Shielding Options for FP Maintenance Approach with External VV

Laila El-Guebaly
Fusion Technology Institute
University of Wisconsin - Madison

With input from:
L. Waganer (Boeing),
R. Raffray, X. Wang (UCSD),
and S. Malang (Germany)

ARIES-CS Project Meeting
June 14-15, 2005
UW - Madison

Liquid Breeder Blanket Concepts

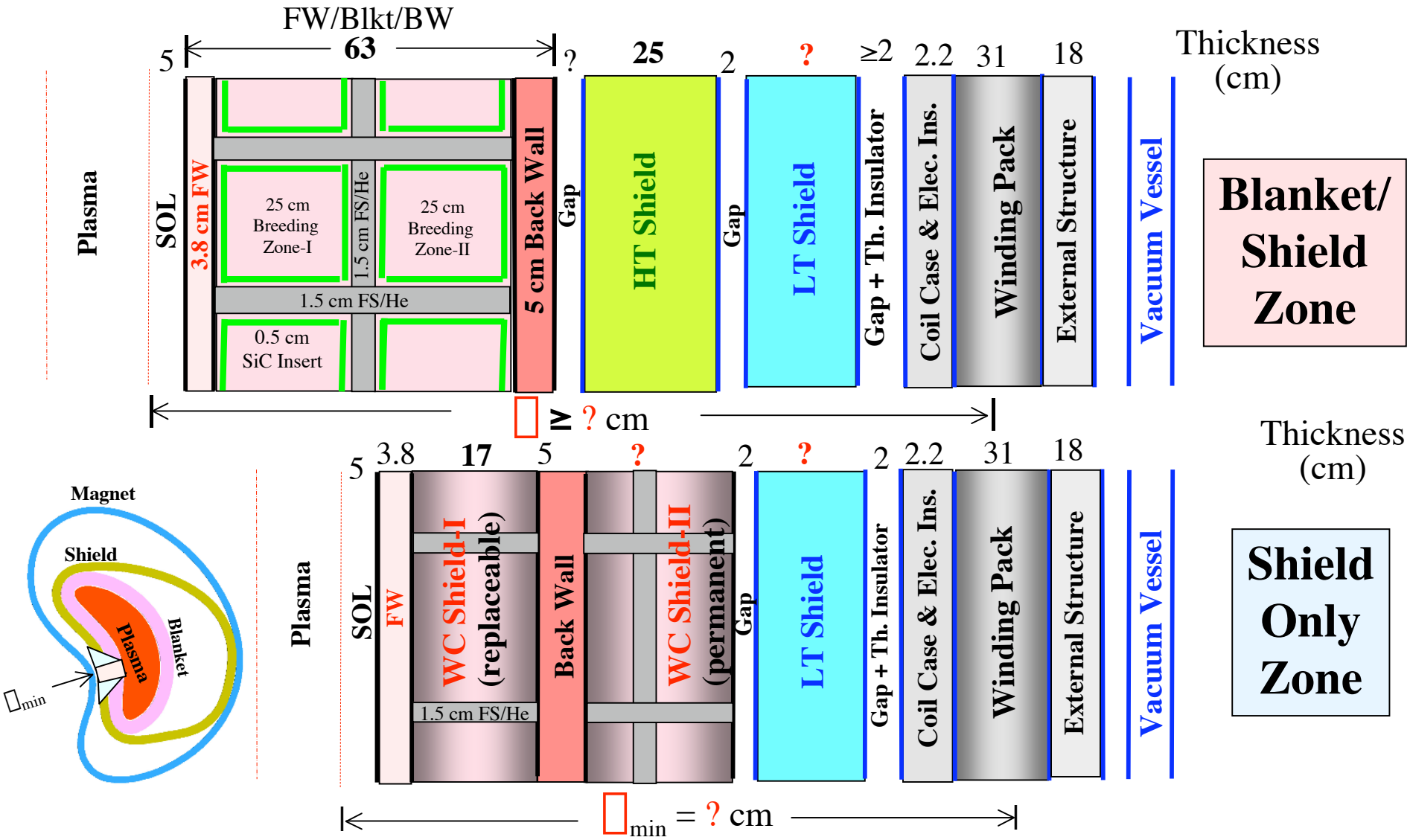
Breeder	Structure	FW/Blanket Coolant	HT Shield Coolant	LT Shield Coolant	VV Coolant
ARIES-CS:					
Internal VV:					
LiPb (reference)	FS	He/LiPb	He	---	H_2O
LiPb (back-up)	SiC	LiPb	LiPb	---	H_2O
External VV:					
LiPb	**FS**	**He/LiPb**	**He**	**He or H_2O**	**He**
LiPb	SiC	LiPb	LiPb	**He or H_2O**	**He**
SPPS:					
External VV:					
Li	V	Li	Li	Li	He

