ANL HOM DAMPERS AND BUNCH LENGTHENING SYSTEM

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JLEIC Collaboration Meeting Spring 2019

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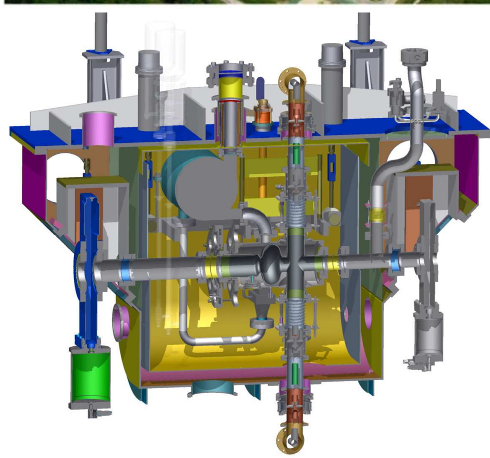
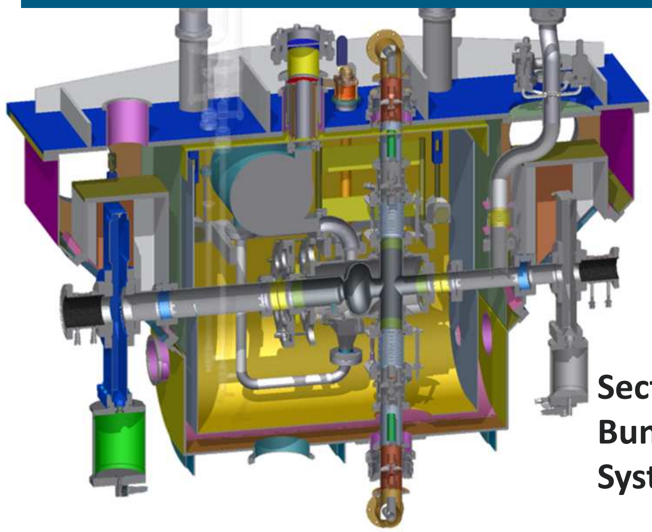
Monday April 1, 2019

PRESENT : Bunch Lengthening Superconducting Cavity for APS-Upgrade



- Practical benefit to future APS-U users by increasing beam lifetime
- Installation/commissioning in FY22/23
- High-power HOM damping relevant to EIC

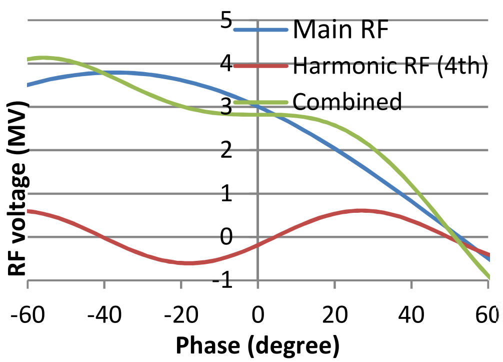
Introduction

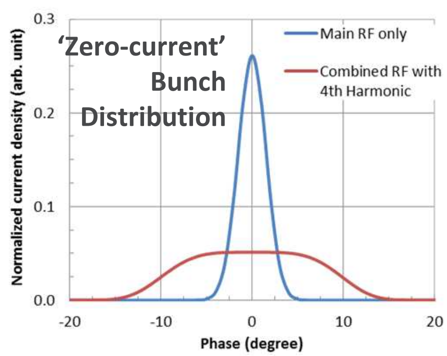


Section view of Bunch Lengthening System module

Why a Bunch Lengthening System ?

- Mitigates beam losses due to Touschek effect
  - –Large angle intra-beam Coulomb scattering otherwise limits beam lifetime in APS-U storage ring to ~1 hour
- Single harmonic system increases Touschek lifetime by 3-5 times
- Reduces unwanted RF heating



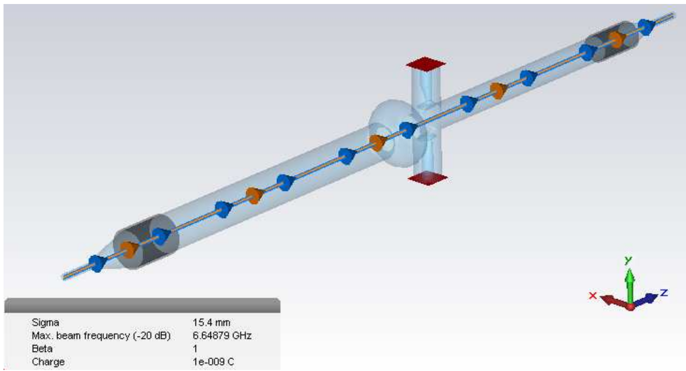


Why Use an SRF Cavity ?

