Updated ARIES-ACT1 Power Core Configuration and Maintenance for R=6.25 m

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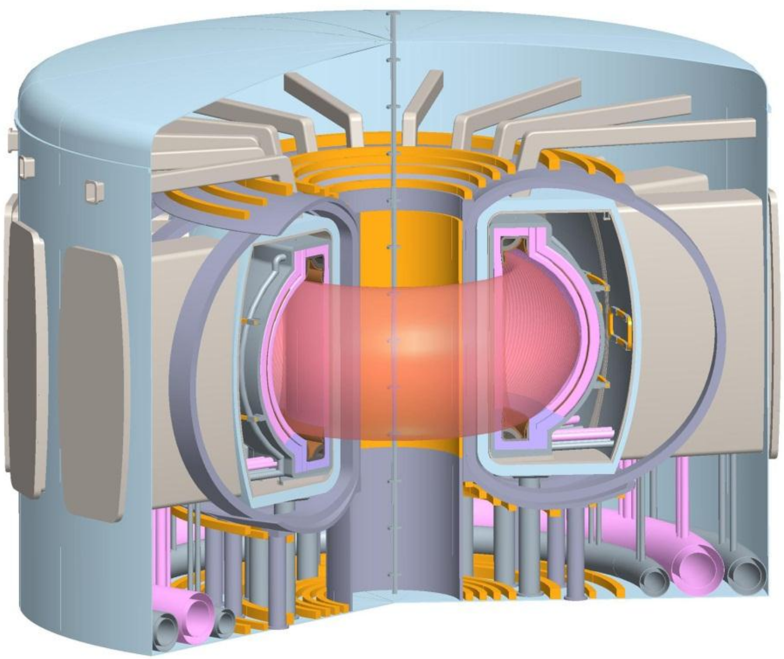
Major Parameters of the ARIES-ACT1 Power Plant

