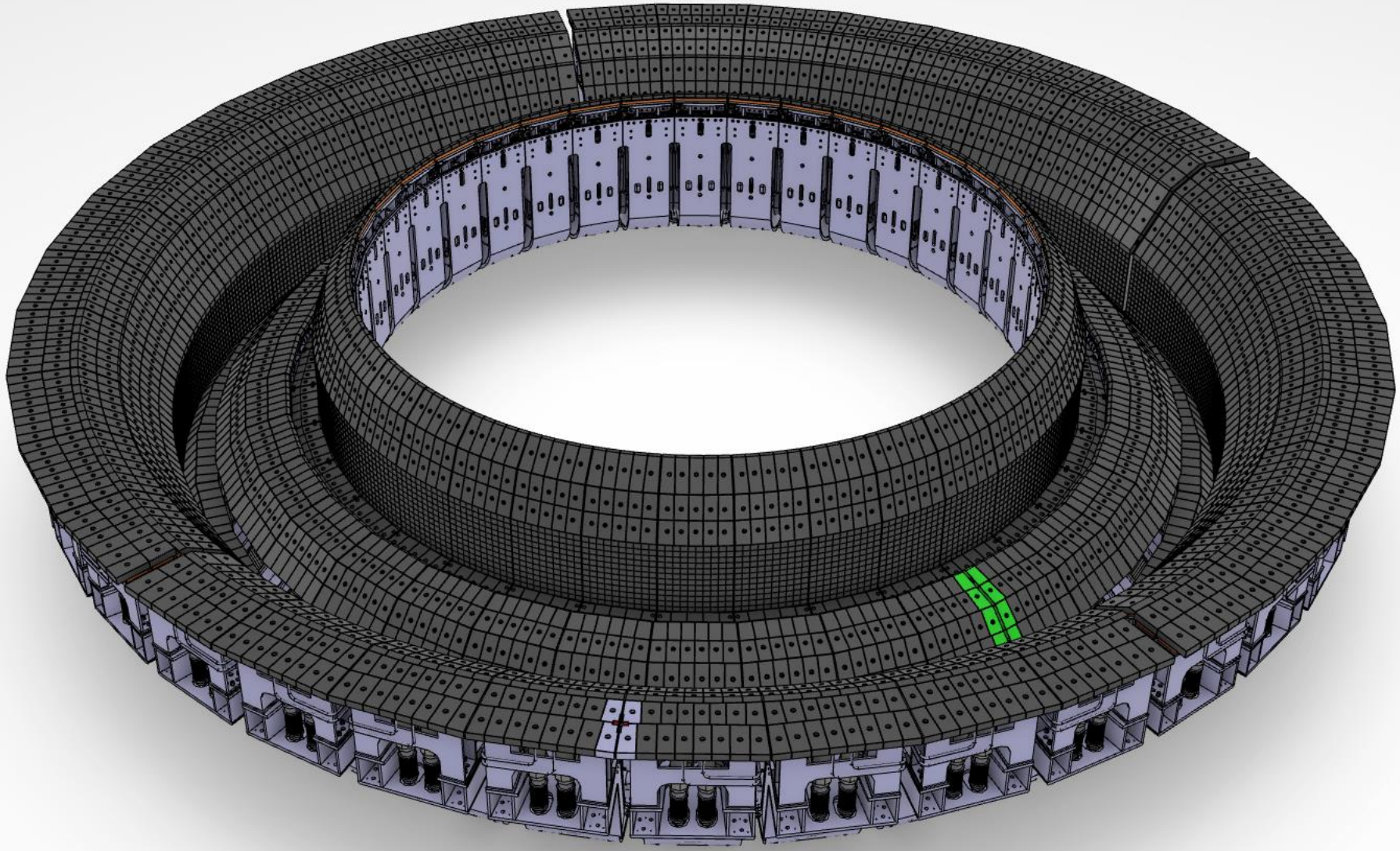
JT-60SA Actively Cooled Divertor
Design, procurement and qualification activities

V. Tomarchio

Fusion for Energy

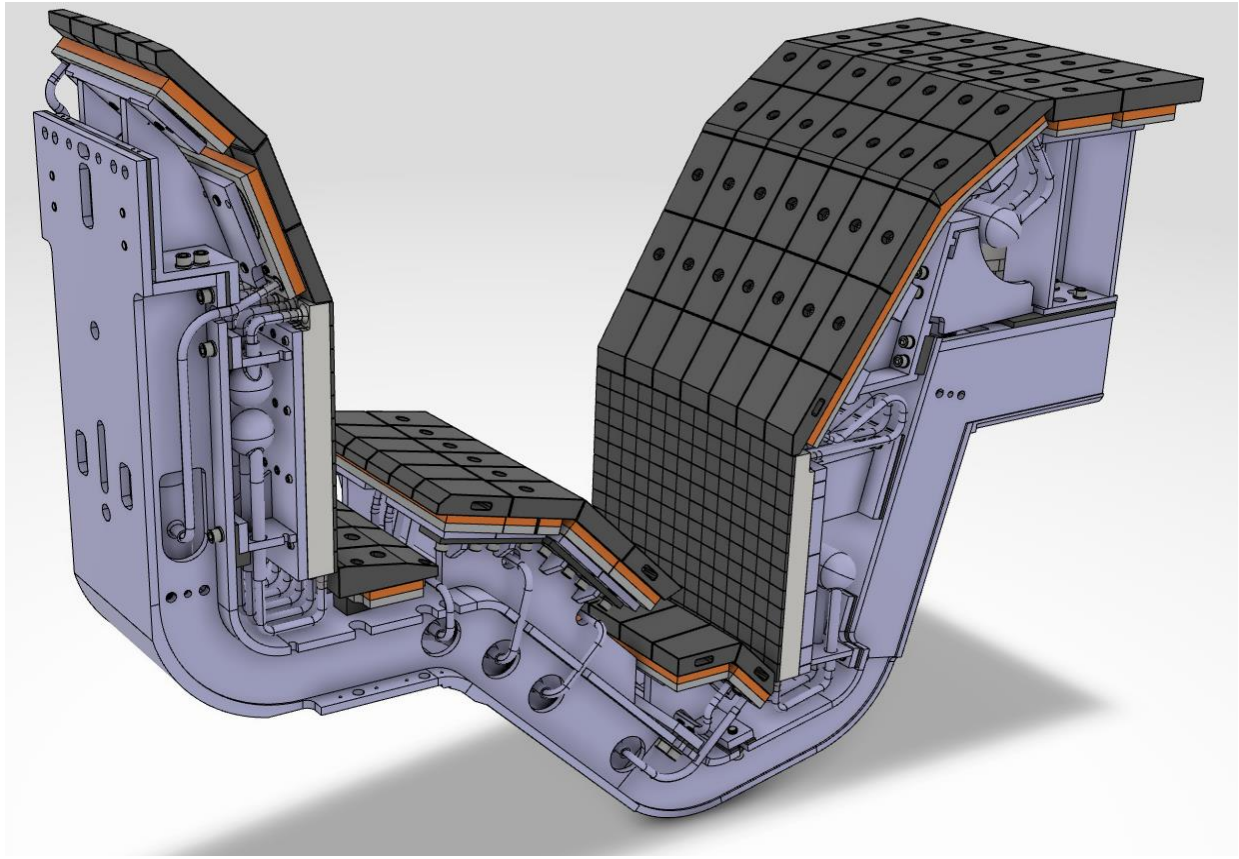
The JT-60SA Actively cooled divertor

FUSION FOR ENERGY



Design parameters

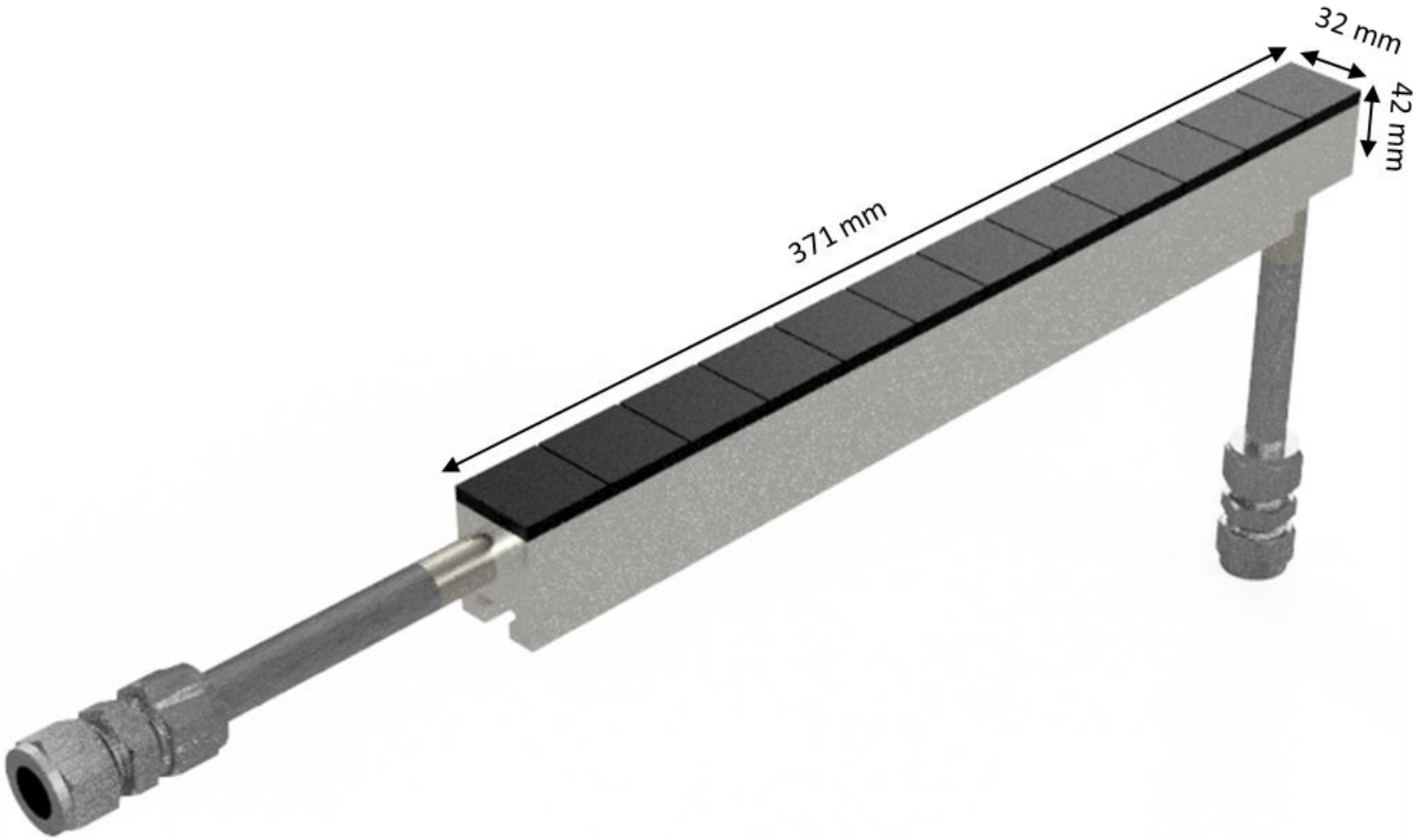
- 36 nearly identical units
- Actively cooled (steady state operation)
- 10MW/m2 nominal steady state heat load (targets)
- Graphite armor
- CuCrZr/TZM heat sinks



Procurement strategy

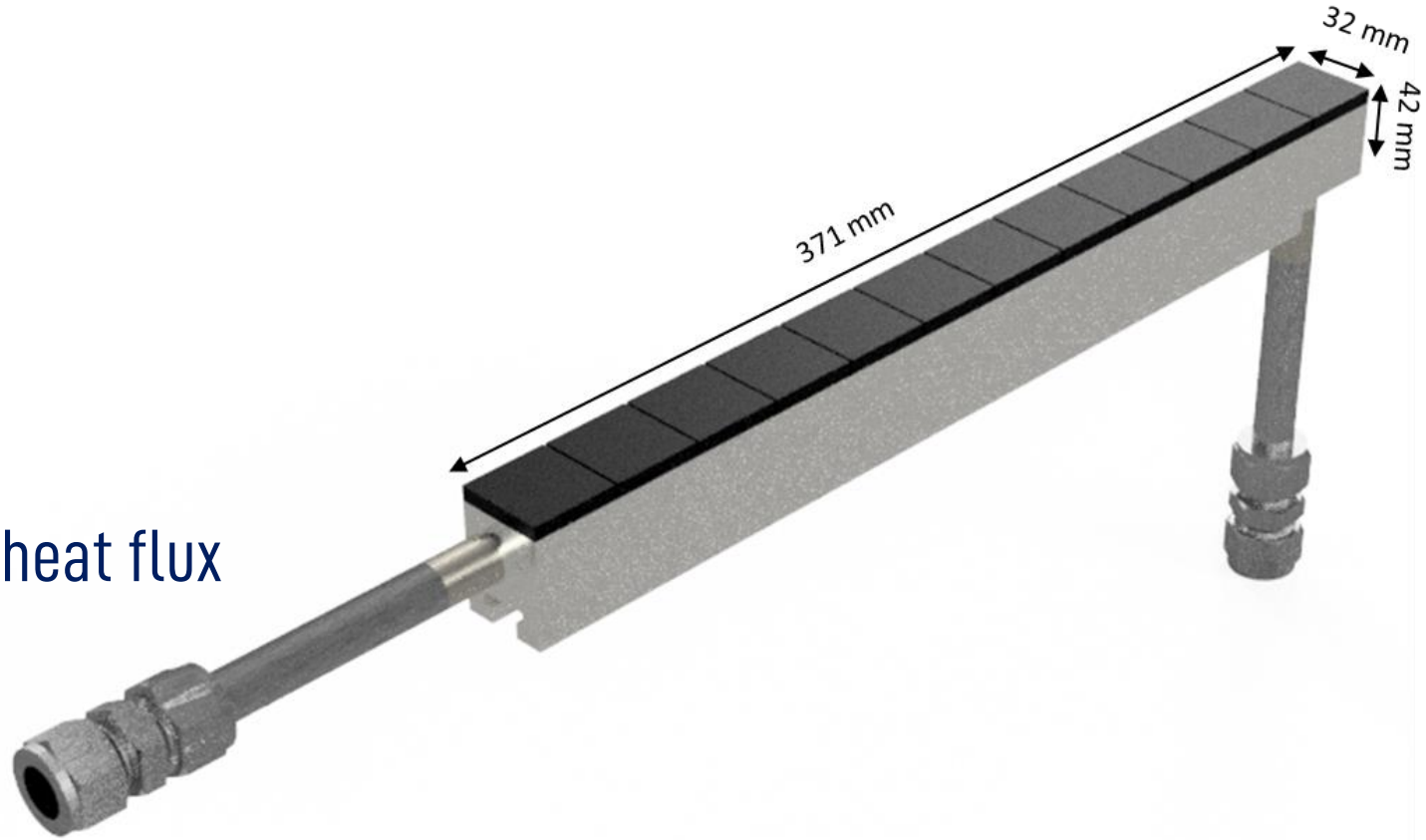
- Procurement split in 4 contracts:
  - **High heat flux elements**
  - **Normal heat flux elements**
  - **Cassette frames**
  - **Diagnostics and integration**

