A new facility to develop high-field magnets in Spain

Carla Martins (on behalf of the CIEMAT SMART-Lab team)

24th September 2025

Outline

- Introduction
- SMART-Lab
- On-going activities

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25 years ago (or more?)…

CIEMAT SC Magnet team, **CEDEX** (Alfonso XII)

Trim Quadrupole **MQTL** and **winding machine**, **CIEMAT Building 2**

Until 3 years ago…

MCBXF Steering Committee (Feb 2020)

CIEMAT Superconducting Magnet Laboratory, CEDEX (Julián Camarillo)

Our sincere gratitude to CEDEX for their support over the years.

New CIEMAT High-Field magnets laboratory

SMART-Lab (**S**uperconducting **MA**gnet **R**esearch and **T**echnology **Lab**oratory)

Officially inaugurated on May 27, 2025

SMART LAB

Ciemat

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- Introduction
- **SMART-Lab**
- On-going activities

SMART-Lab motivation

The **PRISMAC program** was funded by CERN, CDTI, CIEMAT and the Ministry of Science, Innovation and Universities with three objectives:

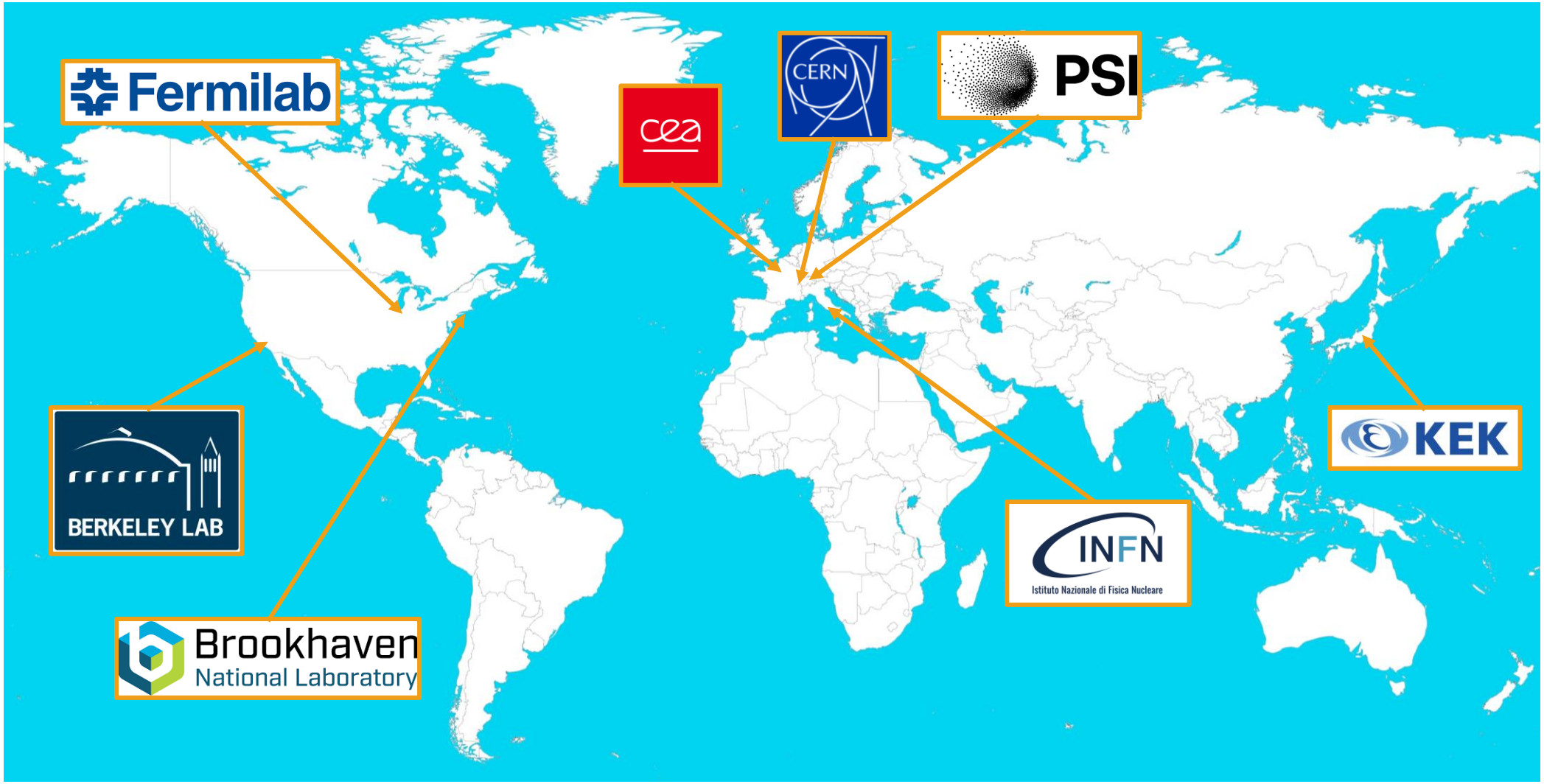
- The development and manufacture of the nested orbit correctors (**MCBXF**) for the HL-LHC.
- The development and manufacture of superconducting magnet prototypes for the **HFM** (High Field Magnet) program coordinated by CERN.
- The development of a **high-field magnet laboratory**. → **SMART-Lab**

The **SMART-Lab** is inspired by the 927 laboratory at CERN*.

