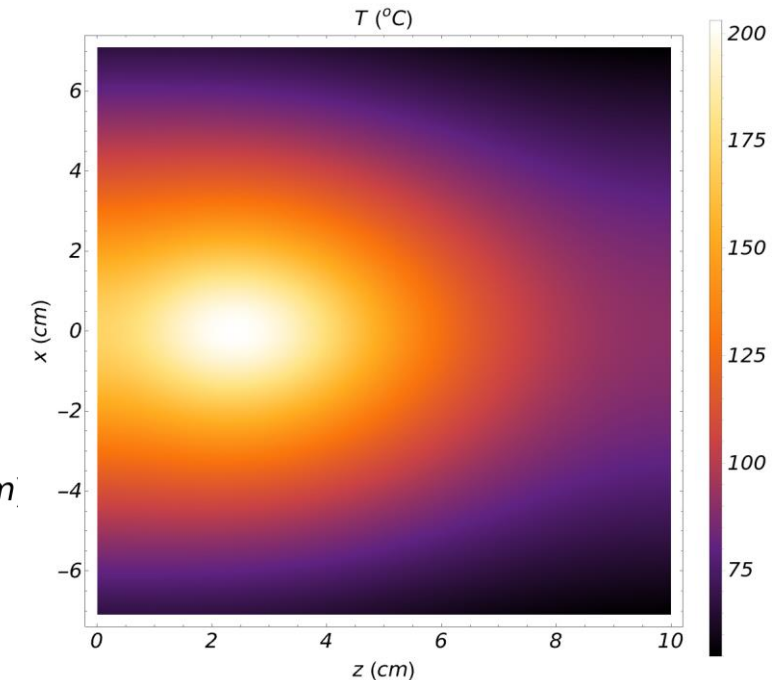
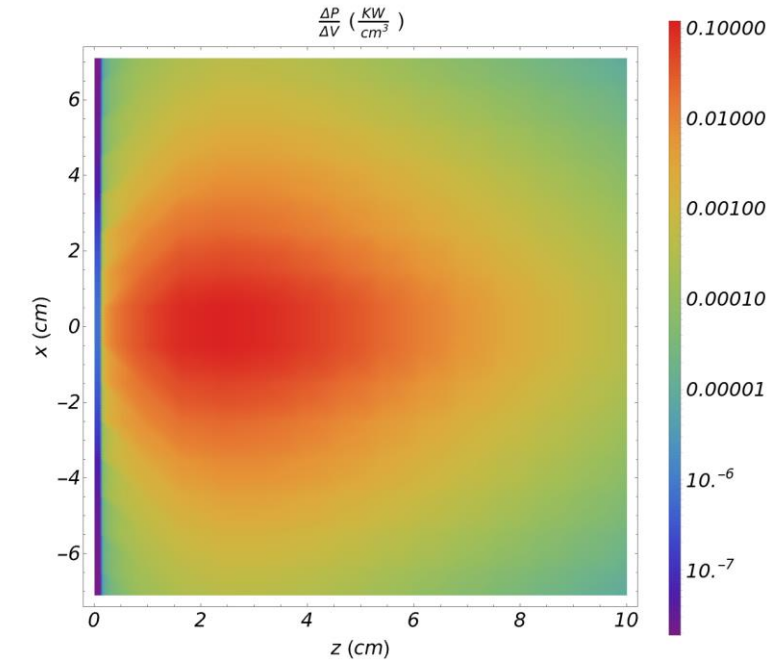
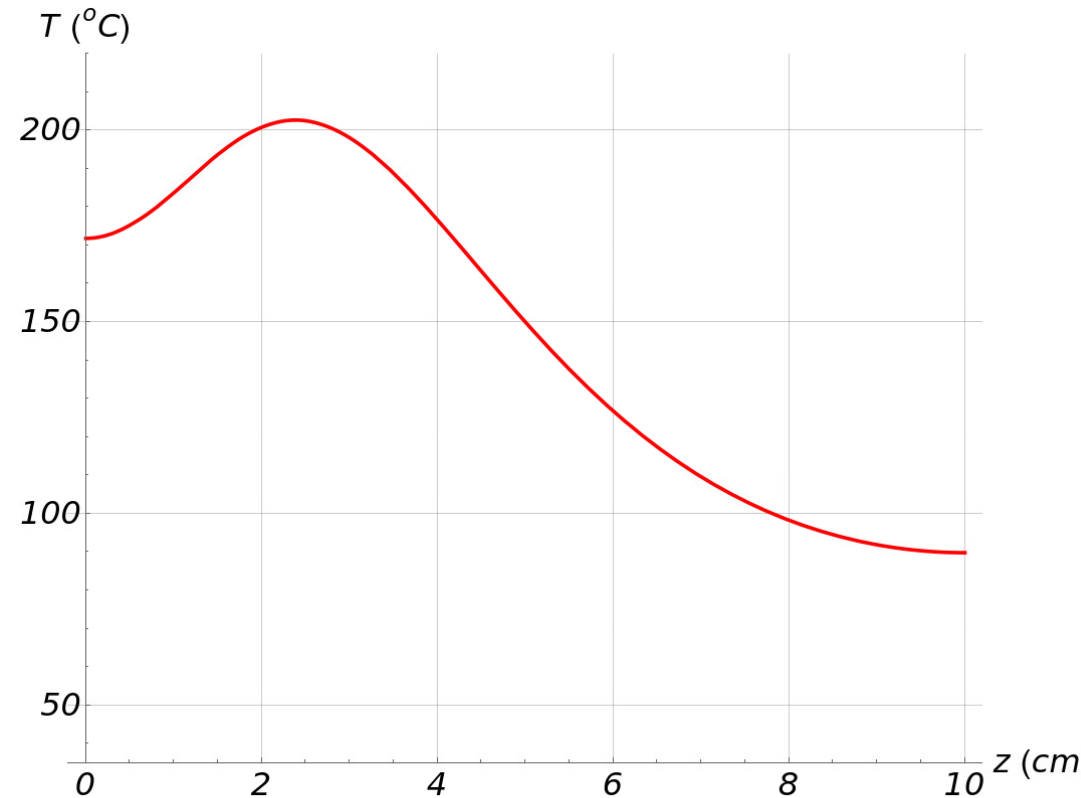


