# ATF2 Cavity BPMs

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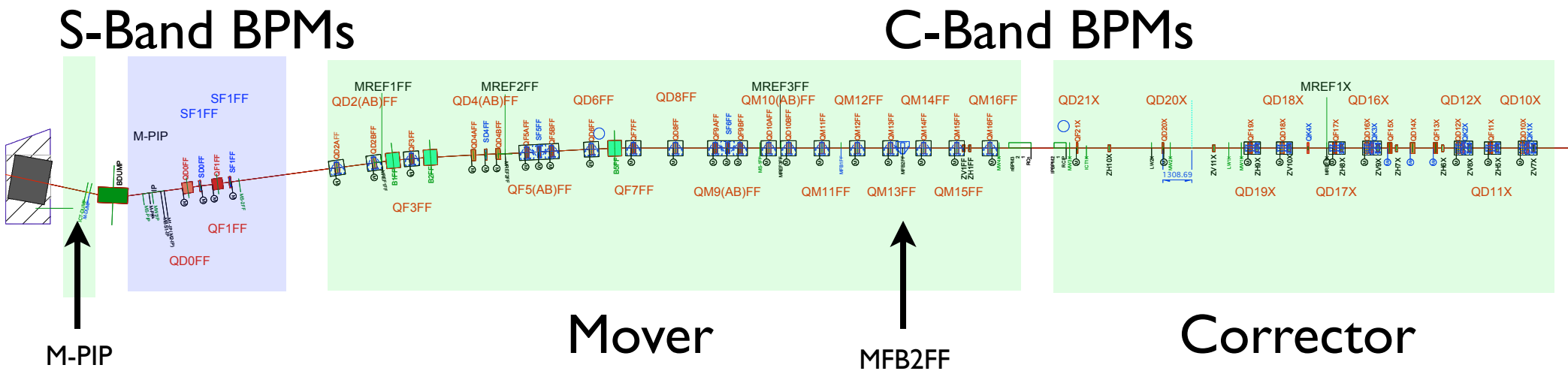
SLAC, KNU, PAL, KEK, JAI-RHUL, UCL
KEK, ATF
https://www.pp.rhul.ac.uk/twiki/bin/view/JAI/BeamPosition

# Introduction

- Progress since last major report
  - Stable operation with C-band BPMs
  - Improved insensitivity to timing problems
    - C-Band and S-Band diode timing references
  - Improved amplitude extrapolation
    - Should be able to reconstruct large offsets
- Software improvements too numerous to list (all plots are online plots)
  - S-band still has some phase (but not amplitude problems)
- Full calibrate entire system, mover, non-mover, C and S band in approximately 4 hours.
  - C-band calibration stable for ~ 3 days (see White's talk)

# ATF2 BPM layout

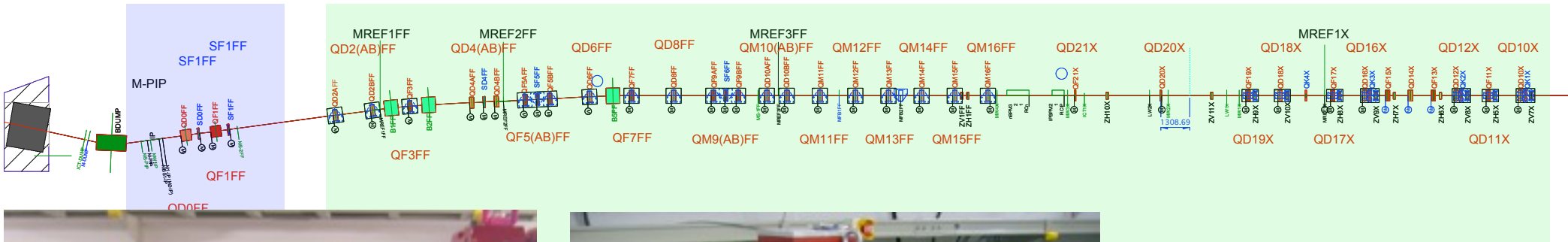


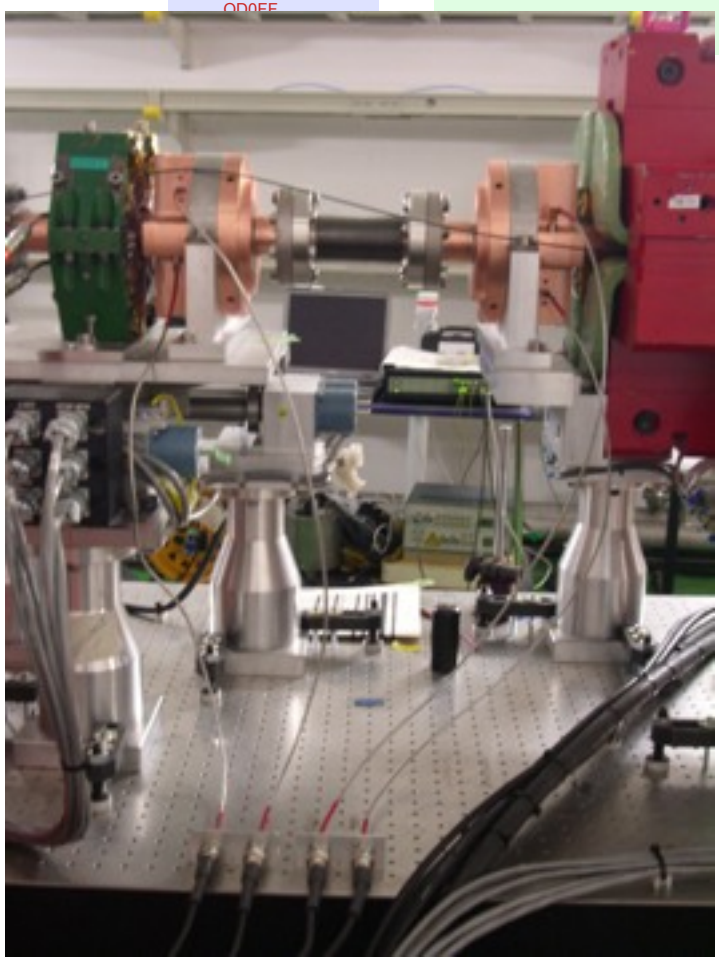

- S-band : 4 (dipole) +1 (ref)
  - Variable attenuation and gain, unlocked local oscillator
- C-band : 33 (dipole) + 4 (ref)
  - Locked LO system
  - Attenuation : 20 db in all channels (1 removed for tests)
  - 10 corrector calibrated
  - 23 mover calibrated

