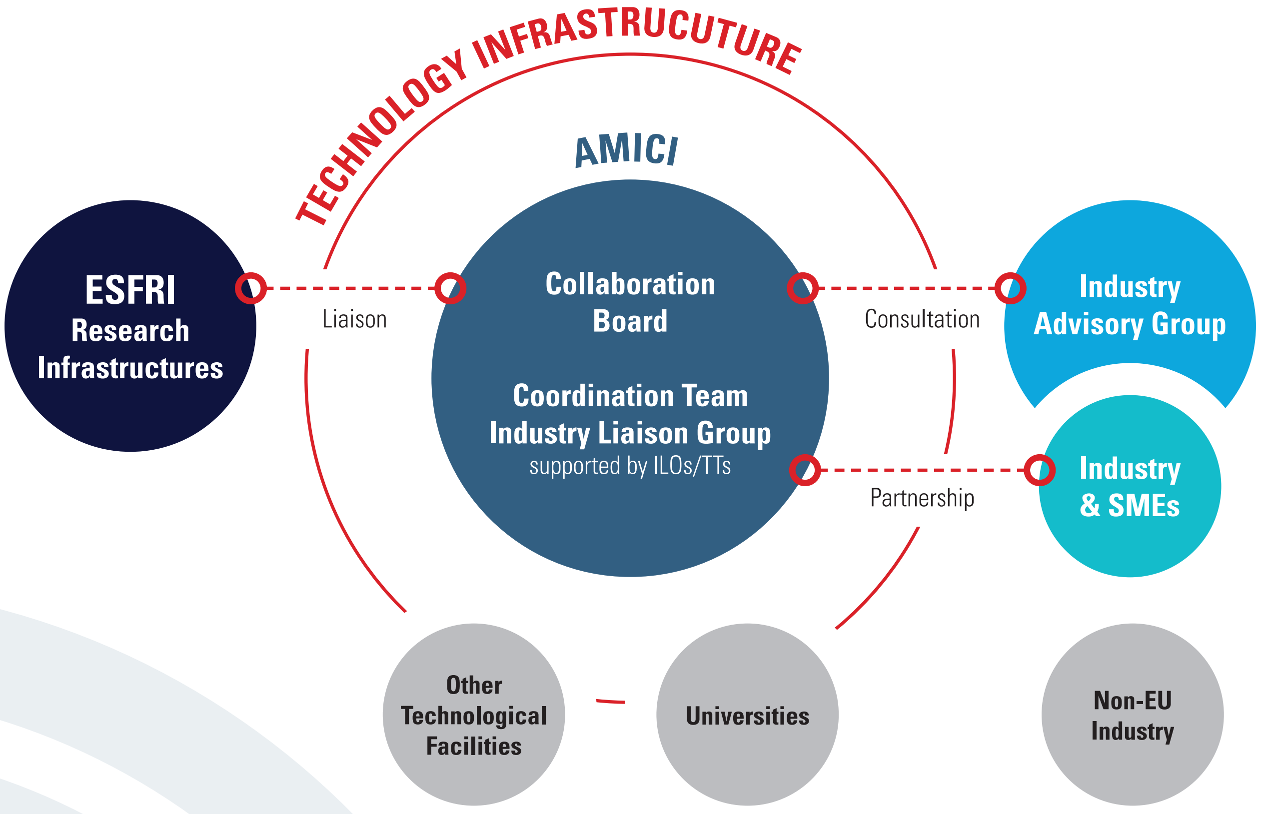
The efficient use of Technical Platforms will be coordinated, available capabilities checked and communicated, and access and service harmonized.

AMICI Core Group members will define the actions of the Collaboration, contribute to its financing and provide human resources dedicated to tasks of general interest.

Associated Partners (smaller TFs and Universities) will be associated to some of the actions, have access to information and communication.

Relations with Industry handled by the Industry Liaison Group inside the Coordination Team and an Industry Advisory Group will be consulted on a regular basis.

Liaison with existing and new Research Infrastructures will be reinforced.



