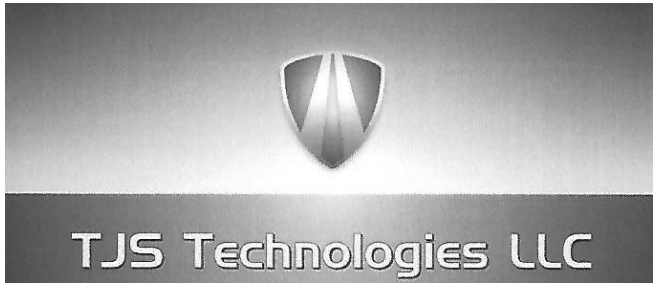

HOM Absorber Design for eRHIC ERL Cavity (Now EIC)

SBIR Grant Award No. DE-SC0018466

T. Schultheiss

TJS Technologies LLC

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2024 SBIR STTR Exchange Meeting

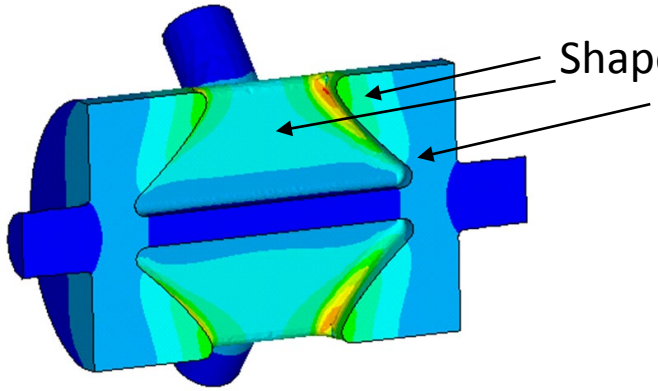
Aug 15, 2024

Outline

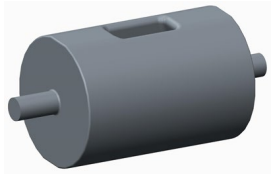
- TJS Technologies LLC (2016)
  - Engineering Services
    - FHI Fritz Harbor Institute - ongoing
      - Free Electron Laser Engineering Analysis
    - JLAB - ongoing
      - SRF Cavity Cooled by Cryocoolers – Thermal Analysis
  - Higher Order Mode Absorber SBIR Phase I & II
    - Fabricated Prototypes
      - B-Shaped Waveguide
      - Beamline HOM Absorber
  - Phase IIA
    - Low Power RF Tests, S11
      - B-Shaped Waveguide HOM Absorber
      - Crab Cavity HOM Absorber
    - High Power Thermal/Structural Tests
      - 2, 3 and 4 tile/backer assemblies
      - Assemblies used to form waveguide and beamline absorbers

Engineering Service FHI

Fritz Haber Institute Free Electron Laser Upgrade for 2 Color FEL

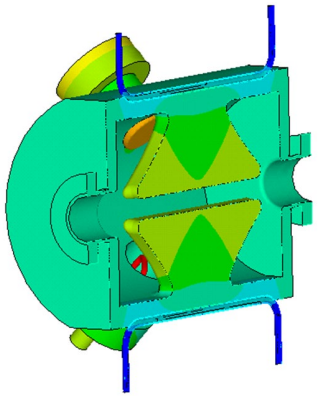


RF Analysis

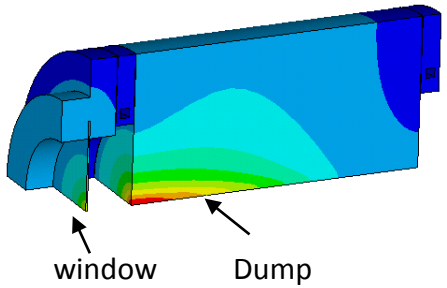


Frequency shift for manufacturing and tuning

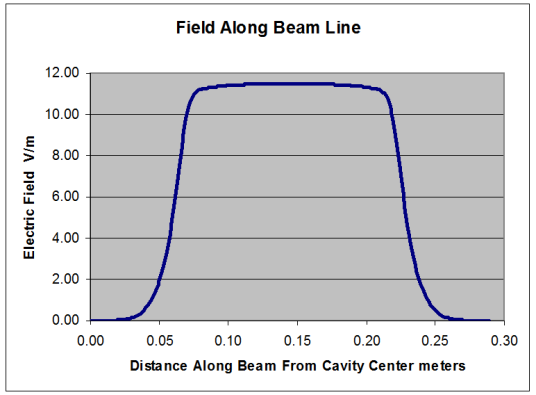
Deflector Cavity



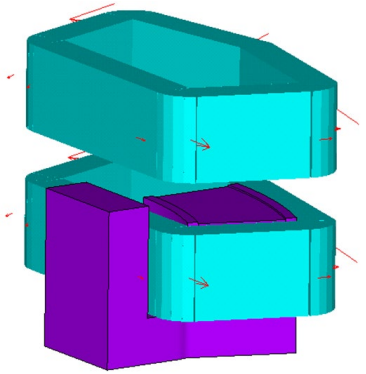
Beam Dump and Window



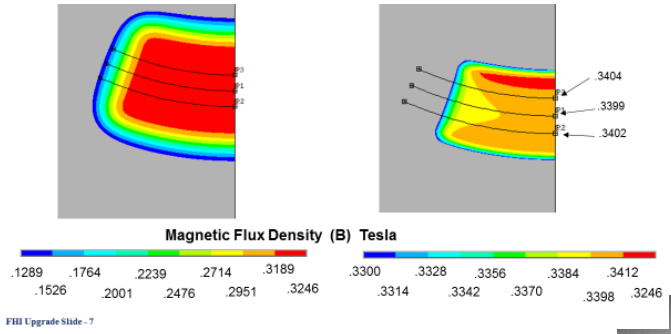
Thermal Analysis



Electric Field Along Beamline

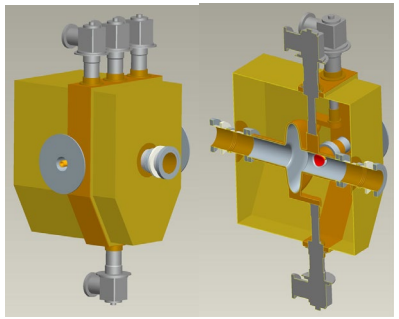


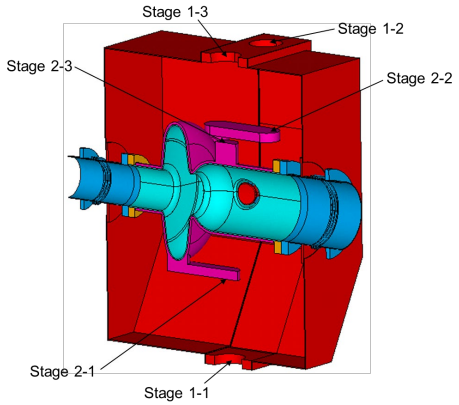
3-D Magnet calcs
Coil geometry Specification
Field Quality



