



New developments in the design of a helium-cooled divertor for the European DEMO

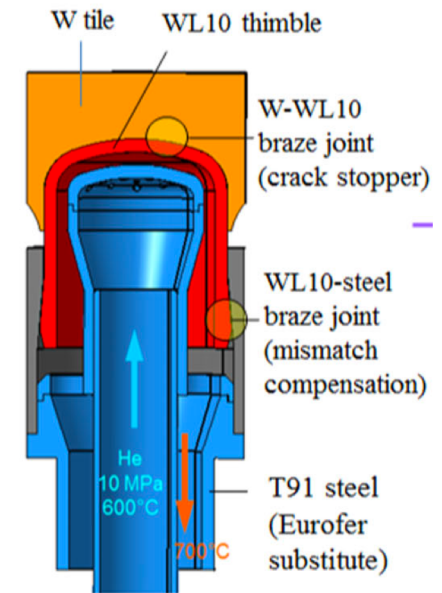
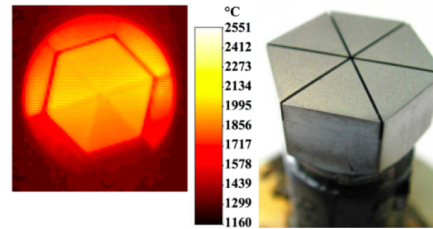
Bradut-Eugen Ghidersa



Helium Multi-Jet (HEMJ) concept



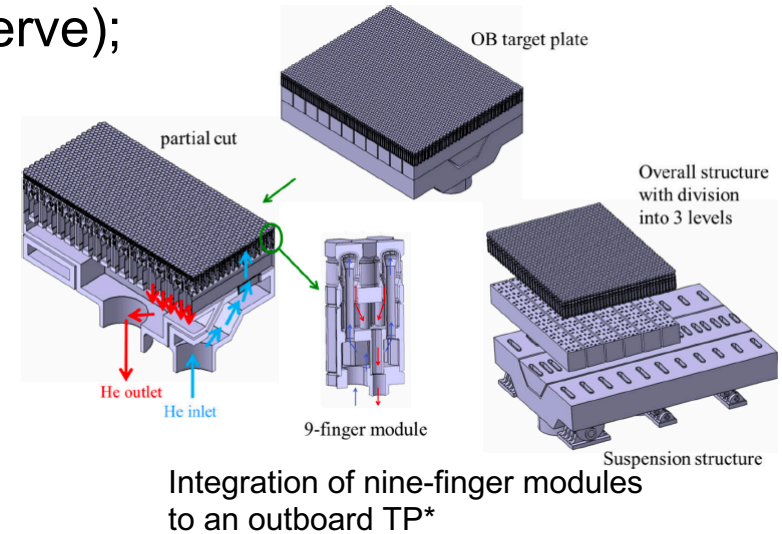
- Starting solution
- High temperature coolant concept (600°C, 10MPa)
- Target made of parallel finger modules
- Experimentally proven heat removal capability of 10 MW/m² (max. 13 MW/m²)



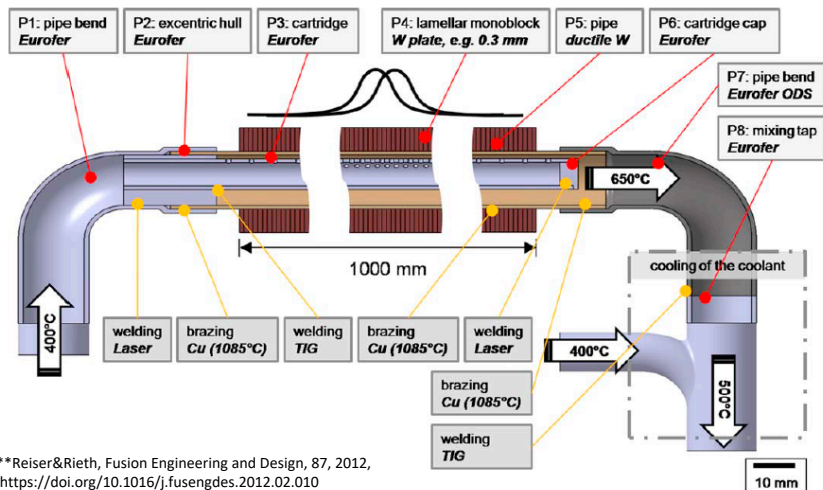
EU-DEMO Divertor



- Quasi-stationary: 10MW/m² (+50% reserve); 20 MW/m for slow transient (<10s)
- High heat flux length on OVT: 645mm
- HEMJ:
 - complex flow path
 - Large number of units (fingers)
 - Large number of welds



