

Building Welded and Brazed Accelerating Structures from Halves

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Outline

- Motivation
- Welded Open Structure
- Structure Brazed-Through-Iris

Motivation

- Novel manufacturing technique: milling structure out of two halves instead of machining and then brazing single cells.
- **Cost efficient**: reduced number of parts and machining operations.
- No currents flow through the rf joint. This makes **pre-joining rf cold test practical** and useful.

And specifically for:

- **Welded Structure**
 - Possible to use with **hard copper alloys** and other materials or coatings which would be degraded by high temperature, potentially **improving high gradient performance** and reducing conditioning time.
 - High temperature brazing changes geometry. The welding allows for practical designs which **does not require tuning after the welding**.
 - Possibility of automation of assembly and joining of parts.
- **Brazed Structure**
 - No rf currents flowing crossing the joint at high power: risk of arcing or erosion in small, uncontrolled gaps between cells is dramatically reduced.

Welded Open Structure

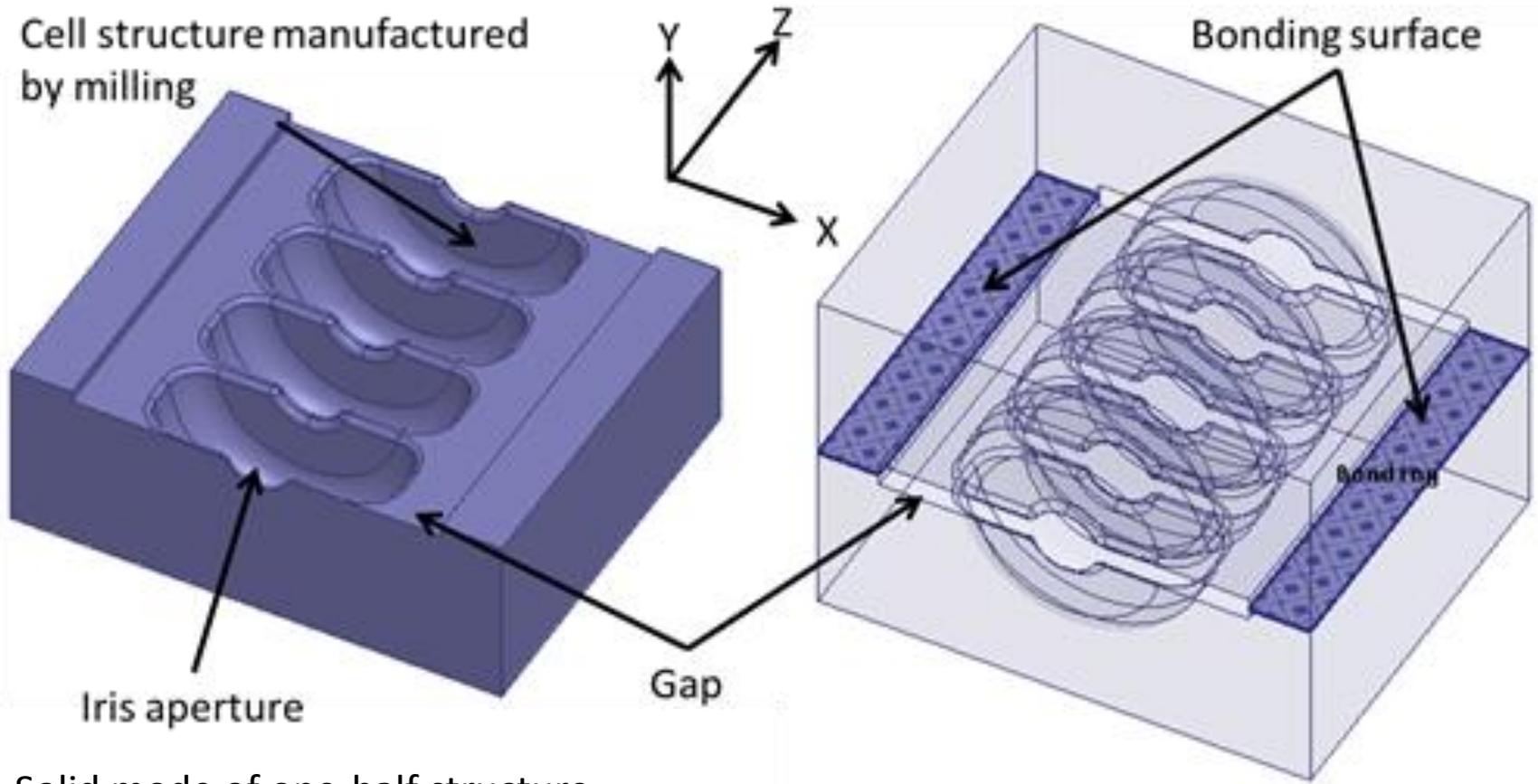
Approach

- Build **copper brazed** open structure first to identify potential problems with the open geometry.
- After successful high power test of the brazed copper version build cavity with an identical geometry but made of **hard, not-heat treated CuAg** and electron-beam-weld it.

Accelerating structure parameters

Loaded gradient* [MV/m]	100
Working frequency [GHz]	11.994
Phase advance per cell	$2\pi/3$
Active structure length [mm]	217
Input/output radii [mm]	3.15/2.35
Input/output iris thickness [mm]	1.67/1.00
Q factor [Cu]	7112/7445
Group velocity [%c]	1.99/1.06
Shunt impedance [M Ω /m]	107/137
Peak input power [MW]	60.9
Filling time [ns]	49.5
Maximum E-field [MV/m]	313
Maximum modified Poynting vector[MW/mm ²]	7.09
Maximum pluse heating temperature rise [K]	35

