Design and Fabrication of a Cryostat for Low Temperature Mechanical Testing for the Mechanical and Material's Engineering Group at CERN

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CERN

ENGINEERING DEPARTMENT

Universidad Carlos III de Madrid

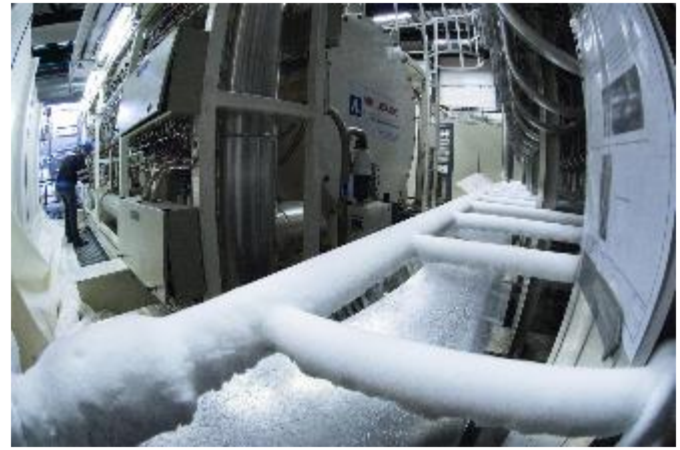
Outline

- Introduction
- Concept and Design
- Validation and Results
- Conclusion

Introduction

Introduction

Superconducting magnets



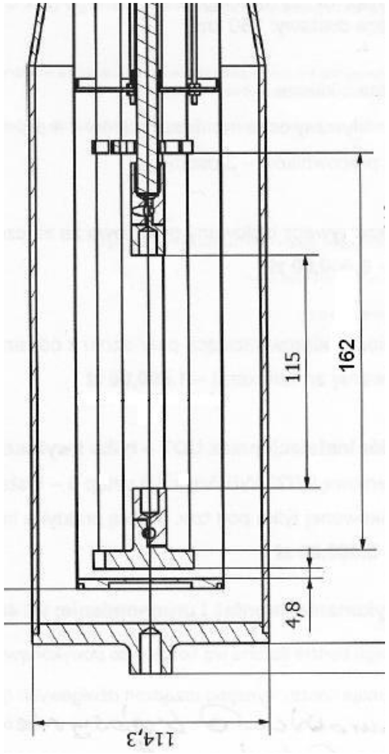
Ancillary equipment for particle detectors

Superconducting RF cavities

Cryogenic supply system

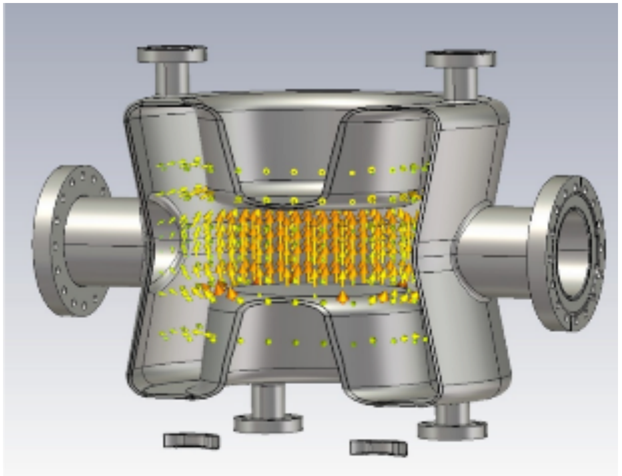
Introduction

- Mechanical characterization of materials at low temperatures has always been of paramount importance at CERN
- Four 18 kN cryogenic tensile systems have served for countless tests with sub-size samples

