Update on cavity production and planning

A. Ratti (LBNL)
for the CC collaboration

Nov. 20, 2014

Cavity Progress - Highlights

- Completed optimization of FPCs
- Released 3D models of DQW and RFD
- Working on finalizing dressed cavities design and documentation
- Started Manufacturing Process
  - Kickoff meeting at CERN on Oct 1-2, 2014
- Producing beampipe test assembly to qualify processes at industrial partner

Requirements for Manufacturing Readiness

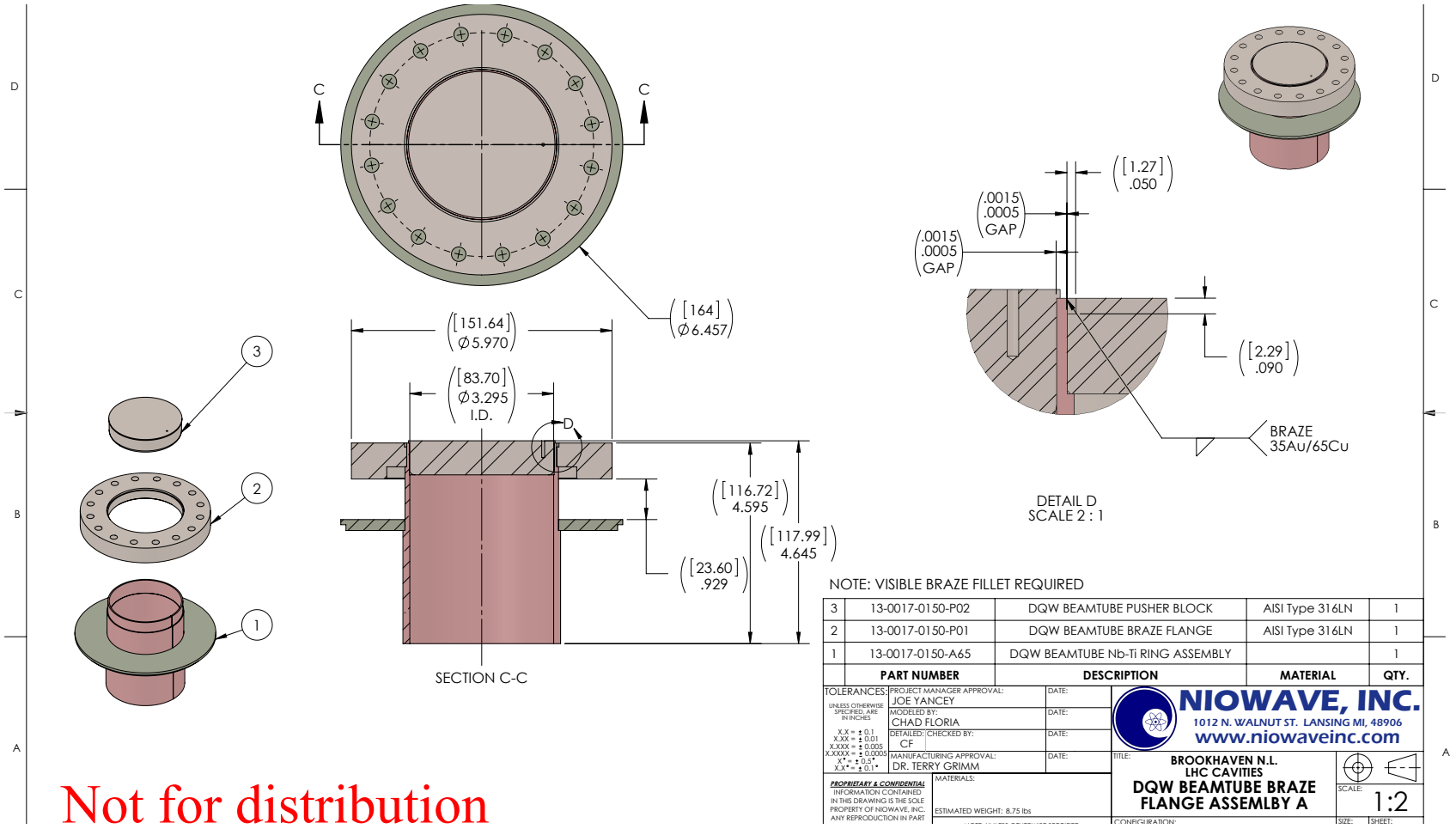
Due 1 month before start of manufacturing for CERN approval

#	Requirements
1	Niobium material samples according to Section 3.2
2	Material certificates and quality control of raw materials (including RRR measurements)
3	Material certificates of welding consumables (whenever applicable)
4	Functional and manufacturing drawings (with tolerances)
5	Design reports demonstrating that welds are designed to withstand the specified load cases (refer to Section 3.6.1)
6	Welding plan including: • Welding maps • Welding and brazing procedure qualification record including CERN acceptance criteria in Section 4.2 (WPQR and BPQR) • Welding and brazing procedure specification (WPS and BPS) • Welders performance qualification (GTAW), Welding and Brazing Operators Performance Qualifications (electron-beam welding and vacuum brazing) – WPQ, WOPQ and BOPQ
7	Manufacturing procedures (whenever required in Annex 6.3)
8	Test procedures (whenever required in Annex 6.3)
9	EB welded and vacuum brazed samples according to the requirements specified in Section 3.8.4
10	NDT personnel qualifications
11	Manufacturing and inspection plan (MIP) – list of all manufacturing and quality control operations.

Planning and Documentation

- Preparing all necessary documents
  - In collaboration with industrial partner
- Starting from Test Beam Pipe Assembly
  - Covers all aspects of fabrication
    - Forming, machining, e-beam weld, braze
- Test pipe under production
  - Will send to CERN for inspection as soon as ready

Beamtube Assembly



NOTE: VISIBLE BRAZE FILLET REQUIRED

3	13-0017-0150-P02	DQW BEAMTUBE PUSHER BLOCK	AISI Type 316LN	1
2	13-0017-0150-P01	DQW BEAMTUBE BRAZE FLANGE	AISI Type 316LN	1
1	13-0017-0150-A65	DQW BEAMTUBE Nb-Ti RING ASSEMBLY		1
	PART NUMBER	DESCRIPTION	MATERIAL	QTY.