Tungsten Plug Temperature Estimates with a 20% Radiator

Hovanes Egiyan

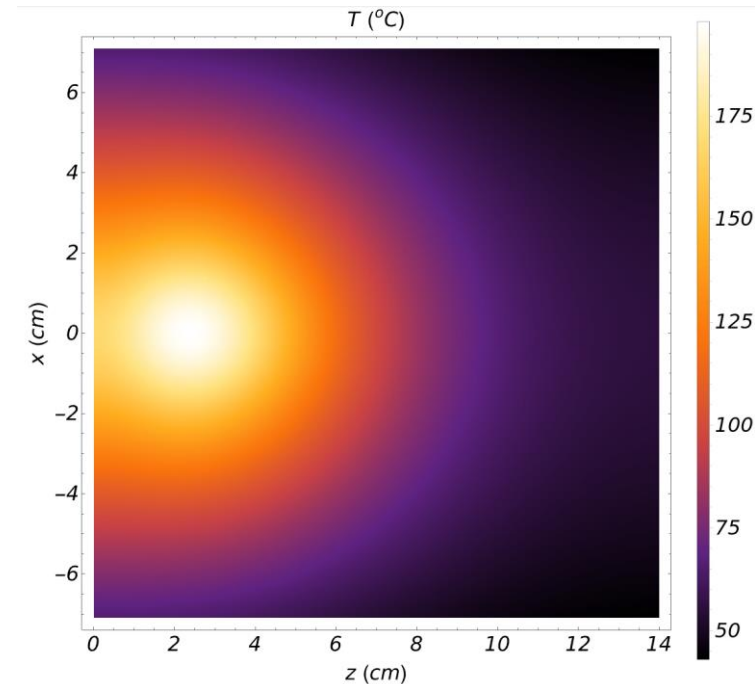
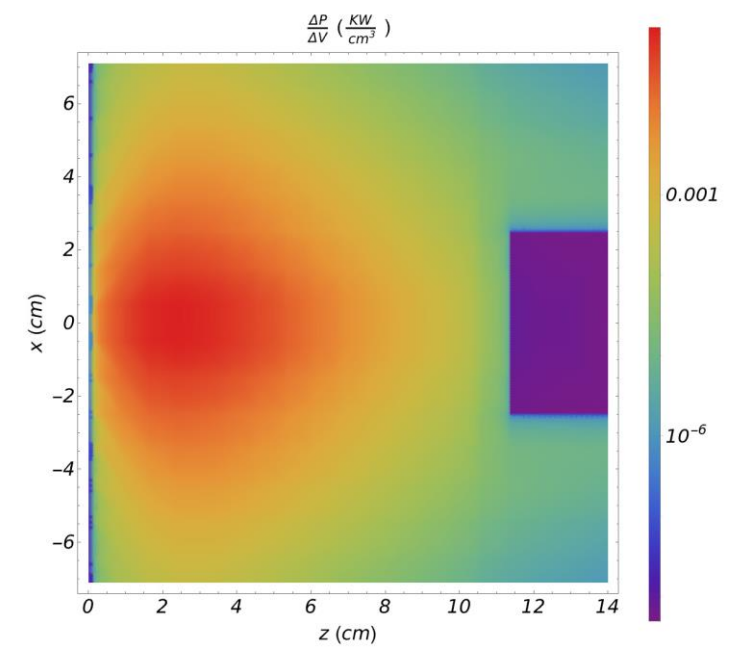
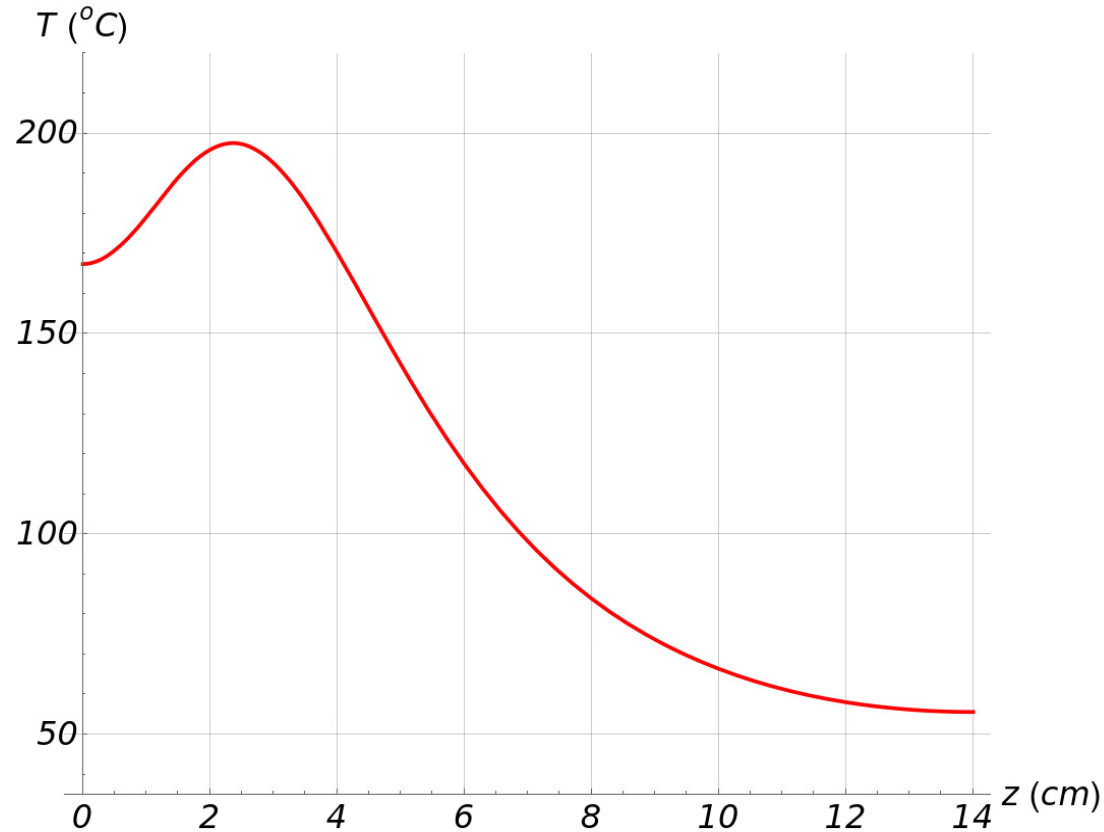
10% Radiator, 10 cm W-plug

