Preliminary ARIES-RS-DCLL Radial Build for ASC

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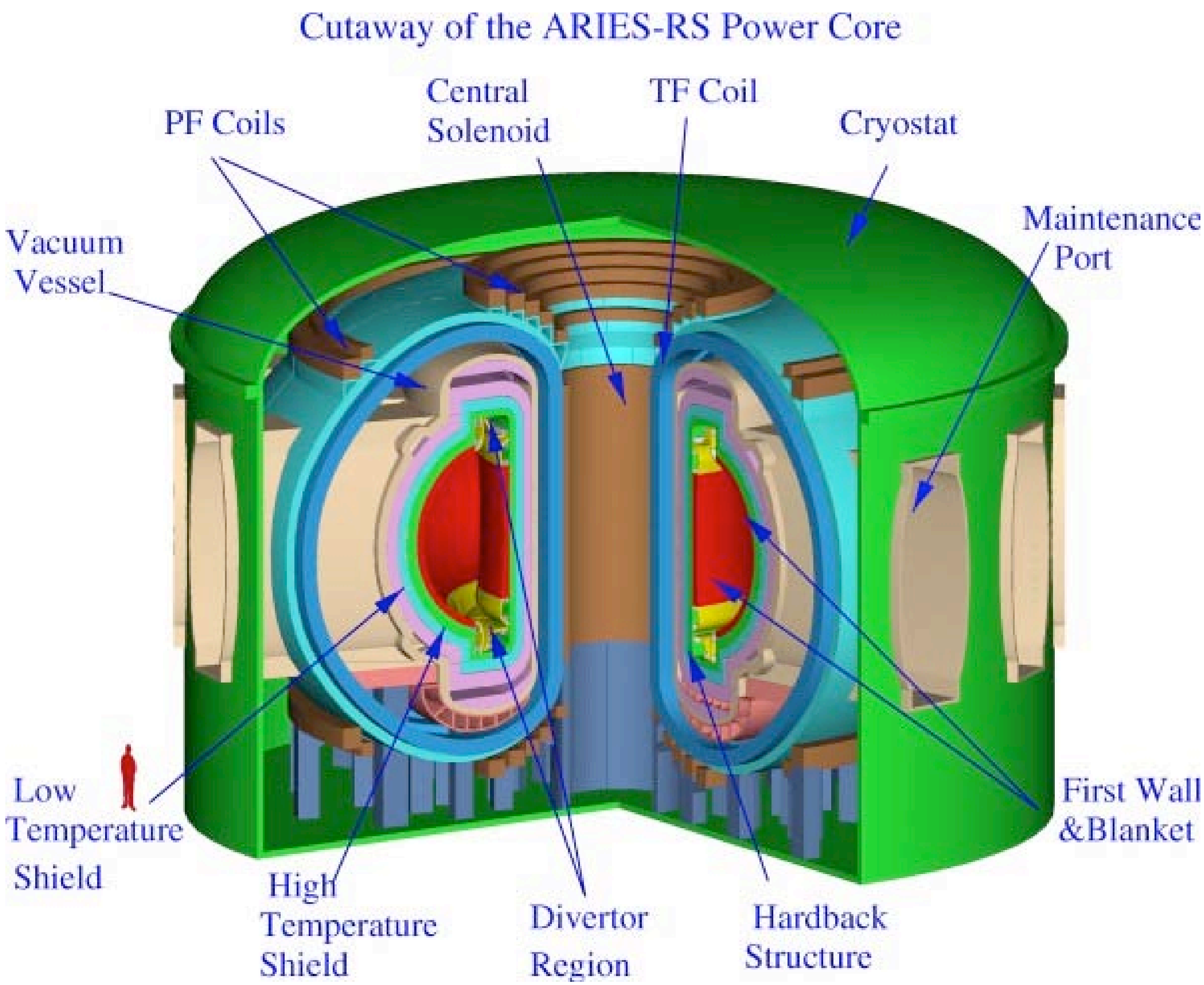
Objectives

- Define preliminary radial builds for ARIES-RS with:
  - DCLL blanket and shield
  - LiPb/He Manifolds (tentative composition/dimension/location)
  - Stabilizing shells.

- Identify potential locations for stabilizing shells and feedback coils and assess impact on TBR, if any.

- Compare reference ARIES-RS with ARIES-RS-DCLL and highlight impact of DCLL system on overall design.

ARIES-RS Reference Design



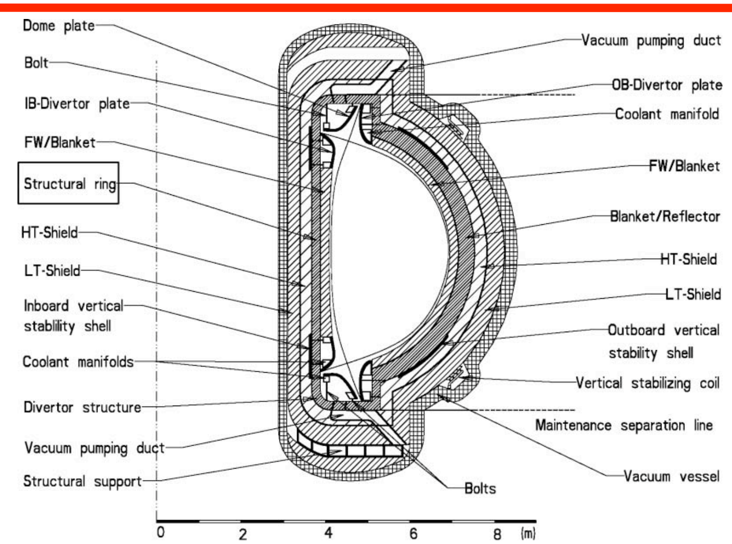
ARIES-RS Reference Design (Cont.)

