ITER In-Vessel Coils
ATTILA Neutronics

Upper and Lower VS Coils

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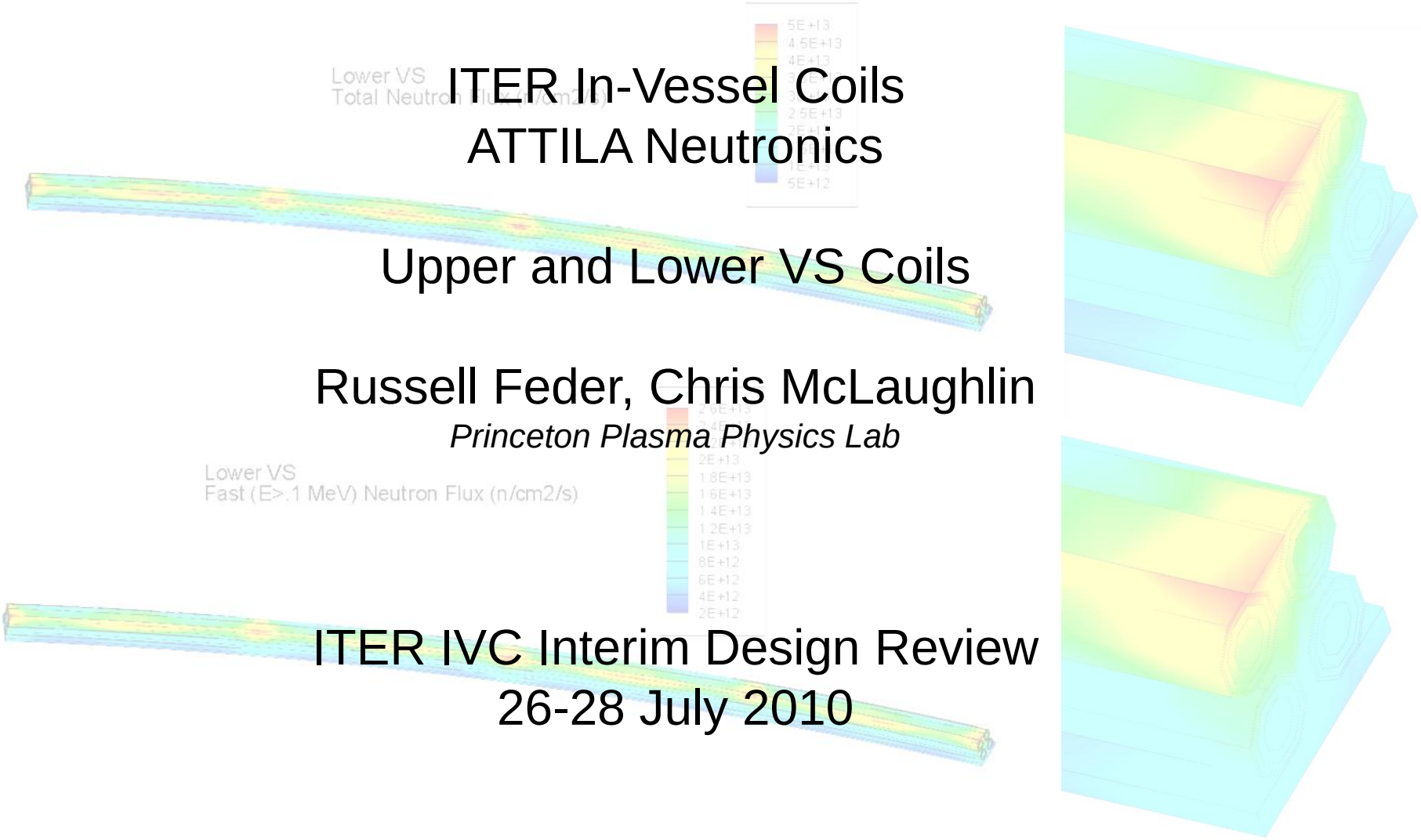
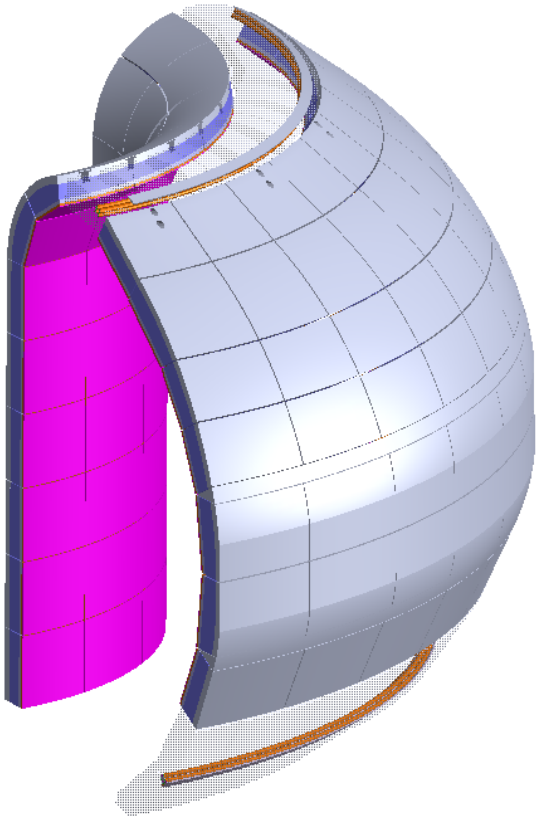


ITER IVC Interim Design Review
26-28 July 2010

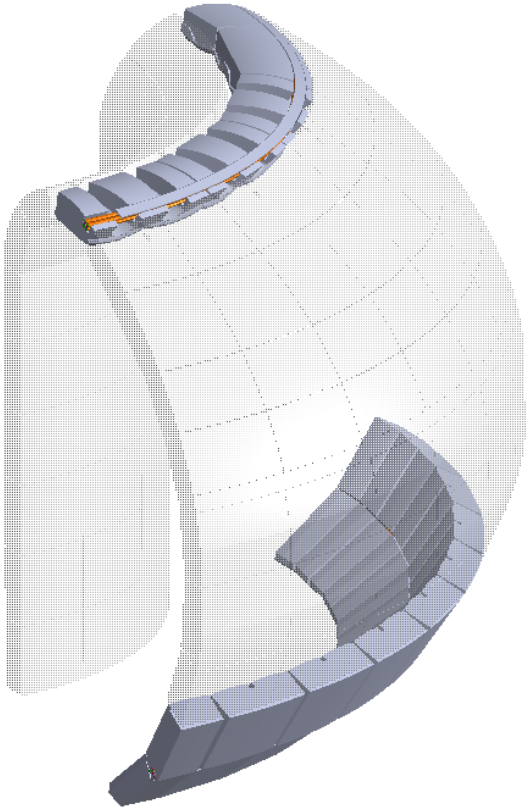
Upper and Lower VS Neutronics Analysis Model

- 90 degree model
- Mixed simplified A-Lite04 BSM with Detailed BSM Around the VS Coils
- "Core" ITER analysis model → No port extensions or external coils included

