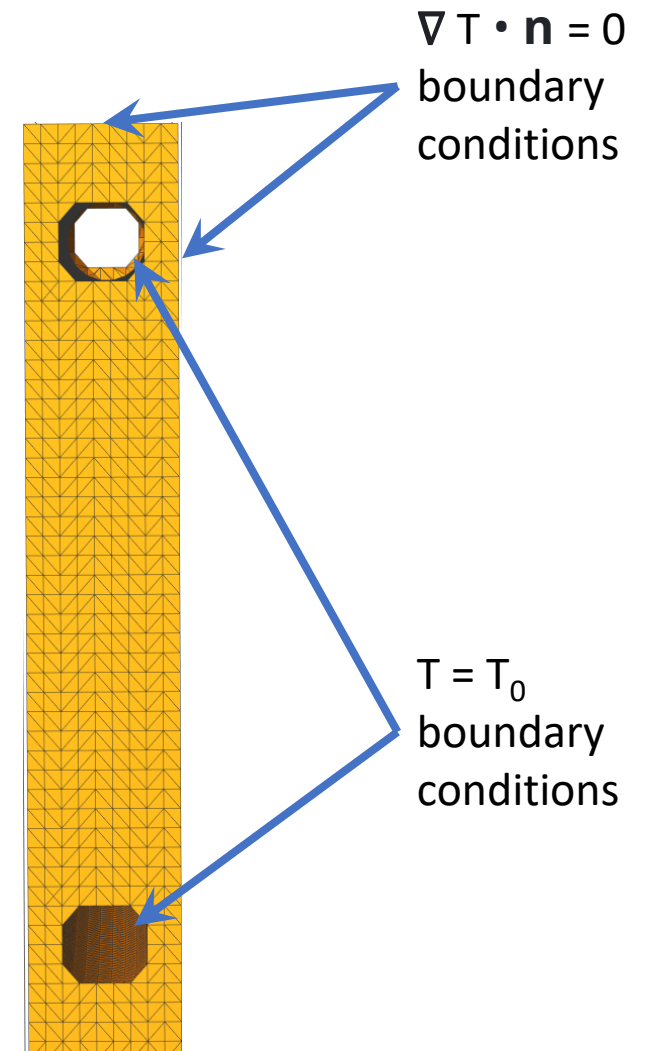


Hovanes Egiyan

# TEMPERATURE EVALUATION FOR CPS MODELS

# Presented method

- The goal of this method is to obtain temperature distribution estimates for the CPS core using a simpler method than full **ANSYS**, in order to verify **ANSYS** results.
  - Only concentrate on the copper core area to get 3D solutions for the equations in a uniform medium.
- Use Poisson's equation with boundary condition to determine the T-distribution.
  - Use finely binned data from FLUKA simulations by Vitaly and Pavel.
  - The solutions for the equations are assumed to be time-independent.
- Solve the equations using **Mathematica** software.
  - JLAB owns license for CUE Linux machines.
  - Can solve Poisson's equation in both Cartesian, Spherical and Cylindrical coordinates.
  - Small details like small 2mm cuts e.t.c. are ignored in geometry.
  - Assumes fixed temperature for the boundary with the cooling water and calculated temperature rise with respect to that boundary temperature.
  - Water flow is assumed to be sufficient for cooling to  $T_0$  value.
- I use  $T_0 = 70$  °C water boundary temperature in the copper.
  - Tim uses 40 °C water temperature in **ANSYS**.

