SPX Cavity Recent Results and Status

A collaboration between Jlab, ANL, FNAL, Cornell, ORNL, LBNL, and SLAC

Jim Kerby for the SPX team
Principal Project Manager
Advanced Photon Source Upgrade

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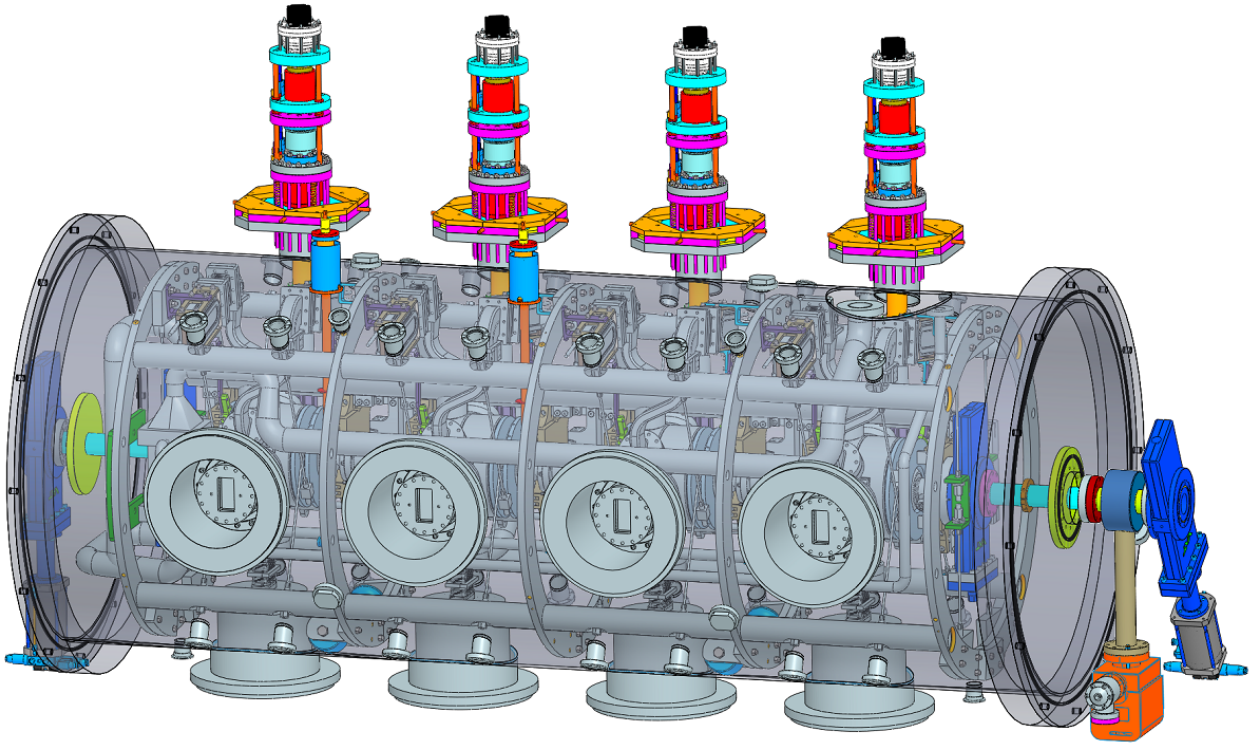
With many(!) thanks to our collaborators for input, pictures, plots and most of all hard work.

The APS Upgrade - Short Pulse X Ray System

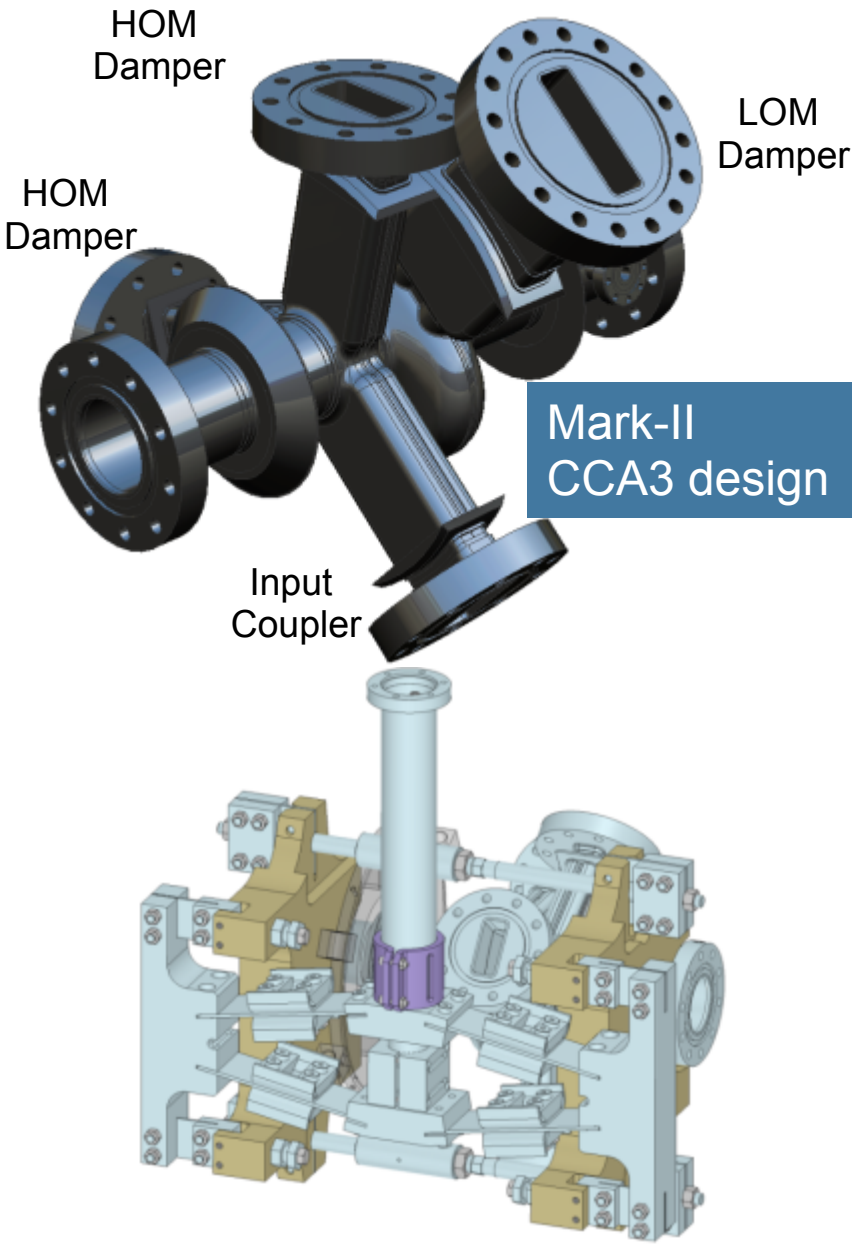
The goal of the SPX system is to provide a 2MV transverse chirp to the APS beam between Sectors 5 and 7 of the machine, providing pulsed X-rays of ~2 picoseconds and opening up new windows of science at the APS