TOLERANCES: UNLESS OTHERWISE SPECIFIED, ARE IN INCHES. X.X = ± 0.1, X.XX = ± 0.01, X.XXX = ± 0.005, X.XXXX = ± 0.0005, X° = ± 0.5°, X.X° = ± 0.1°

PROJECT MANAGER APPROVAL: JOE YANCEY DATE:
MODELED BY: CHAD FLORIA DATE:
DETAILED: CHECKED BY: CF DATE:
MANUFACTURING APPROVAL: DR. TERRY GRIMM DATE:

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MATERIALS:
ESTIMATED WEIGHT: 8.75 lbs

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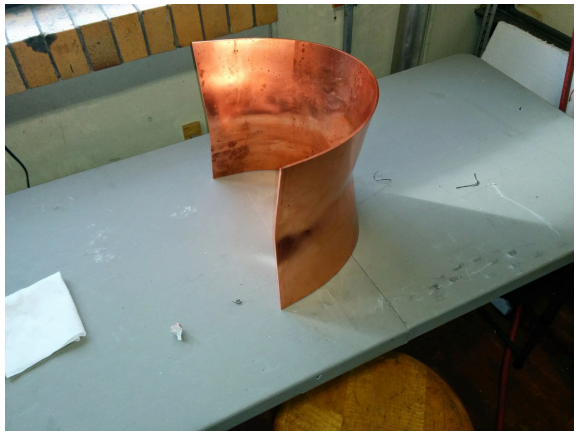
1012 N. WALNUT ST. LANSING MI, 48906
www.niowaveinc.com

TITLE: BROOKHAVEN N.L. LHC CAVITIES
DQW BEAMTUBE BRAZE FLANGE ASSEMLBY A

SCALE: 1:2
SIZE: SHEET:

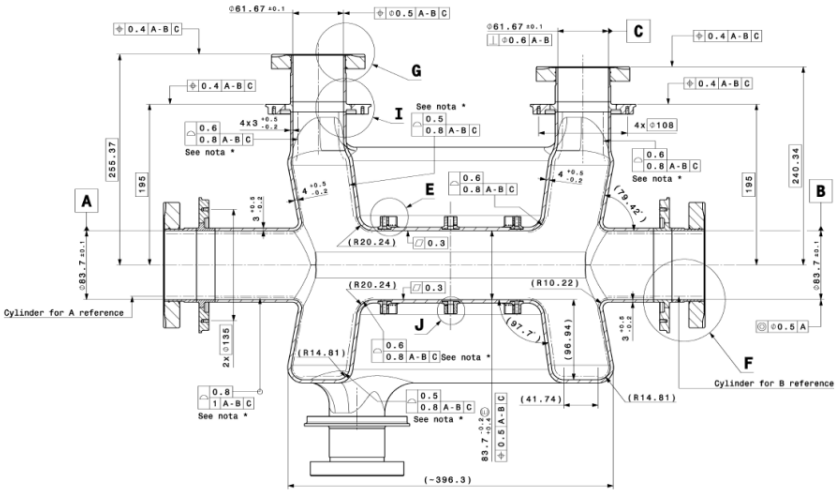
Not for distribution

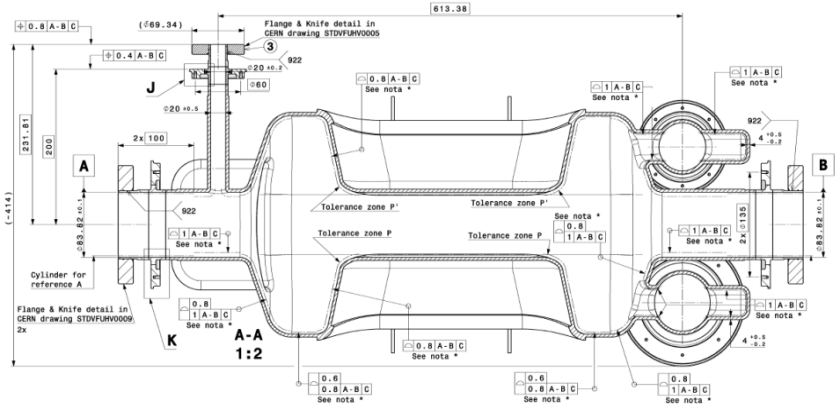
Manufacturing Tooling and Testing

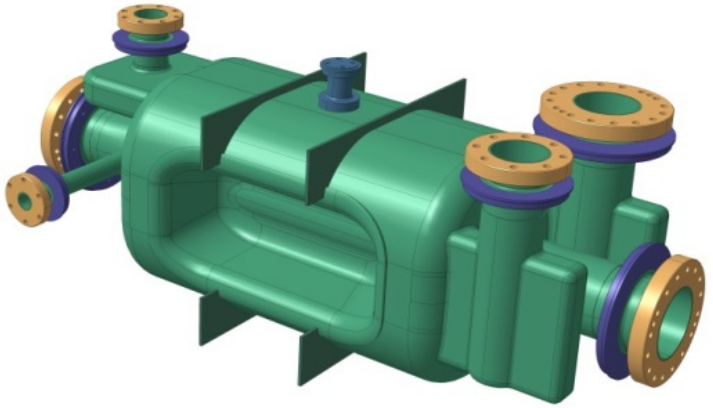


From Niowave

3D Models and Spec. Drawing



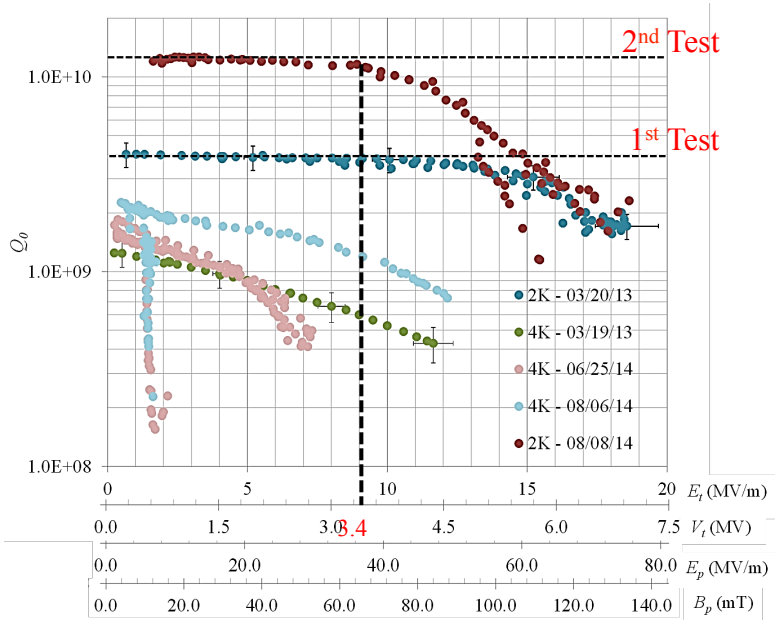


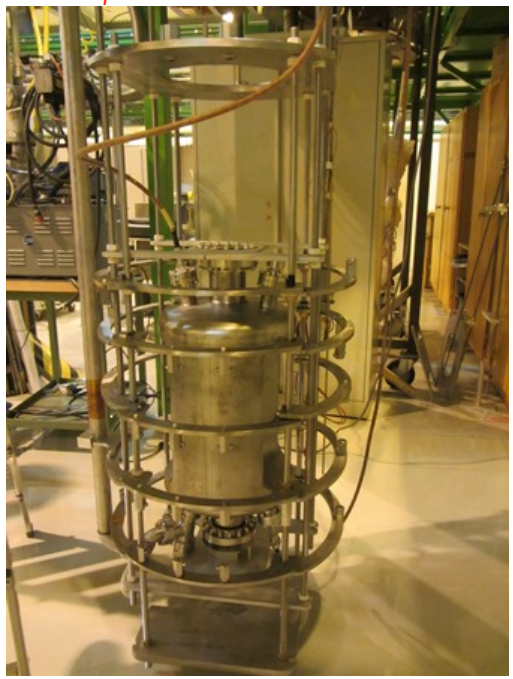


Verification of PoP RFD Test Results

Latest Crab Cavity Test Results – more details in Alick Macpherson's Presentation

- PoP RFD cavity was tested at JLab on Aug-2014 with Nb coated stainless steel blank flanges on beam ports provided by CERN
  - Q_0 increased by a factor of 3 (1.25×10^{10}) and achieved 7.0 MV again
- After the test at JLab cavity was shipped to CERN under vacuum
  - Achieved a Q_0 of 7.0×10^{9} with a V_t of 6.5 MV





RFD Crab Cavity Activities

- Electromagnetic design:

Analysis	Status	Verified
RF Properties	Completed – ODU/ SLAC	LU (Graeme Burt, Ben Hall)
Multipacting	Completed – ODU/ SLAC	LU (Graeme Burt, Ben Hall)
Multipoles analysis	Completed – ODU/ SLAC	LU (Graeme Burt, Ben Hall)
HOM Damping	Completed – ODU/ SLAC	

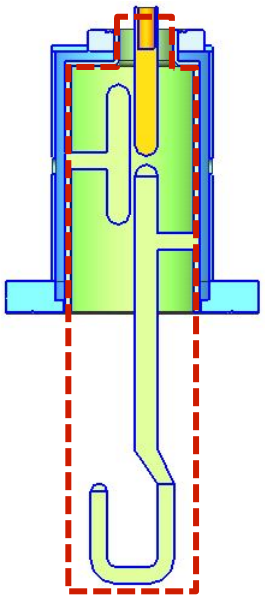
- Mechanical design:

Analysis	Status	Verified
Pressure Safety	Completed – ODU/ SLAC	Tom Nicol – Fermilab
3D Solid Model	Completed – ODU/ SLAC	Tom Nicol – Fermilab
Functional Specification Drawing	Completed	Released by CERN

RFD Crab Cavity – Ongoing

ODU/SLAC

- Finalizing engineering aspects of HOM couplers (HHOM +VHOM)
  - EM design completed
    - Well damped modes up to 2 GHz
  - Tolerance study
  - Window thickness
  - Weld details
  - Fabrication procedure ar tooling



CERN

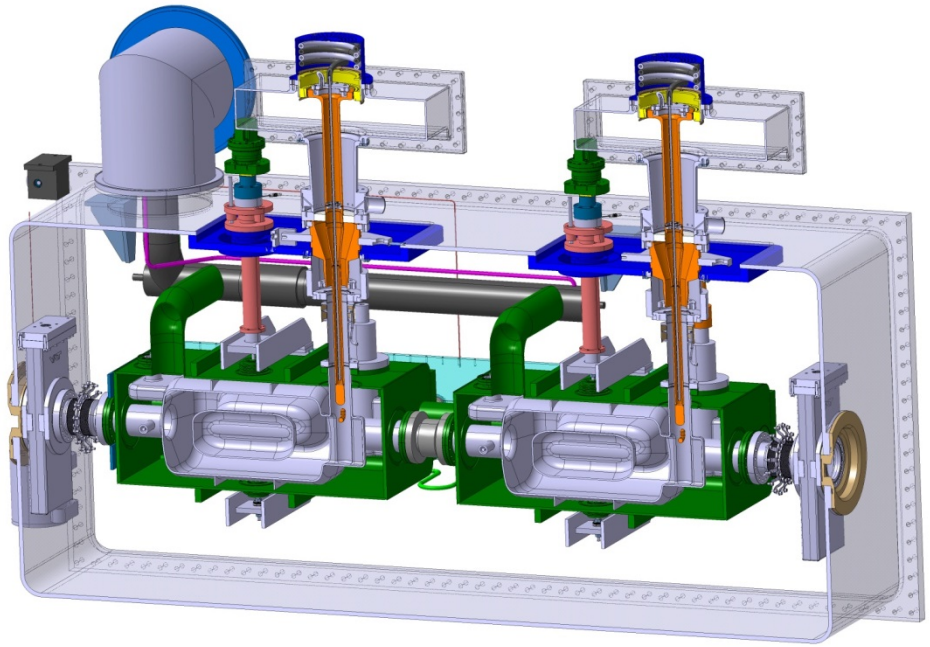
- Cryomodule design
  - Including HOM and FPC
  - Support system
- HOM Couplers functional specification drawing