Building refurbishment finished in June 2023. Started its operation in January 2024. Fully operational before the end of 2025.

** Special thanks to Juan Carlos Pérez for his invaluable support, from the concept of the facilities to the specification of the equipment needed, as well as the purchase and contract follow-up for large equipment.*

Similar laboratories around the world



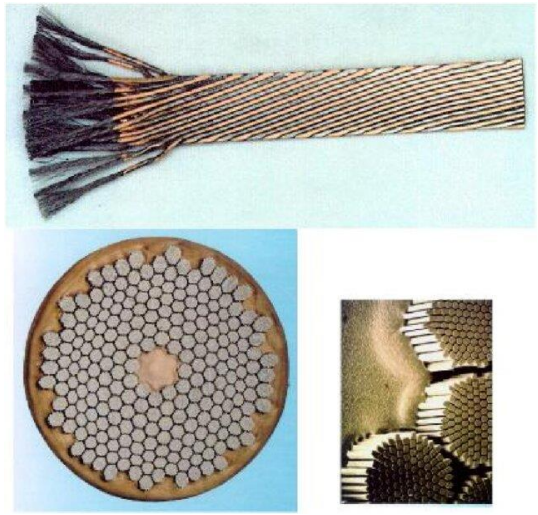
SMART-Lab technical capabilities (I)

Different **superconducting materials**:

- Low temperature (LTS): NbTi, Nb_3Sn…
- High temperature (HTS): MgB_2, REBCO, BSCCO…

Different **cable configurations**: flat, round, tape…

Rutherford

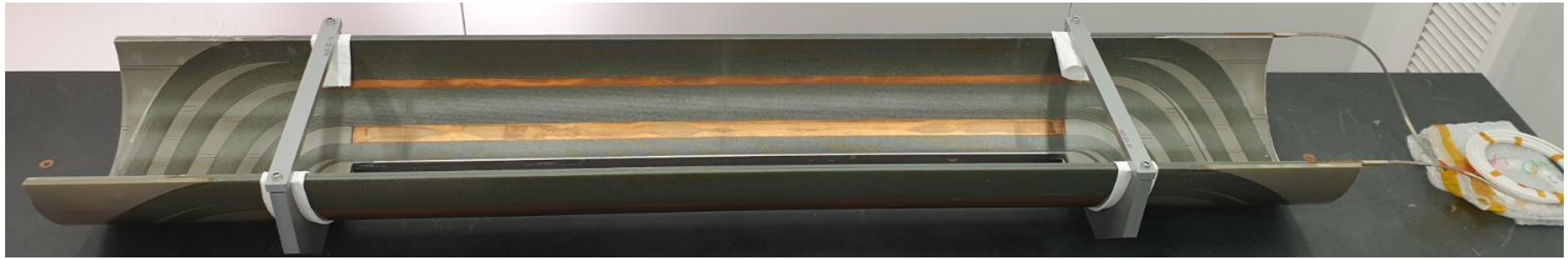


CORC®

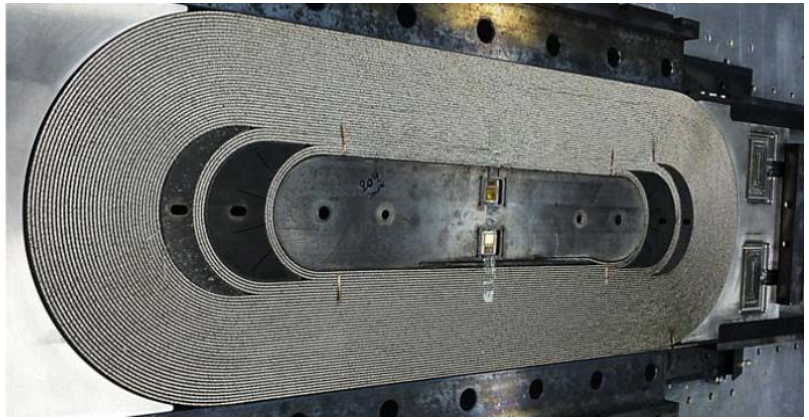
Roebel tape

SMART-Lab technical capabilities (II)

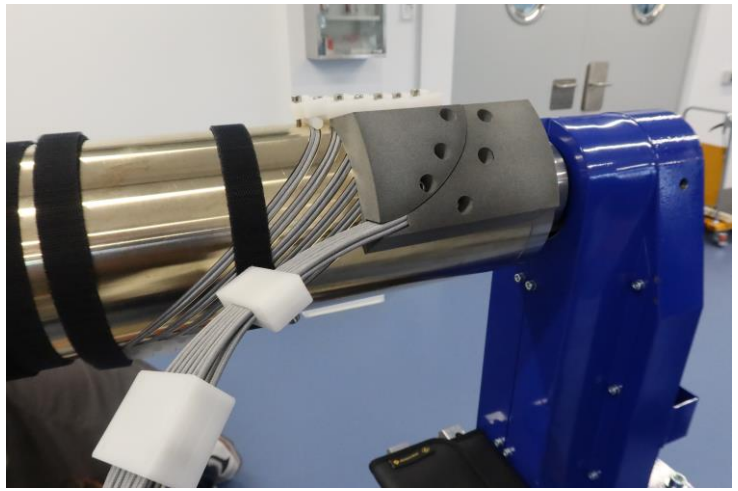
Coil winding in different configurations:



