PARTICLE ACCELERATOR LABS

UAM Universidad Autónoma de Madrid

INFIERI

6th Summer School on INtelligent signal processing for FrotIEr Research and Industry

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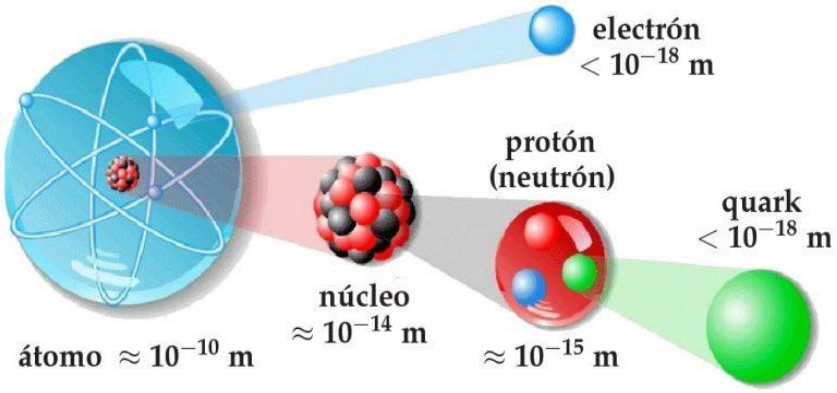
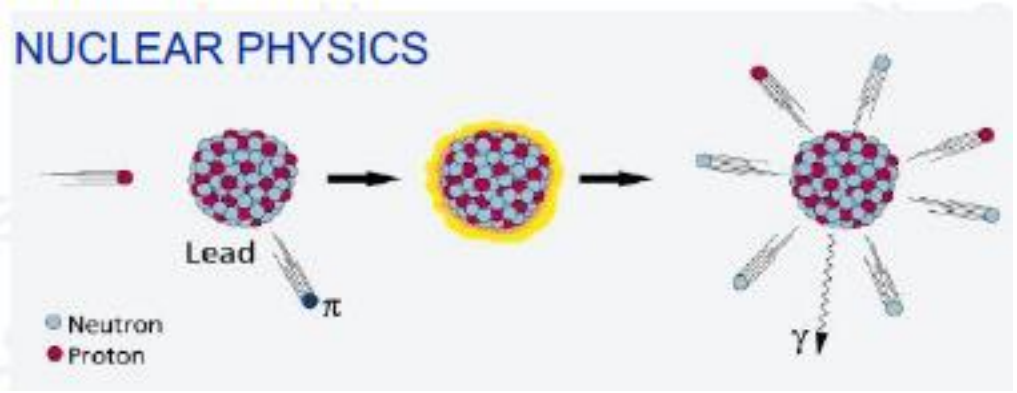
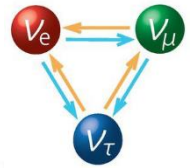
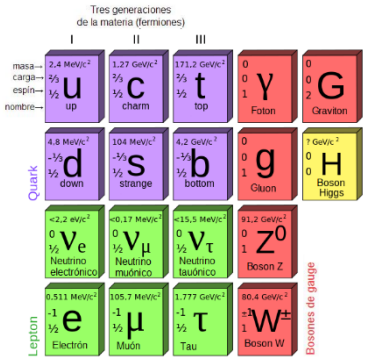
23- 8- 2021

