Synchrotron radiation absorber design

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Outline

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- **Thermo-mechanical behavior**
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Context

Copious amounts of Synchrotron Radiation (SR) power and flux are generated in FCC-ee. Local absorbers approximately every 5-6 m will be used to guarantee a rapid decrease of photon desorption yields and fast vacuum conditioning. This helps to contain the high-energy Compton-scattered secondaries once the beam energy is increased up to 182.5 GeV

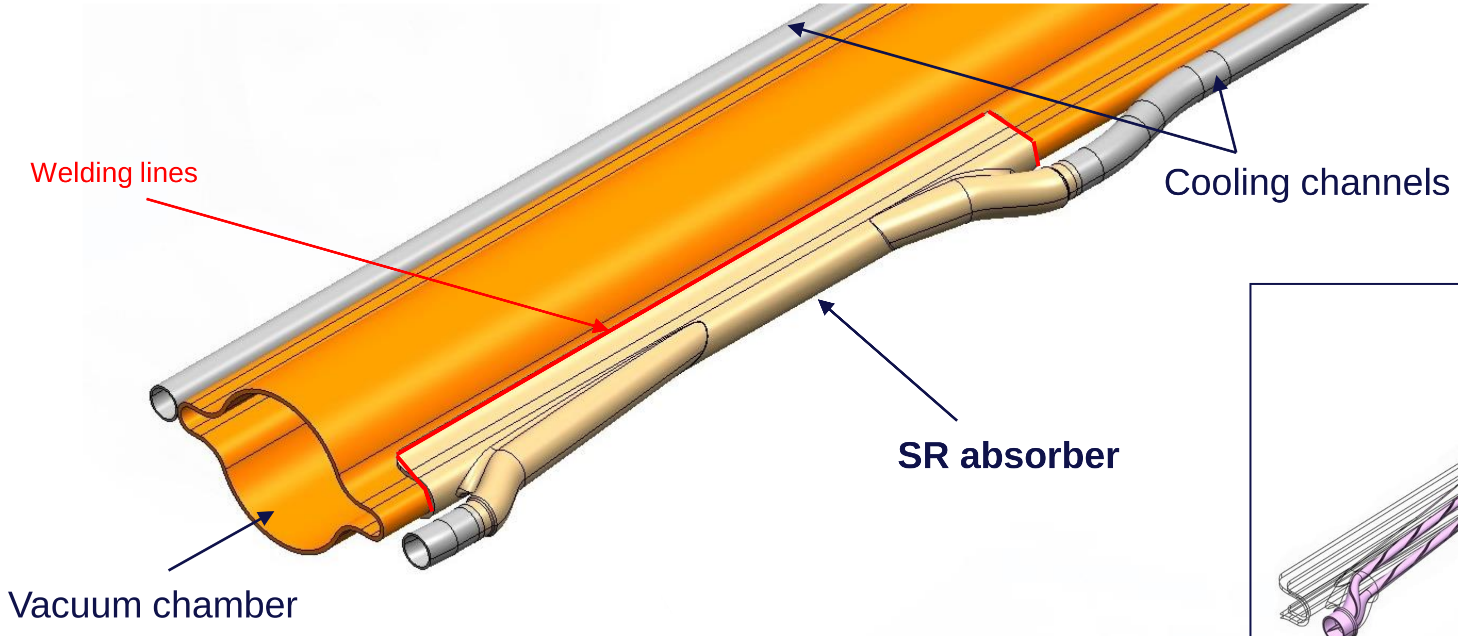
The Synchrotron Radiation Absorbers (SRA) must be:

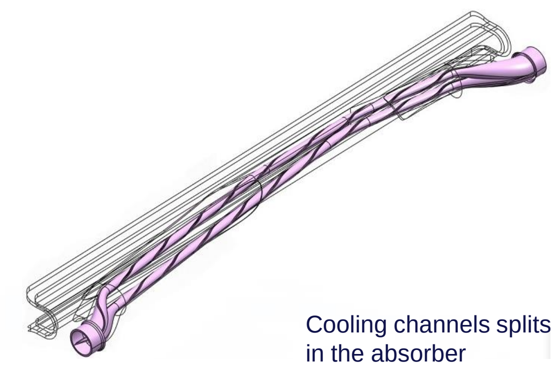
- designed to withstand high temperatures and stresses induced by the photon flux.
- cooled-down to avoid heat dispersion in the tunnel.

