Comparison of Neutronics Features for Candidate Blankets

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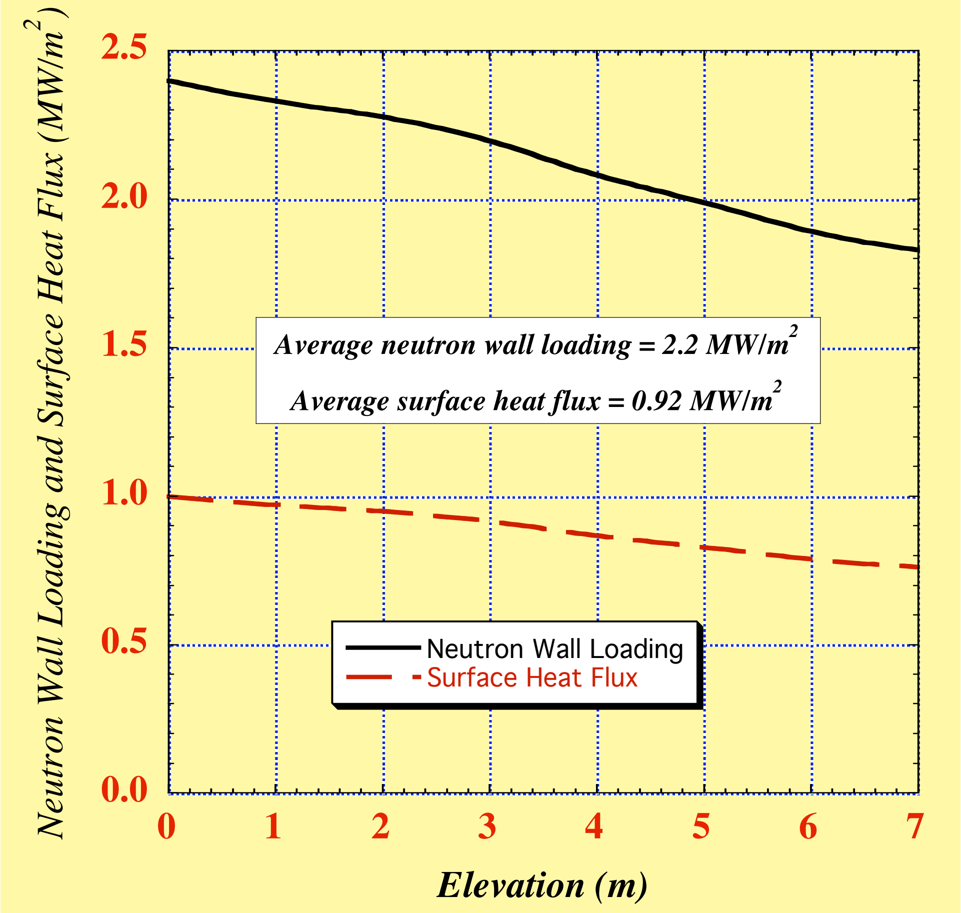
Objectives

- Analysis was presented for two blanket designs in HAPL chamber:
  - Self-cooled Li blanket
  - He-cooled SB blanket with Be multiplier
- LAFS alloy F82H used as structural material
- He-cooled steel shield/VV used
- Neutronics analysis presented here for a dual-coolant LiPb blanket with the same chamber dimensions and target fusion power
- Neutronics features of the three candidate blankets are compared