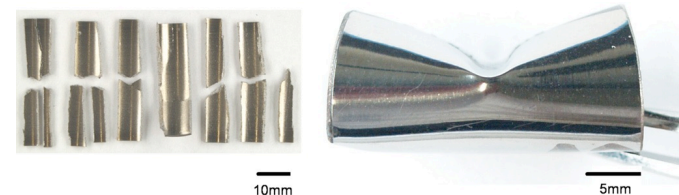
*Norajitra et al., Fusion Science and Technology, 67, 2015, <https://doi.org/10.13182/FST14-832>



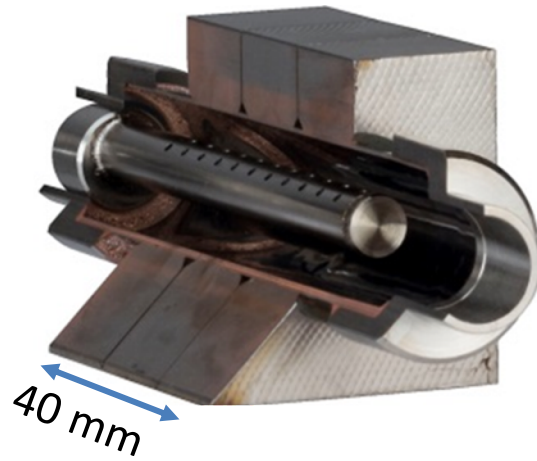
**Reiser&Rieth, Fusion Engineering and Design, 87, 2012, <https://doi.org/10.1016/j.fusengdes.2012.02.010>

• Alternative solution

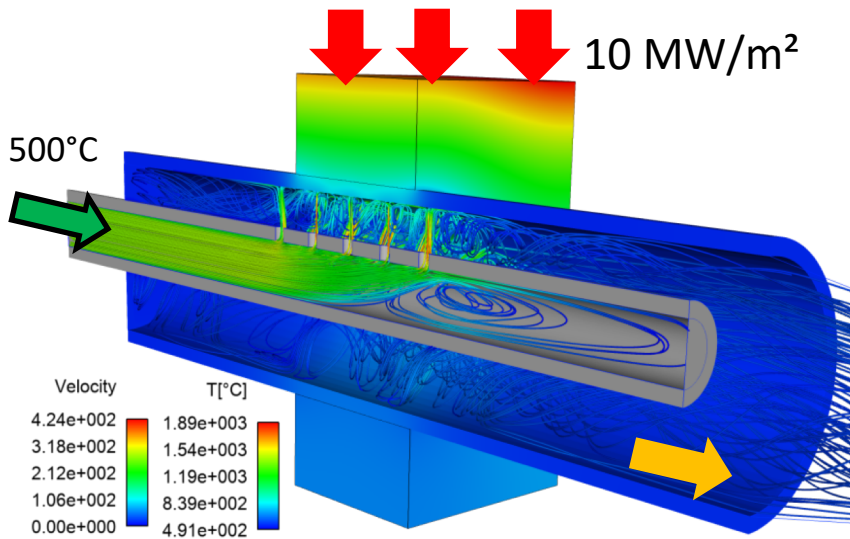
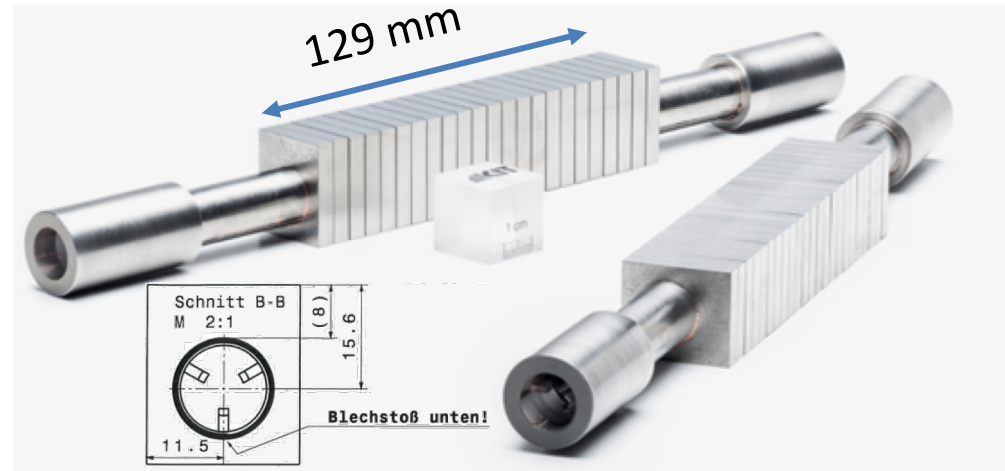
- Multi-Jet Pipe concept
- Use ductile tungsten for pipe