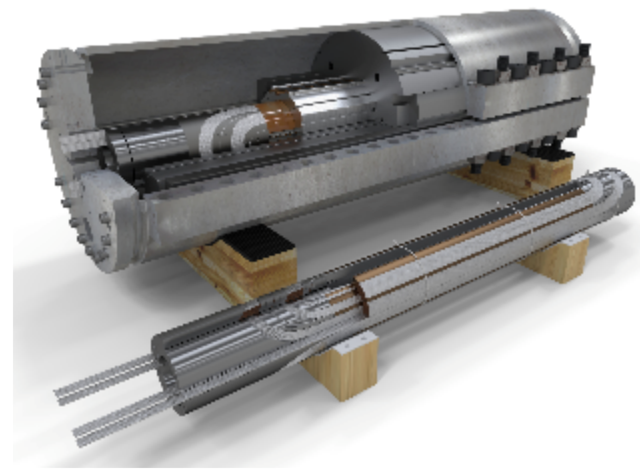


Introduction

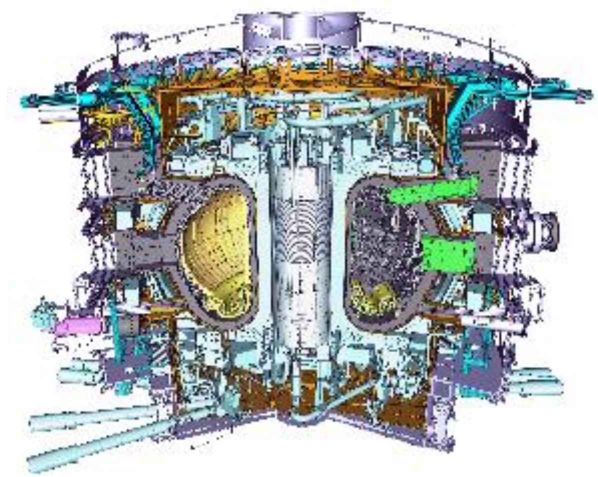
- Increasing demand of mechanical characterization at cryogenic temperatures



Crab cavities (HL-LHC)



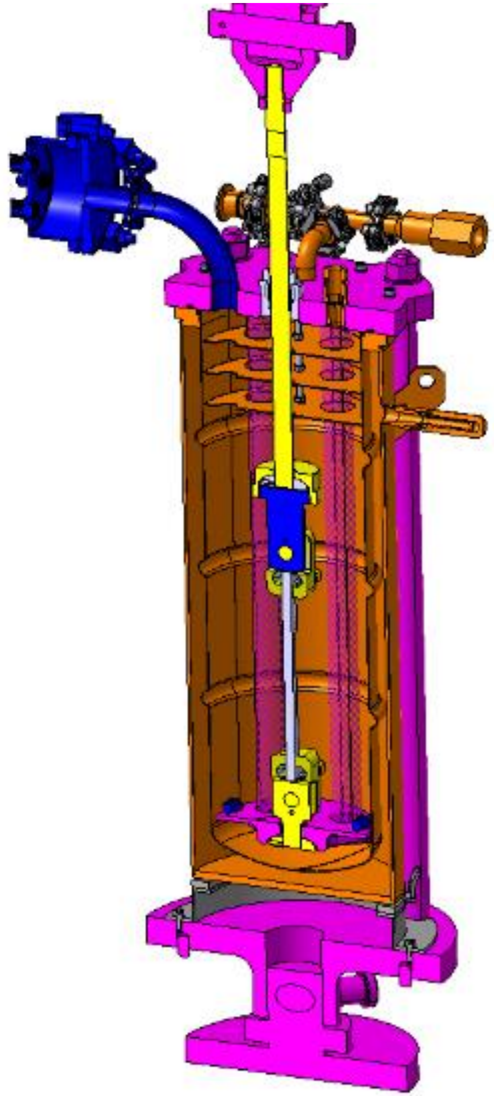
11 T project



ITER tokamak

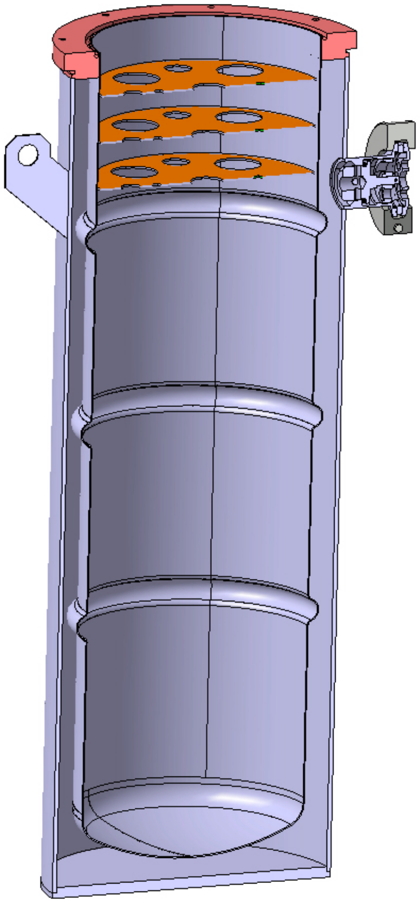
Concept & Design

Concept & Design



- Orange: Thermal components
- Pink: Structural components
- Yellow: Load train
- Blue: Instrumentation

