

IS FUNDAMENTAL RESEARCH ESSENTIAL?



Why Fundamental Research is essential.
INFIERI 2021
4th September 2021

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23/8 to 4/9, 2021, in Madrid
at the UAM Campus



WHY FUNDAMENTAL RESEARCH IS ESSENTIAL.



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Awareness about Fundamental Research

A quite recurrent question repeatedly surveyed...

Questioning People in the streets, at Schools and even at Universities will give you the same feedback...

Fundamental Research is not very well understood!

1st Statement: National, EU Authorities and Managers from Public and Private Sectors are amongst population, **those who show the highest level of awareness and understanding** about the role of Fundamental Research!



What is Fundamental Research?



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What is Fundamental Research?

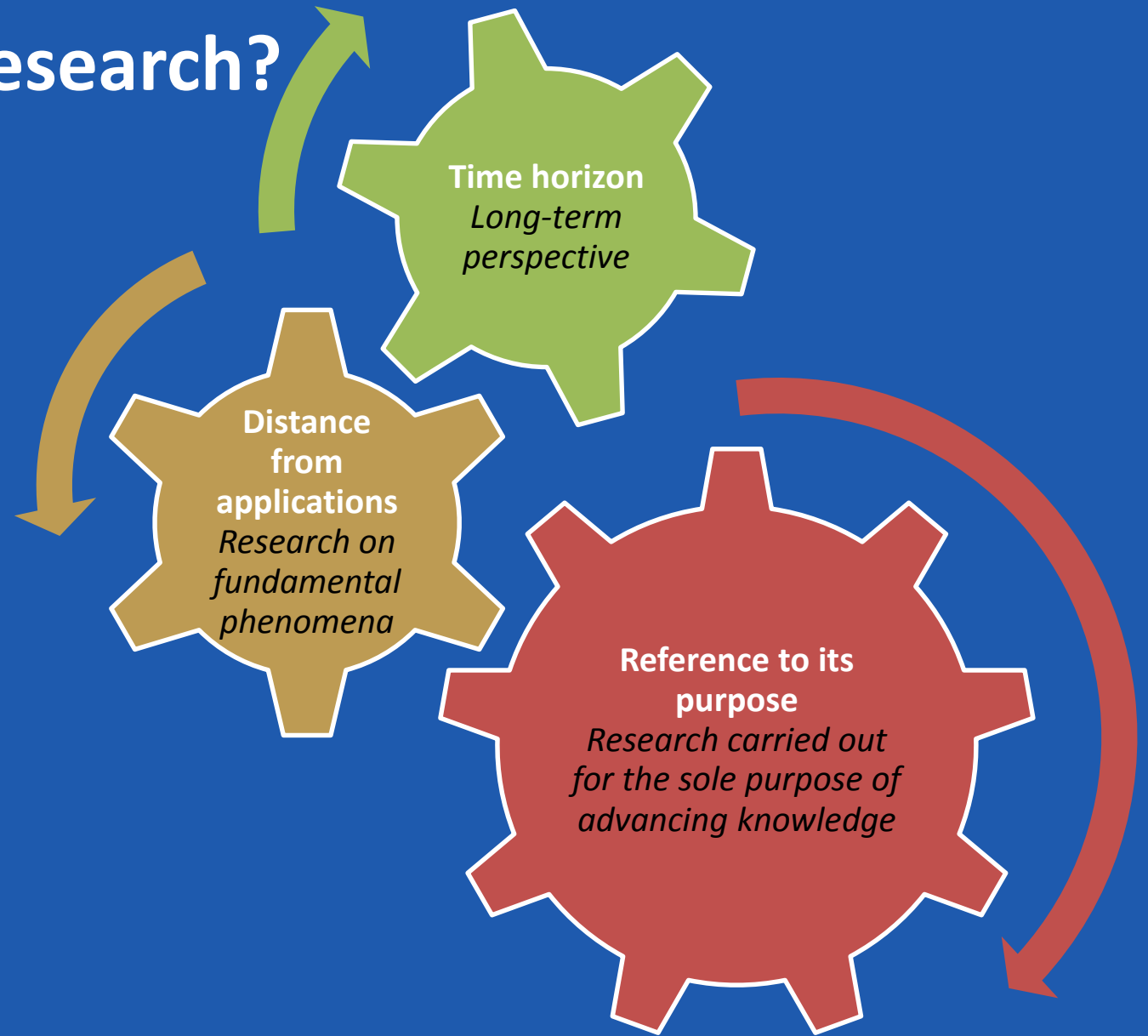
“*Basic research*, also called *pure research* or *fundamental research*, is a type of scientific research with the *aim of improving scientific theories for better understanding and prediction of natural or other phenomena*. In contrast, *applied research* uses scientific theories to *develop technology or techniques* which can be used to intervene and alter natural or other phenomena... *Basic research often fuels the technological innovations of applied science*.” [source: Wikipedia]

“...it remains the type of research, and particularly the *intent and freedom to publish, that identifies 'fundamental research...'*; includes *Basic and applied research in science and engineering, excluding proprietary research or industrial development, design, production, or product utilization*”; “The *resulting information is ordinarily published and shared broadly within the scientific community*”. [source: MIT]



What is Fundamental Research?

Three pinions that
make some consensus
to describe
Fundamental Research



Humm... still, what is Fundamental Research?

The vision of President Roosevelt's Science Adviser, Vannevar Bush, creator of the National Science Foundation (NSF), declared in his famous 1945 report "**Science: the Endless Frontier**": *"To a great extent, scientific progress is the result of the free play of free minds working on subjects of their choice, in a manner determined by their curiosity to explore the unknown"*.

Gradually, in the name of the importance of research for industrial competitiveness and its role in meeting social needs, this emphasis, and with it public funding, has shifted to applied research and technological and industrial development.

2nd Statement: Today, the general value of the advancement of knowledge, and the importance of Fundamental Research for economic and social development, tend to be again fully recognized.



A paradox of Fundamental Research?



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A Cultural on-going (re)evolution... in Academia

“*Traditional*” academic domains tend to be replaced by inter-disciplinary approaches: Example of the EPFL in Lausanne (CH)...

Centers

Centers create networks, collaborations and synergies between researchers and students around state-of-the-art scientific subjects. They build bridges between researchers at EPFL and other academic institutions, foster innovation and contribute to advance and share knowledge on specific themes within and beyond the academic world.

Discover the centers

- Environment
- Imaging
- Fundamental sciences
- Health sciences and technologies
- Science, culture and society
- Digital systems

Facilities

Facilities provide access to cutting-edge technical infrastructure and know-how expertise to EPFL scientists and students to perform their research, making optimal use of resources. They are also a place where knowledge and knowhow is shared and where EPFL contributes to advance the state of the art in the techniques covered by the platform.

Discover the facilities

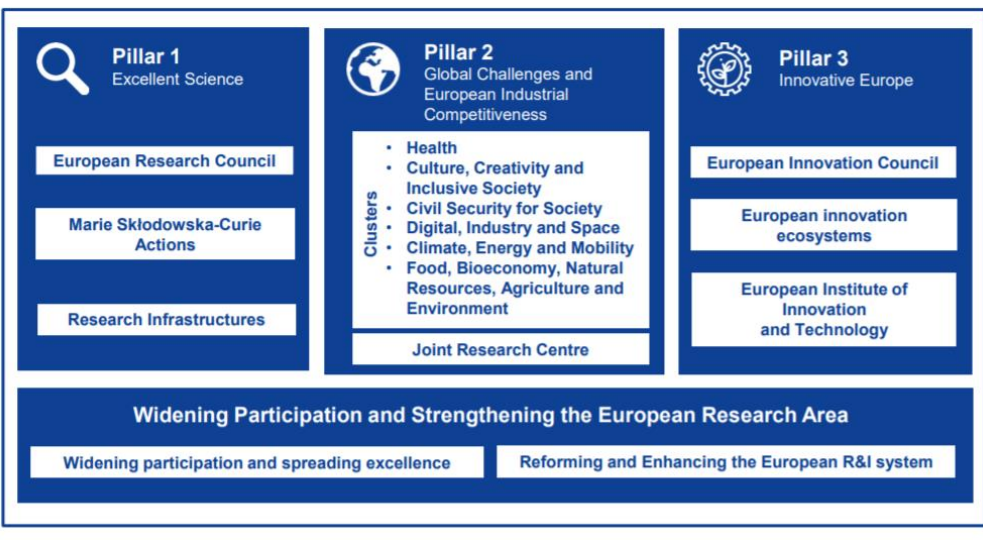
- Characterization
- Energy
- Fabrication
- Imaging
- Computing



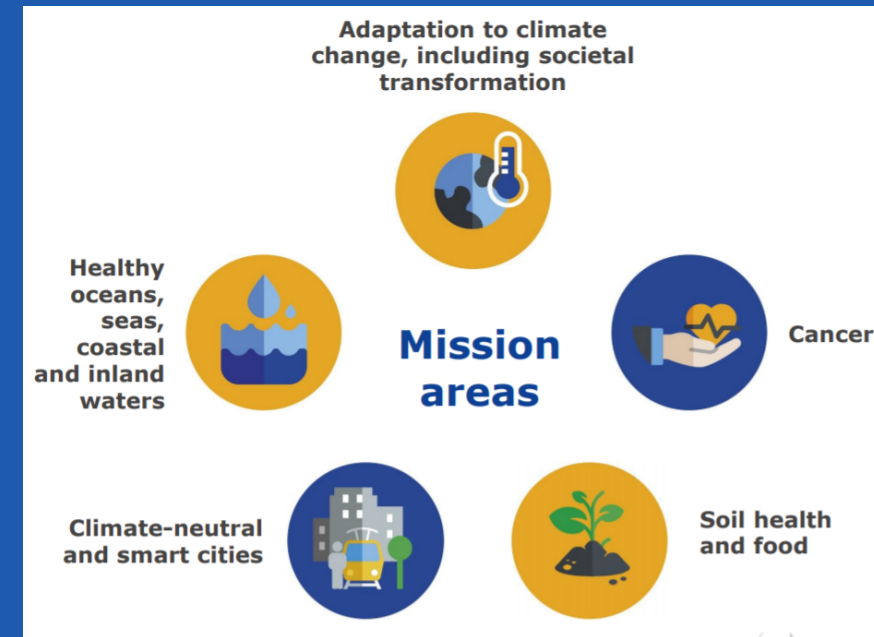
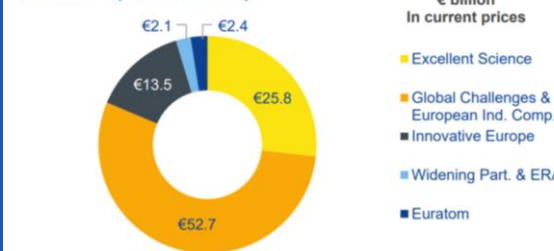
Empowered by the EU Horizon Europe program

... and we will have *all* to spend time to find possible branches (“Parents”) to enhance prospects for financing.

Horizon Europe: Preliminary structure



Commission proposal for budget: €100 billion* (2021-2027)



Optimal balance between basic and applied research?

- Who could have predicted that Professors Andre Geim and Kostya Novosolev from the University of Manchester **would discover graphene while using scotch tape** to remove flakes from a slab of graphite?
 - Graphene is the thinnest, lightest and strongest material known to date and can take any shape. Today, laboratories around the world are exploring its enormous potential.
- ‘We should not forget that **basic science and applied science are two sides of the same coin,**’ recalls the UNESCO Science Report.
 - Most OECD countries still strongly committed to basic research
 - Basic research helps to adapt to a rapidly evolving market
 - Crises have made governments rethink their priorities
 - Science powers commerce – but not only
 - Many emerging economies augmenting support for basic research

[UNESCO Science Report: towards 2030]



An “obsolete” 2-D classification

3rd Statement: what’s yours?

Basic Research	Applied Research
Expands current knowledge	Solves particular life problems
Theoretical and exploratory in nature	Practical and descriptive in nature
Wider scope	More specific scope
Less associated with technology	Associated with the advancement of technology
Predicts future phenomena	Creates solutions or preventions for future problems
Curiosity-driven	Client-driven
Does not have direct commercial objectives	Has direct commercial objectives
Less connected with economy	Highly connected with economical pursuits
Less often appear in academic publications	More often appear in academic publications
Takes place in sterile environment	Occurs in real world settings

[Source: Gene Brown, Difference Between Basic Research and Applied Research]



Funding: one of the missions of Public Authorities

- Support for **Fundamental Research** is traditionally considered **one of the missions of the Public Authorities**.
 - The positive perception of Fundamental Research is more and more widely recognised and supported.
 - The impact, indirect but indisputable, of fundamental research on the economic competence, growth and, more generally, well-being.
- The **increasing cost of Fundamental Research**, due in particular to that of **necessary instruments, equipment and infrastructure**, even that of **complexity of the problems** it deals with, which **increasingly calls for often interdisciplinary approaches**.
 - Cost that the private sector is little inclined to take charge, due to the very indirect nature of the expected financial return;
- The "public good" value of knowledge, which implies ensuring that **knowledge, as a principle, free access**, more easily guaranteed in the case of a public funding.
 - For reasons which, it appears necessary to provide this support to Fundamental Research.

[Source: Report to EU Parliament]



Fundamental Research in few numbers...



