# Design of the FCC-ee positron source target: current status & challenges

Mini workshop on the FCC-ee Injector Studies

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- **Summary**

# Target design: Recap

## Goal:

- To provide a **mechanical design** of the positron's source target.

## Previous results:

- Target's cooling through its shielding
- Parametric analysis
  - geometry & working conditions
- Recommended geometry:
  - C2x2 D7.5mm at 25 m/s and 12.5 bar

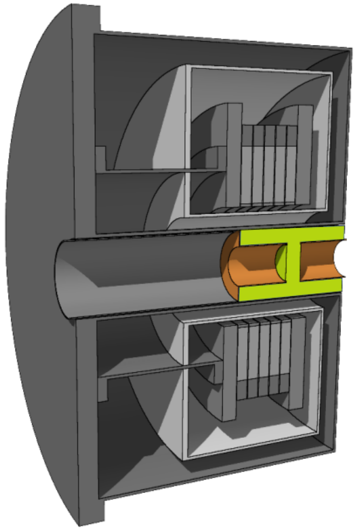

**Fig.** Design's approach:
target and shielding are integrated on a single piece

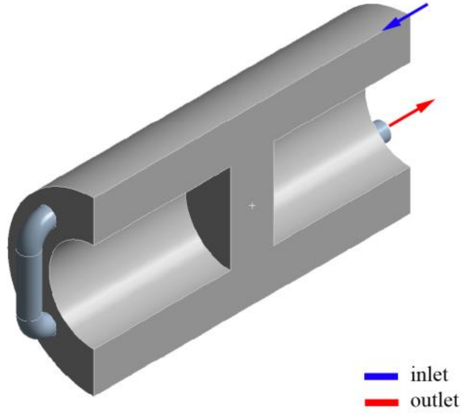


**Fig.** Recommended geometry
C2x2 D7.5mm

**New challenge:** an increase in the energy density deposition by a **factor of 4**

Power to dissipate in the target:
Before: 0.9 kW [Aug-2022]
Current: 3.6 kW [Oct-2022]

# Target design: Updating the energy deposition

## Question:

- Can we still use the previous design?

## Answer:

- No. The new energy density deposition requires a new strategy for cooling.

