COMPASS
INSTITUTE OF PLASMA PHYSICS ASCR

COMPASS-U tokamak
Toroidal field coils

v2.0
18.2.2020

Institute of Plasma Physics of the Czech Academy of Sciences

Content

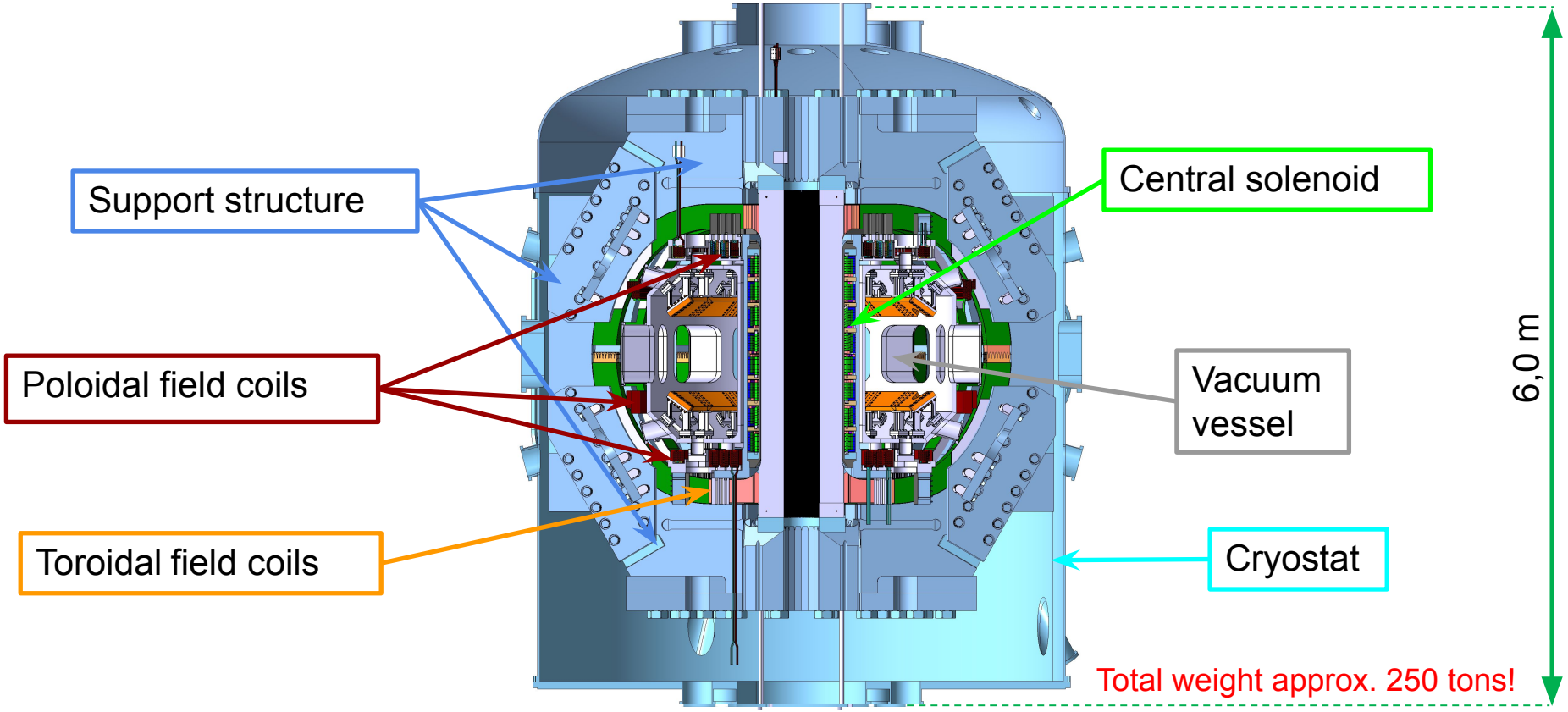
Parameters of new tokamak

Key properties of COMPASS-U:

- High magnetic field to confine plasma (5 T)
- High plasma current (2 mil. Amperes)
- High currents in toroidal field coils up to 200 kA
- High currents in poloidal field coils up to 50 kA
- Both coils systems from copper alloy materials (discharge durations up to several seconds)
- Coils and support structure operate at cryogenic temperature (~80 K)
- Operation with high temperature first wall – up to 500°C
- Mid-size device

