RFD Ancillary Fabrication at JLab

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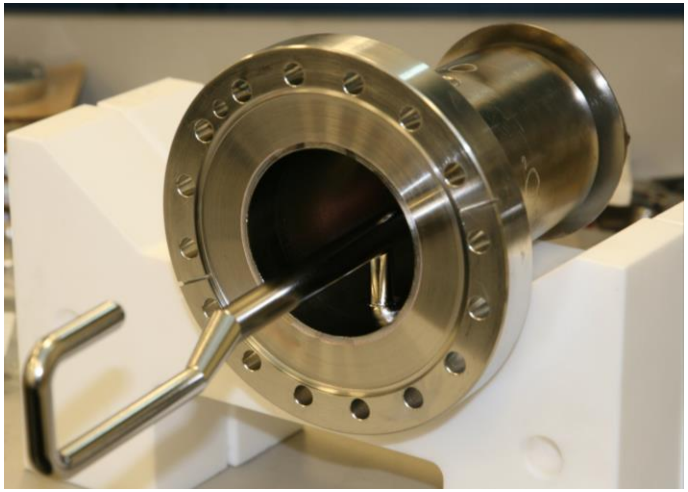
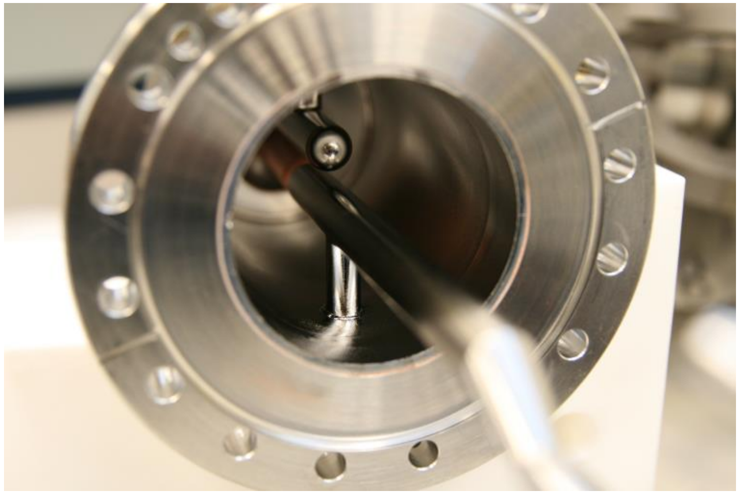
HL-LHC Collaboration Meeting – October 14 - 16, 2019

Introduction

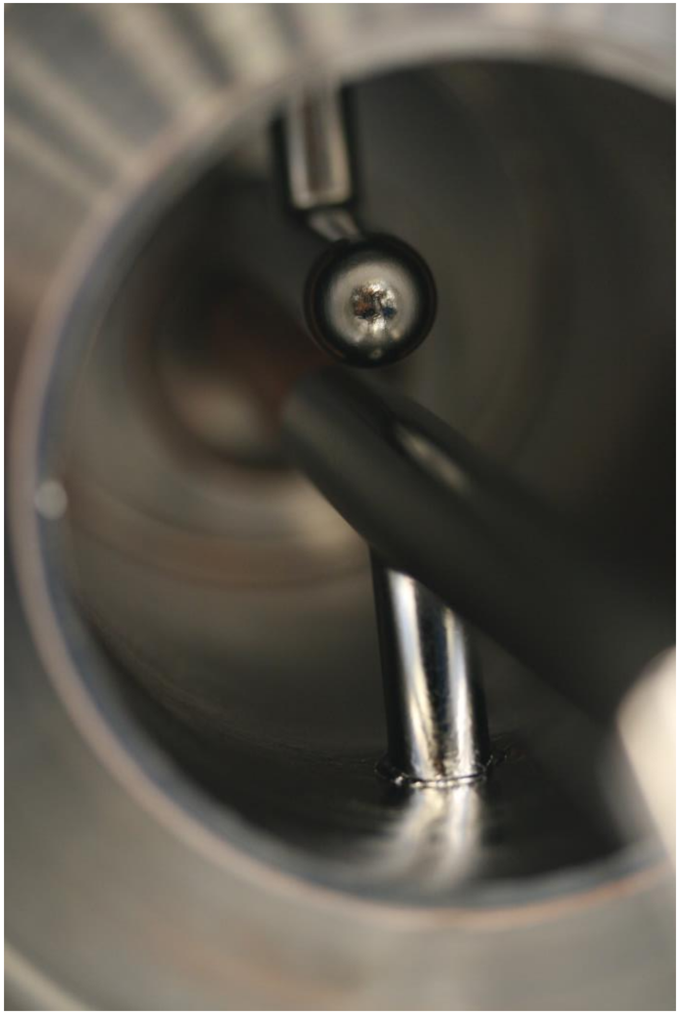
- Dressed RFD cavities have several ancillary components:
  - Horizontal HOM Damper
  - Vertical HOM Damper
  - Field Antenna (Pick-Up)
- These components will be fabricated at JLab
- Initial prototypes were fabricated in 2017/2018 under US-LARP
- The fabrication and performance lessons will be integrated into AUP





JLab Scope of Work

- JLab will be building a total of 17 sets of RFD ancillaries
- Each set consists of a HHOM Damper, VHOM Damper, and Pick-Up
  - The first three sets are prototypes, which rely on an RF design from AUP and a fabrication design from JLab
  - The following four units are Pre-Series, which represent the first articles of the production design
  - The final ten units are production units