- Use power deposition map from Vitaly's FLUKA calculations.
 - Vitaly used 100% tungsten material.
- Cooling water at $T=35^{\circ}\text{C}$ from the four sides of the plug, approximating what is in the engineering model.
 - Tim's ANSYS model has cooling plates at the sides that are cooled by water.
 - Tim's $T_{\text{max}} \sim 230^{\circ}\text{C}$.
- It is better to pay attention to temperature changes between different conditions.
 - The absolute value of T_{max} will be corrected by Tim's calculations.
- Tungsten thermal conductivity is $146 \text{ W}/(\text{m K})$.
- Heat exchange coefficient at the surfaces with water is $5000 \text{ W}/(\text{K m}^2)$.



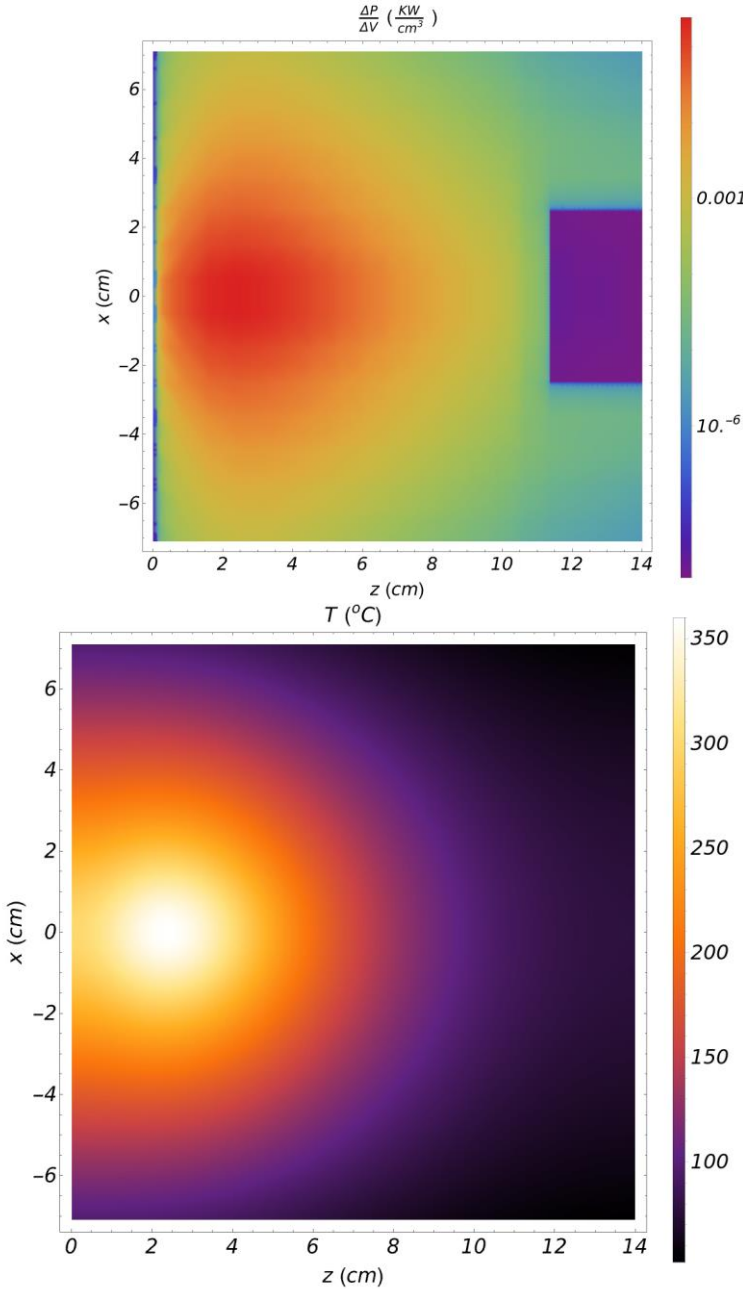
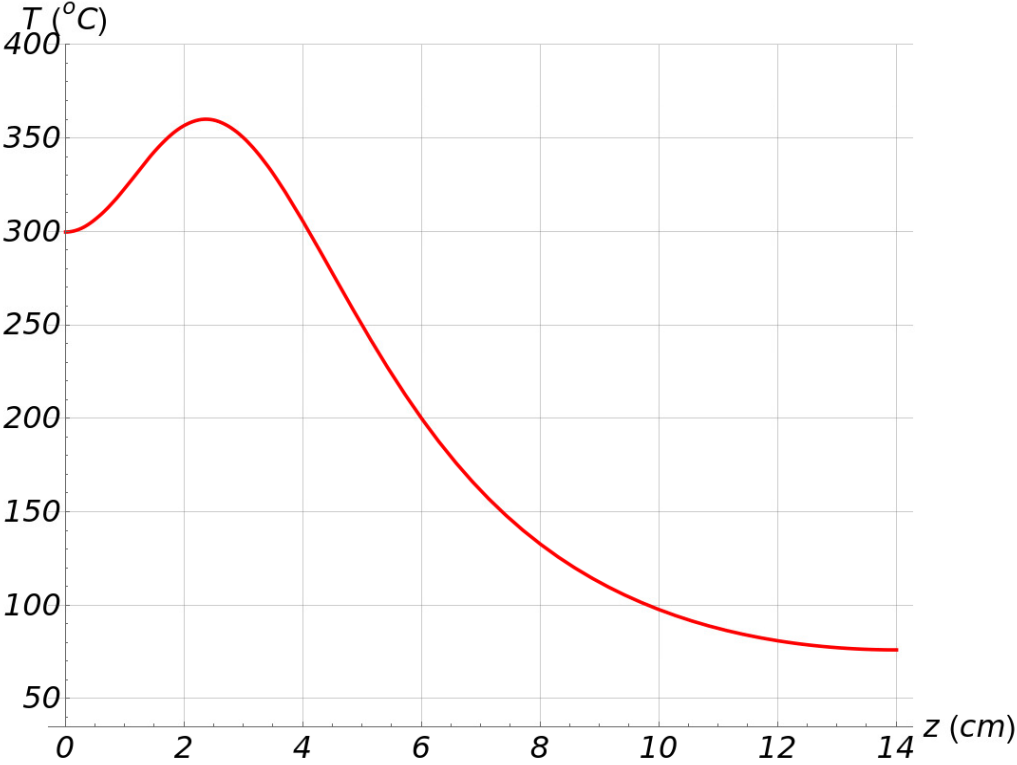
10% Radiator, 14 cm W-plug

- Use the same power deposition map from Vitaly's FLUKA calculations.
 - Vitaly had 10 cm plug, missing some power deposition at the back.
 - Vitaly used 100% tungsten material.
- Increase plug length from 10cm to 14 cm in the thermal analysis.
 - The plug looks like a cube $14.2 \times 14.2 \times 14 \text{ cm}^3$.
- Cooling only from the four sides of the cube, like what is in the engineering model.



