First Mini-Workshop on Nano Project at ATF

KEK, Building 3, First floor meeting room

June 5-6, 2004

This workshop is natural extension of the nanometer BPM mini-workshop and it could be the third one. The purpose of the mini-workshop is to evaluate possible studies and discuss experiments using cavity BPM's and fast (intra-train) feedback system in the ATF extraction line.

Information

- Circulation (pdf)
- Participant List

Program is listed below, where talks can be obtained.

Time	Title	Presenter
5th June 2004	**Saturday**	
Fast feedback System: FONT and FEATHER		
9:00-9:15	Welcome and workshop plan	T.Tauchi
9:15-9:45	Report on FONT2 Beam Runs, Nov03-Jan04 (ppt , pdf)	P.Burrows
9:45-10:15	FONT Hardware : Processing electronics and current beam tests (ppt, pdf)	S. Molloy
10:15-10:45	Coffee break	
10:45-11:15	Very Preliminary FONT3 Jitter Study Data (ppt, pdf)	G.Whilte
11:15-11:45	FEATHER: Feedback AT High Energy Requirements (pdf)	H.Fujimoto (N. Delerue)
11:45-13:30	Lunch	KEK Cafeteria or Restaurant
NanoBPM; SLAC/LLNL System		
13:30-14:00	NanoBPM Analysis Update (pdf)	M. Cooke
14:00-14:30	Common Mode Characteristics of Cavity BPM Receiver (ppt, pdf)	S. Smith

14:30-15:00	nanometer BPM status and plans (ppt, pdf)	M. Ross
15:00-15:30	Coffee break	
15:30-16:00	Measurements of stray field in the NLCTA area (ppt, pdf)	J. Frisch
16:00-16:30	Nanometer BPM alignment and metrology frame (pdf)	J.Gronberg
16:30-17:00	Optical Anchor / Interferometer Status (ppt, pdf)	J. Frisch
17:00-17:30	Vibrational properties of the KEK reference system (ppt, pdf, and movies:1st, 2nd,3rd mode, ref.bar)	H.Yamaoka (T.Tauchi)
18:30-20:30	Workshop dinner	Restaurant
6th June 2004	**Sunday**	
NanoBPM; KEK System		
9:00-9:30	Performance test of mover system, electronics, etc. (pdf)	Y.Honda
9:30-10:00	Current Status of LASER FRAME for KEK Nano-BPMs (ppt, pdf)	Y.Higashi
10:00-10:30	Development of X-band Cavity BPM (ppt, pdf)	T.Naito
10:30-10:50	Coffee break	
10:50-12:00	Discussion on future plan; summary (pdf, htm)	All
	ATF/GLCTA plan (ppt, pdf)	H. Hayano

Present Participant List

Participants	affiliation
Josef Frisch	SLAC
Doug McCormick	SLAC
Mac Ross	SLAC
Steve Smith	SLAC
Mark Cooke	LBNL
Jeff Gronberg	LLNL
Aaron M Tremaine	LLNL
Phillip Burrows	QMUL
Shah Hussain	QMUL
Stephen Molloy	QMUL
Glen White	QMUL
Takayuki Sumiyoshi	Tokyo Metropolitan univ.
Hiroyuki Fujimoto	Tokyo Metropolitan univ.
Ken Watanabe	Tohoku Gakuin univ.
Youichi Inoue	Tohoku Gakuin univ.
Hitoshi Hayano	KEK
Yasuo Higashi	KEK
Yousuke Honda	KEK
Takashi Naito	KEK
Toshiaki Tauchi	KEK
Kiyoshi Kubo	KEK
Nobuhiro Terunuma	KEK

Report on FONT2 Beam Runs, Nov03-Jan04

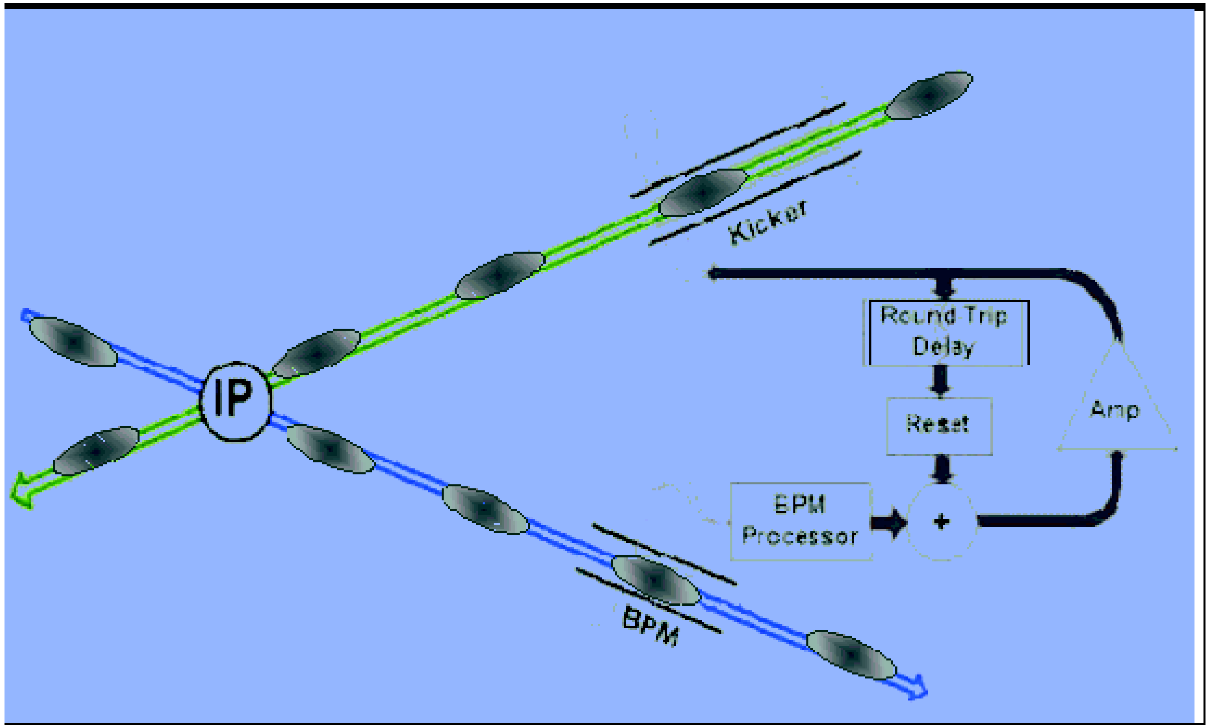
Philip Burrows

Queen Mary, University of London

- System overview
- FONT @ NLCTA
- FONT/FEATHER plans at ATF

Intra-train Beam-based Feedback

Intra-train beam feedback is last line of defence against ground motion



Key components:

Beam position monitor (BPM)

Signal processor

Fast driver amplifier

E.M. kicker

Fast FB circuit

Warm: augments active stabilisation

Cold: principal ground-motion correction

International Fast FB Collaboration

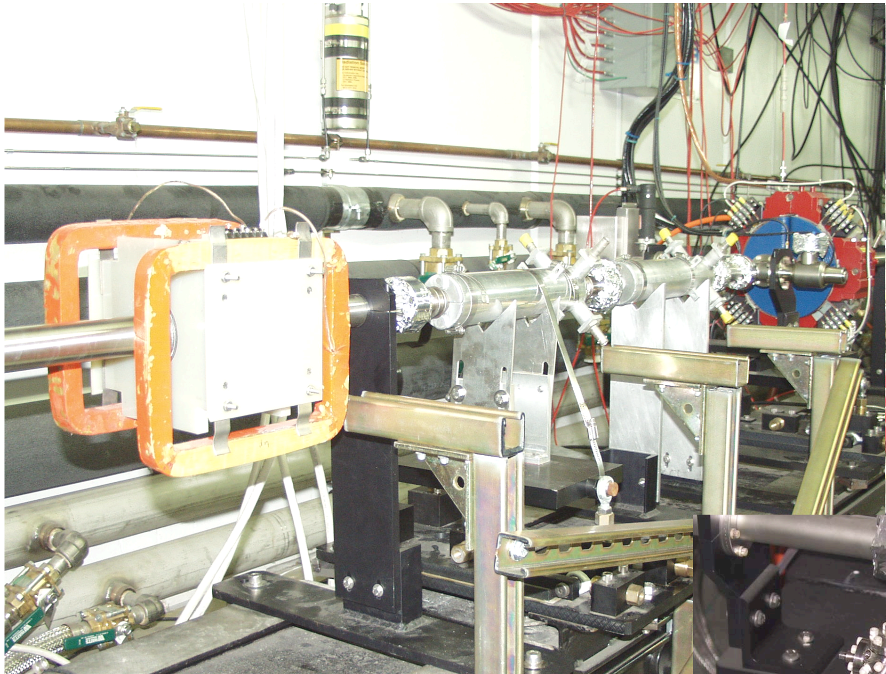
- **FONT:**
  - Queen Mary: Philip Burrows, Glen White, Tony Hartin,
    Stephen Molloy, Shah Hussain, Christine Clarke + 2 new staff
  - Daresbury Lab: Alexander Kalinine, Roy Barlow, Mike Dufau
  - Oxford: Colin Perry, Gerald Myatt, Simon Jolly, Gavin Nesom
  - SLAC: Joe Frisch, Tom Markiewicz, Marc Ross, Chris Adolphsen,
    Keith Jobe, Doug McCormick, Janice Nelson, Tonee Smith,
    Steve Smith, Mark Woodley

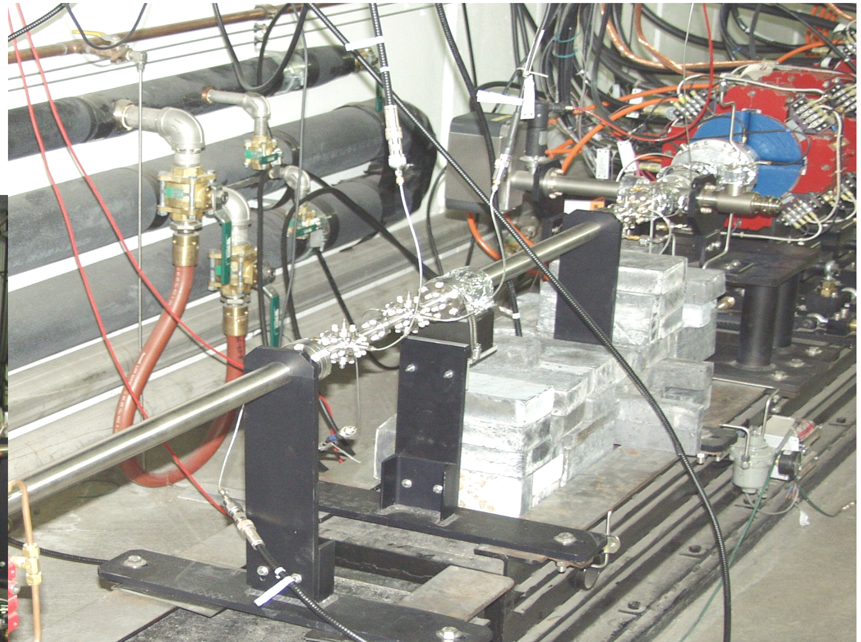
- **FEATHER:**
  - KEK: Nicolas Delerue, Toshiaki Tauchi, Hitoshi Hayano
  - Tokyo Met. University: Takayuki Sumiyoshi

- **Simulations:** Nick Walker (DESY), Daniel Schulte (CERN)

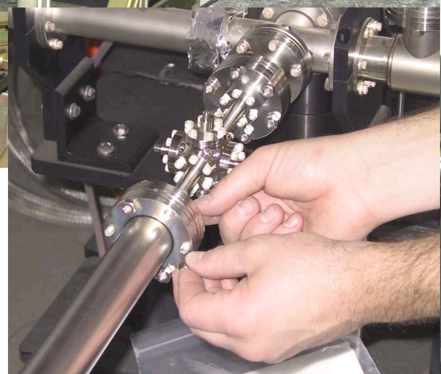
FONT2: beamline configuration

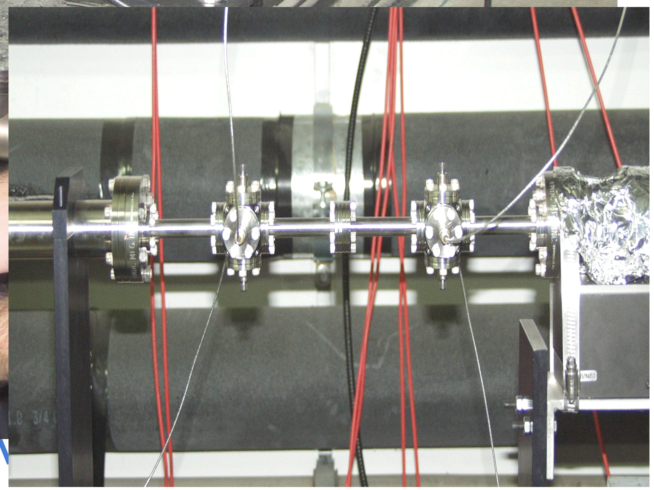
Dipole and kickers





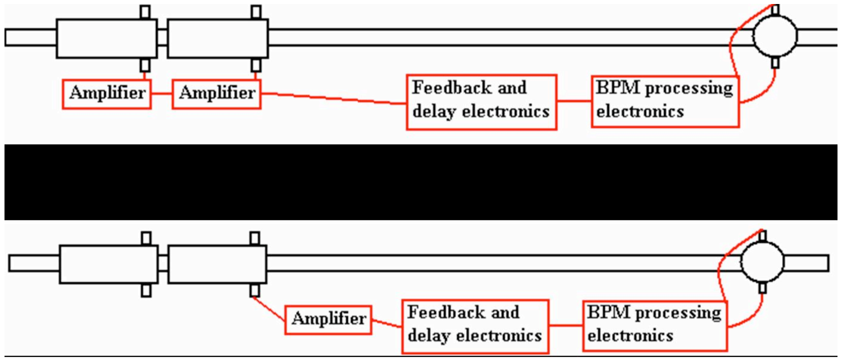
New BPMs





FONT2 final results (Jan 22 2004)

Super-fast modified configuration:

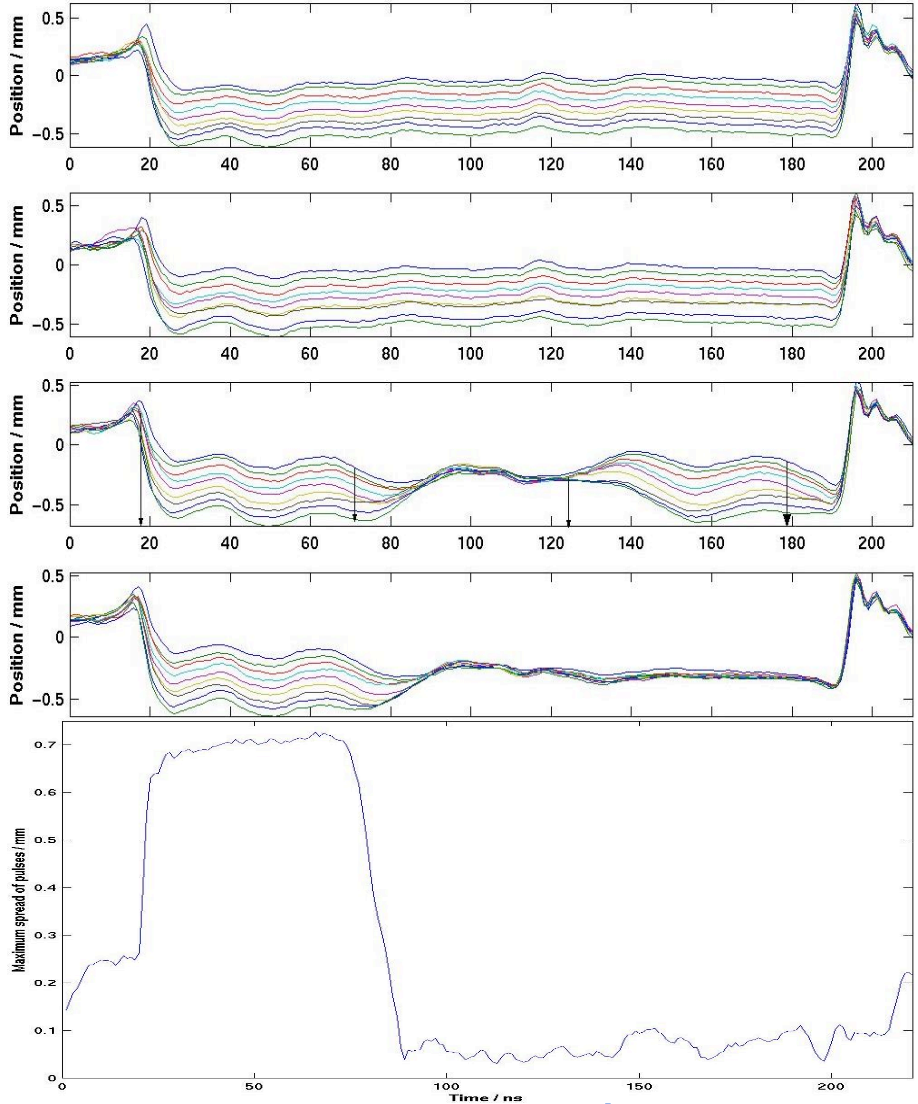


Latency 54ns

Correction 14:1

(limited by gain knob resolution)

dispersion



Philip Burrows

Comparison of NLCTA with ATF

	NLCTA	ATF
Train length	170 ns	300 ns
Bunch spacing	0.08 ns	2.8 ns
Beam size (y)	500 mu	5 mu
Jitter (y)	100 mu	few mu
Beam energy	65 MeV	1.3 GeV

Stabilising 1 GeV beam @ 1 mu ⇔ 1000 GeV @ 1 nm

For the warm machine:

ATF has ‘right’ bunch spacing and train length, and the beam is smaller and more stable than at NLCTA

-> much better place for fast feedback prototypes

Future Experimental Programme at ATF

FONT and FEATHER are joining forces!

1. Stabilisation of extracted bunchtrain at 1 micron level:
   low-power (< 100W), high stability amplifier
   stripline or button BPM w. ~ 1 micron resolution
   these are exactly what are needed for the LC!

