Sources of Field Perturbations

LLRF Lecture Part2

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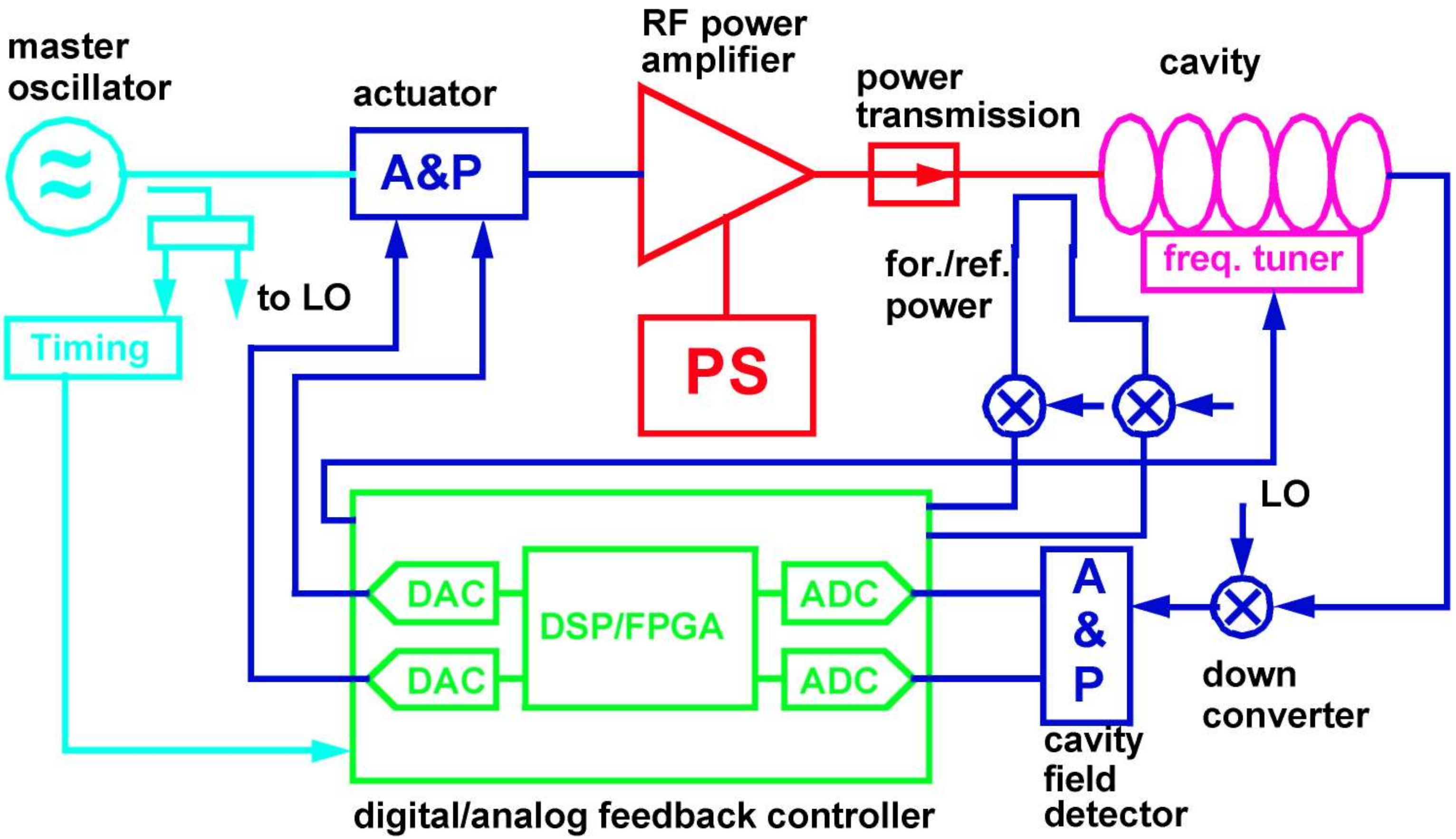
RF System Architecture



Sources of Field Perturbations

o <u>Beam loading</u> - Beam current fluctuations - Pulsed beam transients - Multipacting and field emission - Excitation of HOMs - Excitation of other passband modes - Wake fields	o <u>Cavity dynamics</u> - cavity filling - settling time of field o <u>Cavity resonance frequency change</u> - thermal effects (power dependent) - Microphonics - Lorentz force detuning
o <u>Cavity drive signal</u> - HV- Pulse flatness - HV PS ripple - Phase noise from master oscillator - Timing signal jitter - Mismatch in power distribution	o <u>Other</u> - Response of feedback system - Interlock trips - Thermal drifts (electronics, power amplifiers, cables, power transmission system)

Lorenz Force Detuning

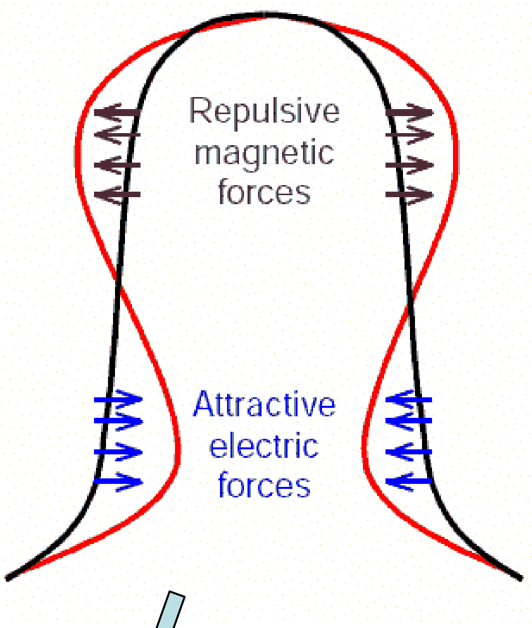
Cavity Deformation by Electromagnetic Field Pressure

