The cavity EM and mechanical design issues and status

Timergali Khabiboulline

PIP-II meeting, 09/16/2014

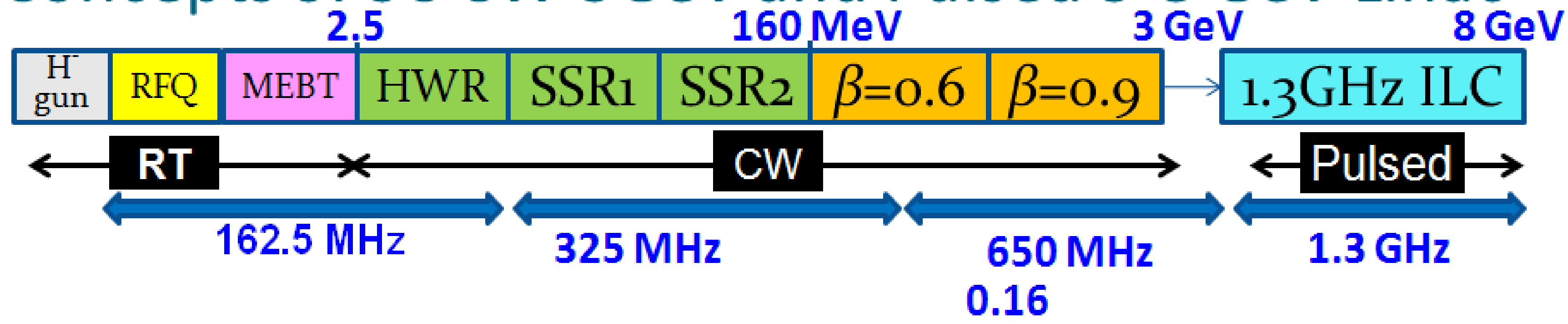
- Difference between CW (Project X) and Pulsed (PIP-II) linacs
- Cavities for PIP II:

  - Normal conducting cavities: RFQ and Re-Buncher

  - SRF cavities: HWR, SSR1, SSR2, 650 MHz (beta = 0.61, beta = 0.92),
- Cavity Types and General Parameters
- Cavity Functional Specification
- Cavity Design Status

Project X concept

Concepts of SC CW 3GeV and Pulsed 3-8 GeV Linac

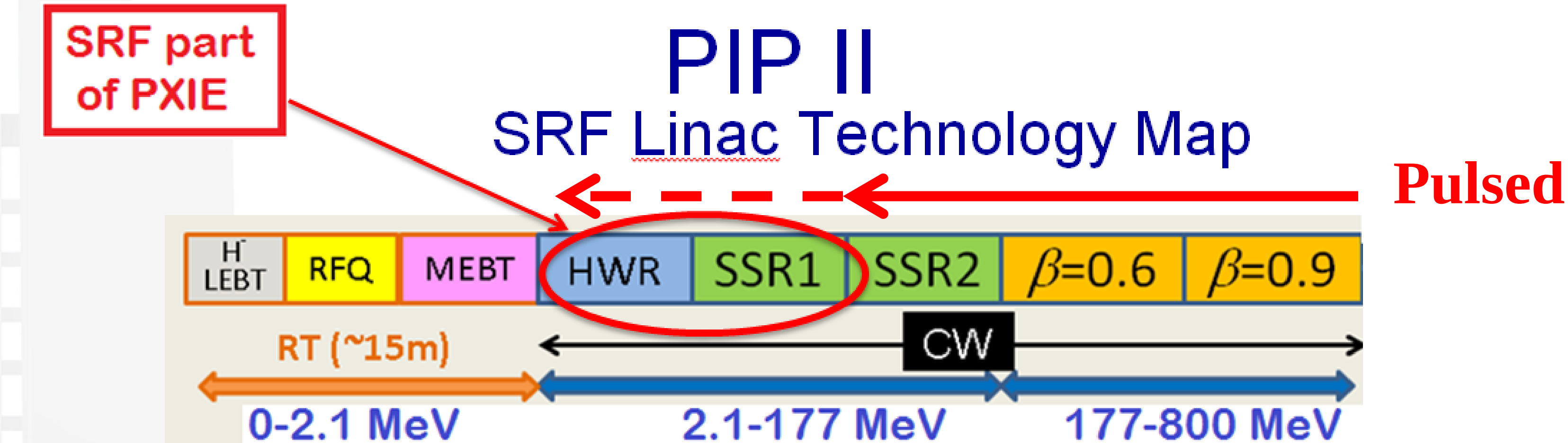


Section	Freq, MHz	Energy(MeV)	Cav/mag/CM	Type
HWR (β_G=0.11)	162.5	2.1-10	8 /8/1	HWR, solenoid, 5.26m
SSR1 (β_G=0.22)	325	10-32	16 /10/ 2	SSR, solenoid, 4.76m
SSR2 (β_G=0.47)	325	32-160	36 /20/ 4	SSR, solenoid, 7.77m
LB 650 (β_G=0.61)	650	160-520	42 /14*/ 7	5-cell ellip, doublet, 7.1m
HB 650 (β_G=0.9)	650	520-3000	152 / 19**/ 19	5-cell ellipt, doubl, 11.2m
ILC 1.3 (β_G=1.0)	1300	3000-8000	224 / 28/ 28+	9-cell ellipt., quad, 12.6m

N.Solyak, PrX Beam Lines PrX Meeting, FNAL, Jan, 2012

1 mA CW operation in SRF part

PIP-II concept



SRF Cavity Type	Freq, MHz	Energy (MeV)	Cav/mag/CM	CM type, length
HWR (β_G=0.11)	162.5	2.1-11	8 /8/1	scscscscscscscsc, 5.3m
SSR1 (β_G=0.22)	325	11-38	16 /8/ 2	csccsccsccsc, 4.8m
SSR2 (β_G=0.51)	325	38-177	35 /21/ 7	sccsccsc, 6.5m
LB 650* (β_G=0.61)	650	177-480	30 /20/5	cccfdccc, 7.1m
HB 650 (β_G=0.9)	650	480-800	24 /6/ 4	cccccc, 9.5m

*3-cavity option is under consideration; CM has no focusing elements.

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2 mA pulsed beam with duty factor from 0 to CW operation

Number of cavities/cryomodules changed for SSR2 and above

PIP-II cryogenics

PIP-II

Cryogenic losses in the PIP II cryo-modules

- In CW regime the total loss is 410 W;
- Pulsed operation limited by power of the cryo-plant;
- 5% duty factor for cryo, or 20.5 W.

	Energy (MeV)	CM	Cav per CM	E_{acc} (MV/m)	ΔE (MeV)	Q_0@2K (10^{10})	Static loss per CM @2 K, W	Total loss per CM @2 K in CW, W
HWR	2.1-11	1	8	8.2	1.7	0.5	14	24
SSR1	11-38	2	8	10	2.05	0.5	16	27
SSR2	38-177	7	5	11.2	5.32	1.2	8.8	52
LB 650	177-480	5	6*	16.5	11.6	1.5	8.1	153
HB 650	480-800	4	6	17.5	17.7	2.0	6.2	153

*3-cavity option is under consideration; CM has no focusing elements.

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Fermilab

~75% of cryogenic losses take place in 650 MHz part

General Issues:

- Low beam loading → narrow cavity bandwidth → microphonics
- Beam current: 1mA →2 mA
- Lorentz Force Detuning (LFD) is an issue in a pulsed mode, and should be analyzed for each cavity type.
- Future CW operation → cryo-losses → high Q_0 is desired. Technology of the cavity processing based on N-doping is developing

Microphonics SRF cavities

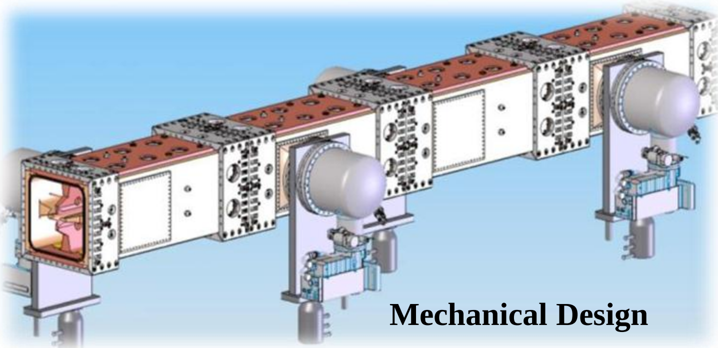
Bandwidth and required power optimized for CW (2 mA)

Section	Freq MHz	Maximal detune (peak Hz)	Minimal Half Bandwidth (Hz)	Max Required Power (kW)
HWR	162.5	20	34	4.8
SSR1	325	20	45	5.3
SSR2	325	20	27	17.0
LB650	650	20	29	33.0
HB650	650	20	31	48.5

Microphonics Control Strategies:

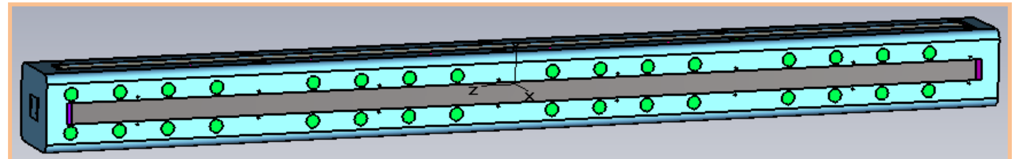
- **Adding RF power to compensate for the expected peak frequency detuning.**
- **Minimizing Helium bath pressure peak to peak variations.**
- **Reducing df/dP , the sensitivity of the cavity resonant frequency to in the helium bath pressure.**
- **Minimizing acoustics from external sources.**
- **Active compensation using a fast tuner driven by feedback from measurements of the cavity resonant frequency.**

Room temperature cavities. RFQ.



