Three-Dimensional Neutronics Analysis of ARIES-CS Using CAD-Based Tools

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Overview

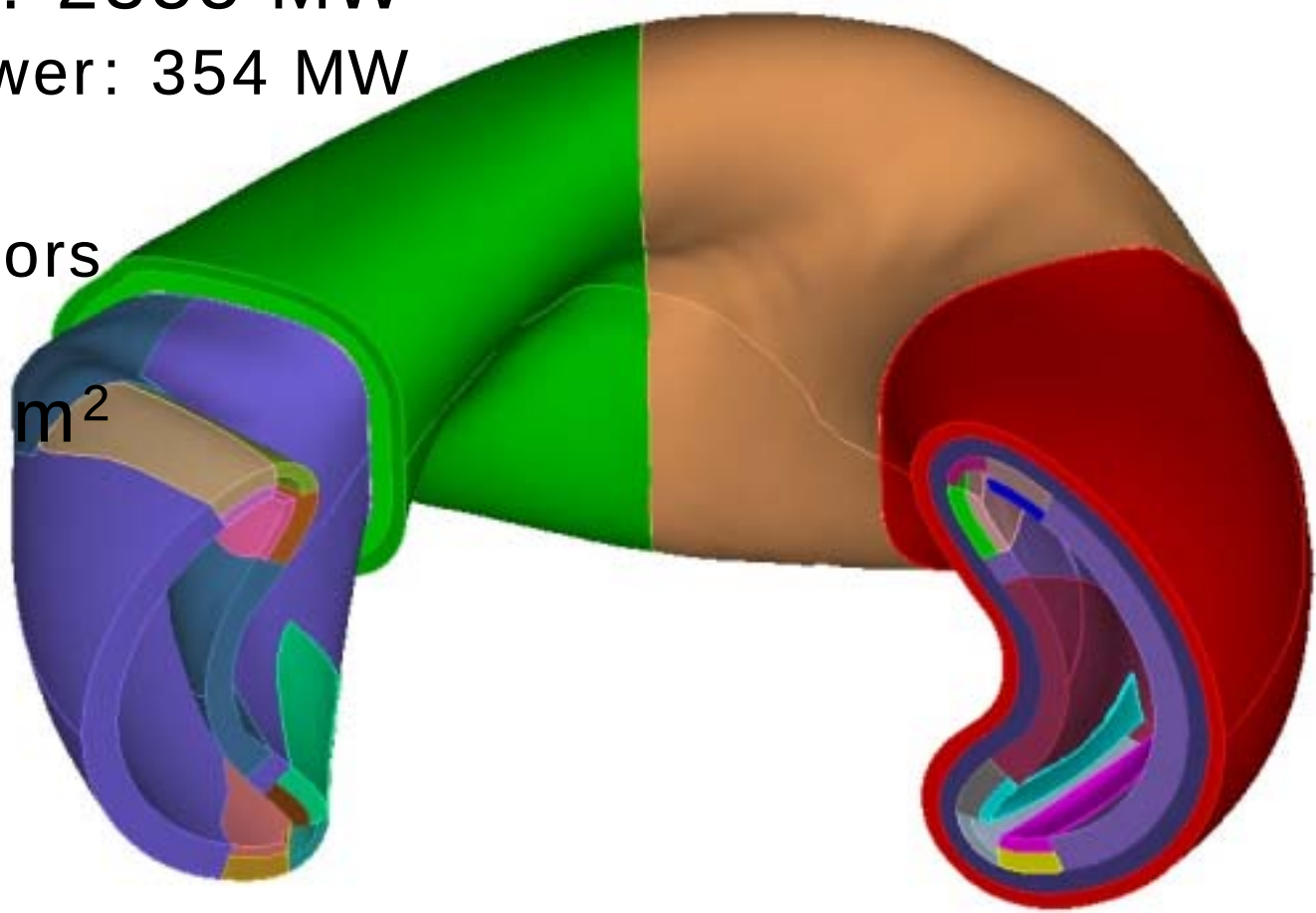
- Introduction
- 3-D Source for MCNP
- Neutron Wall Loading
- Tritium Breeding Ratio
- Divertor Duct Streaming
- Summary

Introduction

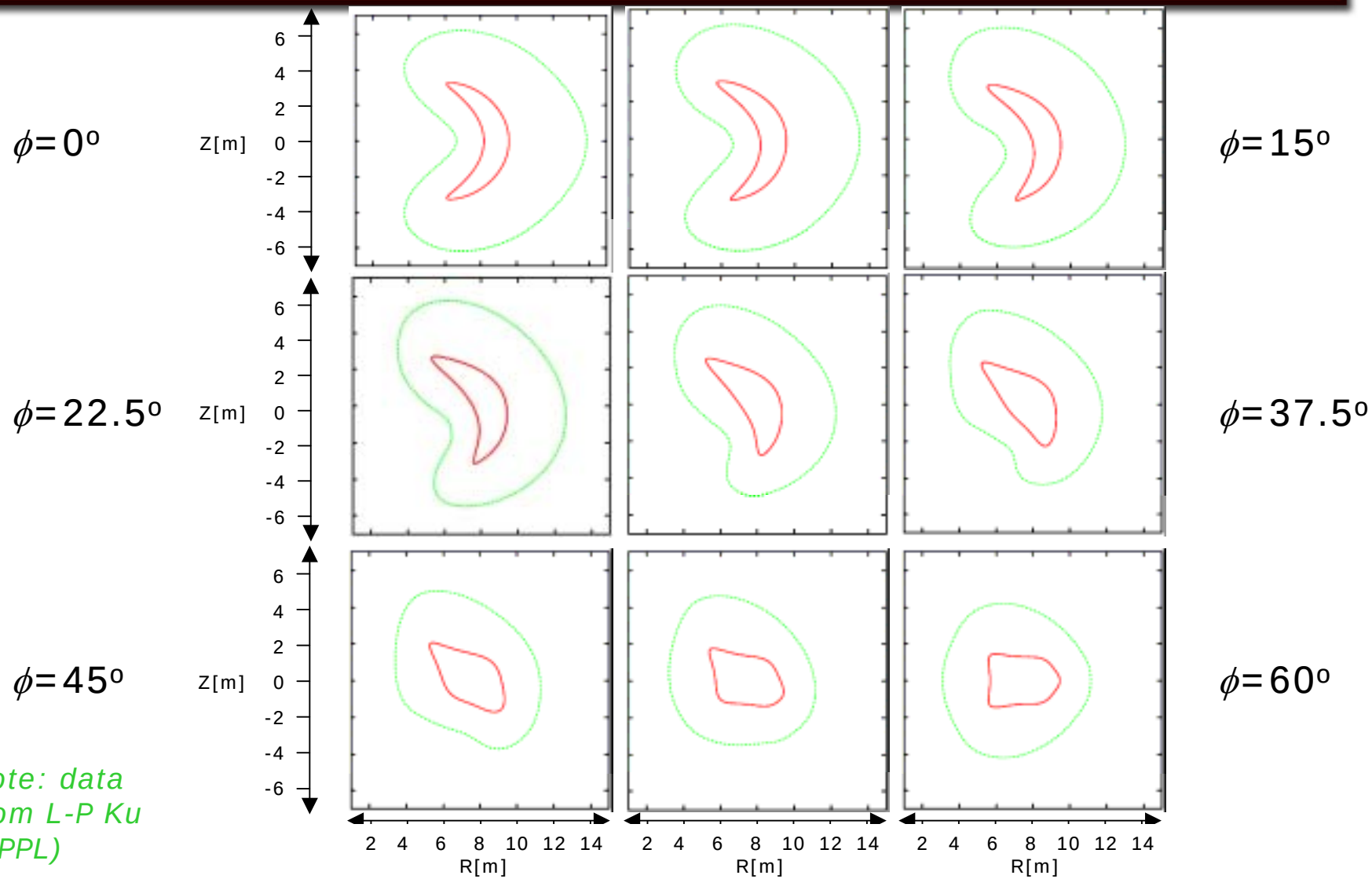
- ARIES-CS has a complex 3-D geometry
  - Plasma surfaces based on high-order Fourier series expansion
  - Machine surfaces based on offsets from last closed magnetic surface
- Previous analyses based on 1-D approximations
- Tools are now available to permit 3-D analysis

