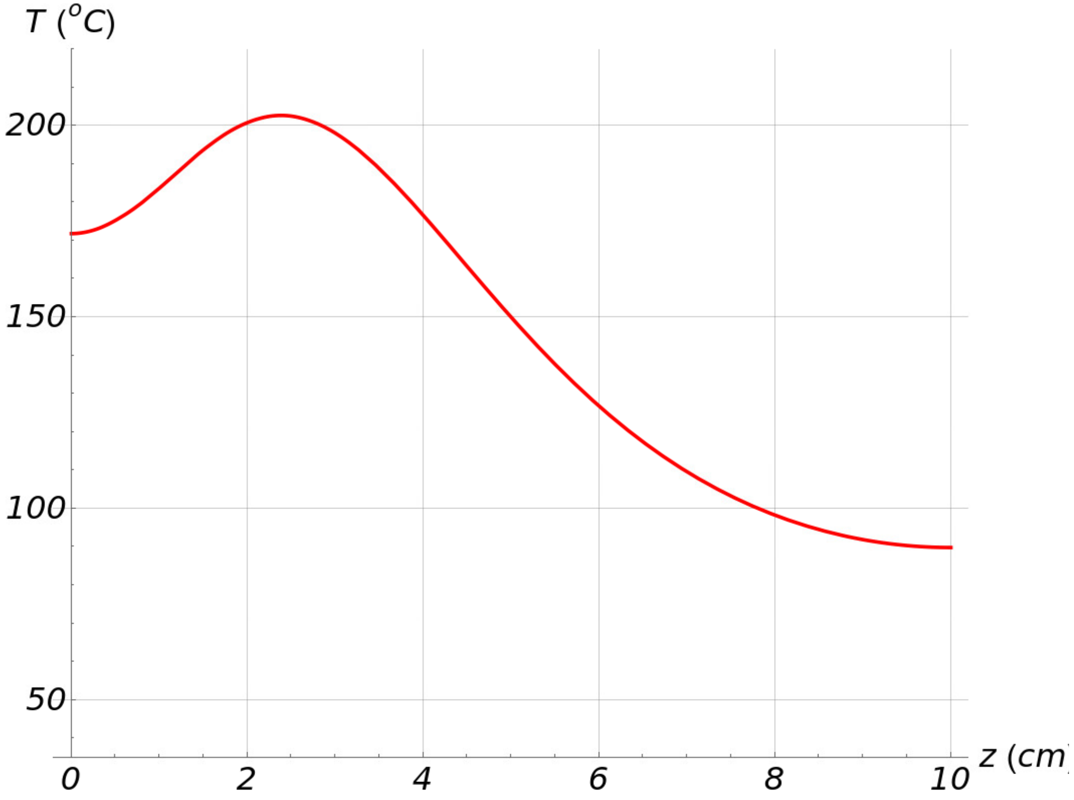
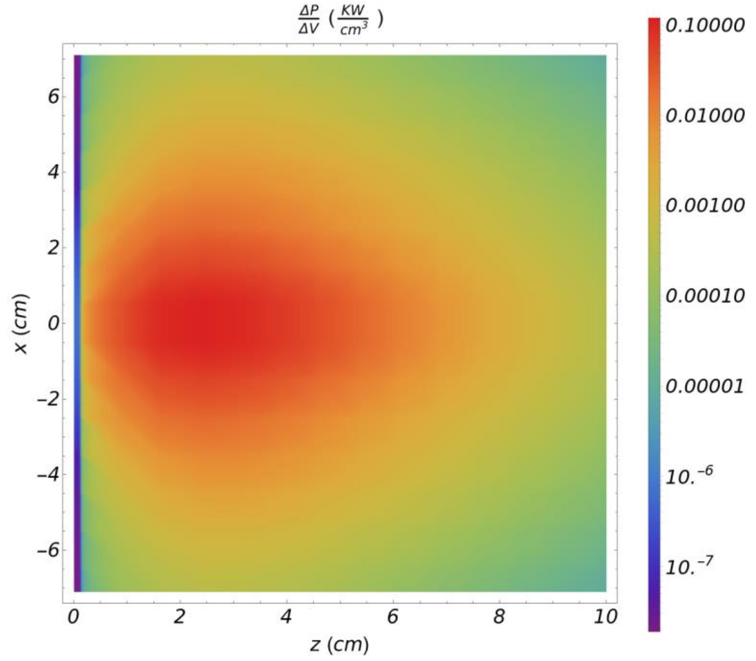
Tungsten Plug Temperature Estimates with a 20% Radiator

