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Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

TFC Winding and Integration

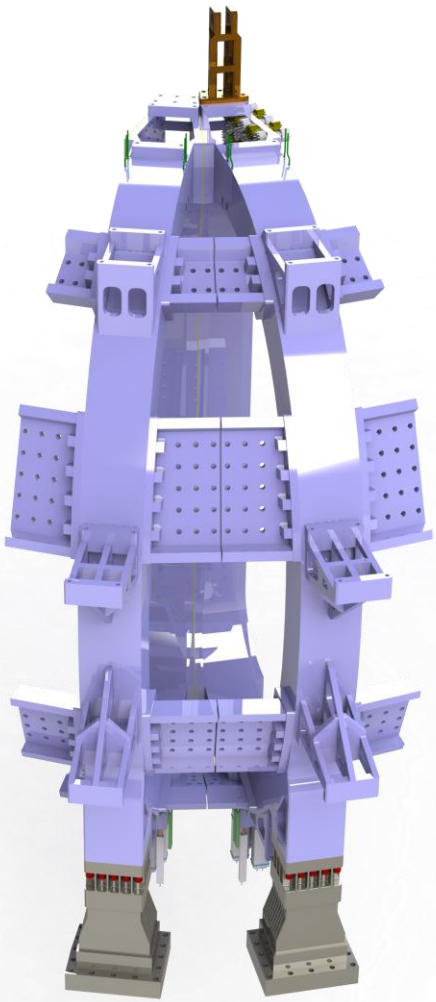
DTT info-day on TF magnets

Aula B. Brunelli, C.R. ENEA Frascati (Rome), Italy – 08/10/2019

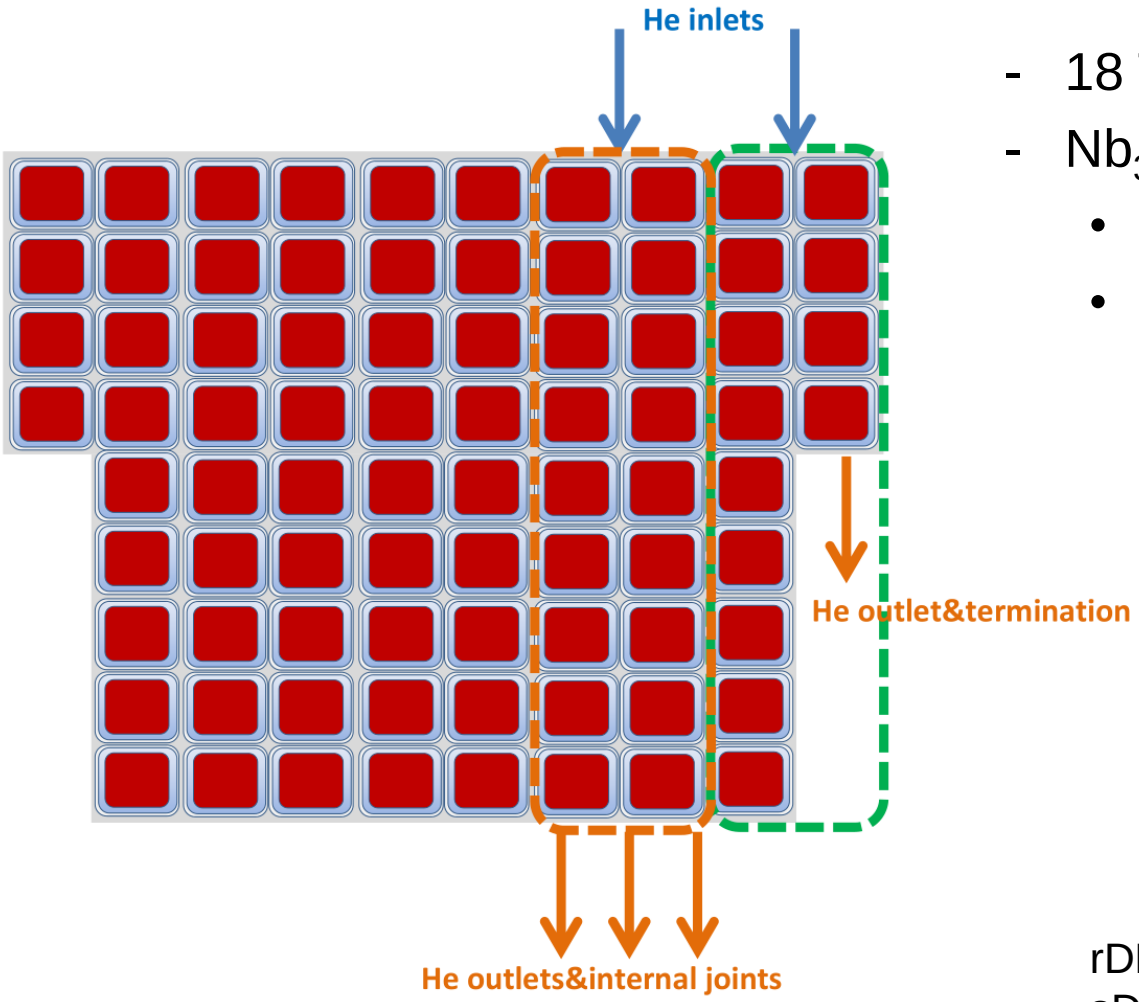
Presenter G. Romanelli on behalf of the DTT team

Outline

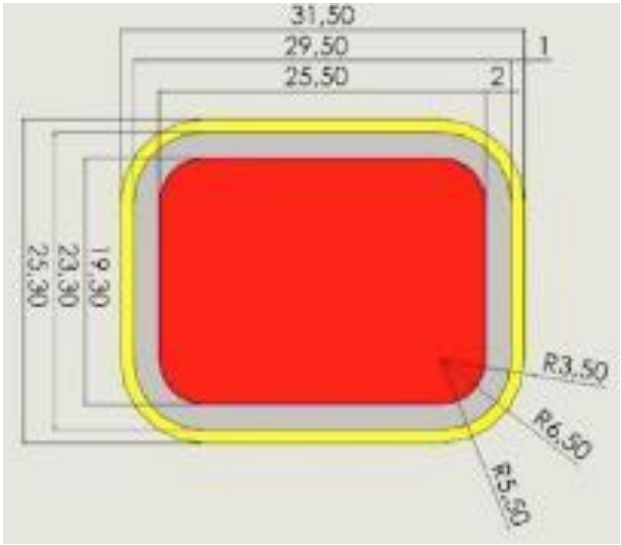
- WP description
- Schedule
- Supply content
- WP manufacturing
- TFC integration
- Final coil preparation
- Conclusions and recommendations



