Cavity Beam Position Monitor System calibration and principle component analysis

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Introduction

- Principle component analysis
  - Similar method used for higher order mode studies
- Development of my thesis work into a usable processing system for cavity BPMs
  - Started in 2011 on test IPBMs
  - Applied to complete ATF2 cavity system
    - Modified the ATF2 BPM calibration code to store raw waveforms
  - This report
- IP calibration
  - Repeated calibrations, stability

CBPM Shifts

- Cavity BPM Shifts (Oct. ~ Dec. 2012)

- 2012/10/17, 25 – modified cavity calibration log file (Add waveform), few mover calibration for test
- 2012/11/07 – Tuned all CBPMs, Mover calibration
- 2012/11/28 - SVD mover calibration, bump calibration, IPA, IPB
- 2012/12/04 - QM13FF, MFB2FF calibration
- 2012/12/18 – MFB2FF calibration

Calibration

- Large set of different calibrations
  - C-band in matching section, S-band : movers
  - IP and C-band in extraction : bump (magnet or correctors)

BPM type	Range	Steps
C-band (mover)	-250 to 250 µm	5
C-band (bump)	-200 to 200 µm	5
MFB2FF (mover)	-50 to 50 µm	5
Long range mover	-1500 to 1500 µm	30
S-band (mover)	-500 to 500 µm	5
IP (bump)	-250 to 250 µm	5

Principal component analysis (PCA)

- Digital Down Conversion (DDC)
  - need 3-4 parameters (frequency, decay time)
  - Tune (determine parameters)
  - Calibration (determine scale and IQ rotation)
  - 8 hours, 1 shift for 40 cavities
- Principle component analysis (PCA)
  - Use full waveform
  - Doesn't require parameters
  - Easy for quick diagnosis and BPM use
- Data
  - November 2011 : IP test BPM area
    - Triplet installed in extraction system
  - November 2012 : IP region and ATF2
    - C-, S-band and IP cavities

Principal component analysis (PCA)

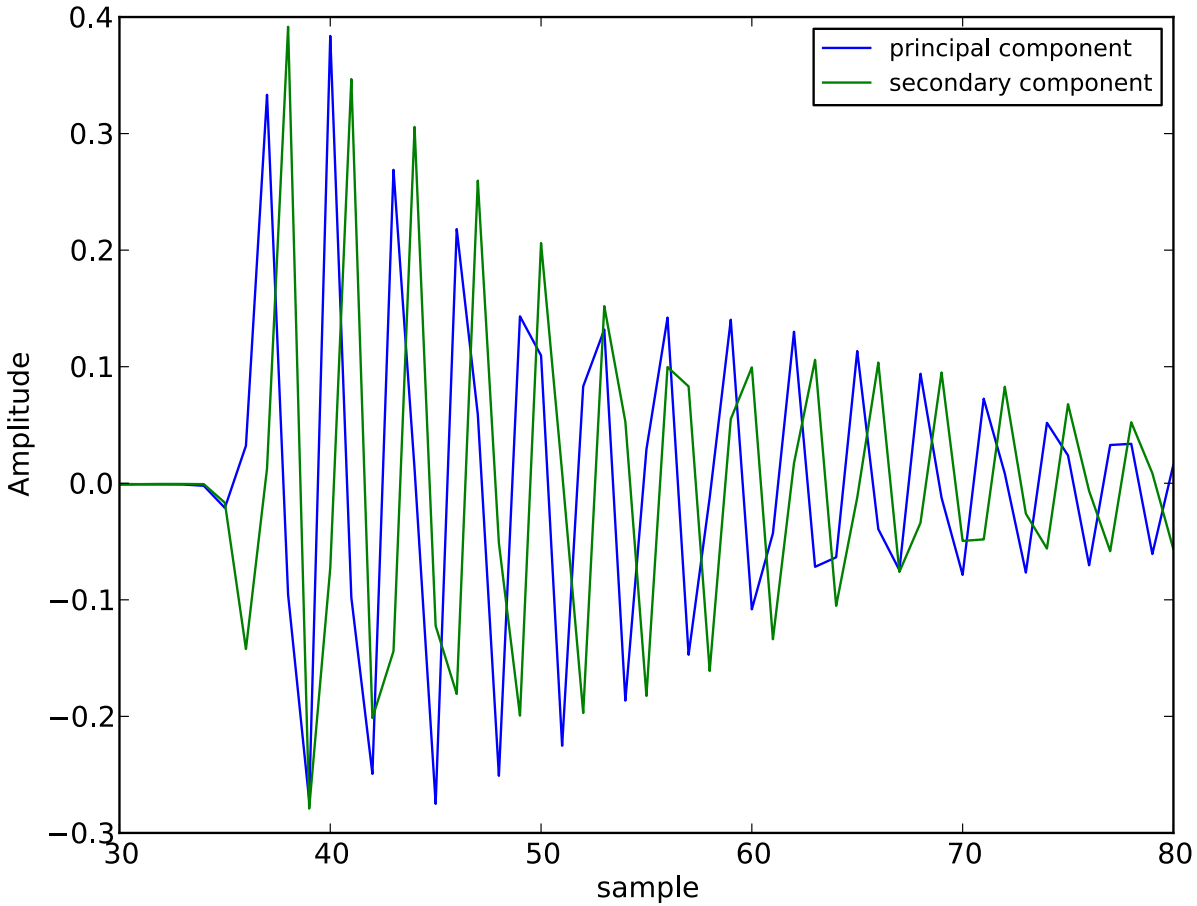
- Principal : Calculate a vector which represents the maximum variability in the data
- Calculation
  - Calculate principal components
  - Dot product
  - Calculate amplitude and phase
  - Normalize by the reference then calculate I and Q
- Calibration, calculate
  - IQ rotation
  - I’ and Q’
  - Scale factor

