RFD Crab Cavity Contribution from the U.S.
Status, Needs and Plans

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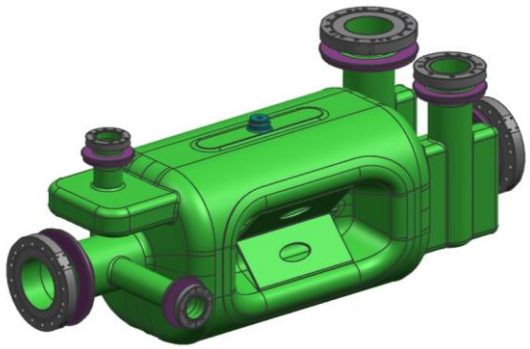
With input from: ANL, BNL, JLAB, ODU, SLAC

8th HL-LHC Collaboration Meeting – CERN, Oct 15-18, 2018

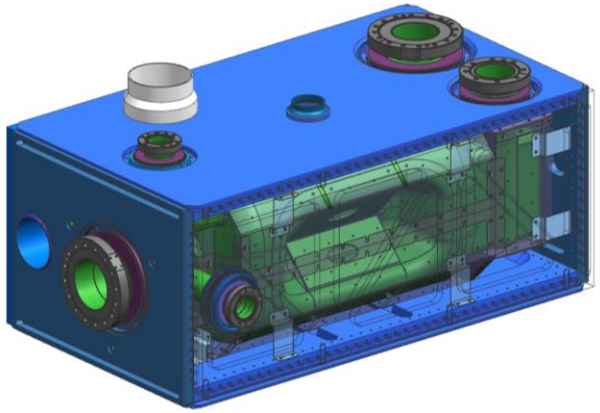
Outline

- Scope and Deliverables
- Technical Achievements of 2018
- Recent Design Review
- Roles & Responsibilities
- Immediate Needs
- Design Deadlines
- Clarification on Delivery Dates
- Plans for 2019
- Some Ideas & Proposals

Scope and Deliverables



Bare RFD Cavity



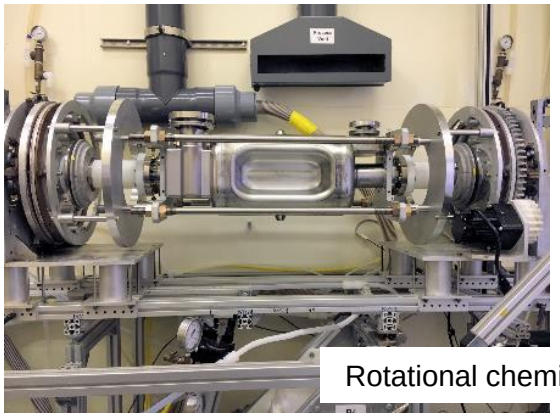
Dressed RFD Cavity
(front wall removed to show internal components)

RF Ancillaries

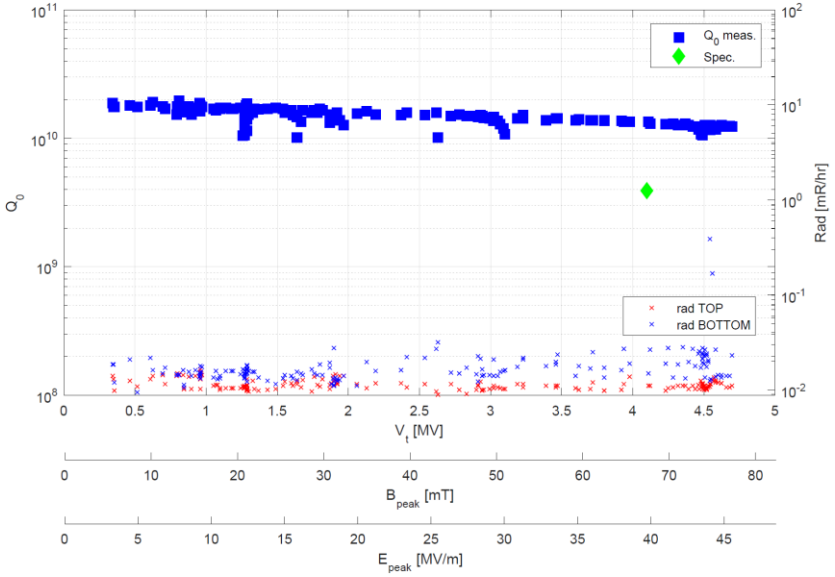
- **Dressed RFD Crab Cavity**
  - **Project Scope includes 2 Prototypes + 2 Pre-Series + 10 Series**
  - Bare Cavities: Intermediate Qualification at FNAL at 2K
  - Assembly: Bare Cavity + Magnetic Shields + Helium Tank + RF Ancillaries
  - Dressed Cavities: Final Qualifications at FNAL at 2K + RF Ancillaries
  - Shipped to CERN ready for integration in cryomodule (CERN scope)
  - Delivery of (10) qualified dressed cavities (objective KPP)

