Neutronics Issues Related to the Magnetic Diversion Concept

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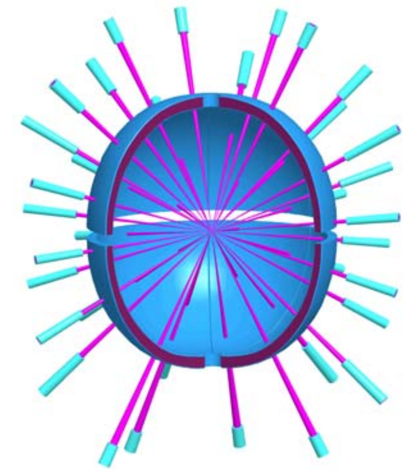
Impact of Streaming on Tritium Breeding

- We assume the polar holes at top and bottom are 60 cm in diameter and toroidal slot at mid-plane is 1 m high
- For a 6.5 m radius chamber this represents a loss of ~8% in blanket coverage (7.7% at mid-plane, 0.1% top/bottom)



- One option is to intercept streaming neutrons from the mid-plane slot by a secondary blanket at a larger radius and recover the lost breeding in the primary blanket
- This secondary blanket will be like a belt with ~2 m height (to intercept majority of streaming neutrons) and about same thickness as primary blanket (to get similar local TBR). Radial location should be far enough in order not to interfere with diverted ions
- Alternatively we can increase the primary blanket thickness and use neutron dumps to intercept streaming neutrons