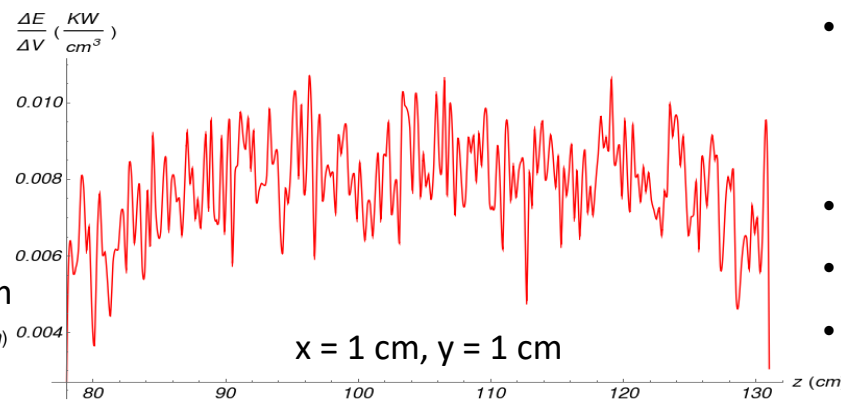
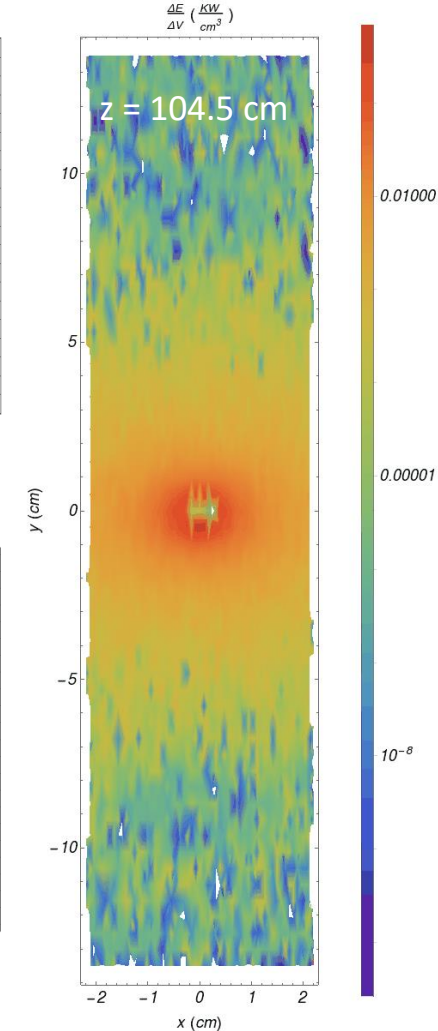
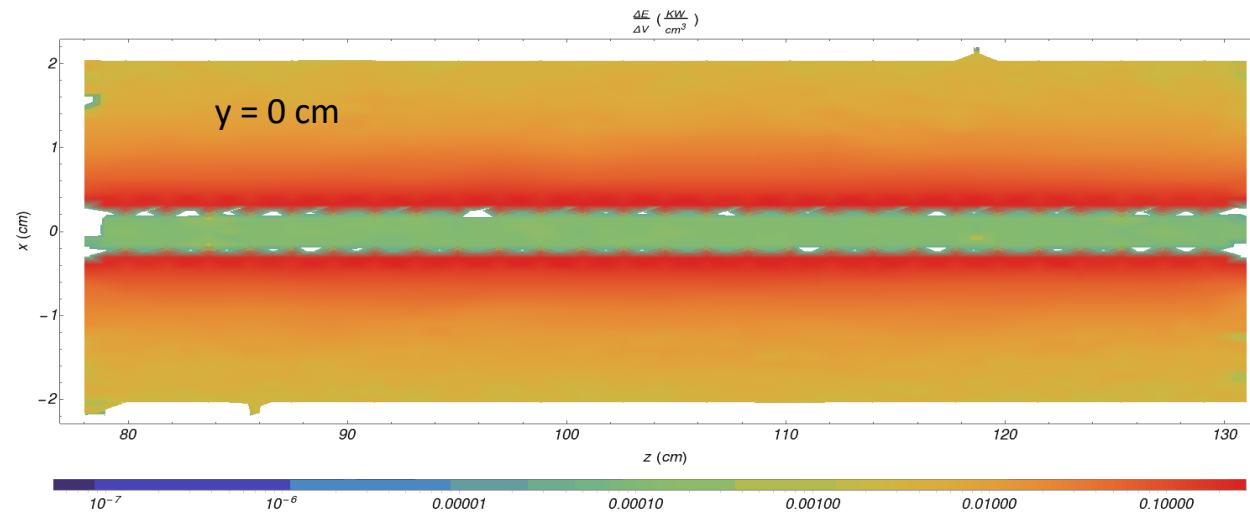
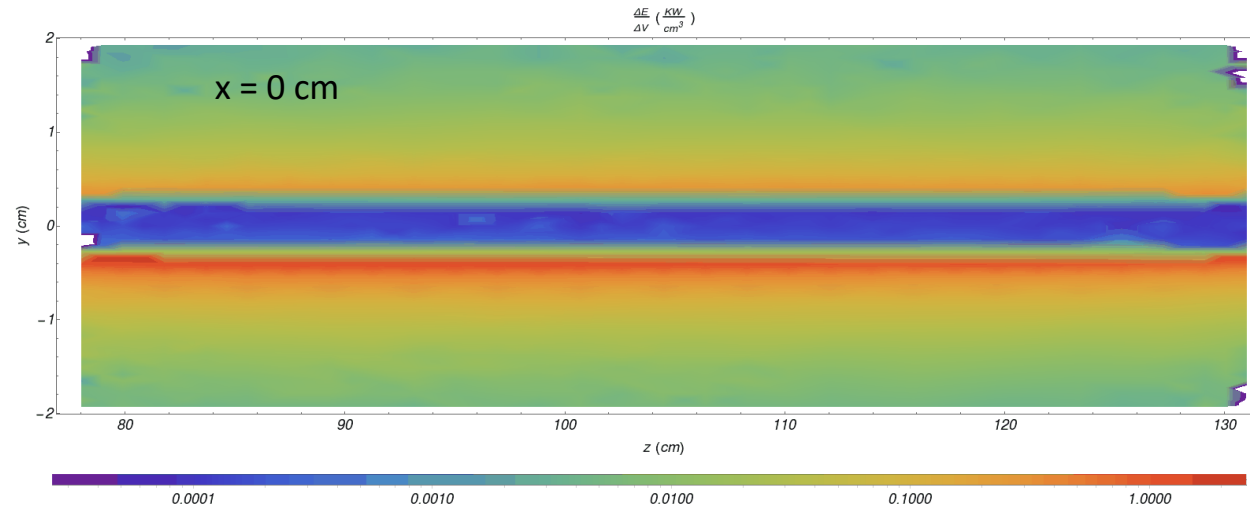
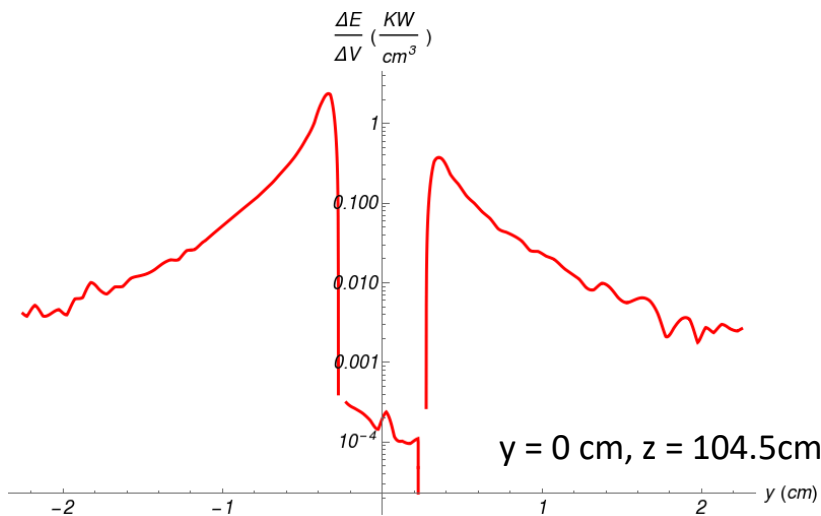
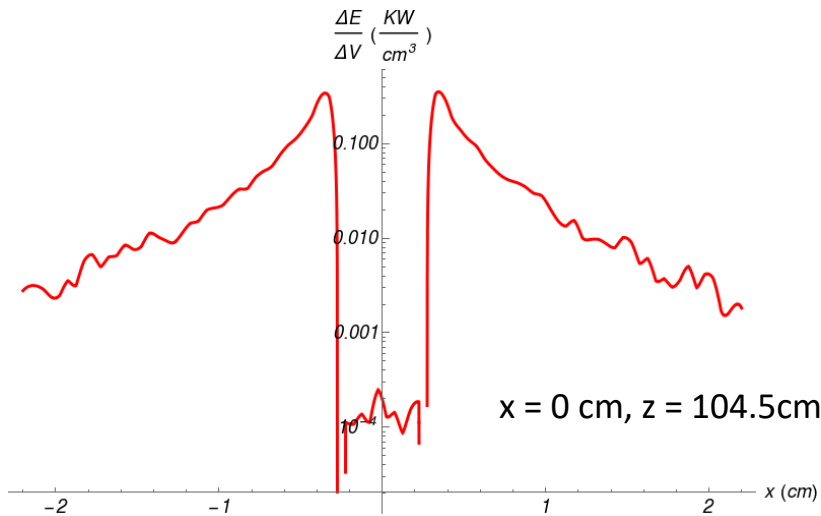


used  $k = 385 \frac{\text{W}}{\text{K m}}$  herer for copper thermal conductivity

