

**Abstract** - The Facility for Antiproton and Ion Research (FAIR), currently being built in Darmstadt (Germany), needs 21 standard superferric dipoles for its Superconducting FRagment Separator (Super-FRS). The dipoles manufacturing contract has been awarded to Elytt (Spain) in Spring 2018 and CEA Paris-Saclay (Commissariat à l'Énergie Atomique) is overseeing the design and manufacturing activities in the context of the in-kind contribution of France to the FAIR project. The design activities are completed and the manufacturing of the First-of-Series (FoS) will be launched by Elytt after it has completed all the mock-up activities which will validate each key manufacturing process. These superferric dipoles have cold NbTi trapezoidal coils (4.5 K) and warm iron (300 K), and several small scale to full-scale mock-ups were developed and tested by Elytt. We develop here, the mechanical tests performed on samples of conductor, the results of the winding tests and the tests carried out on the full-scale Helium vessel mock-up made of stainless steel.

## Coil mock-ups (MU) developments

Prior launching the First-of-Series manufacturing, Elytt is required (specifications) to manufacture a scale-1 coil which is expected to be integrated into a scale-1 half coil casing (or He vessel). Cross section deformation occurred during the transfer of scale-1 Cu coil from winding mandrel to wrapping station due to accumulated mechanical tension.



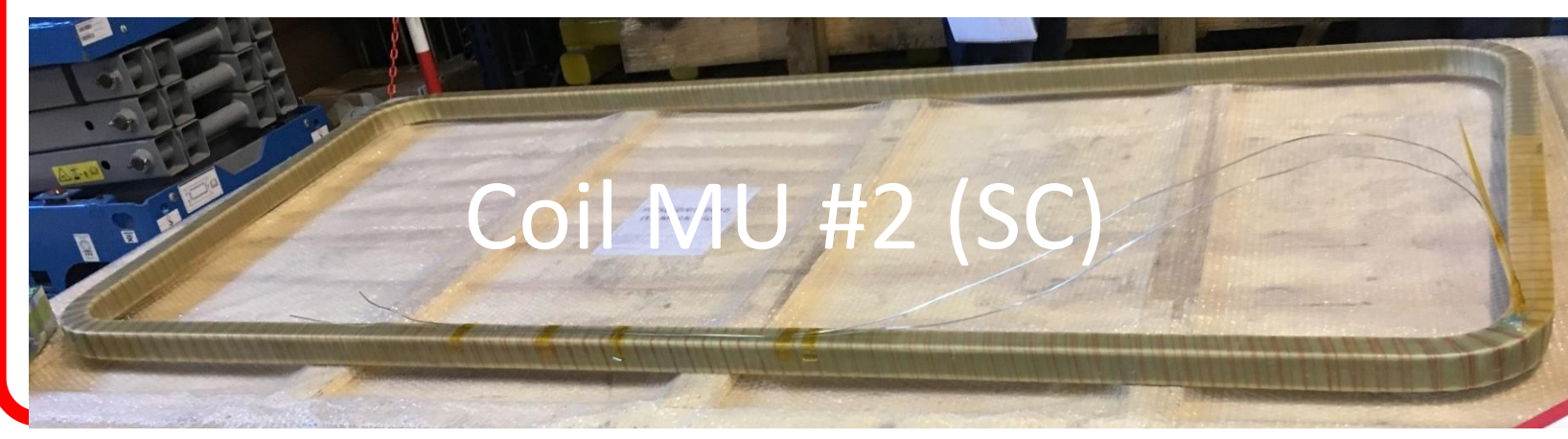
Coil MU #1 (Cu)

Improvement of winding system and winding procedure (pre-binder) were validated with 1m-racetrack coils.



