Completion of the first SSR1 cavity for PXIE

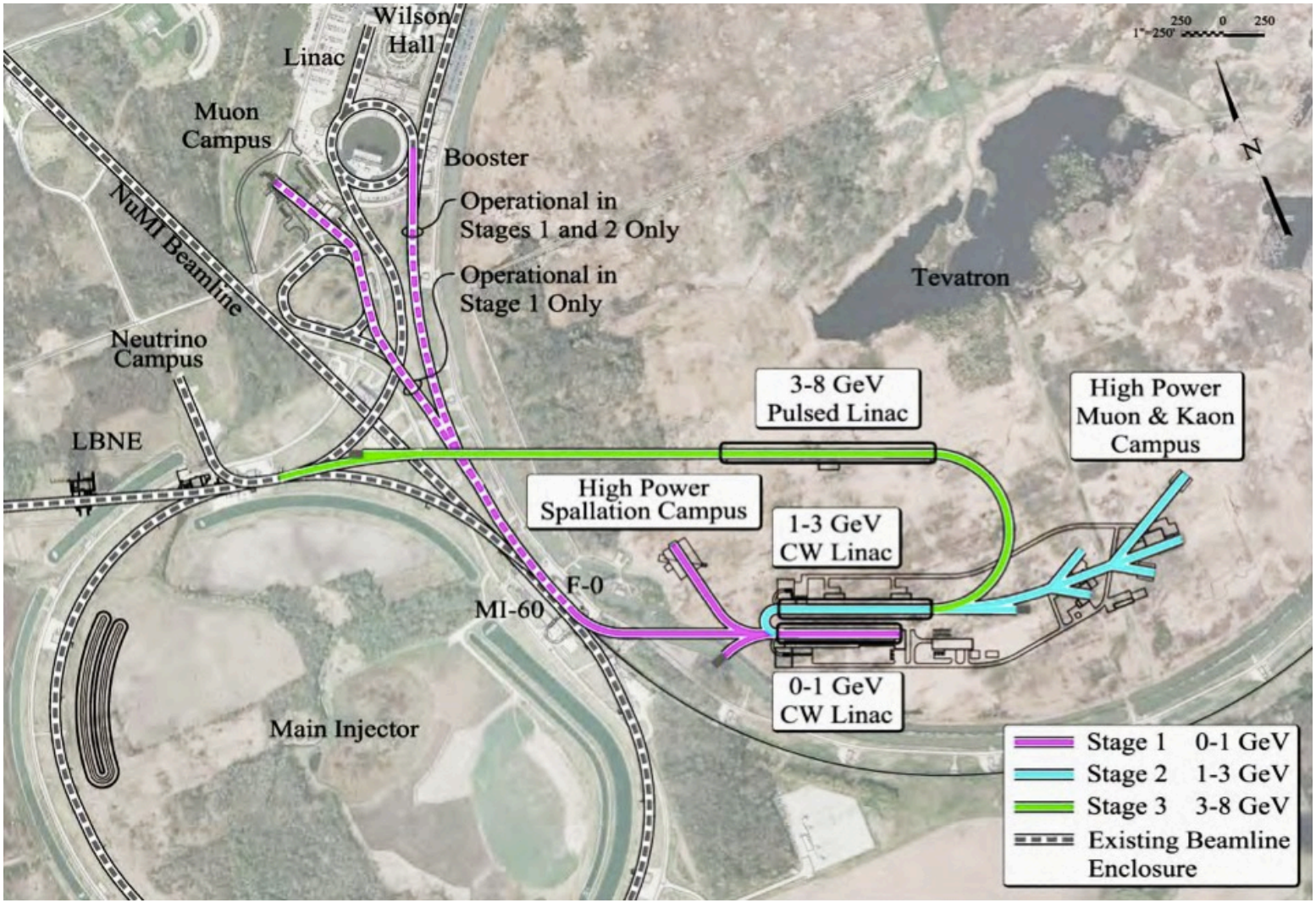
Design, Manufacturing and Qualification

Leonardo Ristori

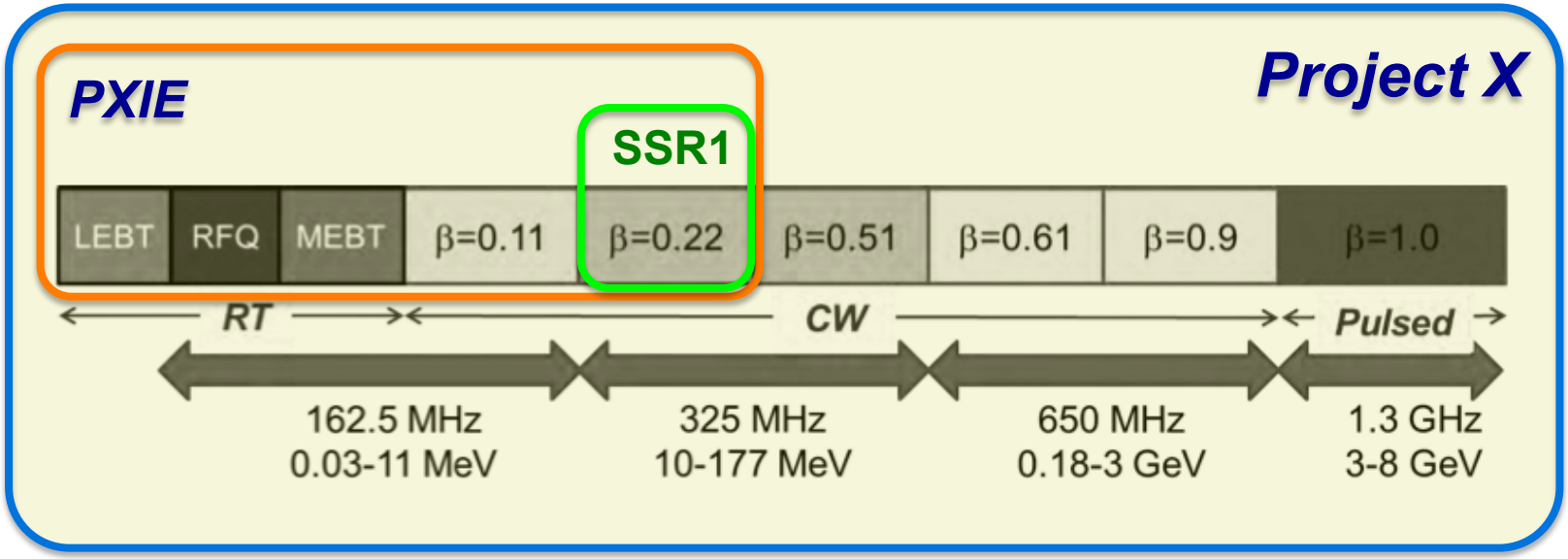
on behalf of the

Fermilab SRF Development Group

Project X at Fermilab

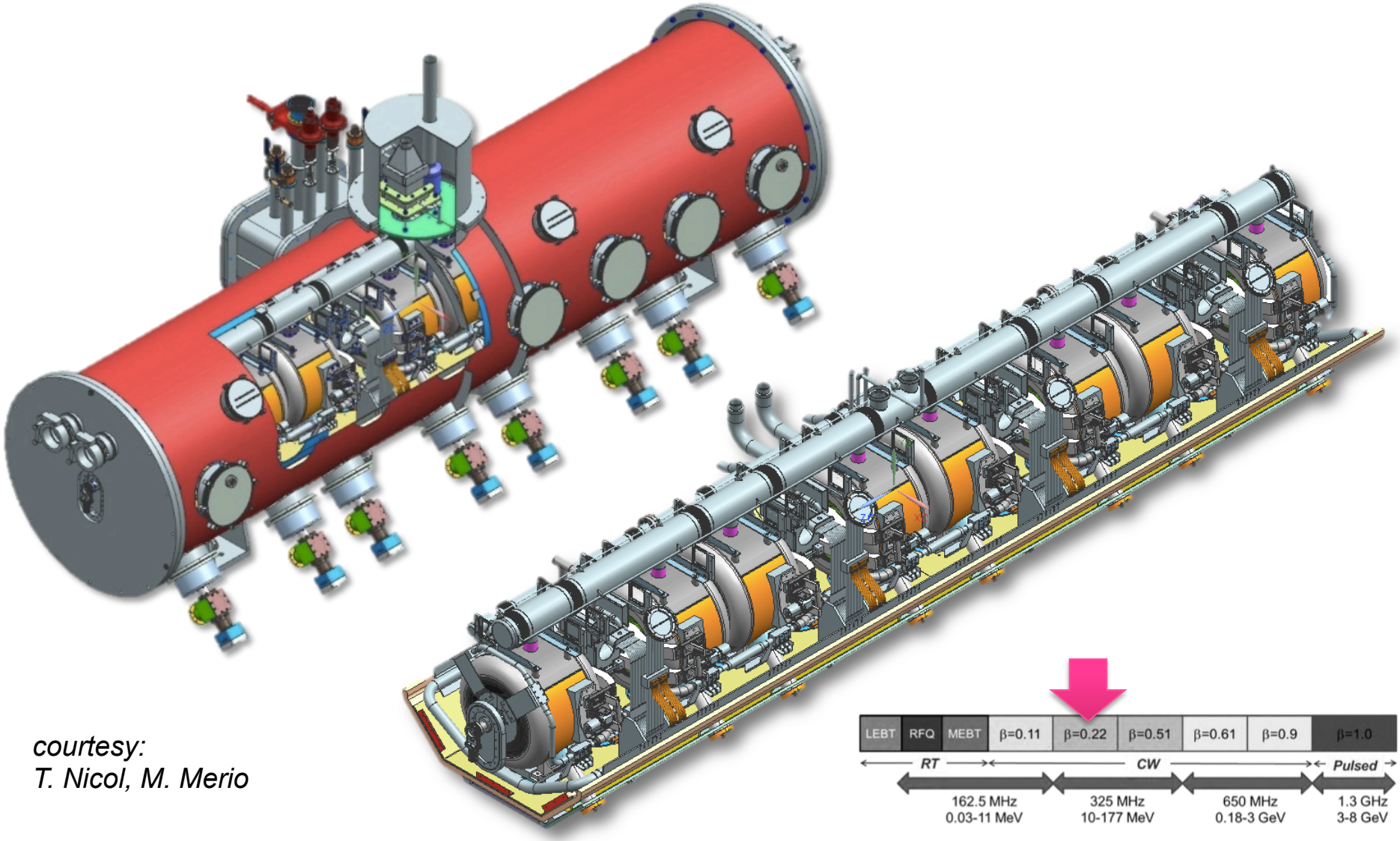


Project X and PXIE



The *Project X Injector Experiment (PXIE)* facility is under construction at Fermilab and will serve in the next years as a test bench for key components of Project X to reduce risk
One cryomodule with 8 ***SSR1*** resonators is part of PXIE

