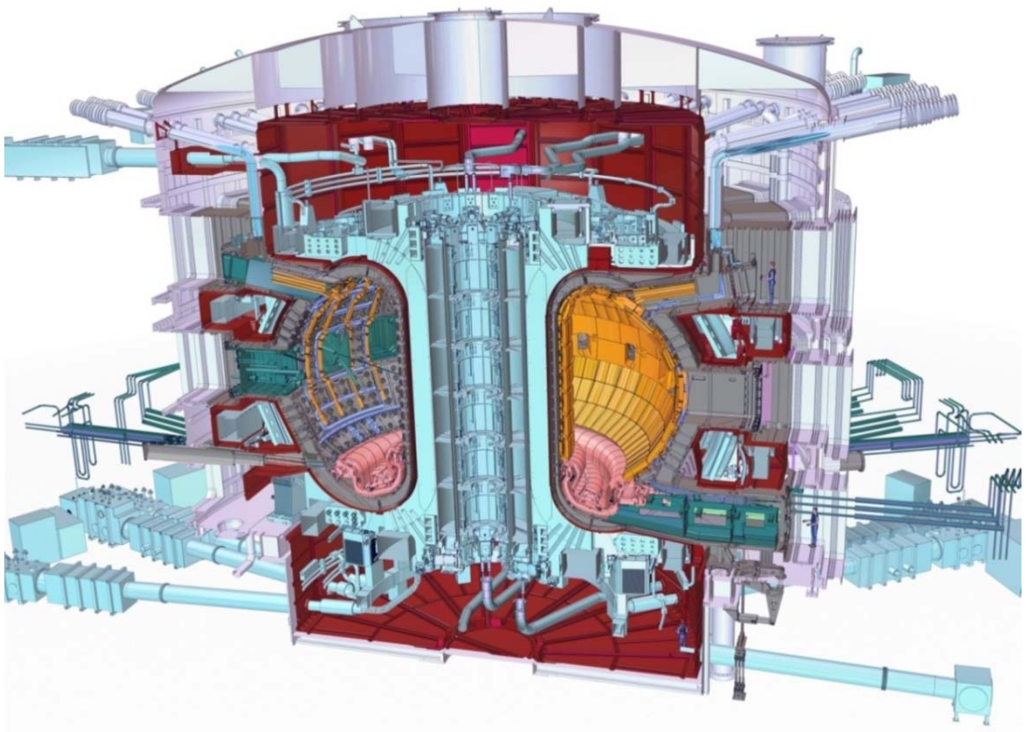
Engineering of In-vessel Components for ITER



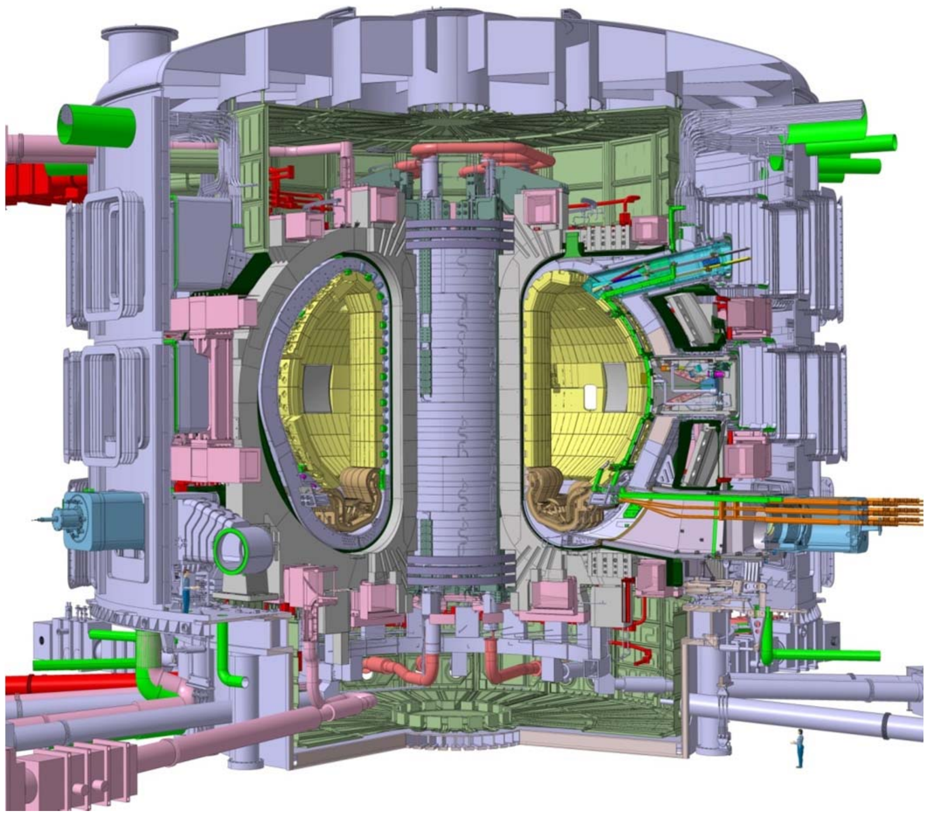
T. Hirai

ITER Organization, In-Vessel Component, Divertor Section

Contents

ITER The way to fusion power

- ITER ("the way") is the essential next step in the development of fusion
- The world's biggest fusion energy research project, and one of the most challenging and innovative scientific projects in the world today.
- Its objective:
  - to demonstrate the scientific and technological feasibility of fusion power
  - demonstrate extended burn of DT plasmas, with steady state as the ultimate goal.
  - integrate and test all essential fusion power reactor technologies and components.
  - demonstrate safety and environmental acceptability of fusion.



Tokamak – 29 m high x 28 m dia. & ~23000 t

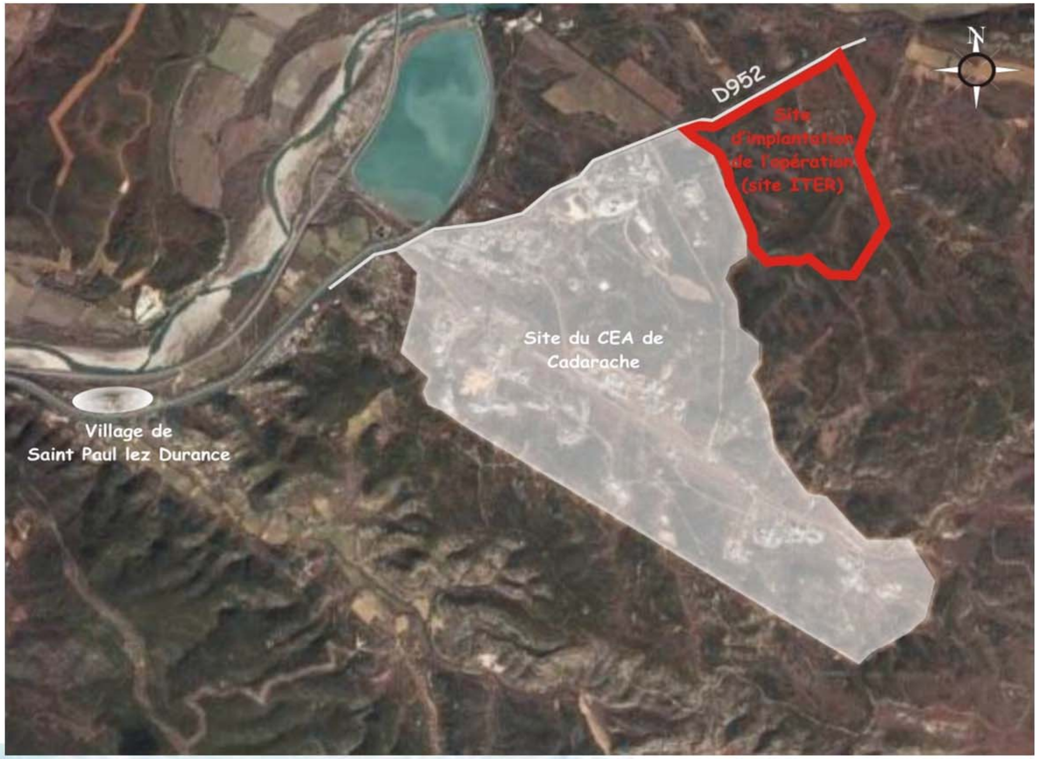
ITER Site

ITER Headquarters :

Saint Paul-lès-Durance,

Provence-Alpes-Côte d'Azur, France.

Site next to **Cadarache**, nuclear research center, CEA



ITER Site in 2011

Contents

ITER In-Vessel Components

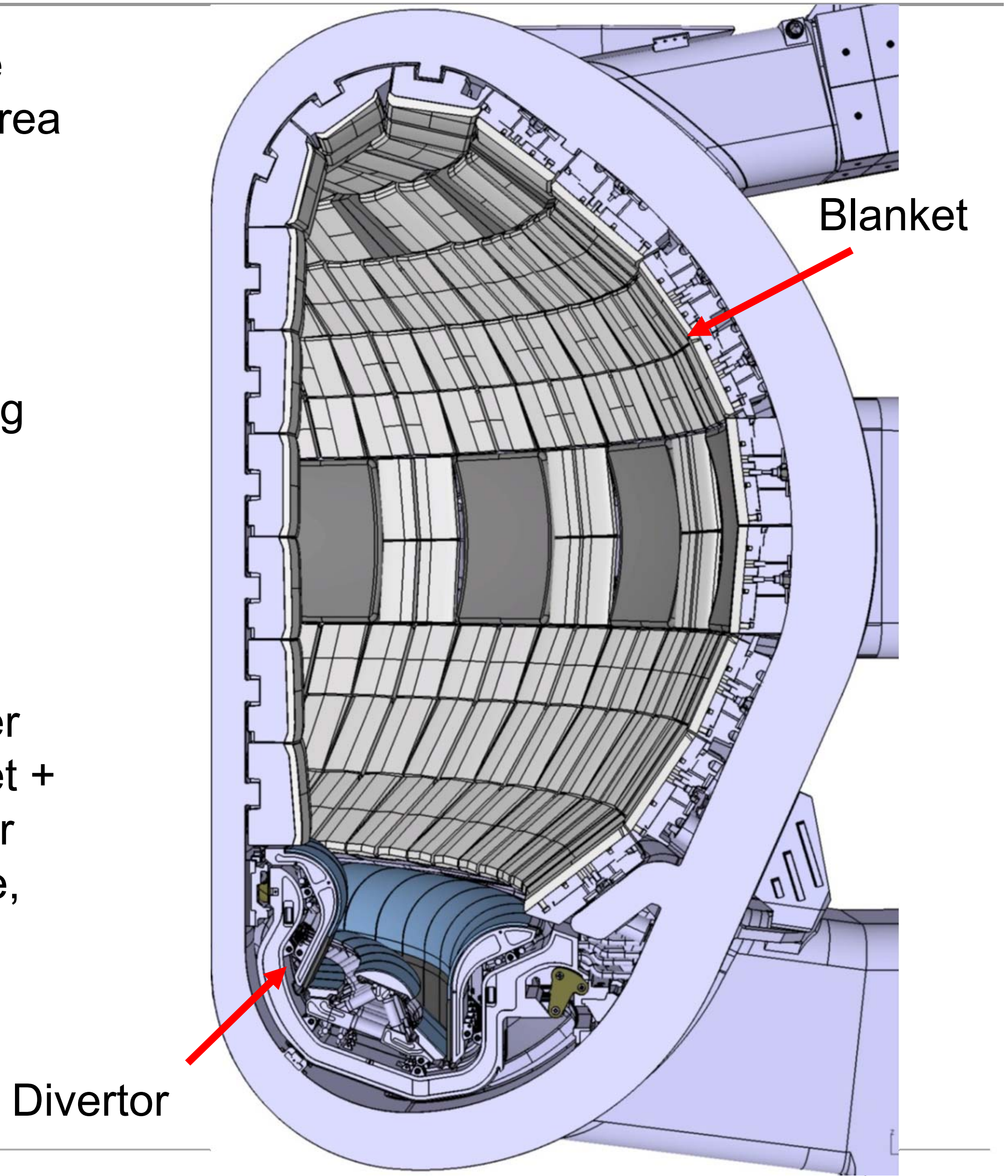
• Divertor and Blanket directly face the thermonuclear plasma and cover an area of about 210 + 620 m^2, respectively.

• All these removable components are mechanically attached to the Vacuum Vessel or Vessel Ports.

• Max heat released in the PFCs during nominal pulsed operation: 847 MW

  – 660 MW nuclear power
  – 110 MW alpha heating
  – 77 additional heating

• Removed by three independent water loops (~1200 ks/s each) for the blanket + port plugs and one loop for the divertor (~1000 kg/s), at 3 MPa water pressure, ~70 °C

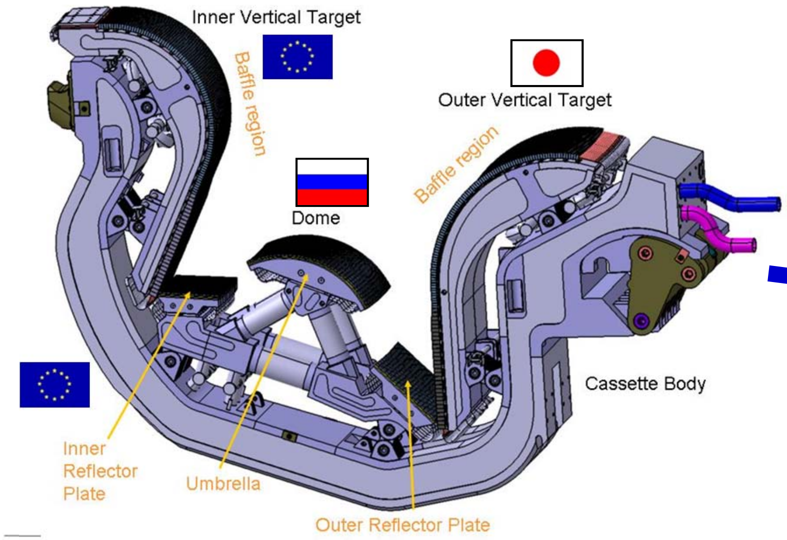


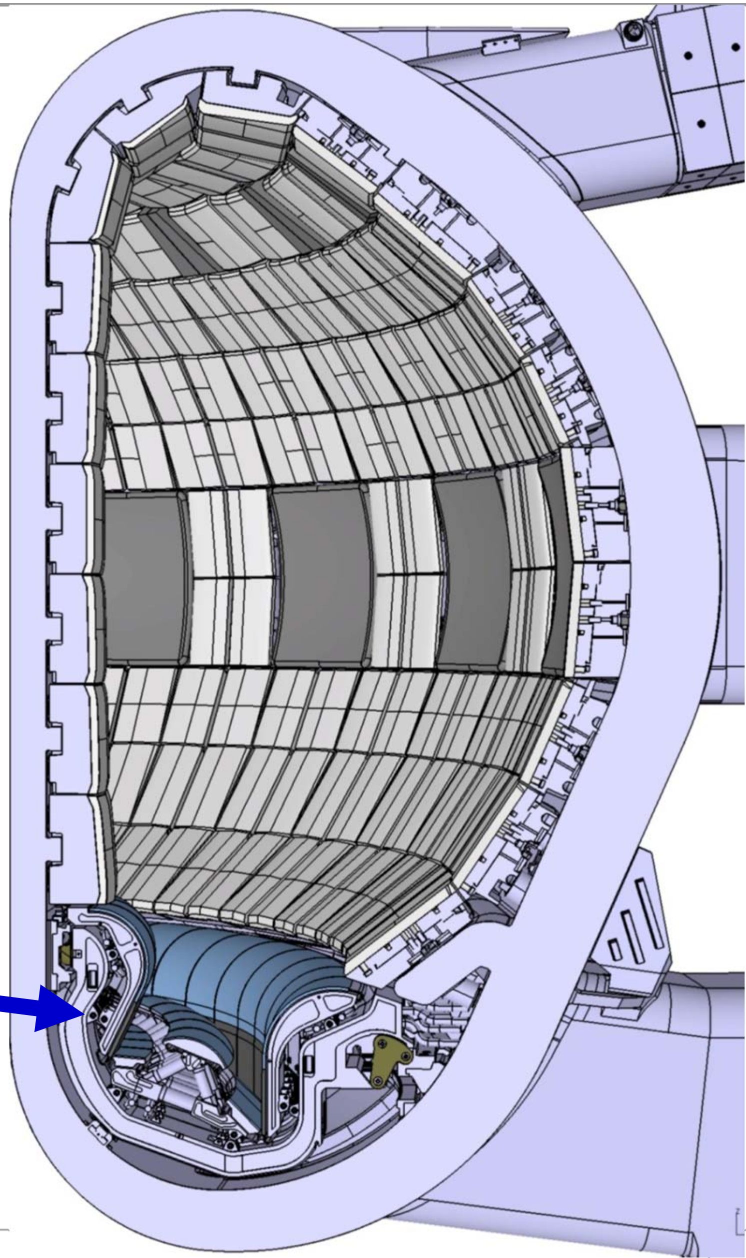
ITER Divertor

Divertor system main functions :

• Exhaust the major part of the plasma thermal power (including alpha power)

• Minimize the helium and impurities content in the plasma



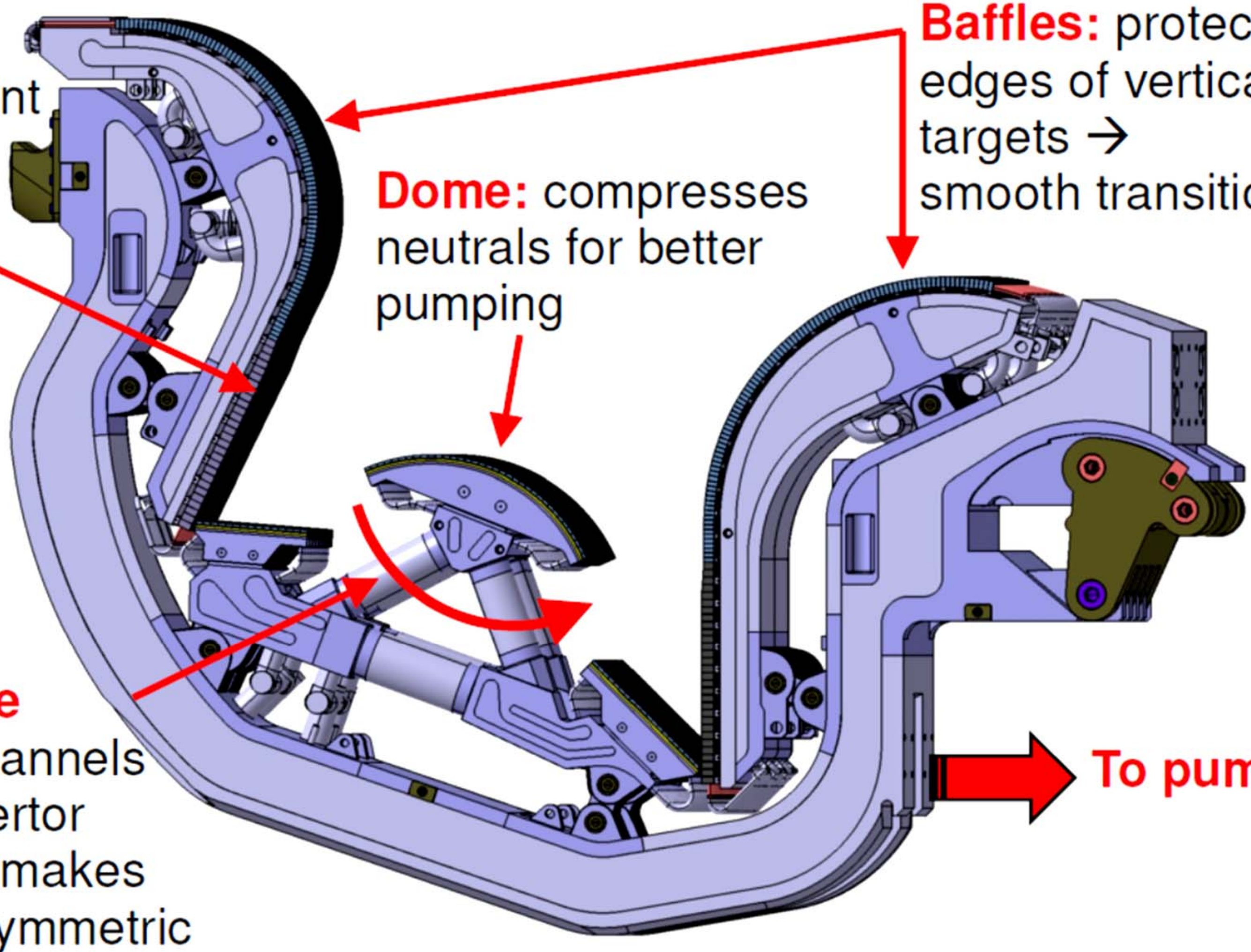


Divertor design

Vertical targets: promote detachment sending neutrals back towards the separatrix strike points

