ICANS XXV

Structural Integrity, Manufacturability and pressure testing of STUMM-PROTO

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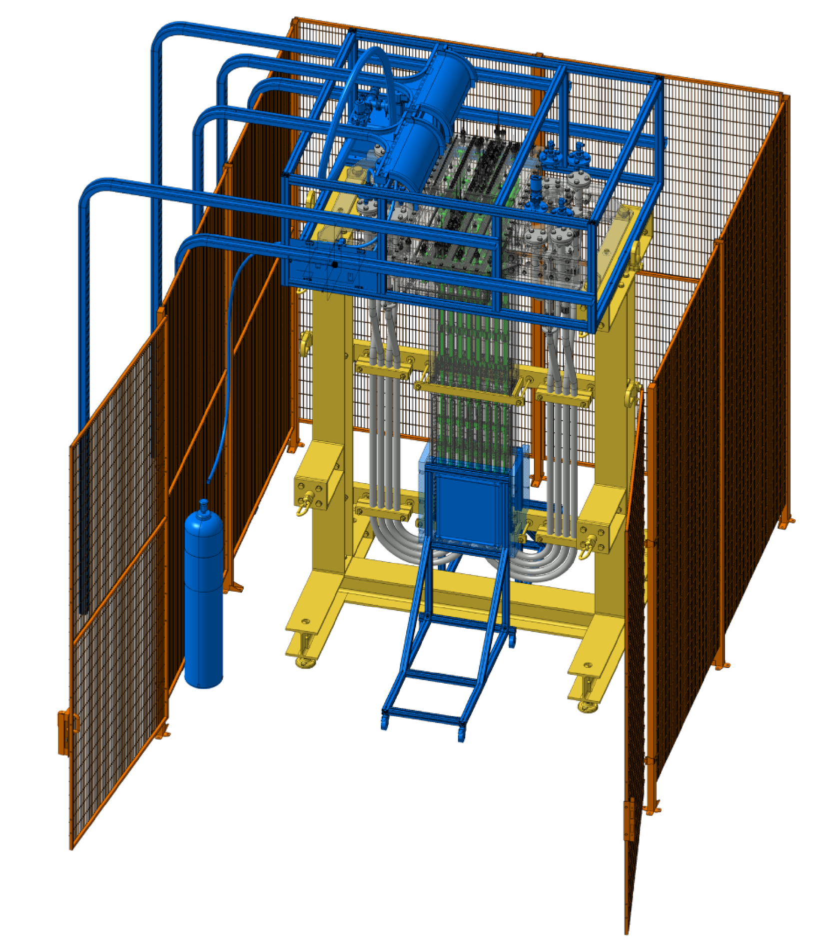
STUMM-PROTO is a full-scale instrumented prototype developed to validate thermal and instrumentation experiments for the STUMM programme, the Start-Up Monitoring Module of IFMIF-DONES. The goal of this work was to demonstrate that the **prototype could be designed, manufactured and experimentally validated** as a pressure-retaining component under RCC-MRx requirements, including verification under both **pressurized and vacuum operating conditions.**

MAIN CHALLENGES

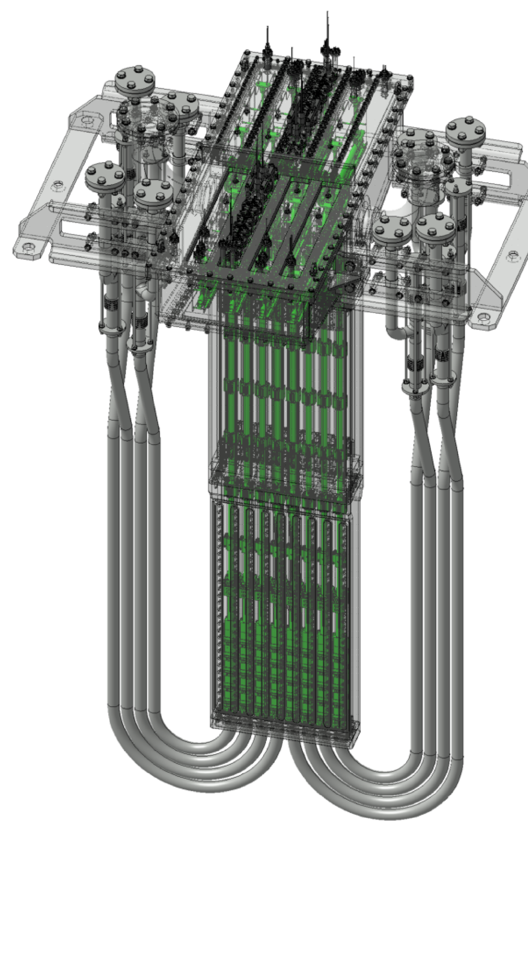
- Manufacturability: 2 mm front wall, continuous TIG welds and tight assembly tolerances.
- Positioning accuracy: precise rig and sensor location.
- Leak-tight interfaces: welded, bolted and sealed joints under pressure and vacuum conditions
- Hot lower vessel and much colder upper closure under the same assembly.
- Dense instrumentation routing from the hot lower region to the upper feedthrough area.