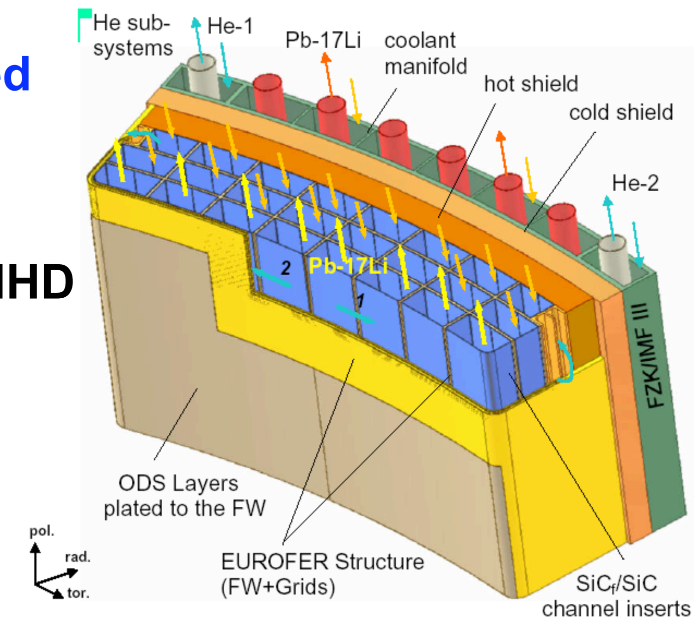
Basic Assumptions

- 1 mm W armor on ferritic steel (F82H) FW
- Used target spectrum from LASNEX results (Perkins) for NRL direct-drive target
- 70.5% of target yield carried by neutrons with 12.4 MeV average energy
- 1.8 GW fusion power
- Chamber radius 6.5 m at mid-plane



KEY FEATURES OF DUAL COOLANT LITHIUM-LEAD CONCEPT (DCLL)

- Helium cools the ferritic steel FW and structure and is used for FW/blanket preheating and possible tritium control
- Breeding $Li_{17}Pb_{83}$ is circulating at low speed
- No separate neutron multiplier needed
- Use flow channel inserts (FCI) to:
  - Provide electrical insulation to reduce MHD pressure drop in MFE systems
  - Provide thermal insulation to decouple LiPb bulk flow temperature from wall temperature
  - Provide additional corrosion resistance since only stagnant LiPb is in contact with the ferritic steel structural walls