JLab Scope of Work

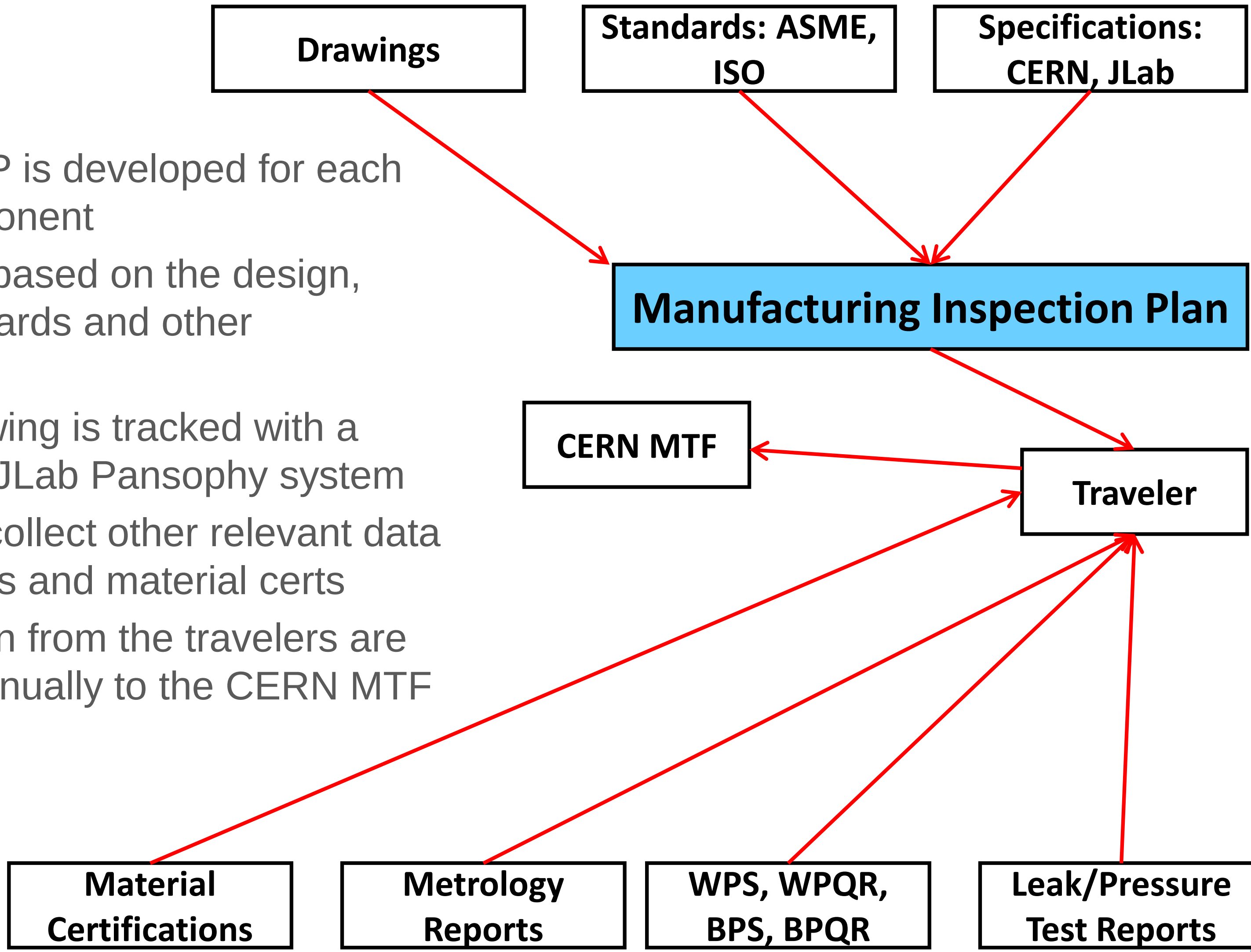
- The components will be fabricated as per the QA/QC requirements from CERN
  - The prototypes are a ‘best effort’ in this regard
  - Pre-series and production units will be based on stricter adherence to the requirements (MIP, MTF etc.)
- All material complies with the agreed list from CERN

Timeline

	FY19		FY20				FY21				FY22	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Qualification/Planning												
Prototype Fabrication												
Pre-Series Fabrication												
Production Fabrication												

Manufacturing Inspection Plan (MIP)

- A separate MIP is developed for each ancillary component
- The MIPs are based on the design, required standards and other specifications
- Each part drawing is tracked with a traveler in the JLab Pansophy system
- The travelers collect other relevant data e.g. test reports and material certs
- The information from the travelers are transferred manually to the CERN MTF

