Proof of Principle Cavity Preparation and Testing: BNL Double Quarter Wave Design

Binping Xiao

On behalf of the DQWCC team

12/09/2013

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High Luminosity LHC

Outline

- Cavity Design
- Flow Chart of the Cavity
- Cavity Test
    - BNL VTF
    - First Cold Test and Analysis
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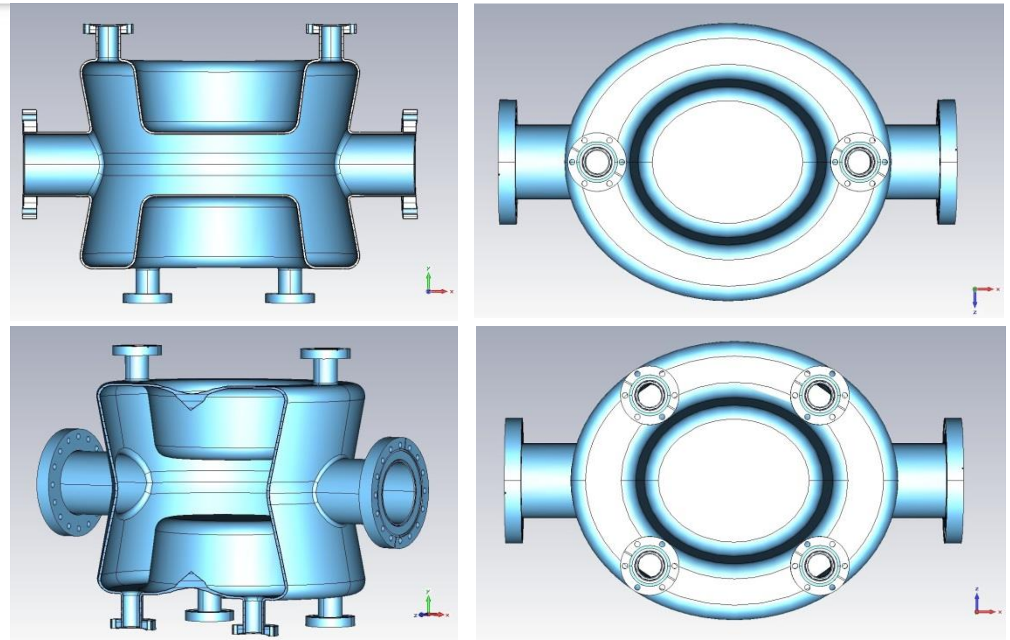
The Double Quarter Wave Cavity



	Crabbing (fundamental) mode freq.	1st HOM	Cavity length	Cavity width and height	Beam pipe diameter	Deflecting voltage	Bpeak
Unit	MHz	MHz	mm	mm	mm	MV	mT
DQW crab cavity	400	580	**390**	**296**	84	3	71.9*

* Due to the insufficient mesh during MWS simulation.

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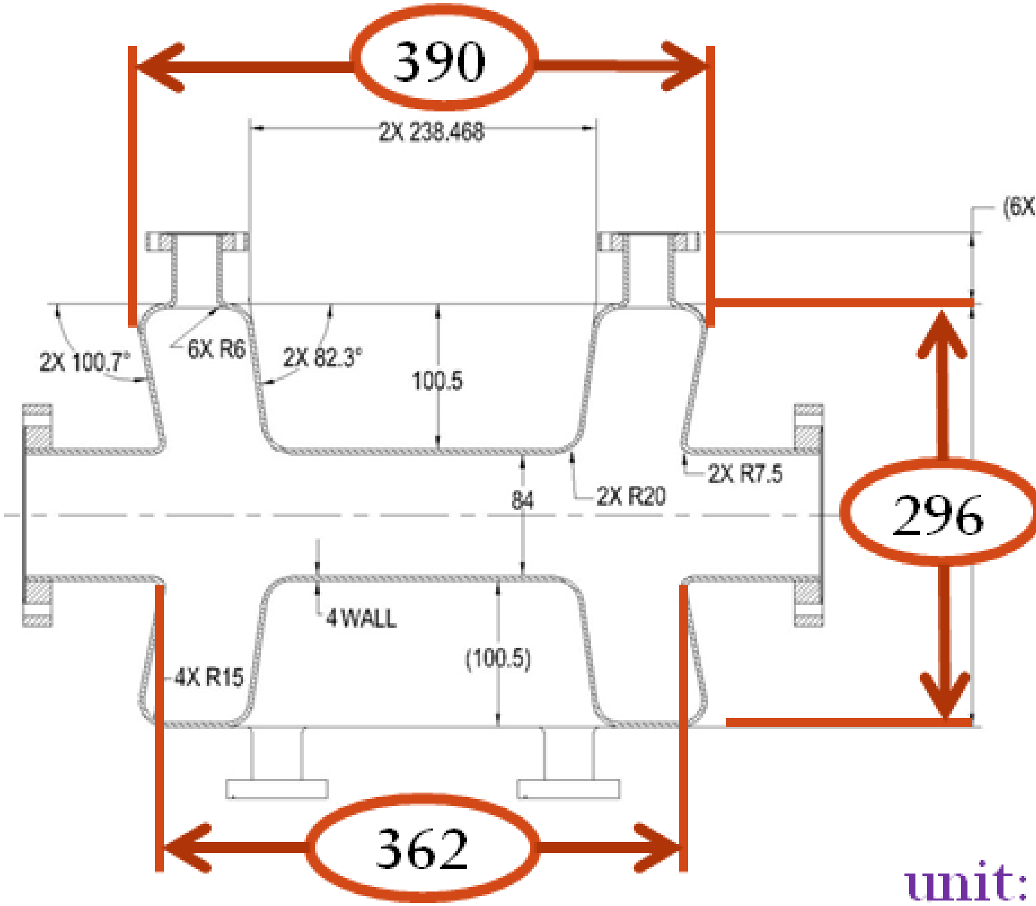
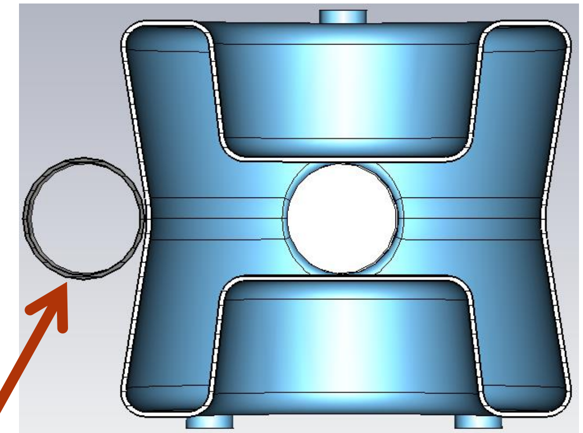
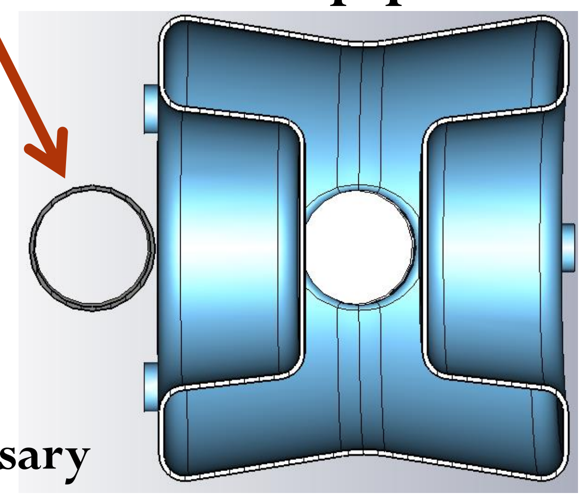




Adjacent beam pipes



unit: mm

The PoP cavity is designed and built with all necessary coupling ports, and allow crabbing on both direction.

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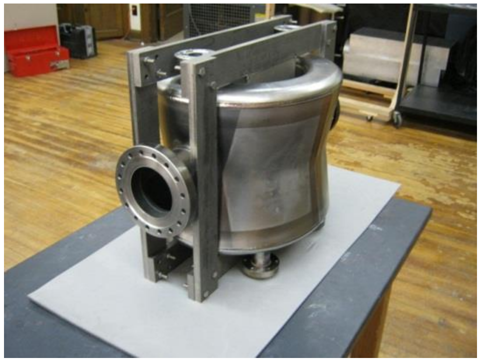
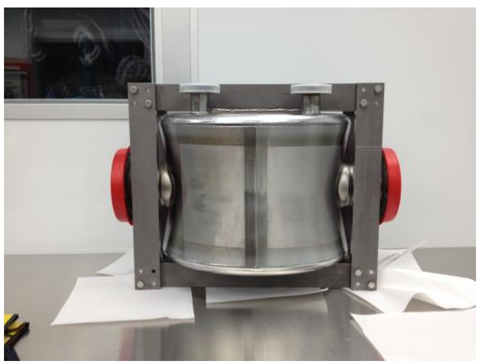
Flow Chart of the PoP Cavity

Courtesy of Niowave Inc.

