# Neutronics Assessment of Solid Breeder Blanket Concept

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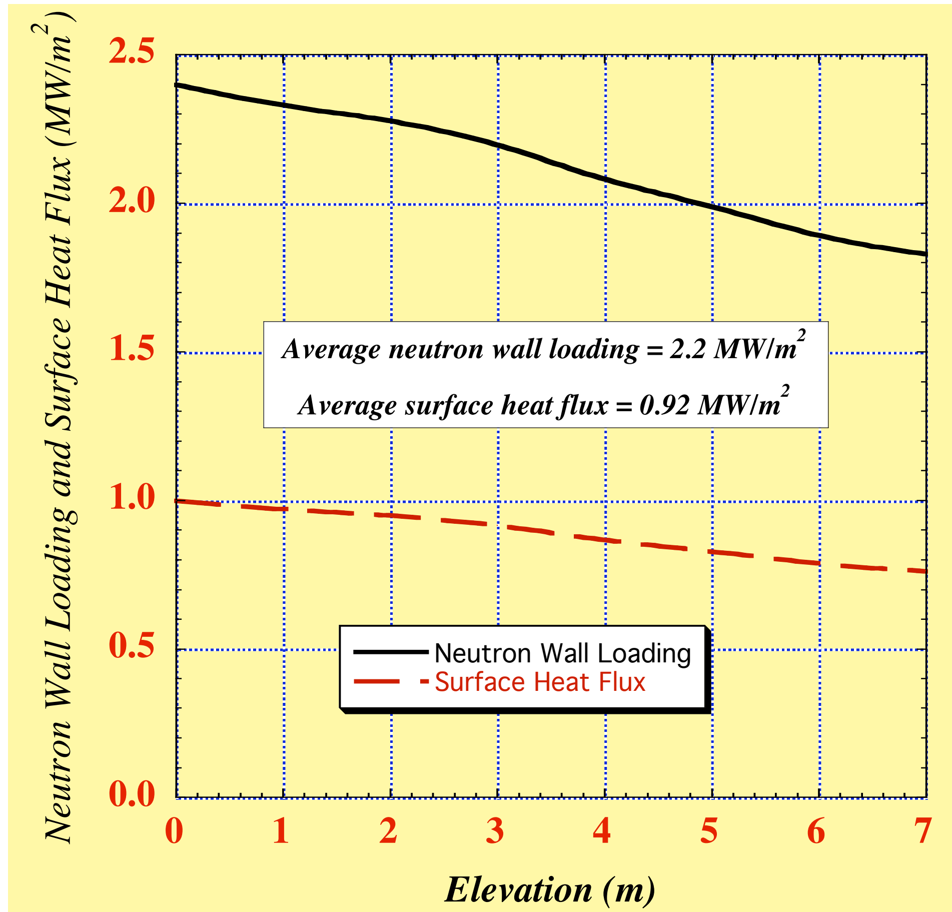
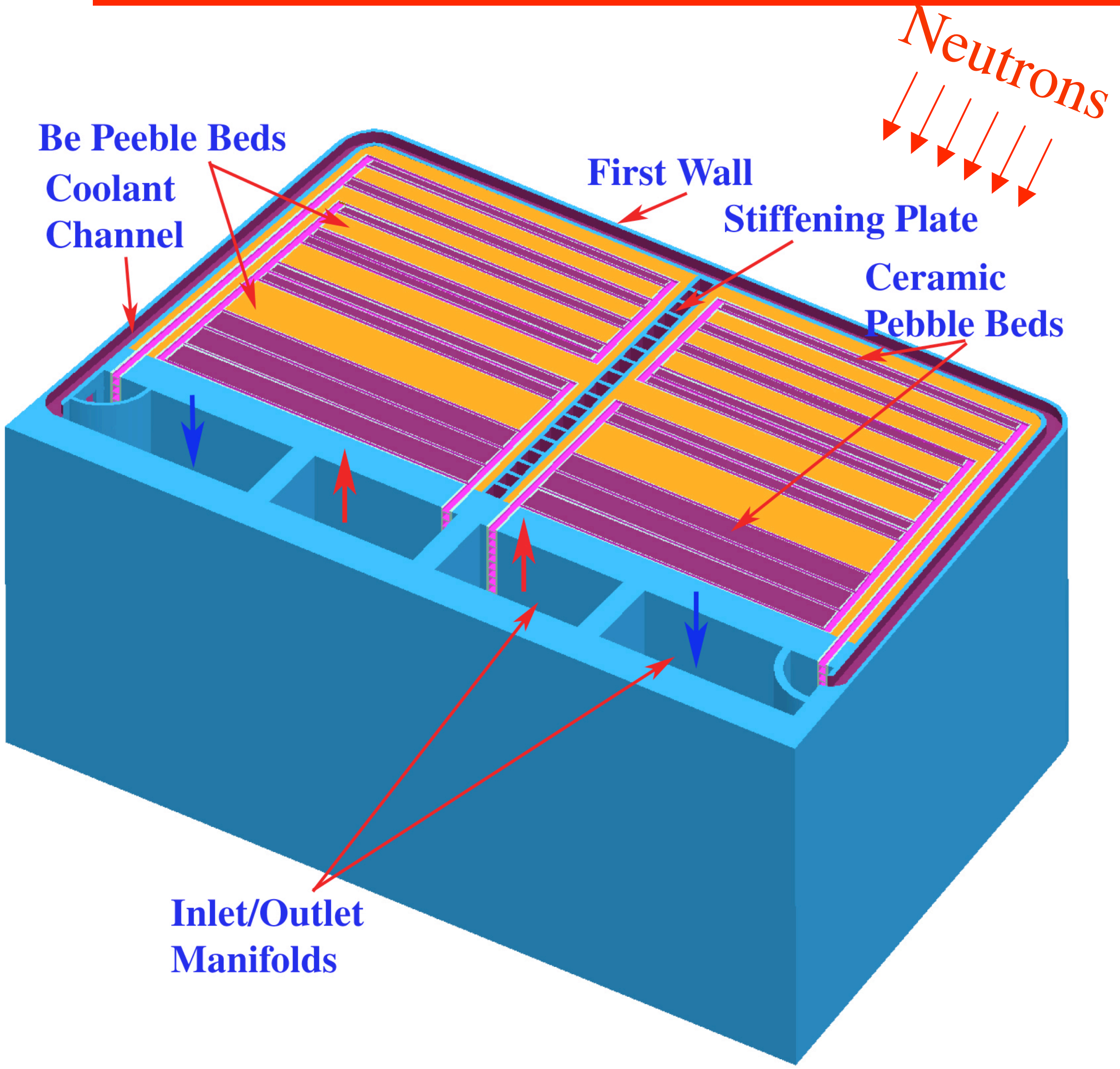
# Basic Assumptions

