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Design of the thermal shield for the DTT facility

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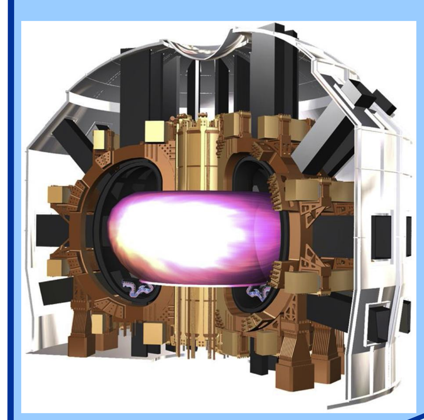
Introduction

- Divertor Tokamak Test (DTT) under construction at ENEA Frascati research centre, Italy
- High field superconducting (SC) tokamak (6T) carrying 5.5 MA plasma current (~ 50 s plasma pulses) with major radius R_0 = 2.19 m
- Thermal shield (TS) needed to minimize the thermal loads on the SC magnets

Aim of the work



[Interim Design Report, April 2019]

Presentation of the conceptual design of the thermal shield

Design requirements

Thermal

- Reduce the radiative heat flux to the magnets below q''_{mag} = 1 W/m^2
- Actively cool the thermal shield with redundancy to maximize availability
- Minimize heat load to the cryoplant (T_{in} = 80 K)
- Reduce the hydraulic impedance (< 2 bar) → flexibility in the refrigerator design/operation

Mechanical

- Withstand static (e.g. dead weight) and dynamic (e.g. electromagnetic, seismic) loads
- Minimize electro-magnetic loads (eddy currents)

Integration

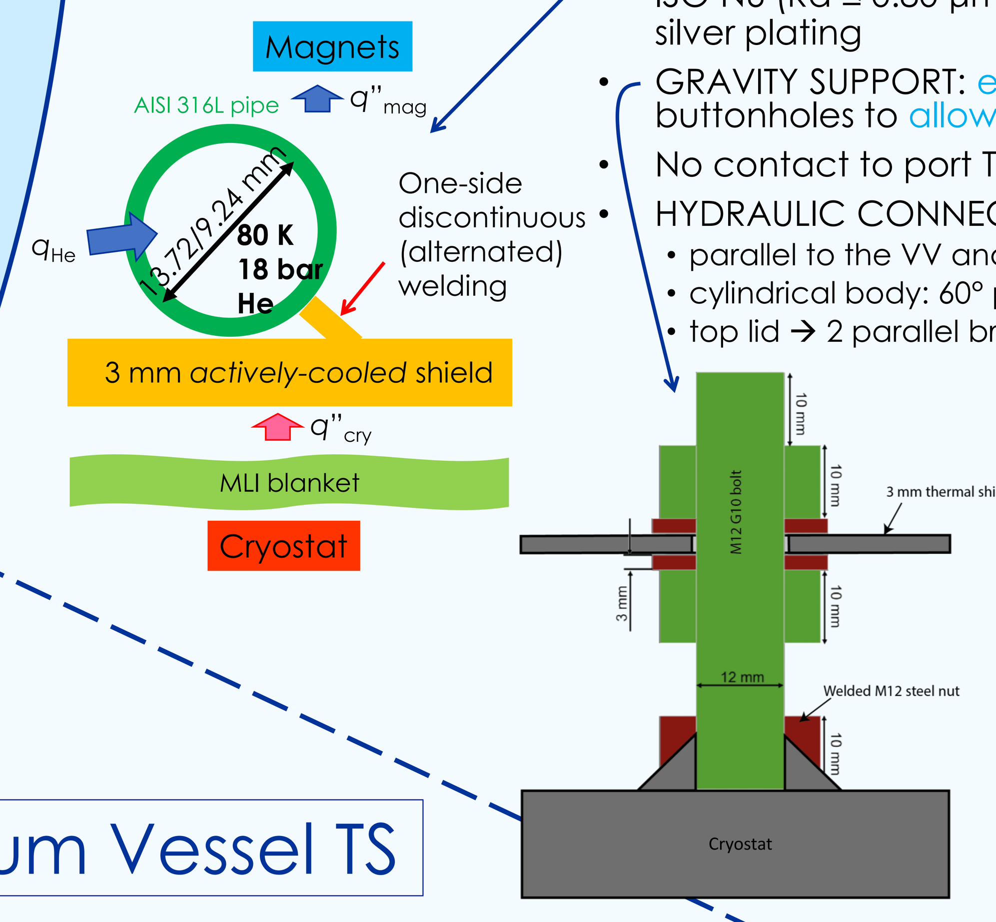
- Comply to the assembly sequence
- Reduce space occupation (no interference with other subsystems)

