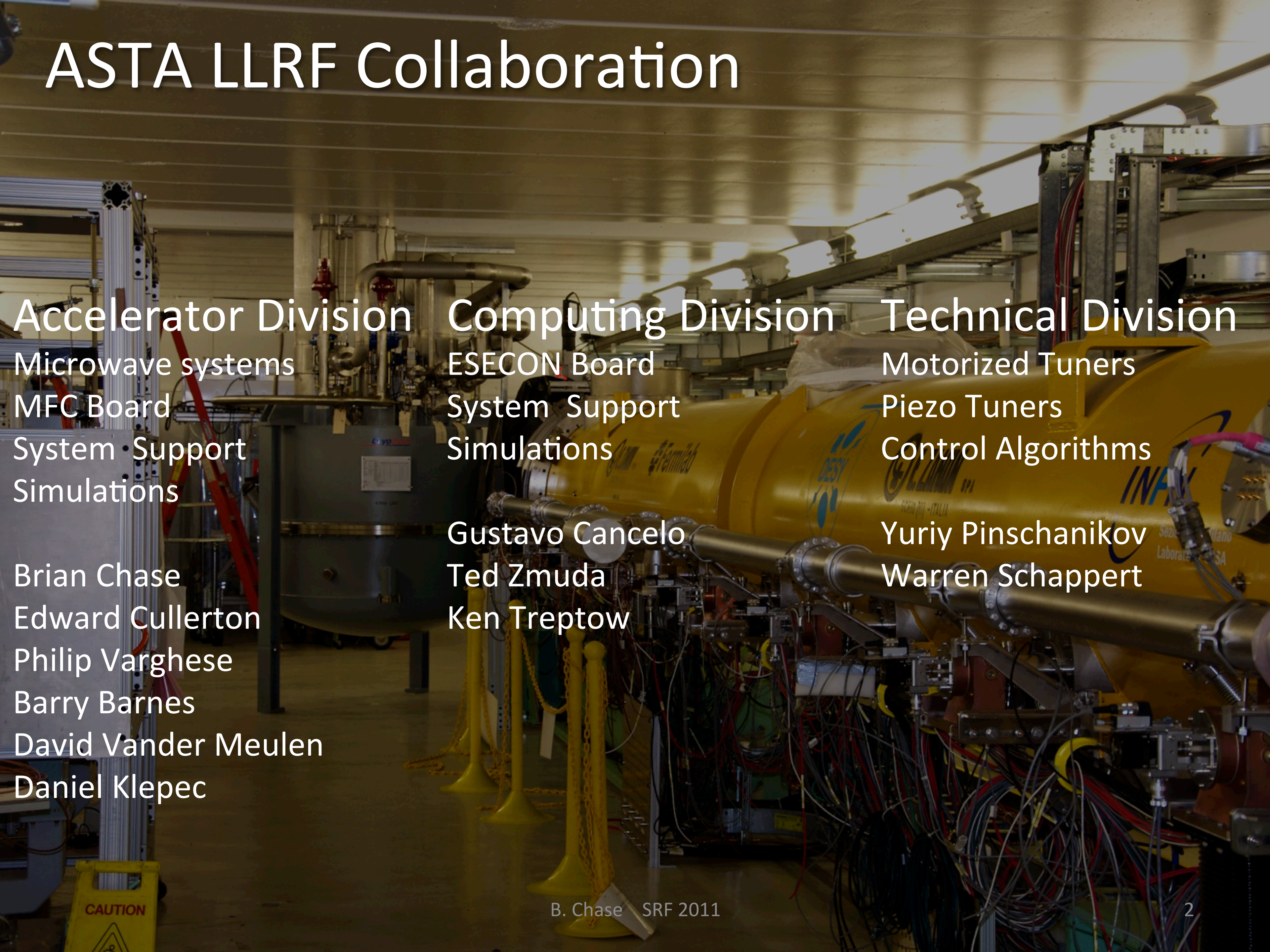
ASTA Low Level RF R&D

Brian Chase
RD Department, Fermilab
for the LLRF Team

ASTA User's Meeting

July 23, 2013



ASTA LLRF Collaboration

Accelerator Division

Microwave systems
MFC Board
System Support
Simulations

Brian Chase
Edward Cullerton
Philip Varghese
Barry Barnes
David Vander Meulen
Daniel Klepec

