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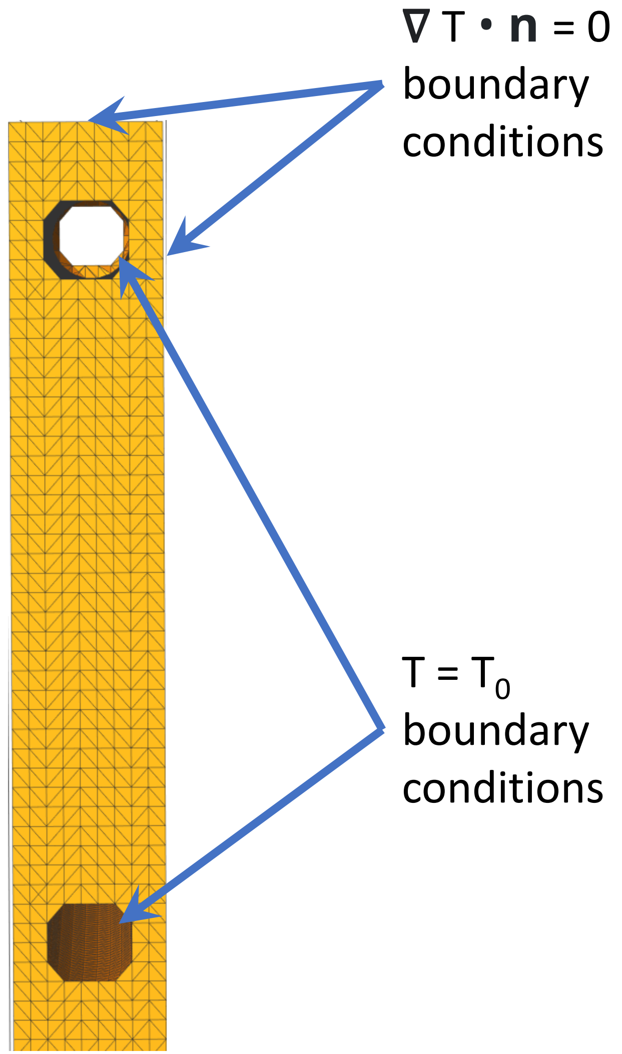
TEMPERATURE EVALUATION FOR CPS MODELS

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 ^{0}C water boundary temperature in the copper.
  - Tim uses 40 ^{0}C water temperature in ***ANSYS.***

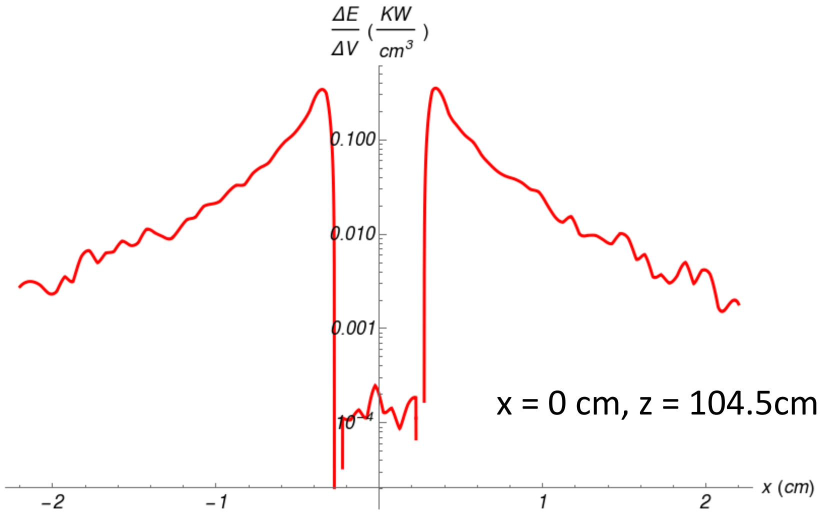


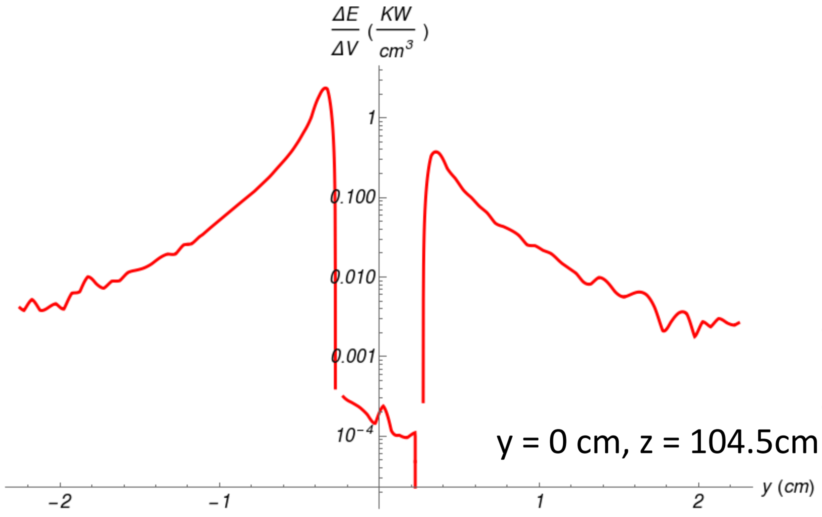
used $k = 385\ \frac{\text{W}}{\text{K m}}$ herer for copper thermal conductivity

