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Neutronics Analysis for ITER Cable Looms

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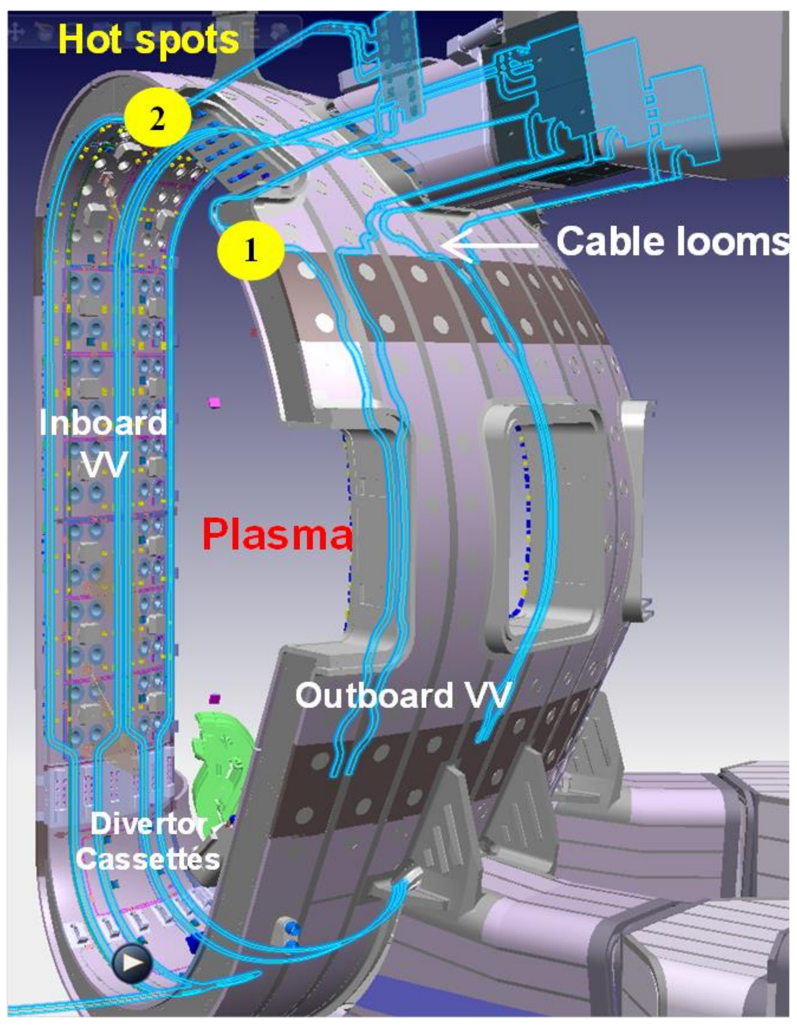
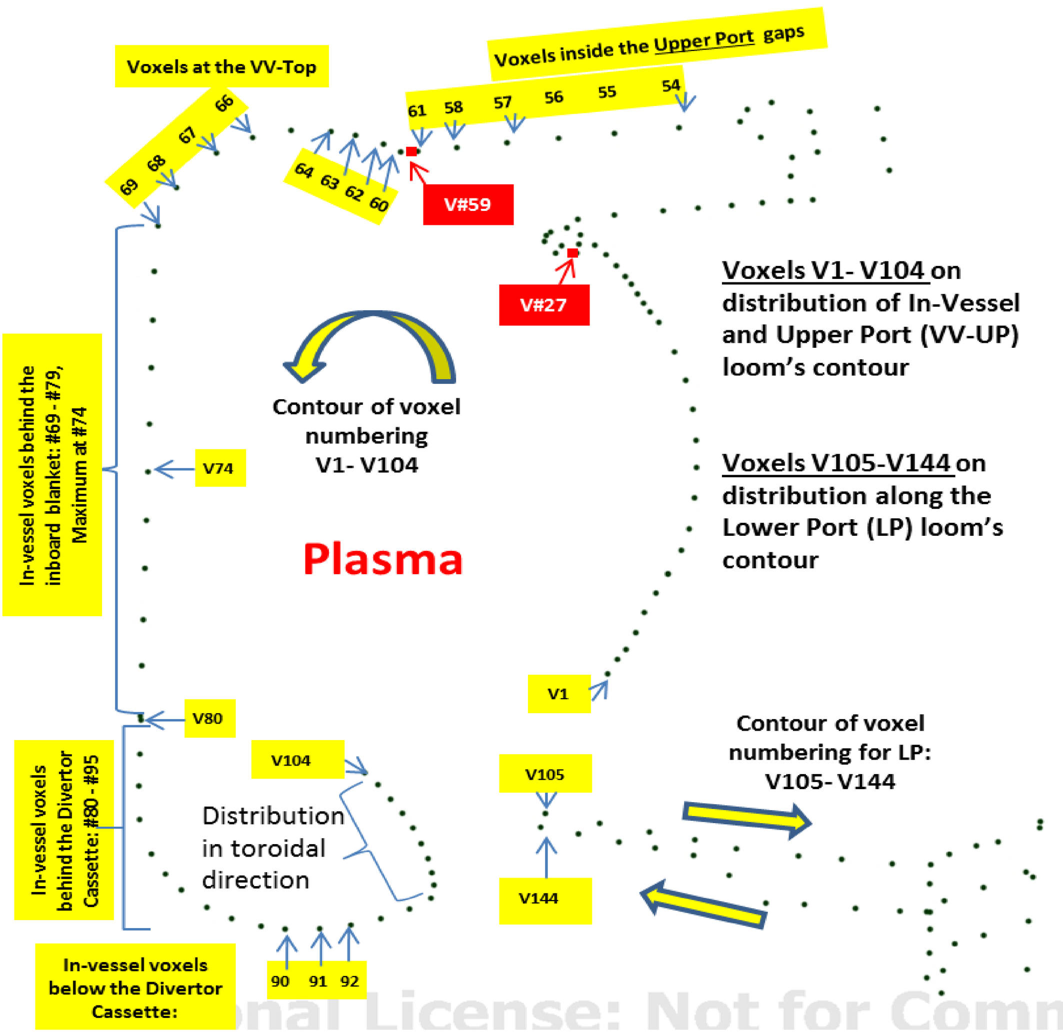
Introduction and Motivation: In-vessel and Divertor Cable Looms

