SRF Activities at Argonne National Laboratory

Alireza Nassiri

Advanced Photon Source

3rd Open Collaboration Meeting on Superconducting Linacs for High Power Proton Beam (SLHiPP-3)

Louvain-la-Neuve, Belgium

17-18 April 2013

Outline

- Low-β cavities
- Deflecting cavities
- Summary

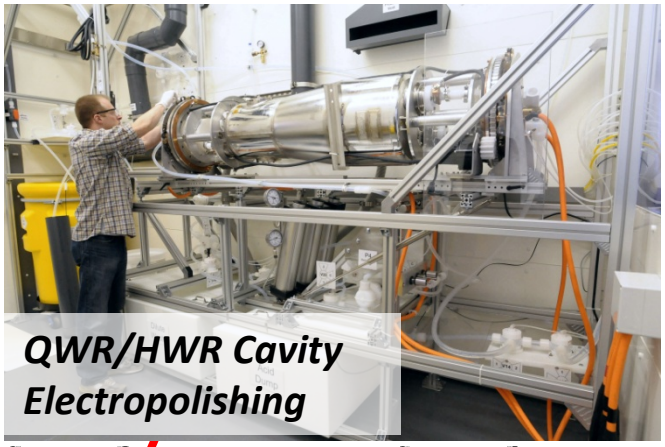
I. Argonne Facilities

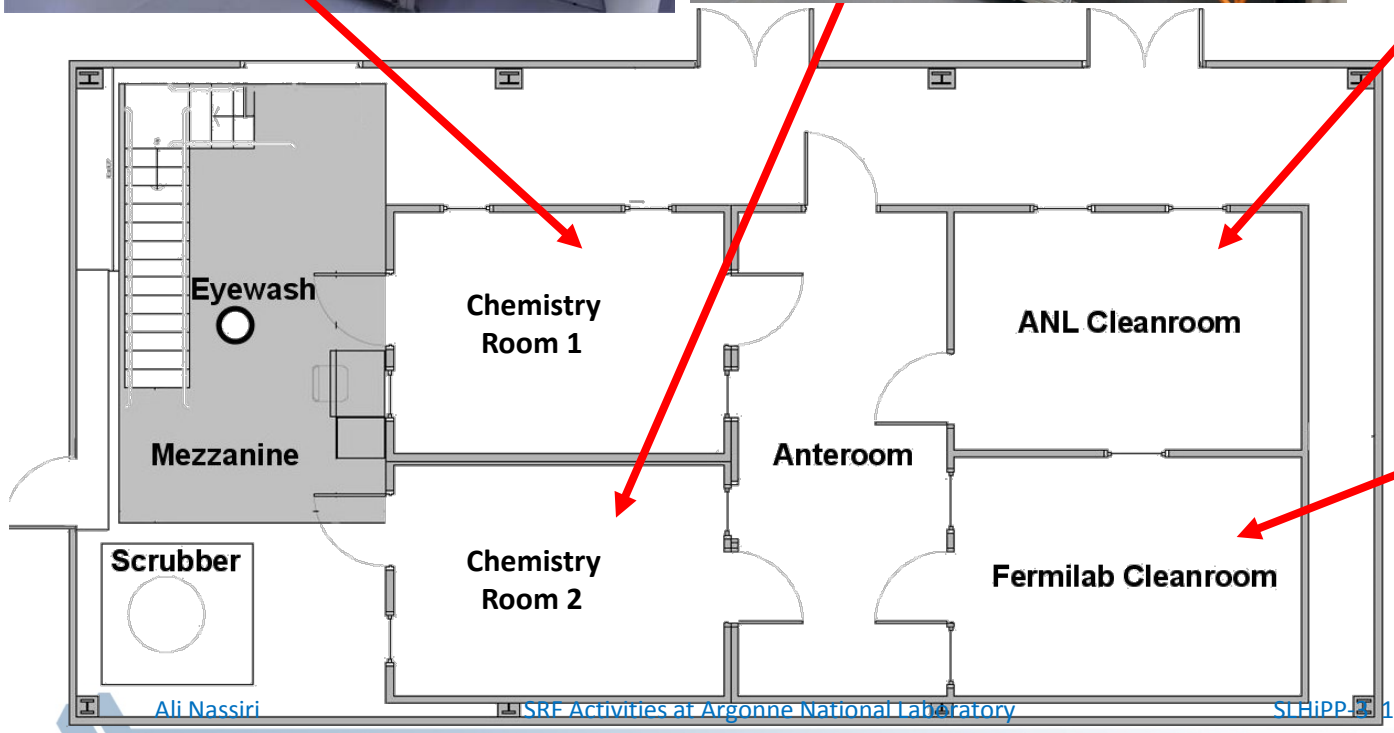
Highest Performing Low-β Cavities in Operation Worldwide

