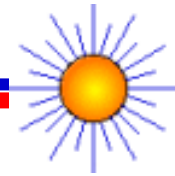
Progress in Assessing CS Maintenance Approaches



Presented by Xueren Wang

Contributors: A.R. Raffray, T.K. Mau, and S. Malang

ARIES Meeting
University of California, San Diego
March 8-9, 2004

Outline

- Refine/Verify Clearances for the Field-Period Maintenance Approach

  -Clearances for removing a whole filed period in radial direction

  -Clearances for removing a replacement unit in toroidal direction(done)

- Update 2 Field-Period Configuration(12 Coils Case) and Maintenance

Field Period Based Maintenance Scheme Presented By S. Malang at Last September ARIES Meeting

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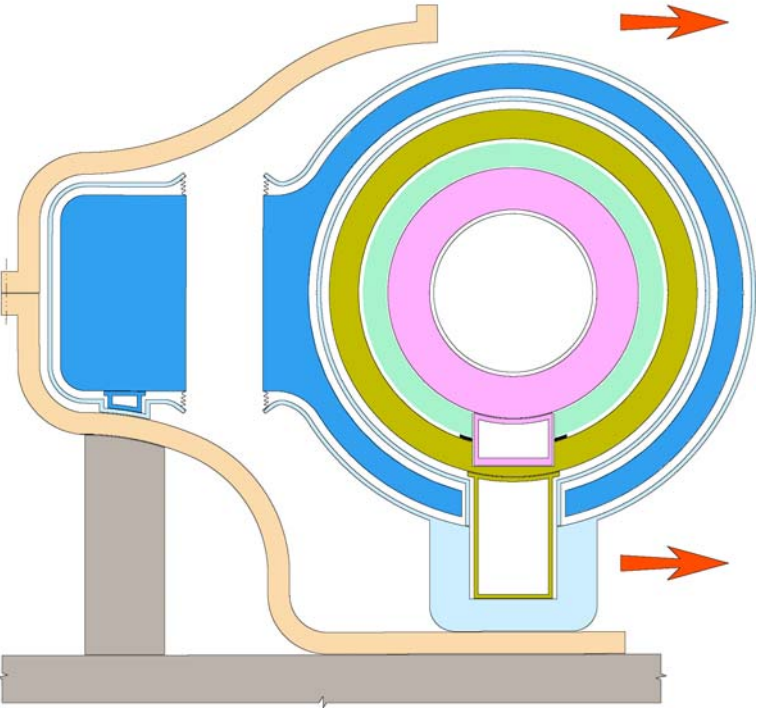
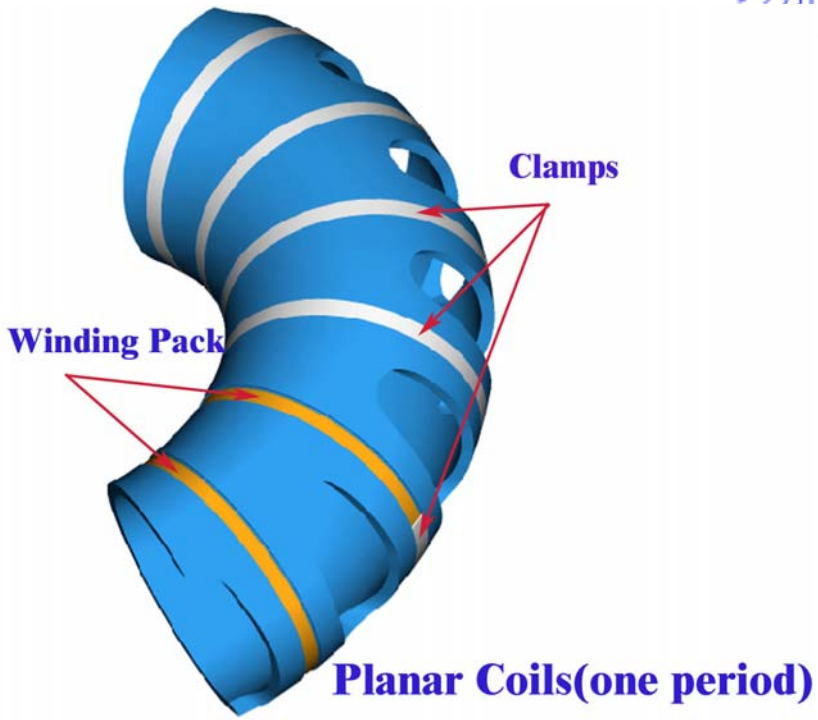
Moving the Entire Sector of One Field Period in Radial Direction





- Open the outside of V.V. (one field period).
- ***Slide the entire field period unit outwards in radial direction on the flat surface at the bottom.***
- ***Slide the replacement unit(pink) out from the opening at the both ends on a rail attached to the replacement unit.***

- **Supporting tube** is composed of inter coil structure, coil cases, and winding pack.
- Coils are wound into grooves in the supporting tube.
- The supporting tube takes all forces and momentums between neighboring coils, and is supported at the inner mantle by bucking cylinder.

Clearances for Removing 100 cm-Thick Blanket Replacement Unit in Toroidal Direction Were Verified

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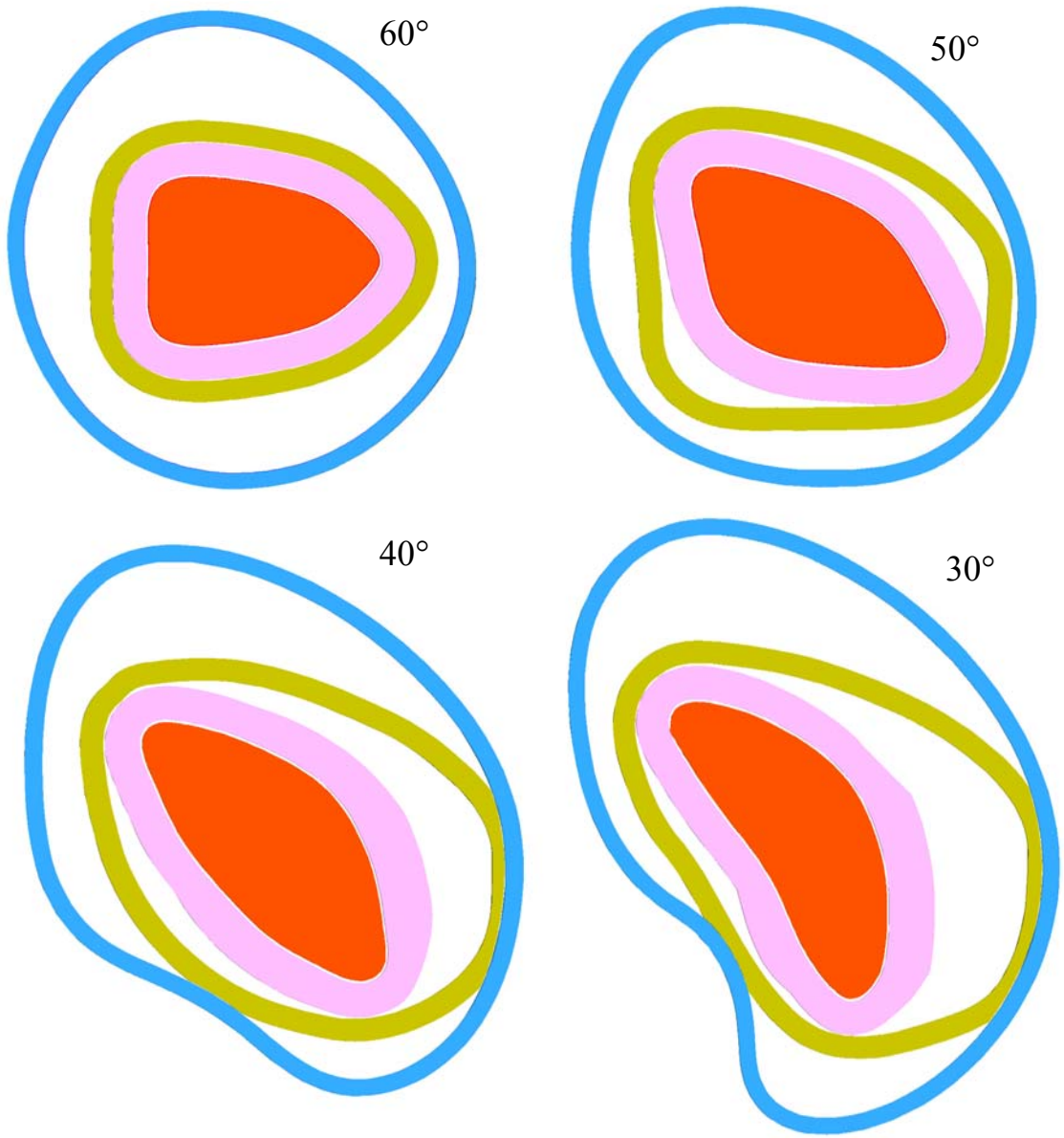
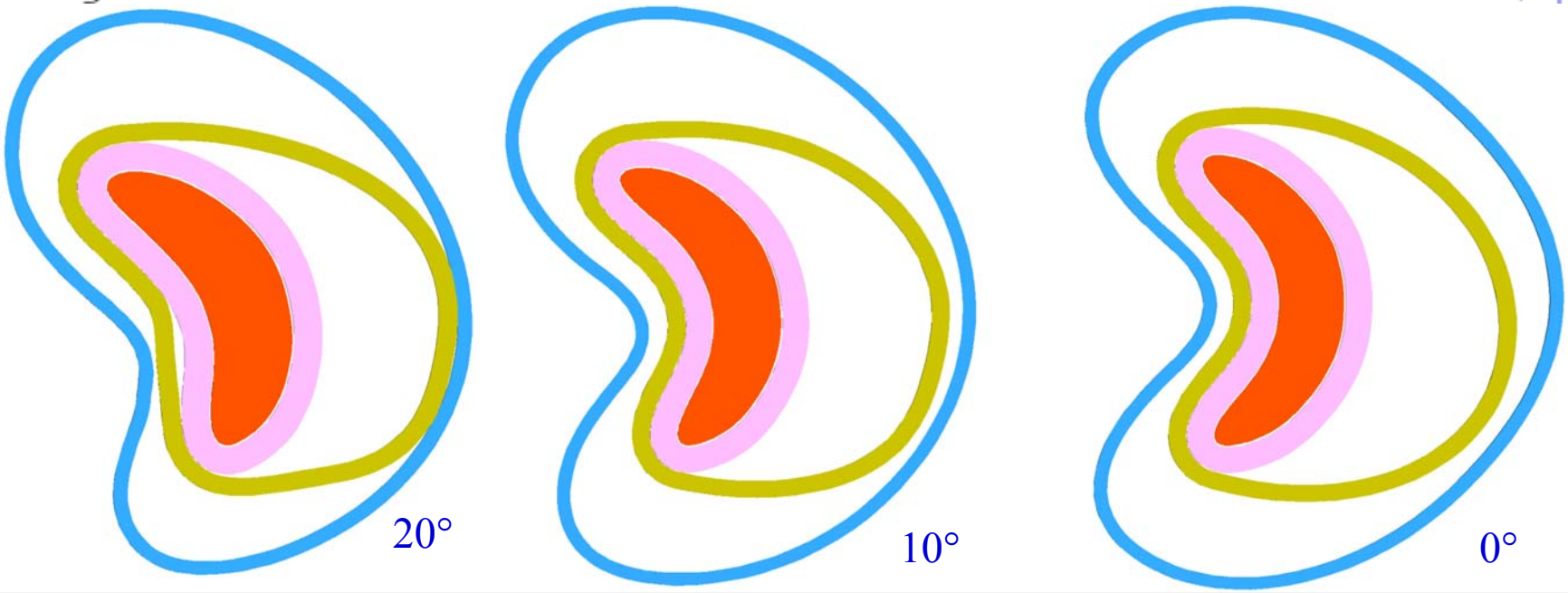
- Minimum distance between FW surface and inner surface of the coils is 100 cm to obtain sufficient shielding of the coil.
- Minimum thickness of replacement unit has to be (4.8+47+9) cm ~60 cm.
- Thickness of the permanent shield is ~40 cm.
- The cross section of shield at θ=0° has to allow for the movement of the replacement unit(***pink***) at 60° and 50°, 40°, 30 °, 20° and 10° during the withdrawal operation.



