ILCTA_NML

Thanks to Sergei Nagaitsev for use of his slides from the ILC School at Fermilab

Purpose of ILCTA_NML

- Provide ILC like beam for SCRF cavity tests
- Provide a facility for use by ILC collaborators
  - *Crab cavities*
  - *Diagnostics*
  - *Personnel training*
  - *Accelerator R&D*

Controls Focus at ILCTA_NML

- Create a stable and robust controls system for SCRF and associated components R&D
  - *Provide automatic procedures for cavity and cryomodule testing*
  - *Provide an infrastructure that can readily integrate components developed at collaborating institutions*
- Provide a venue for ILC Controls & LLRF R&D

Opportunities for Controls R&D

- Timing systems
  - *RF Phase and Distribution*
  - *Data correlation*
  - *Clock System Development*
- High Availability Platform for Beam Instrumentation
  - *BPMs*
- Beam Based Feedback
- Cavity Data Management
- Automation

S2 Task Force

Phase	Completion date	Description
0	2005	TTF/FLASH, not final cavity design, type 3 cryomodule, not full gradient, has beam but work is needed to have regular ILC bunch structure, roughly 2 RF units.
1	2008	1 cryomodule, not final cavity design, type 3 cryomodule (and/or) STF type cryomodule, not full gradient, no beam
1.1	2009	1 RF unit, not all final cavity design, not all type 4 cryomodules, not full gradient, beam not needed for tests, but should be built so it and the LLRF are debugged for the next step
1.2	2010	1 RF unit (replacing cryomodules of phase 1.1), final cavity design, full gradient, type 4 cryomodules, with beam
1.3	2011	1 RF unit (replacing cryomodules of phase 1.2), final cavity design, full gradient, type DFM cryomodules, with beam
1.4	2011	Tunnel mockup above or below ground. 1 RF unit perhaps built with parts taken from earlier tests. Includes RTML and e+ transport, no beam
2	2013	Several RF units at one site (of the final ILC?) as a system test of final designs from multiple manufacturers. Need for beam depends on design changes made after phase 1.4.
3	2013	XFEL
4	2018	First 2.5 km of ILC

ILC basic design parameters

Center-of-mass energy range	GeV	200–500
Peak luminosity[1]	$cm^{-2}s^{-1}$	2×10^{34}
Beam current	mA	9.0
Pulse rate	Hz	5.0
Pulse length (beam)	ms	~1
Number of bunches per pulse		1000–5400
Charge per bunch	nC	1.6–3.2
Accelerating gradient[1]	MV/m	31.5
RF pulse length	ms	1.6
Beam power (per beam)[1]	MW	10.8
Typical beam size at IP[1] ($h\times v$)	nm	640×5.7
Total AC Power consumption[1]	MW	230

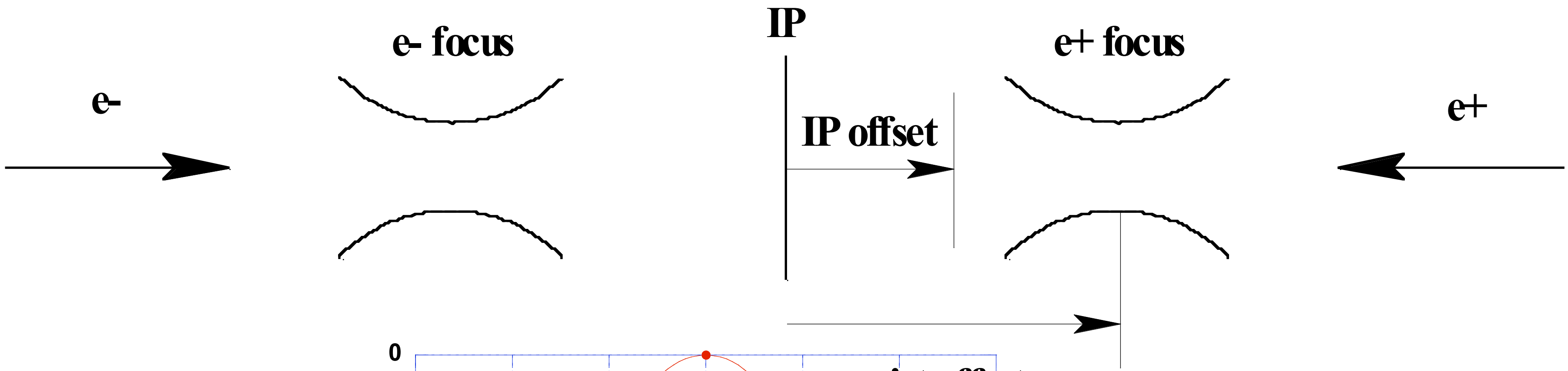
1) at 500 GeV center-of-mass energy

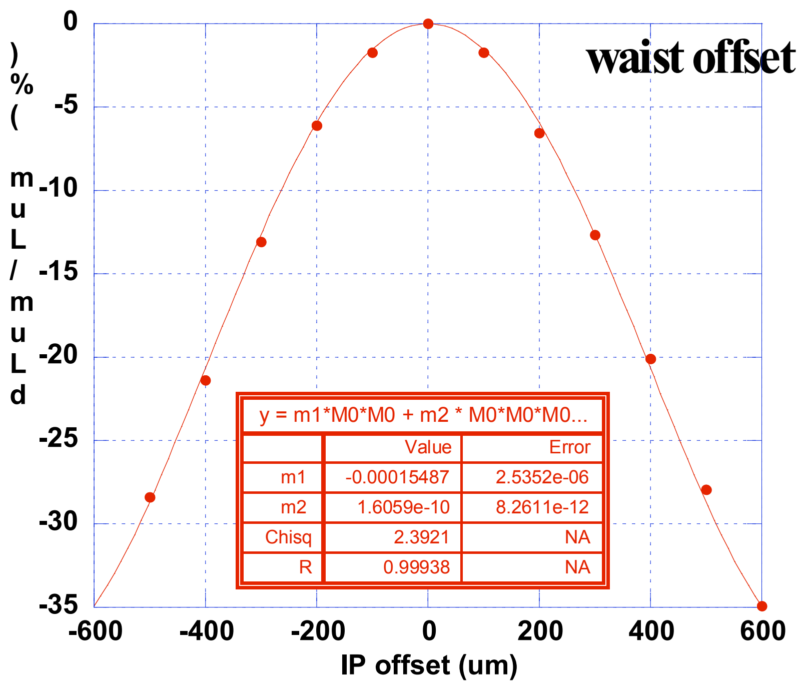
- Bunch length at IP (rms): 0.3 mm or 1 ps or 0.5º (1.3 GHz)

