MuC Target – Shielding Thermal Studies

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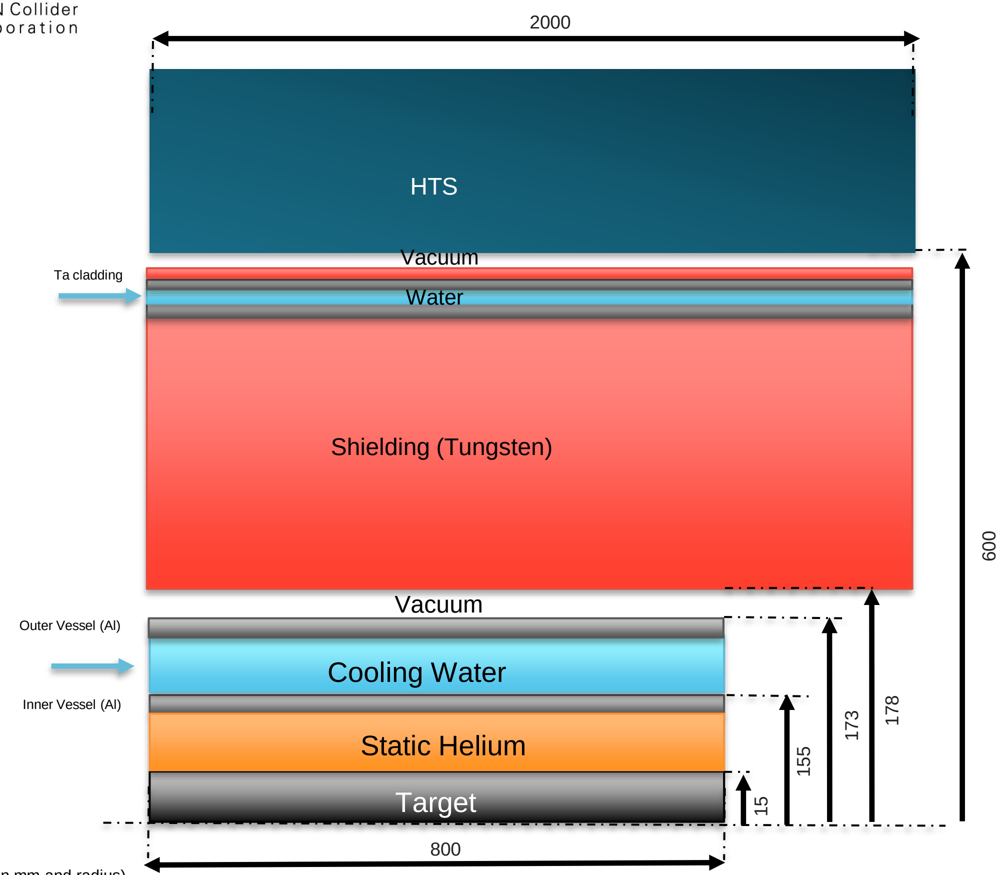
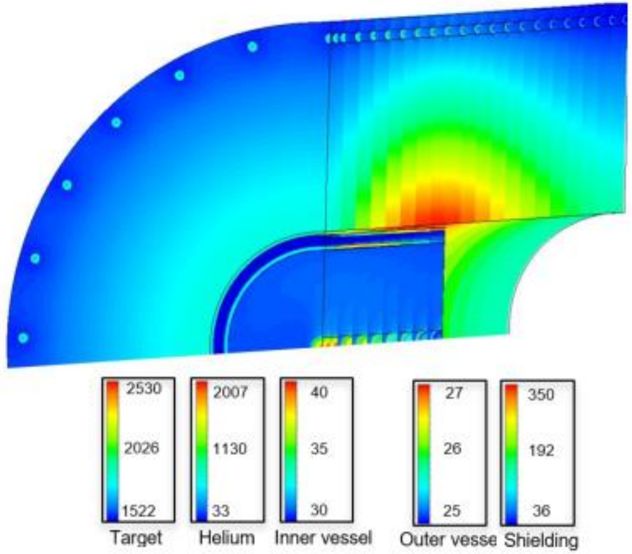
Status at collaboration meeting



