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Optimization process for the design of the DCLL blanket for the European DEMOnstration fusion reactor according to its nuclear performances

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Abstract. The research study focuses on the neutronic design analysis and optimization of one of the options for a fusion reactor designed as DCLL (dual coolant lithium-lead). The main objective has been to develop an efficient and technologically viable modular DCLL blanket using the DEMO generic design specifications established within the EUROfusion Programme. The final neutronic design has to attend the requirements of: tritium self-sufficiency; BB thermal efficiency; preservation of plasma confinement; temperature limits imposed by the materials; and radiation limits to guarantee the largest operational life for all the components. Therefore, a 3D fully heterogeneous DCLL neutronic design has been developed for the DEMO baseline 2014 determining its behaviour under the real operational conditions of the DEMO reactor. Consequent actions have been adopted to improve its performances. Neutronic assessments have specially addressed the Tritium Breeding Ratio, Multiplication Energy Factor, power density distributions, damage and shielding responses. The model has been then adapted to the subsequent DEMO baseline 2015 (with a more powerful and bigger plasma, smaller divertor and bigger blanket segments), implying new design choices to improve the reactor nuclear performances.

1. Introduction

The neutronic radiation coming from the fusion plasma of large machines as the foreseen DEMO could severely affect the stability and the lifetime of the components which constitute the reactor. Nevertheless neutrons are fundamental to allow the reactor to reach the tritium self-sufficiency and to generate and extract enough nuclear power. This means that in the nuclear design of a kind of facilities it is essential to achieve and keep the delicate balance among fuel sustainability and power efficiency vs. radiation shielding.

The paper deals with the neutronic design analysis and optimization of one of the options for a fusion reactor based on a liquid breeder (lithium-lead) and double coolant system (lithium-lead and helium) designed as DCLL (dual coolant lithium-lead). Answering the required duties of a Breeding Blanket (BB) - tritium breeding, heat recovery and shielding - the DCLL uses PbLi as tritium breeder, neutron multiplier and primary coolant, and Eurofer as structural material. The main objective has been to develop, among the EUROfusion WPBB Project for the period 2014-2018, a new, reliable, efficient and technologically viable modular DCLL blanket using the DEMO generic design specifications and operational (pulsed) conditions [1] established in the frame of the EUROfusion PPPT Programme.

The priority condition of fuel self-sufficiency for the viability of a fusion reactor is measured through the Tritium Breeding Ratio (TBR). It is required to obtain a TBR ≥ 1.1 to have a 10% of margin (for final net TBR ≥ 1.0) accounting for possible losses and uncertainties. On the other hand, the plasma confinement can be kept only without overpassing the quench limits posed on the Superconducting Toroidal Field Coils (TFC). Furthermore, structural limits are imposed to the First Wall (FW) and Vacuum Vessel (VV), to maintain their integrity. The requirements taken into account and assessed here are summarized in Table 1 [2].

Starting from the plasma specifications [3] and the generic DEMO1 design [4] established in 2014 among the EUROfusion Programme, a conceptual DCLL design was developed and studied [5] and preliminary neutronic assessments were performed [6][7]. In this paper the previous mentioned nuclear responses are deeper analysed. The paper also describes the progress [8][9] in the DCLL neutronic design in light of the observations and requirements explained above. Further work has included the adaptation of the optimized design of the

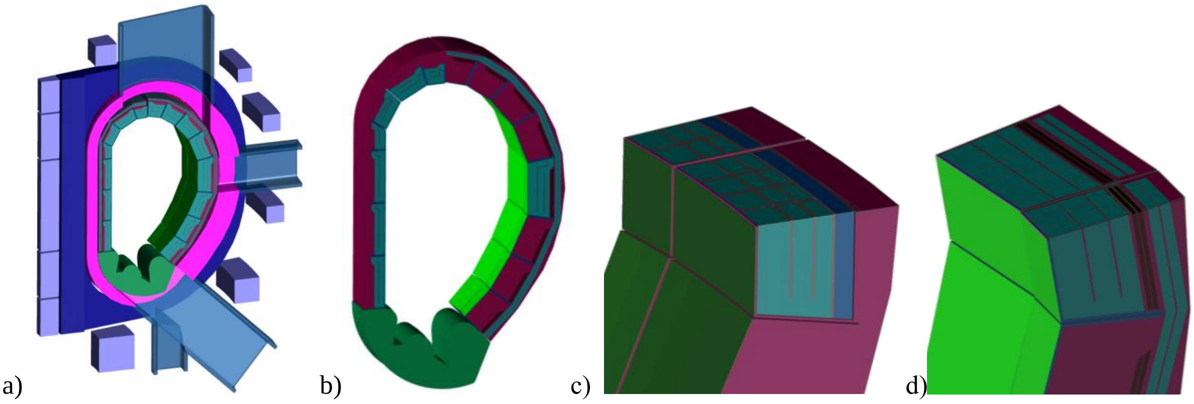
DCLL blankets to the plasma parameters [10] and the generic DEMO1 design [11] established in 2015 in which a reduced divertor and a higher fusion power would allow to keep and improve the generic machine behaviour relaxing the design specifications for the BB. The preliminary results and design improvements applied to the new DEMO2015 specifications are presented. Particle transport calculation has been performed with MCNP5 Monte Carlo code [12] using JEFF 3.1.1 nuclear data library [13].

