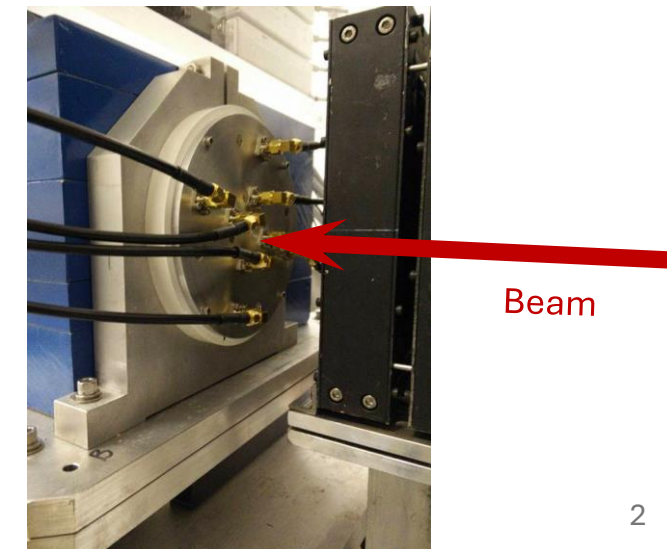
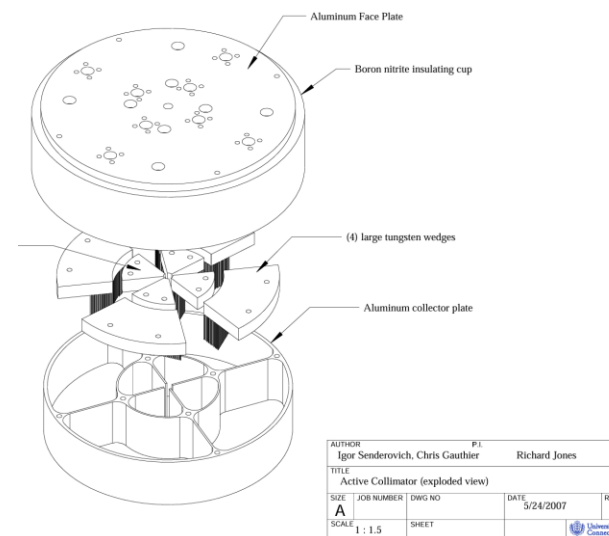
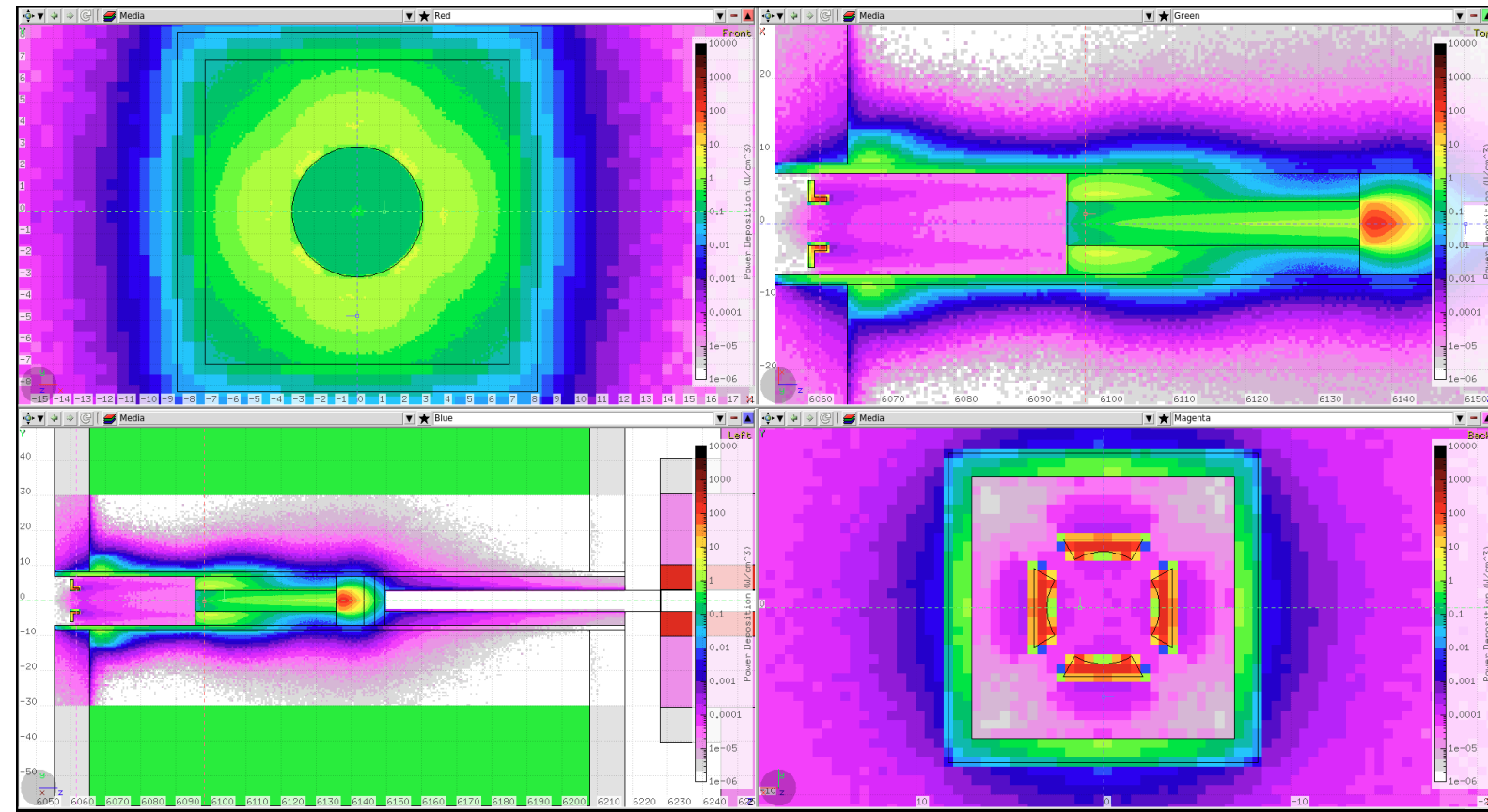