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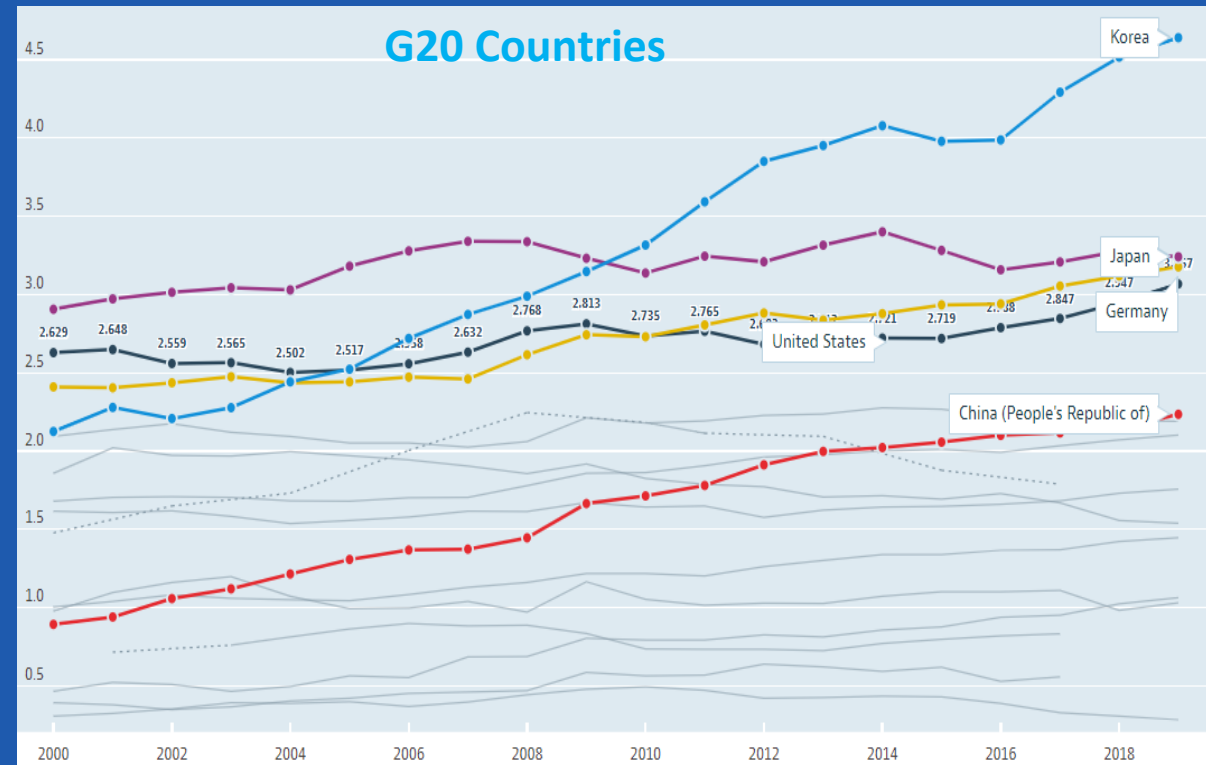
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Fundamental Research in % of GDP



[Source: OECD]



More than absolute numbers, the trend talk by themselves



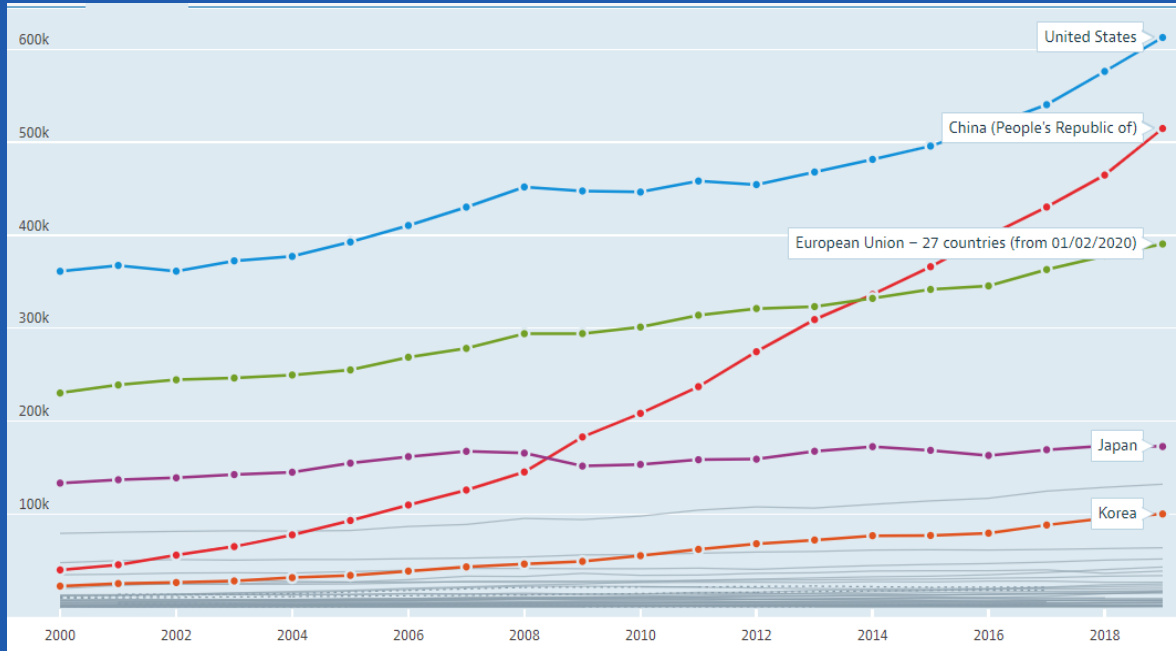
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Fundamental Research in Millions US dollars



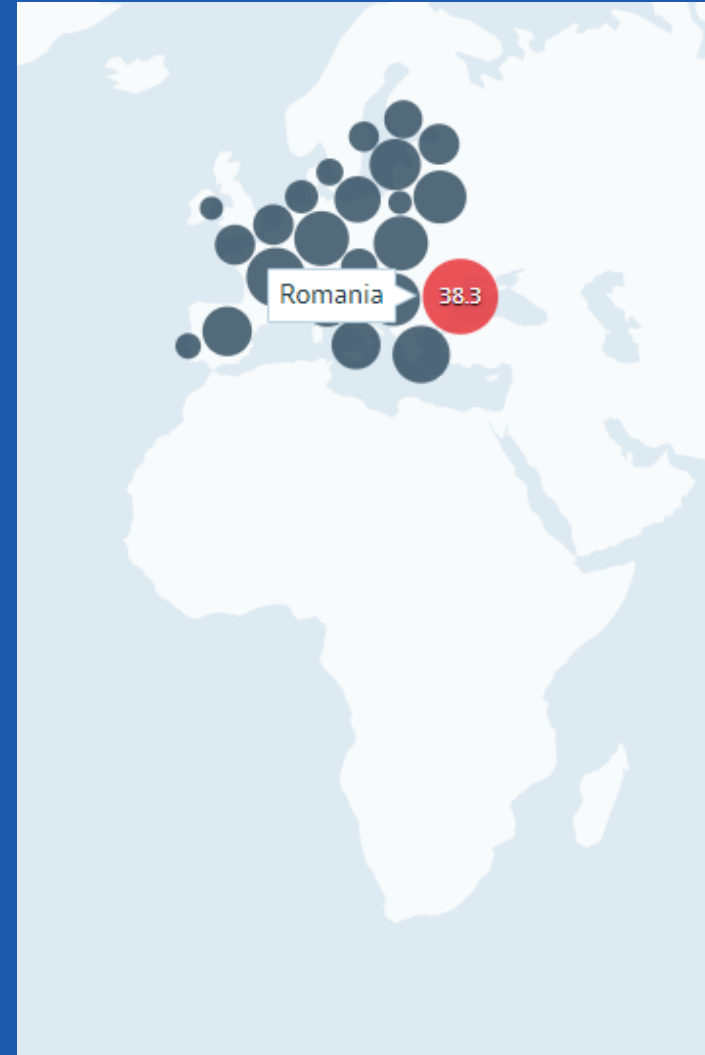
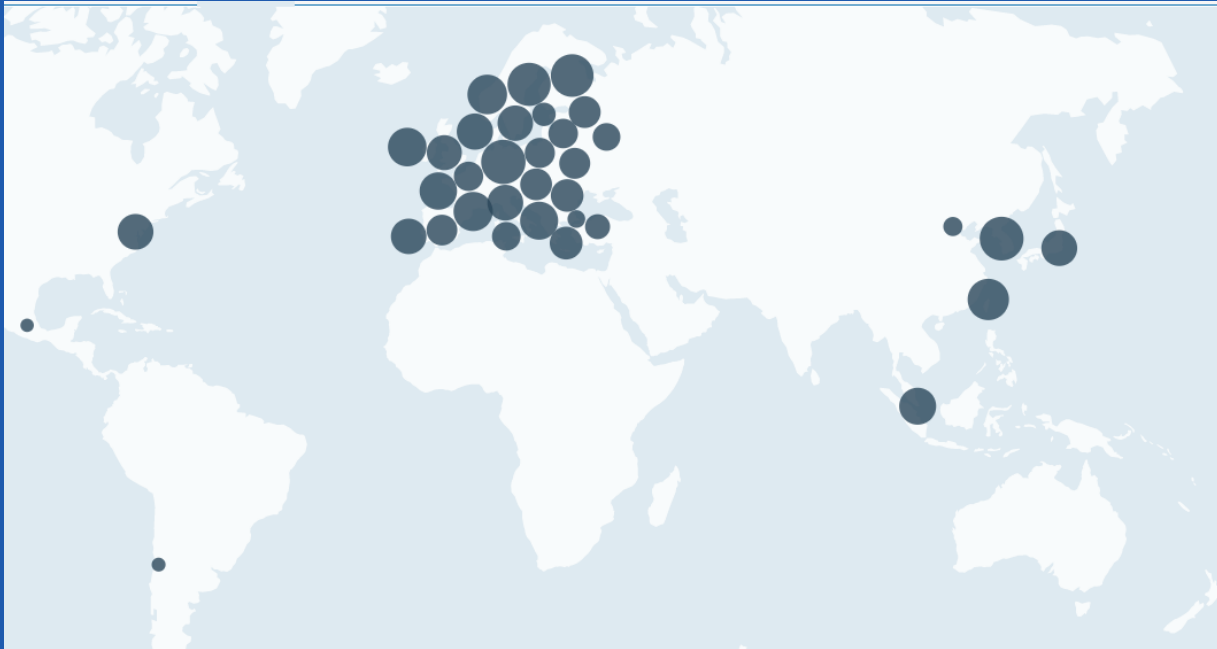
[Source: OECD]

Going for a European common effort seems the way to foster common efforts and ensure competitiveness.



Fundamental Research in number of Researchers

per 1,000 employed in the Public Sector



*4th Statement: complex indicators...
Difficult to judge without entering in details.*

Societal impacts of Fundamental Research?



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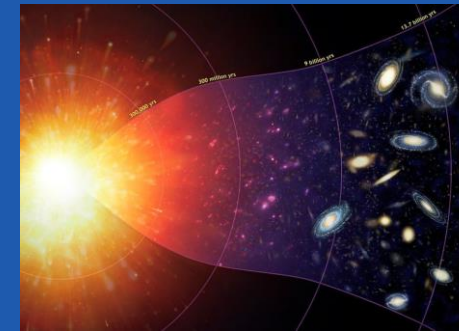
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Impact of Science in the last Century

Almost every modern invention has one or often many fundamental discoveries that make it possible.

- The discovery of the structure of **DNA** shifted our perspectives
- Universe began with a **Big Bang** from a single point
- **Space exploration** have made us more inquisitive about the great unknown



Impact of Science in the last Century

- **GPS** depends on correcting the time from satellites using both the special and general theories of relativity
- Smartphones, tablets, computers depend on many fundamental discoveries. Its CPU depends on integrated and densified chips made up of **transistors**, whose discovery depended on an understanding of quantum mechanics
- Applying particle accelerator and detector's technologies to human tissues was beneficial to the **proton and ion-therapies**, use of **radio-isotopes** for **imagery** or **combined imagery-therapy**



Most recent example of MediPix 3

- Closing the loop- accelerating discoveries at edges of Fundamental and Applied research...

First European hospital receives 3D colour X-ray scanner using CERN technology

MARS Bioimaging's 3D colour X-ray scanner has arrived in Europe for clinical trials that will lead to medical use of a CERN technology

26 AUGUST, 2021 | By Antoine Le Gall



MARS Bioimaging scanner at Lausanne University Hospital (CHUV). (Image: CHUV)

Since 2008, CERN and the New Zealand company MARS Bioimaging have teamed up to develop a 3D colour X-ray scanner based on the Medipix3 technology, developed by the Medipix3 collaboration. Inspired by particle physics detectors, Medipix3 and Timepix3 chips are now used for medical applications, in space and for art authentication.

...

“Trials of this technology in a Swiss hospital clearly demonstrate the pathway from experiments performed in a physics research laboratory to making a difference to patient healthcare,” adds Professor Anthony Butler, President of MARS Bioimaging.

...

[Source: CERN weekly]

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Socioeconomic impact of fundamental Research: CERN LHC

➤ Education and Training

The contribution to human and social capital accumulation is one of the most important socio-economic benefits of Fundamental Research, especially for early-career researchers.

Findings show that an **experience-based learning process at CERN** is instrumental in developing skills and **reveal an expected salary premium between 5% and 11%**, on **average 150 000 EUR cumulative salary increase** per student throughout his/her career (hypothesis 30 years career).

➤ Industrial spillovers

- In the LHC, **4204 companies from 47 countries** had 33,414 contracts.
- Resulting in higher profitability, the **utility sales ratio of CERN is around 3!**

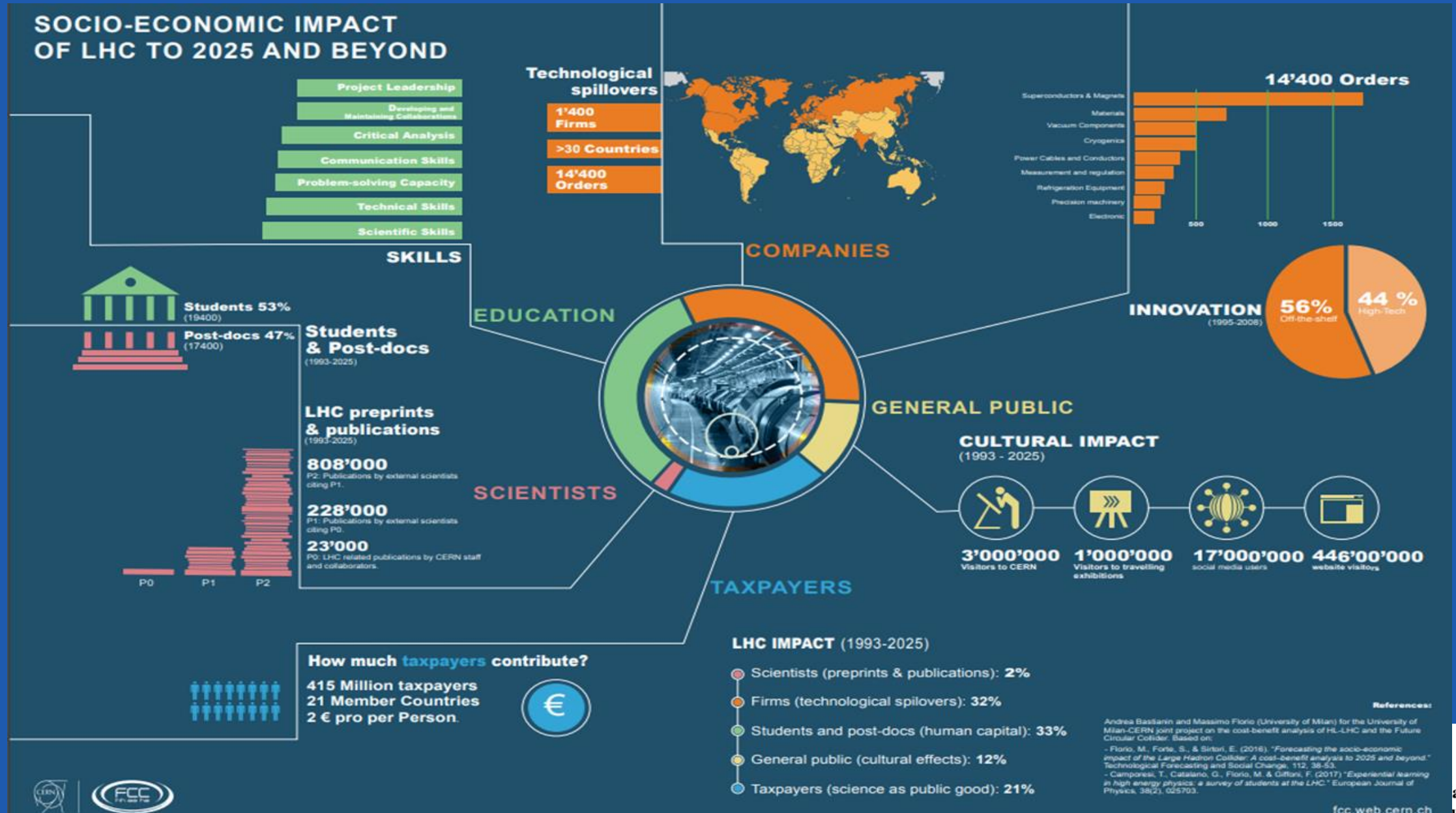
➤ Yearly economic value generation

- **~>83 MCHF** spent by 83,000 Visitors!

