Nuclear Issues for LiPb/FS/He System with Internal VV

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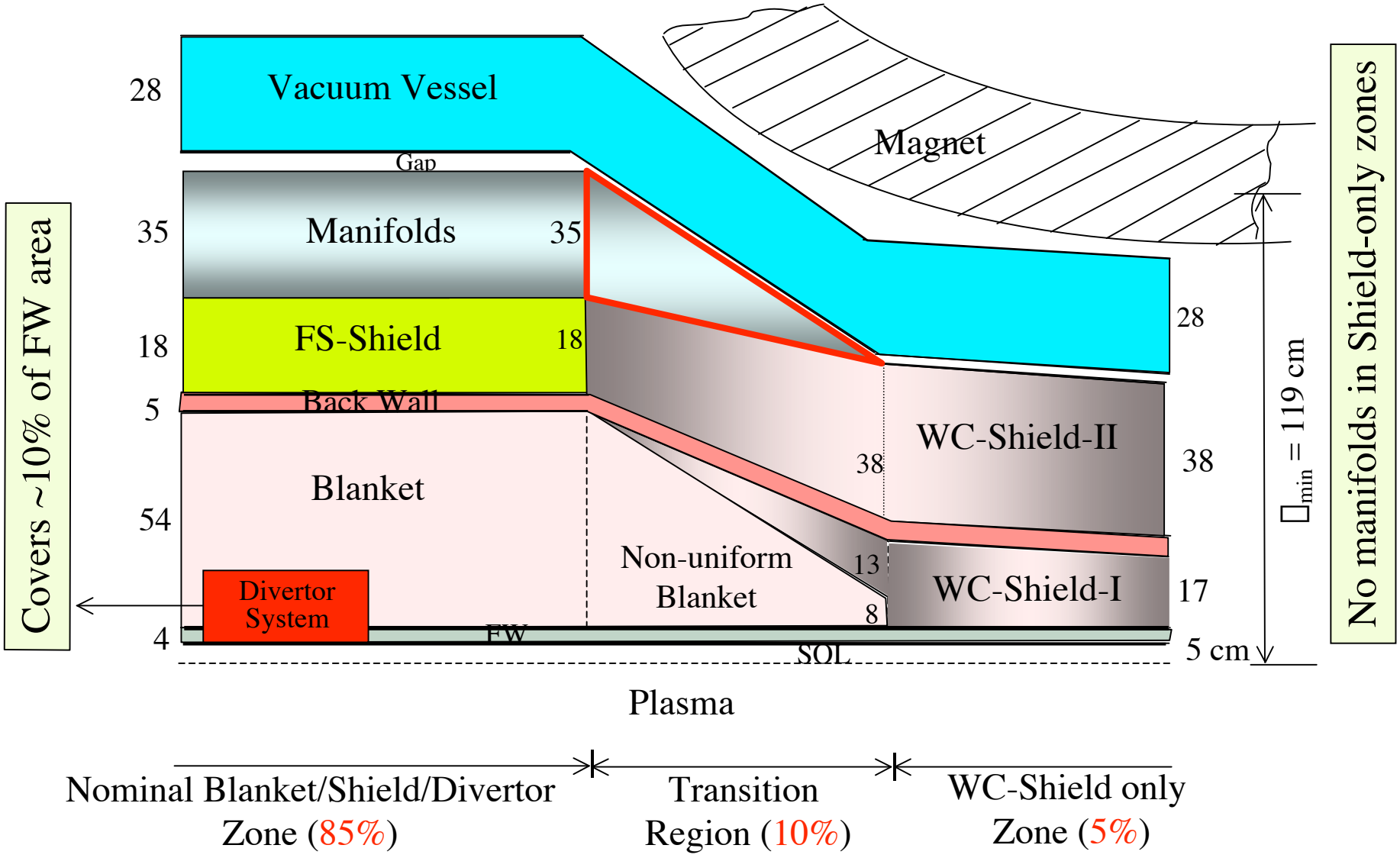
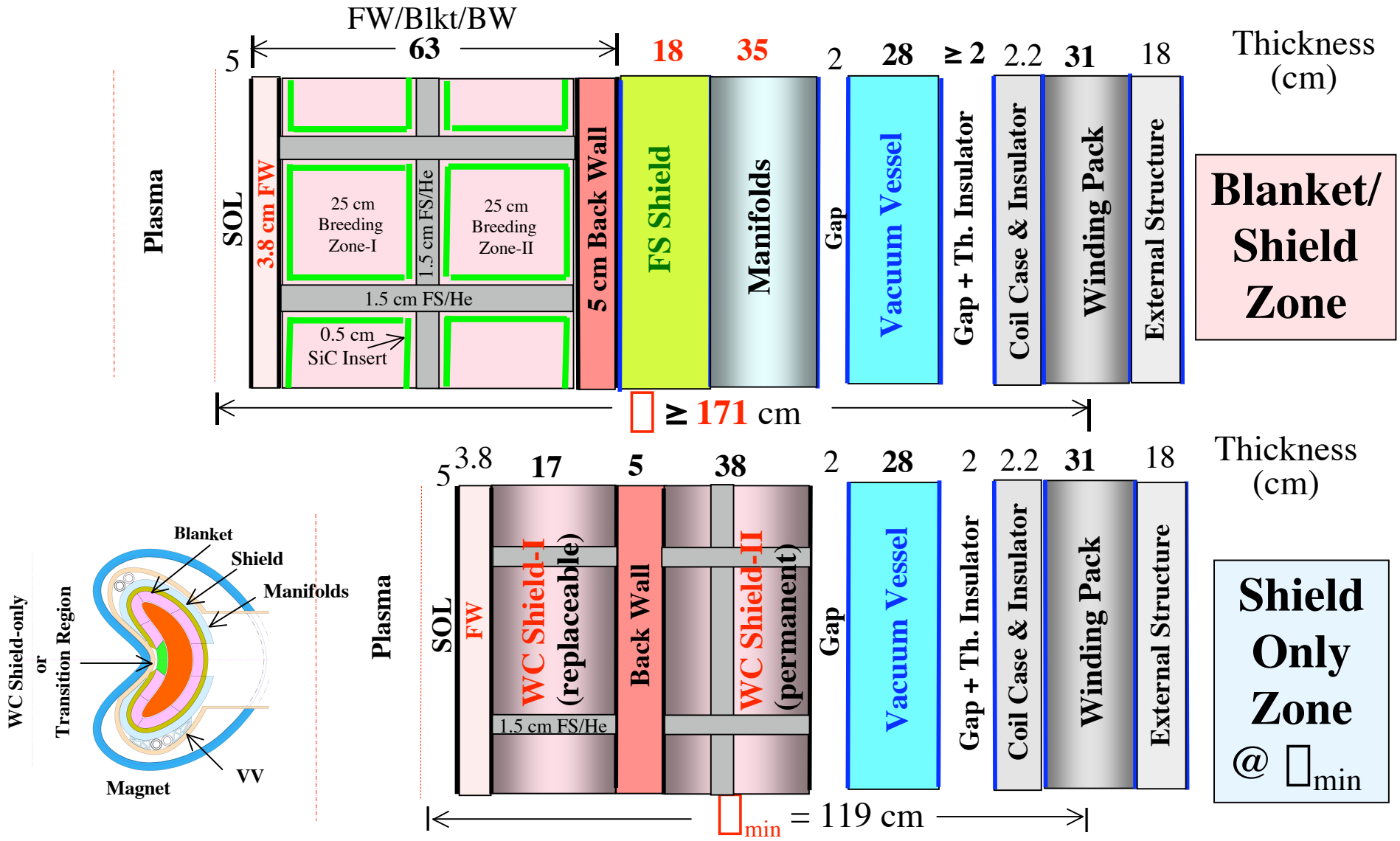
- Reference radial build.
- Hot spots behind LiPb/He access tubes.
- Thermal power split between LiPb and He coolants.
- LiPb decay heat for LOCA/LOFA.
- Radwaste volume comparison.
- Future plan.

