The ITER Divertor

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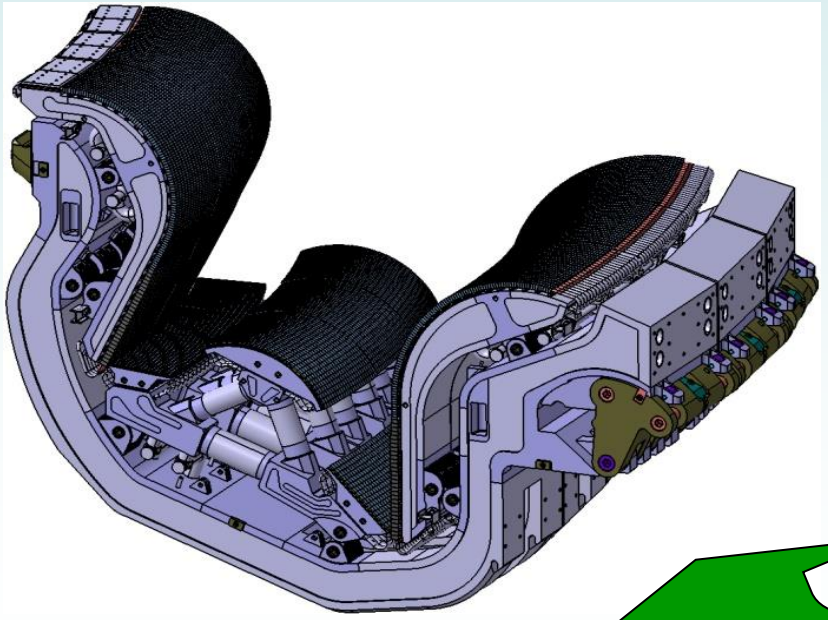
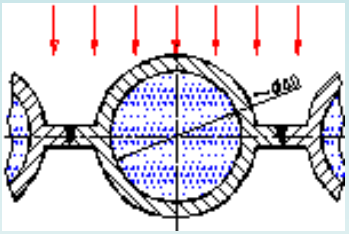
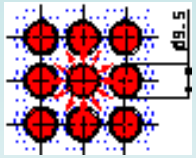
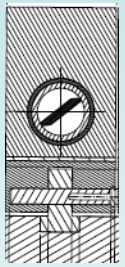
ITER Divertor

Divertor main functions :