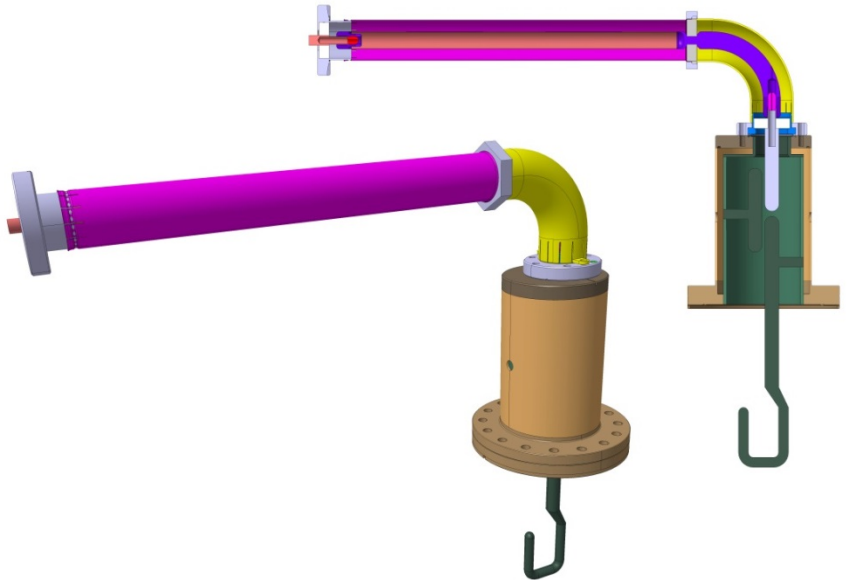
More from Z. Li in next talk

RFD CC CM Integration

CERN

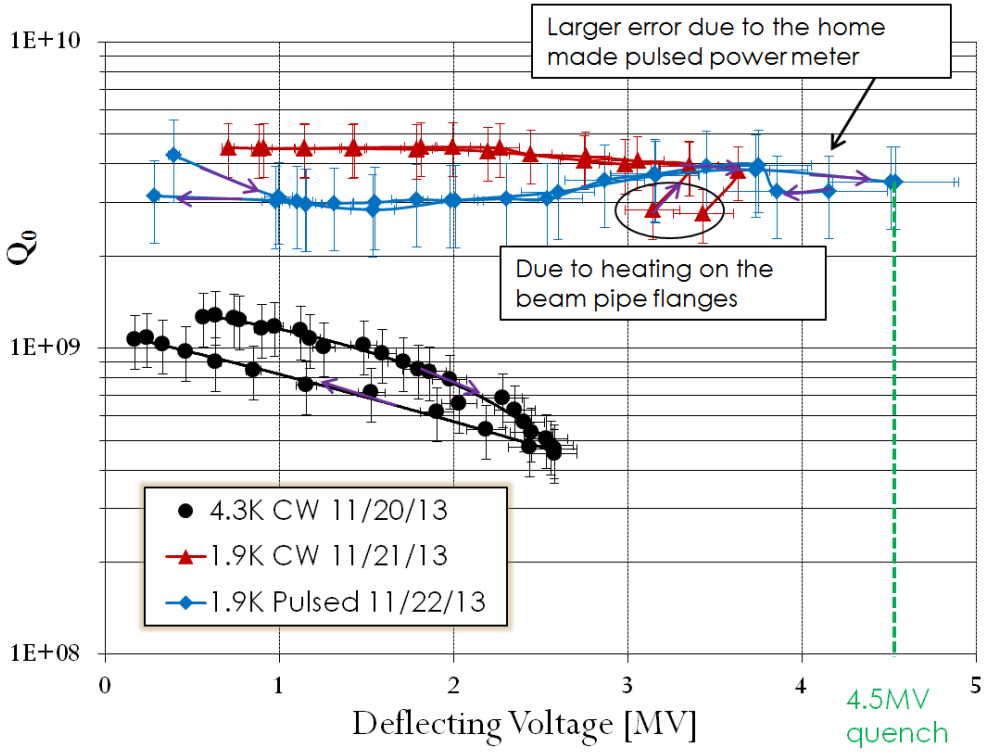
- Cryomodule design near completion
  - Including detailed HOM and FPC
  - Support system
- HOM Couplers functional specification drawing in progress