Cos-Theta (CT)



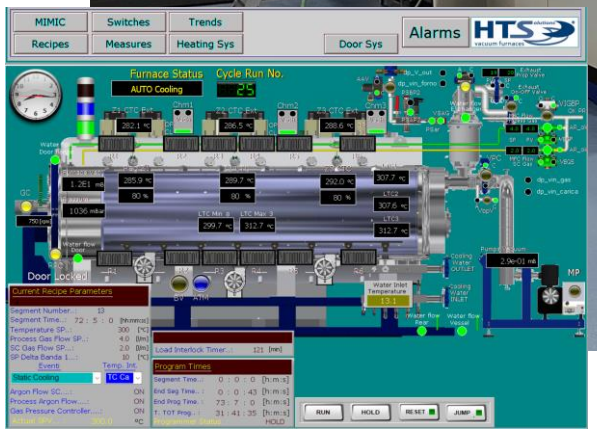
Racetrack



Canted Cos-Theta (CCT)

SMART-Lab technical capabilities (III)

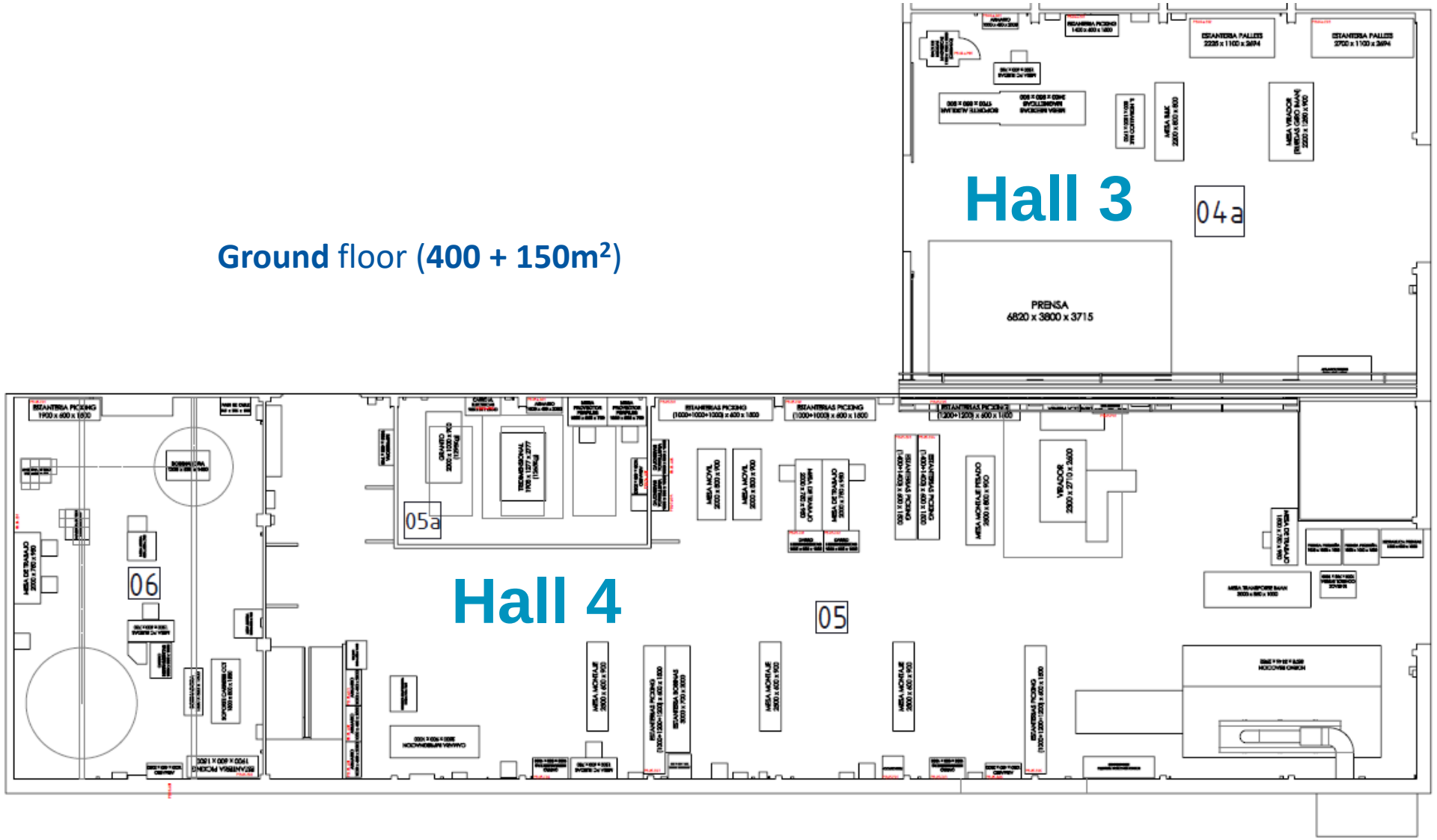
Reaction furnace to produce superconducting materials: Nb_3Sn



Mould up to **2.5 m** (length) & **3 tons**.
Typical 2-week-long cycle, 96h at 650°C.
Argon gas: 10 l/min (chamber), 5 l/min (mould).
Chamber overpressure: 50 mbar.
Max. dispersion: **± 3°C** (constant setpoint temp.)