2. Stabilisation of extracted bunchtrain at 100 nm level:
   requires special (cavity) BPM and signal processing
   useful as part of nanoBPM project

3. Test of intra-train beam-beam scanning system:
   high-stability ramped kicker drive amplifier
   very useful for LC

FONT Hardware

Processing electronics and current beam tests

Stephen Molloy
Queen Mary, University of London

Very Preliminary FONT3 Jitter Study Data

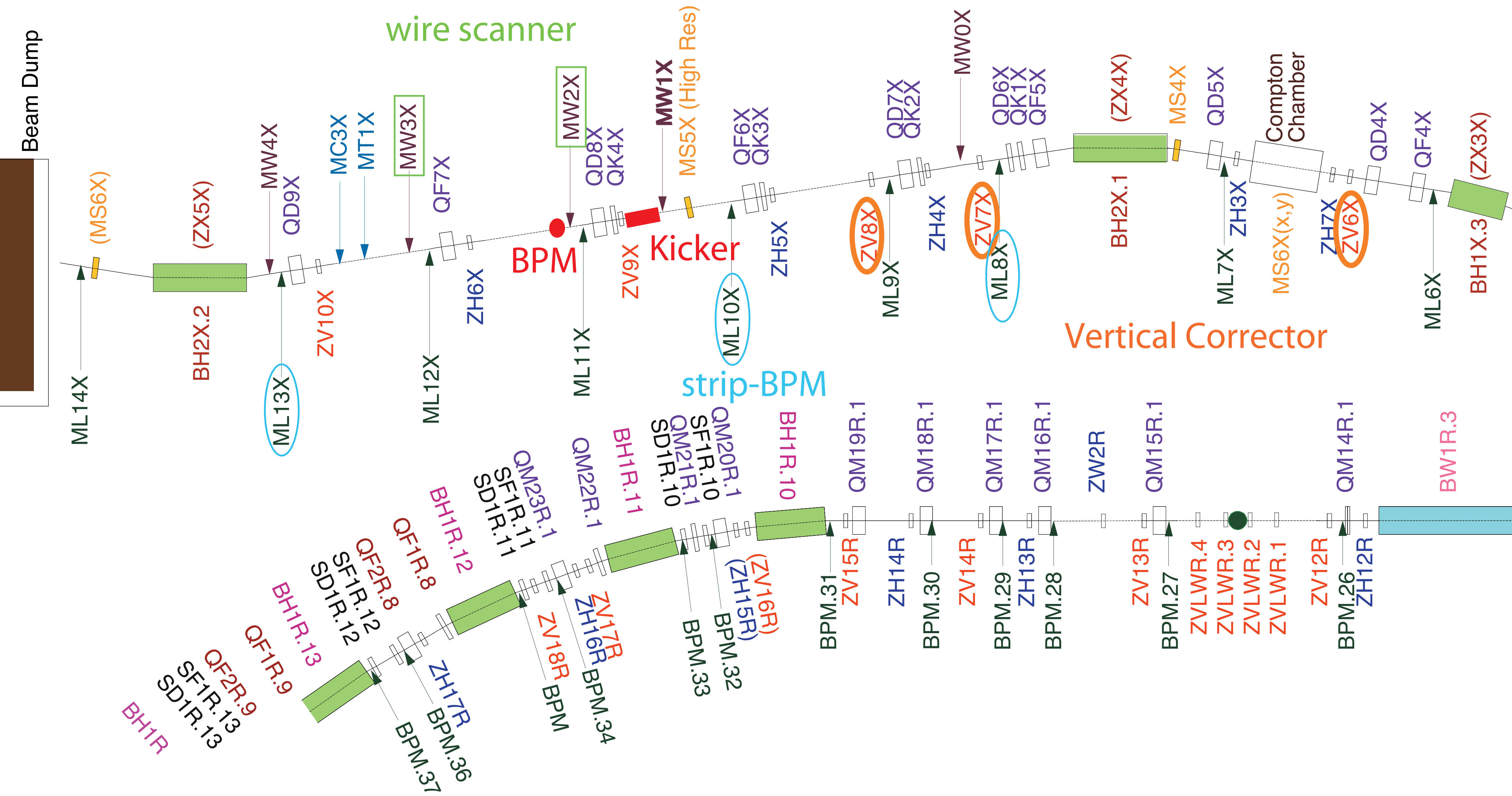
Glen White, QMUL

KEK

5 June 2004

- Aims.
- What we have so far.

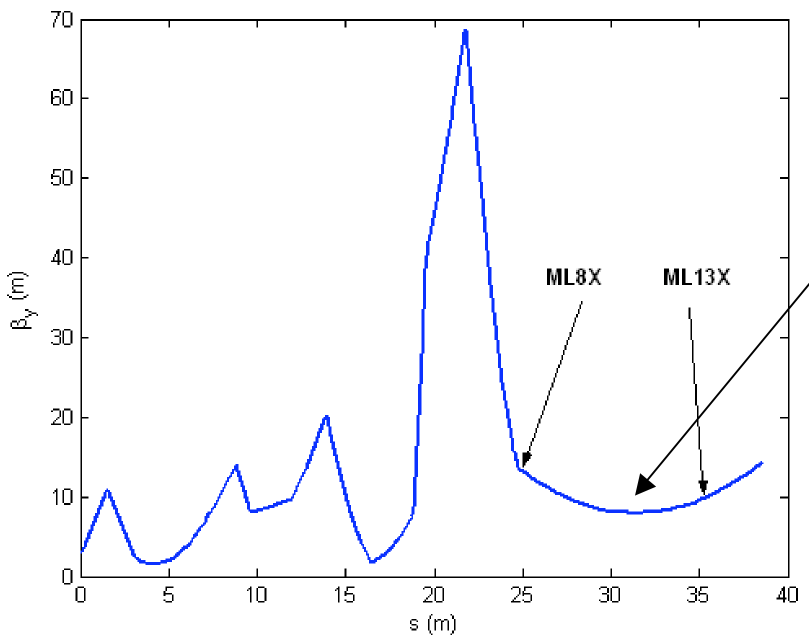
ATF Fast Feedback System



ATF FONT3 Jitter Monitor

•Measure y,y' inter-bunch and inter-train jitter in ATF extraction line to aid in design of FONT3 experiment.

•Switch off QD6X-QD9X, measure y and y' jitter of waist with jitter monitors installed ML8X and ML13X.



$\varepsilon_y = 1.5 \times 10^{-11}$

$$\sqrt{<\sigma_y{}^2>} = \sqrt{\frac{\varepsilon}{\gamma}} = 11\mu\text{m}$$

$$y = \frac{1}{2\sqrt{\varepsilon}}\left(\frac{Y_1}{\sqrt{\beta_1}} + \frac{Y_2}{\sqrt{\beta_2}}\right) \qquad y' = \frac{1}{\sqrt{\gamma\varepsilon}} \cdot \frac{Y_1 - Y_2}{L}$$

$$\sqrt{<s^2>} = \frac{2\sqrt{\varepsilon}}{\xi} \cdot \frac{1}{\sqrt{\frac{1}{\beta_1} + \frac{1}{\beta_2}}} = 4.4\mu\text{m for } 0.1\sigma \text{ resolution}$$

Jitter Measurement

- Jitter measurement from 200 pulse run (file mb_noquads3)
- Vertical emittance measurement: 8.5±1.9 E-11 m.rad.
- Loading magnet settings into DIMAD extraction line model matched to DR exit:
    - β_y=13.35m (ML8X) β_y=9,8682m (ML13X)
    - α_y=0.8219 (ML8X) => γ_y=0.1255
- Vertical waist size: $\sqrt{<\sigma_y{}^2>} = \sqrt{\frac{\varepsilon}{\gamma}}$ = 26μm
- Measure waist from ML8X, ML13X readings (Y_1,Y_2):

$$y = \frac{1}{2\sqrt{\varepsilon}}\left(\frac{Y_1}{\sqrt{\beta_1}} + \frac{Y_2}{\sqrt{\beta_2}}\right) \qquad y' = \frac{1}{\sqrt{\gamma\varepsilon}} \cdot \frac{Y_1 - Y_2}{L}$$

Calibration

•Calculate correction factors for 3 jitter monitor BPMs using vertical corrector magnets ZV6X and ZV7X.

•S(ZV6X) – ML8,10,13X = 5.1 , 9.0, 15.6 m.

•S(ZV7X) – ML10,13X = 3.6, 10.2 m.

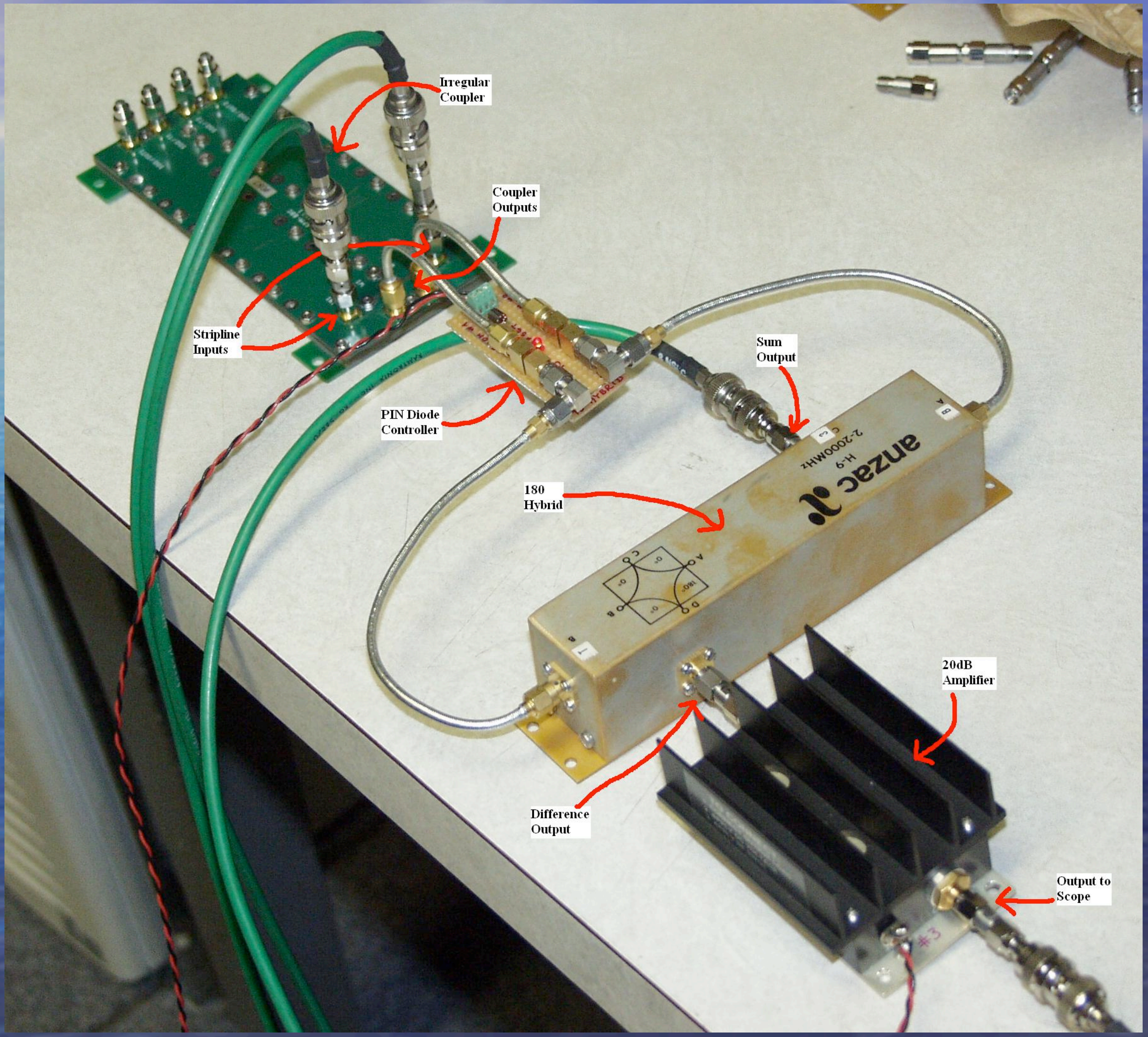
•Additionally switch off QD5,6X and appropriate corrector magnets between SV6X and ML8X.

•From ATF magnet spec sheets for ZV6X and ZV7X:

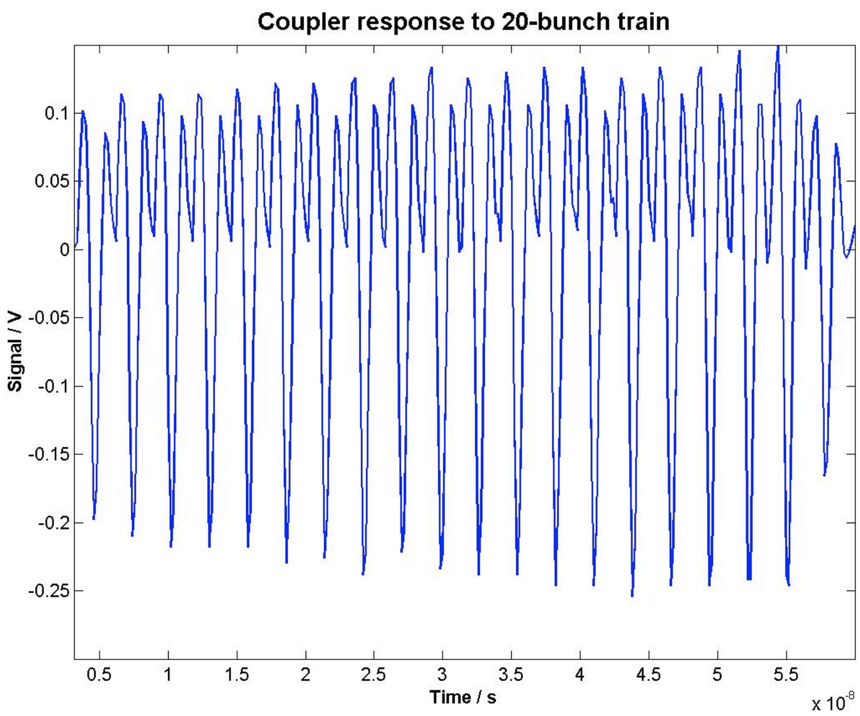
$$L_{eff} = 0.124833\,m \qquad B_0(G) = 112.I(A)$$

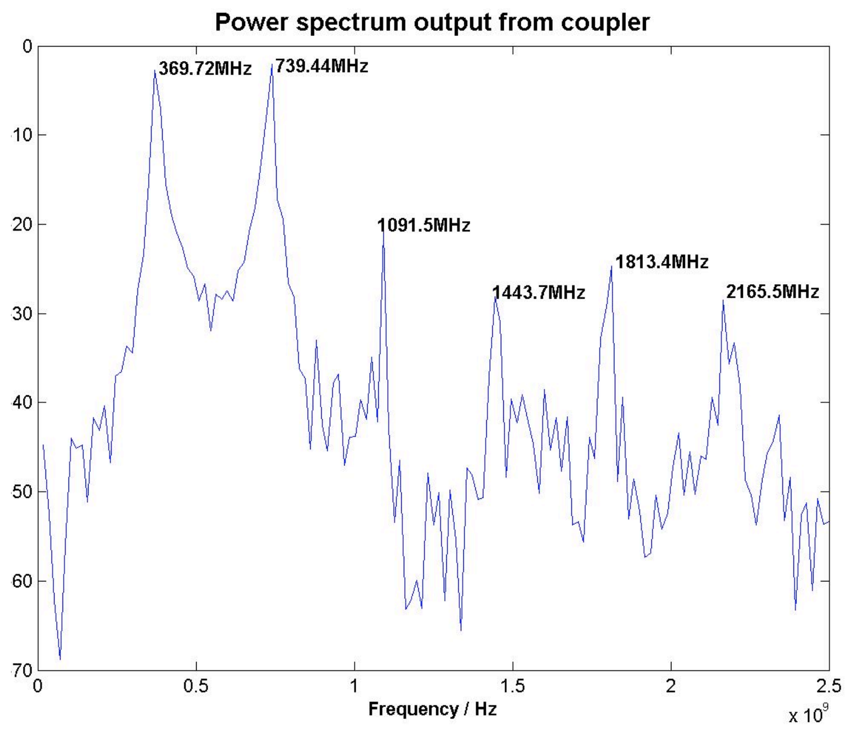
$$\Delta\theta = \frac{\text{dipole strength}\,(KG.m)}{C_b.E(GeV)} = \frac{0.124833 \text{ x } 112}{33.3564 \text{ x } 1.282}.I = 3.2695 \text{ x } 10^{-4}.I\ (rad.)$$