ARIES-CS Parameters

- Major radius: 7.75 m
- Fusion power: 2355 MW
  - Radiative power: 354 MW
- 5cm SOL
  - except divertors (30cm SOL)
- FW area:727 m^2



Plasma & Mid-Coil Profiles



Note: data from L-P Ku (PPPL)

Need 3-D Source Definition

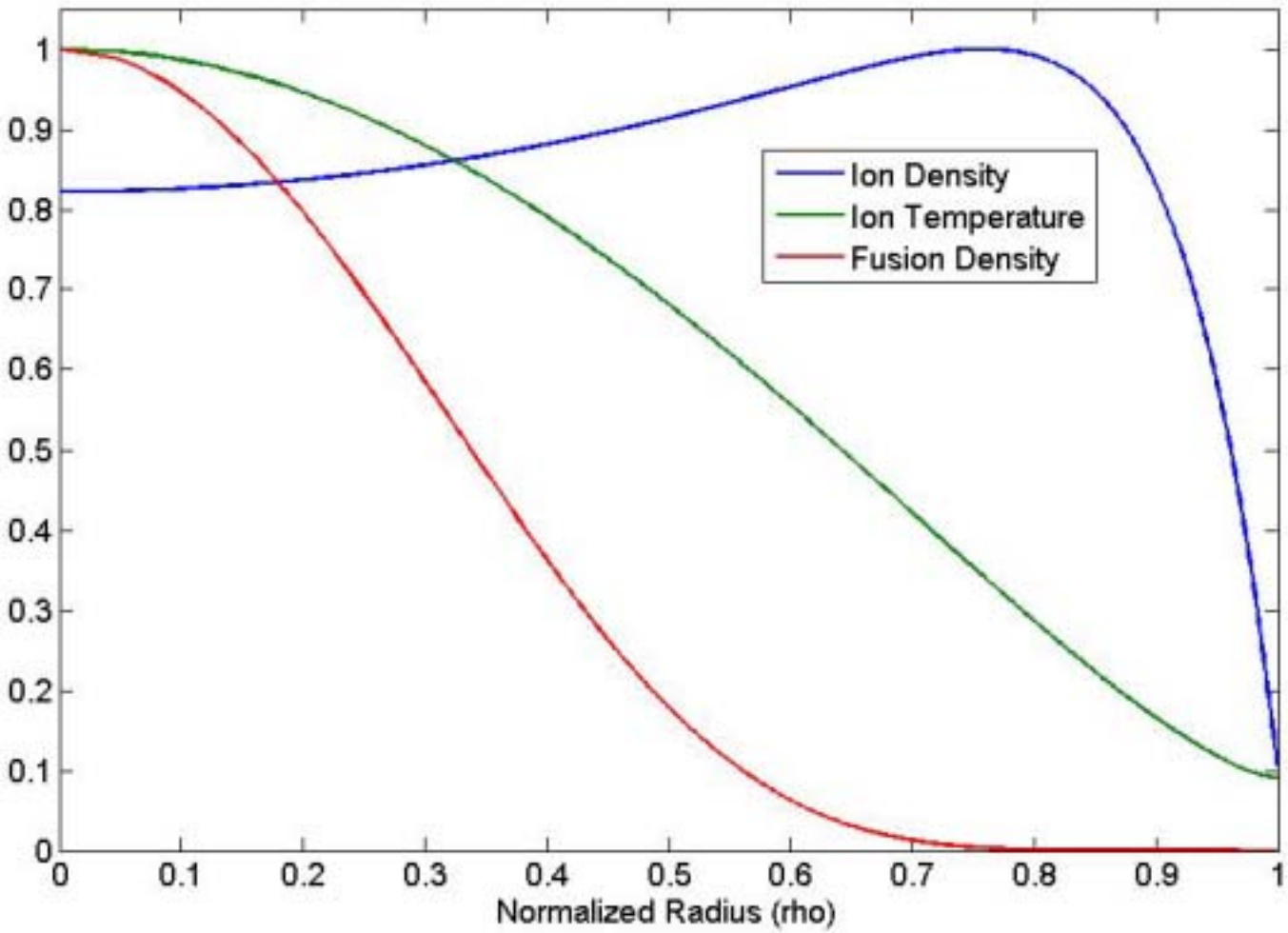
- 1-D modeling
  - Uniform source acceptable approximation
- 3-D modeling enabled by new neutronics tool
  - Source distribution becomes limiting approximation in model analysis

