Design Updates on the Power Core Configuration and Maintenance

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ARIES Meeting

UCSD, California

June 14-15, 2006

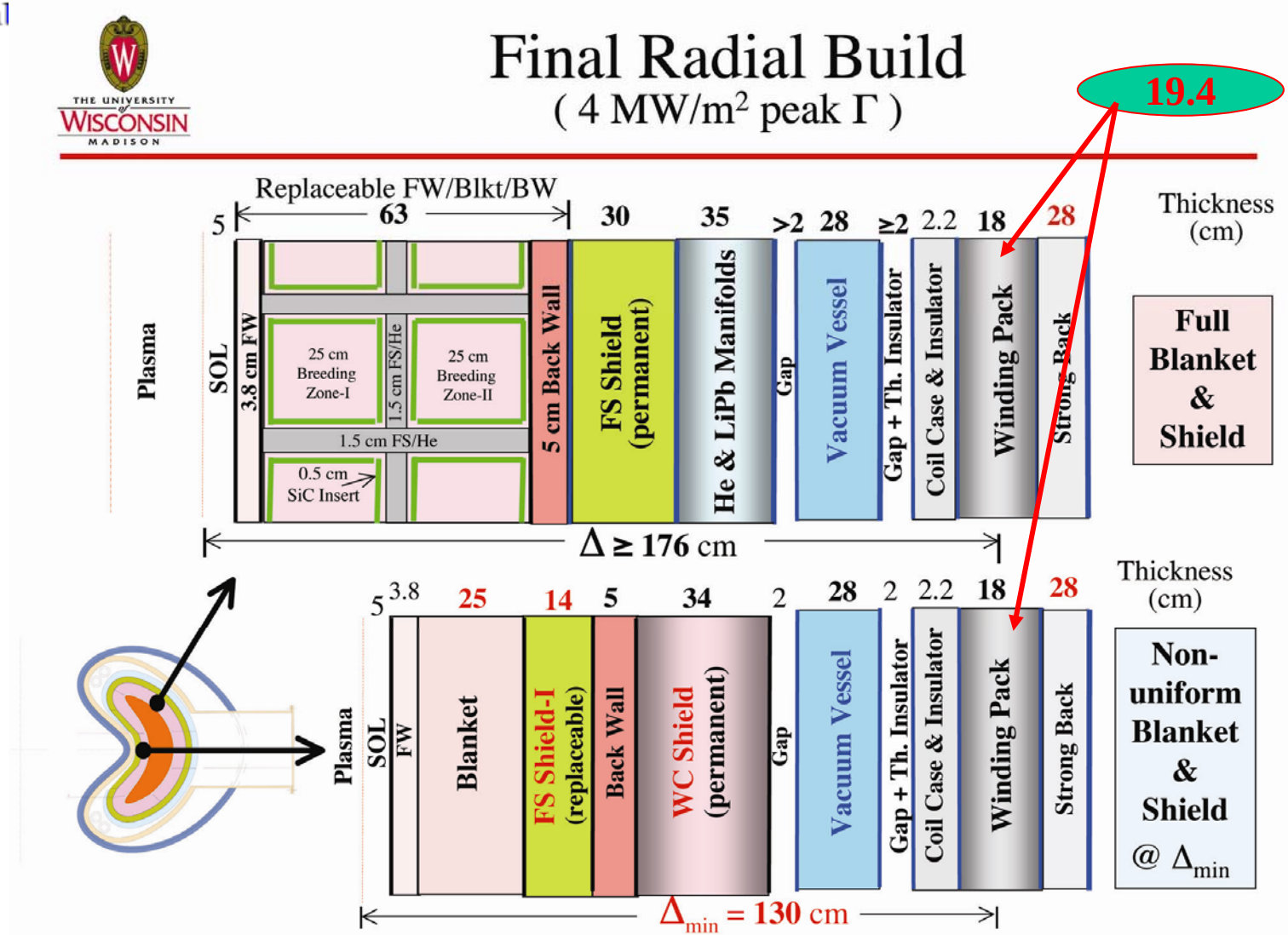
Outline

UC San Diego

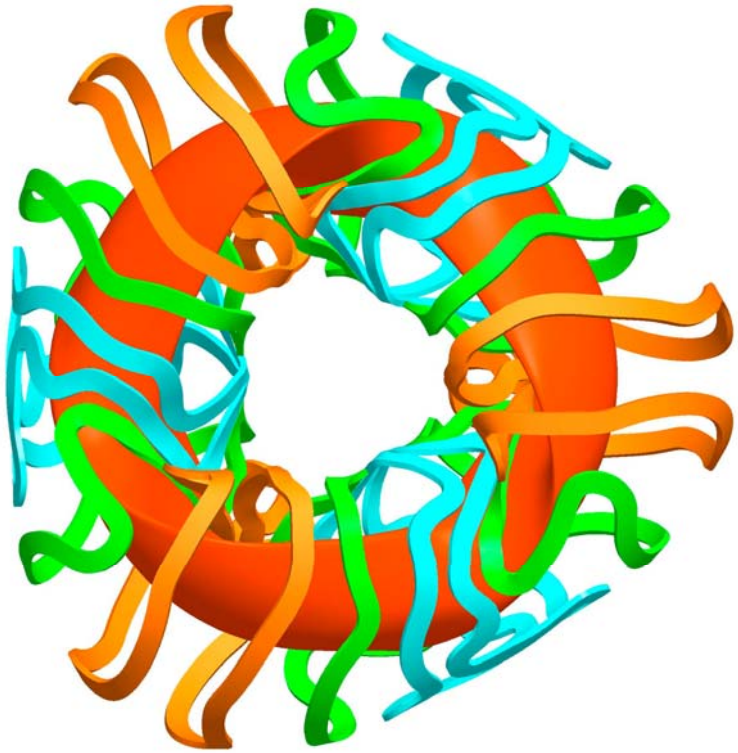
Design updates are based on R=7.75 m and final radial build:

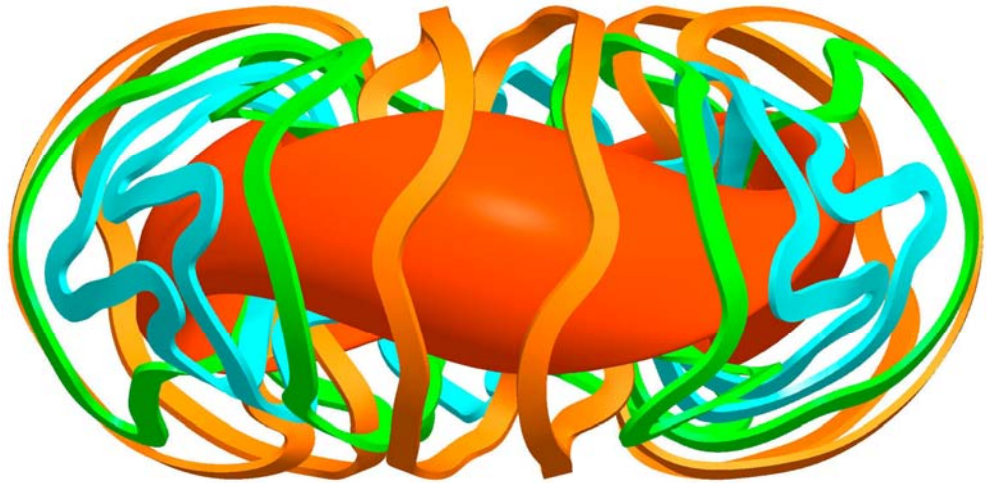
- New coil winding pack and horizontal maintenance port
- Coils structure design
- Blanket module segmentations and power core component arrangement
- Cryostat and bio-shield
- Blanket module replacements