Multi-Jet Pipe Concept



Multi-Jet Pipe Divertor mock-up

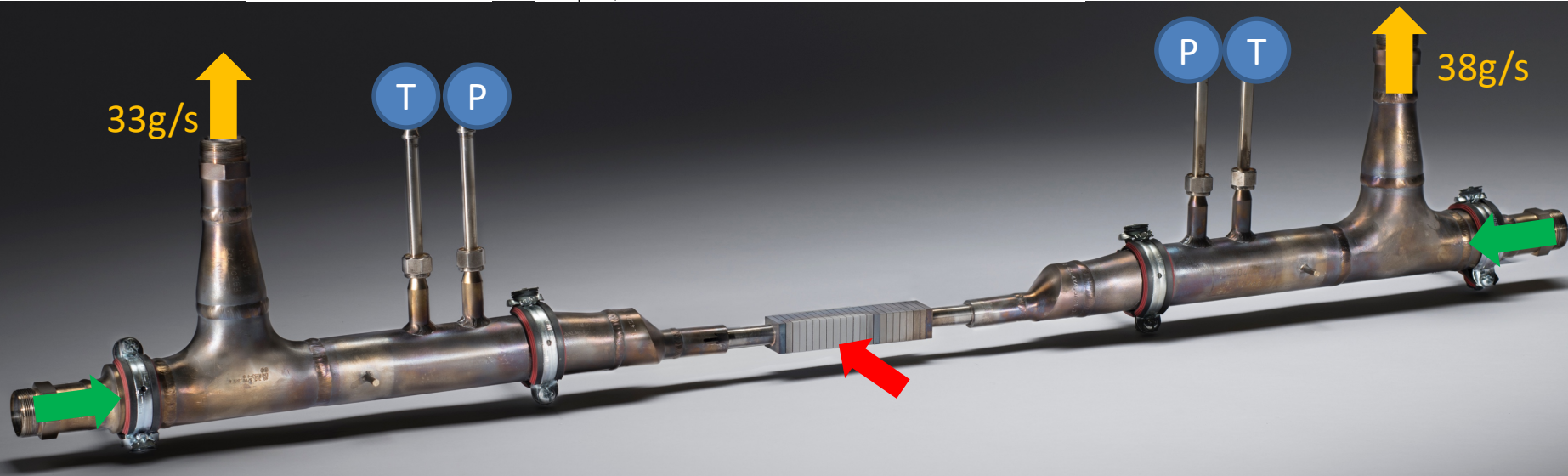
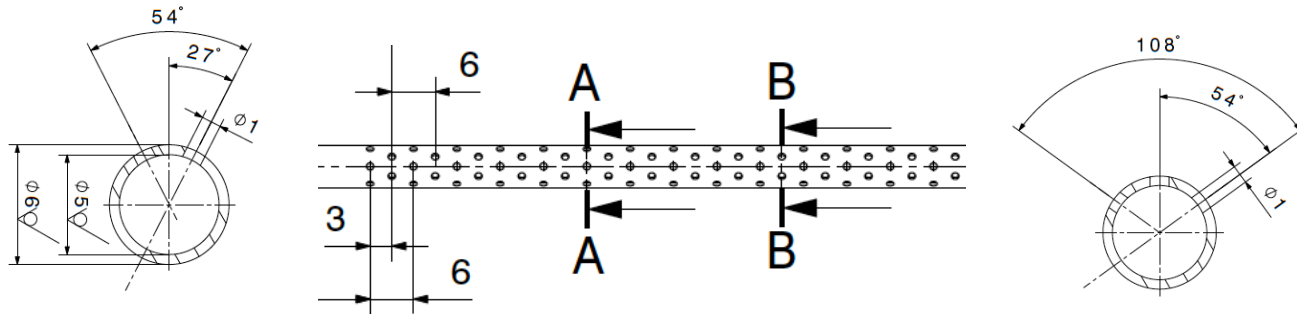