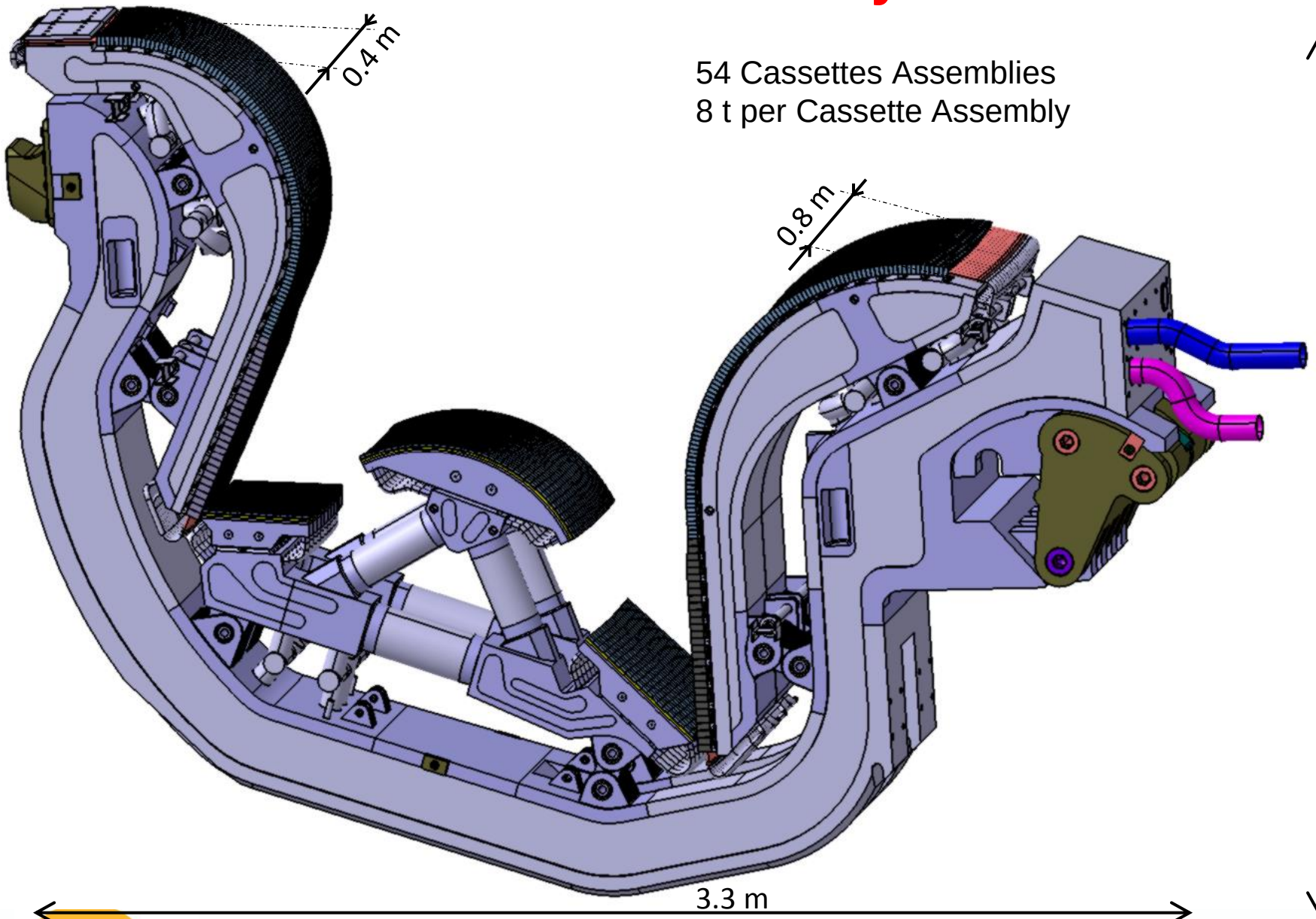
- To minimize the impurity content of the plasma
- To exhaust part of the plasma thermal power



Power Handling Comparison

HIGH HEAT FLUX COMPONENTS	FOSSILE FIRED BOILER WALL (ABB)	FISSION REACTOR (PWR) CORE	ITER DIVERTOR
DESIGN			
HEAT FLUX - average MW/m^2 - maximum MW/m^2	 0.2 0.3	 0.7 1.5	 3 – 5 10 – 20
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}