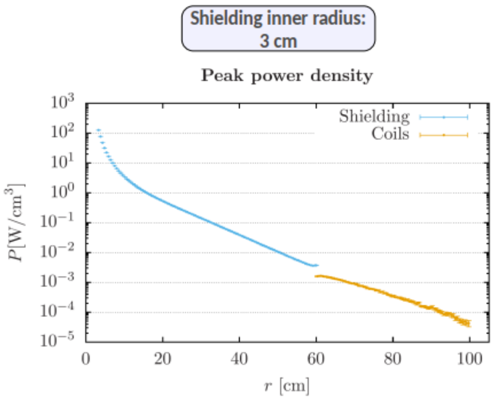
(all dimensions in mm and radius)

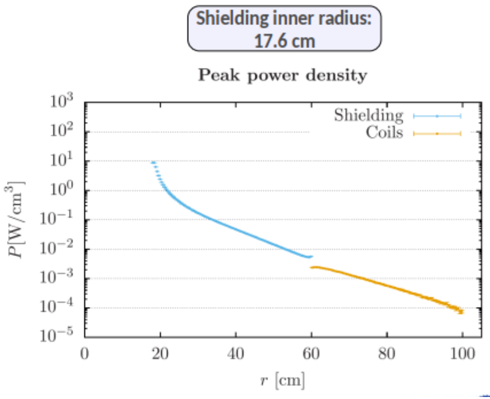


(Temperature in °C)

Energy deposition

- Two shielding - target options were proposed at the Colab. meeting:
  - Shielding bore radius: 3 cm / 17.6 cm
- But having a smaller bore for the shielding does not significantly reduce the power deposition in the coils.





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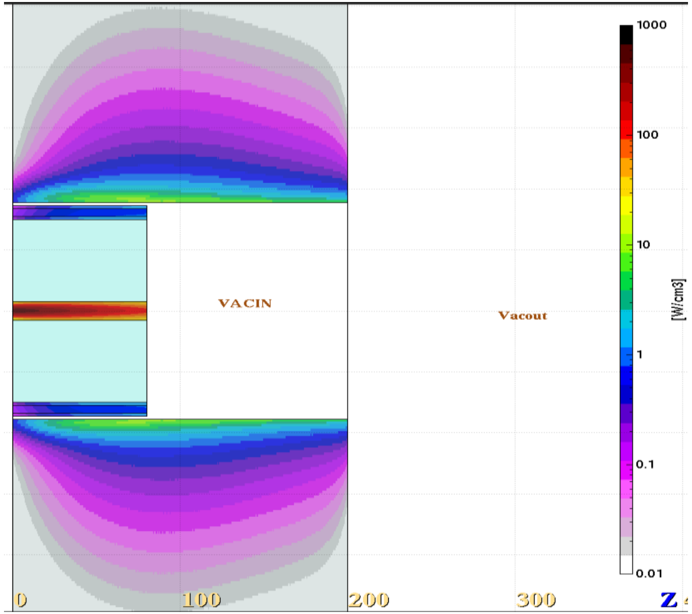
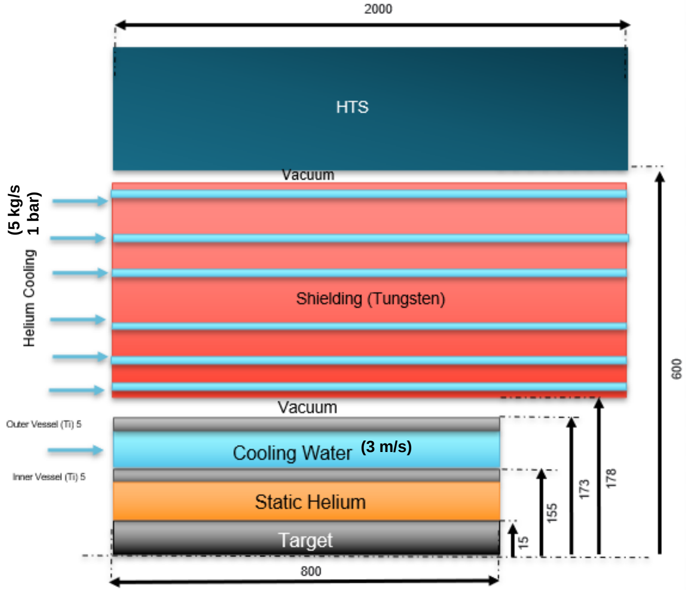
512.3 kW deposited in the shielding