- Manufacturing using W-Cu laminate
 - Pipes up to 1m long (diameter 15mm)
 - 1-step assembly process: pipe + W-slabs
- CFD studies:
 - Cooling capabilities similar to HEMJ (small length)
 - Pipe/cartridge size (15mm/6mm) limits the cooling area/length
 - Using Cu limits the operating window

High heat flux testing: mock-up



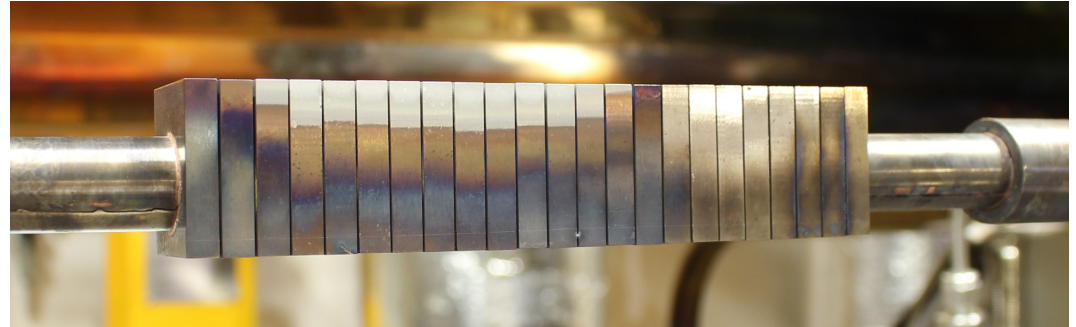
- Mock-up 1:
 - Helium distribution manifold: 6mm pipe
 - Coolant flows from both sides of the mock-up



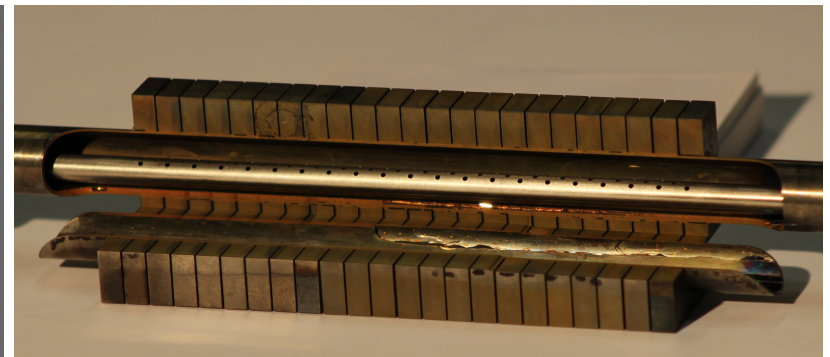
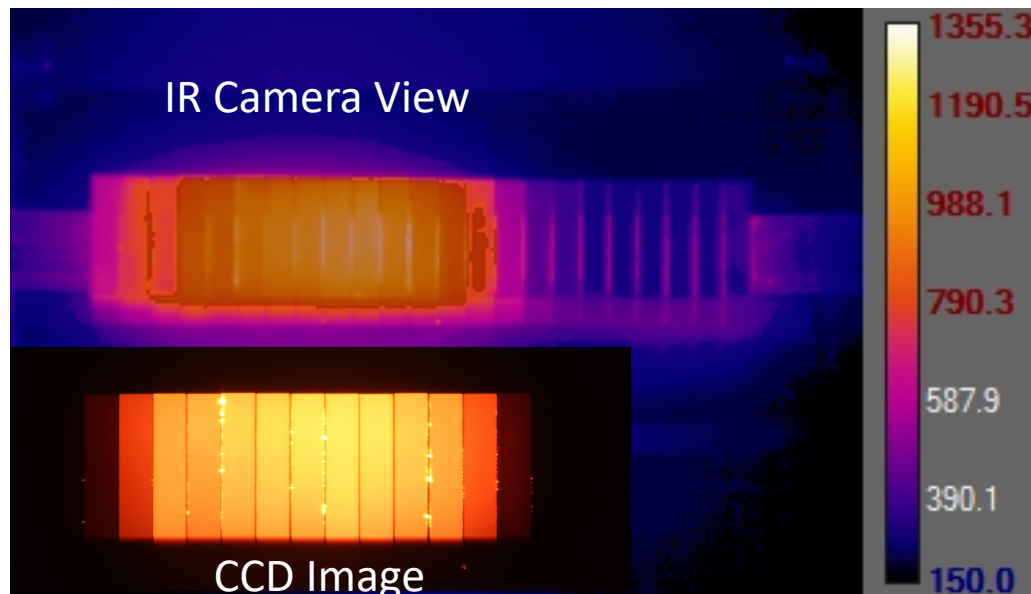
High heat flux testing