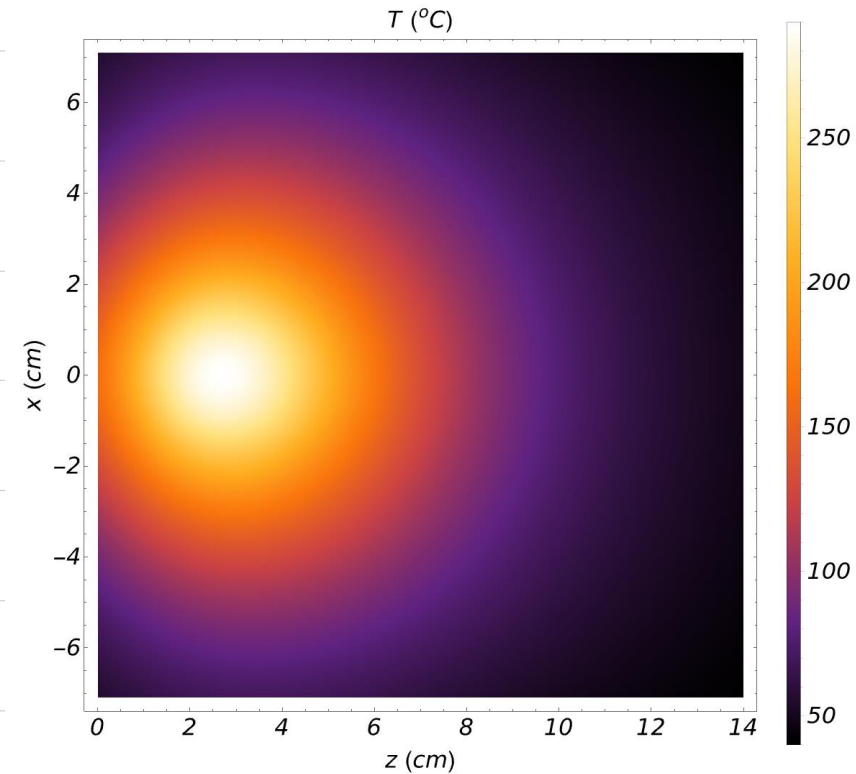
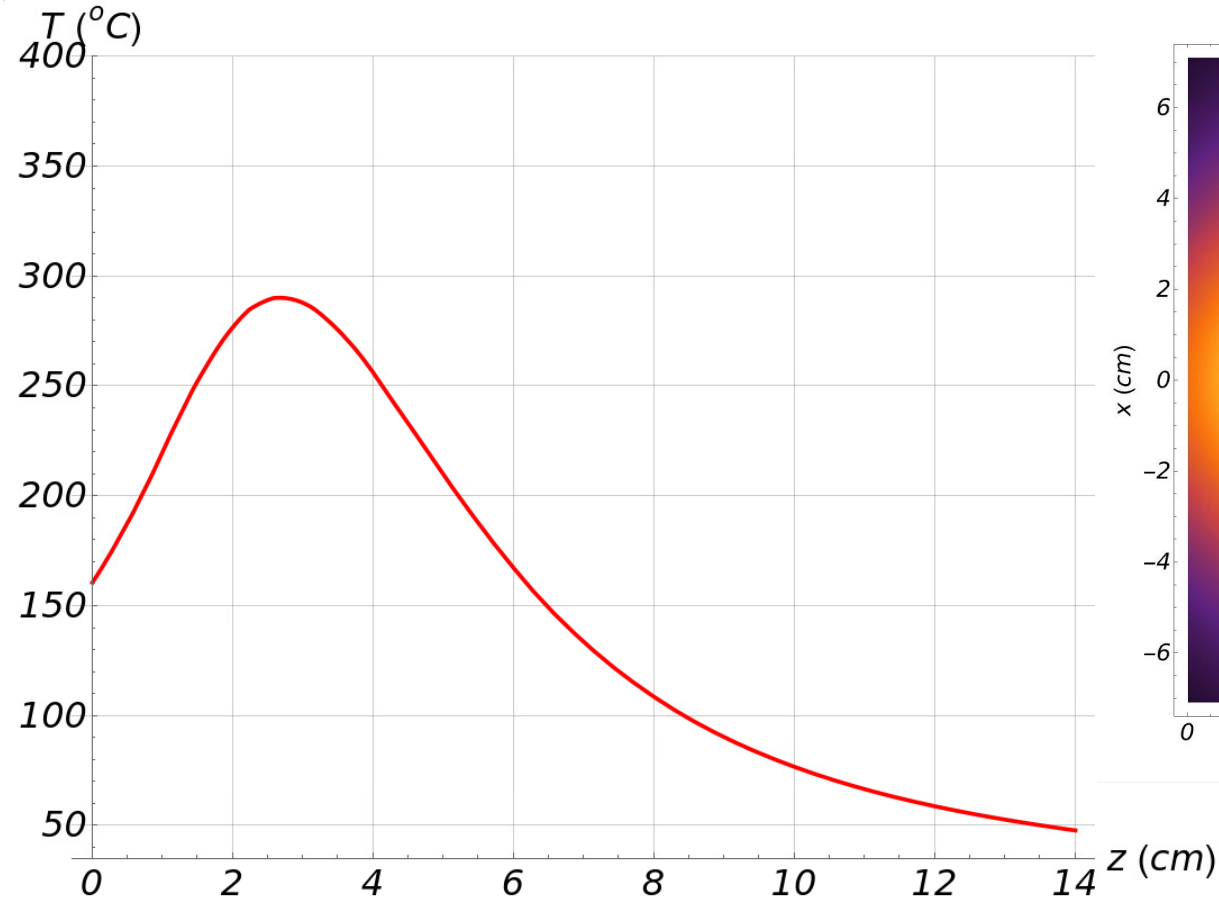
20% Radiator, 14 cm W-plug