Particle accelerator development driven by Nuclear and High Energy Physics

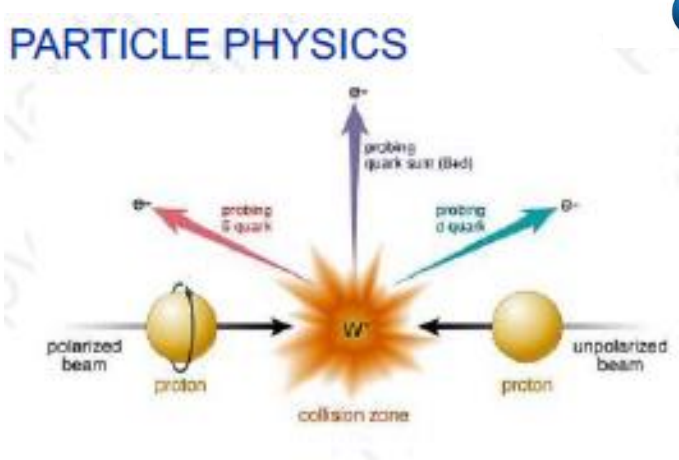


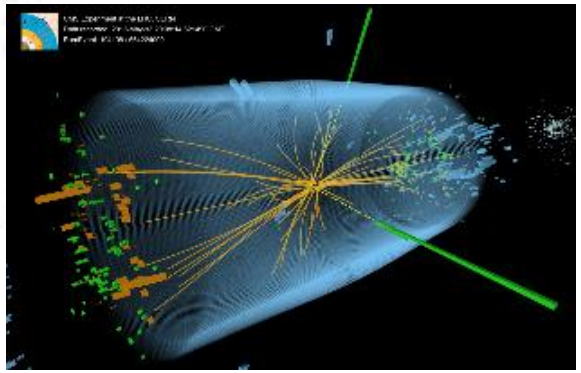






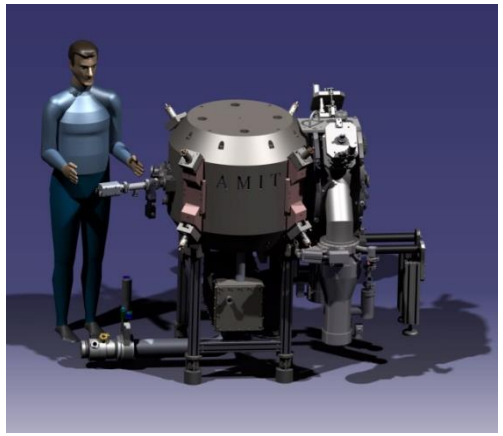
Acceleration of subatomic particles, impacting on atoms or particle collisions allows a better understanding of the world



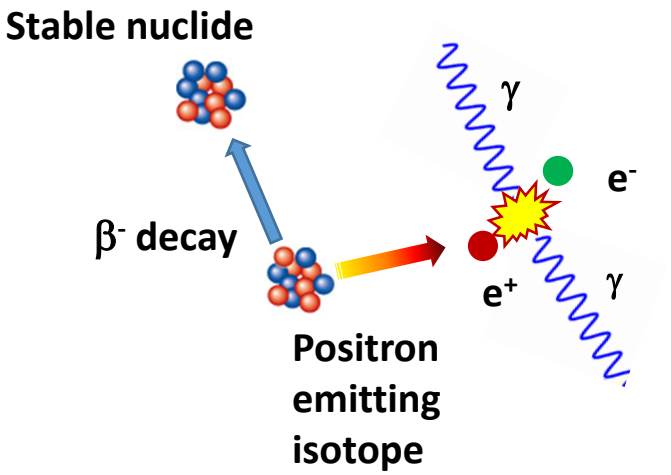


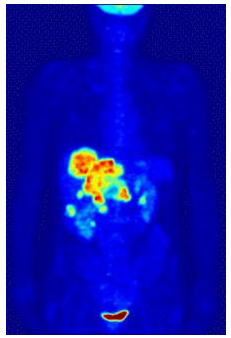
Medicine Application

- Nuclear imaging: radioisotope production (PET, SPECT, theragnostics)
- Therapy: radioisotopes, radiotherapy, protontherapy and therapy with light ions

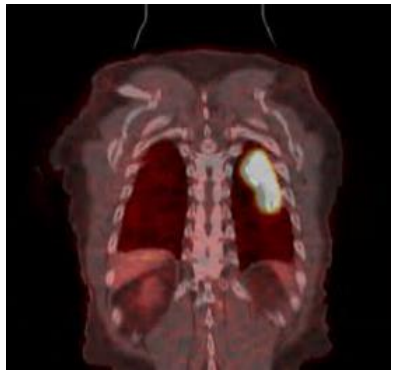


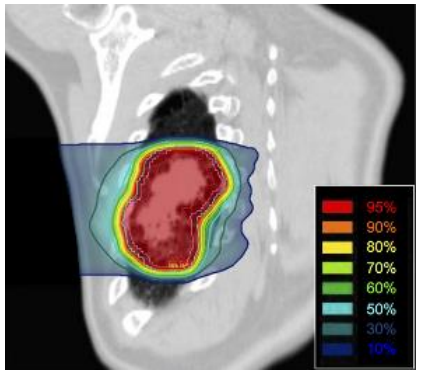
AMIT cyclotron for PET radioisotope (CIEMAT)