Radial/Toroidal Cross Section



Reference Radial Build

(3 MW/m^2 peak □)



Composition
(Nominal Blanket/Shield and Shield-only zones)
(no divertor info)

Component	Thickness	Coverage Fraction	Composition
FW*	3.8 cm	100%	34% FS Structure 66% He Coolant
Blanket*	54.3 cm	85%#	79% LiPb (90% enriched Li) 7% SiC Inserts (95% d.f.) 6% FS Structure 8% He Coolant
Back Wall*	5 cm	100%	80% FS Structure 20% He Coolant
FS Shield	18 cm	85%	15% FS Structure 10% He Coolant 75% Borated Steel Filler
Manifolds	35 cm	85%	52% FS Structure 24% LiPb (90% enriched Li) 24% He Coolant ?% SiC Inserts ??? ←
WC Shield-I* (shield-only zone)	17-21 cm	5%	88% WC Filler 5% FS Structure 7% He Coolant
WC Shield-II (shield-only zone)	38 cm	5%	15% FS Structure 10% He Coolant 75% WC Filler
VV	28 cm	100%	28% FS Structure 49% **Water** 23% Borated Steel Filler

* Replaceable component.

\# For blanket and divertor,

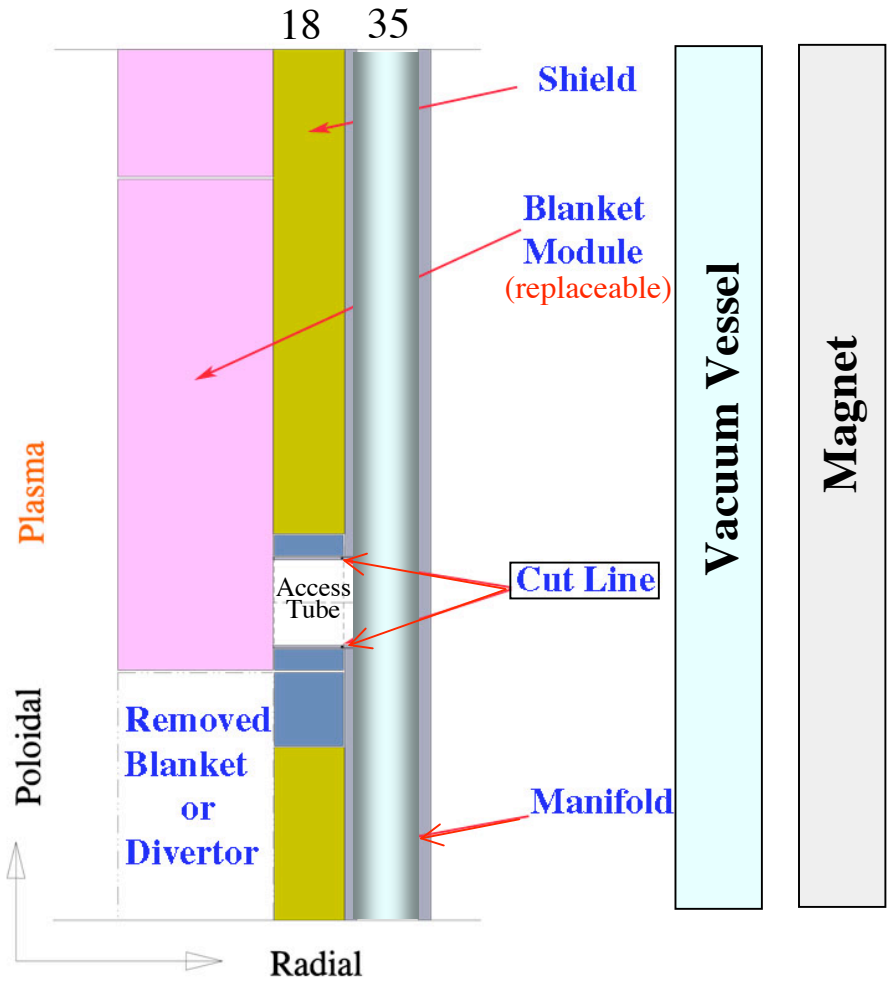
Composition
(Transition Region)

Component	Av. Thickness	Coverage Fraction	Composition
FW*	3.8 cm		34% FS Structure 66% He Coolant
Blanket*	31 cm	10%	~79% LiPb (90% enriched Li) ~ 7% SiC Inserts ~ 6% FS Structure ~ 8% He Coolant
Back Wall*	5 cm		80% FS Structure 20% He Coolant
WC Shield-I*	7 cm	10%	88% WC Filler 5% FS Structure 7% He Coolant
WC Shield-II	28 cm	10%	15% FS Structure 10% He Coolant 75% WC Filler
Manifolds	17 cm	10%	52% FS Structure 24% LiPb (90% enriched Li) 24% He Coolant ?% SiC Inserts ???
VV	28 cm		28% FS Structure 49% **Water** 23% Borated Steel Filler

* Replaceable component.

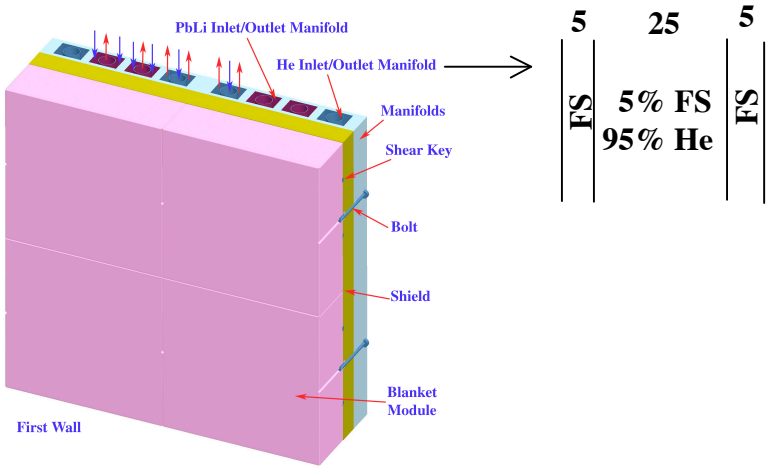
Neutron Streaming Through He/LiPb Access Tubes (23 cm OD)