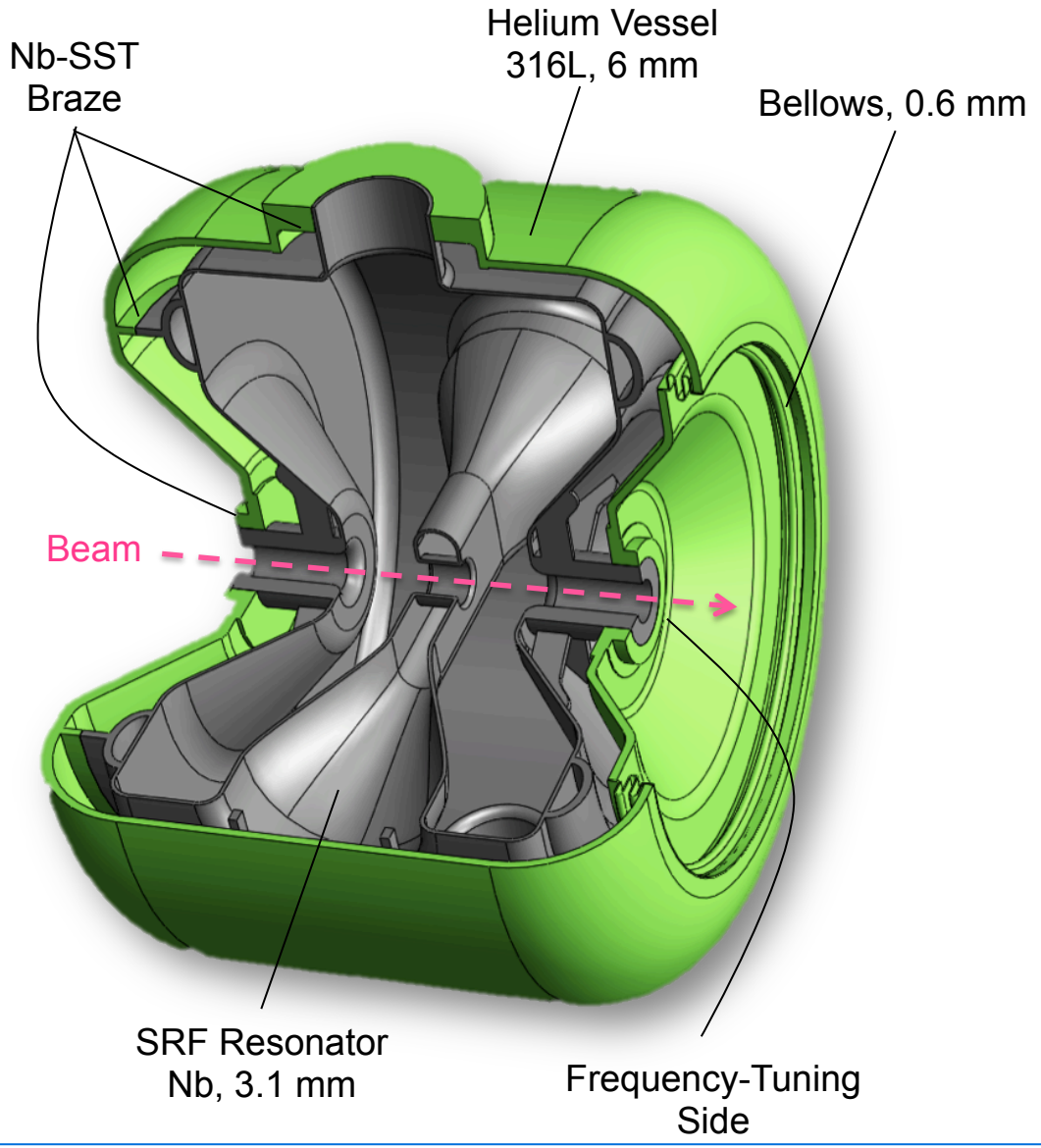
SSR1 Cryomodule



courtesy:
T. Nicol, M. Merio

SSR1 – 325 MHz, 2K

	SSR1
β	0.222
E_p/E_{acc}	3.84
B_p/E_{acc}	5.81 mT/(MV/m)
Aperture	30 mm
Diameter	492 mm
L_{EFF} (βλ)	205 mm
G	84 Ω
R/Q	242 Ω
Oper. Gradient	12 MV/m
Q_0 at E_{acc}	> 0.5 10^{10}
Operating B_{MAX}	70 mT
Operating E_{MAX}	46 MV/m
Tuning constant	40 N/kHz
Sensitivity	< 25 Hz/torr
P (RT, CT)	2 bar, 4 bar



Sensitivity to He pressure variations

Pressure of L_{He} can vary by ± 0.5 Torr in the cryomodule

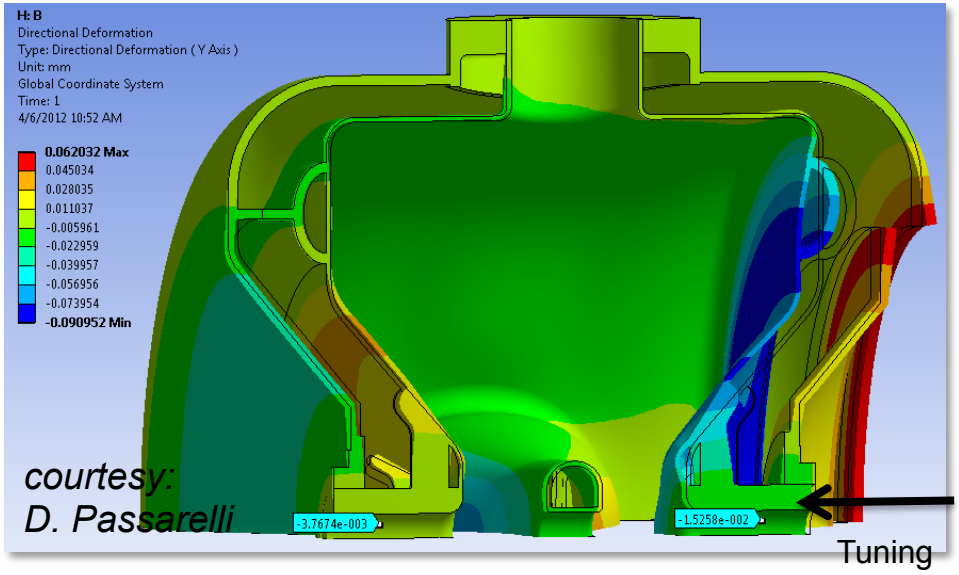
SSR1 must operate within a small bandwidth ± 20 Hz

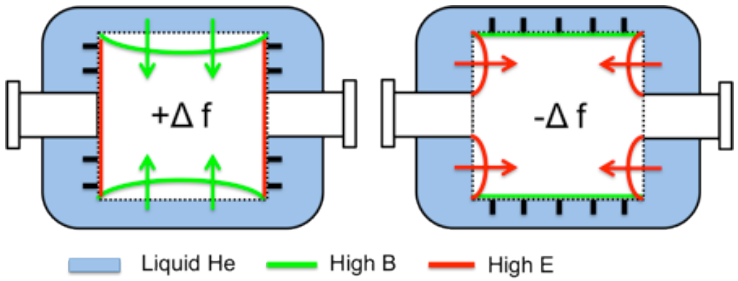
A self-compensating design was developed allowing low sensitivity

Despite non-negligible deformations (see picture), net shift is very low thanks to Slater's Theorem

Bare cavity ~ 600 Hz/Torr, with He vessel ~ 10 Hz/torr

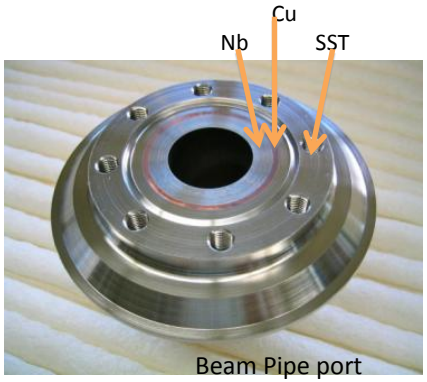
Ease of tuning 39 N/kHz (bare), 40 N/kHz (with He vessel)





- Deformations in high E and B regions balance out resulting in a small frequency shift (Slater's Theorem)

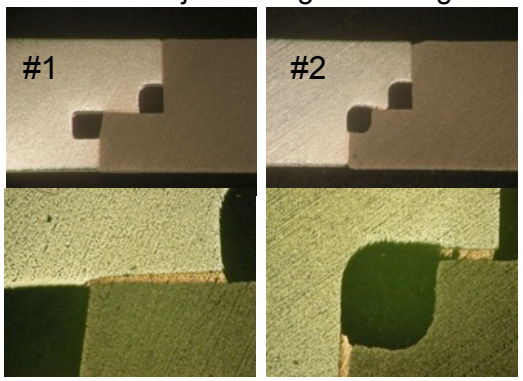
SSR1 Fabrication (Niowave, Roark)



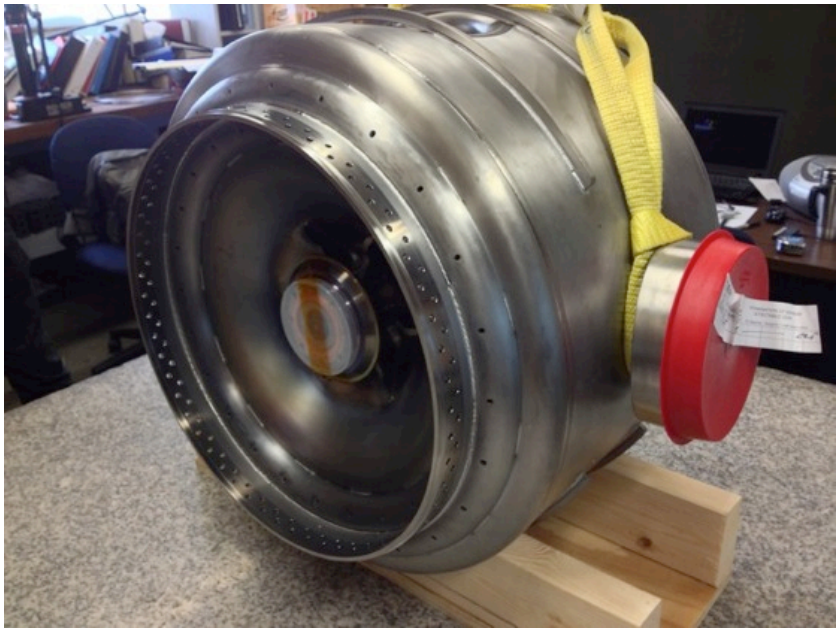
10 SSR1 resonators manufactured in US industry