- Radiation pressure

$$P = \frac{\left(\mu_0 \left|\vec{H}\right|^2 - \varepsilon_0 \left|\vec{E}\right|^2\right)}{4}$$

- Resonance frequency shift

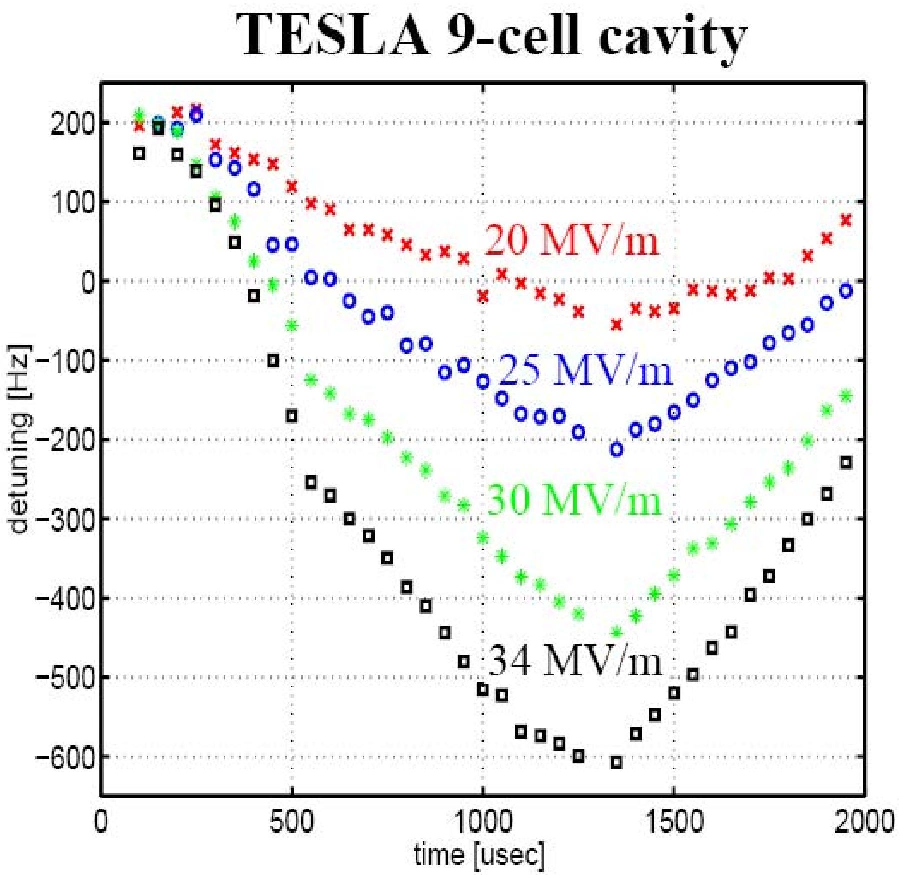
$$\Delta f = -K \cdot E_{acc}^2$$

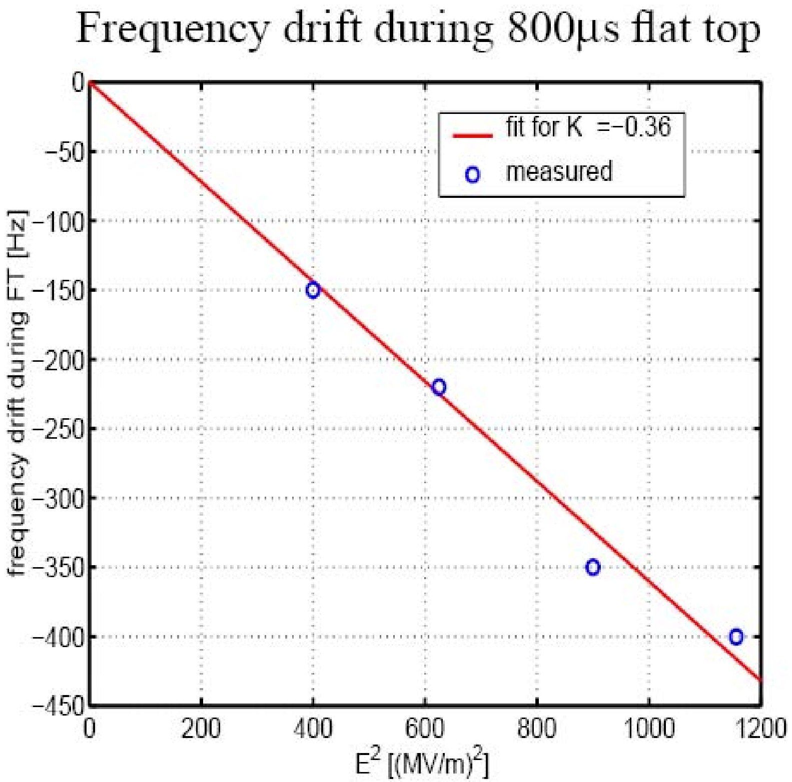


Lorenz Force Detuning

- Effects of Lorenz force detuning
  - Change cavity voltage and phase during RF pulse
  - Generate more reflection power
  - Limit maximum repetition rate of RF pulses
- Properties
  - Gradient dependent
  - Predictable from pulse to pulse
  - Perturbations are correlated from cavity to cavity

