



# Plans for Crab Cavity Production

## *Pre-Series & Series*

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# Outline

- LARP Crab Cavity Contribution
- Strategic Plan
  - Supplier Qualifications
  - Pre-Series + Tests
  - Series + Tests
  - ANL/Fermilab Facilities
- Schedules
  - LARP Pre-Series
  - HL-LHC Series
- Parallel Activities



# LARP Crab Cavity Contribution

- Qualify Cavity Suppliers for CERN
- Provide CERN Design & Fabrication Documentation for integration in CERN Safety Notes of Cavities and Cryomodules
- Provide (4) Pre-Series Bare Cavities (Build and Qualify)
  - 2 RFD + 2 DQW
  - Procurement Processes managed by Fermilab with inputs from LARP collaborating institutions and CERN
- Provide (20) Series Bare Cavities (Build and Qualify)
  - 10 RFD + 10 DQW (Baseline)
  - Be prepared for increasing quantities to 20+20 if requested



# LARP Prototype Cavities

- RFD and DQW prototypes currently in circulation have fundamental role in project
  - Reduce Project Length by preparing facilities (and people!) well in advance of arrival of Pre-Series and Series cavities
  - Uncover potential quality issues with specific forming+welding plan
  - Calibration of models (simulations vs measurements)
- Send to ANL/Fermilab 1+1 Prototypes
  - Develop/Verify chemistry tooling at ANL
  - Develop/Verify VTS hardware at Fermilab
  - Pre-Series Cavities Expected at FNAL 10/2019
    - Prototypes useful at FNAL anytime in 2018



# Qualification of Supplier(s)

- Aim at qualifying 2 suppliers
- Main Motivations:
  - Determine supplier certifications, quality and reliability (adherence to schedule) ahead of time
  - Allow a shorter list of suppliers for award of cavity fabrication contracts
- Strategy
  - TO DO: Prepare specification document to clearly define qualification process (discuss with CERN, qualify for SPS or LHC?)
  - Phase 1: Request For Proposals
    - Proposals to include proof of QA documentation and ASME certifications
    - Proposals to include cost and timeframe to complete a number of weld joints and braze joints with clearly defined specs (dimensional, visual, leak) in agreement with CERN expectations.
  - Phase 2: Award Contracts
    - Technical Award Process (Technical Scoring + Cost) to award 2 contracts. Contingent on timeframe and cost (details TBD with Fermilab procurement group)
  - Phase 3: Grant Qualification
    - CERN to review results and grant qualification to suppliers



# Pre-Series Cavities

- **Raw Materials**
  - Outcome of fabrication of prototype cavities will confirm material needs
    - EBW quality issues may require alternative approaches to forming/welding certain components
  - Request for Quotation: RRR Niobium & Nb55Ti Alloy. 316LN provided by CERN, determine logistics.
    - Procurement process and Inspections at Fermilab (see slide ahead)
- **Cavity Fabrication**
  - TO DO: Prepare a Fabrication Specification Document
  - Contract Award:
    - RFP + Technical Award
    - If 2 suppliers are successfully qualified, preferred option is to split contract (reduced risk)
    - Award contract(s) for a total of 2 RFD + 2 DQW
  - Fabrication:
    - Tight supplier oversight to provide to CERN status updates, necessary documentation and samples
    - Intermediate and final Inspections at supplier's premises with Fermilab involvement
- **Chemistry and Tests (ANL+Fermilab)**
  - BCP, HPR and Clean-Room assemblies at joint ANL/Fermilab Facilities
  - Cold Tests at Fermilab's VTS Facility
  - CERN/LARP to review/approve Cavity Design, Fabrication Process, Processing Plan, Clean Room Procedures

# Cavity Processing joint FNAL/ANL facility at ANL

- Chemical treatments on cavities
  - Buffered Chemical Polishing (BCP)
  - Electropolishing (EP)
  - HF acid rinse
- Clean room activities
  - High pressure water rinsing
  - Assembly of cavities