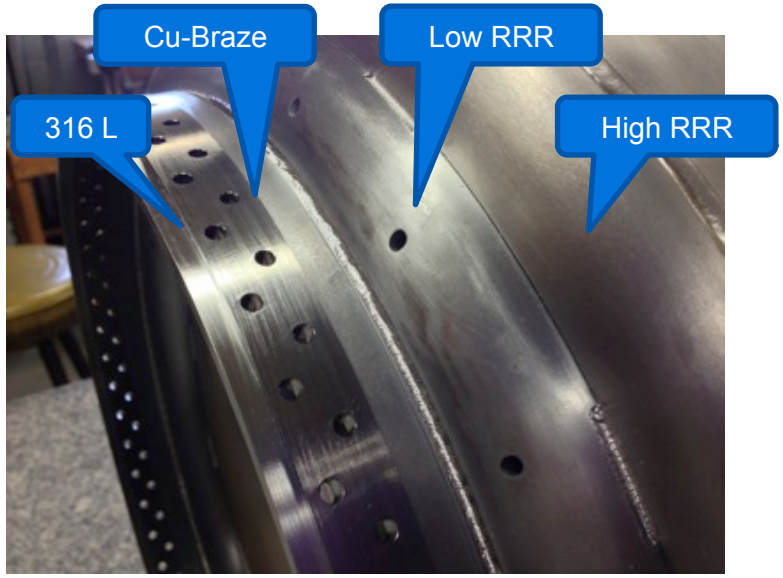
Brazed transition rings (ANL, Roark)

Two different joint designs investigated



courtesy:
W. Toter (ANL)

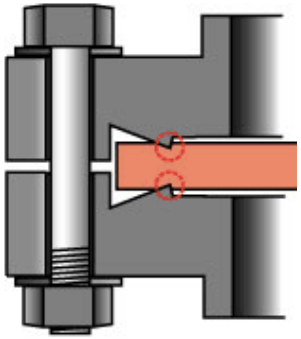




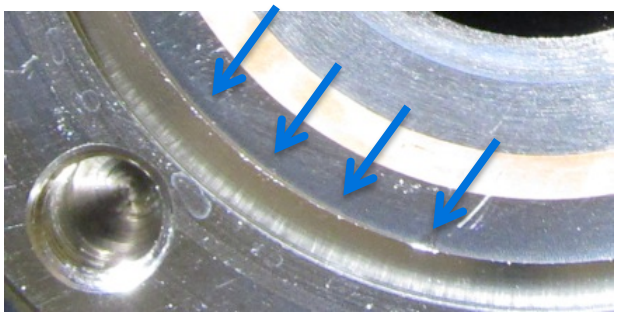
Issues: Vacuum Flanges

- SSR1 uses ConFlat-type flanges
- Sealing unreliable/non-repeatable
  - Rough Machining, Damages
- Generators of Cu-particulates
  - “serrated” knife edges able to peel copper pieces from gasket when disassembled
- Will adopt hex-shaped aluminum seal
  - this seal is widely used in SRF field
  - simple machining of flange, easy to repair

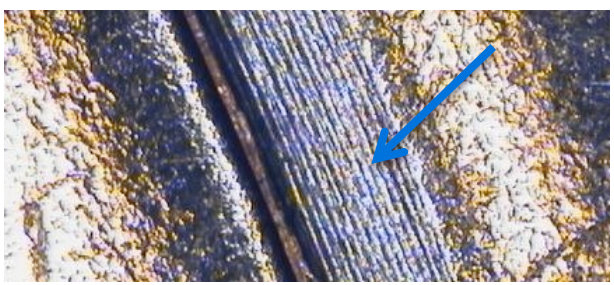
courtesy:
A. Rowe, C. Crawford



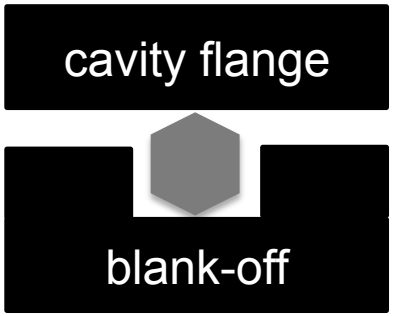
ConFlat-type vacuum seal



Magnification of a knife edge showing extensive damage



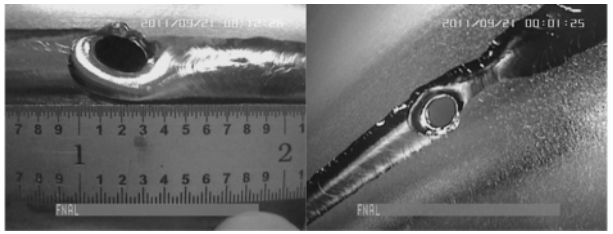
Magnification of a copper gasket after disassembly. The imprint left by the knife edge shows rough machining grooves.



Aluminum Hex Seal

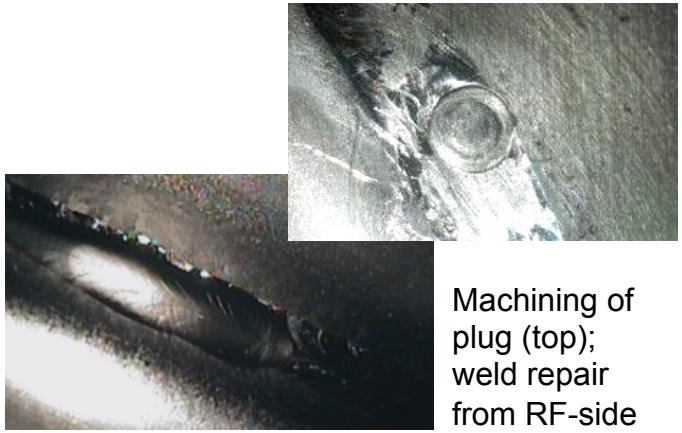
Issues: Electron-Beam welding

- Weld blow-throughs observed in 4 resonators
  - no signs of machine faults or power supply issues
- Extensive studies lead to abatment of events
- New process parameters developed.
- Cause attributed to weld bead instability
  - A thinner bead, faster feed-rate and extreme attention to alignment of parts eliminated occurrences in the last 4 cavities.
- Repairs performed meticulously, cavities tested successfully