Measurement of Lorentz Force Detuning





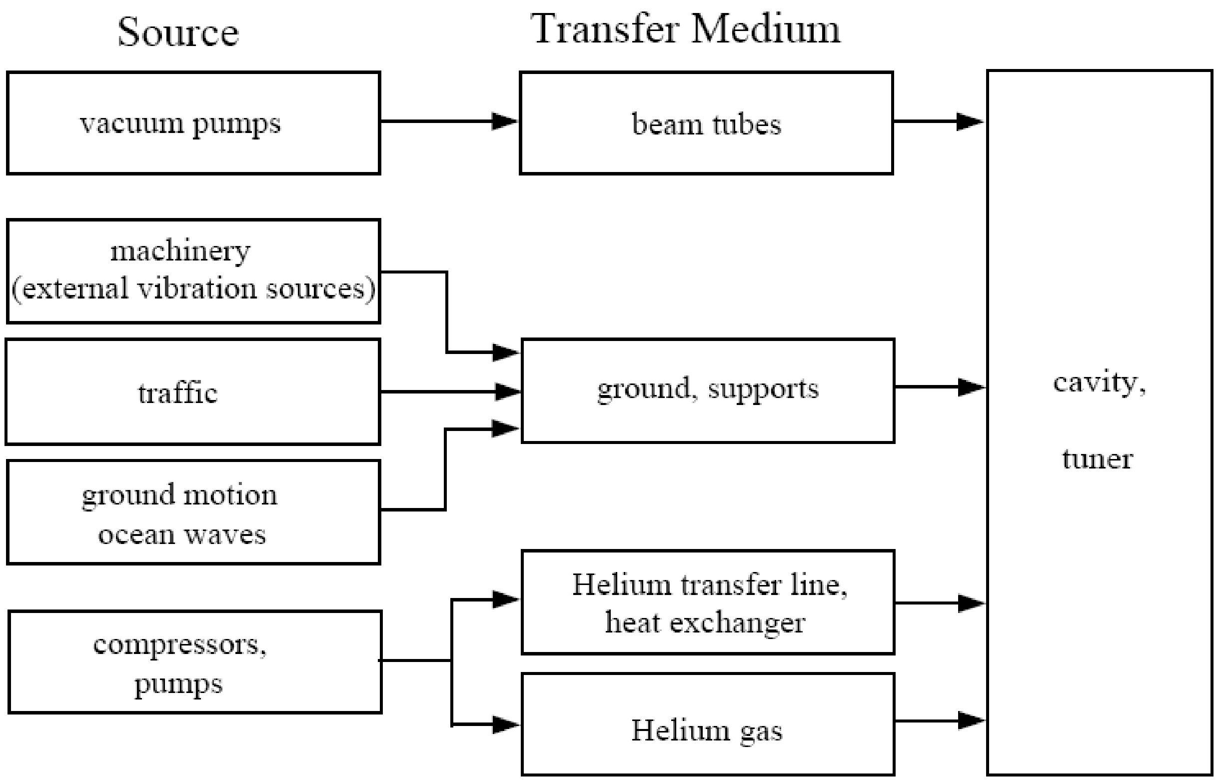
Frequency drift during 950 μs flat top (TESLA 9-cell cavity):