Shielding Considerations

- Shield protects magnet for plant life (40 FPY).
- Divide shield into two components: HT shield and LT shield.
- HT shield sized to allow ≤ 1% of total nuclear heating in LT shield.
- LT shield contains low grade heat and could be cooled with He or water.
- Robustness of LT shield is highly desirable to prevent water leak.
- External VV is subject to very low radiation level
  - reweldable at anytime.
- Manifolds are discrete ignore impact on radial build

LiPb/FS/He Radial Build

(External VV, 3 MW/m^2 peak □)

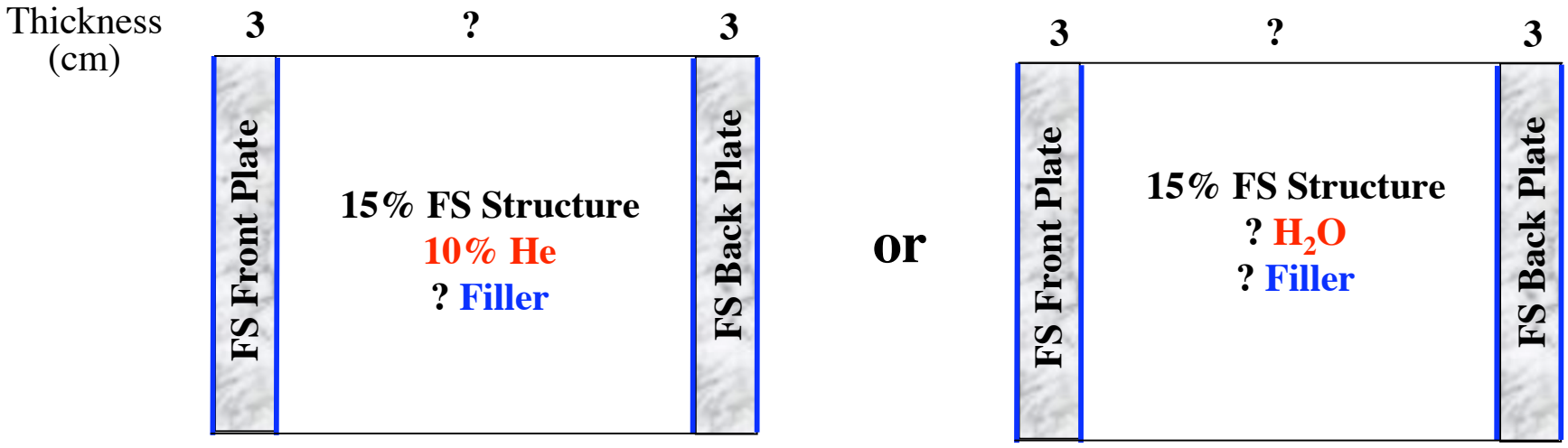


LT Shield Design