Computing Division

ESECON Board
System Support
Simulations

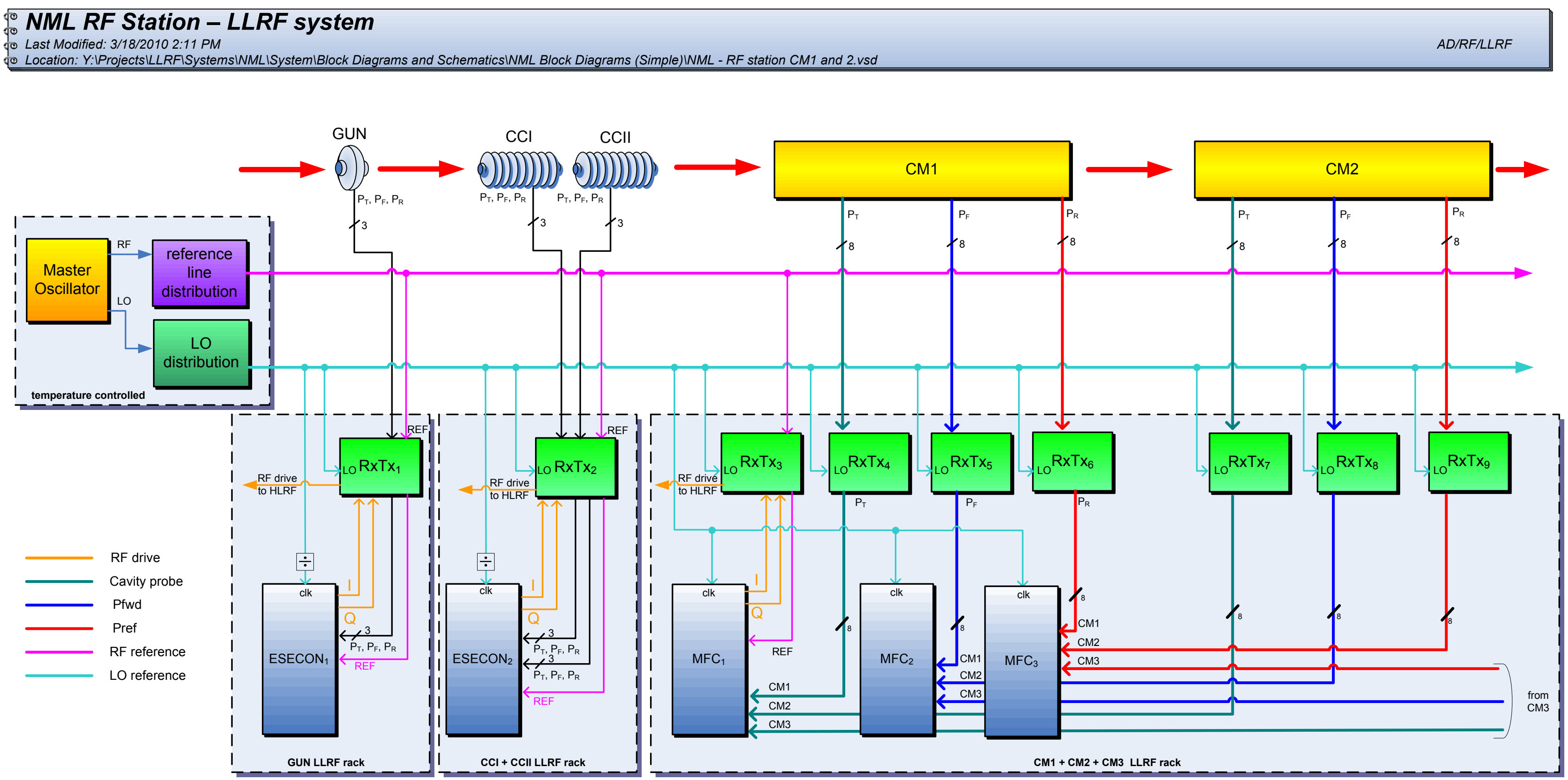
Gustavo Cancelo
Ted Zmuda
Ken Treptow

Technical Division

Motorized Tuners
Piezo Tuners
Control Algorithms

Yuriy Pinschanikov
Warren Schappert

ASTA LLRF Overview



LLRF Performance Strategies for High Stability Beam

- Wideband (150kHz-250kHz) Proportional-Integral feedback
  - 7/9 and 8/9 pi notch filters
  - Highly linear and low noise receivers
- Beam loading compensation
  - Manual and learning feed-forward
- Aggressive resonance control
- High stability reference line
- Future gains will be from beam-based FB

