Instrumentation at ATF / TTF

Accelerator Test Facility (KEK)
Tesla Test Facility – FLASH (DESY)
ESA / LCLS (SLAC)

Marc Ross, SLAC

Overview:

1. Develop instrumentation and related controls for ILC

   (focus on precision position & profile measurements – long. & transverse; focus on LLRF)

2. Seeking out and binding worldwide expertise – develop and demonstrate collaboration
3. Promote the use of ATF, TTF and ESA for this purpose

   ATF (DR, low emittance extracted beam) & TTF (SCRF, short bunch) & ESA (short bunch high E) are unique ILC test facilities

4. Bring - to students - the opportunity to work on hardware in a developmental environment

   Manageable projects beyond the reach of operational pressures

Test Facility Studies 2005-2006

- Projects at ATF (KEK/SLAC +)
  - Cavity Beam position monitors
    - preparation for ‘ATF2’ the beam delivery demonstration
    - energy spectrometer
  - ‘Laserwire’ – laser based beam profile monitor
  - Ring BPM upgrade … aimed at low emittance tuning
- Projects at TTF (DESY/SLAC +)
  - SCRF Cavity Higher Order Mode BPM
    - cavity centers
    - high performance beam position monitors
    - beam to RF phase using monopole modes → precision RF control
  - Controls projects
- SLAC ESA
  - Bunch length monitors (also for LCLS FEL)

- New collaborators:
  - Fermilab computing, accelerator and tech division.
  - Argonne

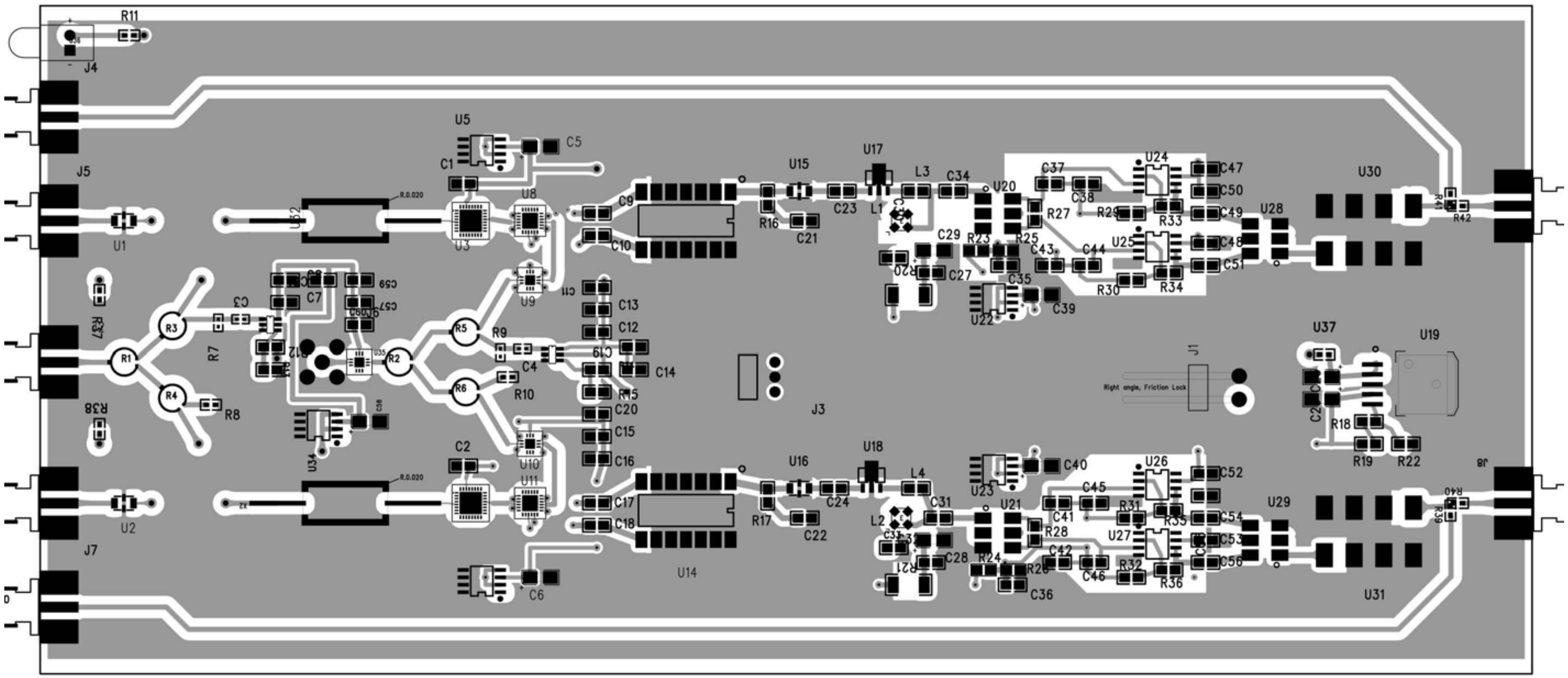
ATF Instrumentation Projects (1):

RF Cavity Beam Position Monitors

- 15 nm rms resolution over 20 minute time scale demonstrated (2004-6)
- ILC will have ~2500 cavity BPM's
  - Linac (large bore, low loss factor, high resolution)
  - BD (large bore, high resolution)
  - Energy spectrometer
- ATF2 and FEL undulators will have ~ few ten's
  - BPM is the most critical beam instrument (SLC, TeV, PEPII…)
- Typical requirements ~ 100 nm resolution
  - one micron accuracy
- Projects in process: Beam tests of 6 BPMs & development of production electronics for ATF2

