Locking Cavity 2A

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ADMX Collaboration Meeting, November 2020

Noah Oblath, Christian Boutan,

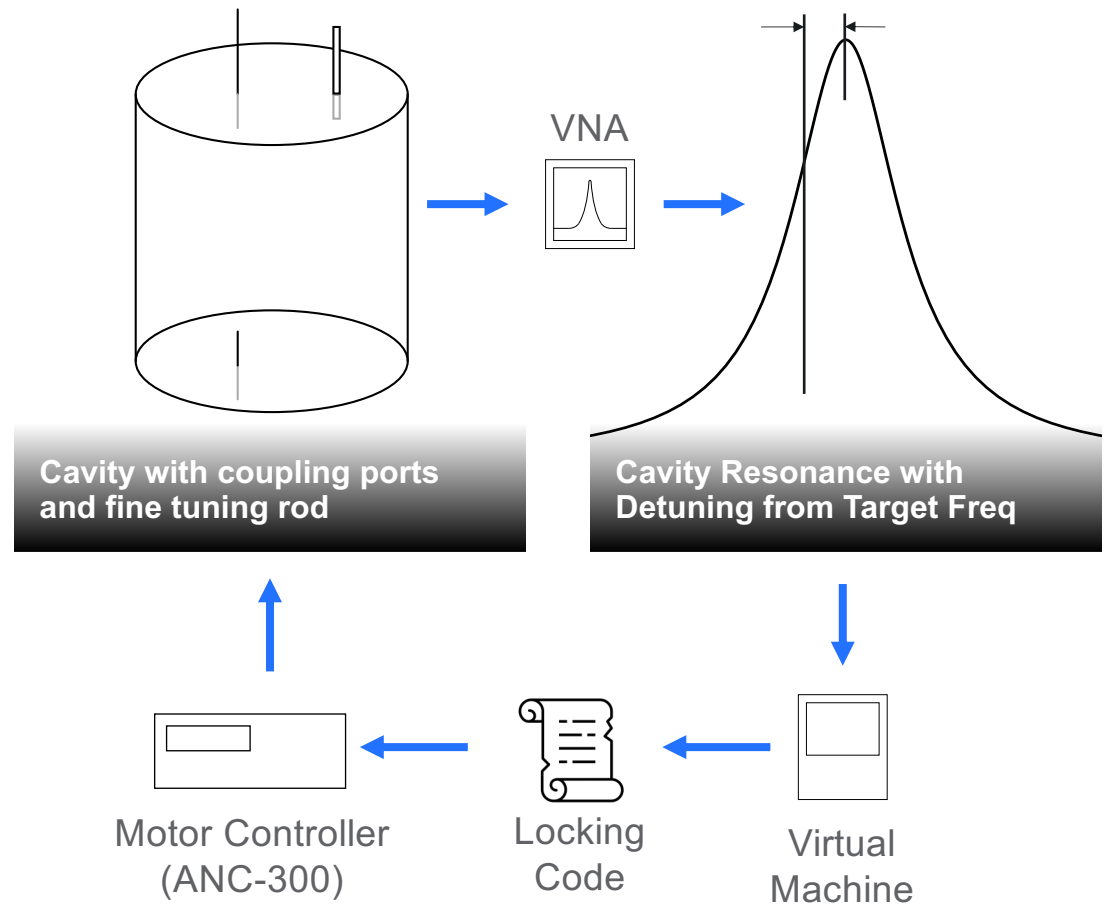Daniel Cain, Ben LaRoque

Outline

- ADMX Cavity 2A Locking Scheme
- Operational Flow Charts
  - Locking / Tuning a single cavity
  - Locking to Target
  - Locking to Average
- Requirements
  - Precision
  - Speed
  - Heating

