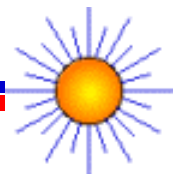


Status of the ARIES-CS Power Core Configuration and Maintenance



Presented by X.R. Wang

Contributors: S. Malang, A.R. Raffray

ARIES Meeting

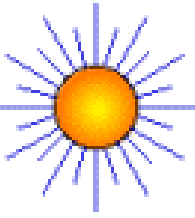
PPPL, NJ

Sept. 15-16, 2005

Outline



UC San Diego

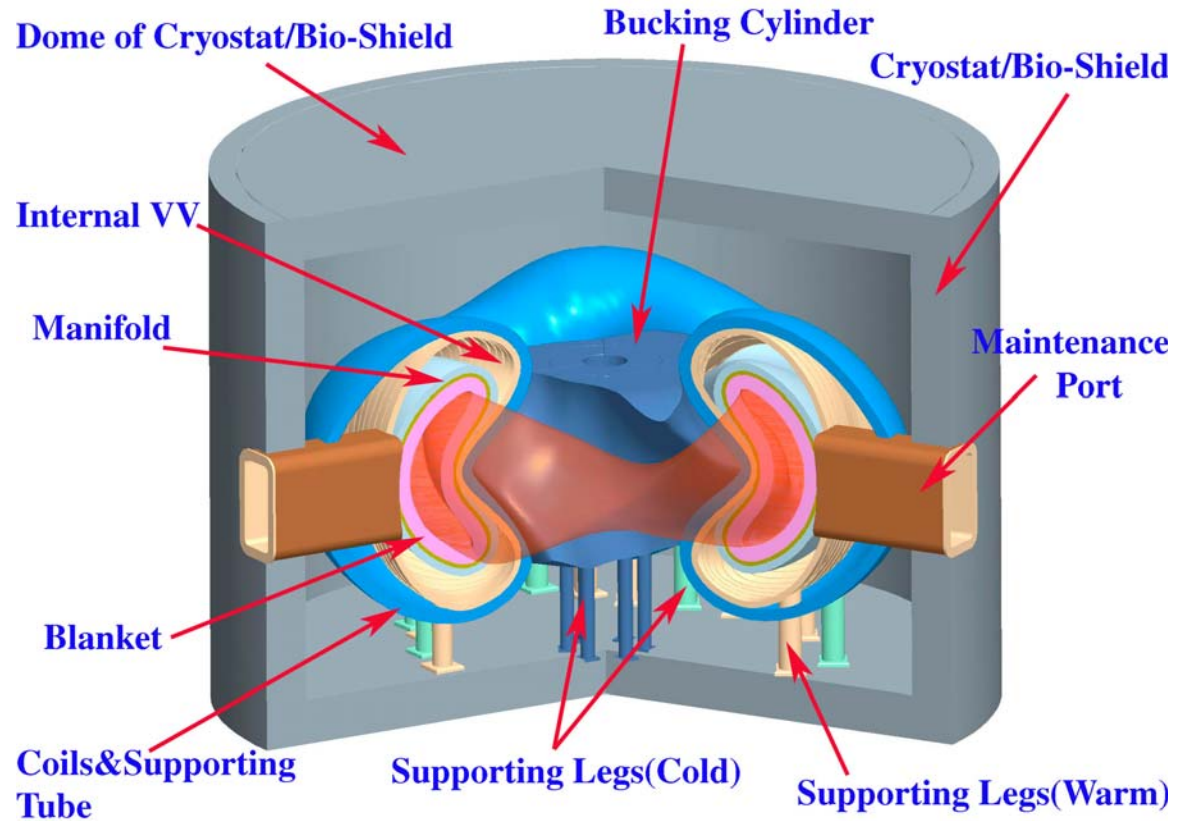
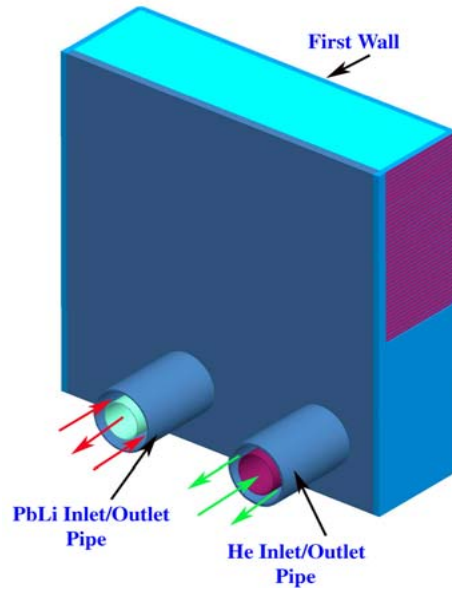
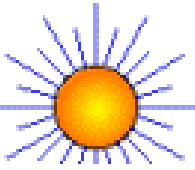


- A concept design to protect the welding joints between outer coolant access pipe and manifold based on the port maintenance scheme.
- Conceptual design of the replacement unit suitable for the field-period maintenance with DCLL blankets.
- Clearances for removing the replacement unit in toroidal direction.
- Summary