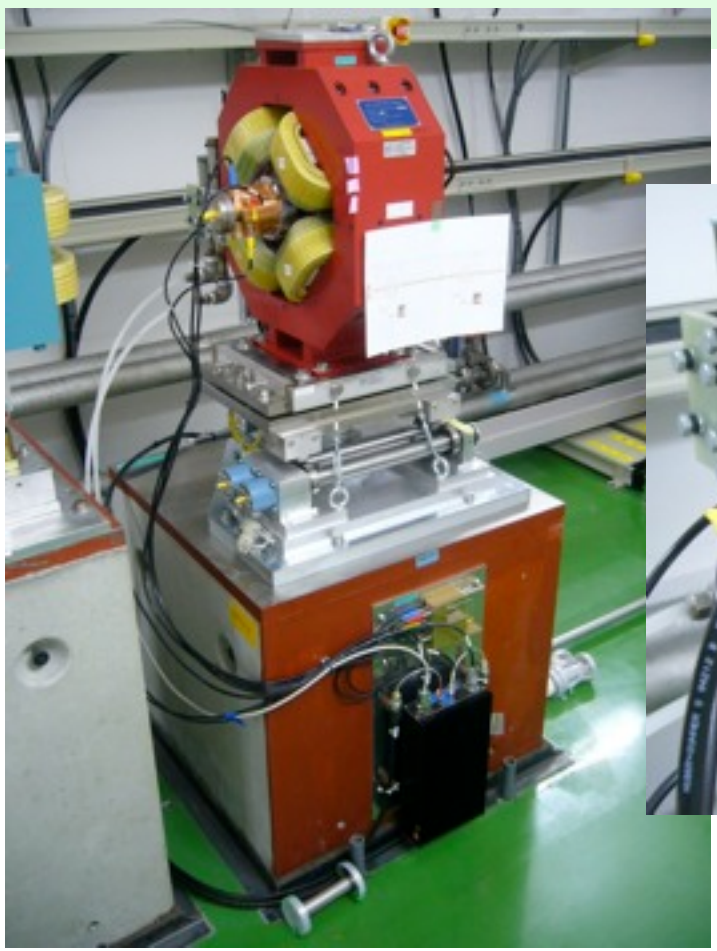
# ATF2 BPM layout

## S-Band BPMs

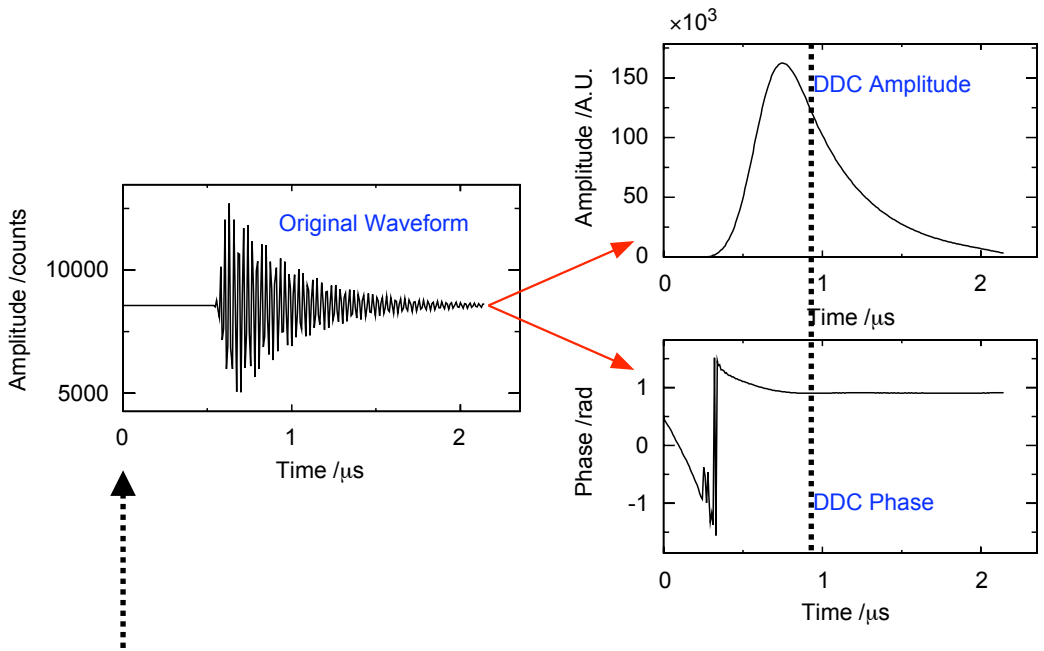
## C-Band BPMs





# Digital processing algorithm (DDC)




Trigger start

Extract phase and amplitude at some specific time

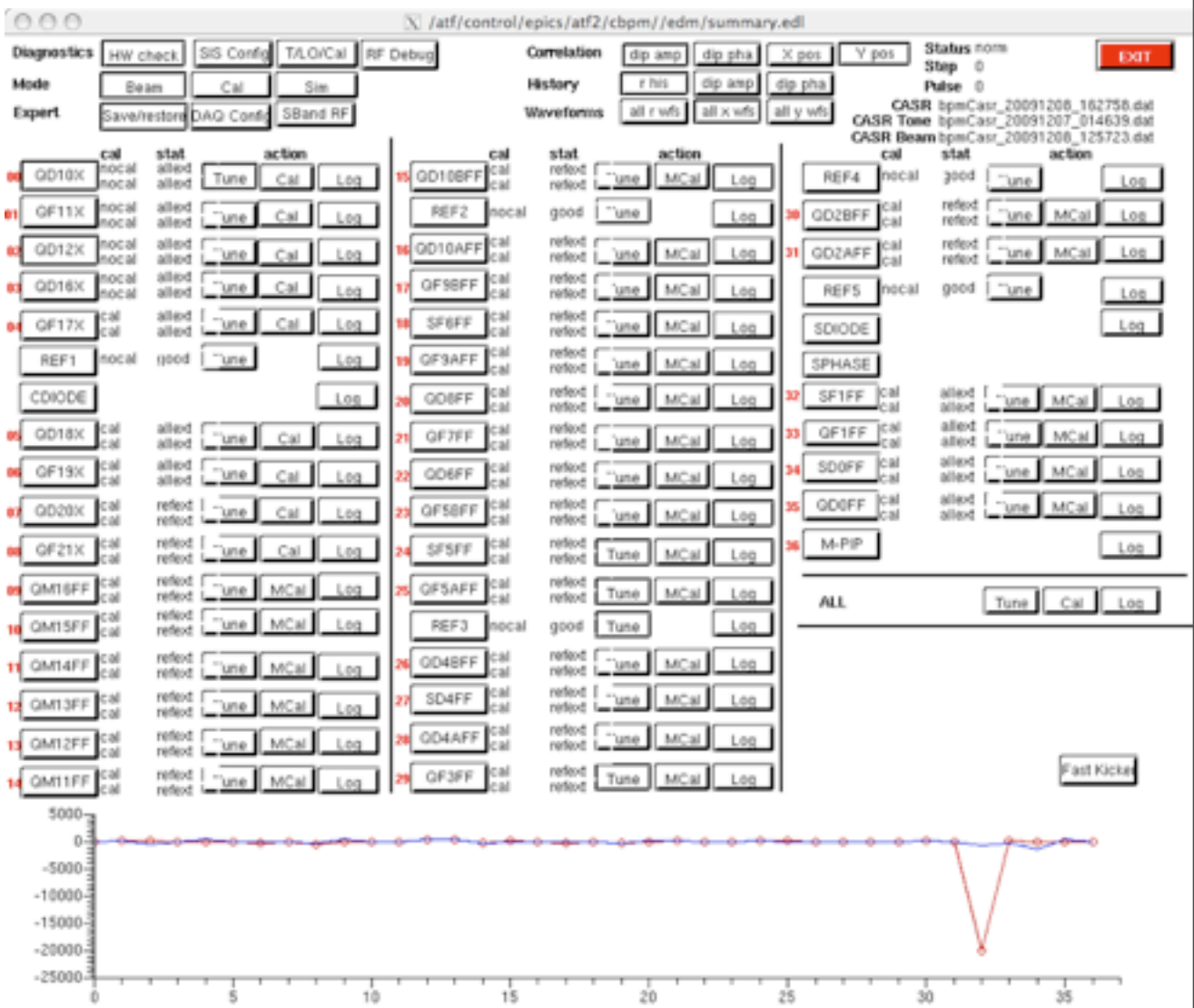
$$I = \frac{A_d}{A_r}\cos\left(\phi_d - \phi_r\right)$$

