Preliminary TBR Analysis and Radial/Vertical Build Definition for ARIES-ACT-2/3 (DCLL) Design

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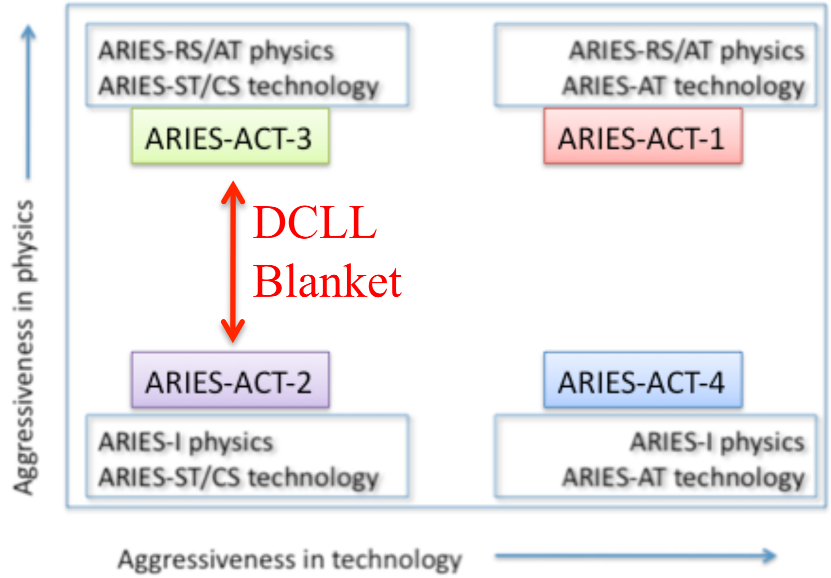
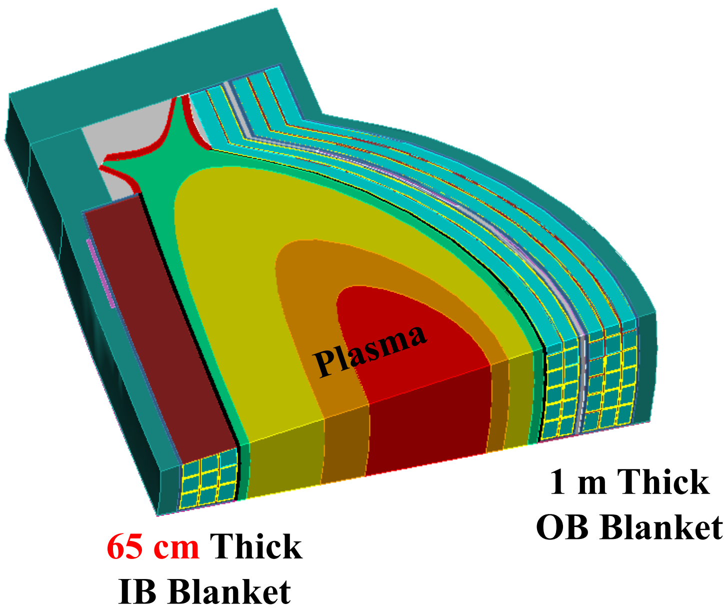


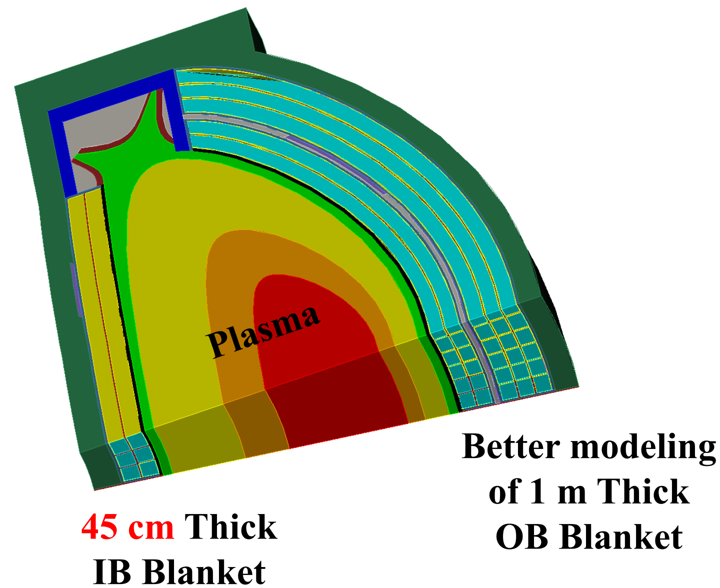
- Preliminary 3-D TBR analysis (to size IB **and** OB DCLL blankets for ARIES-ACT-2/3).
- Preliminary radial/vertical build definition for ARIES-ACT-2.

Preliminary 3-D TBR Analysis

Changes Relative to 7/2011 Presentation

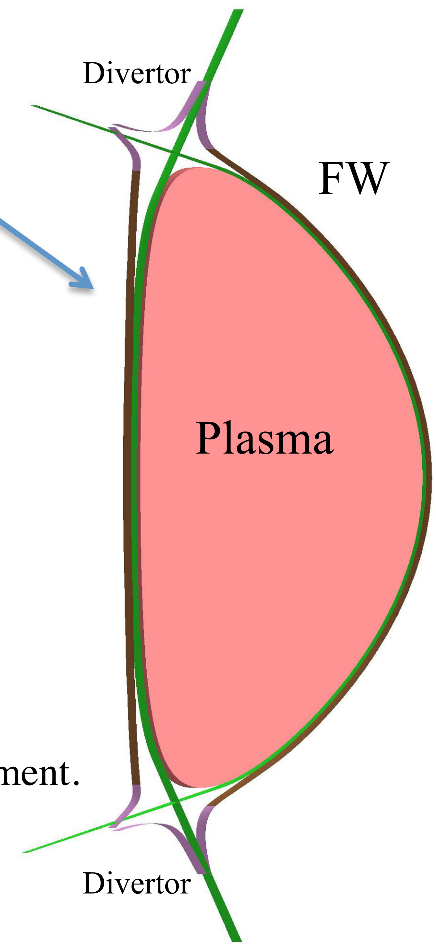
- **Changes**:
  - Better 3-D modeling of OB blanket resulting in more T breeding
  - Examining 1 m thick OB blanket and 45 cm thick IB blanket instead of 65 cm
  - Updating OB penetrations (2% of OB FW area, instead of 1.6%).





3-D TBR Analysis

- Stepwise approach:
  - Build CAD model from scratch, starting with FW/divertor skeleton
  - Couple CAD with MCNP using DAGMC code
  - No homogenization within breeding zones
  - In multiple steps, add:
    - FW
    - side/top/back walls
    - cooling channels
    - SiC Flow Channel Inserts
    - Stabilizing shells
    - penetrations
    - Other design elements (shield, assembly gaps, etc.)
  - Record impact of **9** individual design elements on TBR
  - Vary Li enrichment from natural to 90% to determine operating enrichment.



2011 ARIES-ACT-DCLL
(from X. Wang)

Step 1: Infinite Cylinder

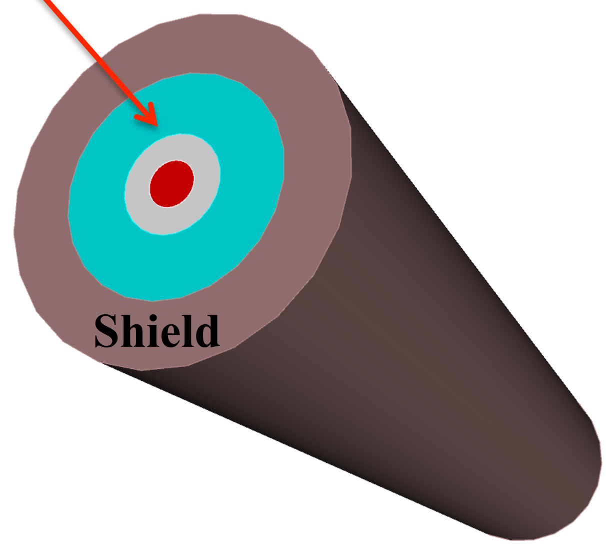
(to estimate maximum achievable TBR)

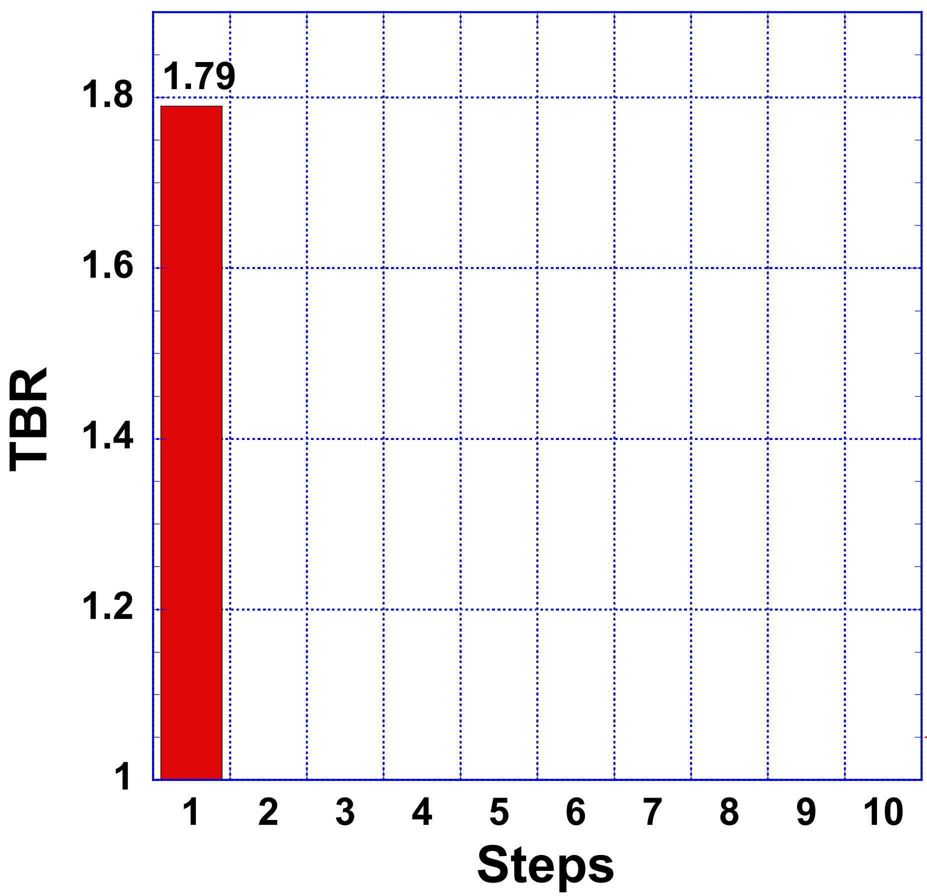
2 m thick LiPb Breeder

($Li_{15.7}\,Pb_{84.3}$)