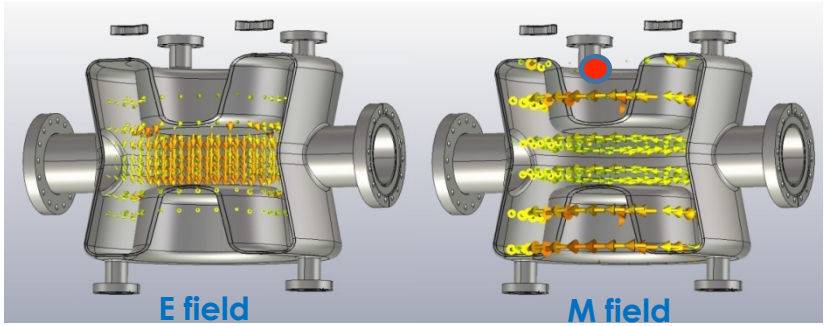


DQW PoP Cavity Testing

	Crabbing (fundamental) mode freq.	1st HOM	Cavity length	Cavity width	Cavity height	Aperture	Deflecting voltage
Unit	MHz	MHz	cm	cm	cm	cm	MV
DQWCC	400	579	38.2	14.7	14.6	8.4	3.34

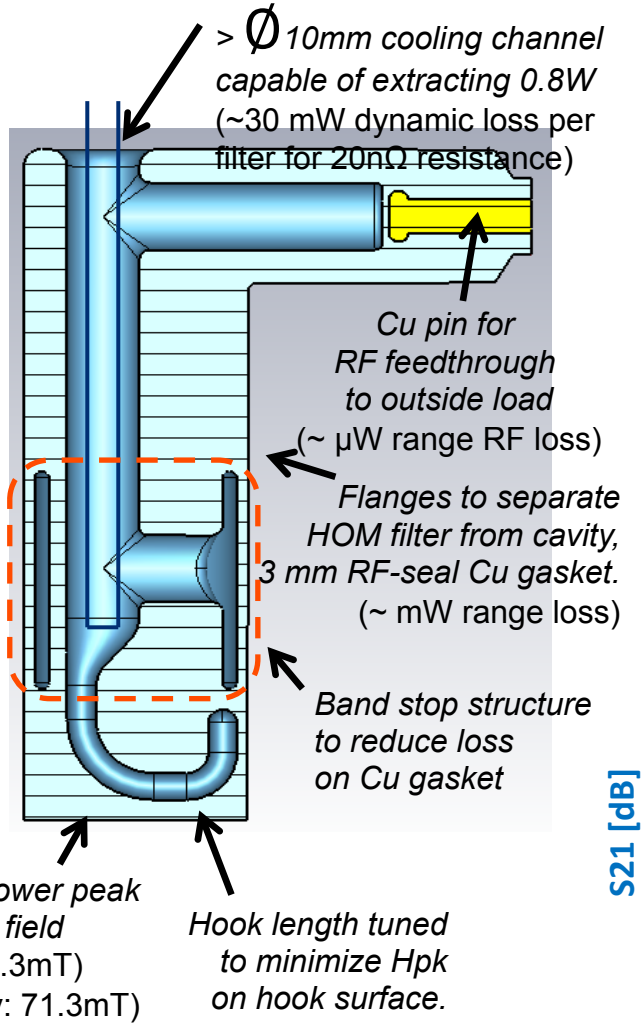


- Q_0 at around 3~4.5e9.
- In CW mode, temperature of beam pipe flanges increase.
- Reached 4.5MV kick in pulsed mode, limited by quench, consistent with conditioning test.
- Temperature increase on pickup port blending area.
- Quench field at ~110mT, with peak E field at 68MV/m

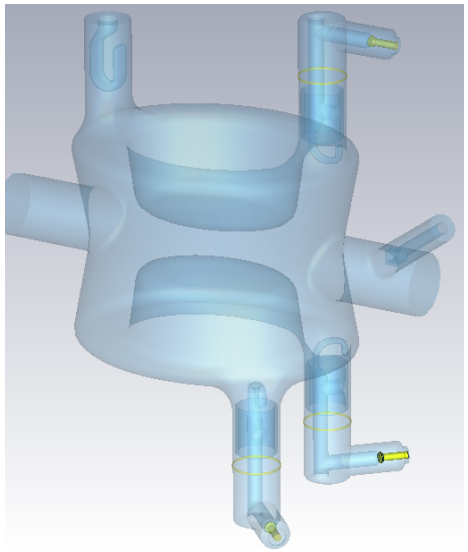


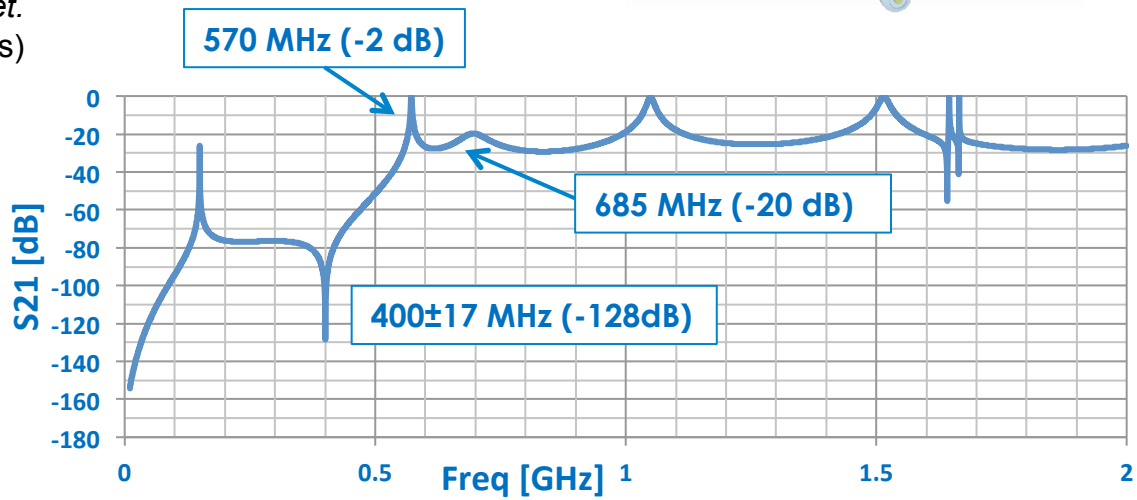
DQW HOM Filter Design (1)

3 HOM filters in one double quarter wave



- Designed to handle kW range HOM power per cavity
- Coupling to 400 MHz: 7.9×10^{9}
  (1.1 W at each port to outside load)
- RF losses on Cu pieces are minimized for crabbing mode with Vt = 3.34 MV
- Simulations by B. Hall suggest that with clean surface the filter is free of multipacting.