Possible assembly sequence

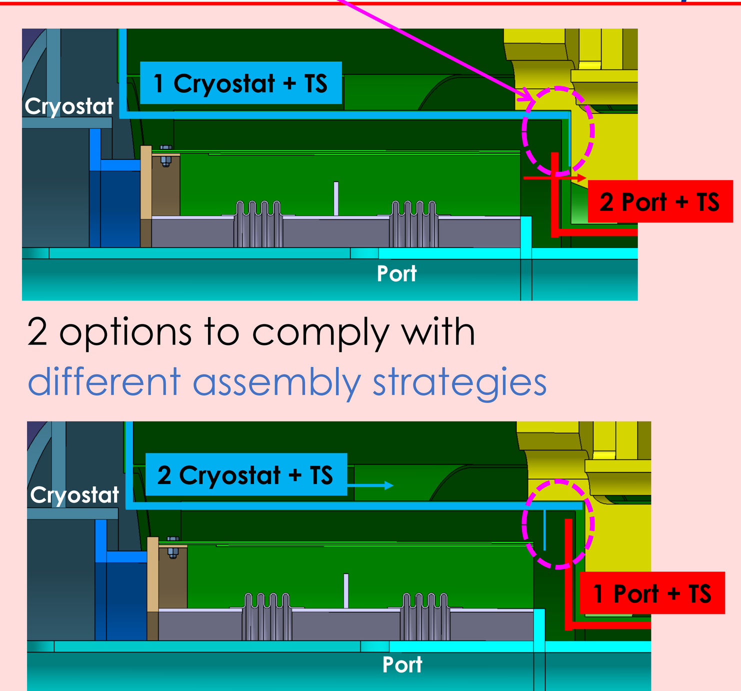
1) 340° of VV without port extensions
2) VV TS
3) TF magnets
4) Last 20° of VV with TS
5) Cryostat with TS
6) Port extensions with TS } TBC