Baffles: protect edges of vertical targets → smooth transition

Dome: compresses neutrals for better pumping



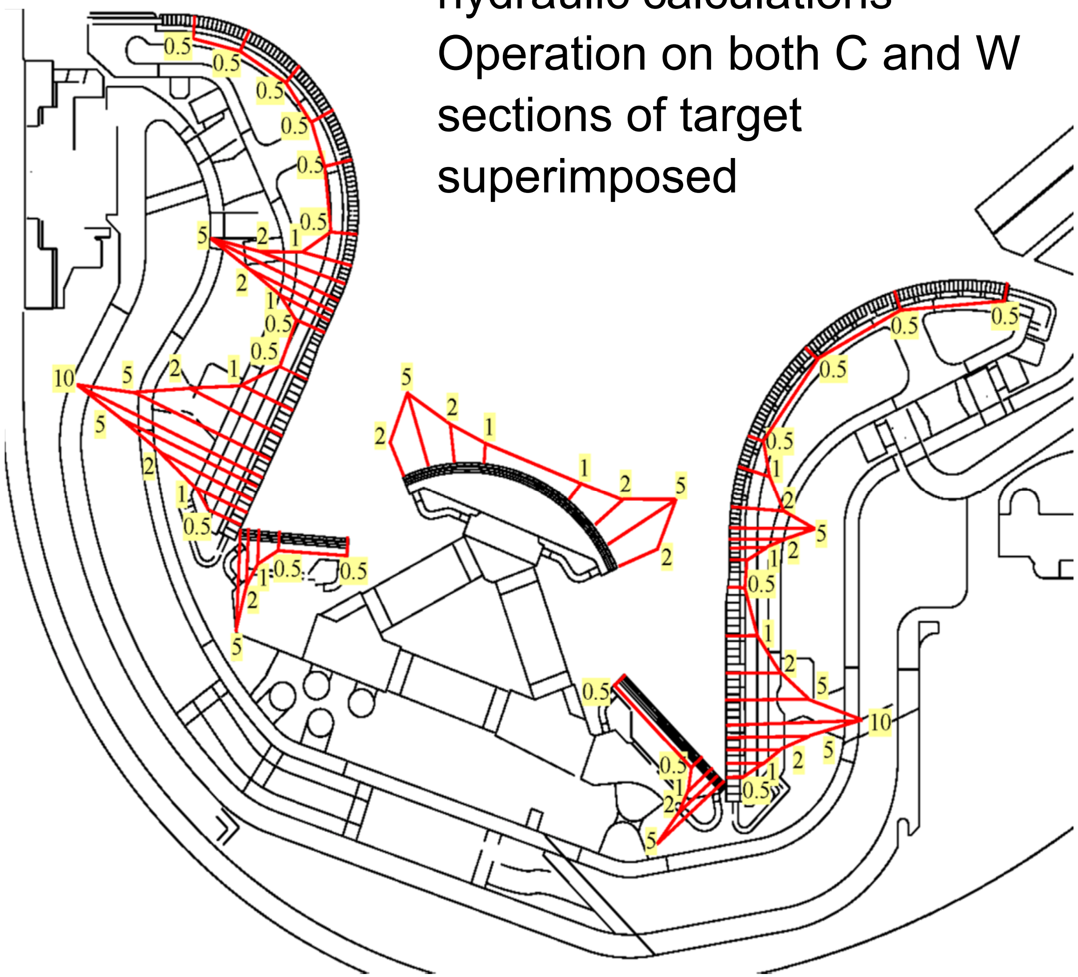
Large conductance between divertor channels increases outer divertor neutral density and makes detachment more symmetric

Design Heat loads of Divertor

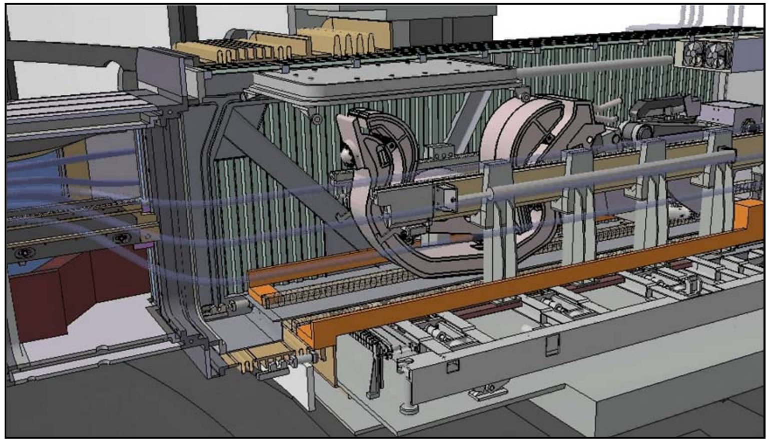
PFCs are qualified for time averaged, steady state loads based on SOLPS simulations for burning plasma, H-mode baseline operation (CFC targets)

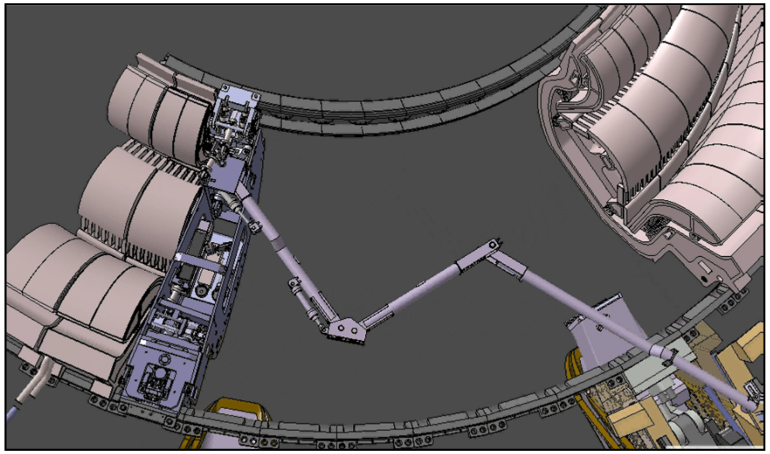
- 10 MWm^{-2} on lower part of vertical targets
- 5 MWm^{-2} on the baffles, dome and reflector plates

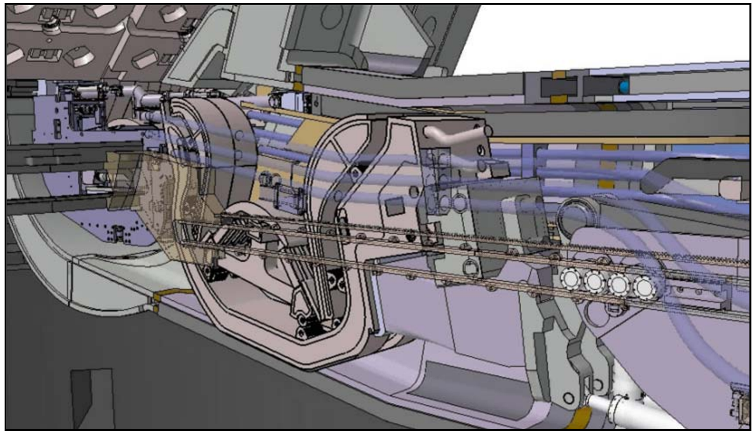
Load envelope for thermo-hydraulic calculations
Operation on both C and W sections of target superimposed



Divertor RH equipments







Three lower ports at port #2, #8 and #14 are allocated for Divertor Remote Handling

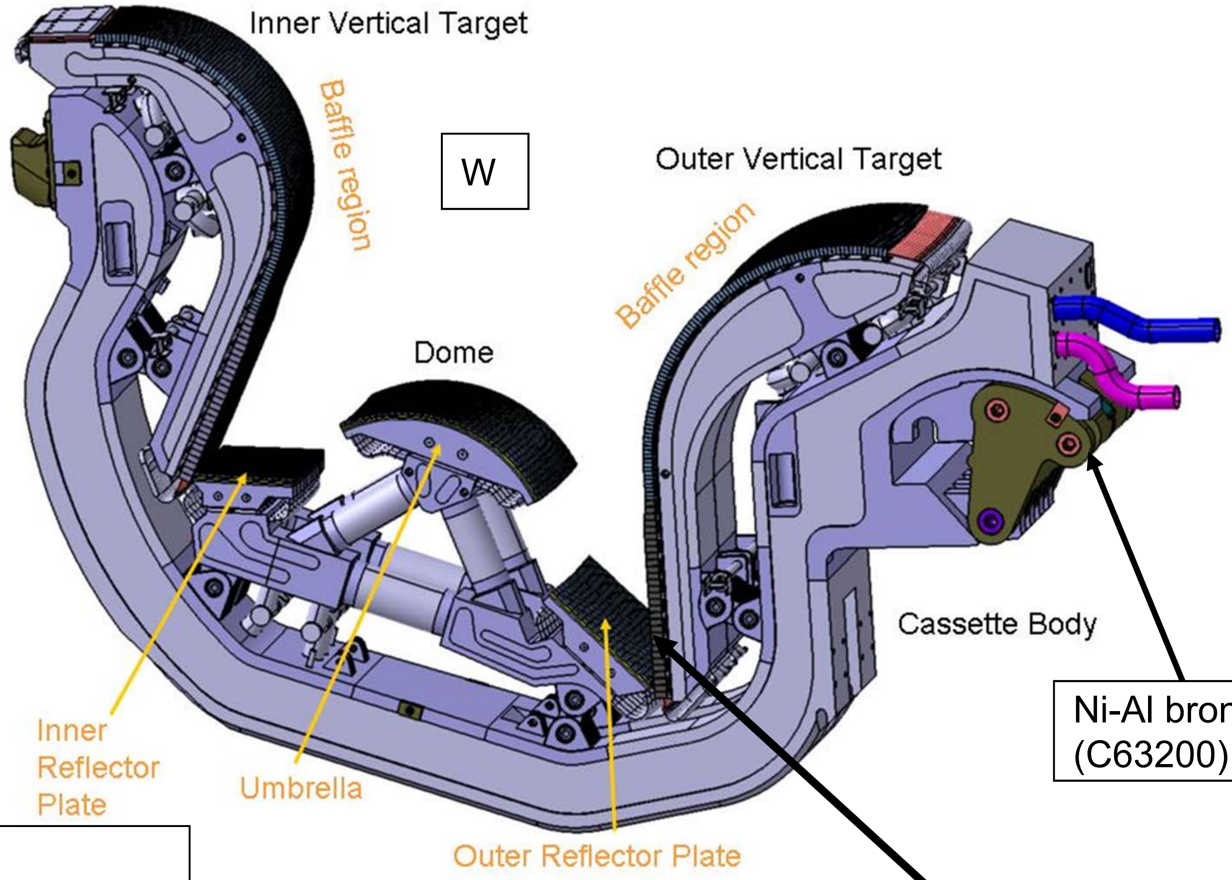
Divertor RH equipment is comprised of Two main types of “cassette mover”:

- **Cassette Multifunctionl Mover (CMM)**
- **Cassette Toroidal Mover (CTM)**

Each are to be equipped with a manipulator arm and RH tooling.

Summary of Divertor Terminology and Materials

Ni-Al bronze
(C63200)

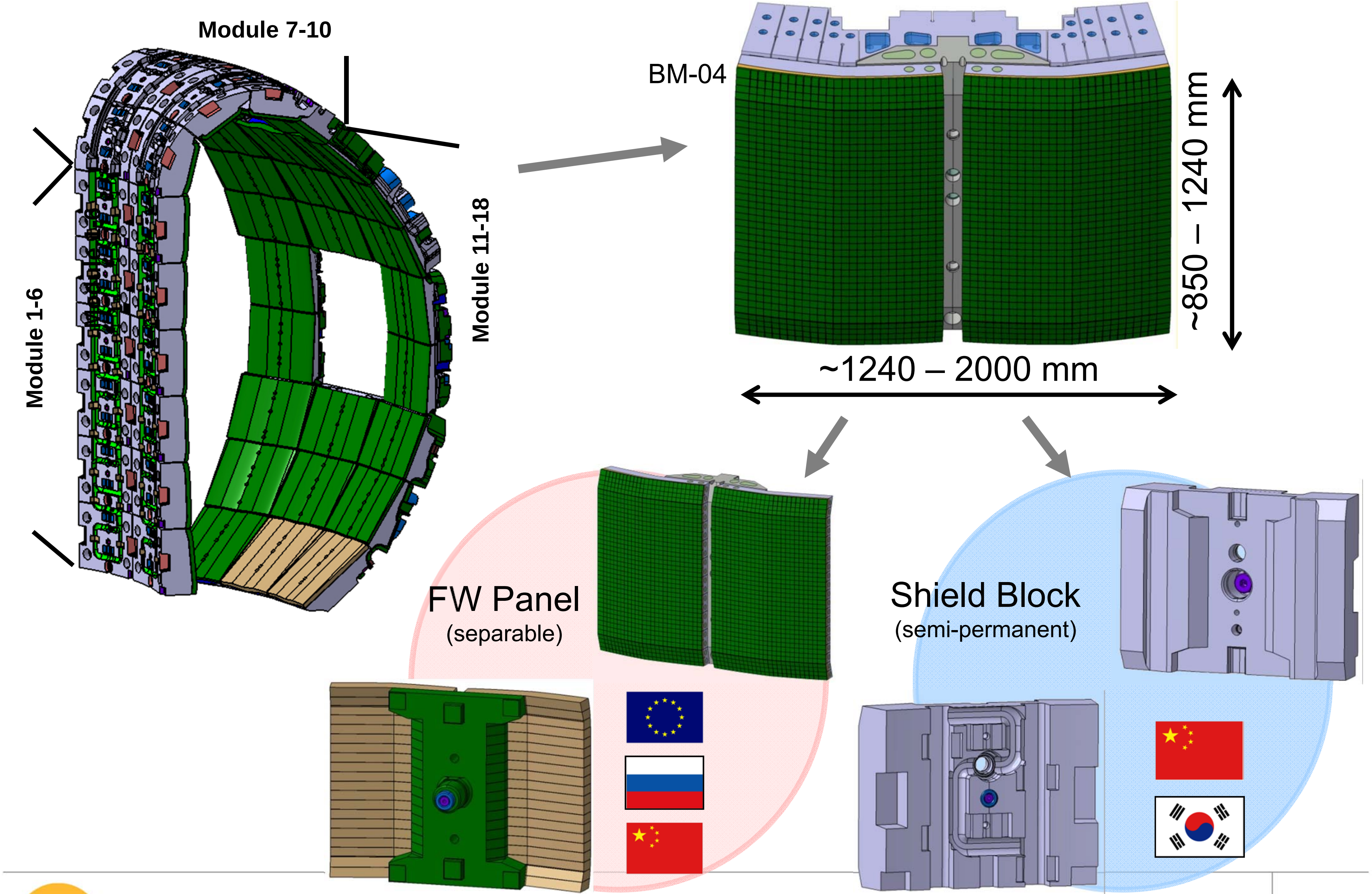


Ni-Al bronze
(C63200)

CFC (first divertor set – H phase)
W (tritium phase)

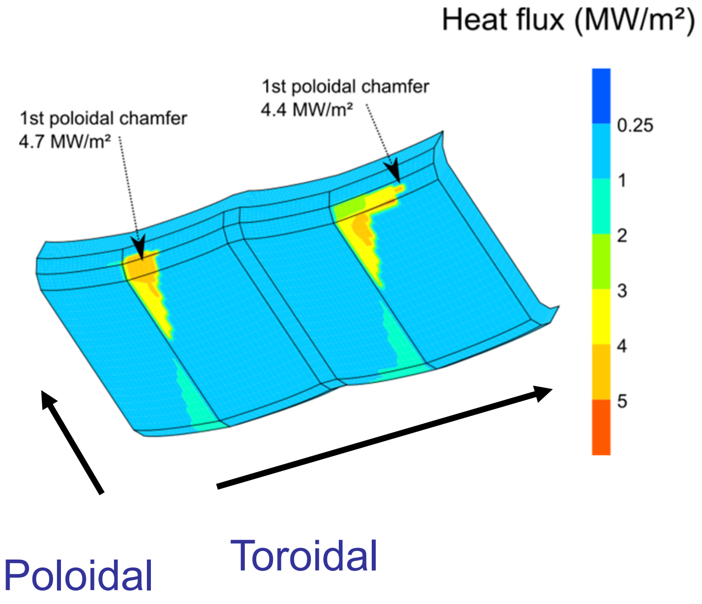
CFC and W: armour
XM-19: all multilinks (lugs and links)
C63200: hollow pins of multilinks
316L(N)-IG: support structures
316L pipe: steel pipes
CuCrZr-IG: heat sink
Steel 660: bolts

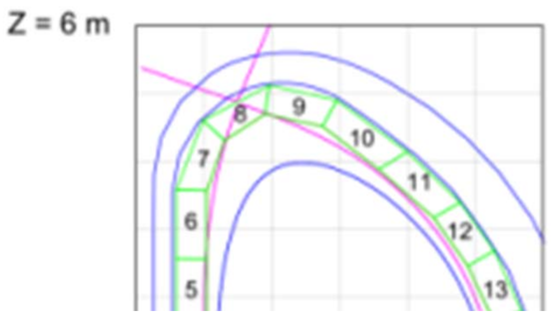
ITER Blanket Modules

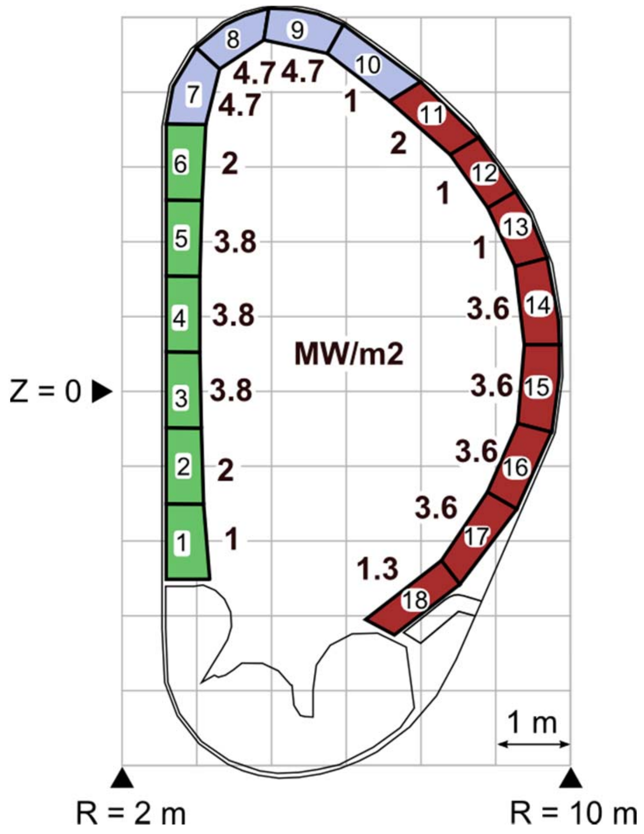


Design Heat load on blanket

Outboard flat top heat load (550 MW)