Candidate Coolants: He and H_2O

Concerns: Water leak

Potential Solution: Robust design with strong front/back plates



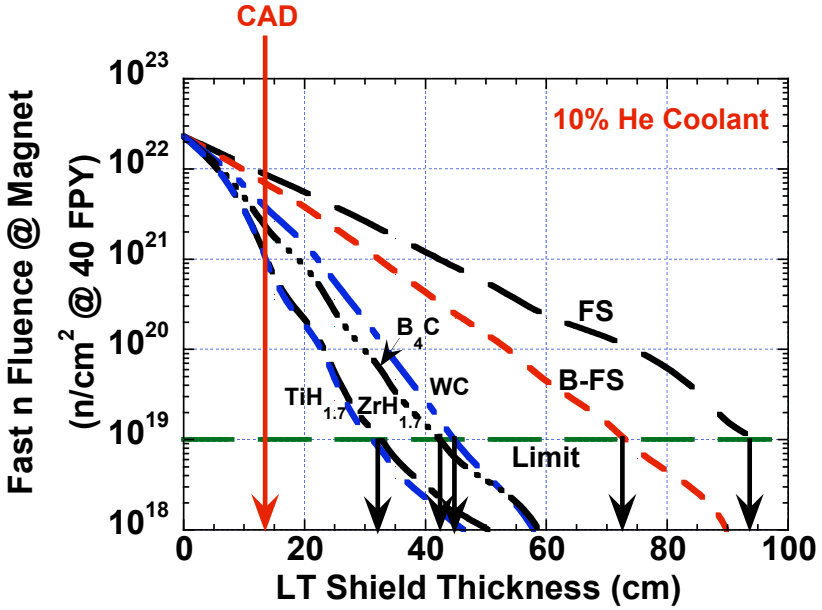
LT Shield Design (Cont.)

Candidate Fillers:

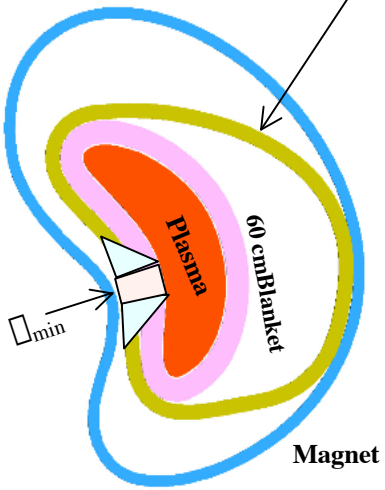
	Density (g/cm^3)	Unit Cost* ($/kg)	Comments
FS	7.8	31	
B-FS	7.8	31	
WC	15.5	30	Heavy
B_4C	2.5	502	Expensive
$ZrH_{1.7}$	5.67	42	Decomposes at 600°C
$TiH_{1.7}$	3.9	?	Decomposes at 600°C

* 2005 $, per L. Waganer

He-Cooled LT Shield Optimization
(3 MW/m^2 peak □)



CAD drawings indicate only 40 cm space for:
25 cm HT Shield
+ 2 cm gap
+ 13 cm LT Shield ?!