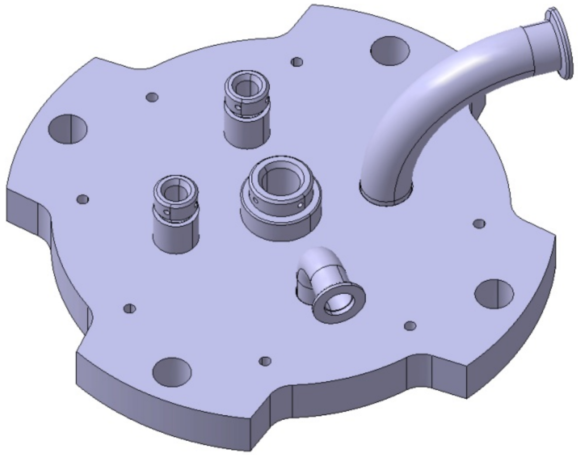
Thermal components



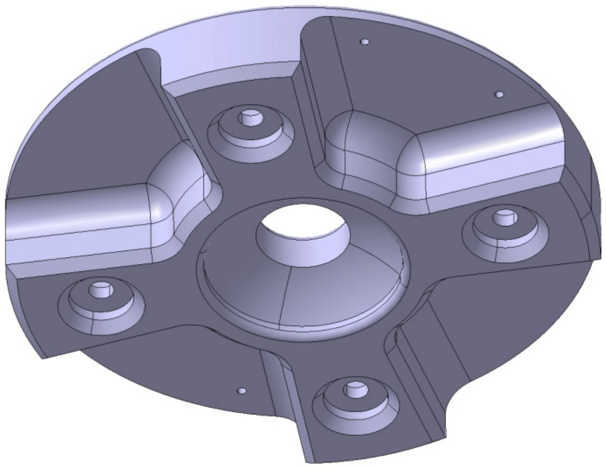
- Dewar:
  - 0.8 mm inner wall thickness
  - Double walled vessel
  - 20 – 25 minutes of filling
  - ~ 20 liters / test consumption

- Thermal screens:
  - 3 ETP copper thermal screens
  - 1.5 mm thickness each

Structural components

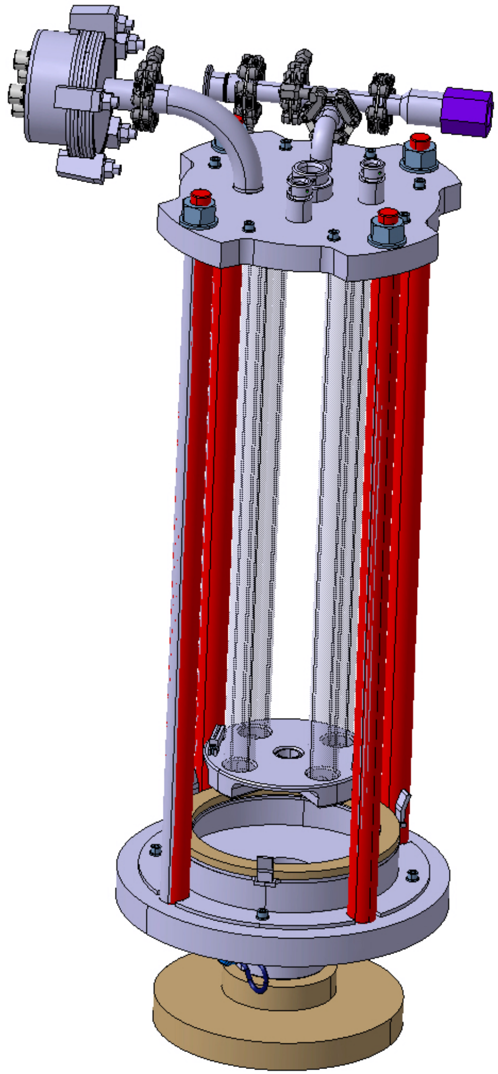


- Top flange:
  - AISI 316 LN (1.4429)
  - CERN technical specification
  - 27 mm thickness
  - Sliding rubber o-ring seal
  - 50 N/m torque for fixation



- Inner bottom plate:
  - Titanium base alloy (Ti6Al4V)
  - Design optimized to reduce mass without endangering mechanical stability
  - Hosts lower ball joint

Structural components

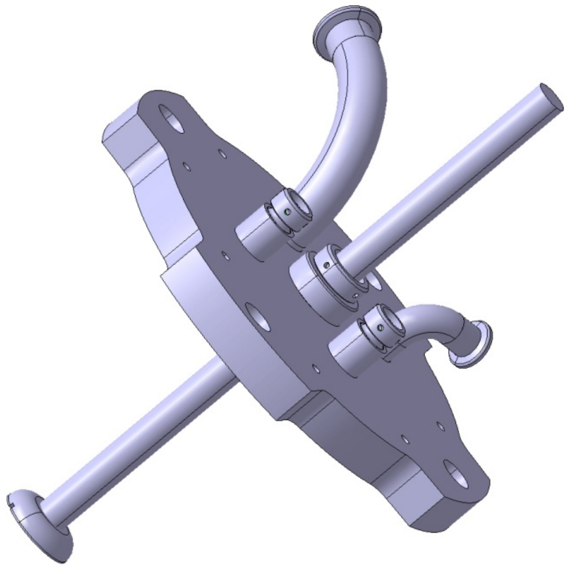


- Internal columns:
  - 4 column system
  - AISI 316 L (1.4404)
  - Hollow structure
  - 2.6 mm wall thickness, 30 mm outer diameter
  - Welded ring for perpendicularity

