

# **RFD Dressed Crab Cavities** *Status, Issues and Delivery Dates*

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L2 Manager – RFD Dressed Crab Cavities Fabrication

11th HL-LHC Collaboration Meeting – 19th October 2021

## **U.S. RFD Team**

#### Institutions in alphabetical order :

- Argonne National Laboratory (Brazing and Cavity Processing):
  - Mike Kelly, Tom Reid, Bill Toter
- Brookaven National Laboratory (Coordination, Interfaces and MIPs):
  - Silvia Verdu Andres
- Fermilab (RF/Mech Design, Procurements, Cold Tests):
  - Paolo Berrutti, Manuele Narduzzi, Alex Melnichuk, Damon Bice
- Jefferson Lab (HOM Dampers Fabrication):
  - Naeem Huque
- Old Dominium University (General Oversight and RF measurements):
  - Jean Delayen, Subashini De Silva
- SLAC National Accelerator Laboratory (RF Design, Coordination):
  - Alessandro Ratti, Zenghai Li

HL-LHC AUP	RFD Dressed Cavities oles and Responsibilities	US-HiLumi-doc-105 Date: 9/26/18 Page 1 of 5
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US-HiLumi-doc-1055

Roles & Responsibilities Response to CD-1/3a recommendation

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### **Scope and Deliverables**



components)

- Project Scope includes 2 Prototypes + 2 Pre-Series + 10 Series
- <u>Bare Cavities:</u> Intermediate Qualification at FNAL at 2K
- Integration: Bare Cavity + Magnetic Shields + Helium Tank
- <u>Dressed Cavities</u>: Final Qualification at FNAL at 2K + RF Ancillaries
- Transport to TRIUMF for acceptance by CERN:
  - 10 qualified dressed cavities (mix of pre-series + series)
  - Warm/Cold tests at TRIUMF  $\rightarrow$  formal acceptance by CERN  $\rightarrow$  hand-off

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## **AUP Prototype #1 - Timeline**

- 9/2020: Cavity received from Zanon
- 10/2020: RF inspection complete
- 12/2020: Metrology and optical inspections complete
- 1/2021: Bulk BCP and heat treatment
- 2/2021: Light BCP
- 3/2021: Flange issues and repairs
- 4/2021: HPR, assembly
- 4/21/21: Succesfull VTS test, achieved 4.2MV (4.1MV requirement)







#### See talk by Paolo Berrutti

### **Prototype #1 – Status and Plans**

- "Somewhat" successful test <u>exceeding</u> <u>acceptance</u> <u>requirements only</u> <u>marginally</u>.
- Still under vacuum since April, we were awaiting results of Proto #2.
- Now it can be released for rework and will be shipped to Zanon for bulk rotational chemistry.



- 2 Goals for Prototype #1:
  - Improve performance of cavity
  - Validate Zanon facility as we transition to production

### **Flange Issues and Repairs**

- <u>Successful maintenance</u> allowed to achieve leak tight connections and maintain momentum towards VTS.
- <u>4 cycles</u> of high-pressure rinsing, assembly, evacuation and leak checking were needed.
- Received input from CERN on details of gaskets, hardware and procedures employed.
- Received one complete hardware kit shipped from CERN.
- Looks like we succeeded!



### **AUP Prototype #2 - Timeline**

- 12/2020: Cavity received from Zanon
- 2/2021: RF Inspection complete
- 3/2021: Metrology and optical inspection complete
- 4/2021: Leak check successful
- 5/2021: Bulk BCP, Heat Treatment
- 6/2021: Light BCP, HPR, <u>leak</u> issues, unsuccessful VTS
- 7/2021: HPR, leaks issues
- 8/2021: HPR, leak tight, successful VTS, <u>achieved 5.8MV</u> (4.1MV requirement)