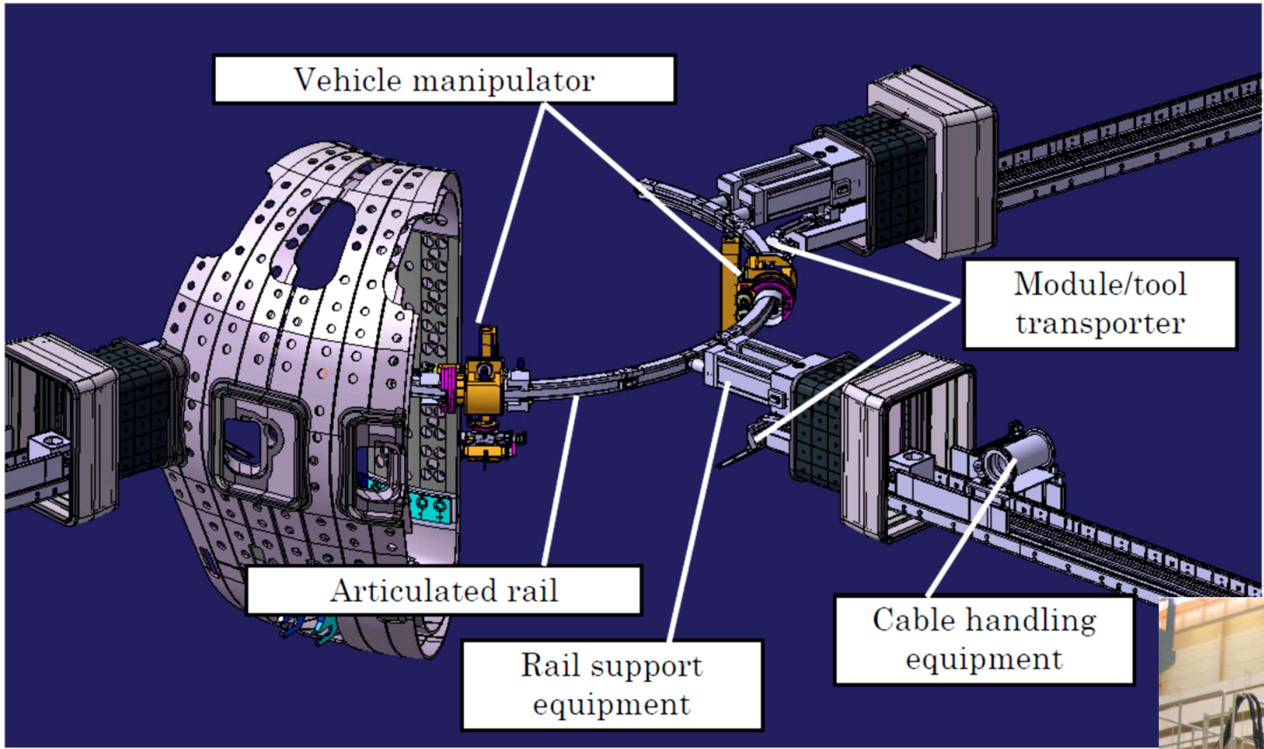




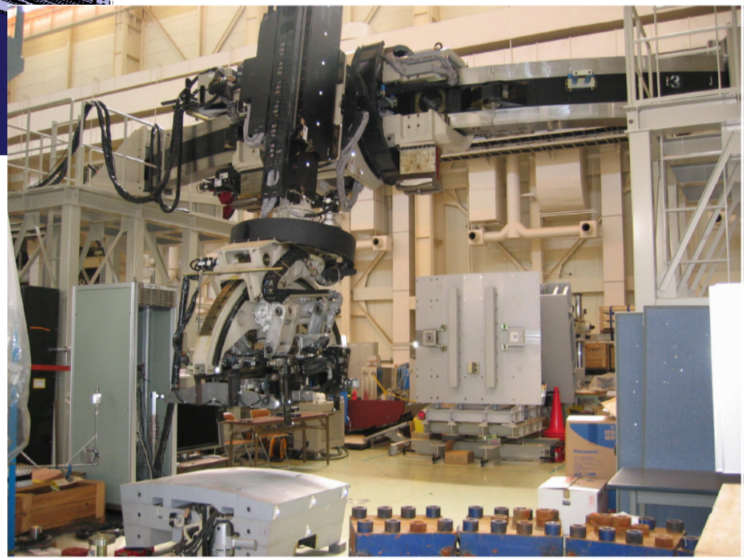
See talk by R. Mitteau

- Group 1 : 1 – 2 MW/m²
  Normal heat flux panels
- Group 2 : 3.5 – 5 MW/m²
  Enhanced heat flux panels

Blanket RH equipments

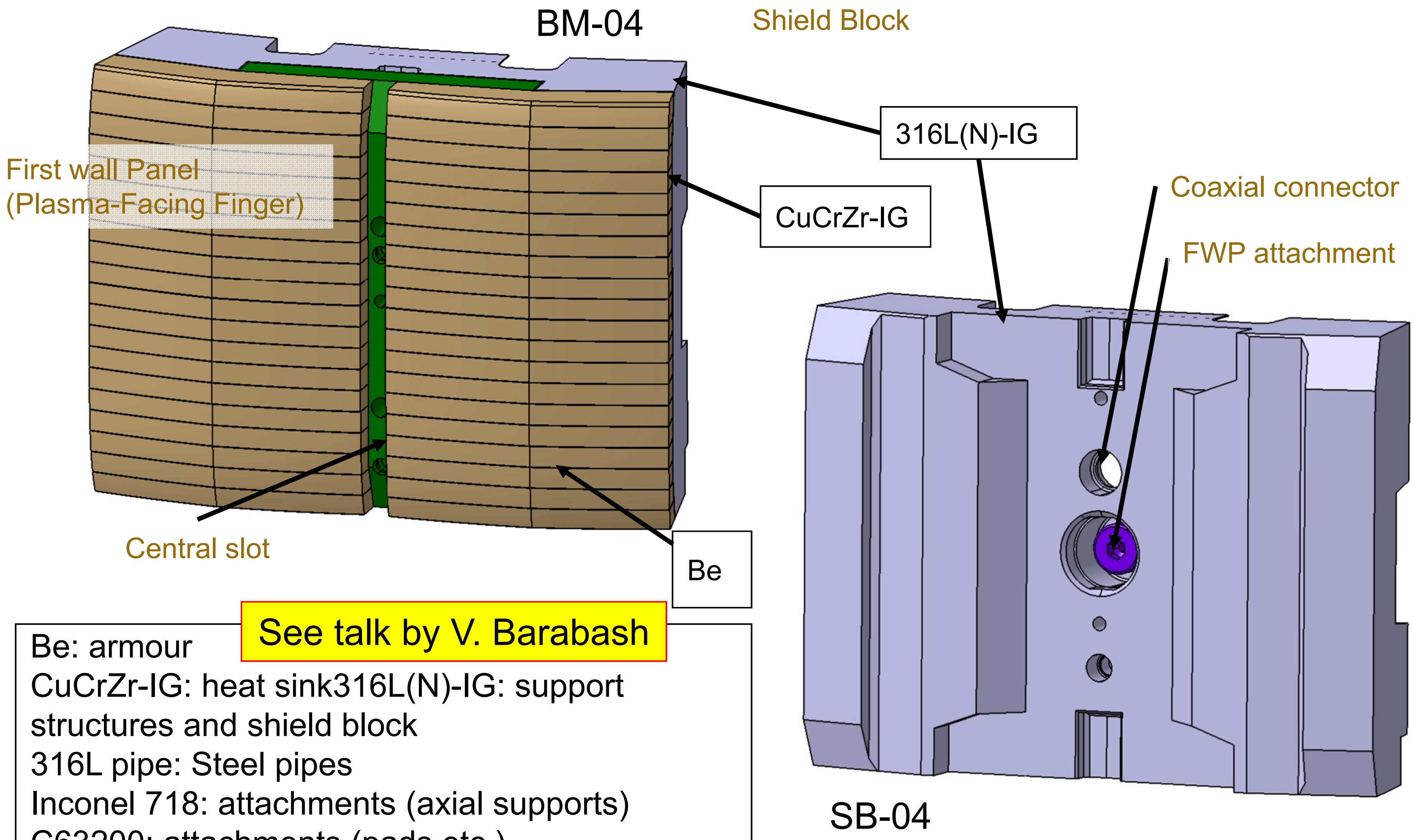


- 4 equatorial ports located at 0, 100, 180 and 280 degrees
- RH operation by In-vessel transporter (IVT) system (handling load 4.5 ton)



Mock-up facility for remote handling

Summary of Blanket Terminology and Materials



See talk by V. Barabash

Be: armour
CuCrZr-IG: heat sink316L(N)-IG: support structures and shield block
316L pipe: Steel pipes
Inconel 718: attachments (axial supports)
C63200: attachments (pads etc.)

Number of components

Comp.	Break-down	Number	
Divertor	OVT PFU	1320	22 x (54 + 6 spares)
	IVT PFU	960	16 x (54 + 6 spares)
	Dome PFU	2040	(10 + 12 + 12) x (54 +6 spares)
Blanket	NHF FW panel	218	440 + 11 spares with ~20 main variants
	EHF FW panel	222	
Divertor	OVT Steel Support	60	54 + 6 spares
	IVT Steel Support	60	54 + 6 spares
	Dome Steel Support	60	54 + 6 spares
	Cassette Body	60	54 + 6 spares
Blanket	Blanket Shield Module	440	about ~40 main variants

Comp.	Break-down	Number	
Divertor	W monoblock for VTs	216 k	(96 x 22 + 93 x 16) x 60
	CFC monoblock for VTs	66 k	(30 x 22 + 28 x 16) x 60
	W tile for Dome	99 k	(30 x 10 + 72 x 12 + 40 x 12) x 60
Blanket	Be tile	~ 1M	

Overview of Material Mass

Material	Application	Mass (ton)
Divertor components		
W	Armor material	53
CFC	Armor material	3
Cu and Cu alloy	Pipes, heat sink, functional material	10
Steel	Structural parts, pipes	430
Ni Al bronze	Knuckle & Nose, pins	21
Blanket components		
Be	Armor material	10
Cu and Cu alloy	Pipes, heat sink, functional material	85
Steel	Structural parts, pipes	1400
Ni Al bronze	Pads, etc.	tbc

Contents

1. ITER Project

2. ITER In-vessel Components: Divertor and Blanket

3. Plasma-facing Units

- Materials, Design, Manufacturing, Non-Destructive Tests -

4. Steel support structures

- Design, Manufacturing, Non-Destructive Tests -

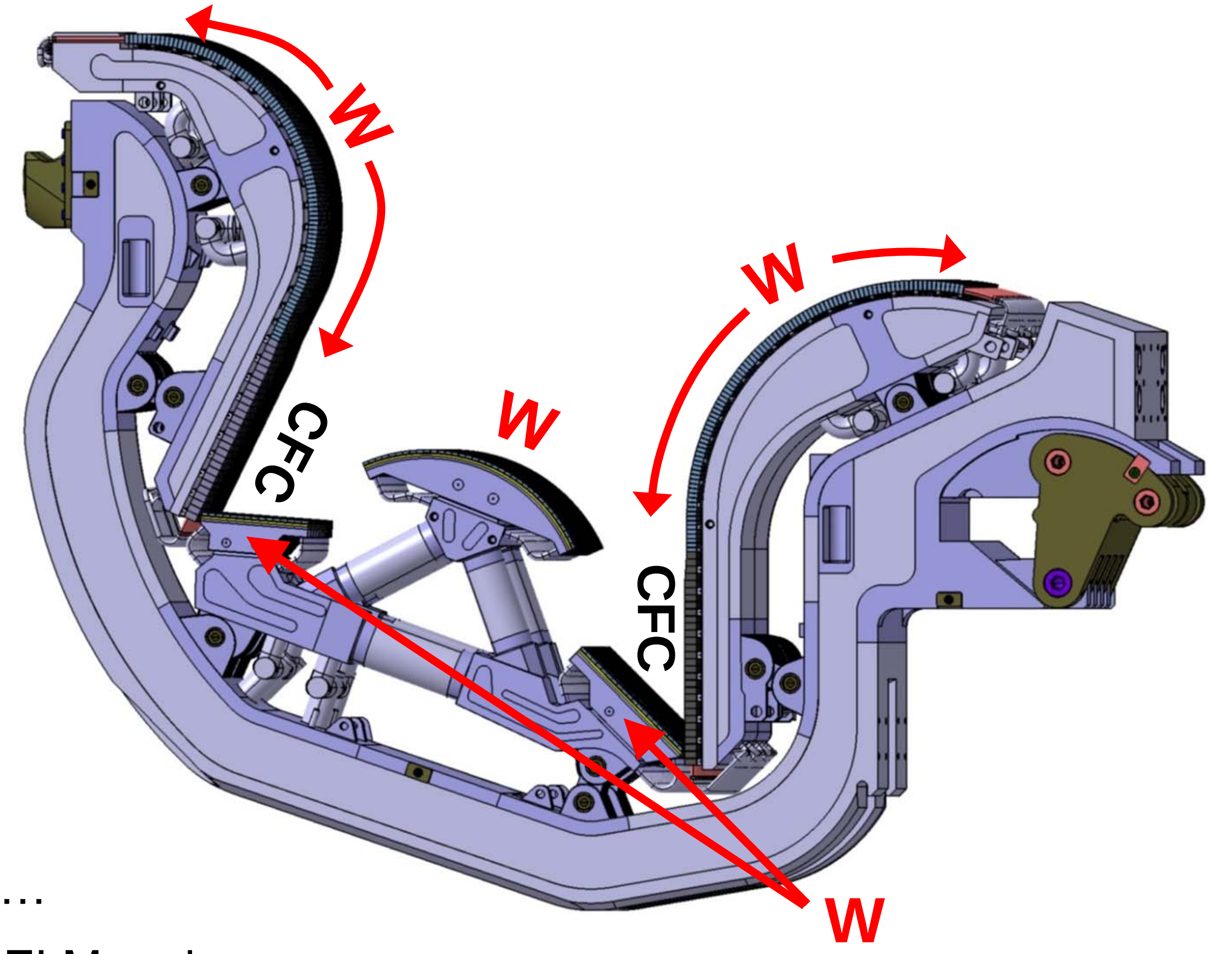
5. Management of In-kind Procurement

6. Status and milestones

Divertor Armour materials choice

Non-active phase (H, He):
CFC at the strike points, W on the baffles

All-W from the start of D operations



Rationale:

- Carbon easier to learn with …
- No melting → easier to test ELM and disruption mitigation strategies before nuclear phase
- T-retention expected to be too high in DT phase with CFC targets

Specification of Divertor Armor Materials / CFC and W

- **CFC**

Requirements
- Carbon content >99.99%C
- Average density
- Thermal conductivity in x-, y-, z-directions at RT and at 800 ^{o}C
- Tensile strength in x-, y-, z-directions

(Thermal expansion in x-, y-, z-directions up to 1000 ^{o}C)

100 % Visual inspection, 100% dimension control, 100% density measurement

- **W** (Standard specification based on ASTM B 760-86)

Requirements
- Chemical composition ≥ 99.94%W
- Density ≥ 19.0 g/cm^3
- Defined rolled direction, Stress relieved condition (not recrystallized)
- Grain size – Microstructure (3 or finer ASTM E 112)
- Hardness: HV30 ≥ 410

Dimension measurement, 100 % Visual inspection, 100% Ultrasonic inspection

Specification of Blanket Armour material / Beryllium

- **Beryllium**

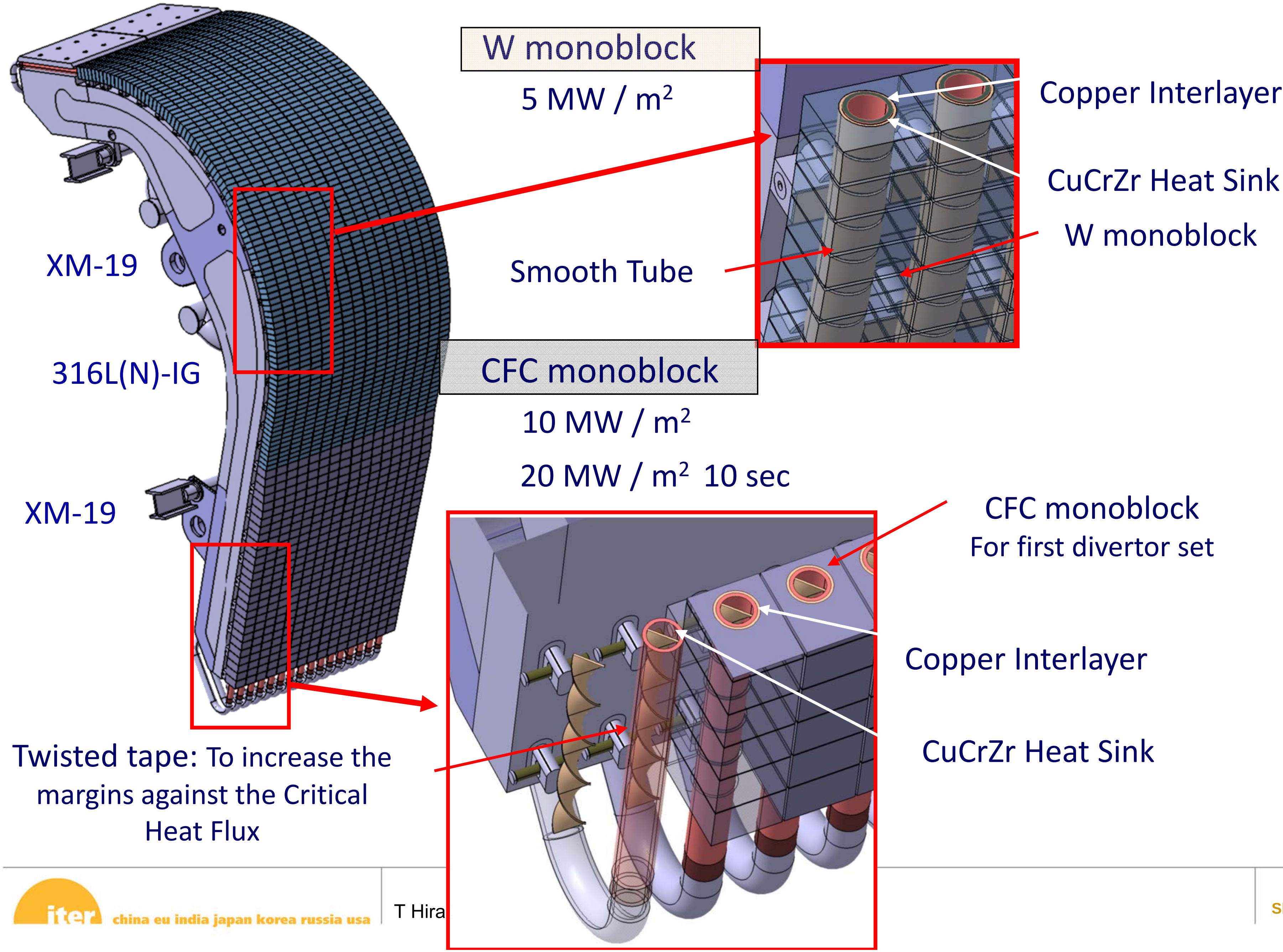
Requirements

- Chemical composition ≥ 99.0%Be (impurity, ≤ 0.0030wt%U, etc)
- Density ≥ 99.0%
- Average grain size < 0.020 mm (ASTM E112)
- Tensile Properties at RT