Design

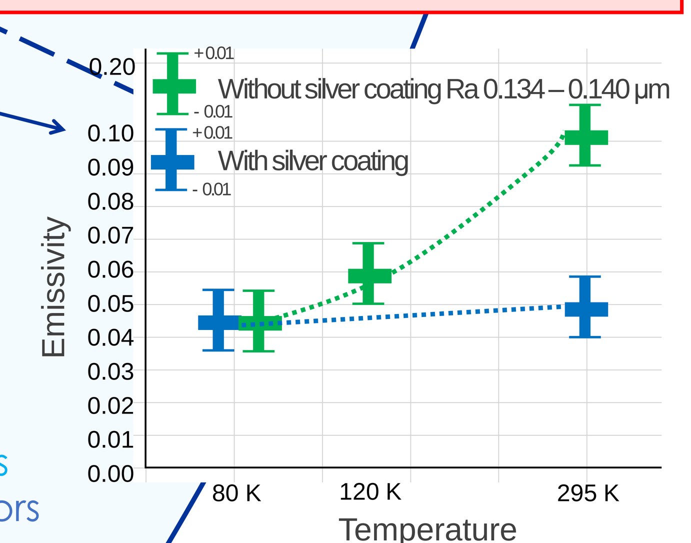
Cryostat TS



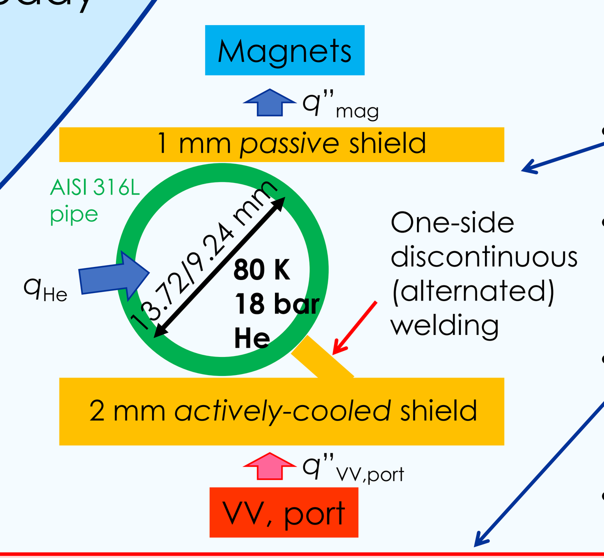
- **Single wall (AISI 316L) actively cooled + multi layer insulation (MLI) blanket** on the warm (cryostat) side
- ISO N6 (Ra ≤ 0.80 μm) trough polishing → ε ≤ 0.17 at 80 K → avoid silver plating
- GRAVITY SUPPORT: electrically isolated bolts on the cryostat, with buttonholes to allow thermal contraction
- No contact to port TS to reduce eddy currents
- HYDRAULIC CONNECTION:
  - parallel to the VV and port TS
  - cylindrical body: 60° periodicity (same as cryostat) → 6 parallel branches
  - top lid → 2 parallel branches (same as lid)



2 options to comply with different assembly strategies

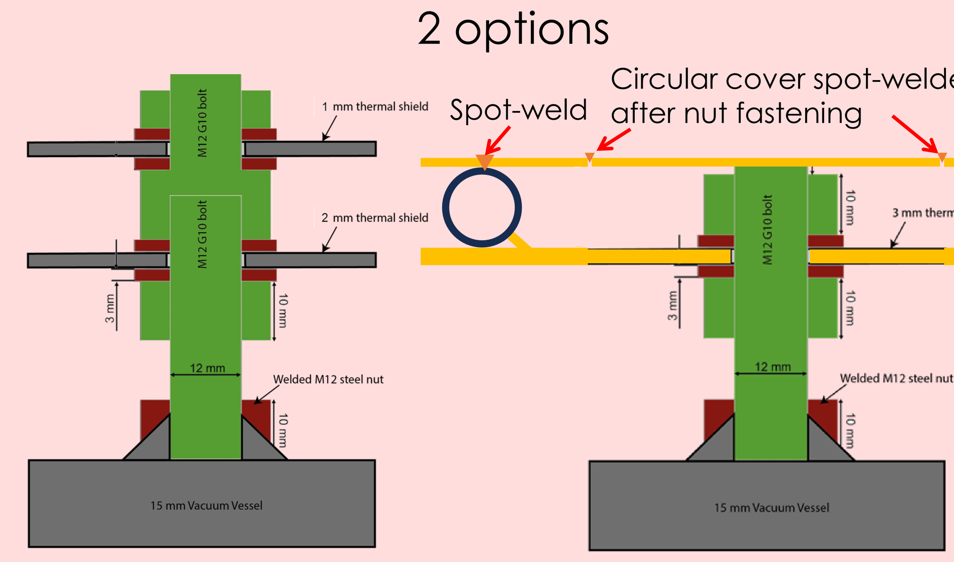


Vacuum Vessel TS



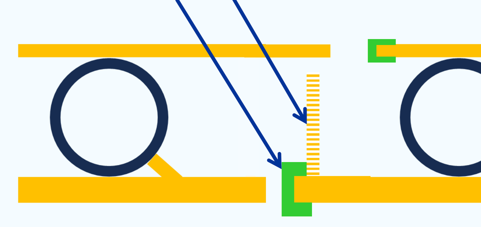
- **Double wall (AISI 316L) actively cooled** on the warm (cryostat) side
- ISO N4 or better (Ra ≤ 0.20 μm) trough polishing ("finely turned on lathe") → ε ≤ 0.07 at 80 K → avoid silver plating
- GRAVITY SUPPORT: electrically isolated bolts on the VV, with buttonholes to allow thermal contraction
- No contact to port TS to reduce eddy currents

2 options



- ✓ Reduce space occupation
- ✗ Direct welding on the pipe (risk for leak tightness)

- Split *poloidally* the TS in 5 segments
- Split *toroidally* the TS in 18 20° sectors
- Isolated interface between neighbouring panels:
  - Rib to avoid direct radiation
  - G10 to avoid electric contact

