Testing the superconducting coils of AMIT cyclotron at MagNet

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Outline

- The AMIT Project
- The AMIT Superconducting Magnet
- Superconducting Magnet Testing
- Conclusions

The AMIT Project: motivation

- There is an increasing demand for radioisotopes, especially for medical applications. Accelerator-based production and particularly cyclotron-based generation is extensively used. Single dose production is becoming very demanded.

- Since conventional Cyclotrons make a massive use of iron, they are bulky and very heavy. The use of Superconductivity can reduce dramatically the sizes of Cyclotrons, due to the strong dependence of its volume with the applied magnetic field.

- Compact Superconducting Cyclotrons can allow its integration into Hospitals and Labs, where the big sizes of conventional ones, make their use unfeasible.

The AMIT Project

Project AMIT: Advanced Molecular Imaging Technologies

Funded by: Centro para el Desarrollo Tecnológico Industrial

Led by: SEDECAL

Partners: 10 Companies, 14 Research Institutes

WORK PACKAGES

WP1. Development of a compact minicyclotron for 11C y 18F single dose production

WP2. Miniaturized radiopharmacy

WP3. PET Instrumentation

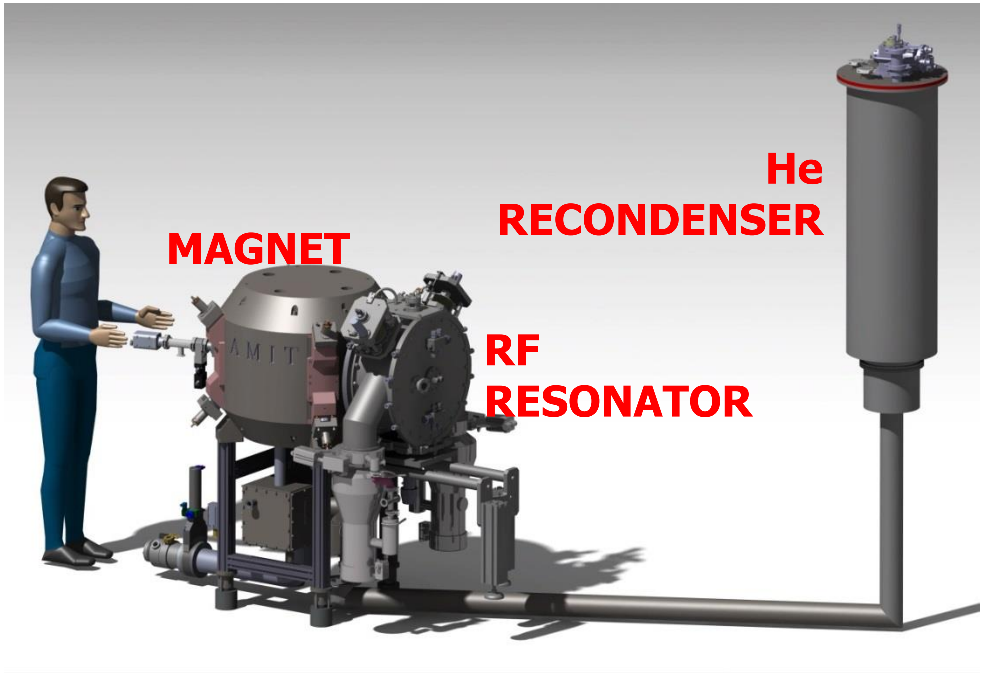
WP4. Advance software imaging (SW tools for analysis, quantification and managing of imaging information for clinical studies)

Target: Brain pathologies, in particular, those derived from mental diseases

The AMIT Cyclotron

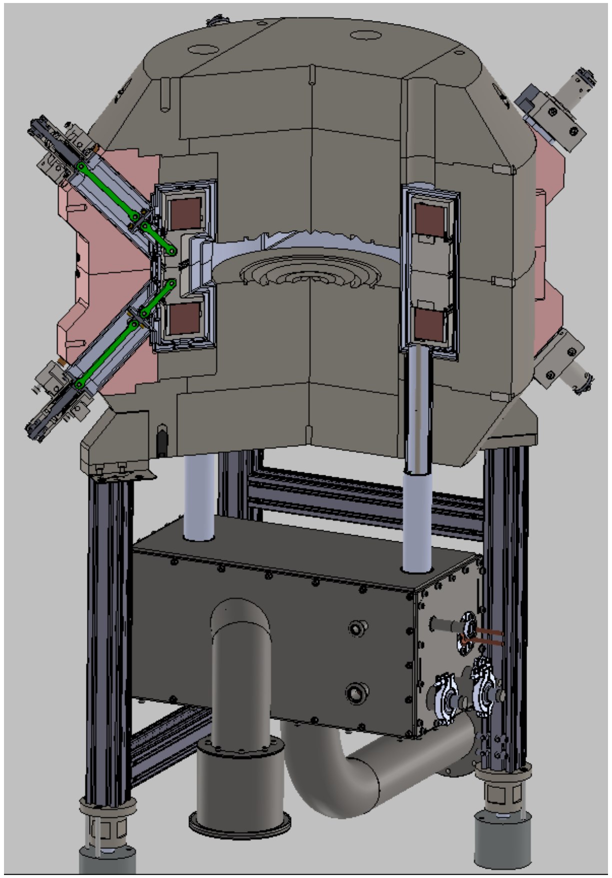
PARAMETER	VALUE	UNITS
GENERAL		
Energy	> 8.5	MeV
Current	>10	µA
Cyclotron Type	Classical	
MAGNET		
Type	Low Tc Superconductor	
Configuration	Warm Iron	
Superconductor	NbTi	
Refrigeration	Two-phase Helium	
Central Field	4	T
RF SYSTEM		
Configuration	One 180º Dee	
Accelerating Voltage	>60	KV
ION SOURCE		
TYPE	Internal	
Ions	H^-	