NML CM1 LLRF Racks

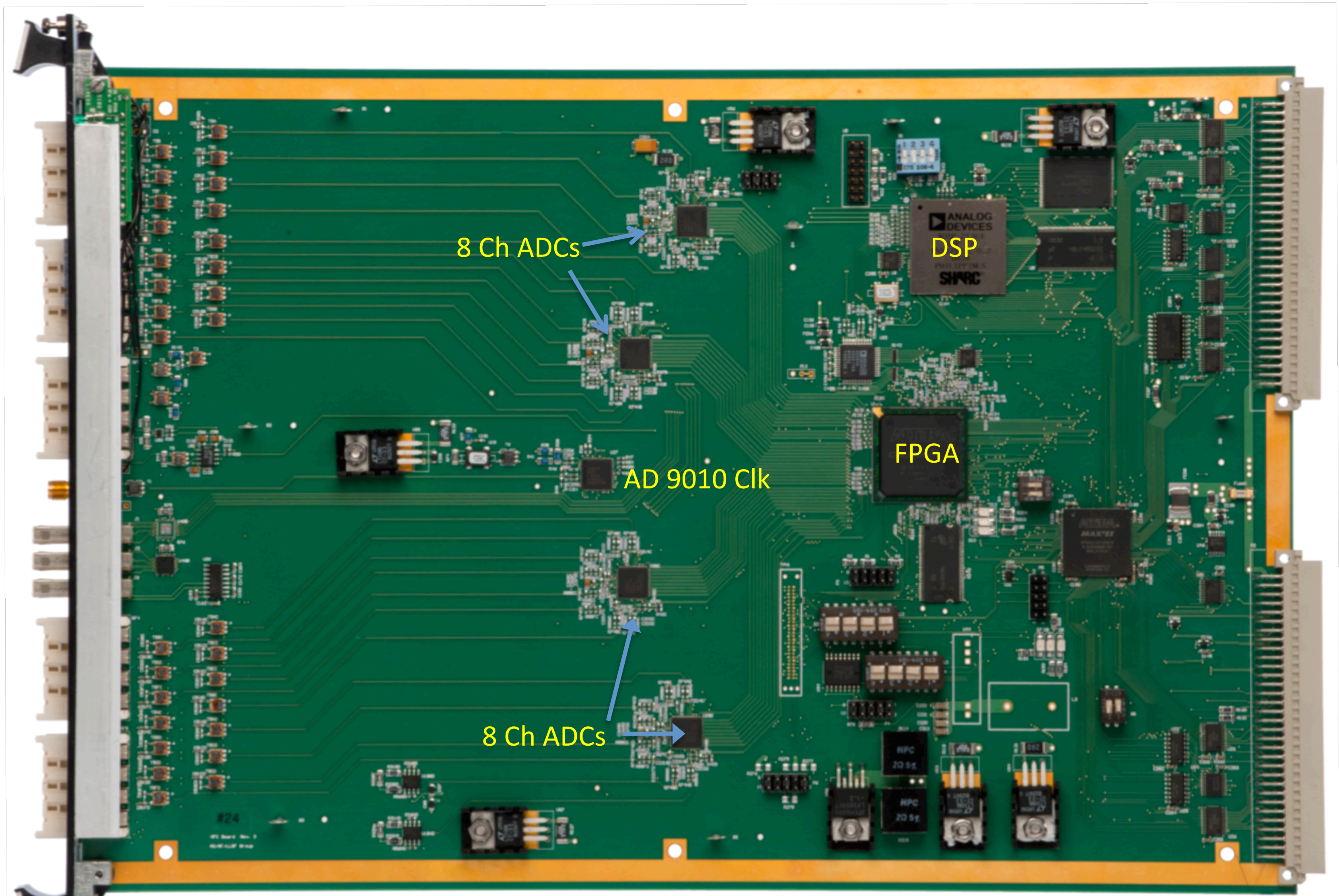
Receivers and Up-converters

VXI CPU &
3 R3MFC Controllers

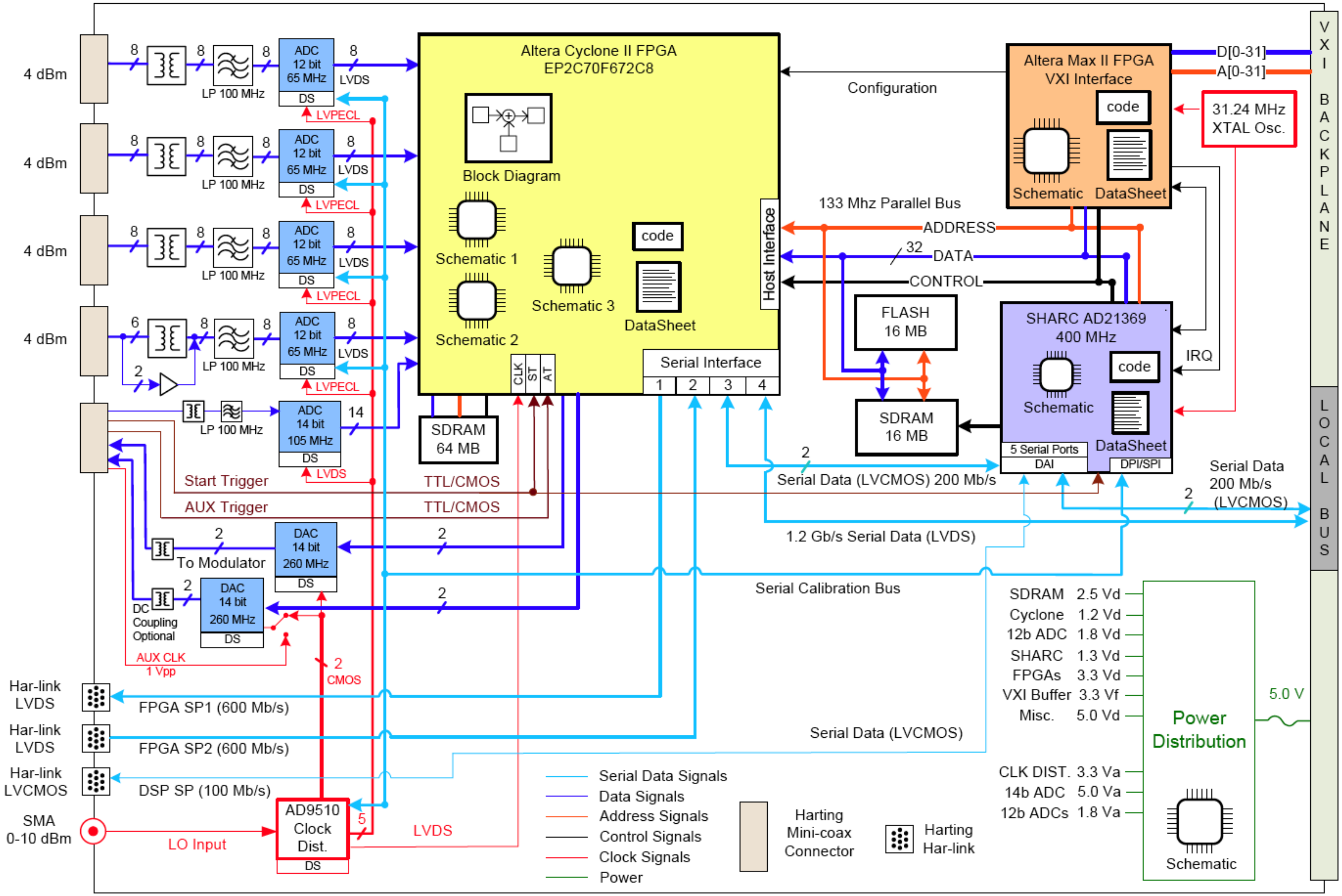
Master Oscillator

Power Supplies

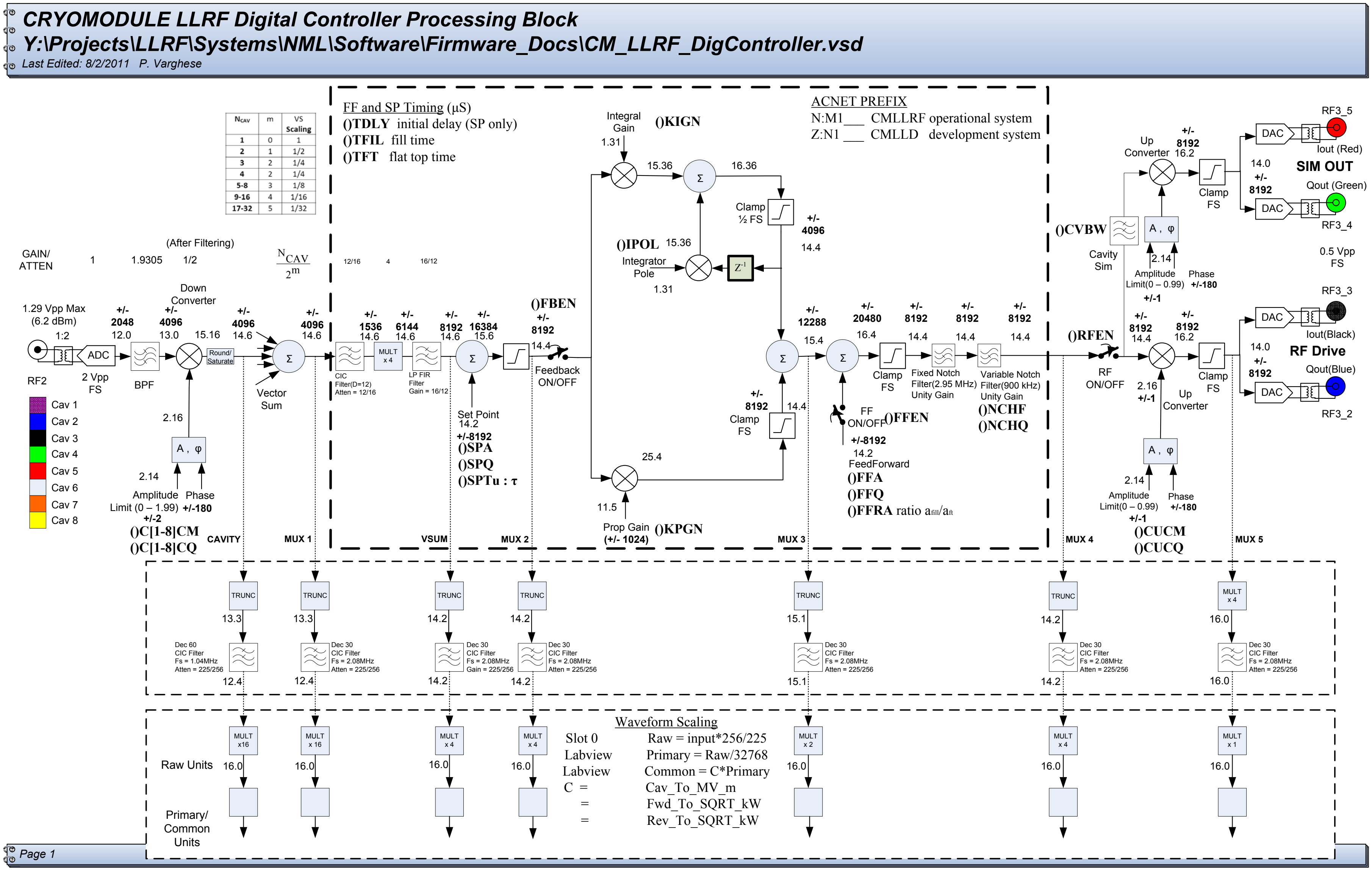
Multi-channel Field Controller (MFC)



