# RFD Testing & HOM Status

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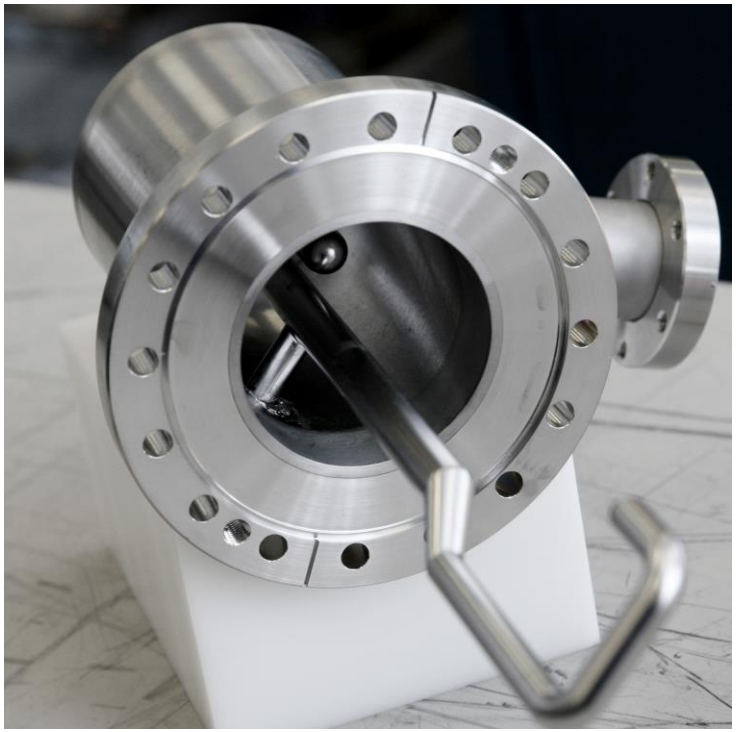
12th HL-LHC Collaboration Meeting. – Sep. 19th–22th 2022

Jefferson Lab
Thomas Jefferson National Accelerator Facility

# Outline

- Scope
- Interfaces
- Prototype Fabrication
- RFD Cavity Testing
- Prototype Validation
- Procurement Status
- Schedule
- QA/QC
- Summary

# JLab Scope of Work

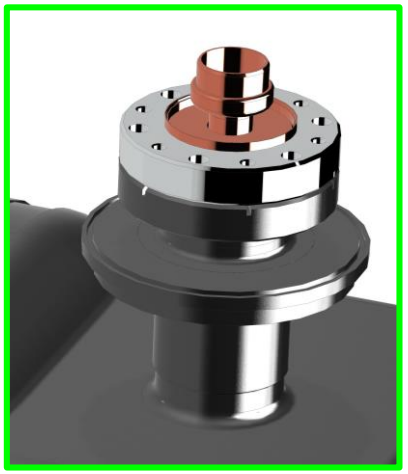


- Fabricate sets of RFD Cavity Ancillaries
  - Prototype: 3 sets (FY21/FY22) **Complete**
  - Pre-Series: 3 sets (FY22/FY23)
  - Series: 8 sets (FY23/FY24)
- RF design is provided by AUP
- All activities are in full compliance with CERN Engineering Specification Document (EDMS 1389669 v2.6)
- Develop manufacturing drawings and strategy
- Develop brazing and welding processes and formal documents
- Share production information with the CERN MTF

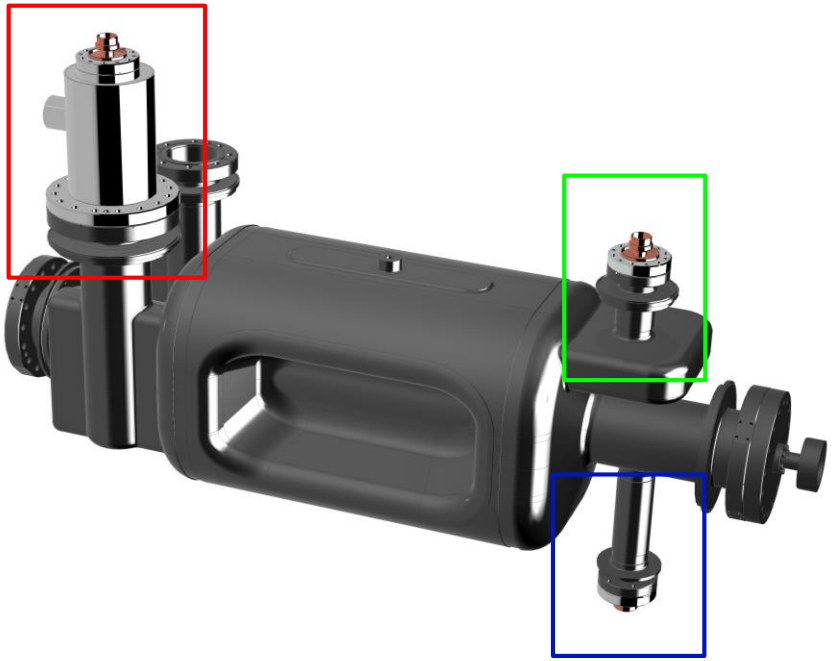
# JLab Scope of Work: Interfaces

- Interfaces are defined in LHCACFDC0001 - CERN EDMS 2420659
- Drawings for JLab scope have been approved by CERN

