HOM Absorber Design for eRHIC ERL Cavity (Now EIC)

SBIR Grant Award No. DE-SC0018466

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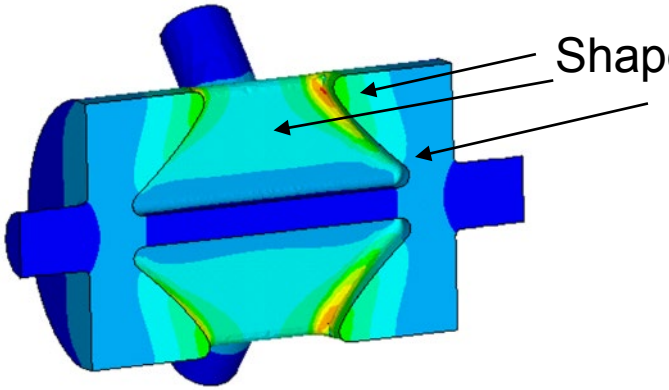
2023 SBIR STTR Exchange Meeting
Aug 16, 2023

Outline

- TJS Technologies LLC (2016)
  - Engineering Services
    - FHI Fritz Harbor Institute - ongoing
      - Free Electron Laser Deflector Cavity
        - » RF Thermal Analysis – Design, Coupling
        - » Beam dump and beam dump window
    - JLAB - ongoing
      - SRF Cavity Cooled by Cryocoolers – Thermal Analysis
      - FPC Coupling to Locate the FPC nearer the cavity (450kW per FPC)
      - Coaxial FPC Evaluation – RF/Thermal Analysis
  - Higher Order Mode Absorber SBIR Phase I, II & IIA
    - Fabricated Prototypes
      - Waveguide
      - Beamline – Delivered to BNL
    - Phase IIA
      - Develop Low Weight Design Perform Low Power Testing
        - » Delivered to BNL
      - Fabricate HOM absorber for Crab Cavity

Engineering Service FHI

Develop a Beam Deflector to Provide 2 500 MHz Beams from a single 1 GHz beam for 2 Color FEL



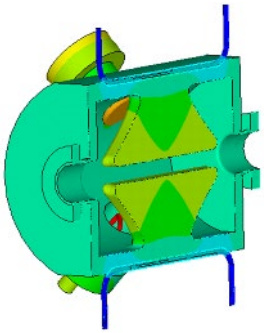
Shape modified for 500 MHz

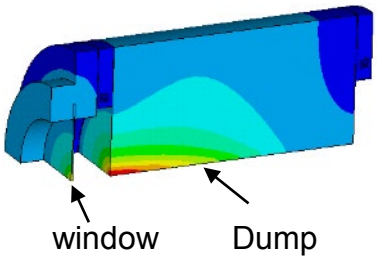
Frequency shift for manufacturing and tuning

RF Analysis

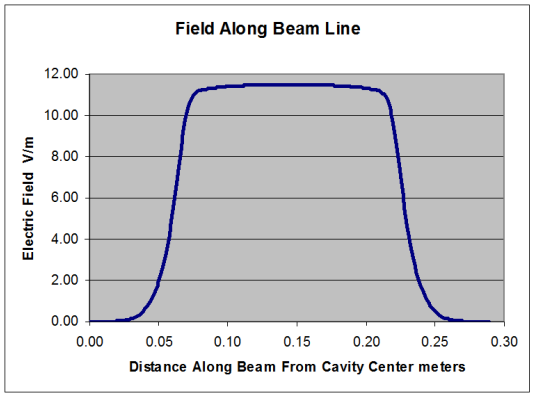
Deflector Cavity

Beam Dump and Window

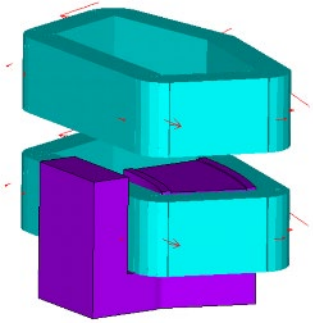




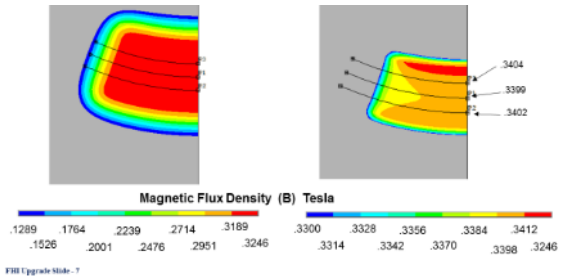
Thermal Analysis



Electric Field Along Beamline

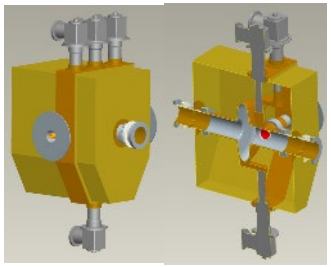


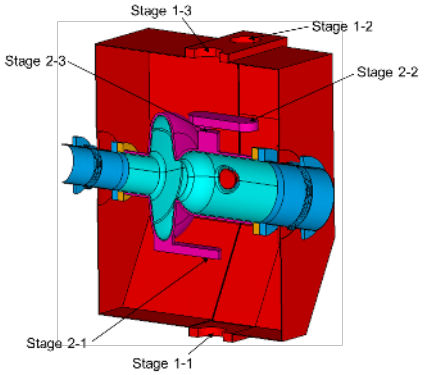
3-D Magnet calcs
Coil geometry
Specification
Field Quality