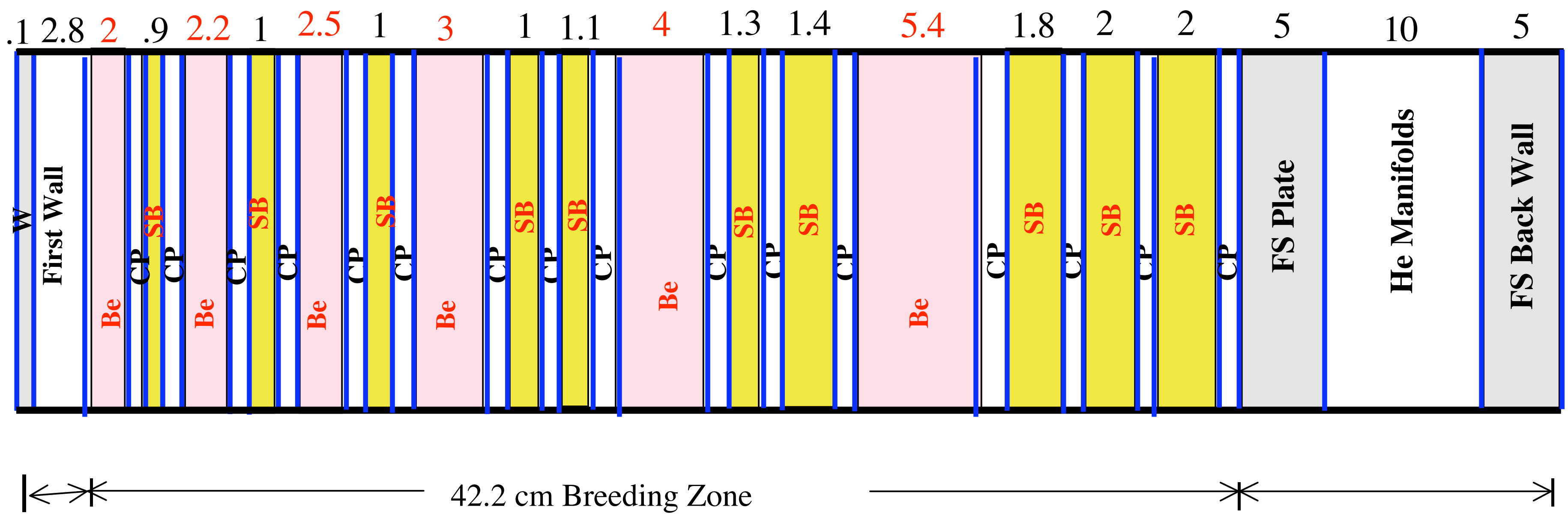
- 1 mm W armor on ferritic steel (F82H) FW
- Used target spectrum from LASNEX results (Perkins) for NRL direct-drive target
- 70.5% of target yield carried by neutrons with 12.4 MeV average energy
- 1.8 GW fusion power
- Chamber radius 6.5 m at mid-plane