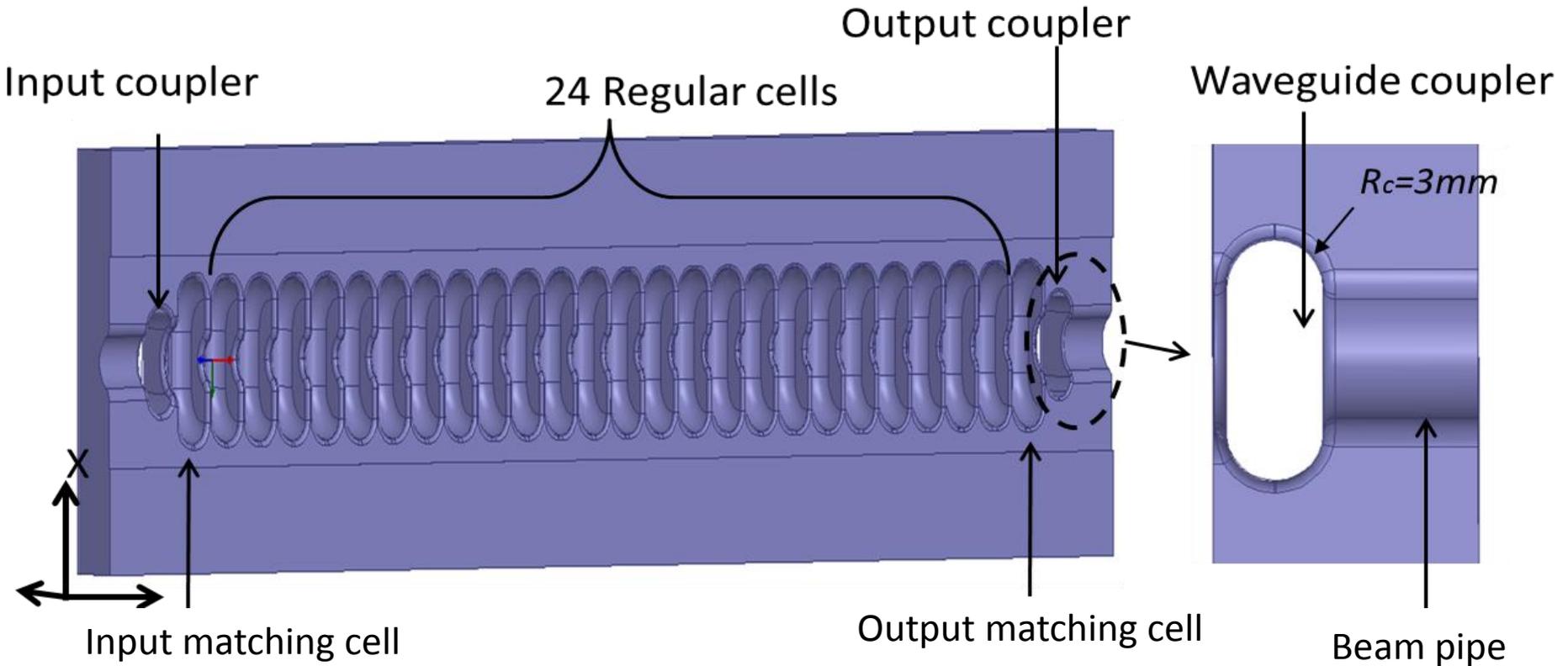
First Step: Brazed Copper Version



Solid mode of one-half structure

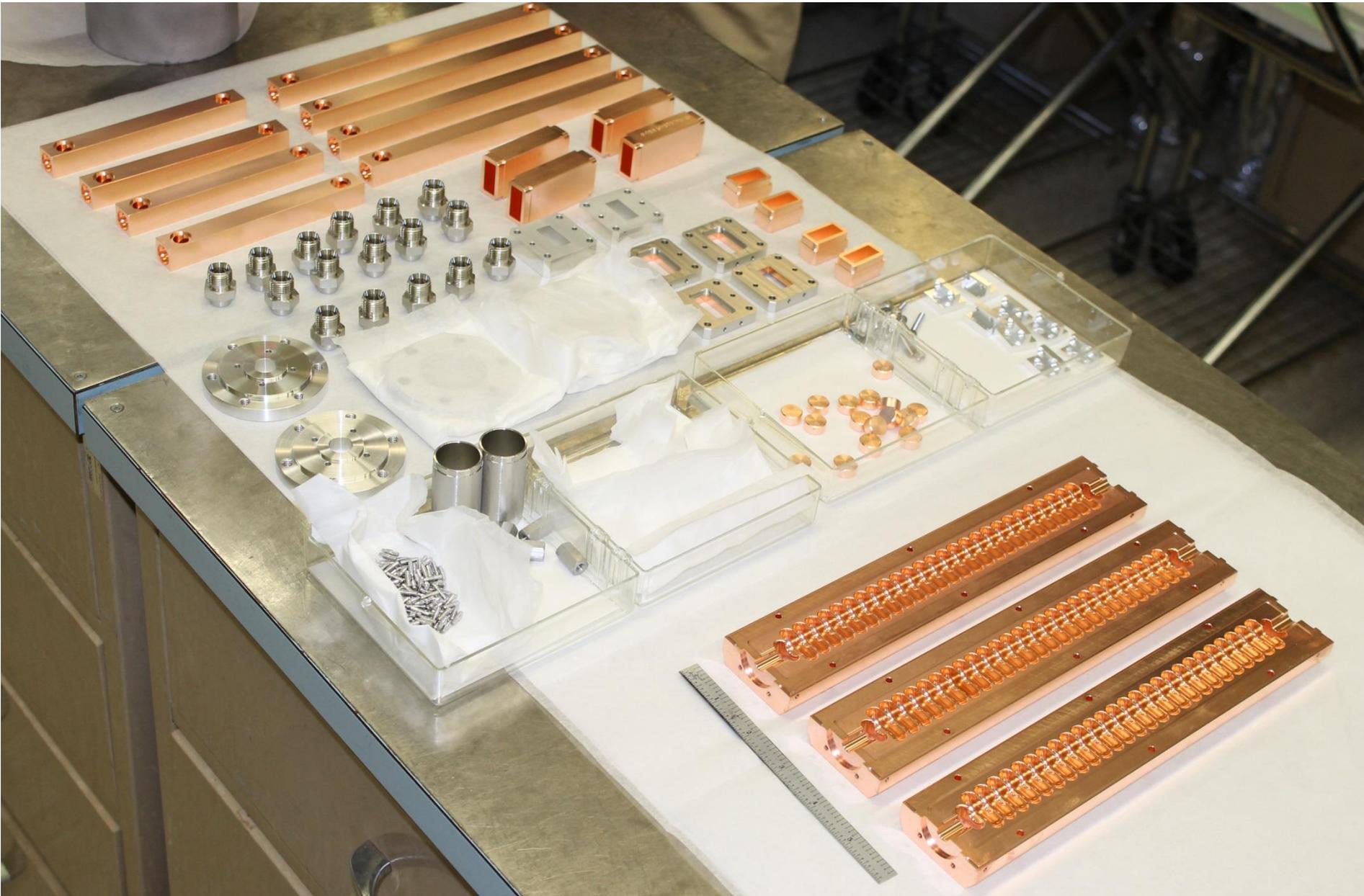
Two halves bonded together

Solid model of half-structure with waveguide couplers



The model is exported from HFSS and imported into SolidEdge

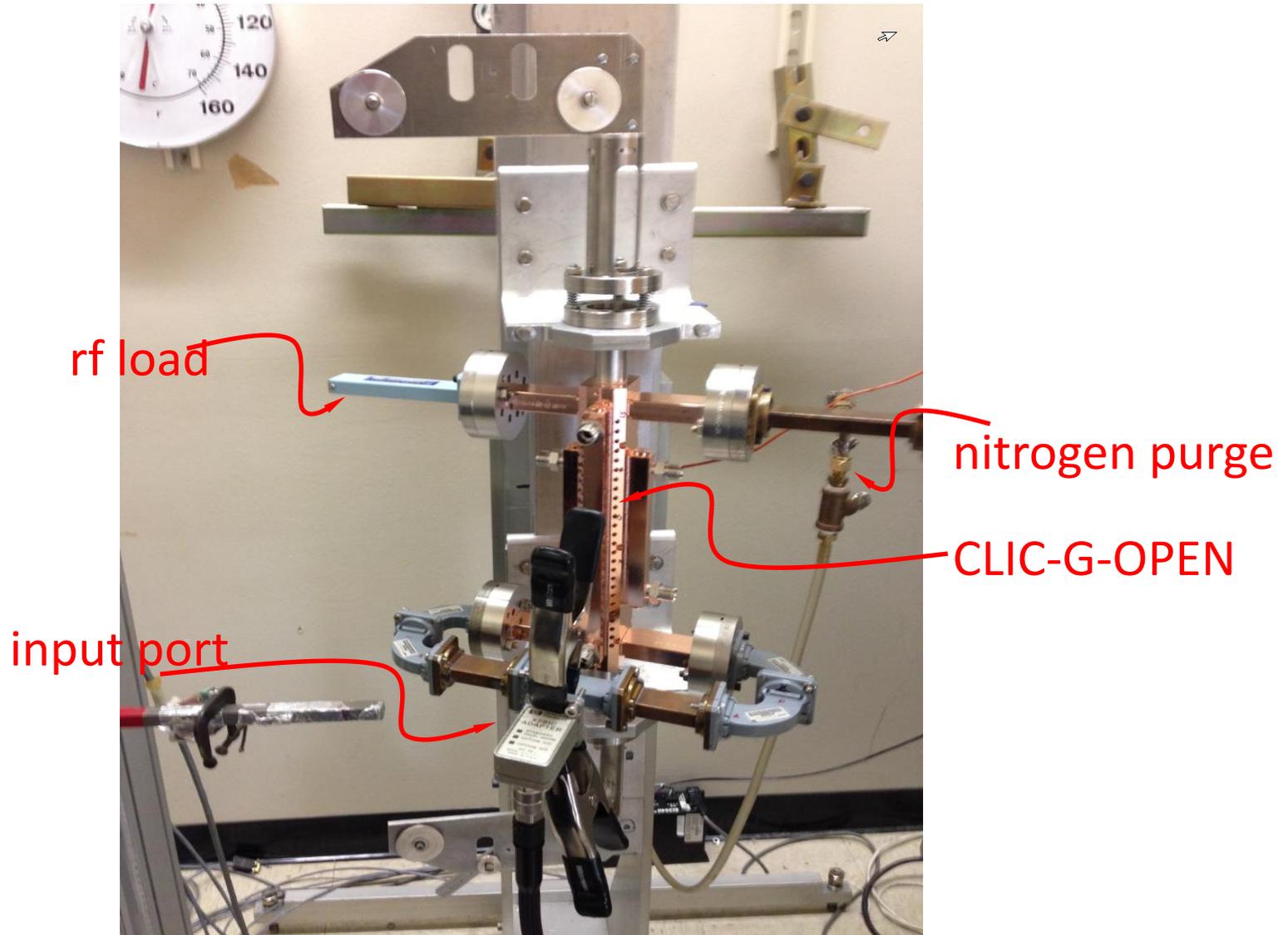
CLIC-G-Open parts ready for pre-brazing cold test



Input Part of the Half-Structure



After-braze Bead-Pull Setup

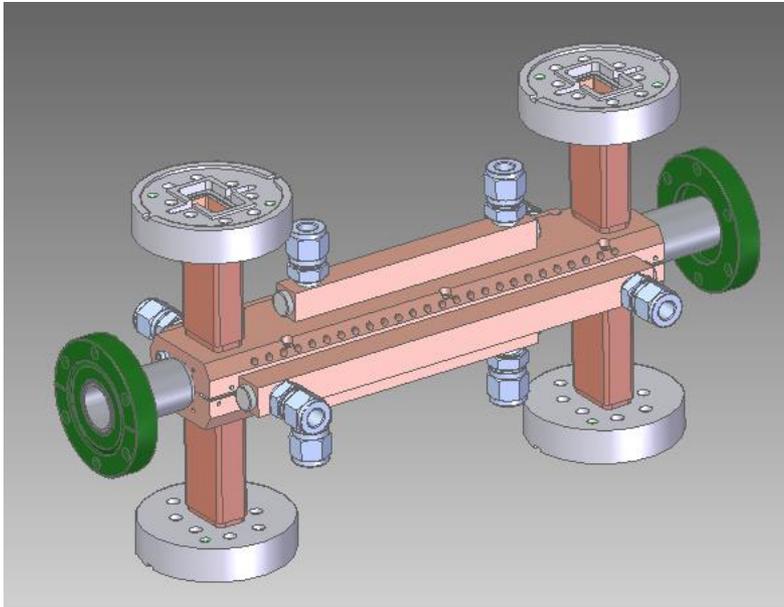


Next Step: Manufacturing of Welded Open Structure

Fabrication plan:

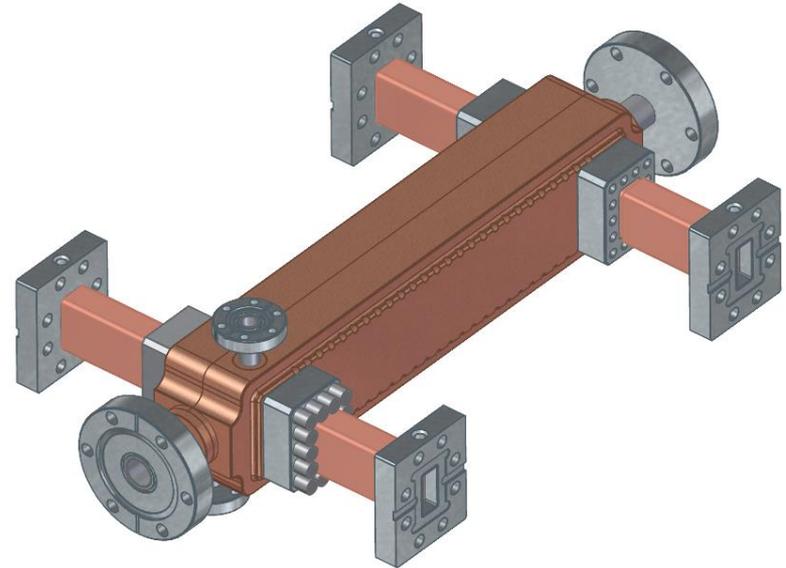
- Slab machining from imported solid model, use scaled model to account for push-only tuning
- Clamped cold testing – pre welding beadpull
- Cleaning
- Brazing of interface flange assemblies
- Electron-Beam-Welding of the halves
- Electron-Beam-Welding of interface flange assemblies to the structure body
- Bolting rf WR90 flanges to the structure body
- Push-only tuning and RF characterization