Upper and Lower VS 90 degree Sector



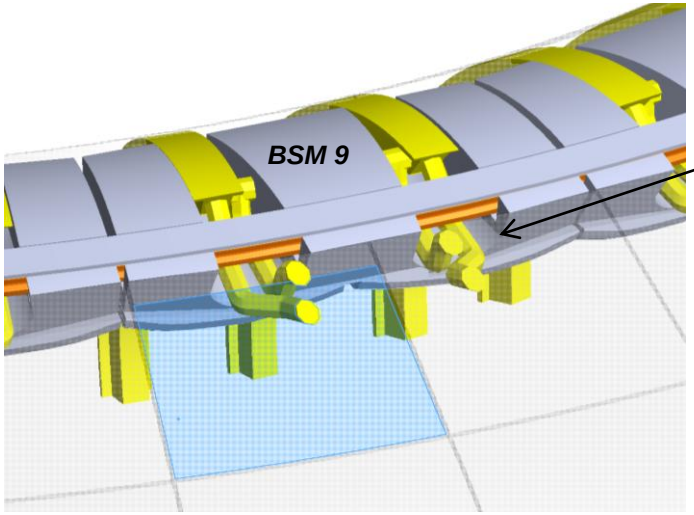
Simplified A-Lite04 BSM



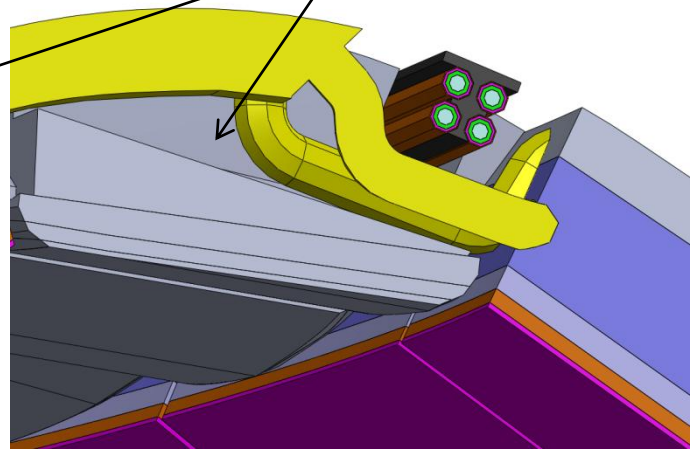
Detailed Shaped BSM Covering VS Coils

Upper and Lower VS Neutronics Analysis Model

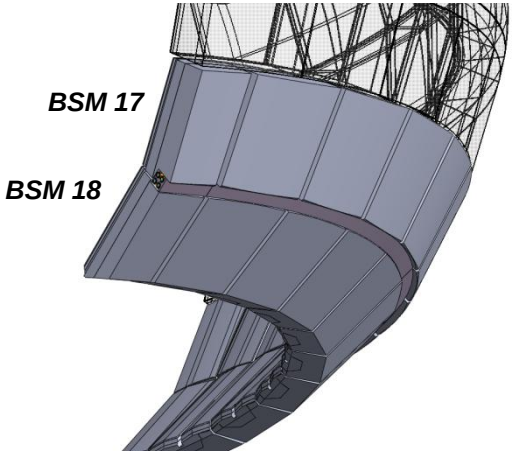
Details Around the Upper VS Coil



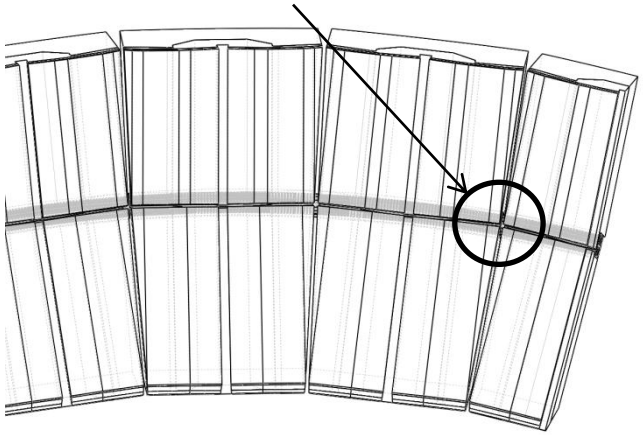
Cavities in the back of BSM 9 are needed to provide installation clearance for the inboard blanket water piping and for the upper VS coils



Details Around the Lower VS Coil

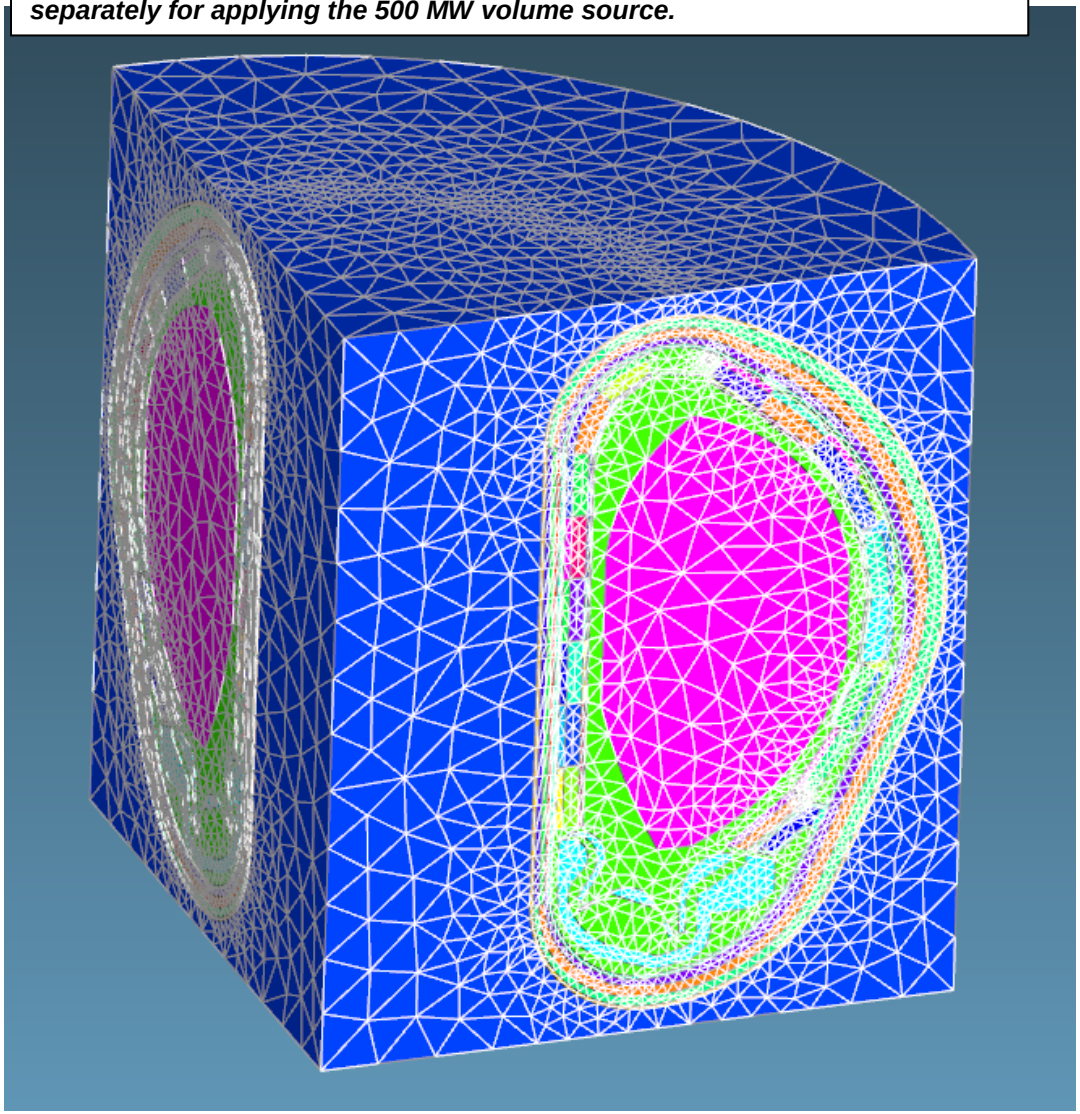


Peak Lower VS Loads are due to streaming through the gaps where BSM 17 and 18 interface.



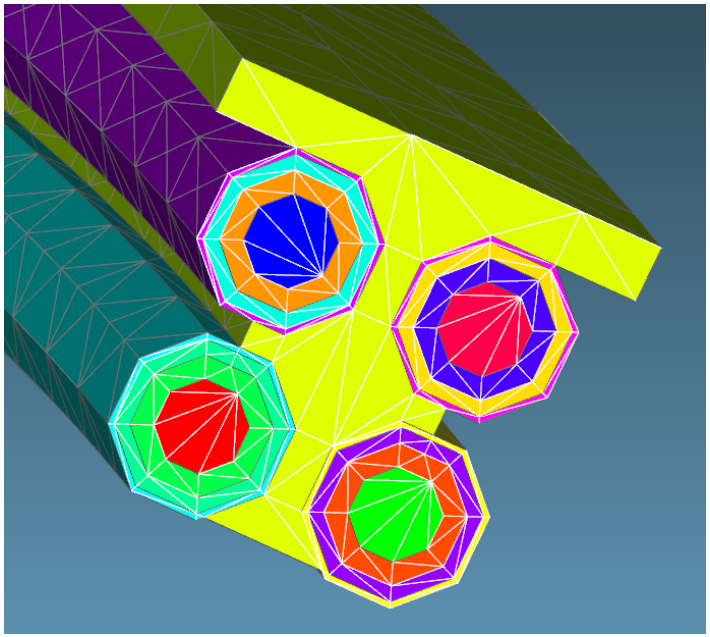
Upper and Lower VS Neutronics Analysis Model

This is a view of the meshed ATTILA model. The dark blue and light green volumes are the "Void" parts. The plasma region is also void but is modeled separately for applying the 500 MW volume source.