Final Radial Build for ARIES-CS



Plasma and New Winding Pack

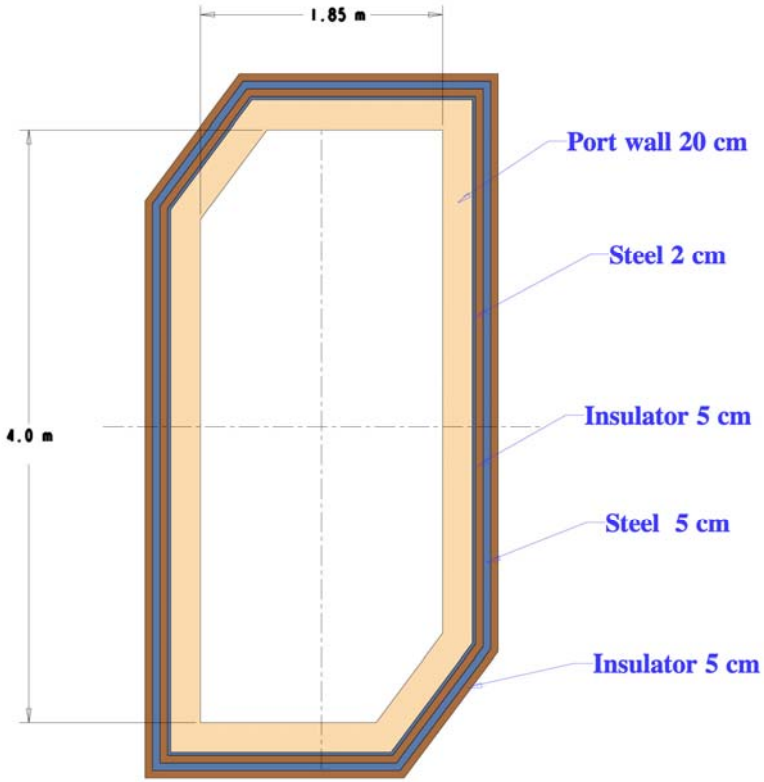




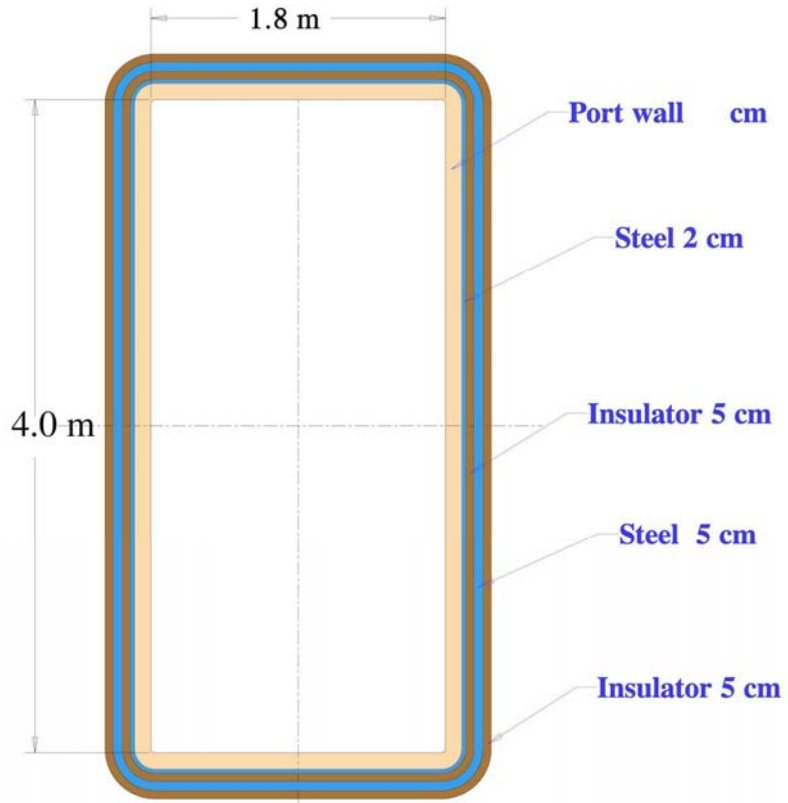
(Long-Poe provides the input data of the winding pack.)

- Cross section of the winding pack has been changed to 0.743 m x 0.194 m (previous design: 0.671 m x 0.184 m).
- Maximum space available for horizontal maintenance port at the mid-plane is 1.8 m x 4 m.

Horizontal Maintenance Ports



R=7.0 m

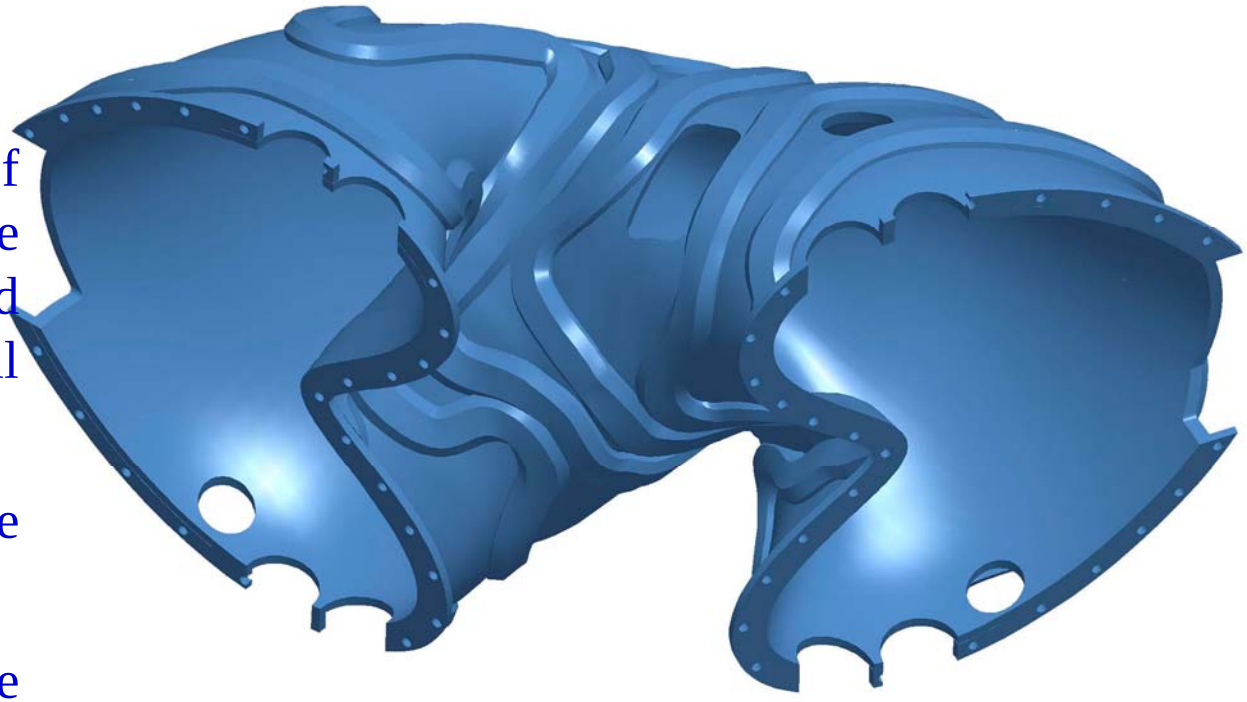


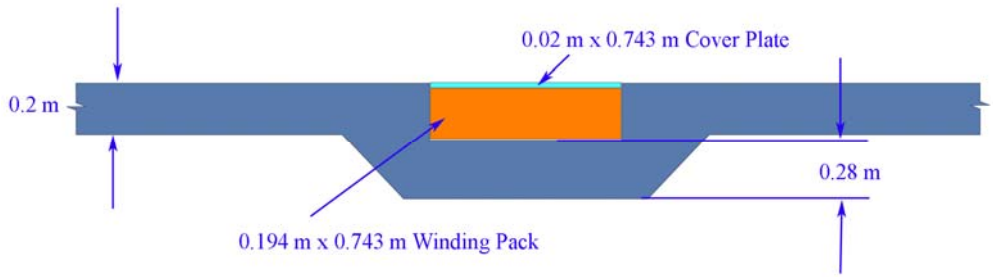
R=7.75 m

Coil Structure Thickness Estimate Based on the Results of the Magnetic-Structural Analysis

UC San Diego

- The average thickness of coil structure is based on the regional stresses and deflections by ANSYS shell modeling.
- The average thickness of the inter-coil structure is ~20 cm.
- The average thickness of the coil strong-back is ~28 cm.





Examples of the Inter-Coil Structure Thickness Estimate

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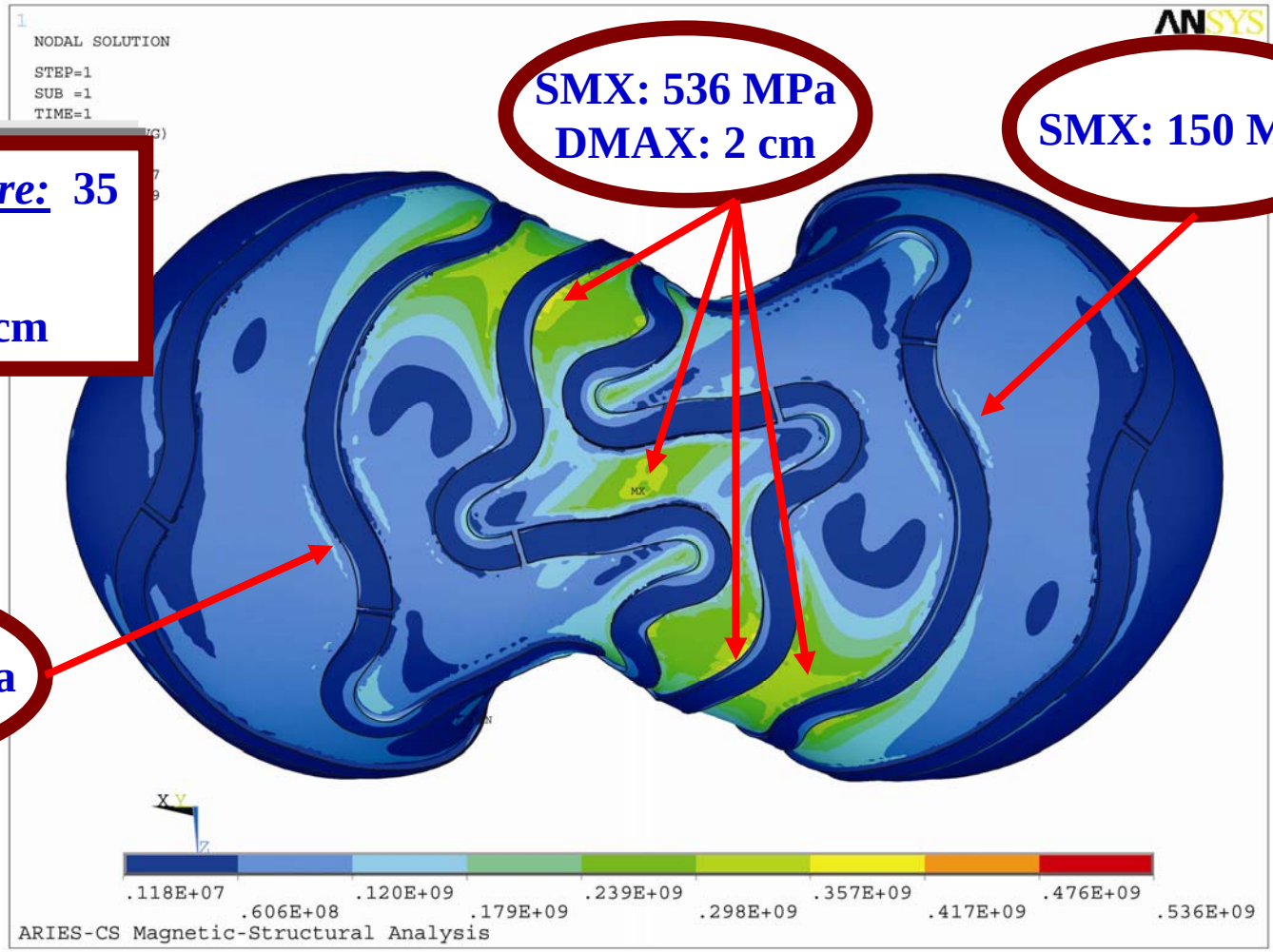
Inter-coil Structure: **35 cm**

