C/S/IP-band cavity BPMs

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SLAC, KNU, PAL, KEK, JAI-RHUL, KEK, ATF

https://www.pp.rhul.ac.uk/twiki/bin/view/JAI/BeamPosition

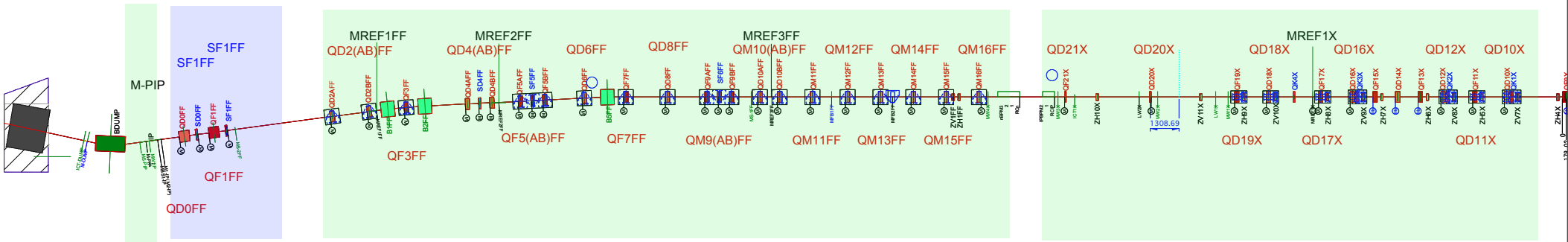
ATF2 Project meeting, SLAC 14th January 2011

Introduction

- ATF2 BPM systems
  - Progress with S-band system
  - Started with IP region
- Calibration tone system
- Systematic effects
  - Calibration stability
  - Beam jitter
  - Quadrupole strengths
  - Passive monitoring of RF stability
- Upgraded LO system
  - IP region
  - Extraction line
- Advanced topics
  - Multi-bunch analysis (Nirav Joshi)
  - Passive BPM monitoring (Frankie Cullinan)
- IP region BPMs (YI Kim)

ATF2 BPM systems

S-Band BPMs C-Band BPMs



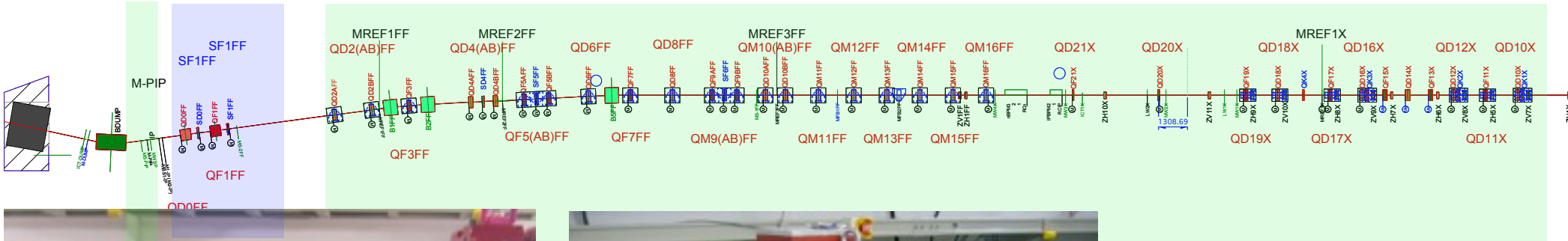
IP BPMs Mover Corrector

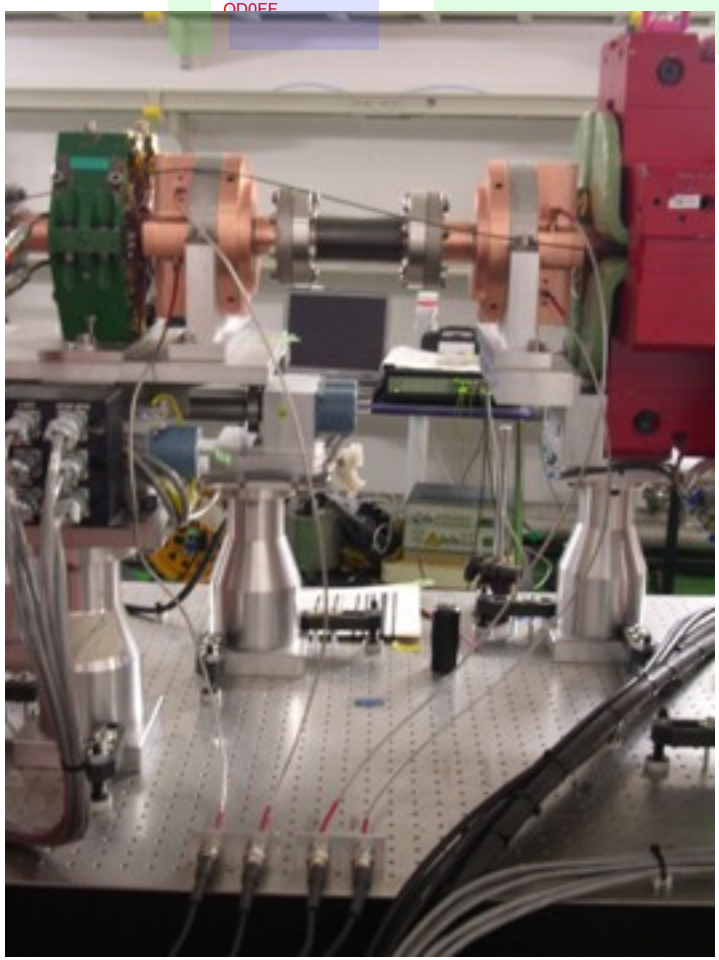
- 41 BPMs in total now
  - 2 IP BPMs, PREIP, M-PIP
  - S-Band BPMs stable without DR RF Δf ramp (see later)
- Diode on first C-band reference
  - Other 3 references not used