RFD Crab Cavities – 2018 Technical Achievements

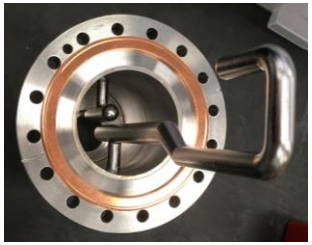
- Validated new rotational-BCP tool at ANL
- Newly fabricated HOM dampers by JLab
  - Warm and cold tests performed
- Continued cold-tests on LARP prototypes
  - Exceeded requirements of field and quality factor
  - Still troubleshooting damper losses
- Placed contract for bare cavity fabrication



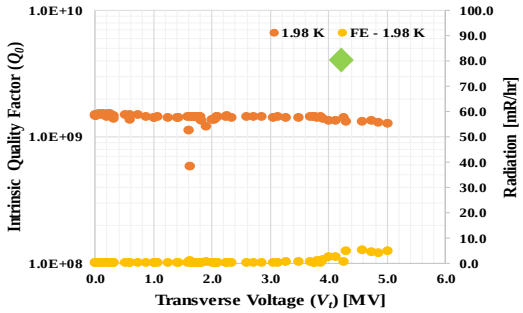
Rotational chemistry at ANL



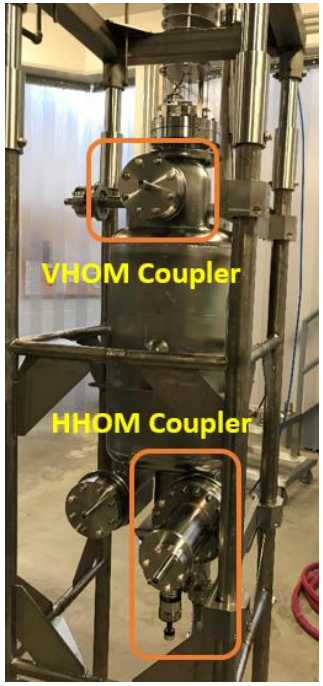
Successful test of bare cavity at 2K (Fermilab).
Exceeded field and quality factor requirements.



Horizontal HOM Damper
designed by SLAC, built by JLab



2K Test of cavity with HOM dampers
showing successful field (~5MV) and low
Quality Factor (ODU/Jlab).