Strong-Back: **30 cm**

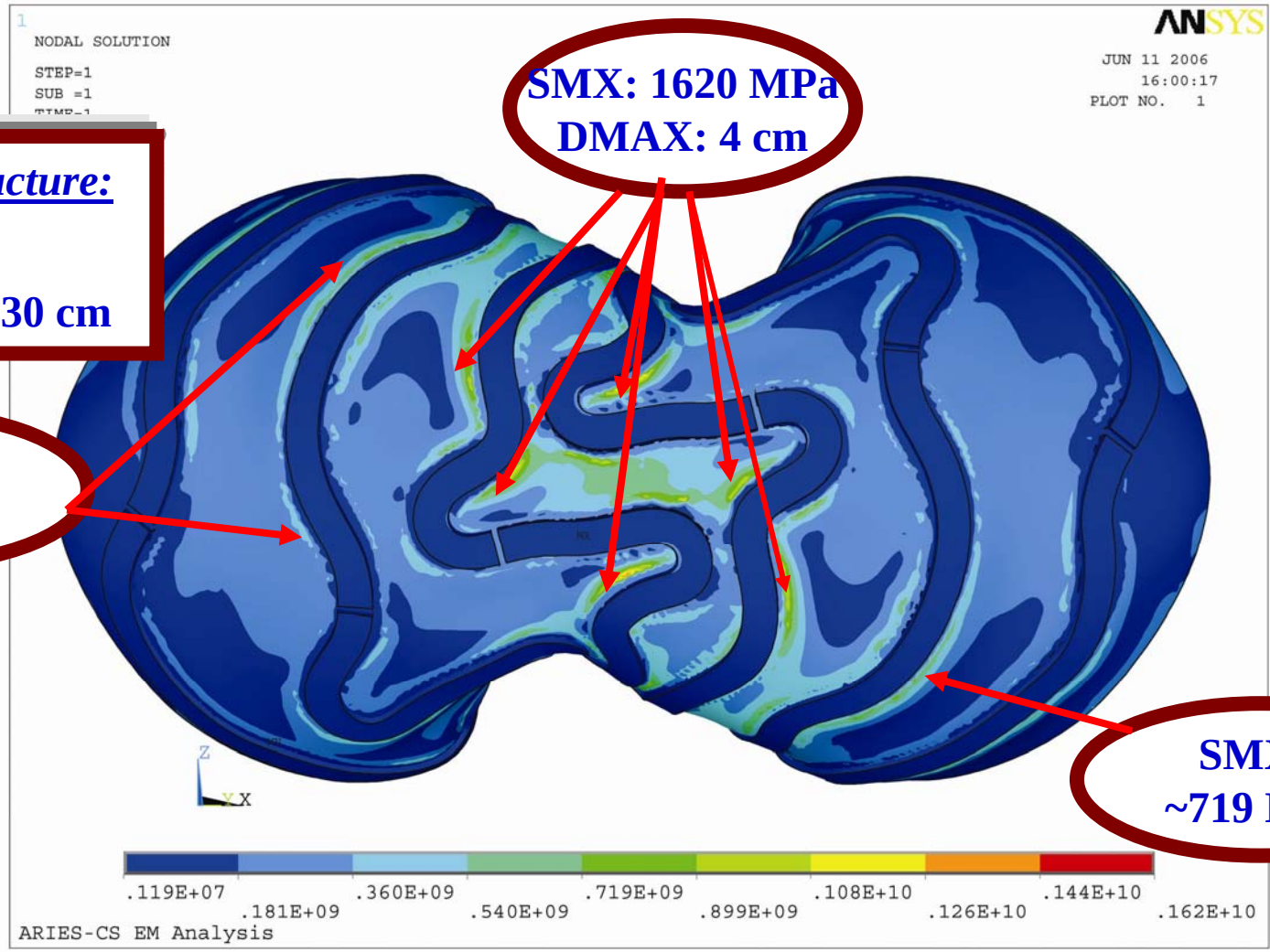


Examples of the Inter-Coil Structure Thickness Estimate (Cont.)

UC San Diego

Inter-coil Structure:
15 cm

Strong-Back: **30 cm**



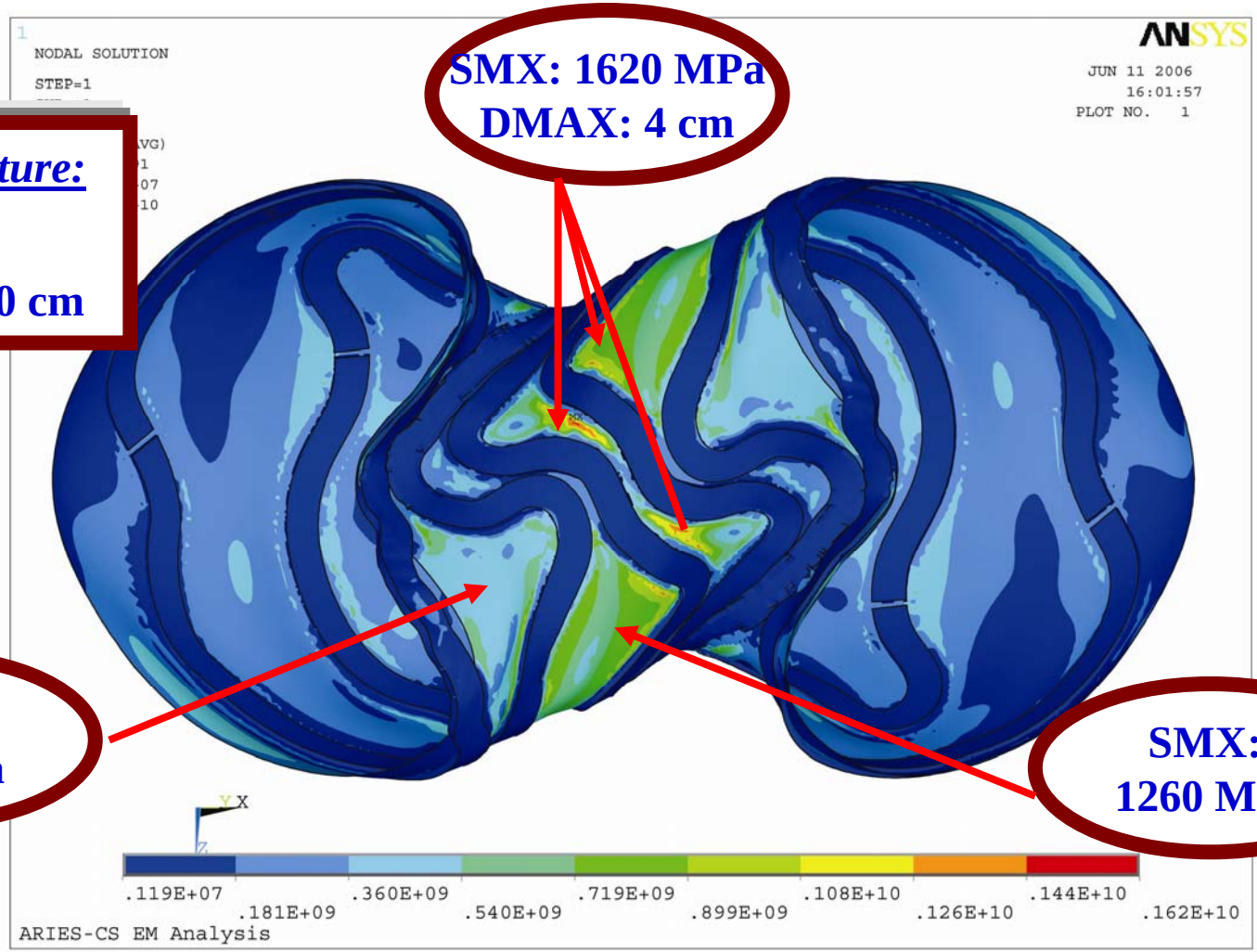
View from Outside

Examples of the Inter-Coil Structure Thickness Estimate (Cont.)