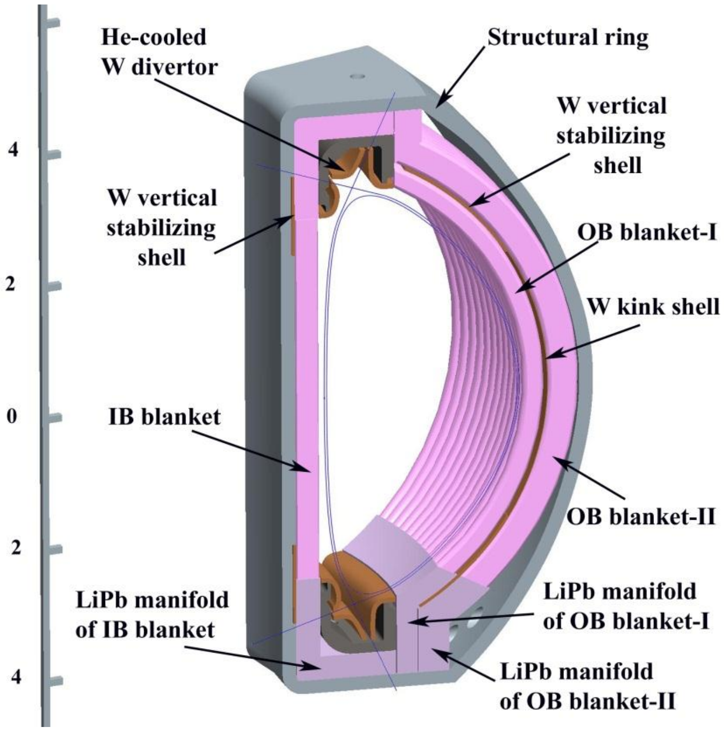


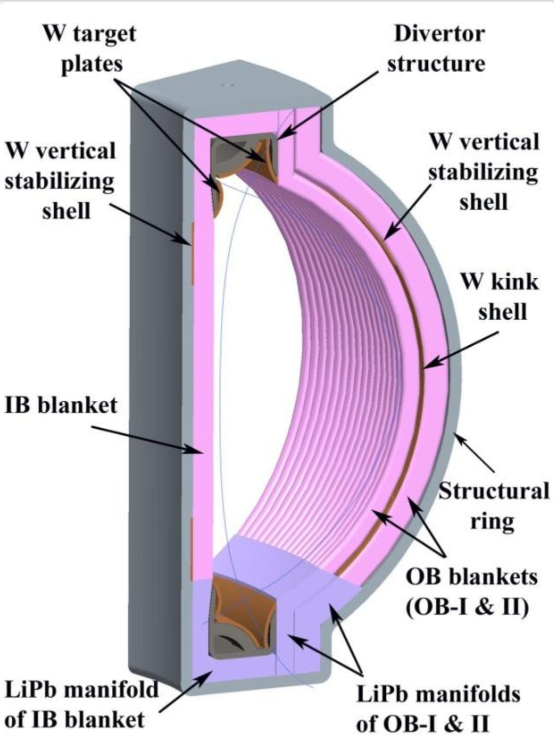
Parameter		**Value**
Major radius	R	**6.25 m**
Aspect ratio	A	**4**
Elongation	k	**2.1**
Toroidal field on axis	B_o	**6 T**
Plasma Current	I_p	**10.93 MA**
Fusion power	P_f	**1813 MW**
Thermal power	P_{th}	**2016 MW**
Recirculating power	P_{recirc}	**154 MW**
Net electric power	P_e	**1006 MW**
Average wall load at FW	P_n	**2.3 MW/m^2**
Maximum wall load at FW		**3.6 MW/m^2**
Power conversion efficiency	η_{th}	**57.9 %**

A Comparison of the ARIES-AT and ARIES-ACT1 Power Core

	ARIES-AT	ARIES-ACT1
Major radius	5.5 m	6.25 m
FW/Blankets	LiPb cooled SiC/SiC structure T_{Inlet}/T_{Outlet}=760/1050˚C η_{th}=58.8%	LiPb cooled SiC/SiC structure T_{Inlet}/T_{Outlet}=740/1030˚C η_{th}=57.9%
Structural ring or HT Shield	LiPb cooled SiC/SiC structure and B-FS filler	He-cooled ODS steel structure T_{Inlet}/T_{Outlet}=650/680˚C
Upper/Lower Divertors	LiPb cooled SiC/SiC structure T_{Inlet}/T_{Outlet}=650/780˚C	He-cooled W-based divertor and ODS steel cartridge T_{Inlet}/T_{Outlet}=700/800˚C
Vacuum vessel	Water-cooled FS structure and WC operating at ~50˚C	He-cooled Bainitic FS (3Cr-3WV) operating in ~400-500˚C
LT shield		Water-cooled Bainitic FS and WC operating at the room temperature

Updated Replacement Unit for R=6.25 m





Presented at last ARIES Meeting

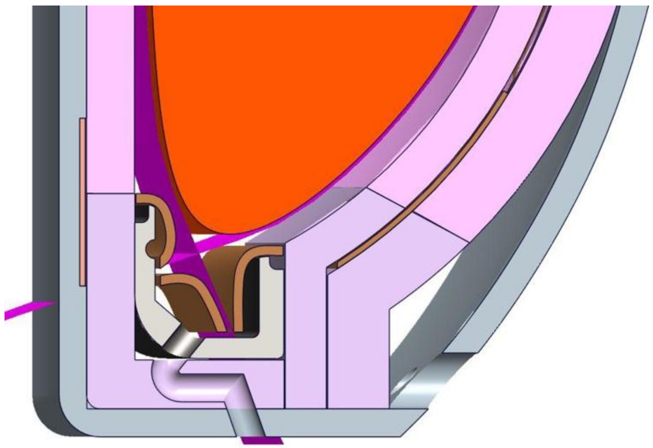
- R=5.5 m
- Straight inboard blanket
- LiPb running from bottom to top, and flowing through the upper divertor region behind and above the divertor structure
- **Short** inboard and outboard divertor slots