ATLAS Energy Upgrade: Commissioned June 2009

14.5 MV in 5 meters using 7 SC Quarter-wave Cavities

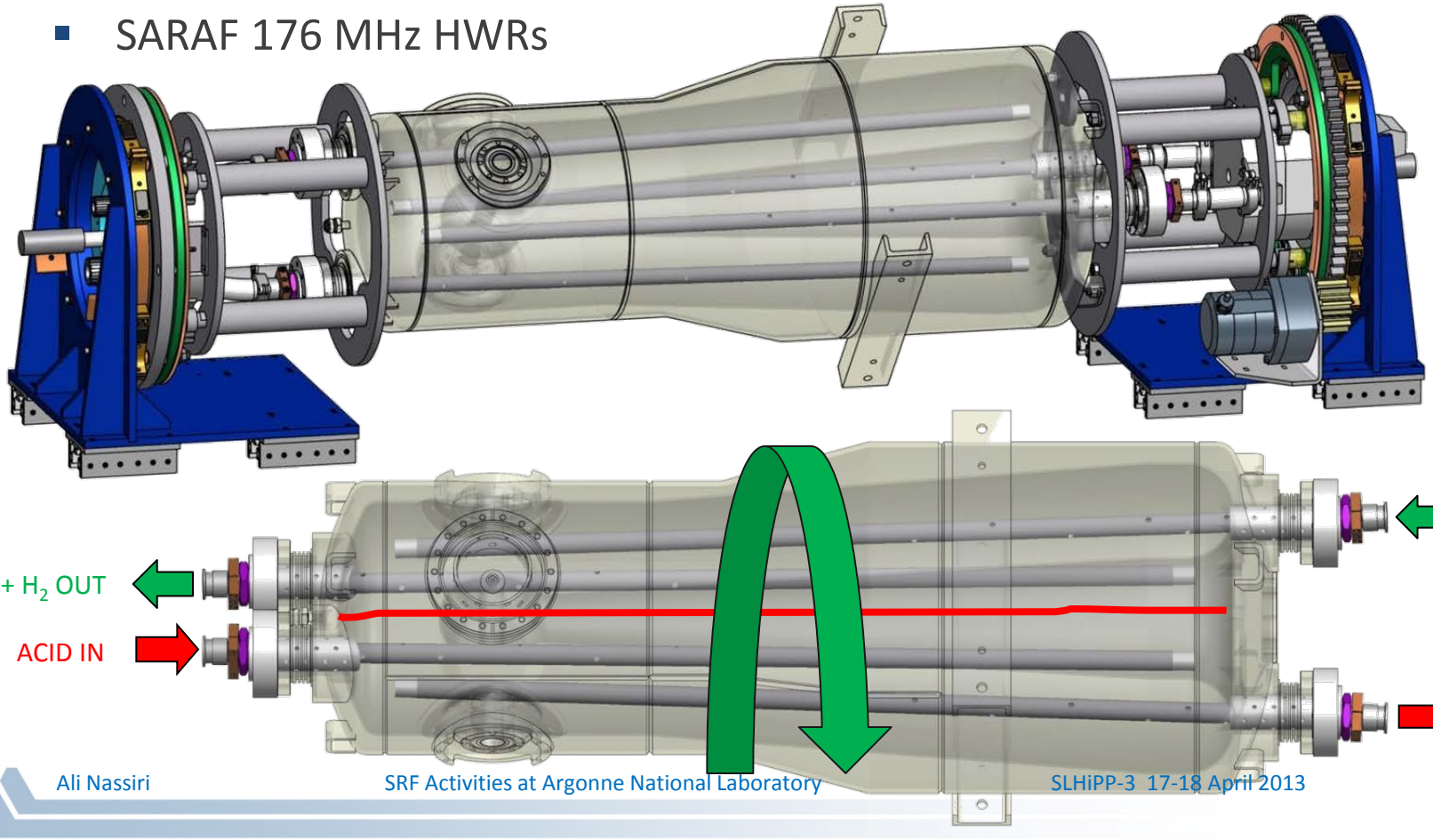
Argonne Facilities: Argonne/Fermilab Superconducting Cavity Processing Facility at ANL



