Changes to LiPb/FS/He System and Implications for Radial Build

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With input from:
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Selected Blanket Concepts
(Internal VV)

Breeder	Structure	FW/Blanket Coolant	Shield Coolant	VV Coolant
LiPb	**SiC**	**LiPb**	**LiPb**	**H_2O**
LiPb (with SiC inserts)	**FS**	**He/LiPb**	**He**	**H_2O**

At present, engineering group is focusing on LiPb/FS/He system, internal VV, modular maintenance, and 3 FP configuration.

Latest Changes to Blanket and Shield Design

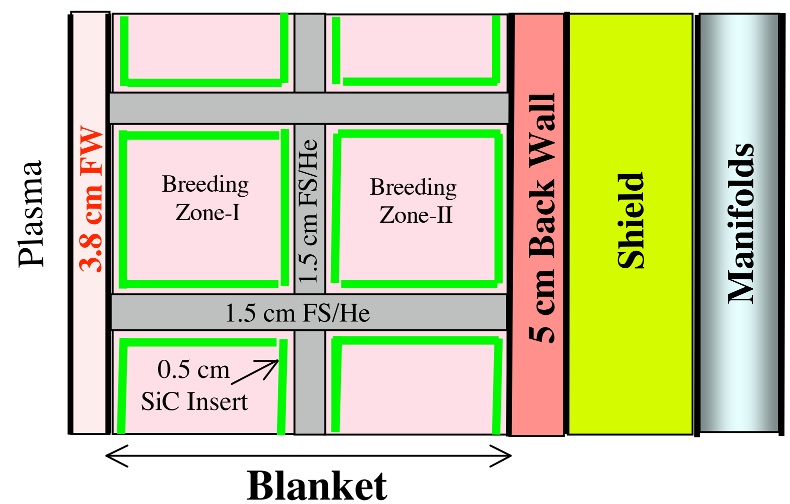
Changes:

– Less blanket coverage (< 92%) due to larger difference between Δ_{min} and $\Delta_{nominal}$ (27 cm, instead of 20 cm).

– 35 cm thick LiPb/He manifolds surrounding FS shield, per Malang/Raffray/Wang.

– Segmented WC-shield to minimize waste stream.

– No gap between back wall & shield to help dissipate decay heat during accident.



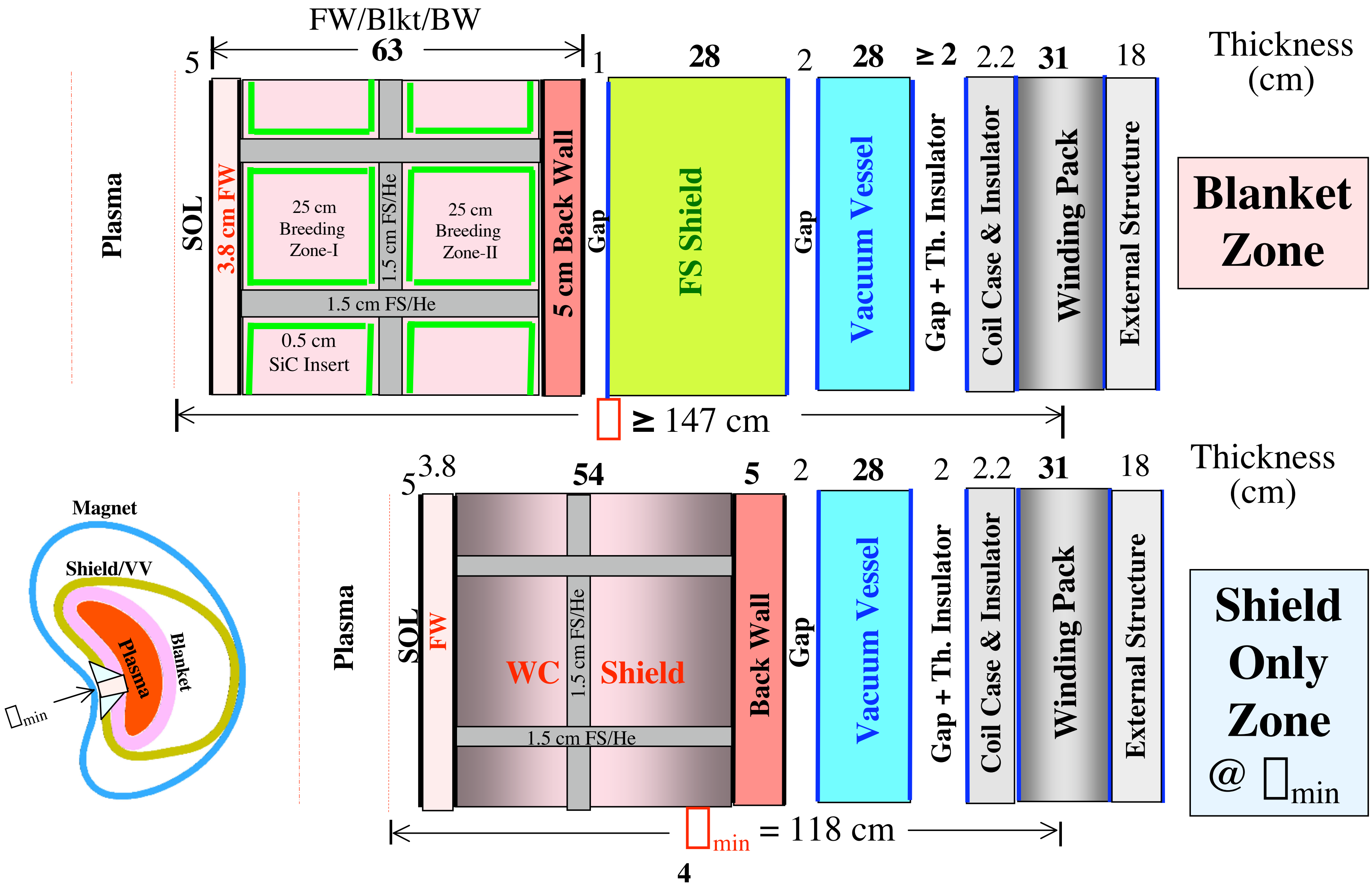
Concerns:

– Loss of breeding due to lower blanket coverage.