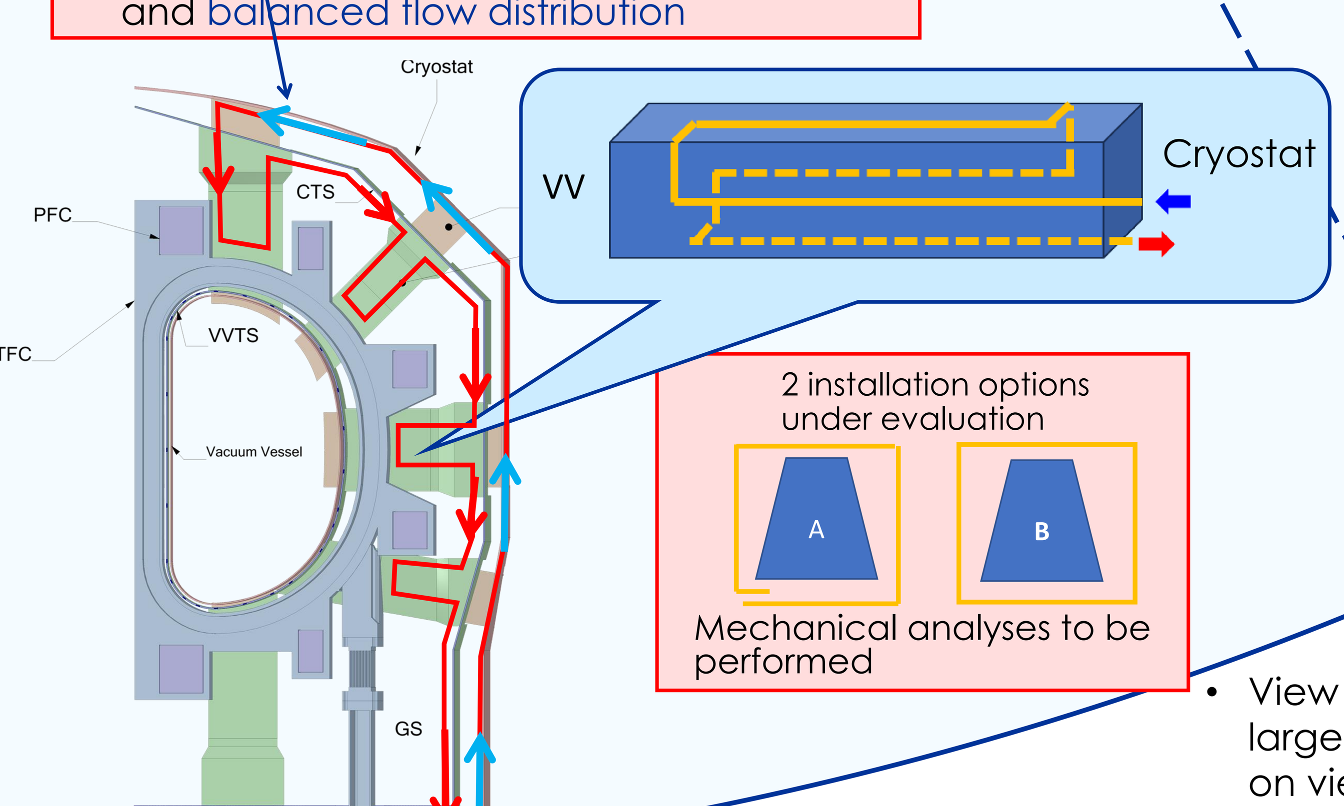


Port TS

- **Double wall (AISI 304) actively cooled** on the warm (port) side, as the VV TS
- Surface polishing and gravity support same as VV TS

HYDRAULIC CONNECTION:

- Parallel to the VV and cryostat TS, inlet from the cryostat side
- Option 1: series (or parallel, to reduce Δp) connection of the ports of the same 20° sector → 18 parallel branches
- Option 2: parallel connection of the ports at the same poloidal position → 4 parallel branches (with 18 sub-branches each) and balanced flow distribution