# Solid Breeder Blanket Configuration



# Radial Build of SB Blanket




- Radial build of ARIES-CS SB blanket used
- 65 cm total blanket thickness
- $Li_4SiO_4$ breeder and RAFS F82H structure
- 1 mm W armor used in front of FW
- Uniform Li enrichment used

***Material composition in radial layers includes module sides***

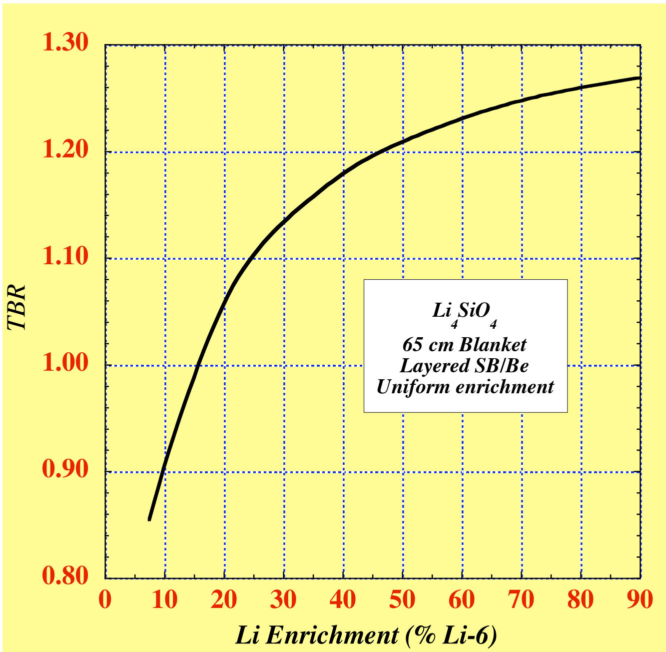
**FW**: 40.7% FS, 59.3% He

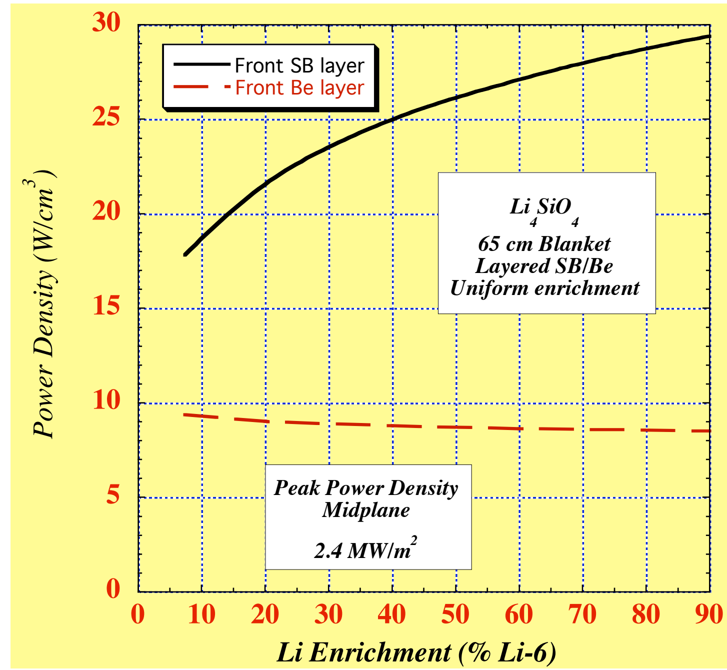