Clearances for Removing 100 cm-Blanket Replacement Unit Towards Toroidal Were Verified(Cont.)

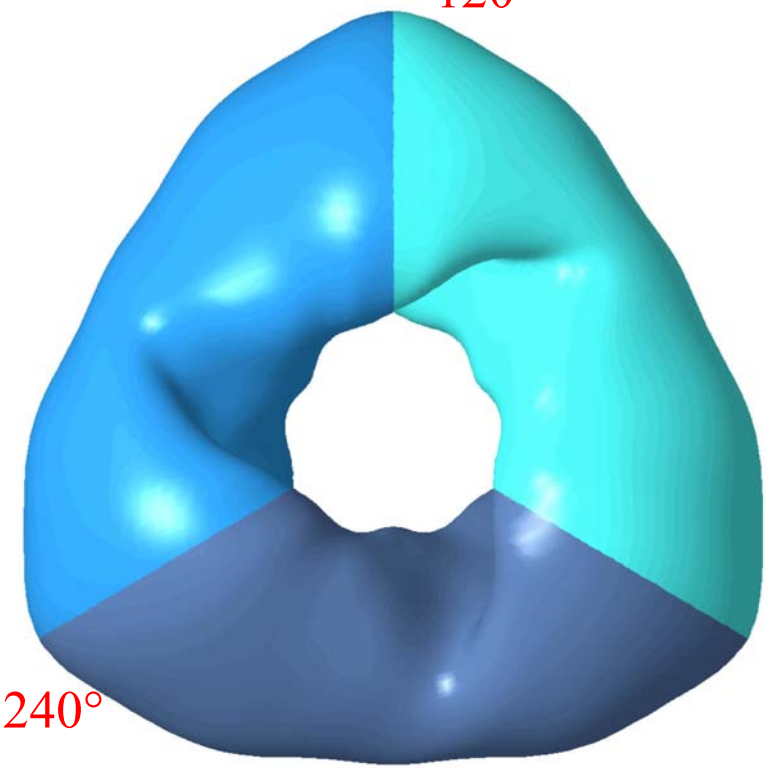


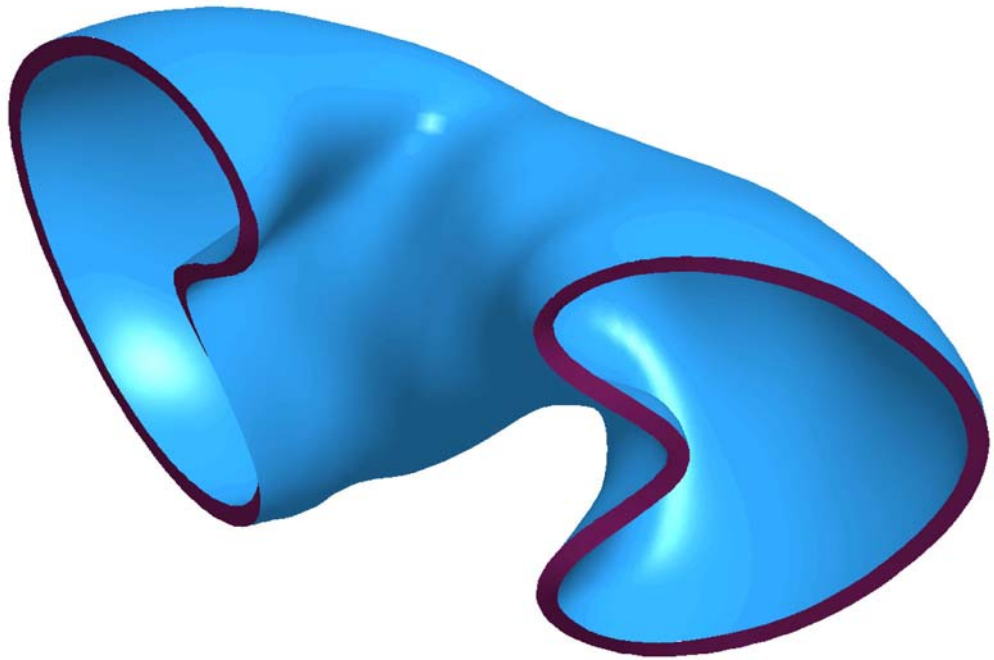
***Conclusion:* Sliding the blanket replacement unit out in toroidal direction seems possible for a combined(blanket+shield) of 100 cm by shaving off the shield thickness and correspondingly adding the blanket thickness at a few locations to prevent interferences.**

** ***Presented by Rene at last ARIES Meeting***

Refine/Verify Clearances for Removing a Whole Field-Period in Radial Direction

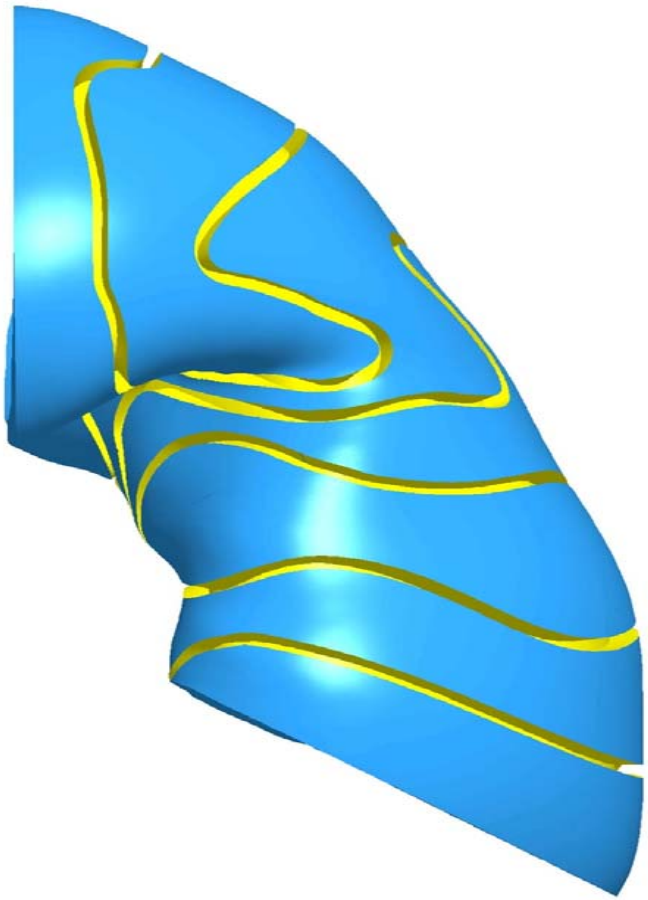
Definition and Segmentation of Coil Supporting Tube