Deflecting Cavity and Tuner

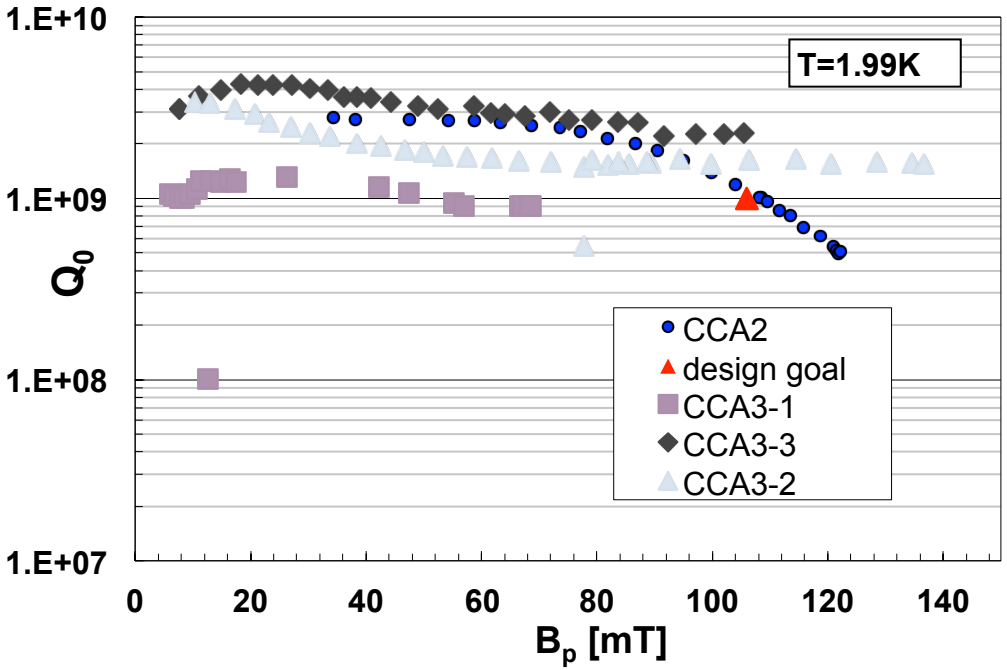
Cavity Parameter	Value	Unit
Operating frequency	2815.486	MHz
Operating Deflecting Voltage	0.5	MV
Vertical Test Acceptance B Field	≥110	mT
Peak Surface B field	106	mT
Peak Surface E field	41	MV/m
R/Q including TTF	37.1	Ω
Niobium wall thickness	3.5	mm
Geometric Factor	227.8	Ω
Operating Q_0	$\geq 10^9$	
Dynamic heat load	7	W
Magnetic Shielding	≤ 20	milligauss
Q_{ext} of Power Coupler	10^6	
RF source available	10	kW

Tuner Parameter	Value	Unit
Range	±200	kHz
Resolution	≤40	Hz
Fast detuning	60	kHz
Fast detuning response time	≤1	ms



Deflecting Cavity Performance

Mark-II Cavity Vertical Tests at JLab and ANL (Best)



Cavity	Q_0	Bpk [mT]
CCA2	1.2×10^9	120±30
CCA3-1	0.9×10^9	68±21
CCA3-2	1.24×10^9	136±35
CCA3-3	2.3×10^9	105±16

As plotted, for LOM flange:

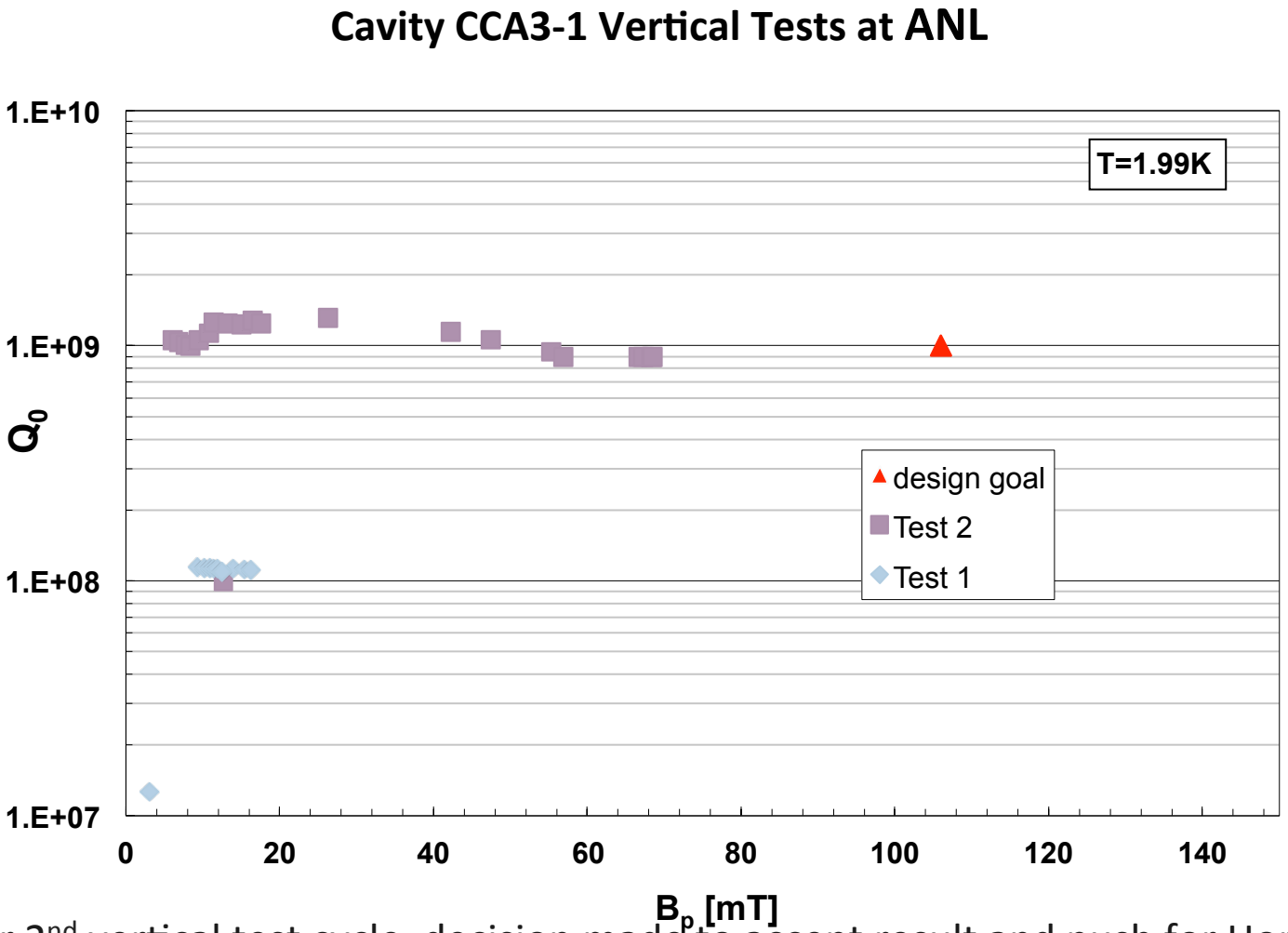
- CCA2 used indium seal
- CCA3-1 used Al/Mg seal
- CCA3-2 used indium seal
- CCA3-3 used indium seal

- LOM coupler Qext was sensitive to the coupler symmetry (solved)
- Heating on Al/Mg gasket and RF shield limits performance (RF shield required for beamline components)
- Particulates in high surface B field area