Updated replacement unit

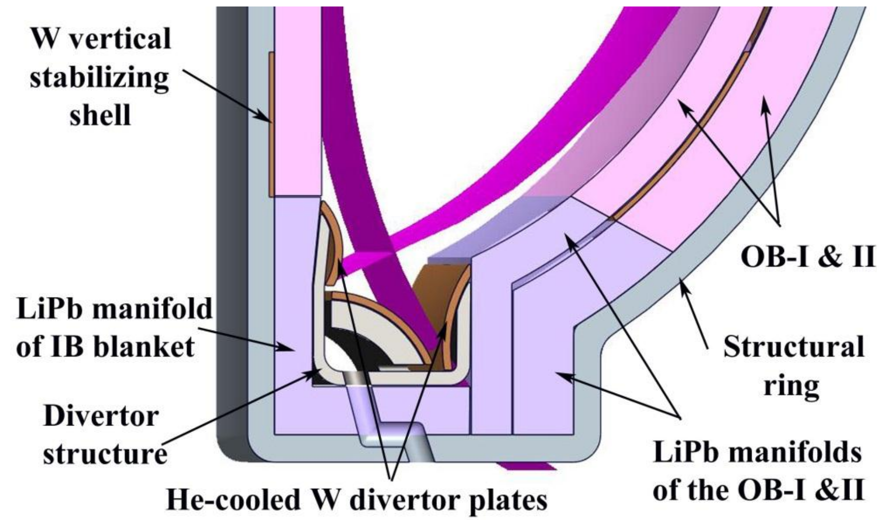
- R=6.25 m, new outmost plasma flux lines provided by Chuck.
- The inboard blanket at the upper and lower divertor regions is tapered by ~7 cm
- **Longer** inboard and outboard divertor slots

Divertor Slots Can Possibly Satisfy Requirement from Edge Plasma Physics

R=5.5 m



R=6.25 m(new outmost plasma flux lines)



Radial build of divertor region:
- ✓ **6** cm W plate + **15** cm ODS structure
- ✓ **35** cm SiC/SiC LiPb
- ✓ **20** cm ODS structural ring

Radial build of divertor region:
- ✓ **6** cm W plate + **8** cm ODS structure
- ✓ **28** cm SiC/SiC LiPb
- ✓ **20** cm ODS structural ring

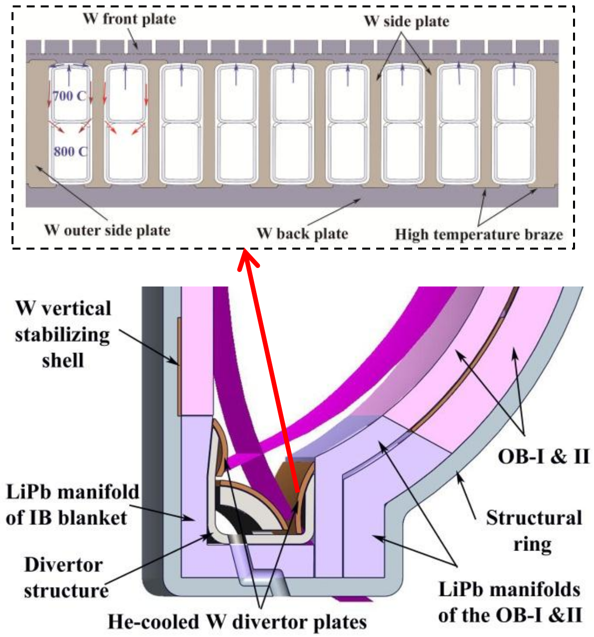
Design requirement of the target plates: IB slot ≥ ~45 cm, OB slot ≥ ~75 cm

IB divertor slot: ~30 cm
OB divertor slot: ~55 cm

IB divertor slot: ~48 cm
OB divertor slot: ~76 cm

- Each target plate is configured with a single curvature to allow for the cartridges being inserted into the coolant channels.