with 90% Li enrichment

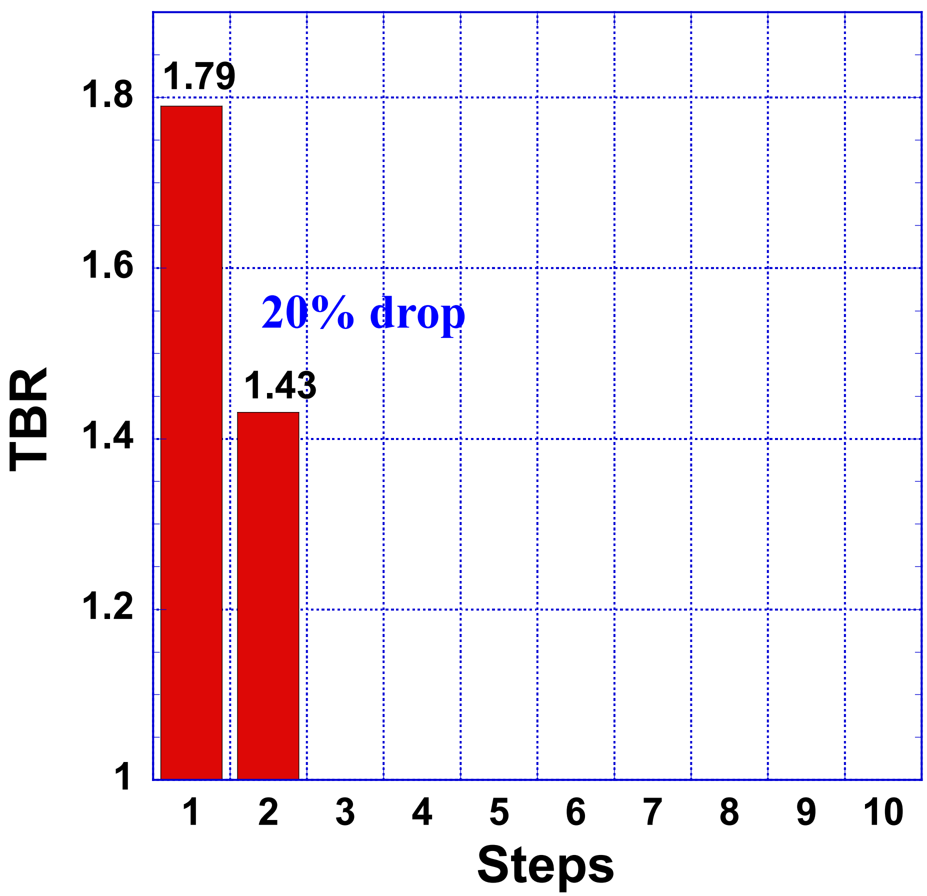
No structure

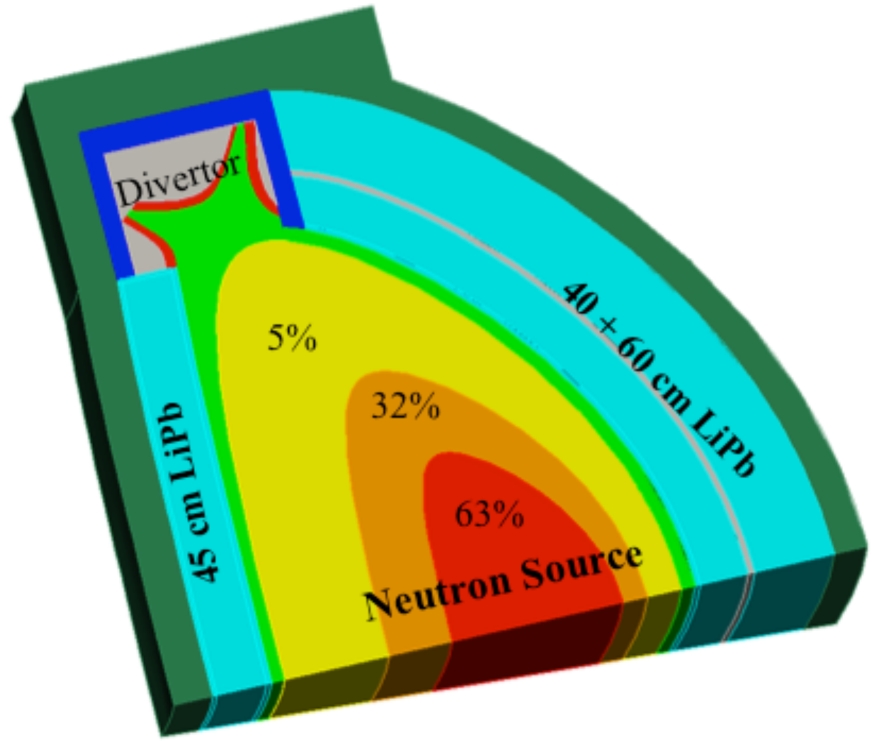




Required Calculated TBR = 1.05

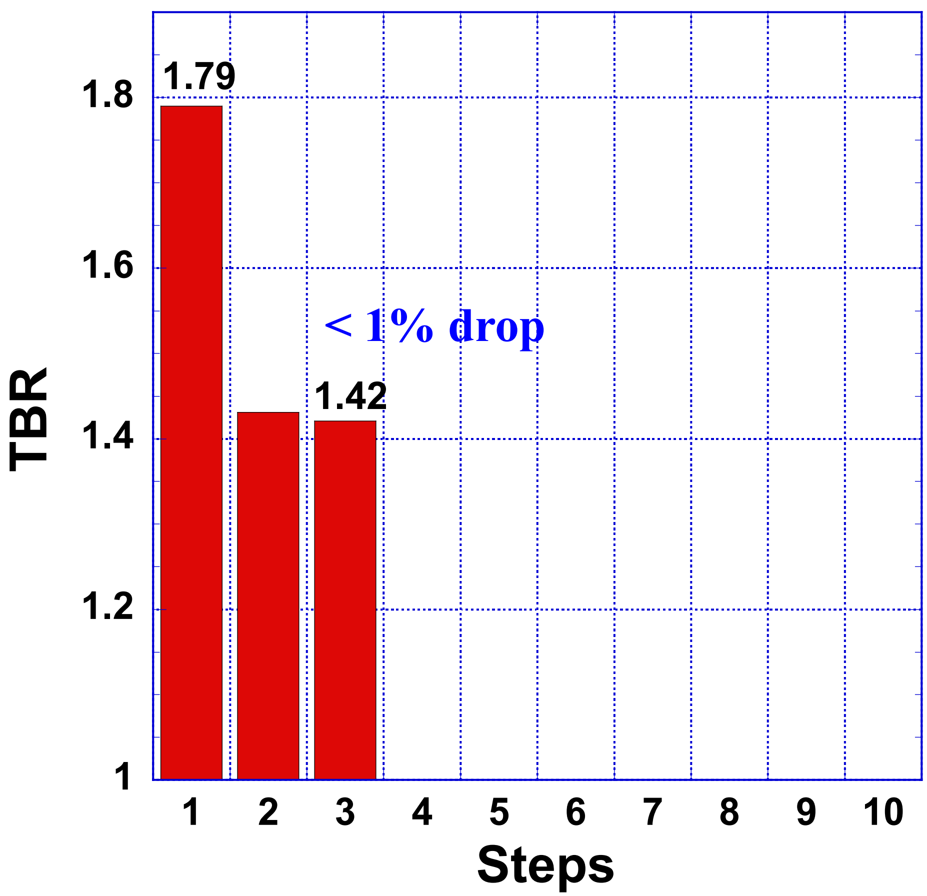
Step 2: 3-D Toroidal Model: $Li_{15.7}Pb_{84.3}$ Confined Radially/Vertically to Blanket; Shield and Divertor Added