$$-\nabla^2 T(x,y,z) = \frac{1}{k} q(x,y,z)$$

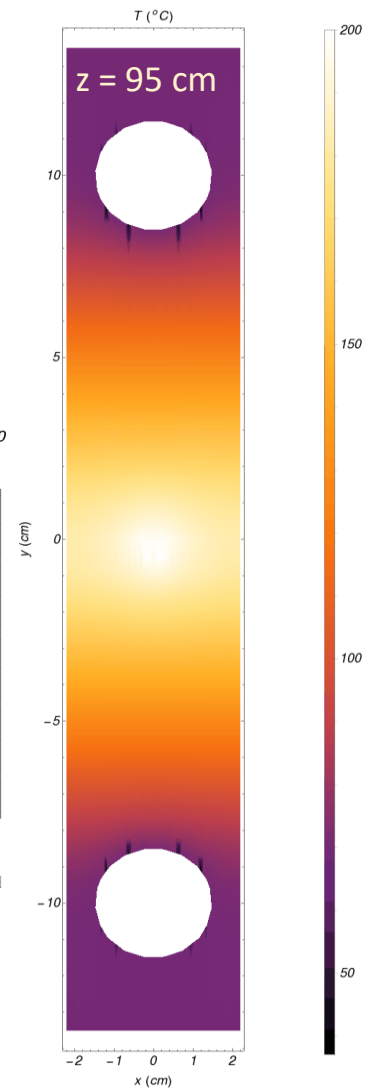
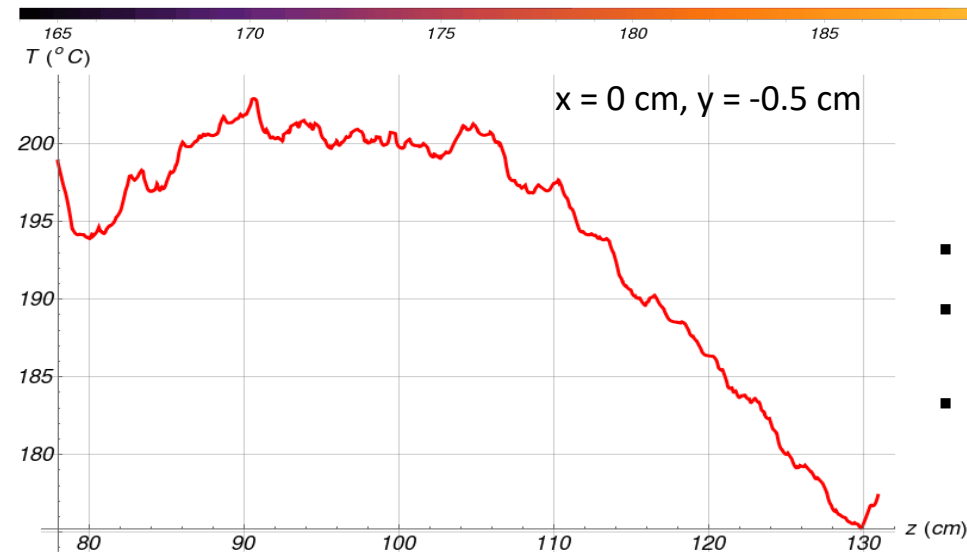
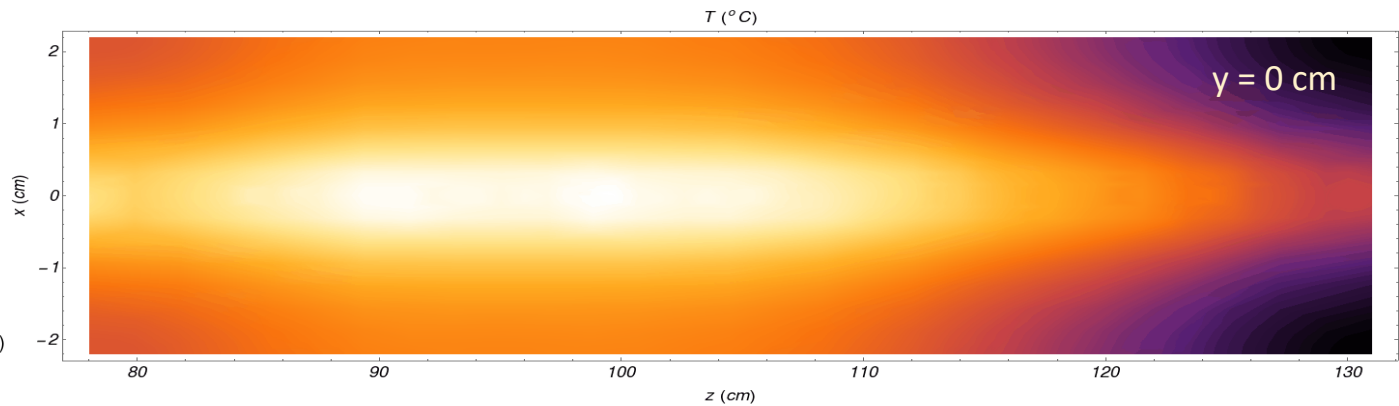
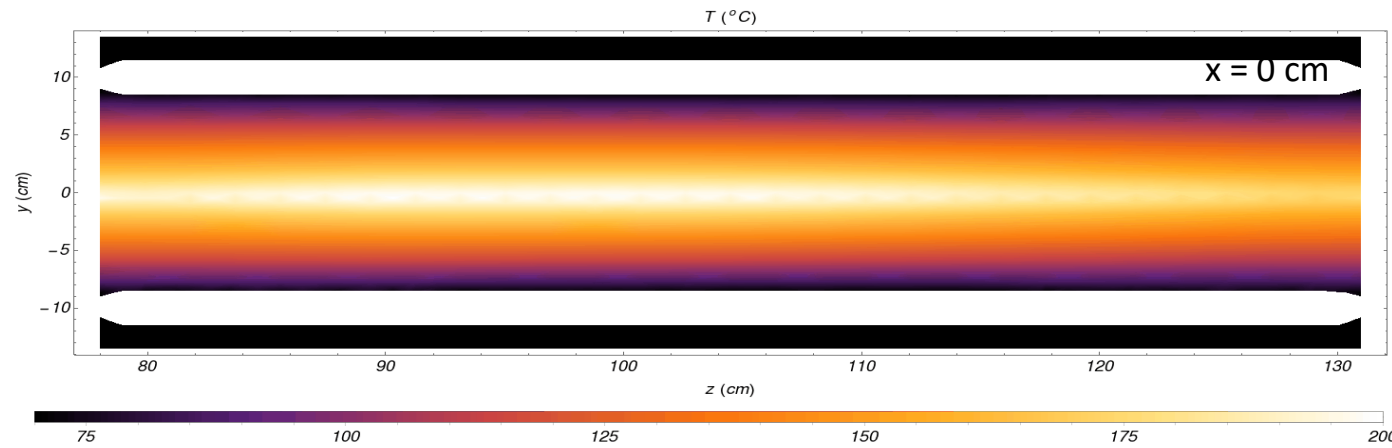
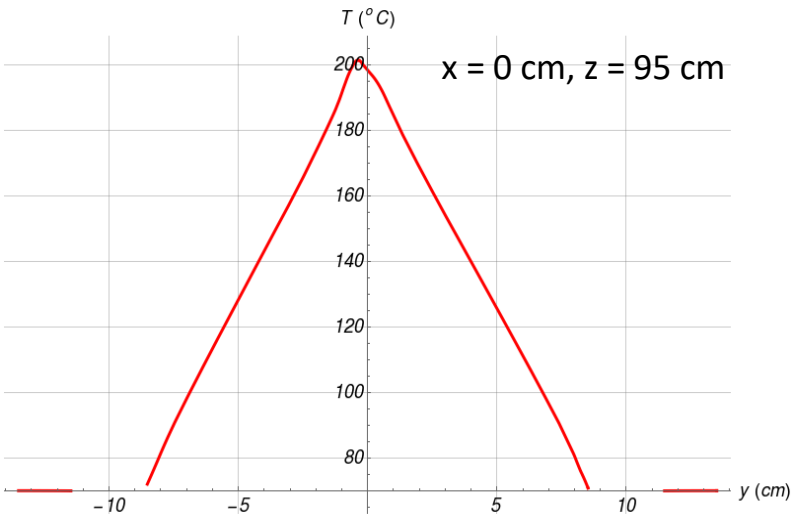
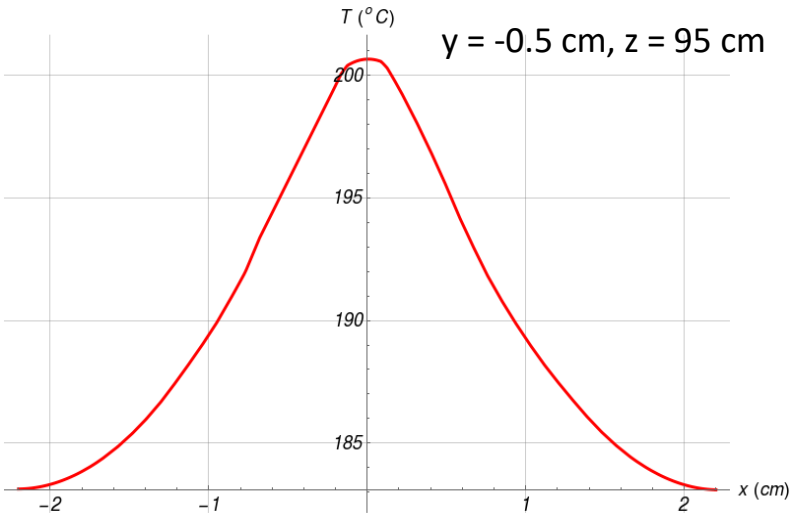
$$-\nabla^2 T(r,\phi,z) = \frac{1}{k} q(r,\phi,z)$$