Example PCA vectors

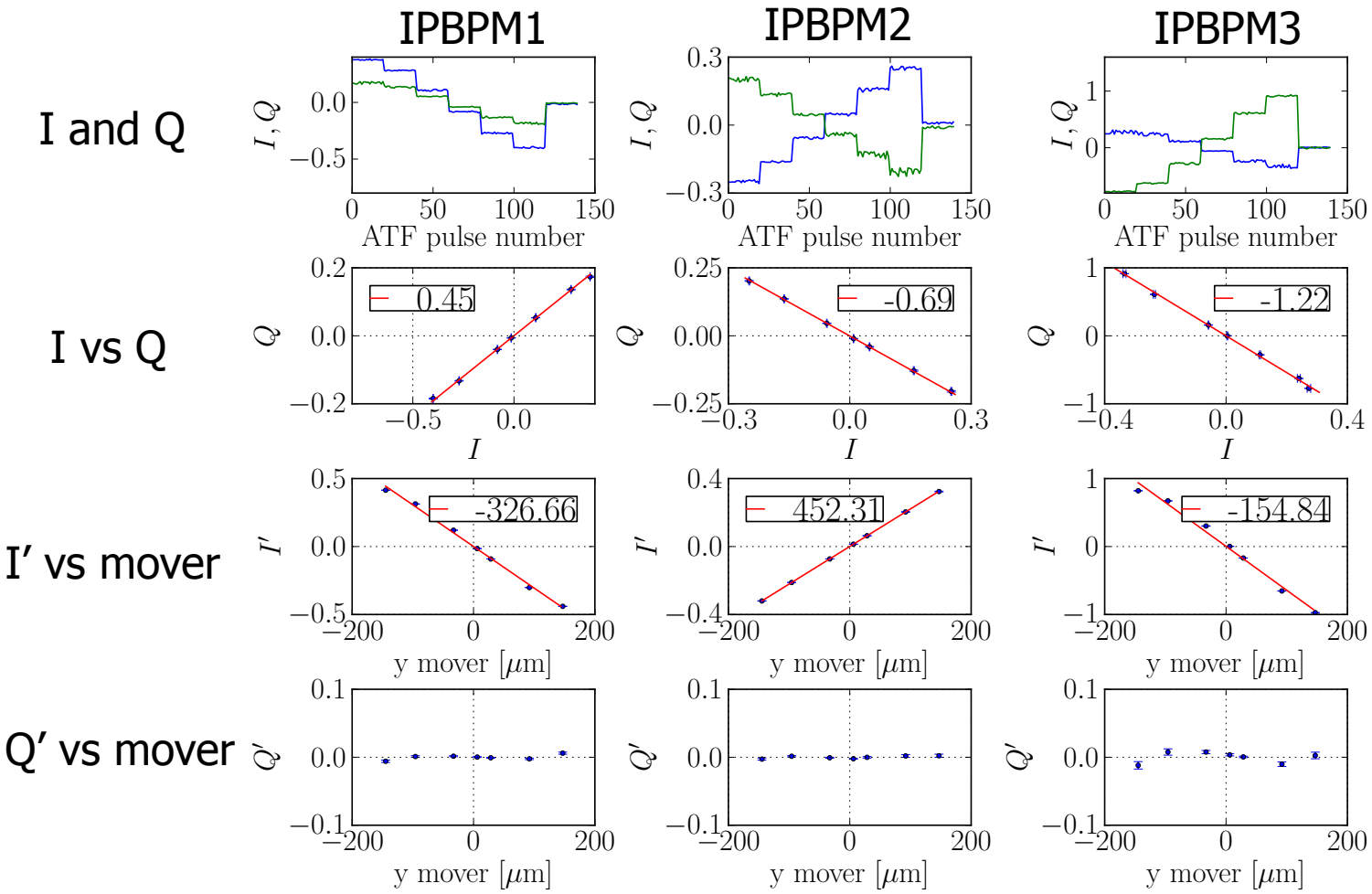
Example, principle and secondary component from calibration data