Within the WP1 of the Project AMIT, a Compact Superconducting Cyclotron is under development. It is a Classical type machine working at 4.2K and refrigerated using a two-phase helium closed circuit. Helium is liquefied in a cryocooler-based recondenser.



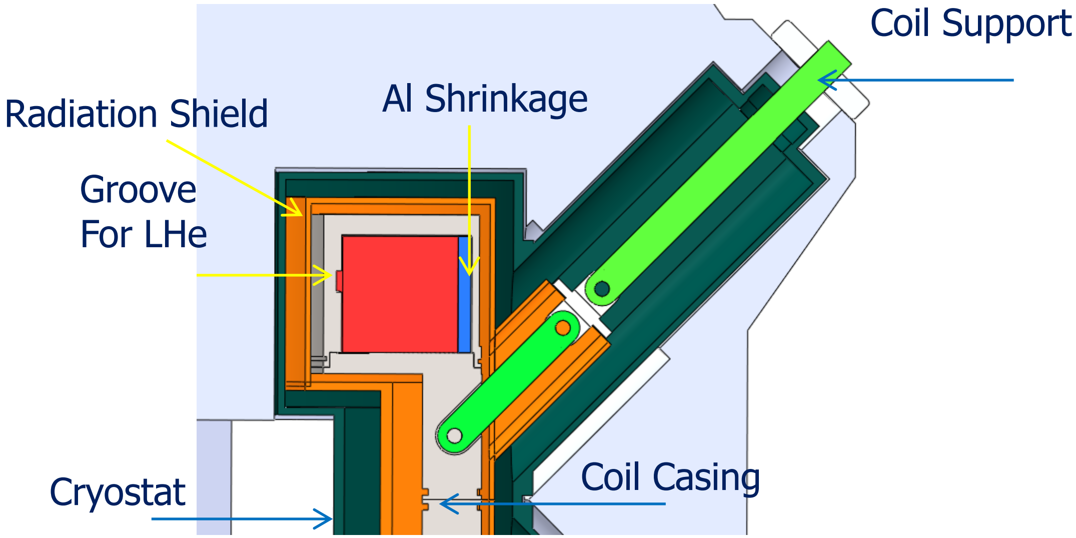
The Superconducting Magnet of the AMIT Cyclotron

The AMIT cyclotron magnet is based on the warm iron approach. Only the coils are cold. They are immersed in a cryostat which is suspended from the iron yoke.
It is developed by ANTEC Magnets, in collaboration with CIEMAT.

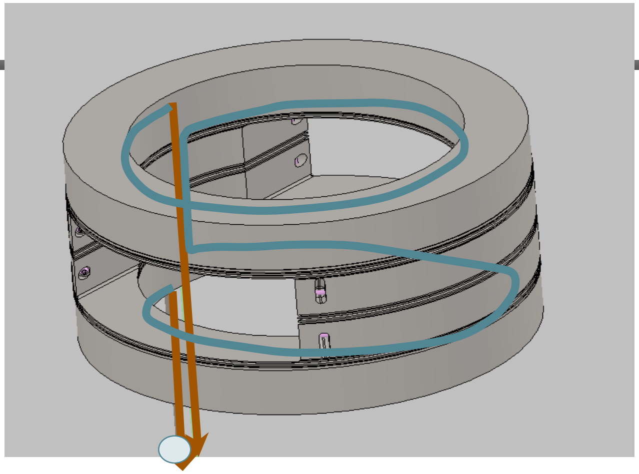


PARAMETER	VALUE	UNITS
Magnetic Central Field	4.00	T
Magnetic Field Radial Gradient @ r=105mm	1.49	%
Nominal Current	108.6	A
Working Point in the Load line @4.2K/4.7 K	70.5/76.5	%
Self Inductance (both coils)@nom. current	38.35	H
Wire Dimension (insulated)	0.896	mm
Cu/Sc	4.5:1	