Replacement Units for the Modular Maintenance with DULL Blankets

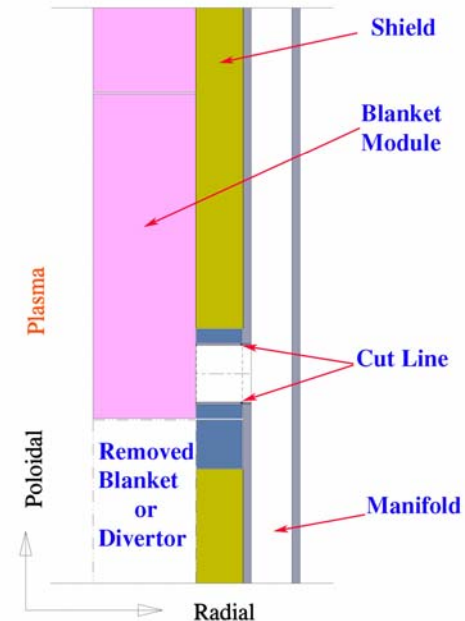
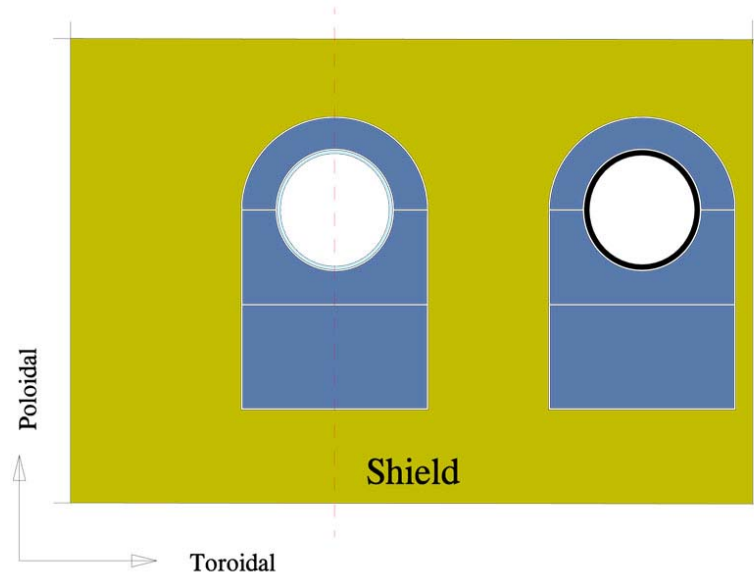
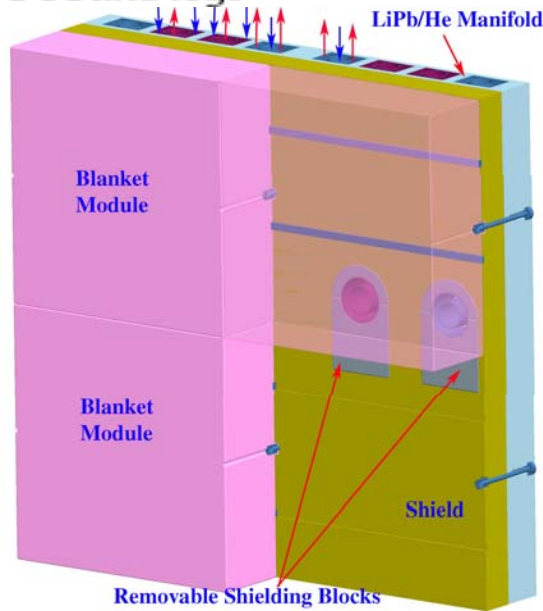
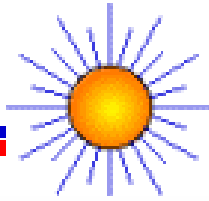


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- DCLL blanket design with Helium-cooled FW and blanket structure and Pb-17Li cooled breeding zone was evaluated based on port maintenance.
- The typical size of the blanket modules is about 2 m (tor.) x 2 m (pol.) x 0.63 m (rad.) in order to be compatible with modular replacement through a small number of designated maintenance ports using articulated booms

Access Pipes Connecting to the Manifolds for the Dual-Cooled Modular Replacement Design Approach

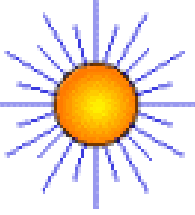


- The basic idea is to design a “hot” power core with a kind of skeleton rings closed in poloidal direction, and to attach the blanket modules to this ring.
- Each blanket module is connected to the manifold region by one concentric pipe for the liquid metal coolant and one concentric pipe for the helium coolant.
- However, the large diameter of the coolant access pipes causes the problem of neutron streaming, making the radiation damage in the weld located at the interface between steel shield and manifold considerably larger than in the undisturbed region.

Possible Solution of the Protecting the Welds Between the Access Pipe Connecting to the Manifold



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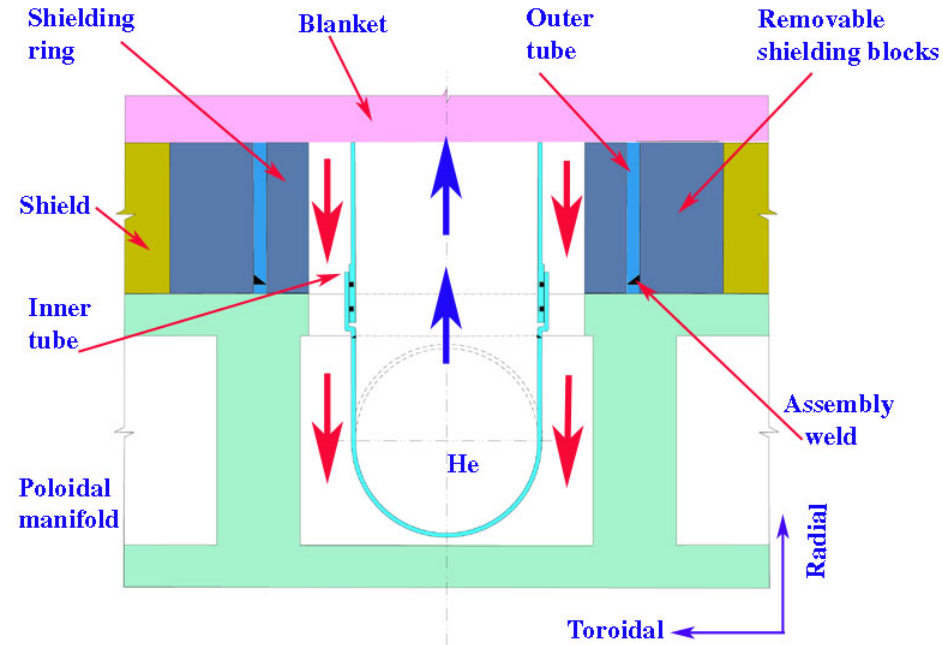