A detailed thermo-mechanical design is needed to satisfy these requirements.

The Synchrotron Radiation Absorber

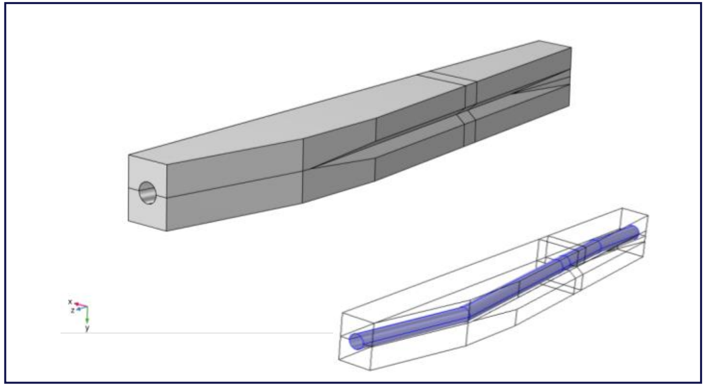
The SR absorber is a complex 3D-printed copper-alloy component welded into a dedicated aperture of the vacuum chamber and connected to the cooling channels running on the chamber's winglets.

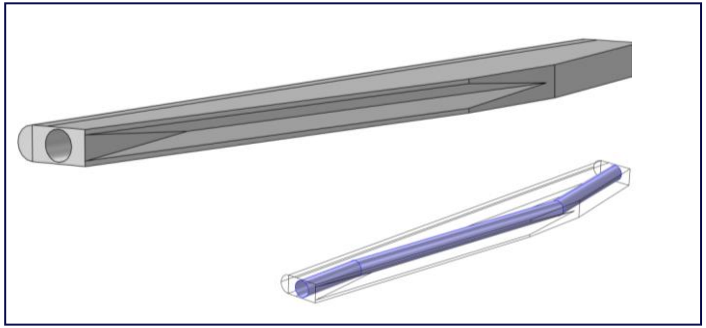


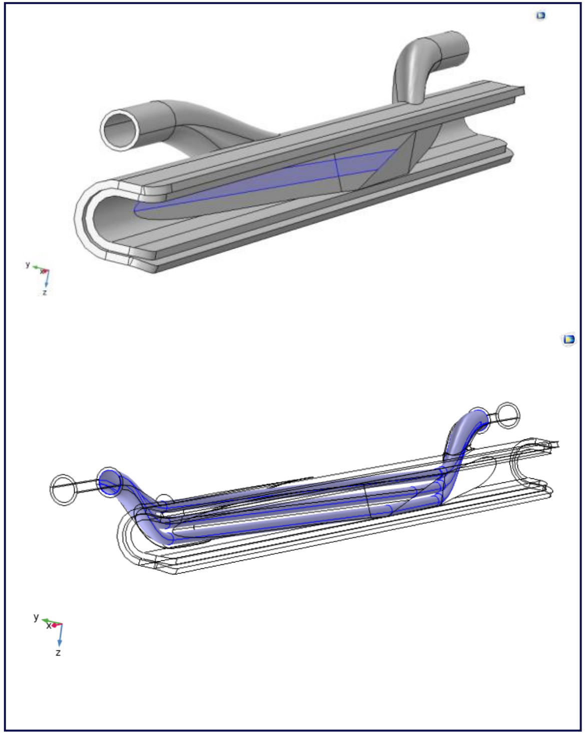

Cooling channels splits in the absorber

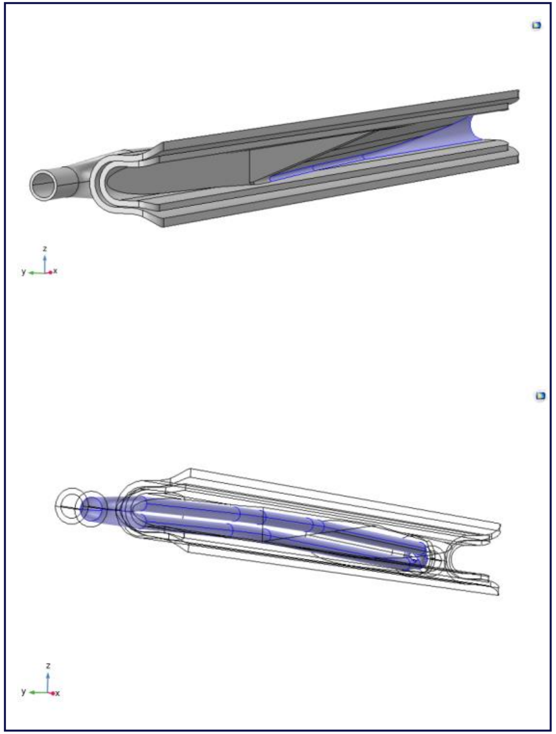
