Cavity BPM: Multi-bunch analysis

N Joshi, S Boogert, A Lyapin, F. Cullinan, et al.

Nirav.Joshi.2009@live.rhul.ac.uk

Royal Holloway University of London,

ATF team.

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System information

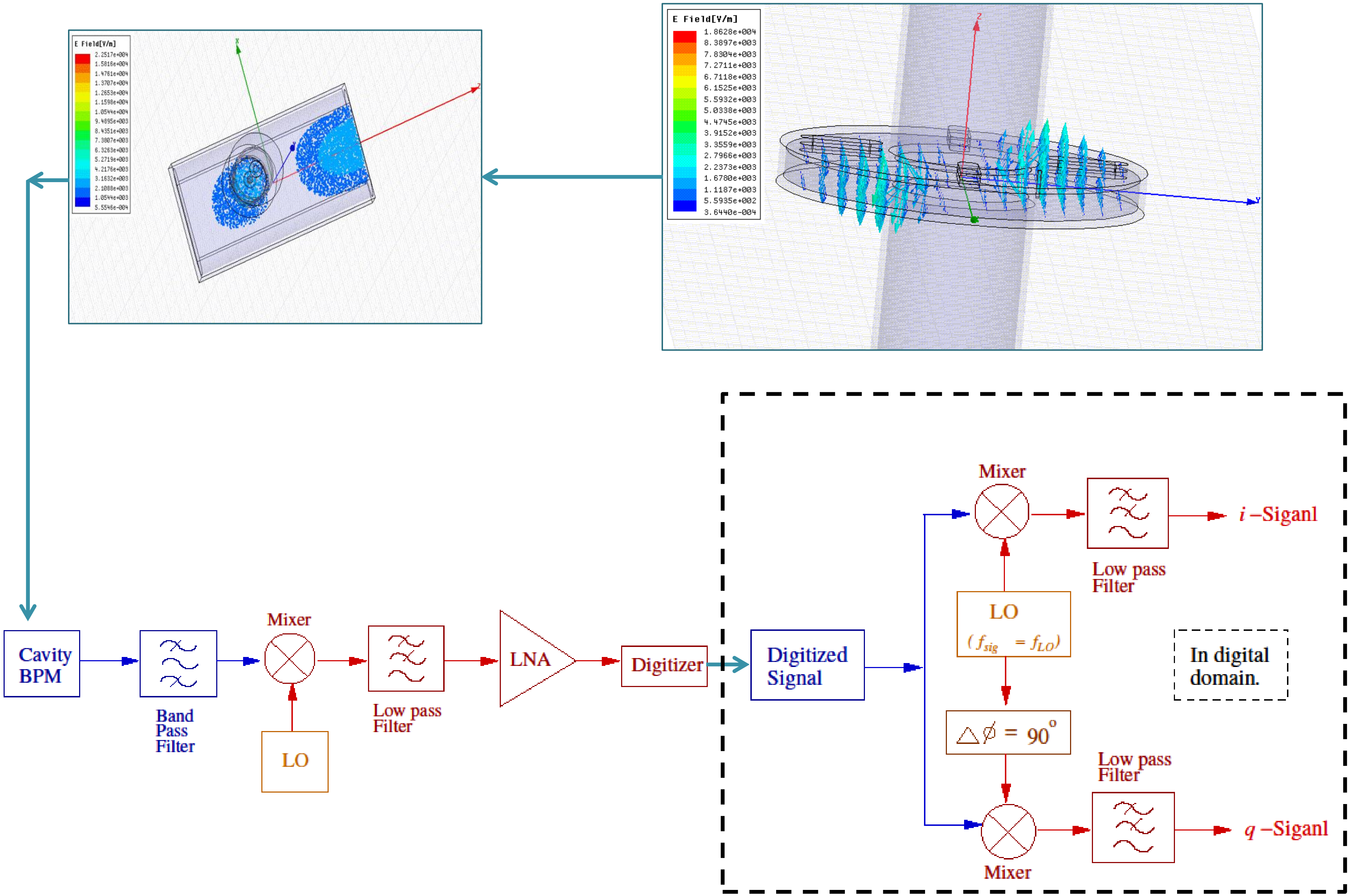
- Data was acquired during the machine operation in multi bunch(train) mode during FONT shifts and a Cavity BPM time slot in Nov-Dec 2011.