SMART-Lab Layout: Ground Floor

Ground floor (**400 + 150m^2**)



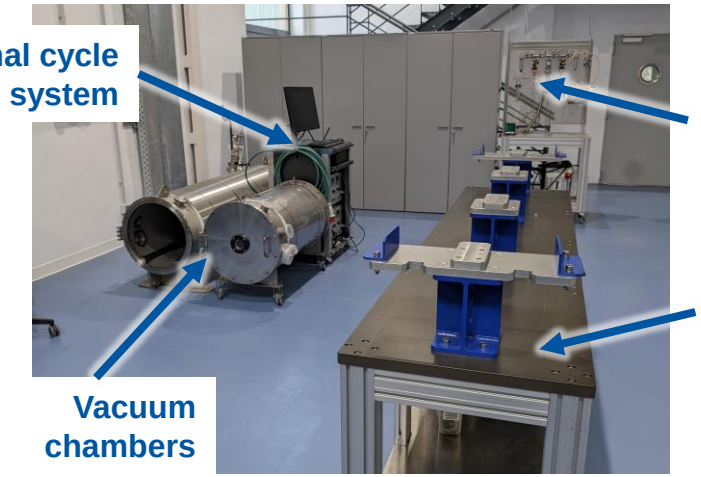
SMART-Lab Layout: Hall 4 - Ground Floor (I)

Electrical hoist

Winding machine

Winding machines and **pay-off** machines for pulling cable tension (**closed-loop** control)

Thermal cycle control system



Impregnation system

Assembly table

Vacuum chambers

Split-type tube Furnace

SMART-Lab Layout: Hall 4 - Ground Floor (II)