$$Q = \frac{A_d}{A_r}\sin\left(\phi_d - \phi_r\right)$$

- I and Q depend on
  - start trigger
  - beam arrival
  - DDC sample point
- E.g. change in trigger start, beam arrival or saturation levels causes change in I and Q and hence calibration
  - Compensate for changes in code

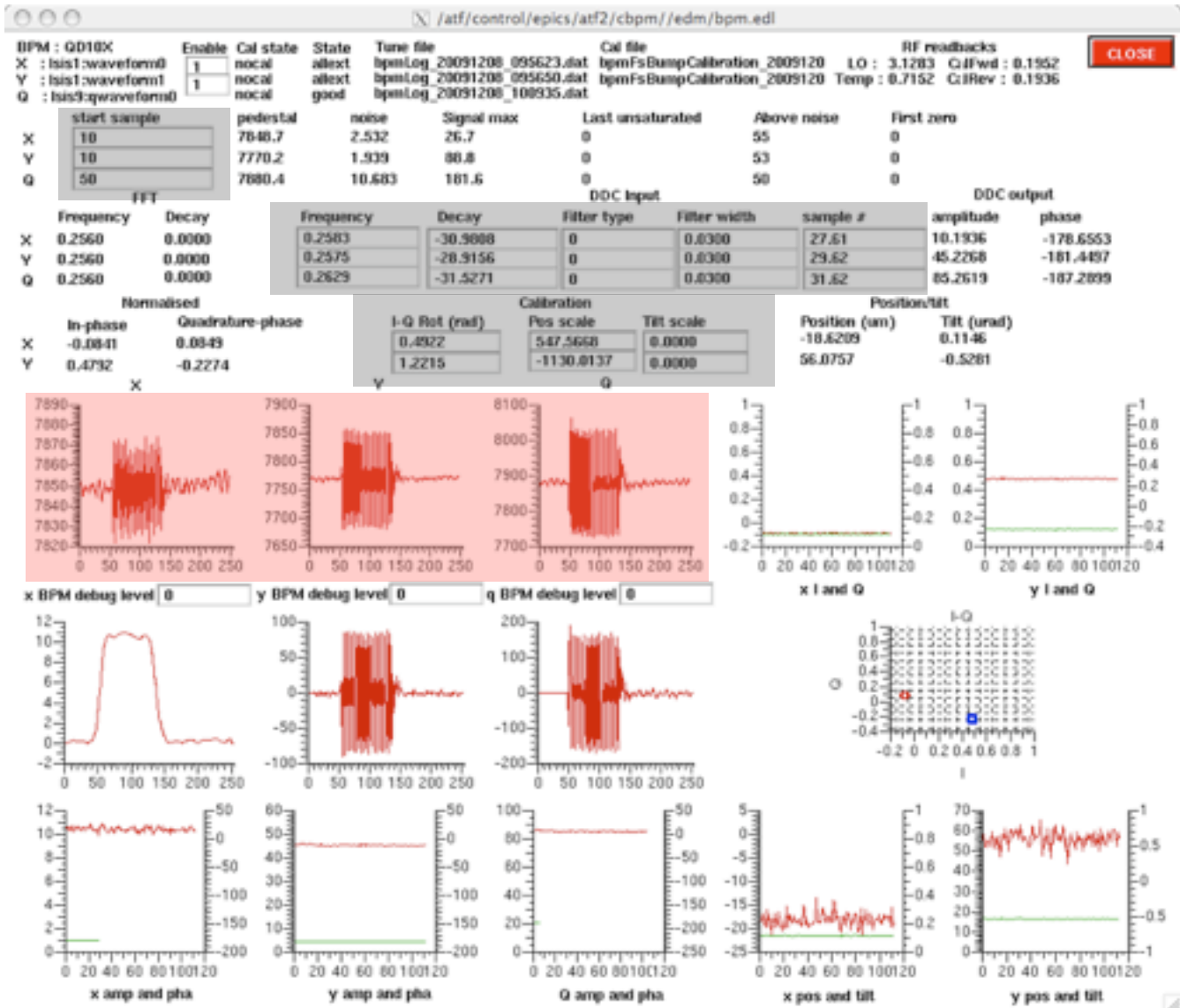
# Software system

- Key element for cavity BPM usage
  - Quick control of all BPM functionality and operating algorithms
  - EPICS based + EDM + python + scipy + matplotlib + catools + ...
- Complete control of entire system
- Easy to integrate new tests
  - IP-BPM electronics + tilt monitor

