EUROfusion

KOM WPPRD LMD 2021: ENEA

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This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

OUTLOOK

- State of the art of the target design
- Wetting, corrosion, protection
- Future work and conclusion

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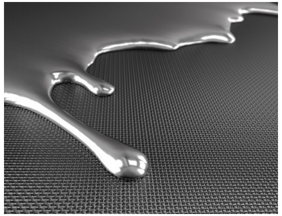
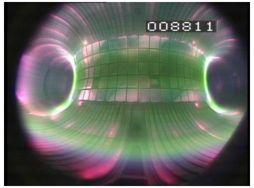
Regarding the target design

Many subsystems need to be combined to an integrated component

Liquid metal confinement

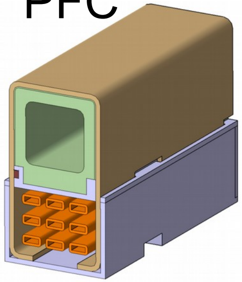


Safety

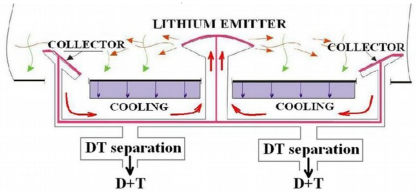


Plasma scenario

Integrated PFC

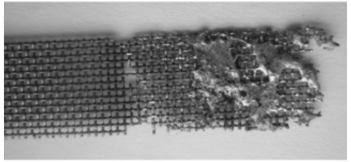


Cooling system



Closed loop

Structural materials



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Flowing vs Static – brief summary

Flowing

PROS:

- Active removal of particles and heat loads
- Easier to operate in vertical target(?)

CONS:

- Splashing
- Need external recycling for T recovery
- Flow instabilities

Static

PROS :

- Simplicity
- No splashing issues
- Flexible (choice of geometry, LM)
- Small quantities of LM
- Concept maturity

CONS:

- Heat load must be exhausted by coolant - Need of a solid support

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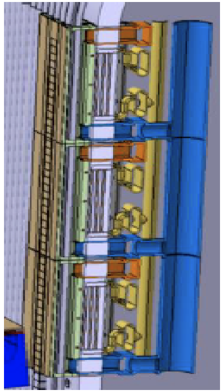
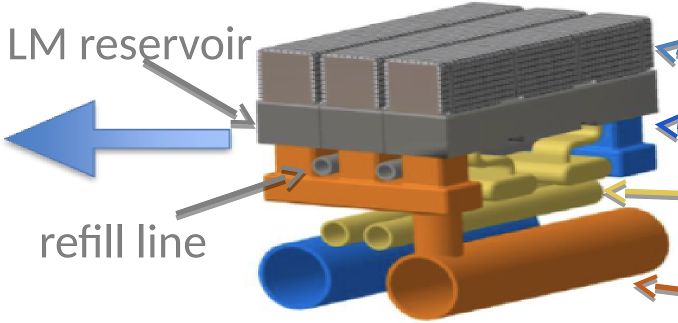
Project of the Divertor module

Definition of the basic requirements for the liquid module





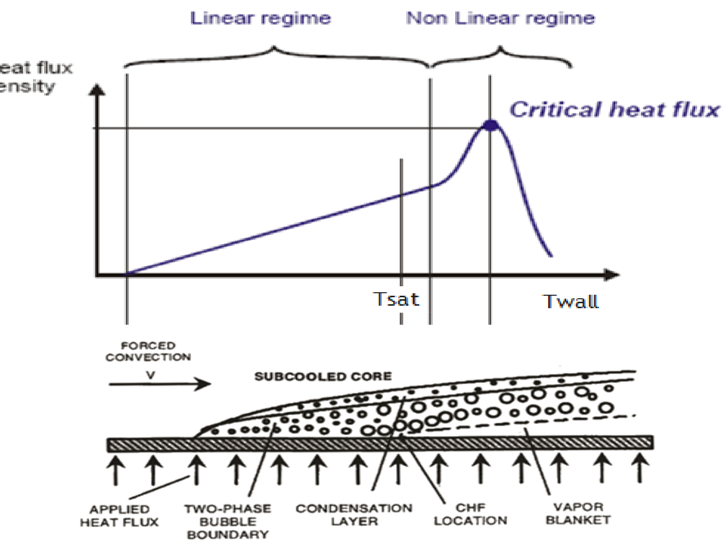
Each liquid metal elementary unit should be provided by:

- Coolant
- LM reservoir and refill line
- Heating system
- Anti-corrosion layer

Water to exhaust heat…

Water has been chosen due to high remove heat capability:

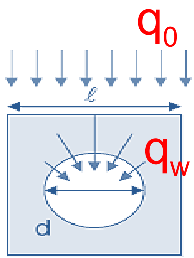
It is possible to keep the Tin below the limit of 1300°C with Incident (and absorbed) Heat Flux (IHF) of 20 MW/m²



