MISSION: IMPOSSIBLE

AT CERN

The creation of superconducting magnets

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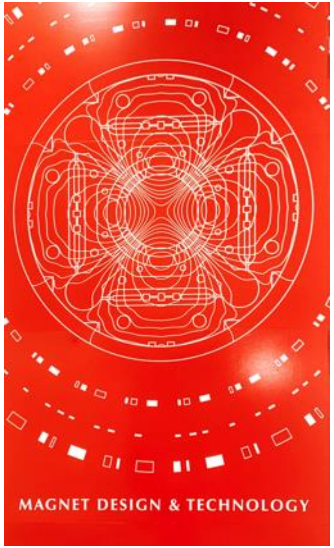
OUR TASK

We have worked in the technology department, in the Magnet Design and Technology section, whose tasks are:

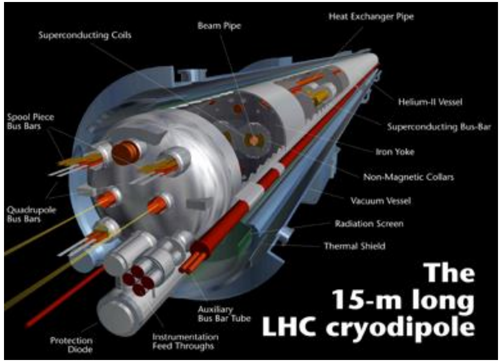


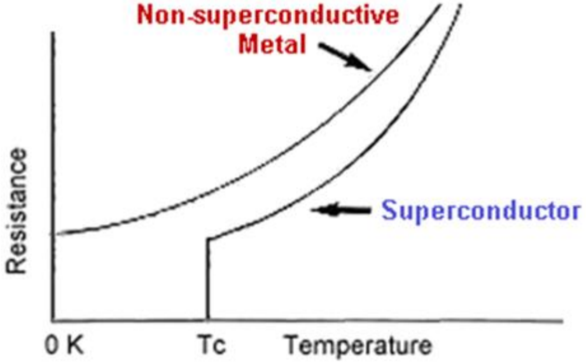
- The design and fabrication of superconducting model magnets.
- Projects linked with the LHC upgrade and high field magnets.
- The analysis of the performance of the magnets.

Our mission was to master the creation of superconducting magnets, and for that we have been working in the Model Magnet Laboratory in building 927, with the help of a multidisciplinary and multicultural group.

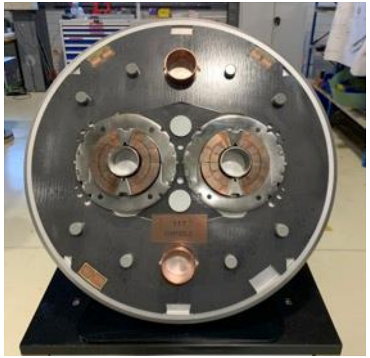
WHAT ARE SUPERCONDUCTING MAGNETS?

Superconducting magnets must be cooled to cryogenic temperatures during operation. In its superconducting state the wire has no electrical resistance and therefore can carry much larger electric currents than ordinary copper wire at room temperature , creating intense magnetic fields.

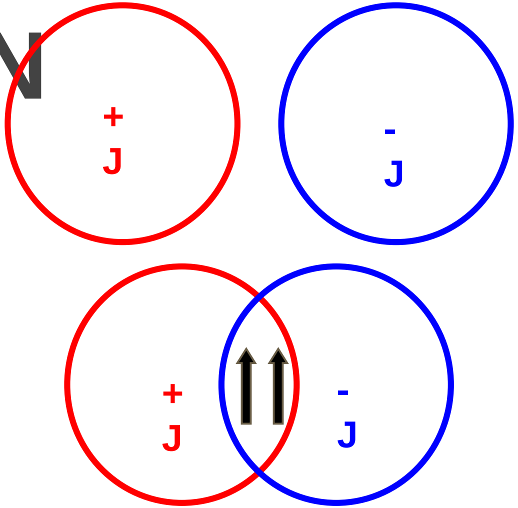


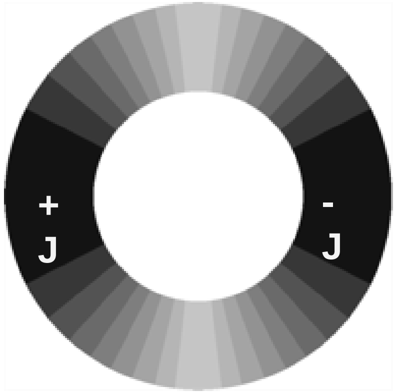


HL-LHC 11T dipole cross-section



MAGNETIC DESIGN





Two intersecting ellipses with

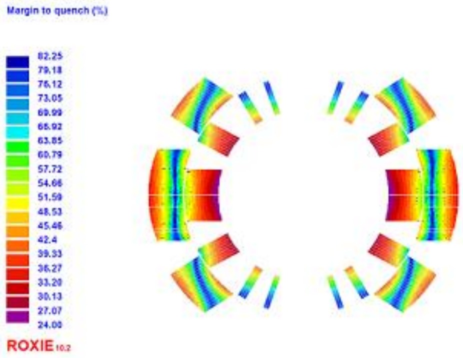
opposite polarity -> perfect dipolar field