ATF2 Cavity BPM Production electronics

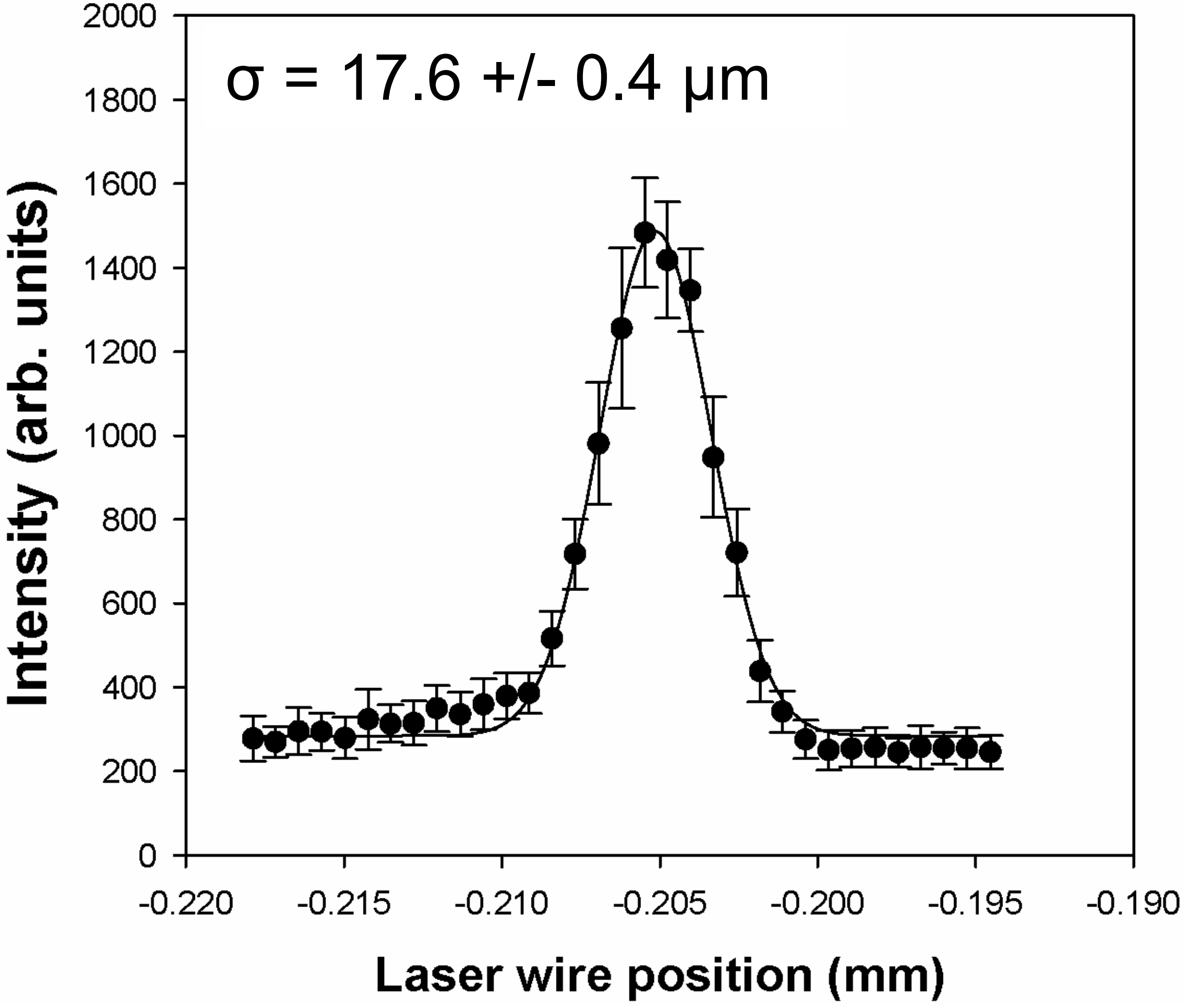
- 6 GHz receiver board layout
- Realistic system design including packaging and mounting hardware
- Tested successfully at ATF April 2006



ATF Instrumentation Projects (2):

2. Laser-based beam profile monitors
   - Mechanical ‘wire’ scanners will not work in ILC
   - Build on experience at ATF (ring), SLC and FFTB
   - Royal Holloway/Oxford lead; SLAC technical partner
   - 1 ~ 2 micron scanner
     - 1% resolution; fast scanning
3. Stabilization systems – beam feedback and other
   - Optical ‘struts’ (extension of ATLAS system) developed at Oxford

ATF laser – wire scan (May 25)