⇒ unique capabilities to address DEMO challenges

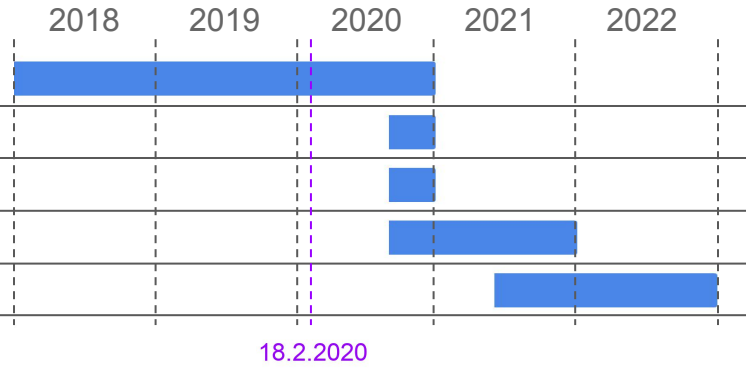
Cross-section of COMPASS-U



Indicative timetable

Key milestones:

Design of the components	2018 - 2020
Final design review (FDR)	end of 2020
Launch of tender for TF coils	end of 2020
TF Coil manufacturing	2021
Assembly and installation	2022



TF coils - scope of work

Presumed scope of work

- Manufacture of 16 toroidal field coils from 20 mm thick plates from certain alloy of high conductivity oxygen free copper

Presumed scope of work on the coil

- Machining of copper plates and connection of sliding/bolted joints
- Insulation
- (Vacuum) epoxy impregnation
- Electrical testing
- Test assembly
- Transport to IPP

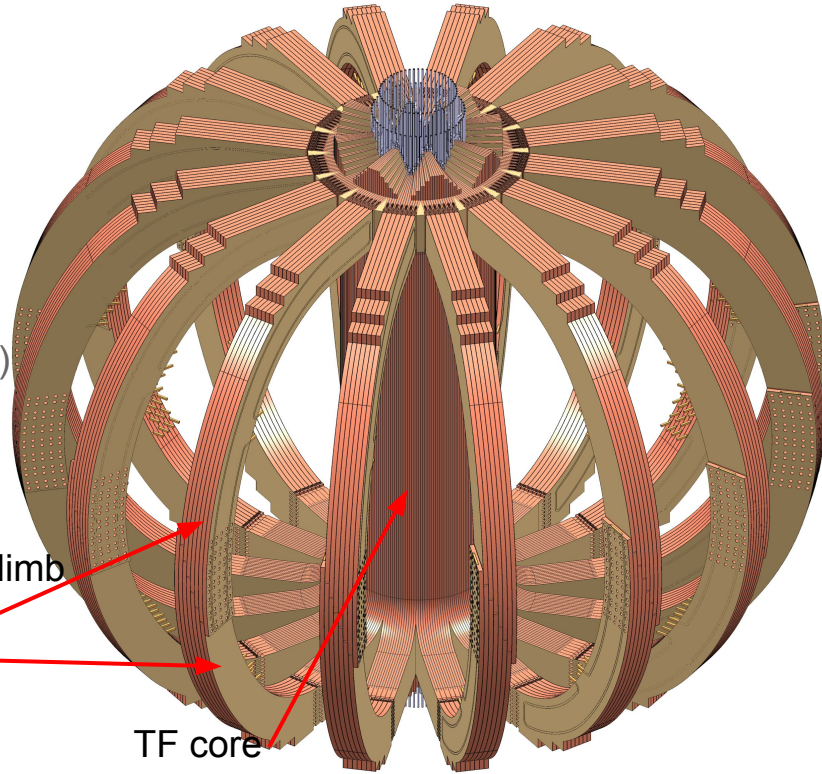
Notes:

- Coil of central solenoid (not part of delivery) has to be wounded on assembled TF core
- Coil models and coil parameters in this presentation are preliminary and could change during preliminary market consultations

TF coils - overview

Preliminary parameters:

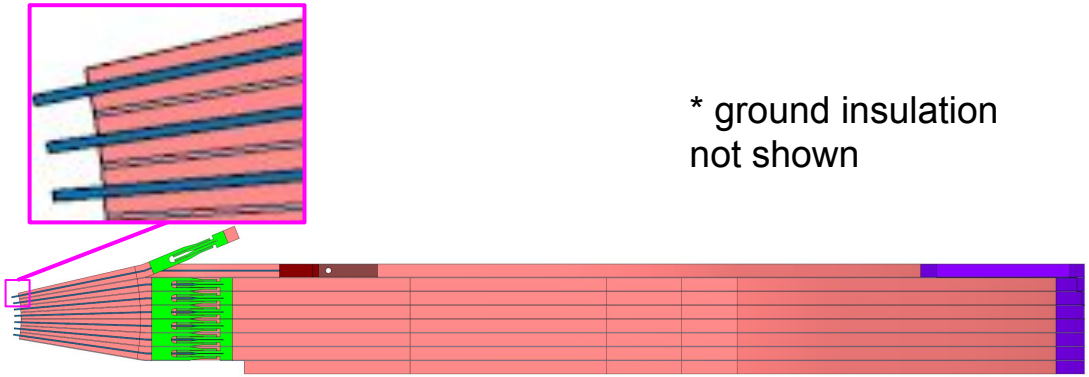
- 112 D-shaped turns grouped to 16 bundles with 7 turns
- Outer dimensions of one turn ~ 2.6 x 1.7 m
- Each turn composed of 3 parts with joints
- Turns insulated by G10 plates
- Current 199.5 kA providing 5T @ R = 0.896 m for ~ 5 s
- Turn cross section 20 x 200 mm made from hardened OFHC copper or similar material (CuAg0.1, CuZr0.1, …)
- Total mass ~ 24 tons
  (TF core ~ 9 tons, Outer limbs ~ 15 tons)
- Cryogenically cooled by gaseous Helium down to T > 50 K by cooling channels in each turn
- TF coils are held in place by support structure (TF coils itself cannot withstand forces during operation)



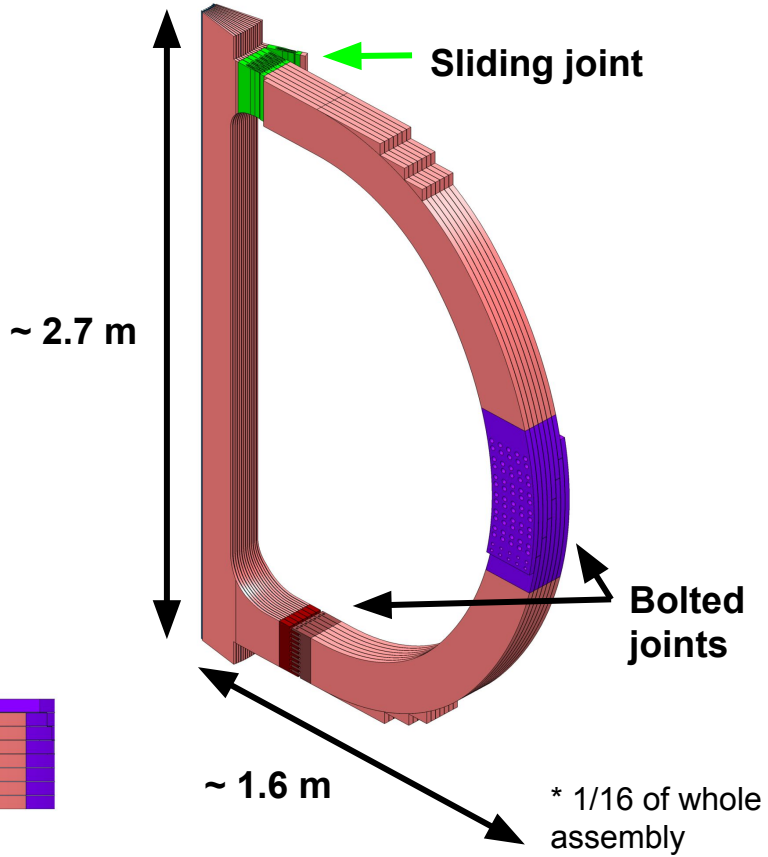
*ground insulation is not shown

TF coils - detailed view

Detailed view (conceptual design)
- pink: copper
- blue: stainless steel reinforcement (2 mm thick)
(preliminary design - the aim is to avoid of using stainless steel plate and made coil only from copper)
- red: location of bottom bolted joint
- purple: location midplane bolted joint
- green: location of sliding joint
- gray: G10 insulation (turn to turn)