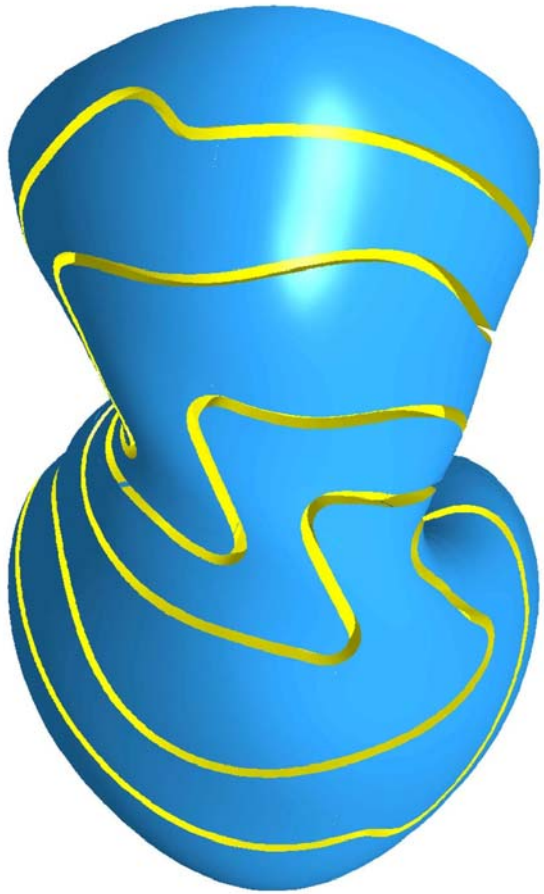


- The optimum locations for segmentations of the coil supporting tube are 0°, 120° and 240° where are the largest cross-sections. This allows sliding out the two blanket replacement units from the opening at the both ends.
- Straight cut line would make the coil supporting tube with flat surface at the both ends.

Winding of Coils into Grooves in the Supporting Tube



Top view



Side view

Six Coils of a Field Period Are Wound on a Common Supporting Tube

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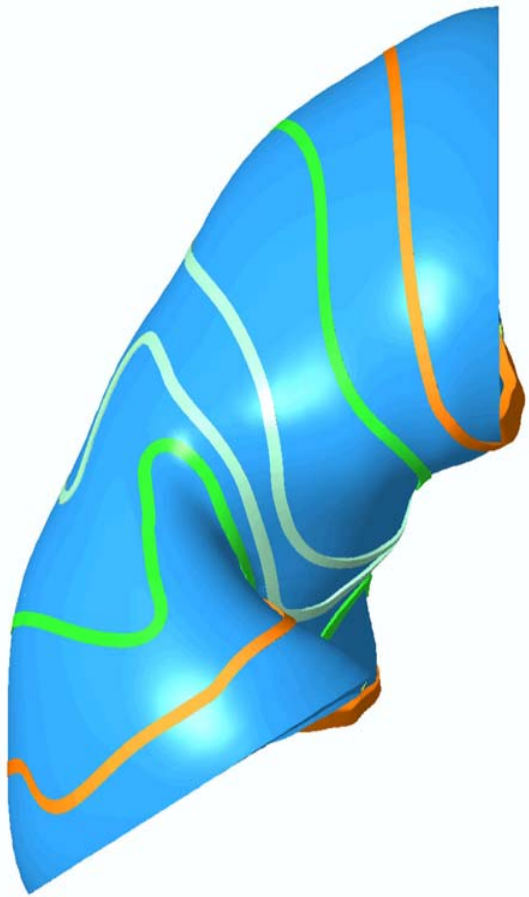
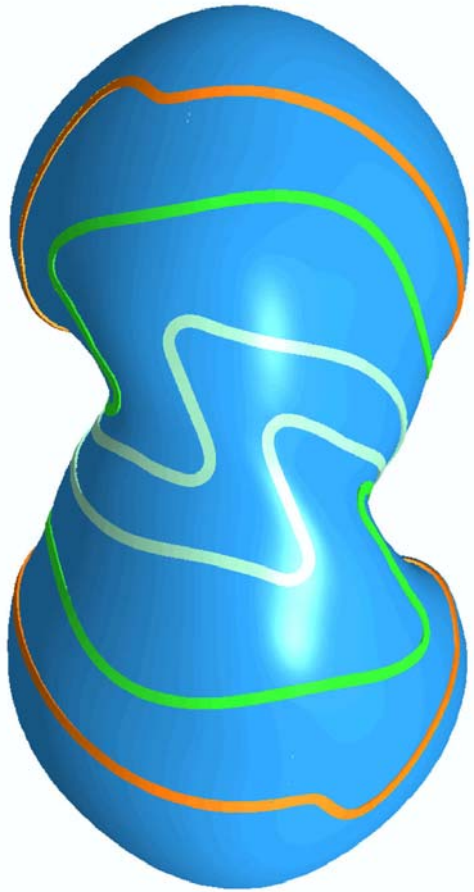
- All six coils of a field period are wound into grooves in the supporting tube.
- All out-of-plane forces of coils inside a field period are taken by the supporting tube, and centering forces are reacted by a strong bucking cylinder in the center of the torus.



Top view



Side view

Interferences Were Found between Adjacent Coil Field Periods

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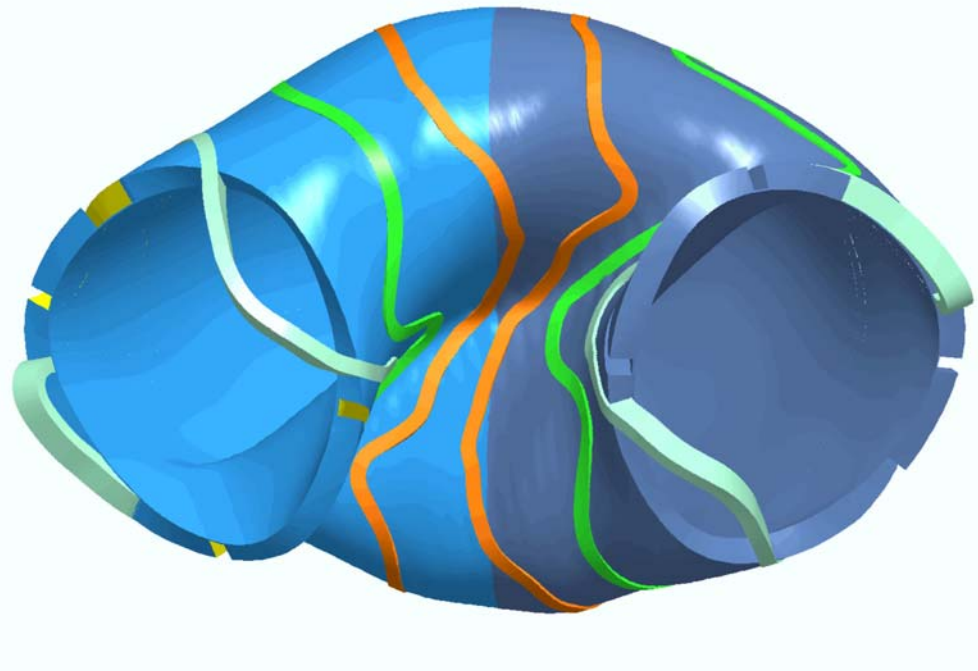
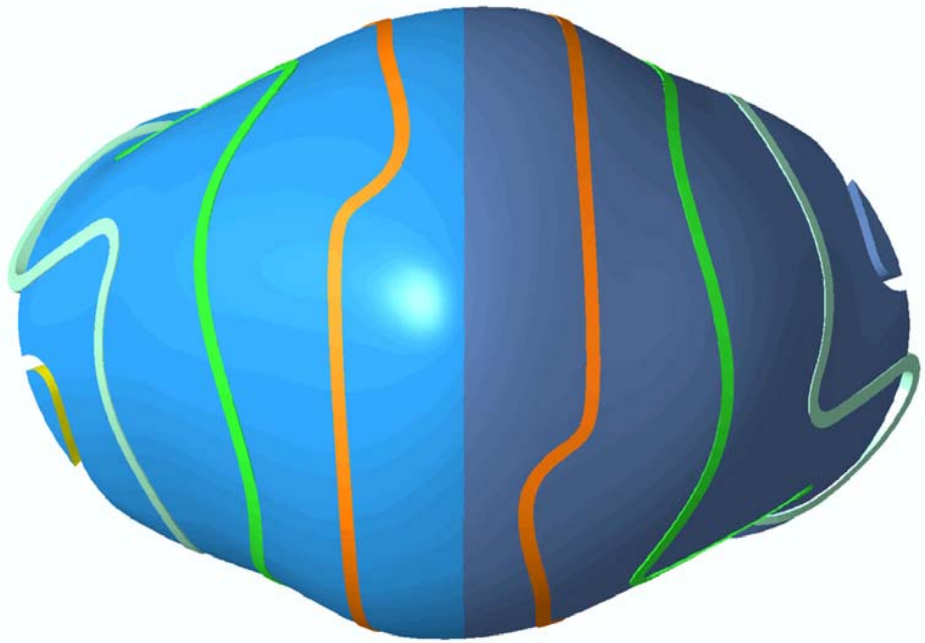