The Synchrotron Radiation Absorber

Several geometries have been tested with different cooling channels, different surfaces to intercept SR fan, masses, etc..



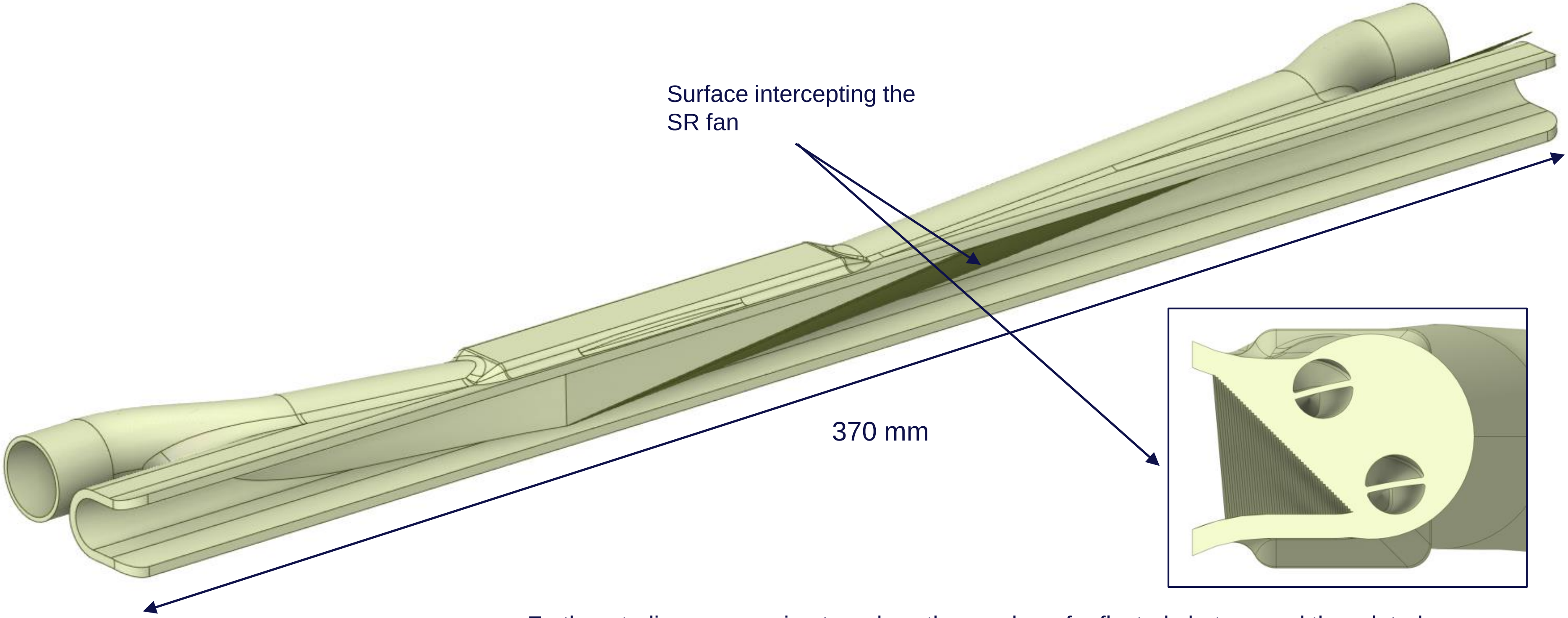






The Synchrotron Radiation Absorber

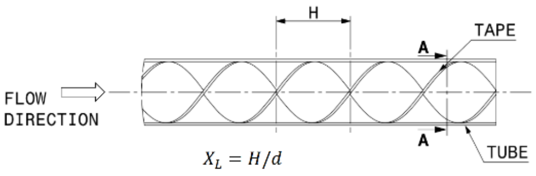
Last version



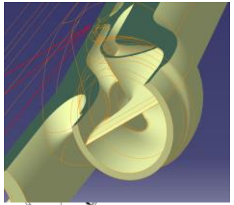
Further studies are ongoing to reduce the number of reflected photons and the related photoelectron generation in the main chamber.