- **Neutronics support** for the design development of the ITER Diagnostics cabling system including its cable looms.
- The cable looms are distributed all around the ITER and attached to the inner wall of the Vacuum Vessel (VV) and under the divertor cassettes.
- The results include distributions of neutronics characteristics calculated with the MCNP5 3D Monte Carlo code assuming ITER operation with 0.54 Full Power Years on 500 MW fusion power of DT neutron source defined in the standard ITER B-lite neutronics model.
- The importance of precise calculation of nuclear heating distribution along the in-vessel cable looms is stressed in Ref. work [1]

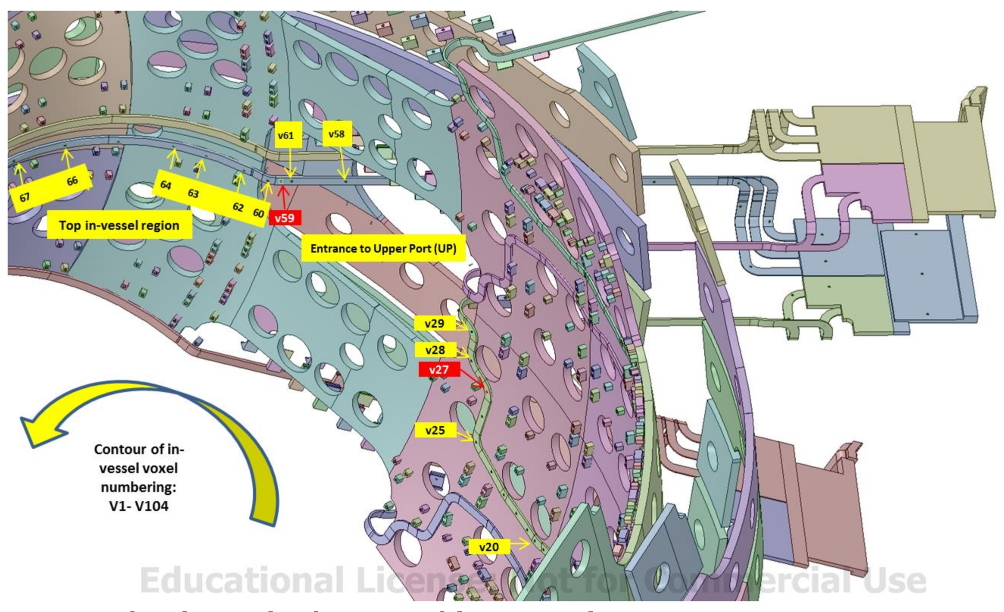
Loom's voxelization - for MCNP tallying



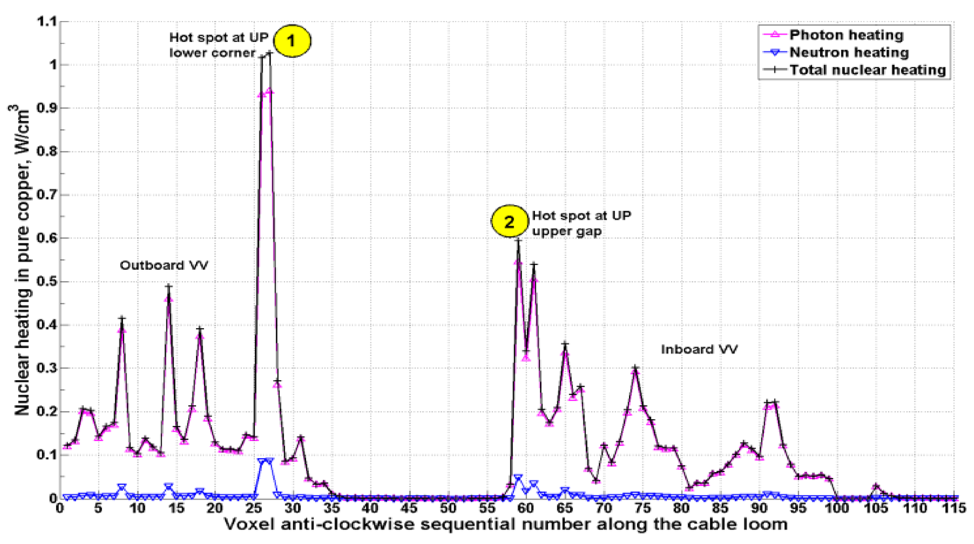
CAD model of ITER sector with highlighted counters of cable looms and two radiation hot spots.



Distribution of the MCNP voxels in the poloidal direction along the in-vessel looms (outboard-VV, UP, top-VV, inboard-VV, divertor cassette region), Lower Port (LP).



Voxels along the in-vessel loom at the entrance to Upper Port and Top of the in-vessel region



Nuclear heating in copper of in-vessel cable loom with labelling of two hot spots at Upper Port (UP).