# THE ACTIVITIES OF THE AMICI COLLABORATION

**Development and optimization of the capabilities of the TFs to support the construction of future accelerator-based RIs and ensure their sustainability:**
- maintain an up-to-date list of the TPs open to external partners with their characteristics and functionalities;
- define the roadmap for the strategic evolution of the AMICI TFs, in view of the possible opportunities of engagement in new projects, in Europe, and outside Europe, with the goal of maximizing and optimizing the involvement of the TFs and their industrial partners ;
- Contribute to harmonize standards specific to the domain ;
- Set up and maintain a database for materials and components ;
- provide services to TFs for evaluating to what extent and under which conditions new or upgraded TPs can be exploited also by Industry ;
- Identify adaptations needed to satisfy the requests from Industry ;
- Explore the different possibilities for financing the necessary developments and upgrades of the TPs ;
- promote the possibilities that resources from the EC are earmarked at regional level to support the development of TPs ;

**Services to industry:**
- central information and contact point for industry and other external partners to access TPs with the aim to ensure the dissemination of information, analysis of requests and contacts to the appropriate TP ;
- promote the use of TPs by organizing regular dissemination initiatives ;
- simplify the use of the TPs by industry with the adoption of well defined procedures, regulations, IP management schemes, cost evaluation schemes, quality standards, etc.  based as much as possible on common models adopted by the TI ;
- develop models for engaging industry in the low TRL phases of development still preserving the ownership by the TFs of the developed technologies ;
- provide services to investigate if industrial partners may be willing to take some responsibility in the design and/or implementation and/or operational phases of new TPs ;
- Setting up common training programs and promoting funding for student internships ;
- establish permanent relationships with Association of companies that are active in the Big Science field  to implement some of the above actions ;

# THE SHORT AND LONG TERM EXPECTED IMPACTS

**In the short term**, the proposed collaboration model would allow the TI to establish itself in Europe and worldwide as a visible, privileged and effective channel of interaction with the TFs to benefit of their services, and consequently contribute to their sustainability by:

- making RIs in Europe and in the world more aware of the role the AMICI collaboration in organizing the engagement of the TFs in new projects
- making companies that are possible users of the TFs aware of the expertise and technical capabilities of the TFs and the services they can provide
- stimulating the active participation of industrial partners in the definition of the technology development roadmap and in planning new or upgrading TPs that may be targeted to satisfy both internal and industrial needs
- enhancing the share of services to industry in TPs and consequently resources for TFs.

**In the longer term**, it would:

- avoid unnecessary duplication through optimal management of resources,
- lead to the further development of the AMICI TI, together with the industrial ecosystem around it,
- contribute to maintain Europe at the forefront of RI construction, which is currently developing faster in other parts of the world,
- reinforce European industry at the forefront of innovation for societal applications.

# DESCRIPTION OF THE AMICI TECHNOLOGY FACILITIES

## INNOVATION SUCCESS STORY

### THE SUCCESSFUL TEST OF THE FIRST TWO IONS SOURCES SILHI2® BUILT BY PANTECHNIK

**The Challenge**

As part of the development of high-intensity accelerators, CEA initiated the development a new cyclotronic electron resonance ion source producing 100 mA of protons at 100 keV : the SILHI2® source.

**The Solution**

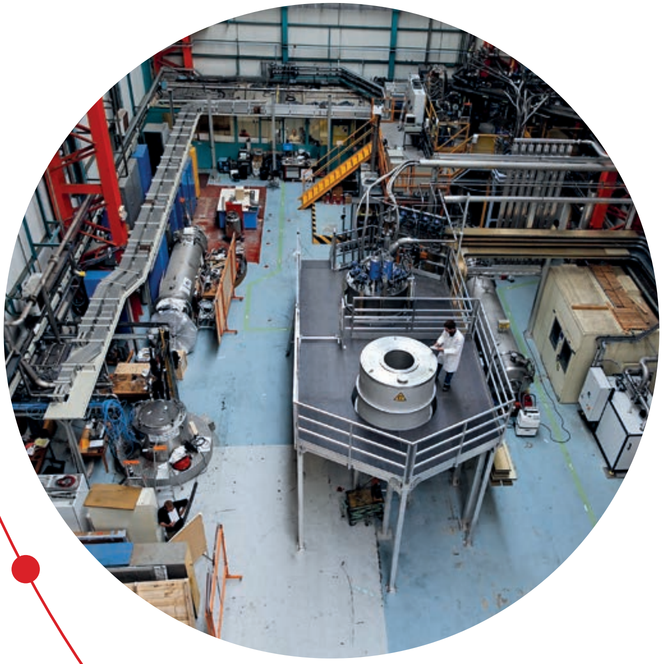
The validation of the characteristics of each source with the diagnostics of the BETSI test bench allowed to qualify the extracted power and the transport in the line allowed to estimate the purity in protons of the extracted power.