WP description



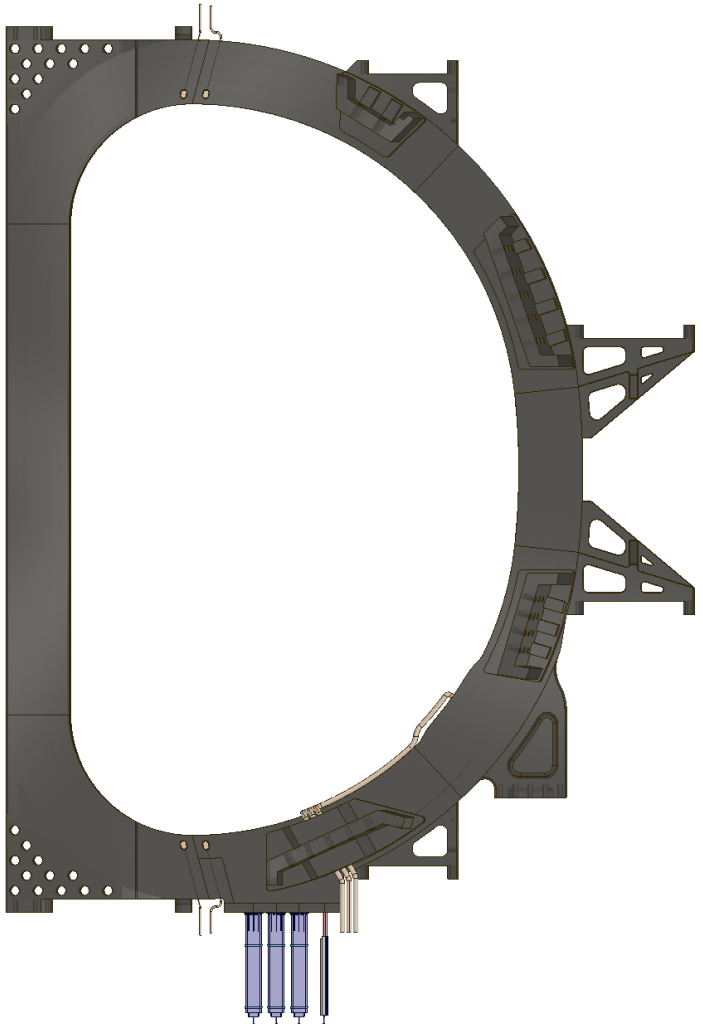
- 18 TFCs;
- Nb_3Sn conductors:
  - 3x rDP (i.e. 9+9 layers)
  - 2x sDP (i.e. 9+4 layers)



rDP = regular Double Pancake
sDP = side Double Pancake

Schedule

- WP winding procedure qualification by Dec 2020;
- First WP by Sep 2021;
- First TFC by May 2022;
- 6 TFCs by Dec 2022;
- 18 TFCs by Feb 2024.



WP = Winding pack
TFC = Toroidal Field Coil

Supply content

Dummy Spools

- 1x dummy:
  - Copper cable;
  - 232 m (i.e. 222 m complete conductor + 5 m empty jacket head + 5 m empty jacket tail);
  - Single layer wound (spool diameter > 2.3 m);
  - For qualification procedures + manufacturing 1x resistive sDP.
- 1x super-dummy:
  - Nb_3Sn cable;
  - 170 m (i.e. 160 m complete conductor + 5 m empty jacket head + 5 m empty jacket tail);
  - Single layer wound (spool diameter > 2.3 m);
  - For manufacturing 1x superconductive sDP

Supply content

Regular Spools

- 54x rDP:
  - SC cable;
  - 232 m (i.e. 222 m complete conductor + 5 m empty jacket head + 5 m empty jacket tail);
  - Single layer wound (spool diameter > 2.3 m);
- 36x sDP:
  - SC cable;
  - 170 m (i.e. 160 m complete conductor + 5 m empty jacket head + 5 m empty jacket tail);
  - Single layer wound (spool diameter > 2.3 m).

Supply content

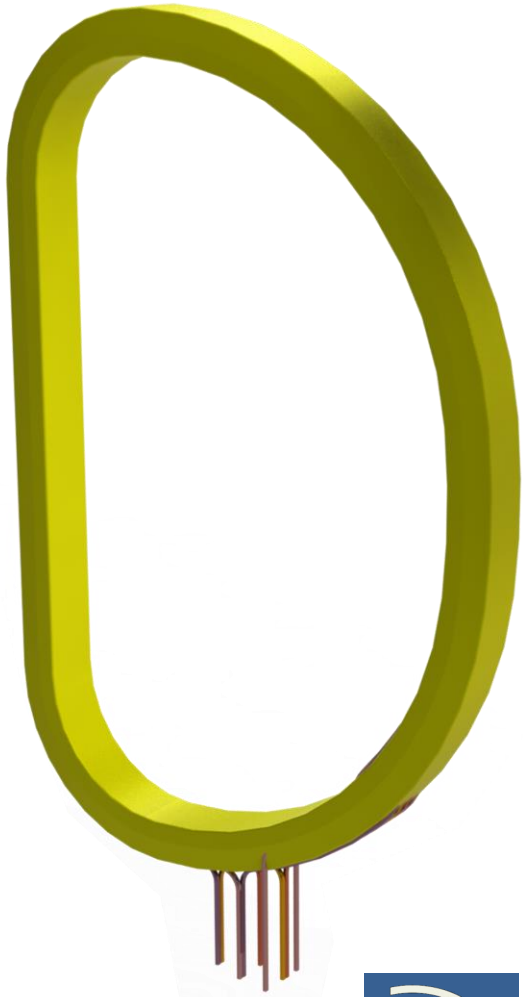
Casing structure (Stainless Steel AISI 316LN)

- 18x Casing structure components to be assembled and welded;
- 1 m inboard leg mockup for integration and welding qualification;
- Inboard-outboard-interface mockup for welding qualification

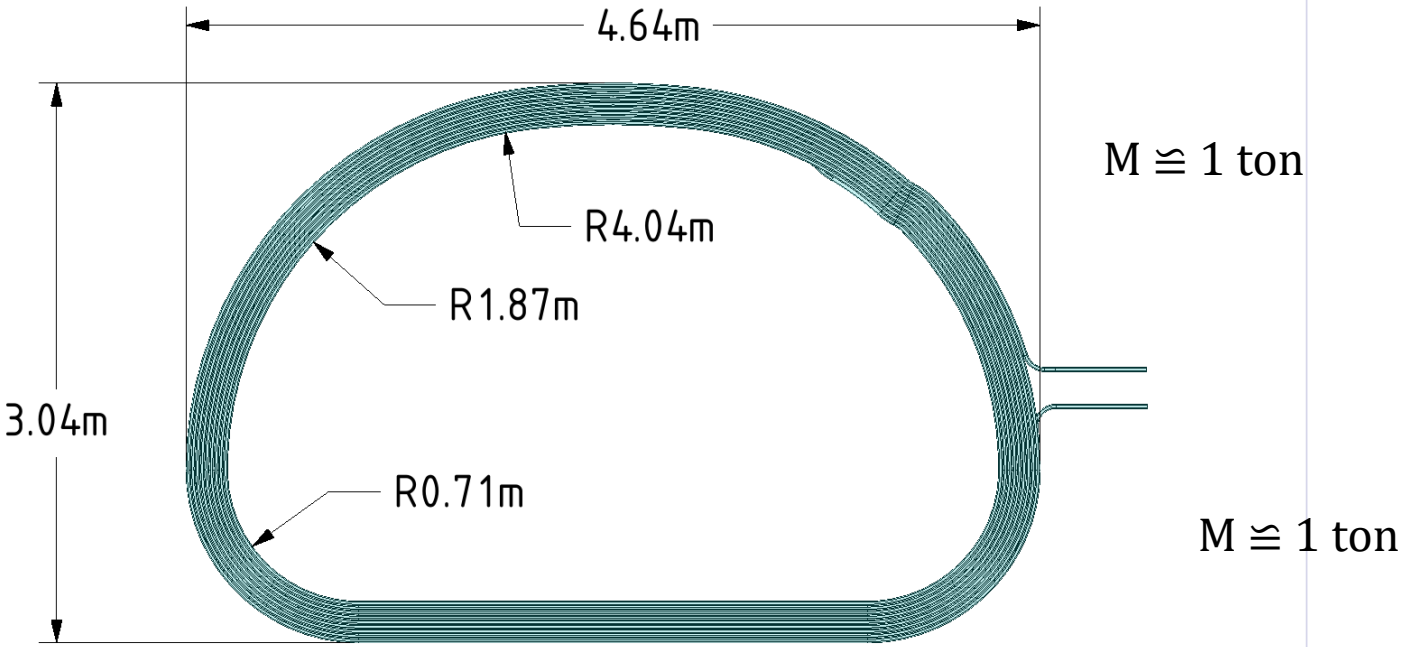
WP manufacturing

Operations to complete x18 WPs

1. 3x rDP and 2x sDP winding;
2. He inlet welding;
3. Internal and terminal joint preparation;
4. Nb_3Sn heat-treatment;
5. Turn insulation application;
6. DP insulation application;
7. DPs stacking;
8. Inter-DP and terminal joint finalization;
9. Ground insulation application;
10. VPI and curing.