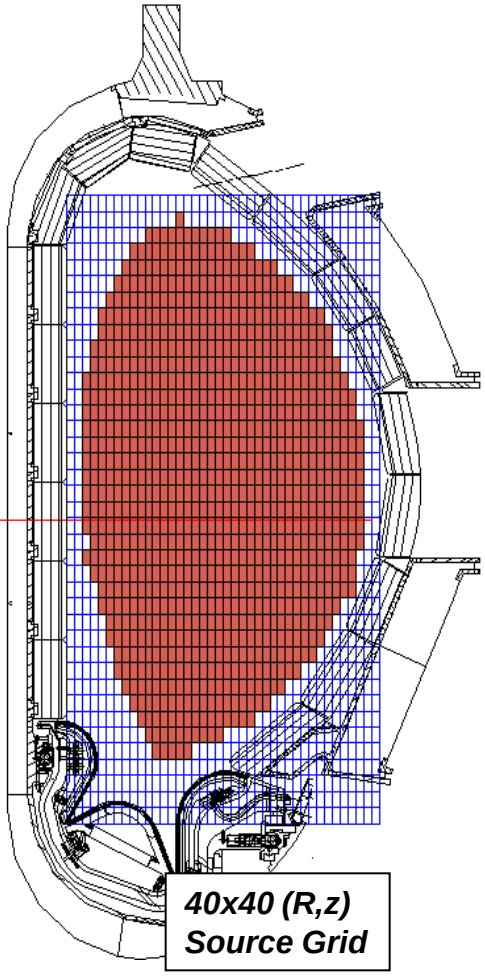
Mesh: 1.6M Cells
Sn32, P3
46-neutron, 21-gamma
reflecting-reflecting B.C.

This is a section through the Upper VS coil model showing the ATTILA mesh. Round objects are modeled as octogons to help resolve the mesh.

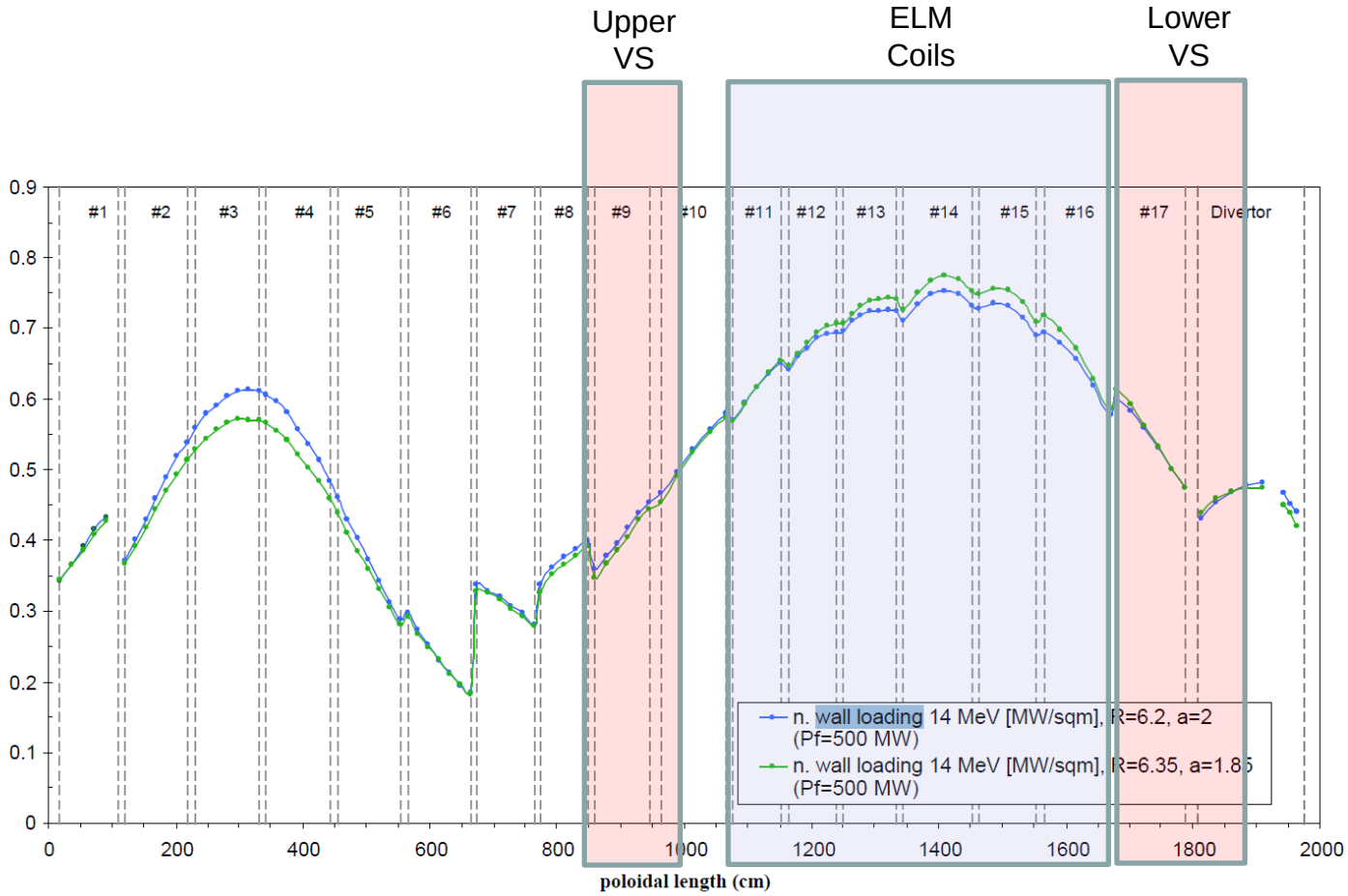


Upper and Lower VS Neutronics – Neutron Source Definition

- ***MCNP and Attila Use a Common 500 MW Neutron Source Definition***
- ***Significant Poloidal variation as illustrated by the Neutron Wall Loading***



