NPS CFD Thermal Analysis of Detector Volume

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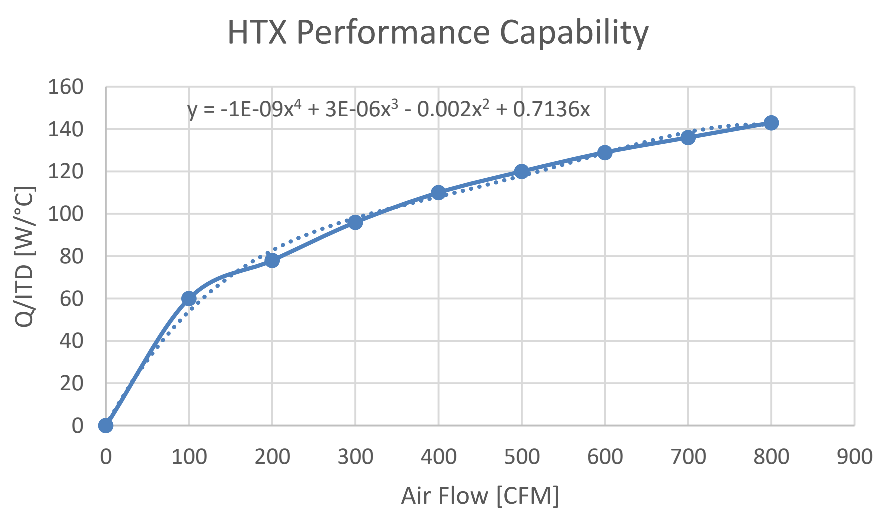
Thermal Parameters

- Calculated thermal parameters for model based information provided by NPS documentation and manufacturers' specifications
  - Heat generated in crystal block array
  - Inlet temperature difference (ITD)
  - Fan flow rate required
  - Heat exchanger performance capability (Q/ITD)
    - Found polynomial based on curves provided in specifications
    - Polynomial line used in Fluent simulation

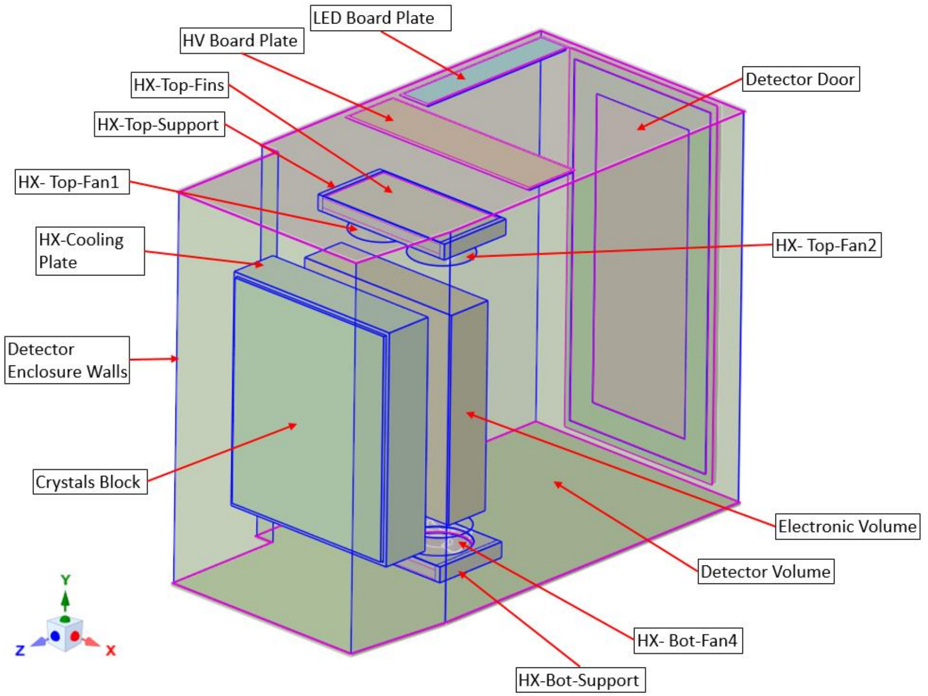
Power per Crystal Block	0.326 W
Total Power Dissipated in Crystal Block Array	341.65 W
Heat Generation Rate	3426.76 W/m3
HX Liquid Inlet Temp	10 °C
HX Max Temp Air Inlet	25 °C
HX Liquid Flow	1 gal/min
HX Air Pressure Drop	24.9 Pascals
HX Fan Flow Rate	500 CFM
HX Fan Angular Vel	1650 RPM
HX Inertial Resistance	386 [m-1]
Inlet Temp Difference (ITD)	15 °C
Performance Capability (Q/IDT)	117 W/°C