– Impact of manifolds on radial build standoff.

– Higher WDR due to WC shield segmentation.

Previous Radial Build
(3 MW/m^2 peak □)



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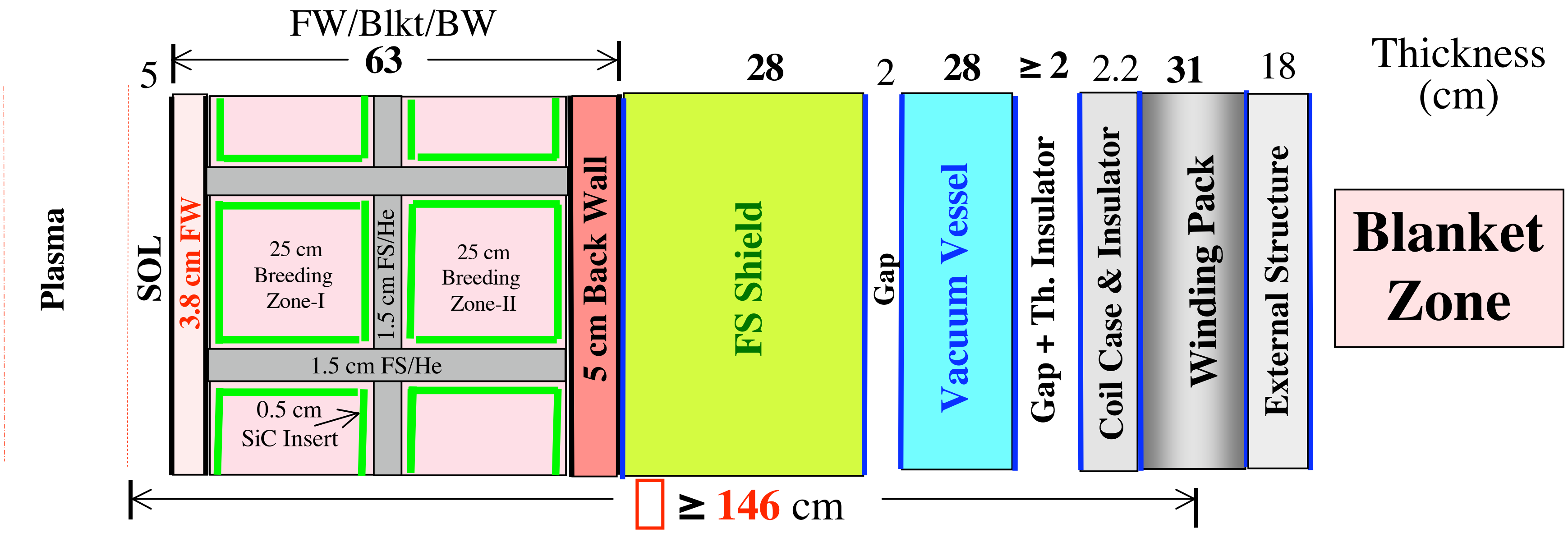
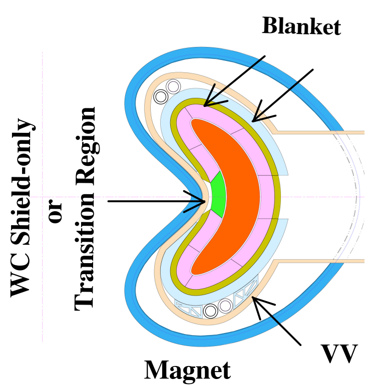
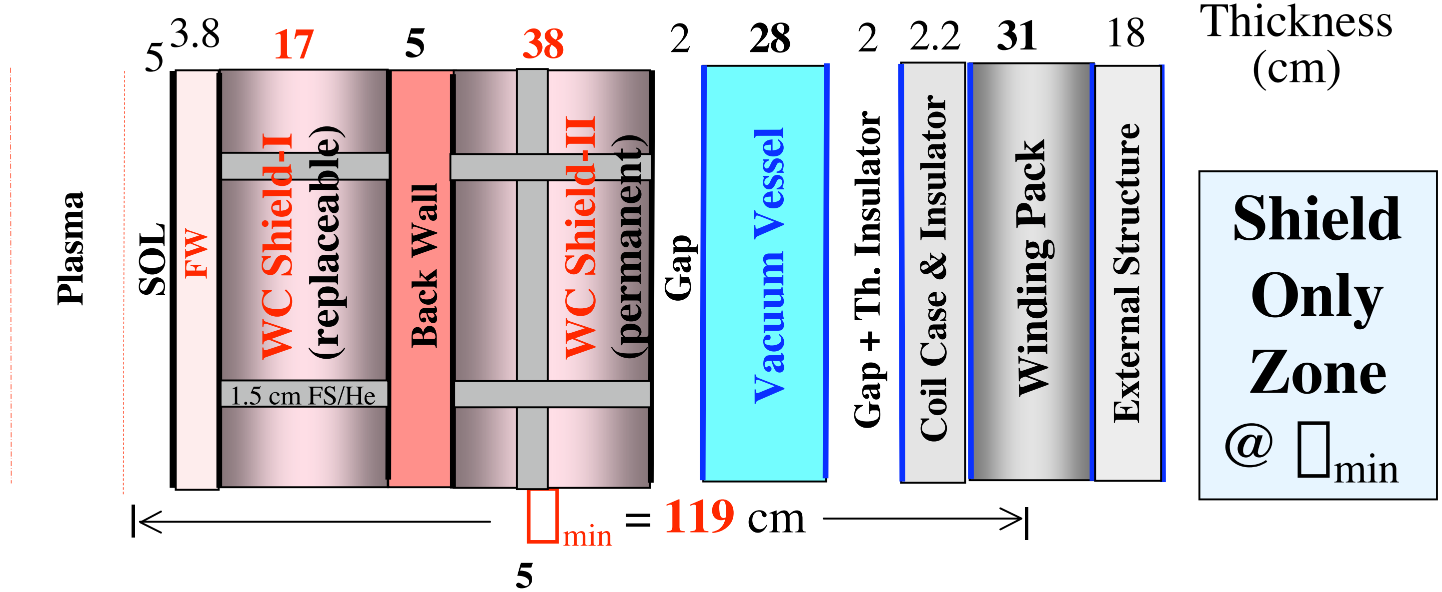
New Radial Build w/o Manifolds