RTML bunch compressor (key

Parameter	Nominal BC1 Value	Nominal BC2 Value
Initial energy	5 GeV	4.88 GeV
Initial energy spread	0.15%	2.5%
Initial bunch length	9 mm	1.0 mm
RF voltage	448 MV	11.4 GV
RF phase	-105°	-27.6°
Wiggler R_{56}	-376 mm	-54 mm
Final energy	4.88 GeV	15.0 GeV
Final energy spread	2.5%	1.5%
Final bunch length	1.0 mm	0.3 mm

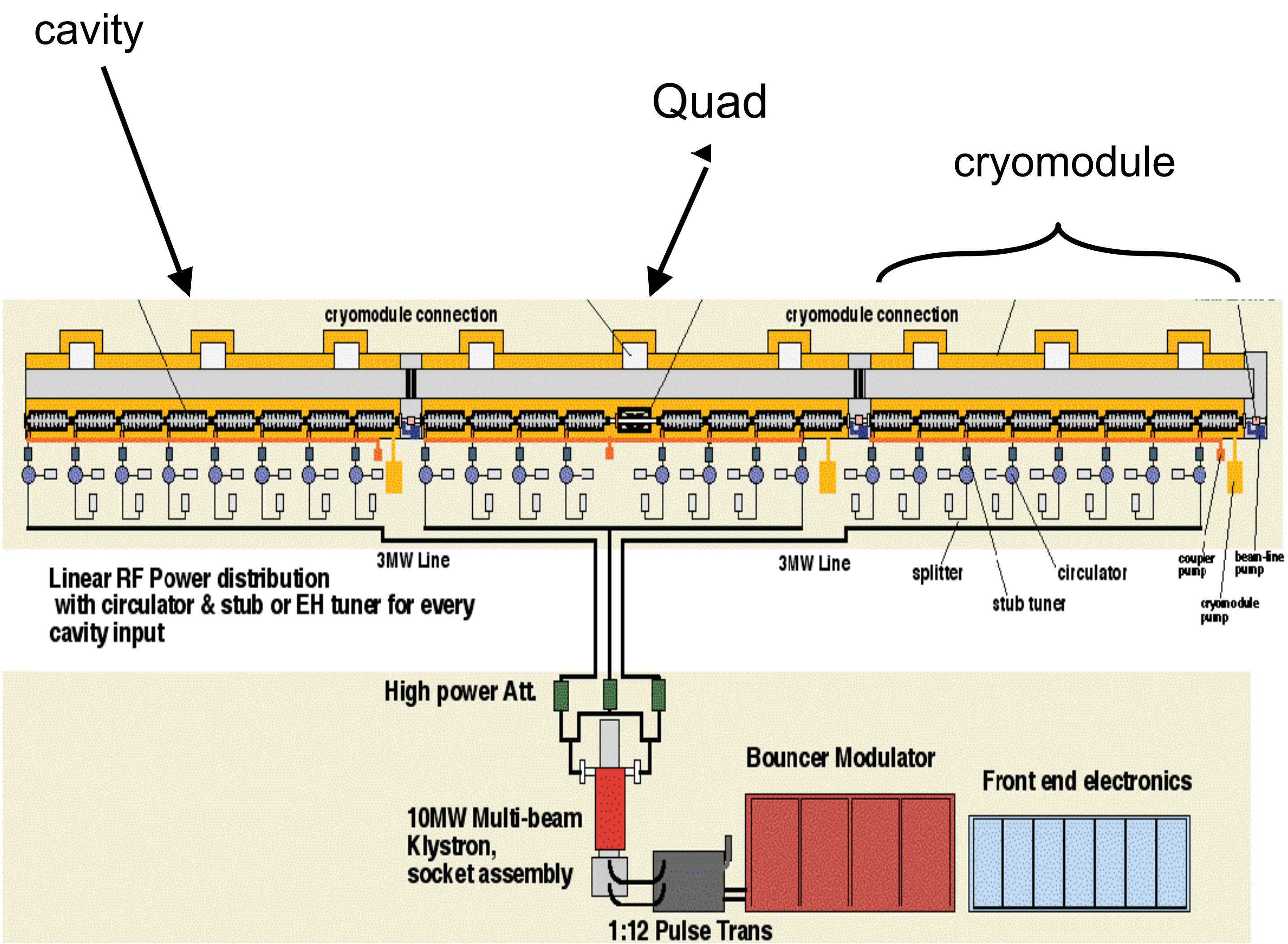
IP offset defines the time jitter of the collision point