Neutron Source Methodology

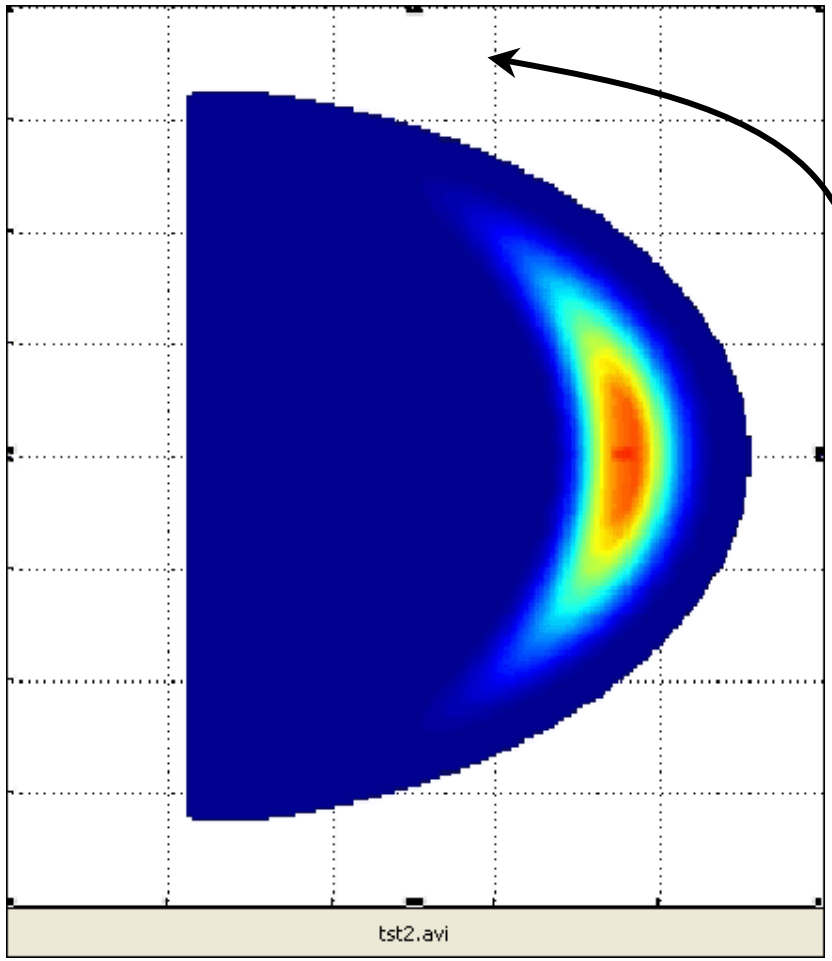
- Generate hex mesh in real space from uniform mesh in flux coordinate space
- Generate cumulative distribution function for source density in hex mesh
- Sample hex mesh and mesh cells for source position

Fundamental Source Density

Note: based on Data from J. Lyon (ORNL)



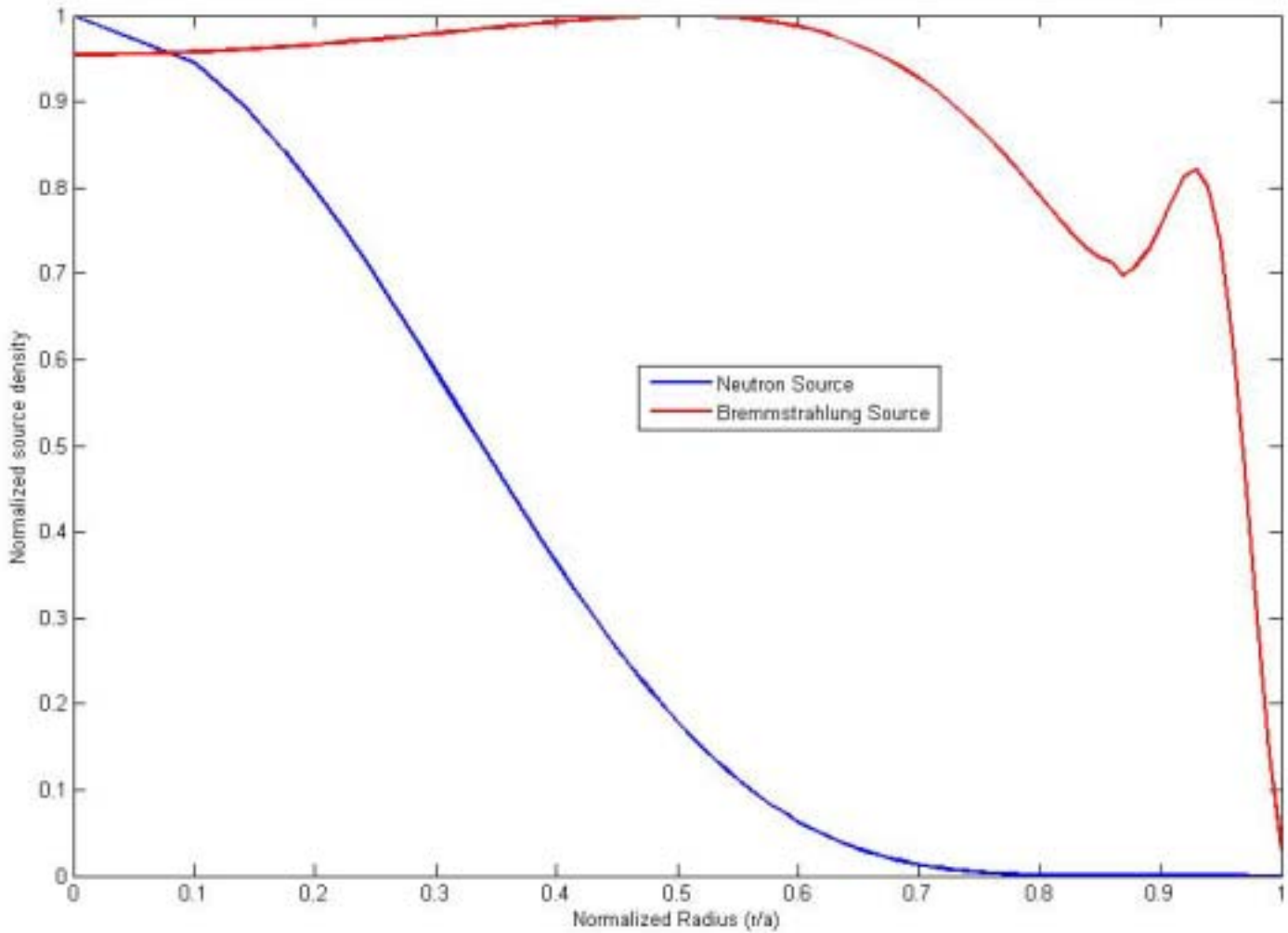
Source Probability Map



Increasing
Poloidal Angle
(0° at O/B midplane)

