Recent CFD-Related Activities at the High Flux Isotope Reactor of ORNL

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Invited Presentation to:

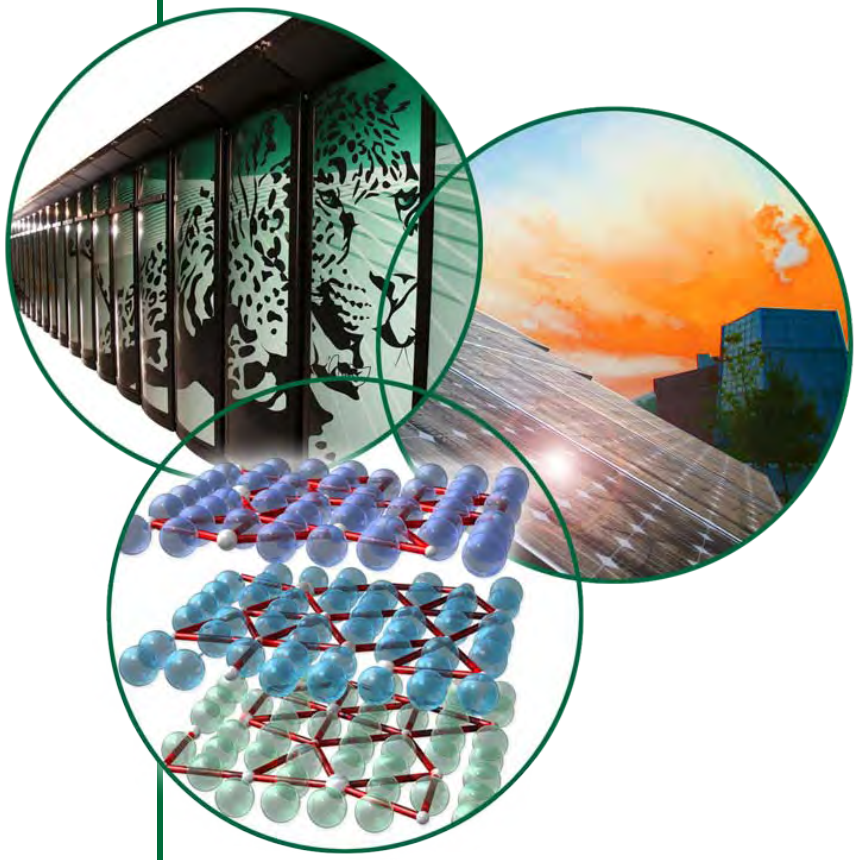
UT CFD Laboratory Colloquium,

University of Tennessee, Knoxville

In Honor of the Retirement of:

Professor A. J. Baker

May 18, 2010



U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY

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Outline of this Presentation

- a brief history of how I got here
- early CFD activities at HFIR
- cold-source (and other upgrades)CFD activities at HFIR
- LEU Conversion Project CFD activities

The Brief History

- MSNE-1979 - computer simulation was my interest
- excellent mentoring brought strong desire for a “better way”
- early 1980s, started pursuing PhD
- 1st class from AJ at OR campus by video tape ~ 1980 ?
- a couple of years later we met and started our journey ~ 1982-1983 ?

The Goal

- to learn how to do it right from the best
- show others in the nuclear industry how it should be done
- where better to do this then at a research reactor ?
- 1991 started at HFIR
- 1992 graduation
- ~ 2003 COMSOL becomes the tool of choice

Early CFD Activities at HFIR

- spent fuel re-racking project
- CFX used to analyze dropped element (Giles, Williams, Kirkpatrick)
- HEATING with user-supplied routines to establish the design basis (Williams)
- conservatively-developed code became the safety basis (Freels)

Upgrade of the HFIR: CFD Plays a Major Role

- permanent Be replacement (CFX)
- beam tube upgrades (CFX)
- cold source moderator vessel (CFX, PICMSS, FLUENT)
- cold source pressurizer (NASTRAN, HEATING, FEMLAB)
- cold source test heater (COMSOL)

HFIR Cold Source Moderator Vessel Analysis

Table 6: Summary of results for H2 Production mode

Variables		FLUENT UDF		CORRECTED UDF		CFX*	
		H2		H2		H2	
Inlet Temperature (K)		18		18		18	
Outlet Temperature (K)		22.1		22.1		22.2	
Heat Load (W)	Total	2302		2402		2781	
	Fluid / Solid	463.6	1838	541.6	1860	693	2087
Heat Load – MCNP (W)		2361					
Maximum Wall Surface Temperature (K)		44.0		42.3		42.5	
Pressure drop (Pa)		1887		1477		1880	

* report C-HFIR-2004-059/R0

HFIR Cold Source Moderator Vessel Analysis

Table 8: Hydrogen parameters in Standby mode

Variables		FLUENT UDF		CORRECTED UDF		CFX*
		H2		H2		H2
Inlet Temperature (K)		80		80		80
Outlet Temperature (K)		92.7		93.0		103.6
Heat Load (W)	Total	1873		1891		na
	Fluid / Solid	35	1838	31	1860	na
Maximum Wall Surface Temperature (K)		136.6		137.2		160
Pressure drop (Pa)		782		874		918

* report C-HFIR-2004-059/R0

HFIR Cold Source Moderator Vessel Analysis

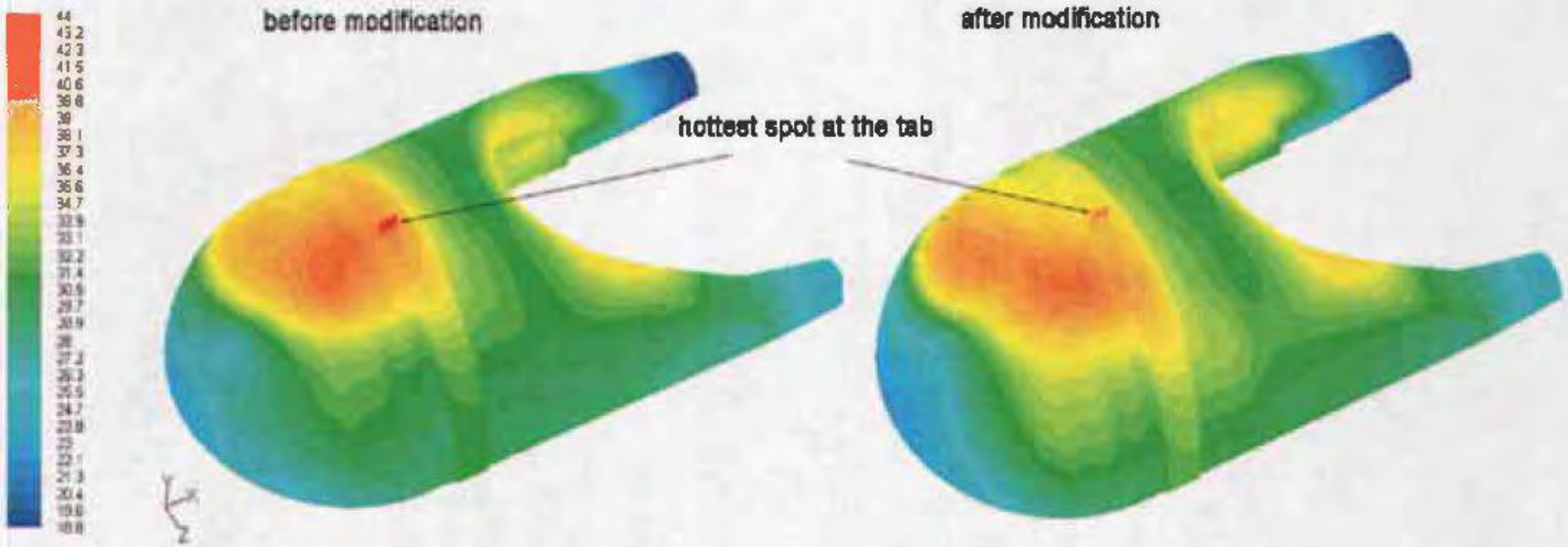
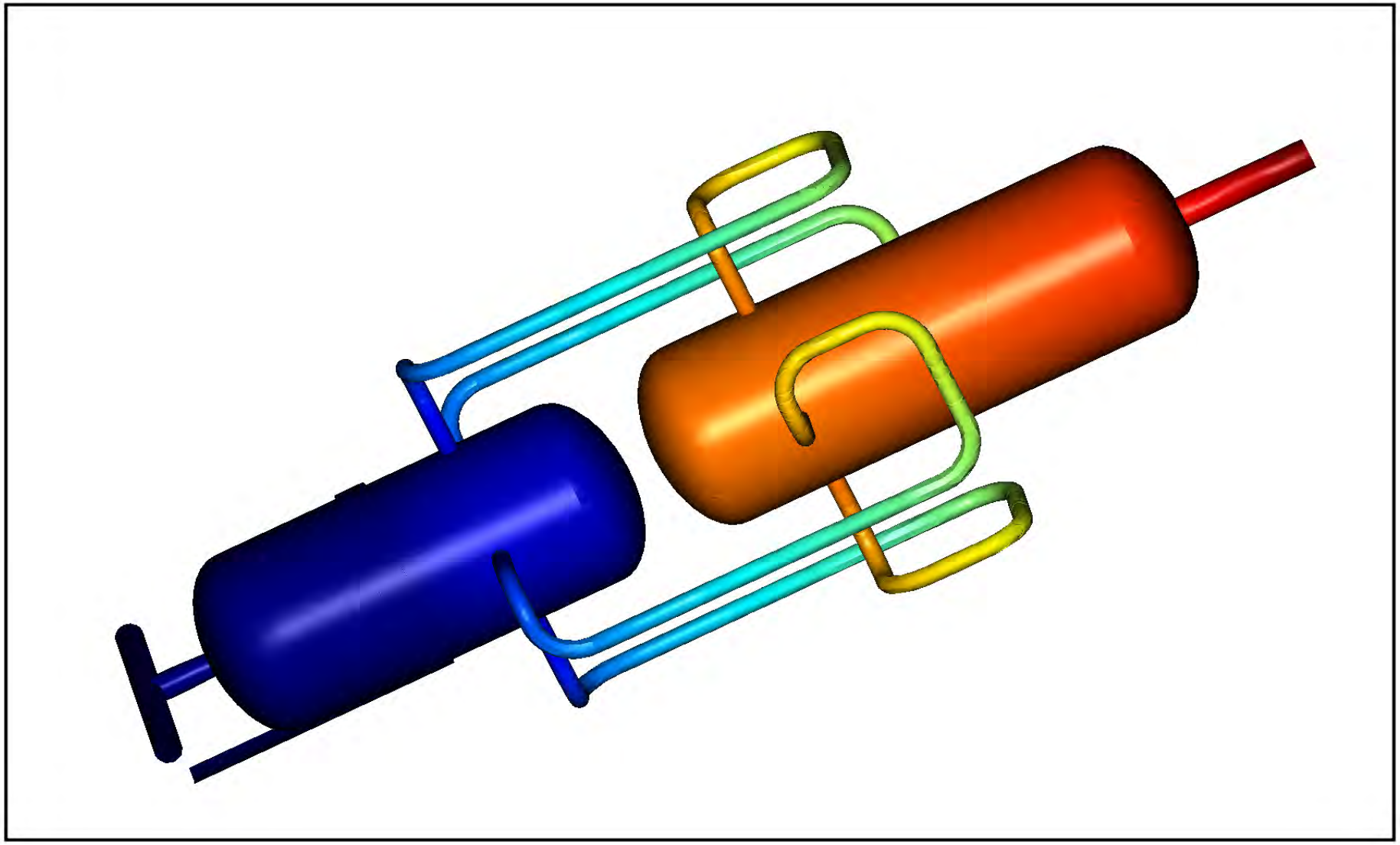