- Tested in HELOKA (KIT) at 400°C, 8MPa
- Pulses 300s long
- 8MW/m² :1000 pulses
- 10MW/m² : 25 pulses

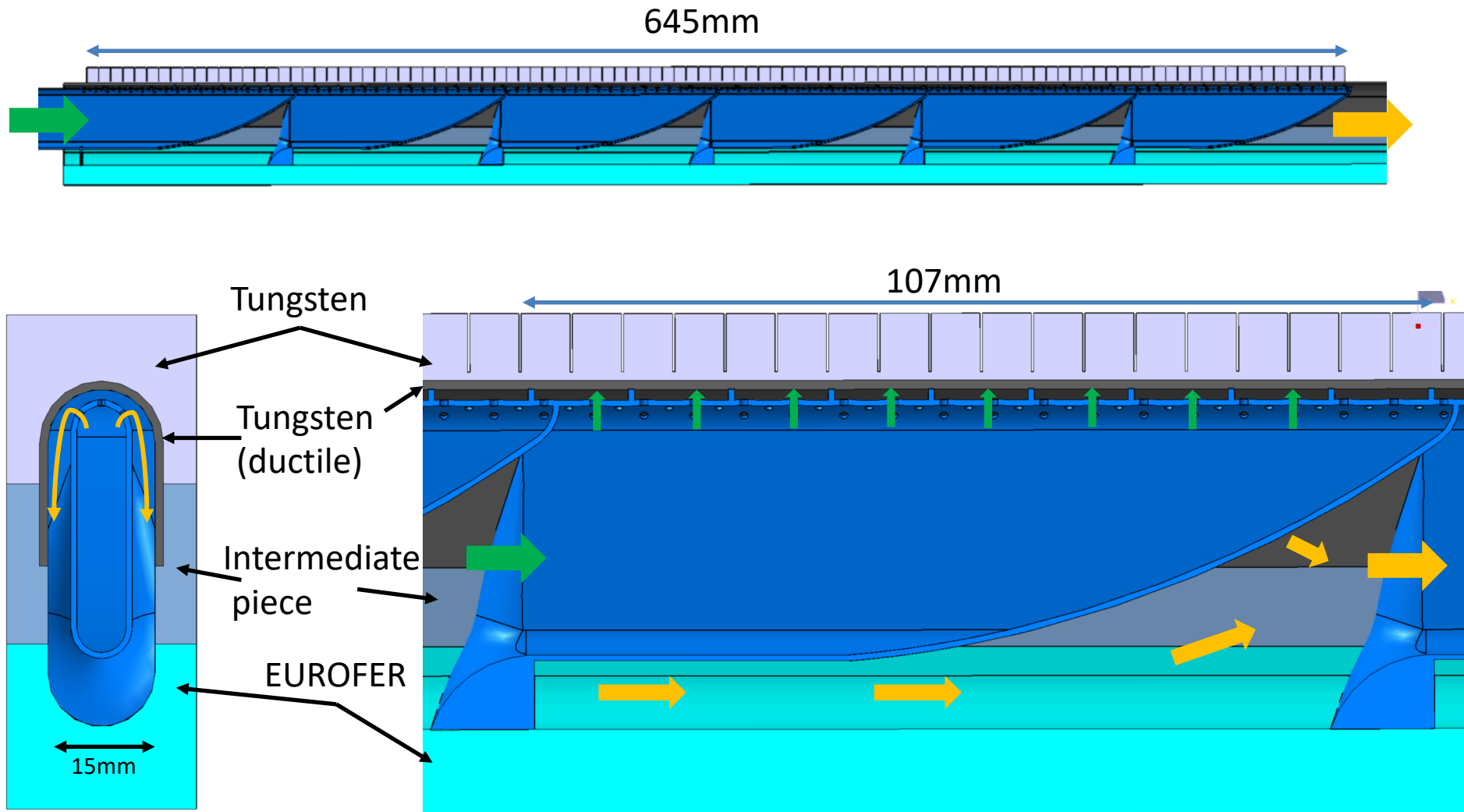


Heat Fluxes estimated based on measured power input and (approximated) heated surface



- Asymmetry of the cooling pattern due to cartridge assembly welds
- Pipe delamination on the cold side
- Metallographic analysis ongoing