- I multiplied the power deposition density from Vitaly by a factor of 2.
 - Does not account for a wider beam spot at the KPT.
- Power deposition in "tungsten plug area" of 11.4 KW.
 - Missing power at the back since Vitaly used 10cm W-plug in FLUKA.
- Cooling only from the four sides of the cube, like what is in the engineering model.
 - No colling from upstream or downstream of the tungsten block.



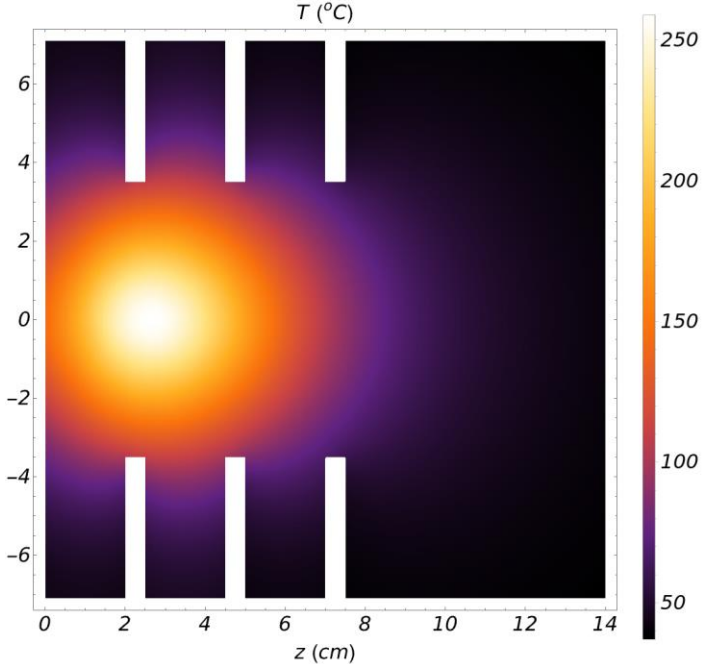
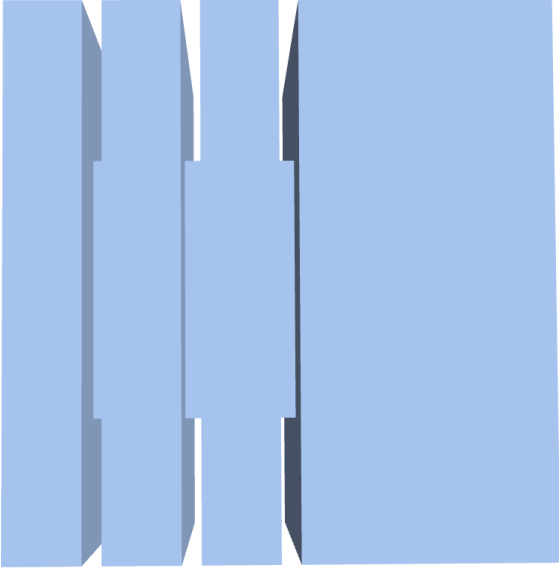
20% Radiator, 14 cm W-plug, Six Cooling Surfaces

- The whole surface of the cube is "covered" with cooling water at $T=35\text{ }^{\circ}\text{C}$.
 - This would correspond to cooling plates at all six surfaces of the cube in Tim's model.
- The temperature near "water" at the upstream face is more than $150\text{ }^{\circ}\text{C}$.
 - Cooling plate at the upstream face will be hot near the beam axis.