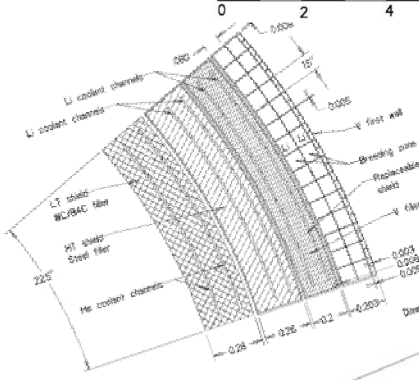
Fusion Power	2167 MW
Major Radius	5.52 m
Minor Radius	1.38 m
Peak Γ @ IB, OB, Div	3.7, 5.6, 2.3 MW/m^2

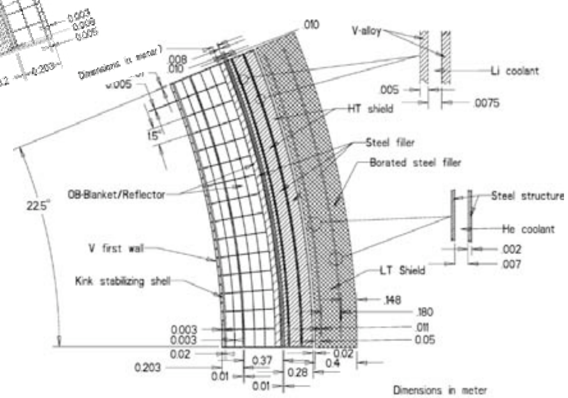
V-4Cr-4Ti Structure
Li/V Blanket
2.5, 7.5, and 40 FPY Components
Discrete Li Manifolds
LT S/C Magnet @ 4 k
No W on FW

Calculated Overall TBR	1.1
η_{th}	46%
Availability	76%

Plasma Control:
- 5 cm W Shells on IB
- 6 cm W Shells on OB
- 2 cm V Kink Shell behind OB FW