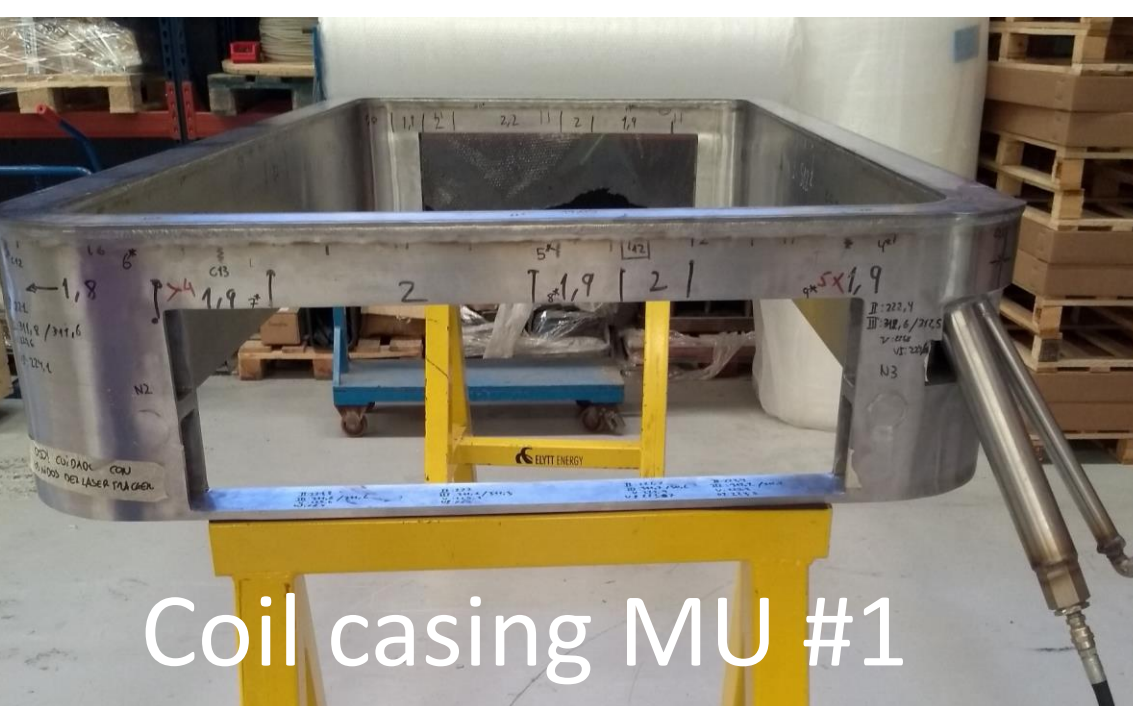
1m-racetrack coils

Successful scale-1 impregnated SC coil



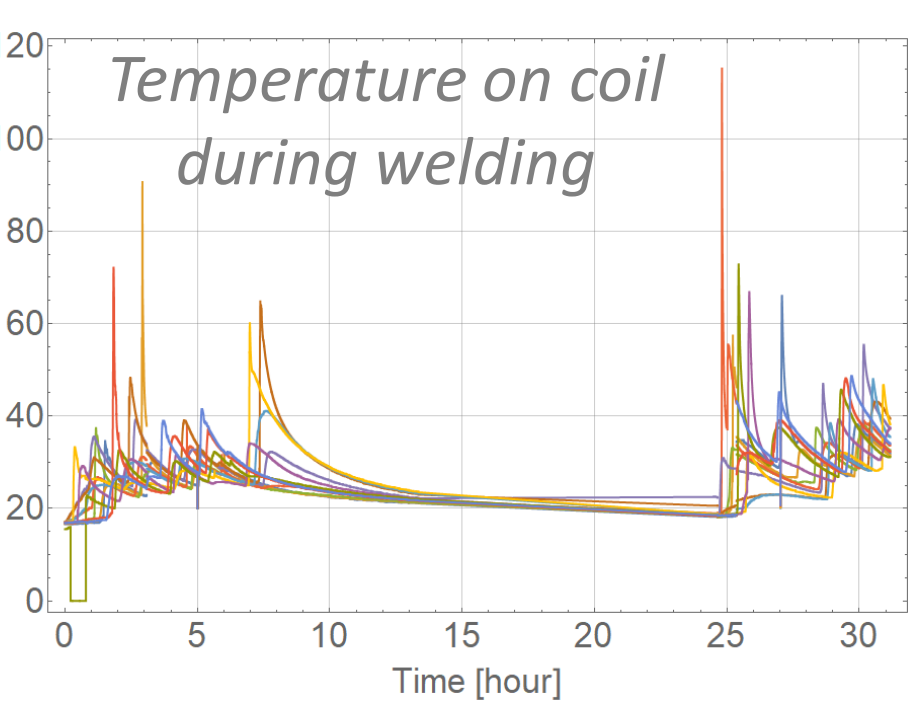
Coil MU #2 (SC)