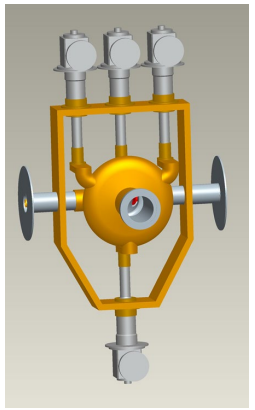
Magnet Analysis

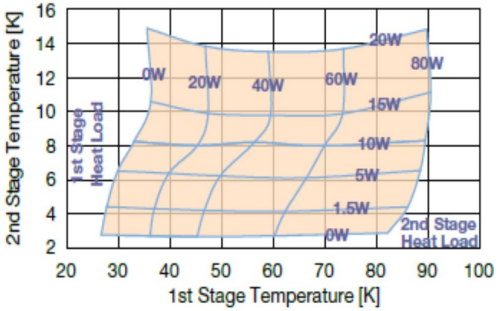
Engineering Service JLAB





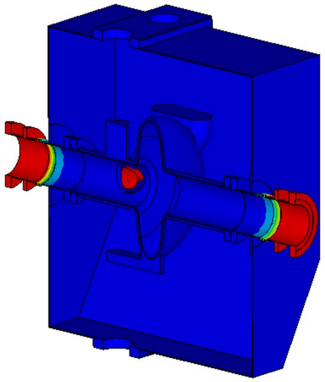
RF and Thermal Analysis

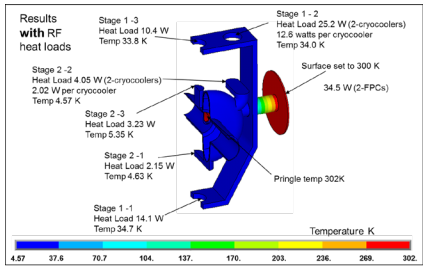


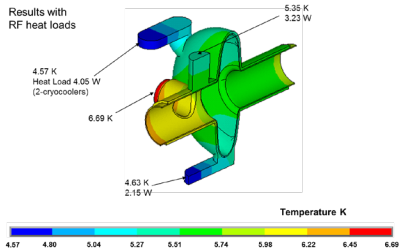


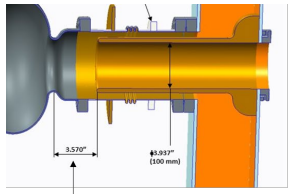
Cryocooler Capacity Map

Cryocoolers cooling SRF Cavities



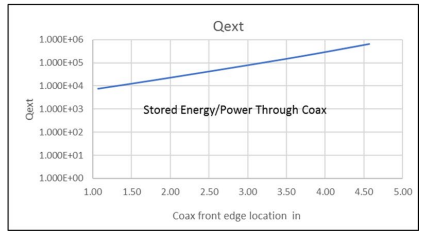


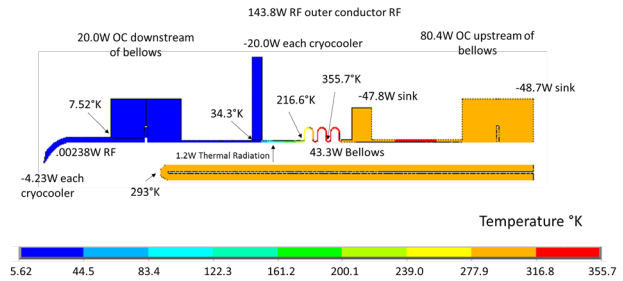




Distance from Cell 1 Iris	Qext
4.57	6.376E+05
3.59	1.658E+05
3.57	1.615E+05
3.47	1.427E+05
2.07	2.482E+04
1.07	7.632E+03

Stored Energy/Power Through Coax
Target Qext = 1.65e5





RF and Thermal Analysis Beam Pipe Coaxial Power Coupling

U.S. DEPARTMENT OF ENERGY | Office of Science

TJS Technologies LLC

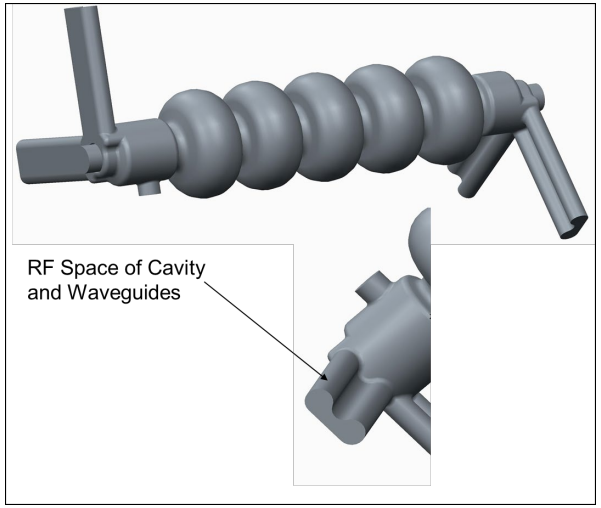
Higher Order Mode Absorber SBIR

- Motivation
  - In 2017 and 2018 BNL evaluated designs for the electron accelerator in eRHIC, now EIC, The Electron-Ion Collider
    - It included electron cooling using a multi-cell cavity with high average current and high bunch charge in CW energy recovery mode. This cavity would require a higher order mode absorber with considerable power absorption capability
    - There is also interest in 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
  - Fabricate Crab Cavity
  - RF sweep tests to determine S11 of HOMs
    - B-Shaped cavity and Crab Cavity
  - High Power absorption tests of tile/backer cores
    - 2,3 and 4 tile/backer assemblies

Designed Absorber For B-shaped waveguide Phase I



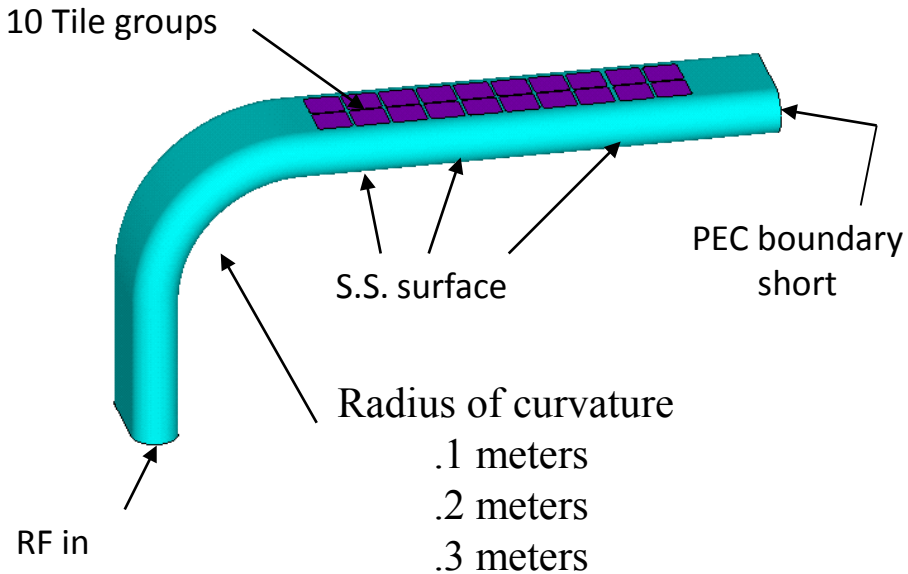
BNL developed a B-Shaped waveguide to suppress multi-pacting and improve impedance, decreasing the number of waveguides per cavity
BNL paper SRF2017 TUPB002