Heat exchanger performance capability curve

Ansys Fluid Setup

- Changes to previous 3D model
  - Added three fans—one for top heat exchanger and two for bottom heat exchanger
  - Added bottom heat exchanger fin area and supports
  - Changed crystal block domain from solid to fluid to allow porosity configuration
- Meshed model with *Ansys Fluent with Meshing* to improve meshing on surfaces and volumes
  - Defined fluid, solid, and void domains for model
  - Added local sizing to improve surface mesh
  - Added boundary layers to improve volume mesh



NPS Detector simplified model used for thermal simulation in Ansys Fluent

Ansys Fluid Setup

- Set cell zone conditions
  - Angular velocity magnitude and direction of heat exchanger fans
  - Heat source for the crystal block array
  - Fixed temperatures for heat exchanger plates and heat exchanger fin area
  - Porous volumes to allow flow through fins and between individual crystal blocks.
- Set boundary conditions
  - Ambient temperature
  - Convection heat transfer applied to the detector enclosure walls

Ansys Fluid Setup

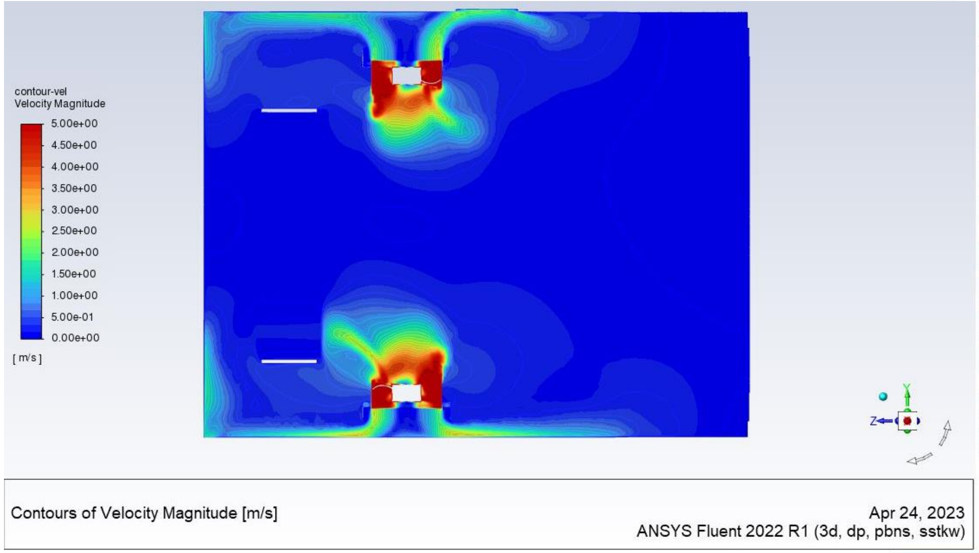
- Generated Expression Report Definitions and Report Definitions to monitor variables
  - For example, performance capability reports for bottom and top heat exchangers; plotted separately and then compared
- Generated contour and pathline plots to visualize the results accurately