**The Benefits**

Pantechnik sold two similar sources, one to the HINEG project in China (requested performance: 50 mA continuous beam at 60 kV) and one for a project at IPR4, an Indian institute (requested performance 30 mA continuous beam at 40 kV).

# CEA - COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES

The CEA-Saclay technical platforms are clustered in a building complex covering an area of 25 000 m$^2$ called "Synergium" as it hosts a large number of technical activities profiting from common skills, personnel and services with complementary themes of development. Besides, the CEA-Grenoble offers platforms specialized in cryogenics.



The technology facilities of CEA have been involved in various Research Infrastructure projects such as:

- ESS
- European X-FEL
- FCC
- GSI Fair
- High-Luminosity LHC
- IFMIF
- Iseult
- JT-60SA
- LNCMI
- SARAF Linac
- SOLEIL
- Spiral2

## TECHNICAL PLATFORMS AT CEA

- Test beam facilities
- Test stations for SC magnets and large cryogenic components
- Test stations under high magnetic field
- Characterization stations at cryogenic temperature
- Test stations for RF devices and SC cavities
- Chemistry, clean room and assembly complex
- Characterization and measurement laboratories
- SC magnet winding and impregnation laboratories

# CERN - EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN operates and maintains a large number of technological infrastructures aimed at the production and testing of magnets and accelerator components, which are placed in different locations on the two main sites of the Laboratory.

The technology facilities of CERN have been involved in various Research Infrastructure projects such as:

- ESS
- GSI Fair
- High-Luminosity LHC

# TECHNICAL PLATFORMS AT CERN

**Facilities for Magnets:**

- Magnetic measurement facilities
- Large Magnet and Long Cryostats Assembly Facility
- Magnet Laboratory
- SM18 Superconducting Magnet Test Facility
- Superconductors and Cabling Facility

**Facilities for Superconducting Cavities:**

- SM18 SC cavities testing area
- Surface treatment workshop for RF cavities

**Technological laboratories and facilities for special technological treatments:**

- Coating Facilities
- Cryogenic Laboratory and Tensile Facility
- Chemistry laboratory
- DCCT and Electrical Standards Laboratory
- High precision Coordinate Measuring Machine
- Horizontal Vacuum Brazing Furnace
- Large Vacuum Furnace for Vacuum Firing Treatments, and Material Characterization for Vacuum Application Workshop
- Polymer laboratory
- Surface analysis laboratory
- Surface treatment workshop

# CNRS - CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

## MAIN ACHIEVEMENTS

CNRS have designed, developed, constructed and assembled the high energy section of SPIRAL2 superconducting high power (200 kW) LINAC. This section consists of 7 cryomodules each housing 2 bulk niobium SC accelerating cavities cooled by liquid helium at 2K : the functional performance of the cryomodule achieved are better than design values.

First experience worldwide of RF power coupler mass production (850 units) for the European XFEL: Production monitoring, quality control, clean room preparation and RF conditioning at a weekly rate of 8 to 10 of power couplers.

CNRS-Orsay's technical platforms related or dedicated to accelerator technology are located in the Orsay Scientific Campus, spread in several building of the two labs. It houses state of the art technological development facilities operated by a high skilled staff in several domains.

The technology facilities of CNRS have been involved in various Research Infrastructure projects such as:

| | | |
|---|---|---|
| - ESS | - LHC | - COXINEL |
| - European X-FEL | - CTF3 | - THOMX |
| - SPIRAL 2 | - ELI-NP | |
| - FLASH | - FAIR | |

## TECHNICAL PLATFORMS AT CNRS

- Test beam facilities
- Chemistry, clean room and assembly complex
- Low and high power Test stations for RF devices and SC cavities
- High temperature vacuum heat treatments furnace for SC cavities
- Warm magnet characterization
- Material characterization test stands at cryogenic temperatures
- Vacuum, surface and material characterization laboratories
- Cryogenic thermometers calibration facility

# DESY - THE DEUTSCHES ELEKTRONEN-SYNCHROTRON

Unique DESY infrastructure and the competences of well-trained technical groups on superconducting accelerator technology are offered within the AMICI program. Partners can profit from dedicated state-of-the-art clean rooms (class 10 / ISO4), cavity treatment (chemical, particle-free high pressure water, dry-ice), assembly facilities for cavities and accelerator modules, and highly developed cold RF testing set-up