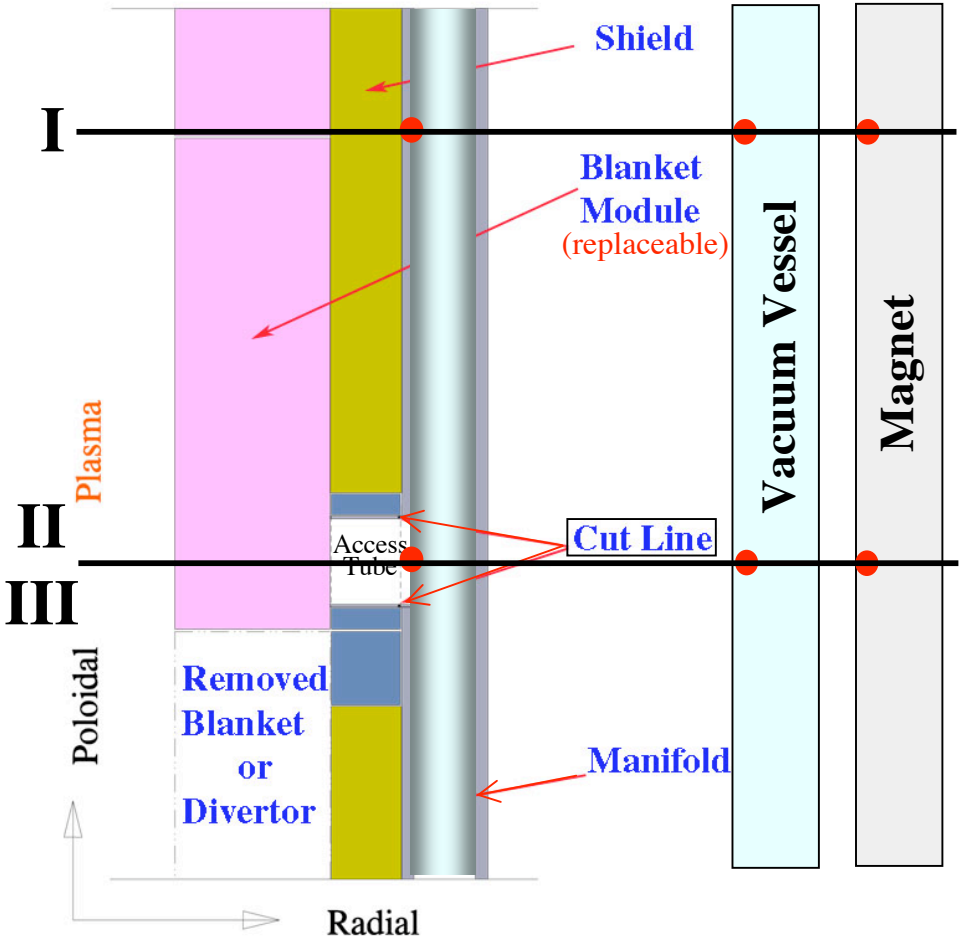
- 18 cm thick shield along with He manifolds protect VV and magnet.
- 18 cm shield does not allow reweldability of manifolds.
- 206 access tubes for each coolant (4 He and 4 LiPb access tubes / m).
- Neutrons streaming through access tubes result in hot spots at VV and magnet.
- Damage behind He access tubes could be excessive (He replaces 22 cm of FS).
- 2-D analysis needed to confirm 1-D findings.



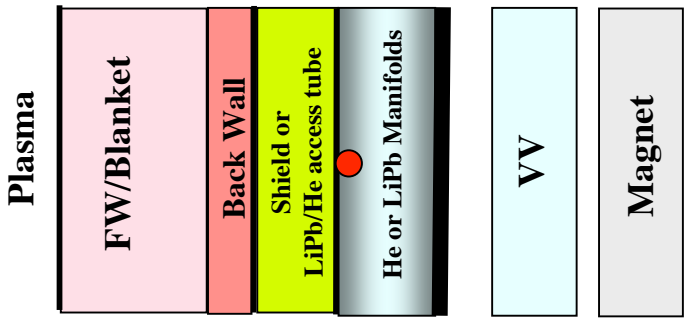
Neutron Streaming Through He/LiPb Access Tubes (Cont.) (23 cm OD)

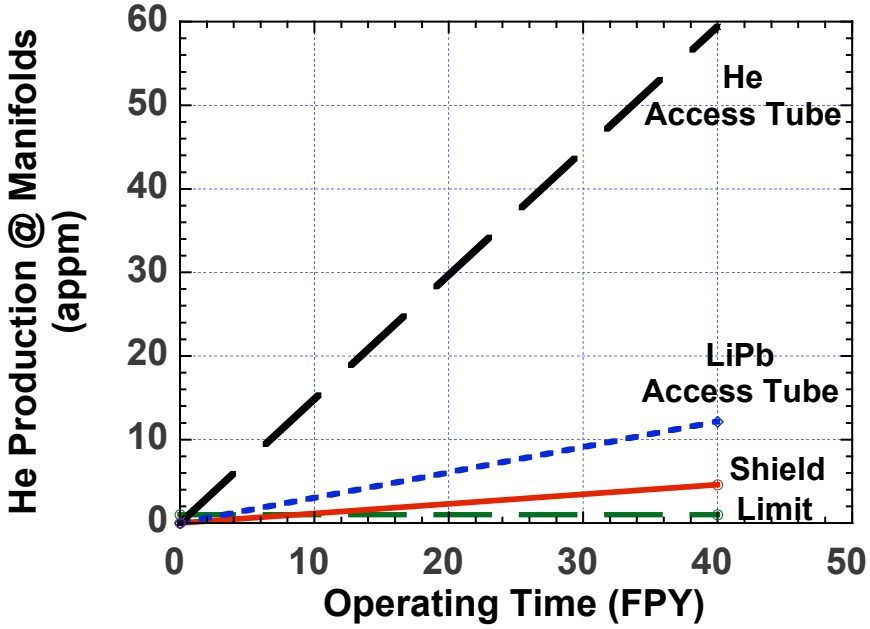
- 1-D analyses performed at 3 cross sections:
  - I- Blanket, shield, He manifolds
  - II- Blanket, LiPb access tube, and LiPb manifolds
  - III- Blanket, He access tube, and He manifolds.
- Conservatively estimated:
  - He production at manifolds
  - He production at VV
  - Fluence at magnet.





