ITER

Plasma Facing Components

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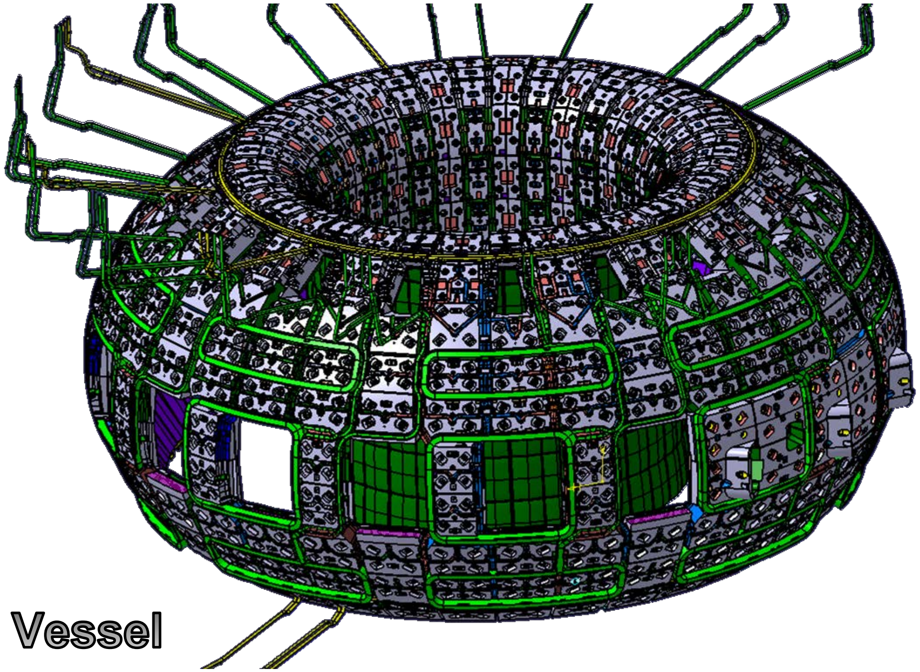
ITER Organization

Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization

Overview

- ❑ ITER Plasma-Facing Components
- ❑ Blanket System
- ❑ Divertor
- ❑ Design Criteria
- ❑ Summary



Internal Components:
rear view, without Vacuum Vessel

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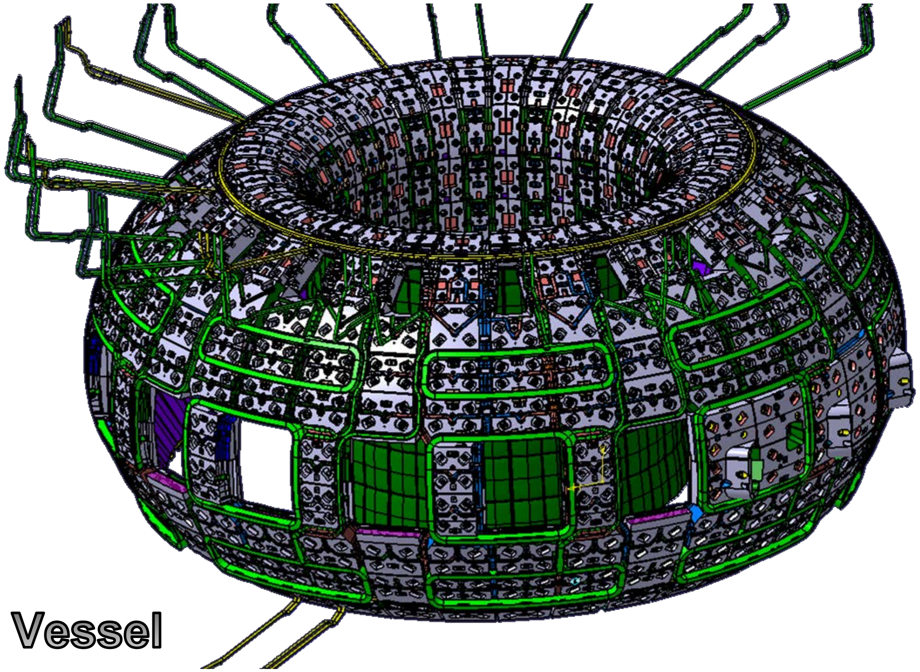
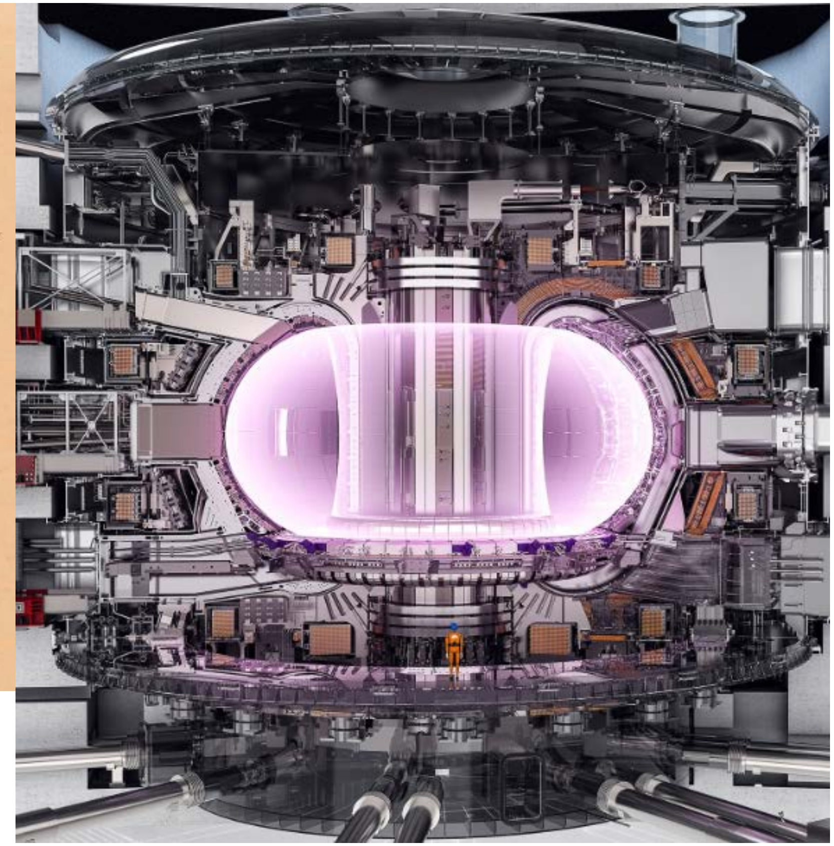


Internal Components:
rear view, without Vacuum Vessel

ITER Internal Components: Divertor and Blanket

ITER Plasma-Facing Components



- Up to 850 MW of power to be removed
- All these components are designed to be replaced by Remote Handling tools
- All these components are "Quality Class 1"
- All these components are "Vacuum Quality Class 1"

ITER Plasma-Facing Components

Main challenges:

- The high and cyclic surface heat flux,
- The high and cyclic electromagnetic loads,
- The extremely tight tolerances,
- The plasma-wall interactions,
- Shall guarantee the ultra-high vacuum - 10,000,000,000 (ten billions) times lower than the atmospheric pressure,
- The various and sometimes conflicting project requirements (shielding, assembly, remote handling)
- Integration with other in-vessel components and diagnostics)

Main design drivers (heat flux, electromagnetic loads)

Manufacturing and cost driver (tolerances)

Armour material driver (plasma-wall interactions)

Design, material, manufacturing driver (ultra-high vacuum)

Each system is not an island… (requirements, integration)

A complex puzzle to solve…

Main Design Drivers

- Surface and cyclic heat flux
- Neutron Flux
- Electromagnetic loads
- Surface erosion

Main Design Drivers

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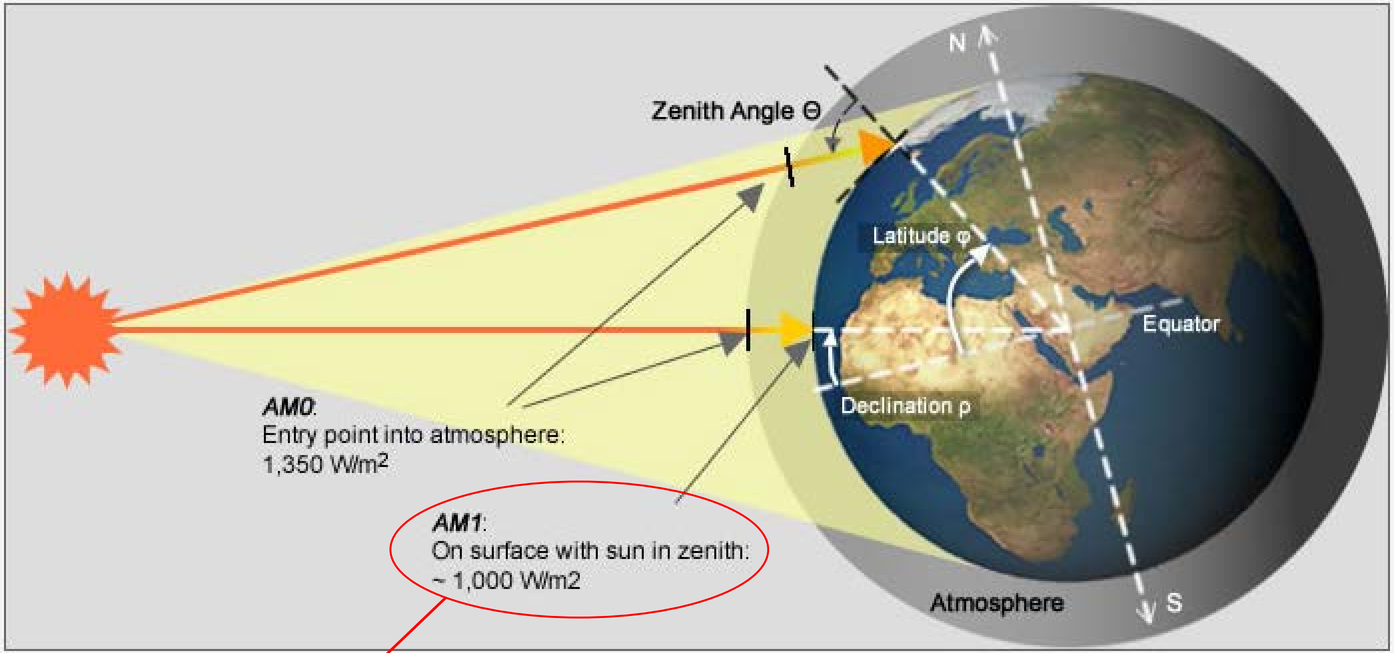
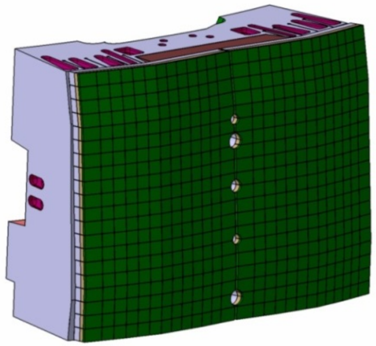
Facing the plasma → High heat Fluxes

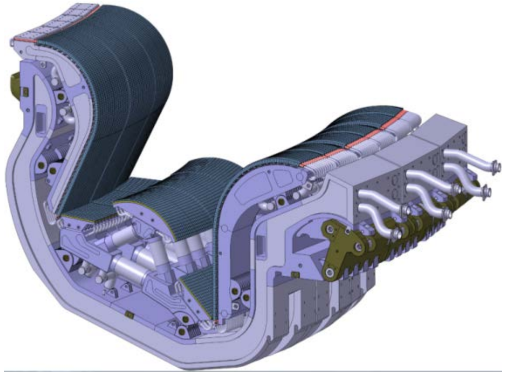


1 kW/m²



ITER Blanket

4,700 kW/m²

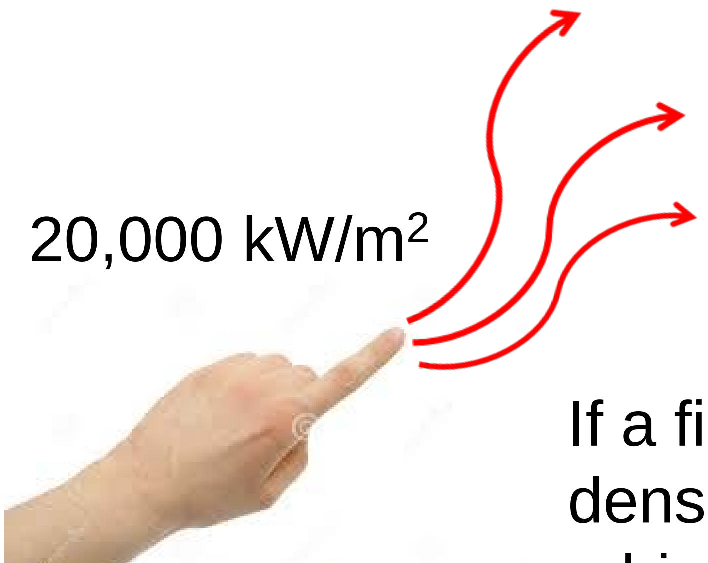


ITER Divertor

20,000 kW/m²

Facing the Plasma → High heat fluxes onto the Divertor

20,000 kW/m^2



If a finger tip could emit the same heat flux density reaching the Divertor, this would heat a big apartment during the winter season

Facing the Plasma → High heat fluxes

❑ Divertor

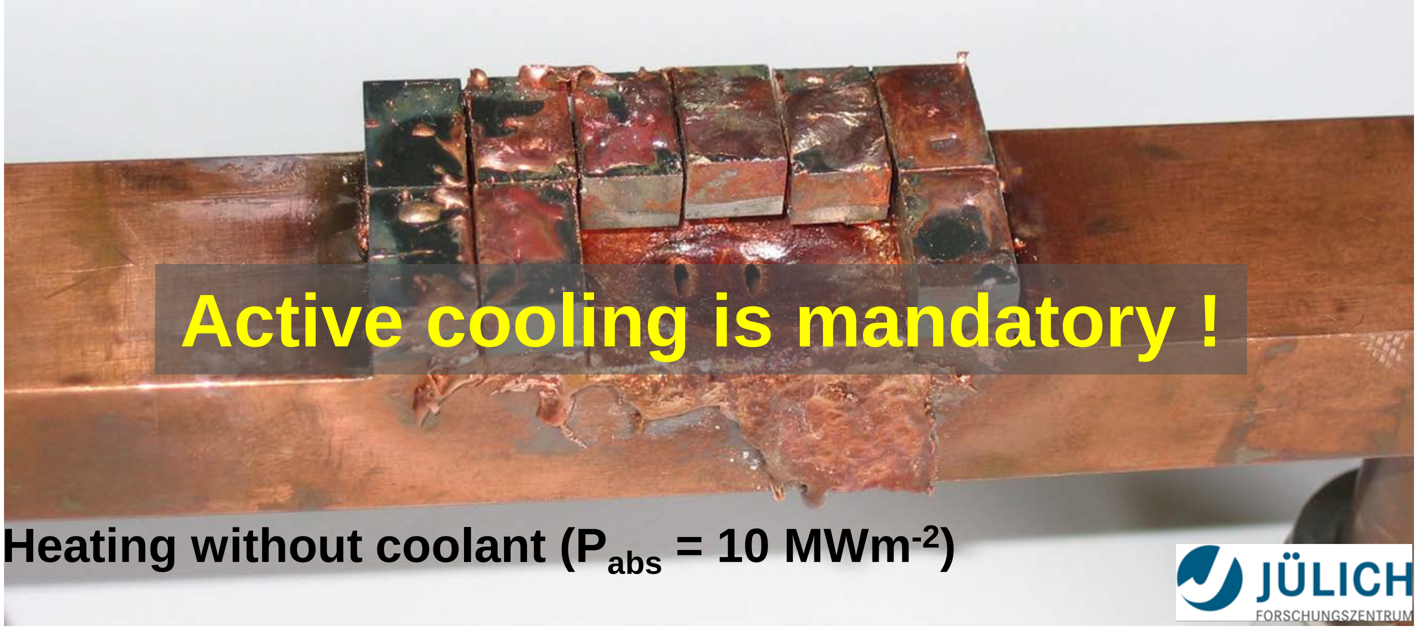
Design loads at Target (axisymmetric)
5000 cycles @ 10 MW/m^2
300 cycles @ 20 MW/m^2

Design loads at Baffle
5000 cycles @ 5 MW/m^2

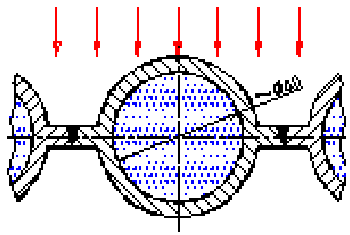
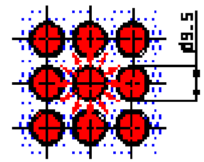
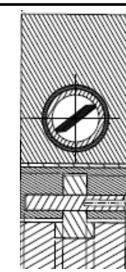
❑ Blanket First wall

Design loads at Enhanced heat flux panel
15 000 cycles @ 4.7 MW/m^2

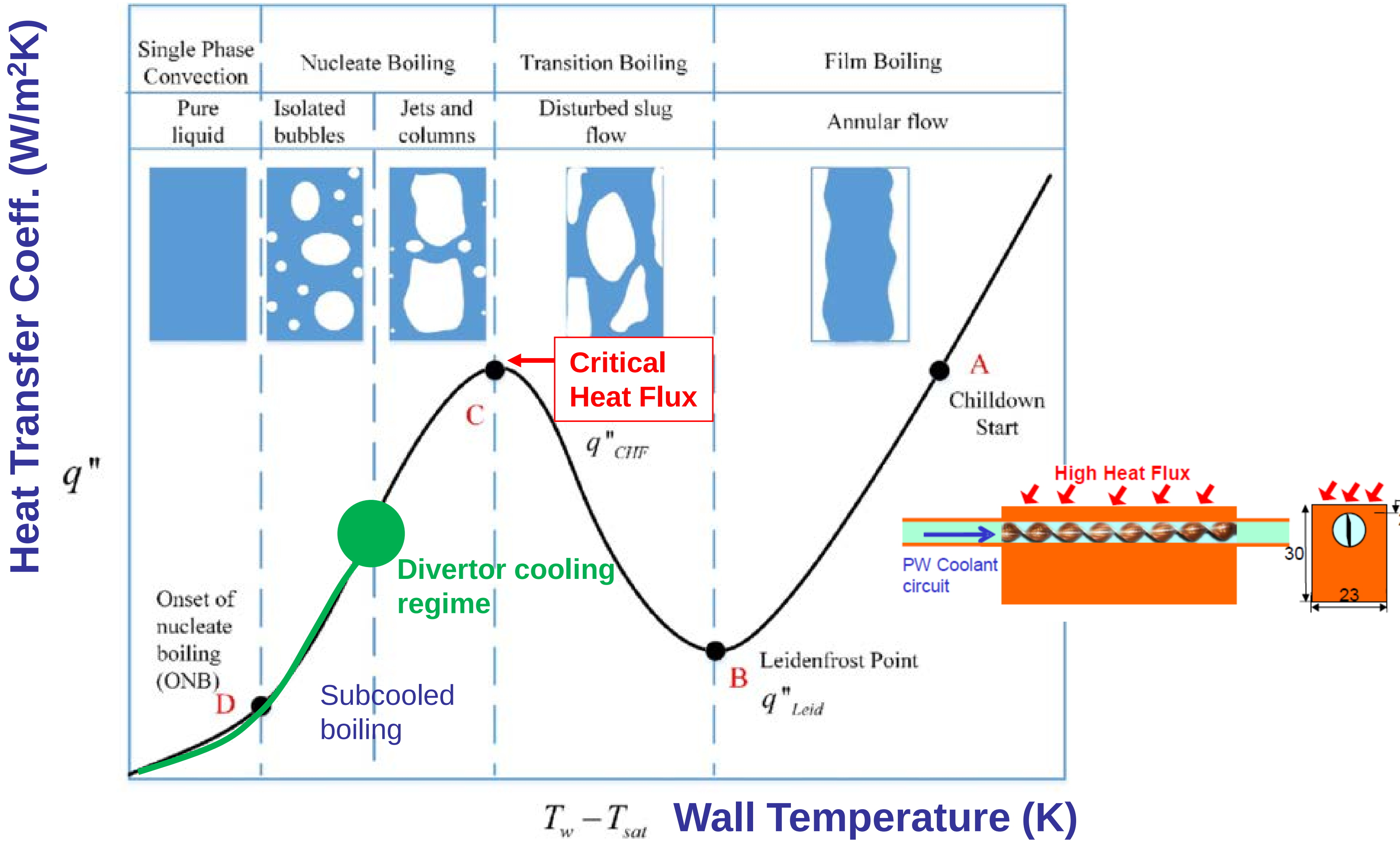
Design loads at Normal heat flux panel
15 000 cycles @ 2.0 MW/m^2



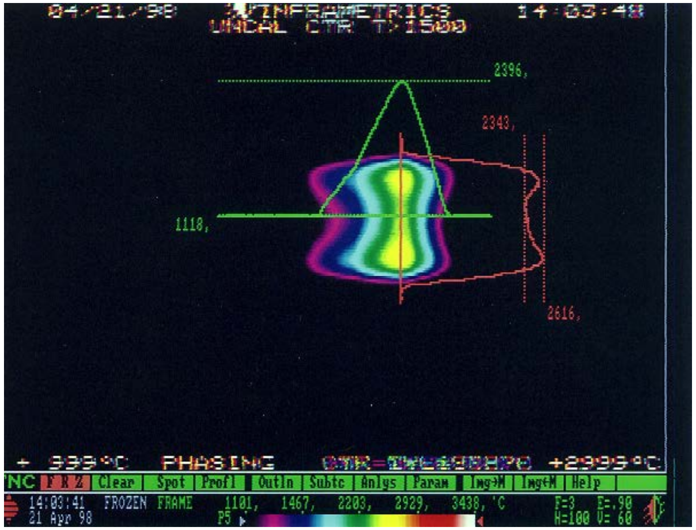
Power Handling Comparisons

HIGH HEAT FLUX COMPONENTS	FOSSILE FIRED BOILER WALL (ABB)	FISSION REACTOR (PWR) CORE	ITER DIVERTOR
DESIGN			 12/15 mm ID/OD
HEAT FLUX - average MW/m^2 - maximum MW/m^2	 0.2 0.3	 0.7 1.5	 3 – 5 10 – 20
Max heat load MJ/m^2 Lifetime years Nr. of full load cycles Neutron damage dpa Materials	- 25 8000 - Ferritic-Martens. steel	- 4 10 10 Zircaloy - 4	10 ~ 10 5000 0.2 CuCrZr & W
Coolant - pressure MPa - temperature °C - velocity m/s - leak rate g/s	Water-Steam 28 280-600 3 <50	Water 15 285-325 5 <50(SG)	Water 4 100 – 150 9 – 11 <10^{-7}

Hydraulic design

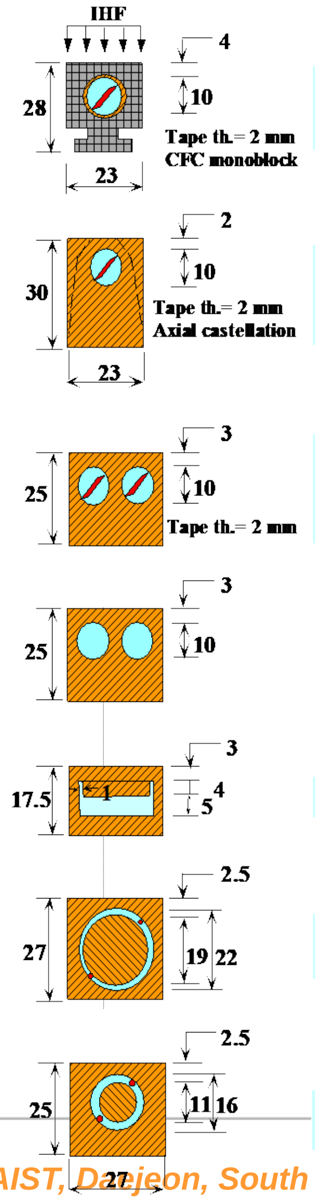


Critical Heat Flux



THERMO-HYDRAULIC TEST RESULTS BY CEA CADARACHE 1996-98

- Mock-ups: CuCrZr (1996), DS-Cu (1997), CFC monoblock (1998)
- Heated length: 100 mm uniform, 200 mm peaked heat flux profile
- Interpolated results for 3.5 MPa, 100 C subcooling, 12 m/s (ITER conditions)



Year		Incident Critical Heat Flux, (MW/m²): Uniform	Peaked	Pressure Drop (MPa/m)
1998	Swirl tube: Twist ratio: 2	~ 22	~ 30	-
1997	Swirl tube: Twist ratio: 2	~ 28	~ 34	~ 0.61
	Twist ratio: 4	~ 21	~ 24	~ 0.41
1996	Swirl tube: Twist ratio 2:	~ 27	~ 45	~ 0.75
	Twist ratio 4:	~ 24	~ 35	~ 0.44
1996	Smooth tube:	~ 17	?	~ 0.20
1996	Hyper-vapotron:	~ 35	~ 43	~ 0.56
1996	Annular flow: Twist ratio: 2	~ 23	?	~ 1.2
1996	Annular flow: Twist ratio: 2	~ 27	?	~ 1.0

Facing the Plasma → High heat fluxes

- **Surface heat flux** due to the radiative and particle flux from the plasma.
- This is of particular concern for the next generation of fusion machines like ITER where, due to the high number of operating cycles, a thermal fatigue problem is anticipated.
- Particularly harmful are the off-normal heat loads, which are associated to plasma instabilities (such as a plasma disruption or vertical displacement). Up to some tens of MJ/m^2 can be deposited onto the PFCs in a fraction of a second resulting in melting and evaporation of the plasma facing material.
- Fatigue and plasma instabilities should substantially decrease in a commercial reactor.

Aggressive cooling of the Plasma-Facing Components
High Heat Flux Technologies

Main Design Drivers

- ❑ Surface and cyclic heat flux
- ❑ Neutron Flux
- ❑ Electromagnetic loads
- ❑ Surface erosion

Neutron flux

- **Neutron flux from the plasma.** The neutron flux is referred to as "wall loading" and measured in MW/m^2. This is the power density transported by the neutrons produced by the fusion reaction.

- The wall loading multiplied by the total plasma burn time gives the neutron fluence, which is measured in MW-year/m^2.

- The two main effects of the neutron flux are the volumetric heat deposition and the neutron damage.

Each cm^3 of the Plasma-Facing Components structure needs to be actively cooled
Finely array of cooling channels

Volumetric heat deposition

- The **volumetric heat deposition** has a typical maximum value of a few W/cm^3 in the FW structures and then decreases radially in an exponential way. It has mainly an impact on the design of the supporting structures, which thus need to be actively cooled.