$$\Delta f_{FT} \approx -(0.4 \text{ to } 0.65)\frac{Hz}{MV/m^2}E_{acc}^2$$

Microphonics

Sources of Microphonics

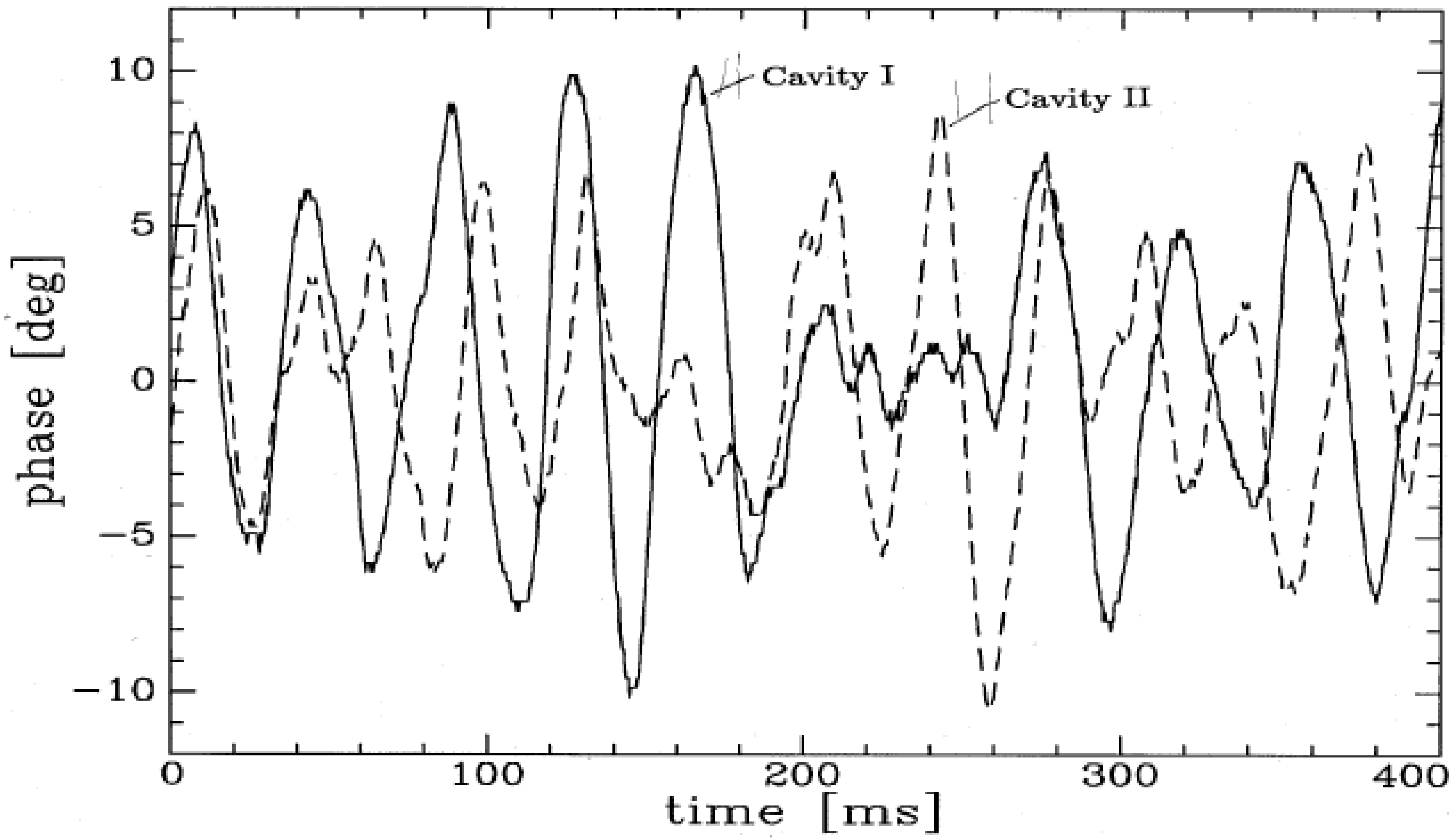
- Mechanical vibrations caused by the accelerator environment are always present and may be transferred to the cavity.