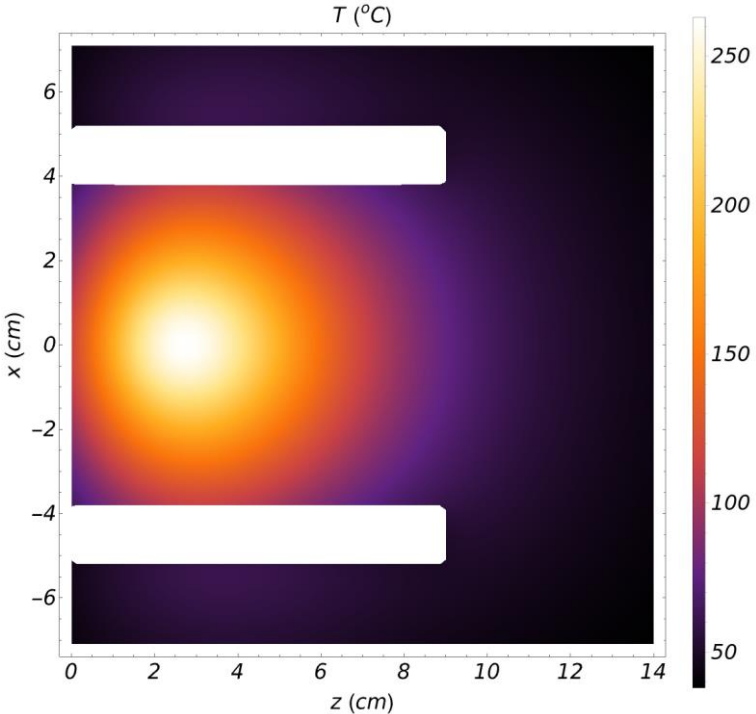
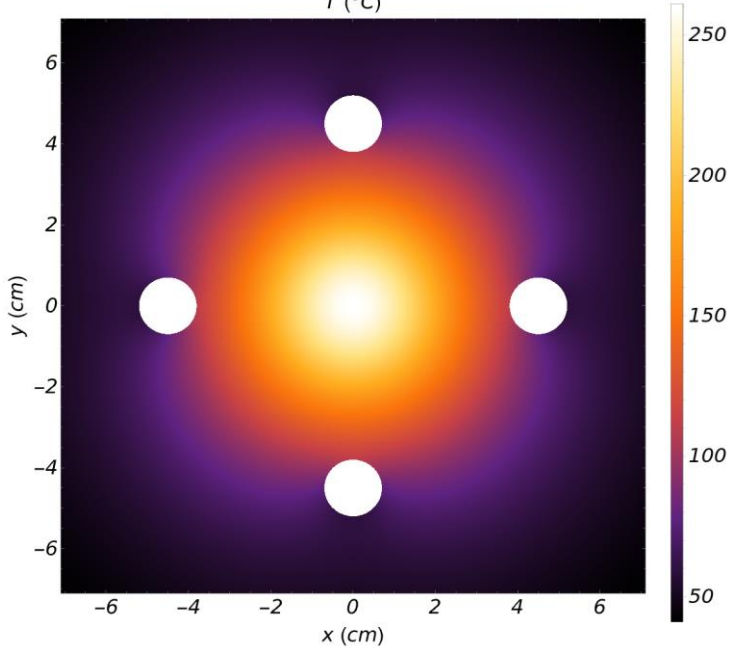
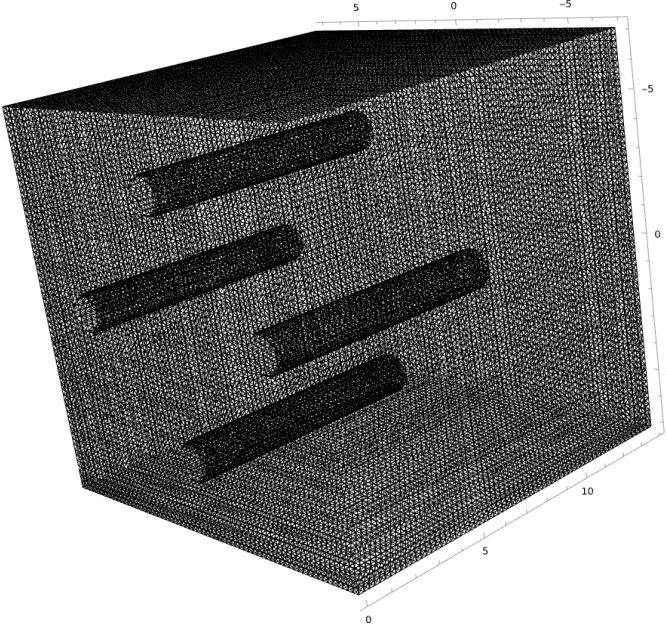