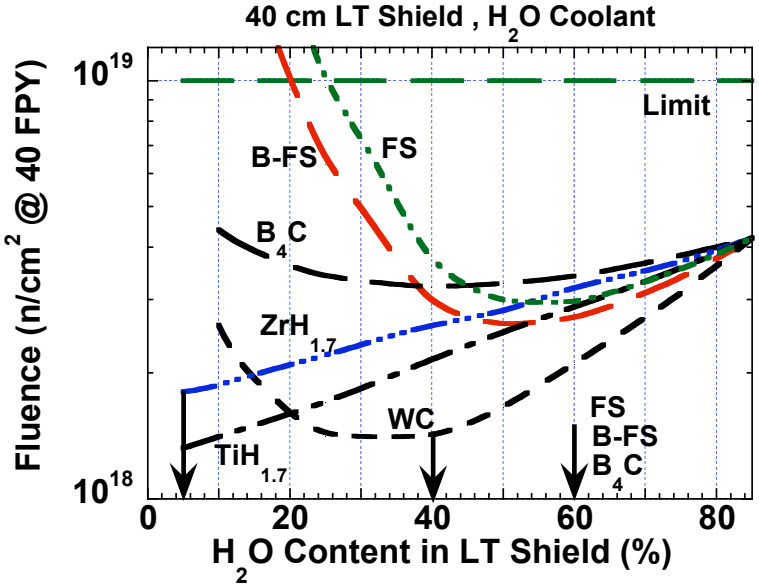


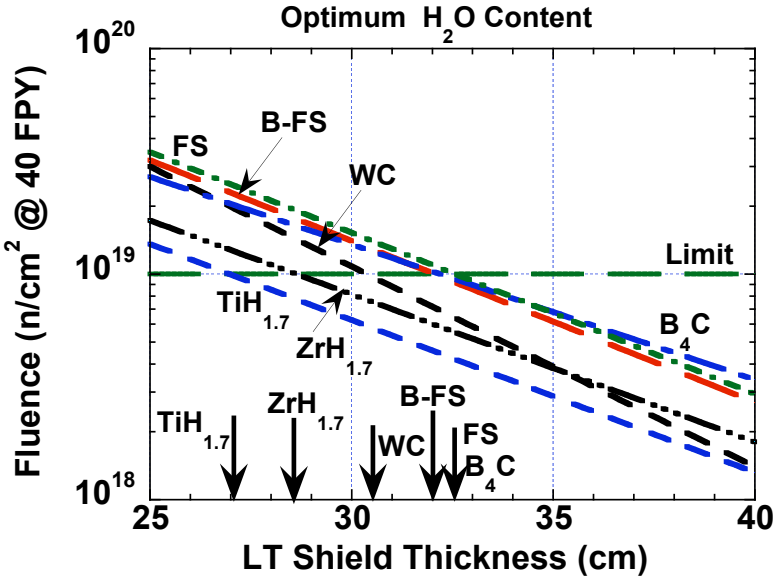
Options:
- 31 cm $TiH_{1.7}$/He shield
- 32 cm $ZrH_{1.7}$/He shield
- 42 cm B_4C/He shield
- 44 cm WC/He shield
- 72 cm B-FS/He shield (same as HT shield)
- 94 cm FS/He shield

□ **All shields > 13 cm. Modify CAD drawings to include more shield**

H_2O-Cooled LT Shield Optimization

(3 MW/m^2 peak □)



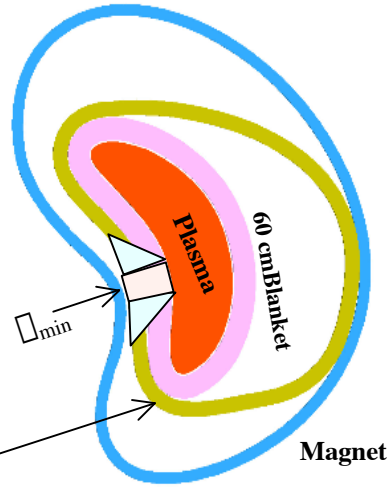


Options:

- 27 cm $TiH_{1.7}/H_2O$ shield (80/5)
- 29 cm $ZrH_{1.7}/H_2O$ shield (80/5)
- 31 cm WC/H_2O shield (45/40)
- 32 cm $B\text{-}FS/H_2O$ shield (25/60)
- 33 cm B_4C/H_2O shield (25/60)
- 33 cm FS/H_2O shield (25/60)