Proto #2 inspections

# See talk by Paolo Berrutti Prototype #2 Successful Test 8/25/21





### LARP Cold Tests Summary 2017-2019

Test Date \Xi	Cavity # 🛛 😇	Location =	нном \Xi	VHOM =	Max Voltage \Xi	Q at 4.1MV $=$
2/12/2017	LARP RFD#1	JLab			4.04	1.60E+09
3/23/2017	LARP RFD#1	JLab			4.38	8.21E+09
6/2/2017	LARP RFD#2	JLab			5.75	1.13E+10
8/20/2017	LARP RFD#1	FNAL			4.70	1.10E+10
4/30/2018	LARP RFD#1	FNAL			3.54	N/A
5/8/2018	LARP RFD#2	JLab	$\checkmark$	$\checkmark$	4.77	1.22E+09
5/31/2018	LARP RFD#2	JLab	$\checkmark$	$\checkmark$	5.03	1.32E+09
6/13/2018	LARP RFD#1	FNAL			3.47	N/A
8/16/2018	LARP RFD#2	JLab	$\checkmark$		5.26	A 6.60E+08
10/9/2018	LARP RFD#2	JLab	$\checkmark$		4.18	1.08E+09
11/14/2018	LARP RFD#2	JLab	$\checkmark$	$\checkmark$	<b>B</b> 5.50	5.00E+09
11/28/2018	LARP RFD#2	JLab	$\checkmark$	$\checkmark$	5.50	7.35E+09
3/27/2019	LARP RFD#2	JLab	$\checkmark$	$\checkmark$	5.33	6.50E+09
5/2/2019	LARP RFD#1	FNAL			5.10	1.00E+10

- 2 available LARP prototypes (RFD#1, RFD#2) exceeded Voltage and Q<sub>0</sub> requirements
- All 14 tests (with and w/o dampers) exceeded nominal voltage of 3.4MV
- Highest  $Q_0$  achieved at 4.1 MV with dampers = 7.3 10<sup>9</sup> (~2x requirement)
- (A): Solved issues with RF losses in dampers
- (B): Removed surface defect causing early quench

### LARP + AUP Cold Test Summary



### See talk by Manuele Narduzzi Zanon – Resuming Fabrication after PRR

- Zanon is (FINALLY!) cutting metal as we speak thanks to the approval of MIP →
- **1. Fabrication drawings** 
  - approval ETA ~1 month
- 2. Weld test plan / Welding book
  - approval ETA ~2 weeks

### **3. Manufacturing Procedures**

next slide

Holding productive 3-way meetings (FNAL-Zanon-CERN) to facilitate convergence.

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### **Status of Procedures – Fast Recent Progress**

Snapshot from ~1 month ago, now only 2 procedures remain to be approved!

Description Procedure	Procedure N.	Revision	Status	_
Niobium Sheets	PO 657756	NA	QC Approved	
Niobium & Nb55Ti (Rods/Plates/Disks)	PO 671157	NA	QC Approved	
Niobium Tubes	PO 671490	NA	QC Approved	
<b>RFD Crab Cavity Drawing Package</b>	3326.1.000.000	1	Update Ongoing (ZRI)	
Welding Book	3326.W.001	NA	New version available after WPQR approval	
- section 1: Welding Map	3326.W.001	NA	New version available after WPQR approval	
- section 2: WPS	3326.W.001	NA	New version available after WPQR approval	
- section 3: Test Coupon (WPQR)	3326.W.001	4	Update Ongoing (ZRI)	
- section 4: WOPQ	3326.W.001	3	New version available after WPQR approval	
MIP - Pre-series (QCP @ ZRI)	Z20008.QCP.001	2	Approved	
Cleaning & Chemical Etching	Z20008.BCP	0	Approved*	* administrative update ongoing
Identification, Marking, Traceability	Z20008.IMT	0	Approved*	* administrative update ongoing
Radiographic Examination (RT)	Z20008.RT	0	Approved*	* administrative update ongoing
Radiographic Test Extent	NA	NA	Update Ongoing (ZRI)	
Manufacturing Sequence	NA	NA	Update Ongoing (ZRI)	
Helium Leak (LT)	Z20008.LT	0	Approved*	* administrative update ongoing
Dimensional Control	Z20008.DIM	0	Check Ongoing (CERN)	
Visual Inspection	Z20008.VT	0	Approved*	* administrative update ongoing
Packing Procedure	Z20008.SH	0	Check Ongoing (CERN)	
Grinding Procedure	ZGEN.GR	0	Check Ongoing (CERN)	



### Zanon – Risks in Resuming Fabrication

- As of today, <u>KEY documents and procedures</u> are still not approved by CERN.
- AUP projections show that due to delays this year, we have <u>consumed all float</u> with respect to "late" delivery dates agreed with CERN (see final slide).
- In the interest of schedule, factoring the approved MIP, and extremely advanced stage of drawings, <u>AUP decided to give OK to Zanon</u> to start fabrication of 2x Pre-Series cavities.
- Approval was limited to cutting Niobium sheets and performing deep-drawing of Niobium components.
- Any activity is contingent on the approval of applicable procedures.