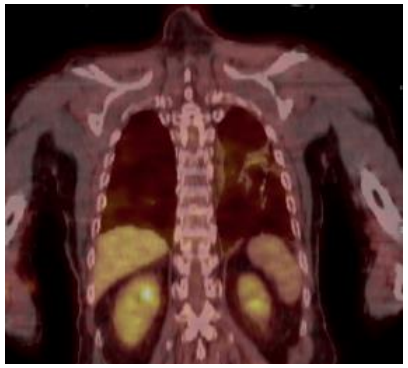




Whole-body PET scan using ^{18}F-FDG

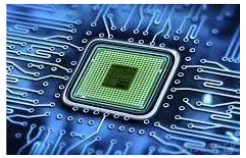


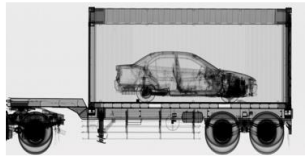




Accelerator in Industry

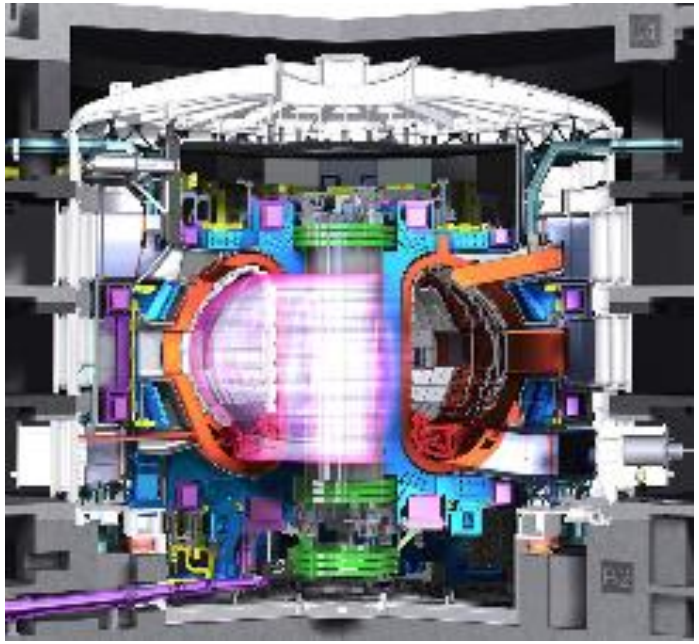
- Ion implantation: Semiconductors manufacturing
- Ion beam analysis
- Electron beam material processing: plastic manufacturing
- Radioisotope production
- Food sterilization
- Cargo inspection and national security (photons, neutrons)

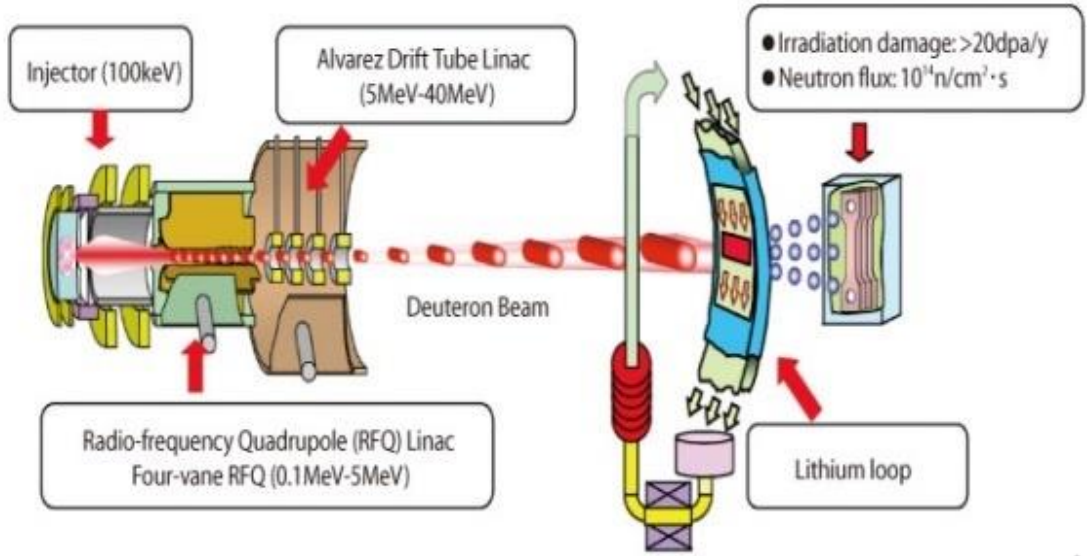




Other applications

- Nuclear fusion: research of materials
- Nuclear waste treatment and controlled fission for energy production (ADS)
- Environmental applications