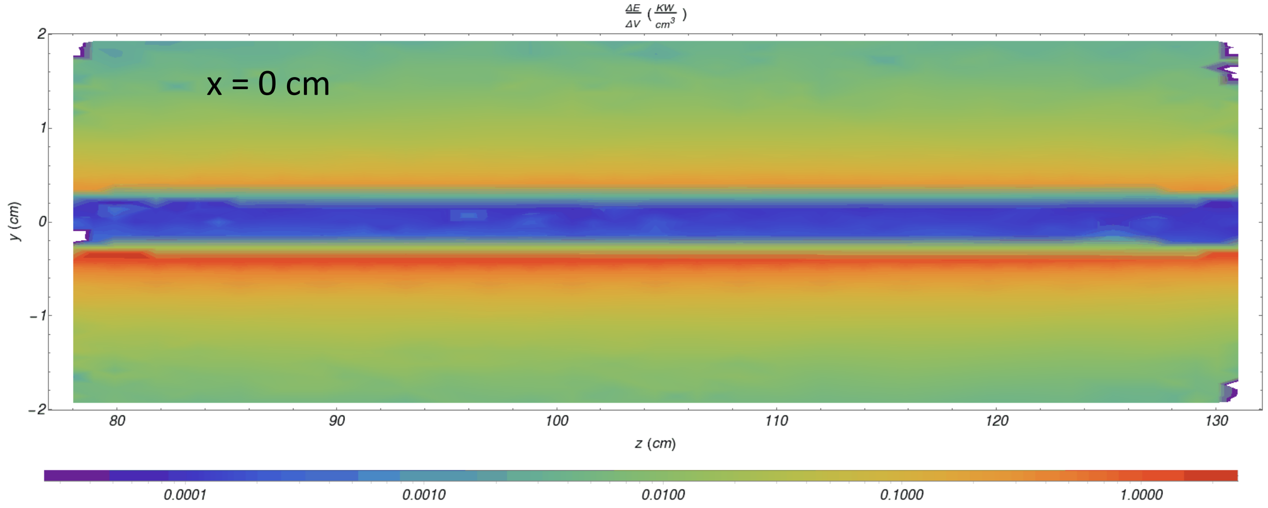
$$-\nabla^2 T(x,y,z) = \frac{1}{k}\, q\,(x,y,z)$$

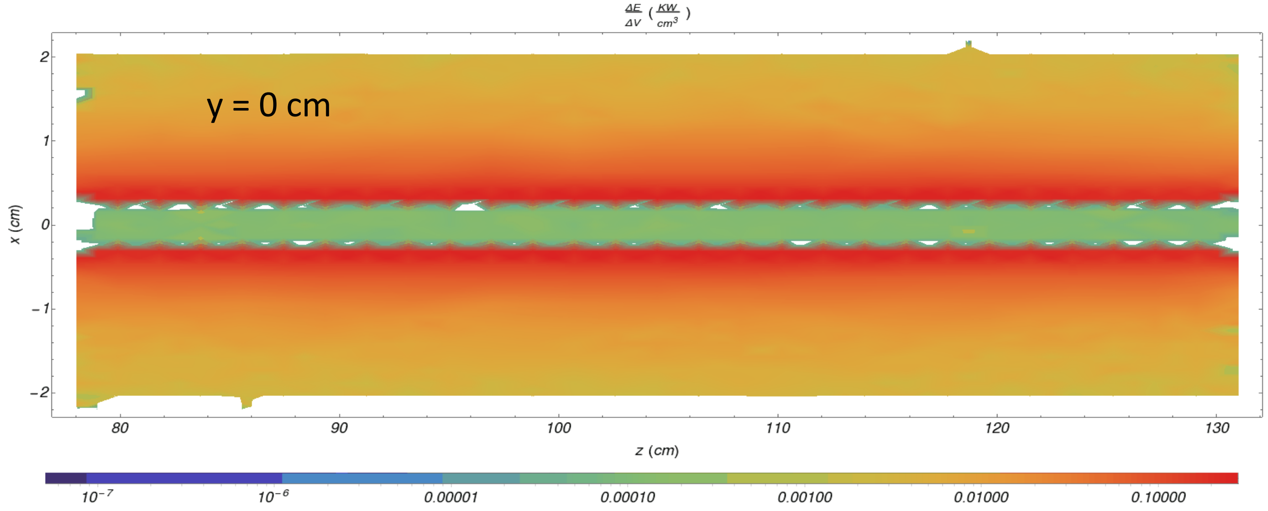
$$-\nabla^2 T(r,\phi,z) = \frac{1}{k}\, q\,(r,\phi,z)$$