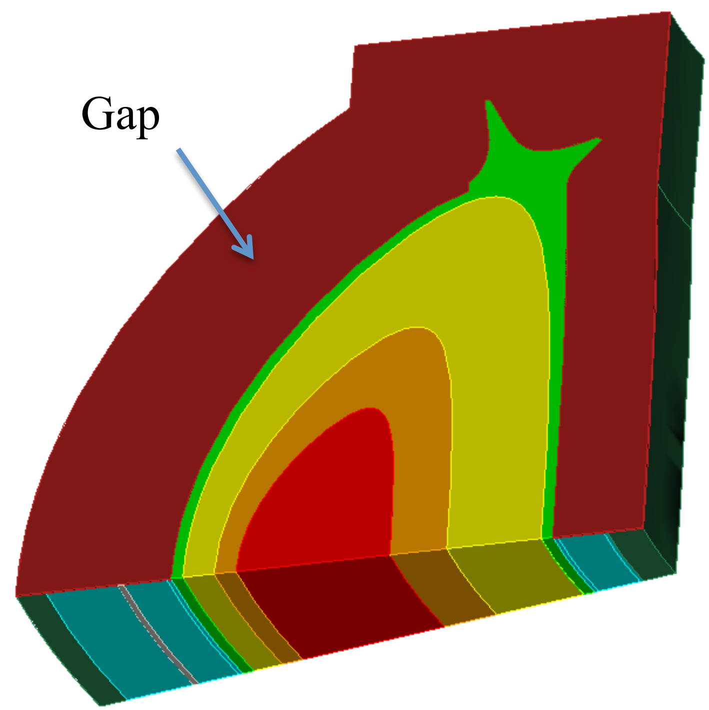




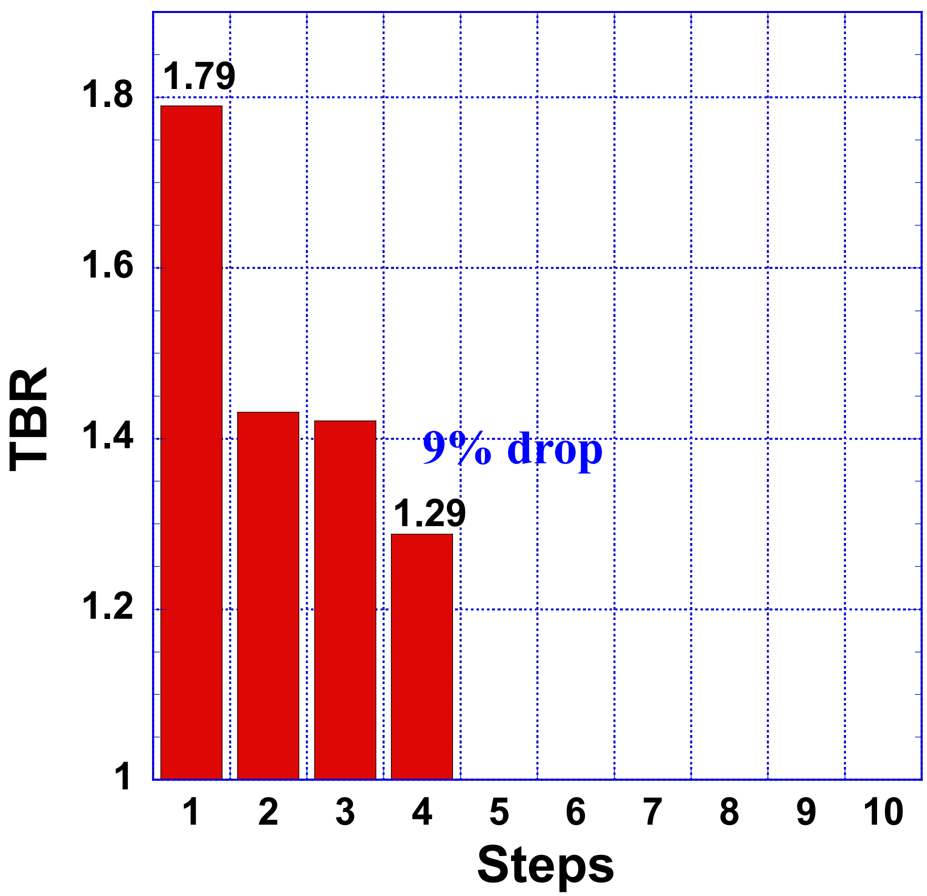
1/64th of ARIES-ACT torus

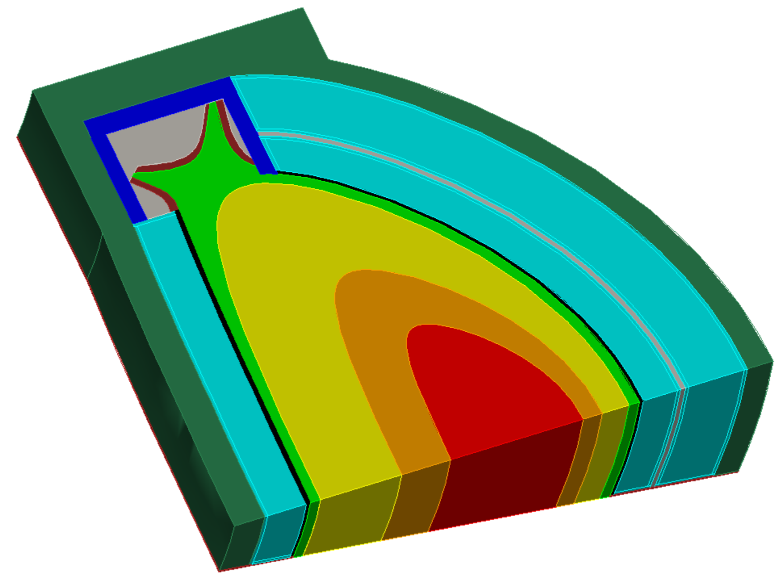
Step 3: 2 cm Wide Assembly Gaps Between Modules (brown)





Step 4: FS/LiPb Materials Assigned to First Wall (black)

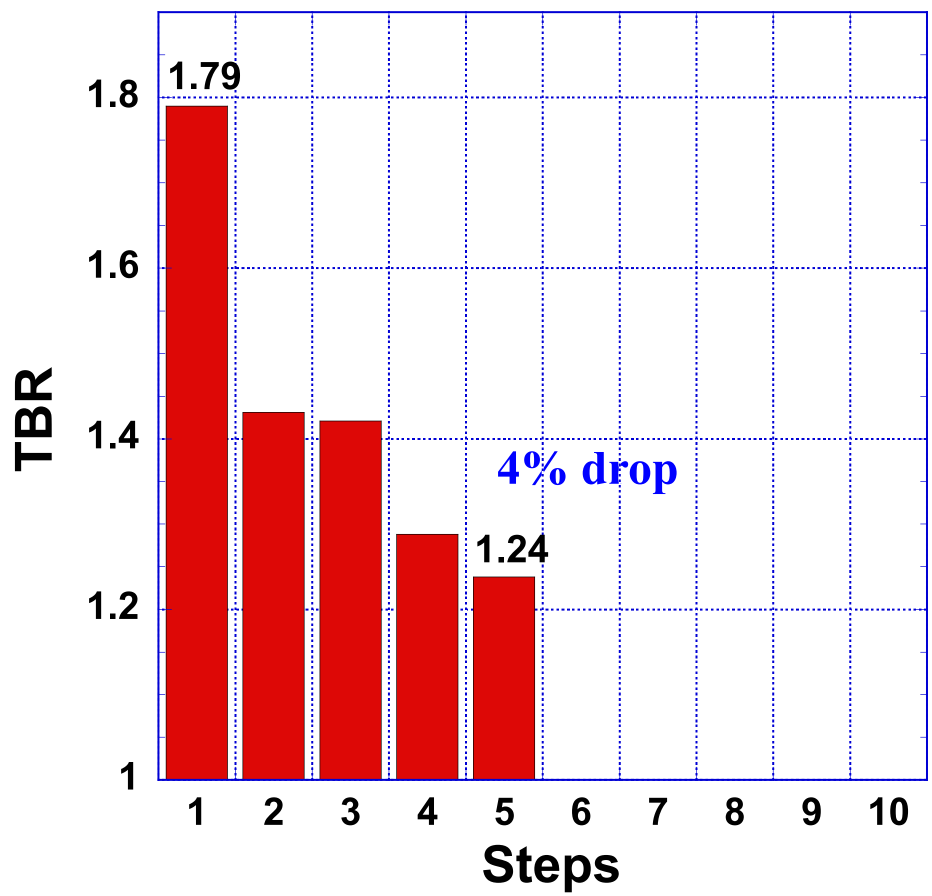


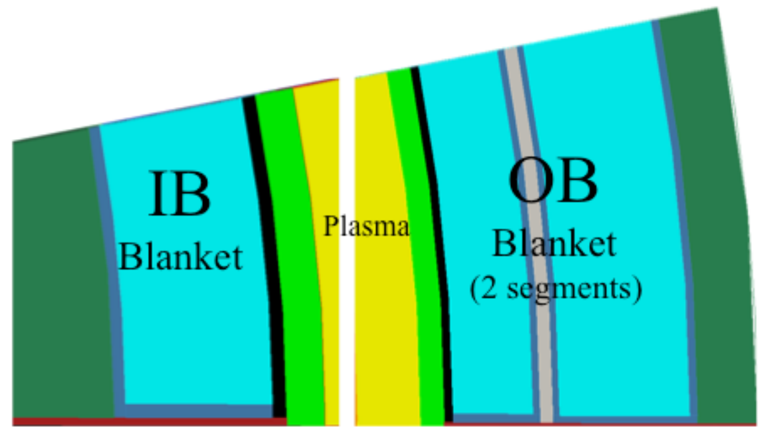


3.8 cm thick First Wall:
8% ODS-FW, 27% MF82H, 65% He

To be confirmed by UCSD

Step 5: FS/LiPb Side, Top, Back Walls Added (dark blue)



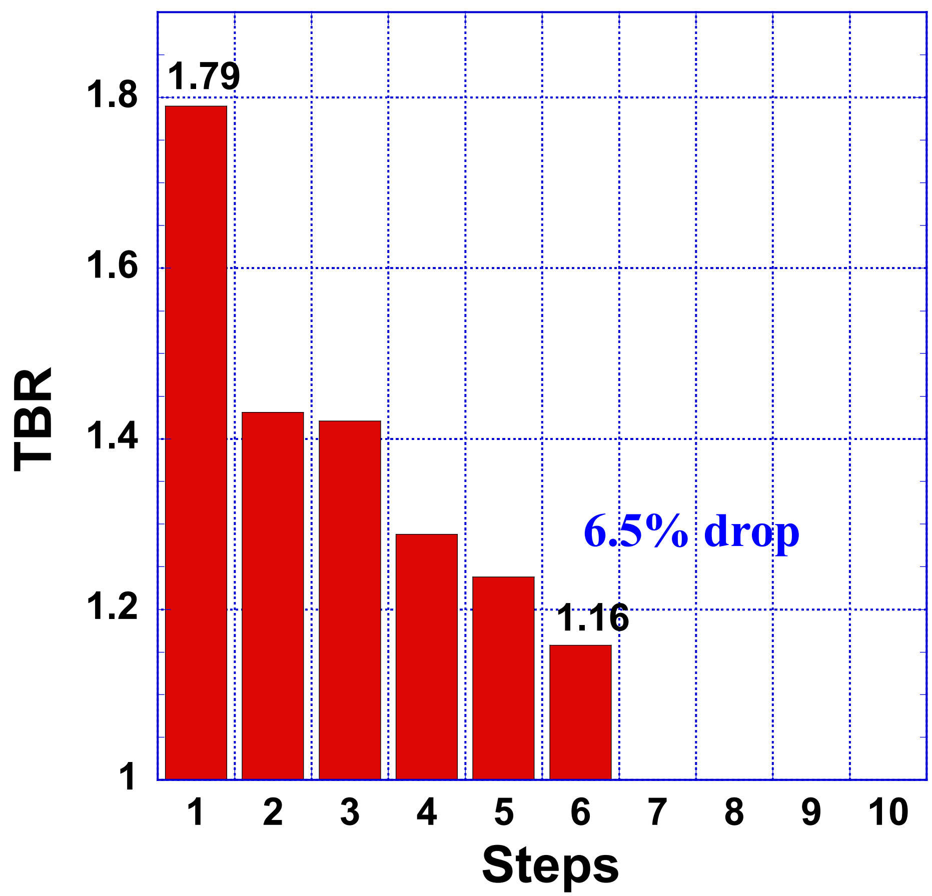


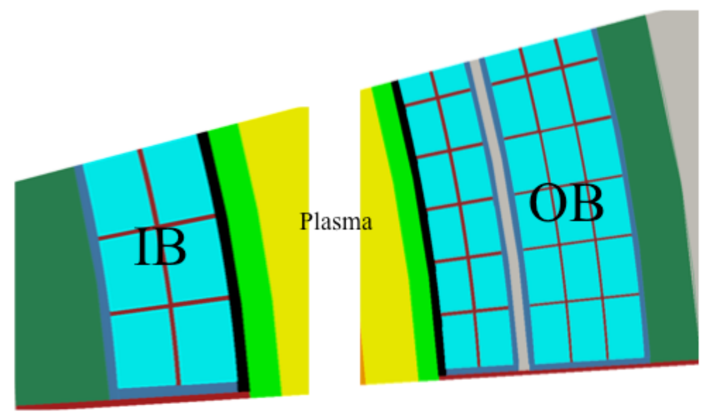
3.5 cm thick:
- IB Blanket side/top walls
- OB Blanket-I side/top walls
- (29% MF82H, 71% He)

3 cm thick:
- IB Blanket back wall
- OB Blanket-I back wall
- OB Blanket-II front/back/side/top walls
- (80% MF82H, 20% He)

To be confirmed by UCSD

Step 6: FS/LiPb Cooling Channels Added within Blanket (dark red)