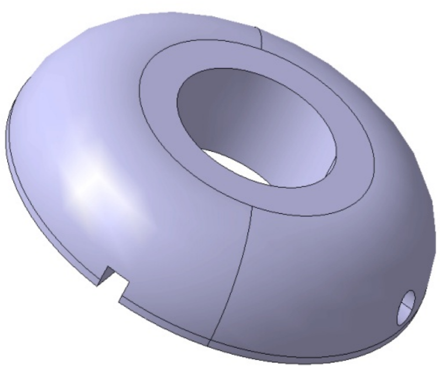
- Outer rods:
  - 36NiCrMo16 (1.6773)
  - Bulk 28 mm diameter
  - Length accuracy to guarantee parallelism

- Bottom flange:
  - EN S355J0 steel (1.0553)
  - Generic pin connection to UTS

Load train

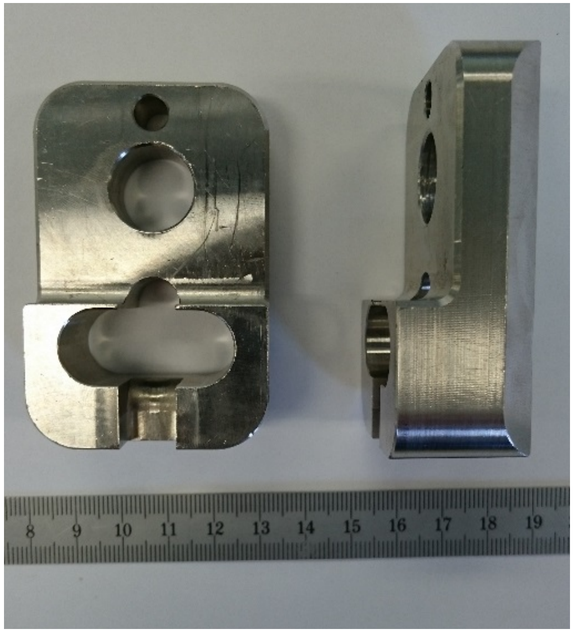


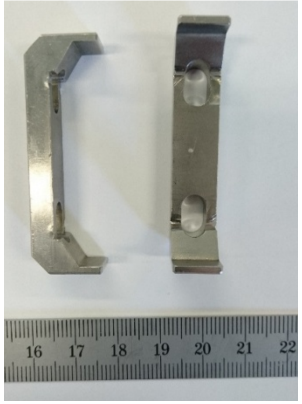
- Pulling rod:
  - Grade 5 titanium (Ti6Al4V)
  - Connected to upper ball joint
  - Connected to top UTS adapter
  - Ra < 1.6 µm



- Ball joints:
  - To correct misalignments
  - Reduce bending between two ball joints
  - Ball joint and its counterpart are identical

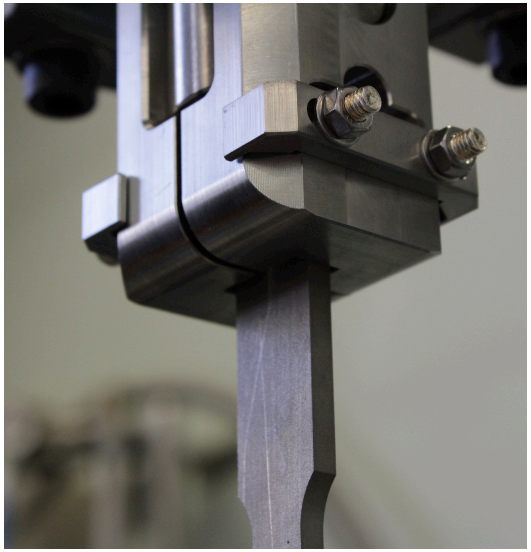
Load train

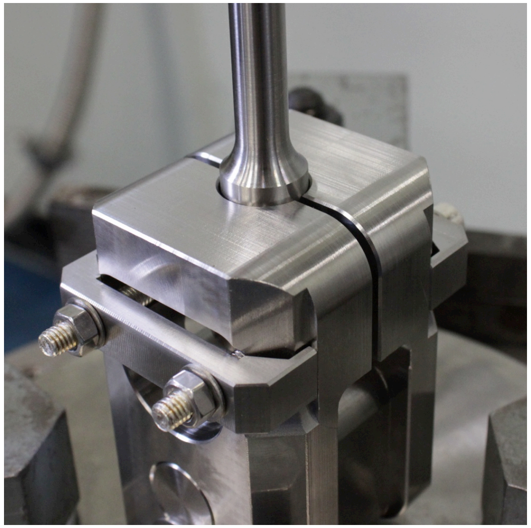




- Sample holders:
  - AISI 316 L (1.4404)
  - Two identical halves
  - Pin connection, allows for rotation
  - Connected to lower ball joint coupler
  - Adapters for different thicknesses
  - Collars to avoid separation