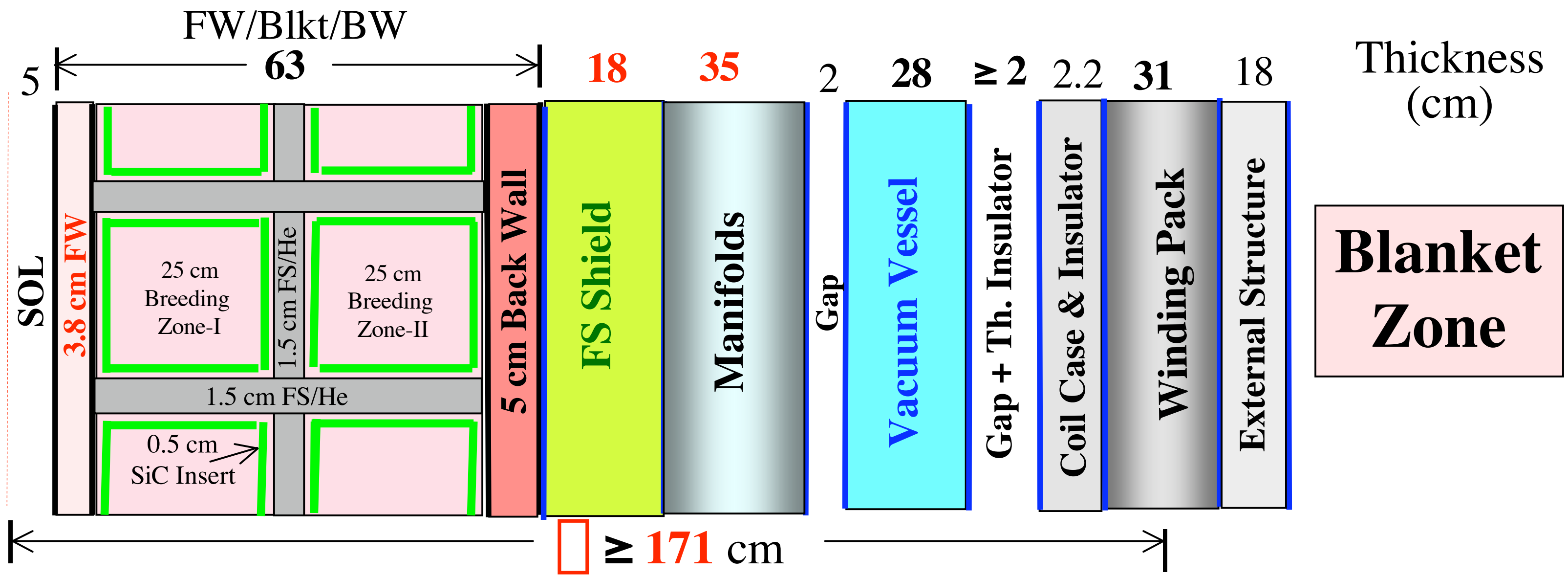
(3 MW/m^2 peak □)