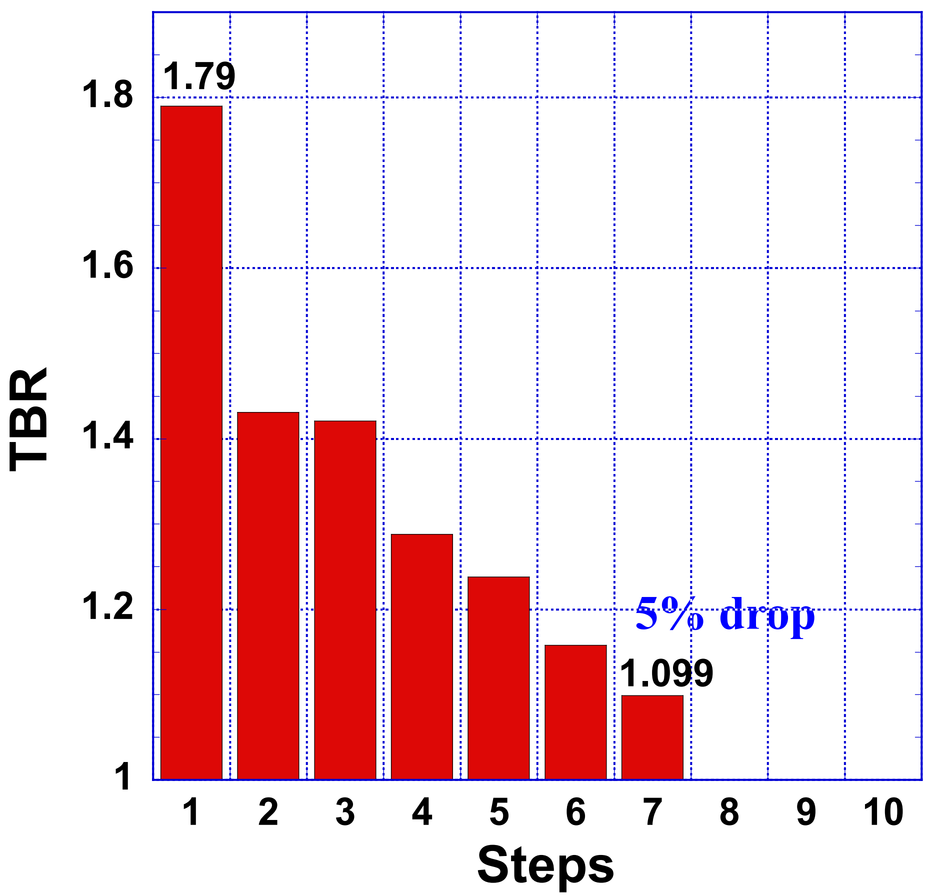


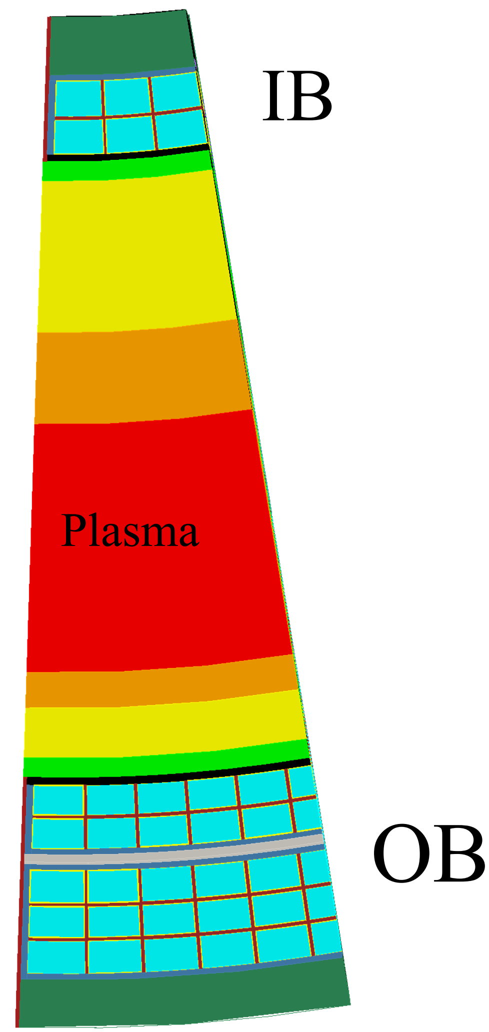


1.5 cm thick Cooling Channels: (58% MF82H, 42% He)

To be confirmed by UCSD

Step 7: SiC Flow Channel Inserts Added (yellow)



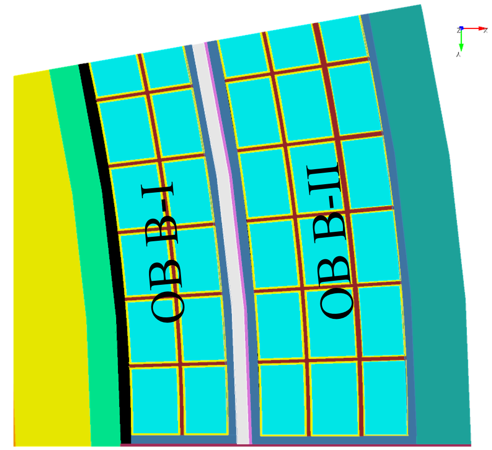


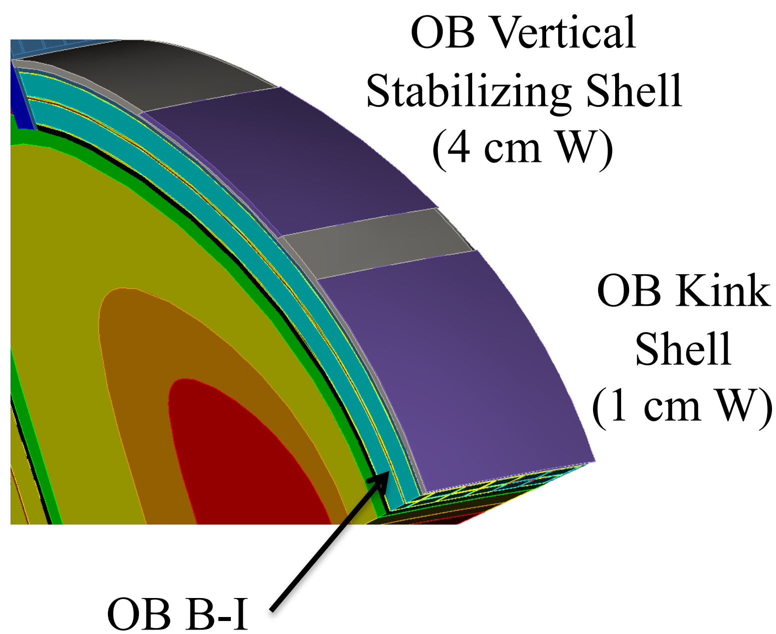
Step 8: W Stabilizing Shells Added Between OB Blanket Segments (purple)

ARIES-ACT-2

IB and OB VS Shells

No OB Kink Shell





ARIES-ACT-3

IB and OB VS Shells

OB Kink Shell

Lower TBR or higher ^{6}Li enrichment

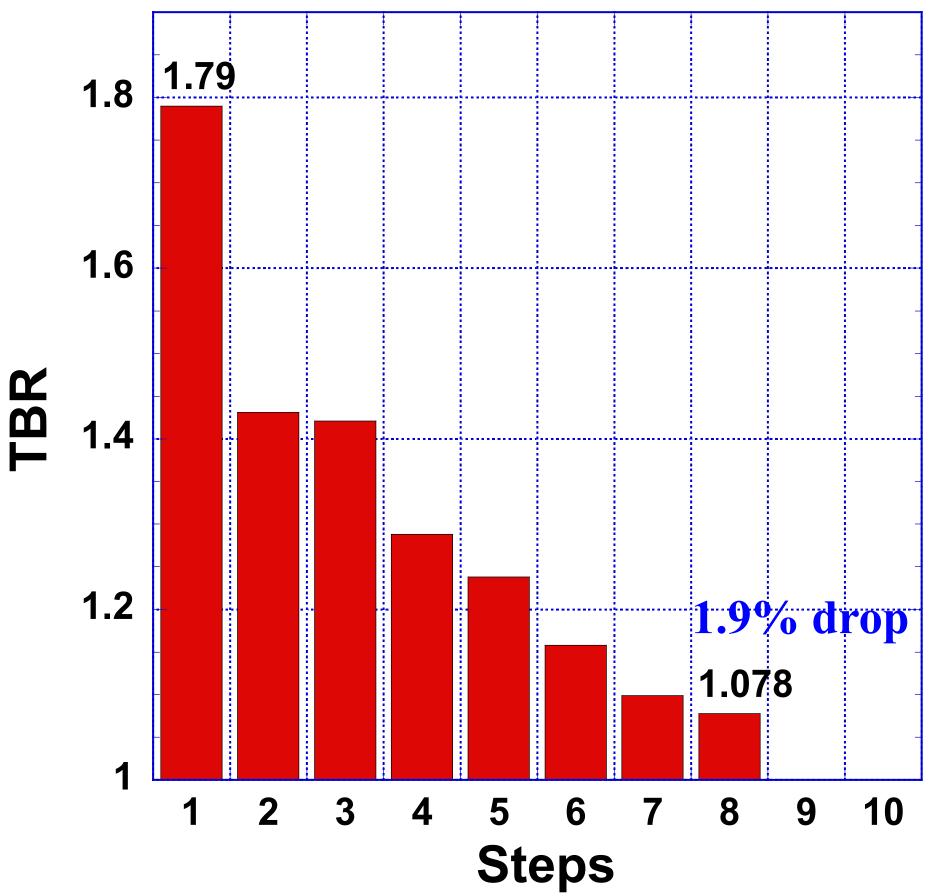
ARIES-ACT-2

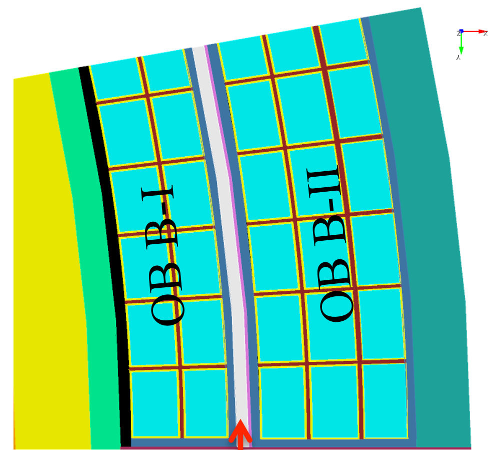
IB and OB VS Shells

No OB Kink Shell

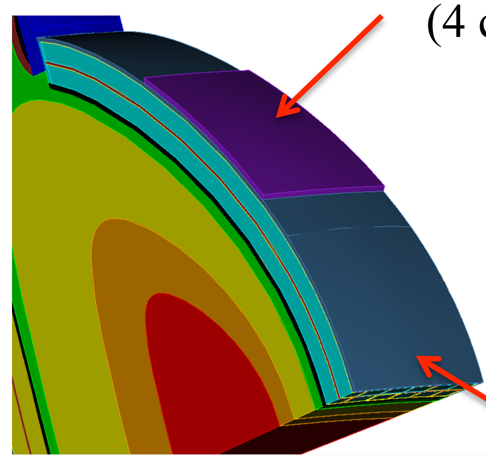
Step 8: IB & OB VS Shells Added (purple)

