



US-LARP crab cavity program and future performance improvement plans

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on behalf of HL-LHC/LARP crab cavity team

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<https://indico.cern.ch/event/647714/>



Outline

- LARP Crab Cavity Development and Testing Summary
 - DQW
 - RFD
- Transition to the US HL-LHC AUP construction project
- Plans for the US FY18
 - LARP(-less)
 - AUP
 - Other

LARP Recap

- Started the Crab Cavity proposal in 2006
 - Rama's first "child"
- Developed Proof of Principle cavities that demonstrated a major point
 - It is possible to achieve the required field strength within the dimensional constraints
 - No more 'global' crab scheme
- Continued to develop initial cavity designs
 - Strong collaboration with CERN and the UK
 - Demonstrated the electromagnetic designs and production processes of bare cavities of both styles
 - Field in excess of required threshold, no field emission
 - Adding HOM couplers and filters now

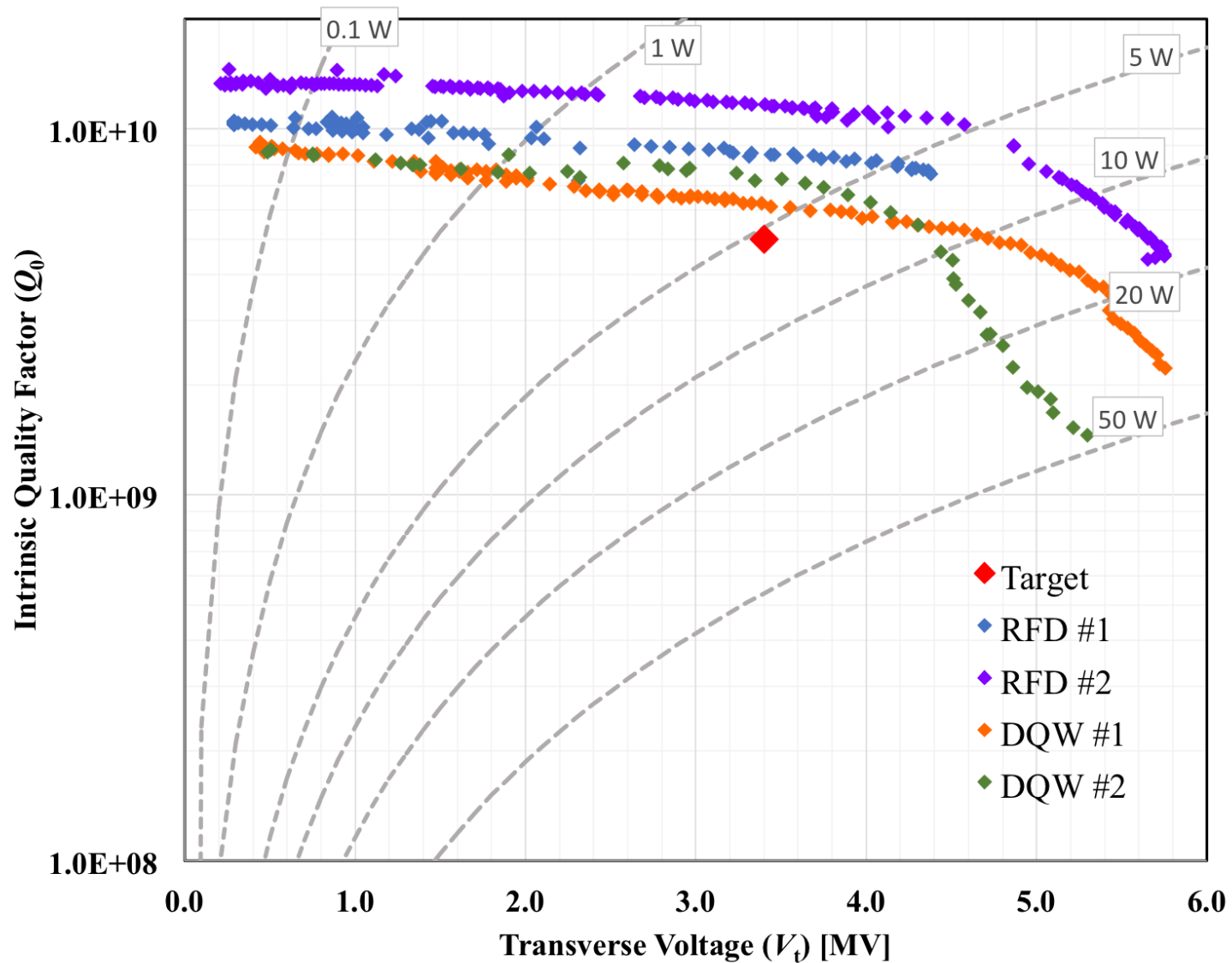
Summary of CC test results

	CERN DQW1	CERN DQW2	USLARP DQW1	USLARP DQW2	USLARP RFD1	USLARP RFD2	USLARP RFD1 @FNAL
Max voltage [MV]	5.0	4.8	5.8	5.3	4.4	5.7	4.7
Epeak [MV/m]	56	54	65	59	42	54	45
Bpeak [mT]	109	103	125	114	73	95	78
Rs min [nOhm]	10	10	9	10	11	7	6
Rs @ 3.4MV [nOhm]	15	18	15	12	13	9	7
FE onset [MV]	4.0	3.5	4.1	2.8	No FE	4.5	
Q0 max			9.2E+9	8.8E+9	1.1E+10	1.5E+10	
Q0 @3.4MV			6.2E+9	7.3E+9	8.5E+9	1.2E+10	

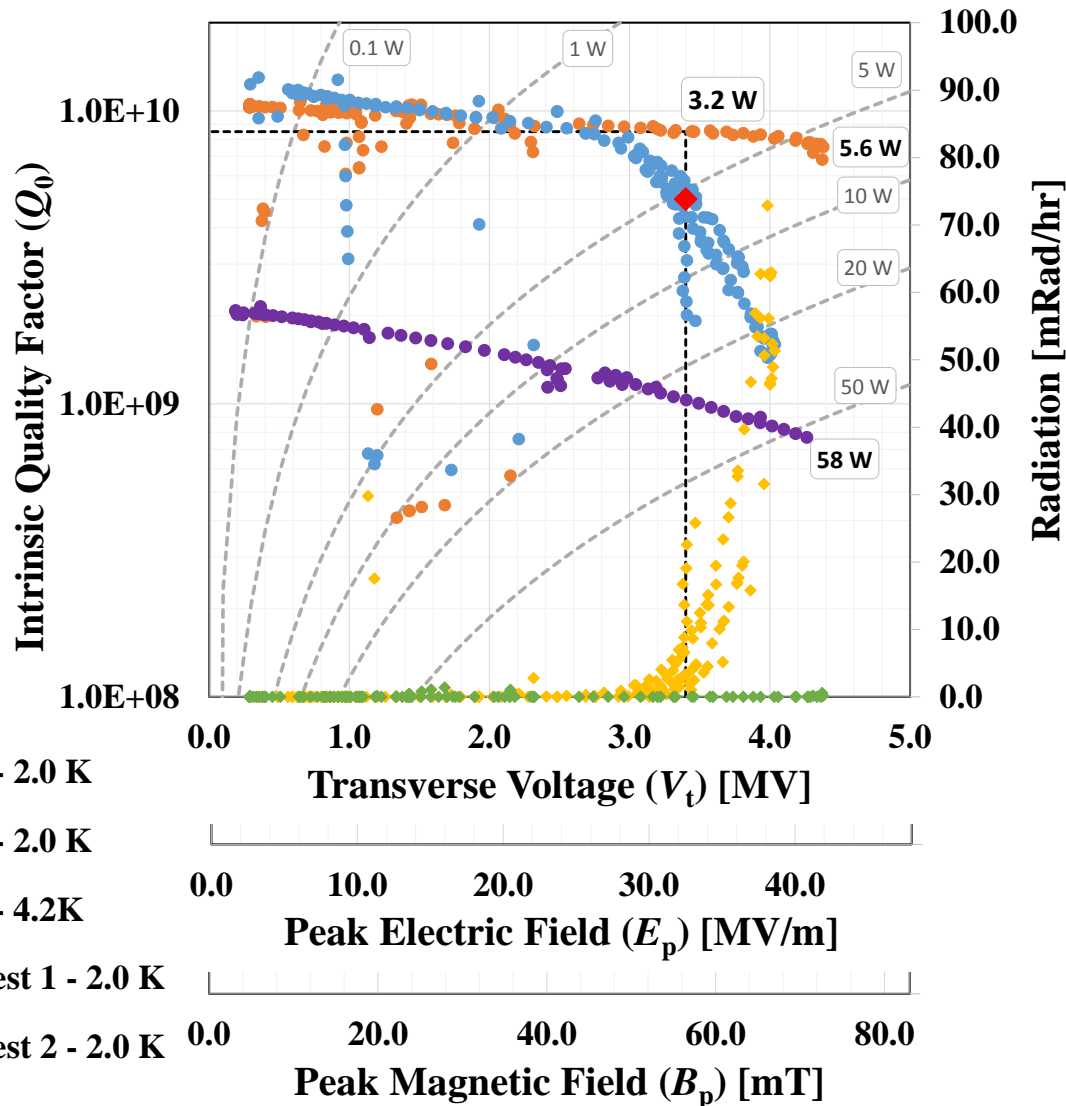
All cavities meet functional requirement: V_{Max} >4.1MV: P_{Loss} of < 5W@3.4MV