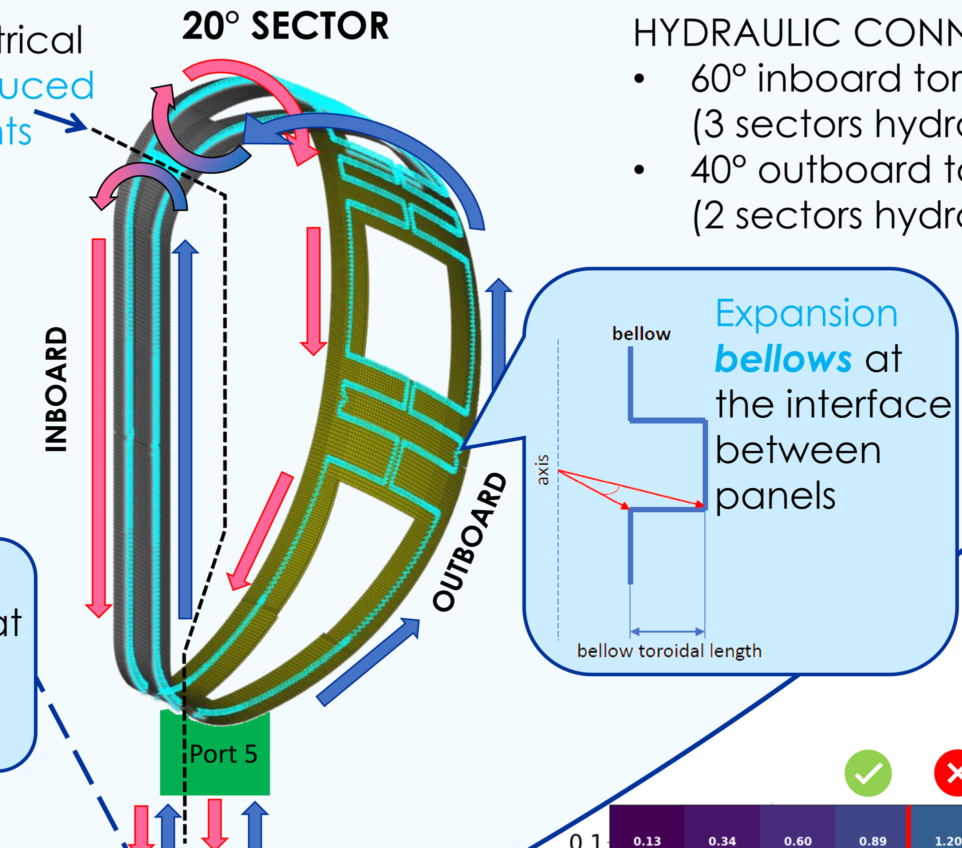


2 installation options under evaluation

A B

Mechanical analyses to be performed

Avoids electrical loops → reduced eddy currents



Expansion *bellows* at the interface between panels

HYDRAULIC CONNECTION:

- 60° inboard toroidal periodicity (3 sectors hydraulically in series)
- 40° outboard toroidal periodicity (2 sectors hydraulically in series)