	Spending	Time value
Groups	53.2 MChf	11.8 MChf _(24h)
Individuals	17.6 MChf	1.5 MChf _(5h)
Per year	70.8 MChf	13.3 MChf
Total	ca. 84 MChf / year	



Socioeconomic impact of fundamental Research: CERN LHC



[Courtesy: Irene Crespo, CERN]
<https://twiki.cern.ch/twiki/bin/view/FCC/ImpactSustainability>



The strength of Fundamental Research and Academia



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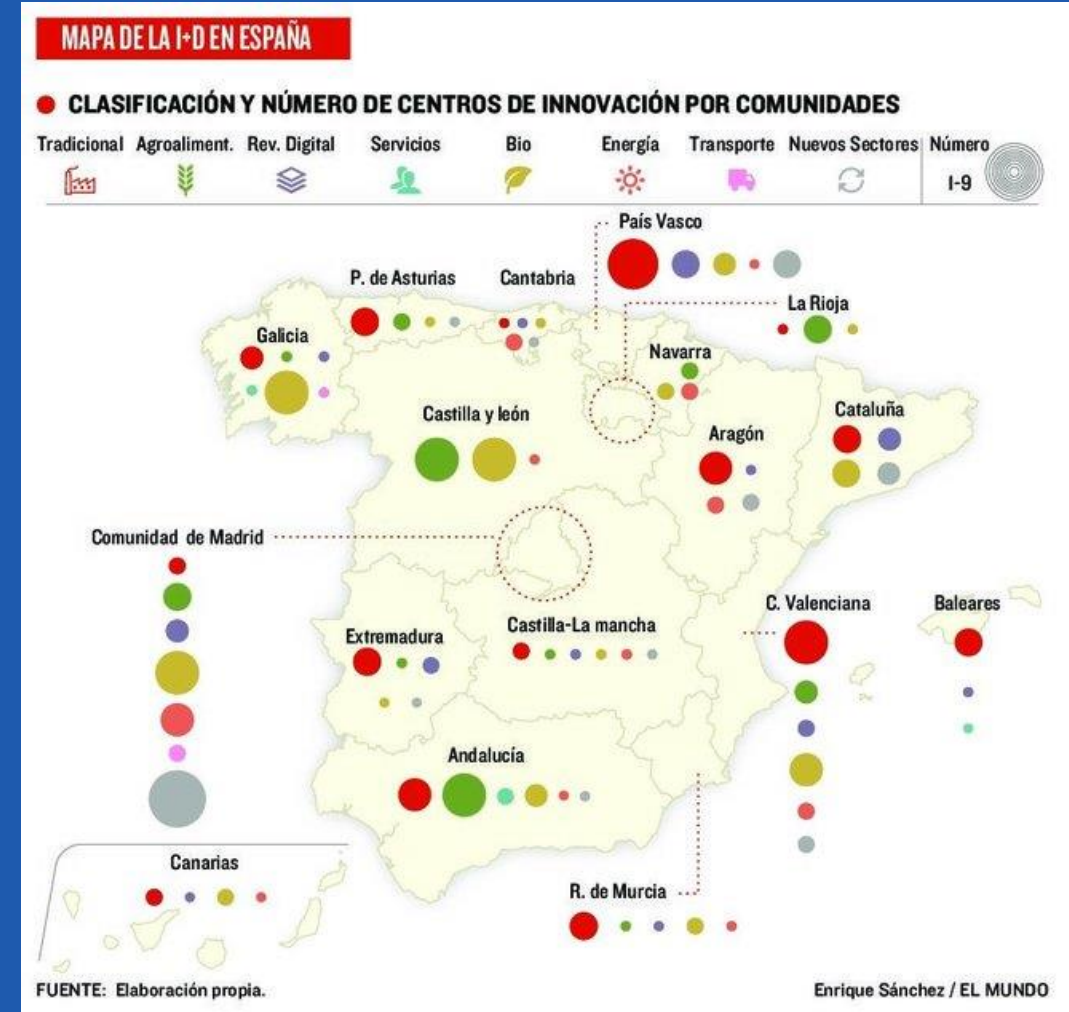
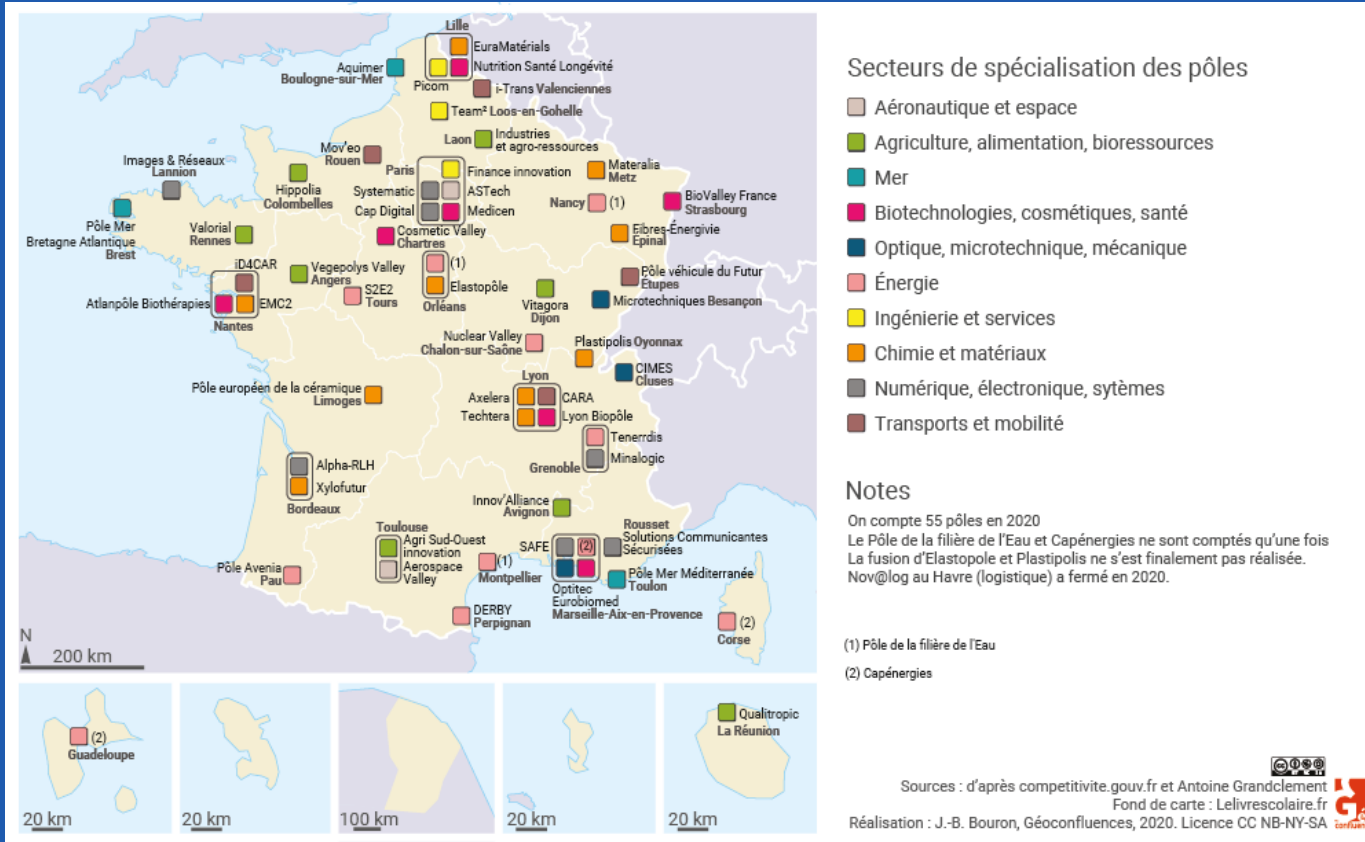
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An amazing Vector for development of Territories!



5th Statement: All Territories show
proudness of their Research capacities



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Diplomacy of Science

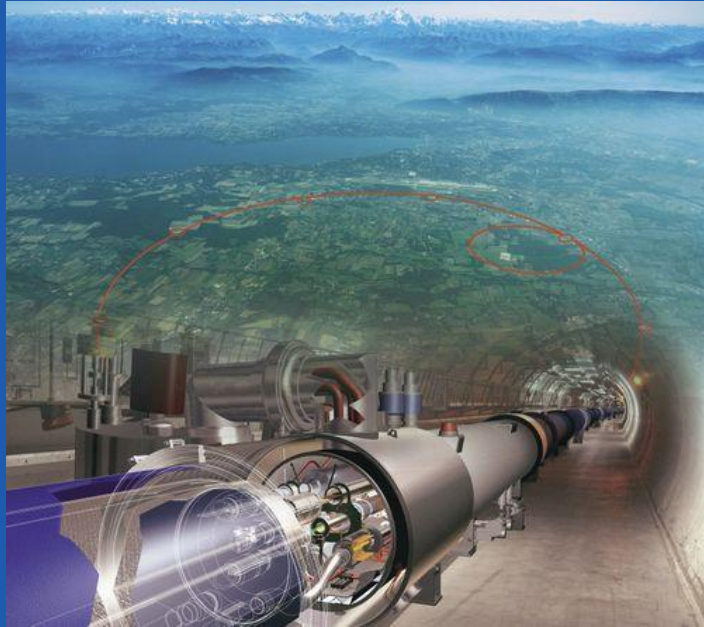
Became strategic during the last decade...

*“the use and application of science cooperation to **help build bridges and enhance relationships between and amongst societies, with a particular interest in working in areas where there might not be other mechanisms for engagement at an official level**”,* said Vaughan Turekian, then-director of AAAS’s Center for Science Diplomacy

- Universal **Values of Science** can transform international relations
- Scientific collaborations are the preferred means to **transform international relations**
- Diplomacy of Science **open the path to discuss more delicate global challenges**
- A way for countries to exercise their own *soft power* and in some case impose the *co-petion model*