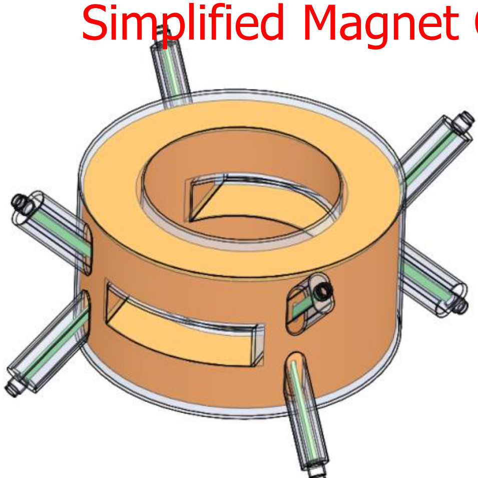
Designing the AMIT Cyclotron Superconducting Magnet



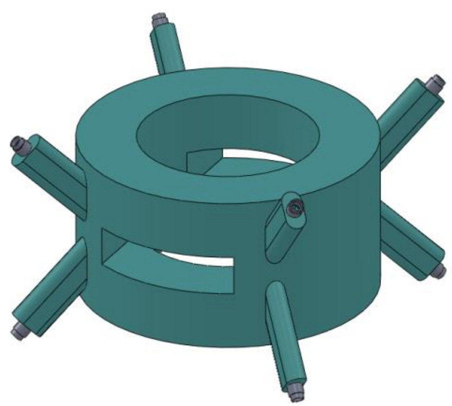
Simplified Magnet Cross Section



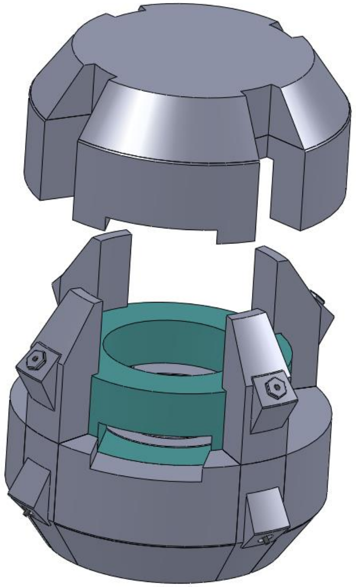
Helium Refrigeration Circuit



Radiation Screen

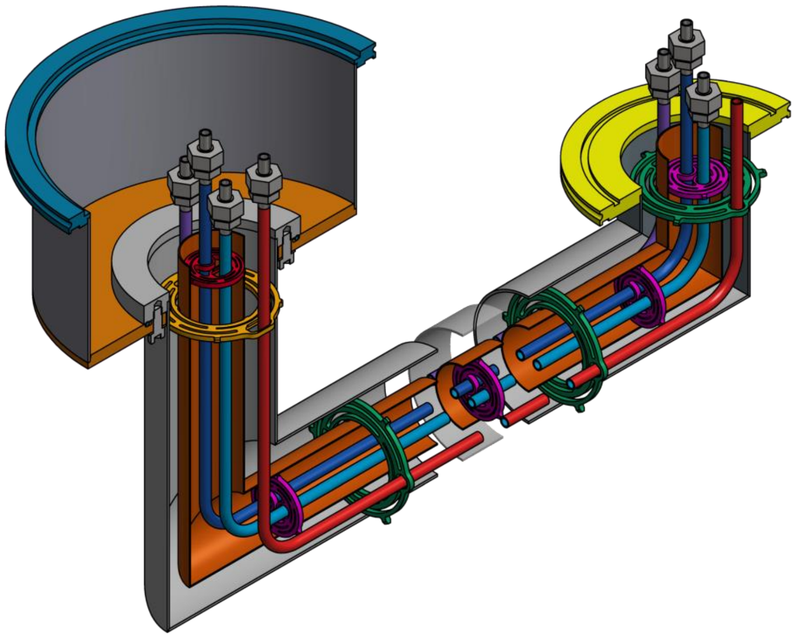


Cryostat



Iron Assembly

The Cooling System for the Superconducting Magnet



Helium Transfer Lline

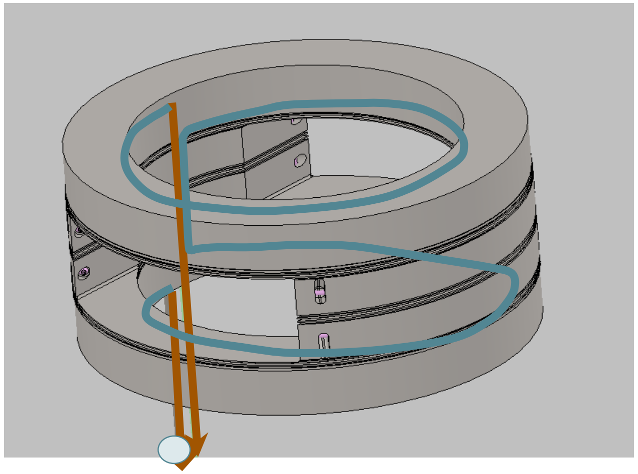
Cryogenic Supply System

The AMIT Cyclotron magnet is cooled down by means of a Cryogenic Supply System developed at CERN which is, basically, a helium re-condenser using heat exchanges and a cryocooler. It supplies He gas to refrigerate the Radiation Screen and Liquid He for the magnet. Both are transferred to the magnet through a low-loss Transfer Line.

The need for the cold test of the superconducting coils

We realized that the test of the superconducting coils before assembly into the helium vessel was necessary:

- The cryostat cannot be disassembled.
- The cooling concept is innovative. It is very difficult to predict the uniformity of the temperature at the coils.
- Testing the coils in a liquid helium bath before assembly would allow to characterize the coils and guarantee their quality.
- Validating the quench simulation performed with CIEMAT code, SQUID.



Helium Refrigeration Circuit

We have no cryostats large enough for this test at CIEMAT.
We asked for the opportunity to test the coils within **MagNet** framework.

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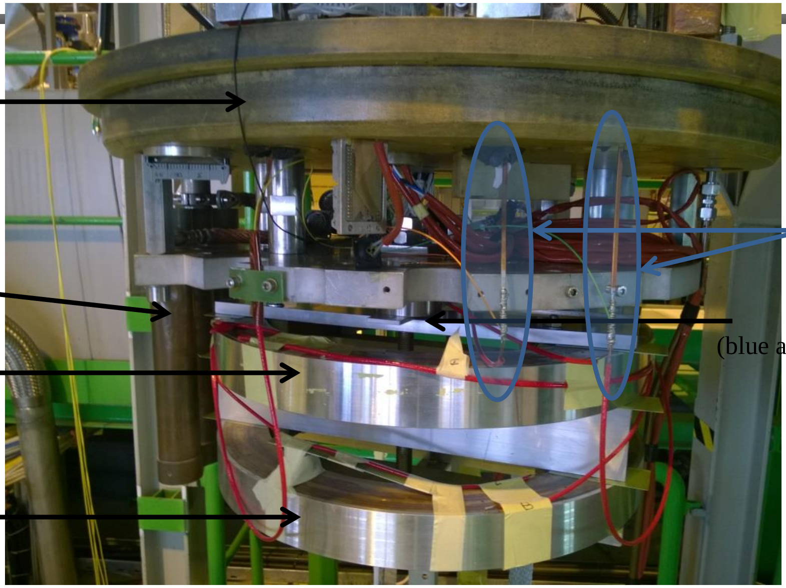
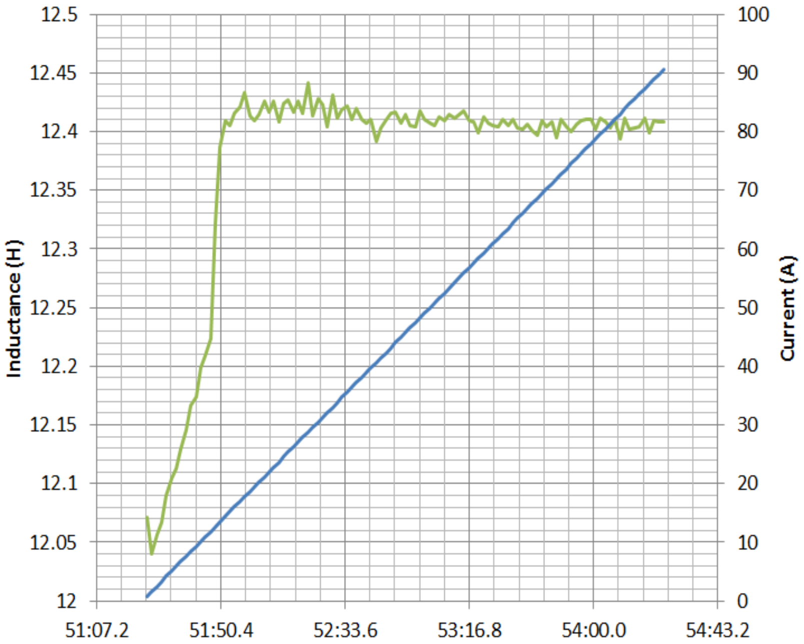
Testing the AMIT Magnet Coils: Set-up

Outer Diameter	537.8 mm
Inner Diameter	413.6 mm
Height	56.1 mm
Nominal Current	125 A
Short sample	Around 190 A
Max current during the powering test	150 A
Ramp rate	0.5 A / s
Overall mass	50 kg
Self-inductance	12.4 H
Number of turns	4235
Stored magnetic energy	97 kJ