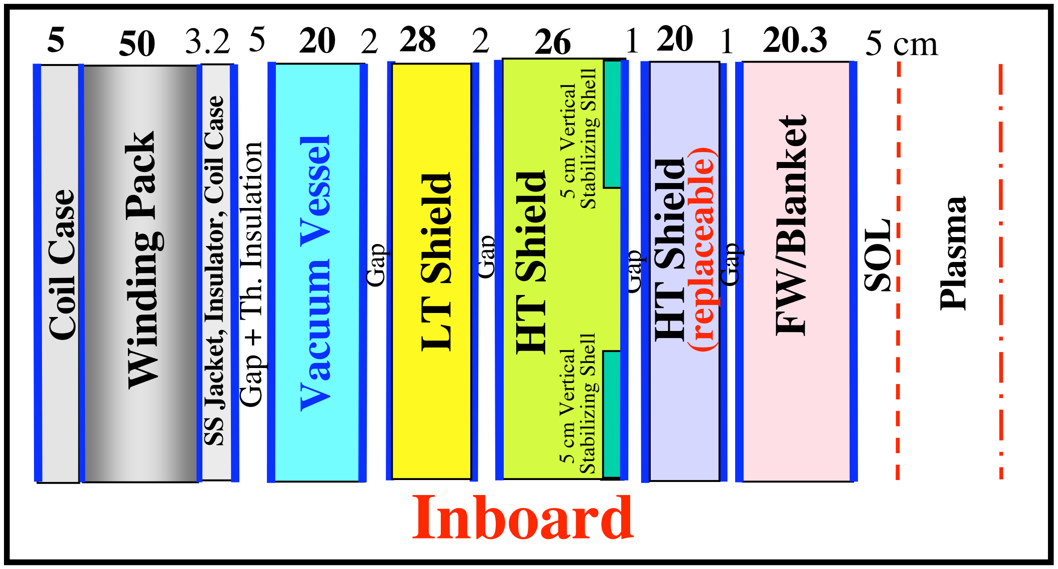


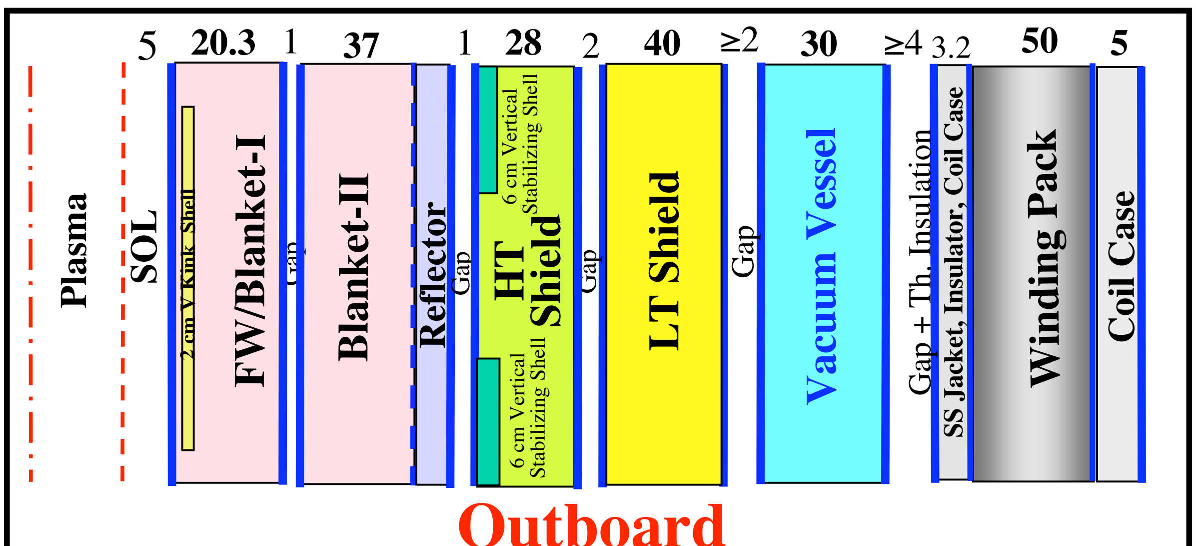
Design Requirements

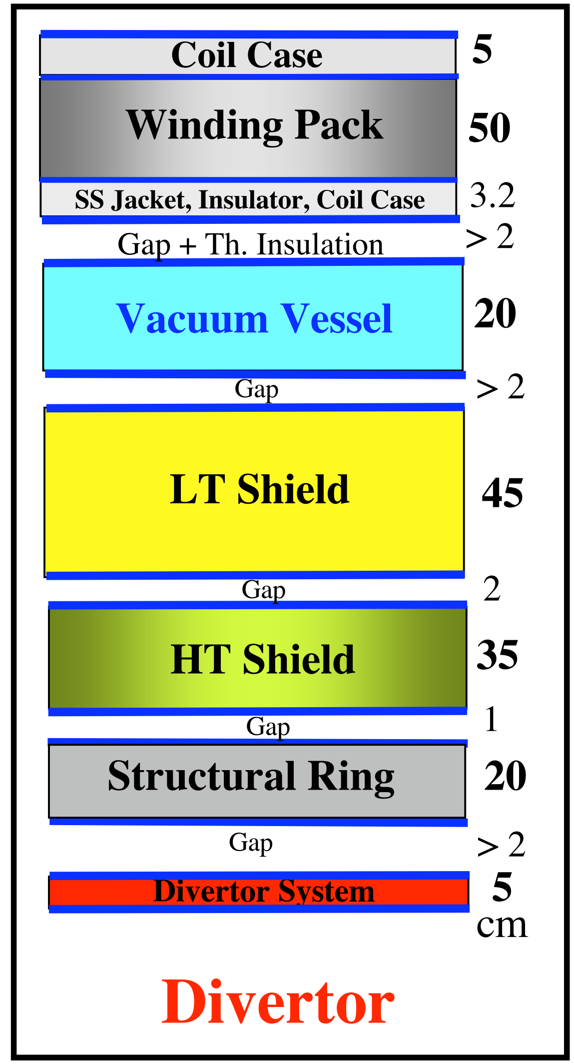
Calculated Overall TBR*	1.1	
Net TBR* (for T self-sufficiency)	~1.01	
Damage to Structure (for structural integrity)	200	dpa - advanced FS or V
Helium Production @ Manifolds and VV (for reweldability of FS)	1	He appm
LT S/C Magnet (@ 4 K):		
Peak Fast n **fluence** to Nb_3Sn ($E_n > 0.1$ MeV)	10^{19}	n/cm^2 ???????????
Peak Nuclear **heating**	2	mW/cm^3
Peak **dpa** to Cu stabilizer	$6x10^{-3}$	dpa
Peak **dose** to electric insulator	$< 10^{11}$	rads
Plant Lifetime	40	FPY
Availability	85%	
Operational Dose to Workers and Public	< 2.5	mrem/h

ARIES-RS Radial Builds: IB, OB, Div

(V Structure, Li Breeder, Li/He Coolants)