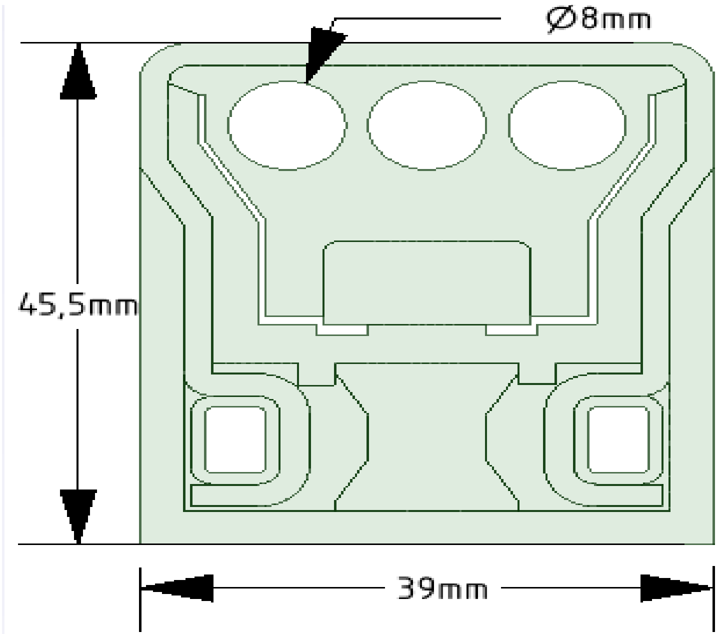
The main issue is to prevent the critical heat flux (CHF)

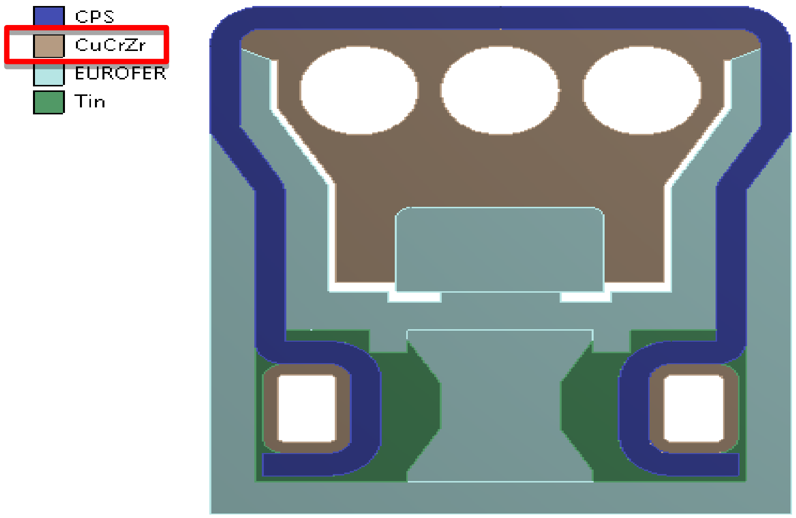
Some definitions:

Peaking factor:	$f_p=q_w/q_0$
Incident CHF:	$ICHF=CHF/f_p$
CHF Margin:	MCHF=ICHF/IHF