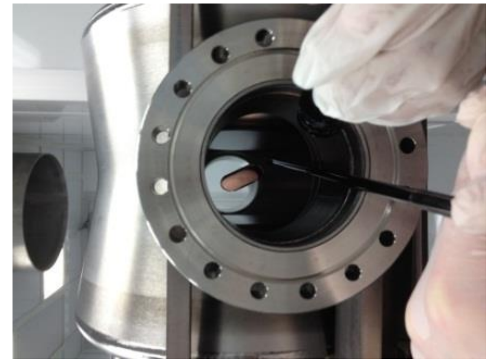
Flow Chart of the PoP Cavity

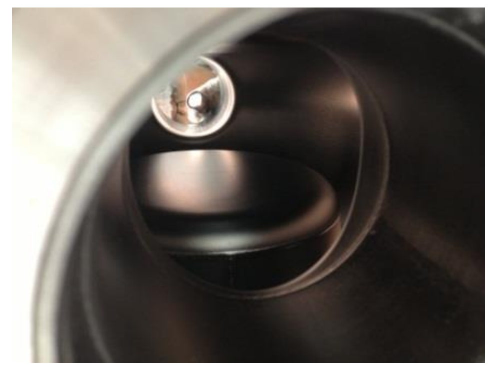




machining, welding, buffer chemical polishing (BCP, 150 um) and assembling

shipped to BNL

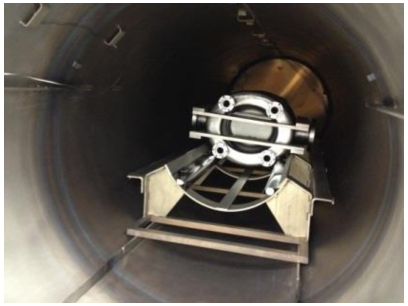




Inspection upon receiving on Feb 25

Flow Chart of the PoP Cavity

10h 600°C vacuum baking. After baking, center resonant frequency is 403.3117 MHz, with room temperature unloaded Q at 5,400



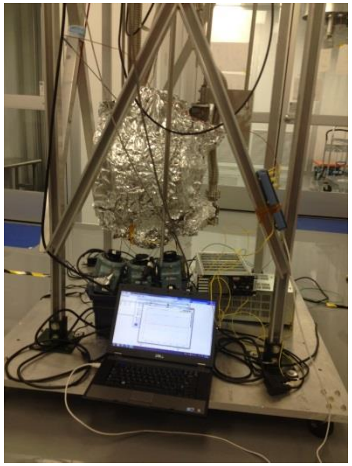
Leak checking

Shipped to Niowave for light BCP and HPR.

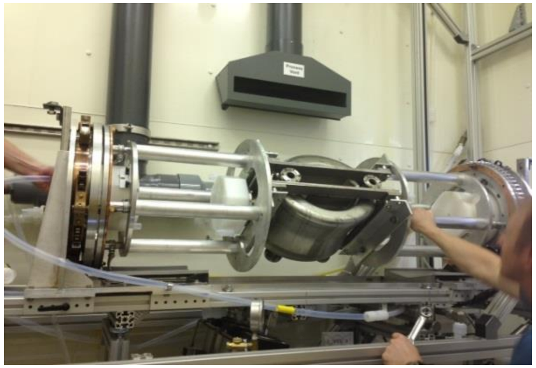
Shipped to BNL for first vertical test, results showed high power loss

Flow Chart of the PoP Cavity

24hour 120°C in situ baking at BNL



Second surface treatment (BCP 40 um and HPR) at ANL



Second cold test

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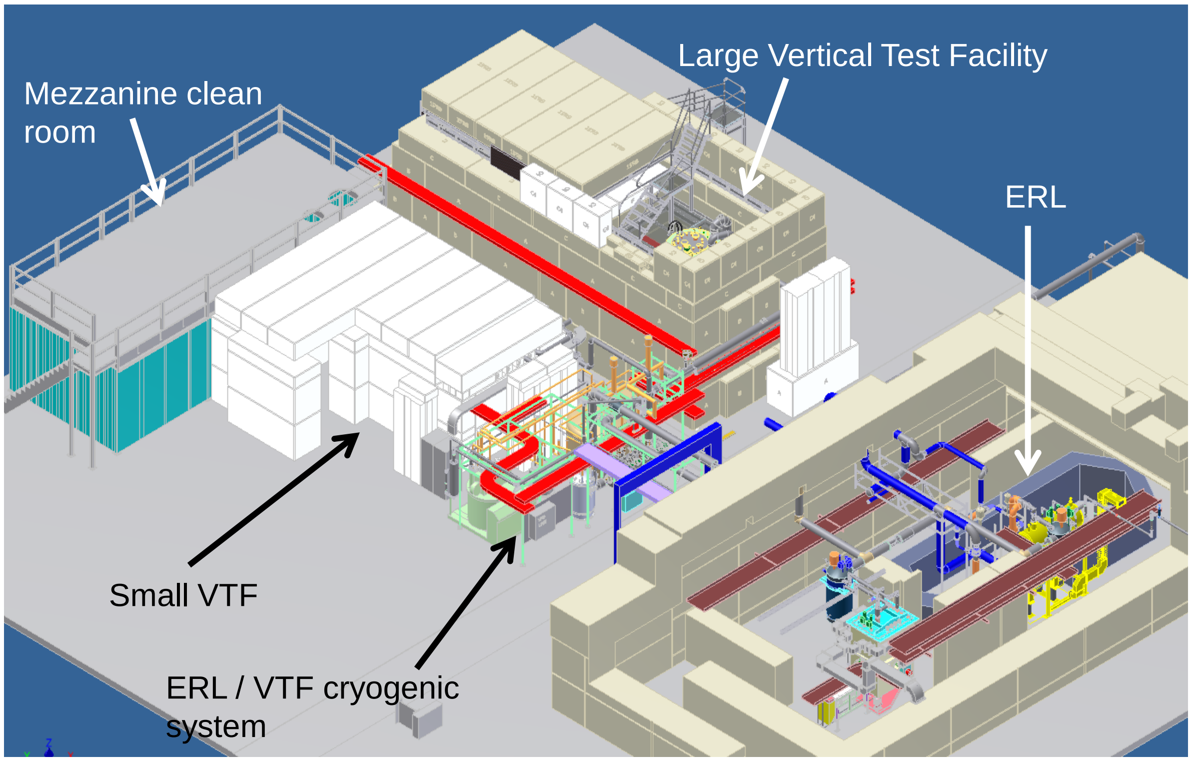
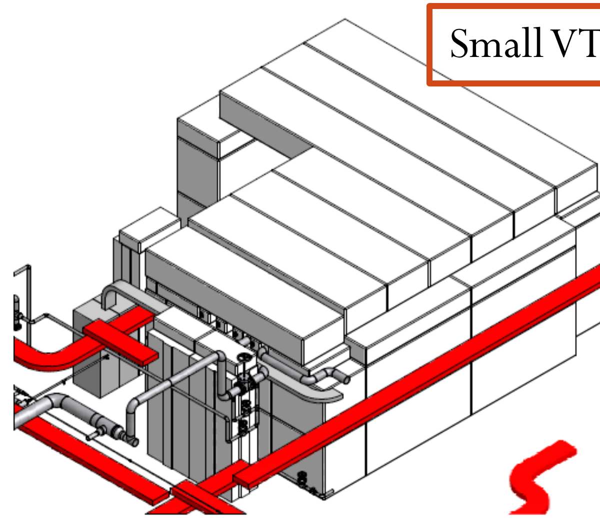
Vertical Test – Small VTF