# Input from Vitaly's model



- FLUKA Model file CPSKPTLEAD1712narrGUNvacTRP\_020323\_21 from February 2023.
  - Tim presented his results on February 23 meeting.
- Pretty uniform in Z power deposition in the copper core.
- $\sim 2$  KW/cm<sup>3</sup> maximum power deposition density.
- Total power 25.6 KW in 53x27x4.4 cm<sup>3</sup> volume of copper.

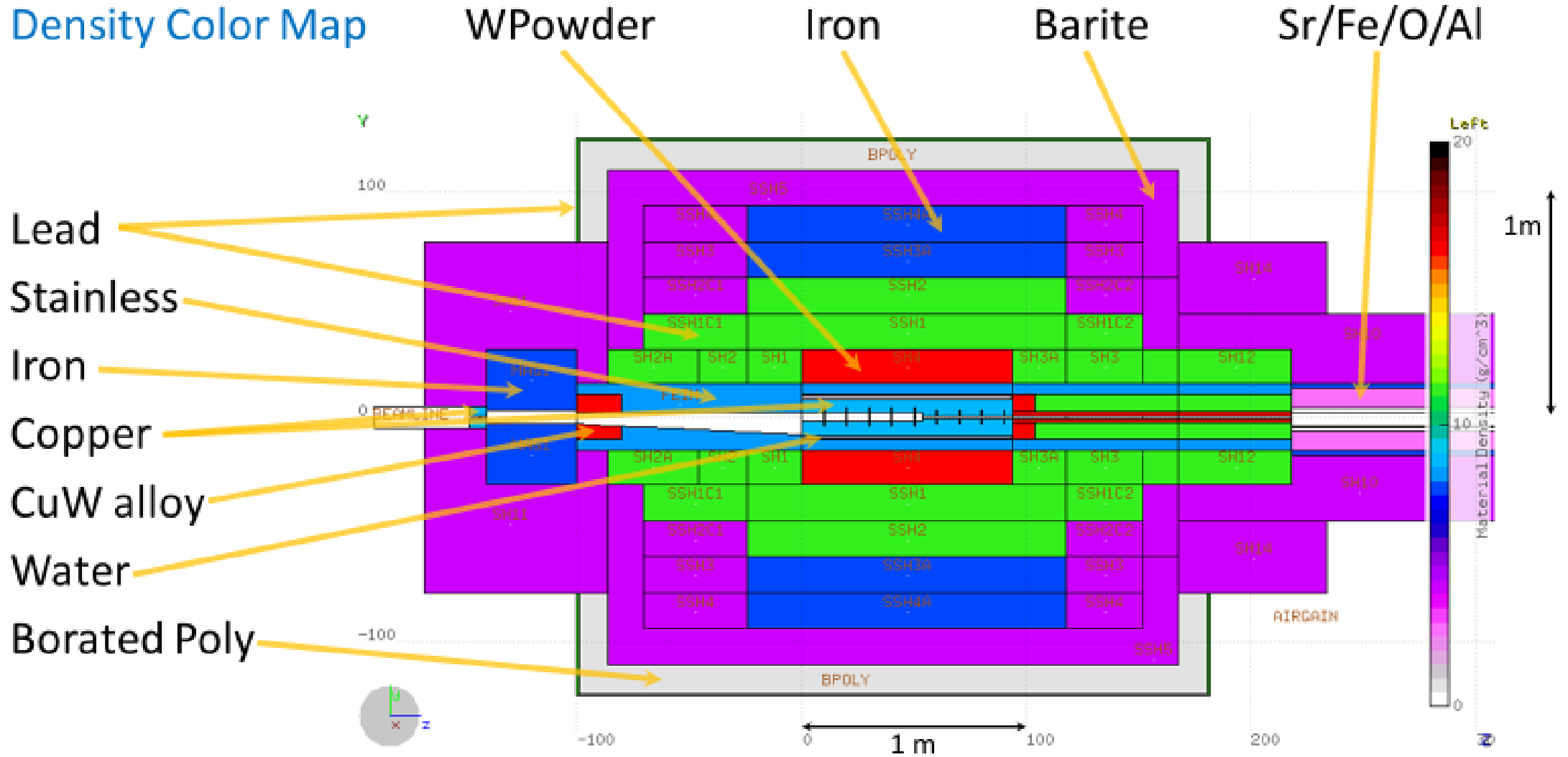
# Results for Vitaly's Model



- Max temperature is about  $T_{\text{max}} \approx 205 \text{ }^{\circ}\text{C}$ .
- Temperature at the horizontal edges could be as high as  $180 \text{ }^{\circ}\text{C}$ .
- Tim is getting  $255 \text{ }^{\circ}\text{C}$  or  $285 \text{ }^{\circ}\text{C}$  from **ANSYS** for the same file even though he assumes  $T_{\text{water}} \approx 40 \text{ }^{\circ}\text{C}$ .
  - Water-to-copper heat transfer is properly taken into account in **ANSYS**.

