Progress in the thermal shield design for the Divertor Tokamak Test (DTT) facility

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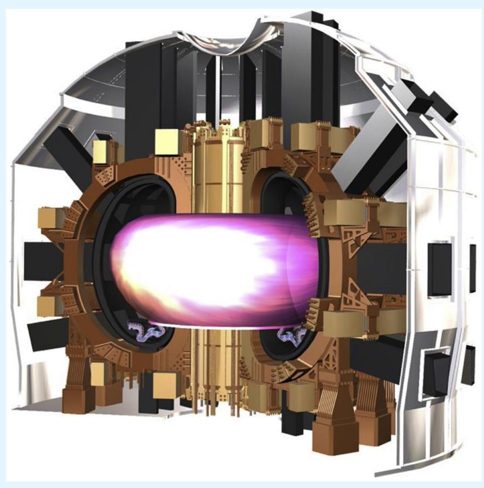
roberto.bonifetto@polito.it

R Bonifetto[1], G Barone[2,3], V Belardi[4], M Dalla Palma[5,6], M De Bastiani[1], P Fanelli[7], G M Polli [2,3] G Ventura[8], G Zavarise[8]

[1] NEMO group, Energy Department, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy
[2] ENEA, Department of Fusion and Nuclear Safety Technology, Via E. Fermi 45, 00044 Frascati, Roma, Italy
[3] DTT S.C.a r.l., Via E. Fermi 45, 00044 Frascati, Roma, Italy [4] Università degli Studi di Roma "Tor Vergata", 00133 Rome, Italy [5] Consorzio RFX, 35127 Padova, Italy
[6] Istituto per la Scienza e Tecnologia dei Plasmi, Consiglio Nazionale delle Ricerche, 35127 Padova, Italy [7] Università degli Studi della Tuscia Viterbo, 01100 Viterbo, Italy
[8] Department of Structural, Geotechnical and Building Engineering, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy

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 (~ 100 s plasma pulses) with major radius R0 = 2,19 m
- Thermal shield (THS) needed to minimize the thermal loads on the magnets from the warm and hot components of the tokamak



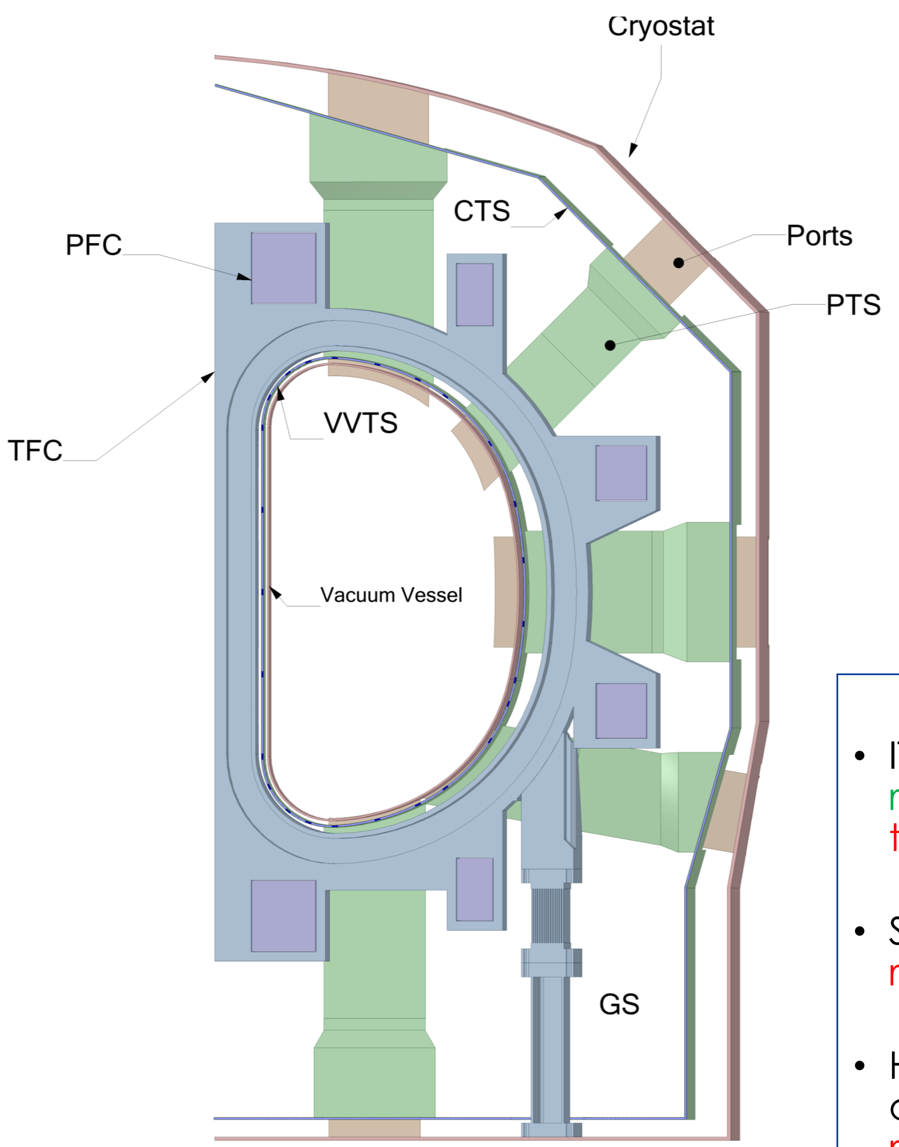
[Interim Design Report, April 2019]

