17-21 October, Fusion Energy Conference 2016 – Kyoto Japan

Temperature Sensitivity Analysis of Nuclear Cross Section using FENDL for Fusion-Fission System

Carlos E. Velasquez[1,2,3], Graiciany de P. Barros[4], Claubia Pereira[1,2,3], Maria Auxiliadora F. Veloso[1,2,3] and Antonella L. Costa[1,2,3]

[1] Departamento de Engenharia Nuclear - Universidade Federal de Minas Gerais
[2] Instituto Nacional de Ciência e Tecnologia de Reatores Nucleares Inovadores/CNPq
[3] Rede Nacional de Fusão (FINEP/CNPq)
[4]Comissão Nacional de Energia Nuclear-CNEN

1. Introduction

In recent years, many concepts of hybrid systems have been a focus on transmuting the long-term minor actinides and fission products, which pose a hazard that, could remain during centauries [1]. The simulation of the fusion-fission system concept must be the closed to a real one, to ensure the transmutation effectiveness. Therefore, the better representation of the system during simulation enhance its performance, transmutation over MA and increase the possibility of adequate design [2]. Most important part is to represent each material at its corresponding work temperature especially in a Tokamak system where there is system exposed to high and low temperatures, such as the first wall material and superconductors [3]. Consequently, the neutron produced in the D-T plasmas pass through different materials at different temperatures. The insertion of a transmutation layer into a Tokamak can probably modify the neutron spectrum over the others Tokamak components.

Through the years, research and development on materials make them less impure or the addition of an element improve the material performance. Hence, a continuously update of the materials should be made to respond to the improvement of them. This work aims to present the update of the fusion materials and their sensitivity under different temperatures, as well as, the neutron interaction in a Tokamak with transmutation layer and without it.

2. Methodology

The criticality calculations have been performed using the MONTEBURNS code [4], which links the MCNP [5] and the ORIGEN2.1 [6] codes. The flux calculations were made using MCNP, and the cross sections were generated at different temperatures with NJOY99.364 [7]. The library used was the FENDL3.1 [8] and the missing elements were completed with ENDF/B-VII.1 [9, 10].

The source multiplication factor (ksrc) of a subcritical assembly, driven by an external neutron source, can be expressed as the ratio of the fission neutrons and the fission neutrons plus the source neutrons. The MONTEBURNS code uses the source definition calculated from the value of the net multiplication obtained from the MCNP output file

$$k_s = \frac{(f_{mult}-1)}{(f_{mult}-1/\upsilon)} \qquad (1)$$

where f_{mult} is the total neutron multiplication factor of the system and υ is the ratio of the source neutrons to the neutron lost to fission [4,5].

2.1. Geometry

In the simulation was used a D–T Tokamak fusion neutron source which was simulated in a torus shape with energy about 14.1 MeV

