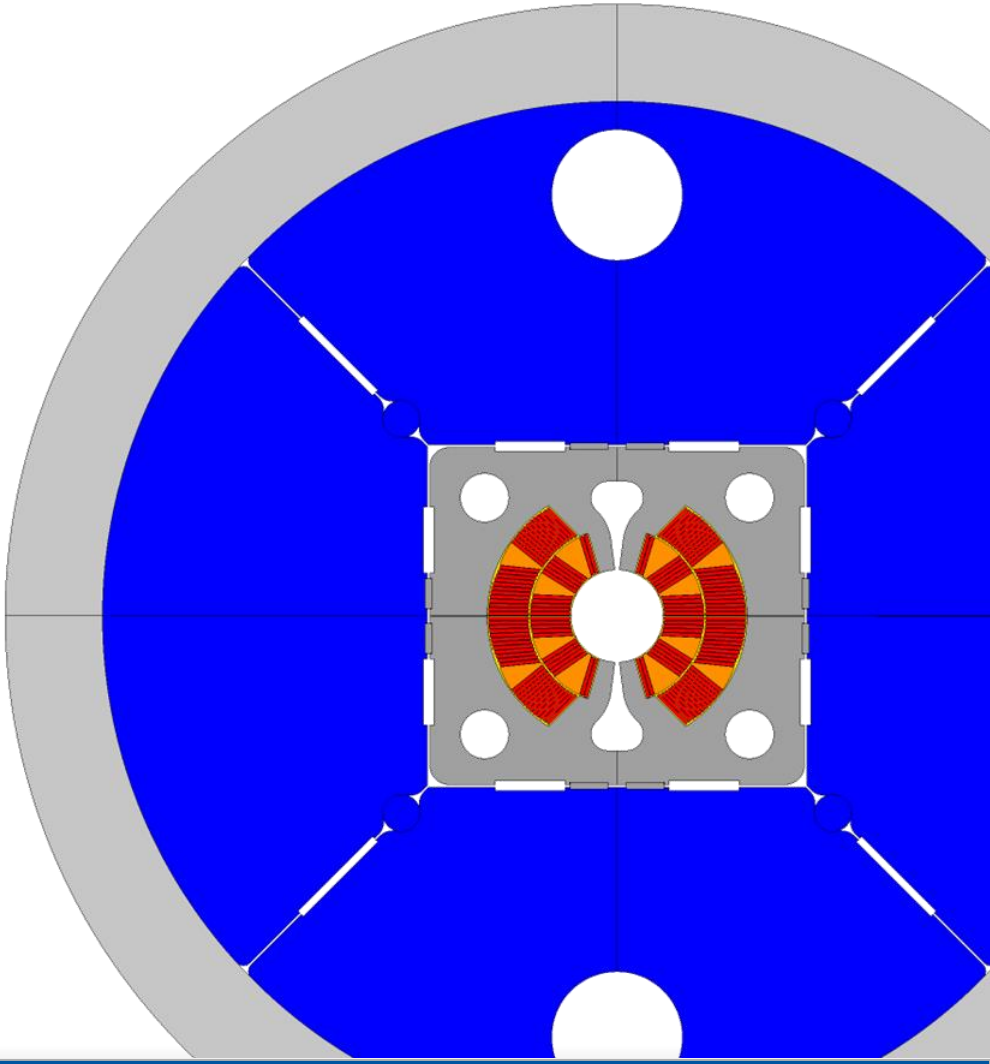
HFM Forum meeting

FalconD design and plans ¶



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on behalf on the INFN Ge/Mi collaboration

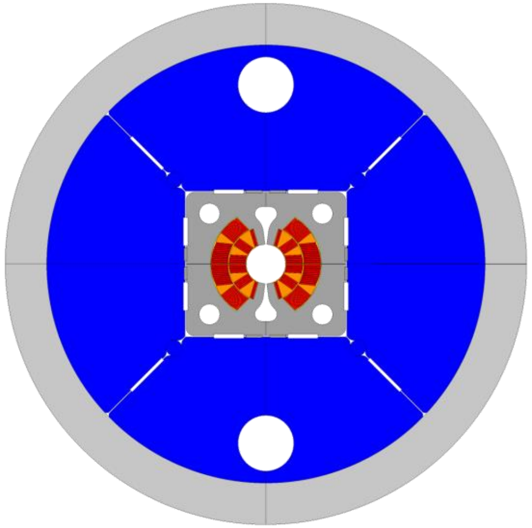
Date: March 28th 2024

FalconD 12 T dipole

- This program is being developed in accordance with the CERN/INFN KE 4102 agreement.
- Amendment N°1 was issued on March 23 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 supports all activities and supplies the magnet **components**, including the cable, spacers, and other necessary items.

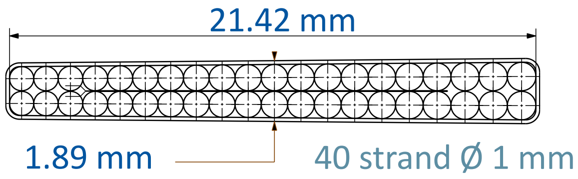
ASG Superconductors is responsible for manufacturing the **coils**, which include 7 Nb_3Sn coils and 1 dummy copper coil.

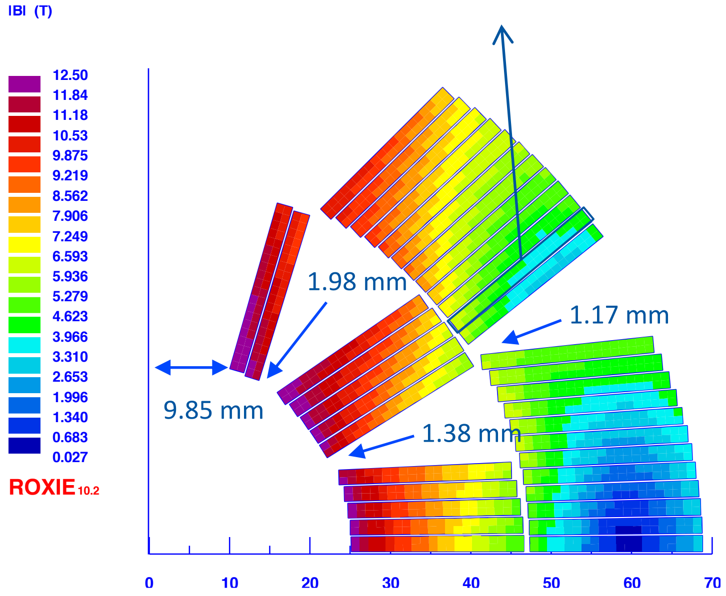
INFN is responsible of the magnet design, **B&K assembly**, and preliminary **test** @ 4.2 K at LASA laboratory in Milan.