AIM OF THE PROJECT: investigate alternative power exhaust solutions in EU DEMO relevant conditions

Aim of the work

Present the current status of the design of the vacuum vessel THS and the conceptual design of the port and cryostat THS. Solutions adopted for:

- minimization of the radiative heat transfer
- proper cooling
- mechanical support



Assembly sequence

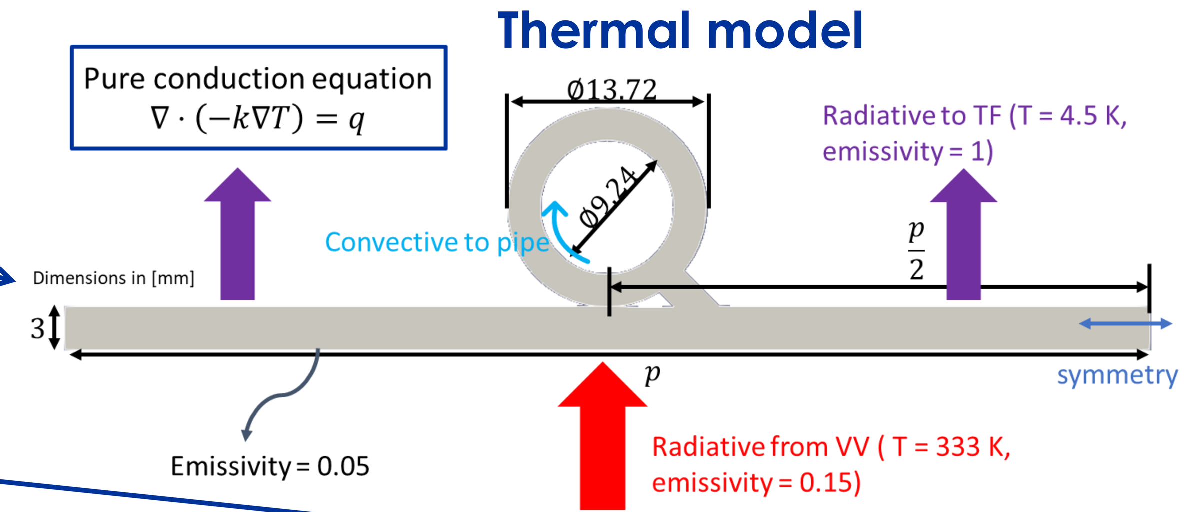
(K-STAR like)

1) 340° of VV without port extensions
2) VV THS
3) Magnets
4) Last 20° of VV
5) Port extensions with THS already installed
6) Cryostat with THS already installed