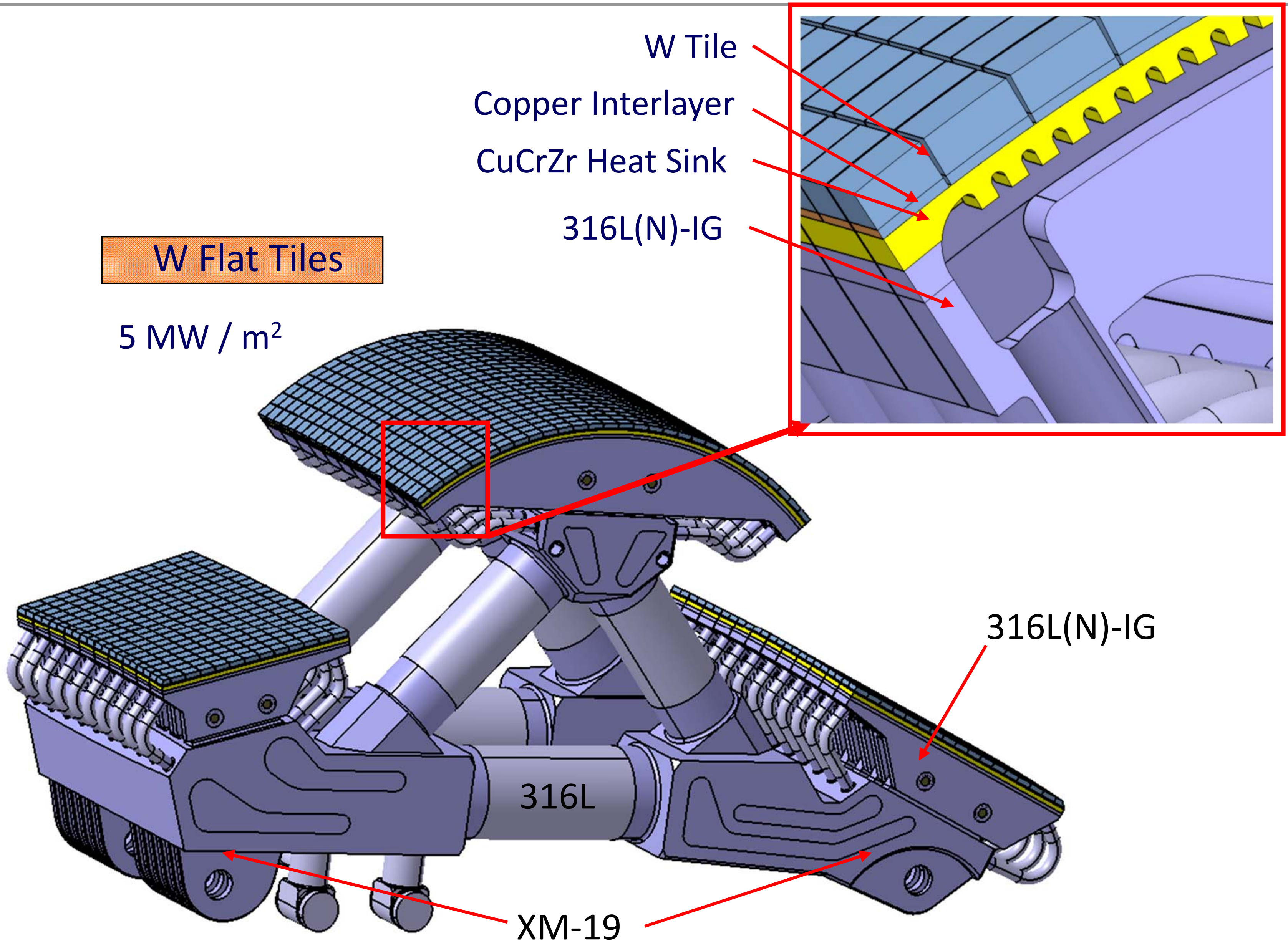
100% Visual inspection, Radiographic inspection, dimension check for each block

See talk by V. Barabash

Divertor vertical targets



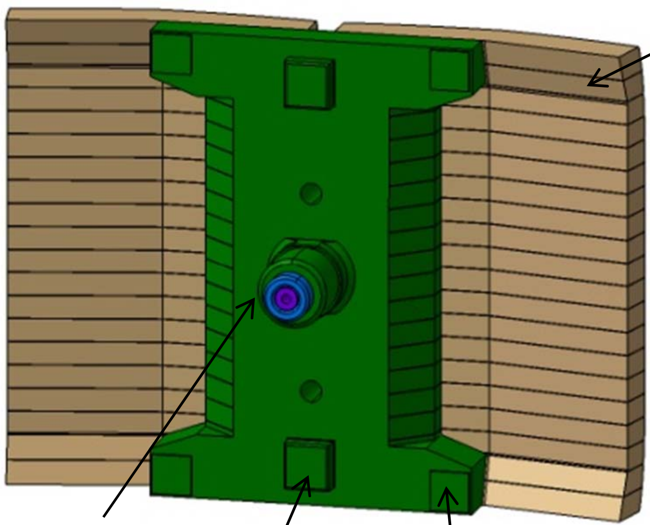
Divertor Dome



Design of First Wall Panel

I shape beam to poloidal torque mitigation

Slitting to reduce Eddy current



- Slits to reduce EM loads, additional slits on the back were introduced to minimize the thermal expansion and bowing (mitigation of EM load)

Deep Central Bolt

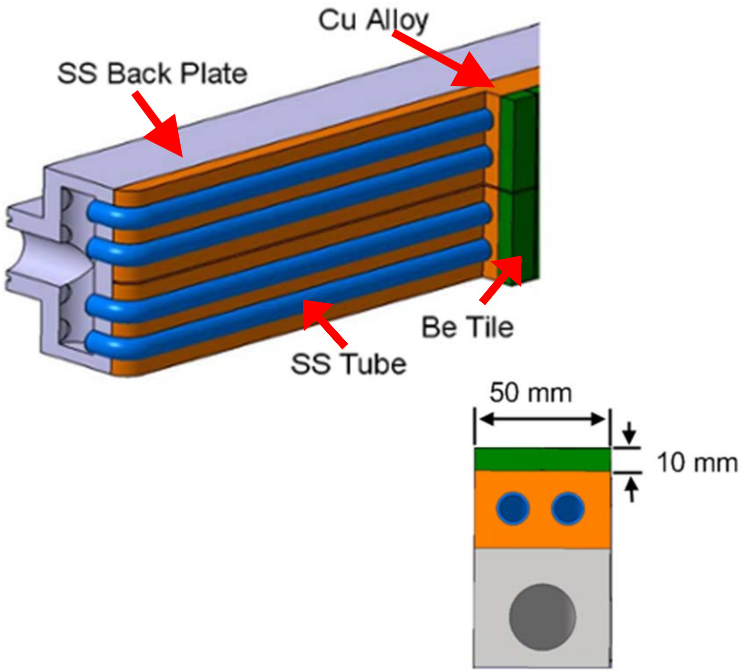
reacting poloidal torque

reacting radial torque

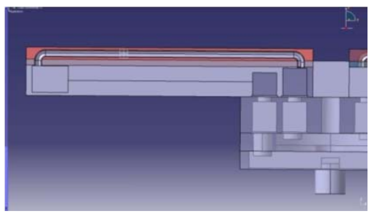
See talk by R. Mitteau

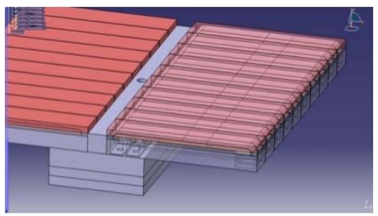
Blanket Normal and Enhanced Heat flux modules

Normal heat flux finger:
concept with Steel Cooling Pipes

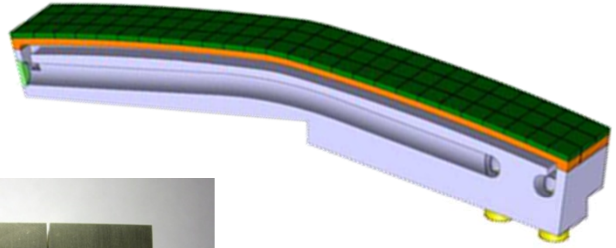


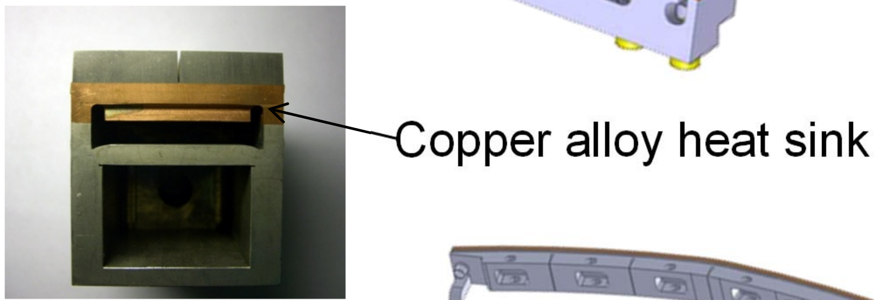
Hot isostatic pressing

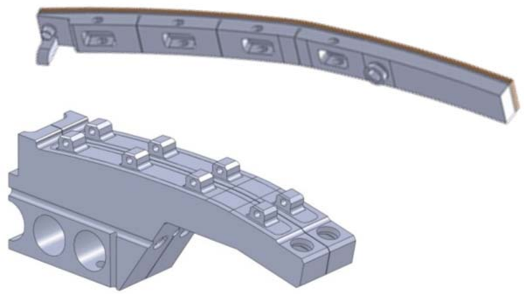


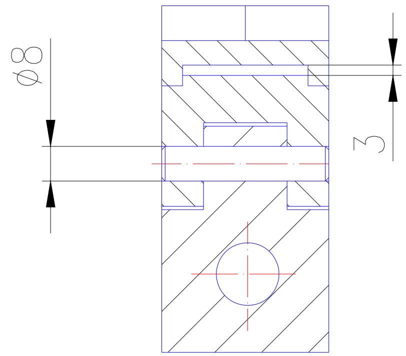


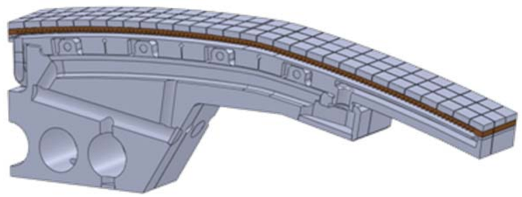
Enhanced heat flux finger:
concept with rectangular channels











Tolerance / General and Specific Tolerance

General Tolerances described in Standards do NOT always meet our requirements
ISO 2768-1:1989 Tolerances for linear and angular dimensions …
ISO 2768-2:1989 Geometrical tolerances ...

Table 1 — Permissible deviations for linear dimensions except for broken edges
(external radii and chamfer heights, see table 2)

Values in millimetres

Tolerance class		Permissible deviations for basic size range							
Designation	Description	0,5[1] up to 3	over 3 up to 6	over 6 up to 30	over 30 up to 120	over 120 up to 400	over 400 up to 1 000	over 1 000 up to 2 000	over 2 000 up to 4 000
f	fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	–
m	medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
c	coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
v	very coarse	–	±0,5	±1	±1,5	±2,5	±4	±6	±8

1) For nominal sizes below 0,5 mm, the deviations shall be indicated adjacent to the relevant nominal size(s).

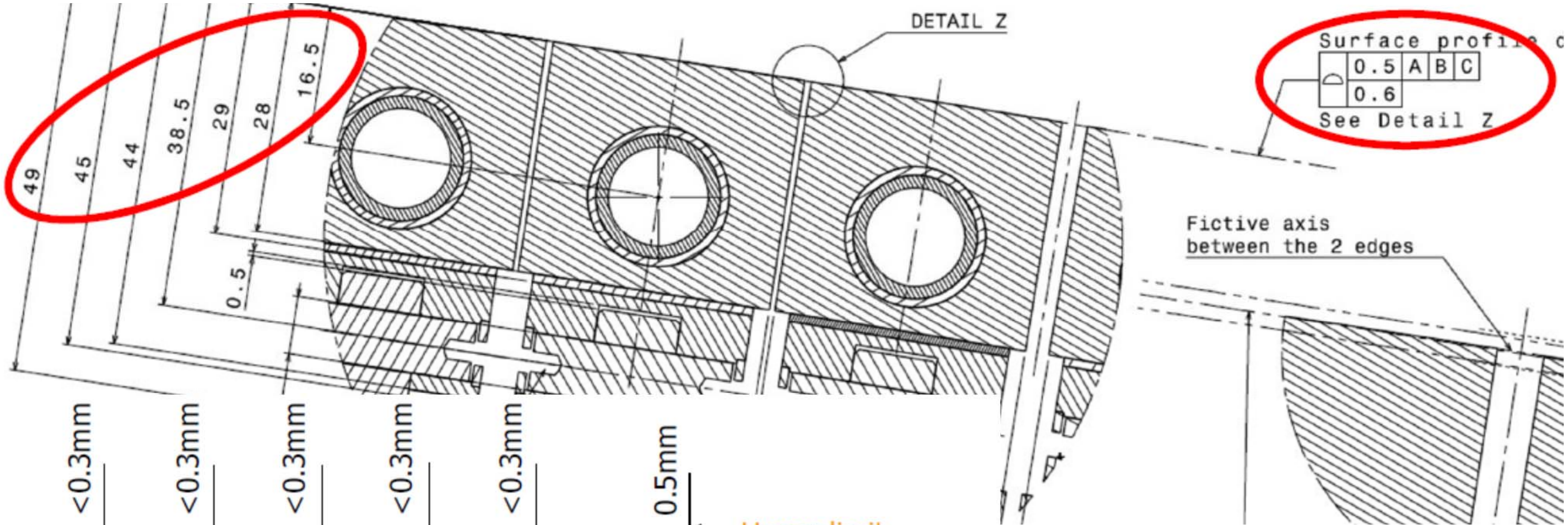
Approach (Specific Tolerance): Priority on the Functionality

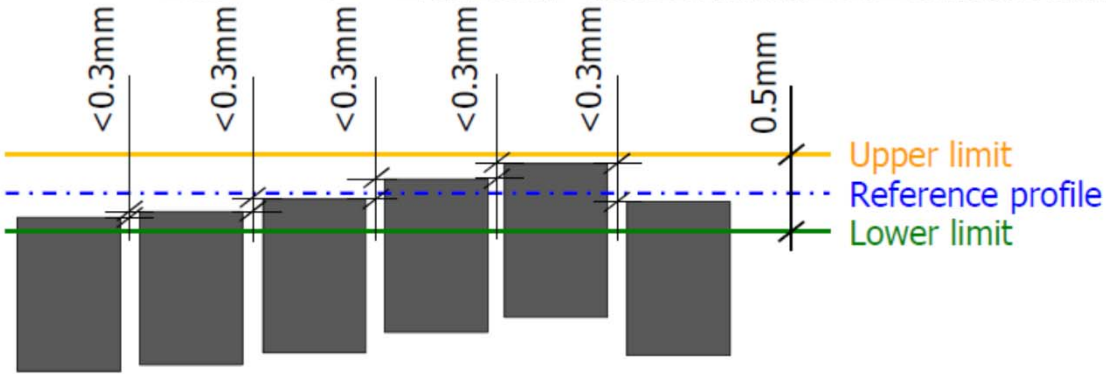
- Ensure mechanical and plasma operation performances
- Leave the manufacturer as much freedom as possible.

N.B. Tolerance directly impact on manufacturing cost.

Tolerance for Divertor PFUs

Geometrical tolerance considering Operational requirements at global and local scales





- ✓ All monoblocks in 0.5 mm tolerance range
- ✓ Steps of neighboring blocks, smaller than 0.3 mm

- Indicate requirements in terms of PFC surface envelop
- Freedom to allocate the tolerances depending on manufacturing processes
- Simplify the control of the components

Concerning Tolerances …

- ❑ Dimension tolerance
  e.g. linear dimensions, angular dimensions

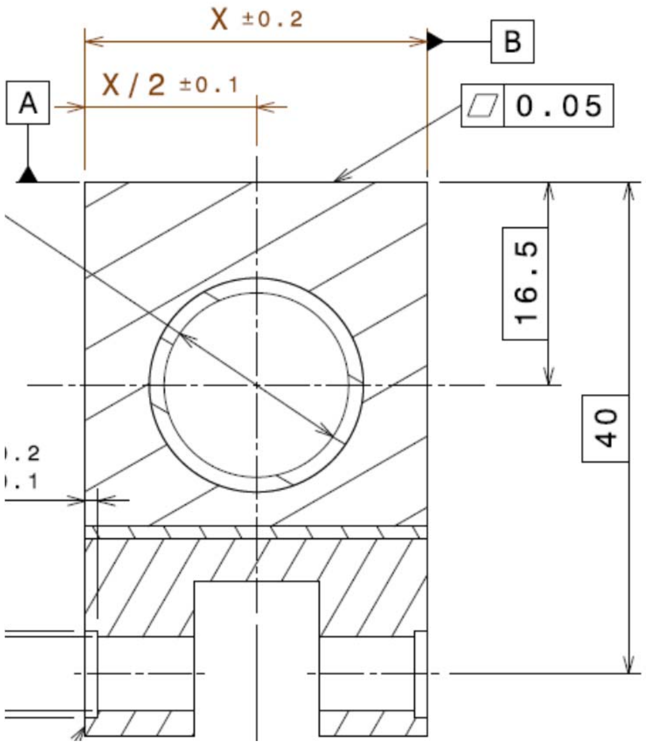
- ❑ Geometrical tolerance
  e.g. Straightness, Flatness (single feature, form),
  Profile, (single or related features)
  Perpendicularity, Parallelism, … (related orientation),
  Coaxiality, Symmetry (related position), …

To achieve required tolerance, …

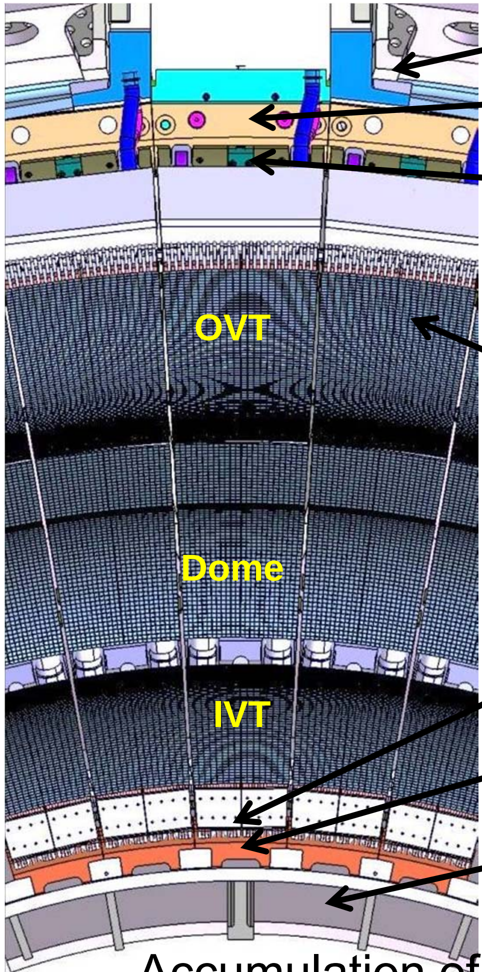
- ➢ Identify poor tolerance operation (joining (welding) and assembly)

- ➢ Recover by Higher tolerance operation (machining) and custom machining of tolerance compensators

N.B.
Selection of appropriate Datums is essential for: (1) Precise manufacturing; and (2) dimension and geometrical control



Assembly tolerances and needs to protect the edges



Vacuum Vessel VV 3D survey tolerance (or Precision)

Outer Hard Cover plate ← Custom machining

Big Knuckle

Each part/ component has manufacturing and assembly tolerances

Divertor Cassette (CB and PFCs)

Divertor PFCs
(Mfg tolerance allocation: ± 0.25 mm)

Nose

Inner Hard Cover plate ← Custom machining

Vacuum Vessel VV 3D survey tolerance (or Precision)