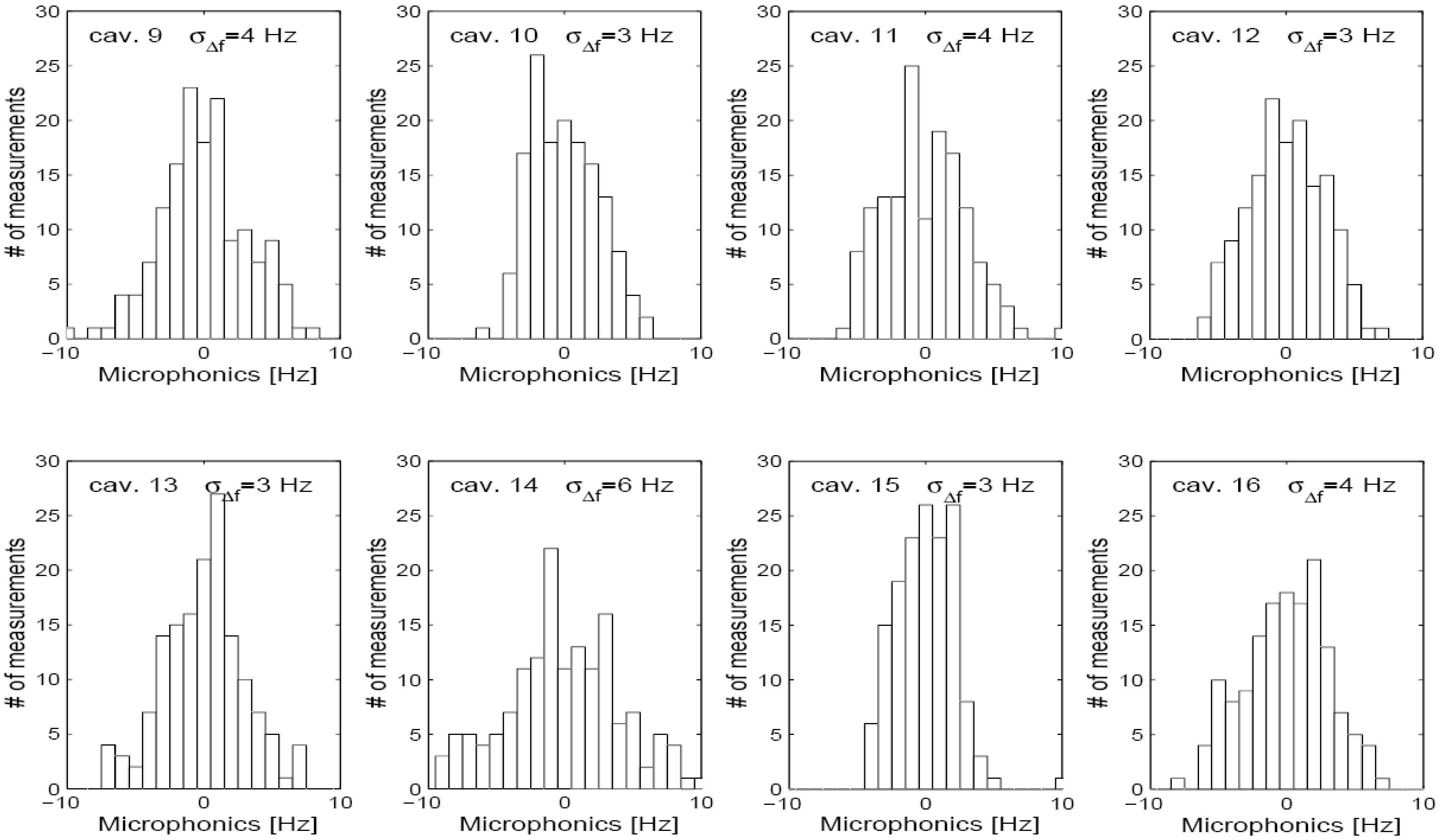
Microphonics

- Effects of microphonics
  - It mainly influences the resonance frequency of the cavity and therefore the RF phase with respect to the beam
- Properties
  - Slow perturbation
  - Not predictable
  - Uncorrelated along the Linac

