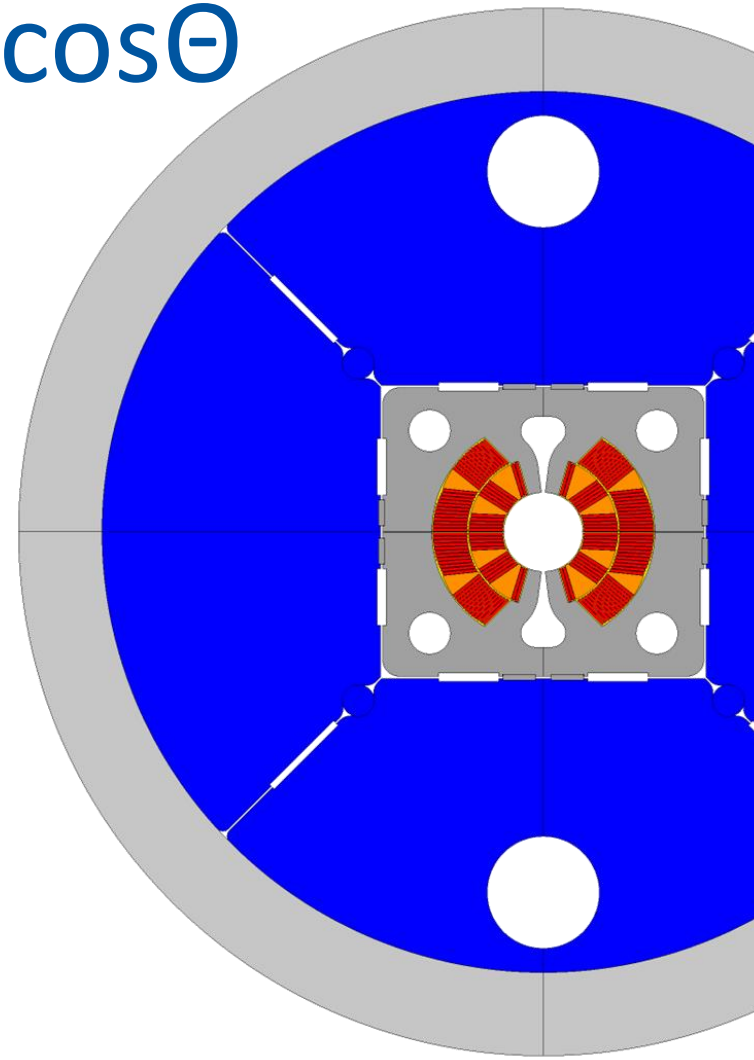
HFM annual meeting 2023

Nb_3Sn single aperture cosΘ bladder & keys 12 T FALCON D dipole model ¶

Authors: Stefania Farinon, Massimo Sorbi, N.Sala, R.Valente
on behalf on the INFN collaboration

Date: November 1st, 2023

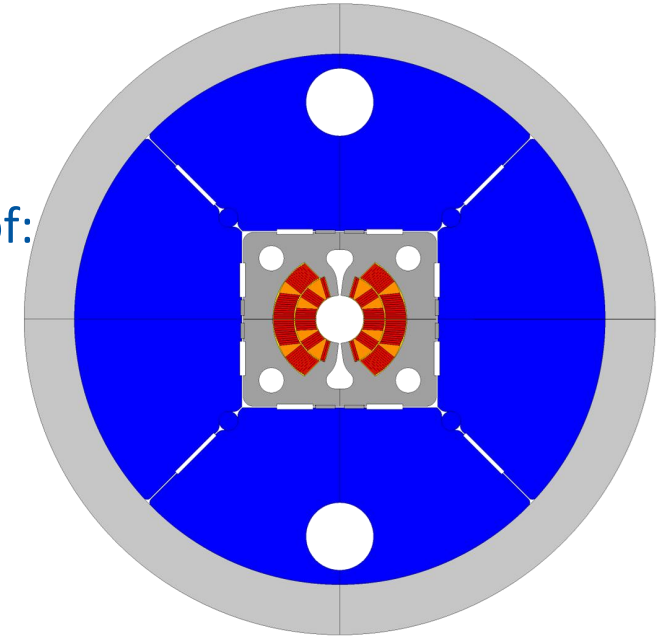


FalconD 12 T dipole

- This program is being developed in accordance with the CERN/INFN KE 4102 agreement.
- A recent amendment was issued to revise the project's scope and schedule.
- The project involves the development and construction of a short model Nb_3Sn dipole with the following specifications:
  - Single aperture with an inner bore of 50 mm.
  - 2-layer cos-theta coil, providing a bore field of 12 T at 1.9 K.
  - Mechanical assembly using bladder & key technology.
  - The total coil length is 1.5 m.