US LARP Cavities Test Summary at JLAB



RFD-1 Test Results



- At low fields for both rf tests Q_0 is $> 1.0 \times 10^{10}$
- Multipacting barrier was processed easily and didn't reoccur
- No field emission observed during Test 2

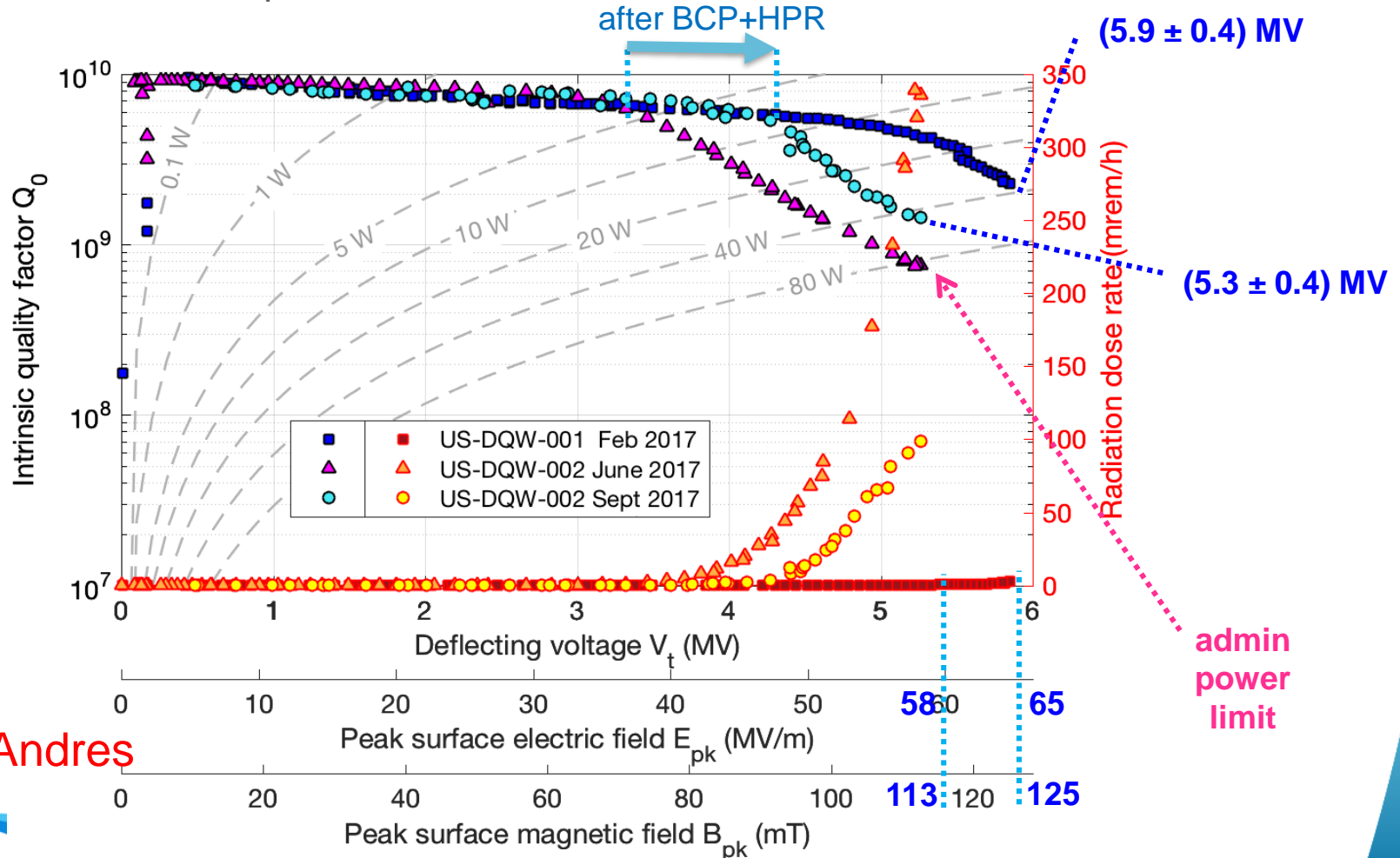
At 2.0 K	Test 2
Max V_t [MV]	4.4 MV
E_p [MV/m]	42
B_p [mT]	73
Q_0 at 3.4 MV	8.5×10^9
P_{diss} at 3.4 MV [W]	3.2

S. De Silva



DQW-2 Test Results

- **Cavity #2: same quench field during CW and pulsed operation** $\sim\sim$ magnetic quench.
- **Improved FE onset for cavity #2 after 18 μm BCP and HPR**, but **still not optimal**: lower Q_0 and higher radiation.
- However, max. B_{peak} **comparable** for both cavities **when uncertainty accounted**.