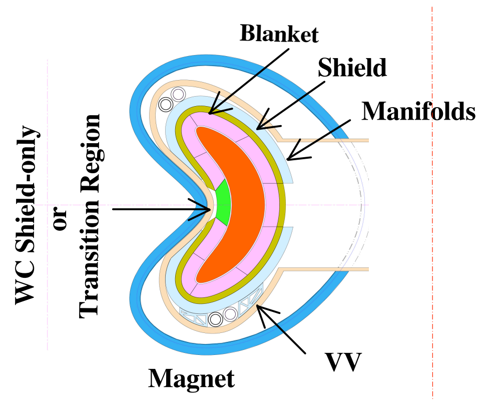


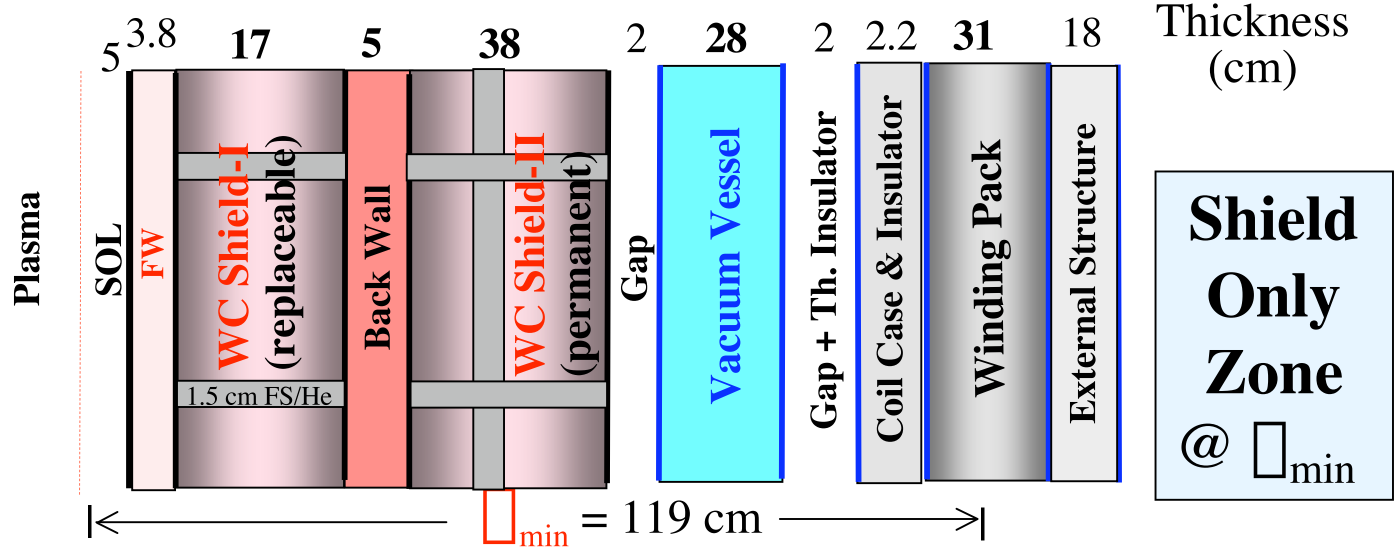




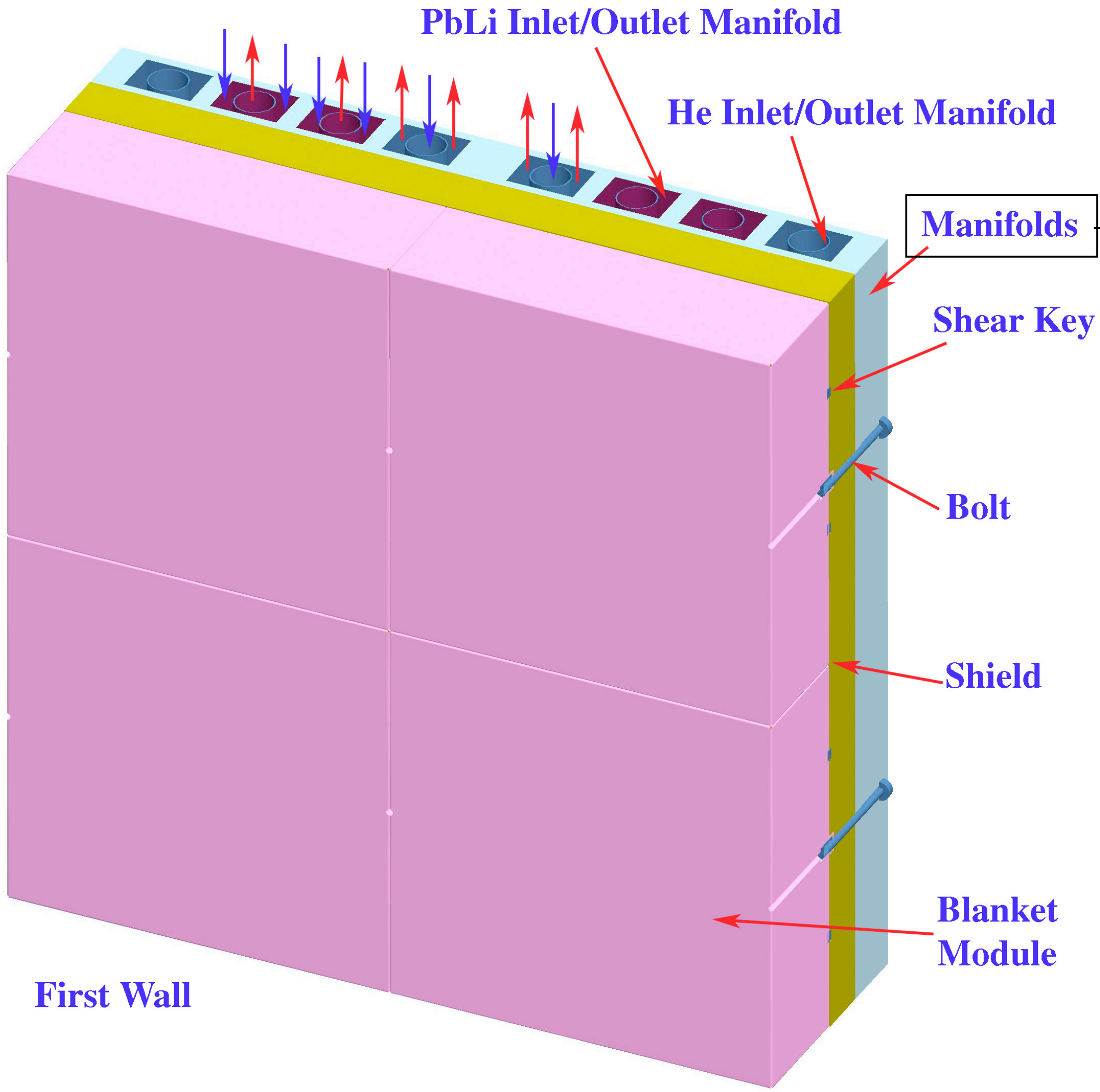
New Radial Build with Manifolds
(3 MW/m^2 peak □)