FalconD 12 T dipole

- The FalconD project includes the following activities:
  - At ASG-Superconductors, the manufacturing of:
    - 1 dummy pole wound with copper cable
    - 2 practice poles wound with Nb_3Sn cable
    - 3 + 2 poles wound with Nb_3Sn cable for the single aperture dipole
  - At INFN-LASA Lab, the assembly and testing @ 4.2 K of the FalconD magnet



CERN supplies the magnet **components**, including the cable, spacers, and other necessary items)

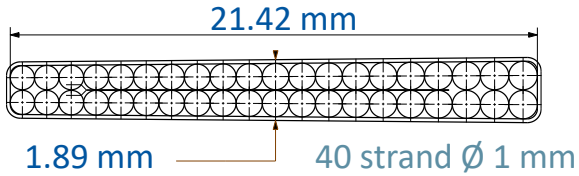
ASG Superconductors is responsible for manufacturing the **coils**, which include 7 Nb_3Sn coils and 1 dummy copper coil.

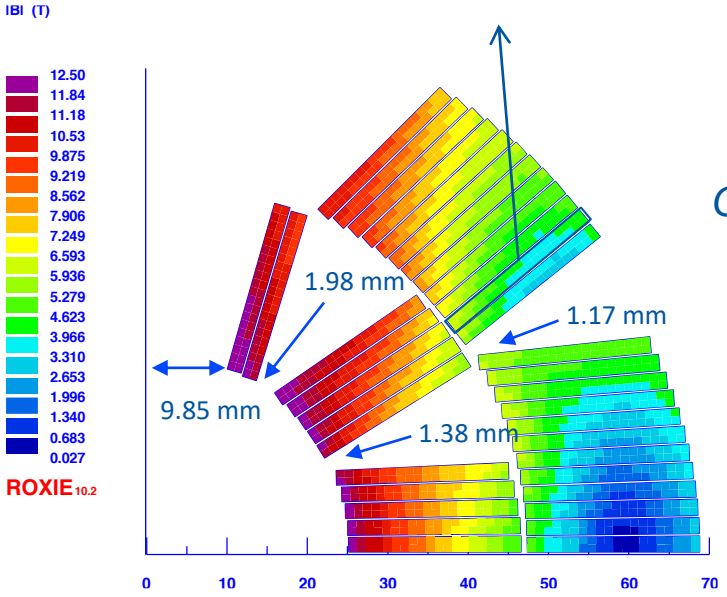
INFN is responsible of the magnet design, **assembly**, and preliminary **test** @ 4.2 K at LASA laboratory in Milan.