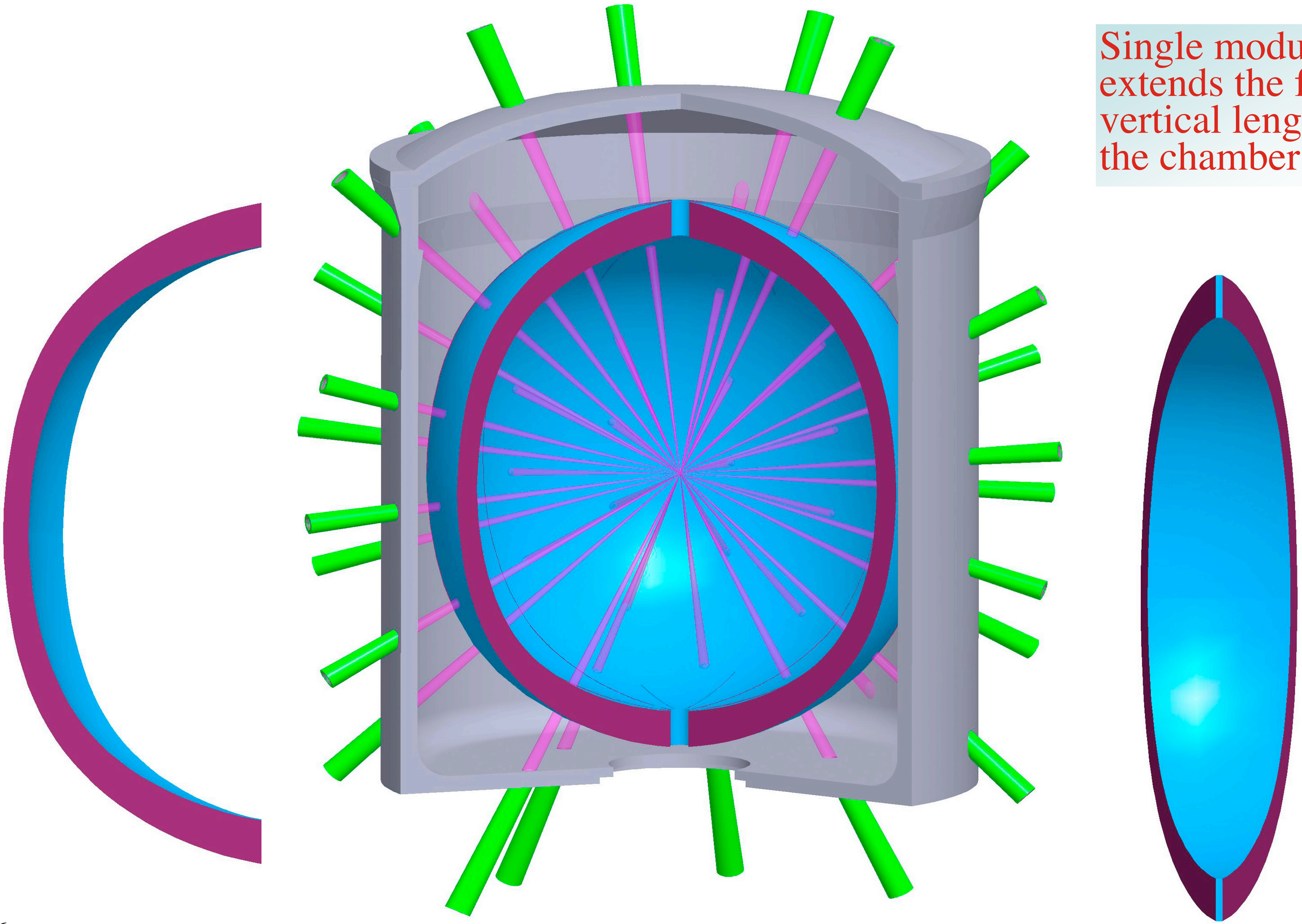
EU Demo Design

DCLL concept used in several MFE designs (EU Demo, US Demo, ARIES-ST, ARIES-CS) and will be tested in ITER TBM

DCLL Configuration in HAPL Chamber

- Blanket designed to cover the entire vertical length of the chamber
- LiPb is admitted at bottom of blanket module, travels vertically upwards in a large channel behind FW, then makes a U turn at top, and travels down exiting the module on bottom. He coolant connections are also made on the bottom
- Toroidal channels are difficult to implement on the module extremities where it comes to a point. At those locations, at a distance of 2m from the ends, the cooling switches to vertical channels
- A horizontal manifold located near the FW feeds the vertical channels, which in turn exhaust into collector manifolds located at the sides of the module

Example Layout of Chamber with LiPb Blanket



Single module extends the full vertical length of the chamber

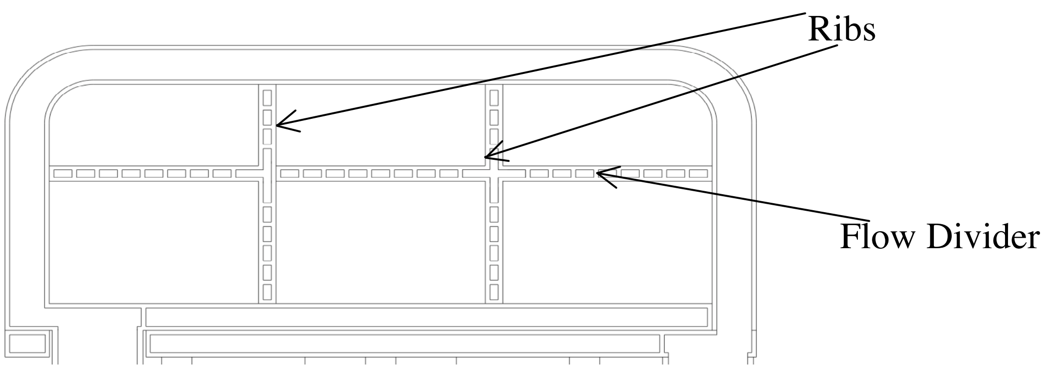
Radial Build and Material Composition

Zone	Description	Thick (mm)	% W	% FS	% LL	% SiC	% He
1	**Armor**	1	100	0	0	0	0
2	**Front wall of FW**	4	0	100	0	0	0
3	**FW cooling channel**	30	0	17	0	0	83
4	**Back wall of FW**	4	0	100	0	0	0
5	**SiC insert 1**	5	0	2	0	94	4
6	**Front breeding channel**	200	0	5	85	4	6
7	**SiC insert 2**	5	0	2	0	94	4
8	**Flow divider plate**	15	0	60	0	0	40
9	**SiC insert 3**	5	0	2	0	94	4
10	**Back breeding channel**	200	0	5	85	4	6
15	**SiC insert 4**	5	0	2	0	94	4
16	**Back wall**	50	0	80	0	0	20
	Total	**524**					