**VHOM**
DN40 CF



**HHOM-FT**
DN40 CF



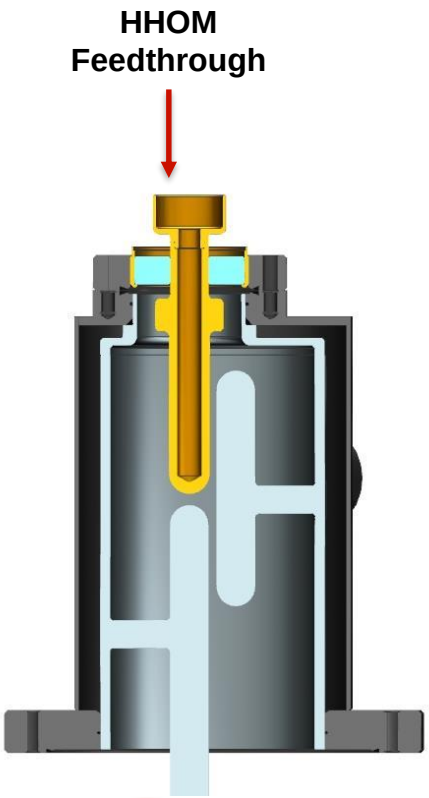
**HHOM**
DN100 CF

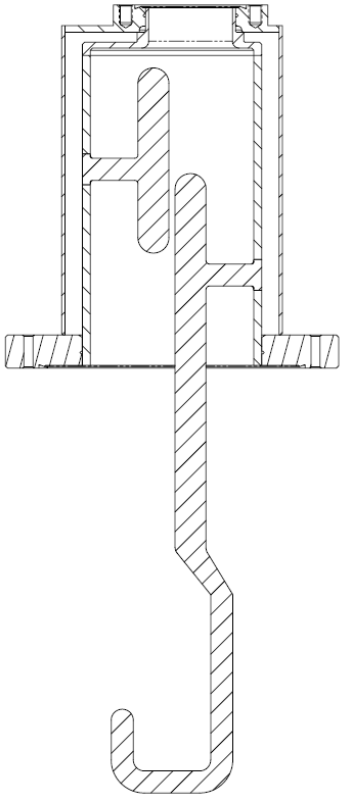
**RFD Cavity**

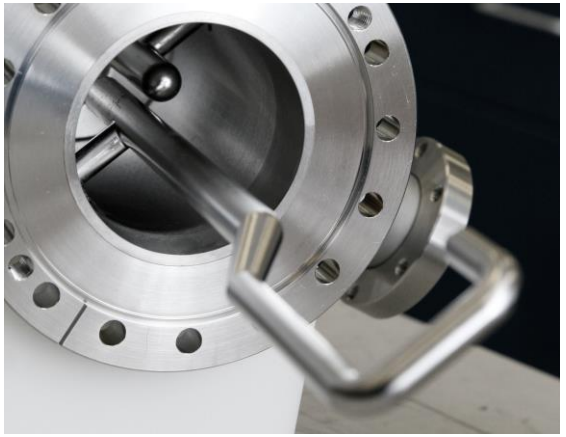
**Pick-Up**
DN40 CF

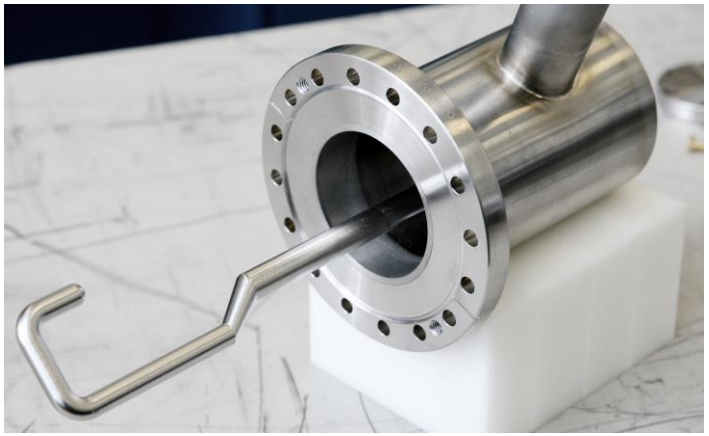
# Prototype Fabrication: HHOM

- The HHOM Damper is constructed primarily of Nb, with 316LN Stainless Steel flanges brazed on, and a 316LN helium jacket
- The full assembly also includes a feedthrough installed on the top flange

