Why 3D-print a 1.3 GHz copper RF cavity?

Motivation

Pulsed low-energy e^+ beam system (PLEPS) at the research neutron source Heinz Maier-Leibnitz (FRM II) enables highly sensitive defect characterization

- Current probing depth: <5 µm
- Target: ~1 MeV positrons
- Expected probing depth: mm range

Overall Goal: Enable the integration of a 1.3 GHz linear accelerator (Linac) in FRM II - based PLEPS setup.

Potential of Additive Manufacturing

Compact cavity with high cooling capacity needed for integration at PLEPS

➢ Use potential of Laser Powder Bed Fusion (L/PBF) to produce RF cavities

Rapid production

More compact

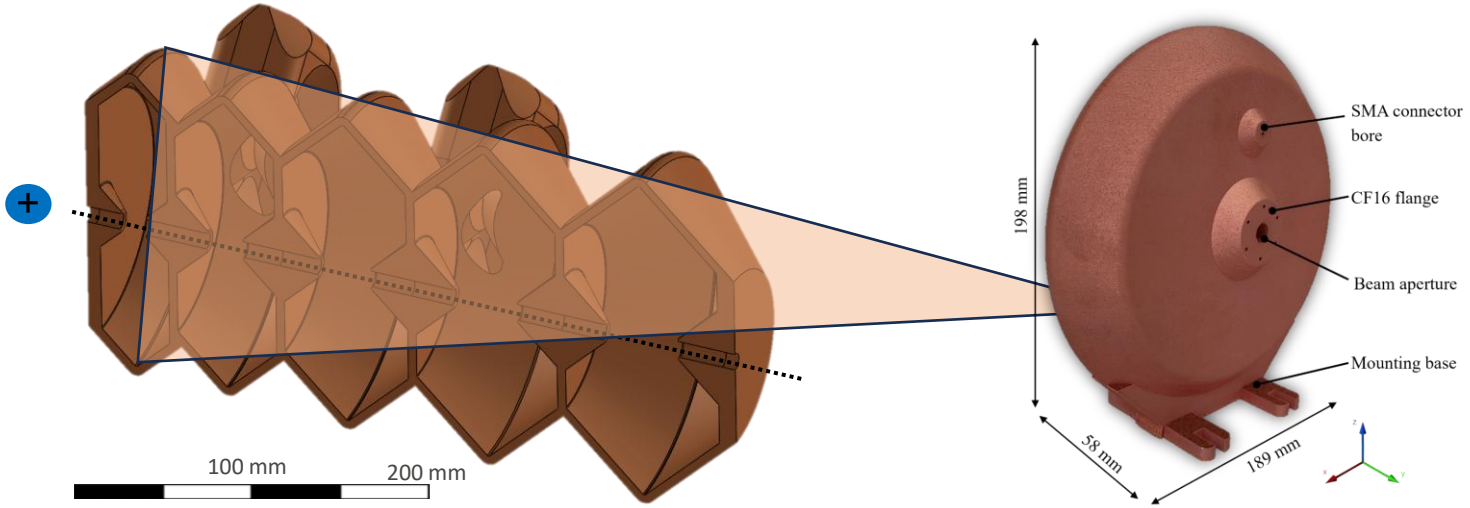
Freedom of design

Lower costs

Enhanced cooling

Future target: multi-cell 1.3 GHz structure

This work: first printed single-cell test cavity



First test cell was produced to analyze:

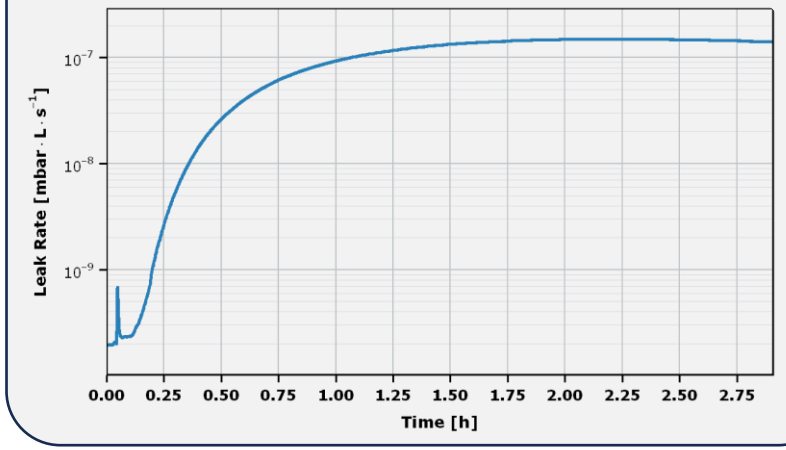
1. **Helium leak rate**
2. **Low-level RF properties: Q_0, σ_{eff}**
3. **Geometric distortion Δ**

First 1.3 GHz Test Cavity for Initial Studies

1. Measurement of helium leak rate

- O-ring permeation leak rate >10^{-7} mbar L/s
- Sufficient for the application, further improvement is desirable

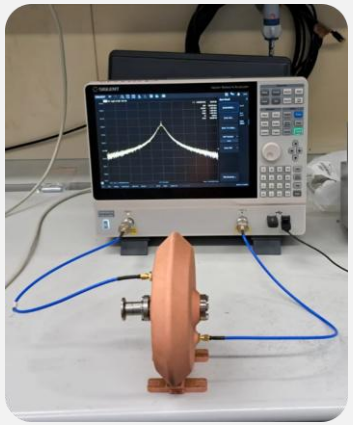
➢ **Improvement by metal gasket system**



2. Low-level RF measurement

- CST-simulation Q_0: approx. 14,200
- Measured Q_0: approx. 8,600
- Reduction of 36 % expected due to roughness

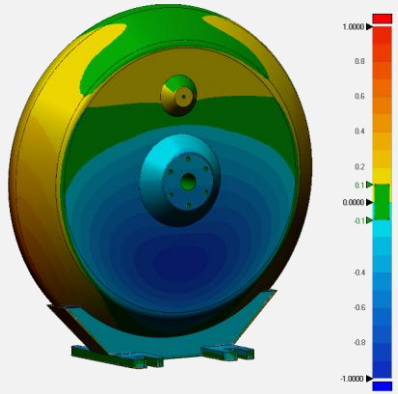
➢ **Post-processing is necessary**



3. Geometric distortion Δ

- Anisotropic distortion: largest Δ in depth; horizontal undersizing, vertical oversizing
- Tuning target: ~1 MHz
- Frequency deviation CST Δf_R : 3.56 MHz

➢ **Frequency deviation → distortion compensation needed**



➢ **Correction of geometric distortion is necessary**

- **Material model development**
  - **Evaluation of simulation software**
    - **CAD to print comparison**

- Production & evaluation of a benchmark geometry
- Simulation of a cavity cooling system
- Evaluation of distortion simulation software

➢ **Pure-copper L/PBF is viable for 1.3 GHz RF cavities — but surface finishing and distortion compensation are essential.**