The High Heat Flux Elements



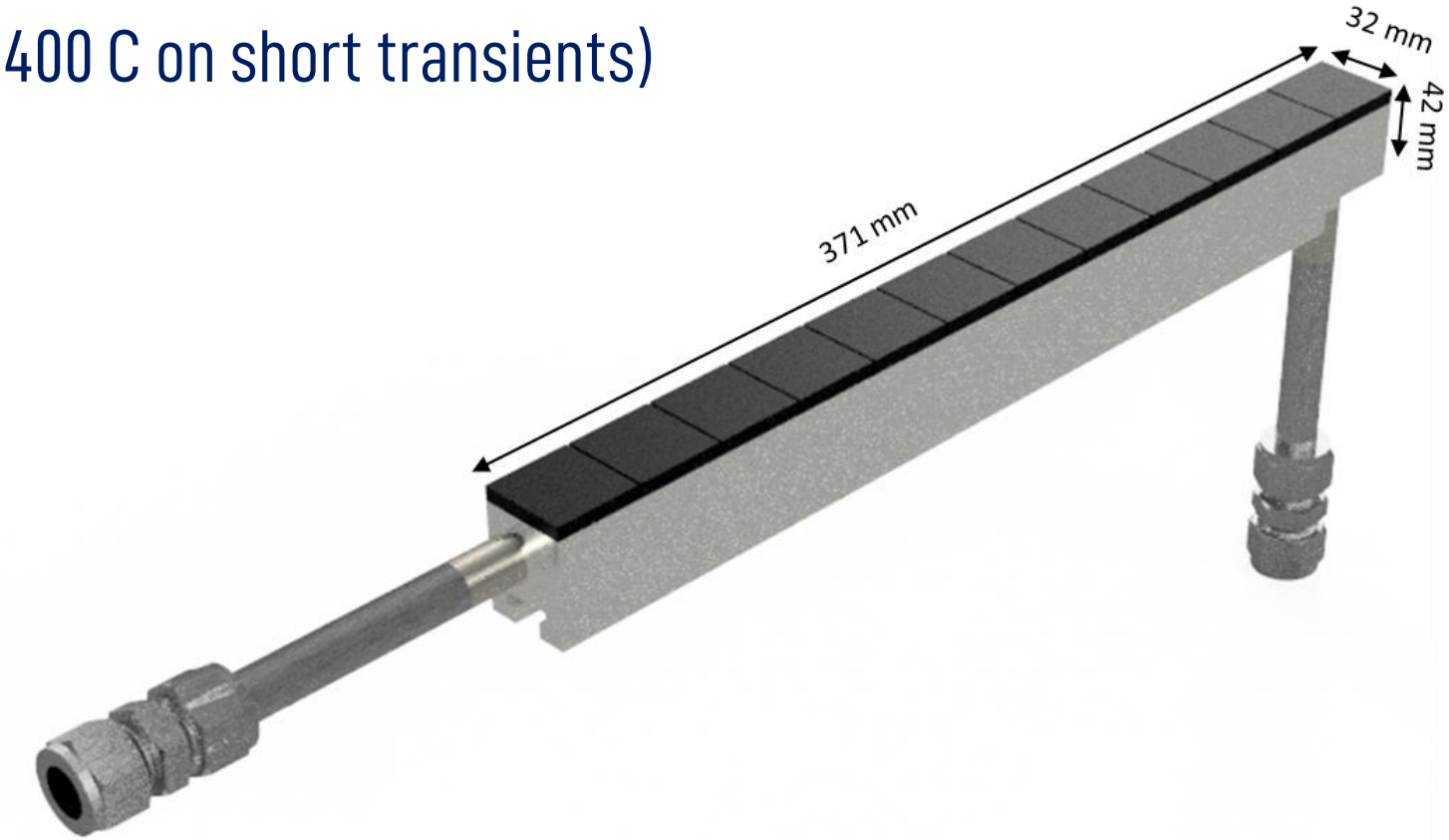
The High Heat Flux Elements

- Design features:
  - Isotropic graphite armor (SGL Carbon Sigrafine R6710)
  - TZM heat sink
  - Internal nickel coating
  - Stainless steel swirl tape
  - Diffusion bonded tiles
  - Laser welded 316L pipes
  - 10 MW/m2 steady state nominal heat flux
  - 15-20 MW/m2 short pulses



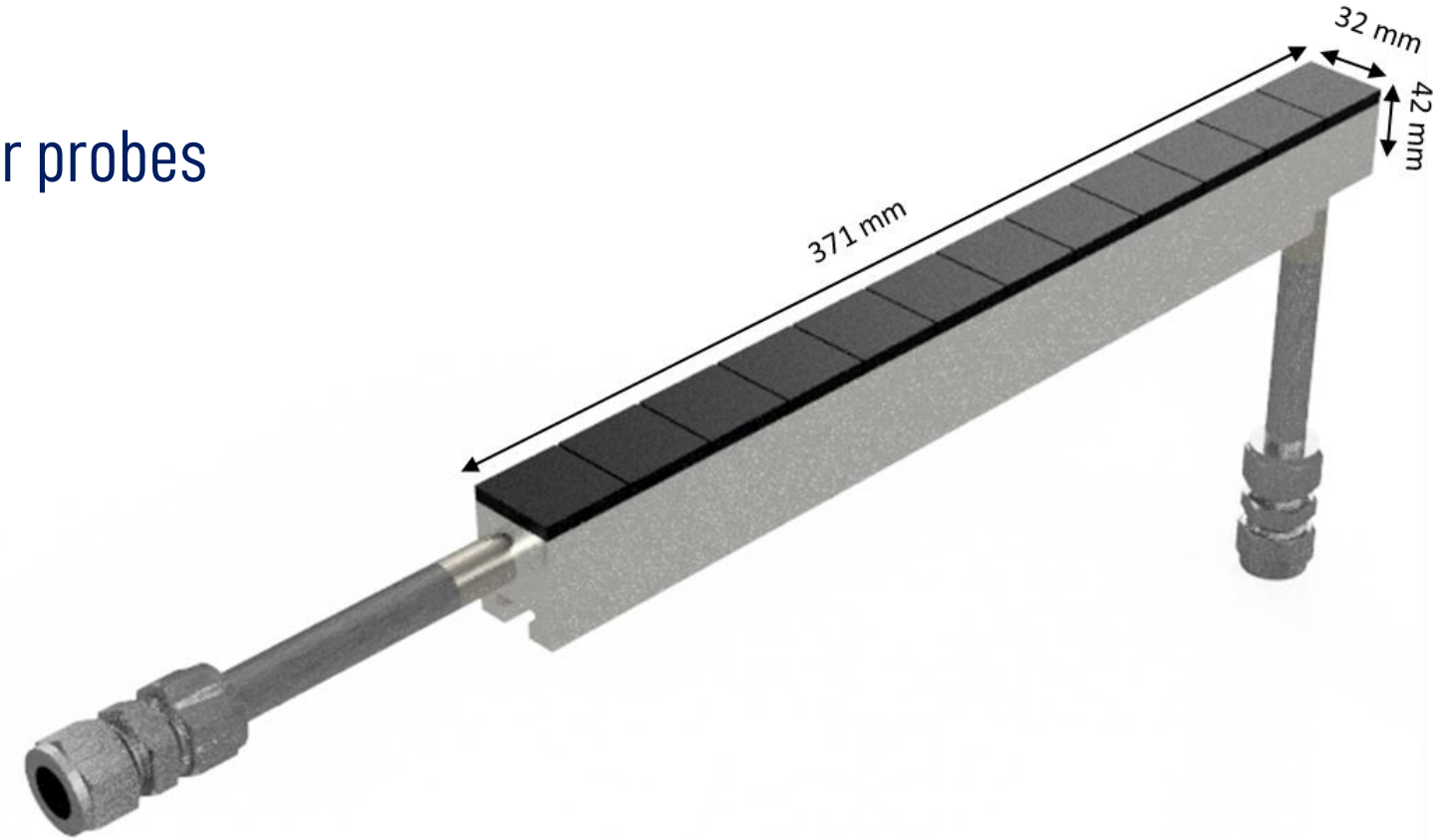
The High Heat Flux Elements

- Requirements:
  - Operating pressure 20 bar
  - Joint temperature 900 C (up to 1400 C on short transients)
  - Leak rate < 10e-8 Pam3/s
  - 13000 nominal power cycles
  - Inlet water temperature 40 C
  - Mass flow rate 0.8 kg/s



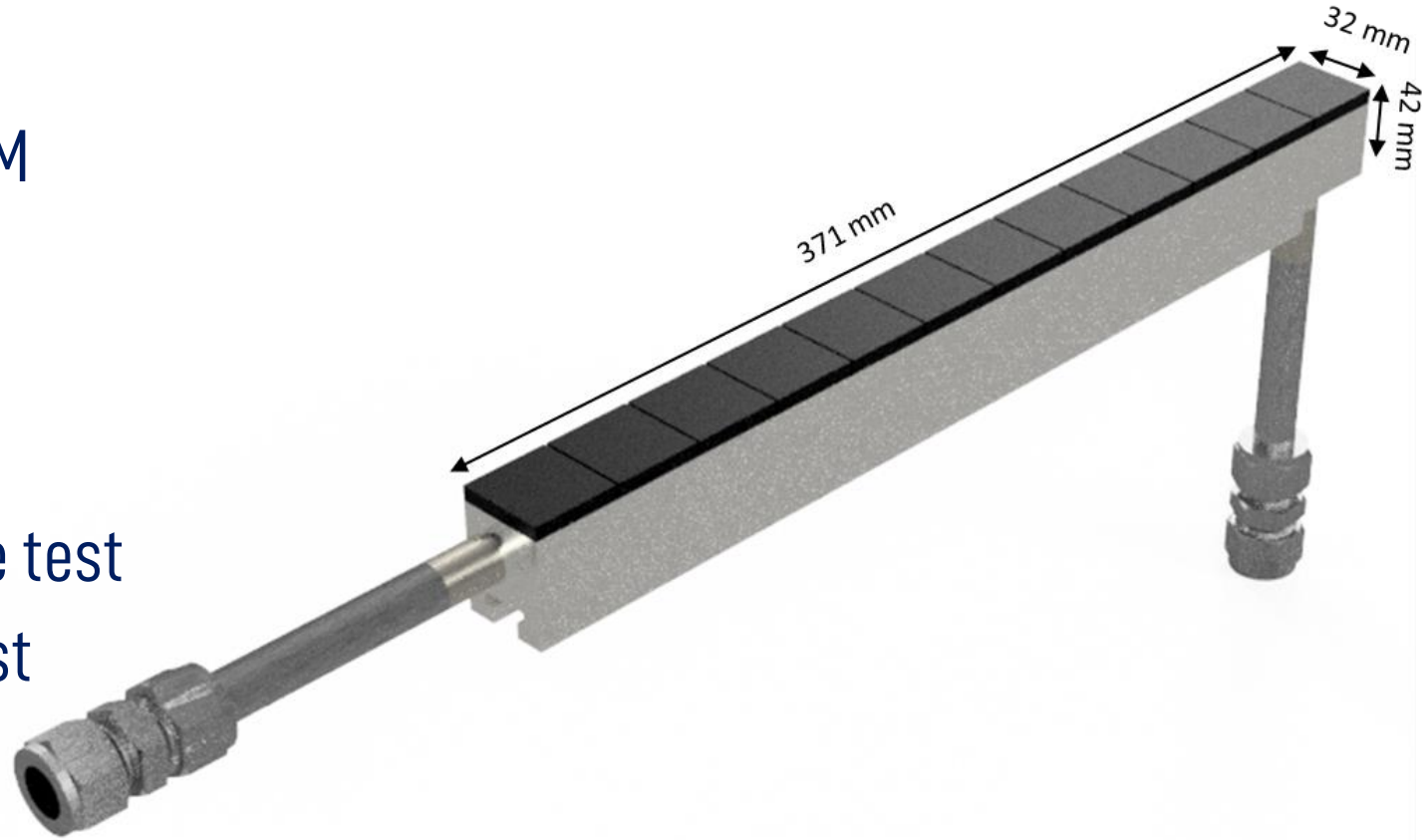
The High Heat Flux Elements

- Scope of contract:
  - 12 small + 12 full scale mockups
  - 1020 standard elements
  - 30 custom element for Langmuir probes