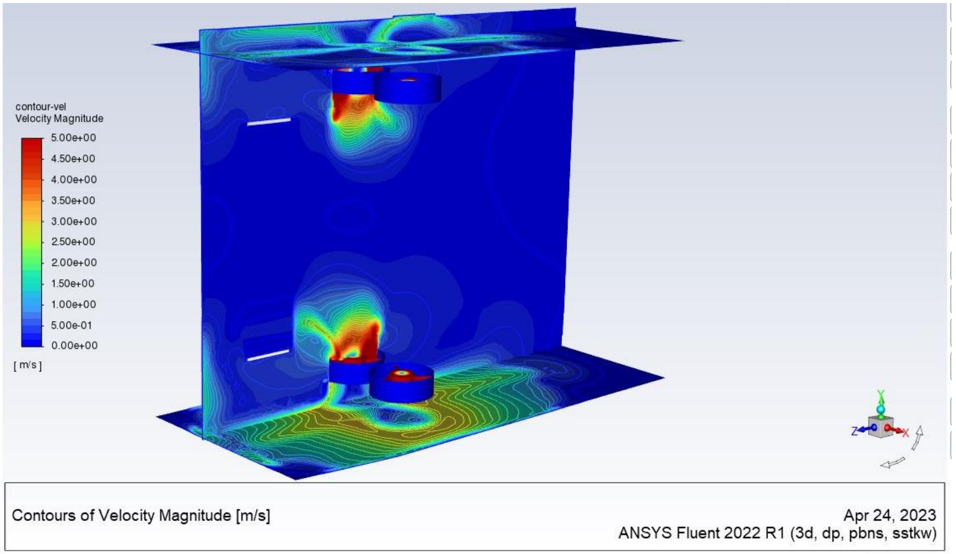
Solver	Fluid Flow Fluent , pressure-based , steady state
Model	k-omega, Shear Stress Transport
Heat Transfer	Convection
Precision	Double
Simulation Iterations	2500
Processors	6
Estimated Time	~13 hrs

Simulation Setup

Results – Air Flow Velocity

Velocity contour plot indicates expected magnitude and direction; maximum velocity is 5 m/s (red areas)