Active Collimator Temperature with a 20% Radiator

Hovanes Egiyan

FLUKA Data

- Use FLUKA power deposition map for a 20% radiator to estimate the temperatures in the Active Collimator (AC), Be-target and W-plug with nominal γ -beam positions.
- Tungsten in AC collimator has aperture of $D=6\text{cm}$
 - 90W is absorbed in each AC wedge.
 - Power deposited in the copper around Be-target is reduced by $\sim 400\text{W}$.
- AC can be cooled
 - With water through the outer edges through boron nitride cup.
 - With forced air via the aluminum backplate and via the boron nitride cup.
 - We need to avoid contact with aluminum back-plate and the collector plate as to not distort AC signals.
- Boron Nitride is not isotropic
 - Manufacturer only provided a single number for thermal conductivity.
 - Unsure about the type of lattice of BN.
- Amount of power dissipated through the mounting of AC into the KPT assembly depends on the details of engineering design and cannot be evaluated at this time.



Water Cooled, Isotropic

$$\vec{\nabla} \cdot (\kappa(\vec{x}) \cdot \vec{\nabla} T(\vec{x})) = p(\vec{x})$$

- Model AC geometry in Mathematica

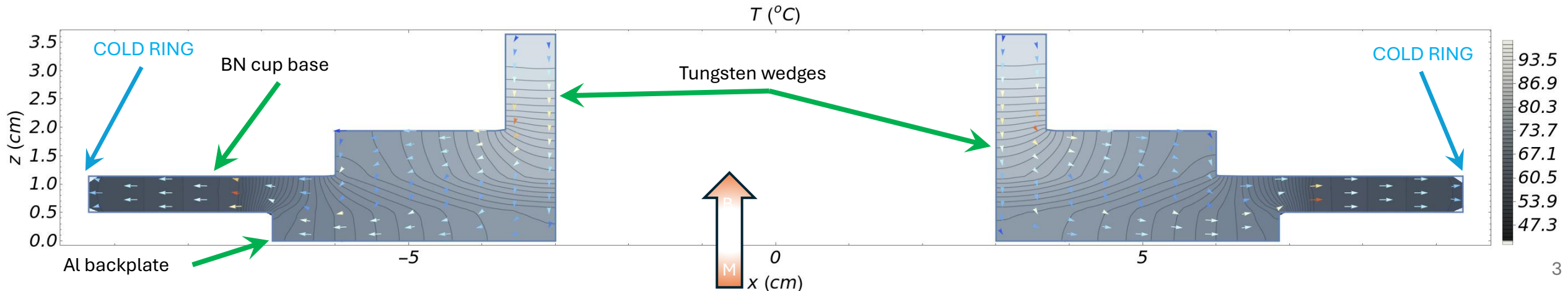
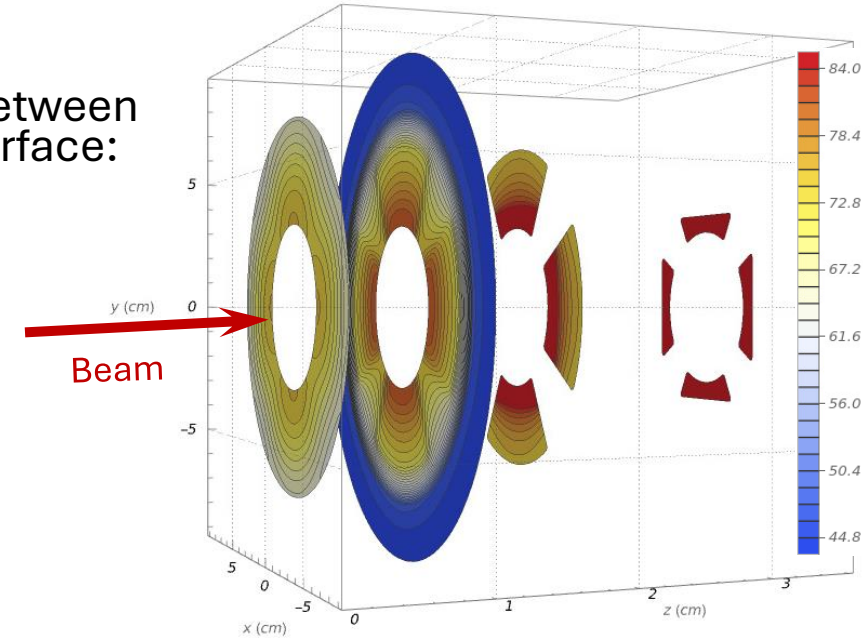
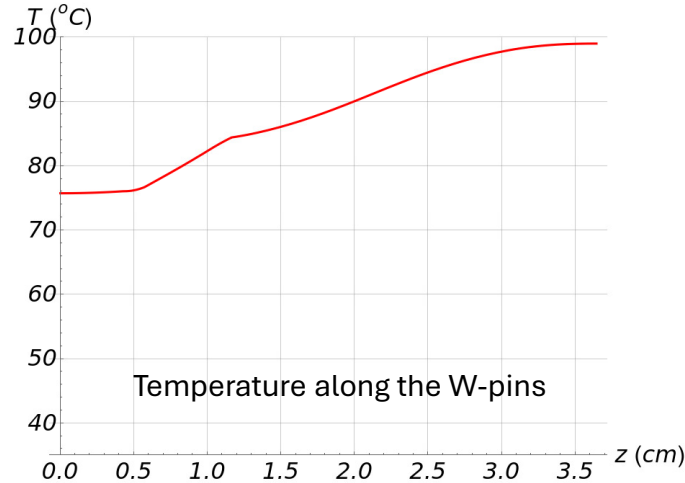
- W-wedges
- Boron Nitride insulator cup
- Al back-plate
- Cu housing ring for cooling
- Scalar thermal conductivity $\kappa(\vec{x})$:
 - 35 W/(m K) for BN-B (PDF document, mfr. site),
 - 146 W/(m K) for W,
 - 238 W/(m K) for Al,
 - 385 W/(m K) for Cu.

- Water cooling through the outer radius of the cooling ring.

- Water average temperature $T=35^\circ\text{C}$.
- Heat exchange coefficient for water is $5000\text{ W}/(\text{K m}^2)$.
- No radiation or convection assumed.

- Temperature drop $\Delta T \approx 55^\circ\text{C}$ between the hotspot and the cooling surface:

- $T_{\text{max}} \sim 100^\circ\text{C}$ at the tip W-pins,
- $T_{\text{Cu}} \sim 45^\circ\text{C}$ in Cu ring,
- $T_{\text{Al}} \sim 75^\circ\text{C}$ in Al back-plate.