UC San Diego

Inter-coil Structure:
15 cm

Strong-Back: **30 cm**



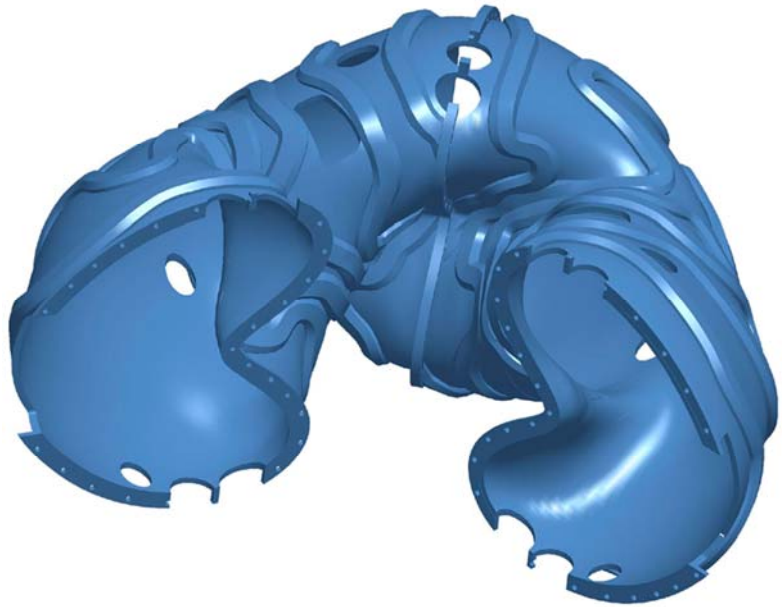
View from Inside of the Torus

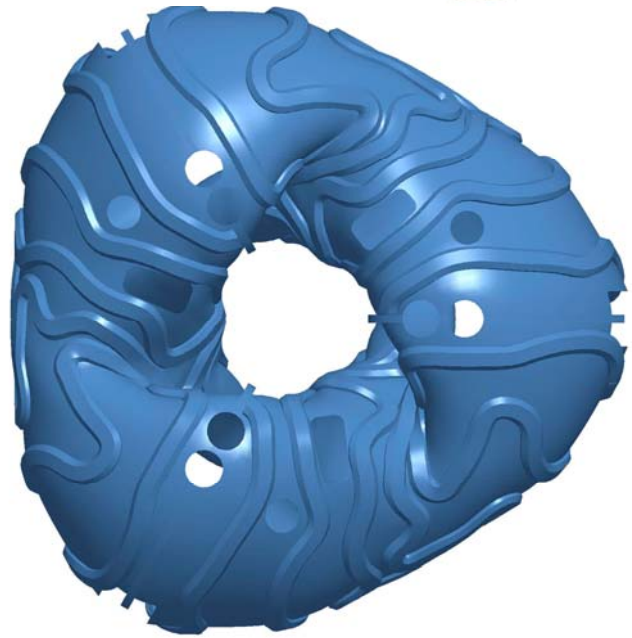
Coil Structural Design

- Three coil supporting tubes (one for each field-period) are bolted together to form a continuous structural ring.
- All the magnetic forces are reacted by the coil tube.
- Possible openings/penetrations:
  - ✓ ***15 Coolant pipes connecting to primary loops:***

    (6 He pipes from blanket, 3 He pipes from divertor

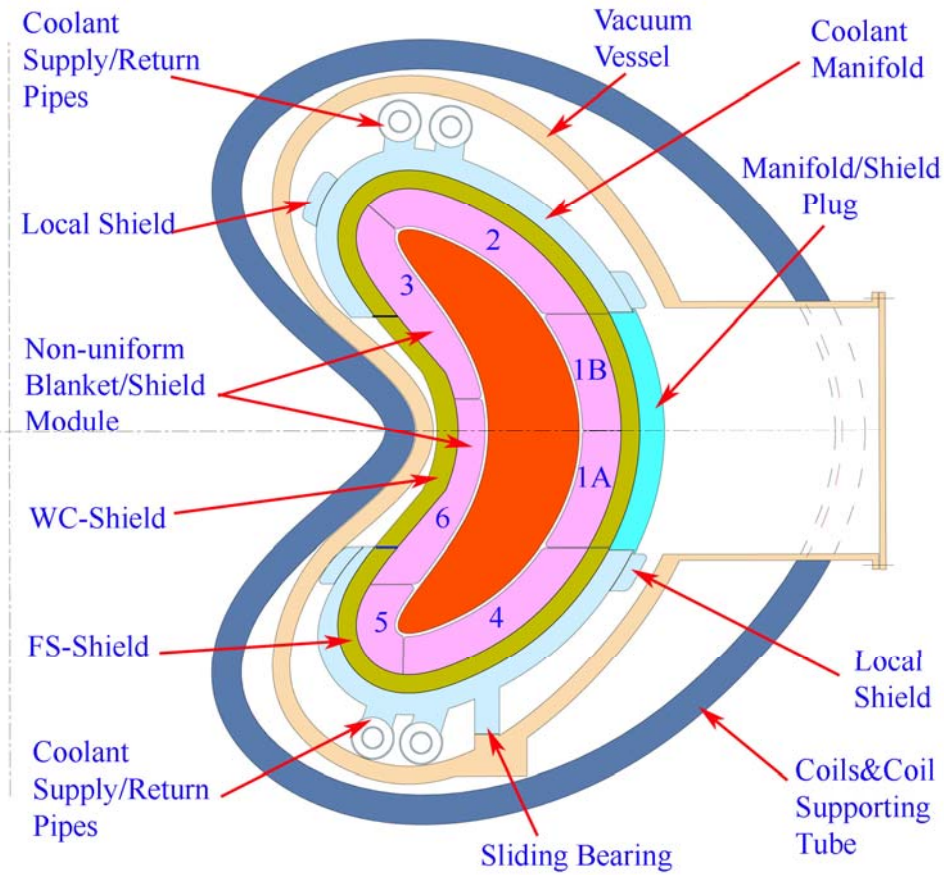
    6 Pb-Li pipes from blanket)
  - ✓ ***3 Maintenance ports;***
  - ✓ ***3 vacuum pumping ducts;***
  - ✓ ***3 x 3 supporting legs for hot power core.***



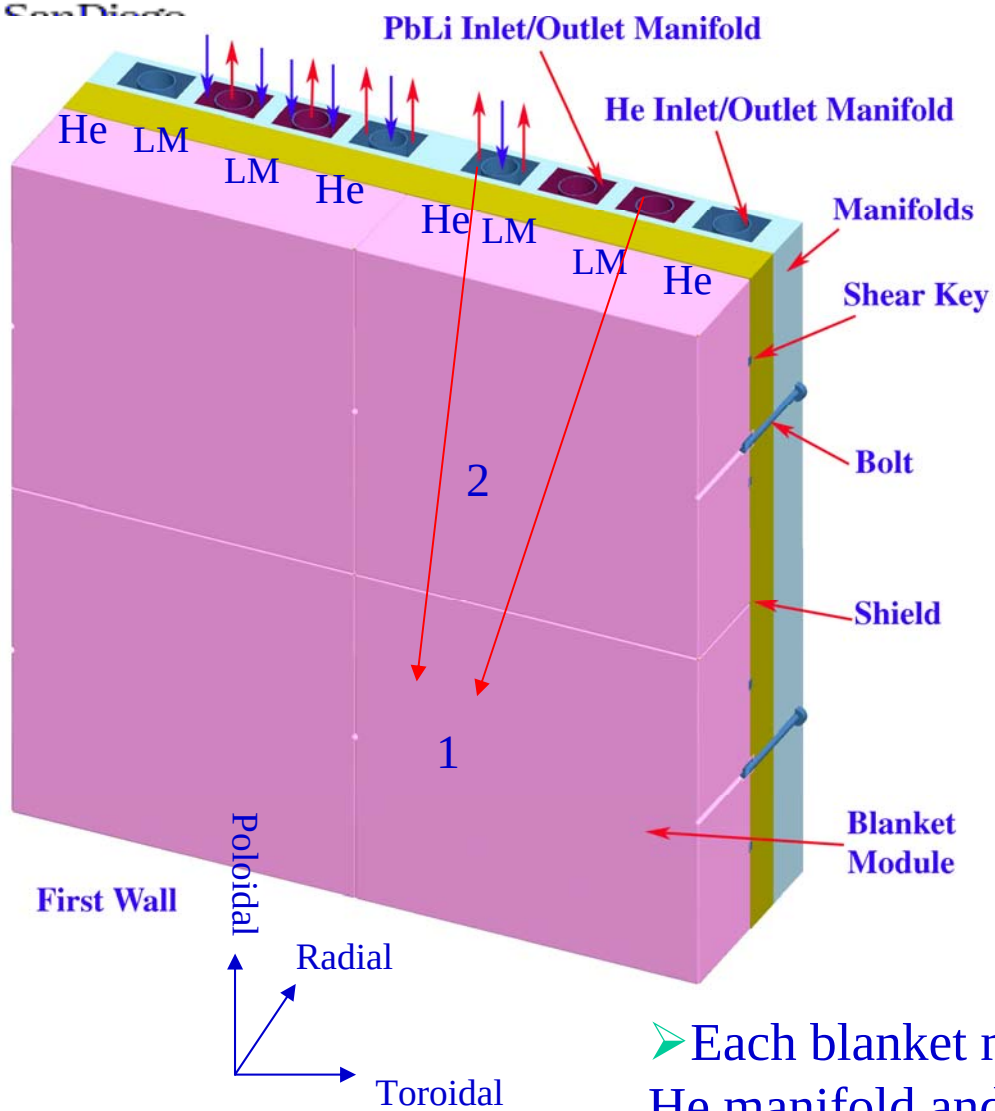


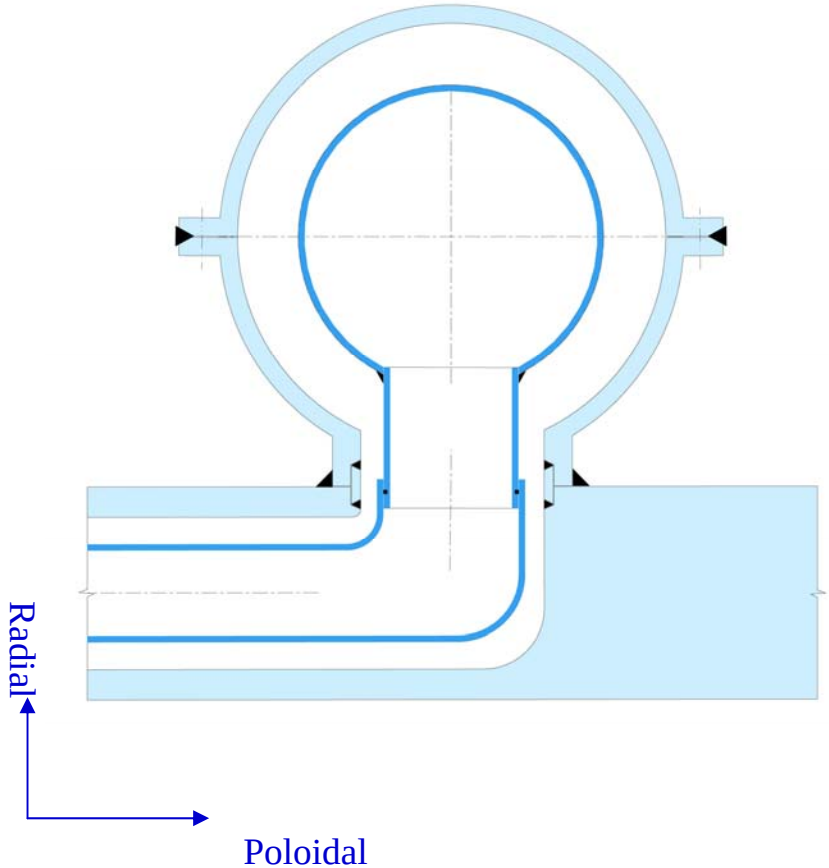
Blanket Segmentation and Power Core Component Arrangement