40x40 (R,z) Source Grid

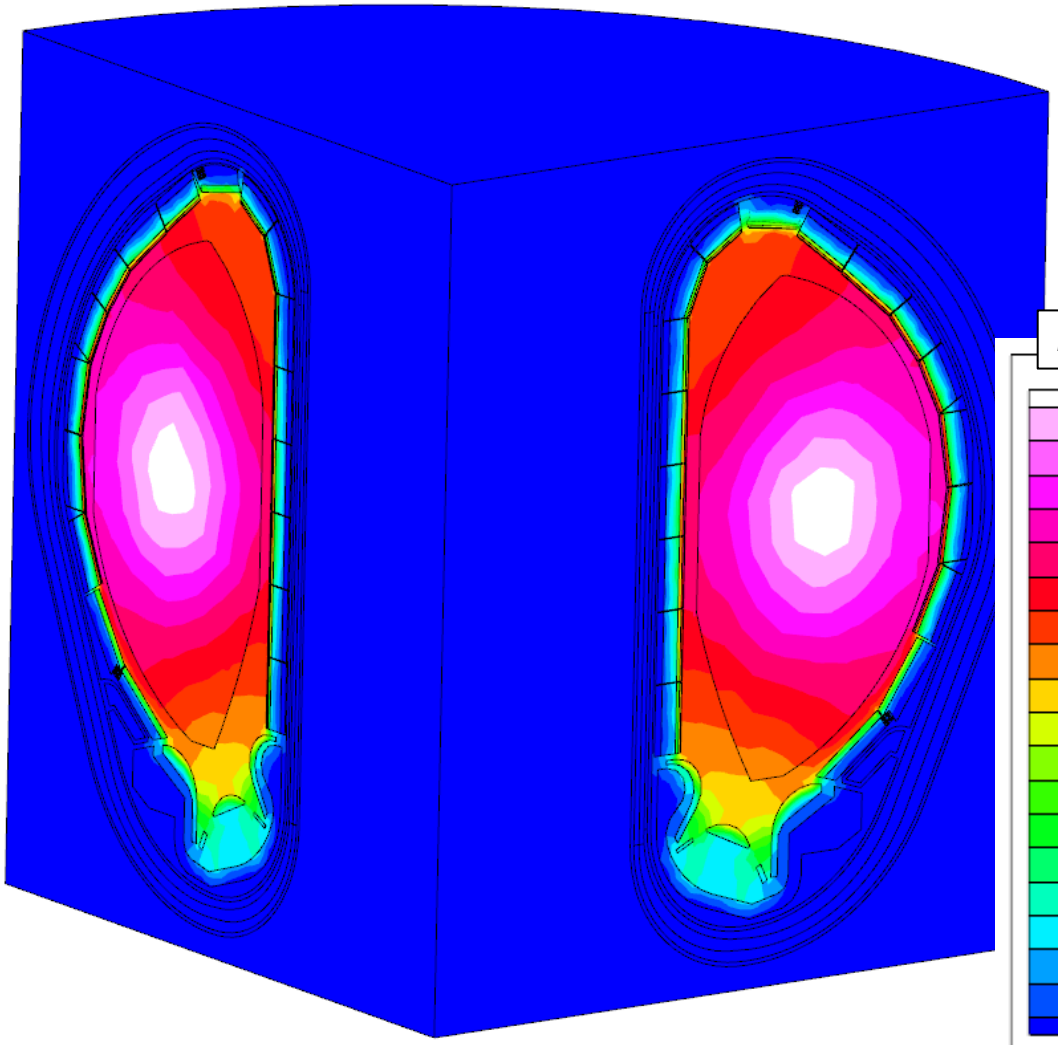


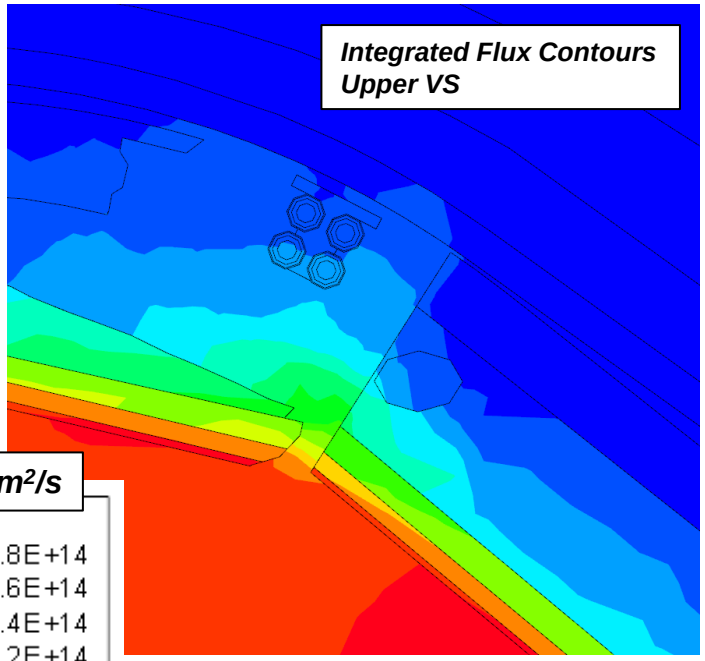
Wall Loading = Incident 14 MeV Neutron <u>Current</u>

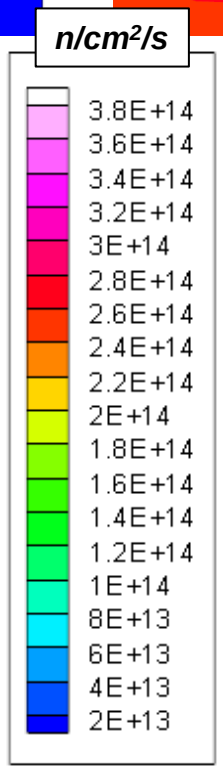
Ref: Figure 4.1.3 from the ITER Nuclear Analysis Report (NAR)
H. Iida, V. Khripunov, L. Petrizzi, G. Federici G 73 DDD 2 W 0.2
July 2004

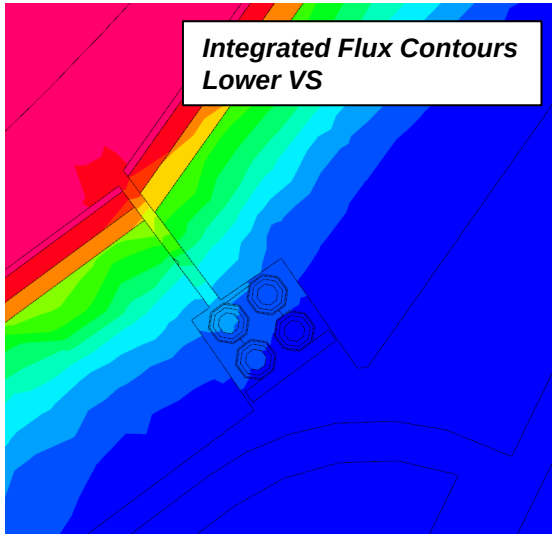
Global Model Integrated Neutron Flux

This plot shows integrated neutron flux contours from the global upper and lower VS ATTILA neutronics analysis. A 90 degree sector of ITER is used so that reflecting boundary conditions can be used in ATTILA.