The High Heat Flux Elements

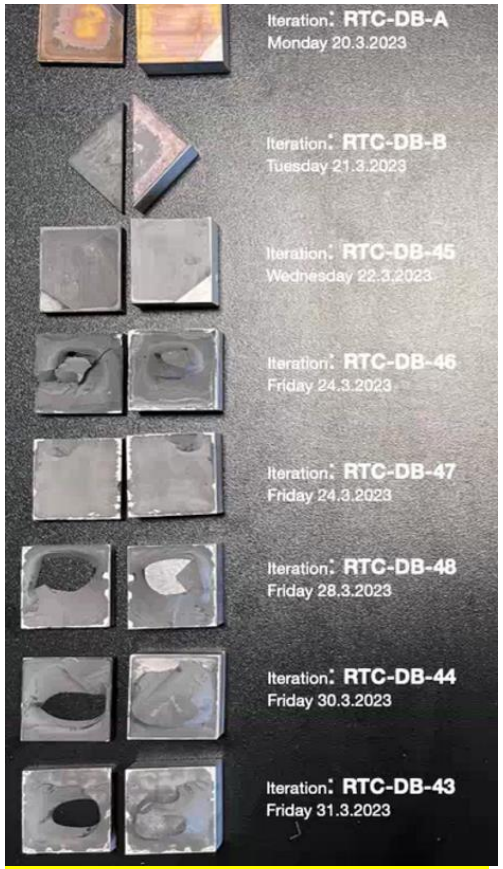
- Qualification activities:
  - Diffusion bonding trials – small square samples
  - Welding trials – pipe samples
  - Material tests – graphite and TZM
    - Mechanical
    - Thermal
  - Mechanical tests
    - Diffusion bonding destructive test
    - Laser welding destructive test