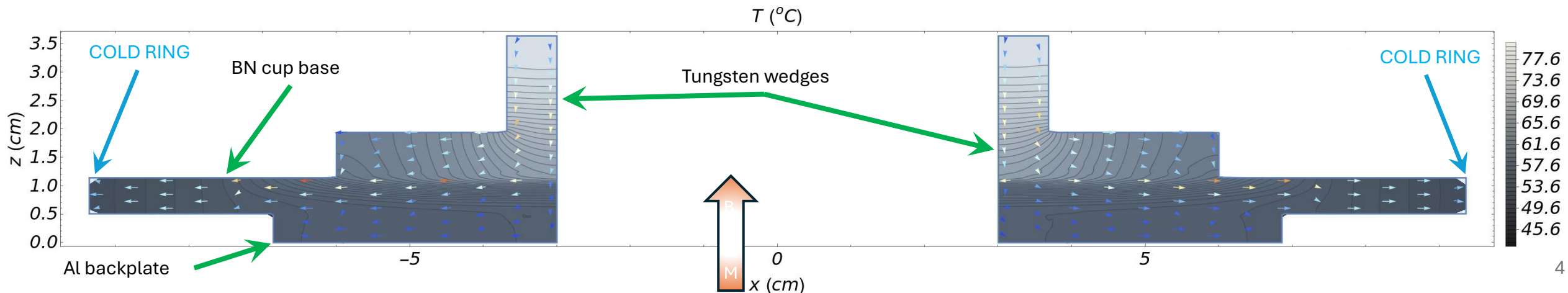
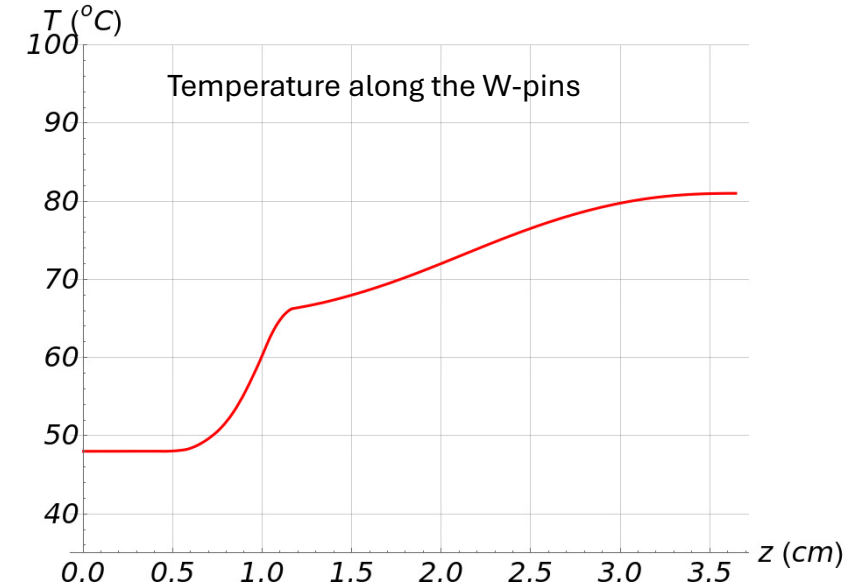
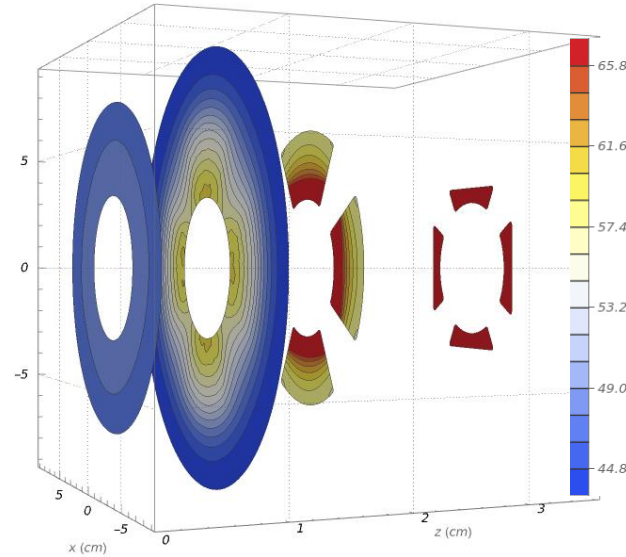


Water-cooled, Anisotropic, Axial

$$\vec{\nabla} \cdot (\kappa(\vec{x}) \cdot \vec{\nabla} T(\vec{x})) = p(\vec{x})$$