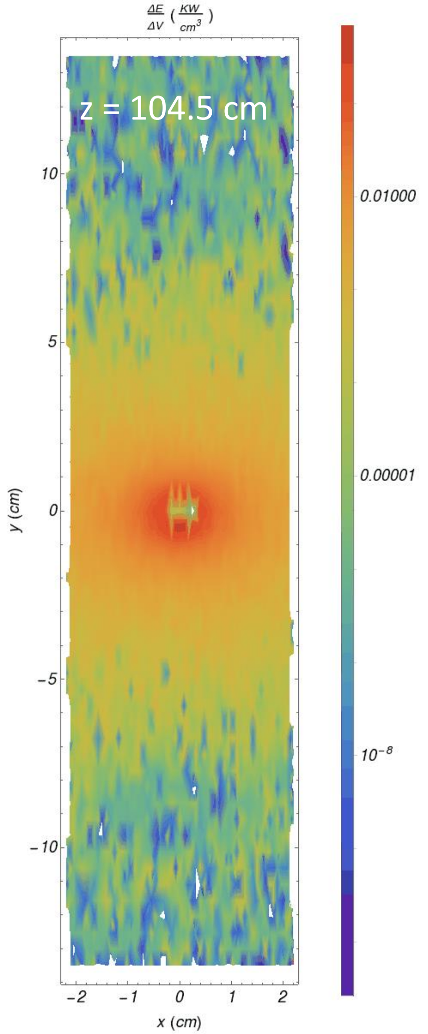
Input from Vitaly's model

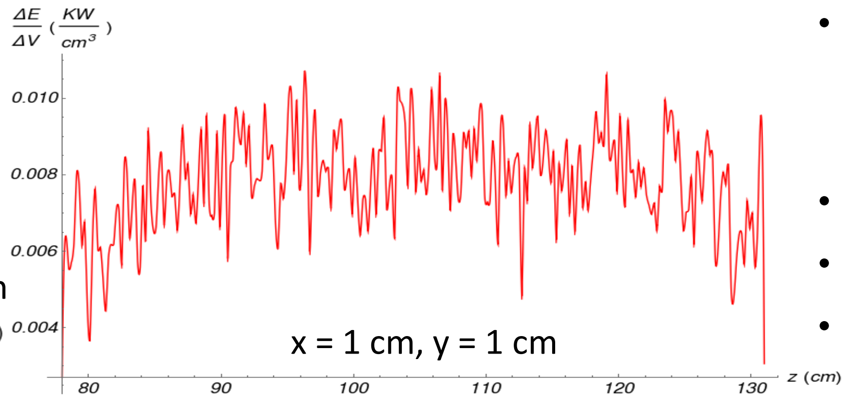






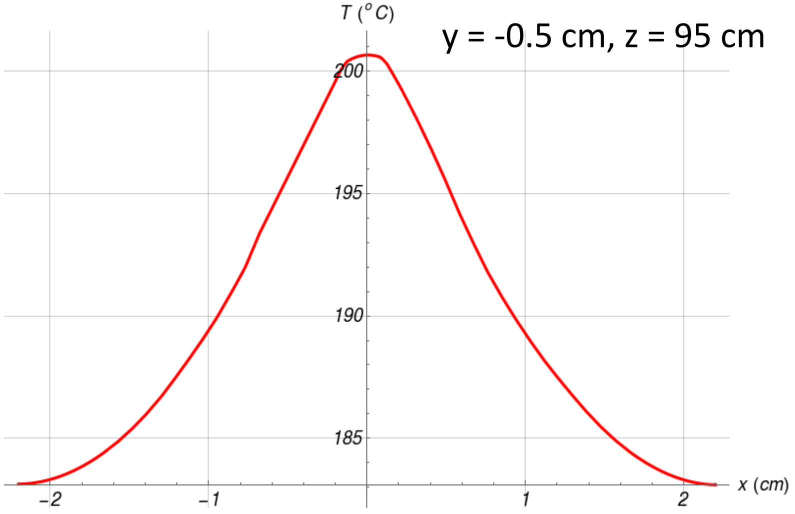


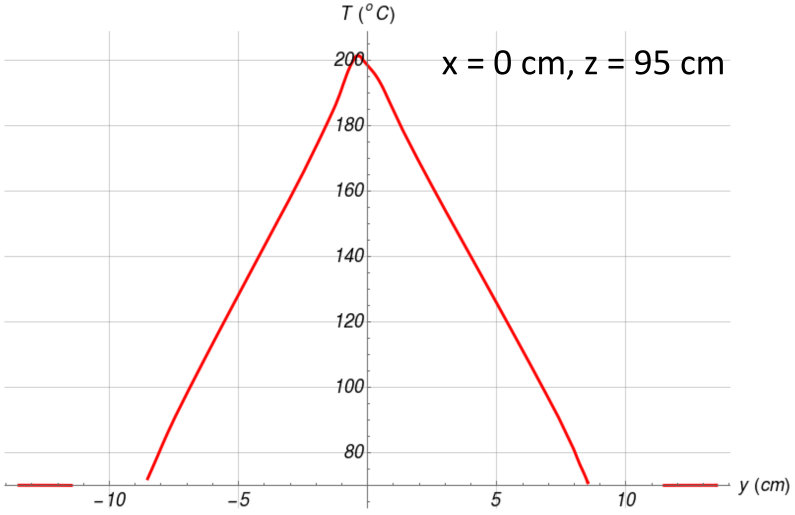


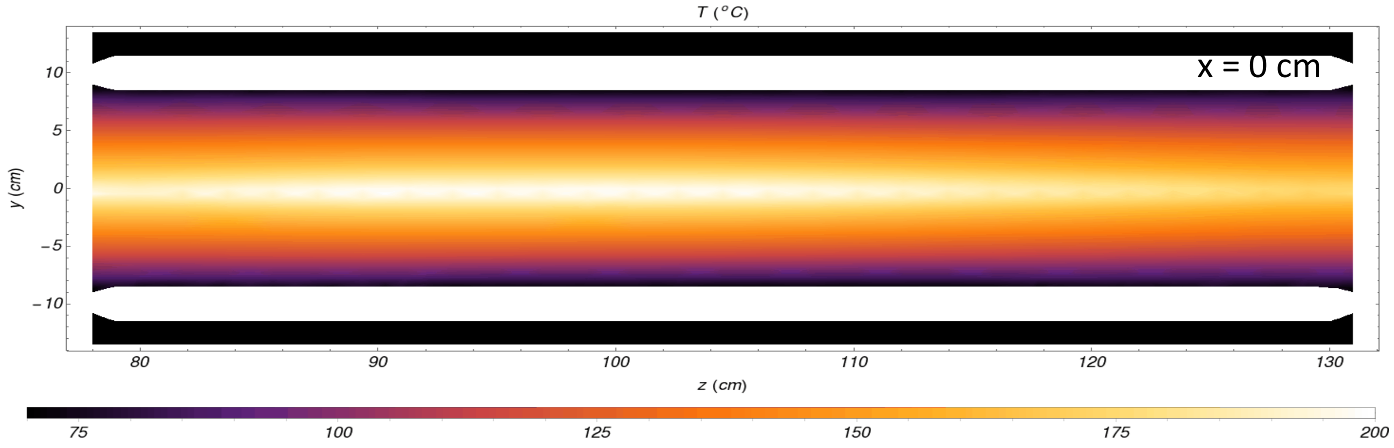


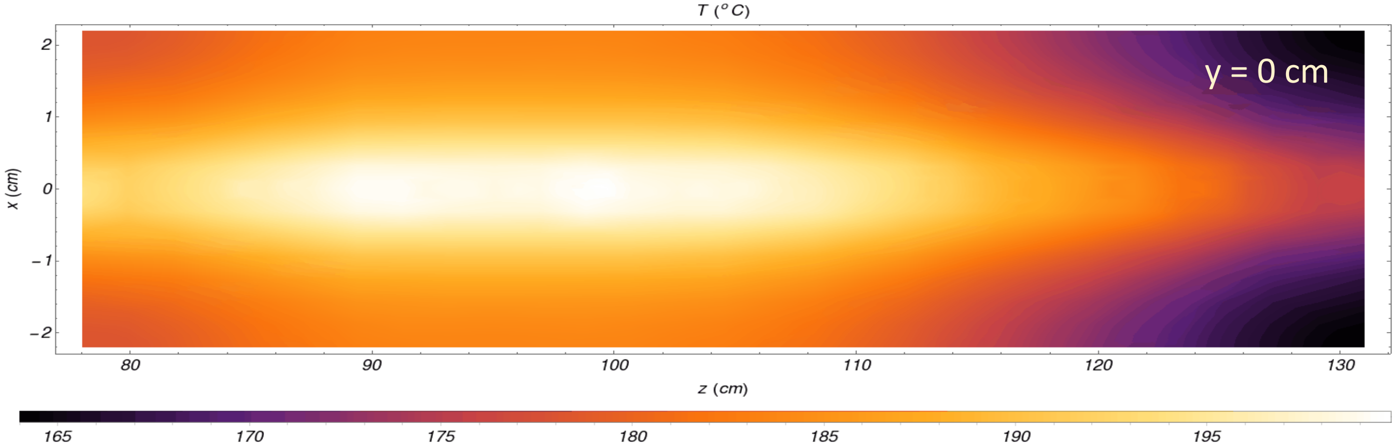
- FLUKA Model file CPSKPTLEAD1712narrGUNvacTRP_020323_21 from February 2023.
    - Tim presented his results on February 23 meeting.
- Pretty uniform in Z power deposition in the copper core.
- ~2 KW/cm^3 maximum power deposition density.
- Total power 25.6 KW in 53x27x4.4 cm^3 volume of copper.