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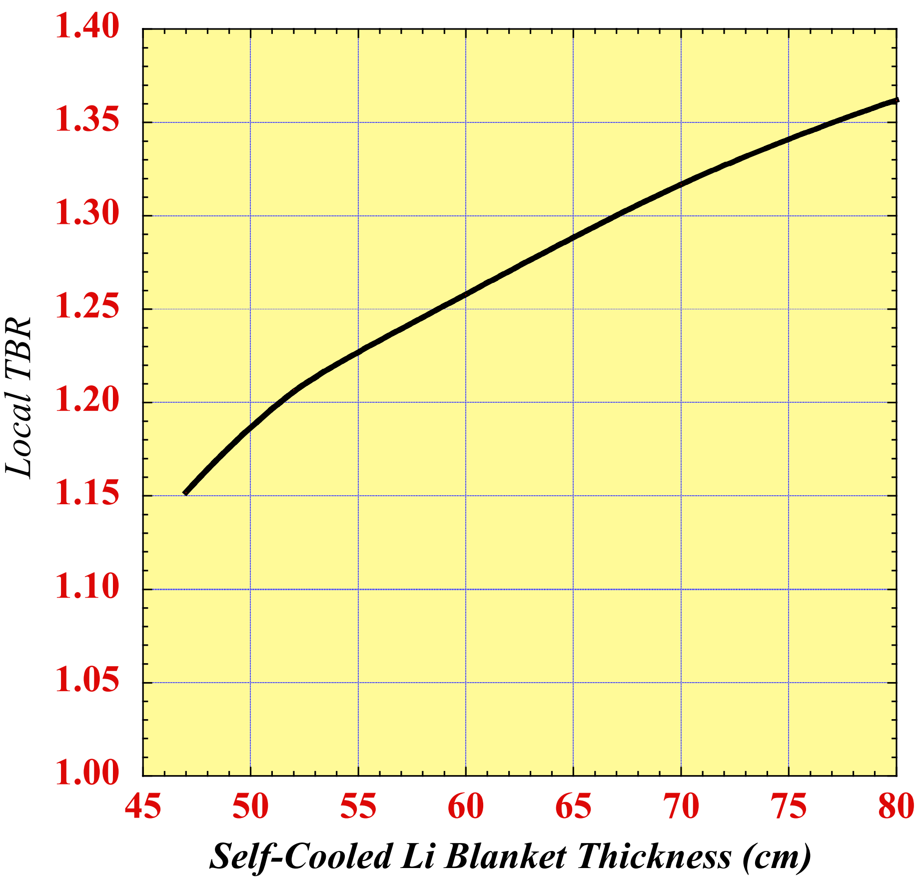
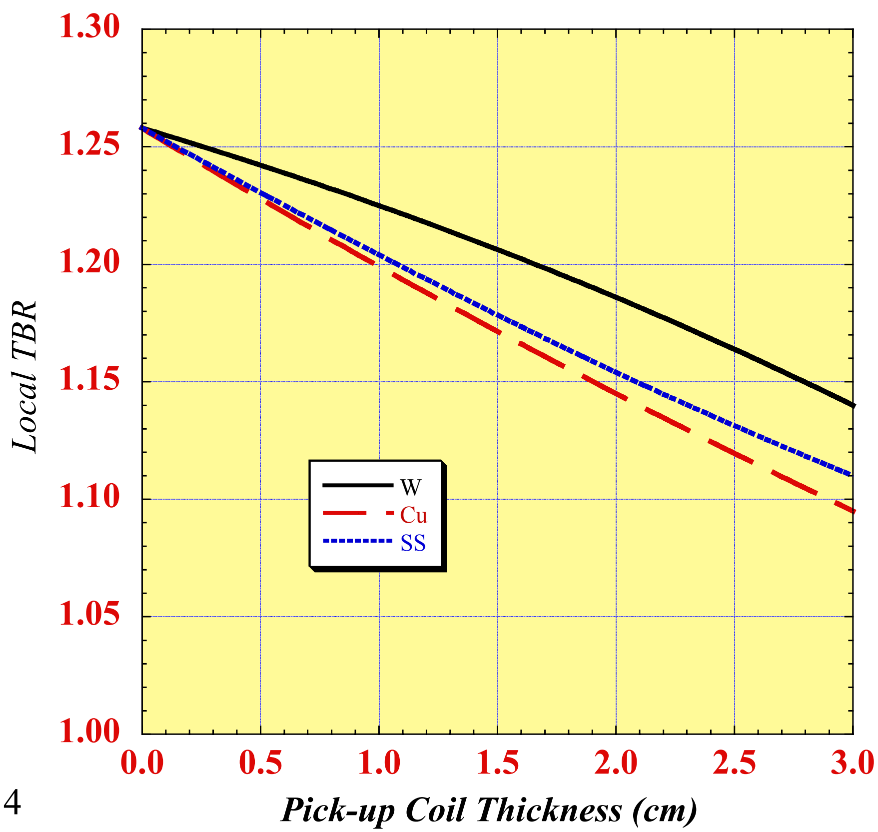
Required Blanket Thickness Increase

- Increasing the self-cooled Li blanket thickness from 47 to ~60 cm will be adequate to compensate for the ~8% loss of blanket coverage
- For solid breeder blanket we estimate that thickness needs to be increased from 65 to ~80 cm with increased Be content



Impact of Pick-up Coils on Tritium Breeding

- Pick-up coils are located inside chamber between target and blanket
- The impact of these coils on the TBR depends on thickness, material and coverage
- We assessed effect of coil thickness on local TBR in a 60 cm thick Li blanket behind it for three candidate materials (W, Cu, SS)



- W has the least impact and Cu has the largest effect on TBR
- These results need to be factored in with coverage fraction and thickness of coils to determine the overall impact on TBR

Nuclear Environment at Pick-up Coils

- Survivability of the pick-up coils in the severe neutron environment inside the chamber is an issue
- Damage rate in candidate materials determined for a 2.4 MW/m^2 neutron wall loading @6.5 m from target
- Damage rate goes up as $1/r^2$ if coils located closer to target