He Production at Manifolds

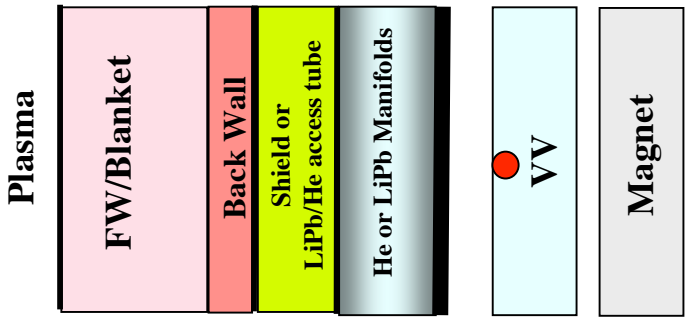


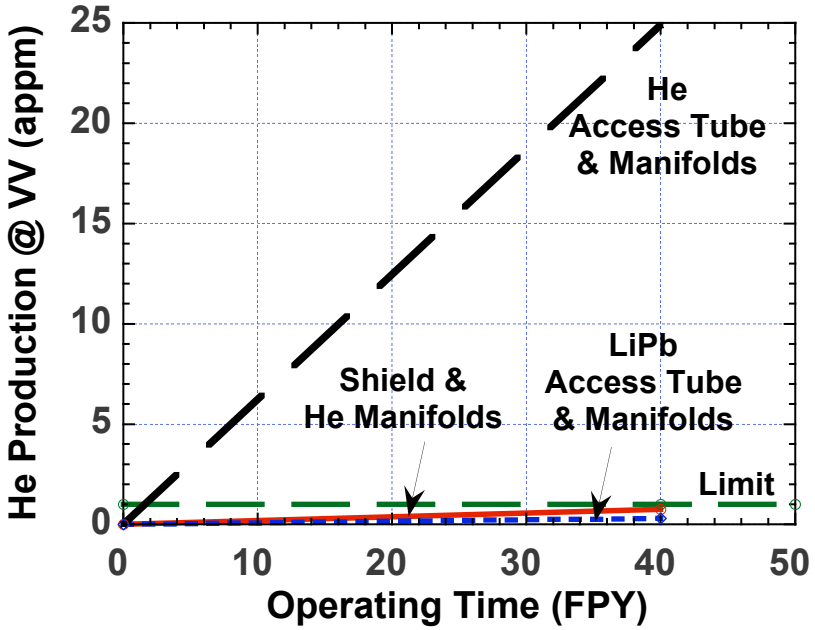


He production at manifolds is excessive

- Modify design to allow reweldability of manifolds

He Production at VV

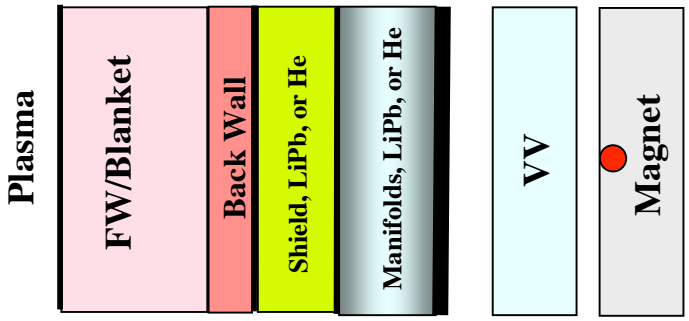


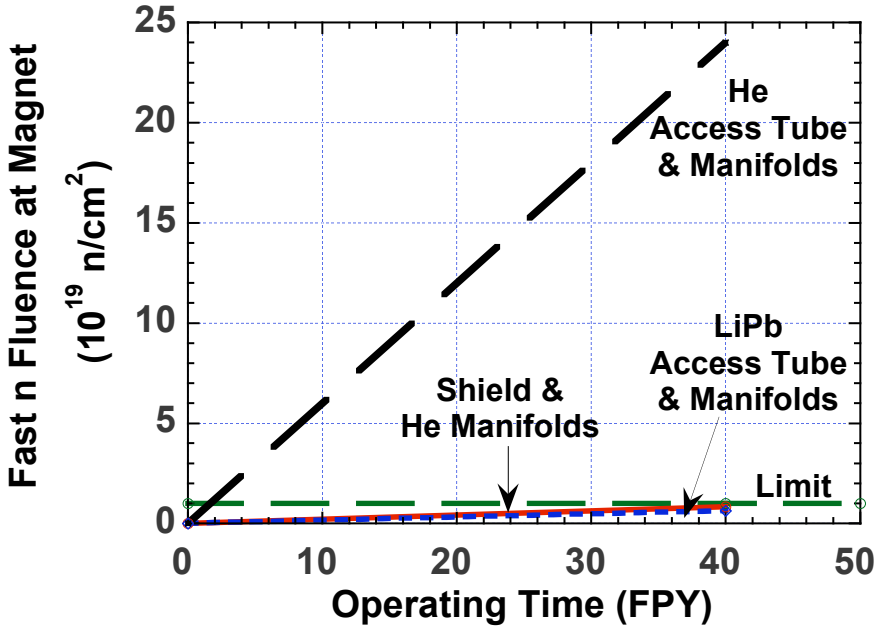


VV cannot be rewelded after few FPY

~25 cm local shield behind 206 He access tubes helps protect VV and magnet. Practical?

