Neutronics Assessment of Self-Cooled Li Blanket Concept

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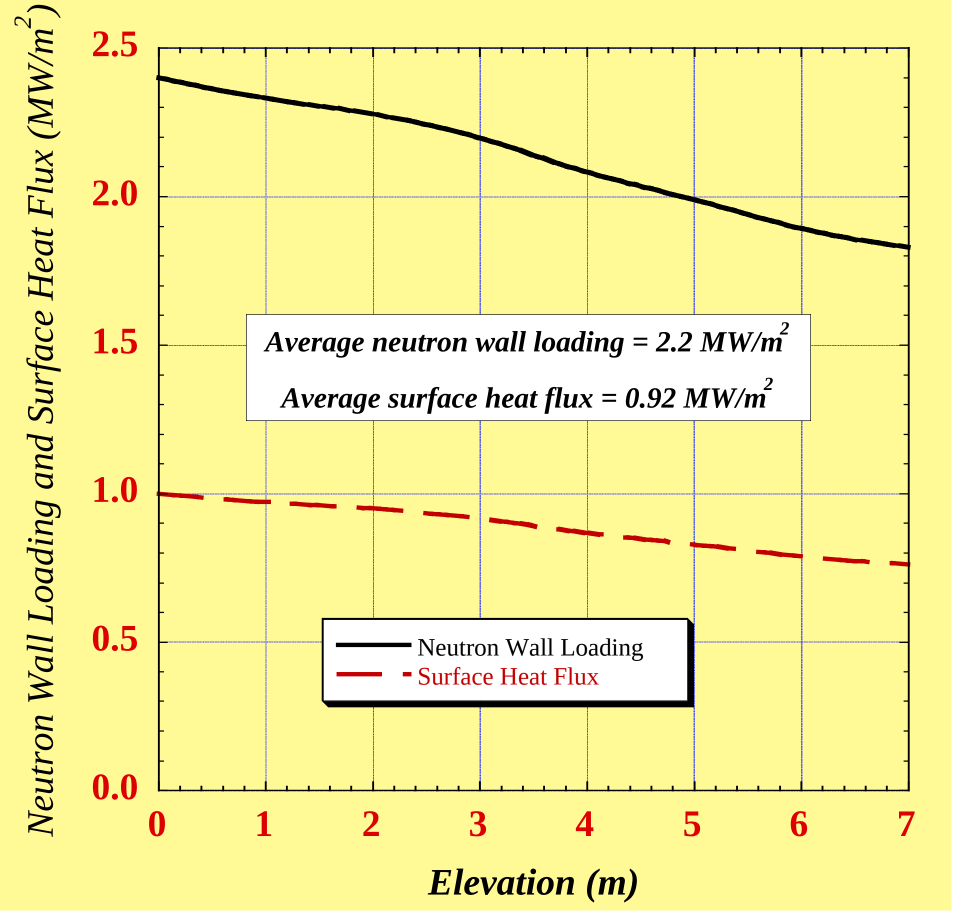
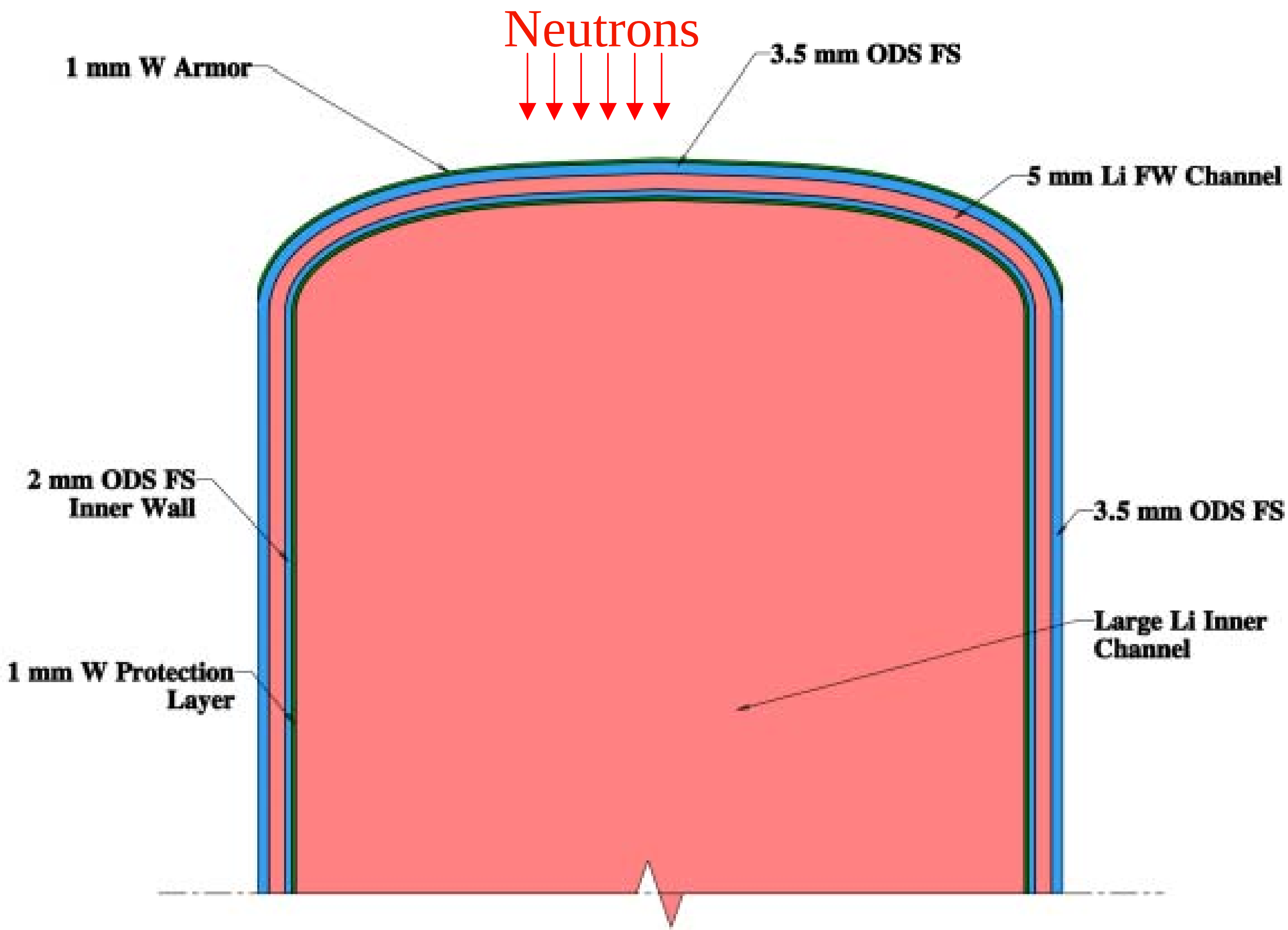
HAPL Meeting
UCLA
June 2-3, 2004