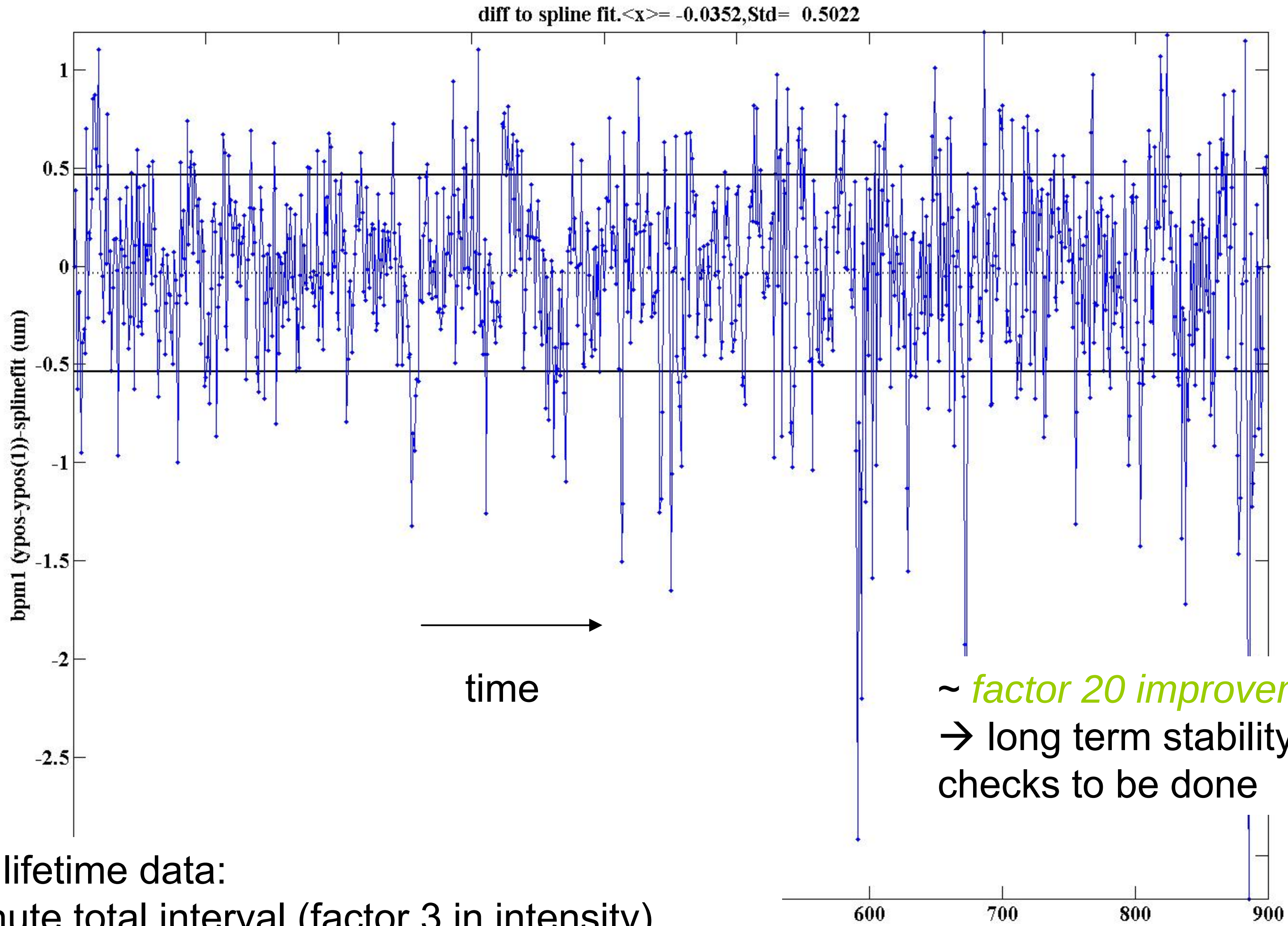
First scans

Optics and laser aberrations

(factor 10 scale error)

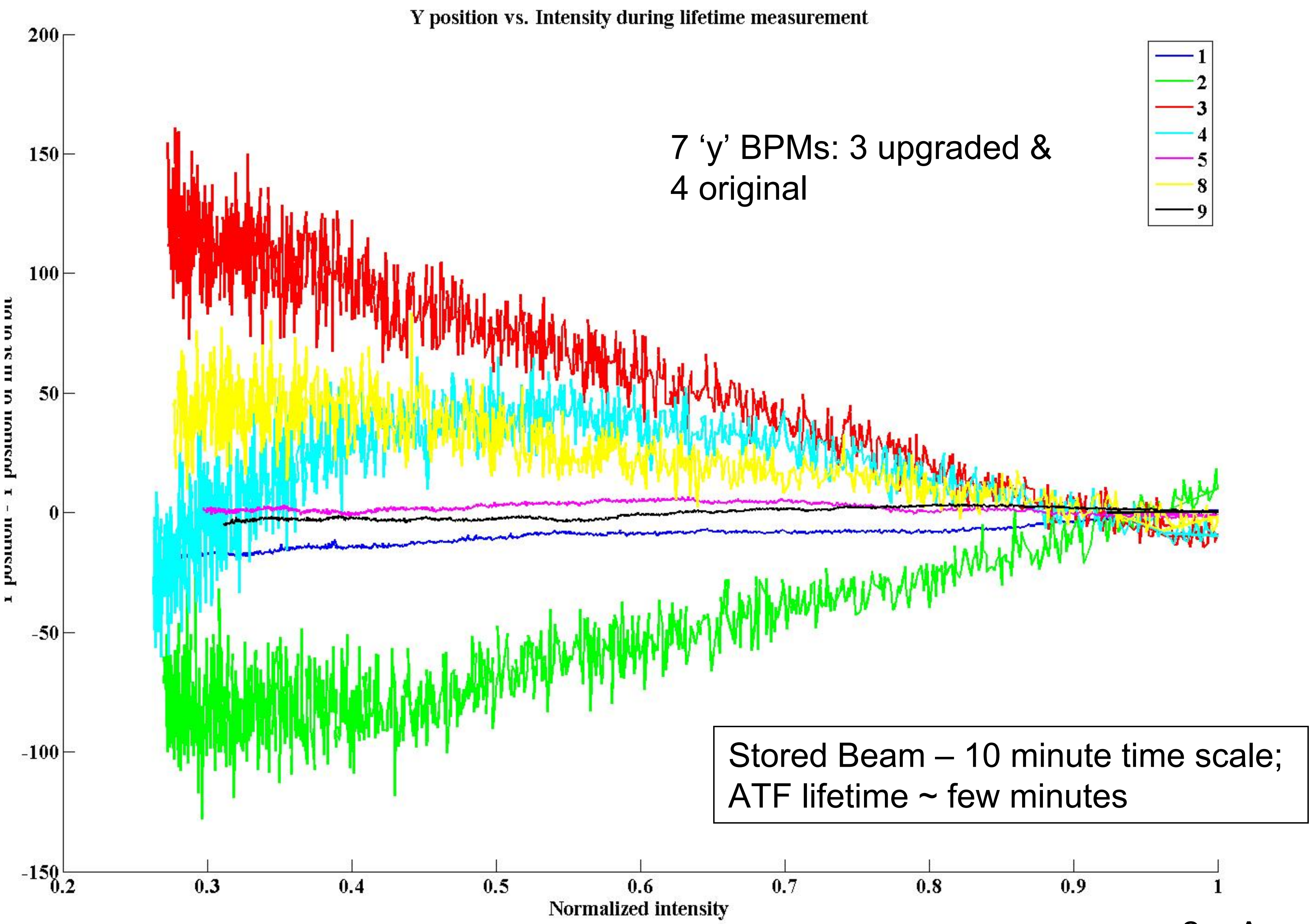
ATF Instrumentation Projects (3):

- Upgrade ring BPM's
  - goal 1/1e4 long term stability; 0.1um resolution
    - more than 100x improvement
  - using heterodyne receiver front end and digital downconvertor
  - similar to recent FNAL BPM upgrades
  - calibration and beam – based 'offset finding' key



~ *factor 20 improvement*
→ long term stability checks to be done

Same lifetime data:
10 minute total interval (factor 3 in intensity)
Residual after removing ~minute scale oscillations
Two lines are +/- 500 nm apart
Residual vertical (over total time) ~ 500 nm.