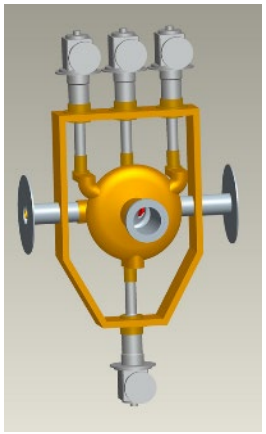


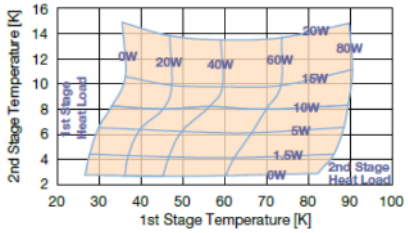
Magnet Analysis

Engineering Service JLAB



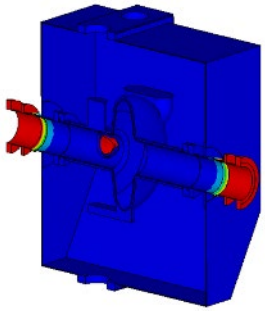


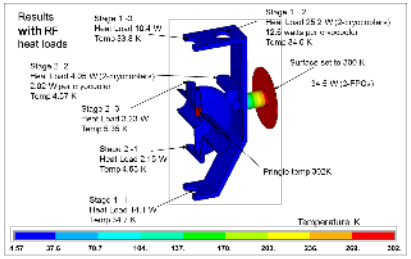


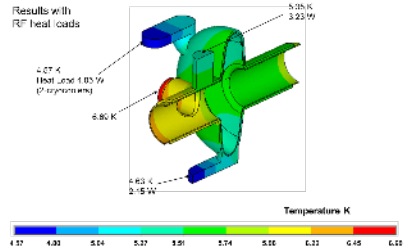


Cryocooler Capacity Map

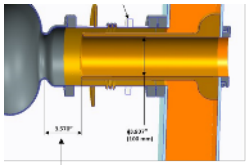
RF and Thermal Analysis and Side Coupling for power couplers





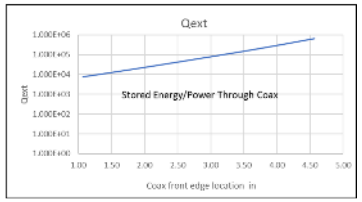


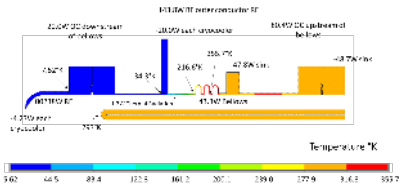
RF and Thermal Analysis Beam Pipe Coaxial Power Coupling



Distance from Cell 1 Iris	Qext
4.57	6.376E+05
3.59	1.658E+05
3.57	1.615E+05
3.47	1.427E+05
2.07	2.482E+04
1.07	7.632E+03

Stored Energy/Power Through Coax
Target Qext = 1.65e5





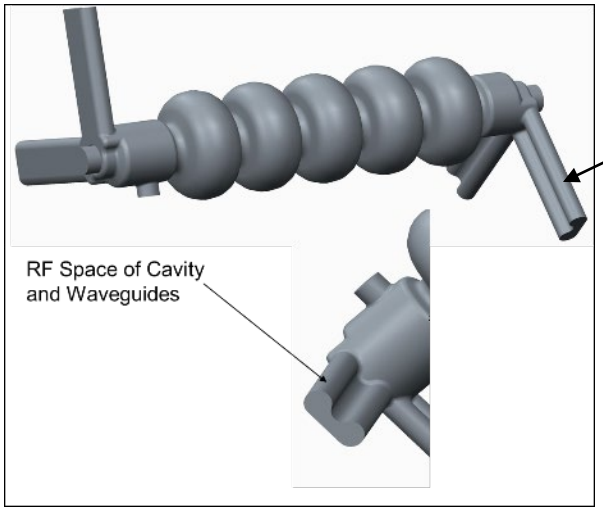
Higher Order Mode Absorber SBIR

- Motivation
  - In 2017 and 2018 BNL evaluated designs for the electron accelerator in eRHIC, now EIC, the proposed electron-ion collider
    - It included a multi-cell
      - high average current
      - high bunch charge
    - Requiring a higher order mode absorber
      - » with considerable power absorption capability
  - Waveguide Shape Absorber near Cavity
  - Beamline HOM Absorber (round)
  - Crab Cavity HOM absorbers

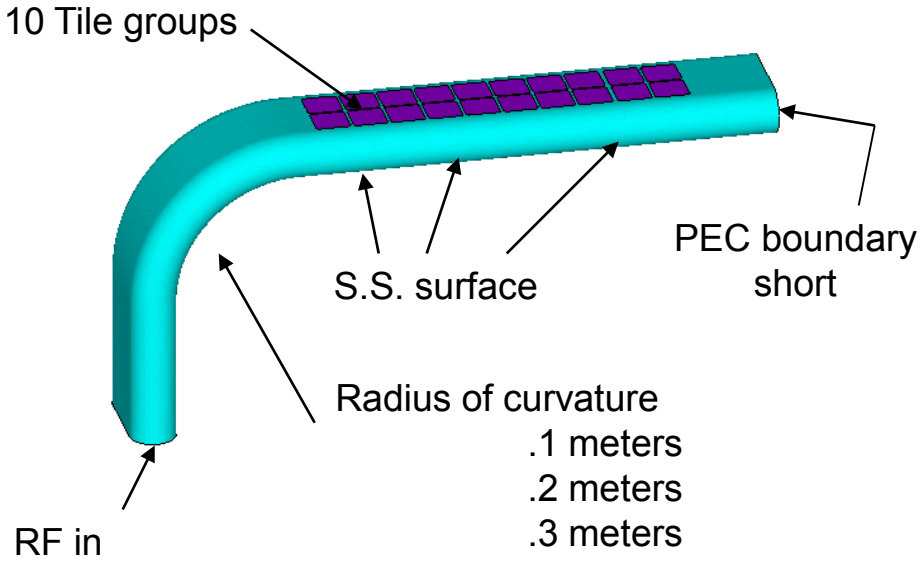
Higher Order Mode Absorber SBIR Tasks

- Phase I
  - Define/update HOM specifications with BNL
  - Develop the concept design of the absorber module
  - Perform RF/Thermal and Structural Analysis of the HOM module
  - Develop manufacturing plan and design for the HOM absorber module to a cost level.
- Phase II
  - Manufacture Prototypes
    - Waveguide HOM
    - Beamline HOM
- Phase II A
  - Develop low weight Crab Cavity HOM absorber
  - RF sweep tests of waveguide prototype to determine S11 of HOMs
  - High Power absorption tests of tile/backer cores