CuCrZr PFU thermal analysis



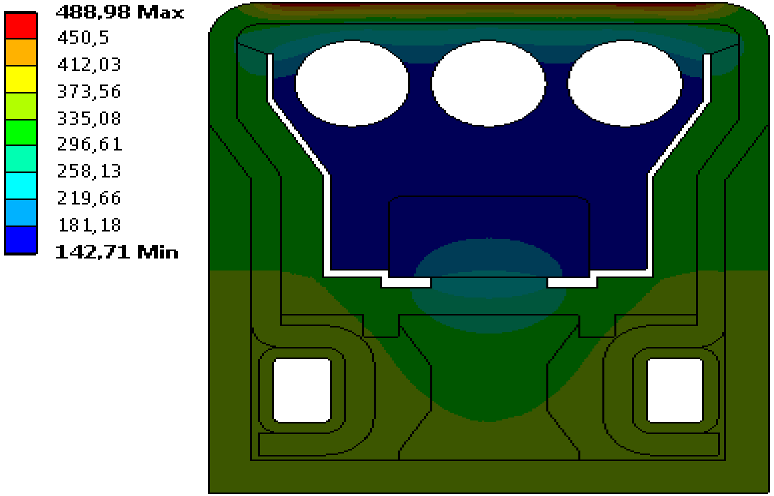


Gas temperature
T = 350°C

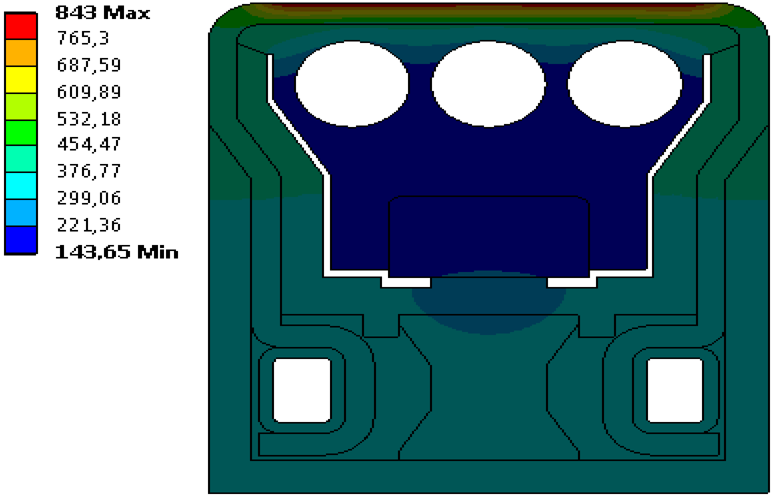
Water hydraulic parameters
T_{bulk} = 140°C
p= 5 MPa
v= 12m/s

CuCrZr PFU thermal analysis

Heat flux = 10 MW/m²



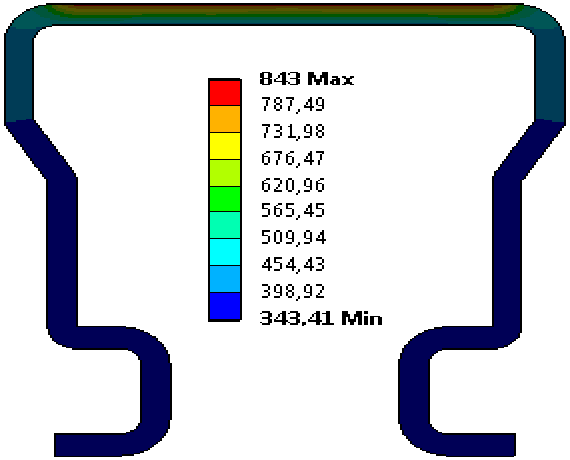
Heat flux = 20 MW/m²



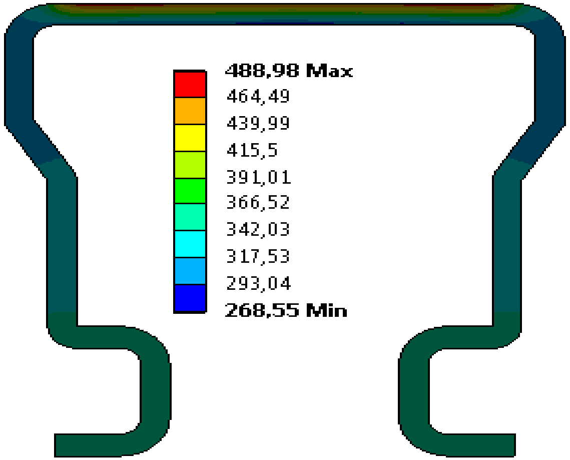
In both cases evaporation is negligible because CPS surface temperature is below 1300 °C