Basic Assumptions

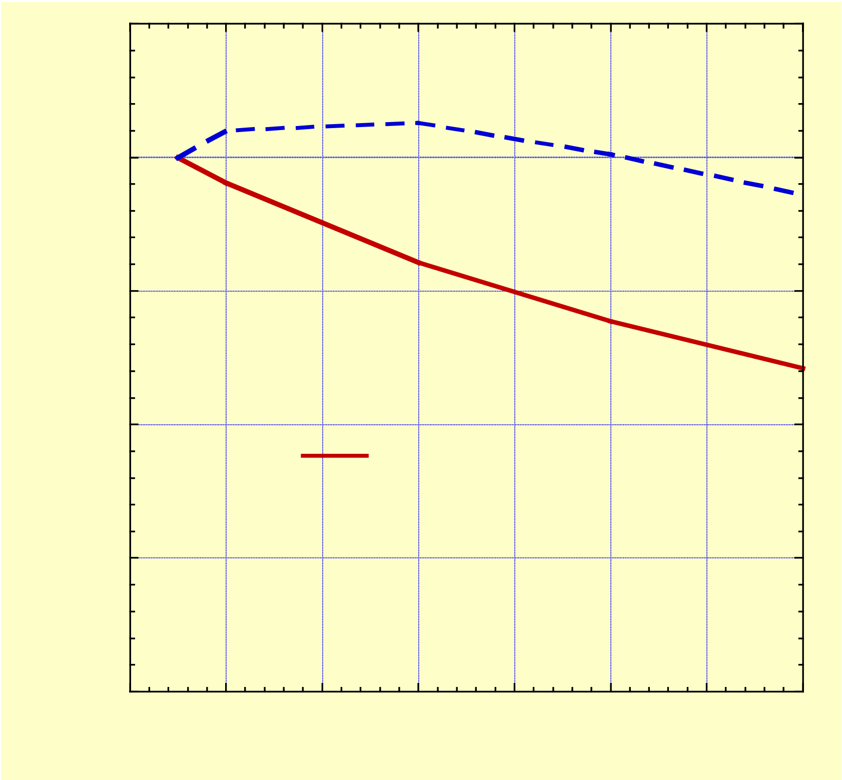
- 1 mm W armor on ferritic steel (F82H) FW
- Used target spectrum from LASNEX results (Perkins) for NRL direct-drive target
- 70.5% of target yield carried by neutrons with 12.4 MeV average energy
- 1.8 GW fusion power
- Chamber radius 6.5 m



