Thermal Analysis of BIC(Barrel Imaging Calorimeter)

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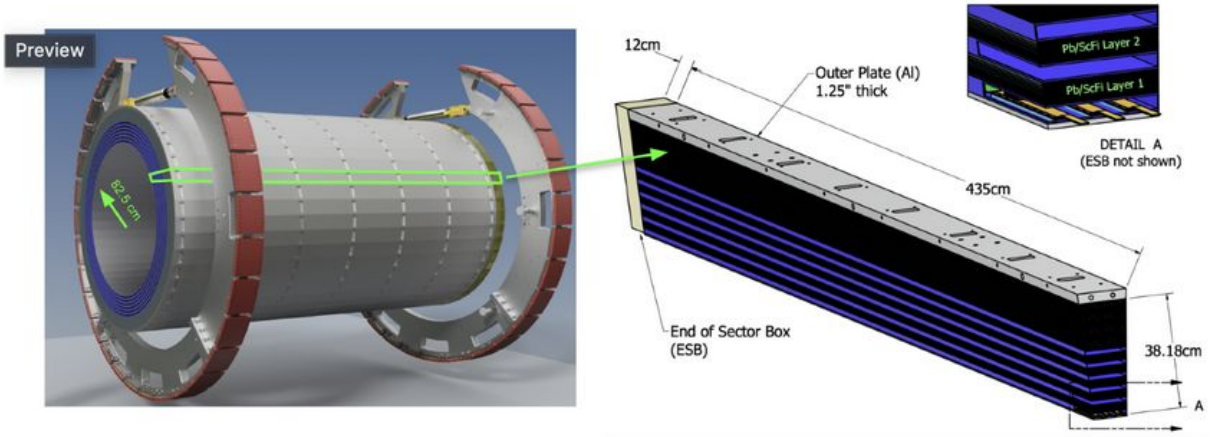
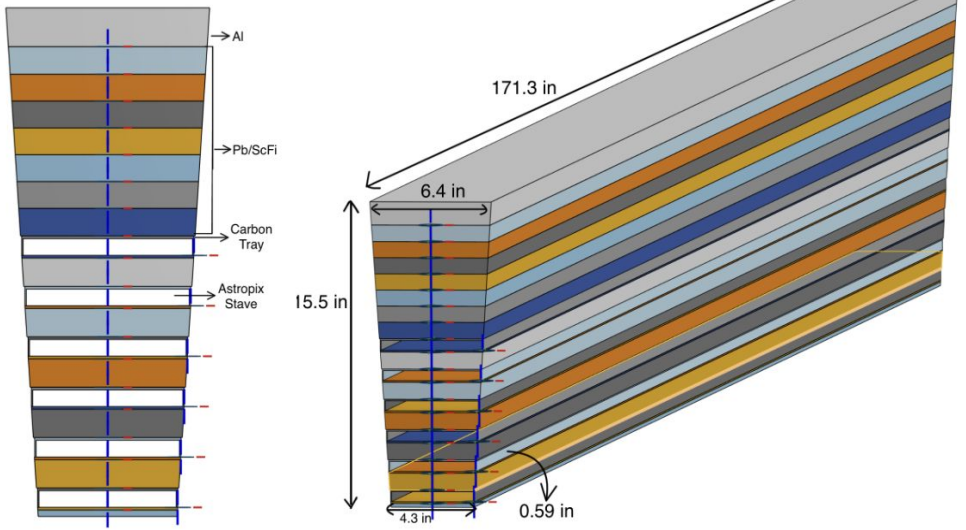
Barrel Imaging Calorimeter

Barrel Imaging Calorimeter (BIC) with 48 sectors: each sector features interleaved Pb/ScFi layers and AstroPix trays for precision tracking and energy measurement. PC: PreTDR.