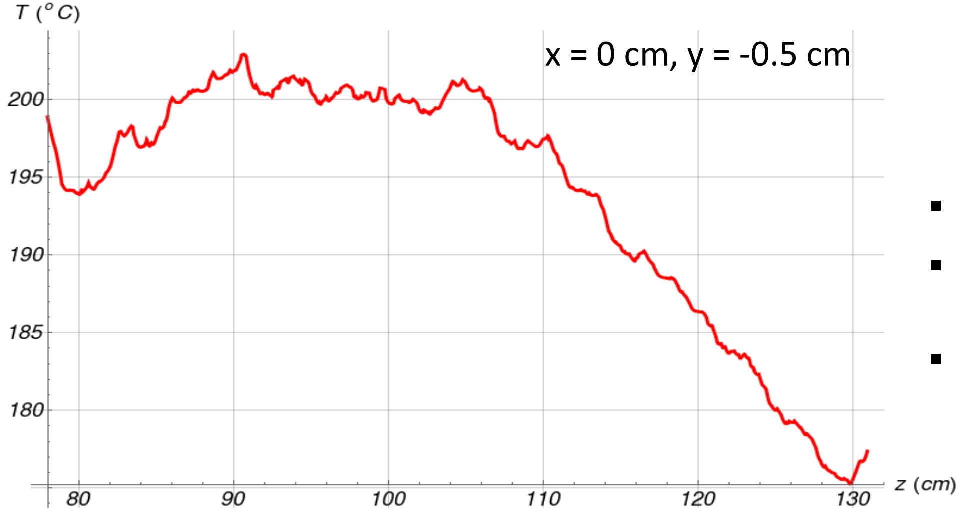
Results for Vitaly's Model

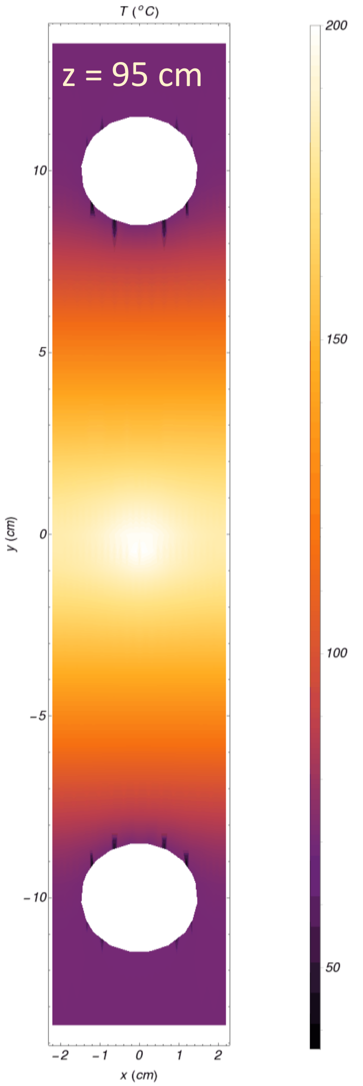






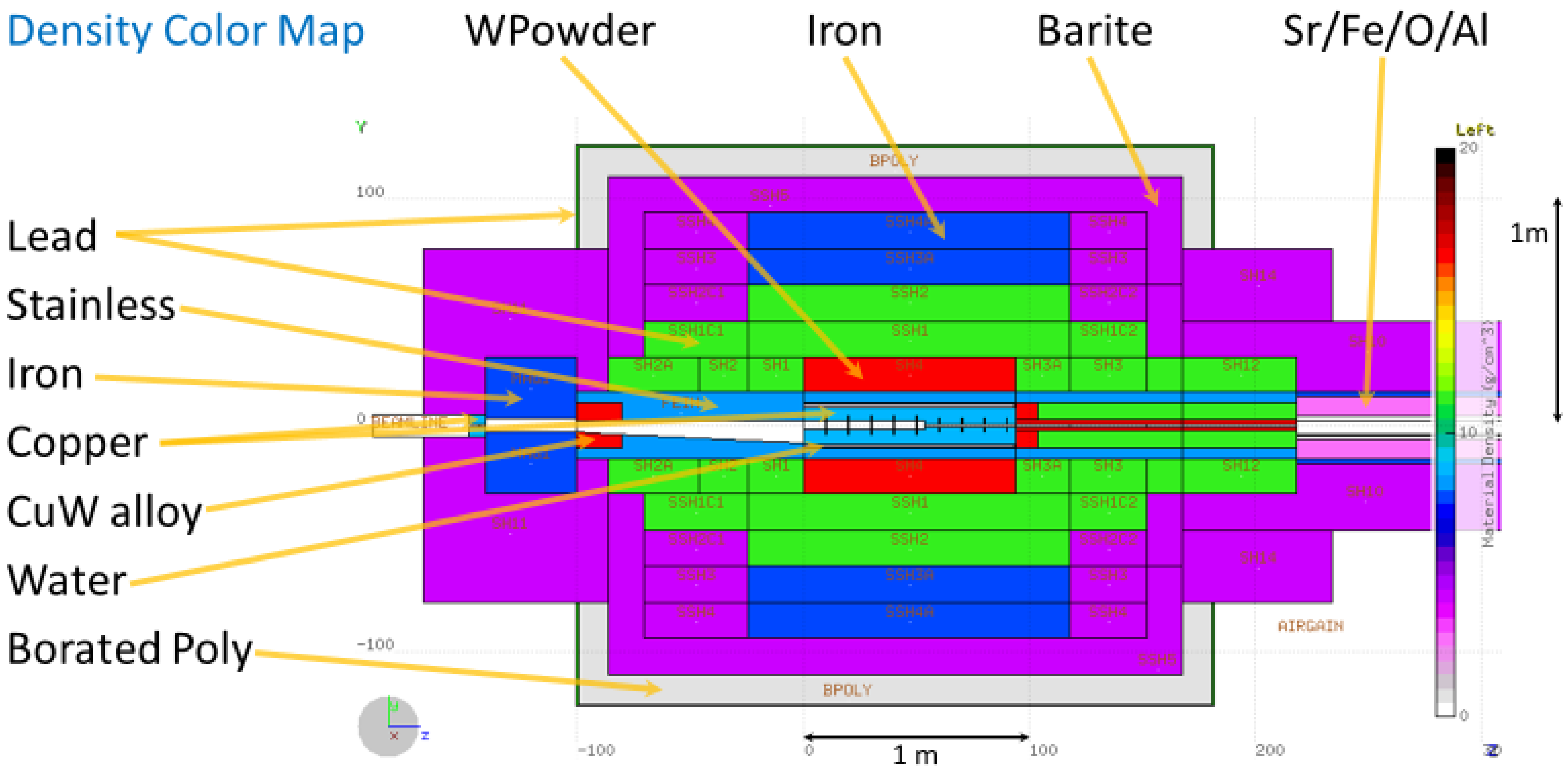






- Max temperature is about $T_{max} \approx 205\ ^0C$.
- Temperature at the horizontal edges could be as high as 180 ^0C.