ATF2 BPM layout

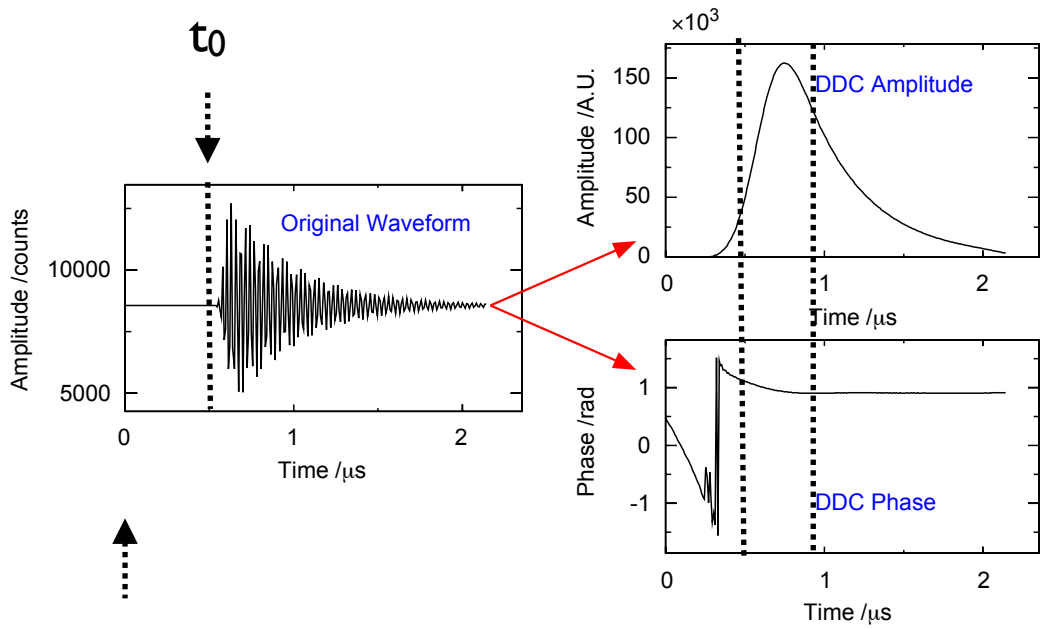
S-Band BPMs

C-Band BPMs





Digital processing algorithm (DDC)



Trigger start

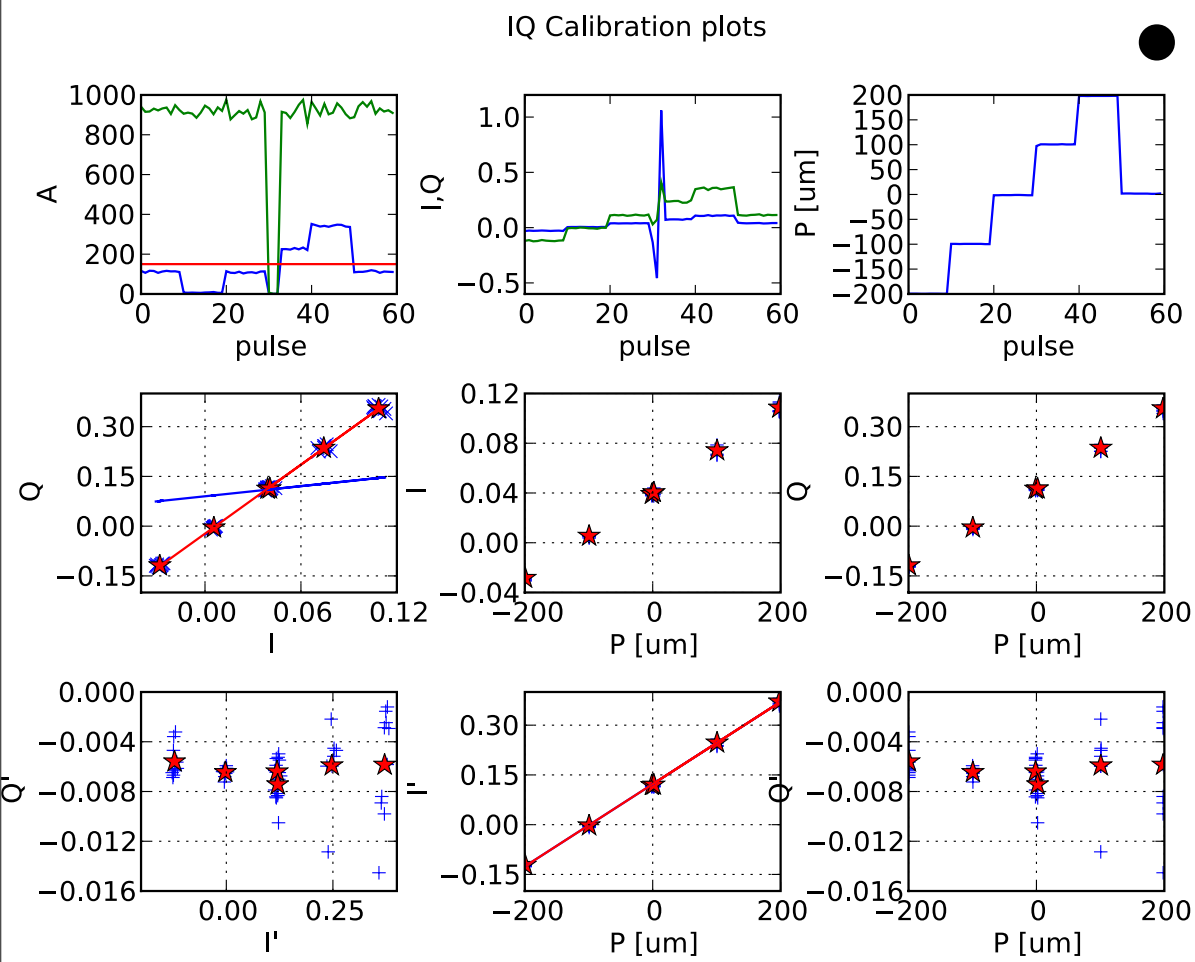
Extract phase and amplitude at some specific time (t_s)