Fluence at Magnet





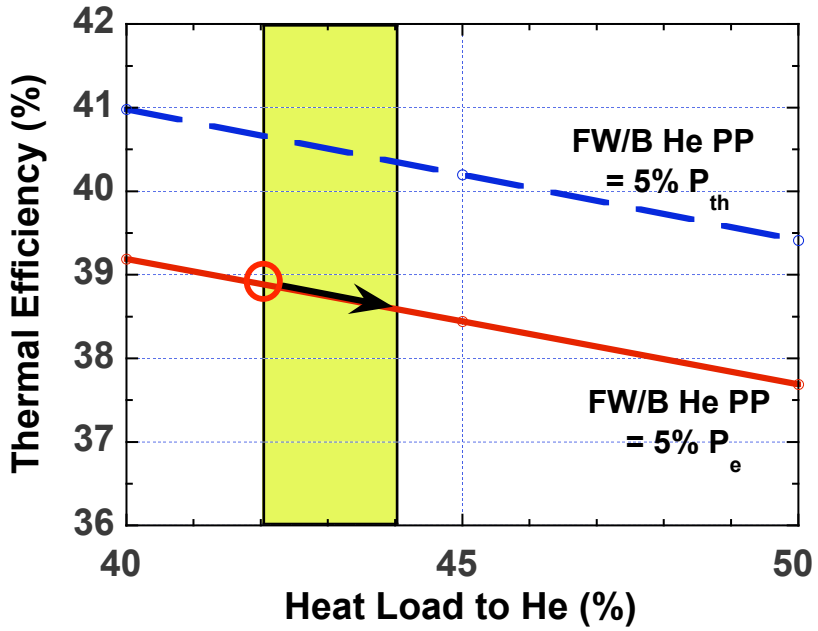
High n fluence behind He access tubes degrades J_c of superconductor

Innovative solutions must be developed to solve streaming problems

Thermal Power Split between LiPb and He Coolants
(2 MW/m^2 av. □)

- **Assumptions**:
  - Full blanket coverage (no shield-only zones)
  - 415 MW surface heating to FW and divertor
  - 90% of He pumping power recovered as thermal heat
  - 100 MW heat leak from hot LiPb to colder He
  - No info on divertor He PP.

Heat Load (MW)	He	LiPb
Surface Heating	415	
90% of FW/B He PP	45	
FW	160	
Breeding Zone-I	108	1122
Breeding Zone-II	23	303
Back wall	12	
Shield/Manifolds	76	4
Leakage from LiPb to He	100	– 100
Total	~940 (~42%)	~1330 (~58%)