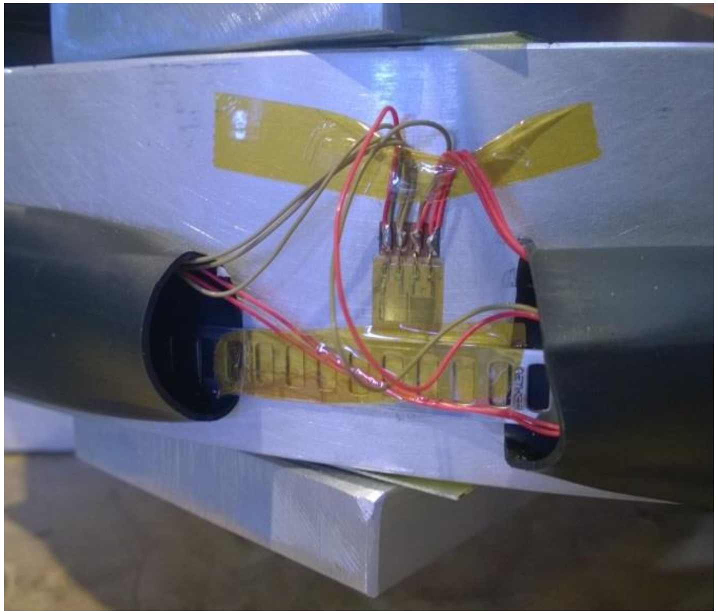


- Magnet superconducting coils have been tested at CERN premises in a vertical cryostat with LHe at 4.2K.
- Nominal current at cyclotron is 110 A. Same peak field is reached at 125 A during the test. Current was limited at 150 A to avoid too high voltages during the quench.
- Notice the transformer effect when both coils are hanging together from the cryostat insert.
- Power supply was controlled in voltage.

Testing the AMIT Magnet Coils: First measurements



Measurement of self-inductance

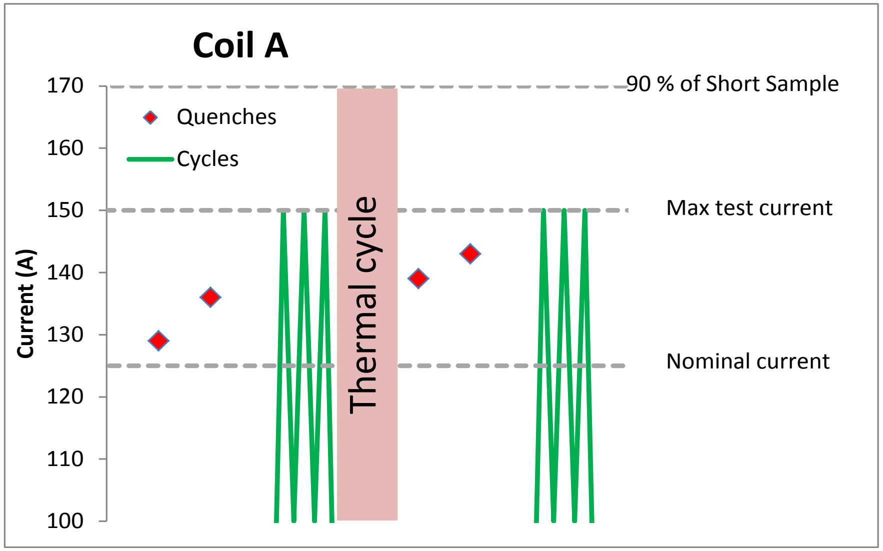


Strain gauges on the aluminium shell

- Calculated self-inductance is confirmed by measurements: 12.4 H.
- One of the shrinking cylinders was equipped with strain gauges. The measurements were close to calculated values, although two of them had opposite sign which could not be explained.

Testing the AMIT Magnet Coils: First coil (I)