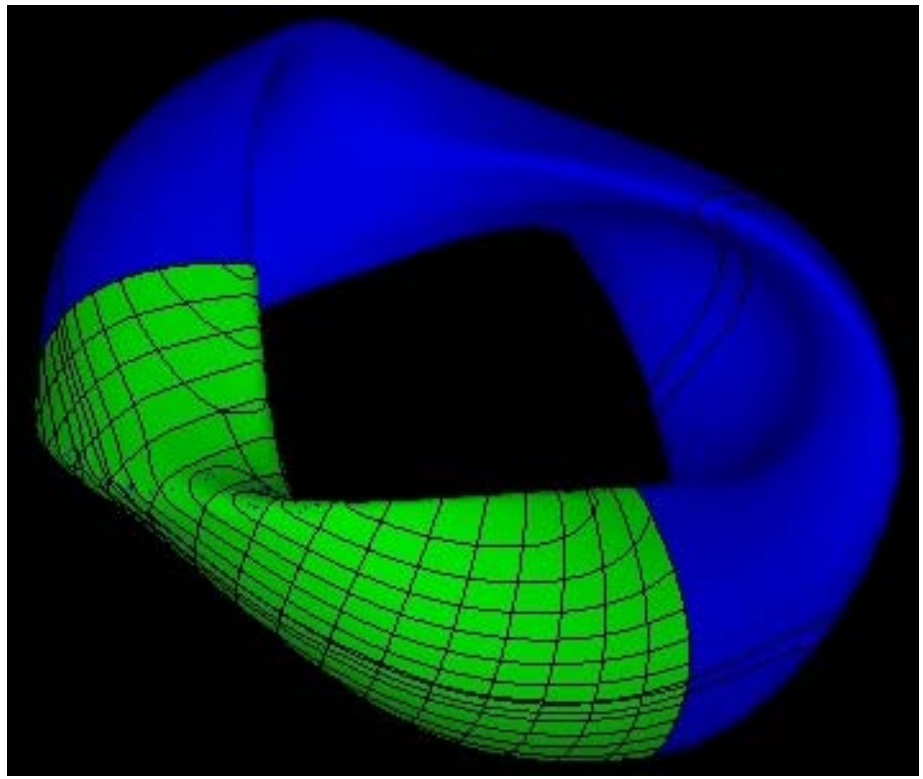
Radiation Heating Source

Note: based on Data from J. Lyon (ORNL)



Results and Analysis

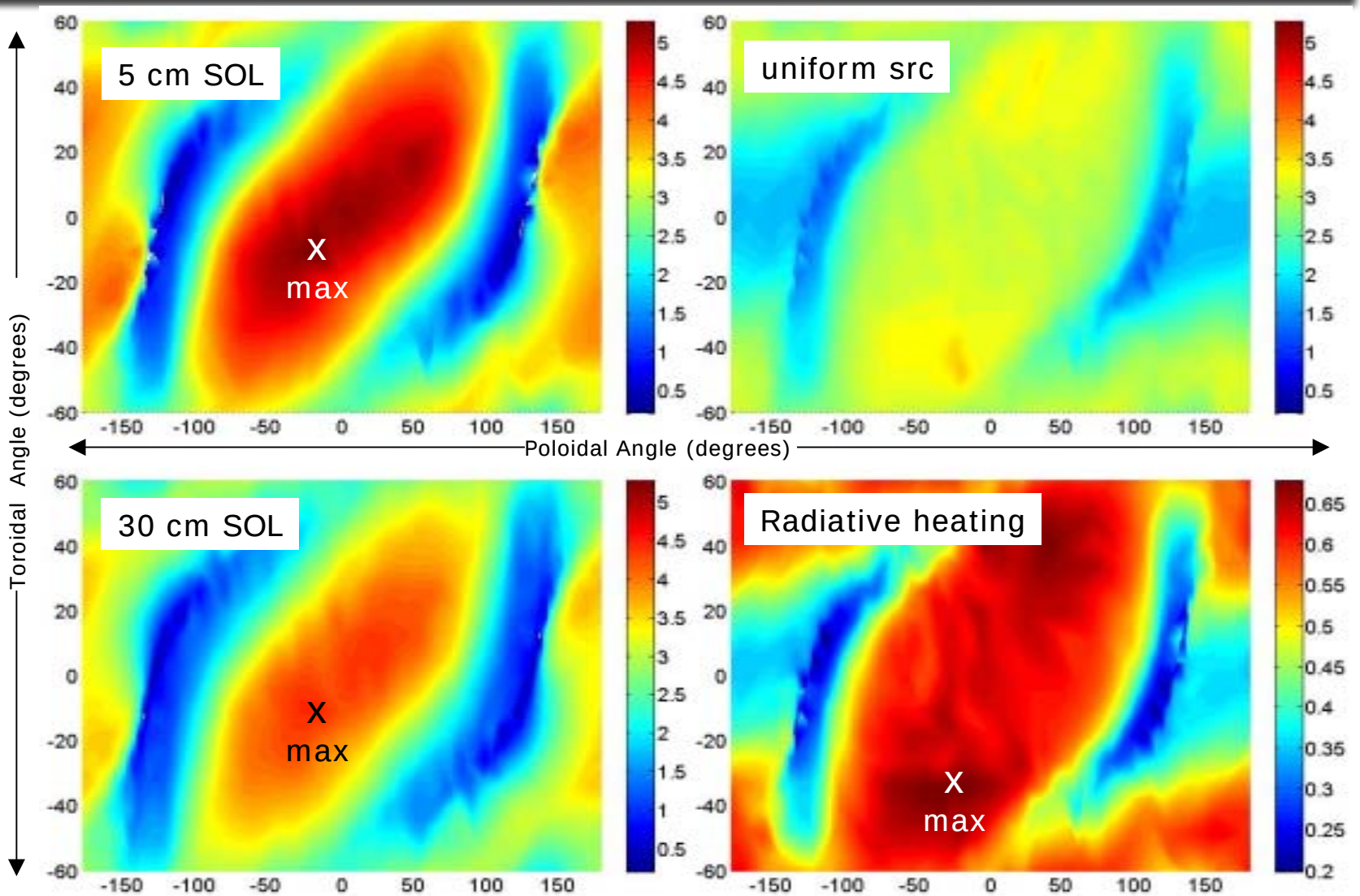
- Calculate NWL on surface grid
  - Some statistical variation
- Transform (x,y,z) coordinates of each patch to (θ_P, ϕ_T)
- Interpolate results on 200 x 200 uniform grid in (θ_P, ϕ_T)