Y position vs. Intensity during lifetime measurement
200
150
100
50
0
-50
-100
-150
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized intensity
1
2
3
4
5
8
9
7 ‘y’ BPMs: 3 upgraded & 4 original
Stored Beam – 10 minute time scale; ATF lifetime ~ few minutes

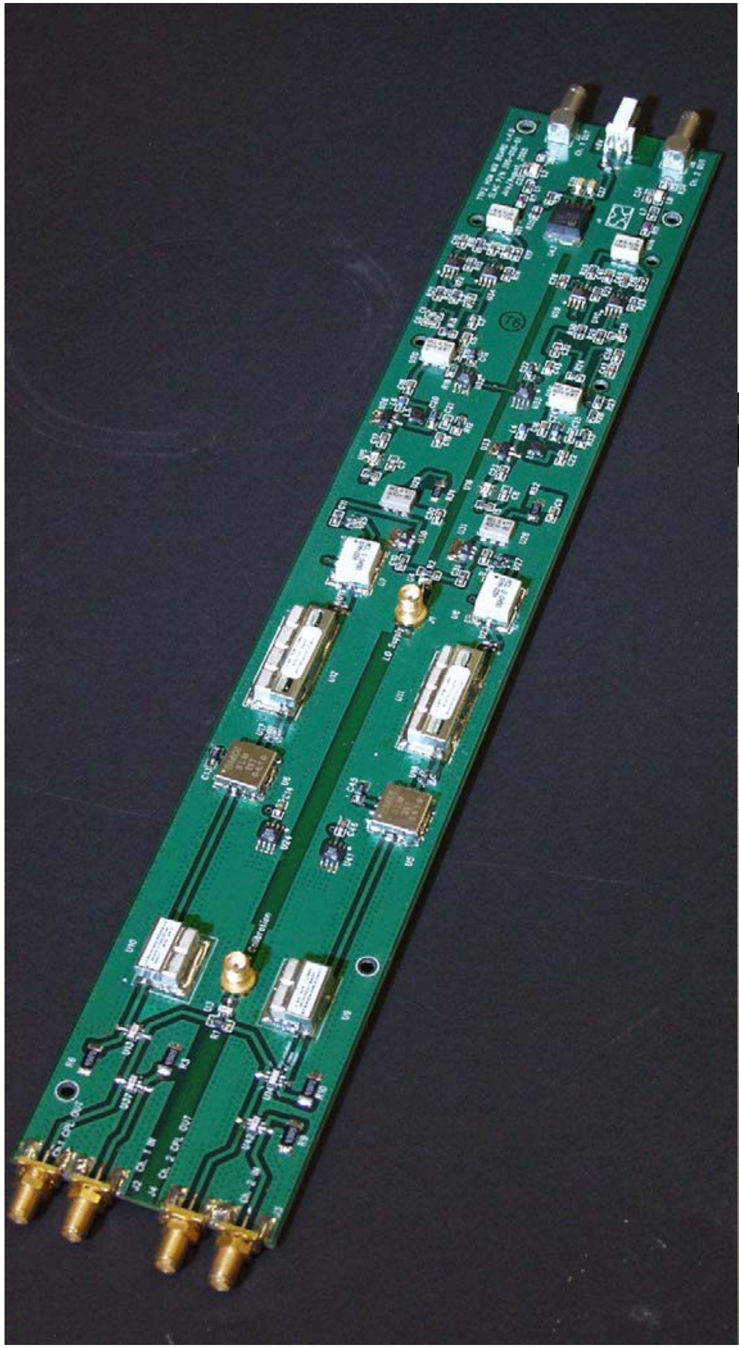
time

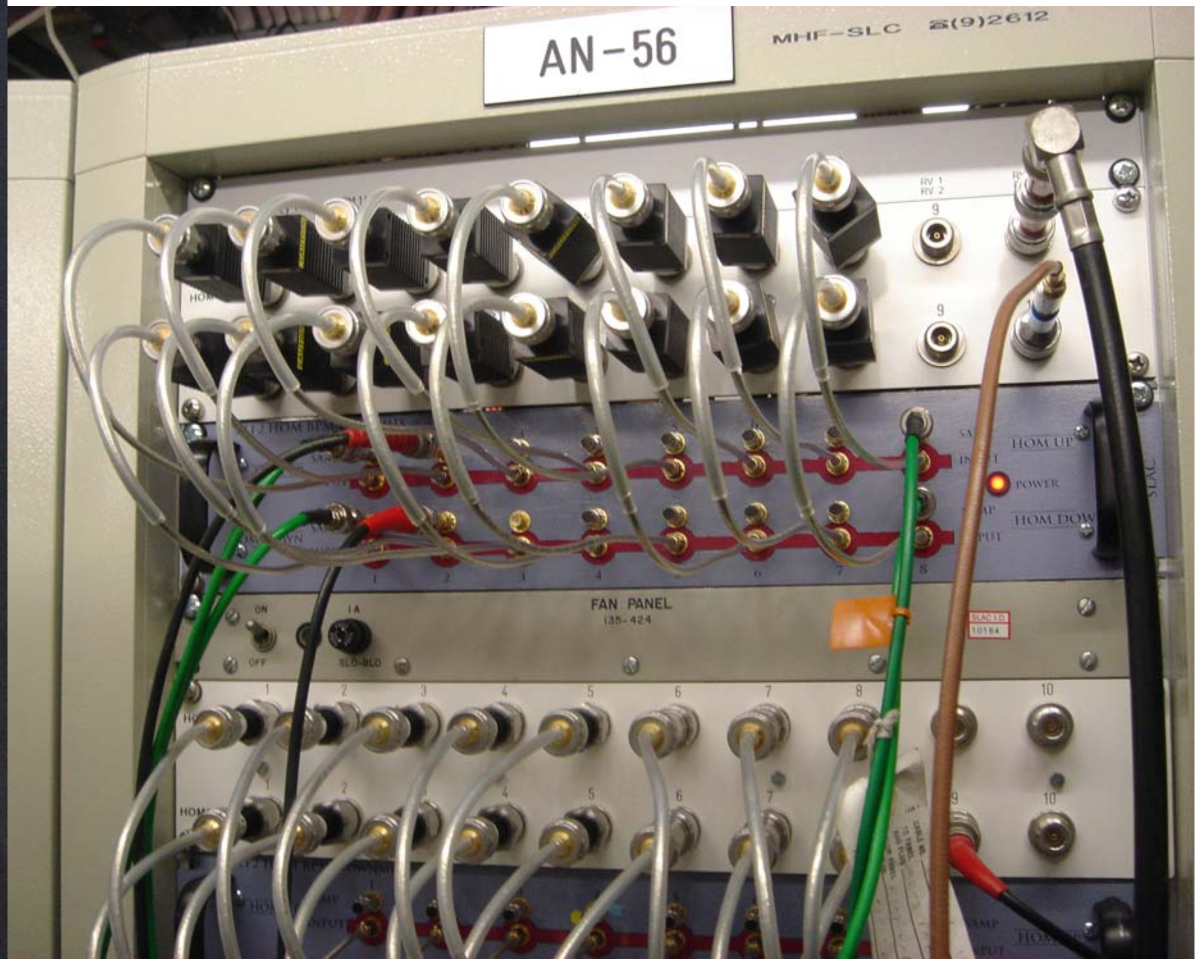
~2 mA

TTF Instrumentation - HOM

- Use of SCRF cavity dipole higher order mode (HOM) signals as beam position monitors
  - (Each cryo-cavity has two HOM couplers)