CuCrZr PFU thermal analysis

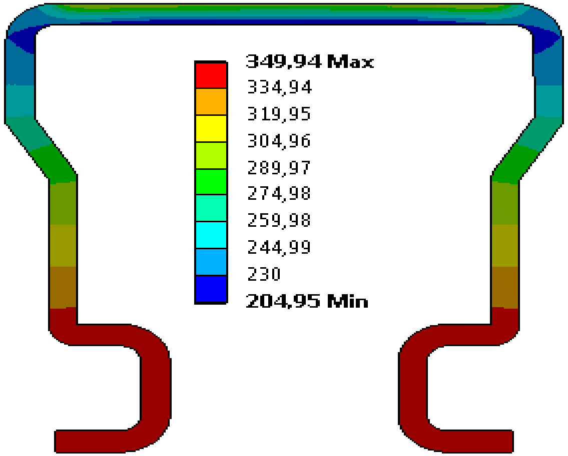
Heat flux = 20 MW/m^2



Heat flux = 10 MW/m^2

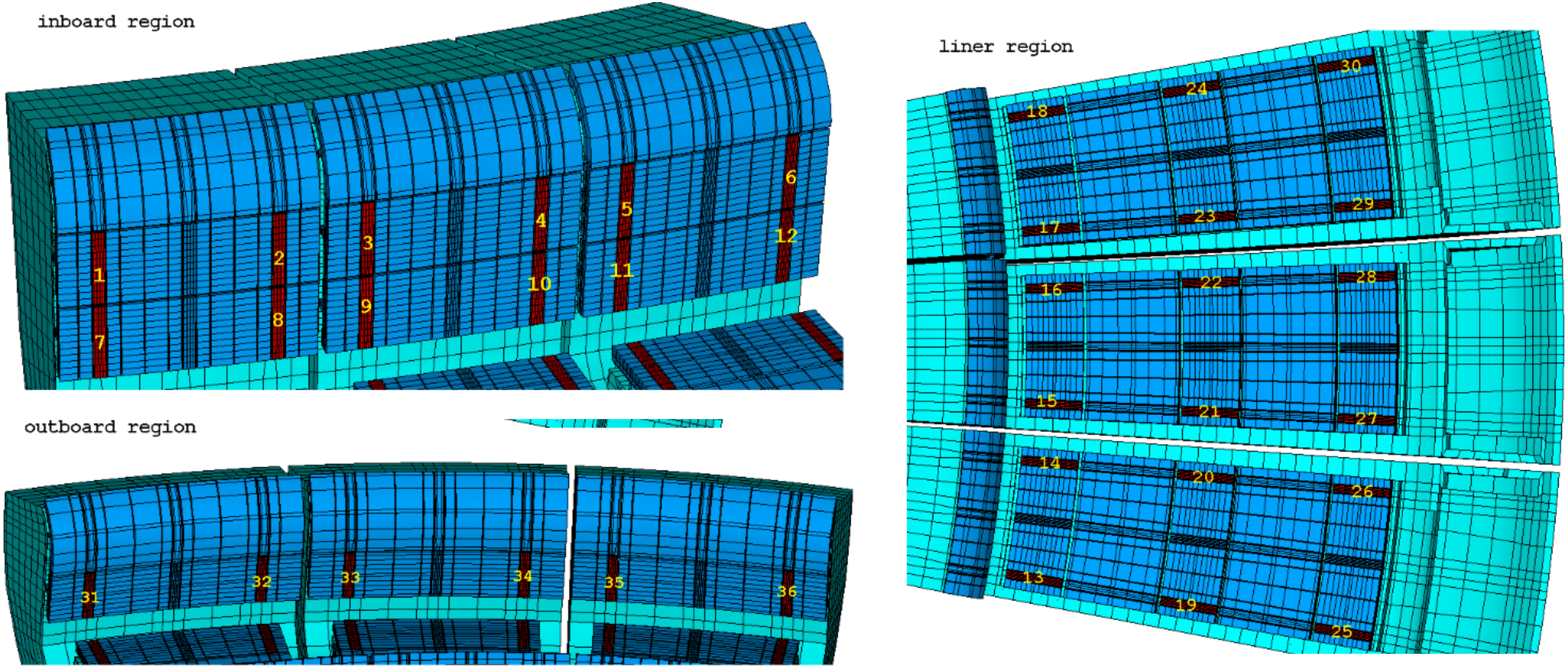


Heat flux = 5 MW/m^2



Tin is always liquid

Electromagnetic load calculations

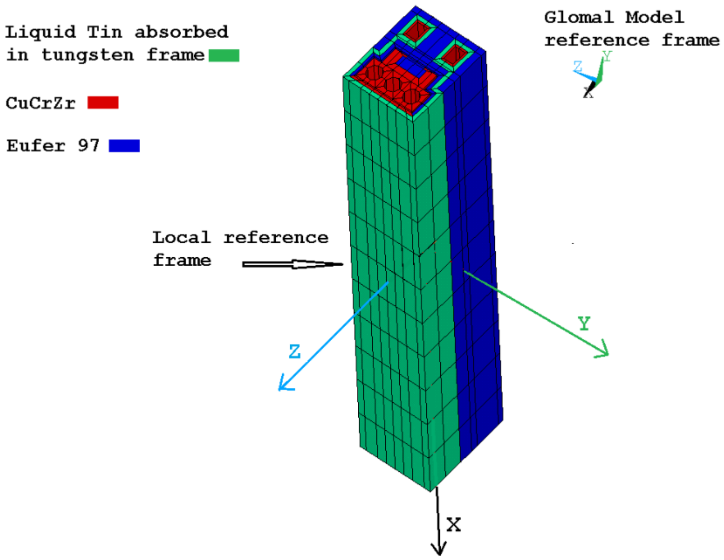


Details of the Units used in the calculations

Electromagnetic load calculations

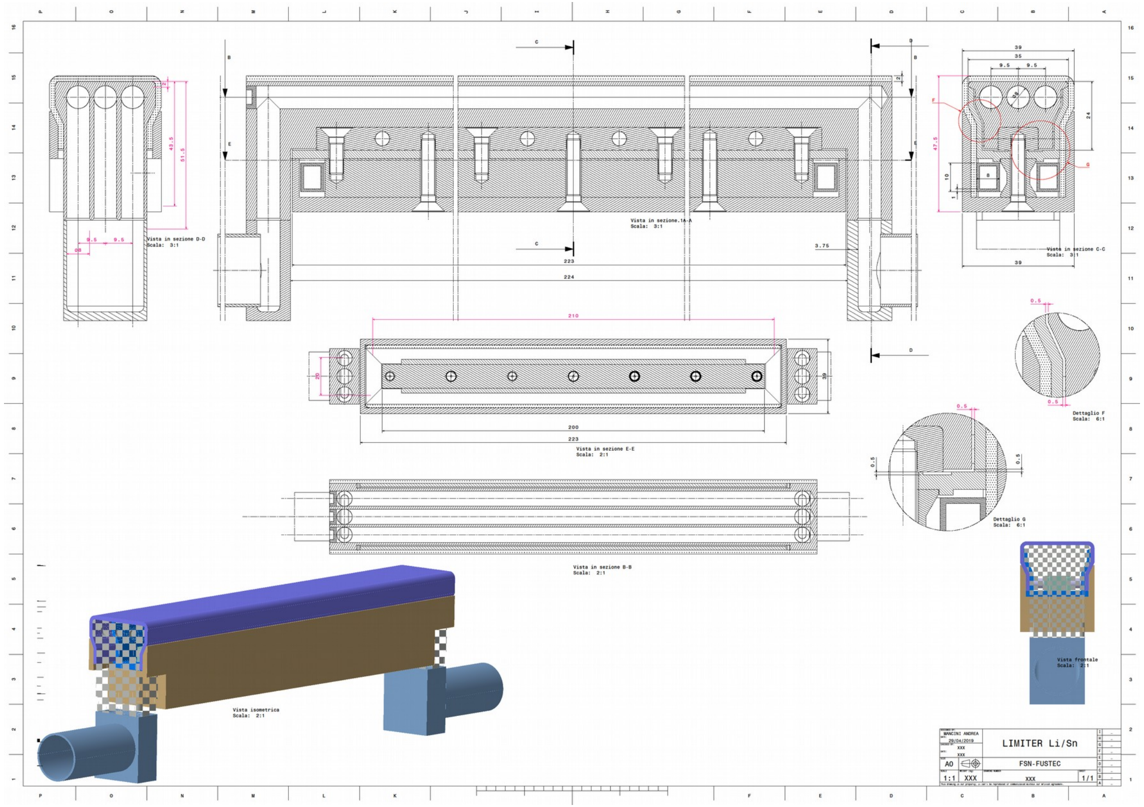
- The analyses showed that the driving loads of the PFC are the **force components in Z**
- Taking into account several contributions (eddy currents, halo currents and magnetization force) the highest positive value of F_z is **1400 N** on two units (27-28) These units lie on the **liner very near to the outboard target**. This load is still somewhat high (between **1100 and 1200 N**) for the two units (31-36) that are attached to the outboard target.