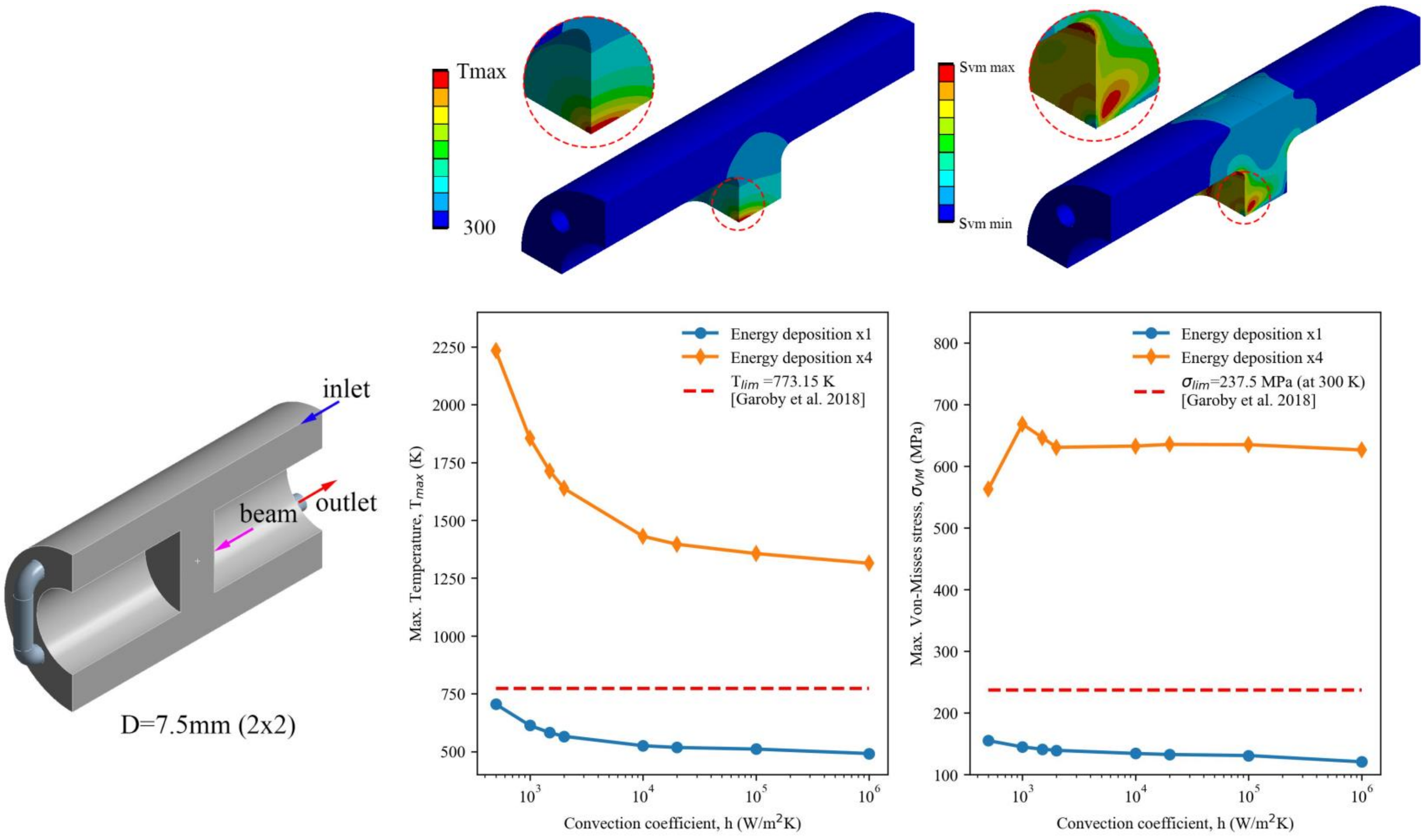


**Fig.** Geometry (left). Maximum temperature Tmax (middle) and Maximum Von-Mises stress (right) as a function of the convection coefficient h