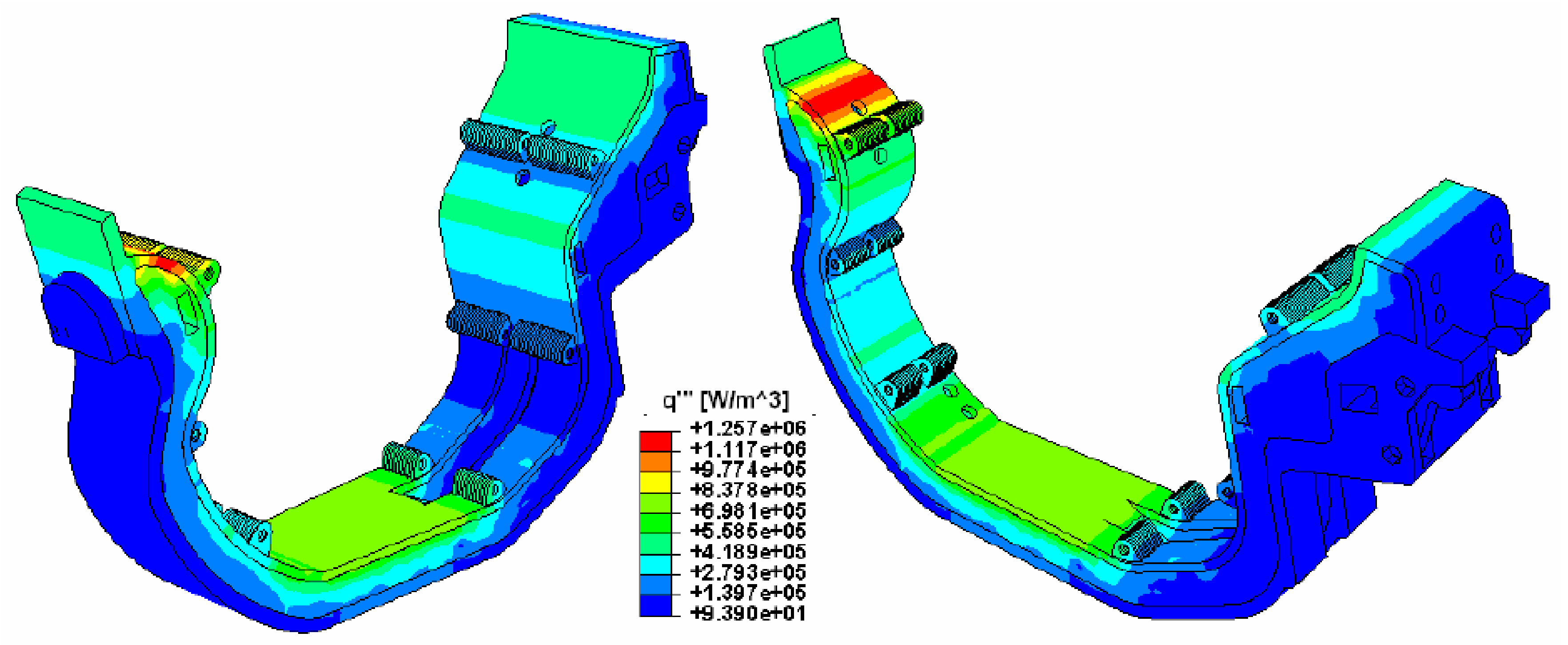
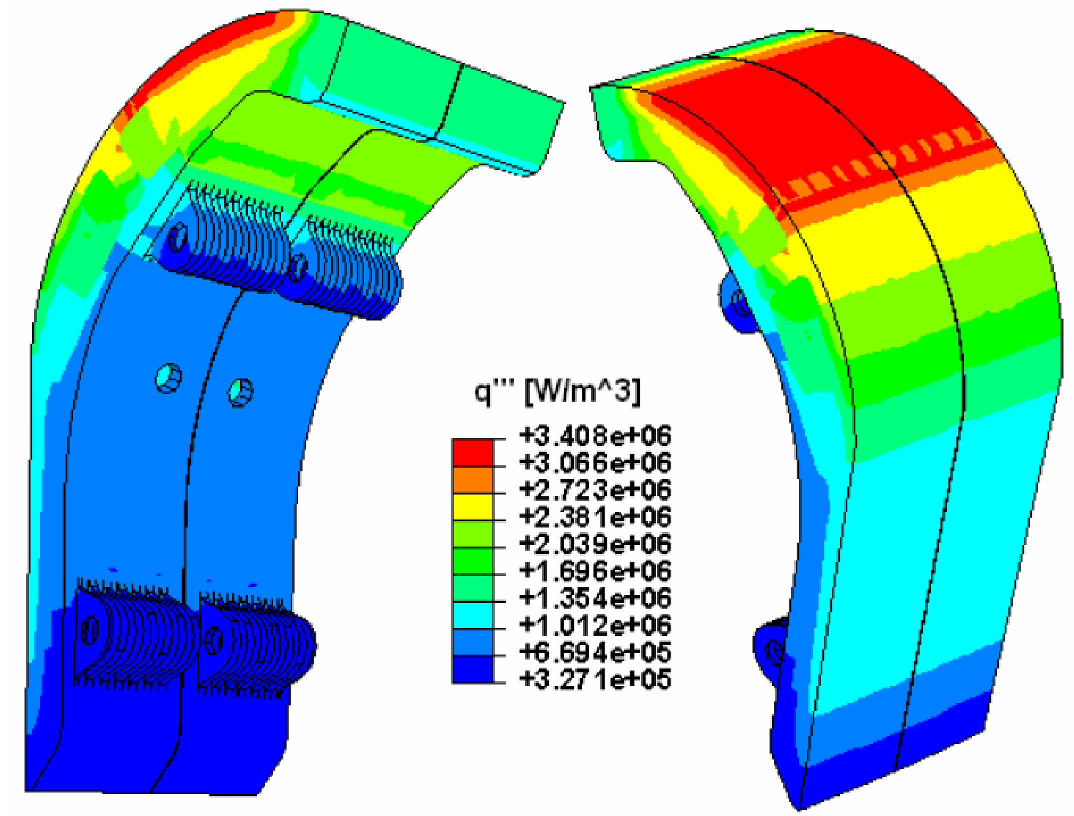
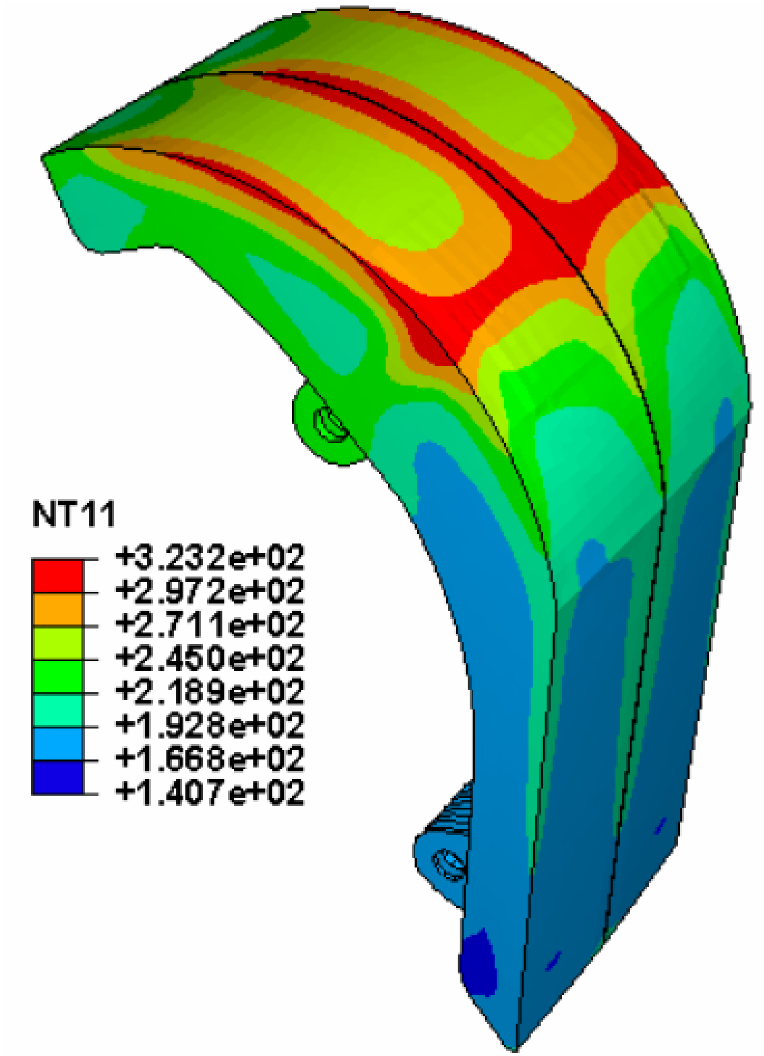


Figure 50: Neutronic heat deposition in the Cassette body

Volumetric heat deposition



Volumetric heat deposition



Resulting temperature

Inner Vertical Target

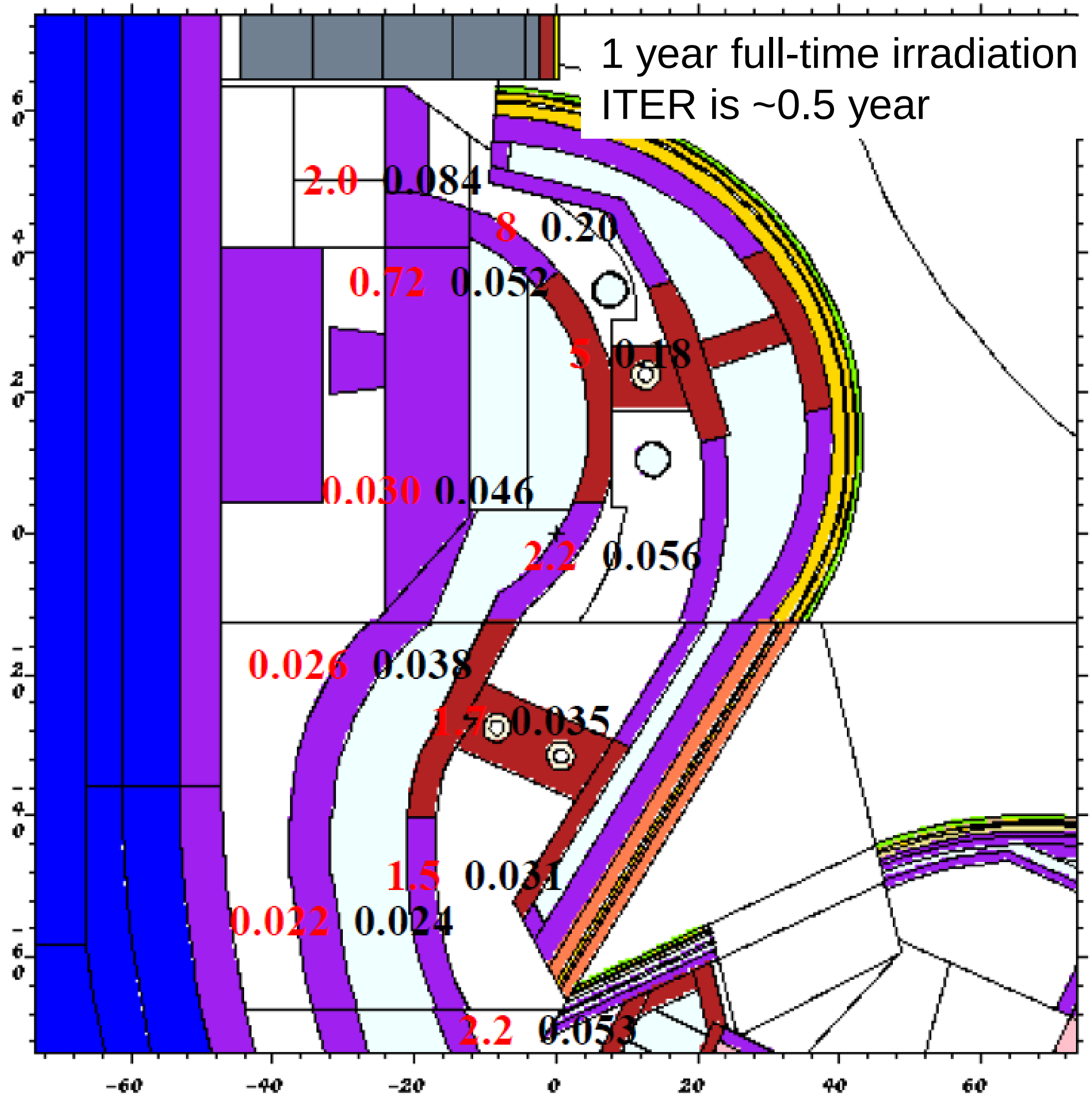
Neutron damage

The **neutron damage** is less than a problem for ITER but it will be the main lifetime limiting phenomenon in a commercial reactor.

It is measured in **"displacements per atom" (dpa)**.

The dpa is proportional to the neutron fluence.

The dpa value is a measure of the neutron damage. **Typical effects of this damage are He production, embrittlement and swelling.**



Red: He production in appm
Black: dpa

Main Design Drivers

- Surface and cyclic heat flux
- Neutron Flux
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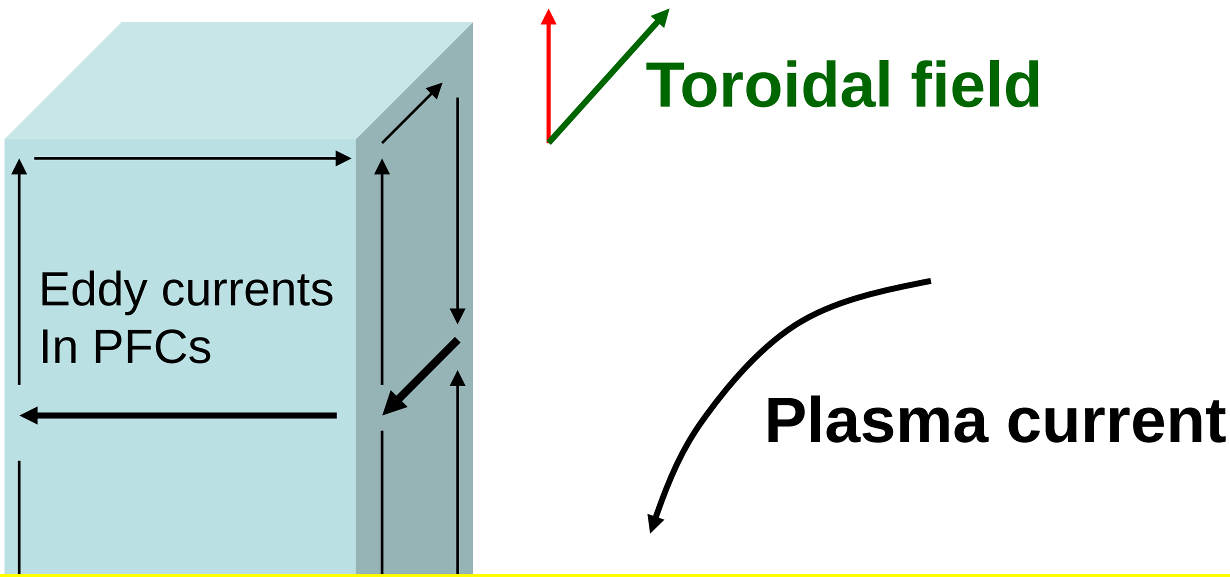
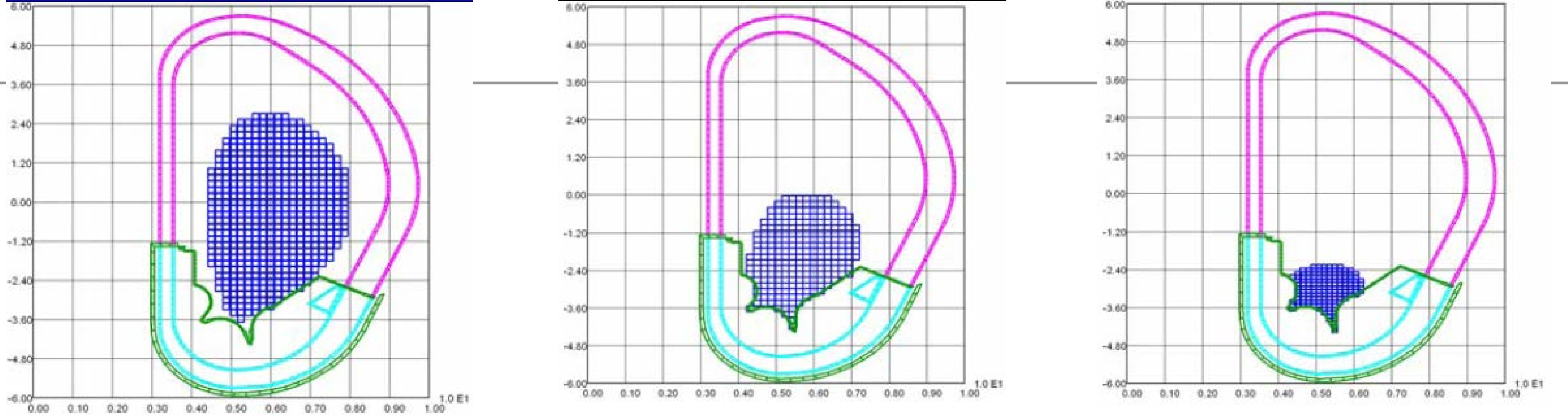
- Surface erosion

Electromagnetic Loads

- **Electromagnetic loads.** During a plasma instabilities eddy currents are induced in the PFCs. These currents interact with the toroidal magnetic field thus resulting in extremely high forces applied to the PFCs. These forces can generate mechanical stresses up to a few hundreds of MPa with a consequent strong impact in the design of the supporting structures.



Extremely robust supporting structures
Specific material grades (to maximize the mechanical strength)



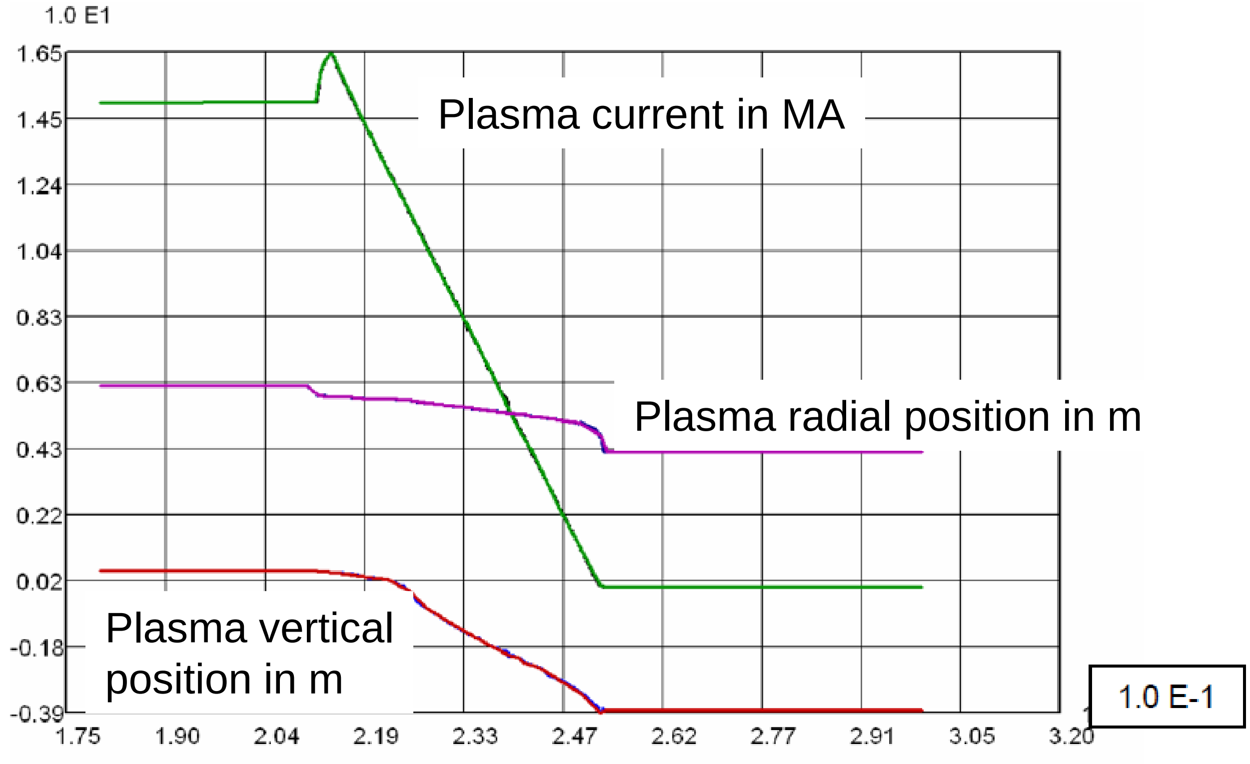


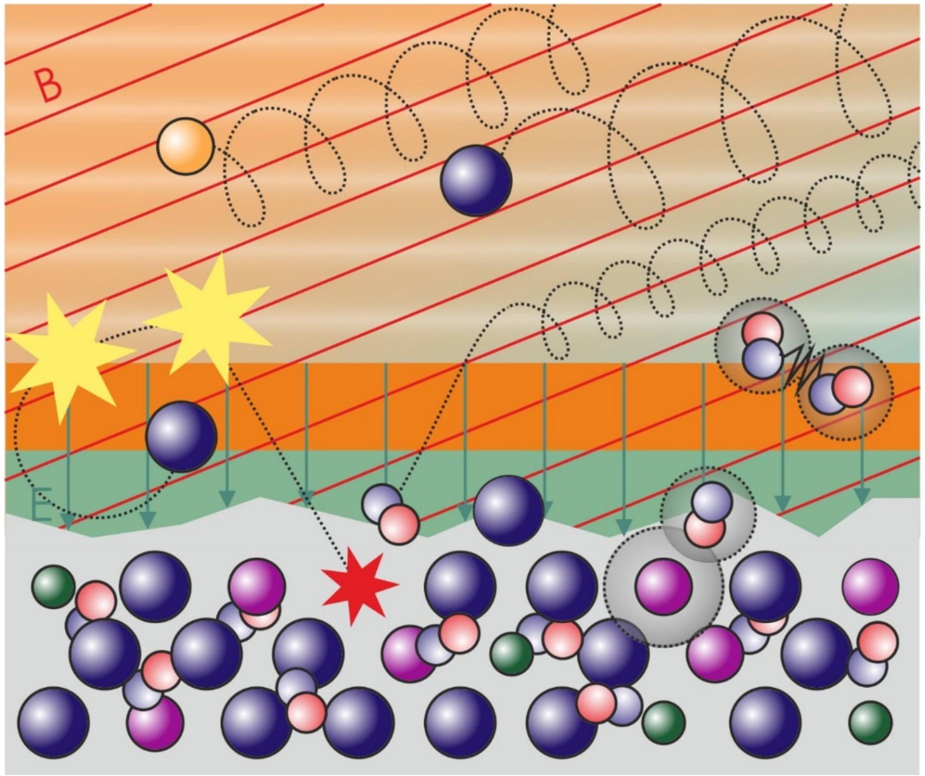
Figure 39: VDEII-36 ms LCQ - Plasma Current and average position.

Main Design Drivers

- ❑ Surface and cyclic heat flux
- ❑ Neutron Flux
- ❑ Electromagnetic loads
- ❑ Surface erosion

Surface erosion

- **Surface erosion.** The particle flux impinging onto the PFCs causes surface erosion due to physical sputtering (and also chemical sputtering in the case of carbon).
  - The thickness of the plasma facing material is progressively reduced.
  - The eroded particles can migrate into the plasma thus increasing the radiative energy loss by *bremsstrahlung* and diluting the deuterium and tritium concentration.

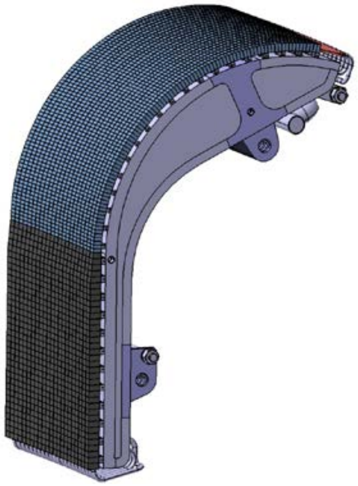


  - Eroded particle (like carbon) may trap tritium atoms when they redeposit onto the surface of the PFCs (the so-called "co-deposition"). This results in an increase of the tritium inventory in the plasma chamber with the associated safety concerns.

Surface erosion dictates the minimum thickness of the plasma-facing material

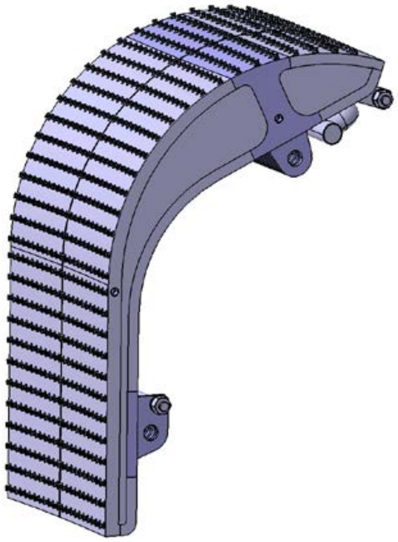
General Design of a Plasma-Facing Component

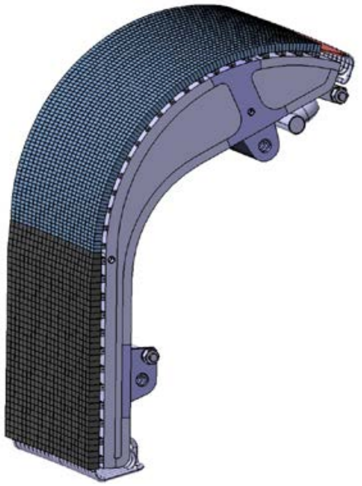
- **Plasma Facing units – The "High Tech" part (replaceable)**
  - **Main scope**: to transfer the heat from the plasma to the water coolant
  - Manufactured in small units to minimize industrial risk.
  - They consist of:
    - An "**armour**" material facing the plasma (beryllium or tungsten)
      - Plasma compatibility
      - High thermal conductivity
      - Low erosion
      - High melting point
    - A "**heat sink**" to transfer the heat from the armour to the cooling channels (copper alloy)
      - High thermal conductivity
      - Adequate mechanical strength
    - The **cooling channels** (copper alloy or steel)
      - Mechanical strength
      - Adequate thermal conductivity
      - Good resistance to erosion / corrosion with water



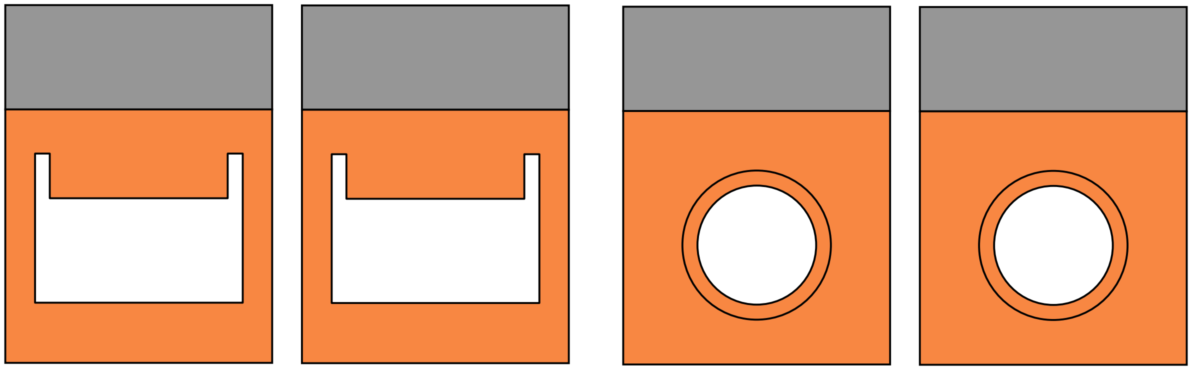
General Design of a Plasma-Facing Component

- **Supporting Structure – The "Conventional Tech" part (semi-permanent)**
  - **Main scope**: to hold the plasma-facing units and to withstand the EM loads
  - Good resistance to erosion / corrosion with water
  - Weldability
  - Extended database for unirradiated and irradiated conditions
  - Largely made of austenitic stainless steel **316 L(N)-IG**.
    - **L** = Low carbon content to limit the precipitations of carbides at the grain boundaries
    - **(N)** = Controlled nitrogen content, i.e. narrow variation of nitrogen content
    - **L(N)** = satisfactory resistance to stress corrosion cracking of the base metal and welds, and more controlled (higher) mechanical properties.
    - **IG** = ITER Grade, optimal combination of the main alloying elements (C, N, Ni, Cr, Mn, Mo) with a tight specification of their allowable composition range. Controlled (low) impurity content of Co, Ta, Nb to reduce activation and decay heat (e.g. activated corrosion products are responsible for about 90% of the occupational dose in fission reactors, reducing the Co content from 0.25% to 0.05% decreases the total decay heat by ~20%)





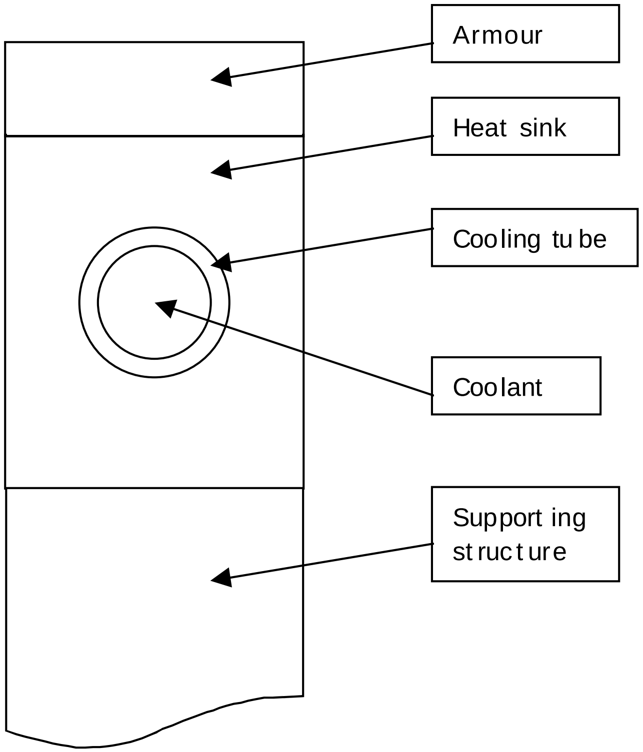
Terminology: Flat Tile and Monoblock

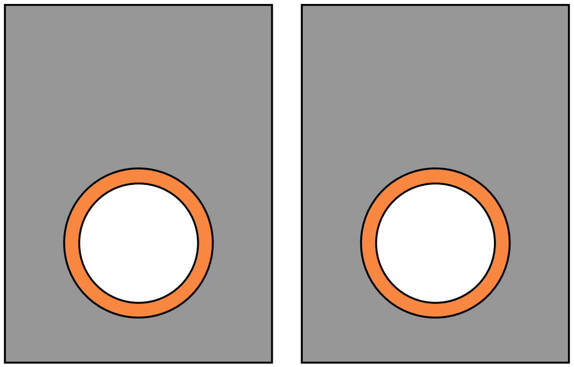


hypervapotron

Circular channels

FLAT TILE





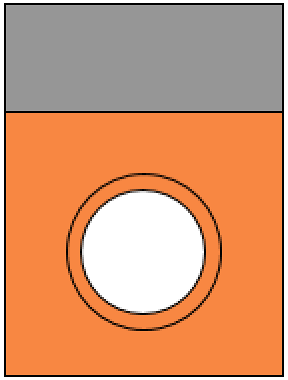
MONOBLOCK

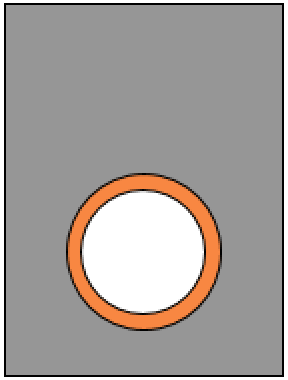
Flat Tile vs Monoblock

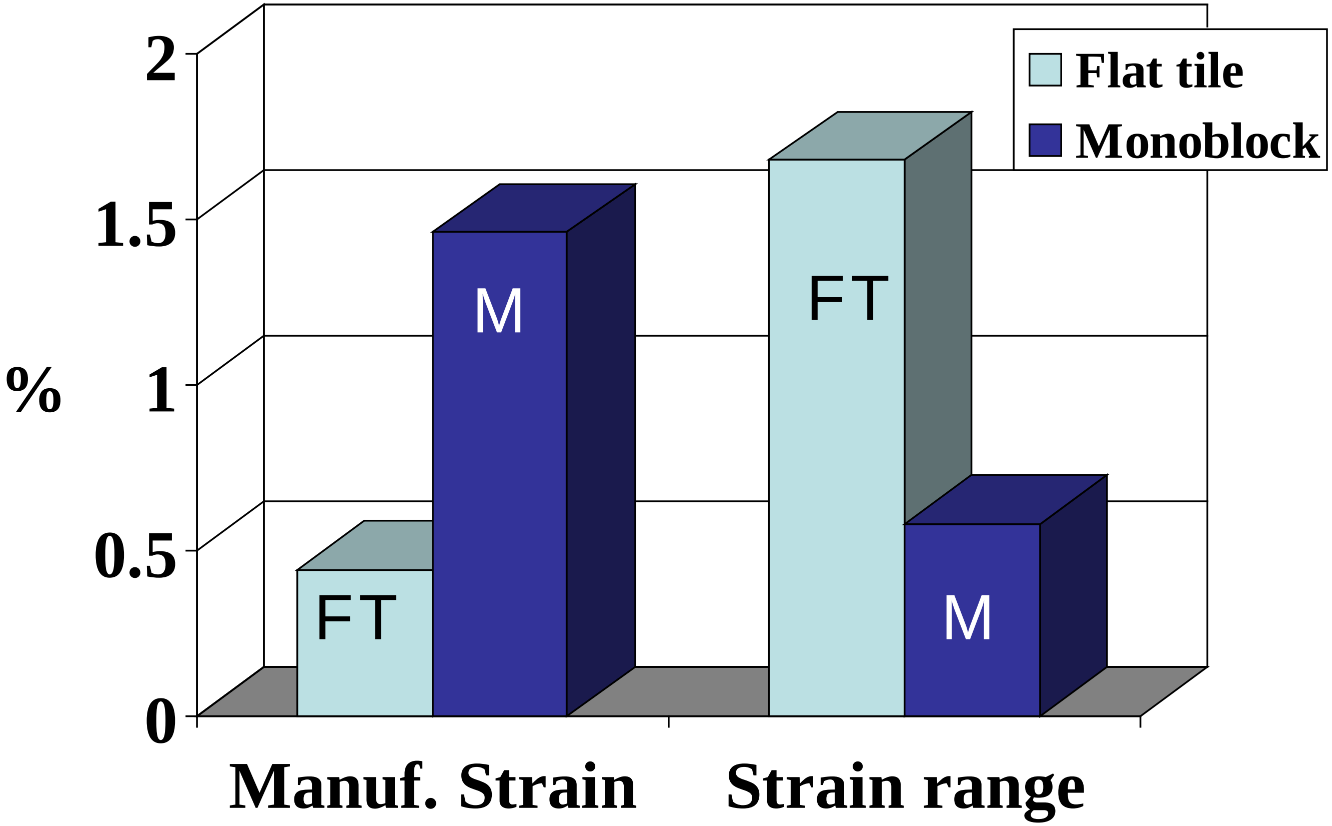
Flat tile: easier to manufacture, but less resistant to cyclic loads