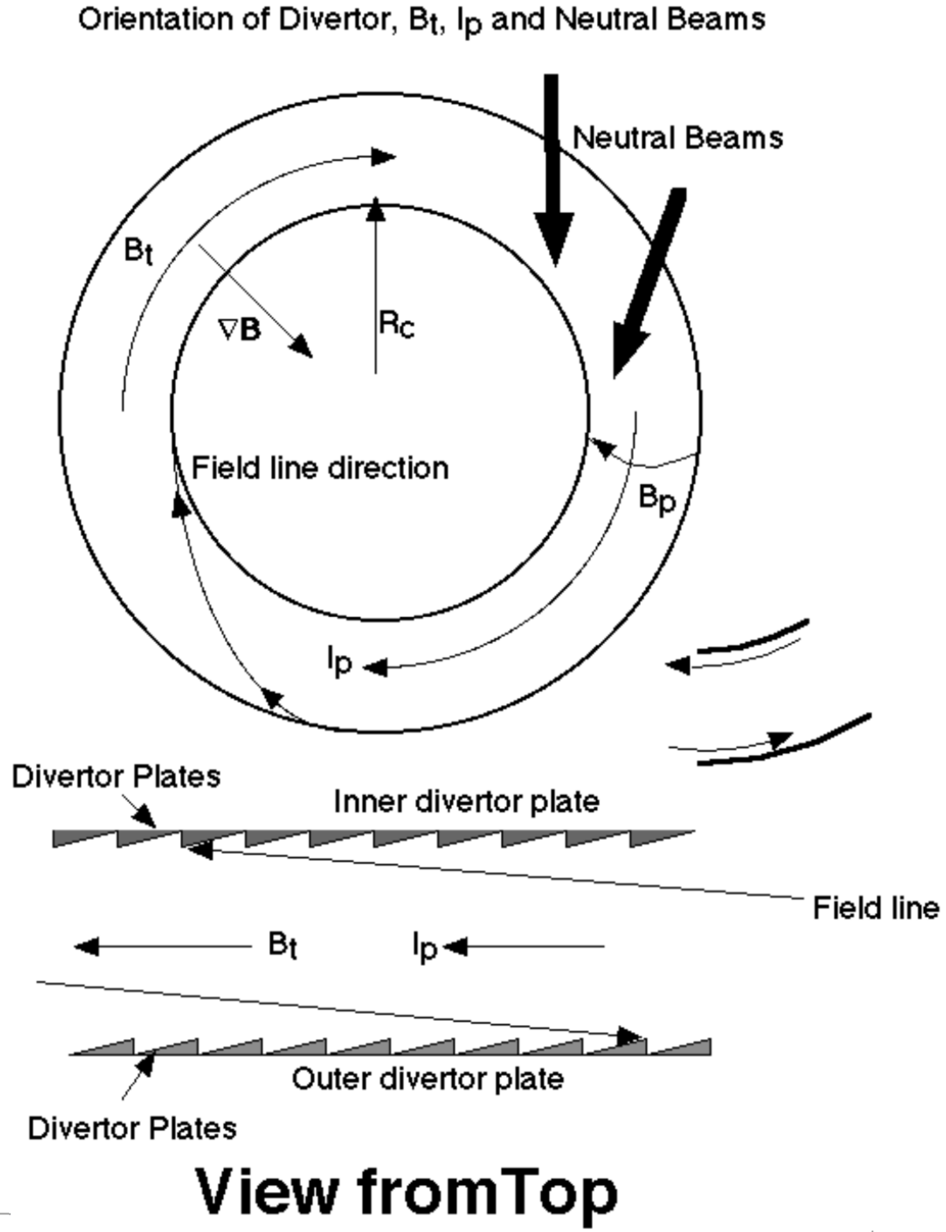
Accumulation of contributors to global misalignment of Plasma-facing surfaces
→ Step at the Plasma-Facing surfaces → Need to protect edge (tilting/ shaping)

	Divertor cassettes	Blanket modules
Assembly tolerance	± 1.5 mm	± 2.5 mm

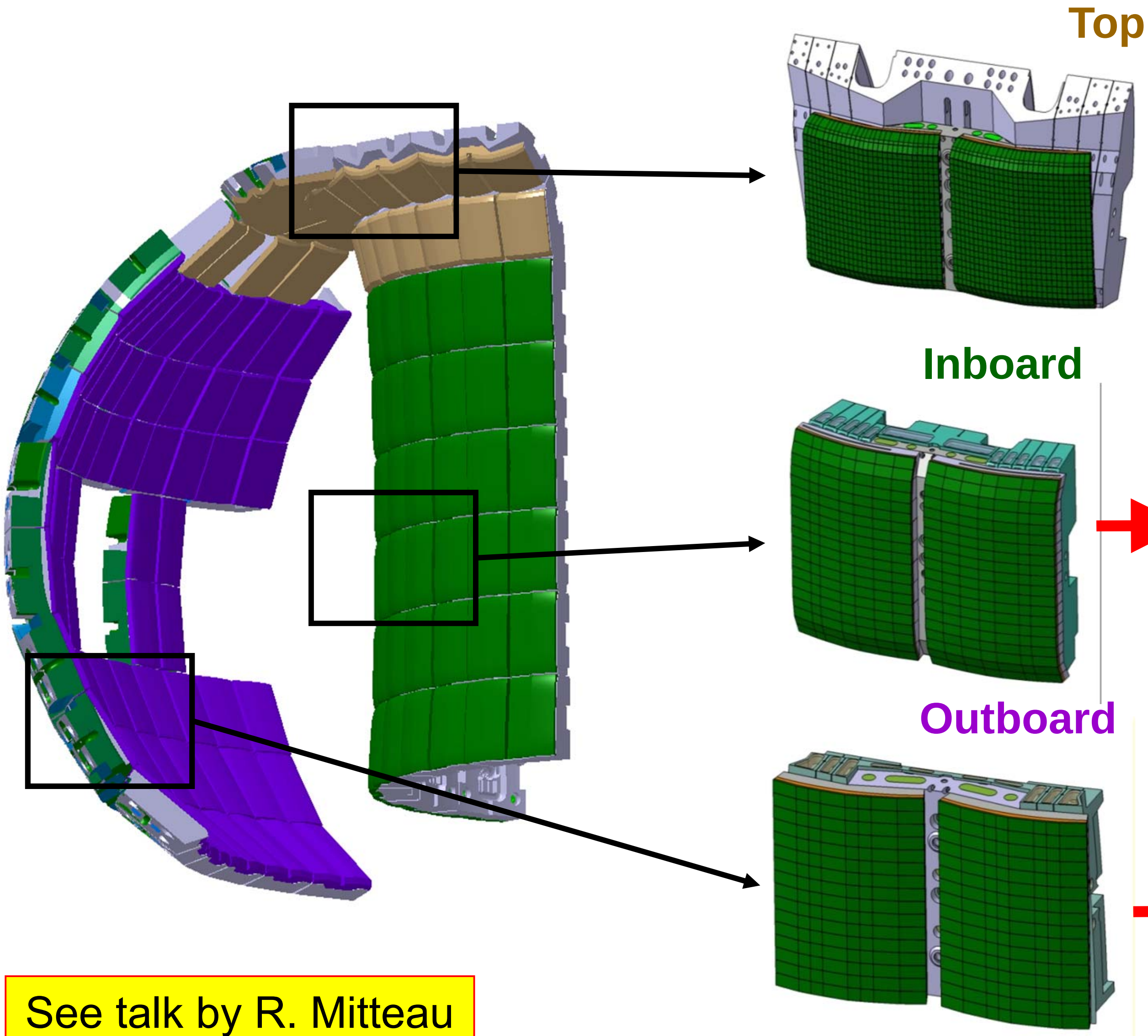
Alignment of Divertor PFCs

The PFCs shall be angled to avoid exposing the leading edges of the armour to the Scrape-Off Layer (SOL), otherwise the near normal incidence of the SOL on these edges would cause large amounts of carbon to be evaporated (or tungsten melted) with the inherent risk of poisoning of the plasma and/or inducing a critical heat flux event in the water coolant.

A nominal step in the toroidal direction between adjacent targets of 3 mm is taken as a requirement



Summary of First Wall shaping



BM #7-10
Secondary divertor region
Toroidal & poloidal shaping

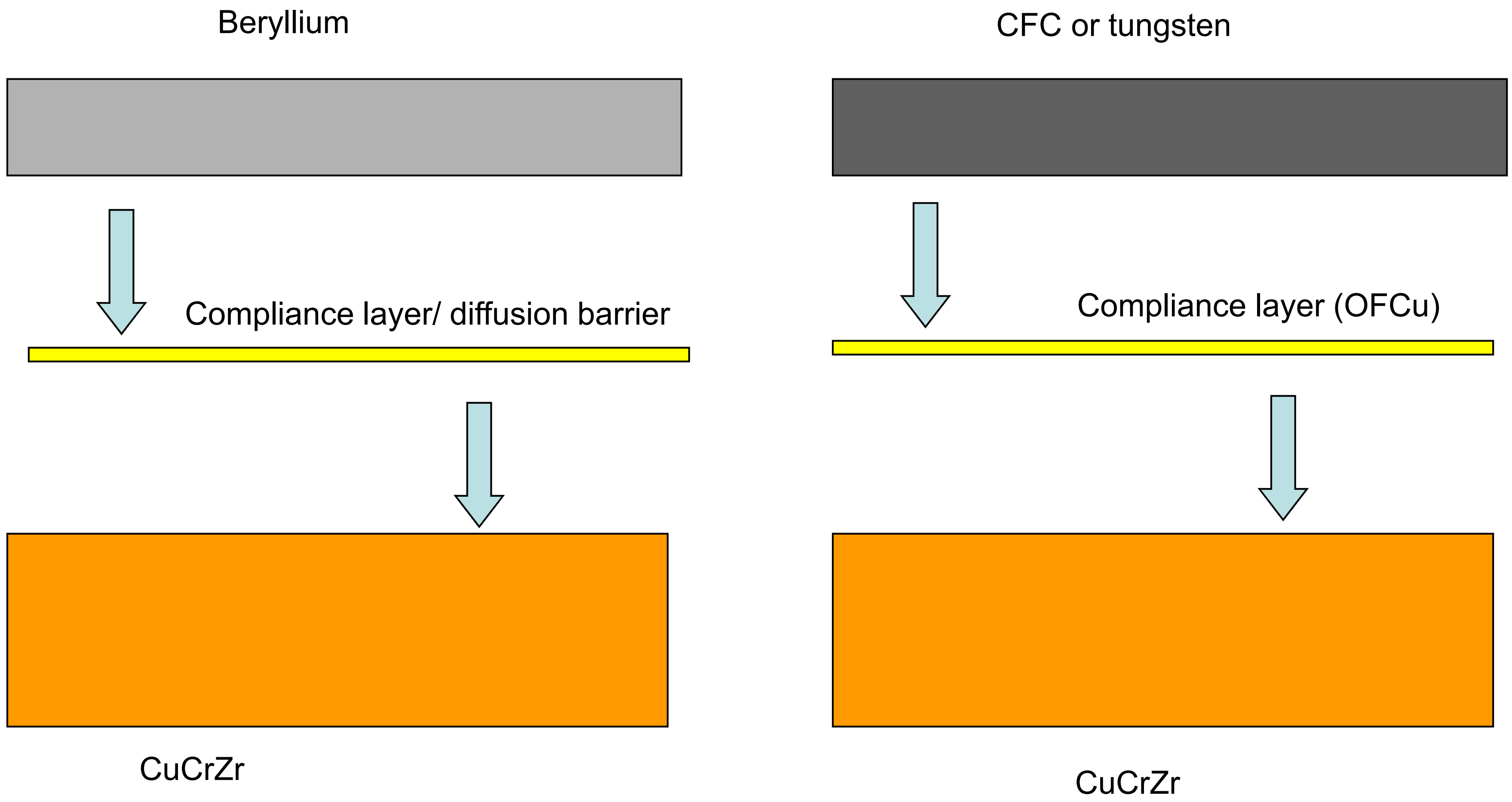
BM #1-6
Central column
HFS start-up
Toroidal & poloidal shaping

BM #11-18
Outboard
LFS start-up/ramp-down
Toroidal shaping

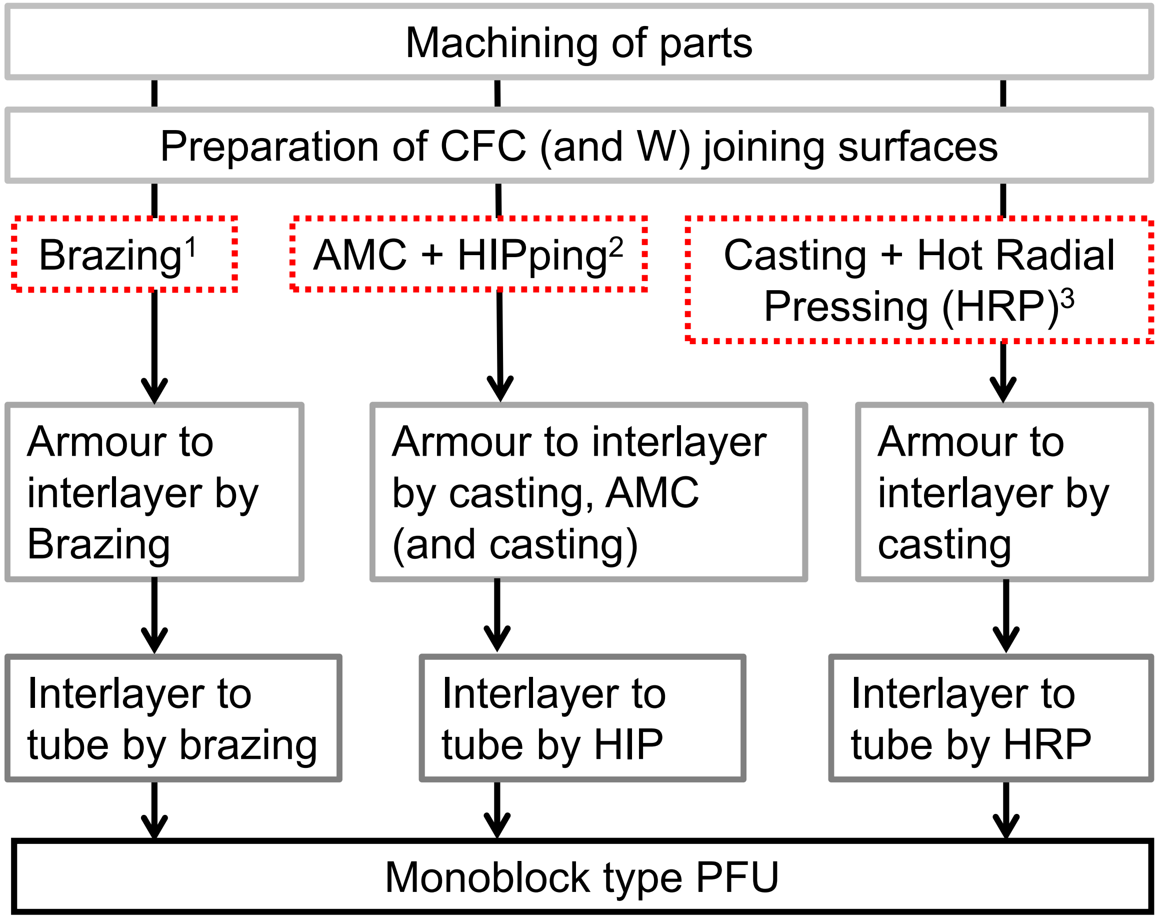
See talk by R. Mitteau

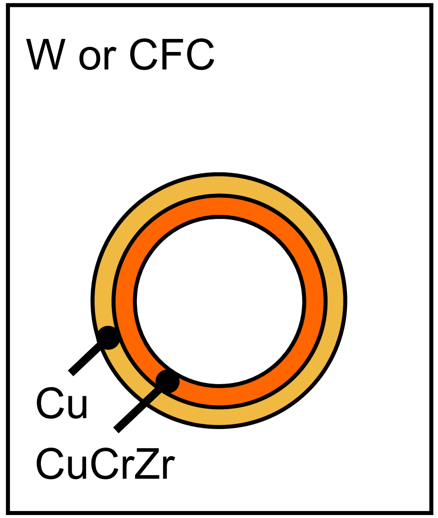
Manufacturing of armour joints

Armour to heat sink joints



Manufacturing / Monoblock type PFUs

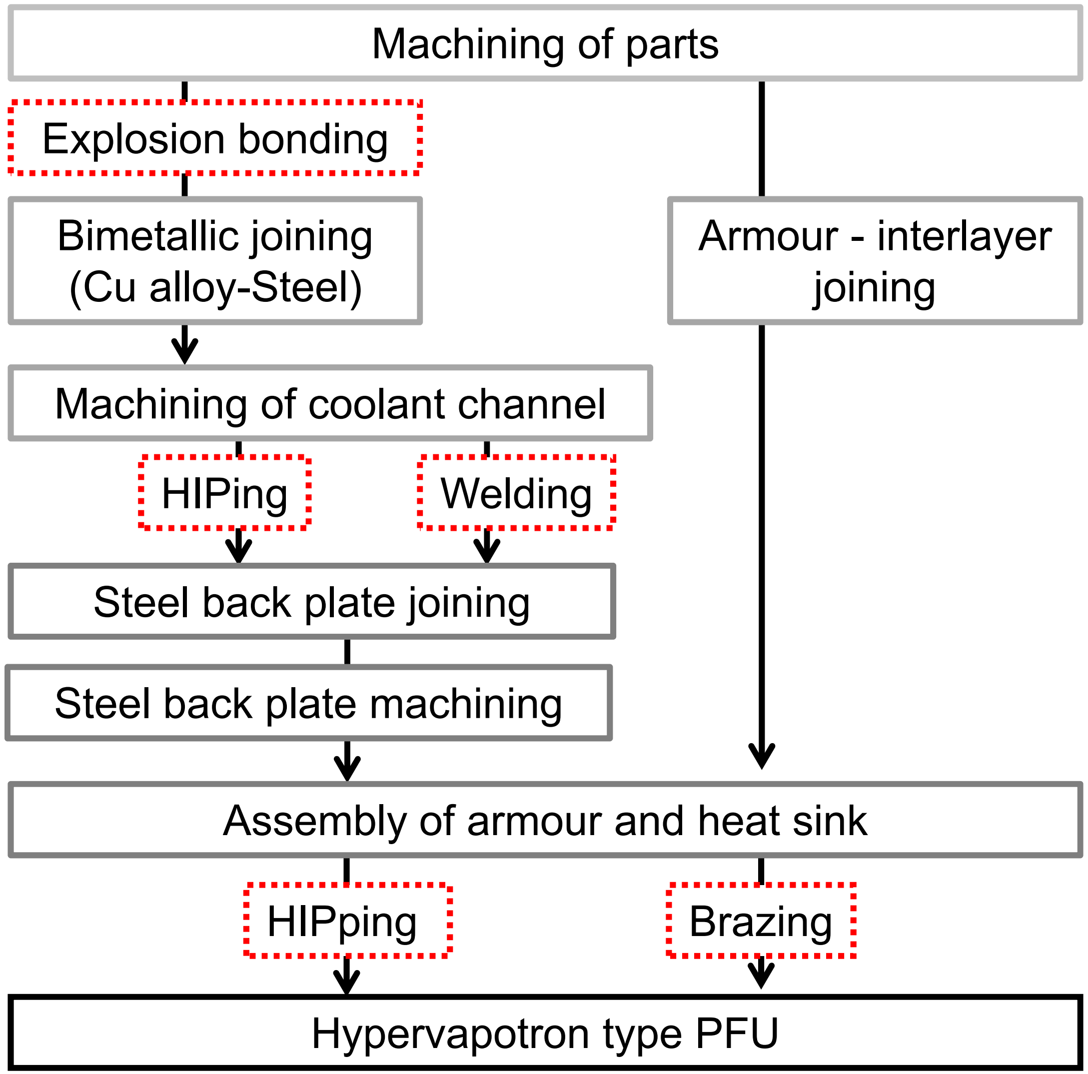


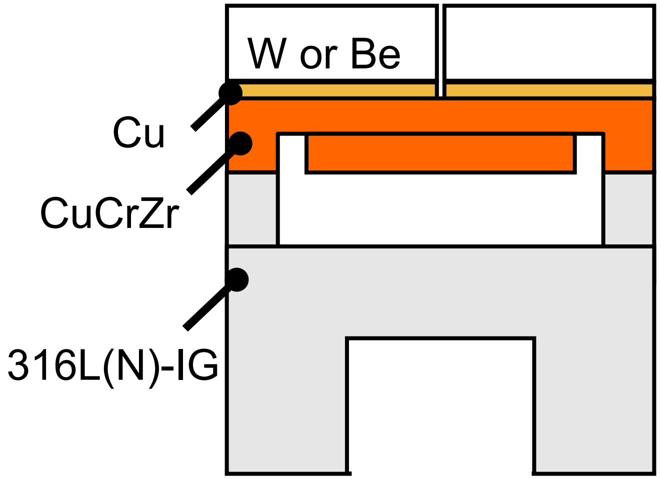


[1] S. Suzuki, et al, Phys Scr T138 (2009) 014003.
[2] T. Huber, et al, Plansee Seminar-17, Reutte Austria, 25-30 May 2009.
[3] E. Visca, et al, Fusion Eng Des, 84 (2009) 309-313.

Selection of reliable and cost-effective manufacturing route(s) is DAs' responsibility.

Manufacturing / Hypervapotron type PFUs





Selection of reliable and cost-effective manufacturing route(s) is DAs' responsibility.