WP manufacturing – DP winding



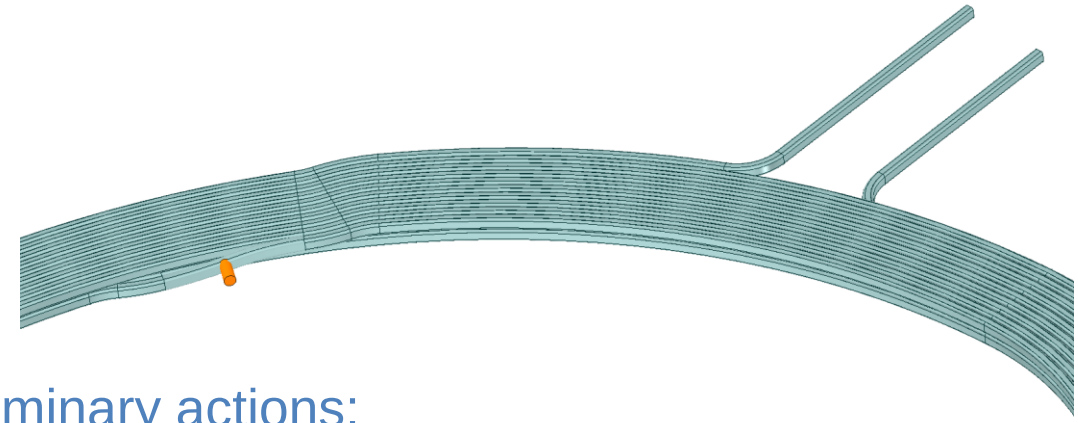
Preliminary actions:

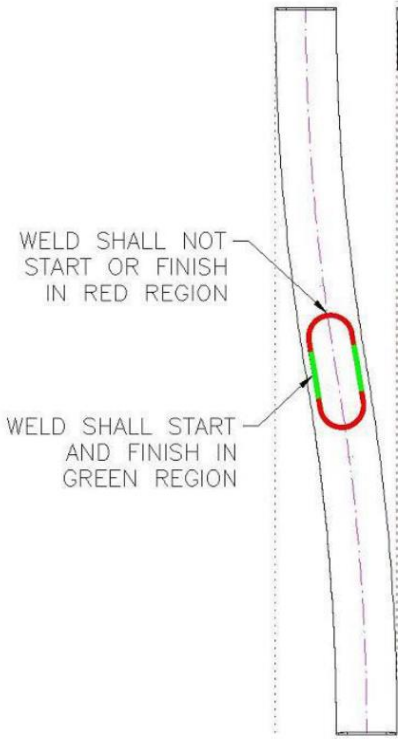
- Review unit-length transportation conformity;
- Visual inspection;
- Nitrogen flow and Helium leak test.

Operations:

- Inline clean and sandblast the conductor surface;
- Wind 3x rDP;
- Wind 2x sDP.

WP manufacturing – He inlet welding





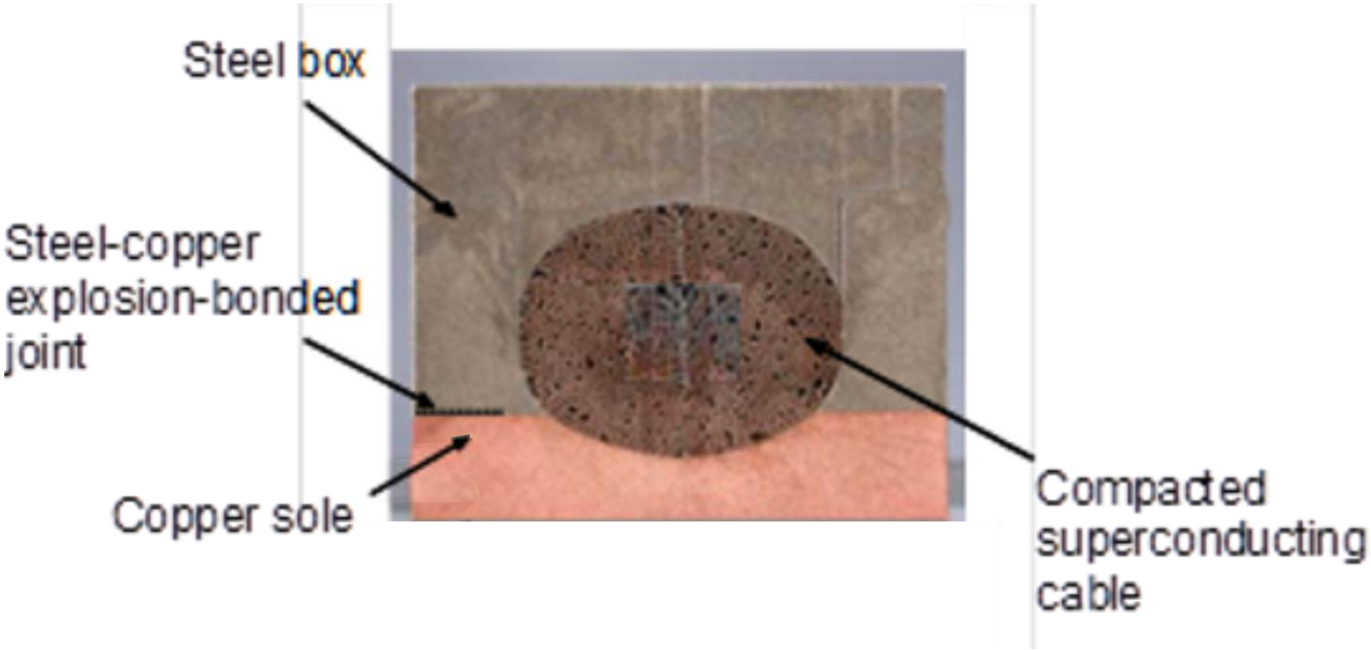
Preliminary actions:

- Weld mockup preparation;
- Non-destructive inspection on mockups;
- Helium leak test on mockups.

Operations:

- Machine jacket opening to fit He inlet;
- Weld 1x He inlet for each DP;
- Perform non-destructive inspection of all inlets;
- Perform Helium leak test on all inlets.