➤ The weld between the outer coolant access pipe and the manifold is protected by a shielding ring inside the tube in order to reduce the neutron flux at the weld location.

➤ This ring as well as the removable shielding blocks at the outside of the pipe can be made of steel, W, or WC with 100 % density without any cooling channels.

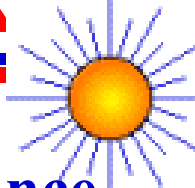
➤ There is an overlapping zone at the connection of the inner coolant access pipe with the manifold, employing piston rings as sliding seals.

➤ The blanket module replacement is based on cutting/re-welding of the outer tube of the concentric pipes from the outside after removing the neighboring blanket module



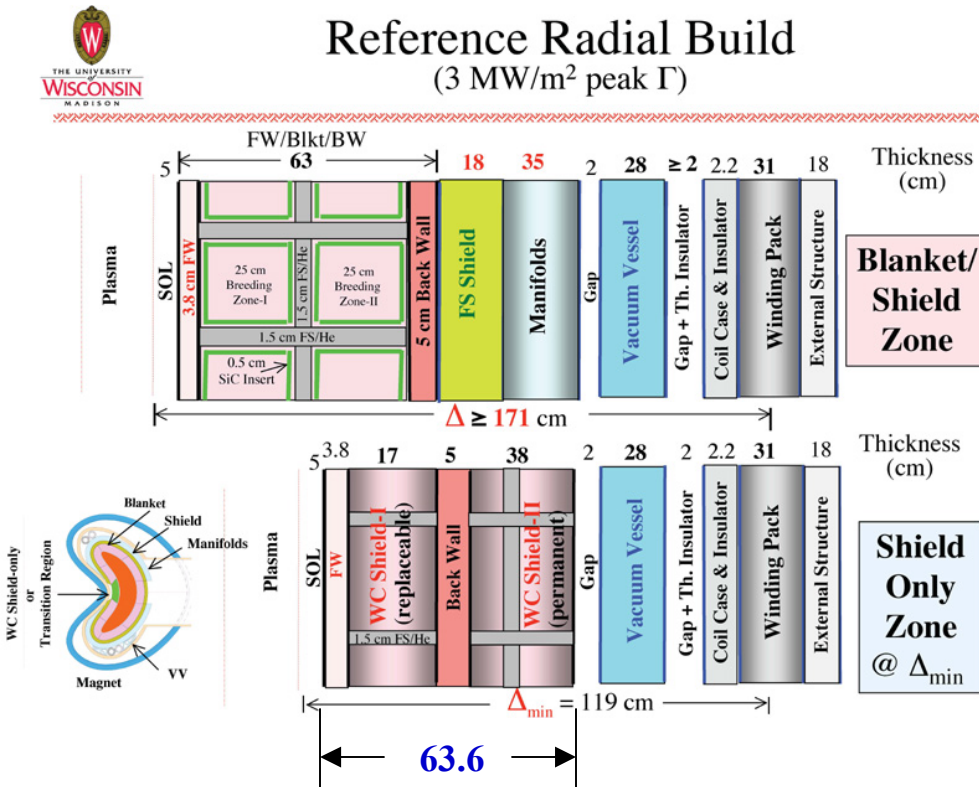
Recommended Radial Builds for Field-Period Maintenance Scheme with DCLL Blanket

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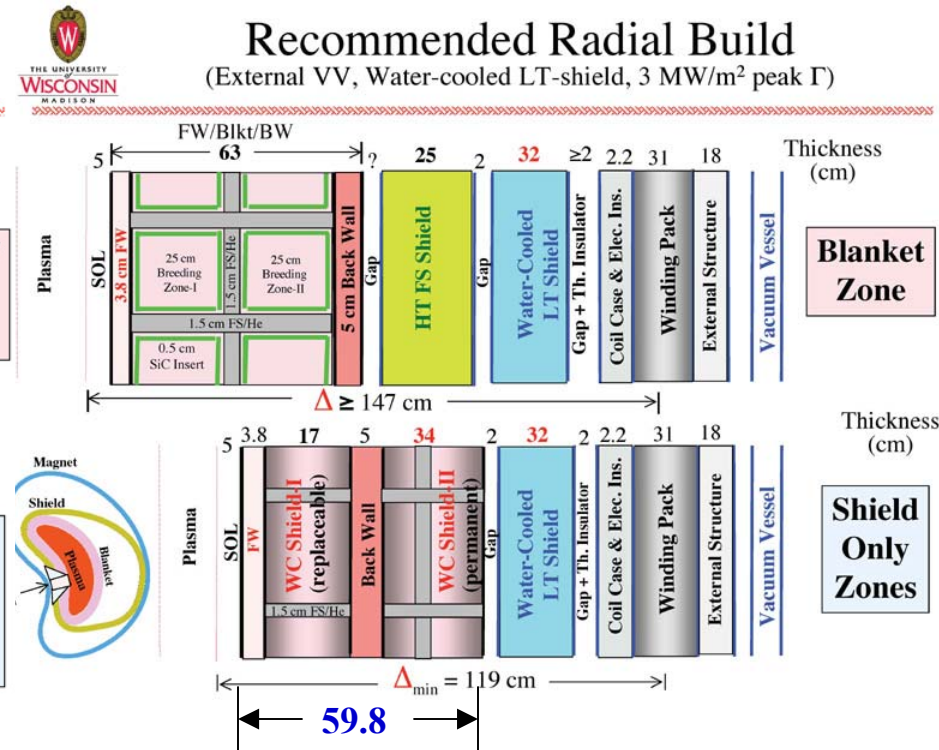
Port Maintenance