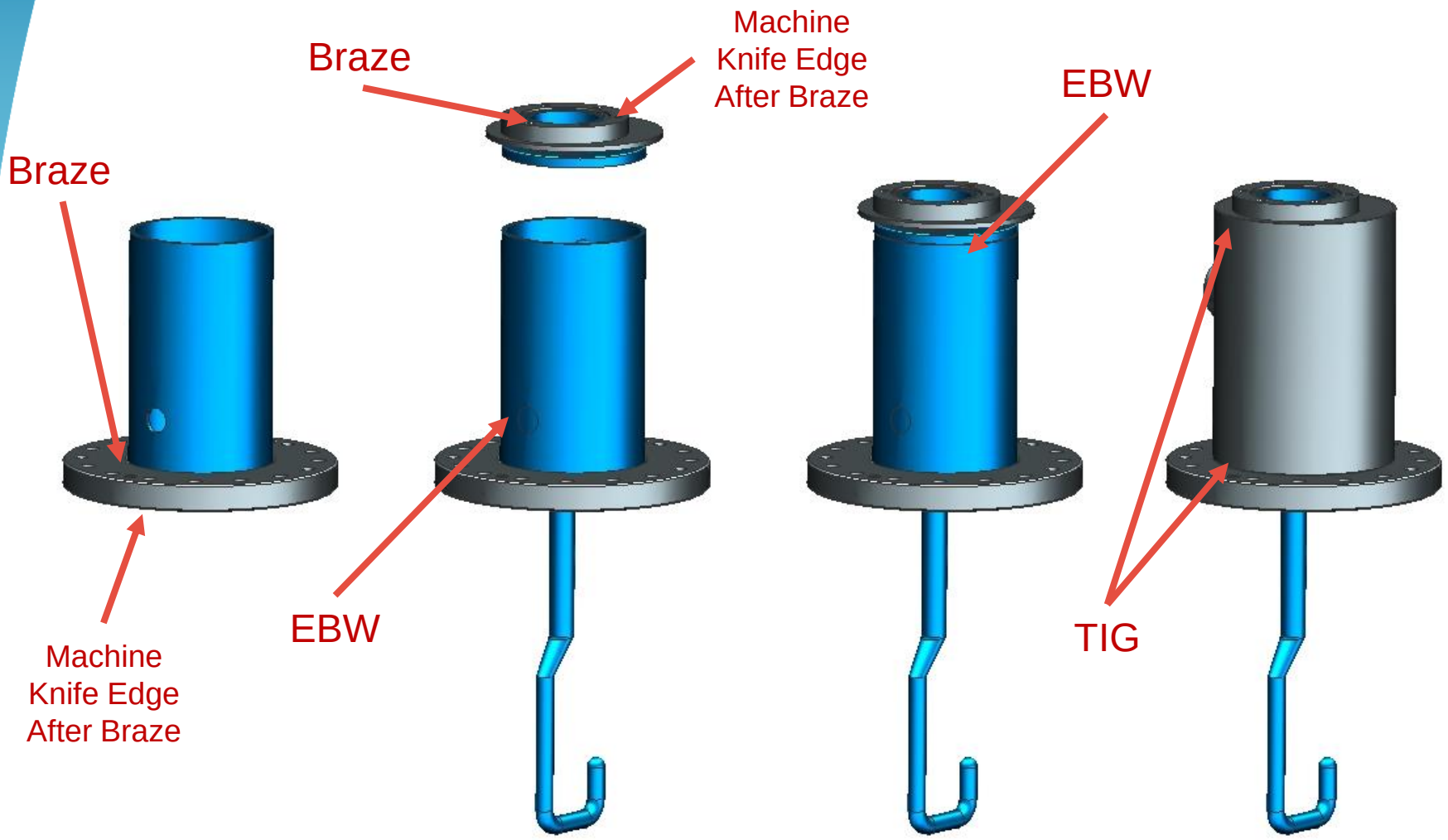




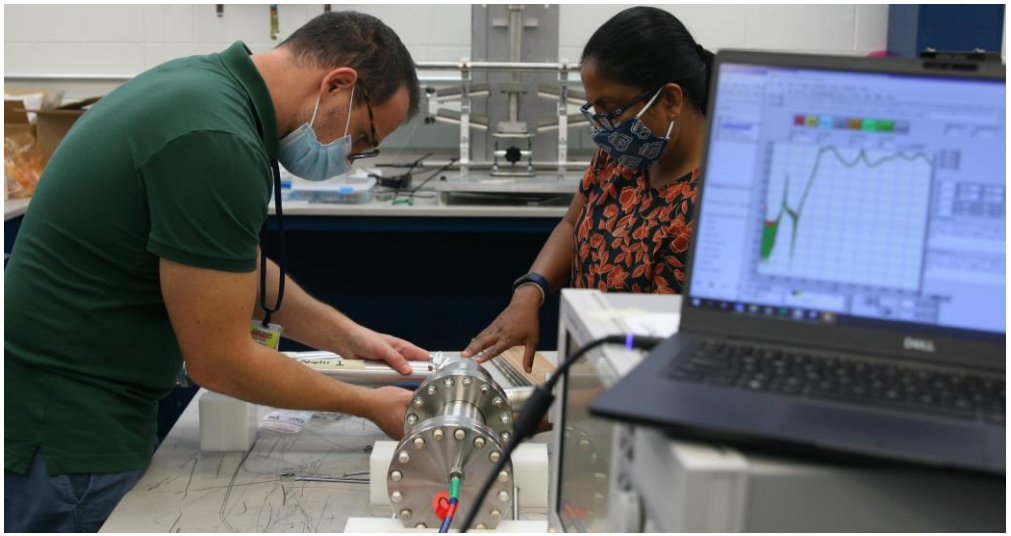


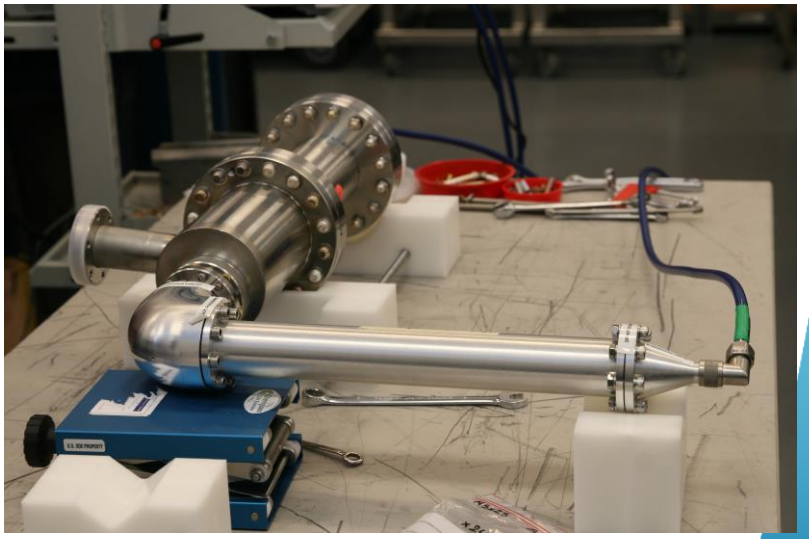
# Prototype Fabrication: HHOM



# Prototype Validation: HHOM RF Tests

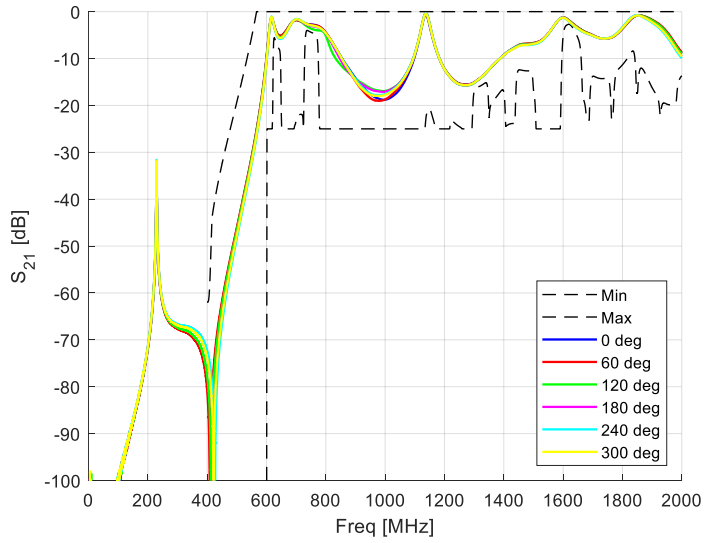
- Warm RF measurements are used to validate the HHOM fabrication
- A test box designed in collaboration with ODU, SLAC, and CERN was used to take the measurements
- The S21 curve must meet the following requirements:
  - $S_{21}$ in the 390 – 410 MHz range must be below < -61 dB
  - $S_{21}$ in the 0.1 – 2000 MHz must be within CERN and AUP mask