WP manufacturing – Internal and terminal joint preparation



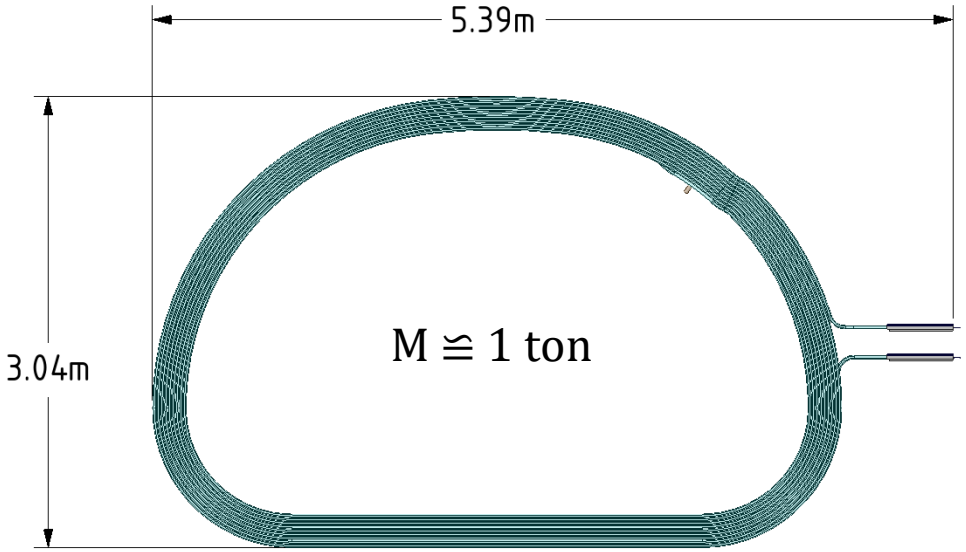
Preliminary actions:

- 1x inter-DP + 2x terminal joint mockup preparation;
- Mockup shipment to ENEA for qualification purposes.

Operations:

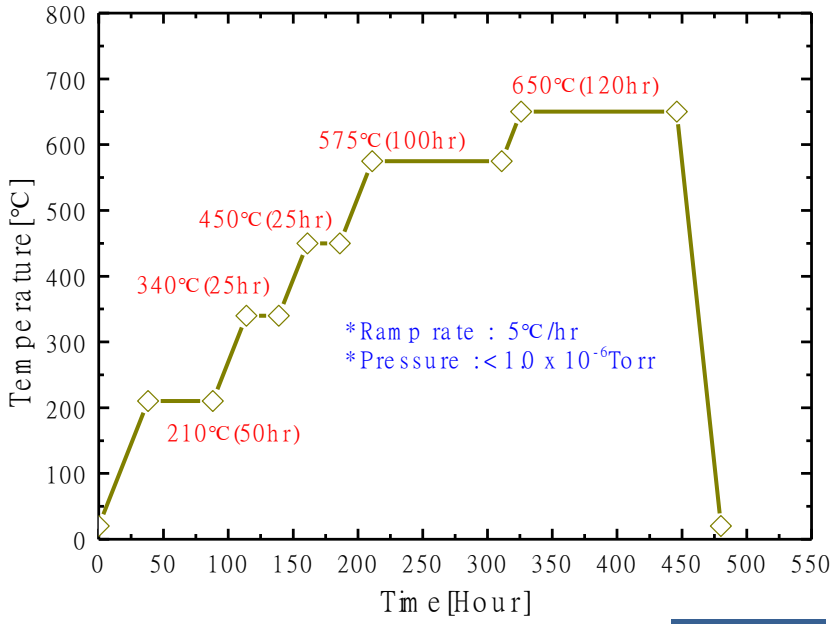
- Finalize 1x inter-DP joint box for each DP;
- Finalize 1x terminal joint box for each DP.

WP manufacturing – Nb_3Sn heat treatment



Operations:

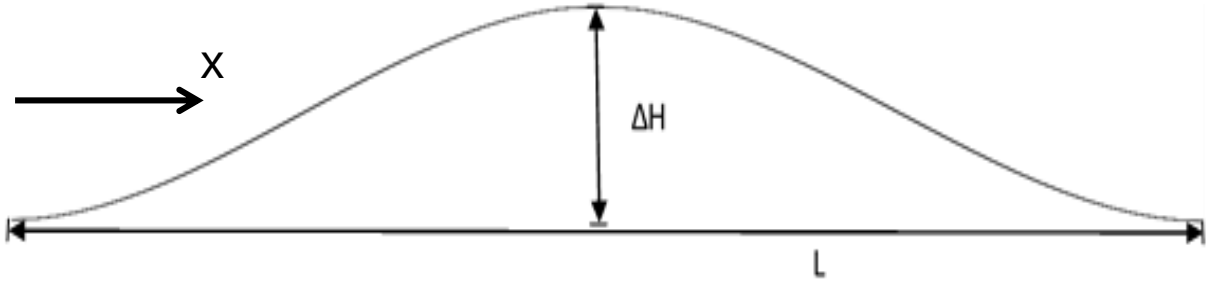
- Perform the Nb_3Sn heat treatment.



WP manufacturing – turn insulation application

Preliminary actions:

- Longitudinal strain on the SC assessment (must be within -0.8% ÷ 0.2% and an additional equivalent strain -0.5% ÷ -0.3% due to heat treatment must be considered);
- Mechanical and electrical performance assessment on mockups.



ENEA assessment:

$\Delta H = 0.7$ m

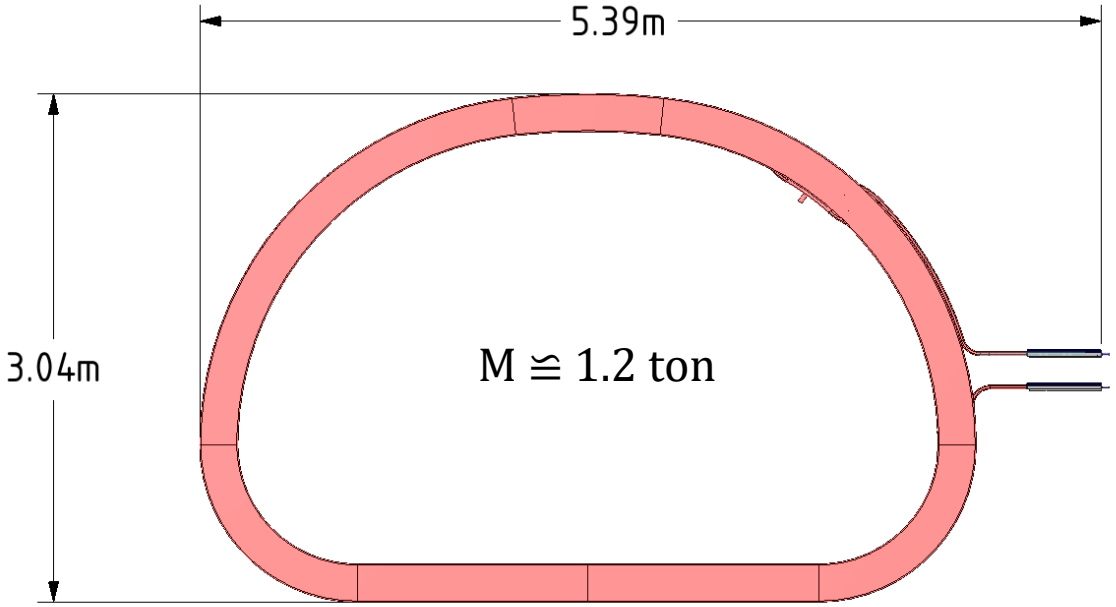
$L = 15$ m

$\varepsilon_{x\_max} = 0.1\%$

Operations:

- Apply 1 mm of E-glass fiber;
- Perform visual inspection of all DPs to check dimensions;
- Verify electrical integrity;
- Verify each DP centerline position.