Jitter monitor

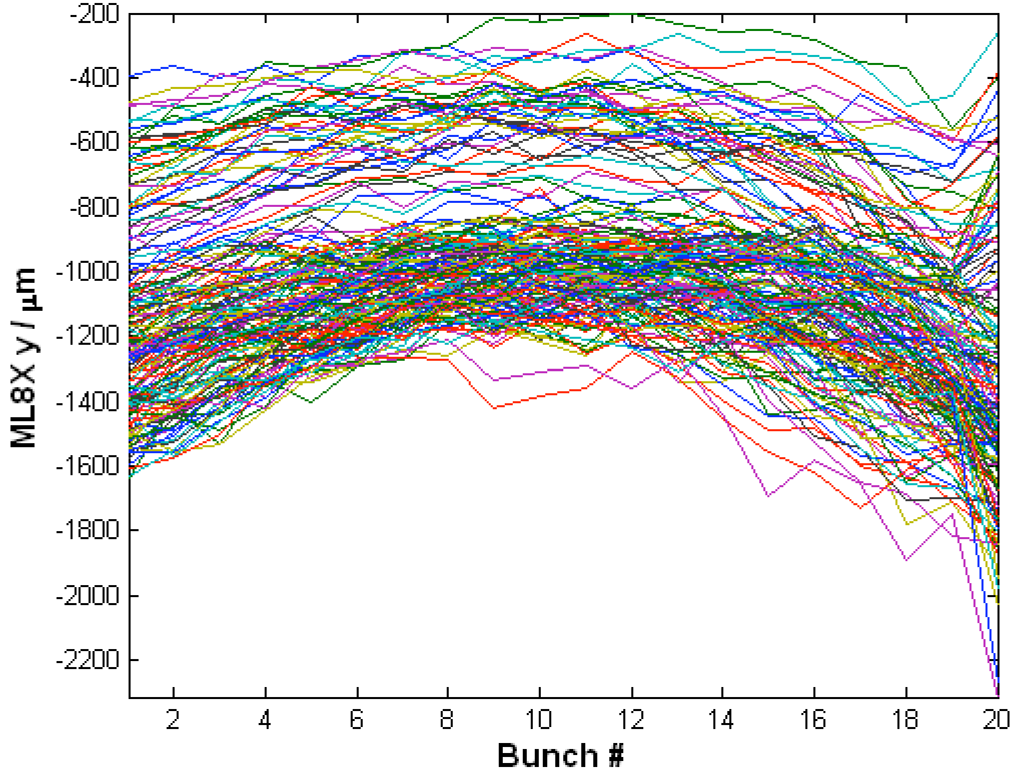


Coupler output - multibunch

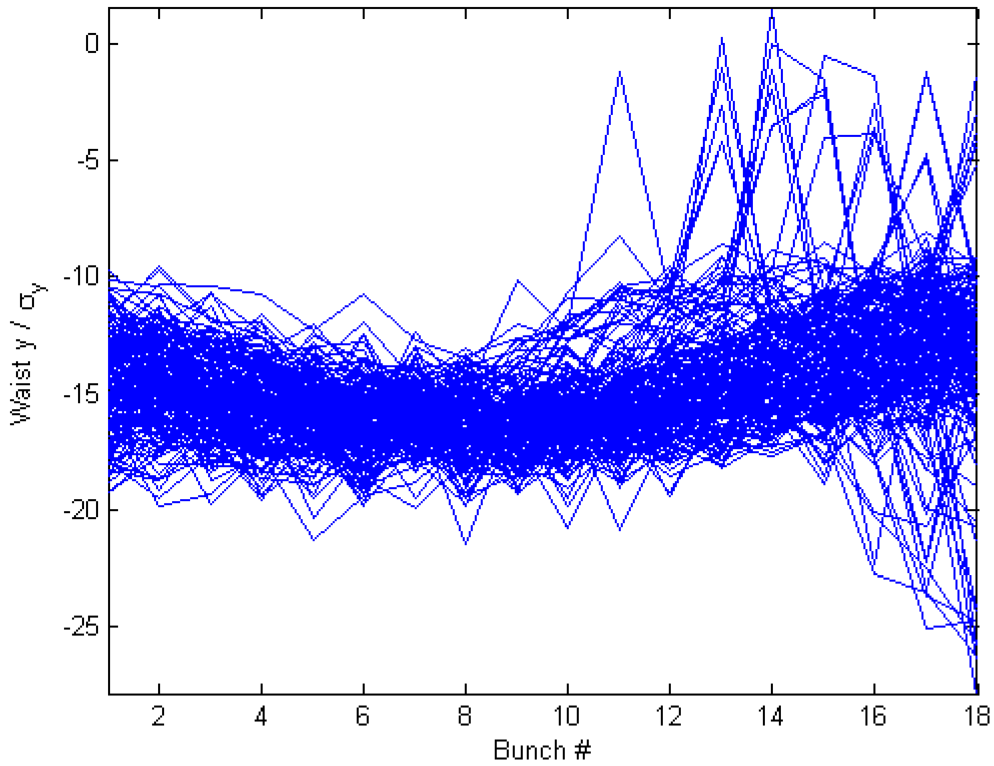




All Bunch Train Position Data



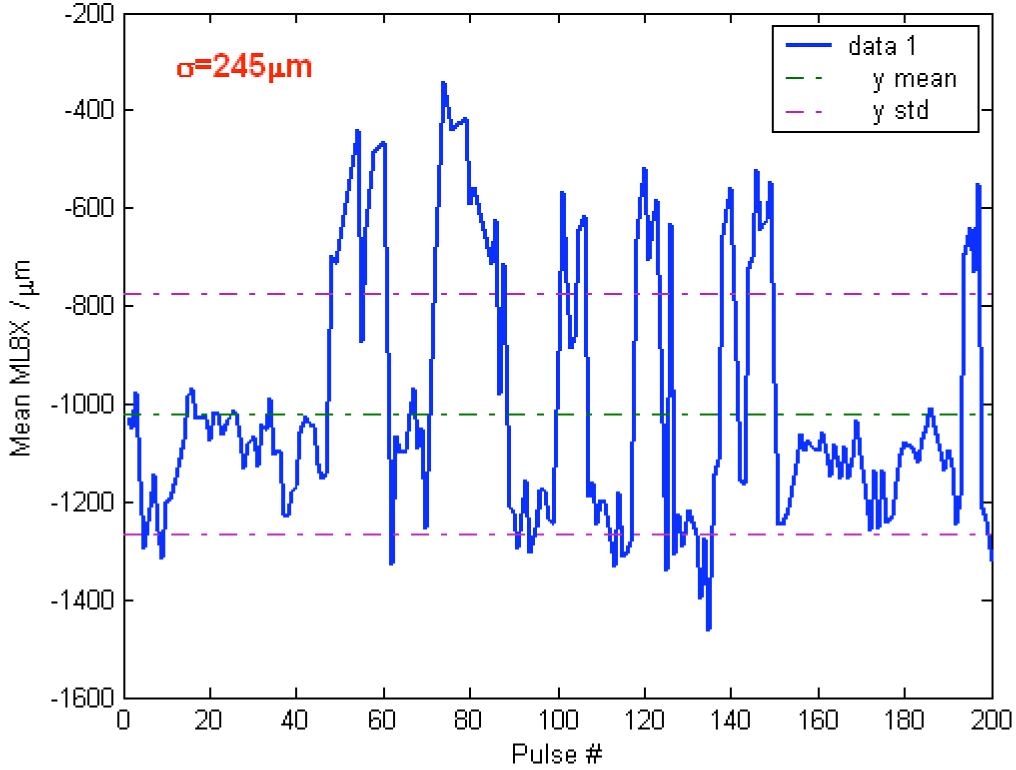
All Bunch Train Position Data



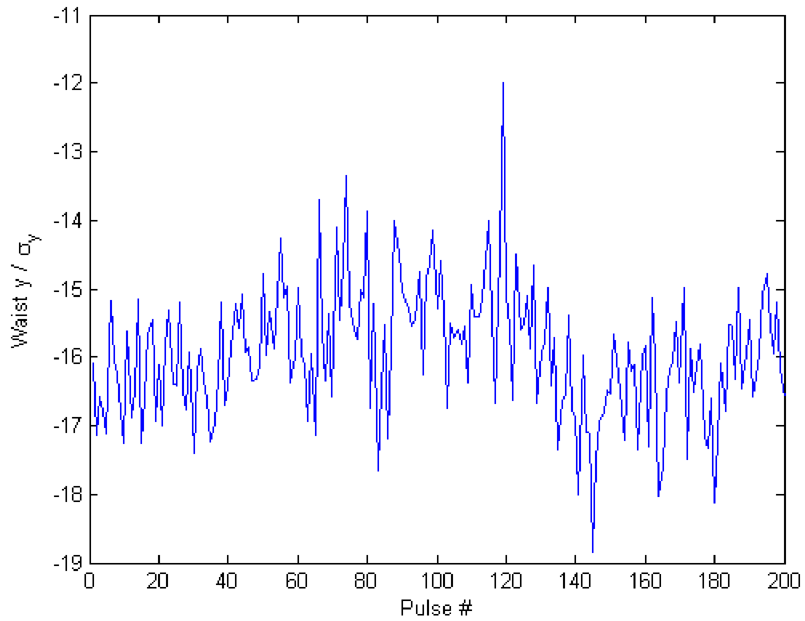
•Position of y waist in units of y waist size (σ_y) for all 200 pulses.

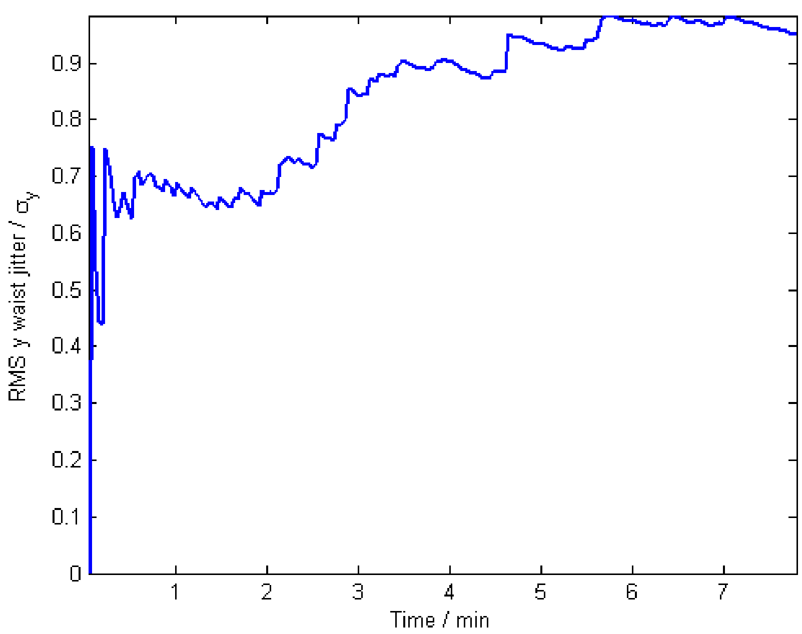
•18 Bunches useable.

Pulse-Pulse Jitter



Train-Train y Jitter



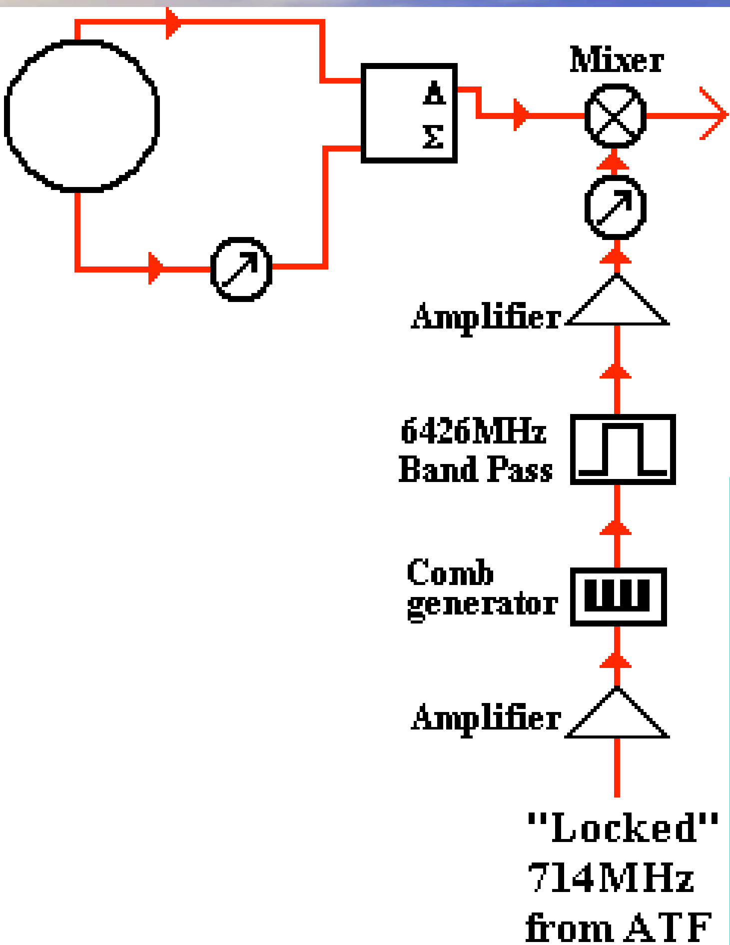


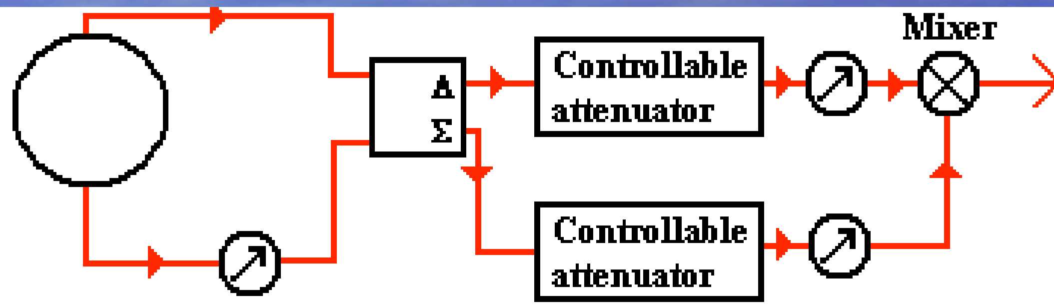
•Use mean position bunches 4-8 for train position.

•Left is plot of waist y position across 200 consecutive pulses.

•Right is plot of RMS jitter as a function of time from the start of this run, assuming 1 pulse taken for every 3 ATF pulses (0.78Hz) as was observed during running.

Processing electronics

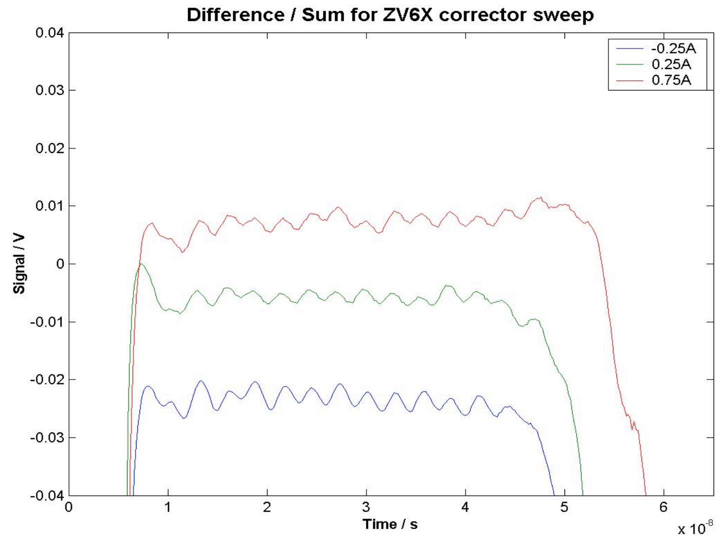


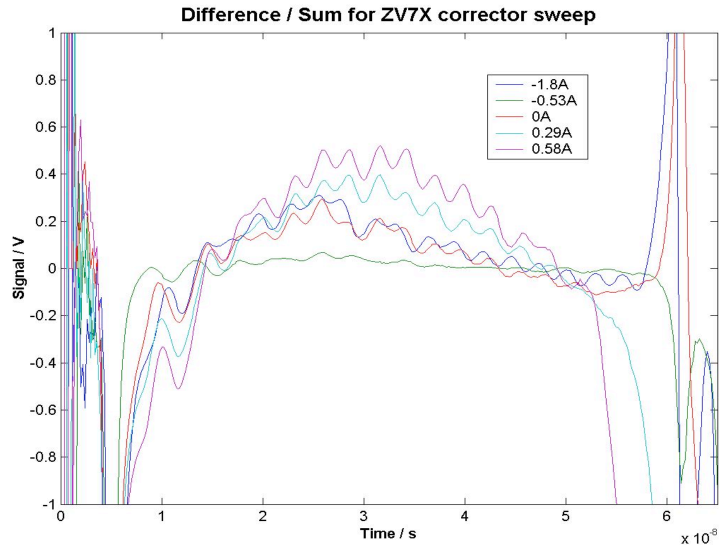


- Position output is mixed down _.
- Difference lies in LO source:
  - Mix with 714MHz reference.
    - Requires stable reference phase.
  - Mix with _.
    - Requires flat charge profile over train.

Normalised positions

- Sweep worked well for ZV6X.
  - Position seems very flat along train.
  - Train length (no. of bunches) deteriorates with time.
  - 357MHz beam frequency clearly visible.
- Very little information from ZV7X sweep.
- Electronics had been installed in tunnel, then removed, so perhaps the LO phase was wrong.





Latency

- Time between input and output = ~5.3ns
  - The initial filter was NOT present for this measurement.
- Hybrid uses ~1ns.
- Mixer ~0.5ns.
- Final filter dominates with ~3.5ns.
- Previous “Smith/Jolly” tests used higher (NLC) bunching frequency of 714MHz.
  - Thus LPF had higher cutoff, which implies lower latency.
  - However, canNOT relax filtering constraints due to large 357MHz component.
    - Colin – Is the present signal OK for your amplifier??

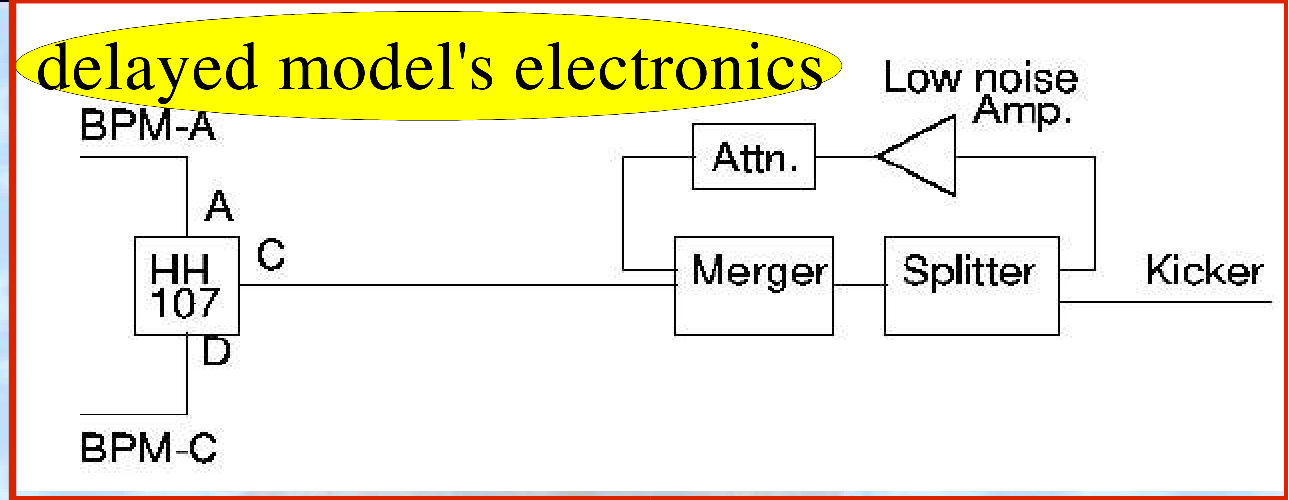
FEATHER: Feedback AT High Energy Requirements

Hayano Hitoshi, Tauchi Toshiaki,
Nicolas Delerue,
Fujimoto Hiroyuki

http://acfahep.kek.jp/subg/ir/feather/

Nano Meeting 05.06.2004

Timing estimation



The response time of our new amplifier has been measured~5.6 ns

- There is ~1 meter between our kicker and our BPM

  = >Beam flight ~ 4 ns

  = >Cable delay ~ 7 ns

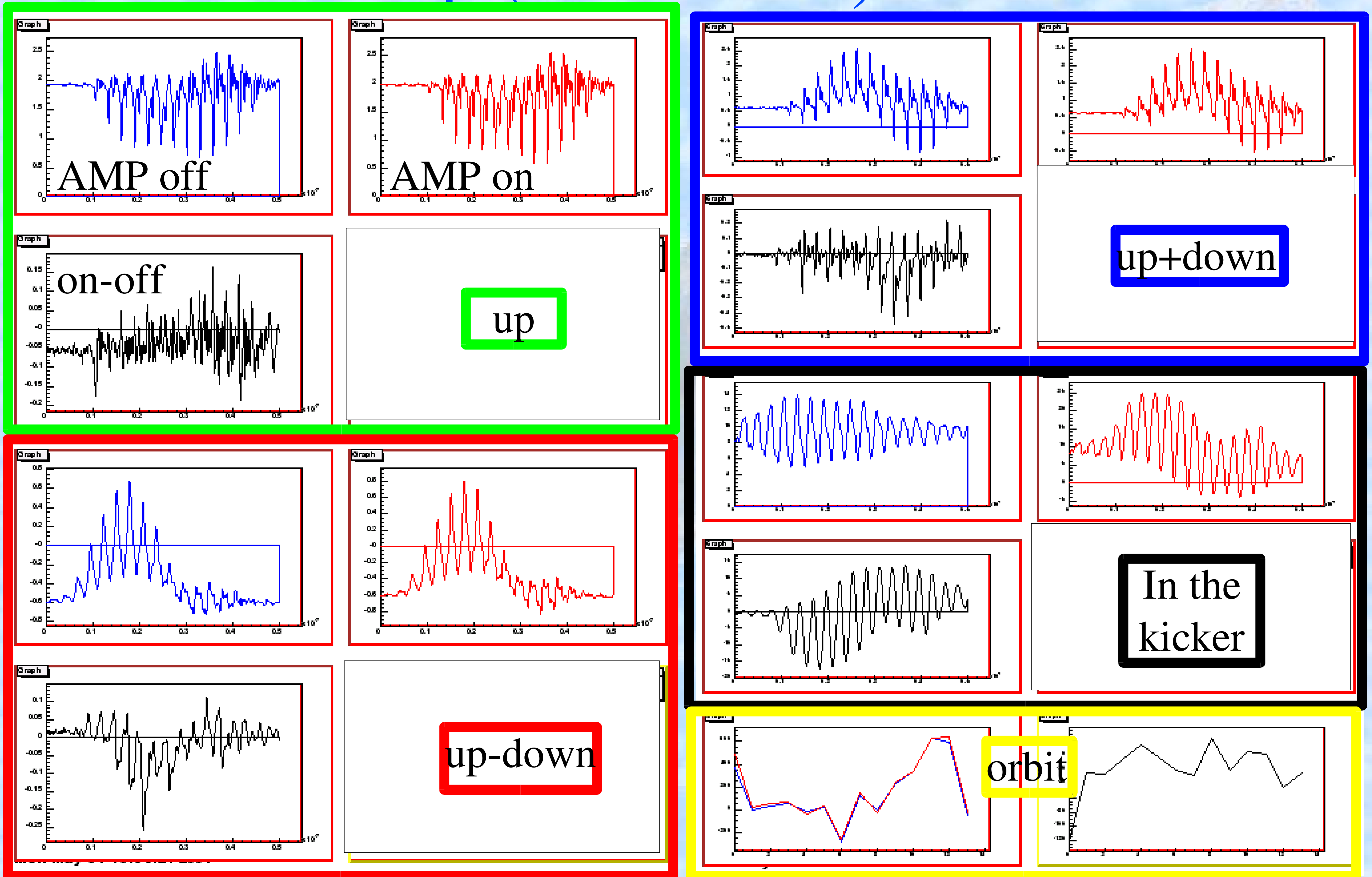
- Various electronics delay should be less than ~5ns (Response should come ~20ns after first bunch)
- Delay loop needs ~11ns more (Total ~35 ns)
- 20 bunches at ~2.8 ns make a ~56ns train.