Typical holes on full-penetration welds

Extensive EBW tests on Nb cylinders

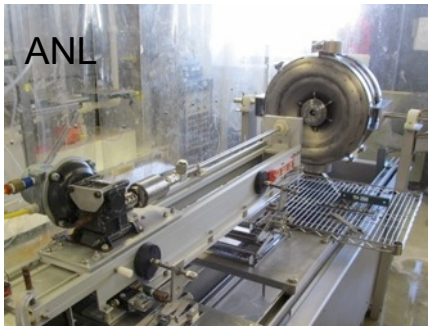


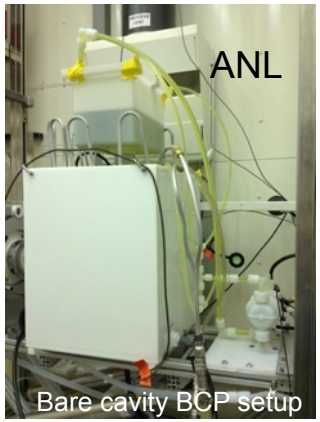
Machining of plug (top); weld repair from RF-side

Processing/Testing steps (ANL, FNAL)

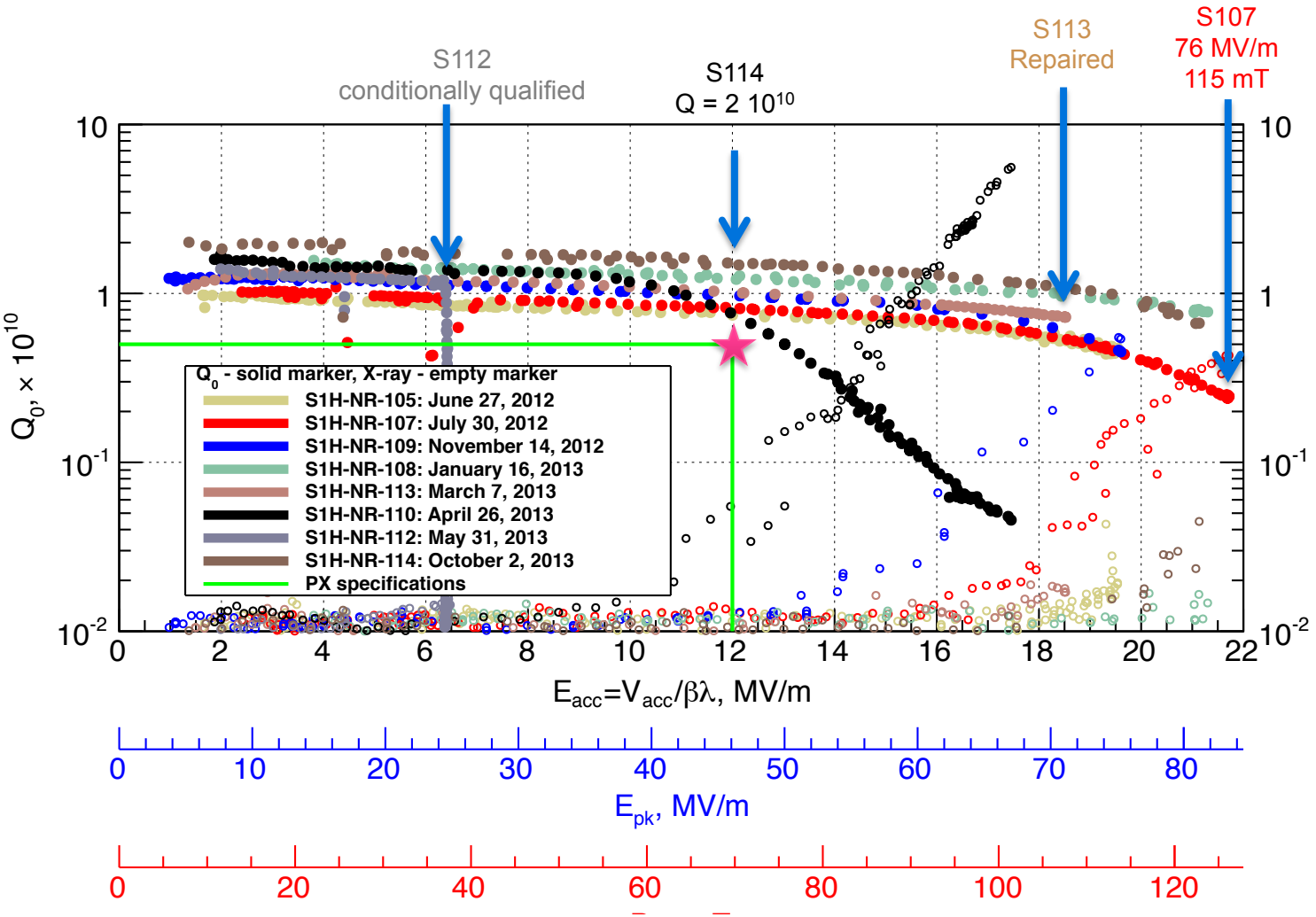
1. Inspection – RF & Optical
2. BCP 120-150 μm (flip half-way)
3. HPR
4. 600 °C, 10 h (< 5°C/min ramp rate)
5. RF Tuning
6. BCP 20-30 μm
7. HPR (horiz + vert)
8. Assemble
9. Evacuate + 120 °C, 48 h
10. Vertical Test
11. Helium Vessel Dressing
12. HPR
13. BCP 20-30 μm
14. HPR
13. Assemble
14. Evacuate + 120 °C, 48 h
15. Horizontal Test
16. Ready for String