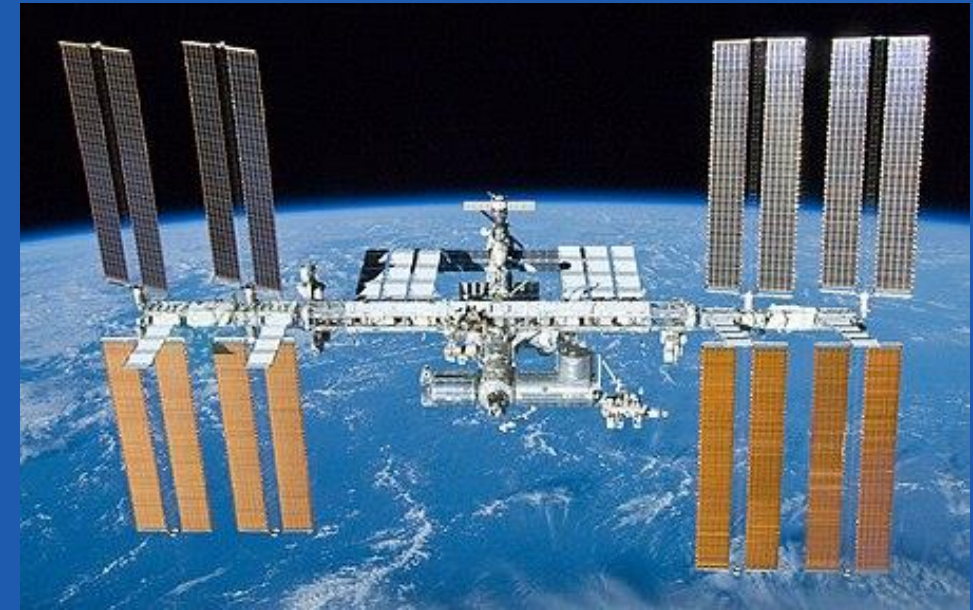


Large Scientific Research Infrastructures... flagships of Diplomacy of Science



European Organization
for Nuclear Research
CERN

International
Thermonuclear
Experimental Reactor
ITER



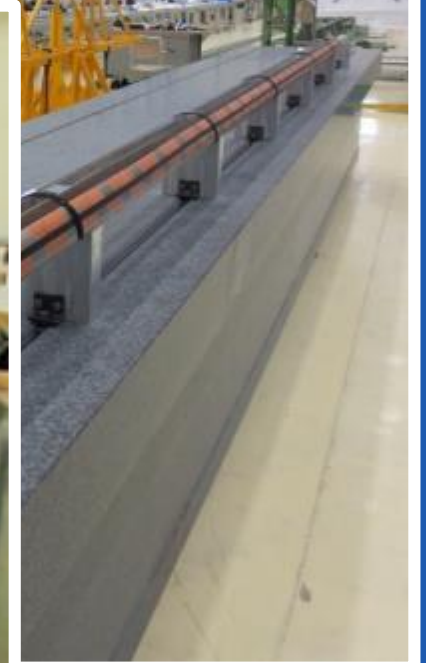
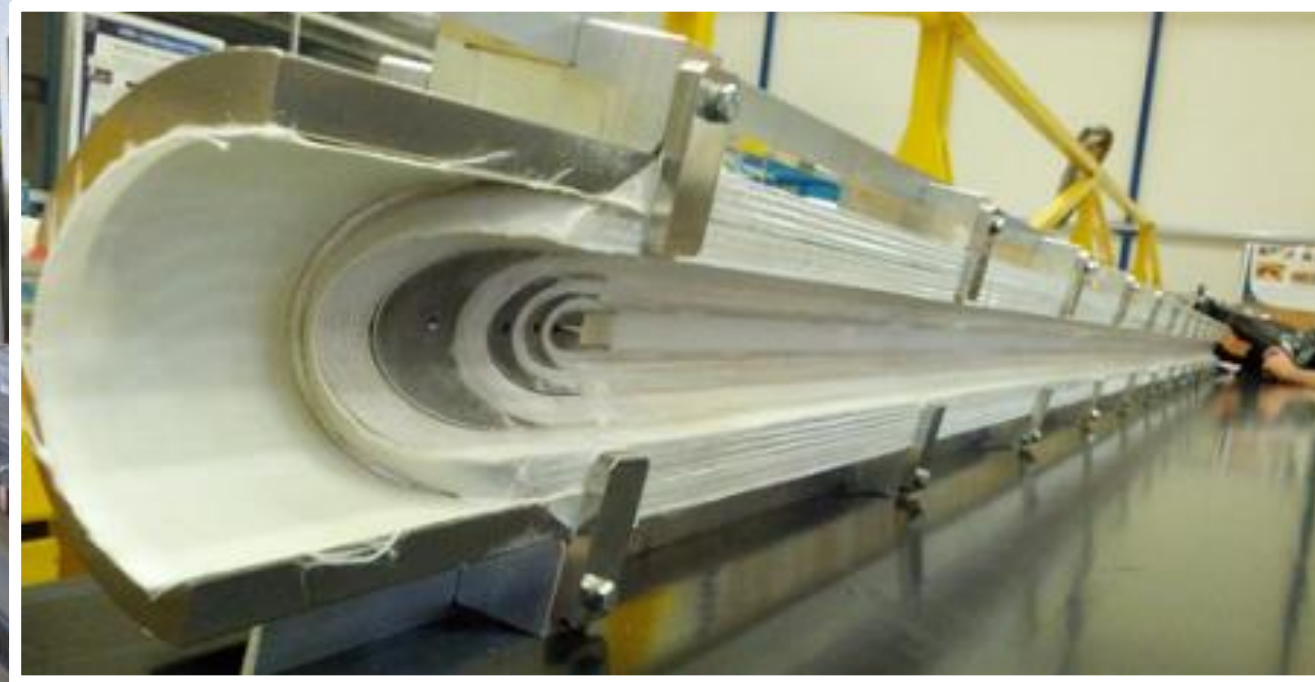
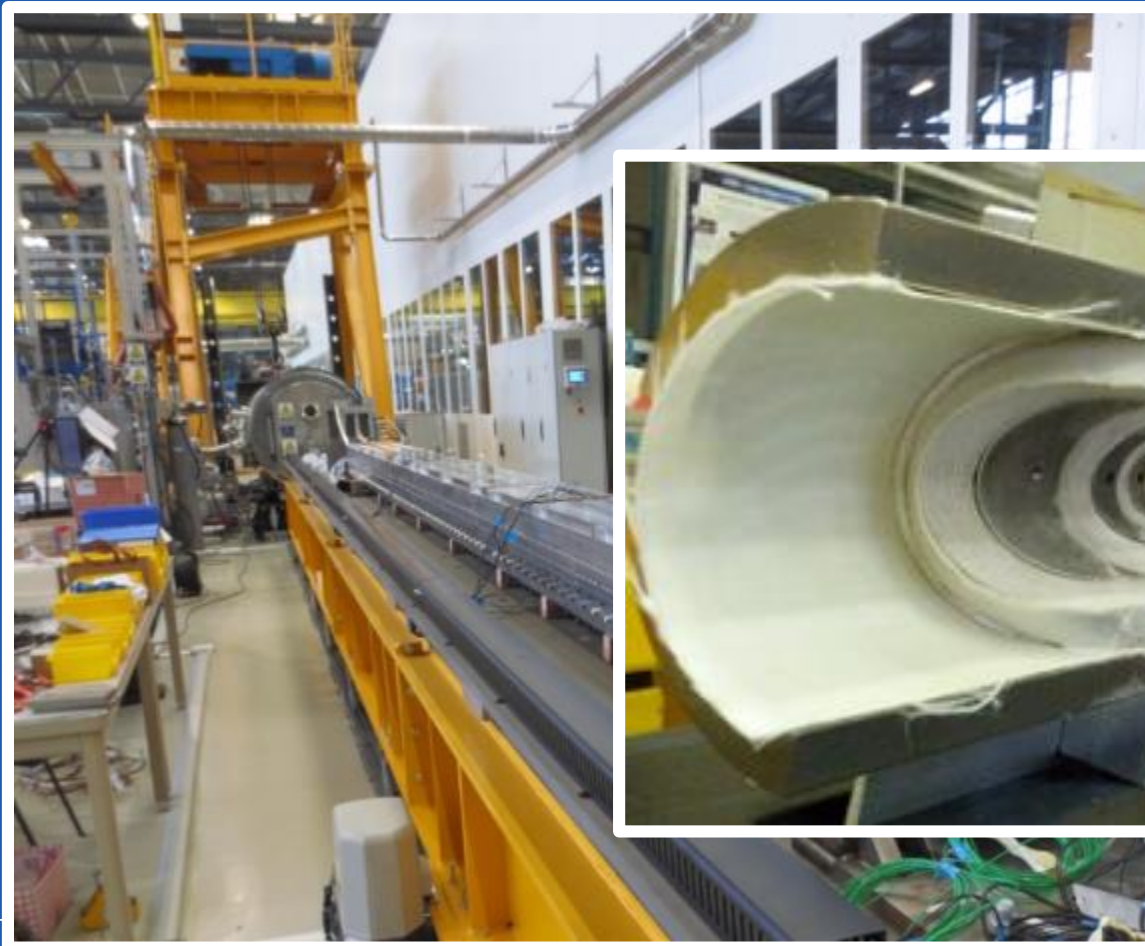
International Space Station
ISS

Multi-purpose large assembly infrastructures Large magnet factory @CERN



Amazing magnet workshops without equivalent worldwide!

Multi-purpose large assembly infrastructures Large magnet factory @CERN



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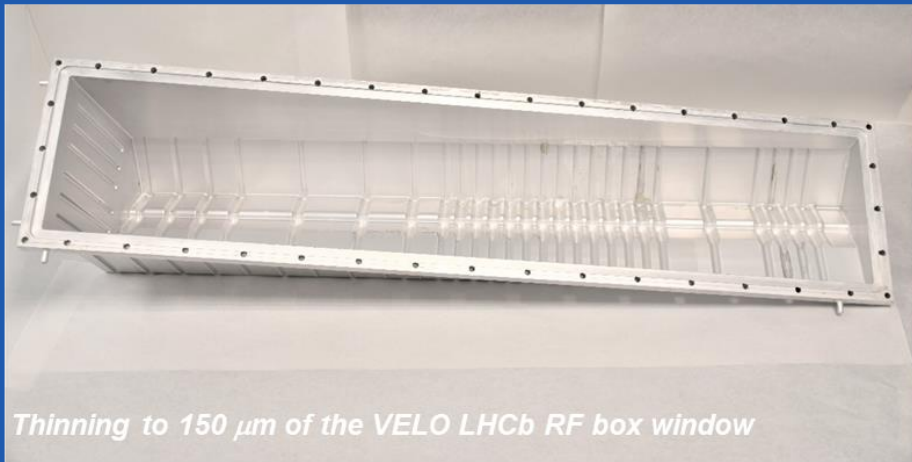
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Continuity of large technical infrastructures Surface treatment plant @CERN

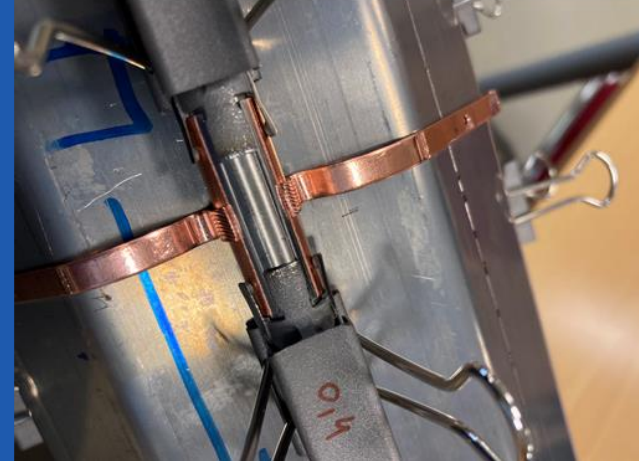
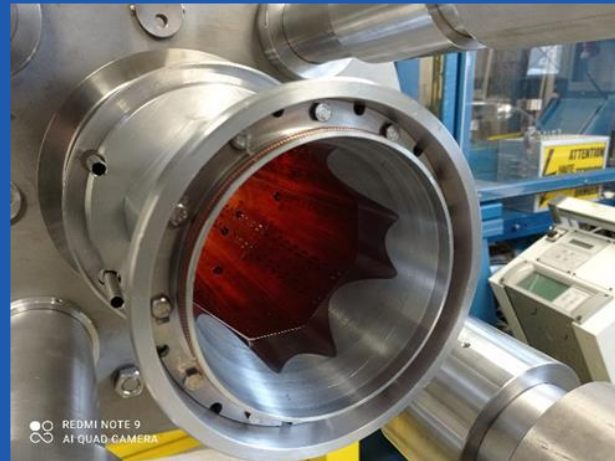
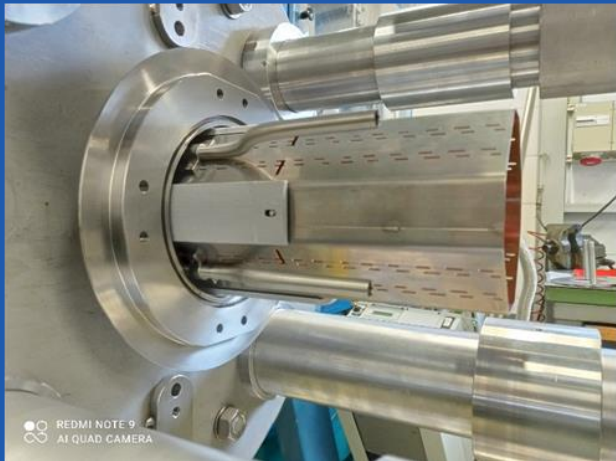
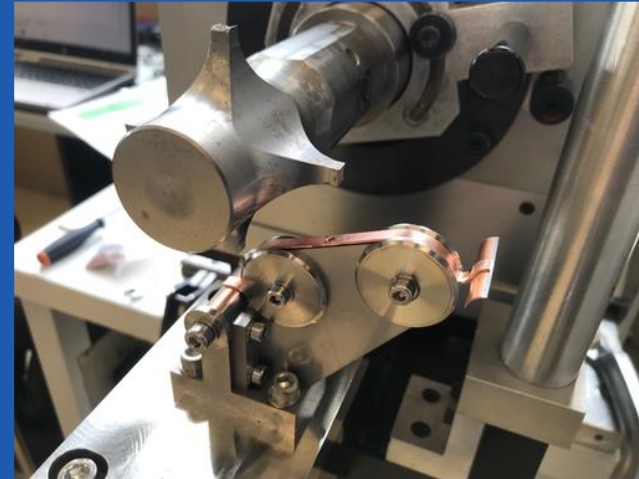
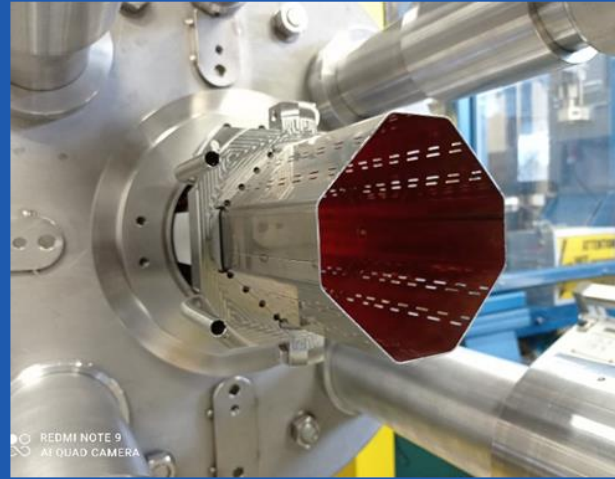
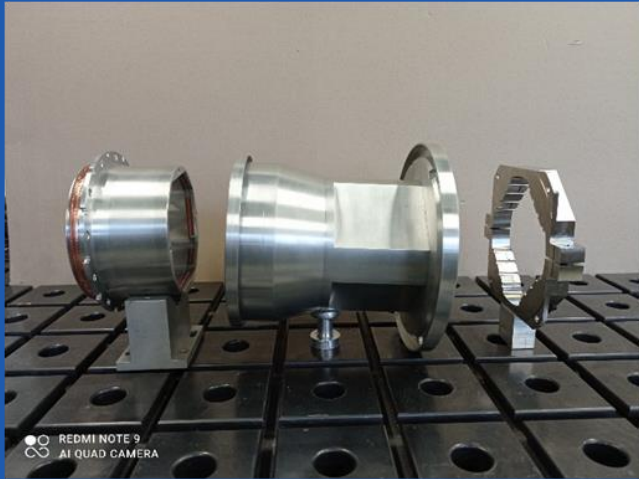


Surface treatments are one of the core competences of CERN, frequently required by Institutes of Member States.
B. 107: Servicing Scientific Labs beyond CERN's areas of activities for the next 30 years.