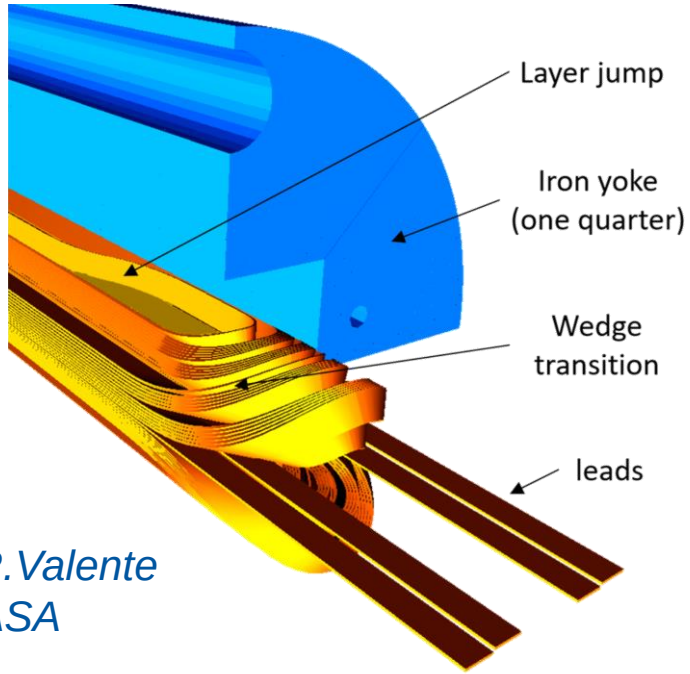
Electromagnetic design

- The electromagnetic design is completed, both in 2D and 3D

Reacted cable
Width +2%
Mid-thick +4.5%







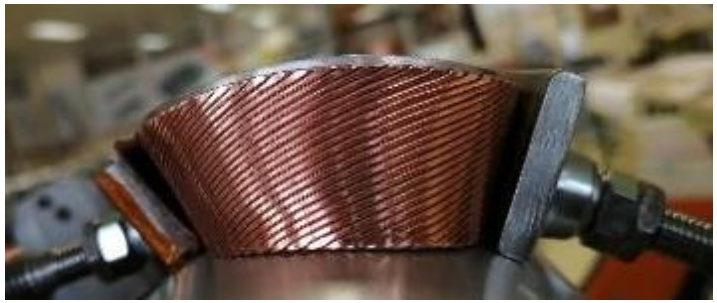
Courtesy of R.Valente
INFN-LASA

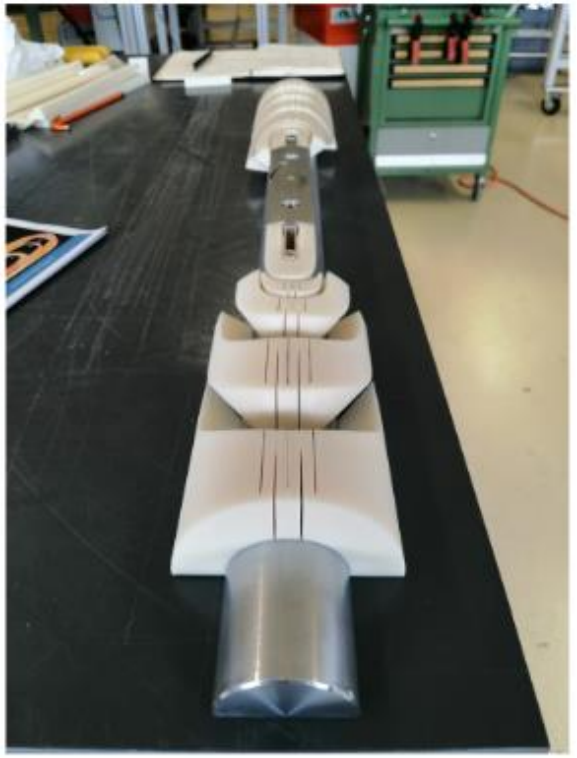
Bore Field	Operating Current	Margin on Loadline @ 1.9 K
12 T	20180 A	24.4%
*13.5 T	23000 A	15%

*intended as mechanical limit

Winding test @ CERN

- 3 winding test campaigns were conducted at CERN. These tests were instrumental in optimizing the cabling parameters and refining the design of the end spacers.