- A single cavity meets APS-U requirement with margin on performance
- Straightforward handling of HOMs
- Lower overall impedance presented to beam
- Flexibility to adjust loaded quality factor

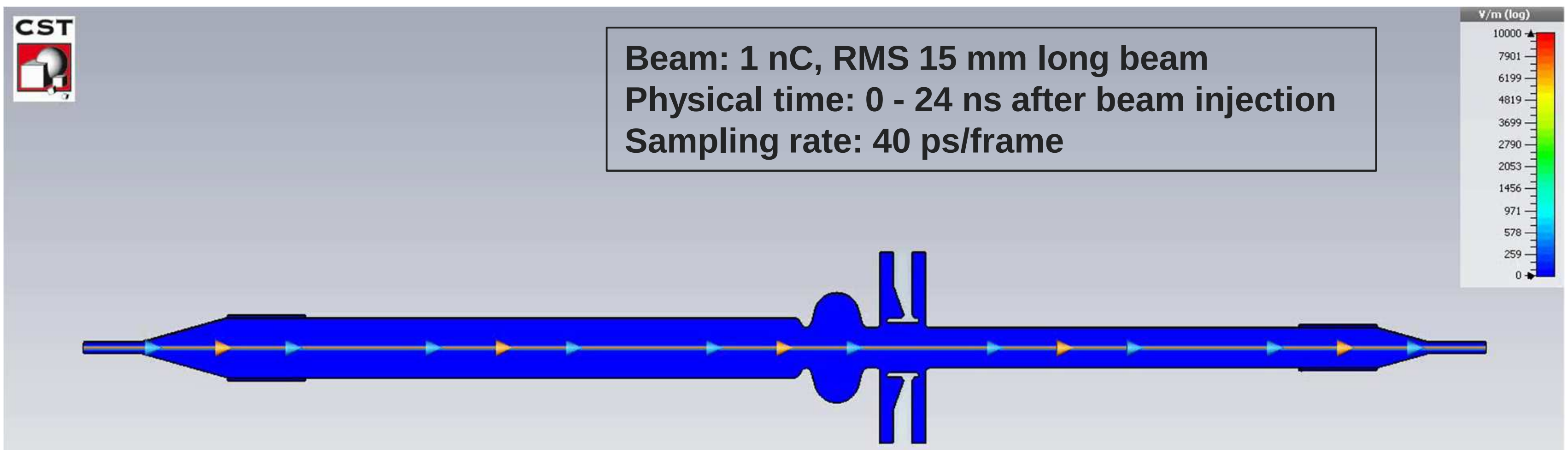
HIGHER ORDER MODES IN THE BUNCH LENGTHENING CAVITY

Higher Order Mode Impedance in the APS-U Bunch Lengthening System

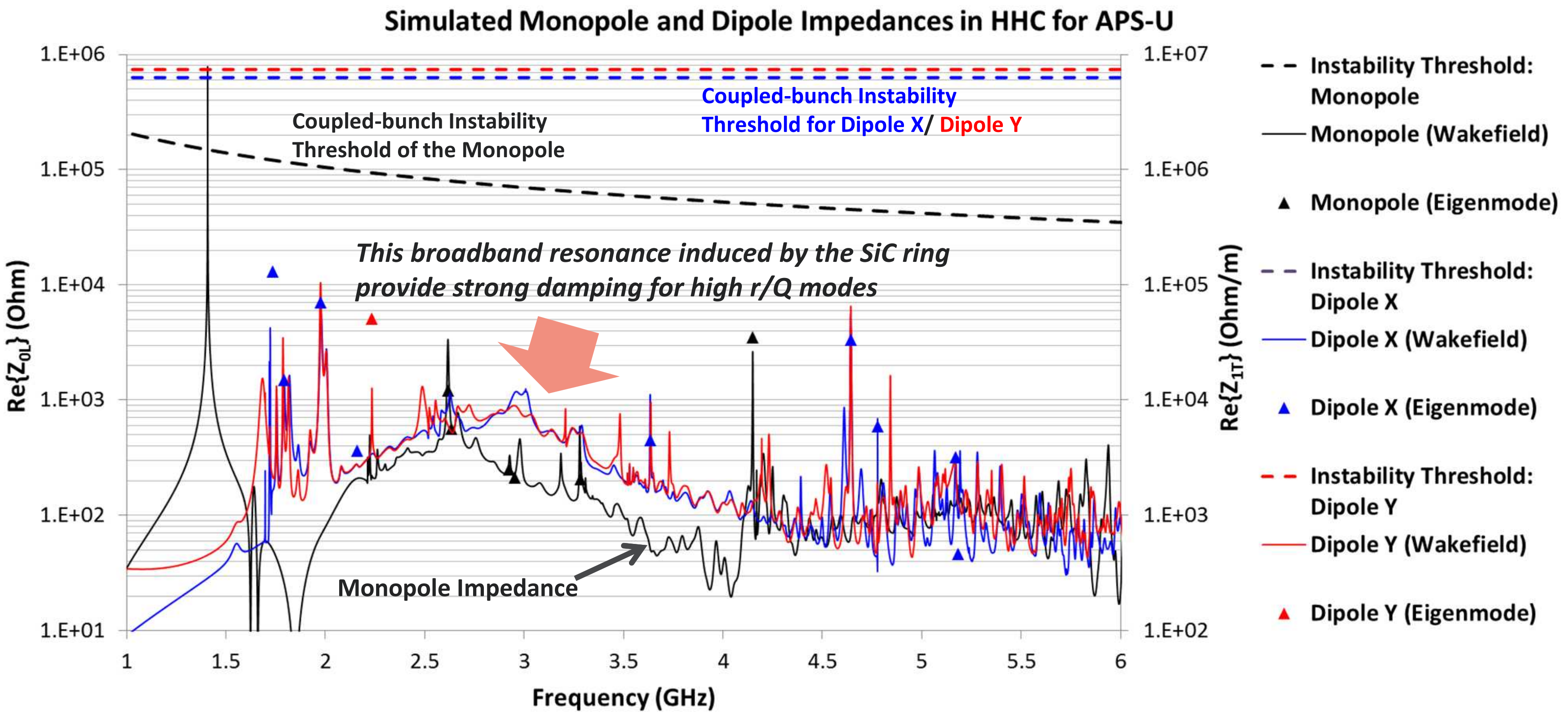


<u>Technical Approach</u>

- Beam tubes sized such that all monopole/dipole HOMs are above the cutoff frequency
- HOM power is dissipated outside of the cryomodule in room temperature (SiC) absorbers
- Conceptually and technically simple with high power handling capability (>10 kW)