- Tim is getting 255 ^0C or 285 ^0C from ***ANSYS*** for the same file even though he assumes $T_{water} \approx 40\ ^0C$.
  - Water-to-copper heat transfer is properly taken into account in **ANSYS**.

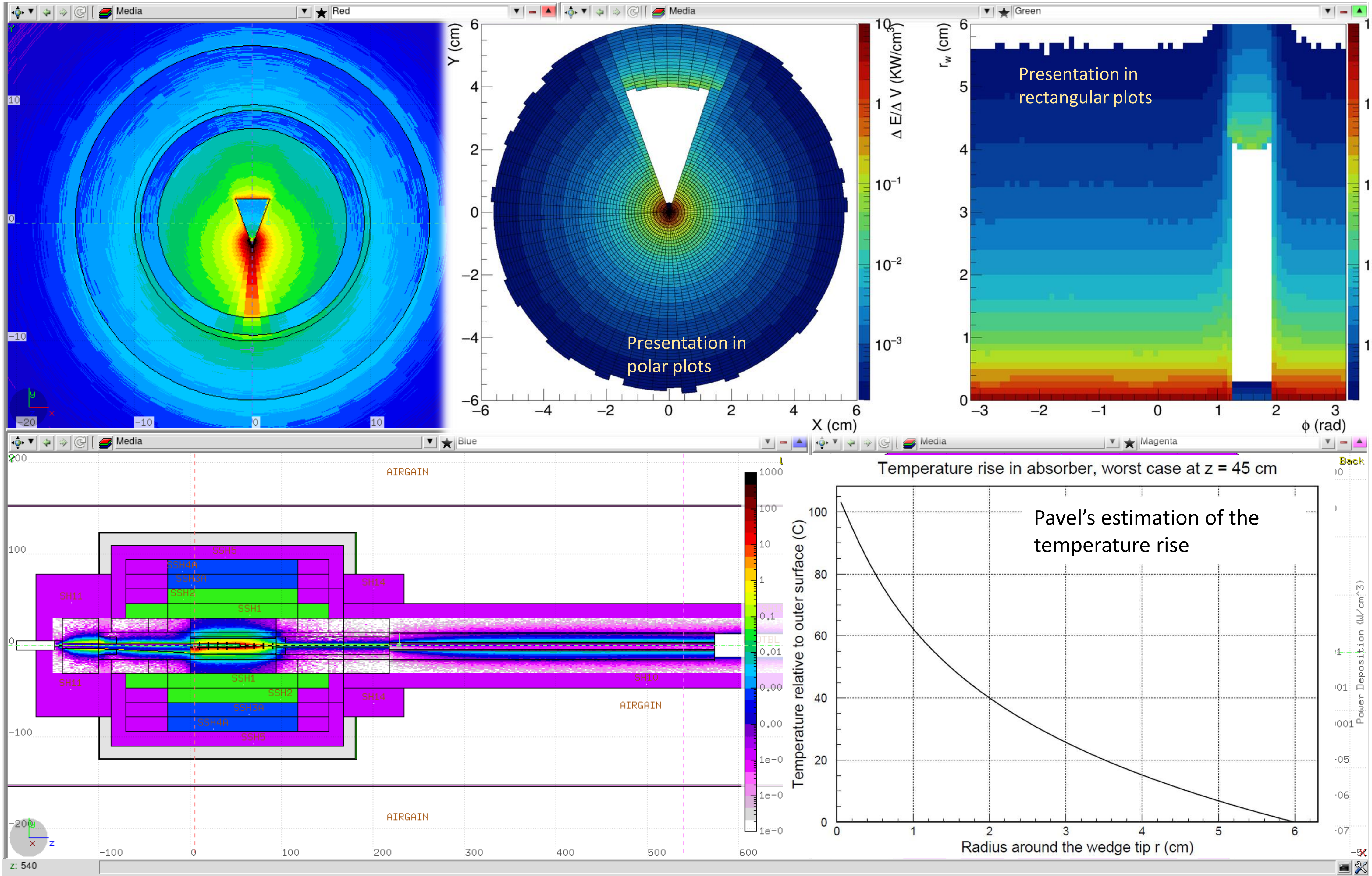
Conceptual Design Update: CPS Shorter by ~50%