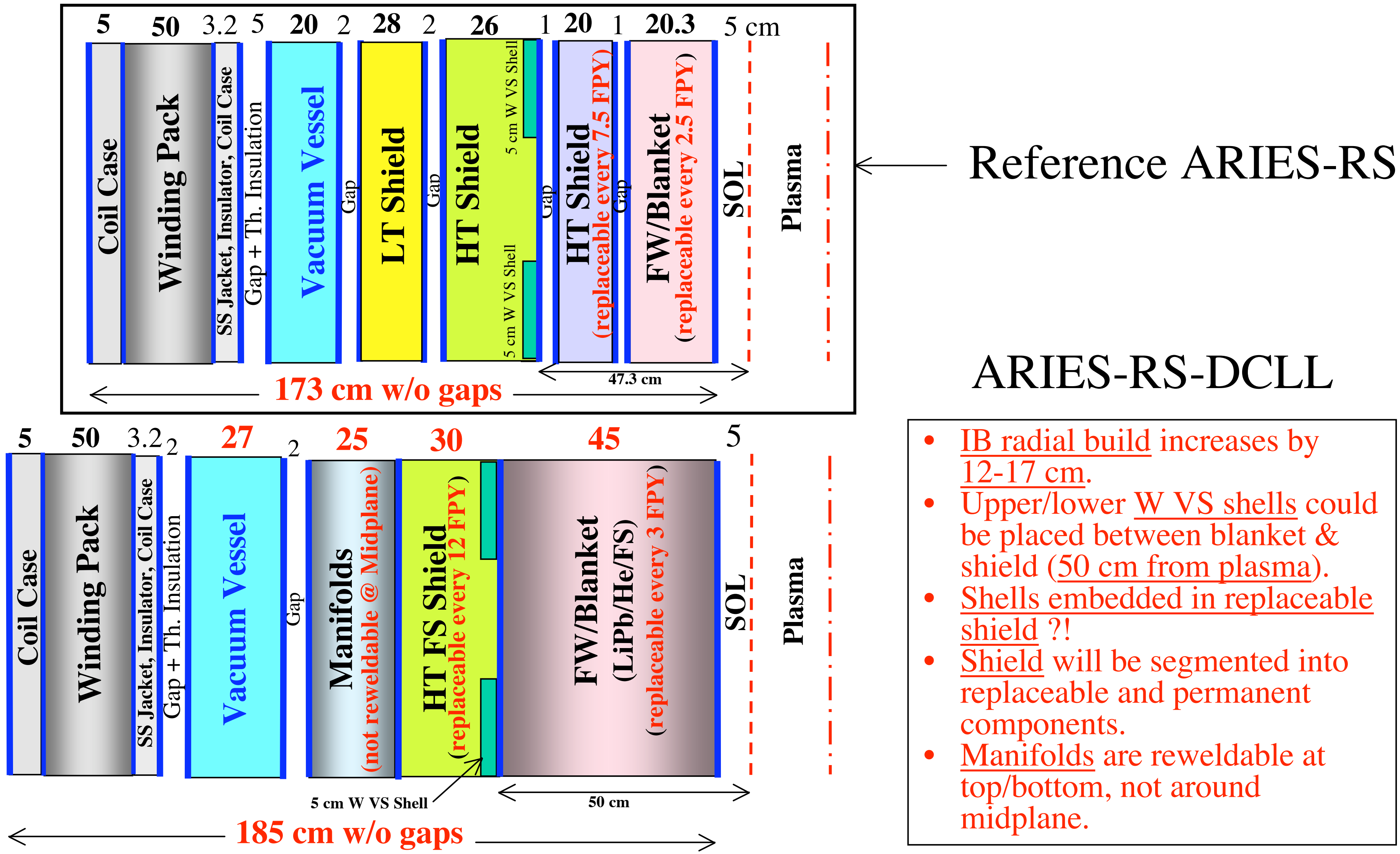




Changes, Updates, and Assumptions

	ARIES-RS-Li/V (Reference Design)	ARIES-RS-DCLL
Peak NWL @ IB, OB, Div	3.7, 5.6, 2.3 MW/m^2	3.7, 5.6, 2.3 MW/m^2 (to be updated)
Structure	V-4Cr-4Ti and Tenelon	MF82H FS
Breeder and Enrichment	Li natural	LiPb 90% (or less)
OB blanket	Two segments	One segment ?
W shells:		
Two 5-cm-thick W VS shells on IB: (toroidally continuous)	Between IB HT shield Segments	Between IB blanket & shield ?
Two 6-cm-thick W VS shells on OB: (toroidally continuous)	Between OB blanket & HT Shield	Behind OB blanket ?
kink shell: (discrete)	**2-cm-thick V** Behind OB FW	Thin Cu shell behind OB FW ?
Breeder/coolant manifolds	Discrete	Toroidally continuous: 25 cm He/LiPb manifolds for IB blanket & shield 35 cm He/LiPb manifolds for OB blanket & shield 20 cm He manifolds for divertor shield
HT Shield coolant	Li	He
LT Shield coolant	He	---
VV coolant	He	H_2O
Gaps between HT components	2 cm	---
VV model	Homogeneous	Heterogeneous with 2-cm-thick plates
Cross section data library	IAEA FENDL-2	IAEA FENDL-2.1

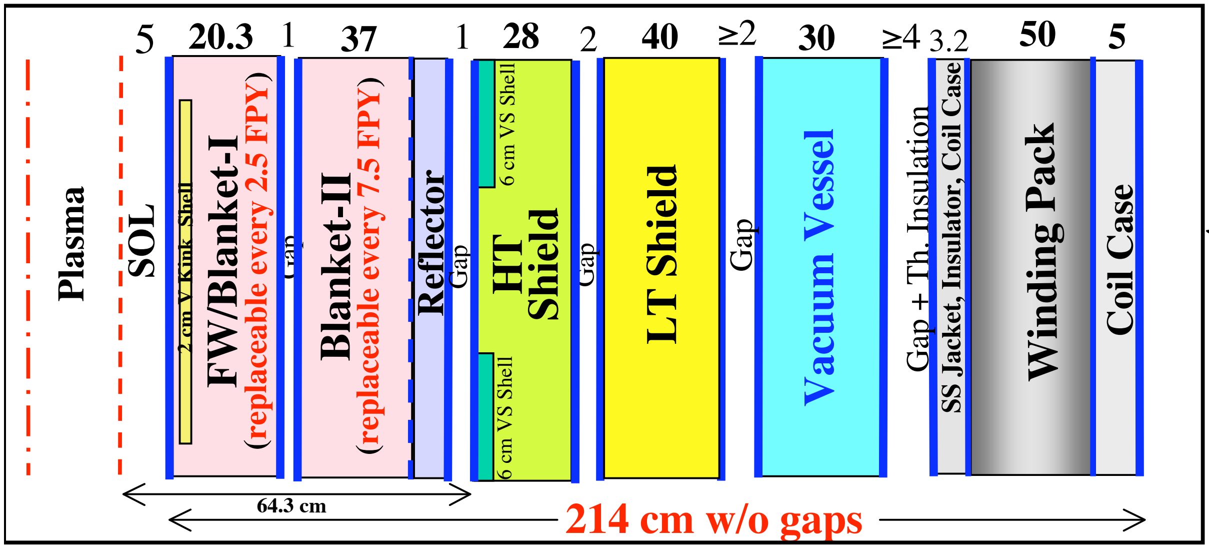
Recommended ARIES-RS-DCLL IB Radial Build (Peak Γ = 3.7 MW/m^2)