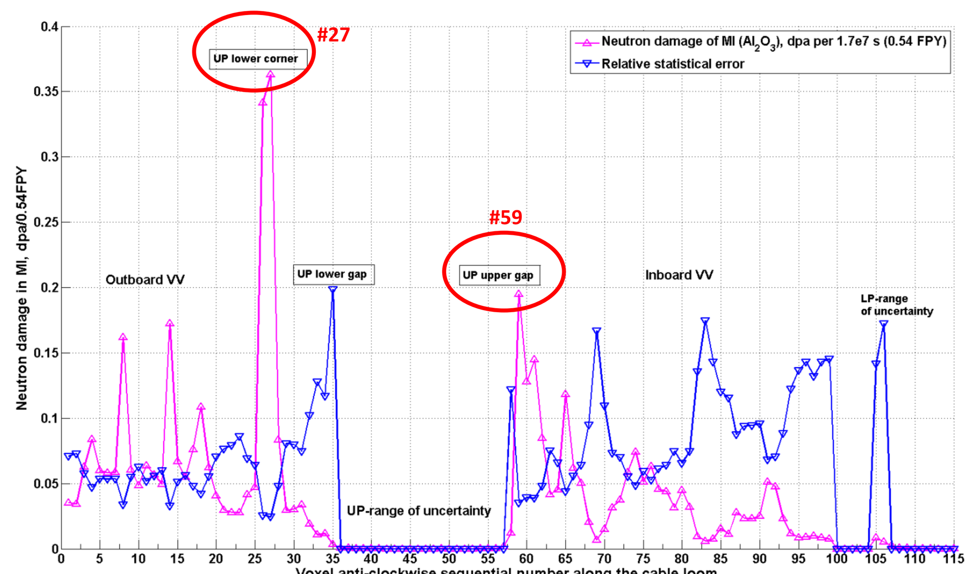
Transmutation of Copper and Gold

- **The major transmutation of gold and copper** is observed on the (n,g) radiative capture reactions.
- **The maximum transmutation** was observed in gold, amounted 3 atom% for the highest radiation spot at the in-vessel loom, and 1 atom% for the divertor cassette.
- **Transmutation of copper is 100 times less than gold**; it is 0.03 atom% for the hot-spot at divertor and 0.01 atom% for in-vessel loom.