**Be zone:** 53% Be, 6% FS, 41% He

**SB zone:** 51% SB, 2.5% Be, 6% FS, 40.5% He

**CP zone:** 52% FS, 2.5 Be, 45.5% He

# Lithium Enrichment




- With near full coverage in HAPL chamber a uniform enrichment of 40% Li-6 is adequate with TBR of 1.18
- Solid angle fraction subtended by beam ports is ~0.4% with minimal impact on overall TBR

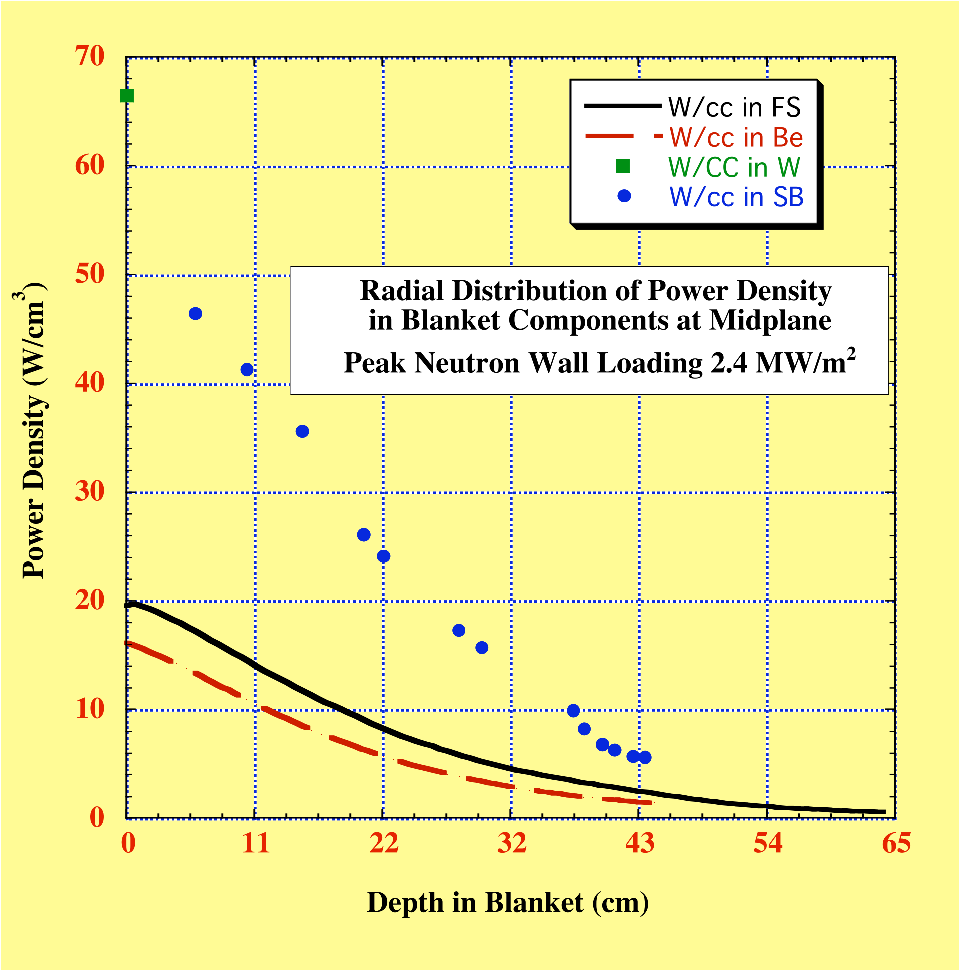
- Moderate power densities in front Be and SB layers ensure maximum temperature limits (750°C Be, 950°C SB) will not be exceeded with the current radial build even if a uniform enrichment of 90% is used