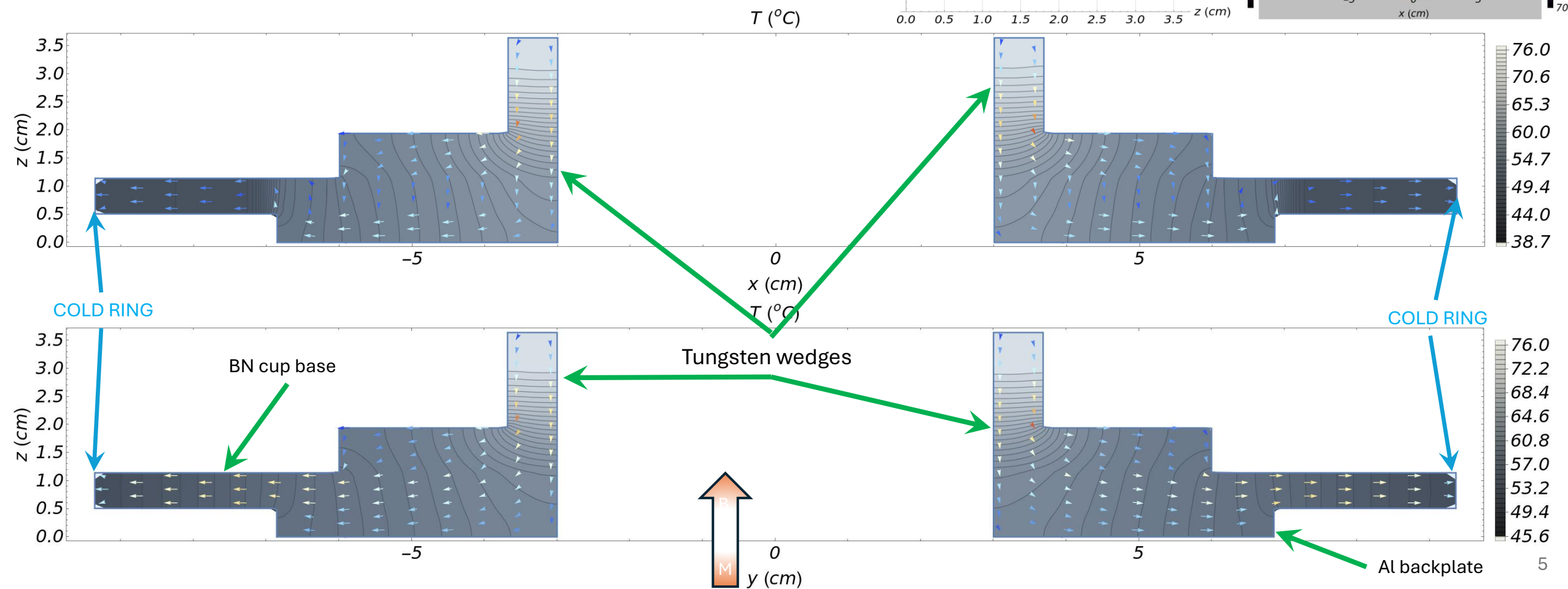
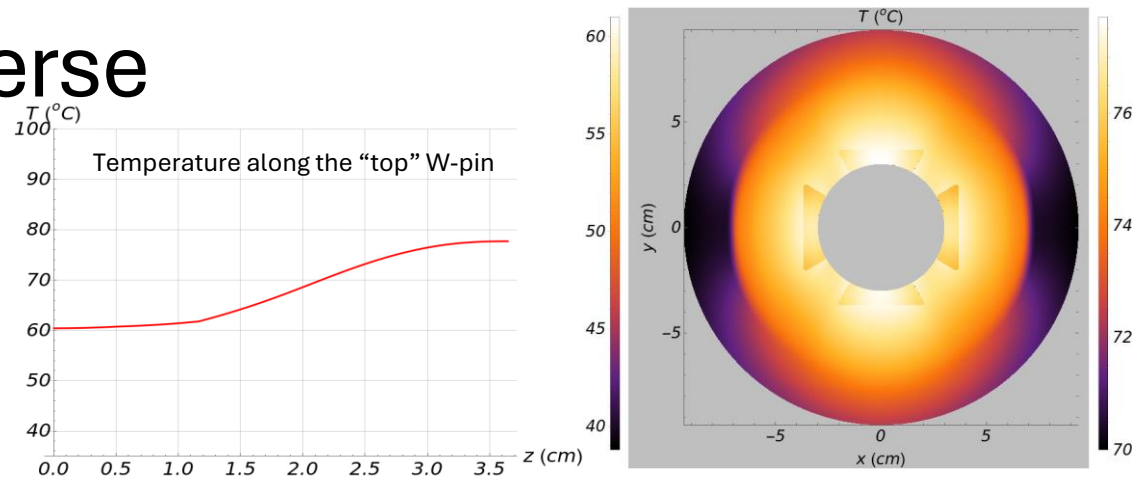
$$\kappa(\vec{x}) = \begin{bmatrix} \kappa_r(\vec{x}) & 0 & 0 \\ 0 & \kappa_r(\vec{x}) & 0 \\ 0 & 0 & \kappa_z(\vec{x}) \end{bmatrix}$$

- Thermal conductivity is a diagonal tensor with three components ($\kappa_r, \kappa_r, \kappa_z$)
 - For BN ceramics they are (400, 400, 4) W/(m K), taken from some article found on the web.
 - For other materials, the thermal conductivity is a unit tensor times the thermal conductivity.
 - 146 W/(m K) for W,
 - 238 W/(m K) for AL,
 - 385 W/(m K) for Cu.
- Water cooling through the outer radius of the cooling ring.
 - Water average temperature $T=35^\circ\text{C}$.
 - Heat exchange coefficient for water is $5000\text{ W}/(\text{K m}^2)$.
 - No radiation or convection assumed.
- Temperature drop $\Delta T \approx 38^\circ\text{C}$ between the hotspot and the cooling surface:
 - $T_{\text{max}} \sim 81^\circ\text{C}$ at the tip W-pins,
 - $T_{\text{Cu}} \sim 43^\circ\text{C}$ in Cu ring,
 - $T_{\text{Al}} \sim 48^\circ\text{C}$ in Al back-plate.



