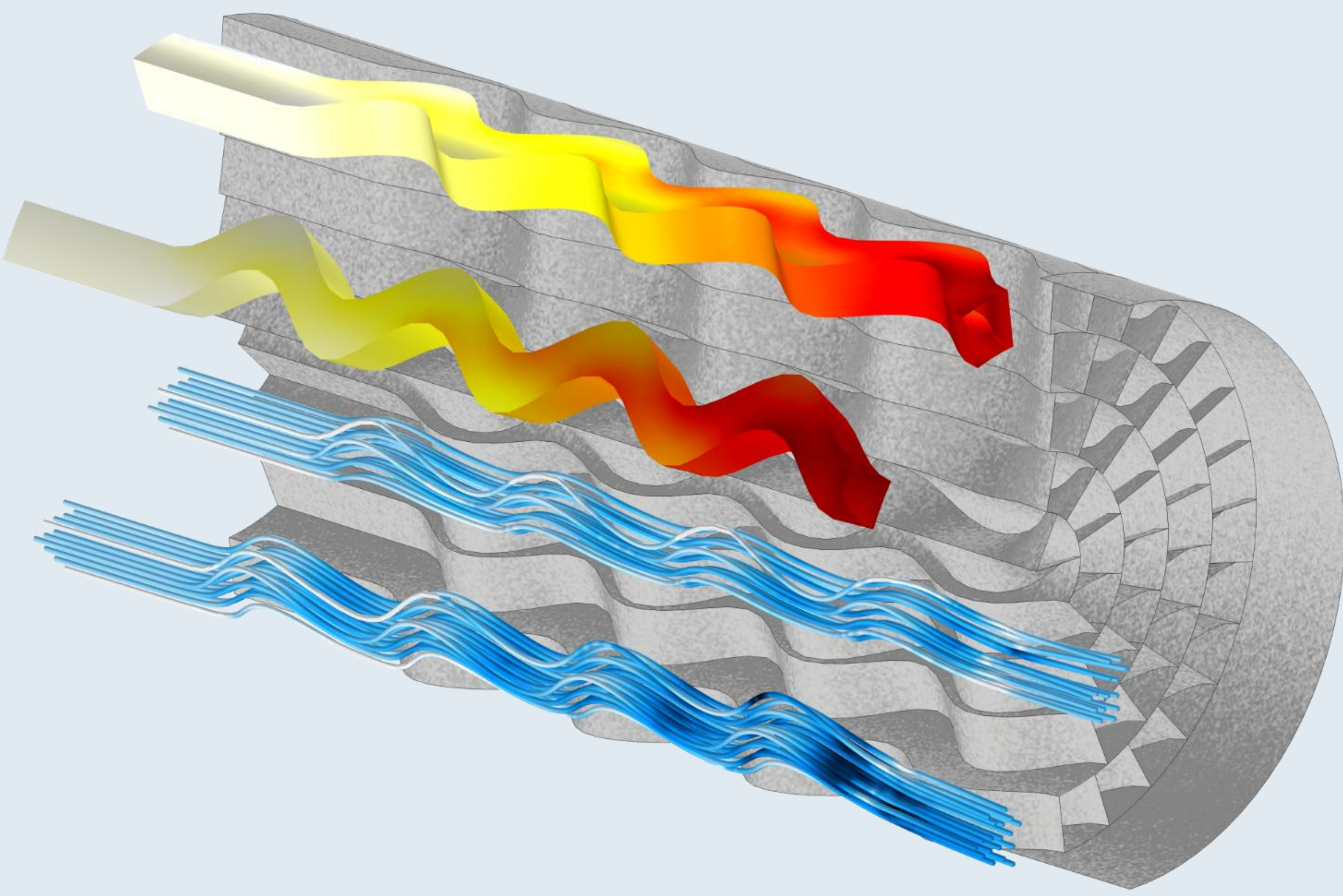




# Multiphysics Simulation Based Development of LPBF Components for High Temperature Furnaces

To develop the next generation of energy efficient refractory metal hot zones for high temperature vacuum furnaces, multiphysics simulations were employed to design and optimize thin-walled, gas-permeable structures that reduce thermal radiation losses while maintaining low flow resistance.

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## Abstract

High-temperature vacuum furnaces typically operate at power levels of several hundred kilowatts and are equipped with rapid cooling systems. However, the rear gas outlet and gas inlet nozzles, commonly implemented as simple openings with recessed shielding in state-of-the-art furnaces, represent a dominant source of radiative heat losses and adversely affect the temperature homogeneity in the load volume. To improve these deficiencies, at Plansee SE with the aid of COMSOL Multiphysics® and analytics, thin-walled, gas-permeable

structures that reduce thermal radiation losses while maintaining low flow resistance were developed. For the rear gas outlet, a so called FlowBox consisting of an array of thin-walled cosine shaped rectangular channels was suggested. This concept combines multiple effective shielding layers for thermal radiation with a low resistance for the gas flow [1]. The corresponding concept was applied to the gas inlet nozzles, featuring an array of cosine channels arranged circumferentially with increasing amplitude in radial direction.