Extract the signal proportional to position and tilt almost directly

Largest variation in position signal



IPBPM @ upstream (Nov 2011)



Shows PCA calibration for 3 BPMs

Details are here : http://www-pnp.physics.ox.ac.uk/~kimy/YoungImKim_Phd_thesis.pdf

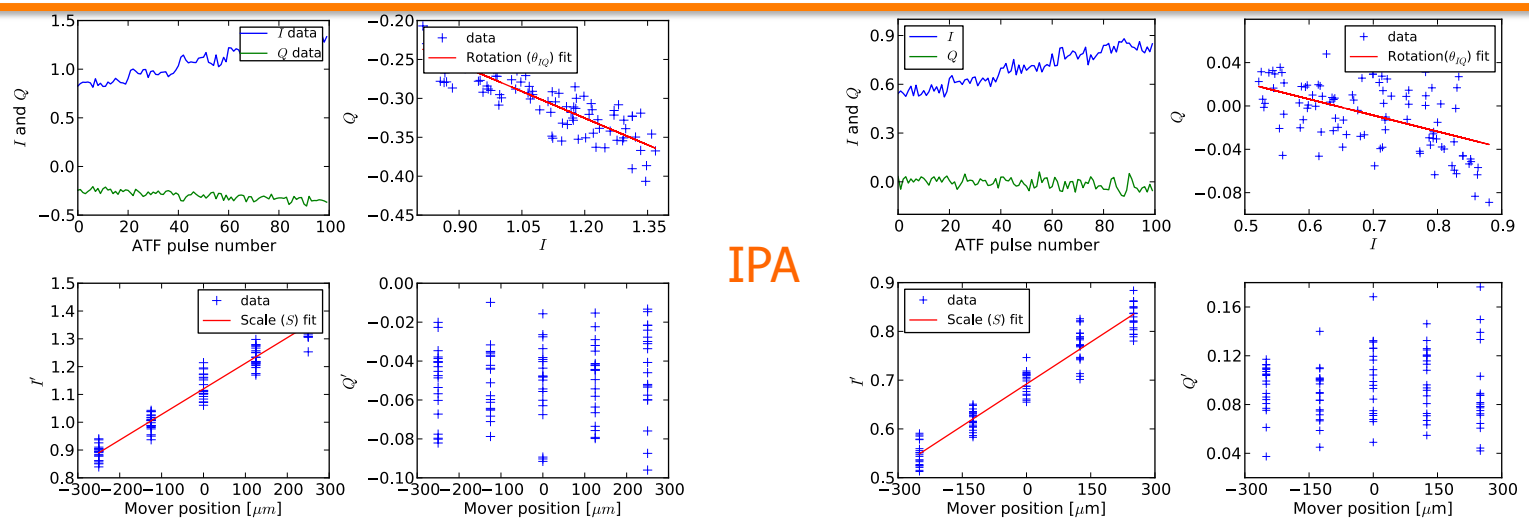
IPA and IPB @ IP (Nov 2012)