Water-cooled, Anisotropic, Transverse

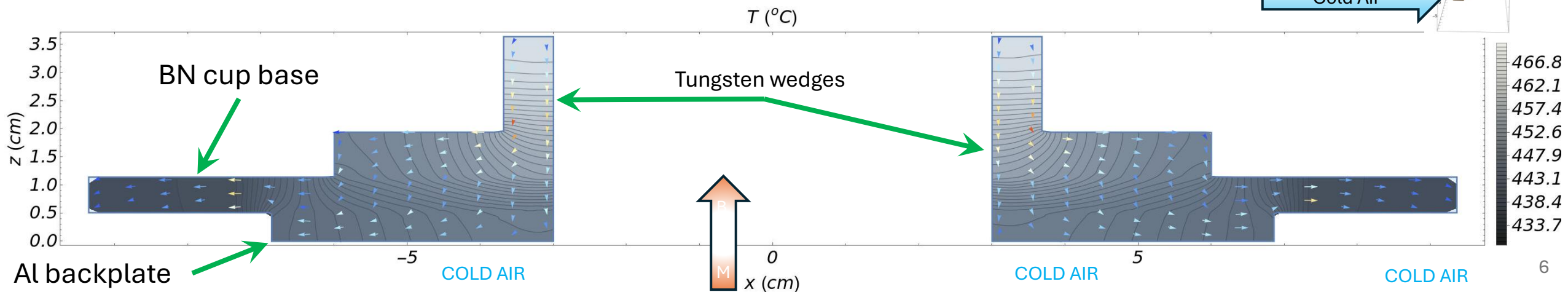
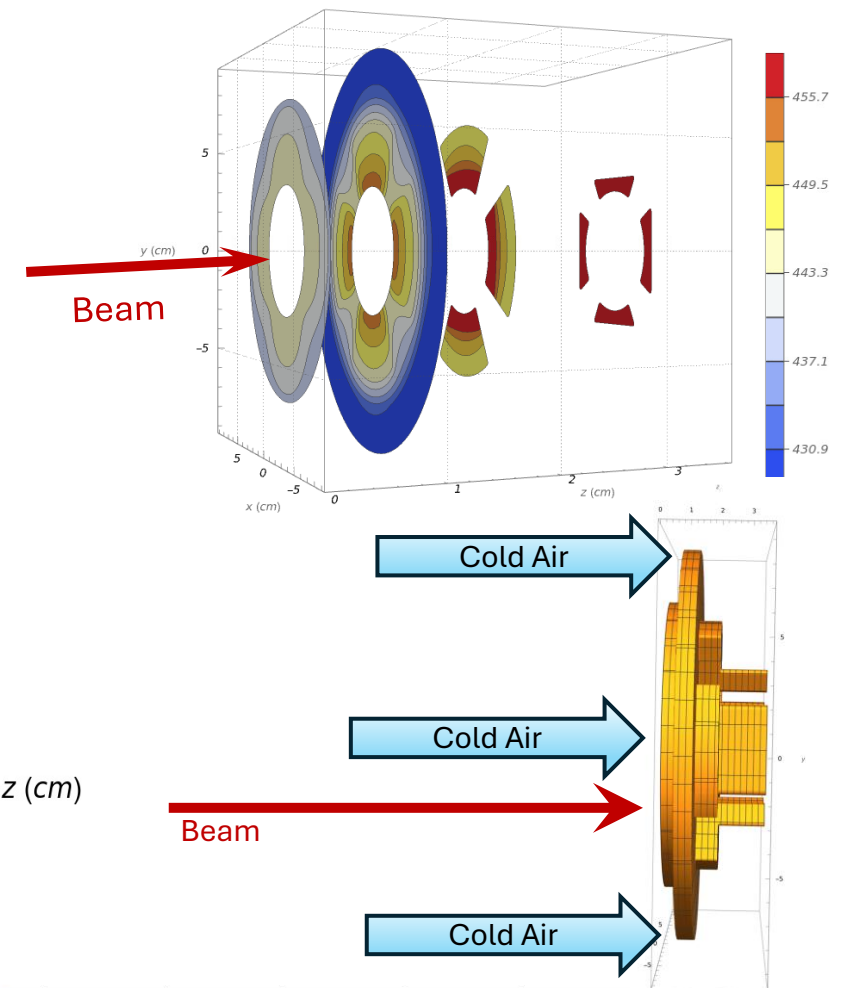
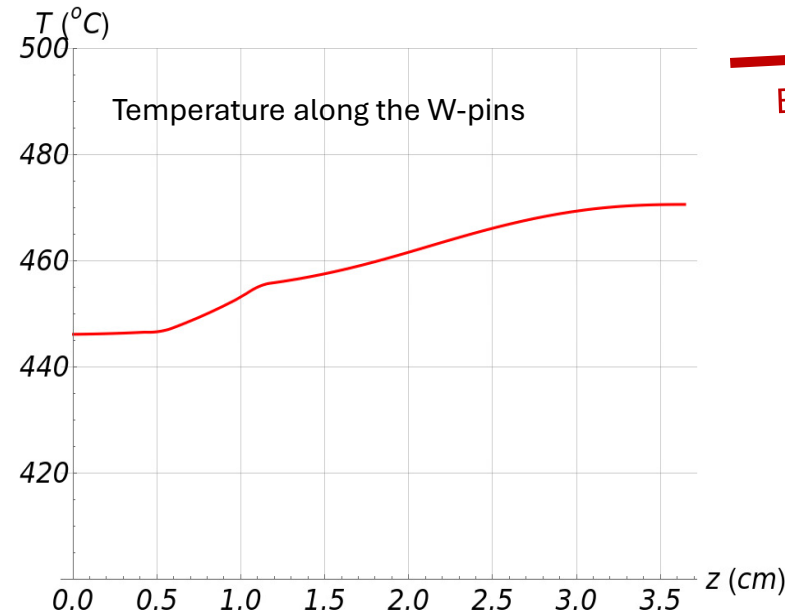
- Assume “bad” conductivity in the x-direction.
- Use parameters as in the axial case and solve the equation.
- Temperatures are low, $T_{\max} \sim 78^\circ\text{C}$ at the tip W-pins, even lower than for the axial case.
 - Not sure of the thermal conductivity tensor from the article really applies to our BN cup.