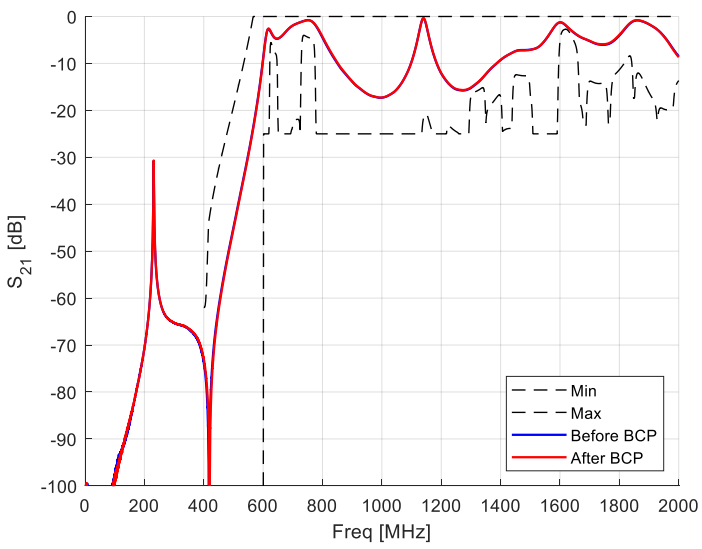




# Prototype Validation: HHOM RF Tests

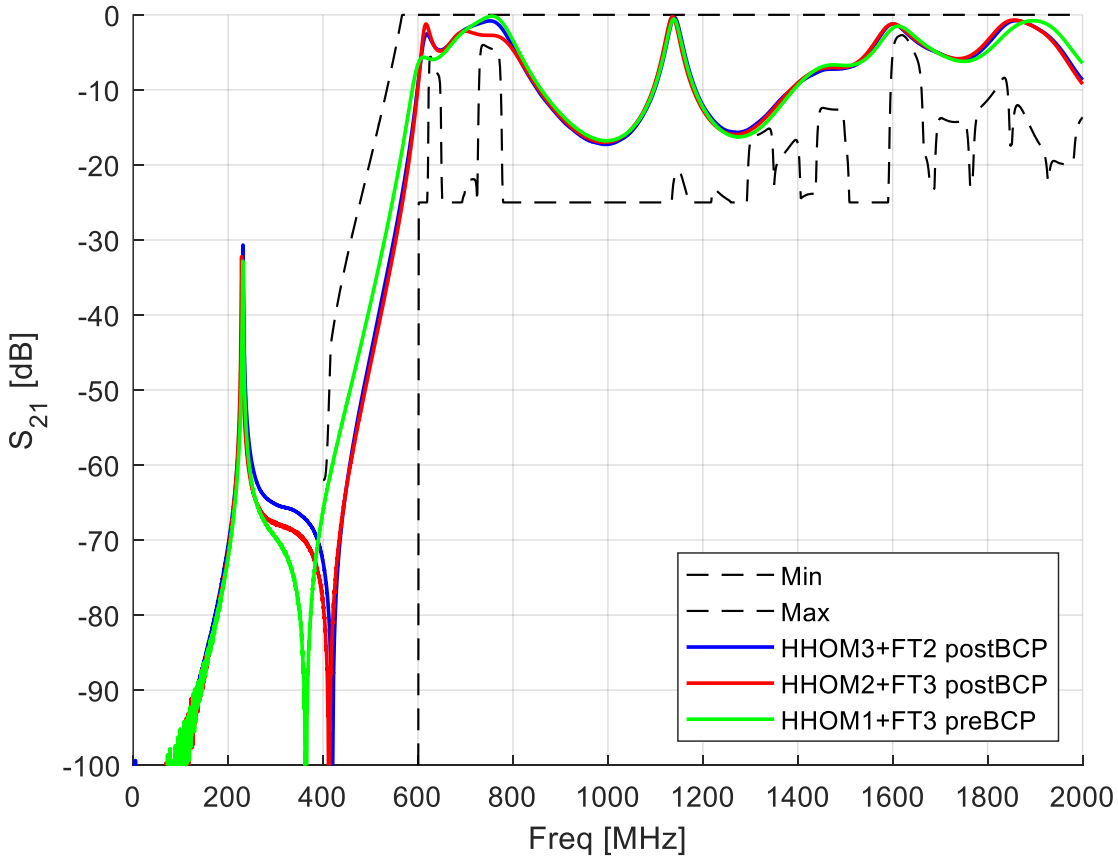
- The three HHOMs were tested using the test box before and after final BCP
  - BCP was not found to affect the results greatly
  - Several rotations of the HHOM-FT were tested to account for manufacturing deviations
- The HHOM-FT (originally oversized) was trimmed to improve results
  - Trimming was not required for HHOM-2, but it further improved the results



# Prototype Validation: HHOM RF Tests

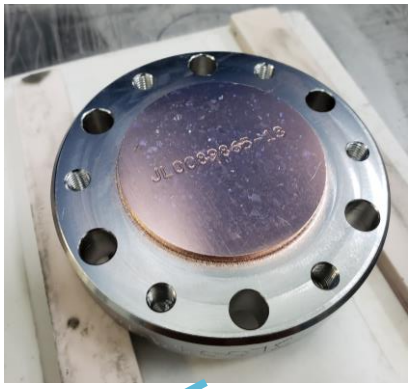
- HHOM-2 and HHOM-3 passed the acceptance tests as-built
- HHOM-1 (which had known dimensional deviation) did not pass, and is off the mask at ~600 MHz (green line)
  - HHOM may meet spec with a trimmed FT

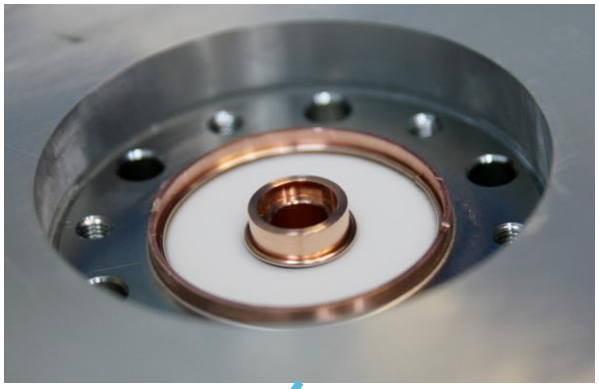


# Prototype Fabrication: Ceramic Feedthroughs

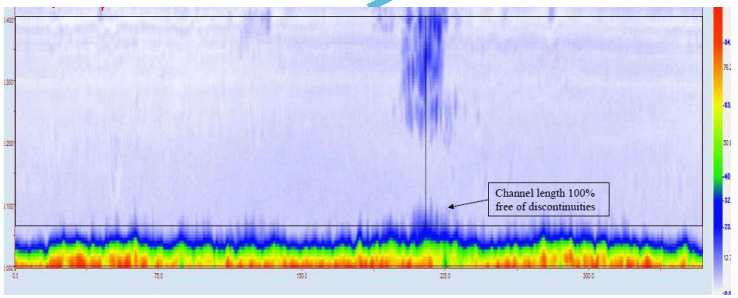
- FTs refer to the HHOM-FT, VHOM and Pick-Up
- Each assembly has a copper probe brazed into the center of a ceramic, which in turn is brazed into a 316LN flange
  - A copper ring is located between the ceramic and 316LN flange

# Prototype Fabrication: Ceramic Feedthrough





Braze 1 → Leak Check → Mach → UT → Braze 2 → LN2 Shock → Leak Check → UT → Mach → EBW → Leak Check → RT




# Prototype Fabrication: Ceramic Feedthrough

- CERN uses a rotatable titanium flange on the ceramic feedthroughs (below right)
- JLab uses a copper interface ring between the ceramic and a 316LN non-rotatable flange (below left)
  - The JLab design will be qualified by the same process as CERN
  - The two designs have been developed in parallel with the possibility of a future down-select