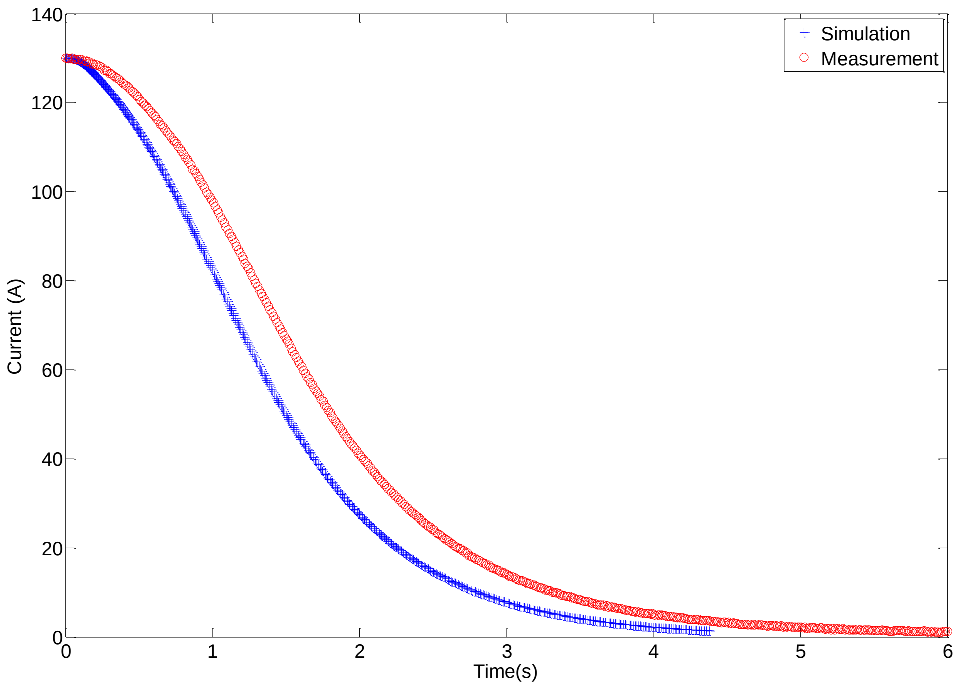
Coil A at the cryostat insert



Training test of Coil A

- First coil was tested alone in the cryostat.
- First quench was above nominal current.
- The coil showed good memory after the thermal cycle.

Testing the AMIT Magnet Coils: First coil (II)

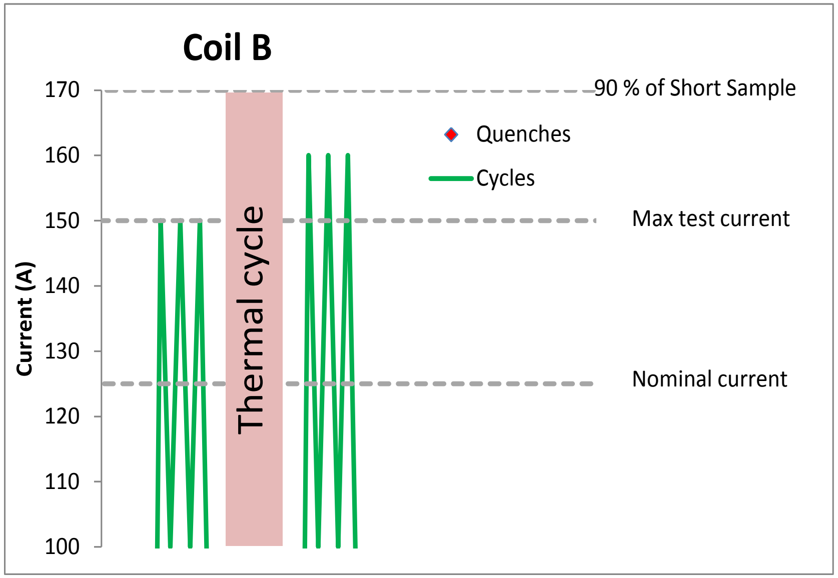


Current decay during first quench of Coil A

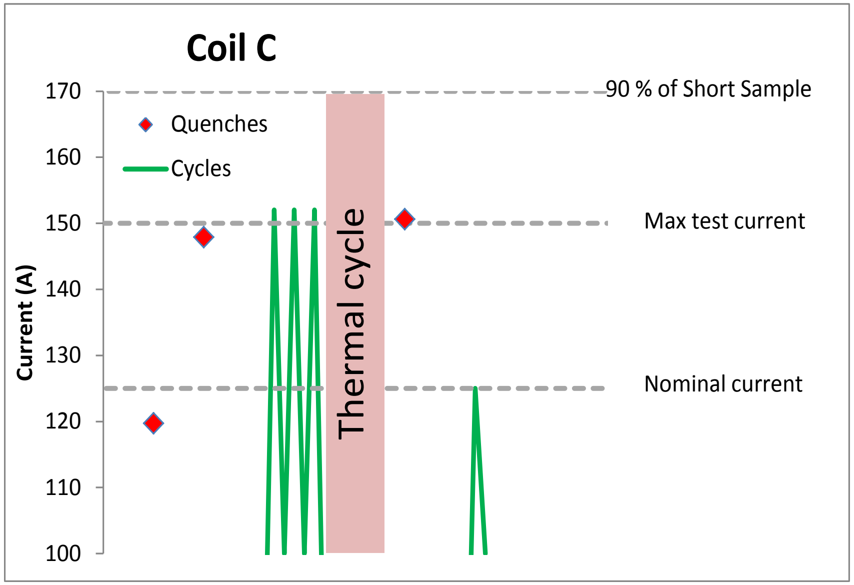
- A good agreement was found between simulations (made with SQUID) and measurements.
- Simulation does not include induced losses in metallic adjacent elements (mainly, aluminum shell). Therefore, the simulated quench shows a faster decay.