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

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

- 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

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

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

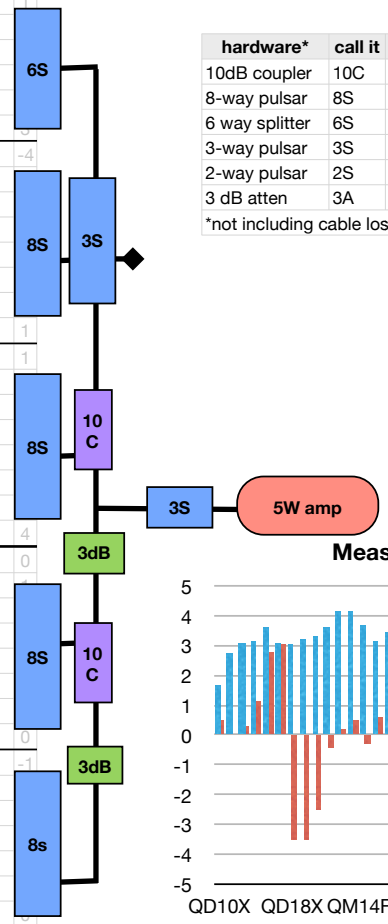
- Scale

$$x = S_x I'$$

Hardware improvements

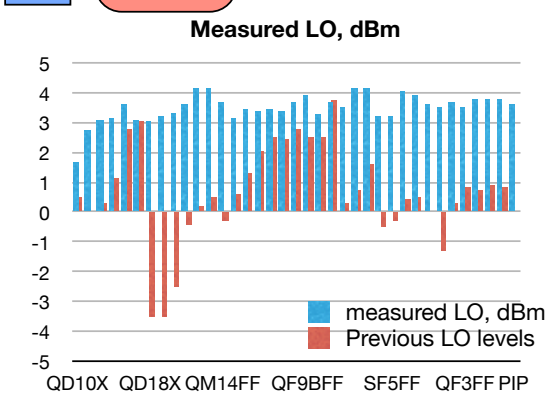
T. Smith

	est losses from hardware*	added atten at box	measured LO, dBm	
QD10X	17.85	0	1.65	1
QF11X	17.85	0	2.71	
QD12X	17.85	0	3.08	
QD16X	17.85	1	3.12	
QF17X	17.85	2	3.62	
REF1X	17.85	3	3.07	0
QD18X	19.15	2	3.02	-4
QF19X	19.15	2	3.21	
QD20X	19.15	3	3.33	
QD21x	19.15	5	3.62	
QM16FF	19.15	6	4.15	
QM15FF	19.15	6	4.17	
QM14FF	19.15	6	3.67	
QM13FF	19.15	6	3.16	1
QM12FF	24	4	3.42	1
QM11FF	24	5	3.37	
QD10BFF	24	5	3.44	
REF3FF	24	5	3.37	
QD10AFF	24	5	3.66	
QF9BFF	24	5	3.9	
SF6FF	24	6	3.24	
QF9AFF	24	6	3.69	4
QD8FF	27	0	3.48	0
QF7FF	27	0	4.12	
QD6FF	27	1	4.13	
QF5BFF	27	0	3.18	
SF5FF	27	0	3.2	
QF5AFF	27	0	4.01	
REF2FF	27	0	3.9	
QD4BFF	27	0	3.59	0
SD4FF	19.75	2	3.5	-1
QD4AFF	19.75	1	3.67	
QF3FF	19.75	4	3.52	
REF1FF	19.75	4	3.79	
QD2BFF	19.75	4	3.81	
QD2AFF	19.75	4	3.8	
PIP	19.75	0	3.62	0



hardware*	call it	IL + split
10dB coupler	10C	10.25
8-way pulsar	8S	10.5
6 way splitter	6S	9.2
3-way pulsar	3S	5.4
2-way pulsar	2S	3.25
3 dB atten	3A	3