- IB radial build increases by 12-17 cm.
- Upper/lower W VS shells could be placed between blanket & shield (50 cm from plasma).
- Shells embedded in replaceable shield ?!
- Shield will be segmented into replaceable and permanent components.
- Manifolds are reweldable at top/bottom, not around midplane.

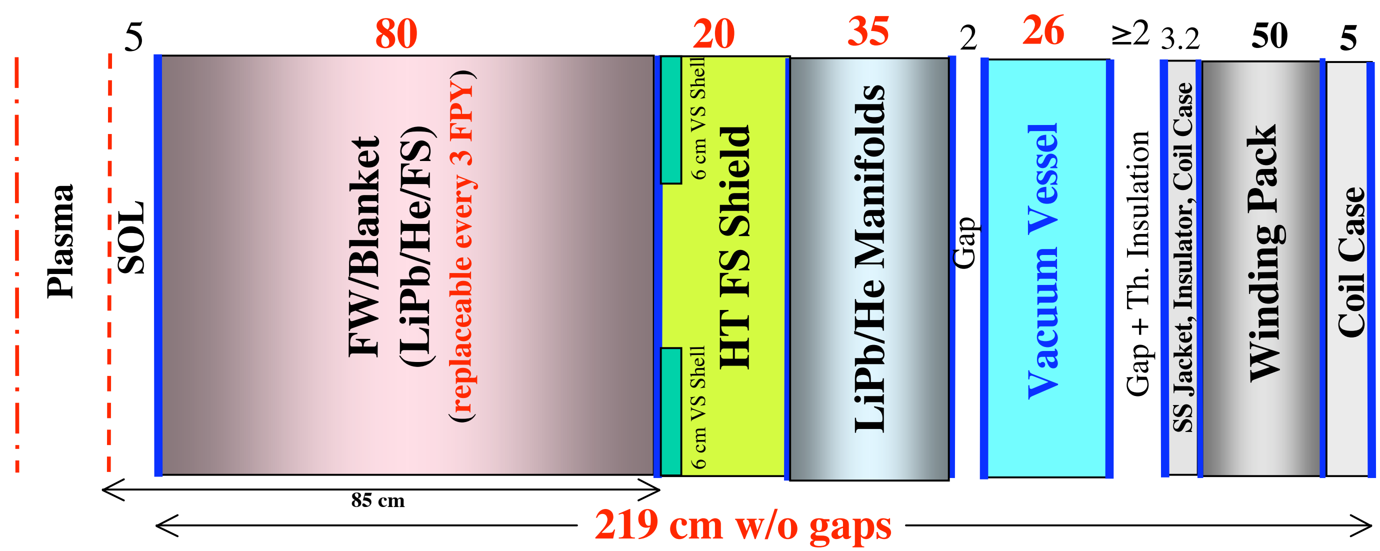
Recommended ARIES-RS-DCLL OB Radial Build (Peak Γ = 5.6 MW/m²)

(Cross Section through Magnet*)