courtesy: A. Rowe



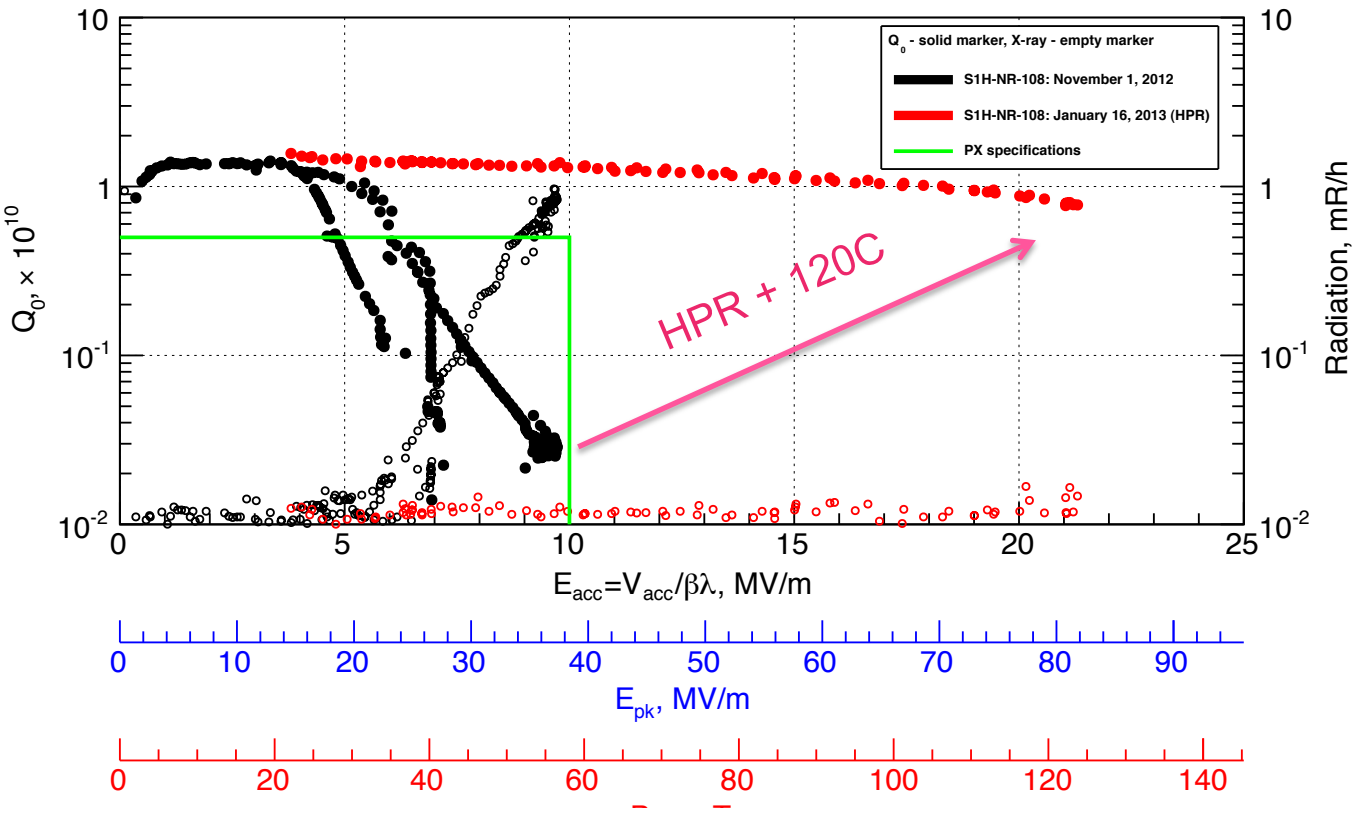


VTS Qualification – 8 qualified



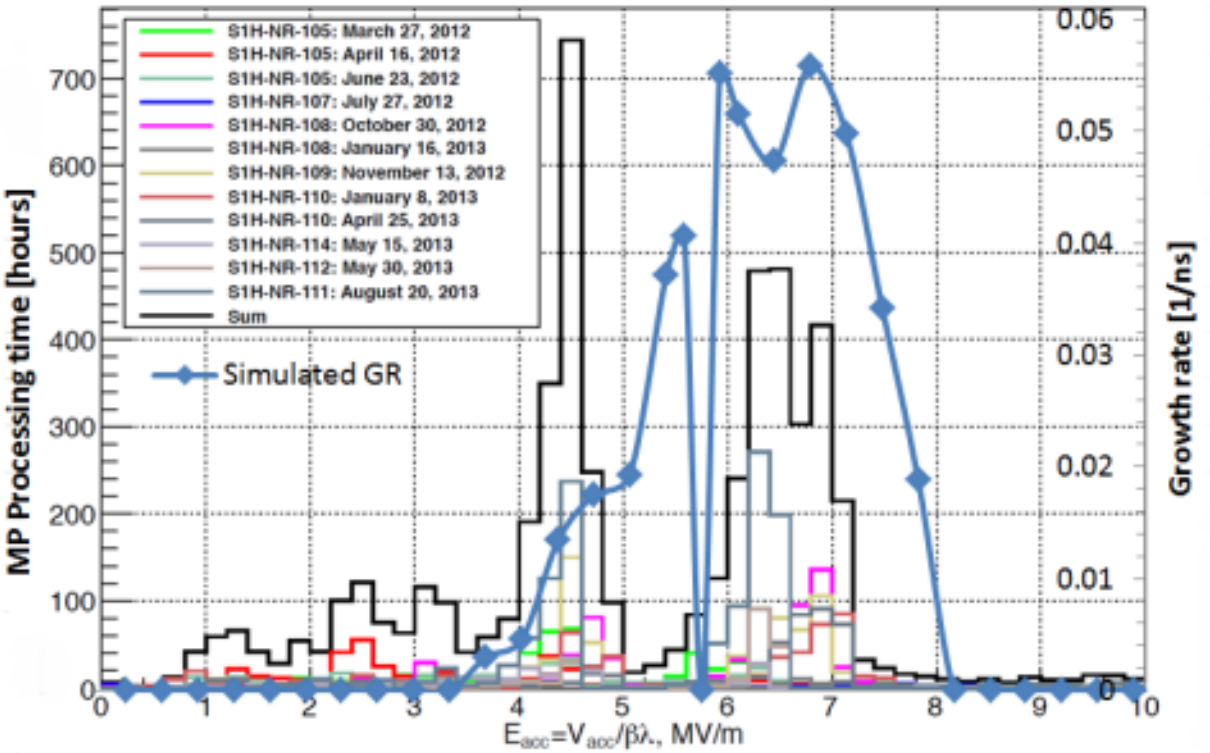
courtesy:
A. Sukhanov

Example of S108 – 1st and 2nd pass



courtesy:
A. Sukhanov

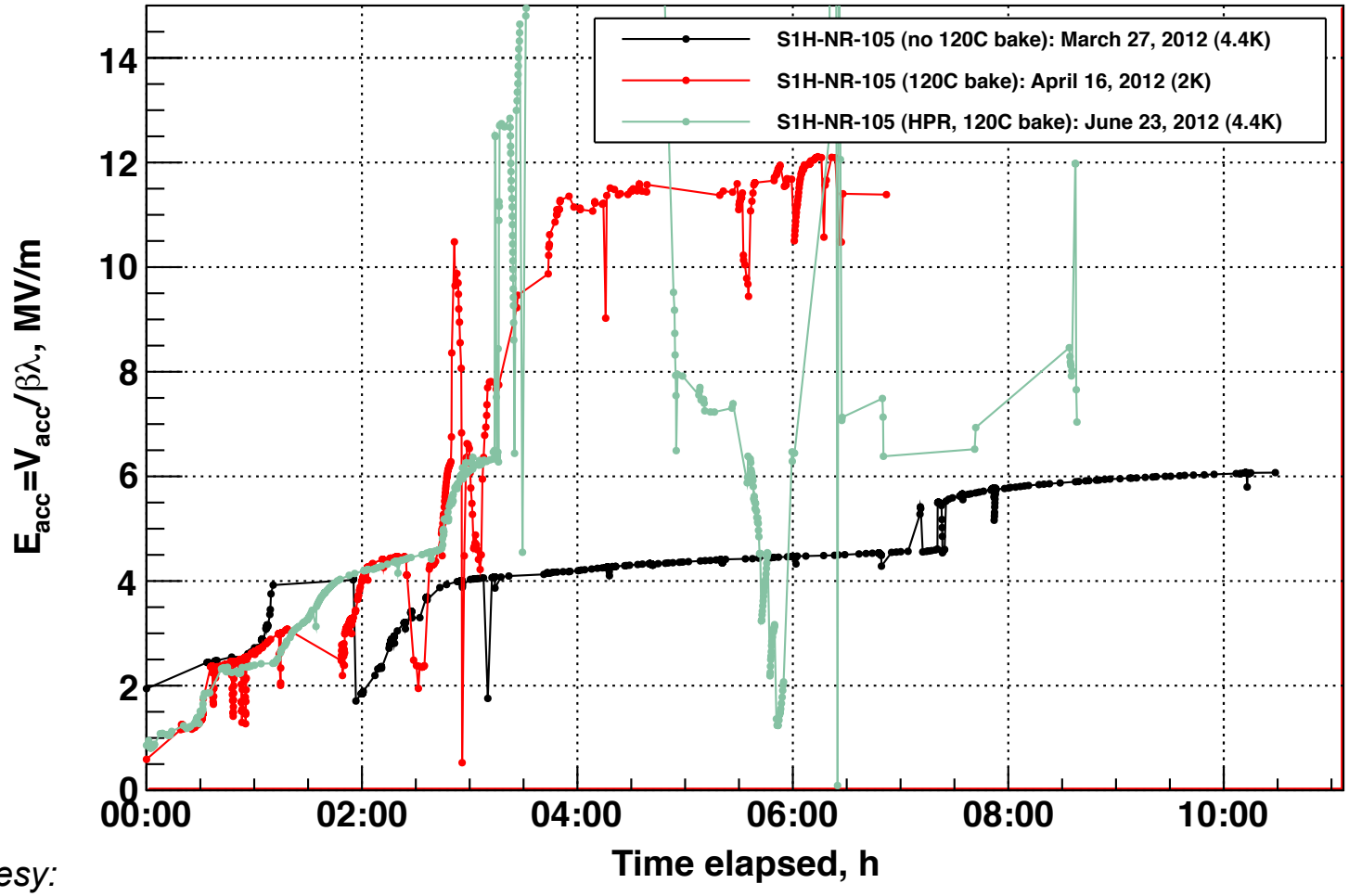
Issues - Multipacting Barriers