BNL Designed Cavity and B-shaped waveguide Phase I



BNL developed a B-Shaped waveguide to suppress multi-pacting and improve impedance, decreasing the number of waveguides per cavity
BNL paper SRF2017 TUPB002



Input Excitation Port

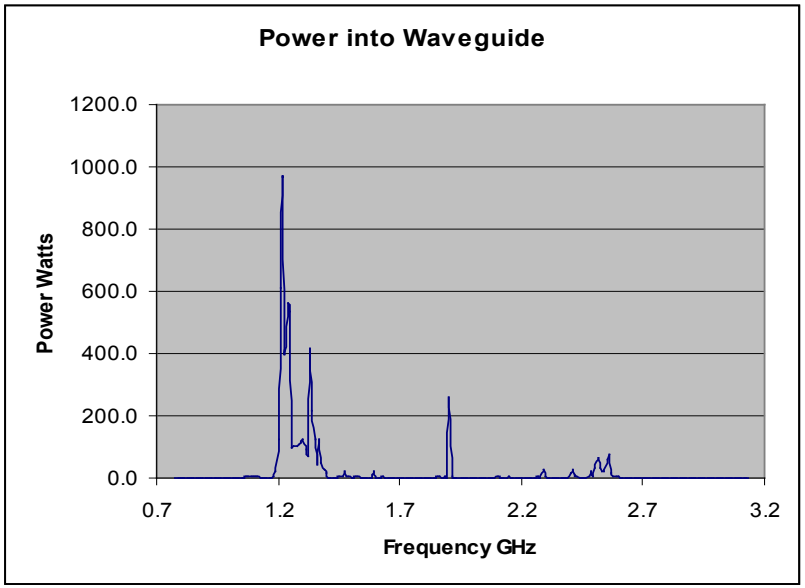
Frequency Dependent permittivity and Loss tangent

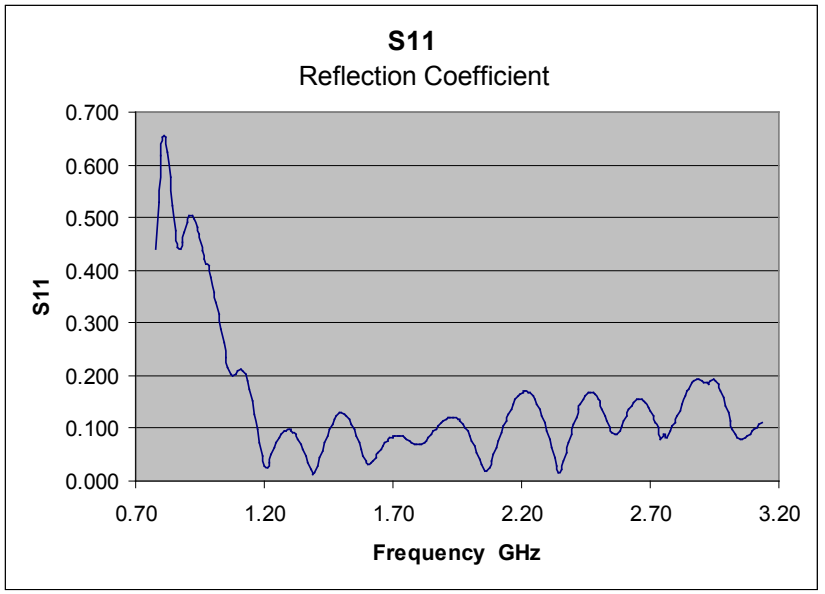
Surface Losses assuming Stainless Steel

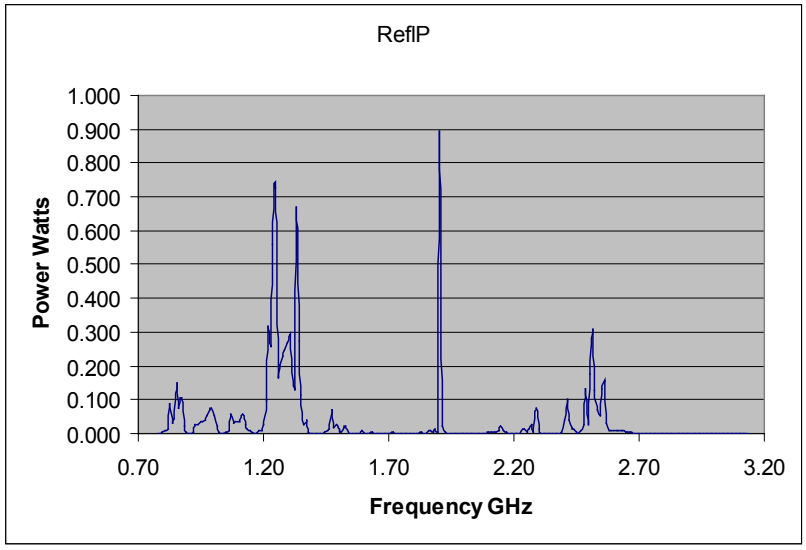
Output
S11, Power for each tile group
For each Frequency
Sum Power for each tile group over HOM frequencies

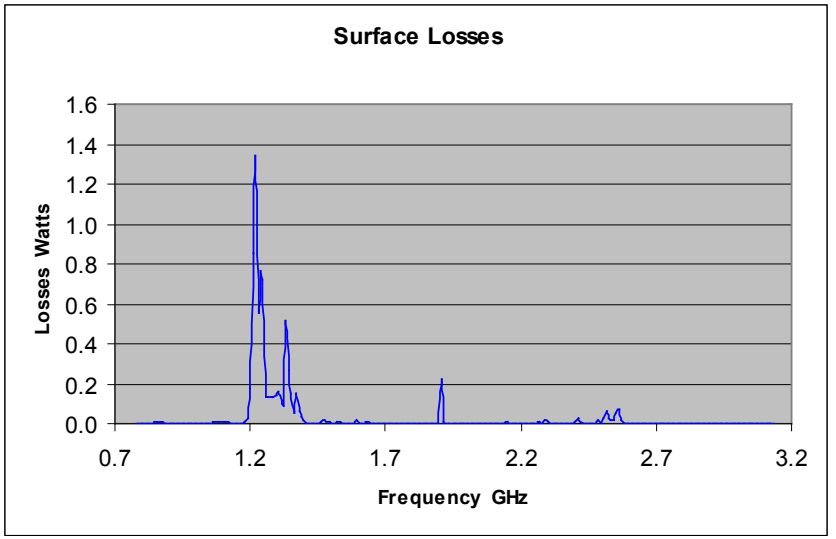
Tile groups with varying thickness
Made from SC-35, graphite loaded Silicon Carbide