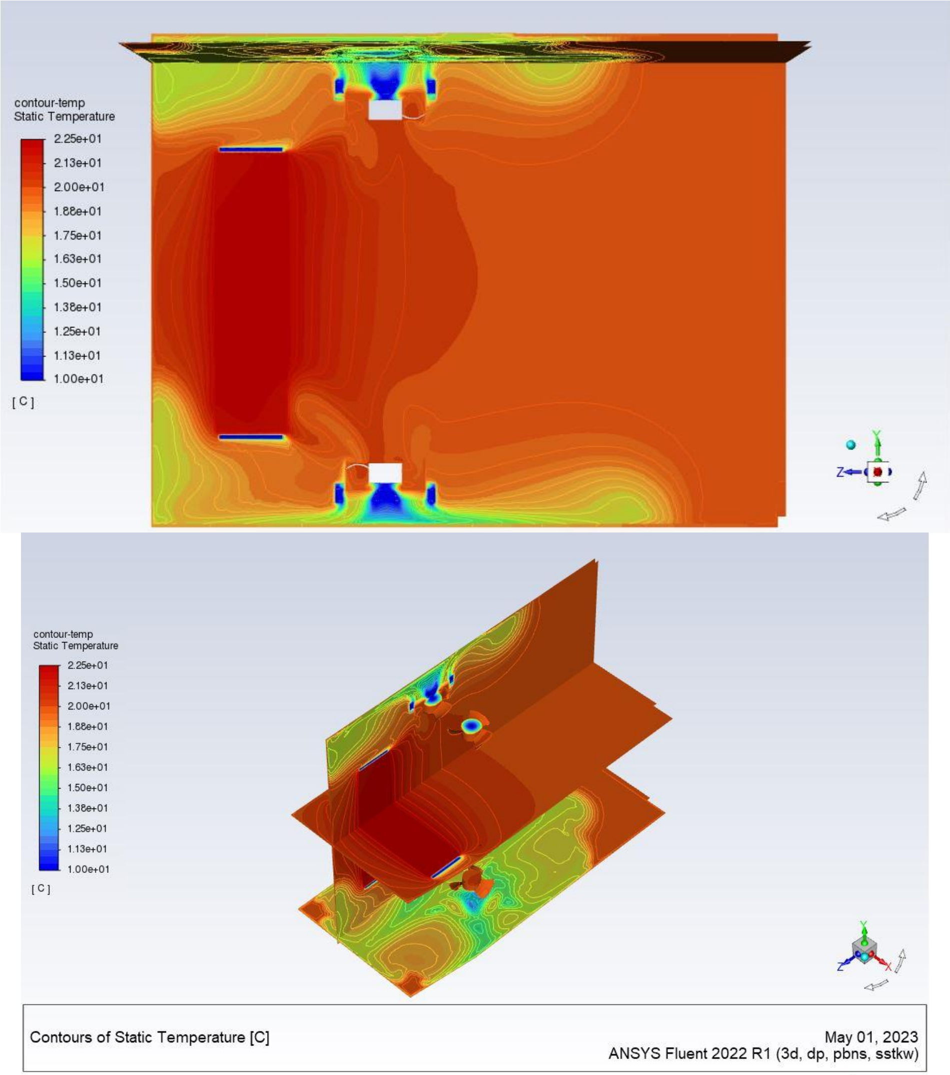




Velocity contour plots – Right view (top) and isometric view (bottom)

Results – Temperature

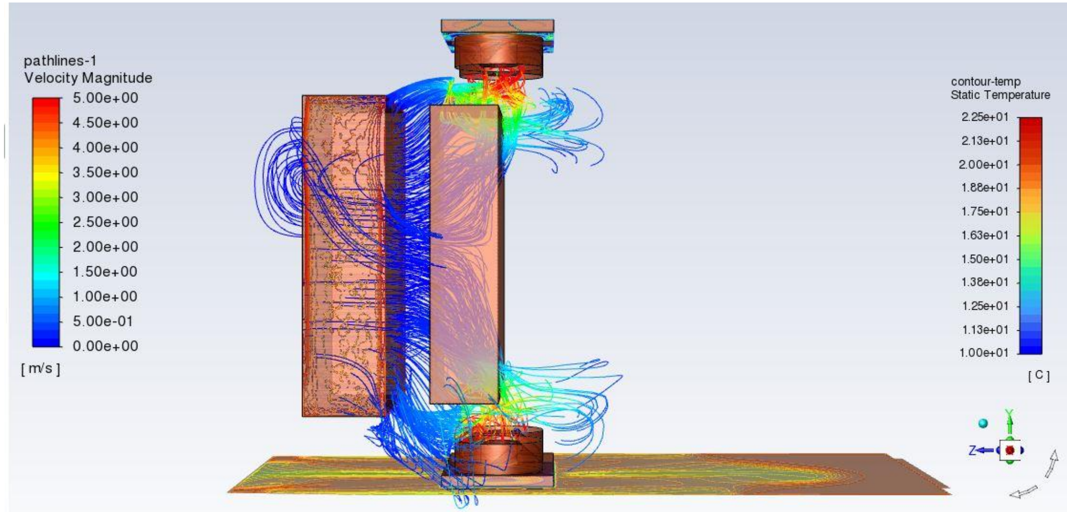
Temperature contour plot shows maximum temperature for crystal block array of 22.92°C