IFMIF DONES GRANADA

Technology for accelerators

1) Beam Dynamics of CMAM accelerator

CMAM facility

2) Design of a Superconducting Magnet for the HL-LHC

CIEMAT-CEDEX Lab (Madrid)

3) Experimental Concepts in Applied Superconductivity

CIEMAT-CEDEX Lab (Madrid)

Coordinators:

Local:
Gastón García (CMAM-UAM), Luis García-Tabarés (CIEMAT), Concepción Oliver (CIEMAT), Fernando Toral (CIEMAT)

International:
Pierre Vedrine (IRFU-CEA/DACM, Paris Saclay, France

Other participants:

- Silvia Viñals, Miguel Crespillo (CMAM-UAM)
- Javier Munilla, Oscar Durán (CIEMAT)
- Support from *Royal Holloway University*: Alberto Arteche, William Shields, Laurie Nevay

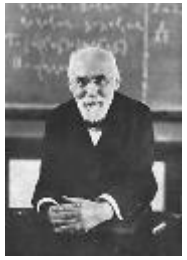
1. BEAM DYNAMICS FOR CMAM ACCELERATOR

Gastón García**, Silvia Viñals, Miguel Crespillo **(CMAM-UAM), Concepción Oliver (CIEMAT)

Main goal

Beam dynamics studies aim at the analysis of the beam acceleration and transport under the different electromagnetic fields produced by the accelerating structures and focusing elements integrated in an accelerator.

Charged particles can be accelerated and transported by using electromagnetic fields