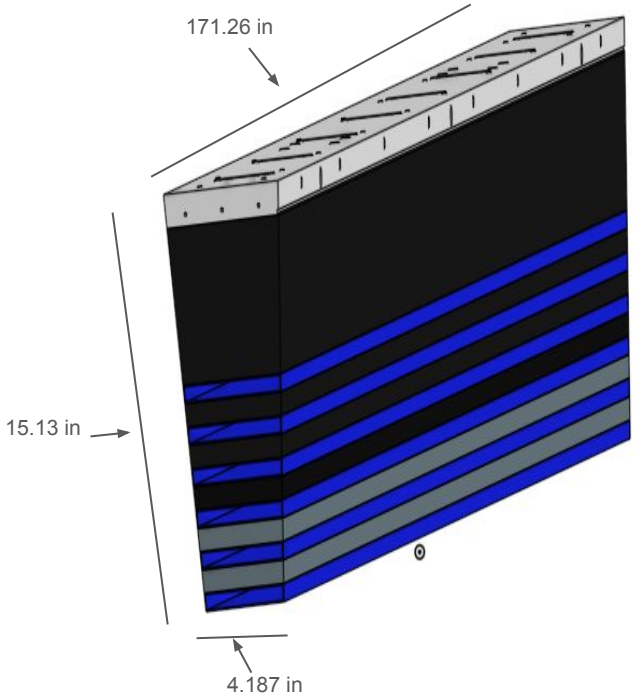


Barrel Imaging Calorimeter (BIC) with 48 sectors: each sector features interleaved Pb/ScFi layers and AstroPix trays for precision tracking and energy measurement. PC: PreTDR.

BIC CAD Render(New vs Old Version)