  - Bunch Separation : 186.7 ns (Paracitic data between 182 to 285 ns)
  - Number of bunches : 2

- Cavity parameters

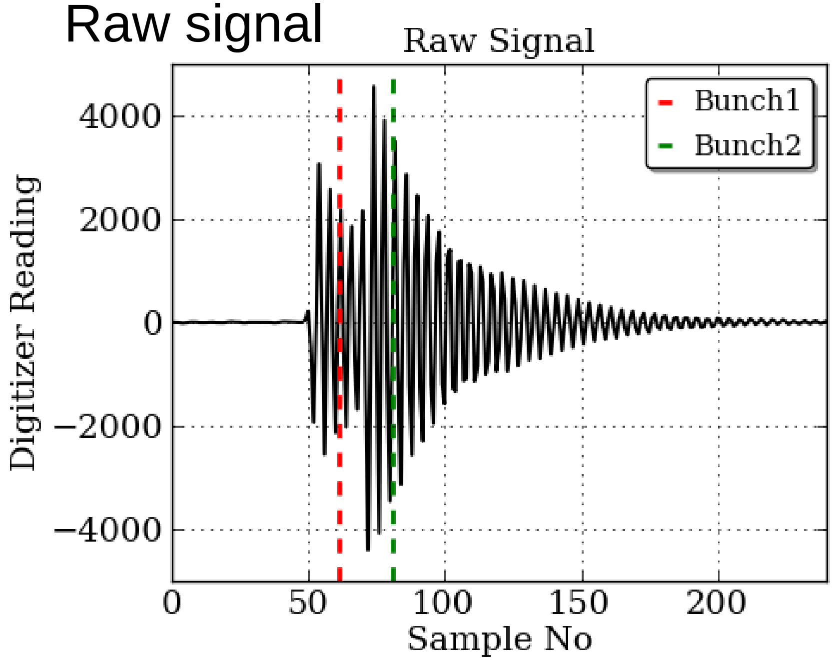
Parameter	**Dipole cavity**	**Reference cavity**
Cavity used for calculation	QM13FF QM12FF QM11FF	REF1
Direction	X and Y	
Cavity Frequency (GHz)	~6.42	~6.4223
Decay time constant τ (ns)	~305.49	~300.66

Block diagram : Process flow



Digital Down Conversion (DDC) and signal extraction

Raw signal



Colour convention:

Bunch1

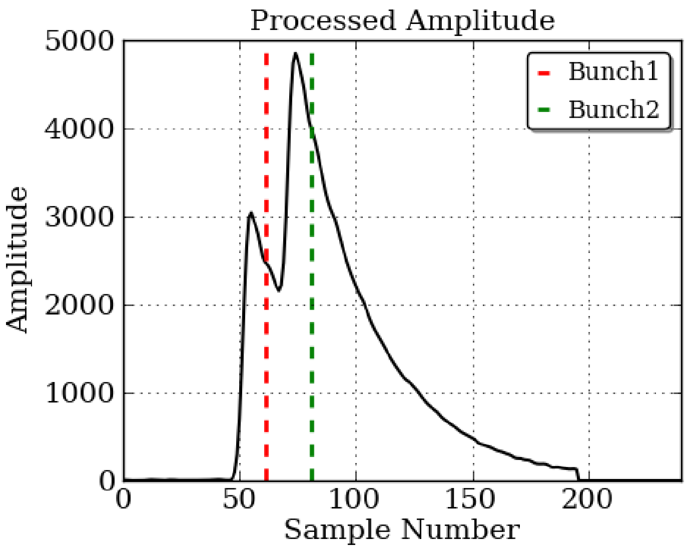
Bunch2

Normalization:

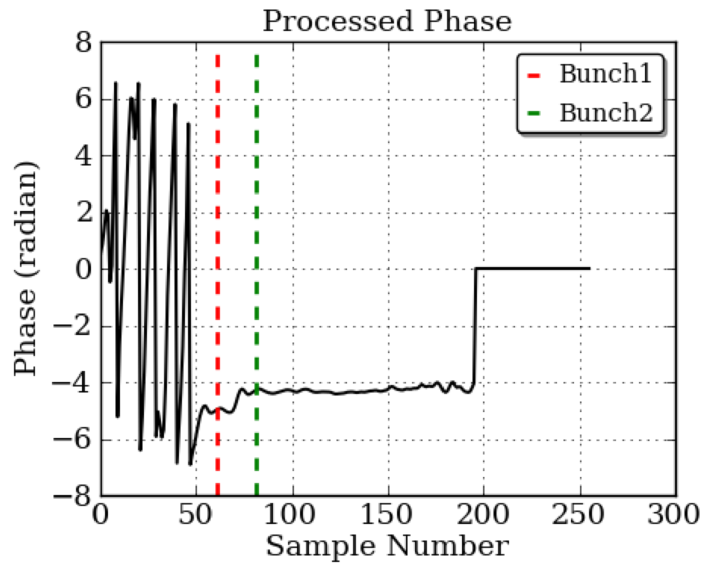
$$I(n) = \frac{A_{BPM}}{A_{REF}} \cos(\phi_{BPM} - \phi_{REF})$$