DDC calibration

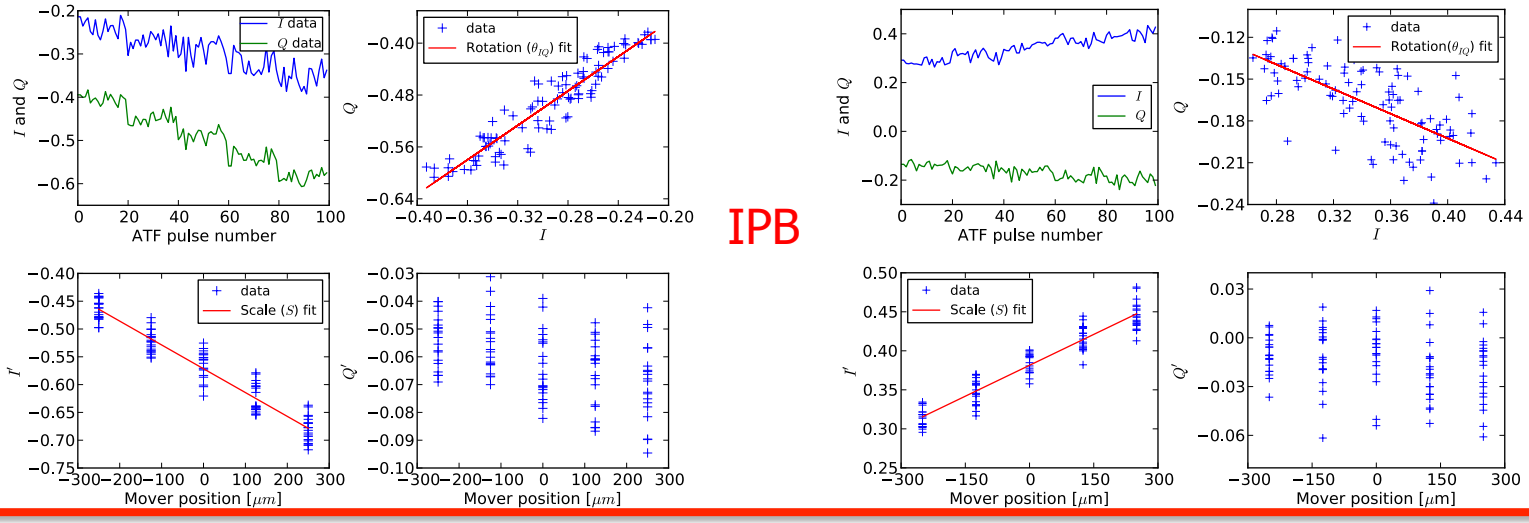
PCA calibration

Generate bump
Horizontal direction

IPA

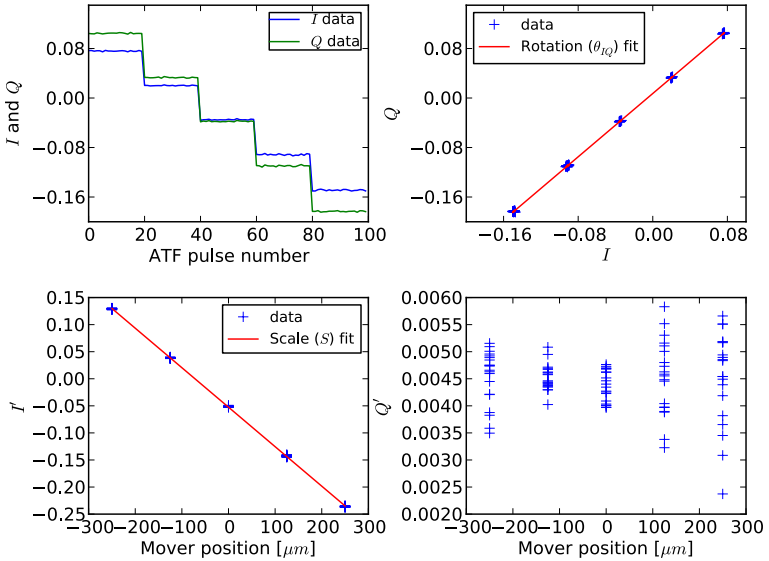


IPB



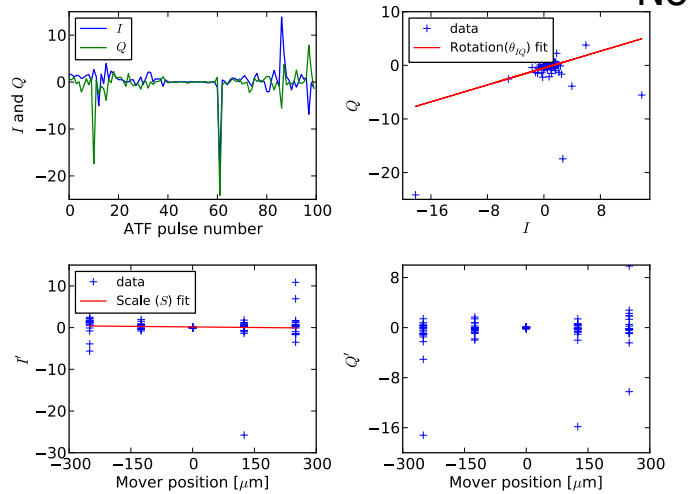
C-band non-mover QD16X (Nov 2012)