# Target design: Understanding the "physical limits"

## Hypothesis 1:

The whole shielding is perfectly cooled at T=300K

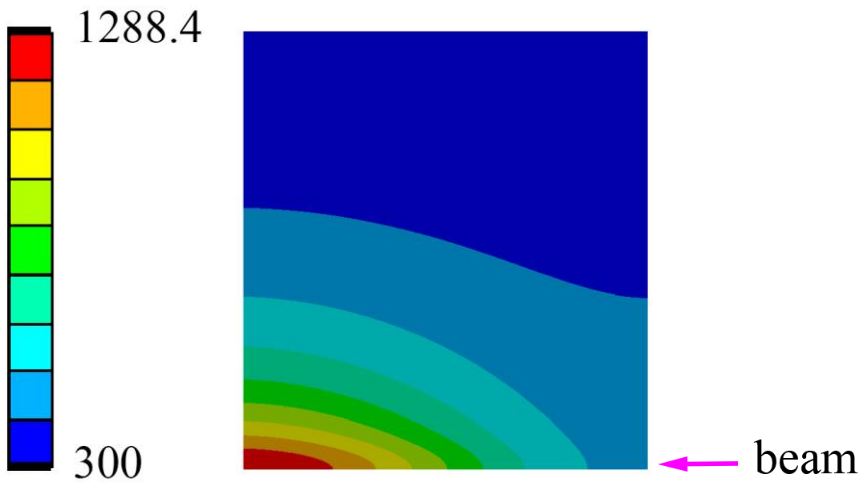


**Fig.** Temperature distribution in the target for hypothesis 1

## Hypothesis 2:

The external surface of the target is perfectly cooled at T=300K

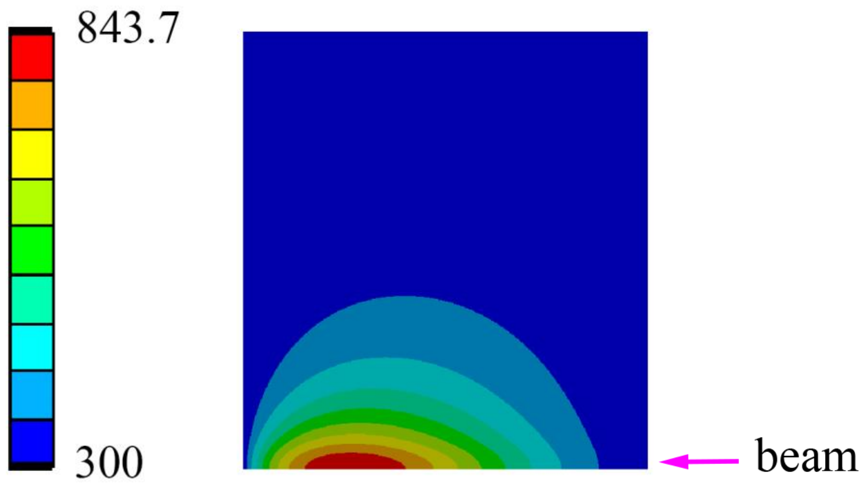


**Fig.** Temperature distribution in the target for hypothesis 2

**Take away message:** the maximum temperature in the target will be "bounded" between both values

# Target design: W-Cu model

## Features:

Material selection based on ITER* and SuperKEKB**

Target embedded in a copper interface

4 loops for cooling

Shielding is divided in two parts

## Model:

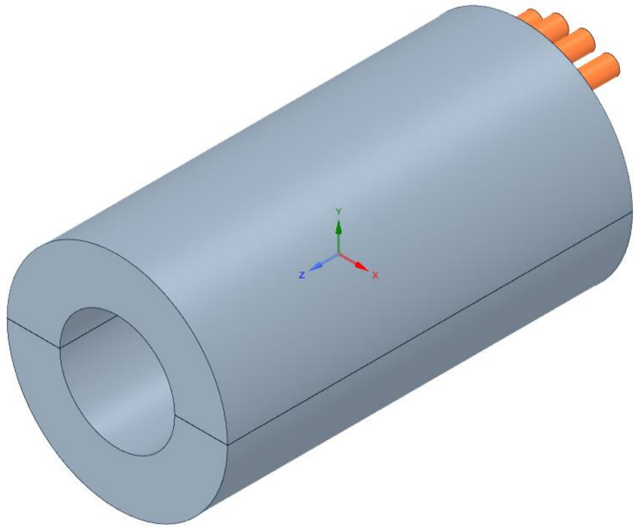

**Fig.** W-Cu target model components

*T. Hirai and G. Pintsuk, Fusion Engineering and Design 82 (2007) 389–393

** T. Kamitani, M. Akemoto, D. Arakawa, Y. Arakida, A. Enomoto, S. Fukuda et al., SuperKEKB positron source construction status, in Proceedings of the 5th International Particle Accelerator Conference, Dresden, Germany, 15–20 June 2014, pp. 579–581.