Design solution up to about 10 MW/m^2 (e.g. Blanket)

Monoblock: more difficult to manufacture, but excellent resistant to cyclic loads. Design solution > 10 MW/m^2 (e.g. Divertor)



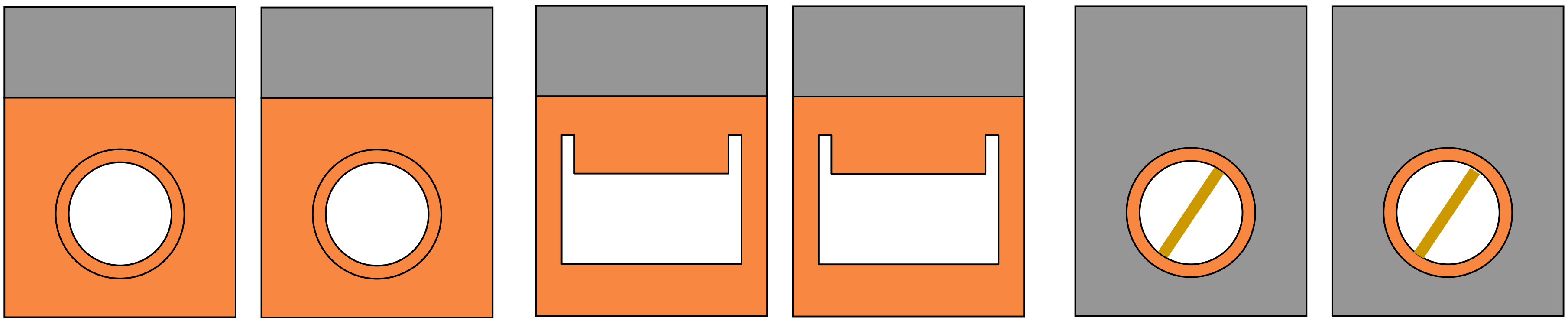




Cooling geometries vs design heat flux

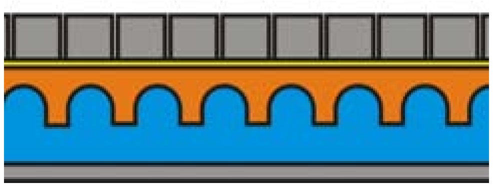
HF < 2 (5)* MW/m^2 | **2 (5)* MW/m^2 < HF < 10 MW/m^2** | **HF > 10 MW/m^2**

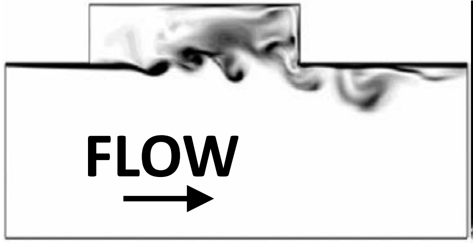
* In case of high > 8 m/s flow velocity

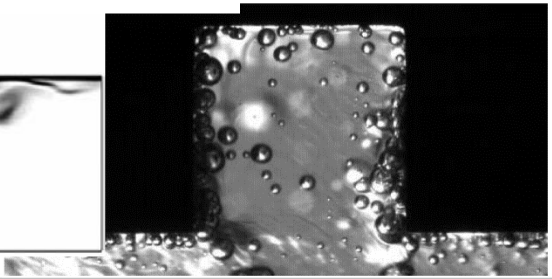


Smooth tube | ***hypervapotron*** | ***Twisted tape***

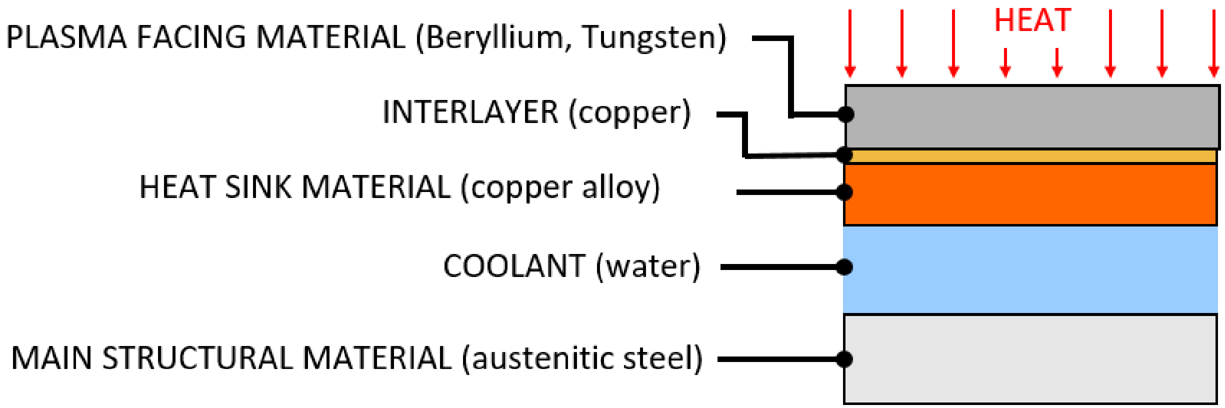
FLAT TILE | ***MONOBLOCK***



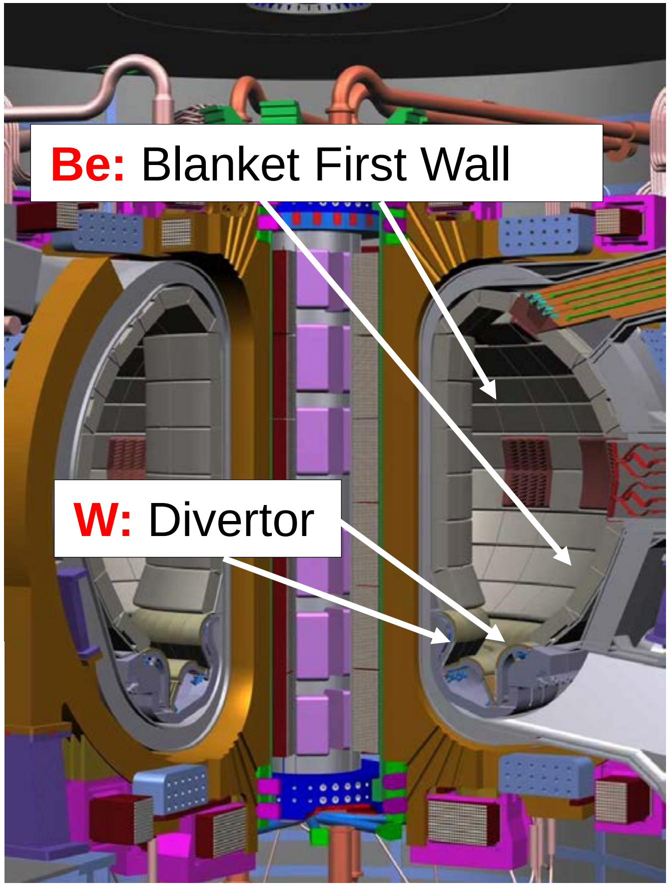




Material Combination in PFCs



PLASMA-FACING COMPONENT



Why Be and W as Armour Materials ?

Beryllium → Blanket

+ Low atomic number (Z) materials
+ Oxygen gettering
+ Good thermal conductivity ~ 200 W.m/K
+ Relatively high melting point 1287 °C
+ Similar thermal expansion as structural materials
- High sputtering yield
- Carcinogenic risk

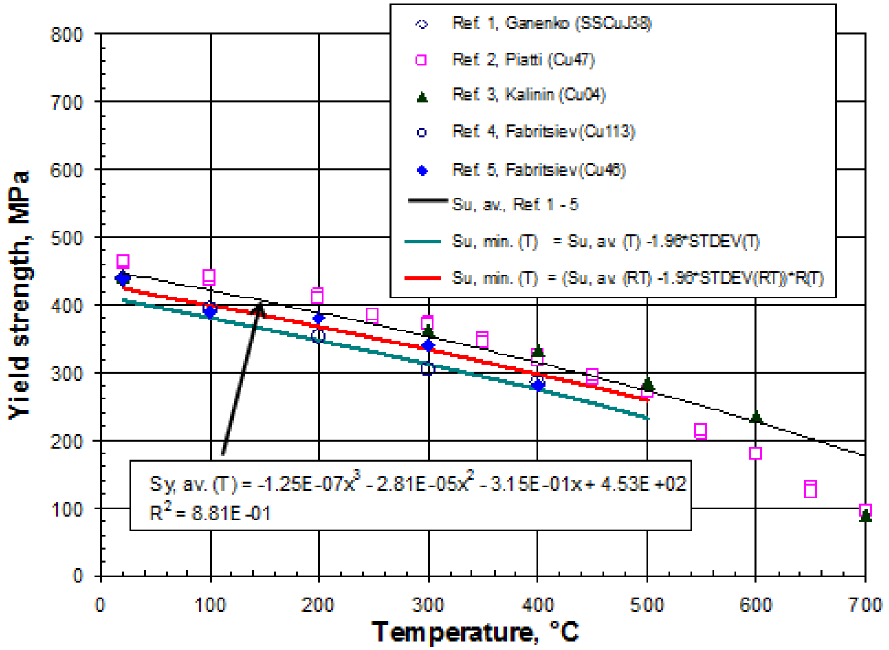
Tungsten (from the Swedish *tung sten* "heavy stone") → Divertor

+ High melting point 3400 °C
+ good thermal conductivity ~170 W.m/K
+ Low sputtering yield
+ Low tritium retention
- High radiation loss in plasma
- Smaller thermal expansion than structural materials

Two armour materials were selected from plasma point of view….

Why Copper Alloy (CuCrZr) as Heat Sink Material ?

+ High thermal conductivity > 300 W.m/K
+ Good mechanical properties 280 MPa UTS
+ Significant amount of data about the CuCrZr alloy (0.6-0.9 wt%Cr, 0.07-0.15 wt%Zr) have been generated during worldwide R&D
+ Available in different form from different suppliers in market
+ Proven weldability
- Sensitive to heat treatment… Precipitation (Cu_nZr) hardening material



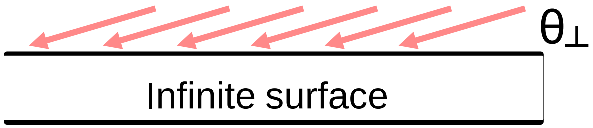
Design of Plasma-Facing Surface

Shape design of plasma facing components for stationary and transient power fluxes

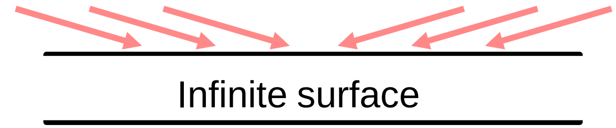
J. Gunn

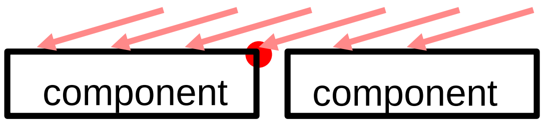
❑ Directional heat flux – shaping

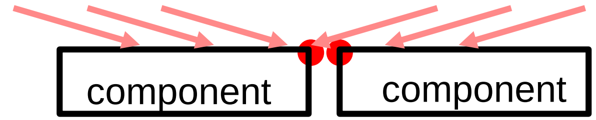
Uni-directional heat flux

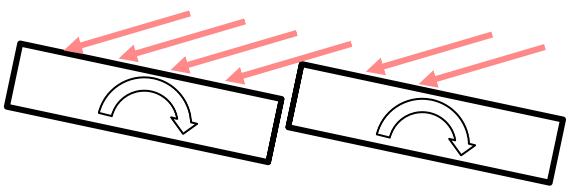


Bi-directional heat flux





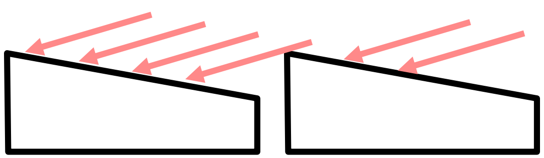




Tilting

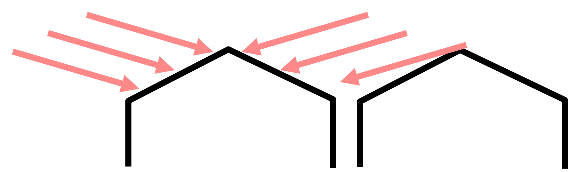
e.g. Divertor target

Gaps between components:
Assembly and RH remote handling
Steps between PFUs:
manufacturing tolerance



beveling

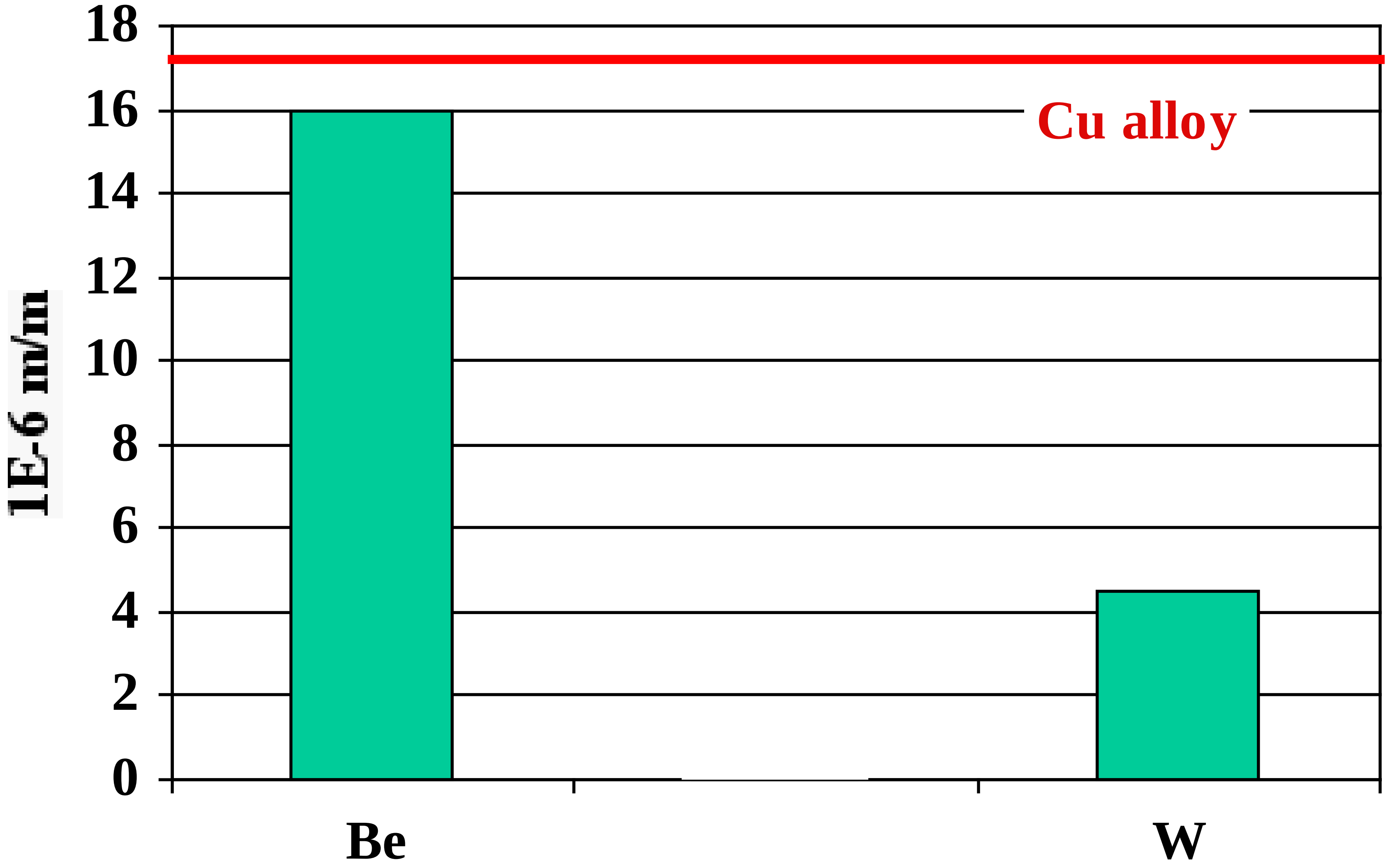
e.g.
Divertor
monoblock



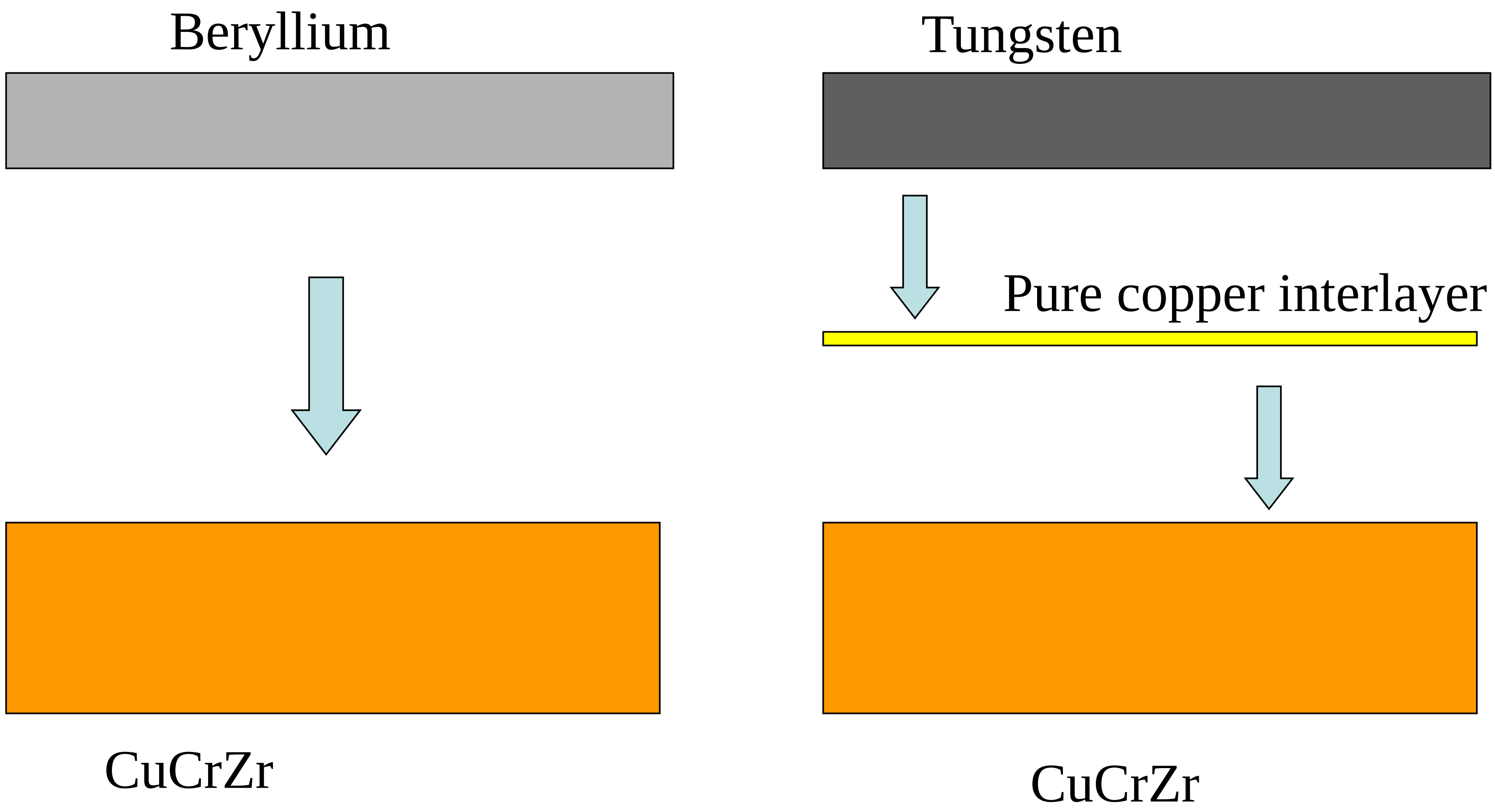
beveling

e.g. Divertor baffle,
Blanket First Wall panels

Thermal expansion at 300 °C

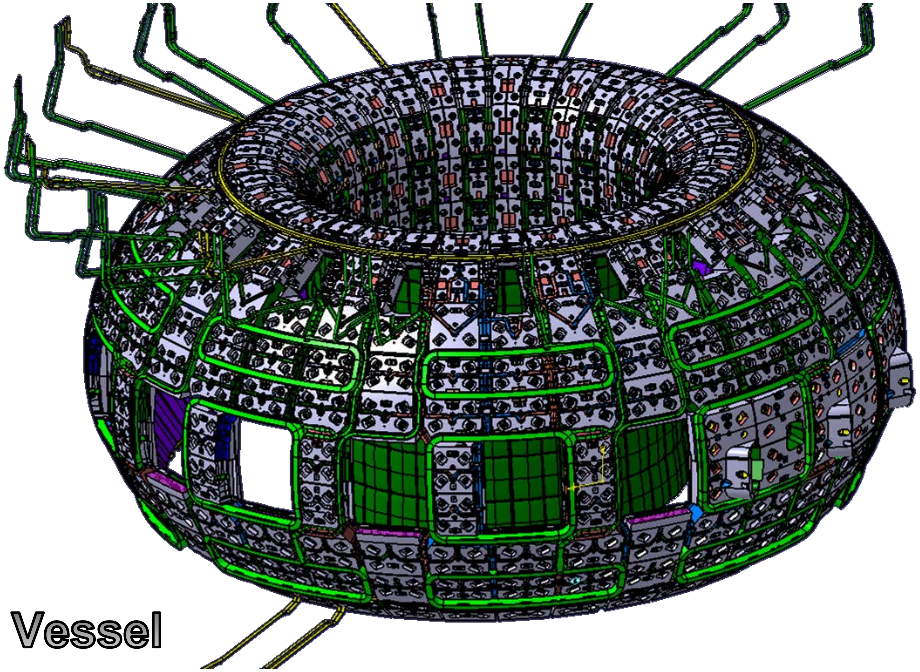


Armour to heat sink joints



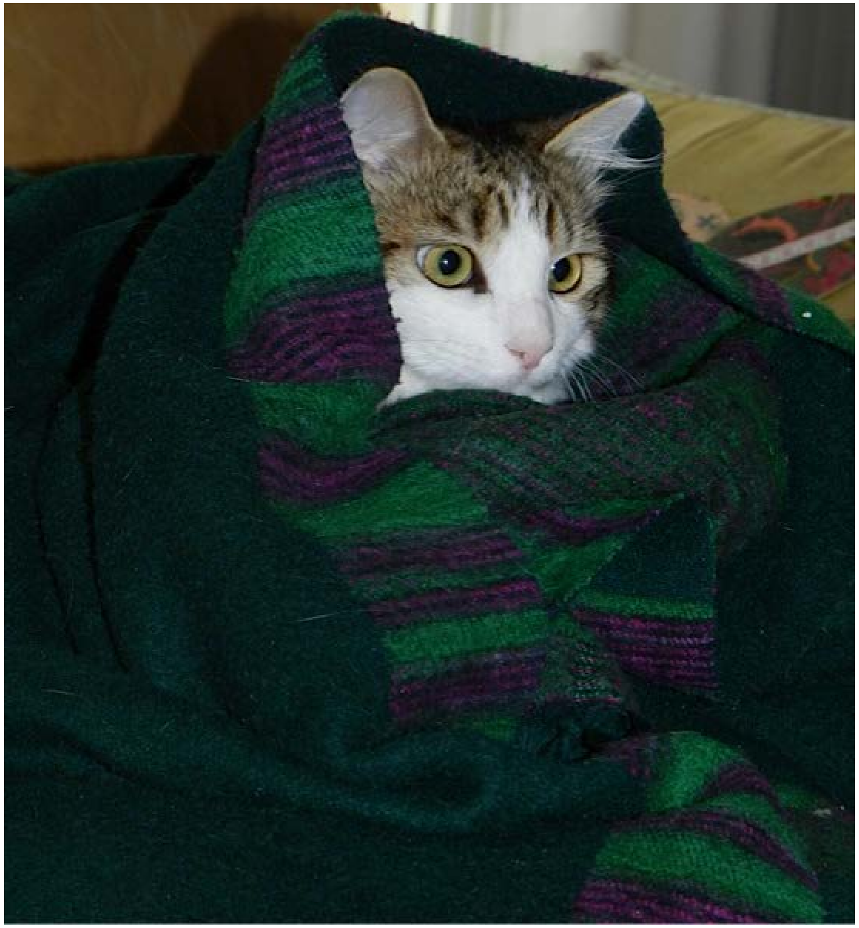
Overview

- ❑ ITER Plasma-Facing Components
- ❑ **Blanket System**
- ❑ Divertor
- ❑ Design Criteria
- ❑ Summary



Internal Components:
rear view, without Vacuum Vessel

What Image Comes to Mind When You Think of a Blanket?



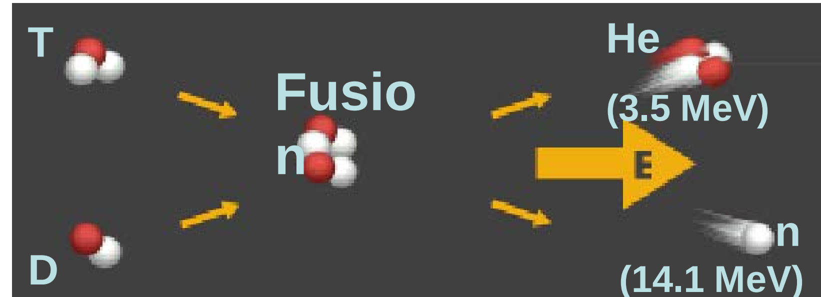
- Cover
- Protection
- Warmth
- Cozy feeling

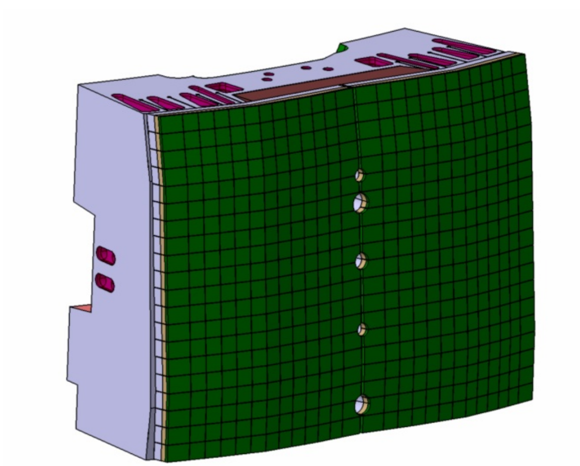
Also applicable to a Fusion Blanket …..except perhaps for the cozy feeling!