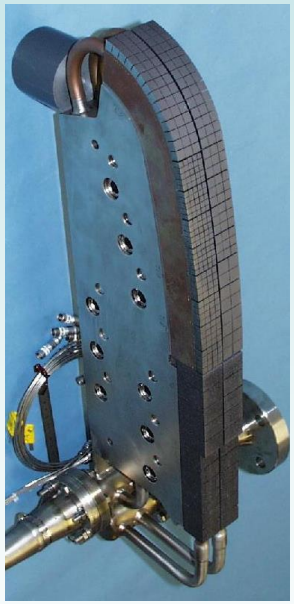
Cassette assembly



Divertor Technology Evolution

1995

1998



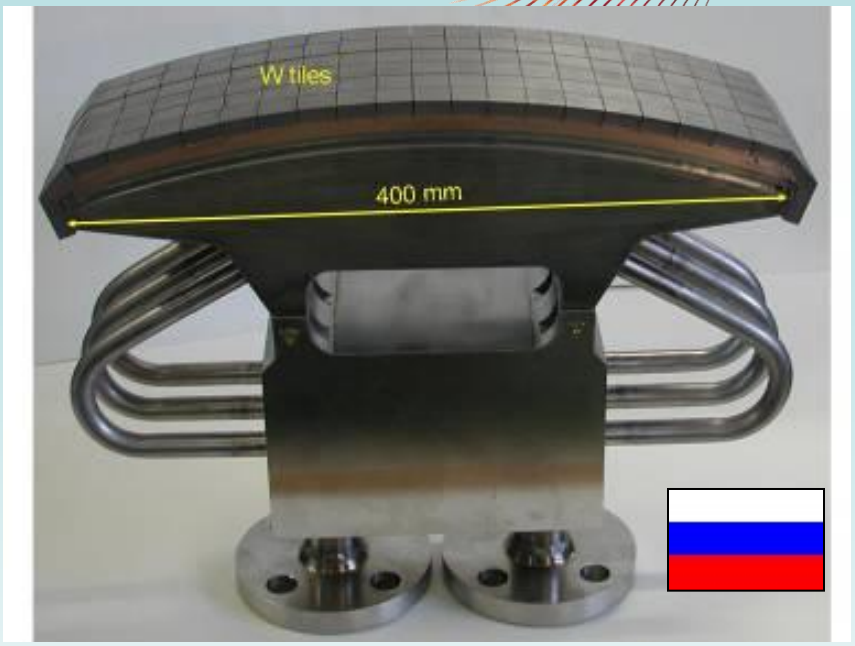
2002

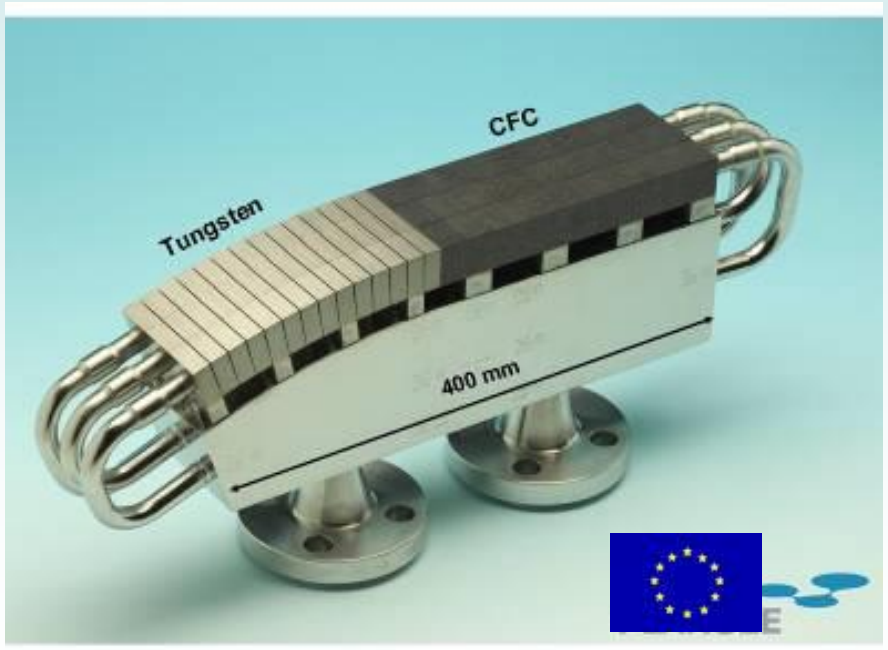
Divertor Qualification Prototypes 2006-2008

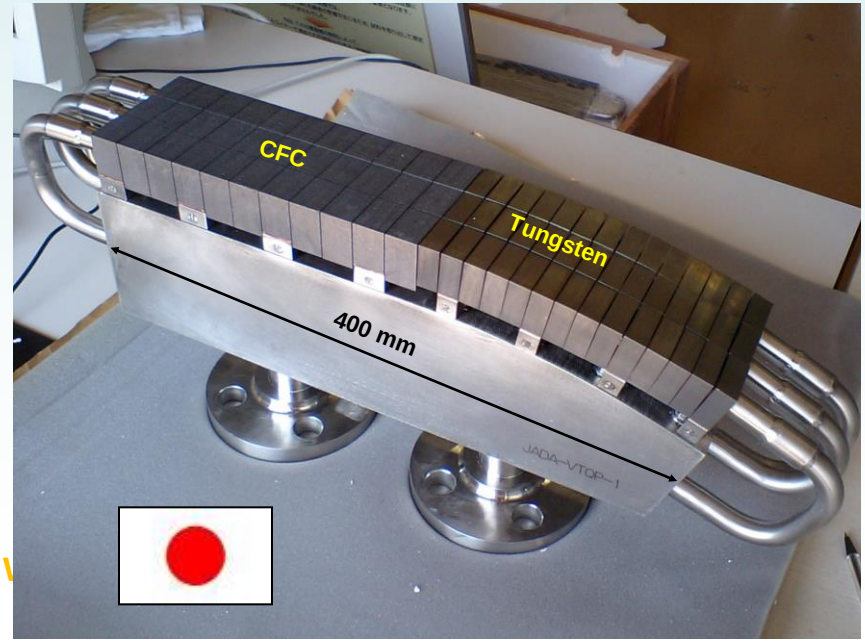
CFC Armoured Areas
1000 cycles at 10 MW/m^2
1000 cycles at 20 MW/m^2