Input Excitation Port

Frequency Dependent permittivity and Loss tangent

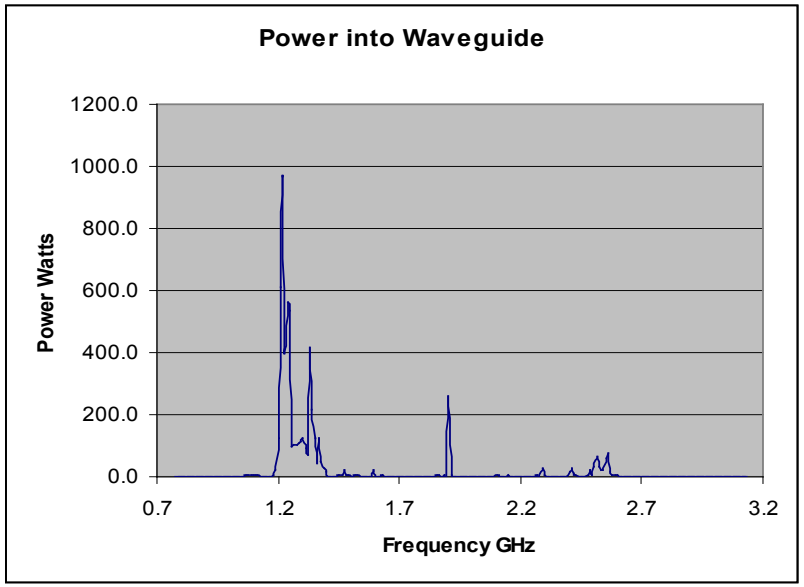
Surface Losses assuming Stainless Steel

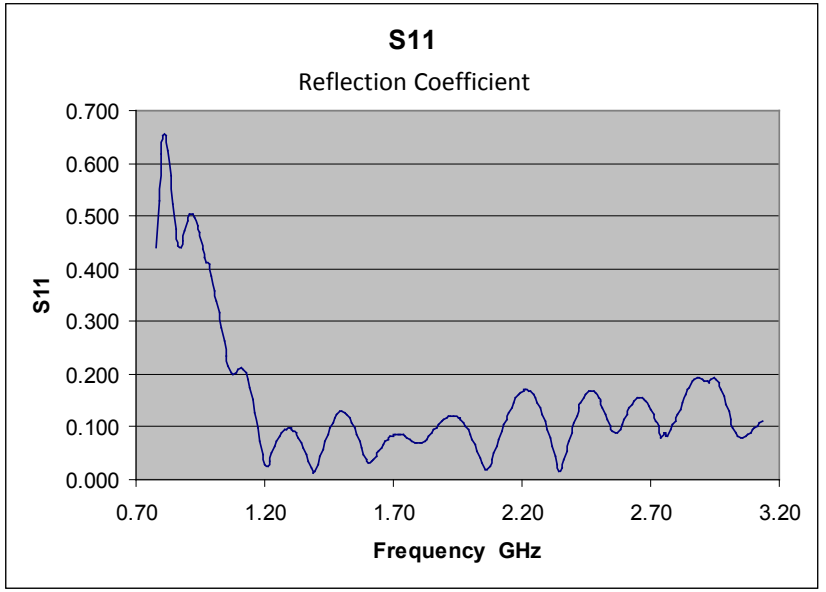
Output
S11, Power for each tile group
For each Frequency
Sum Power for each tile group over HOM frequencies

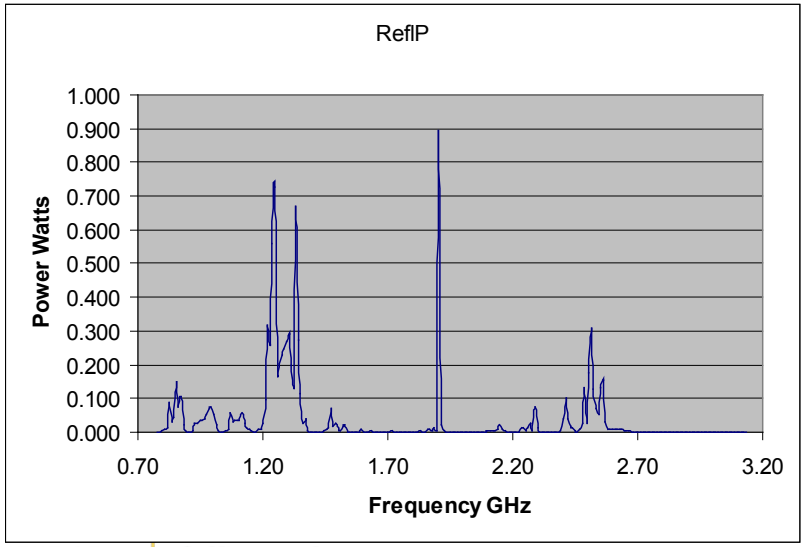


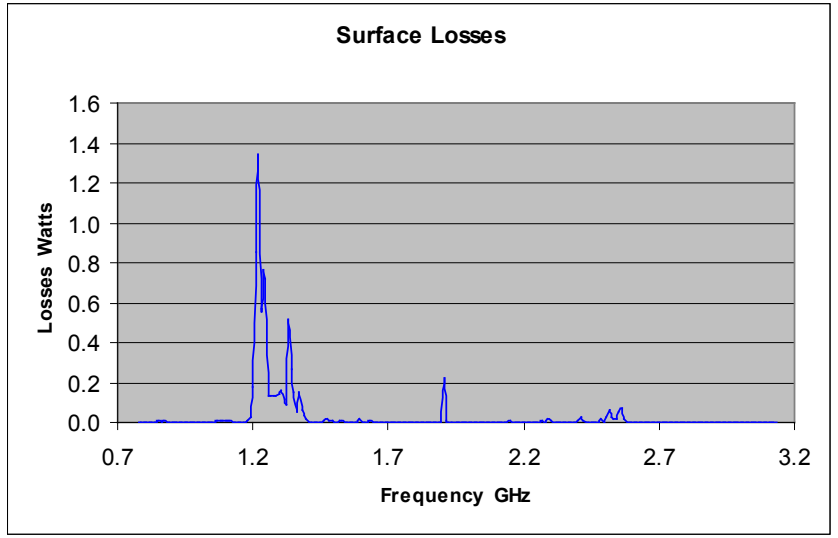
Tile groups with varying thickness
Made from SC-35, graphite loaded Silicon Carbide

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



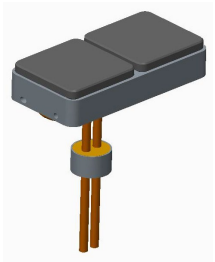




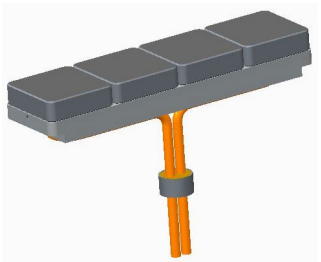


Higher Order Mode Absorber SBIR Phase II

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

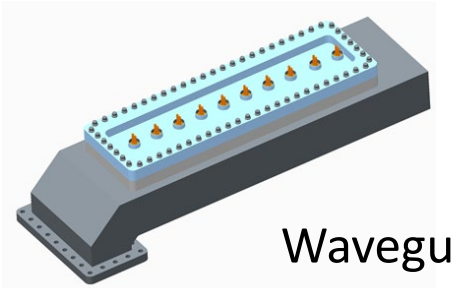



Waveguide core

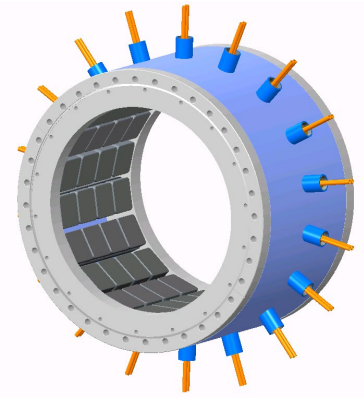
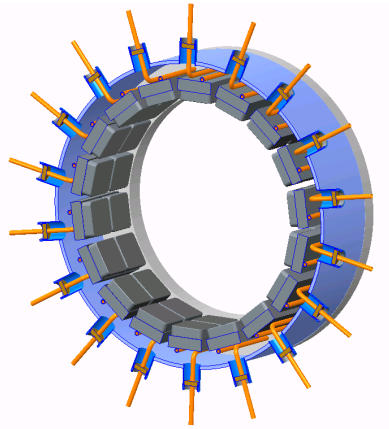