Open Structure External Features: Brazed vs. Welded



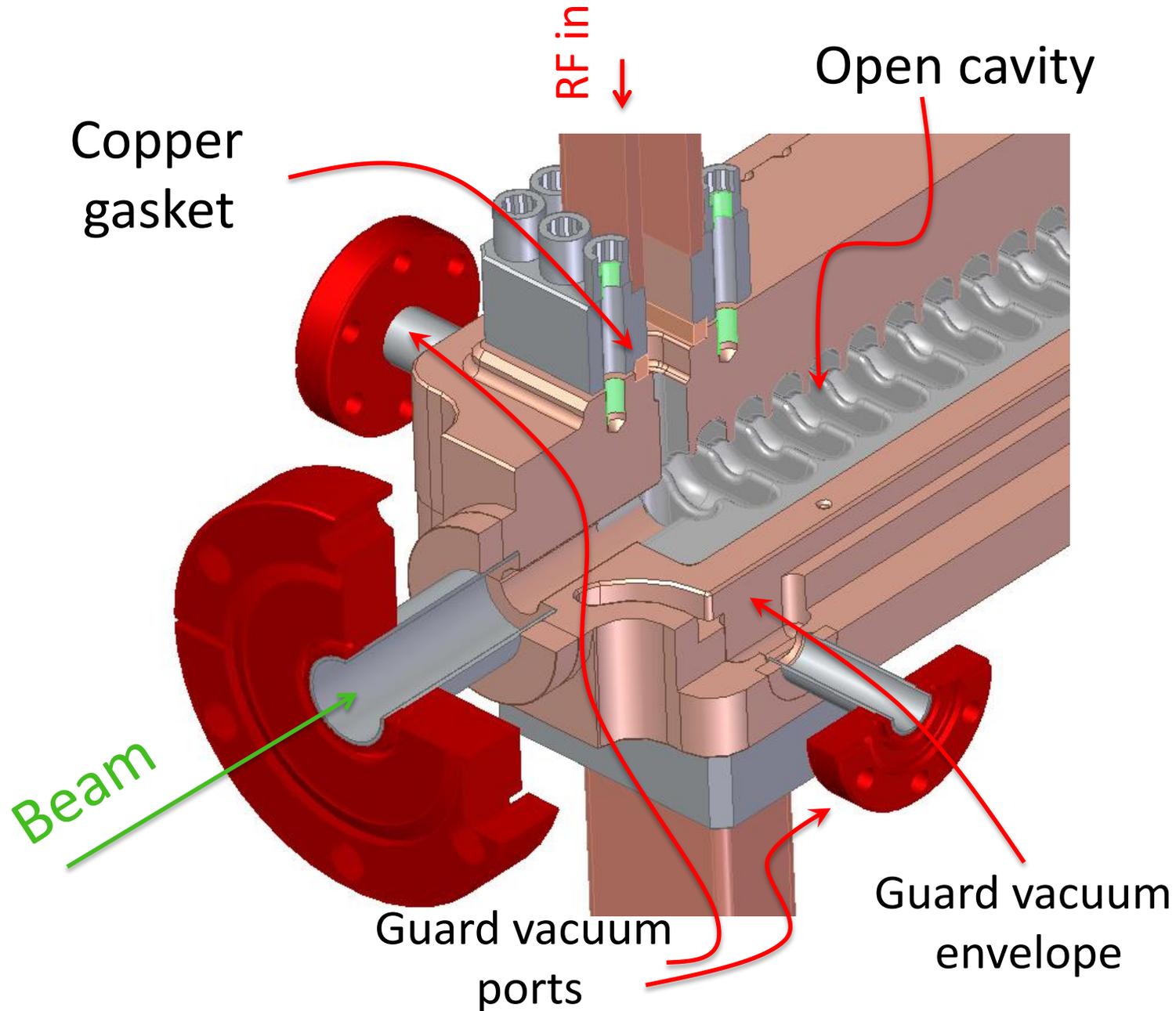
- SLAC RF flanges
- Brazed cooling circuit
- Brazed tuning pins

vs.



- International RF flanges
 - Clamped cooling circuit (not shown)
 - No tuning pins
- + Vacuum flanges for guard vacuum

Main Features of Welded Open Structure

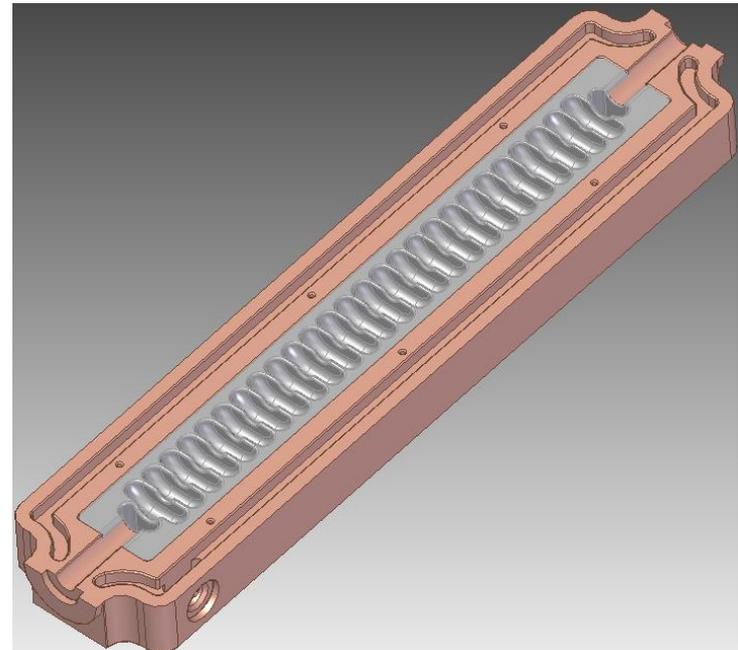
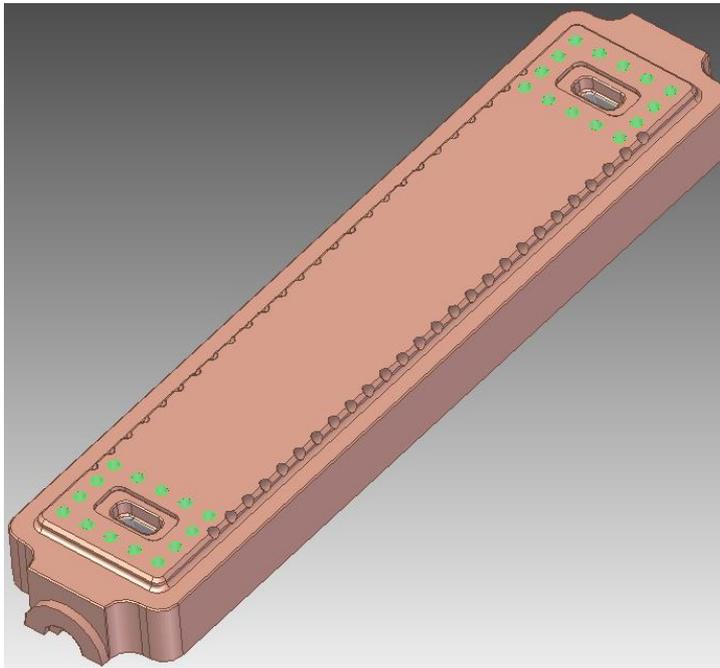


Building Half of Open Welded Structure

Machined features:

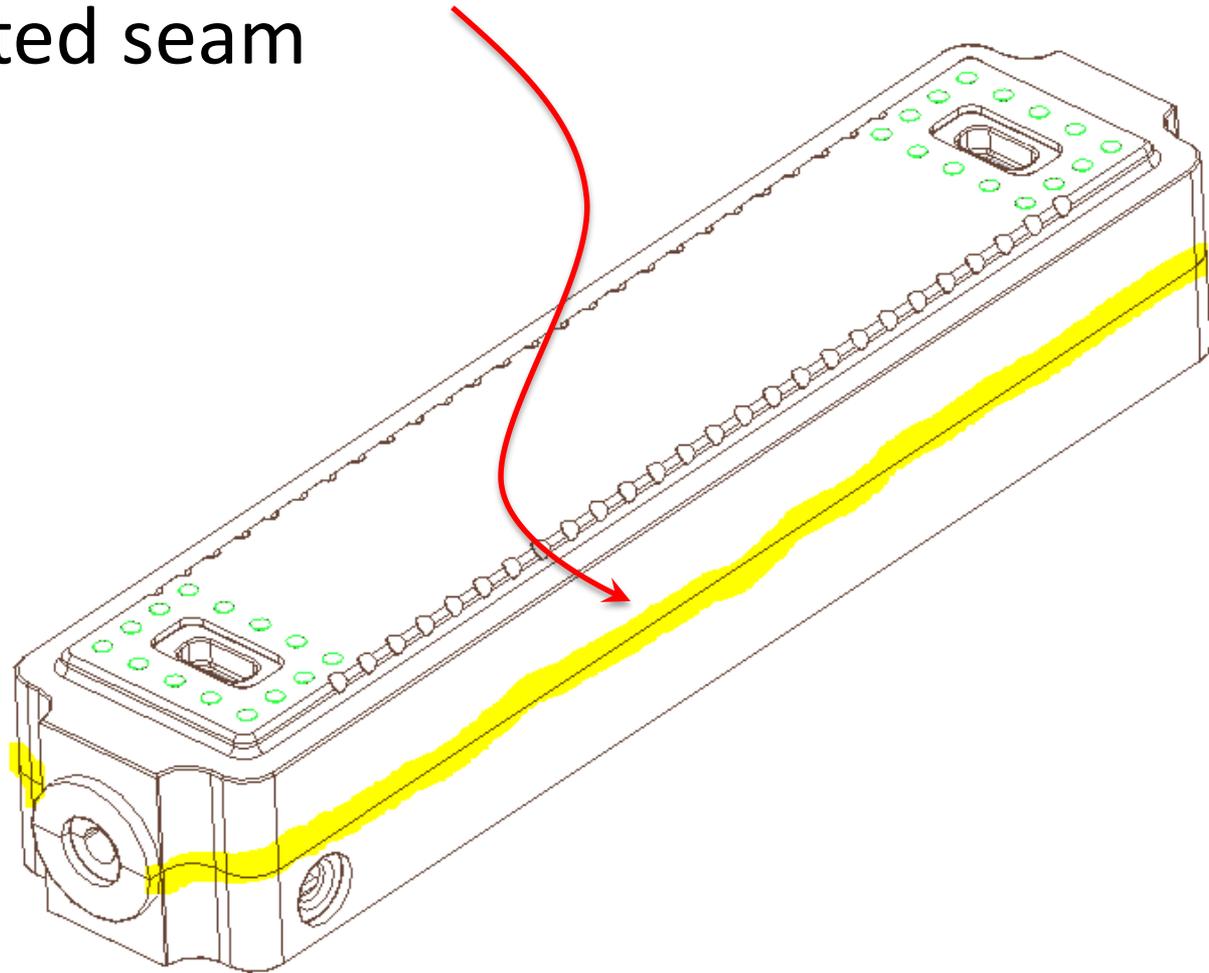
- Half of open cavity
- Input-output coupling waveguides
- Beam pipe connections prepped for welding of beam pipe assemblies
- Guard vacuum envelope and port
- WR90 attachment features
- Push-only tuning pads