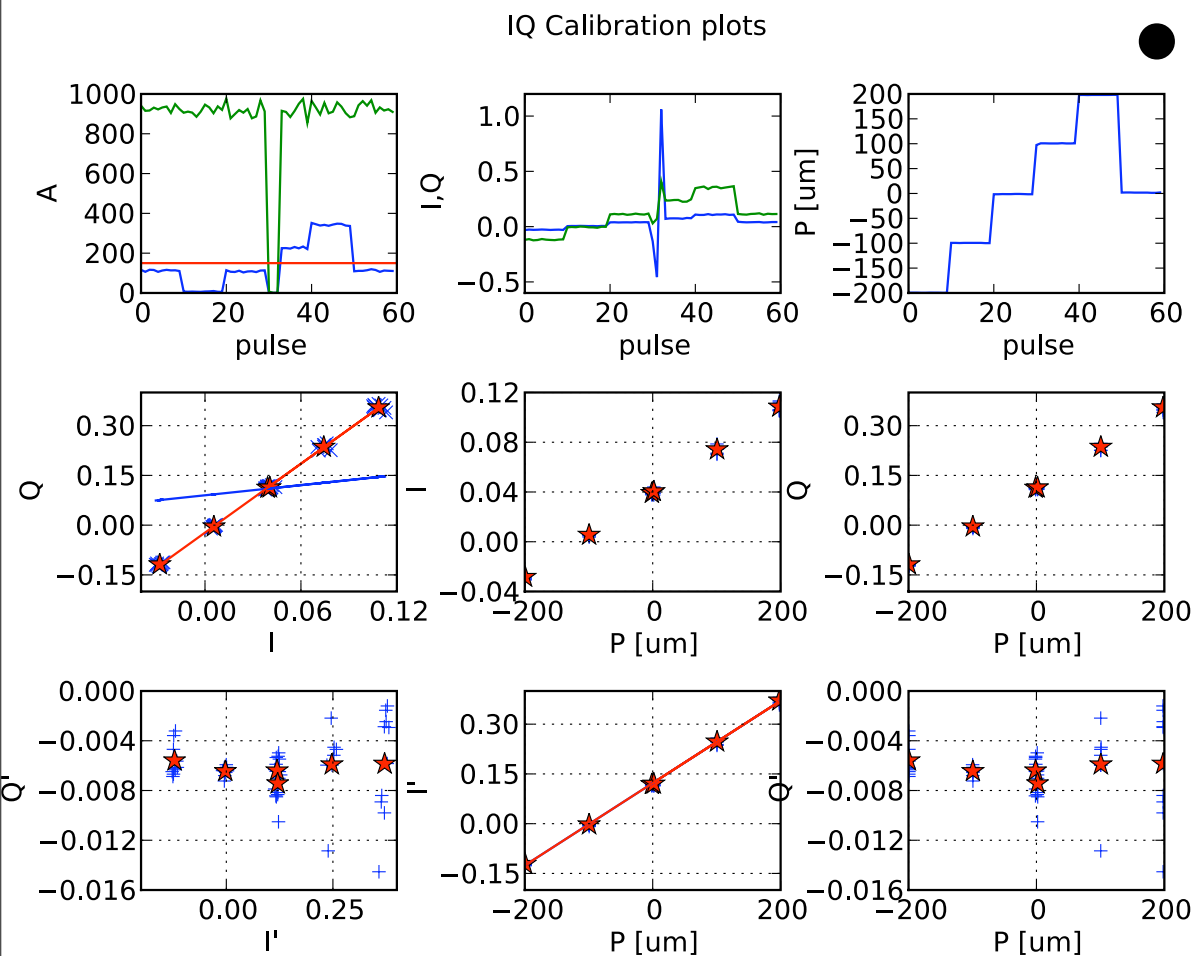


# Software system

- Raw data from digitizers
- Determine parameters for BPM
  - Frequency, decay time, sample time
- Displays algorithm state, input parameters, output etc



# Calibration




Every pulse : Blue points
Average at location : Red stars

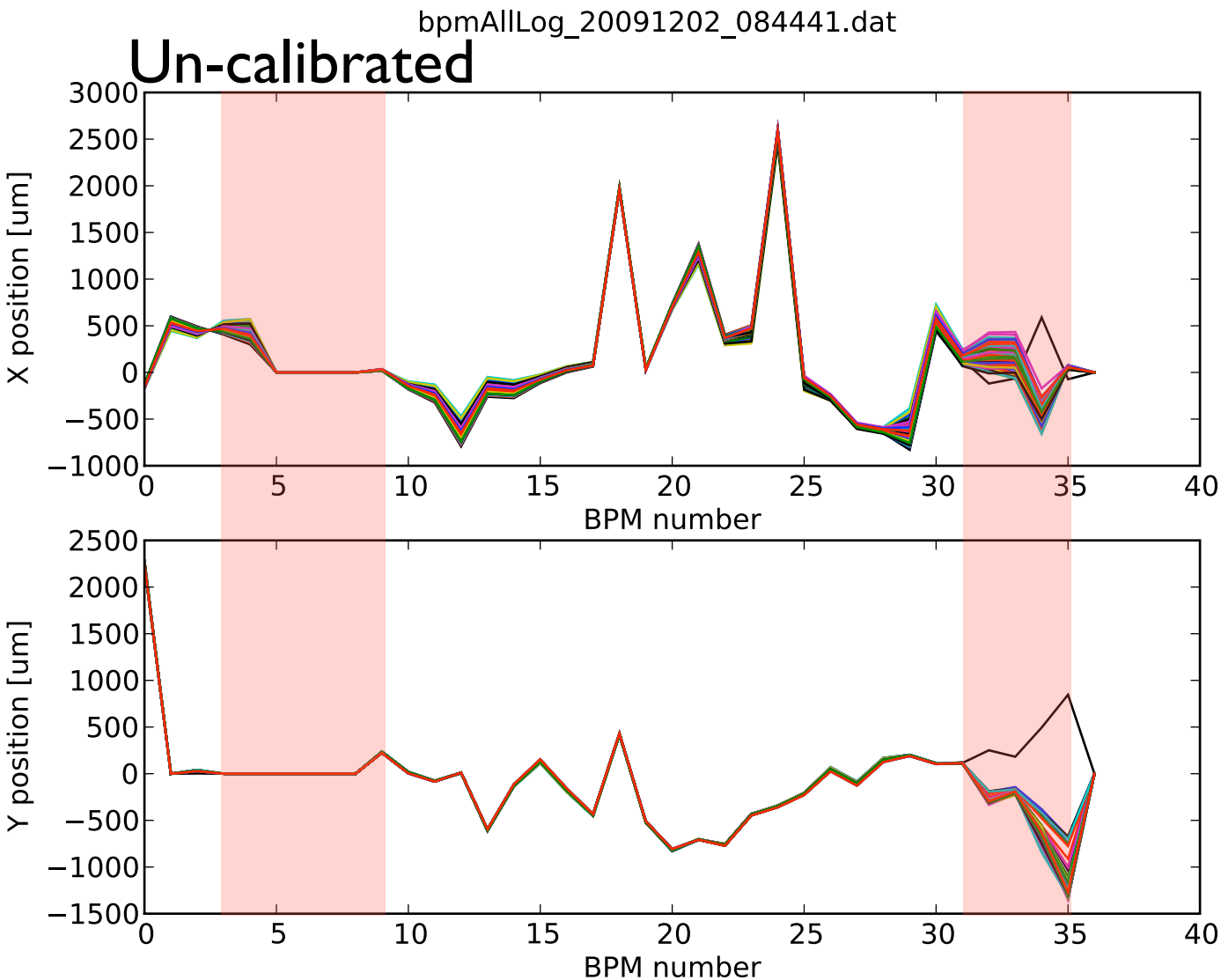
- Calibration method
  - Move BPM typically +- 200 um
  - Record I-Q
  - Determine I-Q rotation such that all variation is in rotated-I

$$I' = I\cos\theta_{IQ} + Q\sin\theta_{IQ}$$
$$Q' = -I\sin\theta_{IQ} + Q\cos\theta_{IQ}$$