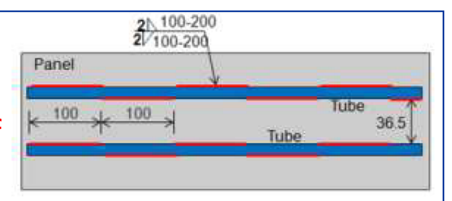
Thermal shield (THS) design

- Set of **3 mm thick silver-plated stainless-steel panels** surrounding vacuum vessel (VV), port extensions and cryostat
- Actively cooled by gaseous He at ~20 bar and ~80 K in **pipes laying on the surface of the panels**
- Withstand mechanical (weight, seismic, thermal-contraction) and electro-magnetic loads → **gravity supports**
- Radiative **heat load from the hot components** + conductive heat load due to gravity supports

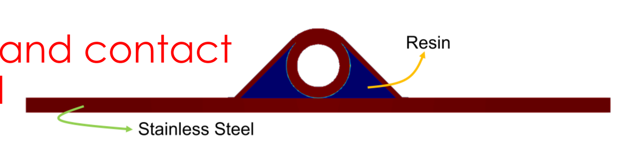
Thermal model



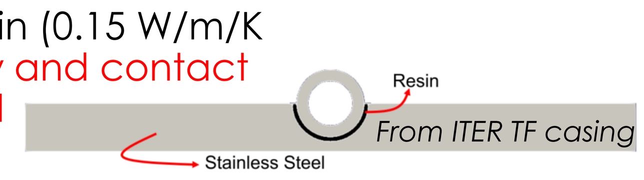
- ITER-like alternate welding (thin panels to reduce stresses on tubes, direct welding of the pipe wall)



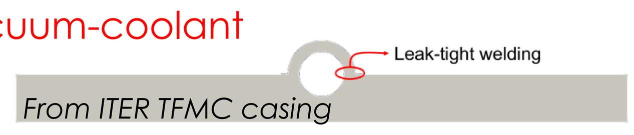
- SS foil: vacuum compatibility and contact reliability to be demonstrated



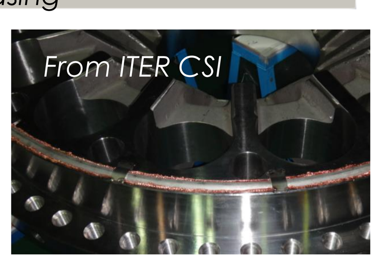
- High thermal conductivity resin (0.15 W/m/K at 4 K): vacuum compatibility and contact reliability to be demonstrated