← Reference ARIES-RS

ARIES-RS-DCLL

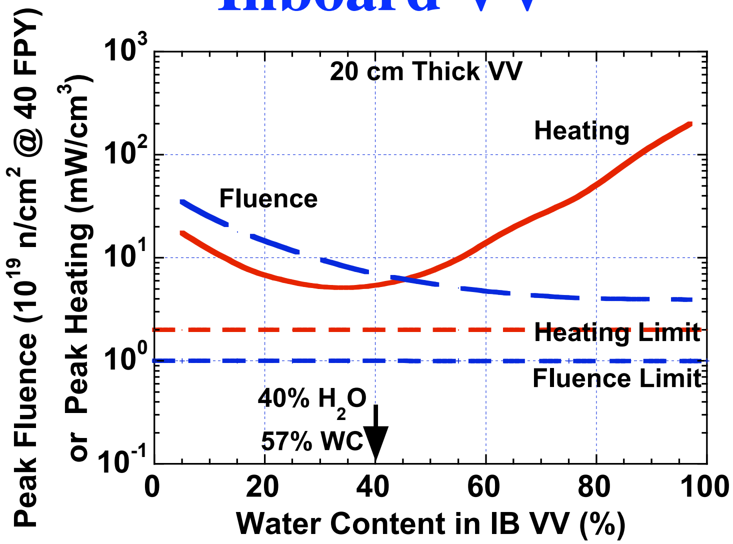


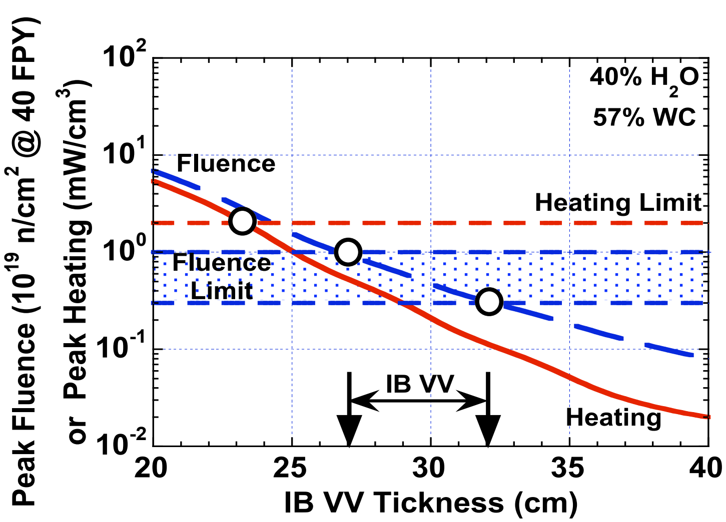
- OB radial build increases by 5-7 cm.
- Upper/lower W VS shells could be placed between blanket & shield (85 cm from plasma).
- Feedback coils could be placed behind manifolds (140 cm from plasma).

* Cross section between magnets TBD.