  = > Should be possible to test our delayed model!

ニコラ デレル Nicolas@post.kek.jp
http://acfahep.kek.jp/subg/ir/feather/

Feedback loop (<500MHz)

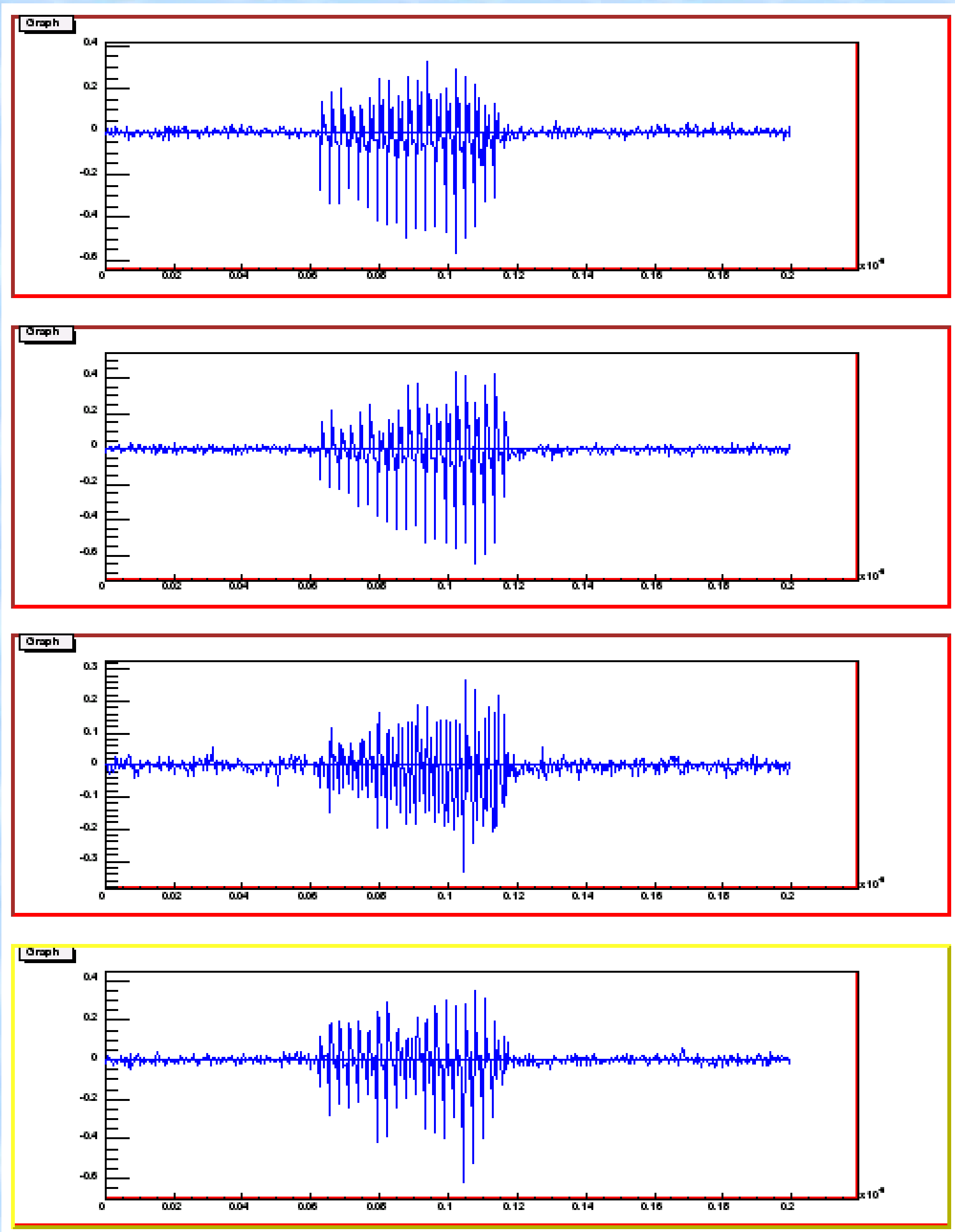
FEATHER (羽)



ニコラ デレル Nicolas@post.kek.jp
http://acfahep.kek.jp/subg/ir/feather/

Train to train fluctuations

FEATHER (羽)

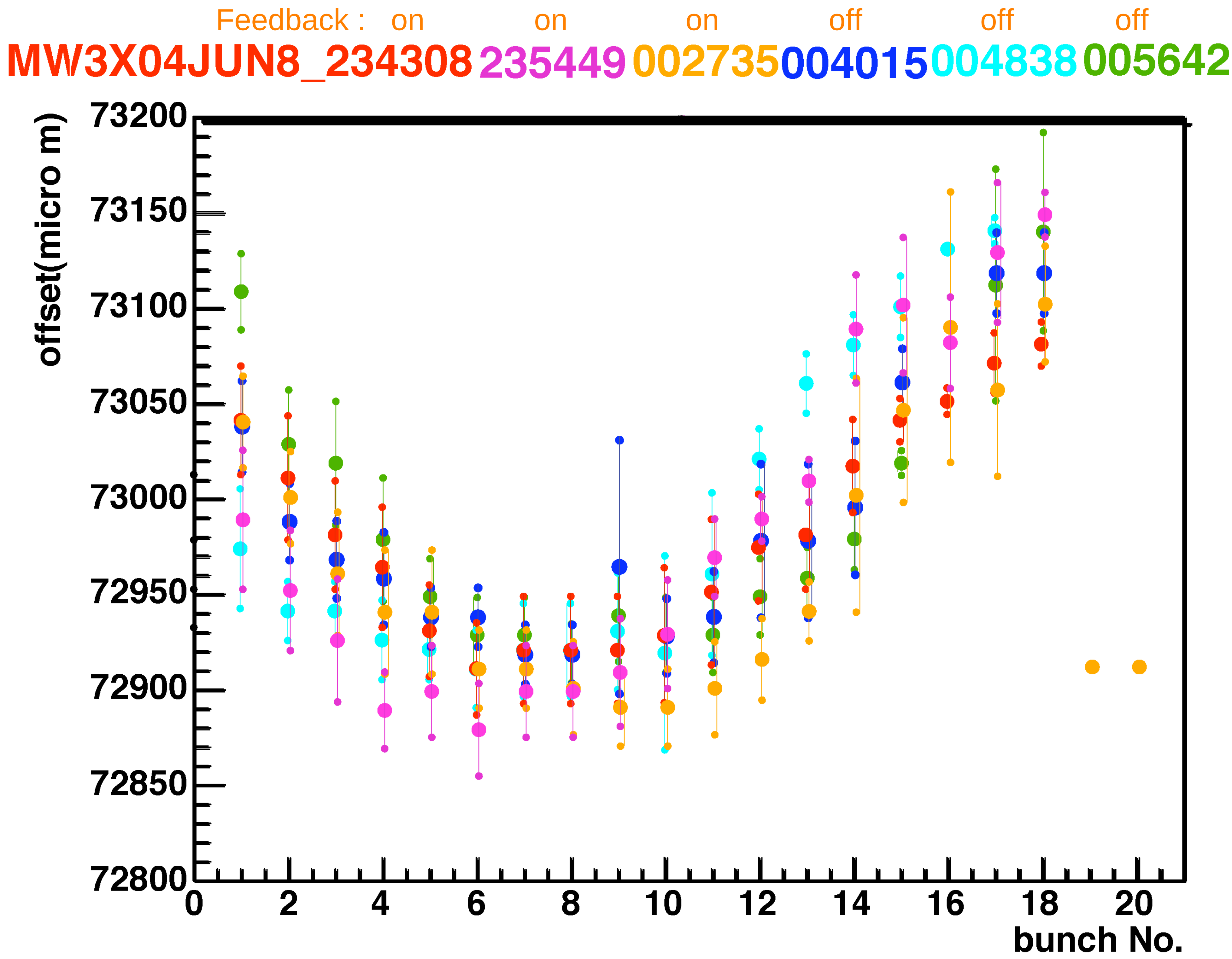


•Train to train fluctuation of the BPM signal are dominating the measurement. (Kick with 40 dBm at 20MHz has been measured with wire scanner.)

•Kick is of the order of 20 microns. Comparing the measurement resolution with the train to train observed fluctuations...

We need to get rid of these fluctuations...

ニコラ デレル Nicolas@post.kek.jp
http://acfahep.kek.jp/subg/ir/feather/



Feedback : on on on off off off
MW3X04JUN8_234308 235449 002735 004015 004838 005642
offset(micro m)
73200
73150
73100
73050
73000
72950
72900
72850
72800
0 2 4 6 8 10 12 14 16 18 20
bunch No.

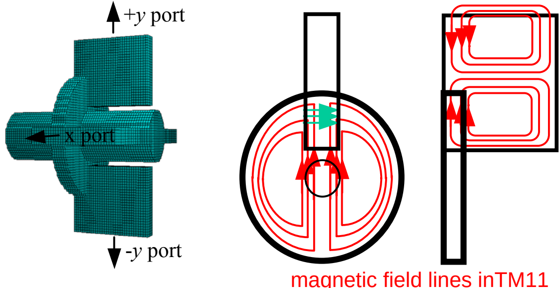


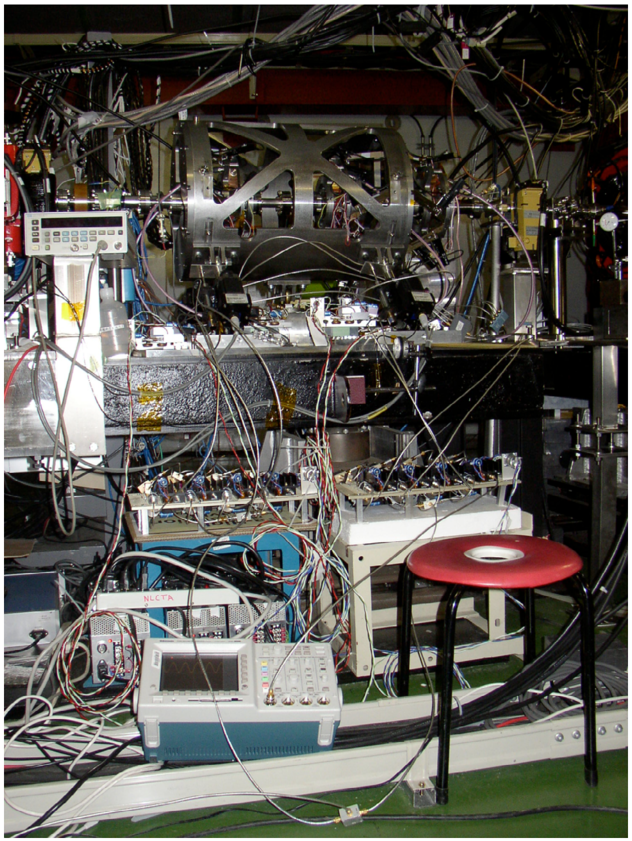
Figure 1 Cavity BPM with dipole mode selective coupler.

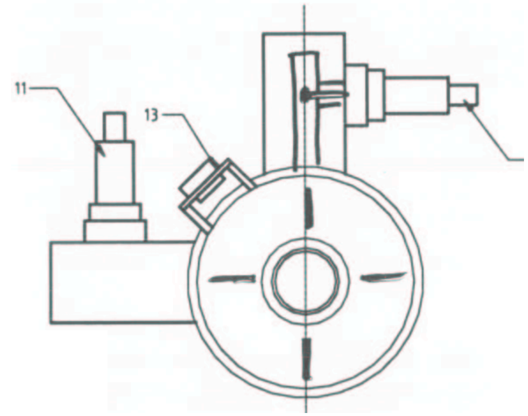
y port signals for X-offset

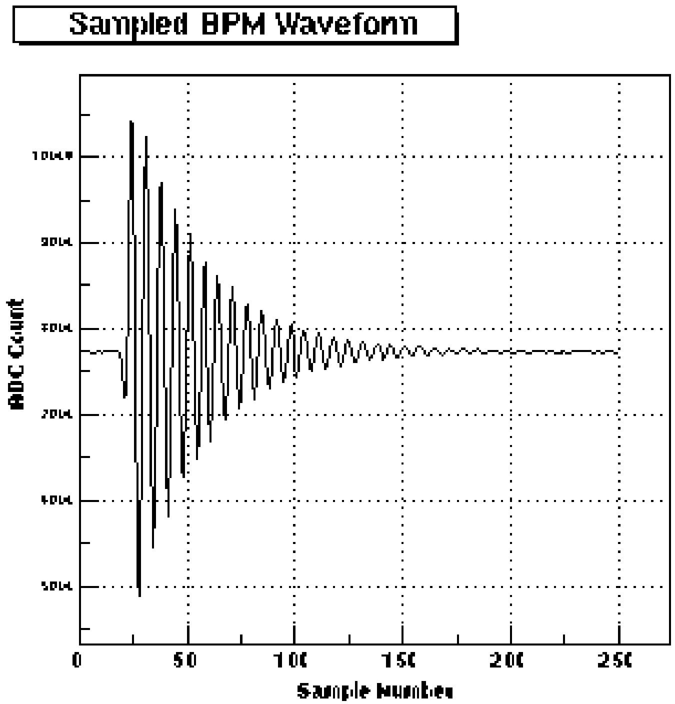
NanoBPM Analysis Update

Results and Lessons from the Feb/March 2004 Run

Mark S. Cooke, Yury G. Kolomensky
UC Berkeley, LBNL
2004.06.05



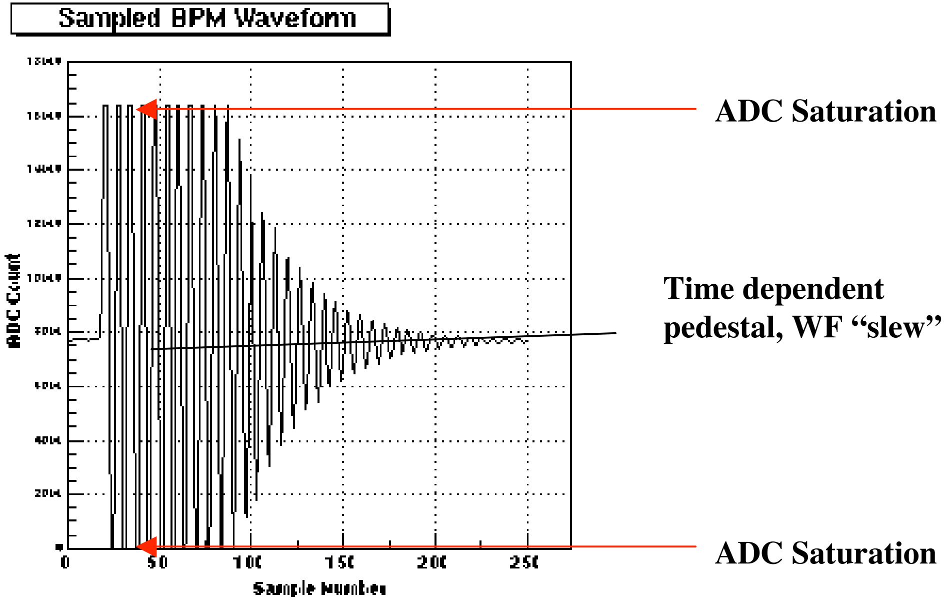


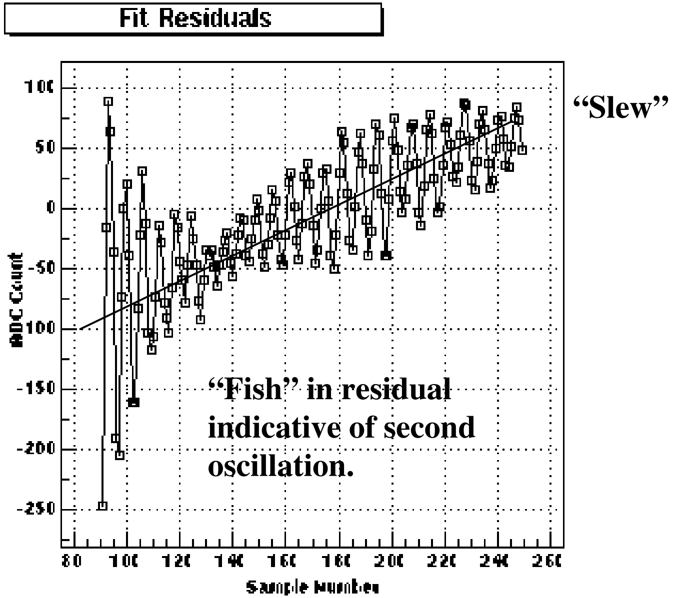


Some Systematic Effects Which Complicate Fit Analysis

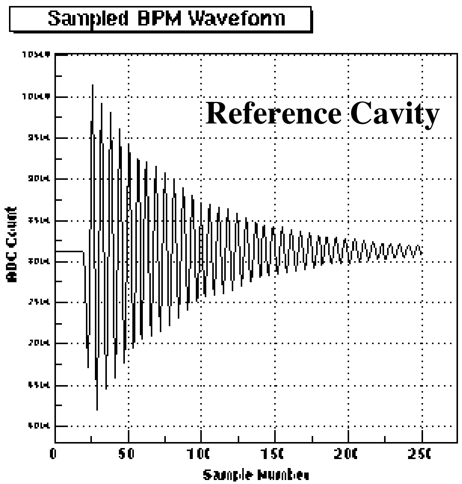
A typical waveform may have a several "interesting" features

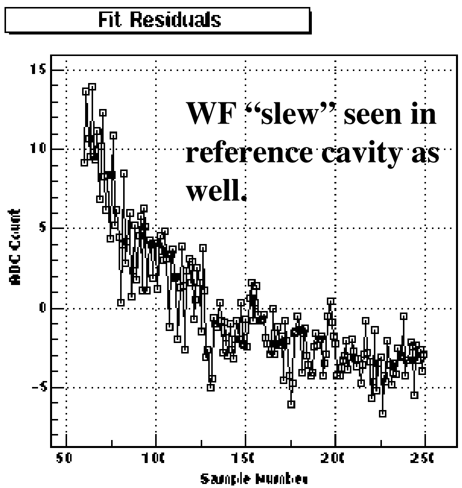
19_52, file 60, BPMy1 start 60 w/ error 10, pulse #4





19_52, file 3, BPMy3 start 60 w/ error 100, pulse #5





19_52, file 60, RefBPM start 60 w/ error 10, pulse #5

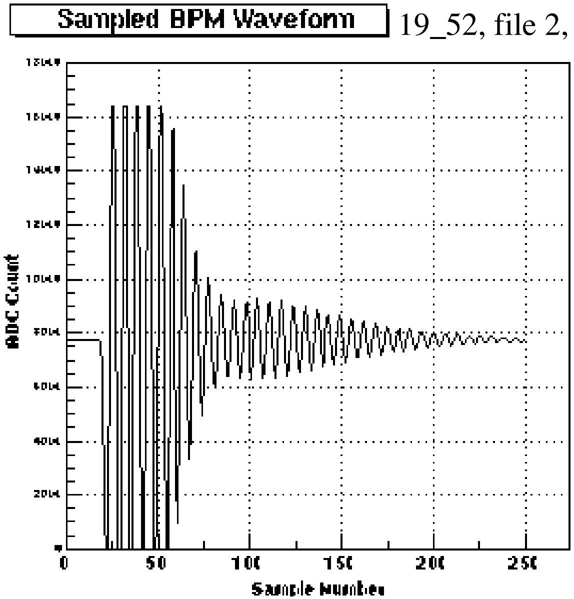
Severe Interference Is Observed On Some Waveforms ...

Waveforms,
Not Fit Residuals!