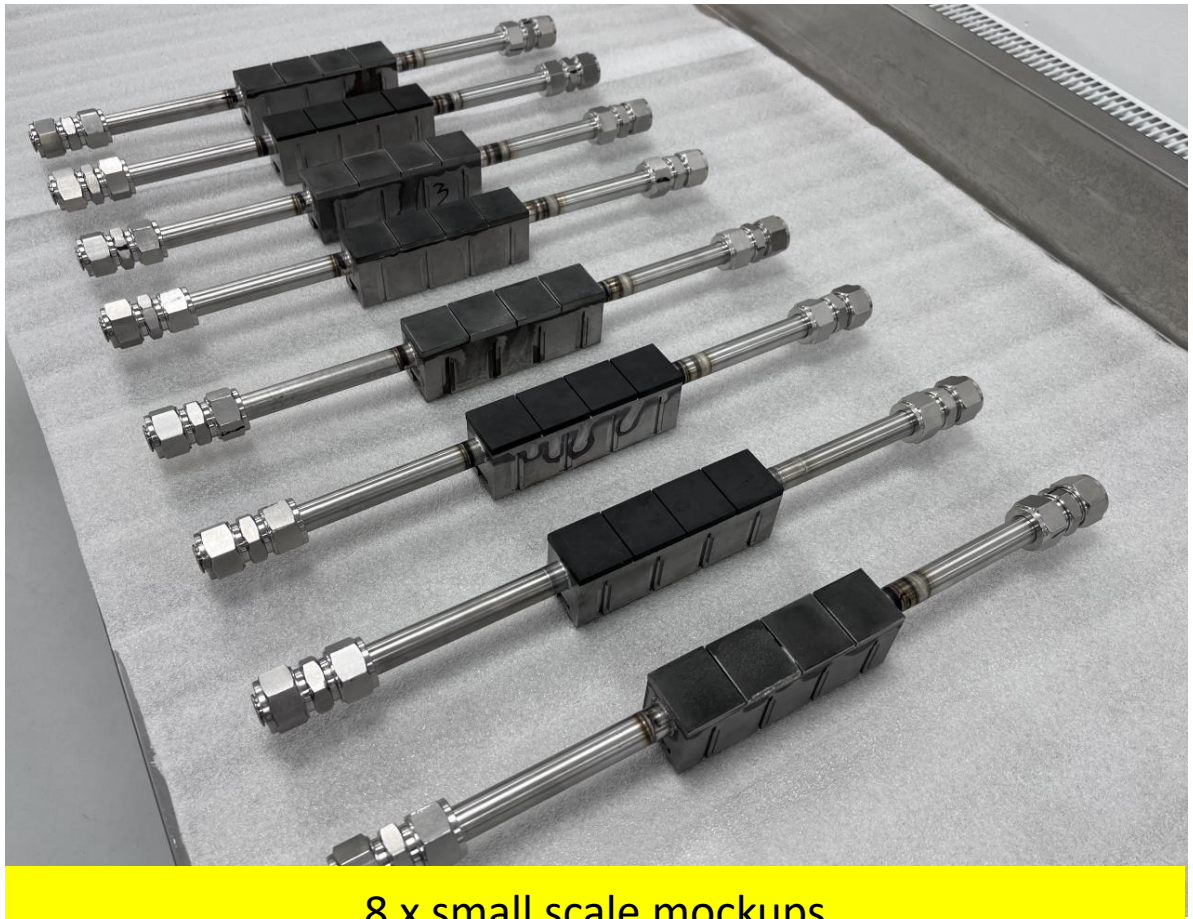
The High Heat Flux Elements

Small diffusion bonding sample

Destructive testing => 120 Nm

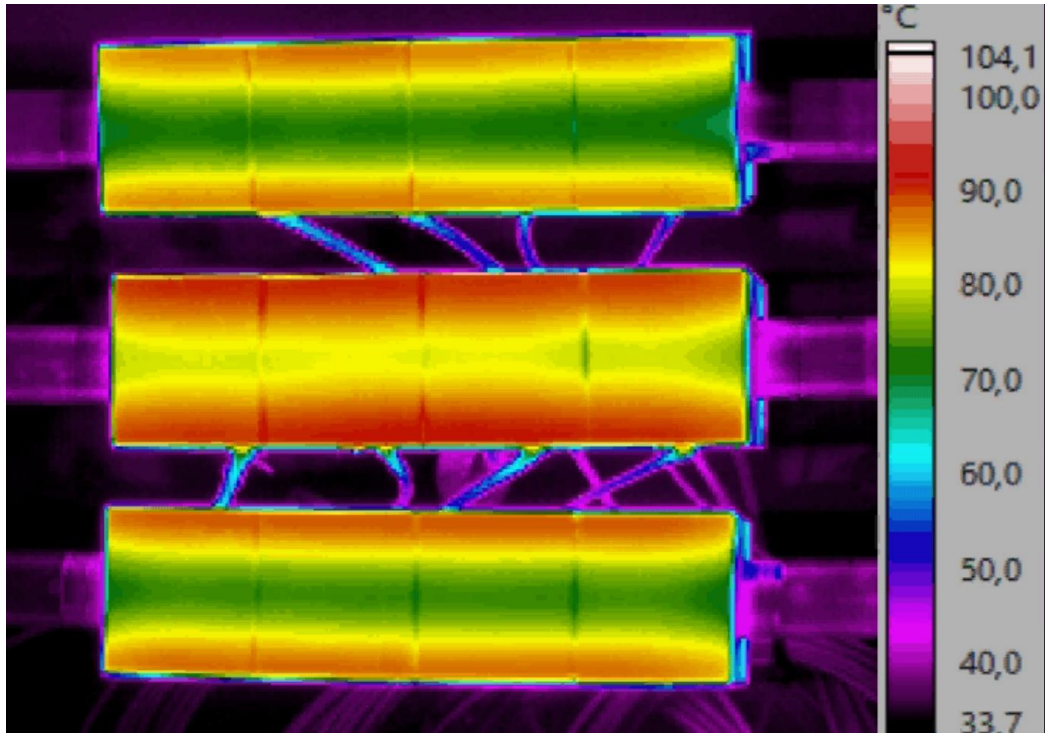


Bonding iterations

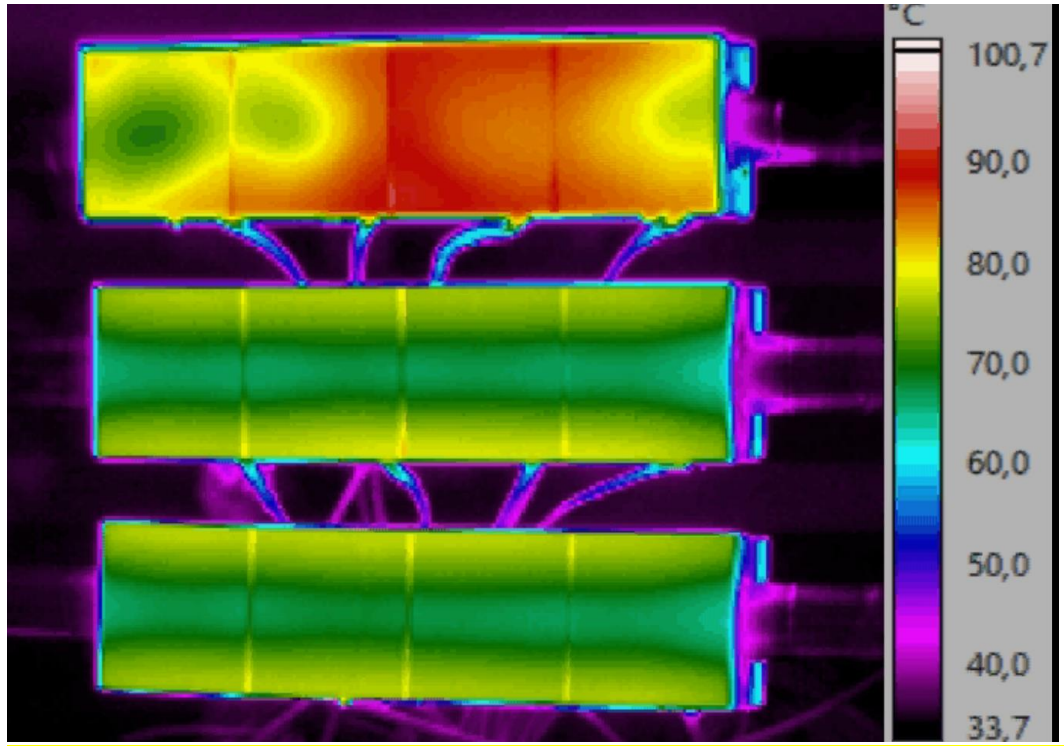


8 x small scale mockups

The High Heat Flux Elements

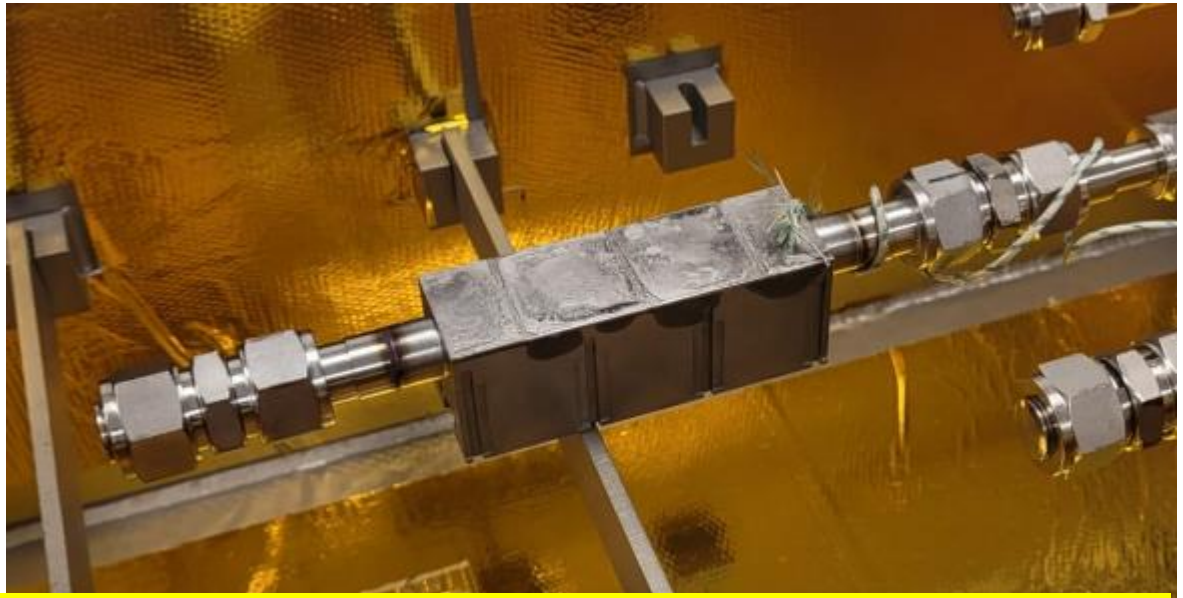


Infrared Thermography tests



Infrared Thermography tests

The High Heat Flux Elements



Laser welding trial

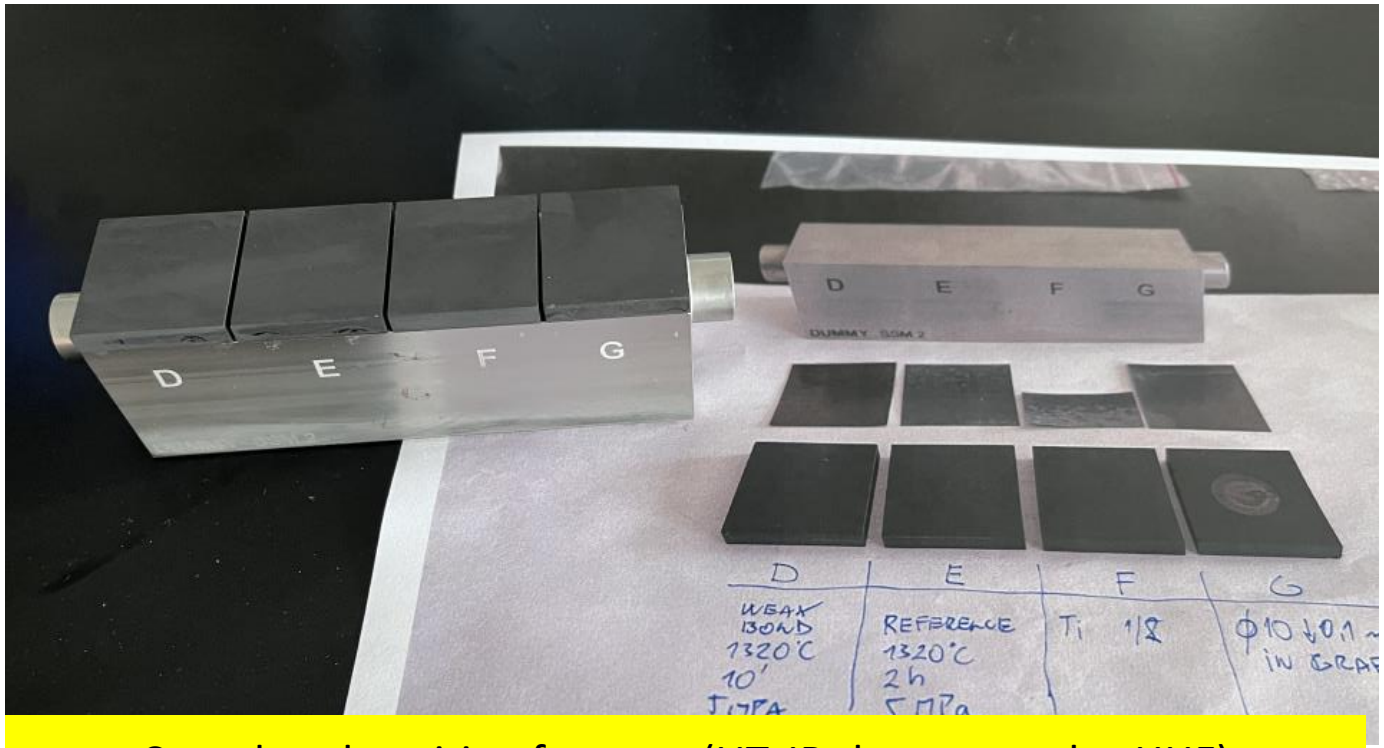
Ni Coating samples

Hot leak test at 200 C 25 bar

Corresponding leak rate

The High Heat Flux Elements

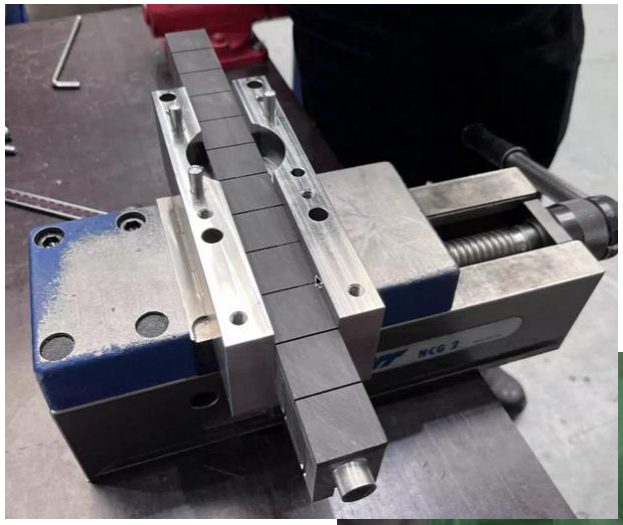
Diffusion bonding sample with defects



Completed, waiting for tests (UT, IR thermography, HHF)