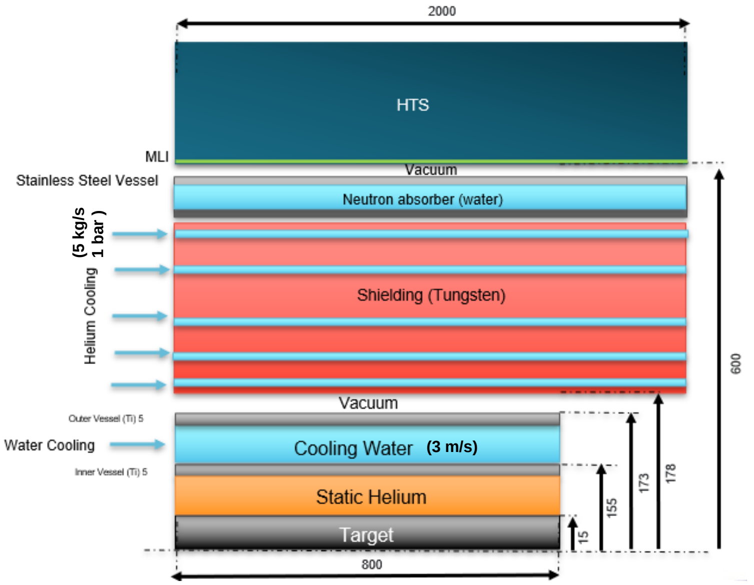


Current shielding cooling concept

Current concept



Next evolution

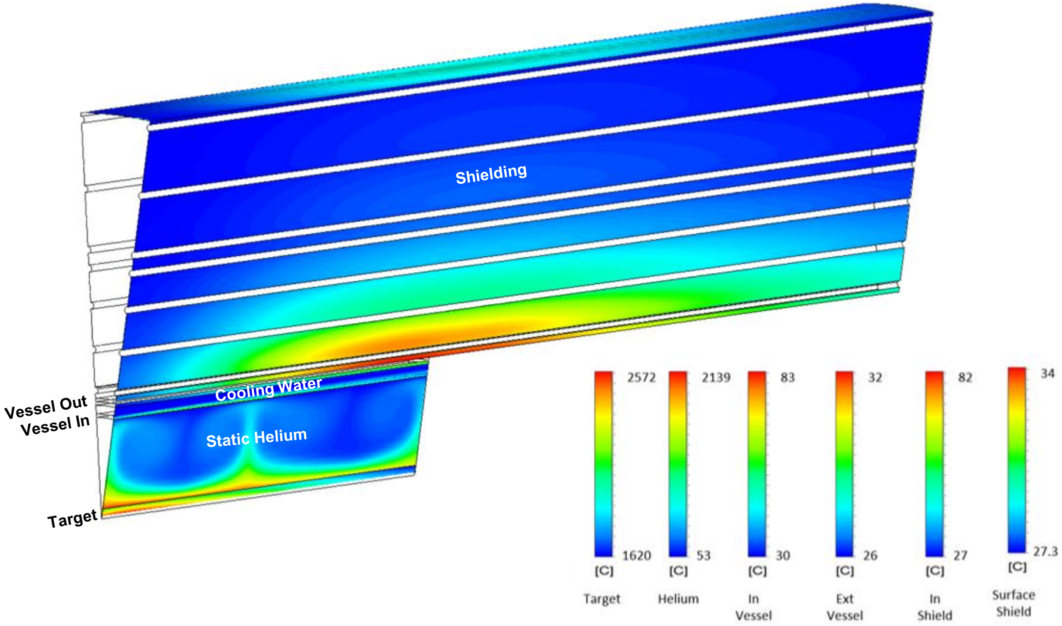


- Several cooling pipes through the shield (not only the surface). Helium cooling without Ta cladding instead of water (+ Ta cladding).
- Vessel in titanium (durability, thermal resistance).