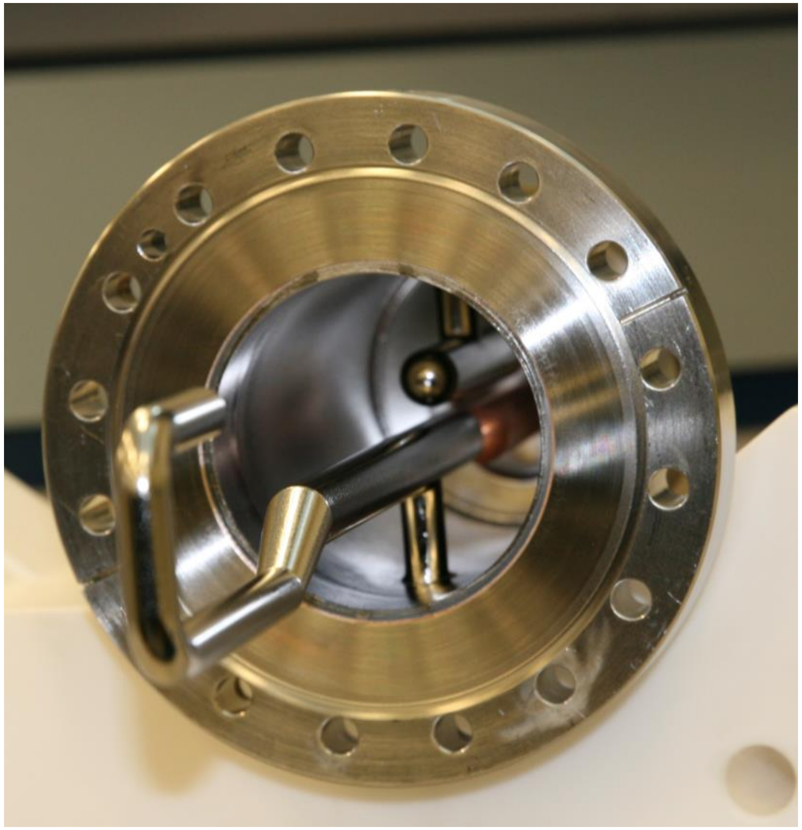


US-LARP Damper Fabrication

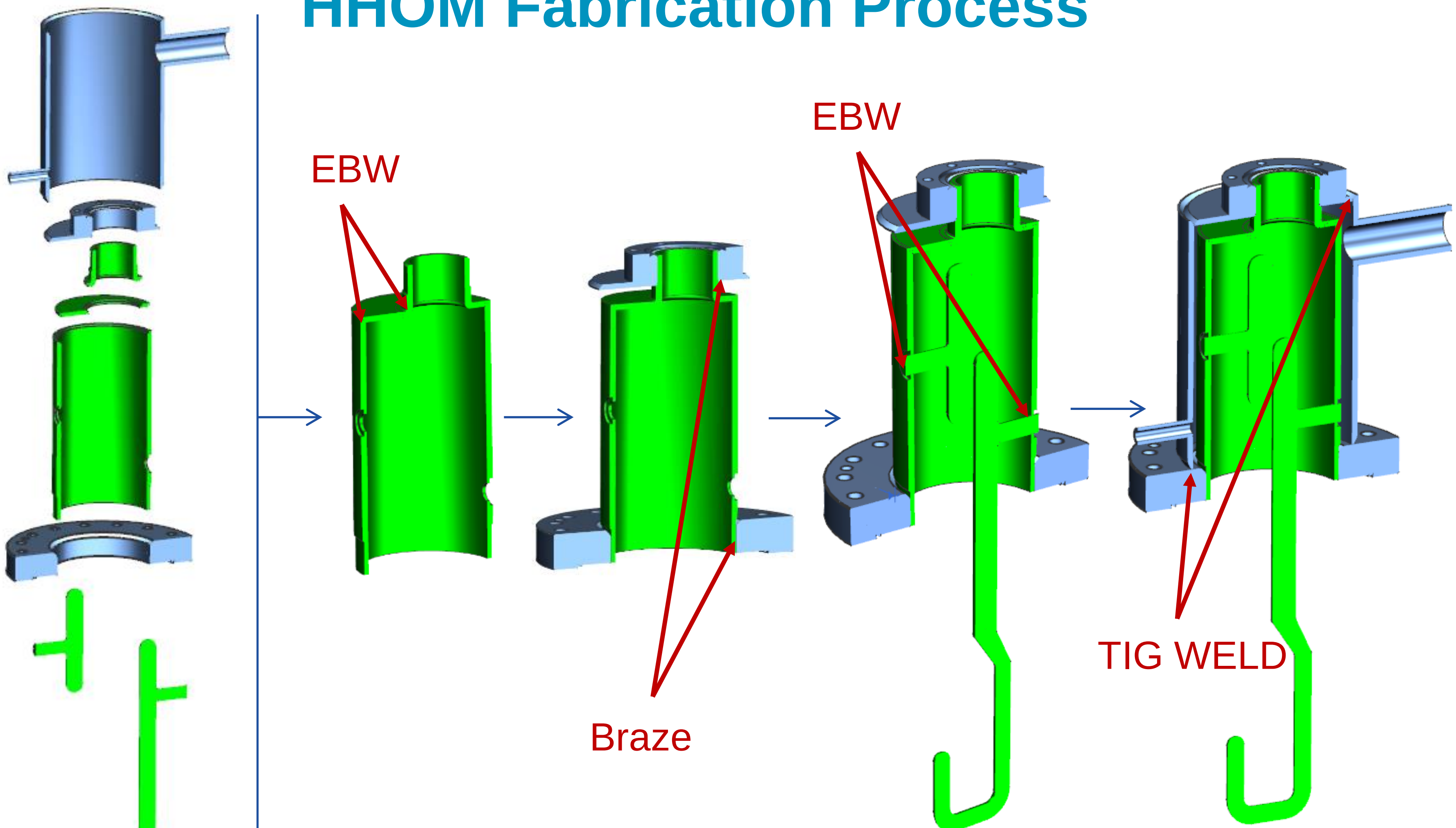
- Two sets of HHOM Dampers were fabricated to be used for vertical RFD cavity tests
- Designs for the feedthrough of the HHOM, VHOM and Pick-Up were not available at the time
  - Commercial feedthroughs with custom probes were used for vertical testing

US-LARP Damper Fabrication

HHOM Damper (left), HHOM Damper Feedthrough (center), VHOM Damper Probe (right)



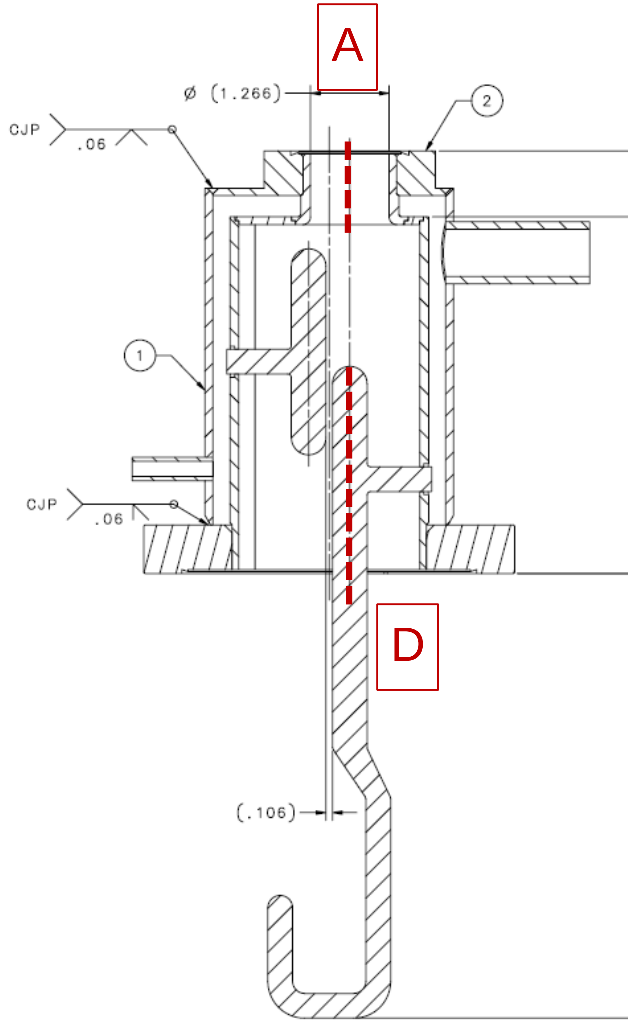
HHOM Fabrication Process



(green)	Niobium (RRR>300)
(dark blue)	316L SS (Helium Jacket)
(dark blue)	316LN SS (Flanges)

HHOM Fabrication Process

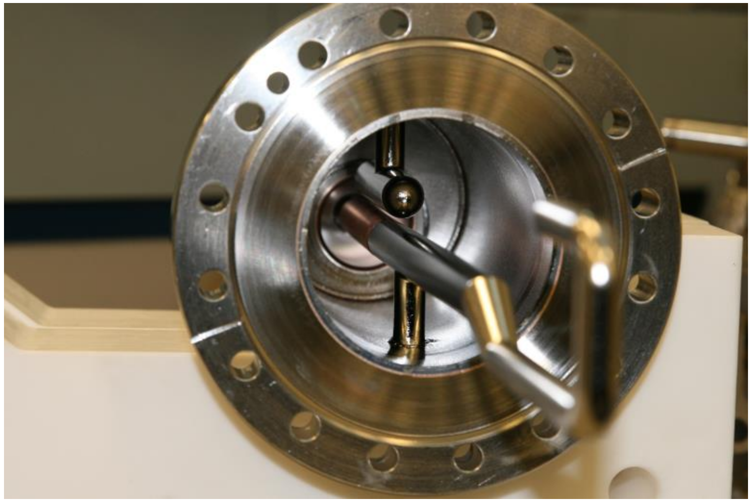
HHOM Lessons Learned



- The concentricity of datums A and D were out of tolerance (0.090 and 0.106)
- The EBW fixture allowed a free degree of freedom
- Weld shrinkage in this direction caused displacement of the Hook and Tee
- A redesigned weld fixture will be used for AUP HHOM dampers