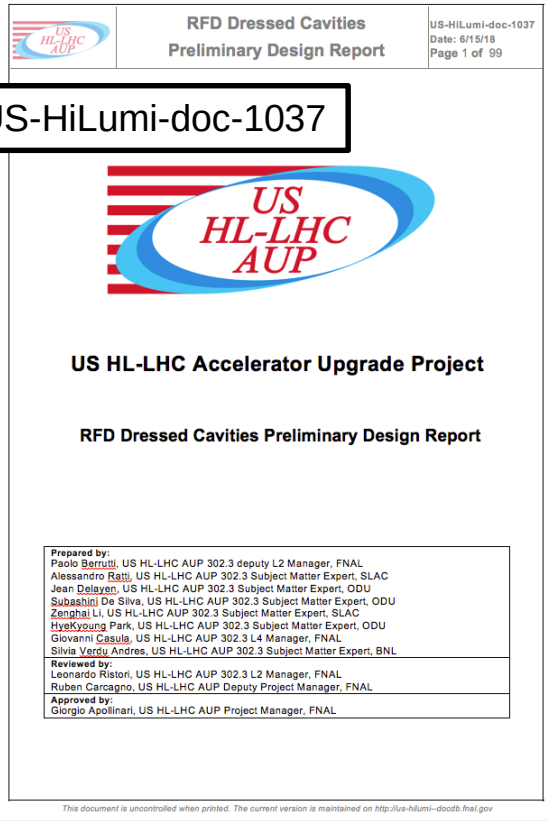


Summary of RFD Cold Tests in U.S.

Test Date	Cavity #	Location	HHOM	VHOM	Max Voltage	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
5/5/2018	LARP RFD#2	JLab	☑	☑	4.77	1.22E+09
5/31/2018	LARP RFD#2	JLab	☑	☑	5.03	1.32E+09
6/13/2018	LARP RFD#1	FNAL	☐	☐	3.47	N/A
8/16/2018	LARP RFD#2	JLab	☑	☐	5.26	6.60E+08
10/9/2018	LARP RFD#2	JLab	☑	☐	4.18	1.08E+09

Preliminary Design Report

- Describes entire RFD scope, including LARP experience
- Design meets all requirements
- Presented at Preliminary Design Review



CHAPTERS:

Preliminary Design Report

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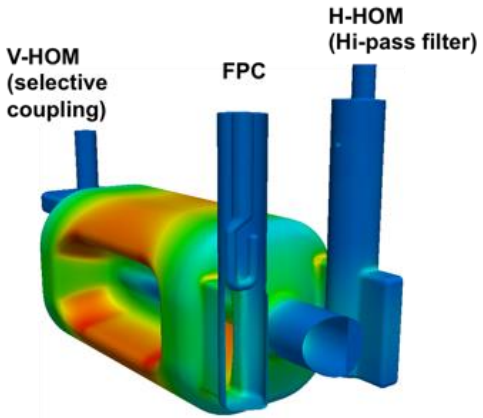
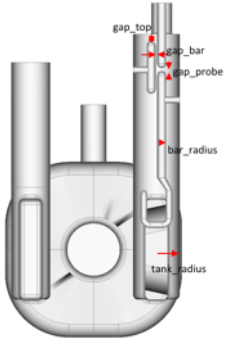
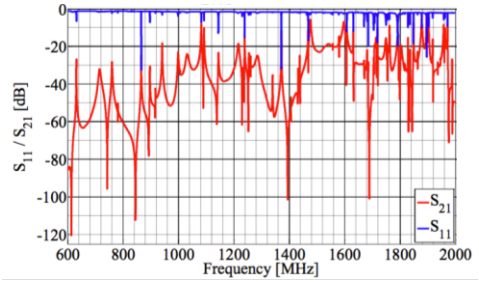
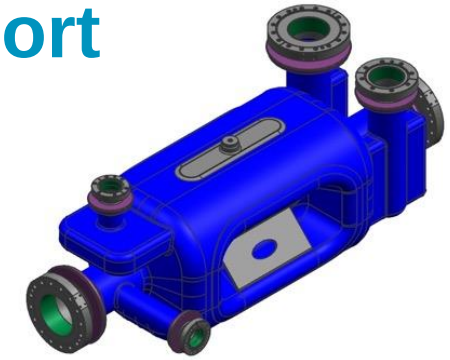
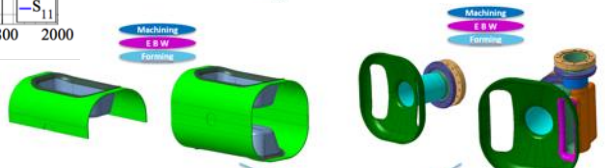
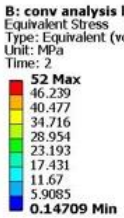