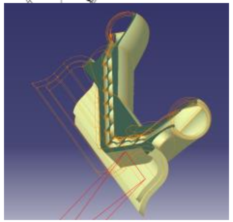
The Synchrotron Radiation Absorber

The complex internal geometry of the SRAs calls for the use of additive manufacturing technology, the water-cooling channels include a twisted-tape 'insert'. The turbulence generated by the tape improves heat transfer capabilities.



Internal helical twist tape



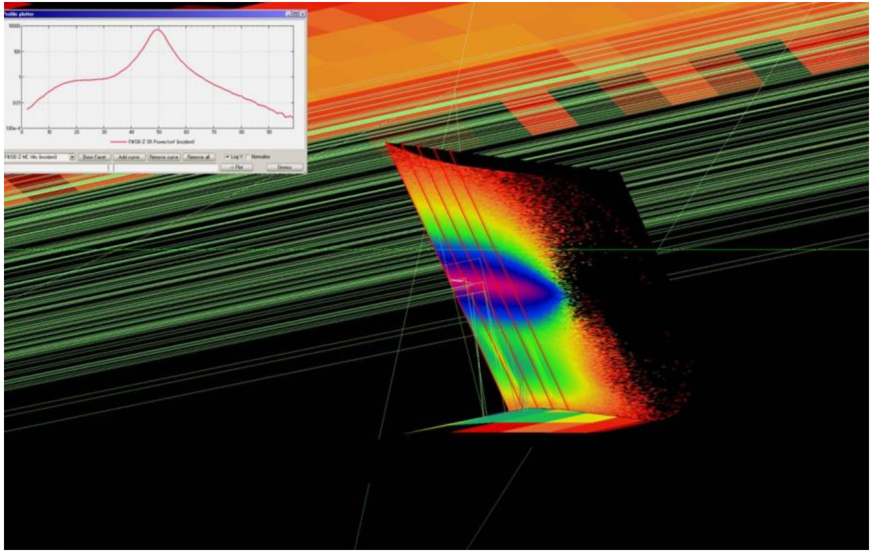


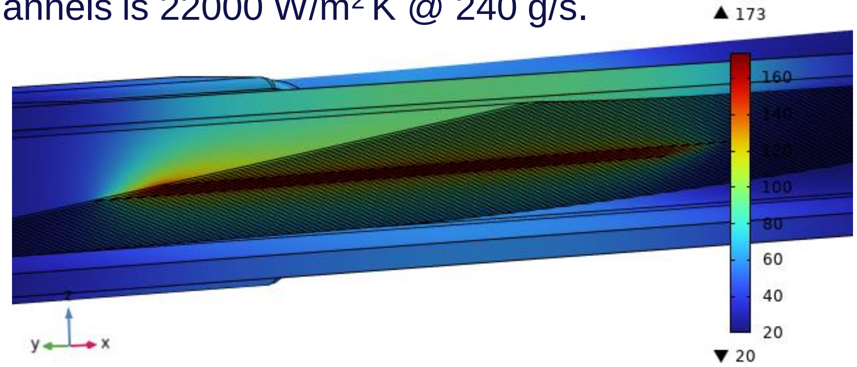
Laser Powder Bed Fusion (LPBF) has been selected as the method for the first prototype.

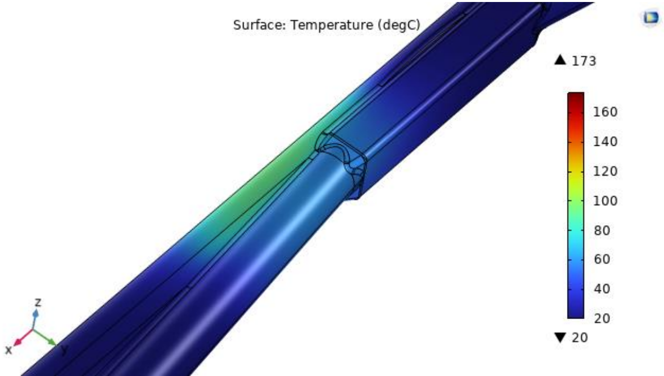
Thermo-mechanical behaviour

Given the beam properties and the magnetic field, the trajectory of the photons and the radiation power density are calculated in Synrad. The updated total power amounts to 2.5 kW/absorber and is assigned to the slanted surfaces.