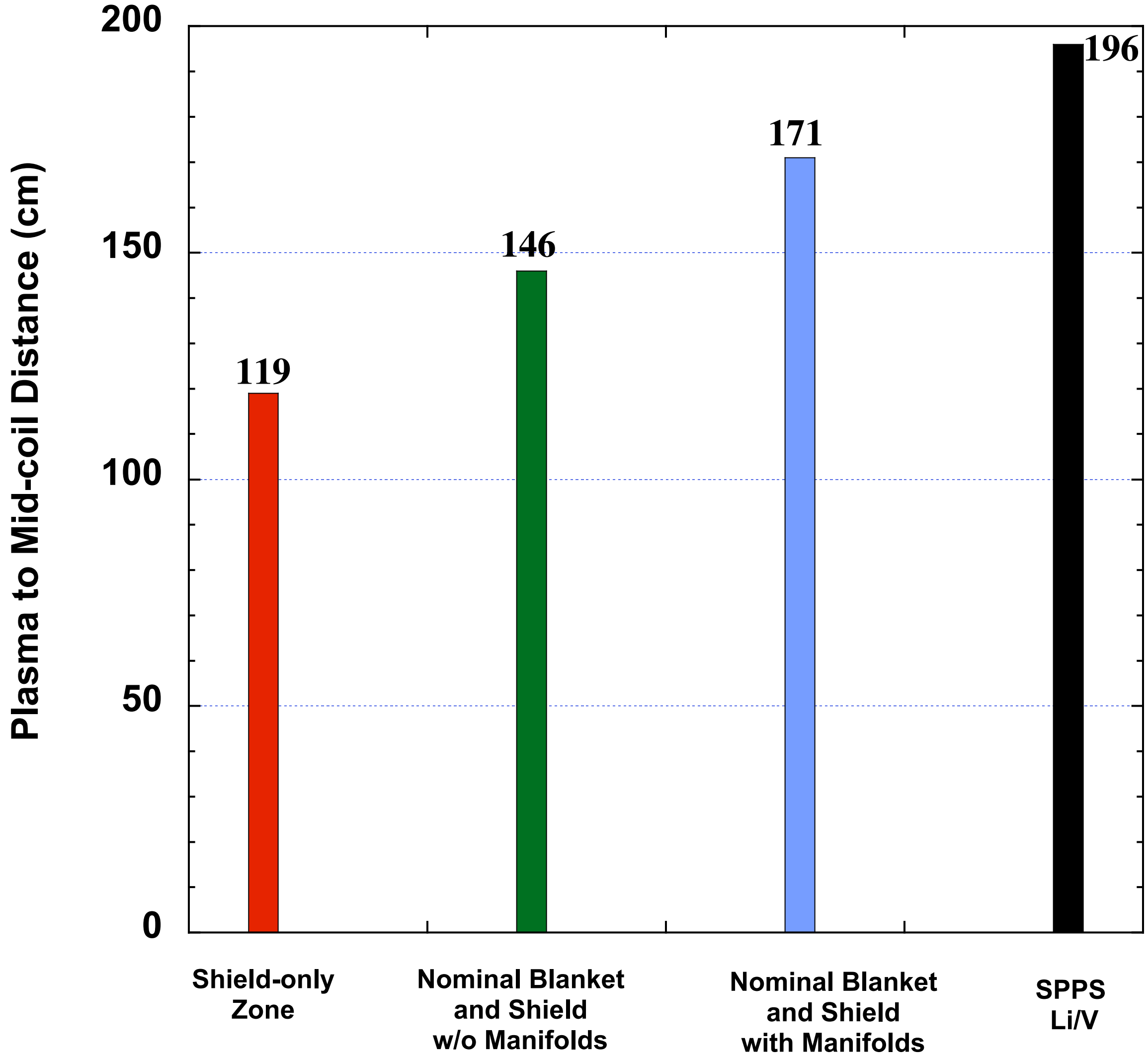


LiPb & He Manifolds
(X. Wang)



52% FS
24% LiPb
24% He

Plasma to Mid-Coil Distance



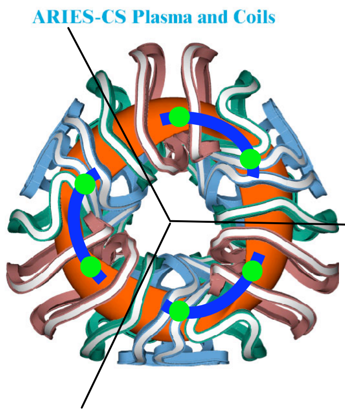
LiPb/FS/He System

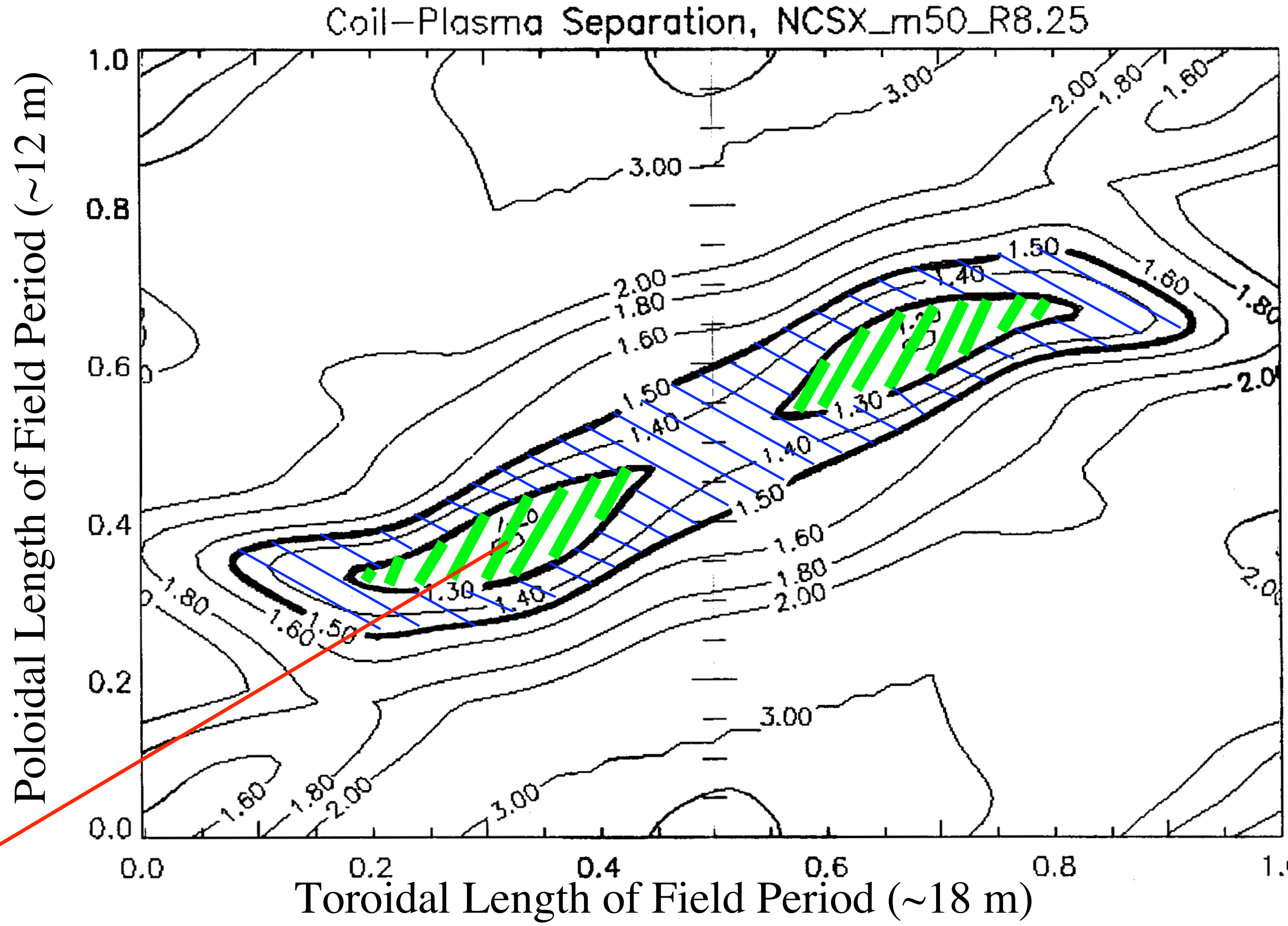
Component	Thickness	Coverage Fraction	Composition
FW*	3.8 cm	100%	34% FS Structure 66% He Coolant
Blanket*	54.3 cm	85%	79% LiPb (90% enriched Li) 7% SiC Inserts 6% FS Structure 8% He Coolant
Back Wall*	5 cm	100%	80% FS Structure 20% He Coolant
FS Shield	18 - 28 cm	80+5% ?	15% FS Structure 10% He Coolant 75% Borated Steel Filler
Manifolds	35 cm	80% ?	52% FS Structure 24% LiPb (90% enriched Li) 24% He Coolant
WC Shield-I*	17 cm	5%	88% WC Filler 5% FS Structure 7% He Coolant
WC Shield-II	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.