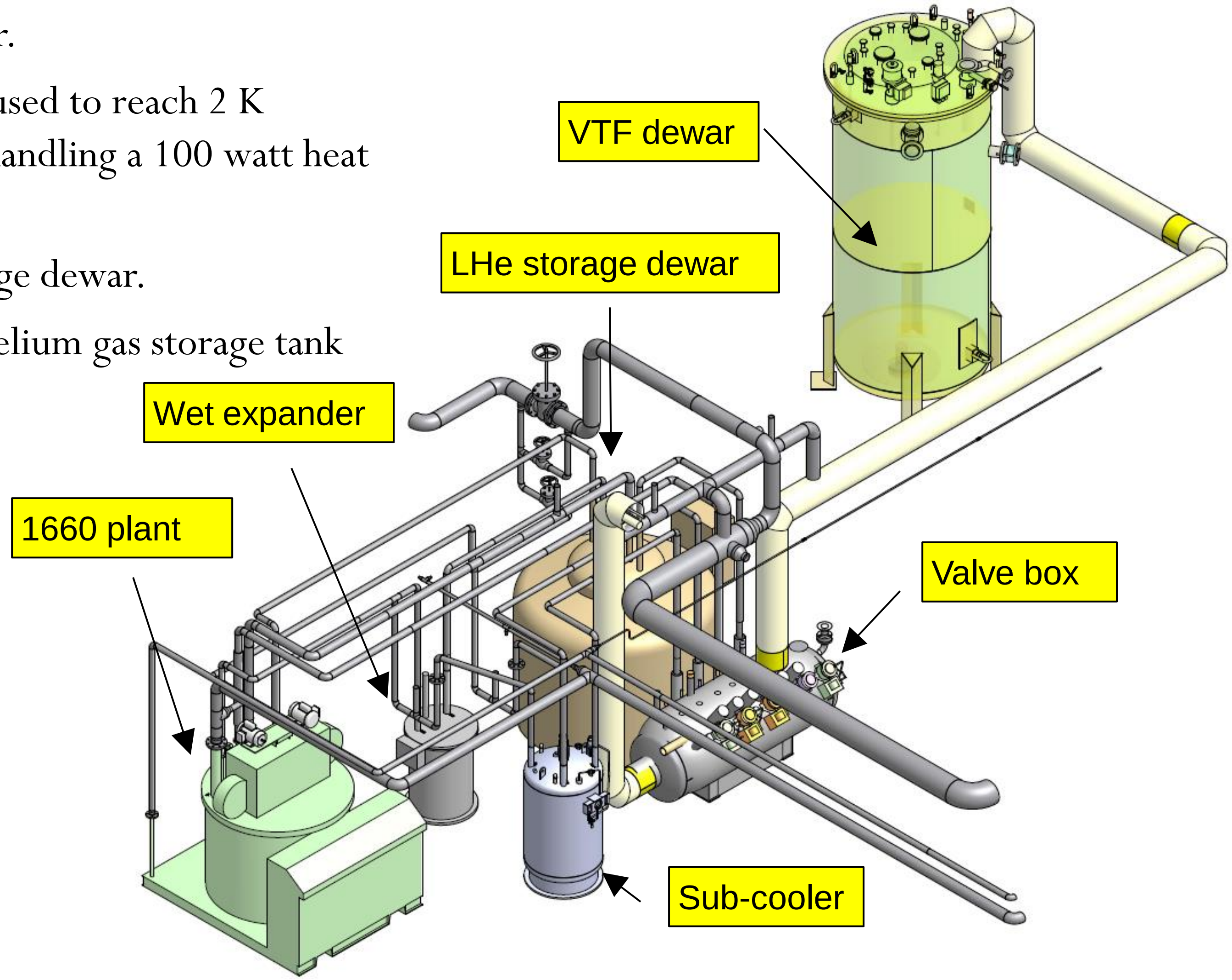
SRF test facility in building 912

Small VTF



Vertical Test – Cryogenic System

- 360 W 4 K refrigerator.
- A liquid ring pump is used to reach 2 K operation, capable of handling a 100 watt heat load.
- 1000 gallon LHe storage dewar.
- 38,000 gallon warm helium gas storage tank (outside the building).



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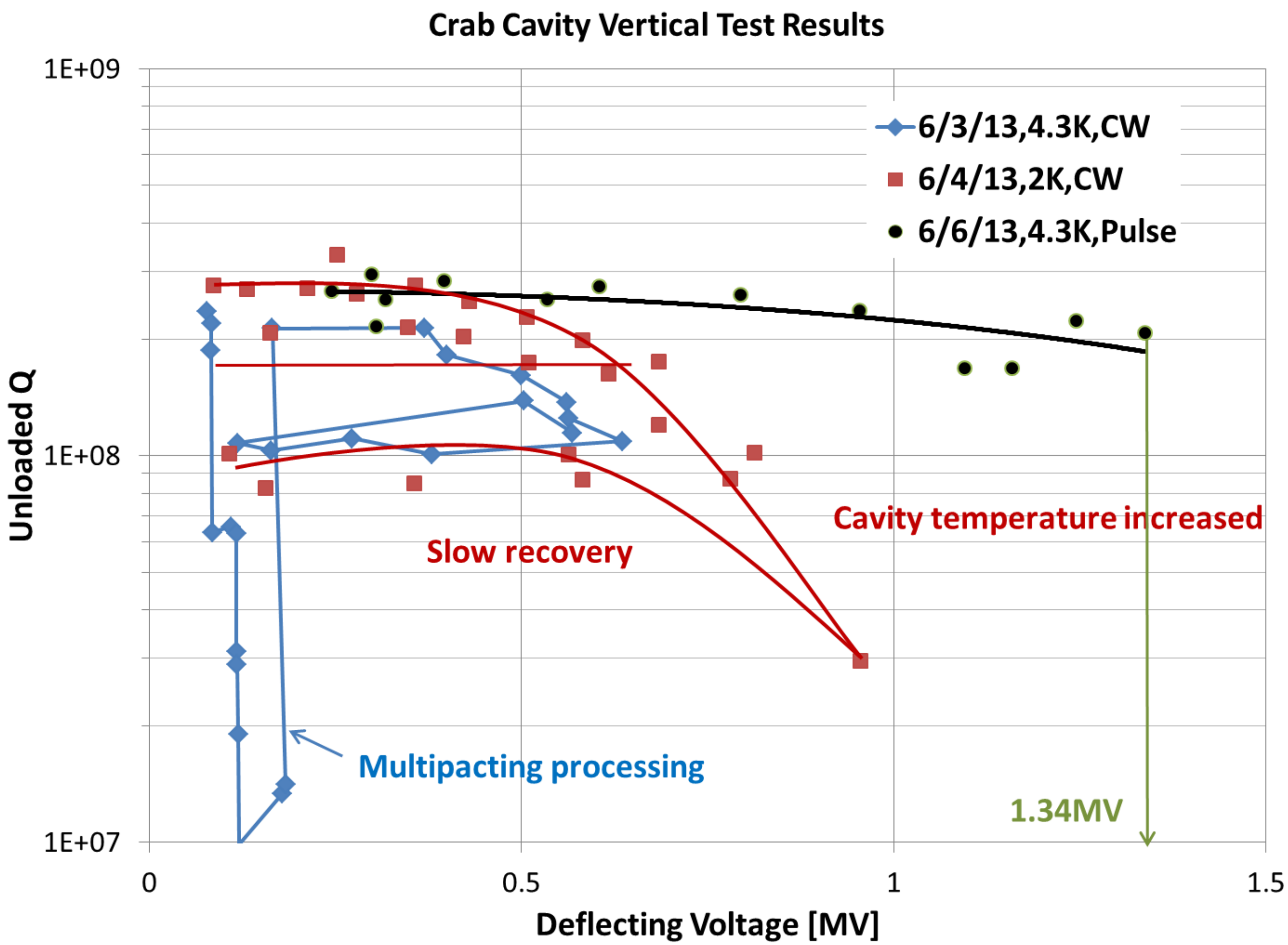
First Cold Test



- Multipacting was found and was overcome for the region of 0.07-0.16 MV during the first test only
- Q_0 was limited to few 10^8 for all three tests even low field level
- Q_0 did not improve by cooling down from 4.2 to 2 K
- Heating on the beam pipe flanges causes Q_0 decrease.
- V_t reached 1.34 MV, limited by the RF power amplifier.