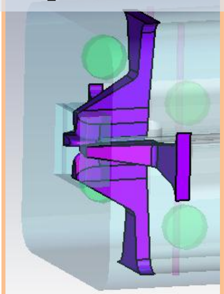
Mechanical Design

By Gennady Romanov

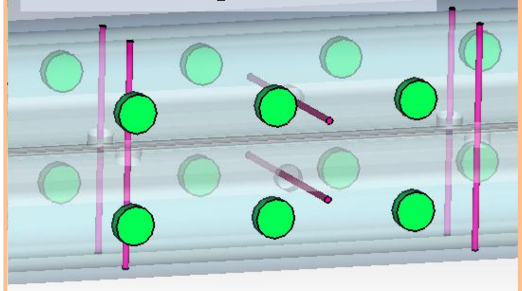


Complete 3D model

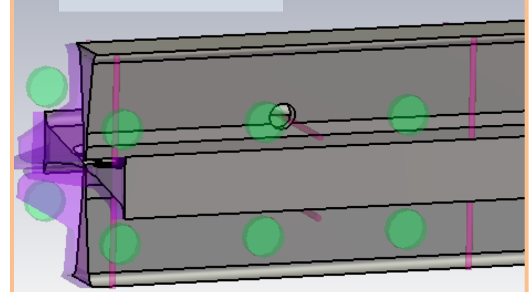
Input cut back



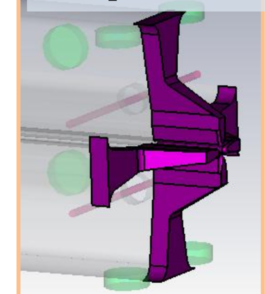
Tuners and pi-mode rods



Vanes



Output cut back

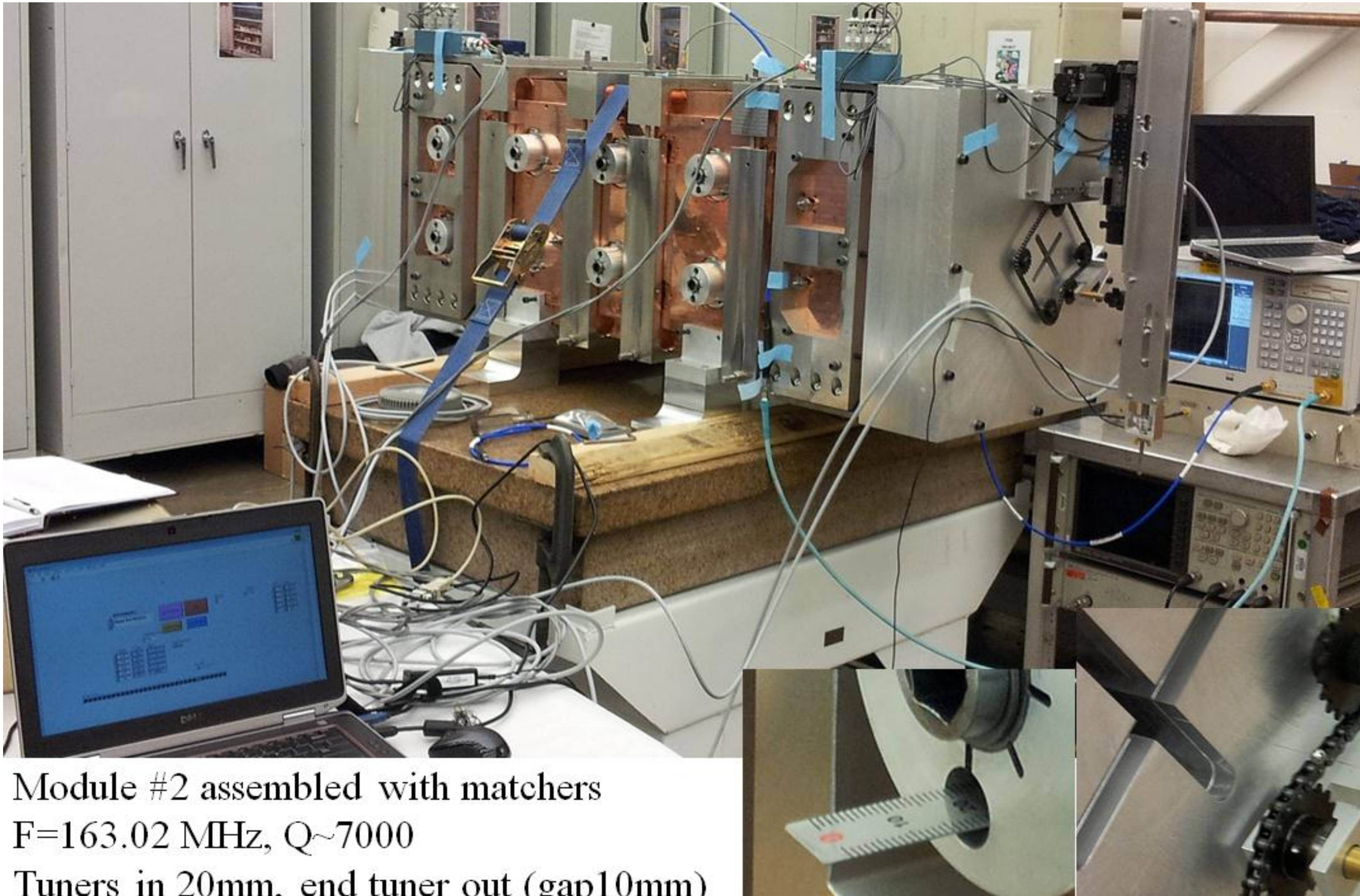


<u>As a part of PXIE RFQ design team we performed:</u>

- Overall RF designs of the PXIE RFQ and IMP RFQ – shape of vanes, positions and dimensions of the tuners and the PISLs, shape and dimension of the end cut-backs etc.
- RF and mechanical design of the novel power couplers.
- Error analysis for the main parameters, impact of the vane modulations on the frequency and field distributions.
- RF losses evaluation and basic thermal analysis.
- Multipacting simulations in the RFQ volume and in the power coupler.
- Verification of the final mechanical design presented in the CAD models with comprehensive EM simulations.
- Beam dynamic simulations with the use of CST PIC solver in the “real” RF fields that take into account influence of the PISLs, tuners, end cut-back tuning, vane tip modulations.
- RF simulations, mechanical design, manufacturing and test bead-pull measurements.

Room temperature cavities. RFQ.

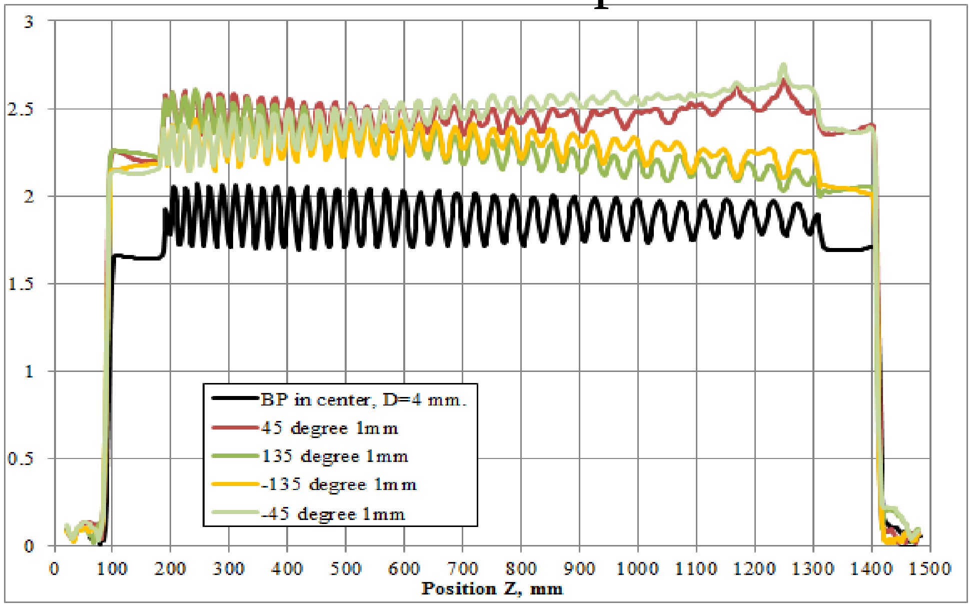
Bead-pull measurements of module #2 of the PXIE RFQ in April 2014



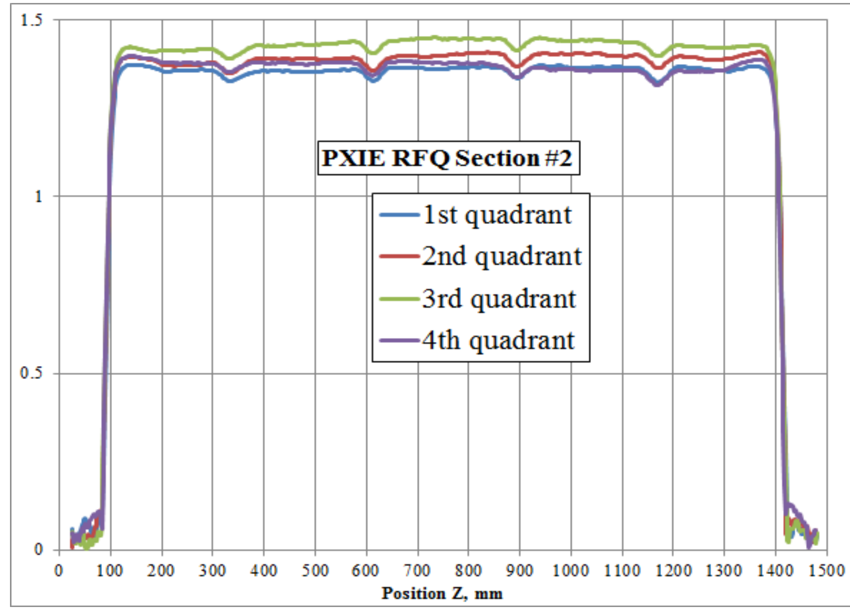
Module #2 assembled with matchers
F=163.02 MHz, Q~7000
Tuners in 20mm, end tuner out (gap10mm)

Room temperature cavities. RFQ.

Bead-pull measurements of module #2



Bead-pull near axes



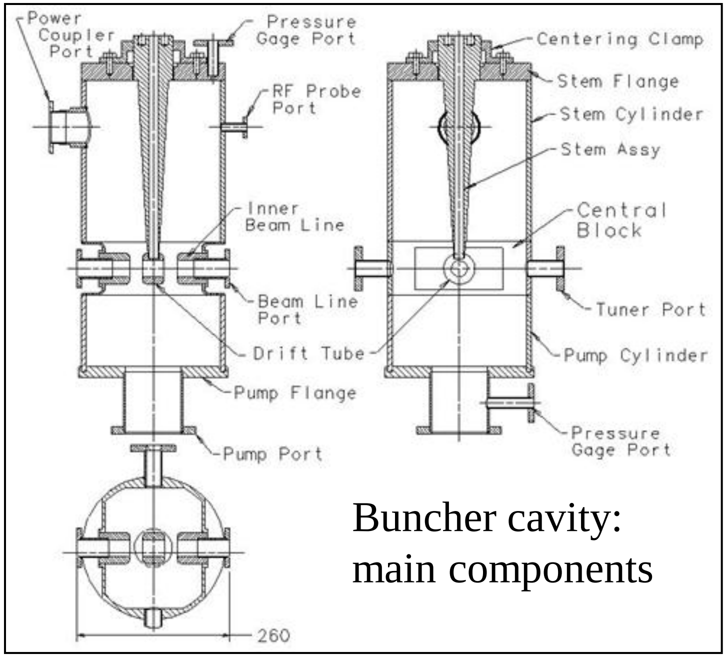
Bead-pull 30 mm off axes

Production status reported by Jim Steimel

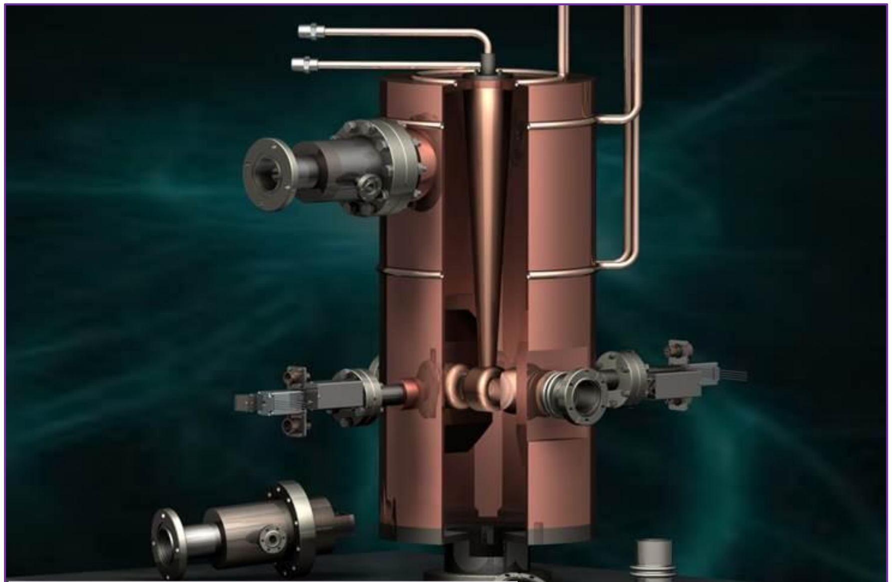
FNAL PXIE Scorecard	M1V	M1V	M1H	M1H	TV	M1Vs	M2V	M2V	M2H	M2H	M3V	M3V	M3H	M3H	M4V	M4V	M4H	M4H	Module 1	Module 2	Module 3	Module 4
8/28/2014																						
Material at LBNL	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Machine ends	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Rough Machine all sides	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Gun drill	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Flow check	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Machine C'bores	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
EBW plugs	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Flow check / vac check	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Back side machine	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Inspection	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Mount to machining plate	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Inside rough machine	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Inspection	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Inside finish machine	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Inspection	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Machine Modulations	toolin	x	cut b	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Full CMM inspection		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
steam clean		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				

Room temperature cavities. Re-Buncher.

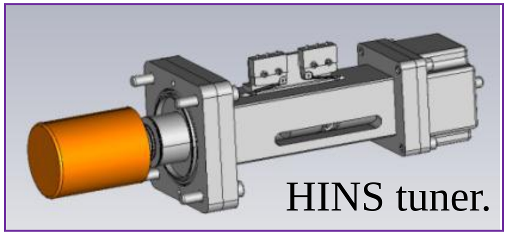
CW ROOM TEMPERATURE RE-BUNCHER FOR THE PIP-II LINAC FRONT END



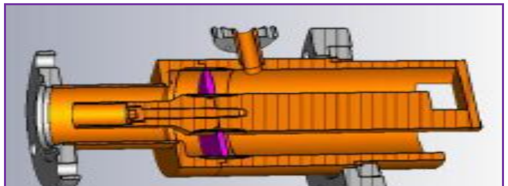
Buncher cavity: main components



Assembled buncher cavity.