Analyses

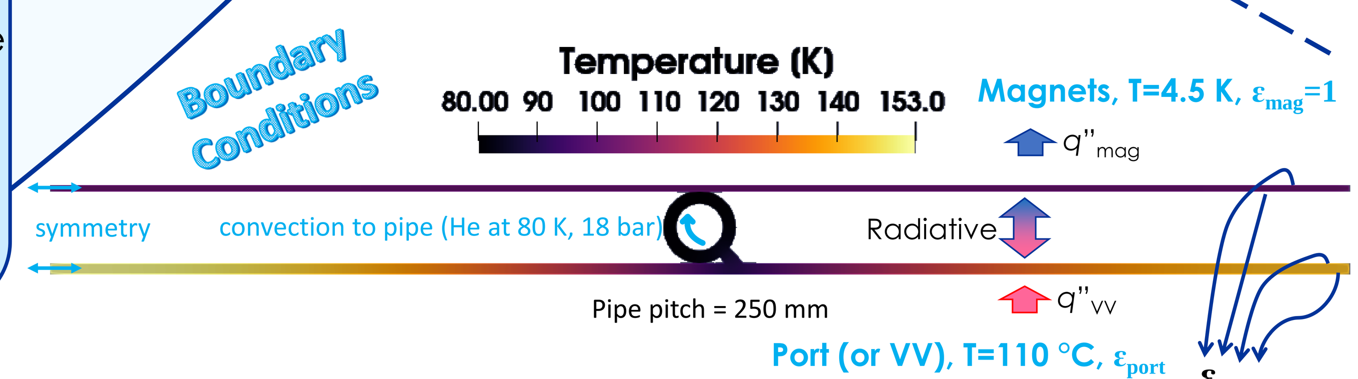
Mechanical

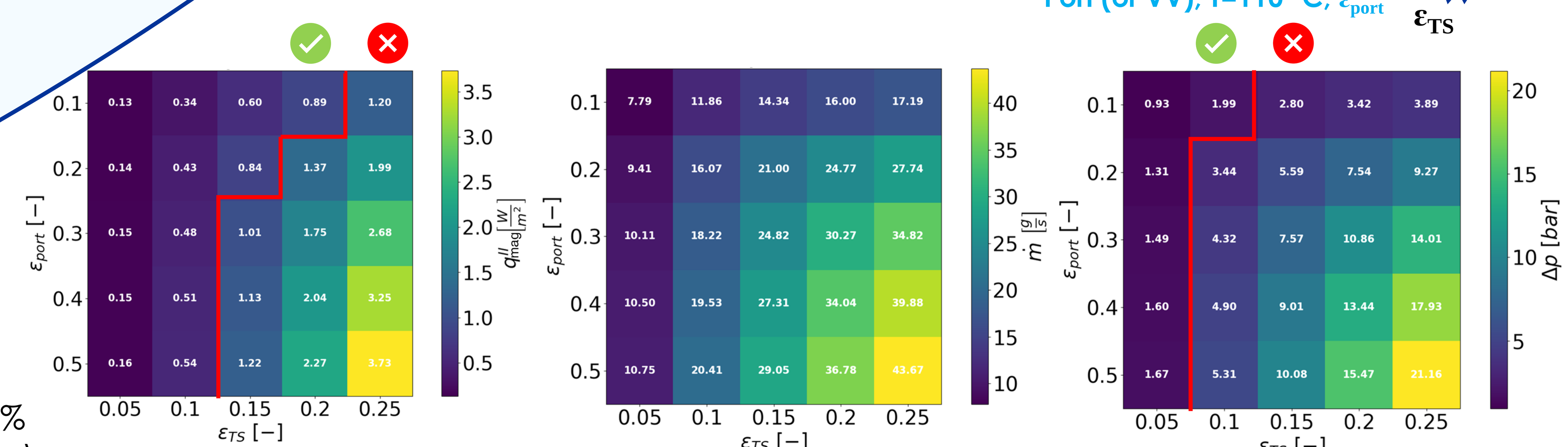
Assess panels and gravity supports for

- Dead weight
- Thermal contraction
- Dynamic loads

More on virtual poster VP-52 by G. Barone

Thermal





- View factor important only for large ε_{TS}, but small impact (-75% on view factor → -17% on q''_{mag})
- Small impact of ε_{mag}: 50% reduction → ~10% reduction in q''_{mag}
- Reducing the ε_{TS} allows relaxing the VV/port polishing
- Reducing the ε_{TS} allows reducing Δp

Relevant heat loads for 250 mm pitch and ε_{TS}=0.17 (conservatively, ISO N6 everywhere), $\varepsilon_{VV/port/CRS}$=0.35

	$\dot{m}$ [g/s]	Δp [bar]	q_{He} [kW at 80K]	q''_{mag} [W/m²]
VV (total)	~90	<1	10	<0.7
Port (total)	~300	<4 (*to be optimized*)	33	<0.8
Cryostat (total), with MLI	<100	TBD	<10	TBD

Parallel connection of all ports

Electro-magnetic

Model being finalized by LTcalcoli

- Fast vertical disruption
- Magnet fast discharge

→ Input for mechanical (dynamic) analyses

Conclusions & perspective

Design of the DTT TS is ongoing:

- Minimization of the radiative heat transfer by double wall configuration and surface polishing
- ITER-like (alternate welding) pipe attachment to panels
- Gravity supports: G12 bolts on VV, port and cryostat

PERSPECTIVE: completion of electro-magnetic, thermal-hydraulic and mechanical analyses → selection of the best options

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