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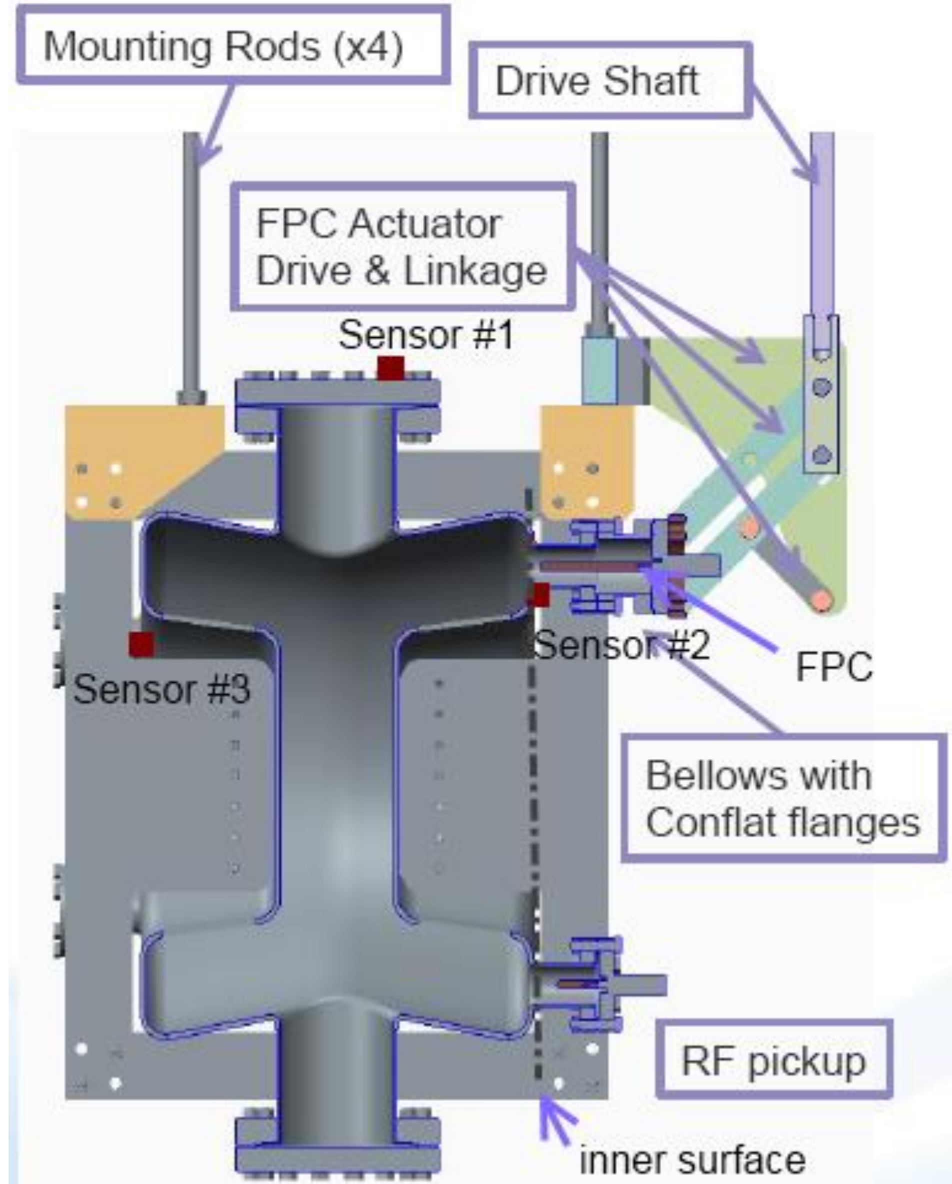
Analysis on First Test Results

Component		Q
Nb cavity	20 nΩ R_s	4.34e9
	1 nΩ R_s	8.69e10
Beam pipe flanges (2 in total)	Stainless steel	2.15e9
	Nb-plated	3.01e15
HOM port flanges (4 in total)	Stainless steel	8.54e10
	Cu disk gasket	3.00e12
FPC with stainless steel feedthrough[1]	Cu E probe	8.78e8
	Cu H probe	2.82e10
Cu pickup coupler with stainless steel feedthrough		2.87e11

[1] E probe 0mm away from inner surface
H probe 17.9mm away from inner surface



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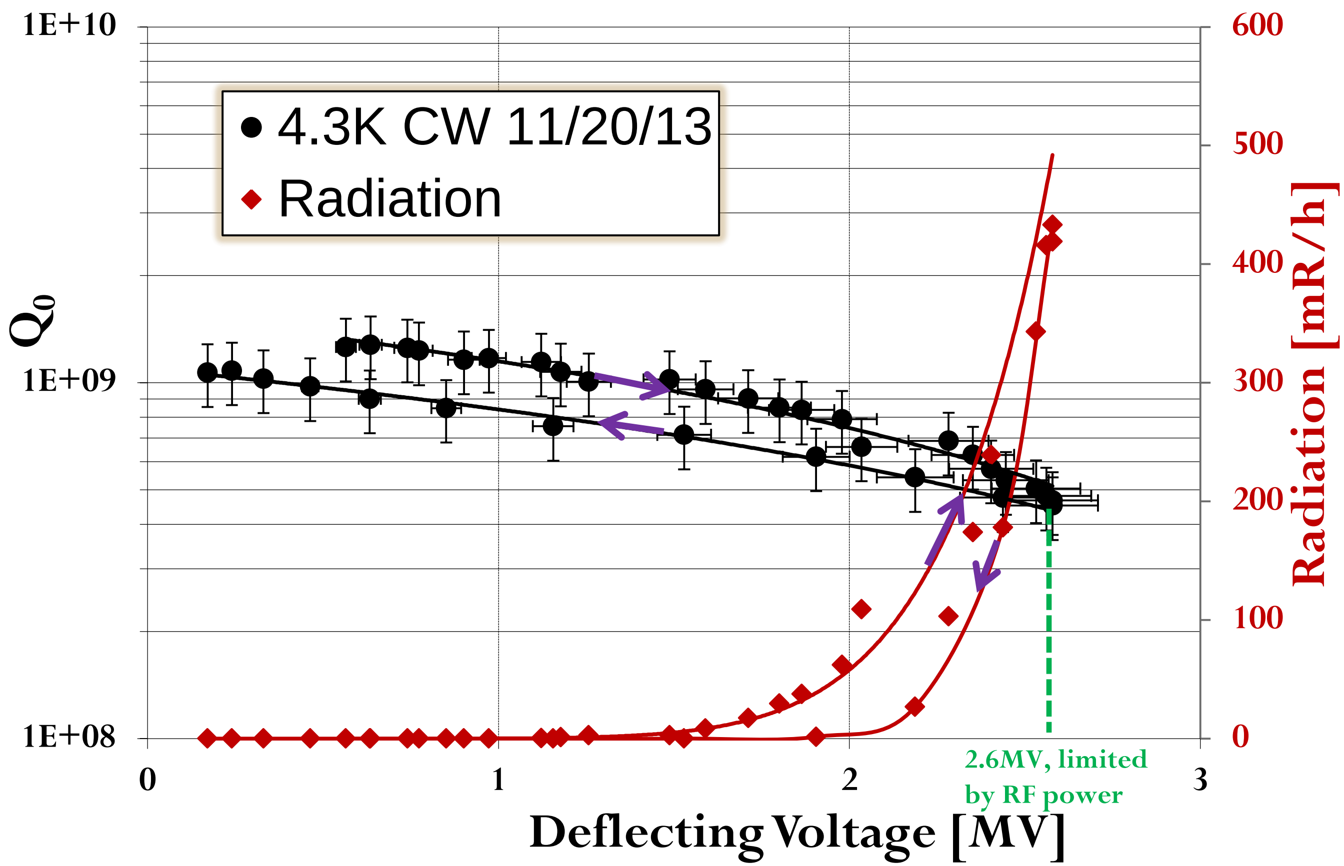
Second Cold Test: 4.3K Test Result



- No multipacting was found.
- Q_0 was measured at 10^9 range.
- Radiation started to increase at 1.5 MV
- Heating on the beam pipe flanges causes Q_0 decrease.
- V_t reached 2.6 MV, limited by the RF power amplifier.

After subtracting loss on Cu FPC with Q at 2.82e10, applies to all results.

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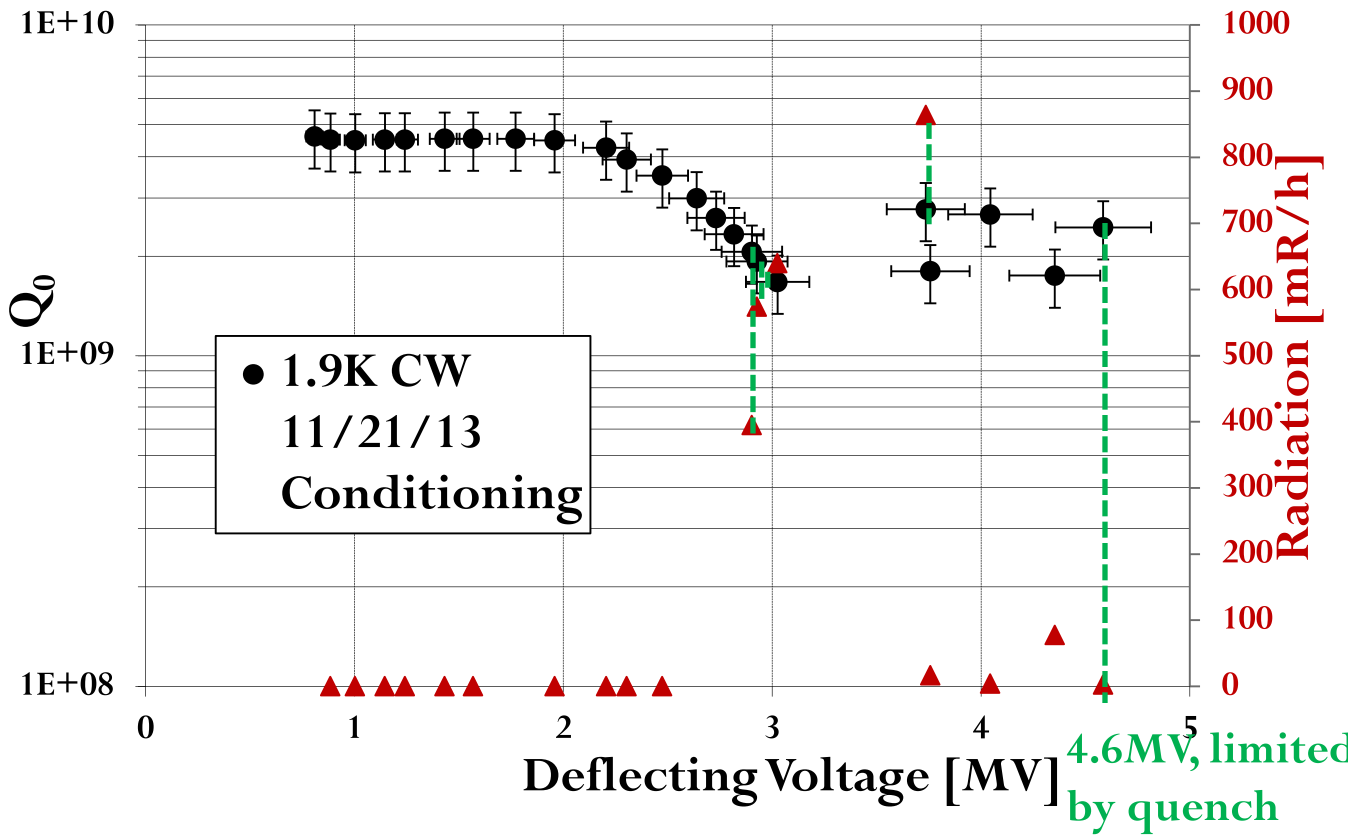
Second Cold Test: 1.9K Conditioning