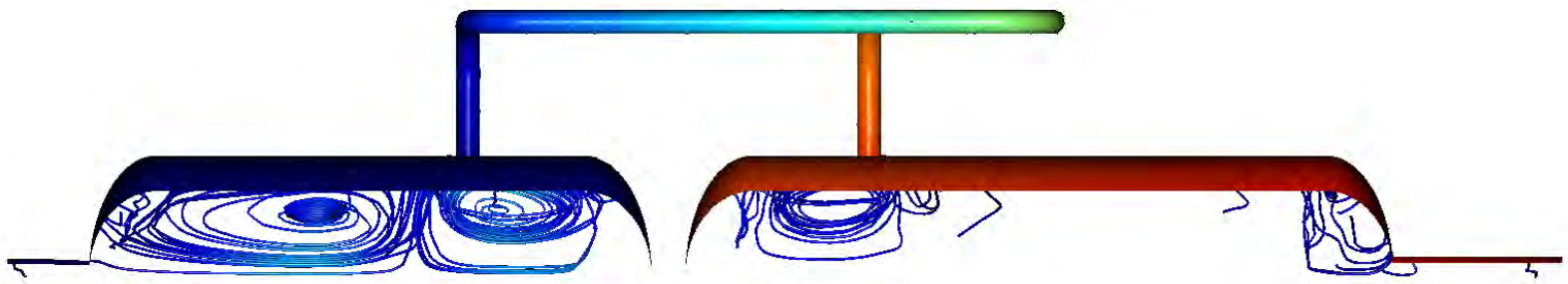
Figure 14: Hydrogen Production mode wall temperatures, K

Upgrade of the HFIR: CFD Plays a Major Role



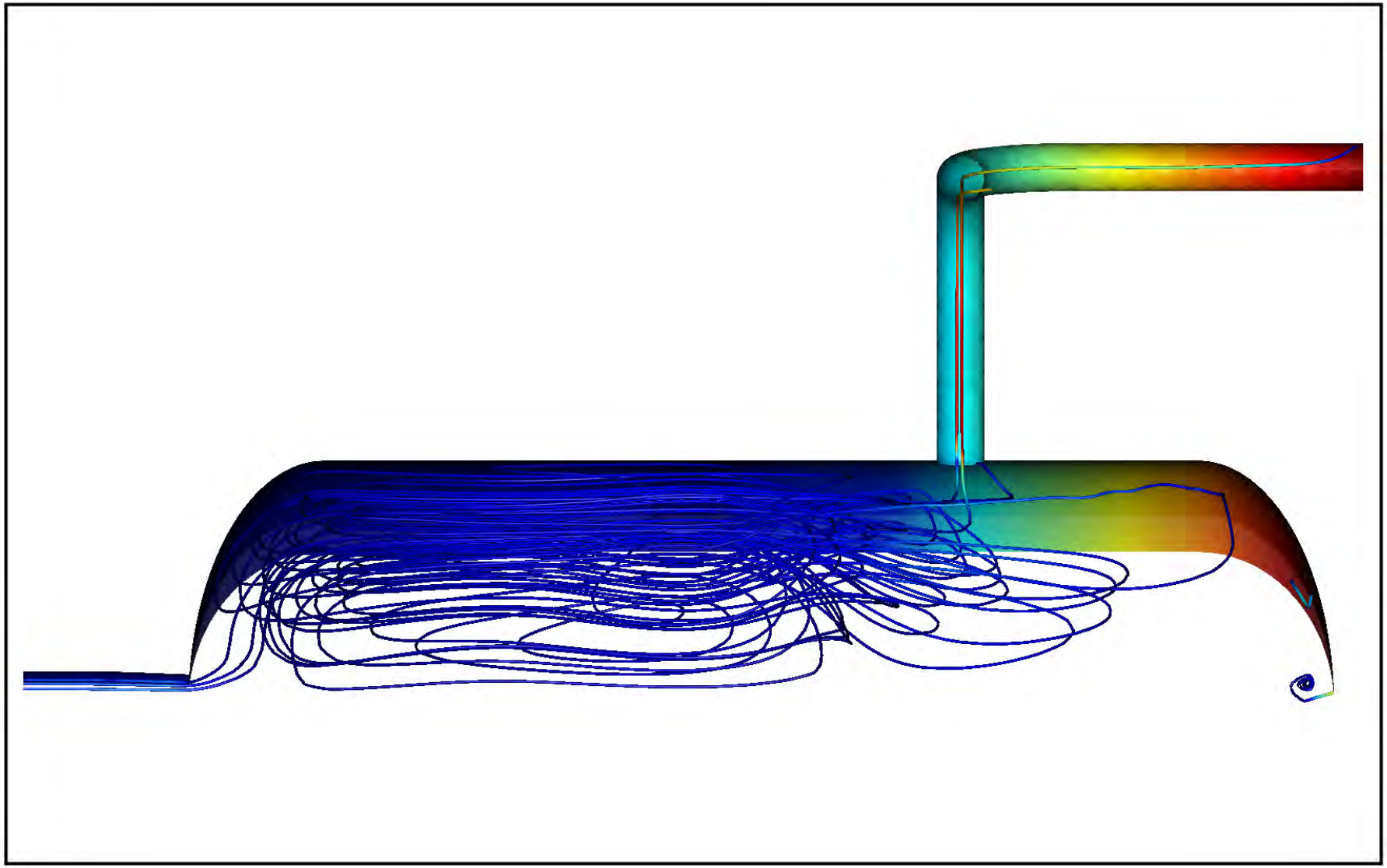
HFIR cold source pressurizer design calculations

Upgrade of the HFIR: CFD Plays a Major Role



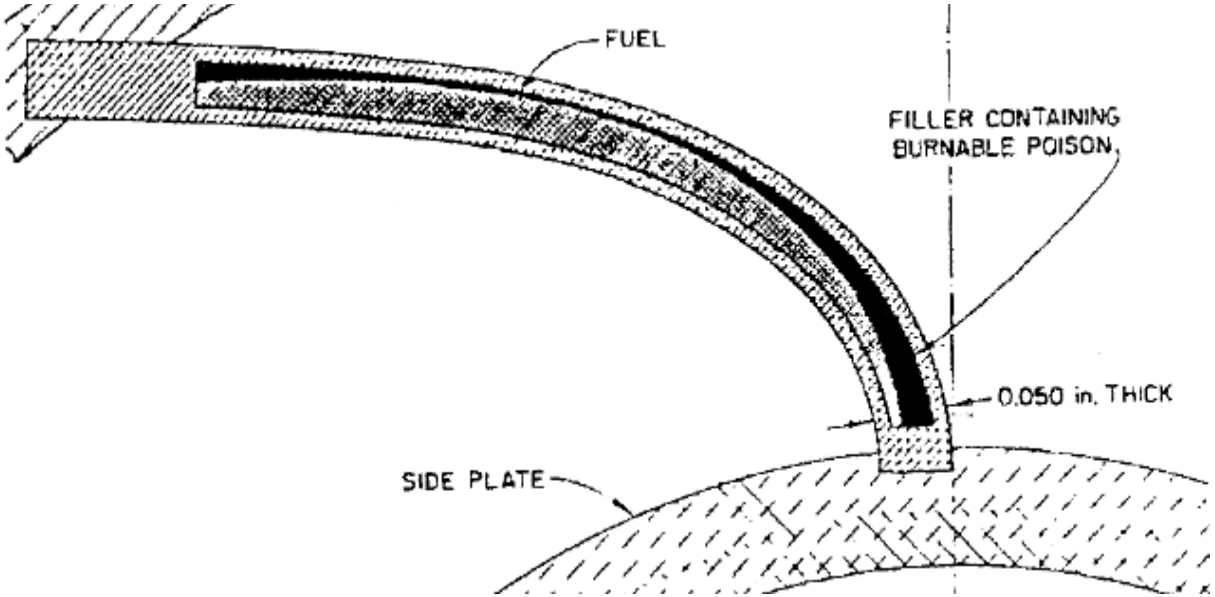
examine internal natural circulation flow at cryogenic temperature

Upgrade of the HFIR: CFD Plays a Major Role

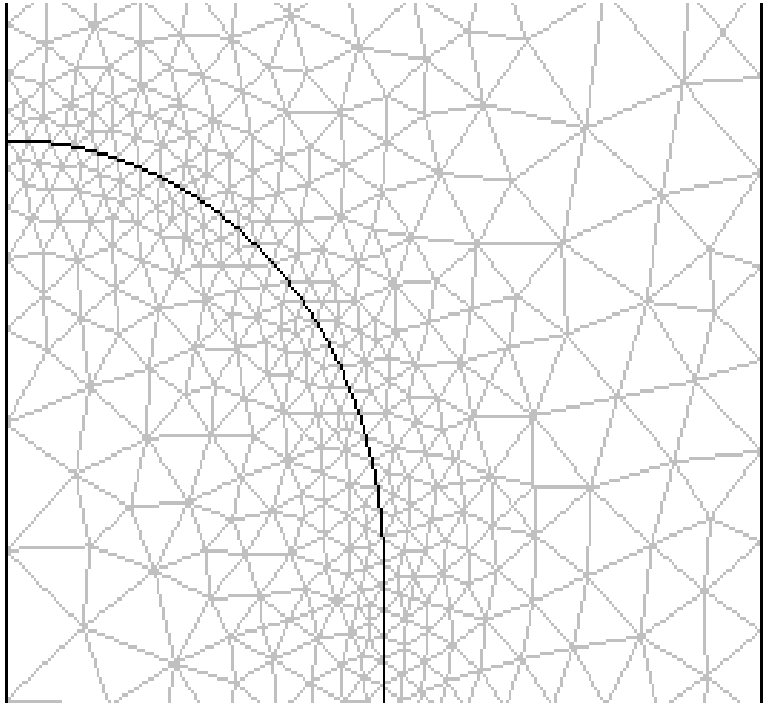


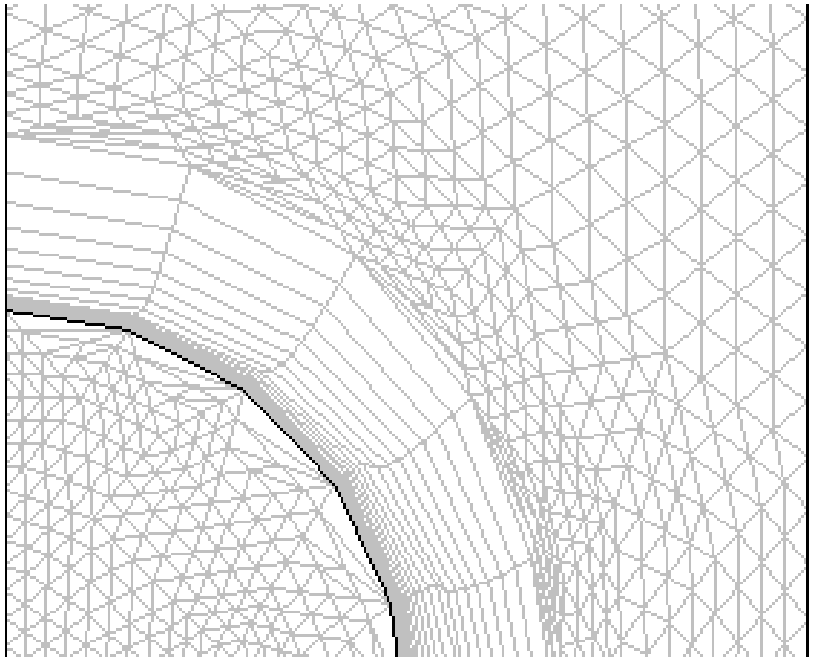
details !