Reference Radial Build
(3 MW/m² peak Γ)



Field-Period Maintenance

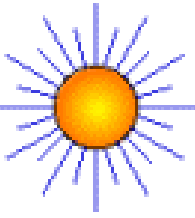
Recommended Radial Build
(External VV, Water-cooled LT-shield, 3 MW/m² peak Γ)



Designs of the Replacement Unit for Field-Period Maintenance



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Alternative A:

- Combine the 63 cm FW/Blanket/Back wall with the 25 cm HT shield and consider the total thickness of ~90 cm as replacement unit to be disposed of with every blanket replacement.

Alternative B:

- Design a combination of the 63 cm thick blanket modules attached to a 37 cm thick zone serving as HT shield and coolant manifolds.
- The assembly welds between the blanket modules and manifolds have to be located at least 10 cm deep in the manifold zone in order to provide sufficient shielding of these welds.
- The amount of waste to be disposed of is minimized (only the 63 cm thick breeding module), but an increase of the radial thickness by ~10 cm compared to the Alternative A is necessary.

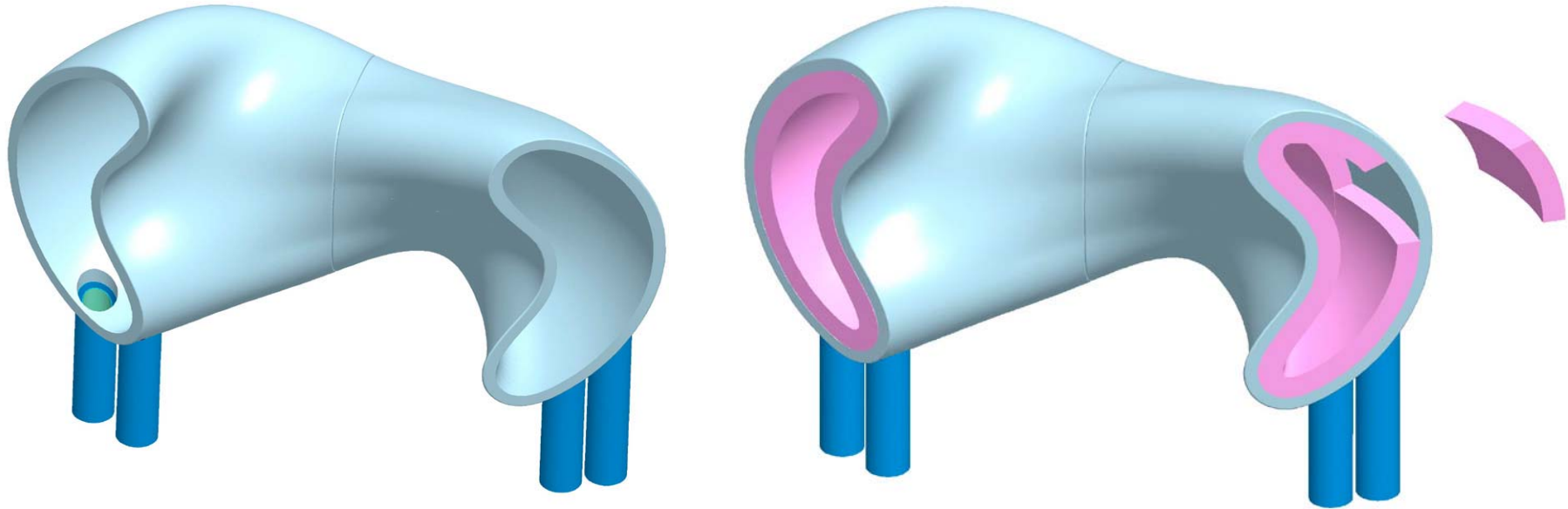
Comparing A and B:

- It appeared that an increase of the radial build thickness by 10 cm is a smaller burden than the increase of waste in case of Alternative A.
- Alternative B offers the additional advantage that in this case nearly identical breeding modules can be used as in the case of the port maintenance.
- The design principle of the Alternative B will be selected as reference design for the field-period maintenance.

Conceptual Design of the Replacement Unit Employing a Re-usable HT Shield and Manifolds



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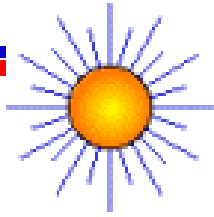


- The replacement unit of each field-period is subdivided into two units with a toroidal width of ~ 9 m and which are closed rings in poloidal direction.
- There are two concentric coolant access pipes to the replacement unit, located at the bottom of the 0 degree(or 120, 240 degree) cross section, one for helium and one for Pb-17Li.
- From the access pipes the coolants are routed in the poloidal direction, and then distributed into the concentric manifold channels with toroidal flow direction. These toroidal manifolds feed the breeder modules via concentric coolant access pipes in radial directions.