**JLab Design**

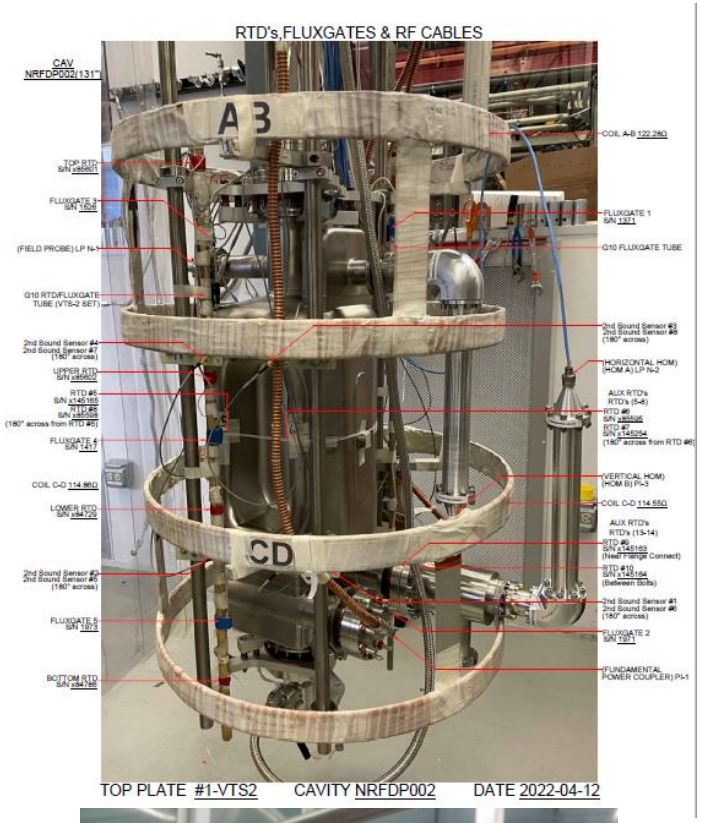
**CERN Design**

# Prototype Validation: Feedthrough Cold Tests

- Earlier CERN iterations of the design found cracks in the ceramic after cold shocks
- JLab cold shocks involved immersing parts in LN2
- The process was changed to line up with the CERN process
- The ceramic is cooled via conduction while installed in an evacuated chamber
- JLab feedthroughs passed leak check after 5 thermal shocks using this process

# Cavity Vertical Testing

- The HOMs were installed on RFD-2 at FNAL for vertical testing
- The assembly passed warm leak checks, but leaked at 4K
  - The issue was found to be the VHOM and Field Antenna feedthroughs
- Bagged leak checks determined that the CF gasket seals were the cause of the leaks
- The ceramics on the feedthroughs were still intact and leak tight
- The ancillaries were returned to JLab to test the knife edge seals




# Prototype Validation: Cold Sealing Tests

- Hardware and torquing scheme were developed to allow seals on the cavity
- HHOM/HHOM-FT assembly was sealed and leak checked in LN2 to prove the seal is not susceptible to cold leaks
- Tests were repeated on other ceramic feedthroughs; all were found to seal when cold
- The RFD 2 Cavity has been sent to JLab for testing in the VTA

# Recent Achievements

- Three sets of prototype ancillaries have been fabricated. The yield was as follows:
  - 3 out of 3 HHOMs
  - 3 out of 3 HHOM-FTs
  - 2 out of 3 VHOMs
  - 1 out of 3 Field Antennas
- All Pre-Series drawings and work control documents have been approved by CERN and are ready for execution
- The Production Readiness Review (PRR) was held in May 2022
  - The project was given the go-ahead to begin Pre-Series fabrication
  - Fabrication of Pre-Series parts has started

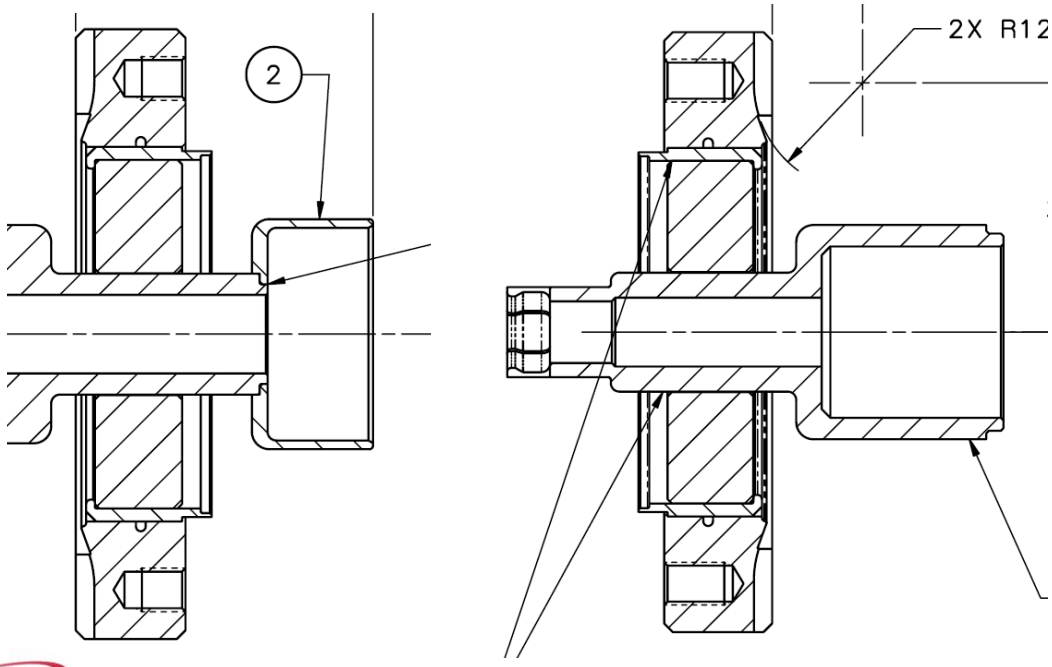
# Lessons Learned: Feedthrough EBW - 1

**Issue:** The EBW on the connectors to the probe damaged the copper/ceramic braze on some assemblies

# Lessons Learned: Feedthrough EBW - 2

**Solution:**

- **VHOM and HHOM-FT:**
  - The weld is moved further away from the braze joint
  - An additional benefit is that ceramic shielding is no longer required
- **Pick-UP:**
  - The connector and the rod are now a single, machined part