Table 1. Limits and requirements for the reactor components taken under considerations.

Design requirements for BB	**value**	**Design limits for the TF-coil**	**value**
Tritium Breeding Ratio	≥ 1.1	Integral neutron fluence for epoxy insulator [m^{-2}]	$\leq 1\times10^{22}$
Energy Multiplication Factor	> 1	Peak fast neutron fluence (E>0.1 MeV) to the Nb3Sn superconductor [m^{-2}]	$\leq 1\times10^{22}$
Structural limits			
Helium production in steel (appm He)	≤ 1	Peak displacement damage to copper stabiliser, [dpa]	$\leq 0.5\sim1\times10^{-4}$
Displacement damage in the FW (dpa)	$\leq 50\text{-}70$	Peak nuclear heating in winding pack [W/m^3]	$\leq 0.05\times10^{3}$
Displacement damage to the VV (dpa)	≤ 2.75		

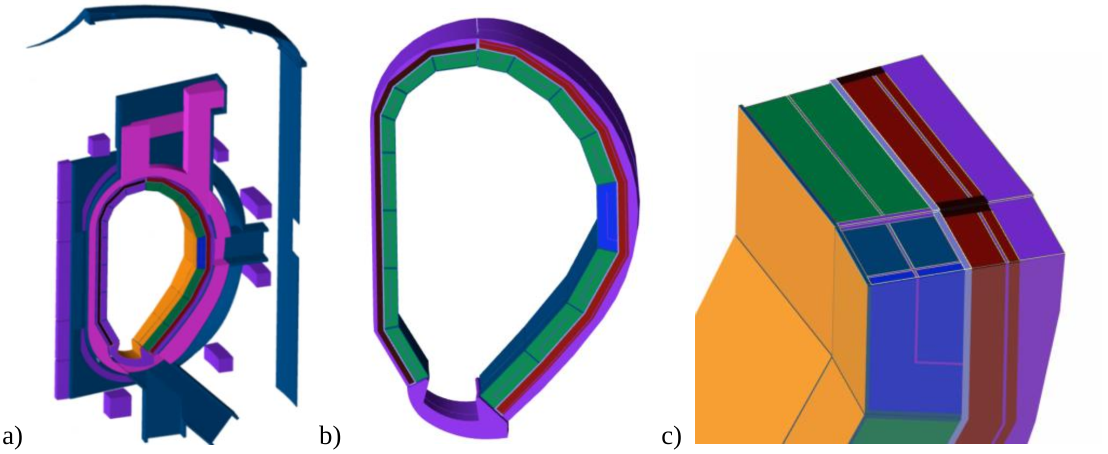
2. DCLL DEMO development

The DEMO design used in the 1st phase of the EUROfusion programme known as "EU DEMO1 Baseline 2014" [4] has 1572 MW fusion power (5.581×10^{20} n/s), plasma major radius of 9 m, minor radius of 2.25 m and elongation of 1.56 [3]. The torus is divided into 16 sectors of 22.5° (given by the number of TFC), each having 3 outboard (OB) and 2 inboard (IB) BB segments. For the neutronic purposes, an 11.25° half-sector has been studied (Fig.1a).



a) b) c) d)

Fig. 1. DCLL DEMO2014: a) whole reactor; b) BB segment, BSS and divertor; c) detail of OB BB equatorial module and the homogenized BSS, version 1; d) OB equatorial module and its heterogenized BSS, version 2.



a) b) c)

Fig. 2. DCLL DEMO2015: a) whole reactor; b) BB segment, BSS and divertor; c) detail of OB BB module (partially heterogenized) and its fully-heterogenized BSS.