Characteristic Feature of the Replacement Unit Design



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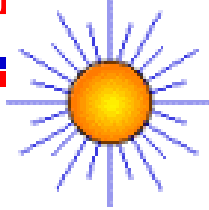


- It is possible to separate the breeder modules from the manifold ring after the replacement unit has been extracted by moving it in toroidal direction.
- The idea is to have a replacement unit as a spare part, and to refurbish the manifold ring outside after the power plant went back into operation.

Access Pipes to Connecting Coolant Manifolds



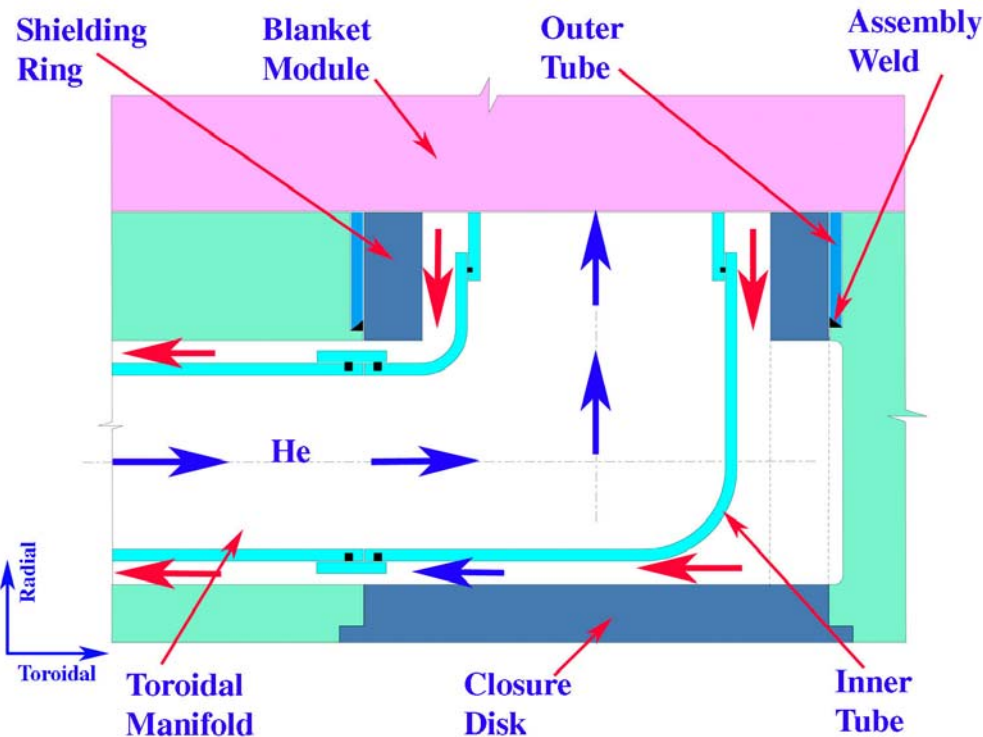
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➤ To disconnect the breeder modules from the manifolds, closure discs at the outer surface of the manifold ring have to be opened, using bayonet-like geometry for force transfer and thin sealing welds.

➤ After removal of the inner tubes between inlet and outlet flow with sliding seals, a shielding ring can be removed and the assembly weld at the outer tube can be cut with in-bore tools.

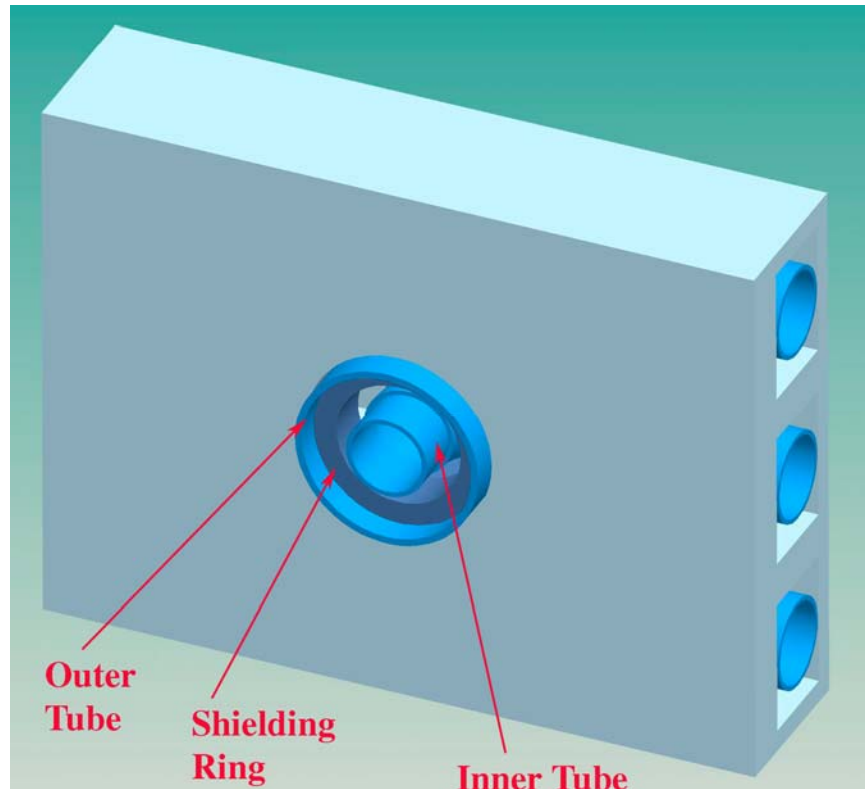
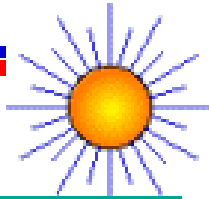
➤ This design offers the possibility to have the assembly welds located about 10 cm inside the manifold in order to provide additional shielding for this weld. This is not possible in the case of the port maintenance, where the assembly weld has to be cut/re-welded with an articulated boom working from the plasma side.