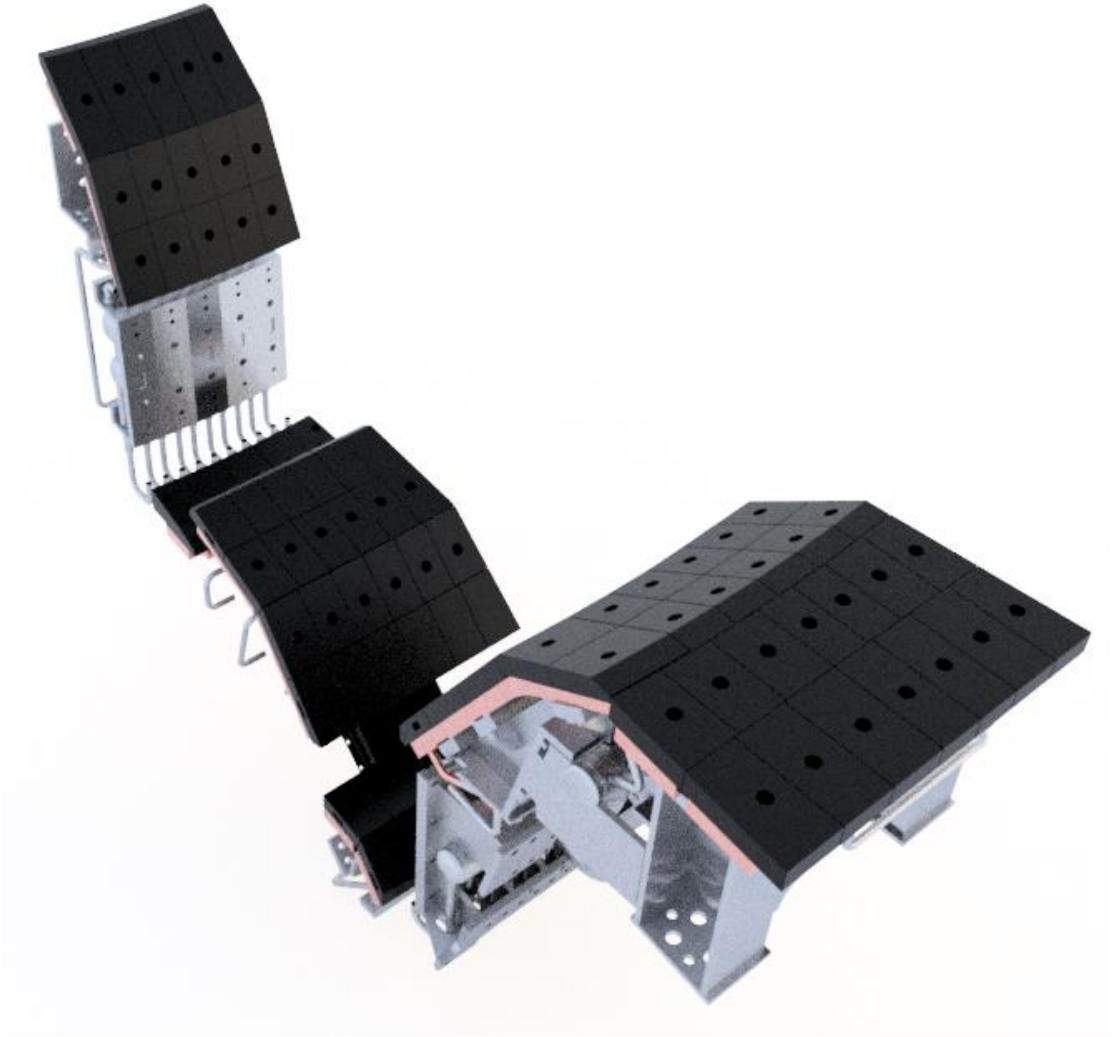
The High Heat Flux Elements

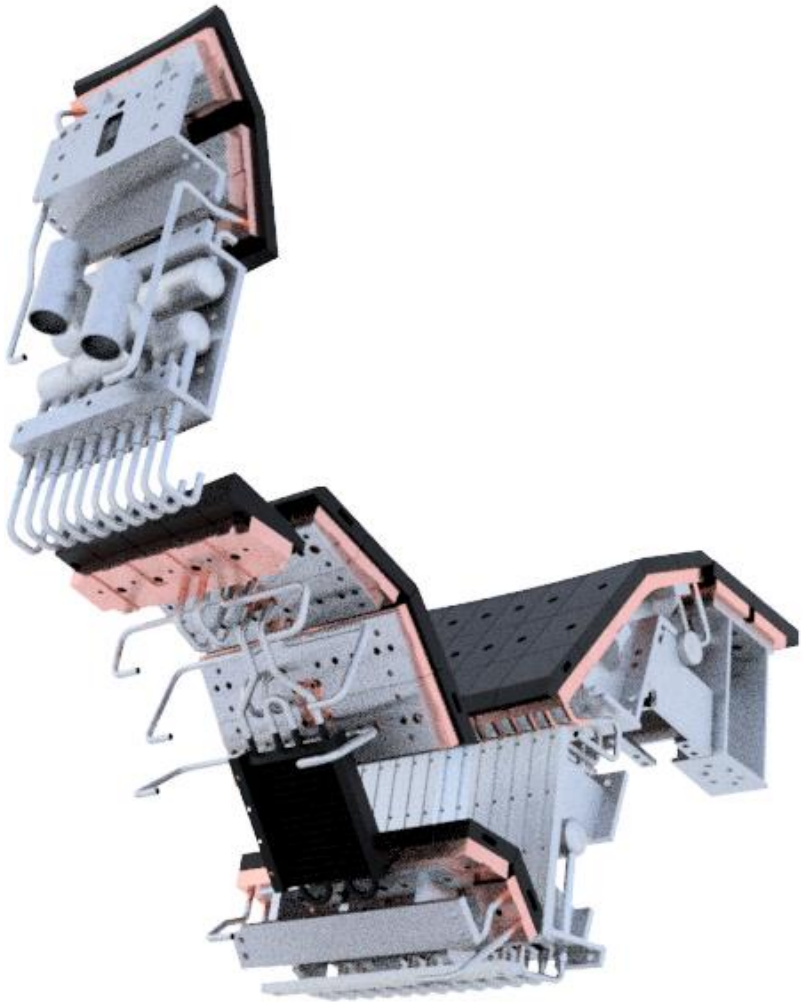
Full scale mockups – pre-series



Destructive tests

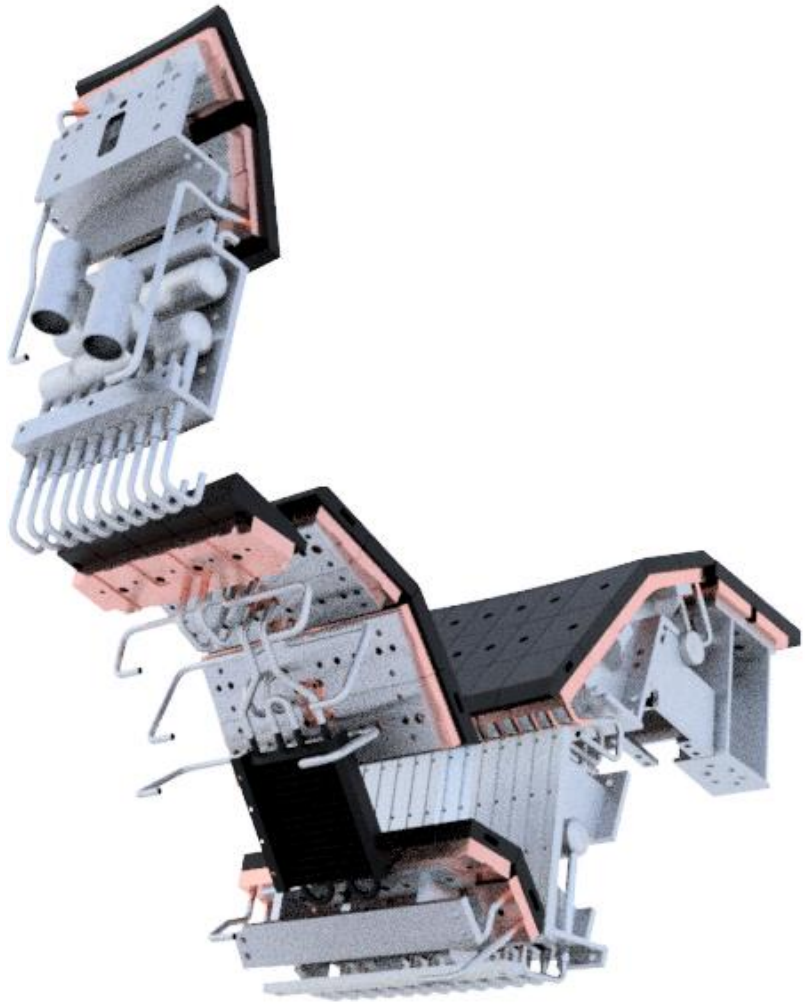
The Normal Heat Flux Elements





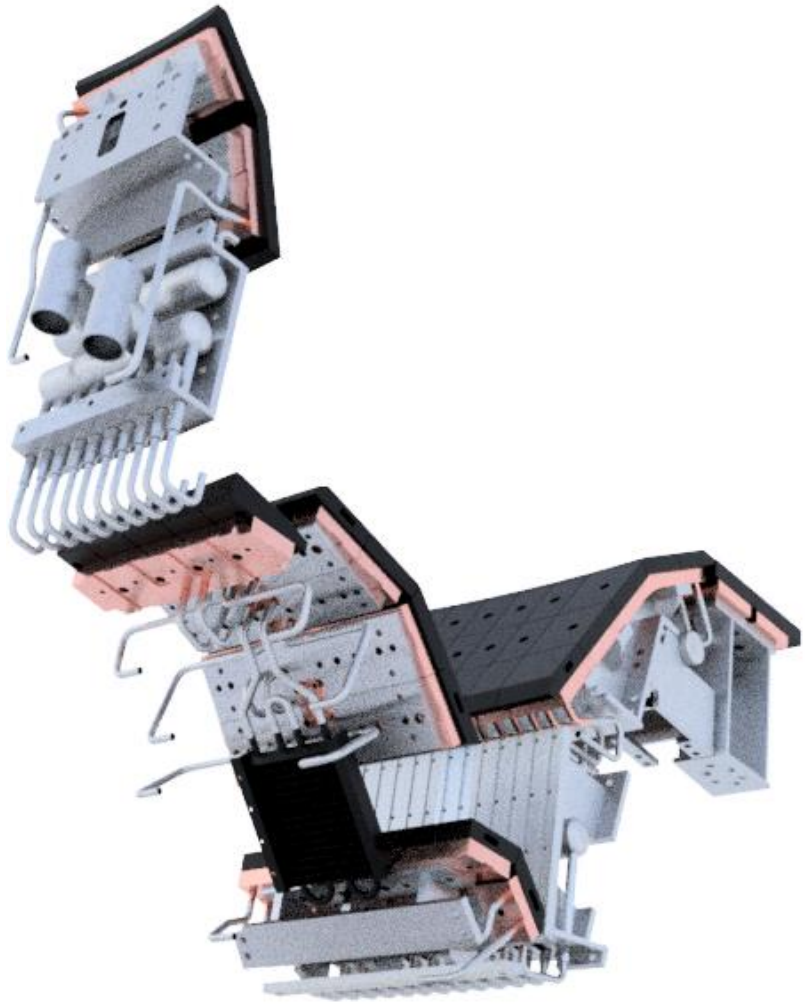
The Normal Heat Flux Elements

- Design features:
  - Isotropic graphite bolted tiles
  - CuCrZr/SS316L heat sink
  - Graphite sheet compliant layer
  - 2 MW/m2 steady state nominal heat flux
  - 10 MW/m2 short pulses



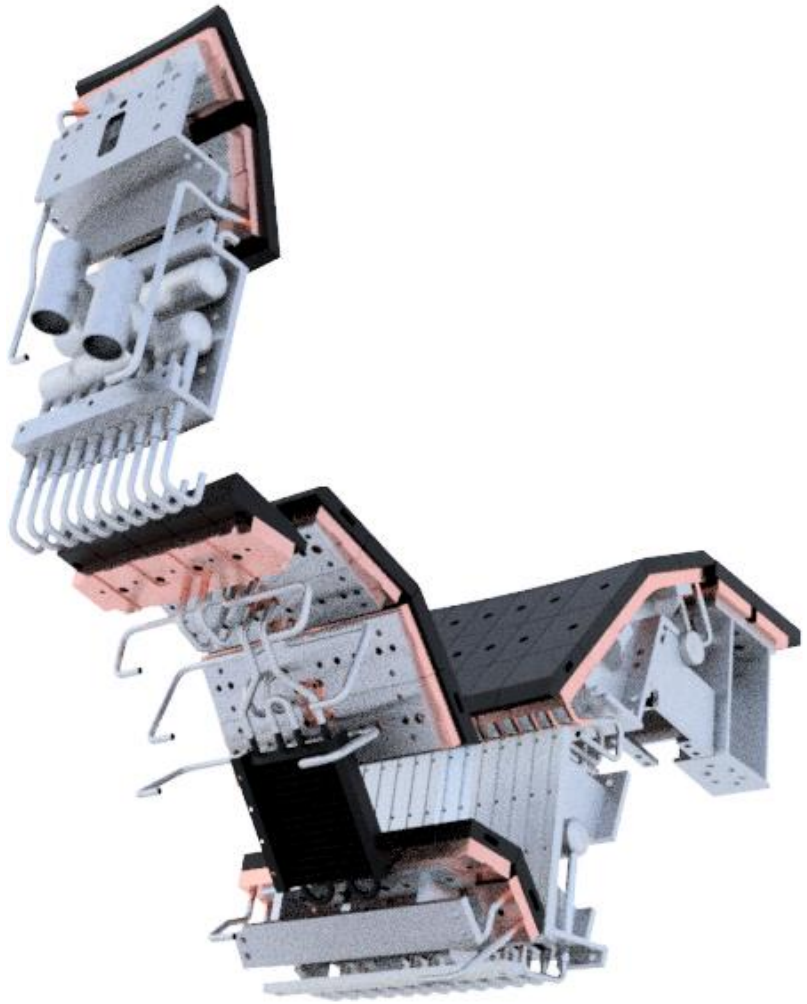
The Normal Heat Flux Elements

- Requirements:
  - Operating pressure 20 bar
  - Leak rate < 10e-8 Pam3/s
  - 13000 nominal power cycles
  - Inlet water temperature 40 C

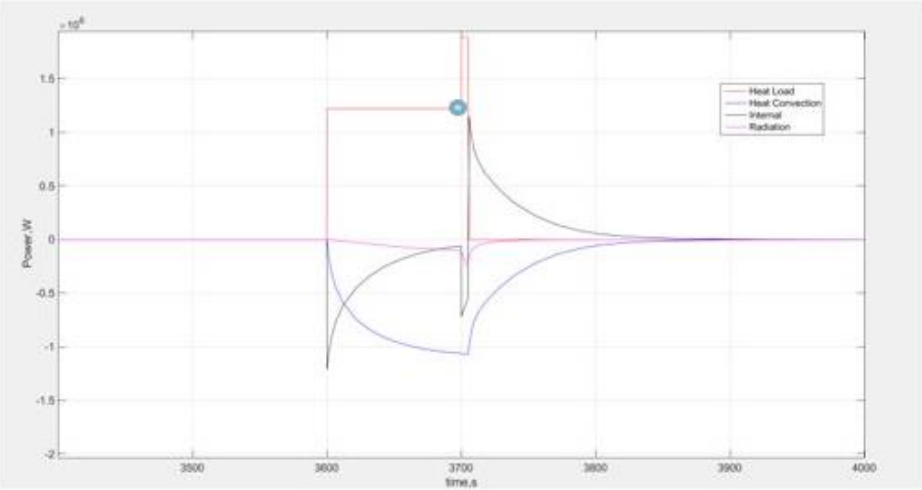


The Normal Heat Flux Elements

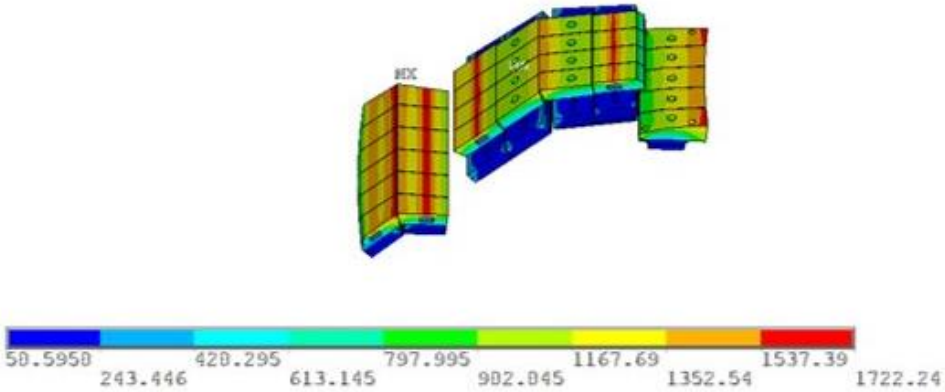
- Scope of contract:
  - 36 NHF element sets + 2 spares
  - Graphite tiles
  - Heat sinks
  - Chevron units
  - Manifolds
  - Branch pipes
  - Graphite sheets
  - Fasteners