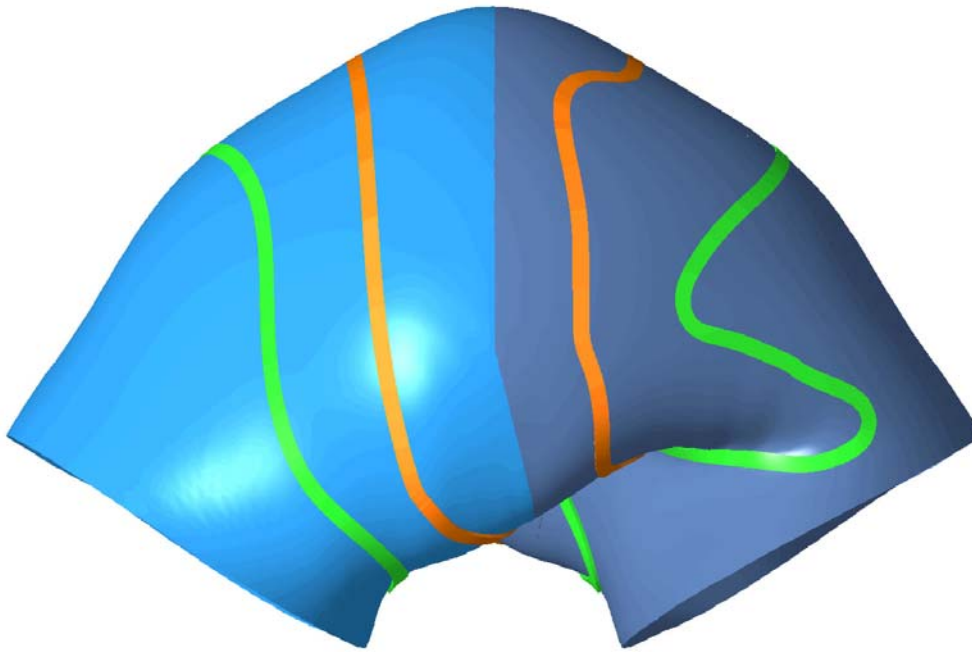
Side view of adjacent coil field periods as viewed from inside



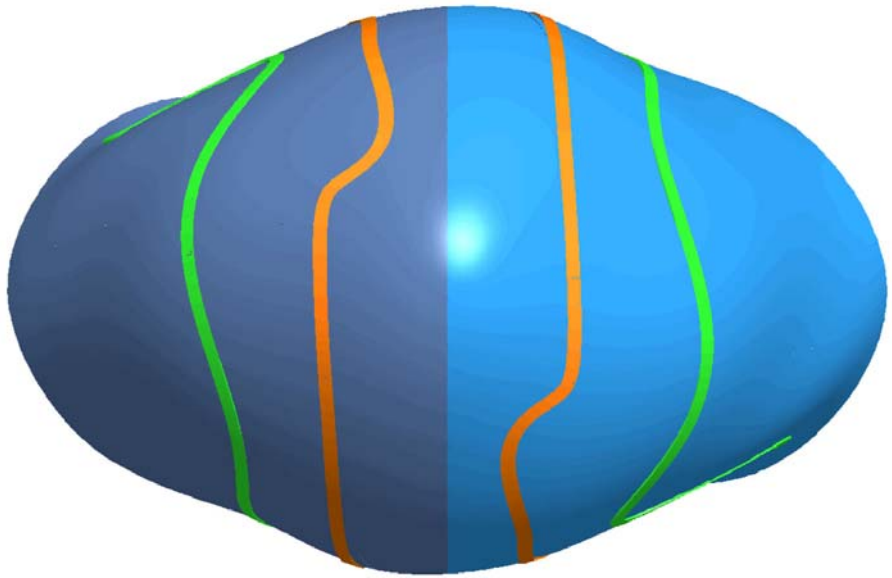
Side view of adjacent coil field period as viewed from outside

A straight cut through the supporting tube would cut through the adjacent coils.

Possible Way to Segment the Coil Supporting Tube to Avoid the Interferences



Top view of the adjacent field periods



Side view of the adjacent field periods

Possible Way to Segment the Supporting Tube to Avoid the Interferences(Cont.)

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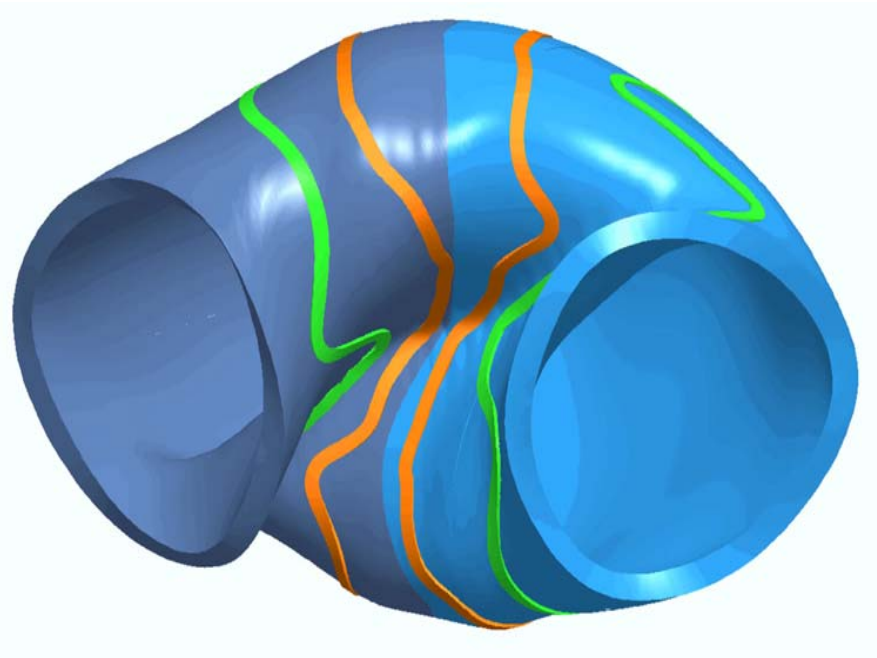
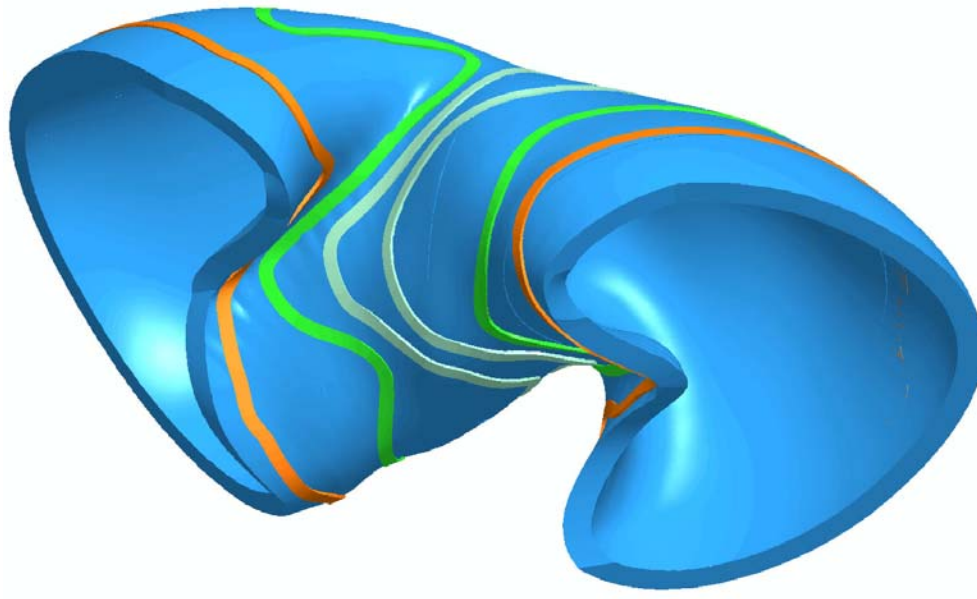


Side view of adjacent coil field periods as viewed from inside



One field period

Solution: The cuts have to follow the shape of the coils.