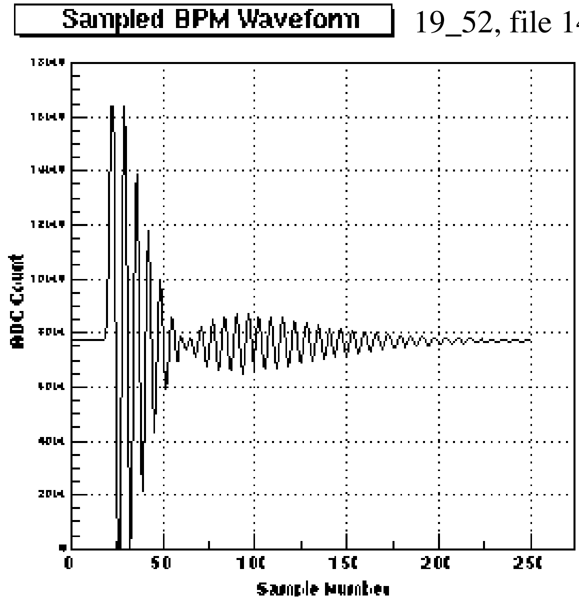
"Fish" in y residuals are common, present to some degree in nearly every pulse.

These waveforms which display a large degree of interference are more rare.

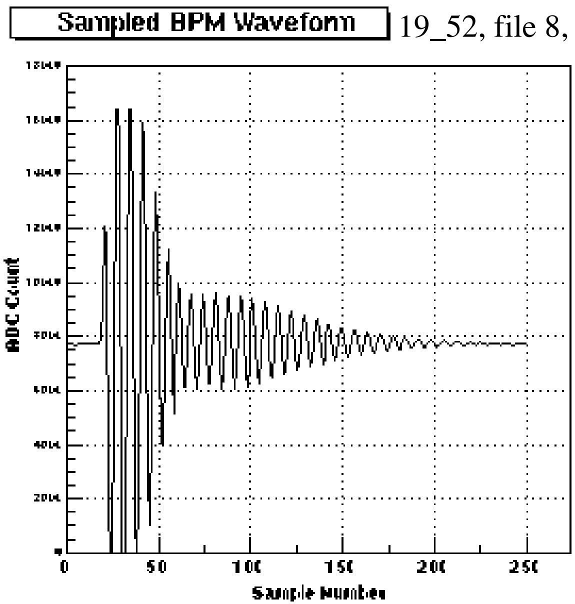
(the two are likely, related of course)



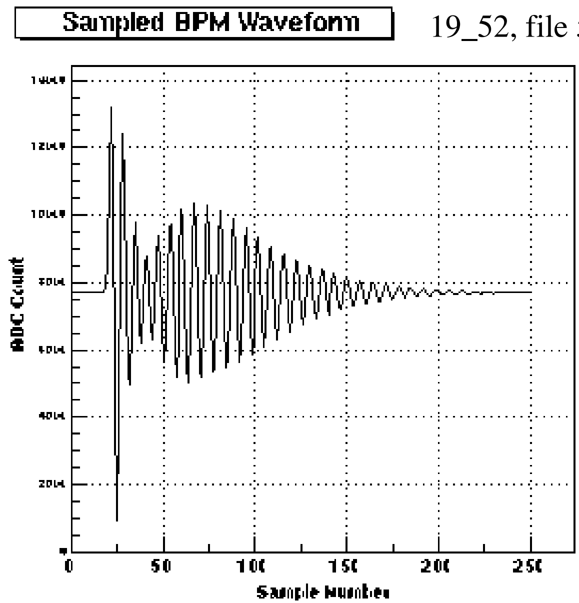
19_52, file 2, y2 #30



19_52, file 14, y2 #5



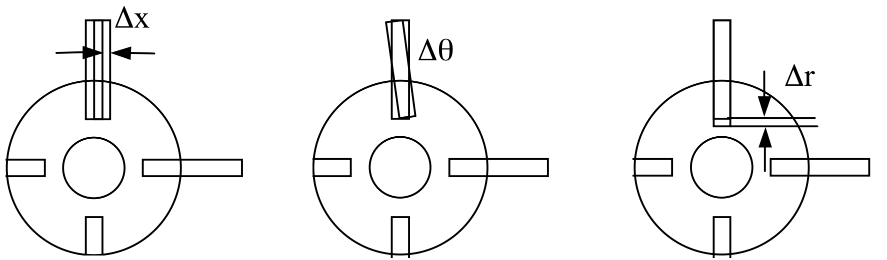
19_52, file 8, y3 #5



19_52, file 52, y3 #1

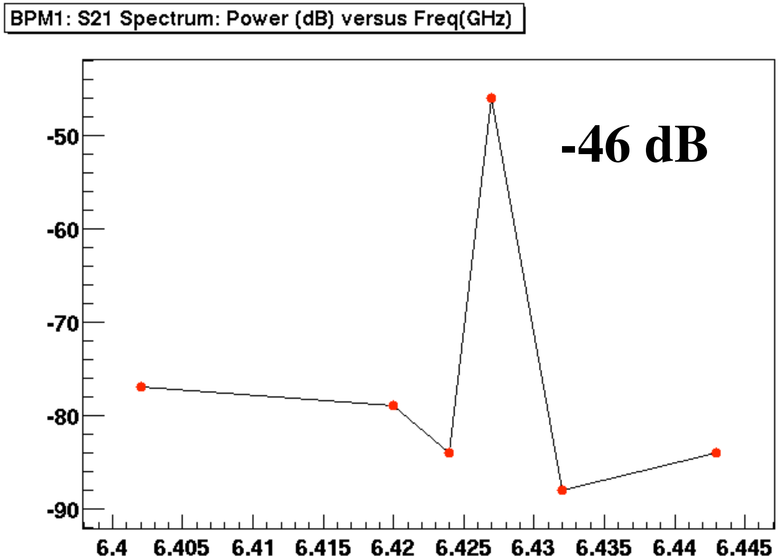
Theoretical Considerations of BPM Imperfections

- Both Δx, $\Delta\theta$ errors result in non-zero projection of the azimuthal magnetic field of the TM_{01} mode along side the slot opening, causing coupling of the TM_{01} mode to the waveguide and *x*-*y* coupling.
- Δr error may shift electric center of modes, results in potential TM_{01} leakage and *x*-*y* coupling.
- Ellipticity of cavity also couples x-y. Couple modes directly.

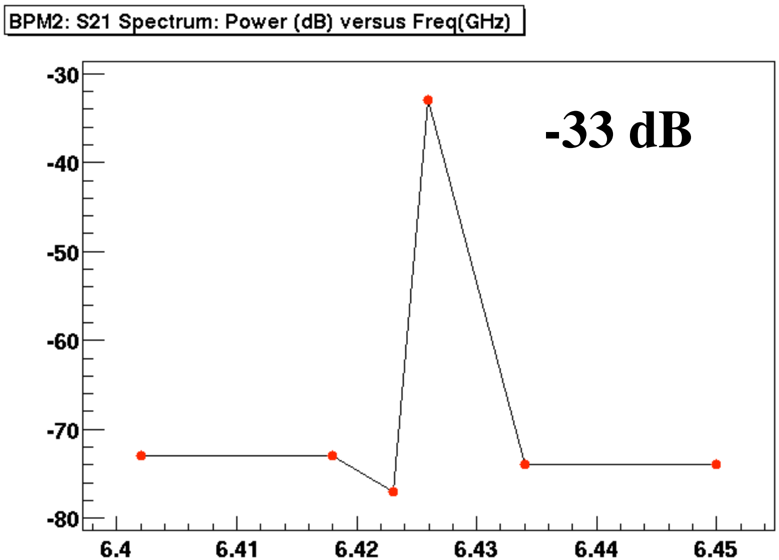


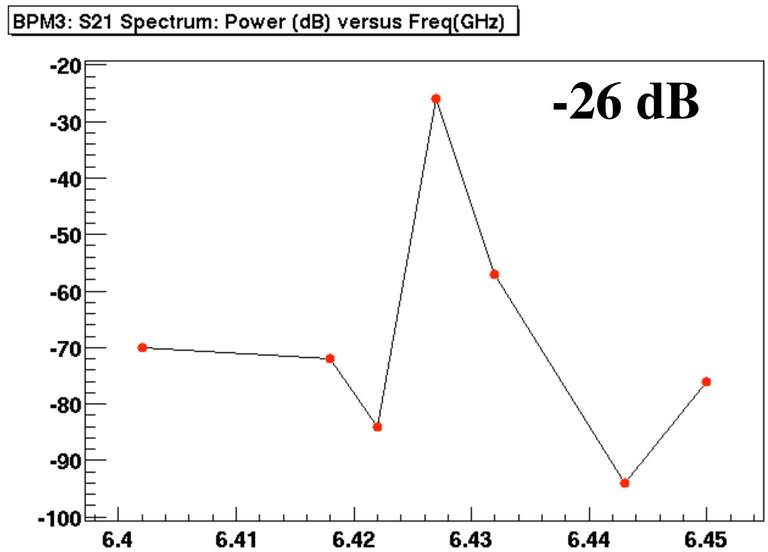
- Also need to consider monopole mode leakage as another possibility.

Network Analyzer Measurements of Cavities (5/29)



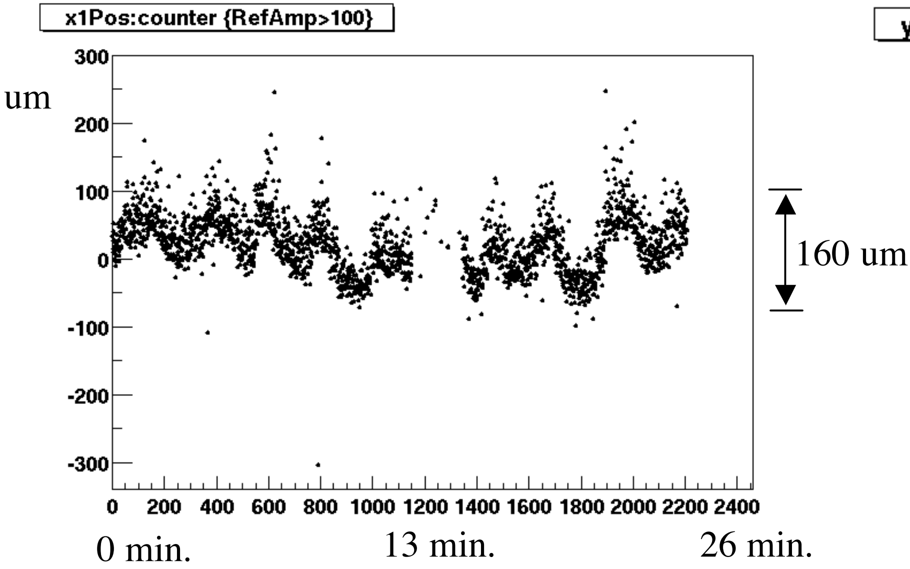
S21 measurements between x and y BPM ports. Coupling strength at resonant peak agrees with magnitude of fit residuals and the frequency of observed waveforms with “severe beating”. Also observed that the magnitude of the difference between S11 and S22 peak frequencies follows this pattern. 122, 208, 404 KHz (BPM 1:2:3).

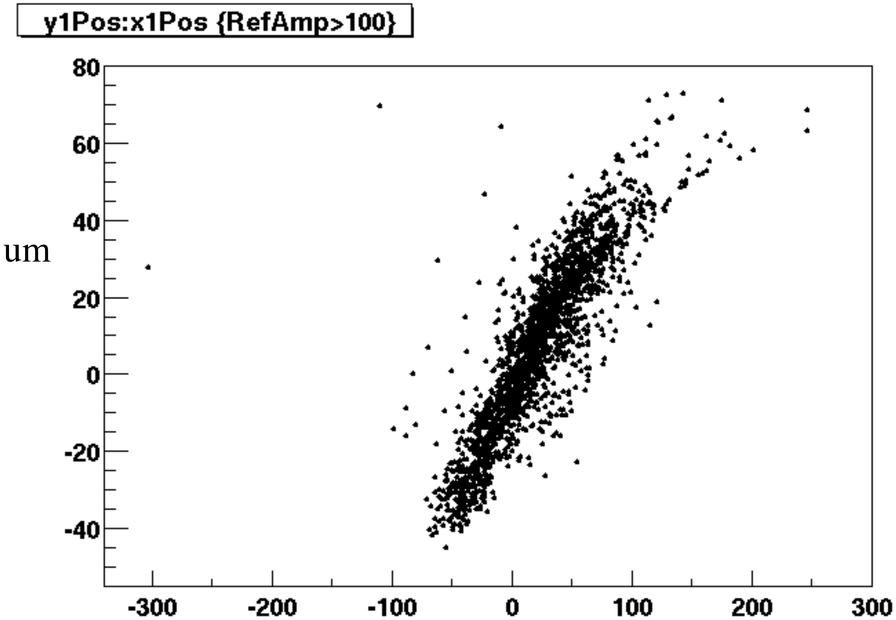


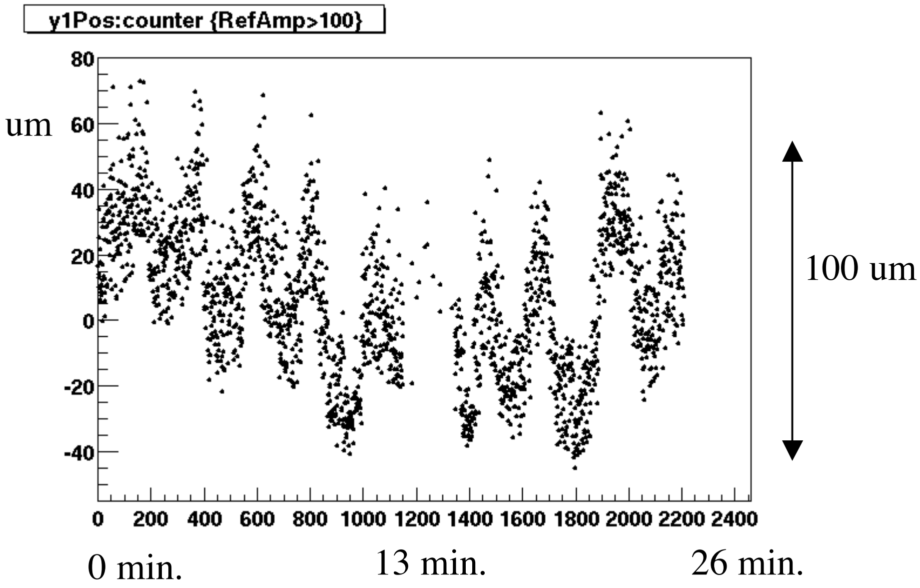


Beam Stability Problems During March Data Run

Periodic (large time scale) correlated beam motion in x and y.







Energy Instability + Uncorrected Dispersion

Extraction Kicker Bad Orbit/Alignment

Oscillation Period ~ **3 min**

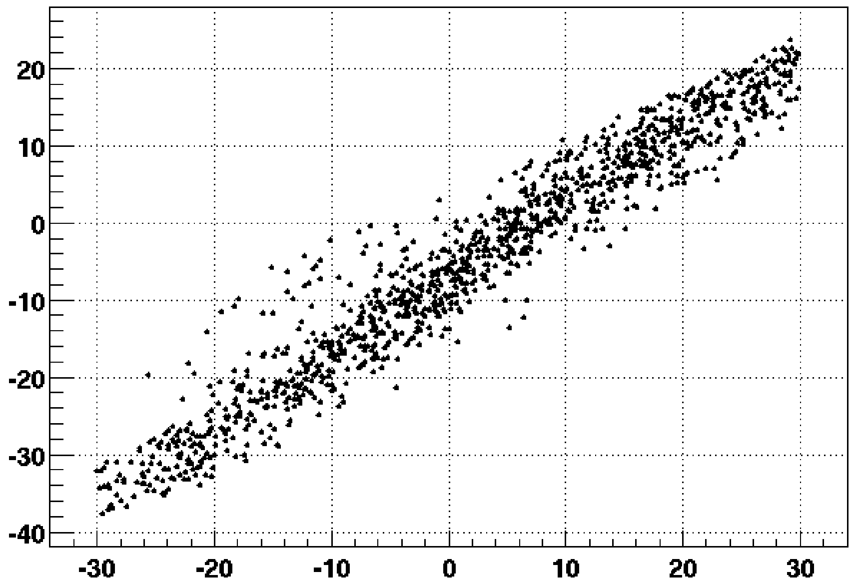
σ_X= 26 um

σ_Y= 13 um

Y BPM Performance

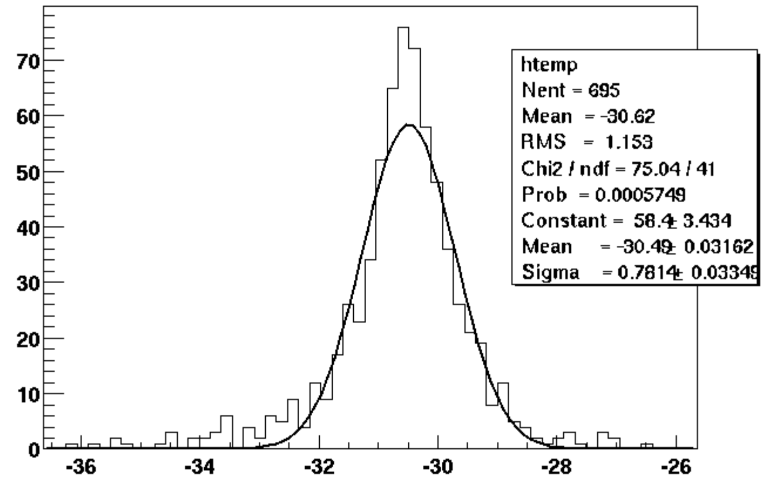
y2 Predicted vs. y2 Meas

um



um

Y Resolution



780 nm Y resolution much worse (by ~ x10) than previous measurements. Raw agreement is 4 um but large correlations to x position and y1 and y3 tilt help reduce the width.

Progress Since March Run

Modified hardware (third generation) at SLAC. Commissioned at KEK on June 6.

Noise measurements performed with beam off and beam on (but BPMs not hooked up to electronics). Digitizer noise in both cases 2-3 counts RMS on all channels. Scope RMS measurements directly before digitizers yield 0.5- 1 mV. Calibrations constants from March imply 4-6 nm electronics noise. Total gain measurements consistent with design.

Improved BPM frame alignment.

<u>First June beam yesterday (thanks FONT for deferring multibunch program)!</u>

With improved alignment, we were able to correct remaining dispersion, achieved much better orbit than March.

“Slew” effect still present, but has been reduced by placement of attenuators after first stage mixer output.

Performed quadrant scan to test dipole-dipole vs. monopole-dipole hypotheses (eager to analyze this).

Still observe severe beating effect and large residuals. Decision made to remove and tune two BPMs. This just in - coupling of the worst cavity is now -50 dB (was -26).