In the 2nd phase a new generic design called “EU DEMO1 Baseline 2015” has been developed [10] having 2037 MW fusion power (7.323x10^{20} n/s), plasma major radius of 9.07 m, minor radius of 2.93 m and elongation of 1.59. The torus is divided into 18 sectors of 20º being the MCNP neutronic model a half-sector of 10º (Fig.2a). The main change in this design from the BB point of view is that the vertical length of the BB segments has been increased at the expense of the divertor size. In fact in the first project year, an ITER-like divertor configuration was considered (Fig.1a). In the second project year (2015) a revised model of cassette was created (Fig.2a) cutting off the outboard and inboard baffles while the breeding blanket segments were extended [14]. The motivation was to increase the TBR by exploiting those areas highly exposed to the plasma. For DEMO 2014 austenitic steel (SS316LN) was considered for the divertor composition being the divertor neutronic design [6] a homogenized massive block of 80% steel and 20% water. In DEMO 2015 the reduced activation 9Cr steel Eurofer97 has been considered being the neutronic divertor model a solid steel body except two thin layers facing the plasma (of tungsten and W/CuCrZr/Cu/water). Apart these 2 compositions another has been tested for both DEMO2014 and DEMO2015 substituting the former for a cassette of 54% Eurofer and 46% water with reduced density.

For DEMO2014 the DCLL design was fully heterogenized meaning that all the internal components of all the BB modules are represented as shown in Fig. 1b (showing the entire BB segment) and 1c-d (showing the OB equatorial module). For DEMO2015 the conceptual DCLL model adapted to the specific feature of DEMO have been prepared. The model is a 3D *quasi*-heterogenized and with the equatorial OB module fully heterogenized (Fig. 2b-c).

3. First phase: DEMO 2014 DCLL improvement and primary responses

Along the 1st phase of the project 2 different versions of the DCLL model based on DEMO2014 have been developed in order to achieve the best behavior in term of nuclear responses but also taking into account mechanical, manufacturing and chemical aspects (corrosion, permeation, pressure drop, among others). Starting from a version [5][6] in which 64 cm of breeder were used in the OB region, the next was to increase it to 69 cm [8][9]. At the same time other changes (Fig. 3) have been implemented in order to improve mainly the structural and safety aspect of the design (with special attention to a possible in-box LOCA). Some of them, relevant for the reactor neutronic behavior, are described in [9] and summarized as follows: increasing of FW thickness and its He fraction, number of toroidal breeding channels (from 4 to 6), radial thickness of the 3 radial OB breeding channels (from 30+18.5+15.5=64 cm to 30+22.2+17=69.2 cm), radial thickness of the IB upper modules #11/10/9 (from 50 cm to 65/70/70cm); reduction of Helium manifolds (from 4 to 2); suppression of 1 stiffening toroidal plate from IB #12-15. Furthermore, from the initial [5] to this 2nd version [8], the use of a detailed BSS and helium collector was implemented although the flow channel inserts (FCI) foreseen to mitigate the MHD effects were not still included. With the exception of the first two points that would have a strong negative impact on the TBR, the other modifications could balance and have positive influence on it. The influence of those changes on the T breeding performance is more widely described in [9]. Summarizing, a reduction in the TBR from 1.13 to 1.104 is produced, although remaining higher than the target. In fact in the 2nd design in which the number of breeder channels increased to improve the structural and pressure drop issues, and the FW thickness has been incremented being crucial to avoid an in-box LOCA but with strong implications on the tritium production, it has been required to take some strategical solution (Fig. 3a) as increasing the upper IB modules radial thickness. This allowed keeping the global TBR higher than 1.1. The effect of the divertor composition is highlighted here (Table 2) showing that the use of a higher amount of water cooling inside the steel cassette implies a deterioration of the breeder structures' performances in a ~3% meaning that the choice of this component is non-detachable from the breeding performances.

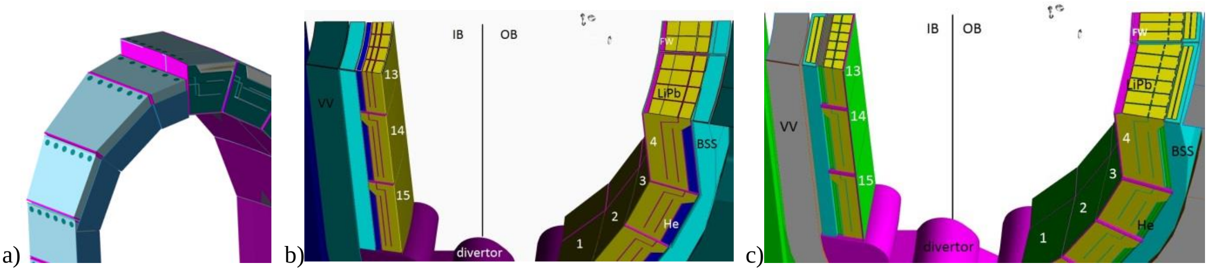


Fig. 3. DCLL evolution: a) increase of IB upper modules' thickness; b) horizontal cut of the 1st DEMO2014 DCLL with 4 toroidal PbLi channels per module and an homogenized BSS; c) 2nd DEMO 2014 DCLL with 6 toroidal PbLi channels per module, a more heterogenized BSS, and the reduction of the IB plates from 2 to 1.