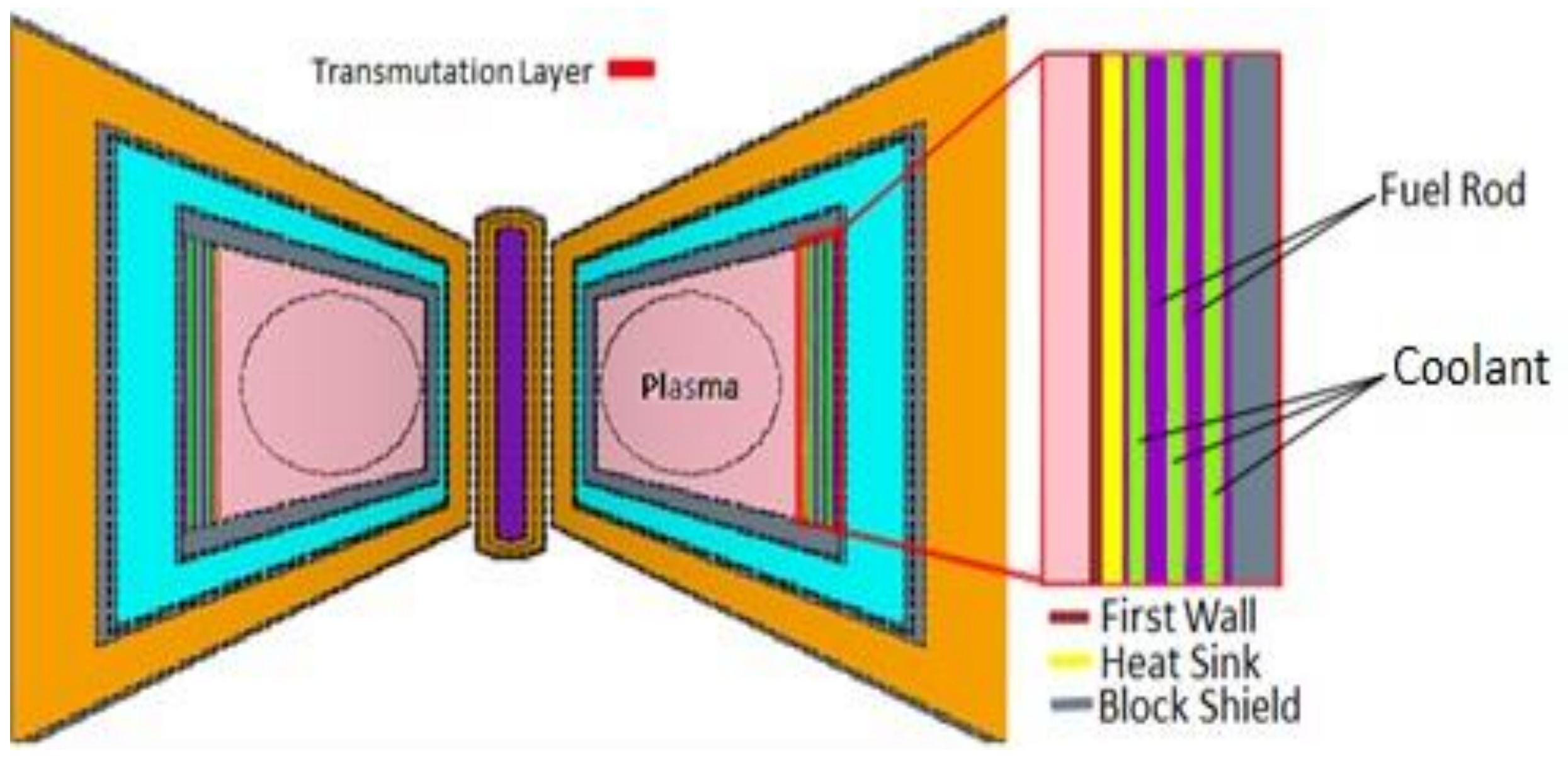


Figure 1. Tokamak with transmutation layer in red mark

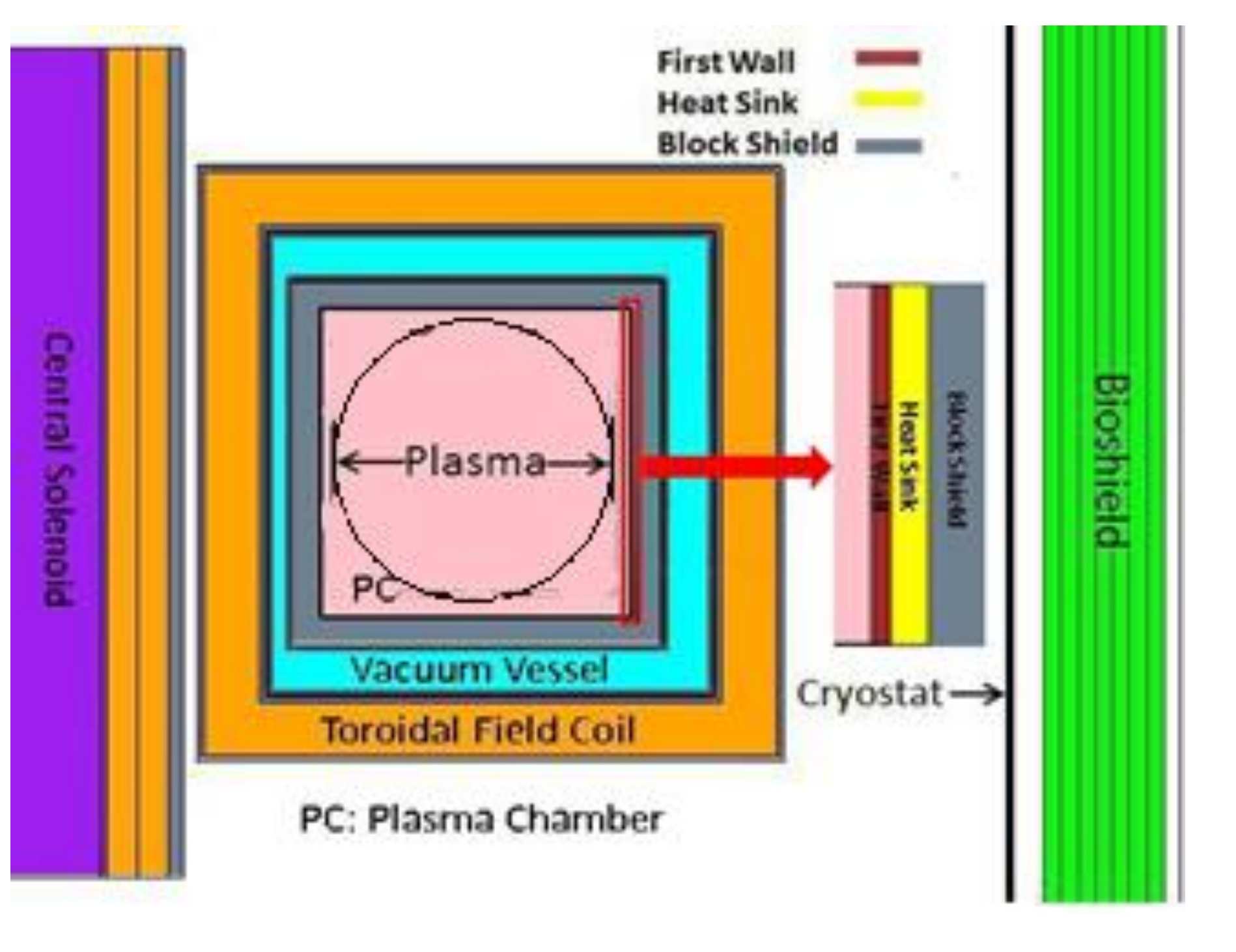


Figure 2. Tokamak without Transmutation Layer

2.2. Materials

Table 1 shows the components, materials, and temperatures used in the simulation. Most of the materials and temperatures were assumed following [13,14]. The fuel loaded into the transmutation layer is a reprocessed spent fuel by UREX+ technique [15] and spiked with thorium.

TABLE 1. MATERIALS AND TEMPERATURES FOR EACH COMPONENT [13-15

Components	Material Composition	Temperature (K)
First wall inboard/outboard	Be-S65E/W1.1TiC	1013.15
Heat Sink	CuCrZr-IG	723.15
Blanket module block shield	SS316L(N)-IG (70%) + Water (30%)	613.15
Vacuum Vessel outer/inner shell	SS316L(N)-IG	533
Vacuum Vessel in wall shield	SS304B7 (55%) + Water (45%)	434.15
Thermal Shield	SS304L	100
TFC outer/inner shell	SS316LN	80
TFC	SS316LN (47.6%)+SS316L(1.5%)+He/liq-(12.9%)+Nb3Sn(6.3%)+r-epoxy(18%)+Cu (13.7%)	80
Cryostat	SS304L	95
Shield	Concrete	300
Central solenoid structure	SS316L(N)-IG	150
CS winding pack	Jk2SS (54.7%) + SS316L(1.2%) + Inconel(0.6%) + He/liq.(11.2%) + Cu(11%) + Nb3Sn(5.5%) + r-epoxy (15.8%)	4.7
CS fill	Nb3Sn	4.7
Coolant	LiPb	613.15
Clad	HT-9	900
Nuclear Fuel	UREX+/Th	1200