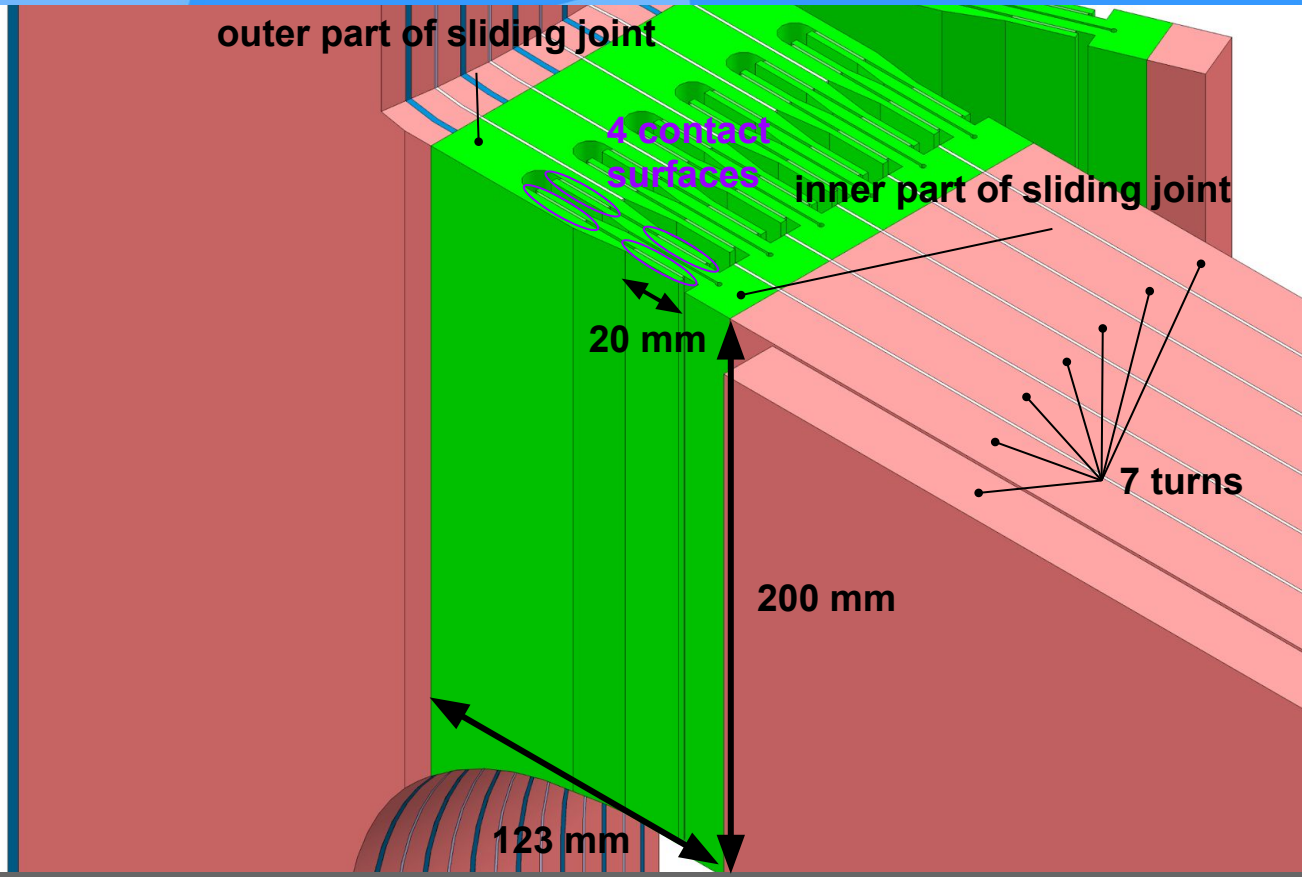


* ground insulation not shown



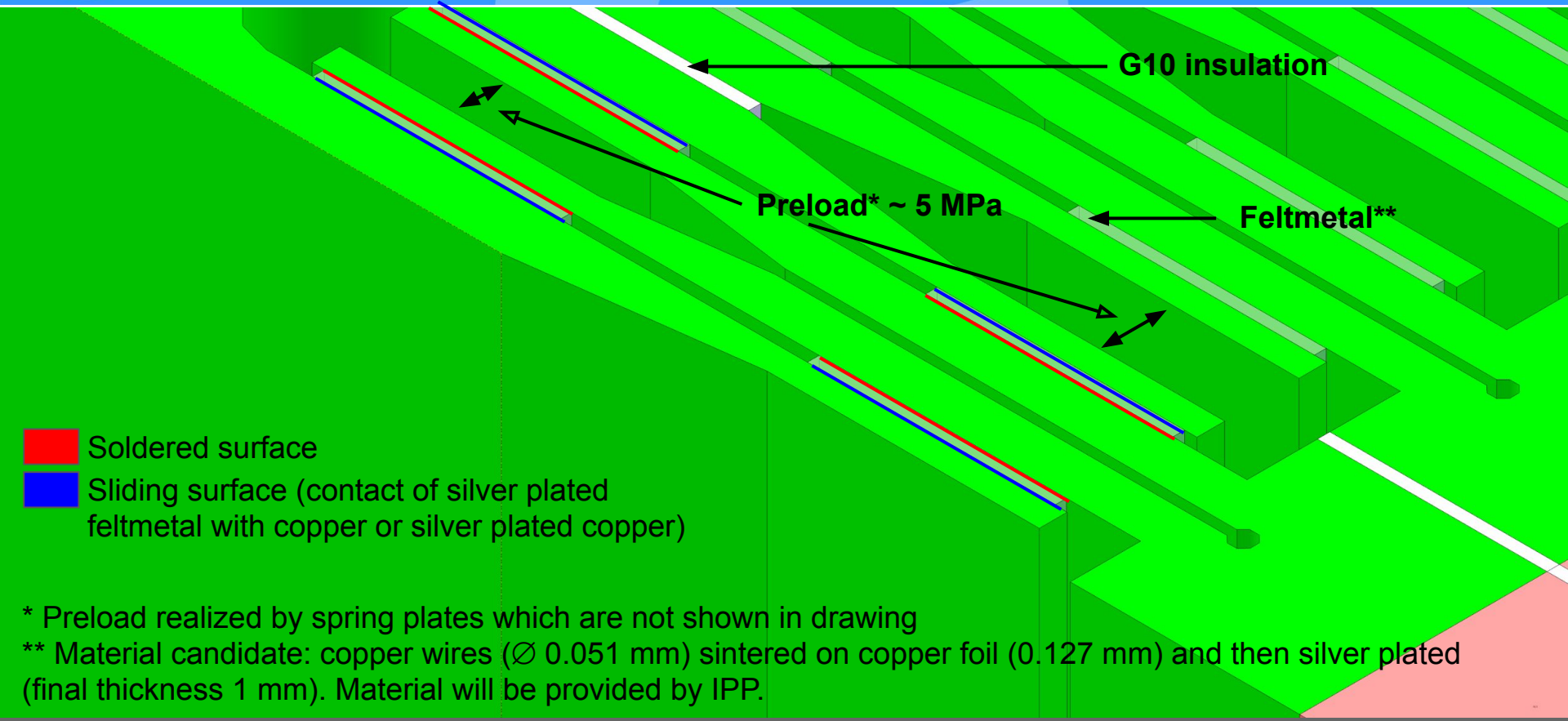
TF coil - sliding joint

- coil current: 200 kA
- 7 turns per coil
- 1 sliding joint per turn
- 4 contact surfaces per joint
- each surface has 20x200 mm
- average current density:
  1.25 kA/cm^2
- peak current density:
  ~ 5 kA/cm^2



COMPASS
INSTITUTE OF PLASMA PHYSICS ASCR

TF coil - sliding joint (detail)