# Conceptual Design Update: CPS Shorter by ~50%

Density Color Map



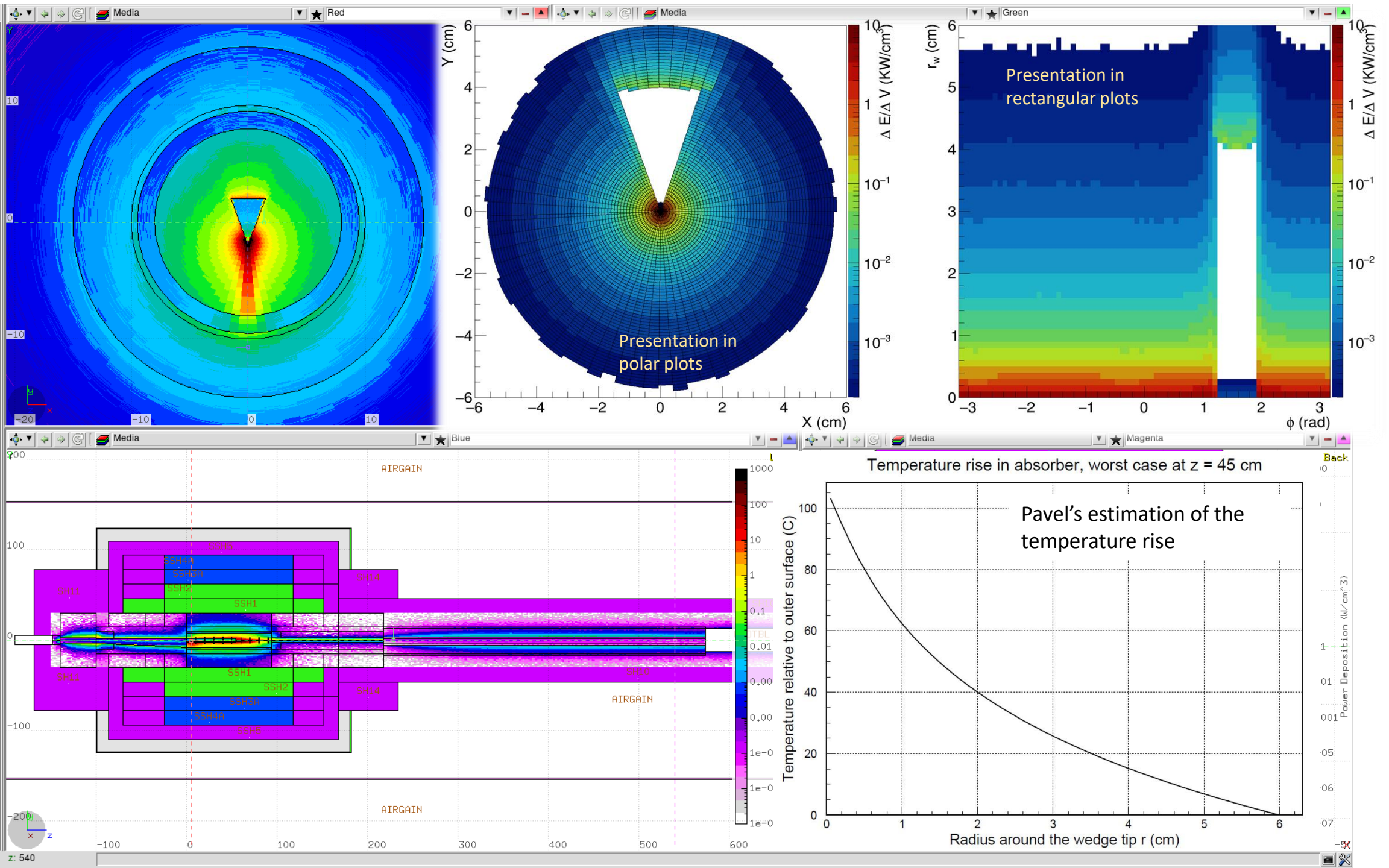
Pavel's Model

- Presented by Pavel on December 22, 2022 as KLCPS44.
- I used Pavel's fine-granulated data from KLCPS55 model.



# Power deposition along the CPS core

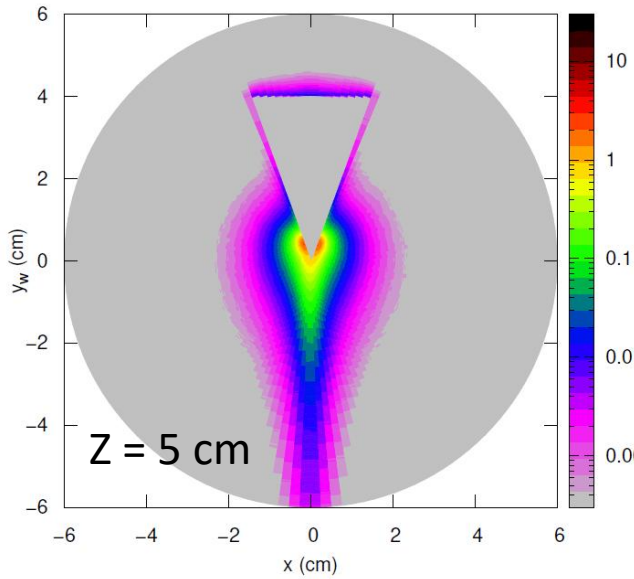
From Pavel



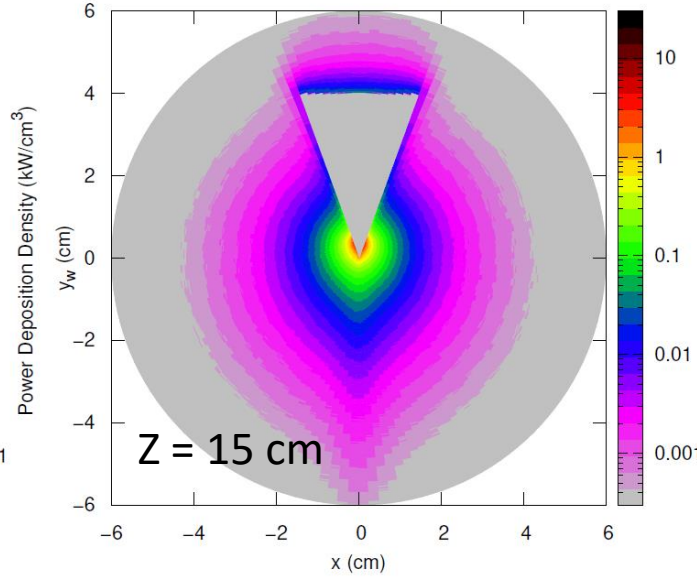
Max power density at the tip  $\sim 7 \text{ kW/cm}^3$

# Power density around the tip of the wedge From Pavel

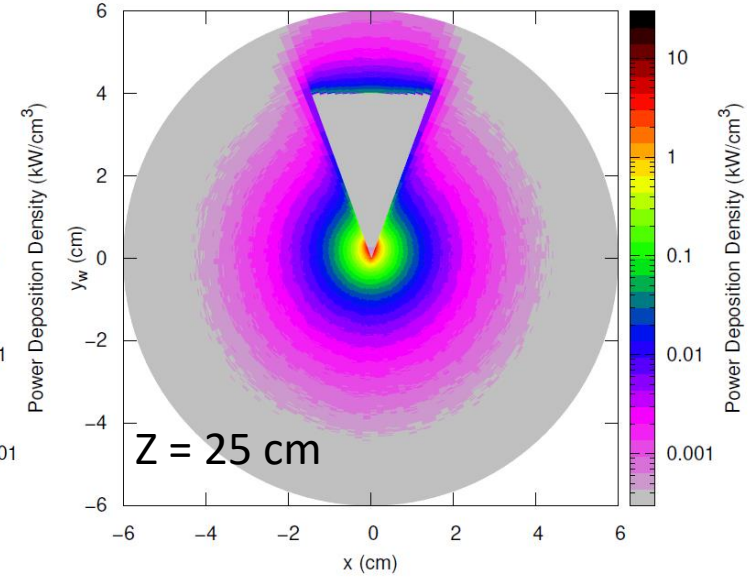
Power distribution around the tip of the cavity wedge,  $5 < z < 6 \text{ cm}$



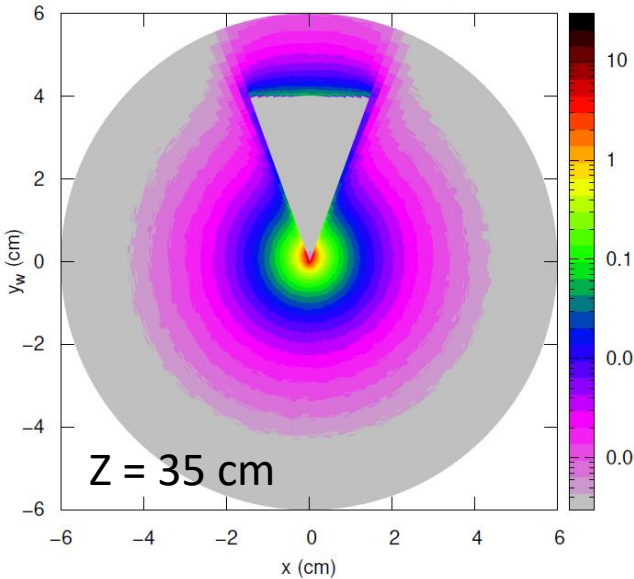
Power distribution around the tip of the cavity wedge,  $15 < z < 16 \text{ cm}$