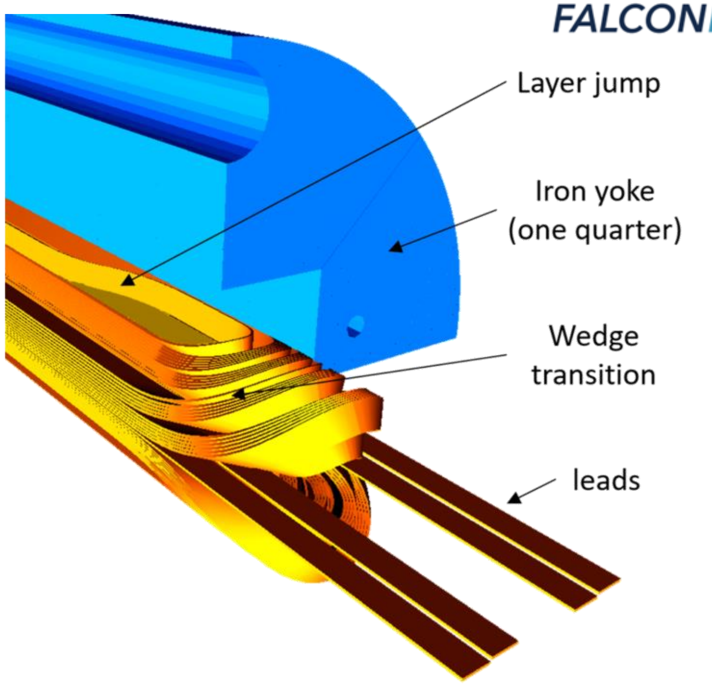
Electromagnetic design

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

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







Courtesy of R.Valente

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

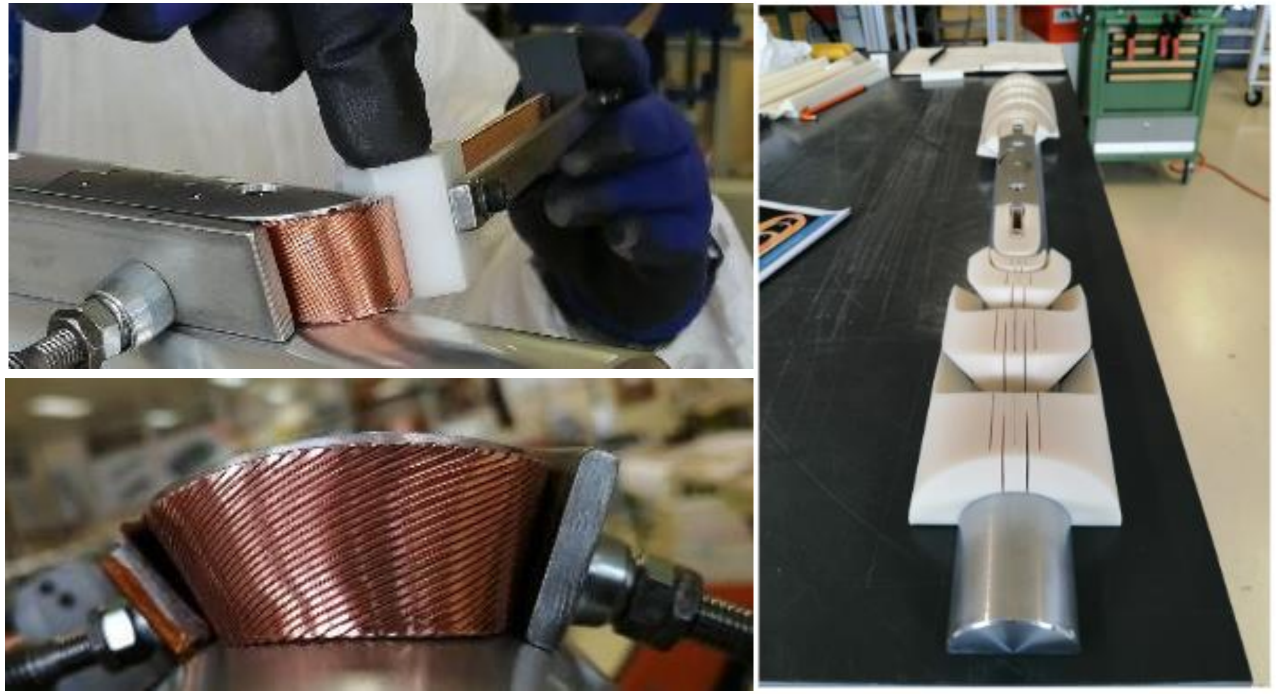
*intended as mechanical limit

Margins are calculated with the EuroCircol JC curve scaled to JC @ 16 T, 4.2 K = 1200 A/mm²

Cu/NCu	0.9
$J_{overall}$ (A/mm^2)	424
J_{SC} (A/mm^2)	1220
W_{eqv} (mm)	37
Number of turns	12+24
Unit length (m)	150

Winding test @ CERN

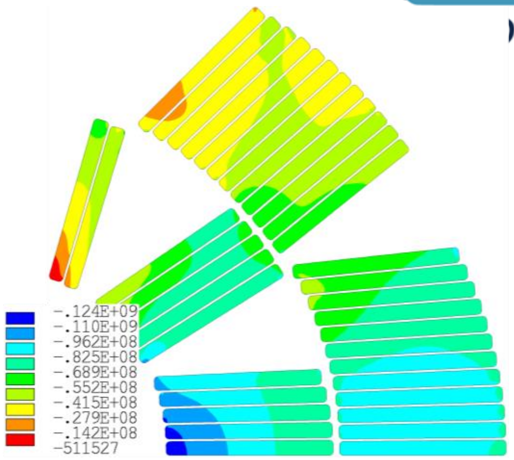
- 3 winding test campaigns were conducted at CERN. These tests were instrumental in optimizing the cabling parameters and refining the design of the end spacers.
- To be noted that none of the tests have been performed with the insulated FalconD cable and SS spacers. Best attempt have been performed using plastic spacers with:
  - Insulated FRESCA cable (not keystoned)
  - Bare FalconD cable
- We are ready to iterate the end spacer design after winding tests at ASG.