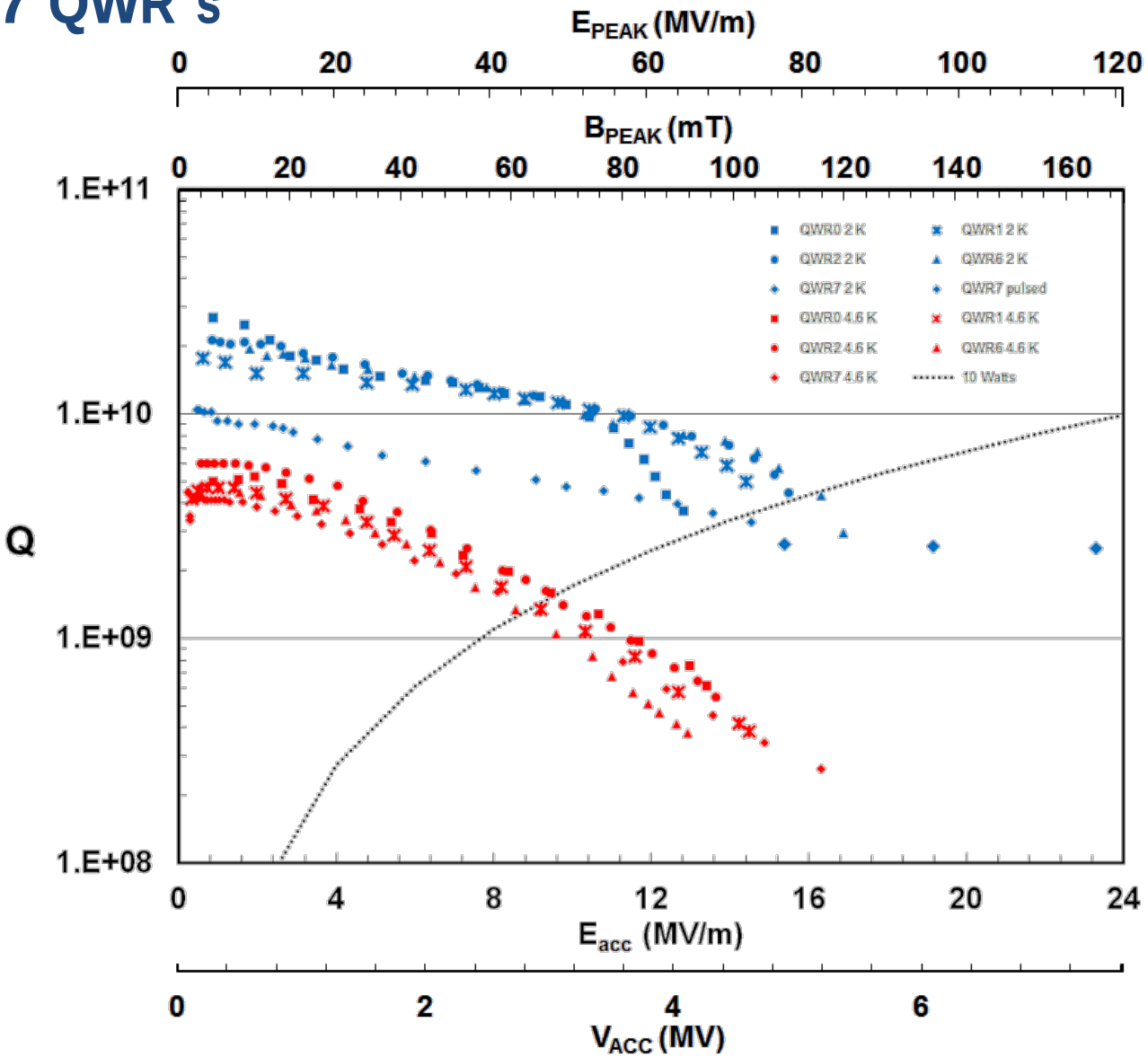


Argonne Facilities: Horizontal electropolishing systems at ANL/FNAL cavity facility

- 8 Argonne 72 MHz QWRs (complete)
- 8 Fermilab 162.5 MHz HWRs (starting fall 2013)
- Fermilab 650 MHz e-cells (2 complete)
- SARAF 176 MHz HWRs