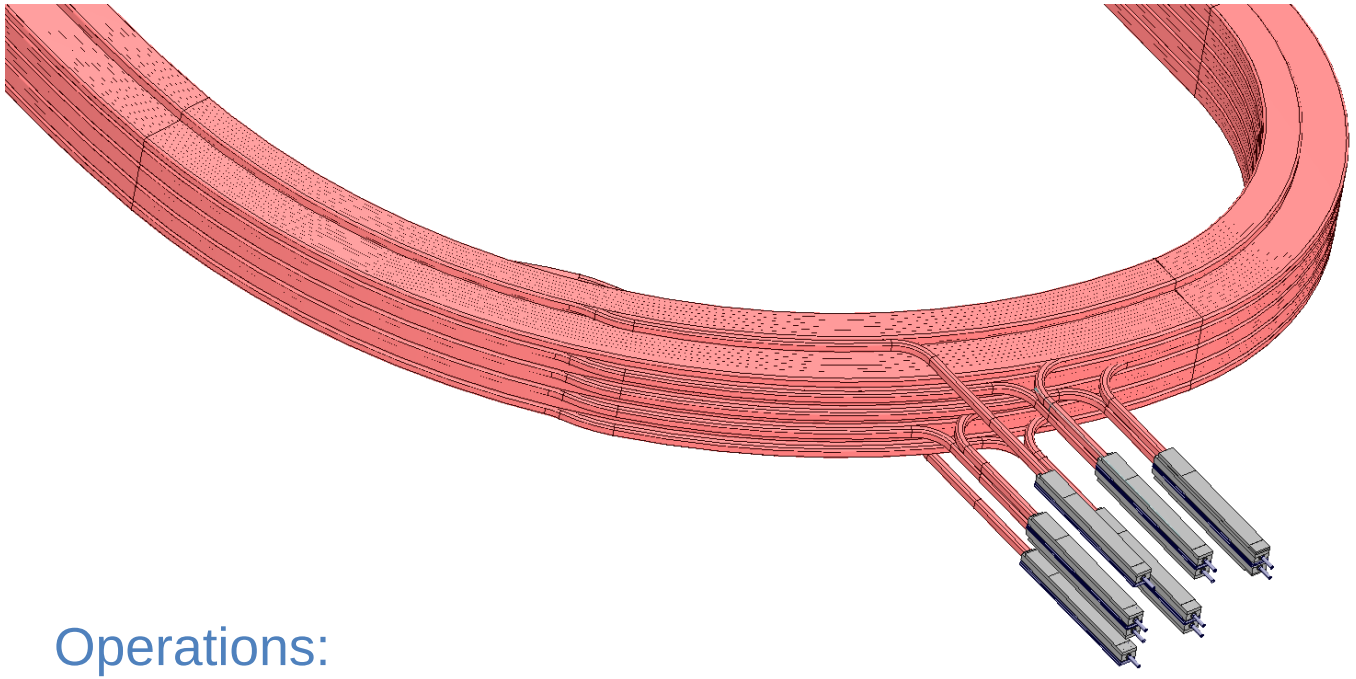
WP manufacturing – DP insulation application + DP stacking



Operations:

- Apply 0.5 mm of E-glass fiber;
- Verify space allowances and positioning tolerance are met (i.e. general class medium tolerances required);
- Allign inter-DP joint boxes;
- Verify electrical integrity;
- Verify WP centerline position.

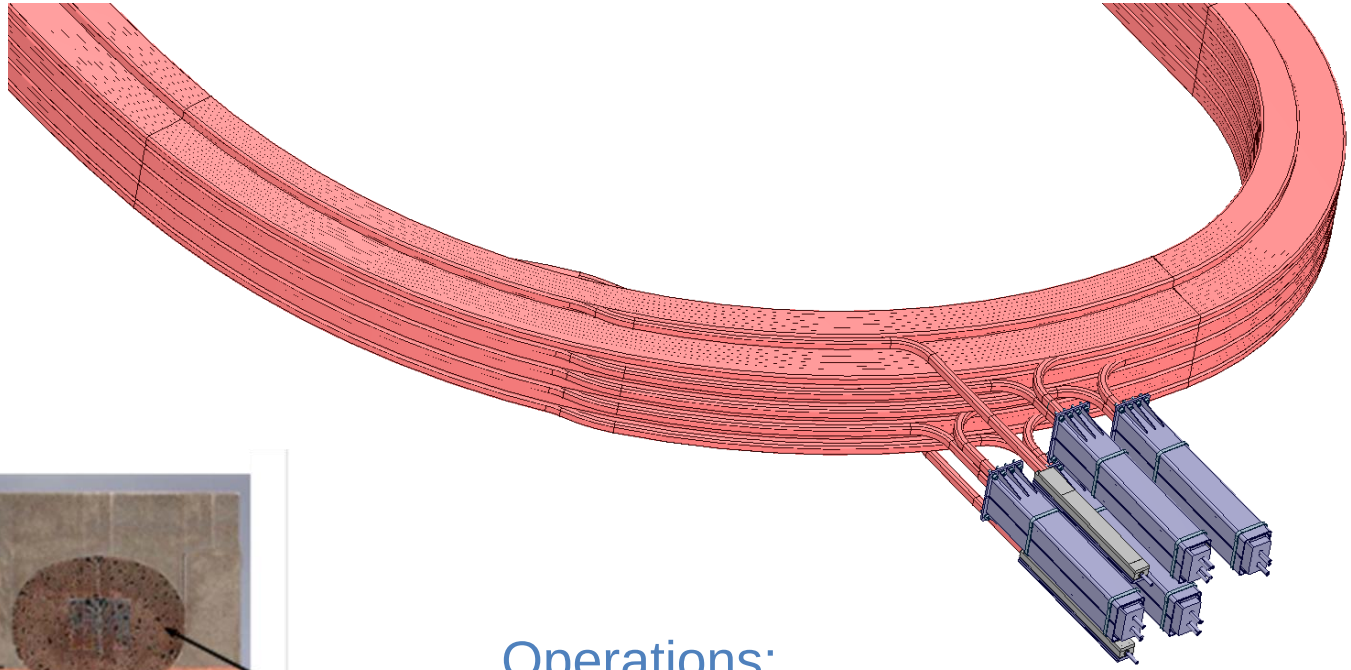
WP manufacturing – DP insulation application + DP stacking

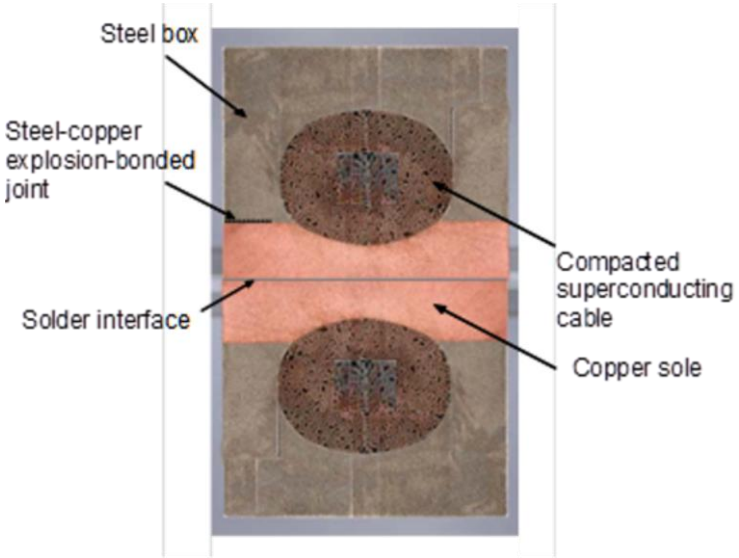


Operations:

- Apply 0.5 mm of E-glass fiber;
- Verify space allowances and positioning tolerance are met (i.e. general class medium tolerances required);
- Allign inter-DP joint boxes;
- Verify electrical integrity;
- Verify WP centerline position.