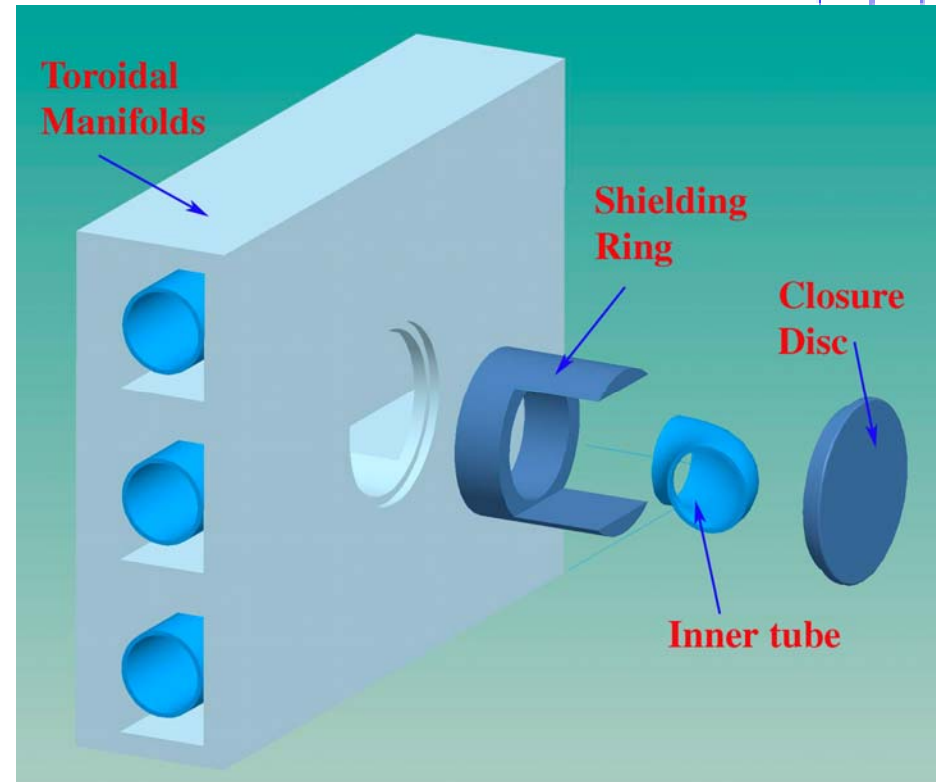
3D Drawings Showing the Access Pipes to Connecting Coolant Manifolds



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View from the front of manifolds

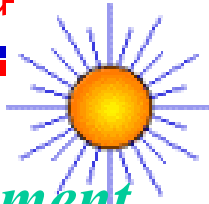


View from the back of manifolds

Toroidal Movement of the Replacement Unit, Clearance to the Low Temperature Shield



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In a previous study, we had already investigated such a movement and found:

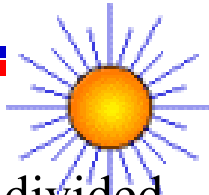
It is feasible to move the replacement unit (~60 cm) out in toroidal direction after locally shaving slightly the shield and adding the materials removed to the blanket.

- Total thickness of the replacement unit of 100 cm (63 cm (breeding zone) + 37 cm (HT shield and manifolds)) would be extracted in toroidal direction, and the low temperature shield would stay at the power core during the maintenance operation.
- Can local shaving the blanket provide a space for removal the replacement unit of 100 cm?

Possible Way: (1) Reduction of the Radial Depth of the Breeding Zone



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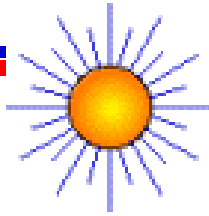


- The nominal thickness of the breeder zone is about 50 cm. This depth is divided into two channels, and the estimated LM velocity about ~ 0.06 m/s.
- From MHD pressure drop of view, we can tolerate an increase of this velocity by about a factor of 5. Therefore, the radial depth of the breeder zone can be reduced from 50 cm to 10 cm. Such a reduction has certainly an impact on tritium breeding and neutron shielding.
 - Assuming the ratio between thinned zones and total FW surface area is small, such a reduction may be compensated for by an increase of the breeding zone thickness in other regions with more space available.
 - The most critical point of the shielding is the limitation of the neutron damage in the winding pack of the coil. It has to be checked if there are coil winding packs located at the locations.

Possible Way: (2) Local Replacement of Breeding Zones by “Shield Only” Zones



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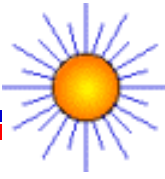


- Previous analyses have indicated that the Shield-Only zone employing WC as shielding material must be about 60 cm thick to ensure sufficient shielding of the coils
- The reduction of tritium breeding by replacing the breeding zones by shielding material must be compensated for by increased breeding in other zone.