- Performance
  - Precision
  - Speed
  - Heating (Steps)
- Pathway forward
  - Move to Cool Prototype Array
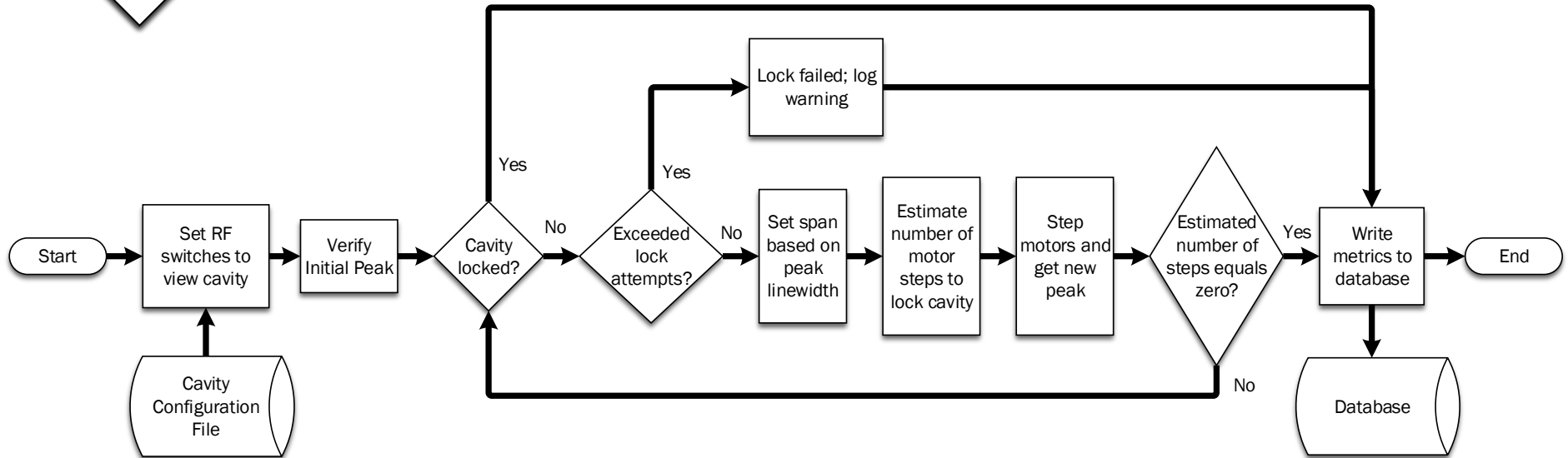 - Move to Final Cavity Array
  - Support

ADMX 2A Locking Scheme

- TM010 Cavity Resonance
- Moved by adjusting Fine Turning Rod
- Detuning detected by VNA
- Locking algorithm drives PZT Motor Controllers
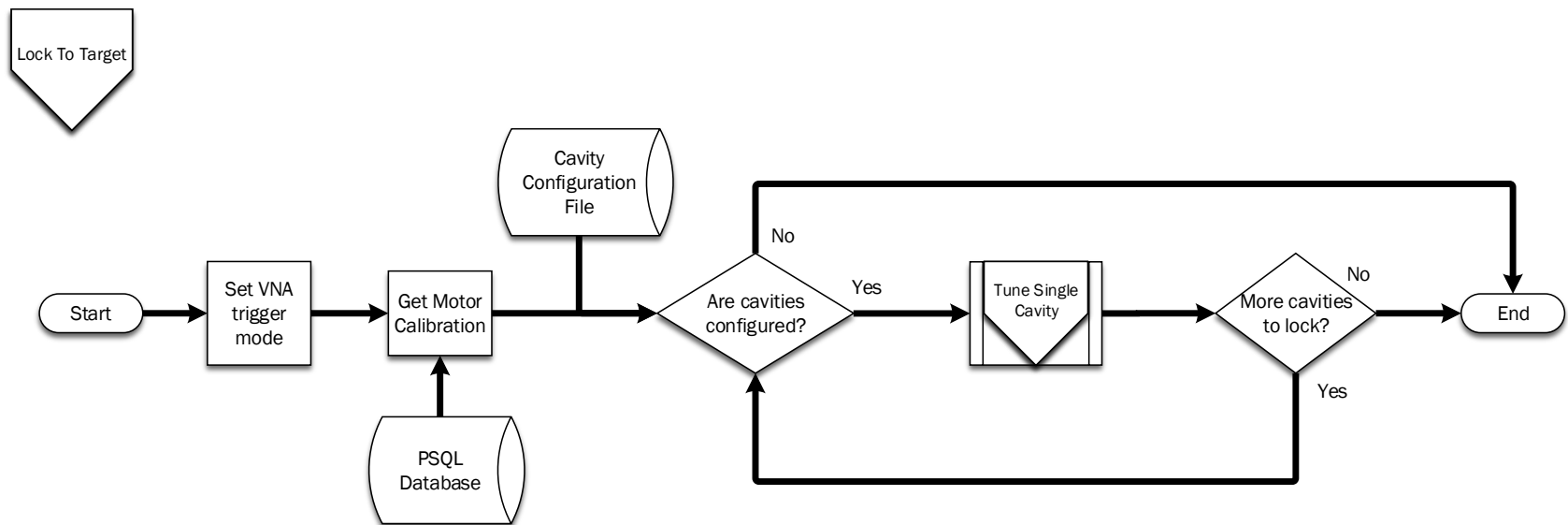- => Detuning driven to (near) zero