The technology facilities of DESY have been involved in various Research Infrastructure projects such as:

| | | |
|---|---|---|
| - ELBE | - FLASH | - ES-DALINAC |
| - ESS | - HZB | - SHINE |
| - European XFEL | - LCLS-II | - SNS |
| | - MESA | - MESA |

# TECHNICAL PLATFORMS AT DESY

- Detailed examination of large series of niobium sheets for the production of superconducting cavities.
- Metallurgy laboratory for the examination of superconducting (s.c.) cavity material.
- Preparation of s.c. cavities including 800°C and 1400°C baking, chemistry for surface treatment (BCP and electro-polishing), high pressure water rinsing, CO2 cleaning with dry ice, large ISO4 clean rooms.
- Several vertical test stands for the characterization of superconducting accelerator cavities
- Assembly infrastructure for the first assembly & for dis-assembly and repair of s.c. accelerator modules.
- Preparation and assembly of particle clean vacuum systems.
- Several horizontal test stands for the characterization of completely assembled s.c. accelerator modules.
- Characterization of smaller s.c. quadrupole magnets.

## INDUSTRIALIZATION SUCCESS STORY

### DESY R&D AND SERVICE CONTRACTS

**The Challenge**
The construction of new research facilities based on superconducting accelerators requires worldwide collaboration between research institutes and industry. Essential and often sophisticated technical platforms exist only at some institutes.

**The Solution**
DESY decided to emphasize collaborative R&D efforts and to offer service contracts using its technical platforms.

**The Benefits**
Several large new Research Infrastructures like LCLS-II, ESS, SHINE profit from quality assurance measures (Niobium scanning, cavity testing) as well as expert training. Universities benefit from collaborative research.

UPPSALA UNIVERSITET

# INNOVATION SUCCESS STORY

## THE EUROSTARS ENEFRF PROJECT AT THE FREIA LABORATORY

### The Challenge

The goal of the project is to contribute to the development of new positron-emission tomography (PET) technologies enabling local production of radionuclides. Currently, vacuum-tube radiofrequency (RF) amplifiers are used to power the radionuclides-producing cyclotrons implying limited efficiency and reliability in their operation.

### The Solution

In collaboration with industrial partners GE Healthcare, Ampegon and Comheat, FREIA is developing new RF amplifiers based on solid-state technologies, which will make the installations more efficient and reliable and less bulky.

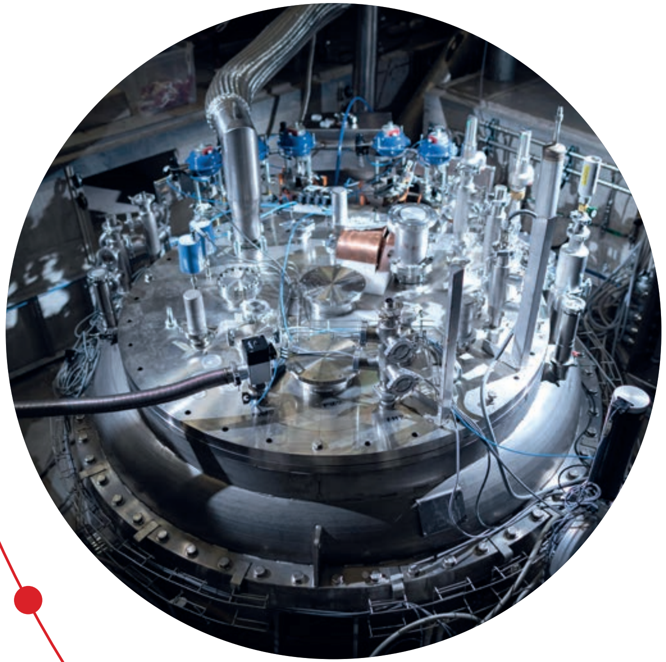
### The Benefits

This will make PET diagnosis more efficient and more accessible, reducing the overall operative costs by improving the reliability and lifetime of the particle accelerator systems.