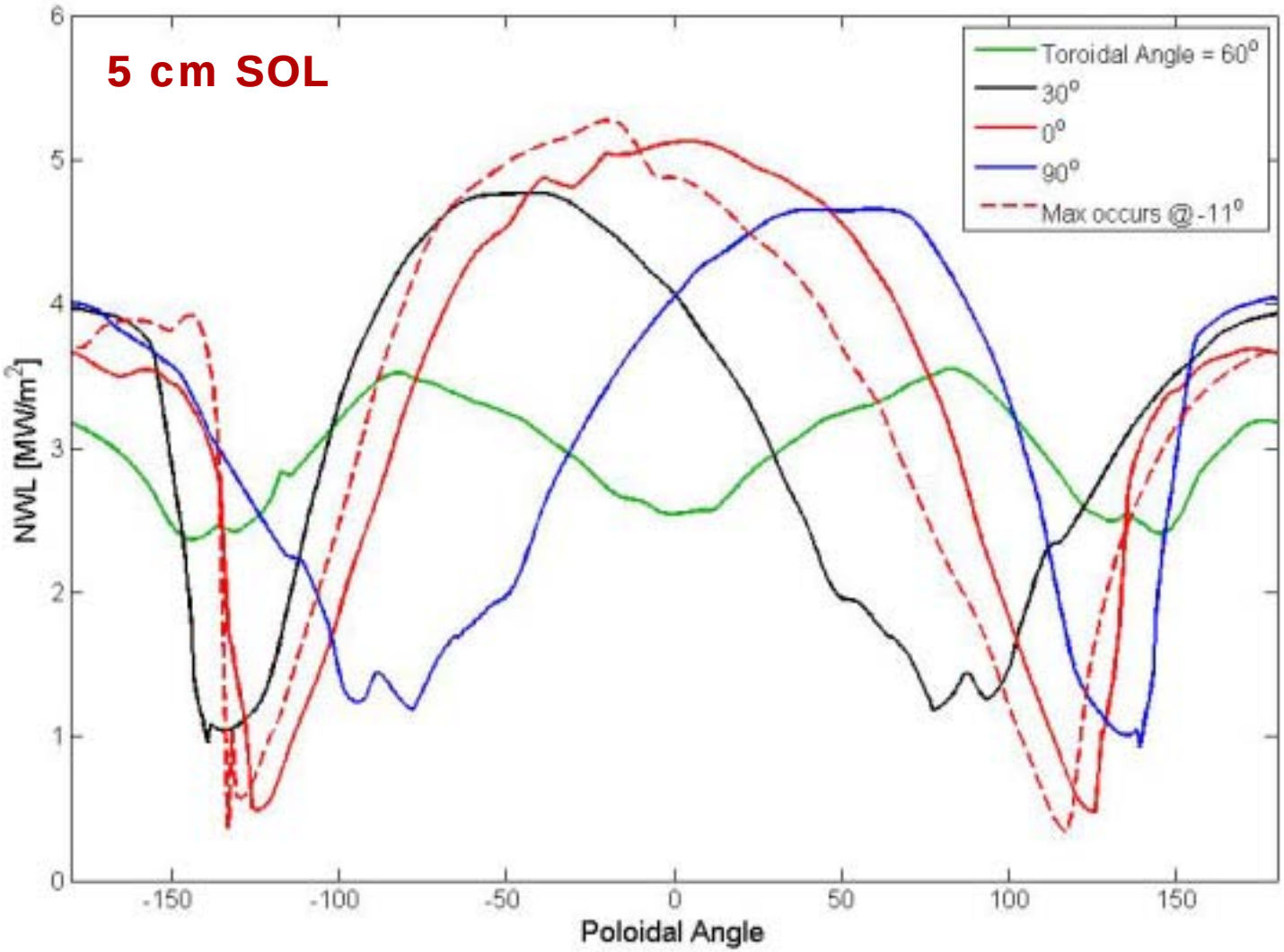
NWL Summary

	Peak (Min) [MW/m^2]	Toroidal Angle (degrees)	Poloidal Angle (degrees)
Real 3-D Source [5 cm SOL]	5.26 (0.32)	-11 (-4)	-18 (-116)
Real 3-D Source [30 cm SOL]	4.42 (0.42)	-11 (-11)	-25 (122)
Uniform Source	3.56	-49	-21
Rad. Heating	0.68 (0.2)	-34 (11)	-17 (-117)