- The subdividing angle is 10 degree and 12 subdivisions in one field-period, and the module toroidal length varies from 1.75 m to 1.22 m, and the poloidal length varies from 2.3 to 3 m.
- The size of the blanket module #1A & #1B is 1.75 m x 1.9 m, and they will be removed together.
- The 0 deg modules would extend from -5 deg to +5 deg, and the subdivisions of this sector is 7, and 72 each field-period.
- The blanket modules will be attached to a skeleton ring which is supported through the VV by sliding bearing.
- 25 cm local shield for protecting the VV and magnets at the coolant access pipes are added.
- The toriodal coolant supply/return pipes are combined to the coolant manifolds.



Possible Connection of the Coolant Supply/Return Pipe to Manifolds

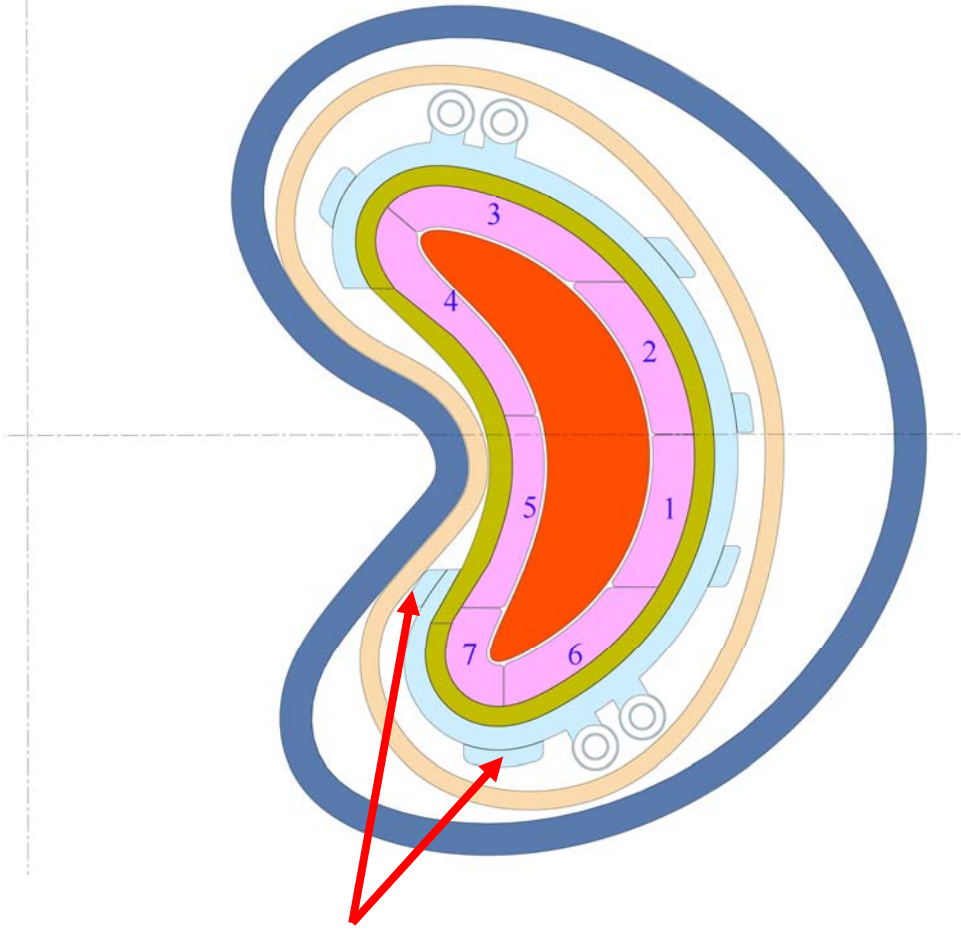




- Each blanket module needs to be fed by one He manifold and one LM manifold.

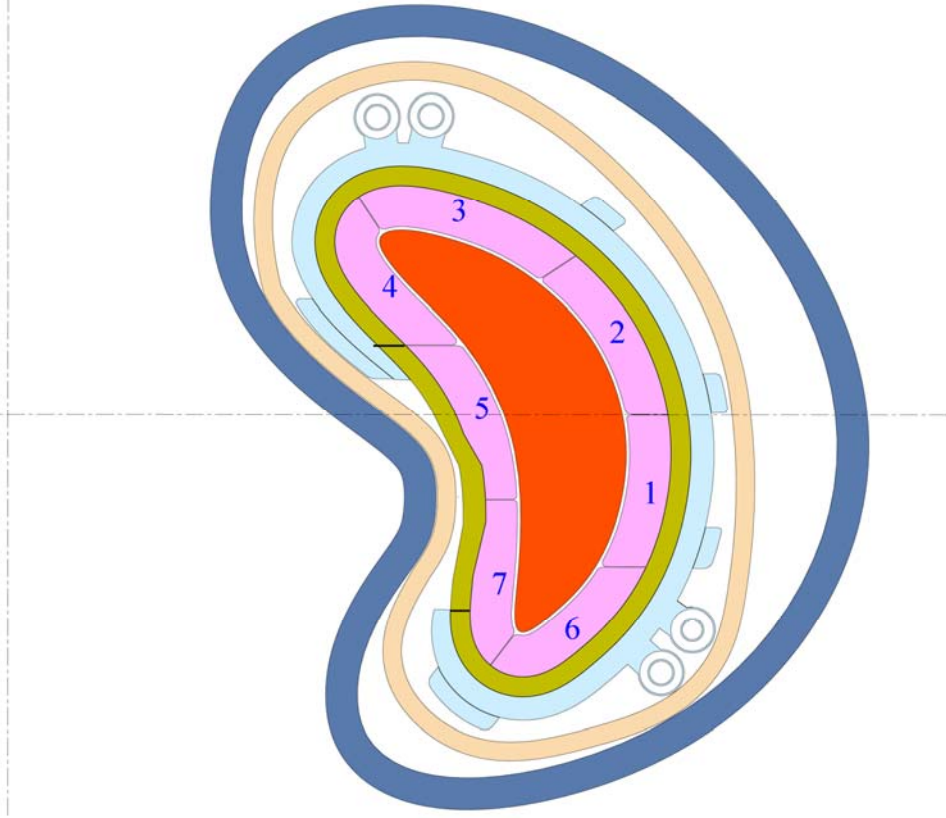
Blanket Segmentation and the Power Core Arrangement (10 Deg)

- The modules at 10 deg. would extend from 5 deg to +15 deg, and 7 subdivisions in the poloidal.
- The blanket module #4 will have to fed from top because there is no enough space for manifold and local shield.
- The other modules are fed from bottom.
- Blanket modules would be withdrawn in order of the module numbers, for example, the blanket module #1 would be removed in first, then, through #2 to #7.

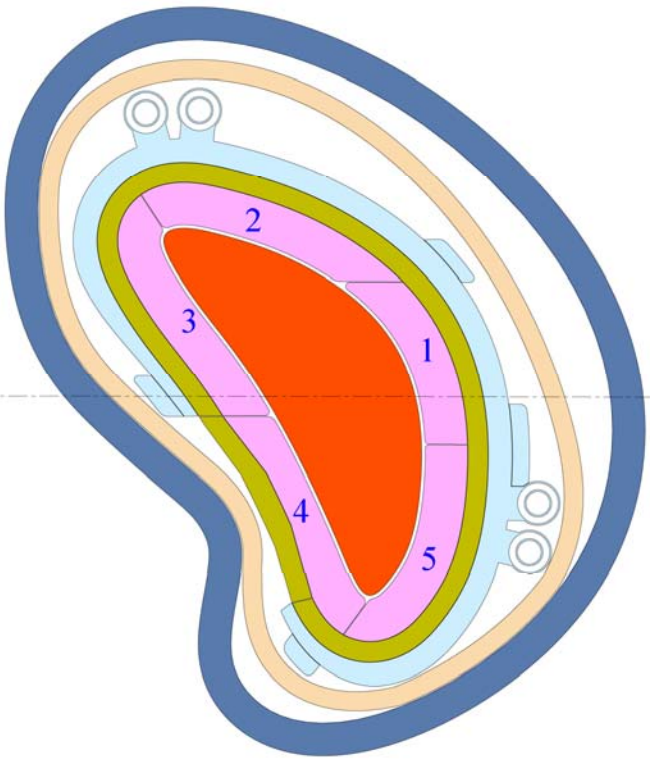


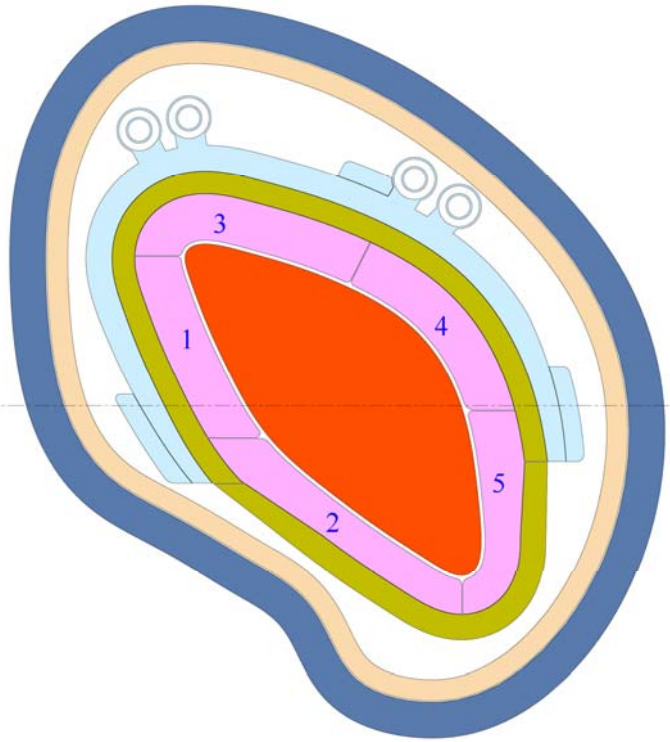
Blanket Segmentation and the Power Core Arrangement (20 Deg)