3. Results

The results show the neutronic evaluation of the Tokamak with and without transmutation blanket. Figure 3 shows the neutron flux for a hybrids system based on a Tokamak with transmutation layer at work temperature WTTL and room temperature RTTL, as well as, the neutron flux for a Tokamak along their different systems at work temperature WTNTL and at room temperature RTNTL. The systems studied are: First wall, heat sink, shield block (SB), Transmutation Layer (TL) and Vacuum Vessel (VV). It can be seen that there is a big difference in the neutron flux along the different systems when is considered the transmutation layer on the Tokamak, but the differences were small for temperature variations. Besides the small differences between the work and room temperature for the neutron flux in each system, in contrast, the criticality calculations as presented in Figure 4a, shows higher differences due to the temperature variations. The absolute difference of the multiplication factor between the working temperature and the room temperature is presented in Figure 4b. The highest difference is about -1476 pcm.

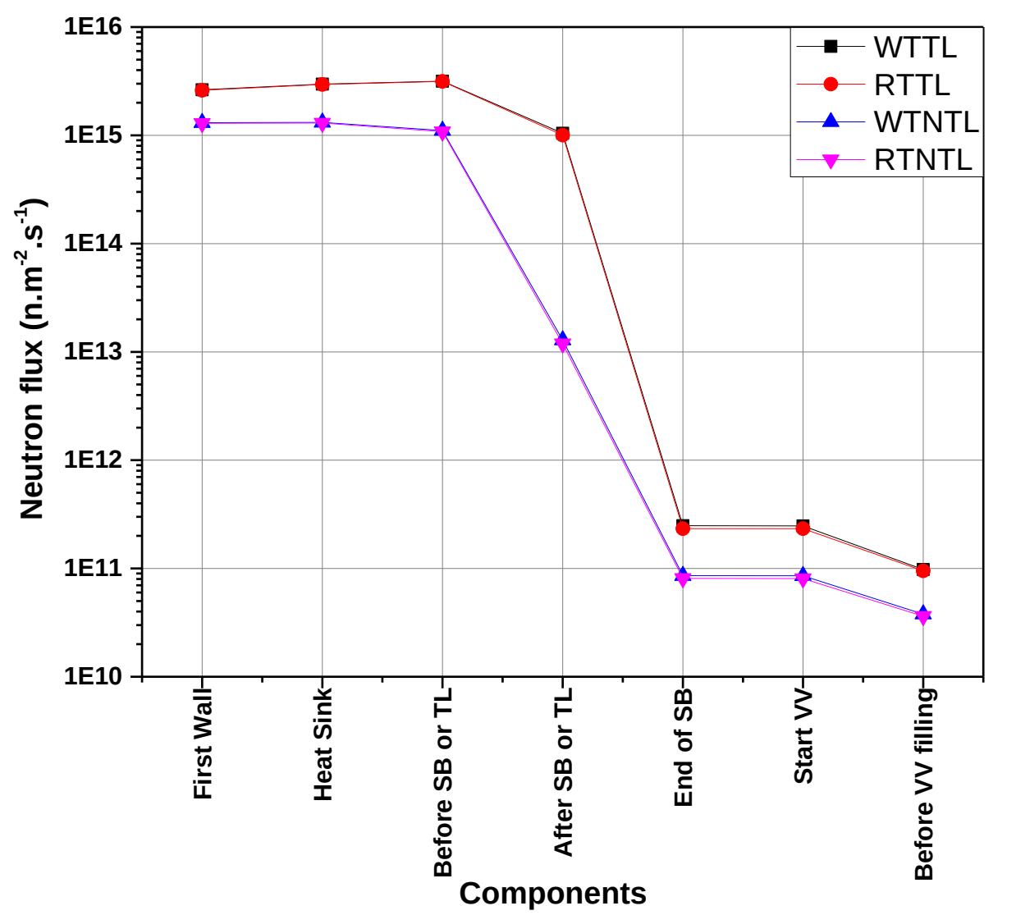


Figure 3. Neutron flux along the FFS and the Tokamak

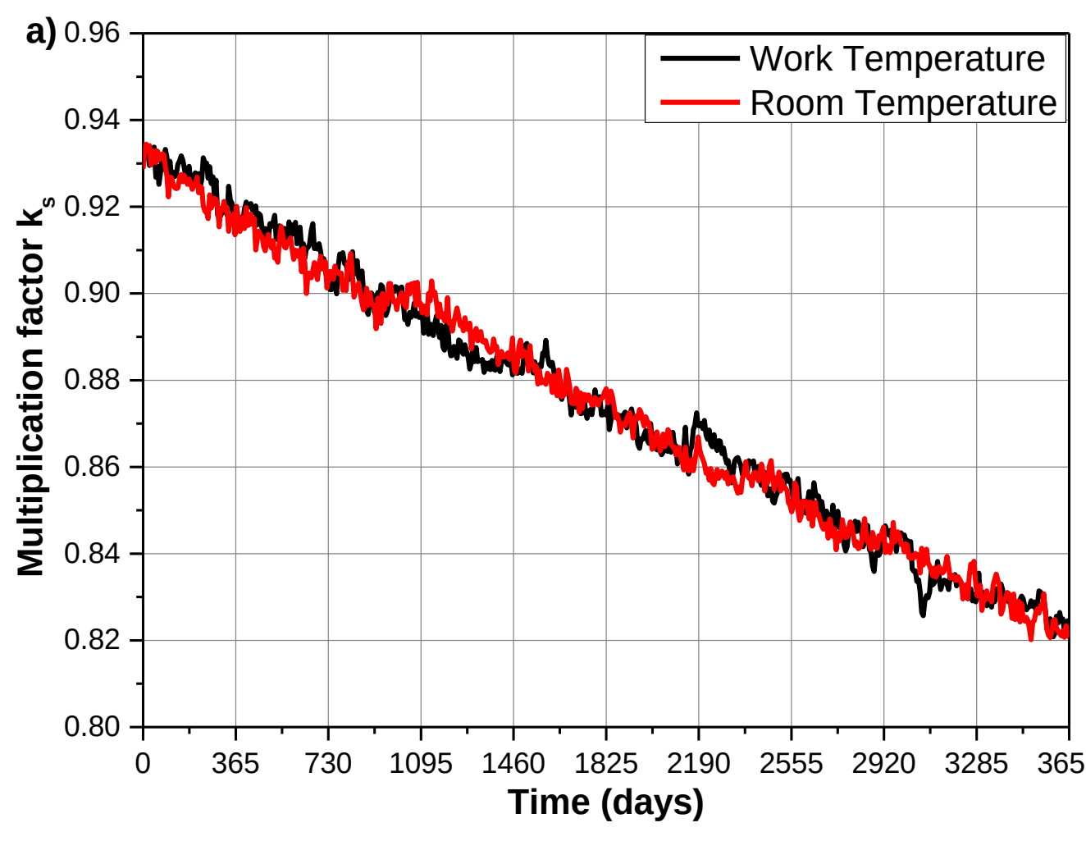
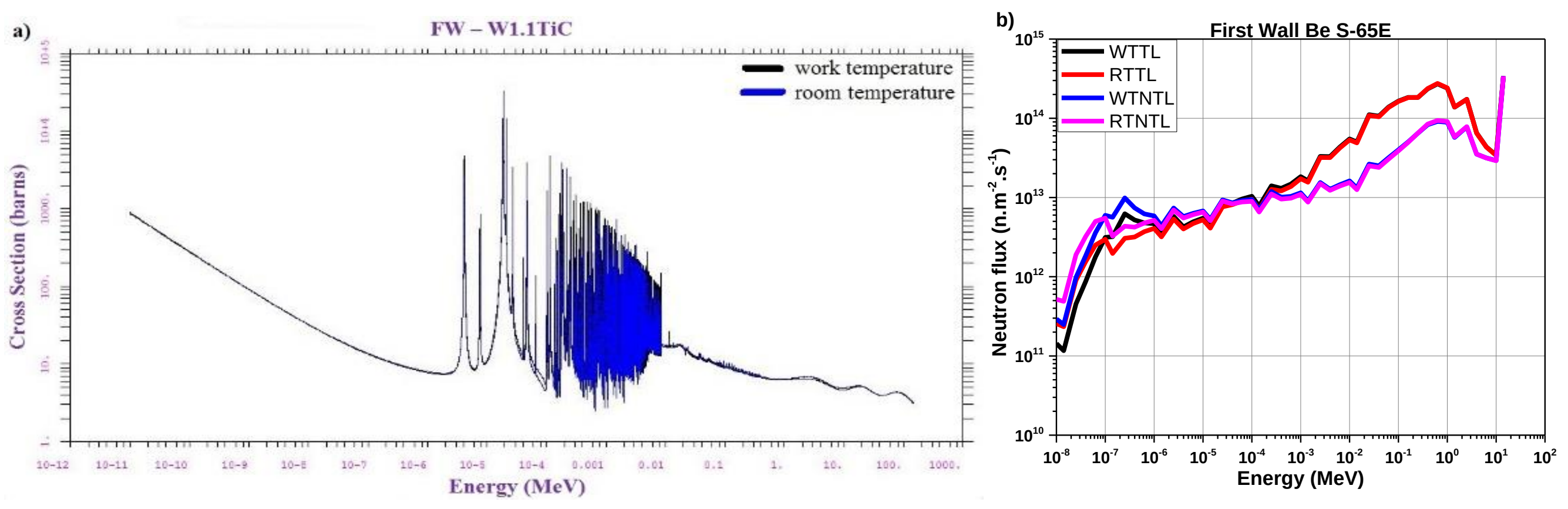