WP manufacturing - Inter-DP and terminal joint finalization





Operations:

- Finalize Inter-DP and termination twin-box joints;
- Verify space allowances are met;
- Perform Nitrogen flow and Helium leak tests;
- Verify the final arrangement is Paschen-proof.

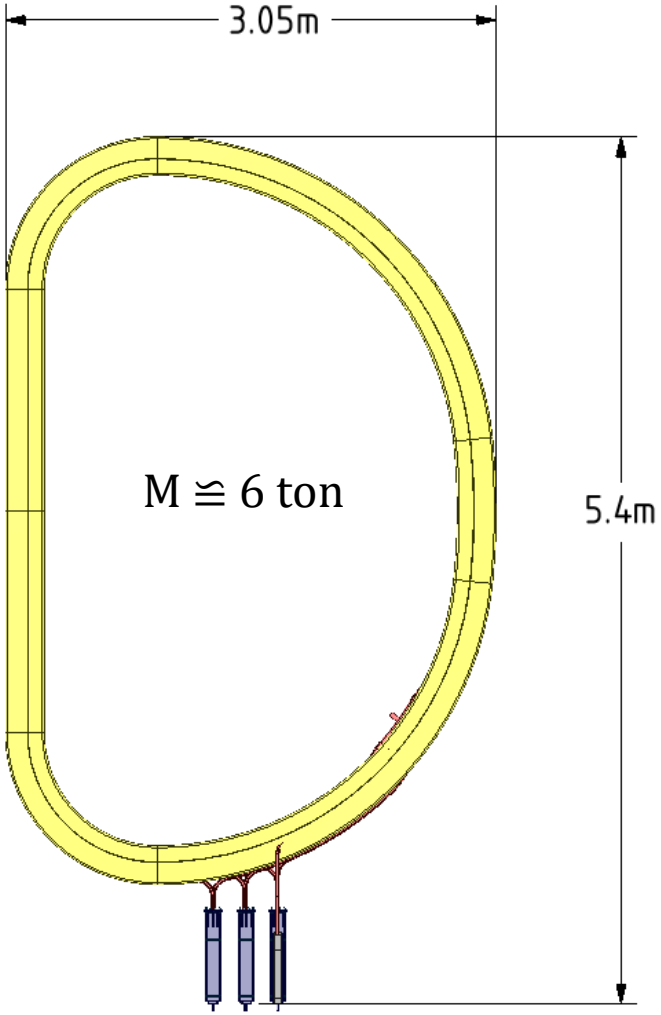
WP manufacturing - Ground insulation application + VPI and curing

Preliminary actions:

- Mechanical and electrical performance assessment on mockups;
- Perform Helium leak tests before and after impregnation;
- Perform Paschen test at 3 kV before and after impregnation.

Operations:

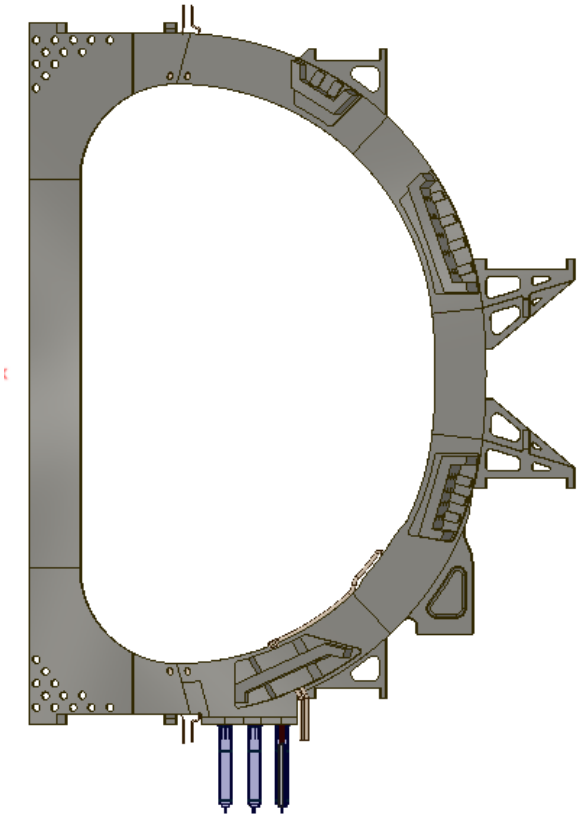
- Add filler material where necessary;
- Apply 2 mm overlapped layers of E-glass fiber and Kapton;
- VPI & curing of the insulation system;
- Apply a conductive finish on the external surface of the WP;
- Apply detaching agents on the external surface of the WP;
- Verify WP centreline position.



TFC integration

Operations to complete x18 TFCs

1. Casing integration and welding;
2. He piping inlet and outlet termination;
3. Surface finish;
4. Bolt holes preparation;
5. Final coil preparation.



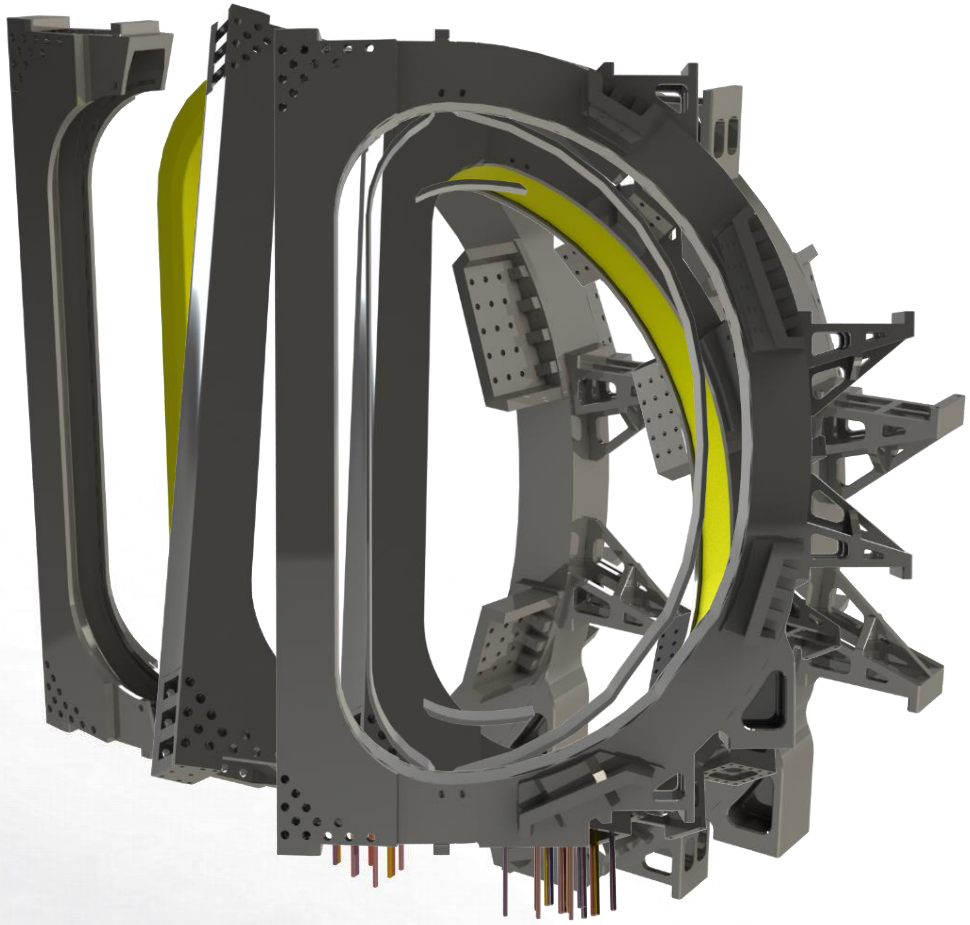
TFC Integration – Casing integration and welding