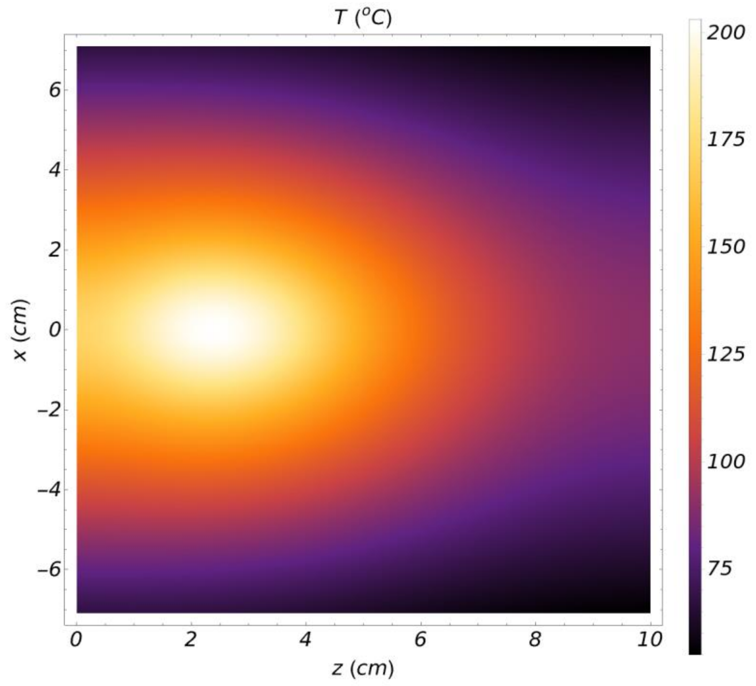
Hovanes Egiyan

10% Radiator, 10 cm W-plug

- Use power deposition map from Vitaly's FLUKA calculations.
    - Vitaly used 100% tungsten material.
- Cooing water at $T=35^{O}C$ 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_{max}~230 ^{O}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 W/(m K).
- Heat exchange coefficient at the surfaces with water is 5000 W/(K m^2).