Blanket System Functions

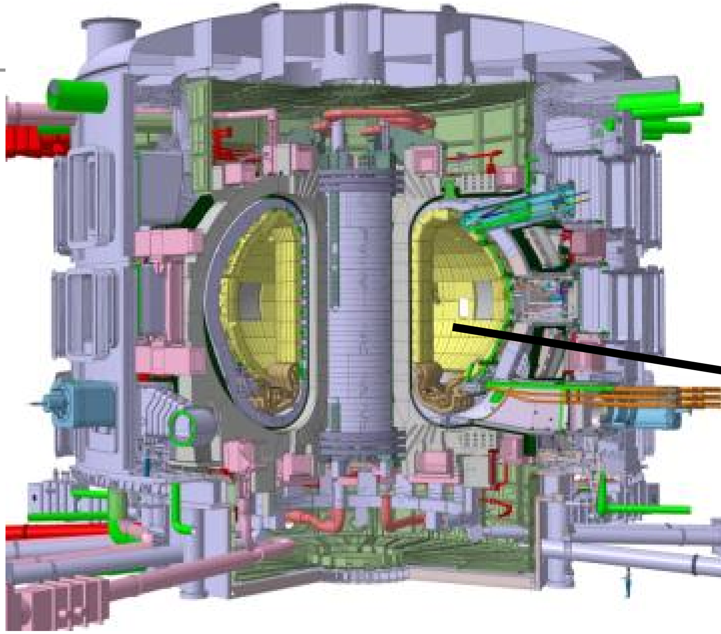
Main functions of ITER Blanket System:

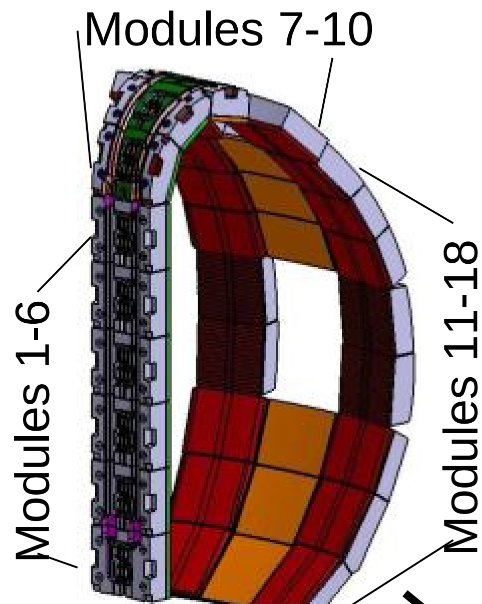
- Exhaust the majority of the plasma power.
- Contribute in providing neutron shielding to superconducting coils.
- Provide limiting surfaces that define the plasma boundary during startup and shutdown.
- Provide passage for and accommodate interface requirements of the plasma diagnostics





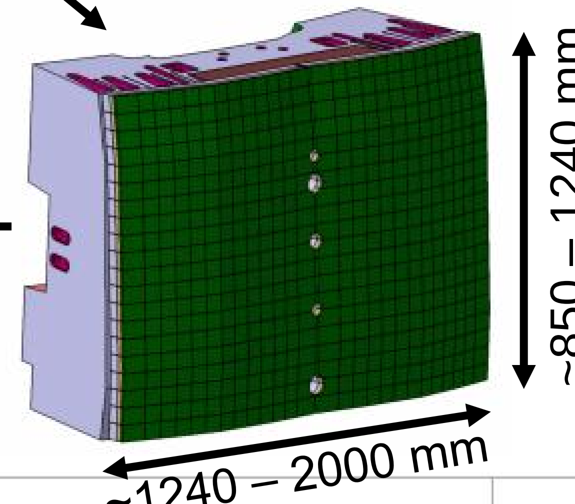
ITER Blanket System





- **The Blanket System consists of Blanket Modules (BM) comprising two major components: a plasma facing First Wall (FW) panel and a Shield Block (SB).**

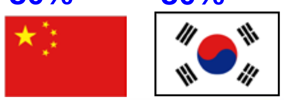
Blanket Module

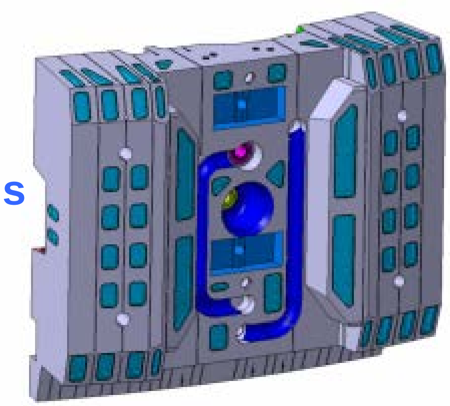


100%

SB Connections to VV

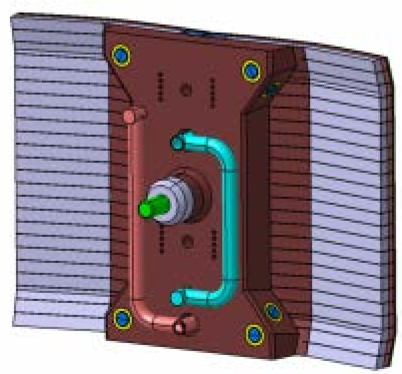
50% **50%**





SB (semi-permanent)

10% **50%** **40%**



FW Panel (separable)

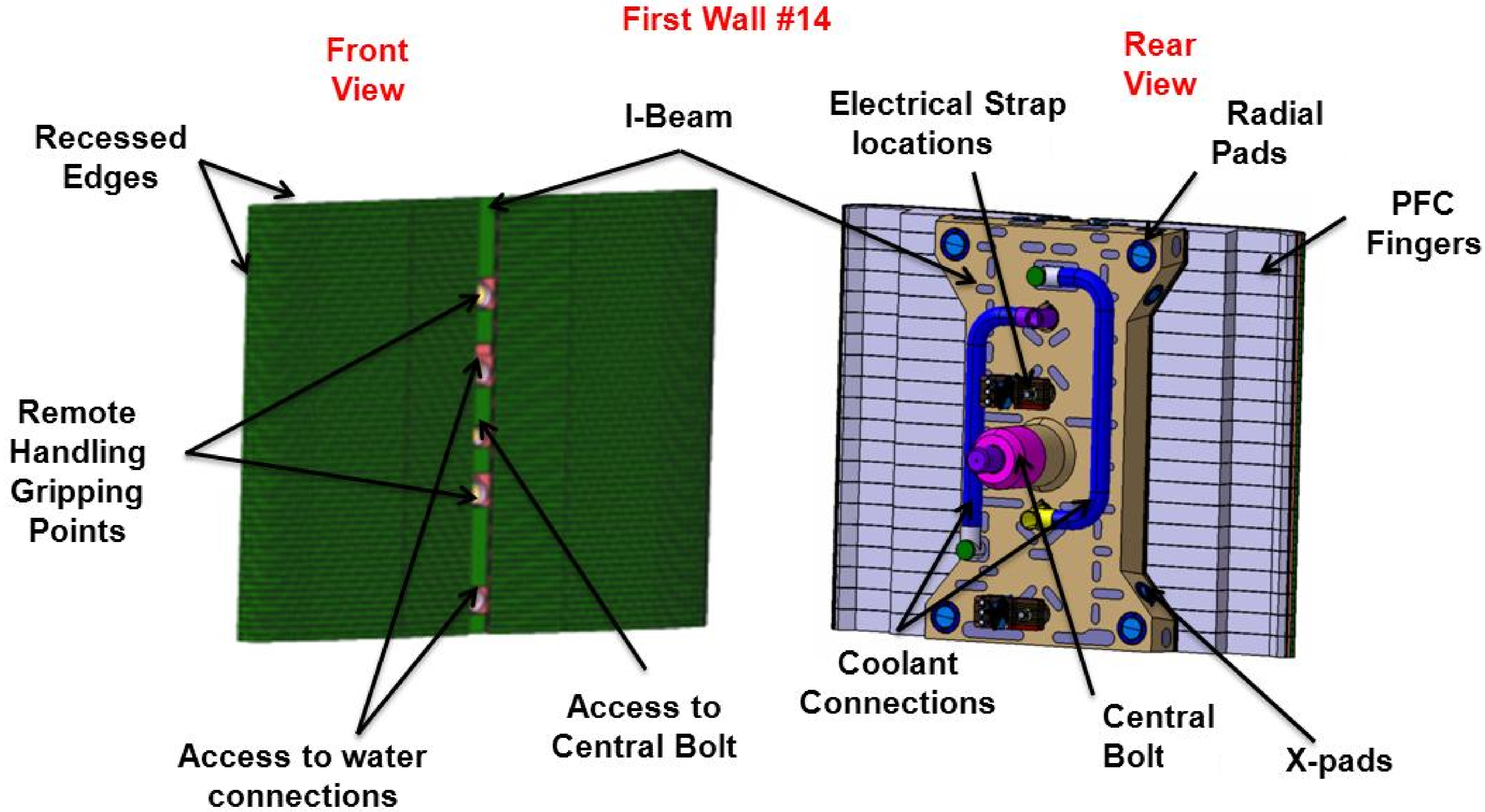
Blanket System in Numbers

Number of Blanket Modules:	**440 (due to remote handling)**
Max allowable mass per module:	**4.5 tons**
Total Mass:	**1530 tons**

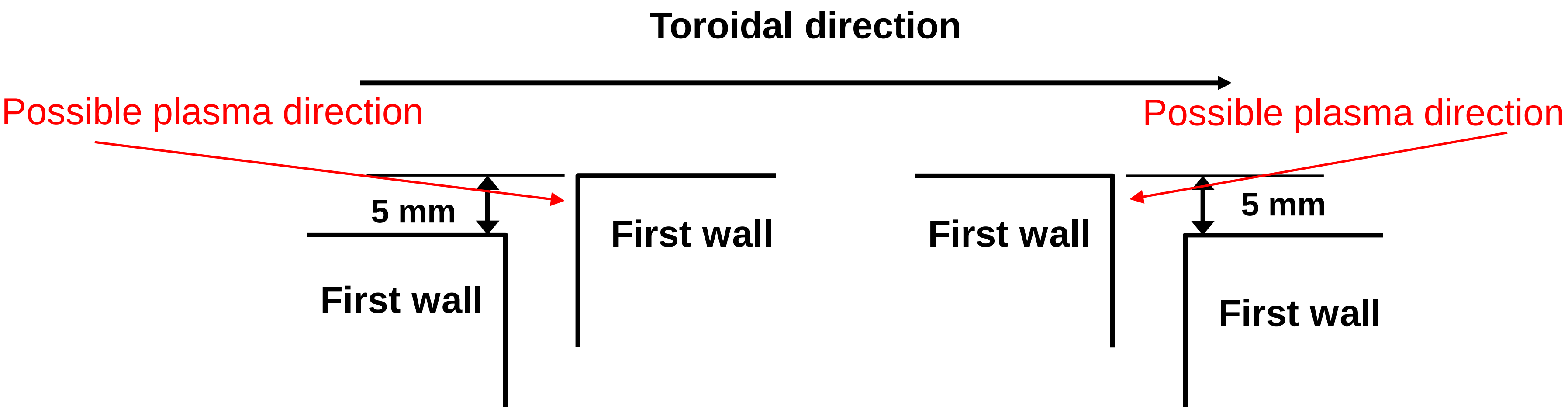
Materials:

- Armor:	Beryllium
- Heat Sink:	CuCrZr
- Steel Structure:	316L(N)-IG

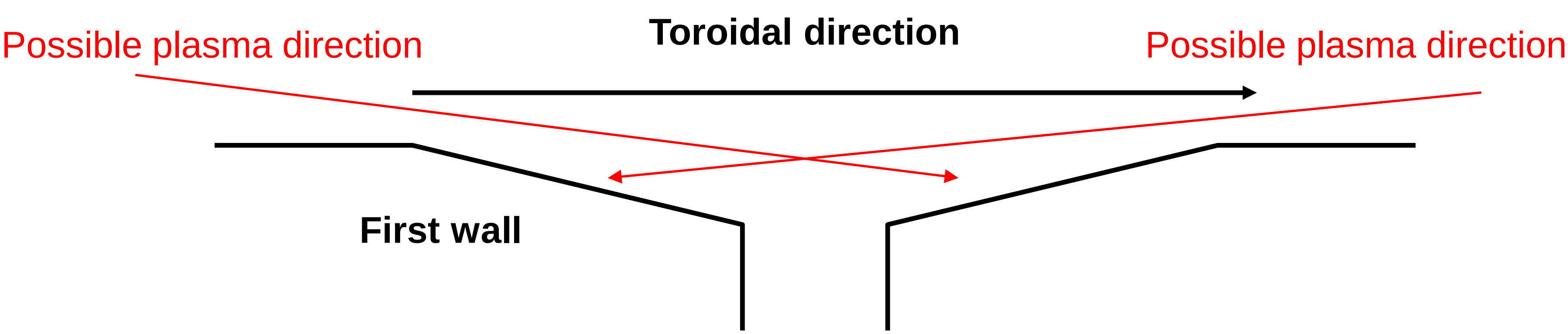
Design of First Wall Panel



Shaping of First Wall Panel

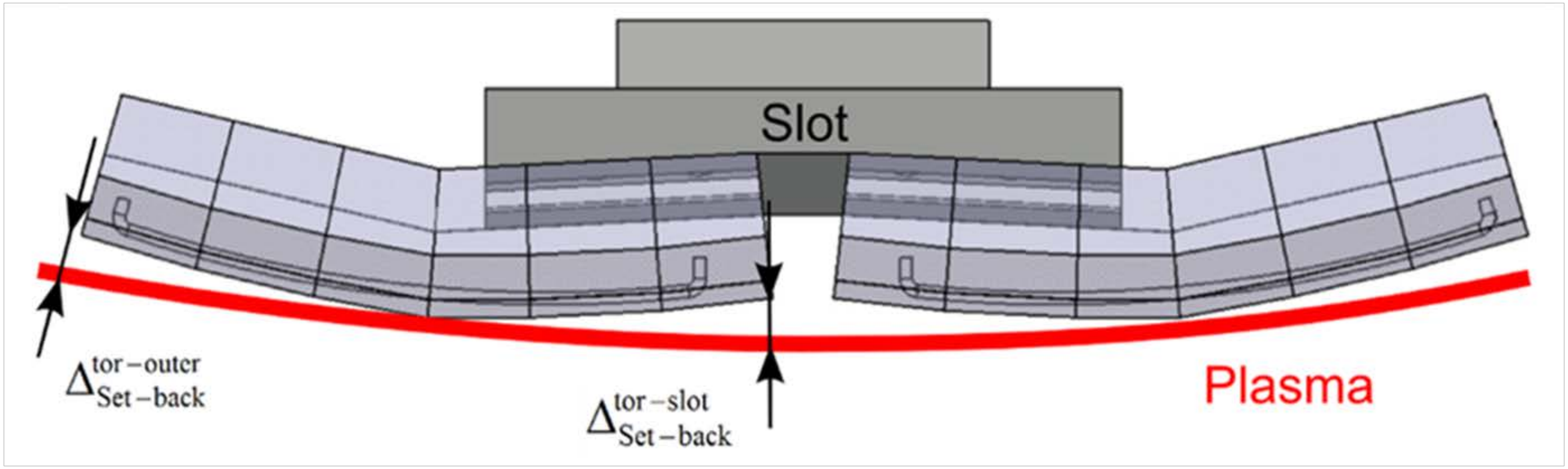


- **The two situations are equally <u>probable</u>**
  ⇒ **So chamfering on both sides is necessary**

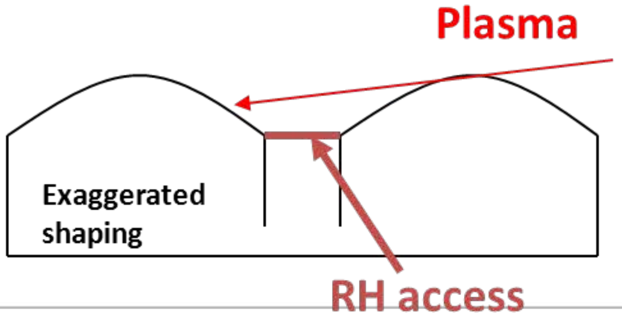


Shaping of First Wall Panel

- Heat load associated with charged particles is a major component of heat flux to first wall.
- The heat flux is oriented along the field lines.
- Thus, the incident heat flux is strongly design-dependent (incidence angle of the field line on the component surface).
- Shaping of FW to shadow leading edges and penetrations.

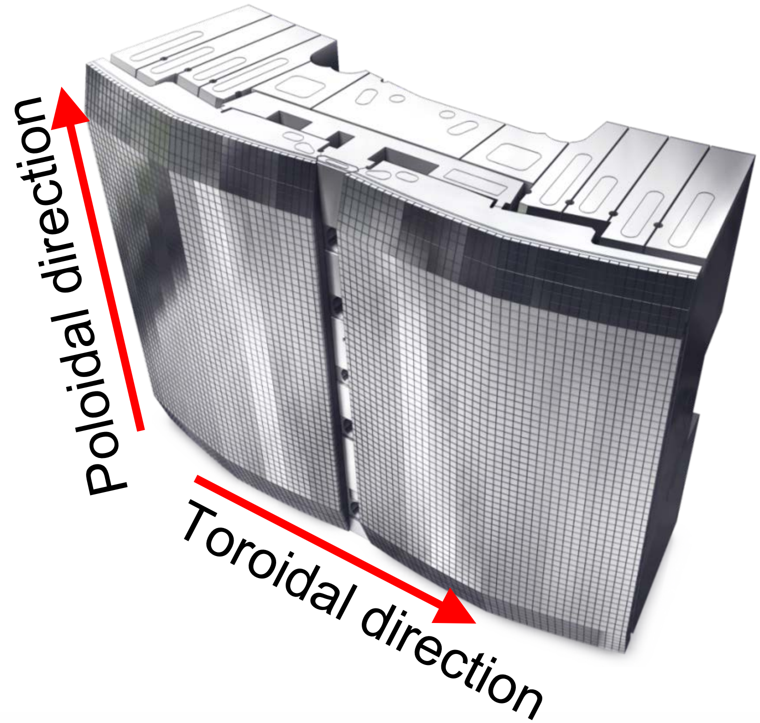


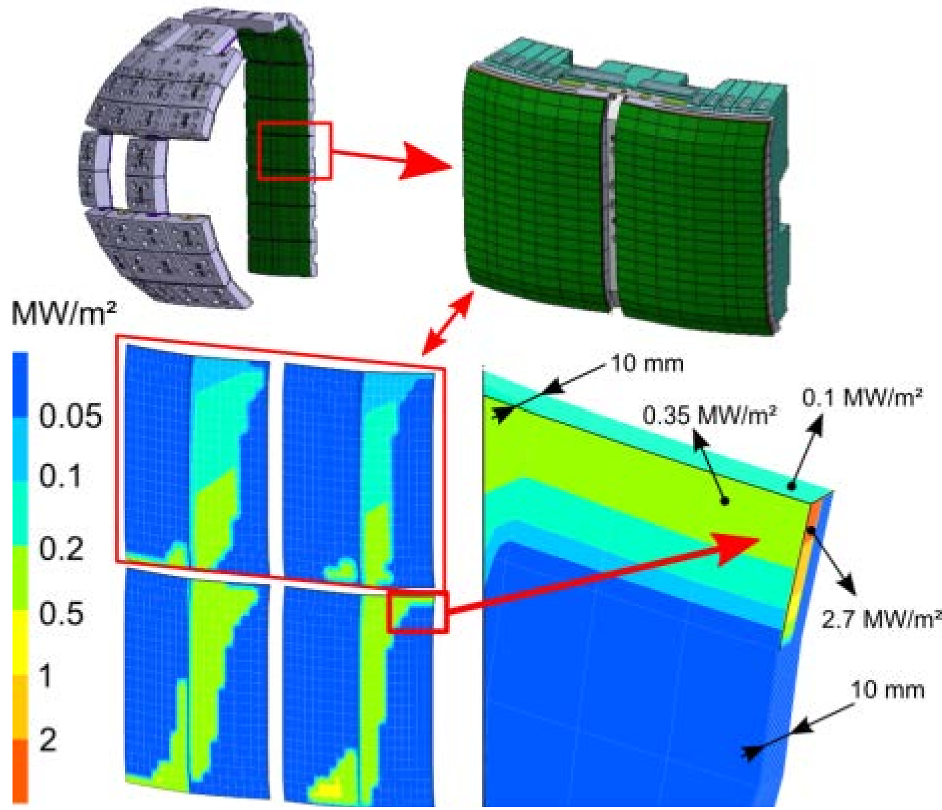
- Allow good access for RH
- Shadow leading edges

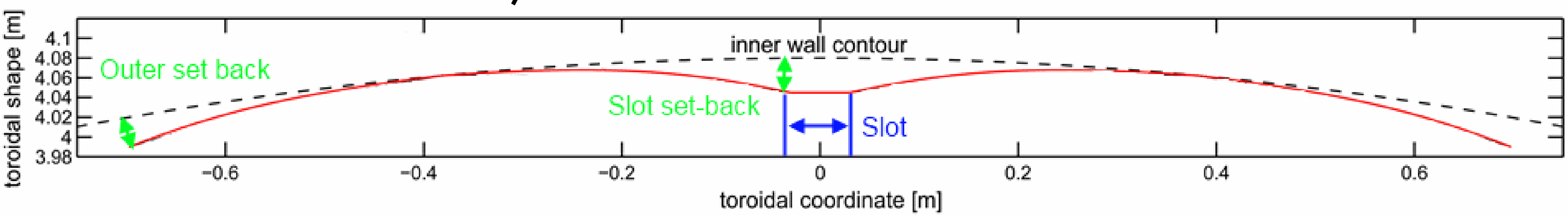


Final Shaping of First Wall Panel

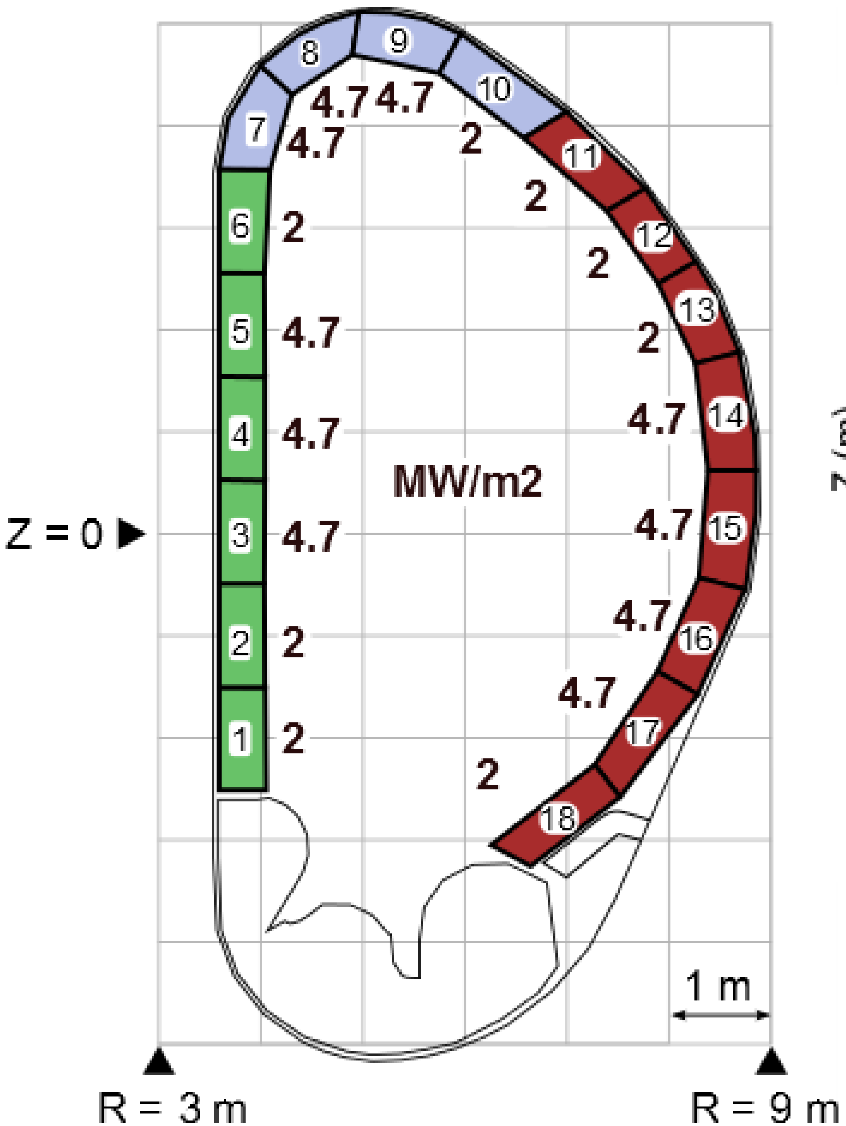
- Toroidal set-backs to protect wings and Remote Handling slots
- **Analytic shape is approximated by series of “global” facets on which smaller Be tiles are arranged**

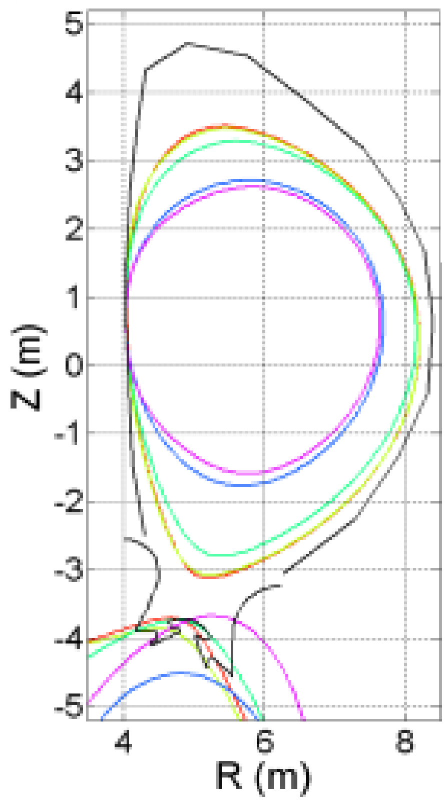


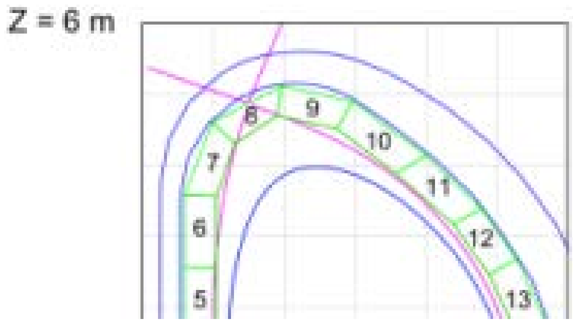




Design Heat Load on the Blanket



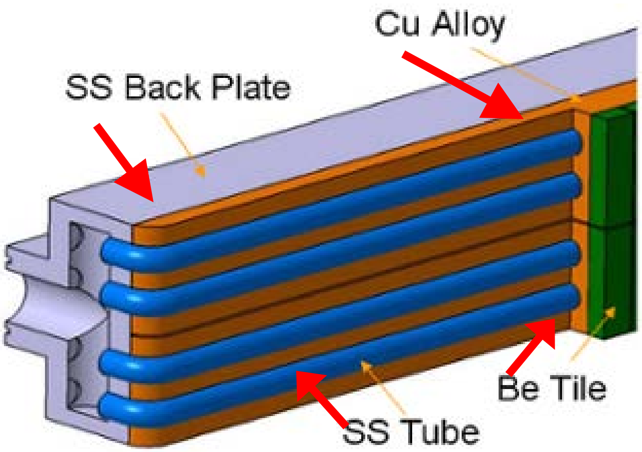




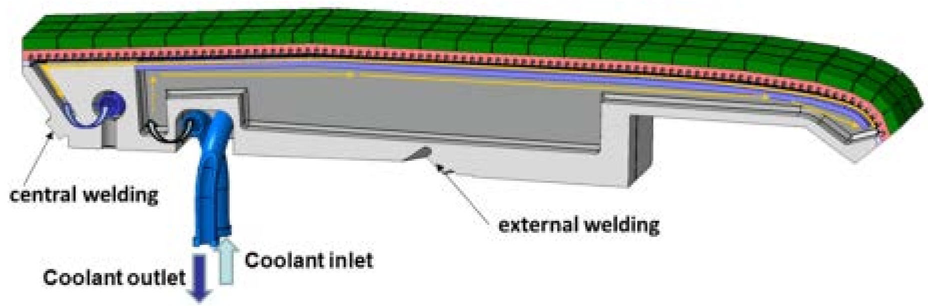
- **Group 1 : 2 MW/m²**
  Normal heat flux panels
- **Group 2 : 4.7 MW/m²**
  Enhanced heat flux panels

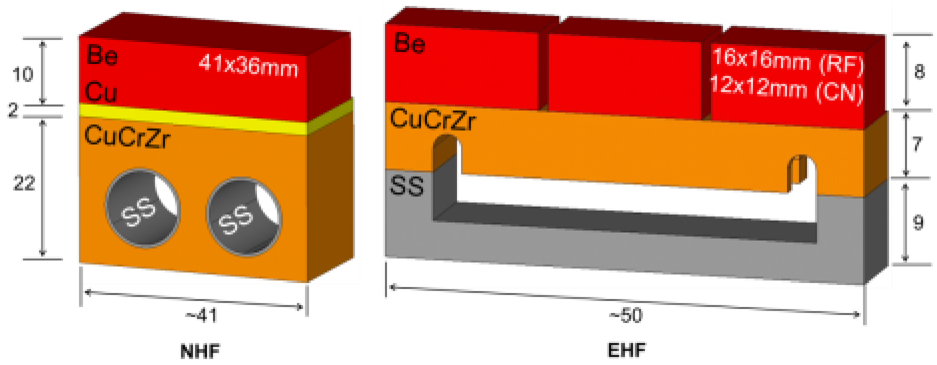
Two technologies for First Wall PFCs

Normal heat flux finger: concept with **Steel Cooling Pipes**

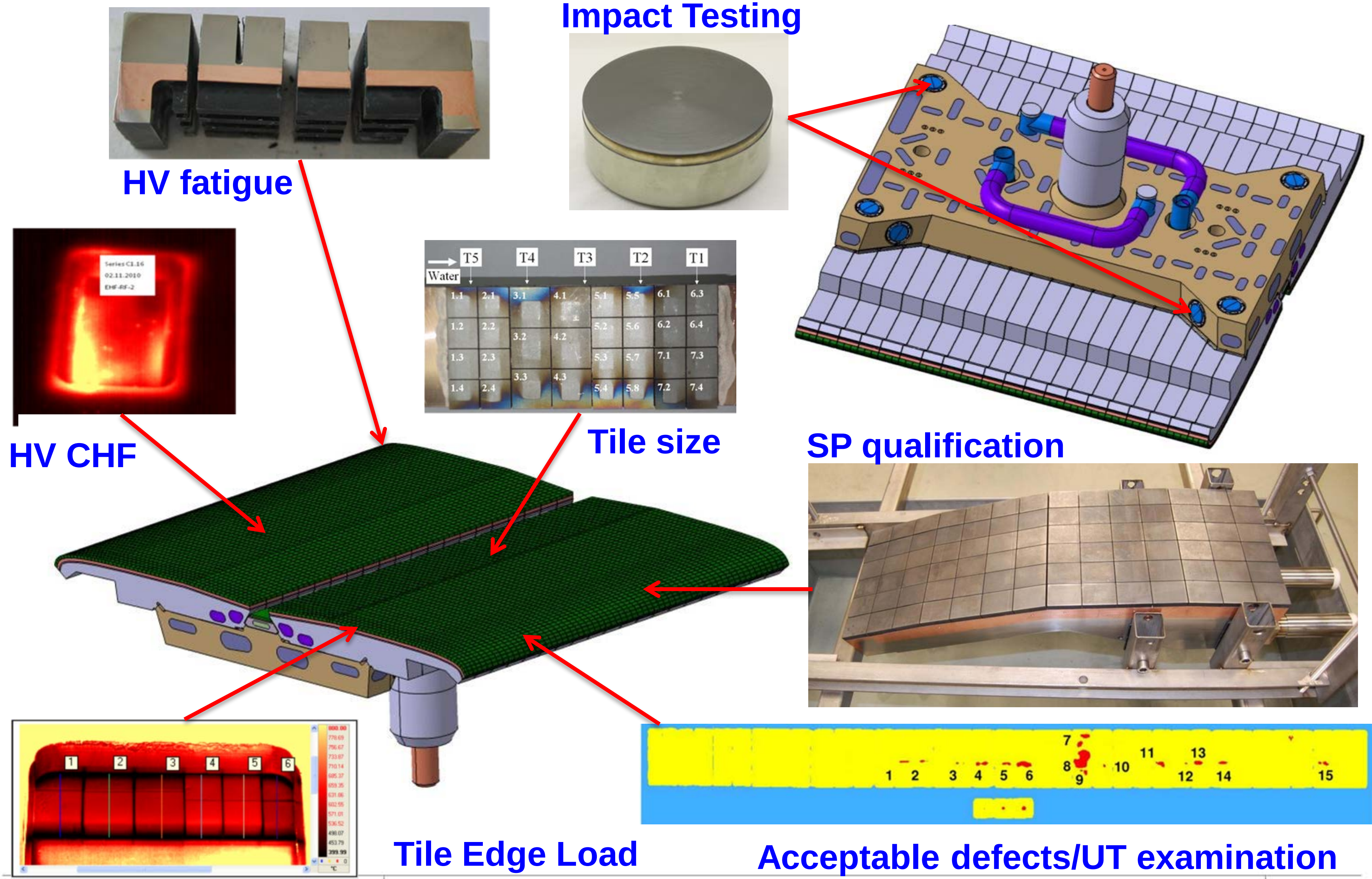


Enhanced heat flux finger: concept with **Copper alloy heat sink** (hypervapotron)



