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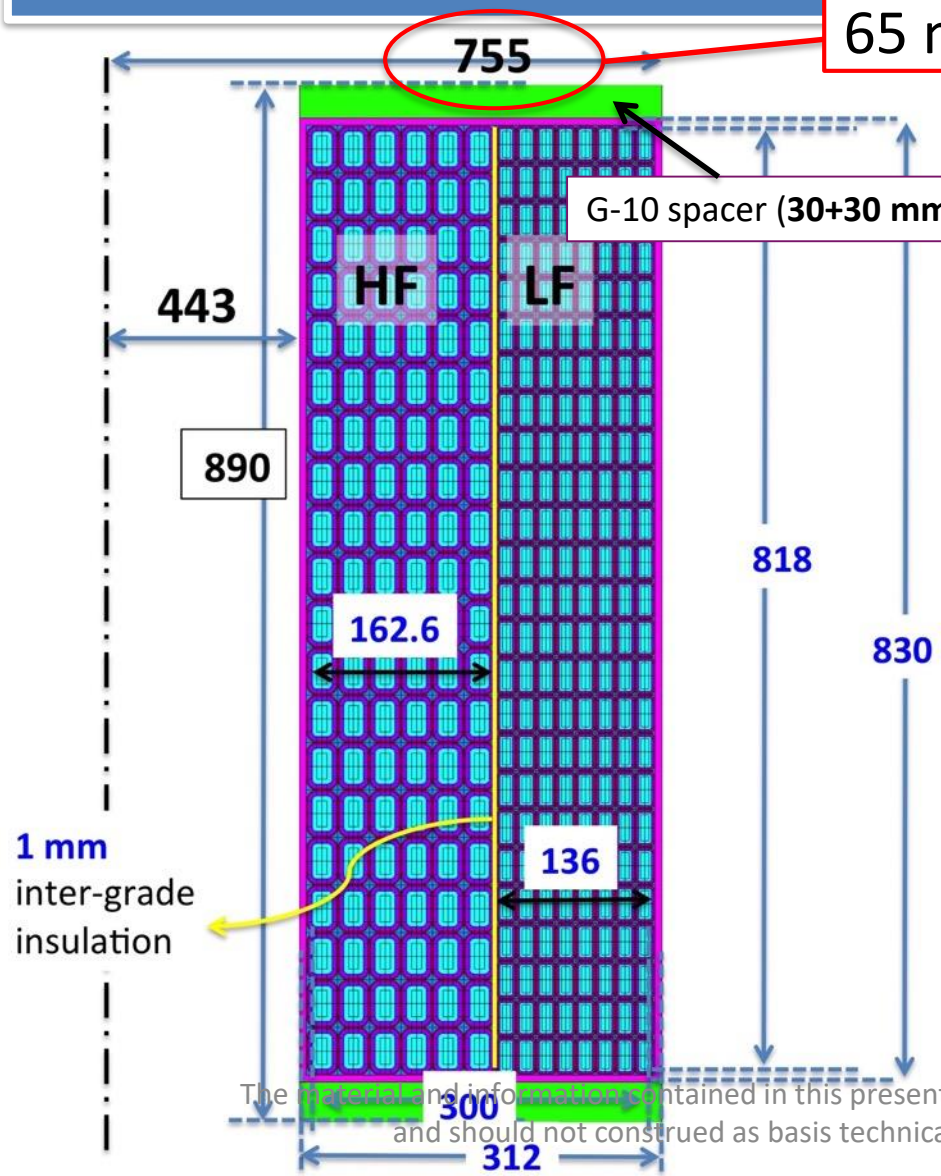
November 2019

CS Winding Pack and Support Structures

CS module: geometry

65 mm clearance wrt TF



DTT CS Coil_Layered_v50

HF:
6 x 20 = 120 turns

LF:
8 x 25 = 200 turns

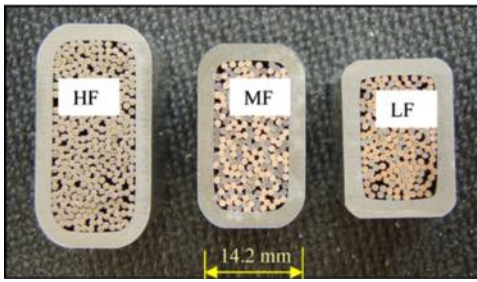
I_op: 29.04 kA

HF CICC (insulated):
40.9 x 27.1 mm²
Jack. Thickness: 4.1 mm
Turn insulation: 1 mm

LF CICC (insulated):
32.7 x 17.0 mm²
Jack. Thickness: 2.0 mm
Turn insulation: 1 mm

Similar CICC concepts

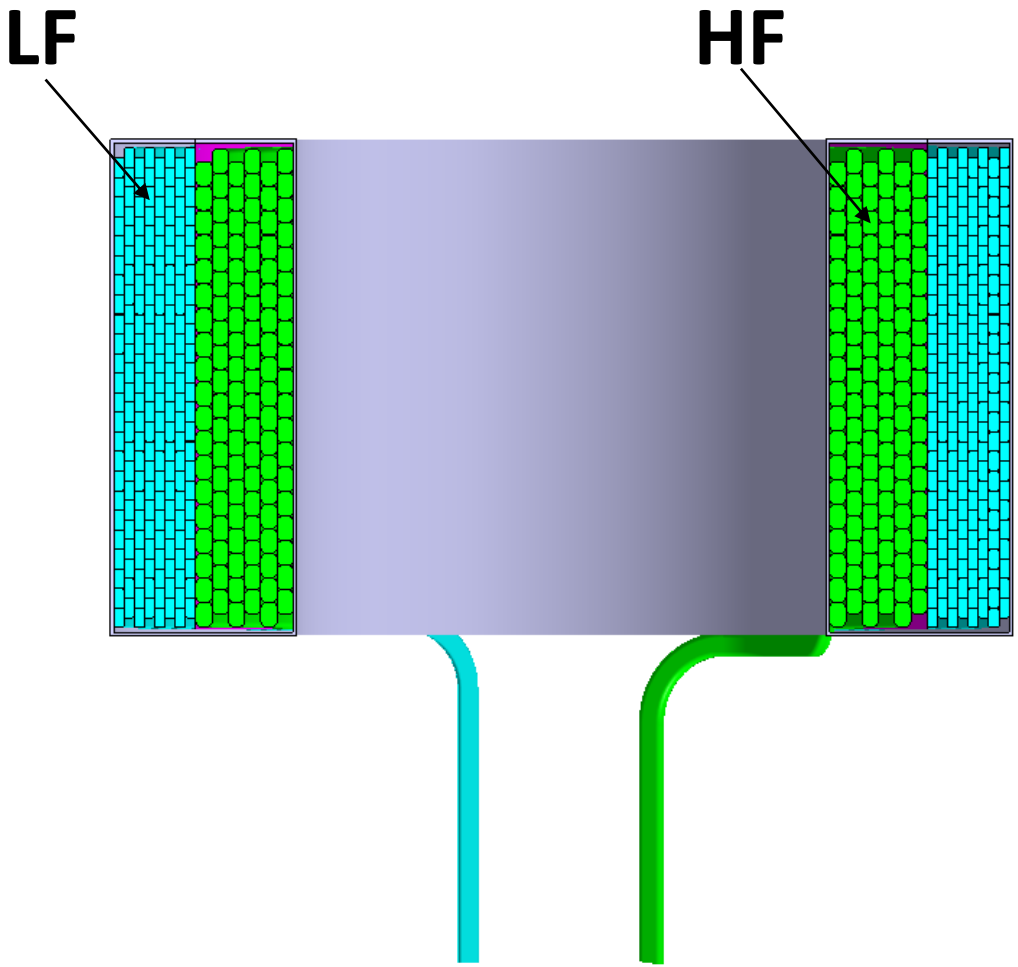
NHMFL



EU-Alt TF

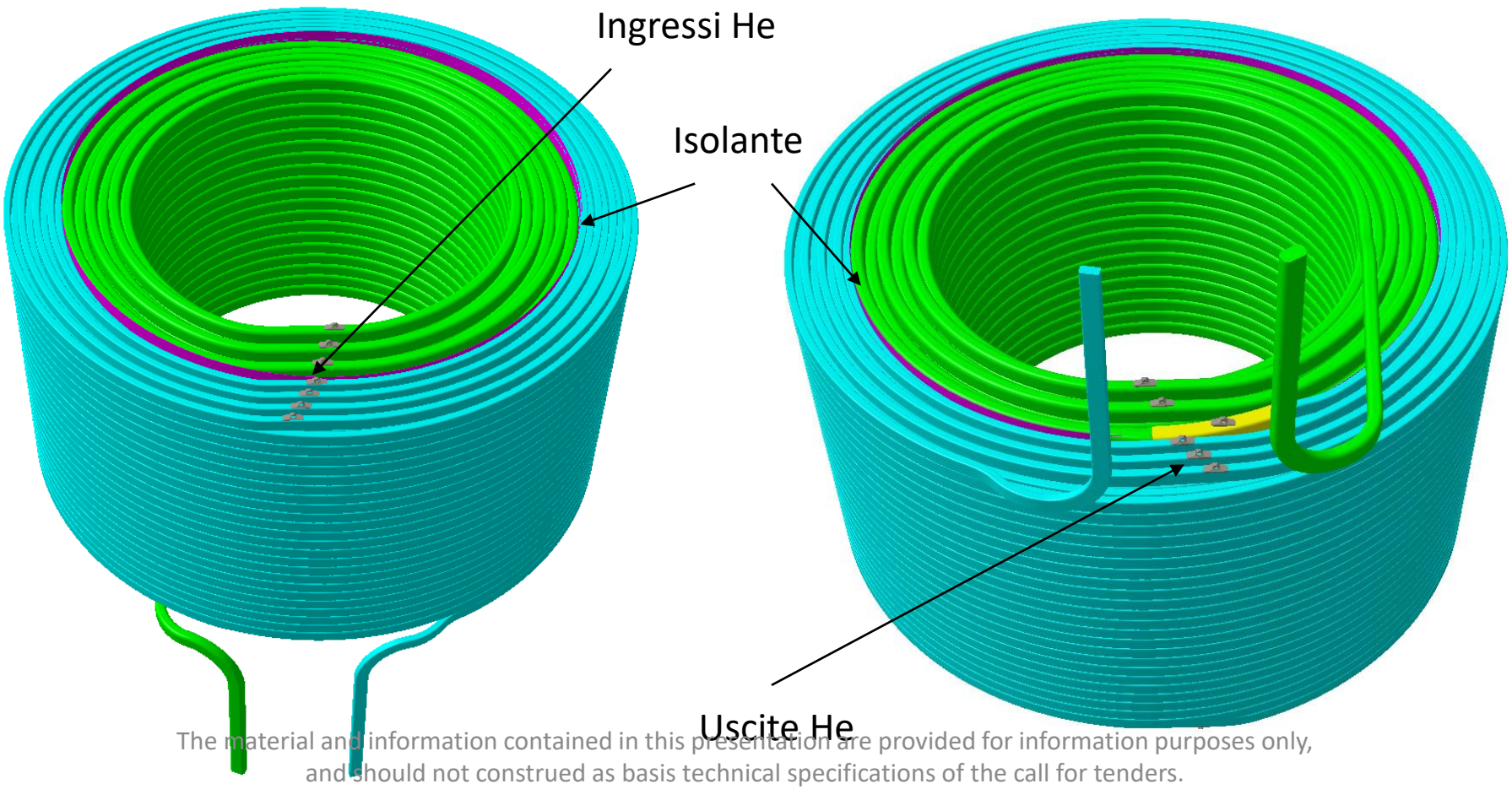
(All dimensions at 4 K)