The other neutronic responses are also examined with reference to the design improvements.

The power breakdown for the major reactor structures is shown in Table 3. Assuming a fusion power of 1572 MW and considering the total generated nuclear power of 1504 MW and 1507 MW for the 2 DCLL versions of 2014, the obtained Energy Multiplication Factors M_E are 1.195 and 1.198 respectively (higher than the criterion of Table 1), being M_E the ratio of the total nuclear power over the fusion neutron power (80% of 1572 MW).

DCLL2014			T/n in 360º		
Version 2		nº	prev. div.	new div.	Δ%
BB	OB	1	7.32E-02	7.05E-02	
		2	9.62E-02	9.32E-02	
		3	1.14E-01	1.11E-01	
		4	1.52E-01	1.48E-01	
		5	1.11E-01	1.07E-01	
		6	8.66E-02	8.41E-02	
		7	6.39E-02	6.15E-02	
		8	4.39E-02	4.24E-02	
		tot	0.7408	0.7179	
	IB	9	3.06E-02	2.95E-02	
		10	4.66E-02	4.51E-02	
		11	3.80E-02	3.69E-02	
		12	2.28E-02	2.22E-02	
		13	5.94E-02	5.77E-02	
		14	5.78E-02	5.60E-02	
		15	4.58E-02	4.35E-02	
		-			
		tot	0.3009	0.2909	
	Total BB		1.0418	1.0088	-3.26%
BSS		OB	2.50E-02	2.46E-02	
		IB	3.76E-02	3.68E-02	
		total	6.26E-02	6.13E-02	-2.04%
		TBR	**1.104**	**1.070**	-3.19%

Table 2. TBR as local values inside the BB modules and BSS PbLi channels for the 2nd version of DEMO2014 DCLL with a standard divertor composition and with a new highly cooled one.

Table 3. Power breakdown along the main components of the DCLL DEMO reactor.

DCLL2014	Power generated (MW)	
Components	Version 1	Version 2
BB + Manifold	1229.32	1225.97
Divertor	262.49	265.08
VV + Ports + Coils	11.98	16.17
Total	1503.79	1507.22
M_E	1.195	1.198

For a preliminary evaluation of the shielding efficiency of the DCLL radial build, the nuclear heating (NH) in the reactor components needs to be assessed, paying attention to the TFC at IB equatorial level. It has been calculated as an average over poloidal regions of 50 cm. The results (Table 4) for the 2 DCLL2014 show that the IB eq. values satisfy in both cases the recommendation for the NH in the winding pack, currently established in 50 W/m^3 (20 times less than the ITER requirement). The limit is not satisfied for the IB upper zone and in the OB side. The problem is visualized in Fig. 4a and b, in which high streaming from the ports is observed affecting these TFC areas. The lack of shield in these zones is not of concern because the plugs were not developed for the generic DEMO2014. The NH has been also calculated as radial profile (Fig. 4c) from the FW to the TFC in voxel of 5x5x5 cm^3 for the 2nd version of DCLL2014. The values are given for Eurofer (from FW to BSS) and for 2 compositions of VV steel with and without 2% of Boron. While in Table 4 the values in vertical ranges of 50 cm (and in the overall TFC thickness) were between 1-3 W/m^3, now the local values (Table 5) highlight peaks of 31-17 W/m^3 although being under the 50 W/m^3 limit.

Table 4. Nuclear Heating on the TF coil for the 2 DEMO2014 DCLL versions.

Distance from plane Z=0 (cm)	Version1 DCLL DEMO2014						Version2 DCLL DEMO2014					
	IB			OB			IB			OB		
	MeV/gr	relative uncert.	W/m^3	MeV/gr	relative uncert.	W/m^3	MeV/gr	relative uncert.	W/m^3	MeV/gr	relative uncert.	W/m^3
>160	1.80E-13	0.010	88.57	5.88E-13	0.007	288.83	2.97E-13	0.0082	145.75	7.74E-13	0.0068	380.25
160:110	9.08E-16	0.200	0.45	1.51E-13	0.053	74.32	2.06E-15	0.2172	1.01	1.89E-13	0.0491	93.00
110:60	1.42E-15	0.323	0.70	1.99E-13	0.045	97.70	3.90E-15	0.2378	1.91	2.63E-13	0.0421	129.12
60:10	2.39E-15	0.350	1.17	2.32E-13	0.040	113.73	2.44E-15	0.2374	1.20	3.01E-13	0.0371	147.67
10:-40	3.32E-15	0.280	1.63	2.51E-13	0.041	123.45	6.08E-15	0.2368	2.99	3.34E-13	0.0385	164.10
-40:-90	3.15E-15	0.383	1.55	2.27E-13	0.043	111.66	6.68E-15	0.2681	3.28	2.89E-13	0.0389	142.14
< -90	9.60E-16	0.113	0.47	4.80E-14	0.022	23.57	1.56E-15	0.0967	0.77	6.37E-14	0.0201	31.26