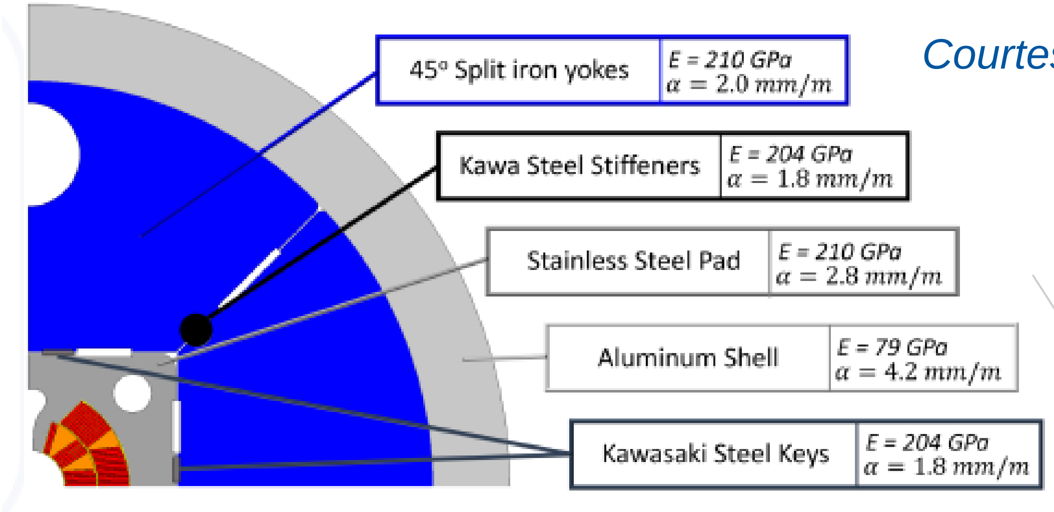
Test performed at CERN building 927

Mechanical design

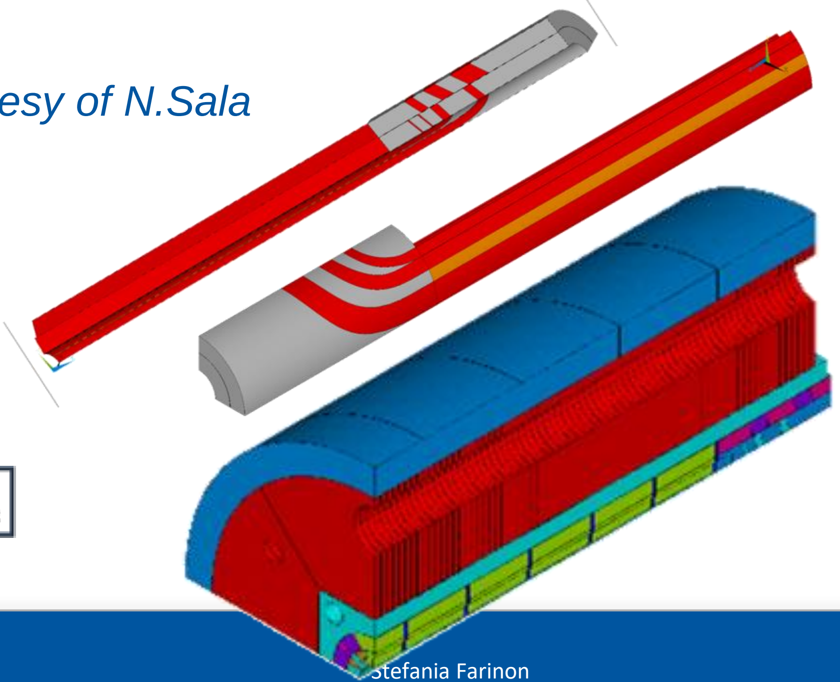
- The 2D mechanical structure design has been recently revised to incorporate material properties obtained from CERN measurements, and it has been re-optimized accordingly.
- Efforts are underway to update the 3D mechanical design which will include the integration of the newly optimized 2D cross-section.