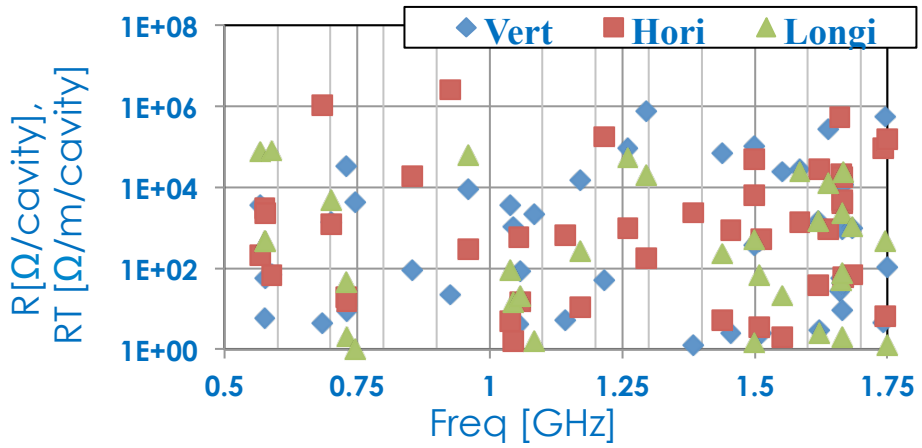


DQW HOM Filter Design (2)

LARP

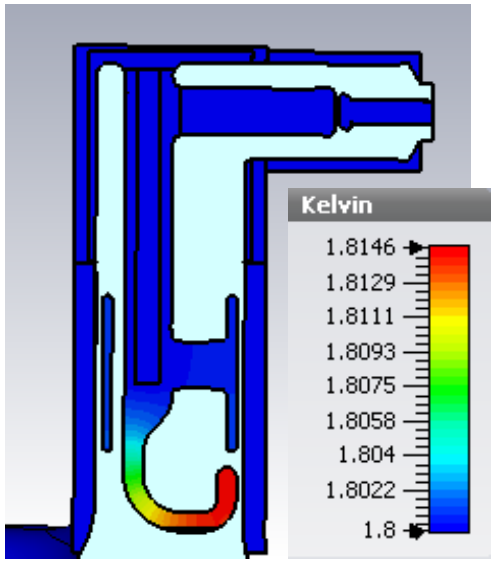
High Luminosity LHC

HOM Impedance

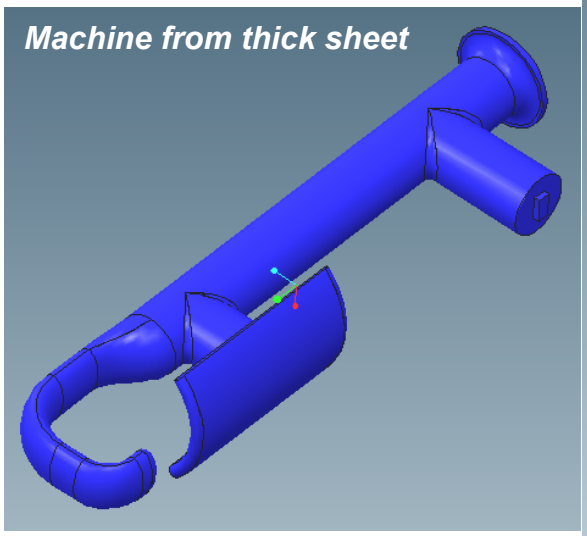


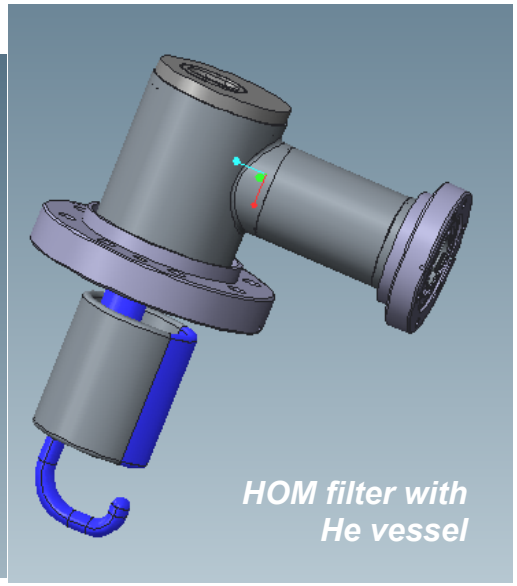
- Impedances are calculated considering the assembling errors. Tables are generated and sent to CERN for verification.
- HOM power is about 69 Watts per cavity. Power of transverse modes estimated based on 5mm offsets.
- In the worst case the power increased to 86 Watts if HOM frequencies shift in ±2.5 MHz range.
- HOM induced heat on the Cu gaskets and Cu pins are in mW range.
- Thermal analysis is on-going
- Machining study is on-going

Thermal analysis



Machining study





DQW Crab Cavity – Ongoing

BNL/UK

- Finalizing engineering aspects of HOM couplers (H and V)
  - Machining Studies
  - Multipactor Analysis
  - Fabrication procedure and tooling

CERN

- Cryomodule design
  - Including HOM and FPC
  - Support system
- HOM Couplers functional specification drawing