New for
welded
structure

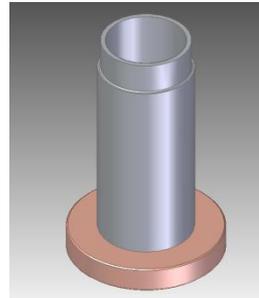
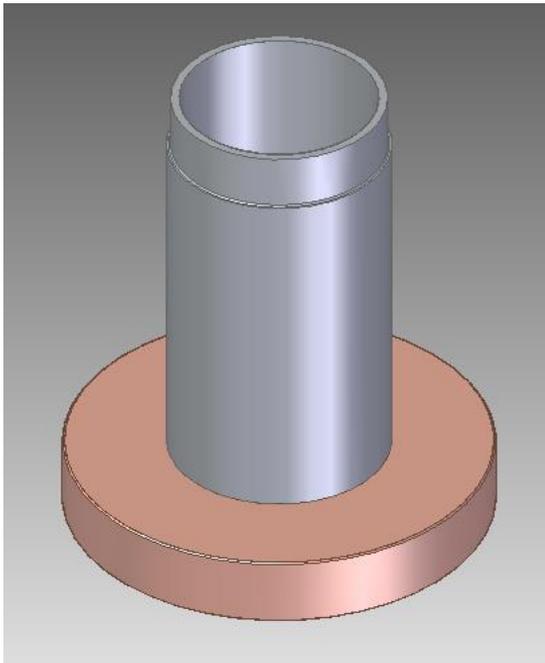


Primary Welding: Structure Body

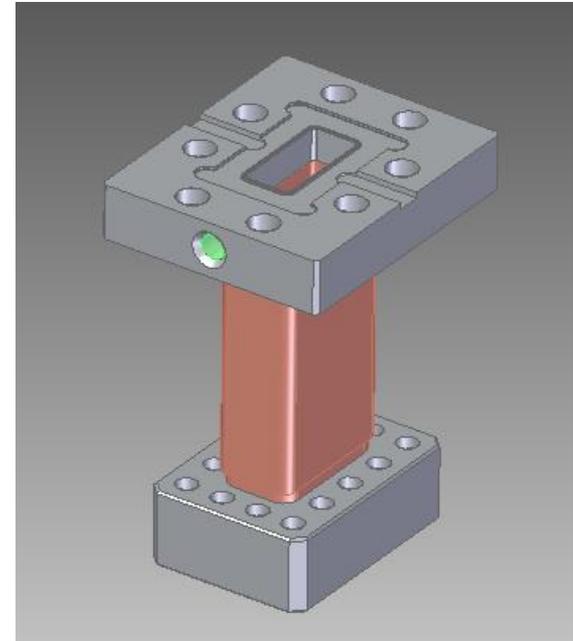
After “pre-welding cold test” the halves are clamped together and welded along the highlighted seam



Brazed Interface Assemblies



“Beam pipe assembly” and
“guard vacuum port assembly”
prepared for electron beam
welding to the structure body

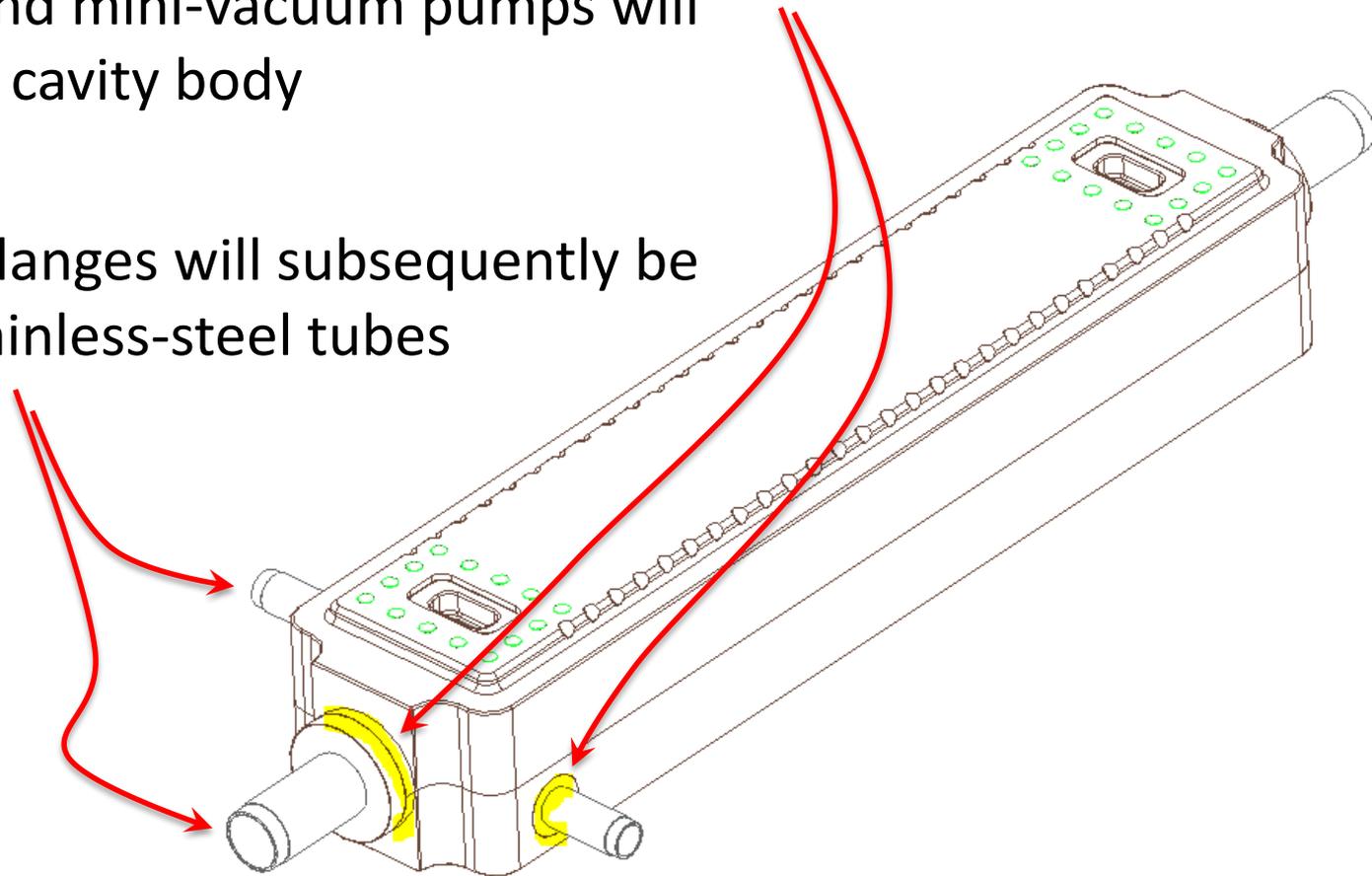


WR90 Brazed assembly
ready for bolting to the
structure body

Secondary Welding: Vacuum Interfaces

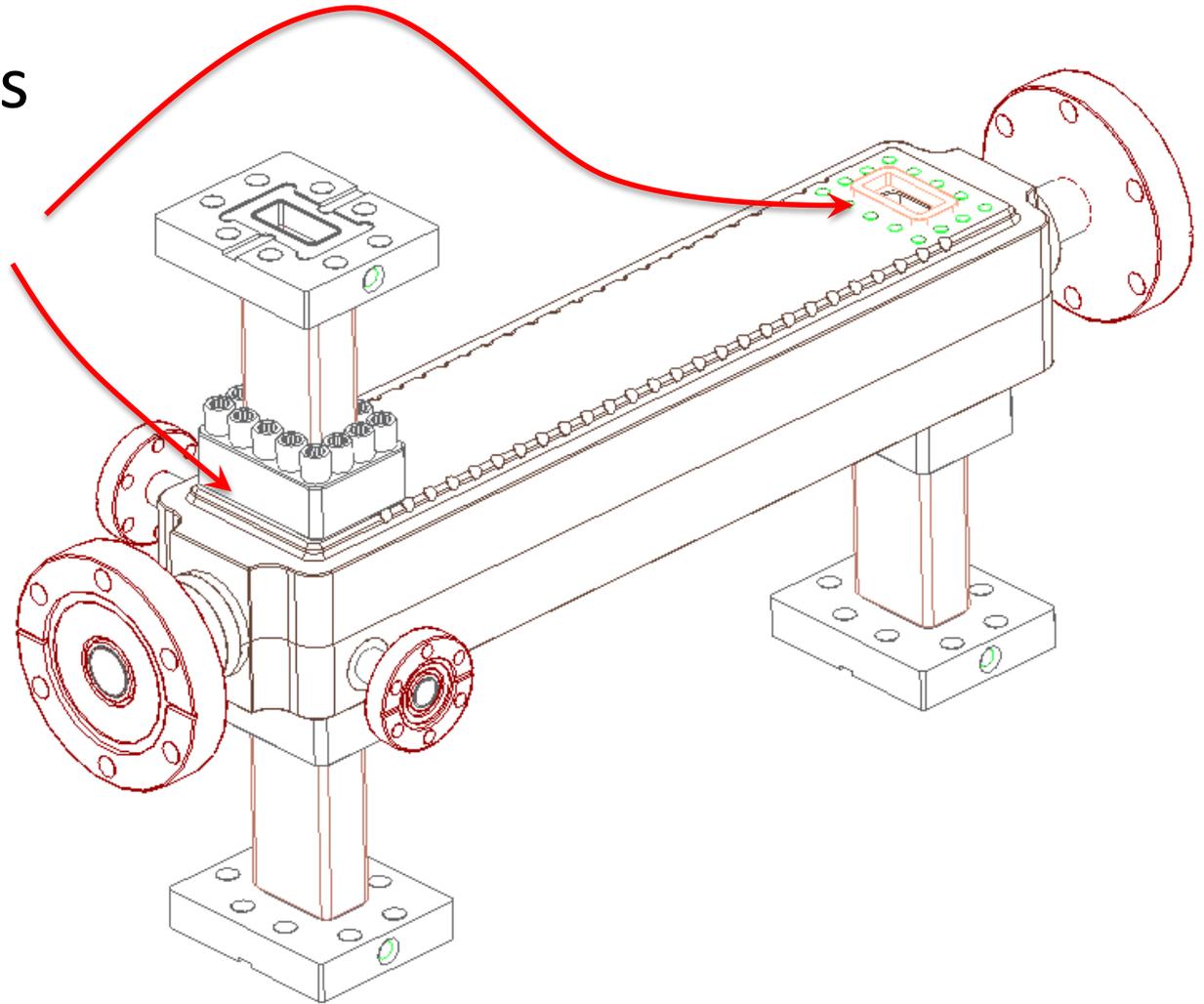
After the welding of the body is complete, previously fabricated “Cu to SST assemblies” for beam pipes and mini-vacuum pumps will be welded to the cavity body

Conflat vacuum flanges will subsequently be welded to the stainless-steel tubes



Final Assembly: Bolting WR90 flanges

The WR90 flanges are attached to the cavity body utilizing an annealed copper gasket



Structure Brazed Through the Irises

Approach:

- We used geometry of T24 PSI 12 GHz. This high-shunt-impedance structure made of symmetric cells with rounded outer diameter. This geometry is suitable for manufacturing by milling.
- We re-designed mode-launcher so it could be milled out of solid copper block.
 - Riccardo Zennaro, Alexej Grudiev, *RF Design of T24_PSI 12 GHz Prototype Structure*, CERN, 2014
 - Massimo Dal Forno *et al.*, “*Design of a high power T M01 mode launcher optimized for manufacturing by milling,*” SLAC-PUB-16902