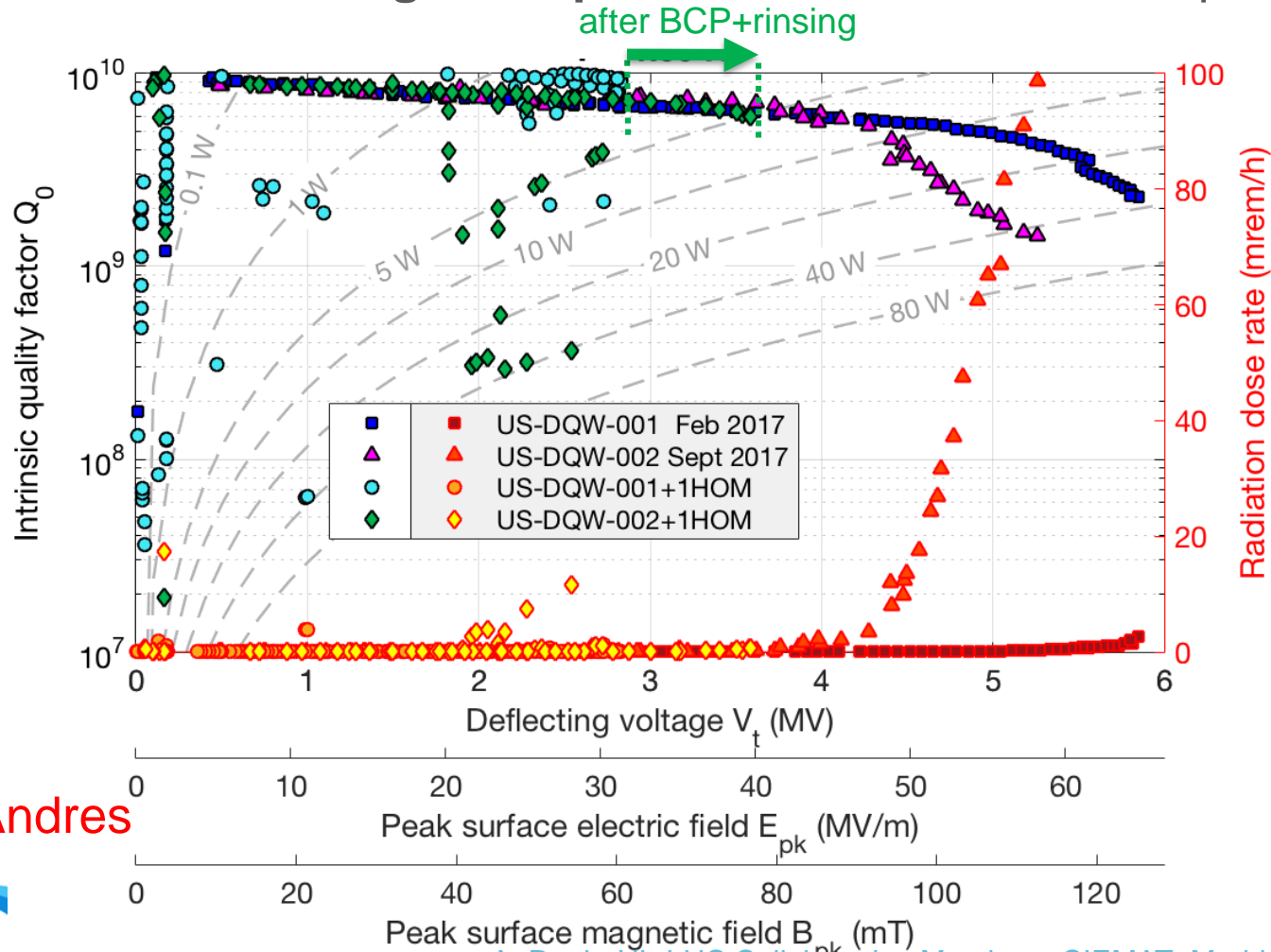


S. Verdu-Andres



DQW2+HOM Test Results

- Quench field level significantly **lower** than for bare cavity tests.
- Sharp **quench at 3.6MV**, with **no significant radiation** increase.
- Quench field level **higher in pulsed mode** $\sim\sim$ thermal quench.