CS module: winding configuration



CS module: winding configuration

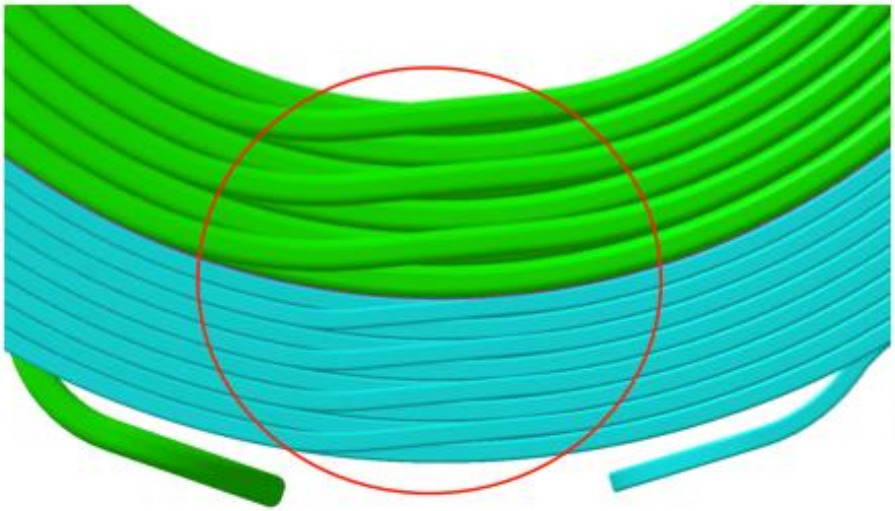
Sol. A: avvolgimento con salto spira distribuito