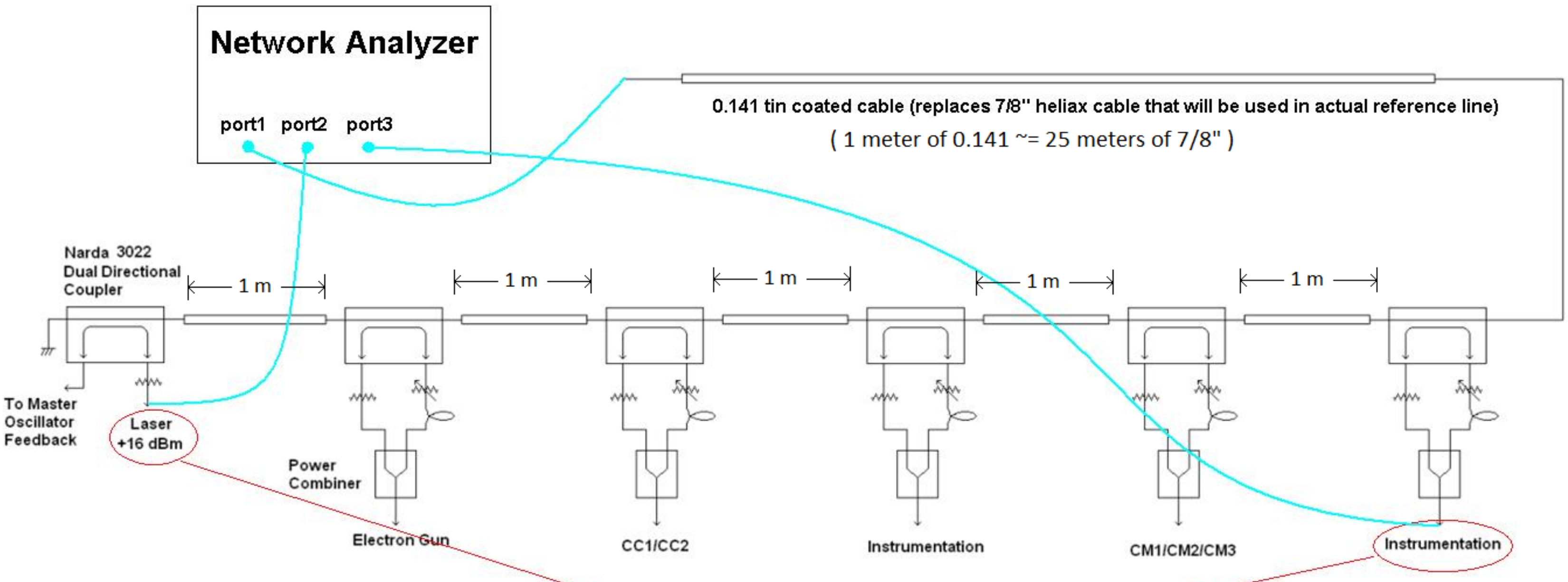
33 Channel Controller (MFC)



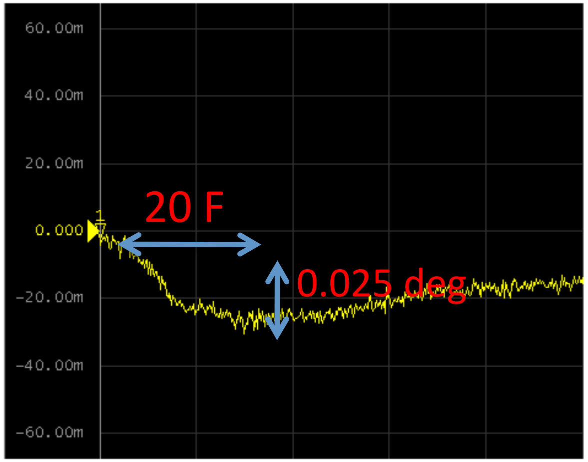
FPGA Signal Processing



Lab Measurements of Phase Averaging Reference Line

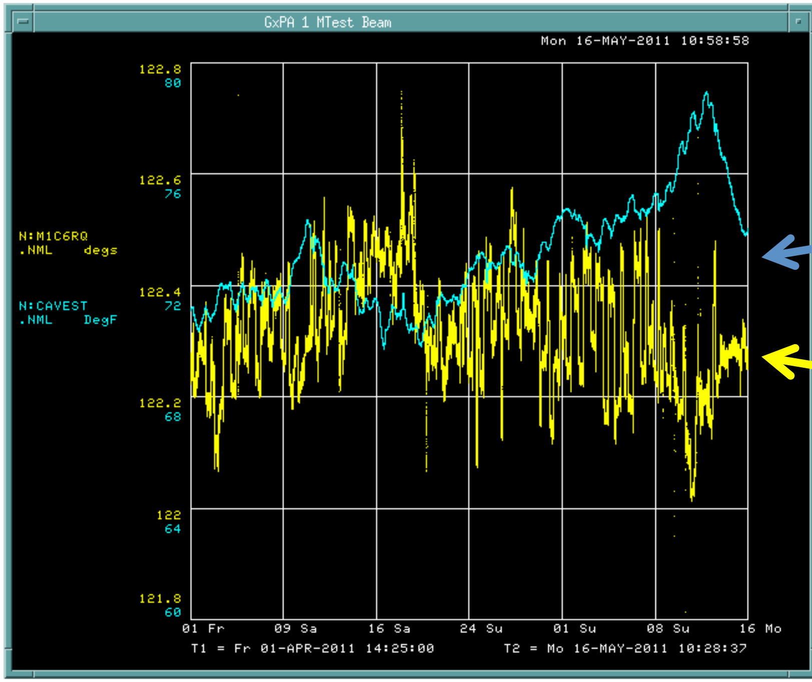


Phase difference between Laser port and Instrumentation port over a 20 degree temperature change (85 - 105 deg F)



- * Measured in the lab using a network analyzer in a temperature controlled oven.
- * Long sections of 7/8 " RFS cable replaced with short sections of tin coated .141 cable that has similar temperature characteristics.
- * Measurement may have small uncertainty due to calibration drift of the network analyzer.
- * Oven temperature ramped from 85 to 105 degrees F in first twenty minutes of measurement.
- * Total measurement time is 1 Hour