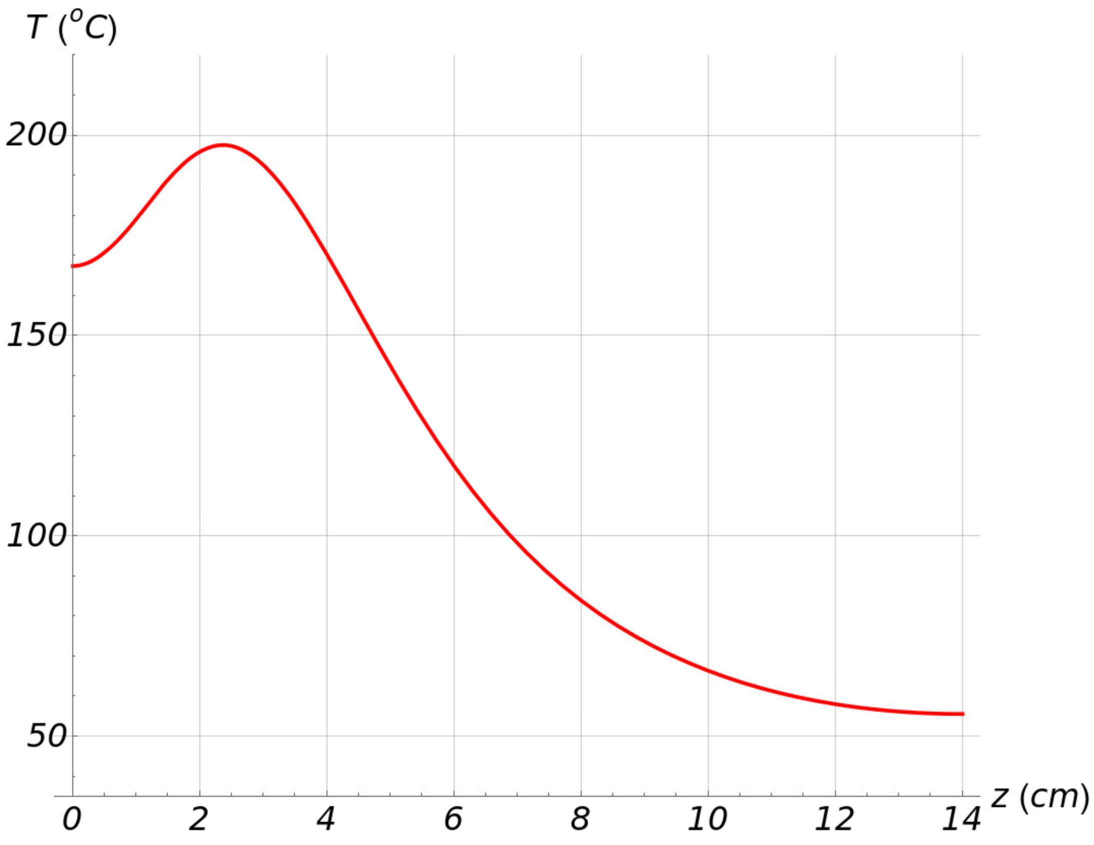


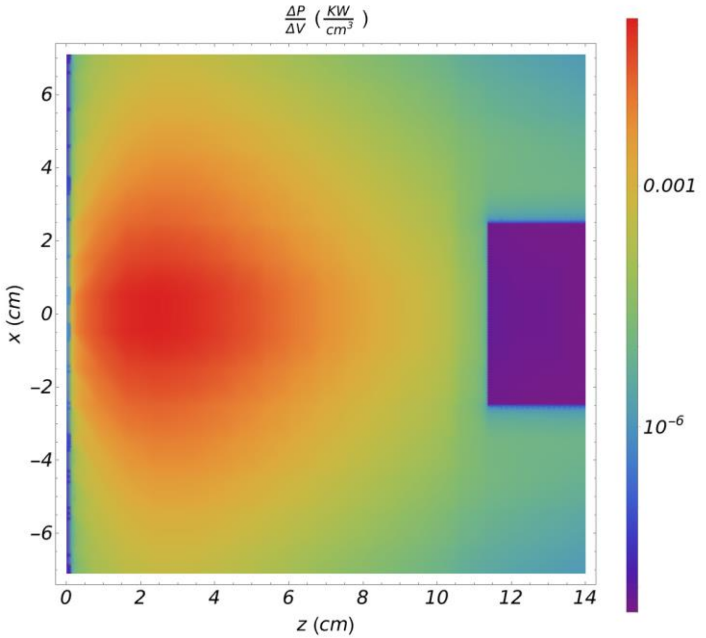


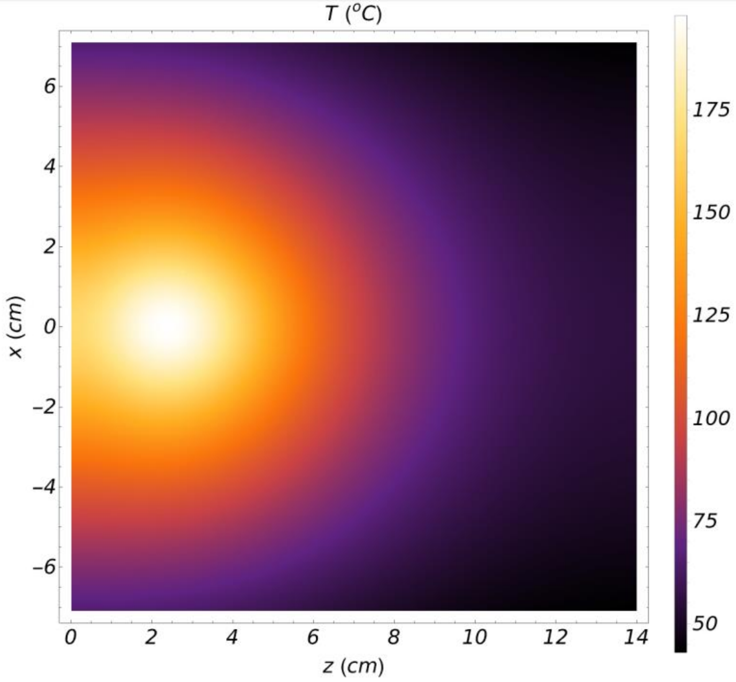


10% Radiator, 14 cm W-plug

- 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 14.2x14.2x14 cm^3.
- Cooing only from the four sides of the cube, like what is in the engineering model.