Coverage Fraction

(3 FP Configuration, R= 8.25 m)

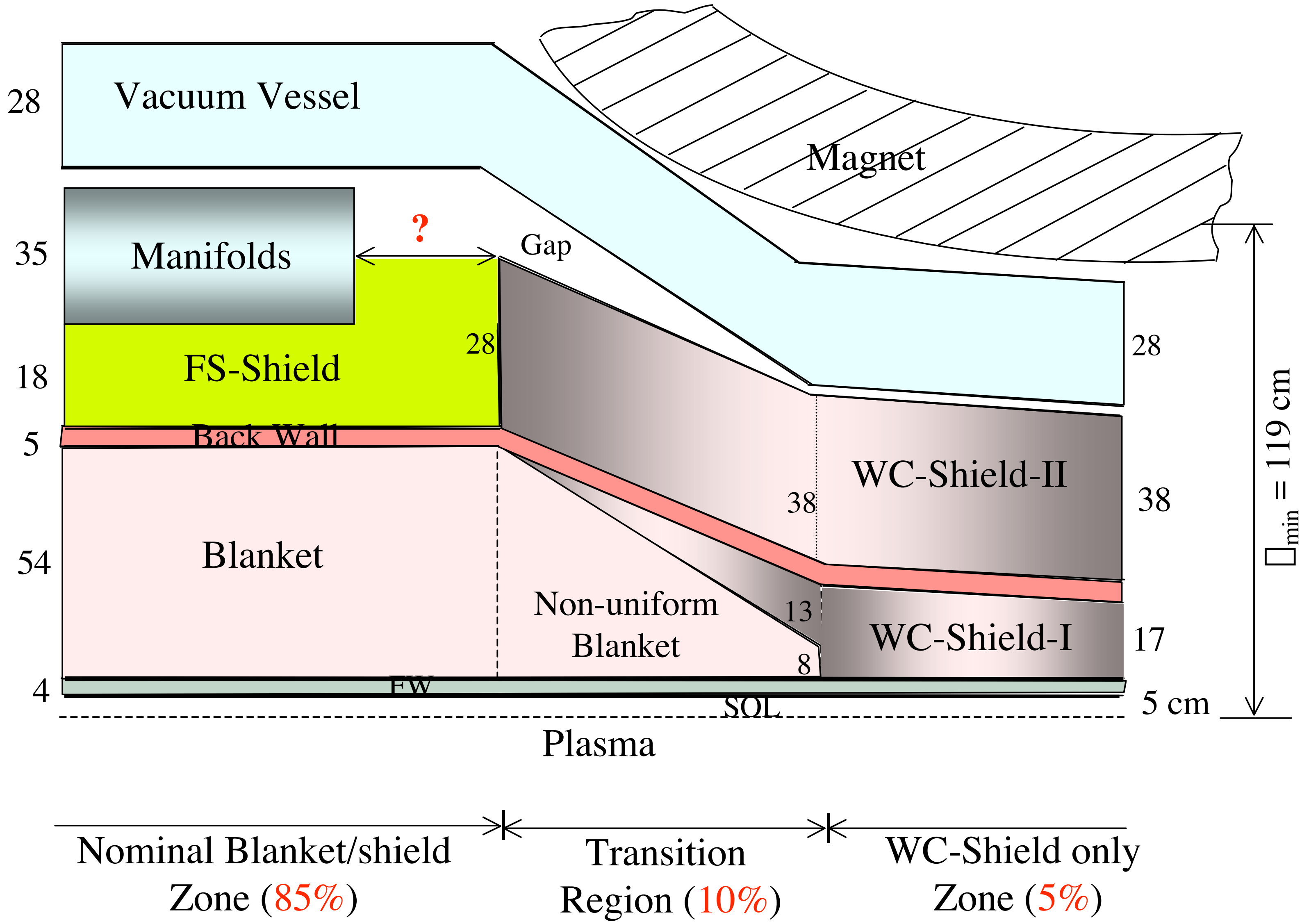




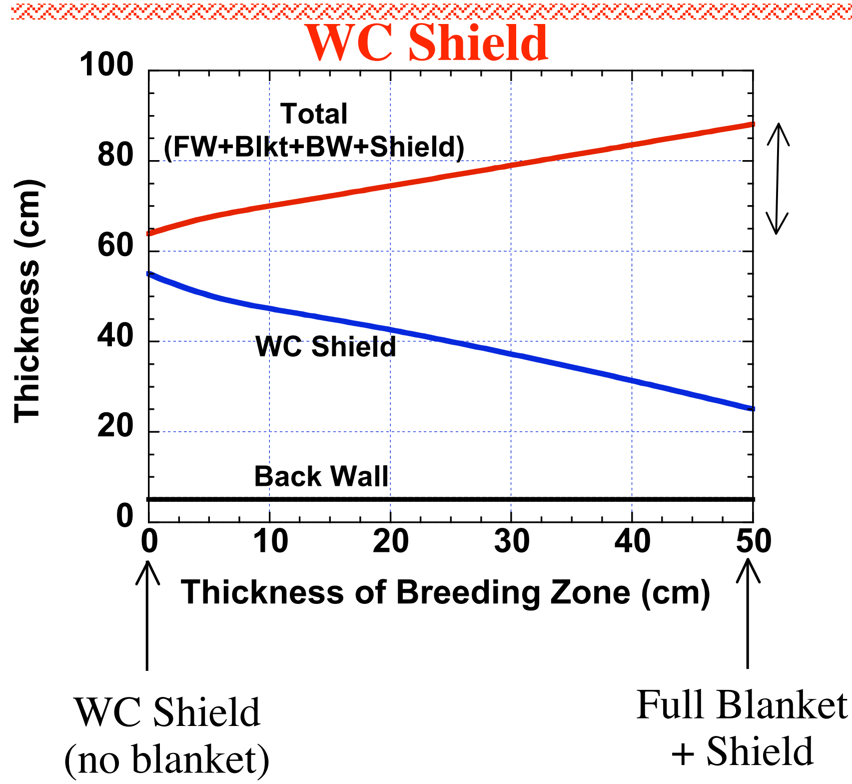
Cross Section (next page)

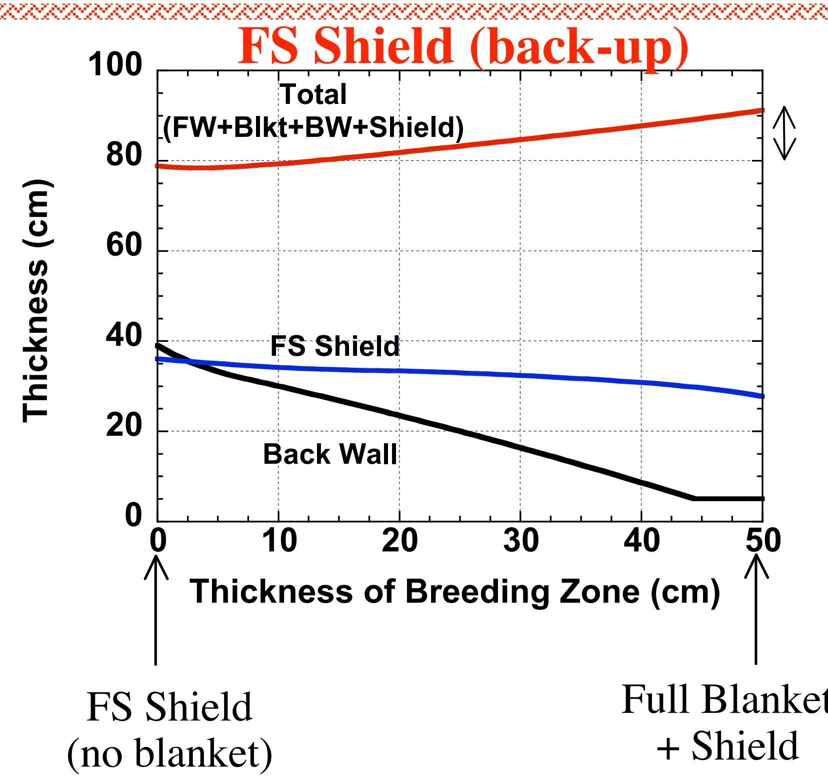
Shield-only zone (green), transition region (blue), and nominal blanket zone cover **5%, 10% and 85%** of FW area, respectively

Non-uniform Blanket for Transition Region to Meet Breeding Requirement



Blanket & Shield for Transition Region





- **Recommendations:**
  - WC-shield for transition region
  - Monitor WC decay heat
  - Less expensive FS-shield elsewhere to improve economics.

Transition Region
(Average Dimension and Composition)

Component	Thickness	Coverage Fraction	Composition
FW*	3.8 cm		34% FS Structure 66% He Coolant
Blanket*	27 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	33 cm	10%	15% FS Structure 10% He Coolant 75% WC Filler