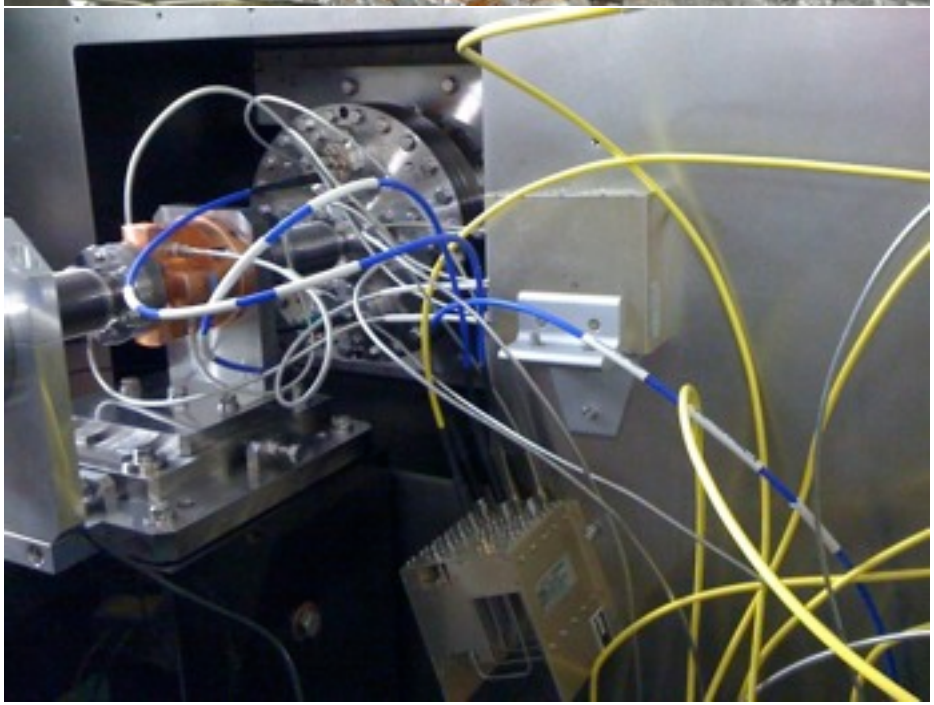
*not including cable losses



- LO system was uneven
  - BPM resolution was dependent on input LO RF power
- Each box now driven by much closer to +3 dBm