Continuity of large technical infrastructures complex mechanical assemblies

Beam screen extremities and interconnections

Thermal links



Often providing know-how and technology transfers to Industries



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Preserving know-how and ensuring transfer to Industry

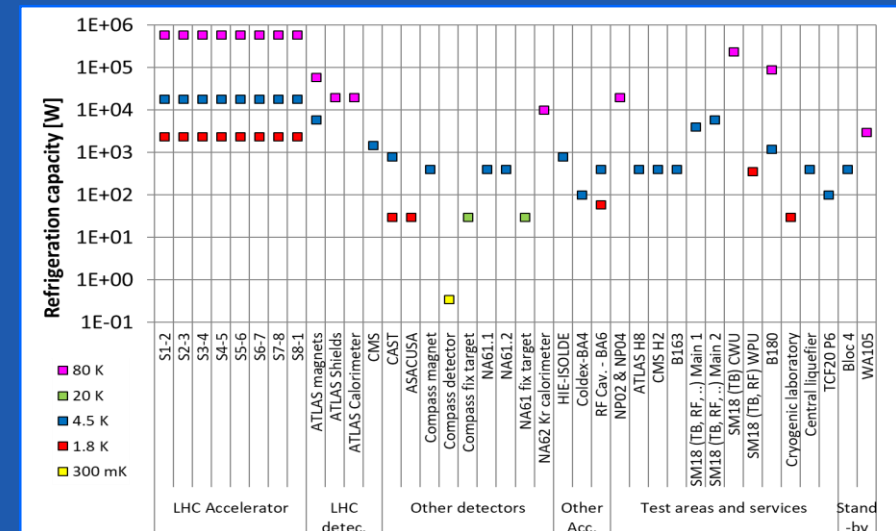
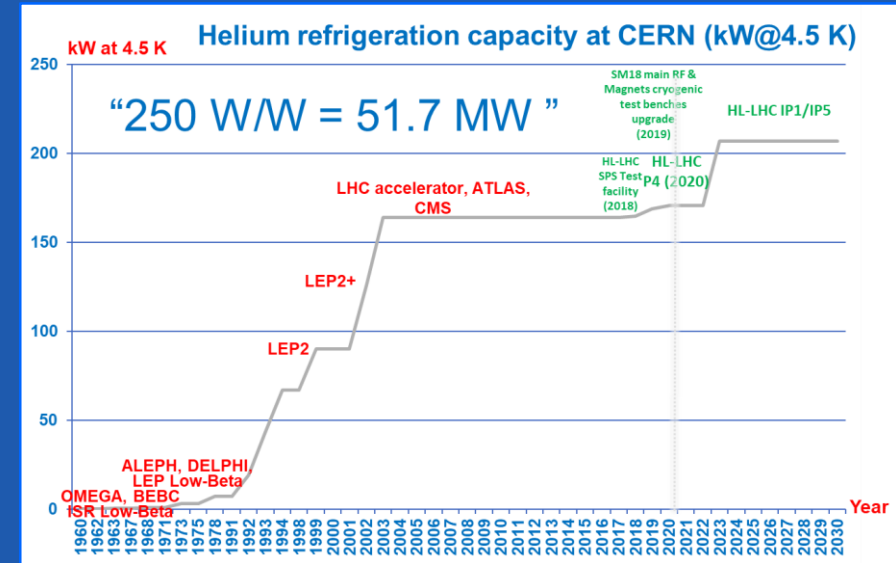
Worldwide recognised Expertise for cryogenic systems

(accelerators and detectors) more specifically in design and operation of large cryogenic systems for LHe and LAr

- LHC with **150 T of LHe** makes CERN the largest cryogenic inventory operating with **38 CryoPlants!**
- **LAr unique expertise** developed for LHC Detectors and consolidated for Neutrino platform in particular and gas purification

At CERN, 1700 t of liquid argon procured achieving a liquid argon purity better than **100ppt O₂ equivalent**

At Fermilab, proximity cryogenics from CERN: former ICARUS detector (**600 m³ of liquid argon**) to be installed as far detector of the short baseline and the near detector of the short baseline neutrino program (**300 m³ of liquid argon**)

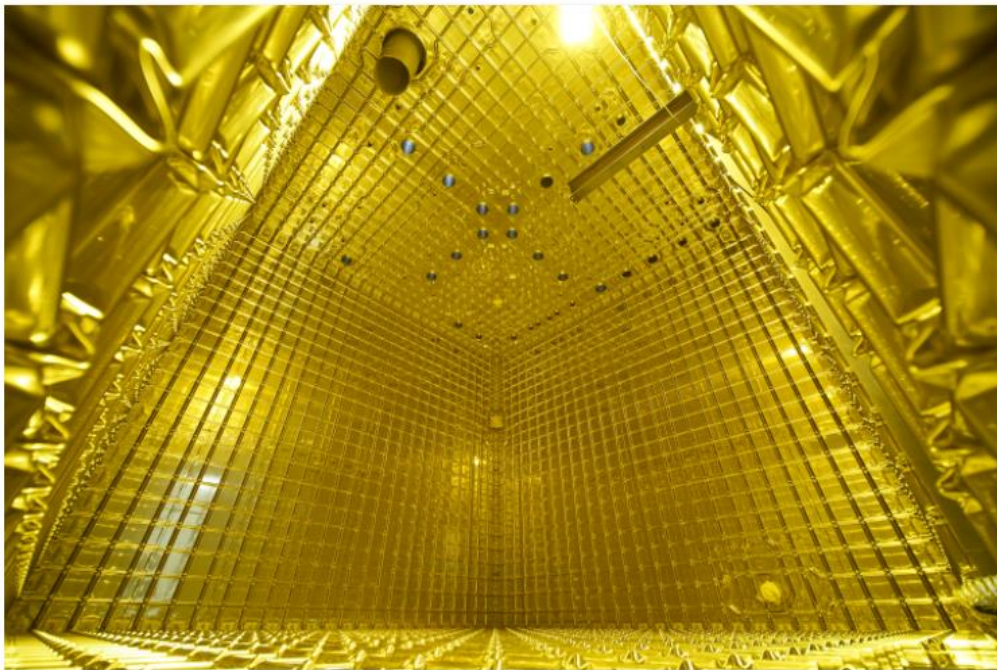


Fostering transnational contributions

CERN to provide second DUNE cryostat

The Laboratory deepens its collaboration with the US-based neutrino experiment with the provision of two enormous stainless-steel vessels for DUNE's cutting-edge liquid-argon detectors

18 AOÛT, 2021 | Par Mark Rayner



Inside a prototype liquid-argon time-projection chamber for the DUNE experiment. (Image: CERN)

Prototyping including all fundamental Argon cryogenic aspects of fluid dynamic and equilibrium between phases



Preserving know-how and ensuring transfer to Industry

Cryogenic equipment with field instrumentation & cables



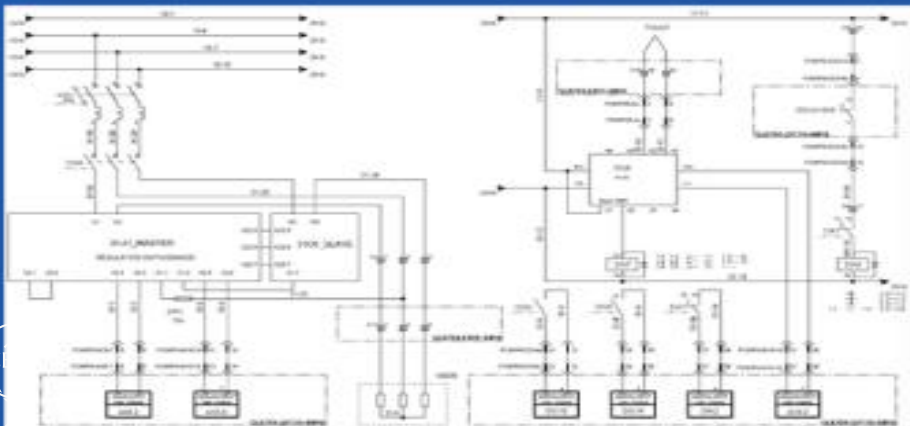
Electrical Interfaces



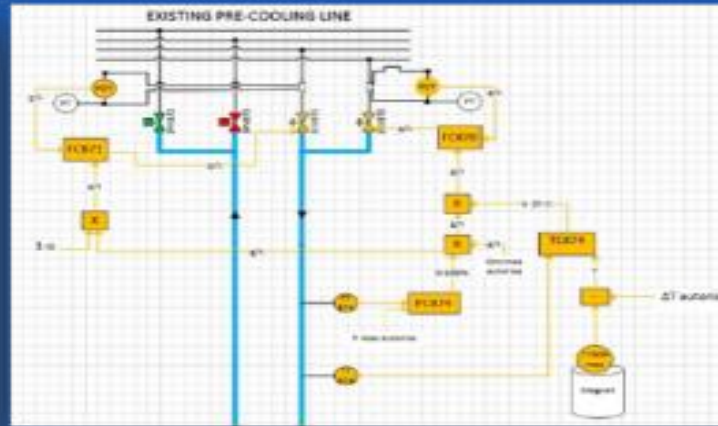
Control Racks



Electrical design



Advanced control logic

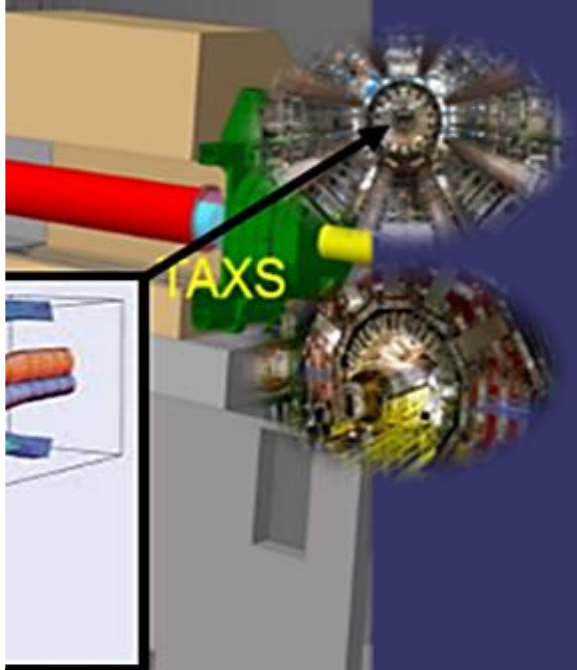
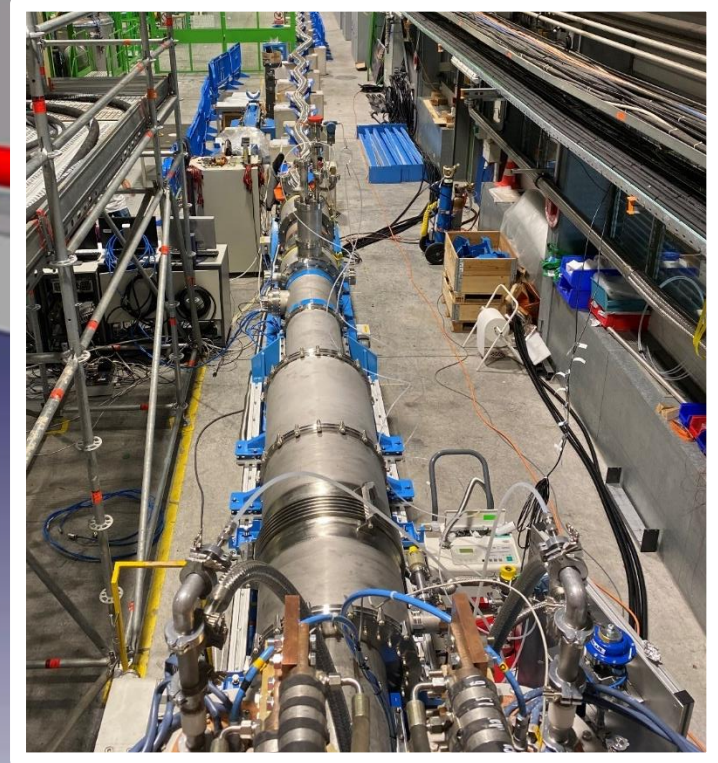
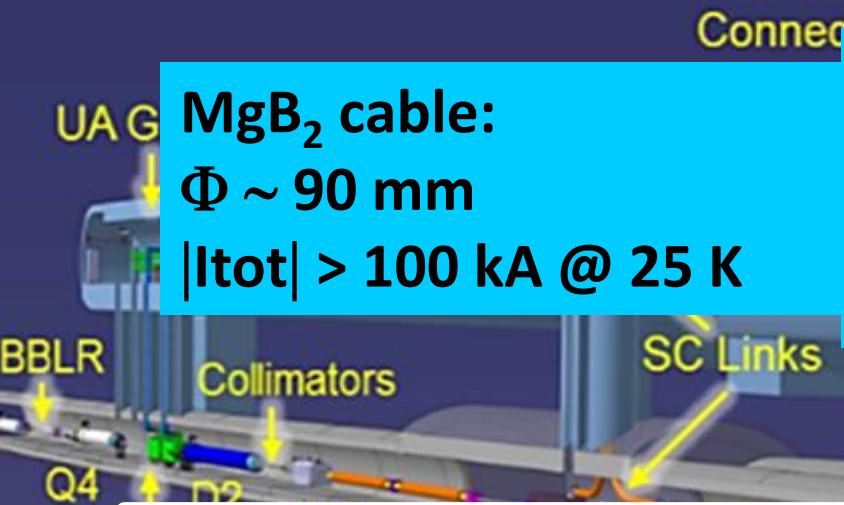
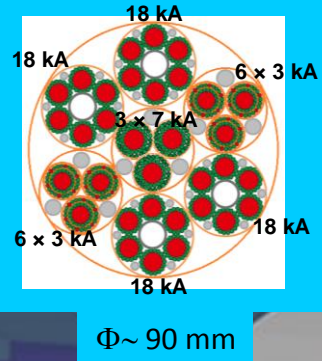


SCADA synoptic



Promoting frontline concept towards pre-industrialisation

MgB₂ cable:
 $\Phi \sim 90$ mm
 $|I_{tot}| > 100$ kA @ 25 K



Promoting frontline concept towards pre-industrialisation

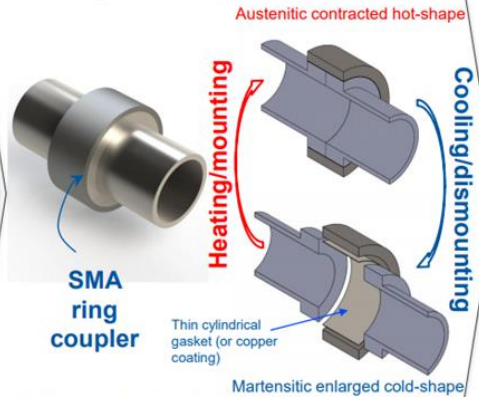
New UHV connectors (SMA)

Standard vacuum coupling systems



Soft/hard materials + mechanical force
Image source: web

Shape memory alloy couplers



Soft/hard materials + temperature control

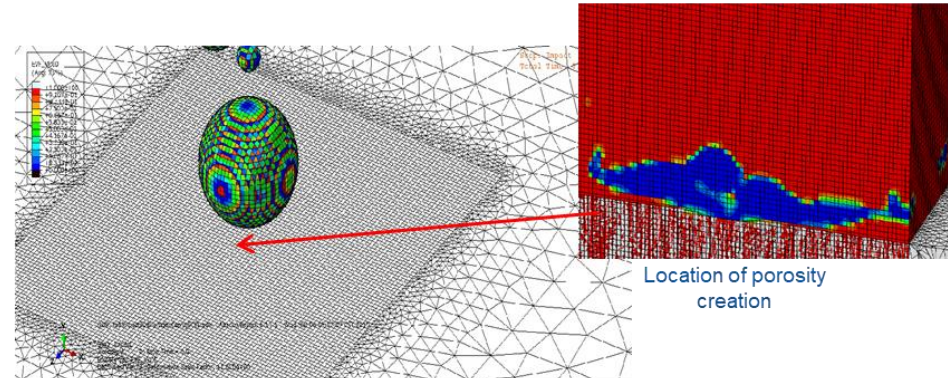
UHV connectors based on shape memory alloy



SMA connectors (up to DN100) suitable also for bimetallic junction

Cold spray manufacturing

Cold spray as additive manufacturing for UHV applications



Simulation of cold spray process and creation of porosities (S. Weiller, Mines ParisTech)



Integrated radiation-hard heating track

Excellence of large testing infrastructures

SM18 HFM (cluster G)