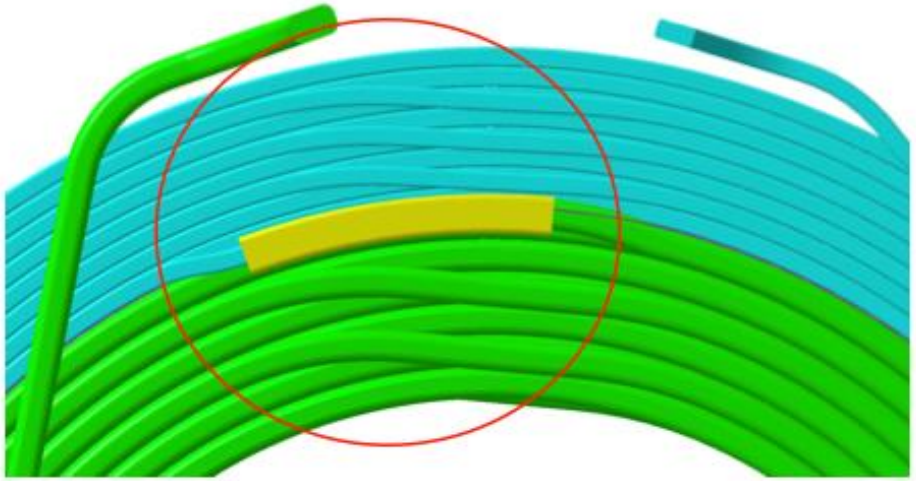
CS module: winding configuration

Sol. A: avvolgimento con salto spira distribuito

Vista da sopra



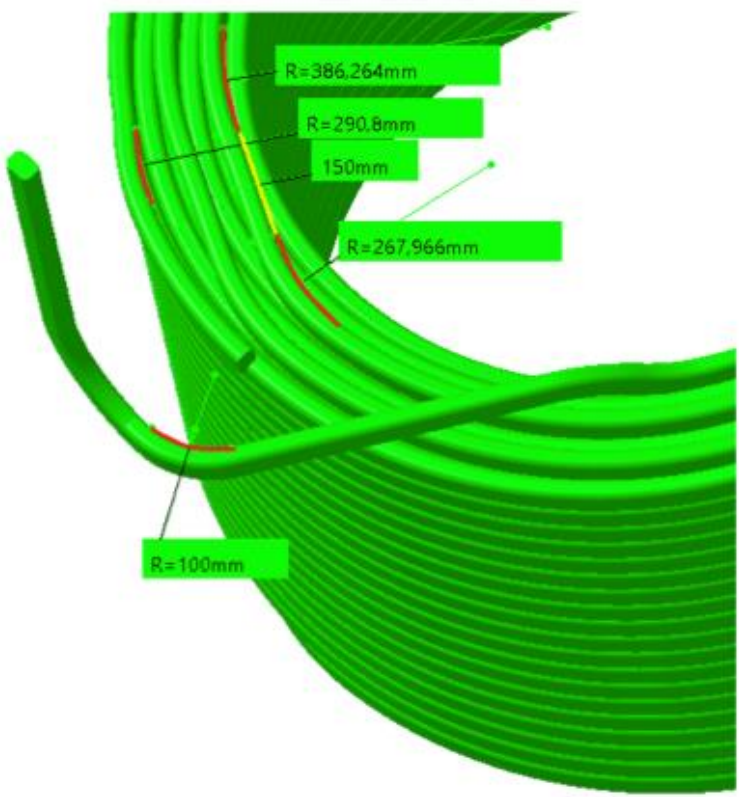
Vista da sotto

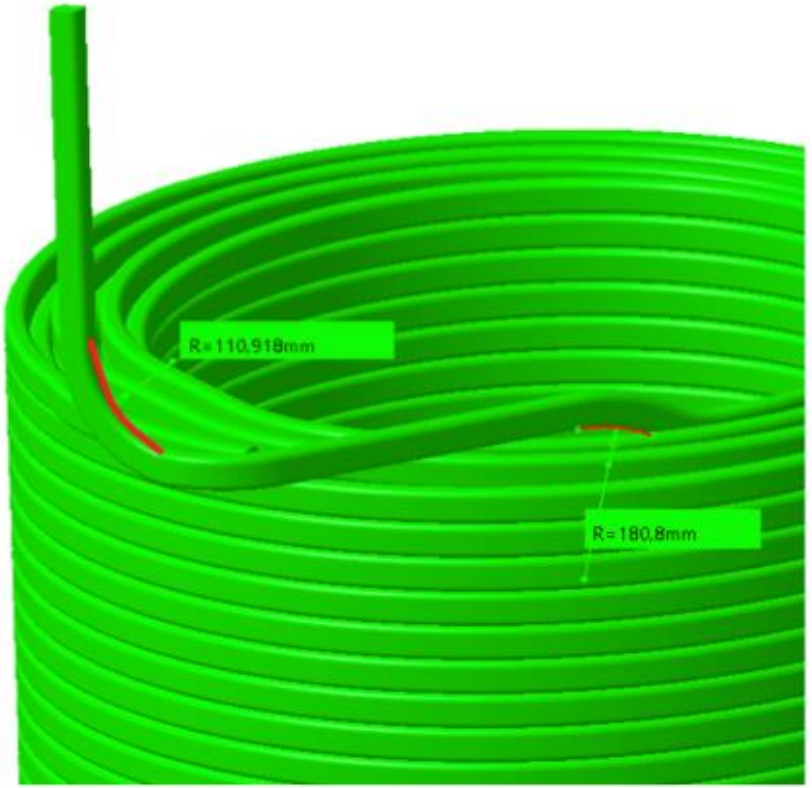


CS module: winding configuration

Sol. A: avvolgimento con salto spira distribuito

HF winding

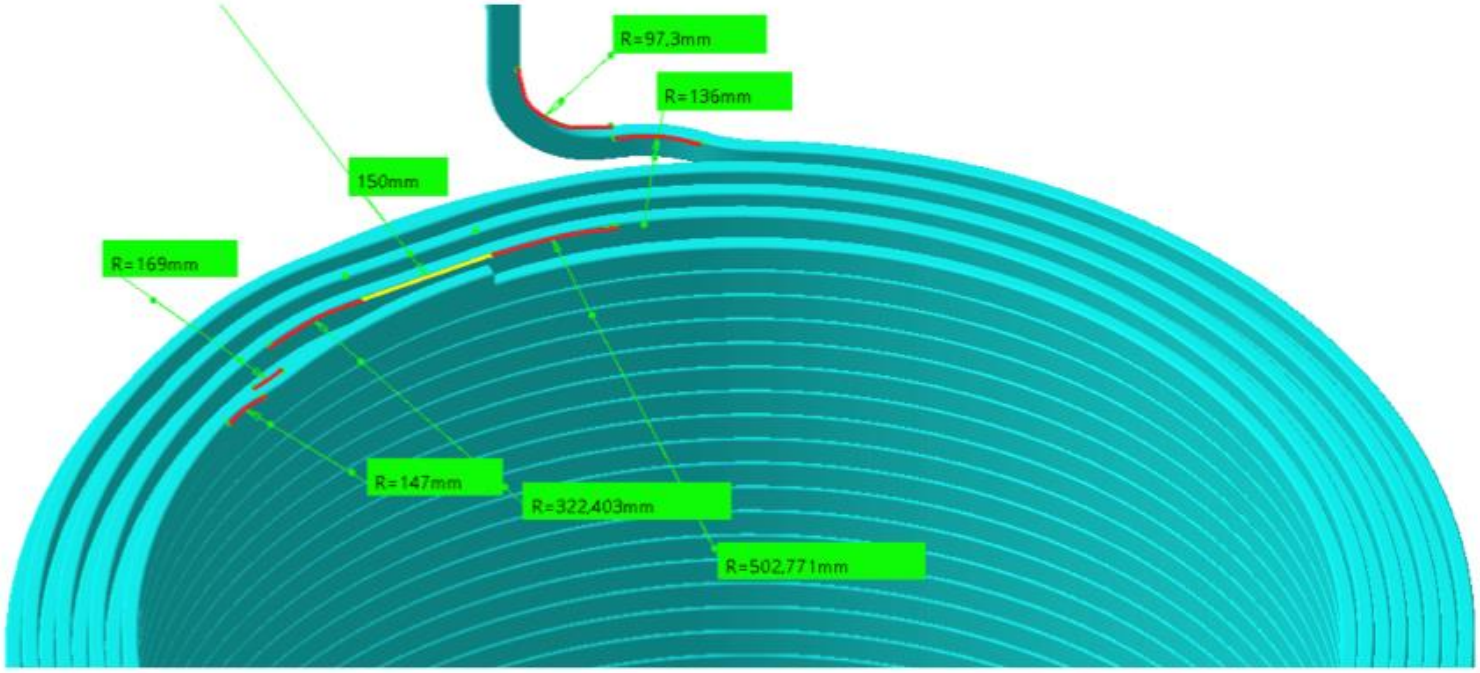




CS module: winding configuration

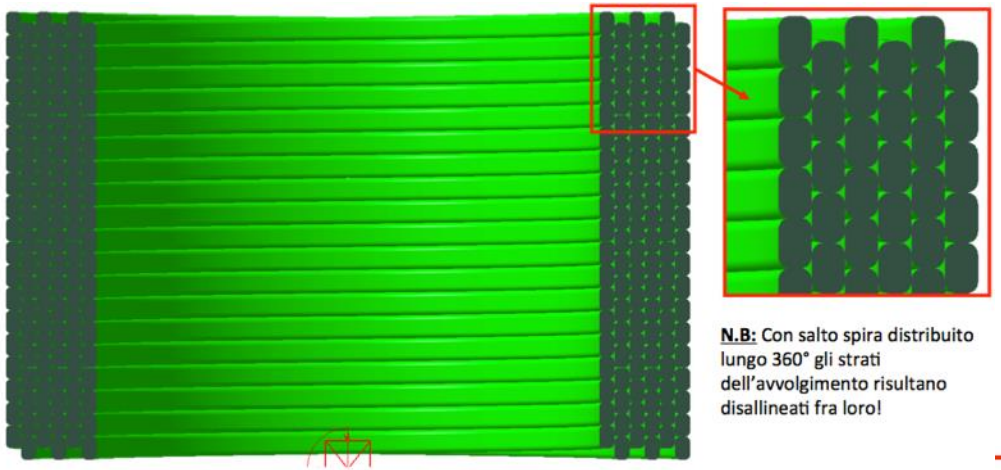
Sol. A: avvolgimento con salto spira distribuito

LF winding



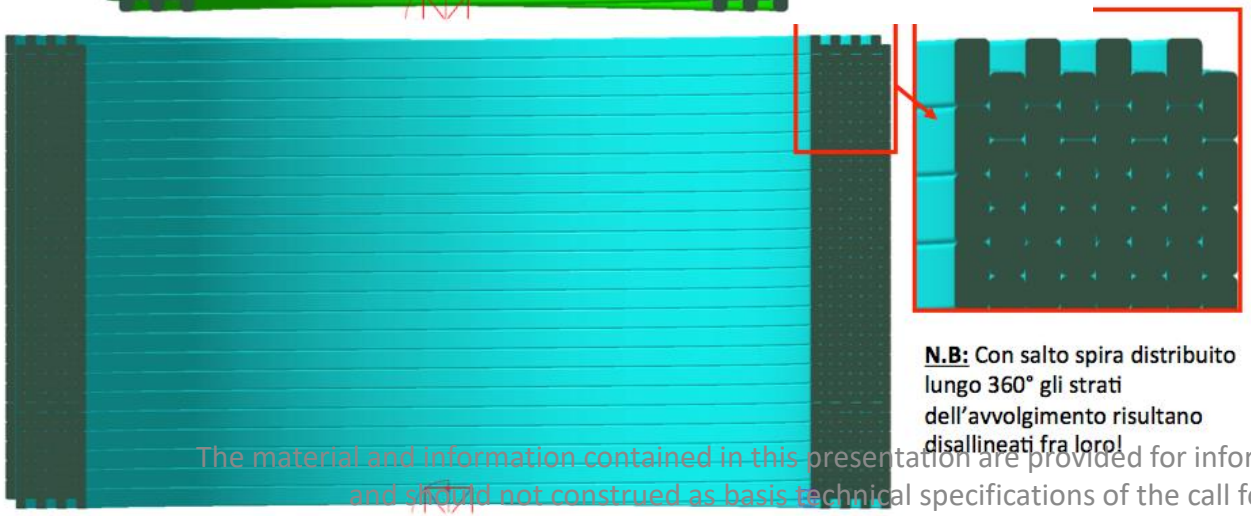
CS module: winding configuration

Sol. A: avvolgimento con salto spira distribuito



N.B: Con salto spira distribuito lungo 360° gli strati dell'avvolgimento risultano disallineati fra loro!

HF winding

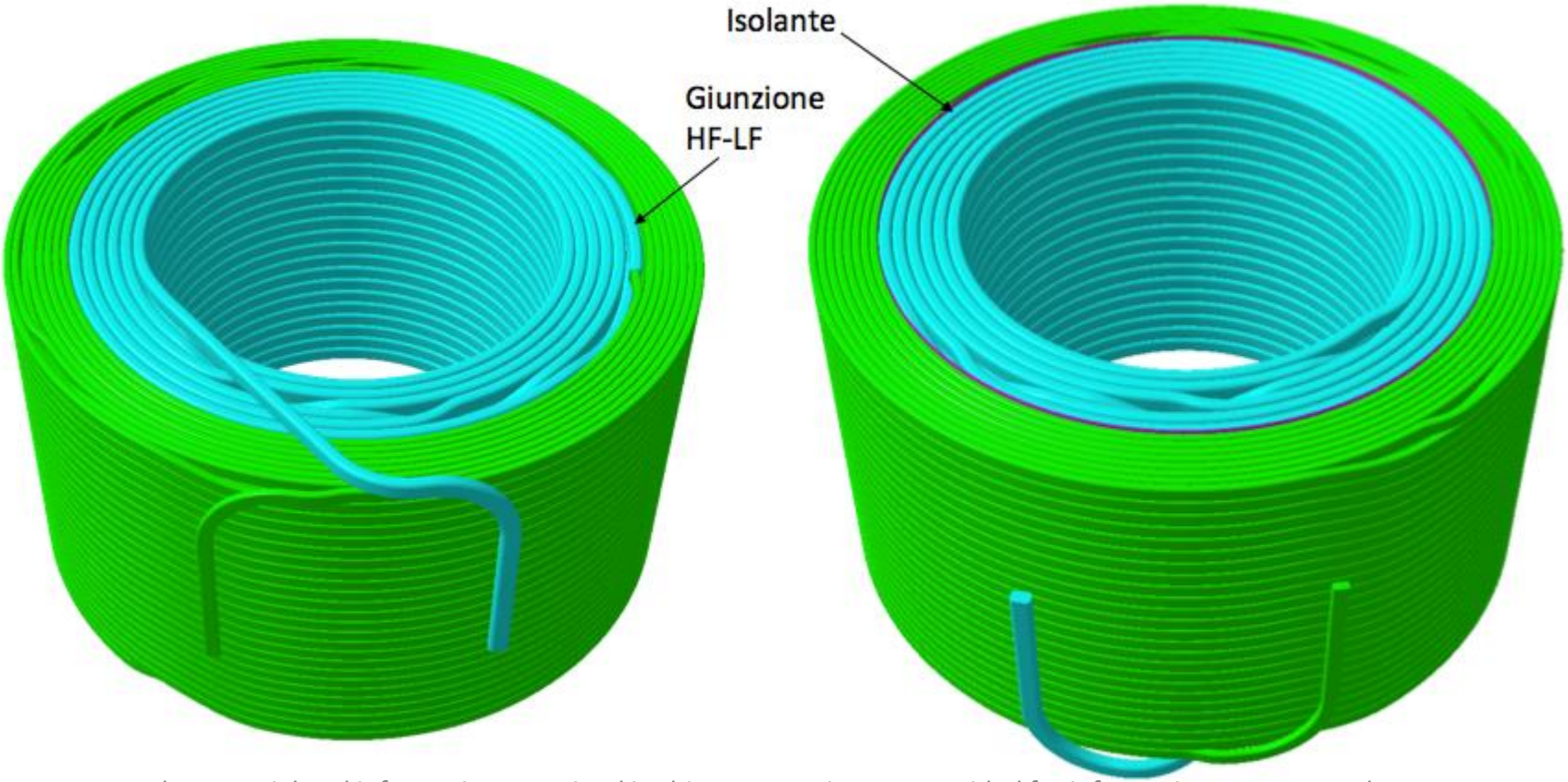


N.B: Con salto spira distribuito lungo 360° gli strati dell'avvolgimento risultano disallineati fra loro!