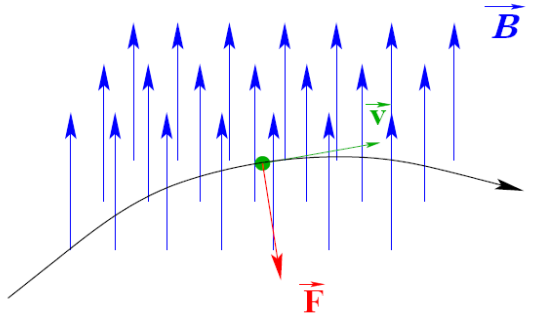
Lorentz's equation

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

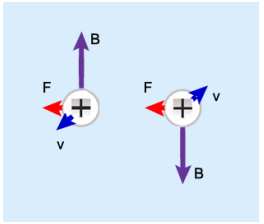
Electric force

Magnetic force

Acceleration



Transport and deflexion

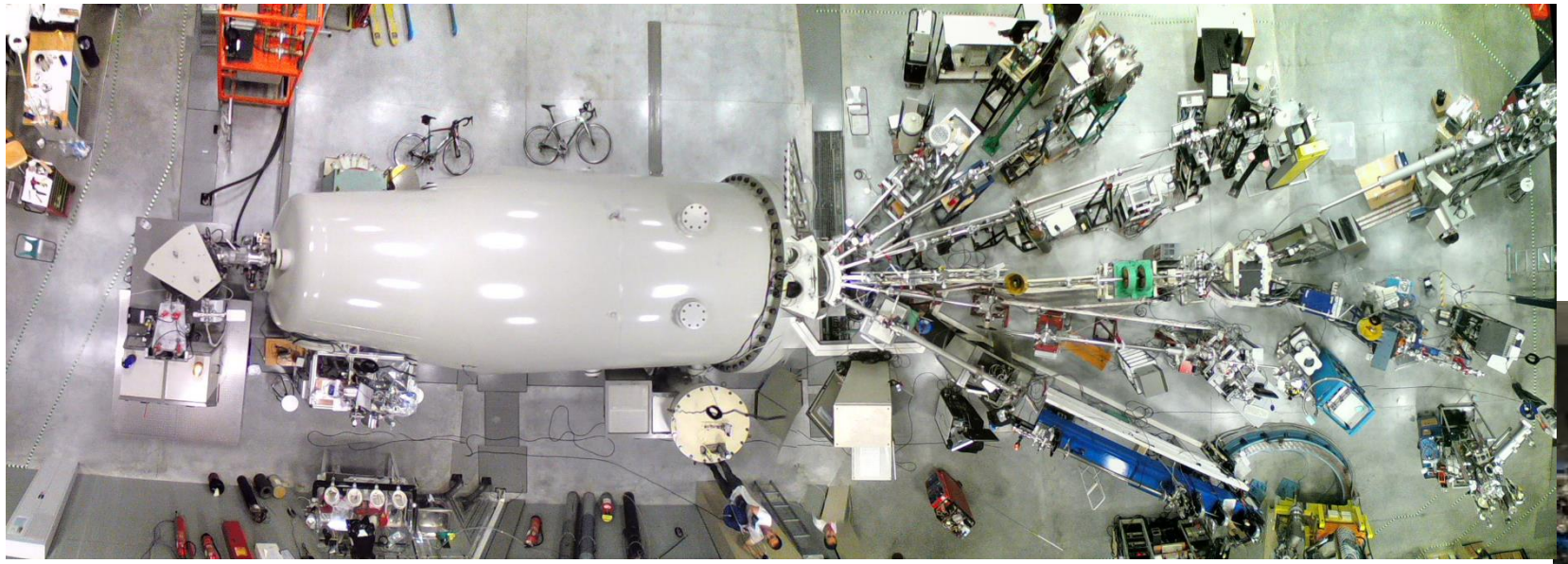


By optimizing the properties of such components, an optimum output beam can be obtained according to the user requirements.

1. BEAM DYNAMICS FOR CMAM ACCELERATOR

***Gastón García**, Silvia Viñals, Miguel Crespillo **(CMAM-UAM)**, **Concepción Oliver** (**CIEMAT**)*

This hands on lab will be hold at the CMAM electrostatic ion accelerator, devoted to the analysis and modification of materials.



CMAM accelerator hall

1. BEAM DYNAMICS FOR CMAM ACCELERATOR

Gastón García**, Silvia Viñals, Miguel Crespillo **(CMAM-UAM), Concepción Oliver (CIEMAT)

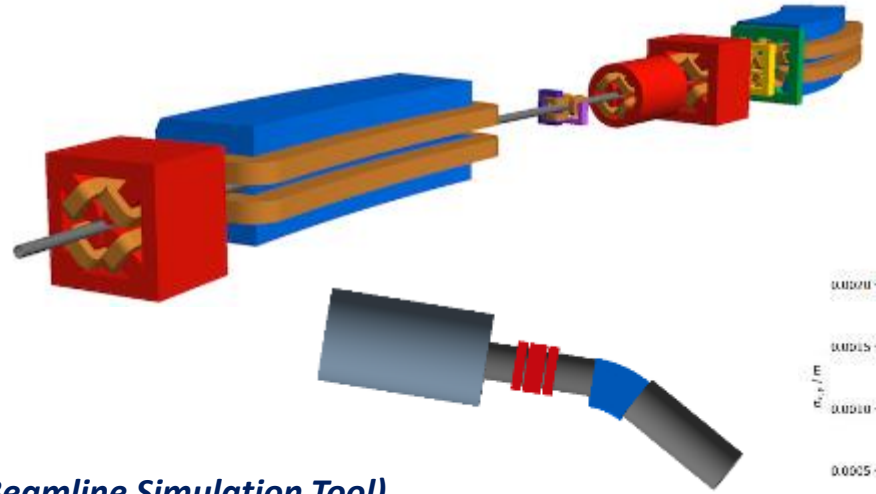
During this lab, the students will be introduced into the beam dynamics of particle acceleration, according to the following scheme:

- Introduction to accelerator and main concepts of beam dynamics
- Introduction to CMAM accelerator
- Description of the BDSIM (Accelerator Beamline Simulation Tool) software for beam dynamics studies
- Calculation of beam dynamics of CMAM accelerator using BDSIM code
- Comparison with experimental results