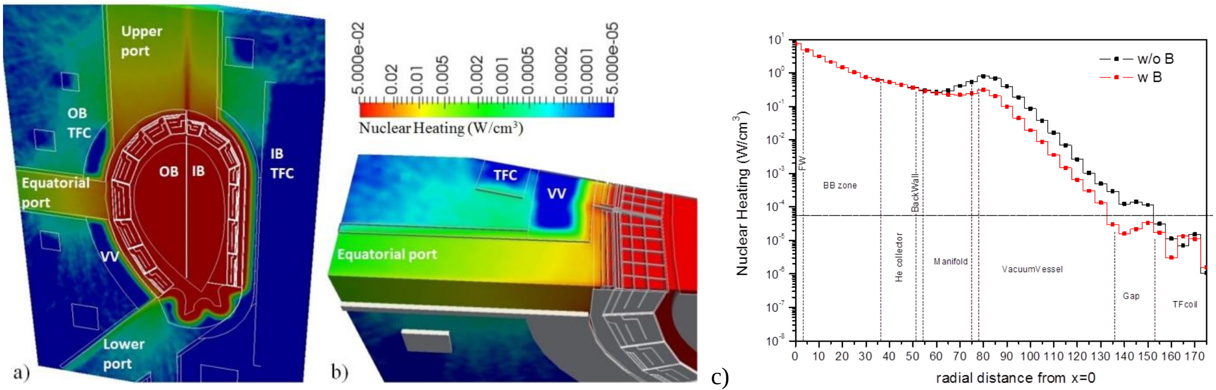


Fig. 4. Nuclear Heating (W/cm^3): a) 3D map "mesh tallies" in the whole DCLL DEMO; b) horizontal cut in the OB side. Due to the unplugged ports the limit ($5{\cdot}10^{-5}$ W/cm^3) is not fulfilled where the colour is warmer than blue; c) radial profiles in the IB mid-plane from the FW to the TF coil.

Table 5. Nuclear Heating (W/cm^3) and integral neutron Fluence (n/cm^2) radial values in the IB TFC mid-plane.

Component	distance from x=0 (cm)	SS316LN Austenitic Steel VV			Borated SS316LN Austenitic Steel (at 2% B) VV		
		Nuclear Heating (W/cm^3)	Total fluence (n/cm^2 x FPY)	at 6 FPY	Nuclear Heating (W/cm^3)	Total fluence (n/cm^2 x FPY)	at 6 FPY
TF coil	502.5	**3.14E-05**	3.25E+16	**1.95E+17**	**1.70E-05**	4.59E+16	**2.75E+17**
	497.5	1.14E-05	2.04E+16	1.22E+17	3.07E-06	2.80E+16	1.68E+17
	492.5	7.00E-06	1.22E+16	7.33E+16	1.33E-05	1.73E+16	1.04E+17
	487.5	1.50E-05	1.20E+16	7.18E+16	1.10E-05	2.48E+16	1.49E+17
	482.5	1.06E-06	9.44E+15	5.66E+16	1.57E-06	3.03E+15	1.82E+16
LIMITS		**<5e-5 W/cm^3**		**<1e18 cm^{-2}**	**<5e-5 W/cm^3**		**<1e18 cm^{-2}**

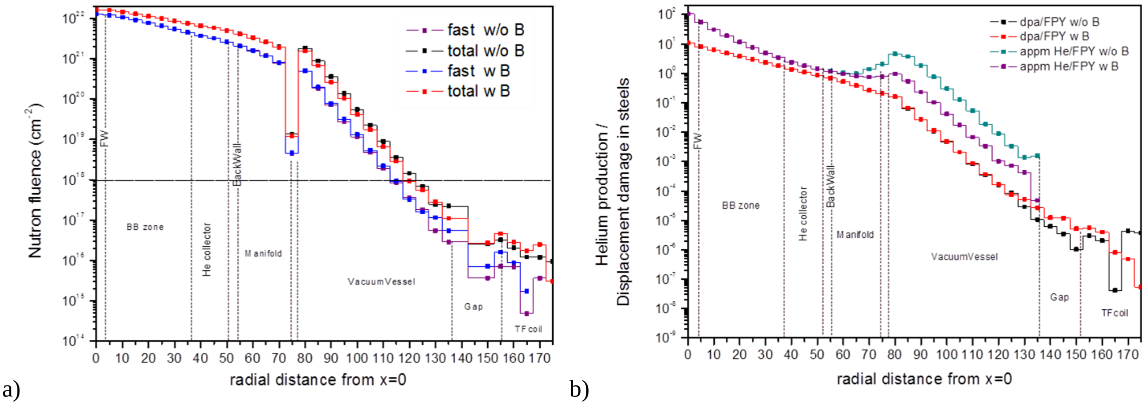
Once established the requirements of TBR, M_E and NH are fulfilled, the other shielding responses, very similar in the 2 versions of the DCLL2014, are shown only on the 2nd one.