LF winding

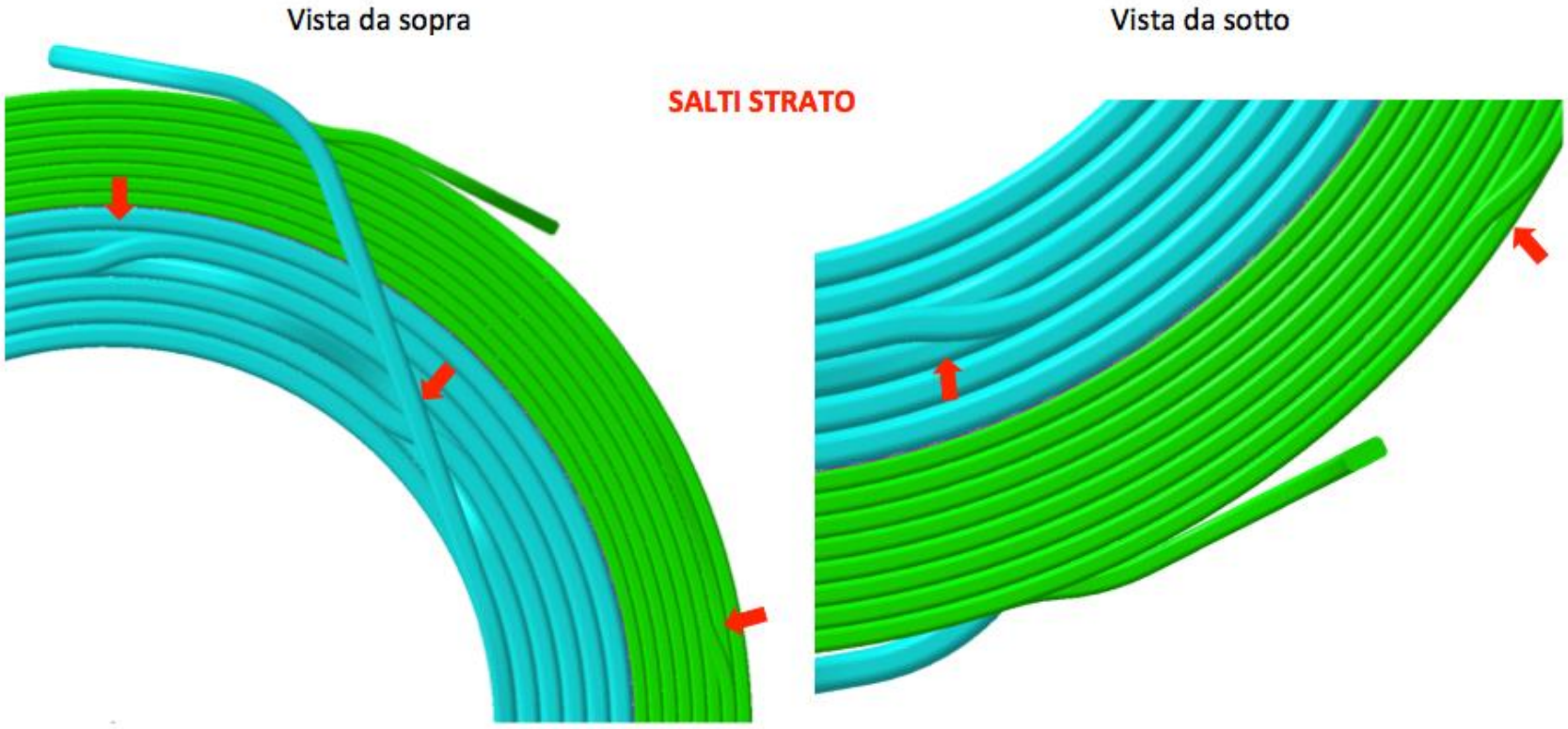
CS module: winding configuration

Sol. B: avvolgimento con salto spira concentrato



CS module: winding configuration

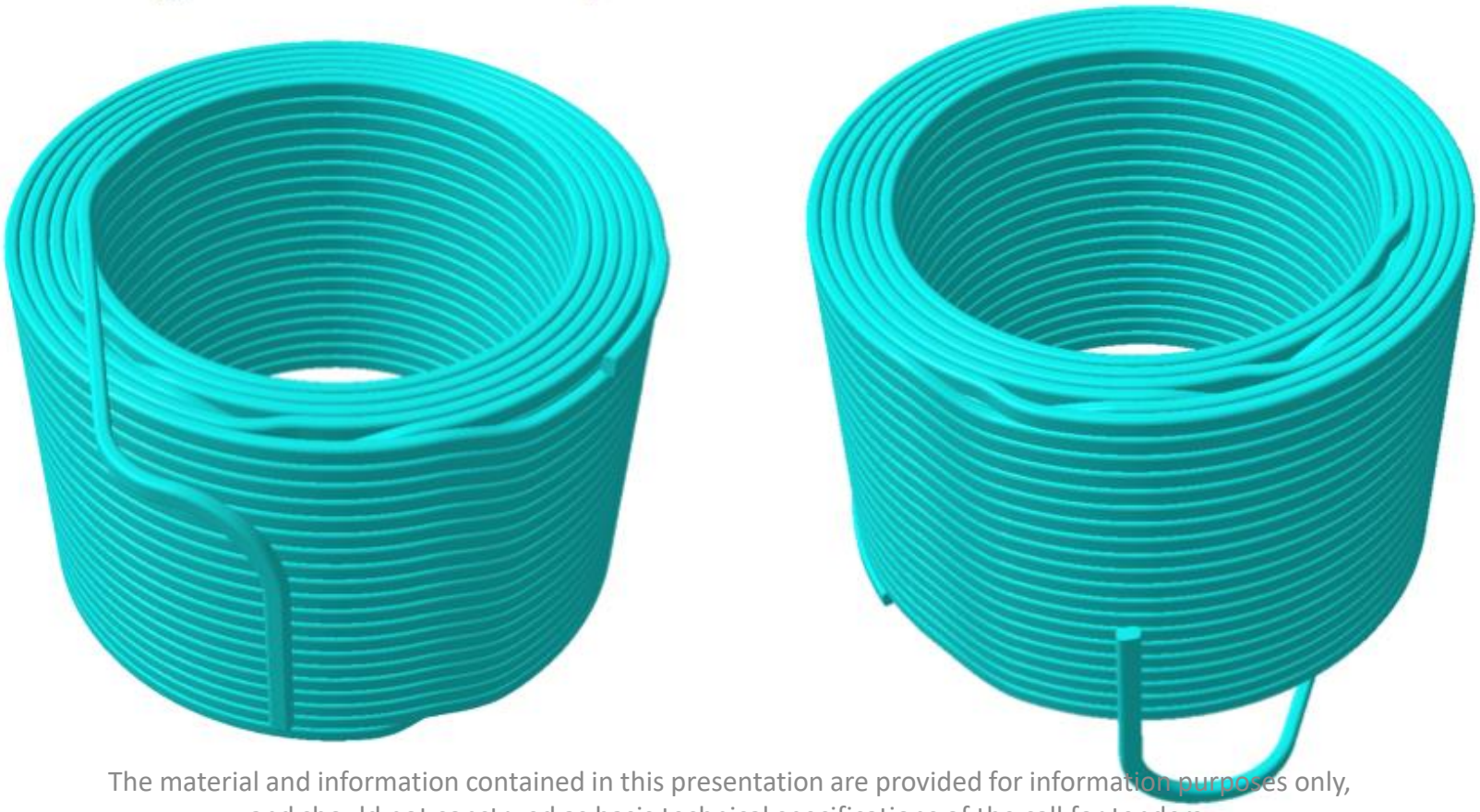
Sol. B: avvolgimento con salto spira concentrato