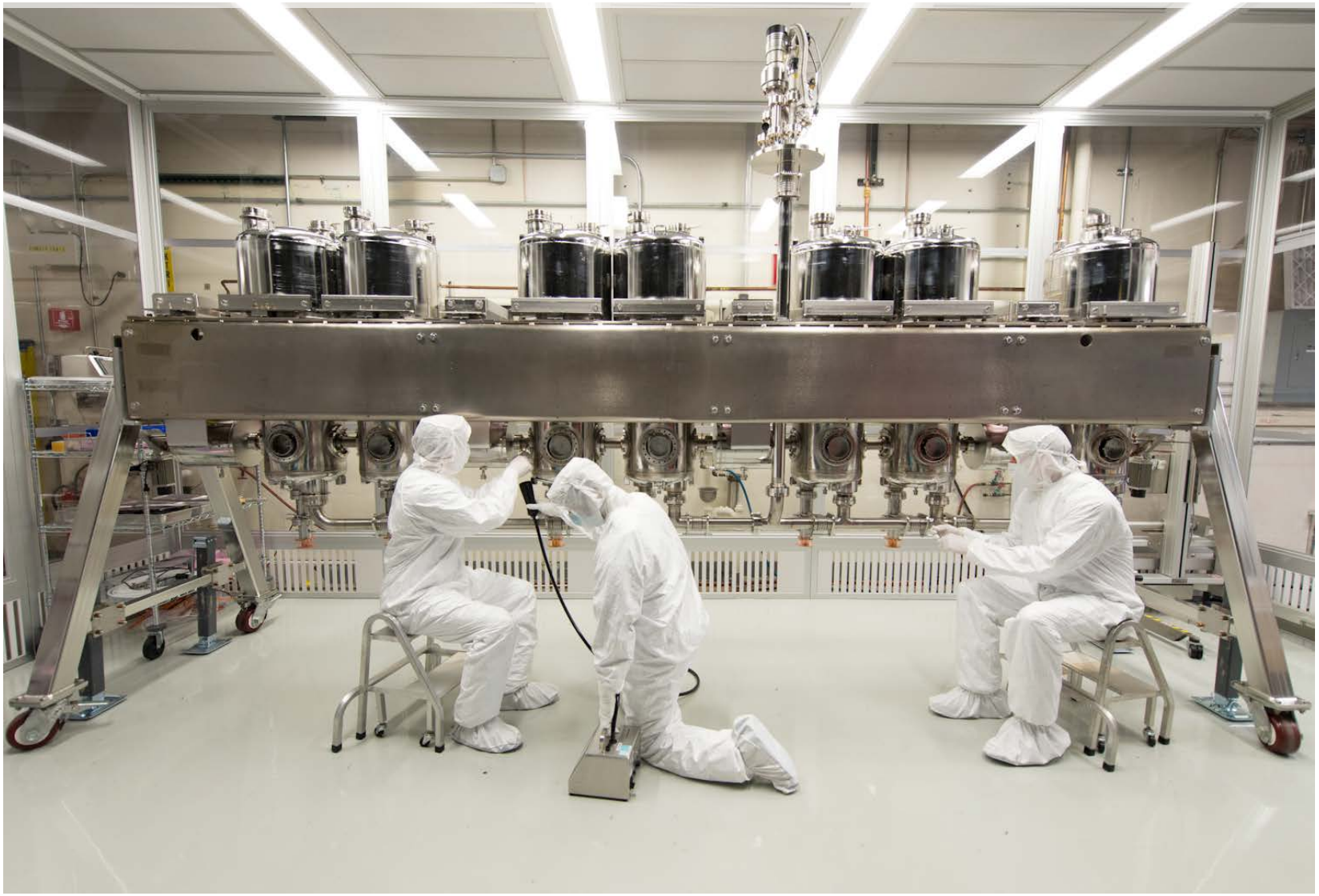
Recent Results: Cold test results for 5 of 8 new 72 MHz β=0.077 QWR's



Argonne ATLAS Intensity Upgrade

To be Commissioned Summer 2013

Planned 17.5 MV in 5 meters using 7 SC Quarter-wave Cavities



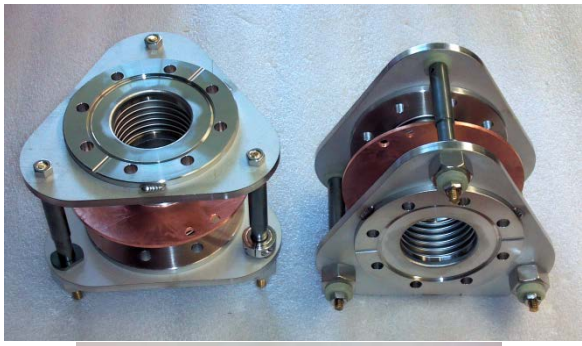
II: Work for others:162.5 MHz Half-wave Cryomodule for PXIE

Cavity Fabrication: February 2013

II: Work for others: 4 to 15 kW Variable Power Couplers for ATLAS, FRIB, Project X, and SARAF

ATLAS Upgrade Production Couplers

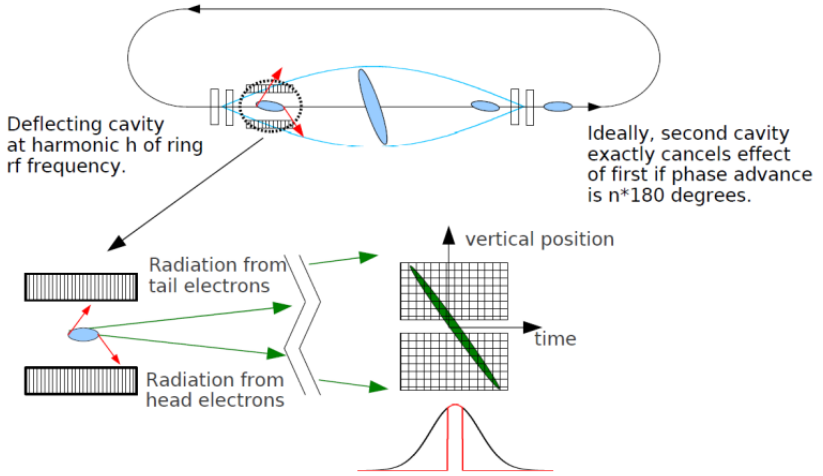
FRIB/ReA3 Couplers for MSU/FRIB



15 kW Coupler for SARAF (Israel)/Project X

SPX SRF Deflecting Cavities

- Elliptical squashed-cell cavity
  - Large grain Nb ingot slicing
  - RRR >300
  - CNC machining
  - Chemical etching/polishing
  - E-beam welding
  - Chemical polishing
  - Hydrogen bake out @600 °C 10 hours
  - Light chemical polishing (BCP)
  - HRP/clean room assembly
  - Low temperature bake
  - Vertical testing
  - Helium vessel dressing
  - Light chemical polishing *BCP)
  - Vertical testing
  - Horizontal testing