	Simulation		Measurements	
Current (A)	Peak voltage (V)	Resistance (ohm)	Peak voltage (V)	Resistance (ohm)
129	840	15,6	773	14,5
136	965	17,1	888	16
138,5	1014	17,7	936	16,5
143	1104	18,8	1029	17,7

Testing the AMIT Magnet Coils: Second and Third Coils



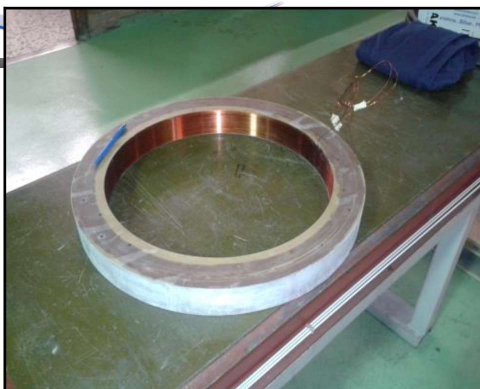
Training test of Coil B



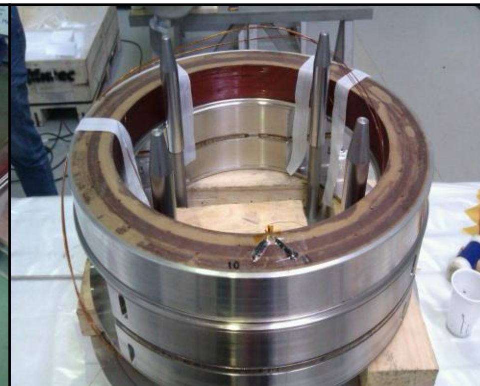
Training test of Coil C

- Second coil did not quench, even at 160 A. However, it has not been assembled into the cryostat because it is suspicious to have a short circuit.
- Third coil showed an early quench, but then trained very well and showed good memory after thermal cycle.

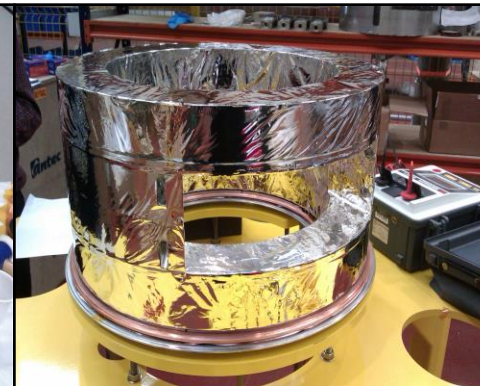
Fabricating the AMIT Cyclotron Superconducting Magnet