1 ps ≈ 0.3 mm ≈ 0.5°

One ILC RF Unit

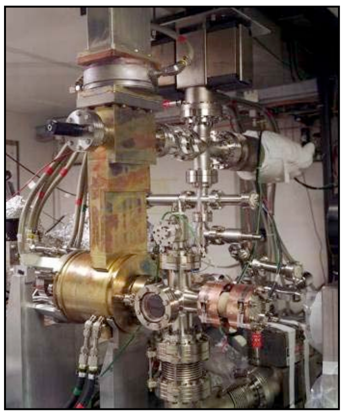


ILCTA Plans

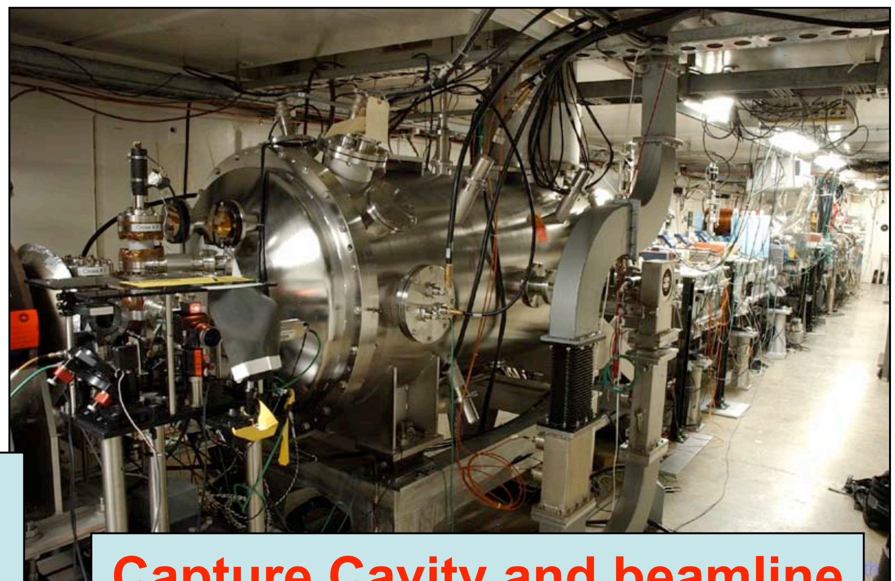
- Effort is Funding limited➔ phased approach
- Cryomodule delivery
  - *1st (Type 3+) cryomodule being assembled now from "kit" of DESY*
  - *2nd (Type 3+) CM – 2008 built with U.S. processed cavities*
  - *3rd (ILC Type 4) CM – 2009 all U.S. components*
  - *Replace all three CMs with ILC Type 4+ in FY2010*
- FY07: Start as a Cryomodule Test Stand
- FY08: move A0 photoinjector, start civil construction for new bldg
- FY09: 1st beam operation, 2-3 CM, low rep rate operations
- FY10: replace all 3 CM with ILC type CM
- FY11: install new refrigerator, ILC RF Unit operations
- Collaboration: DESY, INFN, ANL, Cockroft, NIU, Rochester, KEK

A0 Photo Injector

- The A0 Photo Injector built in collaboration with DESY as part of the TESLA collaboration (essentially a copy of TTFI)
- In operation since late 90's
- Two klystron-based RF systems power the RF Gun & Capture Cavity
- Built a second capture cavity (CCII) using high gradient DESY cavity
- A0 RF assets and CCII will be moved to NML in 2008



RF Gun prior to solenoid installation



Capture Cavity and beamline

Capture Cavity-II

Scope of LLRF Projects

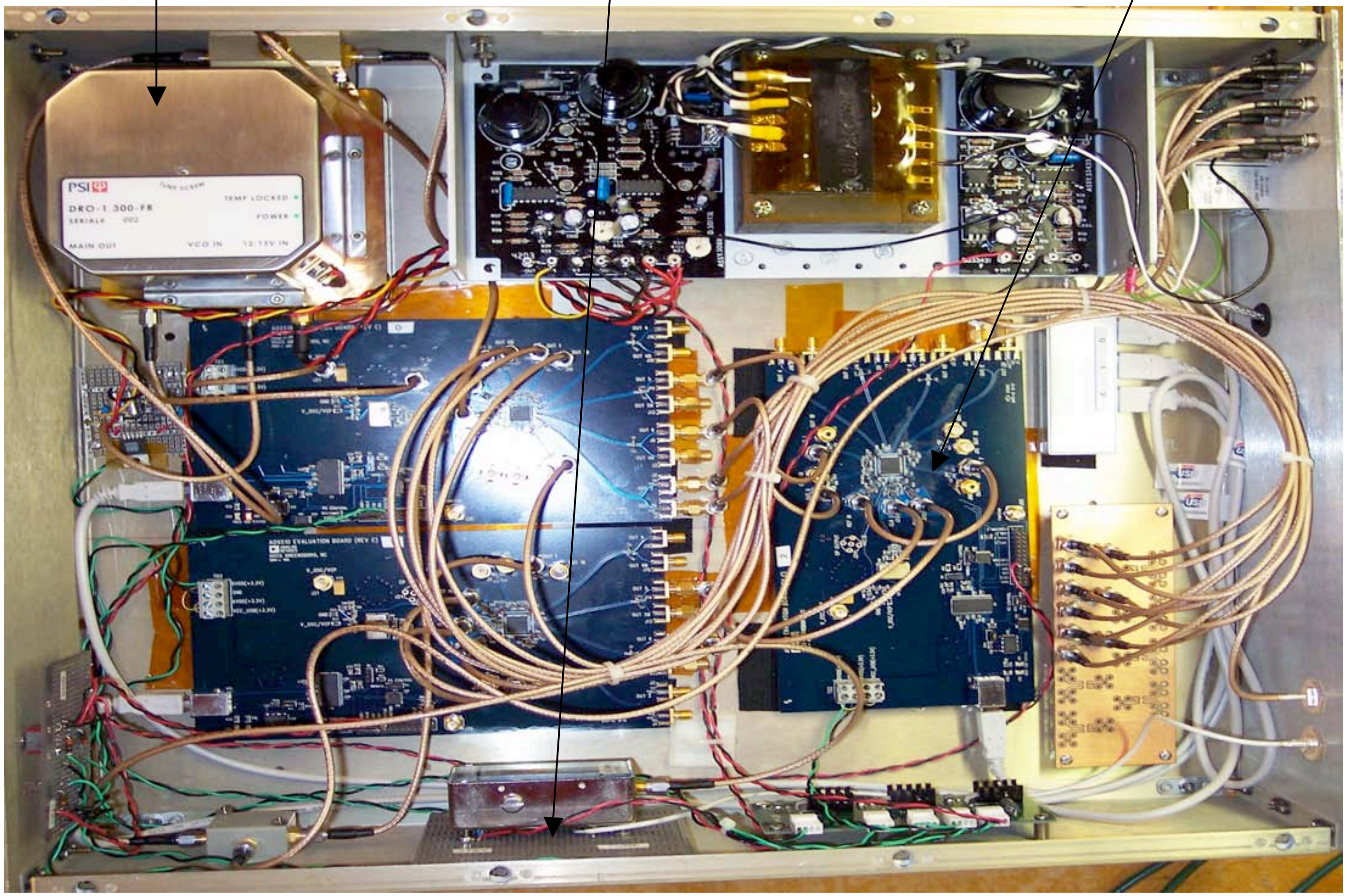
- Vertical Test Stand
  - *Cavity testing with automation - analog LLRF (TD/Jlab)*
- Horizontal Test Stands
  - *Dressed cavity testing - DESY/FNAL LLRF controller(Simcon)*
    - Simcon is a 10 channel input VME controller developed for DESY
- High Intensity Neutrino Source HINS
  - *325 MHz, Fast Ferrite Vector Modulator -, LBNL/SNS//FNAL*
- Coupler Conditioning Stand
  - *1.3 GHz and 3.9 GHz - rack and stack -> Simcon*
- NML - Full RF Unit Test - no beam
  - *3 Cryomodules with 24 cavities - Simcon followed by FNAL design (MFC Module)*
- NML - Photo Injector Source - beam to test string
  - *Beam based calibration, beam loading, phase reference line - Simcon*