Max VM stress: 124 MPa



Courtesy of N.Sala

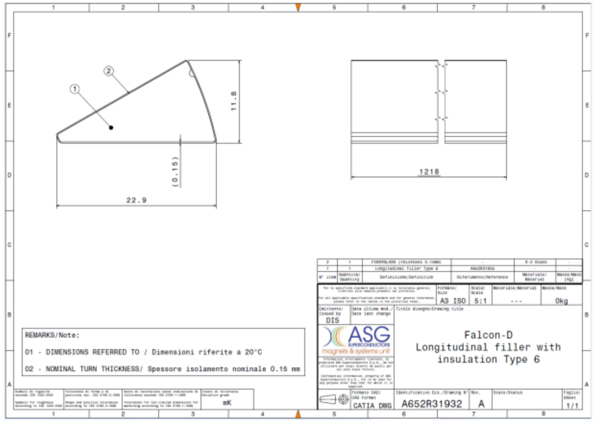


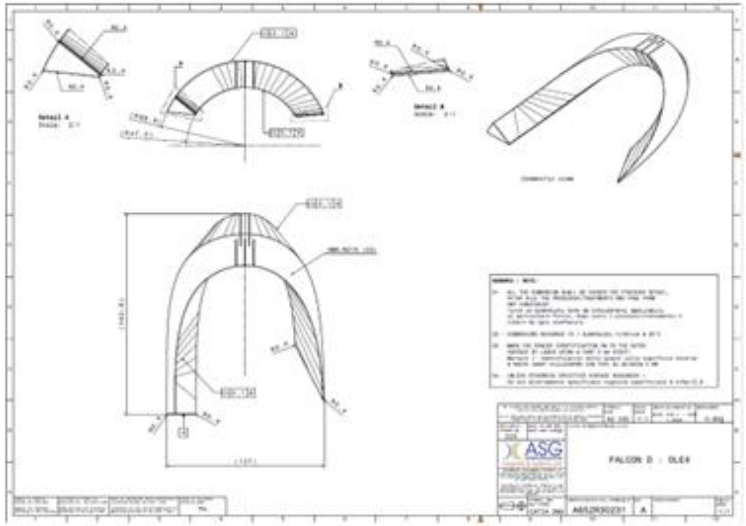
FalconD deliverables

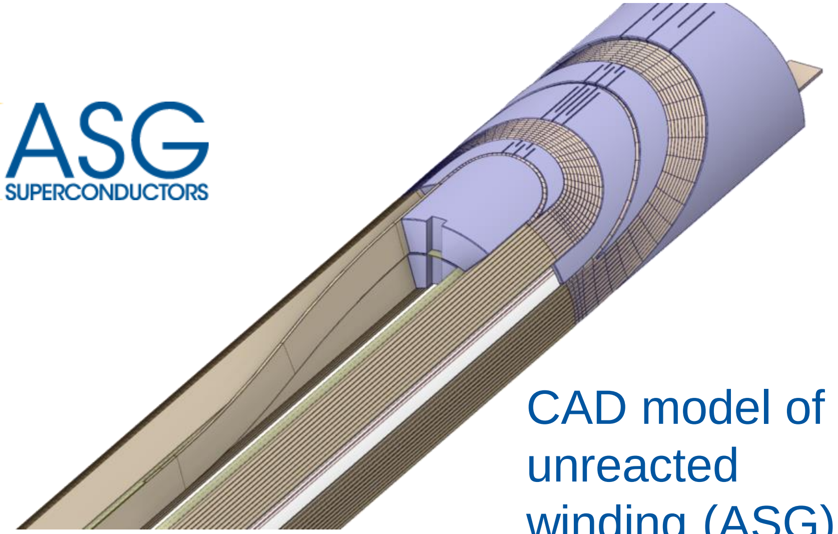
RD Line	Work Package	Tasks, deliverables	TASK/DELIVERABLE DESCRIPTION	End	% completion	Comments
RD3	**WP3.2**	**WP3.2**	**Nb3Sn single aperture cosΘ bladder & keys 12T FALCON D dipole model - INFN collaboration KE4102**	**Mon 01/12/25**	**21%**	
RD3	**WP3.2**	D1.1	Technical desing report	Oct-21	100%	Completed
RD3	**WP3.2**	D1.2	Final desing review	Dec-24	0%	After approval of the drawings, to finalize the design.
RD3	**WP3.2**	D1.3	Confirmation of the schedule	Jun-23	100%	
RD3	**WP3.2**	D1.4	Heat treatment and vacuum pressure impregnation tool ready	Jun-24	80%	All equipment has been ordered from Fantini Srl and is currently in production. Delivery will occur in two separate lots.
RD3	**WP3.2**	D1.5	Approval of manufacturing drawings of cold mass components (CERN, INFN, Industry)	Oct-24	20%	Present goal is to complete the design by summer 24.
RD3	**WP3.2**	D2.1	Magnet assembly Production Readiness Review	Mar-25	5%	The design of the assembly sequence has just started.
RD3	**WP3.2**	D2.2	Acceptance of the 3 magnet poles (one spare)	Nov-25	0%	
RD3	**WP3.2**	D2.3	Magnet assembled keys installed	Feb-26	0%	
RD3	**WP3.2**	D2.4	Magnet acceptance CERN, INFN	Apr-26	0%	
RD3	**WP3.2**	D2.5	Final report	May-26	0%	

FalconD drawing status

- The drawings of Cu wedges and end spacers are ready. CERN is about to place the order (full production of wedges, 1st set of end spacers).
- 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.