Load train





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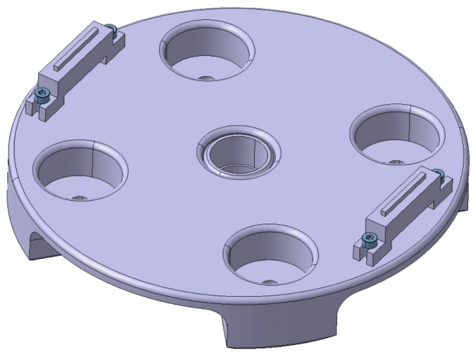
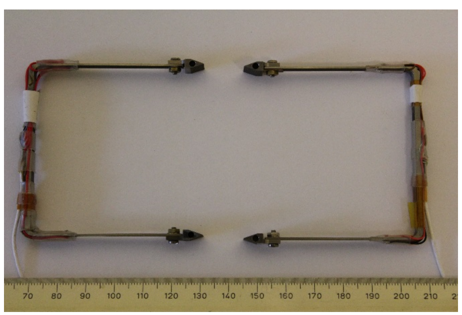
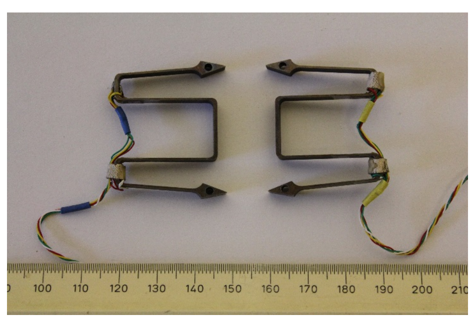
Instrumentation



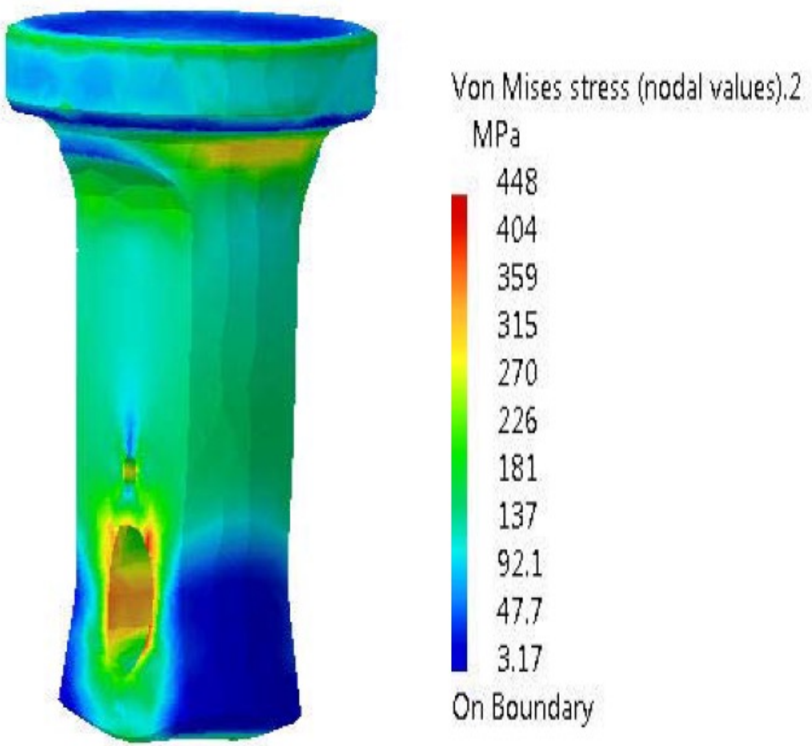




- Connectors:
  - Four sets of 3M® connectors
  - One for load cell and one for extensometers
  - 2 additional available of 12 pins each
  - Instrumentation feedthrough via 4 Fischer® connections
  - Optical connections for a wide variety of sensor attachments

- Extensometers:
  - Strain gages mounted to bending beam element
  - Two types: C-shape and W-shape
  - Calibrated by the supplier and in-house