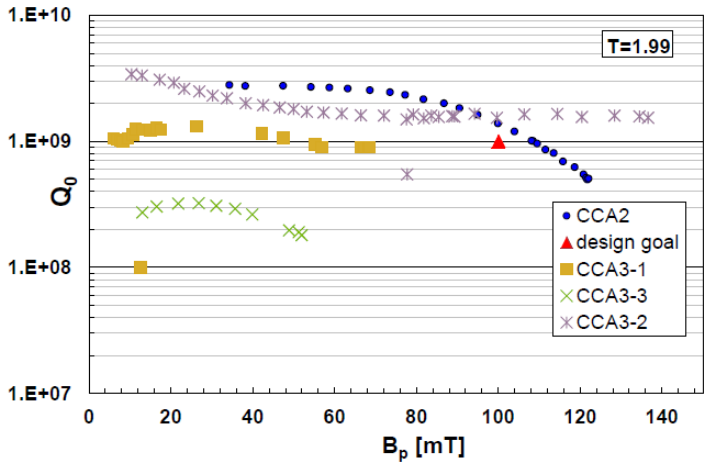


Cavity Parameter	Value	Unit
Operating frequency	2815.486	MHz
Operating Deflecting Voltage	0.5	MV
Vertical Test Acceptance B Field	≥120	mT
Peak Surface B field	106	mT
Peak Surface E field	41	MV/m
R/Q including TTF	37.1	Ω
Niobium wall thickness	3.5	mm
Geometric Factor	227.8	Ω
Operating Q_0	$\geq 10^9$	
Dynamic heat load	7	W
Magnetic Shielding	≤ 20	milligauss
Q_{ext} of Power Coupler	10^6	
RF source available	10	kW

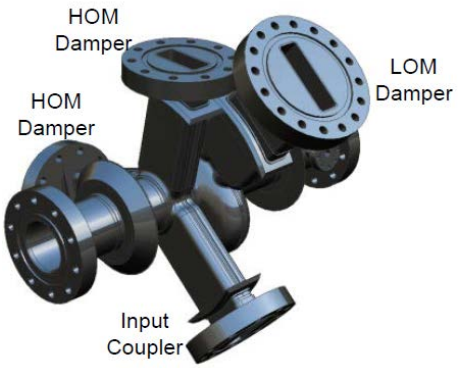
Tuner Parameter	Value	Unit
Range	±200	kHz
Resolution	≤40	Hz
Fast detuning	60	kHz
Fast detuning response time	≤1	ms

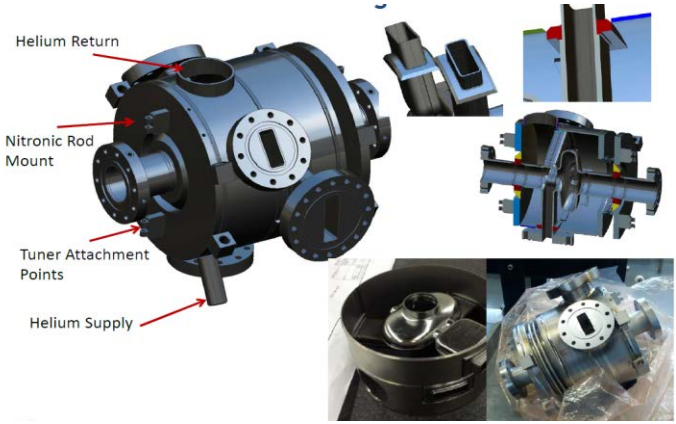
SPX SRF Deflecting Cavities

Mark-II Cavity Vertical Tests at ANL



Cavity	Q_0	Bpk [mT]	Seal
CCA2	$1.2x10^9$	120±30	Indium
CCA3-1	$0.9x10^9$	68±21	Al/Mg without RF shield
CCA3-2	$1.24x10^9$	136±35	Indium
CCA3-3	$0.3x10^9$	52±16	Al/Mg with RF shield