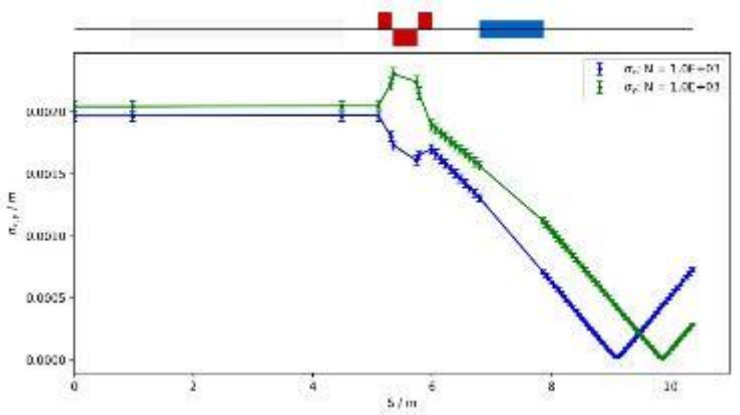
MATERIAL:

- Computers with BDSIM code already installed
- CMAM accelerator lines
- PPT presentation with explanations and guiding remarks

BDSIM Beam Delivery Simulation



BDSIM
(Accelerator Beamline Simulation Tool)



HANDS-ON LABS ON APPLIED SUPERCONDUCTIVITY

- ❑ Design of a Superconducting Magnet for the HL-LHC
- ❑ Experimental Concepts in Applied Superconductivity

Superconductivity

➡ **Two Labs in Superconductivity Magnets**

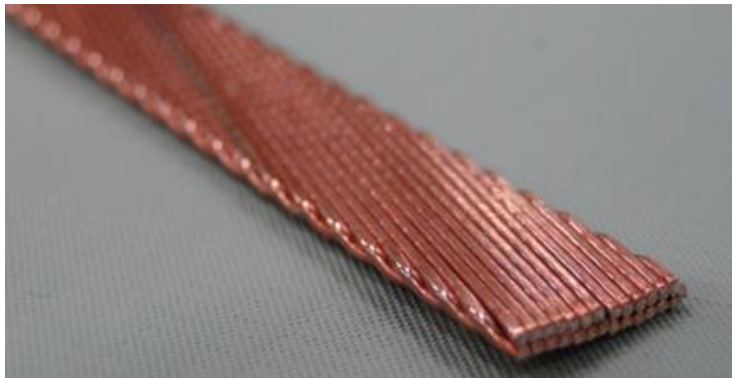
➢Superconductivity:

Some materials present a zero electrical resistance when cooled below a characteristic temperature.

➢Why Superconducting in accelerators?

- Resistive magnets saturates at about 2T
- Superconductivity allows to build magnets that can stand higher electric currents and higher fields (not limited by water cooling)
- It also allows accelerating RF cavities that do not dissipate power and have higher electrical efficiency
- Problem: a superconducting accelerator requires a huge cooling system that keeps all elements at liquid helium temperature


Clean room assembly of superconducting RF cavities



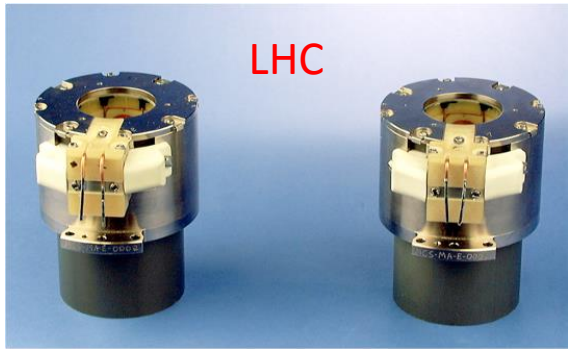
Superconductivity

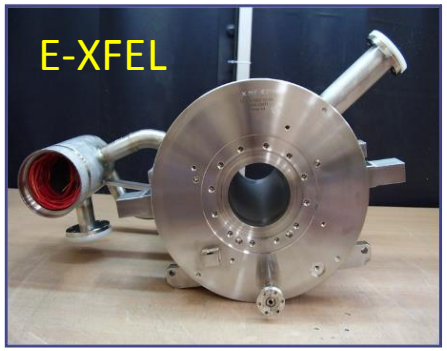
- Superconducting magnets are one of the key components to achieve cutting-edge beam parameters as those required in the modern large High Energy Physics accelerators but they also play a crucial role in the development of compact accelerators for societal applications, as those used in medical applications, for instance.