Coil Material	dpa/FPY	He appm/FPY
W	6.1	4.8
Cu	19.7	157
SS	19.0	176

Shielding Requirement for Cusp Coils

Radiation Limits

1) Superconducting Magnets

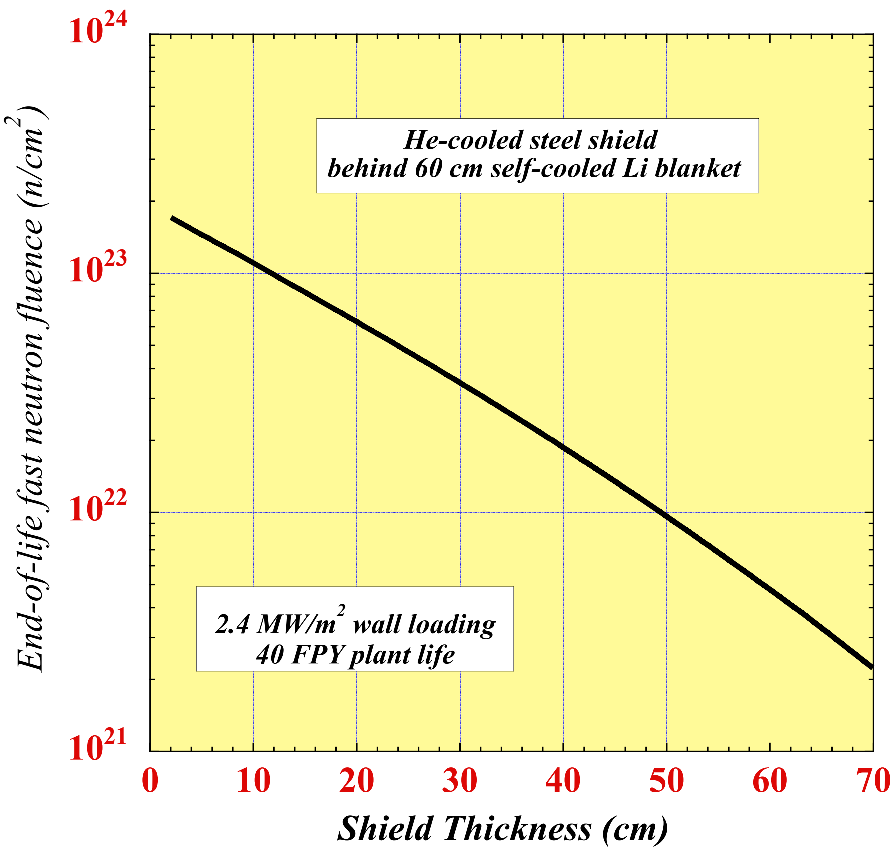
- Fast neutron fluence is limited to 10^{19} n/cm^2 (E>0.1 MeV) due to degradation in J_c of superconductor
- Dose in organic insulator is limited to 10^{10} Rads due to degradation of mechanical properties
- Using more radiation resistant insulator does not help since damage to superconductor will be the limiting factor

2) Normal Magnets

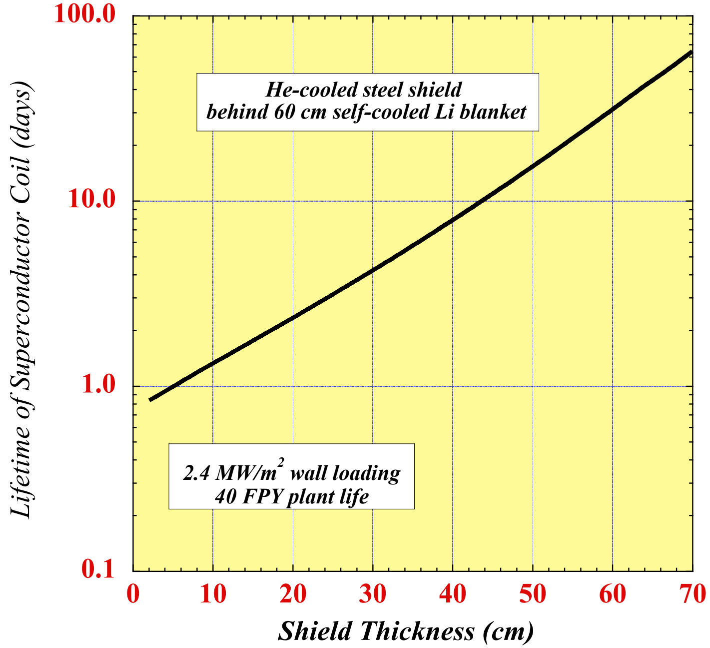
- The more radiation resistant ceramic insulators can be used
- Spinel is limited to 4×10^{22} n/cm^2 fast neutron fluence assuming that 3% swelling can be accommodated