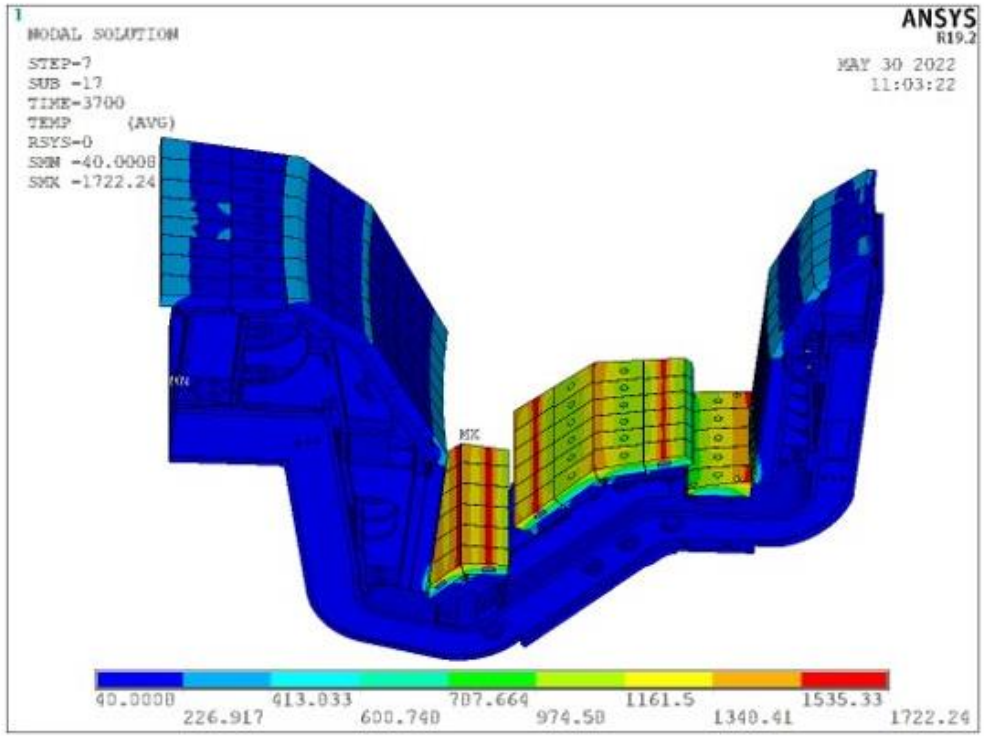


The Normal Heat Flux Elements



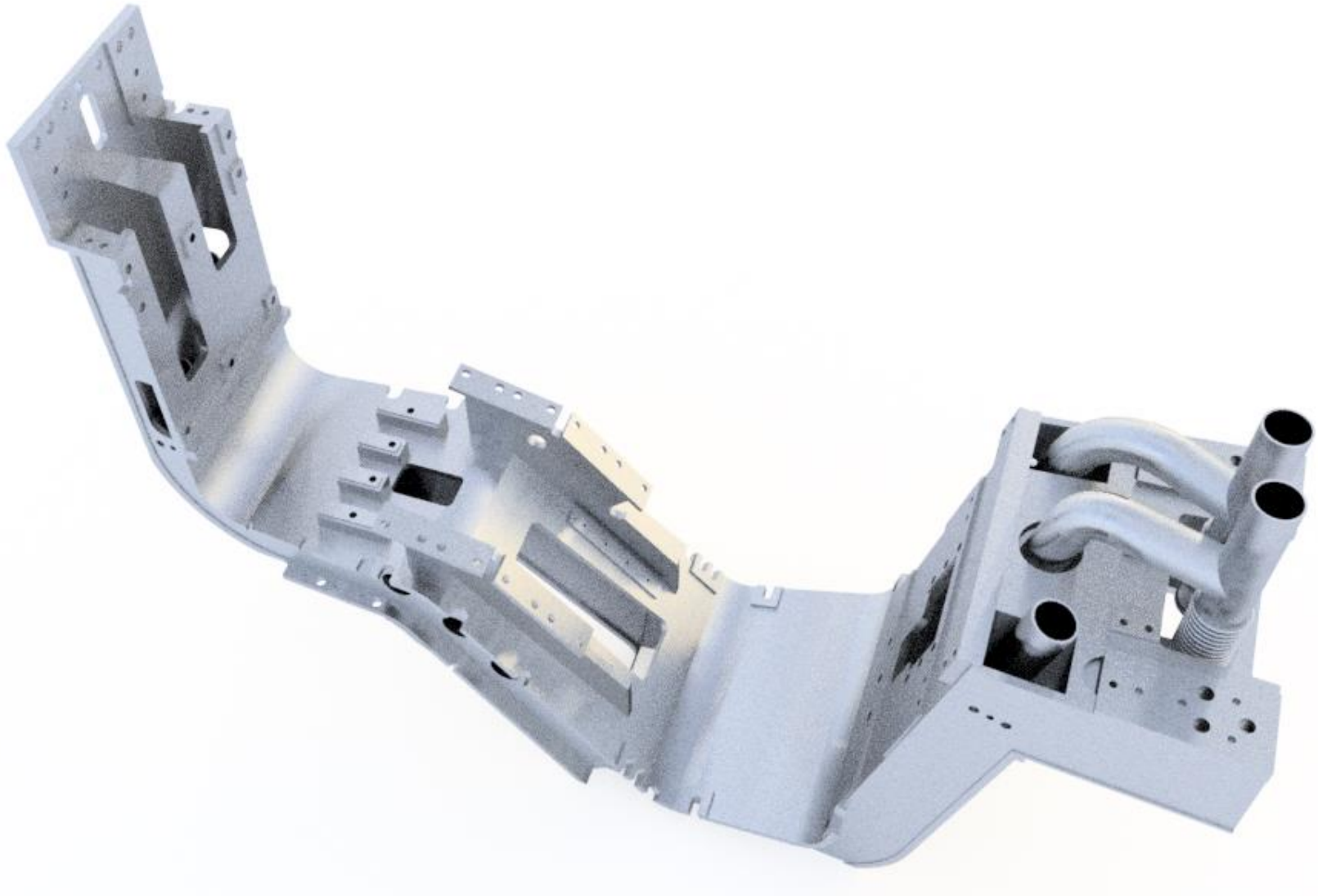
T=3700 s





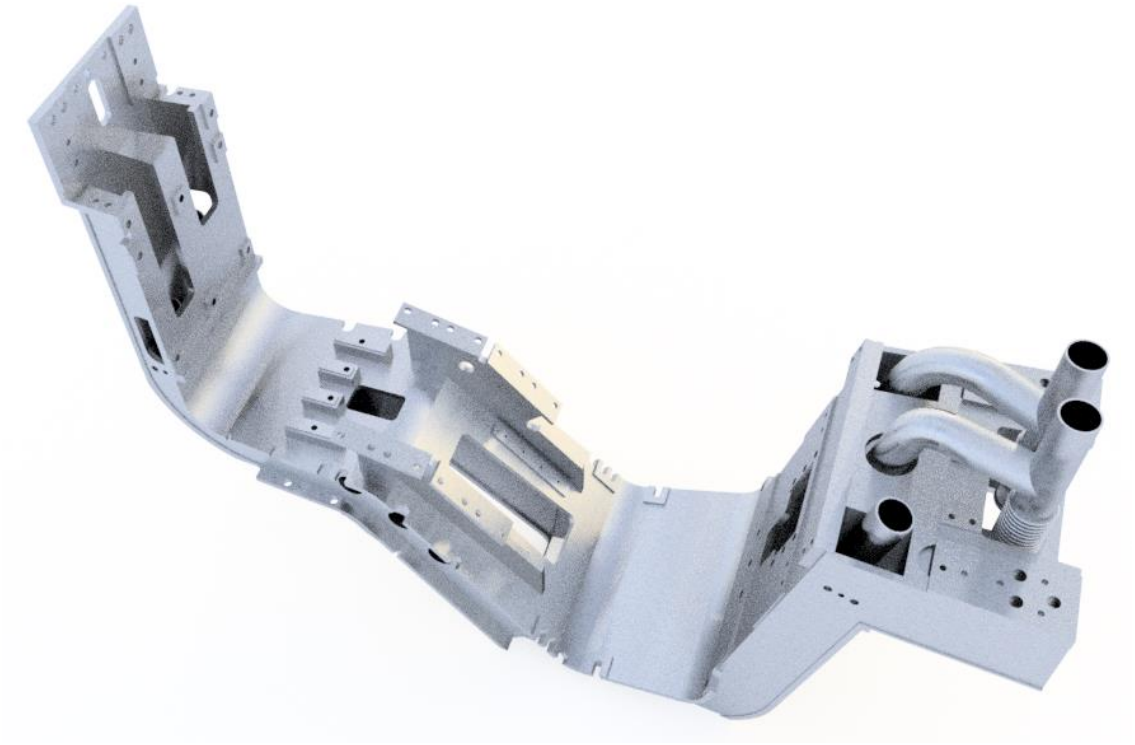
Full 3D thermal analysis

The Cassette Frames



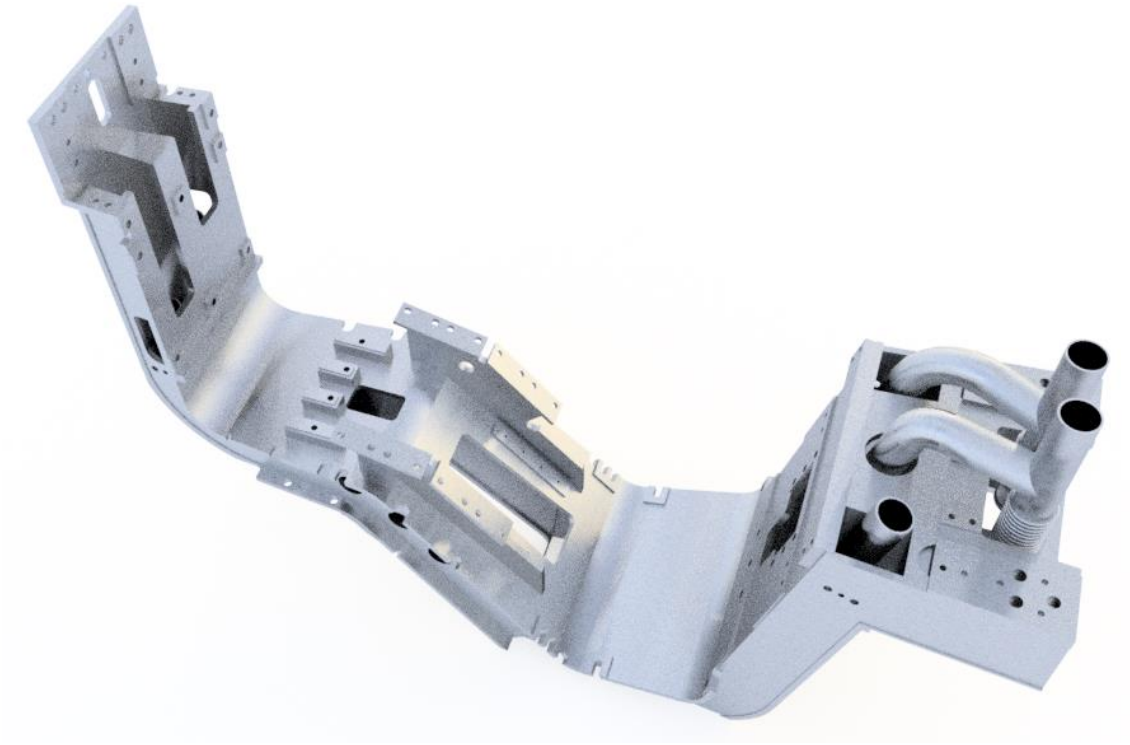
The Cassette Frames

- Design features:
  - SS316L frame and pipes
  - Standard frame construction
  - Customized pipes (left, right)
  - Compatible with LBW on site



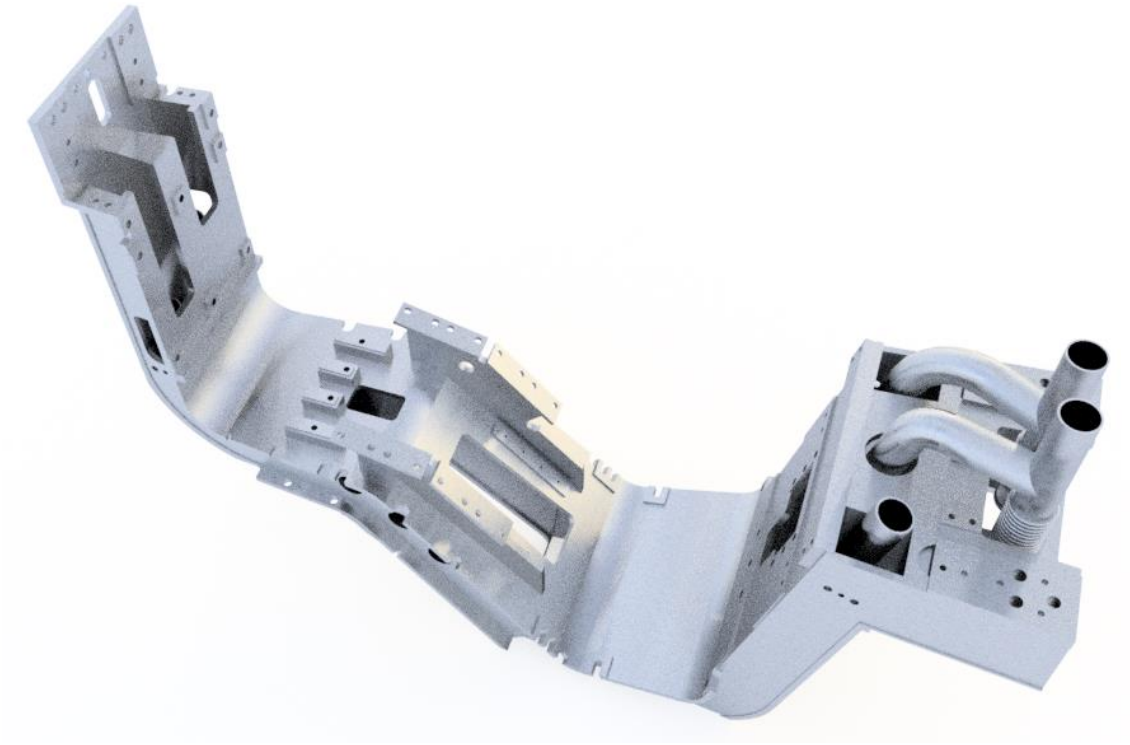
The Cassette Frames

- Requirements:
  - Operating pressure 20 bar
  - Leak rate < 10e-8 Pam3/s
  - Inlet water temperature 40 C

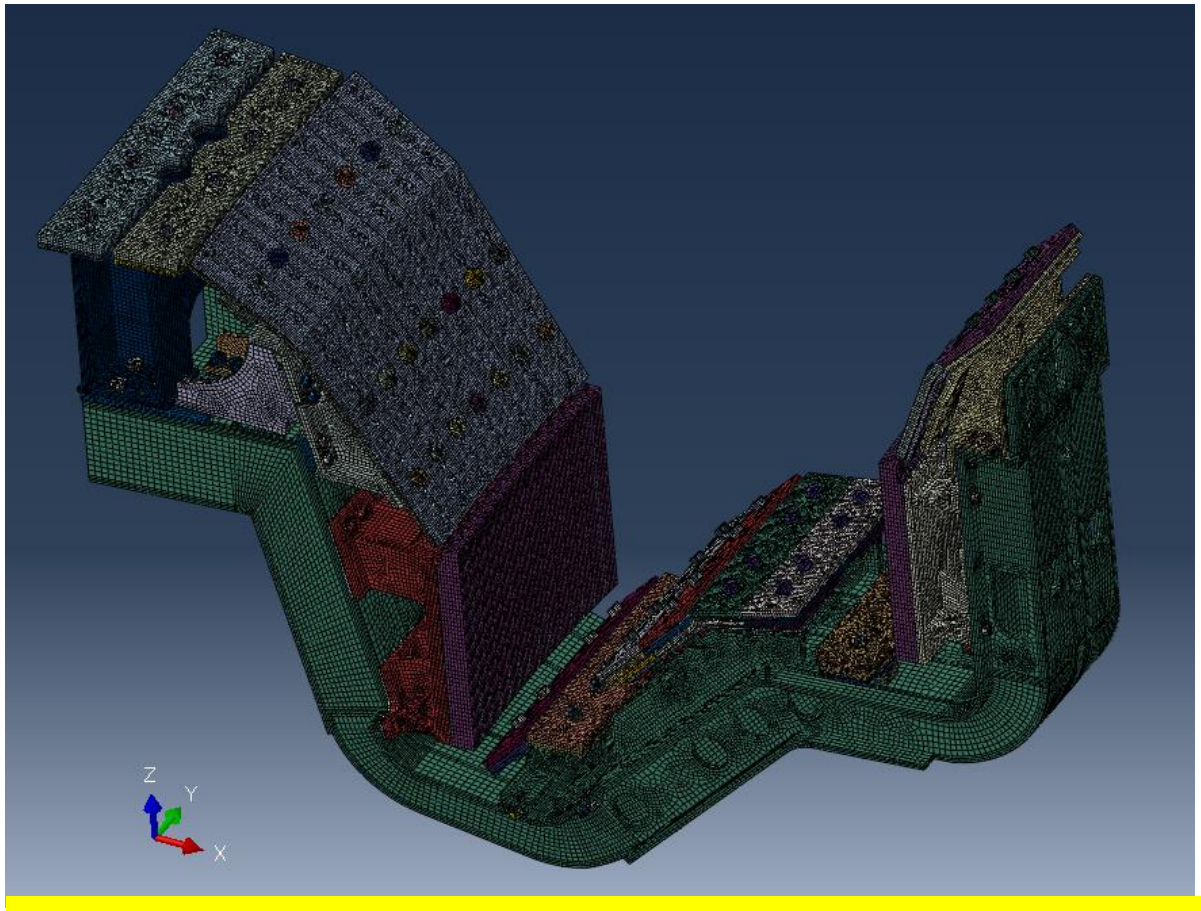


The Cassette Frames

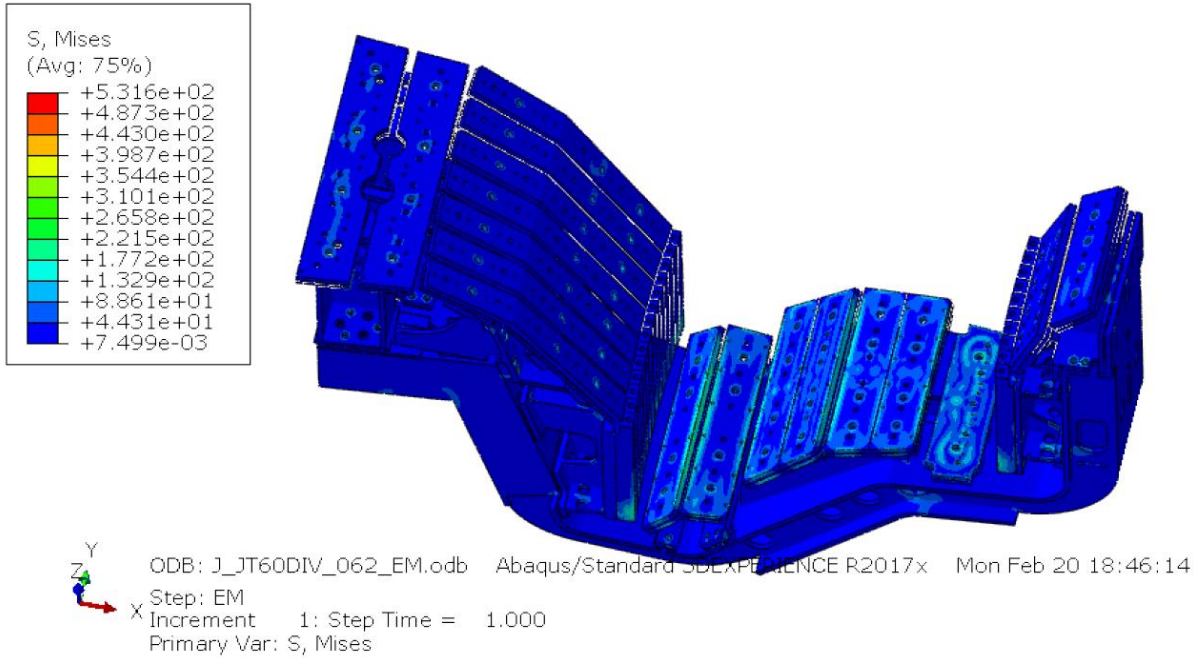
- Scope of contract:
  - 36 cassette frames + pipes + 2 spares
  - Bellows
  - Tee junctions