Major Design Challenge for HFIR: Convert to LEU Fuel

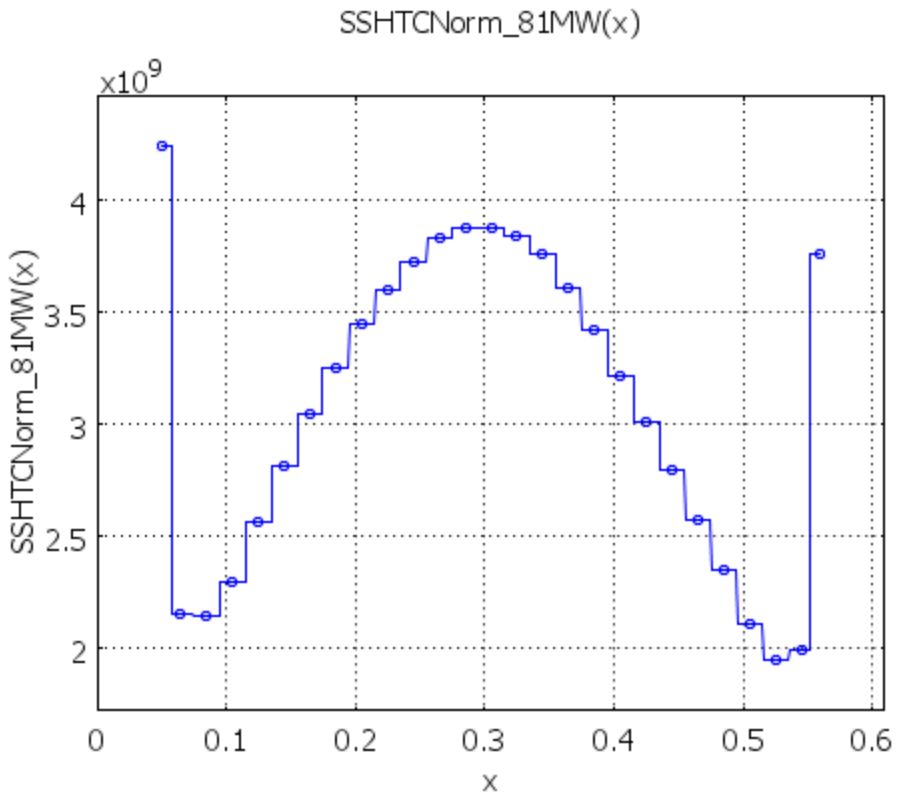


COMSOL Models in 2D Provide Guidance for 3D Decisions

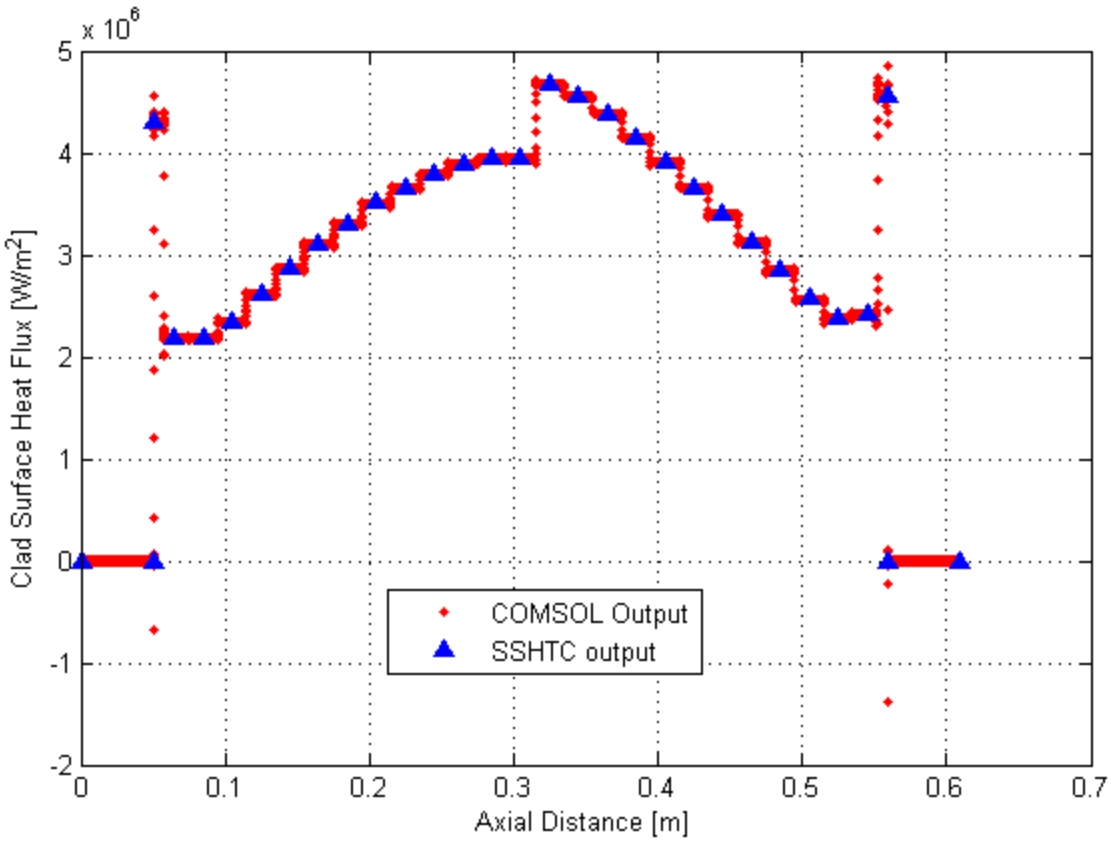




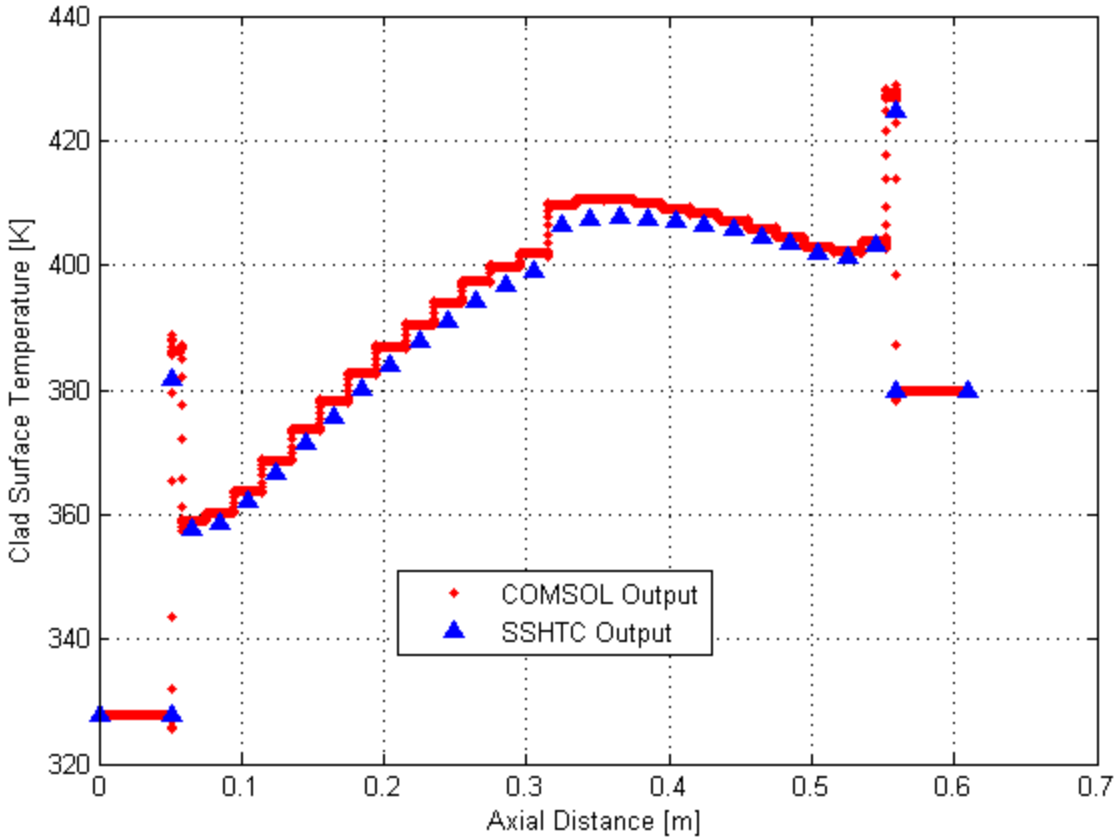
COMSOL Tools Provide Methods to Reproduce Current Safety Basis



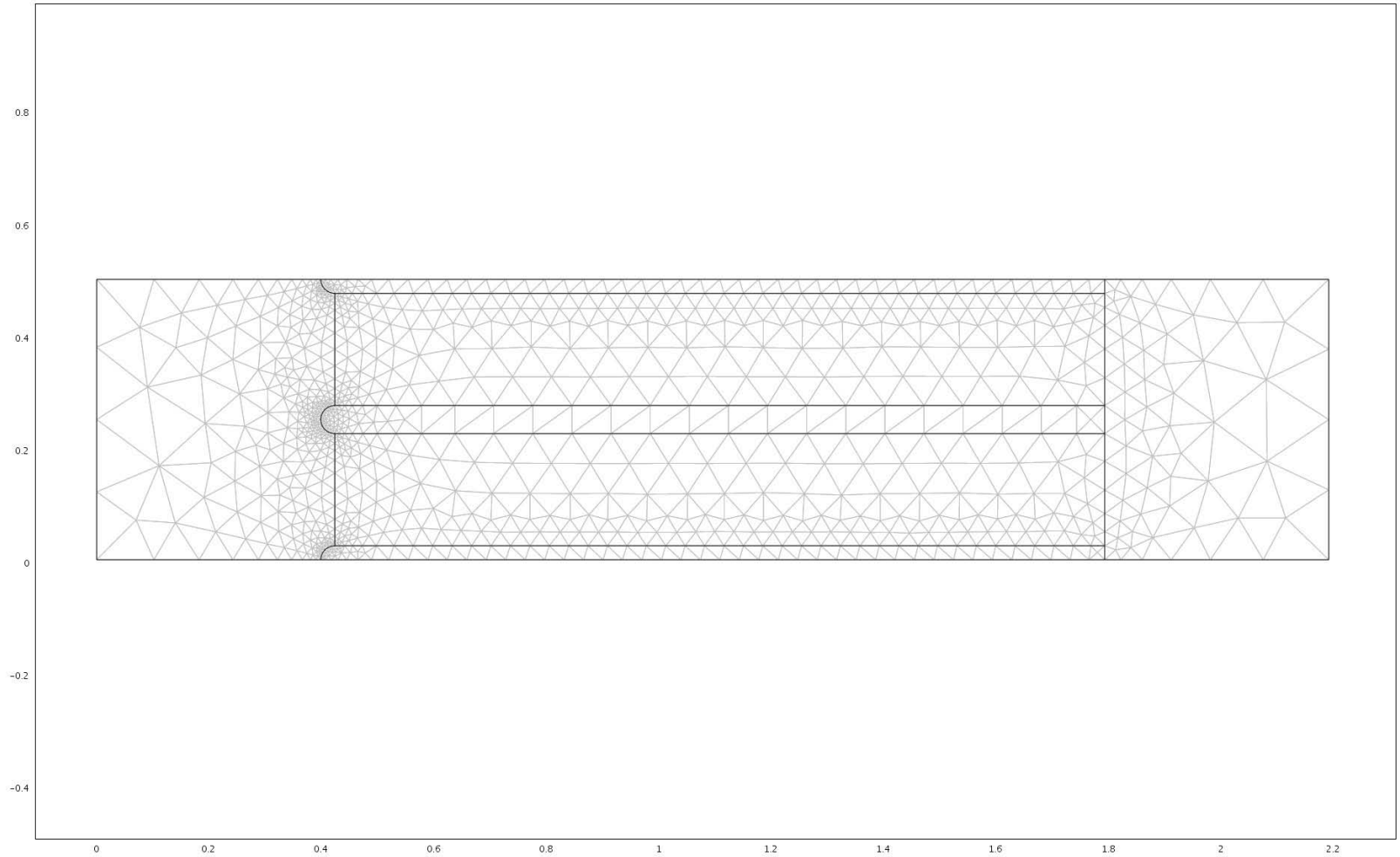
A Consistent Set of Inputs and Assumptions Allow COMSOL to Reproduce the Current Safety Basis (part 1 of 2)