Air-cooled, Isotropic

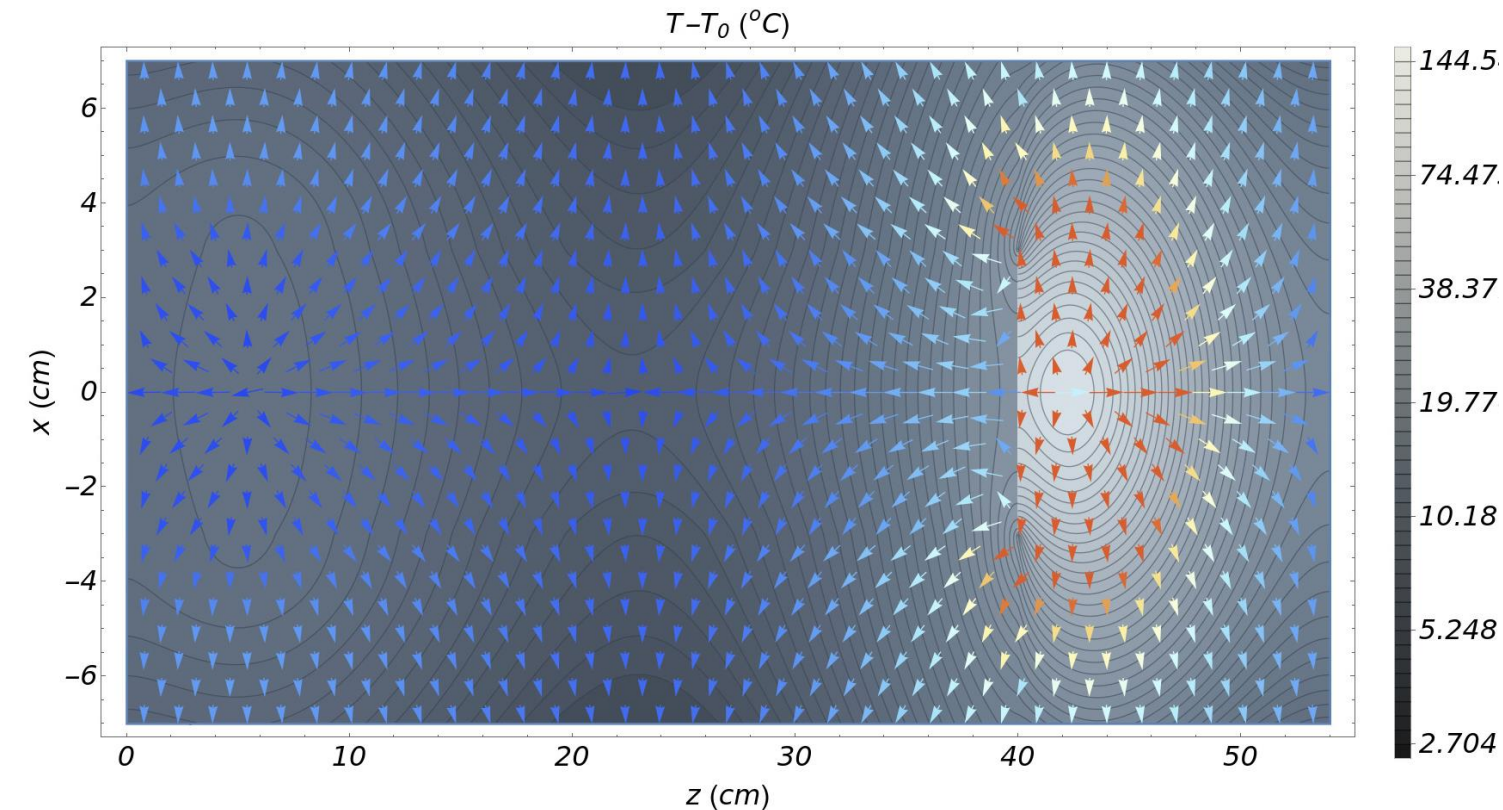
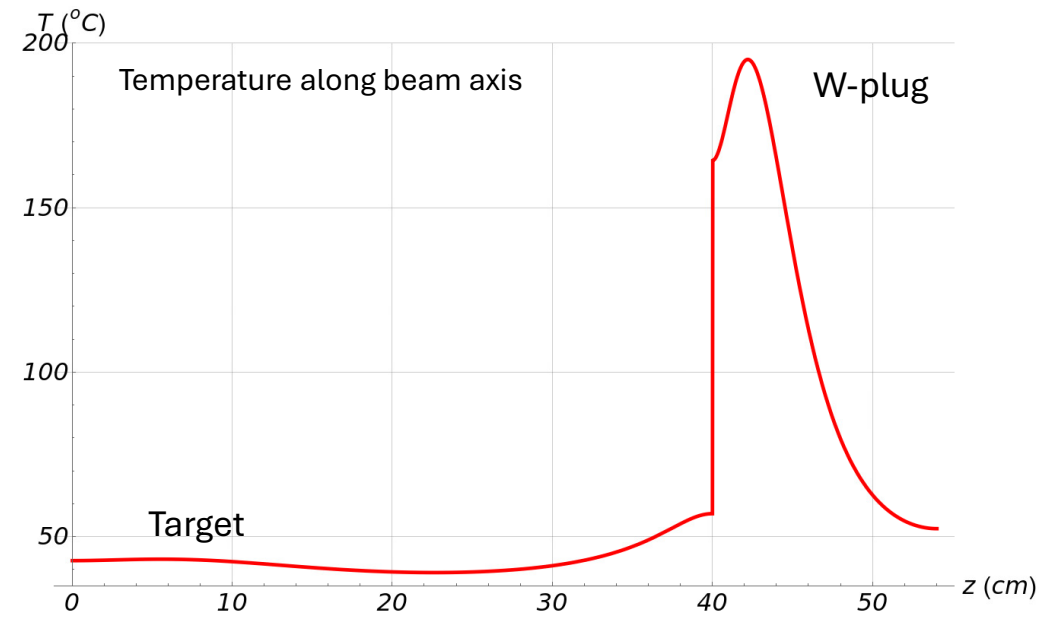
$$\vec{\nabla} \cdot (\kappa(\vec{x}) \cdot \vec{\nabla} T(\vec{x})) = p(\vec{x})$$