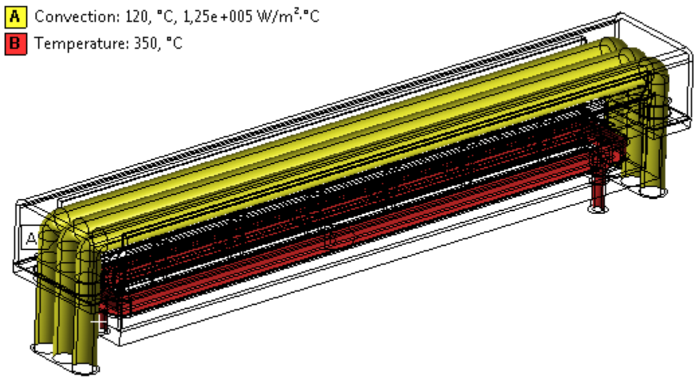
- Two disruptions cases have been analyzed: fast VDE (74ms) and slow VDE (400ms).
- It can be noted that, due to the contribution of the halo current, that in the slow VDEDW400ms are about two times higher than in the fast VDEDW74ms, **the worst EM transient must be considered the VDEDW400ms**.



At this stage these forces are compatible with the actual design.

LMD mock-ups need to be tested





A small mock-up will be ready within few months to be tested in linear plasma devices.

Experiments are needed

LMD mock-ups need to be tested

Two mock-ups have been already manufactured: CuCrZr and W-Cu/80-20

We need to insert the CPS and wet them with tin.

We are waiting for the W yarn delivery in a few weeks.

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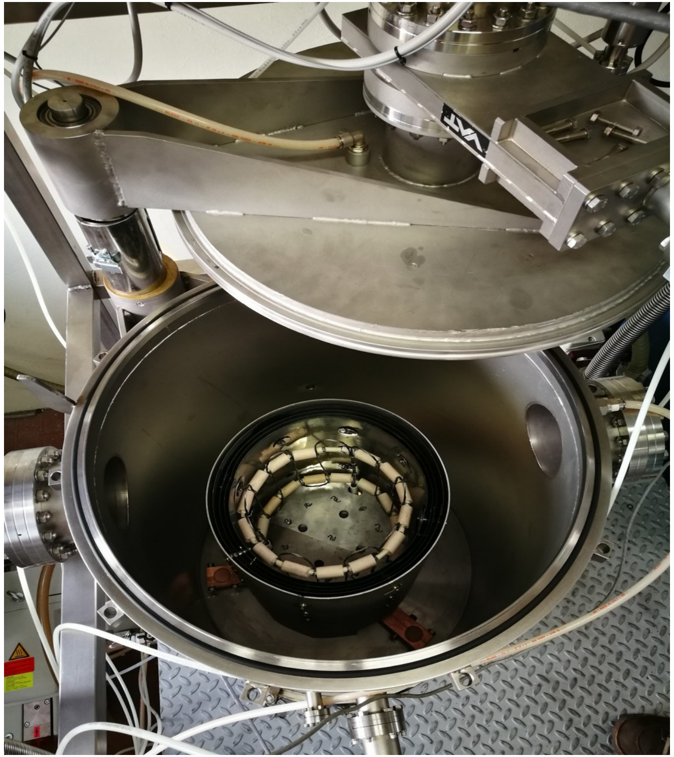
Activities at Frascati Liquid Metal Laboratory