Short term plans

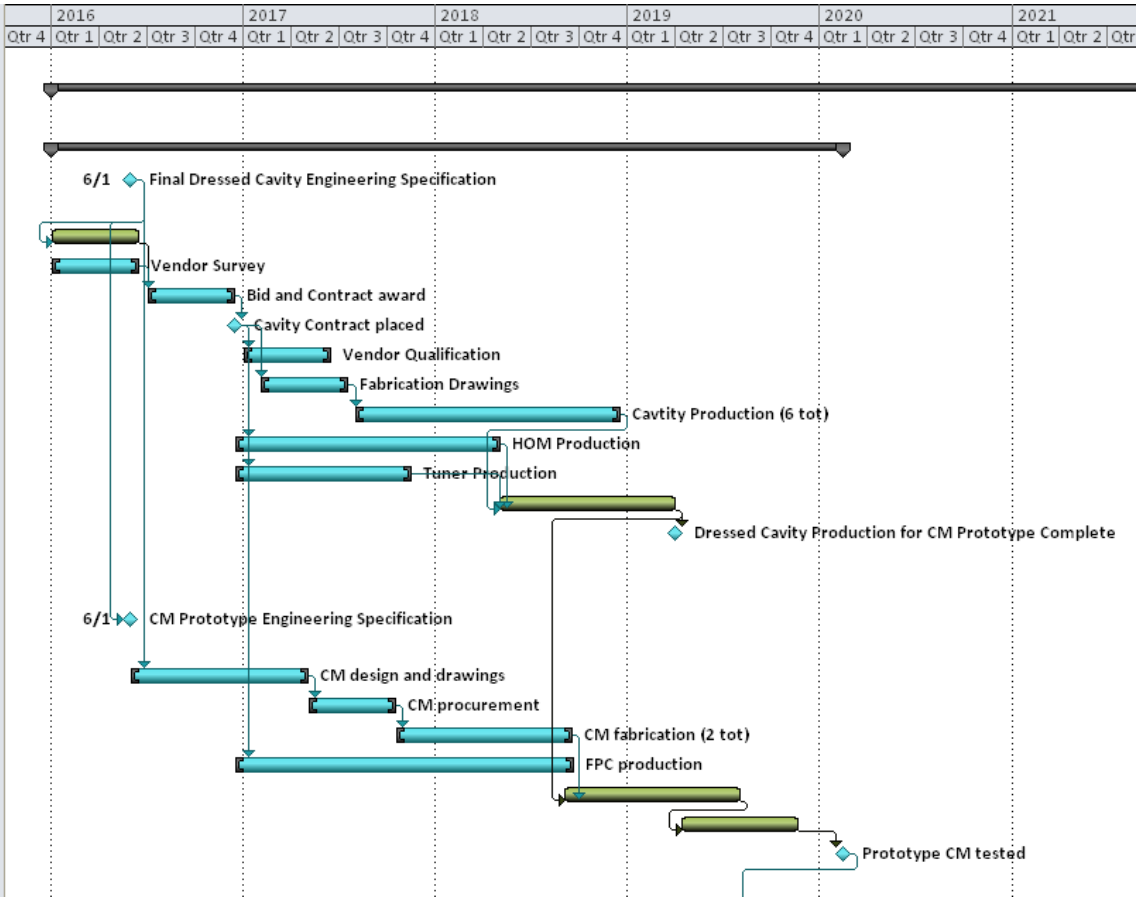
- Start cavity fabrication as soon as beampipe assembly has been tested and approved
- Build two fully dressed cavities of each kind
  - Include HOM filters, tuners – No FPC
  - Vertical test @ US lab before shipping
  - Ship by Dec. 2105
    - Ambitious, in light of current progress
- Integrate cavities in cryomodule(s) for SPS test to begin in 2017

Long Term Plans

- Design and build LHC prototype CMs (2017-2020)
  - H and V, must start while SPS test are ongoing
  - Need to freeze requirements and baseline by mid 2016
- Build production cryomodules (2020-2023)
  - Start upon successful H test of prototypes
  - Includes spares
- Installation (2023-24)