Coil after final impregnation



Casing assembly



Casing insulated with Superinsulation

Casing with the Radiation Screen placed around

Cryostat and Coil Supports assembled

Iron assembled around the Cryostat

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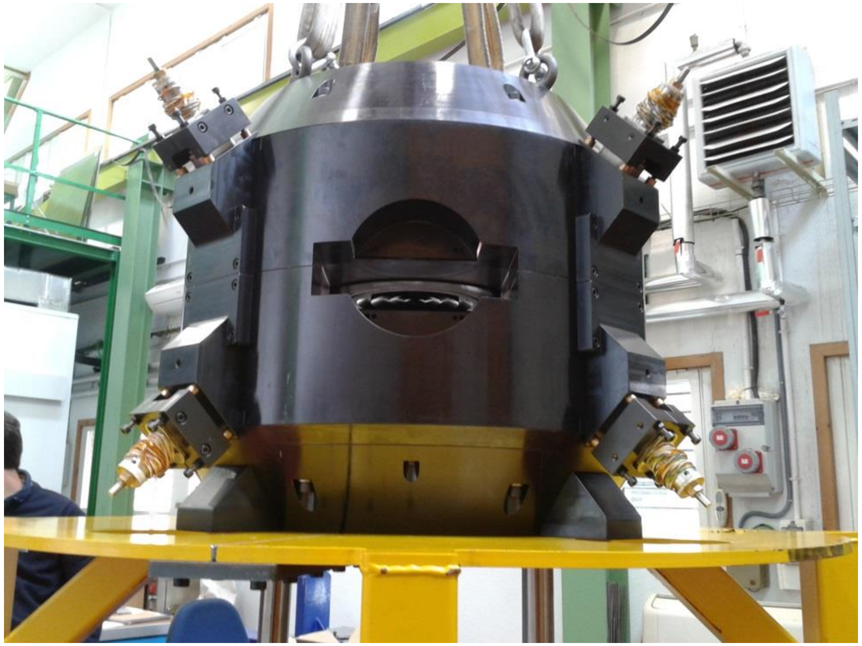
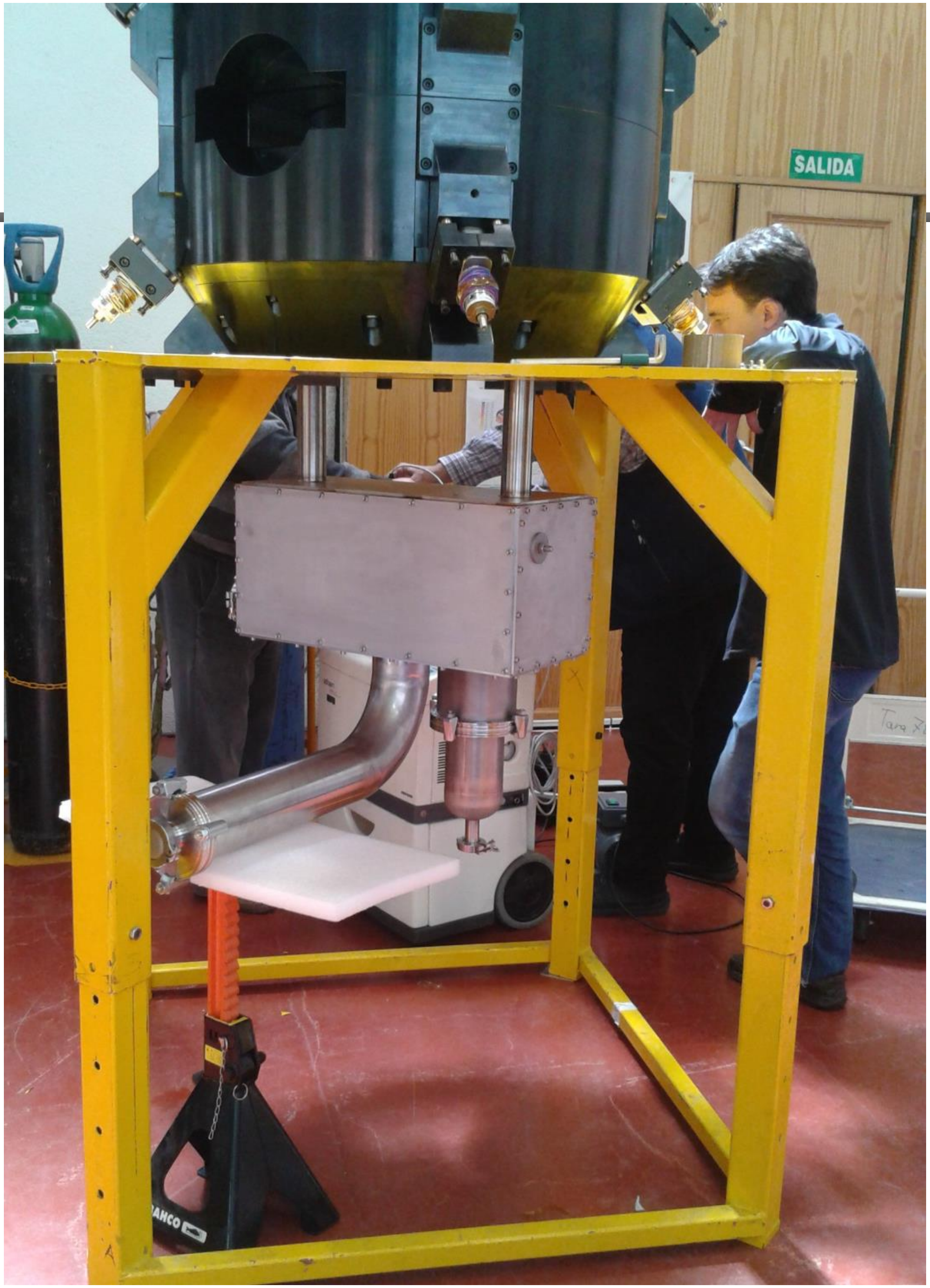
Present Status





Summary and Conclusions

- CIEMAT, in collaboration with other partners, has launched the **AMIT** Project to develop, among other things, a Compact Superconducting Cyclotron.
- The Cyclotron is a Lawrence type machine and the superconducting magnet a warm iron one using NbTi @ 4.5 K. It is cooled down circulating two-phase helium provided by a Cryogenic Supply System (CSS) based on a cryocooler to recondense the gas helium.
- Magnetic, Mechanical and Thermal Calculations of the magnet led to a design based on a magnet which is thermally insulated with a radiation shield and a cryostat and hung from the iron with a low thermal loss supporting structure.
- It was concluded that the coils should be cold tested before integration into the cyclotron cryostat.
- Coils have been successfully tested at CERN (SM18 laboratory) within the **MagNet** framework.
- We are very grateful to MagNet for providing us this possibility.