# UPPSALA UNIVERSITY

The FREIA (Facility For Research Instrumentation And Accelerator Development) technical platform is located in a 1000 $m^2$ experimental hall at the Ångström Laboratory in Uppsala, Sweden. FREIA has a personnel of 25 scientists, engineers and technicians and profits from being integrated in the Science and Technology Faculty of Uppsala University which has a wide research program in physics and technology.The technology facilities of FREIA have been involved in various Research Infrastructure projects such as:

- ESS
- European XFEL
- MAX IV
- High-Luminosity LHC
- CLIC



# TECHNICAL PLATFORMS AT FREIA

- A Helium liquefier with capacity 140 liter per hour
- A horizontal test cryostat for test of dressed superconducting accelerator cavities
- A vertical cryostat for test of superconducting magnets
- Radiofrequency power sources and wave guides
- Low Lever Radiofrequency control systems
- Test bunkers

# IFJ PAN, INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

The Cyclotron Centre Bronowice (CCB) is located in the Institute of Nuclear Physics Polish Academy of Sciences in Krakow (IFJ PAN).

The C-235 cyclotron producing the proton beam with energy from 70 MeV to 230 MeV and intensity from 0.5 nA to 500 nA. It is engaged in the application of cyclotrons in scientific research and tumor radiotherapy. The CCB also includes the experimental room with horizontal beam and with magnetic optical system enabling beam size adjustment, the gantry facility which enables sample irradiation from 0 MeV to 230 MeV using scanning beam (with ⌀2.7 mm or ⌀4 mm spot size) and at a selected angle within the range of 0 to 360, the facility for irradiation with the use of horizontal beam with energy ranging from 0 MeV to 70 MeV; this facility gives a possibility of irradiation using Spread Out Bragg Peak, SOBP. Dose rate: from 0.01 to 1Gy/s, two separate rooms for biological samples preparation (material of animal and human origin).

The possible industrial application are the irradiation of physical and biological material, and the tests of the detectors and the dosimeters.


# TECHNICAL PLATFORMS AT IFJ PAN

- A Helium liquefier with capacity of 40 liter per hour
- A Proteus C-235 cyclotron
- An AIC-144 cyclotron
- An ion microbeam at the van de Graaf accelerator

more: https://www.ifj.edu.pl/en/institute/equipment/

## INNOVATION SUCCESS STORY

### THE PIERRE-AUGER PROJECT UPGRADE AT THE IFJ PAN

**The Challenge**

The IFJ PAN's commitment for the collaboration was to deliver 180 Scintillator Surface Detector units.

**The Solution**

The construction of the detectors was carried out by the Division of Scientific Equipment and Infrastructure Construction (DAI). For assembly of the SSD, appropriate rooms have been adapted, and special equipment and necessary tools have been purchased.

Each assembled detector had be checked and tested prior to shipment to Argentina. For these tests the engineers and technicians from DAI have designed and built an automatic SSD test system controlled by LabView applications.

**The Benefits**

The IFJ PAN developed new skill in construction of equipment for extremely high Energy particles detection.

## INNOVATION SUCCESS STORY

### INFN/CECOM COLLABORATION BRINGS BENEFITS FOR BOTH PARTIES

**The Challenge**
Realization of aluminium vacuum chambers, as proposed by INFN, for high current, low emittance particle accelerators.

**The Solution**
Through the collaboration with INFN-LNF Frascati, CECOM had access to our NC cavities and expertise in the test of the fabricated vacuum chambers. The expertise of INFN's staff in collaboration with CECOM, ensures the success of the realization in term of quality and delivery time.

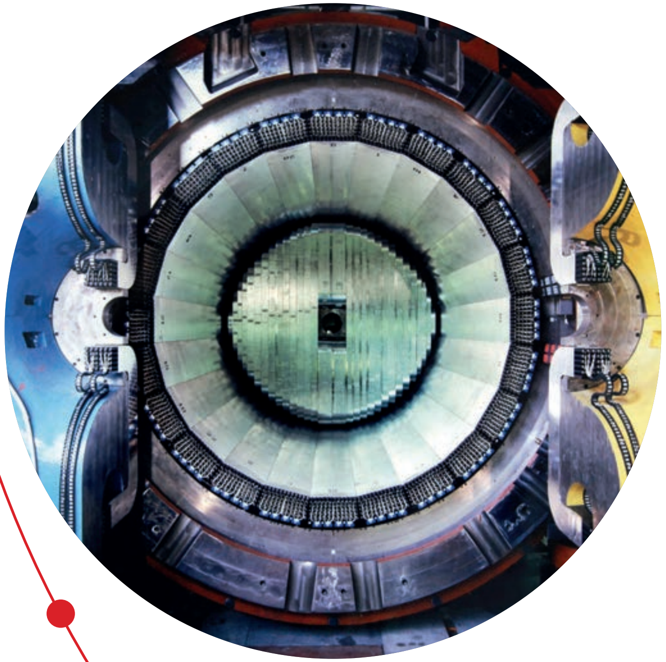
**The Benefits**
Through this engagement, CECOM successfully developed the technology (for manufacturing and testing) of aluminium vacuum chambers for particle accelerators. INFN benefits from the support of CECOM to provide are liable platform for industrial development of new ideas and accelerators components.