HINS tuner.



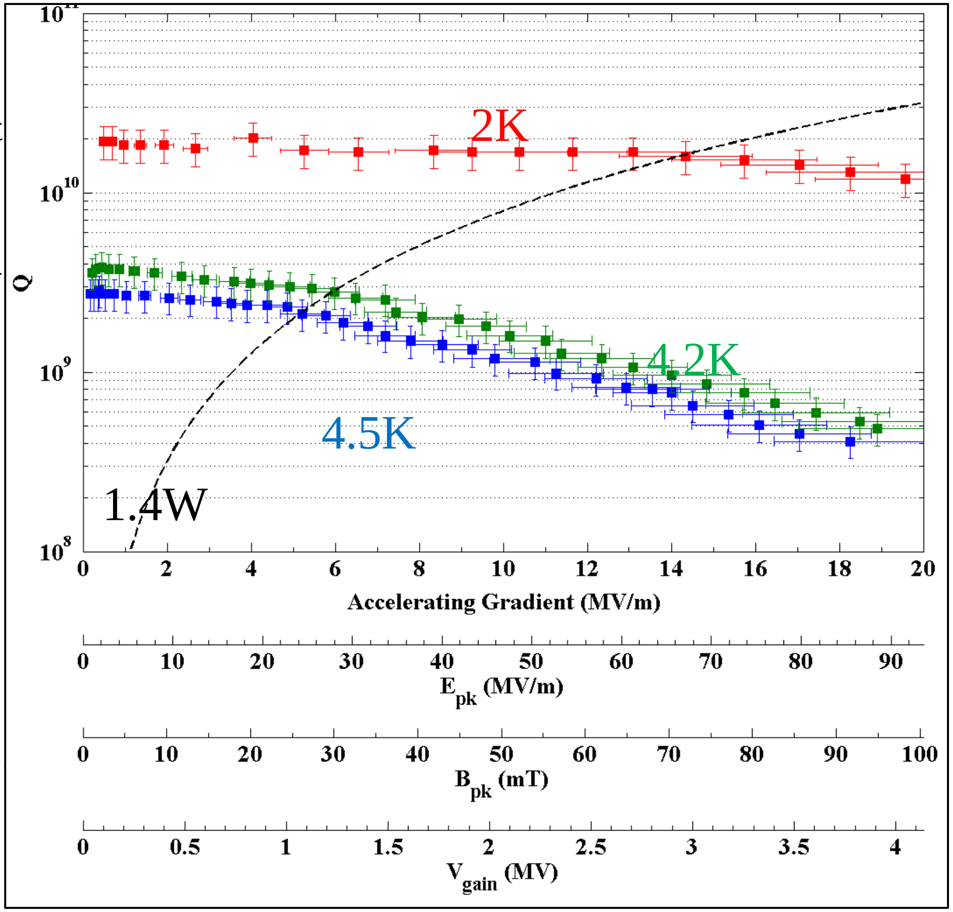
HINS coupler.

1st cavity under production
Expected delivery this year

Main RF parameters of the cavity	
Frequency f, MHz	162.5
Q factor	>10000
Aperture radius, mm	20
Effective voltage (β=0.067), kV	70
Gap, mm	2x23
Power loss in copper, kW	0.92
Effective shunt impedance, Ohm	5.3e6
Max. electric surface field, MV/m	4.2
Tuning range, kHz	440

Superconducting cavities. HWR.

Result of the 1st HWR cavity test by Andrei Lunin:
- ANL successfully performed initial cold RF test of the HWR#0 (Wah-Chang Nb). Cavity has demonstrated excellent performance and almost twice exceeded specification on RF losses at operating conditions, **1.4W** at **1.7MV** at **2K**
- The results correspond to about **3 nΩ** surface resistant at **2K**
- The field emission started at ~ 15MV/m gradient and can be processed further but ANL decided to stop at 20 MV/m and avoid a risk of possible contamination.
- A weak MP has been noticed at ~1MV/m and ~10 MV/m gradients which were easily processed within few minutes. The cavity was equipped with variable coupler (Q ~ 1e7 ... 1e10).
- The measured df/dP at 2K is **13.6 Hz/Torr** , which is 3 times higher comparing to RT result but still safe for reliable cavity operations.
- The measured microphonics **rms** is **11.5 Hz** with few peaks above 50 Hz: 90Hz and 120Hz
- Cavity LFD coefficient is K_{LFD} = **-1.82 Hz/(MV/m)^2**



HWR cavities production status, August 28 2014
- The recent 625C baking test revealed that **50% flanges have leaks** after bake. The reason is unknown. These flanges and joints having been made at local ANL machine shop through many years with no leaks indications. ANL is running intensive investigation (cut-out exam, X-ray diffraction) and planning to rework all flanges and use other vendor (California Brazing) for verifying the technology.
- ANL is requesting additional time to be reserved for another 625C baking tests at large Fermilab oven.
- Because of flanges leaking issue the **HWR production schedule is delayed by 2-3 months**. This delay is still manageable and ANL expects all part to be tested and ready for the HWR cryomodule assembly by the end of 2015.

Superconducting cavities. SSR1.

FRS is written and signed. EM Parameters

Parameter	Value
Frequency	325 MHz
Shape	Single Spoke Resonator
$\boldsymbol{\beta_g, \beta_o}$	0.215, 0.22
$\boldsymbol{L_{eff} = 2*(\beta_o\lambda/2)}$	203 mm
Iris Aperture	30 mm
Inside diameter	492 mm
Bandwidth	90 Hz (2 mA)
$\boldsymbol{E_{pk}/E_{acc}}$	3.84
$\boldsymbol{B_{pk}/E_{acc}}$	5.81 mT/(MV/m)
G	84 Ω
R/Q	242 Ω

Superconducting cavities. SSR1.

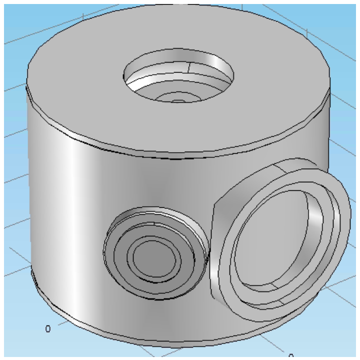
Cavity operational/test requirements

Parameter	Value
Max Leak Rate (room temp)	< 10^{-10} atm-cc/sec
Operating gain per cavity	2.0 MeV
Maximum Gain per cavity	2.4 MeV
Q_0	>5 x 10^9
Maximum power dissipation per cavity at 2 K	5 W
Sensitivity to He pressure fluctuations	< 25 Hz/Torr
Field Flatness	Within ±10%
Multipacting	none within ±10% of operating gradient
Operating temperature	1.8-2.1 K
Operating Pressure	16-41 mbar differential
MAWP	2 bar (RT), 4 bar (2K)
RF power input per cavity	6 kW (CW, operating)

Superconducting cavities. SSR1.

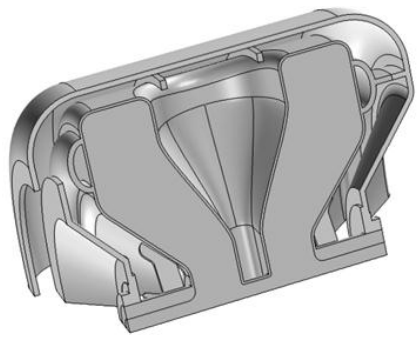
Lorentz Force Detuning in SSR1, by Mohamed Hassan

Old Vessel

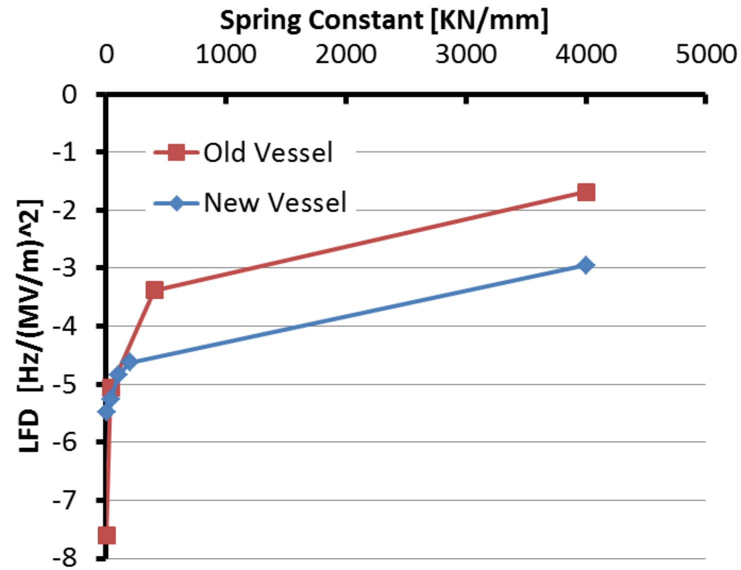


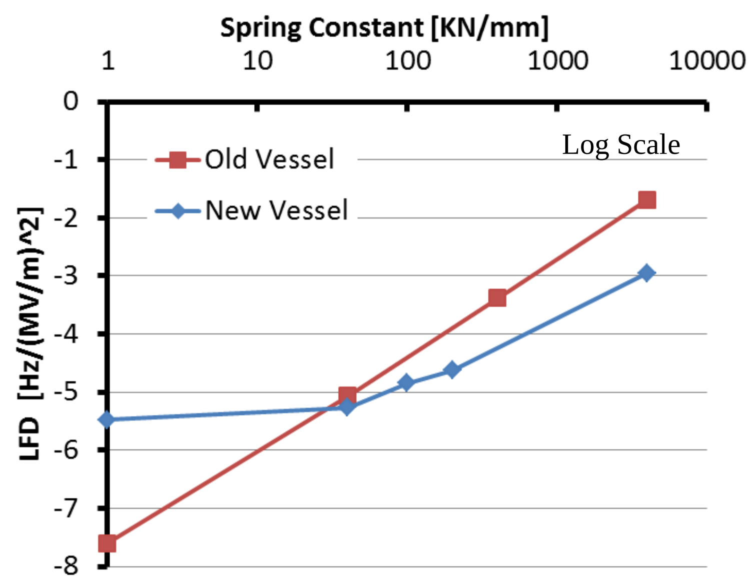
	Spring Const [kN/mm]	LFD [Hz/(MV/m)^2]
Fixed		-1.69
	4000	-1.69
	400	-3.38
	40	-5.07
Free	0	-7.6
Meas		-4.06

New Vessel



	Spring Const [kN/mm]	LFD [Hz/(MV/m)^2]
Fixed		-2.74
	4000	-2.95
	200	-4.63
	100	-4.85
	40	-5.27
Free	0	-5.48