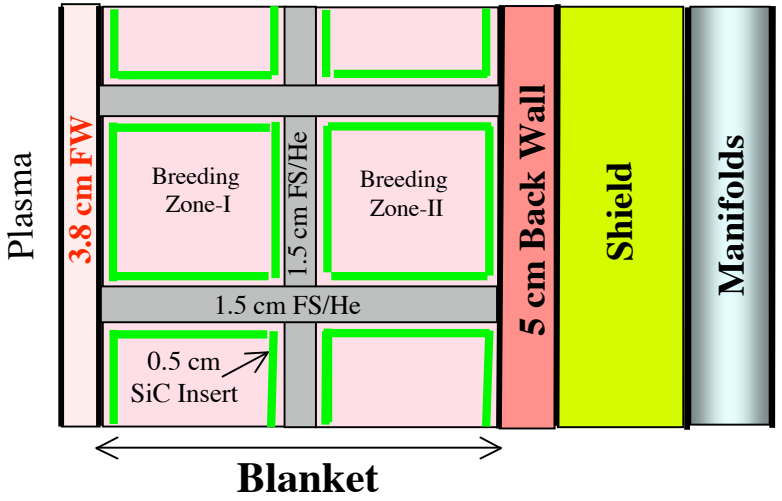


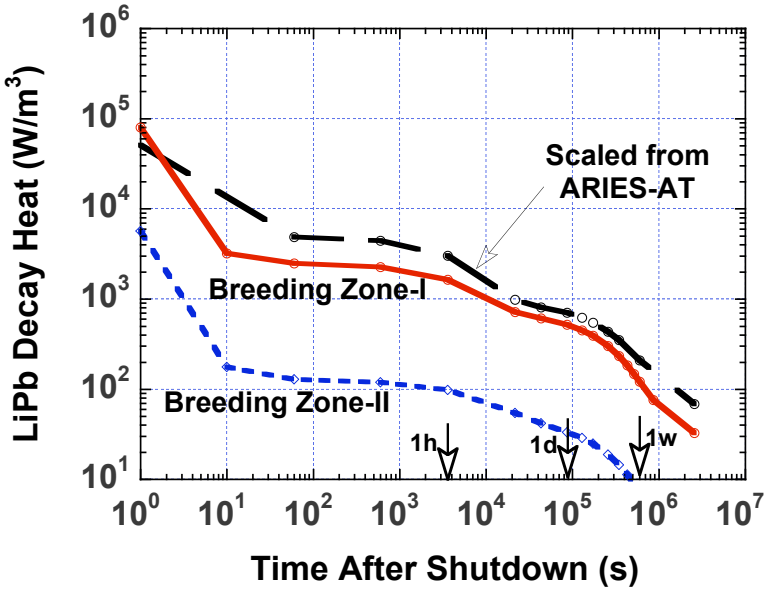
Including shield-only zones and divertor He PP increase heat load to He

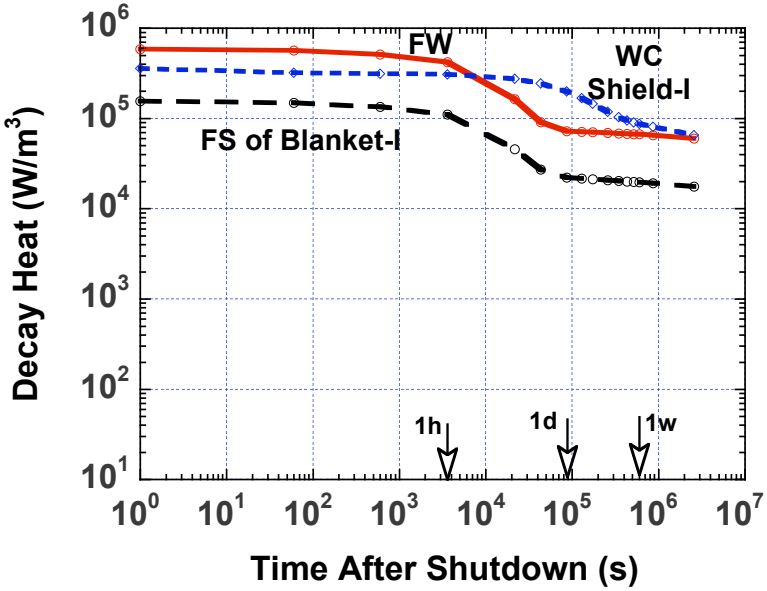
□ □$_{th}$ < 39%

LiPb Decay Heat
(2 MW/m^2 av. □)

- **Assumptions**:
  - LiPb V_{out}/V_{in} ~1.5
  - In-blanket residence time ~1 min
  - Ex-vessel residence time ~1.5 min
  - LiPb contains no T (removed online)
  - 40 FPY of operation with 85% avail.