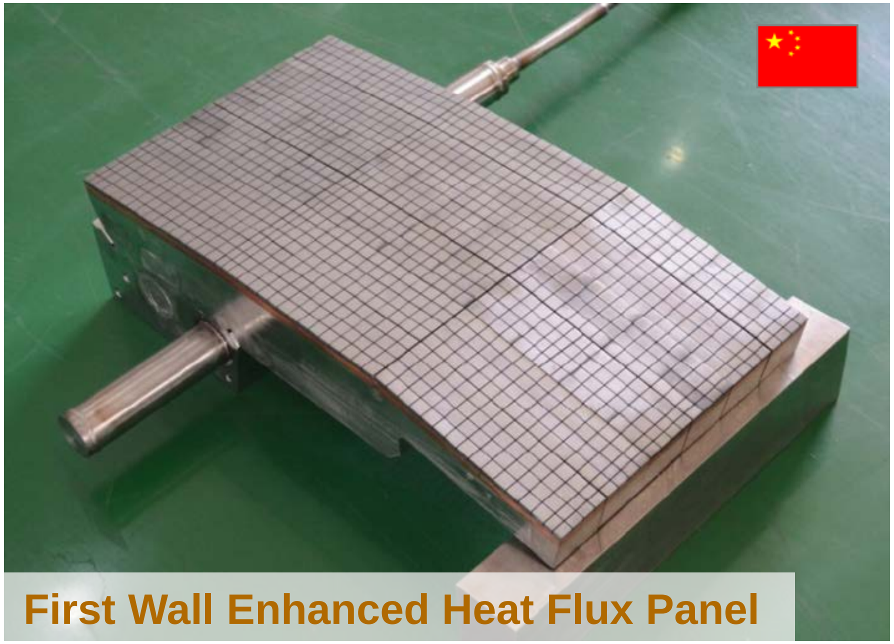


FW Panel R&D Activities

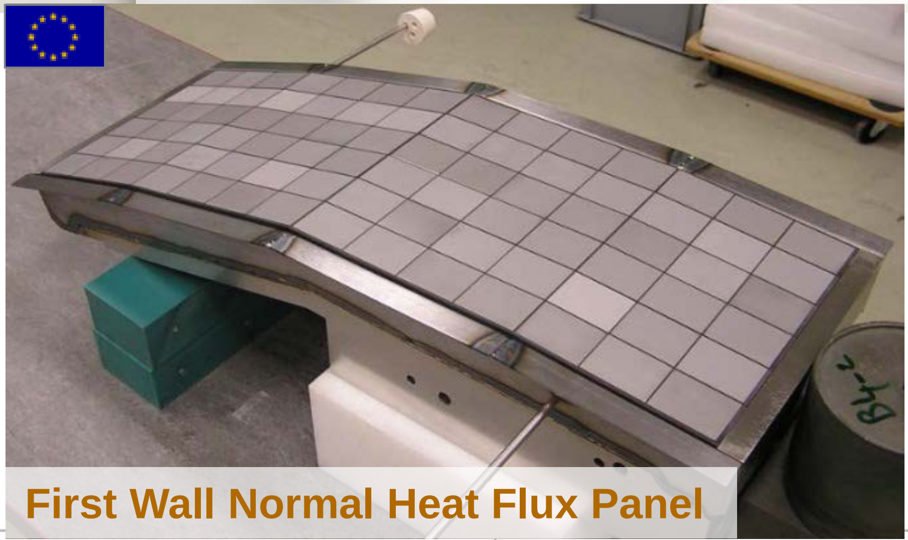


Blanket First Wall Prototypes

First Wall Enhanced Heat Flux Panel



First Wall Enhanced Heat Flux Panel

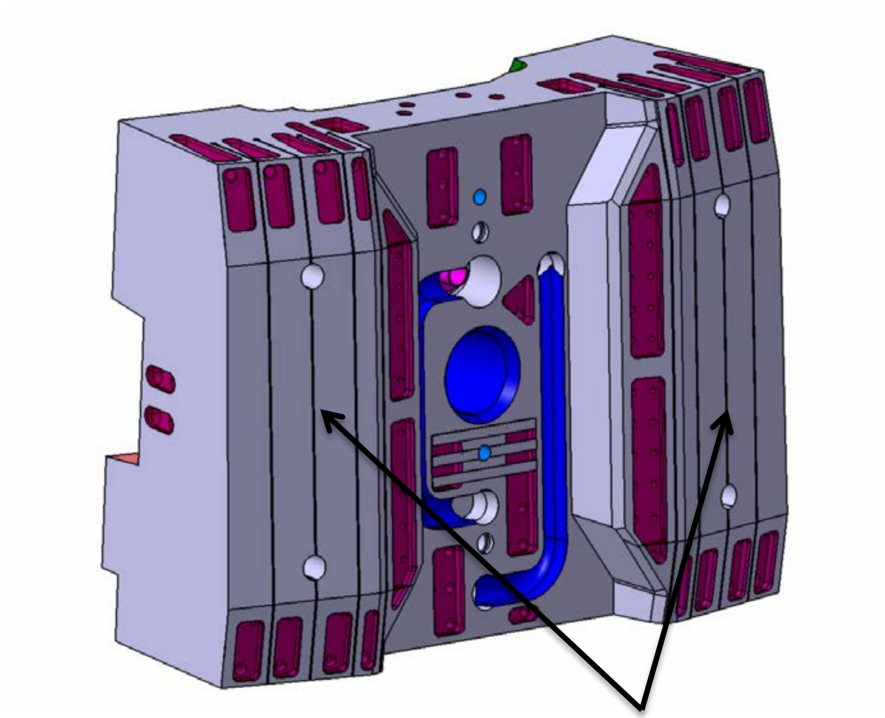


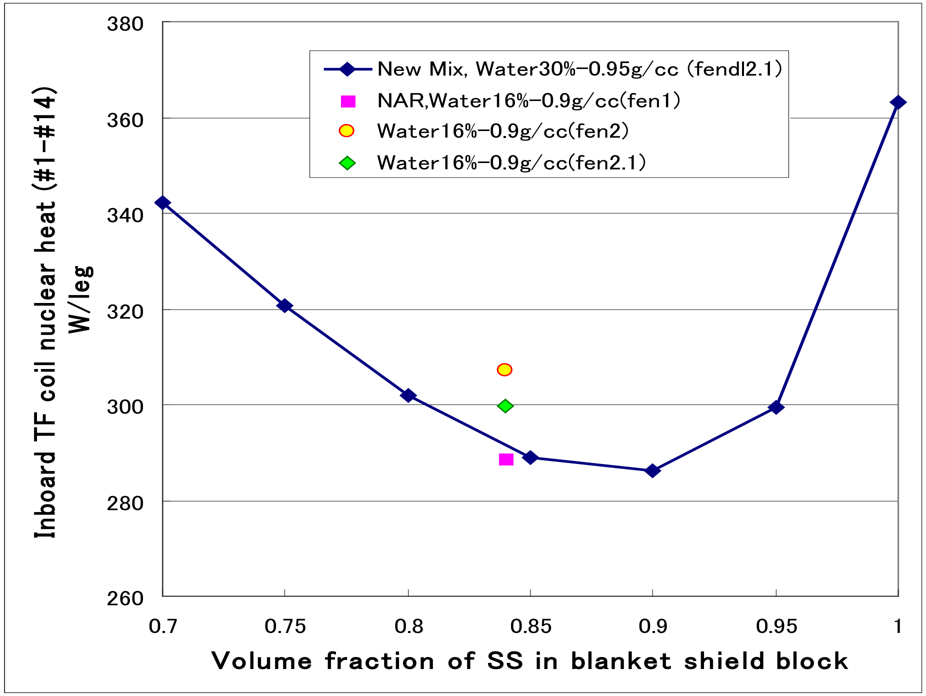
First Wall Normal Heat Flux Panel

Enhanced Heat Flux, ≤ 4.7 MW/m2

Normal Heat Flux, ≤ 2.0 MW/m2

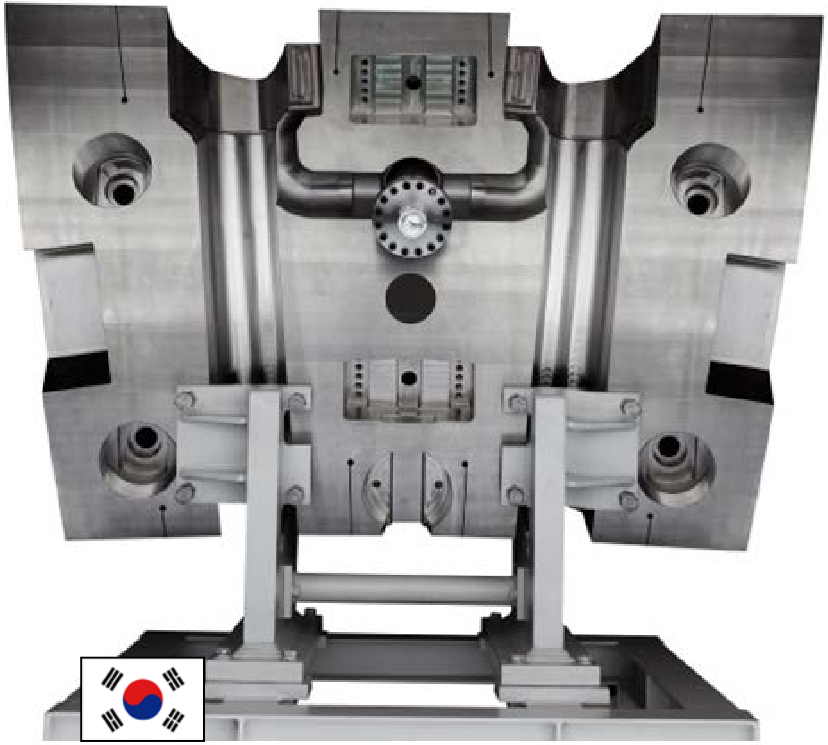
Shield Block Design





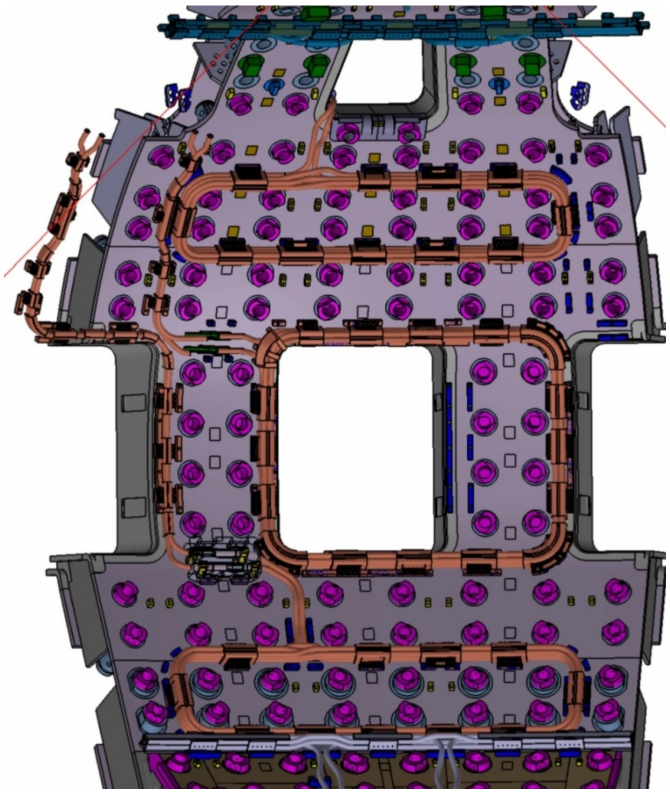
- **Slits to reduce EM loads and minimize thermal expansion and bowing**
- **Cooling holes are optimized for Water/SS ratio (Improving nuclear shielding performance).**
- **Cut-outs at the back to accommodate many interfaces (Manifold, Attachment, In-Vessel Coils).**

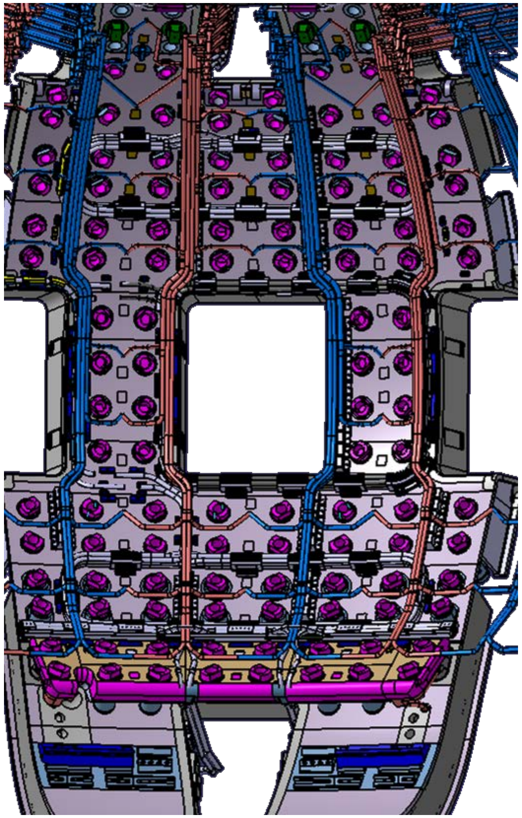
SB Qualification Program

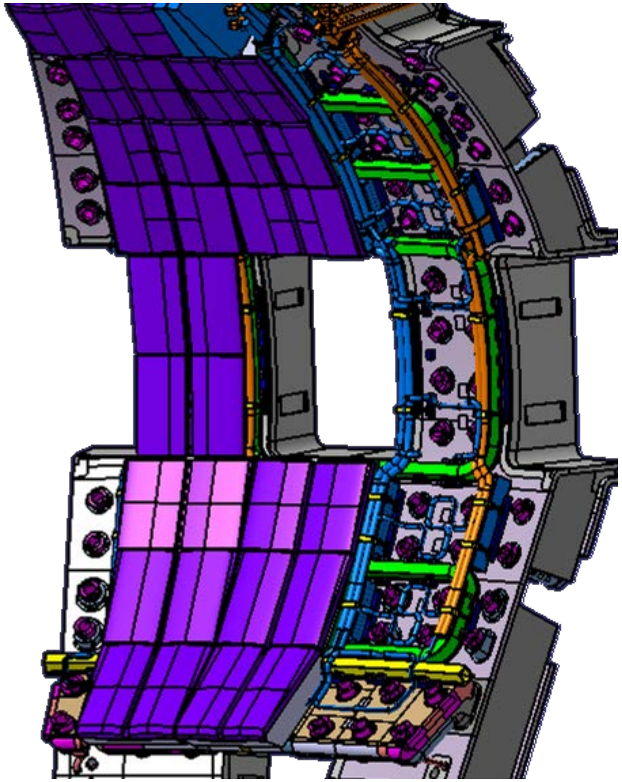


Successful completion of Full-Scale Prototypes Shield Blocks in KO and CN DA

And behind the Blanket Modules ?



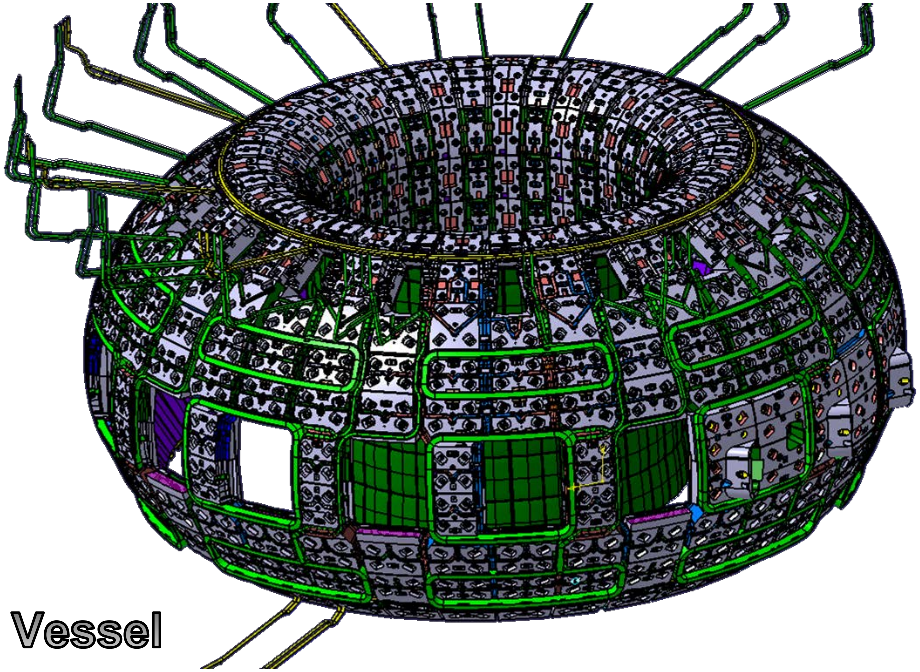




In-Vessel Coils   Blanket Manifold

Overview

- ❑ ITER Plasma-Facing Components
- ❑ Blanket System
- ❑ **Divertor**
- ❑ Design Criteria
- ❑ Summary

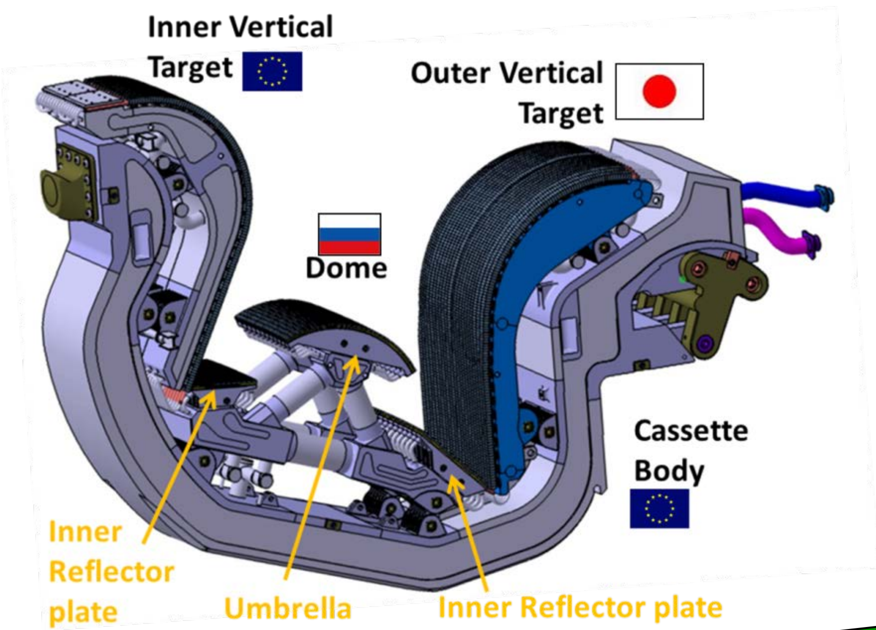


Internal Components:
rear view, without Vacuum Vessel

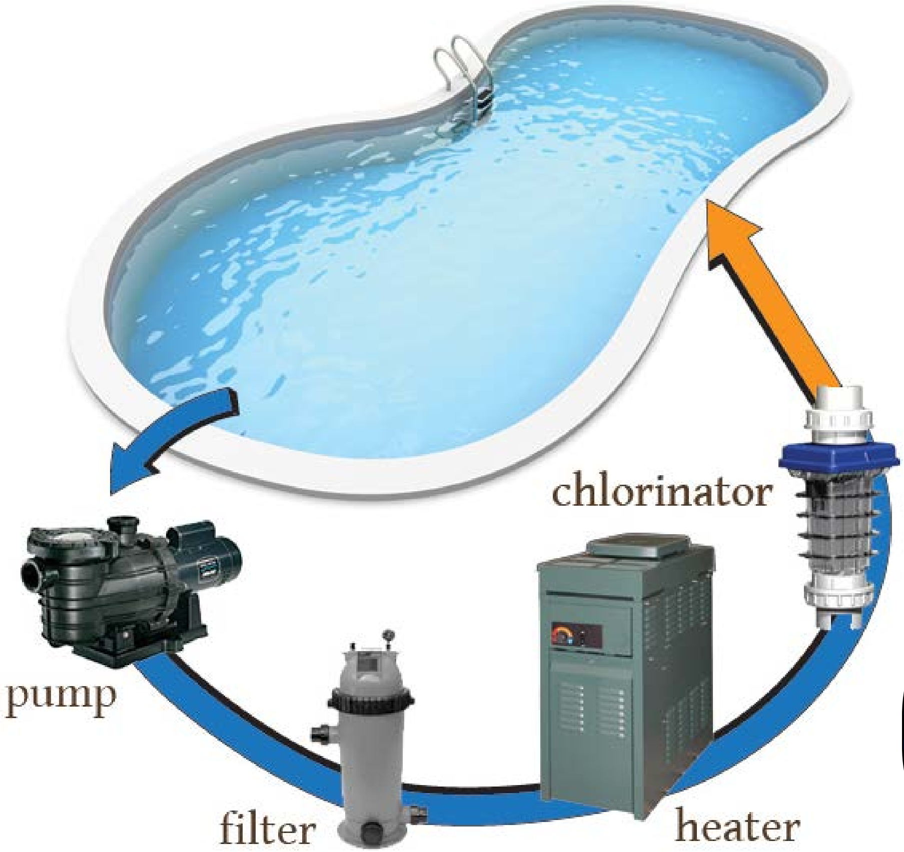
ITER Divertor

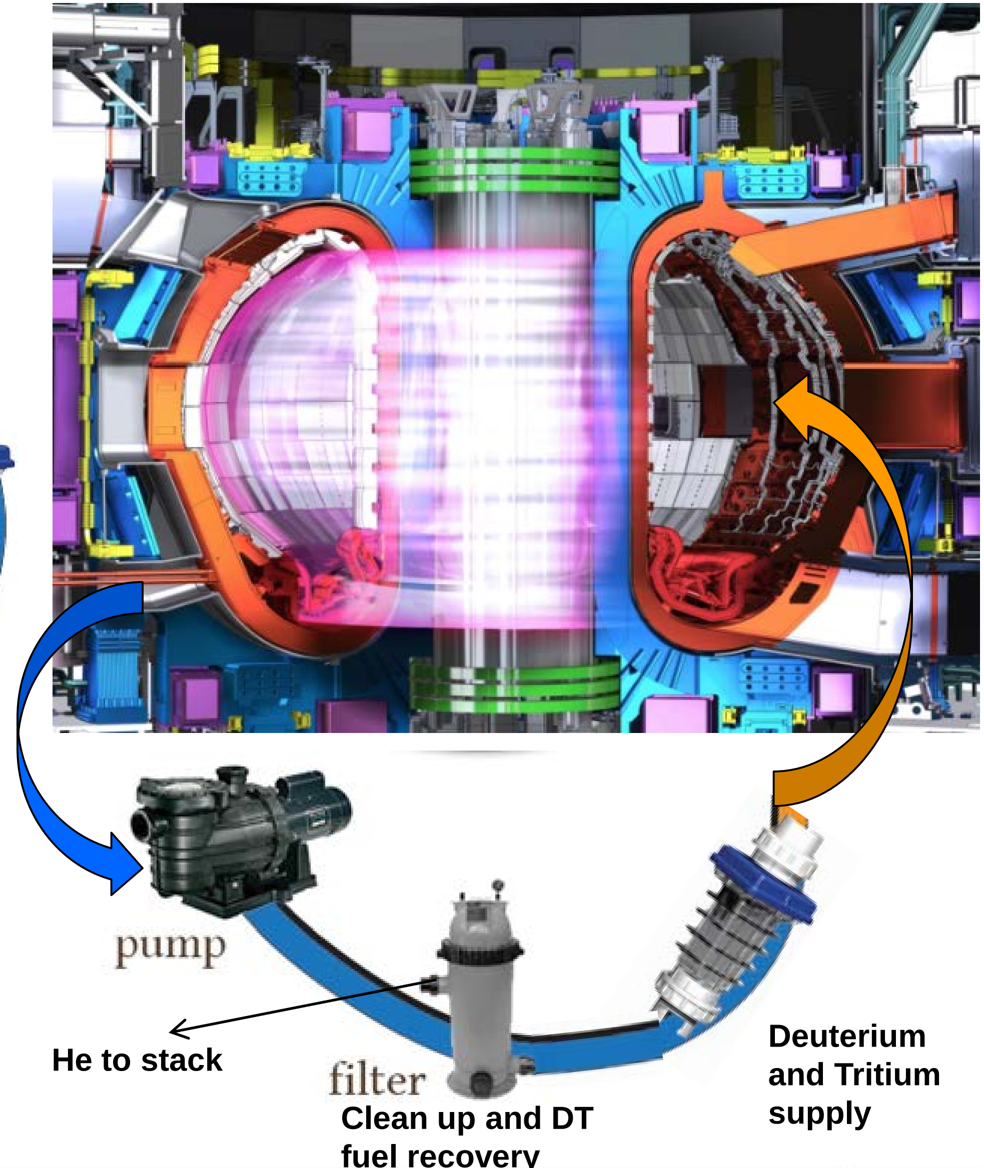
Divertor main functions :

- Minimize the helium and impurities content in the plasma
- Exhaust part of the plasma thermal power



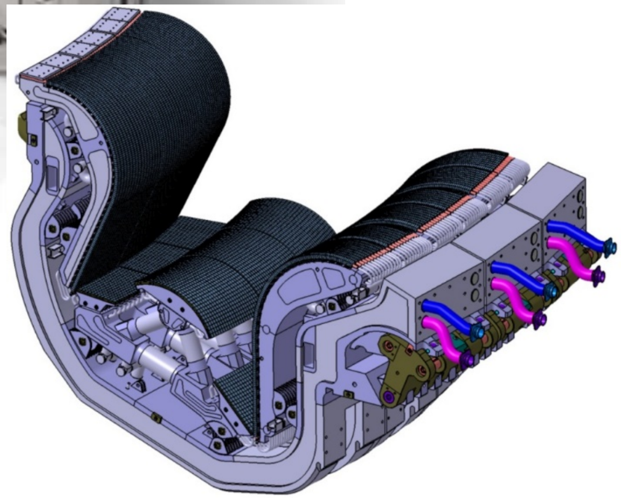
How does a Divertor work ?