$$^{197}Au(n,\gamma)\,^{198}Au \rightarrow \,^{198}Hg + \beta^-$$

$^{65}Cu(n,\gamma)^{66}Cu$ (T1/2 = 5 min beta decay)--> ^{66}Zn

$^{63}Cu(n,\gamma)^{64}Cu$ (T1/2 = 12.7 h positron decay)--> ^{64}Ni



Neutron damage (dpa/0.54 FPY) in Mineral Insulator (MI) made of Al_2O_3 for the in-vessel cable loom.

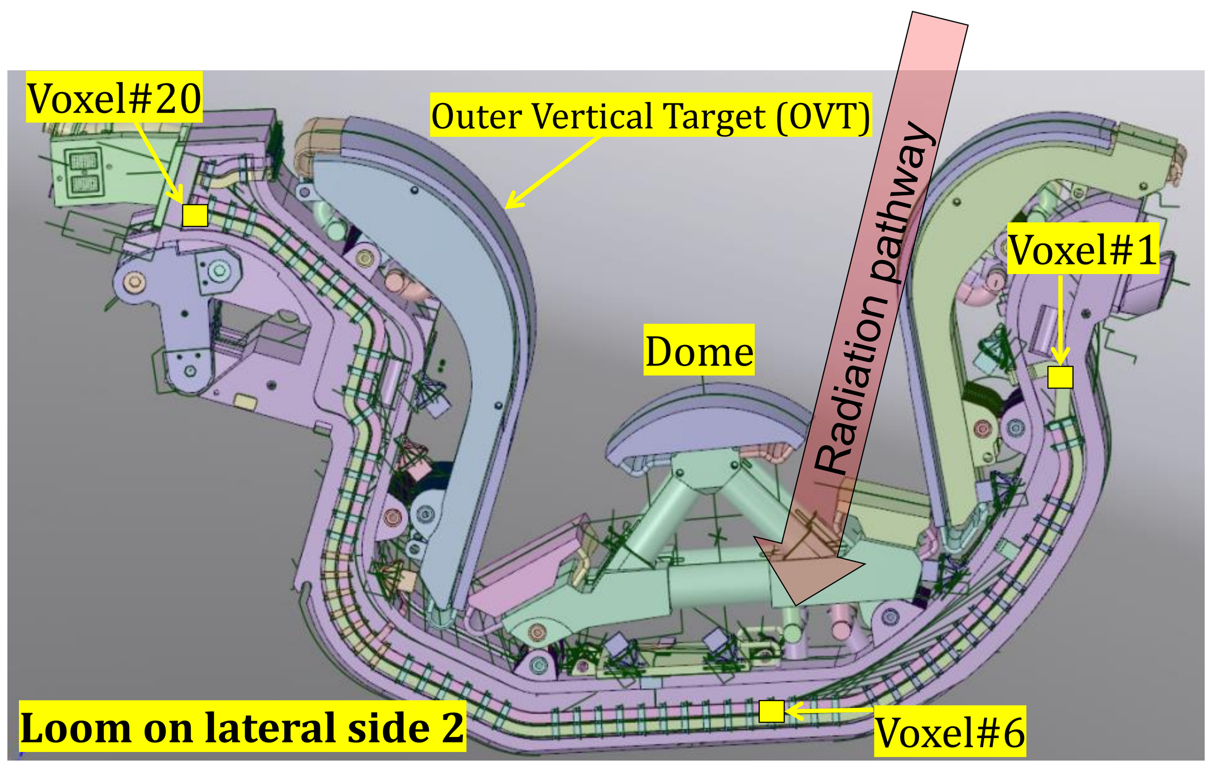
Table 1: Transmutation: $^{63}Cu \rightarrow {}^{64}Ni$ and $^{65}Cu \rightarrow {}^{66}Zn$