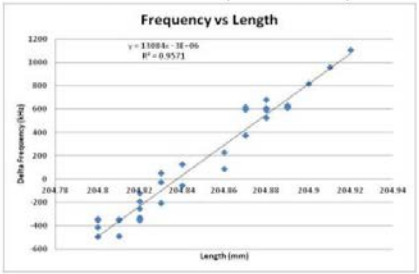


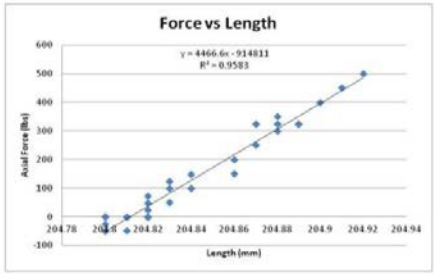


	Tuning Sensitivity (Mhz/mm)*	Cavity Stiffness (klbs / in)**
Predicted	12.2	113.5
Measured	13.0	101.6

✓ Modeling Validated

* - The tuning sensitivity with a He vessel is expected to decrease by 26%
** - The stiffness with a He vessel is expected to increase by 12%

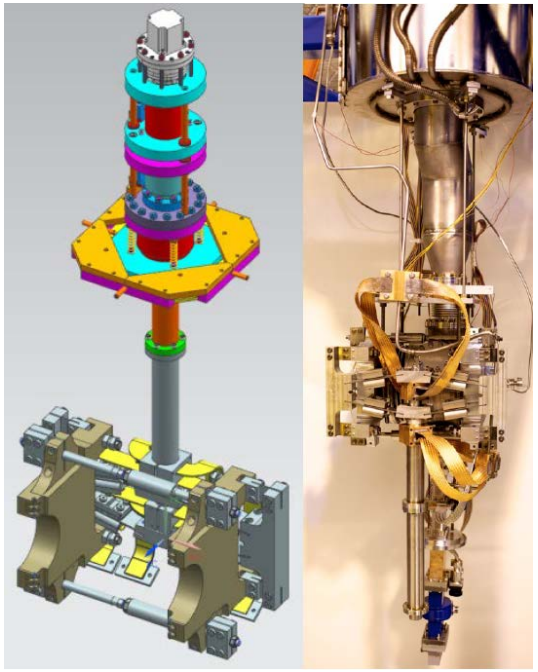




Tuner Specification	Value	Unit
Operating frequency	2815.486	MHz
Range	±200	kHz
Resolution	≤40	Hz
Fast detuning	3	KHz
Fast detuning response time	≤1	ms