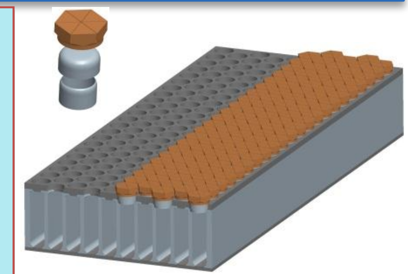
Integration of the He-cooled W-based Divertor in the ACT1 Power Core



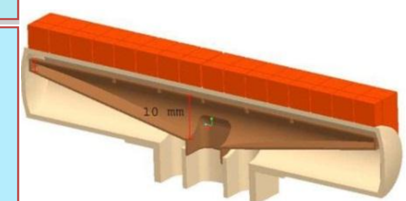
Divertor region of the ARIES-ACT1

- The selection of the divertor depends on the peak heat flux and heat flux profile of the ACT1.
- Plate-type divertor concept is selected for the ARIES-ACT1 with peak-time average heat flux of 10.6 MW/m^2.

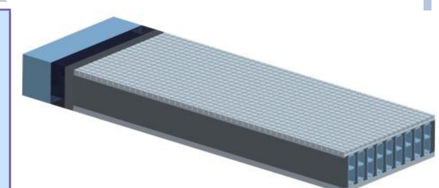
- Fingers arranged over the entire plate
- Imping-jet cooling, T_{in}/T_{exit}=700/800 °C
- **<u>Allowable heat flux up to~14 MW/m^2</u>**
- Avoiding **joints** between W and ODS steel at the high heat flux region
- ~550,000 units for a power plant



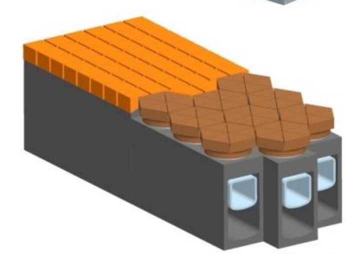
- T-Tube divertor: ~1.5 cm dia. X 10 cm long
- Impinging-jet cooling, T_{in}/T_{exit}=700/800 °C
- **<u>Allowable heat flux up to~11 MW/m^2</u>**
- ~110,000 units for a power plant



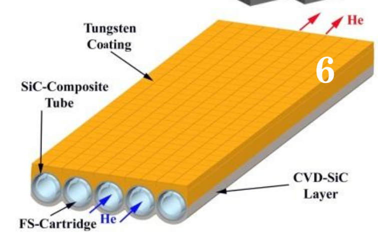
- Plate divertor: 20 cm x 100 cm
- Impinging-jet cooling, T_{in}/T_{exit}=700/800 °C
- **<u>Allowable heat flux up to~9 MW/m^2</u>**
- ~750 units for a power plant



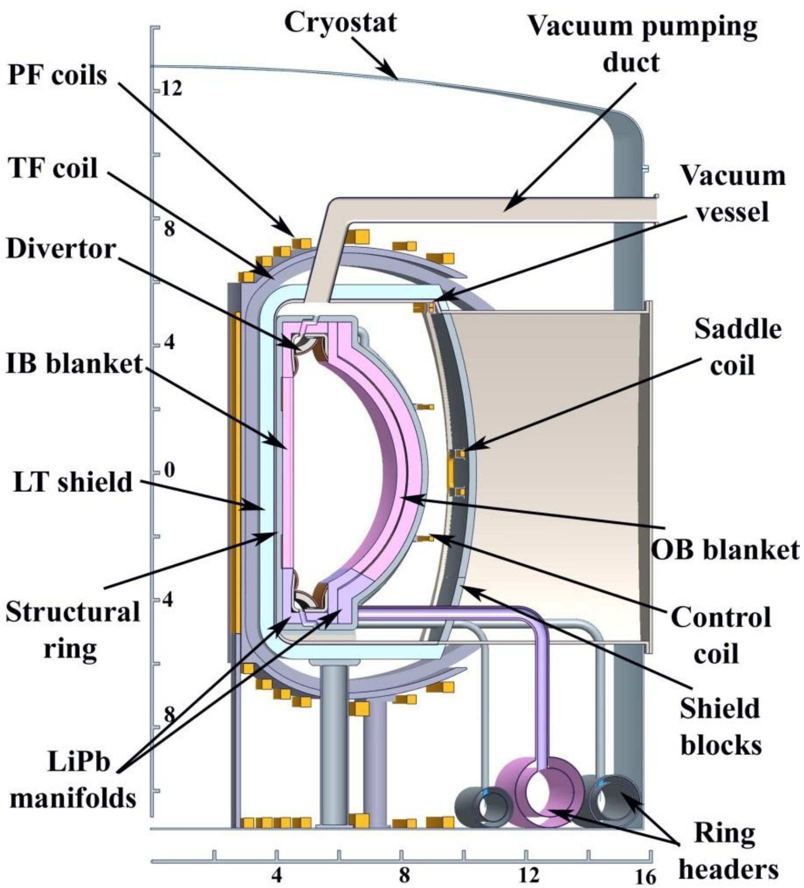
- Two zone divertor (any combination of the plate and finger and T-tube)
- Fingers for q>~8 MW/m^2, plate for q<~8 MW/m^2
- Decreased number of finger units