W Armoured Areas
1000 cycles at 3 MW/m^2
1000 cycles at 5 MW/m^2

All the 3 Domestic Agencies have qualified







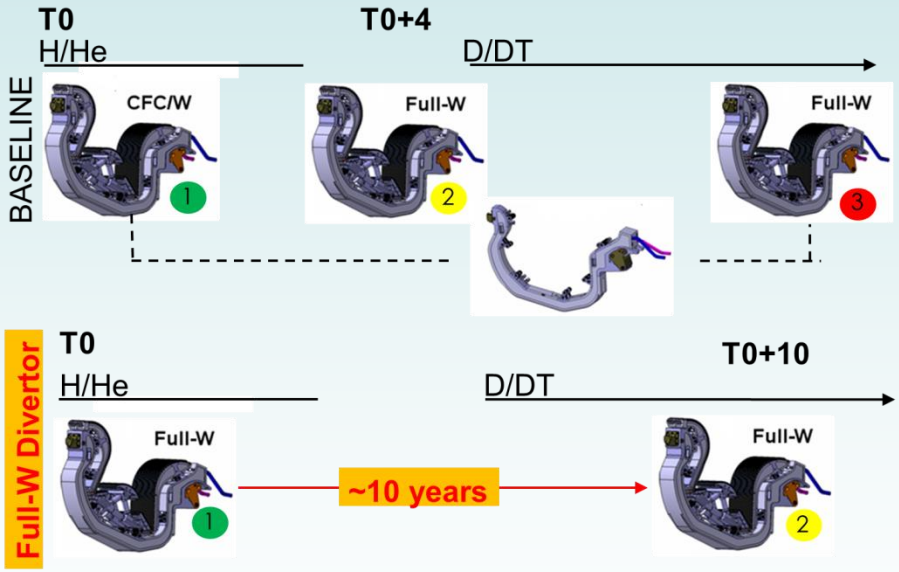
Divertor: Start with a full-W armour

Originally, the ITER Divertor baseline foresaw the use of CFC as plasma-facing material for the lower part of the Vertical Target.

However, the present ITER licensing file excludes the use of carbon during the nuclear phase due to the potential risk of rapid accumulation of tritium by codeposition.

This means that starting the ITER operation with a carbon Divertor would have implied that it should be replaced at the end of the pre-nuclear phase, namely after just 3-4 years of operation.

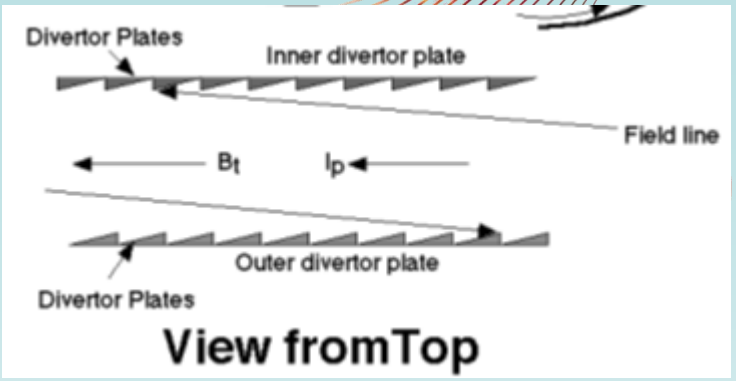
As a consequence, substantial cost reductions could be achieved if a single Divertor, with a full-W armour, were installed from the start of ITER operations and could be guaranteed to survive well into the nuclear phase.