ATF nanoBPM

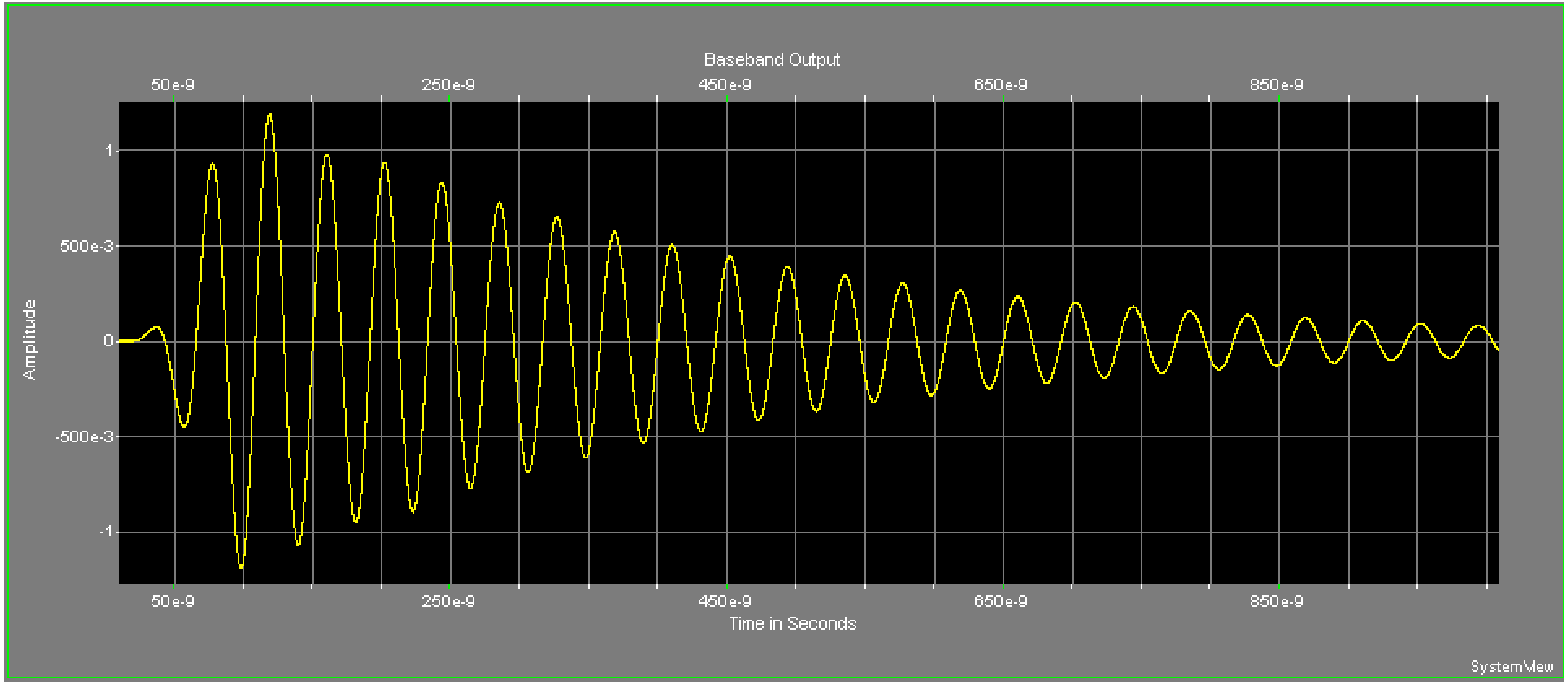
Common Mode Characteristics of Cavity BPM Receiver

Steve Smith
SLAC
June 5, 2004

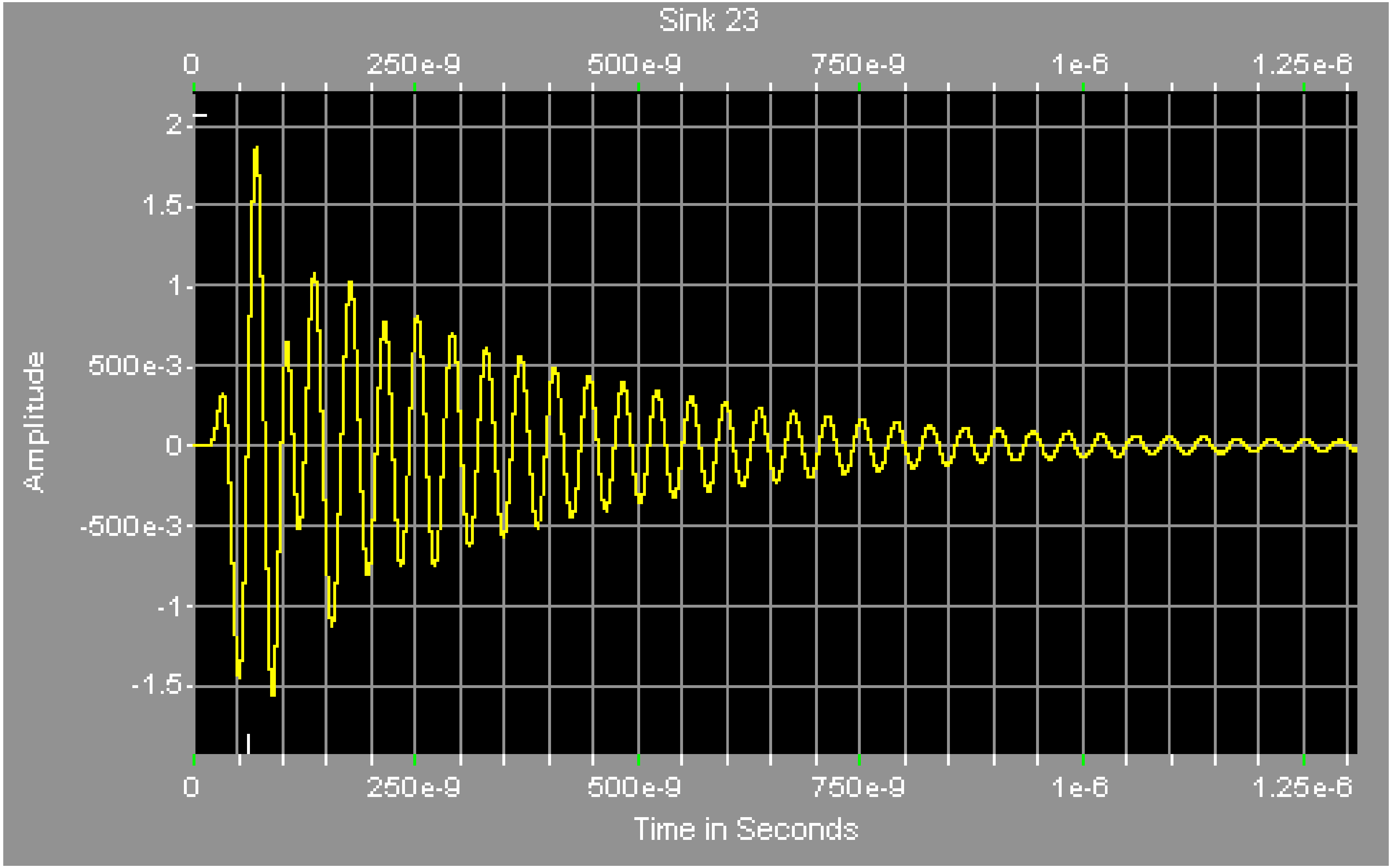
Common Mode Consequences

- Linear & Nonlinear:
- Two characteristic (linear) consequences of monopole mode:
  1. Tail of monopole mode at frequency of dipole mode
     - In band
  2. Leakage of monopole mode through stopband tail of filter
     - Out of band
- Non-linear features:
  - Saturation
  - SystemView amplifier and mixer blocks simulate
    - Compression (P_{1dB})
    - Intermodulation (IP_3)

Pure Dipole Mode Signal

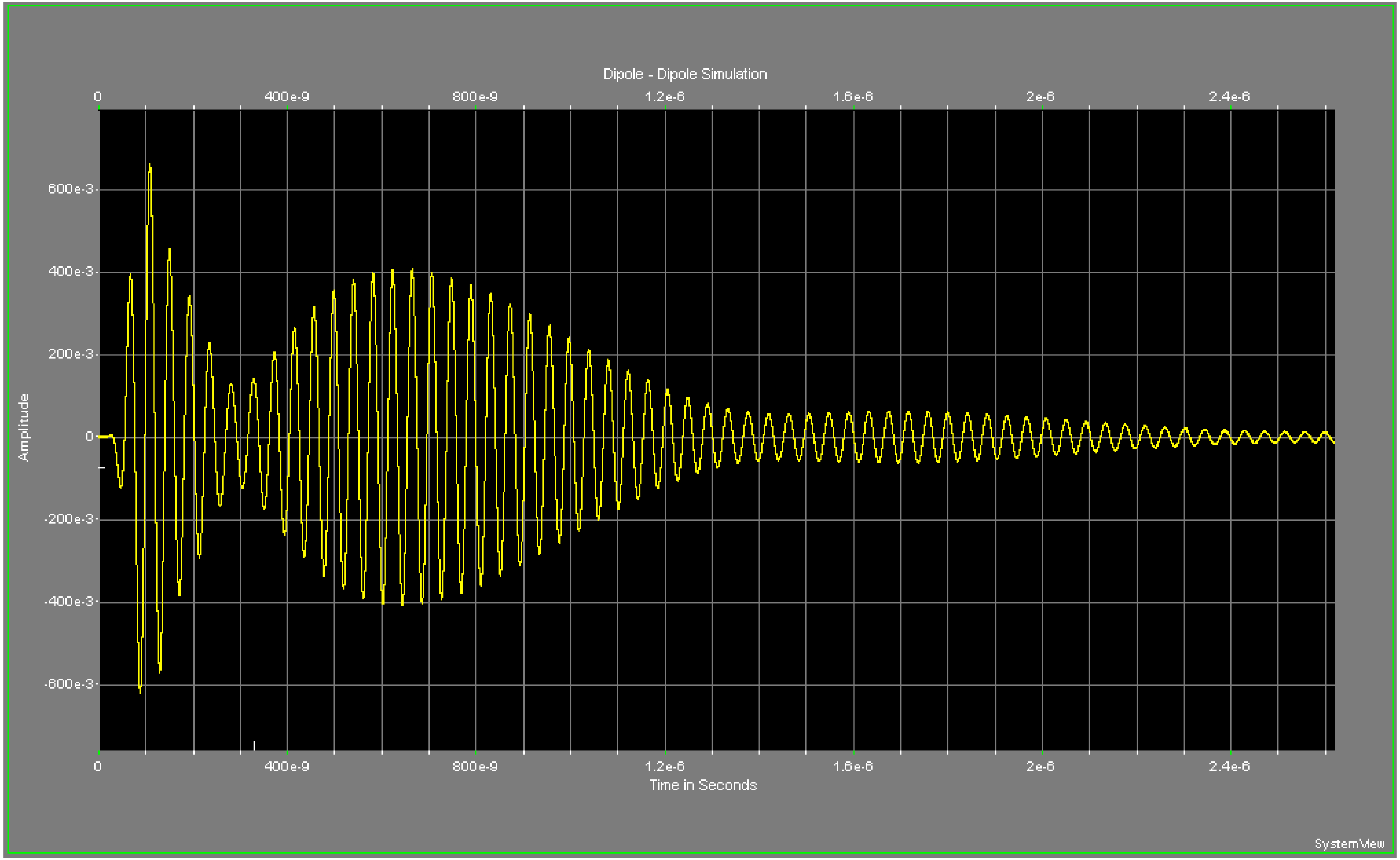


Simulation of Dipole + Monopole



Simulate Dipole-Dipole Beats

ATF nanoBPM



Steve Smith - June '04

Conclusion

- Few-cycle transient at leading edge of pulse can be explained by in-band tail of monopole mode(s)
- Rising- then falling envelope of dipole mode signal looks like what we expect from monopole-mode saturation of amplifier ONLY IF MONOPOLE SIGNAL IS MUCH LARGER THAN EXPECTED
- Probably most of the “fish plots” are due to x-y mode coupling (dipole-dipole)
- Verify monopole mode suppression of cavity/coupler
- Verify monopole mode frequency & width

nanometer BPM status and plans

Saturday, June 5, 2004

Marc Ross

Linear fit with all ...

- X: measurements matrix, 1 row/machine pulse, 13 cols including I, k is the column index
- A: coefficients
- (x is attenuated (20dB))

$1x$	$2x$	$3x$	$1y$	$2y$	$3y$	$1x'$	$2x'$	$3x'$	$1y'$	$2y'$	$3y'$
792	326	551	76	43	82	435	329	290	50	161	42

(nm)

(~nm effective dipole size →~0.1 urad)

Plans

- cavity tuning (done today for 2 out of 3 BPM's by V. Vogel)
- stabilization of ATF beam (!)
  - dispersion of 5mm (typical best)
  - (_~ 1e-3; when energy jitter = _, 5um jitter results);
  - typical uncorrected dispersion ~ 20-50um
  - energy jitter is usually < _
- measure loss factor and coupling (_)
- bench test of noise is ok.
  - (new electronics)

Measurements of stray field in the NLCTA area

Josef Frisch, Peter Tenenbaum,
Tor Raubenhemier

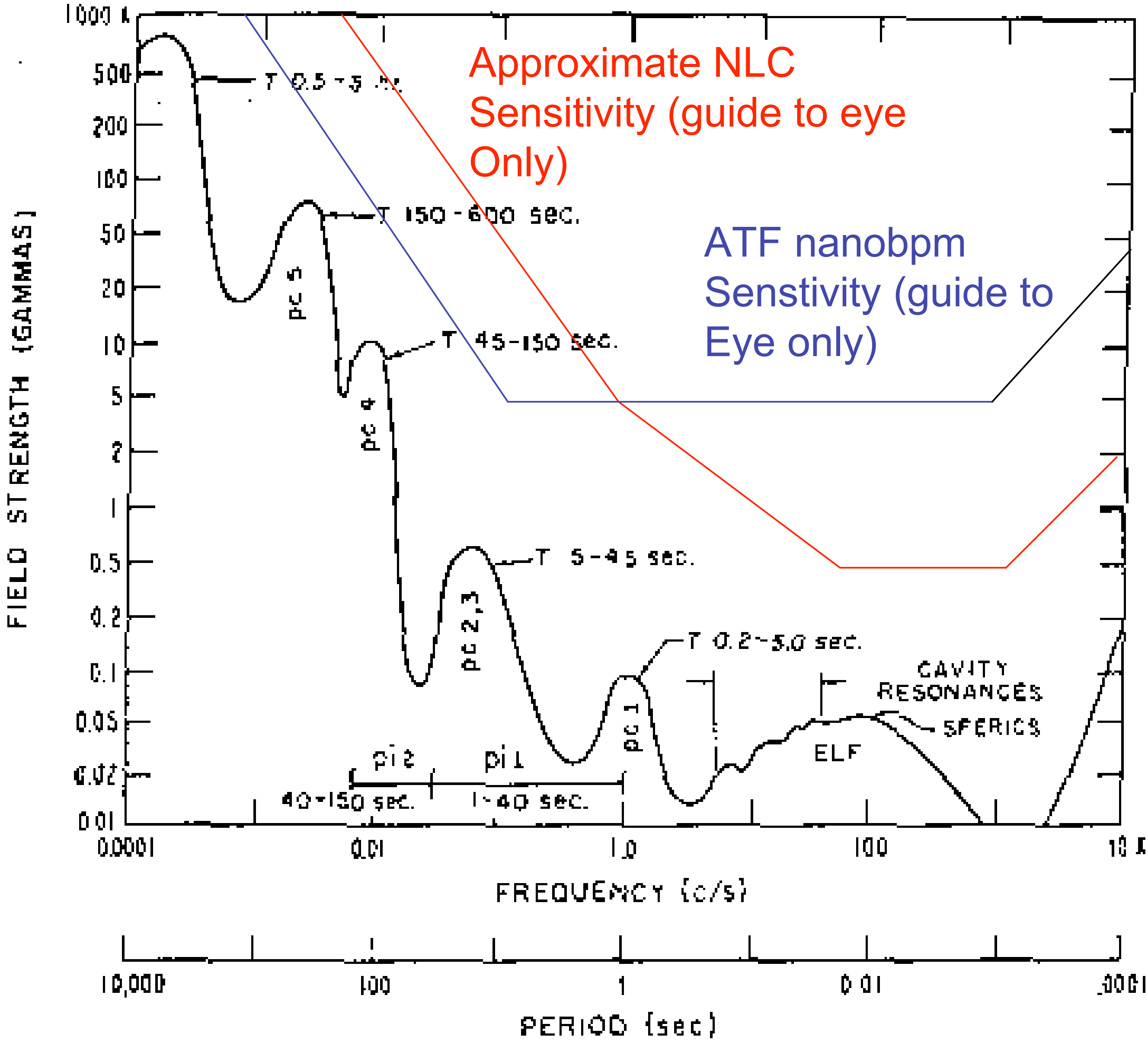
Field Effects

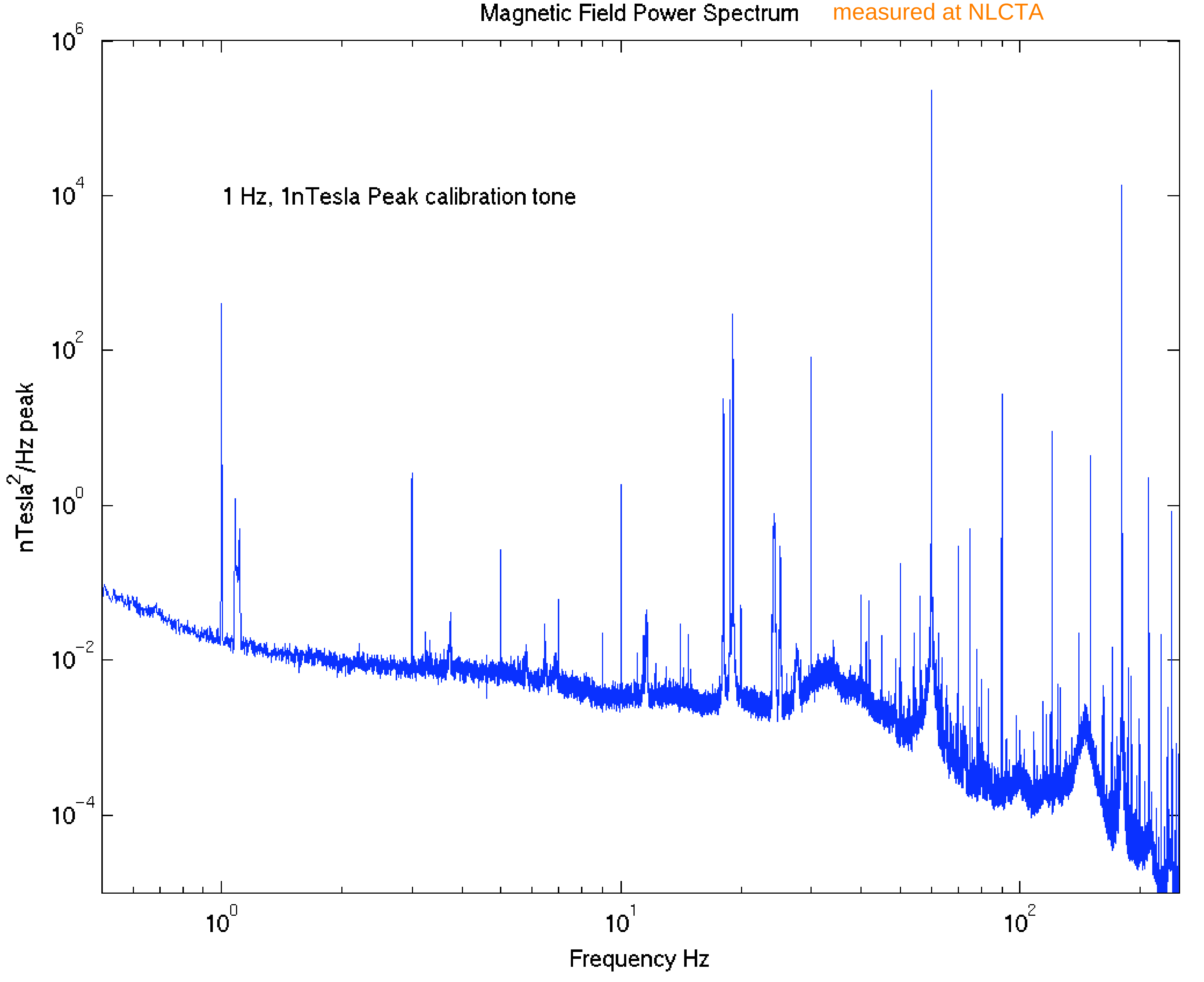
$$\theta = 0.3K_{TM} / P_{GeV/C}$$

- ATF 1nm on NanoBPM ~5nT
- NLC (simulated effects) Maximum sensitivity ~1nT (in beam delivery)
- At High frequencies, structures and beam pipe provide shielding
- At low frequencies (for NLC) feedbacks reduce effect.