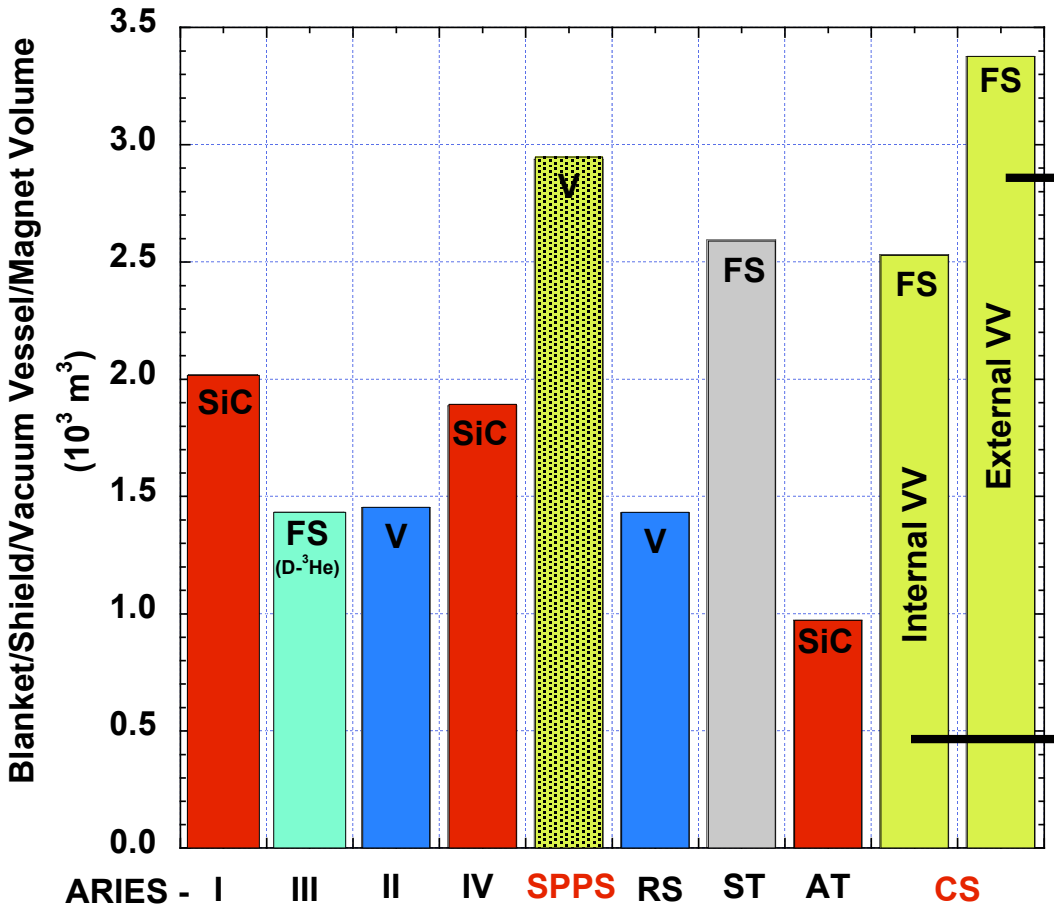


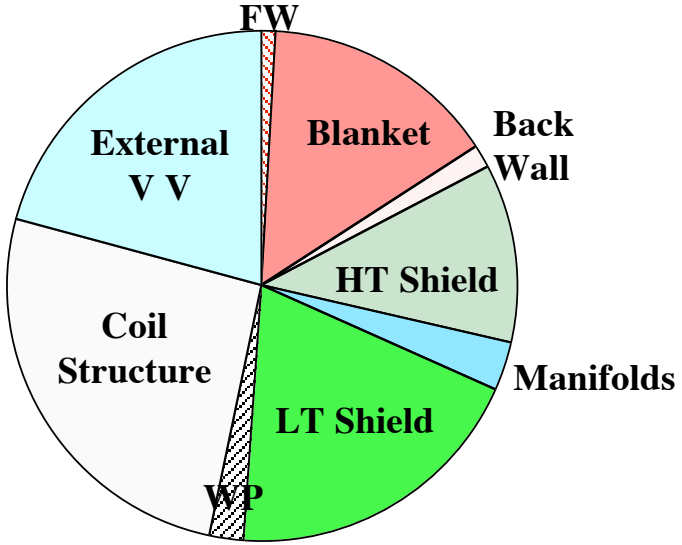


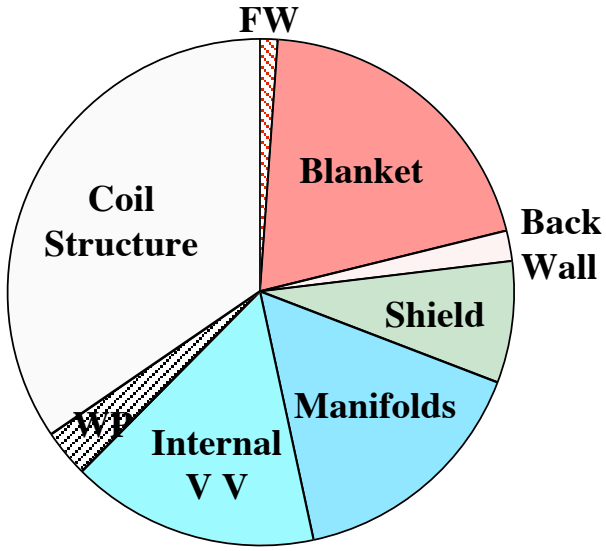


Radwaste Volumes

(un-compacted, no replacements)
(ARIES-CS: 3 FP, R=8.25 m, 100% blanket coverage)







Stellarators generate more radwaste than tokamaks

Reference
Radial Build and Composition

posted @

http://fti.neep.wisc.edu/aries-cs/builds/build.html

& Updated after each project meeting

to reflect latest changes to nuclear parameters

and dimensions/compositions of

ARIES-CS components

(FW, blanket, shield, VV, and magnet)

Future Plan

- If needed, include He manifolds in radial build of shield-only zones and readjust Δ_{min}
- Assess impact of divertor system on overall TBR using 1-D and/or 3-D!
- UW/UCSD solve streaming problem for He access tubes.
- Confirm with 2-D estimate for damage behind modified access tubes.
- Update magnet dimension and composition, if available.
- Develop radial build for 2 FP configuration, if needed.
- **Publications**:

Incorporate reviewers' comments and submit final version to:

- **FS&T journal** :

  Evolution of Clearance Standards and Implications for Radwaste Management of Fusion Power Plants

  L. El-Guebaly, P. Wilson, and D. Paige

- **FED journal**:

  Managing fusion high level waste – a strategy for burning the long-lived products in fusion devices

  L. El-Guebaly

  Potential coatings for Li/V system: nuclear performance and design issues

  L. El-Guebaly

Prepare manuscript for ICFRM-12 conference (12/05):

The Feasibility of Recycling and Clearance of Active Materials from a Fusion Power Plant

M. Zucchetti, L. El-Guebaly, R. Forrest, T. Marshall, N. Taylor, K. Tobita