- 40% enrichment used in reference design
- Li enrichment can be used as a knob in design allowing for adjustment of TBR and shielding if needed

# Nuclear Heating

| Zone | Thickness (cm) | Power Density (W/cm$^3$) |
|---|---|---|
| W | 0.1 | 66.52 |
| FW | 2.8 | 7.95 |
| Be-1 | 2.0 | 8.77 |
| CP | 0.6 | 9.57 |
| SB-1 | 0.9 | 25.06 |
| CP | 0.6 | 8.99 |
| Be-2 | 2.2 | 7.37 |
| CP | 0.6 | 8.12 |
| SB-2 | 1.0 | 22.21 |
| CP | 0.6 | 7.49 |
| Be-3 | 2.5 | 5.89 |
| CP | 0.6 | 6.57 |
| SB-3 | 1.0 | 19.07 |
| CP | 0.6 | 5.99 |
| Be-4 | 3.0 | 4.49 |
| CP | 0.6 | 5.09 |
| SB-4 | 1.0 | 14.03 |
| CP | 0.6 | 4.63 |
| SB-5 | 1.1 | 12.93 |
| CP | 0.6 | 4.14 |
| Be-5 | 4.0 | 2.89 |
| CP | 0.6 | 3.31 |
| SB-6 | 1.3 | 9.26 |
| CP | 0.6 | 2.94 |
| SB-7 | 1.4 | 8.40 |
| CP | 0.6 | 2.56 |
| Be-6 | 5.4 | 1.63 |
| CP | 0.6 | 1.91 |
| SB-8 | 1.8 | 4.88 |
| CP | 0.6 | 1.65 |
| SB-9 | 2.0 | 3.55 |
| CP | 0.6 | 1.42 |
| SB-10 | 2.0 | 3.08 |
| CP | 0.6 | 1.23 |
| Manifold | 20.0 | 0.64 |

- Nuclear heating calculated in radial zones of blanket and used in thermal hydraulics analysis



# Plant Thermal Power

# for 1800 MW Fusion Power

**Total Thermal Power = 2302 MW**

**2254 MW removed from 65 cm blanket by He**

**(531 MW surface + 1723 MW volumetric)**

**48 MW removed from 30 cm VV by He**

## Peak Radiation Damage in Blanket

| | dpa/FPY | He appm/FPY |
|---|---|---|
| W armor | 6.4 | 4.6 |
| FW | 20.1 | 183 |

Blanket lifetime is ~10 FPY

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

| | dpa | He appm |
|---|---|---|
| Front of VV | 19.3 | 33.6 |
| Back of VV | 2.5 | 0.4 |

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

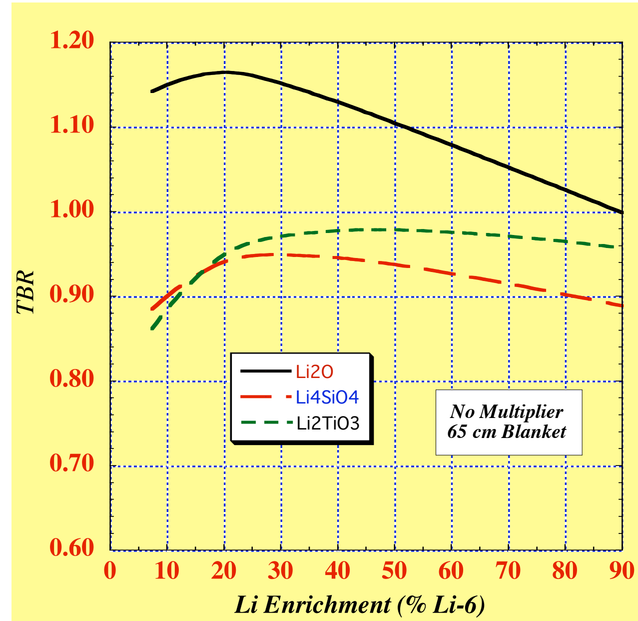
# Comparison between Nuclear Performance of Li and SB Blankets in HAPL