S. Verdu-Andres



Ongoing (final) LARP developments

- RFD HOM Damper prototyping at JLAB
- Final cold testing of DQW with one HOM damper

RFD HOM Damper Fabrication at JLAB

- JLAB is fabricating a full set of H and V HOM couplers and filters for the two existing RFD cavities.
- Expected by early 2018 for cold testing and RF measurements

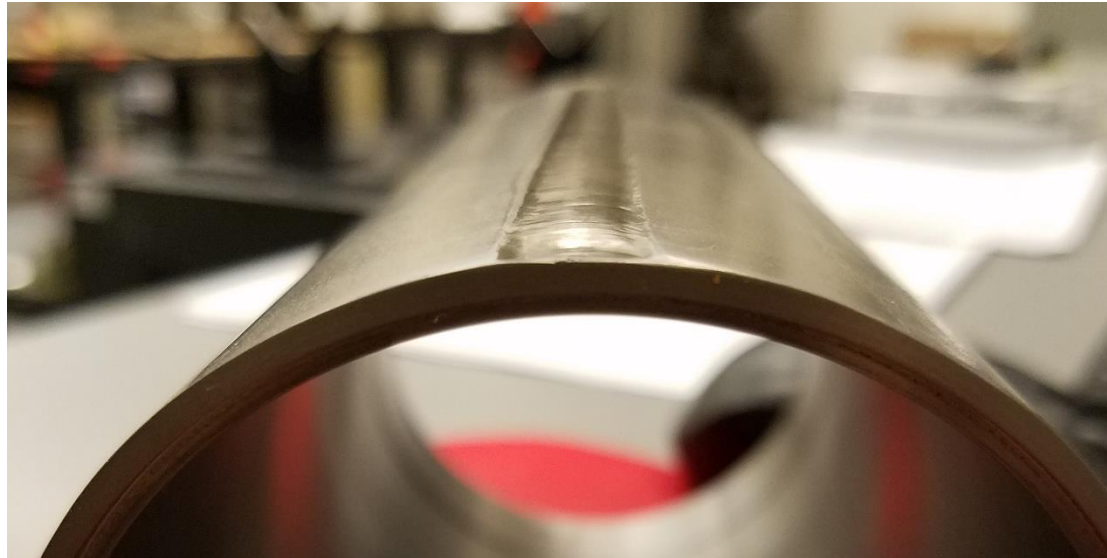


N. Huque



RFD HOM Damper Fabrication at JLAB (2)

- Dummy Nb Can fabrication complete
 - Seam weld being inspected as per CERN standards (ETD this week)
- Brazing tests and qualification underway
 - Other test samples also being brazed (ETD by the end of next week)
- RRR Nb sent to FNAL for QC



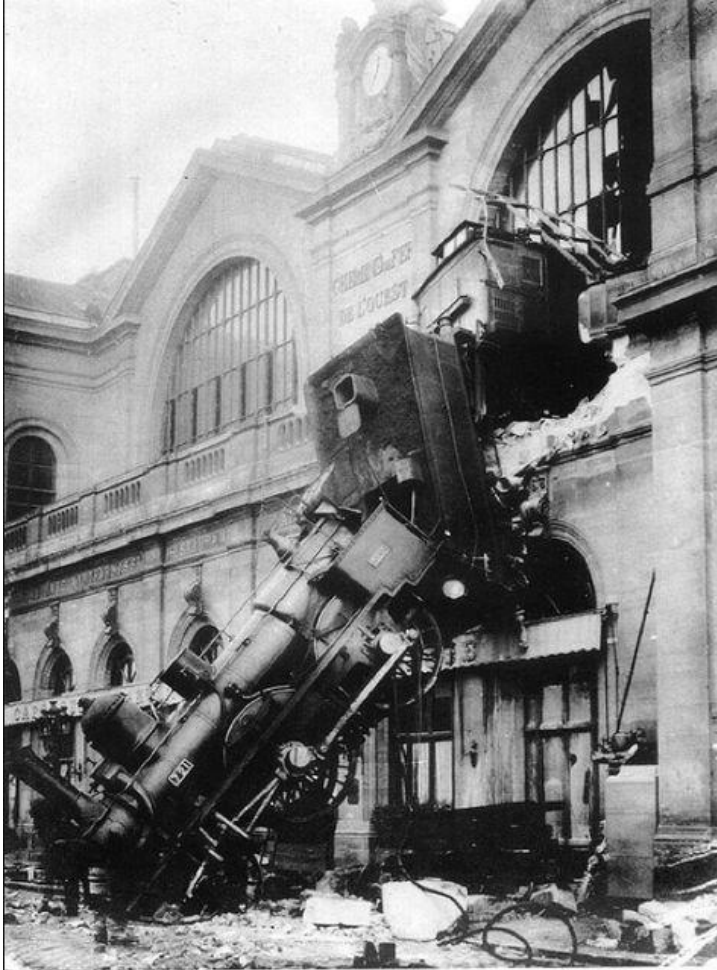
Far Left: Dummy Nb can for weld test. Near Left: Seam weld on Nb can to be inspected