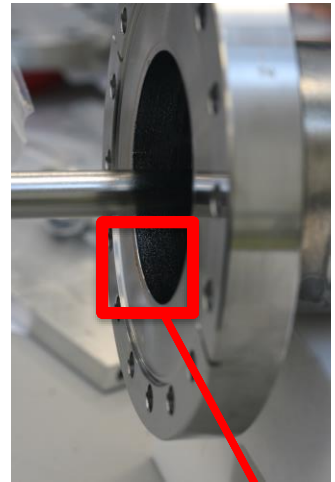
HHOM Lessons Learned

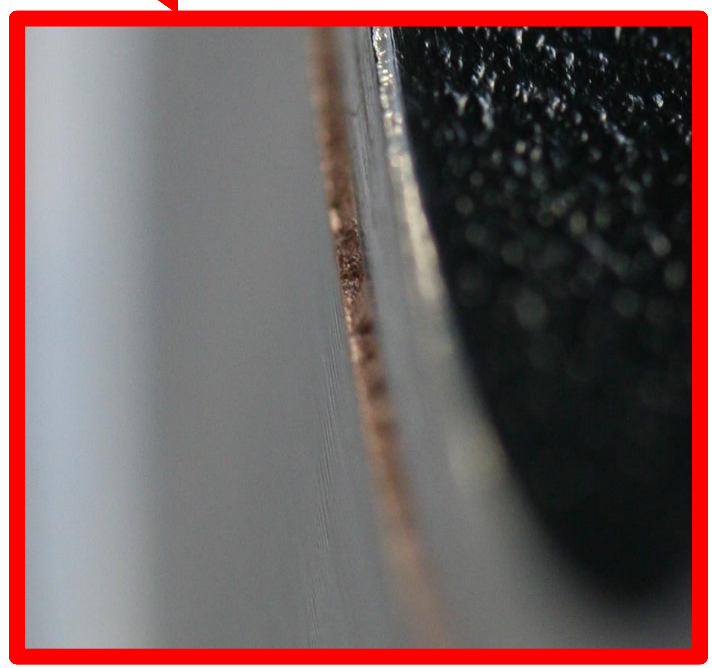
- The weld of the Hook and Tee to the can ID is a critical RF surface
- The plug weld created an inconsistent inner fillet
- RF calculations found this acceptable
- New weld interface will have a machined circular section
- The weld will be a full penetration 3.5mm square weld
- New configuration will reduce number of required EBW qualifications required



HHOM Lessons Learned

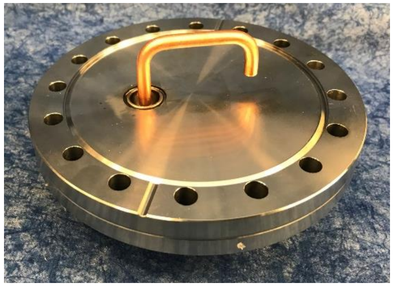
- The Nb tube was not completely flush to the Stainless Steel flange during the braze
- A similar issue was present at the corresponding braze on the cavity
- The exposed stainless steel caused RF heating at the interface
- Custom gaskets with “RF lips” were used to shield the exposed stainless steel
- Use of gasket and copper strips (top right) returned cavity performance to the same levels as without the HOMs
  - V_t~5.5 MV
  - Q_0 1e10
- Revised HHOM damper design will have the flange knife edge machined flush after brazing