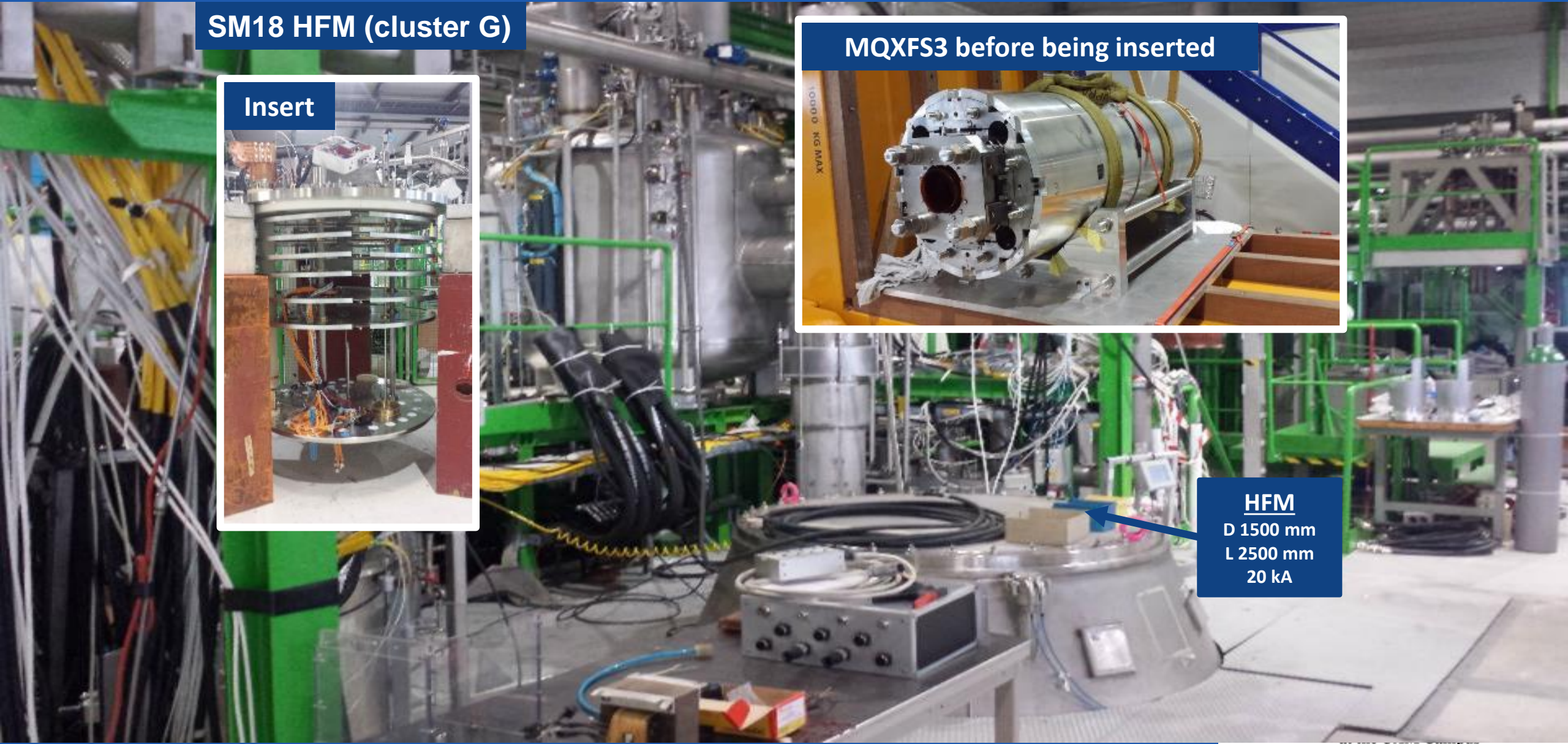
Insert



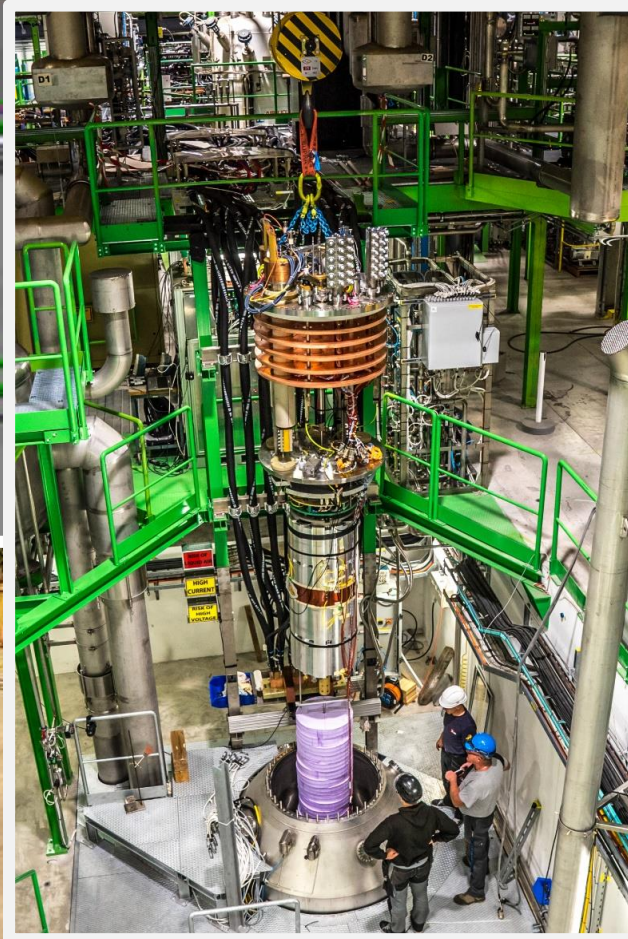
MQXFS3 before being inserted



HFM
D 1500 mm
L 2500 mm
20 kA



Excellence of large testing infrastructures

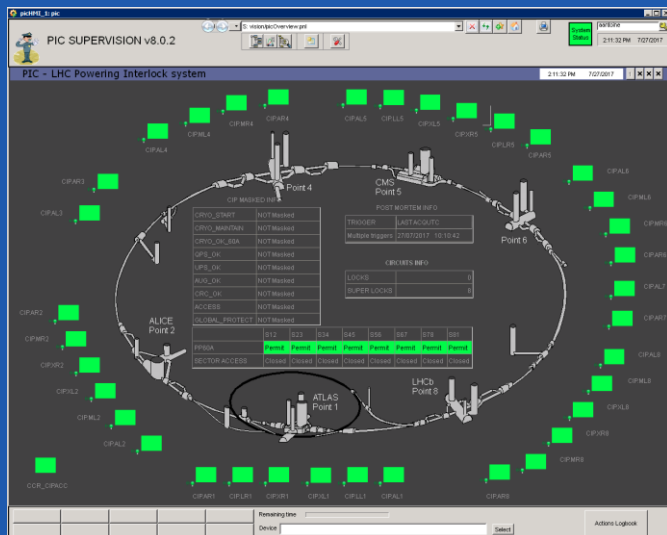


30 kA vertical testing cryostat

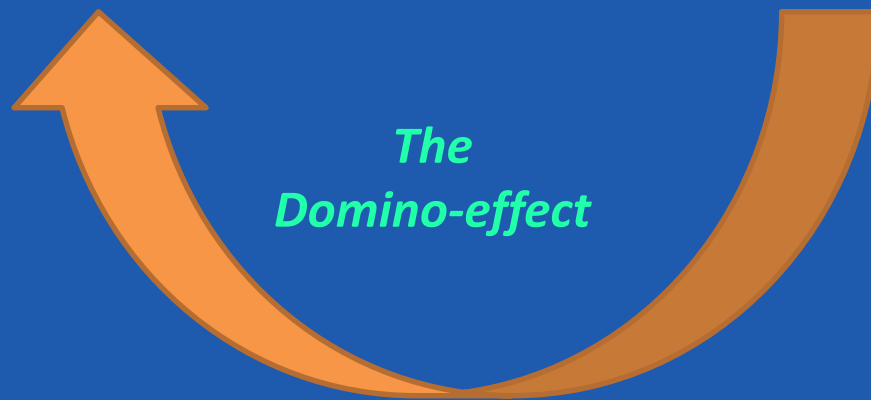
Creating synergies: Powering, Energy Savings & Electronics



Powering with integrated energy saving
Fast expert protection systems (kV/kA)



Developments with high impact on other Large Scientific Instruments used for Fundamental Research



The Domino-effect



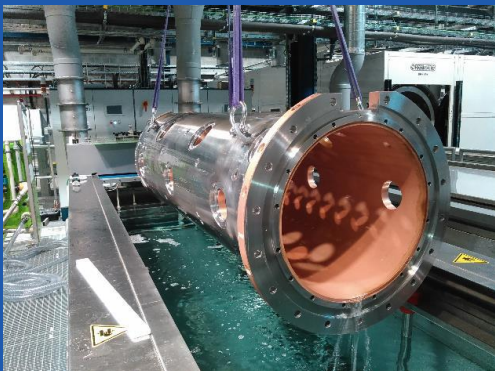
Electric stacks for fast pulse powering



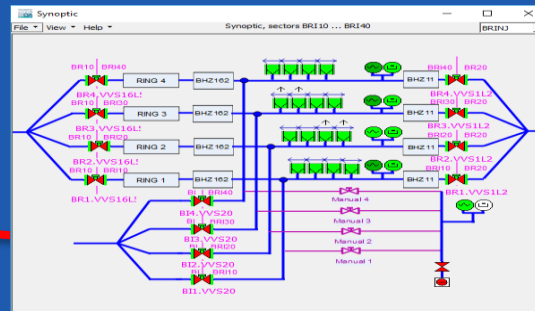
High current breakers (ms/kA)

The virtual circle of Research... Beam-vacuum R&D

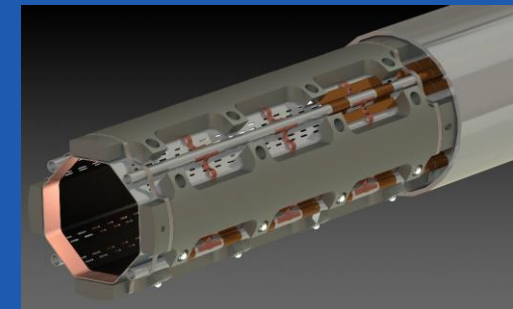
DTL tanks for ESS



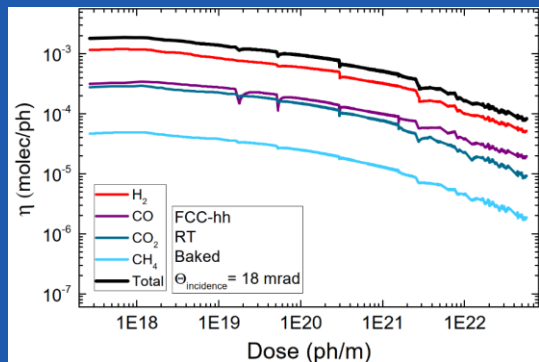
Operation
Maintenance
Consolidation



HL-LHC triplet BS

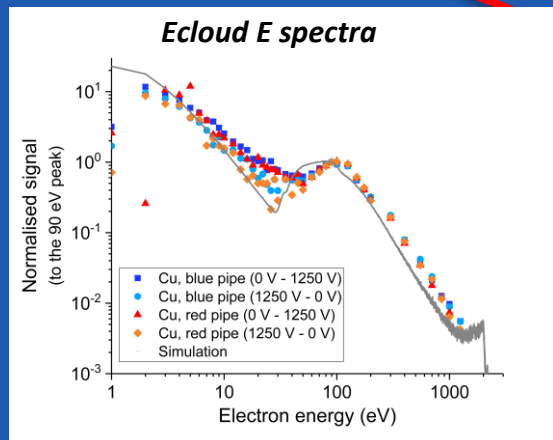


FCC-hh meas. at KARA



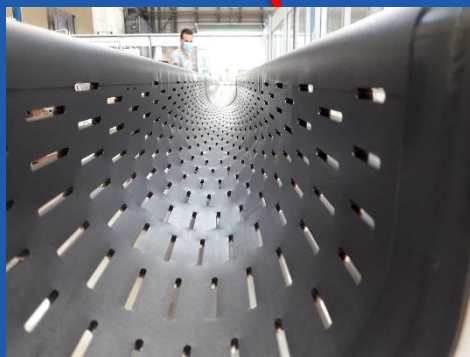
Beam
Vacuum

Ecloud E spectra



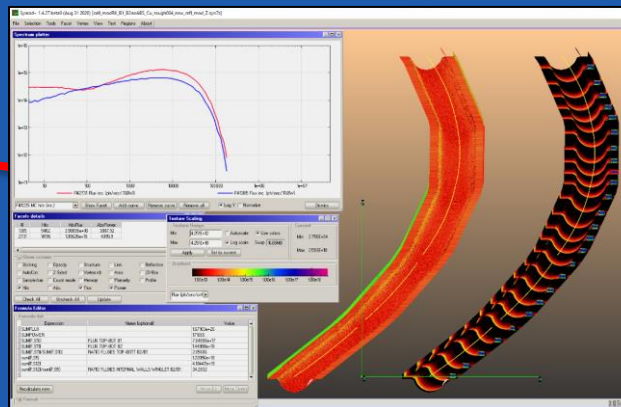
HL-LHC Project

Services for HEP
community



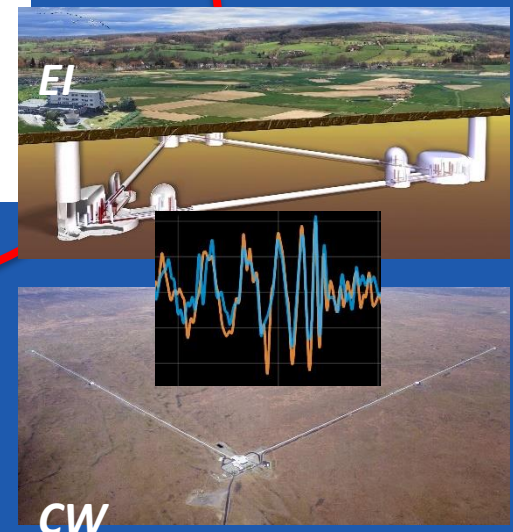
NEG coated TDI mask

Studies



FCC-ee photoadsorbers positioning

Collaborations



CW



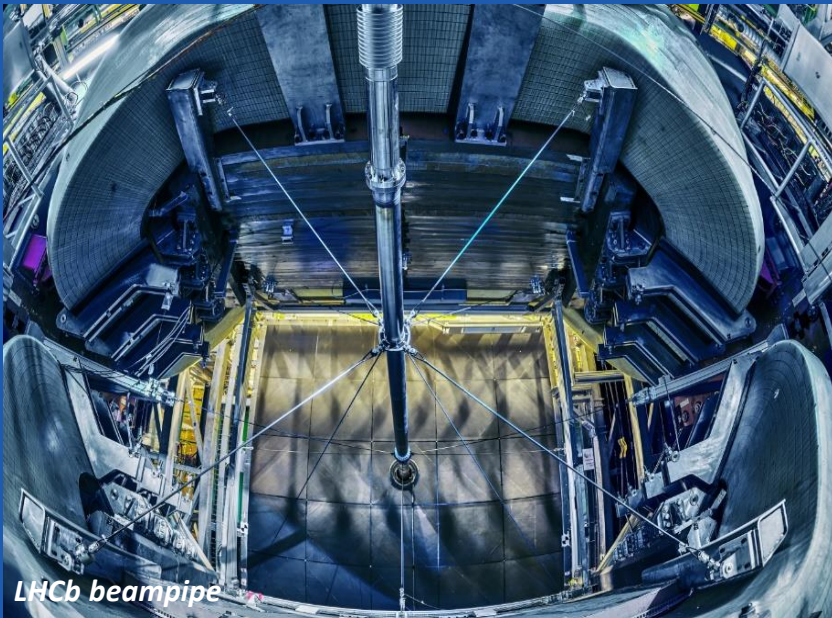
Why Fundamental Research is essential.
 INFIERI 2021
 4th September 2021