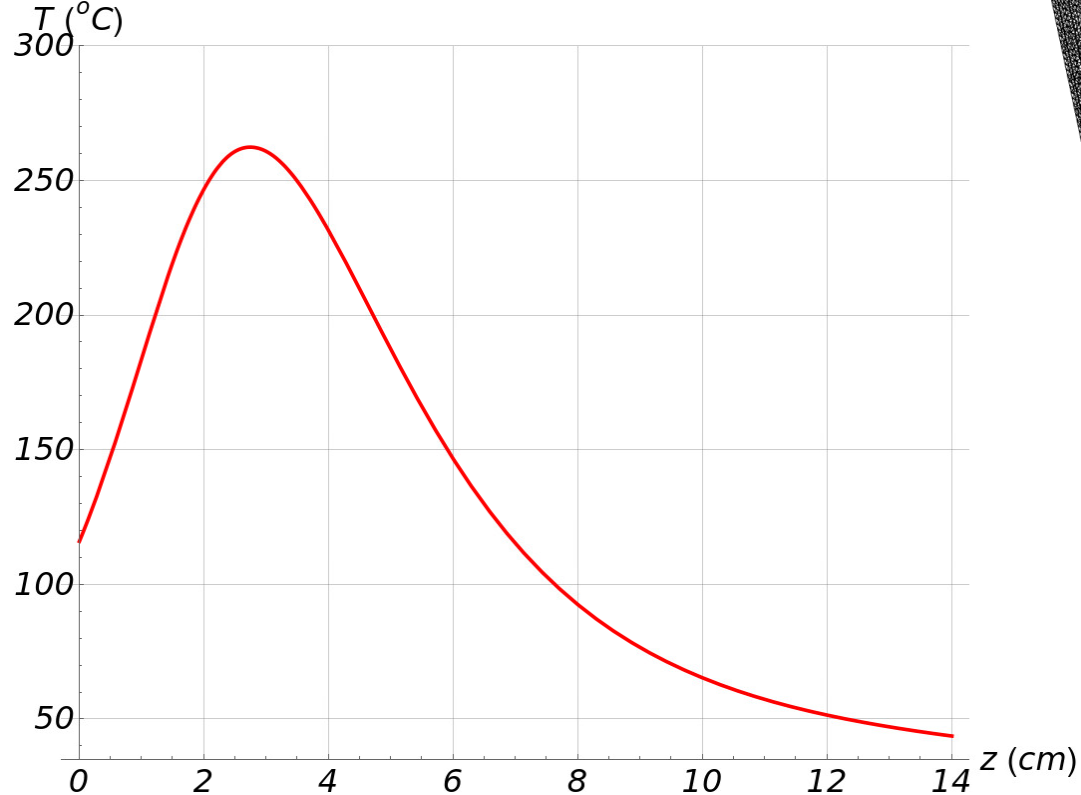
20% Radiator, 14 cm Plug with Cooled Slits