OPERATIONAL ENVELOPE

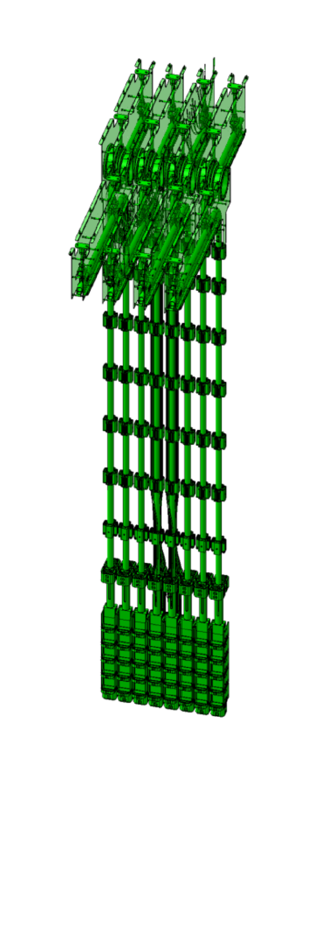
Condition	Pressure [bar(g)]	Temperature [°C]
Operation	2.5	320
Vacuum operation	-1.0	320
Maximum allowable pressure	2.8	350
Overpressure	3.15	350
Pressure test	4.0	20



Complete STUMM-PROTO sytem with external equipment, support frame and safety fence.



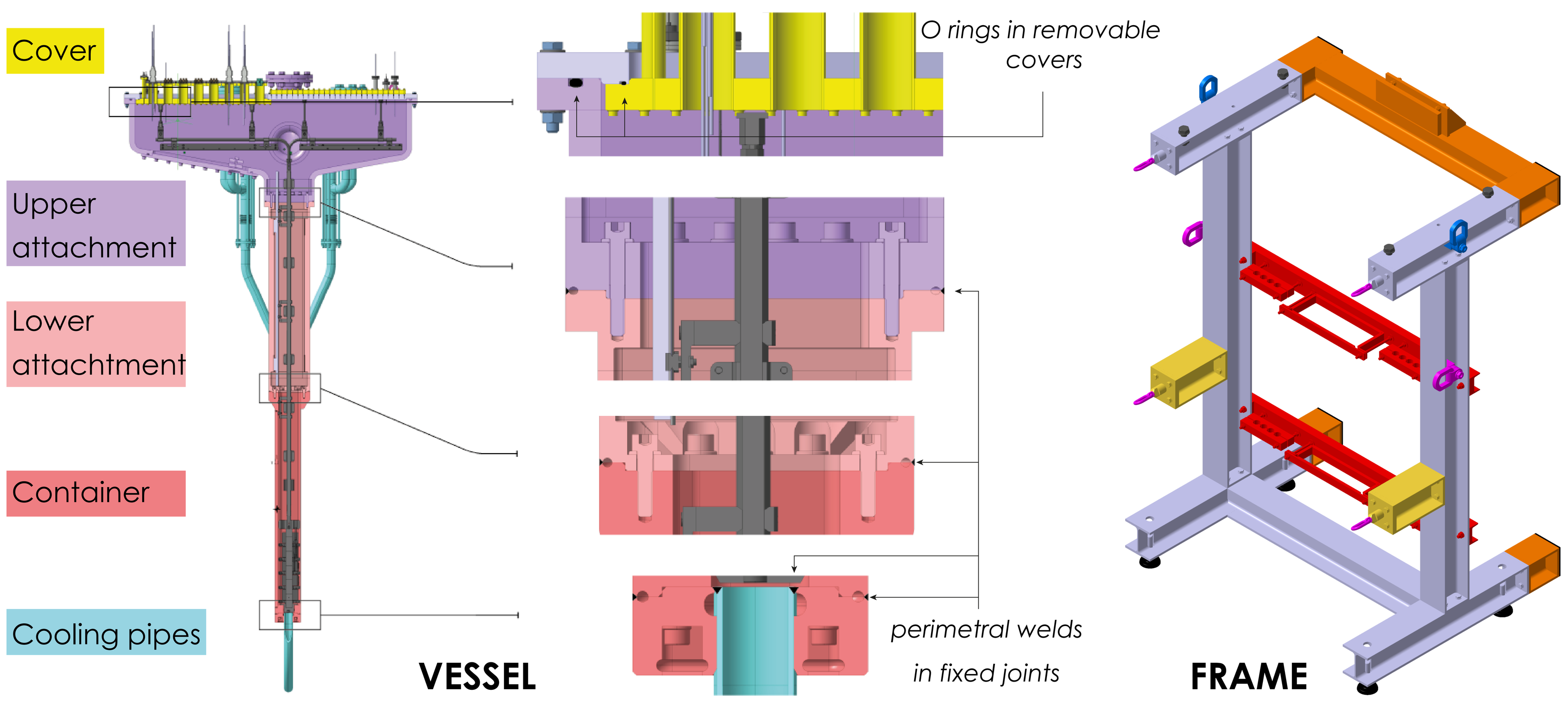
Pressure-retaining vessel.