Soldered surface

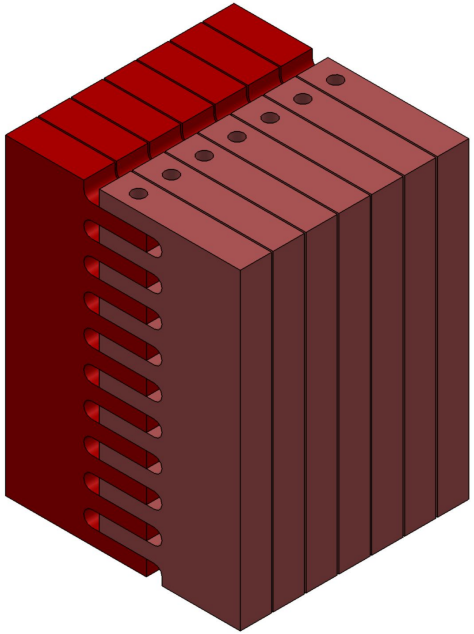
Sliding surface (contact of silver plated feltmetal with copper or silver plated copper)

* Preload realized by spring plates which are not shown in drawing

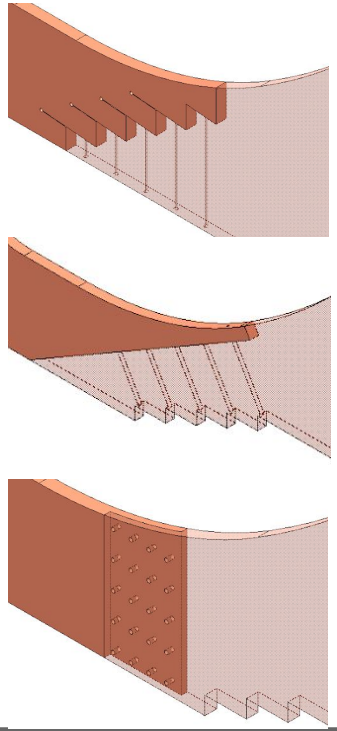
** Material candidate: copper wires (∅ 0.051 mm) sintered on copper foil (0.127 mm) and then silver plated (final thickness 1 mm). Material will be provided by IPP.