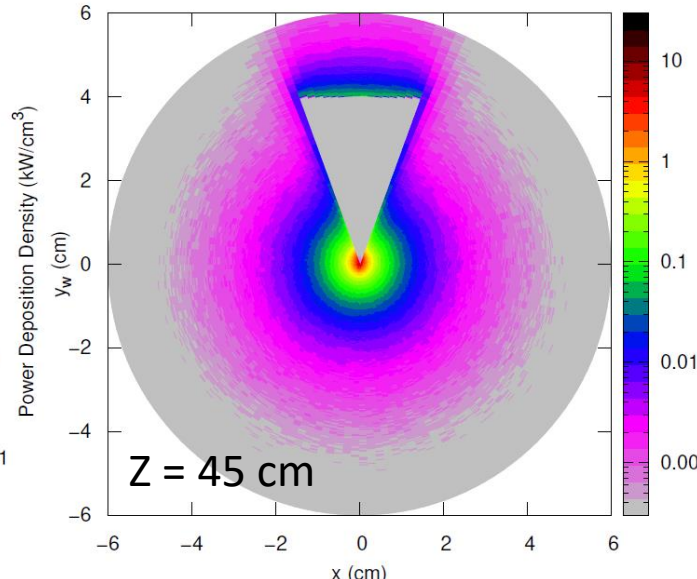
Power distribution around the tip of the cavity wedge,  $25 < z < 26 \text{ cm}$



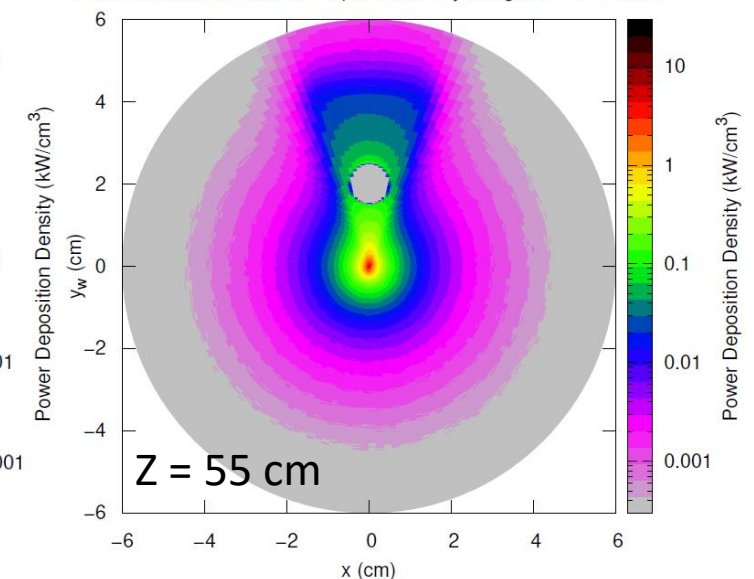
Power distribution around the tip of the cavity wedge,  $35 < z < 36 \text{ cm}$