CS module: winding configuration

Sol. B: avvolgimento con salto spira concentrato

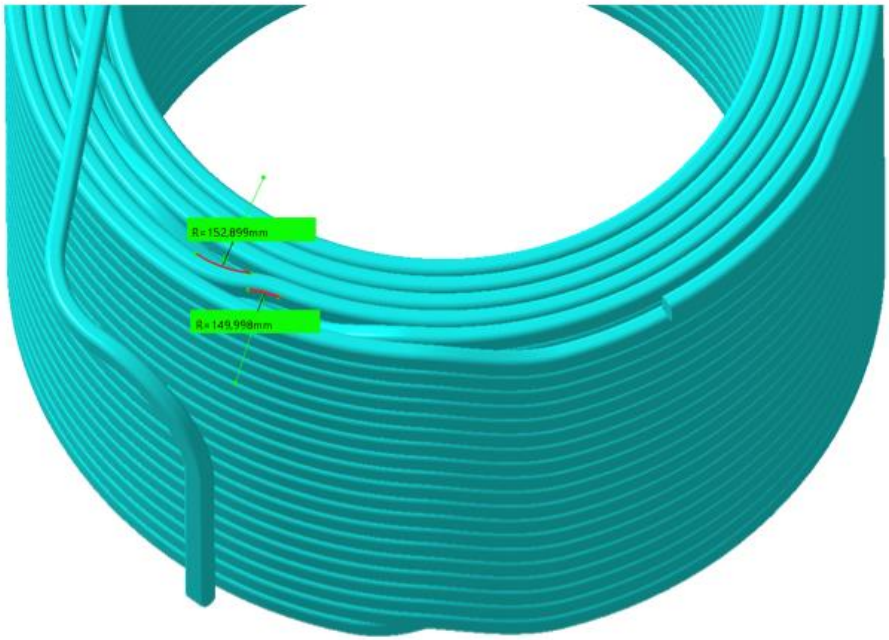
HF Winding



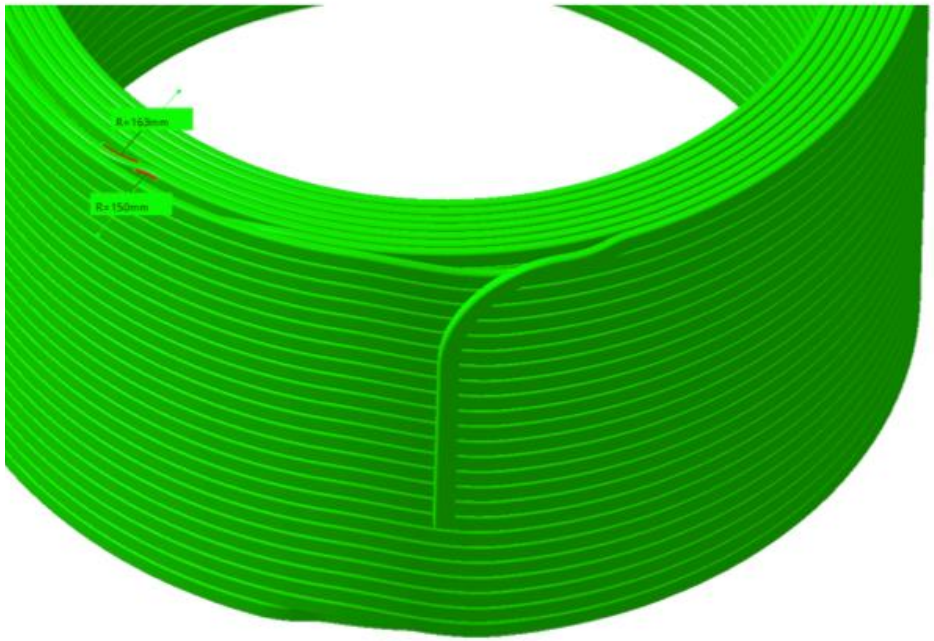
CS module: winding configuration

Sol. B: avvolgimento con salto spira concentrato

HF winding

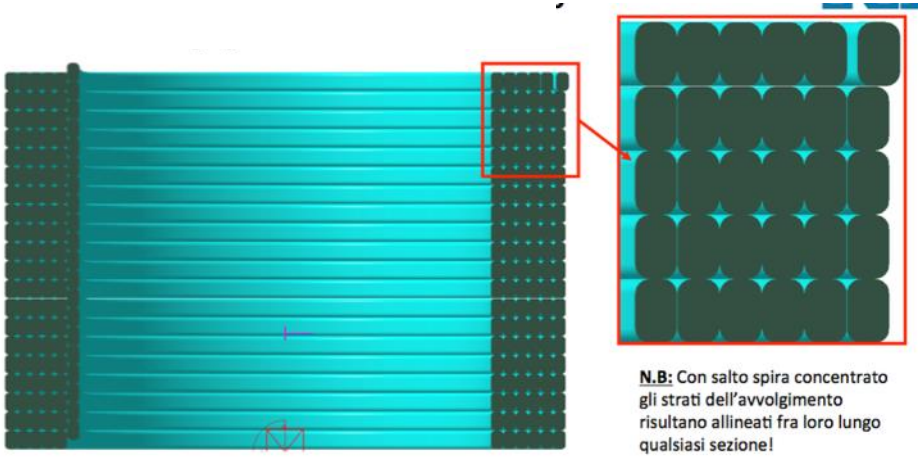


LF winding



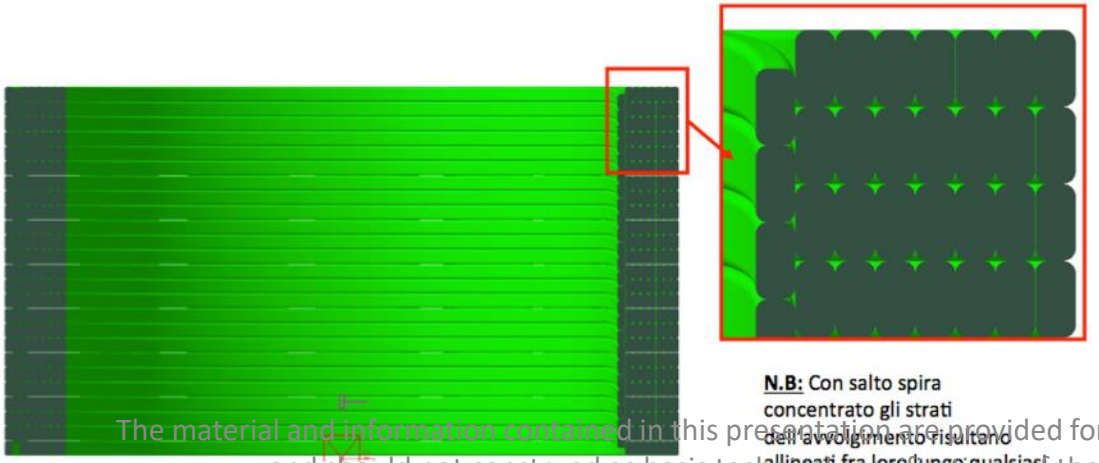
CS module: winding configuration

Sol. B: avvolgimento con salto spira concentrato



N.B: Con salto spira concentrato gli strati dell'avvolgimento risultano allineati fra loro lungo qualsiasi sezione!

HF winding



N.B: Con salto spira concentrato gli strati dell'avvolgimento risultano allineati fra loro lungo qualsiasi sezione!

LF winding

CS module: manufacturing approach

Wind & Insulate → React → Impregnate manufacturing approach

- Insulation to be applied during coil winding, before the Nb_3Sn reaction heat treatment:

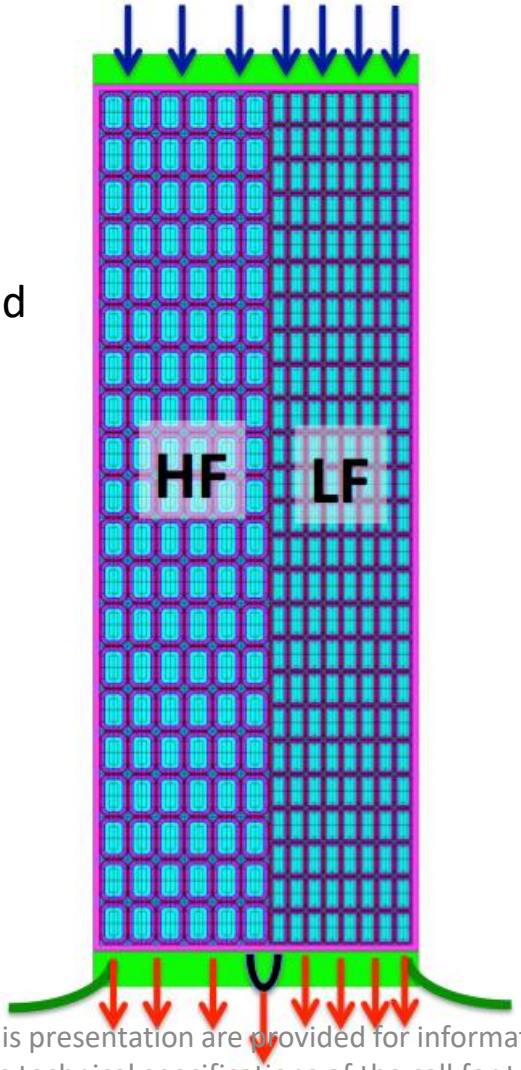
  → turn insulation will not rely on Kapton: but according to computations, it is not necessary for the expected voltage levels (*3.5 kV peak terminal-to-terminal Voltage at plasma breakdown*);

  → most appropriate choice of insulation material (S-glass ? / resin type ?) and manufacturing process?

CS module: HF to LF joint

- Two terminations and one inter-layer joint per module.

- Inter-layer joint: **either** manufactured on the external part of the coil, BUT 65 mm clearance wrt TF.



DTT CS Coil_Layered_v50
Layout 1

Joint 1: HF-LF

Internal termination

External termination

He outlet

He inlet

2 terminations
2 intermediate joints
7 He inlets
8 He outlets

CS module: HF to LF joint

- Two terminations and one inter-layer joint per module.

- Inter-layer joint: **either** manufactured on the external part of the coil, BUT 65 mm clearance wrt TF.

- **or** use “internal” joint, manufactured in-line during winding, thus embedded within the winding pack (*EDIPO / NAFASSY / ITER CS – like*).

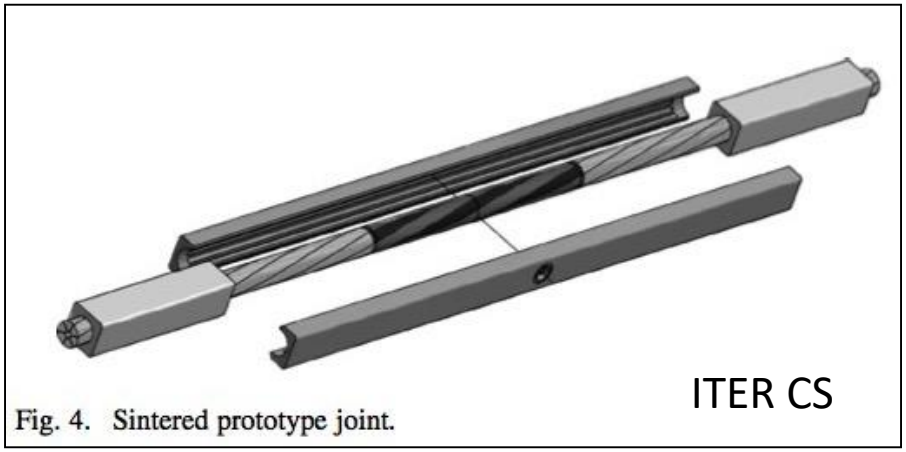
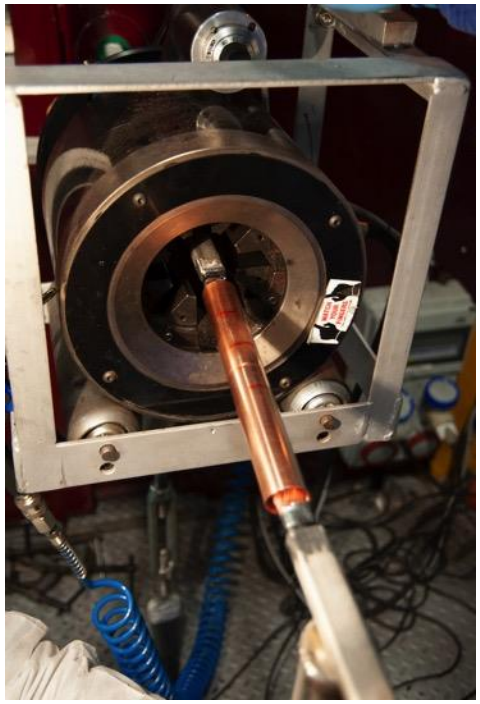


Fig. 4. Sintered prototype joint.