Our Path to Meet these Goals

- Evolve the 10 channel DESY Simcon system
  - *Higher Intermediate Frequency development*
  - *Fermilab is producing a next version Simcon card to improve noise and bandwidth performance*
    - Status: close to production
- Develop a Multi-Channel Field Control Module (MFC)
  - *33 ADC channels, FPGA, DSP, 4 DAC channels*
  - *High density, low cost, low power and is based on VXI*
  - *Status: Front-end testing complete, close to production*
- Develop the analog RF sections
  - *96 channel receivers*
  - *Transmitter*
  - *Master Oscillator*
  - *Phase Reference Distribution with pulsed reference line*

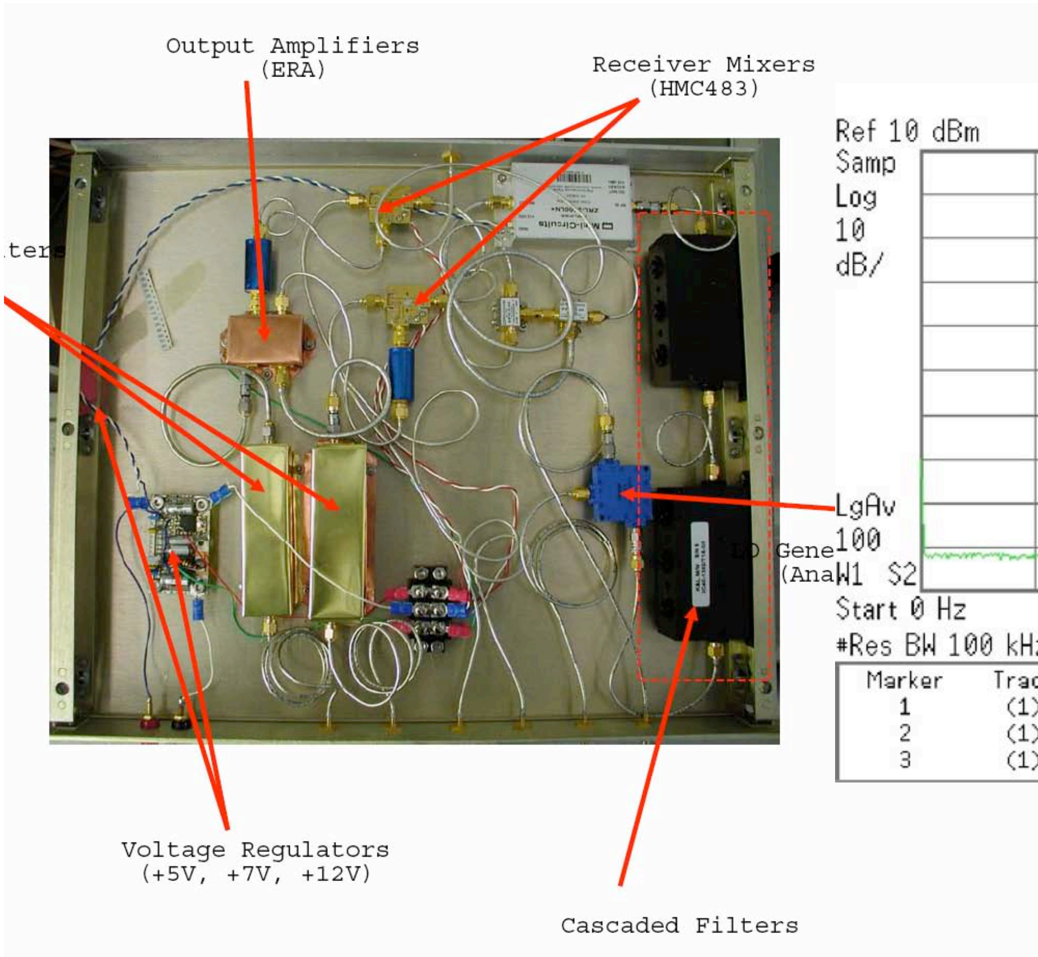
Prototype Master Oscillator

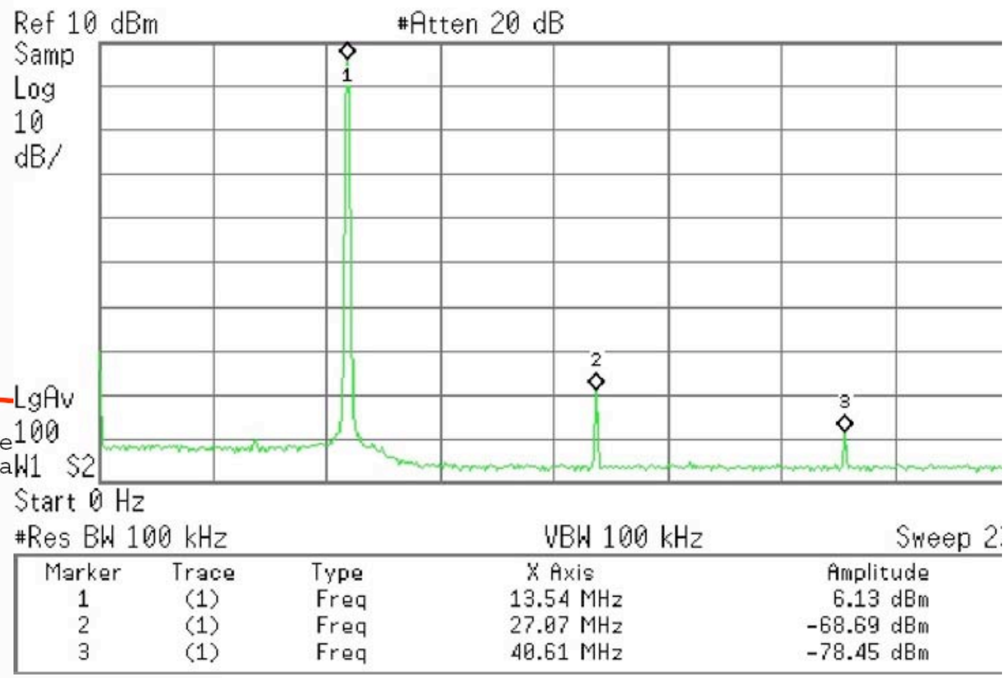
1300 MHz low noise DRO: 10MHz VCXO: Programmable frequency outputs