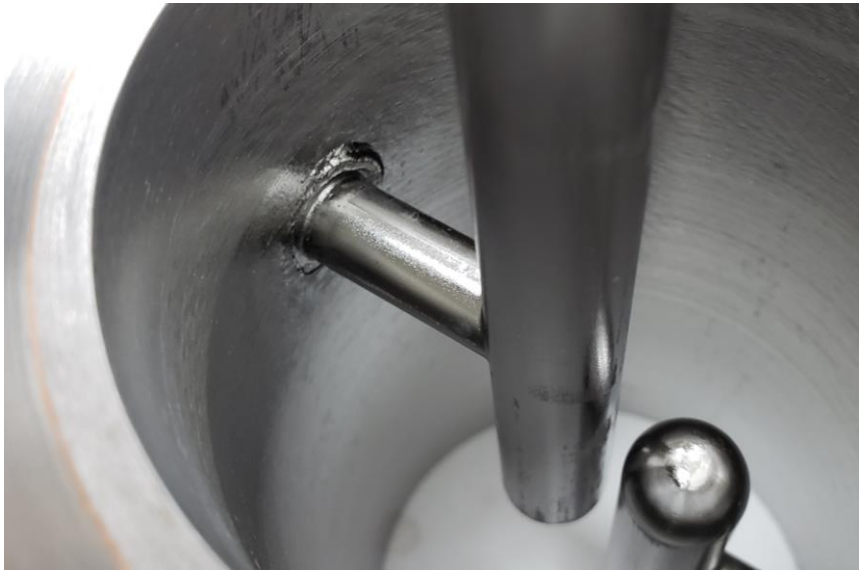
# Lessons Learned: HHOM EBW

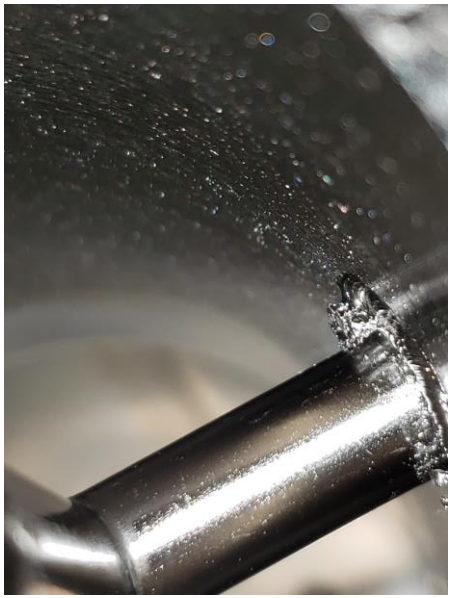
**Issue:** EBW parameters developed on representative samples were not transferrable to production parts

- EBW tooling acted as heat sinks, and welds required additional passes leading to excessive shrinkage and other defects

**Solution:**

- EBW parameters will be recalculated using representative parts that can interface with tooling





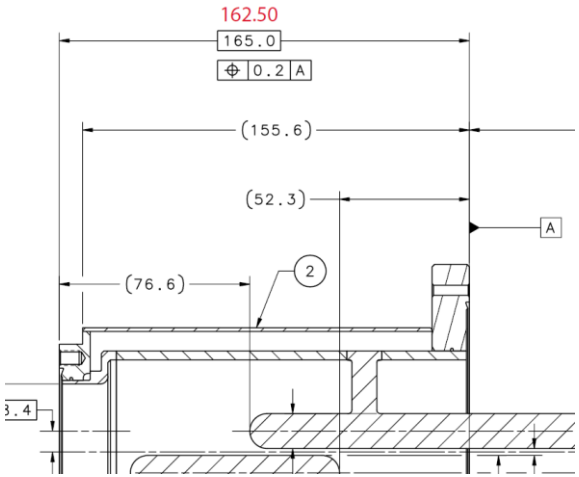
# Lessons Learned: HHOM EBW

**Issue:** EBW on Nb parts created large underbeads and excessive shrinkage/distortion due to additional passes

- The wall thickness used on the JLab design is at the limit of practical full-penetration EBW welds

**Solution:**

- The wall thickness will be reduced from ~3.5mm to 2.6mm, pending successful stress analysis
- New drawings will take shrinkage from representative samples into account



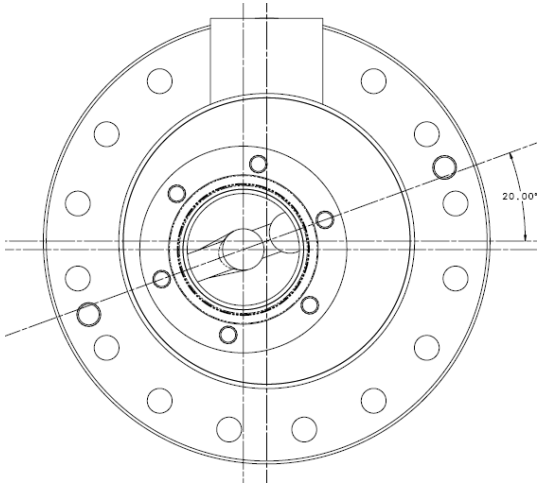

# Lessons Learned: HHOM EBW

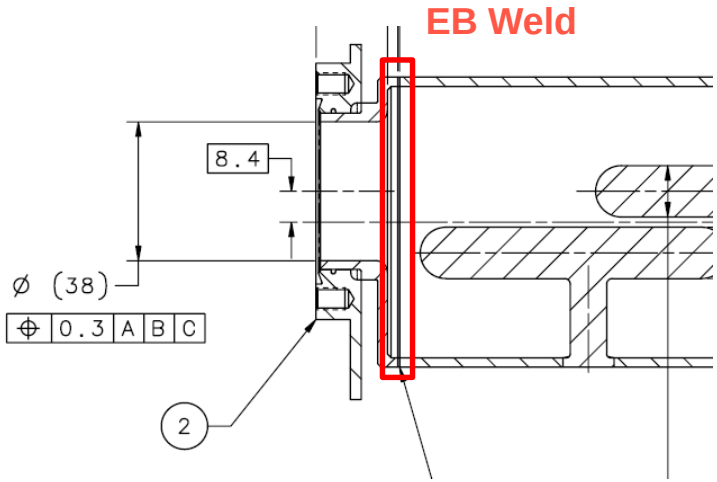
**Issue:** EBW distortion of upper flange weld (Nb Can Lid) lead to concentricity of the HHOM-FT port to be out of tolerance

- The nominal design has the probe of the HHOM-FT concentric to the hook
- Note: due to limited access, this measurement is difficult to accurately measure on the CMM and so is only taken as a reference

**Solution:**

- Reducing the wall thickness of the weld will reduce distortion. The EBW tooling for the weld will be revised and requalified prior to use
- SN-02 and SN-03 passed RF tests