VV	28 cm		28% FS Structure 49% **Water** 23% Borated Steel Filler

* Replaceable component.

Breakdown of TBR

- **Assumptions**:
  - 5 cm thick divertor plates/baffles (50/50 FS/He) covering 15% of FW area
  - Blanket behind divertor plates/baffles
  - Penetrations and assembly gaps occupy 2% of FW area.

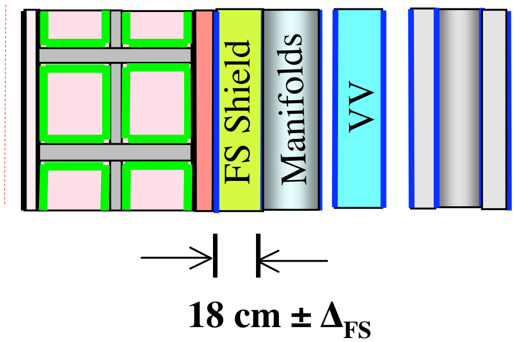
	Coverage Fraction	Local TBR
Full size blanket	0.85	1.25
Non-uniform blanket	0.1	0.84

Overall TBR ~ 1.1

- 3-D analysis needed to confirm overall TBR.
- **If 3-D TBR < 1.1**, modify design as follows:
  - Thicken blanket by 10-20 cm
  - Move manifolds inward, between blanket and shield
  - Install blanket everywhere → larger machine
  - Or, add Be to blanket → safety?!
- **If 3-D TBR > 1.1**, reduce blanket size and/or lower Li enrichment below 90%.