Verify Clearances for Removing the Replacement Unit at Toroidal Angle $\theta=60^\circ$ and 50°



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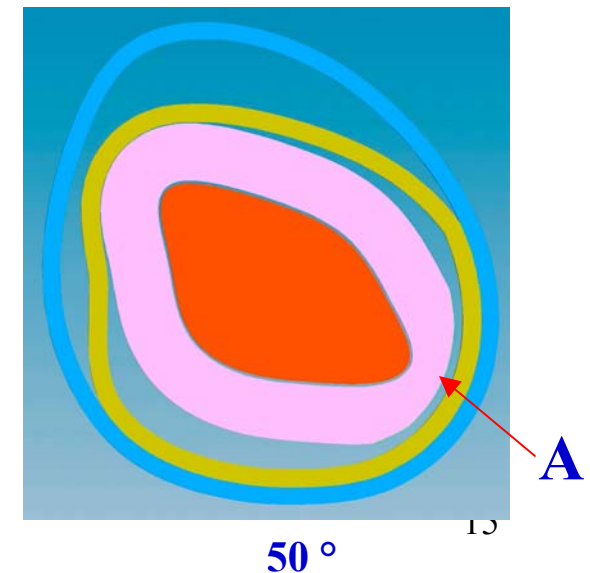
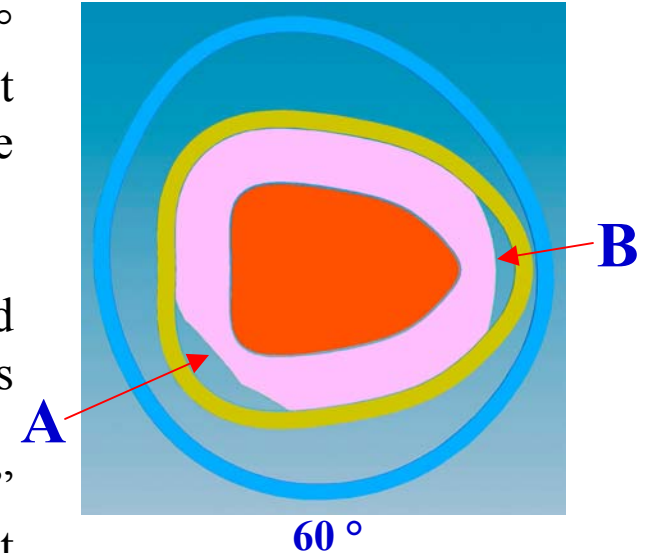
➤ The cross section of the low temperature shield at $\theta=0^\circ$ has to allow for the movement of the replacement unit (PINK) at 60° , 50° , 40° , 30° , 20° and 10° during the withdrawal operation.

➤ The replacement unit has to be shaved to ~ 45.5 cm and 58.5 cm at location A and B, respectively, for the cross section of LT shield at $\theta=60^\circ$ to avoid interference.

-To meet the minimum thickness of “Shield Only” design requirement, the cross section of the coil at 30° needs to be enlarged ~ 15 cm locally.

-Can we locally add materials to the LT shield at the Location A and B to maintain sufficient shielding to the coil?

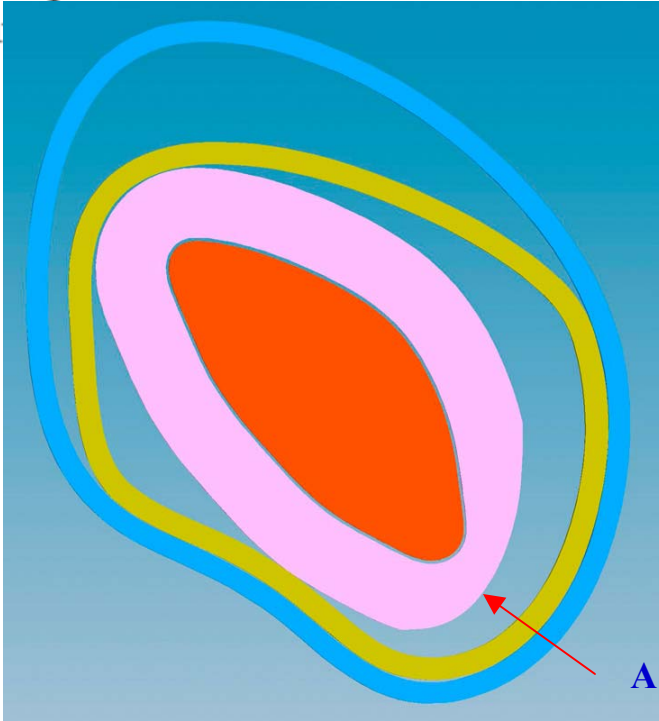
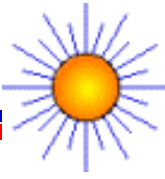
➤ The replacement unit has to be shaved to about 62.1 cm at the location A for the cross section of the LT shield at $\theta=50^\circ$. It means the breeding zone would be reduced to ~ 15 cm, or the “Shield Only” design would be placed.



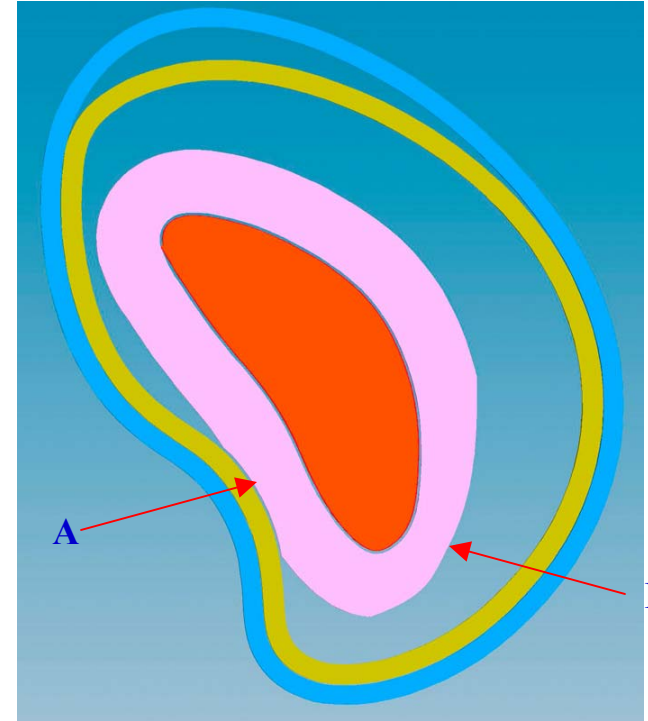
Verify Clearances for Removing the Replacement Unit at Toroidal Angle $\theta=40^\circ$ and 30°