Infieri 2021
 23/8 to 4/9, 2021, in Madrid
 at the UAM Campus



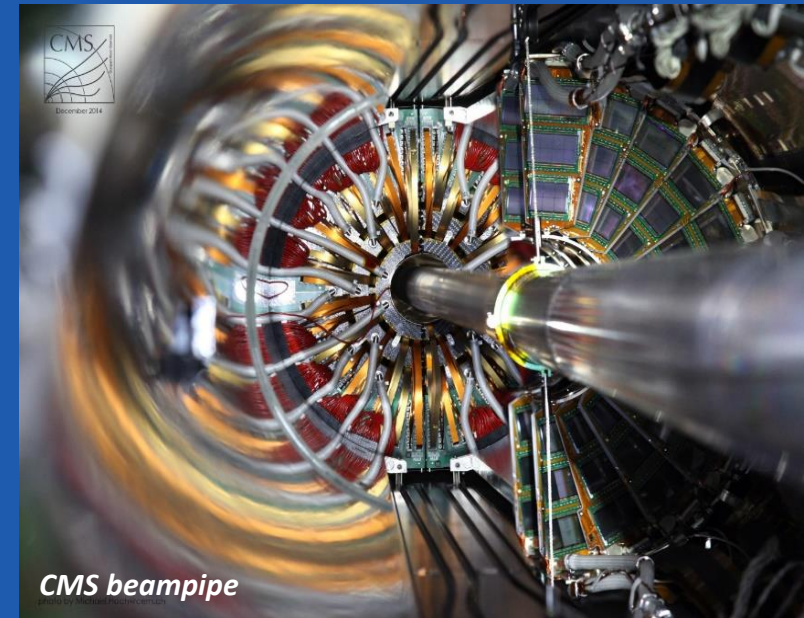
...benefiting the primary Fundamental Research objectives!



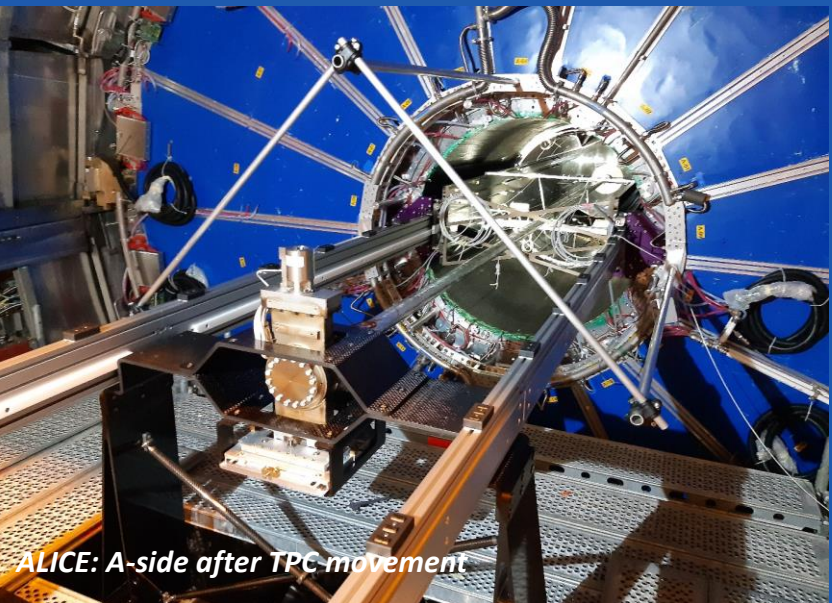
LHCb beampipe



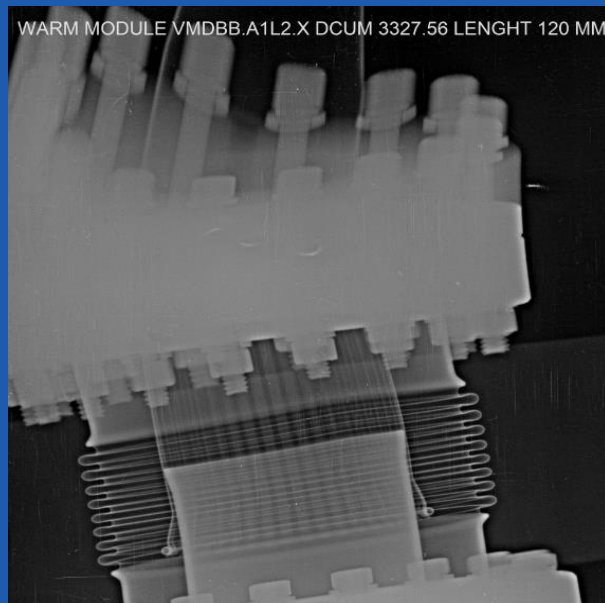
LHCb beampipe



CMS beampipe



ALICE: A-side after TPC movement

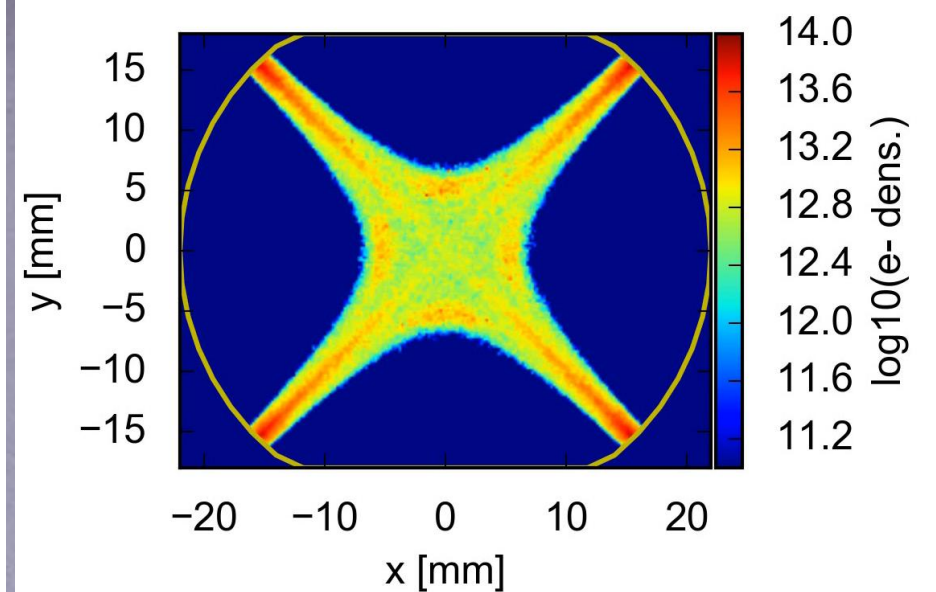
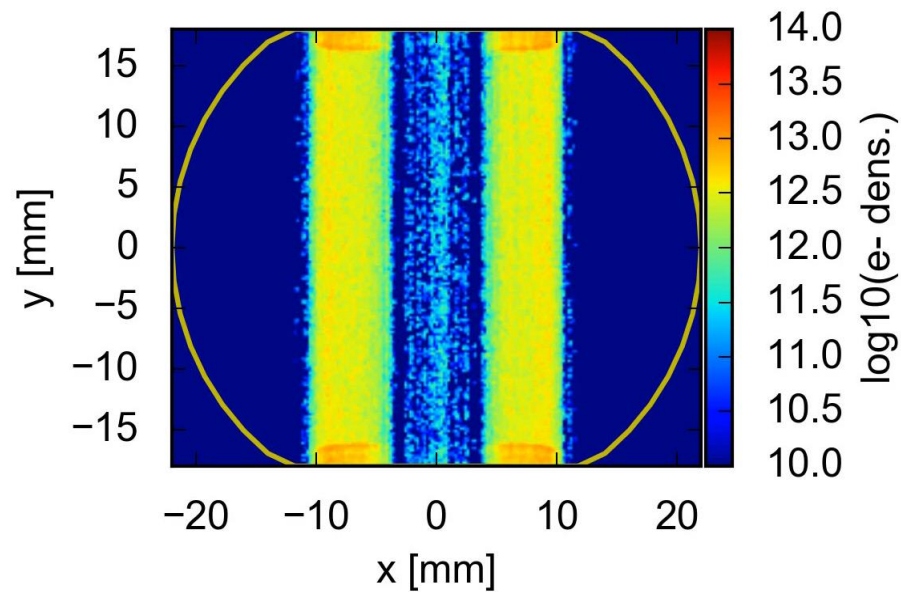
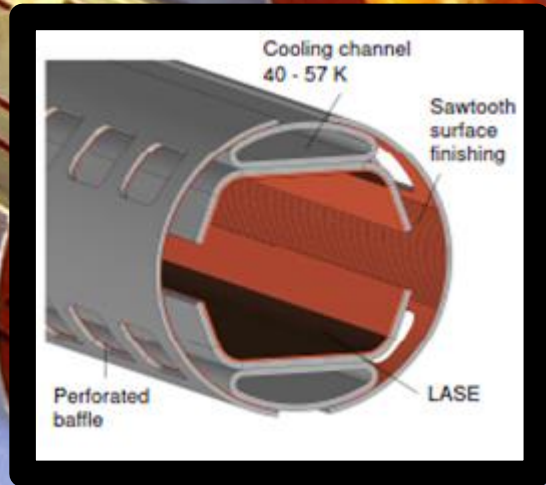
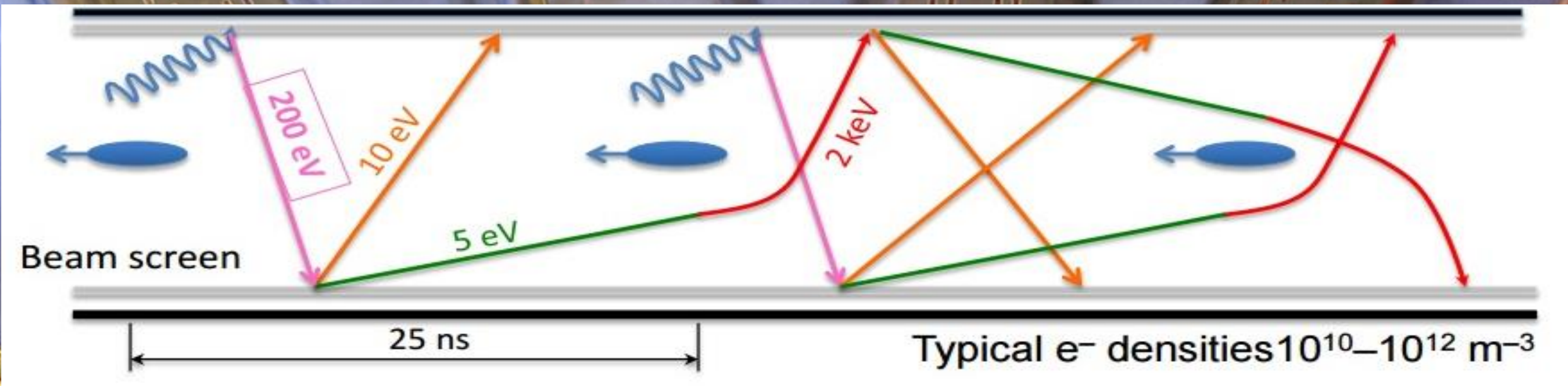


WARM MODULE VMDBB.A1L2.X DCUM 3327.56 LENGHT 120 MM



ATLAS beampipe dismounting

The virtual circle of Research... electron cloud induced beam instabilities



...benefiting the primary Fundamental Research objectives!

- Significant academic efforts with Academia to **understand the mechanisms** behind this electron avalanche...
 - More efforts to predict and quantify the effects on the beams.
- Fundamental research **studies on surfaces** to identify mitigations mechanisms...
 - Multidisciplinary research to find mitigation solutions...
 - ...and huge beam time to validate each steps.
- **Positive impact** on all other accelerator facilities including synchrotron radiation facilities...
 - Significant improvement in brightness and beam stability which enhances performances of all concerned accelerators.



Keeping the Dreams alive...

6th Statement:

“Looking at it through the prism of a Scientist, our Humanity has stimulated a special curiosity for the unknown and what looks imperfect, forcing us to constantly push the frontier of knowledge, looking for breakthroughs...

Convinced that some of them (if not all) will, at the appropriate moment of our civilisation, have a direct or indirect impact on Society...

Improving our preparedness for our well-known challenges ... and for the unknown to come.

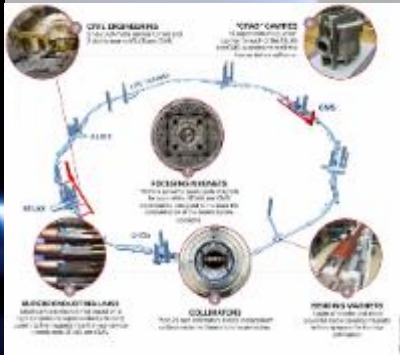
But none of us can escape from its obligation to communicate the potential impact of its Fundamental Research to the Public and Science Authorities.”



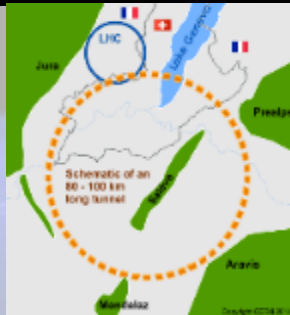
Futures Accelerators: 4 vectors of R&D?