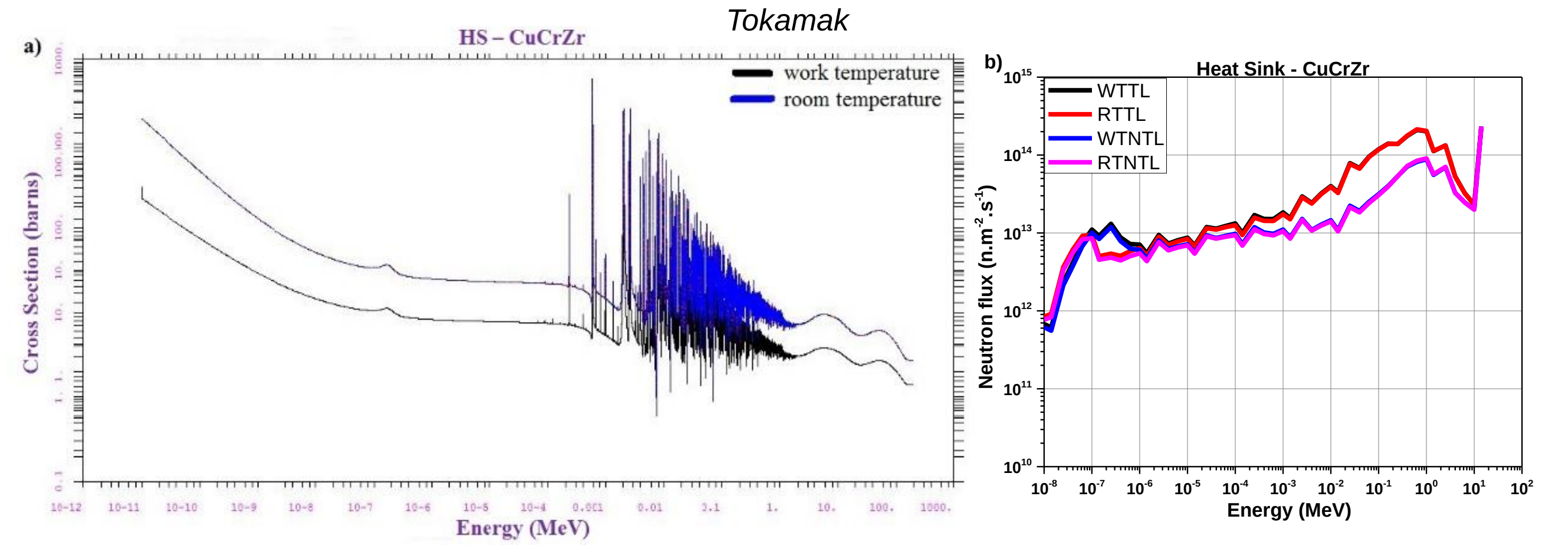
Figure 4. a) Neutron multiplication factor at work and room temperature