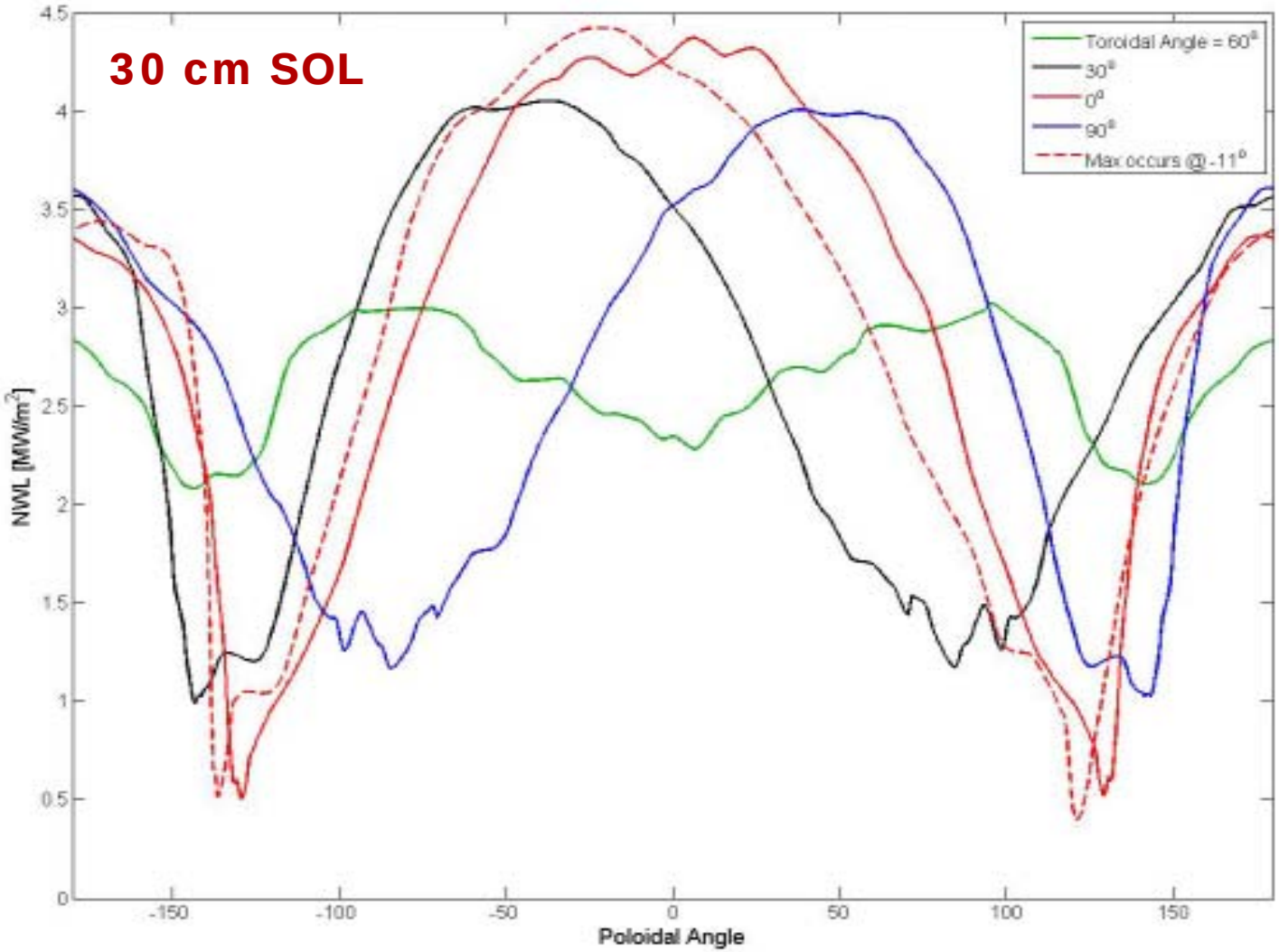
NWL Maps (colormaps in MW/m^2)