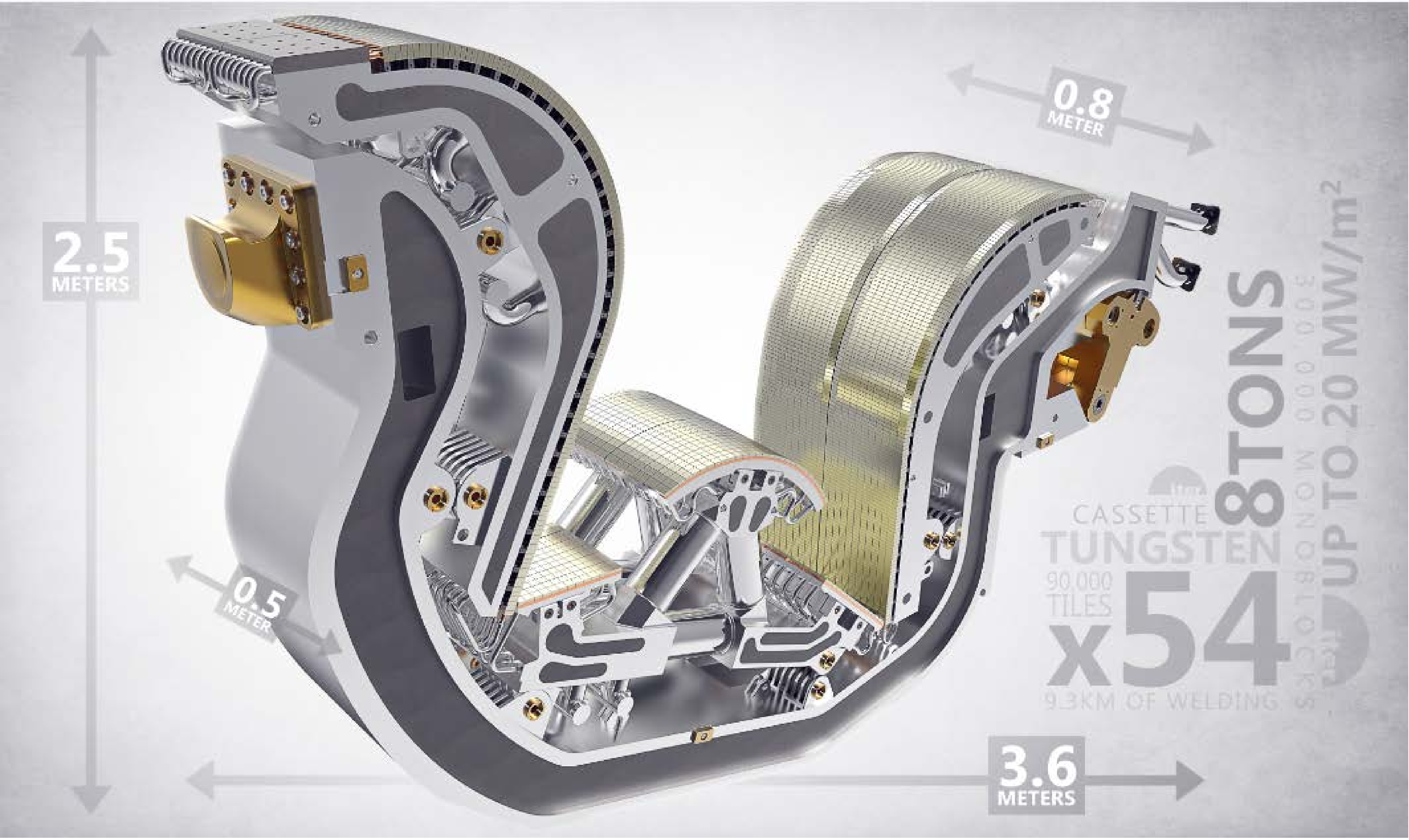
Divertor: Key Facts

3.3 m length, 2.2 m height

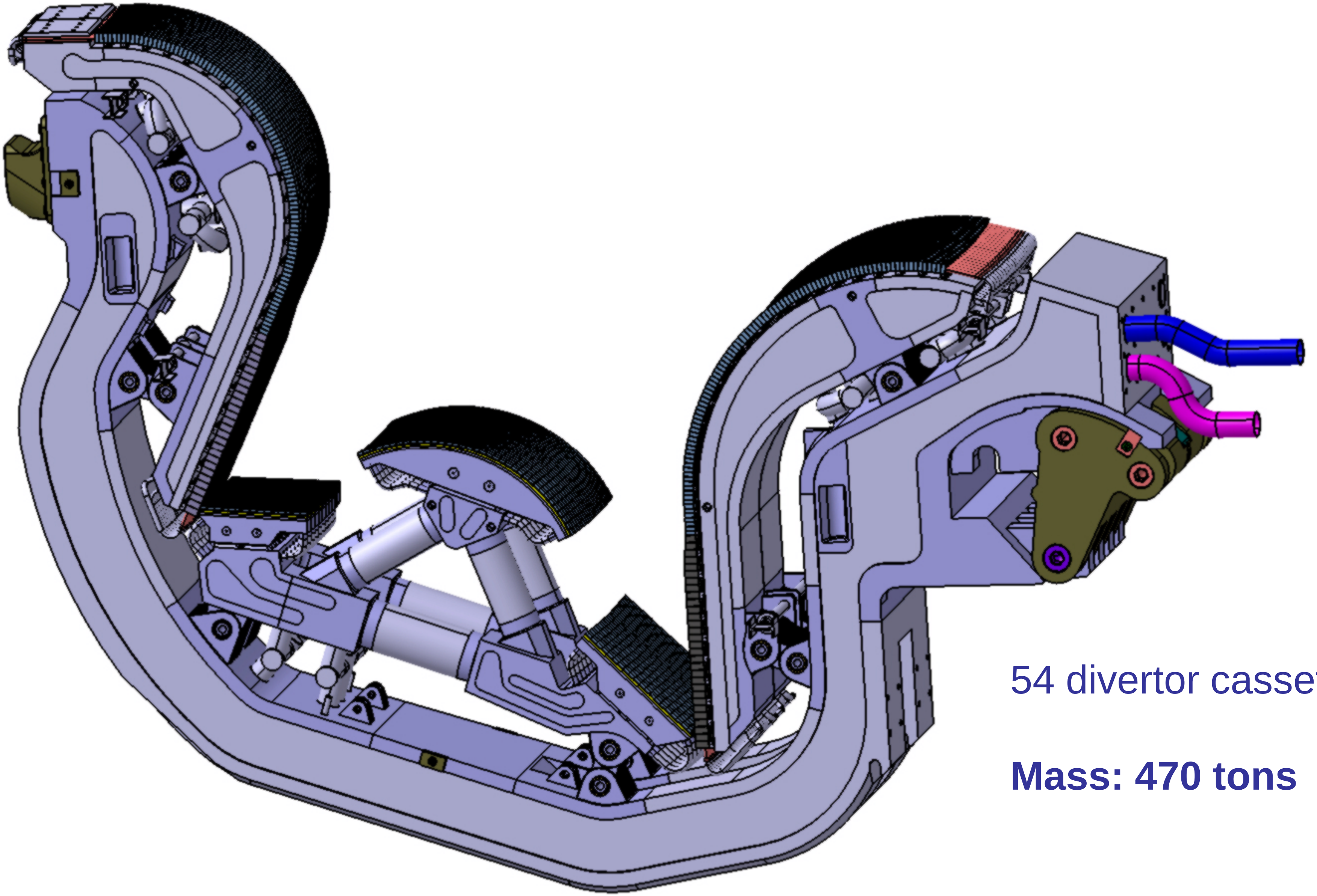


Number of Cassette Assemblies:	54 (dictated by remote handling considerations)
Mass per Cassette Assemblies :	~9 tons
Total Mass:	~490 tons
Armour:	Tungsten
Heat Sink:	Copper alloy CuCrZr
Steel Structure:	Austenitic steels 316L(N)-IG / XM-19

ITER Divertor



Divertor System

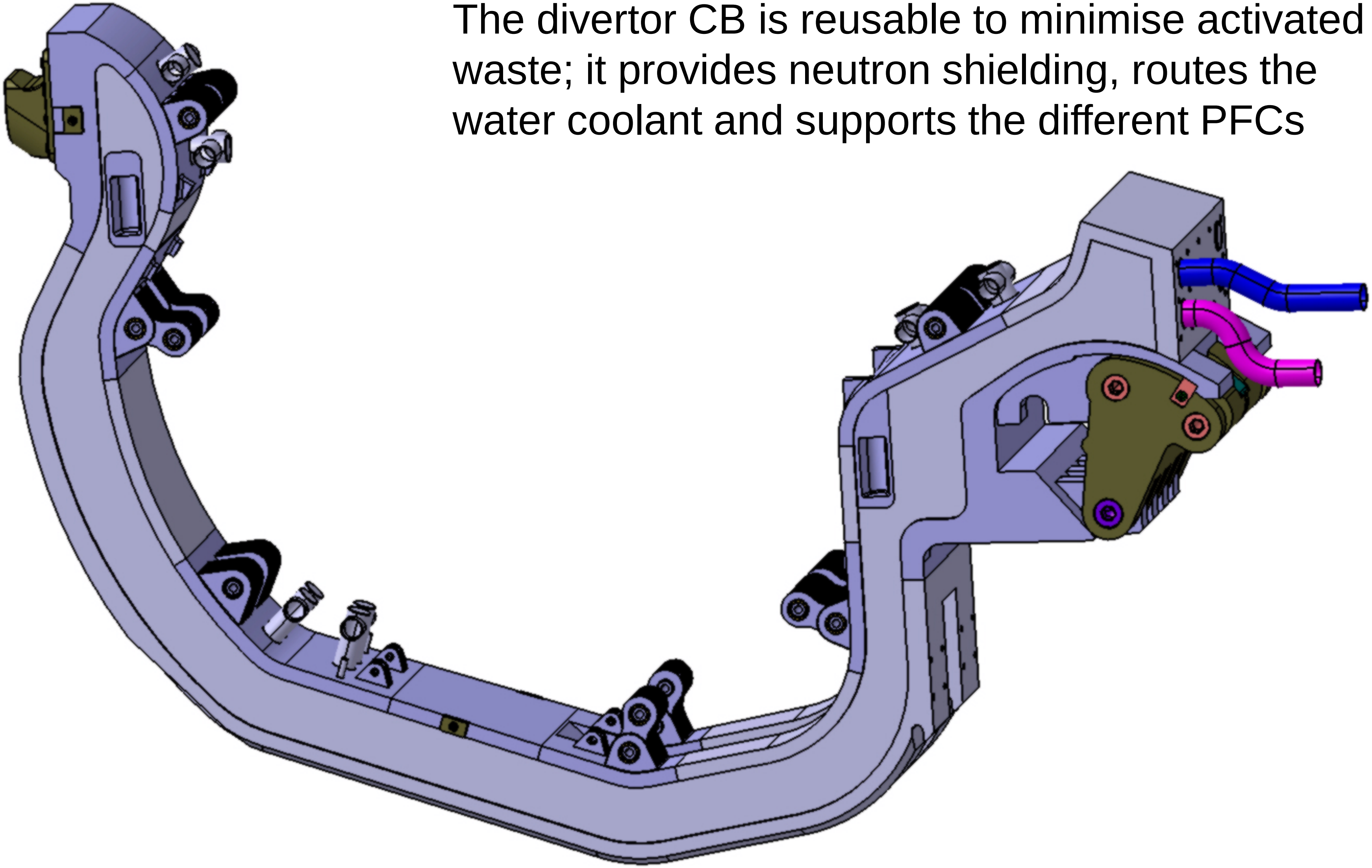


54 divertor cassettes

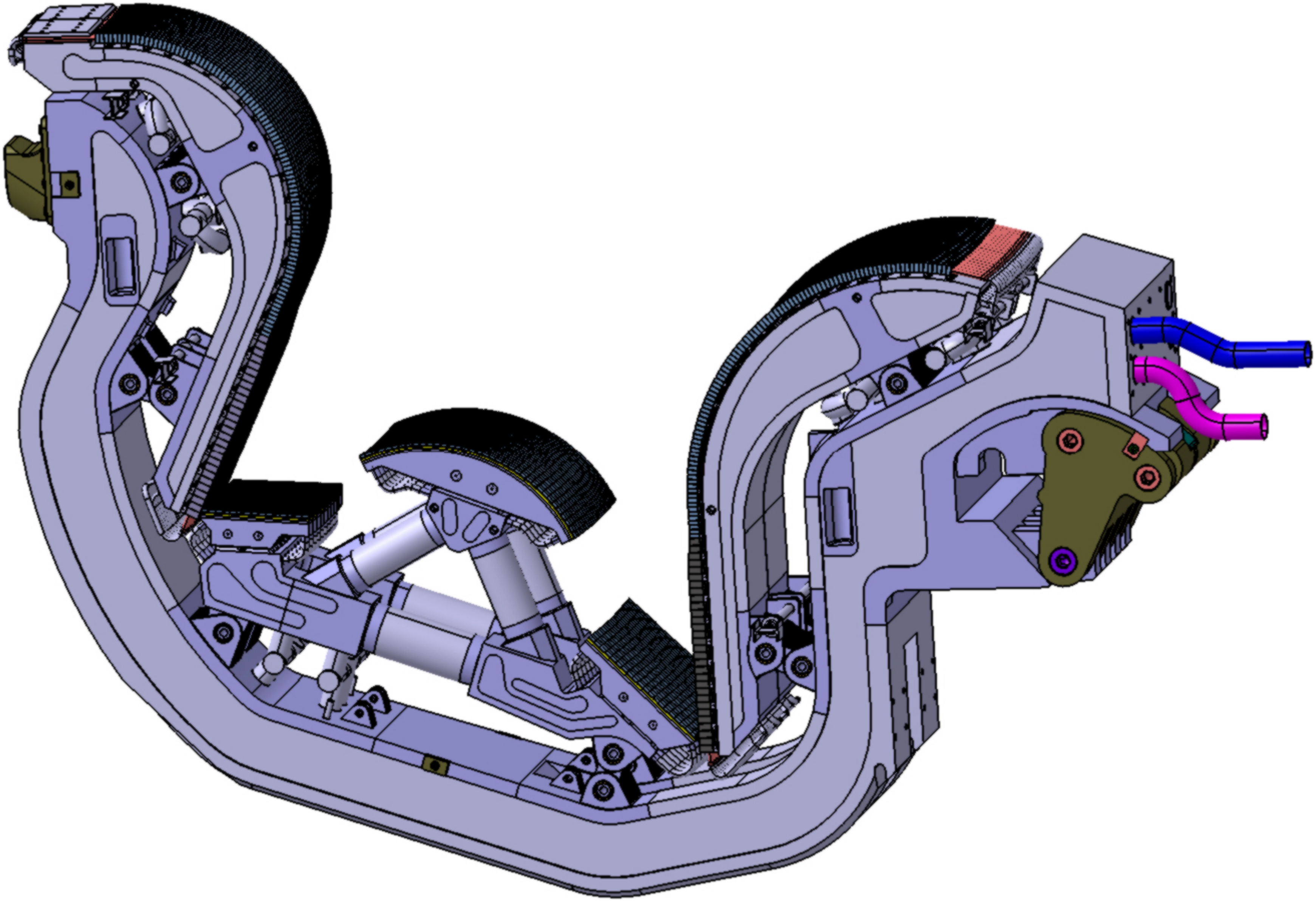
Mass: 470 tons

Cassette body

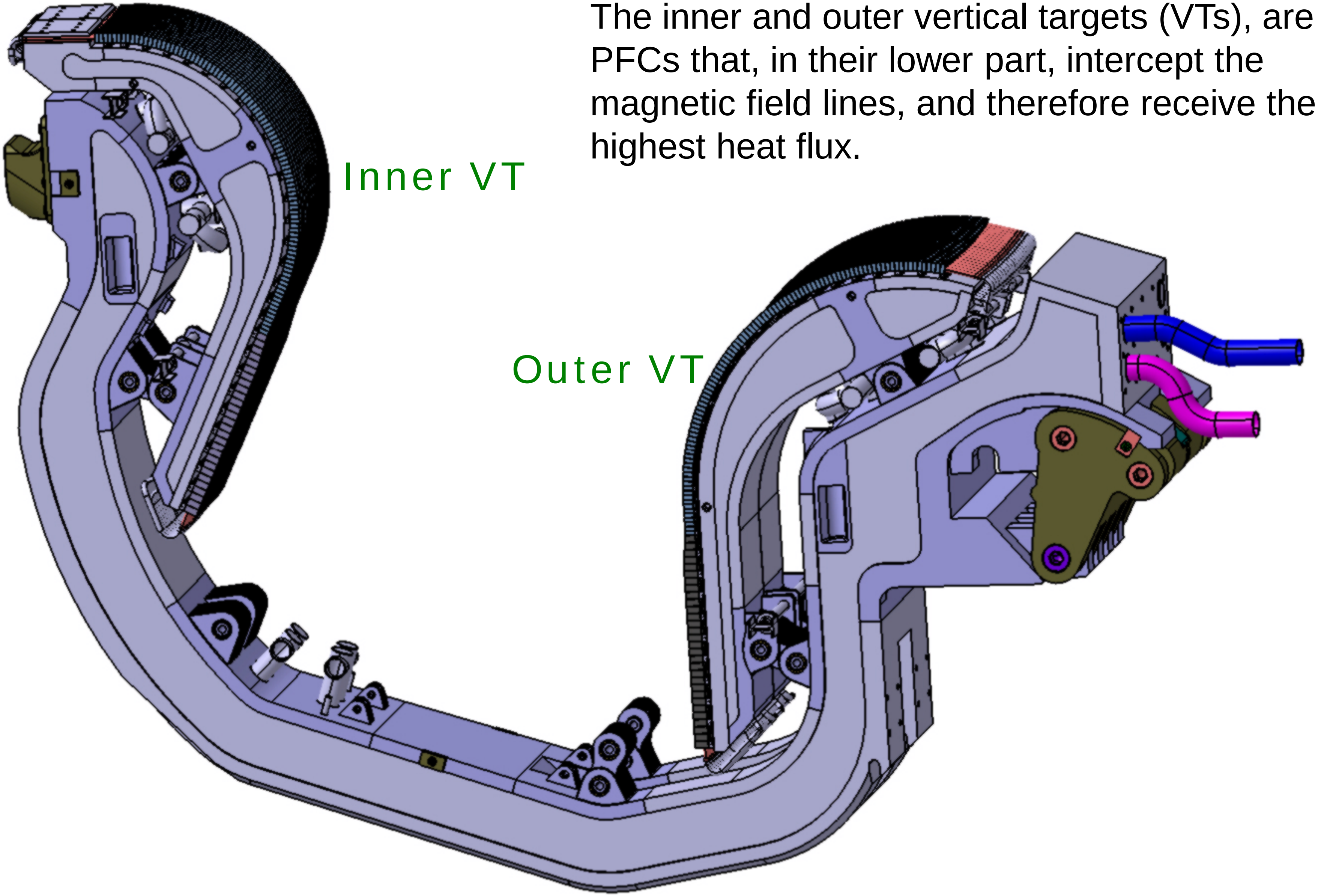
The divertor CB is reusable to minimise activated waste; it provides neutron shielding, routes the water coolant and supports the different PFCs



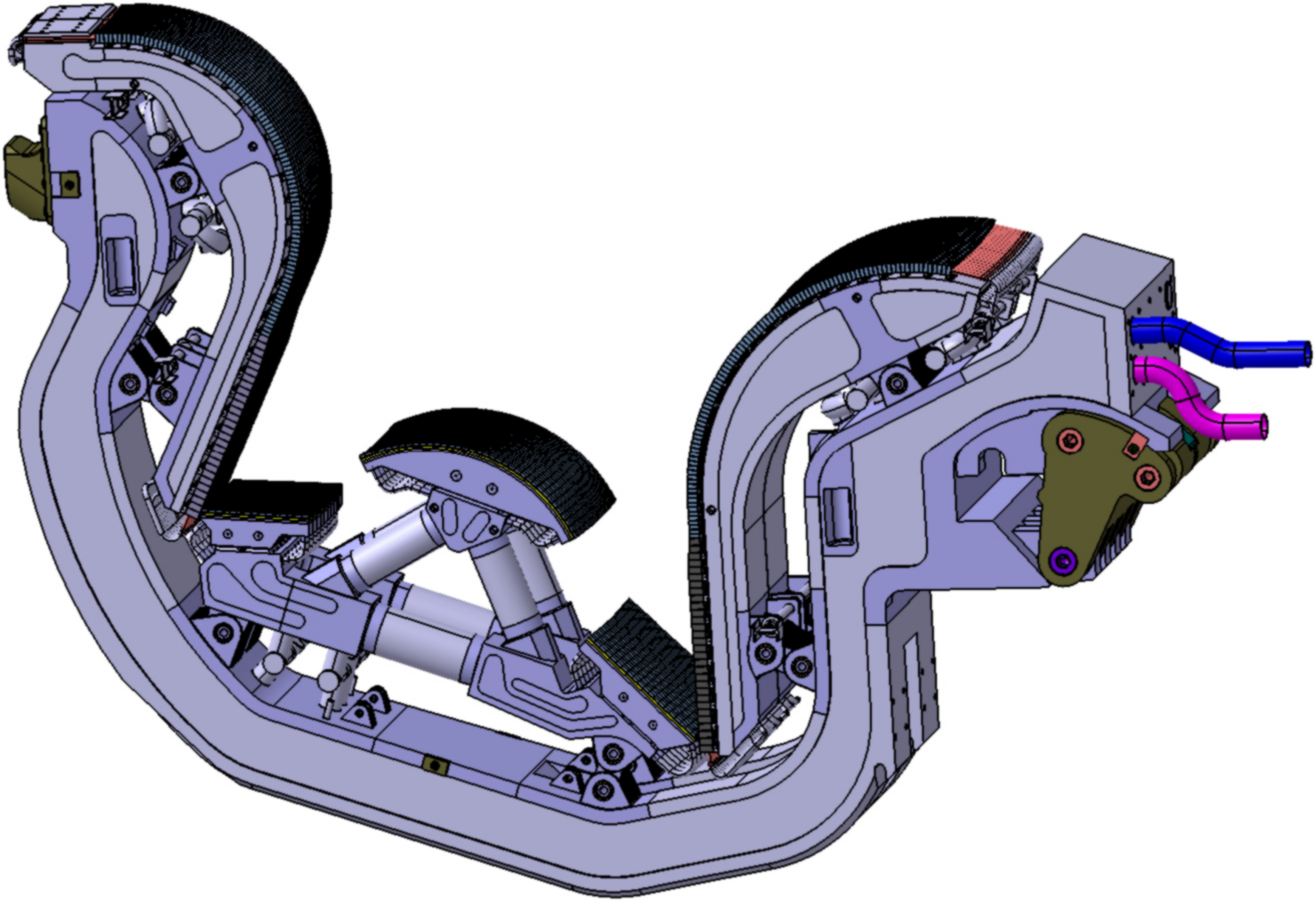
Divertor System



The inner and outer vertical targets (VTs), are the PFCs that, in their lower part, intercept the magnetic field lines, and therefore receive the highest heat flux.



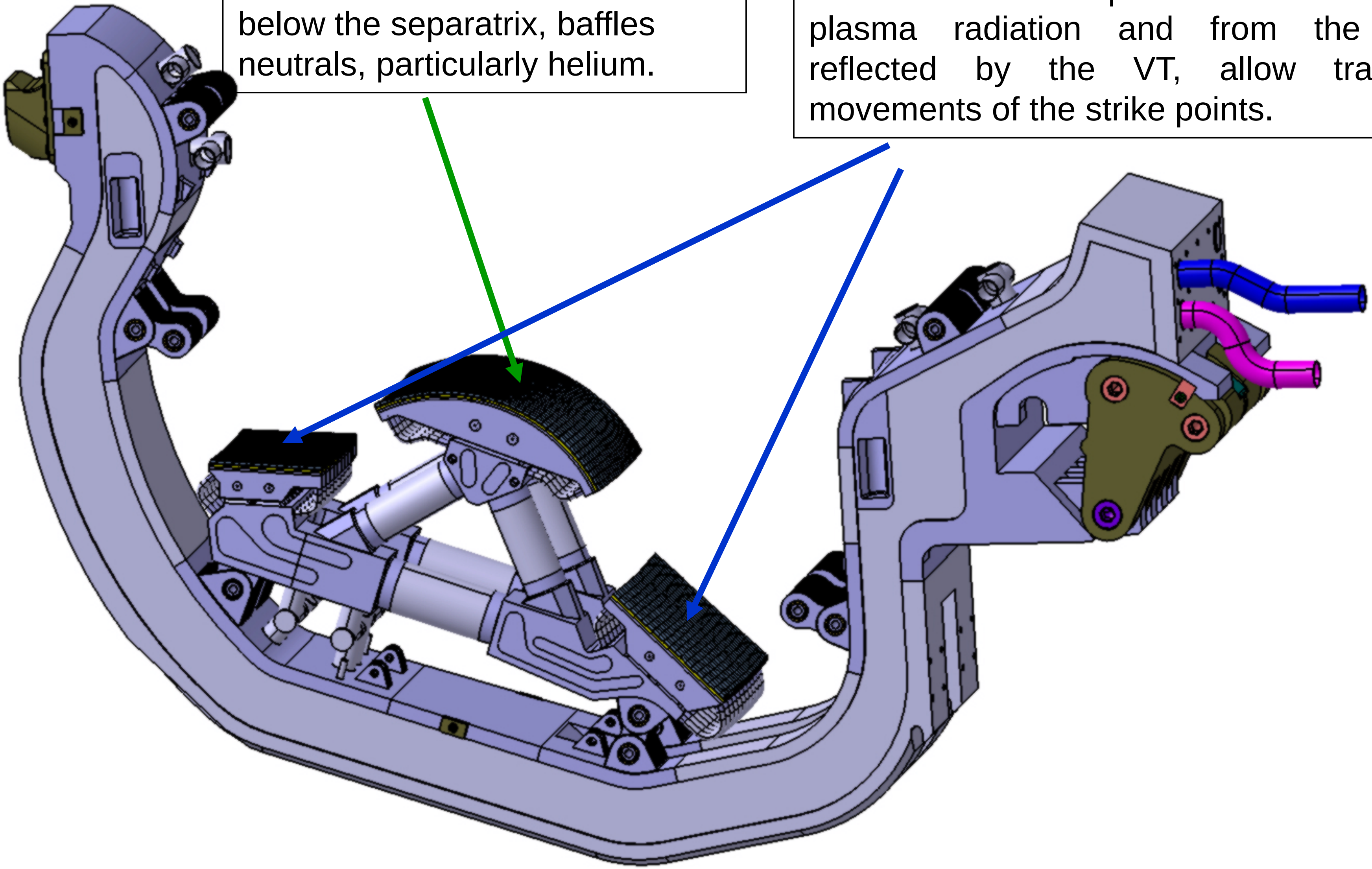
Divertor System



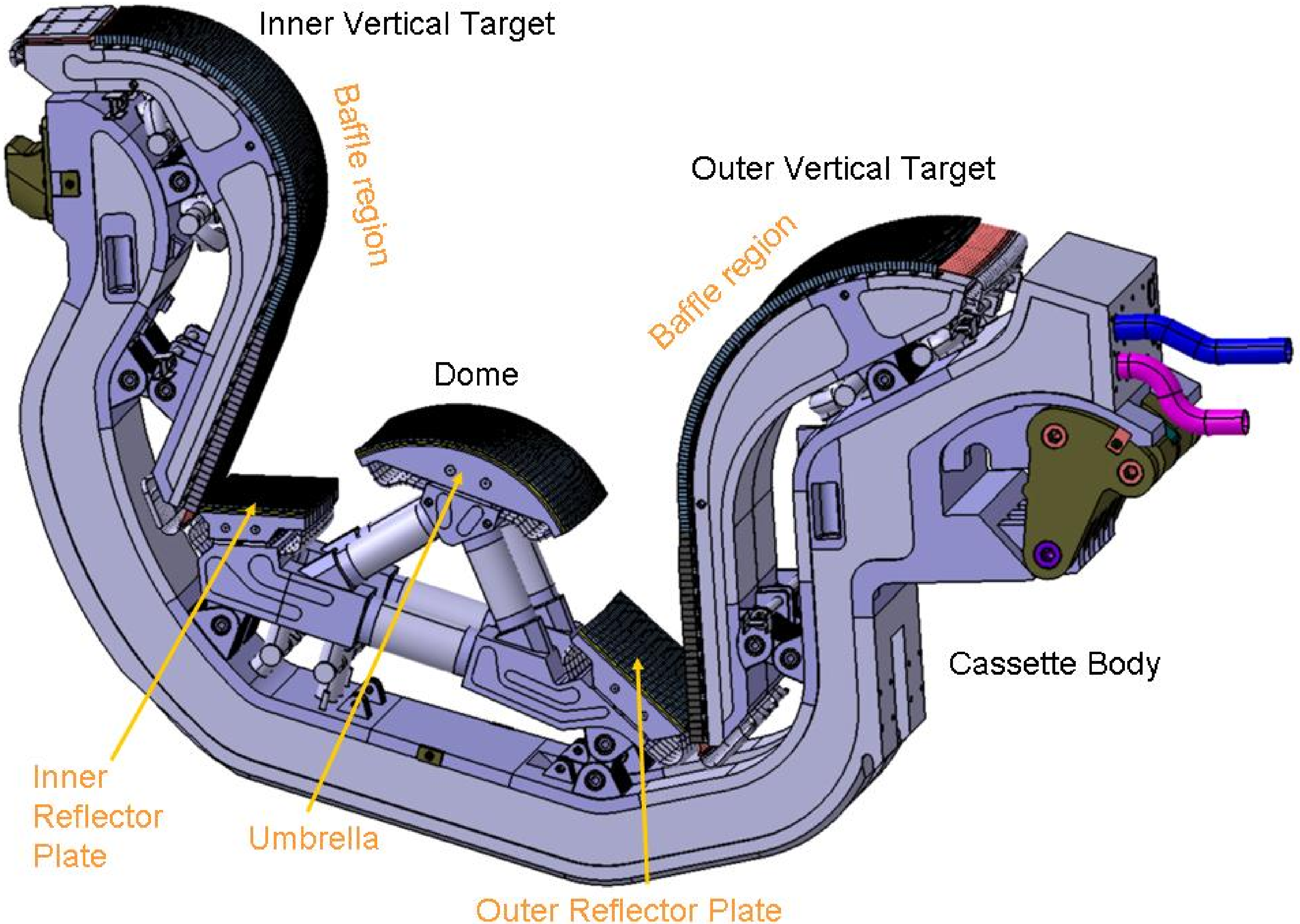
Dome

The "Umbrella", which is located below the separatrix, baffles neutrals, particularly helium.

The inner and outer neutral "Particle Reflector Plates" protect the CB from plasma radiation and from the heat reflected by the VT, allow transient movements of the strike points.



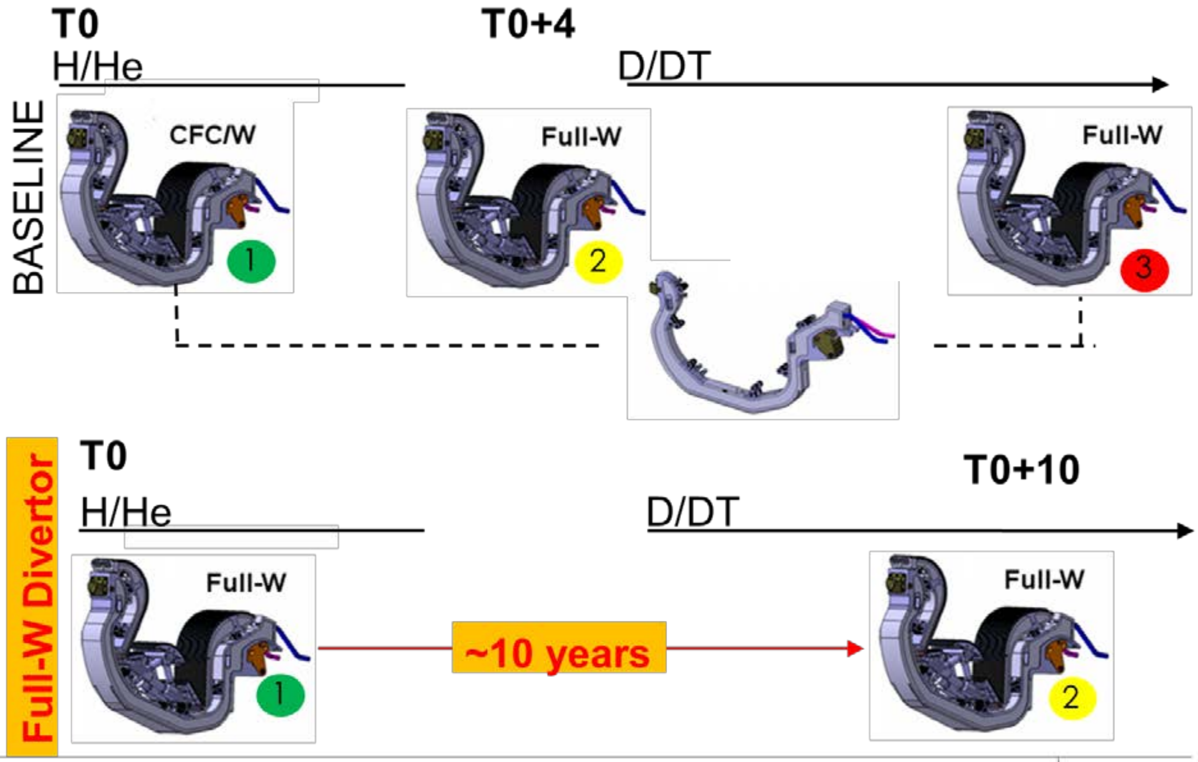
Summary of Terminology



Divertor: Start with a full-W armour

This new strategy enables:

- Saving one divertor set during the operational life of ITER
- Gaining operational experience with a W divertor early on, and thus influence the design of the second divertor to be procured ~ a decade after the first one;
- Learning on how to operate with a W divertor already during the non-nuclear phase;
- Reducing manufacturing risks.