  - Cryomodule assembly alignment check
  - Beam steering and tuning at TTF
- HOM readout 80 channel heterodyne receiver/digitizer system installed and commissioned 11/05 and 3/06.
    - M/S largely funded by DESY/Saclay.
  - 3 micron resolution demonstrated
  - 10 um offset precision

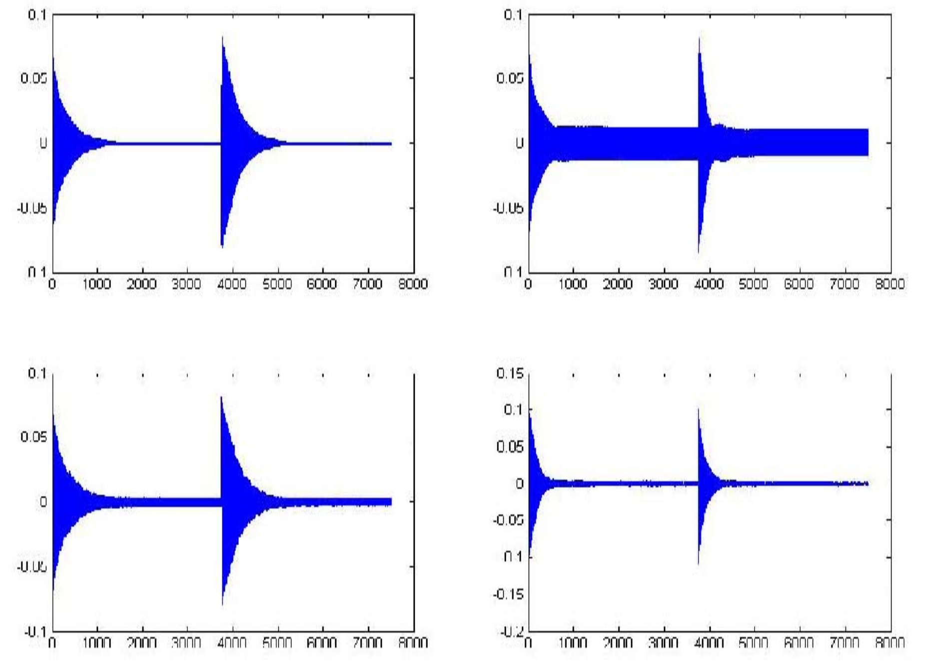
Installation at TTF2

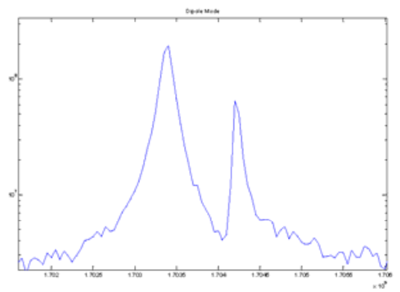




Higher Order Dipole Modes

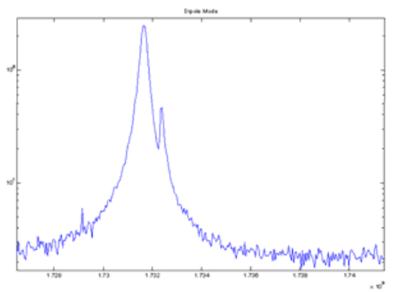
- 1600 to 1900 MHz dipole bands
- nominal 2 polarization directions (*u*, *v*)