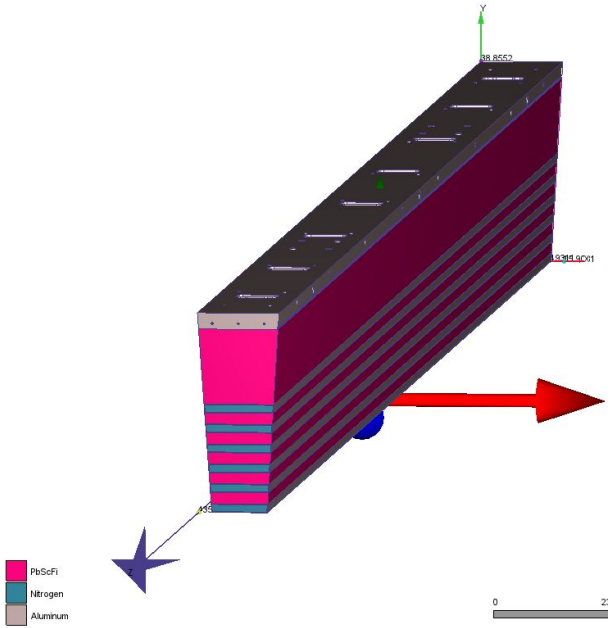


Old Version

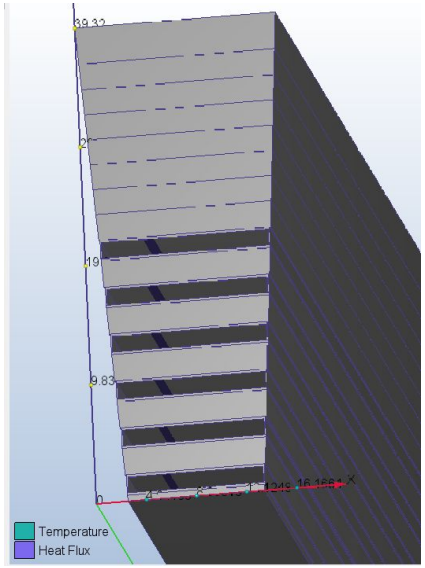


New Version

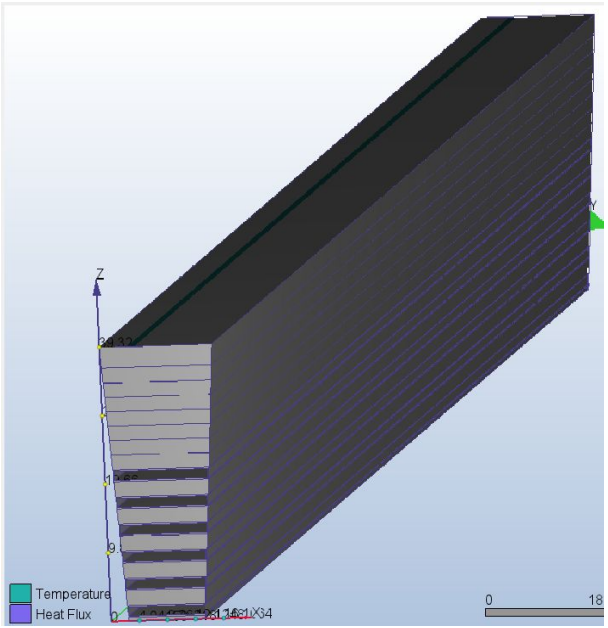
Material Distribution and Boundary Conditions



Material Distribution