3.1 Neutron Fluence

Fundamental requirements regards the total and fast (E> 0.1 MeV) fluence in different parts of the TFC (Table 1). The results calculated using the same procedure than before are given in Fig.5a and Table 5. Values multiplied for the TFC lifetime (6 FPY [1]) indicates that the limit of 10^{18} n/cm^2 is fulfilled for both compositions of VV steel (with and without boron).

3.2 Helium production and radiation damage

The requirements referred as structural requirements (Table 1) and also one of TF coil requirements are relative to helium production (appm He) and radiation damage (dpa). Both have been assessed as radial profiles in the IB mid-plane from FW to TFC (Fig.5b). Tabulated values are given in Table 6. Here the annual values of FW have been multiplied by 1.57 and 4.43 FPY to cover the 2 irradiation scenarios foreseen for blankets [1], while 6 FPY values are extrapolated for VV and TFC. All the limits are satisfied with the exception of the He production in the first 15-25 radial cm of VV (with-w/o B), implying it cannot be re-welded.

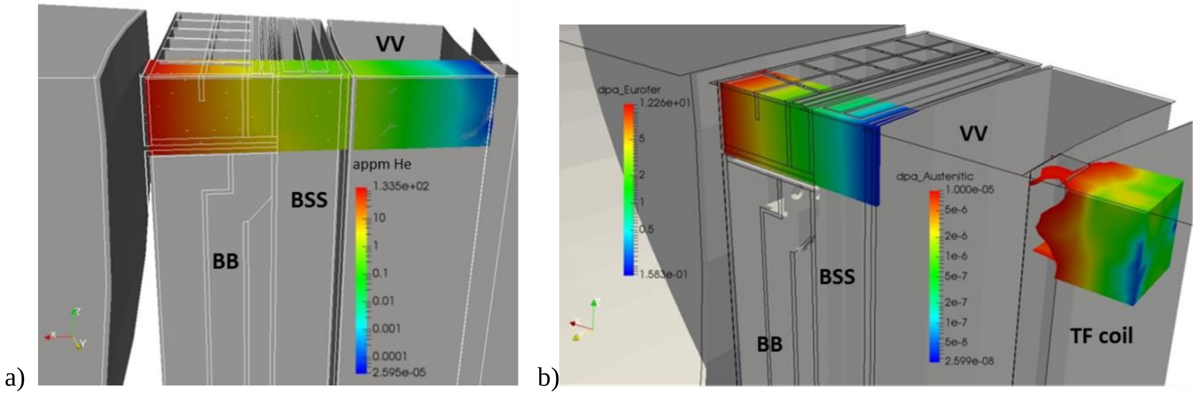


a) b)

Fig. 5. a) Neutron fluence (total and fast as n/cm^2 per FPY); (b) Helium production (appm He/ FPY) and damage (dpa/FPY) radial profiles in the IB mid-plane from the FW to the TF coil.

Table 6. Helium production (appm He) and damage (dpa) radial profiles in the IB mid-plane for the VV, TFC and FW using two steel VV compositions with and without boron.