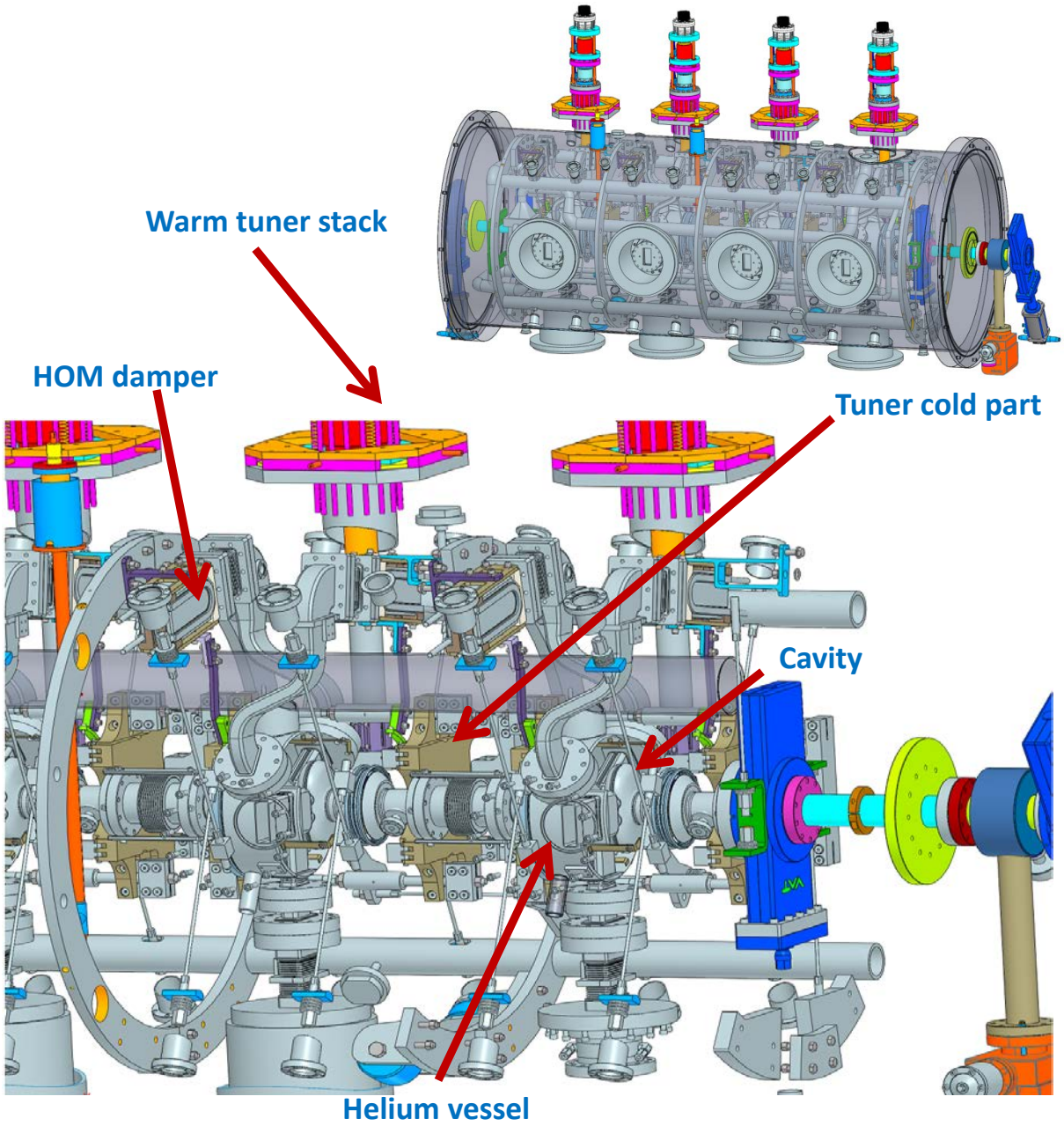
SPX Tuner Parameters

Cavity Related Parameters	
Tuning Sensitivity	9000 KHz/mm
Stiffness	170,000 lbs/in
Deflection for 200KHz shift	22 µm
Force of 200KHz shift	149 lbs
Tuner Related Parameters	
Stepper Motor Resolution	800 Steps/rev
Harmonic Drive Ratio	100
Ball Screw Pitch	2 mm/rev
Stepper Freq. Resolution	
-Full Step Frequency shift	31.6 Hz/increment
-Half Step Frequency Shift	15.8 Hz/increment
-Quarter Step Freqeuncy Shift	7.9 Hz/increment
Piezo Range	
-Drive Axis	60 µm
-Cavity Axis	75.8 KHz
Piezo Resolution	
-Drive Axis	0.13 nm
-Cavity Axis	0.16 Hz



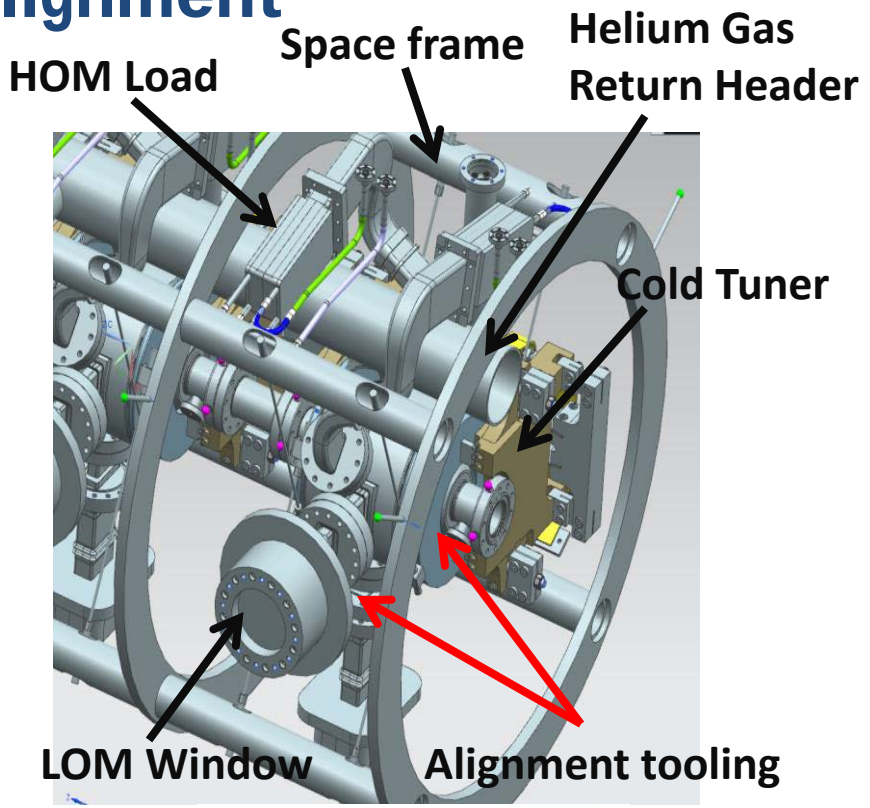
SPX Cryomodule

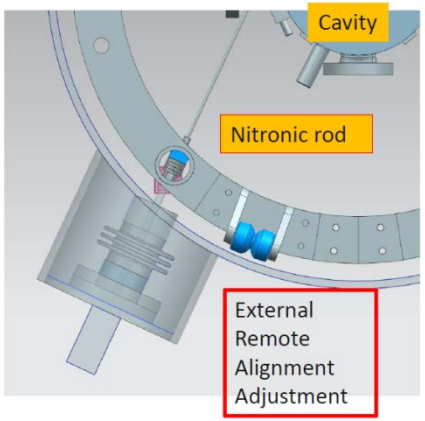
- End load
- JLAB space frame design
- Cryogenic heat exchanger inside an end cap
- Tuner motor and piezo outside of cryostat
- LOM damper outside of cryostat
- Rectangular waveguide FPC