Power In from BNL , S11, Reflected Power, Surface Loss from Analysis

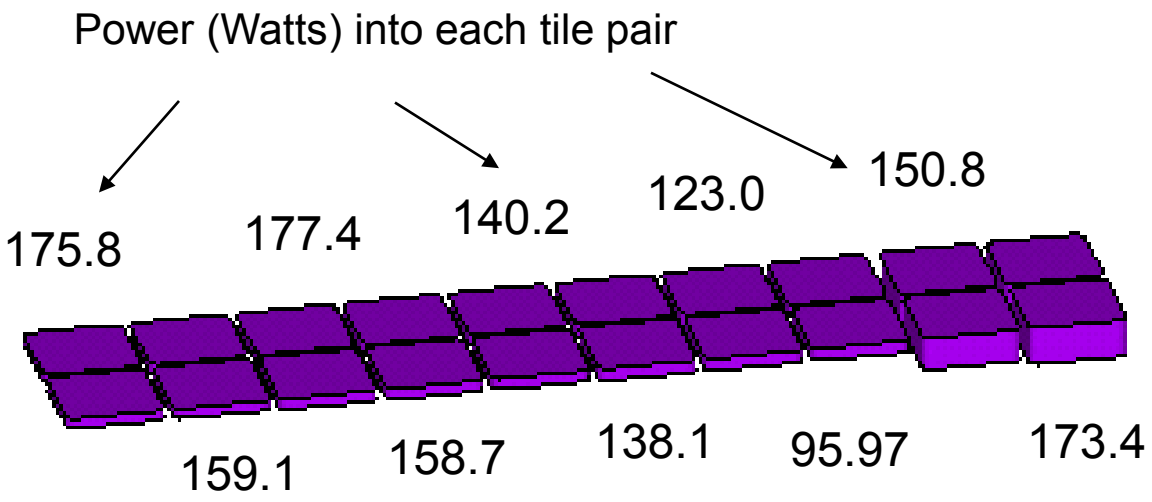








Sum of Power into Waveguide Absorber

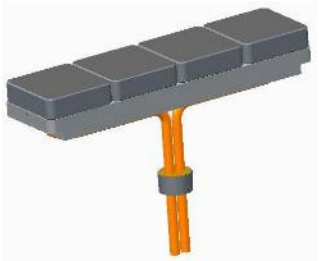


- Initial HOM absorber module geometry (4 HOM Absorbers per cavity)
  - 1492.4 W of 1501.5 W is absorbed 99.7%
  - 10 tile pairs
  - Thickness range .200” to .75”

Higher Order Mode Absorber SBIR Phase II

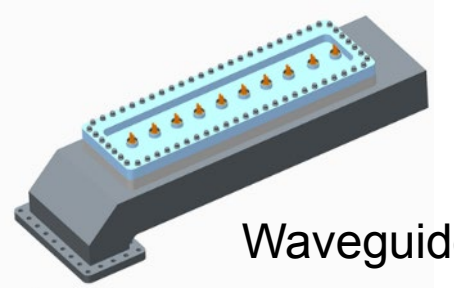
- Manufacture HOM Cores
  - Can be used for Waveguide or Beamline Absorber