- Li in LL enriched to 90% ^{6}Li

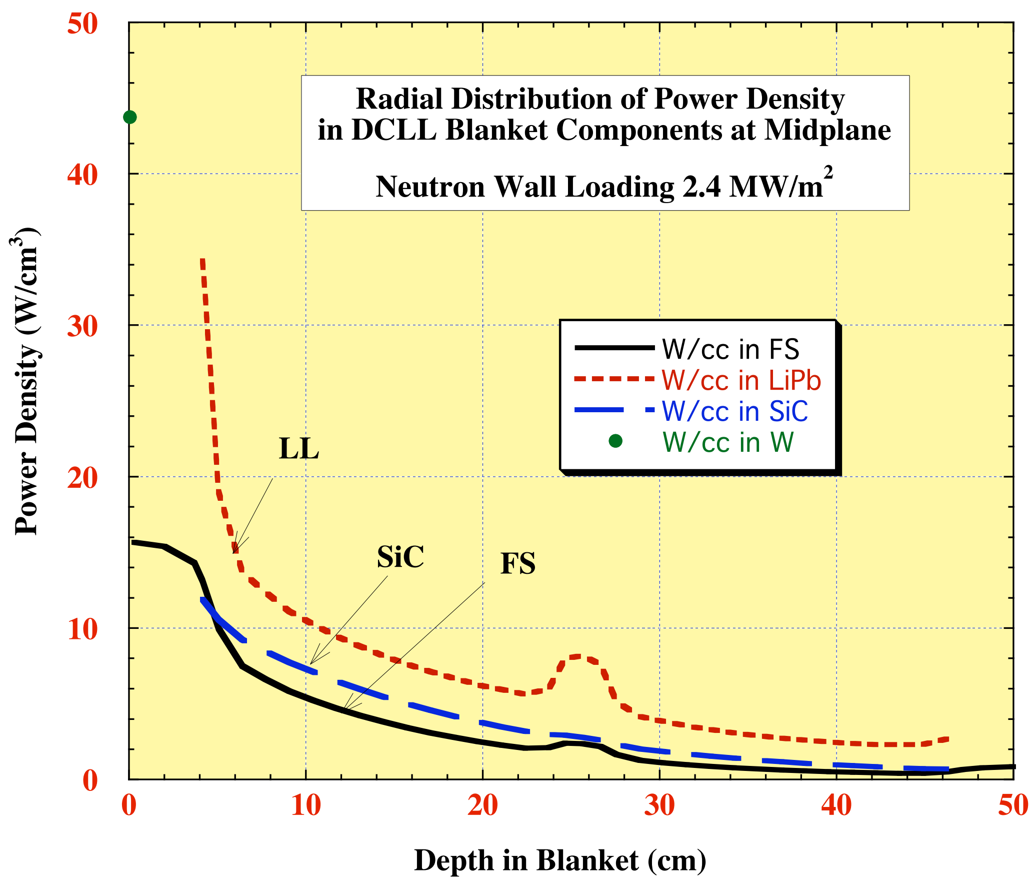
TBR = 1.176

Solid angle fraction subtended by beam ports is ~0.4% with minimal impact on overall TBR



Nuclear Heating

Radial variation of nuclear heating (W/cm^3) determined in the components of the DCLL blanket



- Power density in W armor

  43.8 W/cm^3

- Peak power density in FS structure

  15.6 W/cm^3

- Peak power density in LiPb

  34.2 W/cm^3

- Peak power density in SiC FCI

  11.9 W/cm^3

Plant Thermal Power

for 1800 MW Fusion Power

Total Thermal Power = 2096 MW

- **1231 MW removed from blanket by LiPb**
- **865 MW removed from blanket and VV by He**
  - **742 MW from blanket (531 MW surface + 211 MW volumetric)**
  - **123 MW from VV**