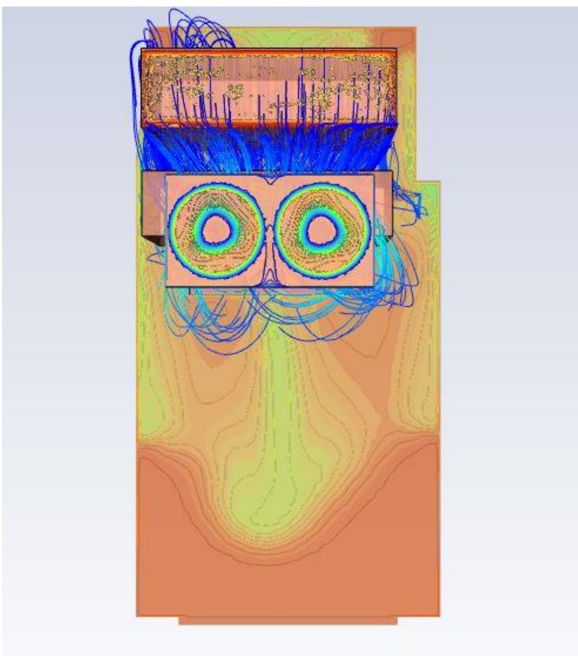
Temperature contour plots – Right view (top) and isometric view (bottom)

Results – Velocity and Temperature Pathlines

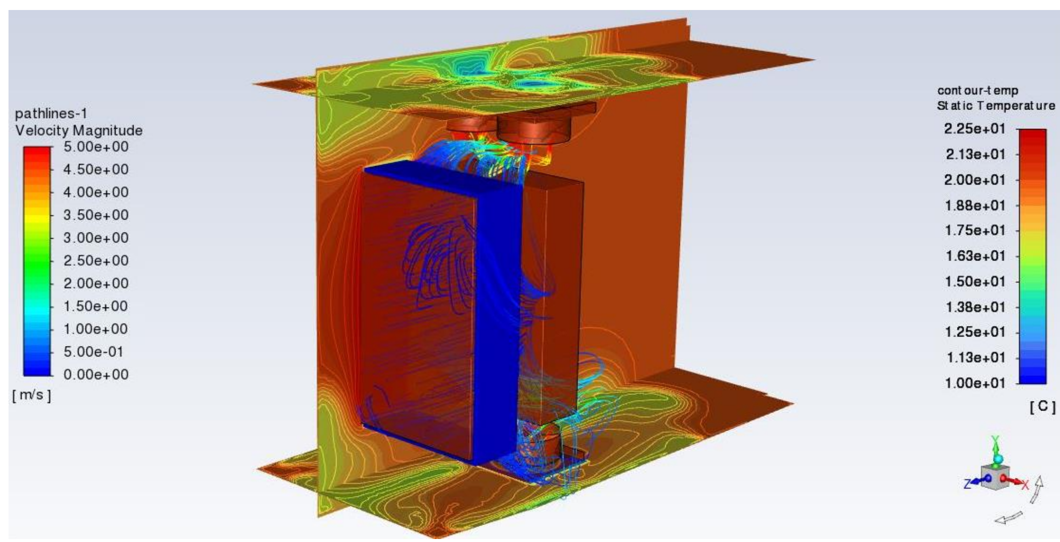
Pathlines and scene-pathlines show that flow passes through the porous zones