# INFN - ISTITUTO NAZIONALE DI FISICA NUCLEARE

The Italian National Institute for Nuclear Physics (INFN) has developed different facilities related to accelerator technology. Nowadays, several groups can provide high level services to physics laboratories and industries working in magnet technology, radiofrequency, cryogenics and radiations.

The technology facilities of INFN have been involved in various Research Infrastructure projects such as:

- CTF3
- High Luminosity LHC
- European XFEL
- ESS
- IFMIF
- FCC
- ELI-NP
- ESFR
- SPES



# TECHNICAL PLATFORMS AT INFN

- Irradiation
- High Magnetic Field Facilities
- Thermal Treatments
- Test Stations for Traditional Magnets
- Test Station for Superconducting Magnets
- Test Stations for Radiofrequency Equipment
- Chemical Treatments

# KIT - KARLSRUHER INSTITUT FÜR TECHNOLOGIE

The ATP is a central access-point to accelerator-relevant technologies and know-how at the Karlsruhe Institute of Technology (KIT). About 300 scientists and technical staff operate the infrastructure and pursue advanced research. ATP covers a wide range of technologies, from superconducting magnets and materials to high-throughput beam diagnostics and imaging. The technology facilities at KIT have been involved in various Research Infrastructure projects such as:

| | | |
|---|---|---|
| - BESSY | - European X-FEL | - ATHENA |
| - Dafne | - FCC | - IFMIF |
| - ELBA/TELBE | - FLASH | - JT-60SA |
| - ESS | - GSI Fair | - LHC |
| | - High luminosity LHC | - SOLEIL |

# TECHNICAL PLATFORMS AT KIT

- Accelerator test facilities (electron storage ring and short-pulse linac)
- Characterization facilities for superconducting magnets and insertion devices
- Cryogenics and cooling test facilities
- Superconducting magnet winding and impregnation laboratories
- Characterization facilities for permanent and normal conducting accelerator magnets
- Test stations for RF, microwave and pulsed power technology
- Test facility for energy systems and electrical networks
- Characterization facilities for materials development (HTS, surfaces)
- Fabrication and characterization facilities for nano- and micro technology
- Electronics interconnect and packaging center

## INNOVATION SUCCESS STORY

### BILFINGER NOELL AND KIT: BRILLIANT LIGHT FROM IN-SERIES PRODUCED SUPERCONDUCTING UNDULATORS

**The Challenge**

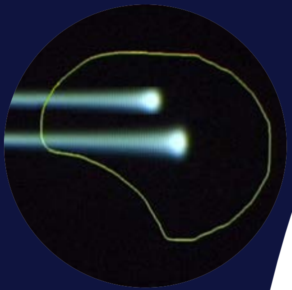
Today's and future light sources require industrial-grade, high-performance, flexible while compact and radiation-resistant insertion devices.

**The Solution**

With its industrial partner BilfingerNoell, KIT initiated the development of superconducting undulators from the laboratory to industrial in-series production. Access to KIT's magnet characterization facilities allows fast-turnaround prototyping and quality assurance.

**The Benefits**

Bilfinger Noell developed the technology for manufacturing superconducting undulators. The community profits from the availability of high-performance, industrial-grade x-ray light sources for storage rings and FEL as commercial products. Rapiscan Systems in maintaining its position as a global market leader.



# INNOVATION SUCCESS STORY

## PROTON THERAPY PENCIL SCANNING TECHNIQUE

**The Challenge**
Proton therapy requires irradiation of malignant tumours over an extended volume with careful control of the irradiation dose to the tumour to be treated and with minimum dose to the surrounding healthy tissue.