Peak Radiation Damage in Blanket

	dpa/FPY	He appm/FPY
W armor	8.2	4.8
FW	26.3	174

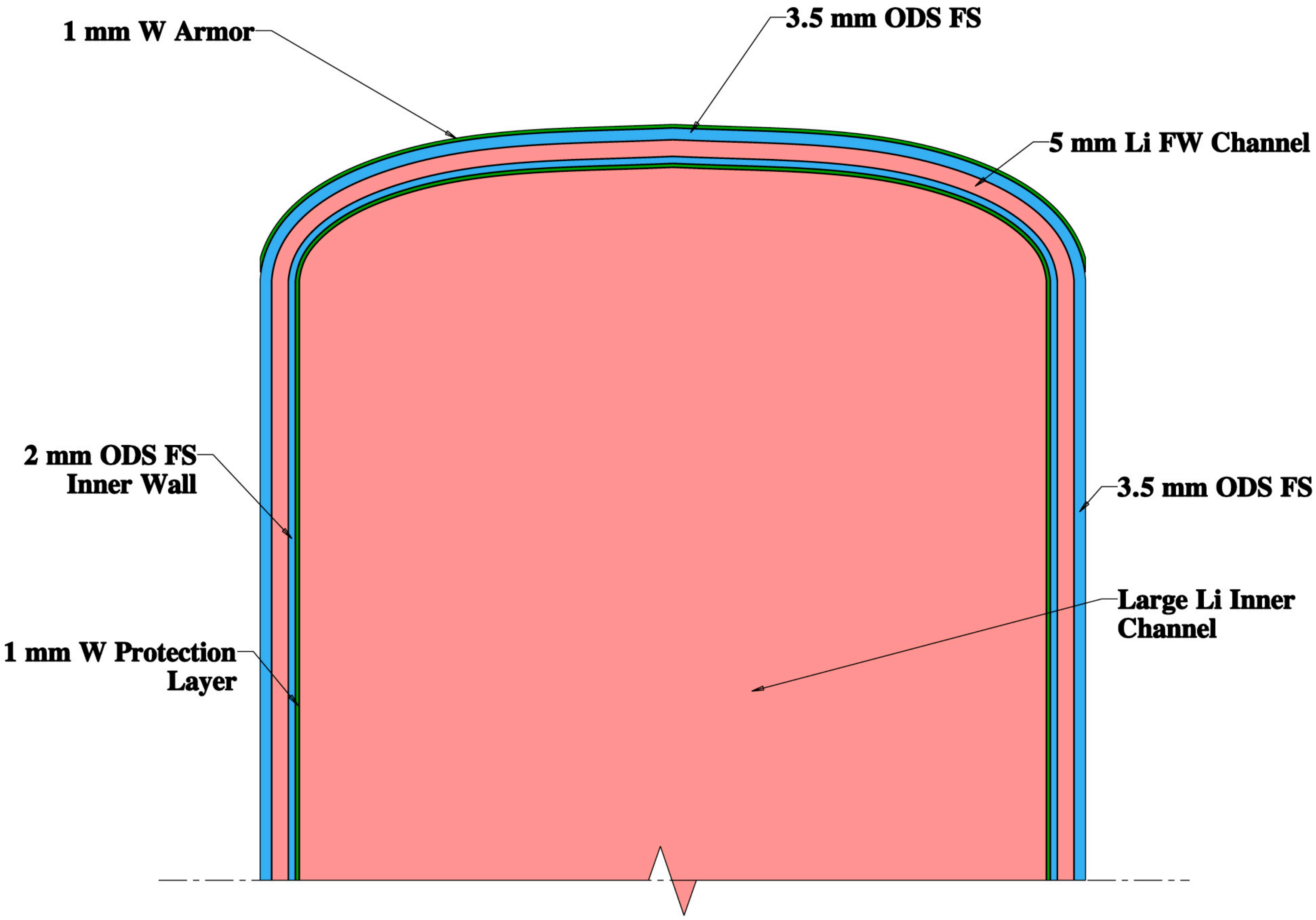
Blanket lifetime is ~7.6 FPY

Peak EOL (40 FPY) Radiation Damage in 30 cm VV

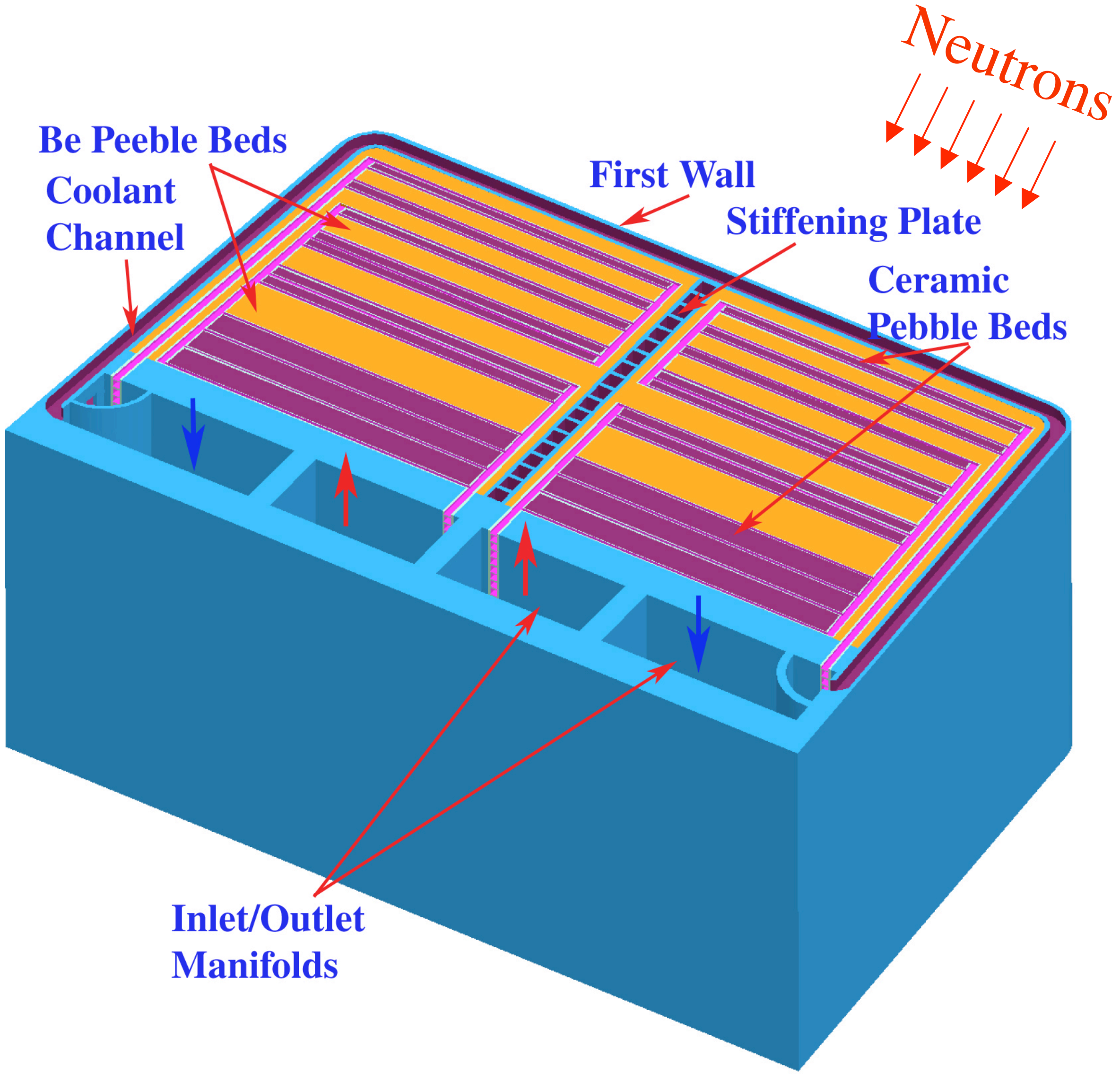
	dpa	He appm
Front of VV	58	35.2
Back of VV	8.4	0.5

- VV is lifetime component
- Rewelding is possible at back of VV

Self-Cooled Li Blanket Configuration



Solid Breeder Blanket Configuration



Comparison between Nuclear Performance of Li, SB, and LiPb Blankets in HAPL

	Li* *Blanket	***SB* *Blanket***	***LiPb* *Blanket***
Overall TBR	1.12	1.17	1.17
Blanket thickness (cm)	47	65	52
Total Thermal power (MW)	2103 (12% He)	2302 (100% He)	2096 (40% He)
Power density in FW structure (W/cm^3)	13	20	16
Peak FS damage rate (dpa/FPY)	19	20	26
Peak EOL (40 FPY) dpa in VV	170	19	58
Blanket lifetime (FPY)	10	10	7
Required VV thickness (cm)	50	30	30
Thermal Efficiency	*~45%*	*~30-35%*	*~40-45%*

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Summary of Nuclear Performance Differences between Candidate Blankets

- Thicker SB blanket with significant amount of Be required for tritium breeding (due to low breeding capability of SB and large amount of structure needed)
- The large amount of Be in SB blanket yields ~10% more thermal power and 20-40% higher power density in FW
- While all of the thermal power is carried by He in the case of SB blanket, only 12%, and 40% is carried by He in cases of Li and LiPb blankets, respectively, with the rest carried by the breeder
- While FW radiation damage is similar for Li and SB, it is about 30% higher for the LiPb blanket which is reflected in shorter blanket lifetime
- Thicker VV is required with Li blanket (due to poor shielding capability of Li) to allow rewelding at back of VV
- VV is a lifetime component in three cases but the margin is smaller for the Li blanket
- Other considerations (material compatibility, safety, tritium retention/control, thermal efficiency, complexity, fabrication, weight, cost, development risk and R&D cost, …) should be accounted for in the blanket selection

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