Right view - Velocity Pathline scene and XZ plane temperature contour plot

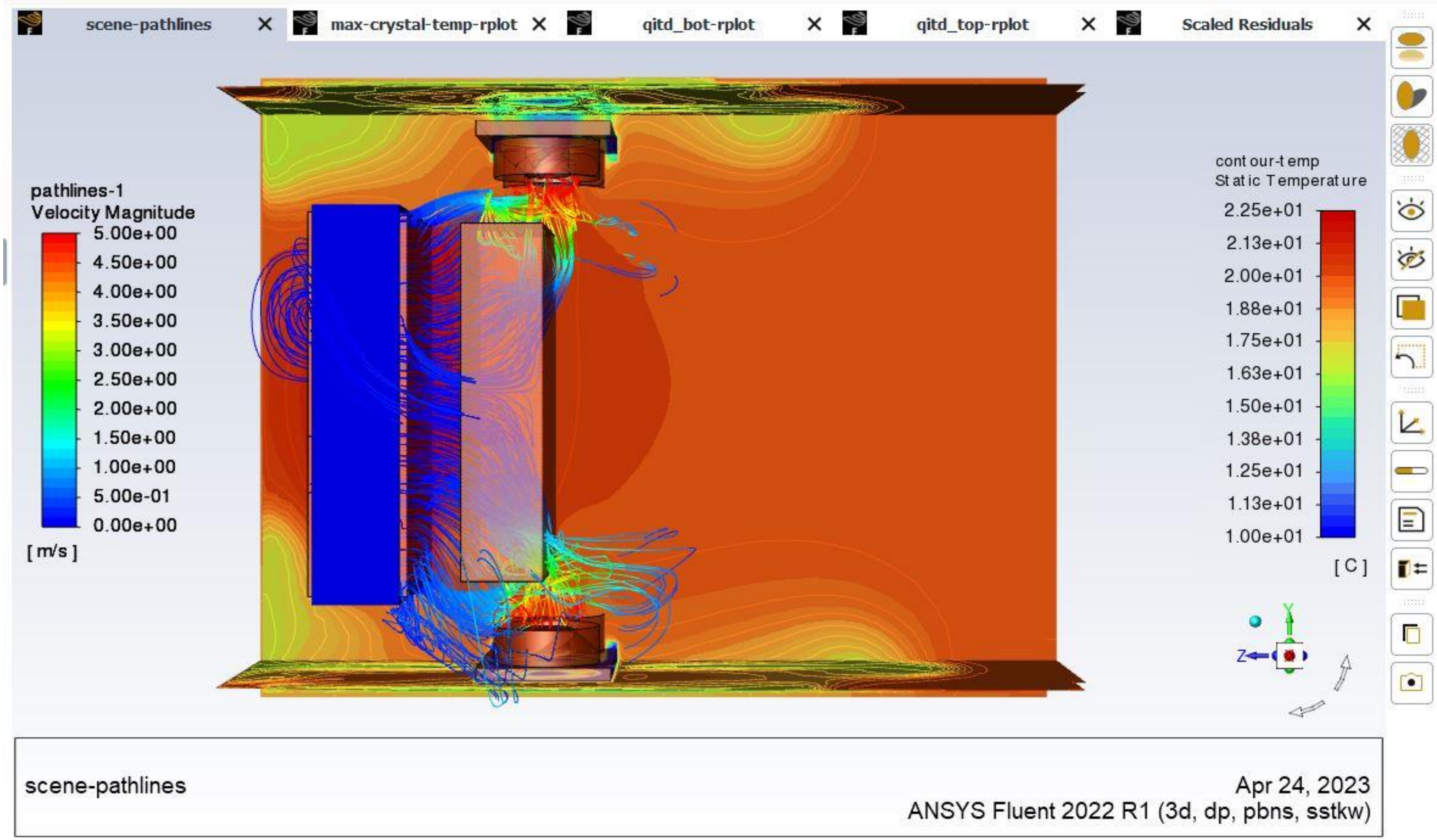


Top view- Velocity Pathline scene and XZ plane temperature contour plot

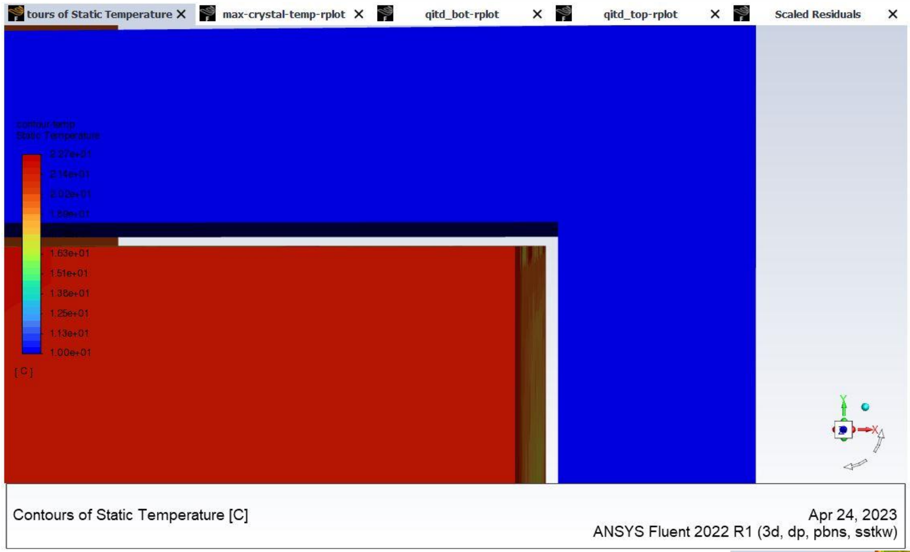


Isometric view - Velocity Pathline scene and temperature contour plot

Results – Velocity and Temperature Pathlines

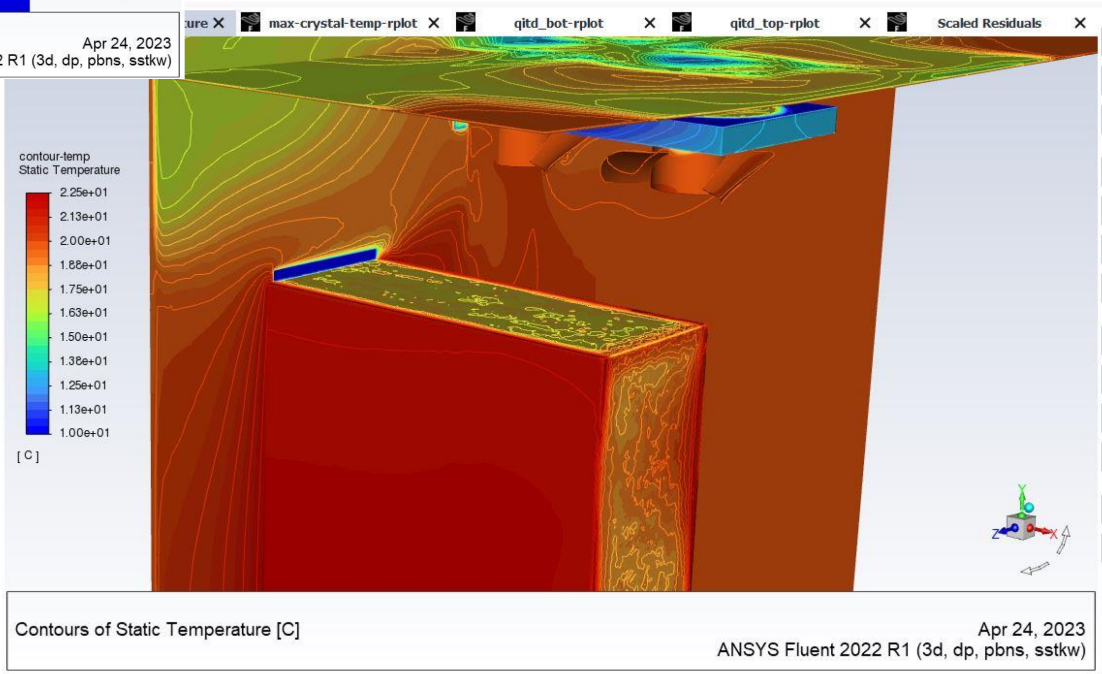


Results - Findings



Separation between HX plate and crystal block array volume

Air through separation cools outer surface of crystal block



Simulation Improvements

- Add plastic and lead tungstate materials for detector enclosure walls and crystal blocks, respectively
- Correct geometry to remove separation between heat exchanger cooling plate and crystal block
- Calculate inertial resistance for crystal block array or implement crystal array with individual blocks and dividers
- Add cell conditions for electronics volume
  - Need to calculate from power consumption electronics datasheet

Conclusions

- Completed the CFD thermal simulation for the initial setup
- Compared performance capability of heat exchangers simulation results with specifications; results are acceptable
- Results showed the expected velocity and direction of airflow and expected temperature of the crystal block array
- CFD thermal simulation will be improved

Thank You