Precision Surface Plate

Coordinate Measuring Machine

700x700x500 mm (LxWxH)
750 kg
Accuracy better than **5 µm**

Tilting device

Measurements

Storage & Assembly

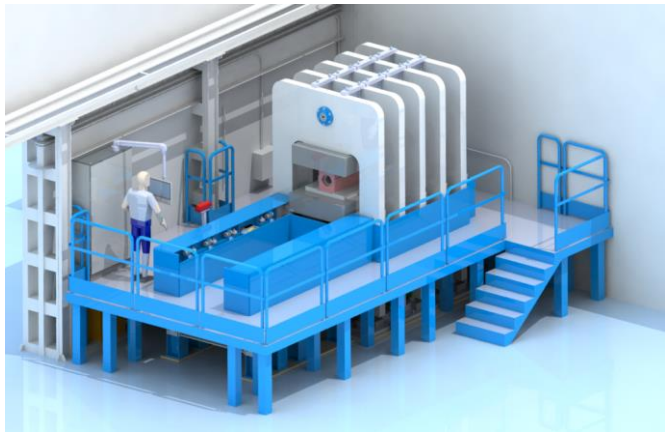
High-load work area

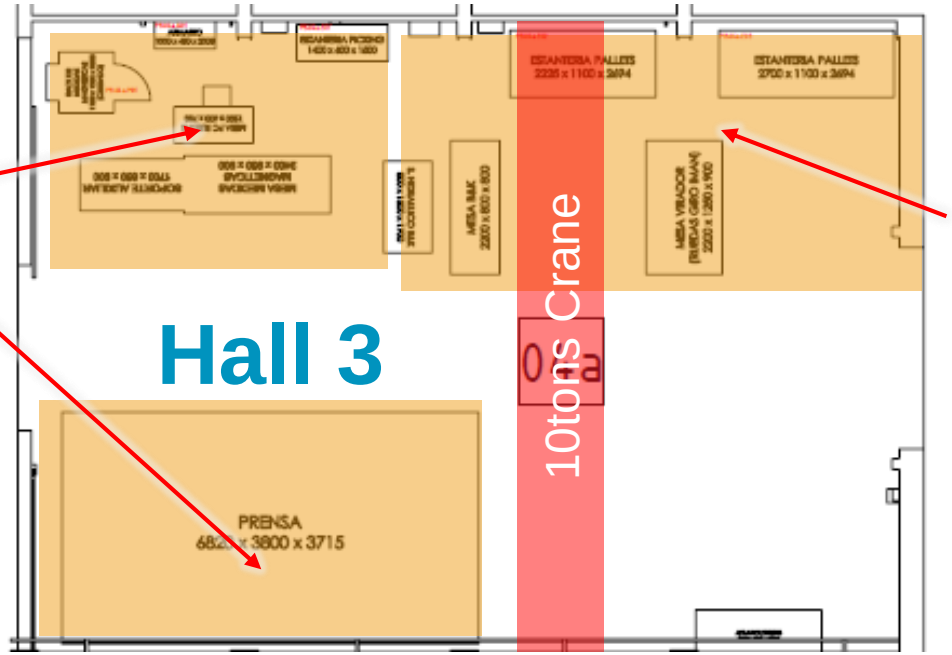
Vertical assembly pit

SMART-Lab Layout: Hall 3 - Ground Floor

Warm magnetic measurements

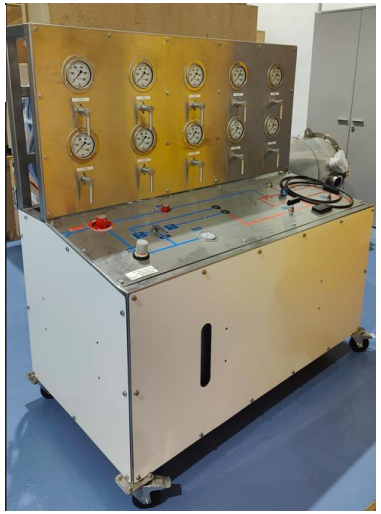
Collaring & curing press





3700 tons with 10 cylinders (5 pairs)
Mould up to 2500x1000x400 mm (LxWxH) & **2 tons**

Bladders & Keys hydraulic system



Magnet assembly

Magnet rotating device

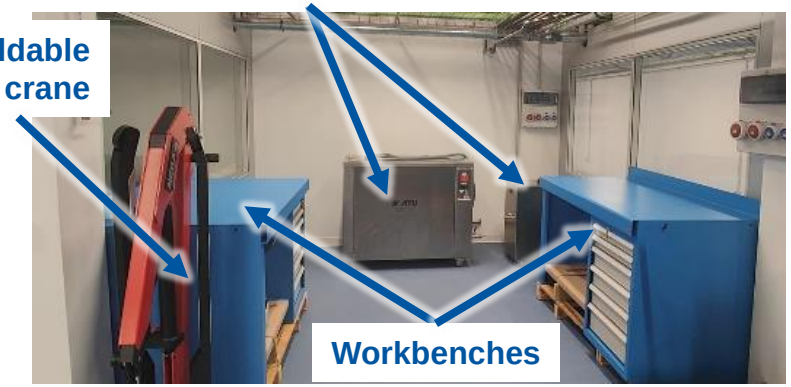
SMART-Lab Layout: Underground Floor

Underground floor (**300m²**)