**The Solution**
PSI has developed a technique of rapidly scanning the volume to be treated with a pencil like proton beam in a highly controlled fashion. The pencil scanning technique requires the use of fast power supplies, laminated magnets and a fast monitor and control system which were developed at PSI and tested on its technical platforms.

**The Benefits**
After demonstrating its possibilities during several years at PSI this development has been adopted by industrial manufacturers of proton therapy accelerators all around the globe. It has allowed thousands of patients to receive improved treatment modalities adding to the effectiveness and safety of this form of therapy.

# PSI - PAUL SCHERRER INSTITUTE

The Paul Scherrer Institut operates state of the art, accelerator based, research facilities for a large multi-disciplinary scientific community. These research infrastructures (RI) are supported by technology infrastructures (production and test facilities) which are essential for the reliable operation, maintenance and continued development of the RIs.

The test and production facilities have also helped PSI to contribute to major external accelerator and superconducting magnet projects such as :

- CLARA
- European X-FEL
- ITER
- CLIC
- FCC
- ESS
- FLASH

# TECHNICAL PLATFORMS AT PSI

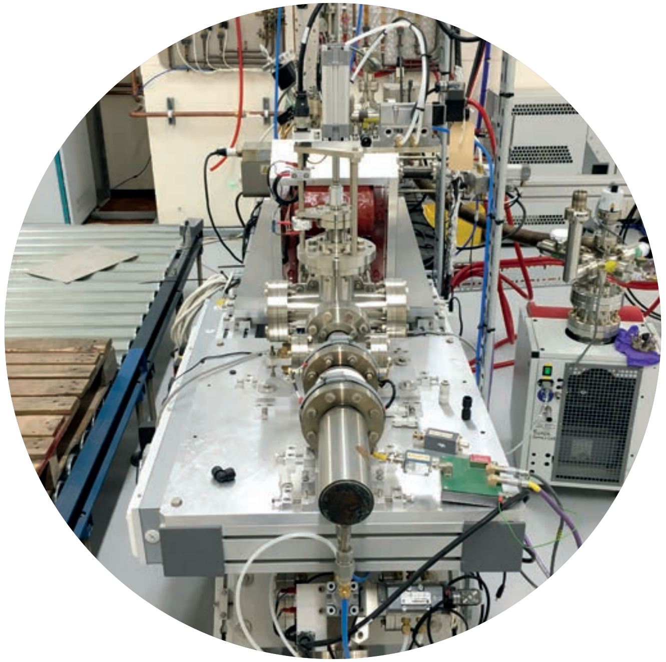
- 500 MHz RF test stand
- 50 MHz RF test stand
- C-band RF test stand
- ECR ion source test stand
- Magnet test and measurement laboratory
- Superconducting  magnet test facility (in preparation)
- Vacuum test laboratory
- Proton Irradiation Facility

# STFC - SCIENCE & TECHNOLOGY FACILITIES COUNCIL

STFC's unique test environment supports research and development in key sub-component technologies including vacuum, magnets and RF, as well as enabling complete accelerator system validation. STFC delivers technological advancements for particle accelerators and beyond through extensive collaborations with international laboratories, academia and industry.

Major projects that STFC's technology facilities have contributed to include:

- CLARA
- CTF3
- ELI-NP
- ESS
- FCC
- FLASH
- HL-LHC
- PIP-II
- SwissFEL



# TECHNICAL PLATFORMS AT STFC

- Compact Linac
- Cryogenics Test Laboratory
- Engineering Technology Centre
- Front End Test Stand
- Magnet Test Laboratory
- Vacuum and Surface Science Laboratory
- Versatile Electron Linear Accelerator

Science & Technology Facilities Council

## INNOVATION SUCCESS STORY

### RAPISCAN TESTS NEW TRAVEL SECURITY TECHNOLOGIES WITH VELA

**The Challenge**

Rapiscan Systems wanted to test their theoretical assumptions for generating 3D X-ray images before committing to longer-term investment in this innovative technology.

**The Solution**

STFC's unique test environment with VELA's high energy and short pulse widths, combined with expert staff, enabled Rapiscan Systems to perform proof-of-concept experiments.

**The Benefits**

Reassurance for long-term investment into this strategic product development programme supporting Rapiscan Systems in maintaining its position as a global market leader.

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