- Leak-tight welding: weak vacuum-coolant boundary

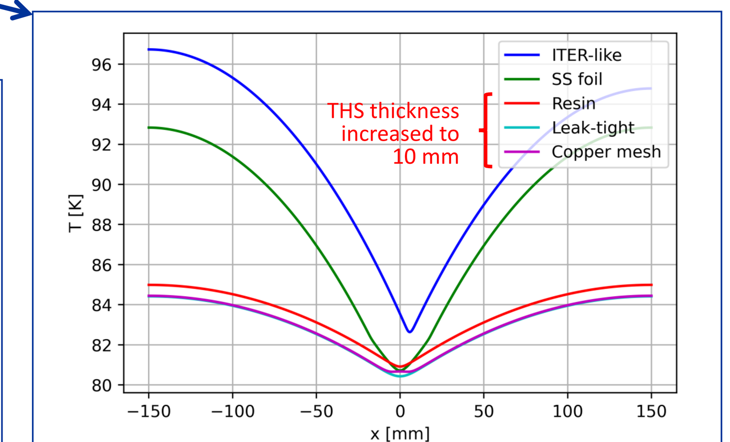


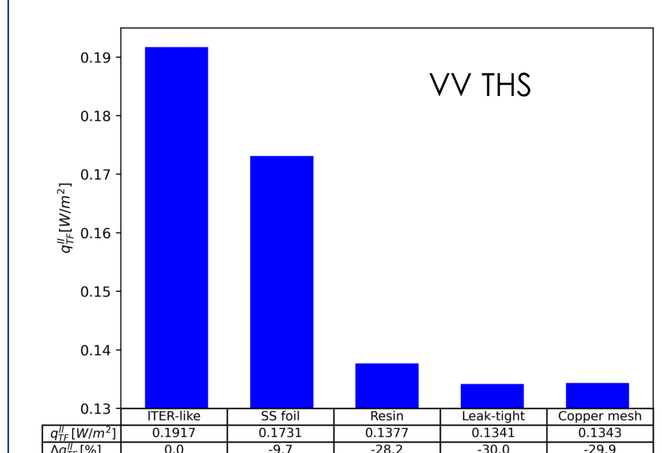
- Copper mesh: expensive due to machining of panels, easy shaping of different parts, assembly operations



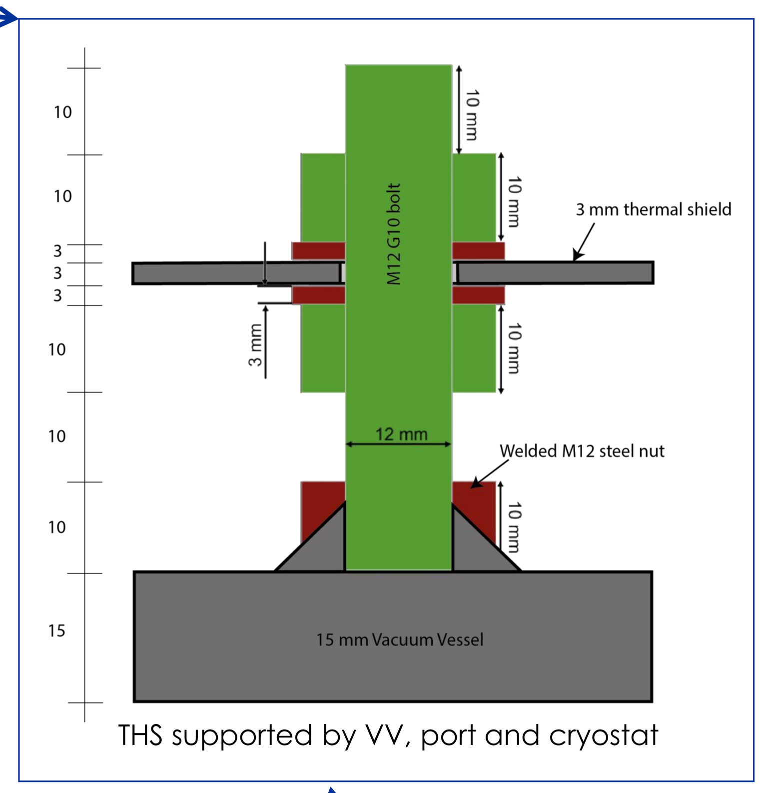
[Martovetsky, Naka 2015]