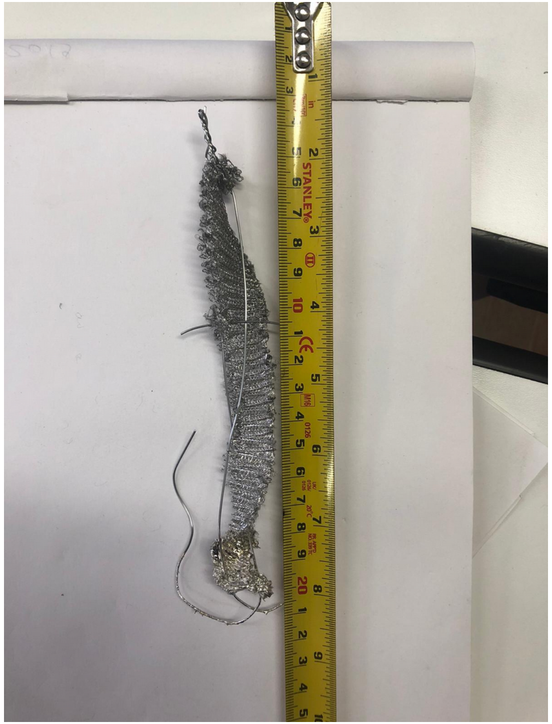


We are mainly focus on wetting and corrosion prevention

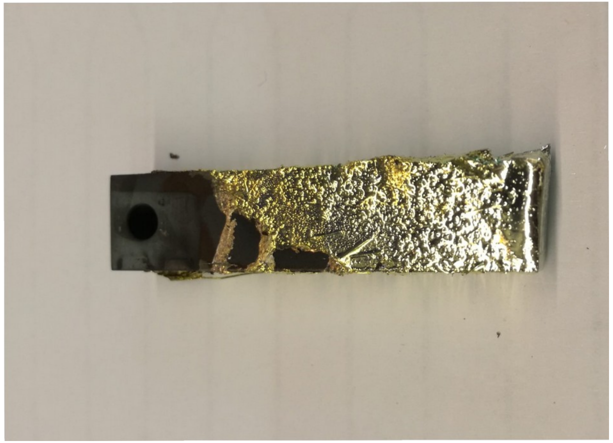
Wetting

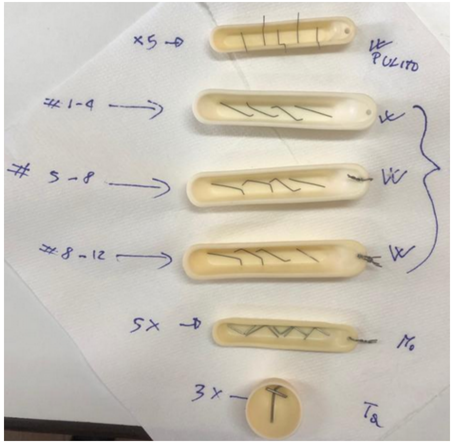
Example of wetting of large and complex CPS compatible with our divertor project module.

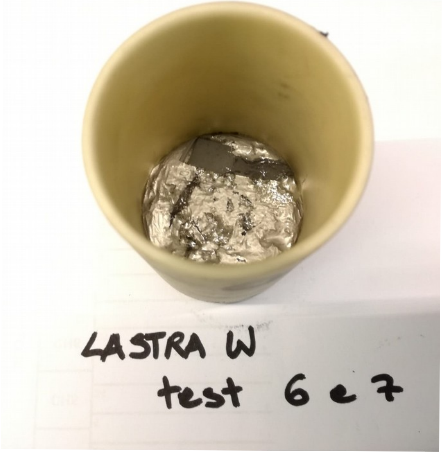
Capillary pressure exceeds 15 cm equivalent liquid tin hydrostatic pressure