Motion Studies Show no Conflicts and Interferences Between Adjacent Coil Field Periods

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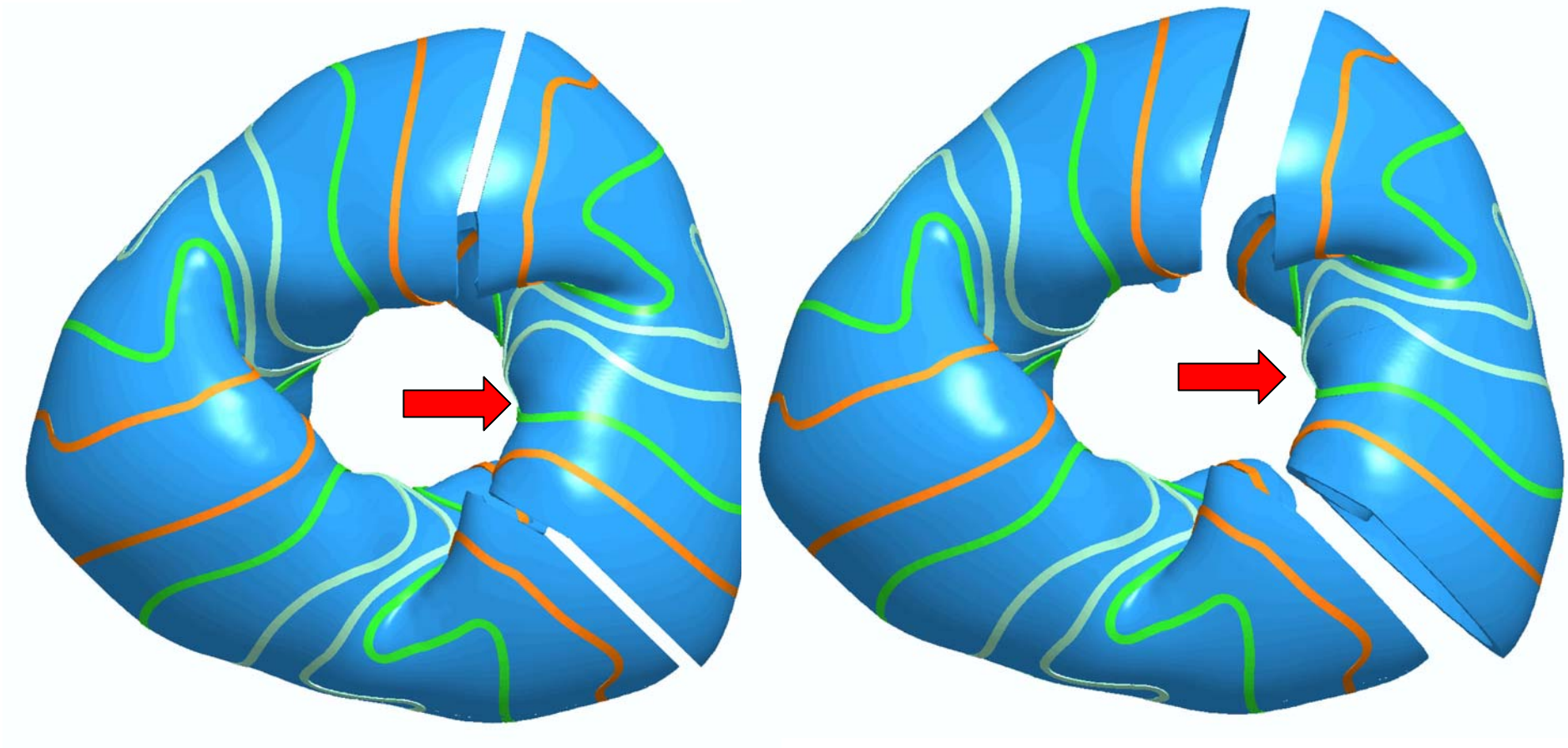

Clearances have been checked every 10 cm movement.

Update 2 Field Period Configuration(12 Coil Case) and Maintenance

New Configuration(12 Coils) Provides More Room for Maintenance Approach with Ports Between all Coils

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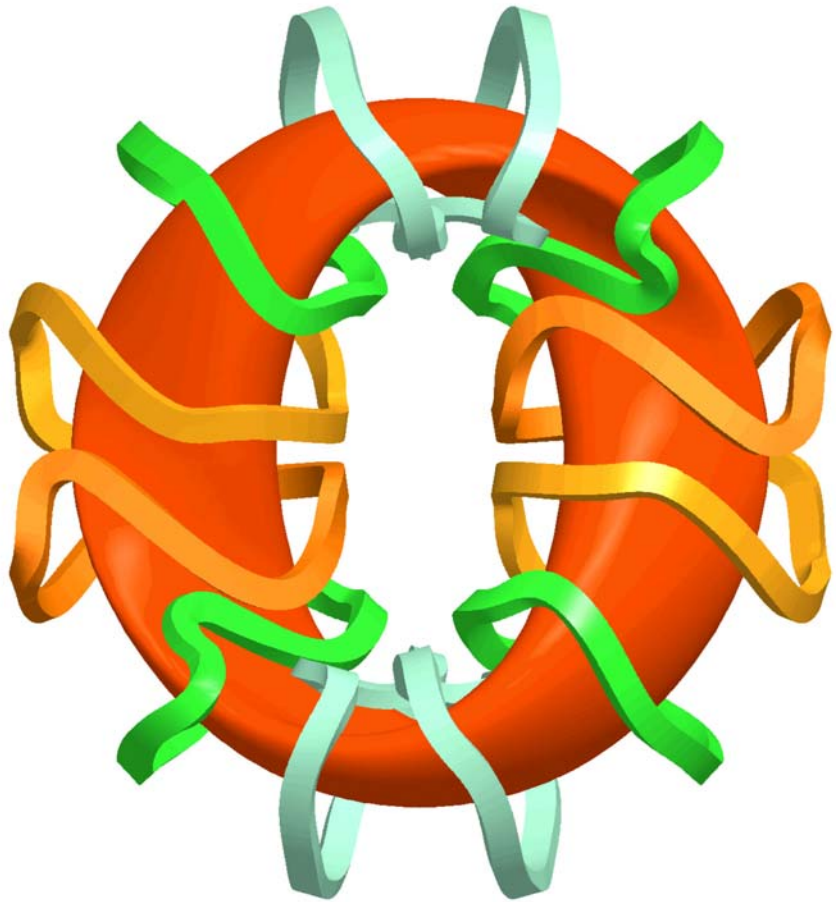
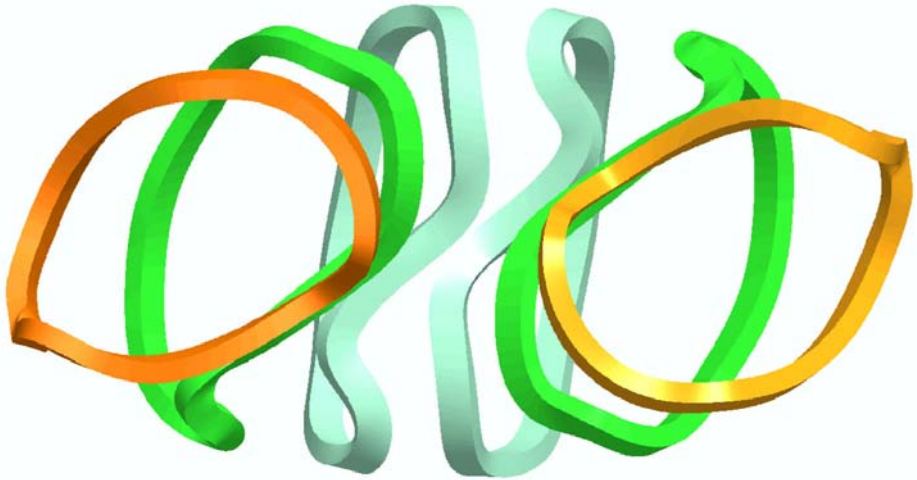
	R=8.3 m (3 FP, 18 coils)	R=6.62 m (2 FP, 12 coils)	R=6.62 m (2 FP, 16 coils)
Port #1	2.5 x 11.0	3.8 x 8.9	3.2 x 8.2
Port #2	1.6 x 10.2	3.5 x 8.4	3.3 x 7.3
Port #3	1.2 x 5.0	4.1 x 6.6	3.5 x 4.4
Port #4	2 x 3.03	4.6 x 3.9	2.4 x 3.8
Port #5	3.5 x 3.6	4.0 x 5.9	3.9 x 4.1
Port #6	2.1 x 10.5	3.7 x 8.5	3.2 x 6.5
Port #7			3.2 x 8.2
Port #8			3.8 x 9.0

Available port sizes are shown. Actual port sizes would depend on coil structure requirement for stress accommodation.