DDC calibration

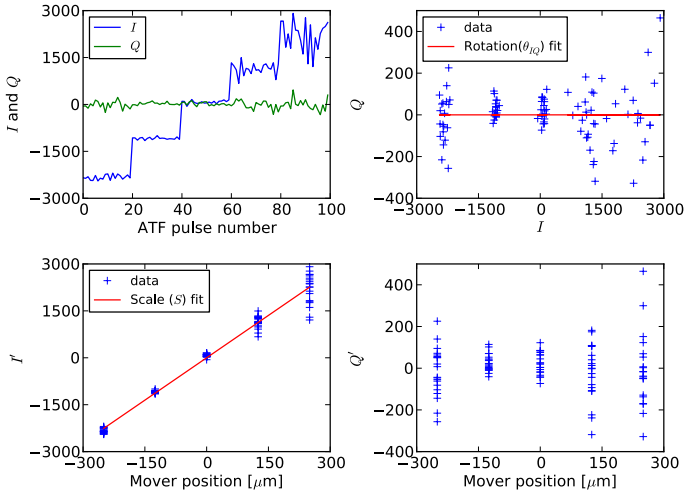


PCA calibration

Normalised by charge



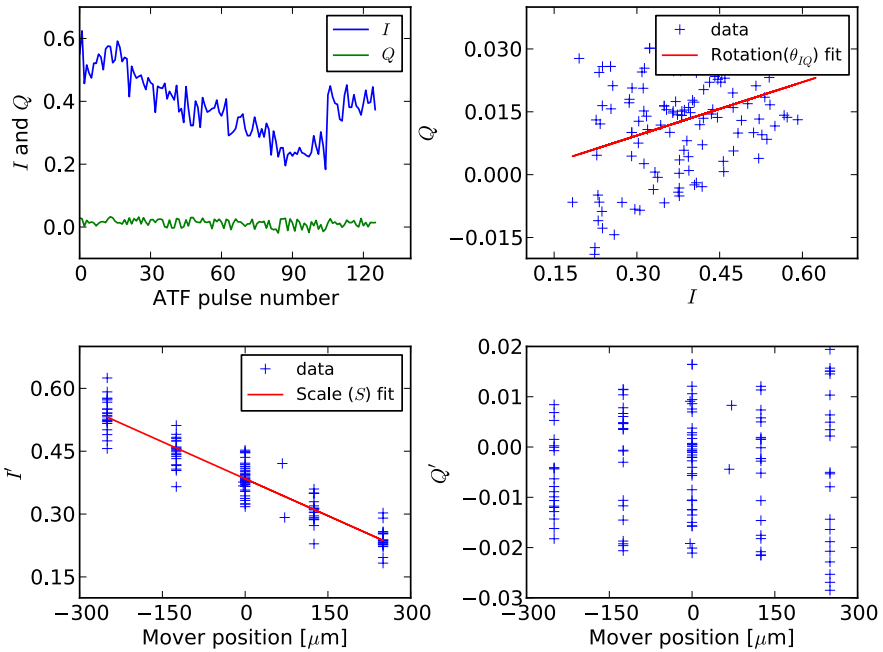
Not normalised by charge



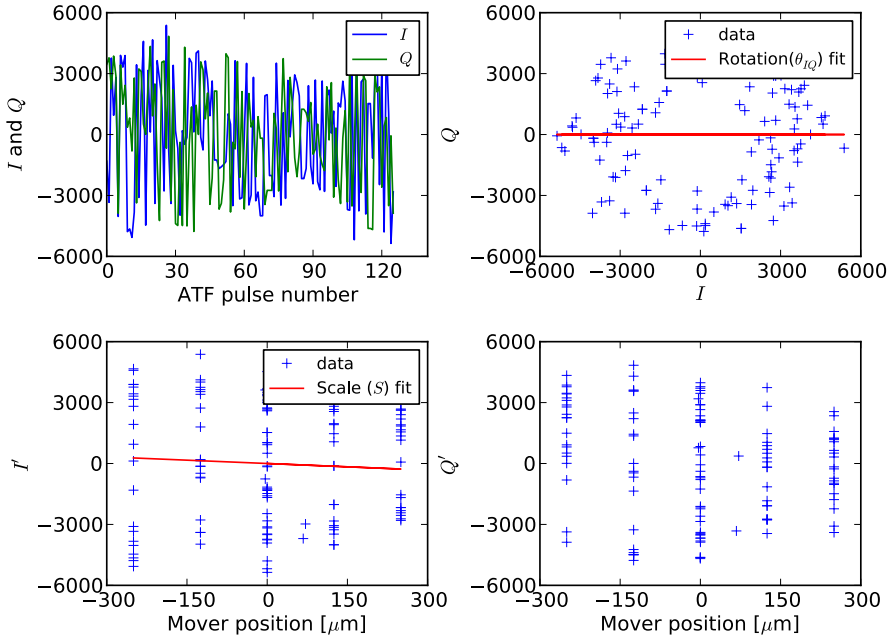
S-band mover SD0FF (Nov 2012)