Prototype LO Gen/Down-converter

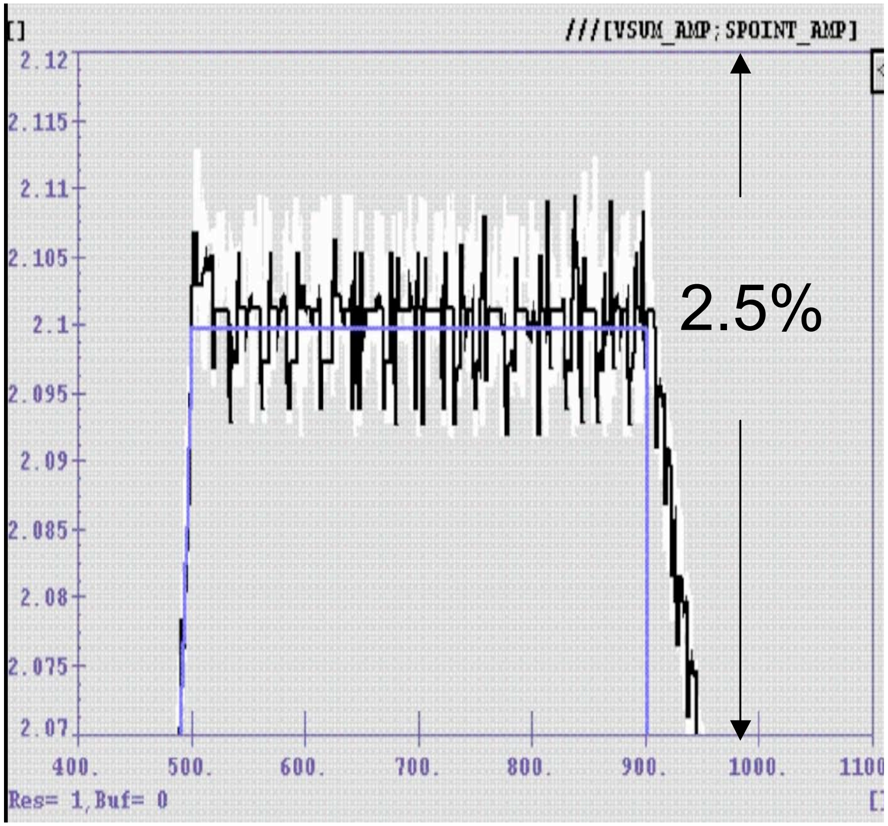
1313 MHz Local Oscillator





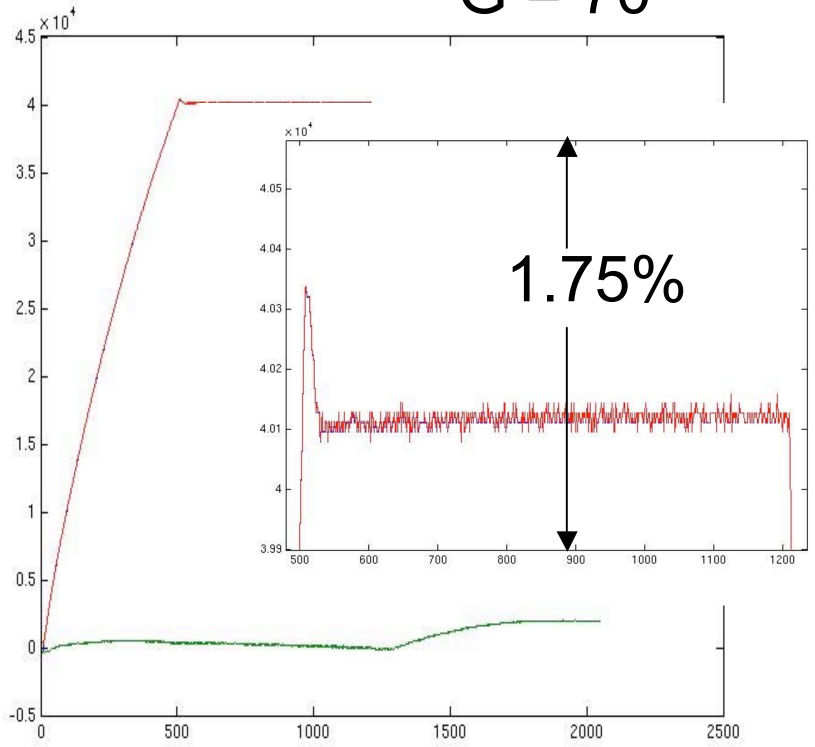
2nd harmonic -69dBc

CC2 Results with 13 MHz IF



250 kHz IF

G = 70