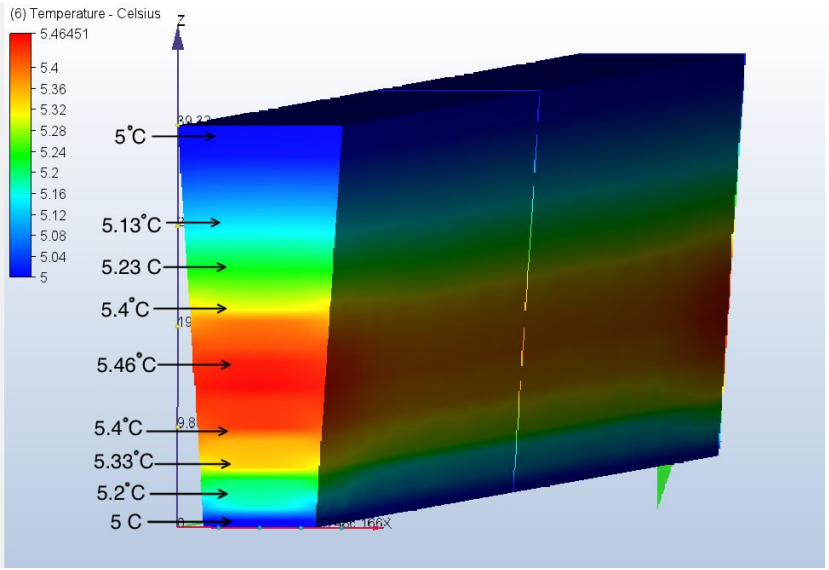


Boundary condition: Heat flux as 0.002 W/cm² on the top of the carbon tray.

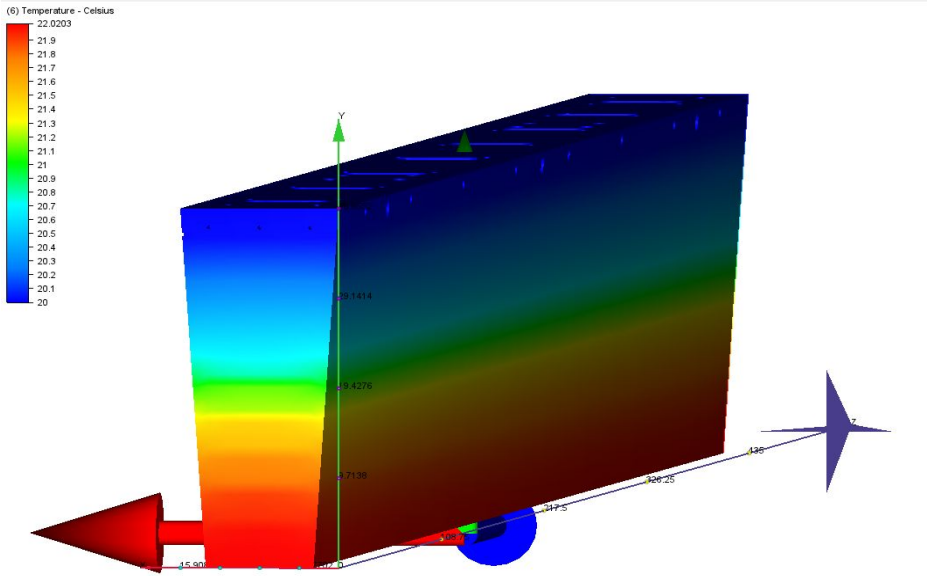


Boundary condition: Temperature as 20°C

Simulation Results (1 Sector)