N. Huque

FY18 DQW studies

- Final cold testing of DQW2 at JLAB with one HOM damper
 - Spending carryover of last CC funds from LARP
 - More studies needed to understand and improve cavity performance with HOM dampers
- Warm measurements to characterize EM behavior
 - Multipoles, HOMs
- DQW2 remains at JLAB for further testing
- DQW1 goes to BNL for warm measurements
 - Field mapping, multipoles, HOM damping...
- Note: not all this work is funded by LARP and is outside of AUP scope
 - CERN support and/or funding could help

Soft Landing of LARP's CC program



- New roles between AUP and CERN for dressed cavities production
 - AUP carries RFD development into production
 - CERN carries DQW development and production
- LARP ending with the completion of RFD HOM and cold testing at JLAB
- US LARP team continues towards the support of AUP's RFD deliverables

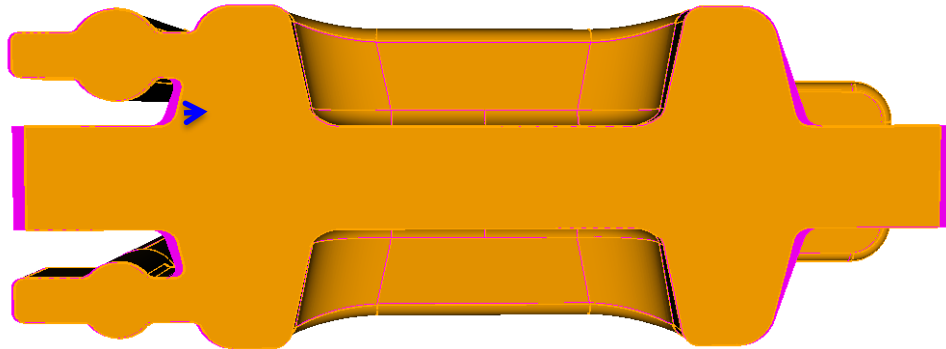
US HL-LHC AUP Project Plans for FY18

- Develop RFD prototype of US cavity deliverable
 - RFD with magnetic shield, He Tank and HOM filters
 - Industrialize production through early vendor selection
 - In close collaboration with CERN
- Finalize cavity design and Complete the preparation of the PDR
 - Including a dressed cavity PD review
- Prepare for CD-2
 - Define scope and cost baseline
 - Complete associated documentation (acceptance criteria, Manufacturing Inspection Plan...)
- Lessons learned from both DQW and RFD fabrication, processing and testing

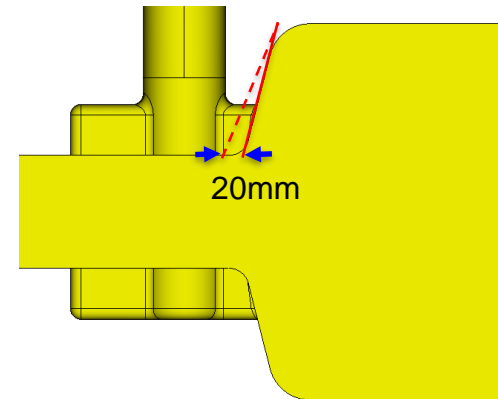
Described in detail tomorrow by Leonardo

Cavity Optimization for HOM

In response to the need to minimize impedance to the beam - Avoiding 760 MHz HOM frequency/beam harmonic