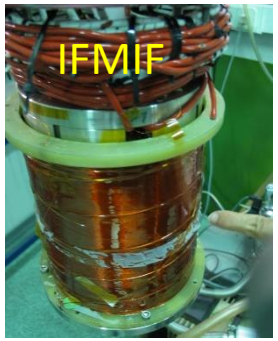
- Nowadays superconductivity finds many applications in different fields spanning from basic science to energy, transportation or medical devices. In most of the cases the superconductors are used in the form of magnets but they can also be used in other devices as magnetic bearings, for instance.

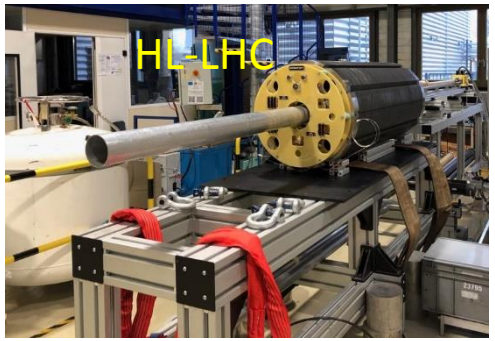
APPLIED SUPERCONDUCTIVITY BACKGROUND AT CIEMAT

PARTICLE ACCELERATORS FOR SCIENCE





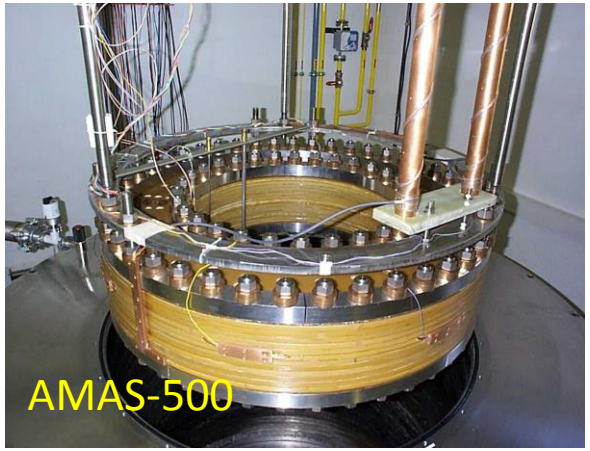


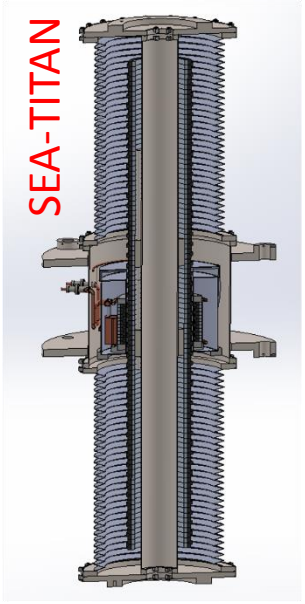


CIEMAT has a long track record in producing Superconducting Devices, specially Superconducting Magnets for Particle Accelerators. In a very usual approach, CIEMAT develops prototypes of magnets which are later series-manufactured at industry. CIEMAT has contributed to LHC, HL-LHC, E-XFEL or IFMIF

APPLIED SUPERCONDUCTIVITY BACKGROUND AT CIEMAT

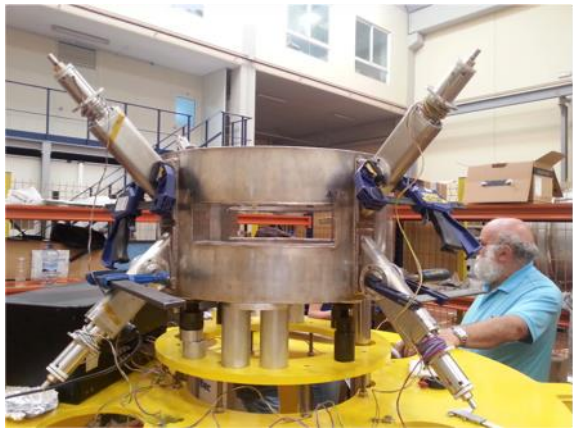
SC MAGNETS FOR ENERGY





CIEMAT has also participated in the development of magnets for Energy Storage, Management and Generation.