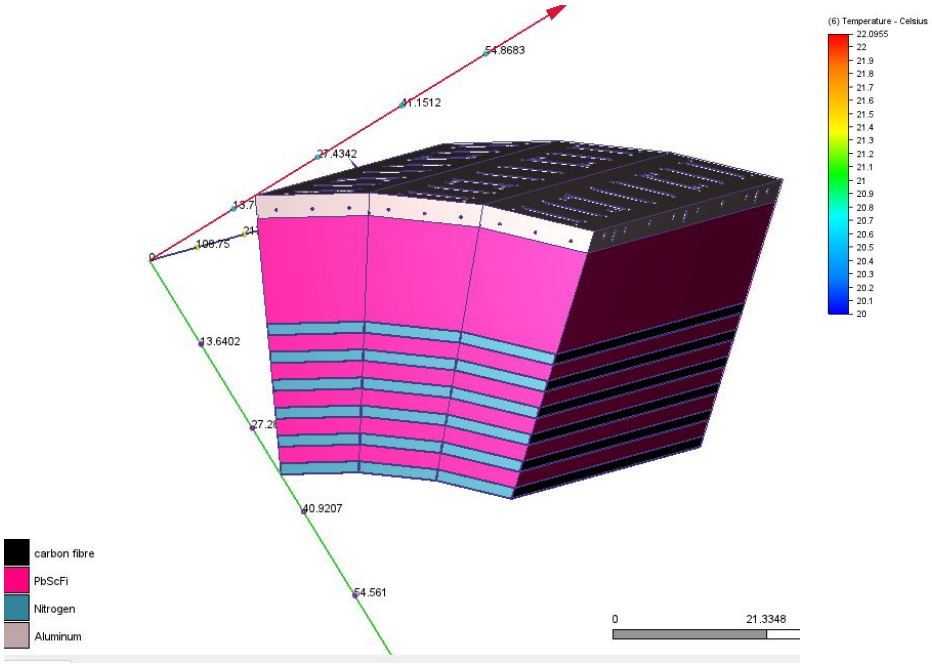


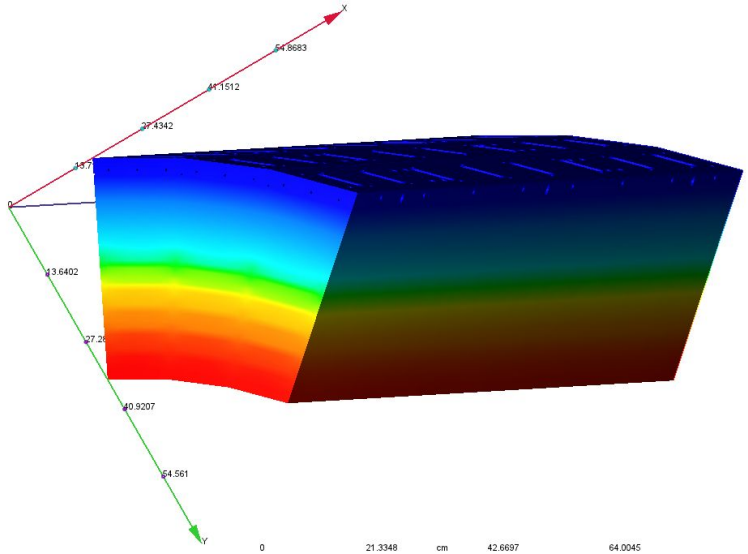
Old simulation results



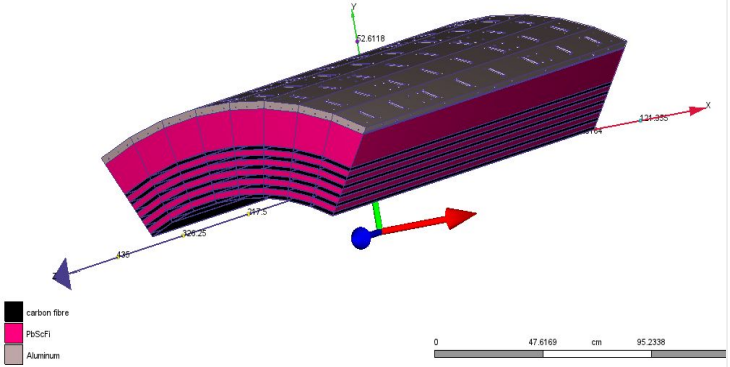
New simulation results

Simulation Results (3 Sector, carbon trays's conductivity: ½ of Aluminum)

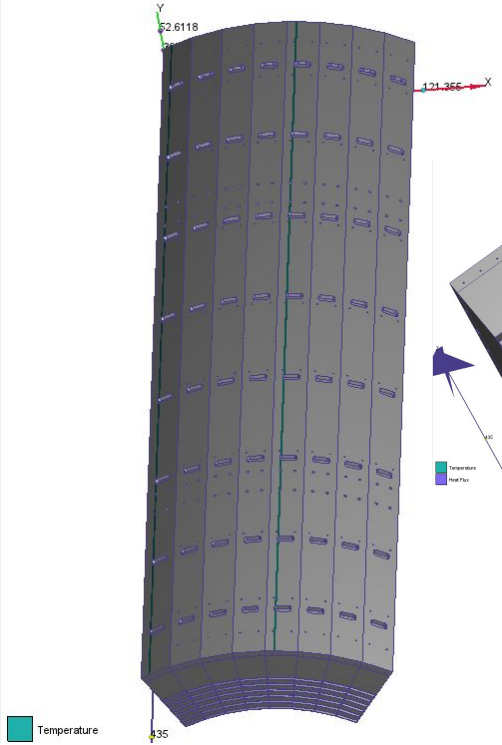




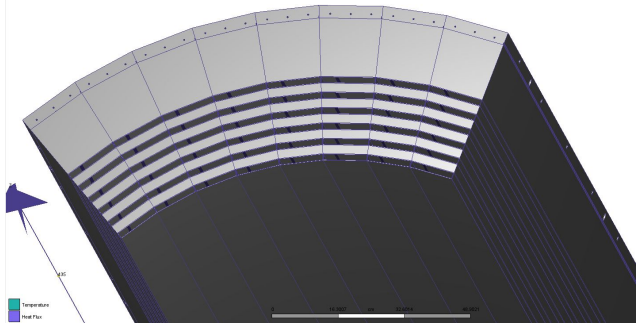
Material Dstribution and Boundary Conditions for 8 Sectors