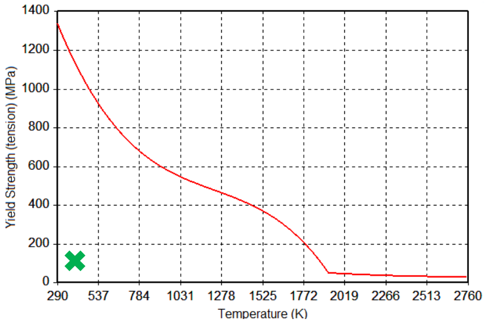
(all dimensions in mm and radius)

Target & Shielding – Thermomechanical Analysis

Temperature field



Shielding tensile stress



- Temperatures are below the material limits. Surface shielding temperature should be acceptable for the surrounding solenoid.
- First structural analysis suggest tensions around 150 Mpa. This value falls under the yield strength and fatigue limit of tungsten (at RT). More detailed structural calculations are foreseen to be done.

Multi Layer Insulation (MLI)

- Preliminary check done to check the boundary condition of the thermal problem & preview the space needed to isolate the solenoid from the shielding:

$$q = q_c + q_r = \frac{C_c N^{2.56} T_m}{n}(T_h - T_c) + \frac{C_r \epsilon_o}{n}(T_h^{4.67} - T_c^{4.67})$$

where:
- q = total heat flux transmitted through the MLI (mW/m^2)
- q_c = conductive heat flux transmitted through the MLI (mW/m^2)
- q_r = radiative heat flux transmitted through the MLI (mW/m^2)
- C_c = conduction constant = 8.95×10^{-5}
- C_r = radiation constant = 5.39×10^{-7}
- T_h = hot side temperature (K)
- T_c = cold side temperature (K)
- T_m = mean MLI temperature (K); typically $(T_h+T_c)/2$
- ϵ_o = MLI shield-layer emissivity at 300 K = 0.031
- N = MLI layer density (layers/cm)
- n = number of facing pairs of low-emittance surfaces in the MLI system

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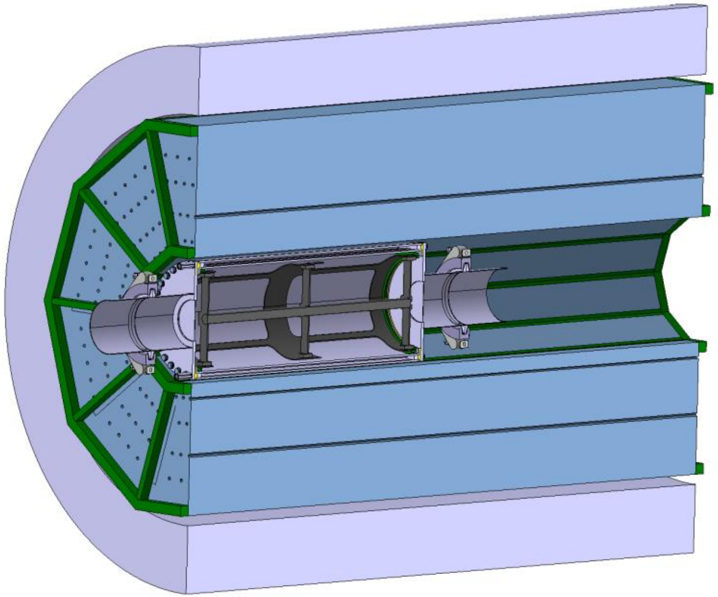
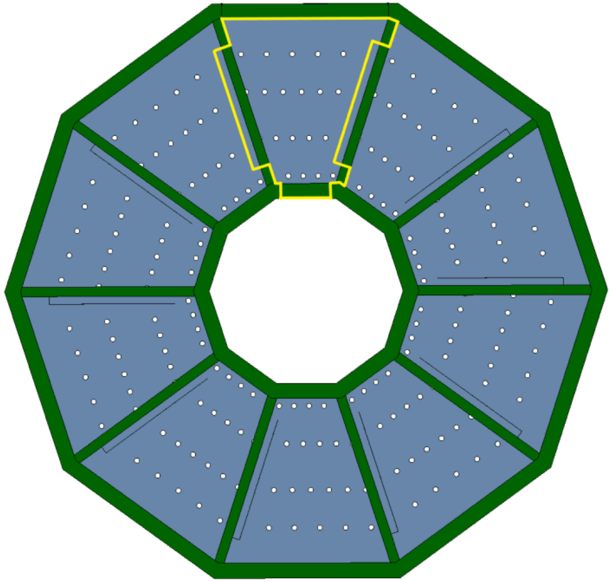
- Where: Th = 300 K, Tc = 10 K, N = 30 layers / cm.
- Imposing a limit of heat transferred from the shielding to the solenoid of 25 W #:
  - 5 layers of MLI are needed (16 mm).