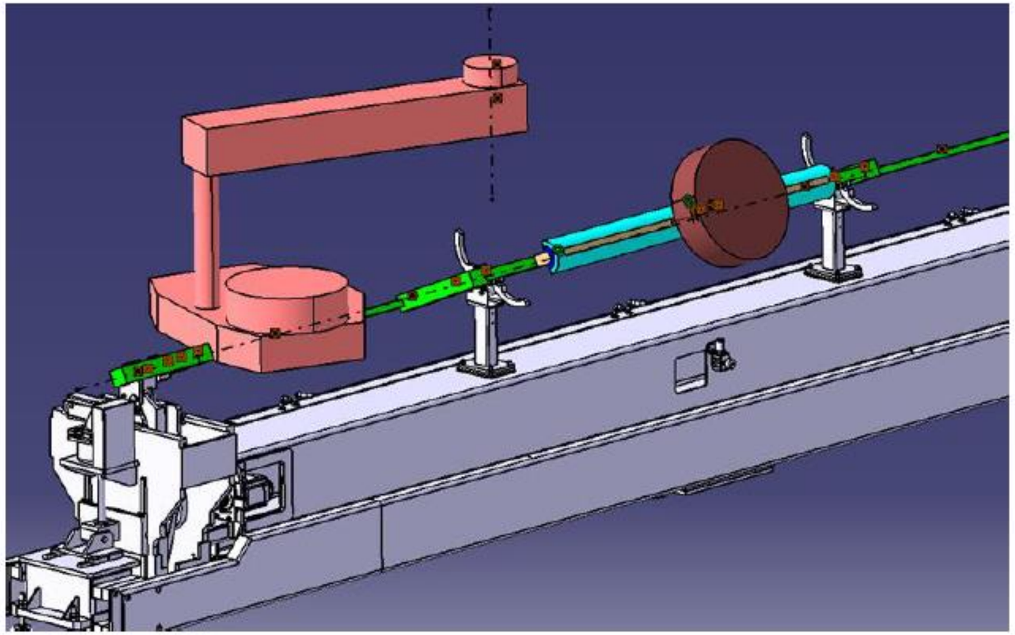


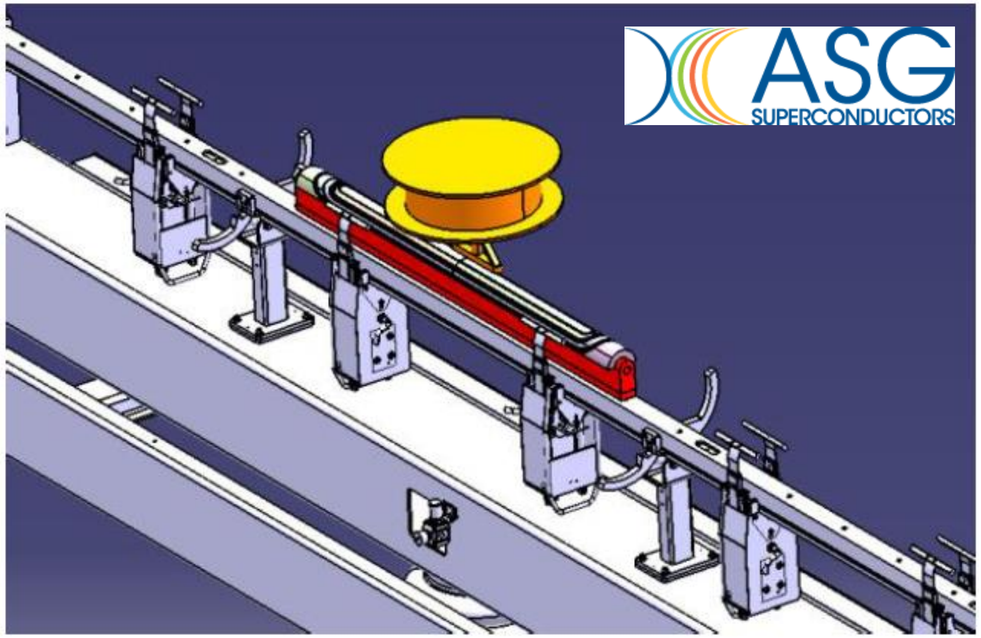


CAD model of unreacted winding (ASG)

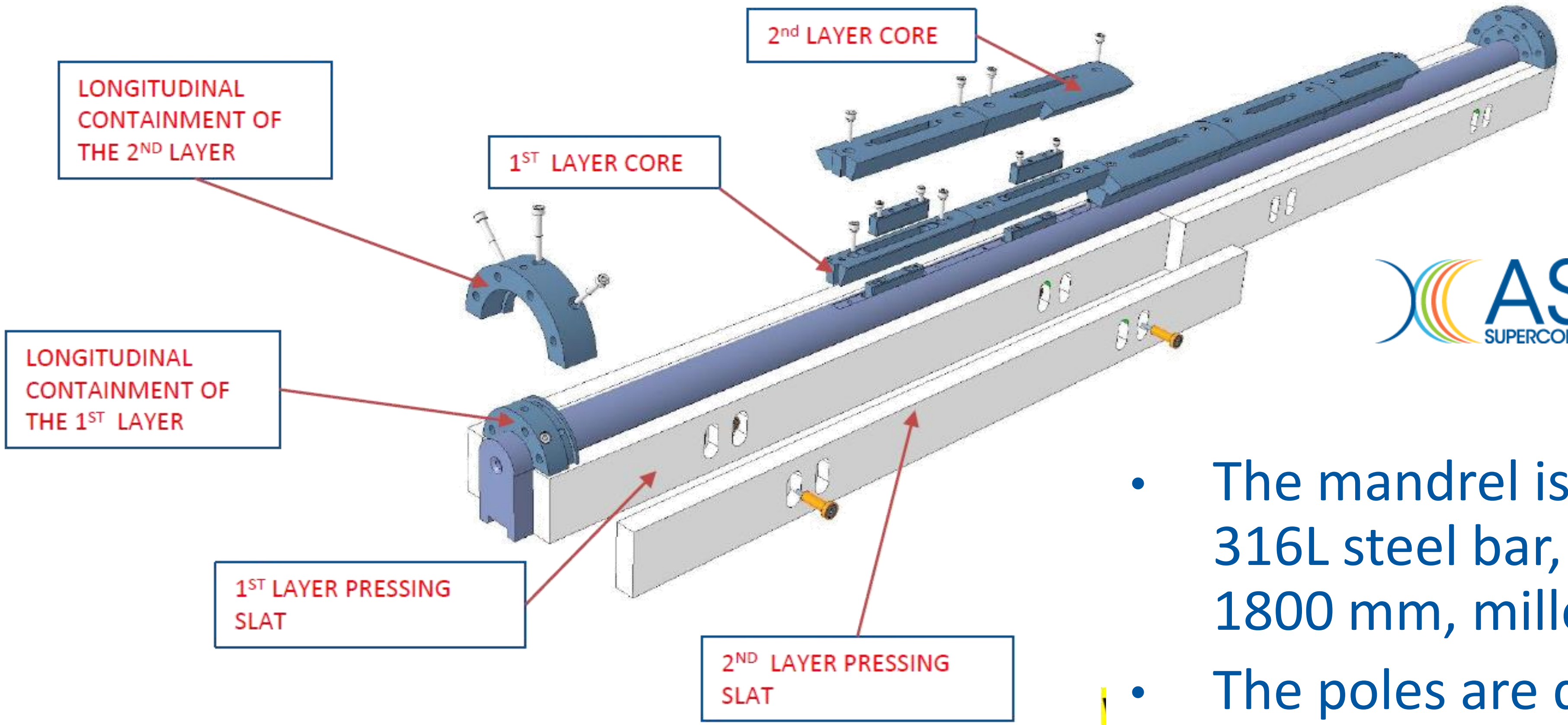
Winding concept

- The coil is a double-layer winding with no intermediate splices, i.e., with the winding starts from an intermediate point.
- The 2nd layer spool support will be fixed to the poles of the 1st layer and will serve to support the coil containing the spare conductor during winding. It will also be equipped with a conductor holding device to prevent unwinding.