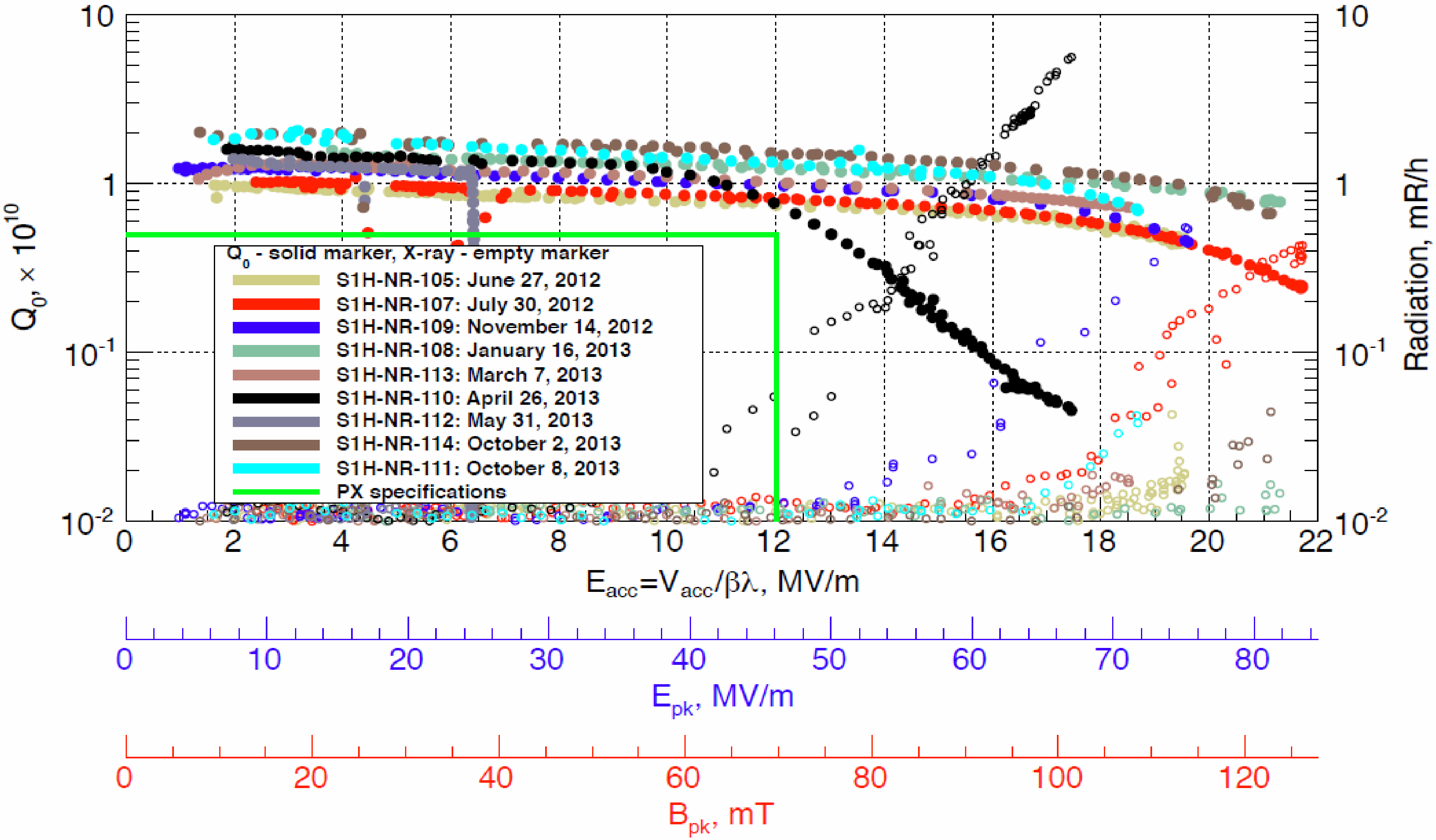




- LFD coef. is dependent on the stiffness of the tuner
- SSR1 with the new vessel exhibits approximately 60% more LFD compared to the old vessel.
- The new vessel response is not logarithmically linear in contrast to the old vessel. It could be because of the one side ring that has been introduced in the new vessel design.

Superconducting cavities. SSR1.

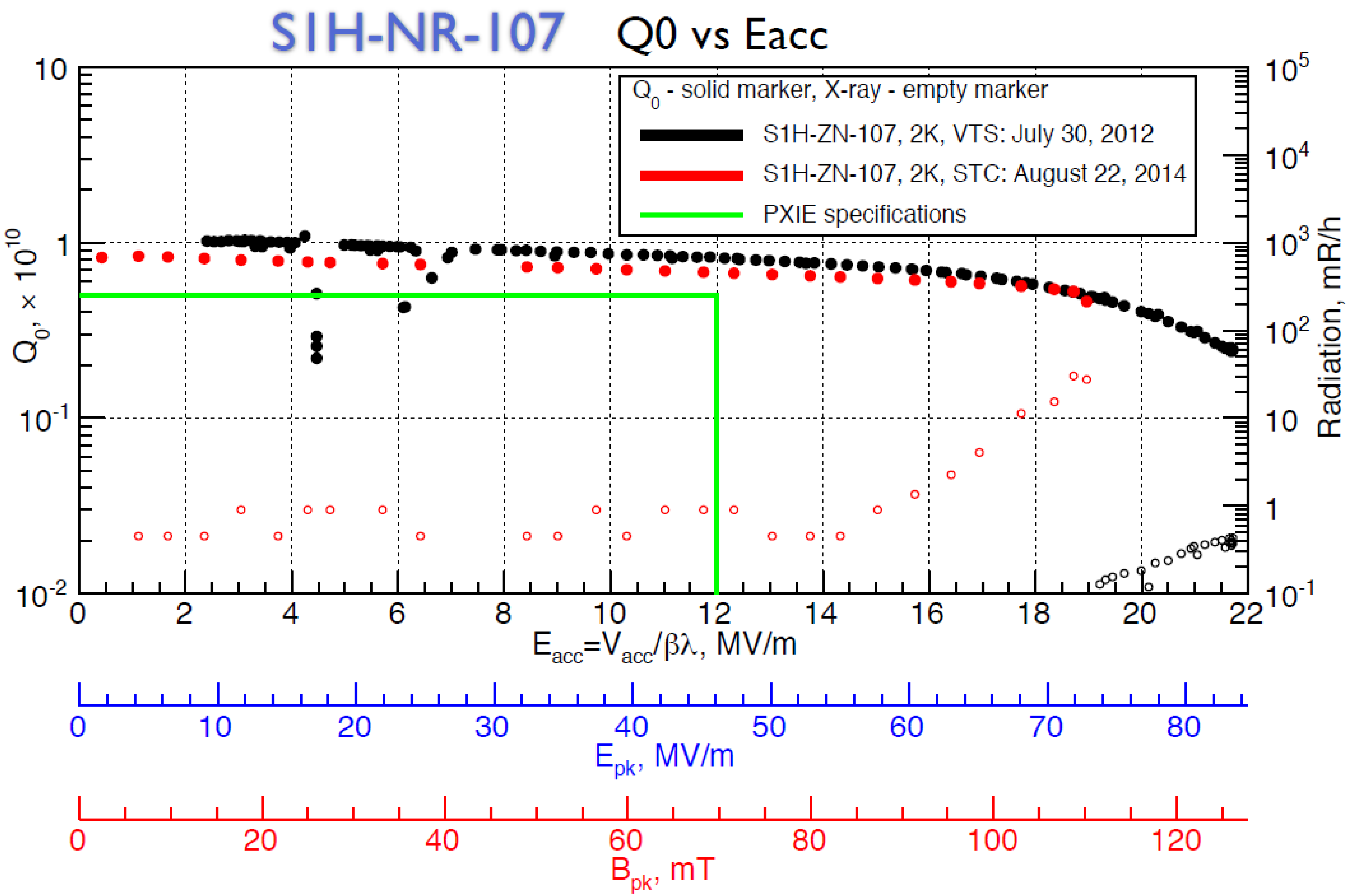
VTS cold test results at 2K



- 9 of 10 production cavities from U.S. Vendor are successfully tested
- Performance at 2 K is above requirements for Project X in both Q_0 and gradient

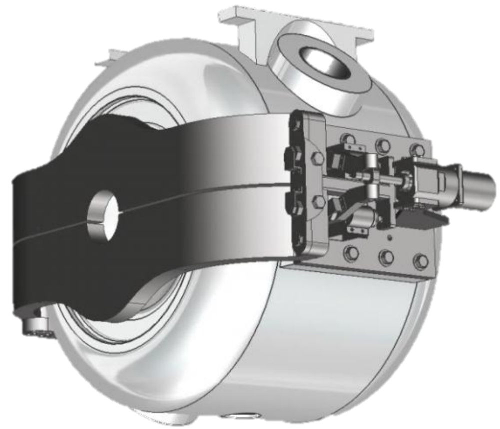
Superconducting cavities. SSR1.

STC cold test results

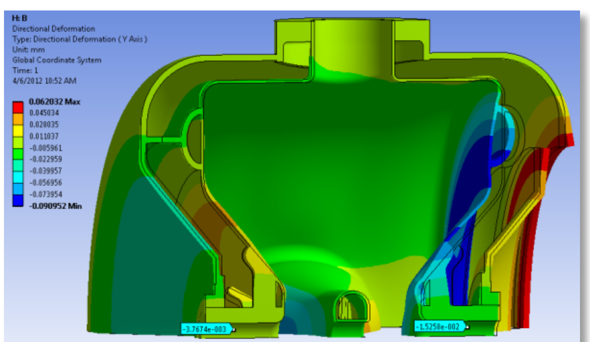


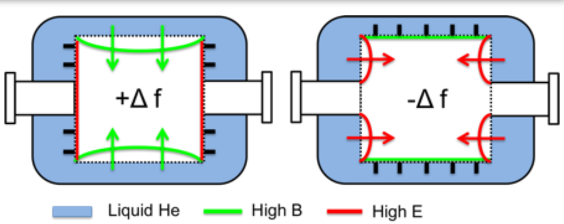
Superconducting cavities. SSR1.

SSR1 He Vessel and tuner

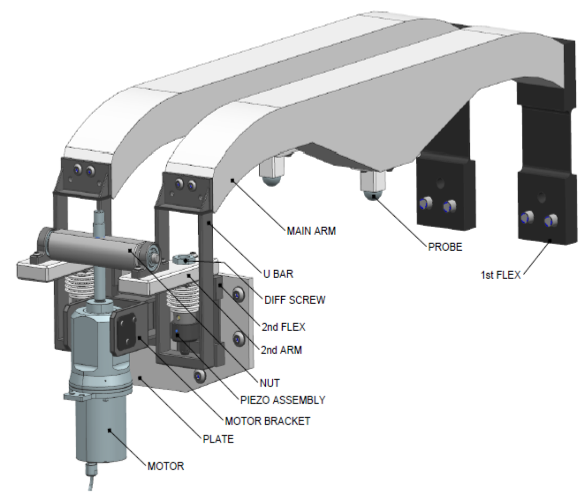


- Pressure of L_{He} can vary by ± 0.1 Torr in the cryomodule
- SSR1 must operate within a small bandwidth ± 20 Hz
- A self-compensating design was developed allowing low sensitivity
- Despite non-negligible deformations (see picture), net shift is very low
- Bare cavity ~ 600 Hz/Torr, with He vessel < <u>10 Hz/Torr (measured)</u>
- Ease of tuning 39 N/kHz (bare), 40 N/kHz (with He vessel)





Dressed SSR1



Actuating elements of the tuning system

Superconducting cavities. SSR1.

SSR1 coupler status

Results of coupler testing:

- **Couplers were testing with matching load at output (TW mode).**

Successfully tested at maximum available power ~7.5 kW, CW.
7 hours run was perfumed without any trip.
Multipactor was conditioned successfully in one day.

- **Coupler was tested with movable short at the output (SW mode).**

Couplers were tested at maximum available power ~ 7 kW.
Successfully tested with 5 positions of the short (step = 50mm).

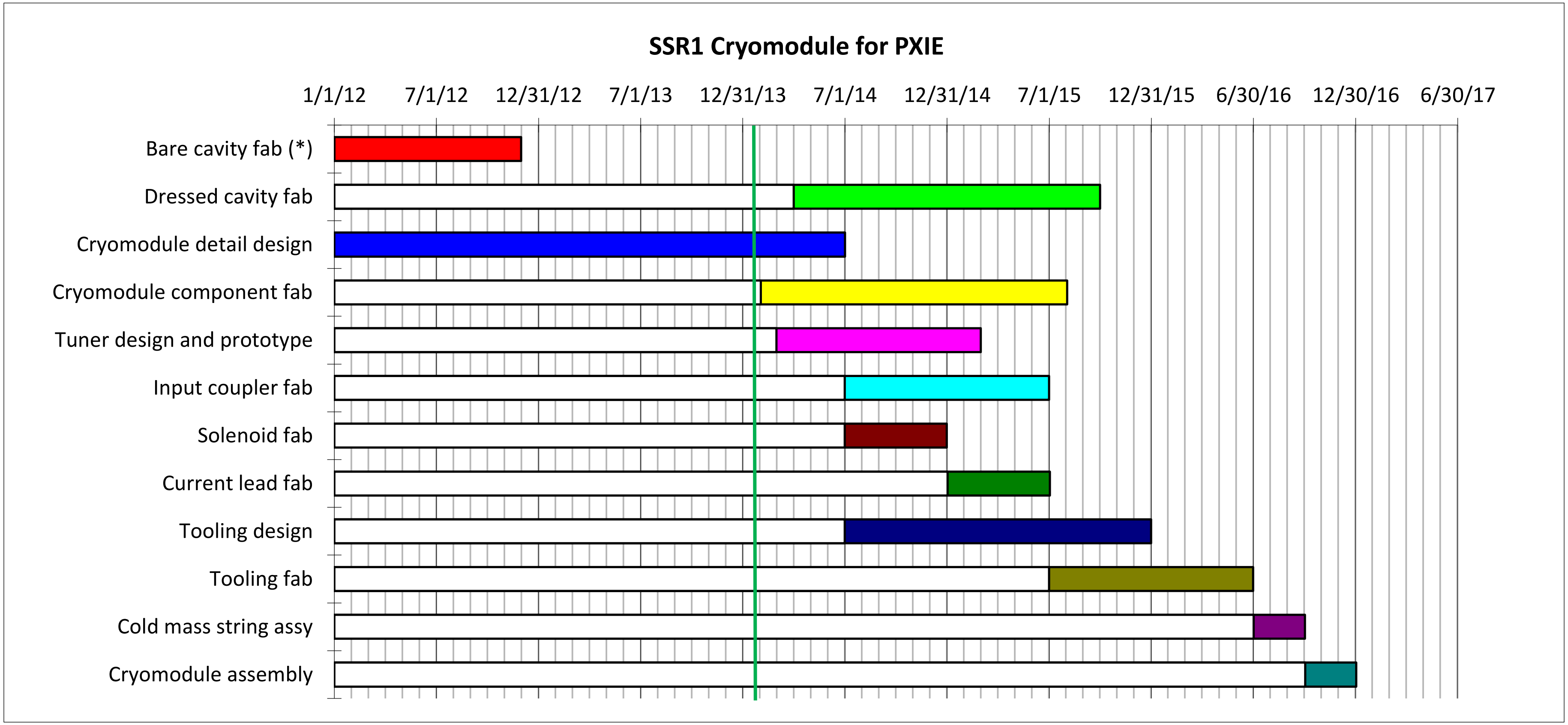
- **Coupler was tested with movable short and bias for multipactor suppression.**