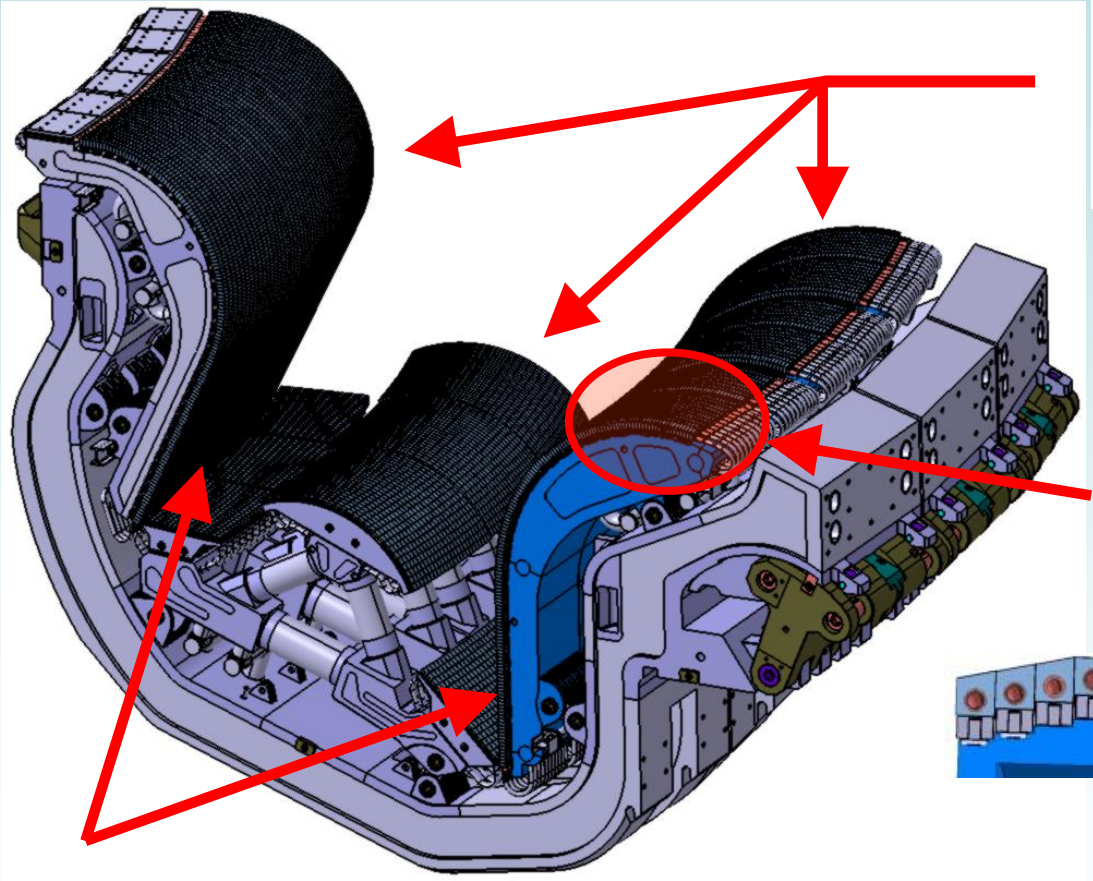


At its 13th meeting on 20-21 November 2013, the ITER Council has approved to start operation with a divertor having a full-W armour