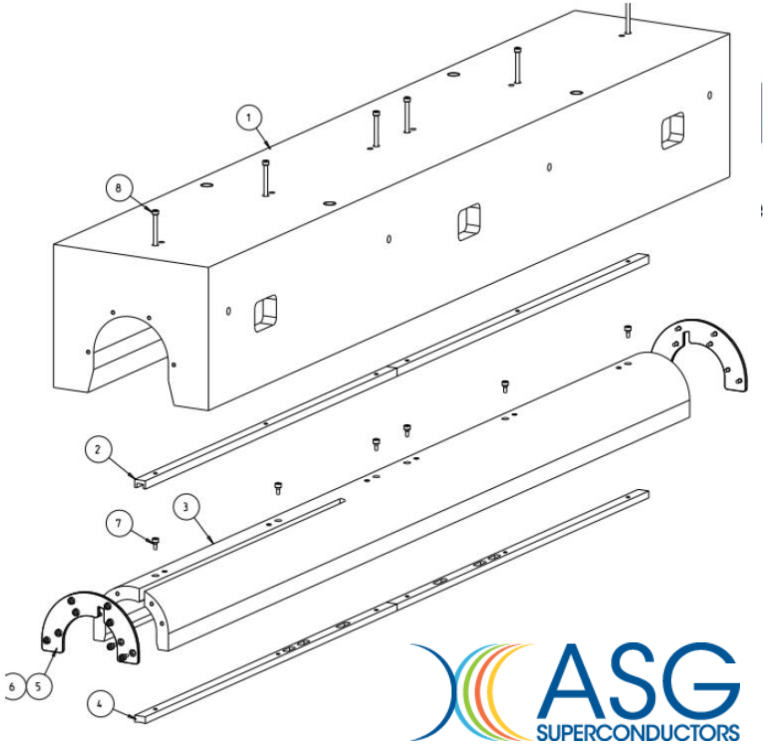
Mandrel assembly



- The mandrel is crafted from a single 316L steel bar, with a total length of 1800 mm, milled using a CNC device.
- The poles are designed as removable features; in the final assembly, the poles are integrated into the pads.

Curing counter-mold

- The ASG baseline procedure is as follows:
  - Wind the 1st layer
  - Brush the binder onto the wound first layer
  - Interpose the interlayer (already cured)
  - Wind the second layer
  - Brush the binder onto the wound second layer
  - Cure under moderate pressure at 165°
- Additionally, ASG is prepared to implement other options if necessary, including:
  - Omitting the application of binder
  - Curing the 1st layer after winding



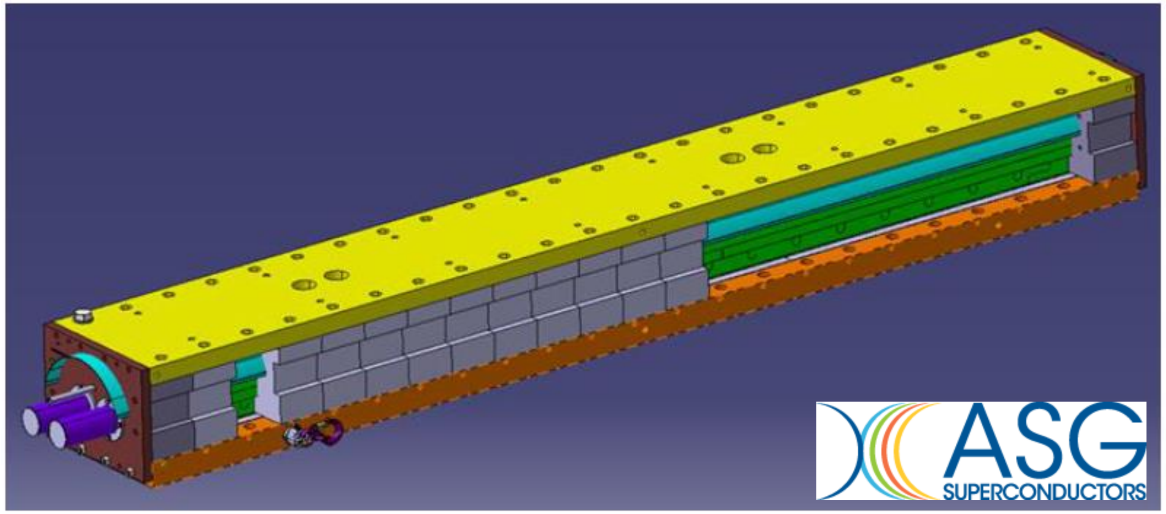
ASG SUPERCONDUCTORS

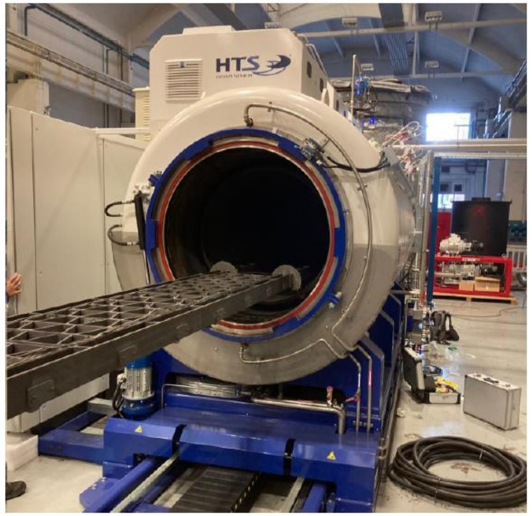
FALCOND

INFN
Istituto Nazionale di Fisica Nucleare

Heat treatment

- A mold is designed to house both the reaction to about 650°C and the impregnation with ceramic resin.
- The walls are made of 316L stainless steel to ensure resin tightness.
- The interior spaces will be filled with appropriately shaped PTFE elements.
- To facilitate detachment and prevent damage to the coil, metal surfaces in contact with it will be covered by mica foils.
- The furnace has been procured by INFN and has successfully passed a Site Acceptance Test, conducted using a 300 kg stainless steel/copper mock-up mass.





ASG schedule (as of Feb.24)

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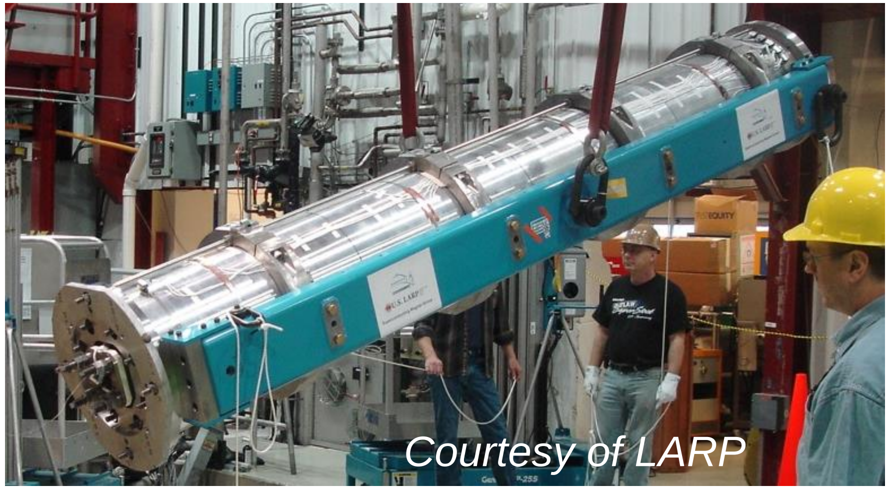
- Equipment procurement.........June 2024
- Winding tests...........................September 2024
- 1st dummy pole.........................December 2024
- 1st practice pole........................April 2025
- 2nd practice pole ....August 2025
- 1st aperture pole ....November 2025
- 2nd aperture pole ....March 2026
- Spare pole ....July 2026
- 1st additional pole ....September 2026
- 2nd additional pole ....January 2027