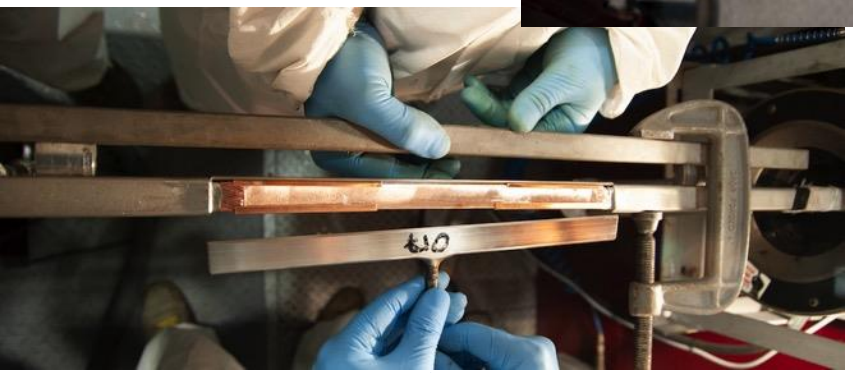
ITER CS

NAFASSY

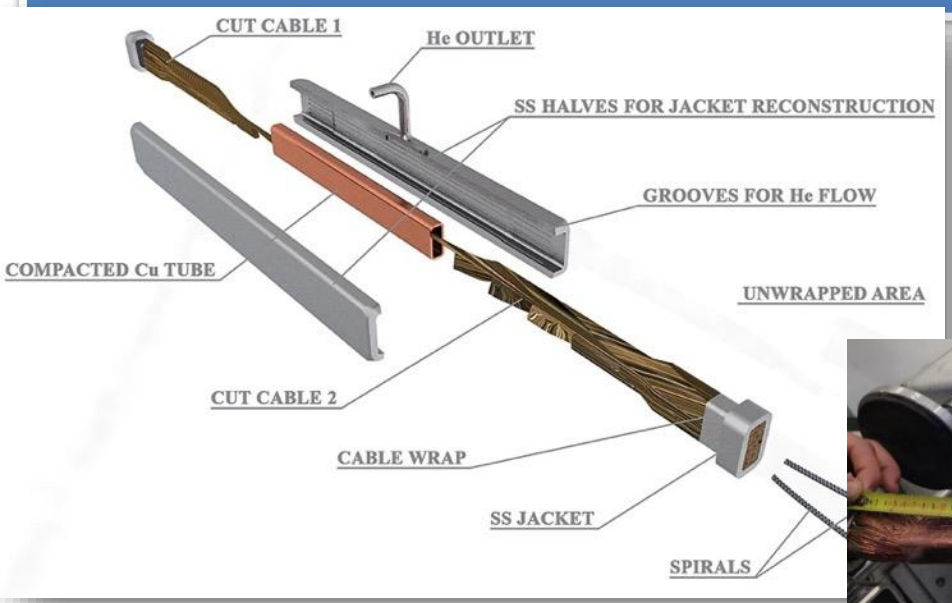
NAFASSY Interlayer Joint

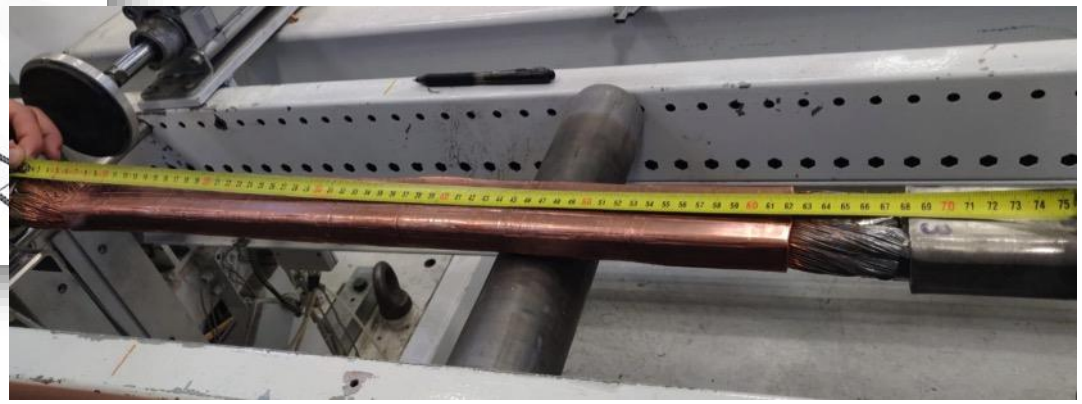


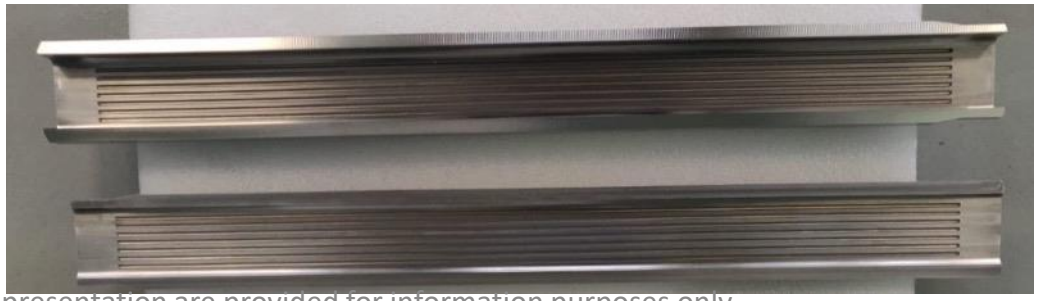
NAFASSY Interlayer Joint



DEMO TF Interlayer Joint



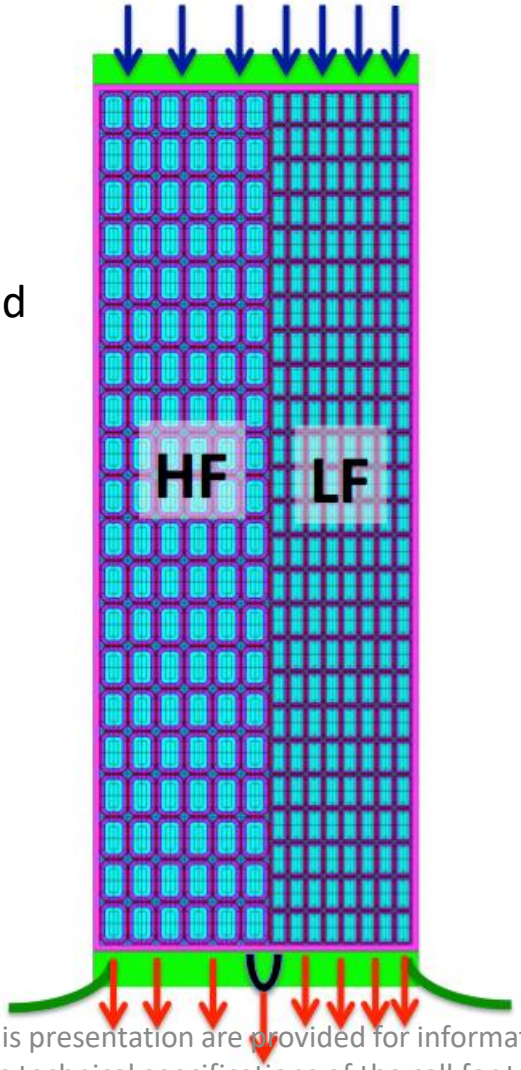




CS module: HF to LF joint

- Two terminations and one inter-layer joint per module.

- Inter-layer joint: **either** manufactured on the external part of the coil, BUT 65 mm clearance wrt TF.



DTT CS Coil_Layered_v50
Layout 1

Joint 1: HF-LF

Internal termination

External termination

He outlet

He inlet

2 terminations
2 intermediate joints
7 He inlets
8 He outlets

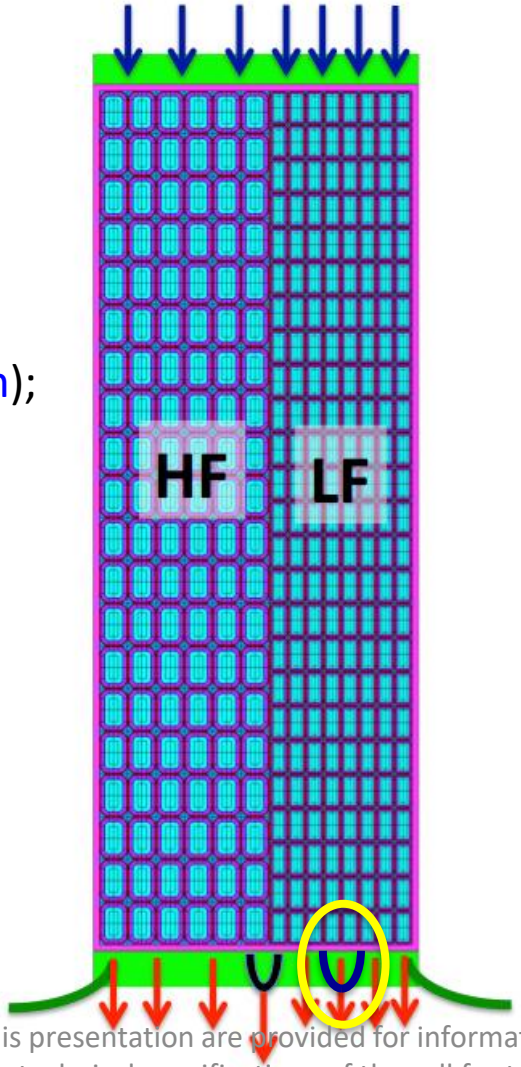
CS module: HF to LF joint

- Two terminations and ~~one~~ two inter-layer joint per module.

- STILL UNDER DISCUSSION:

  LF CICC maybe too long (870m);

so, the LF Winding might be interrupted by an additional (LF to LF) intermediate joint.



DTT CS Coil_Layered_v50
Layout 1

Joint 1: HF-LF

Internal termination

External termination

He outlet

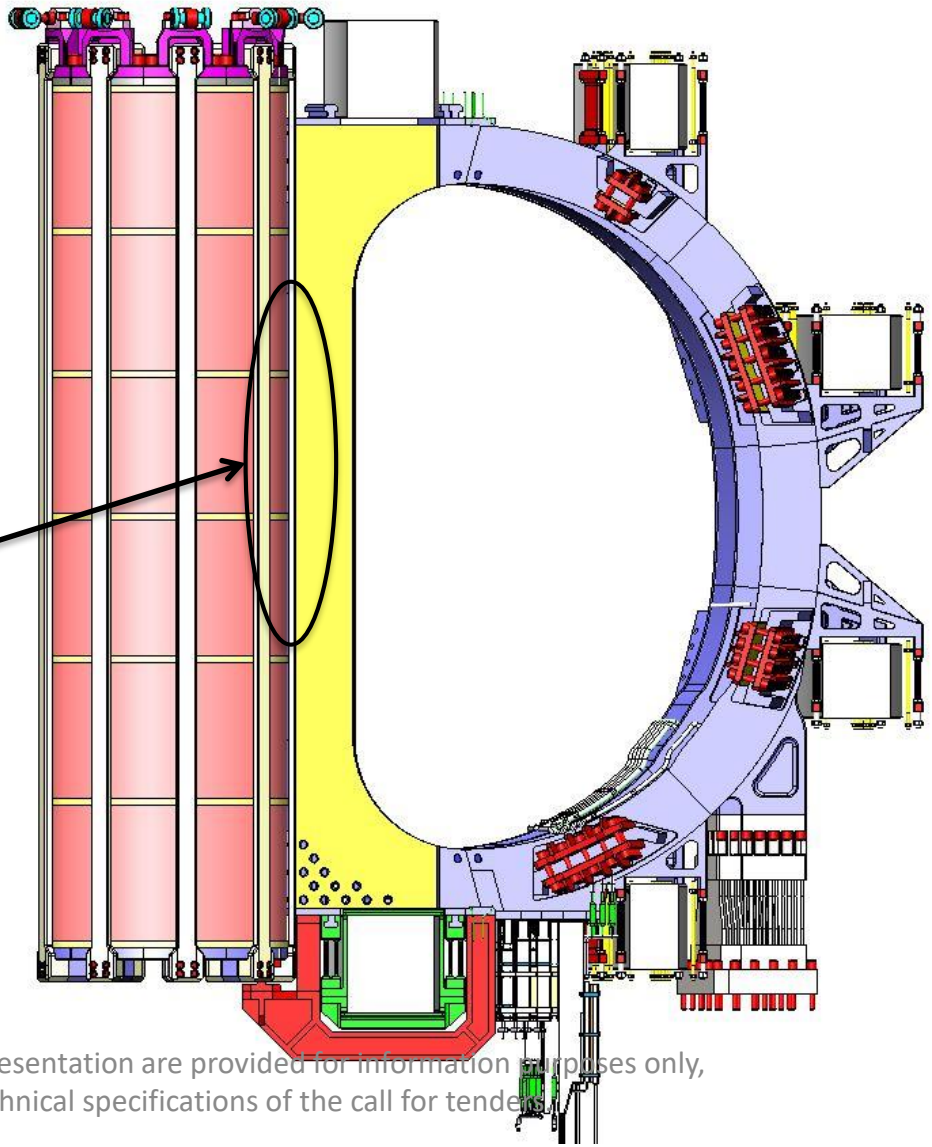
He inlet

2 terminations
2 intermediate joints
7 He inlets
8 He outlets

CS module: termination box

Still to be designed.