BOTH : PCA calibration

Normalised by charge

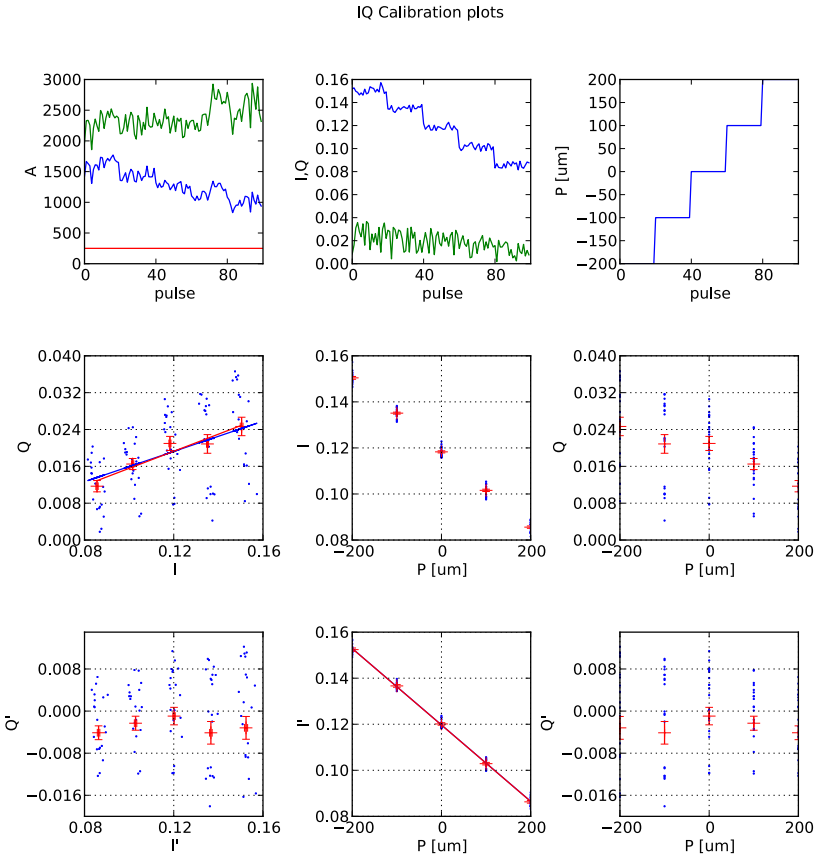


Not normalised by charge

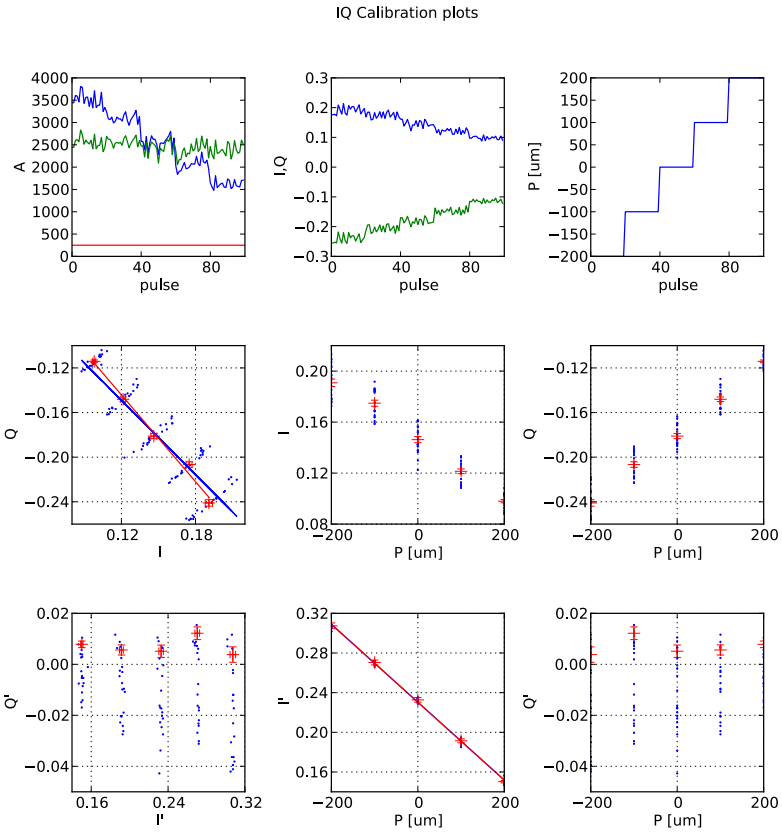


IP bump calibration (Nov 2012)