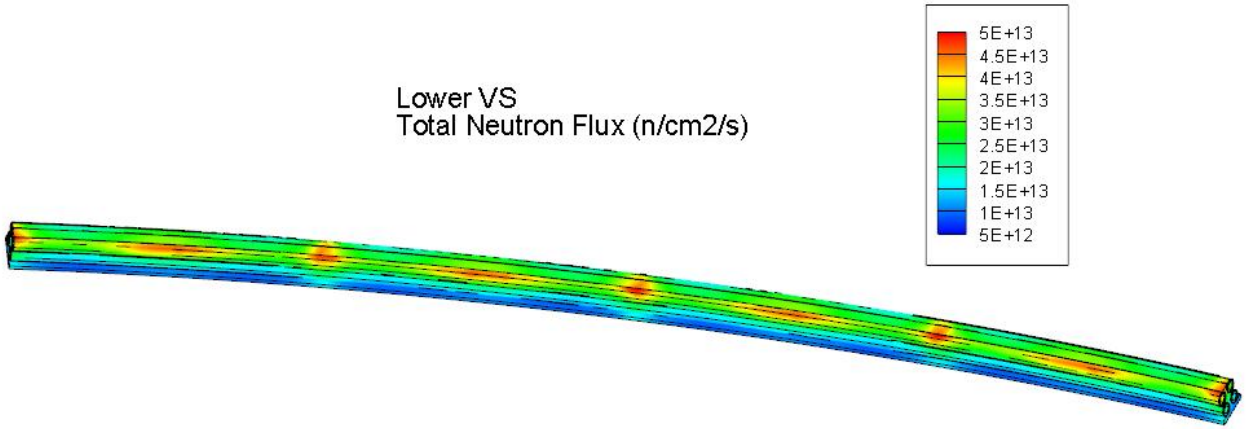


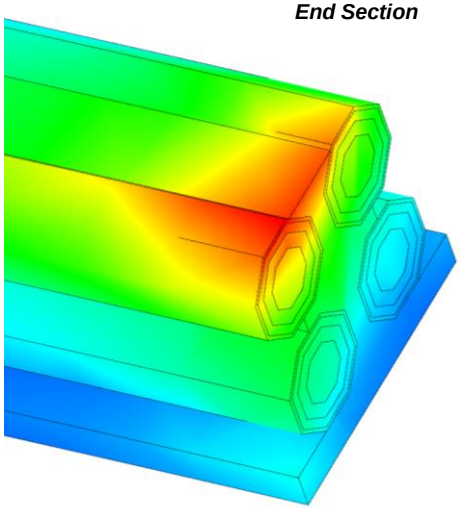


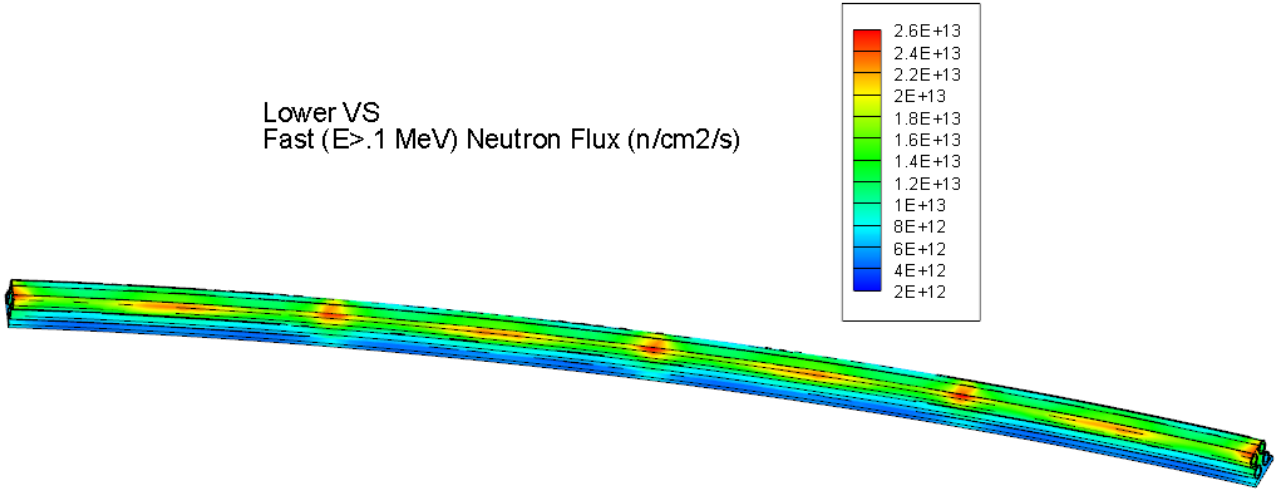


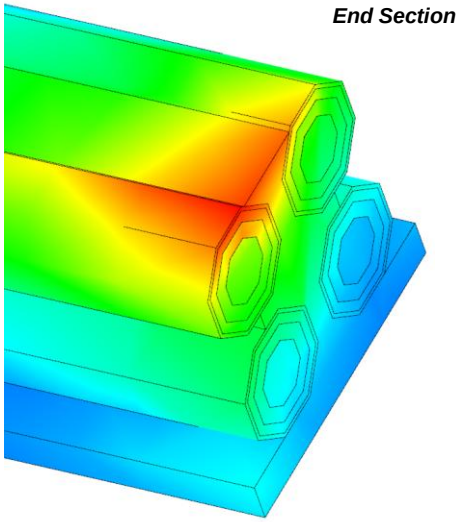


Lower VS Coil 40-deg Sector Neutronics Results



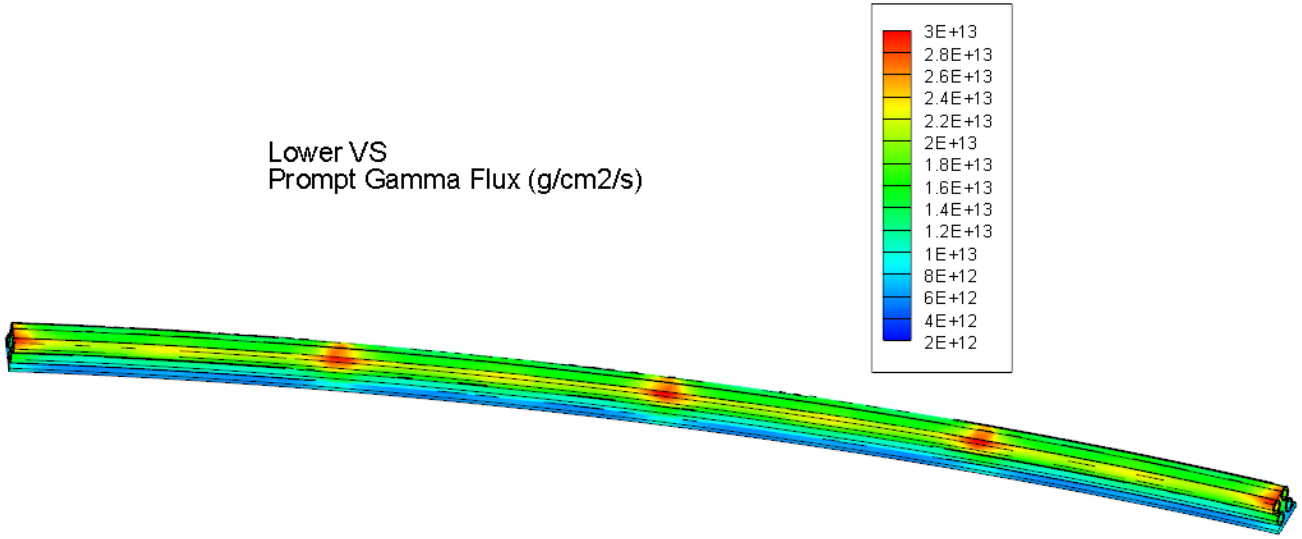




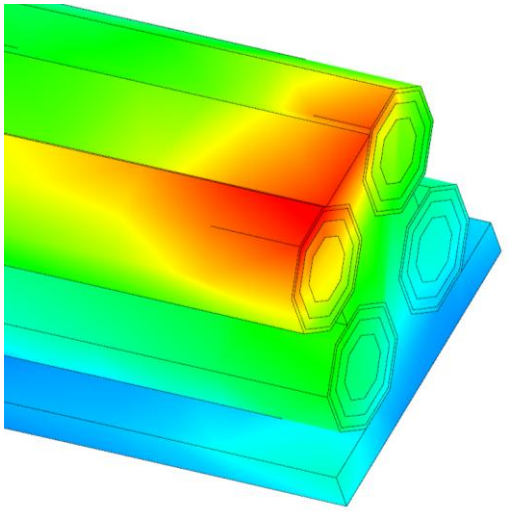


Lower VS Coil 40-deg Sector Neutronics Results

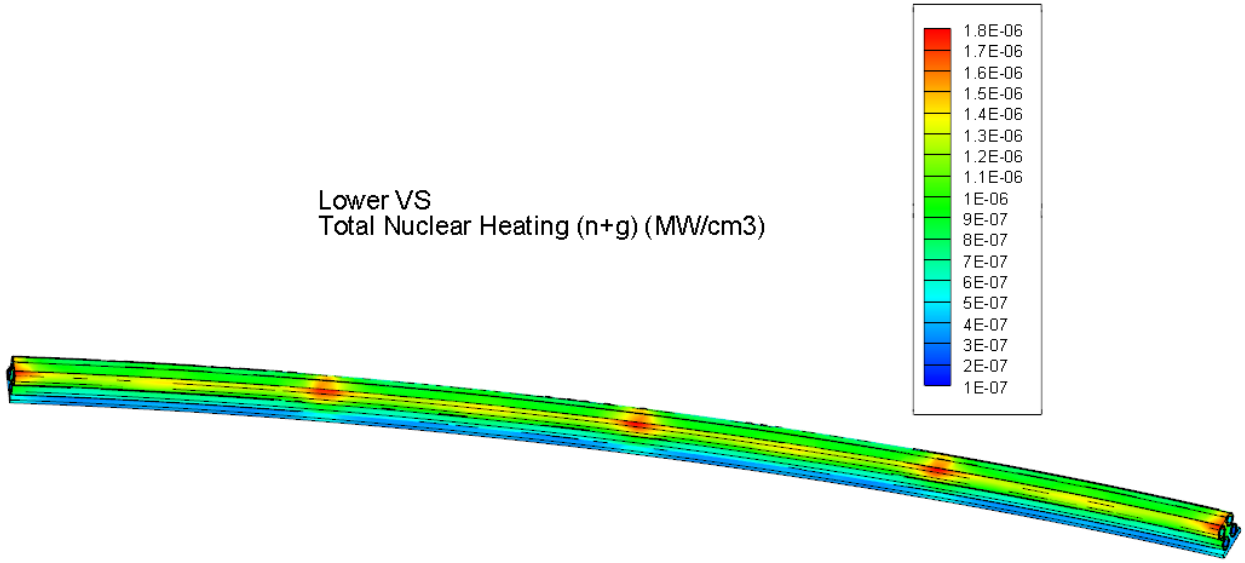
Lower VS
Prompt Gamma Flux (g/cm2/s)



End Section



Lower VS
Total Nuclear Heating (n+g) (MW/cm3)