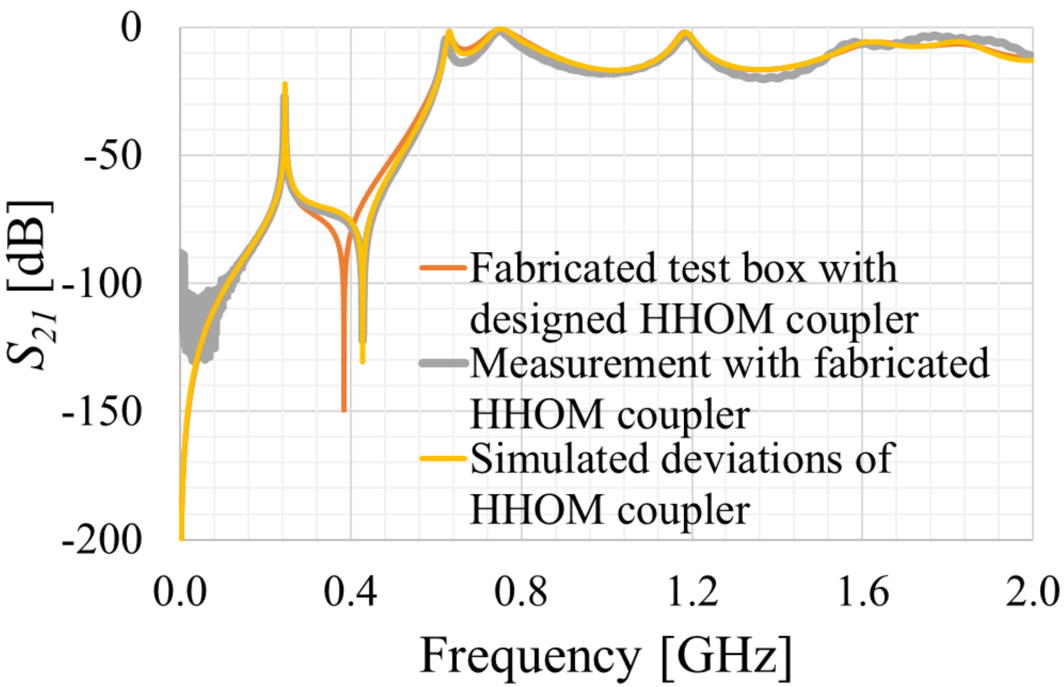




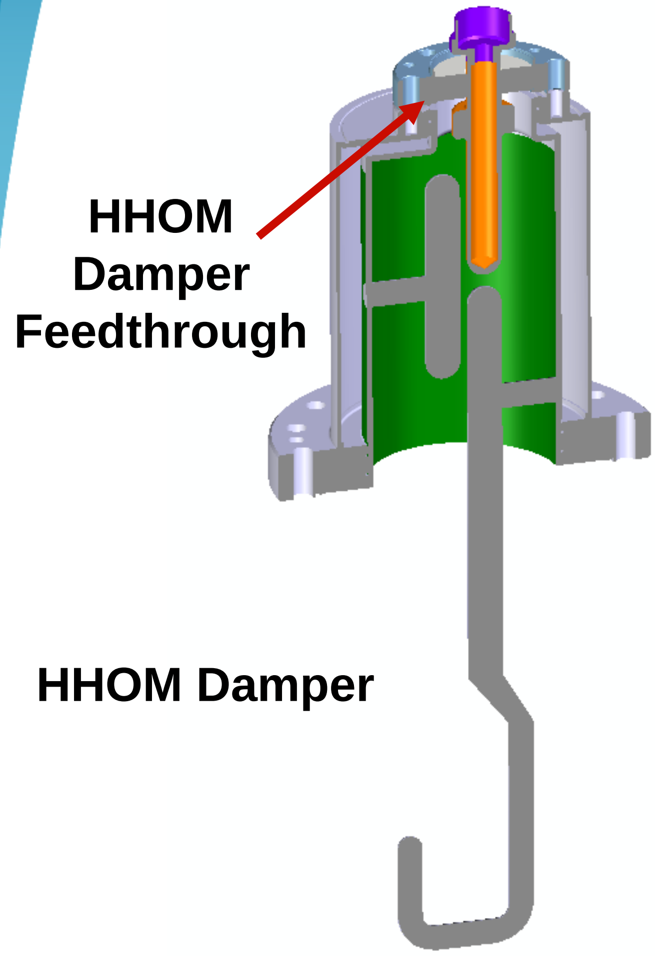
HHOM Performance (Warm)

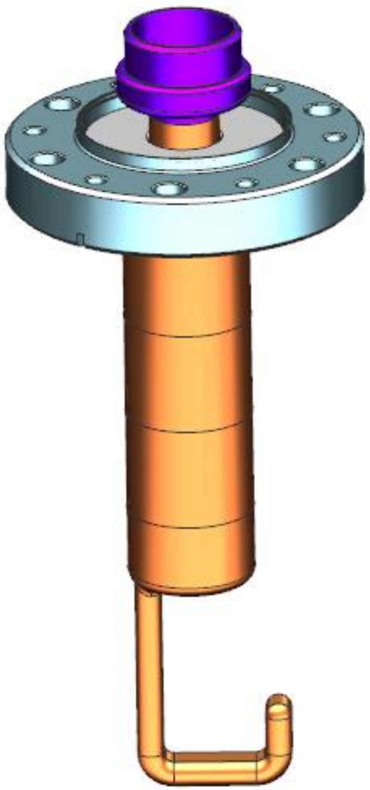
- A Test Box was designed and fabricated to test the HHOM Dampers
- The test box found that the transmission of HOMs above 600 MHz matched the design, but the notch was shifted due to the dimensional deviations
- Adjustments to the Probe length and diameter were used to adjust the notch
- Similar test box will be used for AUP dampers



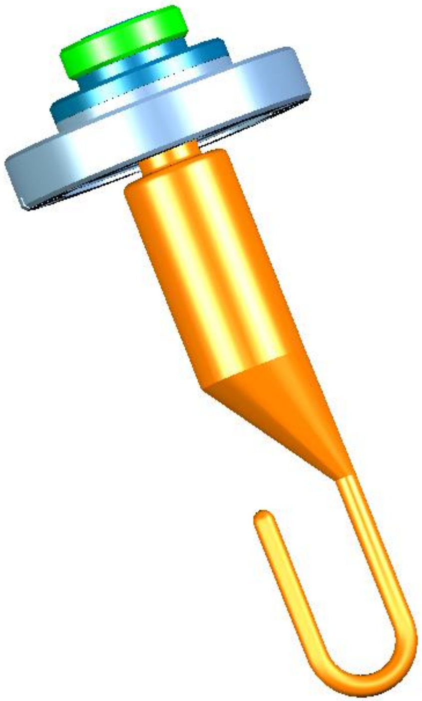


AUP Ancillaries





VHOM Damper



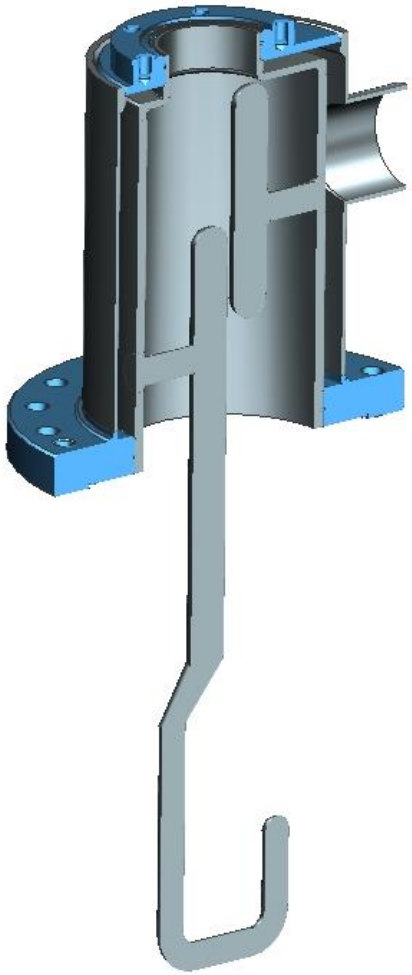
Field Antenna

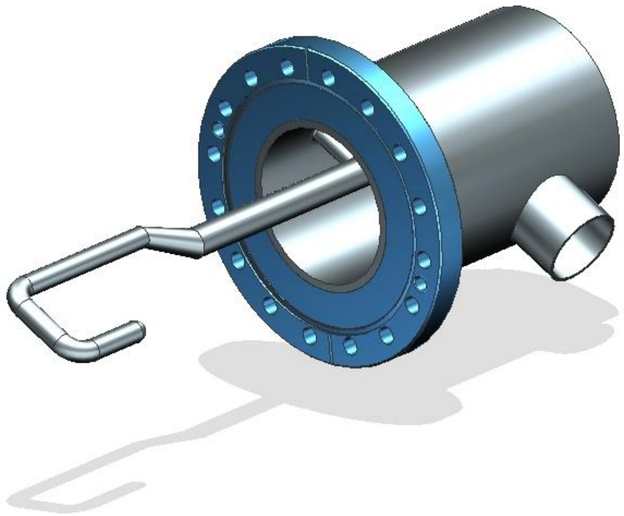
AUP Ancillaries

- The HHOM Feedthrough, VHOM and Field Antenna are all DN40 flanges with brazed ceramic and a probe
  - CERN designs use a Titanium flange and probes made of a combination of Copper and Nb
  - AUP designs will use a 316LN SS flange with fully Copper probes
- Manufacturing drawings will be developed at JLab based on the 300K model from CERN
- Ceramic (97% Al_2O_3) will be purchased in a metalized state
- Brazing and EBW will be carried out at JLab