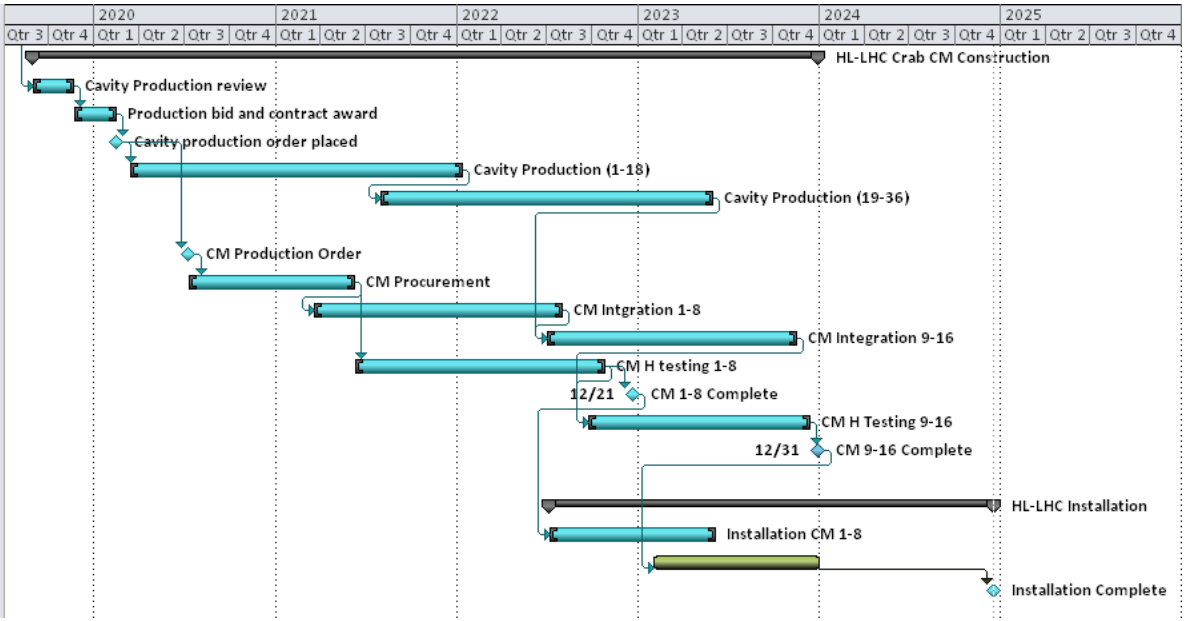
HL-LHC Planning - Prototypes

Task Name	Duration	Start	Finish
HL-LHC Crab Cavities and CM	**2338 days**	**Fri 1/1/16**	**Wed 12/18/24**
LHC Prototype CMs	**1075 days**	**Fri 1/1/16**	**Fri 2/14/20**
Final Dressed Cavity Engineering Specification	0 days	Wed 6/1/16	Wed 6/1/16
Final Cavity Design	6 mons	Fri 1/1/16	Thu 6/16/16
Vendor Survey	6 mons	**Fri 1/1/16**	**Thu 6/16/16**
Bid and Contract award	6 mons	Fri 7/1/16	Thu 12/15/16
Cavity Contract placed	0 days	Fri 12/16/16	Fri 12/16/16
Vendor Qualification	6 mons	Sun 1/1/17	Thu 6/15/17
Fabrication Drawings	6 mons	Wed 2/1/17	Tue 7/18/17
Cavtity Production (6 tot)	18 mons	Tue 8/1/17	Mon 12/17/18
HOM Production	18 mons	Fri 12/16/16	Thu 5/3/18
Tuner Production	12 mons	Fri 12/16/16	Thu 11/16/17
Dressed Cavity V Testing	12 mons	Tue 5/1/18	Mon 4/1/19
Dressed Cavity Production for CM Prototype Complete	0 days	Mon 4/1/19	Mon 4/1/19
CM Prototype Engineering Specification	0 days	Wed 6/1/16	Wed 6/1/16
CM design and drawings	12 mons	Wed 6/1/16	Tue 5/2/17
CM procurement	6 mons	Wed 5/3/17	Tue 10/17/17
CM fabrication (2 tot)	12 mons	Wed 10/18/17	Tue 9/18/18
FPC production	23 mons	Fri 12/16/16	Thu 9/20/18
CM integration	12 mons	Sat 9/1/18	Thu 8/1/19
CM HT	8 mons	Fri 4/12/19	Thu 11/21/19
Prototype CM tested	0 days	Fri 2/14/20	Fri 2/14/20



HL-LHC Planning - Production

Task Name	Duration	Start	Finish
HL-LHC Crab CM Construction	**1131 days**	**Fri 8/30/19**	**Sun 12/31/23**
Cavity Production review	3 mons	Fri 8/30/19	Thu 11/21/19
Production bid and contract award	3 mons	Fri 11/22/19	Thu 2/13/20
Cavity production order placed	0 days	Fri 2/14/20	Fri 2/14/20
Cavity Production (1-18)	24 mons	Fri 3/13/20	Thu 1/13/22
Cavity Production (19-36)	24 mons	Fri 7/30/21	Thu 6/1/23
CM Production Order	0 days	Wed 7/8/20	Wed 7/8/20
CM Procurement	12 mons	Wed 7/8/20	Tue 6/8/21
CM Intgration 1-8	18 mons	Wed 3/17/21	Tue 8/2/22
CM Integration 9-16	18 mons	Fri 7/1/22	Thu 11/16/23
CM H testing 1-8	18 mons	Wed 6/9/21	Tue 10/25/22
CM 1-8 Complete	0 days	Wed 12/21/22	Wed 12/21/22
CM H Testing 9-16	16 mons	Fri 9/23/22	Thu 12/14/23
CM 9-16 Complete	0 days	Sun 12/31/23	Sun 12/31/23
HL-LHC Installation	**640 days**	**Wed 7/6/22**	**Wed 12/18/24**
Installation CM 1-8	12 mons	Wed 7/6/22	Tue 6/6/23
Installation CM 9 -16	12 mons	Wed 2/1/23	Tue 1/2/24
Installation Complete	0 days	Wed 12/18/24	Wed 12/18/24



Planning Assumptions

- Assumes production of 36 cavities – one/month
  - XFEL 8 cavities/week
  - FRIB ~12/month
- Produce 16 Cryomodules – one/1.5 months
  - XFEL 1/week
  - FRIB 1.2-2/month
  - Added 1 year of schedule float
- XFEL ~800 cavities/100 CM, FRIB ~330 Cav/~50 CM
- Considering multiple vendors
- Assumes two production lines

Planning - Comments

- Need to start prototype CMs before SPS test
- Need to start CM industrialization before the completion of prototypes testing

Conclusions

- Completed and released cavity designs
- Finalizing dressed cavity integration in cryomodule
- Production of both cavity designs is underway with industrial partner
- Schedule for SPS test is tight
- Active contributions from all collaborators

Questions

Acknowledgments

- Contributions to this presentation came from the whole collaboration

  - BNL – S. Belomestnykh, S. Verdu-Andres, Q. Wu, B. Xiao
  - CERN – L. Alberty, R. Calaga, O. Capatina
  - FNAL – T. Nicol
  - LBNL – A. Ratti
  - Niowave – J. Hollister, T. Grimm, E. Maddock, J. Yancey
  - ODU – J. Delayen, H. Park, R. Olave, S. da Silva
  - LU/STFC – G. Burt, B. Hall, S. Pattalwar
  - SLAC – Z. Li

Verification of PoP RFD Test Results

- First test (3/2013):
  - $Q_0 \rightarrow 4\times10^9$
  - $V_t \rightarrow 7.0$ MV
- Second test (8/2014): with Nb coated flanges
  - $Q_0 \rightarrow 1.25\times10^{10}$
  - $V_t \rightarrow 7.0$ MV
- Test at CERN (10/2014):
  - $Q_0 \rightarrow 7\times10^9$
  - $V_t \rightarrow 6.5$ MV