In practice, we use a cosθ distribution

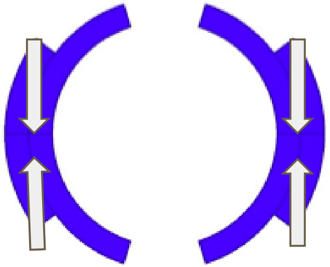
ROXIE:

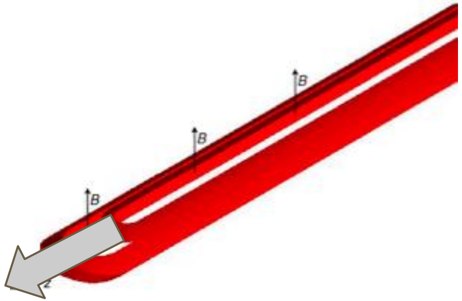
Program used to optimize and modify the parameters of superconducting magnets:

- Magnetic characteristics
- Geometry of the coil



MECHANIC DES

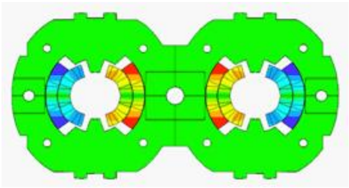




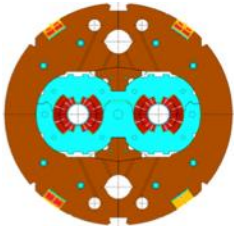
Electro-magnetic forces:

Superconducting coil is subjected to e.m. forces that tend to push the coil.

Mechanical structure:



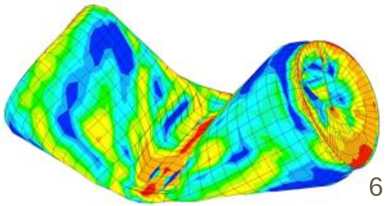
Collars hold the coil in place and prevent it from suffering the effects of e.m. forces



The iron yoke enhances magnetic field and provides rigidity

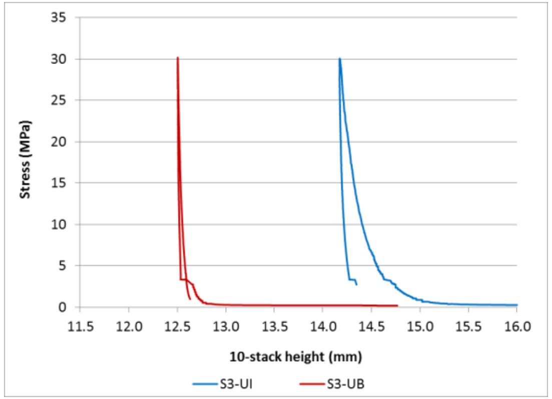
Finite element analysis:

We can divide a complex volume in smaller, simpler shapes in order to obtain the full description.



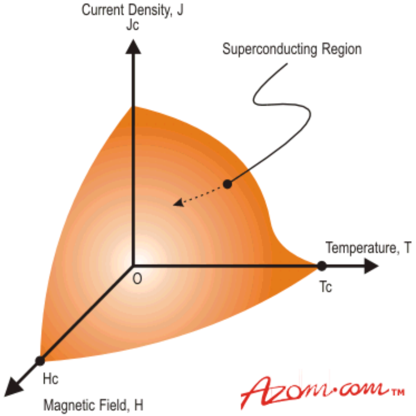
THE Nb_3Sn SUPERCOND

- Insulated with fiberglass and mica: insulation measurements using 10 stacks.



<u>*Superconducting state within three parametres:*</u>

- Temperature
- Magnetic field
- Current density

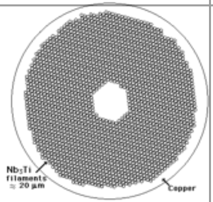
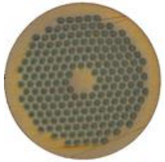


PRODUCING SUPERCONDUCTING CABLES

CERN receives superconducting wires. They are characterised in a cryogenic environment within a magnetic field in which we put the wires in order to test the current density they can absorb. Cables are produced with a cabling machine .

The cables are then measured to quantify the current density degradation due to cabling operation.