1 Gamma =1nT

THE NATURAL FIELD IN THE LOWER FREQUENCIES





Magnetic Field Power Spectrum
measured at NLCTA
1 Hz, 1nTesla Peak calibration tone
nTesla^2/Hz peak
Frequency Hz
10^6
10^4
10^2
10^0
10^{-2}
10^{-4}
10^0
10^1
10^2

Measurements at ATF – possible technical issues.

- Need very low frequency measurement.
  - Theoretical sensitivity of pick up coil 0.25M radius, 1000 turns is <1pT/sec/sqrt(Hz) (easily good enough)
  - Need low frequency pre-amp.
  - May be difficult to separate large 50Hz signal from small DC signal
  - In practice, DC measurement (flip coil, hall probe, or similar may be more appropriate)
- Want smaller DAQ (spectrum analyzer is ~20KG, large volume.
  - Laptop ideal.
- No fundamental difficulties with measurement.

Overall Magnetic Issues

- Geophysical magnetic fields are unlikely to be significant for NLC/JLC
- Tests in SLAC end station B give fields which are significant, but probably acceptable (assuming 60Hz feedback).
- Fields could be significant for NanoBPM
- Need more measurements.

NLC - The Next Linear Collider Project

Nanometer BPM alignment and metrology frame

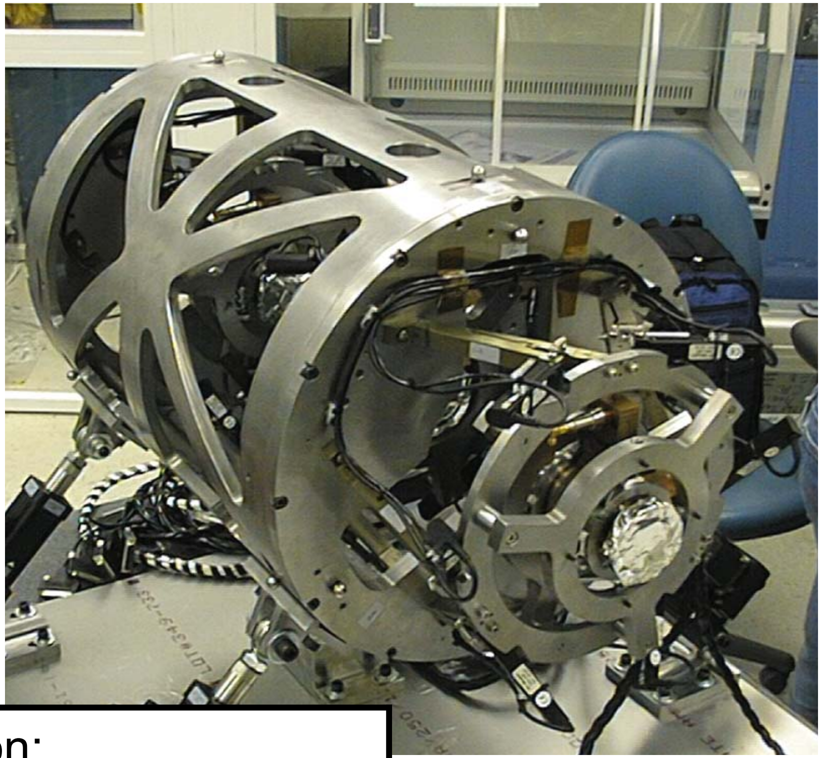
Jeff Gronberg / LLNL

Third Nano-BPM mini-workshop
June 5-6, 2004

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Modal Analysis confirmed the simulations

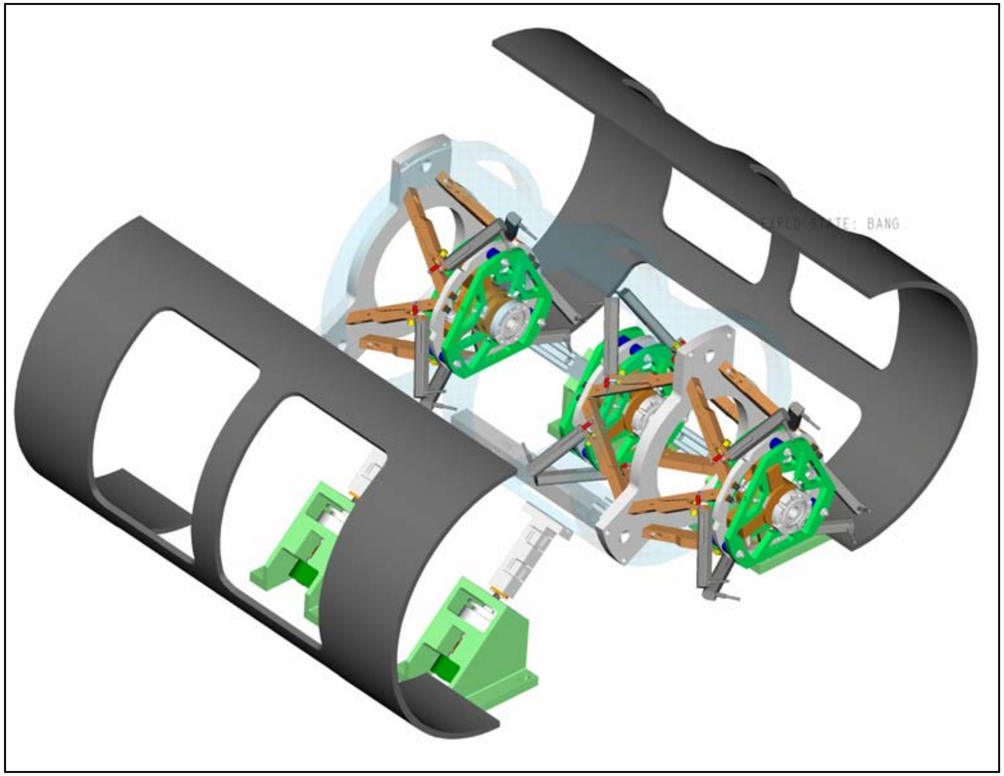
- High rigidity since it is a solid piece of metal bolted together
- The first resonance was predicted to be at 185 Hz
  - Ground motion at this frequency should be sub-nanometer even at a noisy site
  - While the whole assembly will move we should have a rigid body at the nanometer level



Mode:	Simulation:	Measured:	Motion:
1st	185 Hz	195 Hz	Drum head
2^{nd}	220 Hz	210 Hz	BPMs rotating around z out of phase

We want to add a metrology frame to control slow thermal motion

- Differential temperature changes in the struts will cause the BPM to move in all 6 dimensions
  - If temperatures change in synchronous, only z-position changes, not important for us.
- We want a zero coefficient of thermal expansion frame to provide a reference
  - Carbon fiber is a known technology. Precise choice of fiber alignment and materials achieves the zero CTE.
  - Super-Invar frame also considered but expensive.



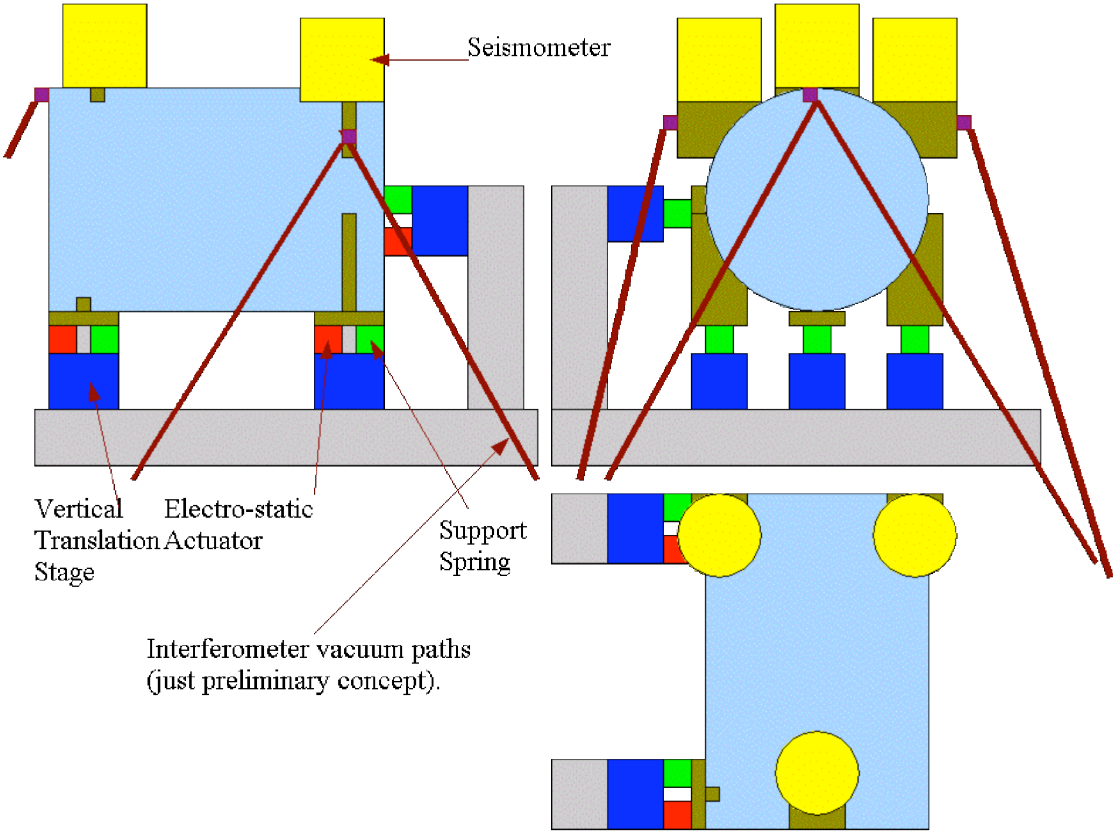
Summary

- Alignment frame is done
  - Installed and operating
- Metrology frame
  - Carbon-fiber frame is being designed and undergoing FEA
  - Nanogrid sensors procured
  - Construction in FY05 for installation spring 2005

Optical Anchor / Interferometer Status: June, 2004

Josef Frisch

Concept (still just a cartoon)



Other Tasks

- Interferometer support hardware
  - Probably need vacuum transport lines
  - Mount corner cubes to support frame / ground (in vacuum?)
- Temperature stabilization
  - 1nm over 1M scale length is ~.0001 degree C.
- Support redesign for feedback:
  - Soft supports, Fast actuators

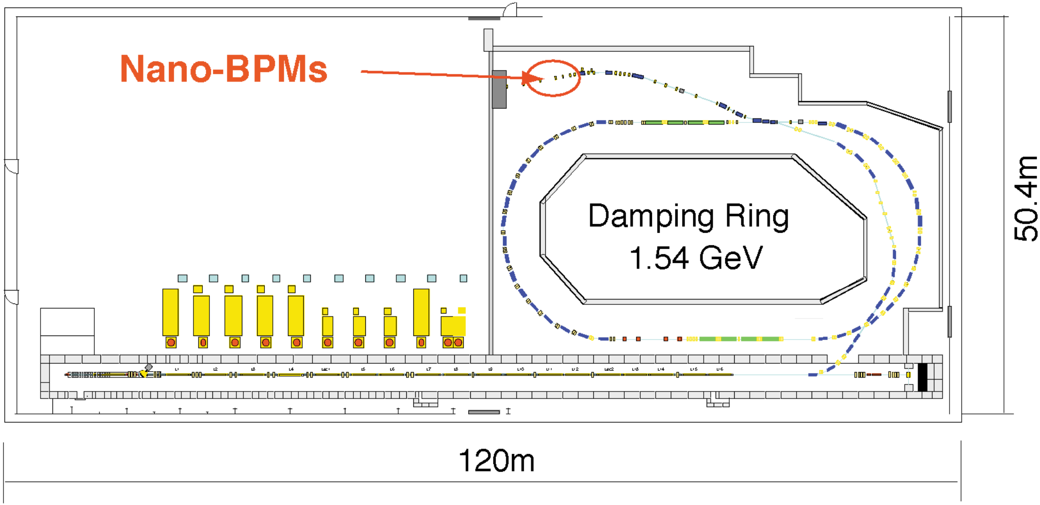
Goals of Interferometer / optical anchor system

- Stabilize a test mass – the NanoBPM support frame
- Can measure performance above ~0.1Hz using STS-2 seismometers.
  - May need multiple seismometers to compare with ground !
- Need to understand beam based experiments.
  - Can we compare 2 support frames with beam? (may be difficult to get 1nm given lever arm).
  - 3 independently supported NanoBPMs?

NEDO grant : Conception Picture

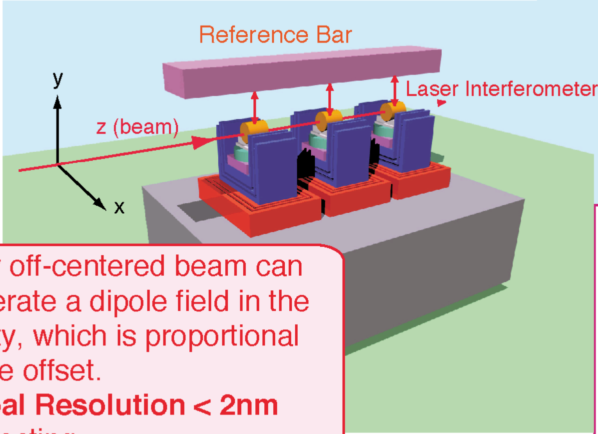
Nanometer Control of Electron beam for a X-ray Source

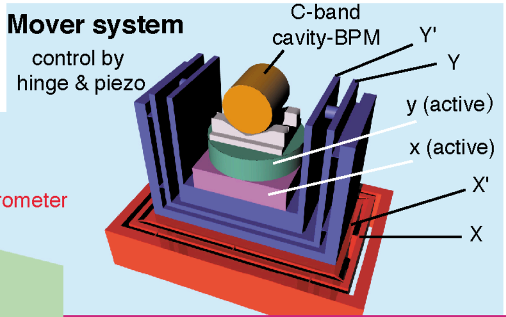
ATF at High Energy Accelerator Research Organization



Cavity-BPM system with nanometer resolution (Nano-BPM)

KEK Nano-BPM





Only off-centered beam can generate a dipole field in the cavity, which is proportional to the offset.

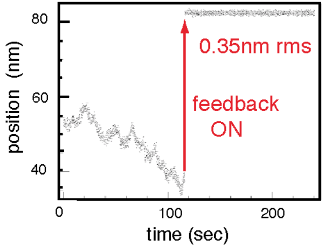
Goal Resolution < 2nm

-expecting

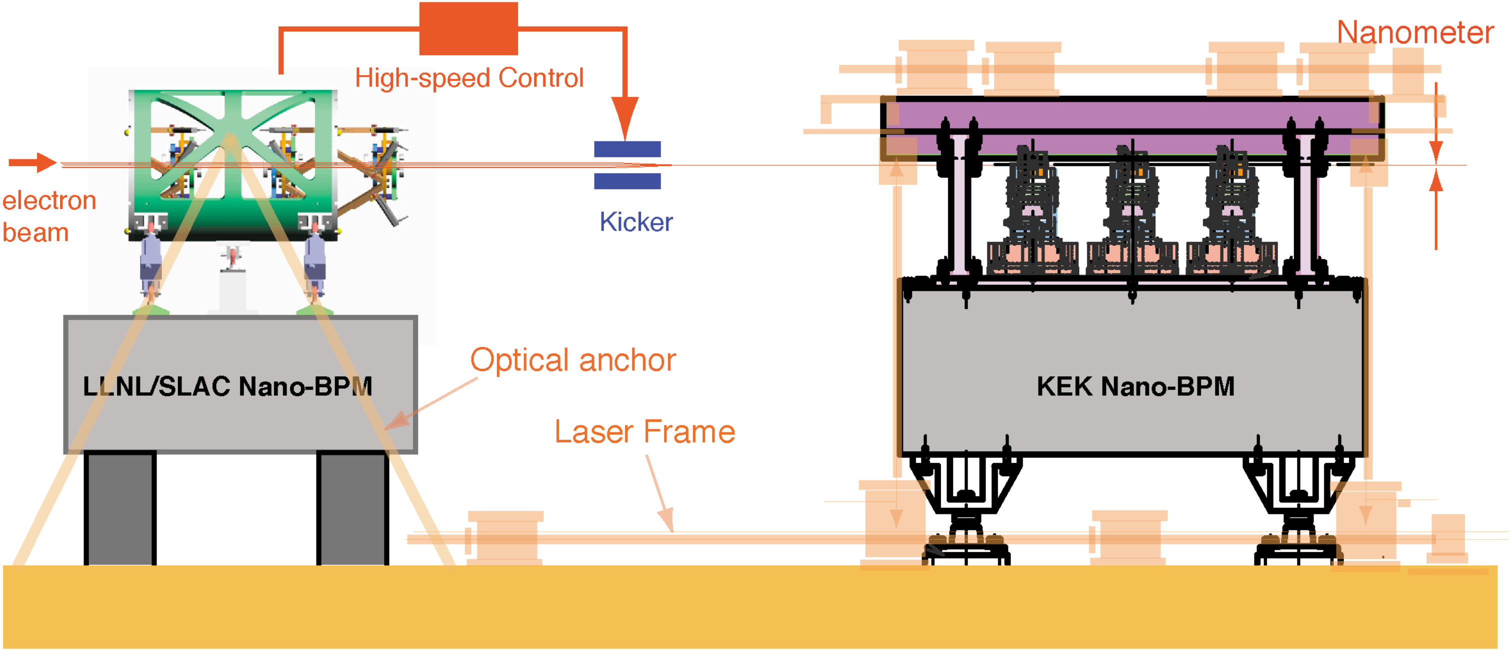
S/N > 2 for 1nm offset

BPM stabilization

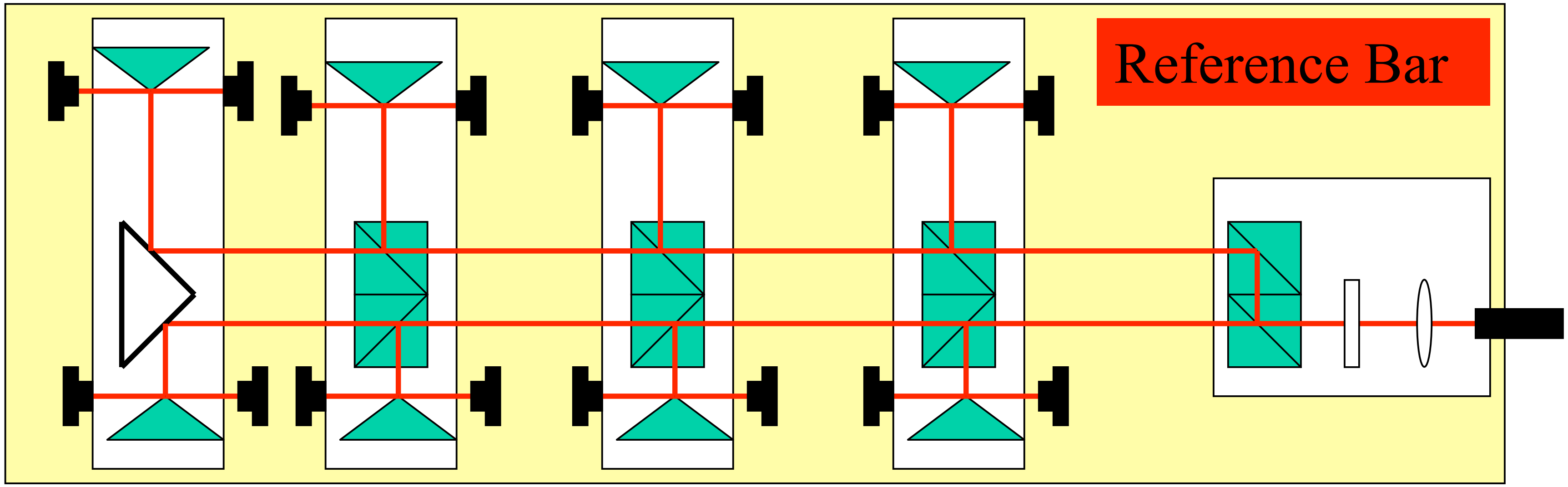
Each BPM will be stabilized by the active feedback. Its movements relative to the reference bar are monitored by laser interferometer. A test bench results show that the stabilization can be achieved at sub-nanometer.