Two multipacting barriers have been experienced at 4-5 MV/m and 6-7 MV/m
Multipacting simulations are in fair agreement with measurements

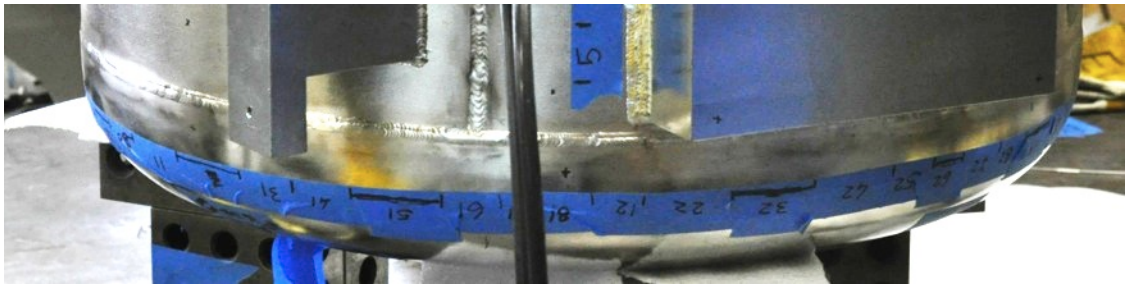
courtesy:
A. Sukhanov

Multipacting Processing vs. 120C Bake

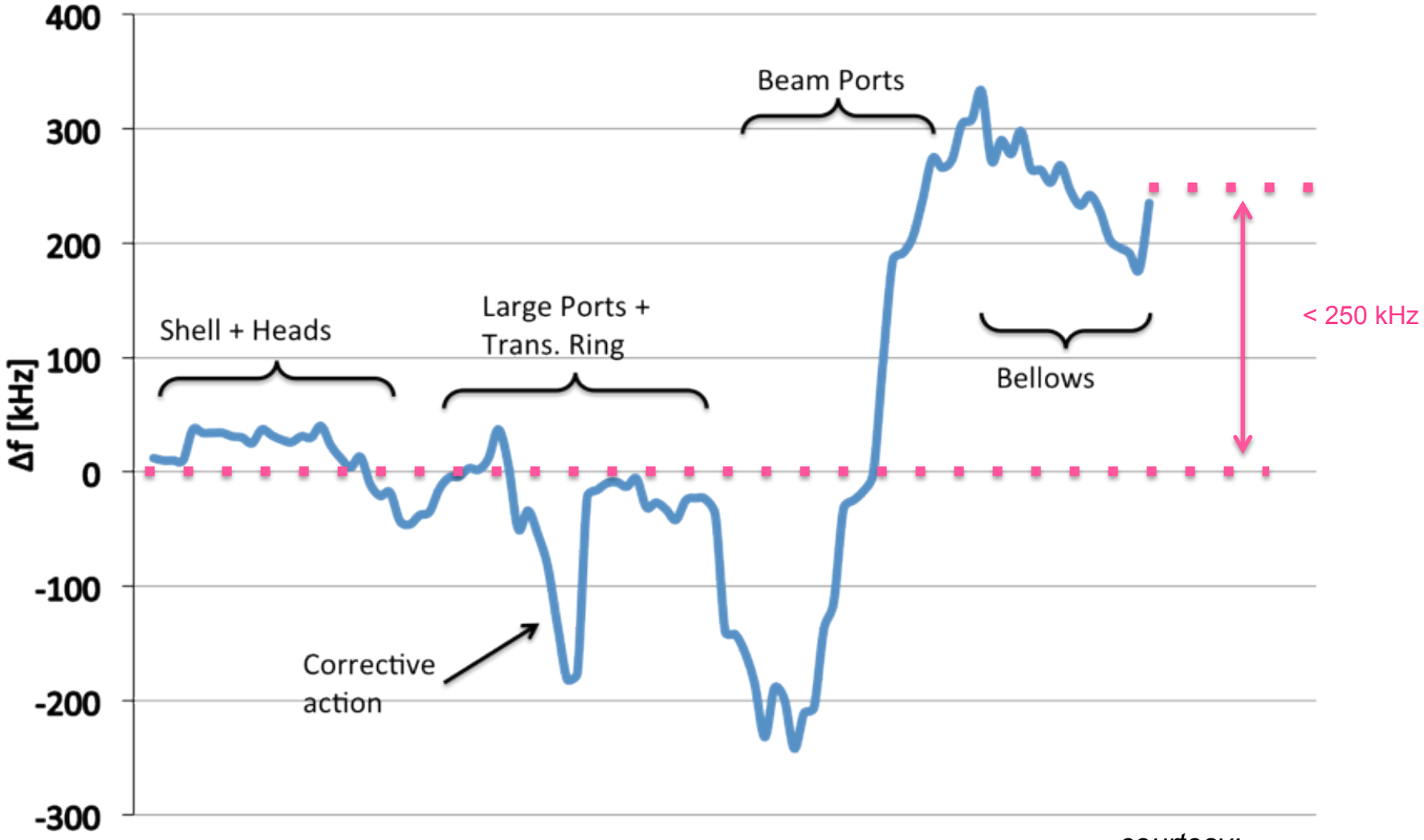


courtesy:
A. Sukhanov

Jacketing Operations (Meyer Tool)