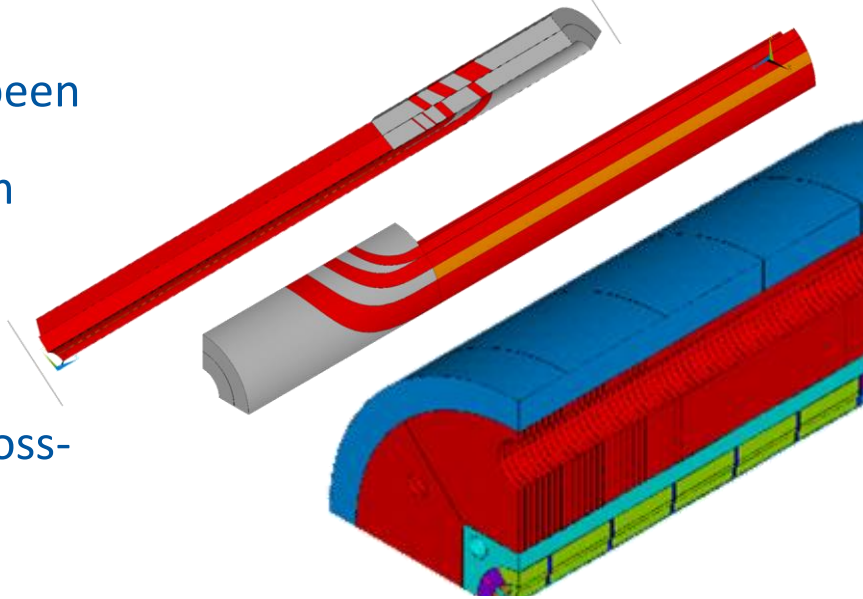




Test performed at CERN building 927

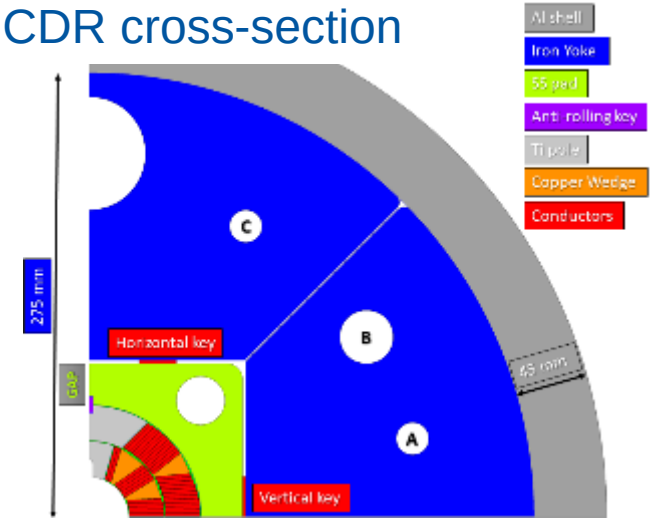
Mechanical design

- The 2D mechanical structure design has been recently revised to incorporate the most current material properties obtained from CERN measurements, and it has been re-optimized accordingly.
- Efforts are underway to update the 3D mechanical design which will include the integration of the newly optimized 2D cross-section.