Blanket Sub-module at Midplane



Lithium Enrichment



- Enrichment helps shielding more than breeding
- 30% enrichment saves only ~3 cm in blanket thickness but increases cost of Li by about an order of magnitude
- TBR maximizes with 20% enrichment but gain is only 2.5%
- Natural Li used
- Li enrichment can be used as a knob in design allowing for adjustment of TBR and shielding if needed

Blanket Thickness

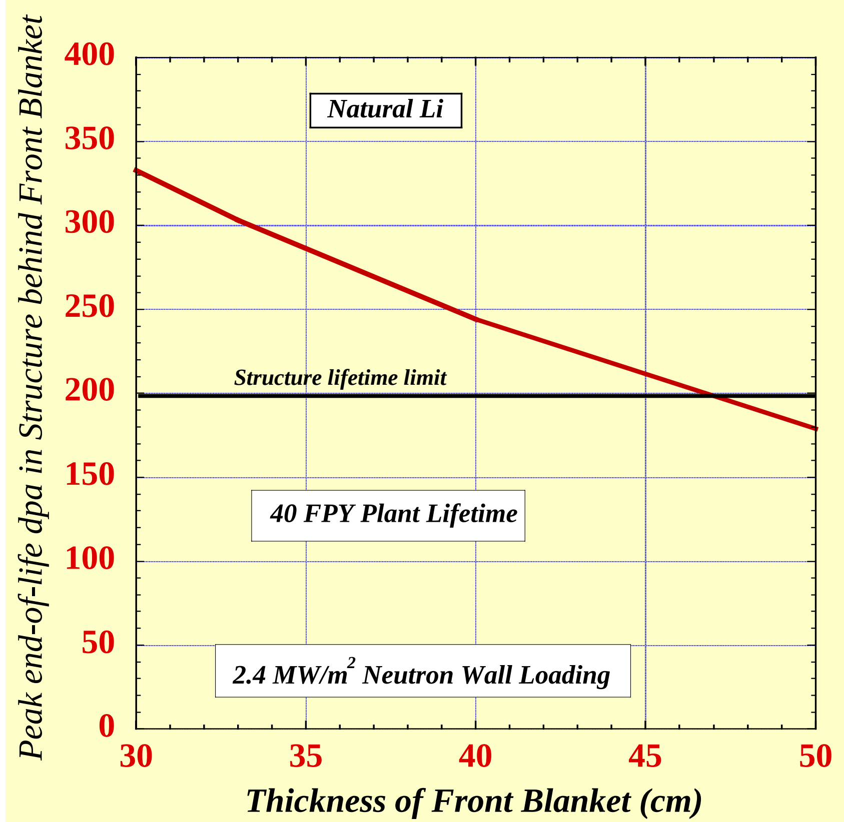
Peak radiation damage rate in FS structure at midplane (2.4 MW/m^2)

	FW	Vacuum Chamber
dpa/FPY	19.15	4.87
He appm/FPY	184.4	27.2

- Minimum blanket thickness required is 47 cm for vacuum chamber to be lifetime component
- Lifetime of blanket is ~10 FPY