Microphonics at JLAB



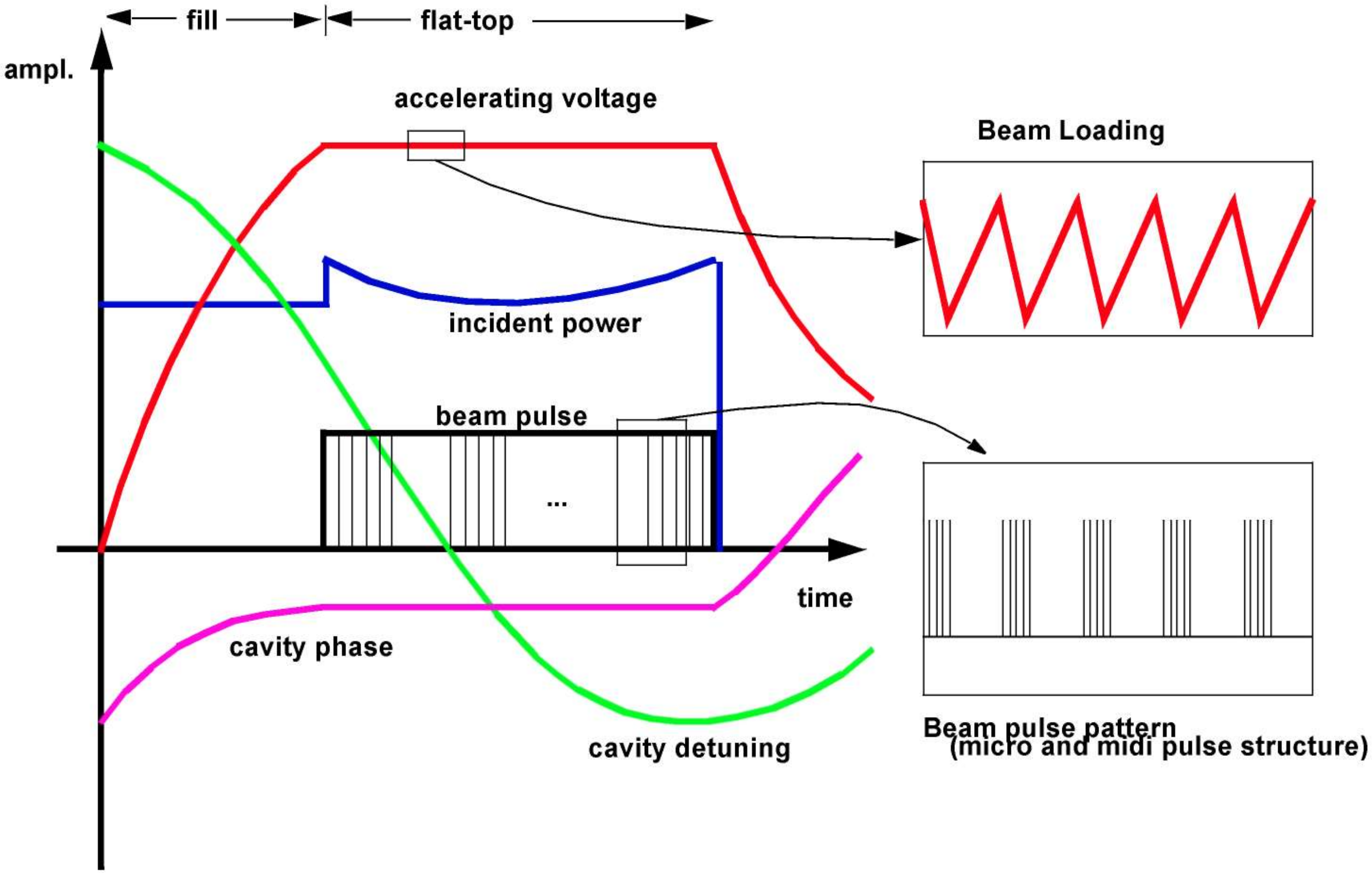
Microphonics at FLASH



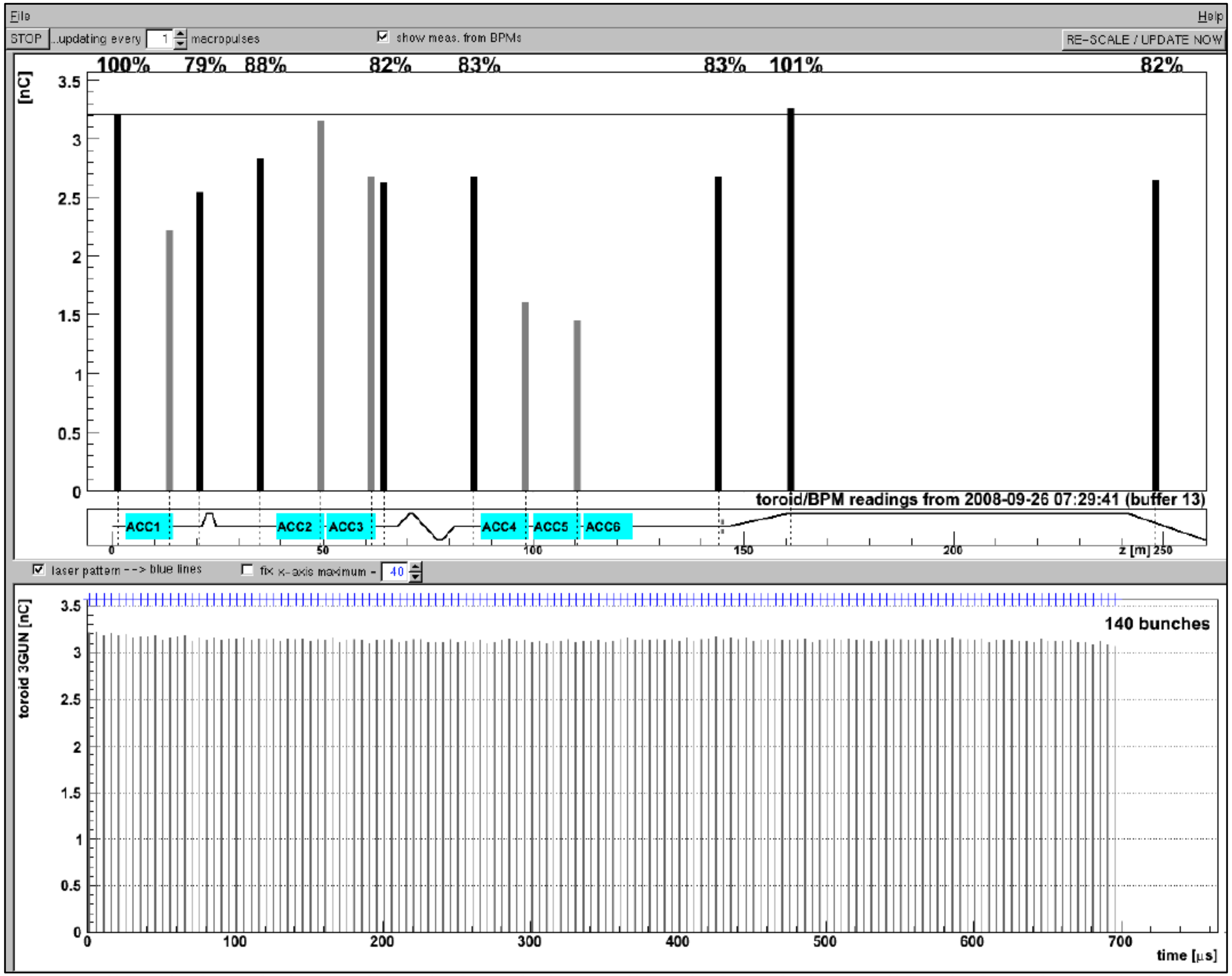
Beam Current (Bunch Charge) Fluctuation

Beam Loading Effect

- Single bunch transient is not controllable
- Bunch charge fluctuation will introduce energy spread