ARIES-ACT-2





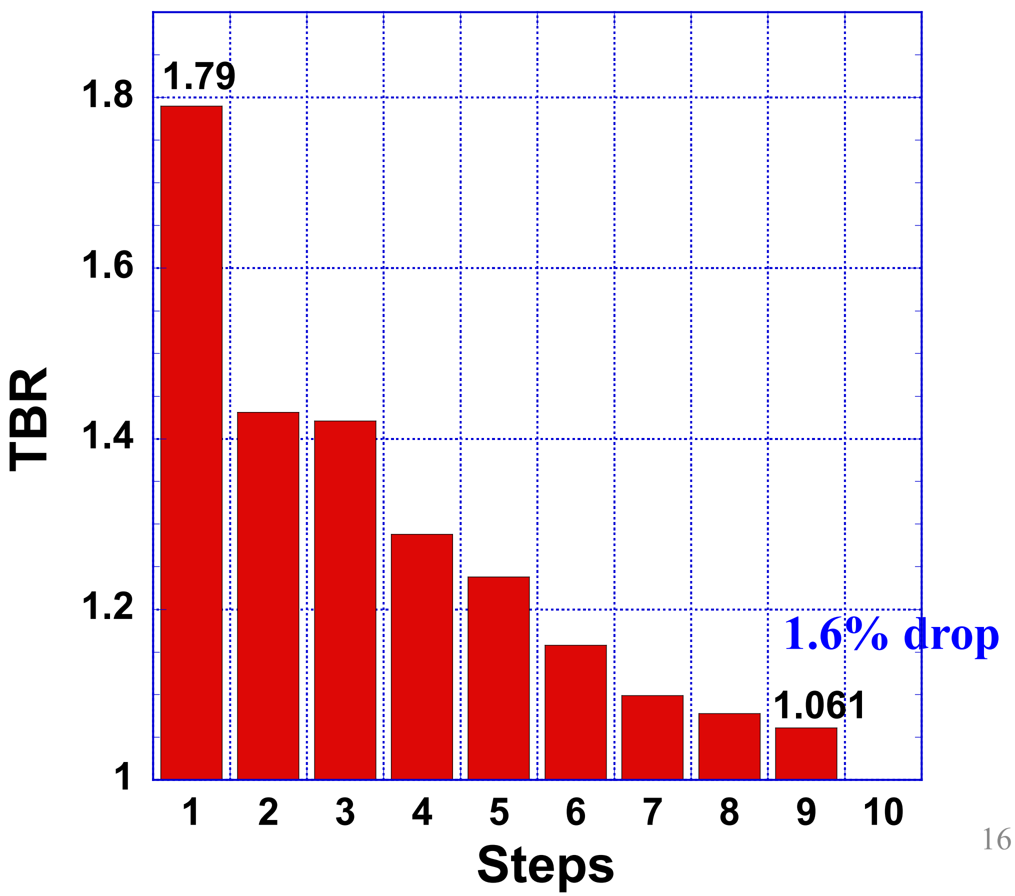
OB Vertical Stabilizing Shell (4 cm W)



OB B-I

Step 9: Including Penetrations on OB

ARIES-ACT-2



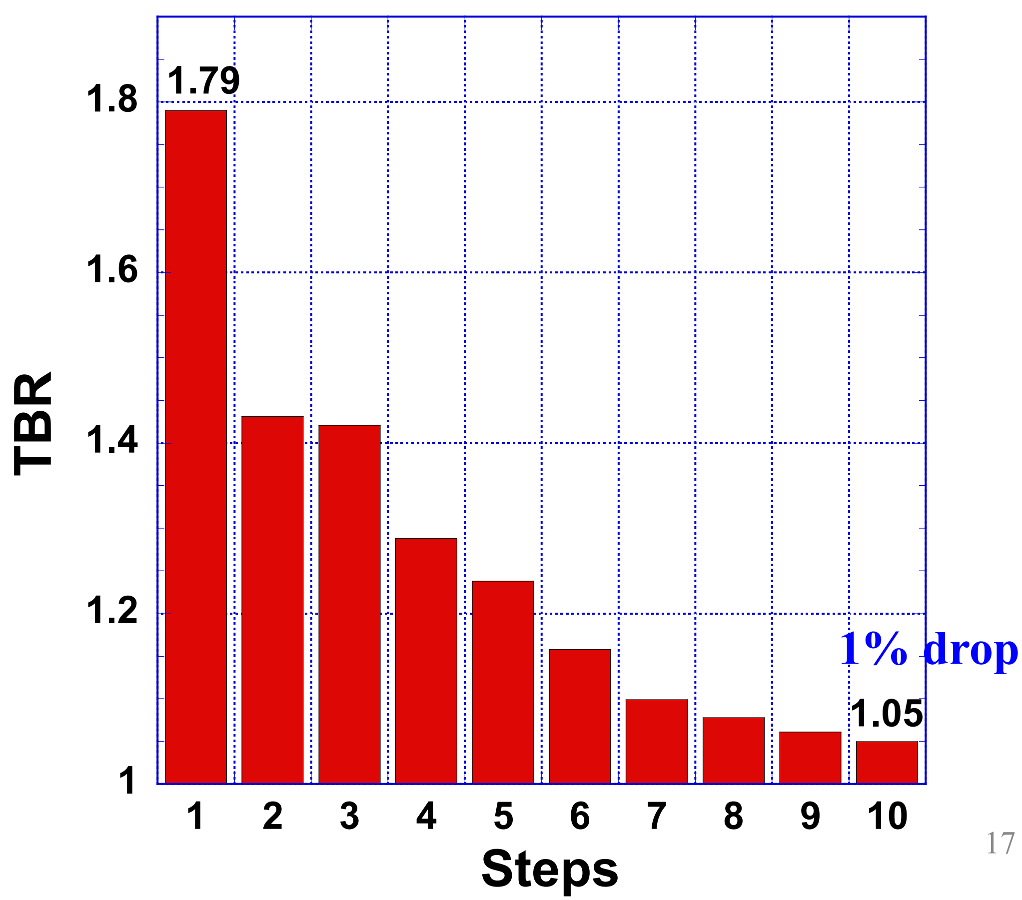
Per C. Kessel, **footprints at FW:**

	> 2 m^2 ICRF
	> 2 m^2 LH
	0.008 m^2 fueling
diagnostics	~ 3 m^2

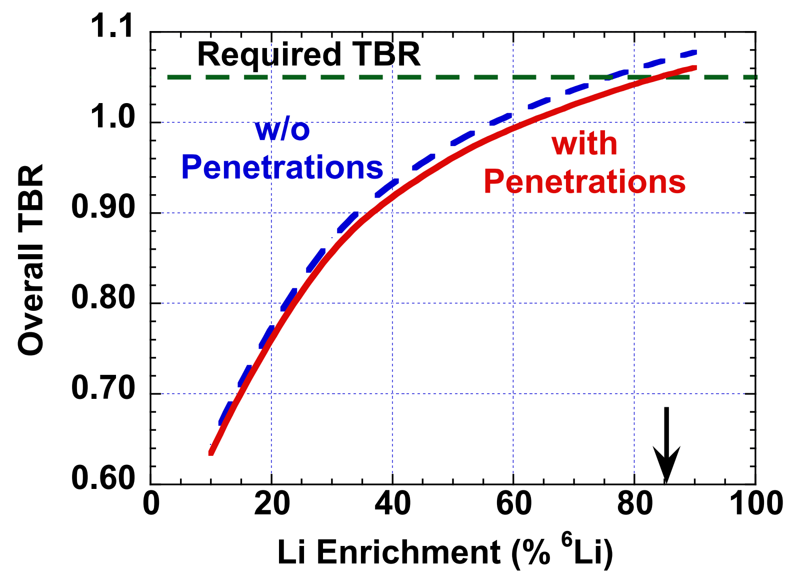
Total	~ 7 m^2

Fraction of OB surface area ~**2%**

Varying Li-6 Enrichment



ARIES-ACT-2



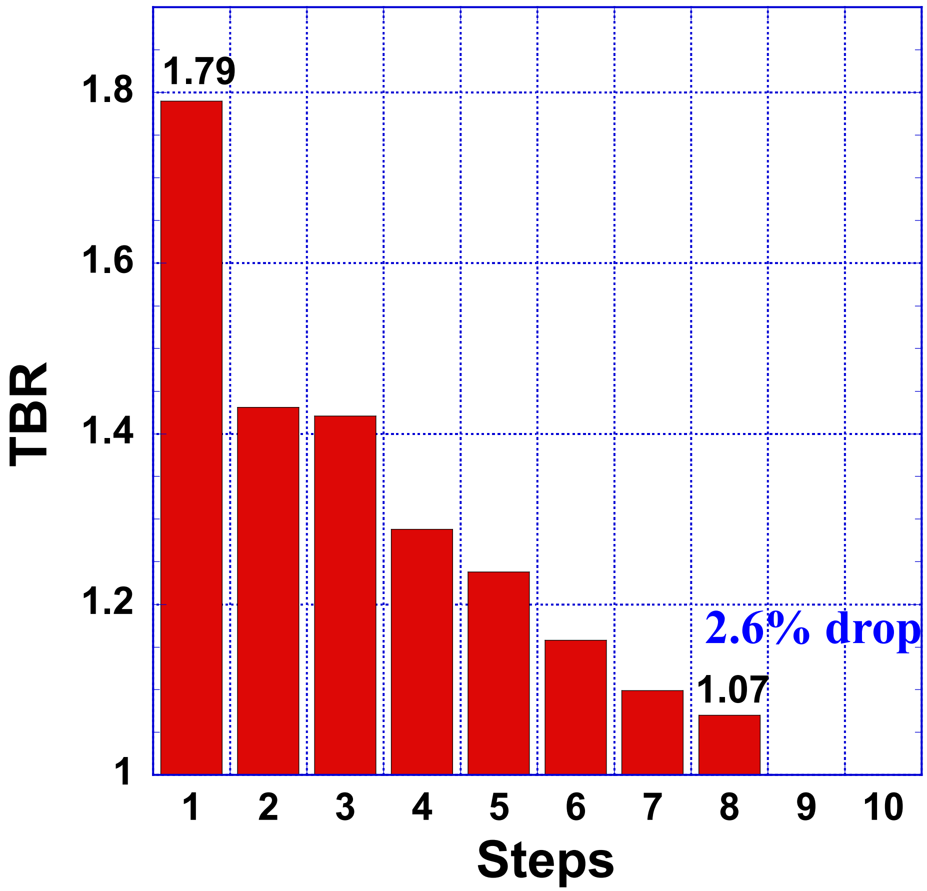
Operating ^{6}Li enrichment is high (85%)

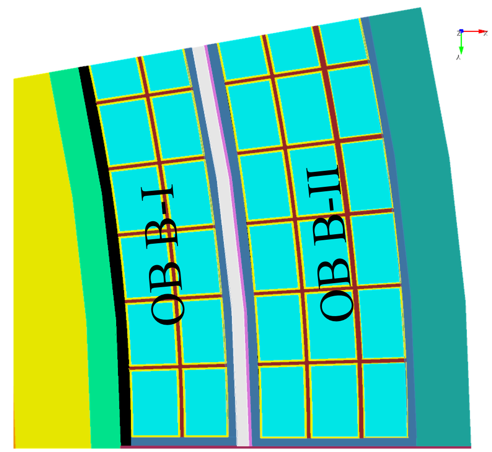
ARIES-ACT-3

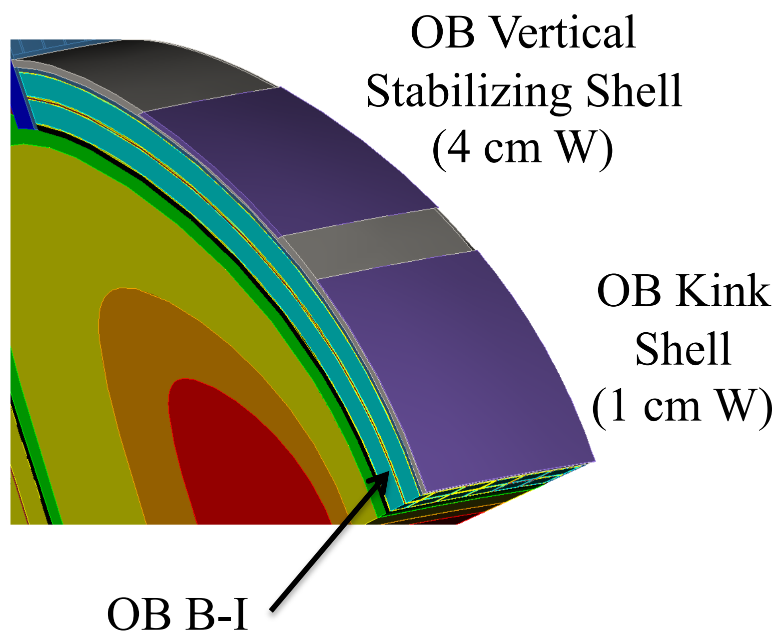
IB and OB VS Shells
OB Kink Shell

Step 8: W Stabilizing Shells Added Between OB Blanket Segments (purple)