Space constraints are extremely demanding!

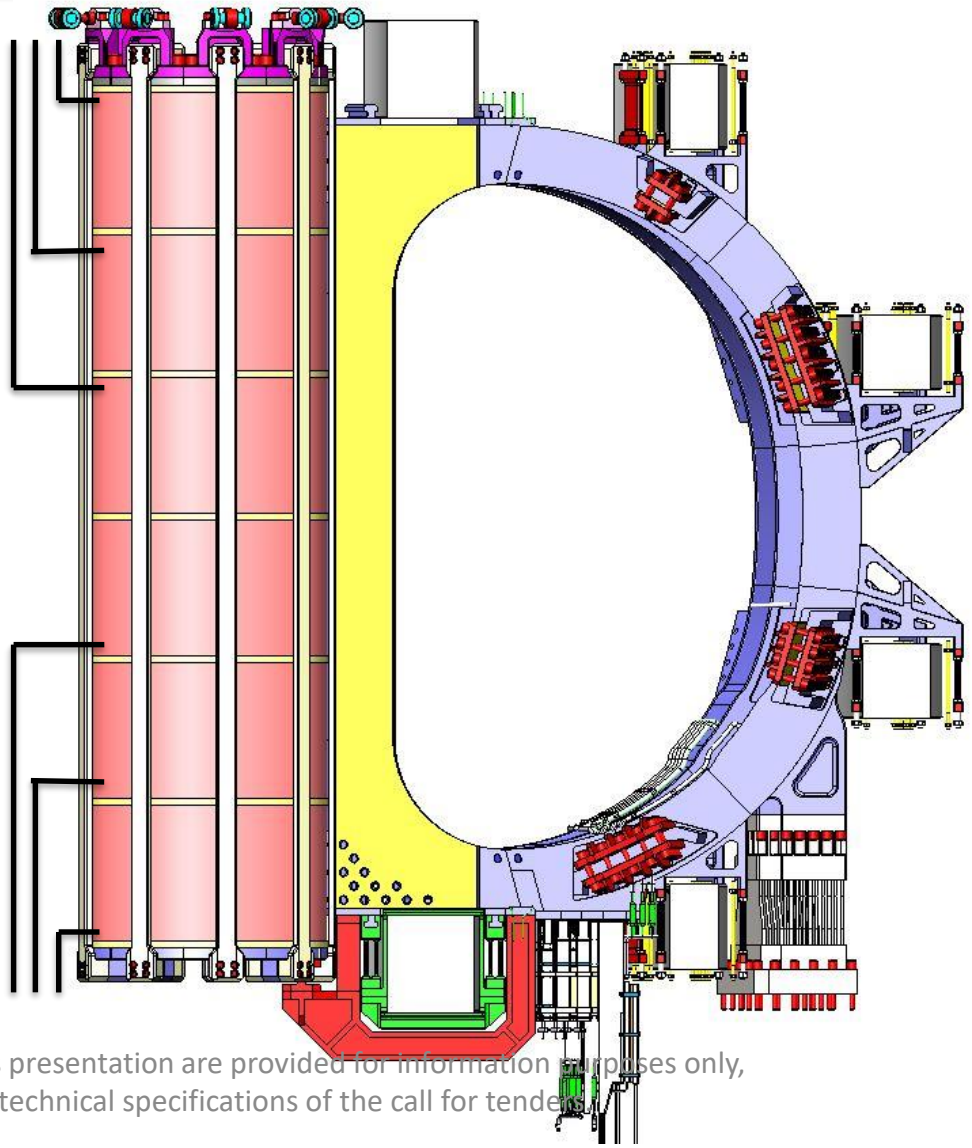


CS module: termination box

Still to be designed.

Space constraints are extremely demanding!

What about extending terminal lengths well outside the module height, thus avoiding joints?



CS module: additional issues

Corner regions:

- S-glass cord

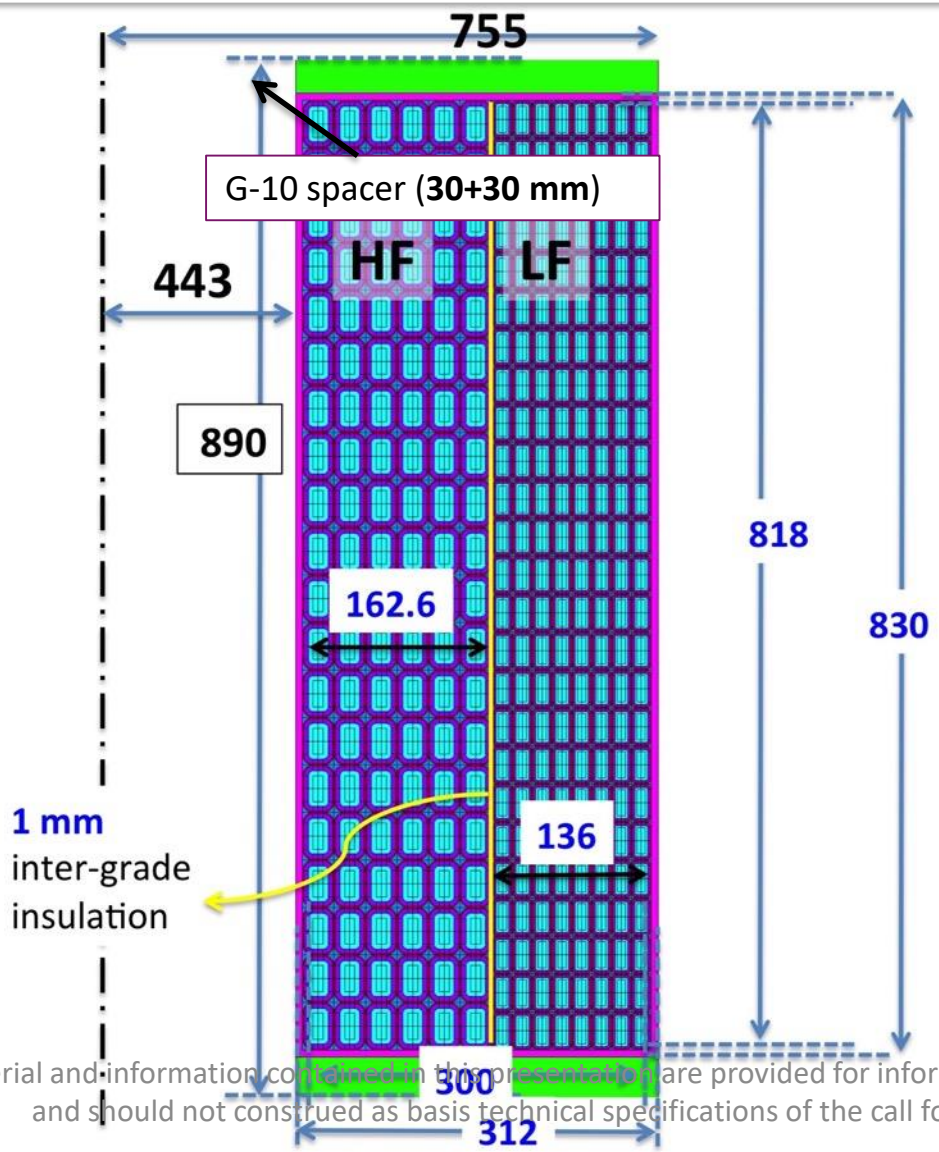
OR

- Glass insulated steel wire (useful also for co-wound V tap)

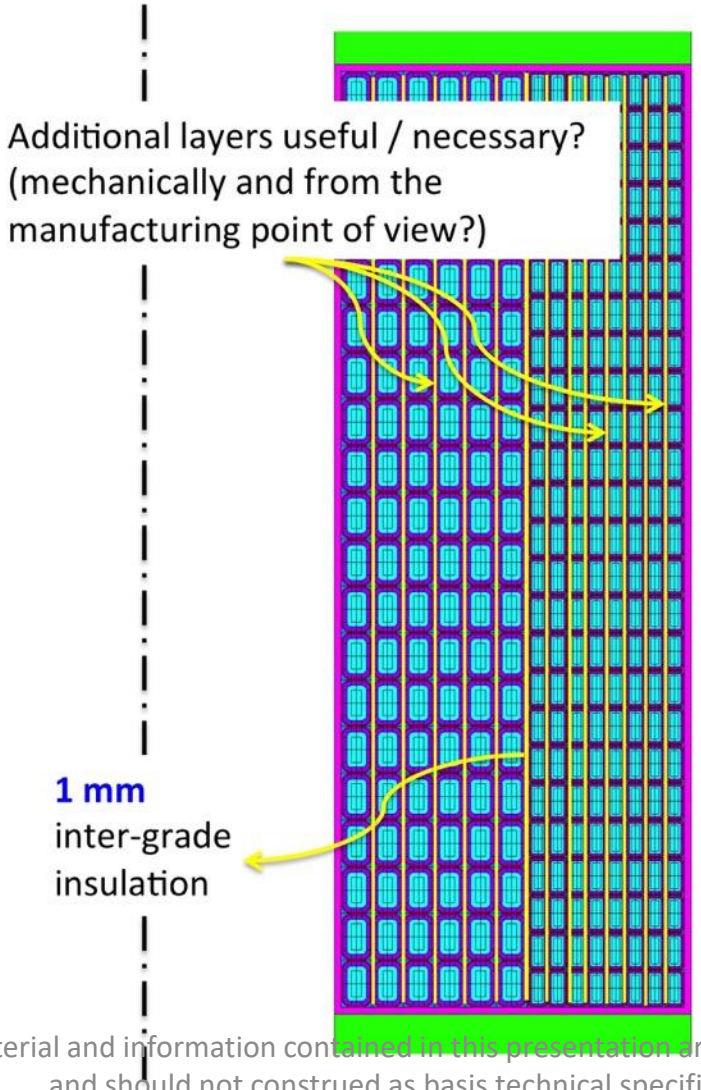
Co-wound tape for quench detection:

- fabric tape wrapped around the conductor (e.g. KSTAR CS)

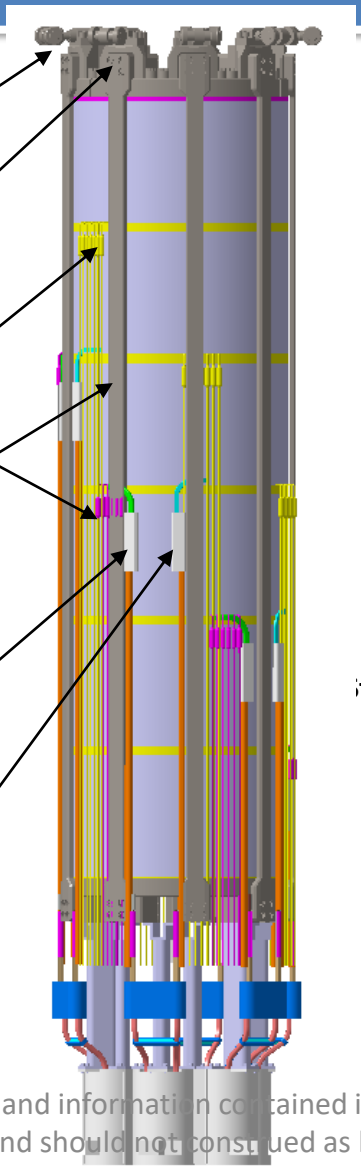
CS module: additional issues

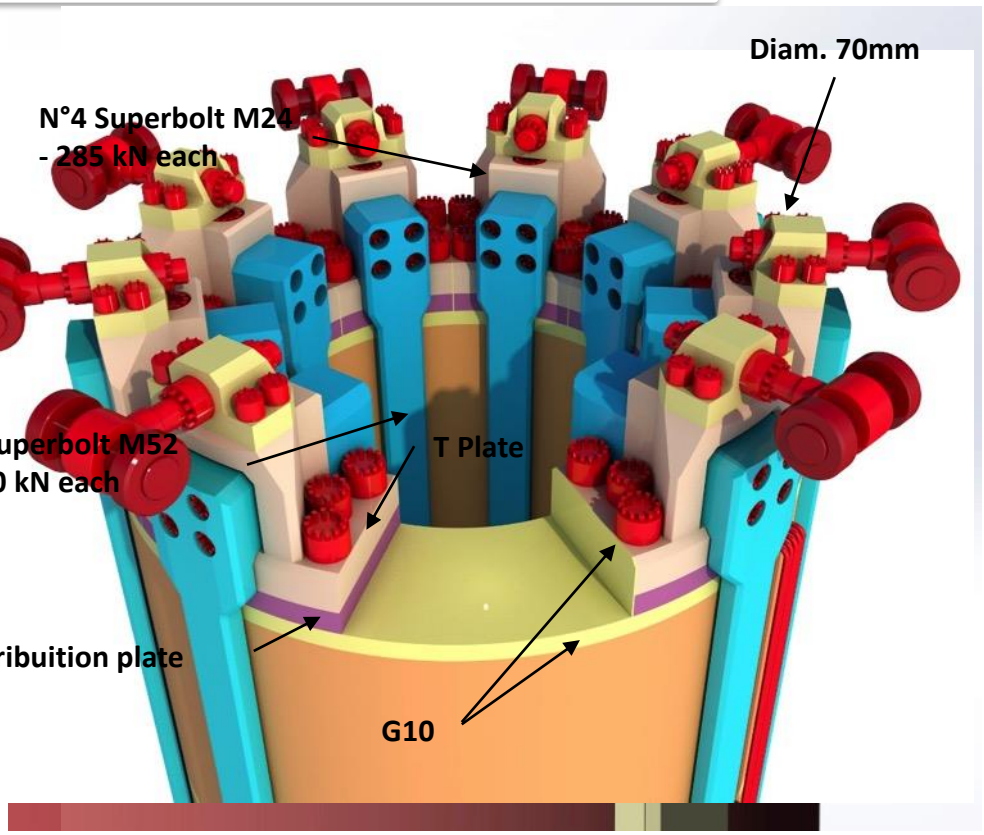


CS module: additional issues

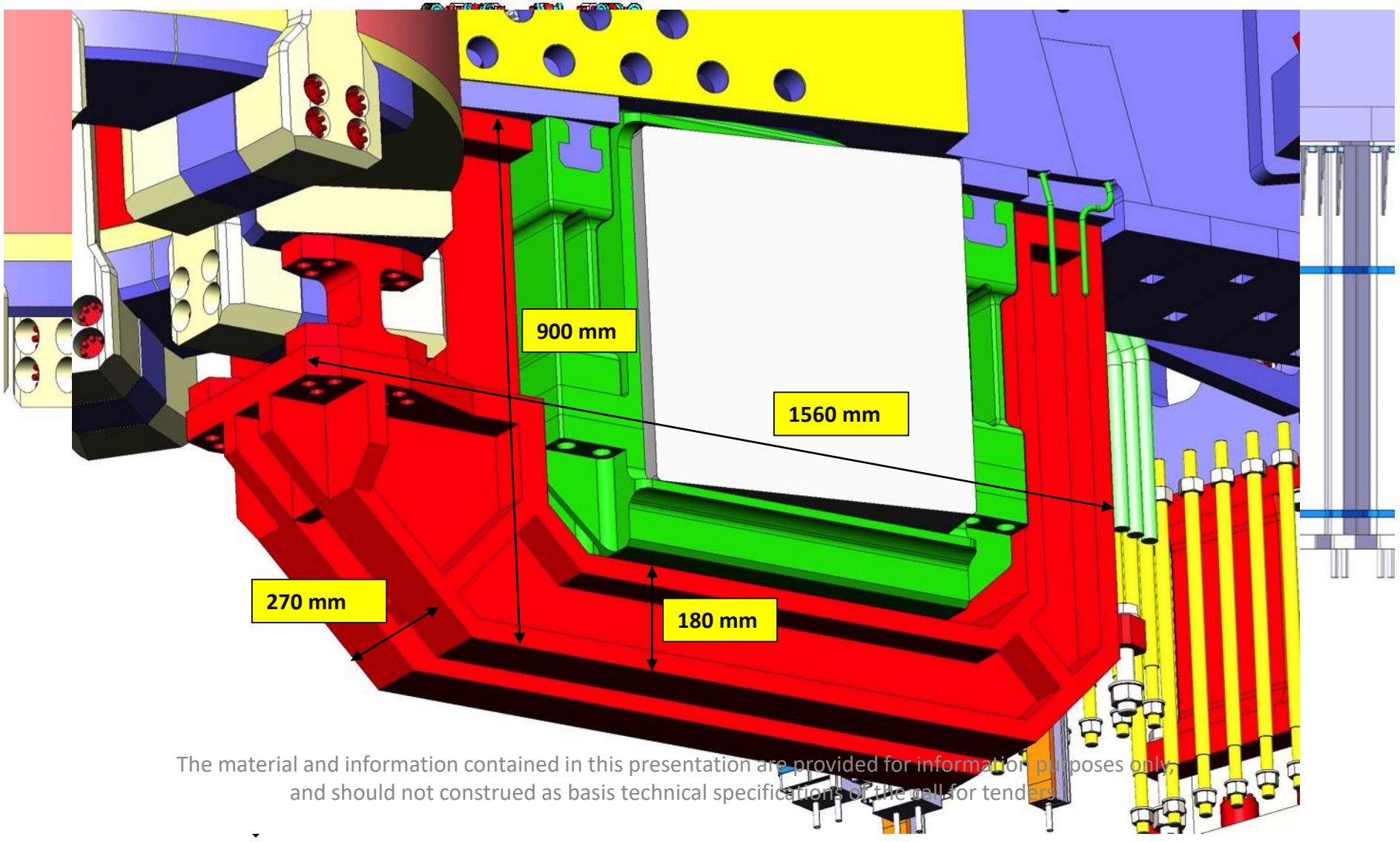


CS: structures and assembly





CS: structures and assembly



CS module preparation

Operations to complete (on each module)

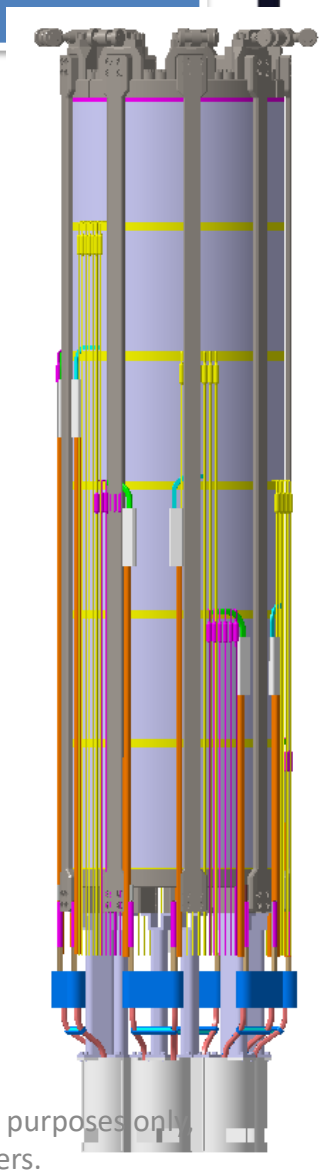
1. HF grade turn insulation & winding;
2. HF He inlets welding (during winding);
3. Internal and terminal joint preparation;
4. LF grade turn insulation & winding;
5. LF He inlets welding (during winding);
6. Heat-treatment at 650°C;
7. Ground insulation application;
8. G10 inter-module grooved spacers insertion
9. VPI and curing;
10. Acceptance tests.

CS coil assembly (tbd)

Each module to be (cold) tested at ENEA. Then:

Operations to complete (6 modules)

1. Module stacking;
2. Pre-compression structures application;
3. Piping welding;
4. Acceptance tests;
5. Transport structure preparation;
6. Shipping to ENEA Frascati.



Conclusions and recommendations

- Detailed engineering design still under development;
- 1 spare module and 1 assembled CS coil made of 6 stacked coils and its pre-compression structures, shall be eventually shipped to ENEA in Frascati.