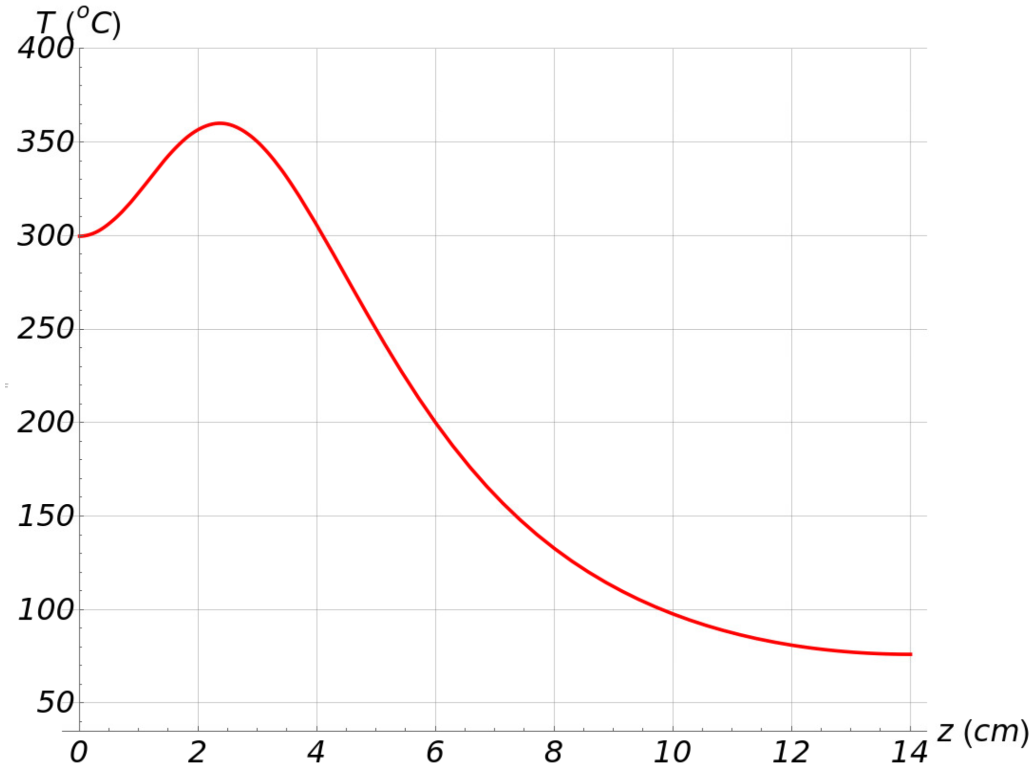


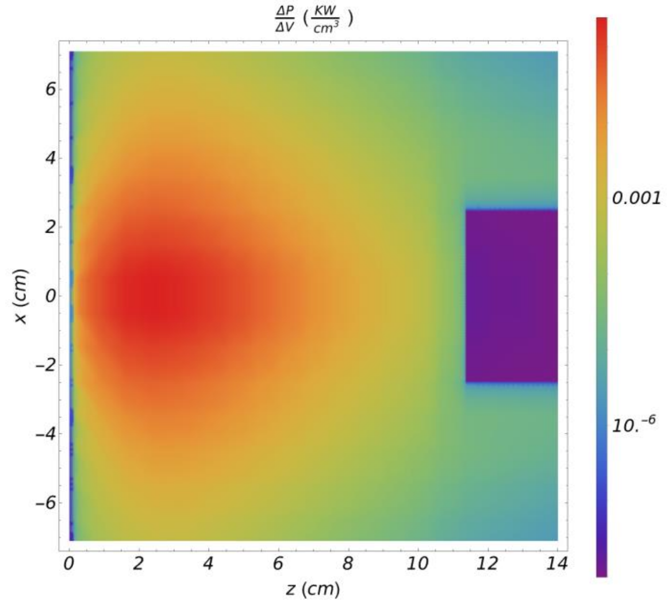


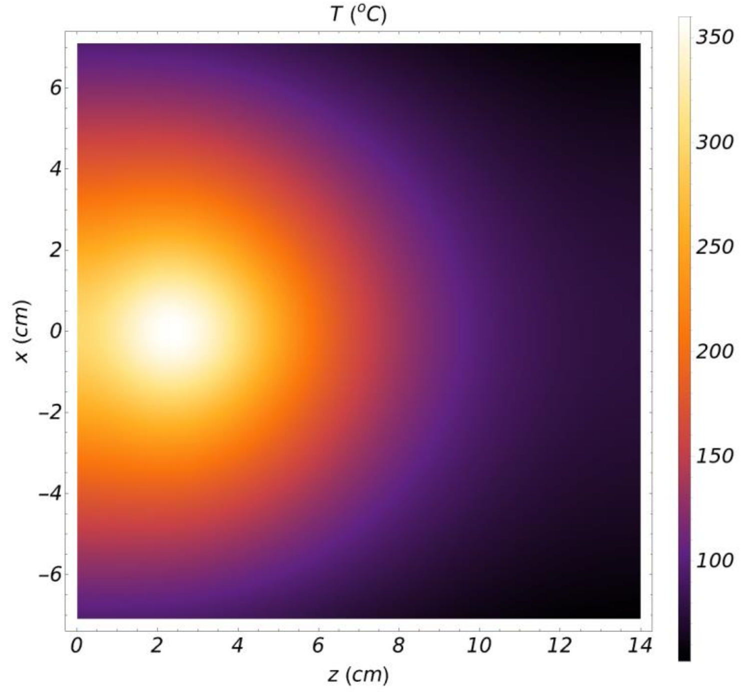


20% Radiator, 14 cm W-plug

- 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.
- Cooing 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.