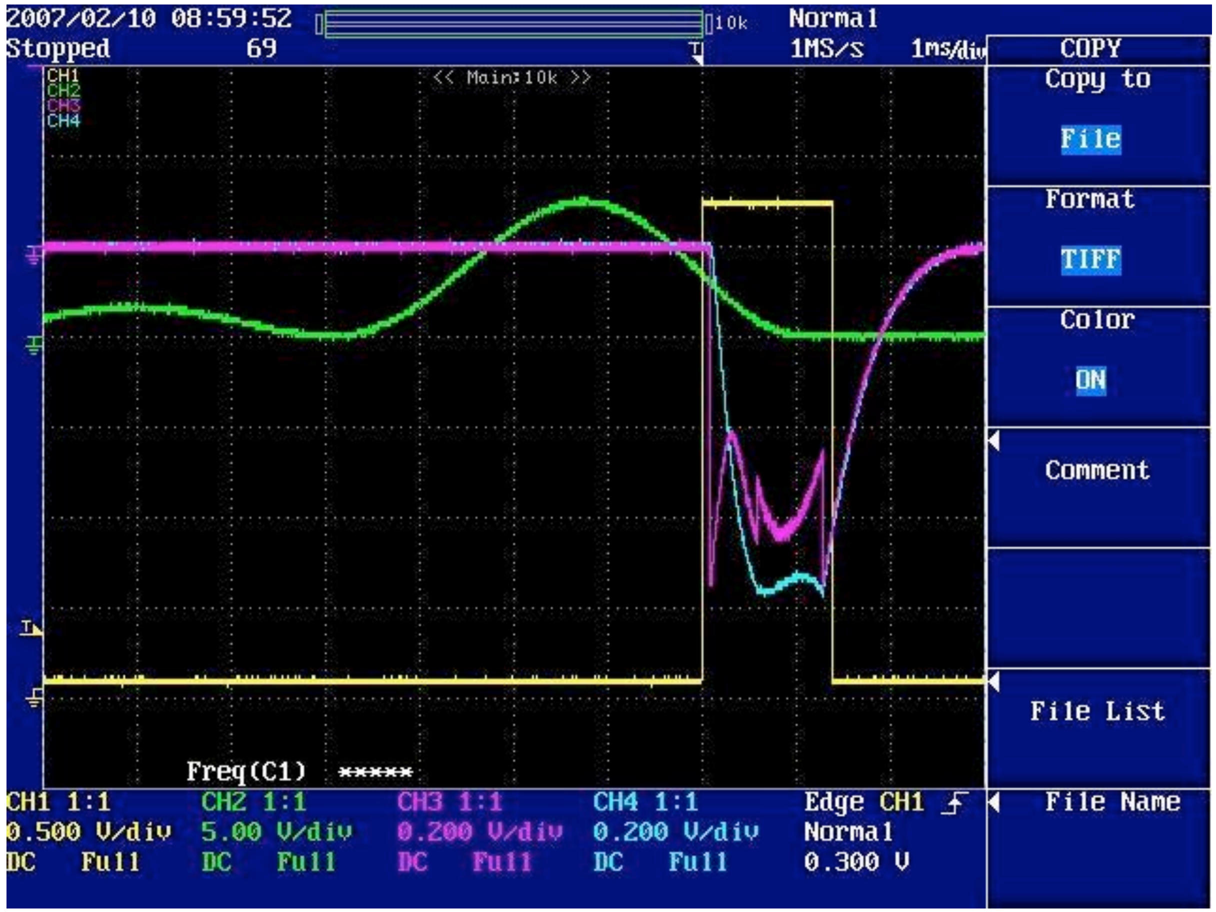


13MHz IF

Piezo-electric Control of CC2

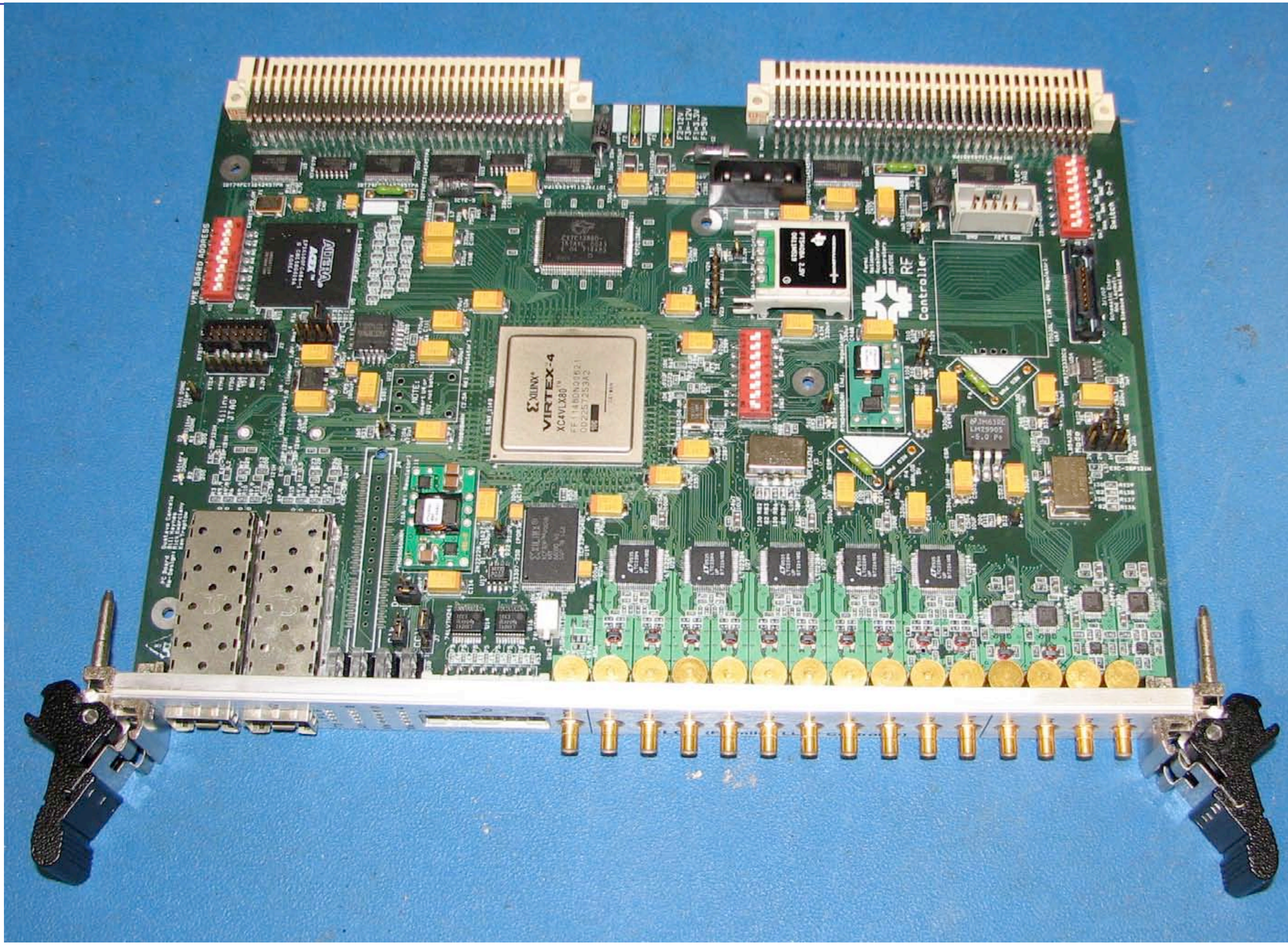
The Piezo-electric actuator counteracts the Lorentz force to maintain the cavity on resonance