Instrumentation

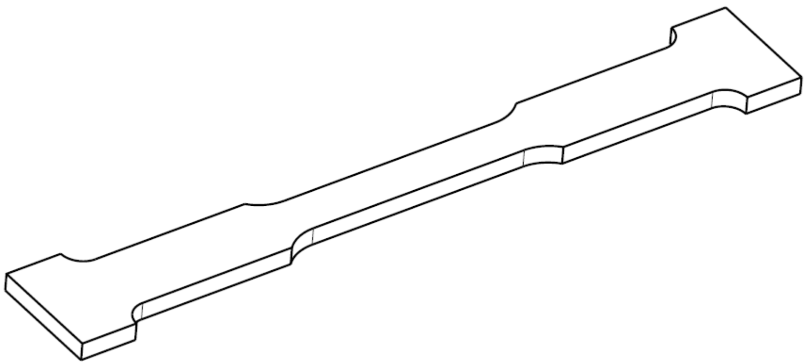


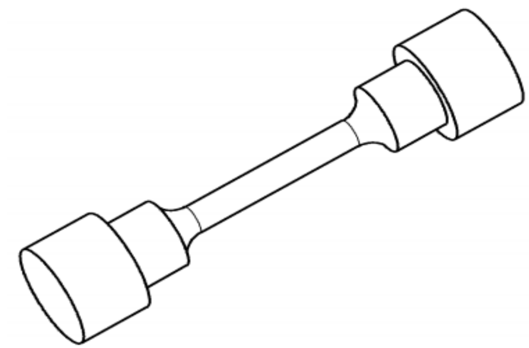
- Internal load cell:
  - Adjacent to the specimen
  - Ti5Al2.5Sn
  - Wheatstone full bridge configuration
  - FEA to validate conditions
  - Calibration up to 80 kN
  - Class 1 following ISO 6892

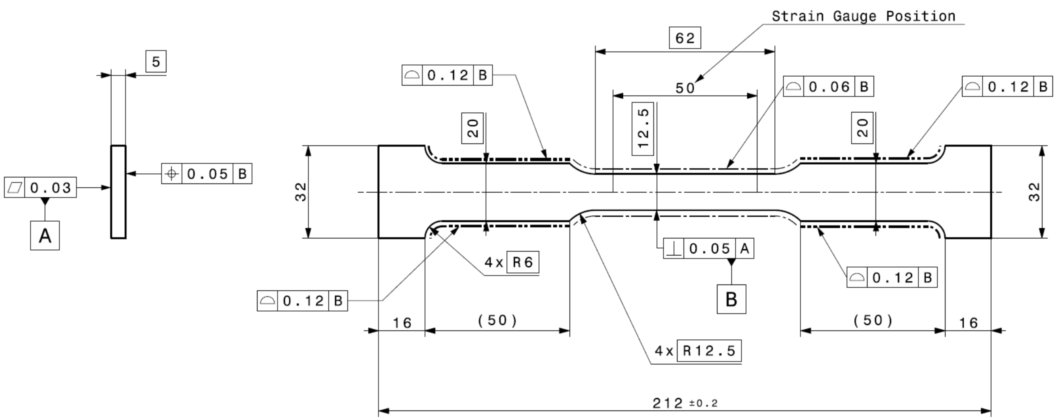
Results and Validation

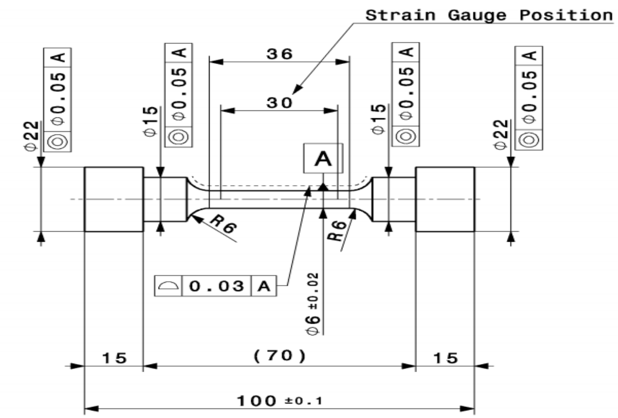
Tensile specimens

Flat and buttonhead specimens are fabricated according to ASTM E1450 and ISO 6892