Material distribution

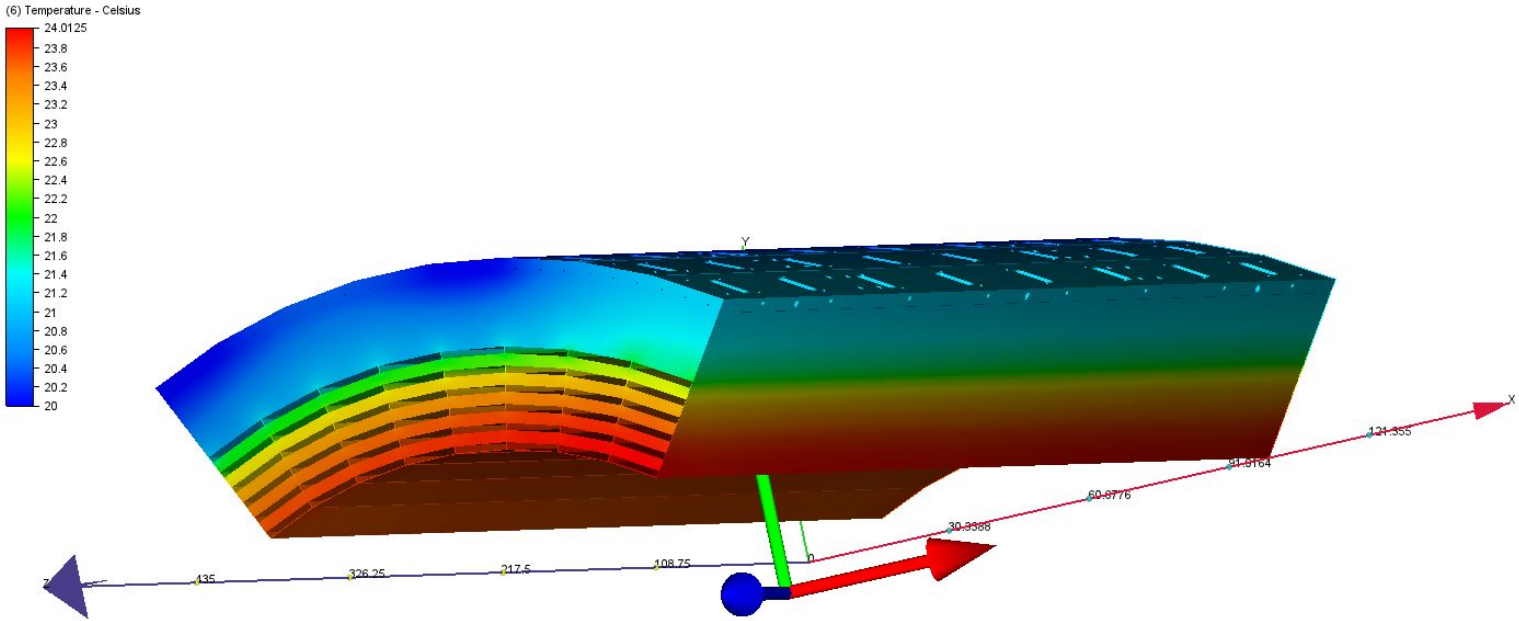


Temperature: 20°C

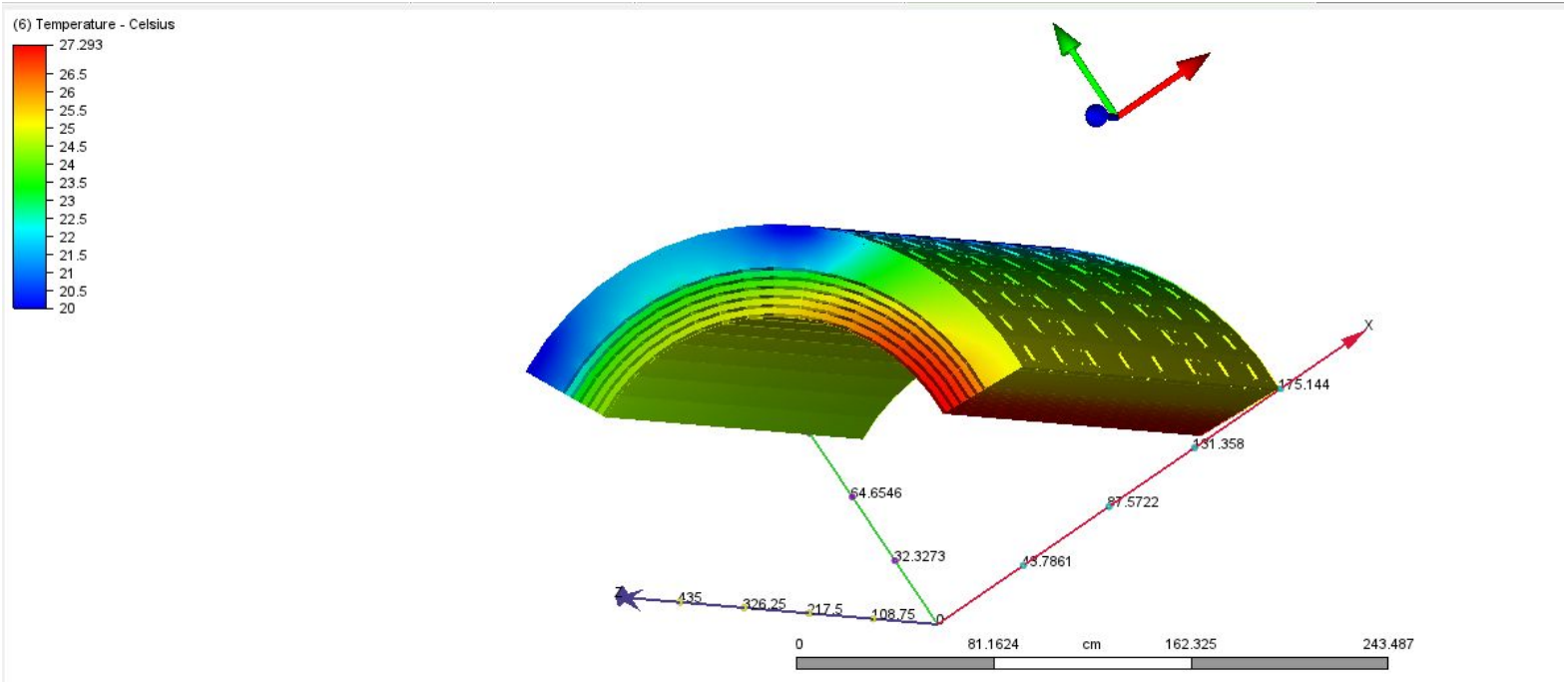


Heat flux: 0.002 W/cm² on the top of the carbon tray

Simulation Results (8 Sector)



Simulation Results (16 Sector)



Key takeaways

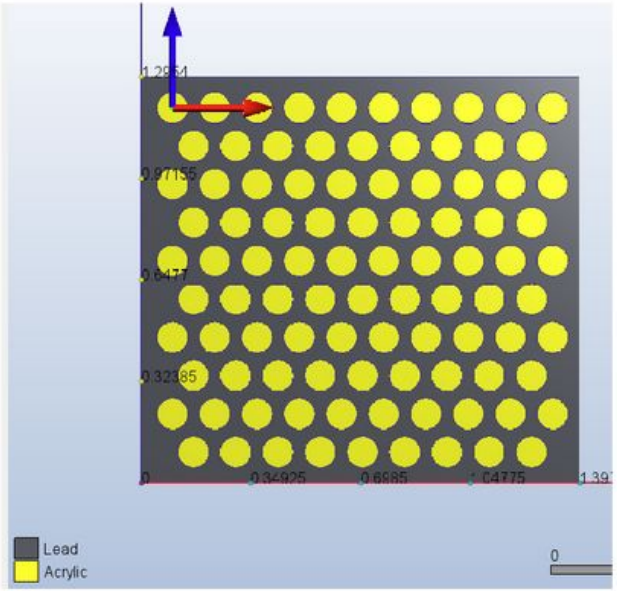
Number of Sectors	Boundary Condition	Max. Temp.
1 sector	20°C on outer aluminum stave	22.023°C (with nitrogen in the carbon tray gaps) 23.04 (without nitrogen in the carbon tray gaps)
3 sectors	20°C on all outer aluminum stave	22.09°C (with nitrogen in the carbon tray gaps)
8 sectors	20°C on every fourth outer aluminum stave	24.02°C
16 sectors	20°C on every eighth outer aluminum stave	27.38°C

- The sector temperatures remain within manageable limits, even under worst-case simulation scenarios.
- The studies with partial geometries(1,3,8 and 16) sectors and the boundary condition studies on every 4th and 8th sector indicate that the thermal behavior of the full detector can be reliably predicted by identifying and generalizing the hot spots from these cases.
- Question: We require detailed information about the mechanical support structure of the BIC sectors to design more efficient and targeted cooling channels.