- Q_0 decreases starting from 2MV, associating with high radiation.
- Q_0 got recovered after ~30 minutes conditioning.
- Radiation is lower than 15mR/h after the conditioning.
- Reached 4.6MV kick, limited by quench. (Why?)
- Temperature increase on both beam pipe flanges and pickup port blending area. How to decouple?

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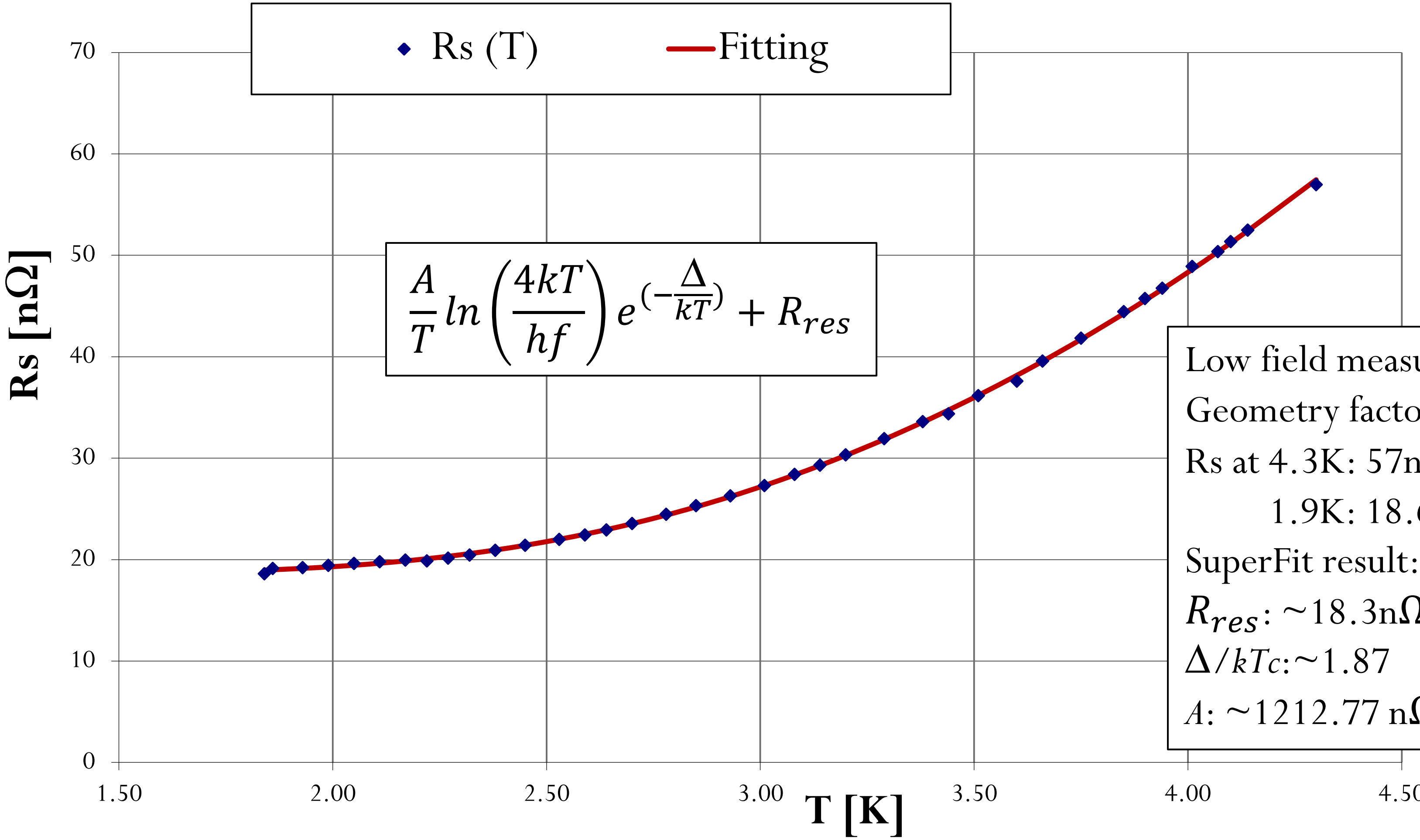
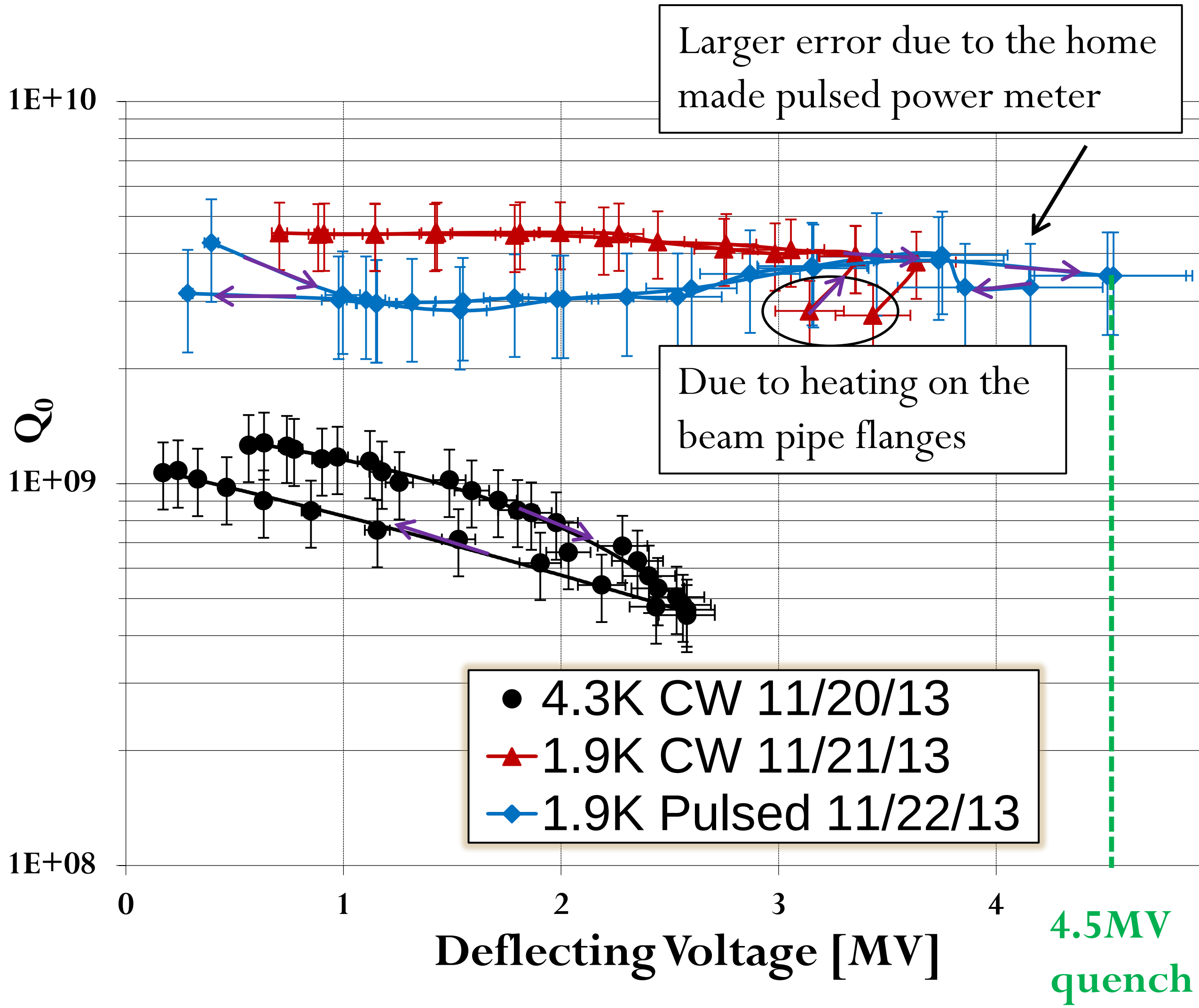
Second Cold Test: 4.3K ~ 1.9K