Further processing and test

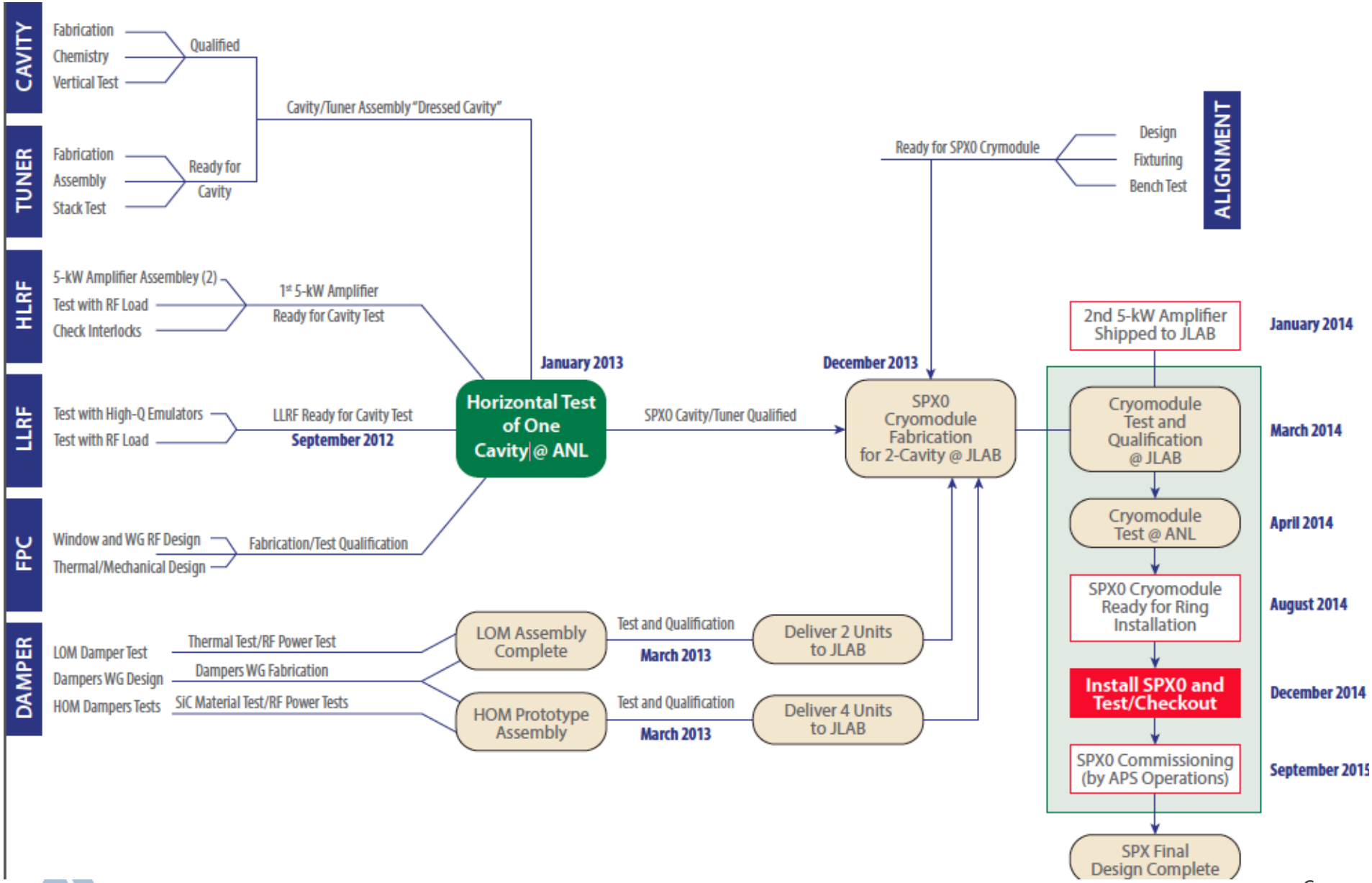
- Additional HPR
- Better RF shield
- Or adopt indium seal

CCA3-1 test results



After 2nd vertical test cycle, decision made to accept result and push for Horizontal Cavity Tuner test to check integrated system

Horizontal Cavity and Tuner Tests



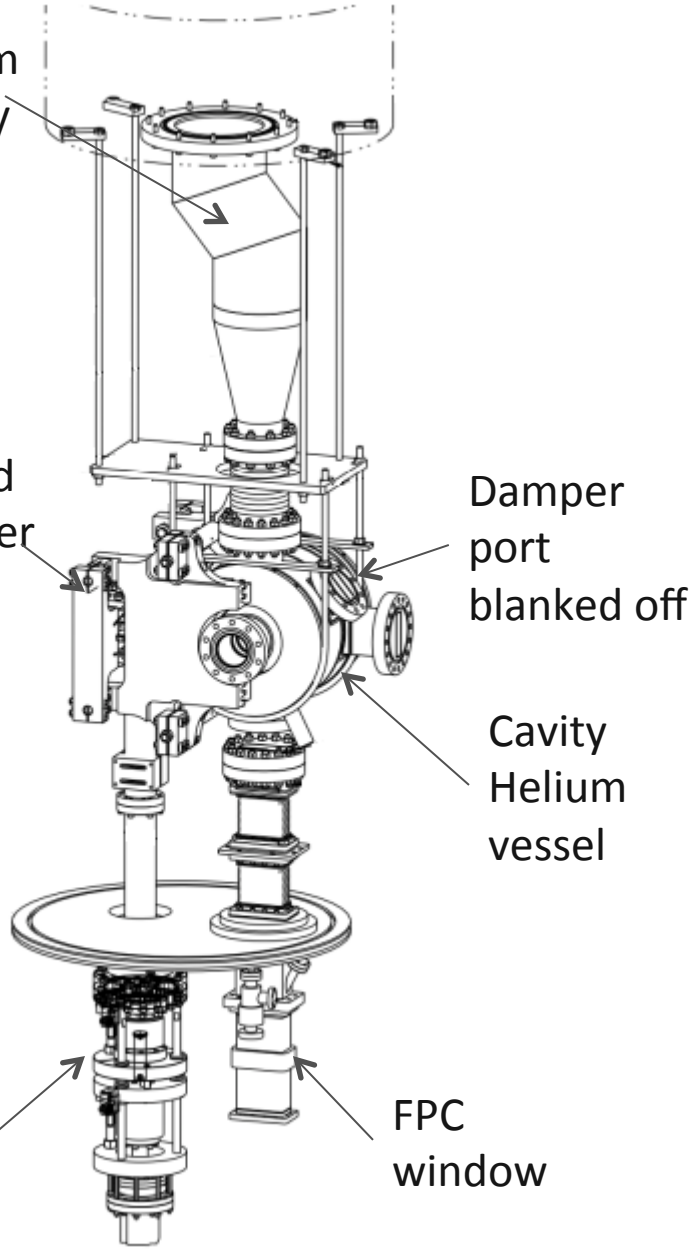
Horizontal Test Stand

Horizontal cavity test at ANL/ATLAS

- ✓ 5 kW amplifier
- ✓ 64 W Cooling @2K
- ✓ Analog and Digital LLRF

Measurements complete during HCT cycles

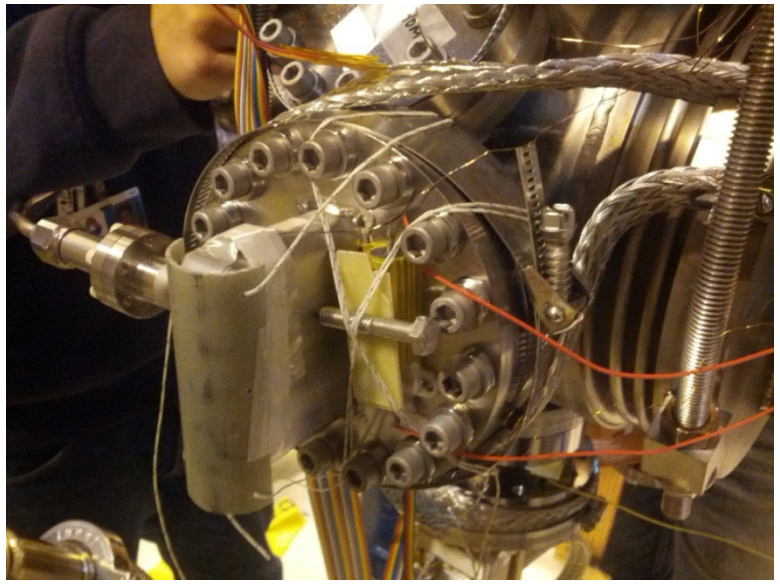
- ✓ Verify helium vessel and tuner design
- ✓ Test LLRF control
- ✓ Measure RF noise
- ✓ Measure microphonics
- ✓ Cavity performance
- ✓ Test fast detuning
- ✓ Demonstrate microphonics compensation