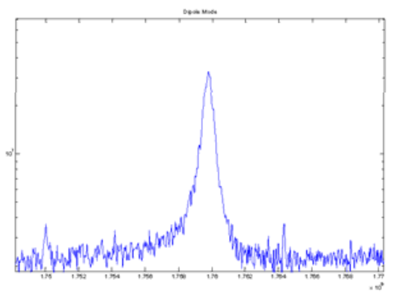




Dipole modes vary from nearly
Completely separate, to indistinguishable

Difficult to fit to peaks to identify frequencies





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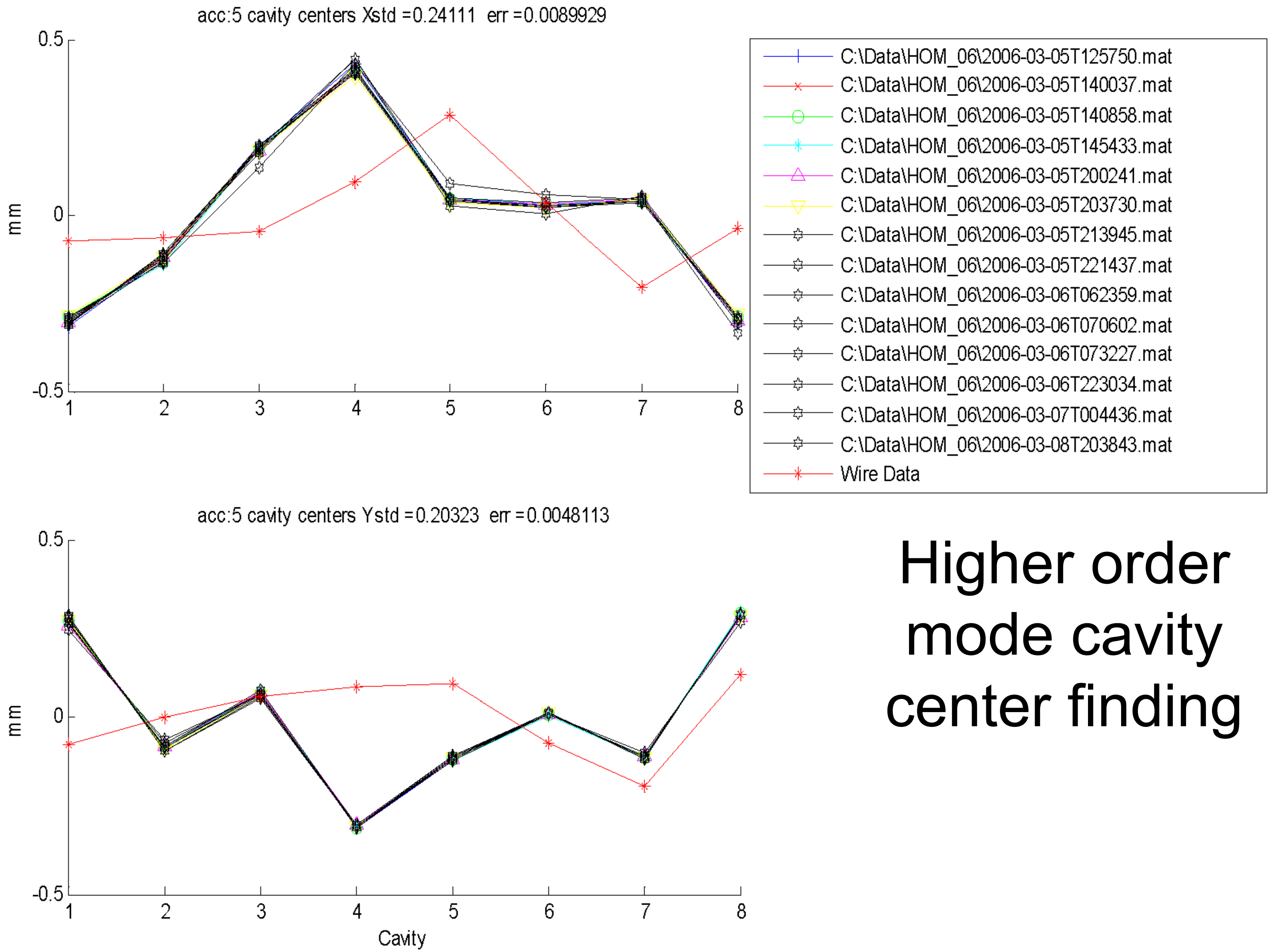
- frequency split, in-phase / quadrature phase → four components
- linear combination of x x’ y y’



Higher order mode cavity center finding

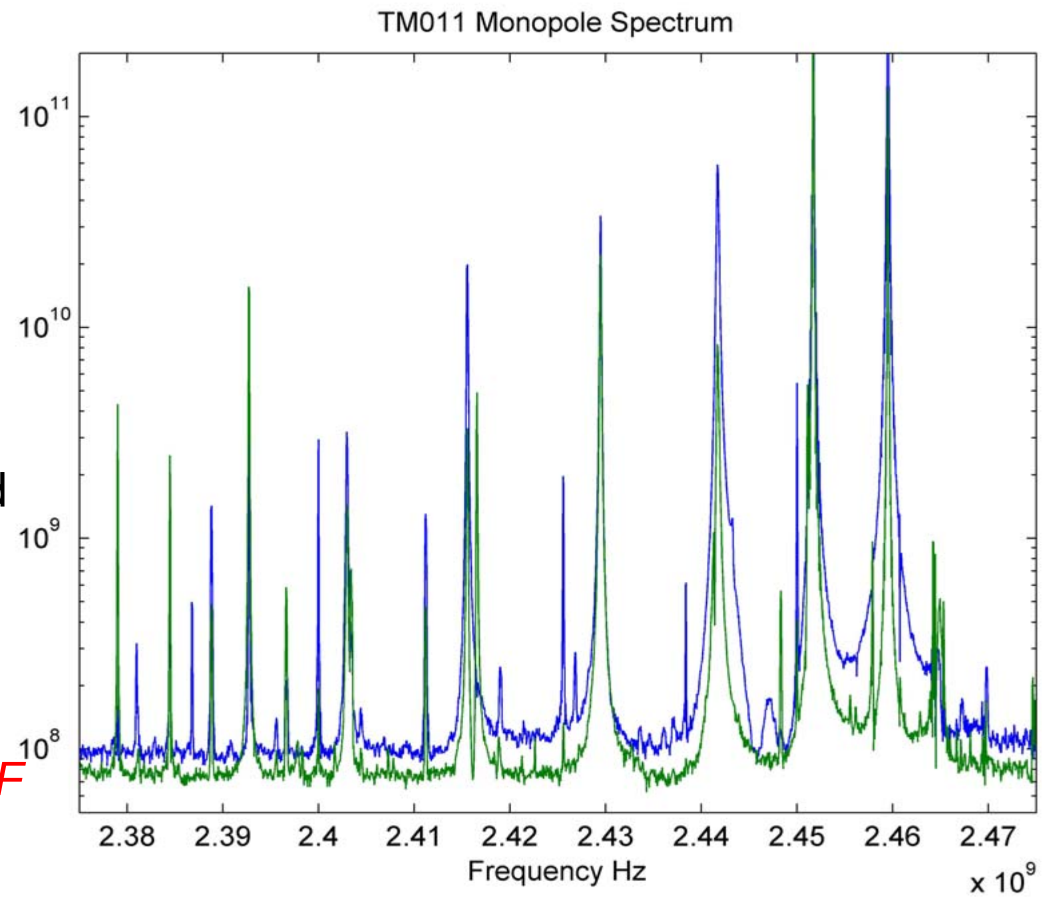
Higher Order Monopole Modes

- 2300 – 2500 MHz
- Both couplers for 1 cavity shown
- 0.1 degree (L-band) precision → 0.2 ps