- Scale

$$x = S_x I'$$

# Charge dependance



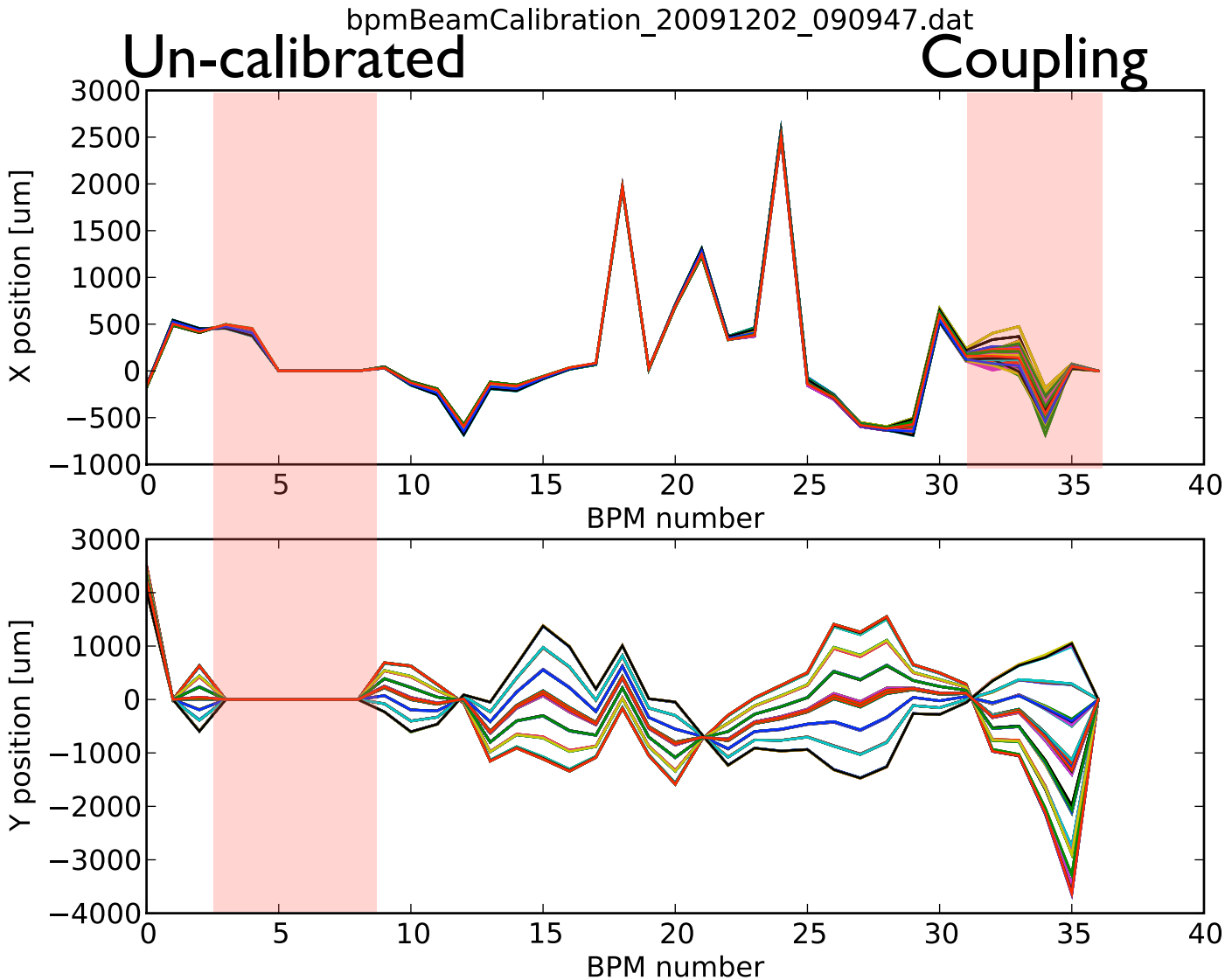

Horizontal orbit jittery due to dispersion

S-band BPMs more noisy

- Similar orbit for charge between 0.1 to $0.5 \times 10^{10}$

# Linearity at large offset

Vertical corrector scan ZV7X



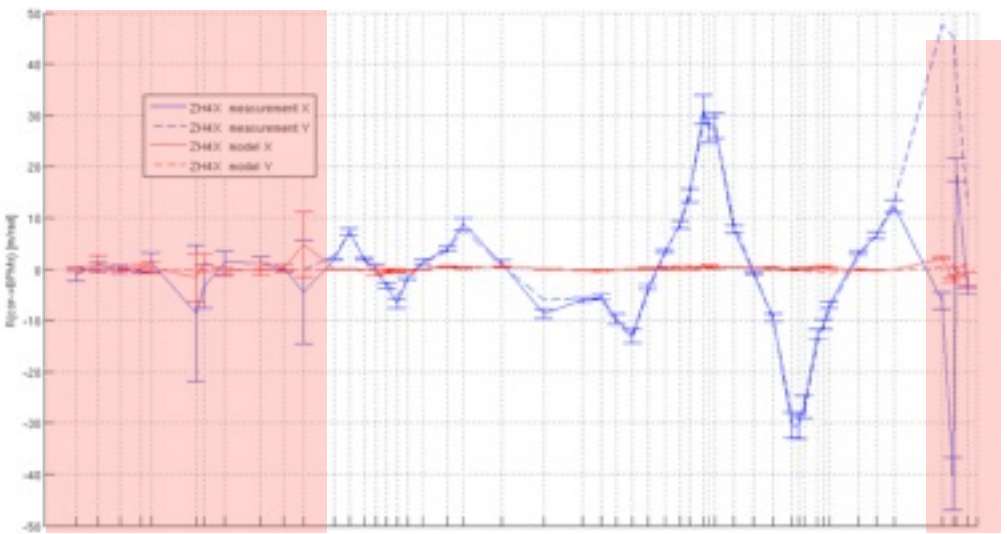

- Good linear dependance!