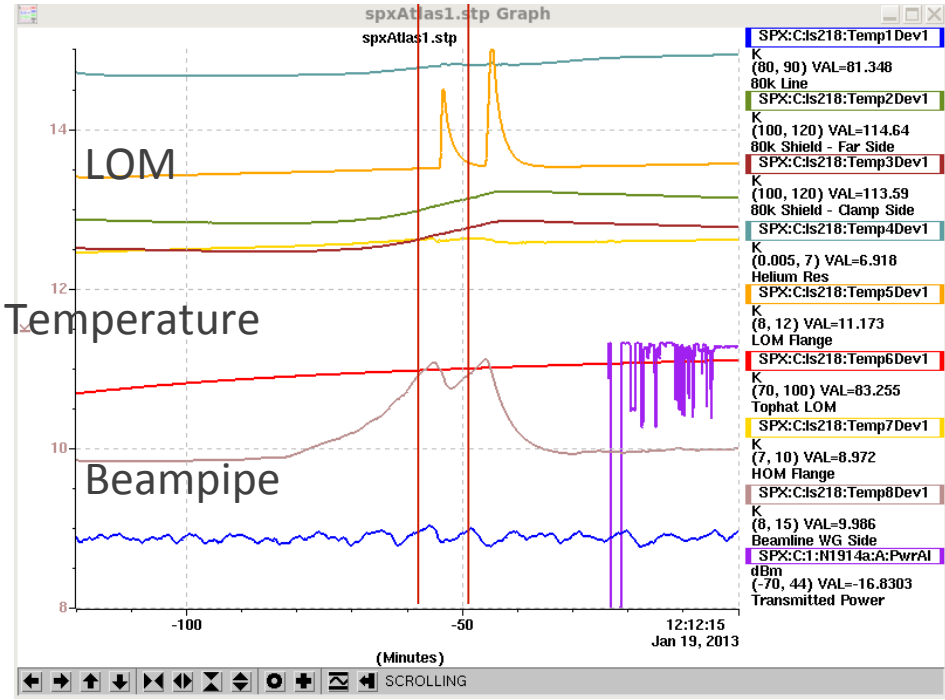


Courtesy of Joel Fuerst

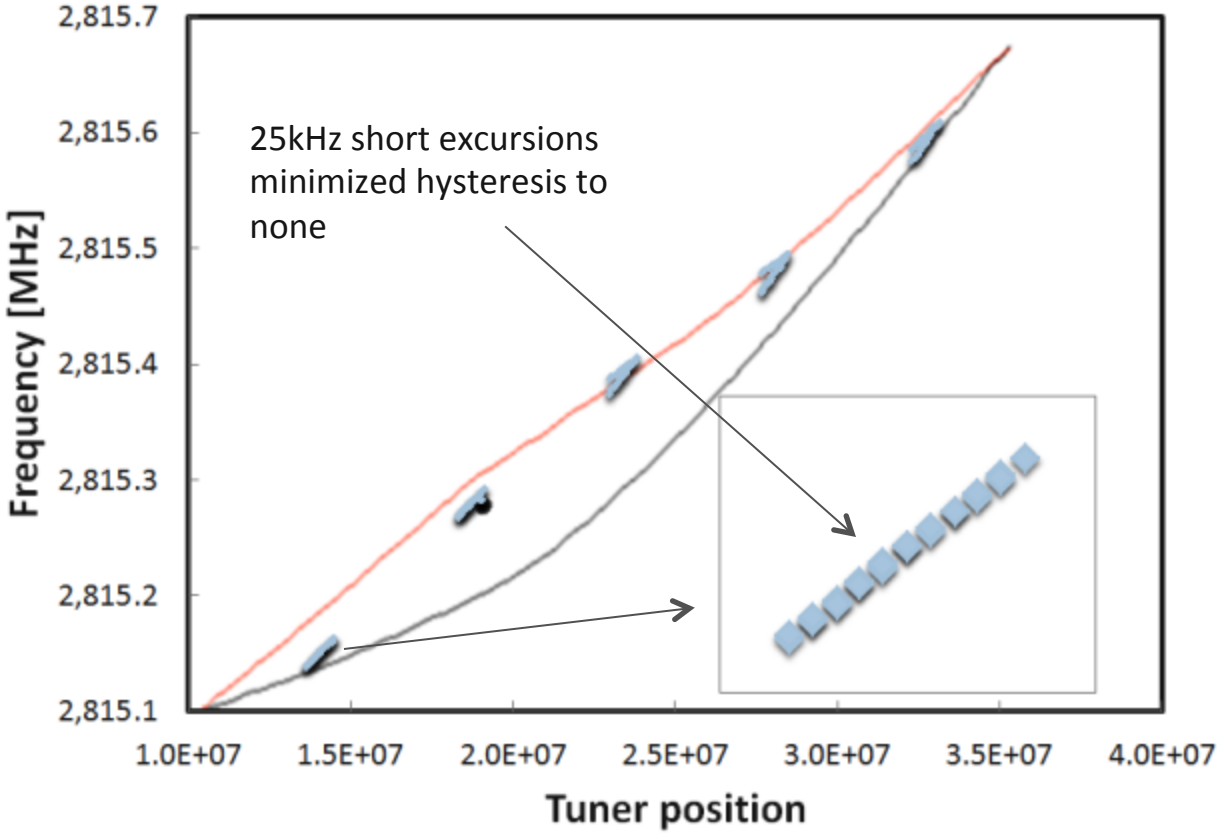
HCT Cavity Performance

- 75mT Stable Performance
  - Stable operation for over an hour at just below Q-Drop limit
  - All sensors thermally stable
  - No conditioning improvement
  - No indication of multipacting
- LOM Thermal Limitation
  - Clear evidence of LOM heating upon Q-Drop
  - Possible Magnetic Quench on NbTi top hat
  - Certification of CCA3-2 adds confidence to this conclusion
  - Second test: cooling improvement reduced recovery time