Waveguide core

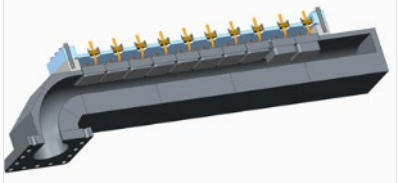


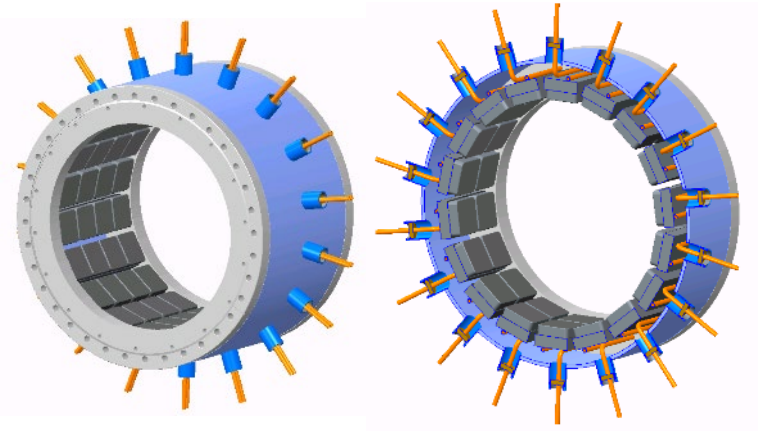
Beamline core

- Manufacture Housing and Assemble Core and Housing



Waveguide HOM





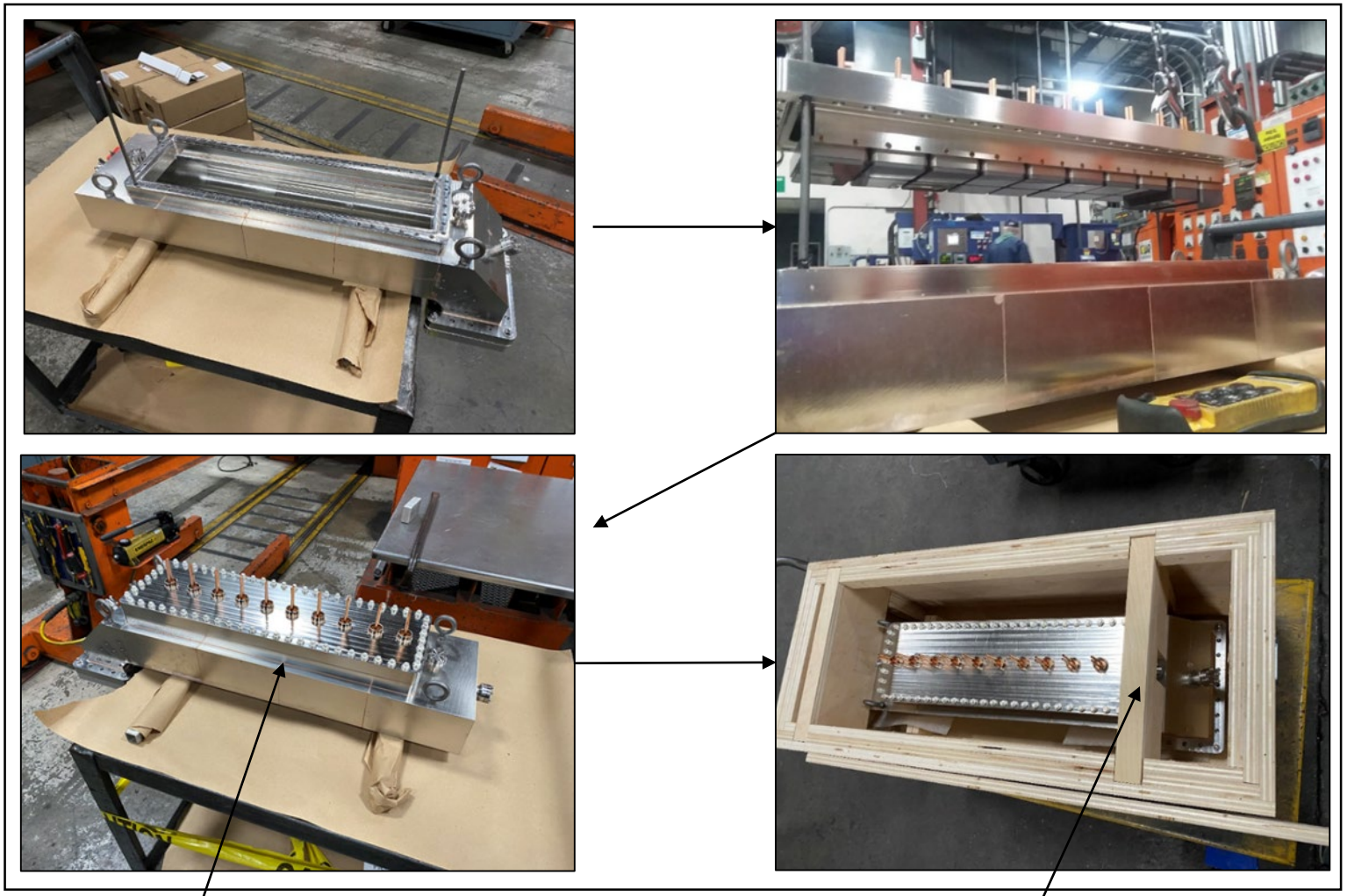
Beamline HOM

Initial Braze Step in Fabrication of Cores

Backer/Cooling Tube Assemblies (without SiC tiles)

Backer-Tile Assemblies shown after joining

First Waveguide HOM Prototype



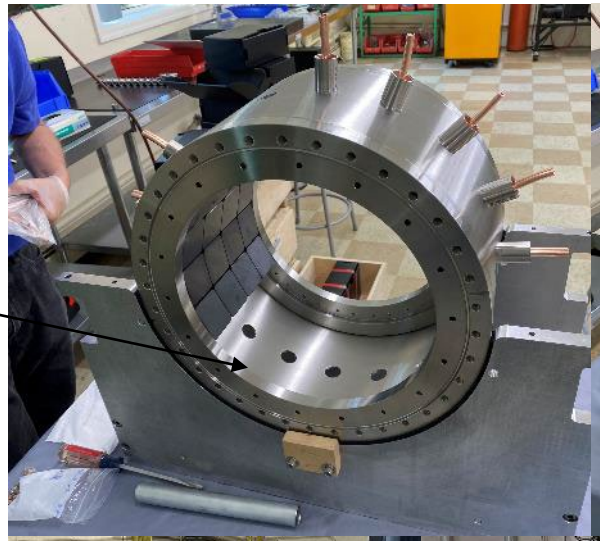
Lowering tile/backer flange assembly into housing

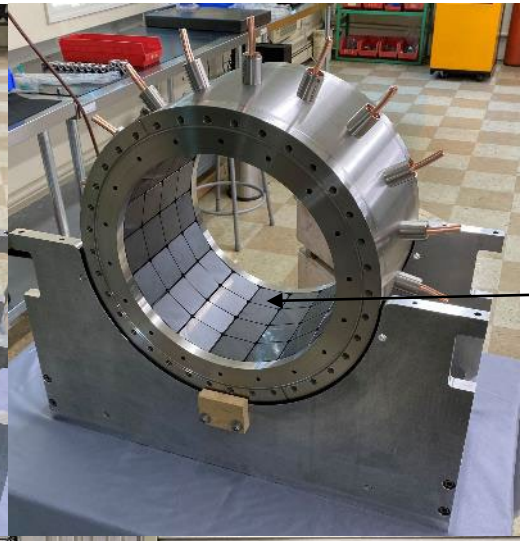
Bolt Flange assembly to housing

Inserting and restraining in crate

First Beamline HOM Prototype

Partially Assembled





Fully Assembled

Lowering into crate

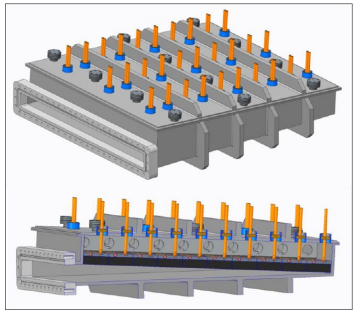
Used BNL design for thickness and depth of SiC and HOM diameter, direct replacement in their test set-up