| | ***Li Blanket*** | ***SB Blanket*** |
|---|---|---|
| Overall TBR | 1.12 | 1.17 |
| Blanket thickness (cm) | 47 | 65 |
| Total Thermal power (MW) | 2103 | 2302 |
| Power density in FW structure (W/cm$^3$) | 13 | 20 |
| Blanket lifetime (FPY) | 10 | 10 |
| Required VV thickness (cm) | 50 | 30 |

- Thicker SB blanket with significant amount of Be required for tritium breeding
- The large amount of Be in SB blanket yields ~10% more thermal power
- While FW radiation damage is similar about 50% higher nuclear heating is generated in FW of SB blanket
- Thicker VV required with Li blanket to allow rewelding at back of VV

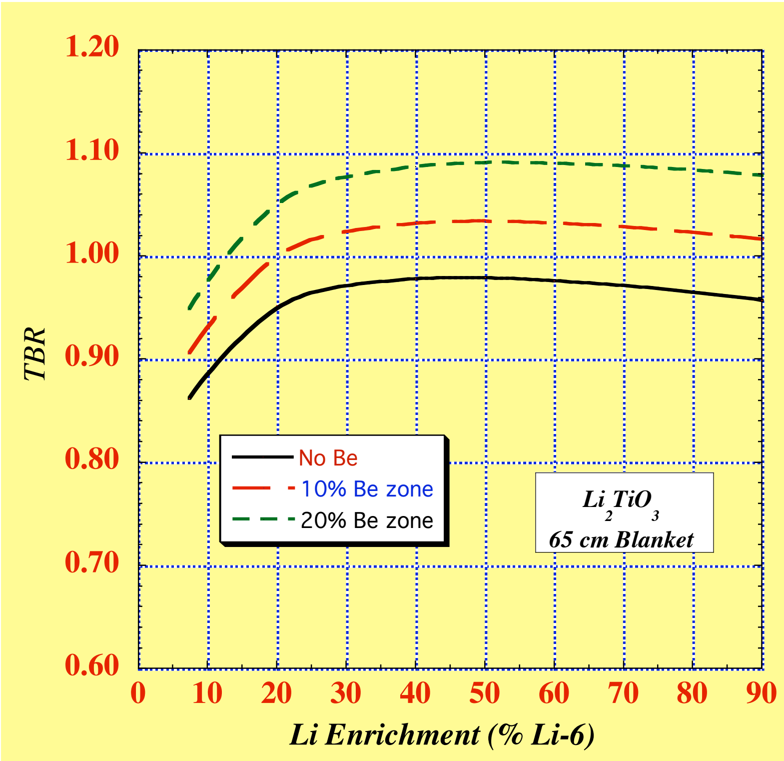
# Neutronics assessment of SB Flowing Bed Blanket