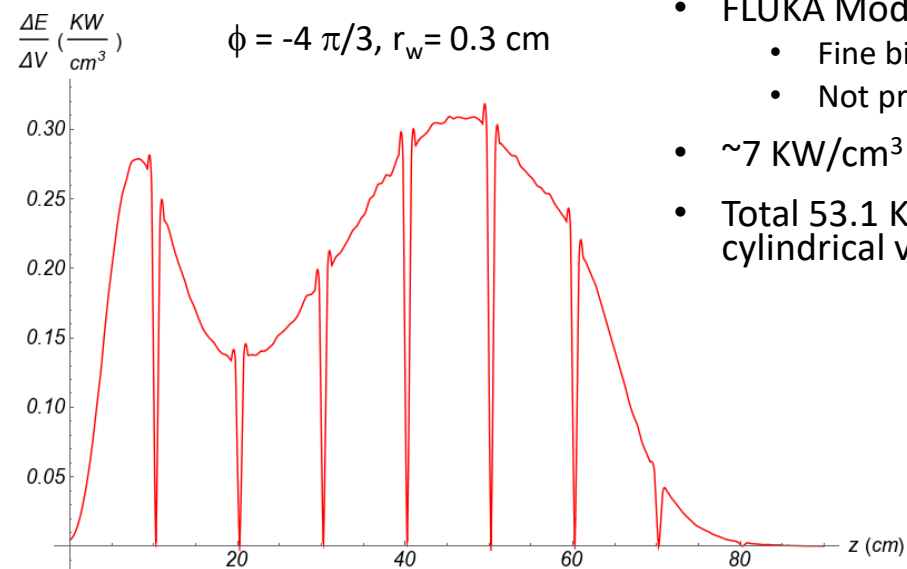
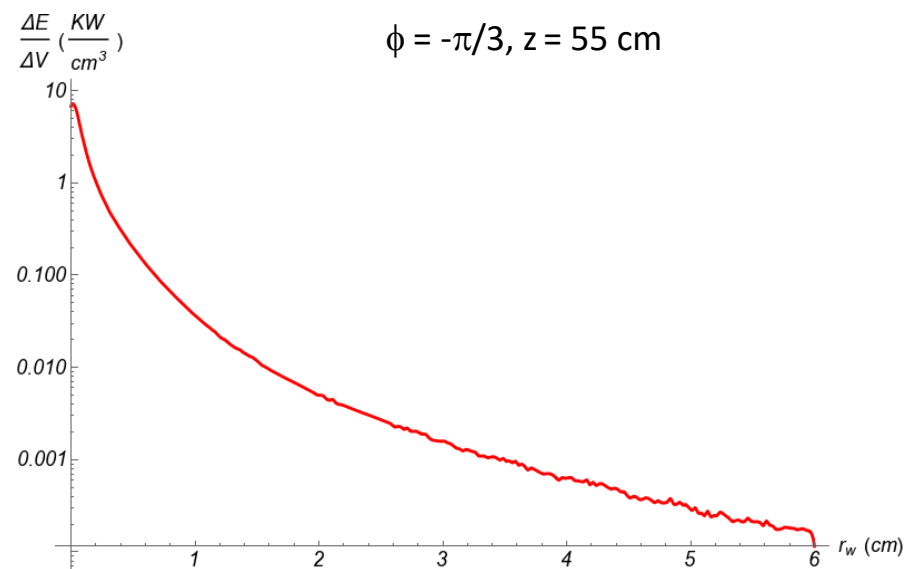
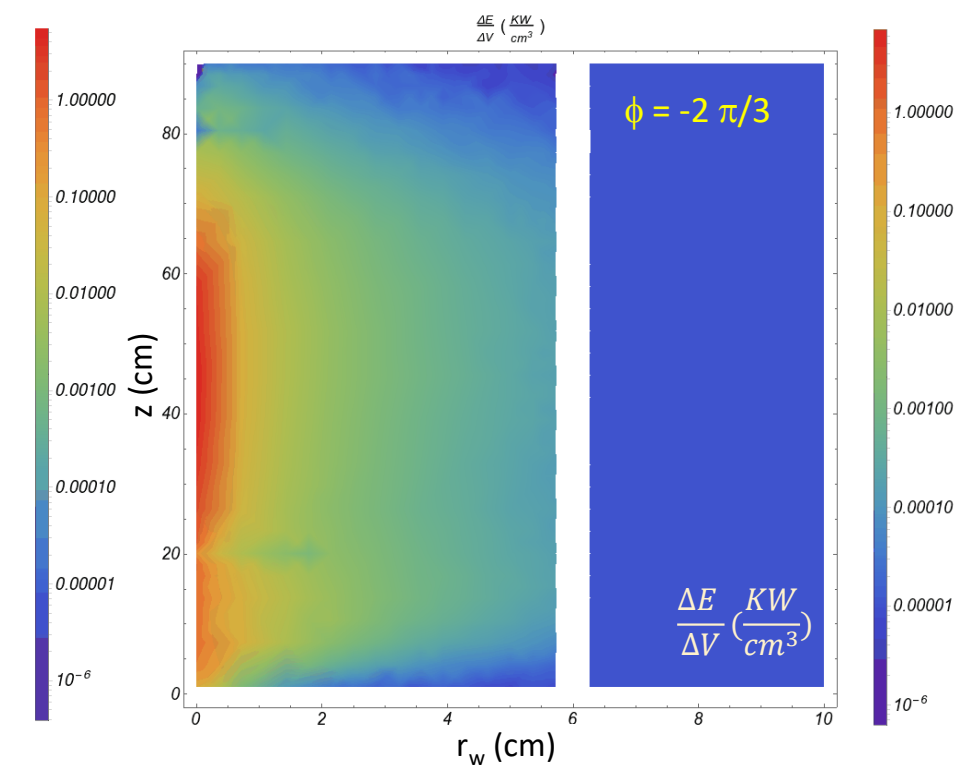
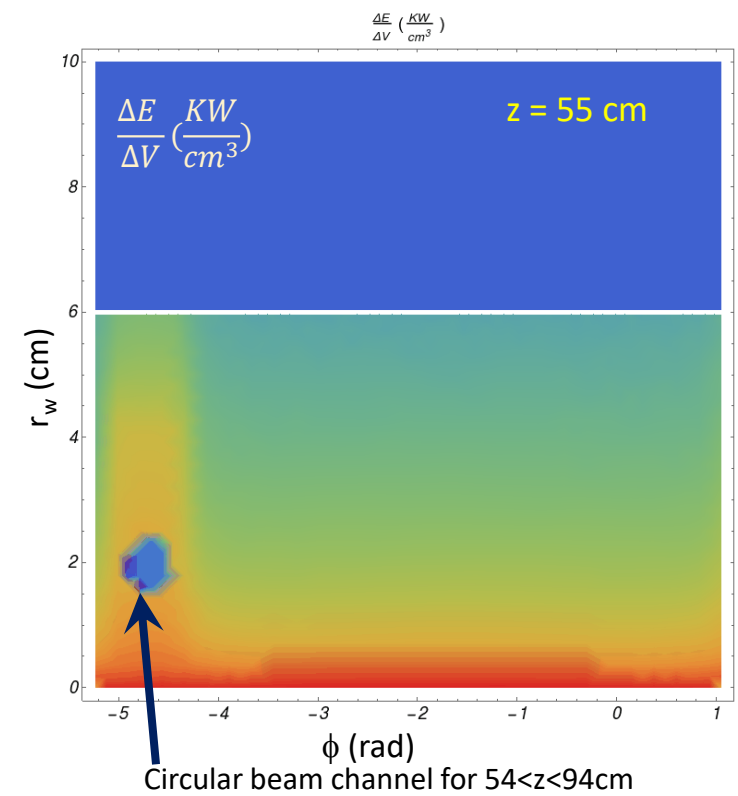
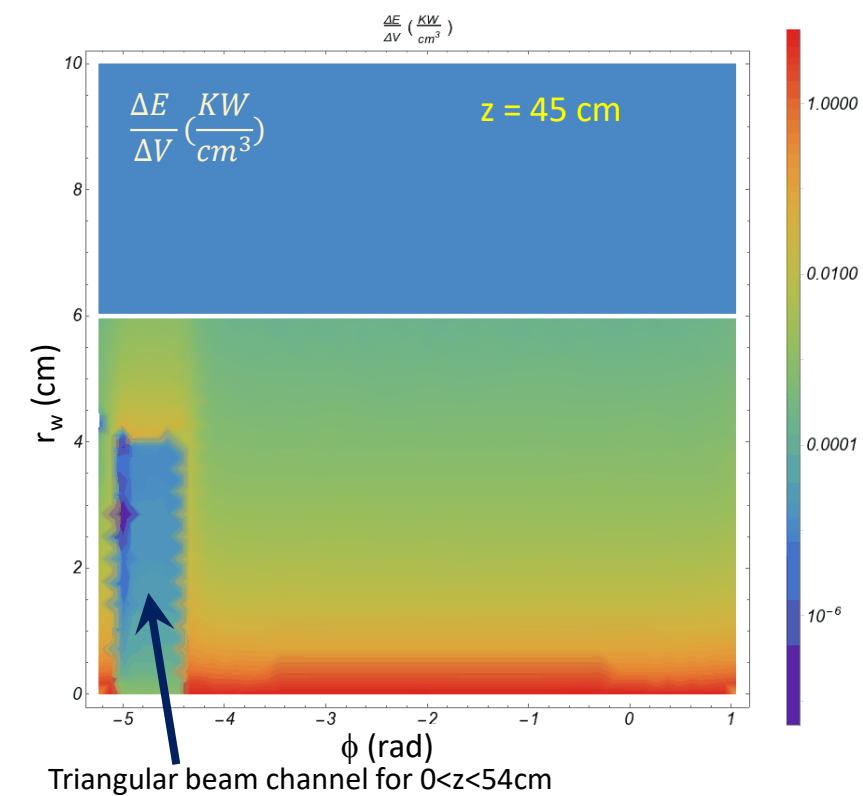


Power distribution around the tip of the cavity wedge,  $45 < z < 46 \text{ cm}$



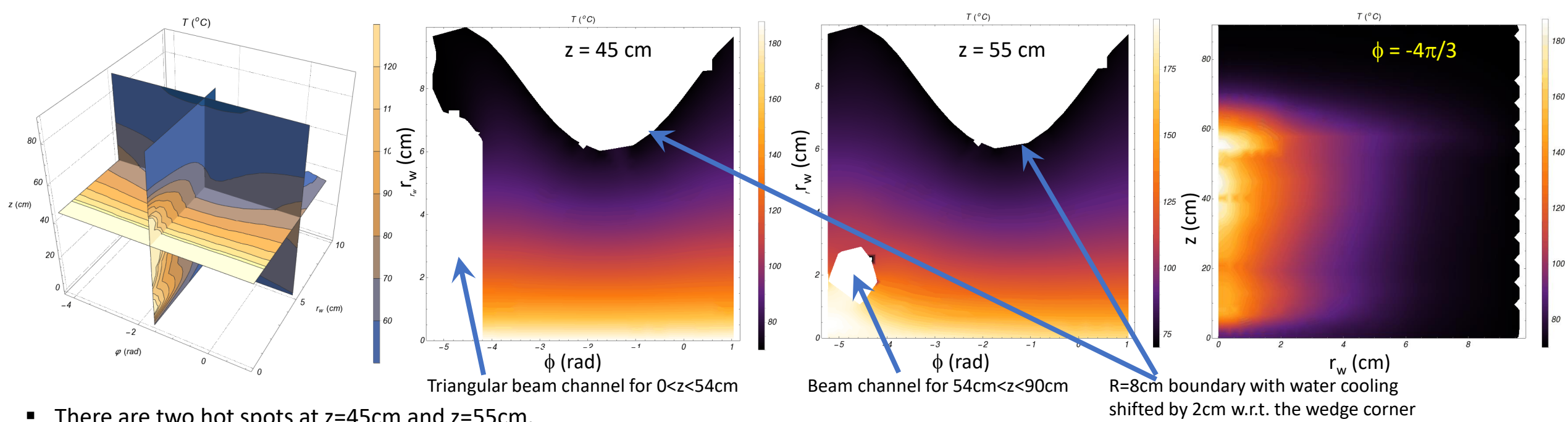
Power distribution around the tip of the cavity wedge,  $55 < z < 56 \text{ cm}$