Tuner Hysteresis Measurements

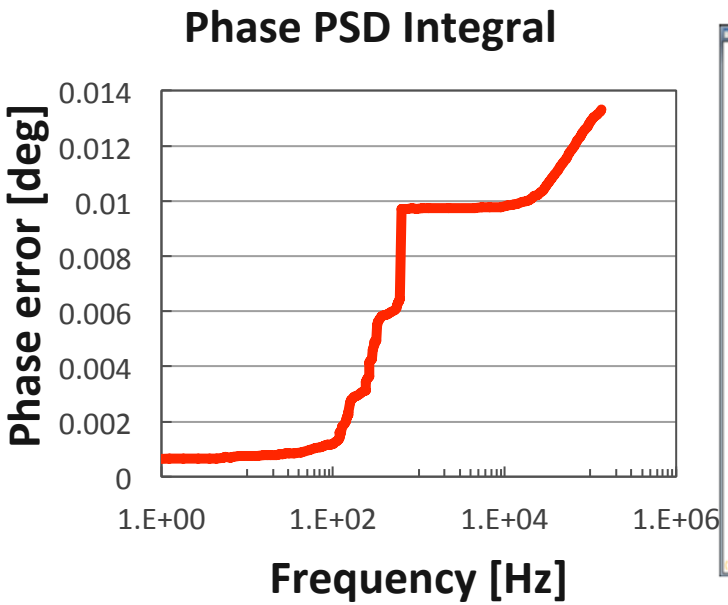


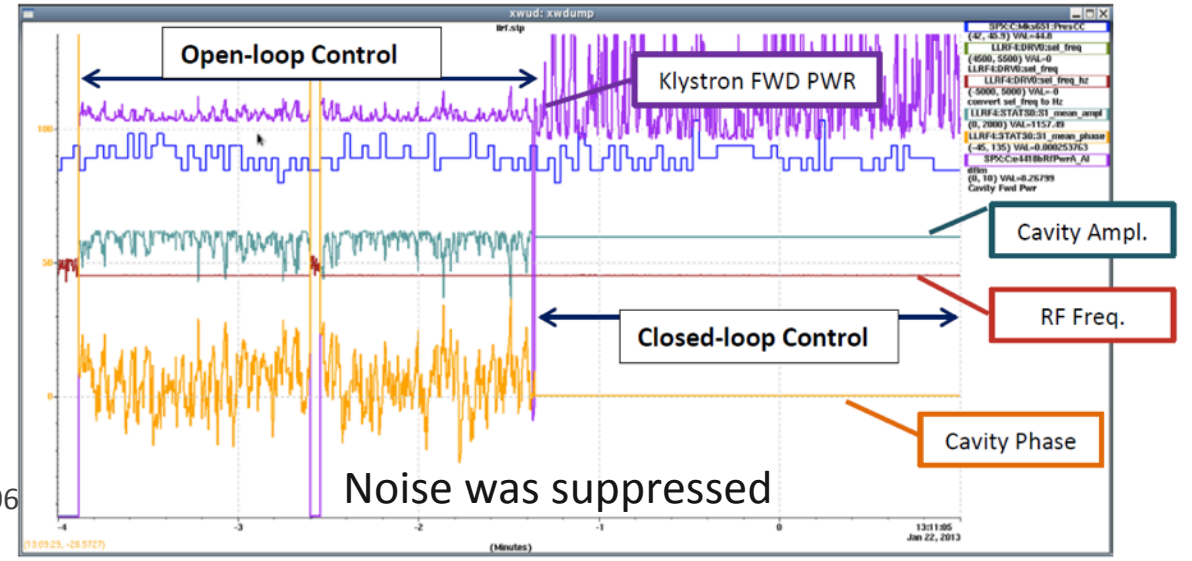
- Tuner exercised ±300kHz (Requirement range ±200KHz)
- Pretension set at 250kHz above natural frequency
- limit switch set close to ±300kHz

Hysteresis negligible within 25kHz range

Digital LLRF Control

The closed-loop control performance of SPX LLRF cavity field controller at ~ 10w RF power level with presence of significant microphonics in SRF.





Closed-loop measurements indicate that the integrated phase error is less than 10 mdeg in the bandwidth of 1Hz to ~ 10 kHz and under 20 mdeg up to 135 kHz

CCA3-1 (con't)

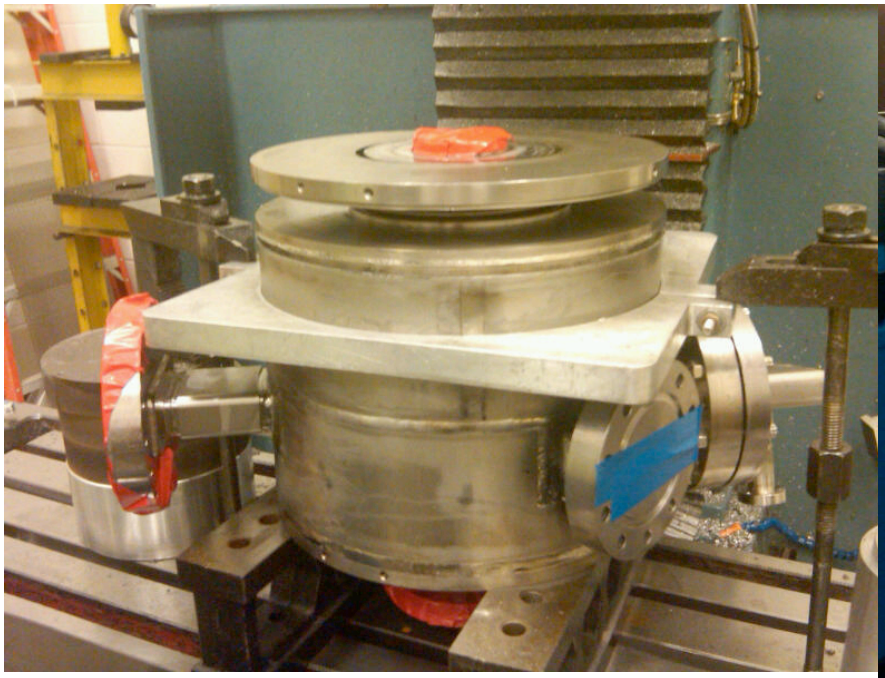
Cavity returned to Jlab for rework and vertical test with the LOM top hat replaced.

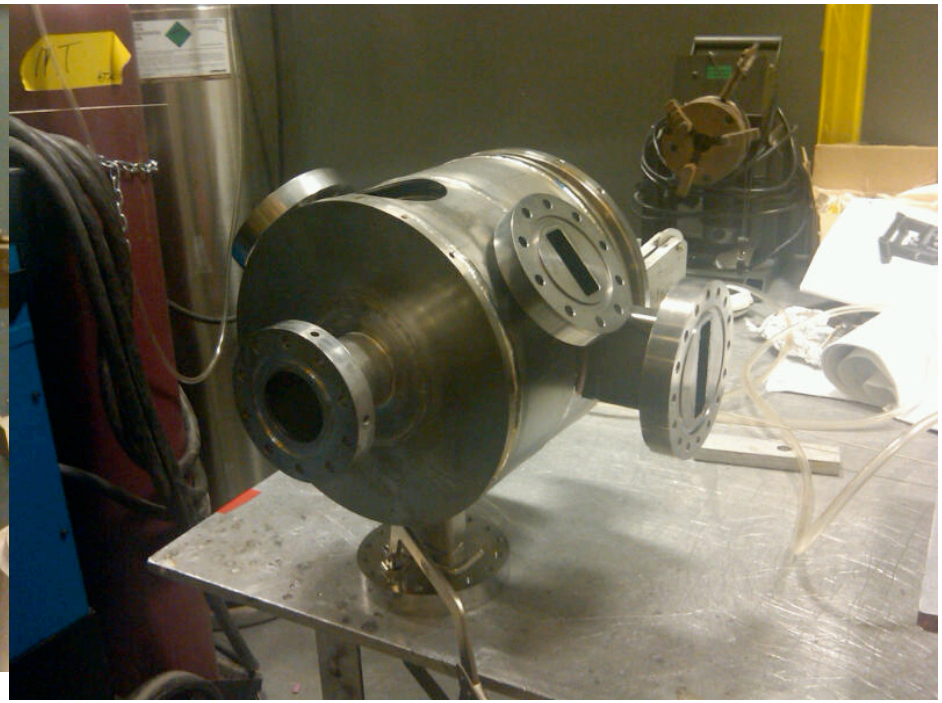
- Limited in test to 59mT, due to multipacting(?) in the area of the LOM dogbone
- SLAC simulations support multipacting at dogbone location
- Further investigation on hold awaiting progress on other cavities