## Coil casing mock-ups

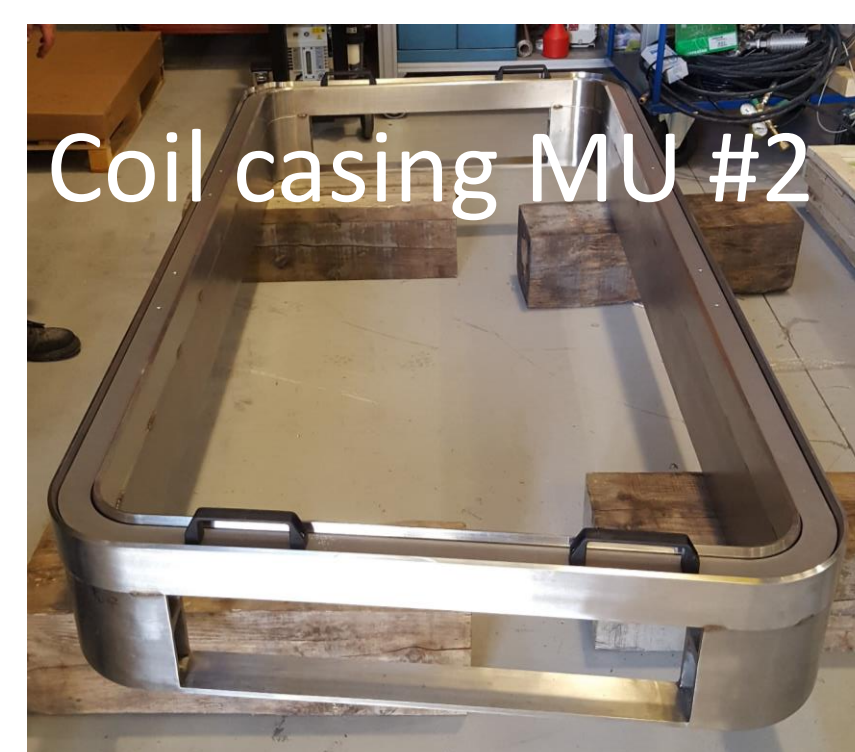


Coil casing MU #1

A first half stainless steel coil-casing (MU #1) was manufactured by Elytt's subcontractor but the welds (X-ray NDT) and dimensional tolerances (laser tracker) were not good enough (specifications). Therefore MU #1 became a practice casing so that Elytt could develop the coil shimming, the closure weld and the Factory Acceptance Tests (FAT) procedures.



A second half coil-casing was then successfully manufactured by Elytt's subcontractor which is currently being assembled with the coil MU #2. Like the 1<sup>st</sup> MU, the 2<sup>nd</sup> MU coil is instrumented with thermocouples to monitor the temperature on the coil during the closing weld process.



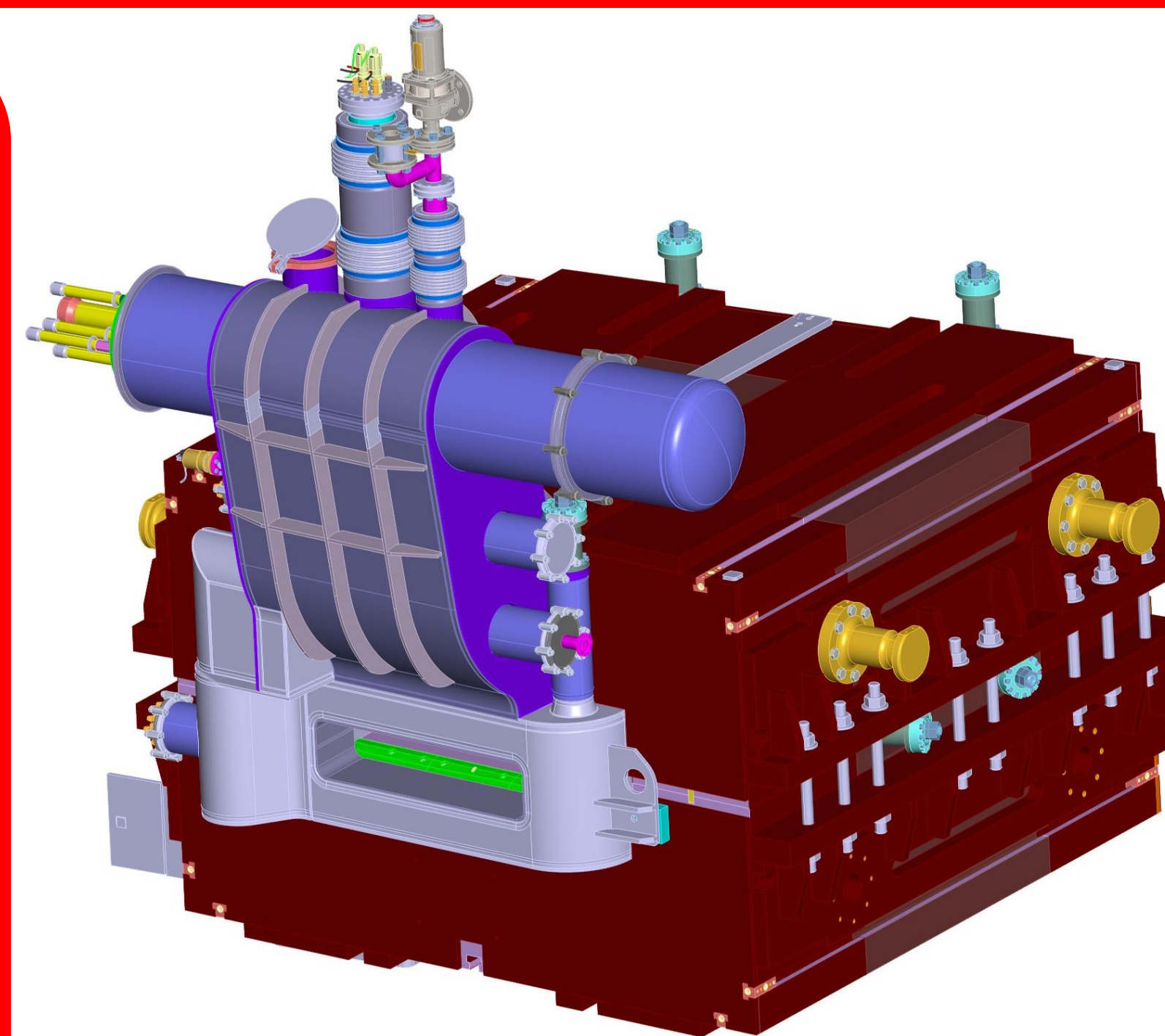
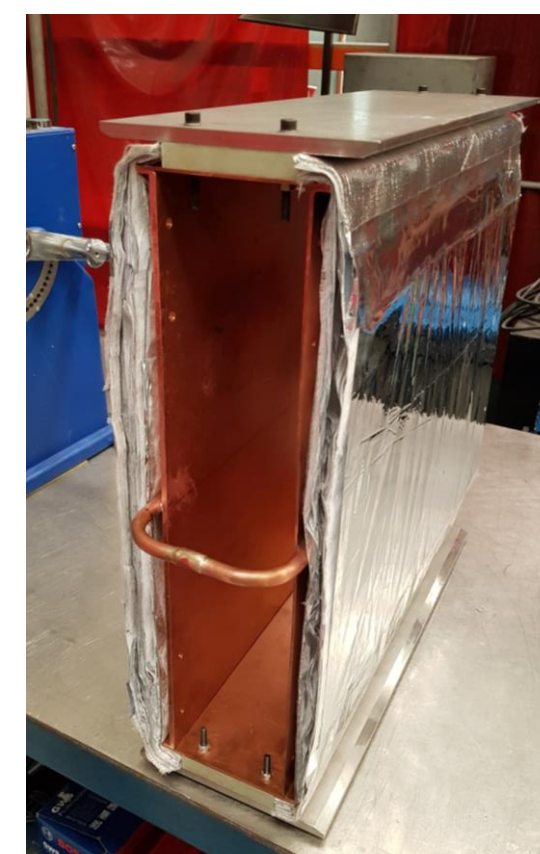
Coil casing MU #2