ARIES-ACT-3

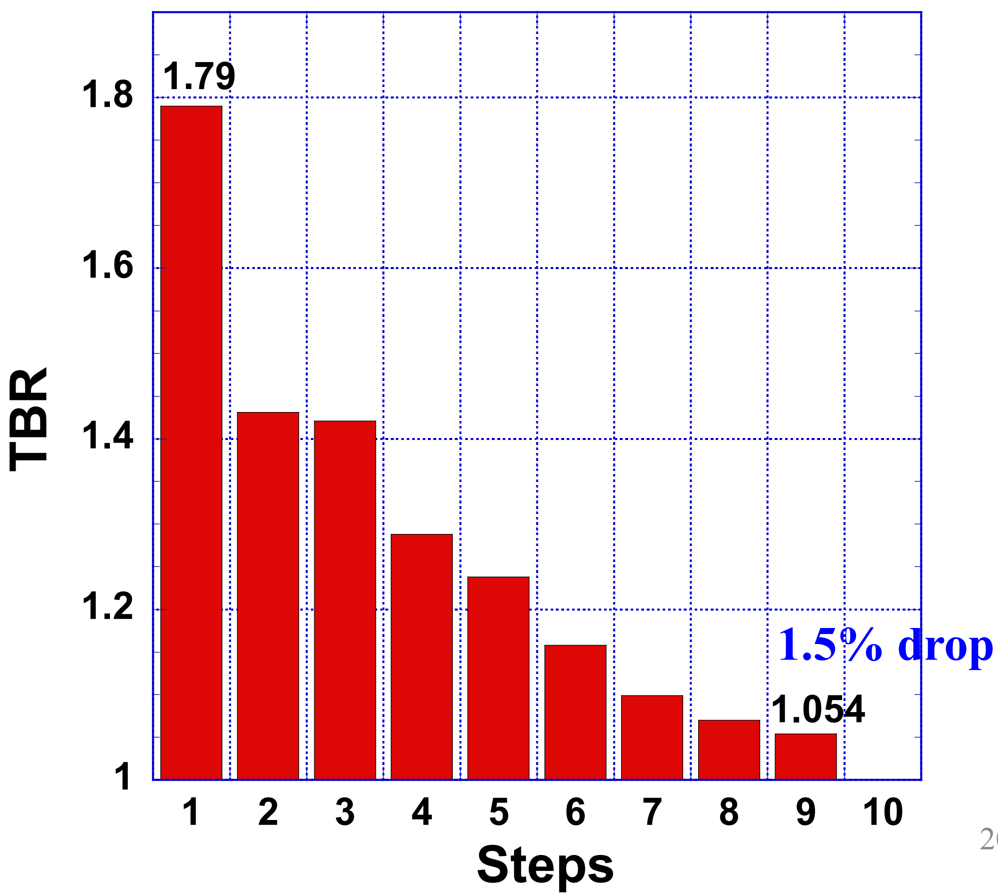






Step 9: Including Penetrations on OB

ARIES-ACT-3



Per C. Kessel, **footprints at FW:**

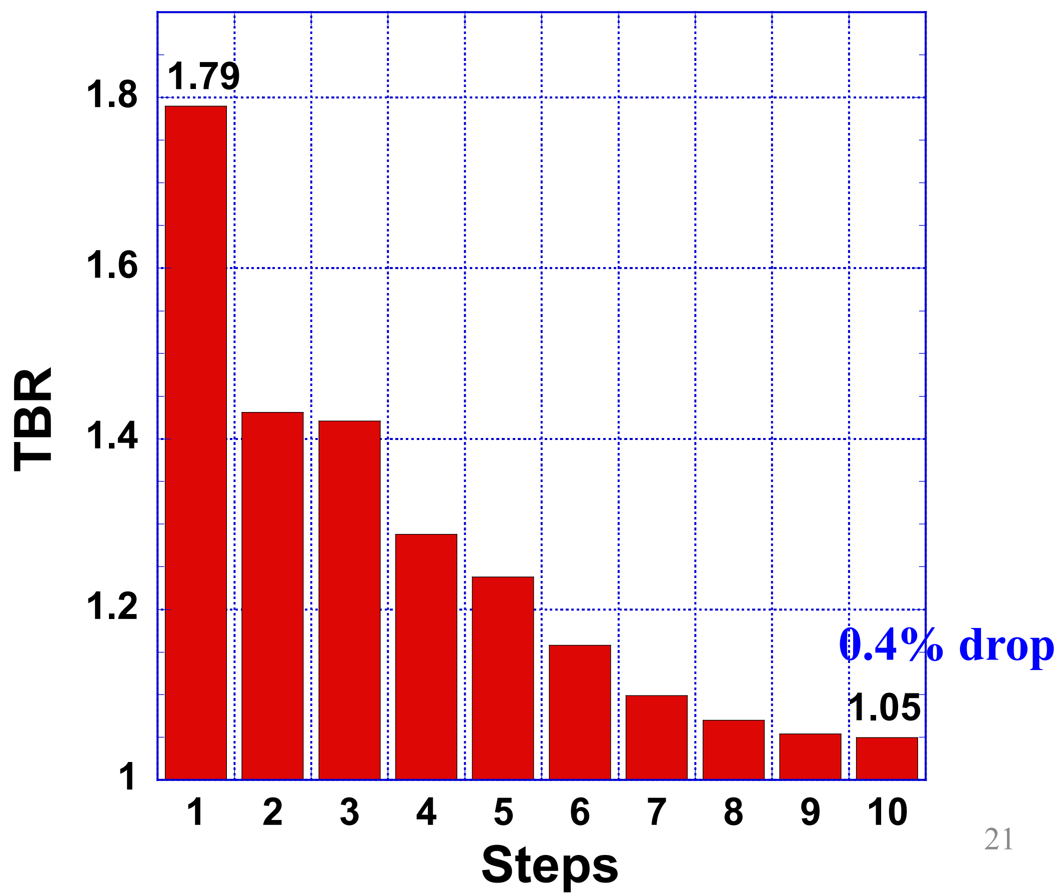
	> 2 m^2 ICRF
	> 2 m^2 LH
	0.008 m^2 fueling
diagnostics	~ 3 m^2

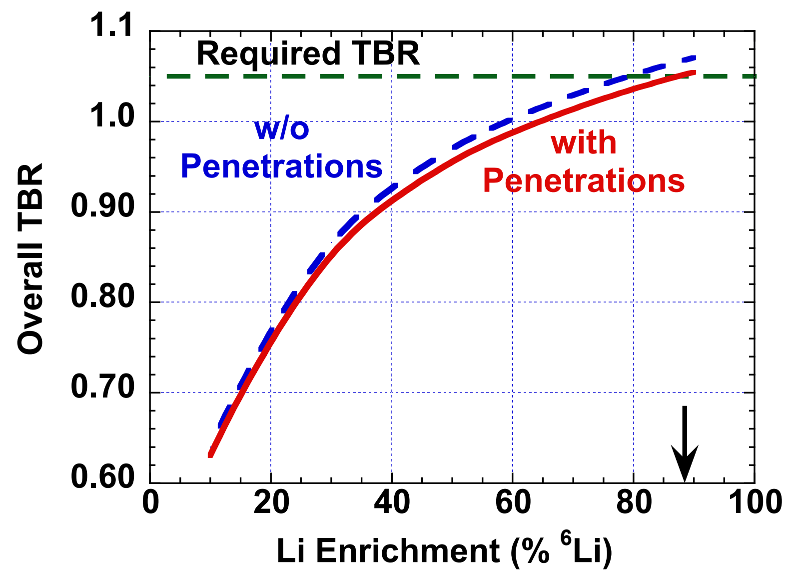
Total	~ 7 m^2

Fraction of OB surface area ~**2%**

Varying Li-6 Enrichment

ARIES-ACT-3





Operating ^{6}Li enrichment is too high (89%)

Main Findings

- Limiting blanket coverage radially and vertically has significant impact on TBR (20%)
- Adding FS structure and FCI has largest reduction in TBR (23%)
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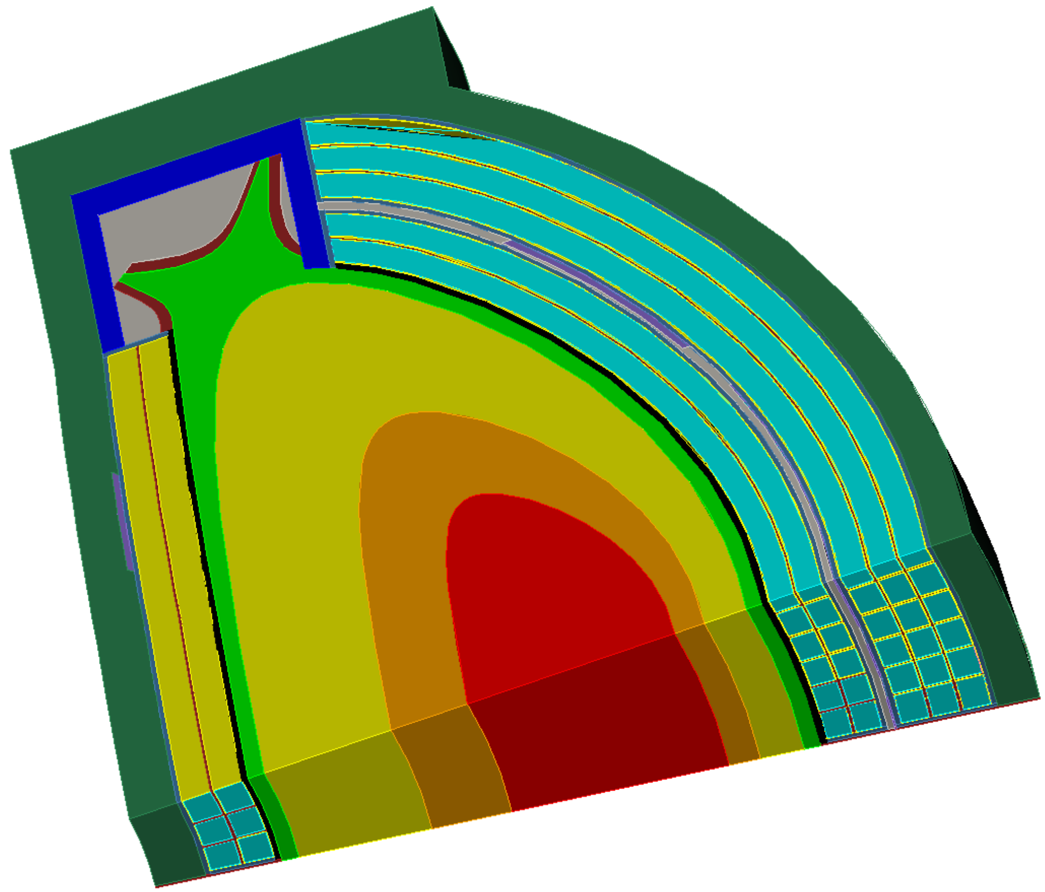
- Inclusion of stabilizing shells has 2-3% impact on TBR
- Adding penetrations and assembly gaps has smaller (2%) but still significant impact on TBR.