- Tubular or T-Tube He-cooled SiC/SiC divertor
- Impinging-jet cooling, T_{in}/T_{exit}=600/700 °C
- **<u>Allowable heat flux up to~5 MW/m^2</u>**



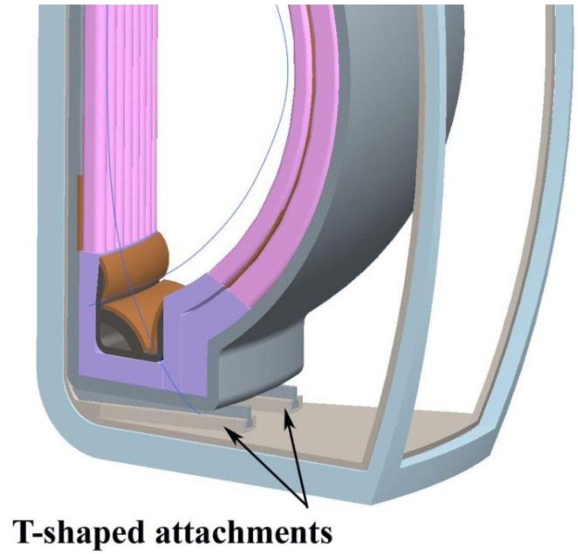
Overall Layout of the ARIES-ACT1 Power Core



Cross section of the ACT1 power core (1/16 sector)

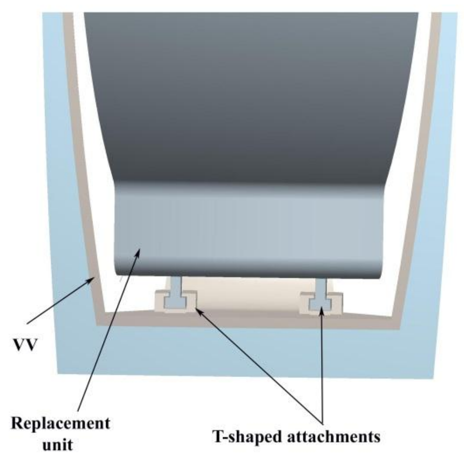
- All the coolant access pipes are connected to the components close to bottom plate.
- Cutting/Reconnection of all the access pipes is located in the port, and all the pipes and shield blocks would be removed for sector maintenance.
- Control coils are supported by the structural ring and be removed to the upper corner of the VV for the sector removal.
- Shield blocks are arranged in the front of the VV port to protect the coils, and they would be cooled by helium if the active cooling required.
- The saddle coil can be attached to the upper shield block and removed together during maintenance.
- Maintenance ports are arranged between the TF coils, and there is only one vacuum door located at the end of the port for each sector.