CCA3-2

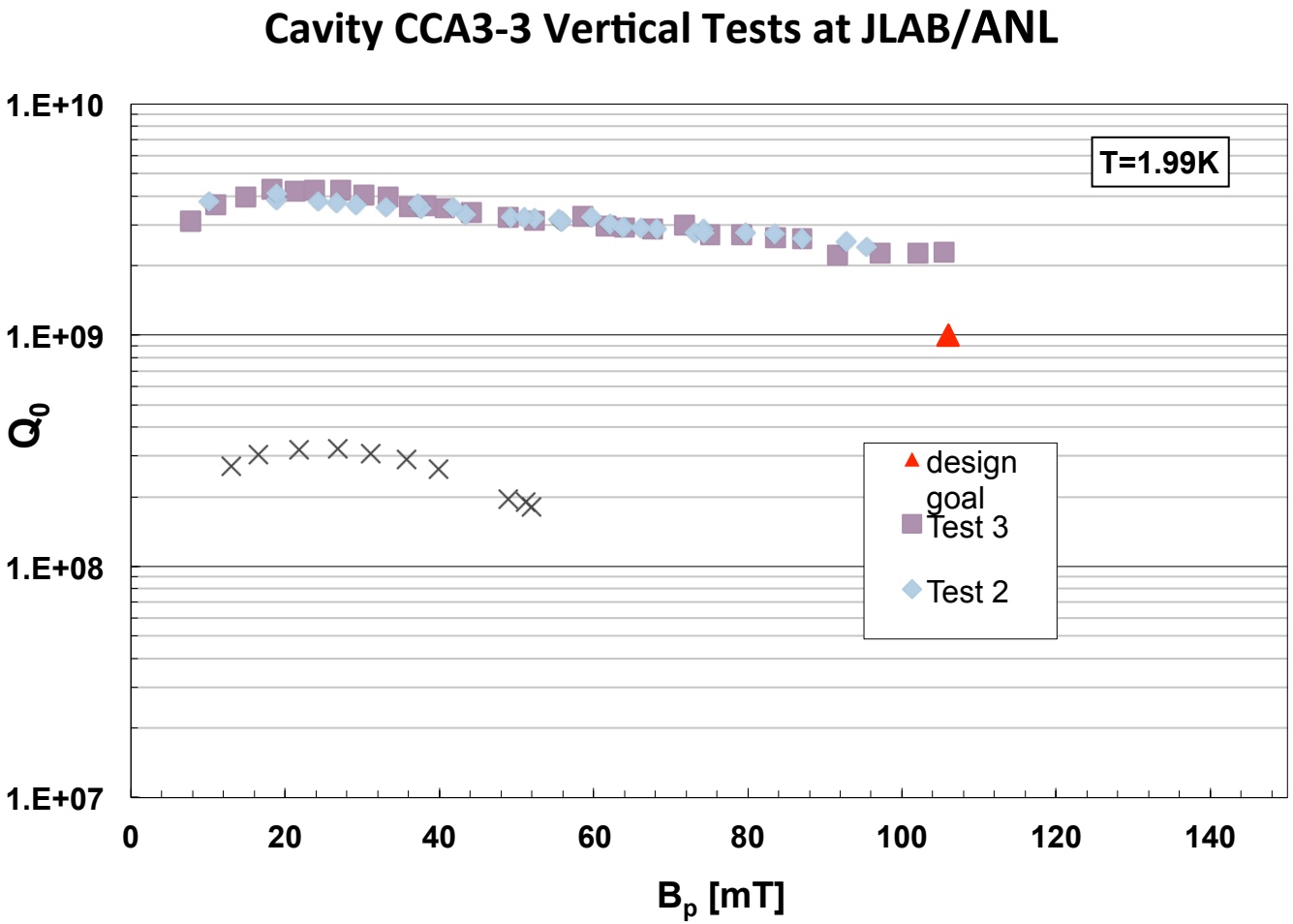
Reached 130mT and with Q0 > 1e9 in first vertical test

- Proceeded to Helium vessel assembly; weld blew through a bellows in the helium vessel; repair almost complete
- HCT at ANL after confirmation of performance