Spoke Resonator Processing Steps



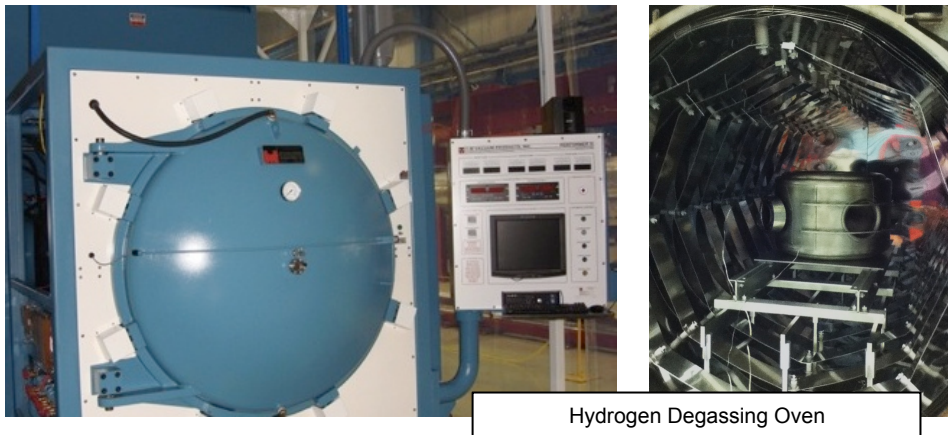
Loading 1300 MHz cavity into HPR



1300 MHz EP tool in SCSPF

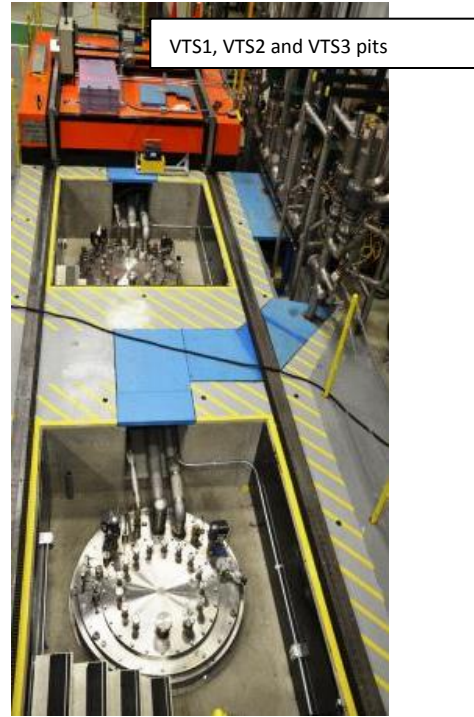
# Heat Treatments at Fermilab

- Hydrogen Degassing Baking (600-800'C)
- Pre-VTS 120'C Bake





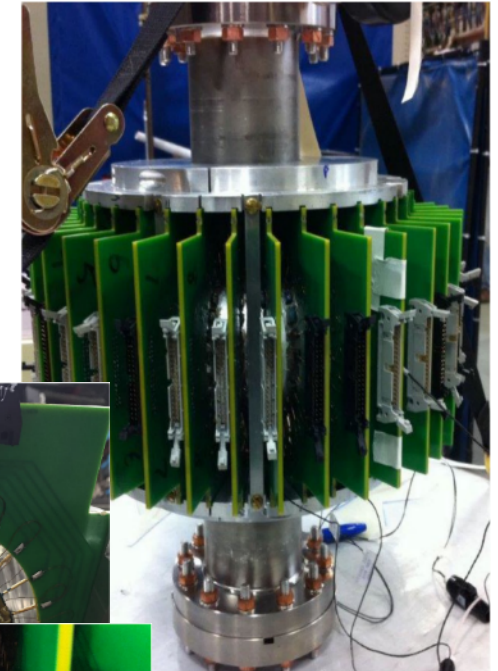
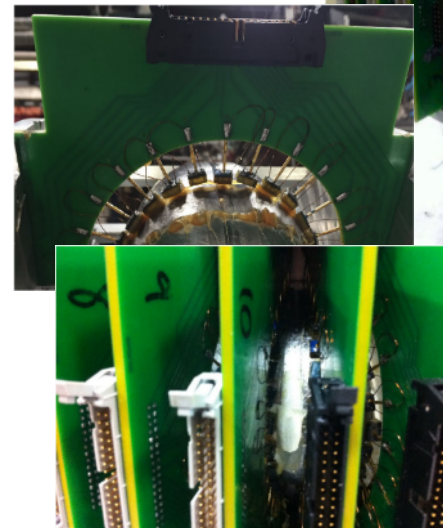
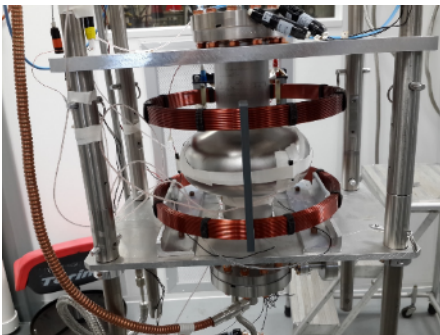
# Fermilab Vertical Test Stands