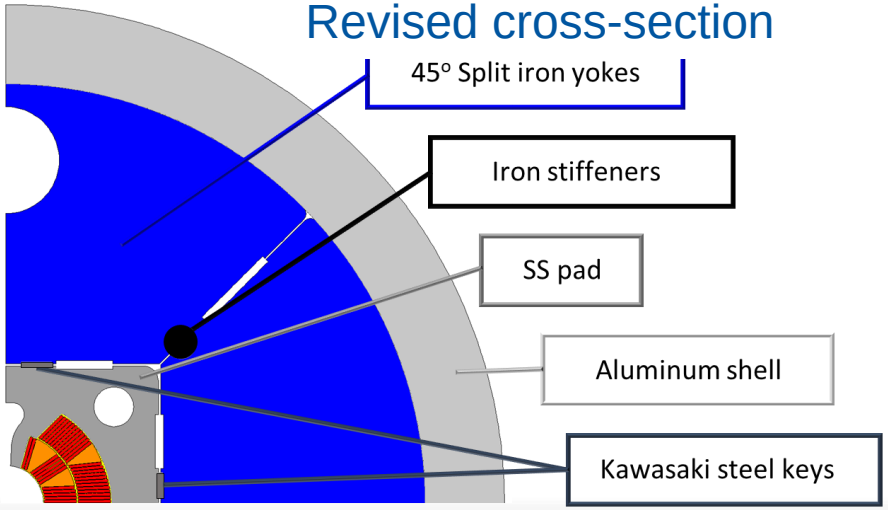


Courtesy of N.Sala
INFN Genova

CDR cross-section

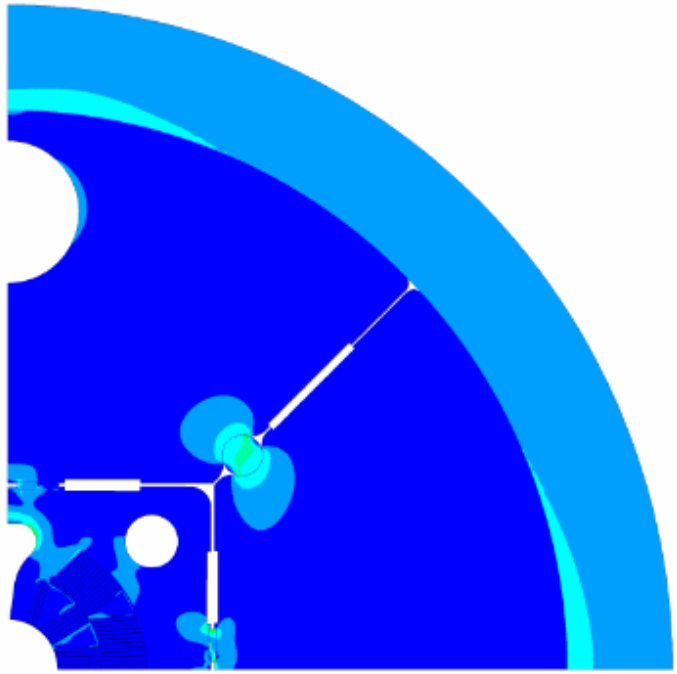


Revised cross-section

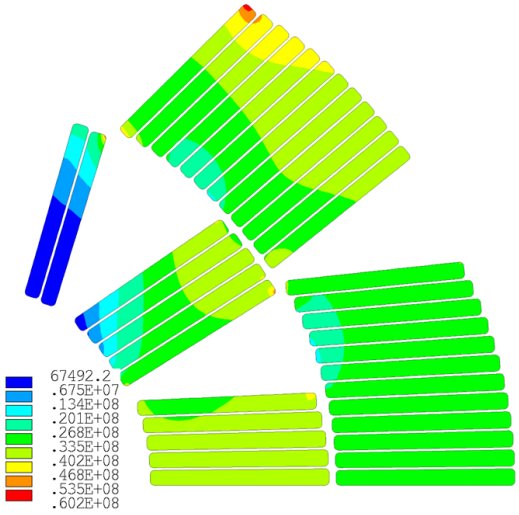


Mechanical structure

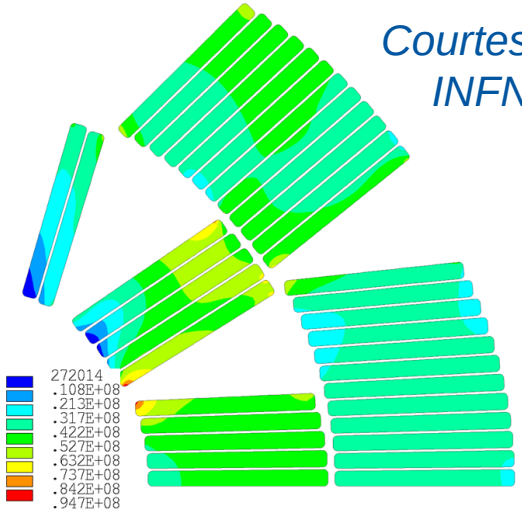
- The mechanical structure is designed to protect coils:
  - soft to assemble @ RT (absorb overstress @ RT)
  - hard to deform @ 1.9 K (lower stress in coils @ 1.9 K)