# C-band calibration

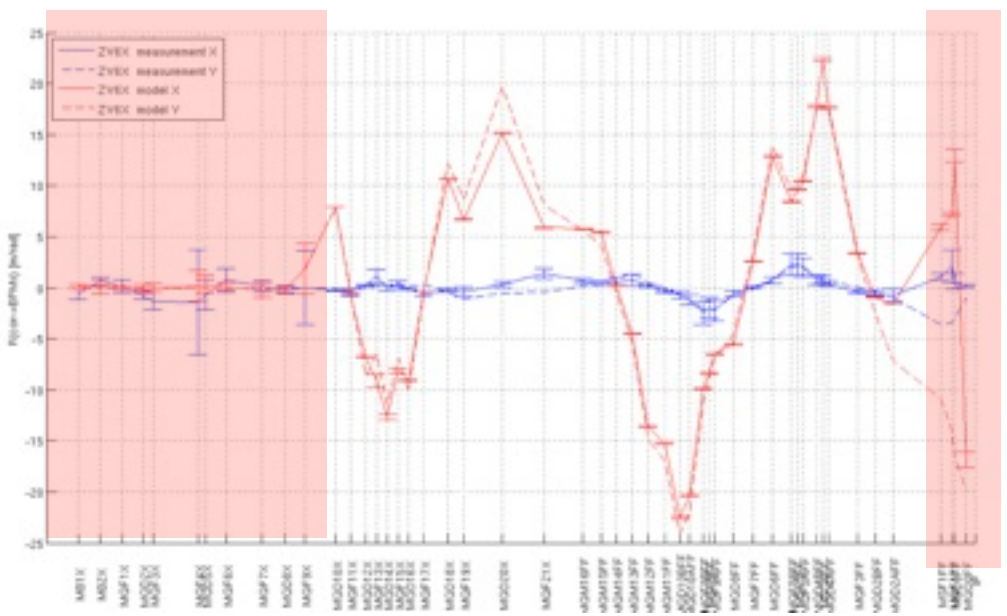
| | | 08/12/2009 AM | | 09/12/2009 AM | |
|---|---|---|---|---|---|
| | | θ | S | θ | S |
| QM13FF | x | -0.4429 | 730.6016 | -0.4344 | 766.3729 |
| | y | -0.5583 | 572.9346 | -0.55217 | 538.1593 |
| QM11FF | x | -1.0601 | 723.4036 | -1.07427 | 733.3487 |
| | y | -1.0132 | 590.5859 | -1.01145 | 571.2461 |
| QD10AFF | x | -1.1935 | -599.1746 | -1.19559 | -579.5771 |
| | y | -0.5458 | 732.6153 | -0.5535 | 747.6142 |
| QF7FF | x | -1.1745 | -649.7678 | -1.17508 | -764.88304 |
| | y | 0.1271 | 637.3934 | 0.11279 | 633.4649 |
| SF5FF | x | -0.1483 | -733.4521 | -0.20396 | -721.3833 |
| | y | 0.2932 | -616.1576 | 0.29688 | -613.8675 |
| SD4FF | x | 0.2479 | 634.7448 | 0.24642 | 737.3457 |
| | y | -0.3946 | -669.6132 | -0.38895 | -672.46778 |
| QD2BFF | x | 0.6555 | -514.9741 | 0.6606 | -496.1783 |
| | y | 0.5636 | -615.7744 | 0.5793 | -594.6615 |

- Excellent calibration for most of operation week
- Phase shifts 0.01 or less at C-band
- Amplitude variation of order 5 to 10 %
- Need calibration tone to correct final scale problems

# BPM system performance

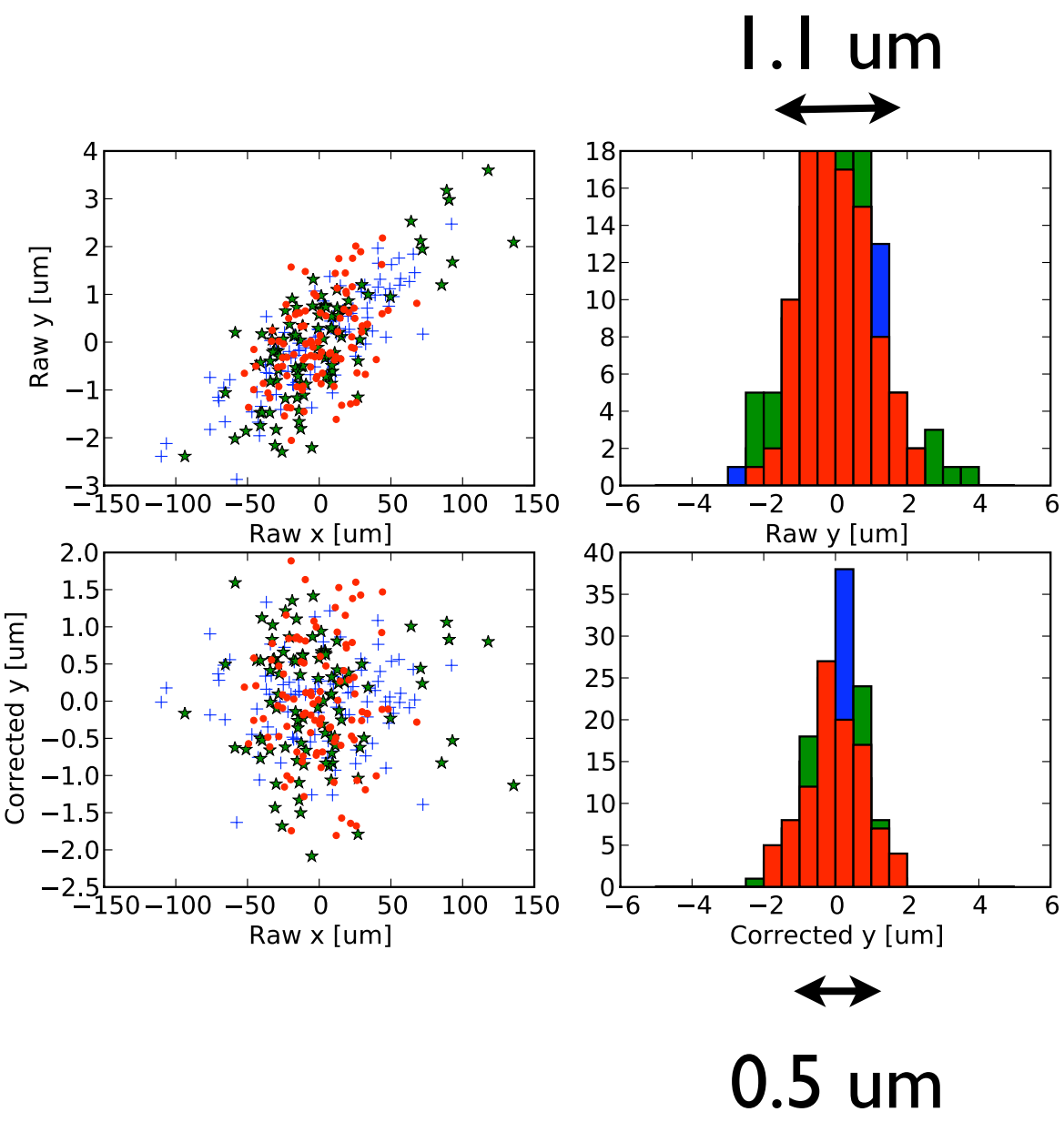


SL CB SB



- Kick beam using correctors
  - ZH4X
  - ZH6X
- Compare
  - Optics model (R matrices)
  - Orbit response with BPM measurements normalised by kick strength