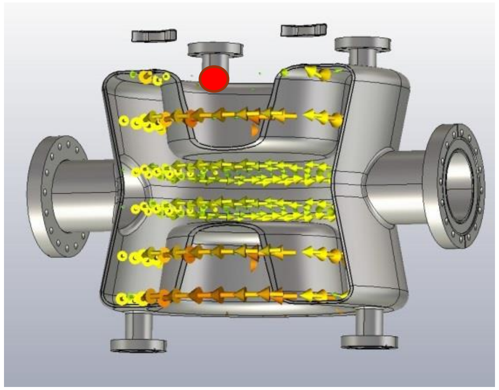
$$\frac{A}{T} ln\left(\frac{4kT}{hf}\right) e^{\left(-\frac{\Delta}{kT}\right)} + R_{res}$$

Low field measurement
Geometry factor: 85
Rs at 4.3K: 57nΩ
1.9K: 18.6nΩ
SuperFit result:
R_{res}: ~18.3nΩ
Δ/kTc:~1.87
A: ~1212.77 nΩ ·K

Second Cold Test: 1.9K CW & Pulsed



- 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 52.8MV/m



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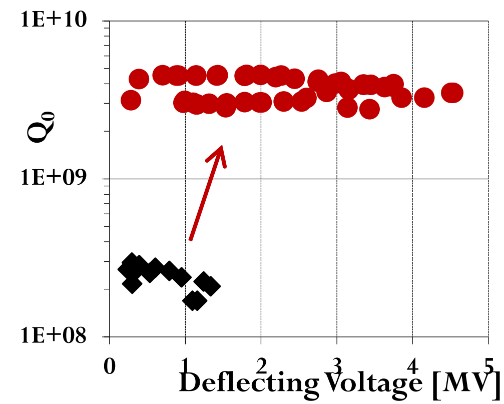
Summary

- The DQWCC can provide high deflection voltage in a very compact dimension.
- The peak surface field of the cavity is in a safe level at the target deflecting voltage.
- Analysis on the first cold test results benefits the second cold test by replacing the lossy components.
- The PoP cavity is tested to meet the requirements with a realistic design, that fits in the LHC and has all the needed coupling ports.
- Following actions will be determined, bead pulling and/or cold testing at CERN?
- SPS cavity will be better as we have better understanding.



G	Q_0	R_s@2K	R/Q	Vt	P_{diss} at 3.34MV
[ohm]		[ohm]	[ohm]	[MV]	[W]
85	4.5×10^9	18.6	400	4.6	6.97

$P_{diss}=(V_t)^2/(R/Q*Q_0)$, with Q_0=4e9

Reference

- B. P. Xiao, S. Verdu-Andres, Q. Wu posters, SRF13, Paris, France, Sep 23-27, 2013
- B. P. Xiao, et. al., IPAC13, Shanghai, China, May 12-27, 2013
- S. Belomestnykh, Q. Wu, B. P. Xiao, presentations, LHC Crab Cavity Engineering Meeting, Fermi Lab, Dec 13-14, 2012
- Q. Wu, R. Calaga & A. Macpherson, K. Brodzinski & L. Tavian, presentations, 2nd Joint HiLumi LHC-LARP Annual Meeting, INFN Frascati, Nov 14-16, 2012
- R. Calaga, et. al., *A Quarter Wave Design for Crab Crossing in the LHC*, Proceedings of IPAC12, New Orleans, LA, May 20-25, 2012
- Q. Wu, presentation, LARP CM18/HiLumi LHC Meeting, Fermi Lab, May 7-9, 2012
- Q. Wu, S. Belomestnykh, I. Ben-Zvi, *Novel deflecting Cavity Design and Fabrication for eRHIC,* Proceedings of SRF11, Chicago, IL, July 25-29, 2011
- R. Calaga, presentation, LHC-CC11, CERN, Nov 14-15, 2011
- I. Ben-Zvi, presentation, LHC-CC10, CERN, Dec 15-17, 2010

Acknowledgement:
BNL: DQWCC team, Y. R. Than, S. P. Pontieri, T. N. Tallerico, J. J. Moore, L. DeSanto Jr., C. Cullen, C. Degen, R. Kellermann, T. Seda
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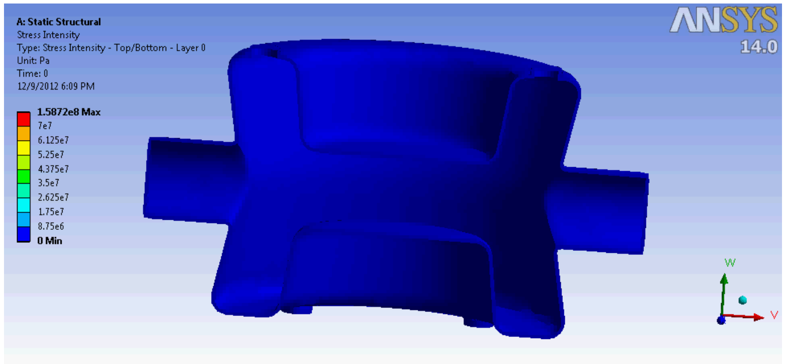
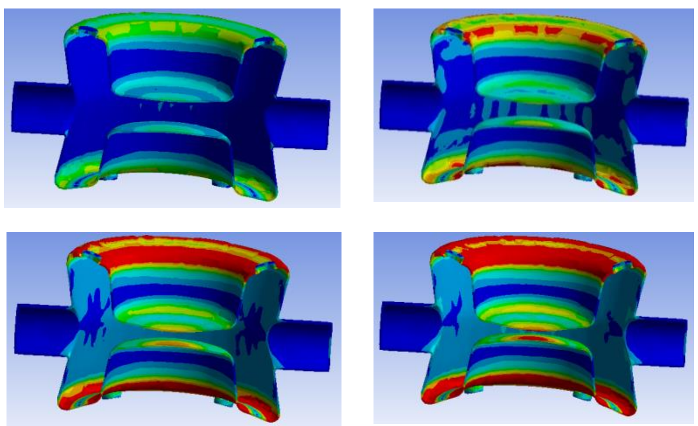
CERN: R. Calaga, Luis Alberty Vieira
SLAC: Z. Li
Niowave: Terry Grimm, Dmitry Gorelov, Chase Boulware, Nick Miller

Thank you!

Backup Slides

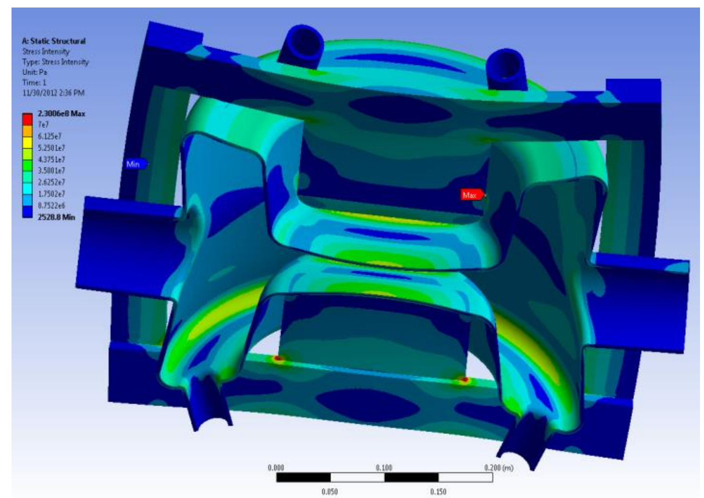
Cavity Stress Analysis





Bare cavity without stiffening frame

- Pressure: 2e5 Pa (2 bar) outside, vacuum inside.
- Fixed Support: One side of beam port.
- Stiffening plates and frames are added to the cavity for vertical cold tests.
- The material for stiffening components can be either Nb or Ti.