		SS316LN Austenitic Steel VV				Borated SS316LN Austenitic Steel (at 2% B) VV			
Component	distance (cm) from x=0	appm He/ FPY	at 6 FPY	dpa/FPY	at 6 FPY	appm He/ FPY	at 6 FPY	dpa/FPY	at 6 FPY
Vacuum Vessel	577.5	4.60	**27.62**	0.159	**0.953**	0.944	**5.66**	0.161	**0.967**
	572.5	3.75	**22.49**	6.49E-02	0.390	0.535	**3.21**	0.066	0.396
	567.5	1.85	**11.12**	2.62E-02	0.157	0.232	**1.39**	0.027	0.162
	562.5	0.757	**4.54**	1.08E-02	6.50E-02	0.102	0.609	0.011	0.068
	557.5	0.303	**1.82**	4.69E-03	2.81E-02	4.15E-02	0.249	4.84E-03	2.90E-02
	552.5	0.124	0.743	2.06E-03	1.24E-02	1.75E-02	0.105	2.08E-03	1.25E-02
	547.5	5.37E-02	0.322	8.09E-04	4.86E-03	6.68E-03	0.040	8.62E-04	5.17E-03
	542.5	1.86E-02	0.112	3.46E-04	2.08E-03	3.34E-03	2.00E-02	3.64E-04	2.18E-03
	537.5	8.86E-03	5.32E-02	1.59E-04	9.54E-04	1.03E-03	6.18E-03	1.66E-04	9.97E-04
	532.5	3.32E-03	1.99E-02	8.53E-05	5.12E-04	7.20E-04	4.32E-03	7.58E-05	4.55E-04
	527.5	1.39E-03	8.35E-03	2.89E-05	1.73E-04	4.18E-04	2.51E-03	5.11E-05	3.07E-04
	522.5	1.57E-03	9.44E-03	1.06E-05	6.36E-05	4.75E-05	2.85E-04	2.65E-05	1.59E-04
LIMIT			**> 1 appm He**		**< 2.75 dpa**		**> 1 appm He**		**< 2.75 dpa**
TF coil	502.5			2.99E-06	**1.79E-05**			5.47E-06	**3.28E-05**
	497.5			2.06E-06	1.23E-05			3.97E-06	2.38E-05
	492.5			4.17E-08	2.50E-07			8.16E-07	4.90E-06
	487.5			4.25E-06	2.55E-05			4.88E-07	2.93E-06
	482.5			3.73E-06	2.24E-05			5.28E-08	3.17E-07
LIMIT					**<10^{-4}dpa**				**<10^{-4}dpa**
FW Eurofer	657.5	dpa/FPY	10.94	at 1.57 FPY	**17.18**	**<20 dpa**	at 4.43 FPY	**48.47**	**<50 dpa**



a) b)

Fig. 6. Helium production (appm He/ FPY) and damage (dpa/FPY) 3D maps ('mesh tallies') around the IB mid-plane for Eurofer and austenitic steel from the FW to the TF coil.

General 3D maps have been represented in Fig. 6 a) for helium production in Eurofer and austenitic steel components; and in Fig. 6 b) for dpa with a reduced scale to show deeply the results in the TFC. Multiplying the annual values by 6 FPY, we can see that there are not hotspots overpassing the 10^{-4} dpa TF coil quench limit.

4. Second phase: from optimized DCLL DEMO2014 to DCLL DEMO2015

In 2015 an important change was produced among the EUROfusion Programme resulting in the implementation of a strongly different DEMO design. The aspect ratio was identified as one of the most important parameters still relatively unconstrained. A lower aspect ratio implies a larger plasma volume and lower toroidal field, thus a higher TBR, better vertical stability, and lower disruption forces [15]. Thus, the DEMO aspect ratio was changed from 4 to 3.1. The baseline for DEMO determined by the PROCESS system code changed [10] resulting in a larger and more powerful plasma (from 1400 to 2500 m^3 of volume and from 1572 to 2037 MW of fusion power). The divertor was reduced [14] and the higher breeding blanket vertical size allowed reducing its radial dimension maintaining a high TBR potential.

A conceptual DCLL model has been adapted to the specific feature of DEMO2015 and has been studied from the nuclear perspective. Some of the preliminary but primary design features of the 1st DCLL DEMO2015 version which are being investigated from the neutronic point of view (and improved where needed) are summarized as follows: 1) Toroidal breeding channels increased from 6 to 7; 2) Helium collector reduced and inserted horizontally in the bottom of the module instead of vertically in the back; 3) Reduction from 3 to 2 radial OB BB channels (1 stiffening toroidal plate suppressed); 4) Thickness of the 2 breeding channels is 29+29.65=58.65cm/19.65+20=39.65cm OB/IB; 5) The BB radial space is 65/46cm OB/IB while the BSS occupies 66/32cm in the eq. plane for a total of 130/78cm (to be compared with the previous 91/50 BB, 38/24.5 BSS, 129/74.4cm total); 6) number of modules in one segment passed from 15 to 16 (as the vertical dimensions increased). The model is a 3D *quasi*-heterogenized design with the equatorial OB module fully heterogenized (stiffening plates, FCI, breeder channels and walls are all separately described). The main preliminary nuclear responses have been studied as described in the following.

4.1 Neutron Wall Loading, TBR and Nuclear Heating.

The Neutron Wall Loading and TBR have been firstly examined for the newly established DCLL DEMO 2015 version. The NWL poloidal distribution allows seeing the regions in which a special care for shielding could be considered. Such poloidal distribution in comparison with the previous DCLL2014 is presented in Fig. 7 where the same mean value (1.03 MW/m^2) is shown. A similar strong poloidal variation is observed with two peaks at the equatorial level (now shifted to modules nº 3 and nº 14). The tritium production has been also evaluated as essential condition for the reactor viability. The results are presented in Table 7 in which the local values are shown. The total TBR in the breeder modules is 1.158. Adding up the contribution of the BSS PbLi channels the final value reach 1.266. Due to the previously shown relevance of the divertor composition on the breeding performances of the reactor the new highly cooled divertor (at 46% of water) has been also tested. In such case the TBR would drop to 1.203 (-5.24%) being now the difference even stronger than before due to the extreme difference in the divertor composition of the new generic DEMO2015 (Eurofer cassette without water). Lastly the Nuclear Heating map and radial profile from the FW to the TFC in steels for the IB side has been also assessed (Fig. 8a and b). In both it is possible to observe some small hotspot in the front position of the TF coil winding pack. Further improvements are ongoing in order to reduce the radiation impact on the structures having high margins for the TBR.