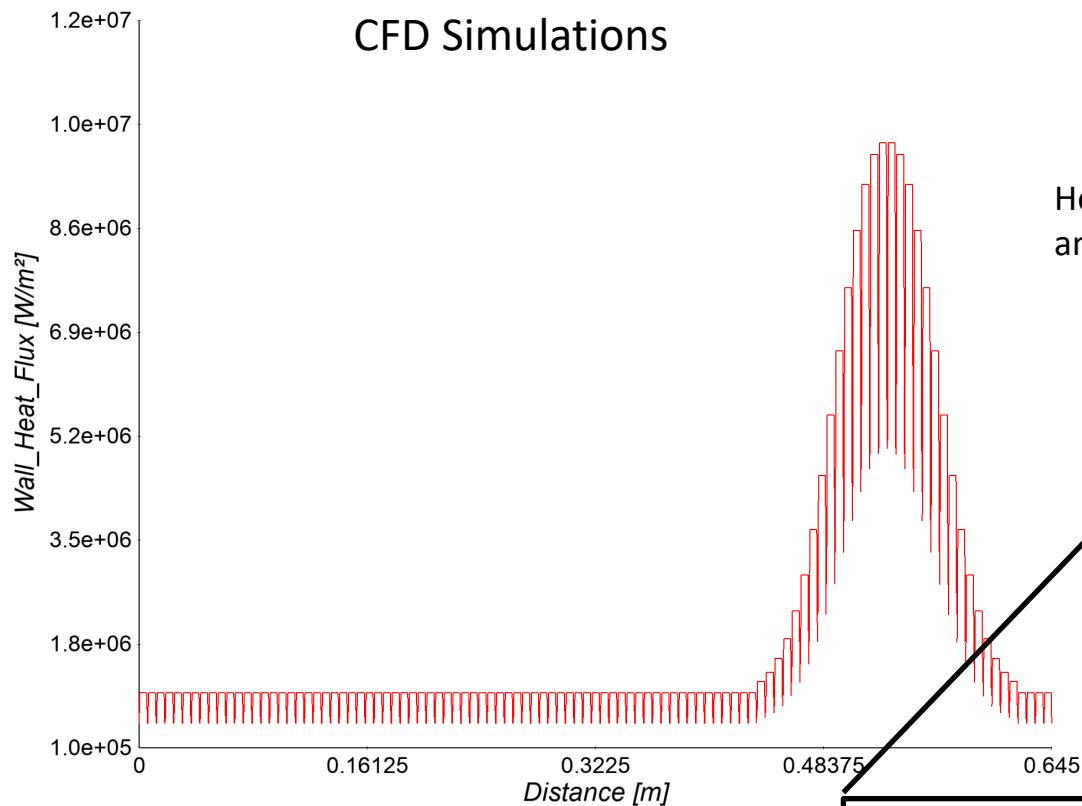
Multi-Jet Pipe: current design



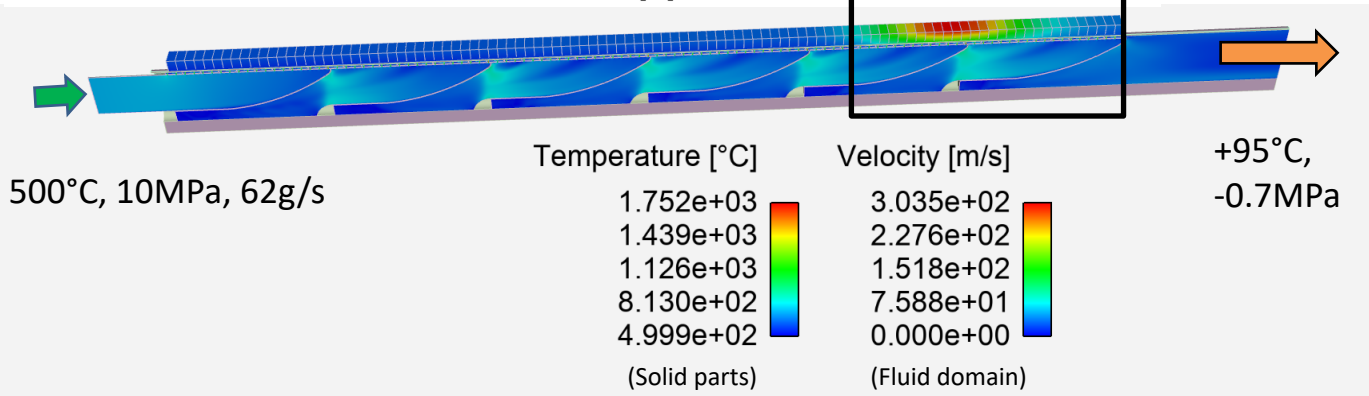
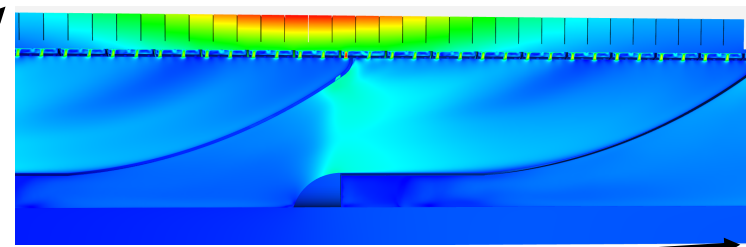
Performance evaluation



CFD Simulations

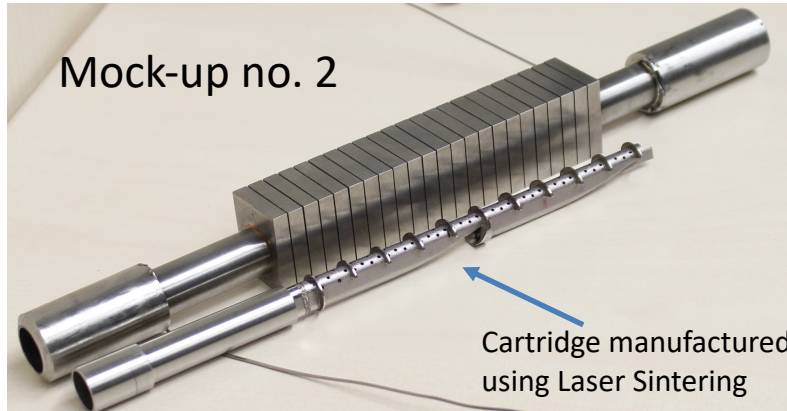


Heat Flux profile assuming a peak value of 10MW/m^2 and a total power at the outer strike point of 26MW^*