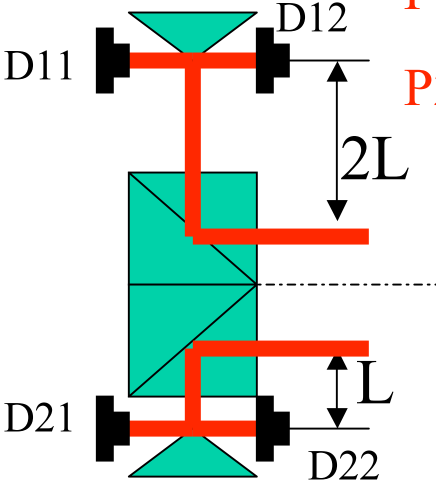


Two Nano-BPMs and High-speed Control System



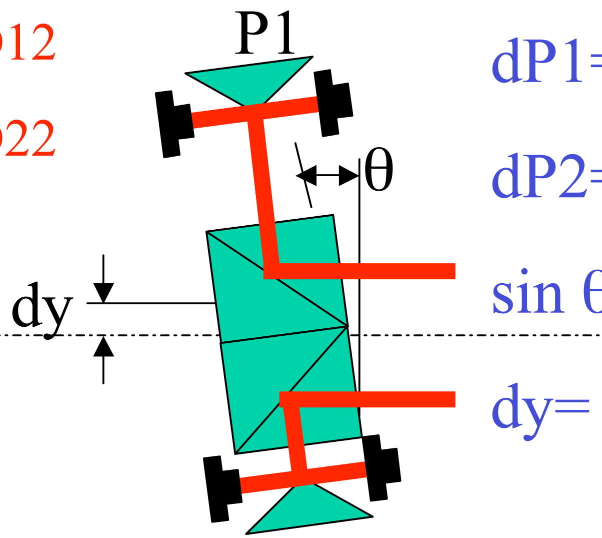
Laser-BPM





$P1 = D11 - D12$

$P2 = D21 - D22$



$dP1 = 2L \sin\theta + dy$

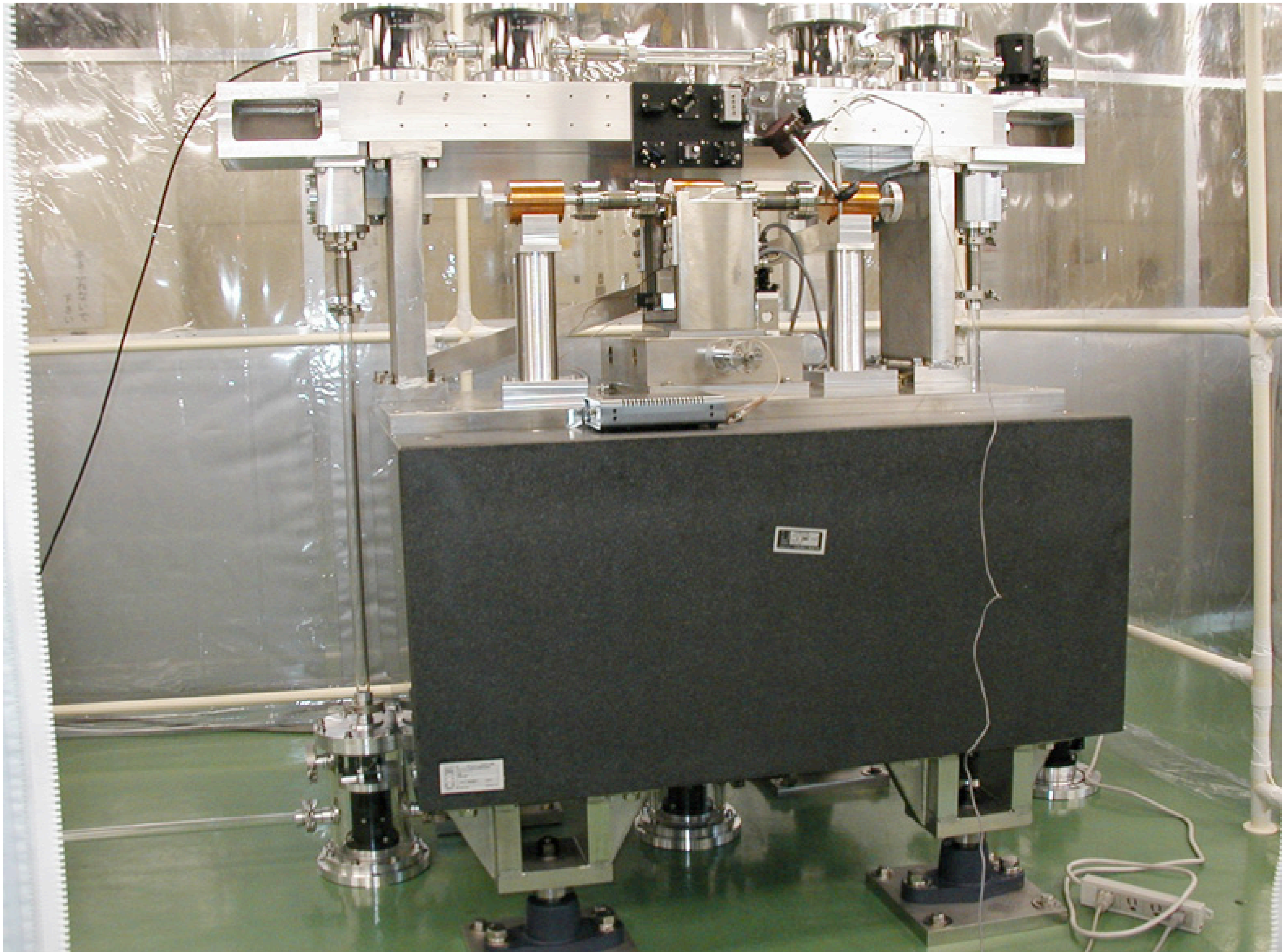
$dP2 = L \sin\theta + dy$

$\sin\theta = (dP1 - dp2)/L$

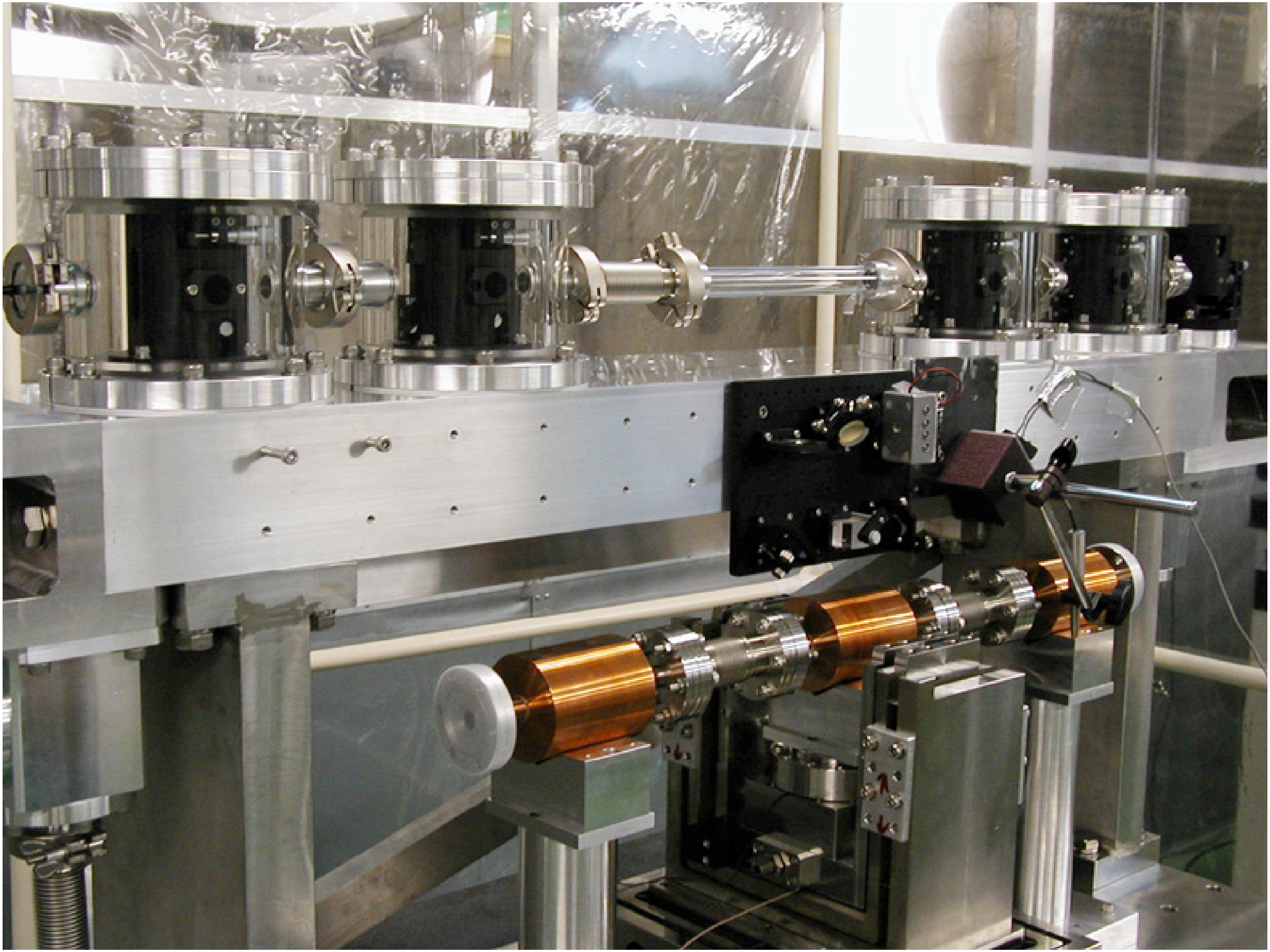
$dy = dP1 + L \sin\theta$

Overview of the Nano-BPMs system

Elevation View



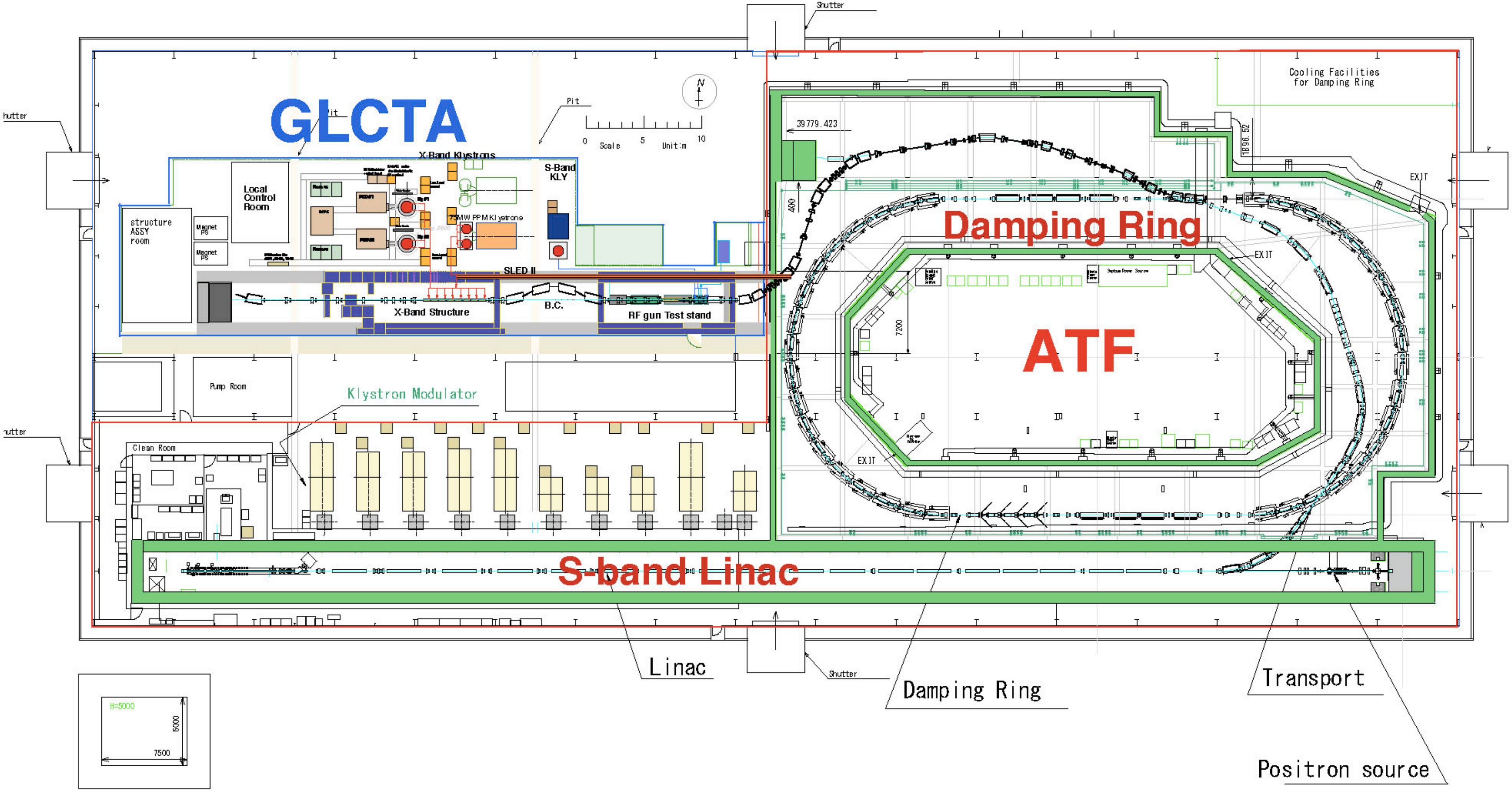
Reference Bar

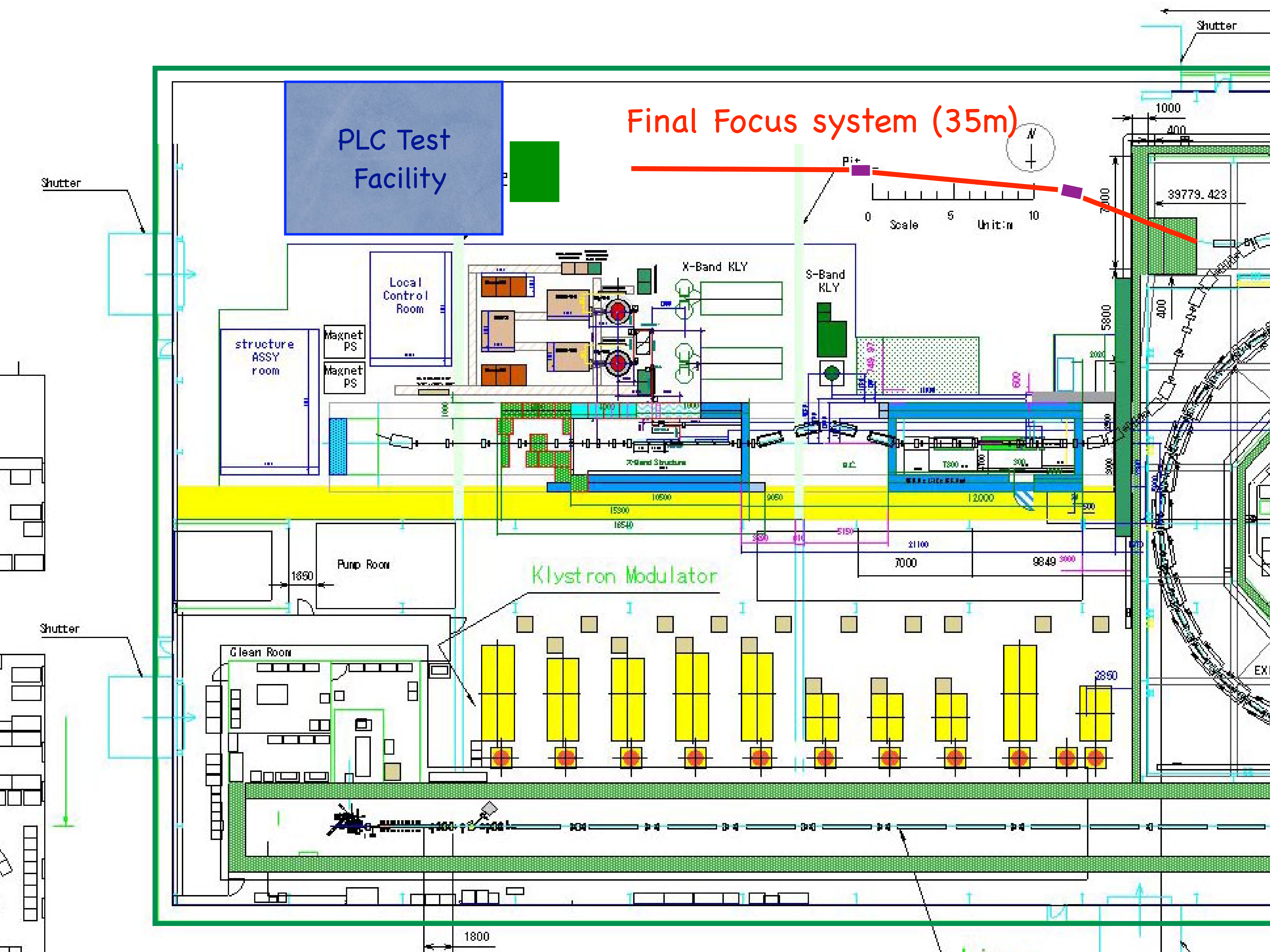


year	mon.	ATF	GLCTA	Fast Feedback Loop	Nano BPM project	
				FONT/FEATHER	SLAC/LLNL	KEK
2004	6			jitter meas./feedback test	beam test	one cavityBPM
	7	ext. kicker and septum;multipole, power supply		update the kicker and electronics		installation of KEK system
	8					
	9					
	10	multi-bunch emittance,wiggler ,stable extraction and multi-train extraction		/feedback test	start to construct metrological frame	
	11			3 BPMs with superfast BPM electronics/feedback test		
	12					
	1					

2005	1					
	2			/feedback test	installation of the frame	
	3			1st feedback test		
	4					
	5					
	6			2nd feedback test		
	7	new extraction kicker ?	concrete shield extension		installatio of optical anchor	
	8					
	9					
	10			feedback with multi-train	nano BPM test with two systems	
	11					
	12					

2006	1		beam line in GLCTA tunnel			
	2			Two Nano BPM systems with FONT/FEATHER		
	3					
	4					
	5					
	6					
	7		beam line in ATF			
	8					
	9					
	10					
	11					
	12					


GLCTA
Damping Ring
ATF
S-band Linac
Shutter
Pit
Scale
0
5
10
Unit:m
N
X-Band Klystrons
S-Band
KLY
Local
Control
Room
structure
ASSY
room
Magnet
PS
75MW PPM Klystrone
SLED II
X-Band Structure
B.C.
RF gun Test stand
Pump Room
Klystron Modulator
Clean Room
Cooling Facilities
for Damping Ring
39779.423
18896.52
400
7200
EXIT
H=5000
5000
7500
Linac
Damping Ring
Transport
Positron source


Final Focus system (35m)
PLC Test Facility
Shutter
Local Control Room
structure ASSY room
Magnet PS
Magnet PS
X-Band KLY
S-Band KLY
Scale
Unit:m
Pump Room
Klystron Modulator
Clean Room
39779.423
1000
400
1850
1800