# Target design: W-Cu model

## CFD results

Cooling fluid: $H_2O$

u= 5 m/s

p= 20 bar

h = 18297.918 W/m2K (average)

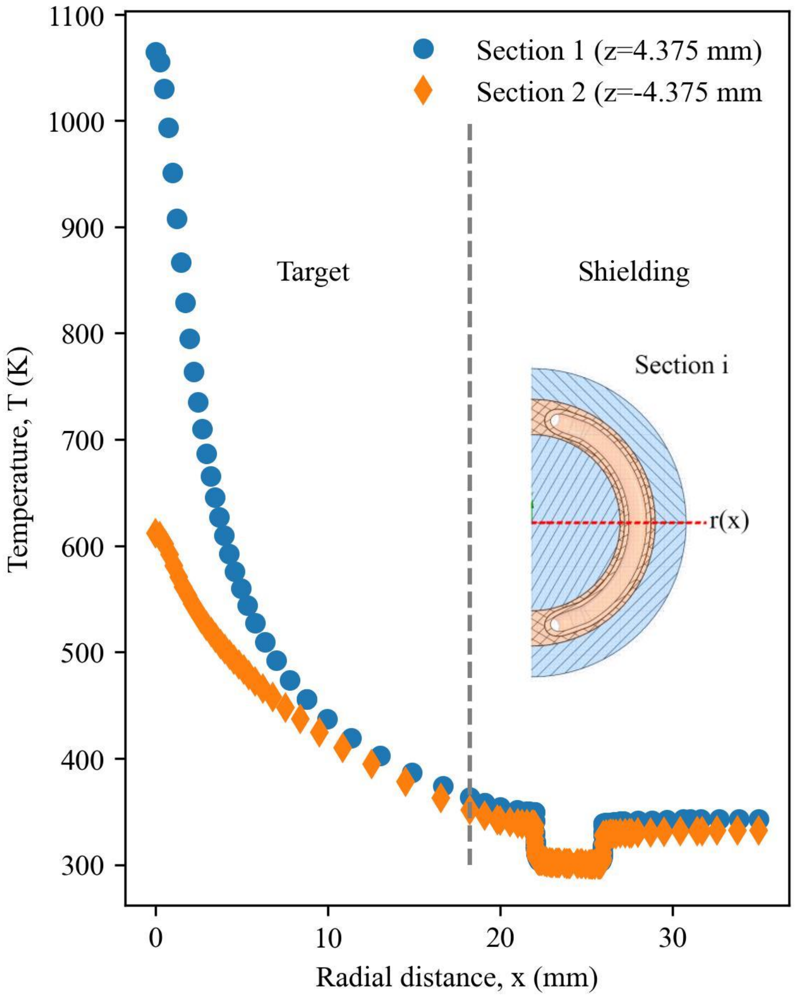


**Fig.** Radial temperature distribution

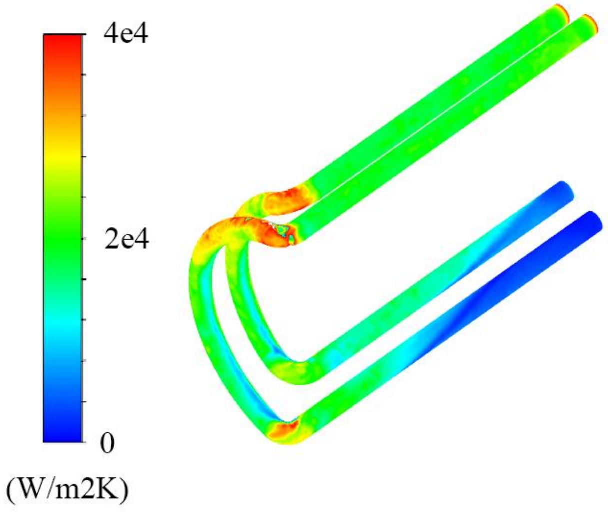


**Fig.** Convection coefficient h (W/m2K) distribution

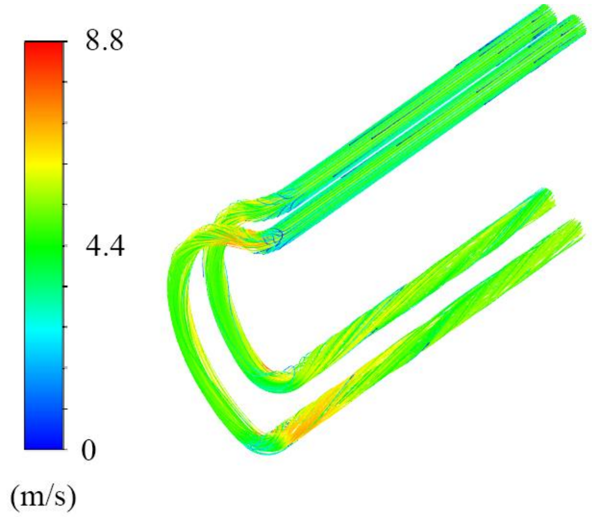


**Fig.** Velocity streamlines (m/s)

# Target design: W-Cu model

## Thermo-mechanical results (1/2)

T limit = 500 C (773.15 K) * 	* Garoby et al 2018 Phys. Scr. 93 014001

σ limit = 273.15 MPa*