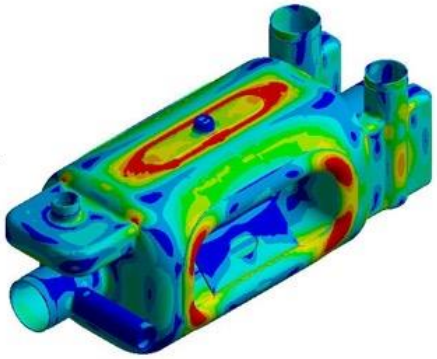


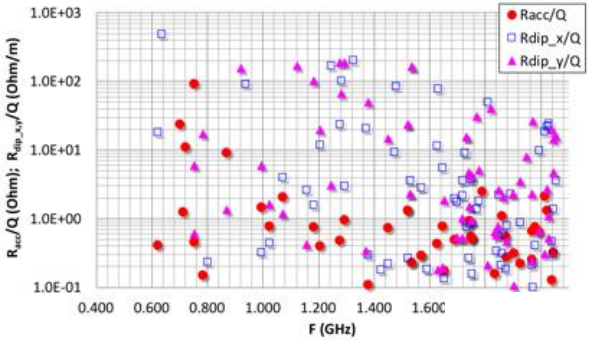


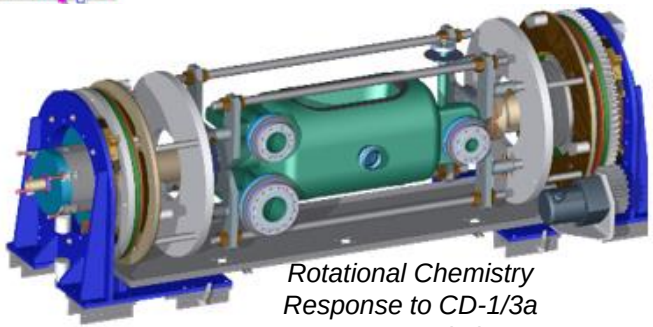




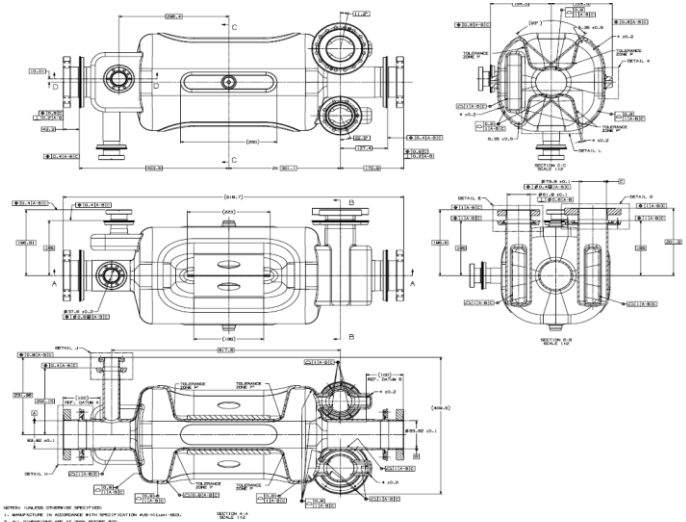








Rotational Chemistry Response to CD-1/3a recommendation



Design Review (June 2018)

Preliminary Design Review of the RFD Cavities and Final Design Review of the Raw Materials

US-HiLumi-doc-1190

The Review Committee Report

Also in response to CD-1/3a recommendation

Committee Members:

Sergey Belomestnykh (Fermilab), Chair
Camille Ginsburg (Fermilab)
Charles Grimm (Fermilab)
Sang-Ho Kim (ORNL), participated remotely
Robert Laxdal (TRIUMF)

Executive Summary

This in-person review was held at Fermilab on June 20-21, 2018. The goal of the review was to assess a preliminary design of the Radio Frequency Dipole (RFD) crab cavity and final specifications of raw materials prior to the Director's Review and CD-2/3b IPR. The committee reviewed several aspects of the RFD design, including electromagnetic design, mechanical design, and test results of LARP prototype cavities. The committee would like to point out that the collaboration between the partner laboratories and Fermilab seems to be very productive and the overall progress should be commended.

Based on the presentations and information provided, the committee thinks that the project is ready for CD-2/3b.