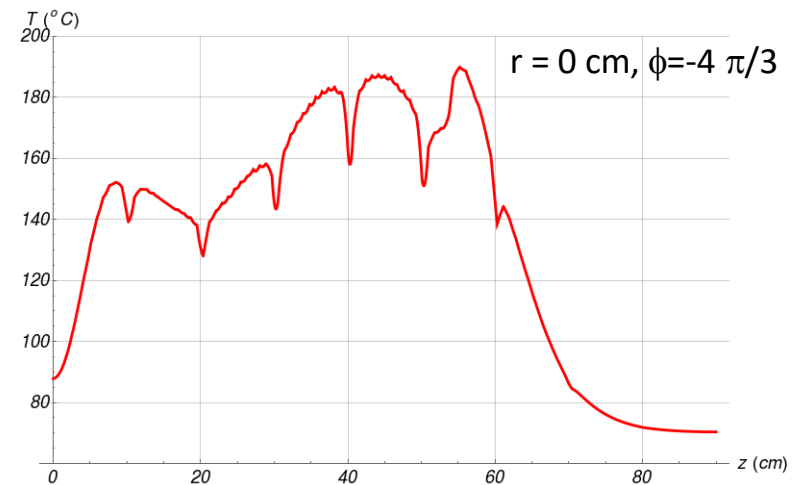
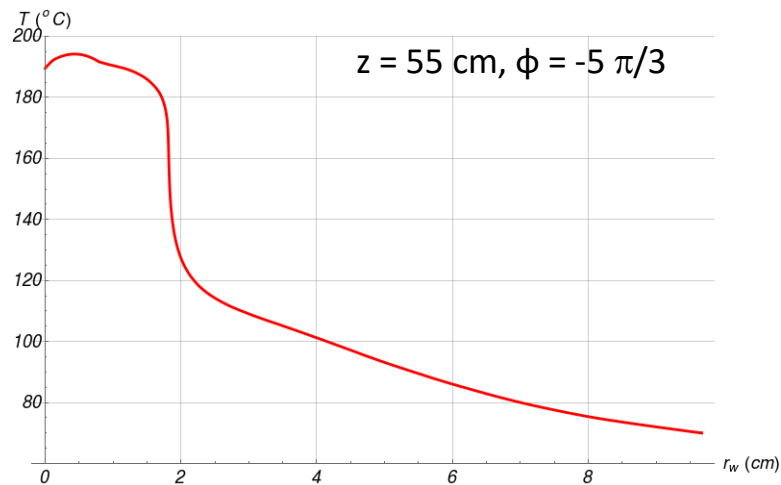
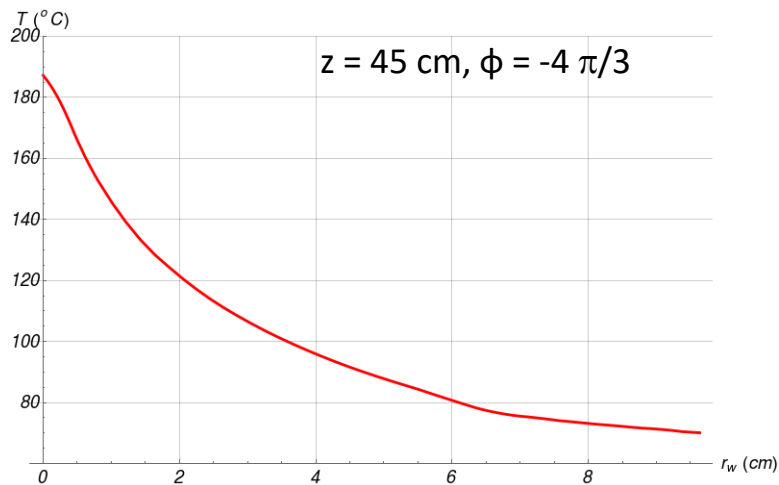


- FLUKA Model KLCPS55 from December 2022.
  - Fine binning of the copper insert.
  - Not presented, but advertised via e-mail
- $\sim 7 \text{ KW/cm}^3$  maximum power deposition density.
- Total  $53.1 \text{ KW}$  power deposited in  $\pi \cdot 6^2 \cdot 94 \text{ cm}^3$  cylindrical volume of copper.





- There are two hot spots at  $z=45$ cm and  $z=55$ cm.
- Maximum temperature is about  $T_{\text{max}} \approx 195$  °C.
  - Pavel estimated  $\Delta T \approx 105$  °C for the temperature rise. With water boundary temperature  $T_0 = 70$  °C, he would get  $T_{\text{max}} \approx 175$  °C.
- Although the power deposition density is high, the temperature at the hot spots is still well under 300 °C
- No hot outer edge seen for this model's copper core.
  - Good for the lead shielding safety.



# Conclusions and Outlook

- Temperature distributions in copper core has been calculated for Vitaly's model.
  - Temperature is closer to what Tim showed in September of 2022,  $T_{\max} \approx 205$  °C (not sure what  $T_{\text{water}}$  was then) than to what he found in February  $T_{\max} \approx 250$  °C from exactly the same file but using  $T_{\text{water}} \approx 40$  °C .
  - The difference between these calculations and **ANSYS** could be due to :
    - a) Temperature gradient at the water-copper boundary that is taken into account in **ANSYS**,
    - b) Unoptimized mesh for geometry ,
    - c) Unoptimized mesh size or low polynomial order for **FLUKA** data interpolation in **Mathematica**,
    - d) Water hole positions in the copper core models need to be the same,
    - e) Absorbed power (29KW shown by Tim vs 26KW shown by Hovanes),
  - I can work with Tim to identify the source of differences.
- Temperature distribution in copper core has been calculated for Pavel's model.
  - Temperature maximum of  $T_{\max} \approx 195$  °C approximately matches what Pavel estimated assuming cylindrically symmetric model.
  - It would be interesting to see if **ANSYS** solution has  $T_{\max} \approx 250$  °C for this file as well.
  - It is highly likely that this model will also provide acceptable temperature distribution for the KLF CPS.
- Both models provide copper core temperatures well under  $T_{\max} \approx 300$  °C using these colutions.
- I need to try different mesh sizes
  - Using large mesh size is memory costly, a better computer is needed.
- This method will provide a quick method to check the temperature inside the copper core in addition to **ANSYS** calculations by Tim.
- I can work with Vitaly and Pavel to help quickly compare temperature distributions for different options of CPS and for electron beam parameters .