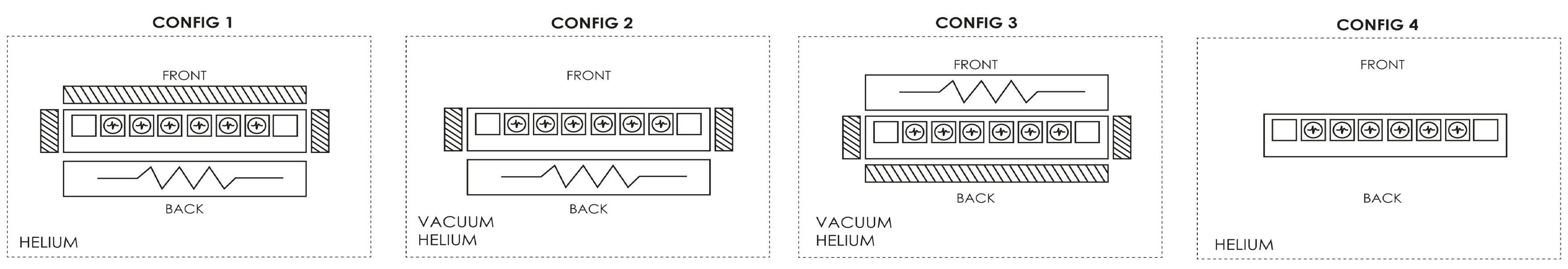
Internal rigs.

DESIGN

The STUMM-PROTO system includes a pressure-retaining vessel, removable instrumented rigs, a support frame and auxiliary external equipment. From the mechanical point of view, the **vessel** and **frame** are the most relevant assemblies. The vessel is composed of the container, lower attachment, upper attachment and cover, connected through **bolted joints**; while **full-penetration external welds** and **o-rings** ensure pressure retention and sealing.



The **heating system** was conceived to provide high experimental versatility, combining an **external heater** on the vessel with internal **heaters integrated in the rigs**, together with different insulation conditions. To make the structural verification manageable, these possibilities were reduced to four representative thermal configurations, which envelope the most relevant operating scenarios of STUMM-PROTO.