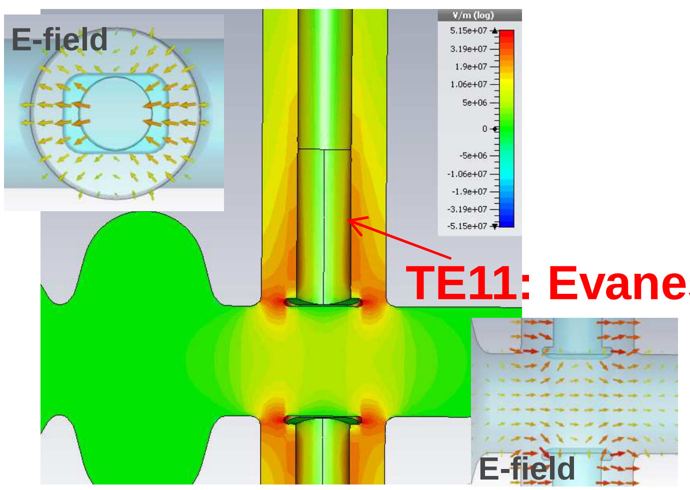
Higher Order Mode Impedance in the APS-U Bunch Lengthening System



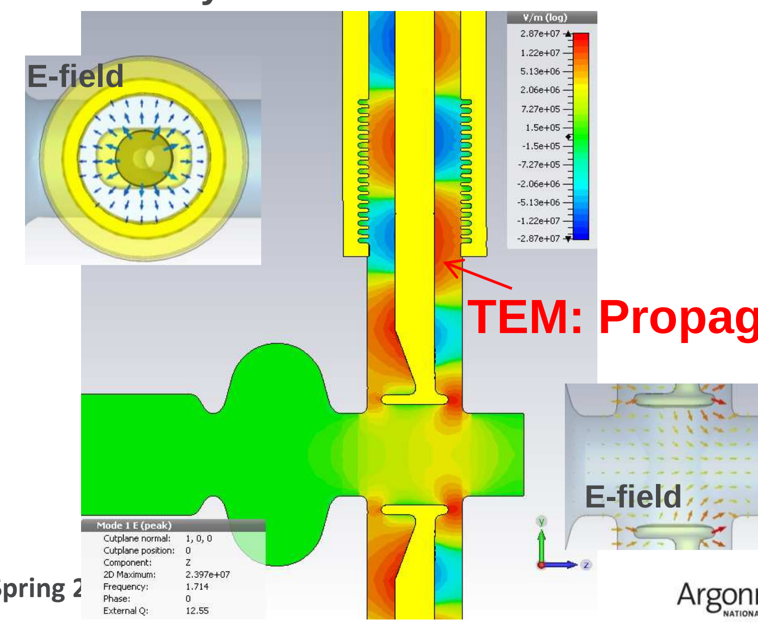
Caveat: No Trapped Cavity HOMs, But Coupler Ports Introduce Modes

- Issue: A trapped mode introduced by the coupler ports was initially present at 1.68 GHz
  - Monopole in the beam pipe but TE11-like in the coupler coax
  - Below the cutoff both the beam pipe (10 mm) and coupler (79 mm)
- Solution: Using a ‘mode converting’ antenna to couple TE-mode to TEM mode
  - previously trapped mode propagate as TEM mode so it propagates through the coupler and is damped in the coax water load