## Cryostat mock-up



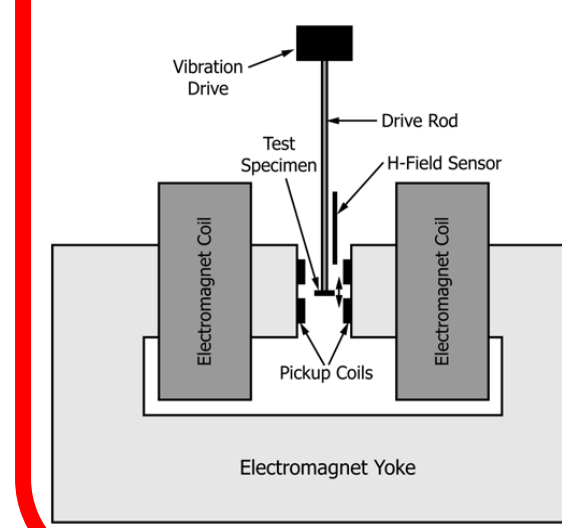
A 0.5x0.5 m<sup>2</sup> cryostat MU is being developed by Elytt to validate its manufacturing procedures. This MU is a small scale assembly of a thermal shield with its cooling pipes, the 30 layers of MLI and the vacuum vessel.

This mock-up will allow the check the thermal shield panel assembly, the routing of the thermal shield cooling pipe, its brazing procedure, the MLI integration and the vacuum vessel welding in the presence of MLI.