A Consistent Set of Inputs and Assumptions Allow COMSOL to Reproduce the Current Safety Basis (part 2 of 2)

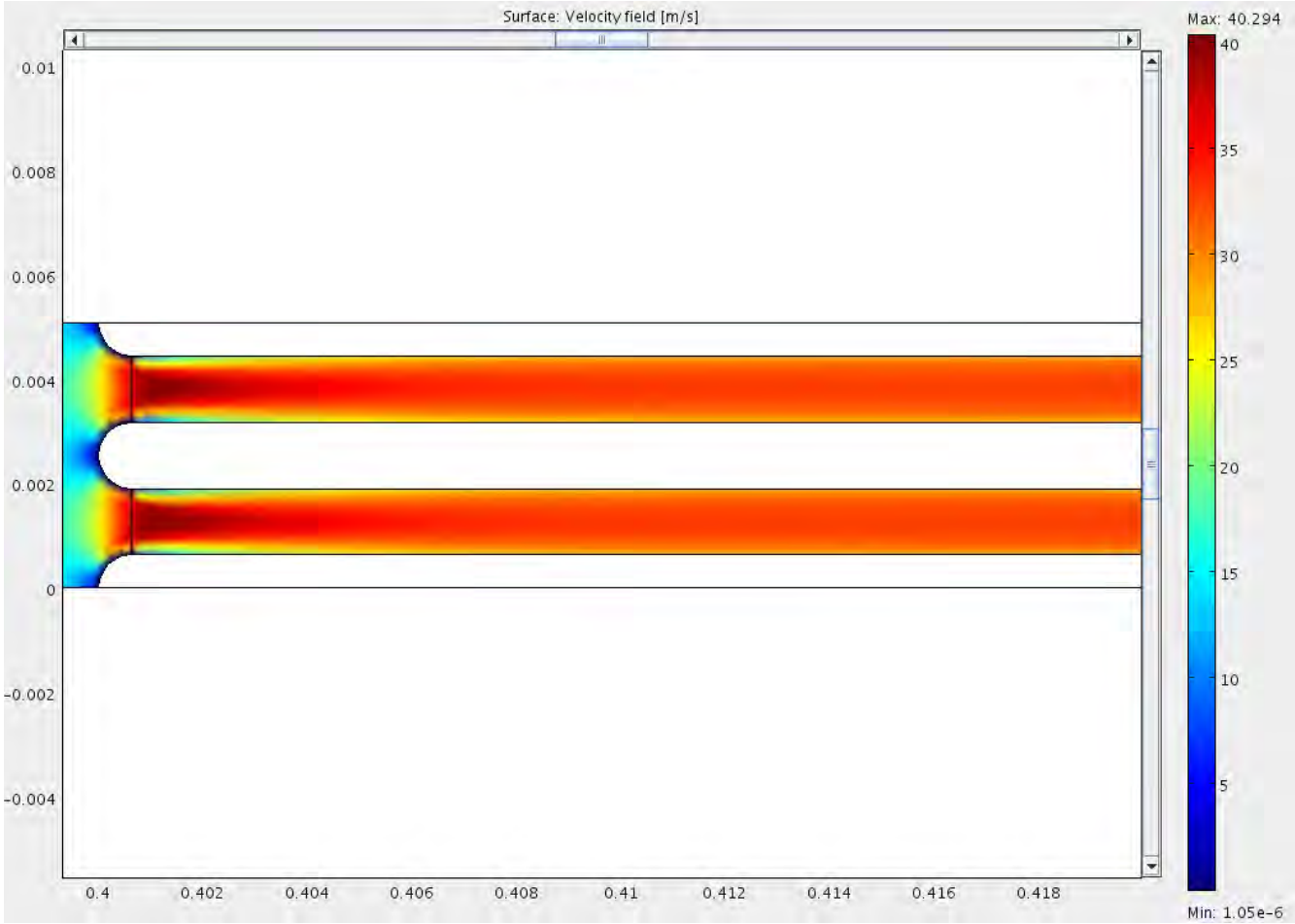


COMSOL 2D Development of Fluid-Structure Interaction with HFIR Fuel Plates (part 1 of 4)



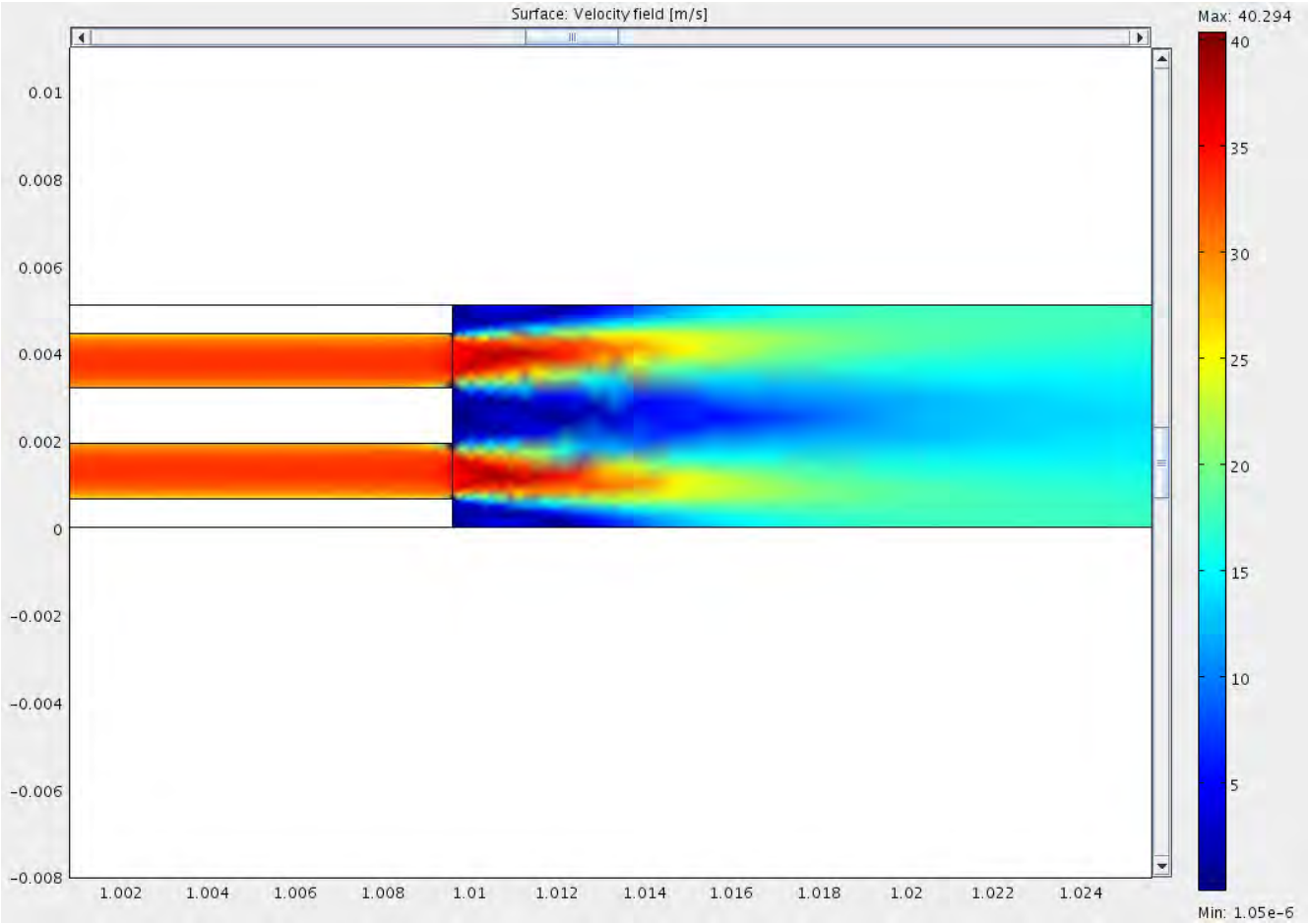
start with laminar flow – see movie of results

COMSOL 2D Development of Fluid-Structure Interaction with HFIR Fuel Plates (part 2 of 4)



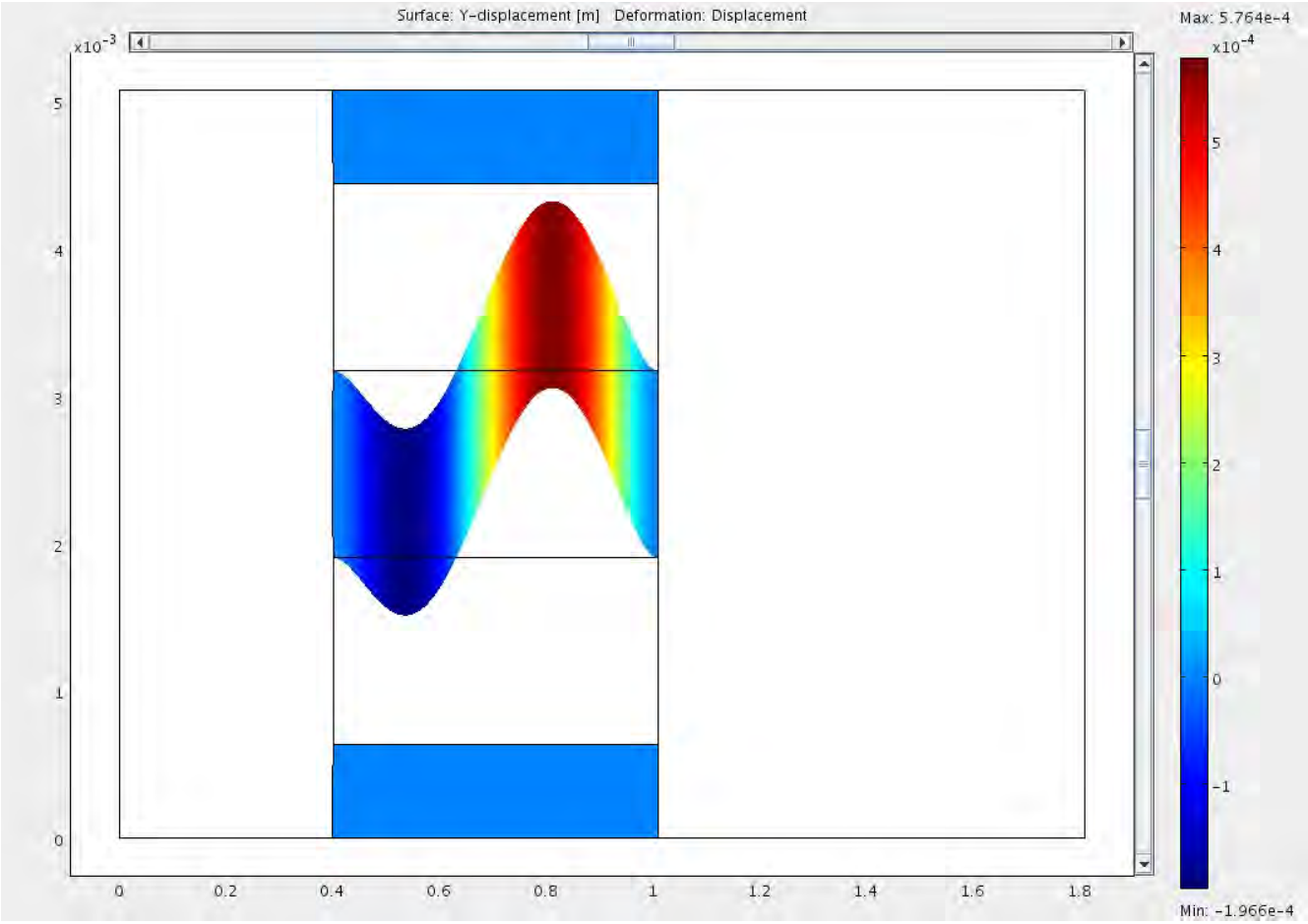
extension to turbulent flow – entrance region