CCA3-3 test results



Limited to 60mT in first vertical test at ANL due to flange heating at LOM

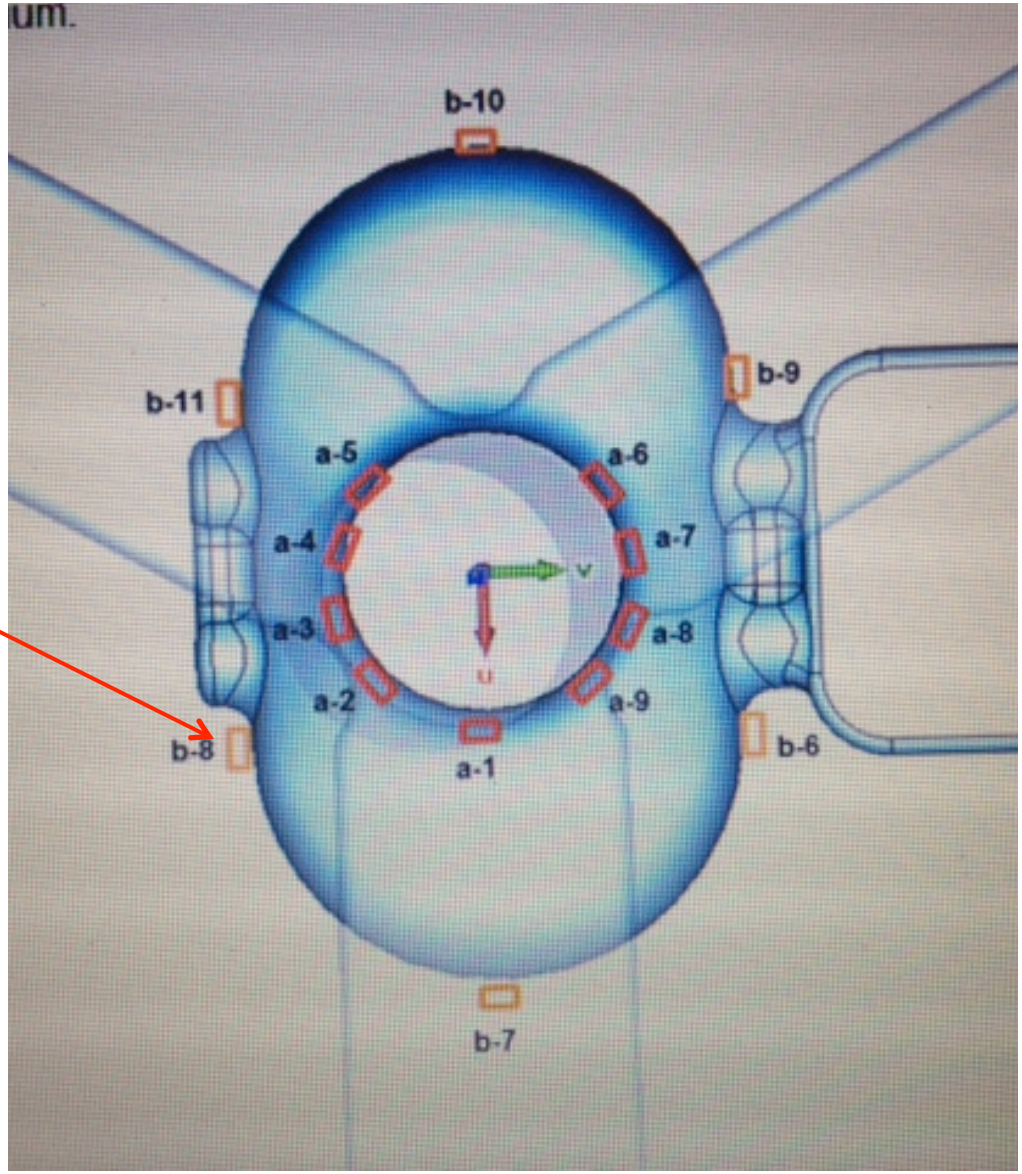
CCA3-3

Reached 95mT w/ Q0 = 1.2e9 in 1st vertical test at JLab

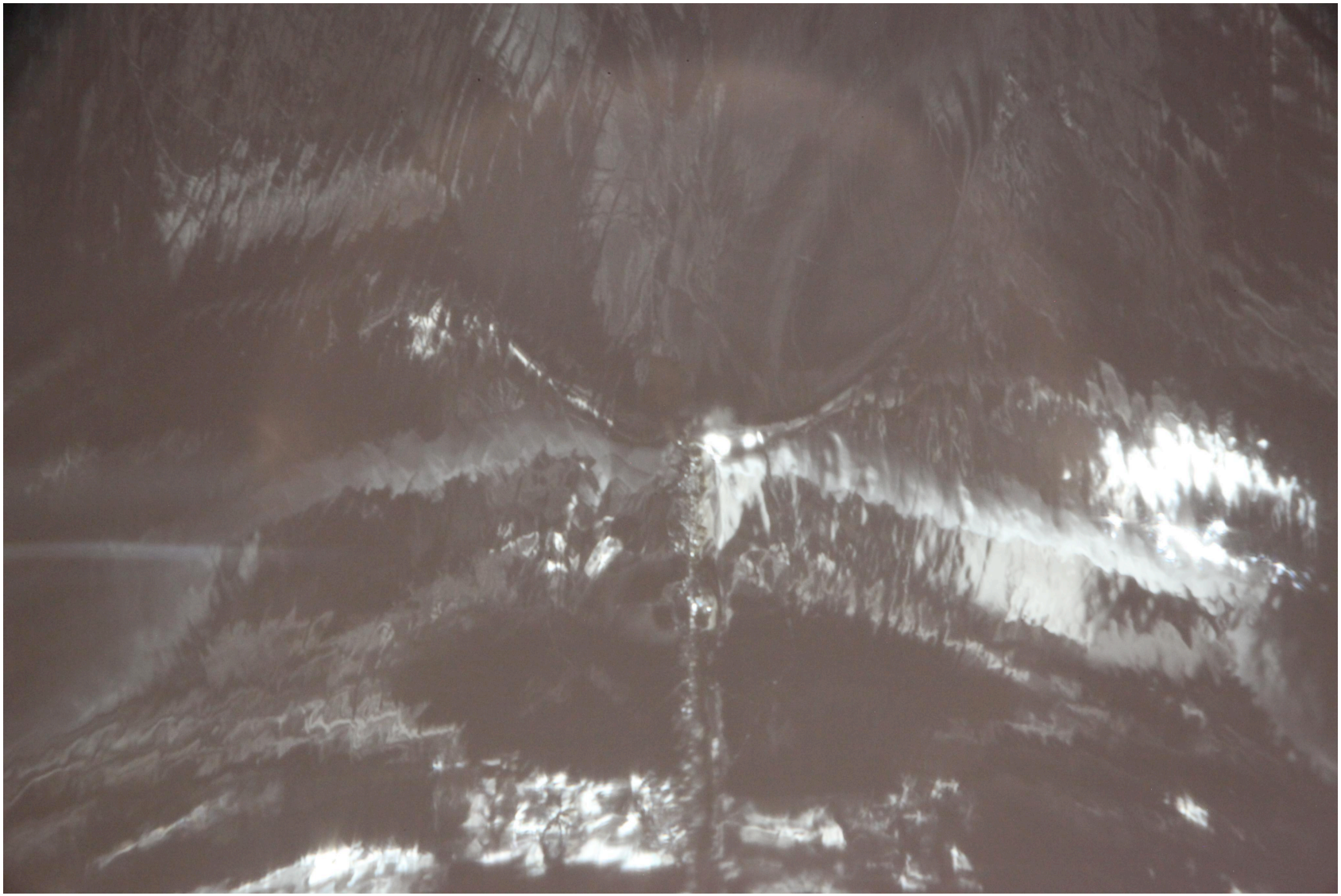
- Repeated w/ Tmap, quench location determined
- Locations B8 and B11 smoothed w/ cosmetic weld passes