Optimization of VV Composition and Thickness

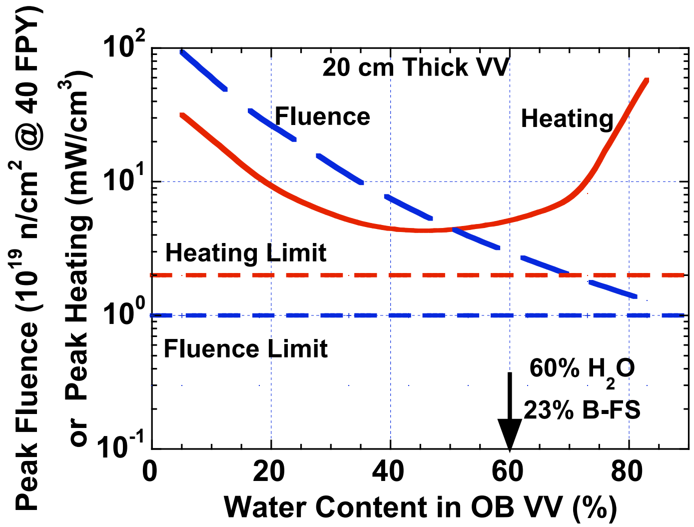
Inboard VV

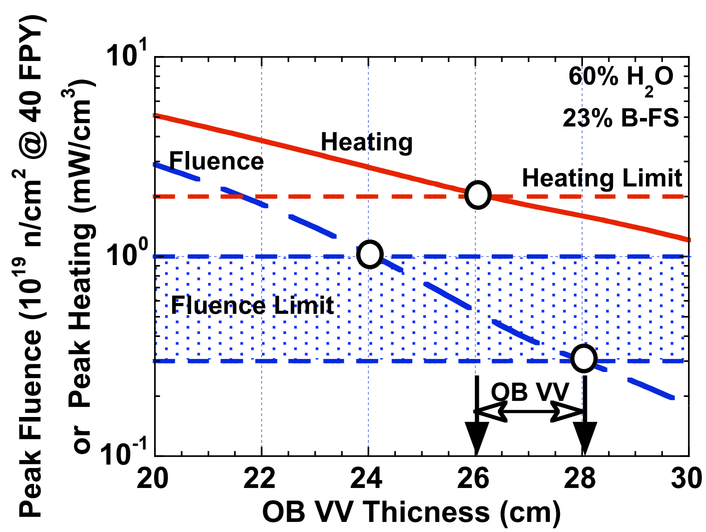




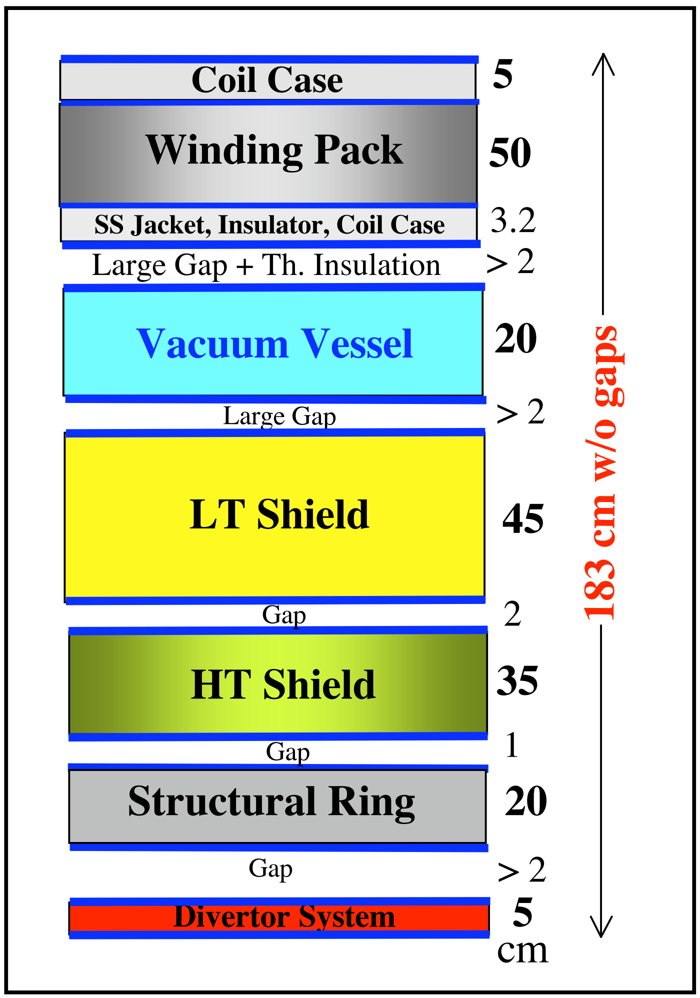
Replacing WC or B-FS with H_2O

Outboard VV



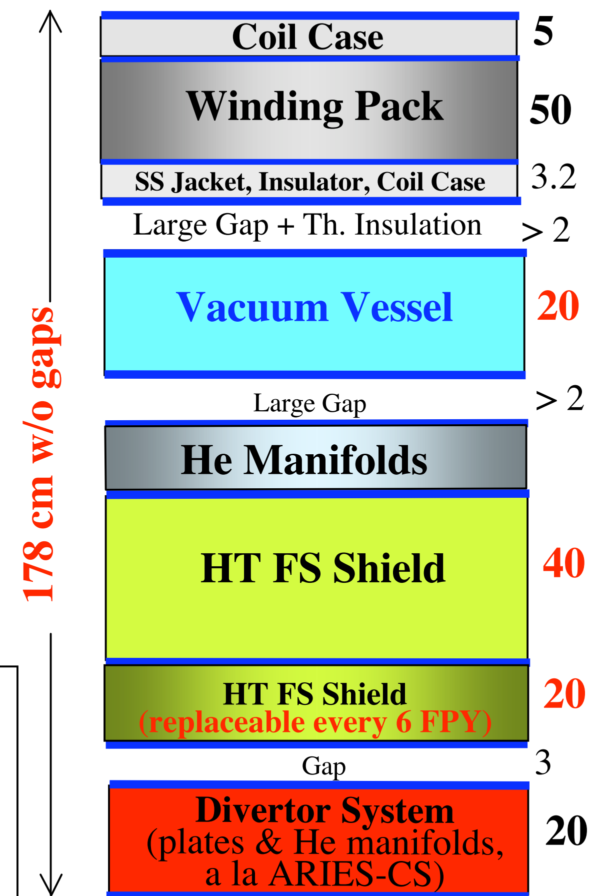


Recommended ARIES-RS-DCLL Divertor Radial Build (Peak Γ = 2.3 MW/m²)



Reference ARIES-RS

- 20 cm replaceable shield (every 6 FPY).
- 20 cm He manifolds.
- Div radial build decreases by 1-5 cm.



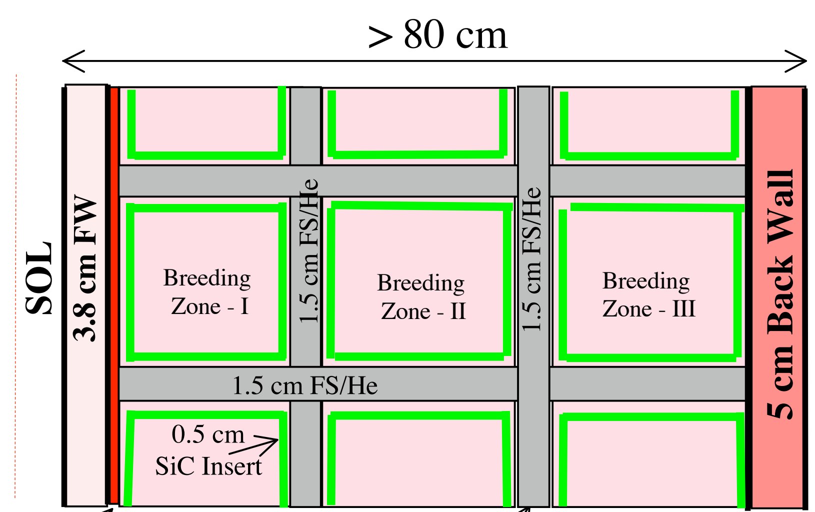
ARIES-RS-DCLL

Potential Locations for Stabilizing Shells and Feedback Coils

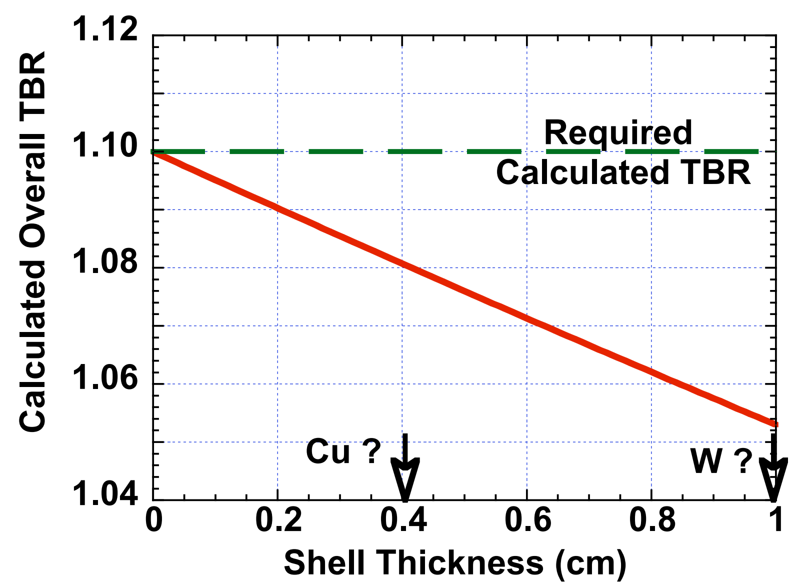
	Distance from Plasma (cm)	
	Reference ARIES-RS	**ARIES-RS-DCLL**
Vertical Stabilizing Shells:		
Inboard (between blanket and shield)	**47**	**50** ?
Outboard (between blanket and shield)	**61**	**85** ?
Kink Shells:		
Outboard	**7** (behind OB FW)	**9** or **45** ? (behind OB FW or between blanket segments)
Feedback Coils:		
Outboard	**134** (behind OB shield)	**140** ? (behind OB manifolds)