The heat transfer coefficient considered for the cooling channels is 22000 W/m^2 K @ 240 g/s. Simulations show max temperature of around 170° C.



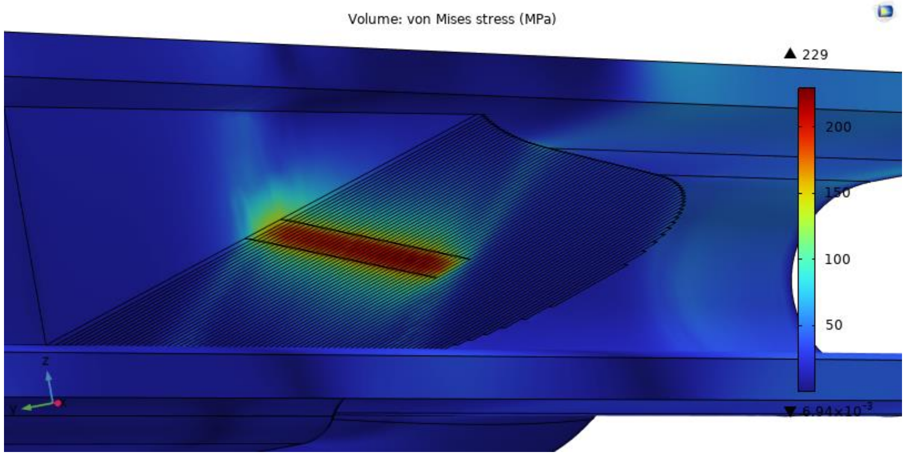


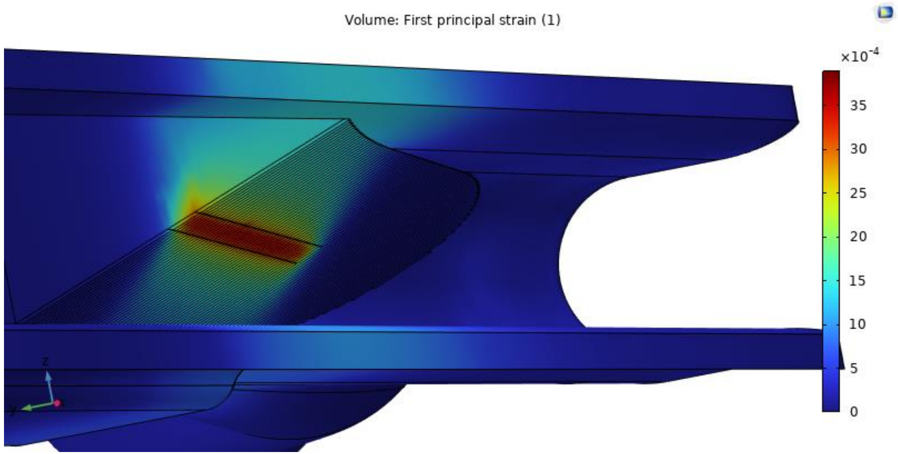


Thermo-mechanical behaviour

The SR heat load leads to an increase of mechanical stress.

Simulations show a max equivalent stress of 229 MPa and a strain of 0.04%.