- Cryogenic RF measurements of bare and dressed cavities of various frequencies
  - 325-650-1300-3900 MHz
  - Temperatures down to 1.4K
  - Other frequencies possible

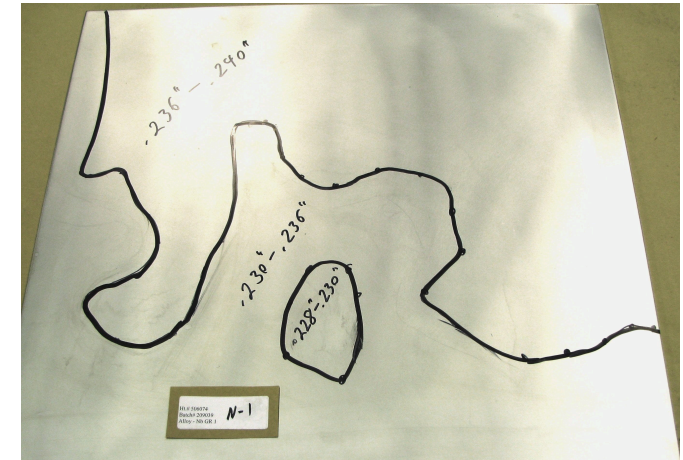
# Fermilab VTS Diagnostics

- Q(E) curves, Q(T)
- Full diagnostics instrumentation
  - Magnetic fields
  - quench detection
  - T-map

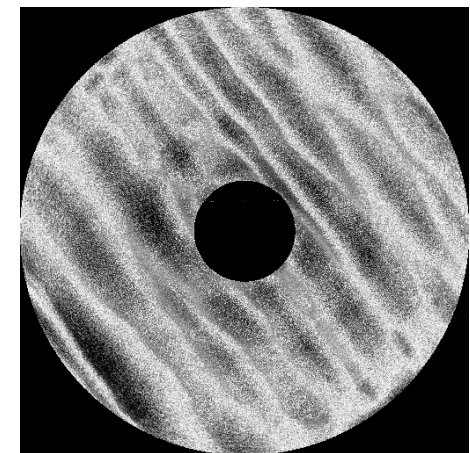


# Niobium QA for large sheets

- Request small coupons (20x20 cm) from each annealed lot
- Collect and verify material certs from supplier
- Engrave traceability info on each sheet
  - Ingot → Annealing Lot → Sheet Number
- 100% Visual Inspections both sides
  - Measure depth of notable scratches
  - Identify RF side (the best of two)
  - Record non-conformances and address issue (fix or return to supplier)
- 100% Dimensional Measurements + Thickness Maps
- 100% Overnight Water Soak
  - Record visible rust spots and address issue (e.g. polish + re-soak)
- Eddy Current Scans (coupons only)
- RRR Measurements (samples from coupons only)



Thickness Map (Ultrasonic Measurements)