It was pulse mode (cable limitations). Pulse was 0.5s, rep. rate 1 pps.
Pulse power – up to 7 kW. Bias + 1.5 kV successfully suppresses multipactor.
Couplers were tested with 11 positions of the movable short (step 50 mm).

Preparations for a cold test in STC with prototype cavity started

Superconducting cavities. SSR1.

SSR1 Schedule



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Superconducting cavities. SSR1.

Status of the SSR1 cavity design

- 10 SSR1 325 MHz, low-beta cavities are manufactured
- 9 of them are processed, tested and qualified, one SSR1 cavity is dressed
- New He vessel with reduced df/dP is designed, manufactured and tested
- Tuner design is in progress
- RF coupler design is completed, 3 prototype couplers are manufactured, 2 couplers are tested at operational power
- Design of the focusing solenoid is completed, the 1st solenoid is manufactured and is tested
- Concept design of the CM is ready, main parts (vacuum vessel, strong back and supports) are ordered

Superconducting cavities. SSR2.

SSR2 FRS EM Parameters

Parameter	Value
Frequency	325 MHz
Shape	Single Spoke Resonator
β_o	0.47
$L_{eff} = 2*(\beta_o\lambda/2)$	434.8 mm
Iris Aperture	40 mm
Inside diameter	560.8 mm
Bandwidth	54 Hz (2 mA)
E_{pk}/E_{acc}	3.45(*)
B_{pk}/E_{acc}	6.2(*) mT/(MV/m)
G	112.98(*) Ω
R/Q(*)	290(*) Ω

(*) *Actual Design Parameters*

Superconducting cavities. SSR2.

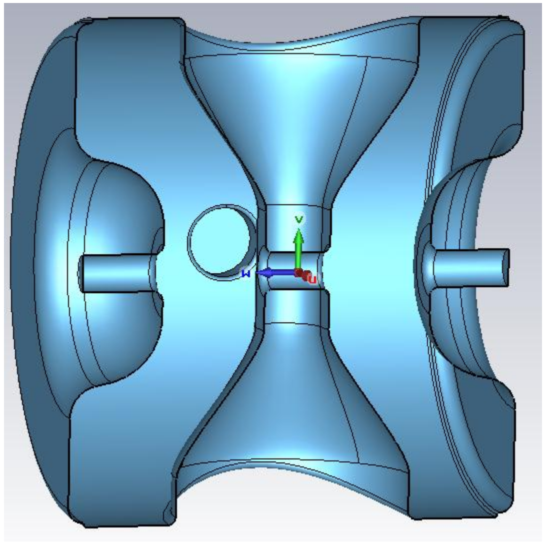
Cavity operational/test requirements

Parameter	Value
Max Leak Rate (room temp)	< 10^{-10} atm-cc/sec
Operating gain per cavity	5 MeV
Q_0	> 8 x 10^9
Maximum power dissipation per cavity at 2 K	13(*) W
Sensitivity to He pressure fluctuations (when jacketed)	< 20Hz/mbar
Field Flatness	Better than 90%
Multipacting	None within ±10% of operating gradient
Operating temperature	1.8-2.1 K
Operating Pressure	16-41 mbar differential
MAWP	2 bar (RT), 4 bar (2K)
RF power input per cavity	17 kW (CW, 2 mA)

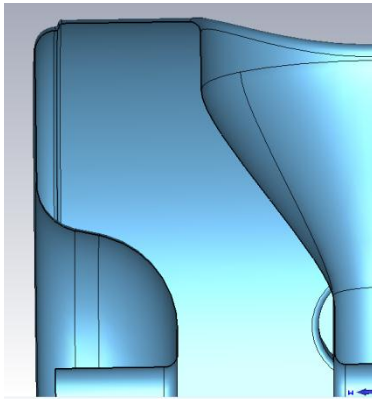
Superconducting cavities. SSR2.

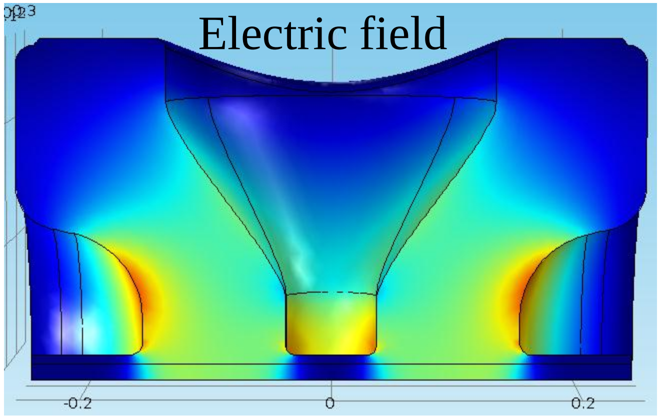
New SSR2 for PIP-II by Paolo Berrutti

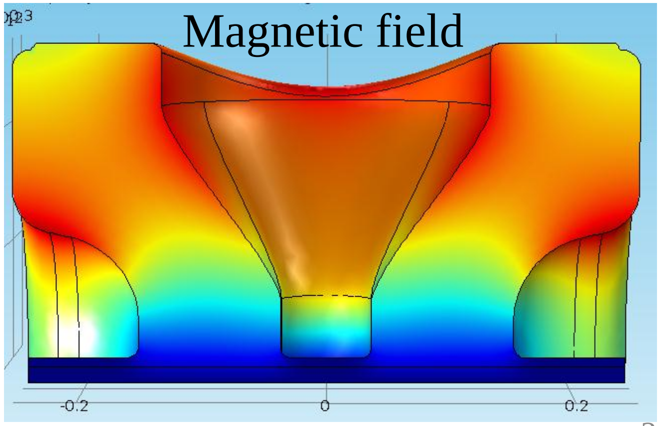
- SSR2 has been redesigned in 2010 since beta went from 0.4 to 0.47.
- Then it was re-optimized to meet RISP needs (beta=0.51).
- Beta optimal is now 0.47 and MP needs to be mitigated.
- Geometry has been remodeled to mitigate MP
- EM parameters look satisfying
- MP study still ongoing to finalize results
- New cavity EM designed completed and shown on the right



SSR2 has now a flat end-wall profile, the old version was round.
To avoid severe MP a ridge has been added on the wall-shell connection to modify the geometry in the area were MP was taking place at high gradient.





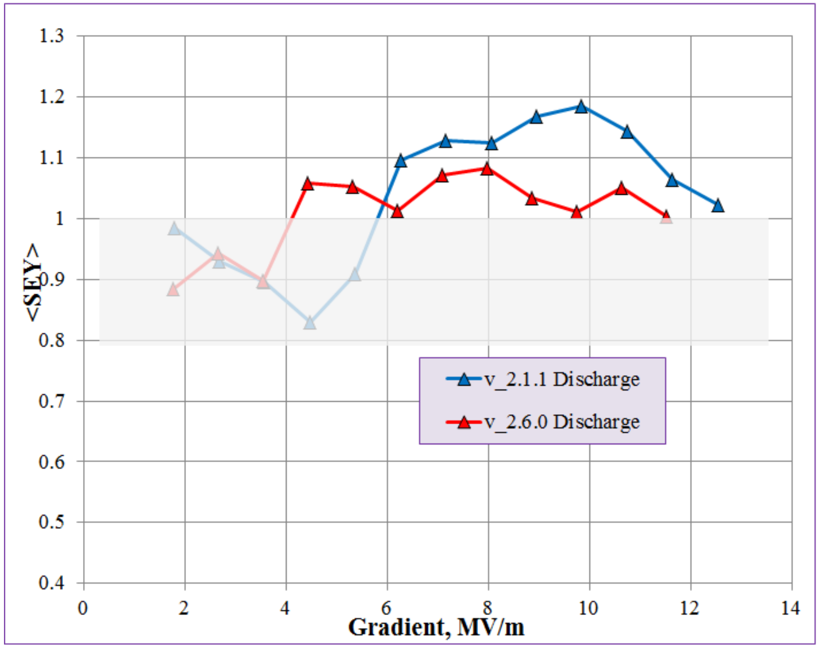


Superconducting cavities. SSR2.

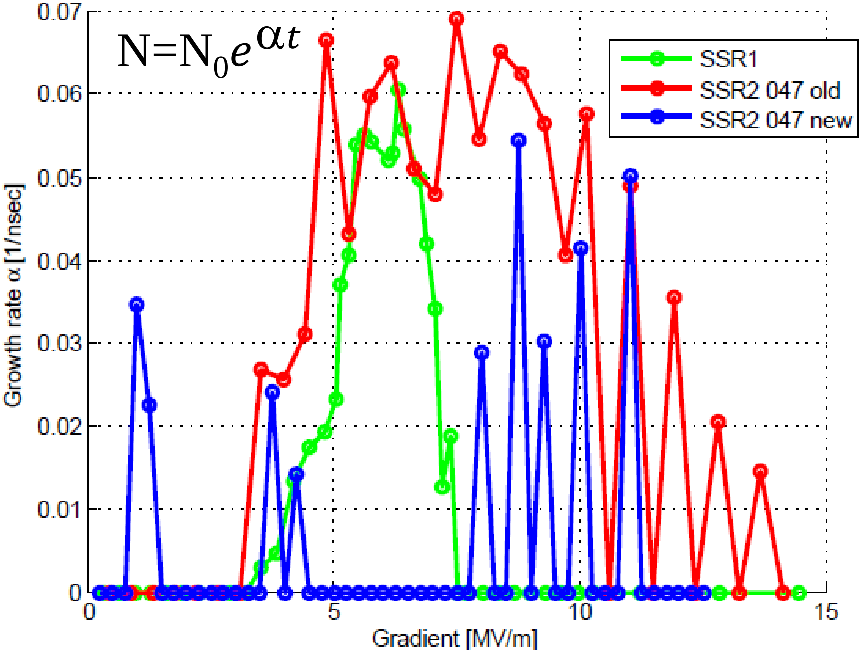
MP Simulations

- MP simulations are still ongoing, final results will be available shortly regarding the comparison between the two different CST solvers (PIC and Tracking)
- There is a good indication that the MP will be reduced, in the gradient range of operation, using the new design.