Beamline core

- Manufacture Housing and Assemble Core and Housing



Waveguide HOM

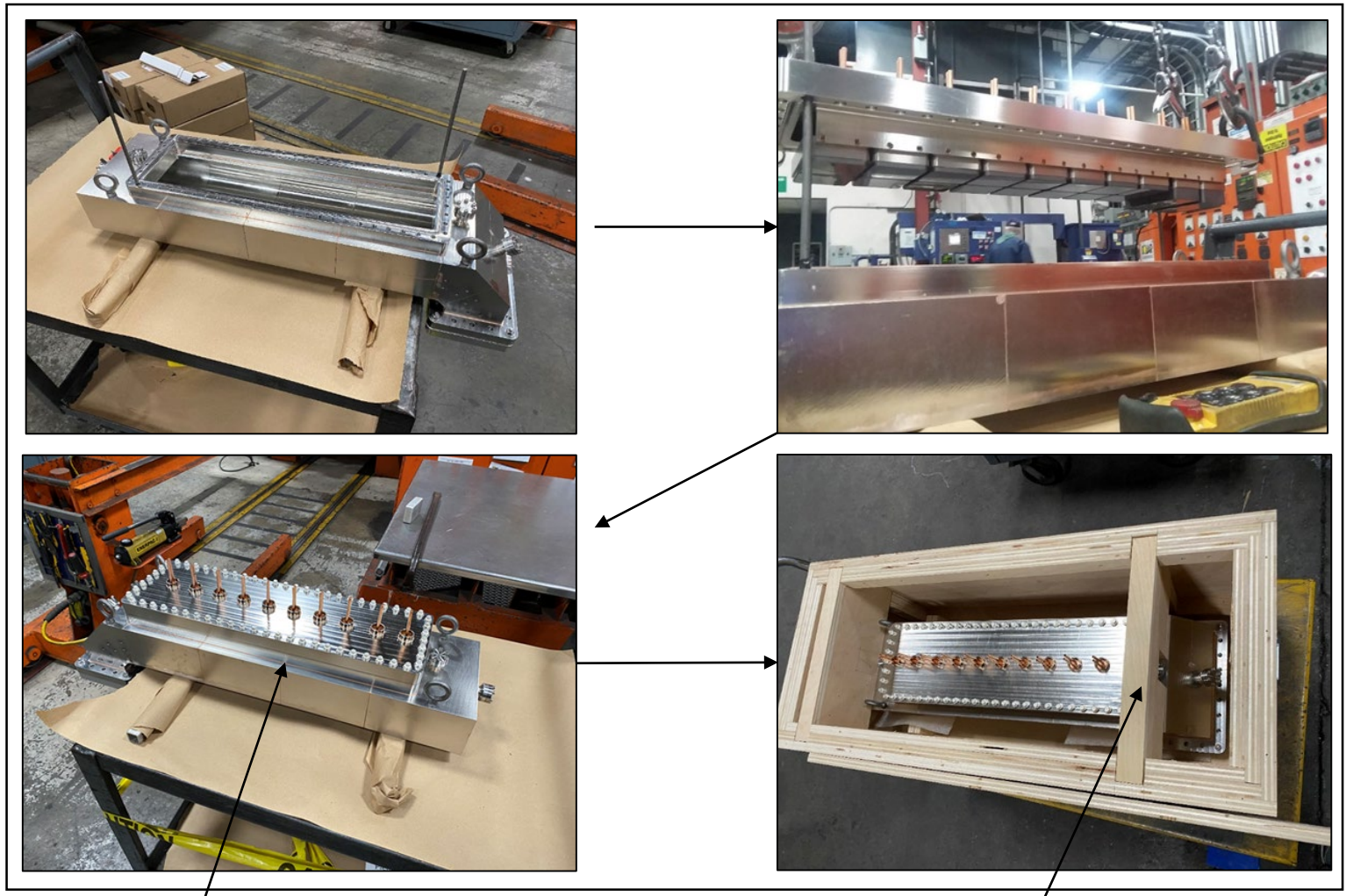
Beamline HOM

Initial Braze Step in Fabrication of Cores

Backer/Cooling Tube
Assemblies (without SiC tiles)

Backer-Tile Assemblies
shown after joining

First Waveguide HOM Prototype



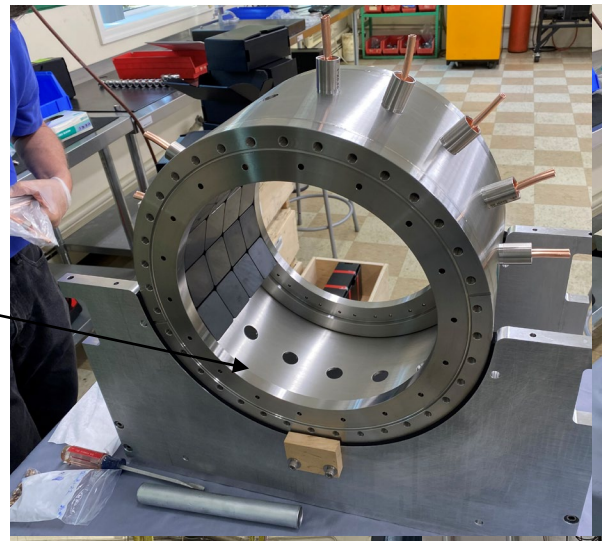
Lowering tile/backer flange assembly into housing

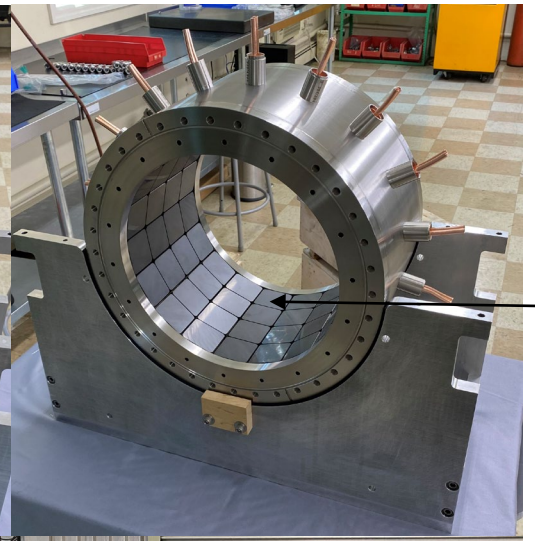
Bolt Flange assembly to housing

Inserting and restraining in crate

First Beamline HOM Prototype

Partially Assembled





Fully Assembled

Lowering into crate

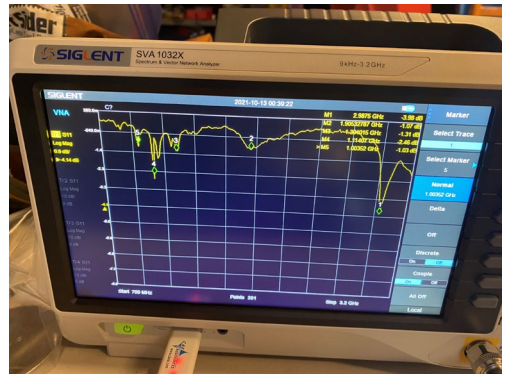
Used BNL design for thickness and depth of SiC and HOM diameter, direct replacement in their test set-up

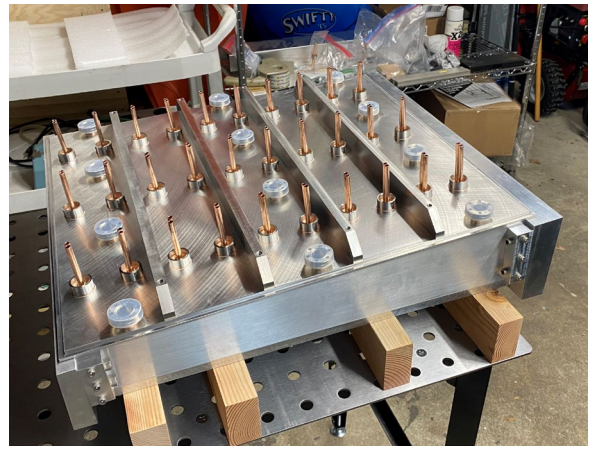
Higher Order Mode Absorber Phase IIA

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

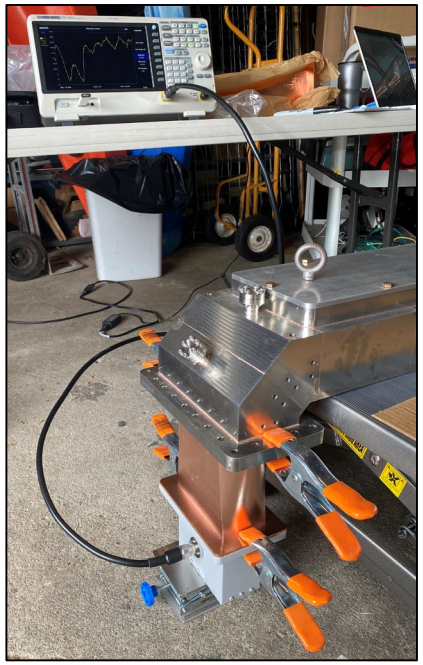
- Power Absorption Tests at BNL
  - Tile/Backer Assembly
  - RF Power in
  - Measure Temperature