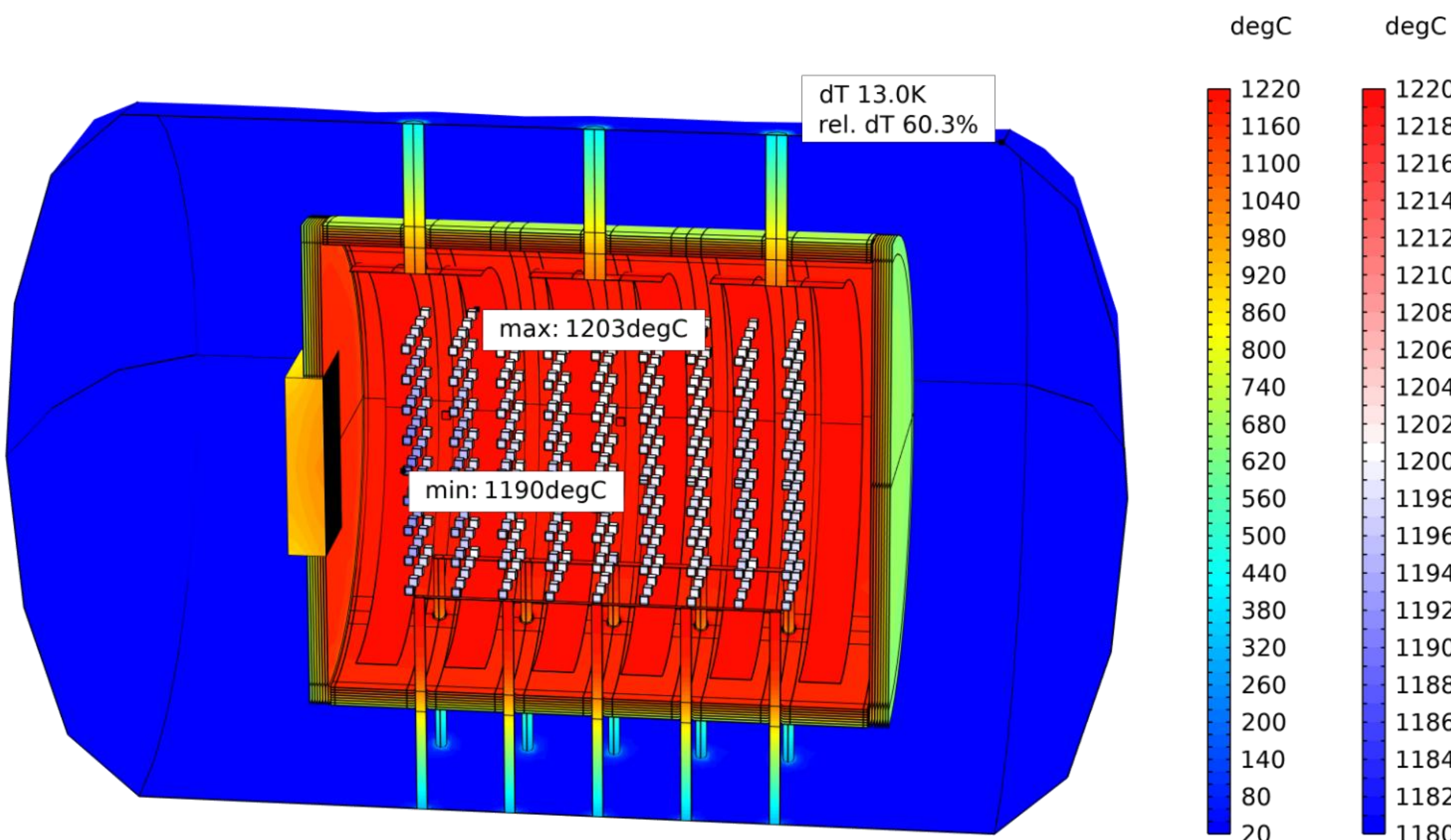


Figure 1: Temperature homogeneity in high temperature vacuum furnace with new rear gas outlet FlowBox.

## Model and Analysis Results

A stationary thermal model of the entire high temperature vacuum furnace was applied to analyse the potential of a FlowBox for an improved temperature homogeneity (Figure 1). Stationary thermal submodels of the rear gas outlet and gas inlet nozzles were used to predict the energy saving potential of the new gas system concept compared to a state-of-the-art gas system (Figure 2). In addition, gas flow and pressure decay, as a measure for cooling efficiency, were evaluated based on fluid dynamic calculations. Significant potential for energy savings at an improved temperature homogeneity without a loss of cooling efficiency is predicted for the newly developed gas system concept.