Option: increase THS thickness only close to the pipe

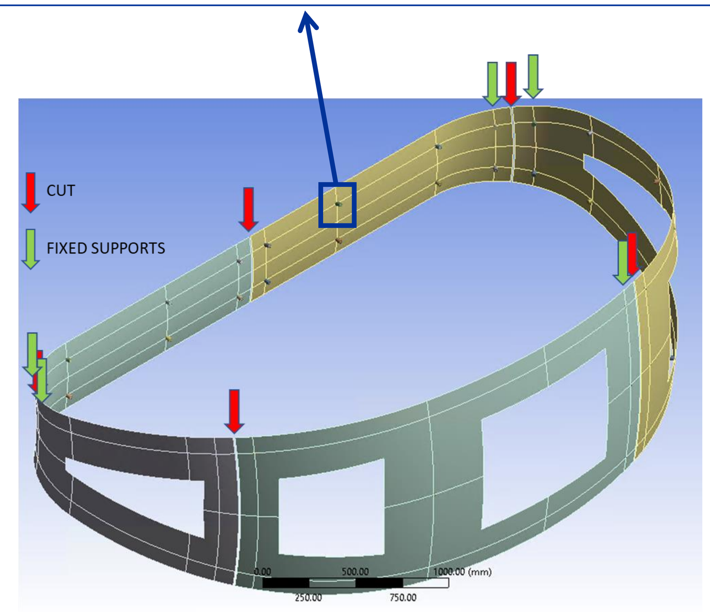




Maximum allowable q''_{TF} = 1 W/m^2



THS supported by VV, port and cryostat



Cryostat THS

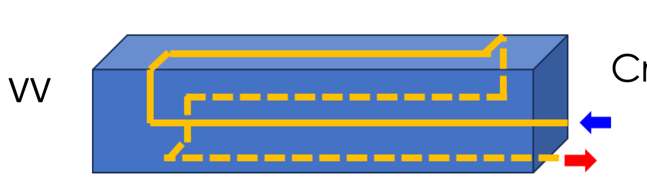
- **Option 1**: active cooling + MLI
  - Gravity support: same as for VV TS
  - No contact to port THS to reduce eddy current circulation
  - Hydraulic connection: parallel to the VV and port THS
- **Option 2**: use of MLI only

ITER CSM#	Upper shield	Scaled radiative heat losses
1	Actively cooled by LN_2	1
2	MLI only	0.6

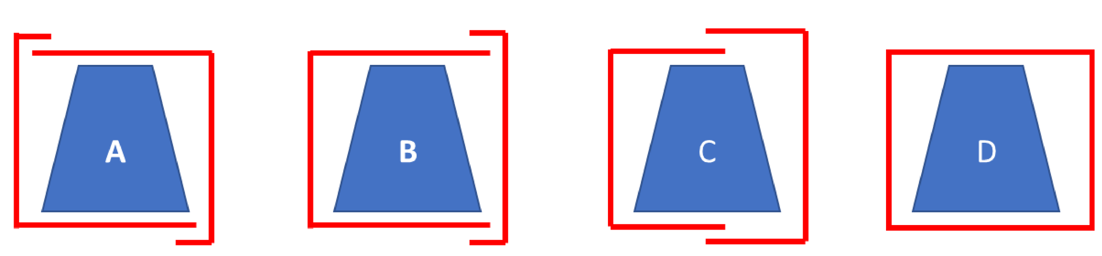
[Martovetsky, IEEE TPS, 2022]

Port THS

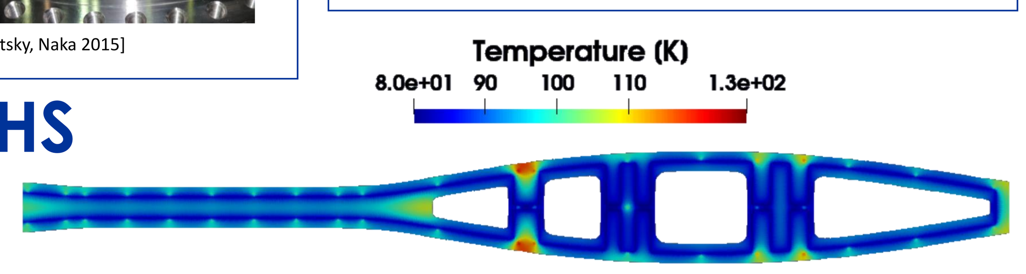
- Gravity support: same as for VV TS
- No contact VV-port-Cryostat THS to reduce eddy current circulation
- Hydraulic connection:
  - Parallel to the VV TS, inlet from the cryostat side
  - Series connection of the ports in the same 20° sector