Radiation damage and gas production in W armor
6.2 dpa/FPY
4.8 He appm/FPY

- Atomic displacement on sides of W/FS interface differ by a factor of 3
- Helium production on sides of W/FS interface differ by a factor of 38



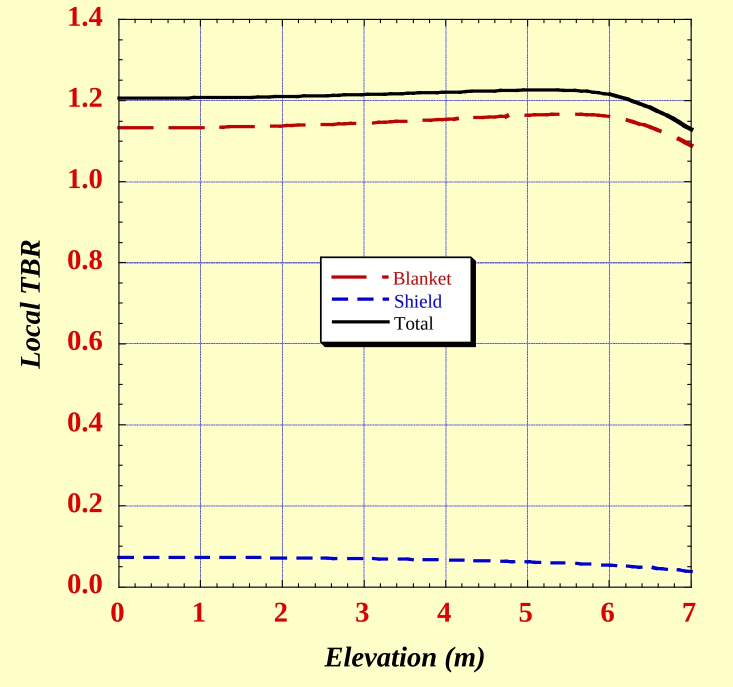
Tritium Breeding Requirement

- Overall TBR required >1.1
- Local TBR calculated at midplane with 47 cm blanket and FS shield cooled with 15% Li
- Steel and W in the side walls of blanket sub-modules accounted for in calculations by adding 4.2% FS and 0.77% W in the Li zones

Local TBR at midplane

Blanket	1.134
Shield	0.073
Total	1.207

- Moving away from midplane towards top and bottom of chamber blanket thickness increases but blanket sub-module width decreases resulting in increased volume fraction of side walls
- Calculations performed to determine local TBR as a function of elevation above midplane



- Average local TBR in side region of chamber is 1.212
- If no breeding blankets are utilized in top and bottom regions overall TBR will be 1.137

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

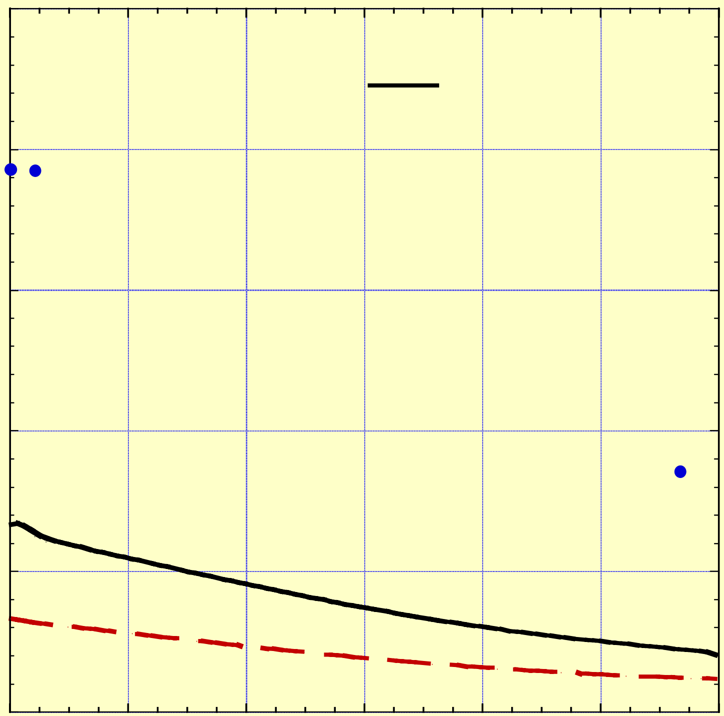
We have the option of designing Li cooled blankets/shields with small Li content at top and bottom and using He-cooled vacuum chamber