CERN
responds to the
European Strategy

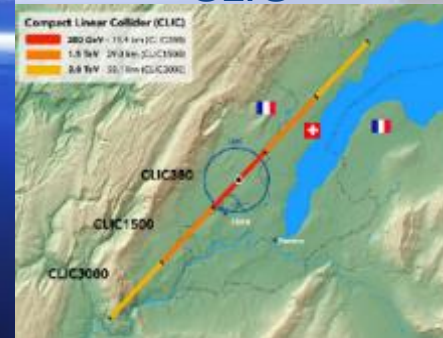
High Luminosity
HL-LHC



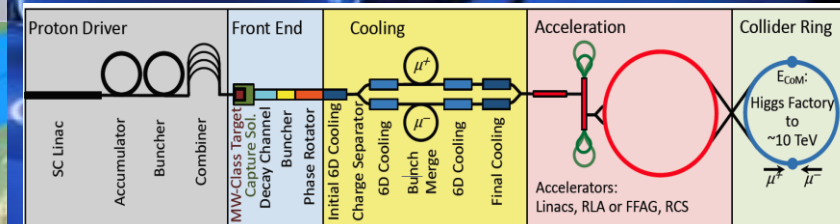
High Energy
FCC and
HE-LHC, as
technology
demonstrator



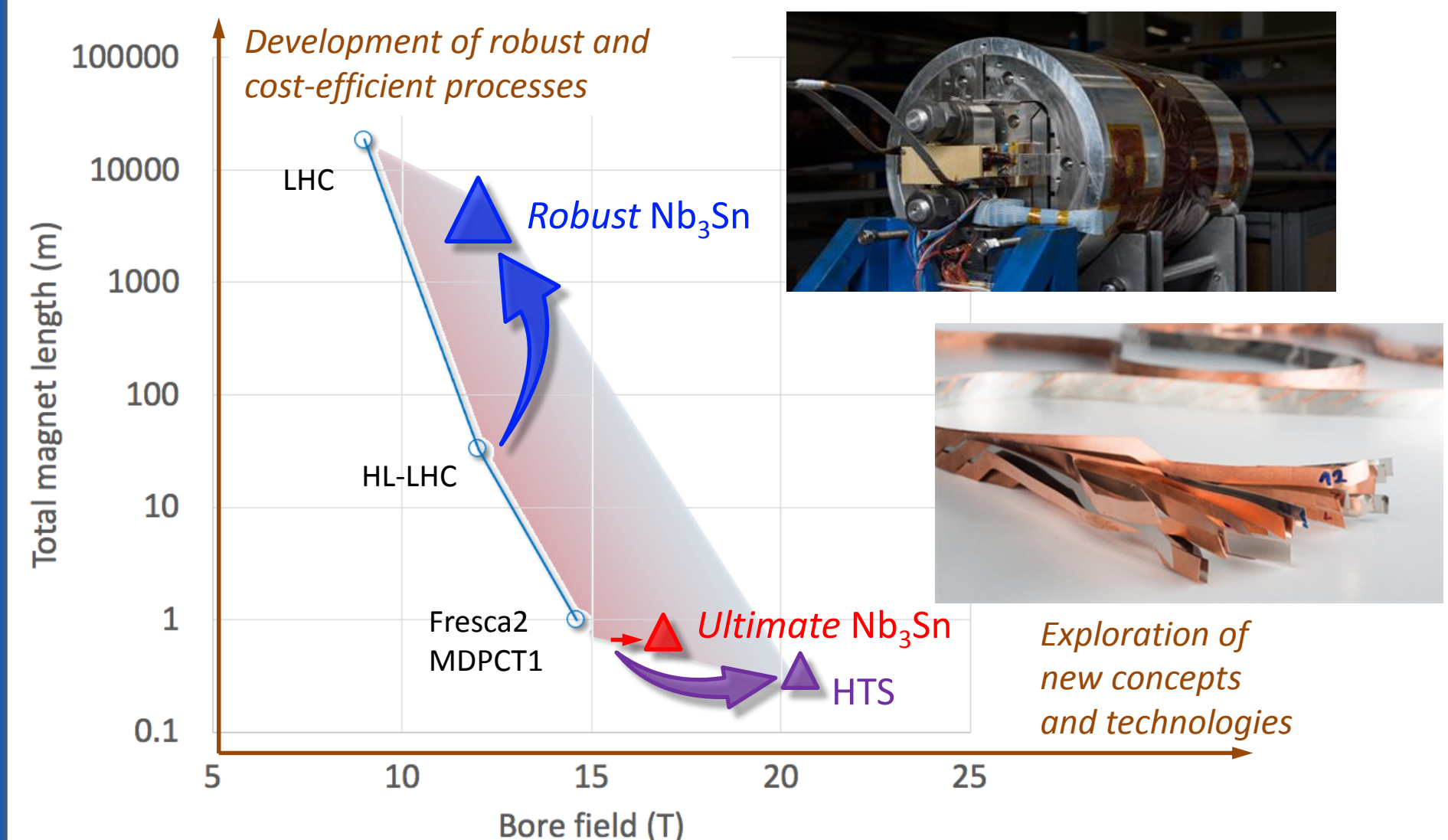
High Energy and
Precision Physics
CLIC



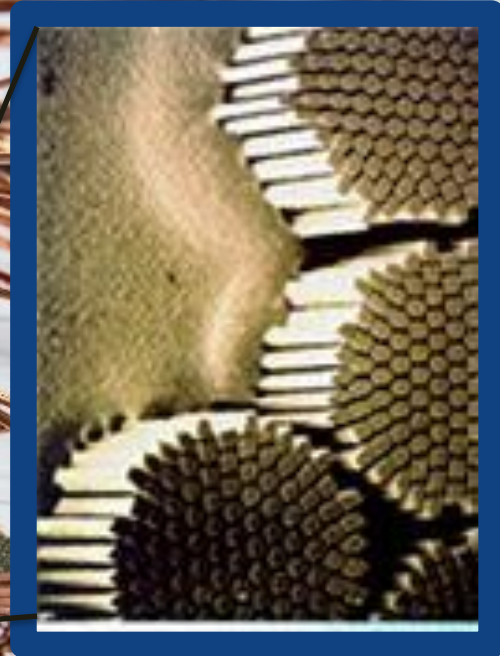
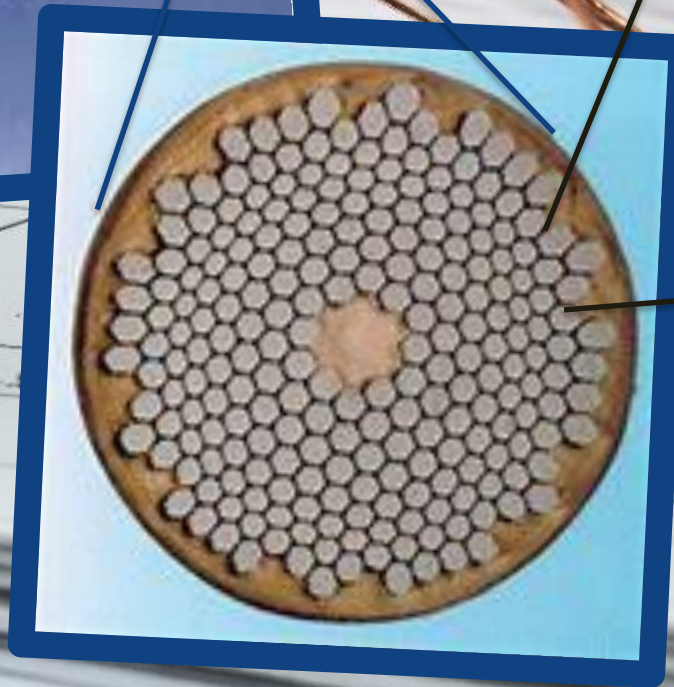
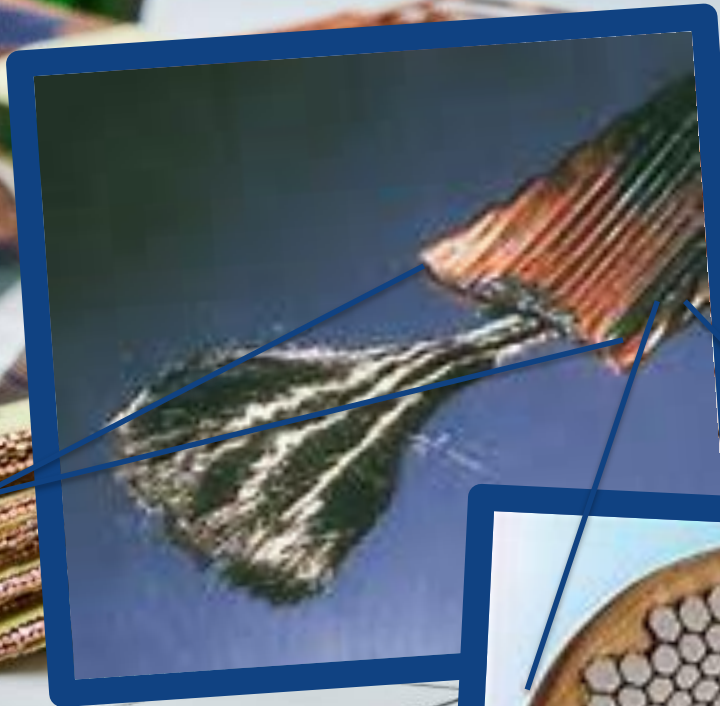
Muon accelerator
feasibility study



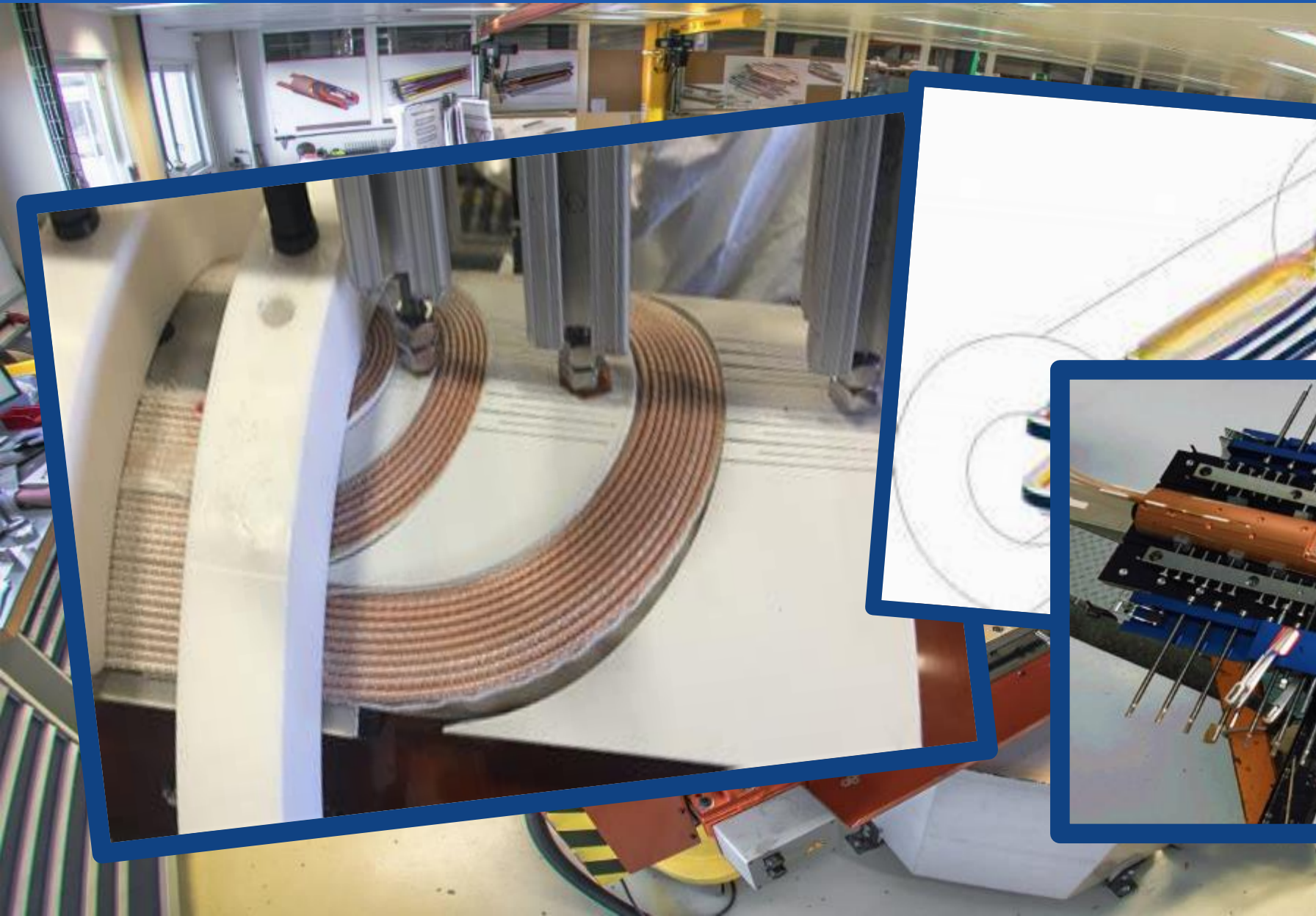
High Field Magnets: an inter-disciplinary challenge!



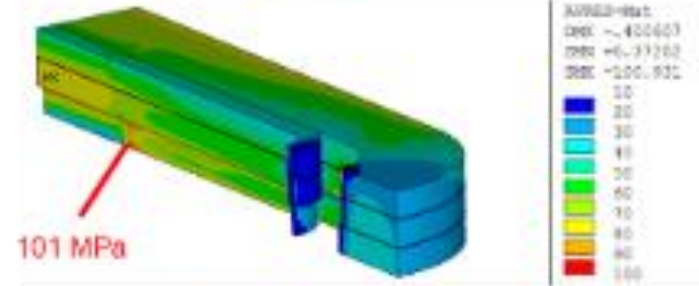
HFM future, held by a wire?



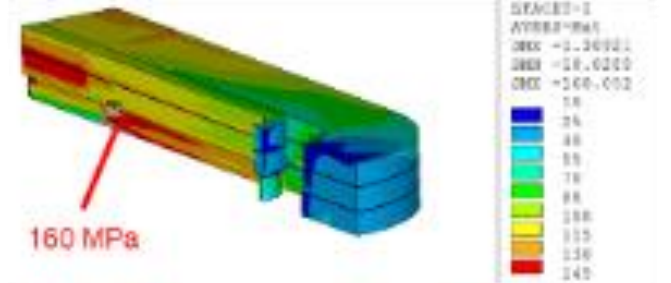
HFM future, forefront thermo-mechanical challenges?



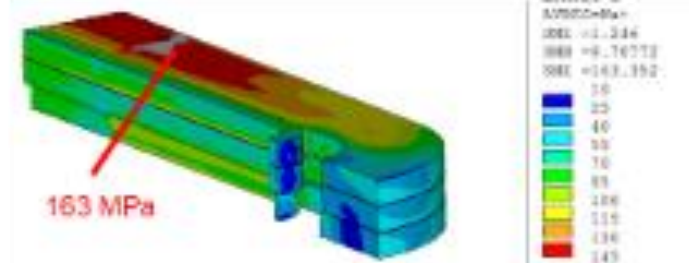
Assembly



Cool Down



Powering at 18 T



Highlights of Accelerating Science and Innovation

LEP Control Room - 1989



LHC Control Room - 2007



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Highlights of Accelerating Science and Innovation



LEP ALEPH Detector- 1989



LHC CMS Detector - 2007



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Highlights of Accelerating Science and Innovation



LEP tunnel - 1989



LHC tunnel - 2007



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The Future is yours... because you're doing/contributing to Fundamental Research

- The *present* tells you where you stand...
- The *1st time-derivative* tells your trend...
- The *2nd time-derivative* tells you how fast you'll get there!

That's the point! **Look far ahead !!!** Anticipate, master risks!

- And never forget that **Technical Training is** more than an asset,
...it's a **Value**.





**«Being a leader is
having vision»**

17th May 1954

CERN work site

Thanks!



Accelerating Science and Innovation