## Permeability meas.

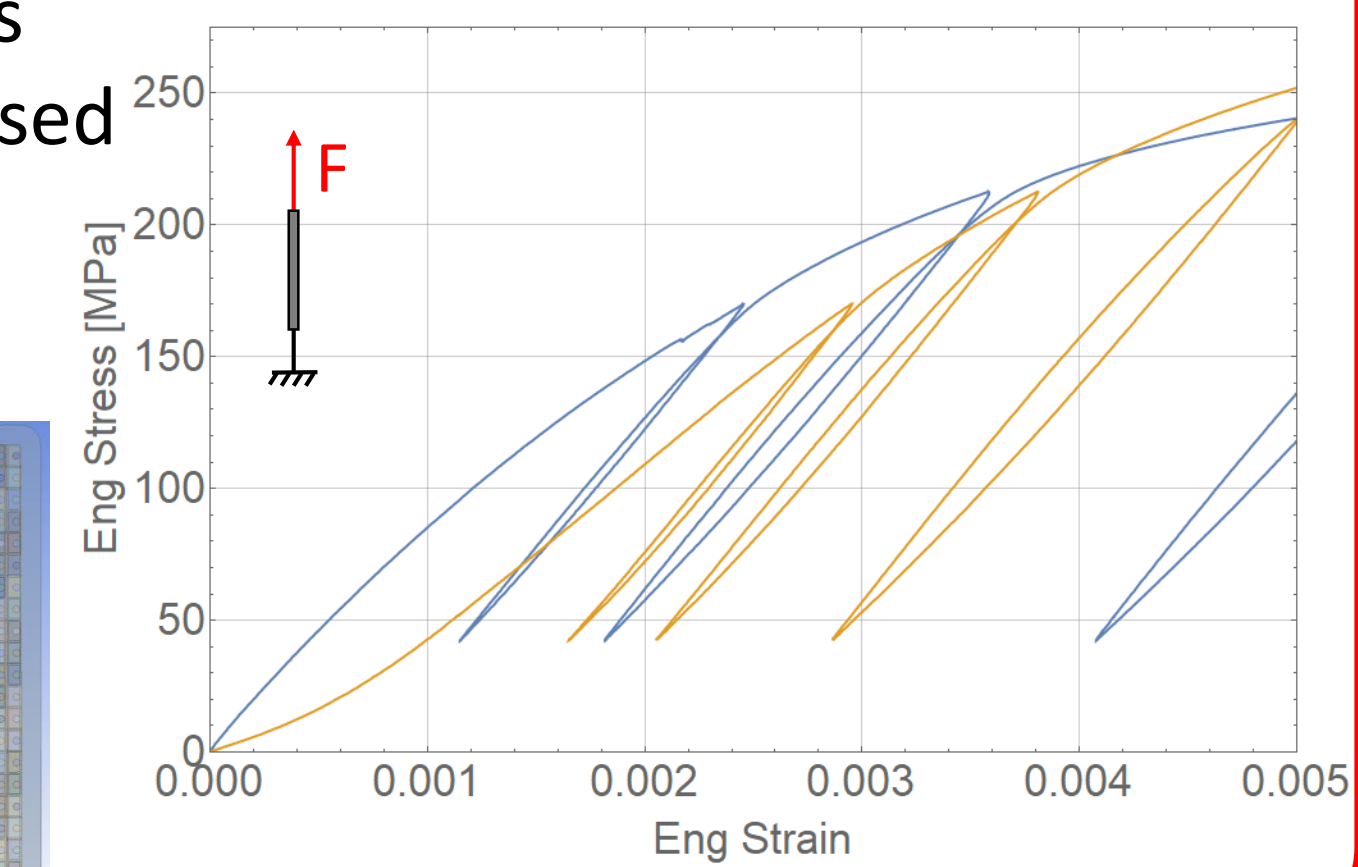
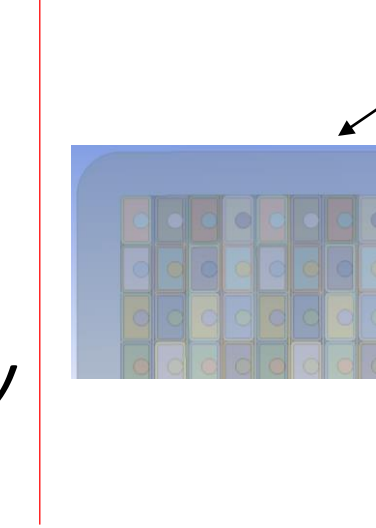
Permeability of welds on welded stainless steel samples has been measured at the University of Bilbao. Samples were measured with a Ferromaster 2018-12 device meas = 1.005 relative permeability



ASTM A342 / A342  
Method 5 - Vibrating  
Sample Magnetometry

## Mechanical meas.

Tensile properties of the NbTi wire-in-conduit conductor have been experimentally evaluated at CEA Paris-Saclay to validate the parameters used in the homogenised model of the coil mech properties.