Full-W Divertor design: Main Features

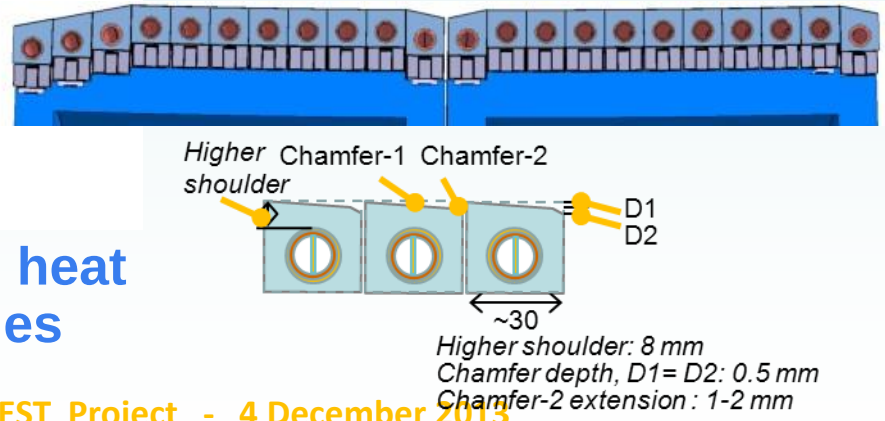
Objective: minimum changes compared with the baseline (CFC/W) variant





Optimize tilting of Vertical Targets and Dome to protect inter-cassette leading edges

Outer baffle shaping to mitigate W melting at downward VDE impact



Individual monoblock shaping in high heat flux areas to protect all leading edges

Full-W Divertor Qualification Program

Step-1: Technology Development and Validation : Demonstration of the *fitness-for-purpose* of the proposed technology by means of small-scale mock-ups manufacturing and High Heat Flux testing in ITER Divertor Test Facility (IDTF)

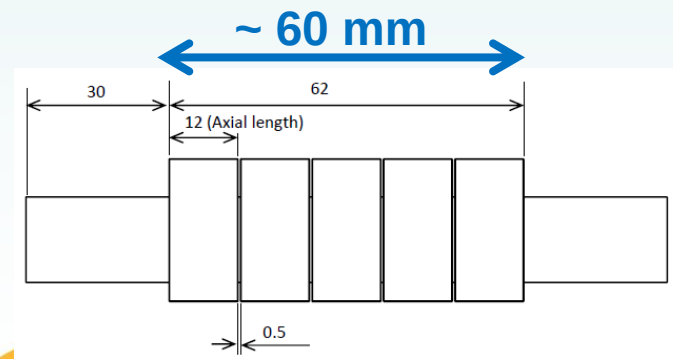
Step-2: Full-scale demonstration: Demonstration of the technology via Full-scale-prototype manufacturing and testing in IDTF

HHF tests for small-scale and full-scale PFU straight part

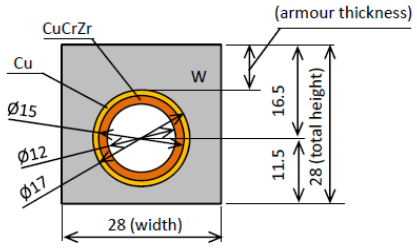
- 5000 cycles at 10 MW/m^2
- 300 cycles at 20 MW/m^2