3D printers

Laser cutting machine

Ultrasonic cleaning machines



Foldable crane

Workbenches

Sanding machines

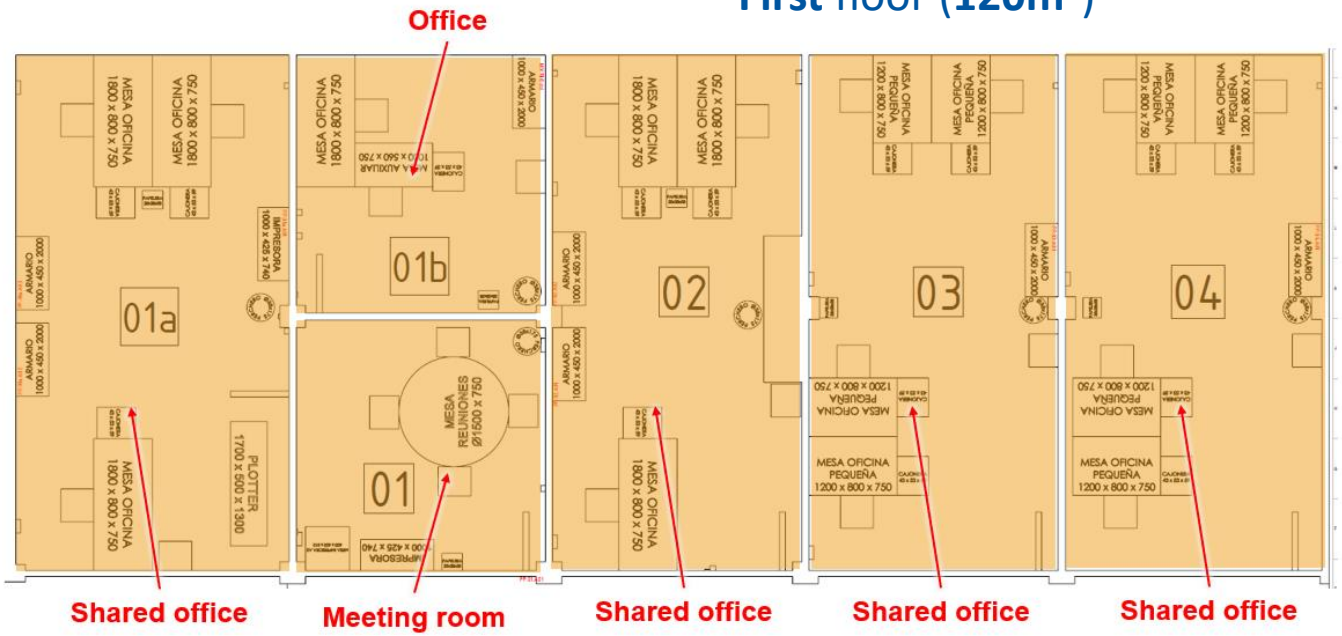
Drilling machine

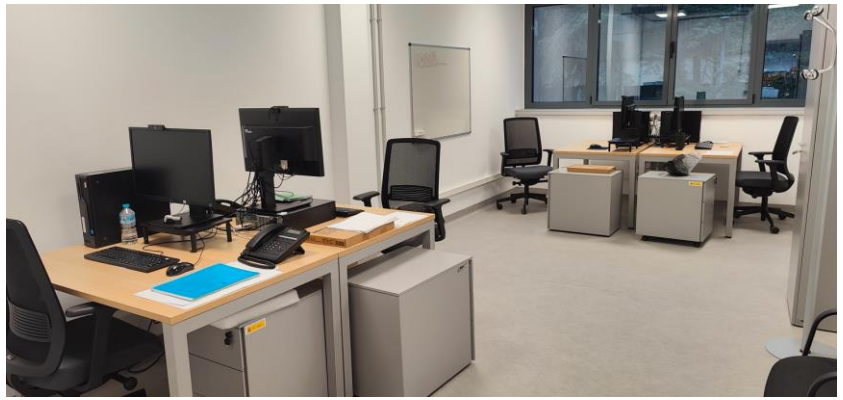
Bandsaw

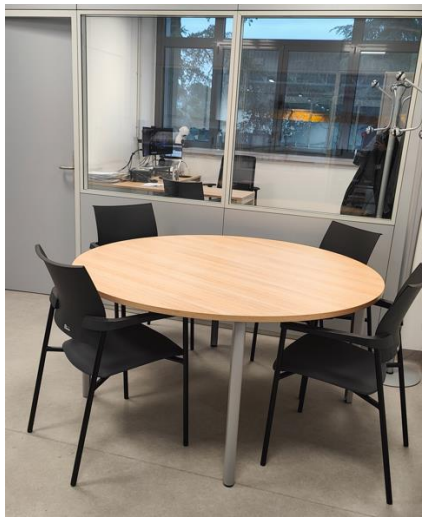
Grinding machine

SMART-Lab Layout: First Floor

First floor (**120m²**)







SMART-Lab targets

- Development and manufacturing of magnets / magnetic components for **scientific facilities** (i.e. high energy physics) **and instrumentation**.
- Development and manufacturing of magnets / magnetic components for acceleration system programs for **social applications,** including:
  - **Medical** applications (advanced radiotherapy),
  - **Energy generation** (coils for new fusion reactors),
  - **Energy storage** (SMES),
  - **Transportation**,
  - **Aerospace and Defense**.

- Magnets up to **2.5 m** in **length** and **10 tons**.

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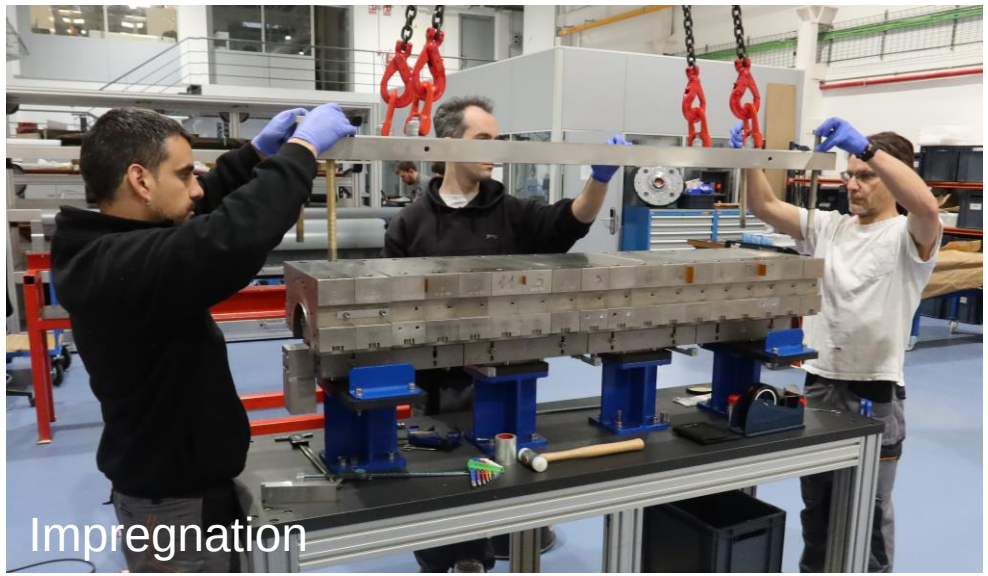
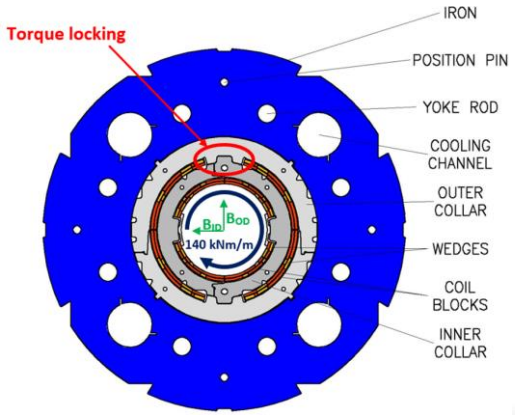
MCBXF: Nested Orbit correctors for HiLumi

Development and manufacture of the nested orbit correctors (**MCBXF**) for the HL-LHC.