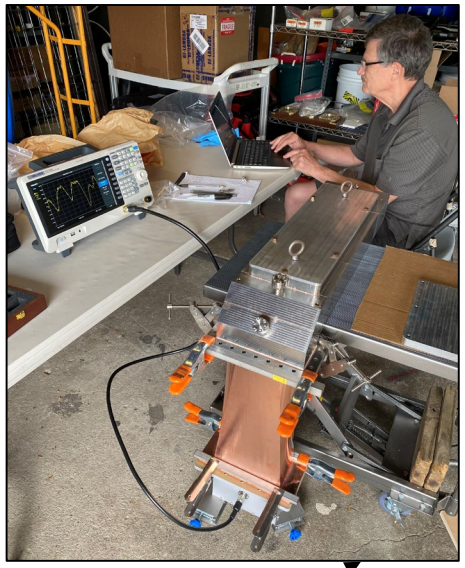
- Develop Low Weight Design
  - Decrease weight of Tile/Backer Assembly
    - Decrease Backer Thickness
  - Decrease weight of Housing
    - For Crab Cavity HOM Absorber
    - Housing for Low Power Tests





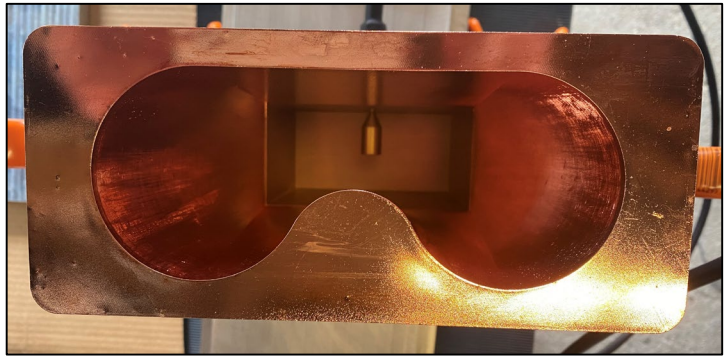
Phase IIA Waveguide HOM RF Sweep Test





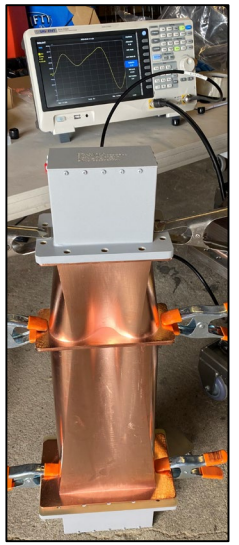
Test With Flush Dummy Insert

Test With HOM Load Assembly

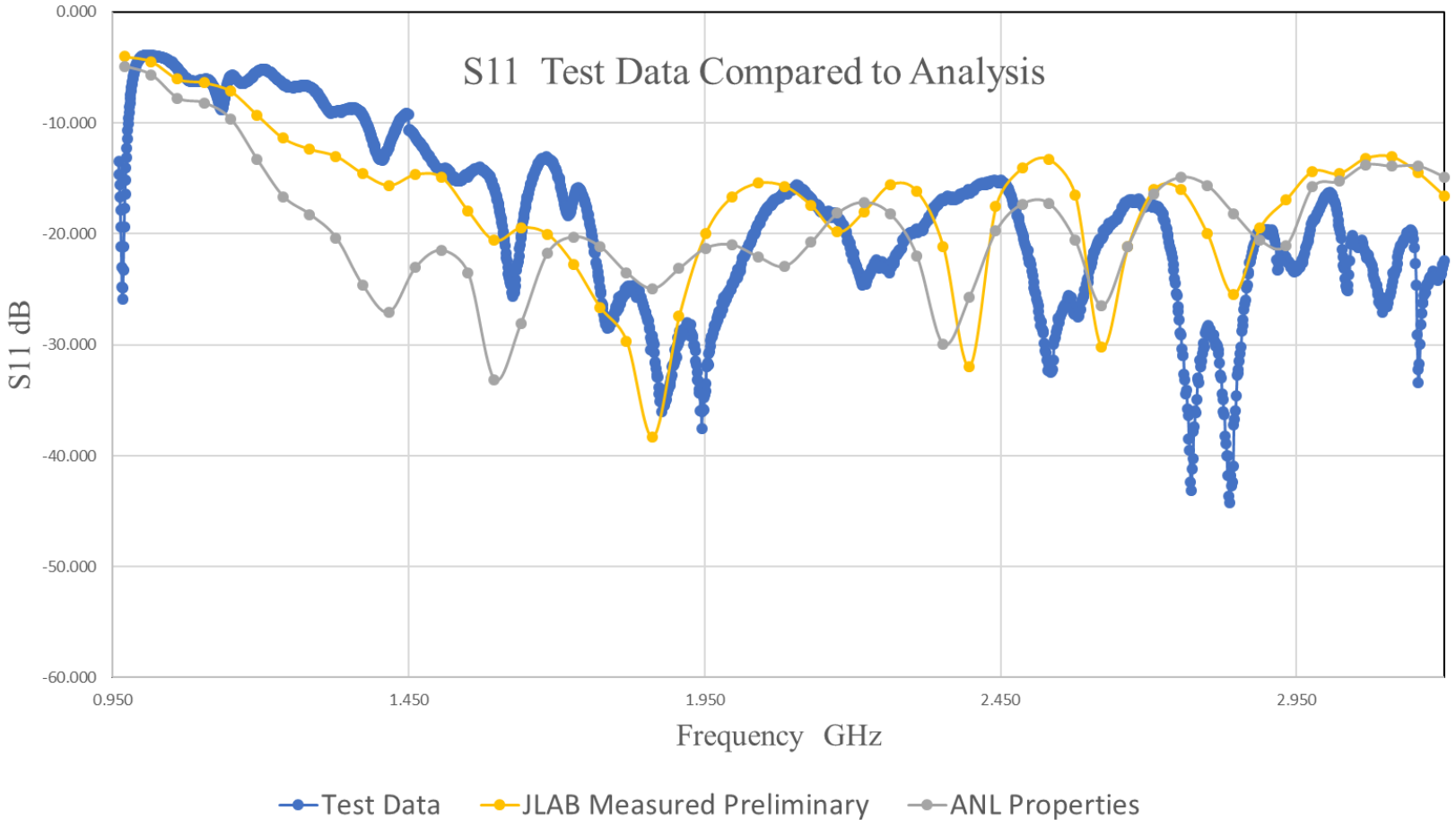


← Adapter-to-Transition Assembly

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



S11 Data – B-Shaped Absorber



Analysis input properties e1 and e11

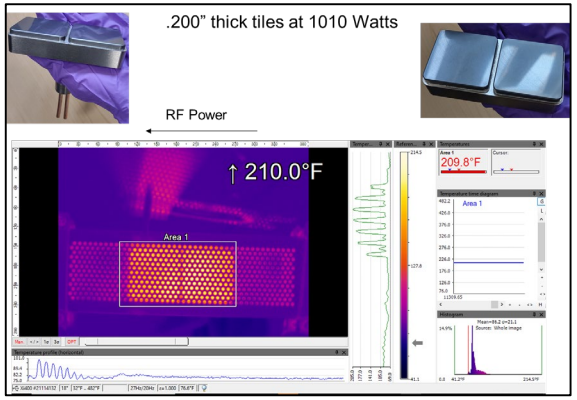
JLAB is evaluating RF Properties at Freq < 1 GHz