Nb sheet cutting at Zanon





### See talk by Naeem Huque / Subashini De Silva RF Ancillaries Fabrication – Jlab



AU



### **Transition Plan: Prototypes, Pre-Series, Series**

### LARP prototypes (2017-2019):

- Validation of cavity design in achieving key performance requirements (e.g. deflecting voltage, quality factor).
- Validation of FNAL/ANL facilities and processes for surface chemical processing, heat-treatments and cold test.
- AUP prototypes (2020-2021):
  - First development of fabrication process at Zanon.
  - First development of QA documentation.
  - Practice with CERN system for Manuf. Records & NCRs.
- NOW Confirmation of FNAL/ANL facilities and processes.
  - Validate Zanon facilities for processing.
  - AUP Pre-Series (2021-2022):
    - Convergence with CERN on fabrication and QA documentation (DWGs, MIP, welding book, NCRs,..).
    - Validate fabrication process, including processing, at Zanon.
  - AUP Series (2022-2023):
    - Repeat process of pre-series, deliver cavities to FNAL ready for VTS.



### **Niobium & Raw Materials Procurement**

- Virtually all <u>material for pre-series</u> is already at Zanon. One last procurement imminent, plus some pieces for certain weld qualifications.
- All (83) <u>Niobium sheets for series</u> have been received from China. Inspection at FNAL completed. <u>Accepted by CERN</u>. Now verifying tensile and RRR properties.
- One last order of material for series (Niobium Tubes) not yet placed with Ningxia as negotiations on payment terms continue. Supplier requested 100% payment before shipment. FNAL proposing maximum 95% payment at acceptance of material certs and inspection reports and remaining 5% after receiving.
- <u>QA contractor hired</u> to tackle increased QA activities (for raw materials, and rest of scope as well).



### **Helium Tanks**

- Prototype magnetic shields were procured from Ad-Vance (U.S.) and are at FNAL.
- Helium Tank fabrication + welding: "lowest cost technically acceptable" proposal received from Zanon (Ita). Only other bid was received from Roark (USA).
- Contract with Zanon is imminent. Will include jacketing operations for 2x prototypes at this moment, a change order will be issued to add quantities for series.
- To allow a seamless transition to series in spring 2022, a <u>final release by CERN of all</u> <u>drawings and supporting documents is needed</u> <u>by end of 2021, early 2022 at the latest</u>.







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### **Delivery Dates**

- Deliveries are starting to fall outside the delivery window which was agreed with CERN <u>before Covid</u>. Dates will need to be renegotiated prior to AUP rebaseline in April 2022.
- Delays are driven (A) by the additional work necessary to fully comply with CERN requirements prior to launching pre-series (~10mo); (B) Covid inefficiencies and impacts at suppliers are also affecting our schedule, to a smaller extent.

Cavity Delivery Date	s with current Plan of 1 bare cavity and 1 dressed cavit	y failure				
	Agreed Early Delivery Date	August 2021 Status Schedule		Agreed Deliver	d Late y Dates	
Cavities 01 & 02	Jun-22		May-23	Jun-23		
Cavities 03 & 04	Sep-22			Sep-23		
Cavities 05 & 06	Nov-22				Dec-23	
Cavities 07 & 08	Jan-23				Feb-24	
Cavities 09 & 10	Mar-23					May-

Cavity Delivery Dates	with no failures					
	Agreed Early Delivery Date	Success Oriented August 2021 Status Schedule		Agreed Late Date	e Delivery es	
Cavities 01 & 02	Jun-22		May-23	Jun-23		
Cavities 03 & 04	Sep-22			Sep-23		
Cavities 05 & 06	Nov-22		Oct-23	1	Dec-23	
Cavities 07 & 08	Jan-23				Feb-24	
Cavities 09 & 10	Mar-23				Apr-23	Ma