Roles & Responsibilities in AUP

Activity	FNAL	SLAC	ODU	BNL	JLAB	ANL
Requirements and EM Design of the cavity and RF Ancillaries	Converge with CERN on functional requirements, interfaces, acceptance. Converge with CERN on EM Design.	Optimization of cavity system EM design to meet functional requirements. Study effects of manufacturing tolerances with respect to requirements. Provide models and documentation as deliverable to the project.	Cavity conceptual EM Design. Warm cavity Measurements in support of design decisions. Data analysis, troubleshooting, and verification of compliance with general system requirements.	Develop Interface control documents for the dressed cavity. Clarify interfaces between AUP and CERN's SM18, SPS, and LHC areas of operation as needed.	Contribute to cavity system requirements and EM design in order to develop qualification criteria for RF ancillaries.	
Cavity Mechanical Design and Fabrication	Converge with CERN on mechanical design of cavity. Issue POs with Industry for fabrication of cavities, magnetic shields, helium tanks.	Support activities by verifying compliance with modeling and requirements. Provide tolerances for fabrication of cavity.	Support quality control activities and cold measurements as needed.	Prepare Manufacturing Inspection Plans.		
RF Ancillaries Mechanical Design and Fabrication	Converge with CERN on requirements and mechanical design of HOM Dampers.	Provide manufacturing tolerances for HOM dampers.	Contribute to fabrication and qualification of HOM dampers through warm and cold measurements.		Contribute to RF, mechanical and thermal design of RF ancillaries. Prepare Manufacturing Inspection Plans. Fabricate and qualify RF ancillaries.	
Magnetic Shields Design and Fabrication	Design and build all magnetic shields. Test and measure for compliance with requirements.	Facilitate information exchange with CERN-UK.		Facilitate information exchange with CERN-UK.		
Bare and Dressed Cavity Qualifications	Coordinate the chemical processing and cold tests leading to final qualification and shipment.	Perform simulations as needed to verify compliance with requirements.	Support qualification activities, data analysis and troubleshooting of results.		Support qualification activities for RF ancillaries.	Develop rotational chemical processing. Perform chemical processing of all cavities.

Immediate Needs (~1month)

- NEED: Convergence, and approval of material list for RFD bare cavity (Nb, NbTi, 316LN, OFE Cu) – next slide..
- NEED: First iteration on Acceptance Criteria DRAFT (Paolo)
  - List of tests/measurements/documentation needed at the end of fabrication to qualify dressed cavity as deliverable vs. non-deliverable
- NEED: First iteration on Interface Control Documents DRAFT (Silvia)
  - Demonstrate mutual understanding of interfaces (physical, cryogenic, RF, vacuum,…)

Material List for Series

Material	Series
RRR Nb Sheets	CERN material specification 3300 ed.4 (EDMS 1095252)
RRR Nb Bars & Plates	CERN material specification 3301 ed.4 (EDMS 1476934)
NbTi	CERN material specification 4055 ed.3 or ed.4? (EDMS 1485727)
316LN	CERN technical specification 1001 ed.5 (EDMS 790775)
OFE Cu	Cu-OFE (UNS C10100)

- For Nb material, need to clarify applicability of specs 3300 vs 3301 with respect to thickness of material
- For NbTi, need to understand additional requirements of Ed.4 before AUP can absorb this revision

Very useful-to-have for Prototypes

- Convergence on bare cavity drawing for prototypes (not deliverables, but basis for series)
  - We (AUP-CERN) are VERY close, just clarifications on some tolerances is needed (functional vs achievable)
  - CERN will implement different pick-up port for 2x prototypes?
- Compare & “cross-pollinate” fabrication strategy of RFD between CERN workshop and AUP Industrial partner
- Compare also QA documentation (EBW qualification plan, manufacturing inspection plan)

Design Deadlines (To respect AUP baseline)