Symmetric Antenna



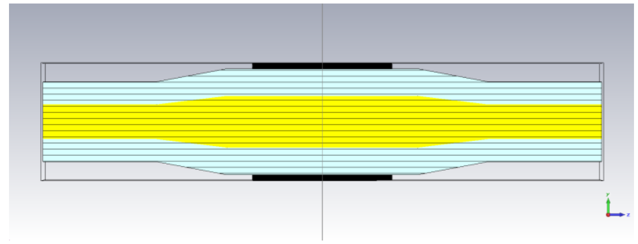
Asymmetric Antenna



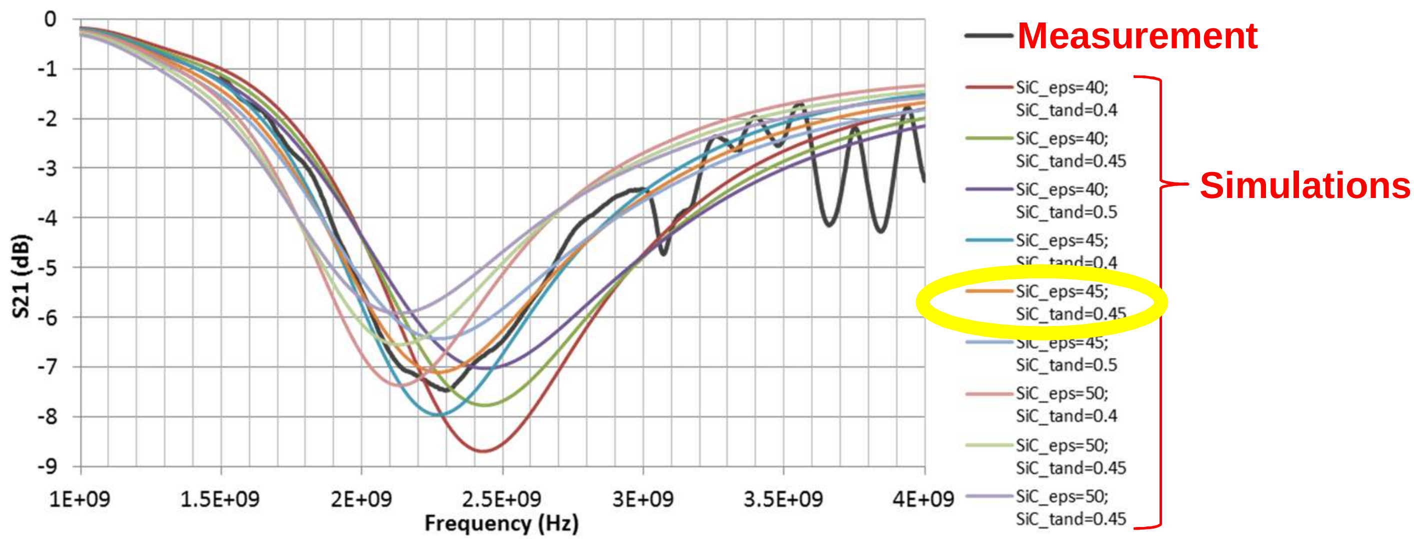
EXPERIMENTAL WORK ON HIGHER ORDER MODE ABSORBERS

Measured Dielectric Properties of Silicon Carbide

Coaxial line with embedded SiC cylinder

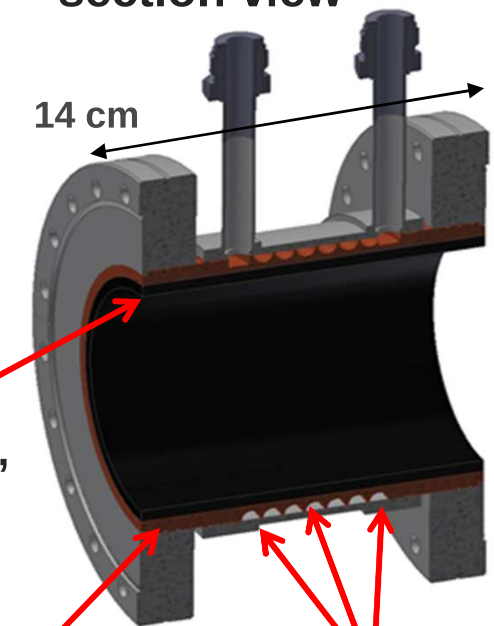


CST Microwave Studio Model



“Shrink Fit” Design of Higher Order Mode Absorber Assembly

HOM absorber assembly section view

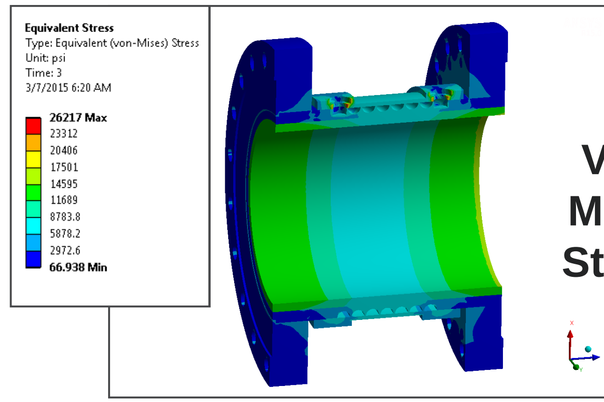


Hollow silicon carbide cylinder ID: 104 mm, Thickness: 5 mm

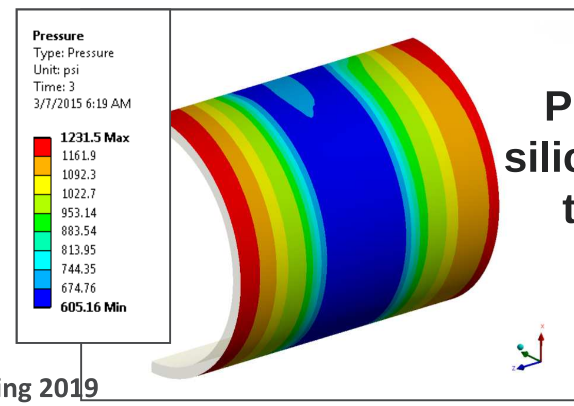
Copper cooling jacket

Cooling channels for water

Mechanical analysis (ANSYS)



Von-Mises Stress



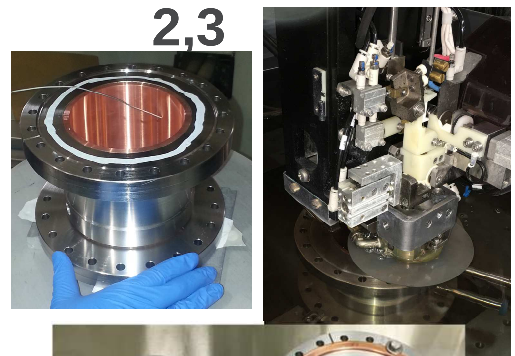
Pressure at silicon carbide-to-copper interface

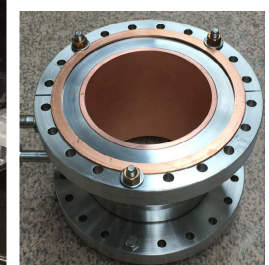