Manufacturing

– Mechanical design

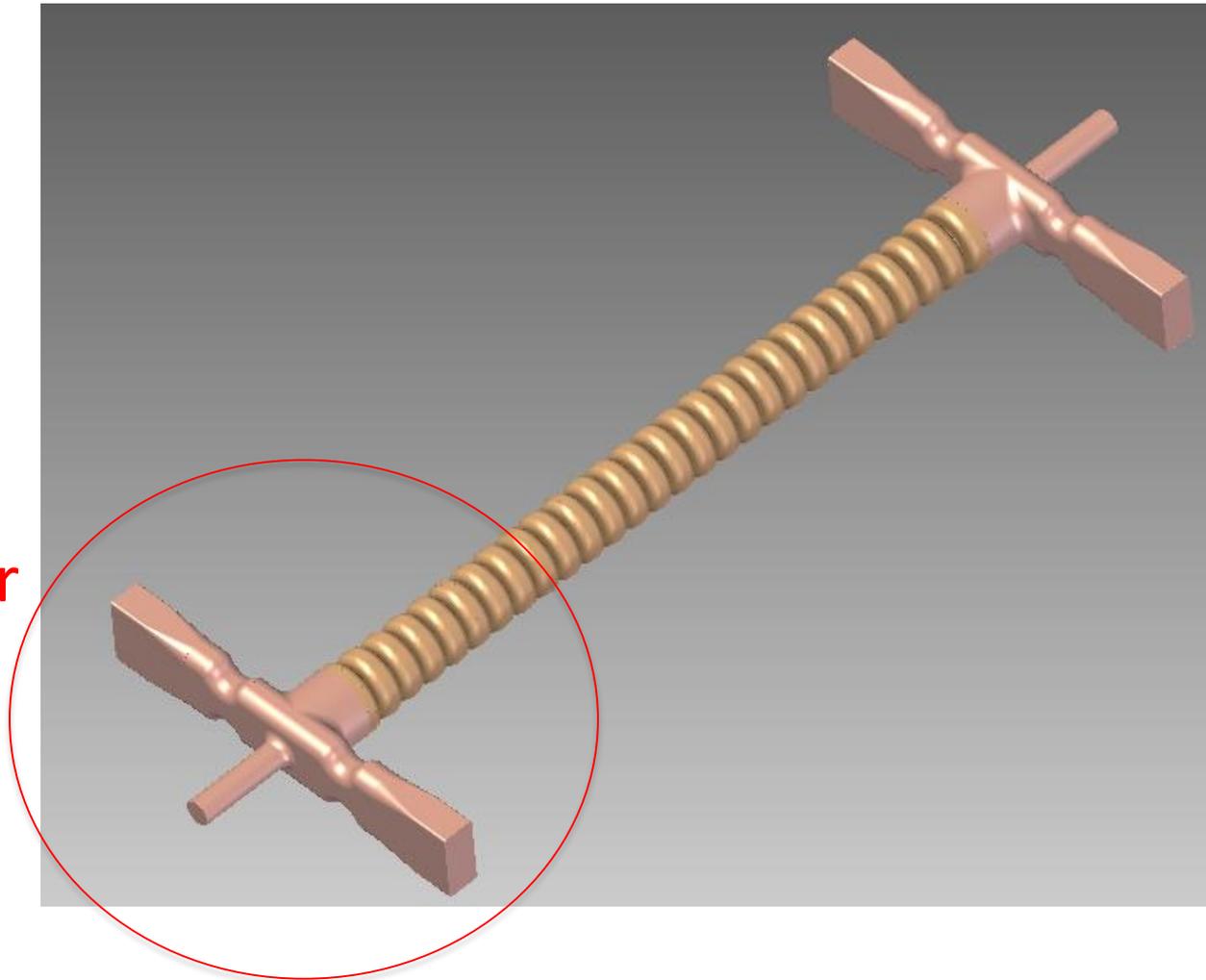
- Building solid model using electric model from HFSS
- Utilization of slab design
- Integration of existing designs/hardware/interfaces

– Fabrication

- Slab machining from imported solid model
- Clamped cold testing – pre brazing beadpull
- Cleaning
- Brazing
- After-braze tuning and characterization
- Vacuum firing

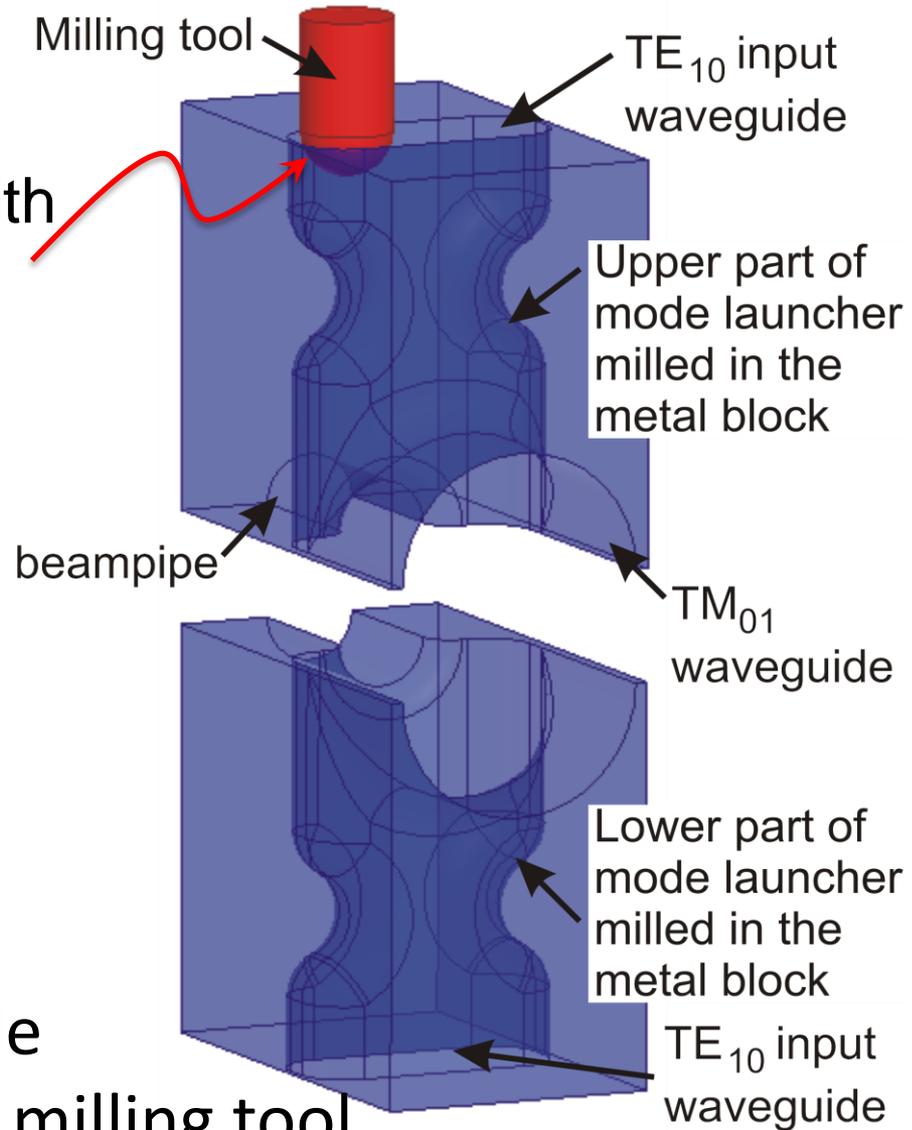
Solid model of RF envelope with re-designed mode launcher as Imported into SolidEdge from HFSS

New
Mode
Launcher



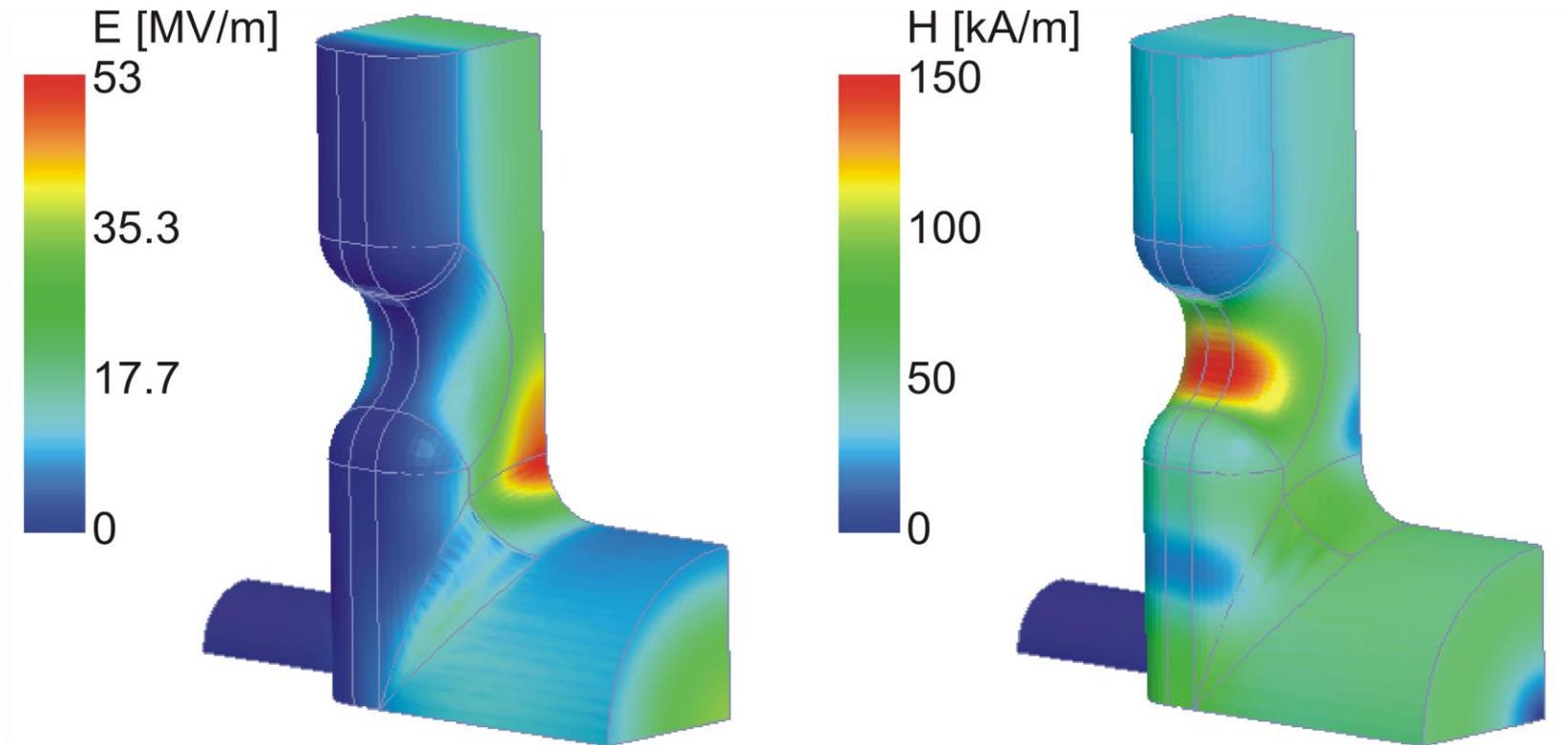
New Mode Launcher: Design Approach

Structures will be milled with a 8 mm diameter tool



Solid model of half mode launcher, with detail of milling tool.