□

All shields > 13 cm.
Modify CAD drawings to include more shield

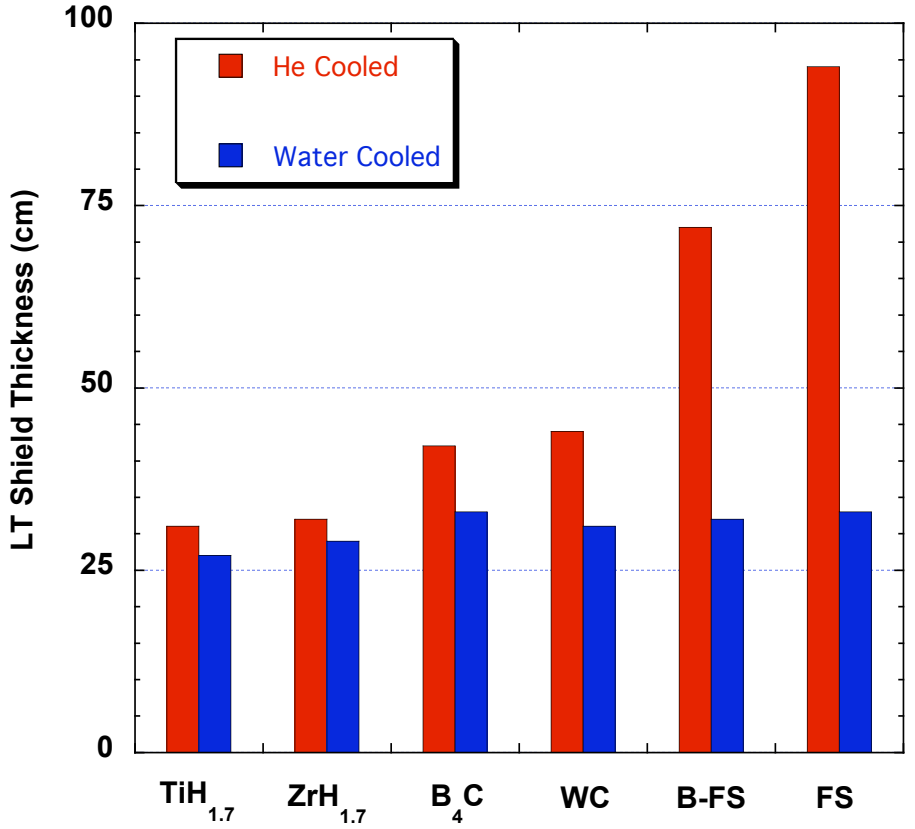


25 cm HT Shield
+ 2 cm gap
+ 13 cm LT Shield ?!

LT Shield Comparison

Thick.* (cm)	He-cooled LT Shield	H_2O-Cooled LT Shield
$TiH_{1.7}$	31	**27** min
$ZrH_{1.7}$	32	29
B_4C	42	33
WC	44	31
B-FS	72	**32**
FS	**94** max	33

* Shield conforms to blanket.



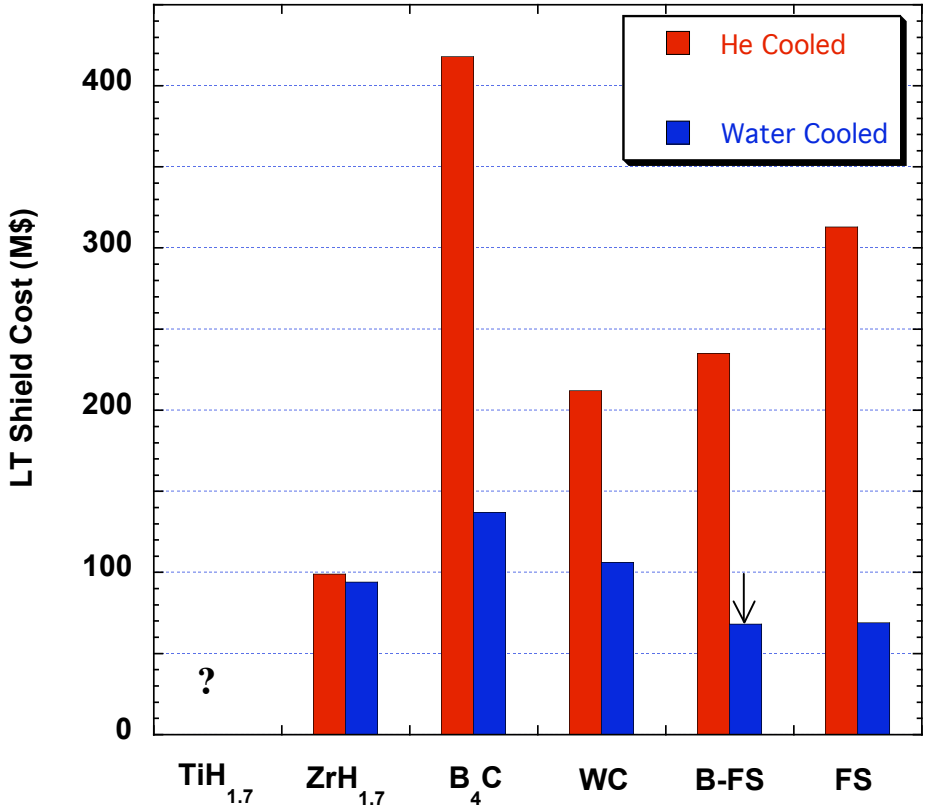
For non-hydride fillers, water reduces LT shield size significantly