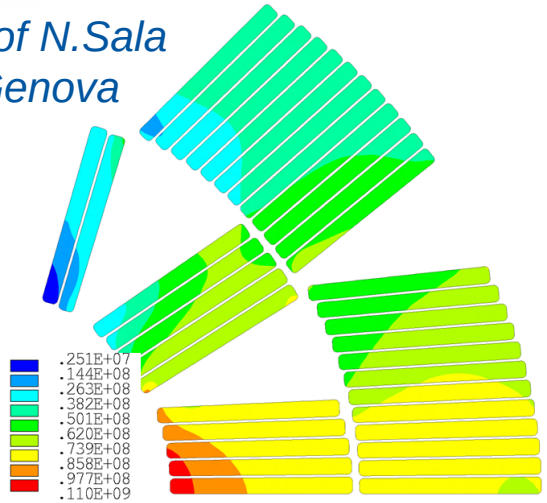
Courtesy of N.Sala INFN Genova



$\sigma_{eqv,max} = 60\ MPa$



$\sigma_{eqv,max} = 94.7\ MPa$

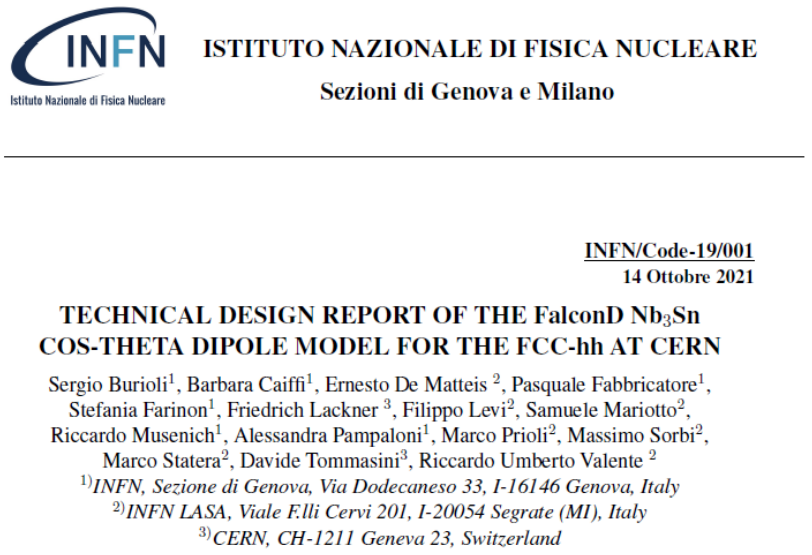


$\sigma_{eqv,max} = 110\ MPa$

Design status

The Technical Design Report (2021) has been reviewed at CERN by a panel of experts in 2022

- Electromagnetic design completed
  2D and 3D model
- Quench protection analysis done
  energy extraction system
- Mechanical design concept finalized, ready to be transferred to ASG for engineering
  3D model to be finalized with the help of ASG