Reached 105mT w/ Q0 = 2.3e9

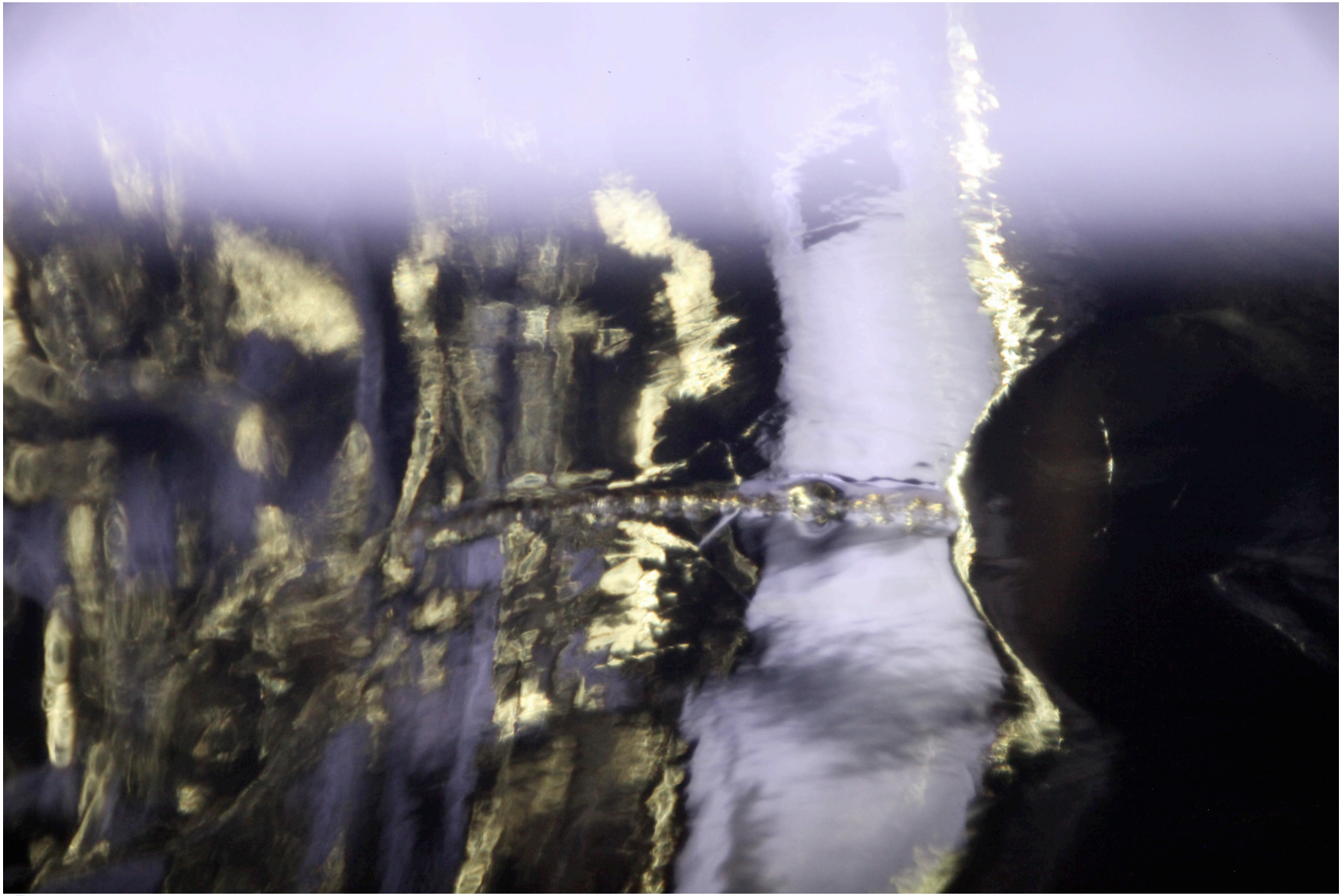
- Quench in same location



CCA3-3

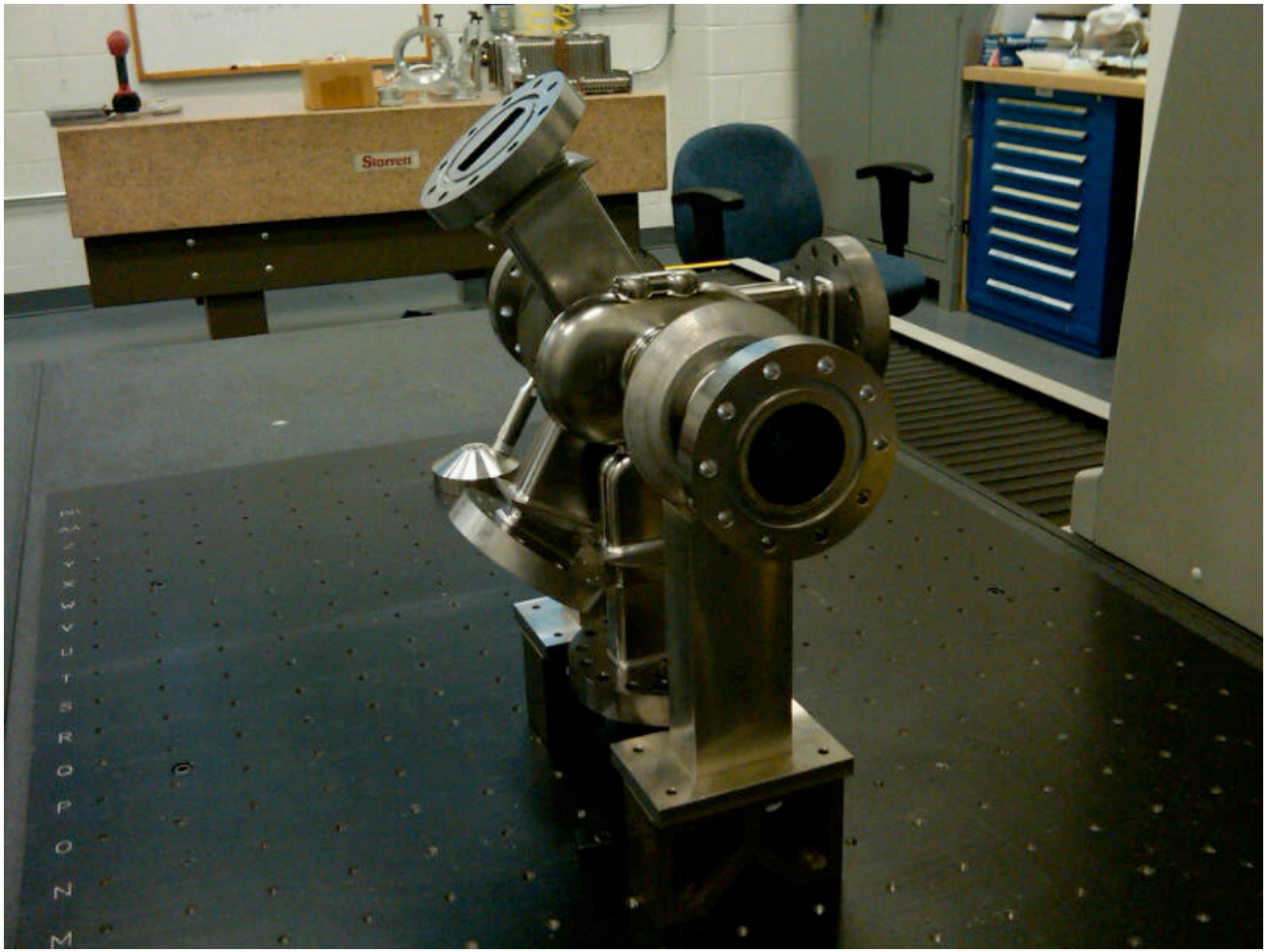


CCA3-3



CCA3-3

Accepted for SPX0, being prepared for helium vessel construction



Summary

SPX0 cavities have made good progress since last fall

- CCA3-2 exceeded operating point in vertical test
- CCA3-3 met operating gradient with better than required quality factor

These cavities are being prepared for HCT tests at ATLAS, to confirm system performance at/above the operating point and verify the LOM flange heating hypothesis

→ And then proceed to SPX0 assembly

- CCA3-1 is currently limited by multipacting, further investigation awaiting progress on other two cavities.

SPX Cavity

SPX0 Cavity Status

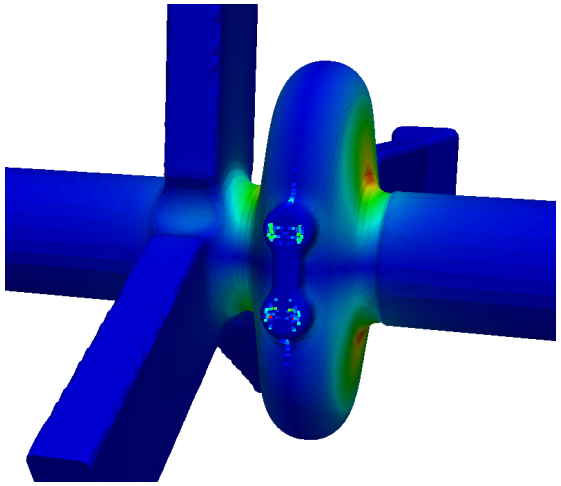
Updated on 5/31/2013

Cavity Name	Test/activity	Location	Date	Status	Latest Results	Comments
CCA2	Vertical Test	JLAB	9/1/2011	Vertical Test completed	Bpk ~ 120mT and Q0 ~ 0.5e9	Gradient met spec, CCA3 design was selected
	Vertical Test	ANL	10/30/2012	Vertical Test completed	Bpk ~ 120mT and Q0 > 1e9	With LOM symmetry tuned
	EP	FNAL	4/2/2013	EP went well		
	HPR	FNAL	4/12/2013	HPR completed		
	RF tested	JLAB	5/8/2013	Vertical Test completed	Bpk ~ 120mT and Q0 > 2e9	
	Baking and shipping	JLAB	5/13/2013	120C baking 12H done, prepare for shipping		to complete EP process studies
CCA3-1	Vertical Test	ANL	9/5/2012	Vertical Test completed	Bpk ~ 16mT and Q0 ~ 0.12e9	Limited by Al/Mg gasket
	Vertical Test	ANL	9/14/2012	Vertical Test after LOM symmetry was tuned	Bpk ~ 57mT and Q0 ~0.9e9	Pulsed field Bpk ~69mT, still limited by Al/Mg gasket
	Horizontal Test	ANL	3/7/2013	Horizontal Cavity Test	Bpk ~ 75 mT and Q0 >0.5e9	Pulsed field Bpk ~80mT, limited by LOM NbTi Tophat
	Dressed Vertical Test	JLAB	3/26/2013	Dressed Vertical Test		test was incomplete due to Non-ideal probe setting
	Dressed Vertical Test	JLAB	4/11/2013	Vertical test completed. Decision pending.	Bpk ~ 56mT and Q0 ~0.9e9	Cavity limitation unknown. Helium vessel prevented T-map.
	Results analysis	JLAB	5/13/2013	SLAC multipacting simulation		
CCA3-2	Vertical Test	JLAB	2/21/2013	Vertical test completed	Bpk ~ 130mT and Q0 > 1e9	Proceed to Helium vessel dressing
	Helium vessel attachment	JLAB		Ti weld qualification and waiting for mu-metal		
	Helium vessel attachment	JLAB	5/31/2013	HV weld prep all done. Arc shield is in fabrication		
CCA3-3	Vertical Test	JLAB	3/14/2013	Vertical test completed	Bpk ~ 95mT and Q0 > 1.2e9	
	Vertical Test	JLAB	4/4/2013	Vertical test with T-map completed	same as above	Quench location identified
	HPR	JLAB	4/23/2013	HPR started, finish today		
	Vertical Test	JLAB	5/3/2013	Vertical test completed, decision pending	Bpk ~ 105 mT and Q0 ~ 2.3e9	

Contact: genfa@anl.gov

MP in the Symmetrizing Stub

No leakage



With leakage: Qext=1e5