Water-cooled LT shield thicknesses vary within 6 cm. Cost?

LT Shield Cost* (M$)

Filler	He-cooled LT Shield	H_2O-Cooled LT Shield
$TiH_{1.7}$	?	?
$ZrH_{1.7}$	99	94
B_4C	**418** max	137
WC	212	106
B-FS	235	**68** min
FS	313	69

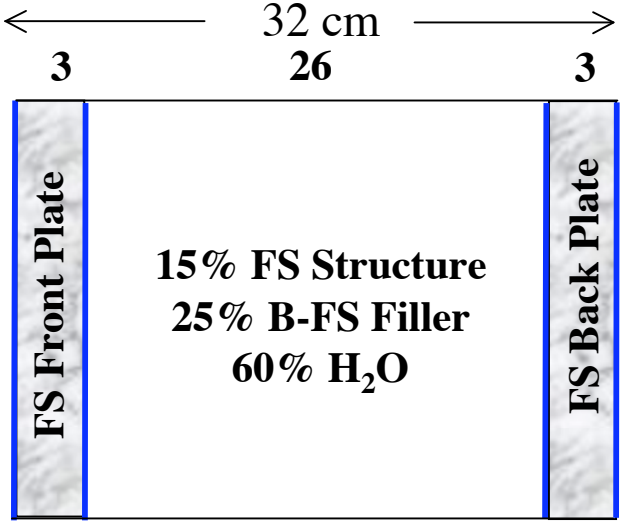
* Shield conforms to blanket.



Combination of **B-FS filler** and **water coolant** offers lowest shield cost

Recommendations

- Recommend water-cooled LT shield that offers:
  - Lowest cost
  - Reasonable size
  - Low magnet heating.