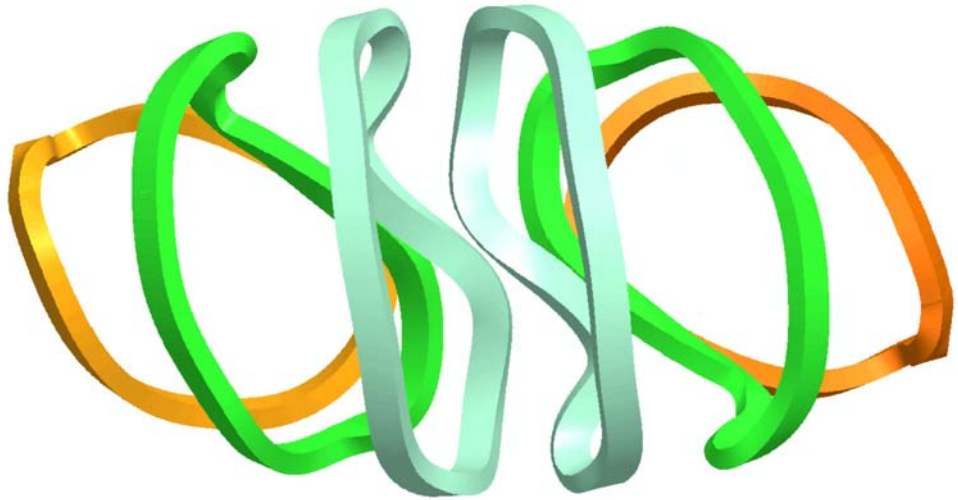


6 coils/field period, 3 type coils

Coil Could be Independently Extracted Radially



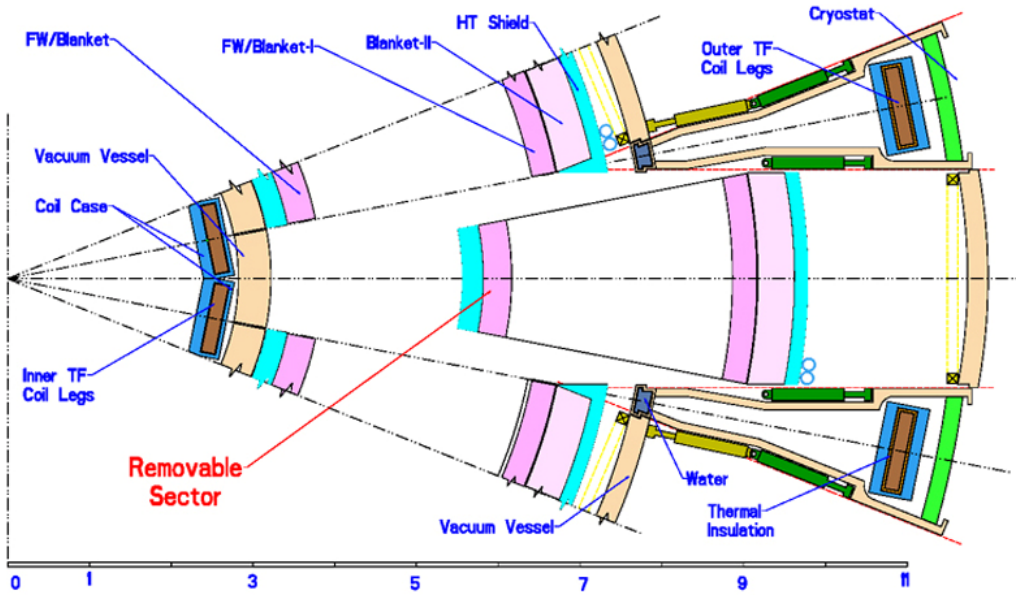
Side view of a field period as viewed from inside

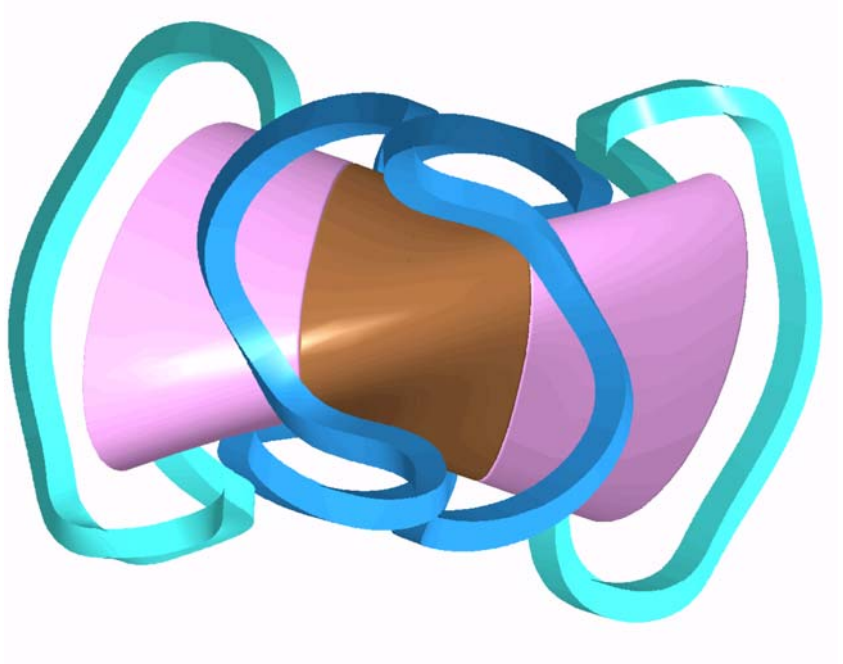


Side view of a field period as viewed from outside

- No conflicts and interferences were found between adjacent coils at the inner radius, and the minimum coil-to-coil distance in toroidal direction is ~5.6 cm(as for major radius of 3.5 m).
- Coil can possibly be extracted independently of the others.
- ***It opens a possibility for a large sector maintenance scheme, for example, by removing half a field-period instead of whole field-period, provided there is no tensile stress between two halves.***

Sector Based Maintenance Scheme(ARIES-AT like) Seems Impossible





- There is no enough space between each pair of adjacent coils to remove a sector.
- Sector based maintenance scheme(ARIES-AT like) seems impossible for either 16 coil case and 12 coil case.

Maintenance Approach with Ports Between Each Pair of Adjacent Coils Is Attractive for MHH2

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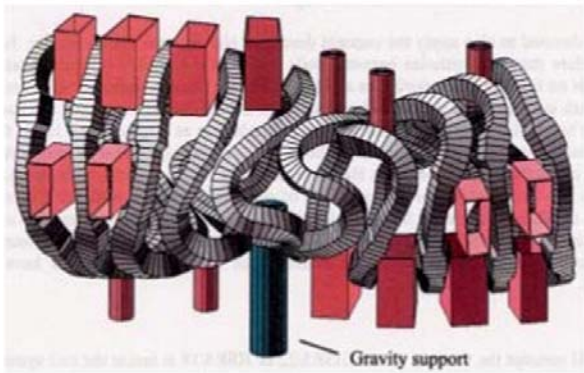
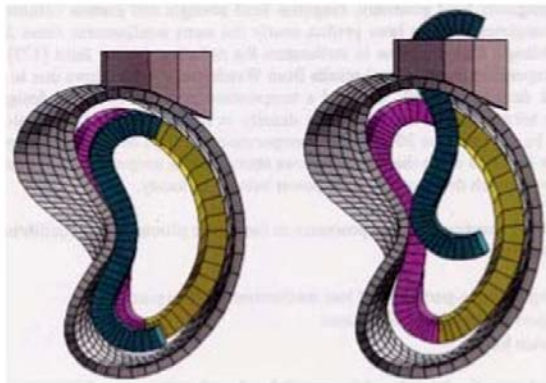
- 2 field period configuration provides more room for maintenance ports, and blanket modules could be maximized to suit the size of ports.
- Number of the blanket modules is far less than that of modular maintenance approach through selected ports with articulated boom.
- Detailed analysis would be needed to design the maintenance ports between each pair of coils and to segment the blanket.

HSR Maintenance Concept

- HSR5/22: small modules thru ports

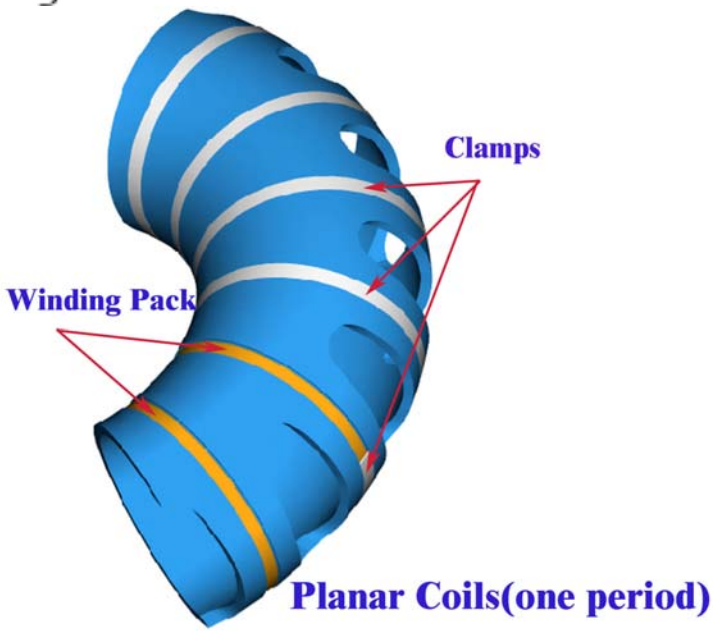


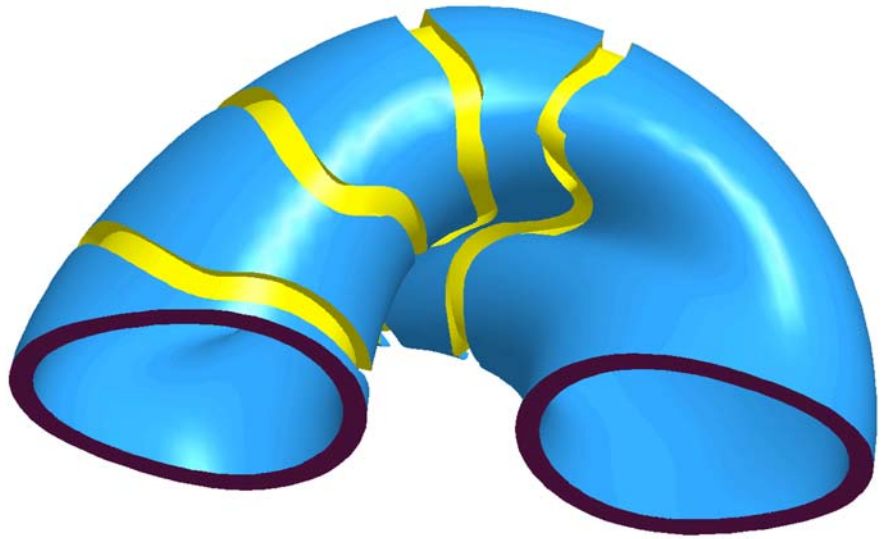
One field period of the coil system with ports