NDT of Plasma-Facing Units

Armor to heat sink joint

Metal / Metal joints 100%

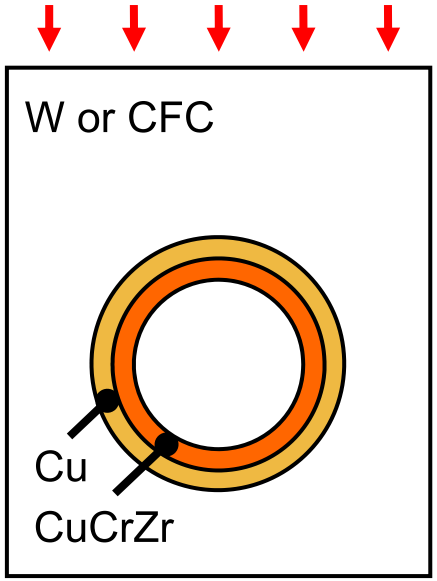
Ultrasonic Test

CFC/Cu joint 100%

Transient Infrared Thermography

or thermal mapping by HHF facility

If UT examination is not applicable



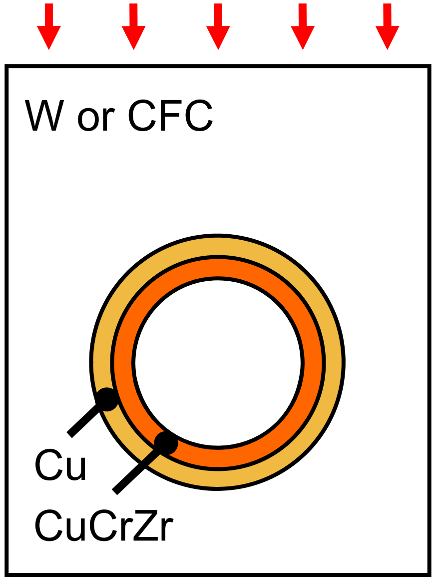
NDT of Plasma-Facing Units: UT for metallic armor joints

❑ **Ultrasonic Test for metallic armor joints (EN 583)**

Pulse echo technique or transmission technique

Indications of defects ← Echo from defects

Important parameters
- Probe (frequency & dimensions)
- Coupling media
- Scanning scheme
- Calibration blocks
etc.



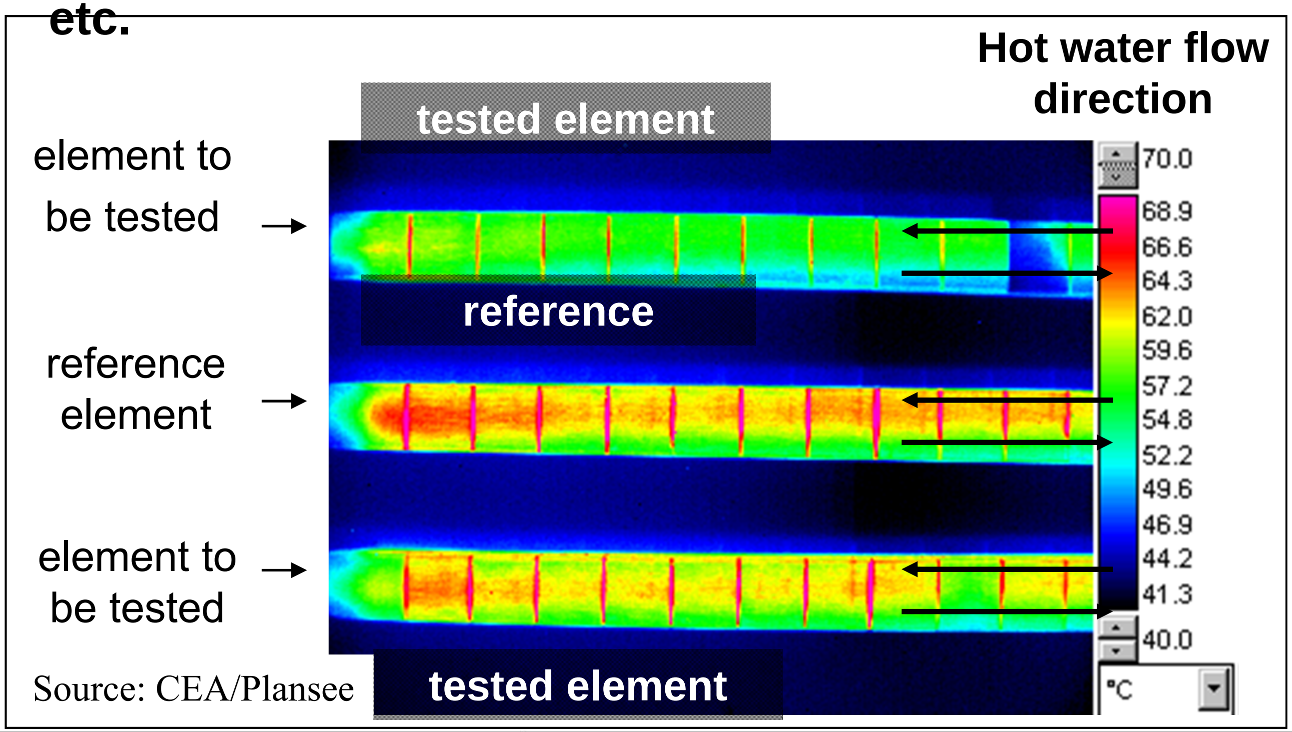
NDT of Plasma-Facing Units: Infra-Red test

Transient Infrared Thermography for CFC-Cu joints

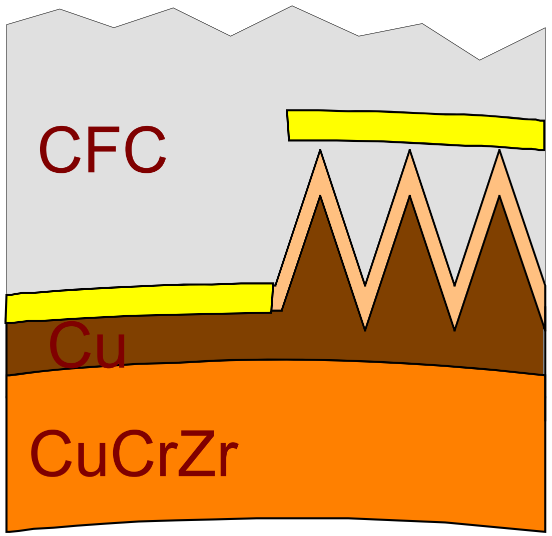
Indications of defects ← Difference of transient thermal responses

Important parameters
- **Thermal transition rate**
- **Homogeneous flow distribution and flow rate between channels**
- **Data acquisition and process**
- **Calibration**

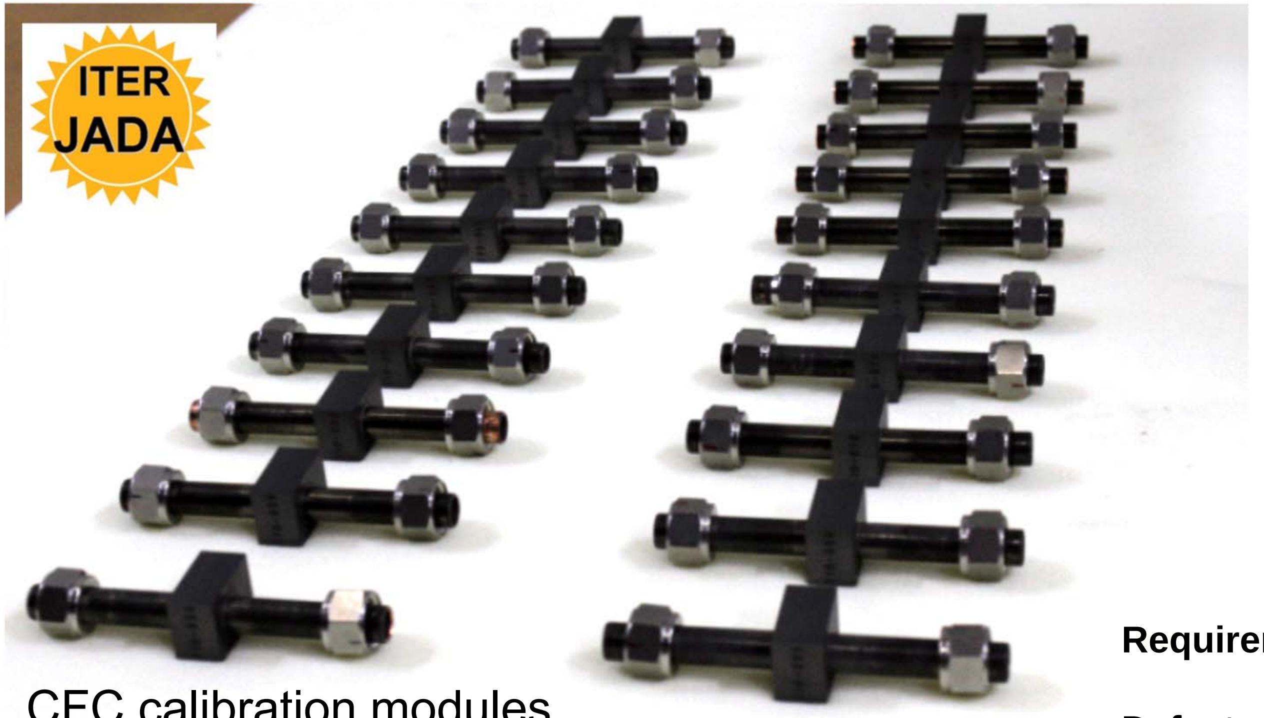
etc.



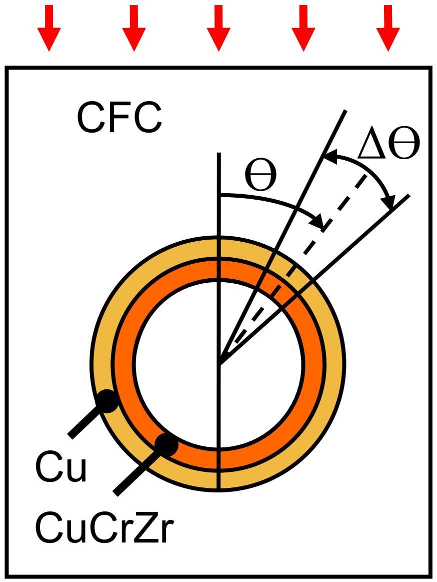
Source: CEA/Plansee



Acceptance Criteria for Plasma-Facing Units



CFC calibration modules

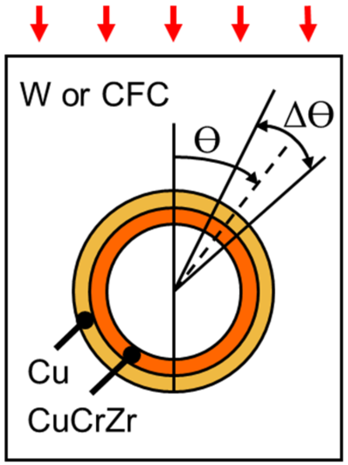


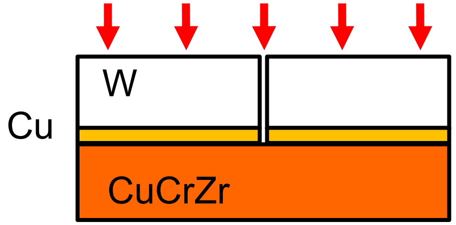
Requirements for Calibration modules:

Defects in the CFC/Cu joint
Location θ = 0°, size $\Delta\theta$ = 40, 50, 60, 70°
Location θ = 45°, size $\Delta\theta$ = 40, 50, 60, 70°

- Correlation between defect size and defect location vs thermal response

Acceptance Criteria for Plasma-Facing Units



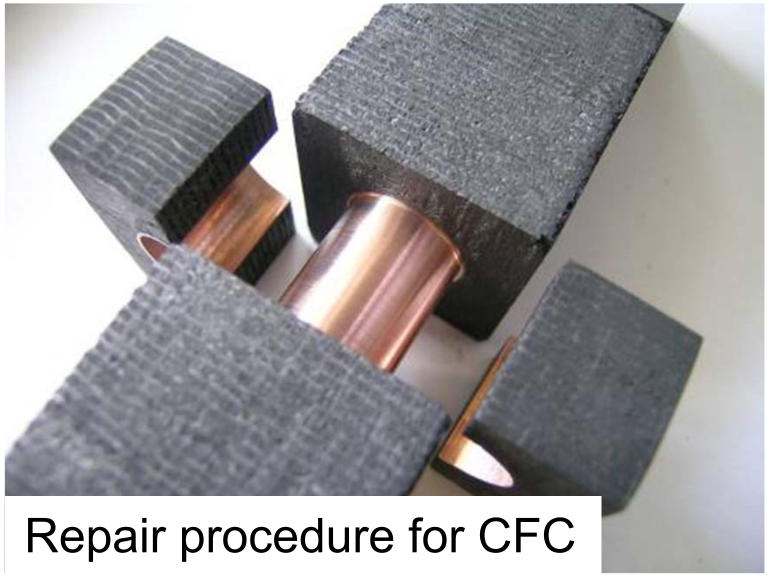


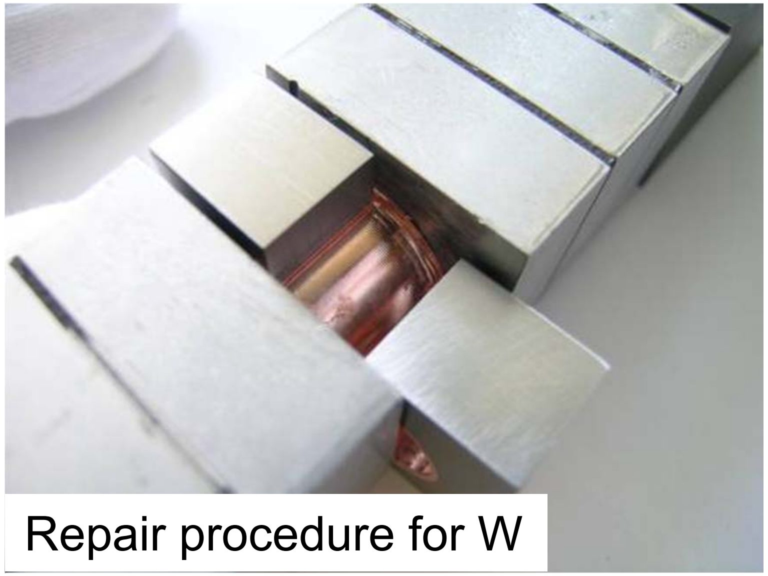
Acceptance criteria

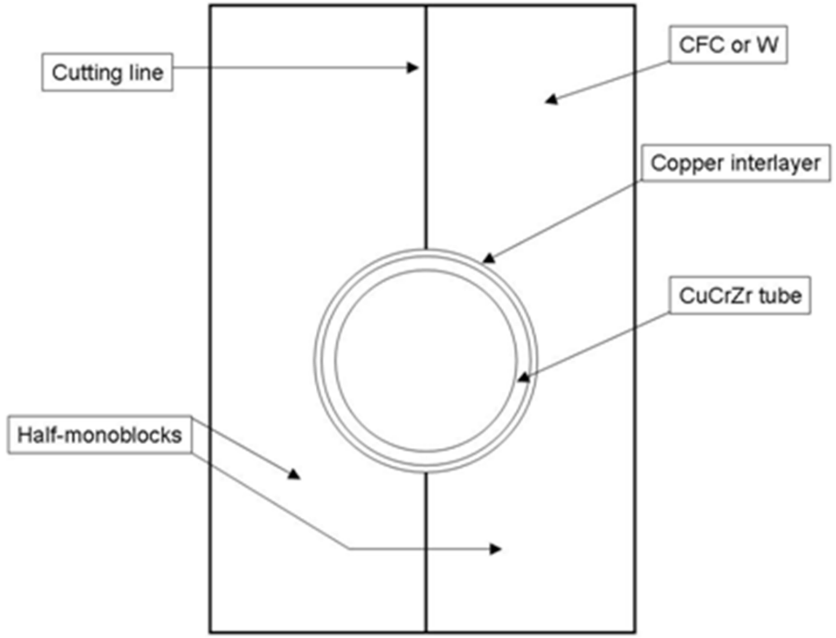
Monoblock geometry (sampling rate)	**Δθ**	**Location, θ**
CFC/Cu (100%)	< 50 º [a]	
Cu/CuCrZr in CFC part (100%)	< 40 º	Within ± 120 º
	< 60 º	Outside ± 120 º
W/Cu, Cu/CuCrZr (100%)	< 50 º	Within ± 120 º in the critical area
	< 70 º	Outside ± 120 º or outside the critical area
Flat tile geometry (sampling rate)	**Size of defect**	
W/Cu, Cu/CuCrZr (100%)	No defect shall have one dimension greater than 4 mm	
CuCrZr/Steel (100%)	No defect shall have one dimension greater than 2 mm	

[a] Acceptance criteria is defined by NB31 calibration modules

Repairing Technology


Repair procedure for CFC


Repair procedure for W



Heat flux performances of the repaired monoblocks are equivalent to those of the non-repaired ones. This shall be demonstrated by the manufacturing and testing of at least 4 relevant mock-ups with repaired and non-repaired monoblocks.

Divertor PFUs HHF tests

Plasma-Facing Unit

Hydraulic Pressure test 100%

He leak test 100%

Thermal fatigue tests in Efremov institute

Performance test for 100% full scale prototype PFU

Series test for 100% of first 10% series production

for 10% of rest of 90% series production

HHF Performance Testing

100 % PFU Full-Scale Prototype

10 MW/m^2 1000 cycles at CFC armor part

20 MW/m^2 500 cycles at CFC armor part

5 MW/m^2 1000 cycles at W armor part

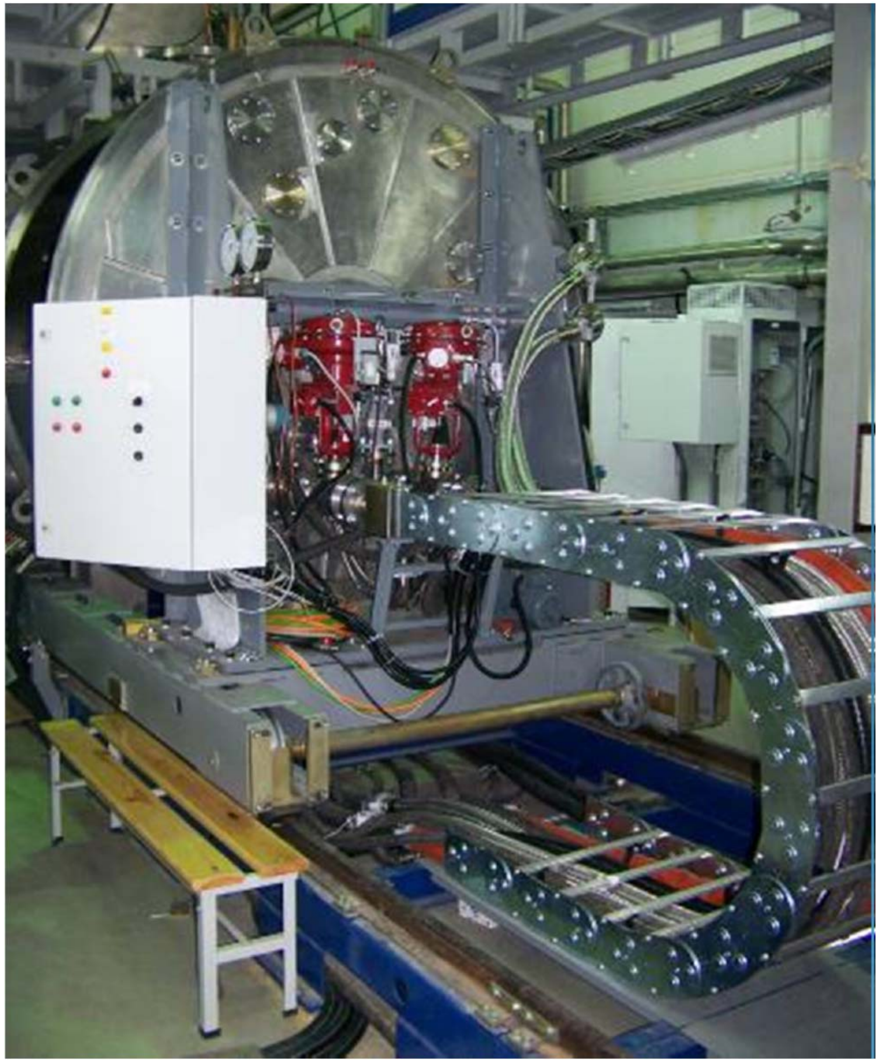
HHF Series Testing

PFU Series Production 19% (100 % of first 10 % + 10 % of the rest (90 %))

10 MW/m^2 100 cycles at CFC armor part

3 MW/m^2 100 cycles at W armour part

ITER Divertor Test Facility (IDTF) for HHF tests of PFUs



IDTF commissioning in July 2011
at Efremov Institute, Russia

Max. beam power: 800 kW
Max. voltage: 60 kV
Max. Deflection angle: 45^o
Design beam diameter : ~15mm
Vacuum chamber: 3 m / diameter 2.2 m

This activity is in the frame of Procurement package (17P2D.RF).