VNA

Cavity with coupling ports and fine tuning rod

Cavity Resonance with Detuning from Target Freq

Motor Controller (ANC-300)

Locking Code

Virtual Machine

Flow Charts – Locking / Tuning a Cavity

Flow Charts – Locking to Target Frequency

Lock To Target

Start → Set VNA trigger mode → Get Motor Calibration

Cavity Configuration File

PSQL Database

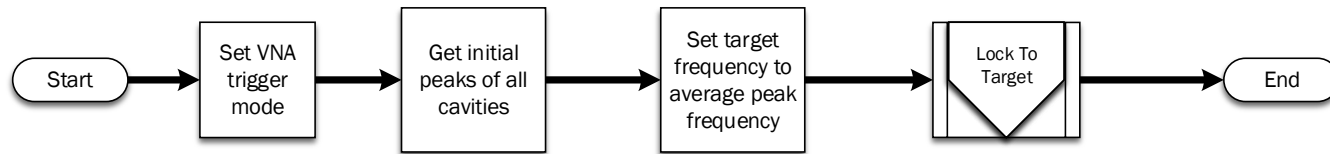Are cavities configured? — No / Yes

Tune Single Cavity

More cavities to lock? — No / Yes

End

# Flow Charts – Locking to Average

Requirements

- Precision
  - All four cavities should be locked within 10% of their line width (FWHM)

- Speed / Time
  - All four cavities should be locked within 10 seconds for each frequency step

- Power Dissipation / Heating
  - The locking process should produce less than 10 mW on average during the process

Performance

- Testing
  - PNNL working directly with Fermilab to lock Prototype Cavity Array
  - All tests to date have been warm

- Locking Scripts
  - Debugged and Automated
  - Dripline and Virtual Environments Operational

- Cavities
  - Most tests with Cavities A, B, D.
  - C recently came online – need to adjust flexure
  - Nominal line width is 900 kHz (warm)
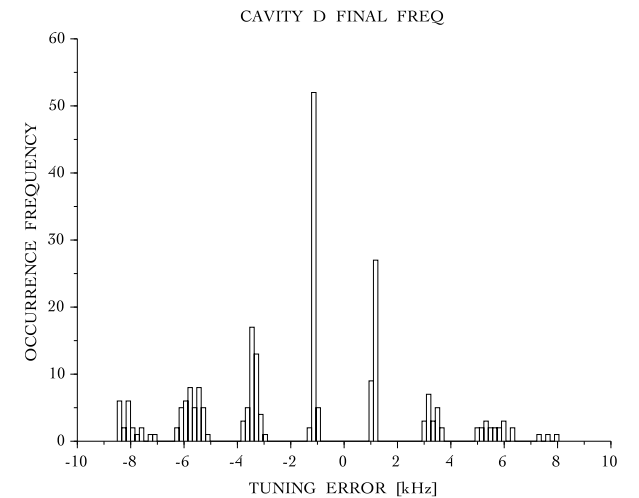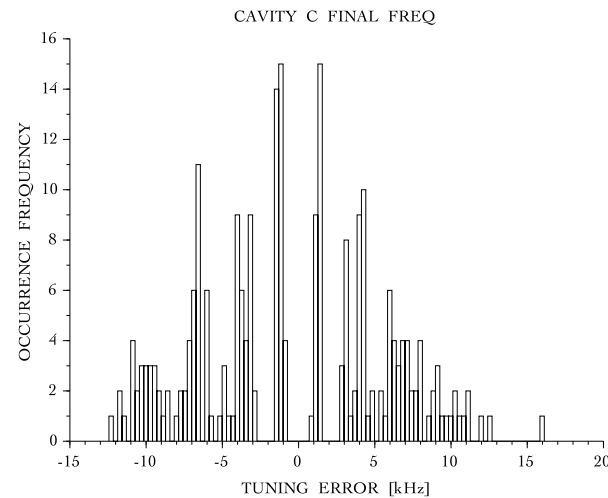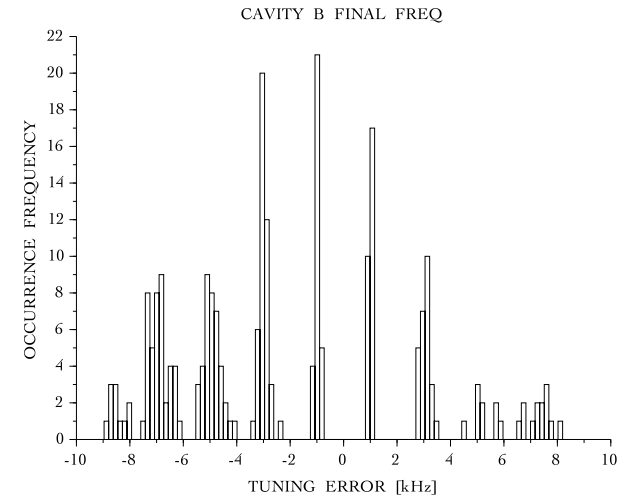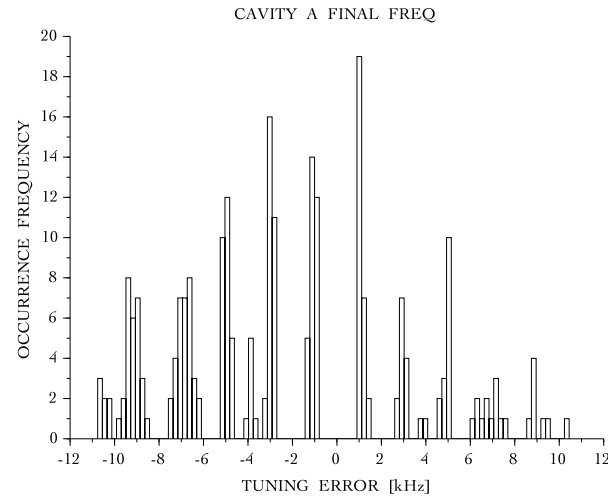 - Nominal Q ~ 6000 (warm)