T-shaped Attachment and Rail System Utilized for Sector Alignment

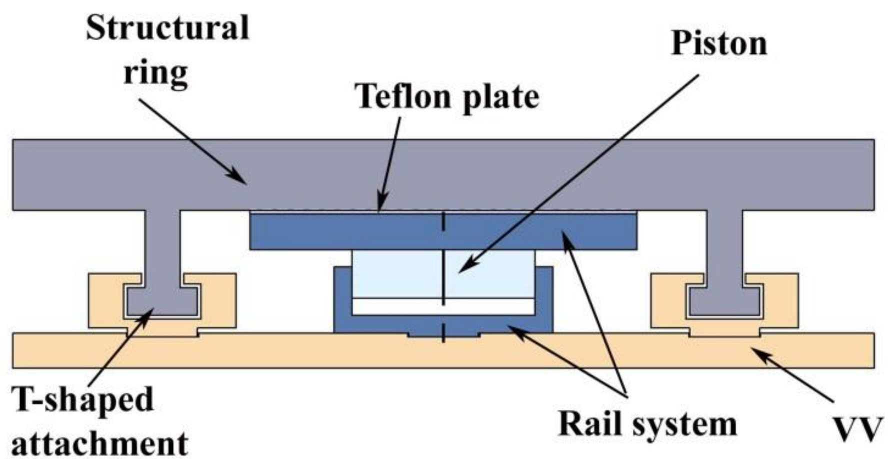


T-shaped attachment for sector support (Bird view)

- During the installation, a rail system with 2 or 3 vertical pistons would be inserted and the sector will be supported by the rail system for the vertical and horizontal alignment.
- There are wide gaps in the wedge allowing the precise alignment of the sector in all directions.
- After the alignment, the grooves of the attachment have to be filled with a suitable liquid metal (possibly a Cu-alloy) and fixed in the position by freezing the T-shaped attachment grooves. Then, the rail system will be withdrawn.