Divertor Shaping Strategy

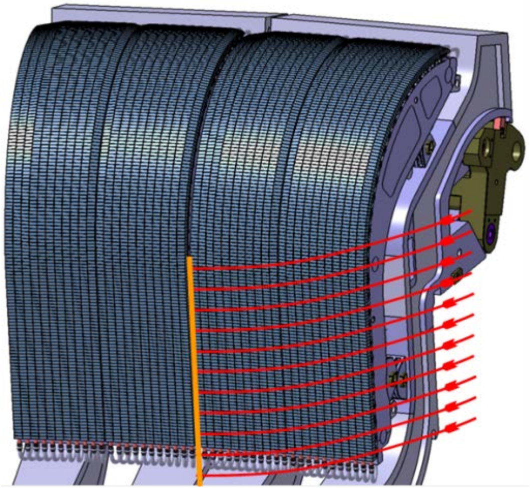
Divertor is not a toroidal continuous structure => leading edges are created by gaps between components or by misalignments because of particle penetration

Remember the very glancing field line angles ~3º

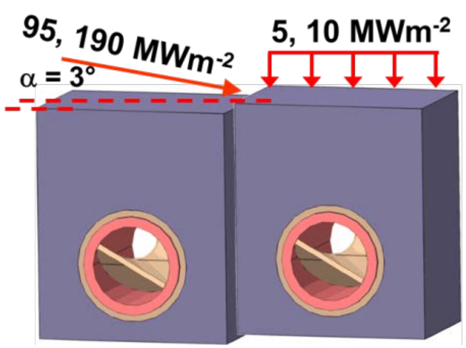
In case of leading edge exposure, projected flux multiplied by ~1/ (sin3) ~20 times !!

⇒ Risk of Melting of W

Any leading edge shall be protected

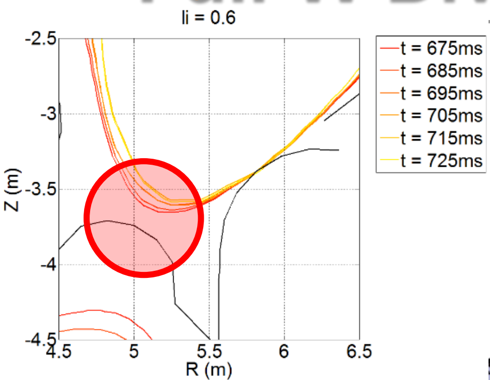


Gap between cassette



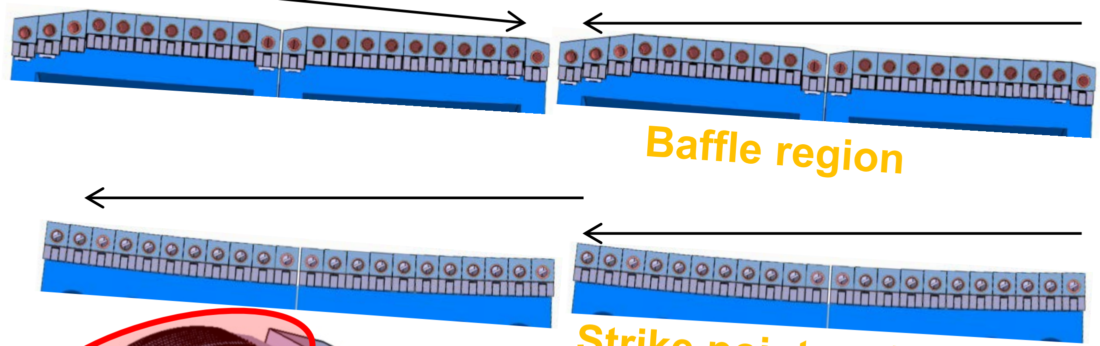
Gap between monoblocks

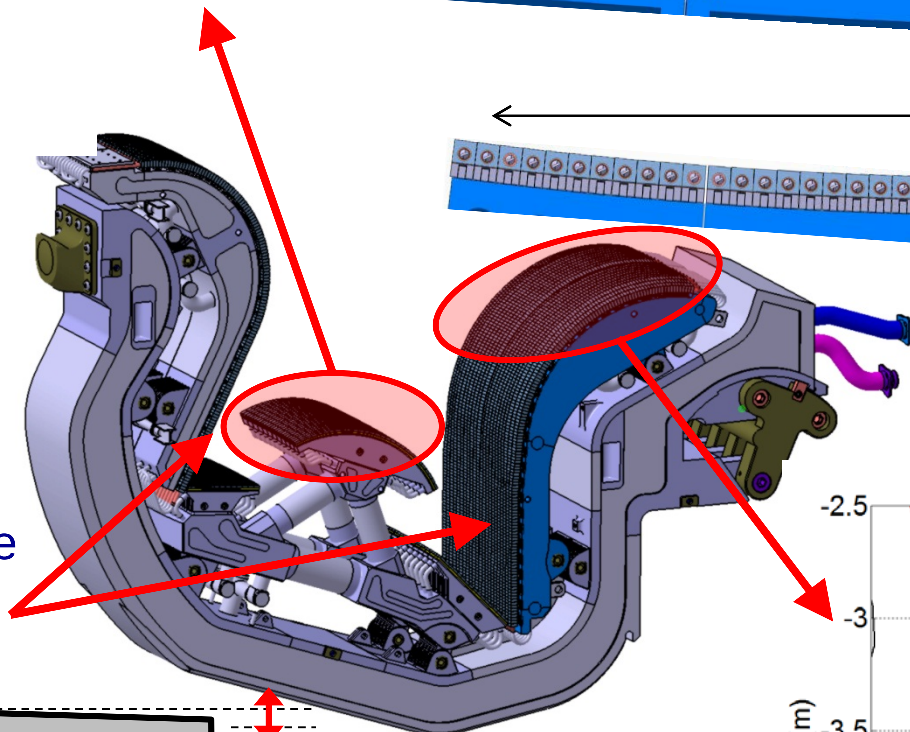
Full-W Divertor Main Design Feature: shaping



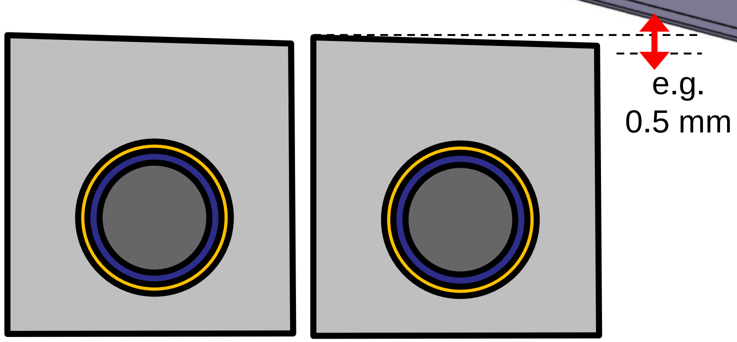
Dome:
no shaping

OVT View from top

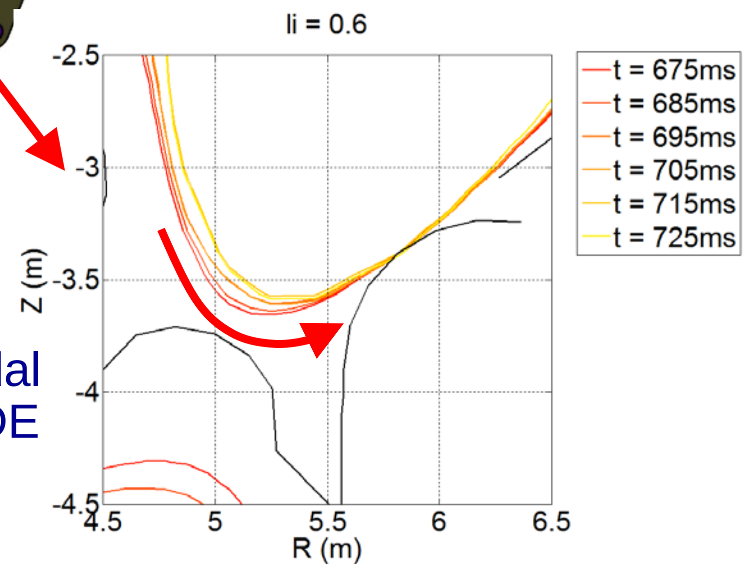




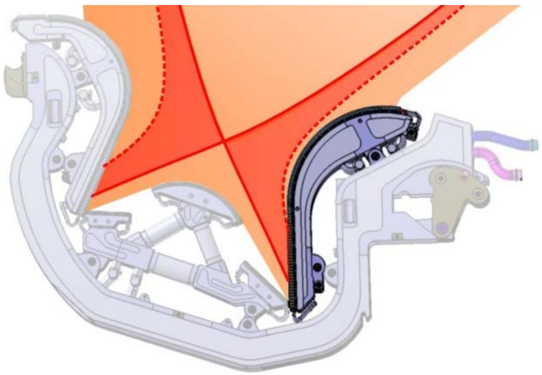
Monoblock chamfering to hide all edges in HHF areas

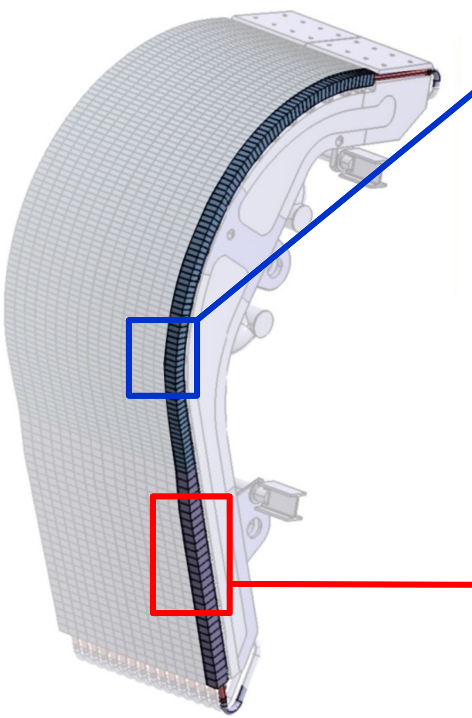


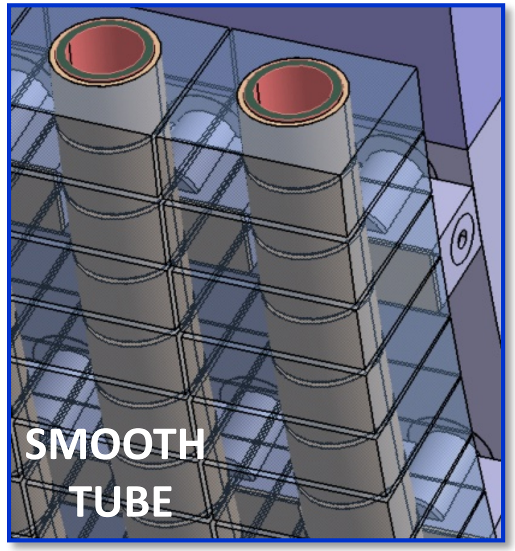
Outer baffle toroidal chamfering for VDE protection

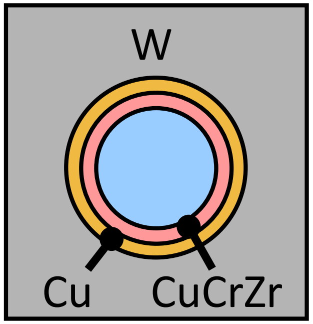


Vertical target and PFU configuration (5-20 MW/m^2)

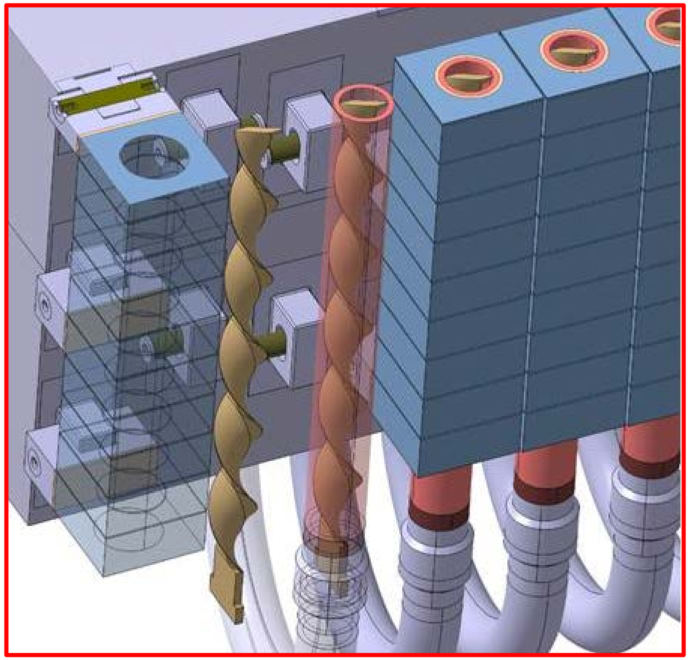






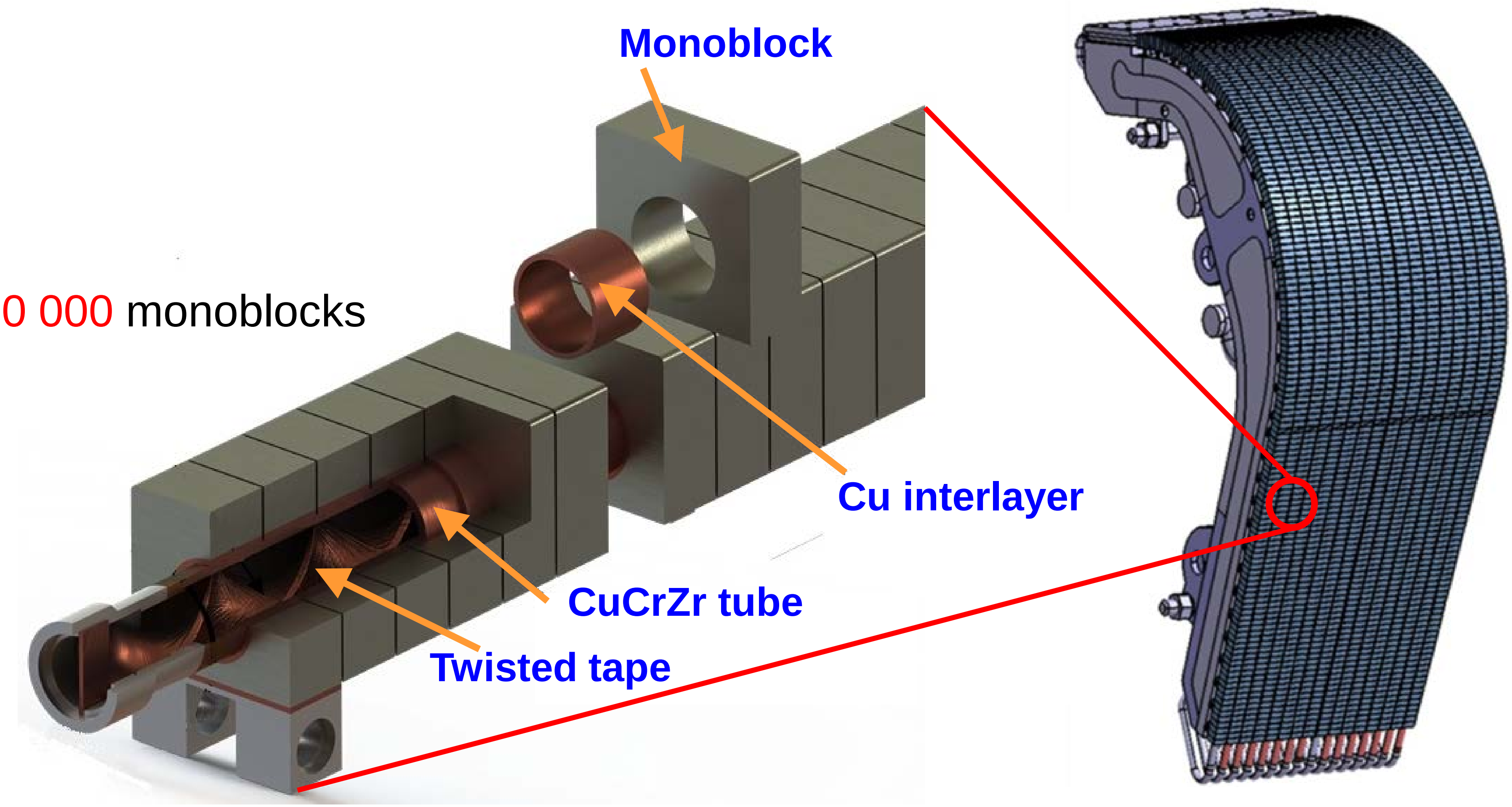


TUBE WITH TWISTED TAPE
→ HIGHEST CHF

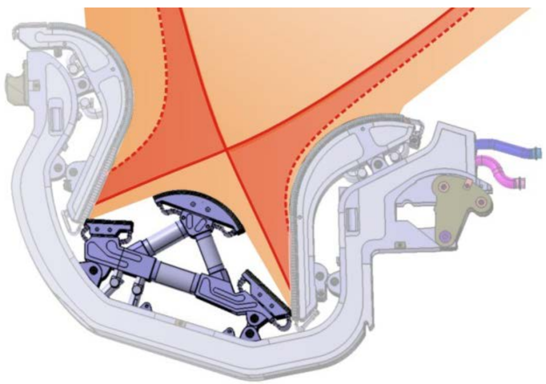


Vertical target and PFU configuration (20 MW/m²)

~300 000 monoblocks

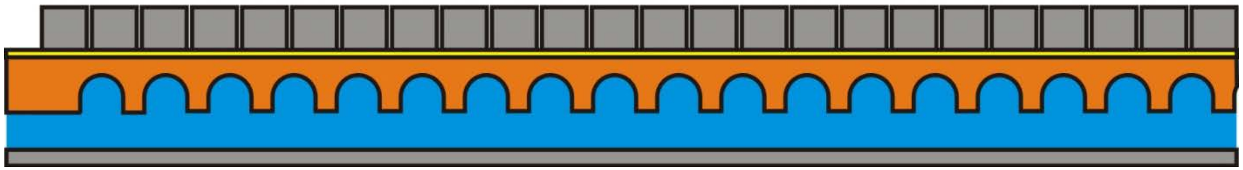


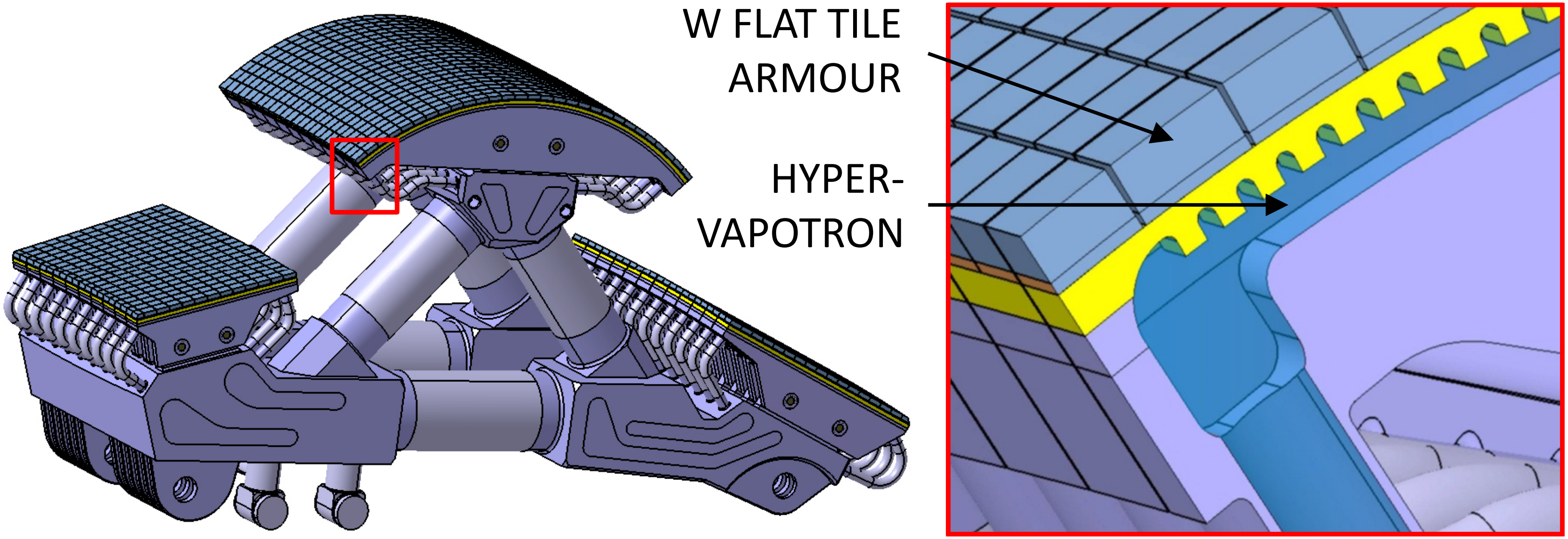
Divertor Dome and PFU configuration (10 MW/m²)



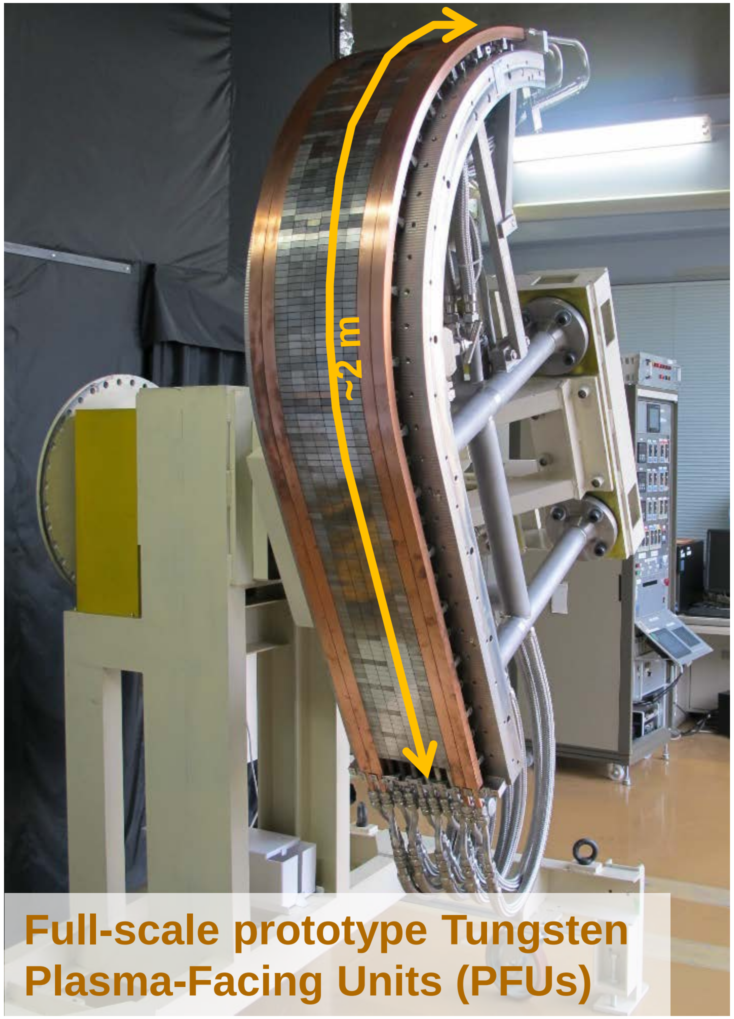
Hypervapotron cooling channel:

- flat tile design
- smaller pressure drop than twisted tape
- higher CHF margin than smooth tube



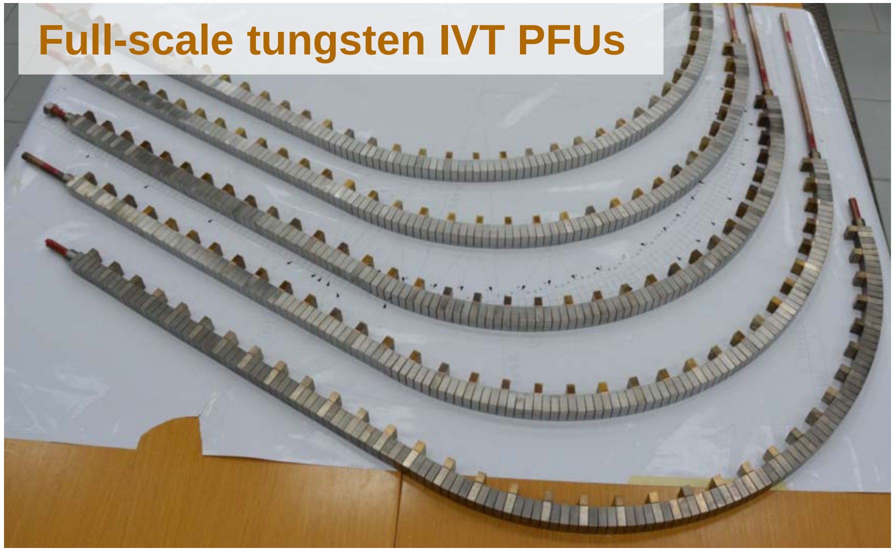


Divertor Prototypes: Plasma Facing Units



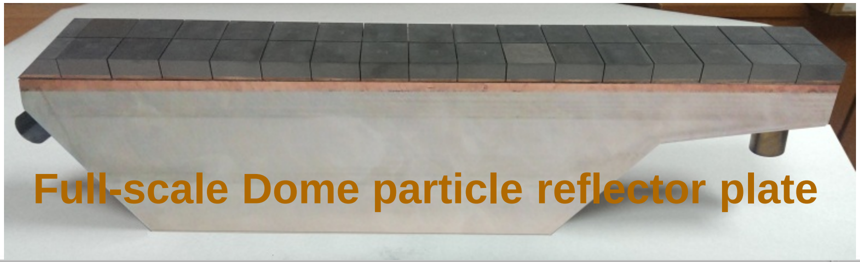
Full-scale prototype Tungsten Plasma-Facing Units (PFUs)

Withstood 5000 cycles at 10 MW/m^2 + 1000 cycles at 20 MW/m^2



Full-scale tungsten IVT PFUs

Full-scale Dome Umbrella

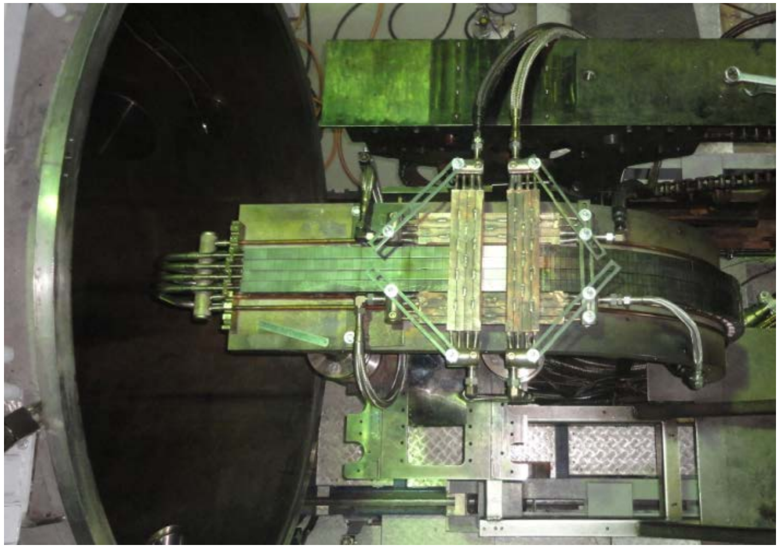


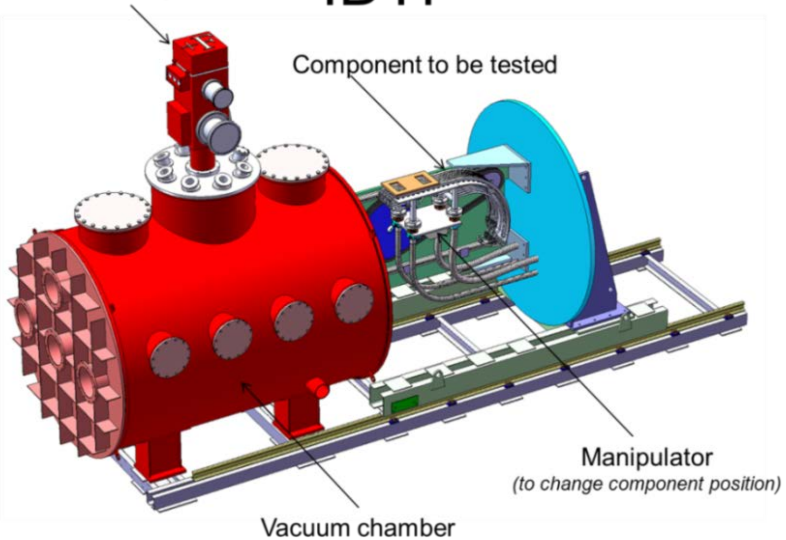
Full-scale Dome particle reflector plate