Winding


Binder

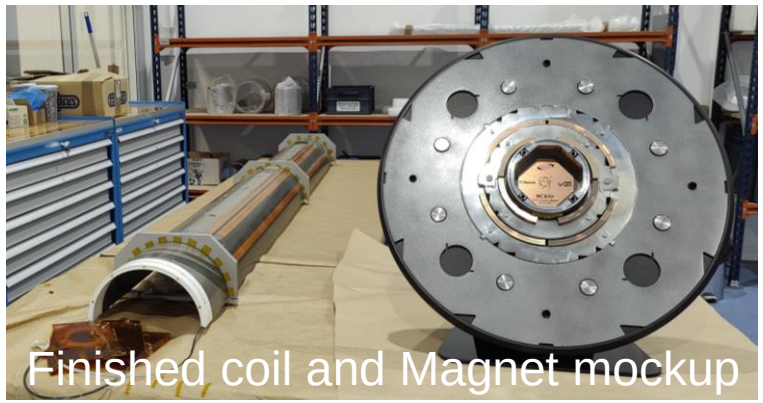

Impregnation



First nested superconducting accelerator magnet with **mechanical torque locking**.

Up to **140 kNm/m**: about **130 times** the electric Porsche Taycan Turbo S motor!!

Assembly being done at **CERN**.

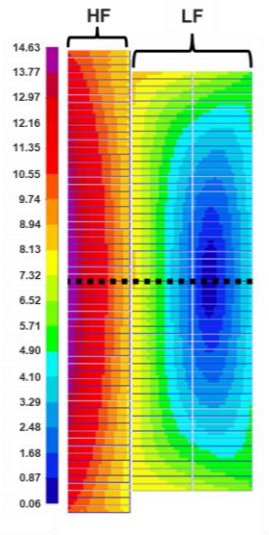

Finished coil and Magnet mockup

HFM: Common Coil

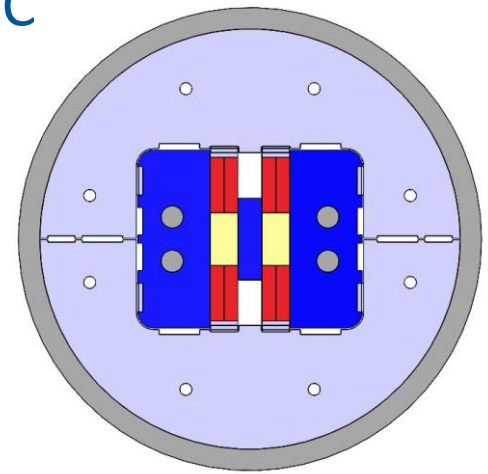
ISAAC: **I**nvestigating **S**uperconducting **A**ssembly to **A**ddress **C**ommon coil mechanics
DAISY: **D**emonstrator for **A**ssembly **I**nnovations in **S**uperconducting common coil technology

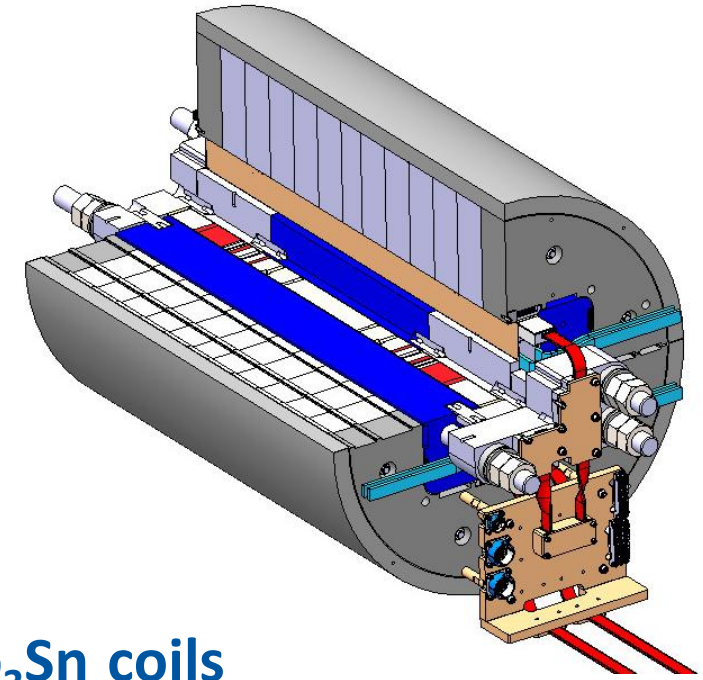
CIEMAT is contributing to the **HFM** (High Field Magnet) program, coordinated by CERN, with the design and manufacturing of a 14T demonstrator in common coil configuration.

ISAAC is a model magnet using existing RMC coils produced by CERN. It will be our first magnet assembly with Bladder & Keys.