Higher Order Mode Absorber Phase IIA

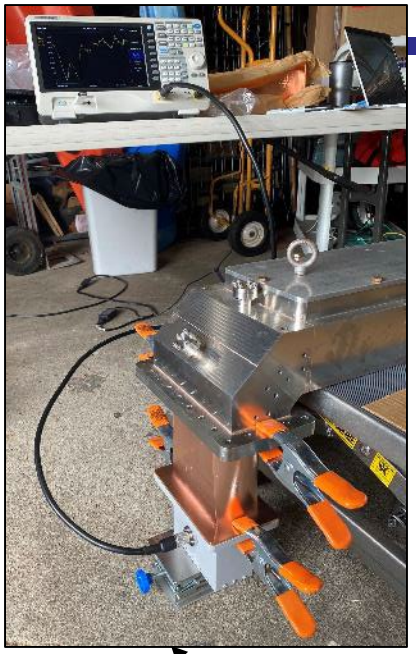
- Low Power RF Tests
  - Waveguide Assembly - S11 vs Frequency
  - Compare to Analysis
  - Evaluate RF Properties

- Power Absorption Tests at BNL
  - Tile/Backer Assembly
  - RF Power in
  - Measure Temperature

- Develop Low Weight Design
  - Decrease weight of Tile/Backer Assembly
    - Decrease Backer Thickness
  - Decrease weight of Housing
    - For Crab Cavity HOM Absorber
      - Minimize wall thickness meeting pressure vessel code

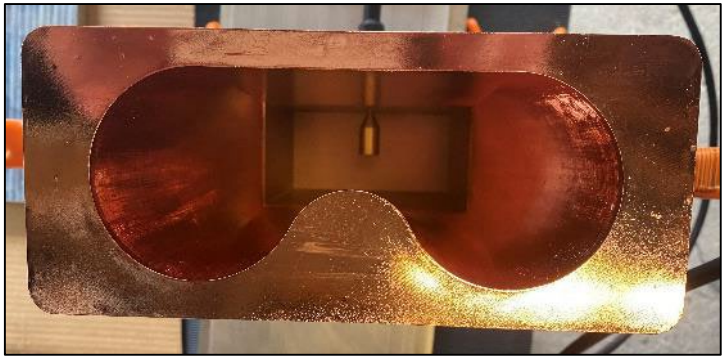


Phase IIA Waveguide HOM RF Sweep Test



Test With Flush Dummy Insert

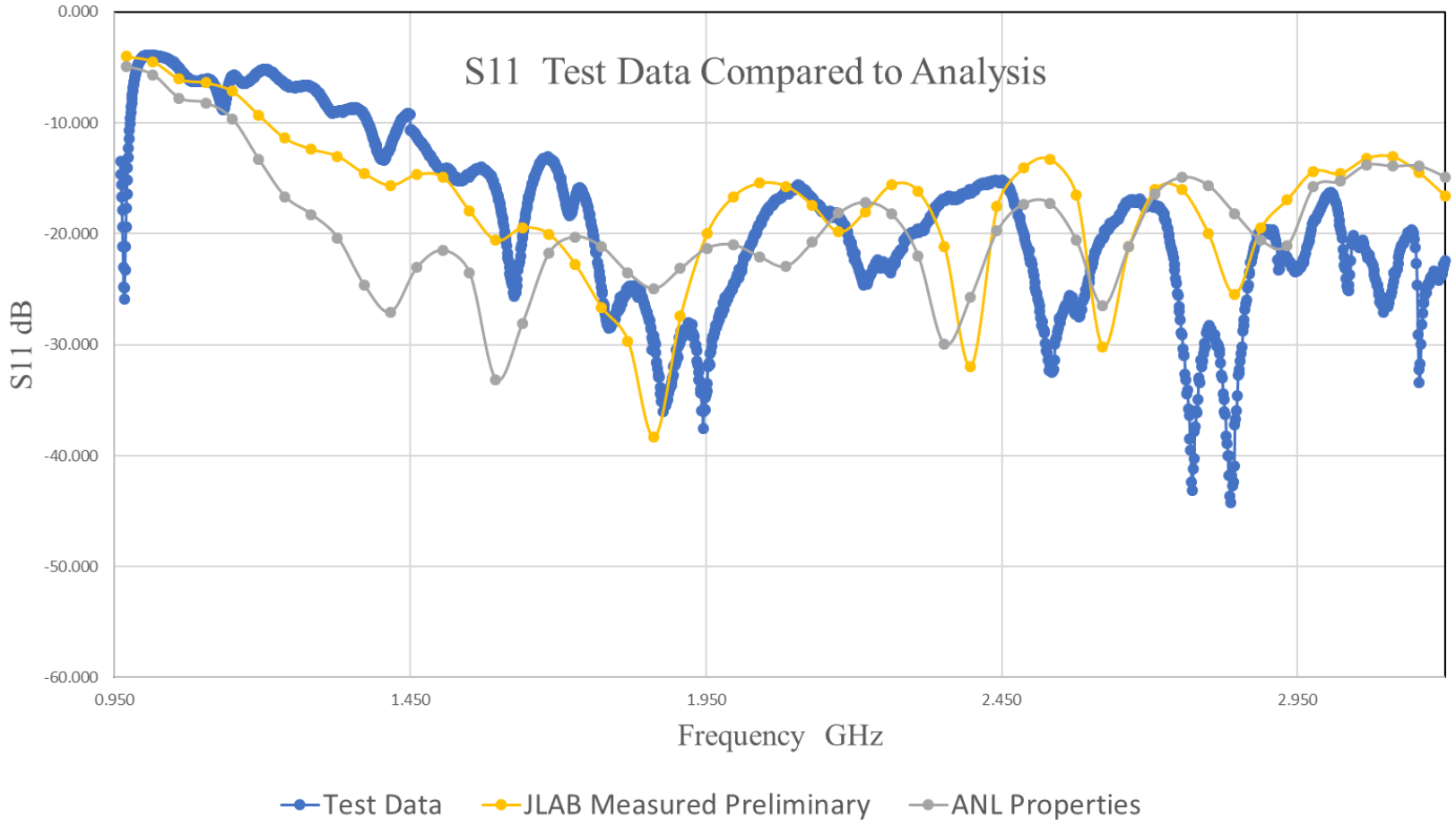
Test With HOM Load Assembly



← Adapter-to-Transition Assembly

Through Measurement of
Two Adapter/Transitions →
(WR770 – WR510)