Receiver Chain Stability Measurement vs Building Temperature



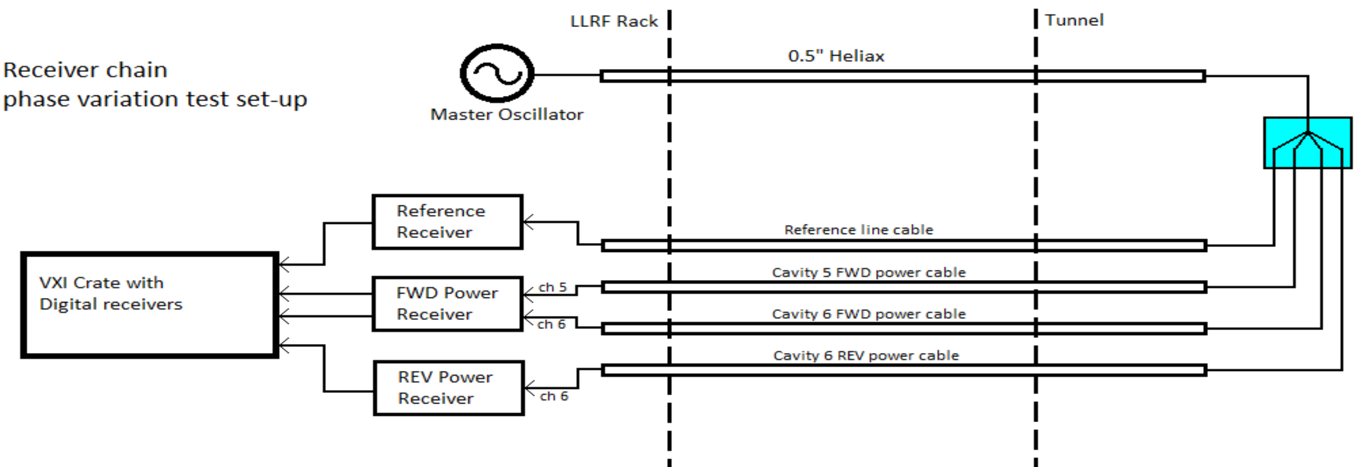
Blue – Building Temperature

Yellow – CH 6 Rev phase

6 week test period

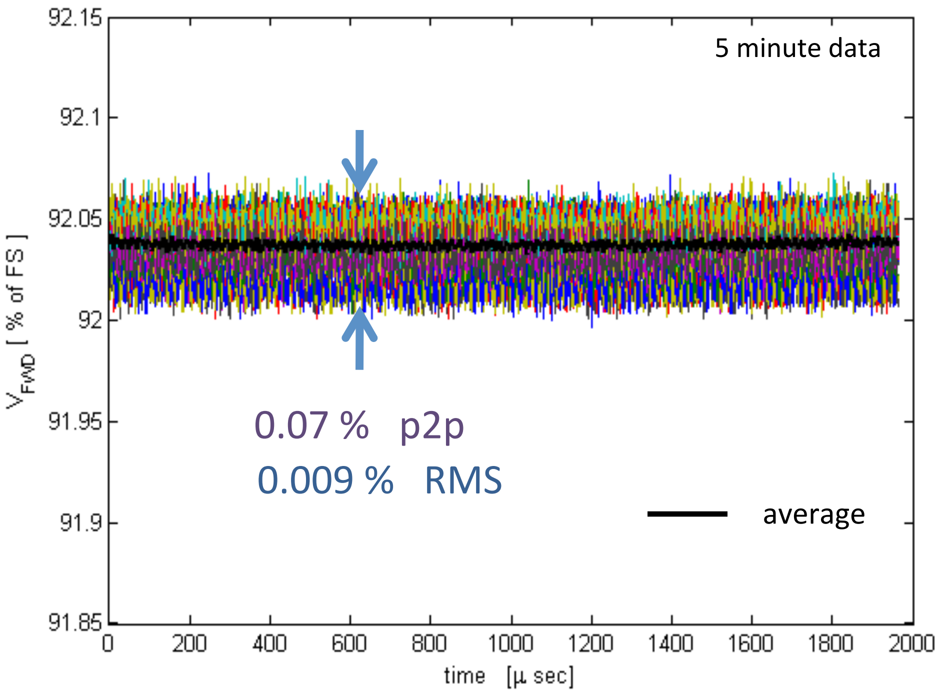
Approximate phase variation = 0.03 degrees / 1 degree F