Contents

1. ITER Project
2. ITER In-vessel Components: Divertor and Blanket
3. Plasma-facing Units
   - Materials, Design, Manufacturing, Non-Destructive Tests -
4. **Steel support structures**
   - Design, Manufacturing, Non-Destructive Tests -
5. Management of In-kind Procurement
6. Status and milestones

Structural Design Criteria

- ITER Structural Design Criteria for In-vessel Components (SDC-IC) was developed as a code for ITER in-vessel components (based mainly on RCC-MR). The SDC-IC code takes into account the ITER-specific conditions such as transient EM-loads, high surface heat fluxes, influence of creep and radiation damage etc.

Note: Revised version of SDC-IC will be issued in 2011.

- **Four categories of loading conditions:**

Cat-I: Operational loads in the performance of its specified service function

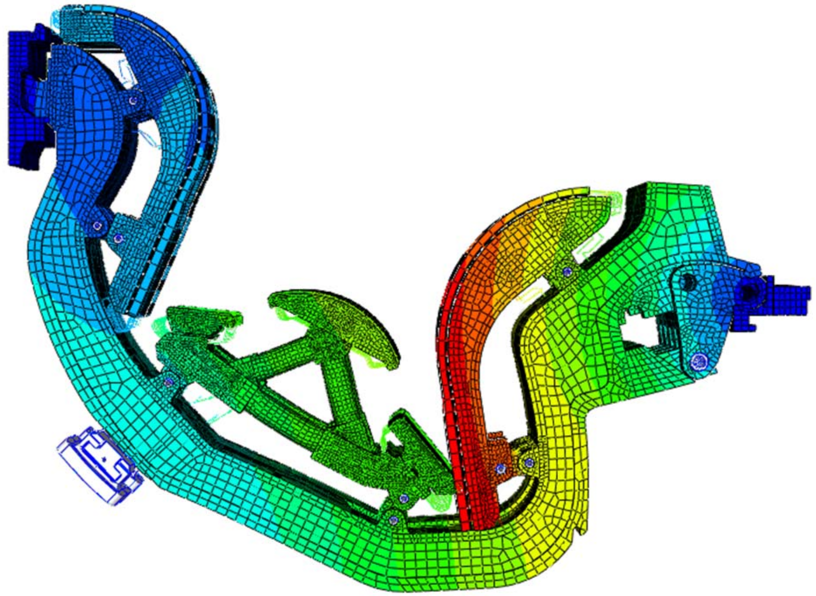
Cat-II: Likely loads which component must withstand without damage requiring repair

Cat-III: Unlikely loads which necessitate shutdown of system and removal of the component from service for inspection or repair.

Cat-IV: Extremely Unlikely loads

- **Many considered failure modes, e.g. including:**
  - Failure modes at monotonic "M-type damage" loads (monotonic loads are steadily and regularly increasing loading, or a constant loading)
  - Failure modes at cyclic "C-type damage" loads (e.g., time-independent/ time dependent fatigues, etc.)

Supporting analysis



• Thermo-mechanical

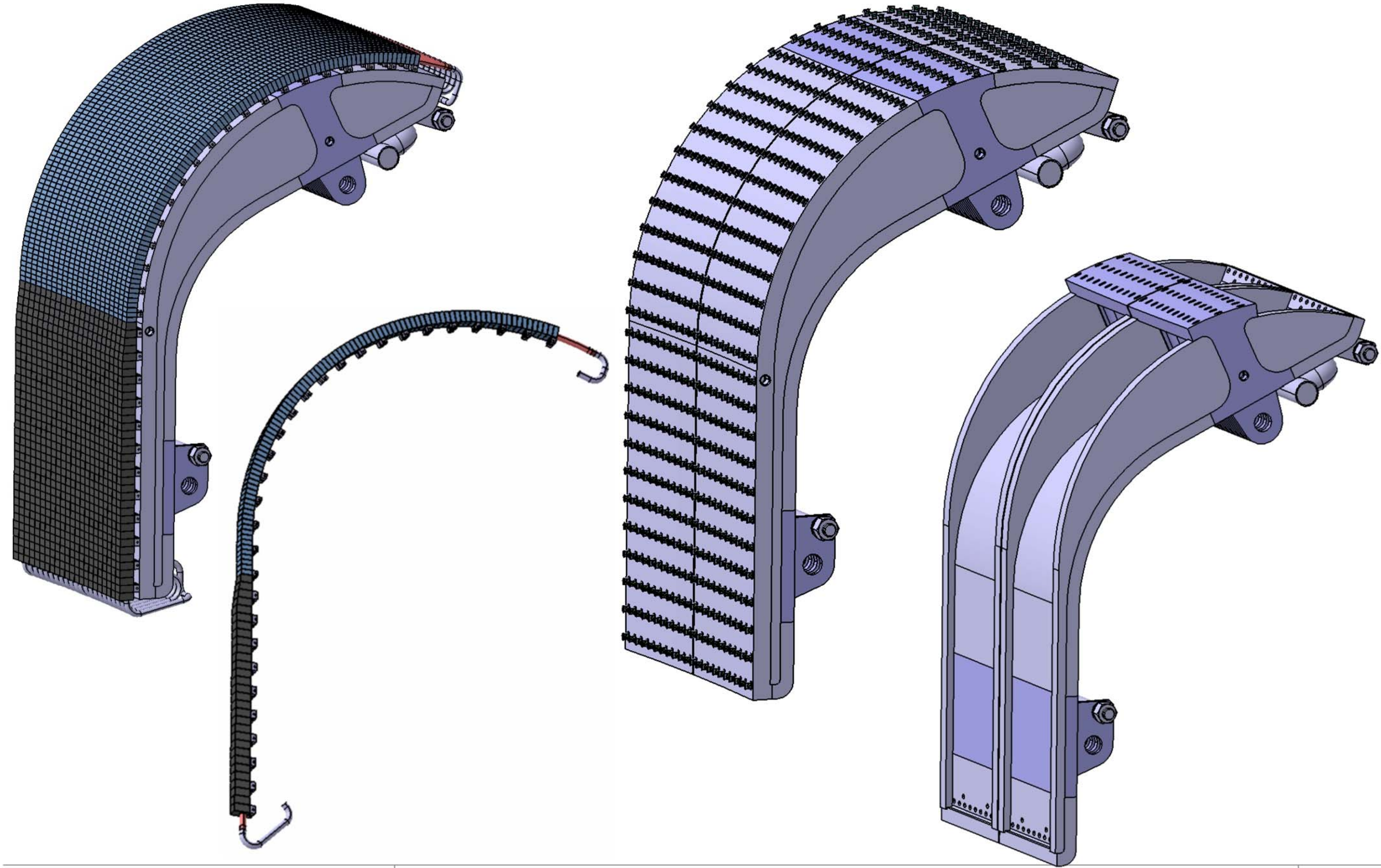
• Electromagnetic (EM)

• Mechanical static and dynamic analysis at EM loads

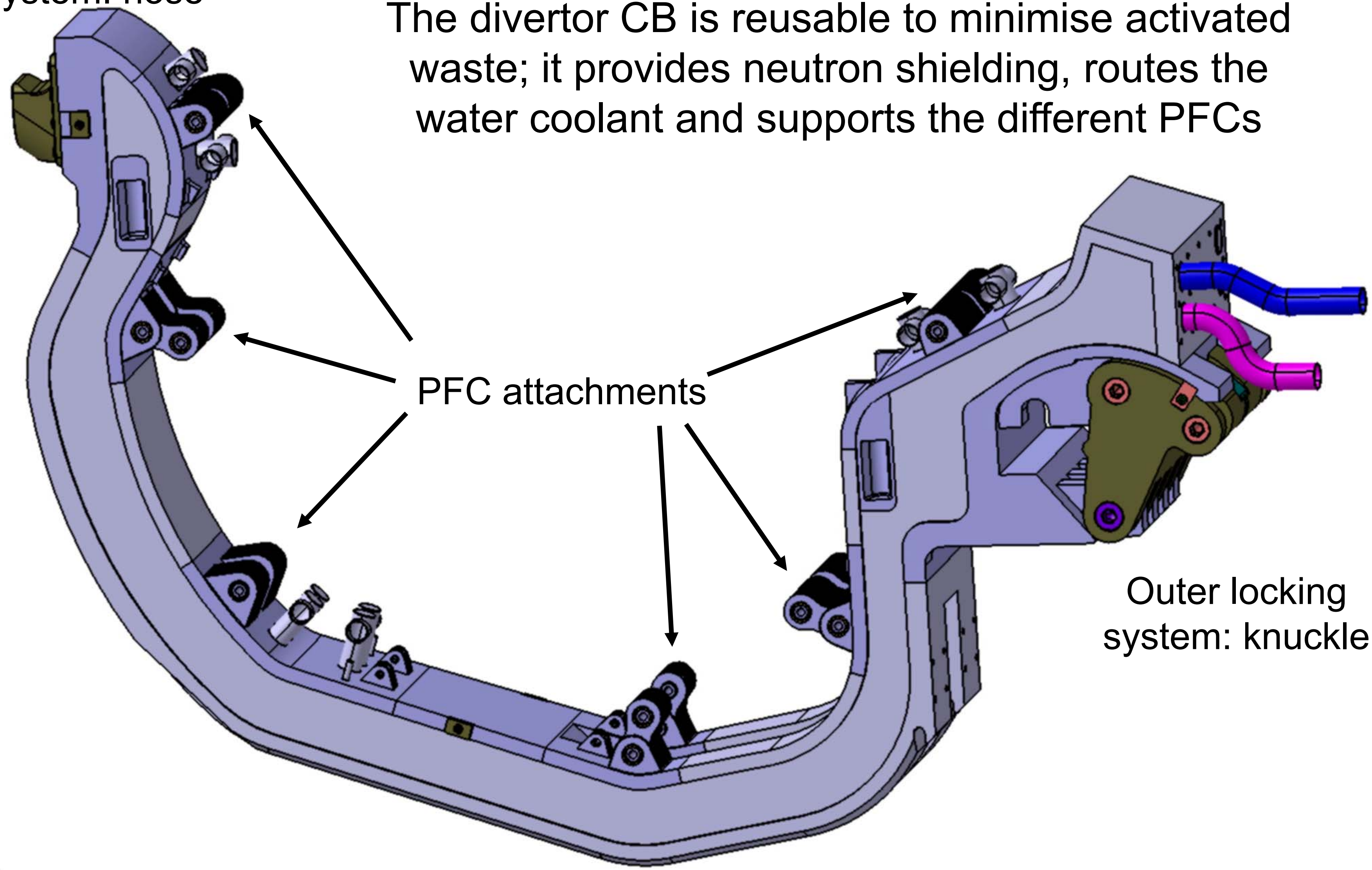
• Mechanical analysis at load combinations (EM, Thermal, dead weight, seismic accelerations, hydraulic pressure)

•Evaluation of static and cyclic strength of divertor parts

Steel Support Structure of Divertor Vertical Targets



Divertor Cassette Body



The divertor CB is reusable to minimise activated waste; it provides neutron shielding, routes the water coolant and supports the different PFCs

Coolant Flow sequence in Divertor

Divertor coolant design parameters

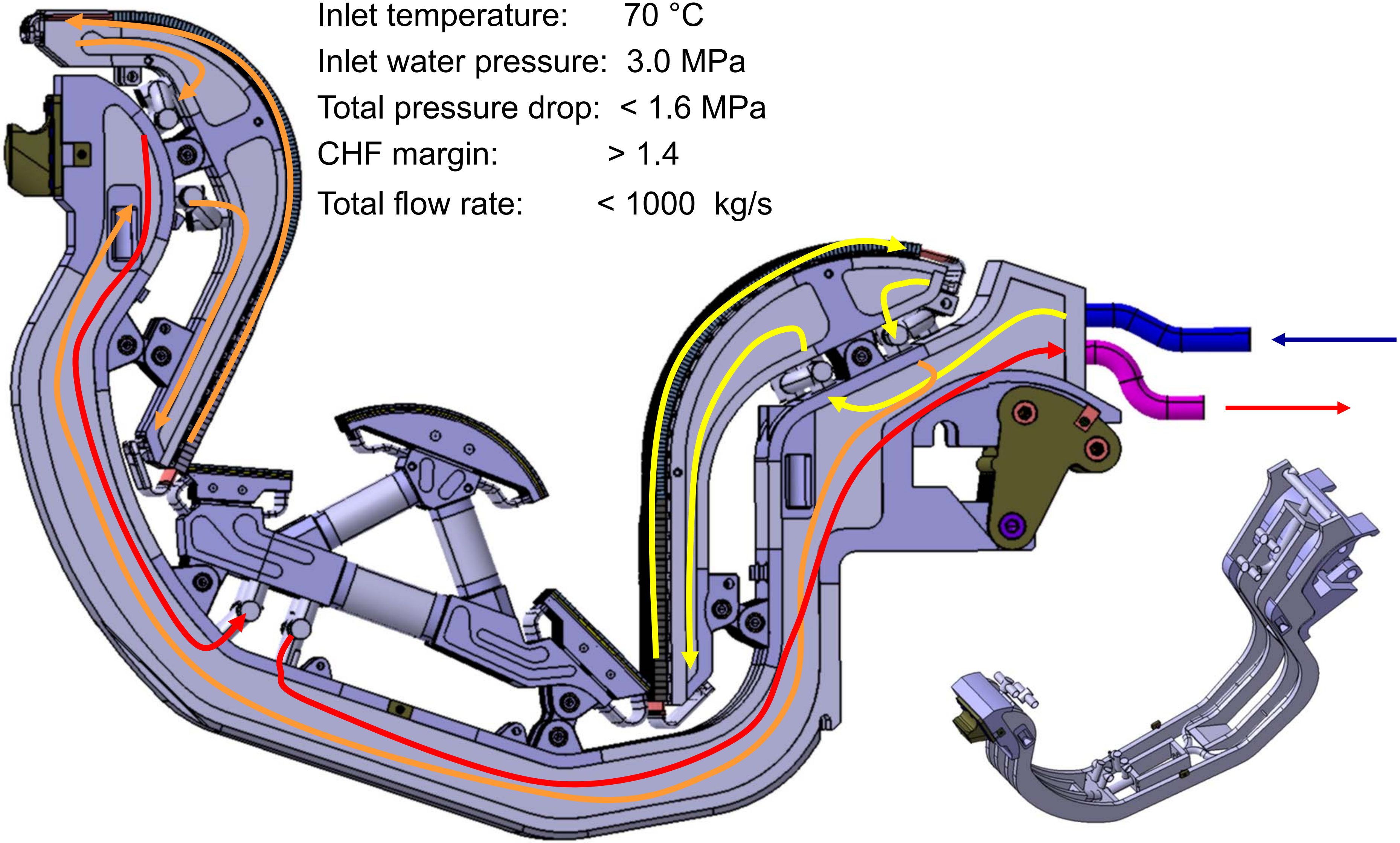
Inlet temperature: 70 °C

Inlet water pressure: 3.0 MPa

Total pressure drop: < 1.6 MPa

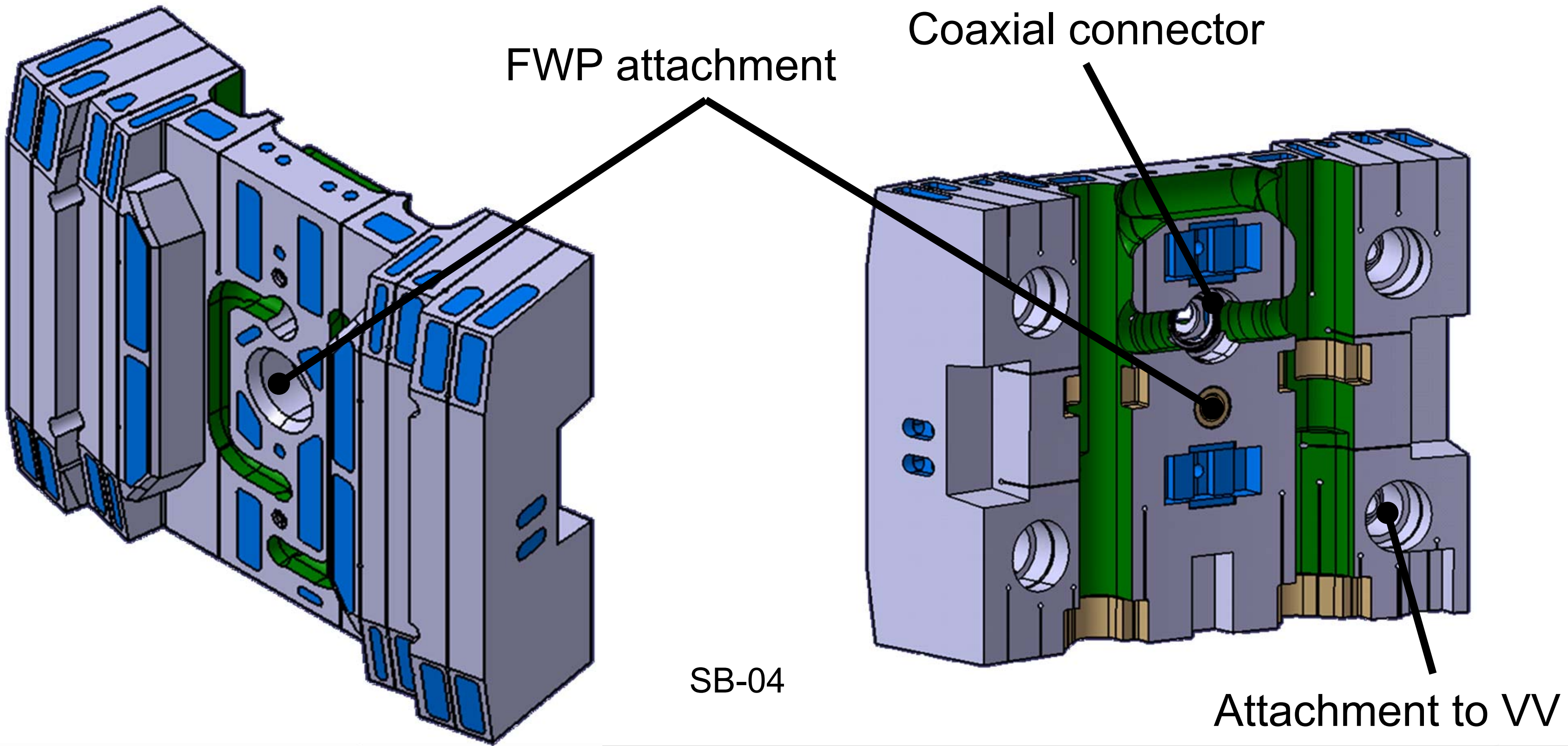
CHF margin: > 1.4

Total flow rate: < 1000 kg/s



Blanket Shield Block

- Modules cover 20^o sector in the inboard and upper, and10^o sector in outboard
- Slits to reduce EM loads, additional slits on the back were introduced to minimize the thermal expansion and bowing (mitigation of EM load)
- Cooling holes are optimized for Water/SS ratio (Improving nuclear shielding performance)
- Material: 316L(N)-IG
- Main Manufacturing process: Drilling, Milling and Welding