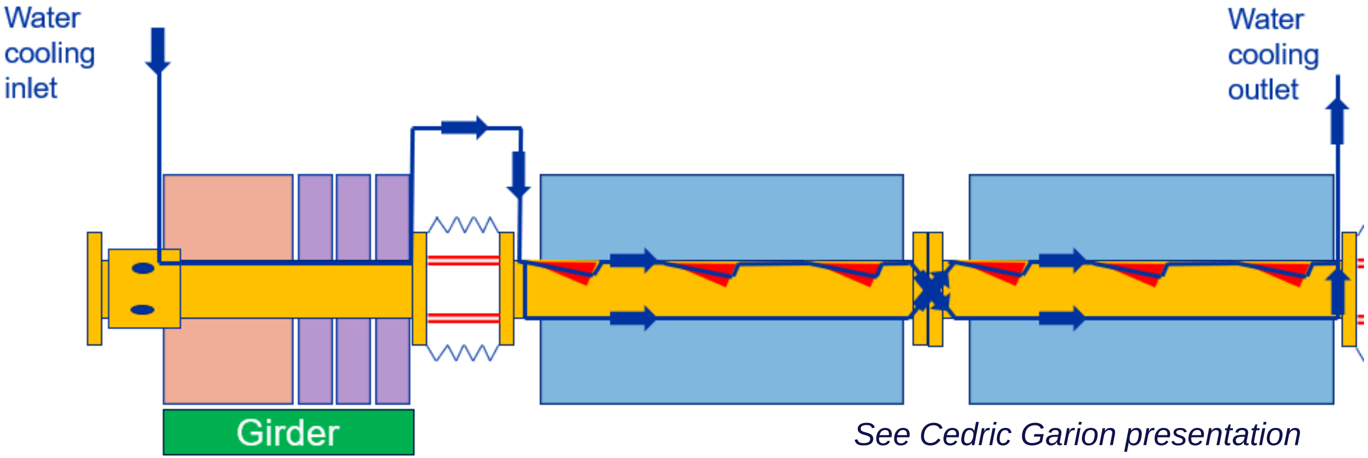
Fluid dynamic behaviour

The analytical formulations of Manglik-Bergles were used to predict the heat transfer coefficient and pressure drop for each absorber.

For an inlet water speed of 3 m/s the pressure drop per absorber is 0.3 bar. Most likely to be higher as material roughness, losses due to the circuit bends and temperature dependent material properties were not considered.

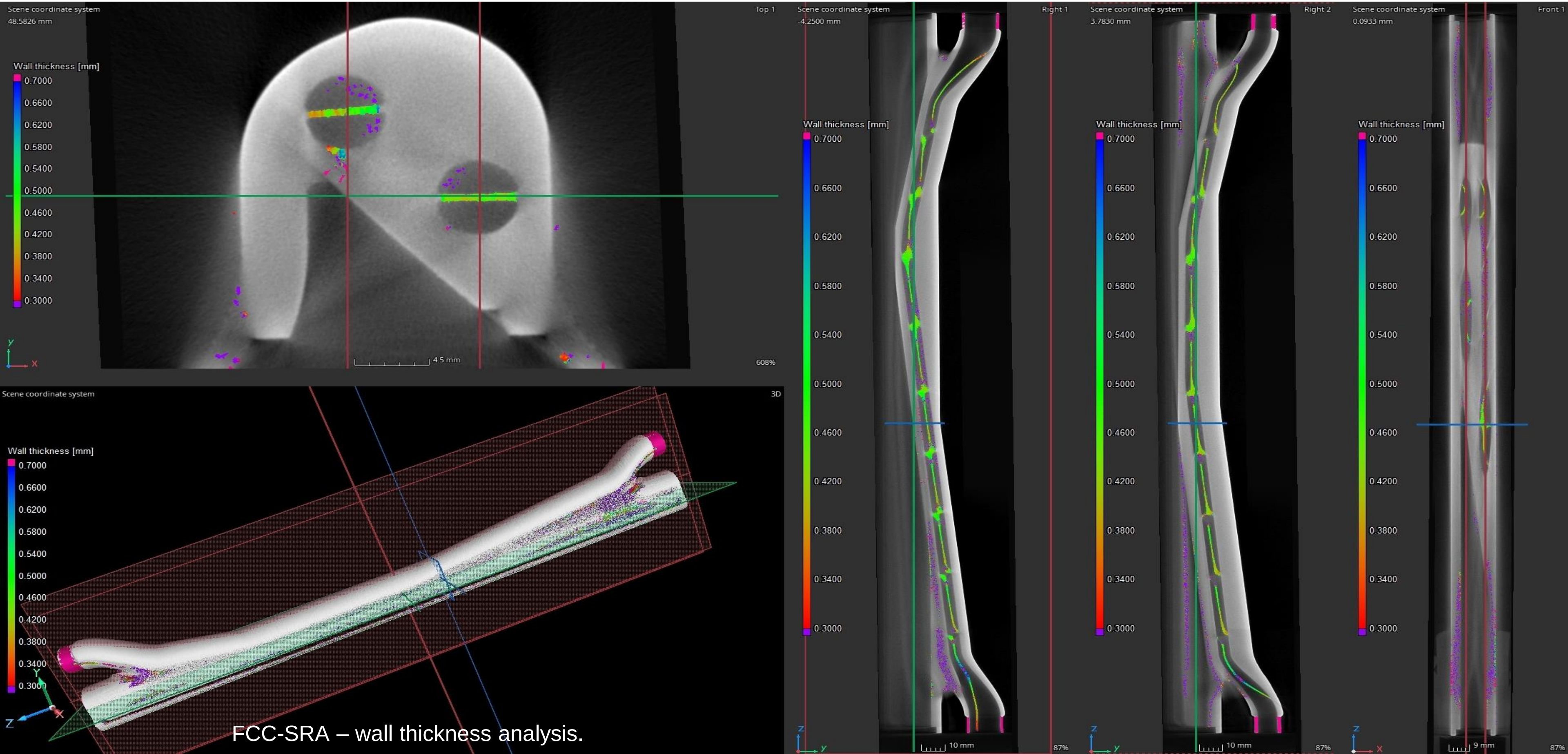
However, 3 absorbers could be connected in series within the same cooling line resulting in a cooling line about 25 m long, see below.