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

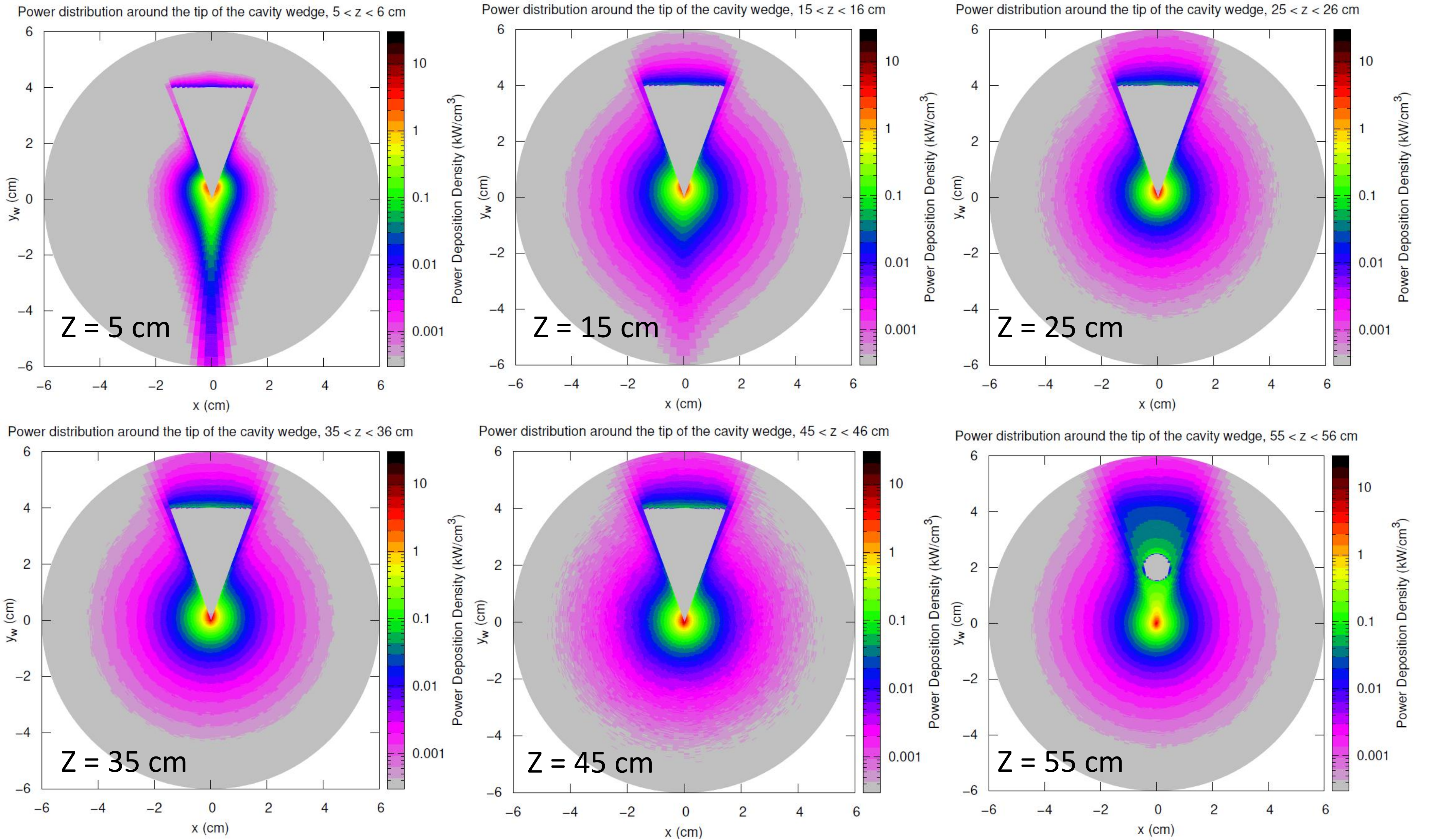


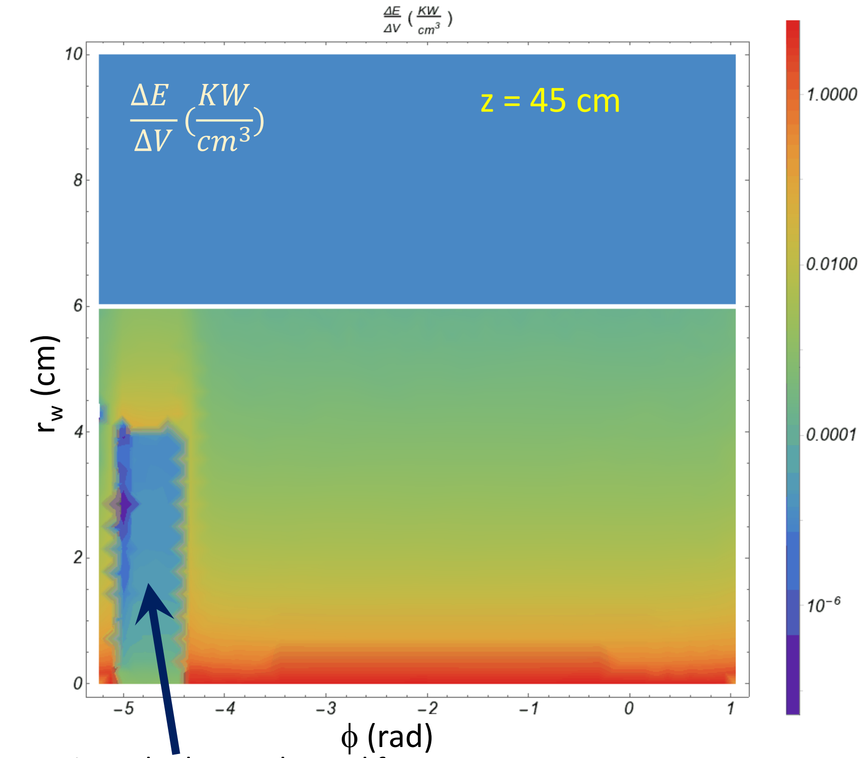
From Pavel

Power density around the tip of the wedge

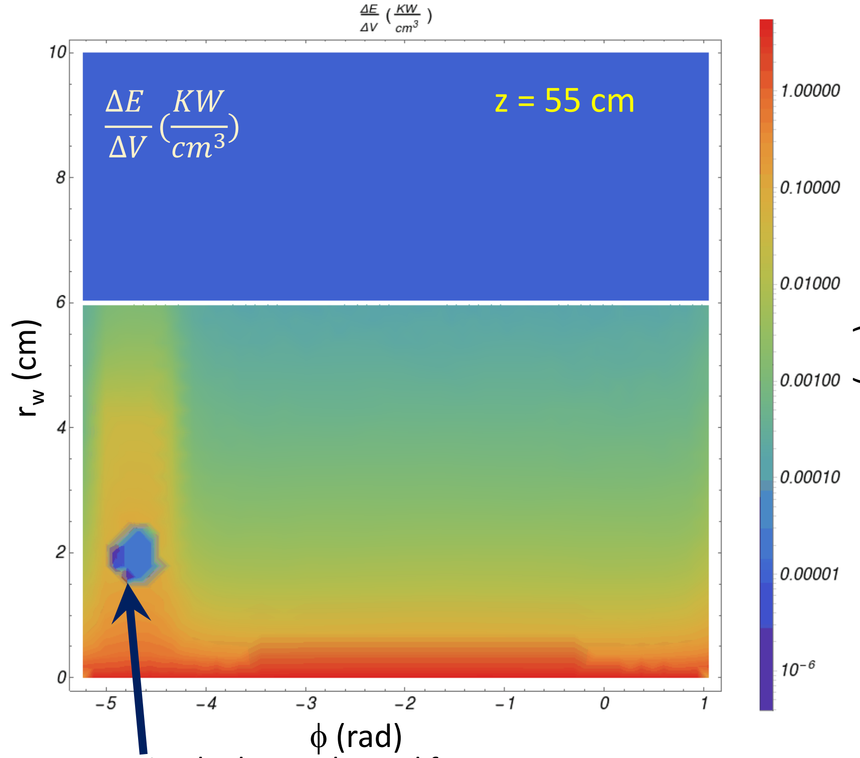
From Pavel

Max power density at the tip ~7 kW/cm^3

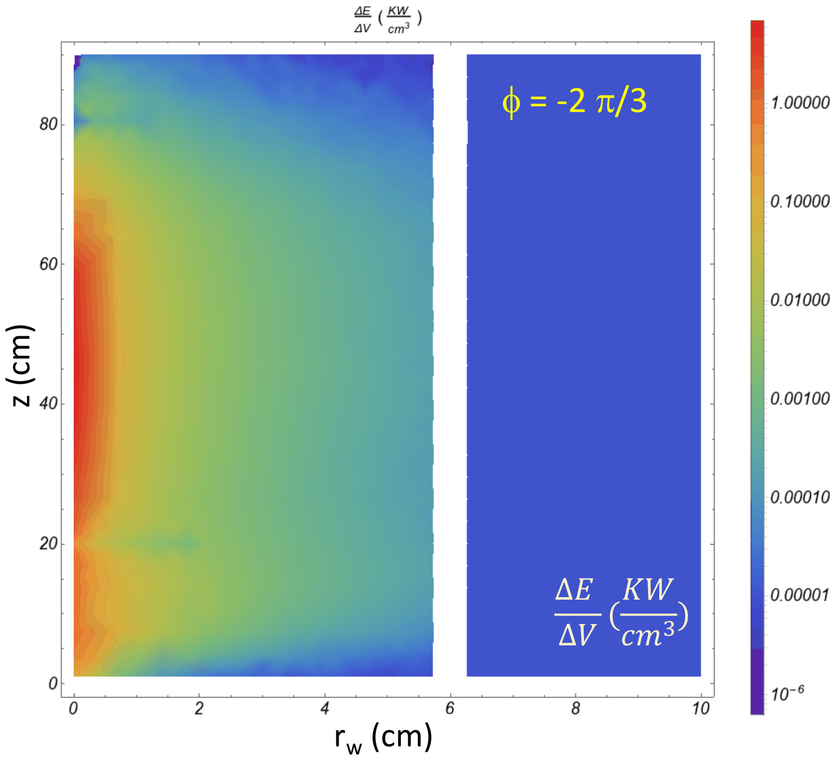


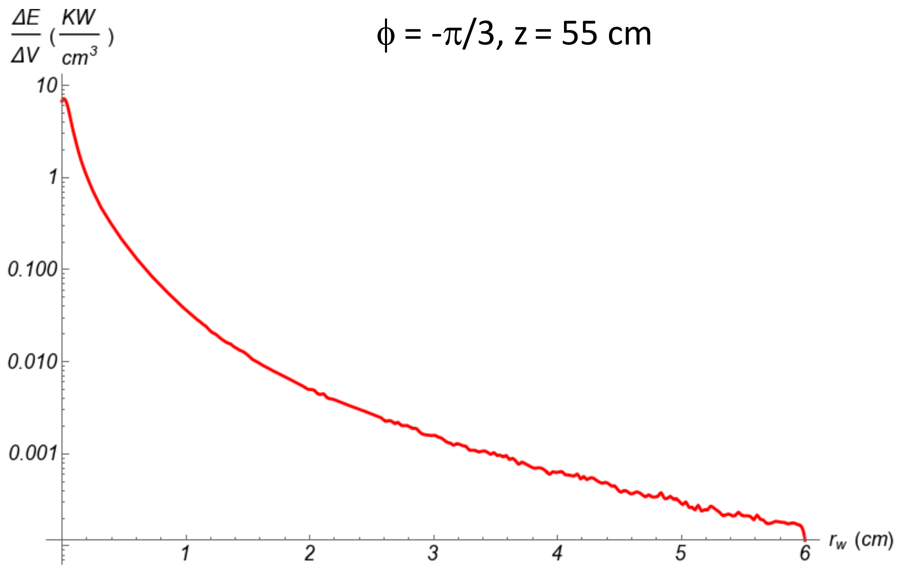


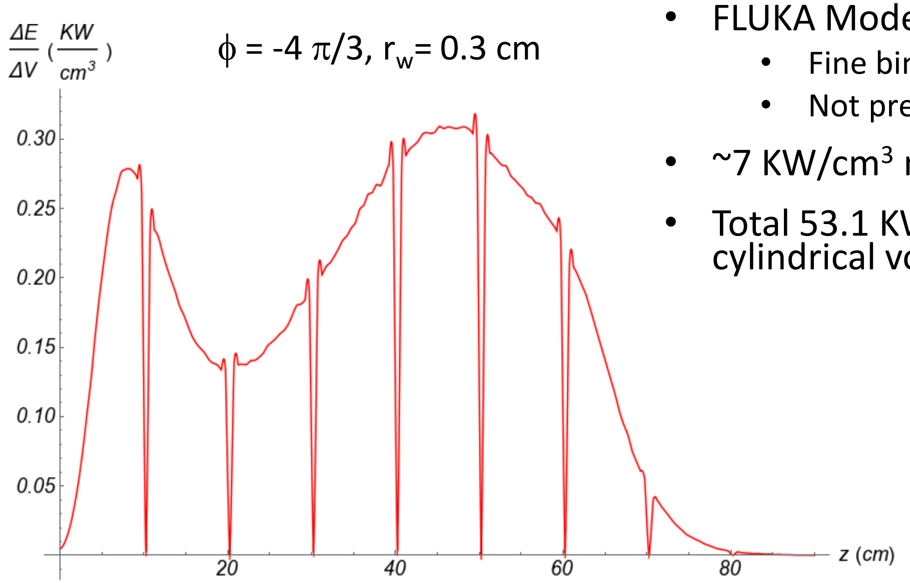
Triangular beam channel for 0<z<54cm



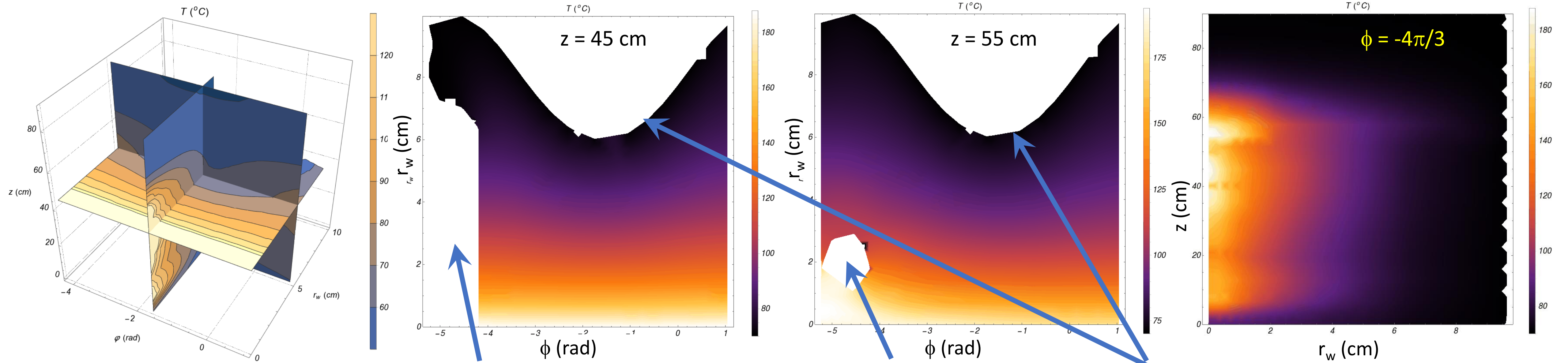
Circular beam channel for 54<z<94cm







- FLUKA Model KLCPS55 from December 2022.
  - Fine binning of the copper insert.
  - Not presented, but advertised via e-mail