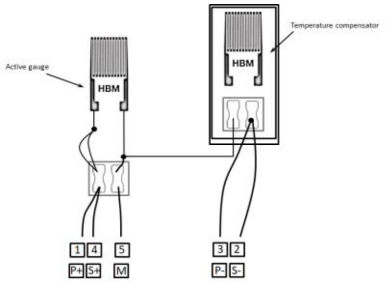
Preliminary assembly sequence

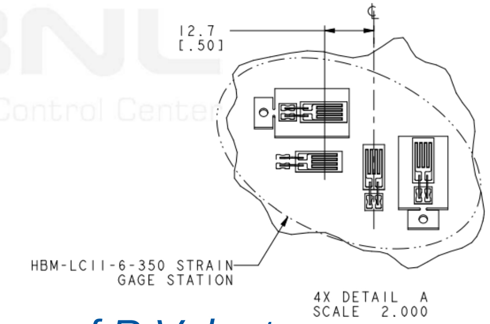
- Work on the assembly has recently started.
- Our plan involves vertically assembling the yokes into the aluminum shells. The coils, pre-assembled in the pad, will be introduced horizontally.
- To allow this process, a flip system is required. This system will allow for the rotation of the shell and iron system, weighing 1.8 tons, as well as the entire magnet after assembly, to facilitate testing in the vertical cryostat.



Aluminum shells

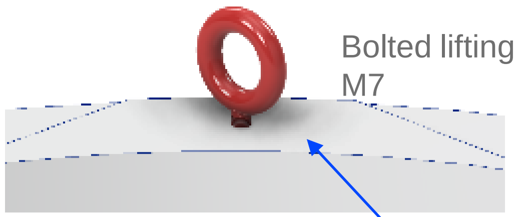
1. Outer diameter: 650 mm
2. 50 mm thick
3. Two segments 750 mm –long
4. 50 kg each



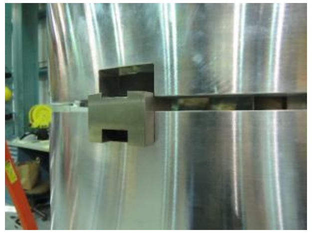


Courtesy of R.Valente

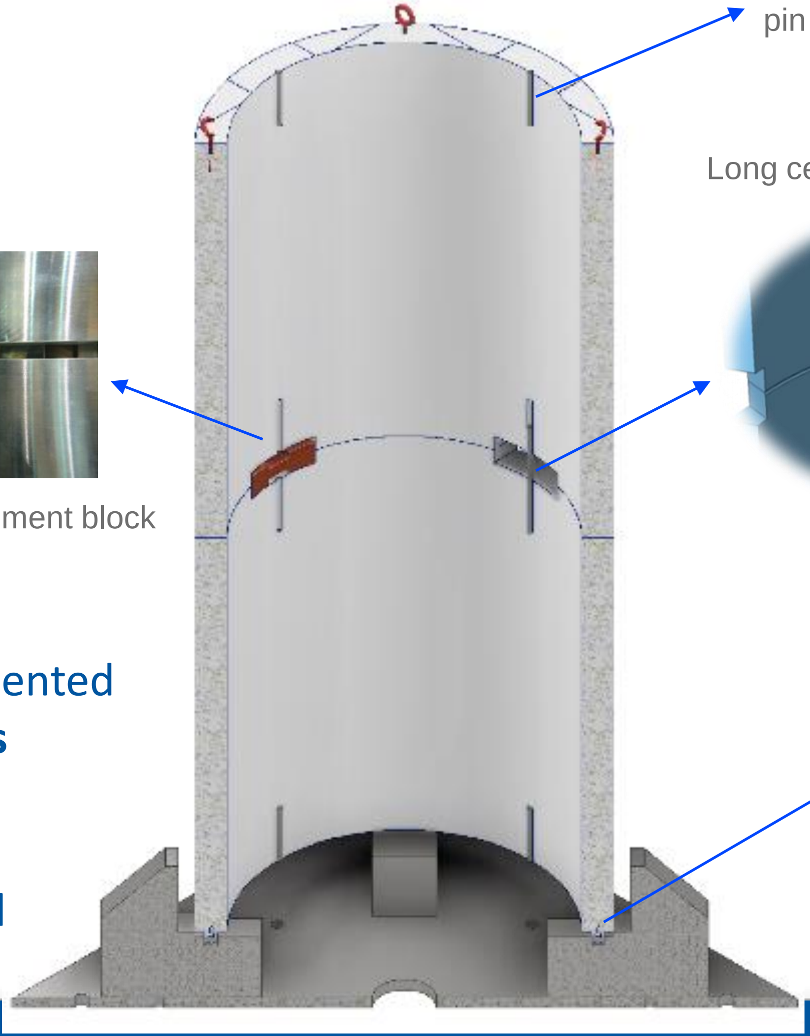
The shells are instrumented with the **strain gauges** before starting the assembly sequence (at least 4 SG per shell segment)



Bolted lifting eyes M7

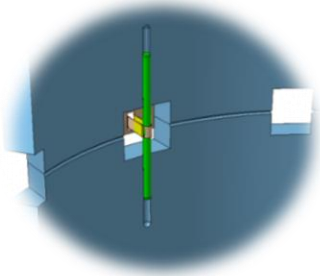


Shell-shell alignment block

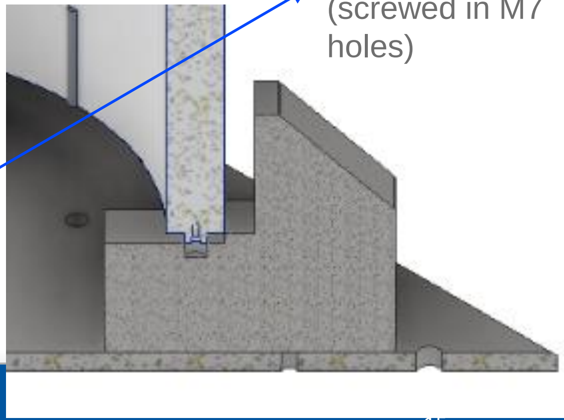


yoke-shell alignment pin (glued)