DCLL2015		nº	T/n in 360º prev. div.	new div.	Δ%
BB	OB	1	8.81E-02	7.92E-02	
		2	1.19E-01	1.14E-01	
		3	1.42E-01	1.37E-01	
		4	1.49E-01	1.43E-01	
		5	1.08E-01	1.03E-01	
		6	9.80E-02	9.32E-02	
		7	8.25E-02	7.83E-02	
		8	4.28E-02	4.06E-02	
		tot	8.29E-01	7.87E-01	
	IB	9	4.81E-02	4.55E-02	
		10	3.65E-02	3.46E-02	
		11	2.44E-02	2.33E-02	
		12	2.63E-02	2.51E-02	
		13	4.98E-02	4.79E-02	
		14	5.03E-02	4.83E-02	
		15	4.52E-02	4.27E-02	
		16	4.78E-02	4.35E-02	
		tot	3.28E-01	3.11E-01	
		total BB	1.158	1.098	-5.4%
BSS		OB	6.93E-02	6.72E-02	
		IB	3.92E-02	3.77E-02	
		total	1.09E-01	1.05E-01	-3.49%
		TBR	**1.266**	**1.203**	-5.24%

Table 7. TBR as local values inside the BB modules and BSS PbLi channels for the DEMO2015 DCLL with a standard divertor composition and with a new highly cooled one.

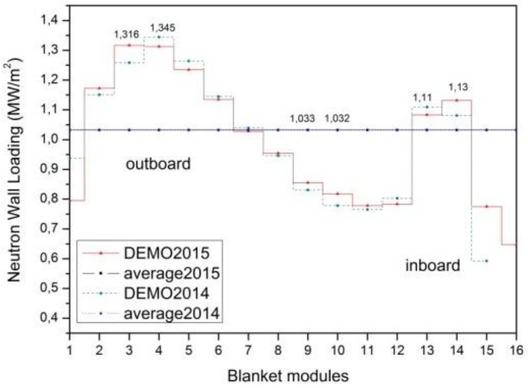


Fig.7. NWL poloidal distributions and averages for DCLL DEMO2014 and 2015.

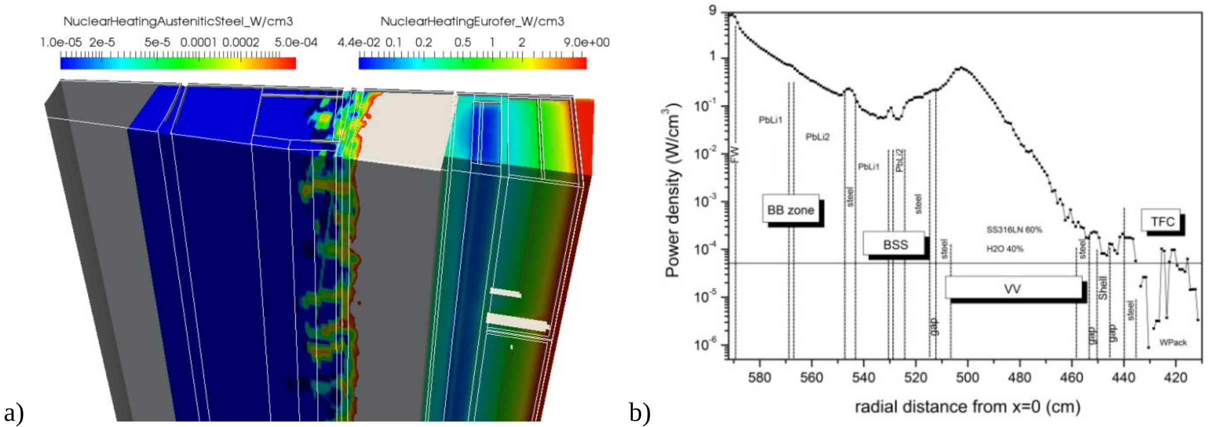


Fig. 8. Nuclear heating a) 3D maps: in the IB side of the DCLL DEMO2015; the limit ($5 \cdot 10^{-5}$ W/cm^3) is not fulfilled where the colour is warmer than green; b) radial profiles in the IB mid-plane from the FW to the TFC.

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