- The 20 deg modules would extend from 15 deg to +25 deg, and 7 subdivisions in the poloidal.
- The blanket module #5 will have to fed from top in order to place 25 cm local shield, and other modules are fed from bottom.
- The blanket modules would be withdrawn in order of the module numbers.



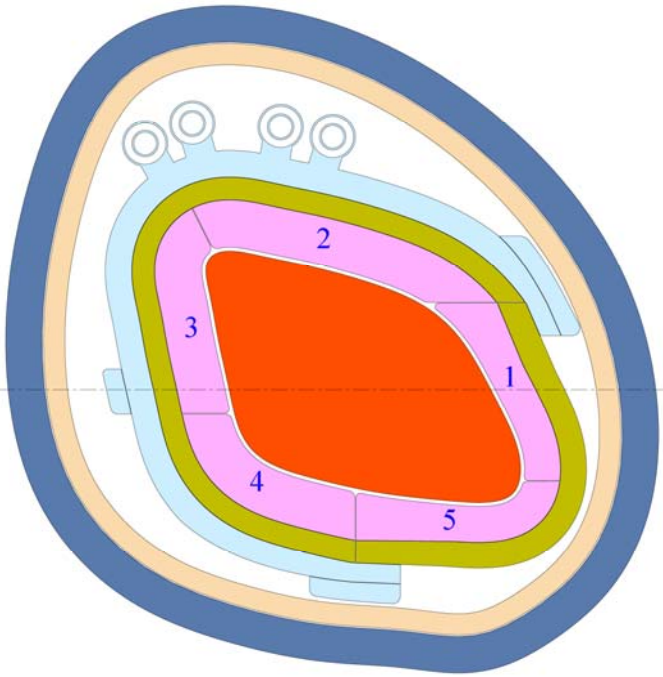
Blanket Segmentation and the Power Core Arrangement (30 and 40 Deg)

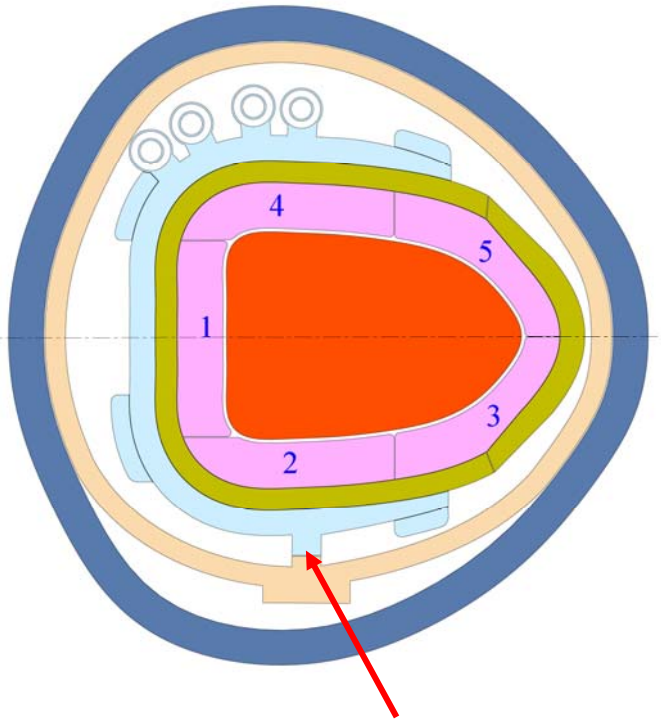




- The modules at 30 deg would extend from 25 deg to 35, and the modules at 40 deg would extend from 35 to 45 deg.
- There are 5 modules each of the sector.

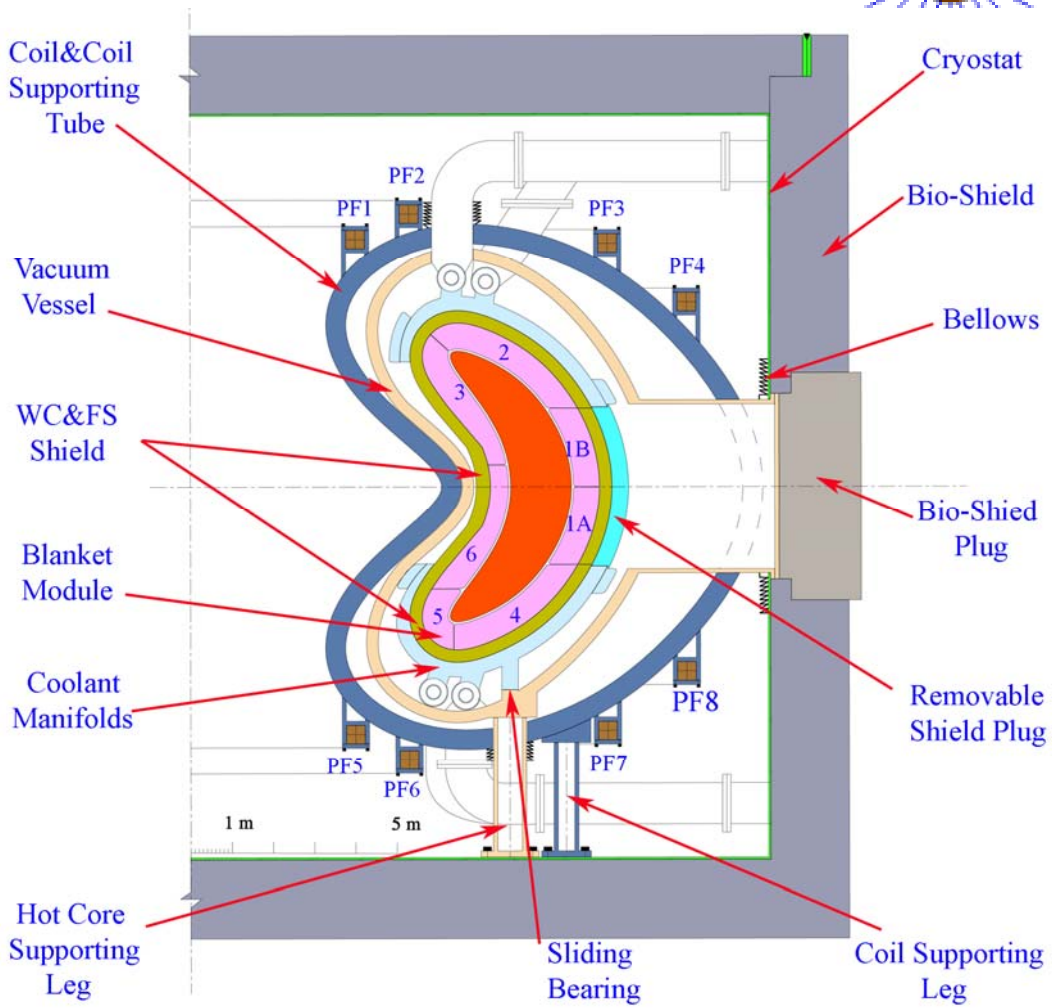
Blanket Segmentation and the Power Core Arrangement (50 and 60 Deg)