## Model validation

Based on these results, molybdenum parts were fabricated using laser powder bed fusion (LPBF). They have been integrated into and tested in a furnace at Plansee SE to evaluate power consumption, temperature homogeneity and cooling efficiency. The results confirmed the predictions of the multiphysics model. Power savings of 13 % and a significantly improved temperature homogeneity as well as an improved cooling efficiency could be demonstrated. This corresponds to energy savings of 70,000 kWh/a assuming typical operation conditions. This equates to cost savings of 14,000 €/a and a CO<sub>2</sub> footprint reduced by 21 tons per year.

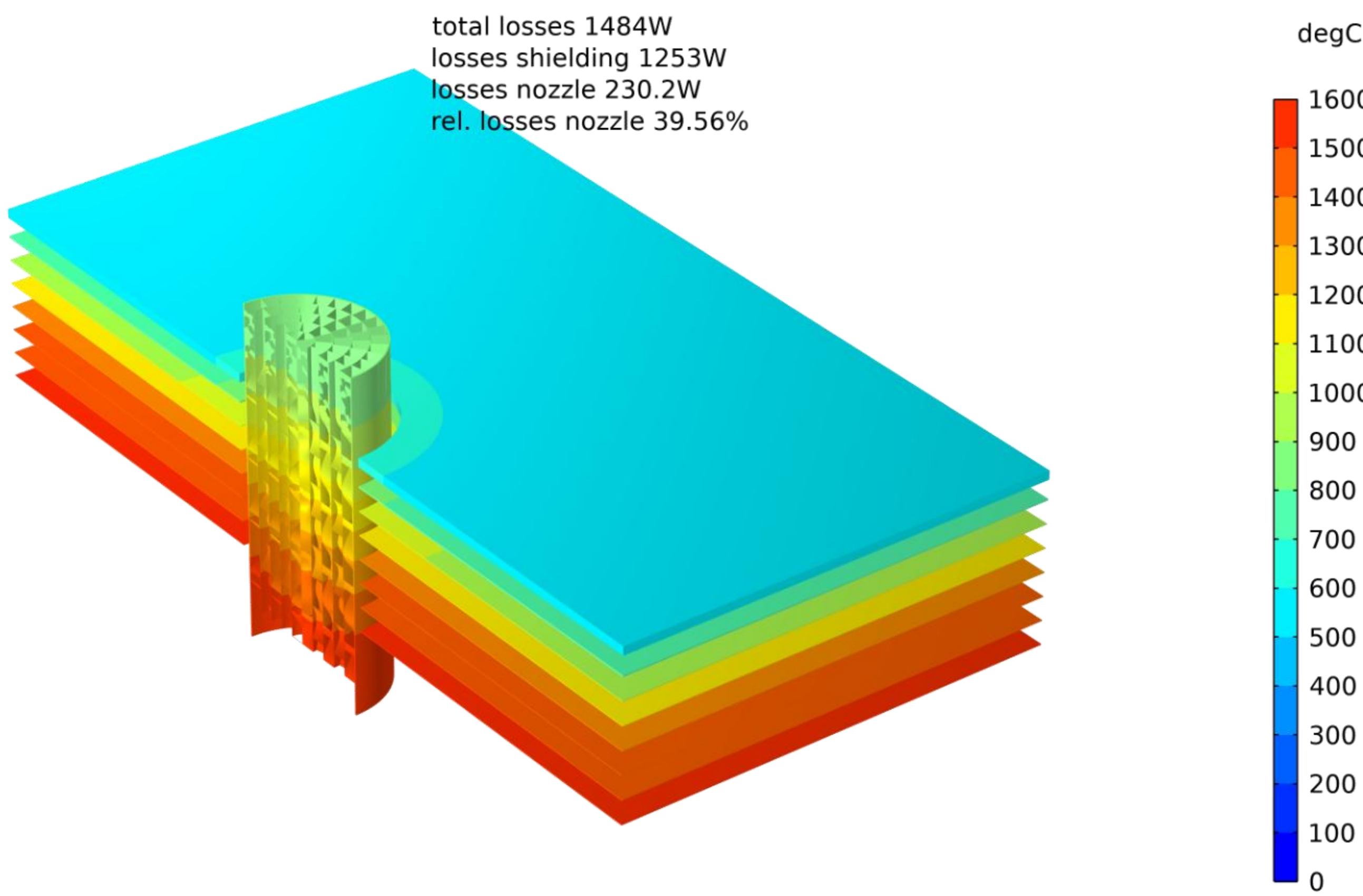


Figure 2: Power losses new gas nozzle concept.

## REFERENCES

[1] P. Schuster, et al., Gebrauchsmusterschrift AT 18094U1, (2023)