Courtesy: J.A. García-Matos





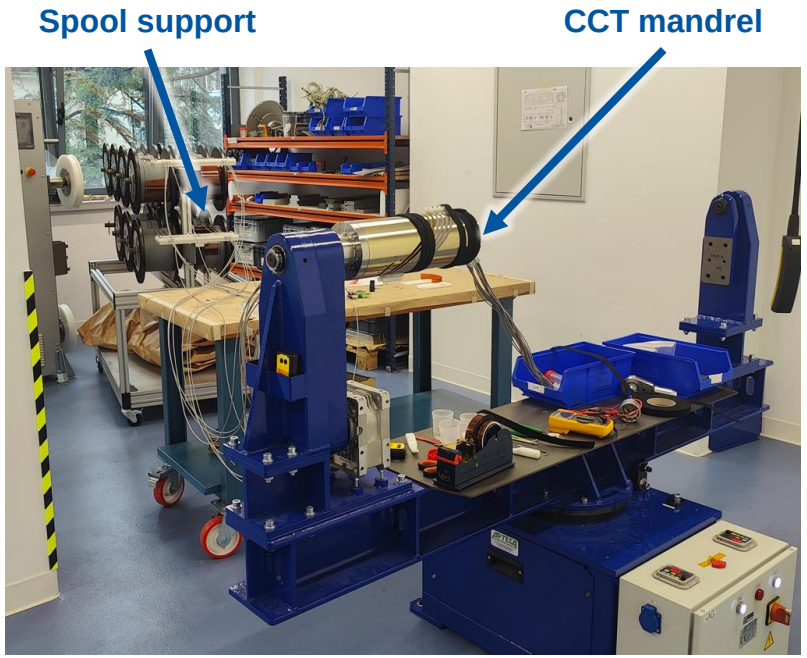
DAISY will be the **first magnet with Nb_3Sn coils** manufactured in the **SMART-Lab.**

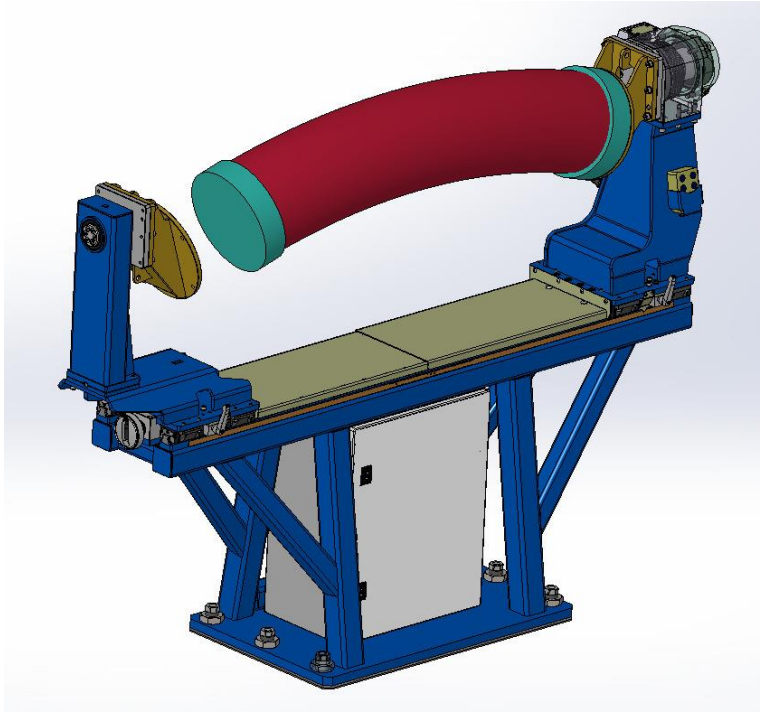
See J.A. García-Matos talk "Progress on the development of high field magnet prototypes for FCC-hh at CIEMAT" 23-09-2025

CCTs

For **medical** applications:

- **IFAST**: Straight CCT (full magnet fabrication)
- **HITRI+**: Curved CCT for hadrontherapy (winding and impregnation of coils)





HTS activities

Goal: **Study HTS needs** of the Spanish Fusion program, within the framework of the European strategy (including industrial scope):

- Design and construction of an **HTS magnet** with flat coils for a **gyrotron** at CIEMAT.
- Analysis of the **development** of an **HTS cable**.

Potential interest in opening a program similar to PRISMAC, focusing on applying superconducting magnets to develop **pre-industrial** compact **fusion power generation equipment**.

SMART-Lab with the Spanish industry

SMART-Lab will contribute to **boosting** Spanish industrial capacity:

- Aims to be a **reference and support facility** for **Spanish companies** interested in **developing magnetic components.**
- Supports the **participation of Spanish companies** in **big scientific facilities** (i.e. main dipoles manufacturing for the FCC-hh).

The **Spanish industry** is already **contributing**:

- **SMART-Lab equipment**.
- **Tooling** manufacturing for **coil and magnet components production**.
- **Tooling** manufacturing for **magnet assembly**.
- **Magnet components** manufacturing.

Thanks to everyone who has contributed to making this laboratory a reality