- ~7 KW/cm^3 maximum power deposition density.
- Total 53.1 KW power deposited in π*6^{2}x94 cm^3 cylindrical volume of copper.



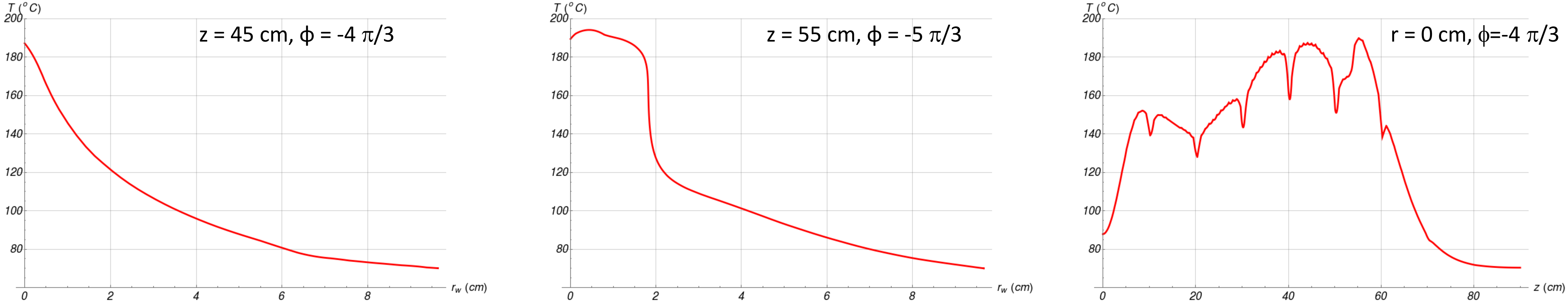
Triangular beam channel for 0<z<54cm

Beam channel for 54cm<z<90cm

R=8cm boundary with water cooling shifted by 2cm w.r.t. the wedge corner

- There are two hot spots at z=45cm and z=55cm.
- Maximum temperature is about $T_{max} \approx 195\ ^0C$.
  - Pavel estimated $\Delta T \approx 105\ ^0C$ for the temperature rise. With water boundary temperature $T_0 = 70\ ^0C$, he would get $T_{max} \approx 175^0C$.
- Although the power deposition density is high, the temperature at the hot spots is still well under 300 ^0C

- 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, $T_{max} \approx 205\ ^0C$ (not sure what T_{water} was then) than to what he found in February $T_{max} \approx 250\ ^0C$ from exactly the same file but using $T_{water} \approx 40\ ^0C$.
  - 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***.
  - 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 $T_{max} \approx 195\ ^0C$ approximately matches what Pavel estimated assuming cylindrically symmetric model.
  - It would be interesting to see if ***ANSYS*** solution has $T_{max} \approx 250\ ^0C$ 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 $T_{max} \approx 300\ ^0C$ 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 .