Cavity stress with stiffening frame

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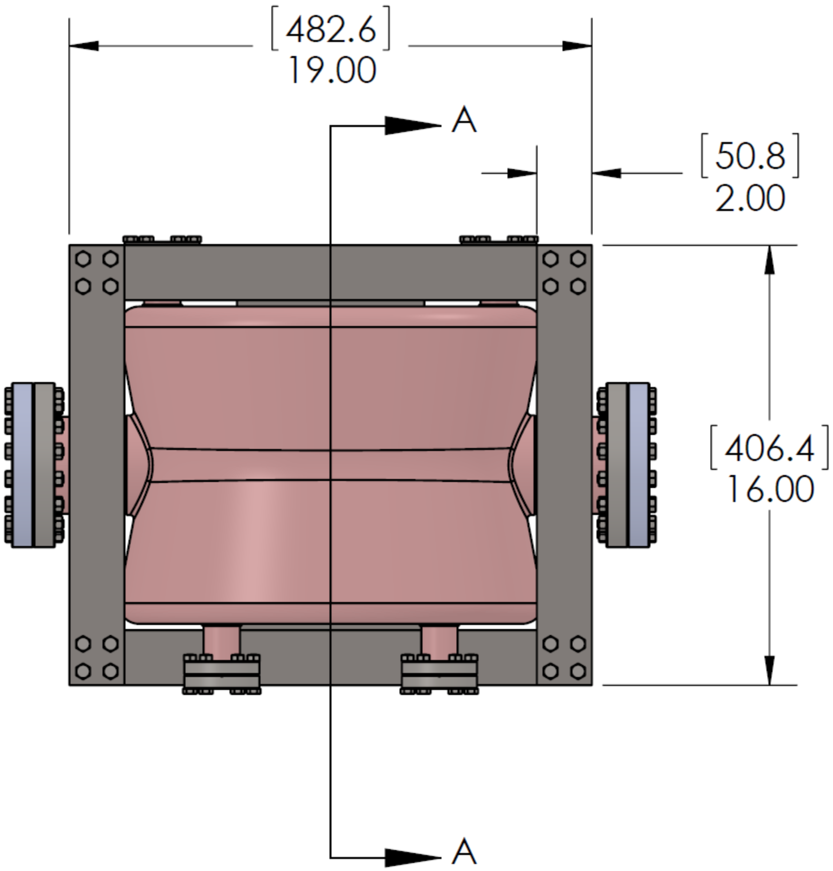
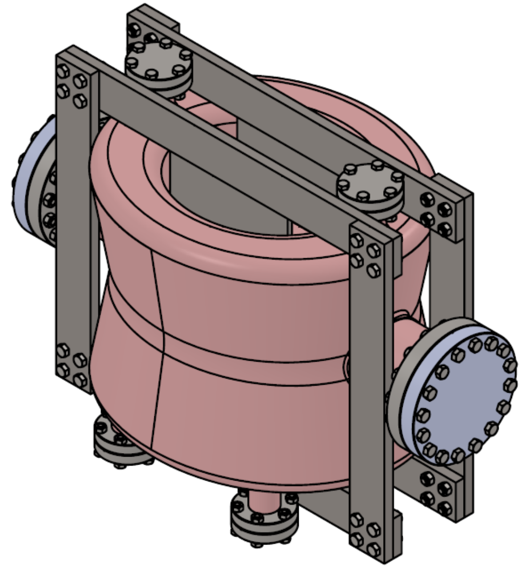
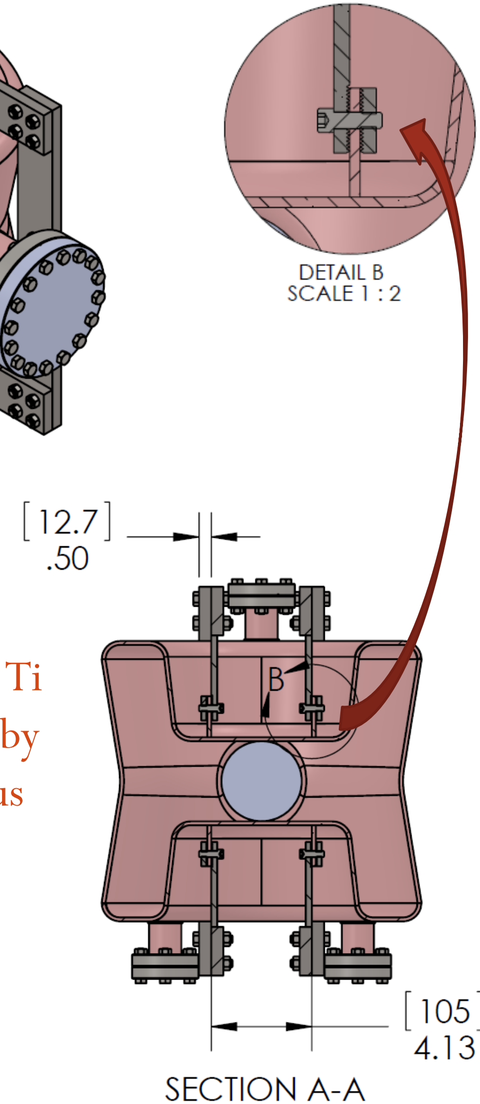
Design of PoP Cavity Stiffening

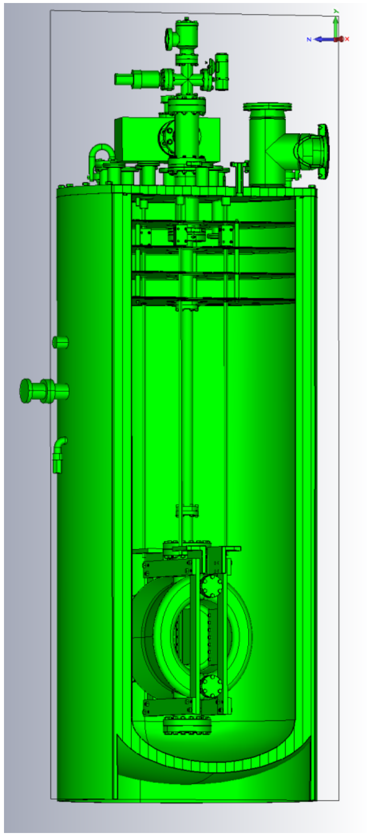




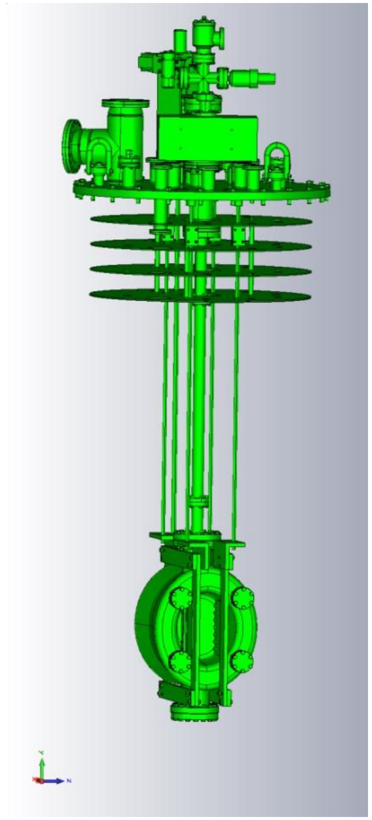


- Stiffening material: Ti
- Nb to Ti transition by serrated surface plus SS bolts
- SS bolts and pins at frame connections