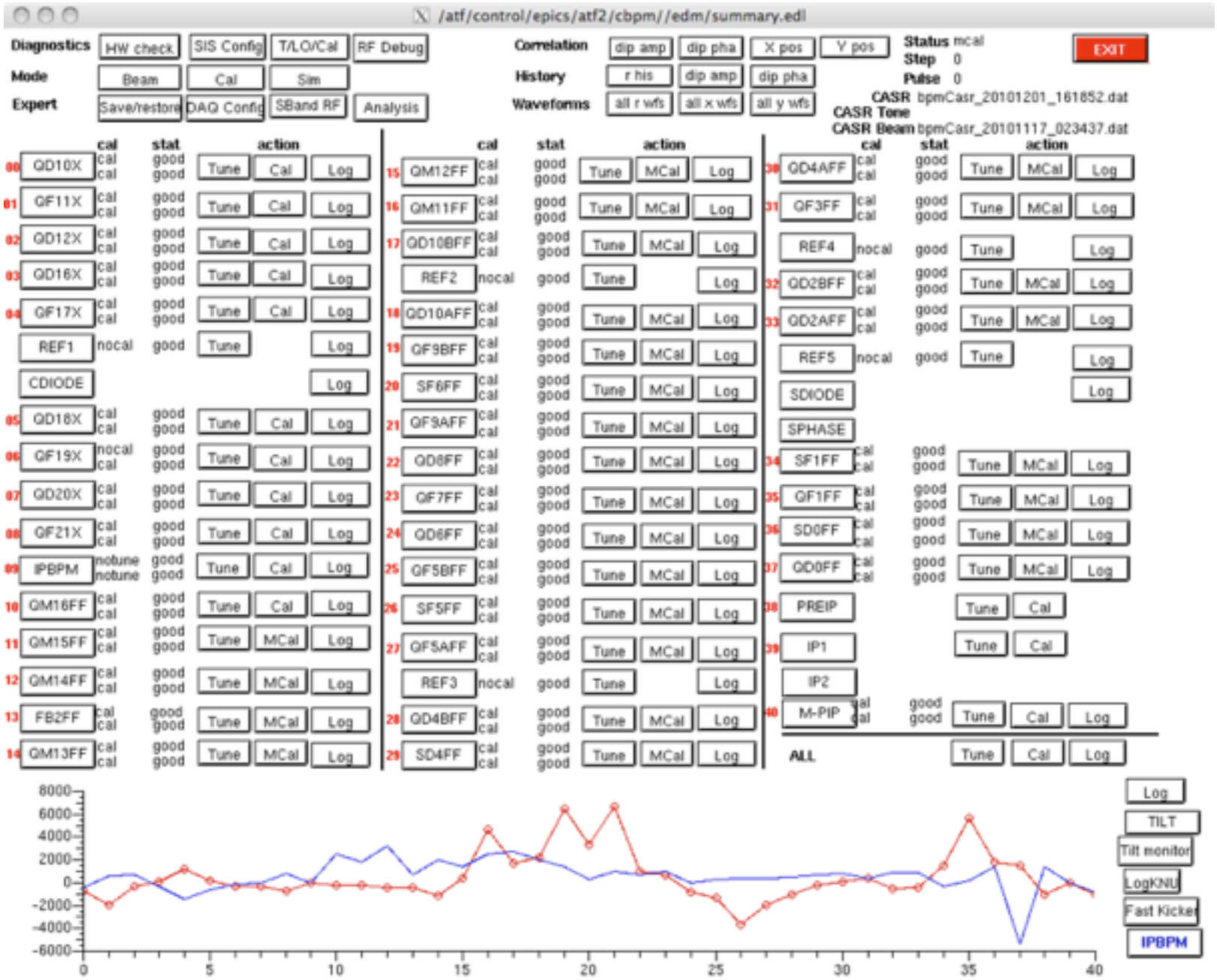
IP region BPM installation

T. Smith/YI Kim



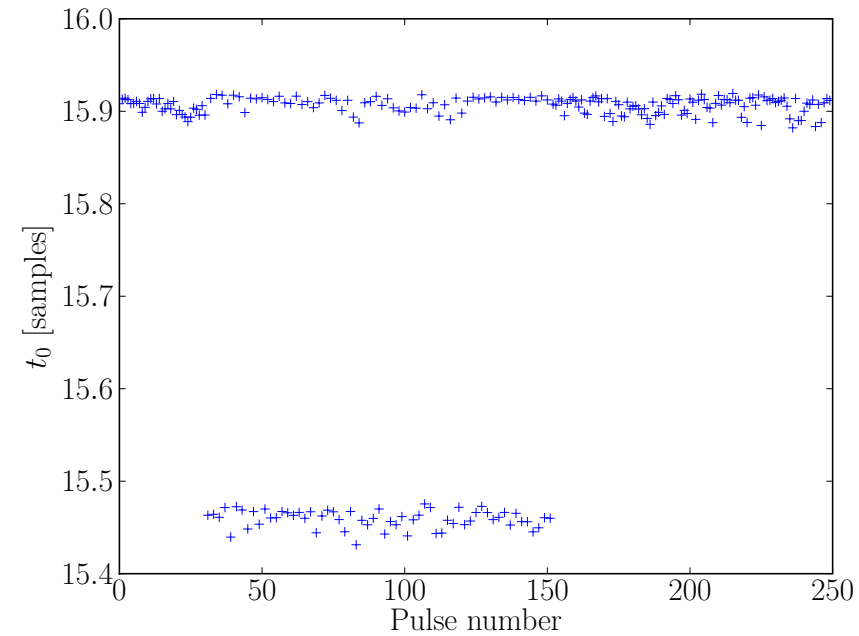
- Honda-san installed
  - 2 BPM, IPBPM block
- T. Smith installed
  - Mixdown electronics
  - 5.7 GHz source for x
- Talk slides from YI Kim later

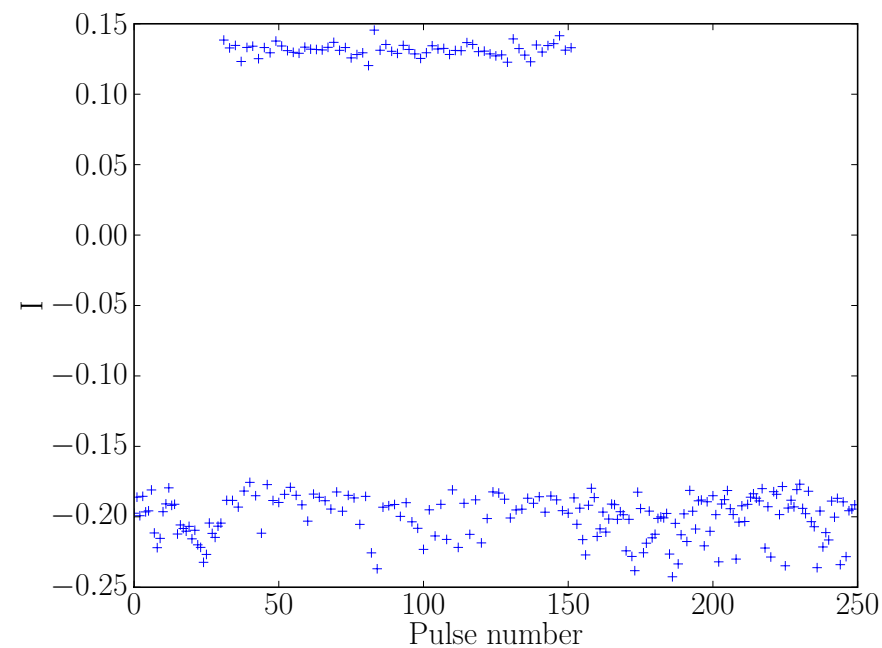
Full BPM system



S-band BPMs

- Last operation year
  - X-Y cross coupling -20 dB
- Cavities retuned over summer
  - X-Y cross coupling -40 dB
- Electronics have high stability
  - <1% and 1 degree @ S-band
- Only residual problem is when the DR RF Δf ramp
  - System develops multi (≥2) state instability
- See later