CST PIC by Gennady



CST Tracking by Paolo



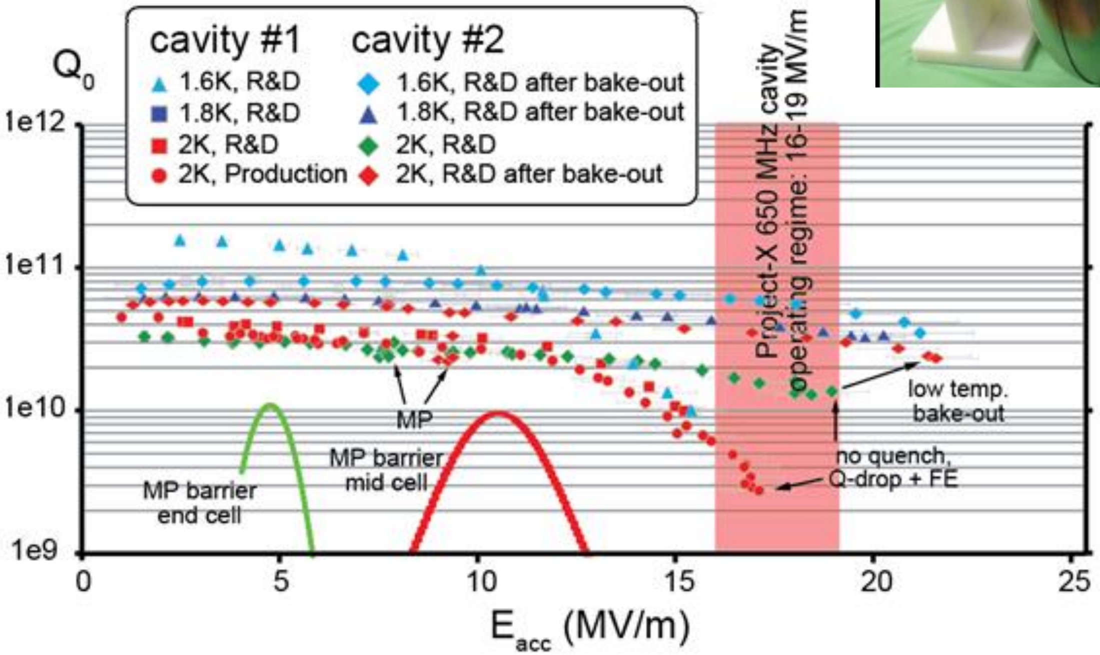
Superconducting cavities. Low β 650 MHz.

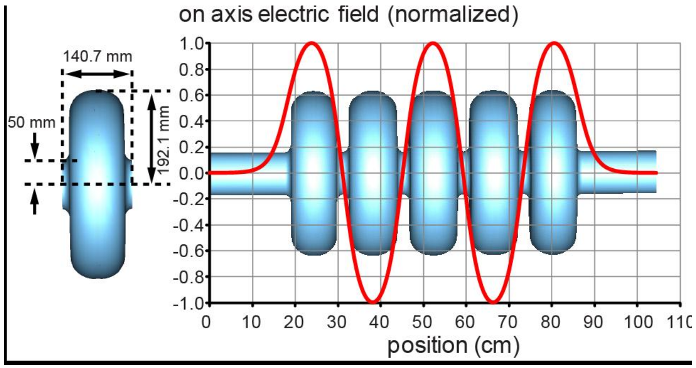
Cavity operational and test requirements

Parameter	Value
Max Leak Rate (room temp)	< 10^{-10} atm-cc/sec
Operating gradient	16.5 MeV/m
Maximum Gain per cavity	11.6 MeV
Q_0	>1.5x 10^9
Maximum power dissipation per cavity at 2 K	24 W
Sensitivity to He pressure fluctuations	< 20 Hz/Torr
Field Flatness	Within ±10%
Multipacting	none within ±10% of operating gradient
Operating temperature	1.8-2.1 K
Operating Pressure	16-41 mbar differential
MAWP	2 bar (RT), 4 bar (2K)
Max RF power input per cavity	33 kW (CW, 2 mA)

Superconducting cavities. Low β 650 MHz.

JLAB 1-cell 650 MHz, beta=0.61 cavity





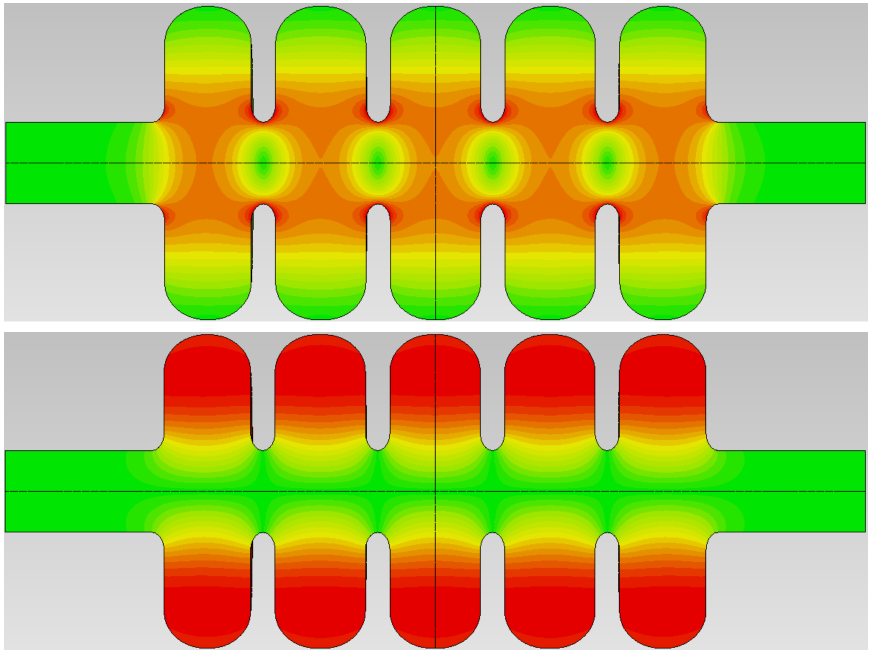
For the cavity #2

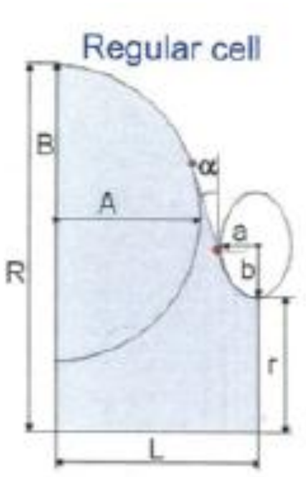
Q_0 >4e10 @17MeV/m

We have 6 more single cell cavities manufactured in RI:
3 JLAB design and 3 FNAL design

Superconducting cavities. Low β 650 MHz.

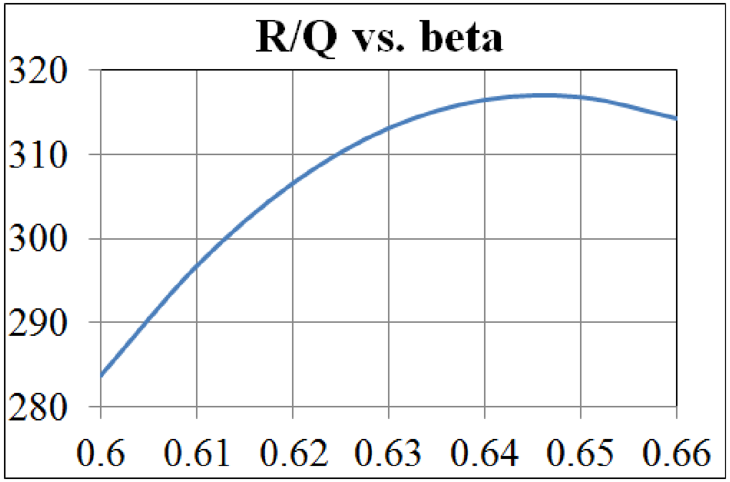
JLAB 650 MHz, beta=0.61, 5 –cell





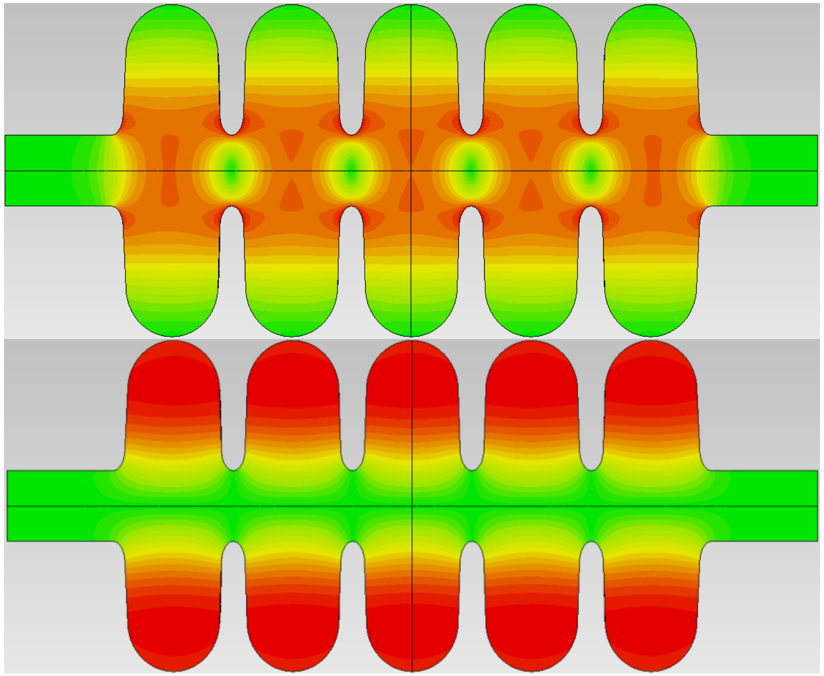
r, mm	50
R, mm	
L, mm	65.62
A, mm	50.46
B, mm	45
a, mm	15
b, mm	22
α,°	0

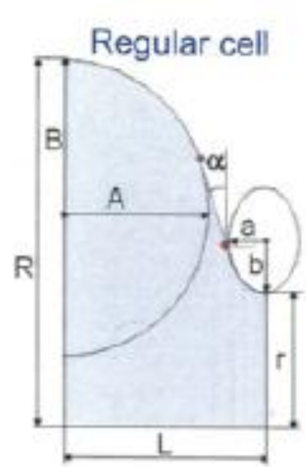
F, MHz	650.00	
Beta	0.61 (g)	0.645(o)
Leff, 5βgλ/2,m	0.703	
R/Q, Ohm	296	317
G, Ohm	190	
Epeak/Eacc	2.73	2.64
Bpeak/Eacc	4.79	4.63



Superconducting cavities. Low β 650 MHz.

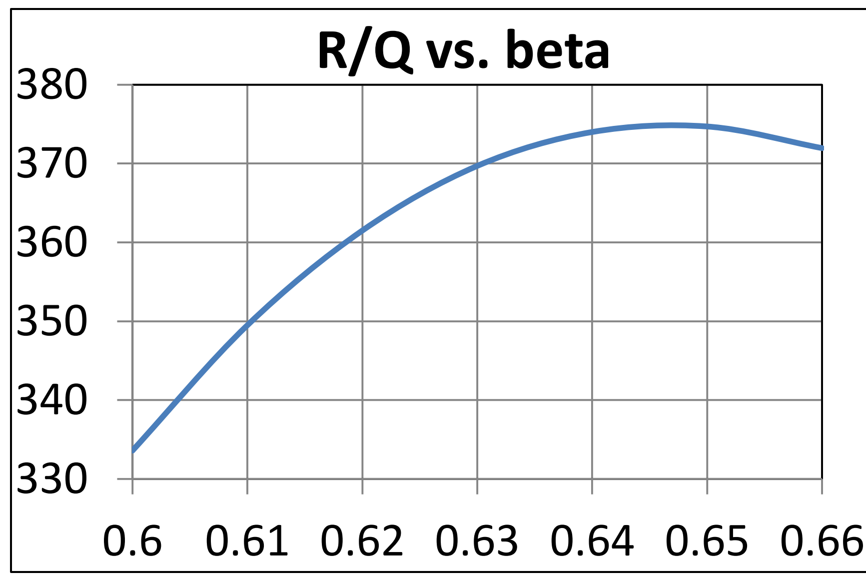
FNAL 650 MHz, beta=0.61, 5 –cell





r, mm	41.5
R, mm	195
L, mm	70.3
A, mm	54
B, mm	58
a, mm	14
b, mm	25
α,°	2

F, MHz	650.00	
Beta	0.61 (g)	0.647(o)
Leff, 5$\beta_g\lambda$/2,m	0.703	
R/Q, Ohm	350.7	375.4
G, Ohm	191	
Epeak/Eacc	2.34	2.26
Bpeak/Eacc	4.36	4.21



Superconducting cavities. Low β 650 MHz.