TF coils - bolted joints

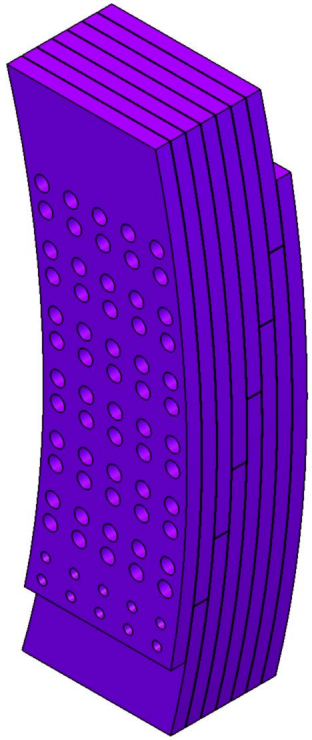
Bottom bolted joint (conceptual design)



other versions



Upper bolted joint (conceptual design)

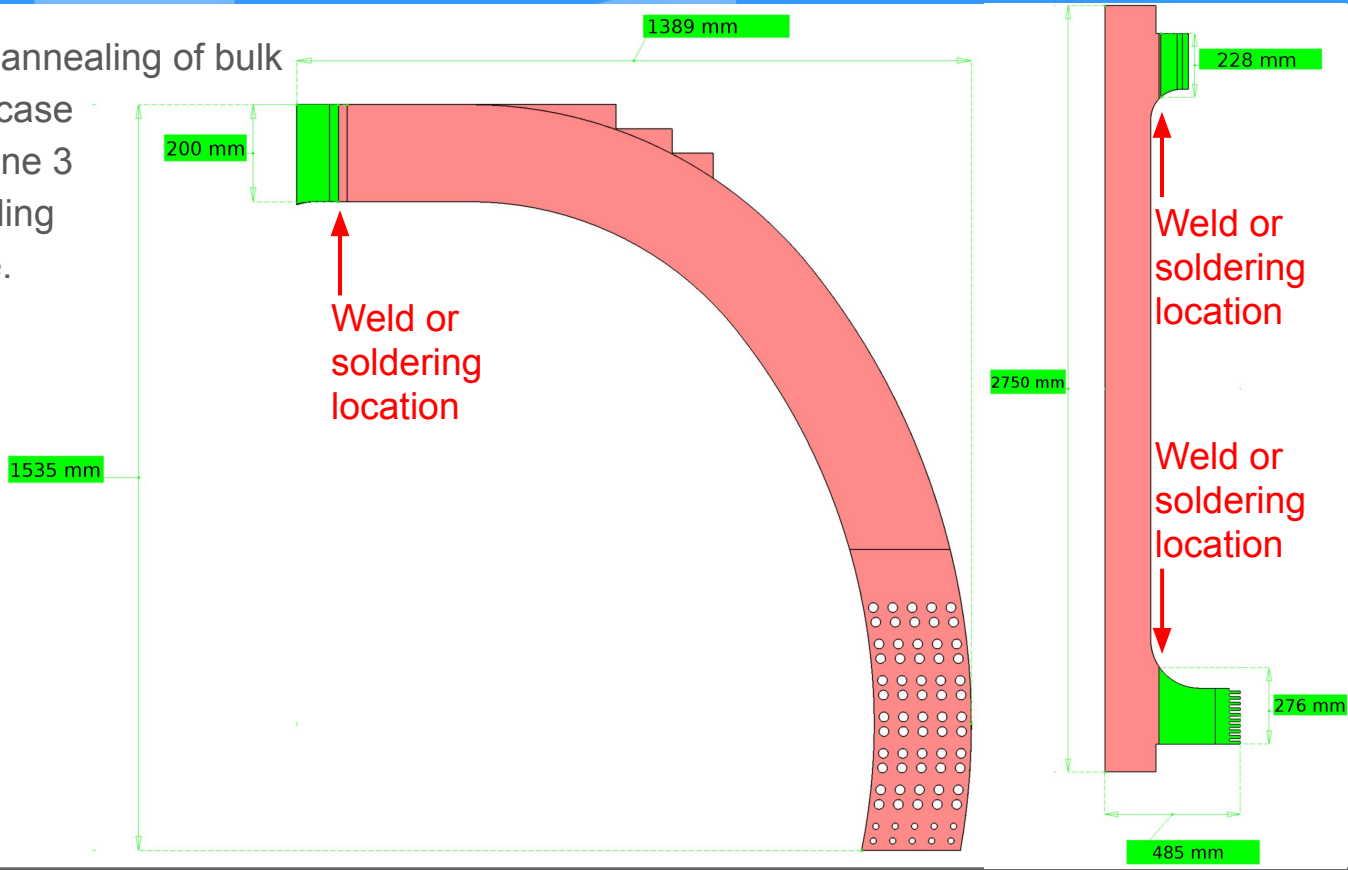


TF coils - machining of parts

Soldering or welding (without annealing of bulk material) may be done in the case that it is not possible to machine 3 parts of turn precisely or bending of TF core turn is not possible.

Length of connections:
- 200 mm
- 228 mm
- 276 mm

Material candidates:
- Silver-bearing oxygen-free copper (UNS C10700)
- Copper Zirconium alloy (UNS C15100)



TF coils - insulation

Operation parameters:
Voltages: turn-to-turn ~ 10 V, first-to-last turn ~ 1000 V, turn-to-ground ~ 1000 V