Voxel number at peak	Reaction of transmutation	^{63}Cu transmutation, appm/0.54 FPY	^{65}Cu transmutation, appm/0.54 FPY
Voxel #6 on loom of divertor side#2	total (n,p)	8.10E+00	9.28E-01
	total (n,He)	1.27E+00	2.29E-01
	(n,g)	3.66E+02	1.76E+02
Voxel #17 on loom of divertor side#2	total (n,p)	5.57E+00	6.12E-01
	total (n,He)	8.44E-01	1.49E-01
	(n,g)	2.67E+02	1.28E+02
Voxel #27 on in-vessel loom	total (n,p)	1.54E+01	1.75E+00
	total (n,He)	2.38E+00	4.38E-01
	(n,g)	1.67E+02	9.07E+01
Voxel #59 on in-vessel loom	total (n,p)	8.41E+00	9.74E-01
	total (n,He)	1.32E+00	2.45E-01
	(n,g)	1.20E+02	4.07E+01

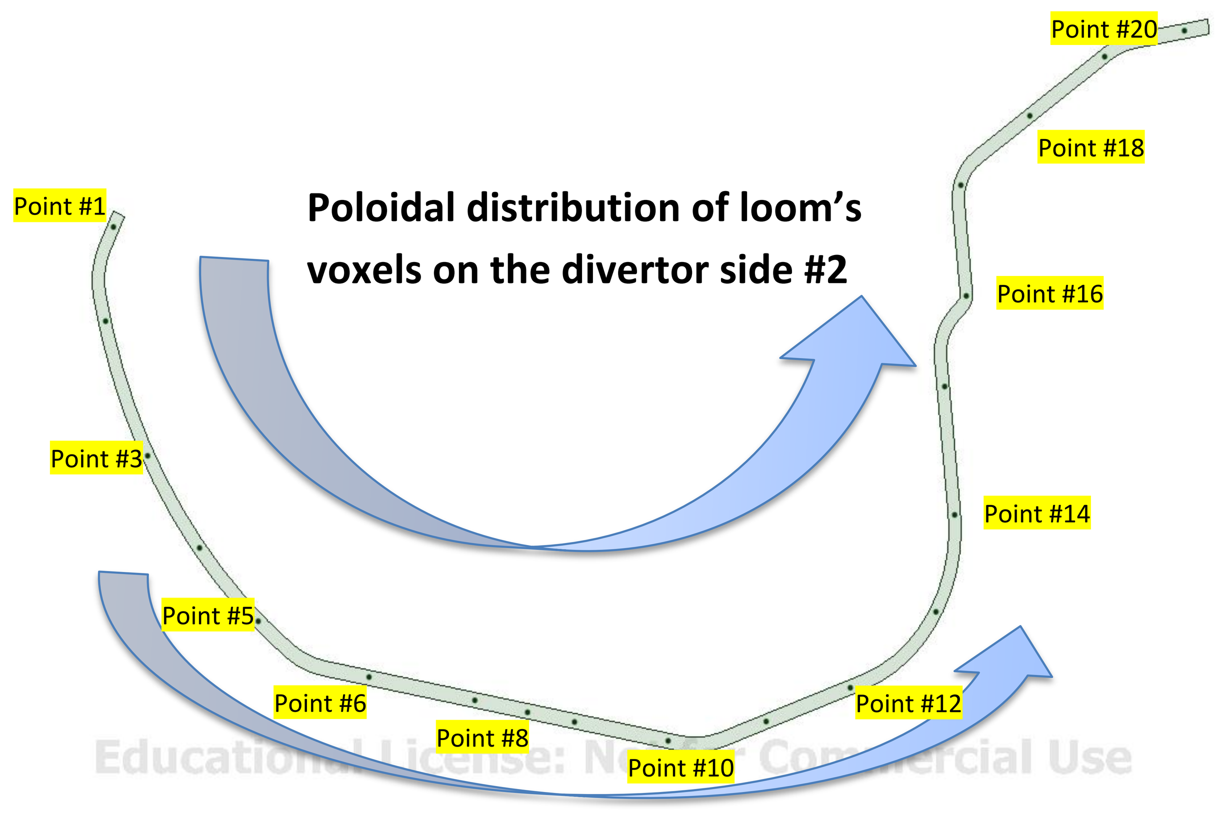
Table 2: Gold transmutation used in cable looms