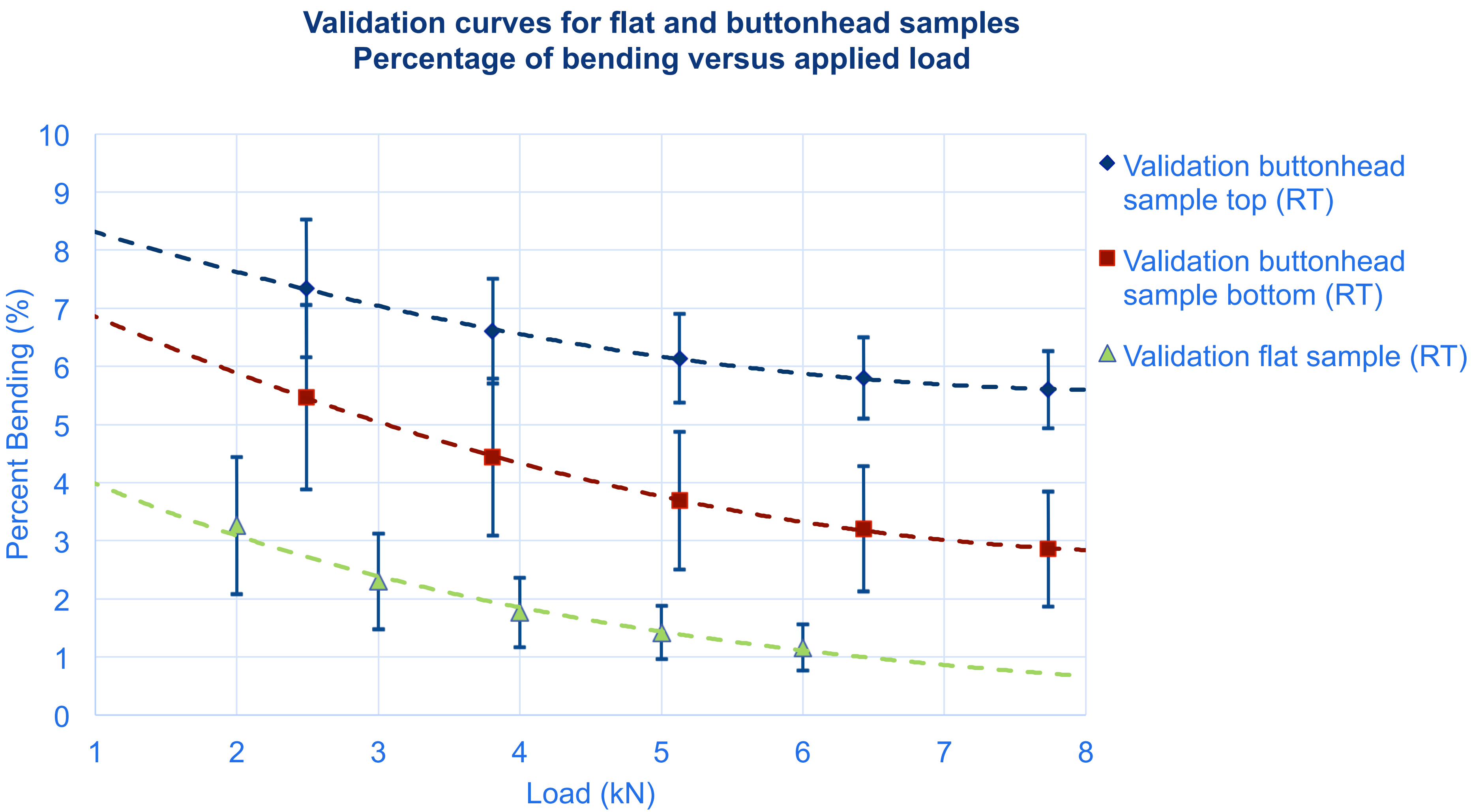








Validation for flat and buttonhead samples

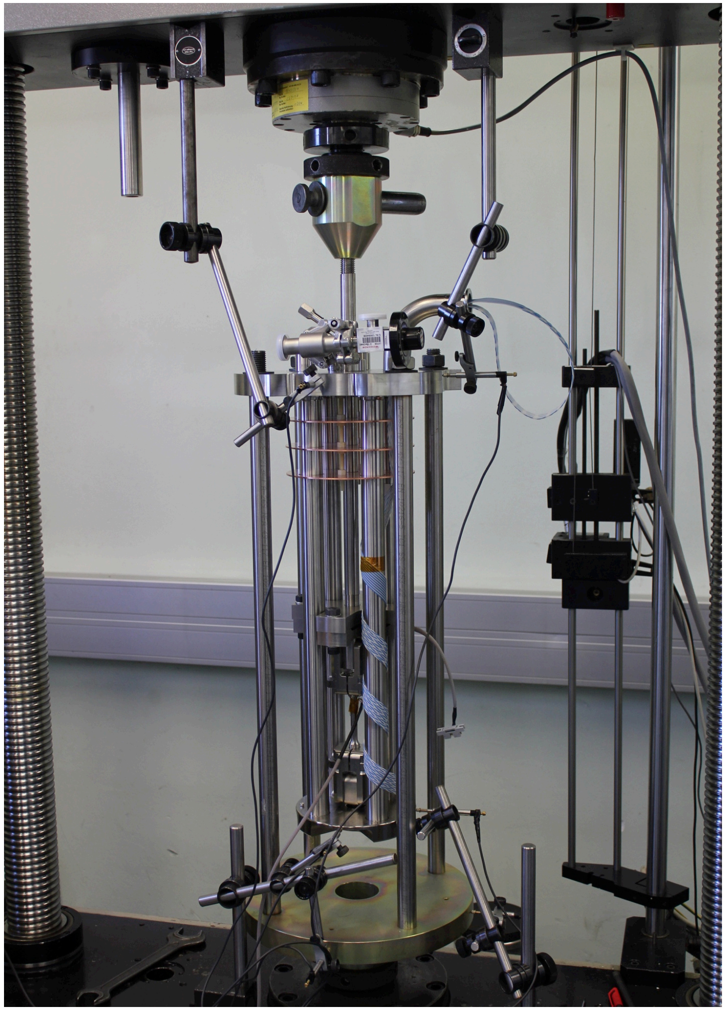


First results

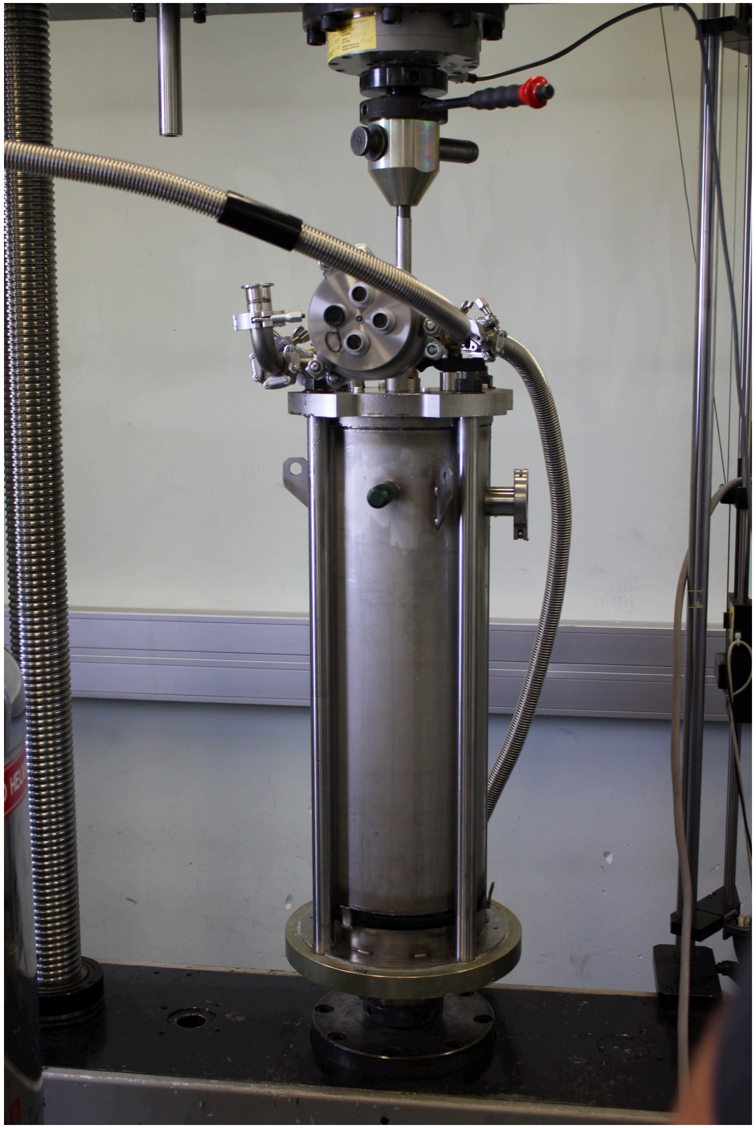
- Preliminary results for selected uniaxial tensile tests at 4 K

Material	Rp0.2 (MPa)	UTS (MPa)	A (%)
OFE - copper	418	522	47
INERMET®180	Failure in the elastic region	1048	0.37

Results



Setup for very first validation test,
Inner structure exposed



Current cryogenic tensile system,
installed for 4 K measurements

Conclusion

- A 100 kN cryogenic mechanical testing system has been designed, fabricated and commissioned to perform uniaxial tensile tests at temperatures ranging from 300 K down to 4 K.
- The developed system is able to test different standard size specimens, which gives the opportunity to assess material properties of flat and round products at cryogenic temperatures.
- All the different solutions which have been implemented have been comprehensively analysed, presented and discussed in detail, including geometries, tolerances and materials.
- The instrumentation of the device, which is a key aspect of the design, has been successfully calibrated and installed. The sensors and connectors which are chosen are thoroughly described and discussed.
- An exhaustive validation of the cryostat has been carried out according to the international standards in play. The deviation from uniaxial stress is confined to less than 10 %, even when extrapolating at low loads.
- Preliminary results at 4 K for a few selected materials are shown. The results obtained are consistent to what it can be found in literature for these materials in a similar temper state.

Thank you for your attention