Eddy Current Scan



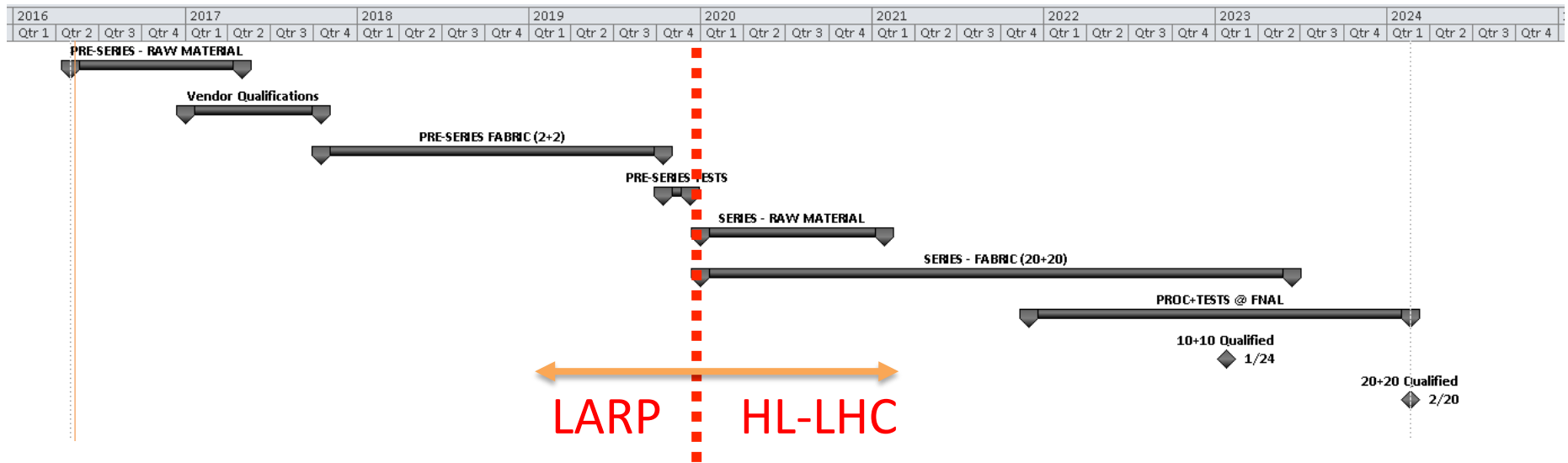


# Series Cavities

- Procure Raw Materials
- Award Contract(s) for Fabrication
  - Same Supplier(s) as Pre-Series Run
  - Fermilab Technical Award Process
  - Suppliers will spend first period increasing tooling for larger series
- Chemistry and Tests (ANL+Fermilab)
  - Same Plan as Pre-Series
- Constraint on Procurements after 1/2020 for HL-LHC Project
  - Raw material in principle could be ordered ~12 months sooner
  - After forming+welding of pre-series is deemed successful
    - Cavity design is assumed to be verified with prototypes



# Schedule



- Raw Materials: PO 6/2016
    - Delivery+QC+Ship, Ready 5/2017
  - Supplier Qualifications: PO 3/2017
    - Qualify 10/2017
  - Pre-Series 2+2: PO 1/2018
    - Delivery+QC 10/2019
  - Processing: ANL 10/2019
  - Testing: FNAL 11-12/2019
- Raw Materials: PO 2/2020
    - Delivery+QC+Ship, Ready 2/2021
  - Series 20+20: PO 3/2020
    - 1<sup>st</sup> Delivery 12/2021
    - 10+10 Delivery 9/2022, 20+20 Delivery 6/2023
  - Tests
    - 1<sup>st</sup> Qualification 1/2022
    - 10+10 Qualifications 2/2023
      - (Total 28 Tests assuming 40% requiring 2<sup>nd</sup> Pass)
    - 20+20 Qualifications 2/2024
      - (Total 56 Tests assuming 40% requiring 2<sup>nd</sup> Pass)



## (Parallel Activities)

- Compile Design Reports for Bare Cavities
  - Requirements, EM Design, Mech Design
  - Input for CERN Safety Documentation
  - Note: For Cold Tests at Fermilab, no formal Engineering note is needed for bare cavities
- Evaluate with CERN outcome of prototypes and adjust specifications if needed
- Adjust Cost Estimates based on most recent strategy