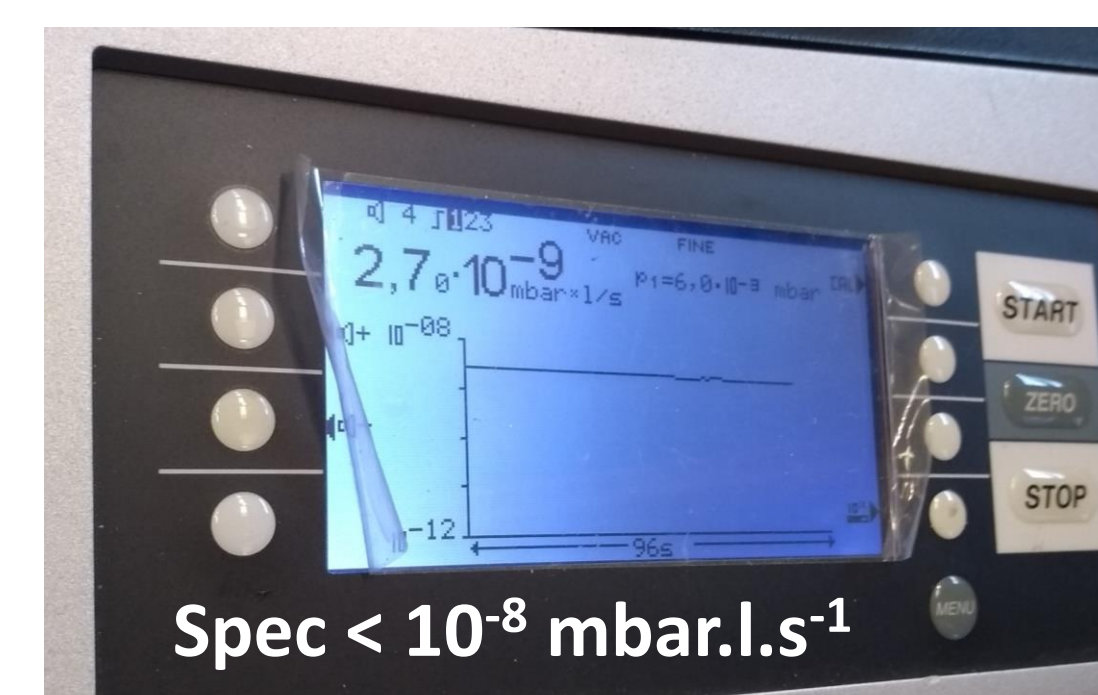


## Factory Acceptance Tests

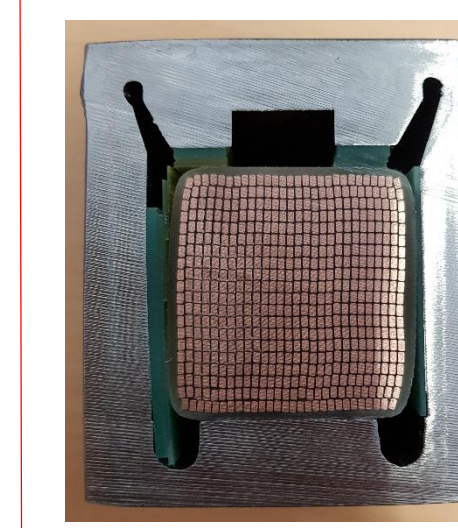
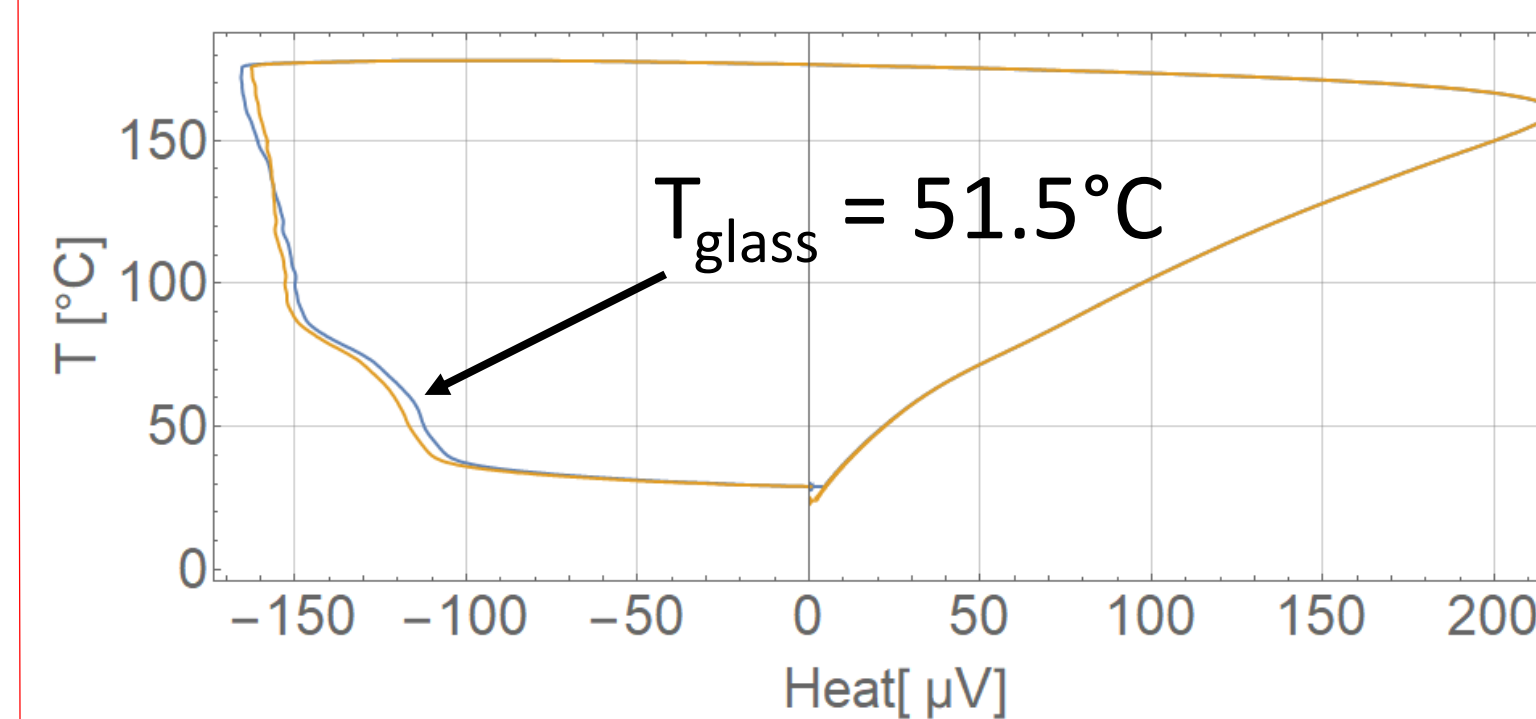
**Mechanical measurements:** Elytt invested in a laser tracker instrument which was used to check the coil and coil casing MUs.