Calibration summary

F. Cullinan

S_x and S_y

Constants from calibration – Position scale

Date	30th November		9th December		% Difference	
Bpm	x	y	x	y	x	y
QF7FF	-1079.16	-920.60	-1114.29	-864.31	3.26	6.12
QD6FF	638.82	1232.23	1226.96	2044.38	92.07	65.91
QF5BFF	-563.35	892.04	-931.15	704.84	65.29	20.99
SF5FF	-1210.70	-914.82	-1428.11	-846.22	17.96	7.50
QF5AFF	-962.03	761.54	-921.47	767.12	4.22	0.73
QD4BFF	1212.31	791.72	871.75	833.71	28.09	5.30
SD4FF	-892.92	-881.22	-766.17	-972.00	14.20	10.30
QD4AFF	893.23	1043.73	756.17	922.45	15.34	11.62
QF3FF	1016.75	1271.86	1046.76	1096.57	2.95	13.78
QD2BFF	-819.97	-1013.89	-745.18	-1033.80	9.12	1.96
QD2AFF	945.95	982.21	979.98	976.45	3.60	0.59
SF1FF	1387.10	-4641.33	1991.18	3568.53	43.55	176.89
QF1FF	-6168.54	-2202.88	-2726.82	-1840.62	55.80	16.45
SD0FF	-2736.45	3039.16	-2728.85	-2074.11	0.28	168.25
QD0FF	-1903.78	12570.09	-1370.41	4570.24	28.02	63.64

Difference between two calibrations typically around 10%

Much worse for some bpms

Calibration summary

F. Cullinan

$\theta_{IQ,x}$ and $\theta_{IQ,y}$

Constants from Calibration – IQ rotations/radians

Date	30th November		9th December		Difference/rad	
Bpm	x	y	x	y	x	y
QF7FF	-1.437	-1.361	-1.421	-1.372	0.016	0.012
QD6FF	0.599	-0.308	0.563	-0.315	0.036	0.008
QF5BFF	-1.127	0.406	-1.199	0.377	0.072	0.030
SF5FF	-1.346	-0.849	-1.381	-0.916	0.035	0.066
QF5AFF	1.411	0.366	1.409	0.462	0.002	0.096
QD4BFF	0.921	0.280	1.011	0.422	0.090	0.142
SD4FF	-0.849	-0.020	-0.833	0.037	0.016	0.057
QD4AFF	1.204	1.296	1.196	1.241	0.008	0.055
QF3FF	-0.568	-0.563	-0.507	-0.523	0.061	0.039
QD2BFF	-1.410	-1.475	-1.349	-1.448	0.061	0.026
QD2AFF	-0.487	-0.016	-0.417	0.094	0.070	0.110
SF1FF	-0.777	-1.380	-1.479	1.088	0.701	2.468
QF1FF	1.382	1.410	0.726	0.685	0.655	0.724
SD0FF	1.428	-1.526	0.996	1.024	0.431	2.550
QD0FF	-0.250	1.211	-0.933	0.402	0.683	0.810

Largest differences in IQ rotation between two calibrations is 0.7 rads to the nearest multiple of π

Most are under 0.1 radians

Short term calibration stability

F. Cullinan

- Repeated calibrations over within 1 hour for QD2AFF
  - Variation in x up to 10%, y a few %
  - <1 degree for θ_{IQ}

$\theta_{IQ,x}$	S_x	$\theta_{IQ,y}$	S_y
-0.452	928.7	0.0748	955.7
-0.446	1075.1	0.0744	958.9
-0.448	997.9	0.0743	961.7
-0.455	907.4	0.0713	959.8
-0.452	963.8	0.0741	961.5