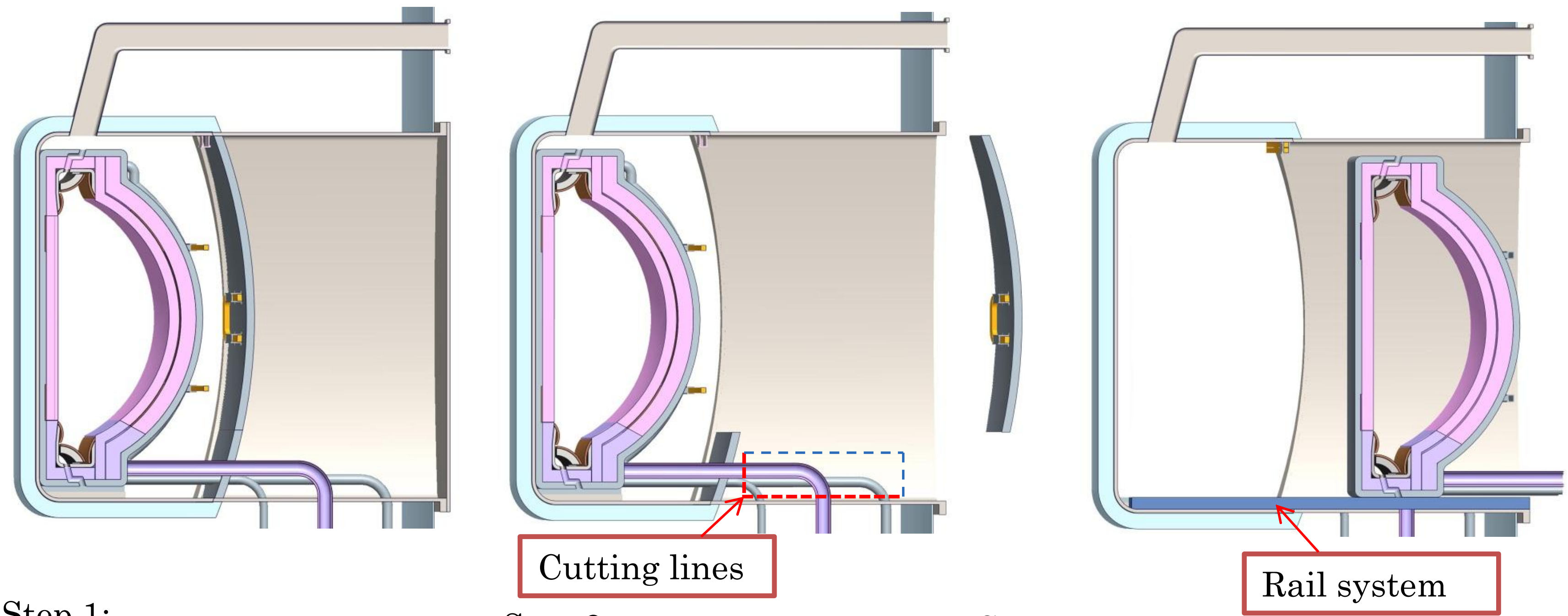


Side view of the sector and T-shaped attachment



Cross-section of T-shaped attachment and rail system

Using the Rail System for Maintenance Operation

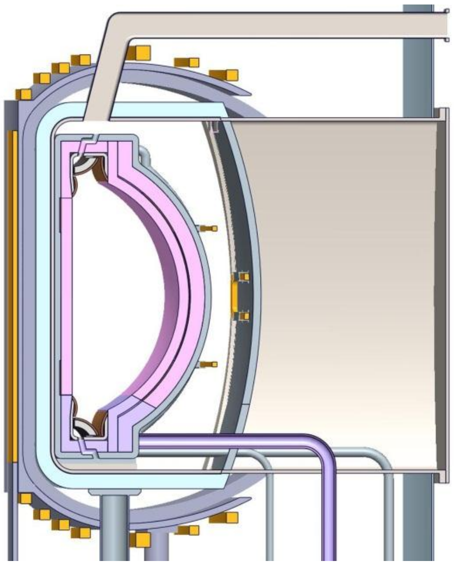


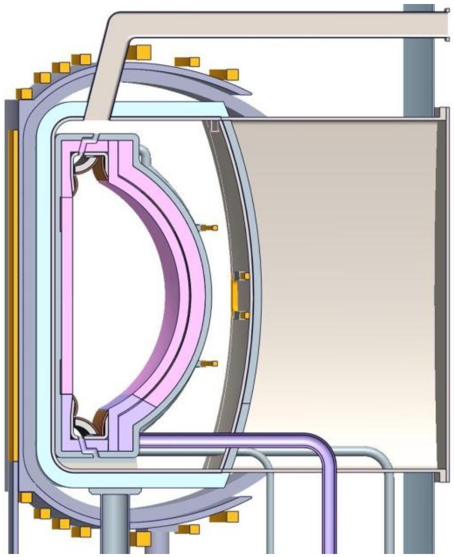
Step 1:
- Engage a transfer flask to the port to avoid any spread of radioactivity during maintenance.
- The transfer flask should have a new blanket, rail system and maintenance equipment.

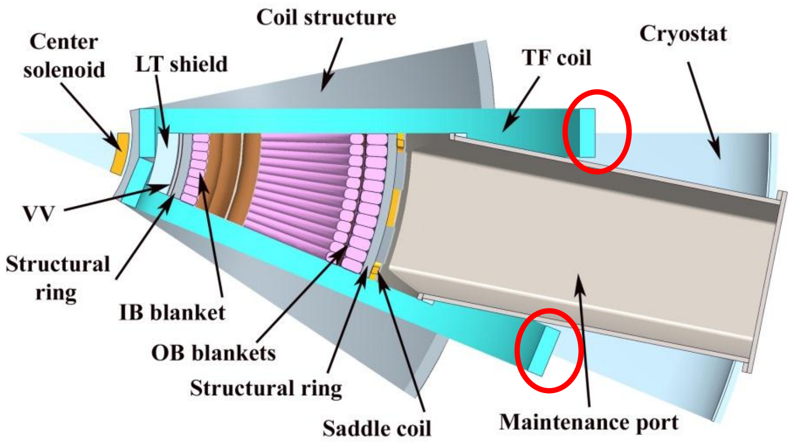
Step 2:
- Open the VV door
- Remove the upper shield block with the saddle coil together into the flask
- Cut and remove the access pipes
- Remove the lower shield block
- Remove the control coils to the upper VV

Step 3:
- Insert the rail system into the space between the SR and VV
- Pressurize the pistons and use the pistons to support the sector
- Melt the metal in the wedges of T-shaped attachment
- Pull out the sector from the plasma chamber into the flask
- Install a new sector and remove the rail system into the flask.