Corrosion Tests



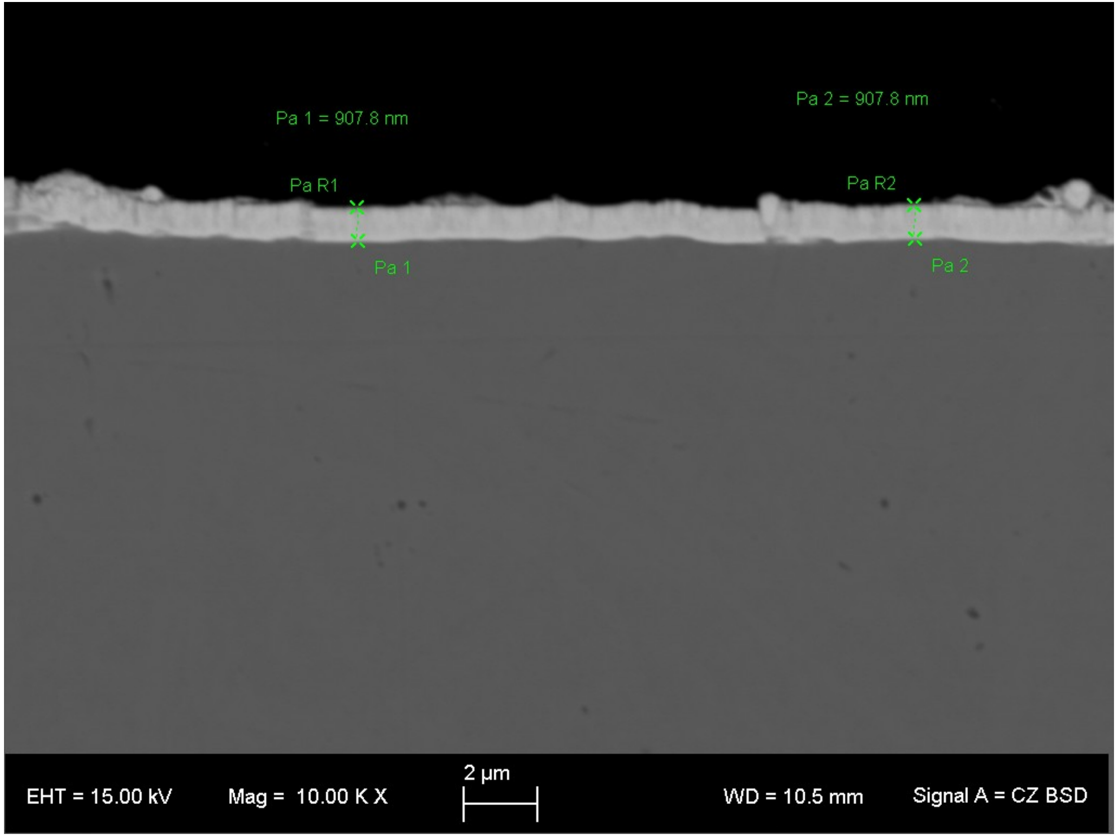




Corrosion test have been performed:

- CuCrZr and SS at low temperature (<500)
- W, Mo, Ta at high temperature (>800)