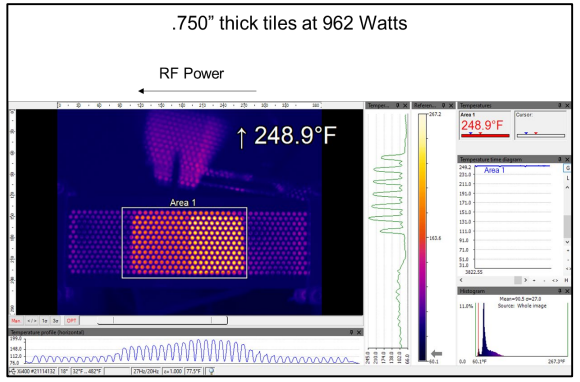
Phase IIA Power Absorption Tests at BNL

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

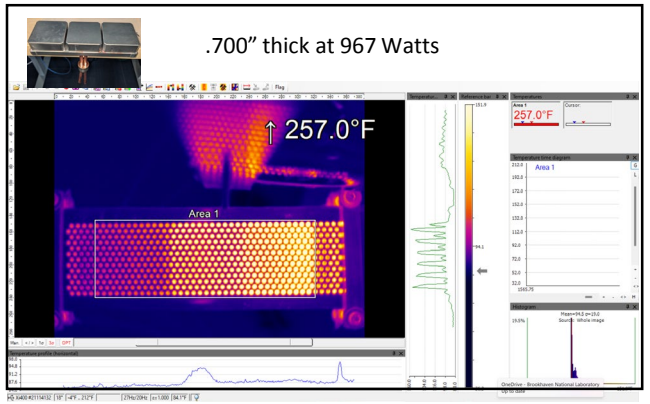
Thermal Image 2,3 and 4 –Tile Cores

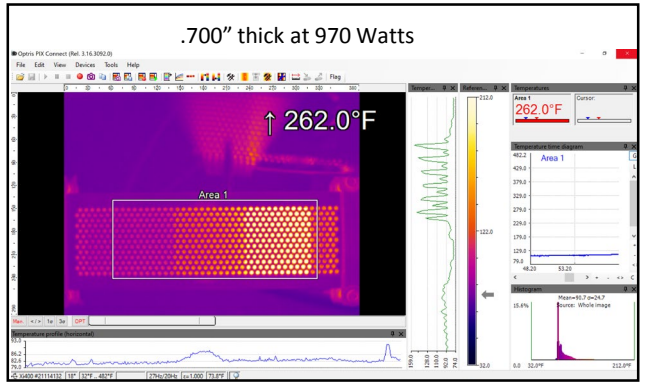
2-Tiles

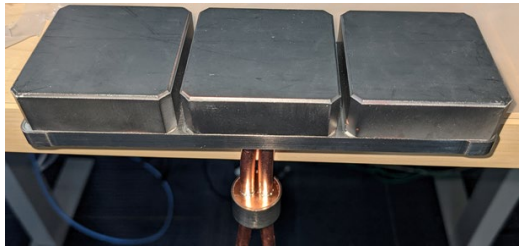




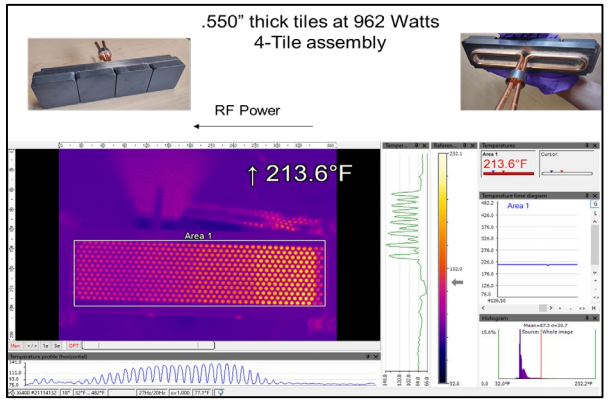
3-Tiles





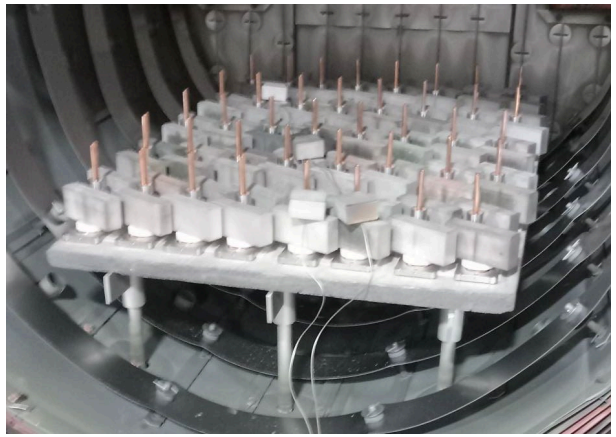


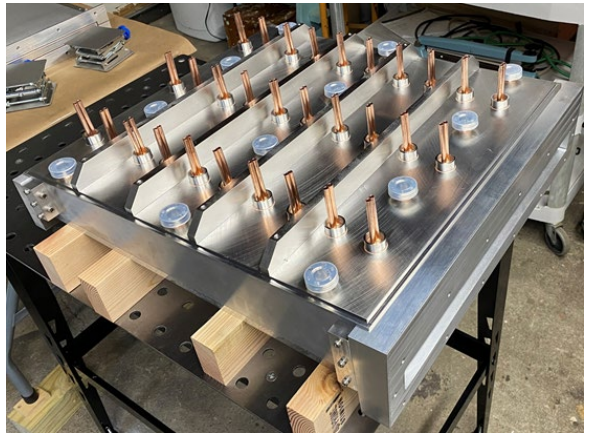
4-Tiles



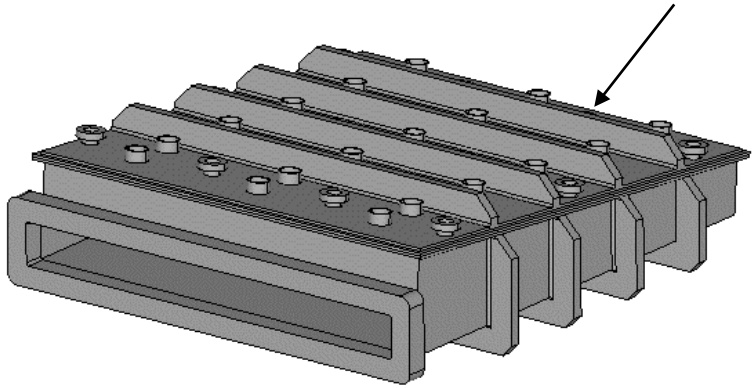
- No tile failures up to 1 kW of power
- Individual Tiles show even temperature distribution
- Thicker tiles show slightly higher temperatures in forward tile
- No change in local temperature near chip or uncoated spot
  - Shows quality of joint between tile and backer
- HOM absorber with 10 rows, 2 tiles per row
  - Capable of 10 kW absorption
- Crab Cavity 3-Tile backers
  - 3-cores per row with 10 Rows
  - Capable of > 30 kW absorption

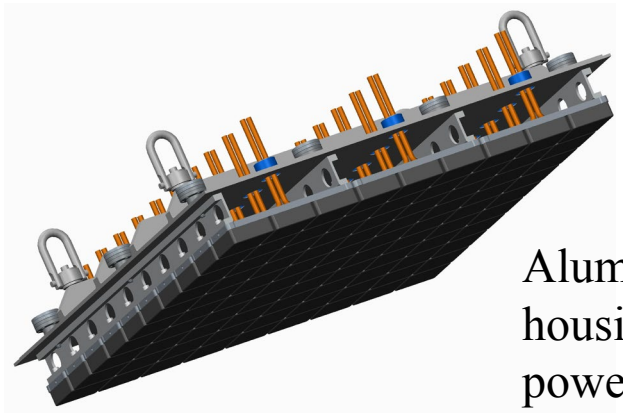
Low Weight Design Tiles and Housing for Crab Cavity



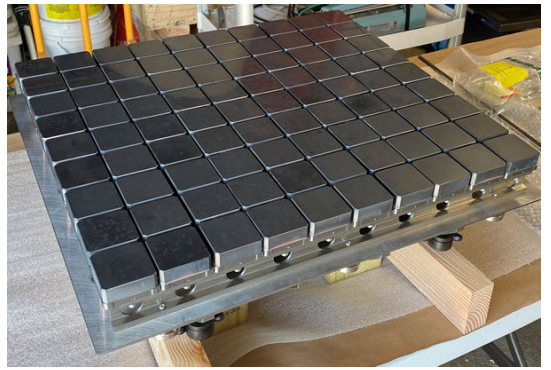


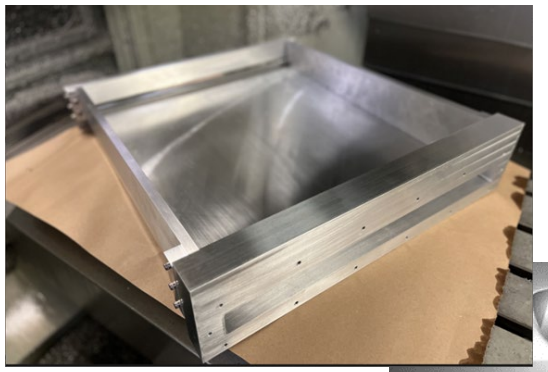
- Minimize Housing Wall Thickness
  - Perform Pressure Vessel Code analysis
    - Crab Cavity HOM expected to be part of Hermetic string