Maintenance scheme for blanket segments

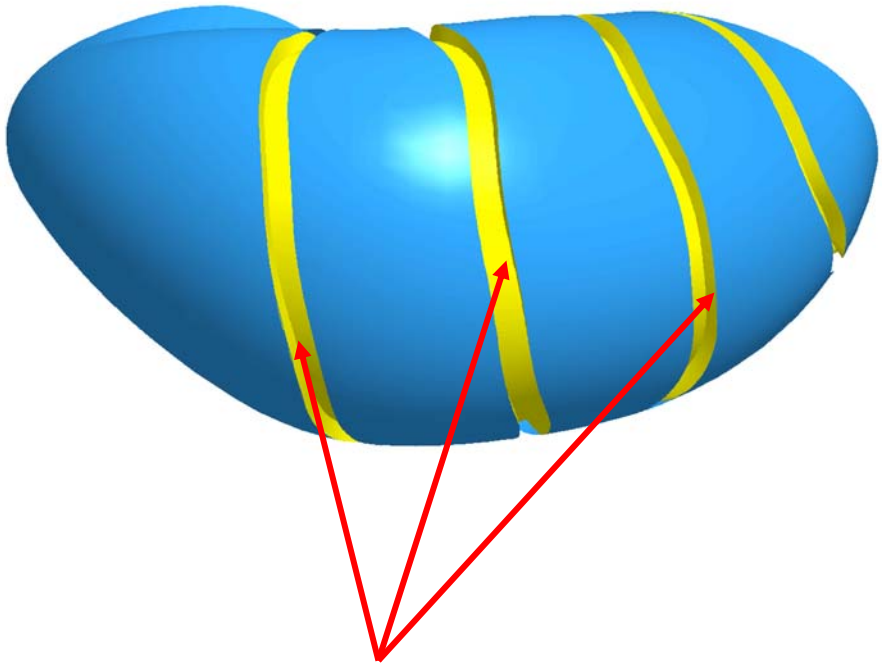
Design Concept of the Coil Supporting Tube for MHH3 Can Be Applied in MHH2



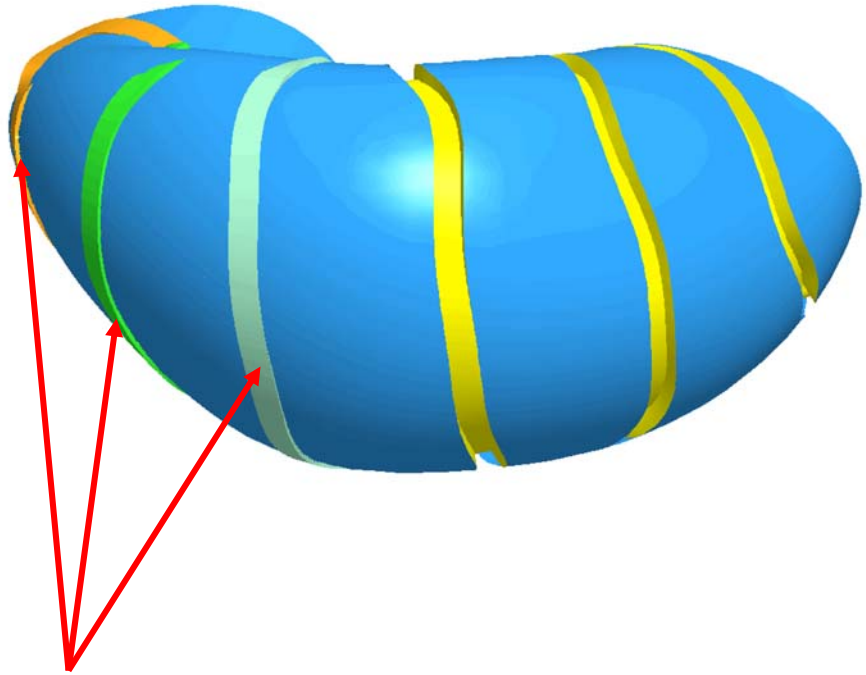


- No separate cryostats for the different field period and the bucking cylinder are required since no disassembly is necessary for a blanket exchange.
- Thermal isolation between the cold coil+inter coil structure and the warm VV has to be provided.

Coils of a Field Period Are Wound on a Common Supporting Structure



Grooves in the supporting tube



Coils are wound into grooves

Required Spaces for Blanket Concepts Presented by Laila at Last Project Meeting

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Nominal Radial Distance Widely Varies with Blanket Concept

(Blanket/Shield Zone; 3 MW/m^2)

Δ (m)	Blanket/Shield/VV	Plasma – Mid Coil
ARIES-CS:		
Internal VV:		
Flibe/FS/Be	1.06 (min)	1.25* (min)
LiPb/SiC	1.13	1.32*
LiPb/FS/He	1.24	1.43*
External VV:	**Blanket/Shield**	
new LiPb/FS/He/B-H_2O	1.26	1.46##
LiPb/FS/He	1.51	1.78#
Li/FS/He	1.70 (max)	1.97# (max)
SPPS:		
External VV:		
Li/V	1.20	1.96@

* Assuming 5 cm SOL, 10 cm half winding pack, 2 cm thick coil case, and 2 cm wide VV-magnet gap.
Assuming 5 cm SOL, 10 cm half winding pack, 3 cm thick coil support tube, and 2 cm wide shield-magnet gap.
Assuming 5 cm SOL, 10 cm half winding pack, 10 cm thick coil support tube, and 2 cm wide shield-magnet gap.
@ 15 cm SOL, 36 cm half winding pack, 15 cm thick cryostat, and 8 cm wide shield-magnet gap.

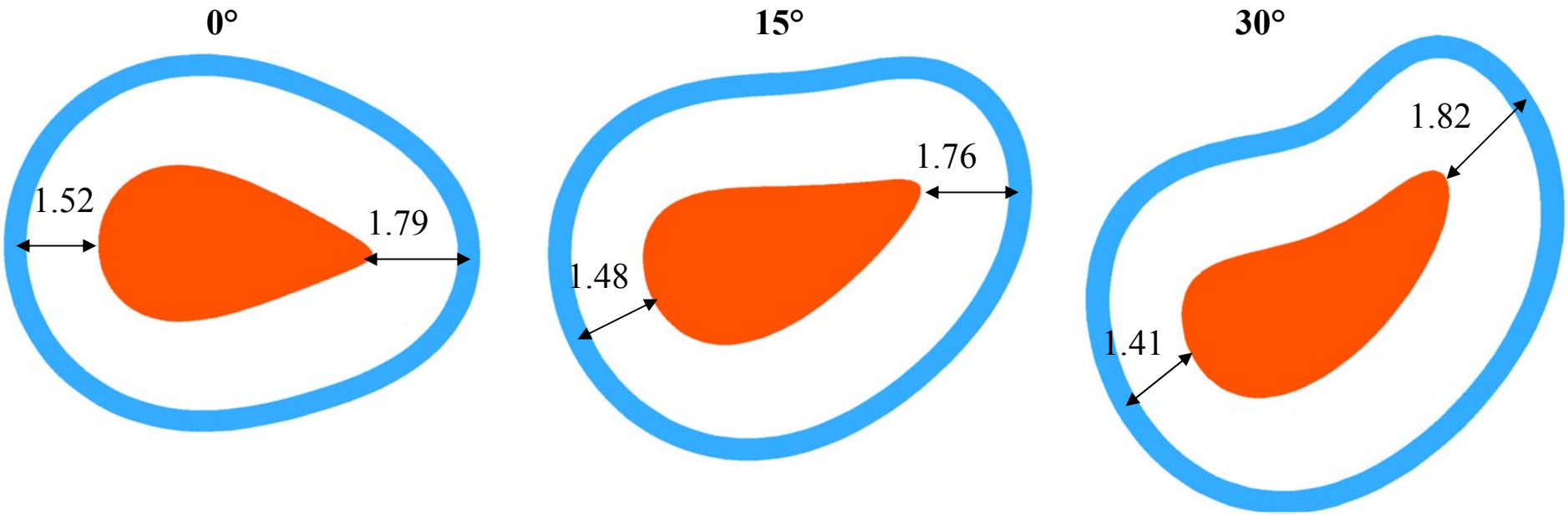
Required Spaces for Blanket Concepts Presented by Laila at Last Project Meeting(Cont.)