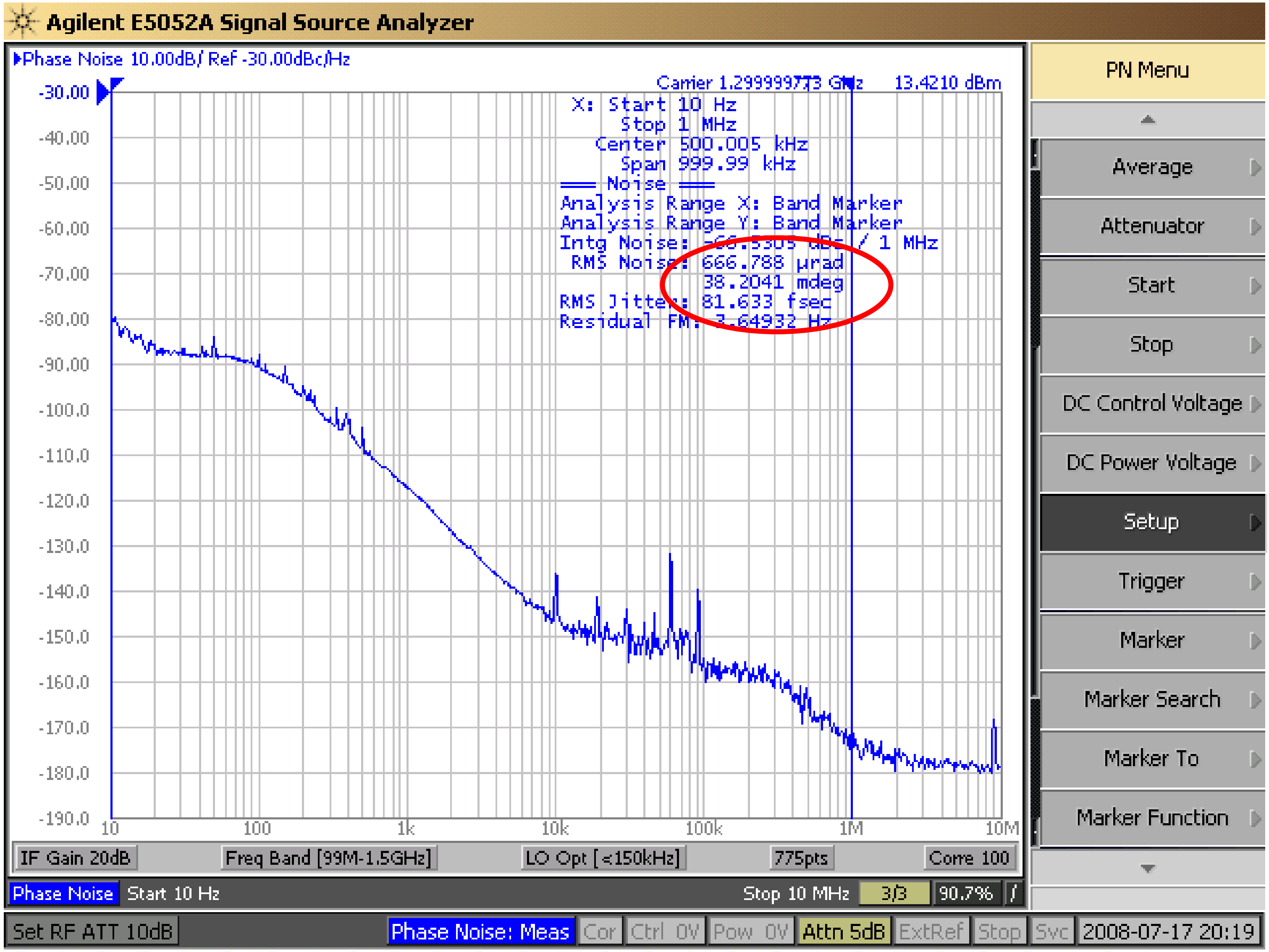


Bunch Charge Pattern at FLASH



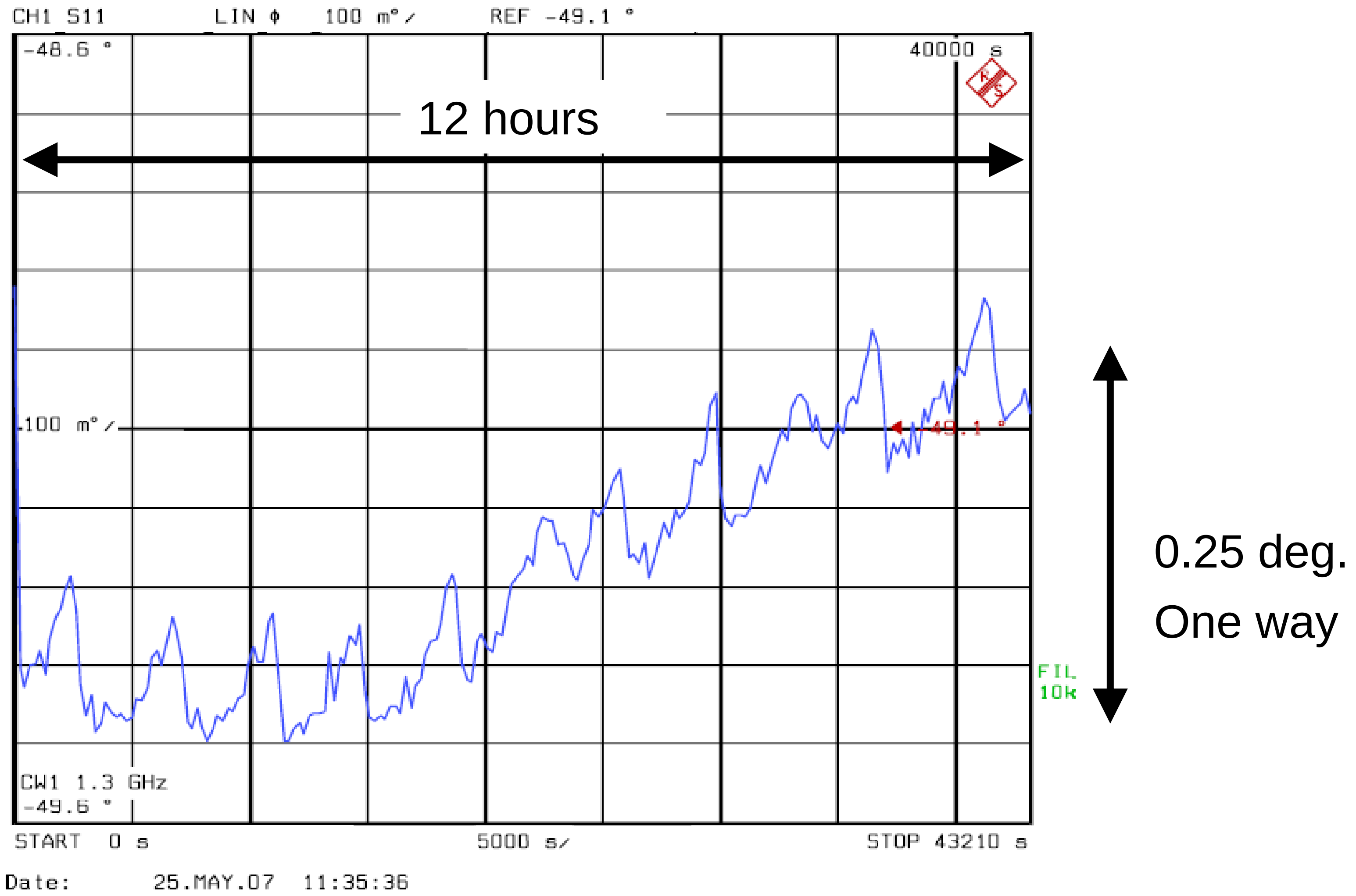
Phase Noise of Master Oscillator

Phase Noise of FLASH MO

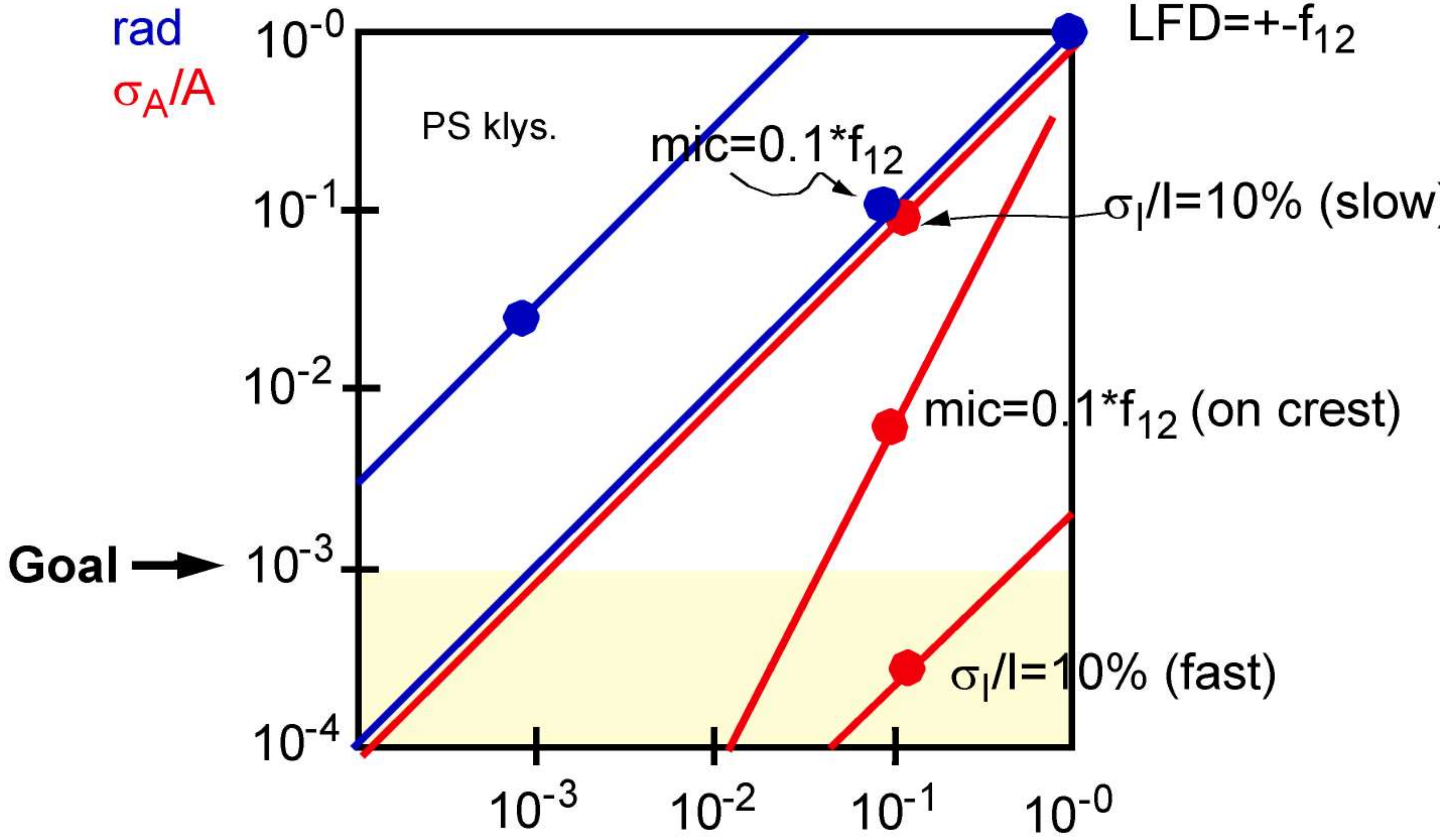


Thermal Drift

Phase Drift of 80 m 7/8“ Reference Line at FLASH



Error Map



rad
σA/A
10-0
10-1
10-2
10-3
10-4
Goal
PS klys.
mic=0.1*f12
LFD=+-f12
σI/I=10% (slow)
mic=0.1*f12 (on crest)
σI/I=10% (fast)
10-3
10-2
10-1
10-0

Reference

[1] T. Schilcher. Vector Sum Control of Pulsed Accelerating Fields in Lorentz Force Detuned Superconducting Cavities. Ph.D. Thesis of DESY, 1998

[2] V. Ayvazyan, S. Simrock. Dynamic Lorenz Force Detuning Studies in TESLA Cavities. EPAC 2004, July 2004.