Fabrication of HOM Absorber Assembly

1. Machining (tolerances for “shrink fit”
2. Furnace brazing
3. ~10 micron precision bore (by wire EDM)
4. Hand polish the copper ID
5. Shrink fit: Heat up the copper/stainless steel assembly then slide the SiC into the copper

1

2,3





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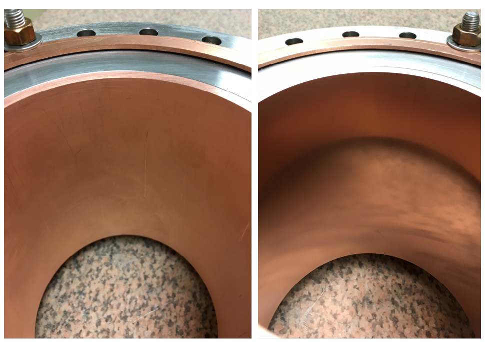

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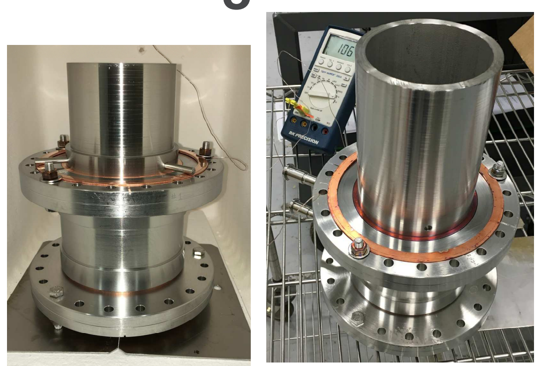


HOM absorber assembly

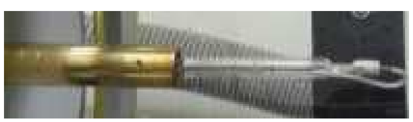
HOM Absorber Power Handling Capability > 10 kW

Calorimetric measurements using a light bulb

- Measured temperature different ΔT between the SiC inner surface and the copper outer surface
- Measured thermal contact conductance at the shrink fit interface is 10^4 W/m^2K:

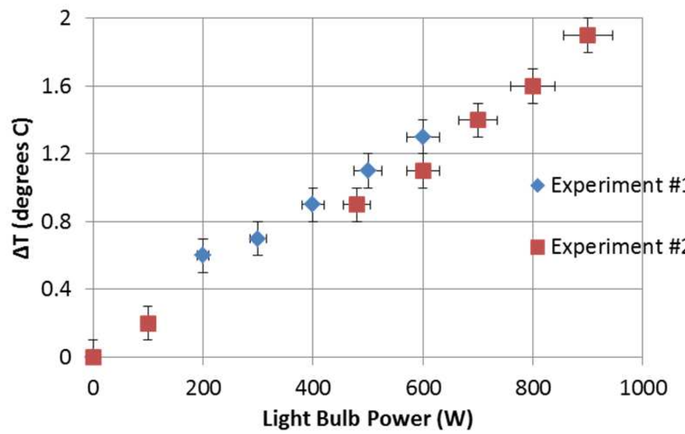
Measured ΔT = ~2℃ at 1 kW heat load

Based on these results, this is capable of working with >10 kW heat load

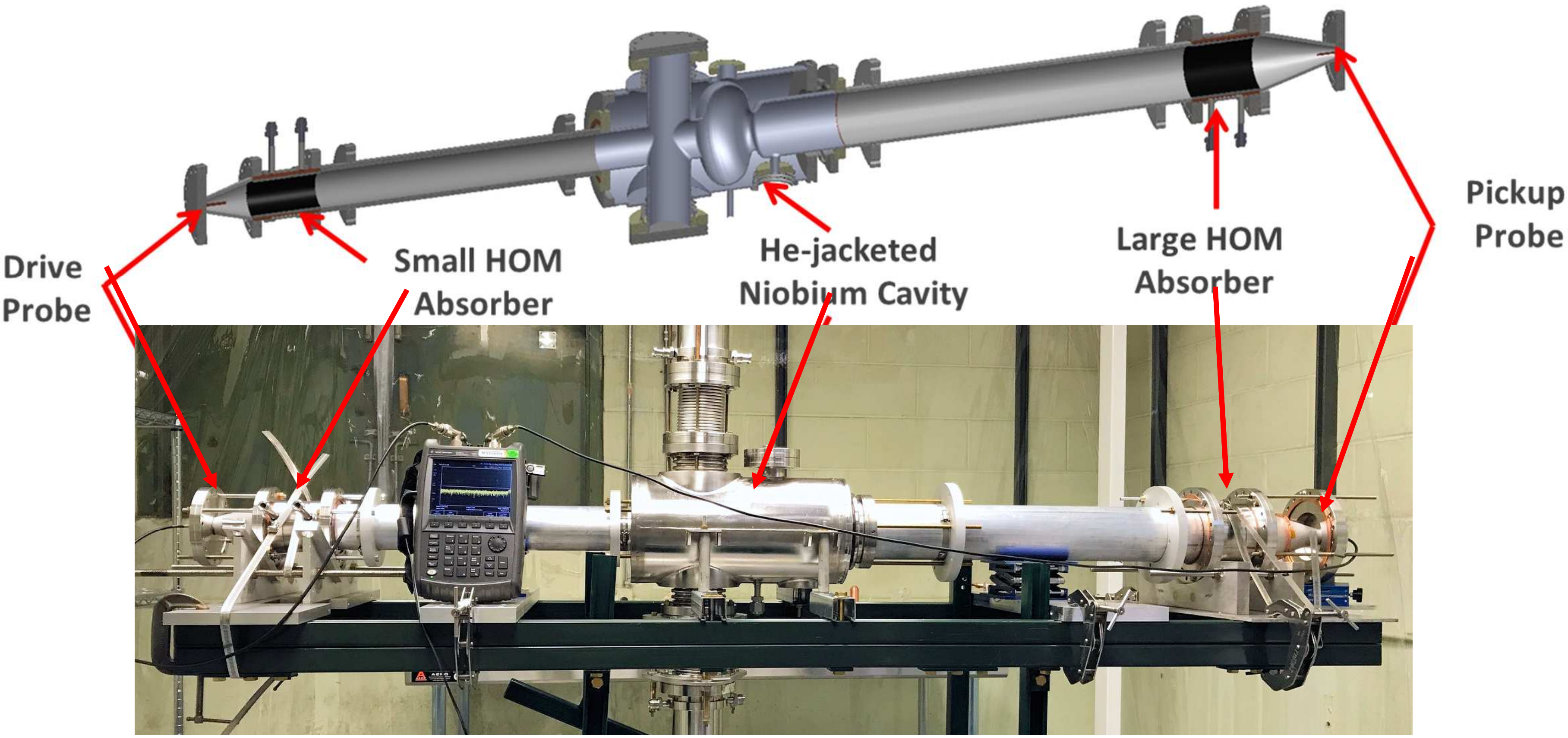


Halogen light bulb

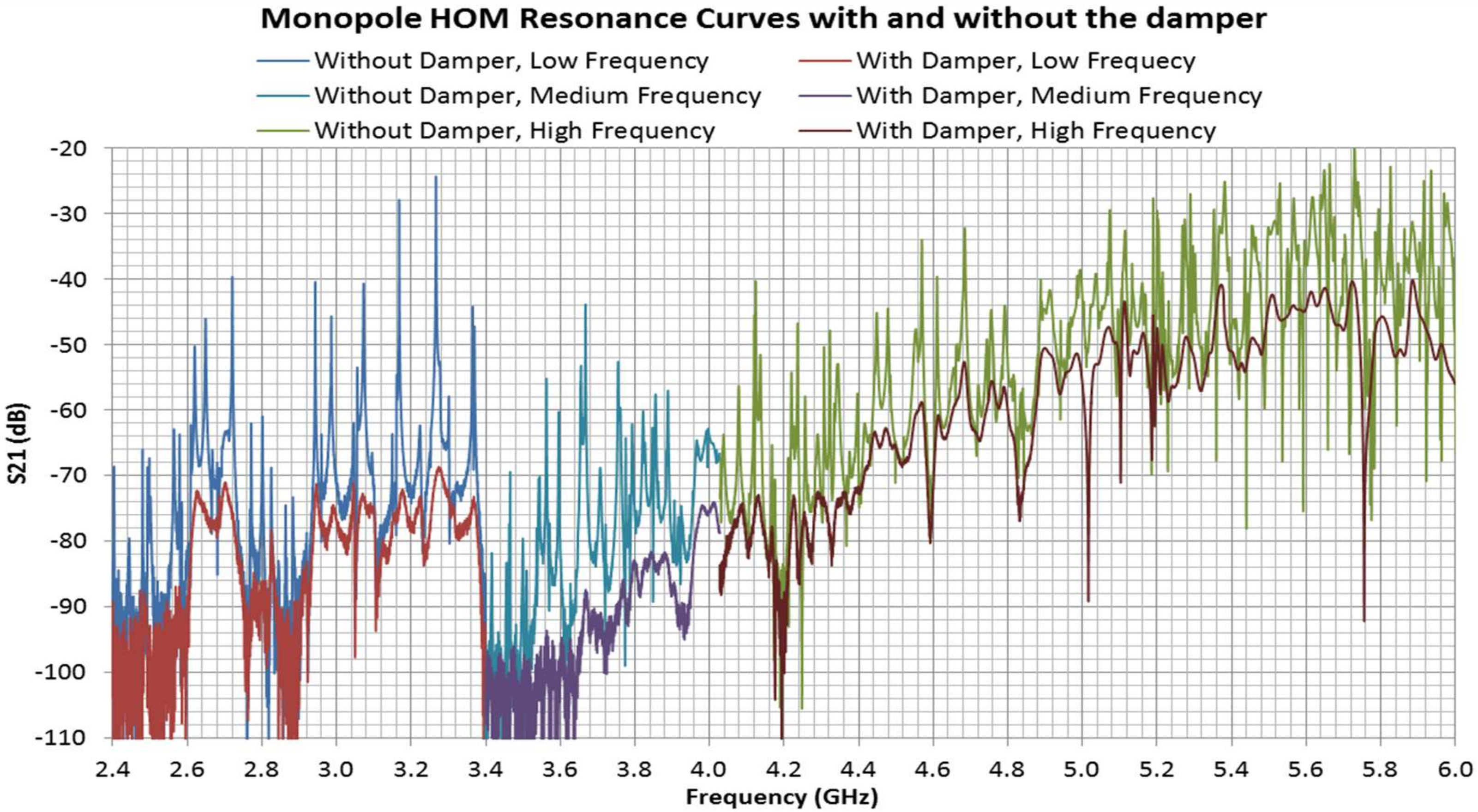
Temperature difference between the inner SiC surface of SiC and outer copper surface



Bench Top Verification of HOM Damping for the Bunch Lengthening System



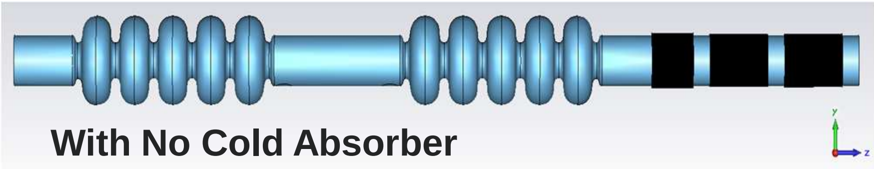
Higher Order Mode Impedance in the APS-U Bunch Lengthening System