ITER Divertor Test Facility

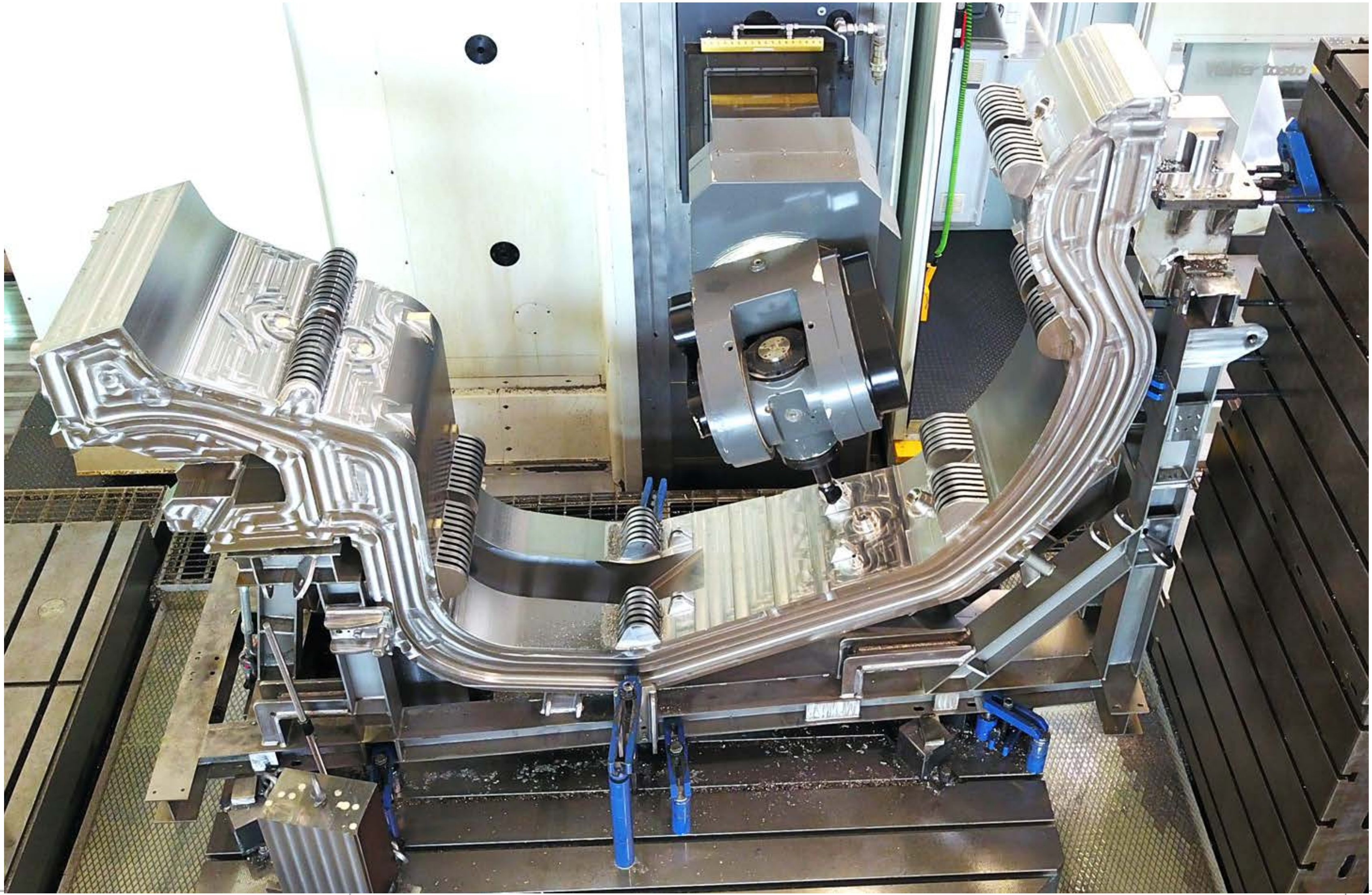
Objective: To qualify and check PFU thermal performance during series production (~20% PFU sampling)

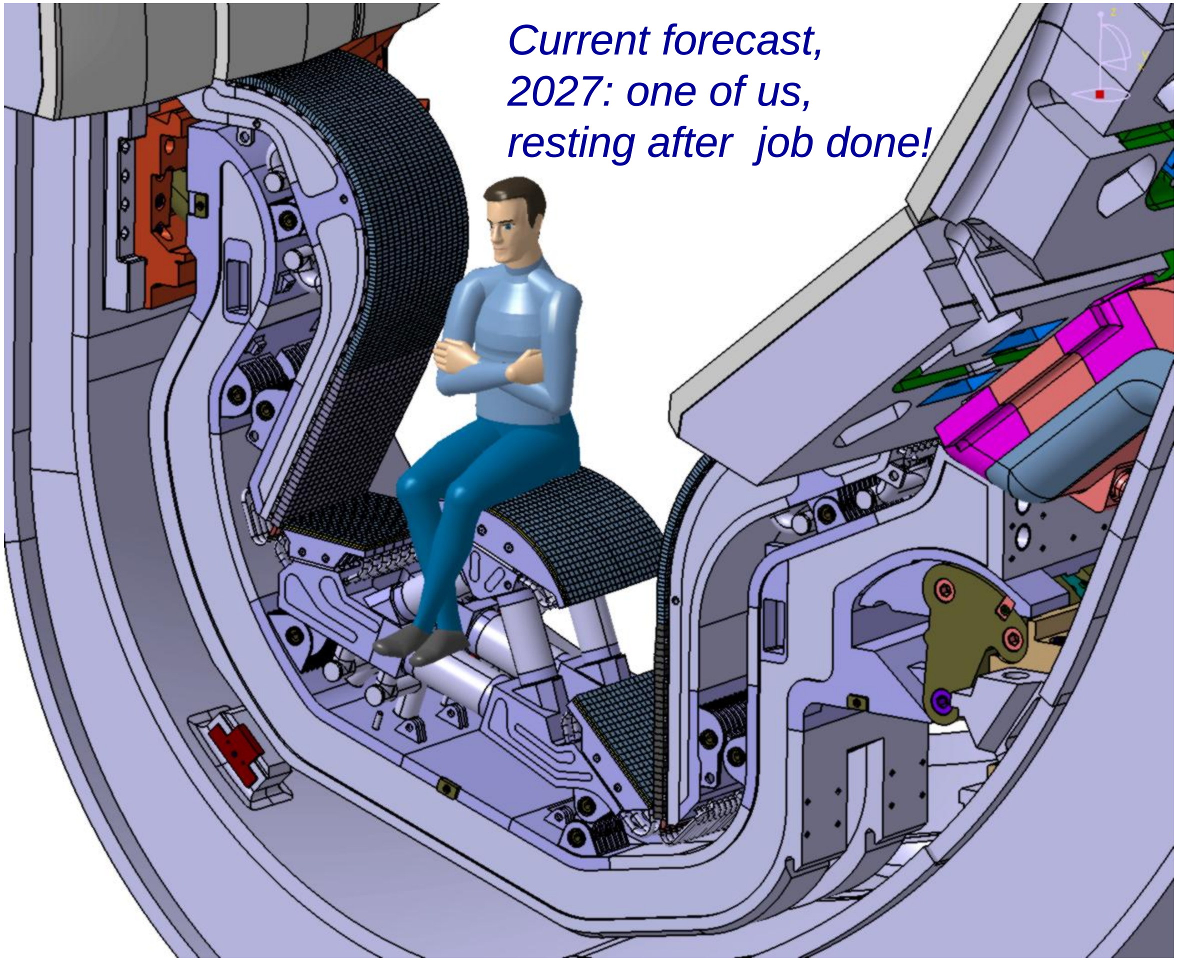
- Location: Efremov Institute, St-Petersburg, RF
- Electron beam test facility
- Maximum electron beam power: 800 kW
- Maximum accelerating voltage: 60kV
- Cooling water parameters are ITER divertor relevant
- Dedicated system of diagnostics





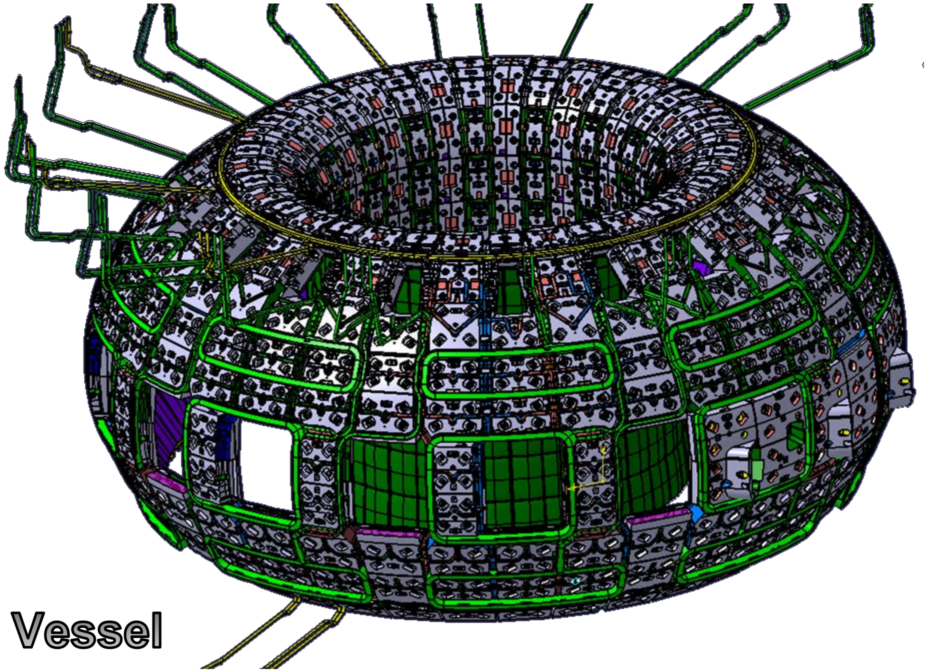
Divertor Prototype: Cassette Body




Current forecast,
2027: one of us,
resting after job done!

Overview

- ❑ ITER Plasma-Facing Components
- ❑ Blanket System
- ❑ Divertor
- ❑ **Design Criteria**
- ❑ Summary



Internal Components:
rear view, without Vacuum Vessel

ITER STRUCTURAL DESIGN CRITERIA FOR IN-VESSEL COMPONENTS

(SDC-IC)

ITER G 74 MA 8 00-11-10 W 0.1

FOREWORD

The Structural Design Criteria for ITER In-vessel Components (SDC-IC) contains interim rules for the structural design of the in-vessel components: first wall, shield / blanket, divertor and the diagnostic components located inside of vacuum vessel. The scope of these criteria is limited to design.

These criteria were developed because existing codes do not address the effects of irradiation on the in-vessel components, which include embrittlement of the material (low ductility and toughness), and may include swelling and creep. Also, the component classifications used with existing codes for the construction of Nuclear Power Plants do not necessarily apply to the in-vessel components.

Question

A bar made of 316 L(N)-IG is loaded axially at room temperature to a stress of 160 MPa

The maximum allowable stress is 147 MPA

Can we state that the load is not acceptable ?

Load Category

Loading Category	Category Conditions (Damage Limits)	SDC-IC Criteria Level	
I Operational Loading	Normal	1	No damage
II Likely Loading	Upset	1	No damage
III Unlikely Loading	Emergency	2	Negligible damage
IV Extremely Unlikely Loading	Faulted	3	May need to inspect and repair/replace

Question

A bar made of 316 L(N)-IG is loaded axially at room temperature to a stress of 160 MPa

The maximum allowable stress is 147 MPA

Can we state that the load is not acceptable ?

Question - Answer

A bar made of 316 L(N)-IG is loaded axially at room temperature to a stress of 160 MPa

The maximum allowable stress is 147 MPA

Can we state that the load is not acceptable ?

If the stress is due to a "Loading Category" III or IV, it is acceptable:
For Cat. III → 147 x 1.2 = 176 MPa
For Cat. IV → 146 x 2.4 = 352 MPa

Question

A bar made of 316 L(N)-IG is loaded axially at room temperature to a stress of 160 MPa (Cat. I)

The maximum allowable stress is 147 MPA

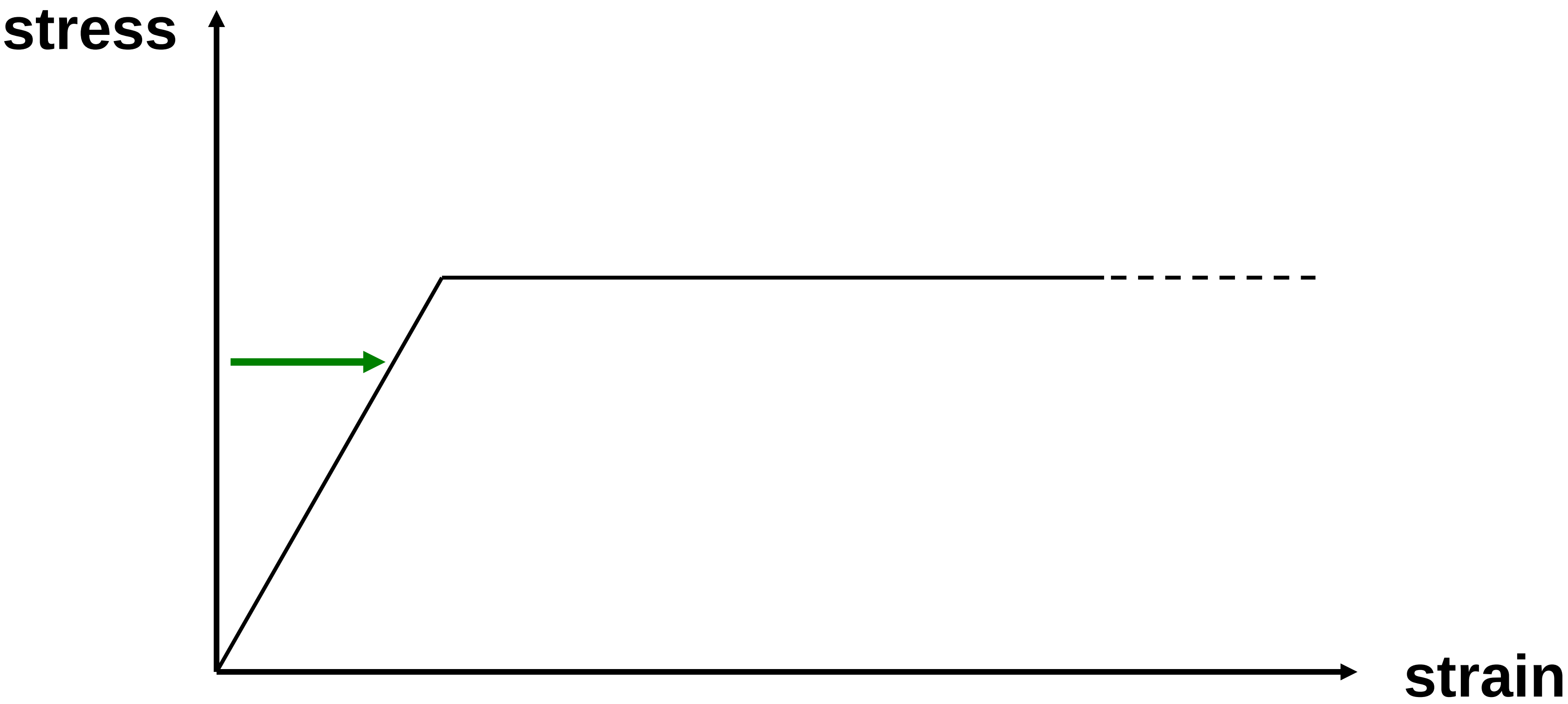
Can we state that the load is not acceptable ?

Stress Definition and Classification: Primary Stress

Definition

The primary stress is defined as that portion of the total stress which is required to satisfy equilibrium with the applied loading and which does not diminish after small scale permanent deformation. Small scale deformation is taken to mean deformation which does not lead either to appreciable change in geometry (large displacements) or to significant stretching (large local deformation).

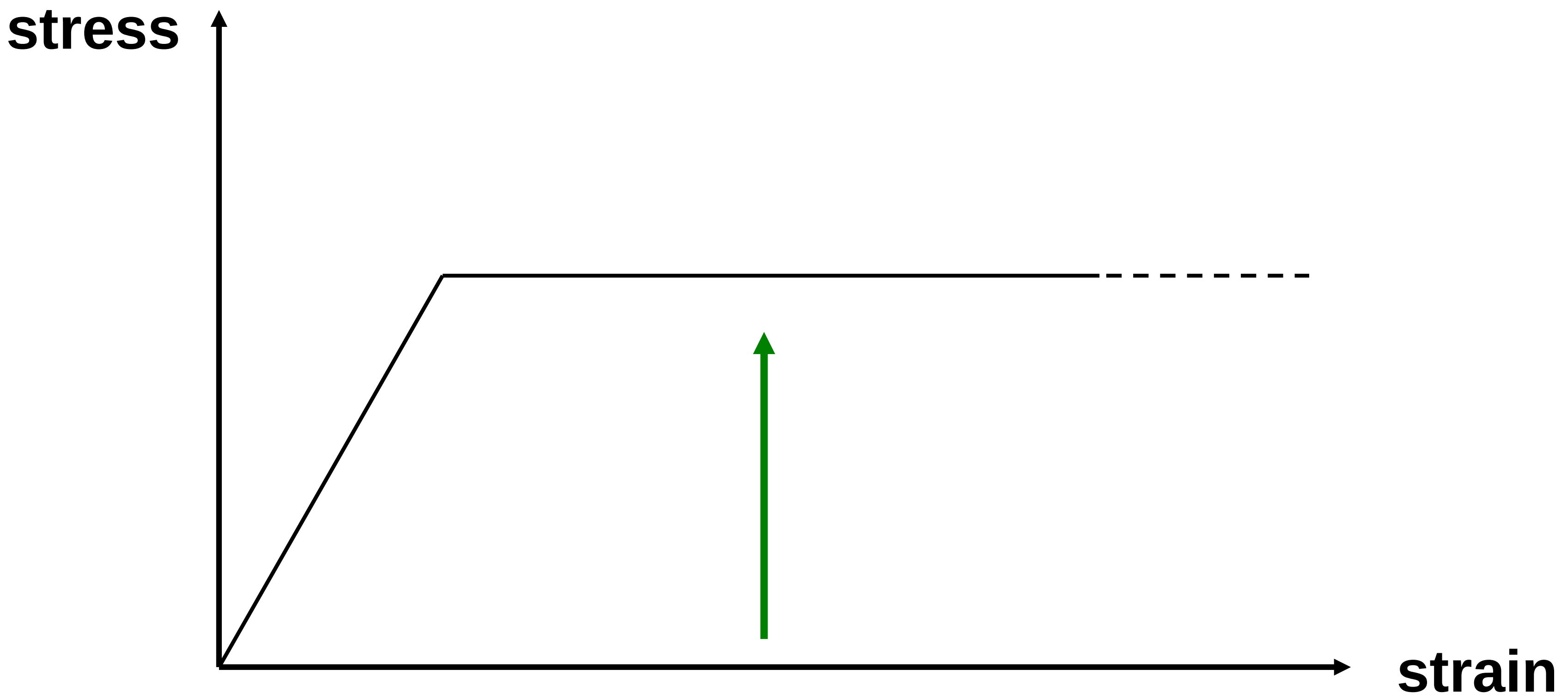
Generated to withstand imposed mechanical loads



Stress Definition and Classification: Secondary Stress

Secondary stress is that portion of the total stress (minus peak stresses, as defined below), which can be relaxed as a result of small scale permanent deformation. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can eliminate the conditions which cause the stress to occur.

Generated to withstand imposed deformation (incl. thermal stress)



Question

A bar made of 316 L(N)-IG is loaded axially at room temperature to a stress of 160 MPa (Cat. I)

The maximum allowable stress is 147 MPA

Can we state that the load is not acceptable ?

Question - Answer

A bar made of 316 L(N)-IG is loaded axially at room temperature to a stress of 160 MPa (Cat. I)

The maximum allowable stress is 147 MPA

Can we state that the load is not acceptable ?

If the stress is a "Secondary" stress, <u>it is acceptable</u>

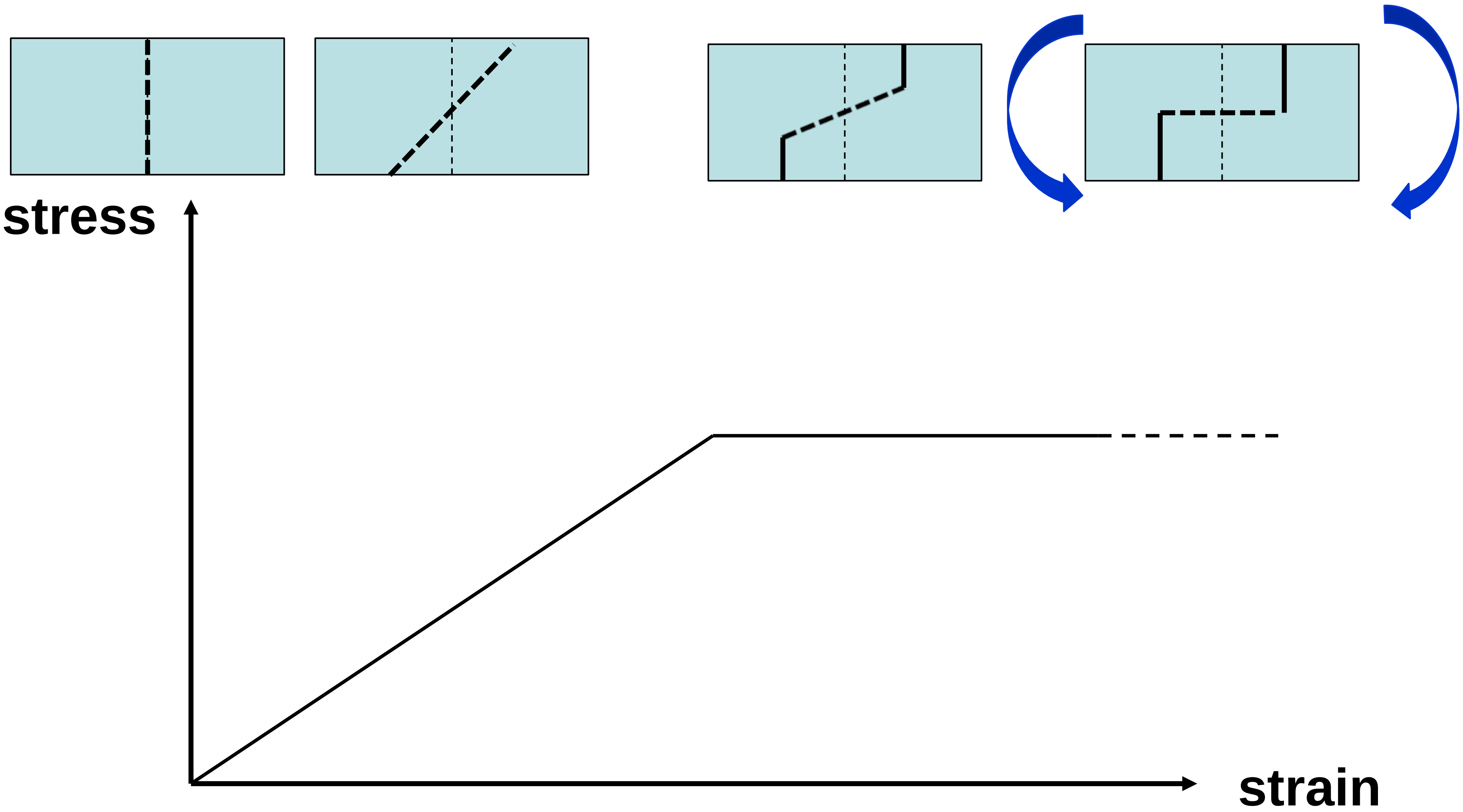
Question

A bar made of 316 L(N)-IG is loaded via a <u>moment</u> at room temperature to a stress of 160 MPa (Cat. I, Primary)

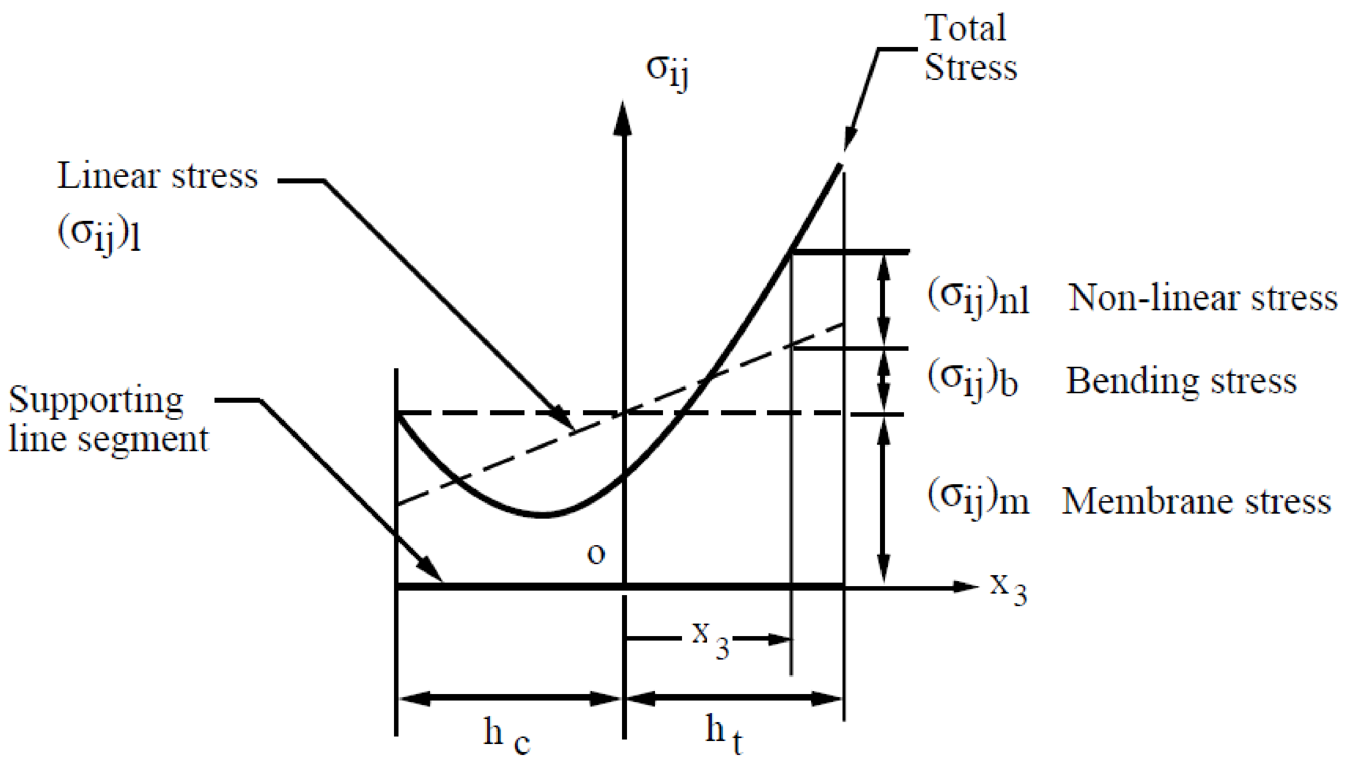
The maximum allowable stress is 147 MPA

Can we state that the load is not acceptable ?

Stress Definition and Classification: Breakdown of Primary



Stress Definition and Classification: Breakdown of Primary



Question

A bar made of 316 L(N)-IG is loaded via a moment at room temperature to a stress of 160 MPa (Cat. I, Primary)

The maximum allowable stress is 147 MPA

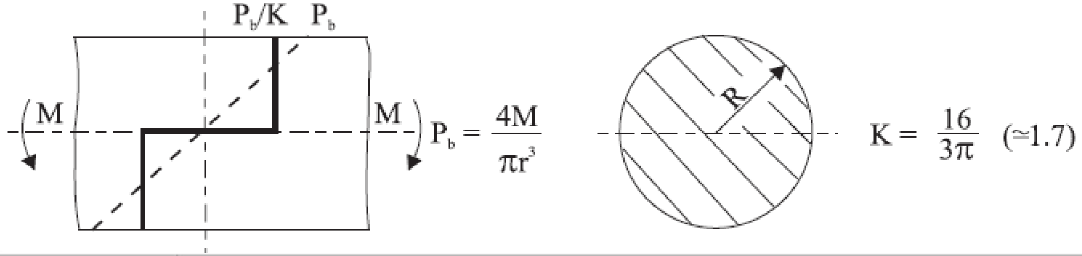
Can we state that the load is not acceptable ?

A bar made of 316 L(N)-IG is loaded via a moment at room temperature to a stress of 160 MPa (Cat. I, Primary)

The maximum allowable stress is 147 MPA

Can we state that the load is not acceptable ?

If the stress is a "Bending" stress, it is acceptable



Stress Definition and Classification: Classification

Total Stress σ				
Primary Stress		Non Primary Stress		
Primary membrane stress	Primary bending stress	Peak stress	Secondary stress	
P_m	P_b	F	Q	

with $\sigma = P_m + P_b + Q + F$

Overview

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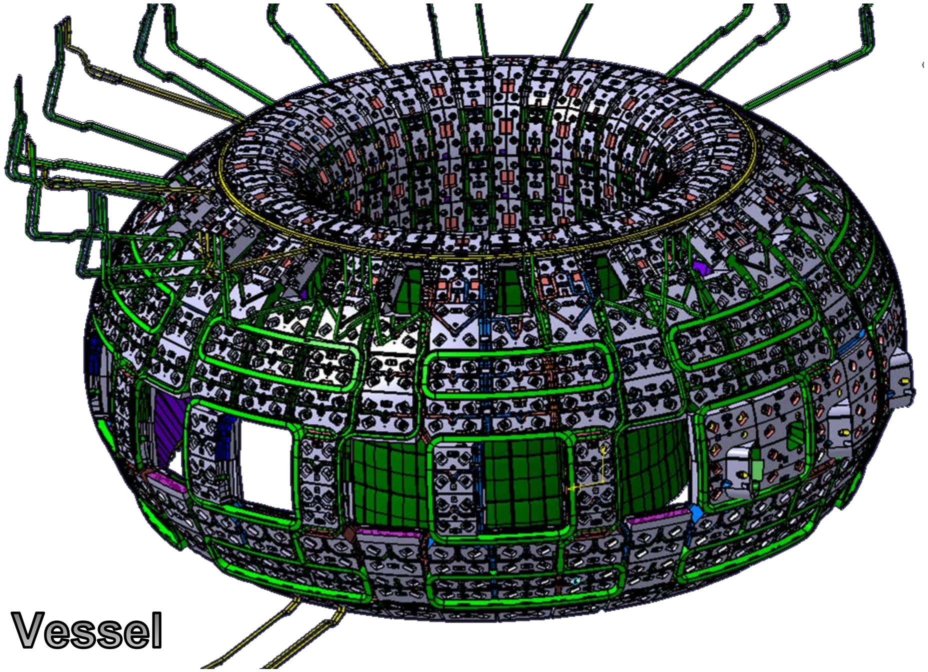

Internal Components:
rear view, without Vacuum Vessel

Summary

- An overview of the main design drivers of the ITER internal components (Blanket and Divertor) has been provided.
- The development of the required high heat flux technologies was an unprecedented engineering worldwide effort.
- The present level of maturity of the design and the successful completion of the qualification programme allows a progressive transition from the design to the procurement phase.
- ***Thanks to all participants from the DAs and IO, working together as a single team, for their large effort and contribution towards the progress of the ITER plasma-facing components***

Thank you for your attention