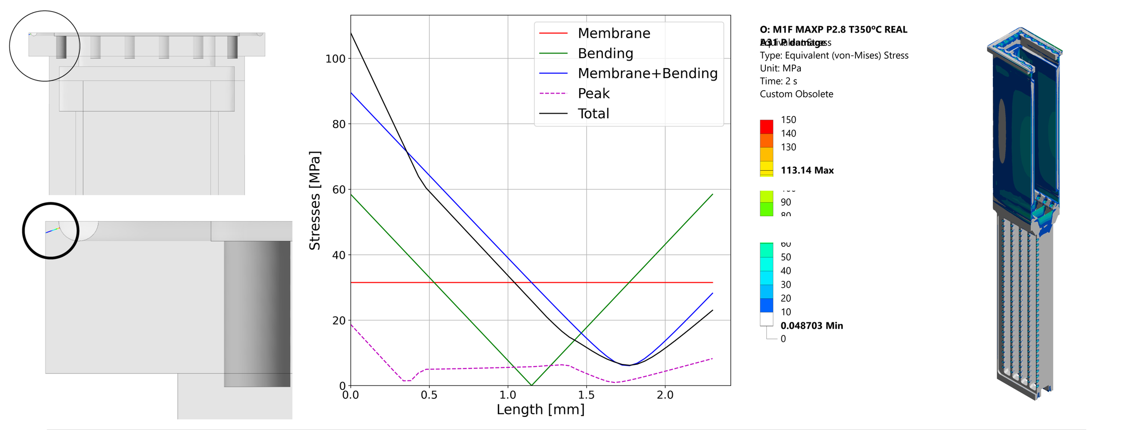


MODELLING & VERIFICATION

STUMM-PROTO was mechanically verified through three FEM sub-models to keep the assessment tractable while preserving local detail. **Type P, S and buckling checks** were performed as applicable according to **RCC-MRx for an N3Rx component.**

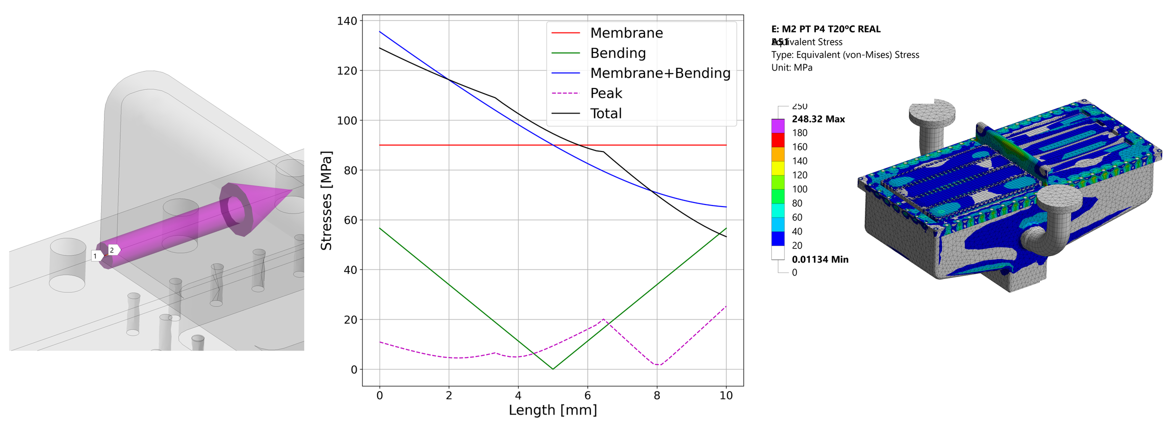
The most restrictive case differs for each sub-model:

In **Model 1**, the lower vessel region is the hottest one (320–350°C), so thermo-pressure loading governs and stress linearization is required in the maximum allowable pressure case.



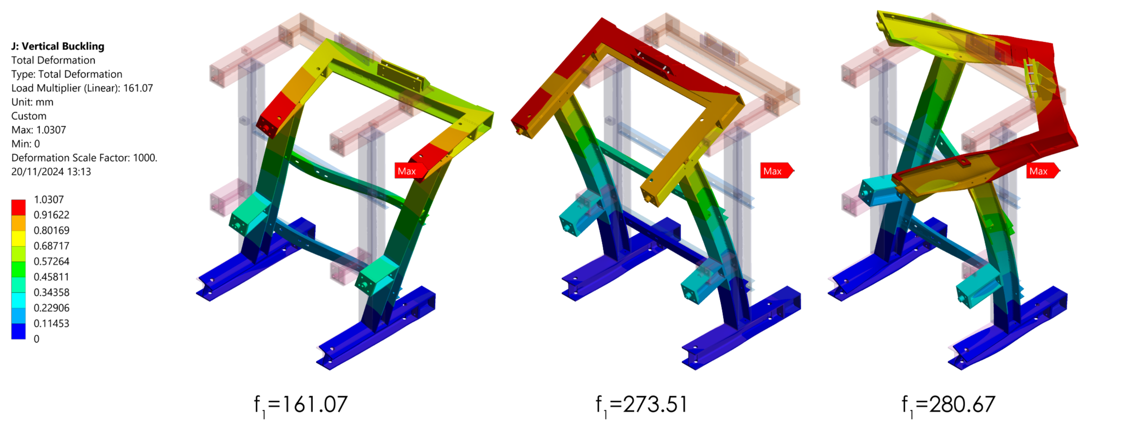
P-type maximum allowable pressure analysis for Model 1

In **Model 2**, the upper region is much colder (60–100°C) and therefore the pressure test becomes more demanding, especially due to the large cover plate, multiple openings and bolted interfaces.