Recommendations

- Thickening IB blanket by 20 cm increases TBR by ~5%, allowing lower enrichment (highly desirable).

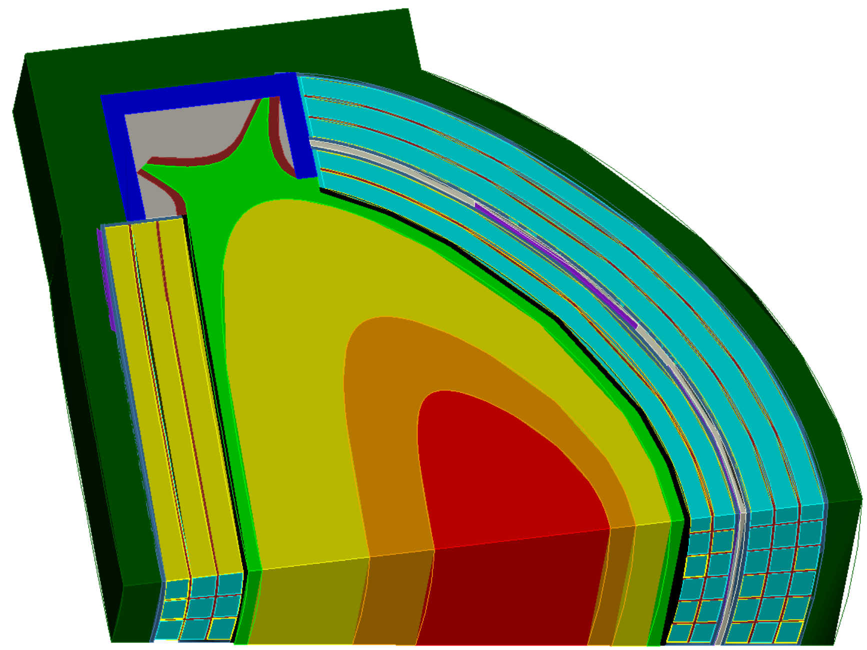
- Recommended blanket thickness:
    - 65 cm thick IB blanket
    - 1 m thick OB blanket.

- **Place holder**: 7 m^2 penetrations on OB (2% of OB FW area; to be confirmed by C. Kessel)

- **Estimated TBR** (to be confirmed with 3-D analysis):

  TBR = 1.05

  with ~70% ^{6}Li enrichment.



65 cm Thick IB Blanket

1 m Thick OB Blanket

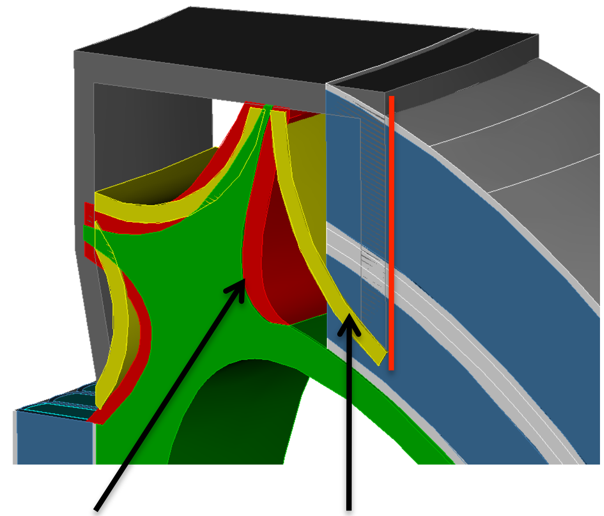
Observations

- Extending IB blanket upward/downward enhances TBR.

- New divertor design (yellow) may call for wider slot. This change will reduce OB breeding by few percent (need input from UCSD on divertor design and layout).

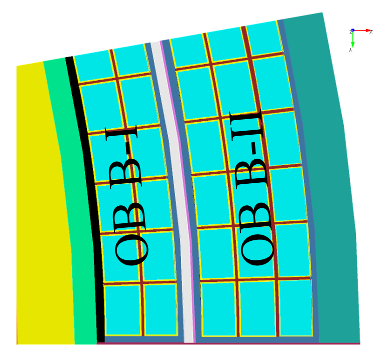
- Changes to FW and structural content within blanket may degrade TBR (need input from UCSD on latest changes to thicknesses and compositions of FW, side walls, and cooling channels).

ARIES-ACT-1 Divertor



Old layout (red)

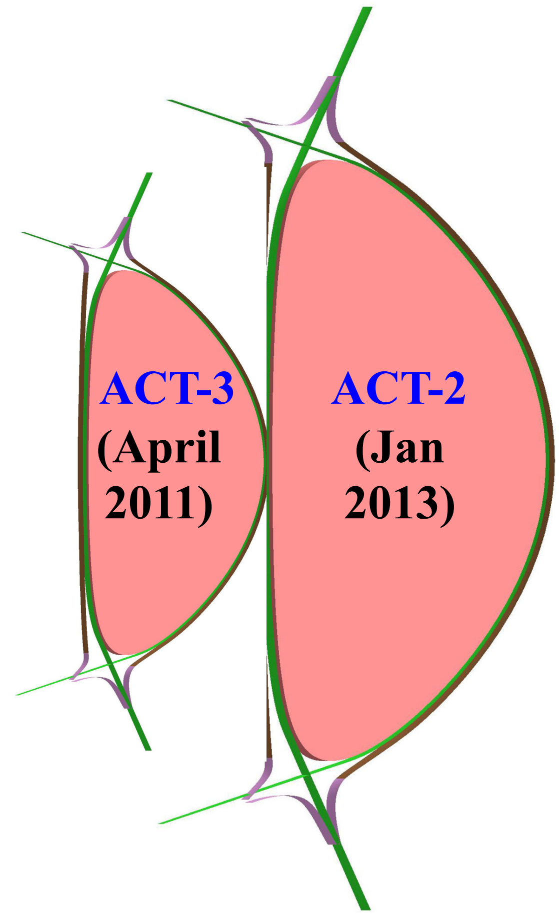
New layout (yellow)



Preliminary Radial/Vertical Build Definition

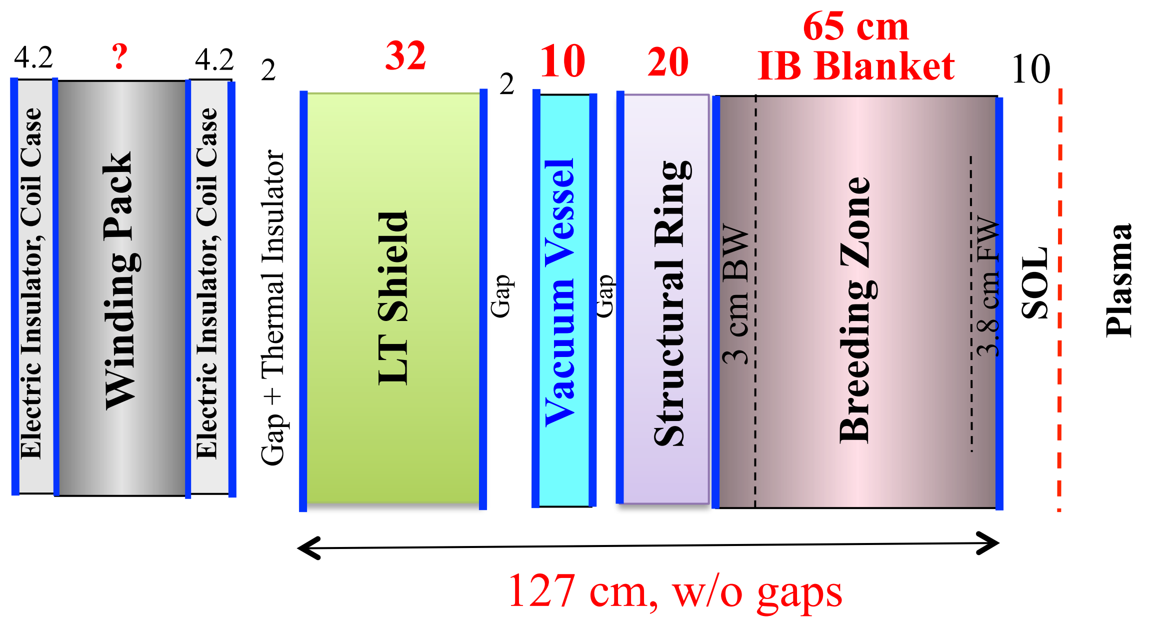
ARIES-ACT-2/3 Parameters

	ARIES-ACT-3 Aggressive Physics April 2011 (to be updated)	ARIES-ACT-2 Conservative Physics Jan 2013
Fusion Power (MW)	2767.5	~3000
Major Radius (m)	6	~10
Minor Radius (m)	1.5	~2.5
Aspect Ratio	4	4
Elongation	2.2	2.2
NWL (MW/m^2):		
Average (@ 10 cm from plasma)	3.7	~1.45
Peak IB	4.4	1.7
Peak OB	5.5	2.2
Peak div	2.2	0.9