IPA y



IPB y

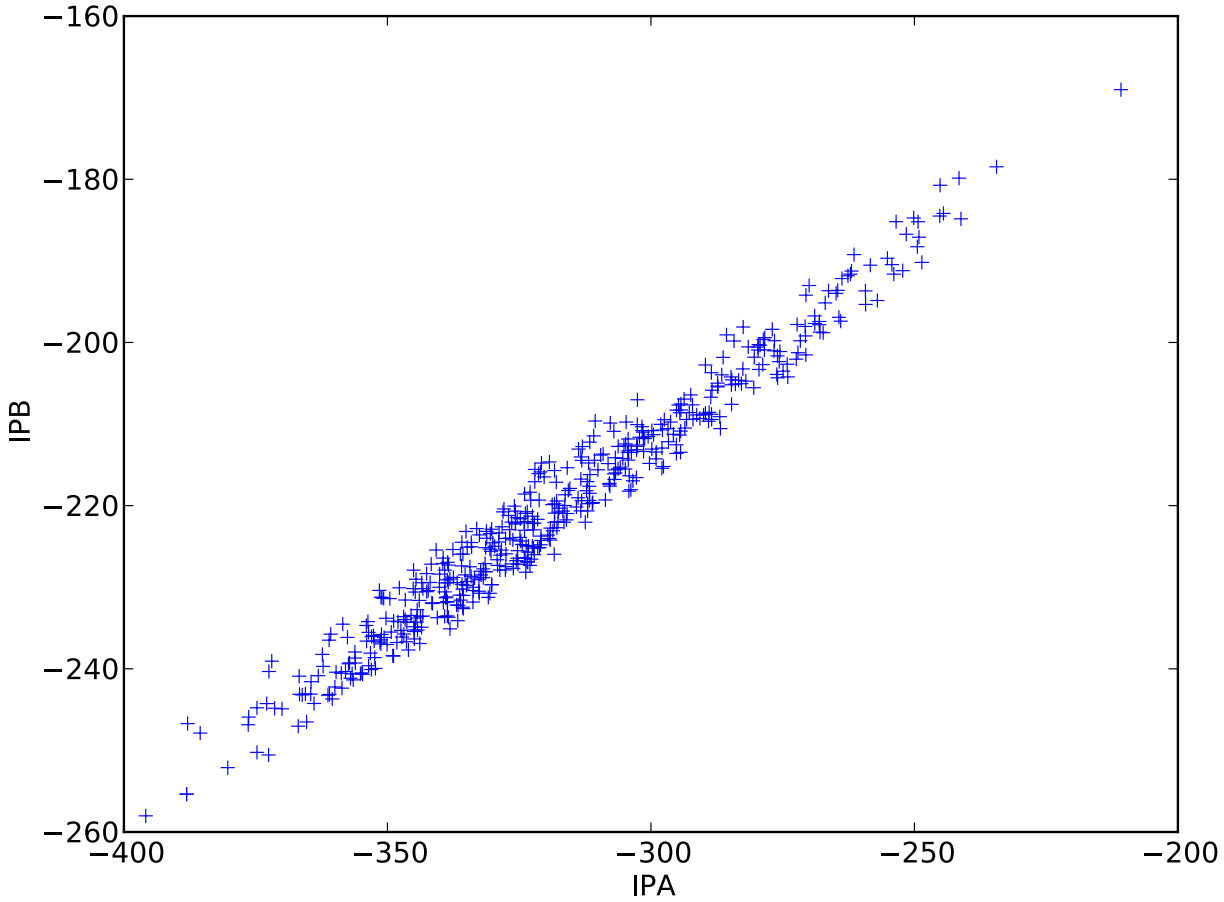


Calibration @ IP region

	IQ rot 1	IQ rot 2	Pos scale 1	Pos scale 2
Pre-IP x	0.4789	0.4800	1298.12	1239.22
Pre-IP y	1.1346	1.0267	-988.00	-851.97
IPA x	-0.2213	-0.2149	1283.14	1086.51
IPA y	0.1834	0.1346	-6025.28	-6498.69
IPB x	1.0331	0.9999	-2186.63	-2327.88
IPB y	-0.9136	-0.8667	-2542.03	-3014.74
MPIP x	-0.0178	-0.0047	3701.22	4204.18
MPIP y	0.7983	0.8961	246.13	262.51

IPA and IPB position scales are expected to be at a similar level

IPA and IPB : vertical correlation



Good correlation observed

98.4 % correlation coefficient in vertical direction

Summary

- Reference cavities at ATF2
  - C-band BPMs
  - S-band BPMs
  - IPBPMs
- PCA calibration results were expected to show similar and/or better results compare with traditional method
  - Difference in Q…. Much longer data records for high-Q
- But C-band BPMs show strange phenomenon
  - Reference phase?
  - We could put more reference cavities and check
  - Use wakefield reference cavity
- Writing a paper on PCA for cavity signal processing
  - IPBPMs data @ upstream (Nov 2011)