Note that different lines have different couplings to the 2 couplers

Monopole lines due to beam, and phase is related to beam time of arrival

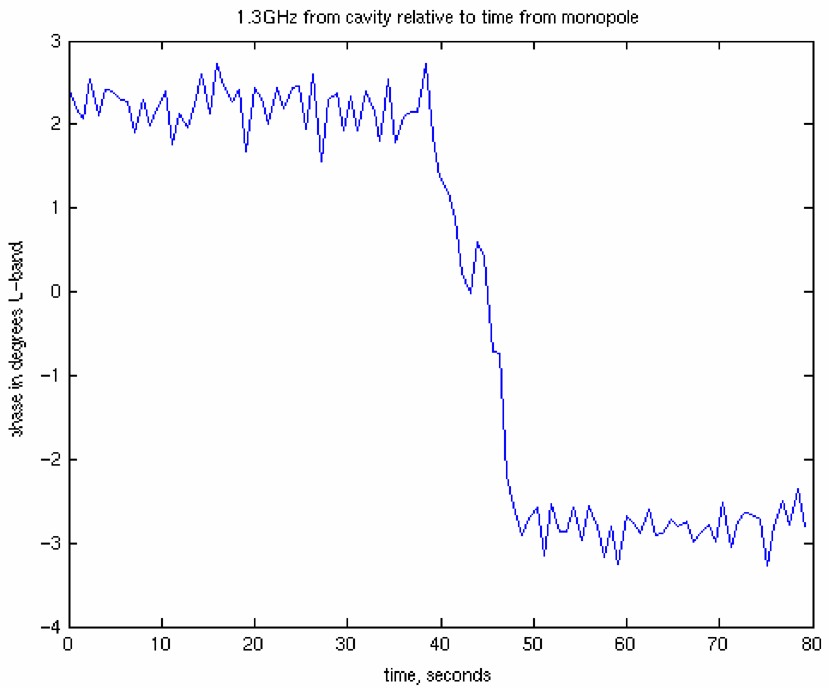
Fundamental 1.3GHz line also couples out – *provides precise RF to beam phase for control*

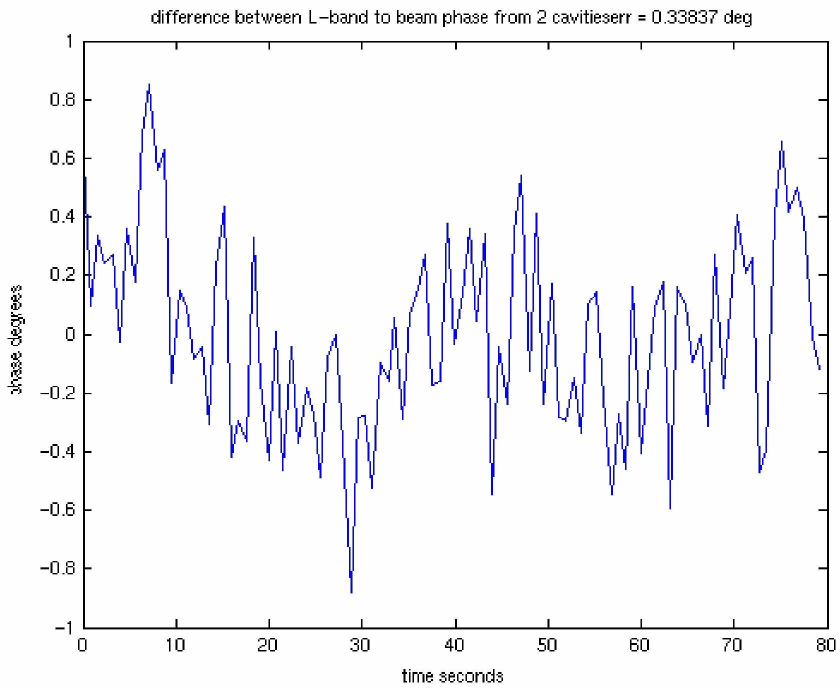


Beam Phase vs. RF Measurement During 5 Degree Phase Shift

Measure 5 degree phase shift commanded by control system

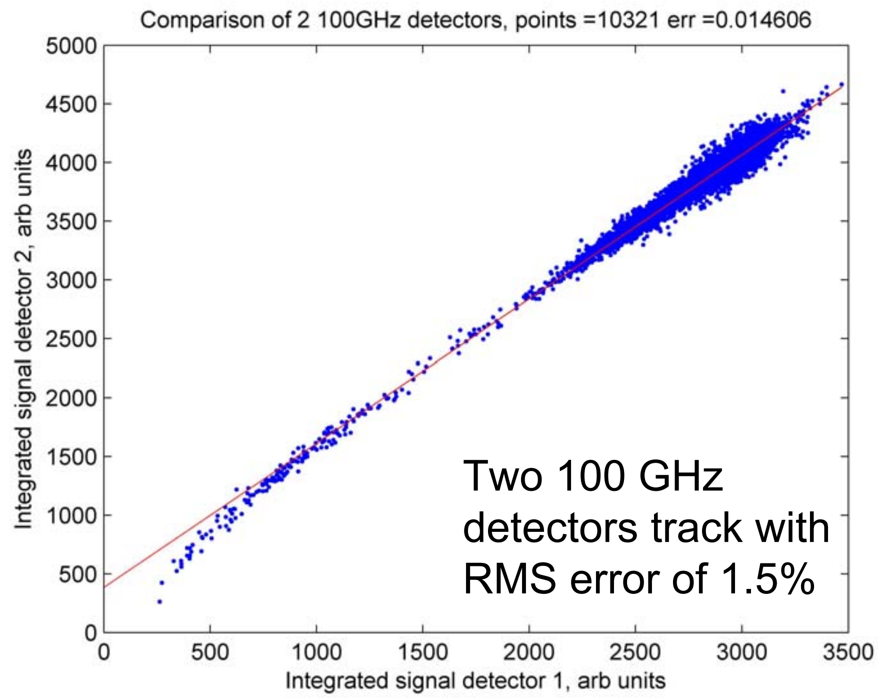
2 cavities, same structure give 0.34 degree L-band RMS phase difference