The Cassette Frames

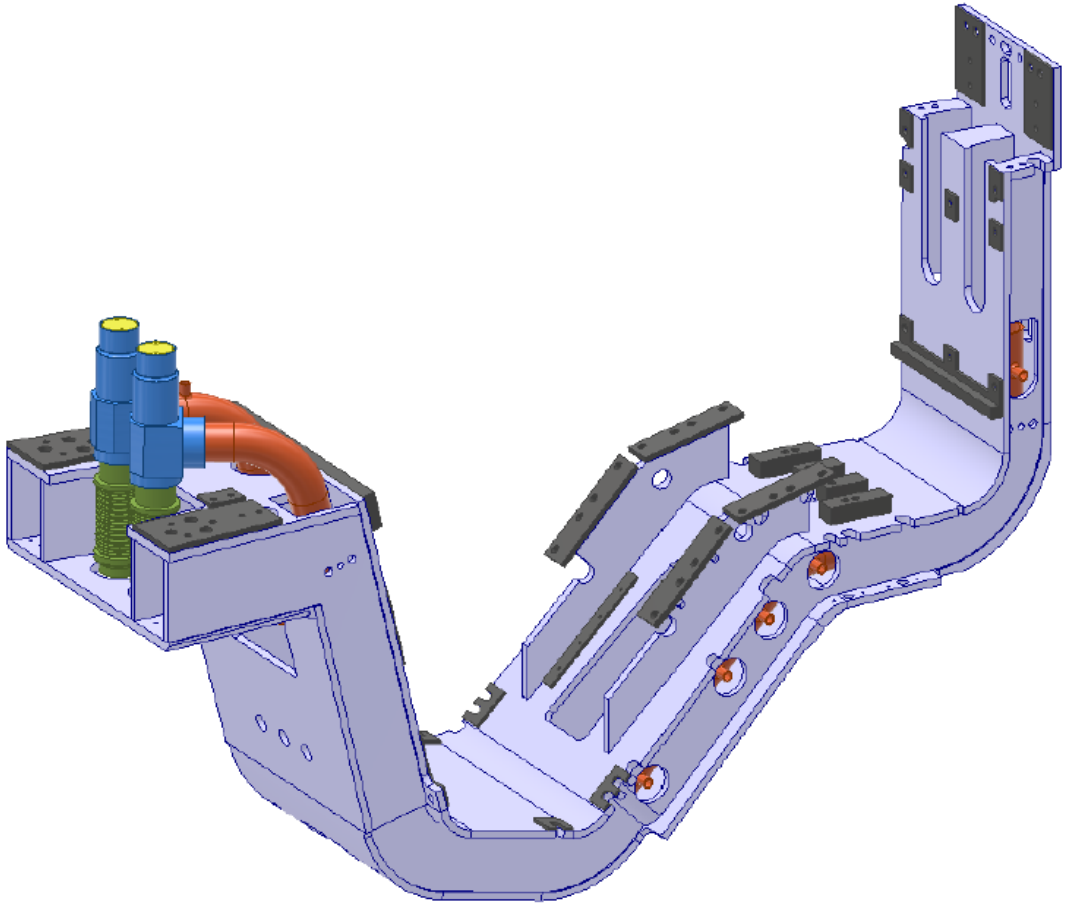


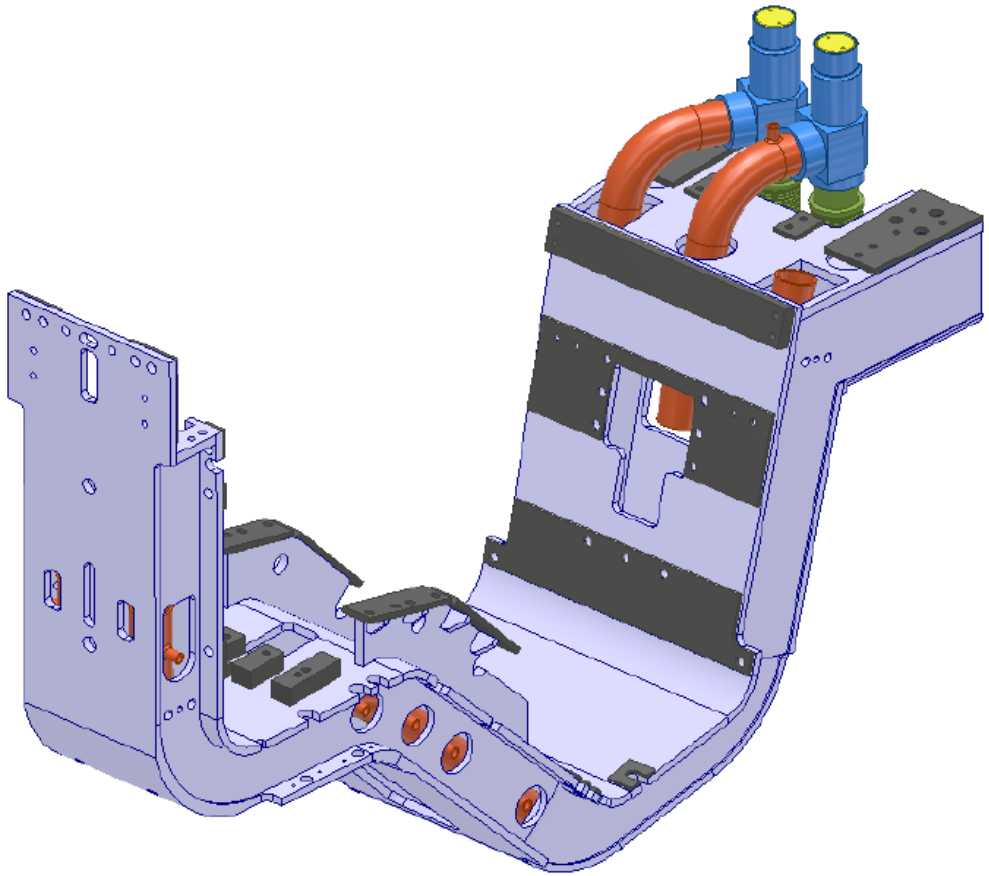
Full 3D structural analysis



Thermal + pressure + EM loads (disruption)

The Cassette Frames



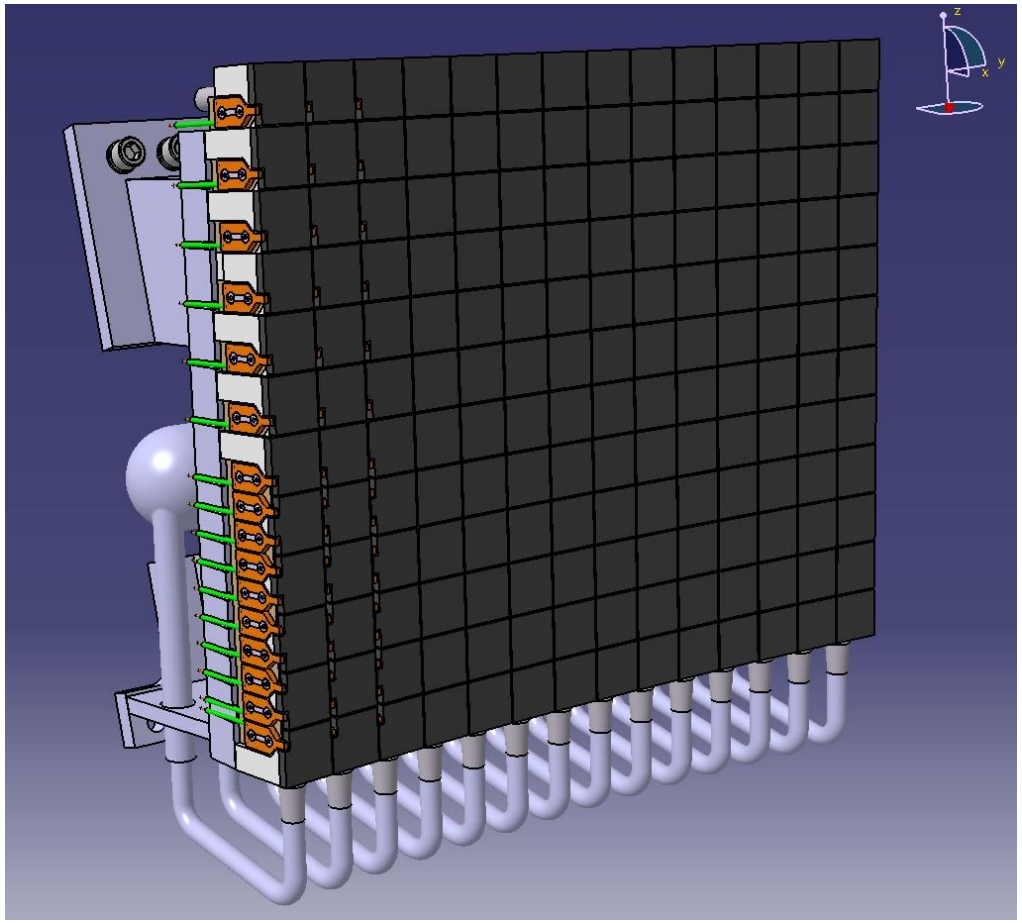


Supplier 3D models – now in preparation for material purchase

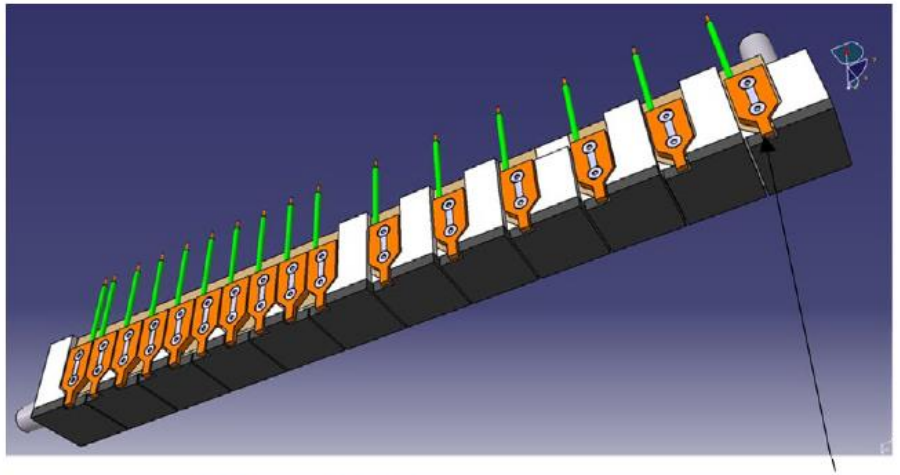
Diagnostics and integration

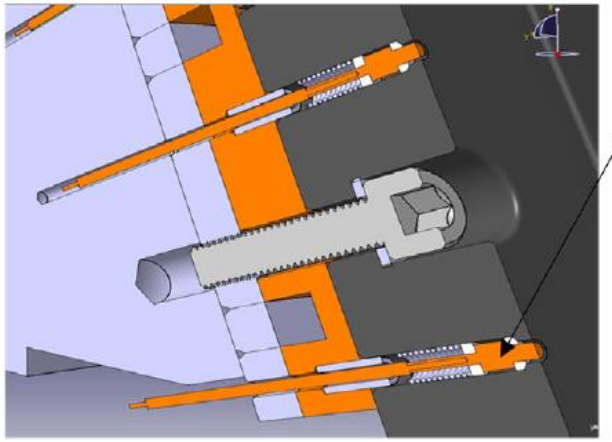
- The 36 units will be integrated in a facility in Europe
- The call for tender is being prepared and should be launched this year
- The diagnostics for the ACD include:
  - Langmuir probes
  - Thermocouples
  - Halo current coils
  - Diagnostic openings