| Concentricity | |
|---|---|
| SN-01 | 0.3 |
| SN-02 | 0.9 |
| SN-03 | 0.5 |

# Procurement Status

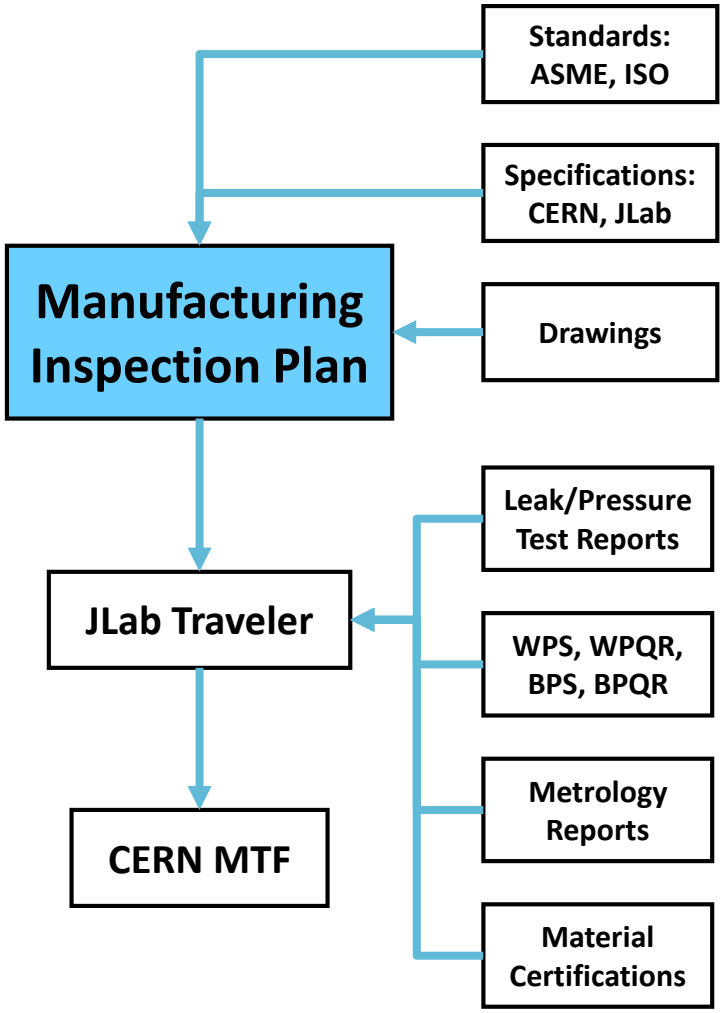
- All raw material for Pre-Series has been ordered and delivered
- Due to the long lead time, high-RRR Niobium and OFE Copper has also been purchased for Series units
  - Niobium is due at JLab in March 2023
  - Series OFE Copper has been received at JLab
- Part fabrication, both internal and external to JLab, is treated as a procurement
  - Pre-Series part fabrication has started
  - Where possible, prototype vendors are being used for Pre-Series contracts

# Schedule

| | 2022 | | | | | | | 2023 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
| Qualifications | | | | | | | | | | |
| Part Fabrication | | | | | | | | | | |
| Assembly | | | | | | | | | | |
| Acceptance | | | | | | | | | | |

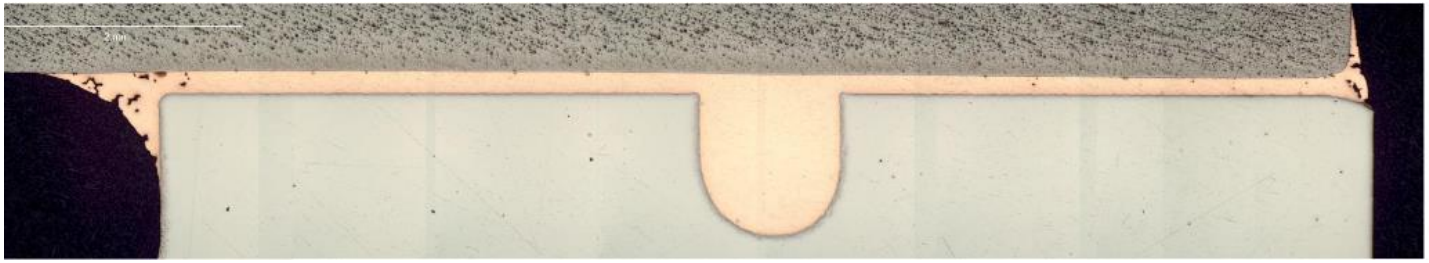
# Manufacturing Inspection Plans (MIPs)

- A separate MIP is developed for each ancillary component
- The MIPs are based on the design, required standards and the CERN engineering specification
  - The MIP is the master document that lists all the fabrication and inspection steps
  - The MIP defines the structures of the individual travelers
- Each assembly is tracked with a traveler in the JLab Pansophy system
- The travelers collect relevant data during production e.g. test reports and dimensional inspection results
  - The travelers also collect sign-offs that particular operations have been carried out
- The information from the travelers are transferred manually to the CERN MTF



# Upcoming Work

- Fabrication of parts has started in the JLab Machine Shop and external vendor
- Welding and brazing documents (WPQRs, BPQRs etc.) are in progress
  - Strategy documents outlining the welding/brazing tests have been approved by CERN
  - Assembly work will not begin until the relevant process documents are approved



# Summary

- Prototype ancillaries were fabricated at JLab
  - Issues were encountered for the Field Antennas; they are understood and have been addressed in the Pre-Series design
- Drawings and process documents are complete and approved by CERN for Pre-Series fabrication
- Raw material procurement for Pre-Series is complete
- Production Readiness Review gave the go-ahead to move forward with Pre-Series
  - Production has started at JLab

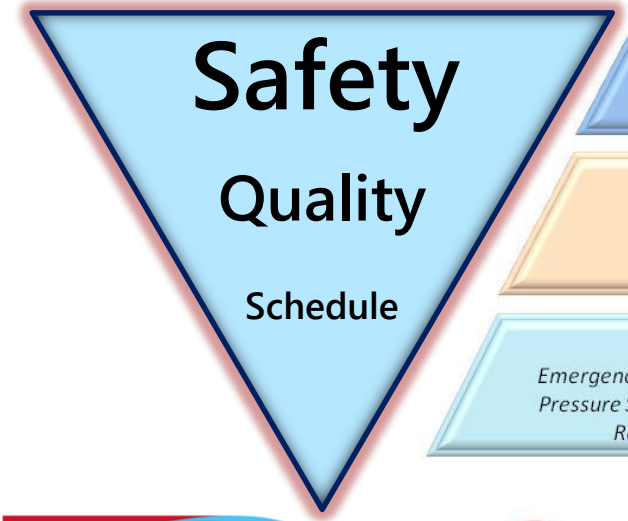
# Thanks to the RFD Ancillary Team

- **Fermilab** – Paolo Berrutti, Manuele Narduzzi, Colin Narug, Leonardo Ristori
- **ODU** – Suba De Silva, Jean Delayen
- **SLAC** – Zenghai Li
- **CERN** – Nuria Valverde Alonso, Adria Gallifa Terricabras, Eric Montesinos

# Back-Up Slides

# Safety

Safety processes leverage JLab's work planning and control system as well as ESH Manual for program guidance




**Expectations Established:**

- Line Management Responsibility for Safety
- R2A2
- PEMP Metrics
- Policies
- Procedures
- Key Performance Indicators
- Training

**Performance Measured:**

- Performance Evaluations
- Independent Assessments
- Management Self-Assessments
- Safety Observations


**Director's Safety Council feedback informs Lab's ES&H programs, policy, procedures, performance metrics, and other expectations.**