$$Q(n) = \frac{A_{BPM}}{A_{REF}} \sin(\phi_{BPM} - \phi_{REF})$$

Processed Amplitude

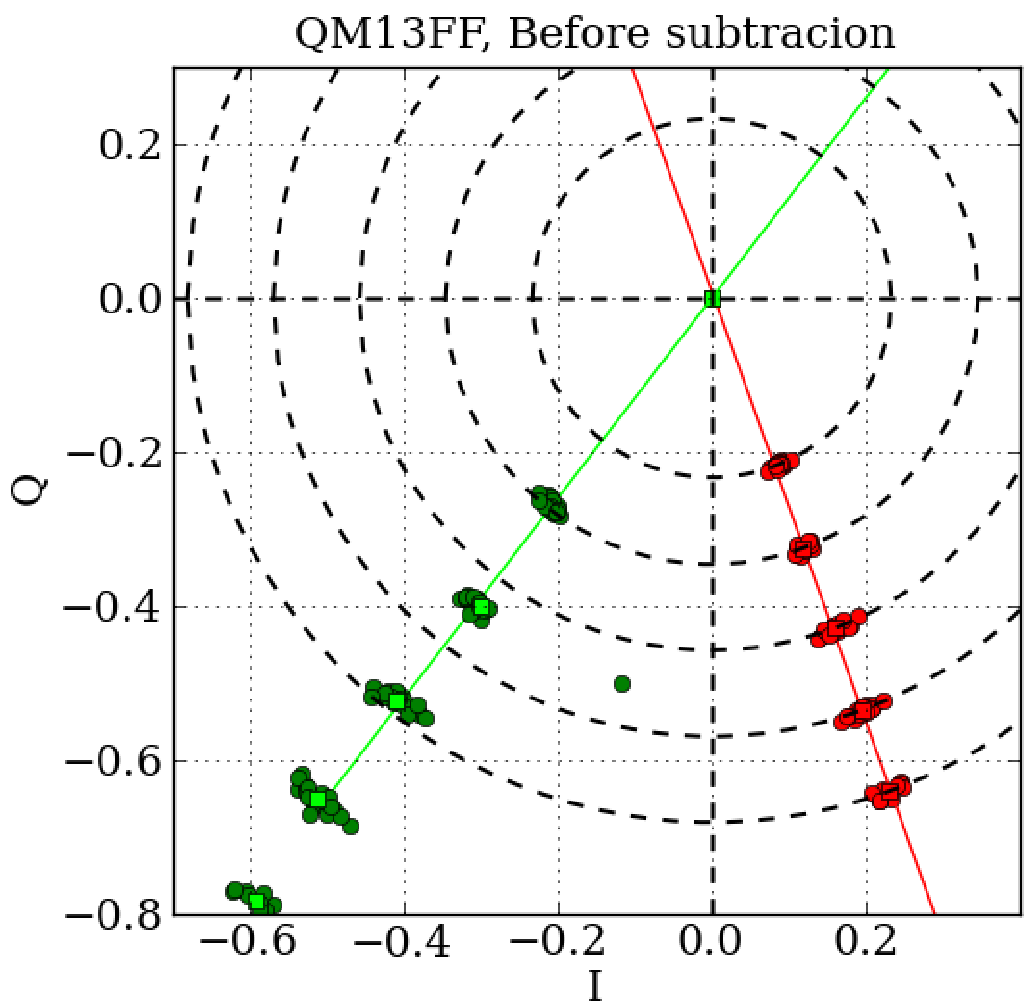


Processed Phase



Calibration: IQ Plots

- BPM is moved along axis between -200 to 200 µm in step of 100 µm
- I & Q are calculated in a similar way as single bunch calibration, without any bunch subtraction.
- With change in mover position, I&Q from 1st bunch moves along a straight line in IQ plane passing through (0,0)
- Steps along straight lines in IQ plane from 2nd and 3rd bunches shows the behaviour expected from a cavity BPM.
- IQ signal from a bunch is polluted by the decayed signal from previous bunches.
- Bunch 2 position will be over estimated by ~50%



IQ : After bunch subtraction

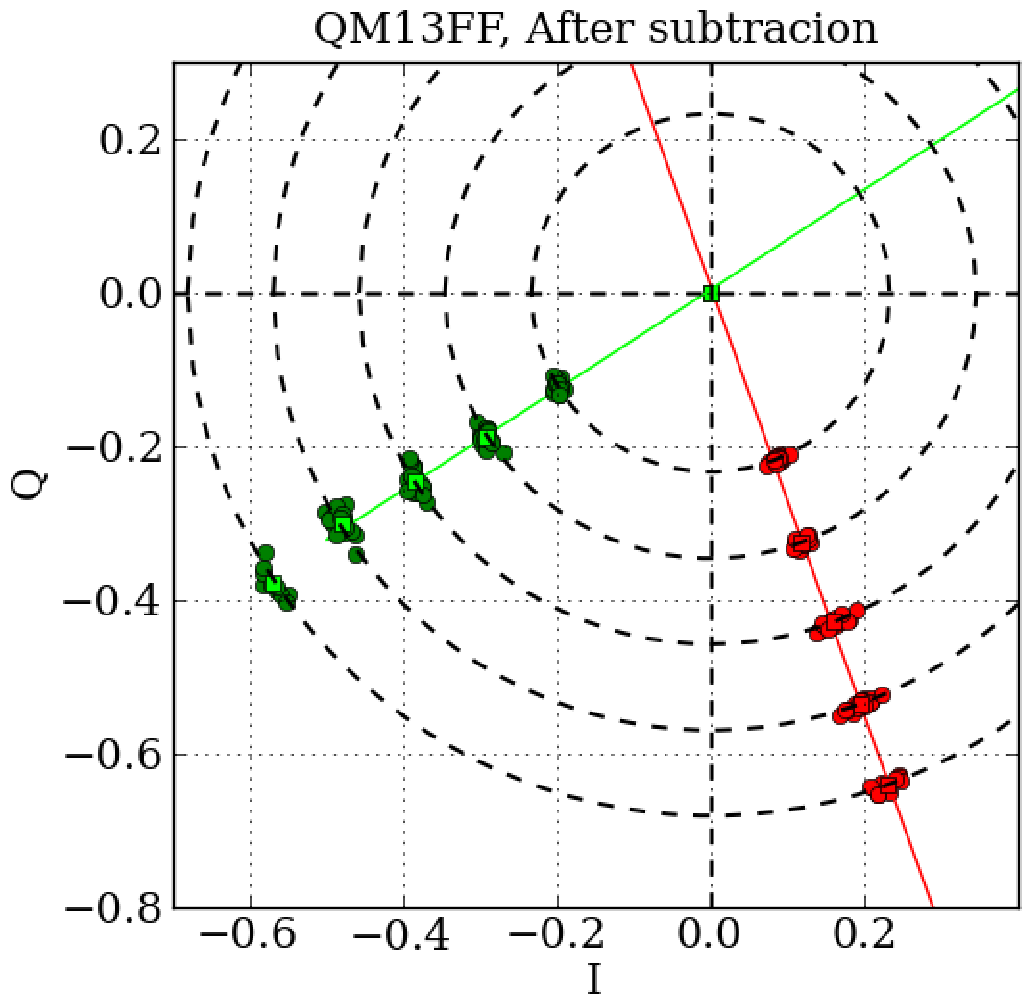
Bunch Subtraction:

- ***i*** & ***q*** signals from BPM and reference cavities are subtracted separately before normalization.
- Decayed *i* & *q* from previous bunch is subtracted from current bunch.