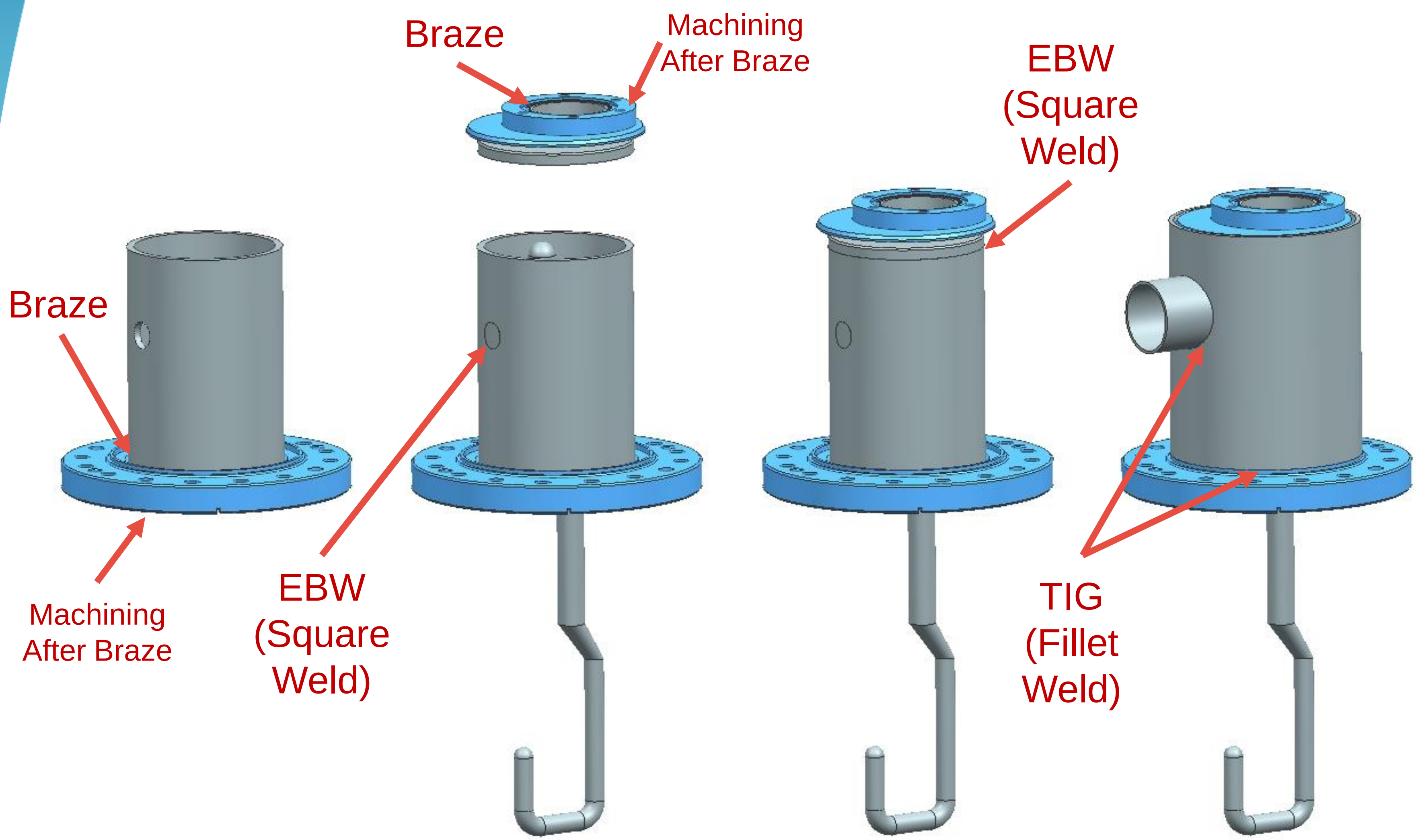
AUP HHOM Damper

- Changed weld interface designs
  - Plug welds for the Hook and Tee are replaced by square welds
  - Fillet-style welds on top can lid replaced by square weld
- Flange knife edges to be machined after brazing
- Nb can may be machined from solid rod instead of rolling from sheet
- Redesigned EBW fixtures to control Hook/Tee positions
- All EBWs and brazes undergo UT after leak check