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40°



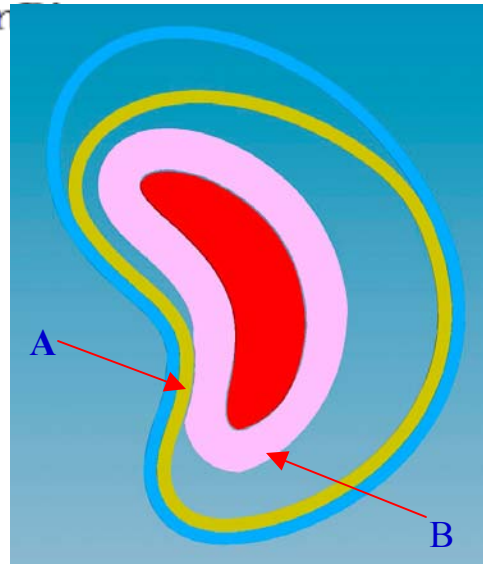
30°

- The replacement unit has to be shaved to ~ 58 cm at the location A for the cross section of LT shield at $\theta=40^\circ$. To solve this issue, it needs to enlarge the coil about ~ 2 cm at the Location A to place a Shield Only module.
- The replacement unit would be shaved to about 78 cm and 66.4 cm at location A and B respectively for the cross section of the LT shield at $\theta=30^\circ$.

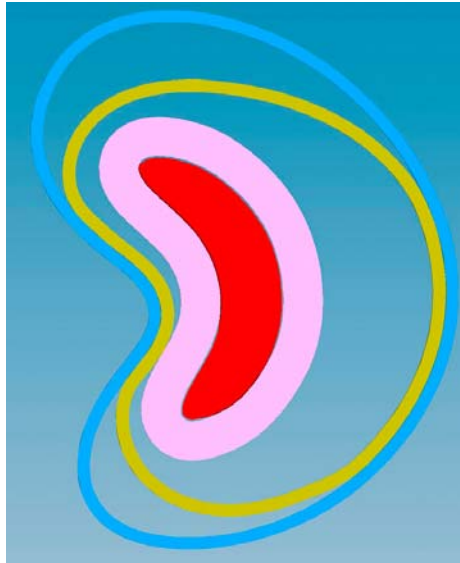
Verify Clearances for Removing the Replacement Unit at Toroidal Angle $\theta=20^\circ$, 10° and 0°



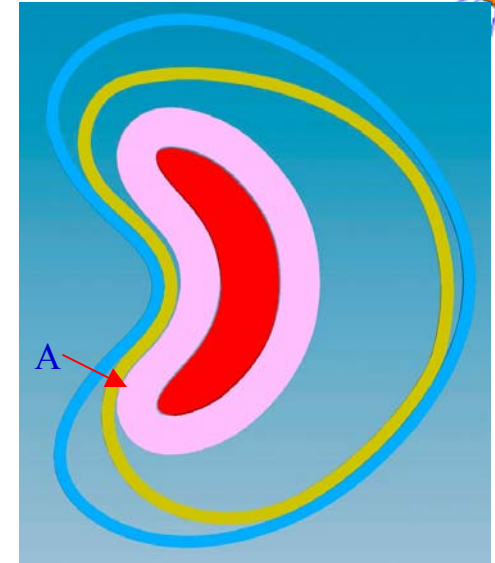
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20°



10°



0°

- The thickness of the replacement unit would be shaved to ~ 81.8 cm and 81.4 cm at location A and B, respectively, for the cross section of LT shield at $\theta=20^\circ$.
- The thickness of the replacement unit would be shaved to about 88.0 cm at the location A for the cross section of the LT shield at $\theta=0^\circ$.
- *The motion analysis shows that there are not enough space at toroidal angle $\theta=40^\circ$ and $\theta=30^\circ$ to allow for the replacement unit removal if the thickness of the replacement unit maintains the minimum thickness of the “Shield Only” design (~ 60 cm).*

Summary



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- A possible solution of protecting the assembly welds between the access pipes connecting to the coolant manifolds for the port maintenance with DCLL blankets has been found. This solution has to be verified by 2D neutronics analysis.
- A conceptual design of the replacement unit for field-period maintenance with DCLL blanket is proposed. The combination of the 63 cm blanket modules attached to a 37 cm thick zone serving as HT shield and manifolds is suggested.
- CAD motion analysis found that there are not enough clearances to remove the replacement unit out in toroidal direction and keep thickness of the replacement unit as the same as the minimum thickness of the “Shield Only”. Possible ways allowing for this movement are:
 - Reduction of the radial depth of the breeding zone;
 - Local replacement of breeding zones by “Shield Only” zones;
 - Can we locally enlarge the coil ~14.5 cm and 2 cm at the toroidal angle of 30° and 40°, respectively to place the Shield Only module?*
 - Can we locally add materials to the LT shield at the Location A and B to maintain sufficient shielding to the coil at $\theta=20^\circ$?*