3.1. Sensitivity Analyses

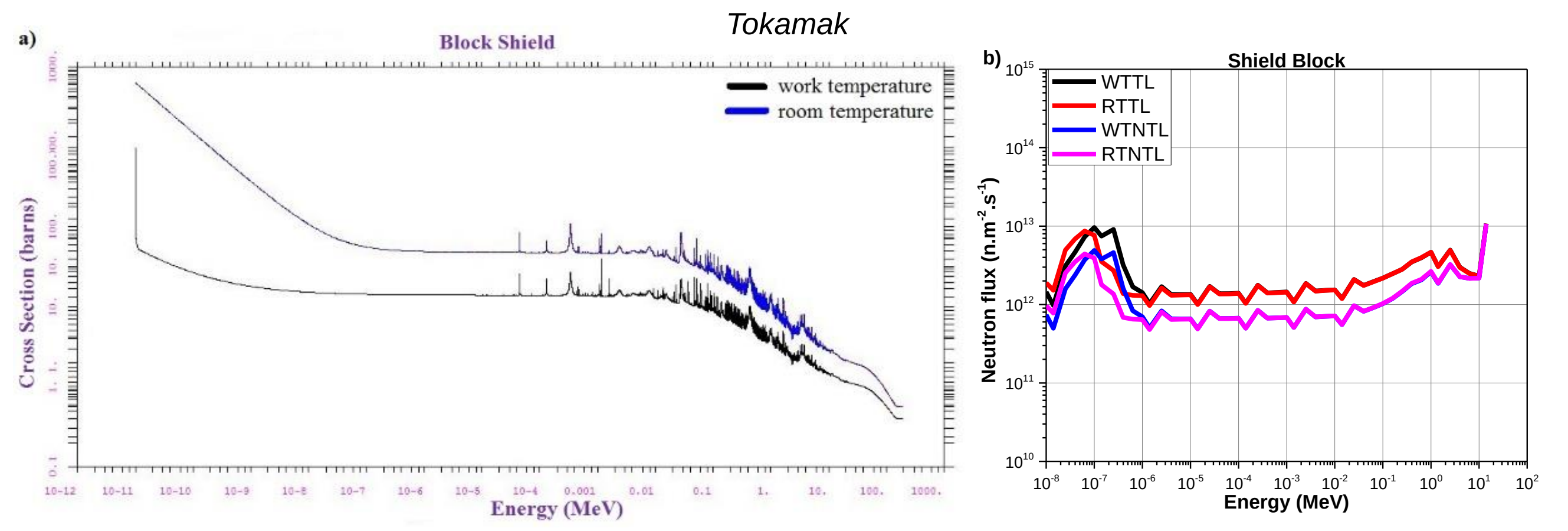
This analyzes focus on cross section for each material and the neutron flux variations due to the temperature variations on the different components and materials from the hybrid reactor or the one for the Tokamak.