Receiver chain phase variation test set-up

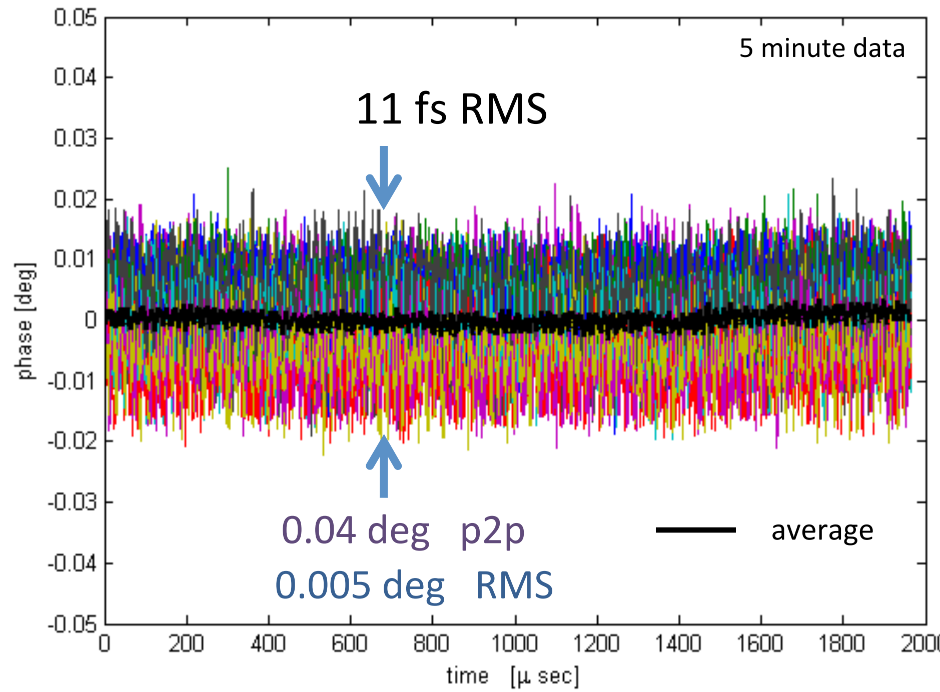


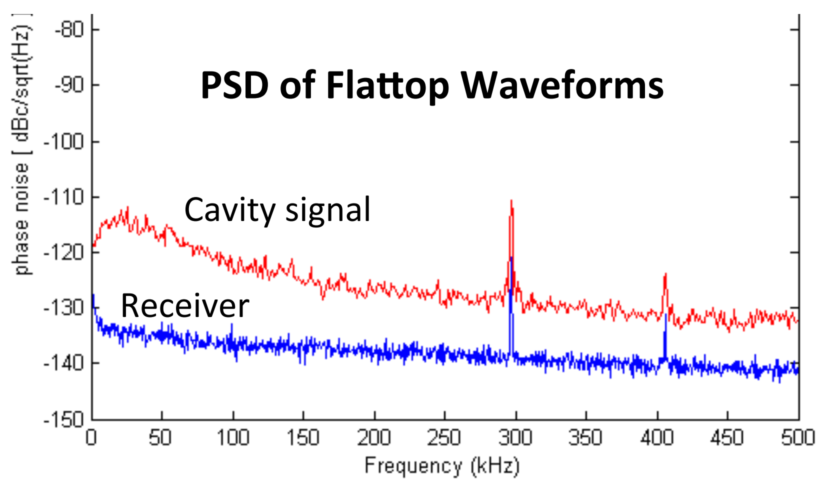
Receiver noise

Amplitude

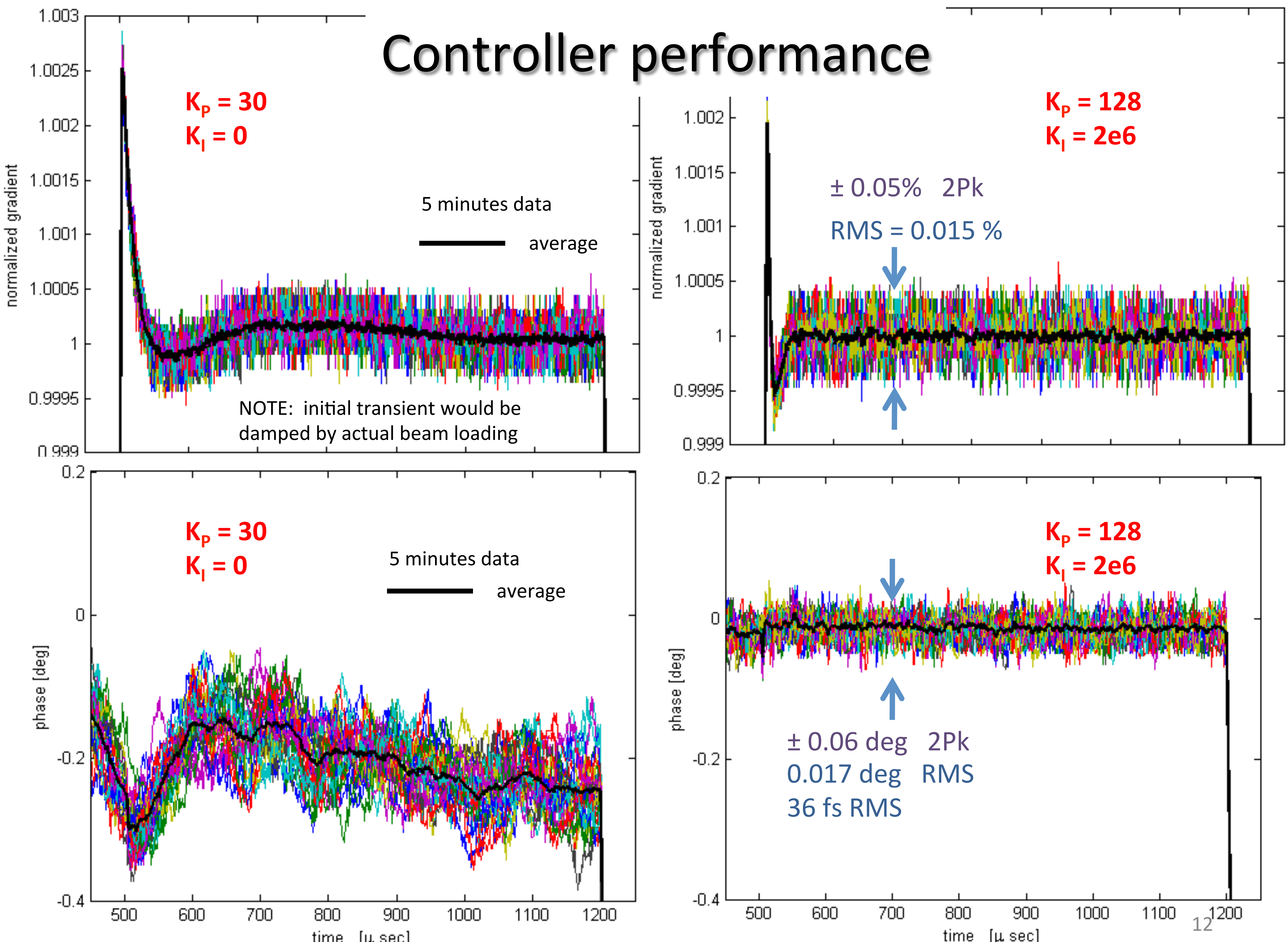


Phase

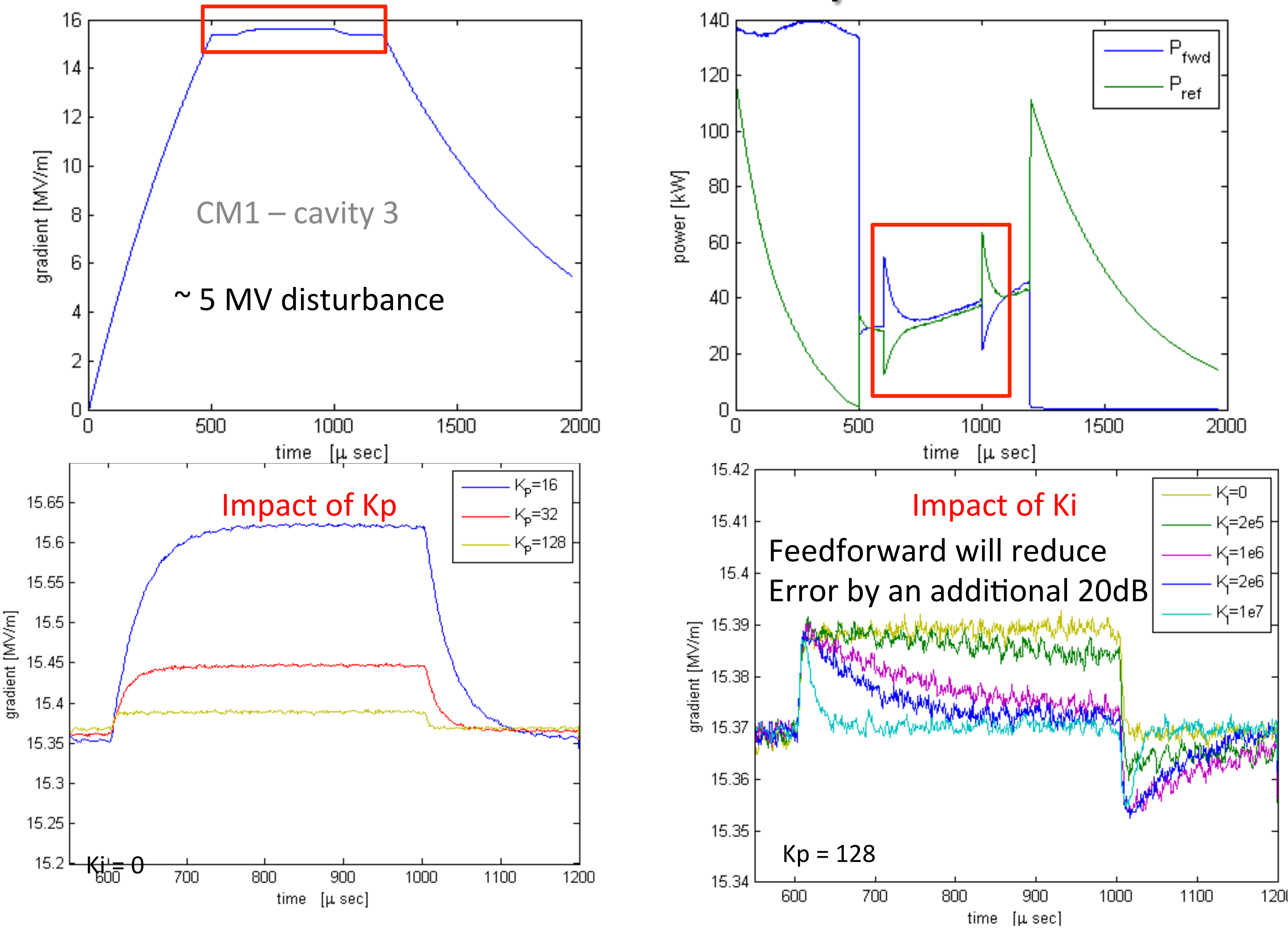




Controller performance



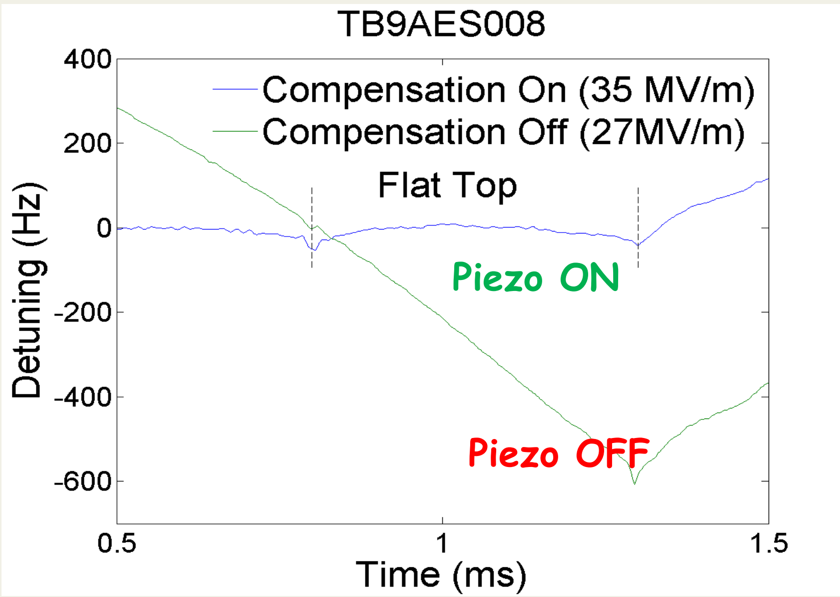