Preliminary actions:

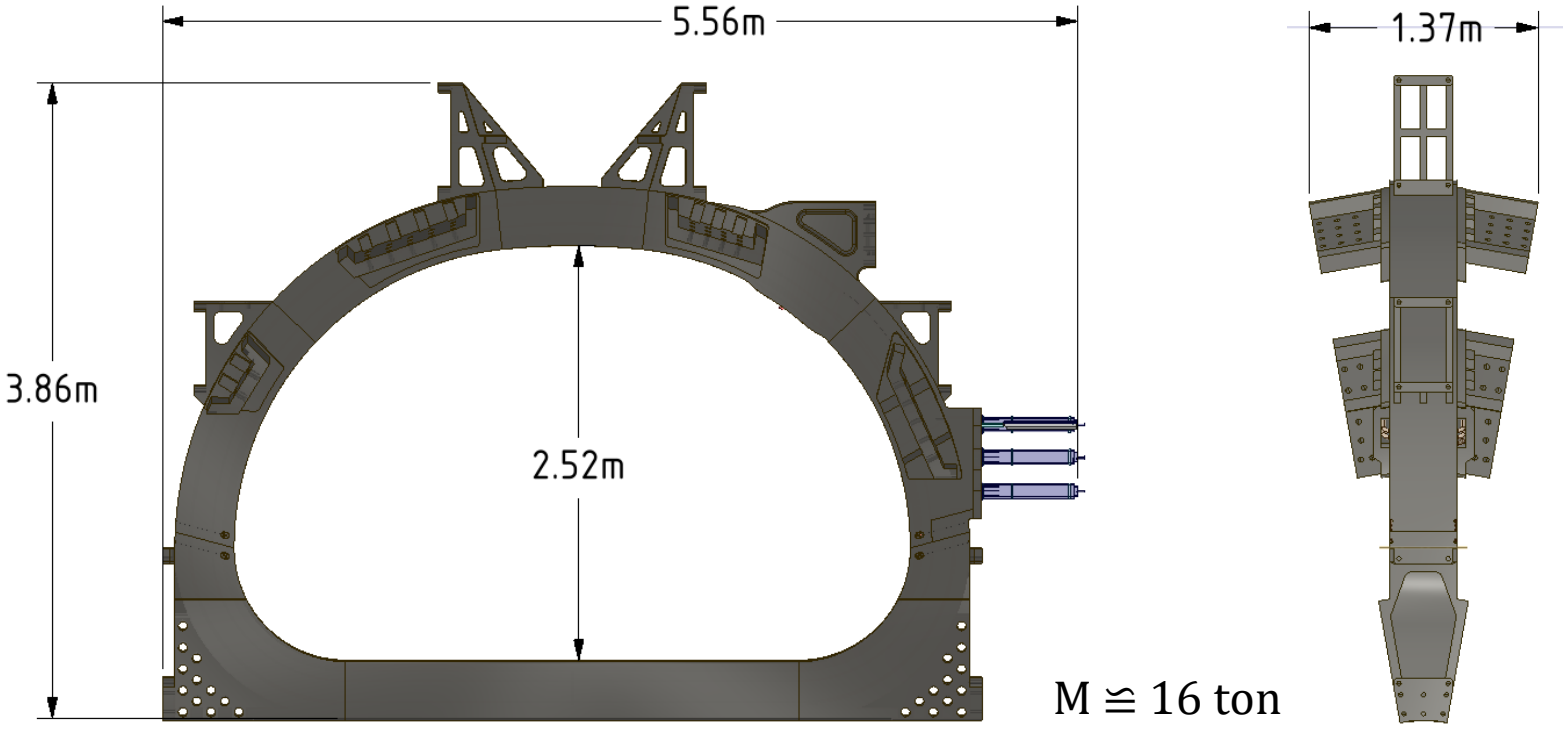
- Complete 1 m long WP mockup embedding inside 1 m long inboard leg mockup;
- Perform welding of 1 mockup of the Inboard-outboard-interface mockup.

Operations:

- Integrate 4 mm E-glass fiber as filler material;
- Embed the WP;
- Perform all welds;
- Perform non destructive tests on welds;
- Perform in-case impregnation & curing of filler material.



TFC Integration – Casing integration and welding

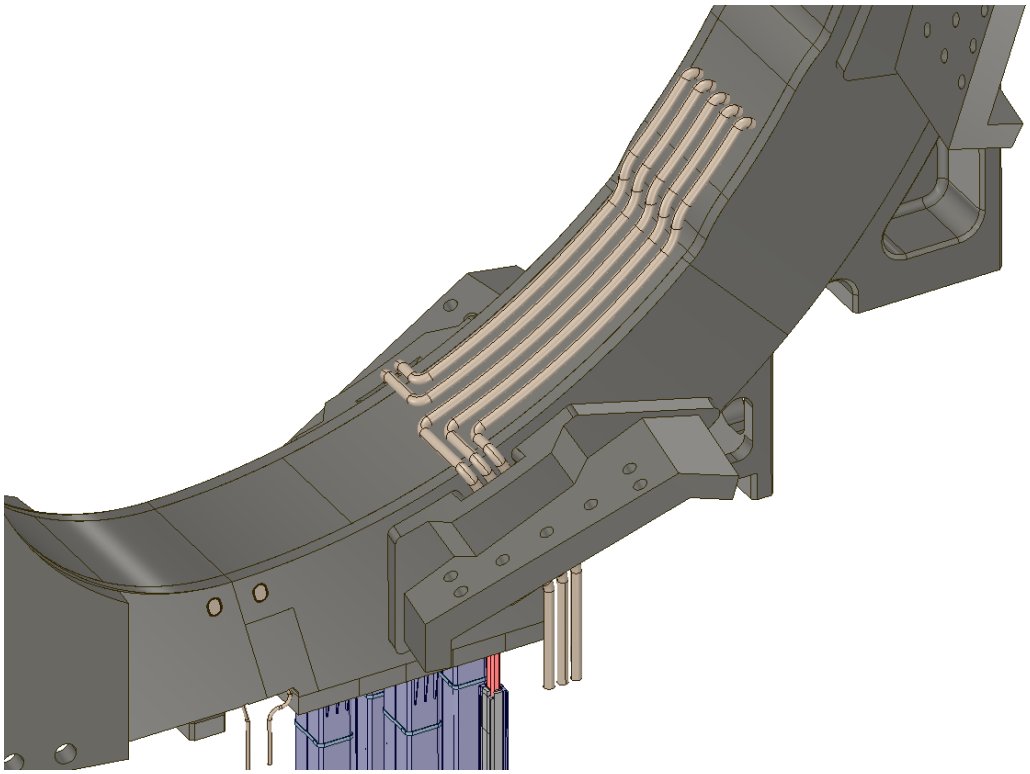


M ≅ 16 ton

Operations:

- Verify all tolerances are met;
- Verify relative position between inboard and outboard leg;
- Verify WP centerline position.