LB 650 status

- EM design of both LB 650 versions, JLAB and FNAL, are ready
- Four single-cell cavities LB 650 JLAB and three LB 650 FNAL are manufactured
- Two LB 650 JLAB cavities are processed and tested
- We plan to test LB 650 FNAL cavities in order to make a choice between them and continue design

Superconducting cavities. High β 650 MHz.

HB 650 FRS EM Parameters

Parameter	**Value**
Frequency	650 MHz
Shape, number of cells	Elliptical, 5 cells
Geometric beta β_g	0.92
$L_{eff} = 5*(\beta_g\lambda/2)$	1060.8 mm
Iris Aperture	118 mm
Bandwidth	62 Hz (2 mA)
E_{peak} at operating gradient	< 36 MV/m
B_{peak} at operating gradient	< 68 mT
Cavity quality factor Q_0 at 2K	$> 2.0_{*}10^{10}$

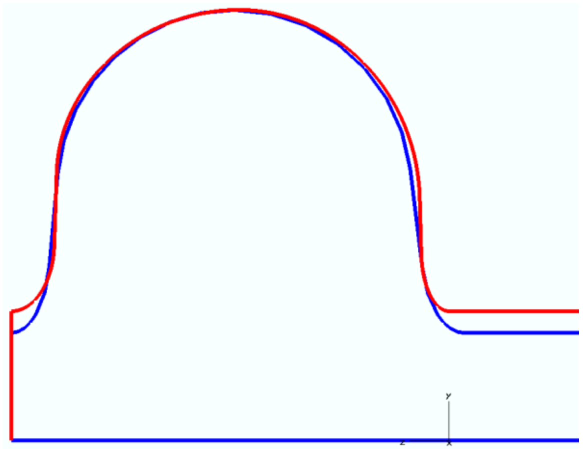
Superconducting cavities. High β 650 MHz.

Cavity operational and test requirements

Parameter	Value
Operating node	CW
Max Leak Rate (room temp)	$< 10^{-10}$ atm-cc/sec
Operating gain per cavity	17.7 MeV
Maximum Gain per cavity in VTS	> 21 MeV
Operating power dissipation per cavity at 2 K	< 25 W
Sensitivity to He pressure fluctuations	< 15 Hz/mbar (dressed cavity)
Field Flatness dressed cavity	> 90%
Operating temperature	2.0 K
Operating Pressure	30 mbar
MAWP	2 bar (RT), 4 bar (2K)
RF power input per cavity	50 kW (CW, 2 mA)
Cavity longitudinal stiffness	$< 10^{4}$ N/mm
Tuning sensitivity	> 180 kHz/mm

Superconducting cavities. High β 650 MHz.

Dimensions and main parameters of β= 0.9 & 0.92 Cavities



Regular half-cell | End half-cell

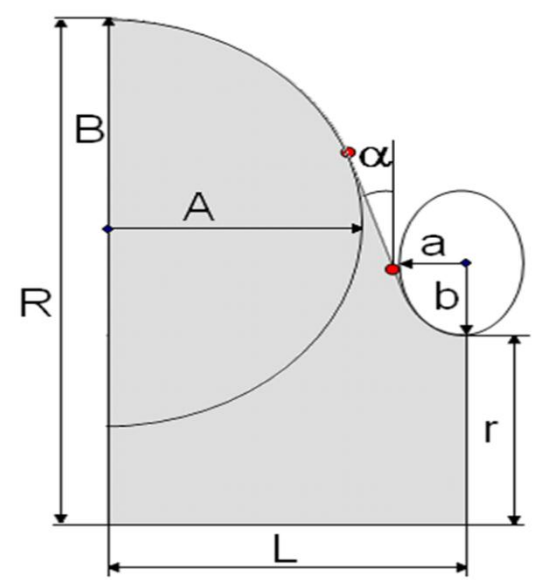
Quantity	Old	New
G, Ω	256	260
R_{sh}/Q_0 max, Ω	638	609
β_{opt}	0.95	0.97
E_{surf}/E_{acc}*	2.08	2.04
B_{surf}/E_{acc}*, mT/MV/m	3.81	3.85
K_{couple}, %	0.75	1.29
Monopole HOM Q_{ext}	10^{10}	10^{6}

Regular half-cell:

	OLD	NEW
r	**50**	**59**
R	200.3	200.052
L	103.8	106.08
A	82.5	85
B	84	78
a	18	20
b	38	33
α	**5.2°**	**1.9°**

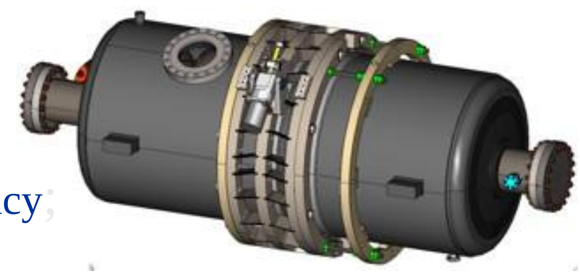
End half-cell:

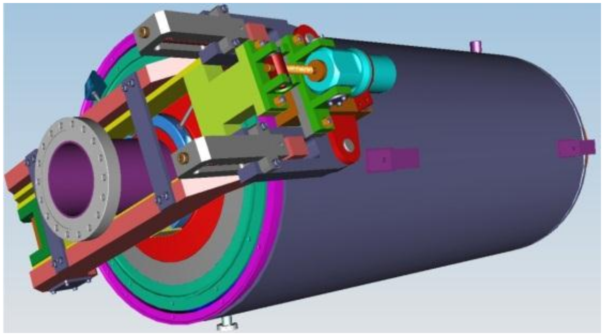
	OLD	NEW
r	**50**	**59**
R	200.3	200.052
L	107	97.555
A	82.5	84
B	84.5	90
a	20	13
b	39.5	28
α	**7°**	**1.3°**



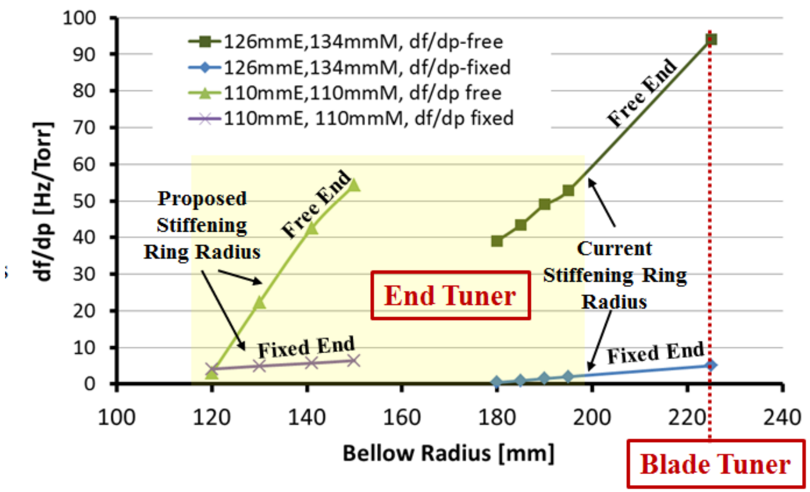
Superconducting cavities. High β 650 MHz.

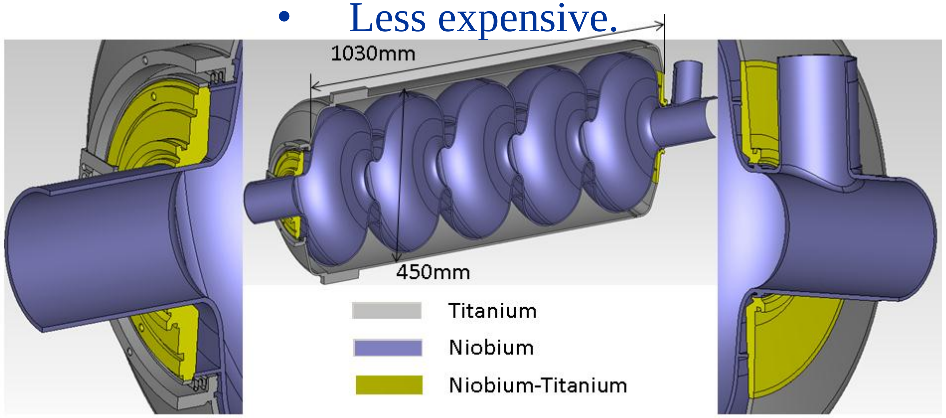
Blade Tuner – scaled ILC:
- High df/dP
- Insufficient tuning efficiency;





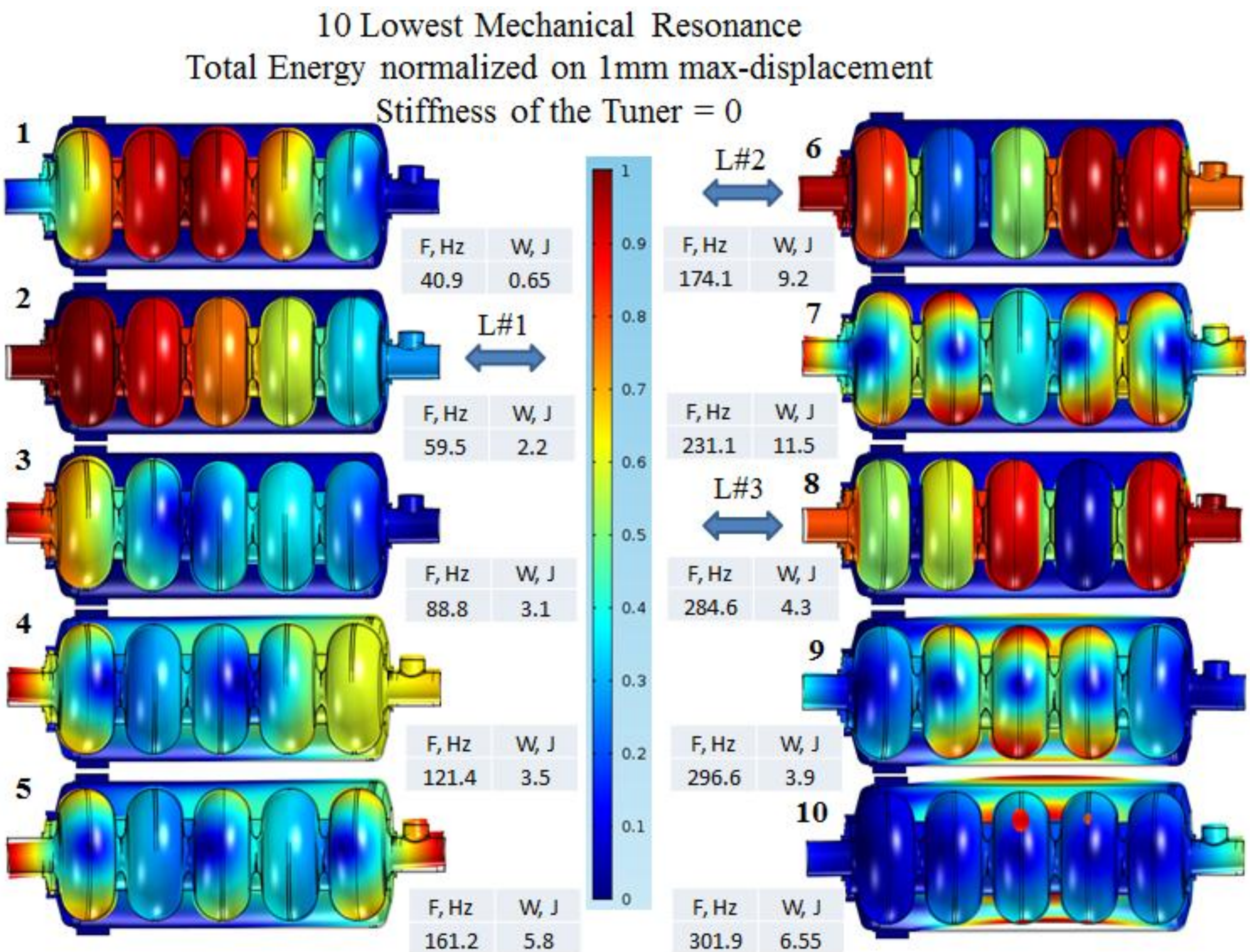
New End Tuner design:
- Low df/dP,
- Mechanical resonance s > 60 Hz;
- Good tunability;
- Less expensive.