COMSOL 2D Development of Fluid-Structure Interaction with HFIR Fuel Plates (part 3 of 4)



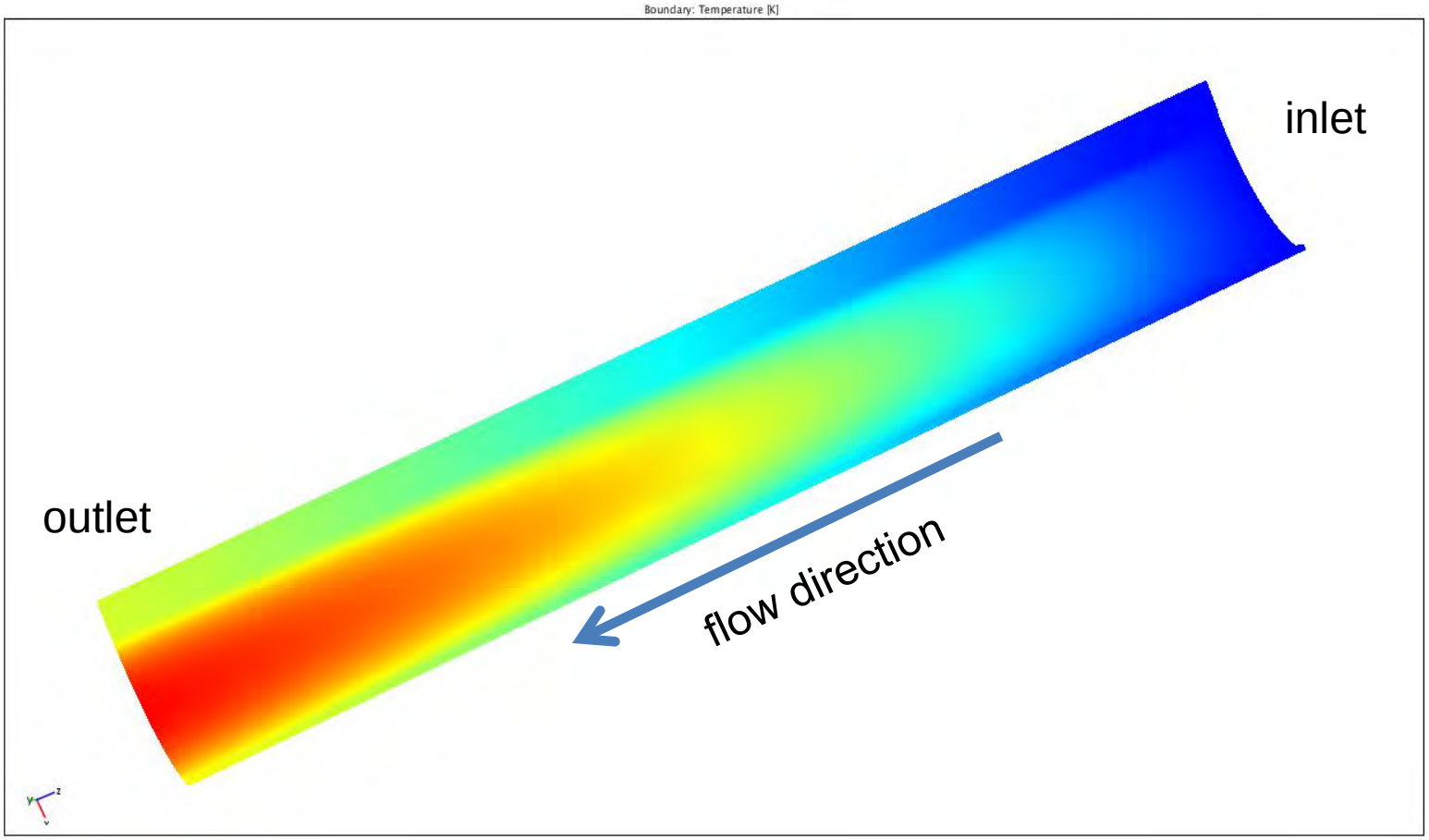
extension to turbulent flow – exit region

COMSOL 2D Development of Fluid-Structure Interaction with HFIR Fuel Plates (part 4 of 4)



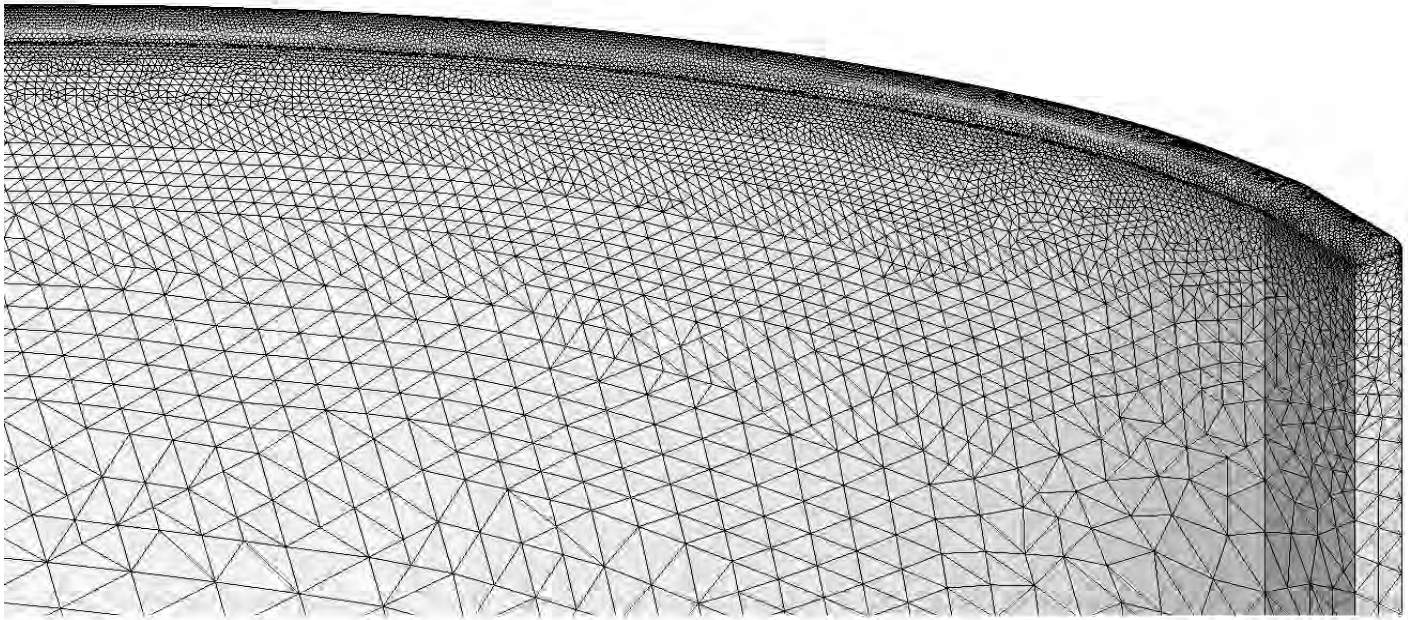
extension to turbulent flow – dramatic interaction for settings used in 2D

Typical 3D result: metal surface temperature

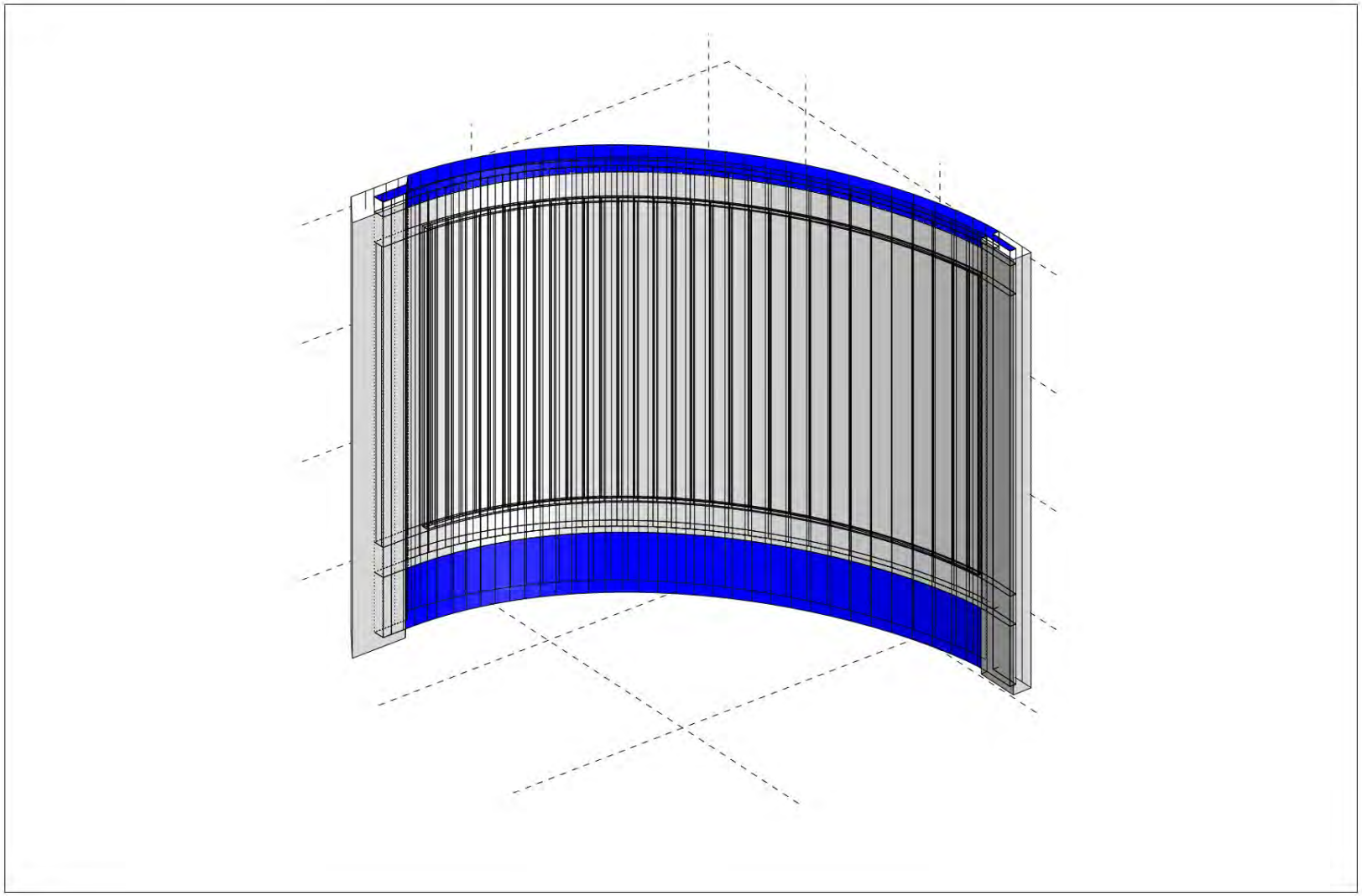


shown is the clad surface temperature adjacent to the turbulent-wall of the coolant