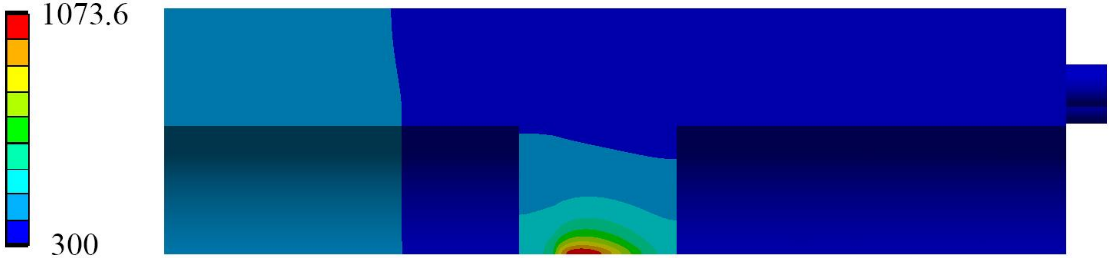


**Fig.** Temperature distribution in the target (K)

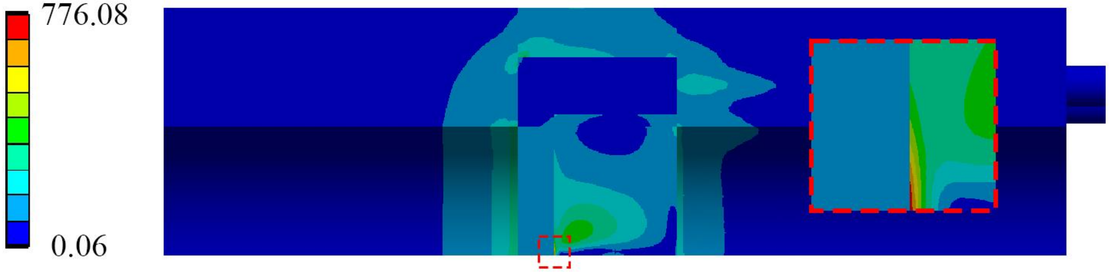


**Fig.** Von-Mises equivalent stress (MPa)

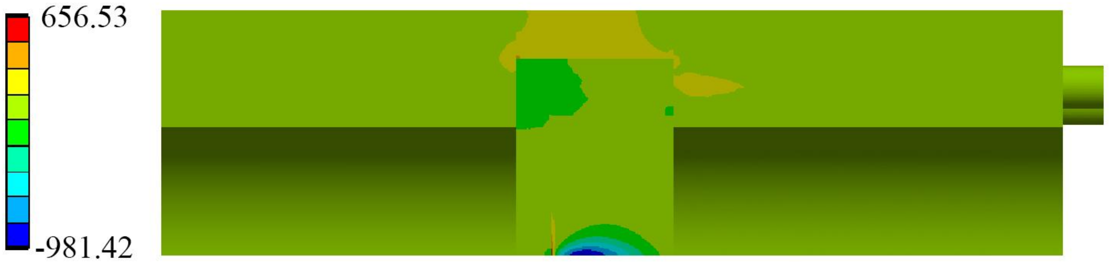


**Fig.** Principal stress $\sigma_1$ (MPa)


**Fig.** Principal stress $\sigma_2$ (MPa)

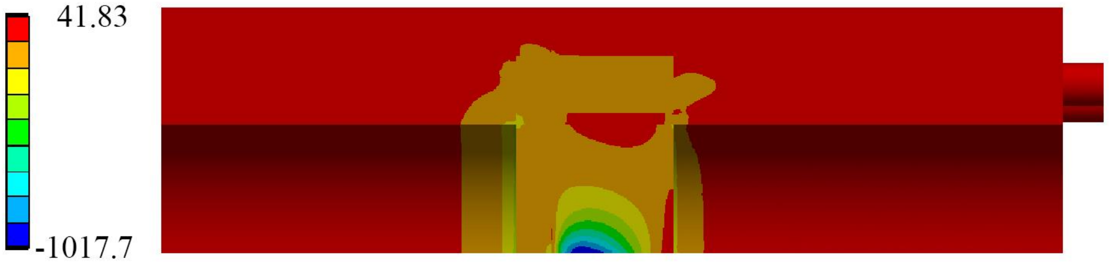


**Fig.** Principal stress $\sigma_3$ (MPa)

# Target design: W-Cu model

## Thermo-mechanical results (2/2)

The temperature at the location of maximum Von-Mises stress (776.08 MPa) is 658.8 K (385.65 C)