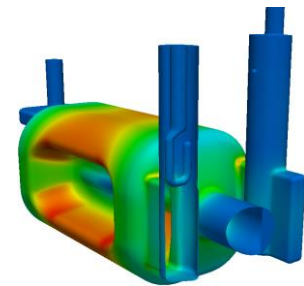


End-plate reduced tilt angle



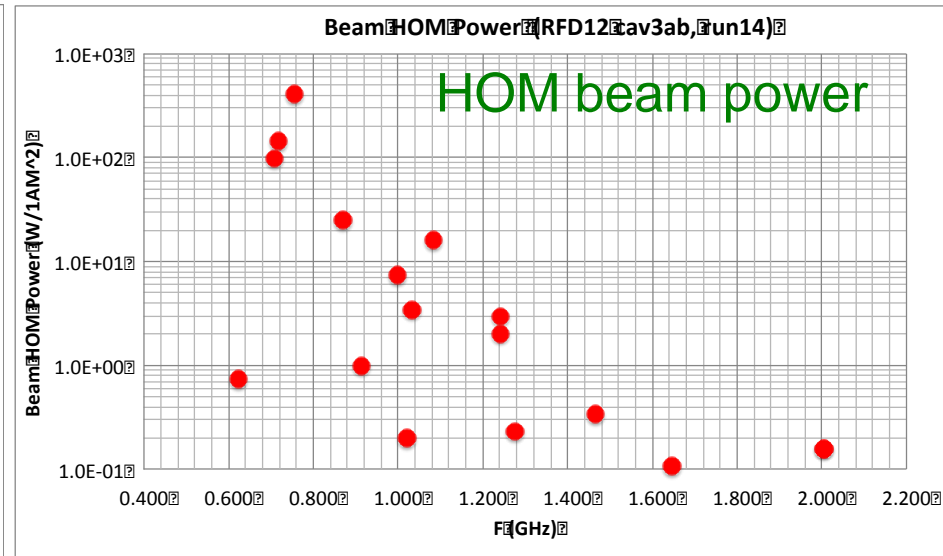
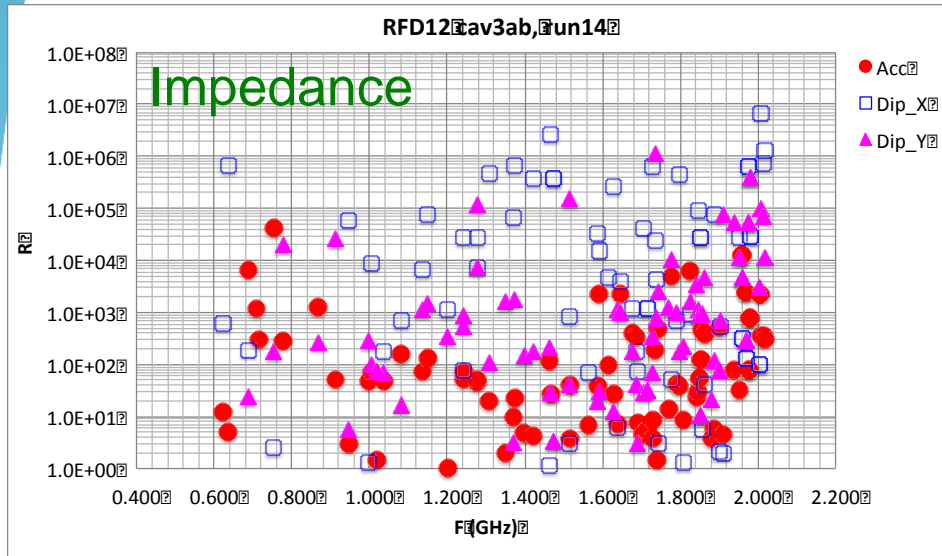
Shrink gap from the end plate lowers 760 MHz mode frequency

Operating mode tuned to 400 MHz by change outer can rounding



Z. Li, S. De Silva

760.9MHz HOM now detuned to 755MHz



- HOM impedance spectrum provided to CERN beam dynamics team for beam instability analysis

- HOM power calculated for 1-AM beam
- $\sigma_z=76\text{mm}$ factor included in power calculation