Heat load for steady state = 25 W (from MAP studies, Ramesh Gupta 20T Target Solenoid with
HTS Insert Solenoid Capture Workshop, BNL, Nov. 29th, 2010) -> 6.63 W/m^2

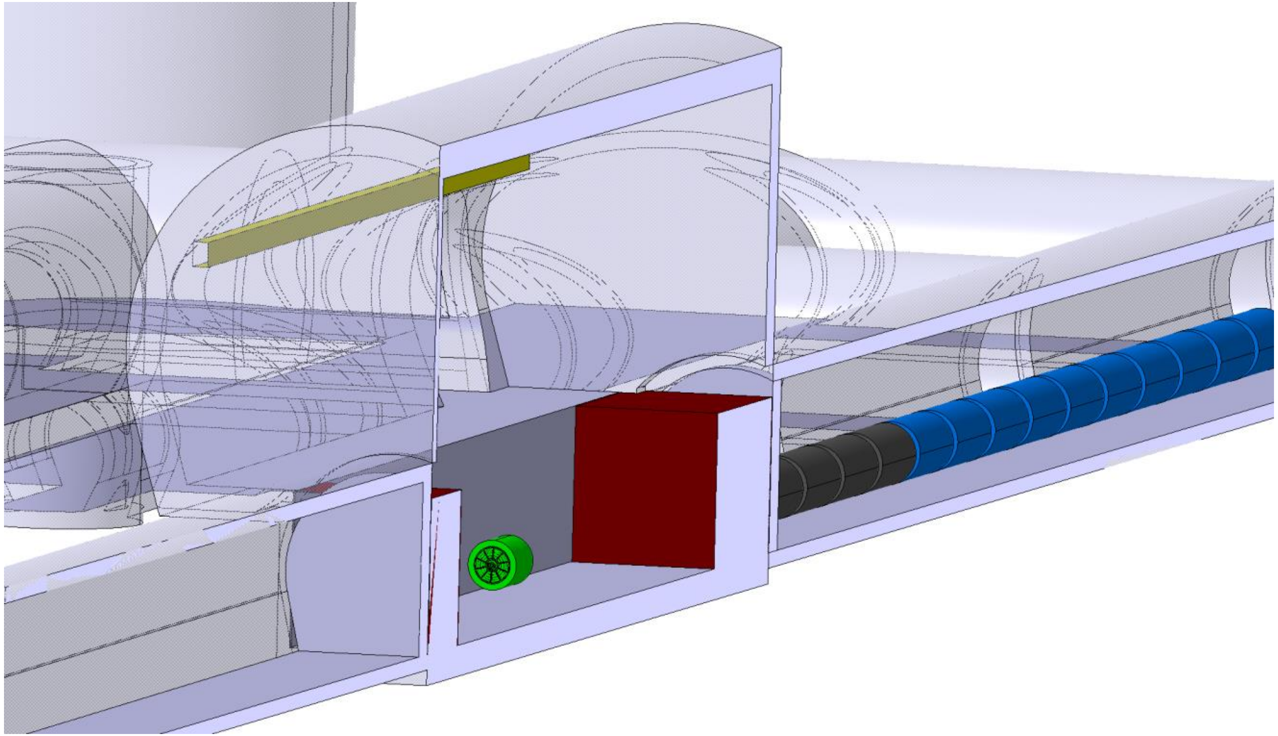
First ideas of the shielding assembly





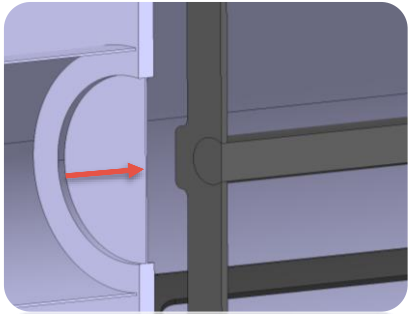
- Brainstorming! Any idea is welcome. CAD model useful to detect future construction and integration problems.
- Tungsten sectors supported by an external structure (structure material and dimensions to be defined).
- Shape thought in order to block direct radial radiation paths to the solenoid.

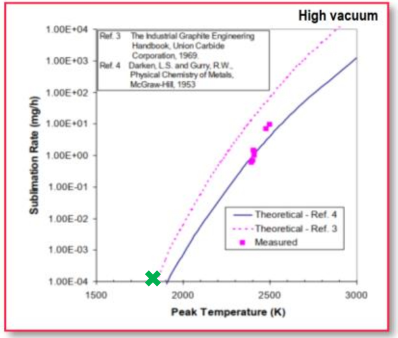
Integration in the building



Window

- A window is necessary to store static helium because:
  - In high vacuum, graphite may sublimate in a rate of around 1e-04 mg/h.
  - Experiments using an atmosphere of static helium reduced the graphite sublimation rate by a factor of 30. *#C.C. Tsai*

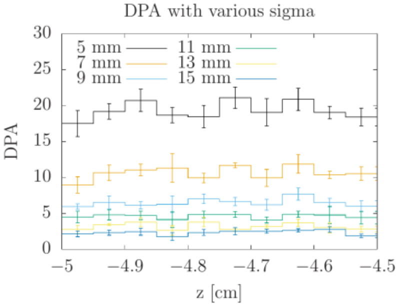




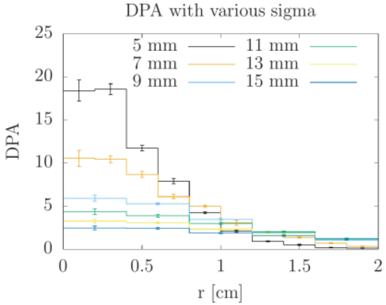
#Graphite sublimation rate - J.R. Haines & C.C. Tsai -2001

- First aproximations foresee excesive high temperatures, stresses and DPA. (Due mainly to the small beam size)
- This fact entails the need of a remote handling system (such as T2K), to exchange the vessel, positioning and to align back into place.
- But still a lot of work needs to be done to assess and improve the window lifetime.

Longitudinal DPA distribution (uniform)



Radial DPA distribution



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Conclusions & future work

Conclusions

- The current shielding design is acceptable in terms of solenoid protection, temperatures and thermal stresses.
- First ideas about construction and integration have been provided.
- The target window is currently the most challenging part in terms of DPA, temperatures and stresses.

Future work

- A neutron absorber layer will be integrated in the shielding.
- We will continue detailing the mechanical design of the whole target/shielding to have a realistic idea of how it will look and finding construction & integration problems.
- More work will be done to improve the window durability and the remote handling to exchange the whole vessel.

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Thank you for attention

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