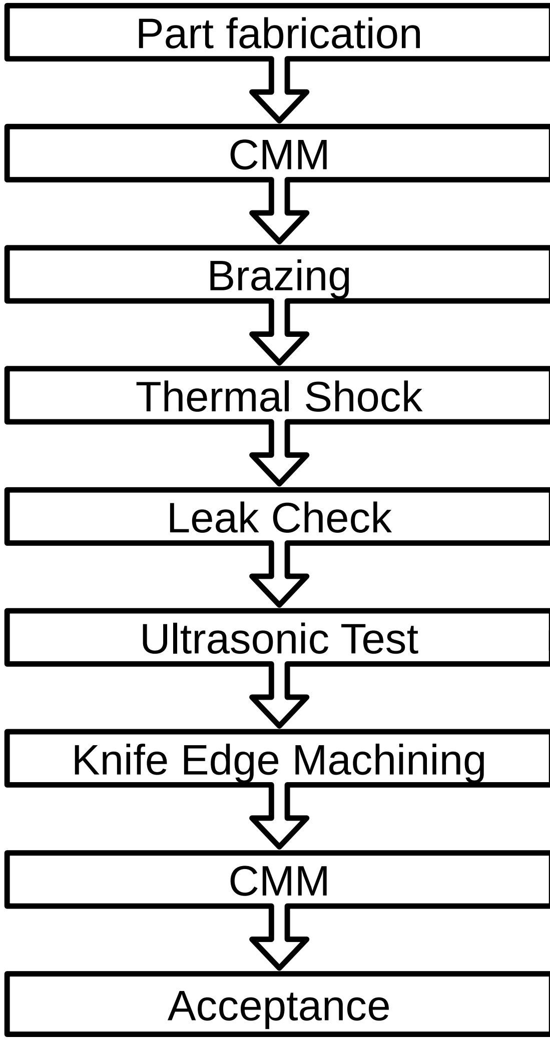


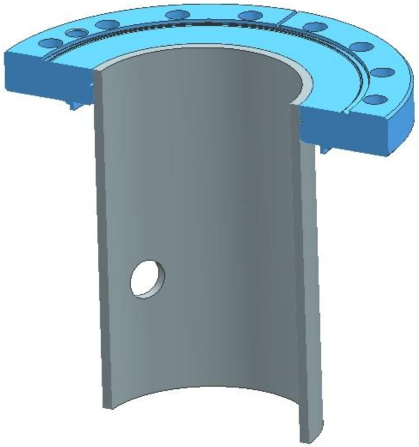
AUP HHOM Damper Fabrication Sequence

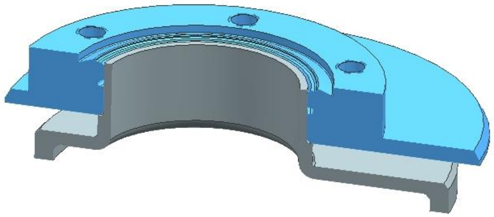


Brazing Scheme – Nb to SS

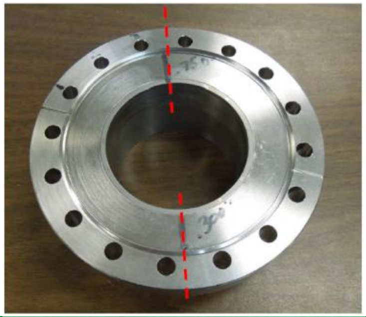
- A DN100 CF flange is brazed to the Nb tube, forming in the inner Nb chamber of the HHOM damper (right image)
- Filler material is OFHC Copper
- The process goes through several CMM and inspection processes
- The knife edge of the DN100 CF flange is machined after the braze
- The braze for the DN40 flange (bottom image) is carried out with the same steps
- Braze filler material is OFHC Copper



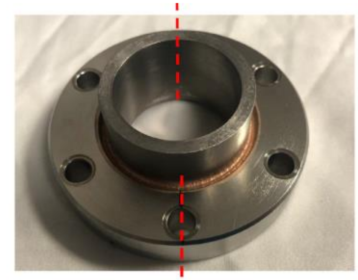


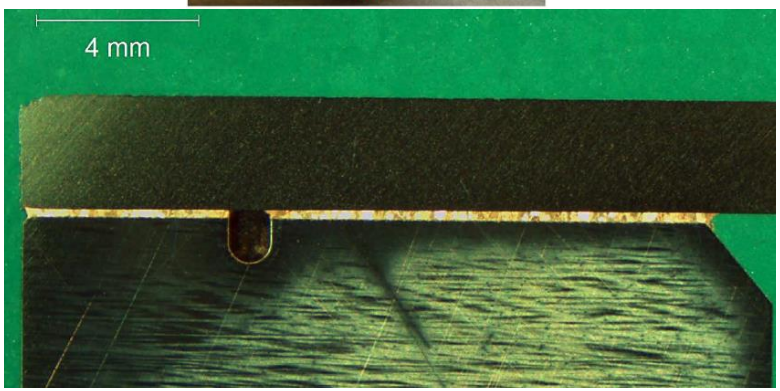


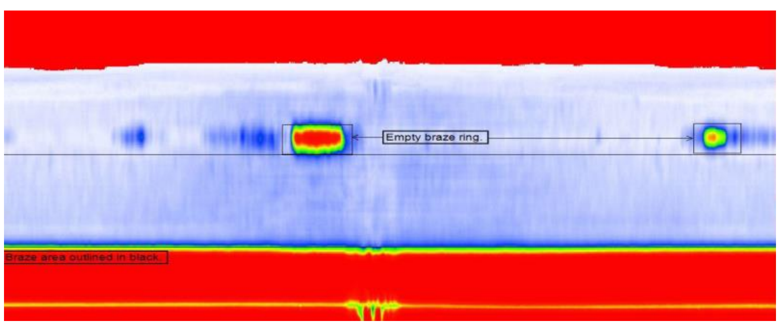
NB-SS Braze Qualification

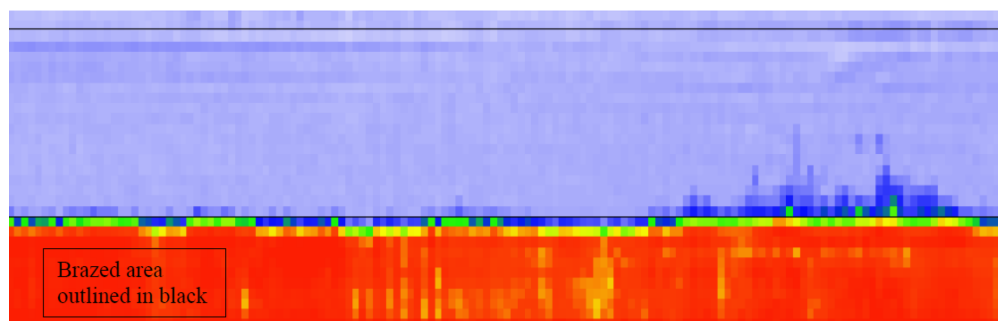


- Assemblies passed leak check after thermal shock
- Brazes were good to ISO 18279 Level B+