Surface Fields in the New Mode Launcher



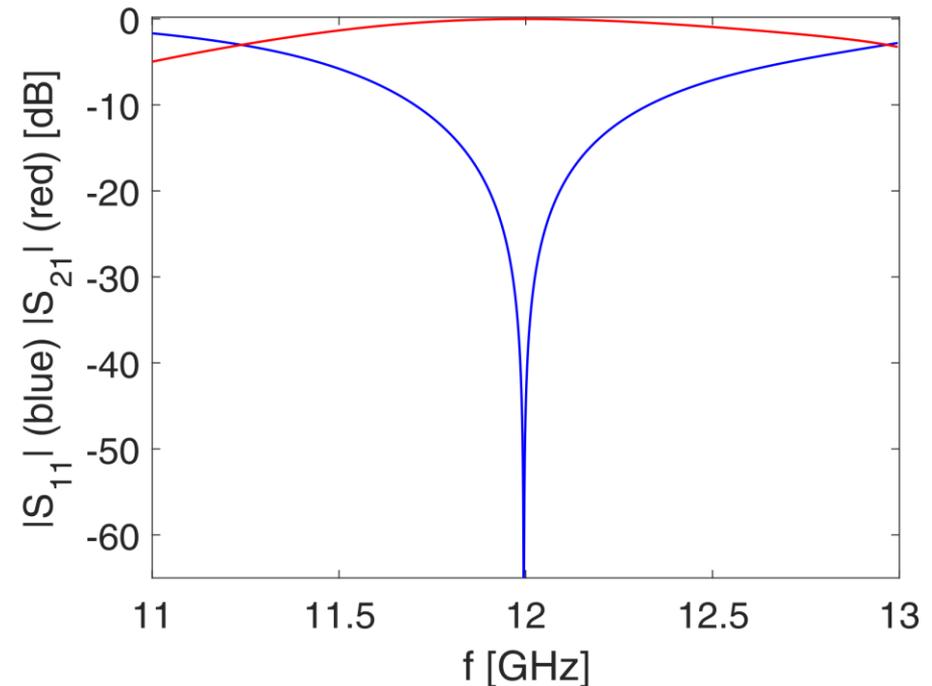
Peak fields for 100 MW of transmitted power.
Peak pulsed surface heating = 14 K for 2 μ s RF pulse

New Mode Launcher: Parameters

- $S_{11} = -65$ dB (@ $f = 11.9942$ GHz).
- 60 MHz bandwidth (@ -30 dB of reflection).

For 100 MW square pulse with $\tau_p = 2 \mu\text{s}$:

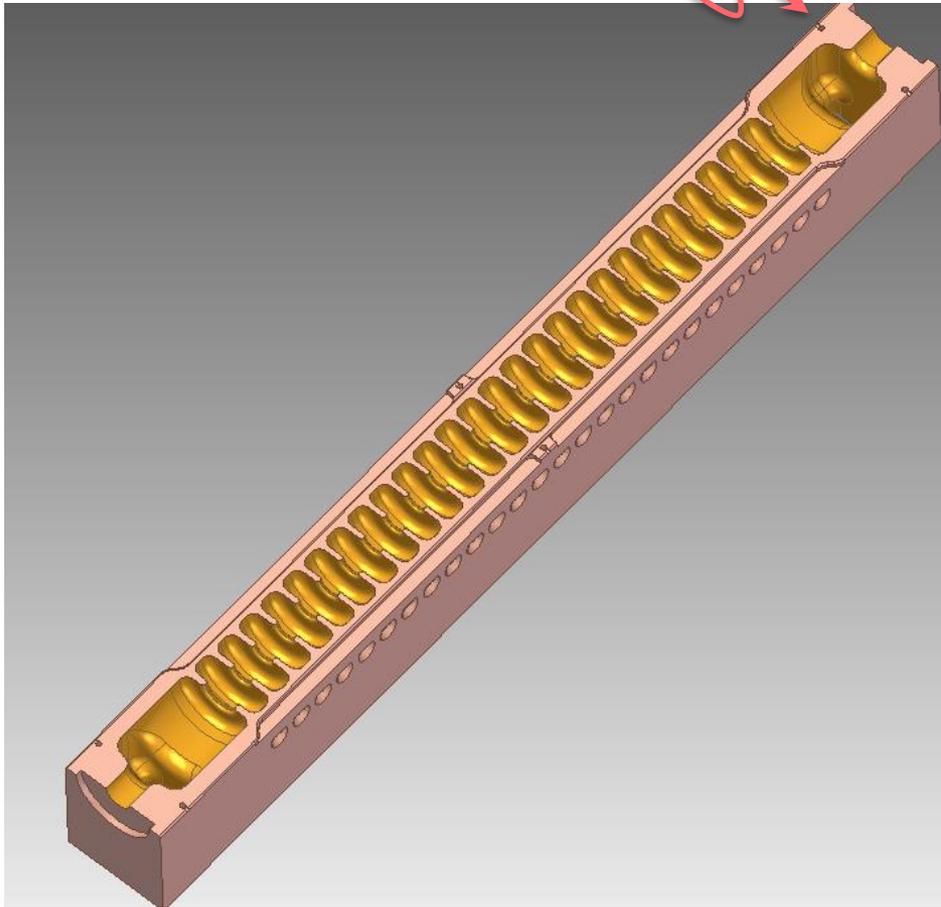
- $E_{\text{max}} = 53$ MV/m;
- $H_{\text{max}} = 150$ kA/m;
- peak pulsed surface heating = 14 K ().