**Leak tests:** Leak tests of MU #1 were performed before and after the 28.6 bar(a) pressure test. In both cases the leak rate was within the spec.



**VP Impregnation:** Cured resin samples were tested at CEA Paris-Saclay with a Differential Scanning Calorimeter (DSC) to check the quality and repeatability of the curing process by comparing for example the glass transition temperatures.

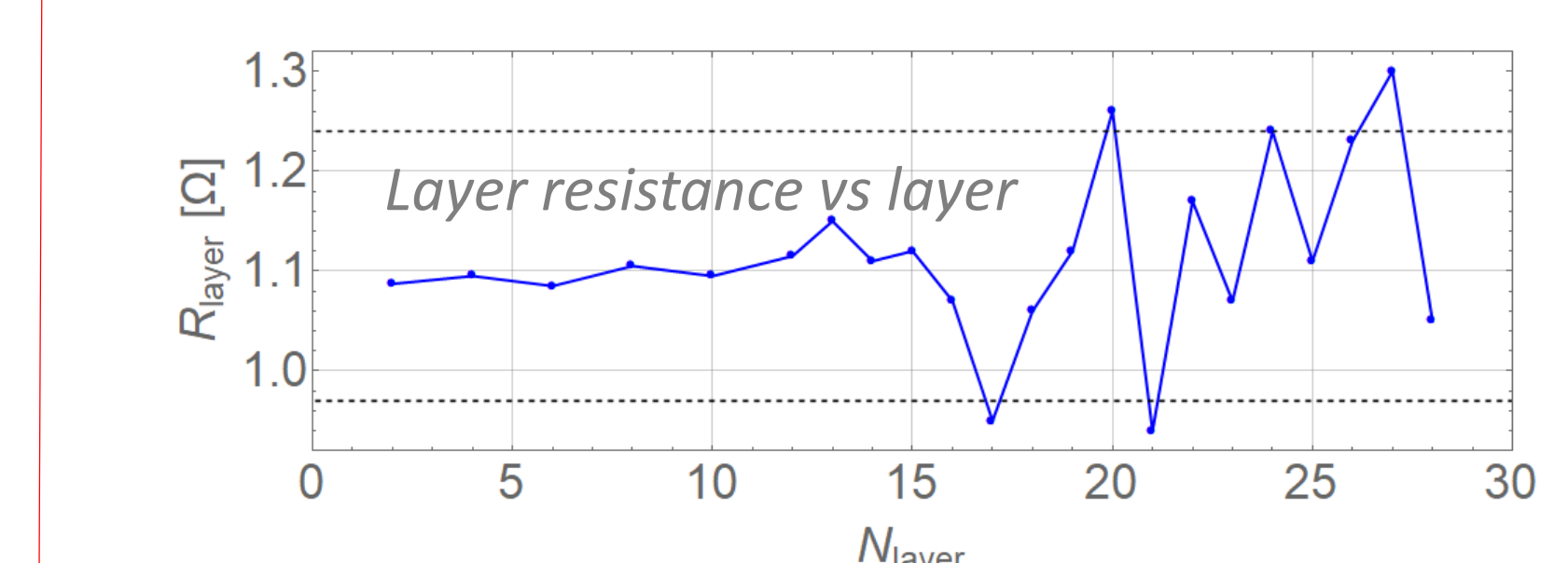


Some of the coils were cut to visually inspect the winding and impregnation quality over the cross section.