S11 Data – Properties Comparison



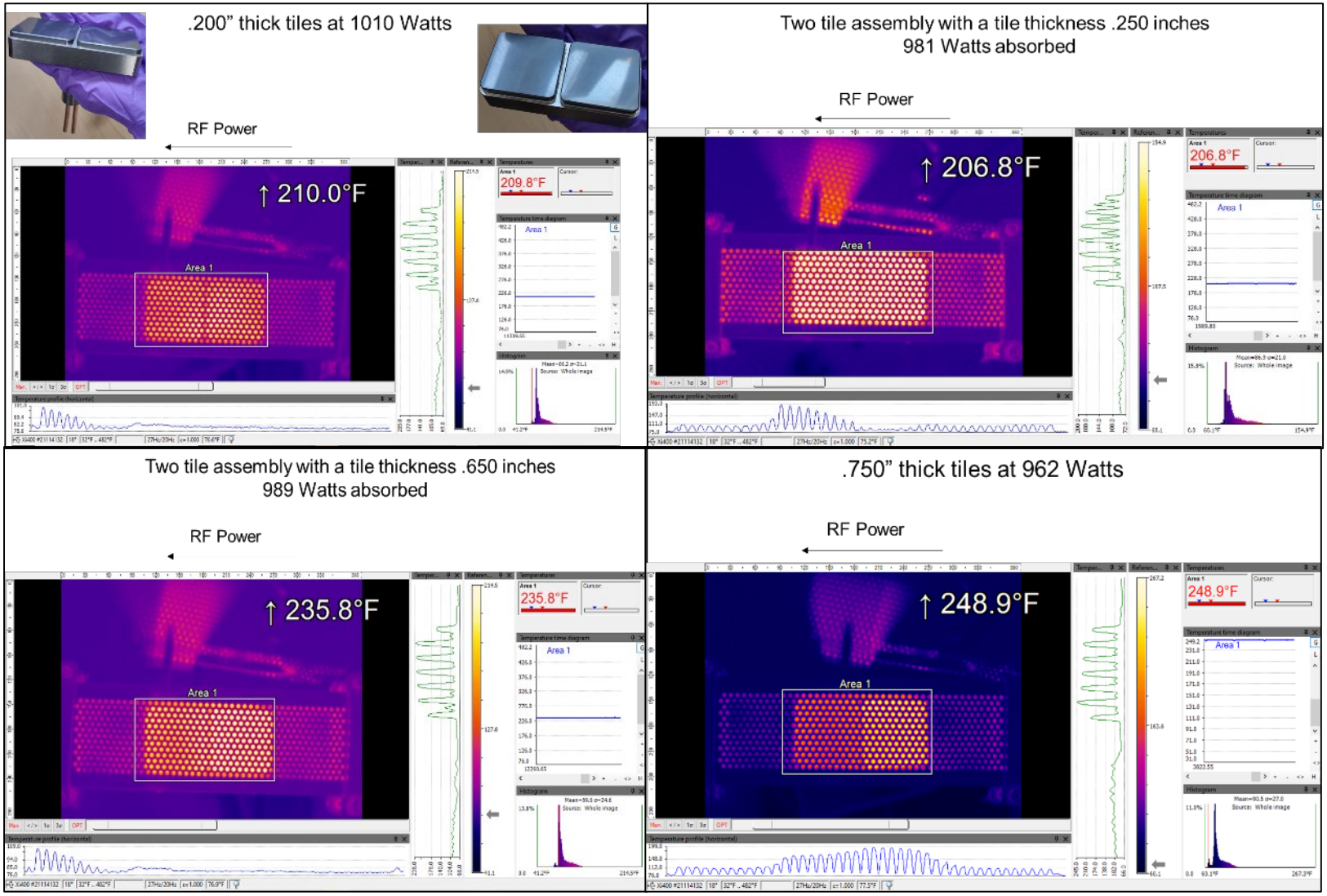
Analysis input properties e1 and e11

JLAB is evaluating RF Properties at Freq < 1 GHz

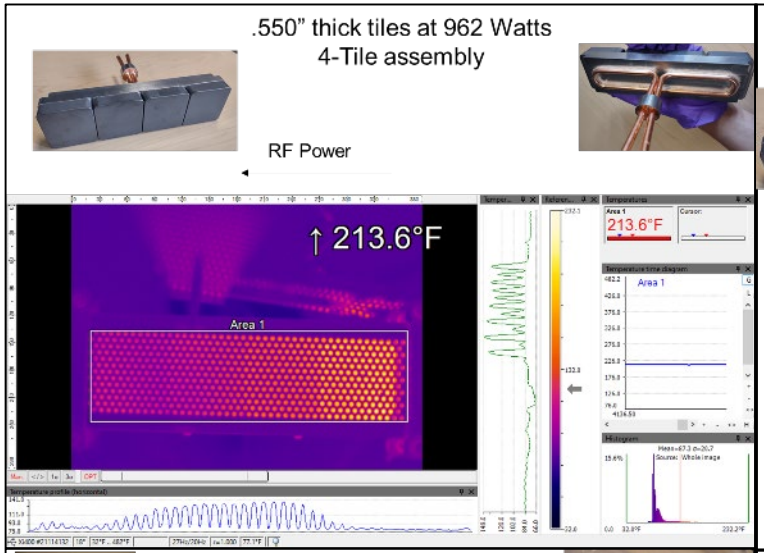
Phase IIA Power Absorption Tests at BNL

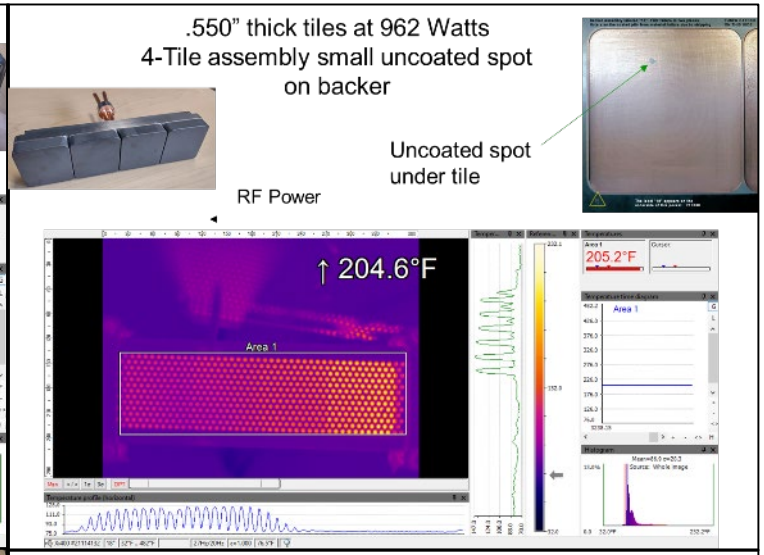
A Optris Xi 400 thermal camera replacement was installed. The entire stand was raised to make installation of test pieces easier.