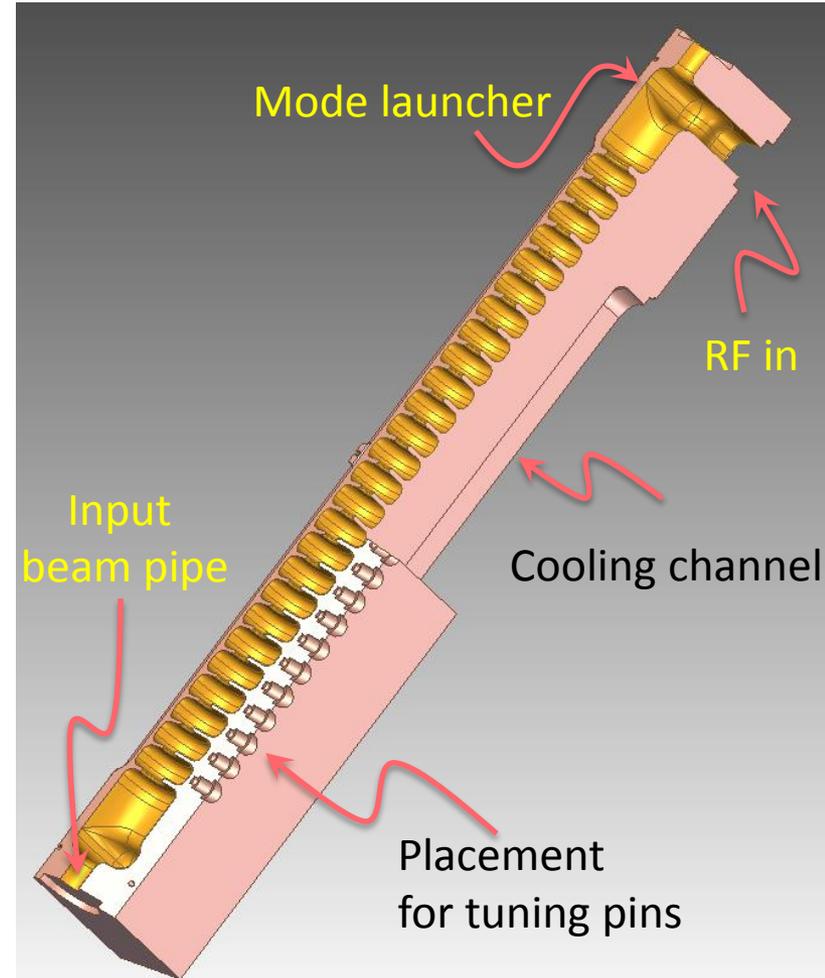
S11 vs. Frequency

Half Cavity

Holes
for alignment pins

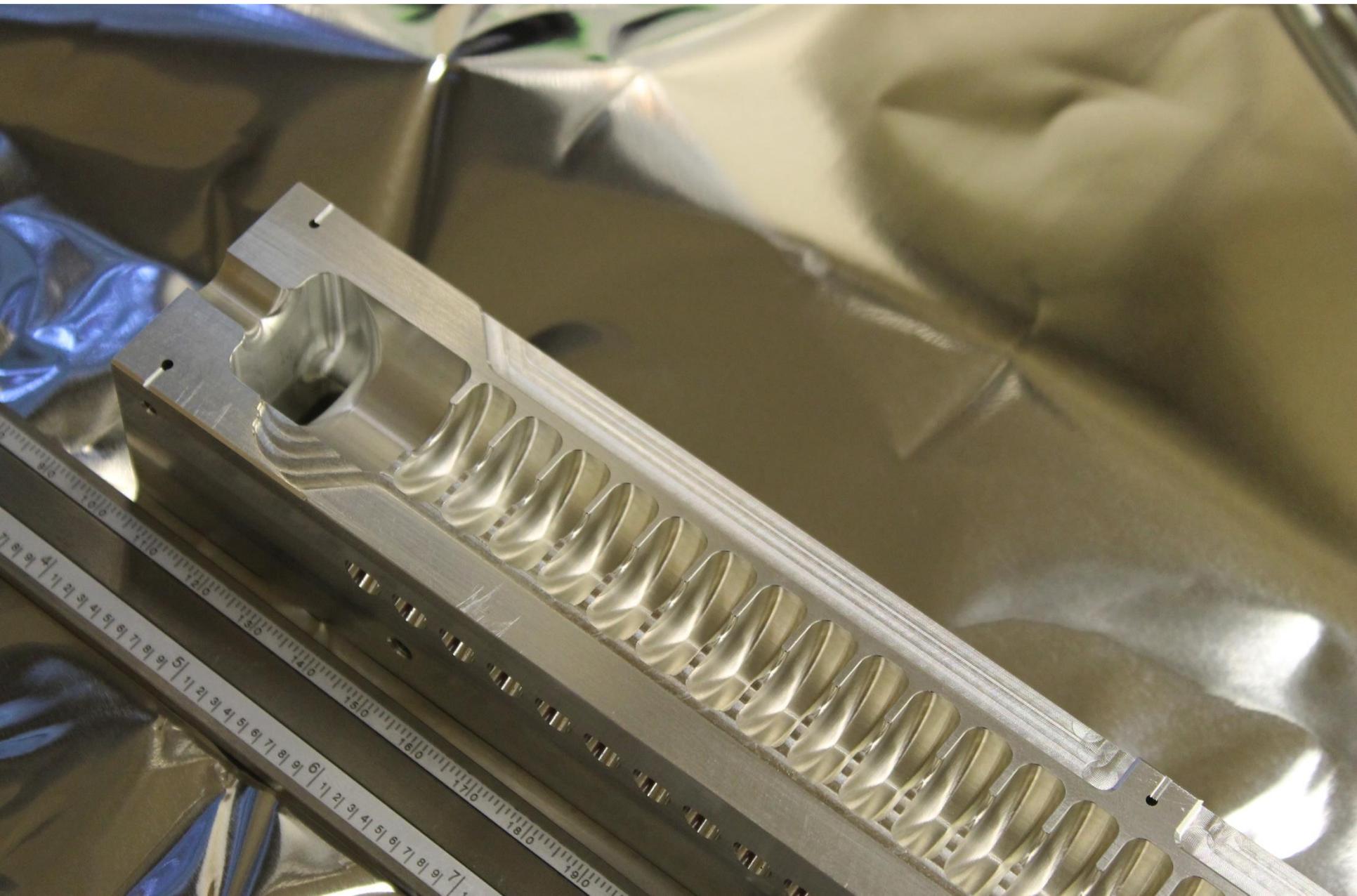


Solid model of half cavity

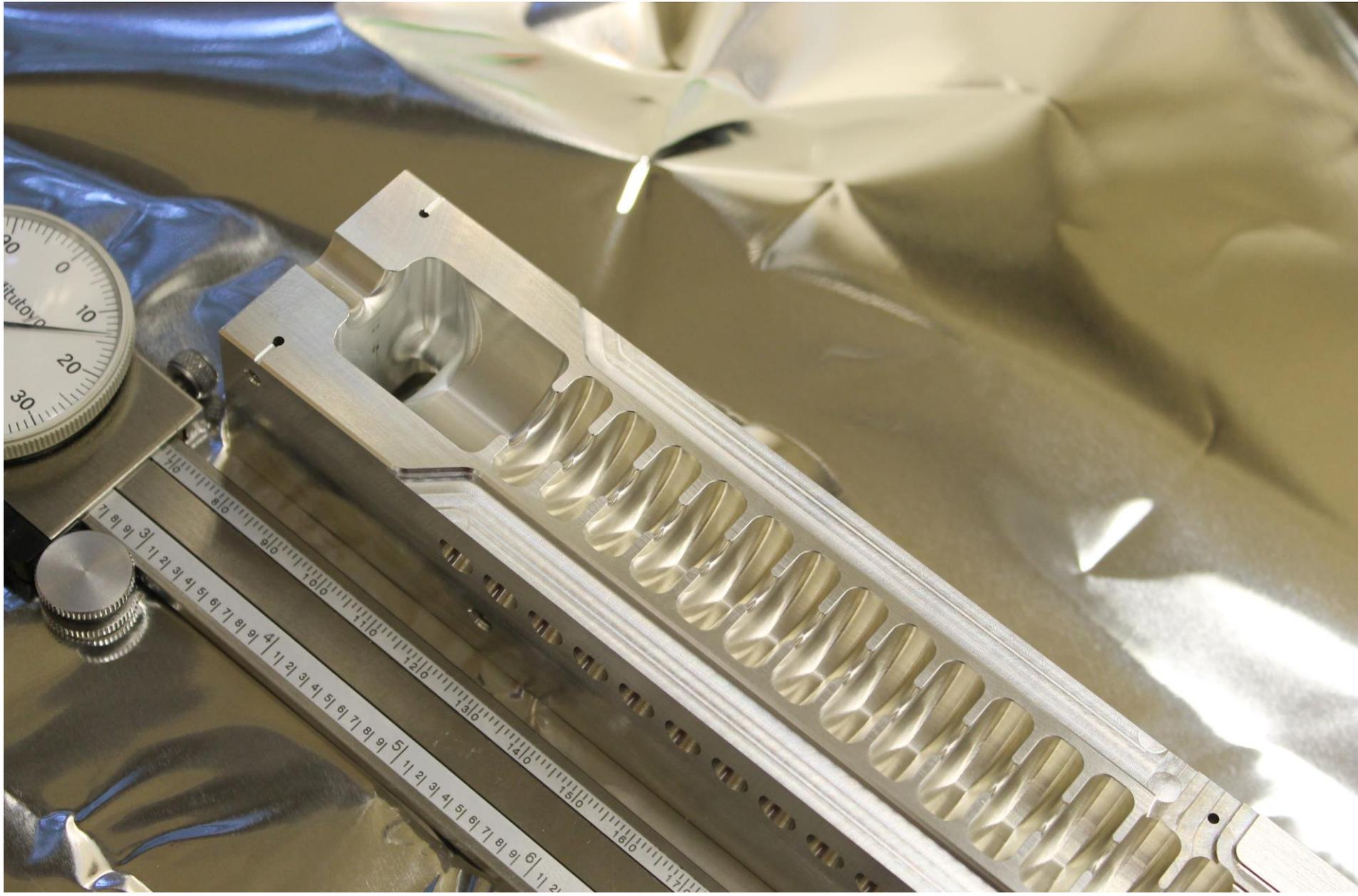


Cutaway of the solid model

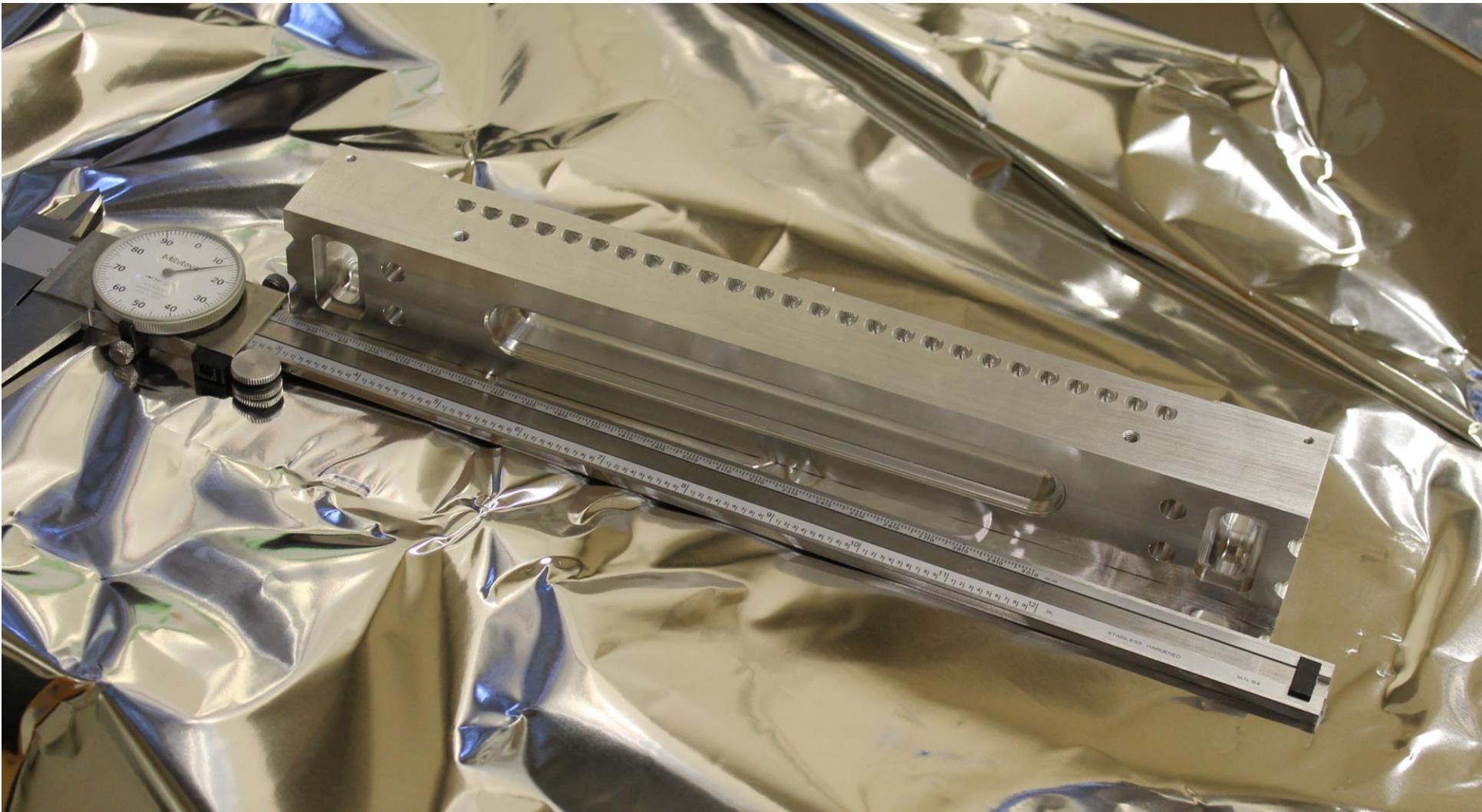
Aluminum Prototype of the Brazen Structure Half: Input Part