# Best resolution (MFB2FF)




- Sub-micron "resolution" confirmed
  - MFB2FF at waist, so beam jitter low
  - BPM rolled
  - Beam size ~3 um
  - RMS ~ 0.5 um
  - Includes beam drift and jitter
  - Will correct for this effect this evening (see later)

# S-band phase problem

| BPM | | 08/12/2009 AM | | 09/12/2009 AM | |
|---|---|---|---|---|---|
| | | θ | S | θ | S |
| SF1FF | x | -0.7064 | 2337.6932 | -1.297 | 1370.8098 |
| | y | 0.1932 | 5573.9676 | -0.3856 | 5606.9855 |
| QF1FF | x | 0.0656 | -4206.818 | -0.5275 | -6115.9601 |
| | y | -1.4801 | 3038.1829 | 1.0234 | -3038.7735 |
| SD0FF | x | 0.9269 | 3593.66 | -0.6671 | 3922.61 |
| | y | -0.213 | 62200 | -0.807 | 57386.7 |
| QD0FF | x | 0.3181 | -1862.4049 | -0.3421 | -1891.254 |
| | y | -1.3504 | -6065.5702 | 1.10605 | 5687.257 |

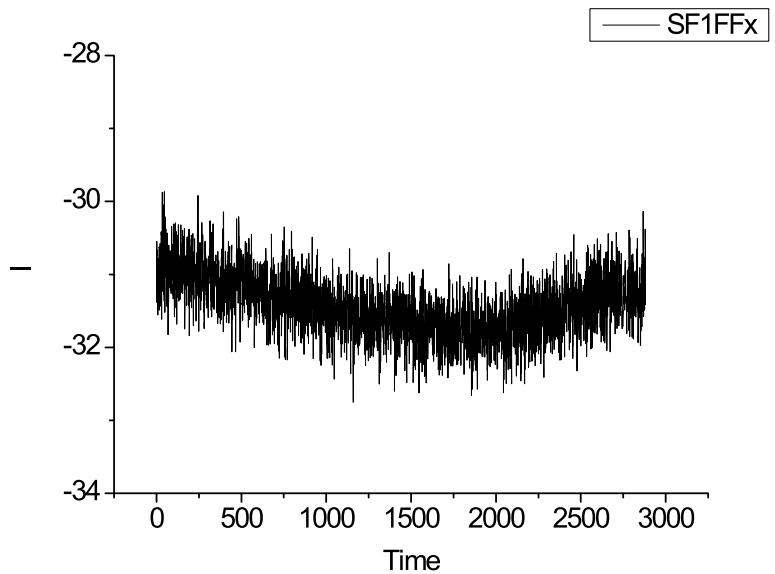
- S-Band BPMs have not had as much attention
  - BPM crew has been joined by two student from Kyungpook National University (Aeyoung Heo, Youngim Kim)
  - Plus Professor HyangKyu Park
  - Calibration, stability and performance study of S-band system

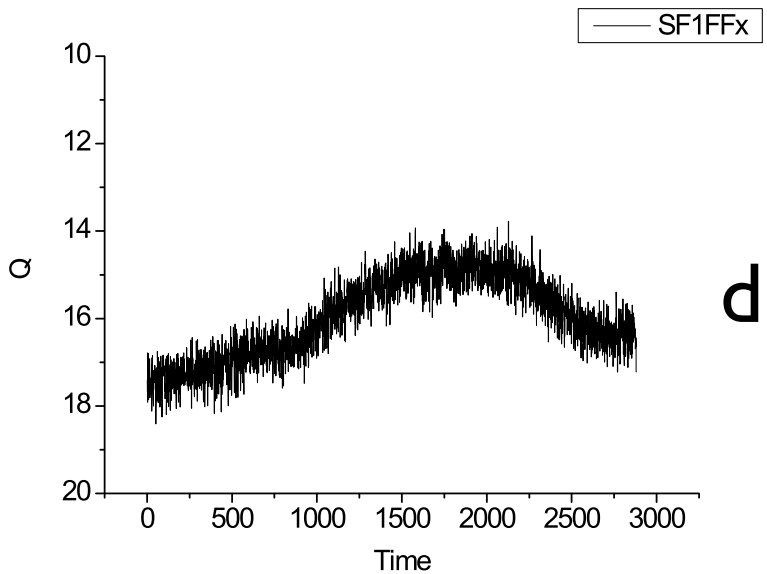
# S-band phase problem

| BPM | Amplitude (beam) | Phase (beam, rad) | Amplitude (cal) | Phase (cal, rad) |
|---|---|---|---|---|
| SF1FF x | 0.322 | 0.292 | 0.296 | 0.010 |
| SF1FF y | 0.023 | 0.356 | 0.154 | 0.010 |
| QF1FF x | 0.014 | 0.209 | 0.275 | 0.010 |
| QF1FF y | 0.002 | 0.153 | 0.218 | 0.010 |
| SD0FF x | 0.125 | 0.562 | 0.240 | 0.014 |
| SD0FF y | 0.006 | 0.366 | 0.244 | 0.010 |
| QD0FF x | 0.023 | 0.773 | 0.240 | 0.010 |
| QD0FF y | 0.117 | 0.373 | 0.244 | 0.010 |

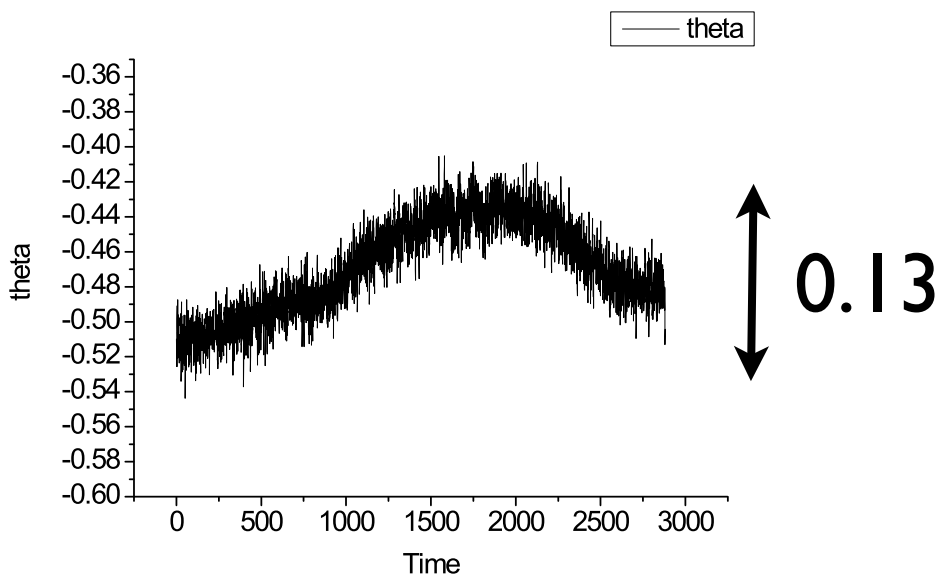
- Beam (05/12/09 1:30 am)
- Calibration tone (05/12/09 2:00 am)
  - Inject directly to electronics in Eel's bedroom