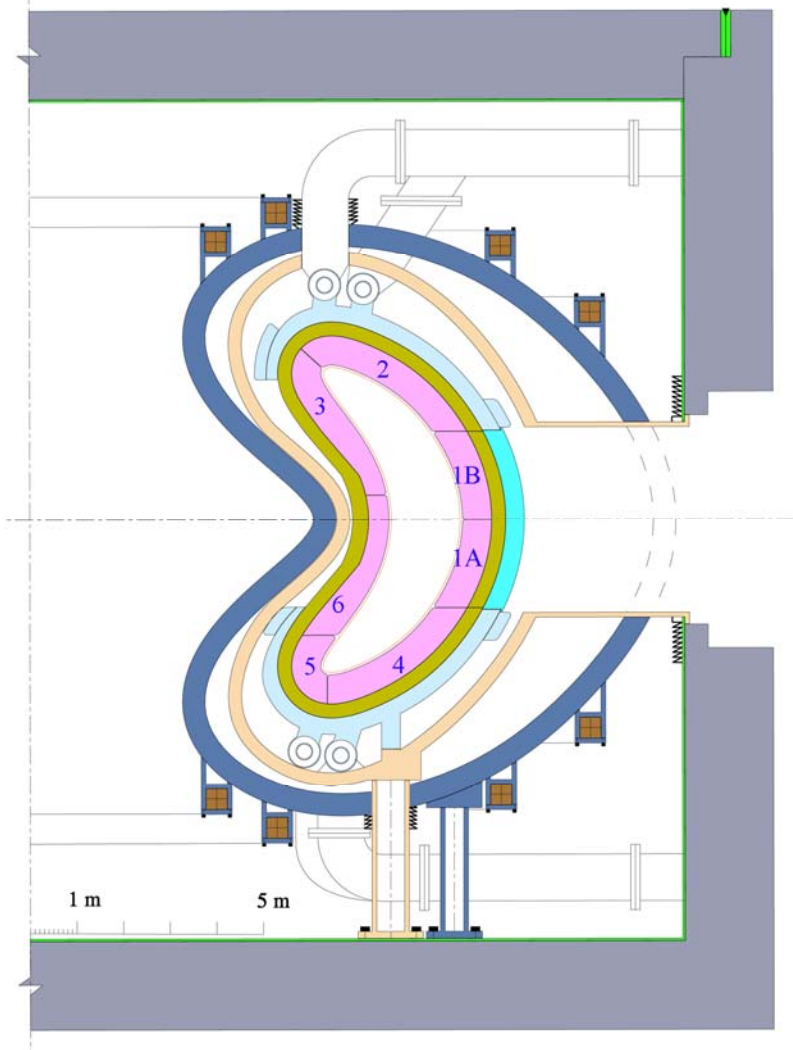


Design of External Cryostat and Bio-Shield

- For thermal insulation, the entire coil system has to be enclosed in a common cryostat.
- The cryostat could be a single wall cylindrical shell with flat top and bottom (~5 cm) and attached to the concrete vessel (~1.9 m) serving as a biological shield and a second containment for the tritium in the VV.
- The "removable shield plug" would severs the coolant manifolds to feed the blanket module #1A & #1B, and it will connect both top and bottom supply/return ring pipes by concentric tubes.
- PF coils are supported by the modular coil structure.