Perturbation analysis

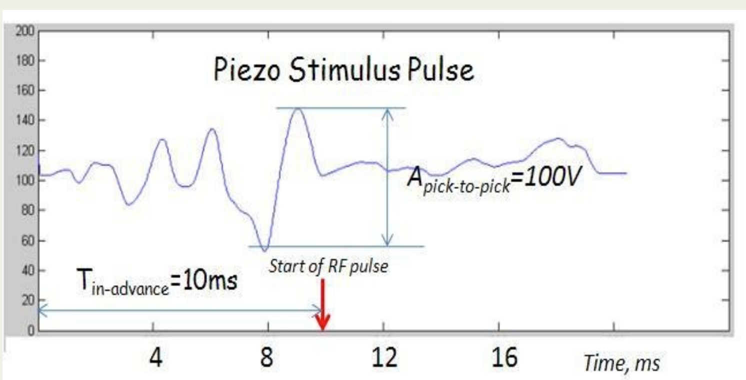


LFD compensation at MDB FNAL

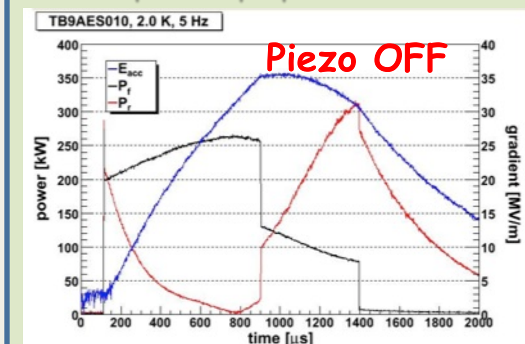
LFD during 1,3ms RF-pulse (Fill+FlatTop) was ~**2300Hz**

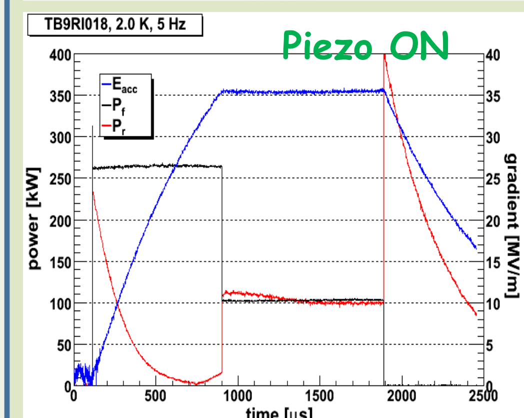
LS LFD compensation -- to less than **20Hz** during 1,3ms pulse