Beam HOM power well below design requirement of 1 kW

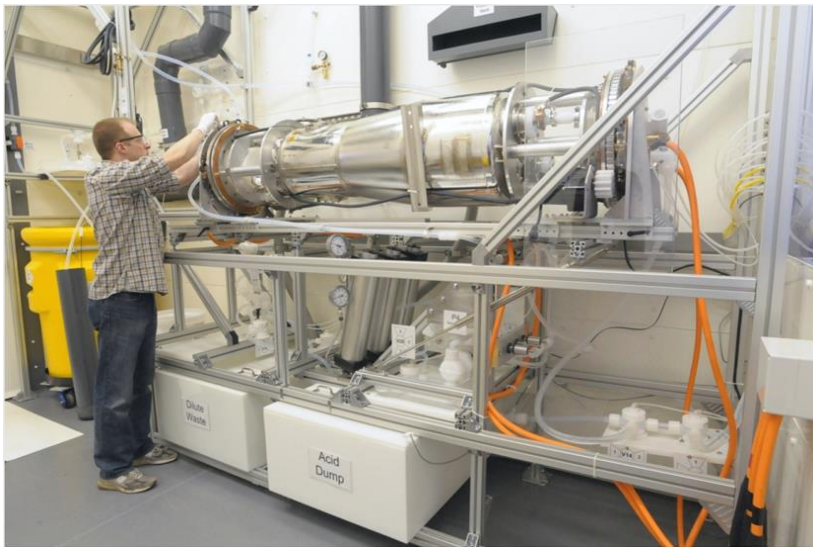
Z. Li/S. De Silva

3D Model and HOM spectra released to CERN for review

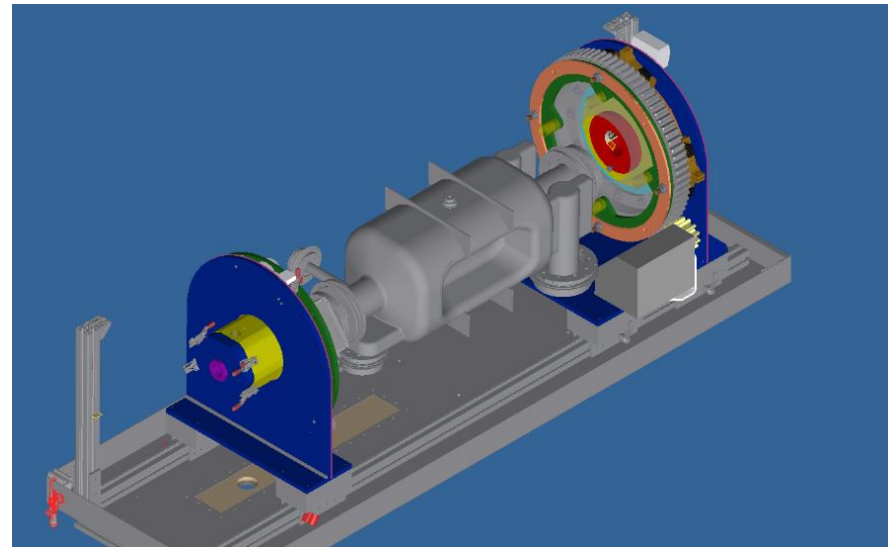


RFD1 - Next Steps

- RFD 1 cavity now at ANL
- PO with ANL in place for upgrade of rotational BCP tool to accept RFD cavity (see image)
- Buffer Chemical Polishing at ANL in Jan 2018
- Test at FNAL in March 2018



Existing Rotational Tool at ANL (with QWR resonator installed)



Upgrade of Rotational Tool at ANL to accept RFD Cavity

RFD2 - Next Steps

- Cavity remains at JLAB/ODU for:
 - Field mapping, multipole measurements,
 - Elastic and plastic tuning sensitivity studies

- In addition, ODU interested in more studies
 - Nitrogen doping treatment and Vertical Tests
 - Work outside the scope of AUP, yet of interest to the collaboration

Non-FNAL AUP Team Activities for FY18

BNL	ODU	SLAC
Interfaces in SM18, SPS and LHC	Warm measurements of electromagnetic and mechanical properties of the RFD cavity	Produce a RFD cavity design addressing the 760 MHz HOM issue
Lessons learned from DQW production	Elastic and plastic tuning sensitivity, including behavior of fundamental and higher-order modes	Calculate the full HOM impedance spectrum up to 2 GHz
Preliminary MIP for RFD pre-series production	Warm measurement of the electromagnetic properties of the HOM couplers	Design HOM coupler RF windows (feed through)
	Oversee Design of dressed cavity (bare cavity, magnetic shields and helium tank)	Analyze cavity and coupler tolerance for engineering design;
Contribute the relevant sections of the Preliminary Design Report	Contribute the relevant sections of the Preliminary Design Report	Contribute the relevant sections of the Preliminary Design Report

L. Ristori



Conclusions

- Lots of progress made since the last HL-LHC collaboration meeting
- Both cavity designs demonstrated performance required for SPS test and LHC
 - Much work left to be done
 - Leveraging existing cavities to support HL-LHC pre-series
- With AUP's achievement of CD-1, the collaboration transitioned to new roles
 - Still working together with CERN and the UK
 - Planning for a CD2 review in ~1 year
- LARP's CC R&D ends after many successes...
 - ...and the rollercoaster ride continues into the AUP Project