INFN
Istituto Nazionale di Fisica Nucleare

ISTITUTO NAZIONALE DI FISICA NUCLEARE
Sezioni di Genova e Milano

INFN/Code-19/001
14 Ottobre 2021

TECHNICAL DESIGN REPORT OF THE FalconD Nb_3Sn COS-THETA DIPOLE MODEL FOR THE FCC-hh AT CERN

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FalconD deliverables

HFM Programme schedule

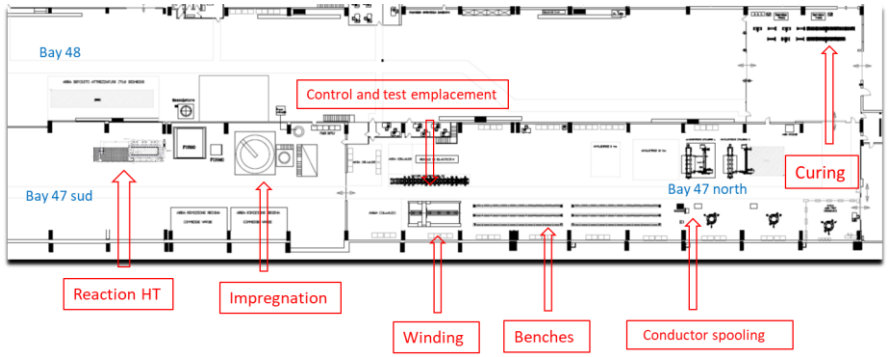
Programme Leader: A. Siemko

Progress on : 20.09.2023

Tasks, deliverables	TASK/DELIVERABLE DESCRIPTION	Assigned	PLAN START	PLAN END	CERN monetary contribution (kEUR)	Progress	Status	Comment on status
D1.2	Final desing review		01/09/2018	01/04/2023	150			
D1.3	Confirmation of the schedule		01/09/2018	01/06/2023	0	100%	Completed	
D1.4	Heat treatment and vacuum pressure impregnation tool ready		01/09/2018	01/09/2023	100	60%	In progress	HT furnace installed and ready, vacuum impregnation tool in procurement (ASG placed the order for the tooling (winding, curing, etc.) in May, the mandrel delivery is planned for November 23)
D1.5	Approval of manufacturing drawings of cold mass components (CERN, INFN, Industry)		01/09/2018	01/11/2023	100	20%	In progress	Drawings of Cu wedges sent for production, drawings of the end spacers ready
D2.1	Magnet assembly Production Readiness Review		01/09/2018	01/12/2023	100	0%	Not started	
D2.2	Acceptance of the 3 magnet poles (one spare)		01/09/2018	01/12/2024	100	0%	Not started	
D2.3	Magnet assembled keys installed		01/09/2018	01/05/2025	100	0%	Not started	
D2.4	Magnet acceptance CERN, INFN		01/09/2018	01/06/2025	150	0%	Not started	
D2.5	Final report		01/09/2018	01/12/2025	100	0%	Not started	

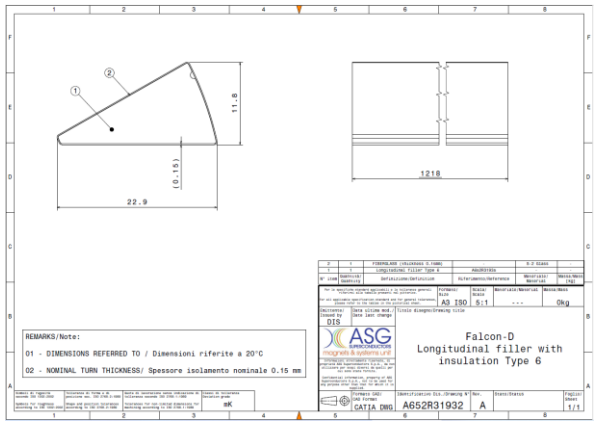
FalconD tooling status

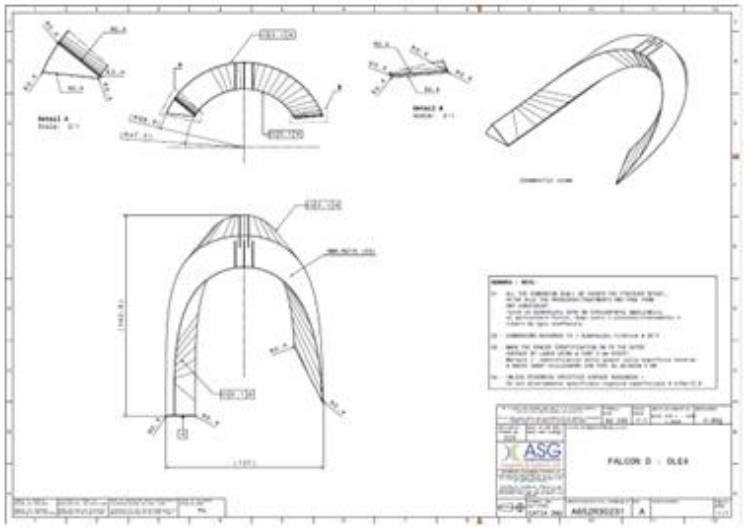
- The HT furnace has been procured by INFN and is now ready to be used.
- ASG has placed the order for the design and construction of all the necessary equipment required for coil production, (with the exception of the oven and winding machine, which are already available) to the Italian company Fantini SpA.
- The mandrel for the first winding trials is expected to be available in late autumn 2023.
- The fabrication area is ready for use.