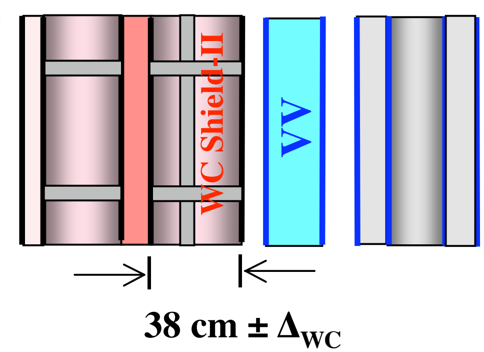
Scaling of Shield with Average □*

- **18 cm FS shield:**



$$\Delta_{\text{FS-shield}} = 7.3 \ \ln (□ / 2)$$

- **38 cm WC shield-II:**



$$\Delta_{\text{WC-shield}} = 6.1 \ \ln (□ / 2)$$

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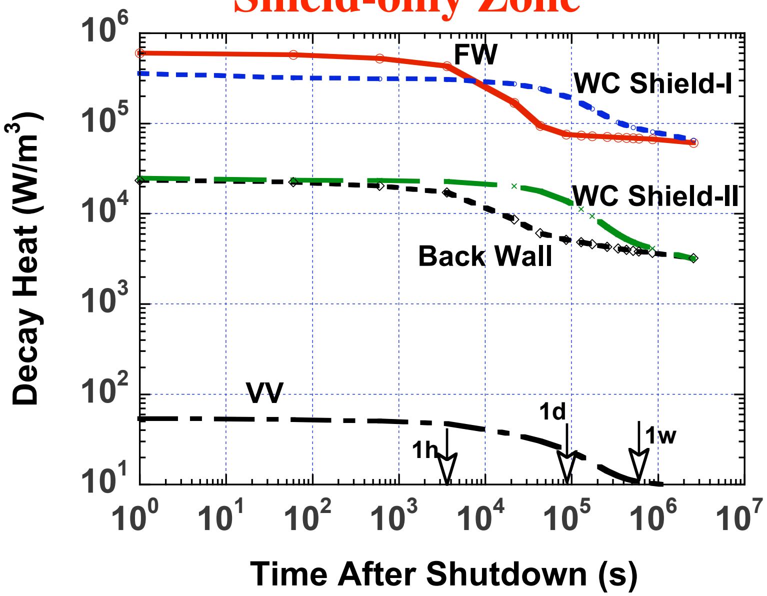
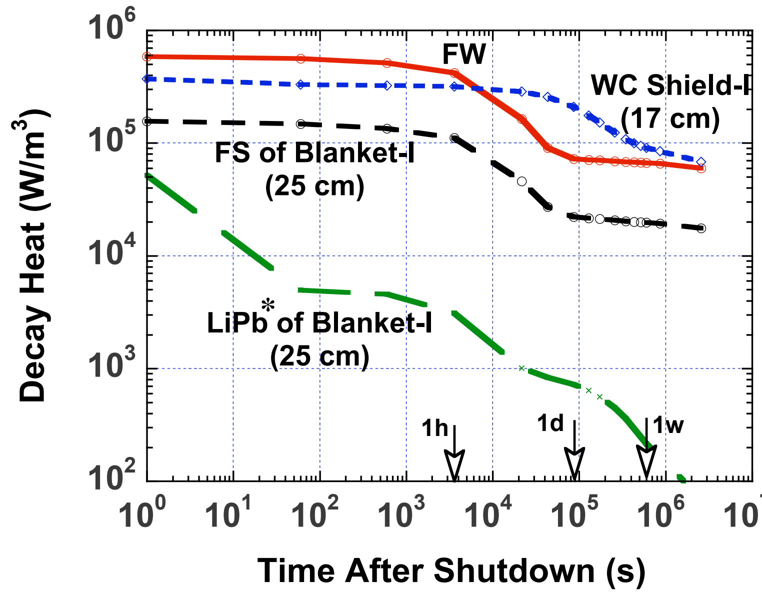
* Δ in cm and □ in MW/m^2.

Decay Heat*

(for Safety and LOCA/LOFA Analyses; 2 MW/m^2 av. □)

Shield-only Zone





WC decay heat dominates after 1 hr and drops slowly with time

Higher □ □ higher decay heat

* LiPb results scaled from ARIES-AT.

Waste Disposal Rating
(2 MW/m^2 av. □)

- **Assumptions**:
  - WDR at 100 y after shutdown
  - Fully compacted waste
  - Fetter's low limits for Class C waste

	WDR
FW/WC-shield-I/Back Wall	**0.9**
WC-shield-II	**0.3**

Segmented WC-shield generates low-level waste

Higher □ □ shorter life □ ~ same WDR

Reference
Radial Build and Composition

Latest LiPb/FS/He parameters will be added to

Radial Build Document

posted @

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

Updated frequently
to reflect latest changes to nuclear parameters
and dimensions/compositions of
ARIES-CS components
(FW, blanket, shield, VV, and magnet)

Future Plan

- Generate LiPb decay heat using ARIES-CS parameters. **Need**
  - LiPb residence time in blanket (1-2 min ?)
  - LiPb residence time outside blanket (~2 min ?)
  - LiPb V_{out}/V_{in} (~1.5 ?).
- Assess impact of new divertor on breeding.
- Perform 3-D TBR analysis using MCNP/CAD interface. **Need** CAD input for FW, blanket, shield, divertor, penetrations, shield-only and transition regions.
- Provide heat loads, upon request:
  - For detailed thermal analysis
  - Split between LiPb and He.
- Develop radial build for 2 FP configuration, if needed.
- **Publications**:
  - **Submit manuscript to FS&T**:

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

    L. El-Guebaly, P. Wilson, and D. Paige
  - **Prepare ISFNT-7 presentations**:

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

    L. El-Guebaly

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

    L. El-Guebaly