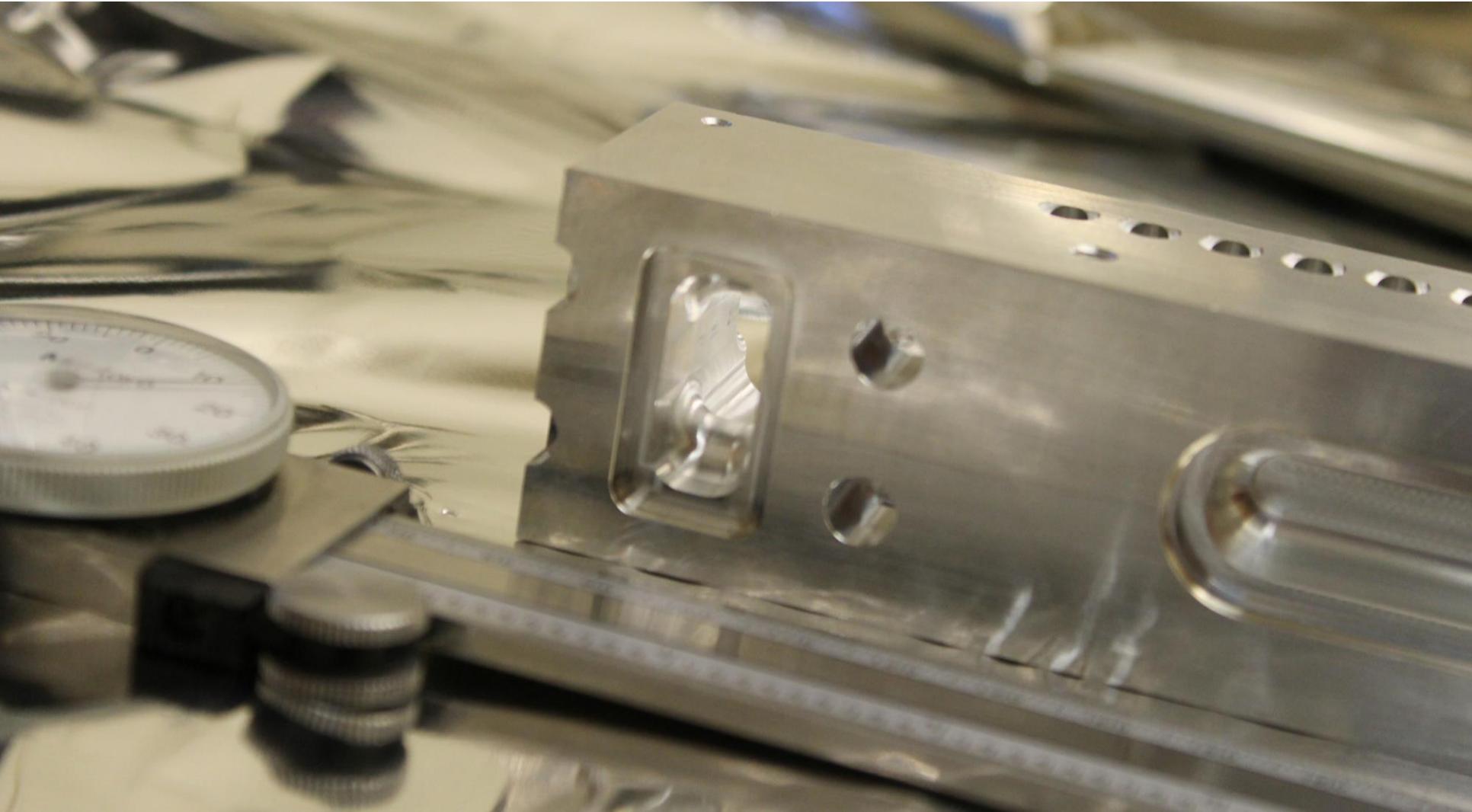
Aluminum Prototype of the Brazen Structure Half: Output Part



Aluminum Prototype of the Brazen Structure Half: Cooling Channel, Placement for Tuning Pins

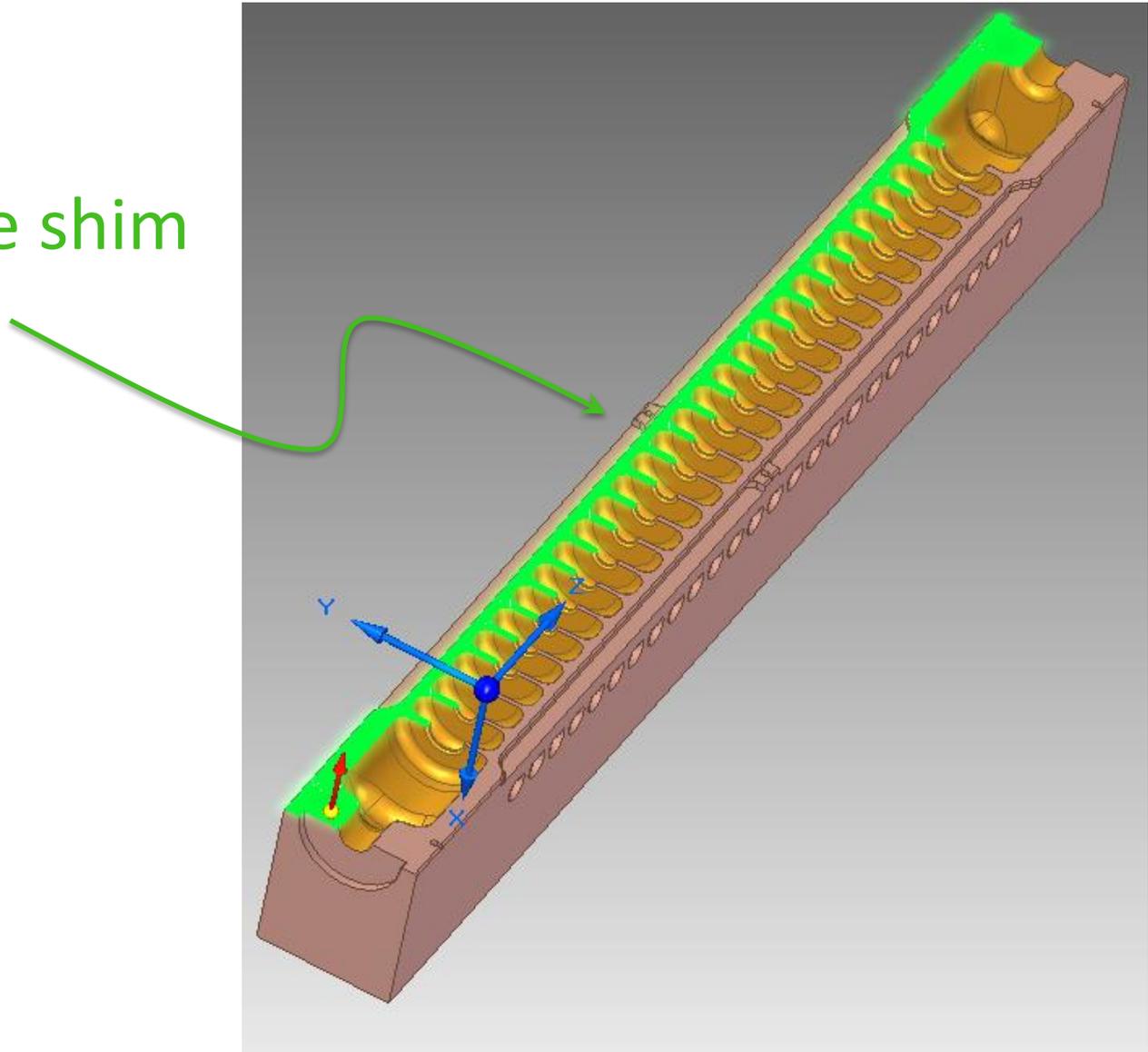


Aluminum Prototype of the Brazen Structure Half: Input Waveguide

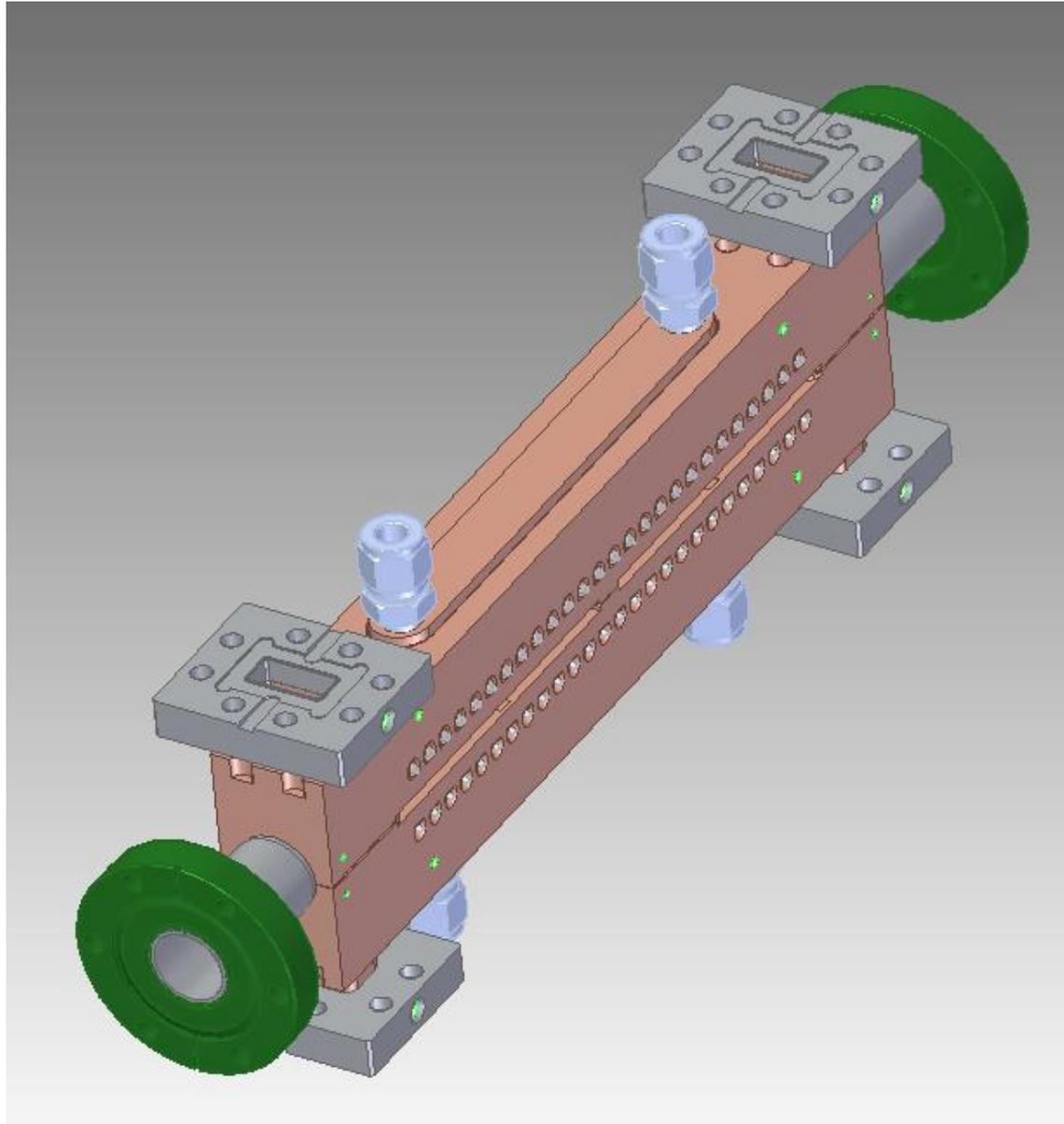


Braze Shim Design

.002" braze shim



Final Assembly of the Brazed Structure



Summary

We started marching of the structure brazed through the irises and about to start machining of the open welded structure.