Remaining Design Issue 1: the Location of the VV Door and Local Shield







1: VV door at the end of port and shield blocks arranged near the SR

- ✓ access pipes penetrate the shield blocks and don't require vacuum seal
- ✓ larger vacuum volume (inside VV and port) for 10 MPa He leak
- ✓ lower disruption loads
- ✓ easier rail system access

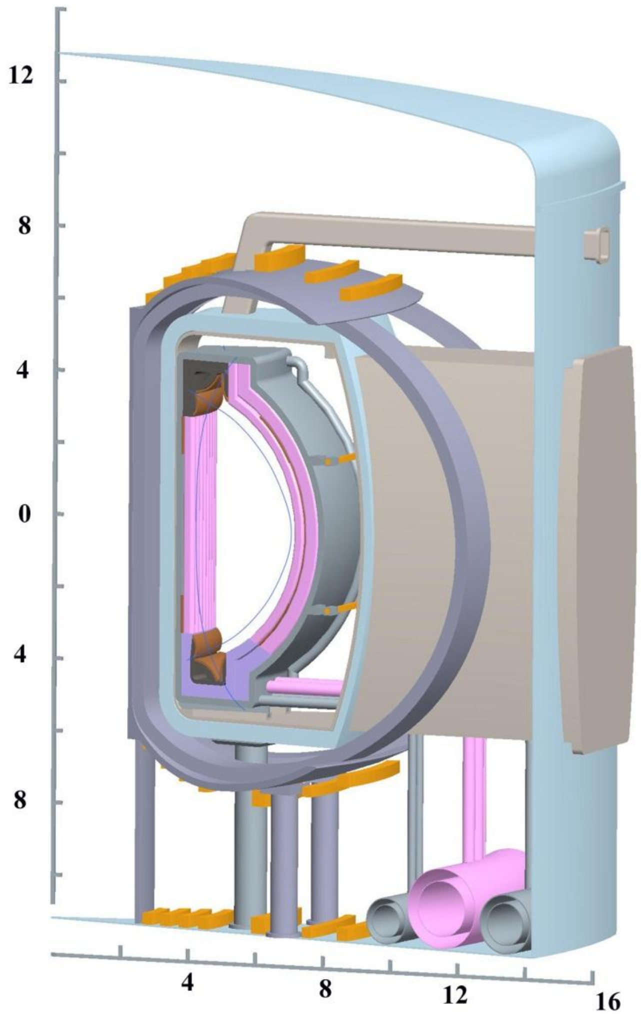
2: VV door near the SR and H_2O-cooled shield behind the door

- ✓ double containment
- ✓ smaller vacuum volume for 10 MPa He leak
- ✓ access pipes penetrating the door and shield block and require vacuum seel on the door
- ✓ cutting the vacuum seals for access pipe removal

3: VV door at the end of port and local shield in front and side of the TF outer legs

- ✓ no penetration through door
- ✓ larger vacuum volume for He leak
- ✓ lower disruption loads
- ✓ easer rail system access
- ✓ need change the cross-section of TF outer leg

Remaining Design Issue 2: Layout of the Vacuum Pumping Ducts



One of the ACT1 power core sectors

1. Utilize ARIES-AT design approach:
   - ✓ Vacuum ducts penetrating the upper and lower divertor regions and using the space between the structural ring and the VV to form a vacuum path.
   - ✓ Pumping out from the top for each sector
2. Arrange an vacuum duct from bottom to top and connect to the top vacuum duct for pumping from the top (proposed by Chuck)
   - ✓ Space at the bottom is limited
   - ✓ Need re-arrange all the access pipes
   - ✓ Size of the vacuum pumping duct?

More Remaining Design Issues for the ACT1?

1. Location of the VV door and local shield

   what would be the thickness of He-cooled shield blocks if the design option 1 was slected?

2. Layout of the vacuum pumping duct

   the size of the vacuum pumping ducts?

3. ?

4.?

Or More?