Considering only the heat intercepted by the SR absorbers the water outlet temperature should be around 45 °C (inlet temperature 27 °C).



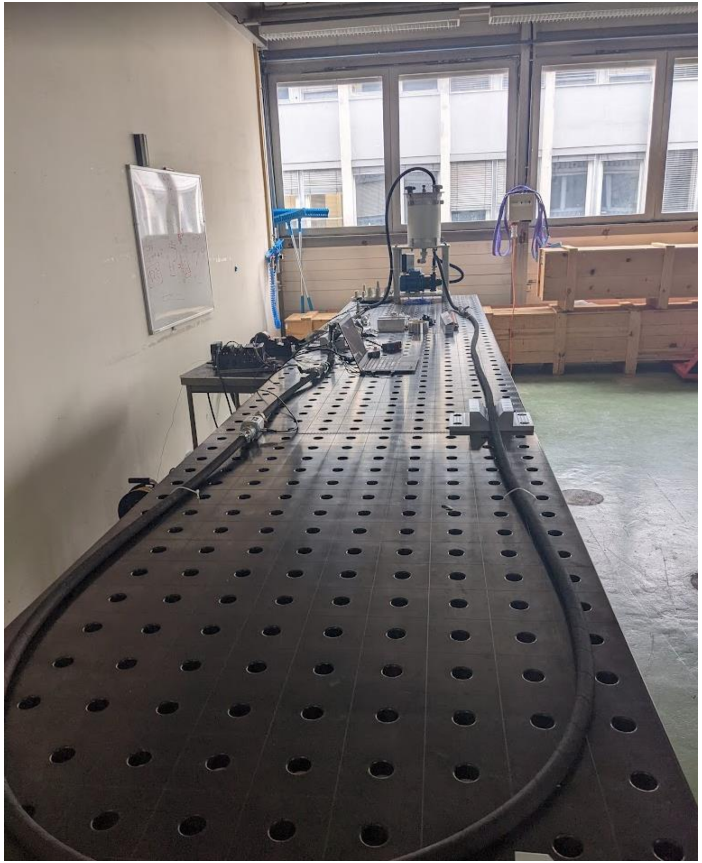
See Cedric Garion presentation

Tests (CT scan)



FCC-SRA – wall thickness analysis.

Tests (fluid-dynamic)



Fluid-dynamic test bench developed in our labs to:

- Measure pressure drop at different water velocities;
- Measure heat transfer coefficients;
- Assess erosion and dynamic effects.

Physical properties measurements :

- First samples of the SRA and pieces for mechanical characterisation successfully 3D printed in Cu-ETP and CuCrZr
- Tensile tests, fracture toughness, hardness
- Thermal conductivity, thermal fatigue

Conclusions and Future Outlook

- SRA prototyping is progress ... al design has been presented.
- First SRA samples have be ... sting campaign to validate the thermal and fluid-dynamic p
- A study of the fatigue behav ... per materials has been initiated in TE/VSC.
- The mechanical and therma ... esentative 3D printed copper samples are essential to va ... behaviour.

Of c ... sage…

FUTURE CIRCULAR COLLIDER

Thank you for your attention