Steps of Extracting the Blanket Modules at the Maintenance Port

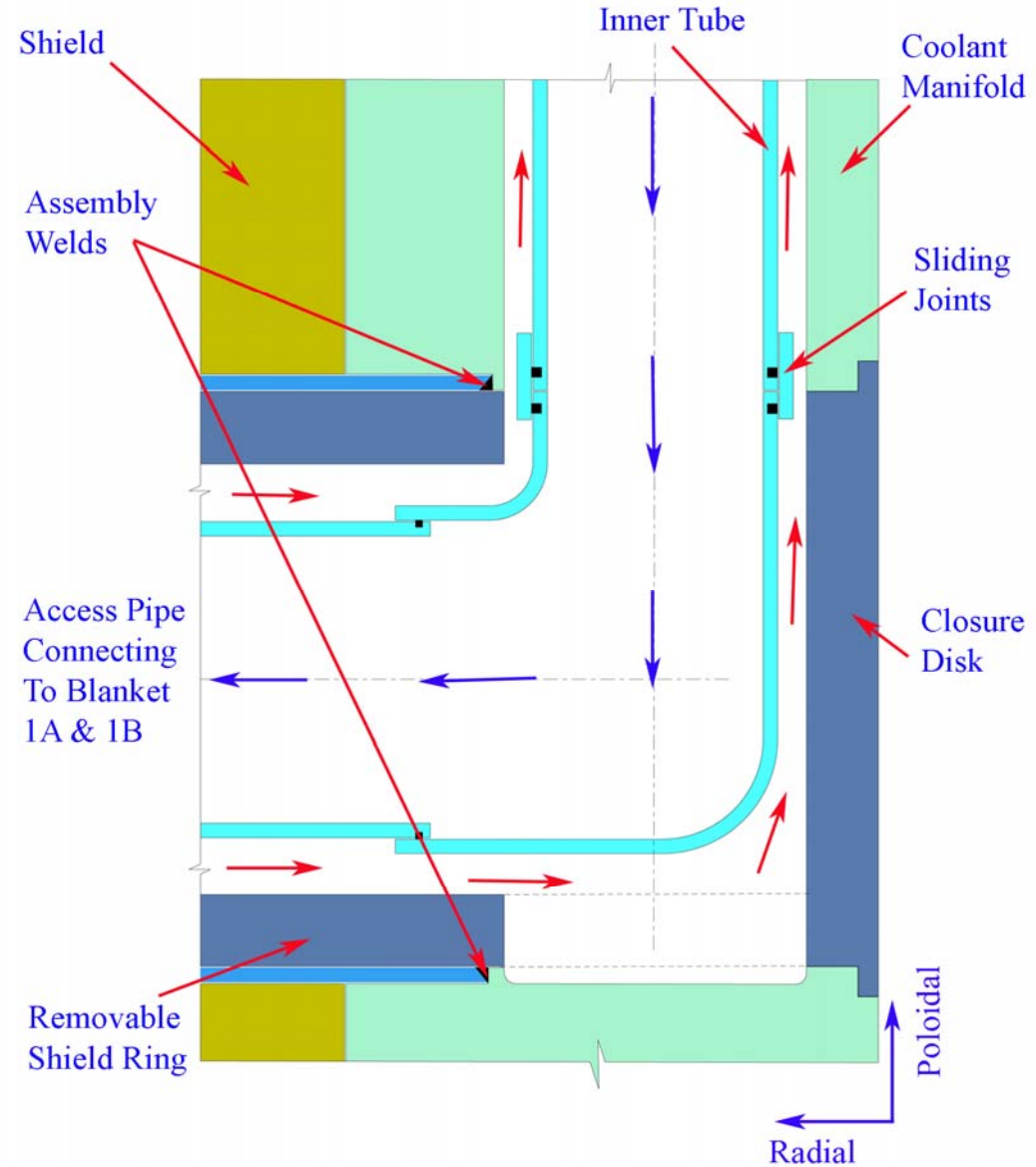


Remove the bio-shield plug

Remove the VV door

Remove the manifold behind 1A & 1B

Disconnecting Access Pipes To Blanket Module 1A & 1B From Back



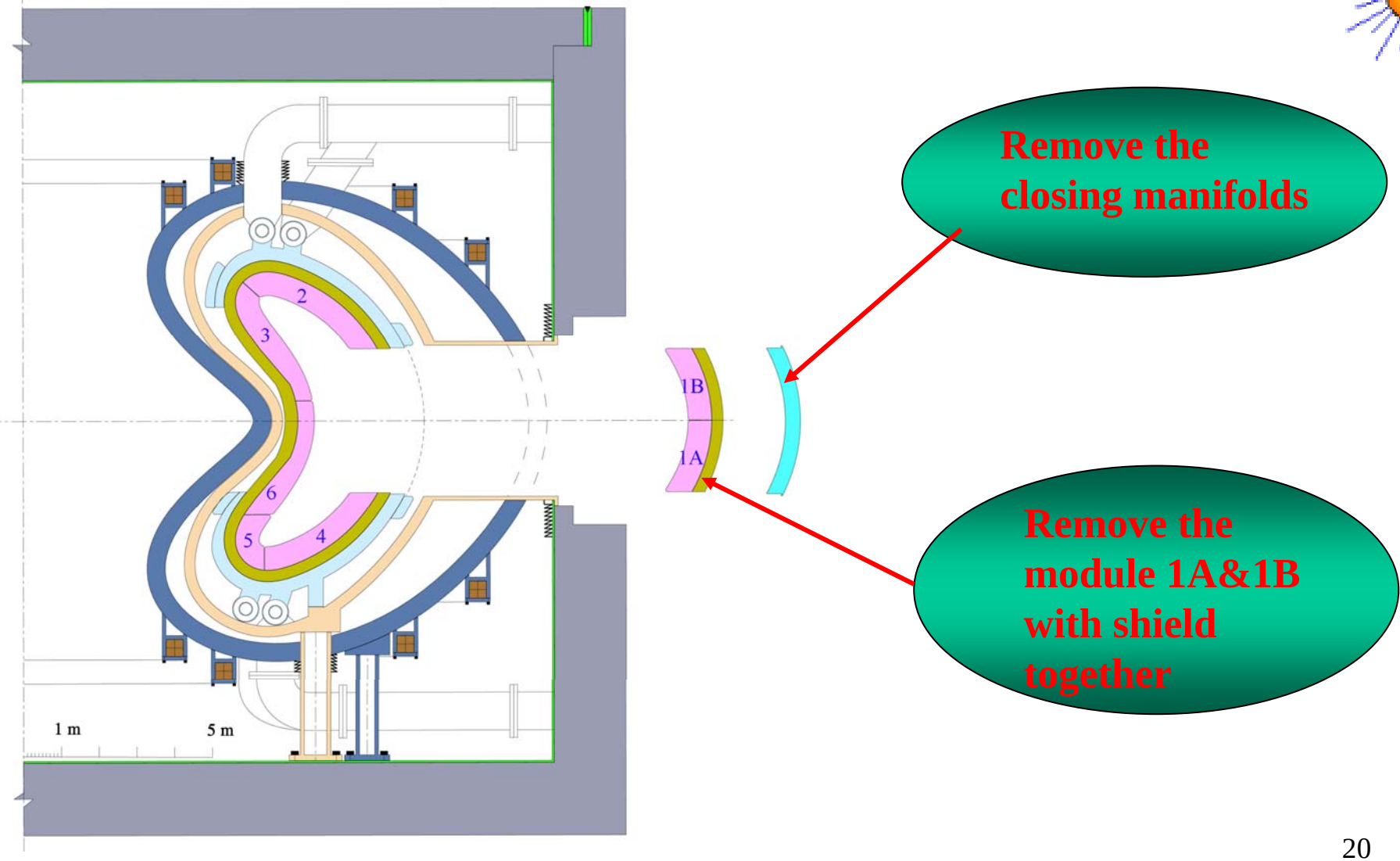
Open and remove the closure disk

Remove partial inner tube

Remove shield ring

Cut the welds of access pipe

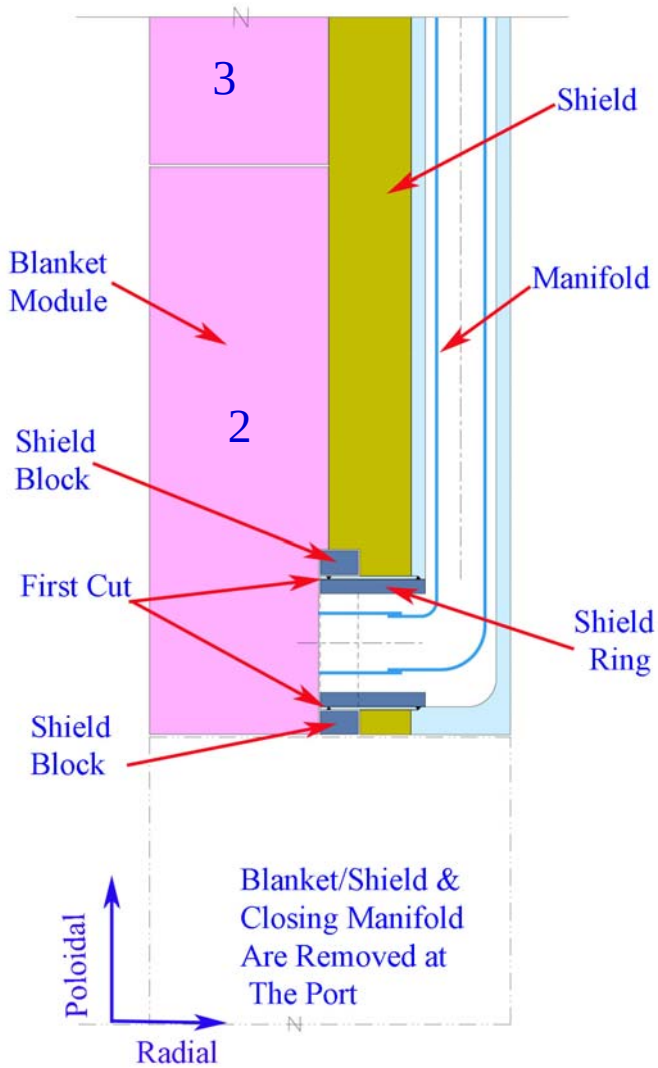
Steps of Extracting Blanket Modules at the Maintenance Port (Cont.)

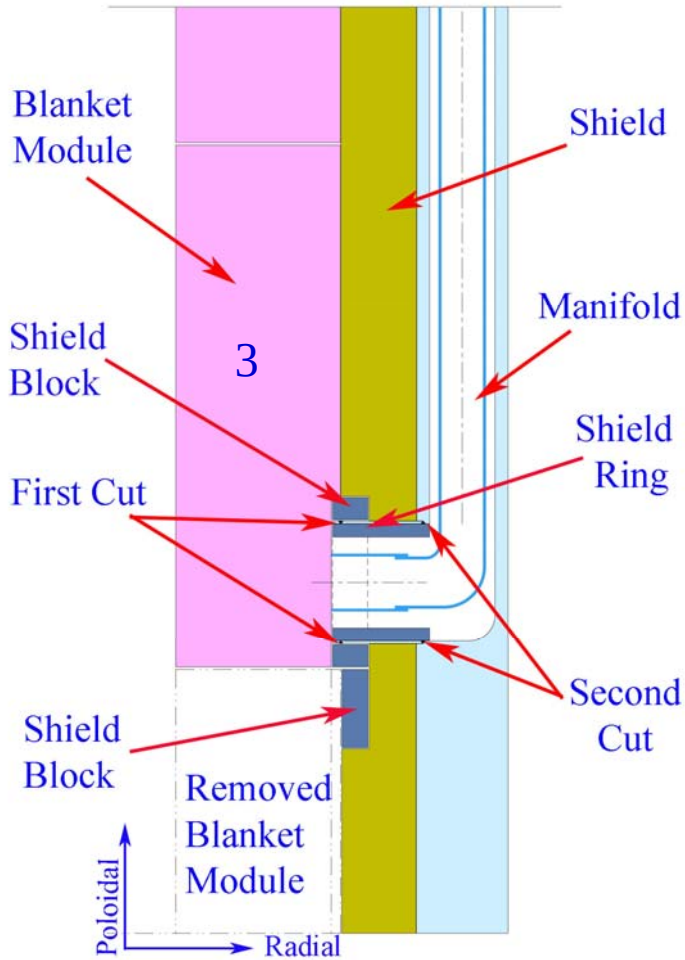


Remove the closing manifolds

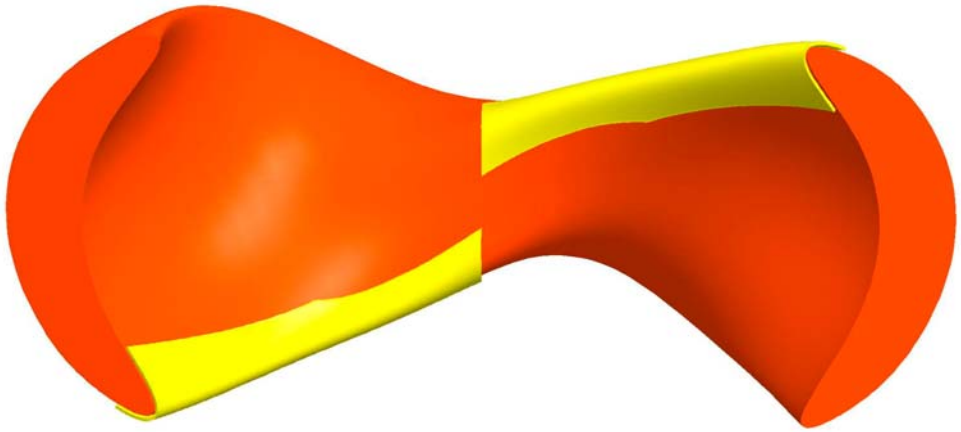
Remove the module 1A&1B with shield together

Example of the Blanket Module 2 & 3 Replacements



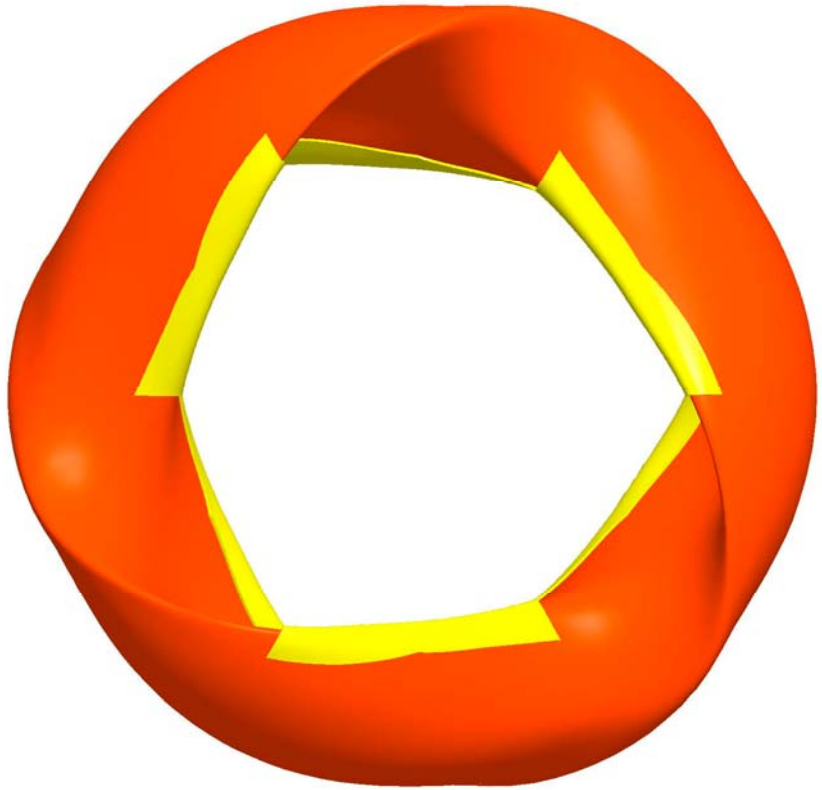


Initial Layout of the Divertor Plates



120 o 60 o 0 o

(Diverter plate data from T.K.)



Top View

- Add three plates with same surface area at the bottom.
- The total divert plate area is ~6 x 11 m^2.
- The surface coverage fraction is ~9.14%.

Summary

- The coil structure design has been updated, and the average thickness of the inter-coil structure and coil strong-back has been estimated as 20 cm and 28 cm respectively.

- Based on the dimensions of maintenance ports, 1.8 m (toi.) x 4 m (pol.), the blanket would be subdivided into 216 modules.

- Power core component design, including cryostat, bio-shield, coil winding pack, coil structure, coolant manifolds, WC&FS shield, blanket have been updated to R=7.75 m reactor.

- Three abstracts have been submitted to 17TOFE conference.

  X.R. Wang1, L.A. El-Guebaly, S. Malang, A. R. Raffray and The ARIES Team , "Integration of the Modular Dual Coolant Pb-17Li Blanket Concept in the ARIES-CS Power Plant"

  X.R Wang1, S. Malang, A.R. Raffray and The ARIES Team, "Configuration Design and Maintenance Approach for the ARIES-CS Stellarator Power Plant"

  X.R. Wang1, S. Malang, C. Martin, A. R. Raffray and The ARIES Team, "Coil Structural Design and Magnetic-Structural Analysis of the AIRIES-CS Coil System"

- Some of the updated CAD drawings for R=7.75 m have been published at ARIES web site, and will continue to update the drawings on web site.