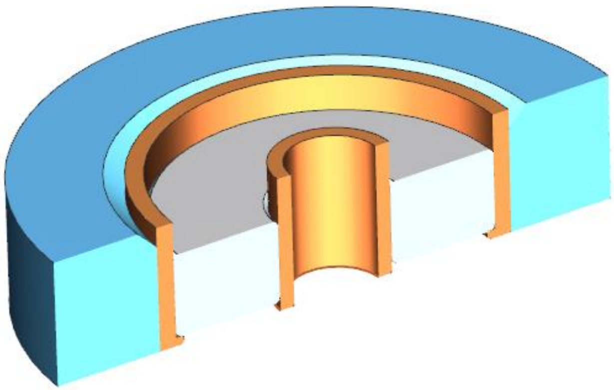


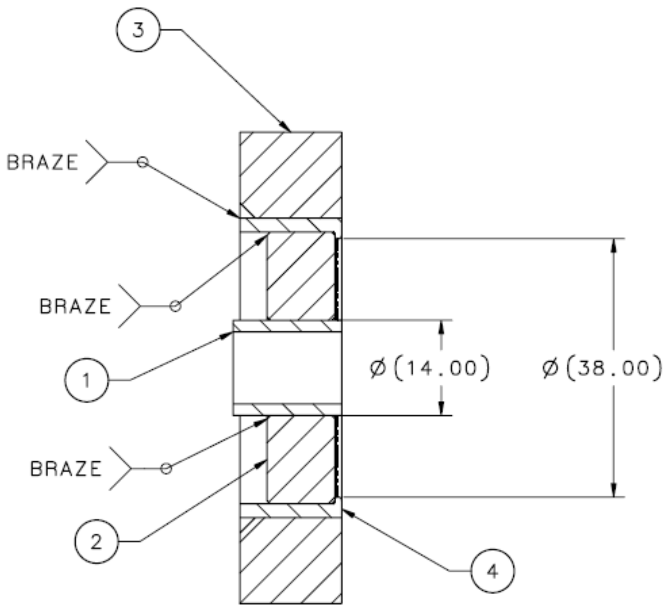




Brazing Scheme – SS to Ceramic

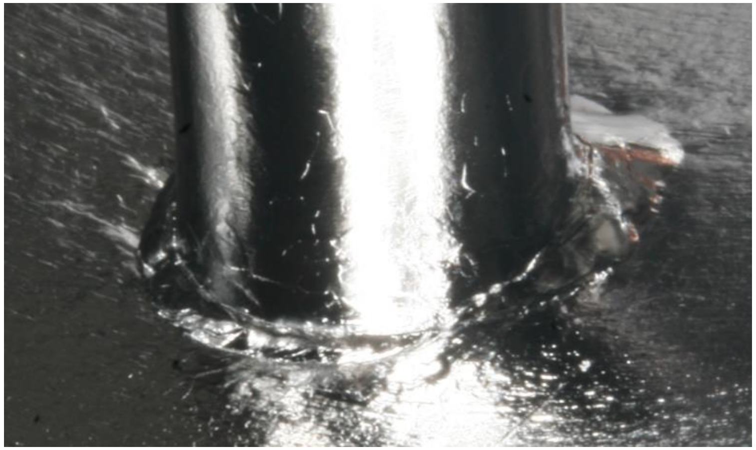
- The HHOM Feedthrough, VHOM damper and Pick-Up all use copper probes brazed on to ceramics
- Braze interfaces will be designed using a thin copper ring between the stainless steel flange and the ceramic
- The copper ring acts as a buffer between the different expansion coefficients of ceramic and stainless steel
- The stainless steel flange will be fit inside a molybdenum ring
- Filler material is 50-50 AuCu wire and foil
- The braze will be done in a single run
- UT will be performed via a probe into the hollow copper





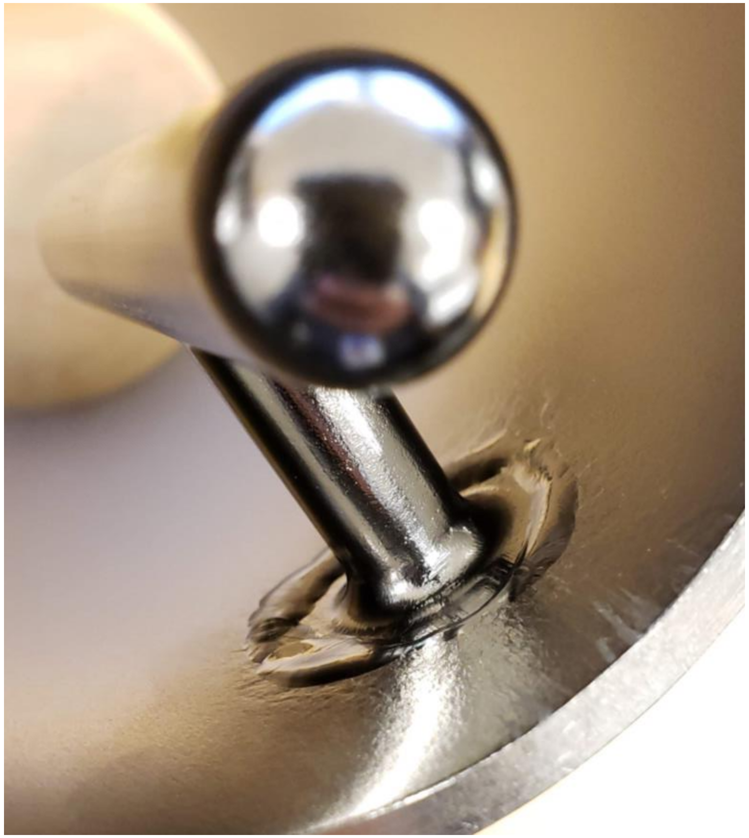
HHOM EBW

- The most complex weld in the HHOM is the connection of the Hook/Tee to the Nb can ID
- LARP HHOM used a thin ‘well’ section
  - A Rosette weld style was used
  - Protruding section of Hook/Tee was consumed and filled the ‘well’
- The process was successful but had issues
  - Weld fillet on ID of Nb can was not uniform



HHOM EBW Testing

- The weld interface of Hook/Tee has been replaced by a machined, curved section
  - Interface matches the ID and OD of the Nb can
  - Fillet at the interface is machined into the Hook/Tee stub
  - Complicated weld is replaced with a simpler full penetration fillet weld
- A first test run was conducted
  - The bead on the ID of the Nb can is considered too large
  - The circular welding section will be reduced from Φ25mm to Φ14mm



Upcoming Tasks – FY20 Q1

- Develop brazing procedure (BPS) and qualification record (BPQR) for ceramic parts
  - Used on Field Antenna, HHOM Feedthrough and VHOM
- Finalize HHOM drawings and MIP
  - Set up MTF account for data upload
- Develop drawings and MIPs for VHOM, HHOM FT and Field Antenna

Upcoming Tasks – FY20 Q2/Q3

- Repeat BPS and BPQR for Nb-SS brazes using material bought with CERN specs
- Repeat WPS and WPQR for Nb EBW with CERN specification material
- Complete fabrication of three Ancillary sets
  - Deliver to FNAL by end of Q3 FY20

Upcoming Tasks – FY20 Q4

- Finalize all QA/QC documentation for ancillaries
- Prepare plan and estimate for Pre-Production deliveries
- Prepare Lessons Learned documentation from Prototype fabrication effort
- Begin Pre-series fabrication effort

Summary

- Three sets of RFD Ancillaries will be delivered to FNAL by end of Q3 FY20
  - Prototype fabrication is a ‘best effort’ to asses manufacturability aspects and feed into decisions for Pre-Series units
- Lessons from US-LARP ancillary production will be taken into account