Preliminary design:
Turn-to-turn insulation ~ 1 mm thick (2 options):

- G10 plates bonded with epoxy resin to copper plates
- (Vacuum) epoxy impregnation of E(S) glass wrap around each turn

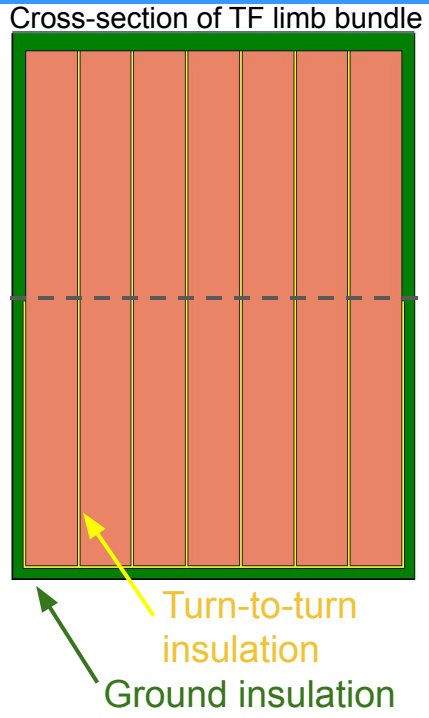
Ground insulation ~ 5 mm thick:

- (Vacuum) epoxy impregnation of E(S) glass wrap around TF core/each bundle

Joint insulation + joint for TF leads:

- extra pieces of G10 around joints - no direct visibility of parts at different electric potential

Note: Subcontractor is encouraged to propose an alternative insulation process with equivalent or superior properties meeting the machining tolerances.



TF coils - cooling

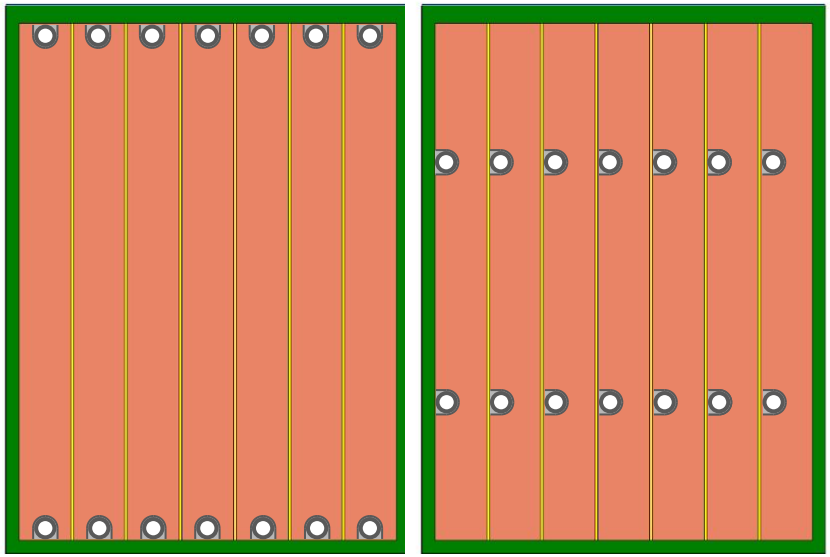
Operational parameters:

- Initial temperature from 50 to 77 K, temperature change of 60 K in ~ 10 s

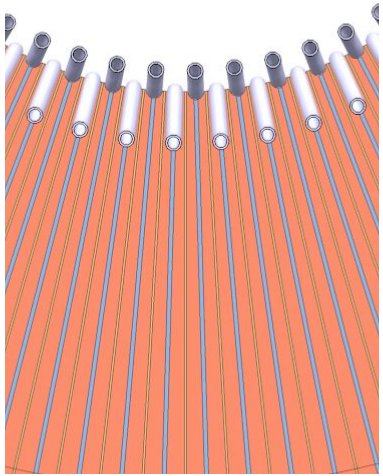
Cooling channels:

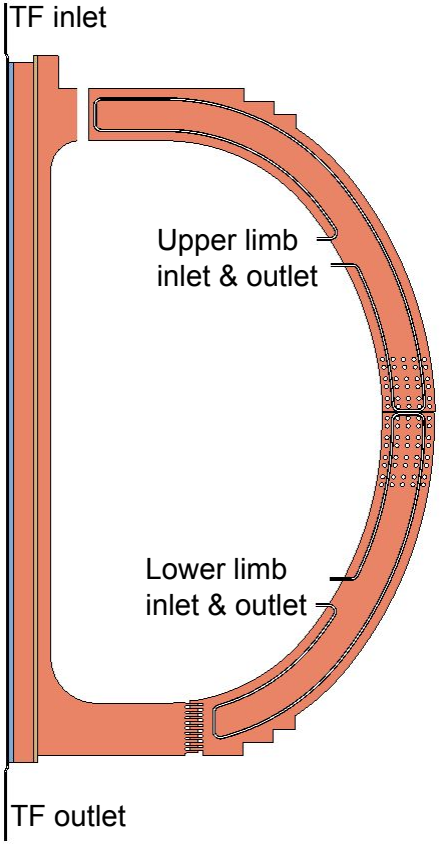
- copper pipes (outer ∅ 8 mm, inner ∅ 6 mm) soldered in grooves
- 2 possibility of groove location in outer limbs

Outer limbs



TF core





TF coils - machining tolerances & tests

Machining tolerances:

- General tolerances will be set by DIN ISO 2768 mK.
- Tolerances for preliminary design of TF core are shown in attachment *HFCU-04-00-v7-3_B.pdf* (Sheets 1-4)

Electrical Tests:

- Turn to turn voltage 700 V
- First turn to last turn voltage 3500 V
- Coil to ground voltage 3500 V

Questions

We would like to kindly ask you to answer the following questions:

1. Propose shape of cooling tubes (rectangular with hole, circular) and suggest the manufacturing process (soldering into grooves, electron beam welding etc.) - *this process has to avoid annealing of the TF base material.*
2. Propose insulation process.
3. Is it possible to machine each of the 3 parts of one TF turn out of one copper plate (including the precise machining of the sliding/bolted joint area) or would you recommend to machine the sliding/bolted joint area separately and connect it (EBW, soldering) to the rest of the given TF part? (see slide 12)
4. Propose solution for transition from the copper cooling tubes to stainless steel tubes (EBW, brazing, explosively bonded Cu/SS transition piece ...)
5. Estimate approximate cost for manufacturing of the TF coils.

Contacts

More informations about preliminary market consultation can be found at:

http://www.ipp.cas.cz/o-ufp/Verejne_zakazky/doc.html

At website tenders electronic daily

Notification Number at Tender electronic daily: 2019/S 113-276584
(Číslo oznámení TED: 2019/S 113-276584)

Contact persons:

Ivan Němec email: nemec@ipp.cas.cz
Jaroslav Krbec email: krbec@ipp.cas.cz

Attachment description

Attachment:

- *HFCU-04-00-v7-3_B.zip*
  - Model of TF coils:
    - *HFCU-04-00-v7-3.stp*
  - Drawings and machining tolerances of TF coils
    - *HFCU-04-00-v7-3_B_Sheet_1.pdf*
    - *HFCU-04-00-v7-3_B_Sheet_2.pdf*
    - *HFCU-04-00-v7-3_B_Sheet_3.pdf*
    - *HFCU-04-00-v7-3_B_Sheet_4.pdf*