Typical 3D issue: creating accurate geometry

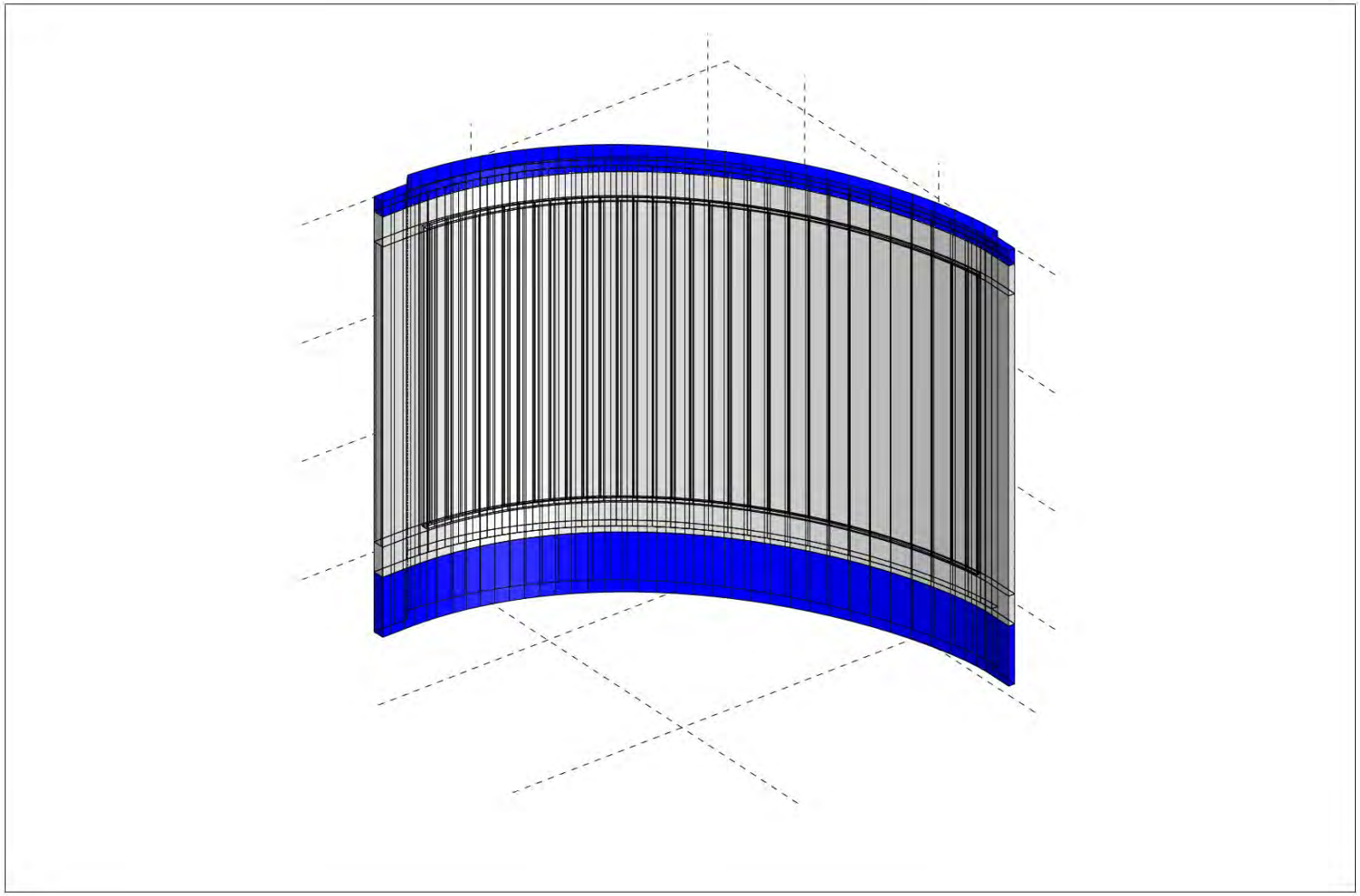


COMSOL CAD Tools have Limited Versatility



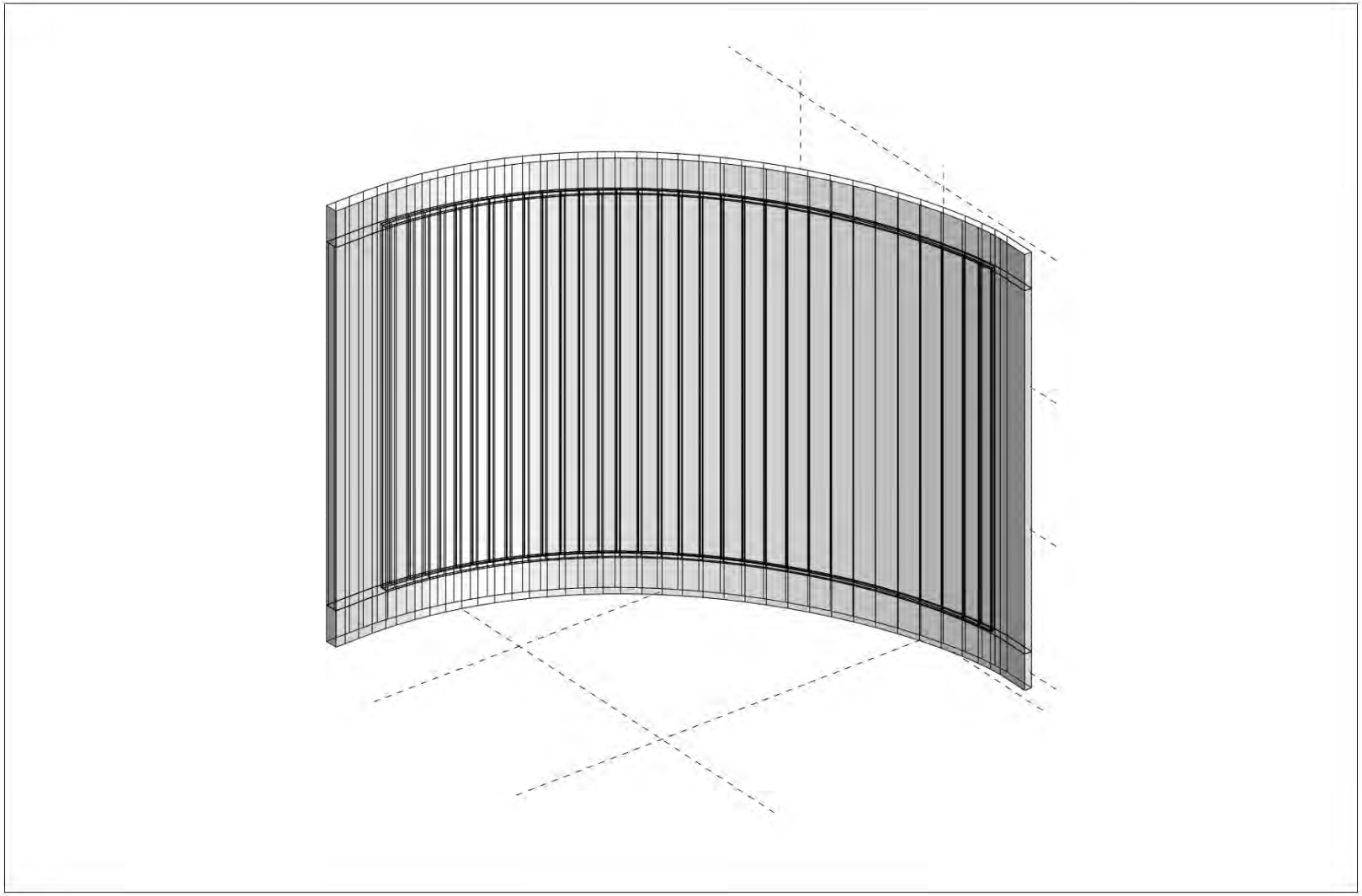
all geometry parts shown

COMSOL CAD Tools have Limited Versatility



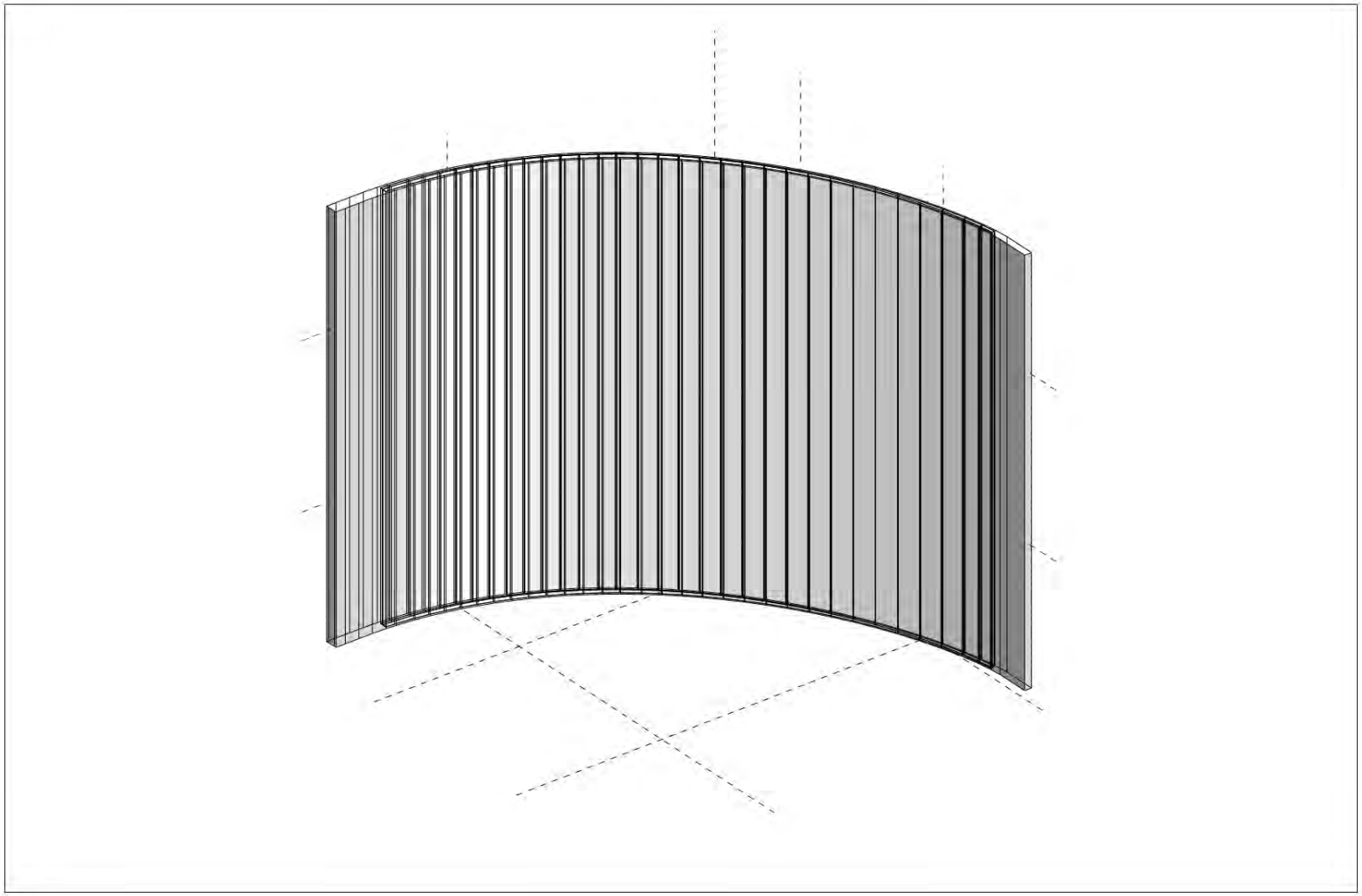
remove side plates from view

COMSOL CAD Tools have Limited Versatility



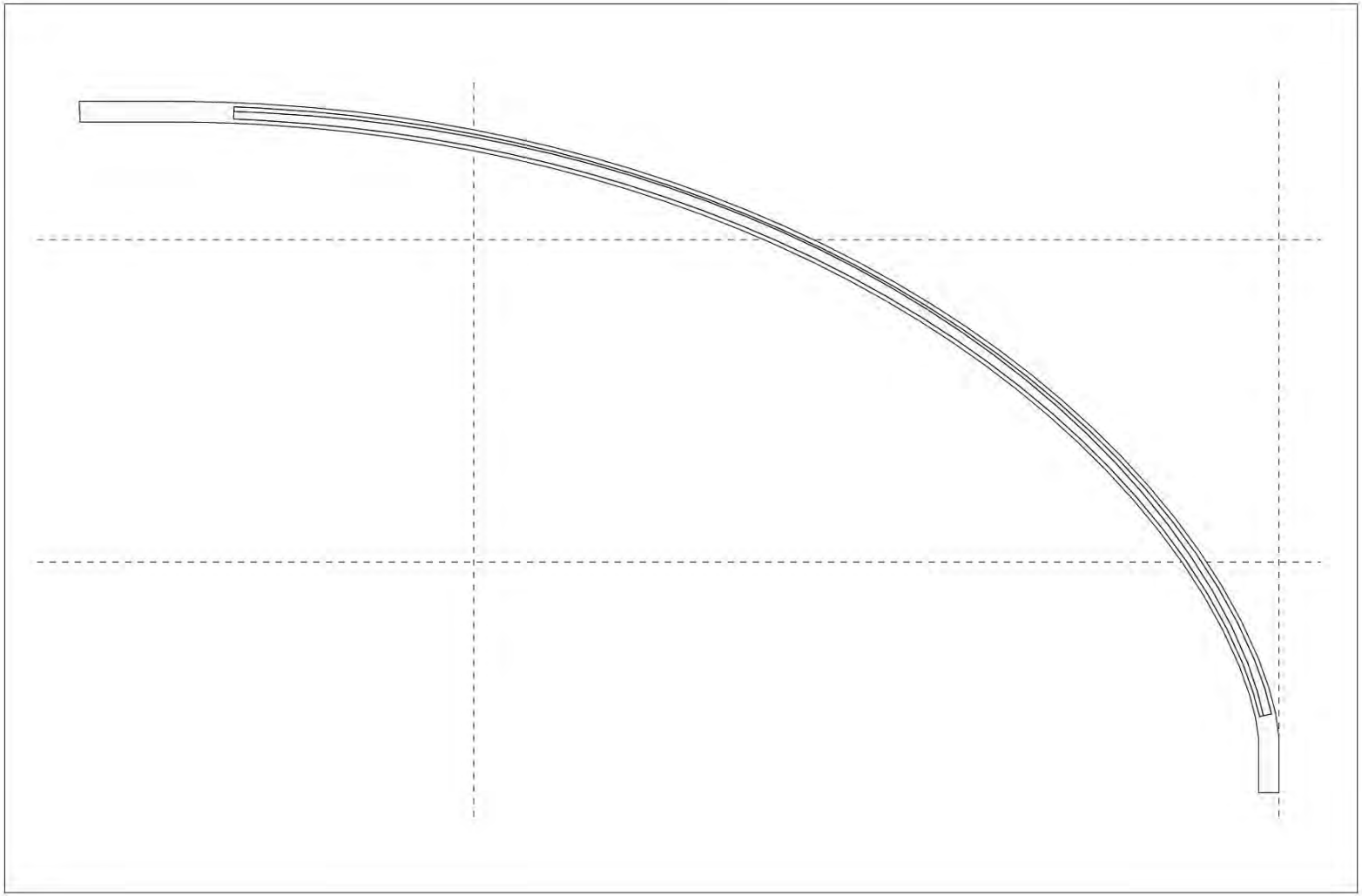
remove coolant from view

COMSOL CAD Tools have Limited Versatility



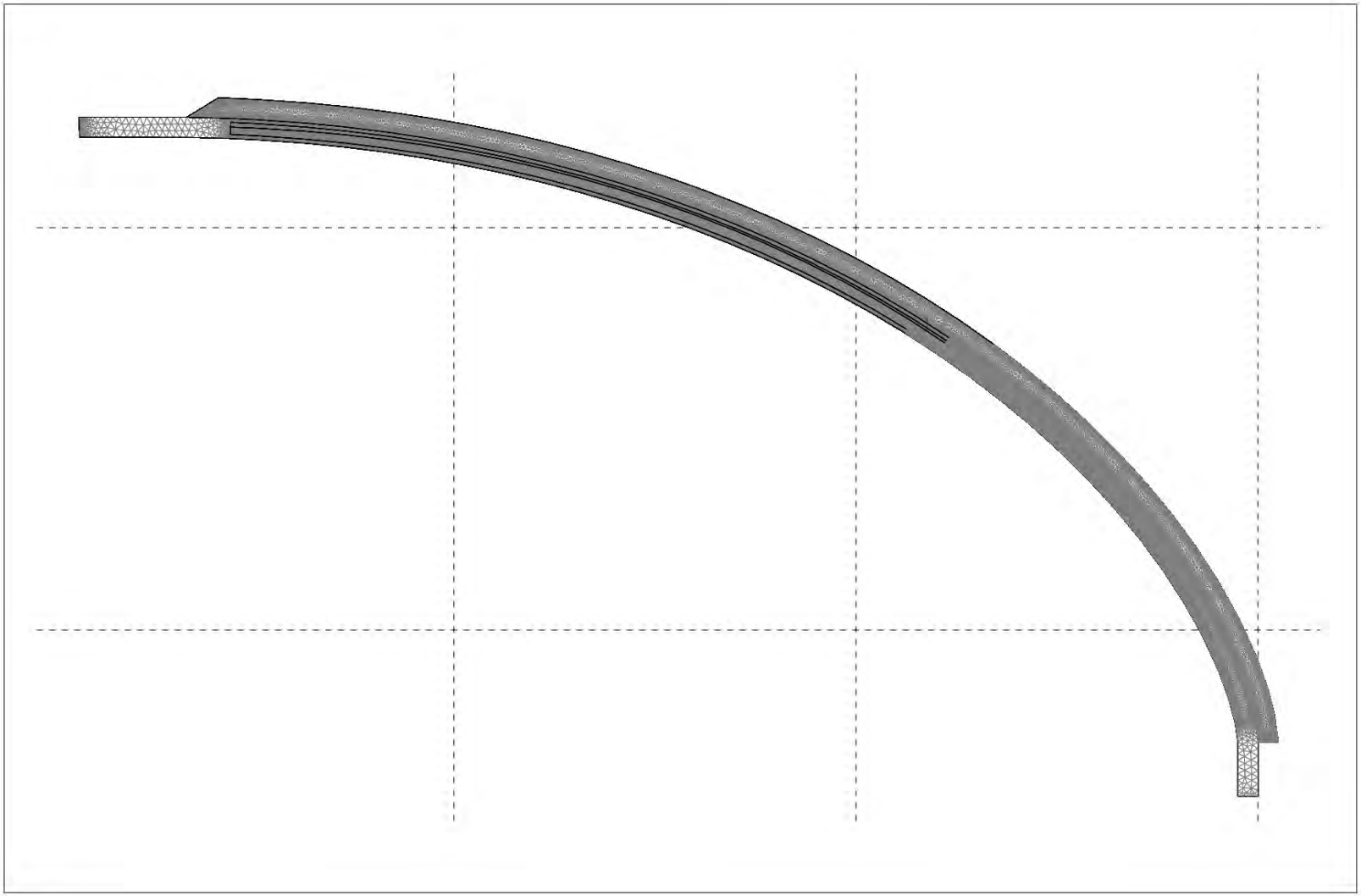
remove clad top and bottom from view

COMSOL CAD Tools have Limited Versatility



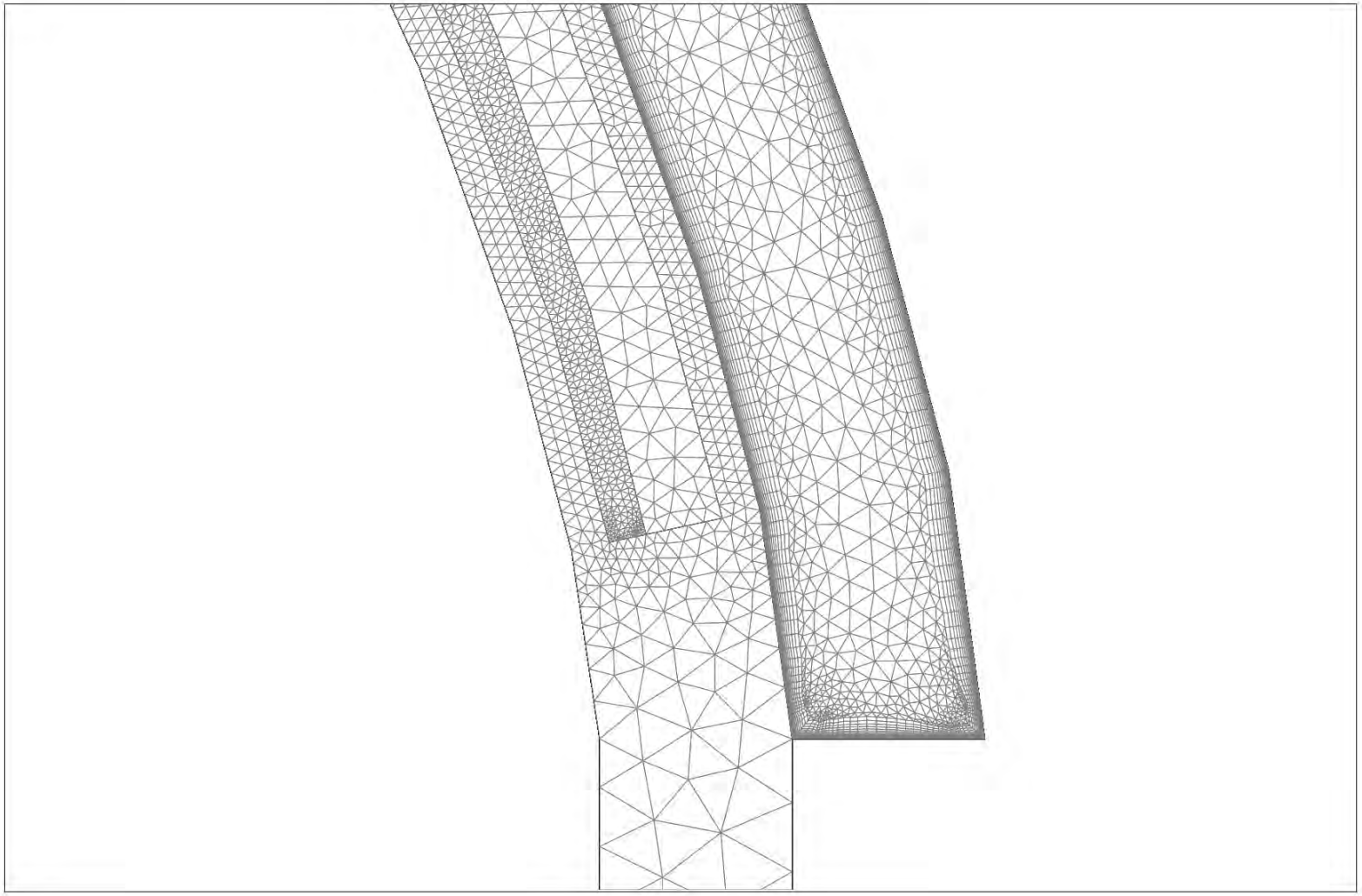
fuel details top view