Vertical Test – Test Stand



Crab cavity in the SVTF Cryostat



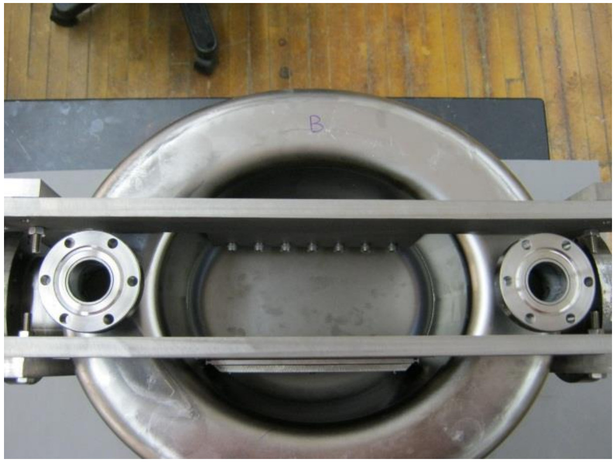
Crab cavity mounted on the insert

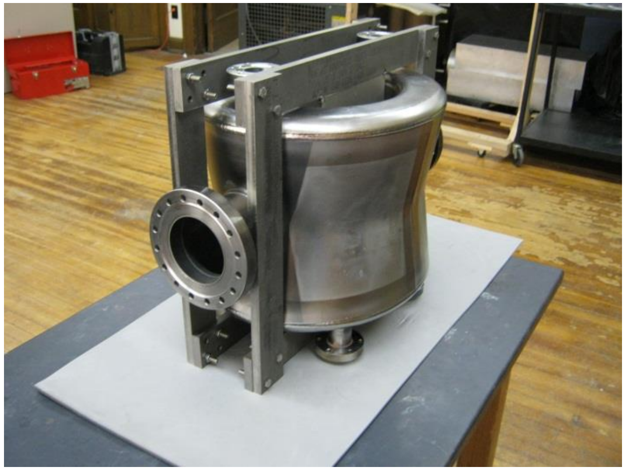
Vertical cryostat insert

28” diameter vertical cryostat

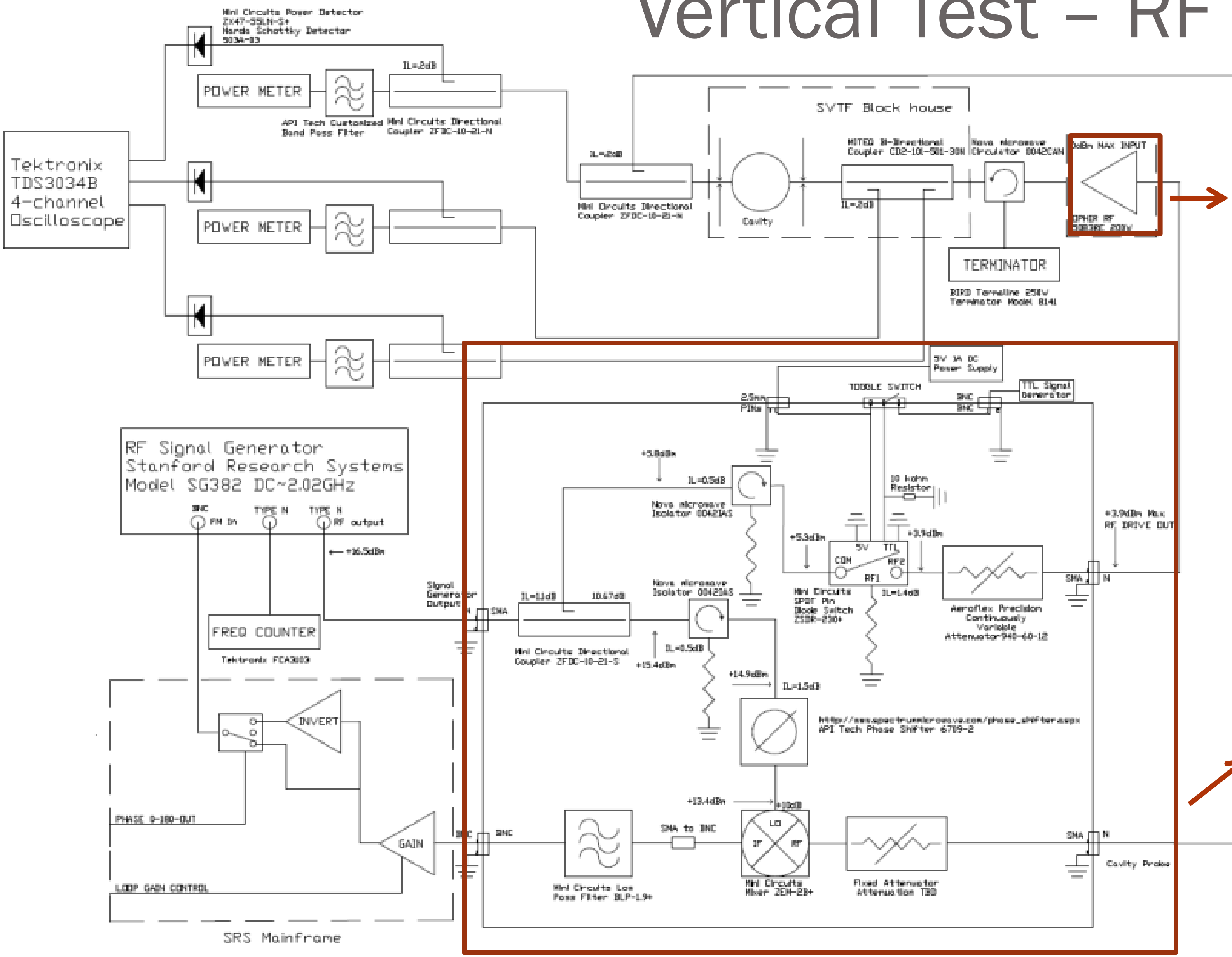
Fabrication of the PoP Cavity (2)

Courtesy of Niowave Inc.



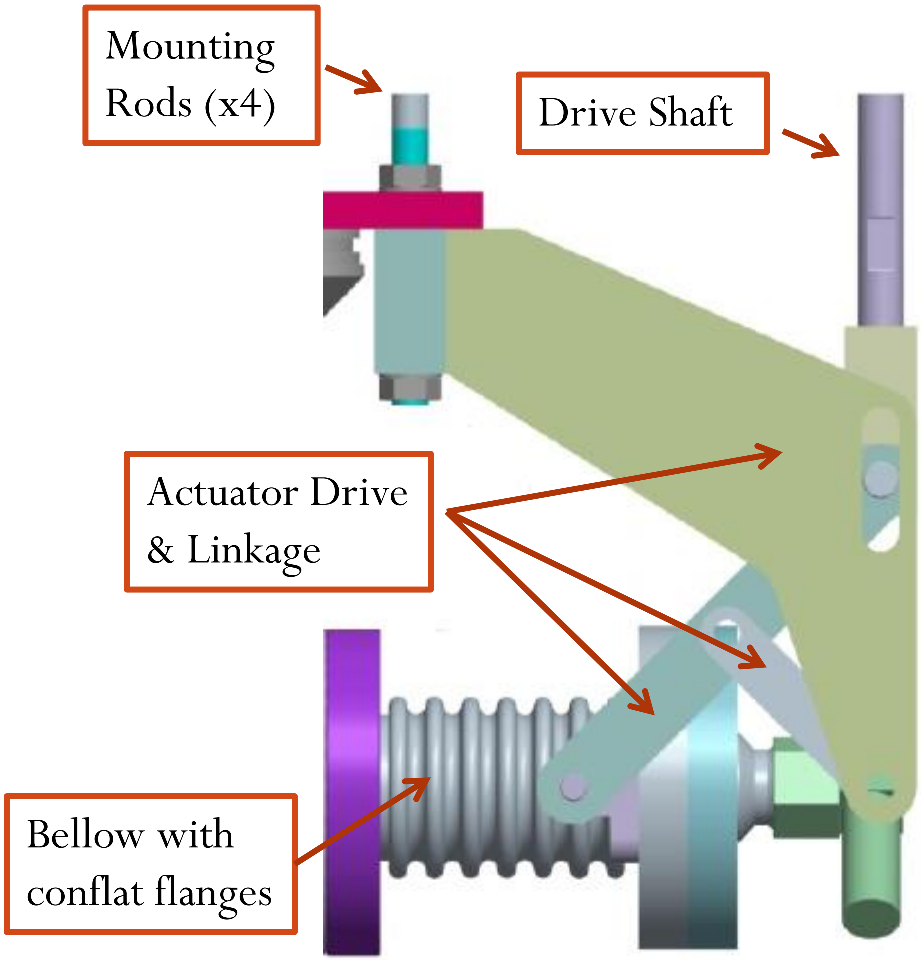


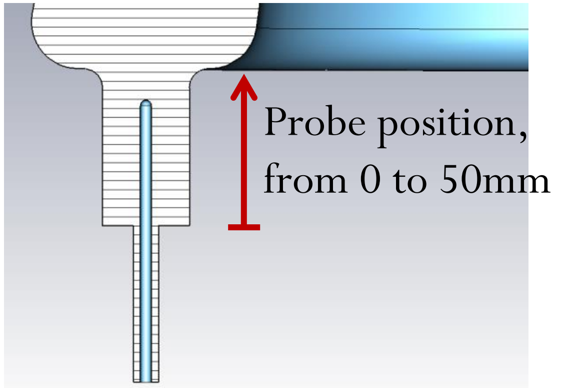
Vertical Test – RF System

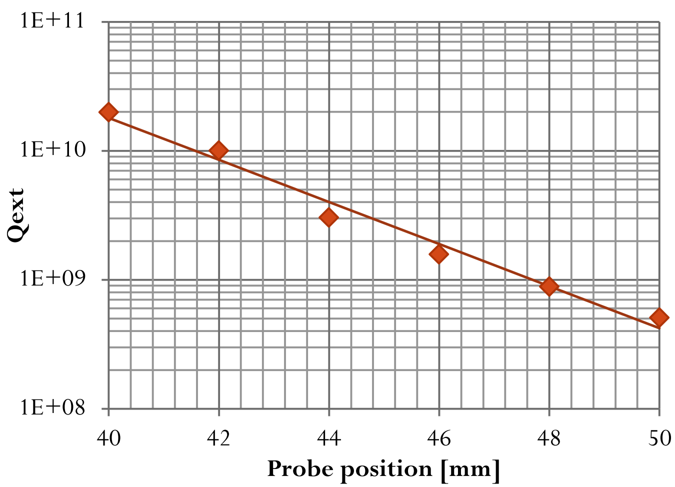


200W max power with 56±0.5dB gain

Vertical Test – FPC and PU Couplers







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