Cavity field @ 25 MV/m

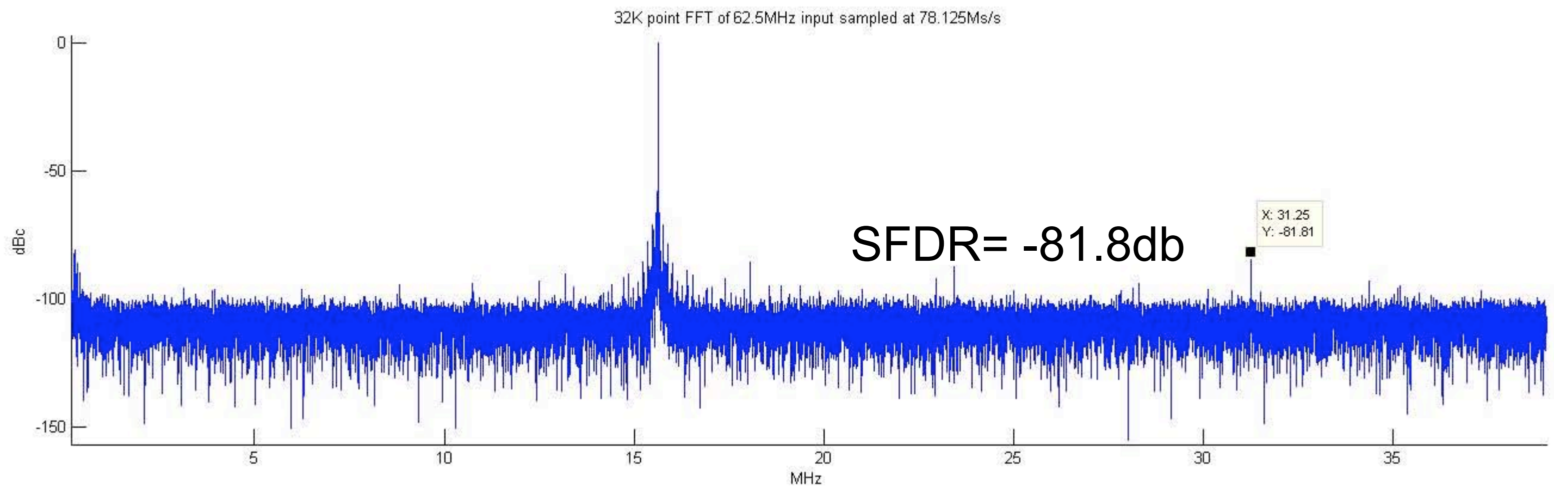


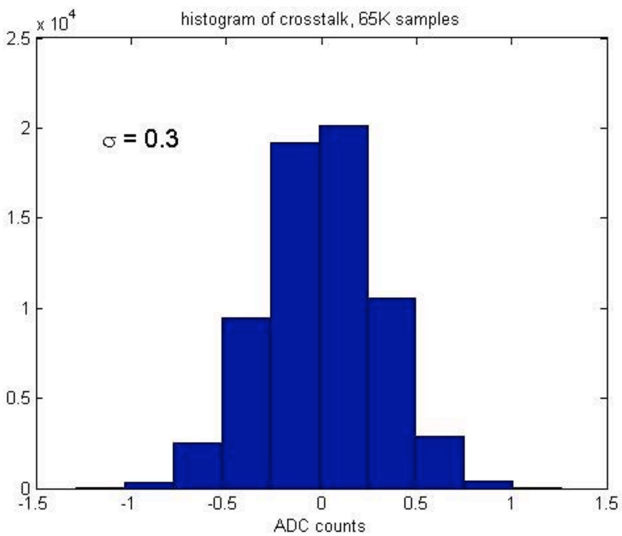
Piezo Drive -green
Cavity Probe - Cyan
Reflected Power - Magenta