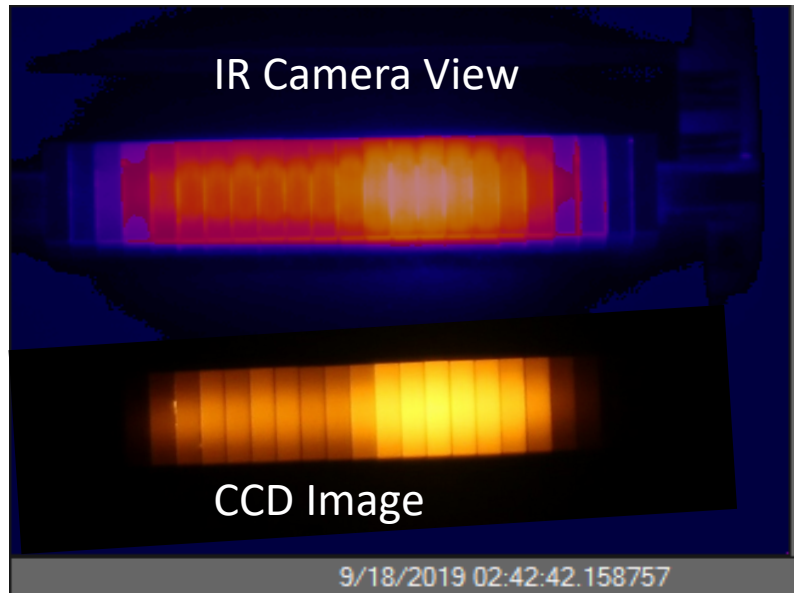
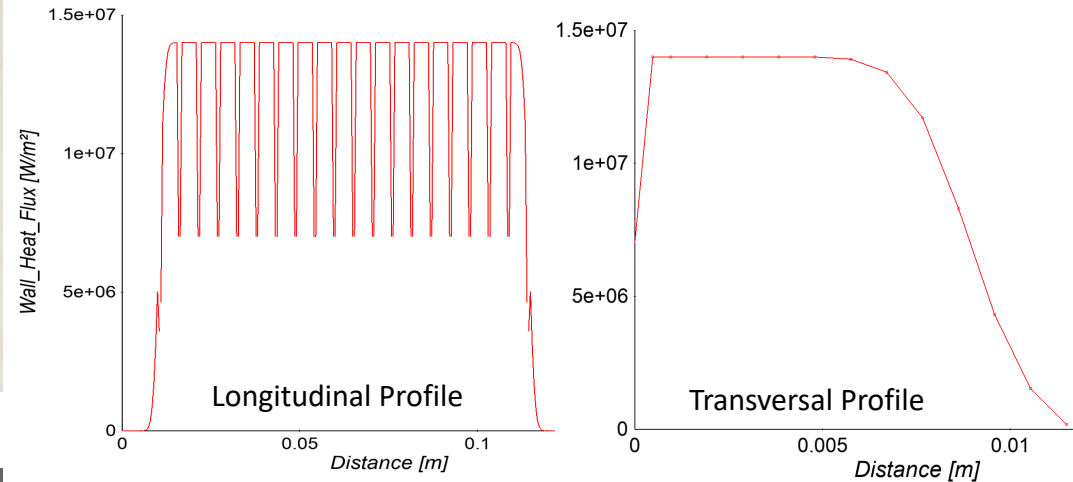


* Bachmann et al., Fusion Engineering and Design, 112, (2016)
<https://doi.org/10.1016/j.fusengdes.2016.05.040>

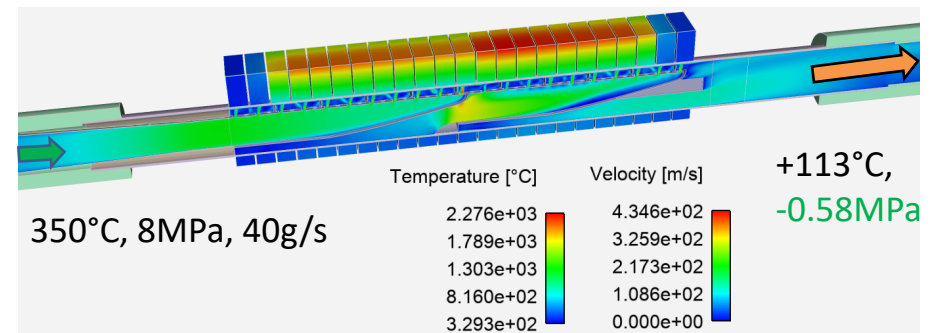
High heat flux testing: mock-up no. 2



Experiment Simulations



Peak heat flux: value increased until (CFD) calculated power matched the experimental value





- Multi-jet Pipe: new divertor concept
 - Cooling capabilities similar with HEMJ (CFD and experimental)
 - 1000 pulses at 8MW/m^2 (83h), 25 pulses at 10MW/m^2 (2h)
 - New design allowing the integration into a EU-DEMO target plate
- Further steps:
 - Metallographic analysis of the mock-ups
 - Process the experimental data
 - Setting-up a manufacturing path for the current design
 - Experimental evaluation of cooling performances at design conditions (KATHELO: 500°C , 10MPa)