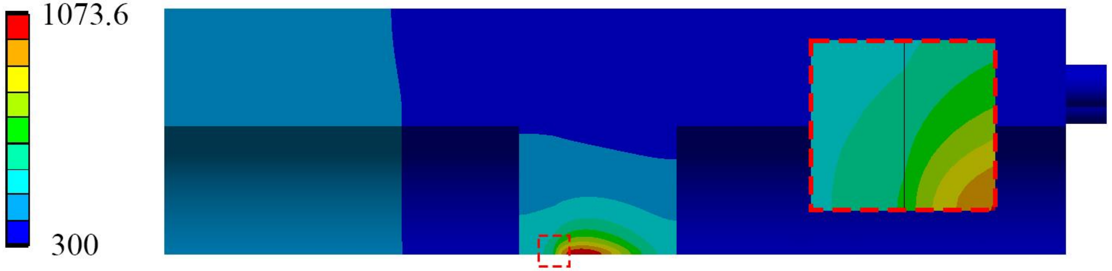


**Fig.** Temperature distribution in the target (K)

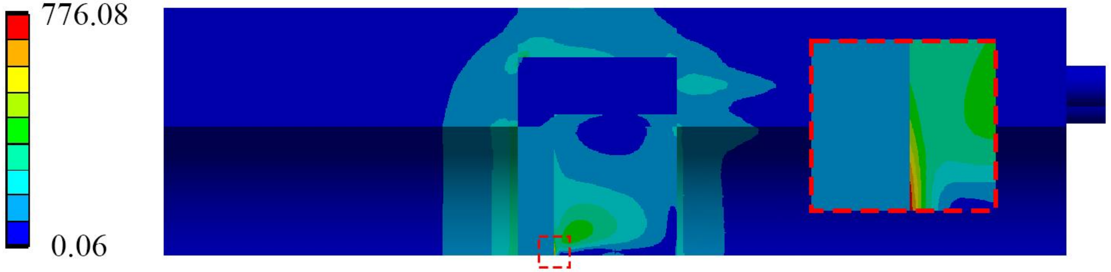


**Fig.** Von-Mises equivalent stress (MPa)

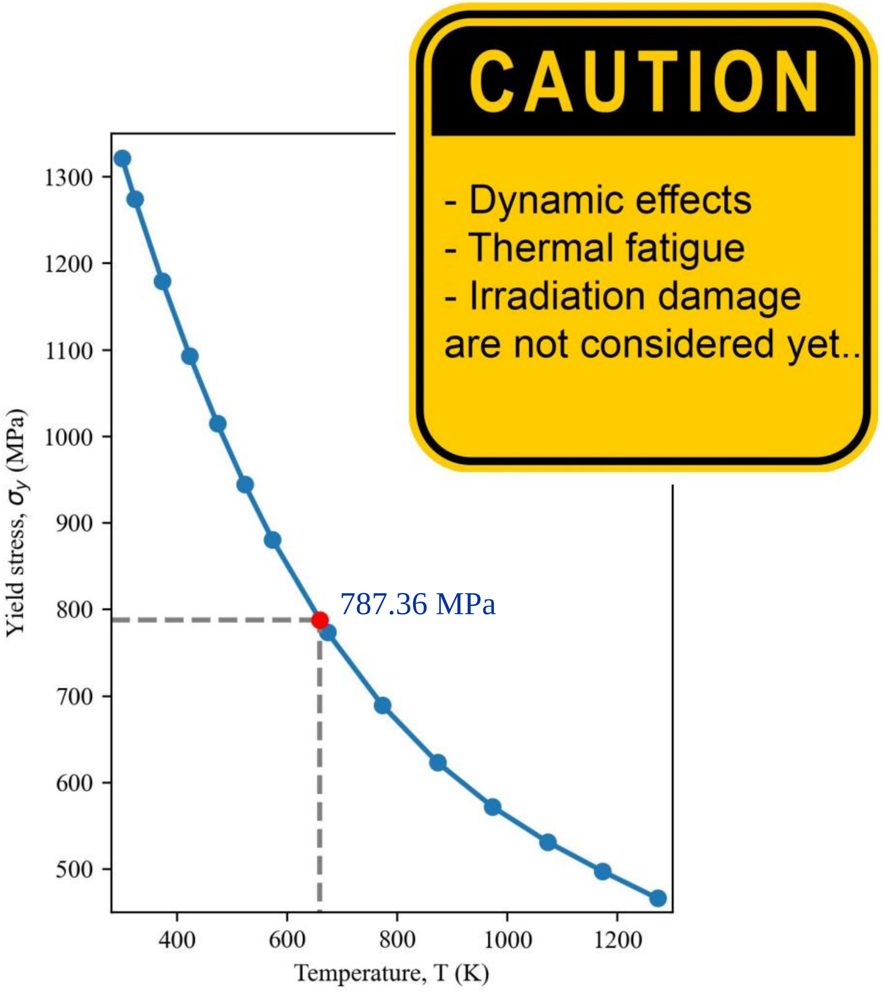


**Fig.** Yield stress $\sigma_y$ as a function of temperature [MPDB 2022]

# Target design: Discussion

## Design workflow

Step 1 — Thermal analysis

Step 2 — Thermal stresses

Step 3 — Fatigue analysis

## Ideas to explore:

The increment in energy deposition (x4) causes an **important rise of temperature** in the target (x3).

As a consequence, the obtained **thermal stresses** are **on the limit** of the elastic range of tungsten.

Ideas to explore:

- Physics: beam configuration (size)
- Cooling: material selection and/or design optimization
- Geometry: target thickness
- Design: rotary target?

# Summary

As a reference, the SuperKEKB target has a thickness of **14mm** and dissipates a power of 0.5-3 kW. To deal with this power, it is embedded in a copper interface. On the other hand, the FCC-ee target has a thickness of **17.5mm** and with the updated energy deposition mapping, it must dissipate 3.6 kW. Following this philosophy, a preliminary design was presented.

With the **current specifications**, the material is subjected to significant thermal gradients and thermal stresses. The presented results are considering a steady-state scenario only and the material is close to its yield limit. Therefore, it is important to discuss **possible strategies** to mitigate this potential issue.

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