ARIES-ACT-2 IB Radial Build

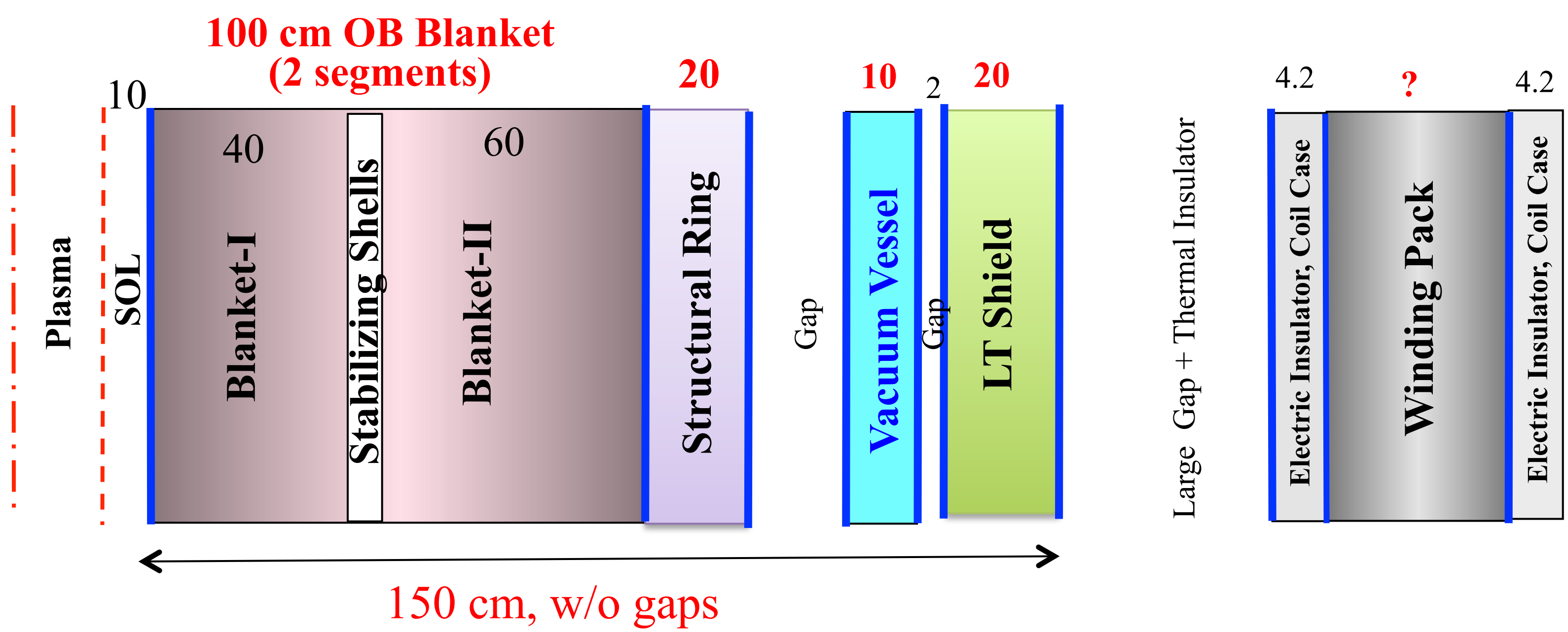
(Peak IB Γ = 1.7 MW/m^2)



- WC-free IB to control decay heat.
- SR and VV are not reweldable around midplane.
- Without gaps, SR, VV, LT shield, and magnet are life-of-plant components.
- Effect of neutron streaming through assembly gaps on damage and lifetimes of SR, VV, LT shield, and magnet should be assessed with 3-D analysis.

ARIES-ACT-2 OB Radial Build

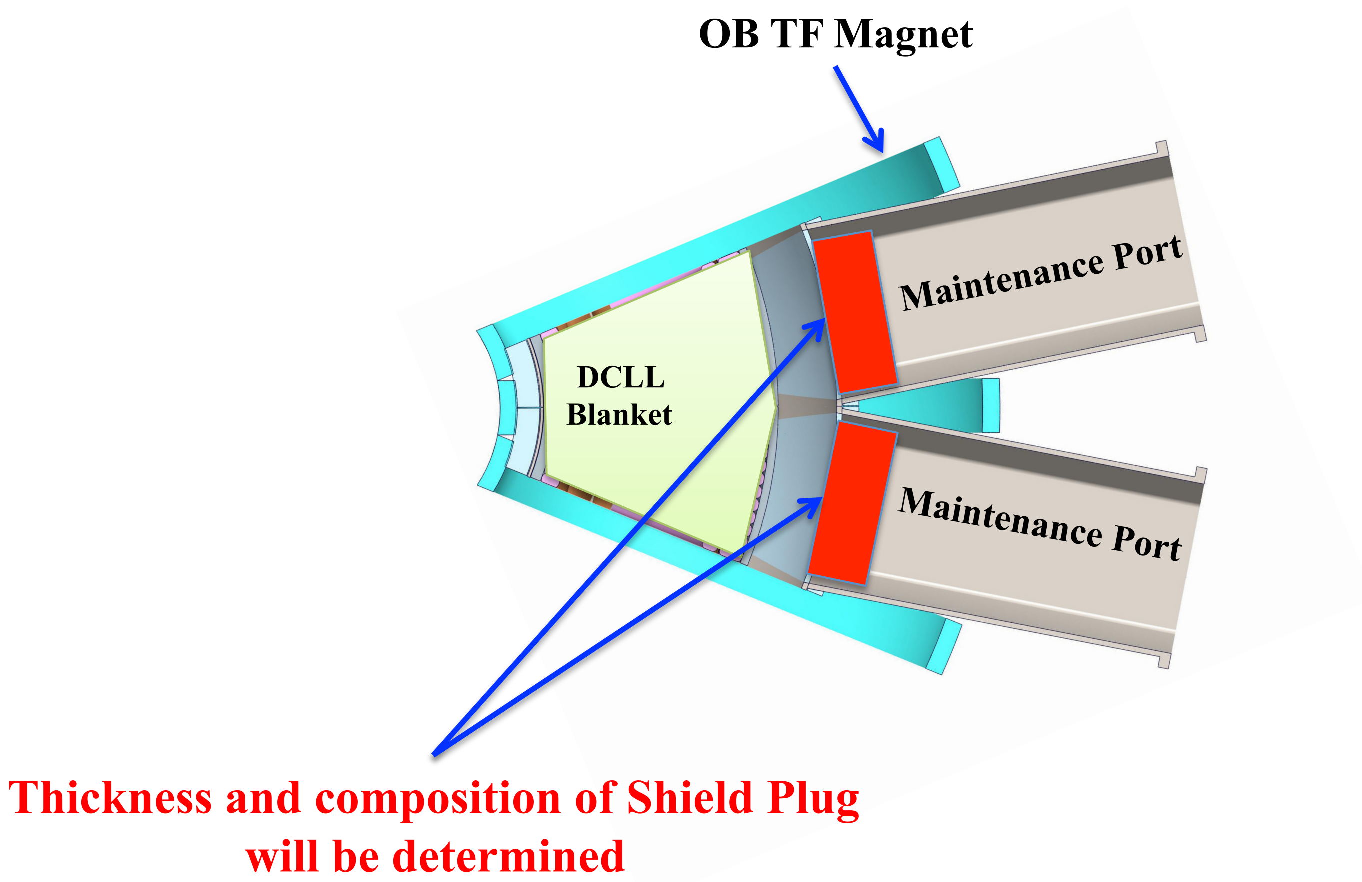
(midplane cross section through TF magnets; Peak OB Γ = 2.2 MW/m^2)



- Blanket-I lifetime = 6 FPY.
- Blanket-II, SR, and VV are life-of-plant components in absence of assembly gaps.
- SR and VV are reweldable away from assembly gaps and penetrations.
- Effect of neutron streaming through assembly gaps on damage and lifetimes of B-II, SR, VV, LT shield, and magnet should be assessed with 3-D analysis.

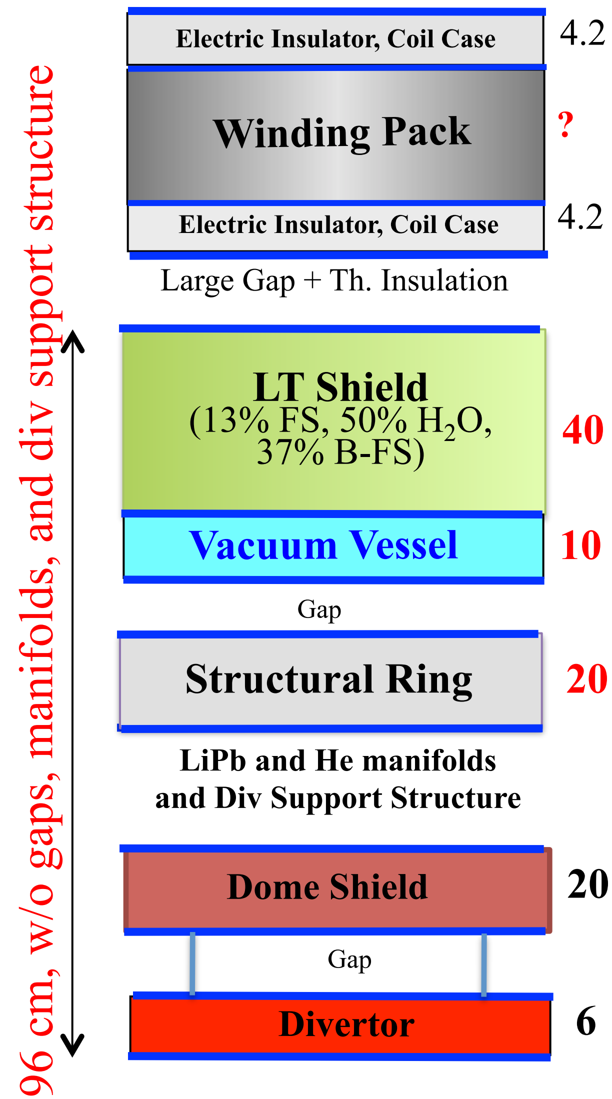
ARIES-ACT-2 OB Radial Build

(cross section between TF magnets; Peak OB Γ = 2.2 MW/m^2)



ARIES-ACT-2 Vertical Radial Build
(Peak div Γ = 0.9 MW/m^2)

- Lifetime of W-based divertor is unknown. To be replaced with blanket.
- None of vertical components is reweldable.
- Without gaps, SR, VV, LT shield, and magnet could be life-of-plant components with careful accommodation of pumping ducts.
- Effect of neutron streaming through assembly gaps and pumping ducts on damage and lifetimes of SR, VV, LT shield, and magnet should be assessed with 3-D analysis.



Compositions

$Li_{15.7}Pb_{84.3}$ @ 580 ^{o}C; 9 g/cm^3 density; 70% enriched Li

	Thickness (cm)	Composition (volume %)
IB Blanket	**65**	
FW	3.8	8% ODS FS 27% MF82H FS, 65% He
Breeding Zone	58.2	77% LiPb, 7% MF82H FS, 3.7% SiC, 12.3% He/void
Back Wall	3	80% MF82H FS, 20% He

Compositions (Cont.)

OB Blanket	Thickness (cm)	Composition (volume %)
Blanket-I:	**40**	
FW	3.8	8% ODS FS 27% MF82H FS, 65% He
Breeding Zone-I	33.2	77.2% LiPb, 7% MF82H FS, 4.2% SiC, 11.6% He/void
Back Wall	3	80% MF82H FS, 20% He
Blanket-II:	**60**	
Front Wall	3	80% MF82H FS, 20% He
Breeding Zone-II	54	78.4% LiPb, 8.3% MF82H FS, 3.9% SiC, 9.4% He/void
Back Wall	3	80% MF82H FS, 20% He

Compositions (Cont.)

	Thickness (cm)	Composition (volume %)
Divertor Plates	6	9% W armor, 36% W alloy (W-TiC), 11% ODS-FS, 44% He
Structural Ring	20	80% MF82H FS, 20% He
Vacuum Vessel	10	60% 3Cr-3WV FS, 40% He
LT Shield*	32 IB, 40 div, 20 OB	20% 3Cr-3WV FS, 35% B-FS, 45% H_2O
Coil Case	3	95% JK2LB steel, 5% LHe
Winding Pack	???	75% JK2LB steel, 12% Cu, 2% Nb_3Sn, 8.5% LHe, 2.5% GFF Polyimide

* To be optimized.