- Added more water-cooled surfaces to the plug by introducing.
 - The slits themselves are filled, but there is cooling water on the surface.
- One can place copper cooling plates in the plug alternating with tungsten plates, thus splitting the plug into multiple pieces.
- Temperature of the tungsten near the "water" inside the slits reaches $107\text{ }^{\circ}\text{C}$.
- The temperature near "water" at the upstream face is around $140\text{ }^{\circ}\text{C}$.



20% Radiator, 14 cm Plug with Holes

- In addition to cooling from upstream end, also use four cooling holes similar to CPS core cooling
 - Water temperature 35 °C
 - R=7 mm, offset from center 4.5 cm
 - The length of these channels in z is 9cm
 - Downstream end and the sides are not cooled.
- Temperature of the tungsten near the around cooling holes reaches 111 °C.
- The temperature near "water" at the upstream face is around 116 °C.



Conclusions

- Doubling the radiator thickness leads to increase of plug temperature to $T_{\max} \approx 400 \text{ }^{\circ}\text{C}$.
- With modifications to the cooling system of the plug, the temperature could be reduced to below $T_{\max} < 300 \text{ }^{\circ}\text{C}$.
- We need a new power deposition map in the W-plug from FLUKA with a 20% CPS radiator and with a 14cm (or whatever the final thickness will be) of the tungsten plug length.
 - Beam spot at KPT is wider with 20% radiator.
 - Less dense 10/90 CuW compound should have wider spread of the power in the tungsten.
- Other modifications are possible as well to lower Tmax.
 - CuW 80/20 with thermal conductivity of $182 \text{ W}/(\text{m K})$ without any slits, but may reduce kaon rate.
- Tim will need to analyze this with ANSYS to find the optimal cooling solution and evaluate mechanical stresses from repeated thermal cycling.
- Tungsten plug design and its cooling will need modifications to accommodate a 20% radiator in CPS.
 - There does not seem to be a major problem.
 - Will require extra engineer and designer work on KPT.