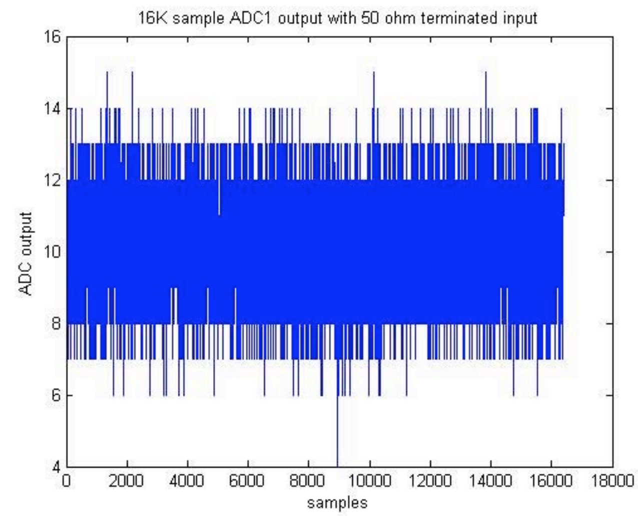
ESECON 10 channel LLRF controller



10 channel LLRF controller measurements





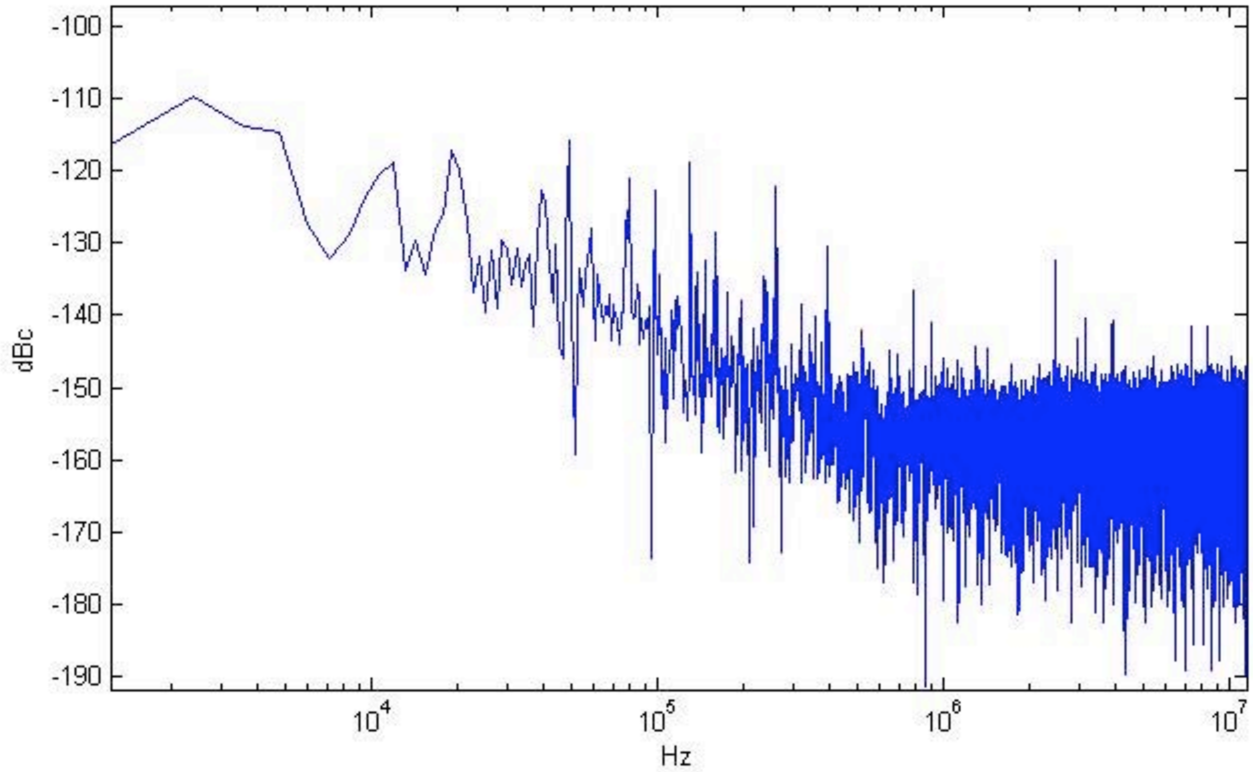


- Crosstalk on ADC2 when ADC1 input is 2V pk-to-pk , 62.5MHz.
- Histogram is average of 10 65K samples, individual sigma is 0.9

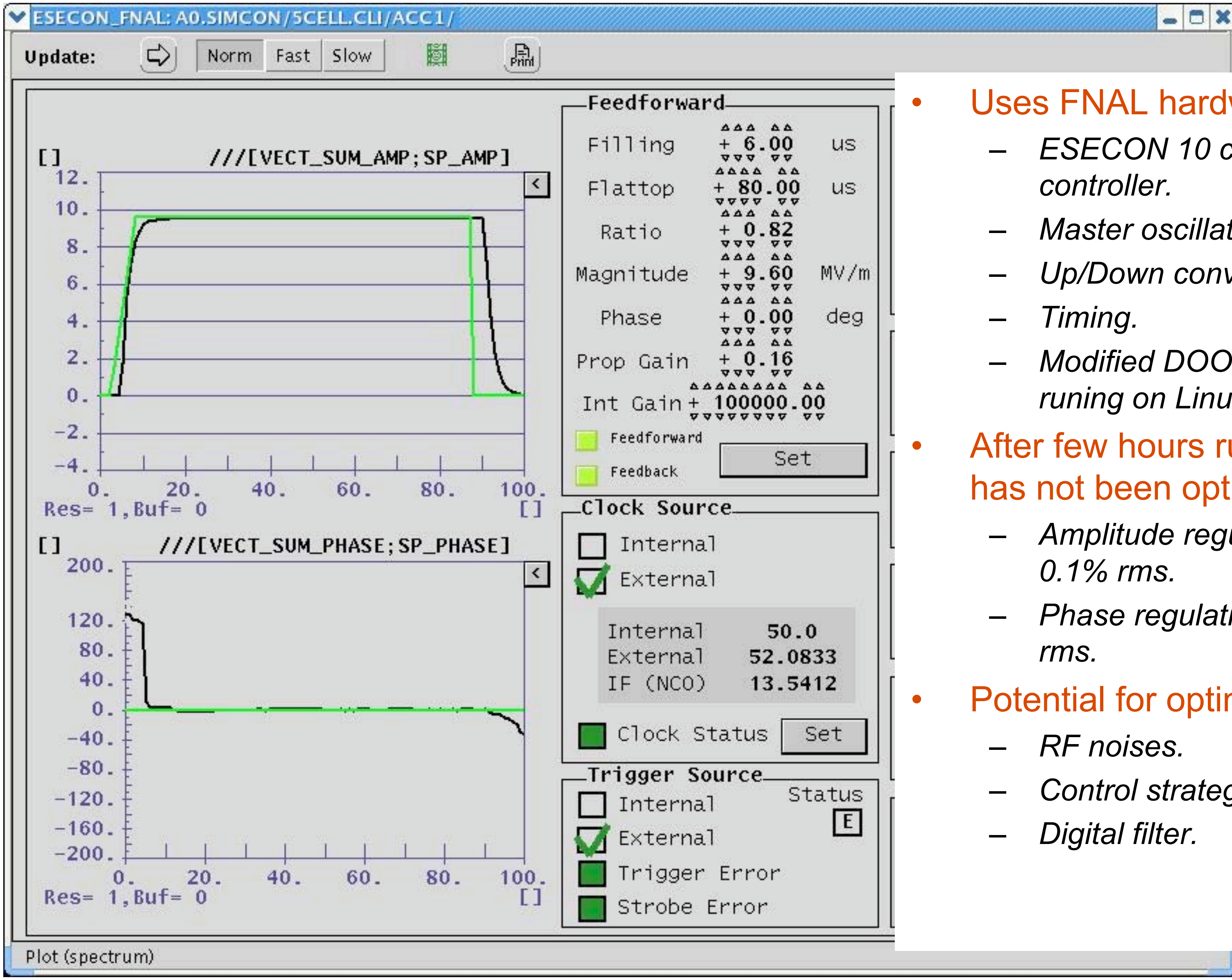
10 channel LLRF controller measurements

This plot is still preliminary

ADC phase noise at zero crossing. f_s=78.125MHz, f_{in}=62.5MHz



3.9 GHz deflecting mode Cu cavity



- Uses FNAL hardware:
  - *ESECON 10 channel LLRF controller.*
  - *Master oscillator.*
  - *Up/Down converters.*
  - *Timing.*
  - *Modified DOOCS server and GUIs runing on Linux-VME.*
- After few hours running, (system has not been optimized yet)
  - *Amplitude regulation better than 0.1% rms.*
  - *Phase regulation better than 0.05º rms.*
- Potential for optimization:
  - *RF noises.*
  - *Control strategy.*
  - *Digital filter.*

Conclusions

- For a single RF unit:
  - *Need a bunch compressor to resolve 0.05-degrees or 100-fs. Bunch length of 1-ps should work, 10-ps will not.*
  - *Can not run beam close to zero-crossing because of energy spread induced by rf slope and low injection energy.*
  - *Need also to measured the incoming bunch-to-bunch energy jitter so this calls for dispersive section (a compressor) before the CM*
- For two RF units:
  - *Need two rf units or, at least, two rf systems powering two cryomodules*
  - *Does not require bunch arrival jitter measurements.*
  - *Can run beam at zero-crossing*