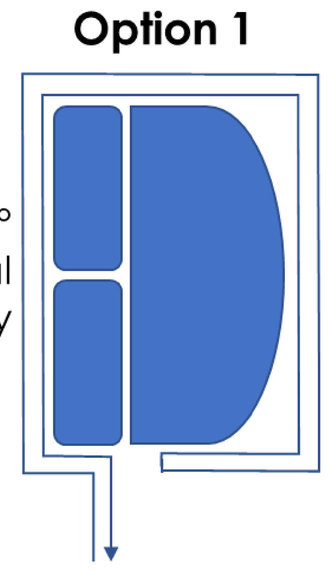
Installation options under evaluation



Vacuum Vessel THS

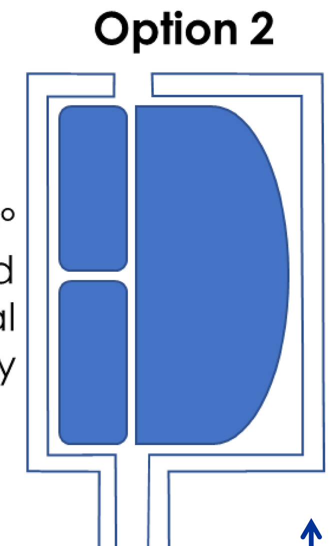


Option 1



20° toroidal periodicity

Option 2



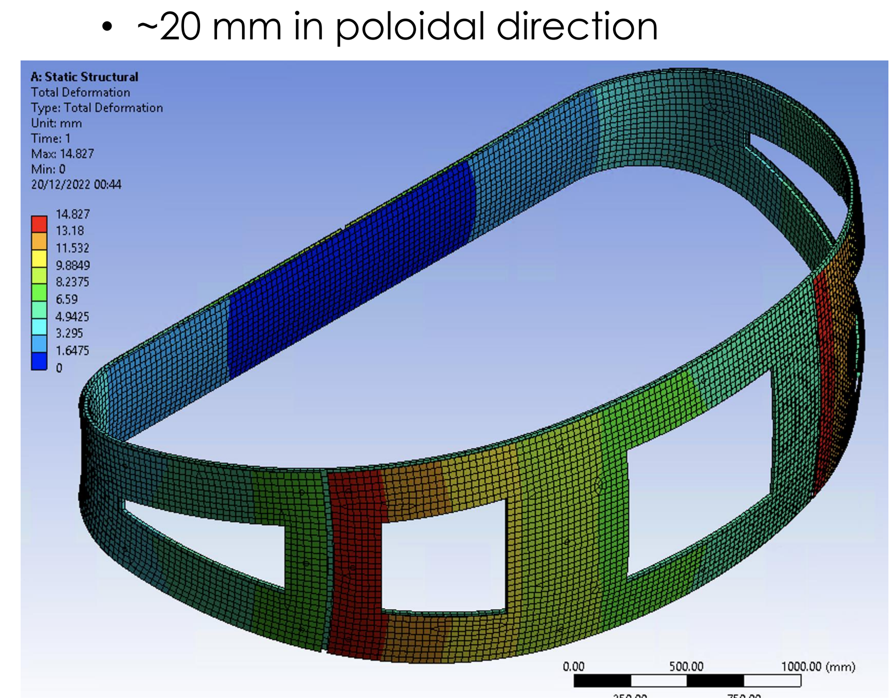
40°-60° inboard toroidal periodicity

20°-40° outboard toroidal periodicity

Interruption of the poloidal path:

- no need of electrical breaks between segments (bottom opening)
- no need of electrical breaks at tubes
- different toroidal periodicity between inboard and outboard (→ room for circuit optimization)

- Split poloidally the THS in 5 segments fixed to the vacuum vessel with 45 supports
- →relative thermal displacements at the support points during baking:
  - ~2 mm in toroidal direction
  - ~20 mm in poloidal direction



Conclusions & perspective

- Status of the ongoing design of the vacuum vessel THS and conceptual design of the port and cryostat THS reported
- Minimization of the radiative heat transfer by silver plating and active cooling
- ITER-like (pipe welding) and clamps + copper mesh preferred solutions for pipe attachment to panels
- Gravity supports: G10 bolts on VV, port and cryostat

PERSPECTIVE: finalization of the THS design, completion of the electro-magnetic, thermal-hydraulic and mechanical analyses (pressure drop, seismic loads, …) and down-selection of the best options

This contribution is part of a set of papers (Invited and Oral presentations, and a few dozen posters) presented at SOFE Oxford to illustrate the state of implementation of the DTT program. The DTT Team will be happy to provide any further information; please contact info@dtt-project.it.