TFC Integration – He piping inlet and outlet termination + breaker installation



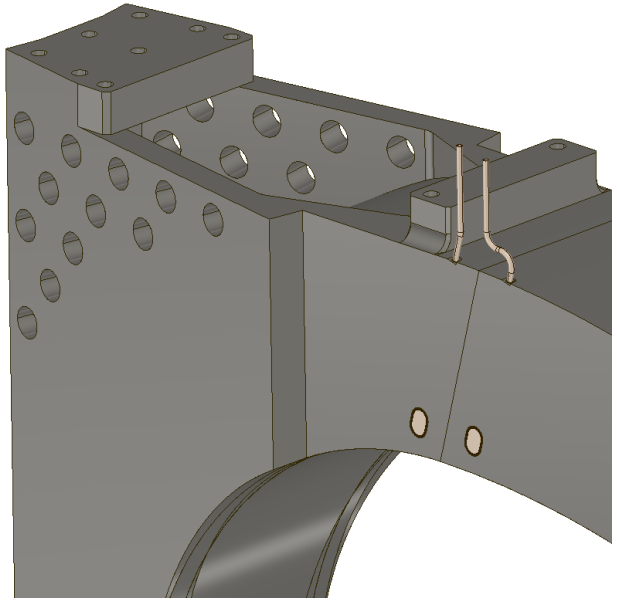
Operations:

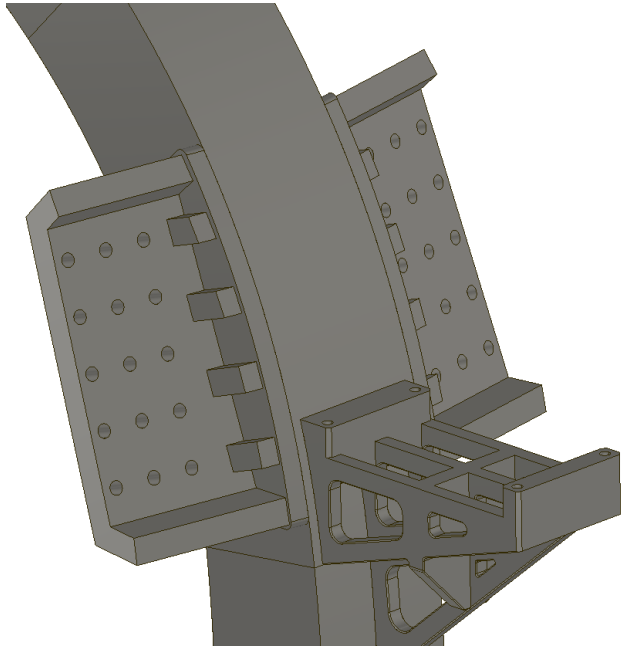
- Complete installation of Helium piping;
- Integrate the electric breaker to the terminations;
- Perform Helium leak test of all TFCs;
- Perform Paschen test at 3 kV of all TFCs.

TFC Integration – Surface finish + bolt holes preparation

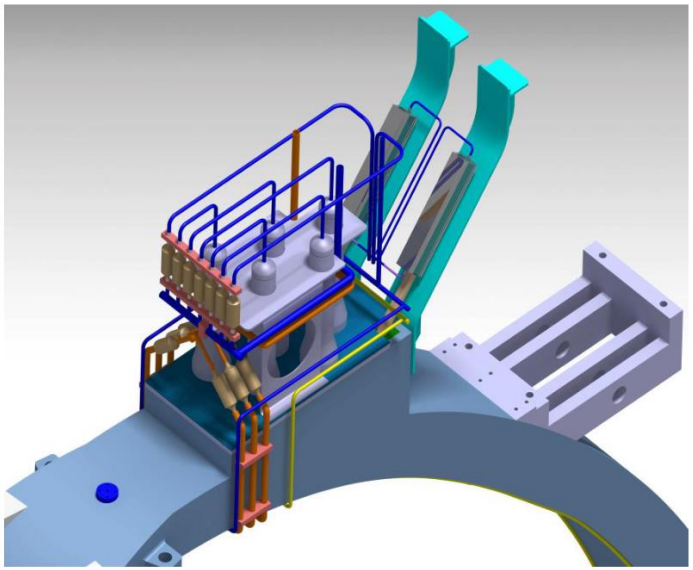
Operations:

- Finish the external surface of the TFCs for the assembly process;
- Drill holes for the installation of inter-coil structure bolts and leave material in excess to recover alignment tolerances during the assembly.



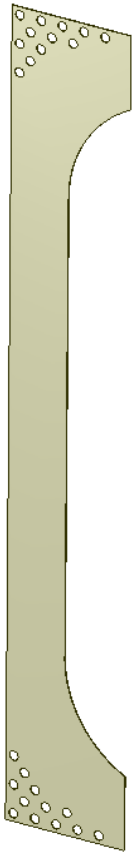


TFC Integration – final coil preparation



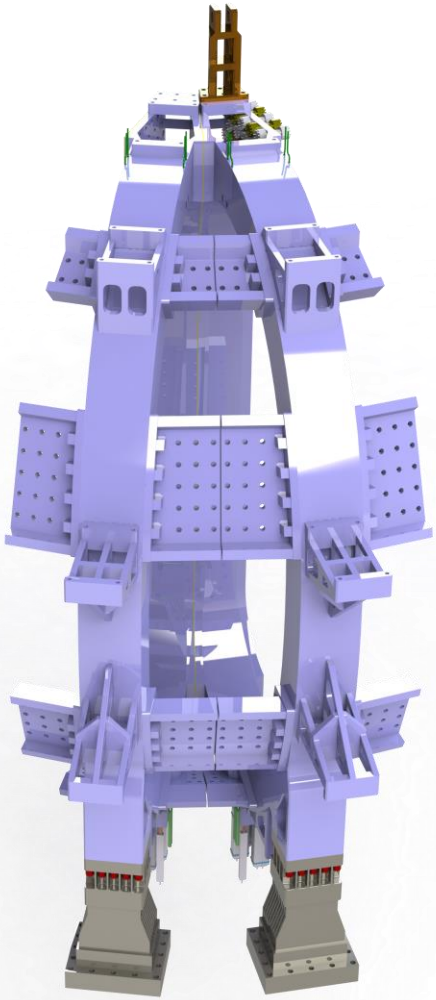
Operations:

- Prepare support structures to protect He-piping, inter-DP and termination joints during transport;
- Prepare the insulation plate to electrically insulate TFCs on the wedge;
- Prepare the transport jig for each TFC.



Conclusions & Recommendations

- 6 TFCs shall be completed by 2022;
- 3 complete TFCs shall be shipped to ENEA by 2022;
- All dimensions and tolerances included in this presentation will be subjected to review before being officially published in the Technical Specifications.



QUESTIONS?

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