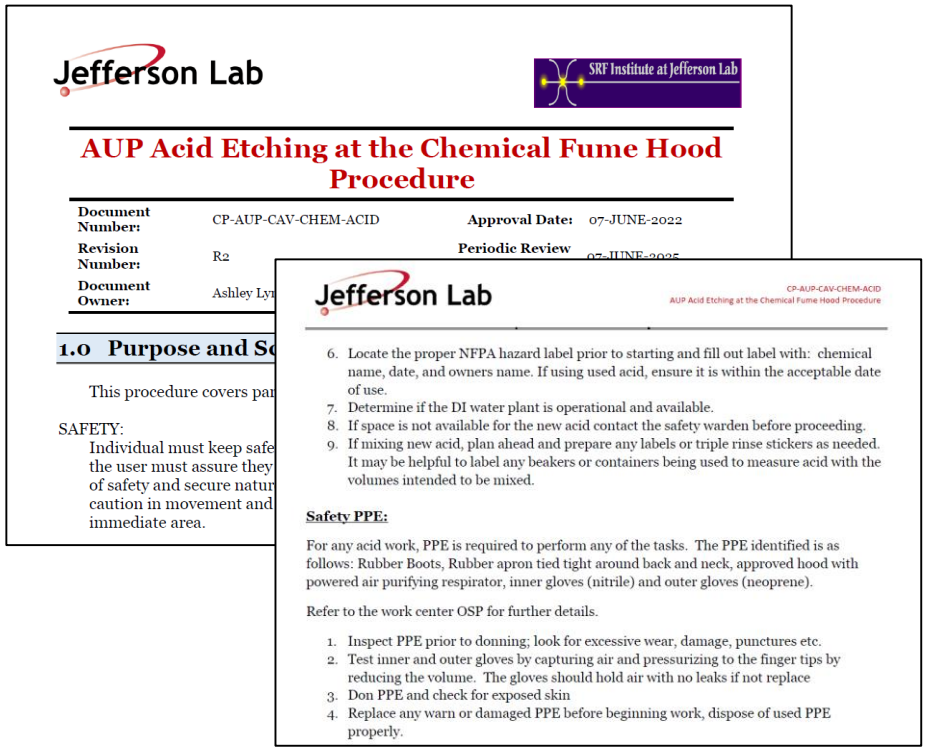
**All committees and programmatic support groups routinely report new requirements, issues and resolutions to the Director's Safety Council.**

**Worker Feedback:**

- Electronic Work Planning Tools
- Safety Observations
- Telephone Hot-Line
- Pre-Job Briefs
- Job Hazard Walk-Downs
- Post-Job Reviews
- Employee Concerns/Suggestions
- Safety Meeting Actions
- Employee Committee Actions
- Safety Warden Work Area Inspections

# Safety

- In addition to JLab's EH&S manual, safety processes are specified in individual AUP procedures



Jefferson Lab

SRF Institute at Jefferson Lab

**AUP Acid Etching at the Chemical Fume Hood Procedure**

| | | | |
|---|---|---|---|
| **Document Number:** | CP-AUP-CAV-CHEM-ACID | **Approval Date:** | 07-JUNE-2022 |
| **Revision Number:** | R2 | **Periodic Review** | 07-JUNE-2025 |
| **Document Owner:** | Ashley Ly | | |

**1.0 Purpose and Sc**

This procedure covers par

SAFETY:
Individual must keep safe
the user must assure they
of safety and secure natur
caution in movement and
immediate area.



Jefferson Lab

CP-AUP-CAV-CHEM-ACID
AUP Acid Etching at the Chemical Fume Hood Procedure

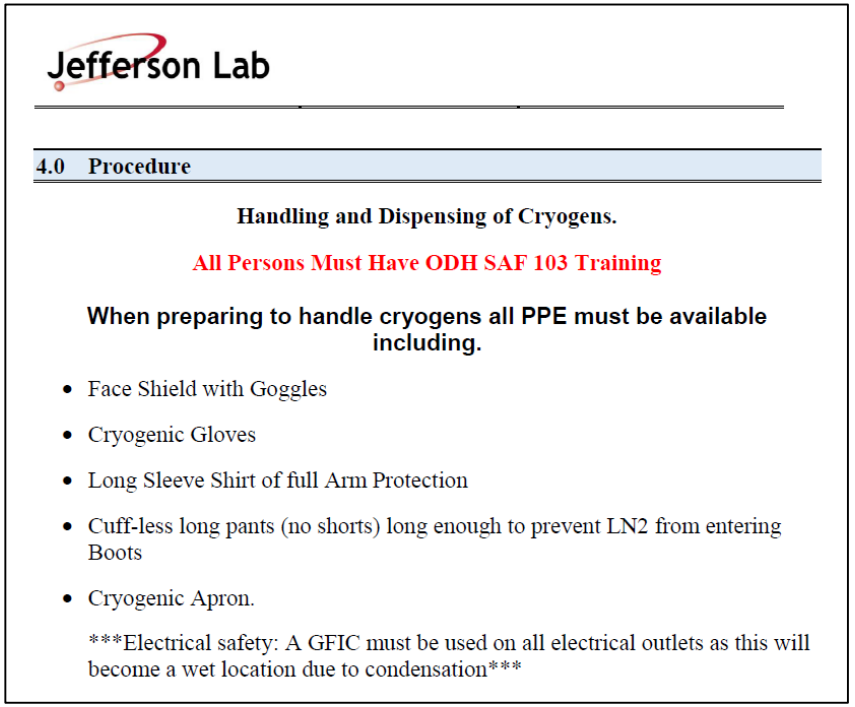
6. Locate the proper NFPA hazard label prior to starting and fill out label with: chemical name, date, and owners name. If using used acid, ensure it is within the acceptable date of use.
7. Determine if the DI water plant is operational and available.
8. If space is not available for the new acid contact the safety warden before proceeding.
9. If mixing new acid, plan ahead and prepare any labels or triple rinse stickers as needed. It may be helpful to label any beakers or containers being used to measure acid with the volumes intended to be mixed.

**Safety PPE:**

For any acid work, PPE is required to perform any of the tasks. The PPE identified is as follows: Rubber Boots, Rubber apron tied tight around back and neck, approved hood with powered air purifying respirator, inner gloves (nitrile) and outer gloves (neoprene).

Refer to the work center OSP for further details.

1. Inspect PPE prior to donning; look for excessive wear, damage, punctures etc.
2. Test inner and outer gloves by capturing air and pressurizing to the finger tips by reducing the volume. The gloves should hold air with no leaks if not replace
3. Don PPE and check for exposed skin
4. Replace any warn or damaged PPE before beginning work, dispose of used PPE properly.



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**4.0 Procedure**

**Handling and Dispensing of Cryogens.**

**All Persons Must Have ODH SAF 103 Training**

**When preparing to handle cryogens all PPE must be available including.**

- Face Shield with Goggles
- Cryogenic Gloves
- Long Sleeve Shirt of full Arm Protection
- Cuff-less long pants (no shorts) long enough to prevent LN2 from entering Boots
- Cryogenic Apron.

***Electrical safety: A GFIC must be used on all electrical outlets as this will become a wet location due to condensation***