DIFFERENT SUPERCONDUCTING WIRES

Nb-Ti	Nb_3Sn
Critical temperature: 10 K	Critical temperature: 18 K
Critical magnetic field: 9 T	Critical magnetic field: 20 T
Filaments: 5-7 µm	Filaments: 30 µm
Covered by copper, to transport current if superconductive state is lost.	Covered by copper, to transport current if superconductive state is lost
Superconductor when delivered 	These cables need a heat treatment 

WINDING

Coils' construction starts embedding the superconducting cables in stainless steel matrix (the poles) they provide mechanical stability and provides a path for large currents in case the superconducting state is lost. These superconducting magnets must be cooled with liquid helium in order to have 0 resistance.

If we use Nb_3Sn, it is necessary to put the coil through a thermal treatment, to get the quality of superconductivity.

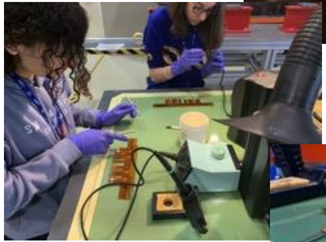
COIL INSTRUMENTATION

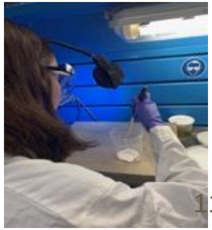
NbTi is spliced into Nb_3Sn cable, which is added to its future connection to the magnet. A polyamide trace is assembled in order to monitor the coil during the powering test and to protect it during quench.

POLYMERS' LAB

The coils are impregnated using EPOXY resin to provide mechanical rigidity and electrical insulation. Some magnet components are made in the polymer lab using 3D printing techniques.

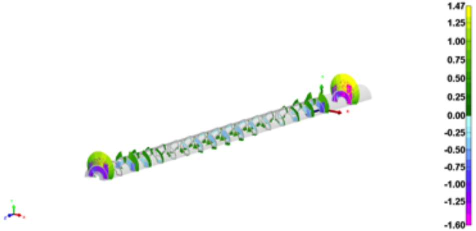


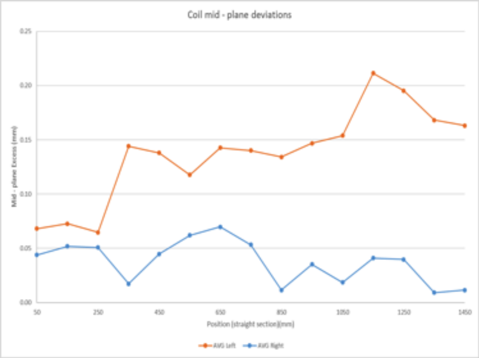


FARO-ARM

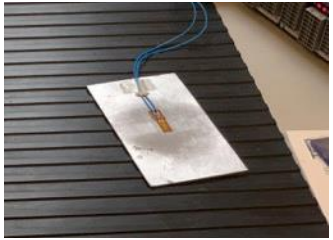
Coils and magnet components need to be accurately measured. The 3D measuring machine, called FaroArm, is composed by a long arm that can be moved and a short piece that looks like a gun. The gun must be calibrated. When the calibration is completed, we can start taking measurements of the different components.





MAGNET ASSEMBLY

To complete the magnet assembly we need to put together all the parts we have been fabricating. We take coils, poles and collars and we put it on an assembly tooling that will be introduced in a press.