Backup Slides

Pb/Scintillating Fibre's thermal conductivity in different directions

The property that tells how well the heat is transferred through a material due to a temperature gradient is called the thermal conductivity. It can be described by Fourier's law in 1-D as: **q = −k (dT/dx)**.

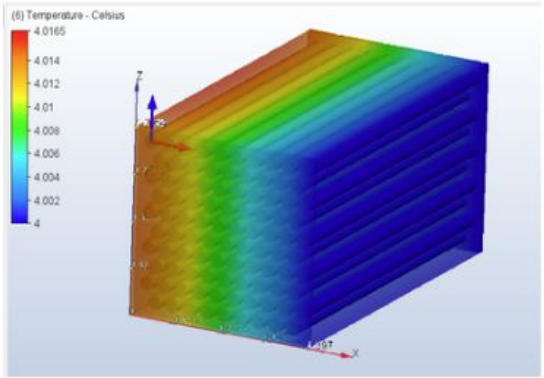


CAD model for the Pb scintillating fibres (glue layers ignored, probably similar k as acrylic).

ScFi Radial (y) separation: **1.22 mm**

ScFi Azimuthal (x) separation:**1.35 mm**

Thermal conductivities in x,y,z direction



Thermal conductivity (k) (x-axis): **15.7 W/(m-K)**.

Boundary conditions: Heat flux: **0.002 W/cm²**.
Temperature: **4°C**.

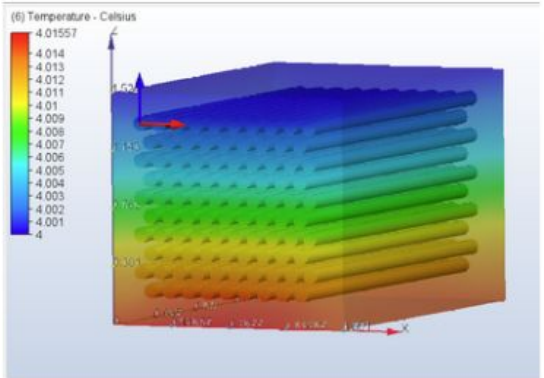
Length along x axis = 1.3 cm

k_{Pb} = 35 W/(m-K)

k_{Ac} = 0.19 W/(m-K)

k_x = **0.44** k_{Pb}

k_x = **82.6** k_{Ac}



Thermal conductivity (k) (y-axis): **18.4 W/(m-K)**.

Boundary conditions: Heat flux: **0.002 W/cm²**.
Temperature: **4°C**.

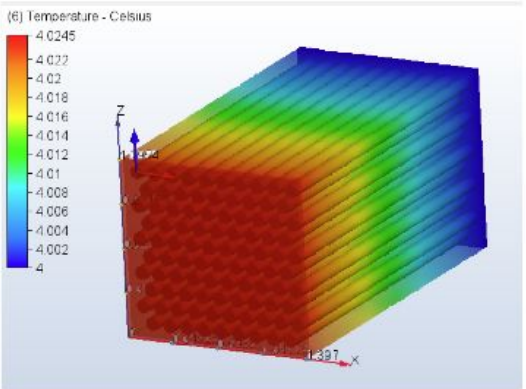
Length along y axis = 1.4 cm

k_{Pb} = 35 W/(m-K)

k_{Ac} = 0.19 W/(m-K)

k_y = **0.53** k_{Pb}

k_y = **96.8** k_{Ac}



Thermal conductivity (k) (z-axis): **21.55 W/(m-K)**.

Boundary conditions: Heat flux: **0.002 W/cm²**.
Temperature: **4°C**.

Length along z axis = 2.6 cm

k_{Pb} = 35 W/(m-K)

k_{Ac} = 0.19 W/(m-K)

k_z = **0.62** k_{Pb}

k_z = **113.4** k_{Ac}