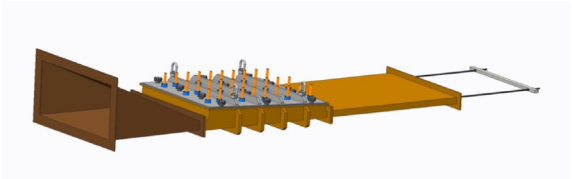


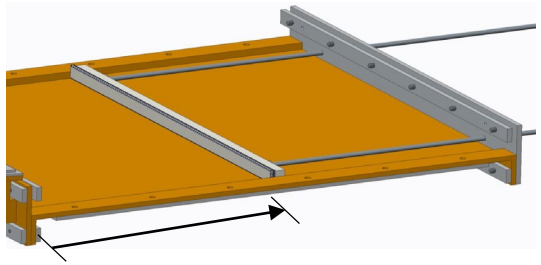
Aluminum bolted housing for low power RF tests



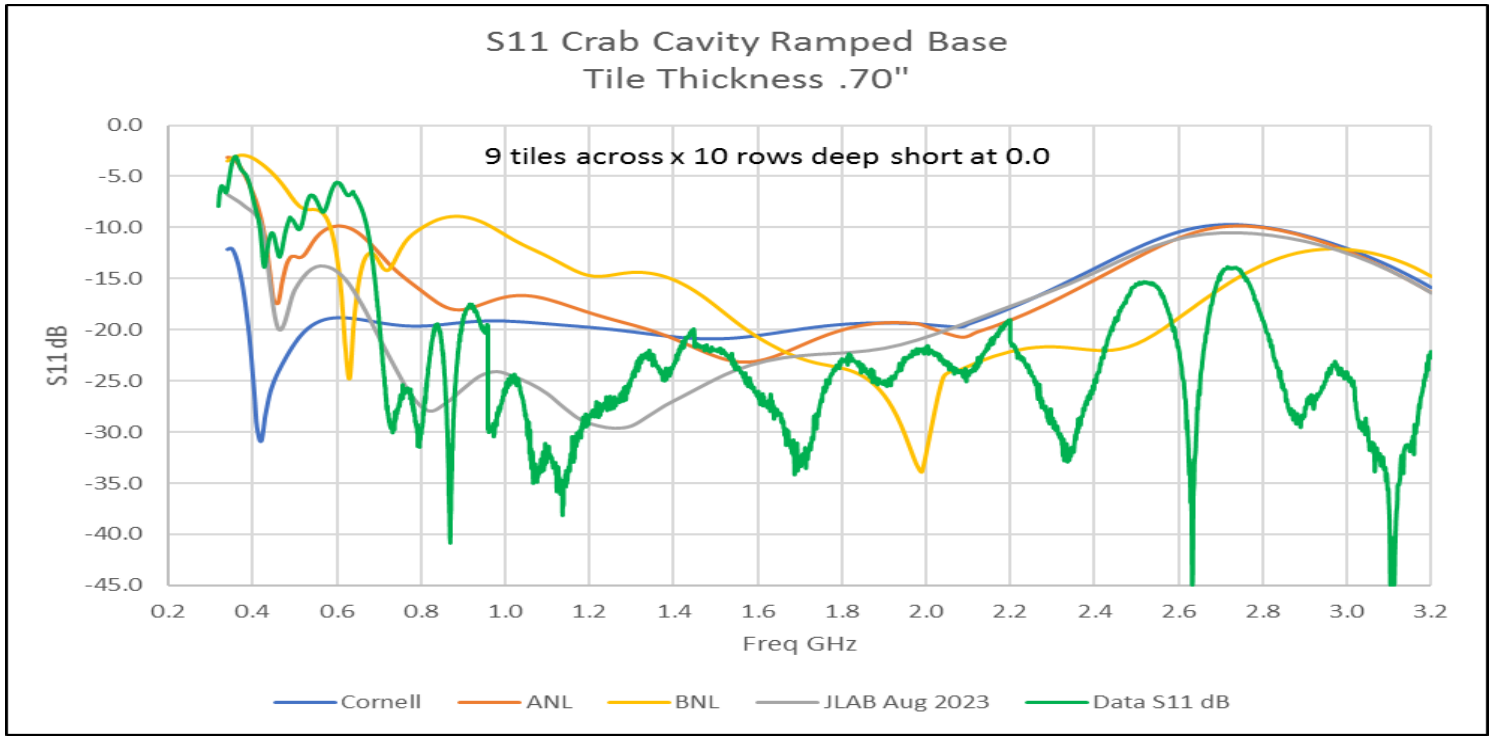


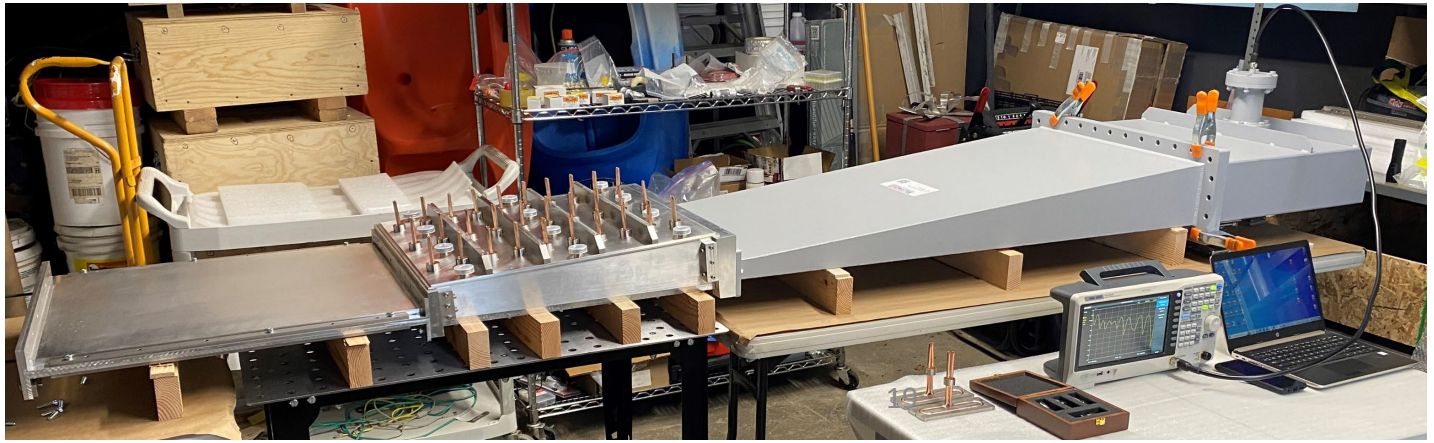
S11 Data Crab - Cavity



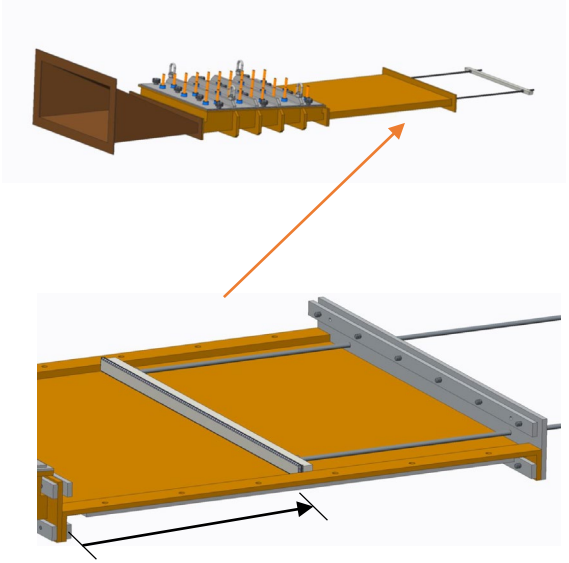


Short distance

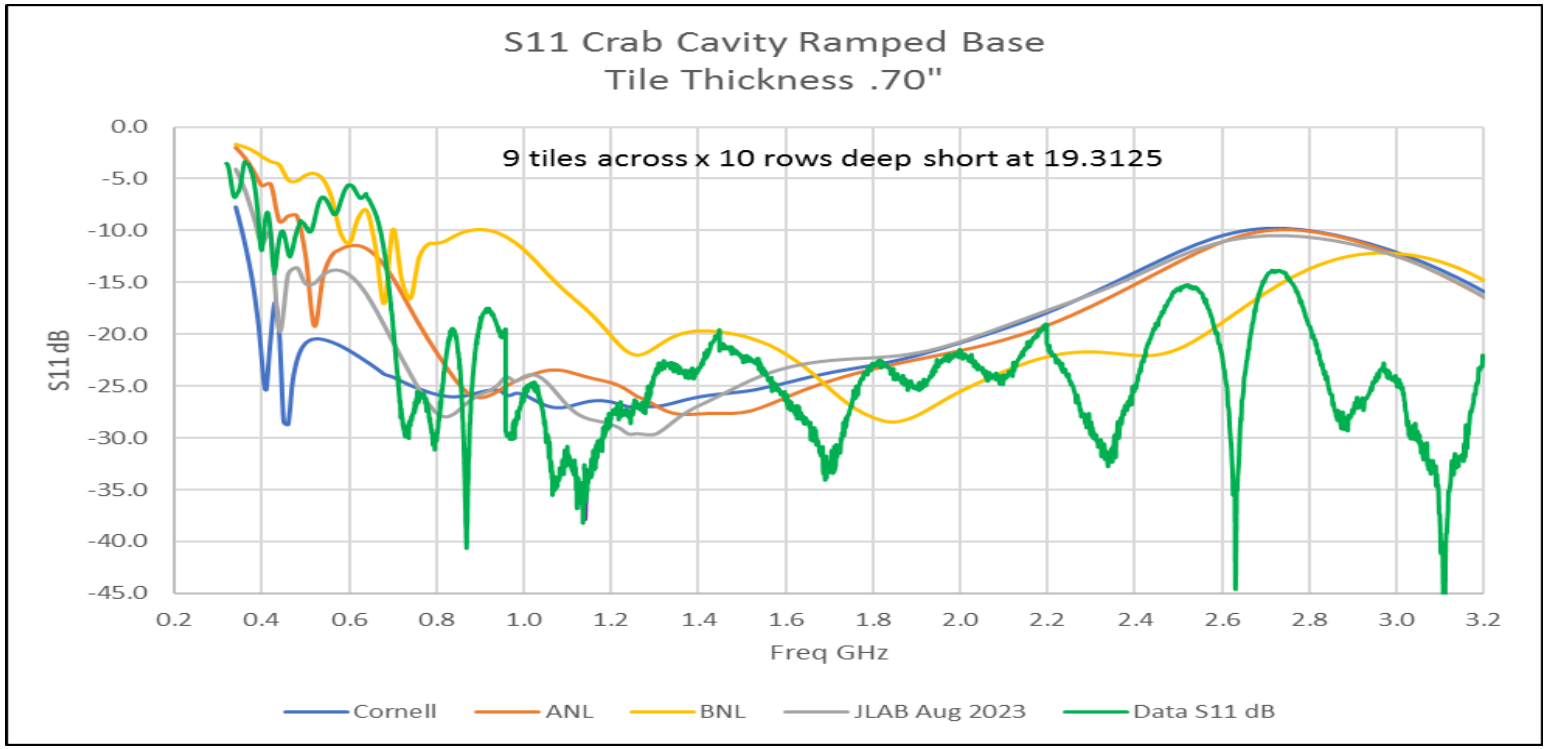




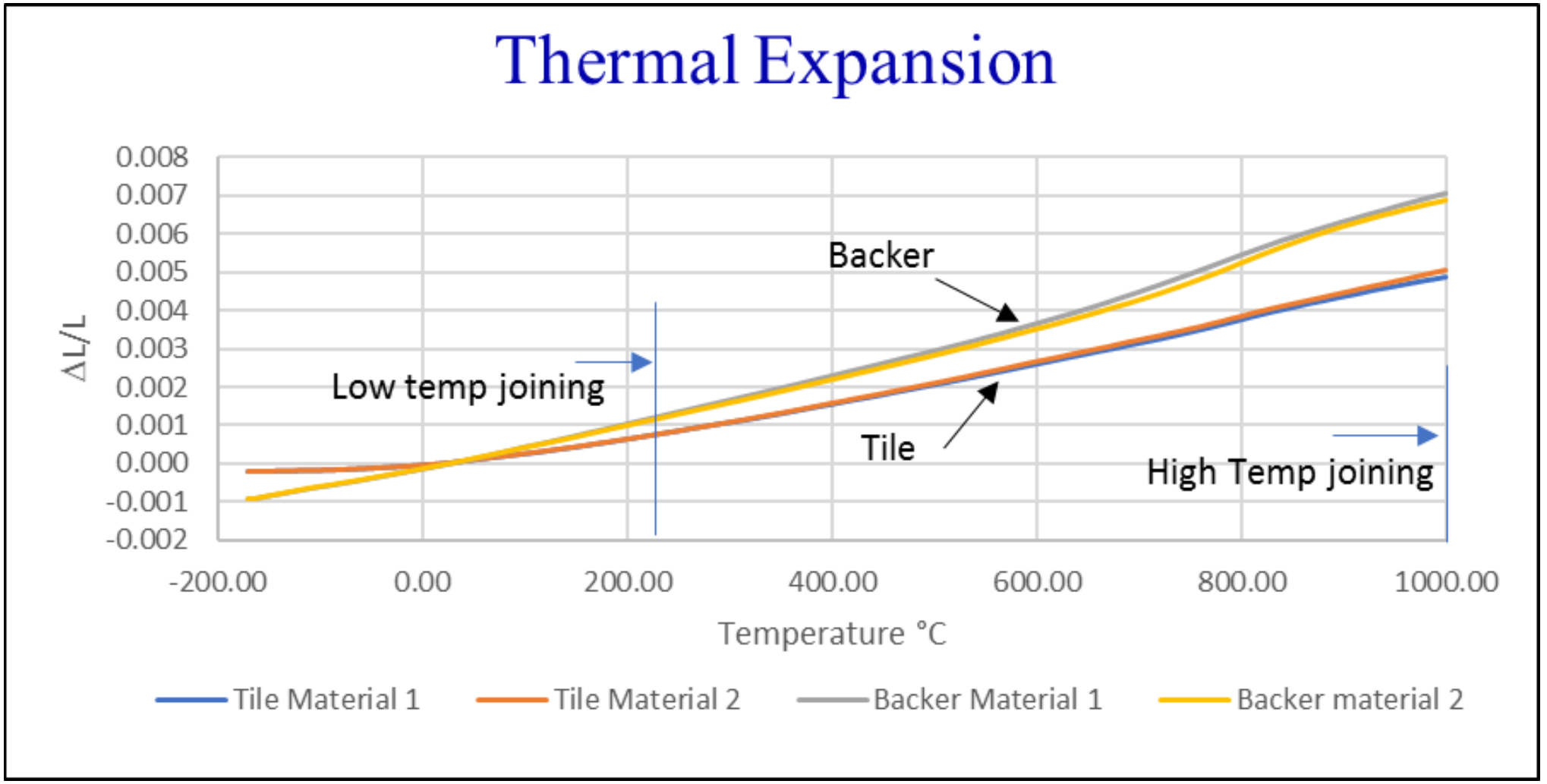
S11 Data Crab - Cavity



Short distance
19.313



CTE Data Tiles and backer material



SBIR Summary

- Fabricated waveguide and Beamline HOM Absorbers
  - B-Shaped
  - Crab Cavity
  - Beamline
- Compare RF properties Gr loaded SiC and DATA
- Developed Lightweight Backer Design
- Using HOM core can develop many geometries to accomplish HOM absorption
- 2, 3 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

- Thank You
  - Michelle, BNL, JLAB, DOE