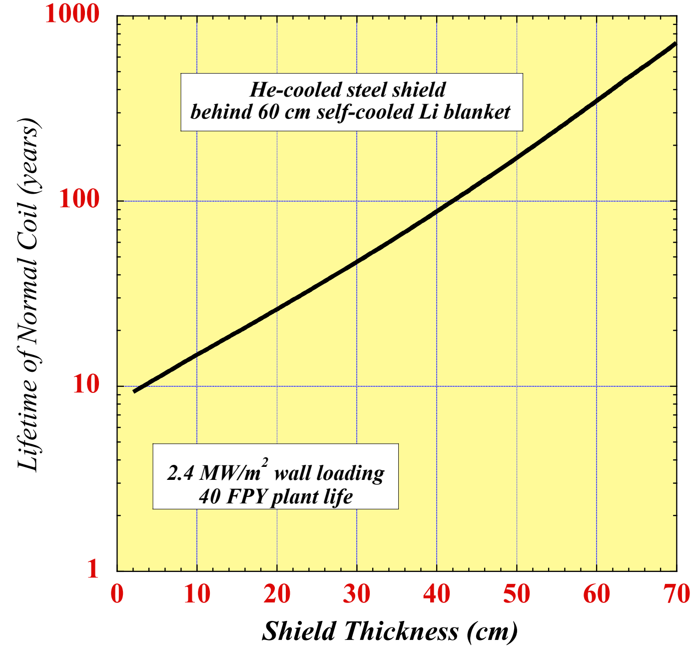
Nuclear Environment behind Li Blanket

- If magnet is placed behind the 60 cm Li blanket without additional shield end-of-life (40 FPY) fluence and insulator dose are $1.7\text{x}10^{23}$ n/cm^2 and $1.2\text{x}10^{14}$ Rads. Lifetime will be only 20 h for superconducting magnet and 9 y for normal magnet
- Adding He-cooled steel shield between blanket and cusp coils reduces flux at magnet and increases lifetime



Additional Shield Required behind Blanket





- Lifetime of superconductor magnets is very limited and large amount of shield is needed for reasonable lifetime
- We estimate that ~1.4 m thick shield is required behind Li blanket to make cusp magnets lifetime components
- With 80 cm thick SB blanket (better shielding performance) ~1 m thick shield is required

- Reasonable lifetime can be obtained for normal magnets with modest shield thickness
- We estimate that ~30 cm thick shield is needed behind Li blanket to make magnets lifetime components
- With 80 cm thick SB blanket no additional separate shield is required

Using more efficient (but expensive) shielding materials (W, WC, B_4C, etc) could reduce the required shield thickness by ~20-40%

Summary

- Increasing blanket thickness by ~25% will be adequate to compensate for the ~8% loss of blanket coverage
- Impact of pick-up coils on TBR depends on thickness, material and coverage with W having the least impact
- With superconducting cusp coils an additional 1-1.4 m thick shield is required behind blanket
- With normal Cu cusp coils an additional 30 cm shield is required behind Li blanket and no additional shield is needed with SB blanket
- Smaller shield can be used if cusp coil replacement is acceptable

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