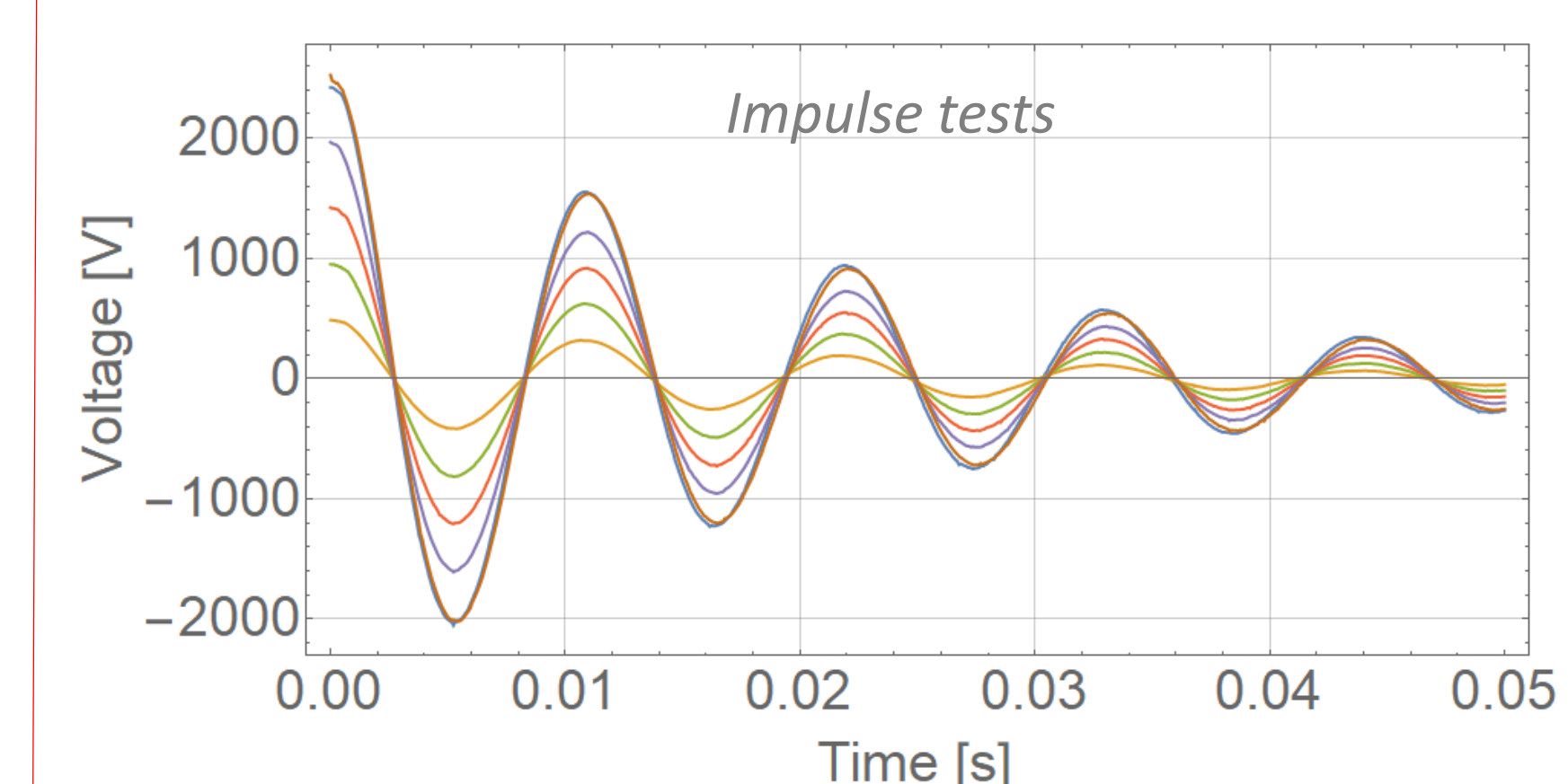
**Pressure test:** Coil casing MU#1 has been tested to a pressure of 28.6 bar(a) according to the European Pressure Equipment Directive.



**Resistance and LCR meas.:** For quality monitoring during winding, layer by layer resistances and LCR meter measurements were taken.



**Impulse tests:** Coil MU #2 has been tested up to 2.5 kV both through impulse and ground insulation tests.



**Ground insulation tests:** Coil MU #2 ground insulation has been tested wrapped in soaked cloth. R=171 GΩ @ U=2.5 kV (spec: 2.5 GΩ)

**Next steps** - Elytt has developed several mock-ups to validate its manufacturing procedures (2 scale-1 coils and half coil casings, 1 small scale cryostat). Many tests and measurements were carried out to check the material properties of the mock-up samples. There are still few measurements to be carried out yet: conductor splices, mechanical characterization of impregnated coil sample (homogenised coil model validation).