Tritium breeding performance of a DEMO based on the Double Null divertor configuration

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Objectives

Assessment of the tritium breeding ratio (TBR) of a Double-Null (DN) DEMO with different in-vessel components (IVCs).

The following auxiliary IVCs were considered:

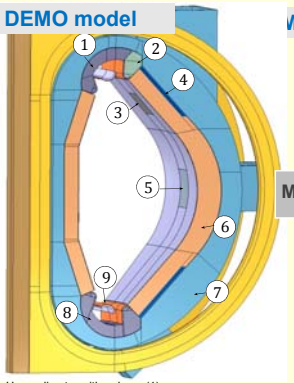
- *Upper divertor with a dome,*
- *Upper port limiters,*
- *Equatorial port limiter*
- *Extensions of the vacuum vessel (radial and poloidal)*

MCNP geometry model

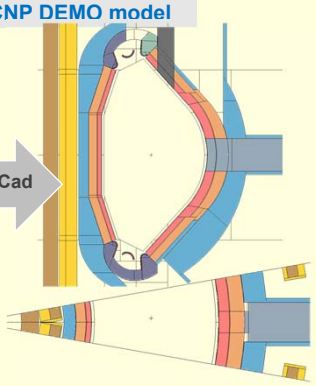
- Fully automated procedure to generate an MCNP geometry model
- Full size 3D model of 20° torus DN DEMO segment
- The FW (25 mm) with a W layer (2 mm) is modeled
- 3 Layers water cooled divertor
- Blanket breeder space is homogeneous
- No poloidal and toroidal gaps
- VV, TF coils, ports are included
- 3D neutron plasma source

Double-null DEMO MCNP model

CAD DEMO model



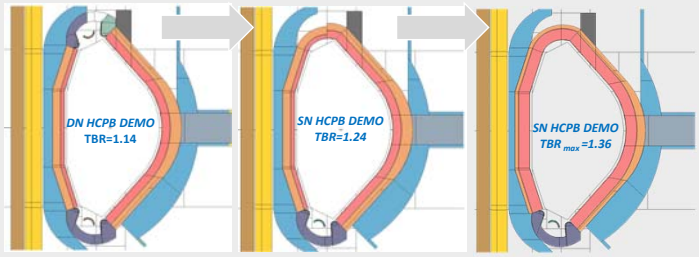
MCNP DEMO model

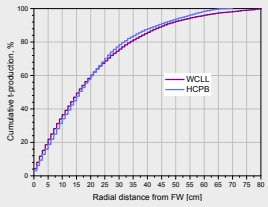


- Upper divertor with a dome (1)
- Outer upper target
- An upper port limiter of 100x100 cm (toroidal x poloidal) (3)
- Possible extension of the VV (4)
- An equatorial port limiter (100 x 300 cm) (5)
- Breeder blankets volume (6)
- Vacuum vessel (7)
- Lower divertor (8) and dome (9)

	HCPB	WCLL	HCLL	DCLL
BZ: IB/OB	23/52	47/80	49/80	40/63
BSS: IB/OB	58/70	26/45	21/22	36/64

Pseudo SN configuration



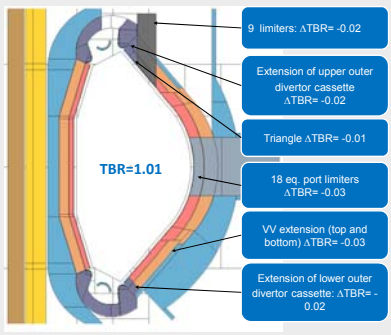


The breeder zone thickness both in IB and OB sides was enlarged:

- *In case of HCPB – up to 70 cm*
- *In case of PbLi concepts – up to 80 cm*

DN DEMO concept	TBR SN	TBR Ref.
HCPB	1.36	1.15
WCLL	1.24	1.13
HCLL	1.27	1.17
DCLL	1.27	1.20

DN DEMO with different IVCs



Element of the design	Loss of the TBR, ΔTBR
Upper limiters	
-18	-0.04
-9	-0.02
-4	-0.01
Triangular piece	-0.01
Extension of the divertor cassette	
-upper	-0.02
-lower	-0.02
18 equatorial ports	
-1x2 m	-0.02
-1x3 m	-0.03
Extension of the vacuum vessel	-0.03
Total:	-0.13

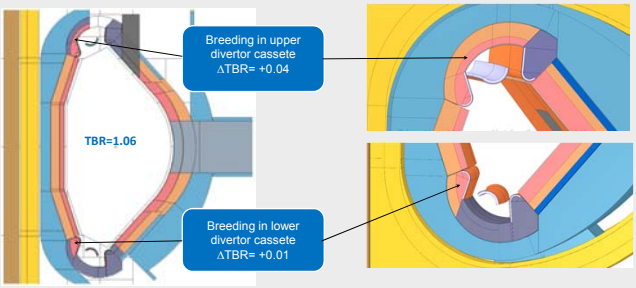
The inclusion of the auxiliary IVCs results in the significant decrease of the TBR:

- *second divertor - ΔTBR=-0.10*
- *upper limiters - ΔTBR=-0.02*
- *bigger divertors - ΔTBR=-0.04*
- *equatorial ports - ΔTBR=-0.03*

DN DEMO concept with IVCs	TBR
HCPB	1.01
WCLL	0.96
HCLL	0.97
DCLL	0.97

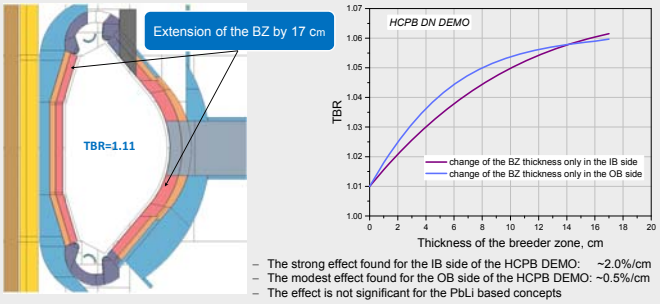
Design modifications to compensate the loss of TBR

I. The arrangement of the breeder materials in the both divertor cassettes



DEMO concept	DN DEMO with additional IVCs	DN DEMO with additional IVC and tritium breeding in divertors
HCPB	1.01	1.06
WCLL	0.96	1.00

II. The enlargement of the available breeder zone



- The strong effect found for the IB side of the HCPB DEMO: ~2.0%/cm
- The modest effect found for the OB side of the HCPB DEMO: ~0.5%/cm
- The effect is not significant for the PbLi based concepts

Conclusions

- The inclusion of the upper divertor in the reactor design (double null configuration) results in a significant loss of the total tritium production by ~8%.
- For a simplified DN DEMO configuration based on the HCPB blanket concept a TBR of 1.14 was found without inclusion of any auxiliary equipment.
- The additional IVC design modifications introduced including 9 upper port limiters and 18 equatorial port plugs led to a significant reduction of the tritium breeding of the DN DEMO up to TBR=1.01 in case of an HCPB
- The design modifications to compensate the loss of the breeder space can bring up to ΔTBR=+0.15 :
  - *arrangement of the breeder materials in the both divertor cassettes shows ΔTBR=+0.05*
  - *the enlargement of the available breeder zone shows ΔTBR=+0.10 (in the PbLi concepts is not significant)*
  - *further extension of the IB breeder zone needs another radial build of the tokamak.*
- Meeting the TBR requirement in a DN DEMO with an HCLL, WCLL, or DCLL breeding blanket seems challenging and would certainly require more significant changes to the overall configuration of the IVCs

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