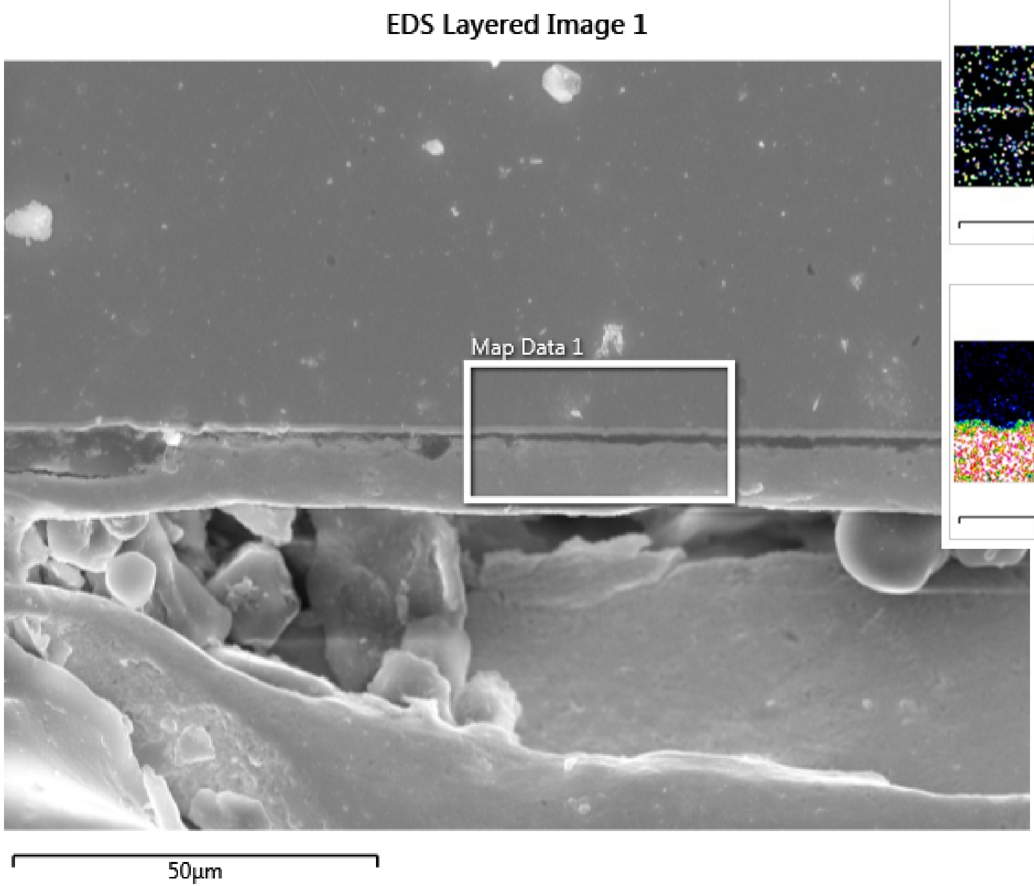
Preventing corrosion

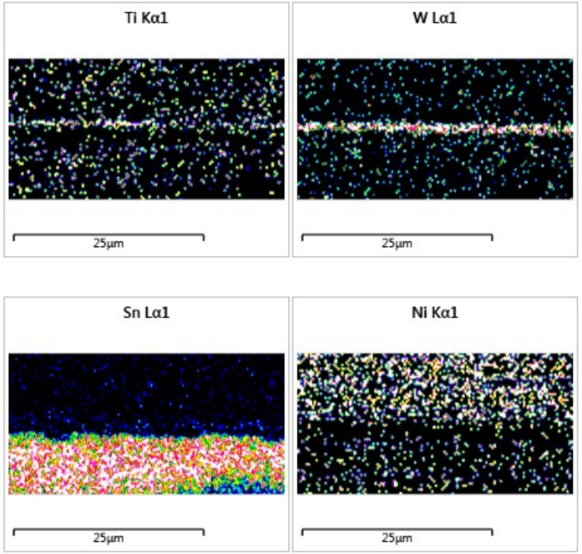


W PVD coating is actually under test.

The results on AISI316 are promising. Further improvements for CuCrZr are required.

Preventing corrosion





The W protective layer on AISI316 showed promising results after test in liquid tin 50h @ 500°C.

Further analysis and improvements are on going.

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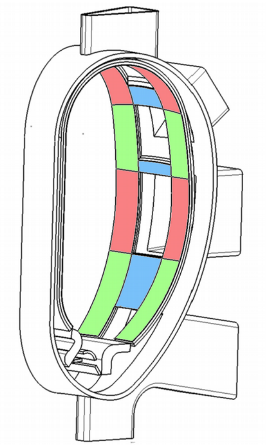
Future work

- Mock-ups assembly including anti-corrosion layer and CPS wetted with tin
- Mock-ups tests in linear devices
- Start planning future experiments on tokamaks? Asdex-U manipulator? COMPASS-U? DTT?

Divertor Tokamak Test Facility



DTT Objectives

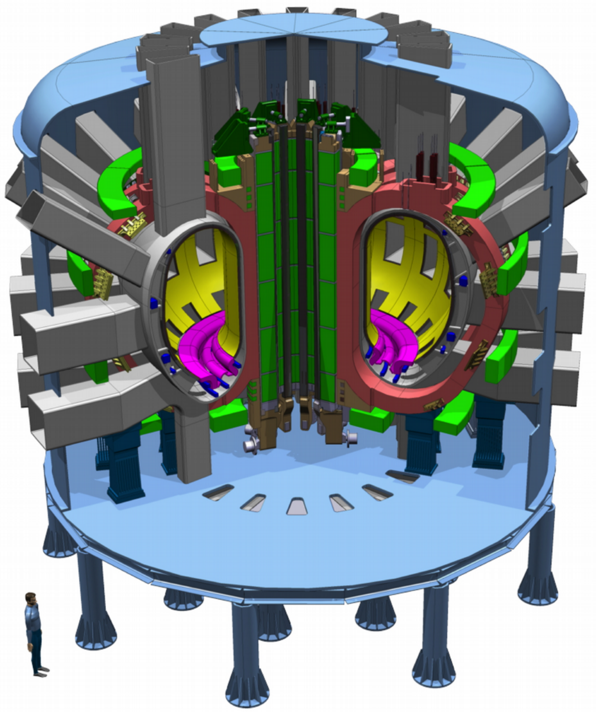
The DTT facility will test the physics and technology of various alternative divertor concepts under conditions that can confidently be extrapolated to DEMO.

First wall

- Cooled replaceable W coating panels
- Working temperature up to 300°C

Standard W divertor

- compatible with advanced magnetic configurations



A liquid metal module divertor is under design.

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Publications and talks

- Roccella, S., Dose, G., de Luca, R., Iafrati, M, et al. CPS Based Liquid Metal Divertor Target for EU-DEMO. J Fusion Energy (2020). https://doi.org/10.1007/s10894-020-00263-4

- Thermomechanical design and manufacturing of a liquid metal divertor target
  G. Dose, S. Roccella, R. De Luca, M. Iafrati , A. Mancini and G. Mazzitelli
  31st Symposium on Fusion Technology (SOFT2020) 20TH – 25TH September 2020, virtual edition