P-type maximum allowable pressure analysis for Model 2

In **Model 3**, the frame remains well within stress limits and buckling is highly non-limiting, with a first load factor of 161 in the most relevant vertical configuration.



Vertical loaded buckling analysis for Model 3

MANUFACTURING & INSTALLATION

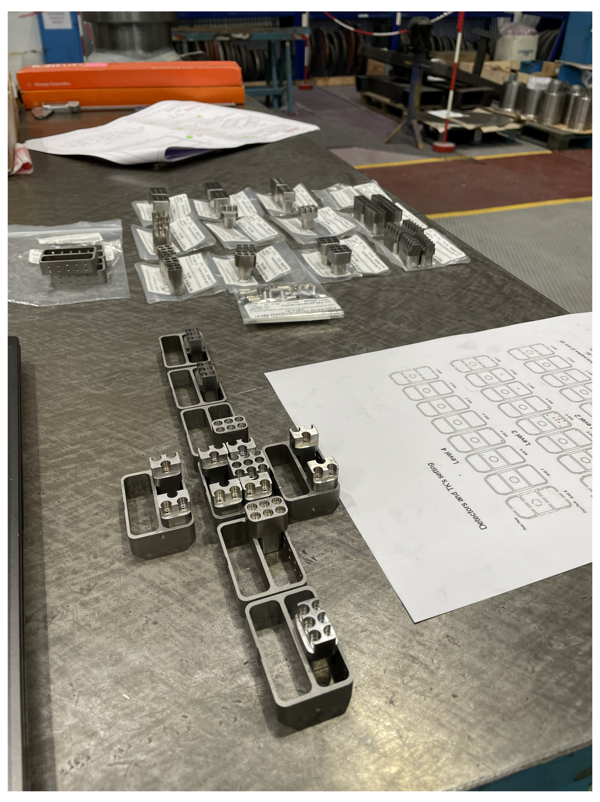
Manufacturing was a major design driver of STUMM-PROTO. The pressure-retaining vessel combines 2 mm wall thickness, continuous TIG welds, tight tolerances, multiple bolted interfaces and sealing surfaces, which makes fabrication especially demanding. To overcome these constraints, the final configuration was reached through an iterative design-for-manufacture process carried out jointly with the manufacturer (Thuneureka). This process included geometry refinements, adjustment of bolt patterns and local interface modifications so that conventional machining and welding routes could be used in critical areas without resorting to wire-EDM.

STUMM-PROTO installed at the IFMIF-DONES site in Escúzar, Spain.

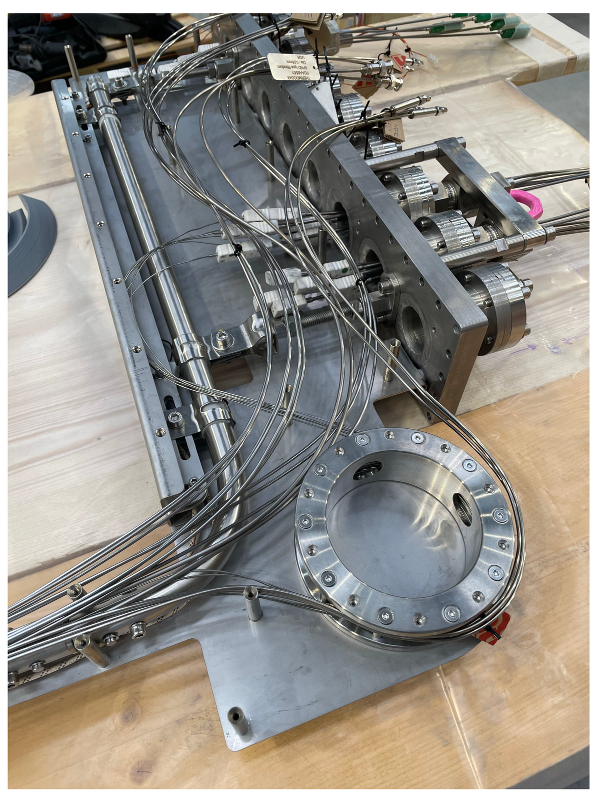
Custom CF upper flanges on the cover, designed for pressure/vacuum with welding to the upper closures.

Detail of the rig lateral fins in the instrumentation region, introduced to improve thermal coupling.

Instrumented rig prepared for SAT, showing the integrated sensors and internal layout.



Sensor-holder configuration used during FAT, including the different mounting layouts evaluated.



Upper cable routing from the rig towards the top flanges feedthrough interfaces.

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