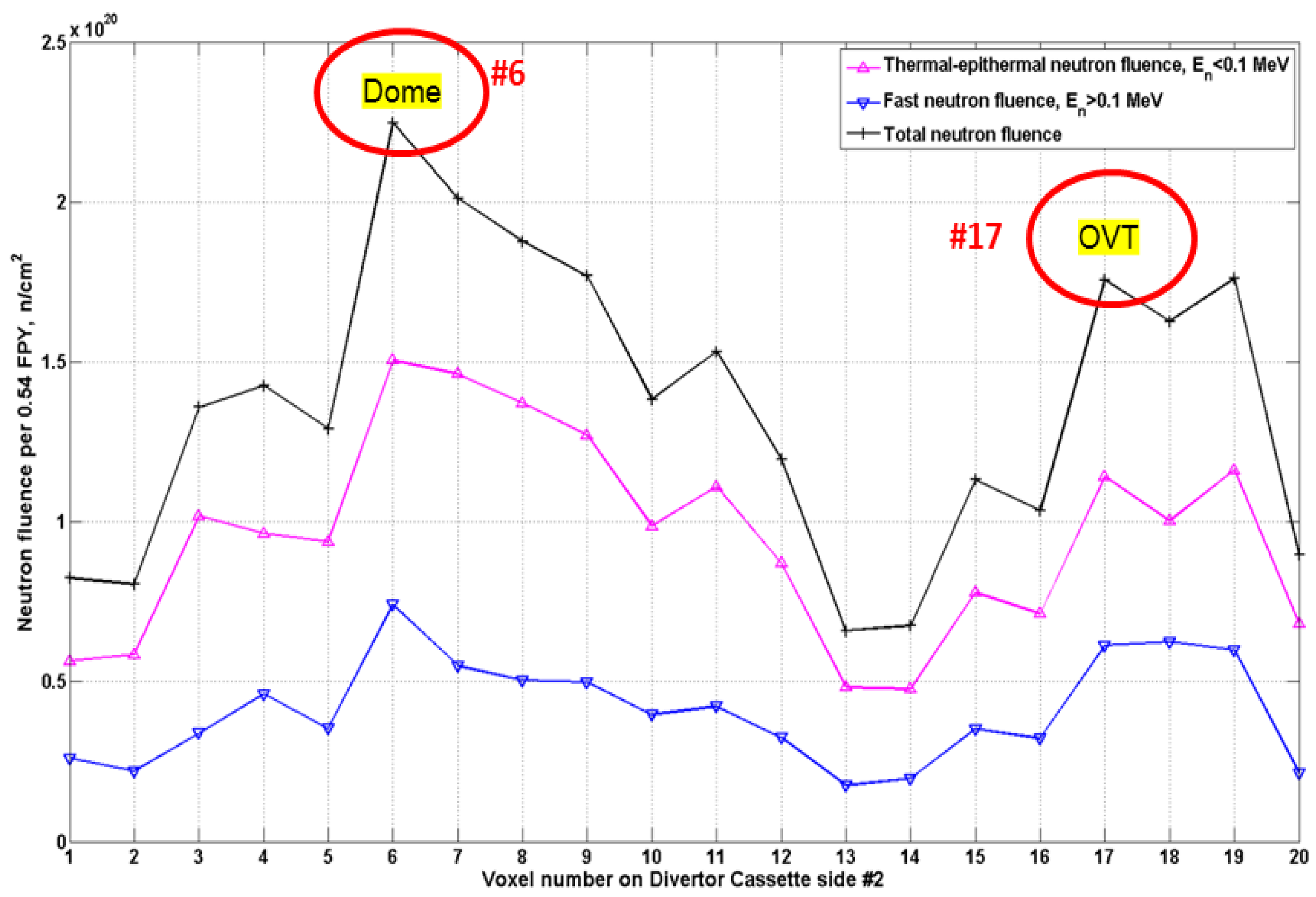
Voxel number at peak of radiation	Reaction of transmutation	Au transmutation, appm/0.54 FPY	Relative stat. error of Au transmut. reaction
Voxel #6 on loom of divertor side#2	total (n,p)	3.86E-02	4.55E-02
	total (n,He)	5.78E-03	4.61E-02
	(n,g)	1.33E+04	8.98E-02
Voxel #17 on loom of divertor side#2	total (n,p)	2.49E-02	5.69E-02
	total (n,He)	3.77E-03	5.77E-02
	(n,g)	1.12E+04	1.35E-01
Voxel #27 on in-vessel loom	total (n,p)	7.43E-02	2.99E-02
	total (n,He)	1.10E-02	3.04E-02
	(n,g)	2.97E+04	1.04E-01
Voxel #59 on in-vessel loom	total (n,p)	4.16E-02	4.15E-02
	total (n,He)	6.19E-03	4.21E-02
	(n,g)	1.49E+04	1.45E-01

Distributions for the looms at divertor cassette



Vertical cut of the CAD model of the divertor cassette with the cable loom on the lateral side #2.





Neutron fluence distributions for the loom along the divertor cassette lateral side #2.

Conclusions and Further Analyses

- The peak value for nuclear heating is ~1 W/cc in Inconel alloy 718. It is important is to reduce the temperature variation along the cable looms by achieving good thermal contact with the water cooled VV structure.
- Based on the nuclear heating results, the temperature distributions will be estimated later. The temperature gradients together with the nuclear transmutation of the cable's copper could result in formation of thermocouples and hence non-inductive parasitic voltages due the Radiation-Induced Thermoelectric Sensitivity (RITES) effect [2].

Acknowledgment

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References

[1] J. González, M. Clough, A. Martin, N. Woods, A. Suarez, G. Martinez, Distribution of the in-vessel diagnostics, this SOFT Conference, Sep.29th-Oct.3rd 2014.
[2] G. Vayakis, et al., Radiation-induced thermoelectric sensitivity (RITES) in ITER prototype magnetic sensors, Review of Scientific Instruments, 75 (2004) 4324-4327.

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