Run 2A Cavity System

Coarse Rod Motor location

Coarse Tuning Rod

Fine Tuning Rods

Antenna Drives

Cavities
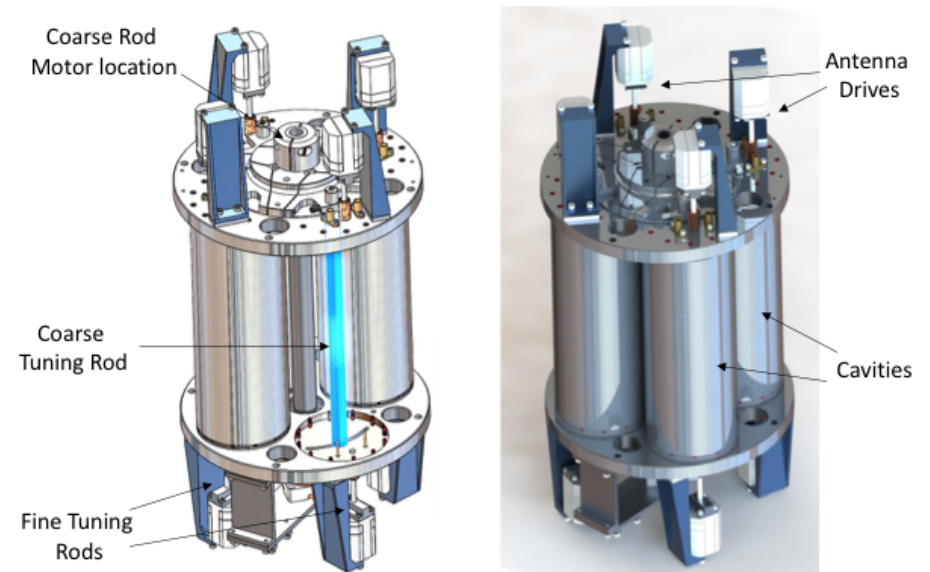
Precision
±1% to ±1.5%

- Routinely achieving ±1% to ±1.5%
- Clumping due to VNA digitization/ resolution