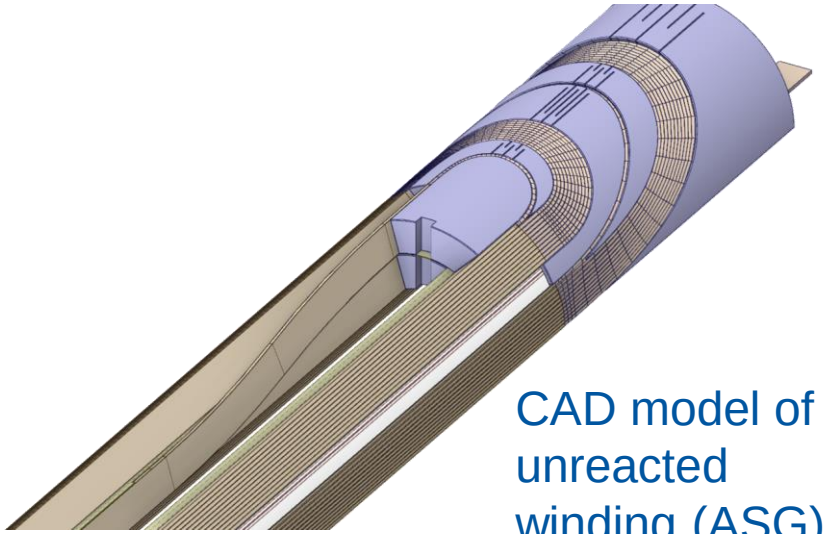


FalconD drawing status

- Drawings of Cu wedges sent to CERN for production on June 2023 (order of full production placed)
- Drawings of end spacers sent to CERN for production on Sept. 2023 (order of 1st set ready to be placed)
- It has been decided to wind the 1st (dummy) coil with the end spacers that have been optimized by INFN. The winding trial at ASG could potentially lead to a final refinement, which will then be incorporated into the first Nb_3Sn coil.





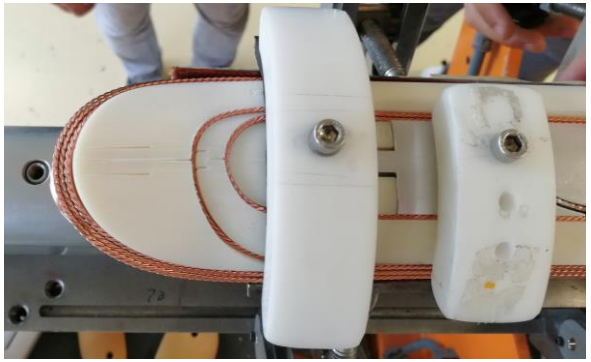


CAD model of unreacted winding (ASG)

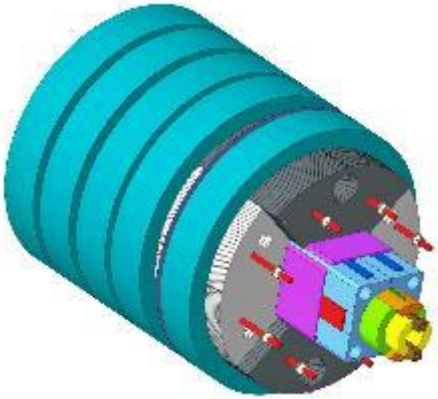
ASG schedule

- Equipment procurement
  - winding — Dec 23
  - curing — Mar 24
  - HT and impregnation — May 24
  - Handling — Dec 23
- Winding tests — Nov 23 to Jan 24
- 1st dummy coil — Feb 23 to June 24

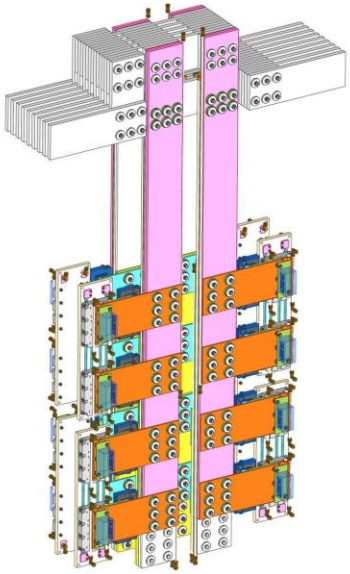
Next future Plans



Winding tests in the industry (December 2023)
Following the preliminary winding test at CERN



Mockup tests at INFN Genova (early 2024)
Mechanical model and material properties validation



30 kA power supply and lines to be completely renewed with fast IGBT switch at LASA laboratory

Conclusions

- Design activities are mostly completed
- The manufacturing phase is going to start in the industry
  - INFN and ASG are currently in the process of procuring the required equipment
- All the fabrication steps are defined
  - To be tested through trials in the industry and mockups at INFN Genova.