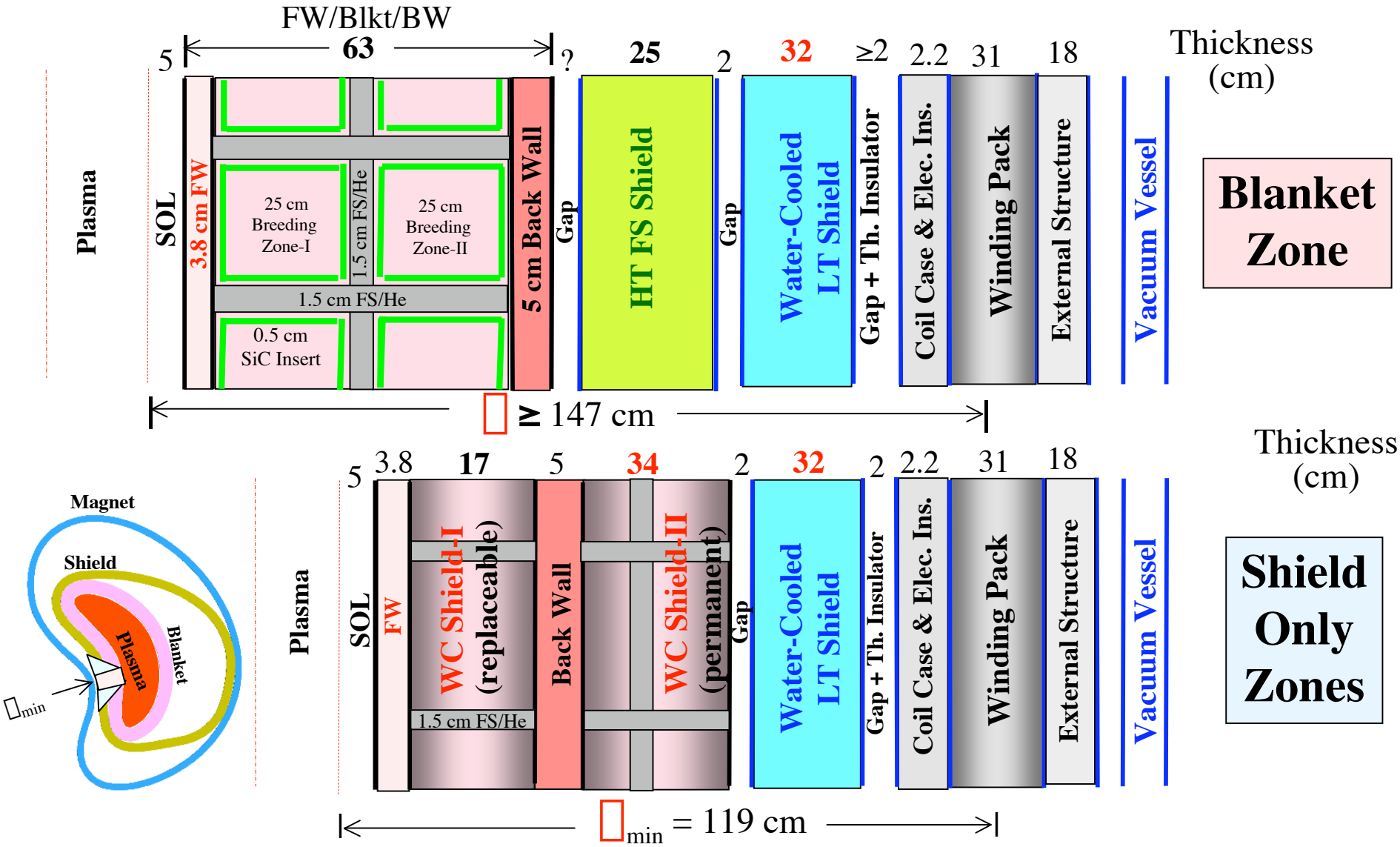


- Use more expensive $TiH_{1.7}/ZrH_{1.7}$ shield locally at interference points to free 4-6 cm of shielding space.

- Hydrides decompose at T > 600 °C keep temp below 600 °C during LOCA/LOFA events.

Recommended Radial Build

(External VV, Water-cooled LT-shield, 3 MW/m^2 peak □)



Concluding Remarks

- Recommend water-cooled LT shield with B-FS filler to reduce shield size and cost.
- Design **leak-free**, robust LT shield with 30% FS structure.
- CAD drawings must be modified to reflect 60 cm (not 40 cm) space for HT shield, gap, and LT shield.
- $TiH_{1.7}/ZrH_{1.7}$ could be used locally at interference points to free 4-6 cm of shielding space.
- If major interference problem exists for LiPb/FS/He blanket replacement, consider LiPb/SiC option that offers much thinner replaceable blanket (25 cm thick).
- Identical $\square_{min}$ (119 cm) for both internal and external VV options
  - $\square$ ~ same major radius.
- If manifolds needed for shield-only zones, $\square_{min} > 119$ cm.

Future Plan

- If needed, include He manifolds in radial build of shield-only zones and readjust $\square_{min}$.

- Post reference radial build and composition on UW web site:

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