MEDICAL ACCELERATORS



Recently a compact accelerator for medical applications has been developed at CIEMAT based on a Superconducting magnet.

THE PLACE WHERE THE SUPERCONDCUTIVITY SESSIONS WILL TAKE PLACE

These sessions will take place in a shared facility between CEDEX and CIEMAT.
CEDEX owns the Laboratorio de Interoperabilidad Ferroviaria (LIF) for validating components and systems based on the European Rail Traffic Management System (ERTMS) while CIEMAT owns the Laboratorio de Electromagnetismo Aplicado to develop Superconducting Magnets, Particle Accelerators Components and Electric Drives for Power Systems.

The Lab is located in:

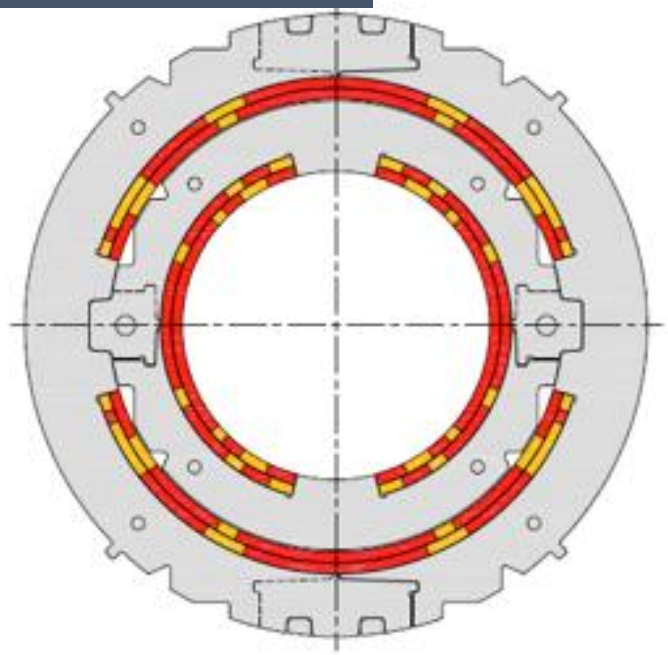
Calle Julian Camarillo 30
28037 MADRID

Contac person: Luis García-Tabarés
luis.garcia@ciemat.es

2. DESIGNING A SUPERCONDUCTING MAGNET LAB for HL-LHC corrector

Fernando Toral**, Oscar Durán, Javier Munilla, Luis García-Tabarés, **CIEMAT

- Starting from the specifications, the conceptual design of a superconducting magnet for HL-LHC orbit correction will be presented. The criteria to decide the layout of the coils and the main dimensions will be presented.
- Some basic calculations of magnetic field based on analytical expressions will be shown.
- Finally, a simple numerical simulation using a FEM code will allow to cross-check the calculations.
- During the class, a visit will be paid to the facility for building superconducting magnets for High Lumi-LHC



THE **MCBX MAGNET** FOR THE HIGH LUMINOSITY LHC WHICH WILL BE THE CORE OF THE LESSON

2. DESIGNING A SUPERCONDUCTING MAGNET LAB

Fernando Toral**, Oscar Durán, Javier Munilla, Luis García-Tabarés, **CIEMAT

MATERIAL:

- One laptop provided by CIEMAT with one or several FEM codes installed to perform the calculations in a collaborative form between all the students and the tutor.
- PPT presentation with explanations and guiding remarks
- Videos
- Visit to the manufacturing facility

FACILITY FOR MANUFACTURING SUPERCONDUCTING MAGNETS AT CEDEX/CIEMAT

3. APPLIED SUPERCONDUCTIVITY LAB

Luis García-Tabarés**, Fernando Toral, Javier Munilla, Oscar Durán, **CIEMAT

MAGNETIC BEARING BASED ON A HTS BULK SUPERCONDUCTOR

WORKSHOP/CLASS WHERE THE LESSON WILL BE GIVEN

MAGNET BASED ON A HTS TAPE

This session will alternate oral explanations of the main aspects of applied superconductivity, with practical realizations of two applications of superconductivity developed with two different types of superconductors. The first is a HTS reduced-scale magnet similar to those used in several applications like NMR, Accelerators and others, while the second one is a demonstrator of a superconducting magnetic bearing for applications in kinetic energy storage systems (KESS).

Thanks for your attention