Shifts caused by jacketing

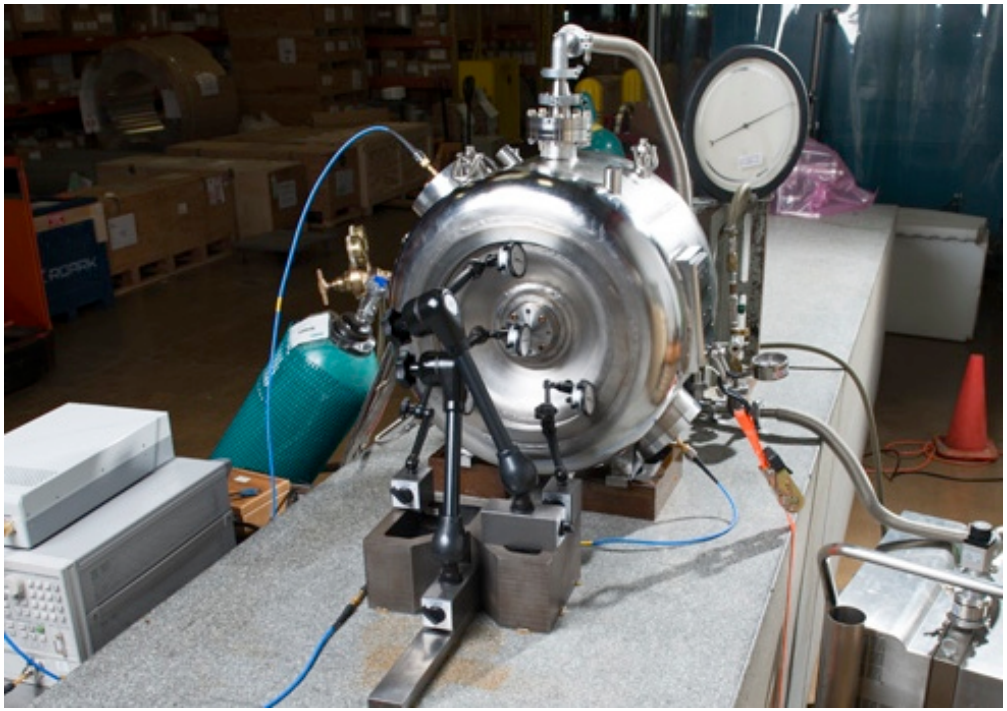


courtesy:
P. Berrutti

First SSR1 Cavity for PXIE

Measurements of Sensitivity

- Pressure in He space was cycled between 0-1.5 atm using Nitrogen
- Frequency measurements taken at different pressure increments
- Dial indicators provided valuable information for calibrating our model

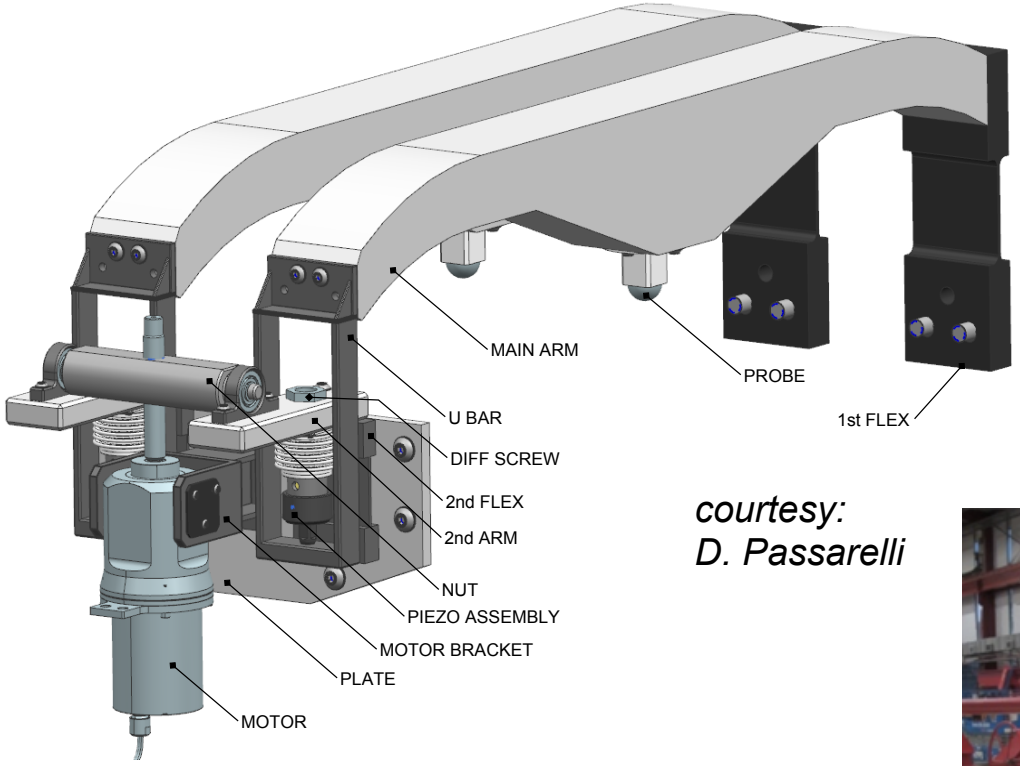


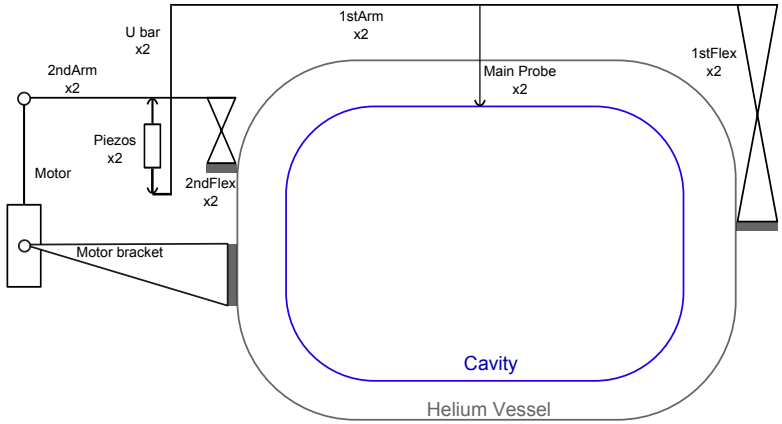
- Results:
  - + 10 Hz/torr (free)
  - + 4 Hz/torr (with dummy tuner)

- Requirement is < 25 Hz/torr

courtesy: D. Passarelli

The double-lever tuner





courtesy:
D. Passarelli

Coarse Range	135 kHz (0.25 mm)
Motor F_{MAX}	1250 N (1:6)
Fine Range	1 kHz (2 μm)

Summary and Outlook

- 10 Production SSR1 received (8 needed for 1st CM)
- EBW holes repaired, process improved
- Decision to modify flanges from ConFlat to Aluminum Seal
- 8 Cavities qualified for PXIE SSR1 Cryomodule
- First Jacketed cavity received, sensitivity meets requirements

- Next:
  - Qualification of Jacketed SSR1's
  - Manufacturing of SSR1 Cryomodule