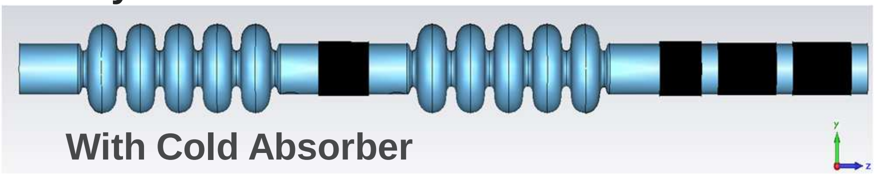


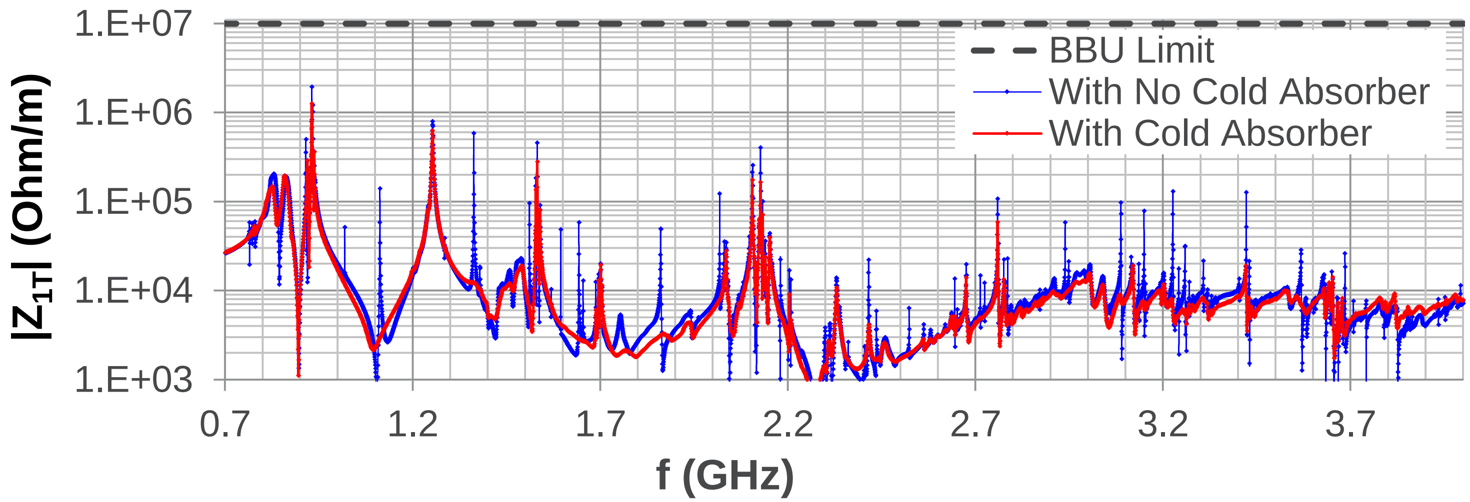
Beamline Absorbers as a Possible Alternative to Ridged Waveguides

May be possible to provide strong damping with only beamline absorbers; a 'cold' absorber is necessary to avoid potential trapped modes

647 MHz 5-cell cavity







FINAL COMMENTS

- Beamline HOM absorber solutions can be reliably simulated and are relevant to single and multi-cell SRF cavities
- Hardware has been developed with high power handling capability and appears to be robust
- HOM damping will be critical for a reliable EIC; ANL is eager to integrate HOM work, into ***e.g.*** a harmonic cavity cryomodule for EIC bunch lengthening (see talks at 2018 EIC Workshop)

ACKNOWLEDGEMENTS

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  - PHY: *Sang-hoon Kim* (presently FRIB), B. Mustapha, Z.A. Conway, K.W. Shepard, S. Kutsaev (now at Radiabeam)
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  - NE: A. Barcikowski, G. Cherry, R. Fischer
  - Central Shops: W. Toter, D. Carvelli
- Outside vendors: Coorstek, Advanced Energy System, Meyer Tools, Anderson-Dahlen

BACKUP

BUNCH LENGTHENING SYSTEM PARAMETERS

Parameter	Symbol	Unit	Value
Operating Temperature	T	K	2.1
R/Q	r/Q	Ohm	104
Cavity Quality Factor (2.1 K)	Q_0		$6x10^9$
External Q range	Q_{ext}		$4x10^5$-$4x10^7$
Detuning Frequency	Δf_r	kHz	10
Q_L nominal	Q_L		$6x10^5$
Cavity Resonant Frequency	f_r	MHz	1408
Beam-Induced Voltage	V_b	MV	1.25
Detuning angle	ψ_h	degrees	83.0
Cavity Loaded Bandwidth	Δf_{BW}	kHz	2.35
Total Beam Loss Power @ nominal Q_L=$6x10^5$	P_b	kW	25
Cavity Wall Loss Power (2.1 K)	P_{wall}	W	2.5
Peak Surface Electric Field	E_{peak}	MV/m	24
Peak Surface Magnetic Field	B_{peak}	mT	49