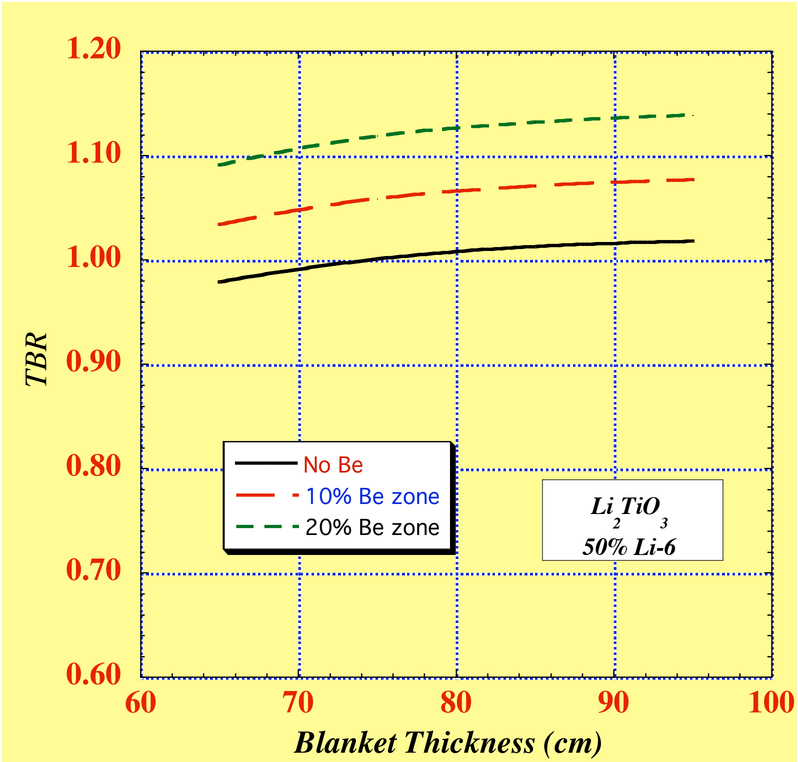
- The layered 42.2 cm breeding region is replaced by a homogenized composition of 3.67% FS, 62.61% SB, 33.72% He
- The 20 cm manifold zone at the back has 57.5% FS, 42.5% He
- Total blanket thickness 65 cm
- Blanket thickness allowed to change by changing thickness of breeding region
- Three breeders considered ($Li_2O$, $Li_4SiO_4$, $Li_2TiO_3$)
- Considered the option of adding Be zones (53% Be, 6% FS, 41% He) in the breeding region to enhance TBR
- Used uniform Li-6 enrichment in SB



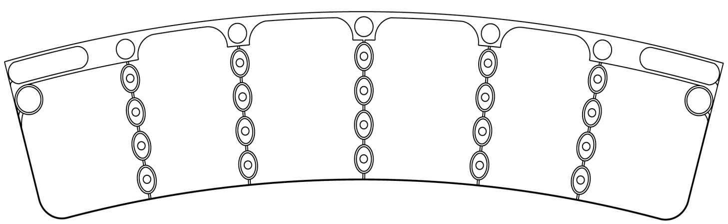

- We must add Be and/or increase blanket thickness if the $Li_4SiO_4$ or $Li_2TiO_3$ breeders are used
- With $Li_2O$ we can keep blanket thickness at 65 cm and there is no need for enrichment

# Adding Be and Increasing Thickness to Enhance TBR




- With $Li_4SiO_4$ or $Li_2TiO_3$ breeders blanket thickness should be increased to ~85 cm in addition to enriching and adding up to 20% Be zone in breeding region



# Neutronics Parameters for SB Flowing Bed Blanket Options

| Breeder | Enrich | Be zone | Blanket Thick (cm) | Local TBR | Blanket lifetime (FPY) | VV dpa @ 40 FPY | Required VV thick (cm) |
|---|---|---|---|---|---|---|---|
| $Li_2O$ | Nat. | 0% | 65 | 1.142 | 10 | 17.3 | 30 |
| $Li_4SiO_4$ | 40% | 20% | 85 | 1.139 | 10 | 4 | 15 |
| $Li_2TiO_3$ | 50% | 20% | 85 | 1.132 | 10 | 2.5 | 10 |

- Using $Li_2O$ flowing bed allows achieving adequate TBR in the 65 cm blanket without enrichment or adding Be
- Using $Li_4SiO_4$ or $Li_2TiO_3$ flowing bed a 20 cm thicker blanket should be used with smaller amount of Be compared to the static layered SB case. A much thinner VV can also be used

# *Summary*

- Overall TBR >1.1 can be achieved with 65 cm thick SB blanket with significant amount of Be and Li-6 enrichment
- VV can be lifetime component and its back can be reweldable if its thickness is at least 30 cm
- Blanket lifetime expected to be ~10 FPY
- For 1800 $MW_f$, total thermal power is 2300 $MW_{th}$ which is ~10% larger than that in Li blanket. About 50% higher nuclear heating is generated in FW and front part of blanket
- Using $Li_4SiO_4$ or $Li_2TiO_3$ flowing bed a 20 cm thicker blanket should be used with smaller amount of Be and much thinner VV compared to the static layered SB case