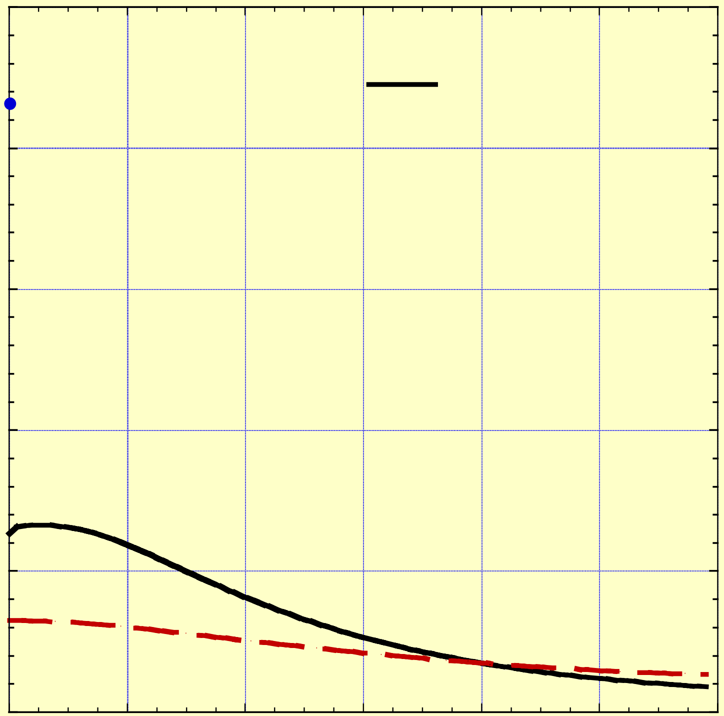
Tritium Breeding for Reference Design

- Lithium content in top/bottom blanket is 20%
- While side blanket thickness at midplane of 47 cm is required to make VV lifetime component, top/bottom blanket thickness required is only 30 cm
- 50 cm thick SS VV used with 15% helium cooling

Overall TBR = *1.124*
Contribution from side blanket modules = 1.1
Contribution from top/bottom blankets = 0.024

Nuclear Heating Distribution





Side Blanket

Top/Bottom Blanket

Plant Thermal Power

for 1800 MW Fusion Power

Total Thermal Power = 2103 MW

1842 MW removed from blanket by Li

261 MW removed from VV by He

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1730 MW in side blanket (500 MW surface + 1230 MW volumetric)

112 MW in top/bottom blankets (31 MW surface + 81 MW volumetric)

+

245 MW in side VV

16 MW in top/bottom VV

Structure Radiation Damage for Reference Design

	Side	Top/bottom
Peak FW dpa/FPY	19.2	15.6
Estimated Blanket Lifetime (FPY)	10.4	12.8

	Side	Top/bottom
EOL (40 FPY) dpa at Front of VV	170	65
EOL He appm at Back of VV	0.67	0.12

- Blanket lifetime is ~10 FPY
- VV is lifetime component
- Rewelding is possible at back of VV

Summary

- Overall TBR >1.1 can be achieved with small Li content in top/bottom blanket (20%) and no breeder in VV. There is no need to enrich Li in Li-6
- VV can be lifetime component with minimum blanket thickness of 47 cm on the side and 30 cm in top/bottom
- Blanket lifetime expected to be ~10 FPY
- The He-cooled VV should be at least 50 cm thick to allow rewelding at its back
- For 1800 MW_f, total thermal power is 2100 MW_{th} with 12.5% of it carried by the He coolant of the VV
- Differential swelling at the interface between W armor and FS FW needs to be assessed. At interface, W dpa is lower than FS dpa by a factor of 3 and W He production is lower by a factor of 38. Nuclear heating in W is higher by a factor of 3