- Forced air cooling through the upstream surface of BN cup, and Al back-plate, and upstream and side face of copper ring, .
 - Air with average temperature $T=20\text{ }^{\circ}\text{C}$.
 - Heat exchange coefficient for air is $20\text{ W}/(\text{K m}^2)$.
 - Not sure about this number.
 - No other modes of power dissipation assumed.
- Temperature drop $\Delta T \approx 40\text{ }^{\circ}\text{C}$ between the hotspot and the cooling surface:
 - $T_{\text{max}} \sim 475\text{ }^{\circ}\text{C}$ at the tip W-pins,
 - $T_{\text{Cu}} \sim 445\text{ }^{\circ}\text{C}$ in Cu ring,
 - $T_{\text{Al}} \sim 435\text{ }^{\circ}\text{C}$ in Al back-plate.
- The back-plate surface will become hot $>400\text{ }^{\circ}\text{C}$.
 - Heat flow through the mounting surface to the bulk of KPT assembly will reduce the temperature.
 - If heat exchange coefficient is lower, then the temperature will be higher.



Be-target and W-plug Temperature

- Used the same Mathematica notebook as I did for last week
 - Cooling from four sides with water at average temperature $T_0=35^\circ\text{C}$.
- Not much difference observed in the temperature distribution near the KPT target due to adding AC to FLUKA geometry.



- Not much difference observed in the temperature distribution near the KPT target due to adding AC to FLUKA geometry.
- Tungsten plug temperature is the same as without AC, $T_{\text{max}}=195^\circ\text{C}$.
 - Water temperature at the surface may reach $T_{\text{ws}}=55^\circ\text{C}$.
- Be-target $T_{\text{max}}=43^\circ\text{C}$, decreased by $\sim 2^\circ\text{C}$.
 - ~ 400 Wats taken by AC from the copper around Be-target.

Conclusions

- Active collimator used with a 20% radiator can be water-cooled from radial periphery of BN cup.
 - The temperatures of AC with active cooling look OK for thermal conductivity values considered here.
 - The temperature distribution depends on the thermal conductivity of Boron Nitride ceramic cup.
 - Need to get the specifications for the BN cup from the manufacturer to predict the AC temperature.
- With only forced air cooling, the temperatures in AC can get quite high.
 - Heat transfer to the support structure may help, not evaluated here.
- Temperatures around the Be-target are OK, assuming modified configuration of Be-target.
- There does not seem to be a serious problem with high temperatures when using a 20% radiator in CPS with nominal beam positions at KPT.
 - The design of the KPT cooling system will need significant modifications to work with a with 20% radiator.
 - Consider using copper plates instead of aluminum in AC.
 - Photon beam excursions from the nominal positions at KPT may produce higher temperatures.