- Prototype Cavities:
  - RF Ancillaries (HHOM, VHOM, Pickup): Feb 2019
  - Mag. Shields: Feb 2019
  - Helium Tank: Feb 2019
- Production Cavities:
  - Everything to be reviewed before Spring 2020 (Final Design Review, date TBD)
  - Outcome to be presented at CD-3 review to obtain approval for construction in U.S. in late Summer 2020
  - Place order for cavities: Fall 2020
  - Place order for RF ancillaries: Spring 2021
  - Place order for Shields+Tanks: Fall 2021

Clarification on Delivery Dates

- AUP will launch 2 prototype dressed cavities (not deliverables) + 12 production dressed cavities (resulting in 10 deliveries).
- Note that delivery dates below (agreed between AUP & HL-LHC) do not include the 2x early prototypes.
- “Availability” dates and destination of prototypes are still under discussion
- We should not use any set of dates other than these below

RFD Dressed Cavities

	Early Delivery Date	Late Delivery Date
	HL project schedule	US project schedule
HCACFDC002-UP000001	July 2022	June 2023
HCACFDC002-UP000002	July 2022	June 2023
HCACFDC002-UP000003	September 2022	September 2023
HCACFDC002-UP000004	September 2022	September 2023
HCACFDC002-UP000005	November 2022	December 2023
HCACFDC002-UP000006	November 2022	December 2023
HCACFDC002-UP000007	January 2023	February 2024
HCACFDC002-UP000008	January 2023	February 2024
HCACFDC002-UP000009	March 2023	May 2024
HCACFDC002-UP000010	March 2023	May 2024

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Procurement of RFD Cavities

- Main goal of prototypes is to lead the path for production in 2020-2021
- Order placed 5 Sept 2018 with Ettore Zanon for 2 prototypes + option for additional 12 cavities to be exercised at later time
- Currently developing fabrication drawings with deadline end of October
- Decision under discussion to utilize thick plates for waveguide transition similarly to CERN approach. Discussing with Zanon options for procuring this material.
- Next month dedicated to developing quality control plan (QCP) as they call it, should be the MIP. And the welding qualification plan.
- Nb-SST braze joints finished at ANL, enough for 4 cavities plus specimens utilized for qualification. Discussing with CERN details of qualification performed according to ASME + integrative tests (e.g. UT, cold shock)

Plans for FY2019

- Continue troubleshooting HHOM performance in cold tests at JLab
- Monitor progress at Industrial partner for 2x prototypes with information exchange with CERN.
- Jointly finalize with CERN design of RF ancillaries, magnetic shields, helium tanks
- Launch fabrication of RF ancillaries prototypes at Jlab
- Launch procurement of magnetic shields and Helium tanks for prototypes

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Topics for Discussion

- Establish change control for requirements, specifications, drawings.
- Fully integrated test of dressed cavity + dampers + FPC
  - It's a necessary validation for entire collaboration
  - Who/how/when/funding?
- Procurement of "peculiar" components
  - Ti-SST bimetallic transition, Helium tank bellows, tuner connection,..
  - Others?
  - Should we consider consolidating efforts by contacting same suppliers, or joining orders or exchanging parts?
- Best use of AUP Prototypes in early 2021?

Proposals to maintain a healthy collaboration

- 1) Continue to secure 1 day at yearly collaboration meeting for open discussions between the teams.
  - Yesterday was an excellent use of a few hours where lots of questions from all teams where answered quickly
  - Live demo of 3D models for both cryomodule types was the basis for fruitful discussions and for insuring synchronization on key design aspects and definition of deliverables, interfaces,..
- 2) Gather another time yearly for 2-3 days, with a collaborative intent to avoid letting 1 year go by. We could call this "WP4 Spring Update"
  - Limit powerpoints, adopt open discussion format
  - Again live demo of cryomodule designs DQW and RFD
  - Cross exchange of fabrication experience at labs
  - Updates on fabrication at cavity suppliers (maybe inviting both to CERN)
  - More…?

Summary

- Already 10 cold tests performed on RFD cavities in U.S.
- Successful design review in June 2018 leading to upcoming CD-2 review in December (baseline of project).
- Immediate needs for certain critical documents to be successful at CD-2.
- Changes need to be properly managed
- Consider one additional yearly meeting to synchronize within WP4