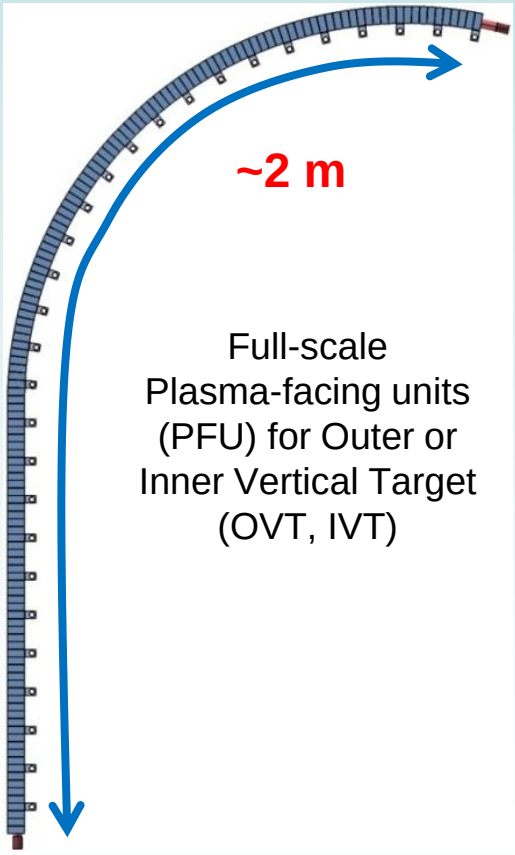
HHF test for prototype PFU curved part

- 5000 cycles at 5 MW/m^2



Small-scale mock-ups

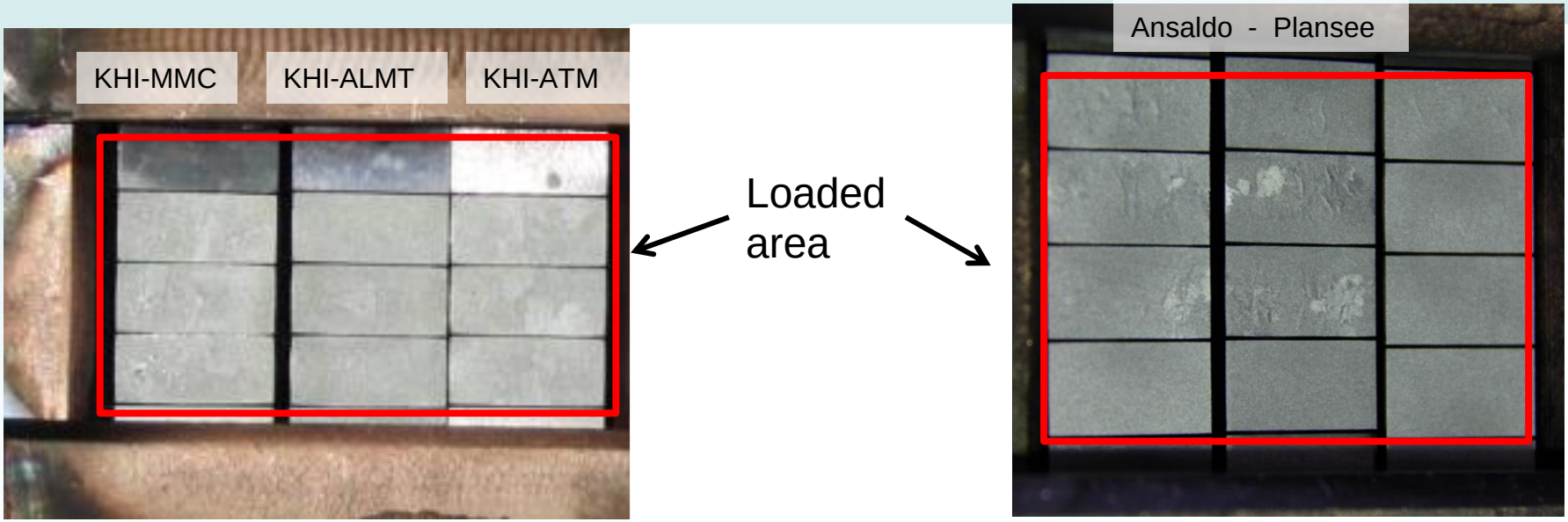




Full-scale Plasma-facing units (PFU) for Outer or Inner Vertical Target (OVT, IVT)

W Divertor R&D Activity in JADA and EUDA

- R&D demonstrated that both JADA and EUDA have developed the W monoblock technology.
- Mock-ups were manufactured by Kawasaki Heavy Industry (KHI) and Mitsubishi Heavy Industry (MHI) and by Plansee and Ansaldo, for JADA and EUDA, respectively.
- High heat flux tests were performed by RFDA in IDTF facility in St Petersburg up to the design load (20 MW/m^2 for 300 cycles) and beyond (20MW/m^2 for 1000 cycles)



JA full-W mockups and EU Mock-ups after HHF test at 20 MW/m^2 300 cycles in IDTF

Summary and Prospects

- A mature full-W divertor design is now in place with the key design supporting analyses essentially complete.
- The design was examined by an expert panel during a Final Design Review in June 2013, as requested by STAC. The review was successfully completed.
- In all DAs supplying the divertor components technology development surpasses the cyclic load specifications.
- The divertor targets consists of about 100,000 tungsten monoblocks, each of them should meet the highest quality standard and demanding design requirements.
- A risk mitigation strategy is therefore essential to maximize the chance of success during the ITER divertor construction.

- **The ITER – CEA collaboration on WEST is a key element of this strategy.**