Jitter subtracted calibration

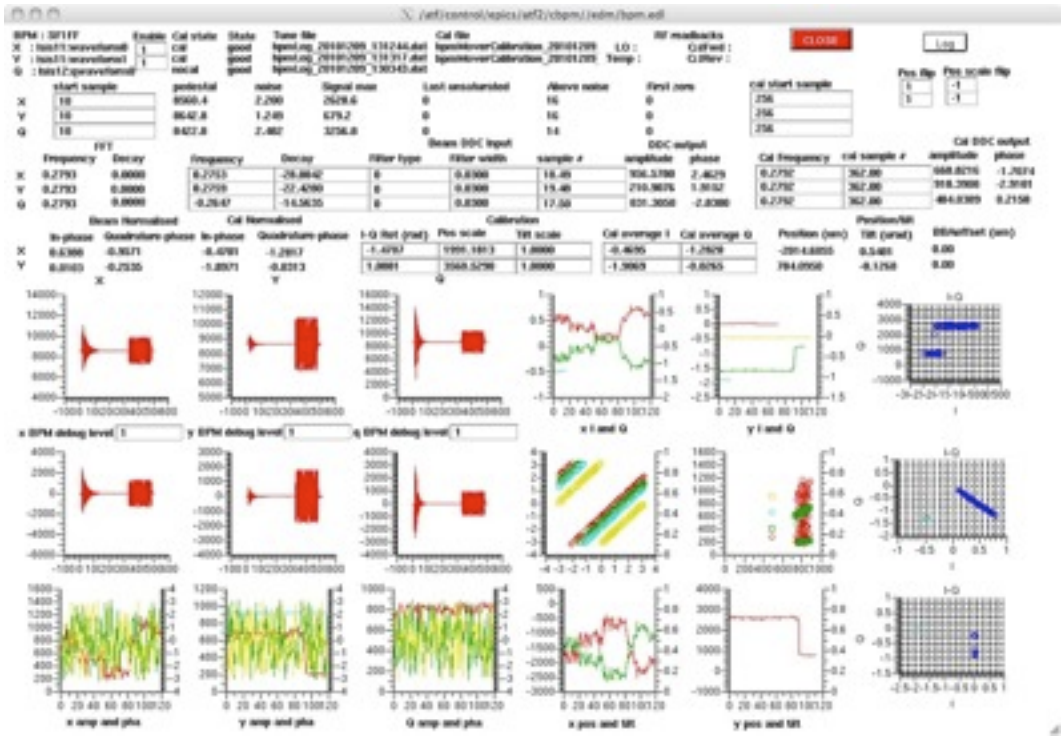
A. Lyapin

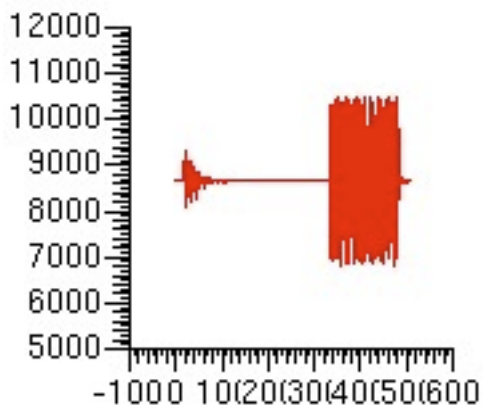
- Subtract beam orbit variation when doing calibration again with QD2AFF

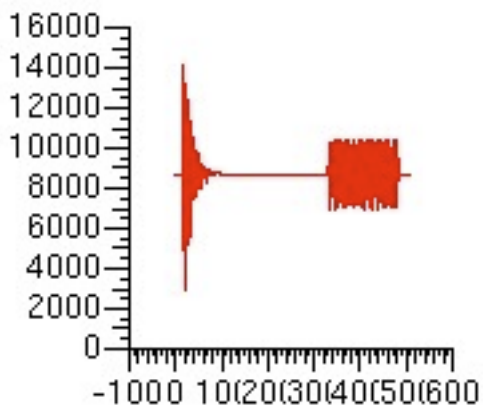
Direction	$\theta_{IQ,x}$	$\theta_{IQ,x}^{sub}$	S	S_{sub}
x	-0.4577	-0.4098	1489.35	951.76
x	-0.4500	-0.4469	1105.67	966.96
x	-0.4615	-0.4140	1257.52	953.72
x	-0.4528	-0.4739	789.21	976.82
x	-0.4492	-0.4087	1853.02	945.40
y	0.0763	0.0800	955.97	946.33
y	0.0711	0.0683	965.42	974.70
y	0.0700	0.0631	963.68	992.35
y	0.0708	0.0802	918.46	898.59
y	0.0755	0.0869	958.96	919.94

Calibration tone

S. Boogert



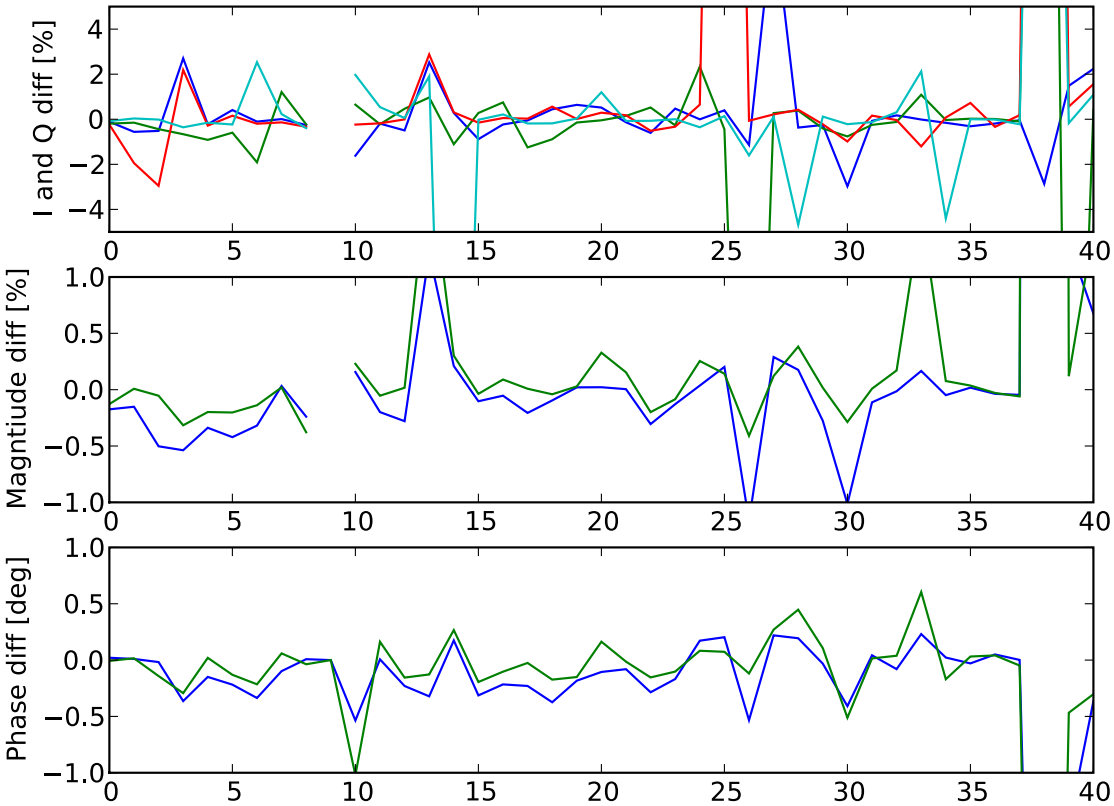




- C band and S-band tones injected directly into electronics
- Reconstruct I and Q from beam and cal tone for each pulse
- Monitor I_{cal} and Q_{cal} for every machine pulse
- Monitor and average during calibration procedure