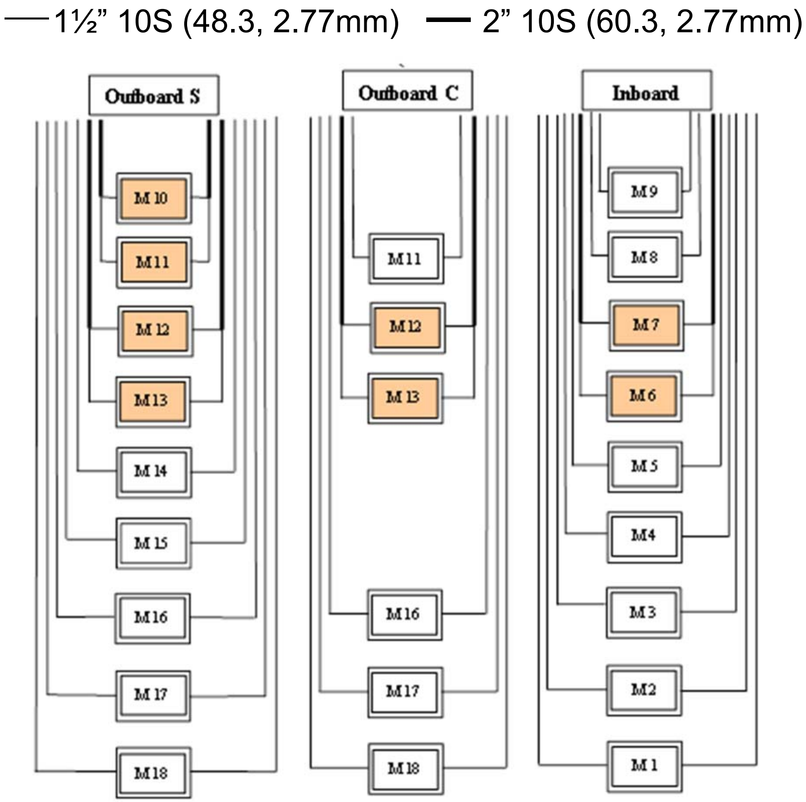
Coolant Flow sequence in Blanket

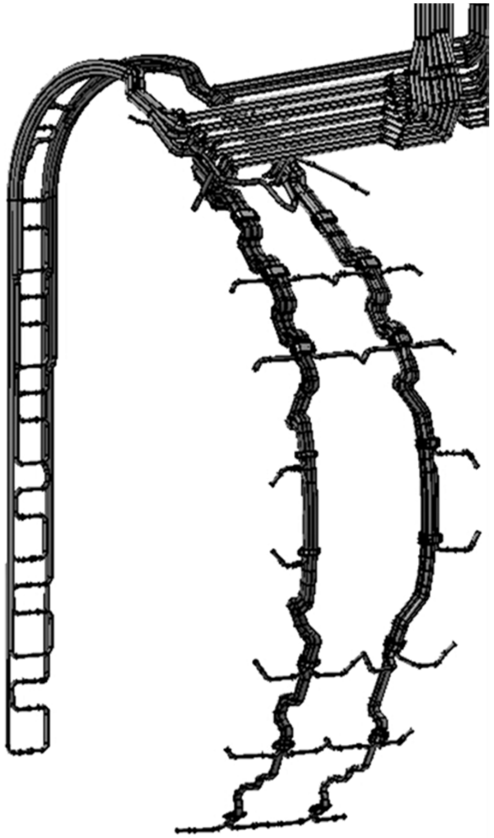
- BMs are cooled in parallel
- Plasma-facing fingers cooled in parallel
- SB sections are cooled in parallel
- FWP – SB cooled in series

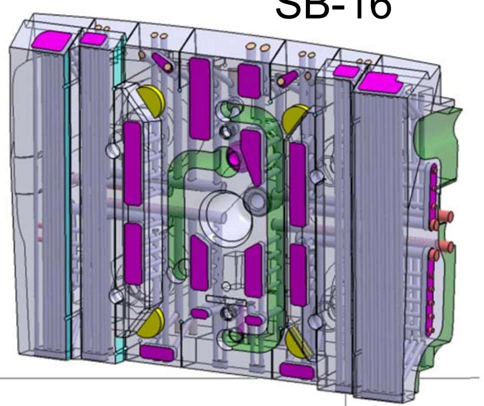
Blanket coolant design parameters

Inlet temperature: 70 °C
Inlet water pressure: 3.0 MPa
CHF margin: > 1.4
Total flow rate: < 3.6 ton/s

Hydraulic Scheme (a standard sector)







Neutronics aspect

1. Radiation Effects

- Increase of strength, loss of ductility
- Removal of heat generated by nuclear heating
- Impact on maintenance strategy due to nuclear heating and activation
- Re-welding issue due to He-production at the re-welding position

Design issues: Efficient removal of heat generated by nuclear heating
Reduction of radiation effects at re-welding position

2. Shielding Function

Design issues: Material selection and distribution (metals and water)
Keep sufficient mass to attenuate neutron flux
Limit cut-out to suppress neutron streaming

	Divertor	Blanket
Radiation damage in ITER lifetime (steel)	< 1 dpa	< 2.5 dpa

Manufacturing / Welding operations of In–Vessel Components

Welding is considered as a special process (ISO 9000)
Results i.e. defect free weld is not 100 % sure although inspection

This needs qualifications in order to make everything for the quality before welding

This basically means qualification of everything which concerns welding

- Welding Procedure Specifications
- Welders/operators
- Inspectors
- Consumables
- etc

- Commonly used Welding processes: Power beam welding and TIG welding
- Commonly used NDTs: Liquid Penetrant Test (PT), Radiographic Test (RT), Ultrasonic Test (UT)

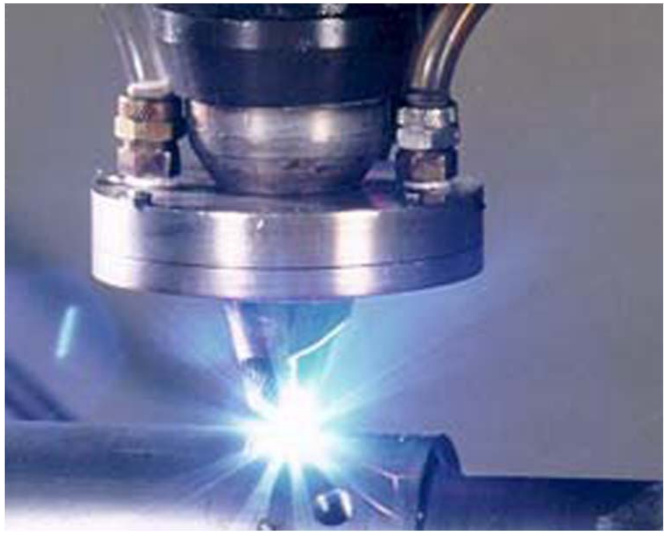
Manufacturing / Power Beam Welding

Electron Beam welding
Gun: high power electron gun

Laser welding
CO_2 laser, Fiber laser, Nd:YAG laser

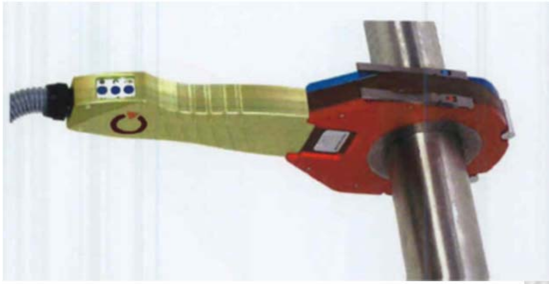
Features:
* Automatic Welding operated by qualified operator
* Thin to thick thickness (~60 mm thick steel)
* High power density
* Single pass welding
* Low angular distortions

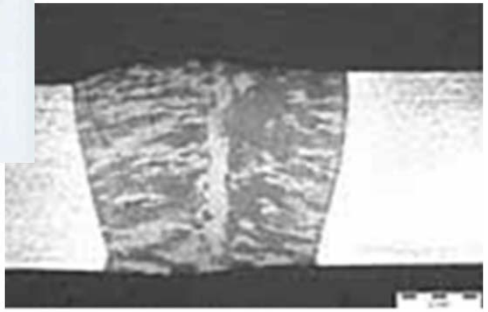
- No use of filler wire -> Risk of hot cracking



Manufacturing: TIG welding

TIG (Tungsten Inert Gas) welding
for In-Vessel components:

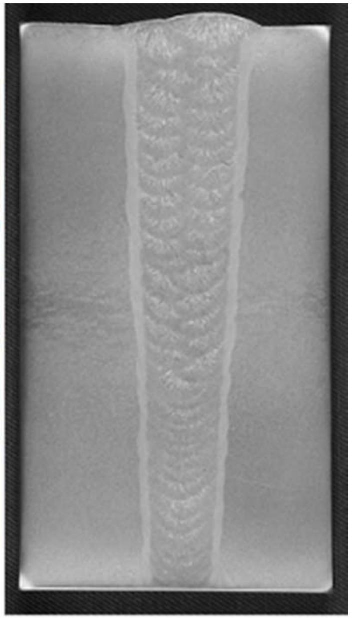




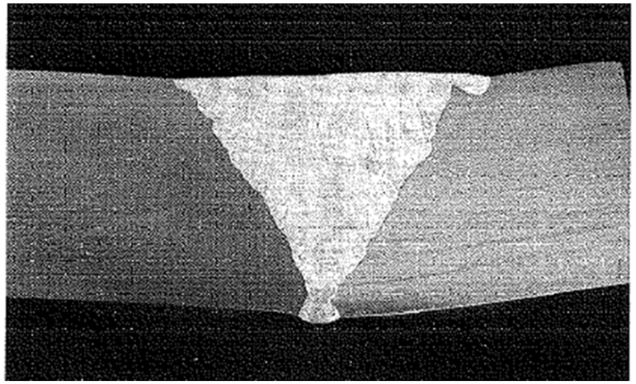
- Single pass
  - * Thickness less than 3 mm
  - * Normally without filler wire
  - * Main application the pipes

- 2. Multi pass
  - * Thickness greater than 3 mm
  - * In principle no limit in thickness
  - * Use of groove and filler wire
  - * Narrow Grooves possible

  - Potential large angular distortions

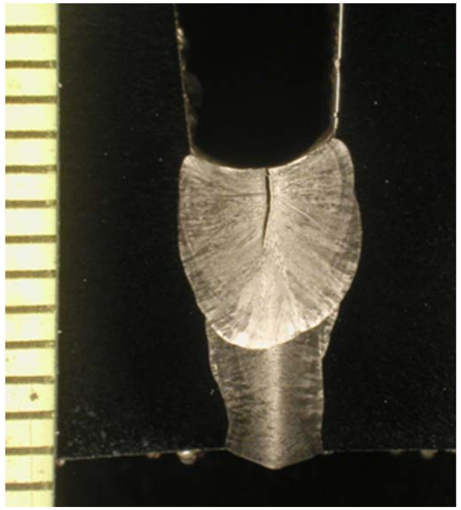


Manufacturing / Challenges in welding of Austenitic Steel



- Distortions
  - Large and accurate structures
  - Austenitic stainless steel
  - Lots of welds

To avoid
Welding sequence, Jigs, Final machining, Balance welding i.e. welding from both sides, Minimize melted metal, e.g. Narrow Grooves and Power beam processes; Laser, EB



- Hot cracking of weld metal
  - Austenitic stainless steels
  - Rigid structure

To avoid
Selection of proper filler material i.e. proper ferrite content

- All the normal weld defects: Cavities and inclusions

Quality level B of EN ISO5817/ EN ISO 13919

Manufacturing / Welding Qualifications

- Qualification of Welding Procedure Specification (WPS)
  - WPS introduced EN ISO 15607 and EN ISO 15609-nn
  - Preliminary WPS is qualified according to EN ISO 15614-nn
  - Qualification if quality level B gained
    - EN ISO 5817 for arc welding
    - EN ISO 13919 serie for power Beam welding
  - Welding Procedure Qualification Record (WPQR)

- The welding qualification for Quality Class 1 components shall be witnessed by ITER recognized Independent Inspection Authority, e.g. Third Party Inspector.

- Welders, operators and NDT personnel shall be qualified (EN 287/ EN1418/ EN 473)

- Other equivalent national or international standards and codes may be acceptable subject to the IO's written approval.

NDT of welds in Steel Supports

- **Surface crack examination**

- **Visual Test for welds (EN 970)**
- **Liquid Penetrant Test for welds (EN 571)**

N.B. ITER Vacuum Handbook requirement: use of qualified liquid penetrants

- **Volumetric examination**

- **Radiographic test for welds (EN 1435)**
- **Ultrasonic Test for welds (EN 22825)**

- **Acceptance Criteria**

- Quality level B of EN ISO5817/ EN ISO 13919
- ITER Vacuum Handbook Attachment 1: Welding

- Other equivalent national or international standards and codes may be acceptable subject to the IO's written approval.

Acceptance test of Divertor Plasma-facing Components

- **Testing of PFCs prior to Assembly on a Cassette**

(i) Flow test to monitor the flow rate distribution, e.g. Hot water (>80 ^{o}C) flow test or other method to monitor flow rates

(ii) Hydraulic pressure (7.6 MPa) test of the cooling system shall be that specified by the Pressure Equipment Directive (EN 13445-5)

(iii) Hot vacuum leak test with an internal pressure of 5 MPa He, and a temperature of 250°C.

Acceptance test of Divertor Cassettes

- **Divertor shall be tested during manufacturing and commissioning**

- **Testing of Divertor Cassette Assemblies (CAs)**

(i) Hot water flow test
(ii) Hydraulic pressure test
(iii) Hydraulic flow test (test in each PFC shall be measured by ultrasonic flow meter or non-intrusive method)
(iv) Cold He leak test

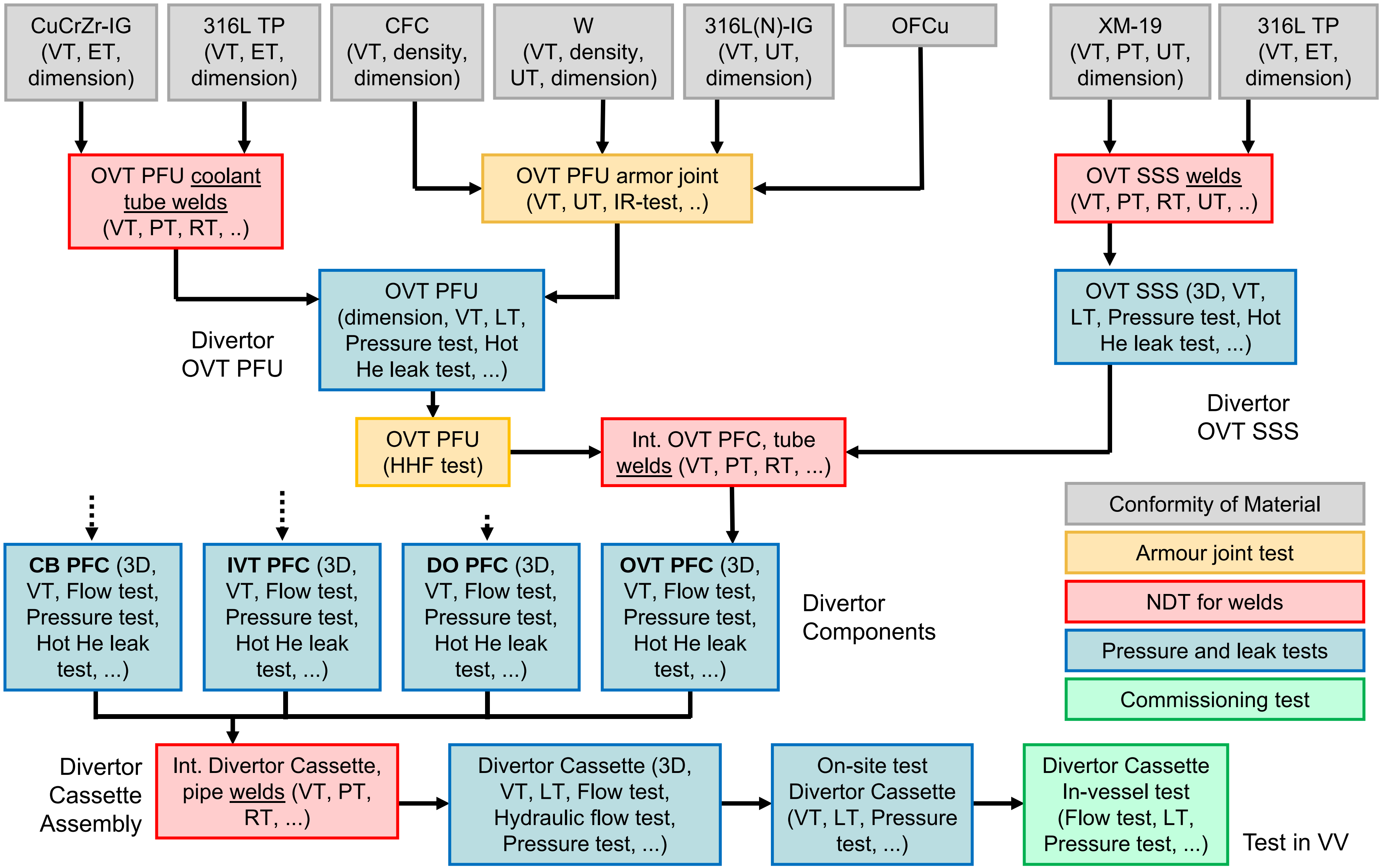
- **On-site Acceptance testing of CAs** (if integration site ≠ ITER site)

(i) Hydraulic pressure test,
(ii) Cold He leak test

- **In-vessel Testing of Divertor Cassettes**

(i) Pressure test,
(ii) Water flow test (~1000 kg/s),
(iii) Cold He leak test

Summary of Inspections/ tests for Divertor OVT and CA



Contents

Integration between IO and DAs

- Basic Roles and Responsibilities

ITER Organization	Seven Members (Domestic Agencies, DA)
– Planning / Design* – Integration / QA / Safety / Licensing / Schedule – Installation – Testing + Commissioning – Operation	– Detailing / Designing* – Procuring / Manufacturing – Delivering – Supporting installation – Conformance

* Depending on type of specification
- Functional: Functional requirements by IO and design by DAs
- Detail Design: Conceptual design by IO and detailed design by DAs
- Build-to-print: Detailed design by IO and fabrication/shop design by DAs

❑ Management responsibility at IO side, Implementation responsibility at DA sides

Management of In-kind Procurement

- Procurement team and contact points:
  1) Technical Responsible Officer (TRO)
  2) Quality Assurance RO (QARO)
  3) Procurement Arrangement RO (PARO)
  4) Planning and Schedule RO (PSRO)
  5) Technical supports from IO personnel

ITER Organization	Domestic Agency
IO-TRO	DA-TRO
IO-QARO	DA-QARO
IO-PARO	DA-PARO
IO-PSRO	DA-PSRO
Technical supports	Technical supports

- Monitoring Procurement Arrangement (PA) execution:
  - Monthly report, Progress Meeting
  - Control Points corresponding to the PA milestones and reviews at each stage

- Quality Assurance requires Quality plan (QP) and Manufacturing and Inspection Plan (MIP)

- Deviation and Non-conformance: Deviation requests and Non-conformance report to be approved by IO (Quality Assurance), possibly followed by Project Change Request (Configuration Management)

- Traceability: all documentation must be kept, e.g. in IDM (ITER Document Management)

Contents

Status and milestones

Divertor

2009-2010	→	Start Procurement of PFCs and HHF testing
2011	→	First Prototype HHF tests after Commissioning of IDTF
End 2011	→	Start Procurement of CBs and Divertor Integration
2013-2014	→	Full Scale Prototype
2019-2020	→	Last Delivery on Site

Blanket

Feb 2010	→	Conceptual Design Review
End 2011	→	Preliminary Design Review
End 2012	→	Final Design Review
Mid-2013	→	Start procurement
End-2019	→	Last Delivery on Site

Thank you for your attention

I would like to appreciate colleagues for their contribution:

V. Barabash, B. Calcagno, P. Chappuis, Y. Demao, R. Eaton, F. Escourbiac, A. Fedosov, L. Ferrand, Z. Fu, A. Furmanek, T. Jokinen, V. Komarov, A. Martin, M. Merola, R. Mitteau, S. Mori, R. Raffray, S. Sadakov
ITER Organization