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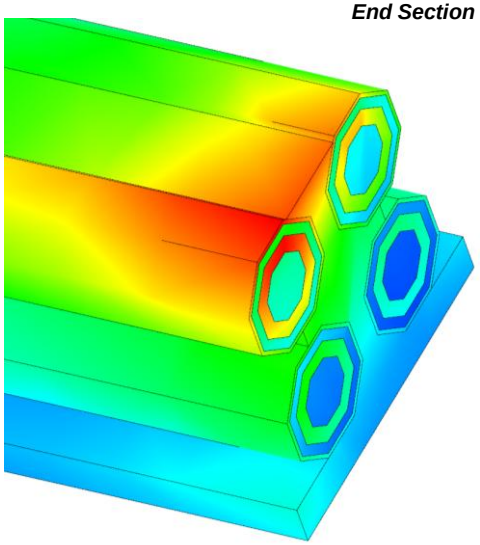
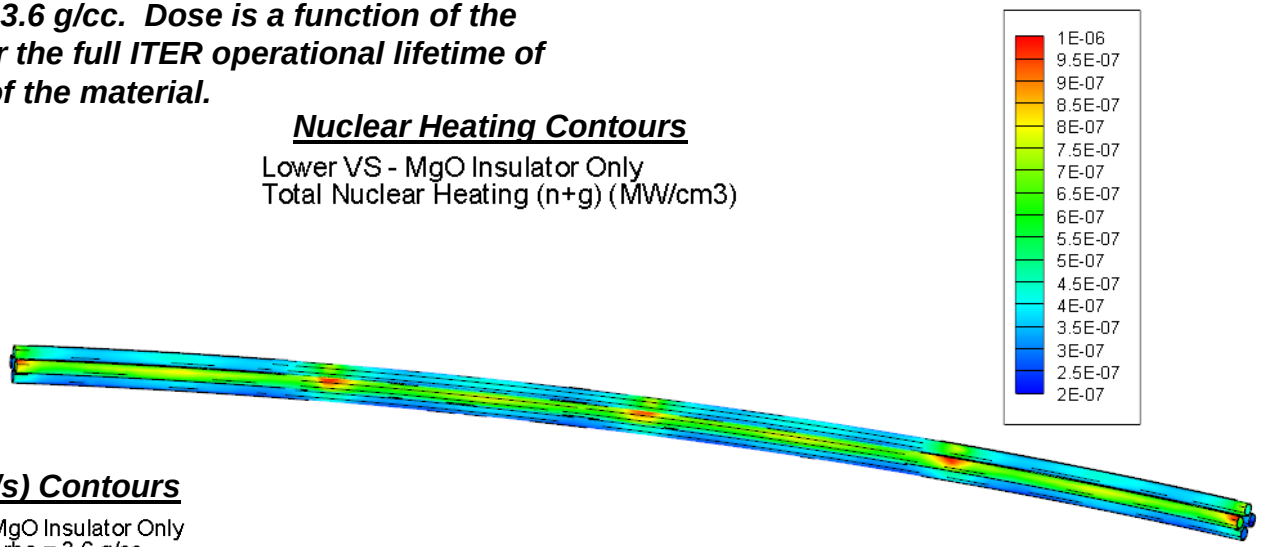


Lower VS Coil 40-deg Sector Neutronics Results – MgO Insulator

These are contour plots of nuclear heating and dose to the MgO insulator layer based on an insulator density of 3.6 g/cc. Dose is a function of the total nuclear heat (n+g) deposited over the full ITER operational lifetime of 1.7E7 seconds as well as the density of the material.

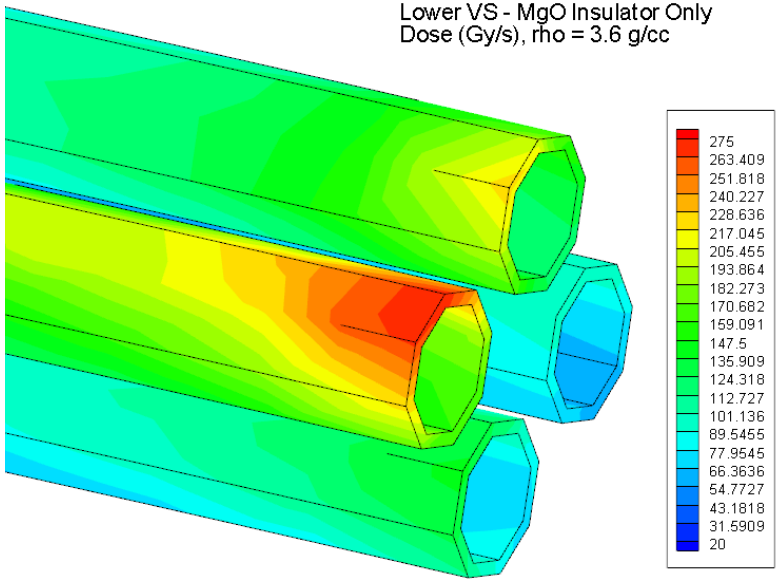
Nuclear Heating Contours

Lower VS - MgO Insulator Only
Total Nuclear Heating (n+g) (MW/cm3)



Dose (Gy/s) Contours

Lower VS - MgO Insulator Only
Dose (Gy/s), rho = 3.6 g/cc



Lower VS Coil 40-deg Sector Neutronics Results

Averaged Data – Get Peak Values from Contour Plots

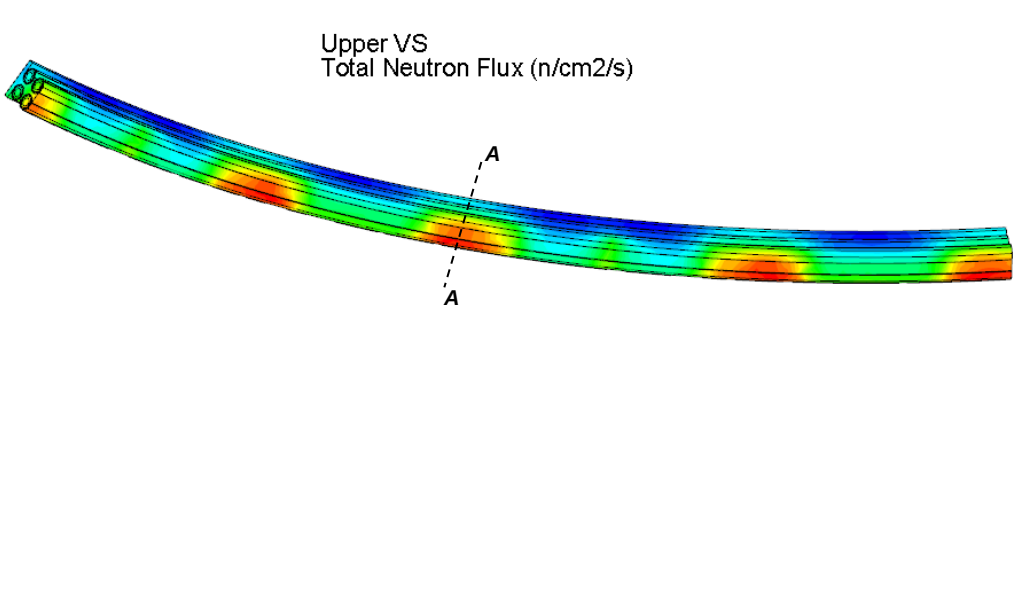
Lower VS										
	n_flux	fast n_flux	g_flux	n_heat		g_heat		total heat		***Average***
Coil 1	(n/cm2/s)	(n/cm2/s)	(g/cm2/s)	MW	MW/cc	MW	MW/cc	MW	MW/cc	***Dose (Gy/s)***
Case	1.96E+13	9.00E+12	1.26E+13	7.94E-05	4.01E-08	1.38E-03	6.97E-07	1.46E-03	7.37E-07	
Insulation	1.96E+13	8.87E+12	1.27E+13	3.80E-04	8.75E-08	1.15E-03	2.64E-07	1.53E-03	3.52E-07	***97.75***
Copper	1.95E+13	8.48E+12	1.25E+13	1.58E-04	3.23E-08	3.92E-03	8.02E-07	4.08E-03	8.35E-07	
Water	2.00E+13	7.44E+12	1.28E+13	7.57E-04	1.94E-07	2.99E-04	7.65E-08		2.70E-07	
Coil 2										
Case	2.76E+13	1.34E+13	1.71E+13	1.66E-04	8.46E-08	1.82E-03	9.28E-07	1.99E-03	1.01E-06	
Insulation	2.78E+13	1.34E+13	1.73E+13	8.01E-04	1.86E-07	1.53E-03	3.56E-07	2.34E-03	5.42E-07	***150.49***
Copper	2.82E+13	1.33E+13	1.74E+13	3.85E-04	7.94E-08	5.28E-03	1.09E-06	5.66E-03	1.17E-06	
Water	2.93E+13	1.22E+13	1.78E+13	1.48E-03	3.81E-07	4.05E-04	1.04E-07		4.85E-07	
Coil 3										
Case	1.10E+13	4.97E+12	6.86E+12	4.10E-05	2.06E-08	7.57E-04	3.81E-07	7.98E-04	4.01E-07	
Insulation	1.10E+13	4.88E+12	6.91E+12	1.98E-04	4.53E-08	6.30E-04	1.44E-07	8.28E-04	1.90E-07	***52.67***
Copper	1.09E+13	4.64E+12	6.83E+12	8.07E-05	1.64E-08	2.15E-03	4.38E-07	2.23E-03	4.55E-07	
Water	1.12E+13	4.05E+12	6.97E+12	4.03E-04	1.03E-07	1.64E-04	4.17E-08		1.44E-07	
Coil 4										
Case	1.42E+13	6.69E+12	8.95E+12	7.49E-05	3.79E-08	9.68E-04	4.90E-07	1.04E-03	5.28E-07	
Insulation	1.42E+13	6.62E+12	9.04E+12	3.56E-04	8.22E-08	8.10E-04	1.87E-07	1.17E-03	2.69E-07	***74.75***
Copper	1.41E+13	6.40E+12	8.99E+12	1.61E-04	3.30E-08	2.77E-03	5.67E-07	2.93E-03	6.00E-07	
Water	1.46E+13	5.73E+12	9.17E+12	6.55E-04	1.68E-07	2.12E-04	5.43E-08		2.22E-07	
T-Bar	1.30E+13	6.33E+12	7.71E+12	9.90E-04	2.84E-08	1.46E-02	4.19E-07	1.56E-02	4.47E-07	