Kink Shell Behind OB FW ?

- Could Cu (or W) kink shell be placed behind OB FW?
- Integration of kink shell with blanket?
- Impact on breeding?



ARIES-RS-DCLL OB Blanket
with kink shell behind FW

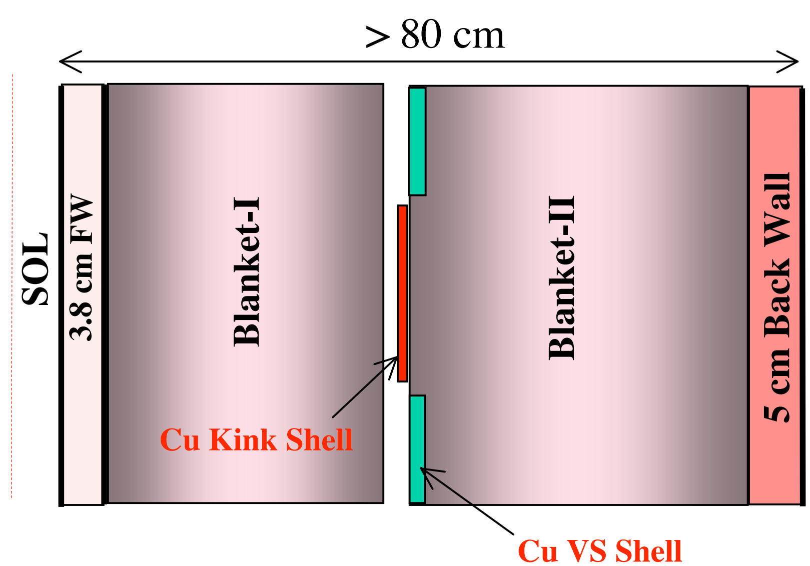


IB and/or OB Blanket
should be thickened to compensate
for breeding losses

Kink Shell Between OB Blanket Segments ?

- Could OB blanket be segmented into two segments?
- **Benefits**:
  - Cu (or W) kink shell placed between OB blanket segments
  - Less integration problems
  - Less impact on breeding
  - Lifetime of back segment > 3 FPY (~15 FPY)
  - Notable reduction in lifecycle radwaste volume.
- If feasible, revisit ARIES-AT-DCLL? d/a ~ 0.35 for VS shells

ARIES-RS-DCLL OB Blanket
With Cu kink and VS shells
between blanket segments
(blanket Temp < 700 °C)



Impact of DCLL System on ARIES-RS Overall Design

	Reference ARIES-RS	ARIES-RS-DCLL
IB, OB, Div radial standoff*	173, 214, 183	185, 219, 178
Limit for max NWL (m)	~ 6	< 5.5 ?
R (m)	5.52	> 5.52
Overall **energy multiplication**	1.2	~ 1.15
η_{th}	46%	40–45%
Structure **unit cost**#	300 $/kg of V	~ 60 $/kg of FS
Blanket/divertor/shield/manifolds **cost***	~ $80M	< $80M
Cost* of **heat transfer/transport system**	$260M	$400-500M
Pumping power	12 MW_e	~ 150 MW_e
LSA factor	2	2
Cost of Electricity#:	**76** mills/kWh	**> 76** mills/kWh
Maintenance approach	Sector Maintenance (with coolant pipes attached at bottom)	?

* Excluding gaps.

\# in 1992$.

Observations, Future Work, and Needed Info

Observations:

- DCLL system increases IB and OB radial standoff
- Kink shell degrades breeding
- Resistivity increases with neutron fluence. Impact on stabilizing shell parameters?

To do:

- Adjust blanket dimensions to accommodate kink shell and estimate TBR for one OB blanket segment or two, if feasible
- Assess breeding potential with < 90% enrichment. This may require fairly thick IB and OB blankets. Impact on locations of vertical stabilizing shell and feedback coils?
- Divide IB shield into replaceable and permanent components to minimize radwaste stream
- Provide OB radial build for Xn between magnets for ASC
- Pay special attention to location and configuration of He-access pipes for upper/lower divertors
- Surround pumping ducts with penetration shield to limit radiation damage at VV and magnet.

Need:

- Info on new fluence limit for Nb_3Sn and reference
- Physics parameters for ARIES-RS-DCLL system to estimate peak IB and OB NWL
- Locations of kink shells, vertical stabilizing shells, and feedback coils
- Blanket composition
- Size, composition, and location of manifolds.