

Neutronic activity for development of the promising alternative water-cooled DEMO concepts

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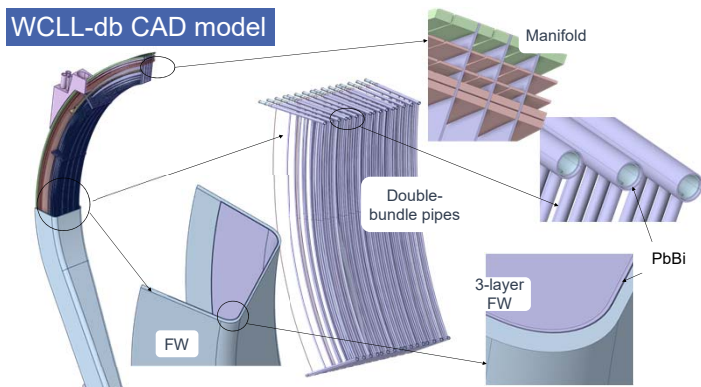
Objectives

- The work is concentrated on an elaboration of the alternative DEMO blanket design with a goal of more rational use of the blanket space and materials compared to a reference WCLL concept.
- Two different design options based on water coolant are developed:
 - WCLL-like blanket with a new double-bundle geometry layout (**WCLL-db**)
 - Hybrid **WLCB** (Water cooled liquid Lead Ceramic Breeder) concept combining breeder ceramic with liquid lead and water cooling technologies.

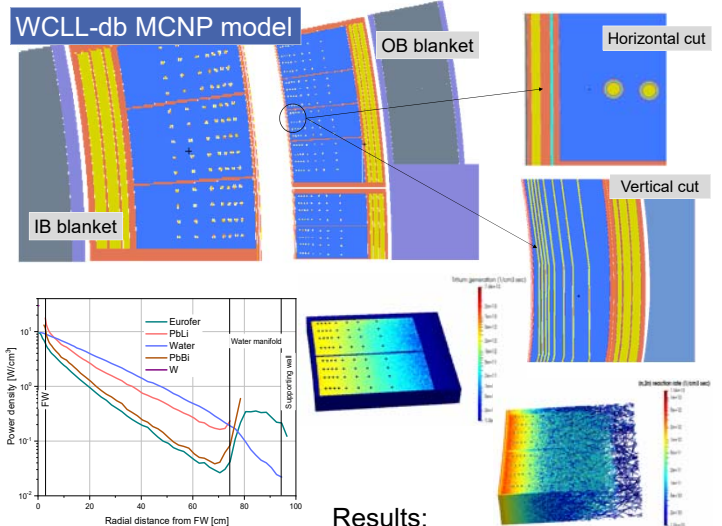
Workflow

- Preparation of the CAD models suitable for neutronic simulations
- Conversion of the CAD models into the MCNP geometry representation
- Verification and validation of the MCNP geometry
- Preparation of the MCNP input files making use of the universes enabling quick geometry modifications
- Neutronic simulations with MCNP code
- Analyses of the results, modifications of the geometry models and a repetition of the full cycle to find a optimal blanket design

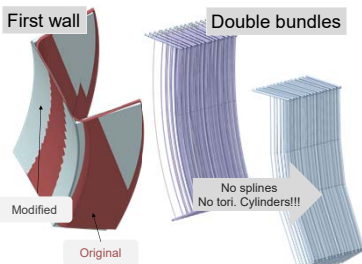
WCLL-db CAD model



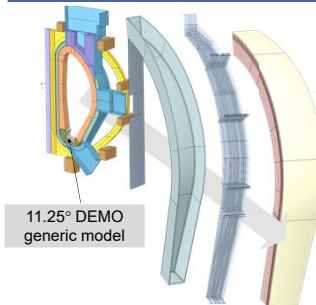
WCLL-db MCNP model



Simplifications in CAD model



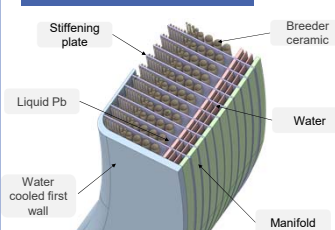
WCLL-db DEMO CAD model



Results:

- TBR results with alternative to PbBi compounds:
- | Compound | Melting point, T°C | TBR |
|-------------------------------------|--------------------|------|
| Pb ₈₈ Zr ₁₂ S | 315 | 1.16 |
| Pd ₉₀ Mn ₁₀ | 290 | 1.16 |
| Pb ₈₅ Ba ₅ | 290 | 1.16 |
| Pb ₈₀ Sn ₂₀ | 280 | 1.16 |
- TBR=1.16
 - Temperature effects of the nuclear data: δTBR<-0.5%.
 - The use of PbBi separating layers results in a huge ²¹⁰Po accumulation: ~500 g in all blankets.
 - Several alternative compounds could be used to replace PbBi without a TBR reduction

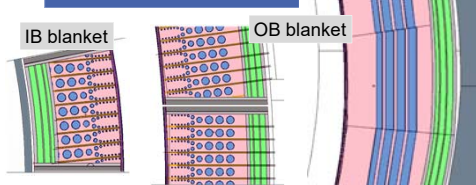
WLCB CAD model



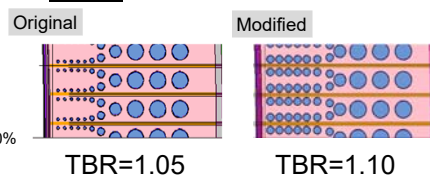
WLCB main features:

- Breeder ceramic Li₄SiO₄ + 37% mol. Li₂TiO₃ (90-100% ⁶Li) as pebbles (64% vol. fraction)
- He purge gas (80 bar)
- Pressurized water coolant (155 bar, 290-320°)
- Liquid Pb as a neutron multiplier (no circulation)
- Eurofer as a structural material
- Poloidal arrangement of the breeder tubes

WLCB MCNP model

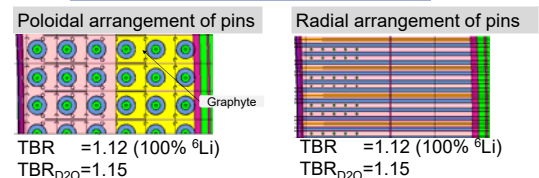


Results:



- Original and modified WLCB blanket designs do not provide sufficient tritium breeding
- The design is technologically complex
- The WLCB blanket layout should be newly developed

WLCB DEMO alternative layouts



Gases generation in the blankets

	¹ H	³ H	He
IB blanket, at/sec	1.87·10 ¹⁵	4.04·10 ¹¹	4.20·10 ¹⁴
OB blanket, at/sec	2.02·10 ¹⁵	4.35·10 ¹¹	4.54·10 ¹⁴
DEMO, mole/FPY	8.25	1.78	1.85

Tritium generation in heavy water coolant

	FW (front)	FW (side)	Stiffening plates	Cooling tubes	Manifold
Tritium generation, Bq/kg FPY	7.40·10 ⁹	1.28·10 ⁹	1.00·10 ⁸	3.43·10 ⁹	9.68·10 ⁹

Conclusions:

- Tritium breeding performance of the WLCB DEMO can achieve TBR=1.12 with 100% ⁶Li enrichment of the breeder ceramic
- The use of pressurized **heavy water coolant** can provide TBR=1.15
- Tritium accumulation in heavy water coolant (~7.5·10⁹ Bq/kg per FPY) is much less compared to CANDU