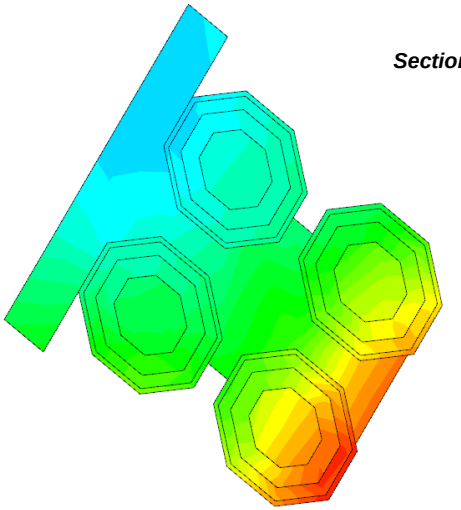
Lower VS insulator Peak dose is ~275 Gy/s

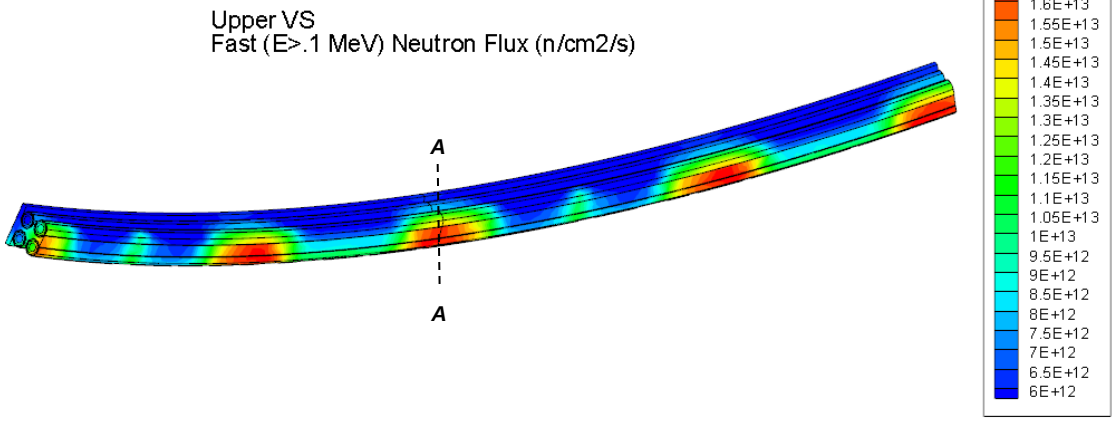
Total nuclear heat for 360 degree Lower VS → 378 kW

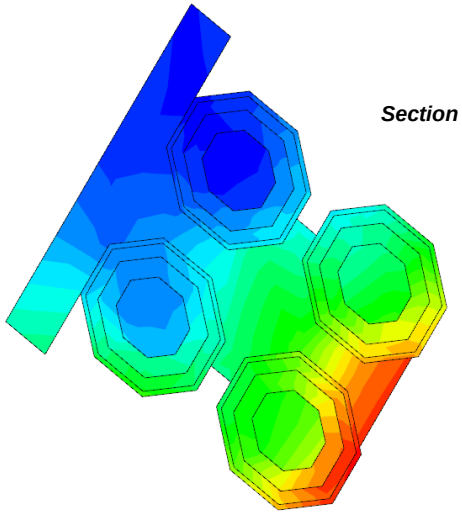
Total Nuclear Heating (kW)	***41.65***

Upper VS Coil 40-deg Sector Neutronics Results

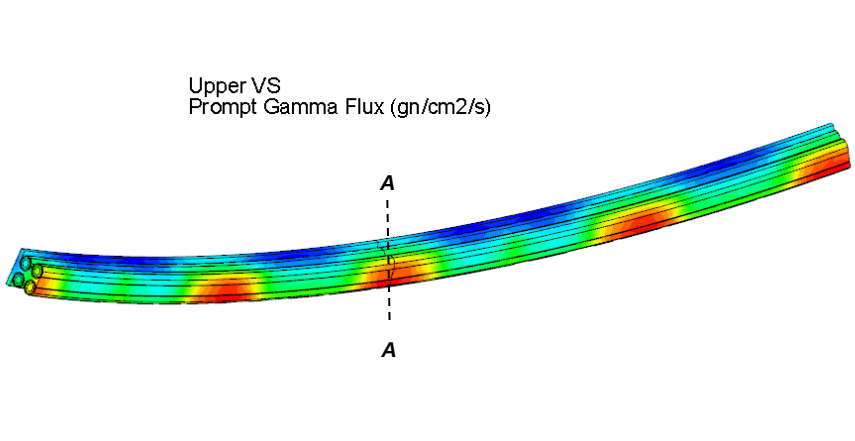


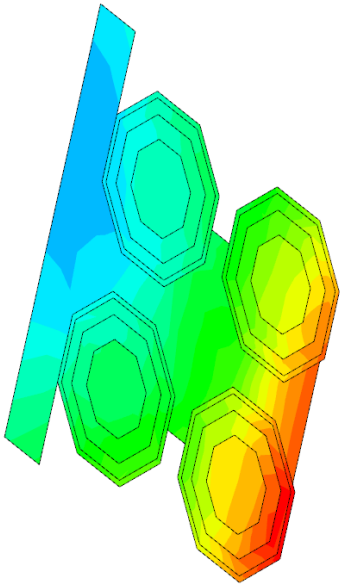




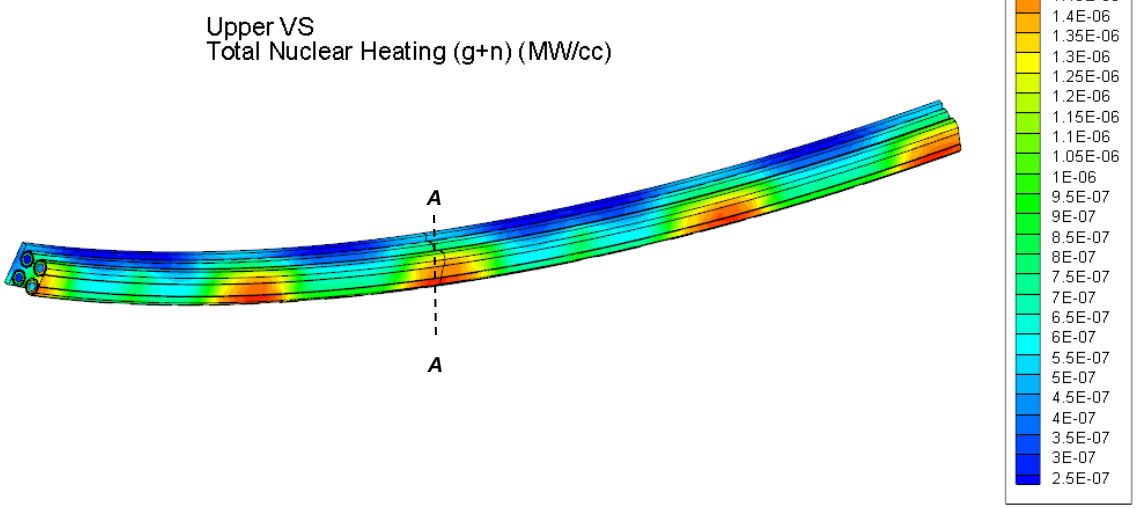


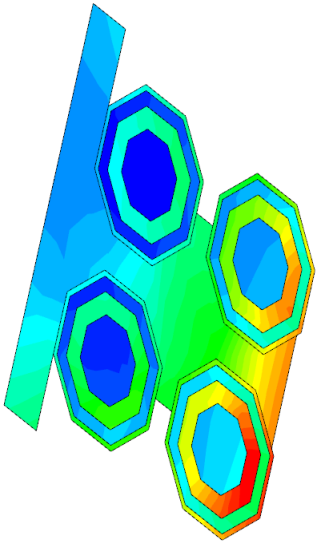
Upper VS Coil 40-deg Sector Neutronics Results