SPPX Cryomodule Concept - Alignment

- Insert cold mass into space frame (support structure)
- Transfer alignment to space frame (fiducial features on space frame)
- Complete cryomodule assembly
- Transfer alignment to vacuum shell (fiducial features outside shell)
- Remote alignment concept
  - (4) Nitronic rods support the cavity
  - External mechanical adjustment
    - Allow for 2 mm movement of each rod





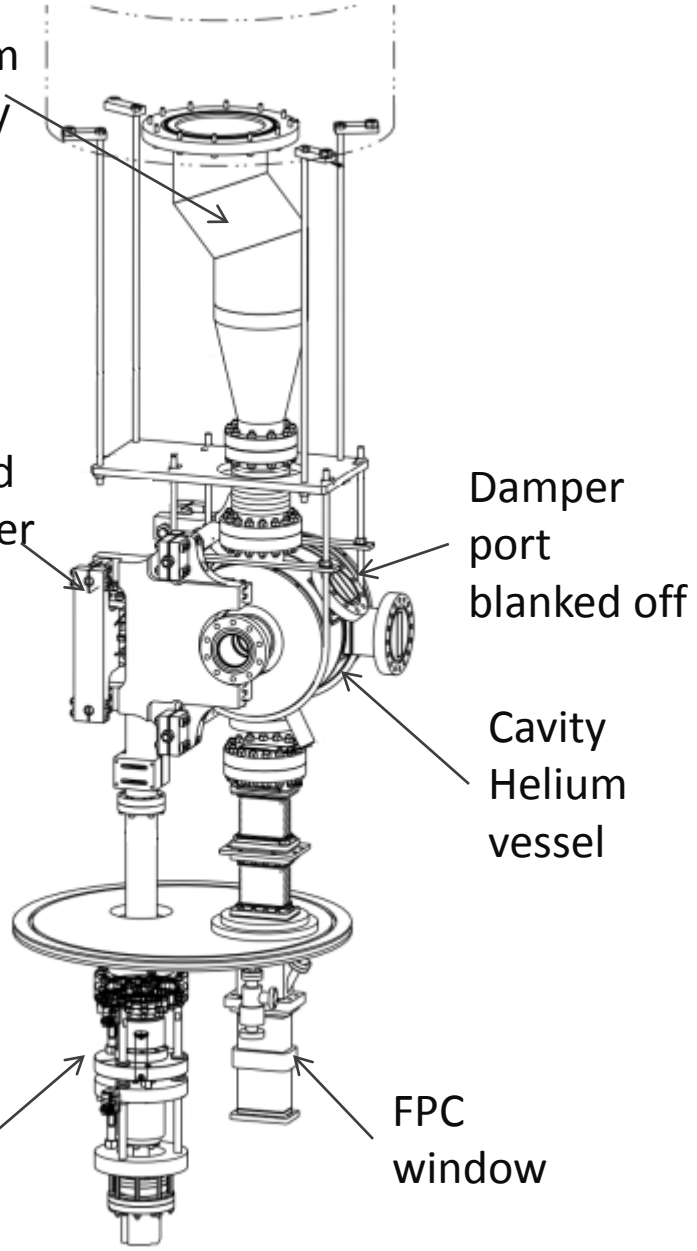
Horizontal Test Stand

Horizontal cavity test at ANL/ATLAS

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

Measurement completed during first HCT

- ✓ 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

Summary

- Low- β Cavities
  - Developing a new half-wave resonator and cryomodule for Project X
  - Designed and built a variable (4 kW - 15kW) power coupler for ATLAS, FRIB , SARAF, and PXIE 162.5 MHz SC HWR
  - Argonne ATLAS upgrade to be commissioned in summer 2013
  - A high throughput ANL/Fermilab facility at ANL for SC RF cavities processing
- SPX deflecting cavities
  - Cavity performance has been demonstrated in vertical in vertical test
  - Cryomodule design concept is well underway
  - Tuner performance verified
    - Range measured in $\pm$300 kHz (exceeds $\pm$200 kHz spec)
    - No hysteresis in 25 kHz short range
    - Good linearity (0.04Hz/μstep with 25 Hz resolution step
    - Microphonics characterized and active compensation looks possible

Acknowledgment

- Mike Kelly
- Genfa Wu
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- Joe Matalevich (JLab)
- Karen Wilson (JLab)