Minimum Radial Distance Varies within 10 cm with Blanket Concept

(Shield-only Zone ; 3 MW/m^2)

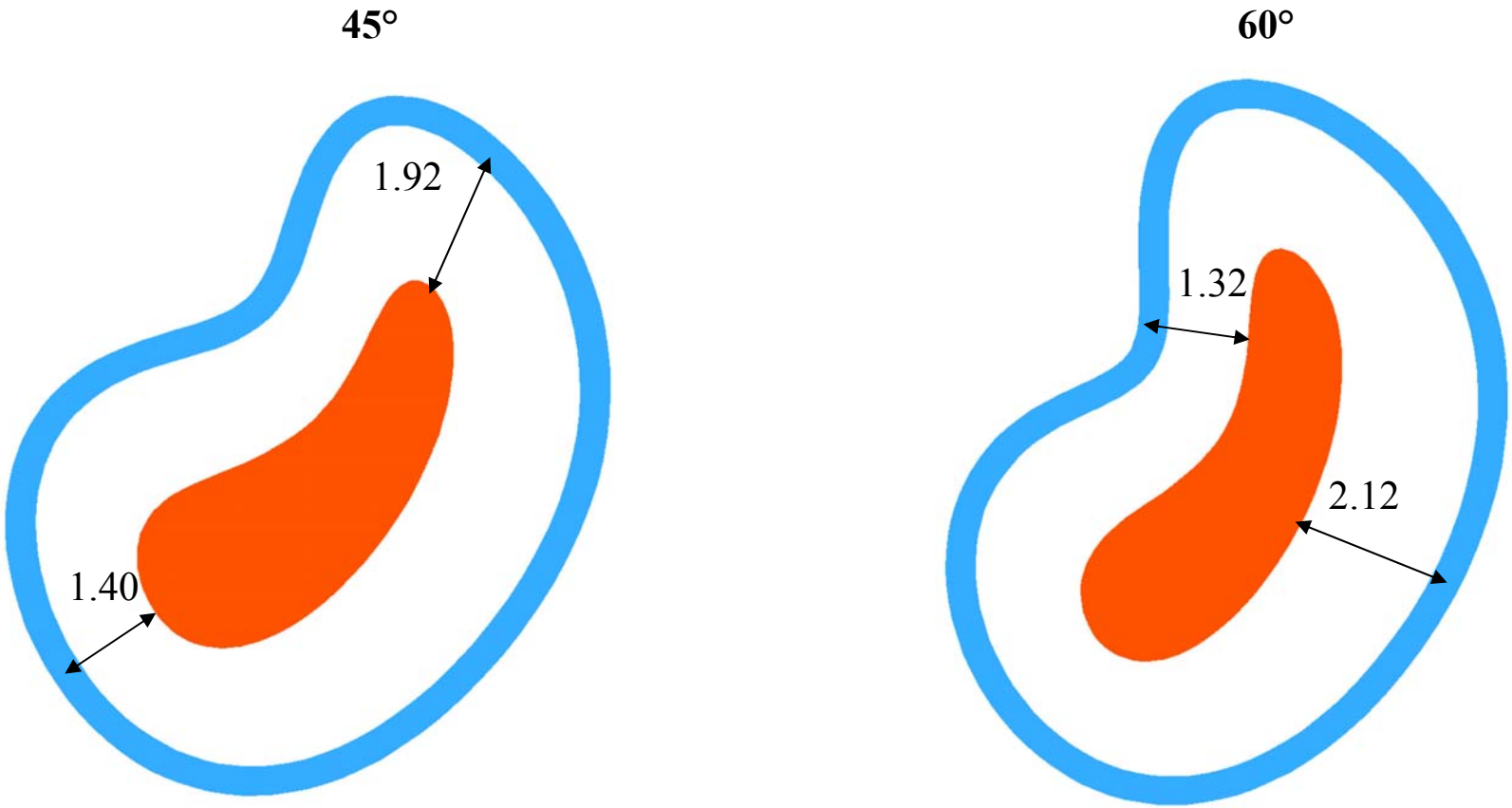
Δ_{min} (m)		
ARIES-CS:		
Internal VV:	**WC-Shield/VV**	**Plasma – Mid Coil**
Flibe/FS/Be	0.86	1.05*
LiPb/SiC	0.89	1.08*
LiPb/FS/He	0.93	1.12*
External VV:	**WC-Shield**	
new LiPb/FS/He/B-H_2O	0.85	1.05##
LiPb/FS/He	0.88	1.15#
Li/FS/He	0.86	1.13#
SPPS:		
External VV:		
Li/V	–	–

Available Spaces at Different Cross-Sections Were Analyzed

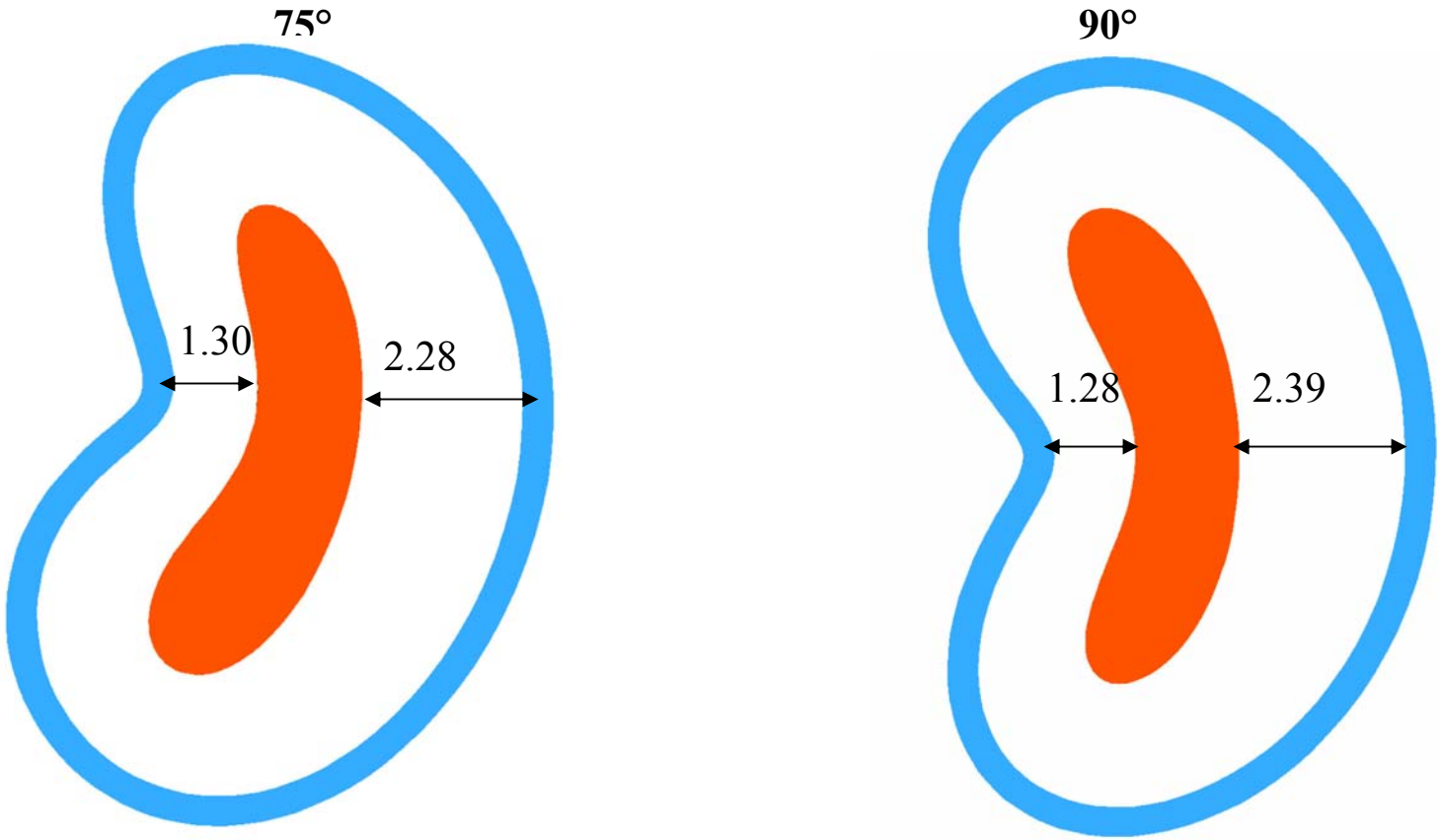


- The plasma and coils are linearly scaled from a major radius of R=3.5 m to R=6.62 m.
- Inboard and outboard spaces of each cross section are measured between plasma surface and center of coil winding pack.
- There is only one **Δ min** location per field period(two **Δ min** locations per field period for 3 filed period configuration); **Δ min** =1.28 m.

Available Spaces at Different Cross-Sections Were Analyzed(Cont.)



Available Spaces at Different Cross-Sections Were Analyzed(Cont.)



Conclusion: This configuration can meet the requirements of blanket thickness.

Summary

- It is feasible to remove a field period unit including coil system and blanket/shield in radial direction during maintenance operation.
- MHH2 new configuration(12 coil case) provides adequate room for maintenance ports and spaces for blanket.
- Sector based maintenance approach(ARIES-AT like) seems impossible for MHH2 because there is enough space between each pair of coils.
- The maintenance approach with ports between each pair of coils seems is attractive for MHH2 configuration.