Calibration stability

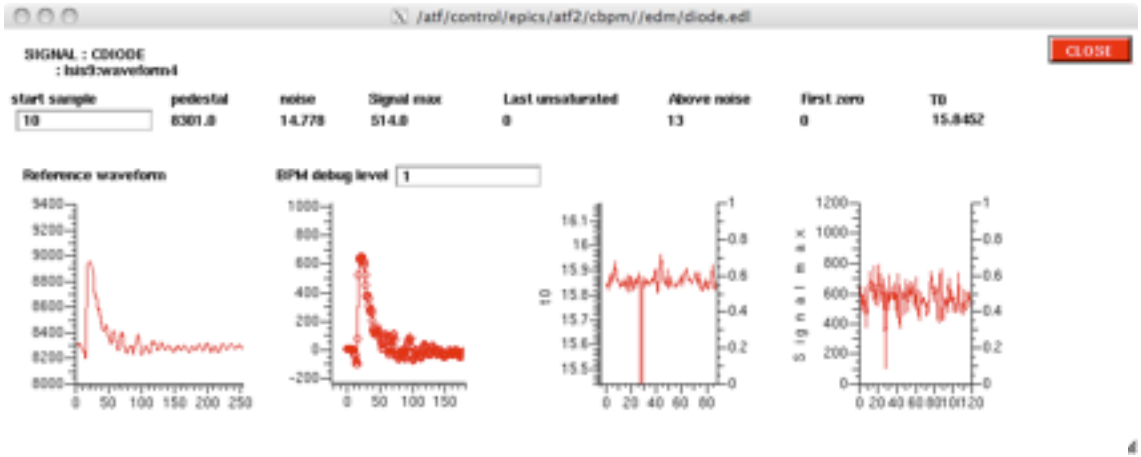
S. Boogert

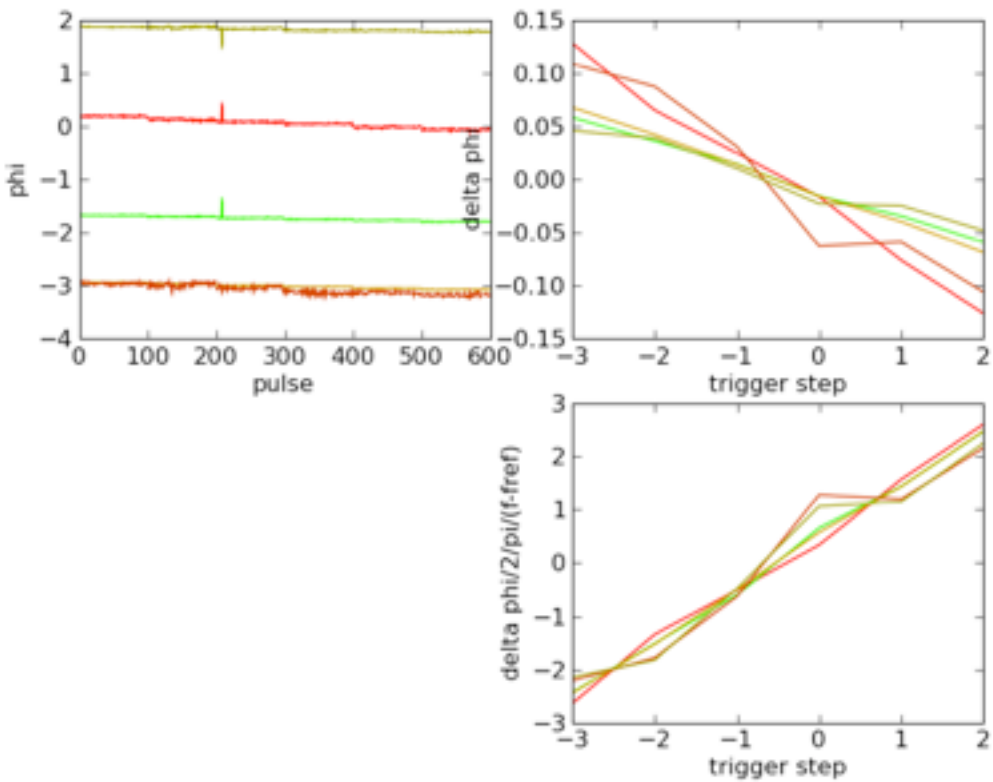


- Monitored during one week
- Summary of I and Q stability
  - Magnitude
  - Phase
- Indicative of calibration scale (S) and IQ rotation (θ_{IQ})

Phase correction

A. Lyapin





- Error/bug/oversight since start of operation

$$\Delta\phi = 2\pi(f_d - f_r)\Delta t_0$$

  - Need a phase correction due to changes in timing of BPM system
- Measure phase difference between dipole and reference
  - As function of CBPM TD2

Work plans

- Jitter subtracted calibration for all BPMs
- Online resolution monitoring
- Passive stability monitoring
- t_0-frequency correction
- Re-commission C-band references
- Continue with IP region BPM
- Check with unlocked C-band sources

Summary

- System "complete" and working well
  - Resolution ~200 nm with 20 dB attenuators
  - Stability good over 1 week time scales
    - Calibration tone and electron beam model check out
  - IP region now the problem
  - C and S band system working well
- Long to-do list
  - Need less intrusive methods to check system performance