Long central alignement pin

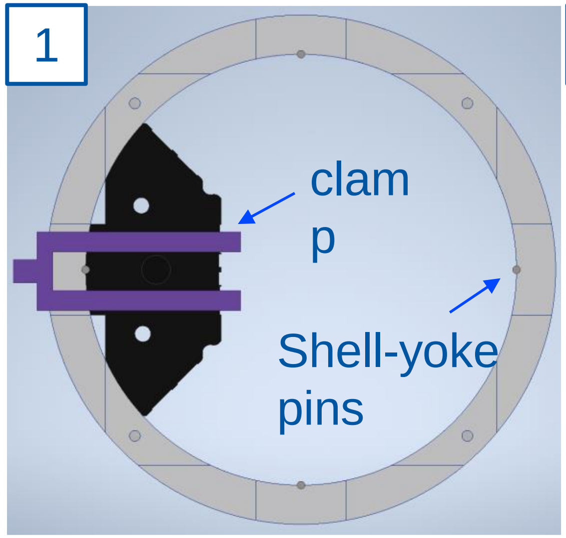


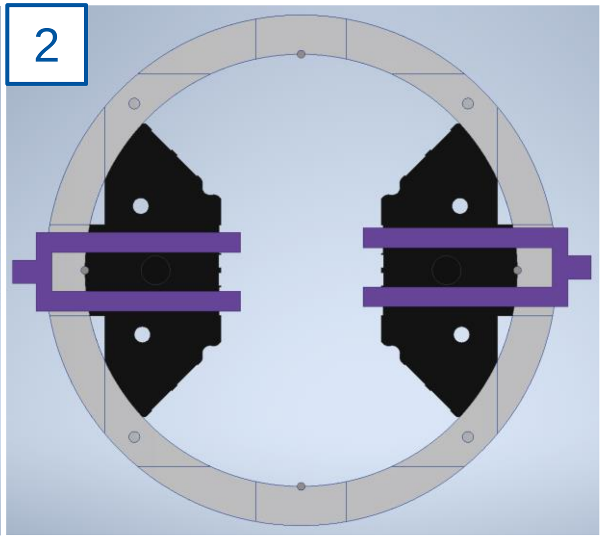
base-shell alignment pin (screwed in M7 holes)

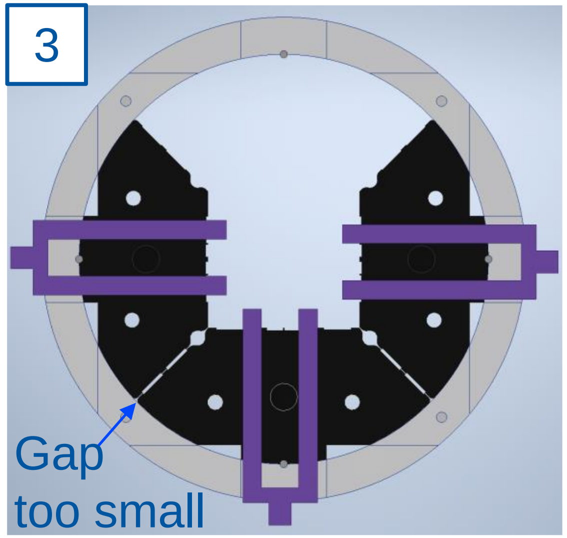


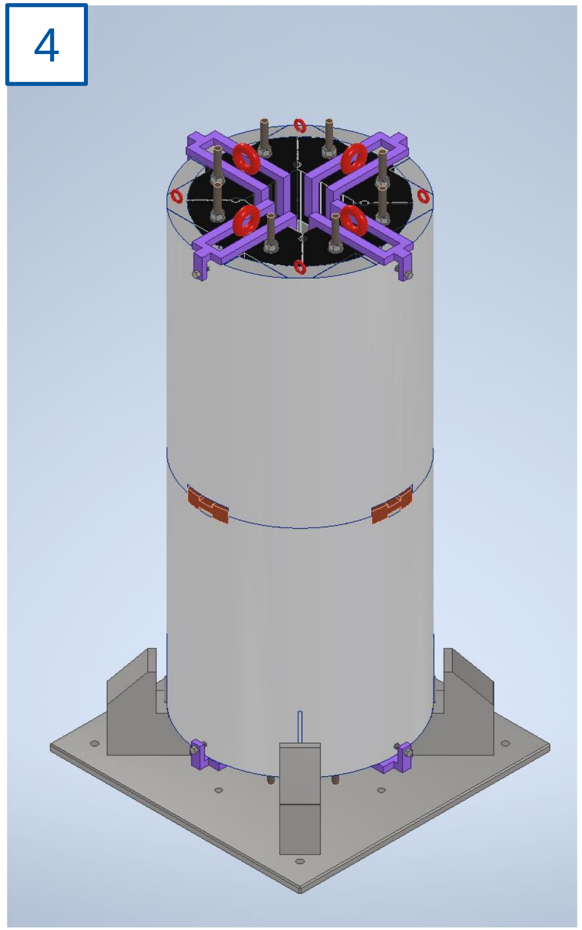
Yoke insertions

Courtesy of R.Valente









- The angular alignment of the first ¼ yoke is defined by 1 long middle pin and 2 small pins located at the shell extremities
- Using the same assembly procedure, the 3rd yoke will interfere with the yokes already installed
- we must increase the gap between ¼ yokes (at least pin dimension – 4 mm)
  The clamps on the top and bottom securely hold the yoke sectors in place.

Conclusions

- The finalization of the design and manufacturing drawings is scheduled to be completed by the end of 2024.
- ASG has already procured the equipment necessary for manufacturing the coils, which will be available by June 2024.
- Winding tests and the fabrication of the first dummy coil are anticipated to be completed by the end of this year.
- Furthermore, we have begun developing the assembly procedure, closely adhering to the assembly procedure of MQXF.