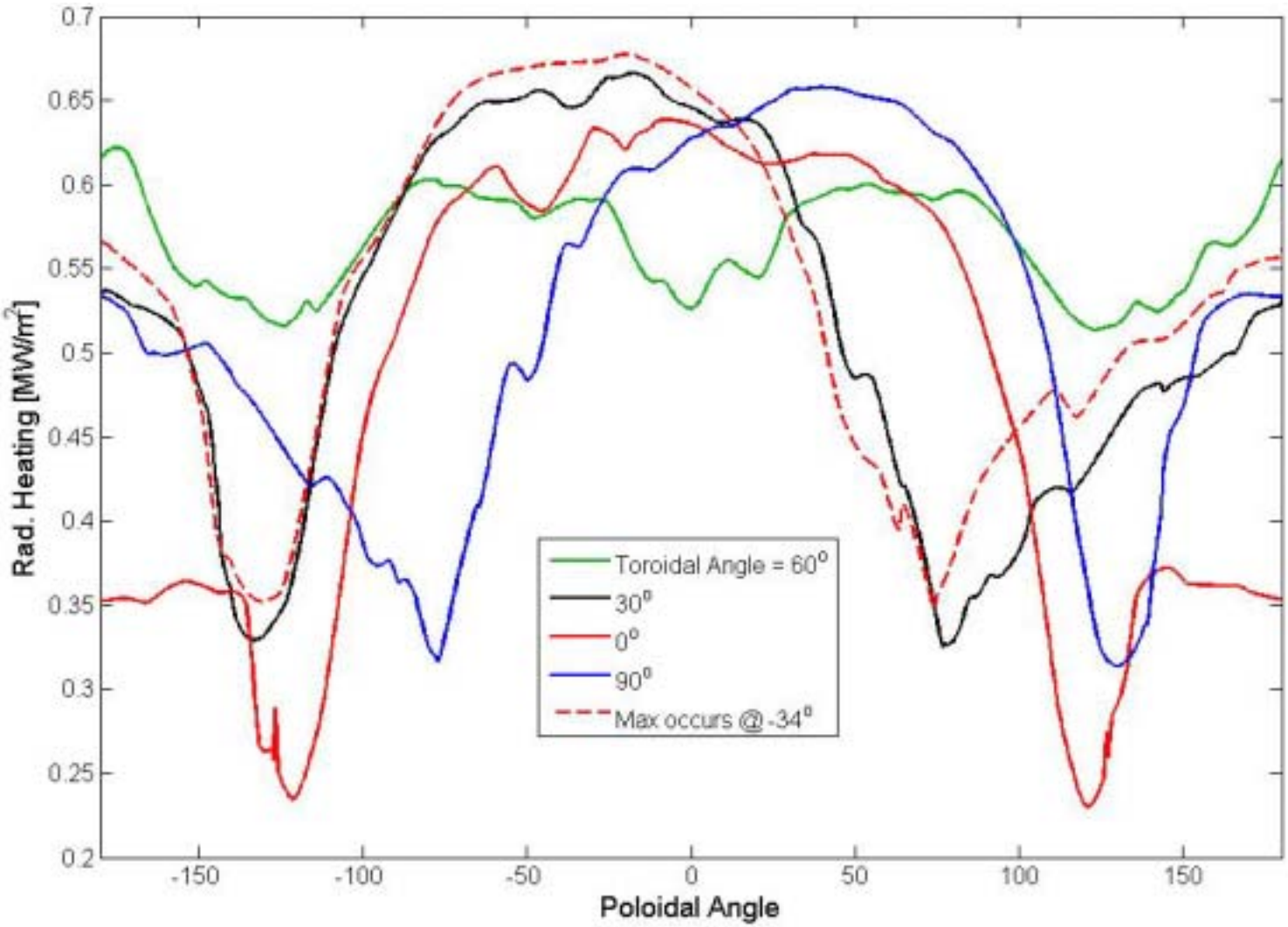
Neutron Wall Loading Profiles



Neutron Wall Loading Profiles

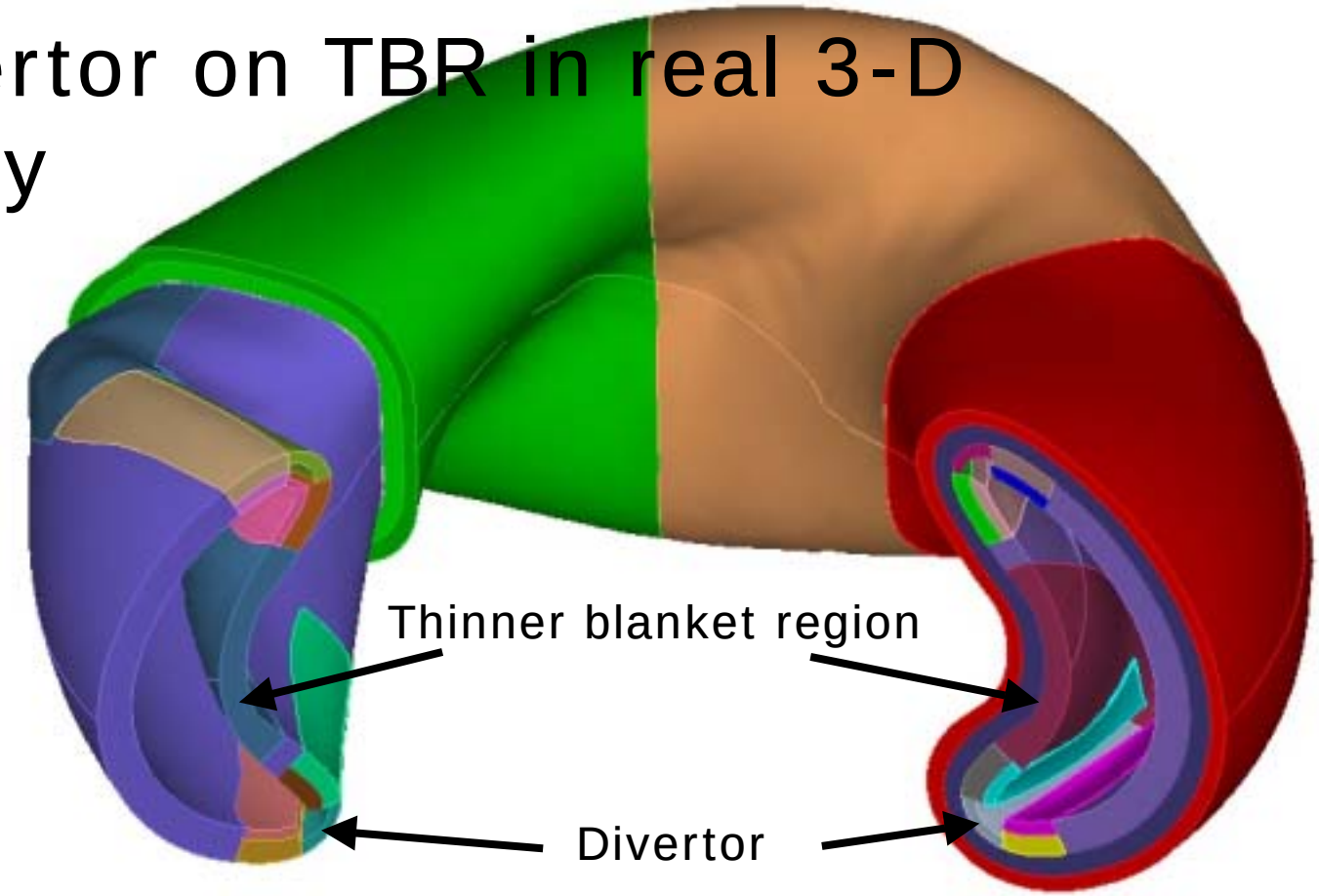


Radiation Heating Profiles

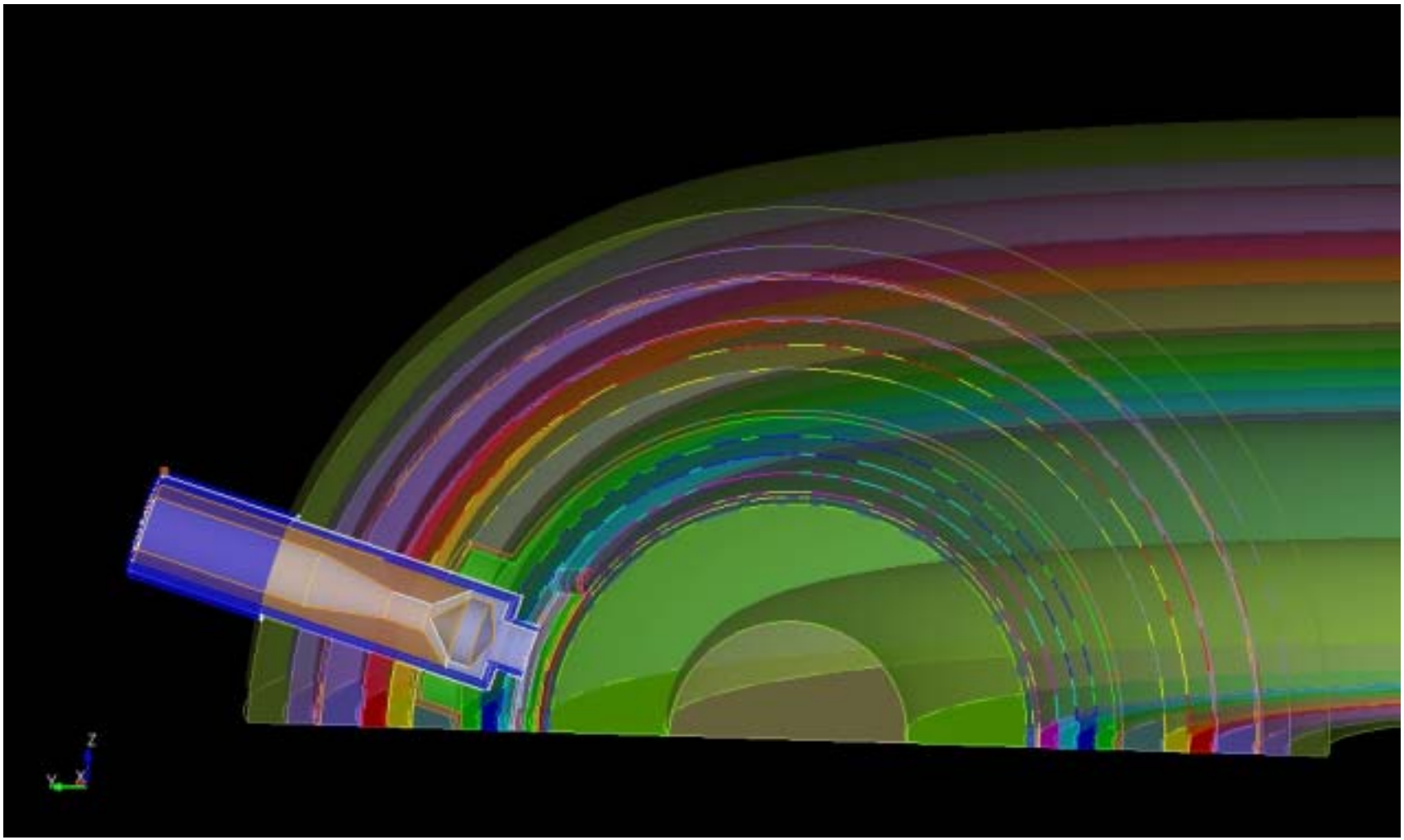


Tritium Breeding Ratio

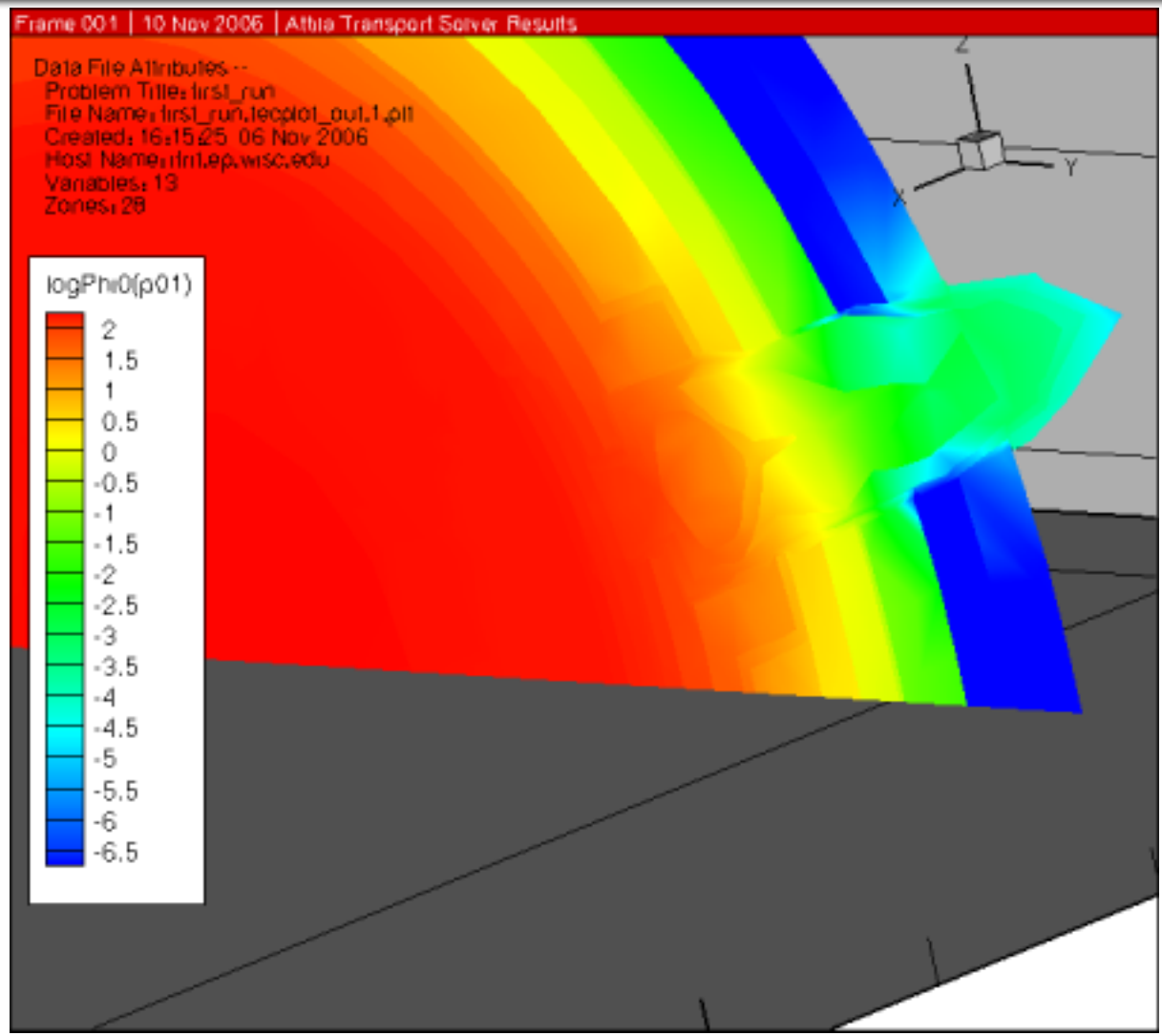
- Examine effect of non-uniform blanket and divertor on TBR in real 3-D geometry



Divertor Duct Shielding



Duct Shielding Response



Summary

- Real 3-D source important for correct modeling of complex geometries
- New CAD-based capabilities are necessary for this geometry
  - Geometry stressed system to near-breaking point

Questions?

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