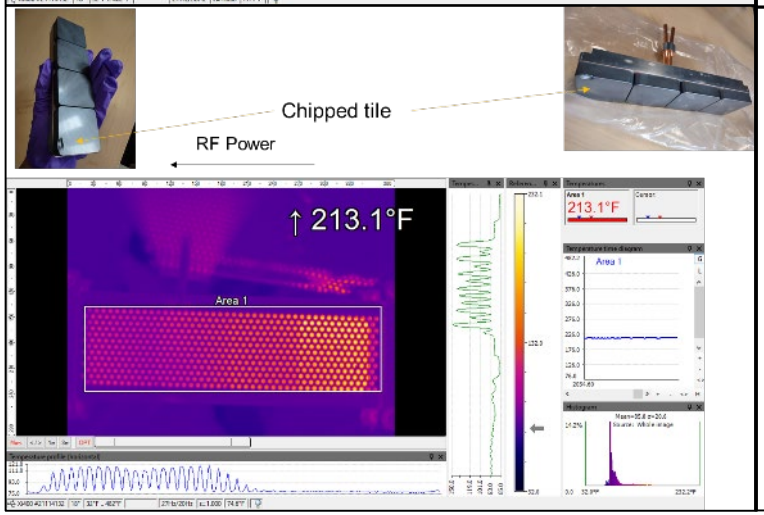
Thermal Image 2-Tile



Thermal Image 4-Tile

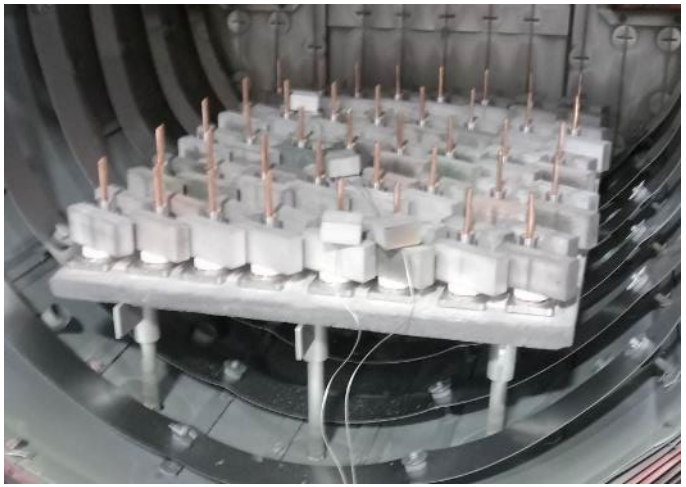




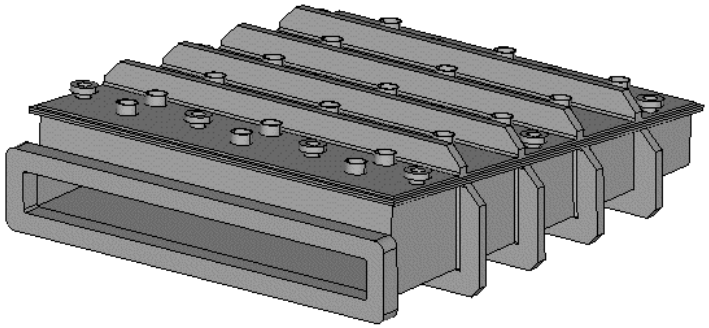


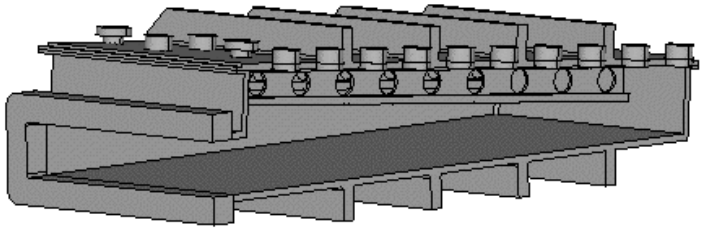
- No tile failures up to 1 kW of power
- Individual Tiles show even temperature distribution
- Thicker tiles show slightly higher temperatures in forward tile
- No change in local temperature near chip or uncoated spot
  - Shows quality of joint between tile and backer
- HOM absorber with 10 rows, 2 tiles per row
  - Capable of 10 kW absorption
- TJS Technologies developing a low weight 3-tile backer
  - Presently have enough funds to test these
  - Will not be ready for testing till spring of 2023

Low Weight Design Tiles and Housing for Crab Cavity



- Minimize Housing Wall Thickness
  - Perform Pressure Vessel Code analysis
    - Crab Cavity HOM expected to be part of Hermetic string





SBIR Summary

- Fabricated waveguide and Beamline HOM Absorbers
- Evaluating HOM absorber for Crab Cavity
  - HOM freq to absorb > 300 MHz
  - JLAB Evaluating RF properties at Freq < 1 GHz
- Developed Lightweight Backer Design
- Using HOM core can develop many geometries to accomplish HOM absorption
- 2-Tile and 4-Tile cores absorb a minimum of 1 kW of energy each
- Present Crab Cavity Design will absorb minimum of 30 kW
  - Crab cavity is a 3-Tile per core design
  - To be tested at BNL

- Thank You
  - Michelle, BNL, JLAB, DOE