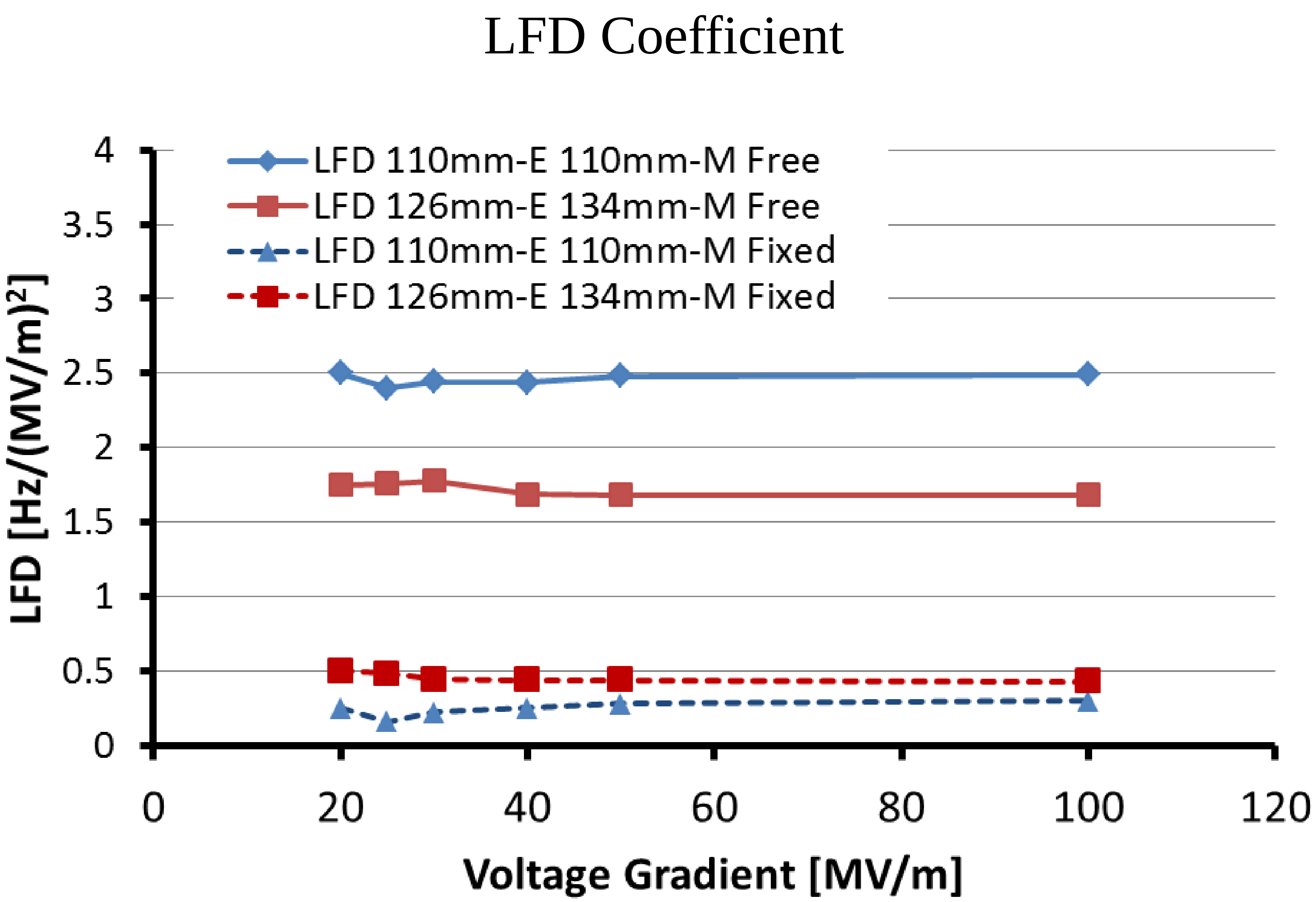


Stiffening rings located to minimize df/dP while maintaining tunability

Superconducting cavities. High β 650 MHz.



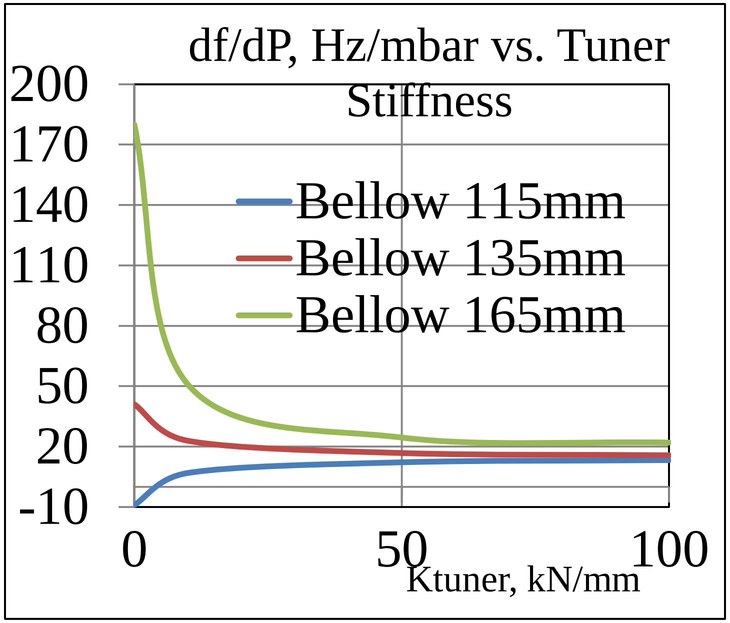
Superconducting cavities. High β 650 MHz.

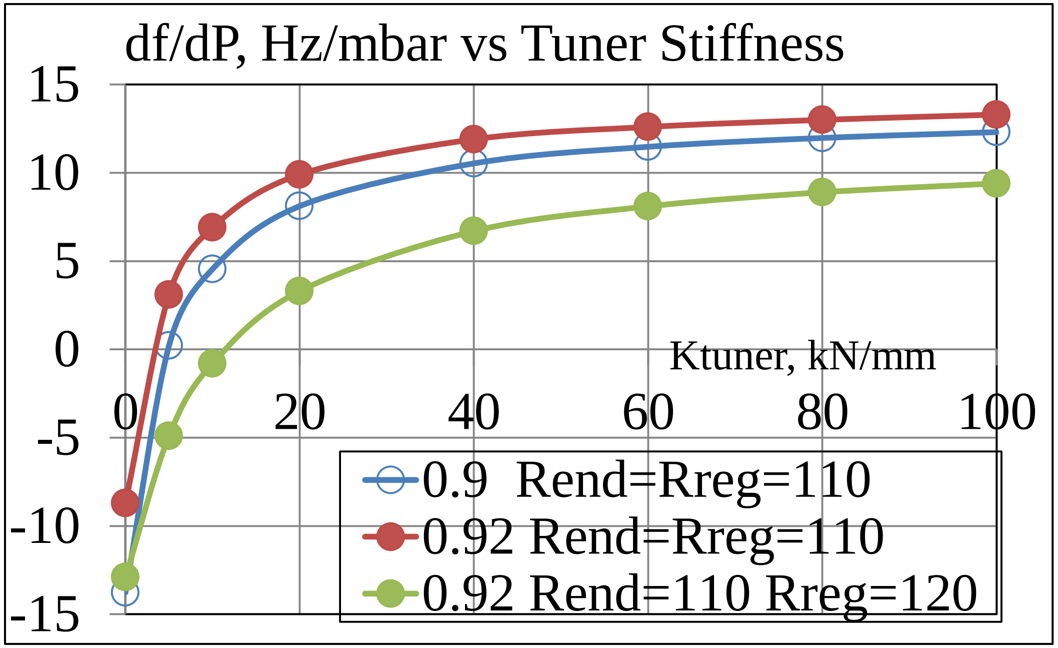


*Leff=n*βλ/2=1.03846153846 m

Superconducting cavities. High β 650 MHz.

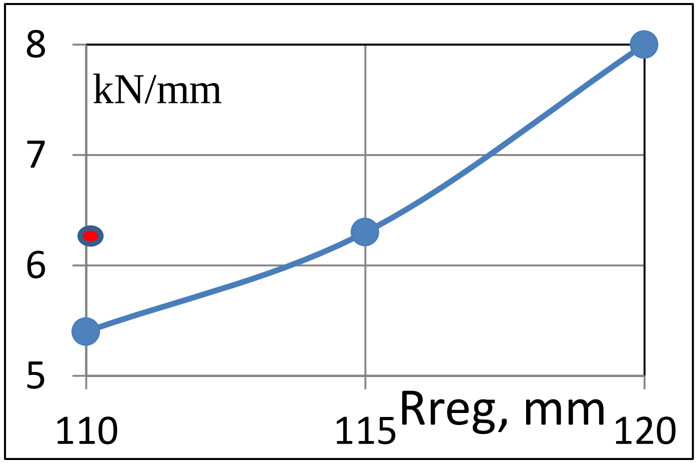
df/dP vs. Tuner Stiffness





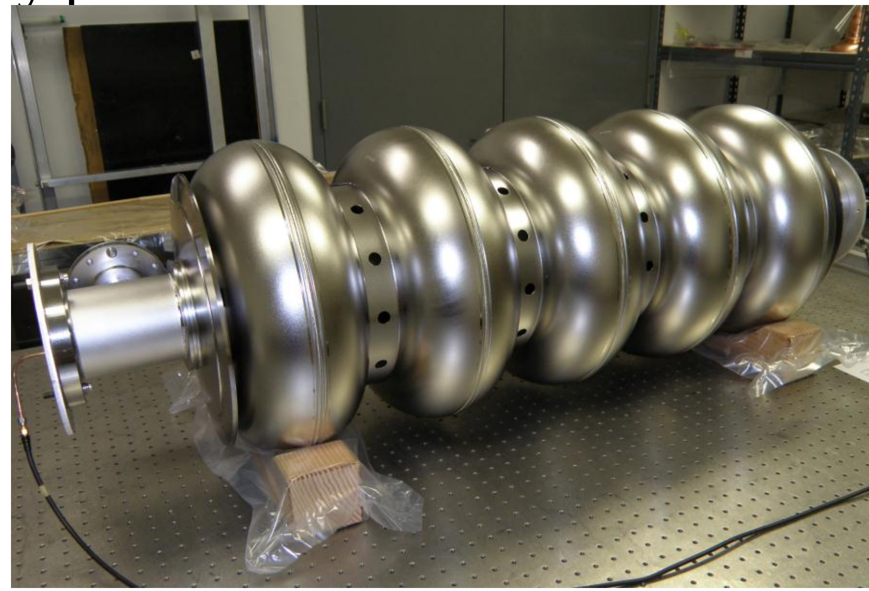
Stiffness of β=0.92 cavity kN/mm vs. Radius of the Regular stiffening ring

- Stiffness of β=0.9 cavity



Superconducting cavities. High β 650 MHz.

HB 650 MHz cavity production status



Currently Available Cavities:

<u>1-Cell 650 MHz</u>

1. B9AS-AES-001*
2. B9AS-AES-002*
3. B9AS-AES-003
4. B9AS-AES-004
5. B9AS-AES-005
6. B9AS-AES-006
7. B9AS-RRCAT-301 *

<u>5-Cell 650 MHz</u>

1. B9A-AES-007
2. B9A-AES-008
3. B9A-AES-009
4. B9A-AES-010

*VTS Tested

Expected Cavities:

<u>1-Cell 650 MHz</u>

Pavac, Inc.

Four delivered and two to be delivered late spring 2014.

<u>5-Cell 650 MHz</u>

Pavac, Inc.

Five to be delivered later 2014.

Summary

1. RFQ under production , delivery spring 2015.
2. Bunching cavity prototype under production , delivery end of 2014. Three more will be ordered later based on tests of prototype.
3. 1st HWR dressed cavity manufactured and successfully tested at ANL. Other cavities are under production.
4. 9 SSR1 production cavities qualified in VTS. One cavity dressed and successfully tested. Prototype couplers are manufactured tested. Tuner production in progress.
5. SSR2 design is in progress. Main issue is multipactor. Low LFD in critical for the pulsed operation. We need to finish with SSR2 design and start with prototype production.
6. LB 650 cavity design is ready in two versions. Need to finish cold tests of both types of single cells and start with design of Helium Vessel with low df/dP and LFD.
7. HB 650 cavity design is in better shape. Four old design cavities manufactured and need to be tested. New design of the dressed 5-cell cavity is complete.