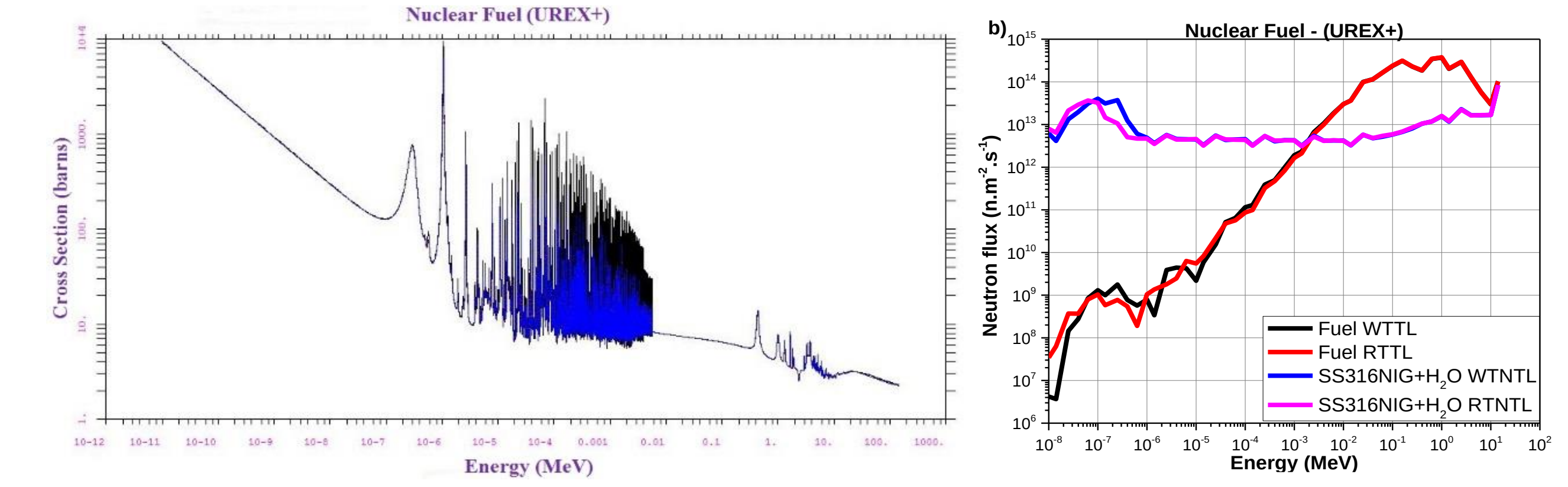
a) W1.1TiC Cross section at different temperatures b) first wall neutron flux for the hybrid system and the Tokamak



a) CuCrZr Cross section at different temperatures b) heat sink neutron flux for the hybrid system and the Tokamak



a) SS316L(N)-IG (70%) + water (30%) Cross section at different temperatures b) block shield neutron flux for the hybrid system and the Tokamak



a) Reprocessed Fuel Cross section at different temperatures b) Nuclear fuel neutron flux for the hybrid system and the Tokamak

4. Conclusions

The transmutation layer insertion inside of a Tokamak contribute to an increment in the neutron flux over the different components, which increases the neutron damage probability over delicate component such as the FW. The absolute difference of the ks shows the fuel sensitivity at different temperatures. There is a strong neutron influence over the different components in the hybrid systems due to insertion of the transmutation layer in the Tokamak system. Most of the differences in the neutron flux between the work temperature and the room temperature appear for low energies, in spite of the differences in the cross sections. Some material has stronger effects with temperature changes such as the LiPb, the SS316L(N)-IG + H_2O and the copper alloy. There is a strong temperature influence on the depletion of the nuclear fuel loaded. The most sensitive nuclides are ^{238}Pu, ^{239}Pu and ^{242m}Am.

5. Acknowledgements

The authors are grateful to CNEN (Brazil), FAPEMIG (Brazil), CAPES (Brazil), CNPq (Brazil)

6. References

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