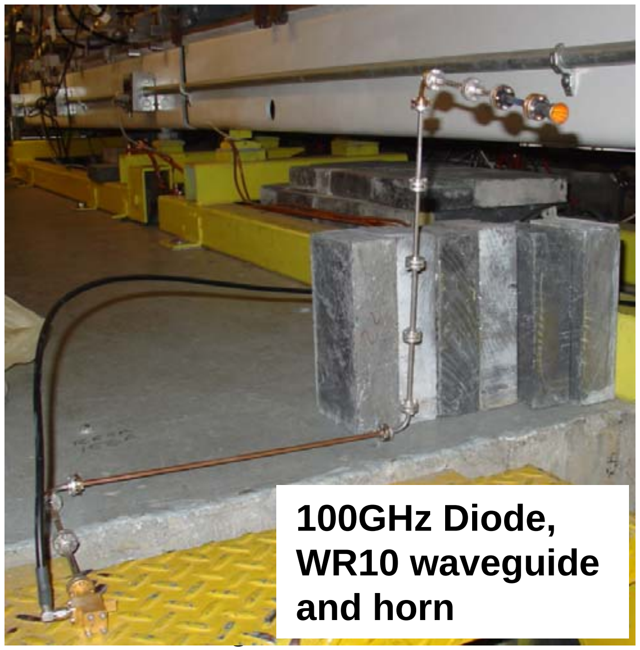


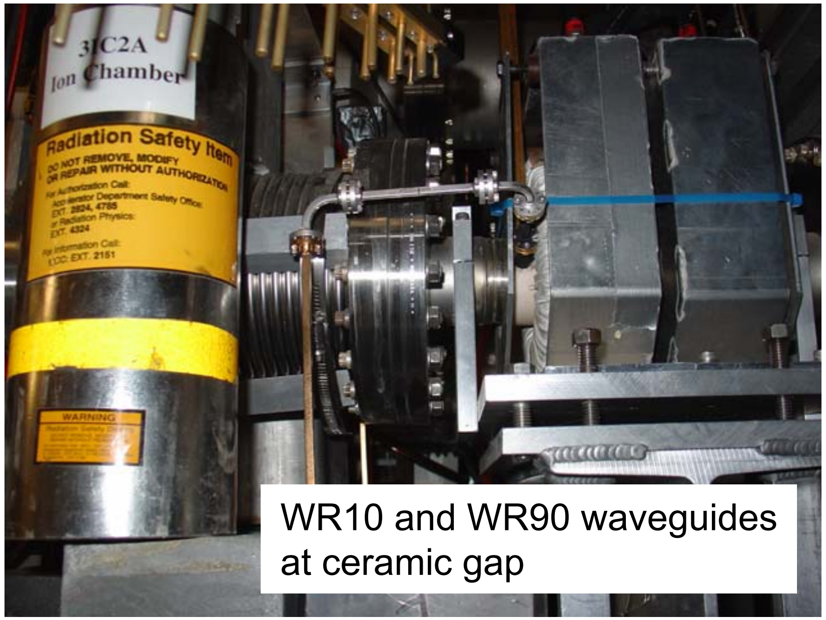


ESA Bunch Length Monitor

- simple ceramic gap and diode detector
- diode and waveguide form crude bandpass filter
- 200 to 400 um bunch length sensitivity (ILC)







Test Facility Plans – 07

- ATF2 preparation
  - component testing and pre-commissioning
  - (movers, beam monitors, tuneup procedures)
  - preparing the ring for ATF2 use → BPM upgrade
- TTF, FNAL and partners
  - LLRF studies using HOM
  - Cavity and cryomodule assembly studies
- ESA / LCLS
  - LCLS bunch length monitor commissioning 11/06

Extra

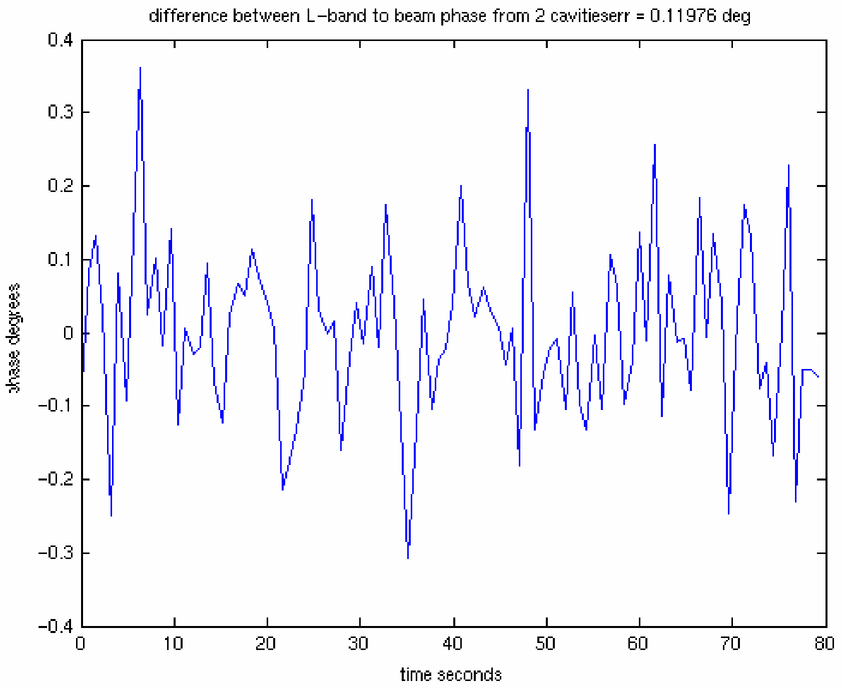
PEP II

- Program: Provide help as requested by SLAC Director (~late 03)
- (not on the agenda, but an important goal for 2004 → extended into this year)
- Two major systems installed:
- LER X-ray Synchrotron Radiation monitor
  - Goal: measure beam size accurately in LER up to full intensity without ‘tilt’ distortion present in existing monitors
  - Smallest measurable beam size ~ 10 um, well below smallest expected LER sigma_y
  - Bunch – by – bunch beam size for EC measurements
- X-ray technology extremely important for ILC DR monitors

What is System Resolution, Drift

Compare 2 couplers on same cavity, RMS difference 0.12 degrees L-band.

Electronics noise ~0.08 degrees cavity to cavity difference (0.3 degrees may be due to microphonics)



Compare 2 cavities for long (7 hour) run. RMS difference 0.69 degrees L-band.

Combination of electronics drift and cavity to cavity phase shifts.