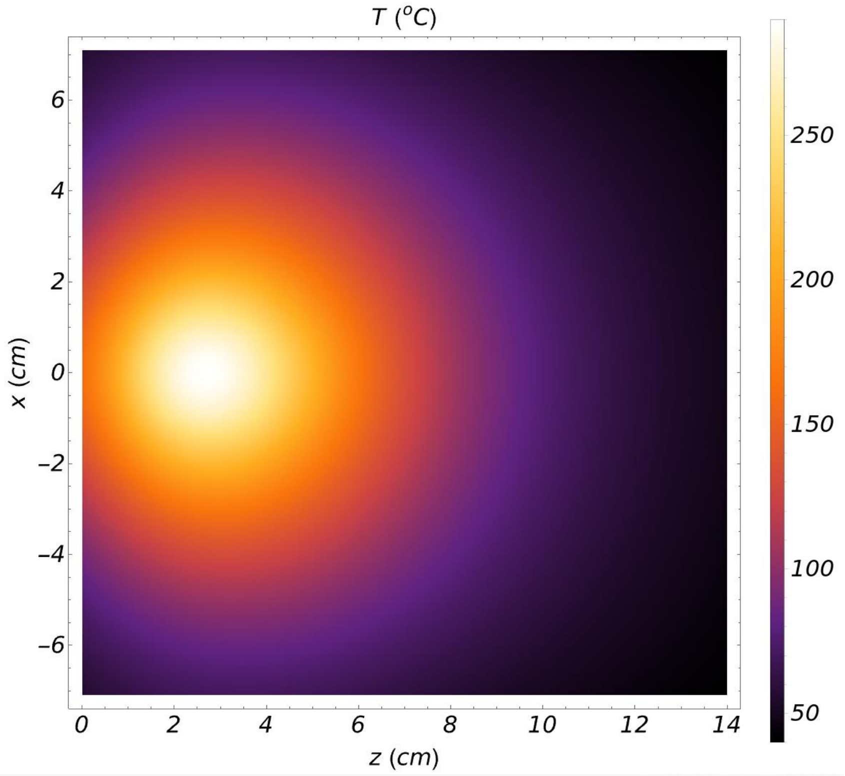






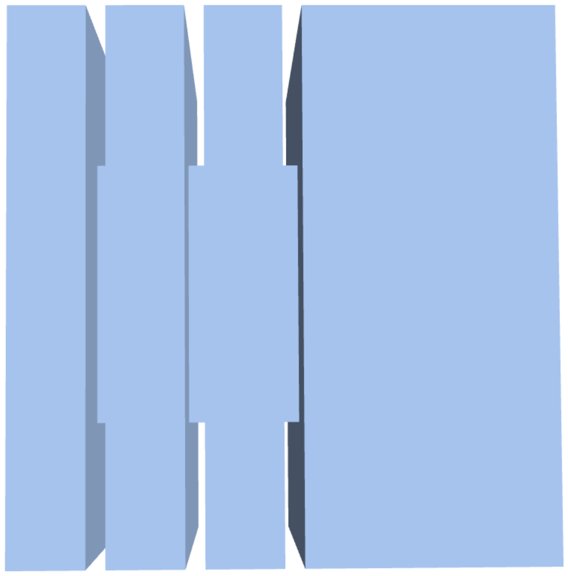
20% Radiator, 14 cm W-plug, Six Cooling Surfaces

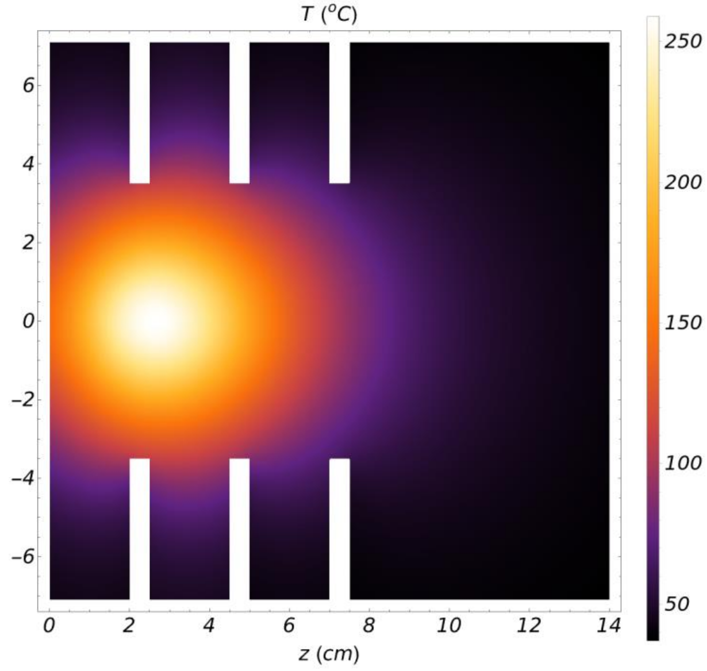
- The whole surface of the cube is "covered" with cooling water at T=35 ^{O}C.
  - This would correspond to cooling plates at all six surfaces of the cube in Tim's model.
- The temperature near "water" at the upstream face is more than 150 ^{O}C.
  - Cooling plate at the upstream face will be hot near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



20% Radiator, 14 cm Plug & More Modifications

- 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.
- Other modifications are possible as well to lower T_{max}.
    - CuW 80/20 with thermal conductivity of 182 W/(m K) without any slits.
    - Tim will need to work this out with more realistic ANSYS models.
- Temperature of the tungsten near the "water" inside the slits reaches 107 ^{O}C.
- The temperature near "water" at the upstream face is around 140 ^{O}C.





Conclusions

- Doubling the radiator thickness leads to increase of plug temperature to $T_{max} \approx 400\ ^{O}C$.
- With modifications to the cooling system of the plug, the temperature could be reduced to below $T_{max} < 300\ ^{O}C$.
- 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.
- 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.