Speed
Median < 1.5 sec
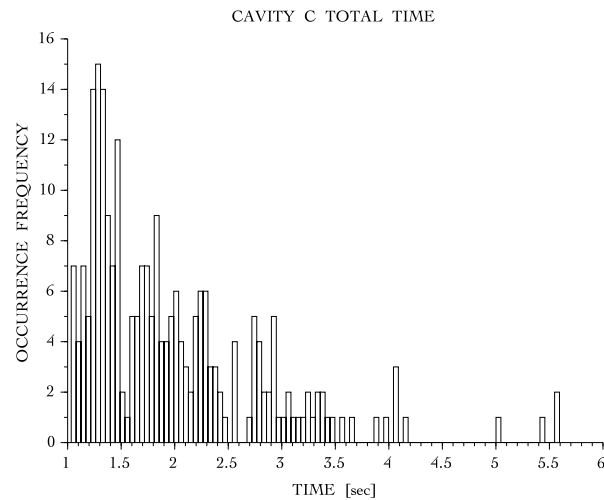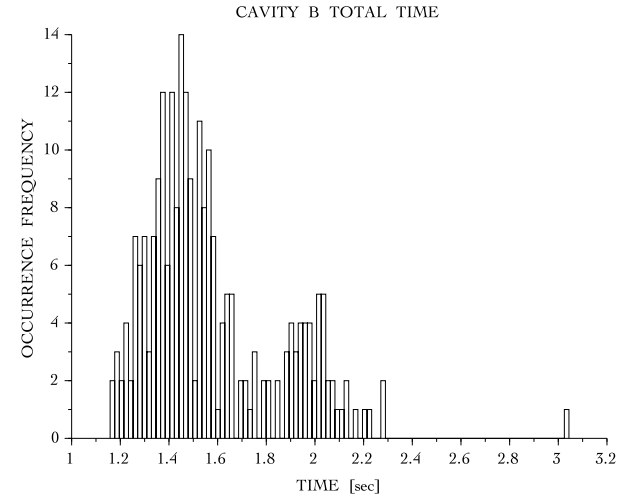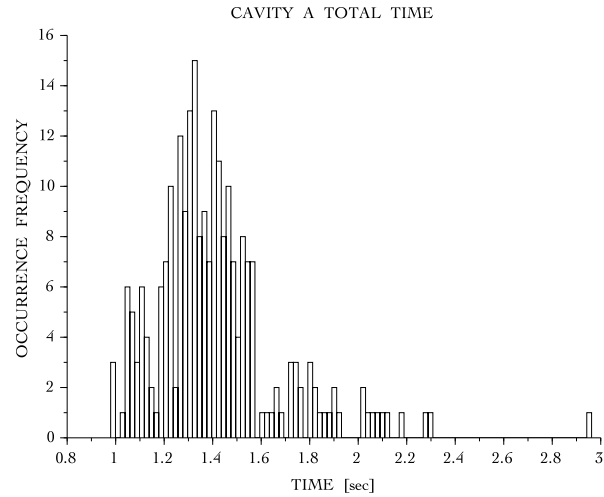
- Nearly always under 2.5 sec / Cavity

- Median is below 1.5 sec / Cavity

- (Cavity C is currently slower)

CAVITY A TOTAL TIME

CAVITY B TOTAL TIME

CAVITY C TOTAL TIME
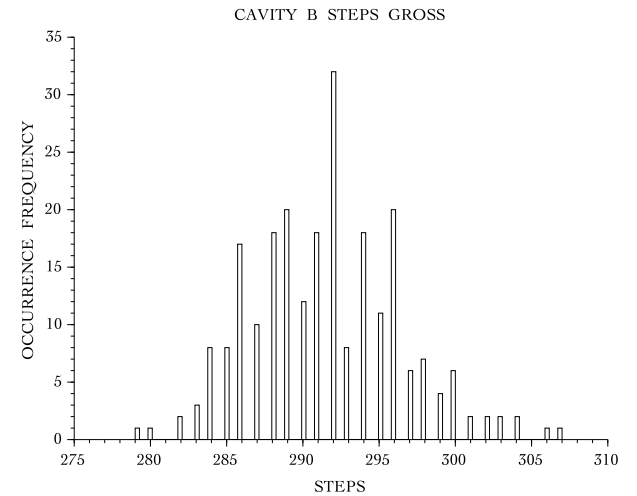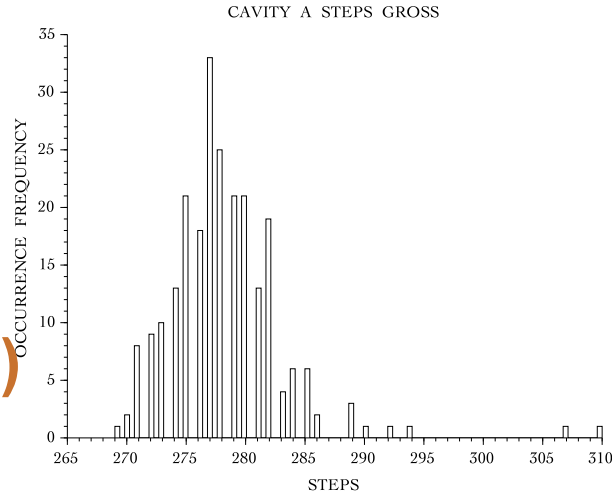