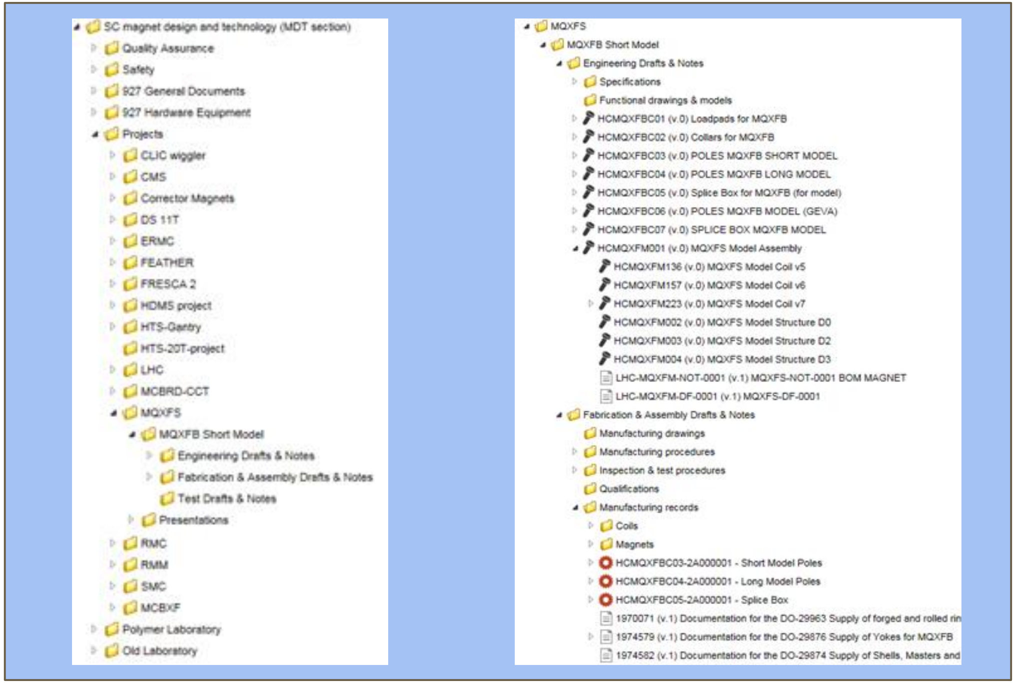


We worked with a short mechanical model in which we used Fuji paper to do a cross-check between the measurements of the strain gauges and said paper. Strain gauges are used during cold powering test to monitor the magnet's mechanical behaviour.

QUALITY ASSURANCE

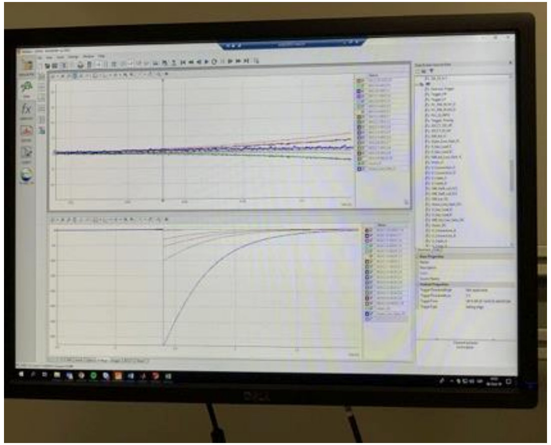
It's a process by which we avoid possible mistakes in the fabrication process and in the end product.

In order to store, organize and control all engineering data throughout the design, manufacturing and maintenance phases, we use a database called EDMS.



CRYOGENIC TEST

We use liquid helium at 1.9K (-271,1C) and measure the magnet performance. The magnets are powered until they quench to define their limits. This testing is made in SM18. There they submerge the magnet in great tins of helium while they observe in graphs how the magnet reacts. Quench heaters are used to protect the magnet during resistive transition.



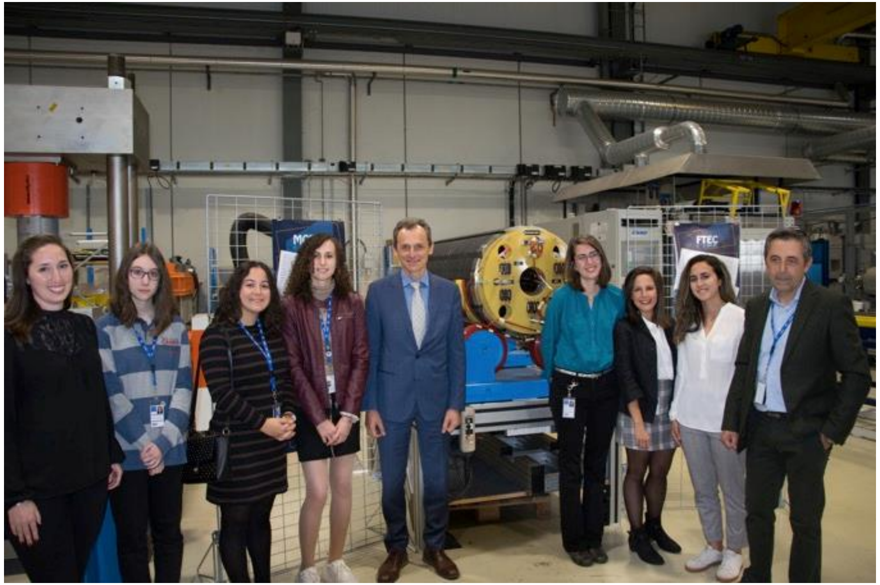
CONCLUSIONS

To sum up, magnets are a very important part of accelerators, and they are not easy to fabricate, so we want to say thank you to the people that have helped and taught us, giving us their time and showing us how much they love their work.

MINISTER’S VISIT

We were extremely lucky to have Spanish science minister and astronaut Pedro Duque with us to show him the newly designed Spanish dipole corrector, which will be installed in the HL-LHC.

We thank him for spending some of his time with us.



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THANK YOU SO MUCH JUAN CARLOS WE WILL MISS YOU