Eacc=35MV/m
Open loop operation

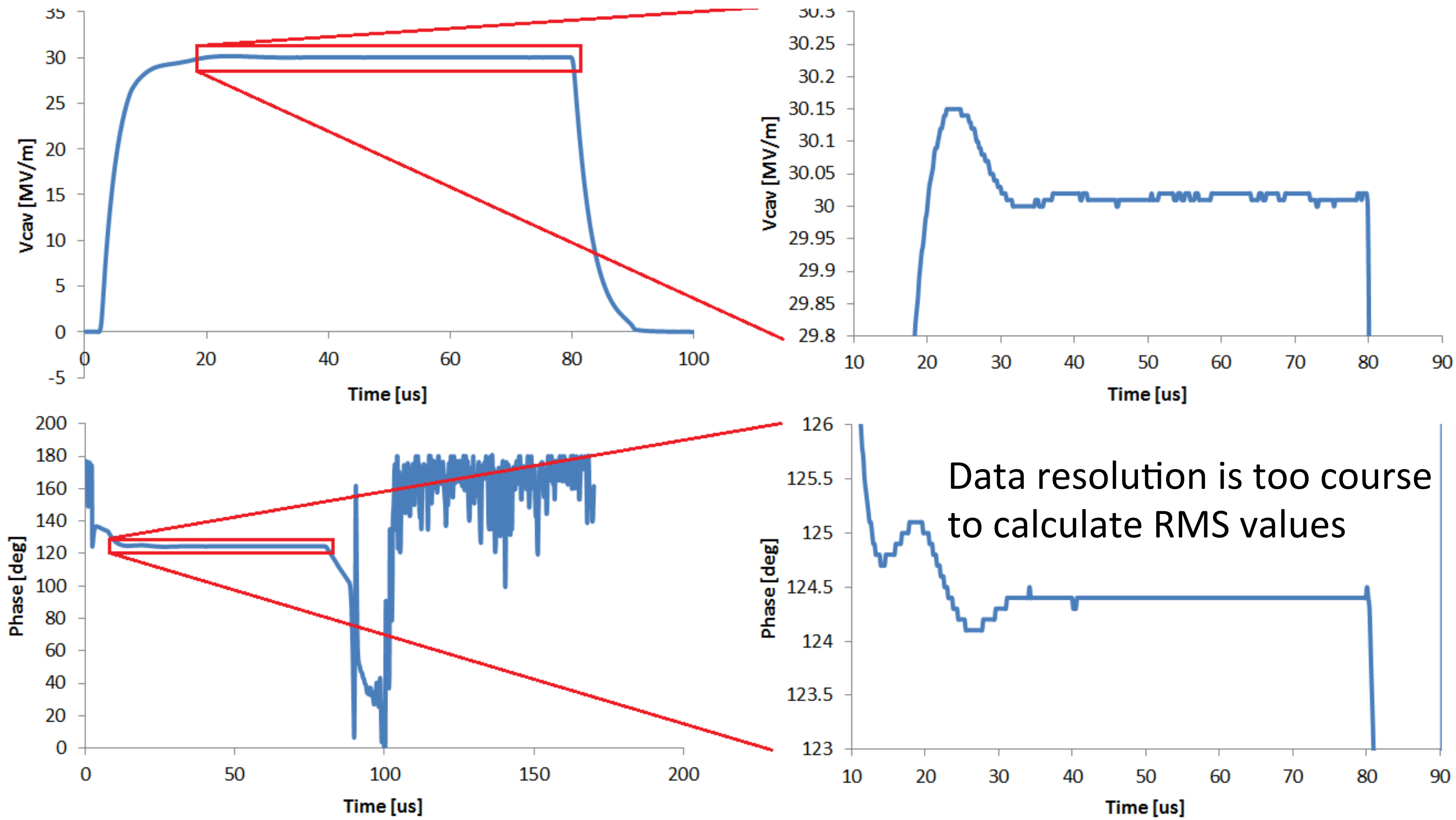




W. Schappert, Y. Pischalnikov

Fermilab

First Gun Regulation Measurements



Data resolution is too course to calculate RMS values

LLRF Status

- Good operational experience with CM1
  - MFC controller with 8 cavity vector sum
  - Resonance control of Lorentz Force Detuning
- Good operational experience with CC2
  - ESECON controller
- Operation of the gun in the last week (short pulse)
  - ESECON controller
  - Resonance control with water loops is progressing
- RF calibration chain of power couplers, cables and LLRF systems
- RF reference line is installed with stability tests in progress
- RF field control is in good shape – waiting for beam…

Towards lower jitter beam

Develop intra train beam-based feedback using:

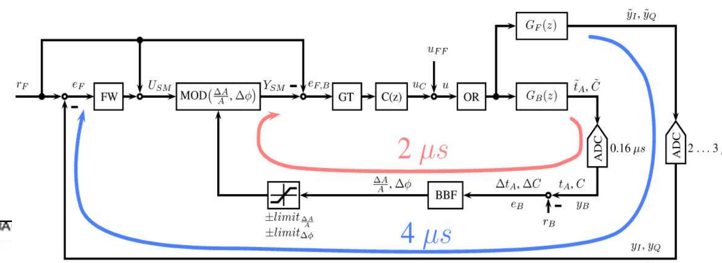
- BAM (Beam Arrival-time Mon.)
- BCM (Beam Compression Mon.)

Error signals are applied to the laser and cavity RF vectors.

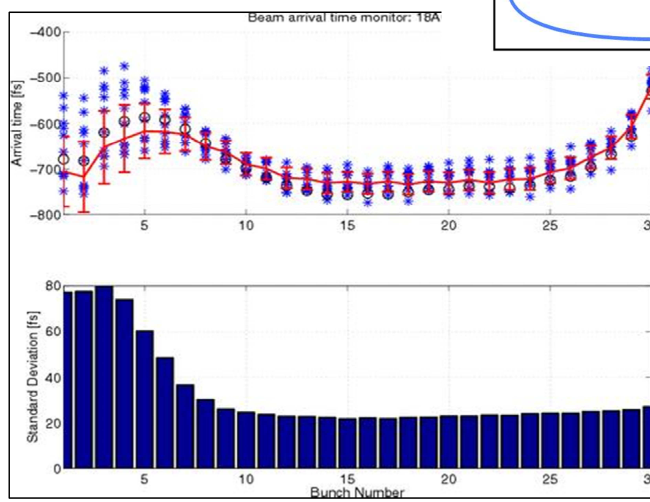
Intra train Beam based feedback

> Cascaded feedback loop:

- reduce latency
- Increase regulation bandwidth



Courtesy: S. Pfeiffer



> Out of loop measurement at 18ACC7

- User arrival time monitor
- Influence on regulation performance of ACC23
- Arrival time jitter can be reduced below 20fs (about x4)

SOURCE: Christian Schmidt for the LLRF team
1st ARD Workshop ST3
"ps-fs Electron and Photon beams"
21.08.2012

Interest from Colorado State University

- Interest in applying neural network based techniques to accelerator control systems and multi-objective parameter optimization
  - *adept at black box and gray box modeling*
  - *incorporation of adaptive components will enable adjustments to slow changes in machine characteristics to be made automatically*
  - *can be combined with existing control systems and analytic models for added robustness*

- Have identified some possible focus areas at ASTA
  - Adaptive field and resonance control of the copper gun
  - Adaptive resonance control of the superconducting RF cavities
  - Superconducting RF cavity field control
  - Self-calibration and control of timing drift
  - Efficient global system start up, mode control, and exception handling

- *Because of its unprecedented beam parameters at the energy/intensity frontiers and use of SCRF technology, ASTA would be an extremely valuable test bed for the development of novel accelerator control schemes*