CAVITY D TOTAL TIME
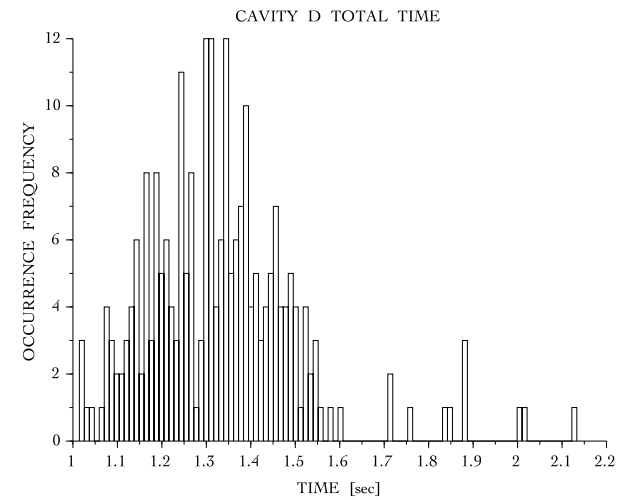
Heating (Steps)

- Varies with Cavity
- Median between 130 and 295
- Haven't extrapolated to heating yet
  - we expect things to change when we cool the cavities

CAVITY A STEPS GROSS

CAVITY B STEPS GROSS

CAVITY C STEPS GROSS

CAVITY D STEPS GROSS
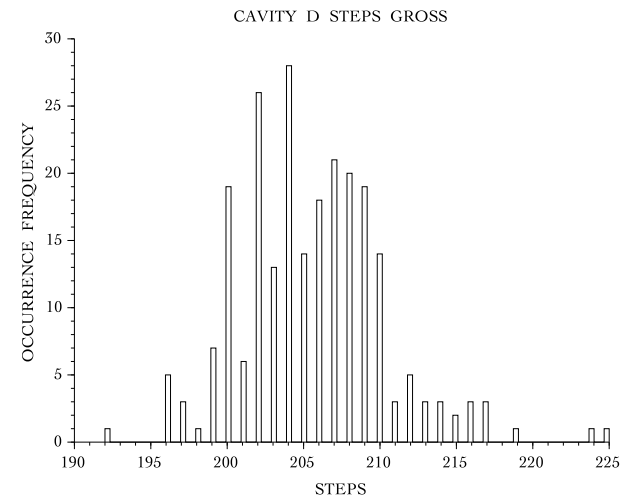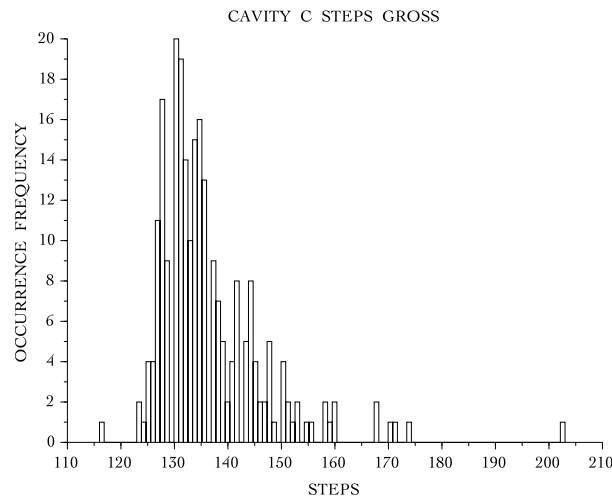
Pathway Forward

- Move to Cool the Prototype Array
  - Certain things will change, including Q and PZT Motor transfer functions
    - ✓ Hopefully in a concomitant way…
    - ✓ … Higher Q, and smaller frequency shift per step
  - Locking System Adjustments
    - ✓ Should be relatively minor
    - ✓ System should remain automated for testing

- Move to Final Cavity Array
  - Full Characterization Warm
  - Characterization Cold
  - Locking Testing Cold
  - Commissioning

- Support

Summary

- Implemented Four Cavity Locking on Prototype Array at Fermilab
- Meeting Speed and Precision Requirements
- Heating not yet ascertained but expected to easily meeting requirements
- Need to discuss next moves
  - Limited funding
  - Delays
  - Do we test prototype cavities cold?
  - … Or wait for final cavity array?

Thank you