Section A-A





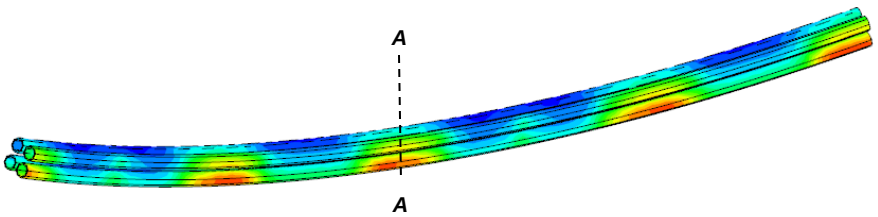
Section A-A

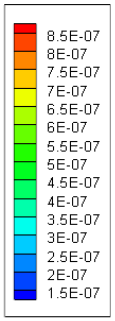
Upper VS Coil 40-deg Sector Neutronics Results – MgO Insulator

These are contour plots of nuclear heating and dose to the MgO insulator layer based on an insulator density of 3.6 g/cc. Dose is a function of the total nuclear heat (n+g) deposited over the full ITER operational lifetime of 1.7E7 seconds as well as the density of the material.

Nuclear Heating Contours

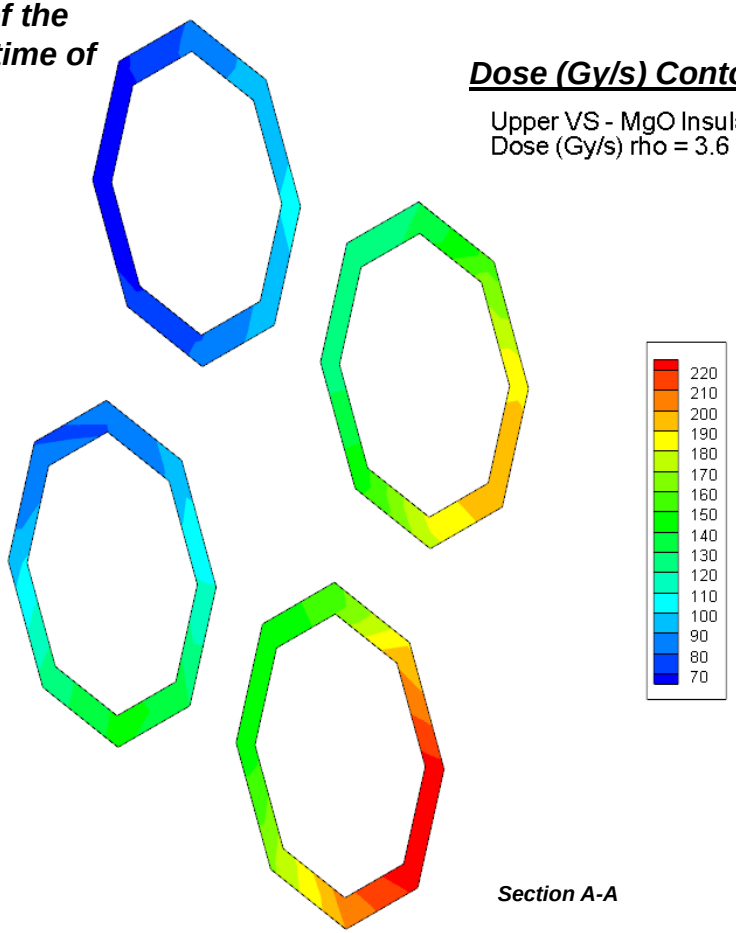
Upper VS - MgO Insulator Only
Total Nuclear Heating (g+n) (MW/cc)





Dose (Gy/s) Contours

Upper VS - MgO Insulator Only
Dose (Gy/s) rho = 3.6 g/cc



Section A-A

Upper VS Coil 40-deg Sector Neutronics Results

Averaged Data – Get Peak Values from Contour Plots

Upper VS										
	n_flux	fast n_flux	g_flux	n_heat		g_heat		total heat		***Average***
Coil 1	(n/cm2/s)	(n/cm2/s)	(g/cm2/s)	MW	MW/cc	MW	MW/cc	MW	MW/cc	***Dose (Gy/s)***
Case	1.63E+13	7.74E+12	1.20E+13	7.04E-05	4.62E-08	1.02E-03	6.69E-07	1.09E-03	7.15E-07	
Insulation	1.63E+13	7.69E+12	1.22E+13	3.29E-04	9.86E-08	8.48E-04	2.54E-07	1.18E-03	3.53E-07	***98.03***
Copper	1.63E+13	7.46E+12	1.20E+13	1.46E-04	3.90E-08	2.88E-03	7.67E-07	3.03E-03	8.06E-07	
Water	1.68E+13	6.68E+12	1.23E+13	5.91E-04	1.97E-07	2.20E-04	7.34E-08		2.70E-07	
Coil 2										
Case	2.05E+13	9.79E+12	1.48E+13	1.03E-04	6.69E-08	1.26E-03	8.17E-07	1.36E-03	8.84E-07	
Insulation	2.04E+13	9.68E+12	1.50E+13	4.69E-04	1.39E-07	1.05E-03	3.11E-07	1.52E-03	4.50E-07	***124.89***
Copper	2.03E+13	9.38E+12	1.48E+13	2.10E-04	5.53E-08	3.56E-03	9.38E-07	3.77E-03	9.93E-07	
Water	2.09E+13	8.42E+12	1.51E+13	7.87E-04	2.59E-07	2.72E-04	8.95E-08		3.49E-07	
Coil 3										
Case	1.09E+13	5.04E+12	7.21E+12	3.58E-05	2.34E-08	6.07E-04	3.98E-07	6.43E-04	4.21E-07	
Insulation	1.09E+13	4.95E+12	7.26E+12	1.69E-04	5.05E-08	5.05E-04	1.51E-07	6.75E-04	2.01E-07	***55.89***
Copper	1.08E+13	4.71E+12	7.15E+12	7.06E-05	1.87E-08	1.72E-03	4.56E-07	1.79E-03	4.74E-07	
Water	1.11E+13	4.12E+12	7.30E+12	3.28E-04	1.09E-07	1.31E-04	4.34E-08		1.52E-07	
Coil 4										
Case	1.40E+13	6.56E+12	9.22E+12	5.97E-05	3.86E-08	7.80E-04	5.05E-07	8.39E-04	5.43E-07	
Insulation	1.39E+13	6.46E+12	9.30E+12	2.77E-04	8.18E-08	6.51E-04	1.92E-07	9.29E-04	2.74E-07	***76.02***
Copper	1.38E+13	6.19E+12	9.18E+12	1.20E-04	3.16E-08	2.21E-03	5.80E-07	2.33E-03	6.12E-07	
Water	1.42E+13	5.47E+12	9.36E+12	4.83E-04	1.58E-07	1.69E-04	5.54E-08		2.14E-07	
T-Bar	1.25E+13	6.12E+12	7.89E+12	8.10E-04	3.00E-08	1.15E-02	4.26E-07	1.23E-02	4.56E-07	

Upper VS insulator Peak dose is ~220 Gy/s

Total nuclear heat for 360 degree Upper VS → 284 kW

Total Nuclear Heating (kW)	***31.48***