COMSOL Meshing Tools Yield High Quality



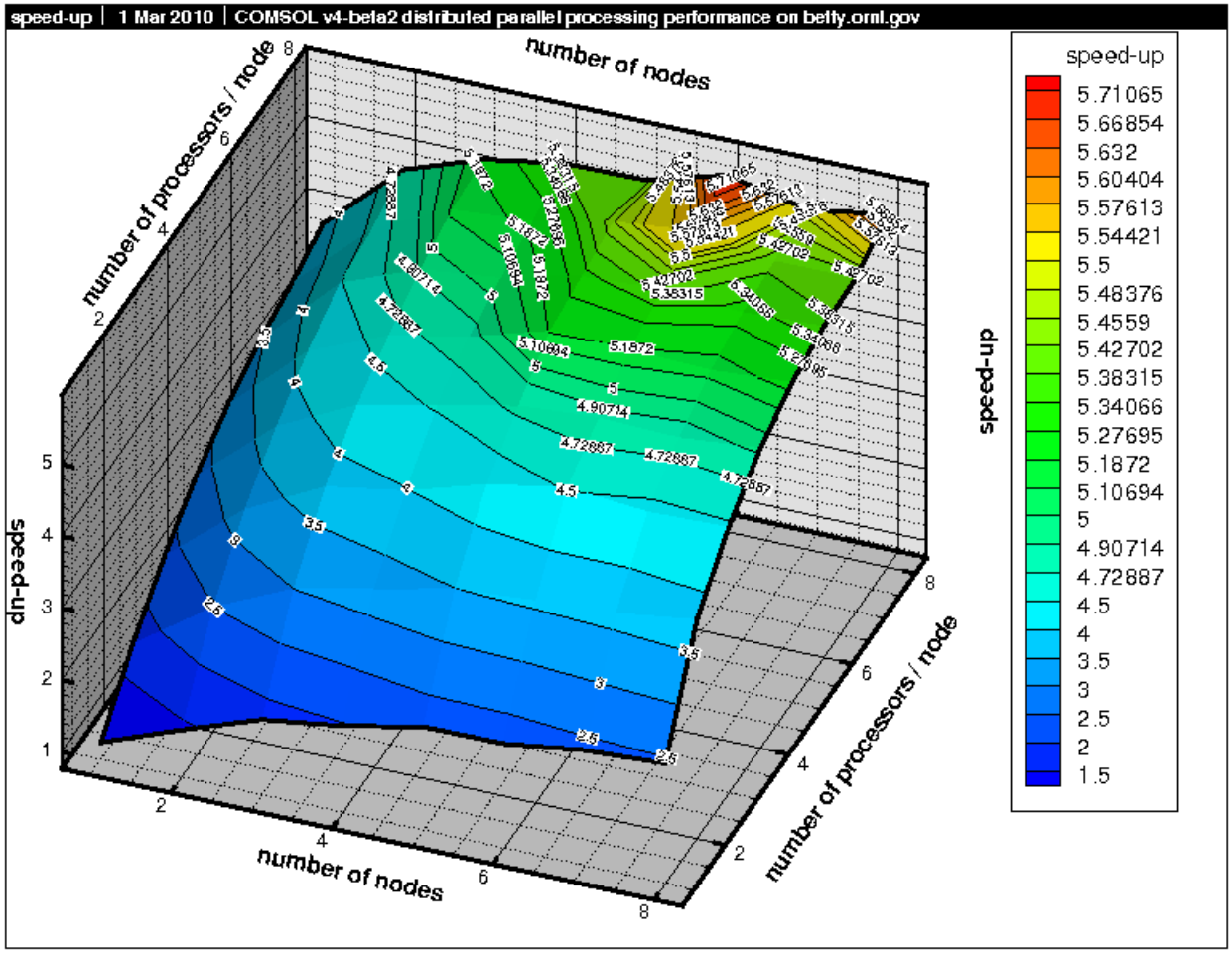
coolant and fuel region meshing top view

COMSOL Meshing Tools Yield High Quality



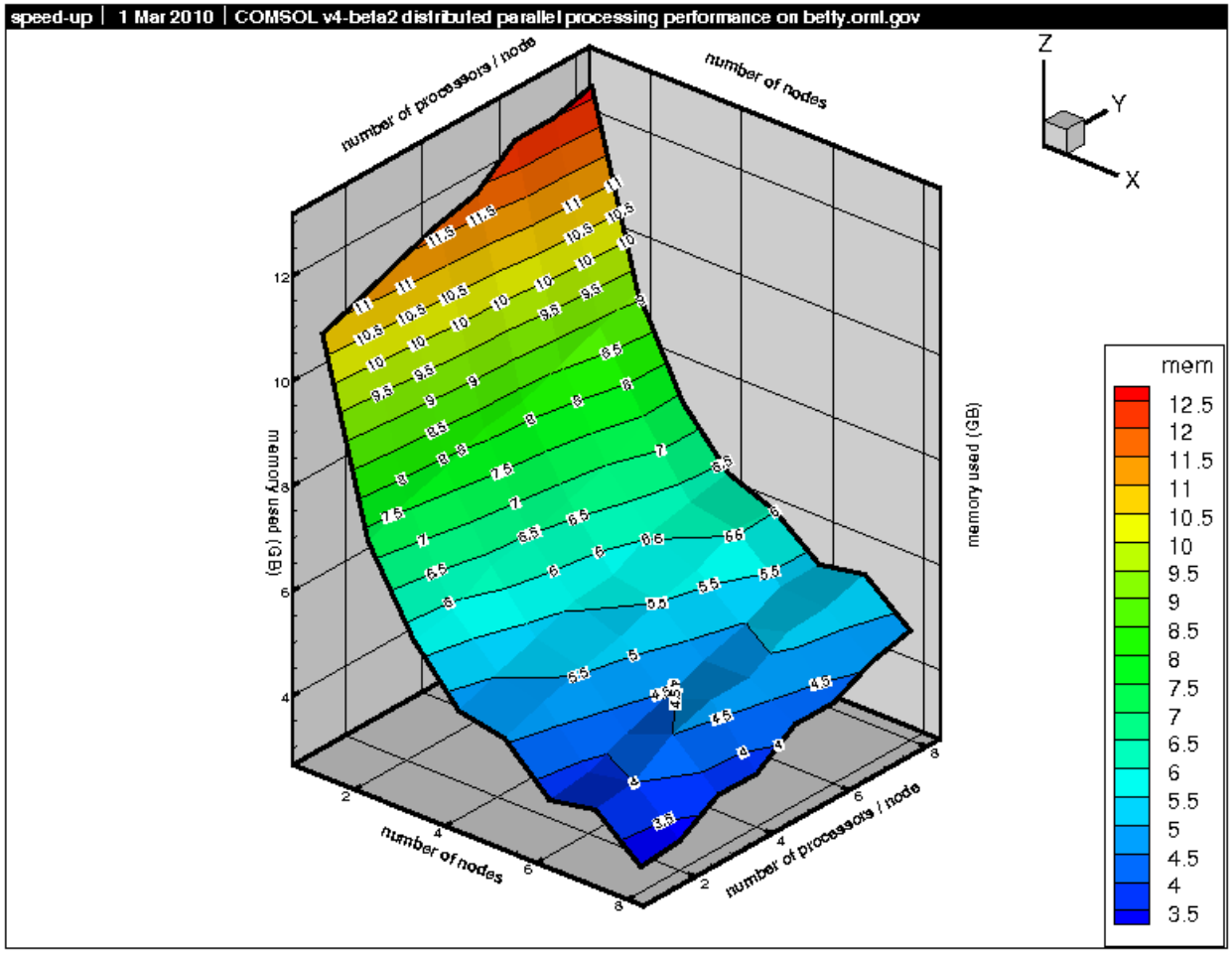
coolant and fuel region meshing top view magnified

COMSOL V4 – Beta2
Distributed Parallel Processing performance



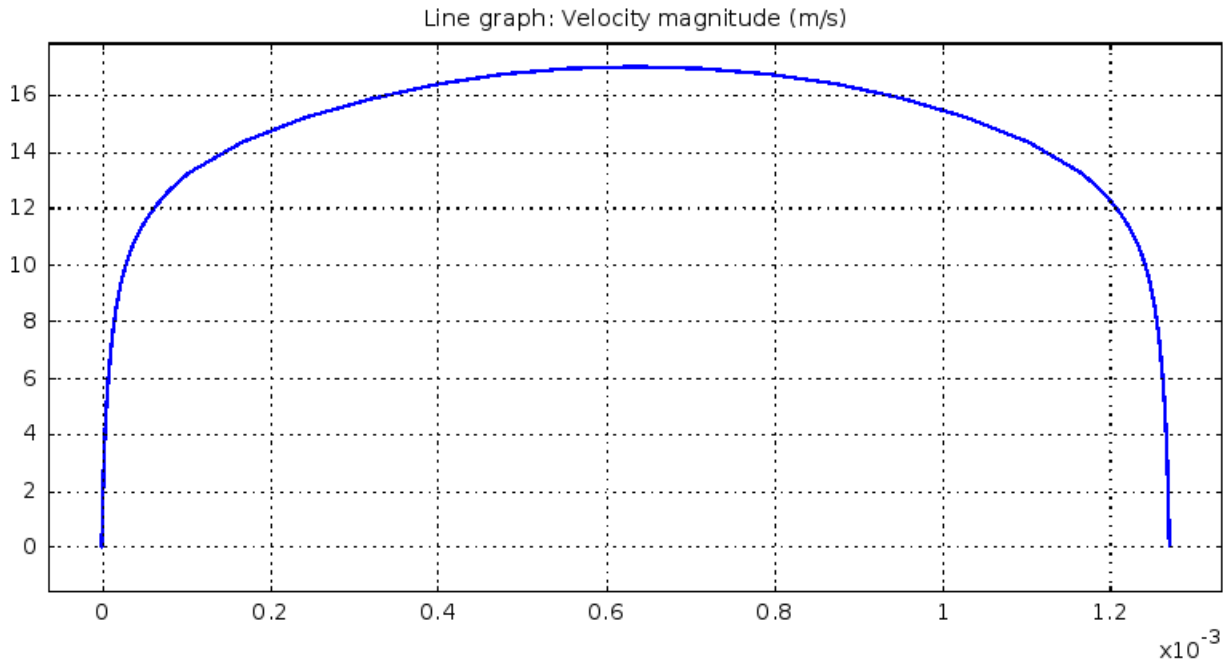
speed-up

COMSOL V4 – Beta2
Distributed Parallel Processing performance



memory usage

COMSOL V4 – CFD Module Beta
New Turbulence Models-Low Rey Extension



this beta version is limited to isothermal flows for the low Rey extension

COMSOL T-H Summary for HFIR

- **COMSOL is providing a modern simulation tool for the design of LEU fuel and analysis of present HEU fuel.**
- **The COMSOL analysis provides details and accuracy heretofore not possible, and allows for precise margin estimates.**
- **The 2D analysis provides a test bed for the 3D analysis to establish consistent parameter set (wall offset, mesh density, solution procedure, etc.)**
- **2D results demonstrate methods that yield accurate benchmarks with established data base.**
- **3D computational requirements have been demonstrated on a representative model. Model development to address axial grading requirements for HFIR LEU fuel are expected in FY10.**