# S-band phase problem




Thermal drift (period ~24H)

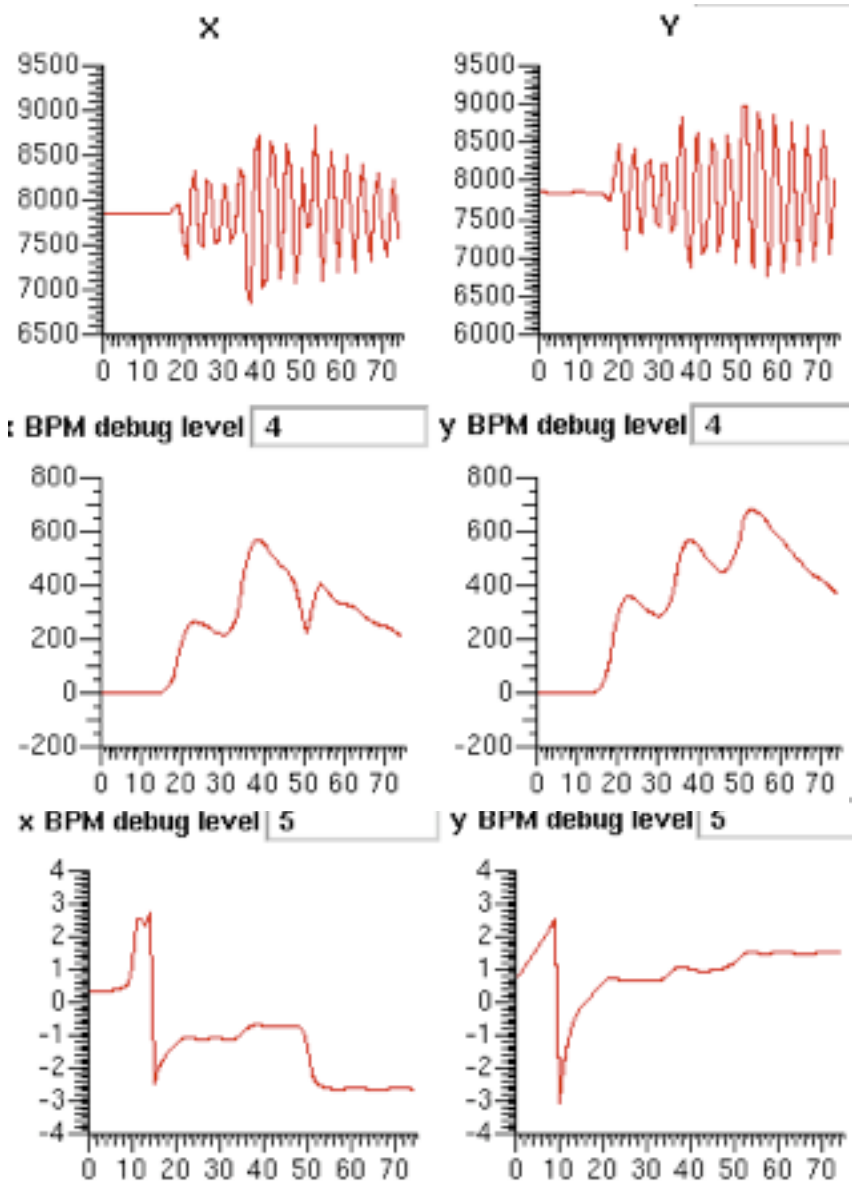



0.13

- Carefully checked one S-band BPM
  - Calibration source in tunnel
  - Maximum variation

# Multi train mode

## 151 ns bunch separation

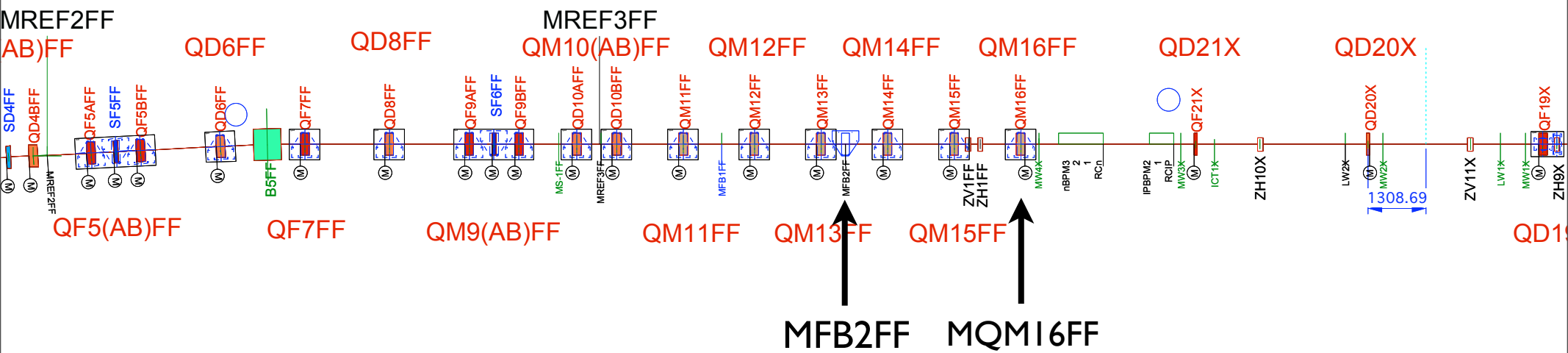



- Preparation for new extraction scheme
  - Modify trigger time by -200 ns
  - Change digital filter parameters
  - DDC filter 3 MHz to 10 MHz
  - Clear amplitude and phase changes
  - Possible to extract postion

# Required upgrades

- Calibration tone (rather low signal)
  - Software needs lots of work
- BBA stability
  - Connection between optics and BBA corrected postions done
- Commission M-PIP (must be connected)
  - IP-BSM orbit)
- S-band system
  - RF phase instability
  - Cable routing, signal size

# Proper resolution studies




- This remove 20 dB attenuators from MQM16FF
  - QM16FF off in nominal optics
  - Compare MQM16FF with MFB2FF
  - MFB2FF is instrumented with Zygo interferometer to measure relative displacement

# Summary

- C-band system looks excellent
  - Easy to calibrate and use
  - Stable within 5% (calibration tone)
- S-band still has a little way to go, but progress is being made
  - Need to improve S-band cable plant
  - Possible software problem for S-band calculations
  - Cables + electronics seem good
  - Problems will be resolved this week
- High resolution mode being tested now (no attn)
- 300 ns separation readout possible (resolution?)