Diagnostics and integration

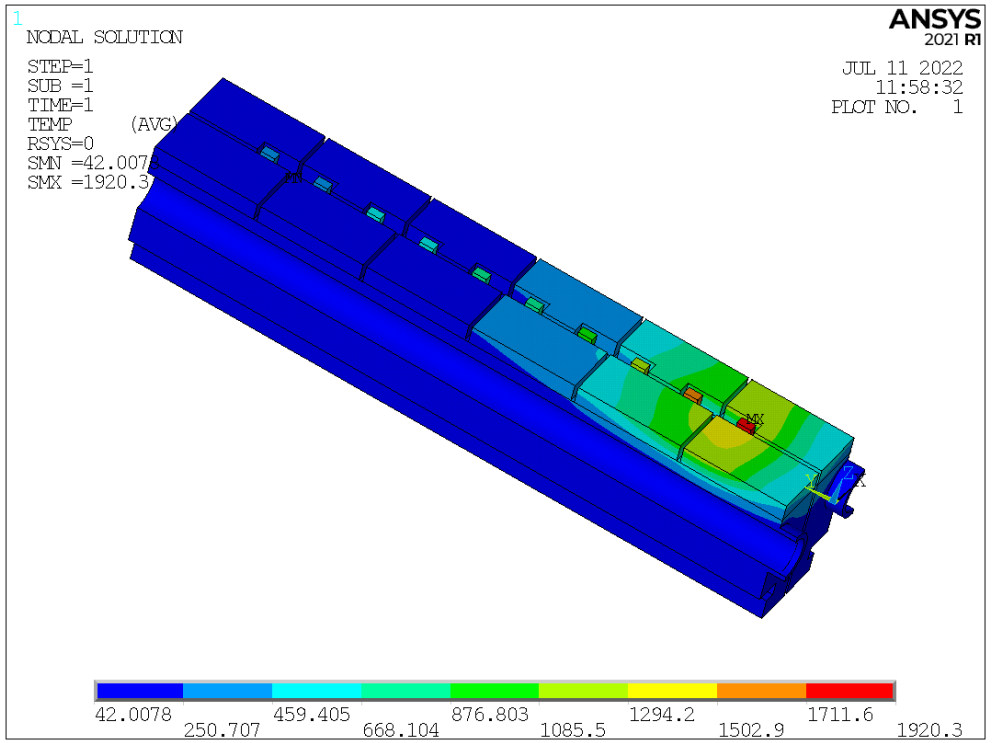


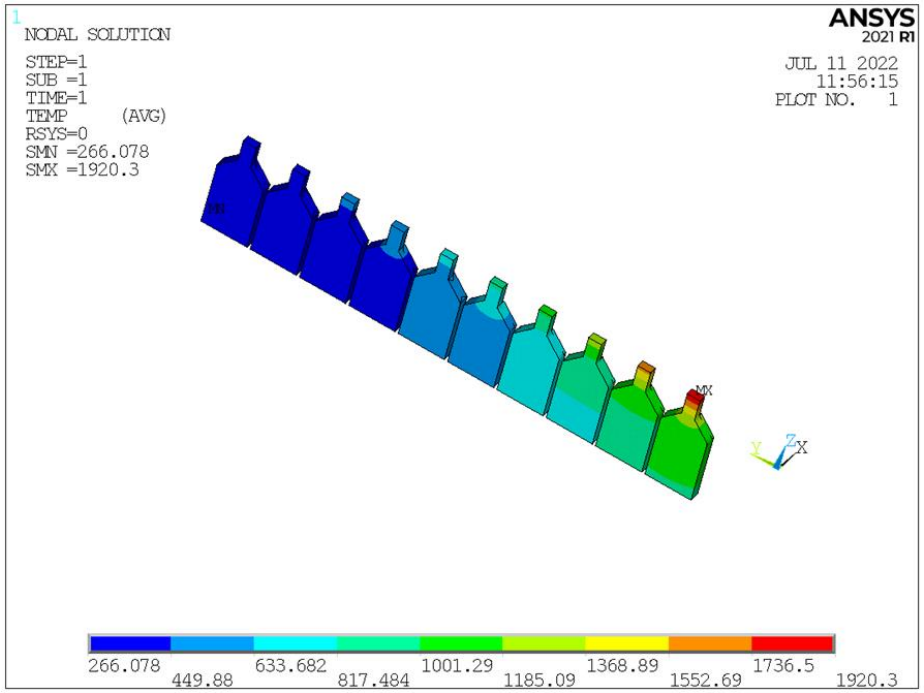
Langmuir probes design





Diagnostics and integration



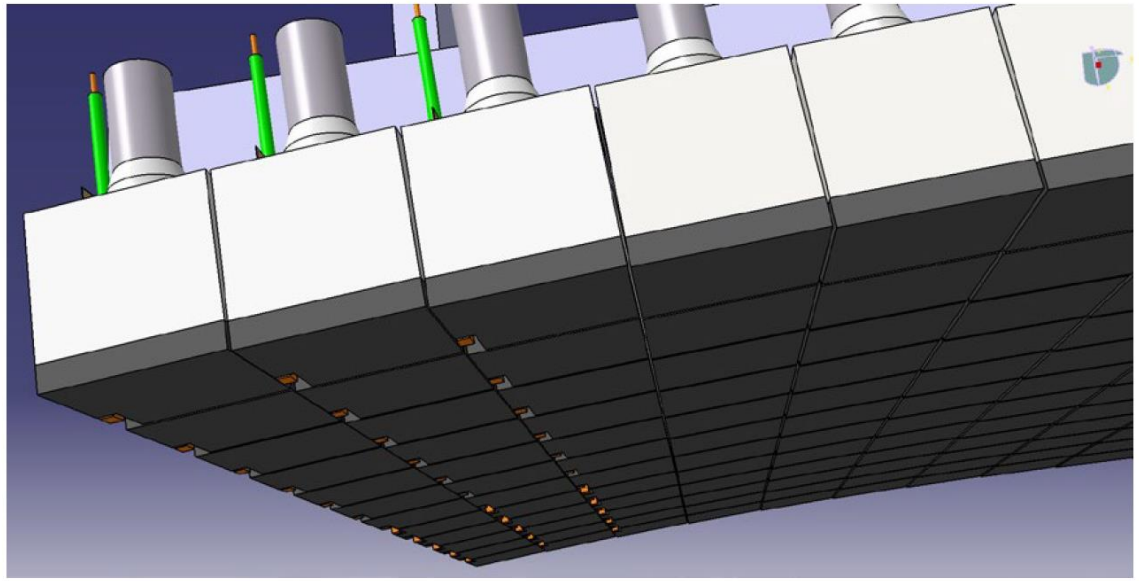


Langmuir probes thermal analyses

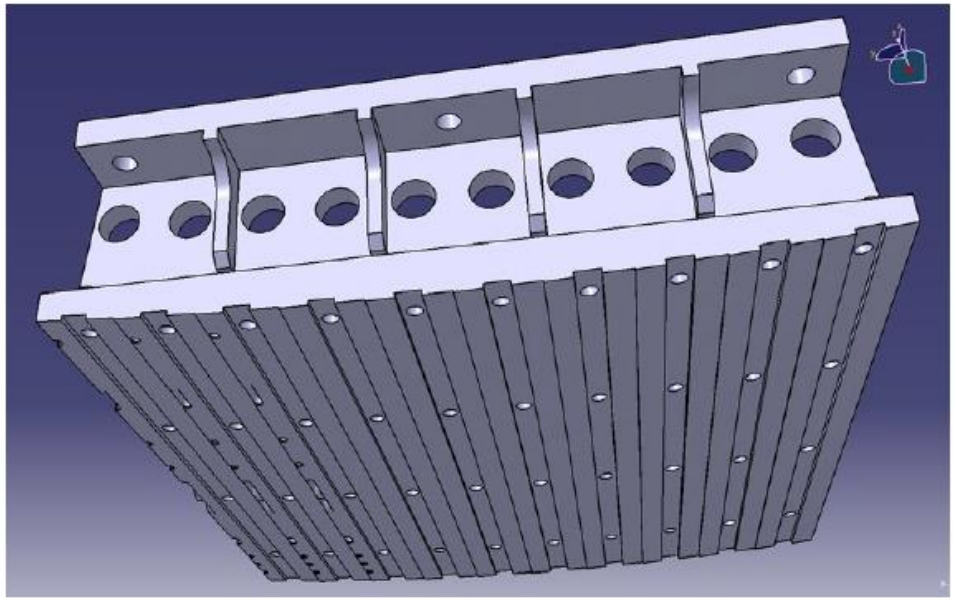
Diagnostics and integration

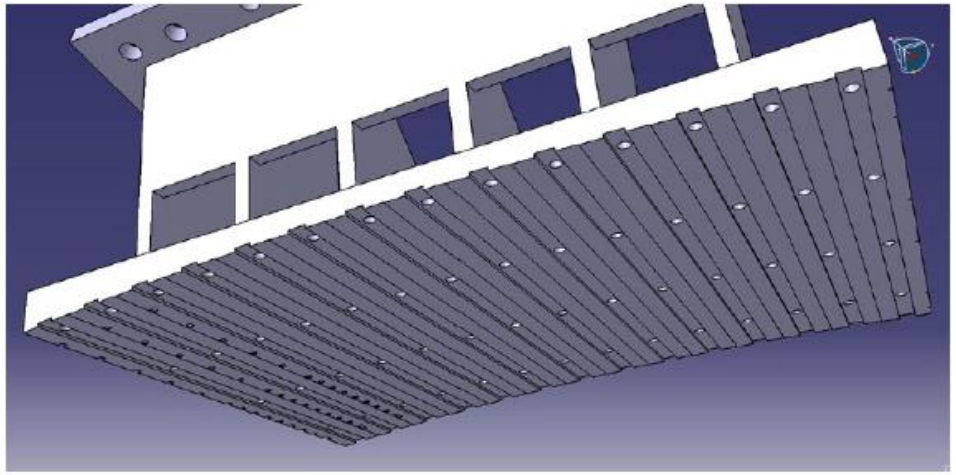
- Integration activities include:
  - Precise positioning of the PFC on the cassette frame
  - Mechanical connection of the components
  - Installation of diagnostics
  - Welding of all pipes + NDE
  - Pressure and (hot) leak testing
  - Flow test

Diagnostics and integration

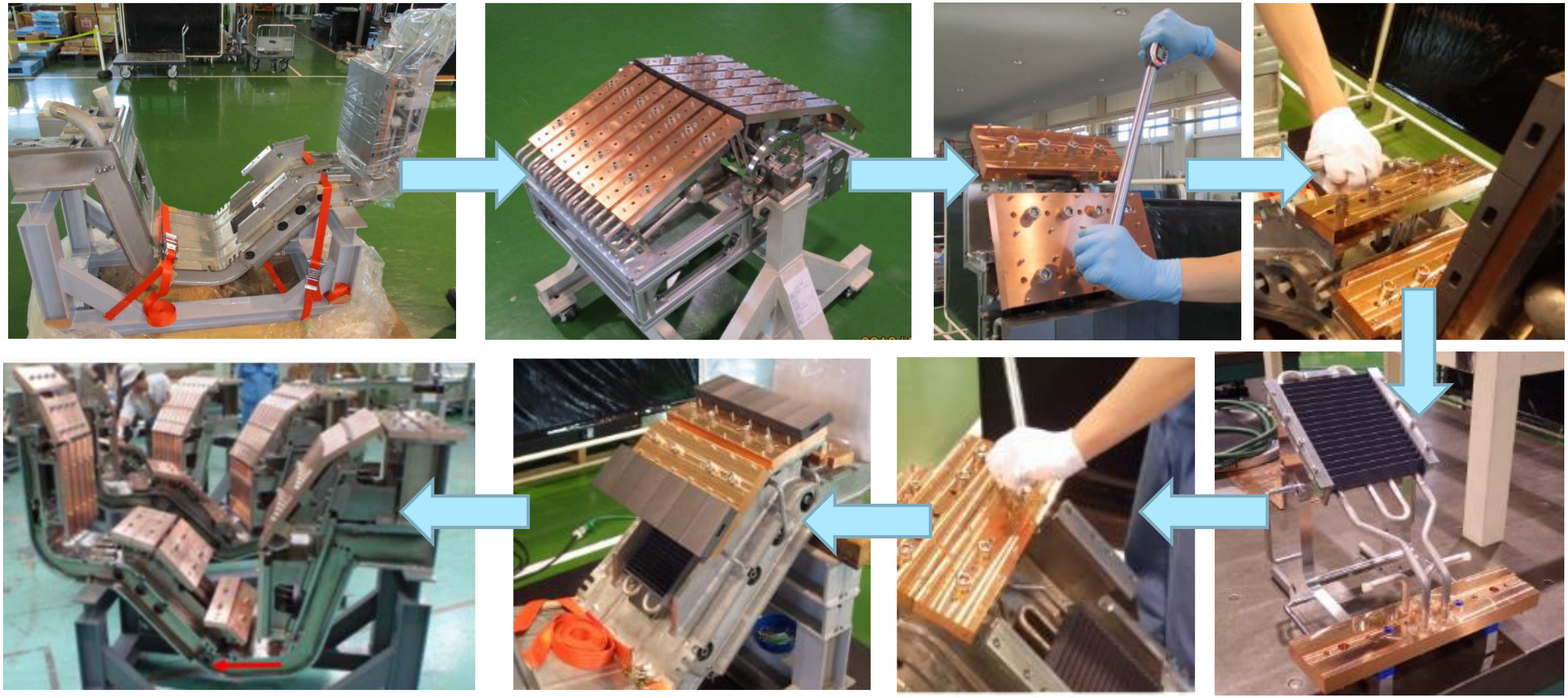


HHF alignment during integration





Diagnostics and integration



Diagnostics and integration