$$i_s(n) = i(n) - i(n-1)e^{\frac{-\Delta t_b}{\tau}}$$

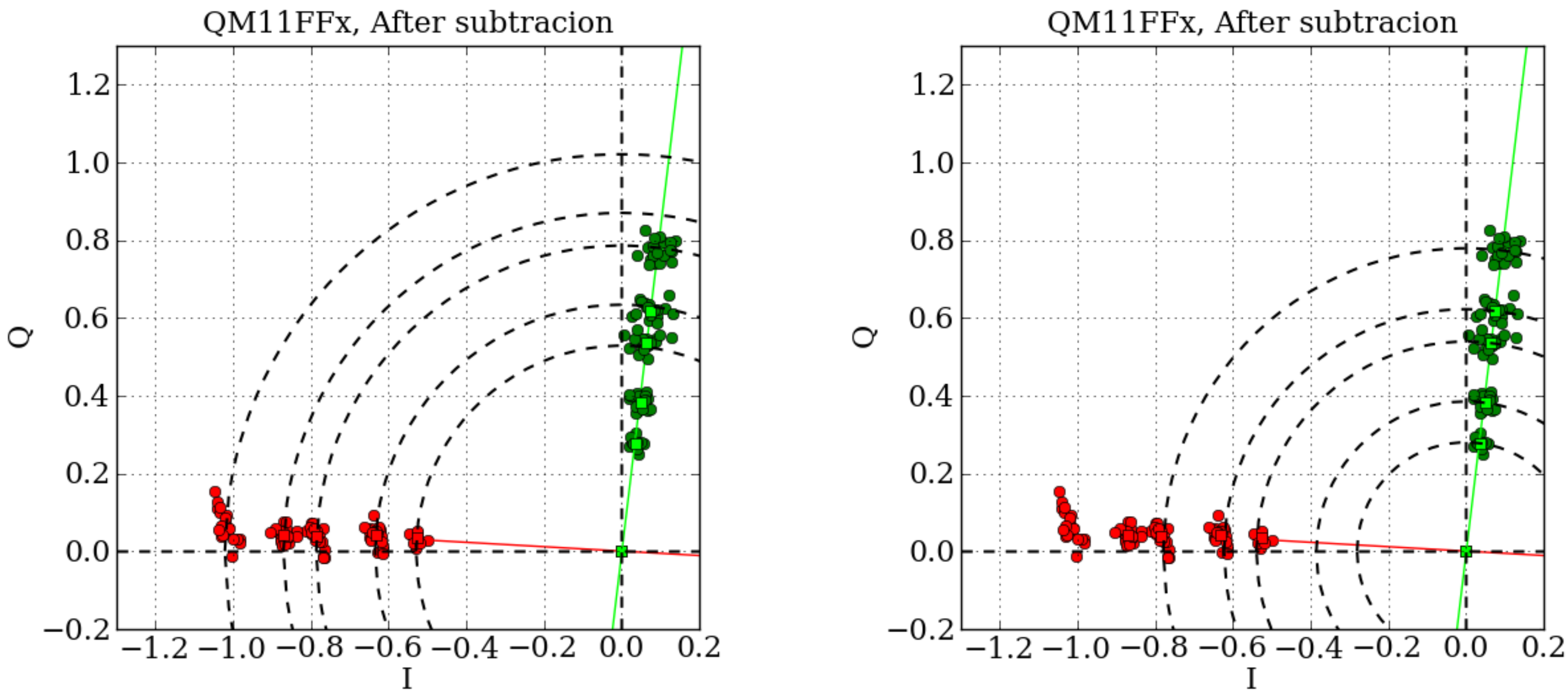
$$q_s(n) = q(n) - q(n-1)e^{\frac{-\Delta t_b}{\tau}}$$

- Subtracted signal is then normalized.
- Phase difference between bunches becomes even.
- Signal pollution from 1st bunch is removed



Calibration: Second bunch at Different position

- ***Amount of change in signal amplitude difference remains same, even if the second bunch arraives at different position offset.***



Mover position change (μm)	**Change in signal amplitude**	
	Bunch 1	Bunch 2
-200 to -100	0.1053	0.1050
-100 to 000	0.1519	0.1541
000 to 100	0.0842	0.0834
100 to 200	0.1509	0.1566

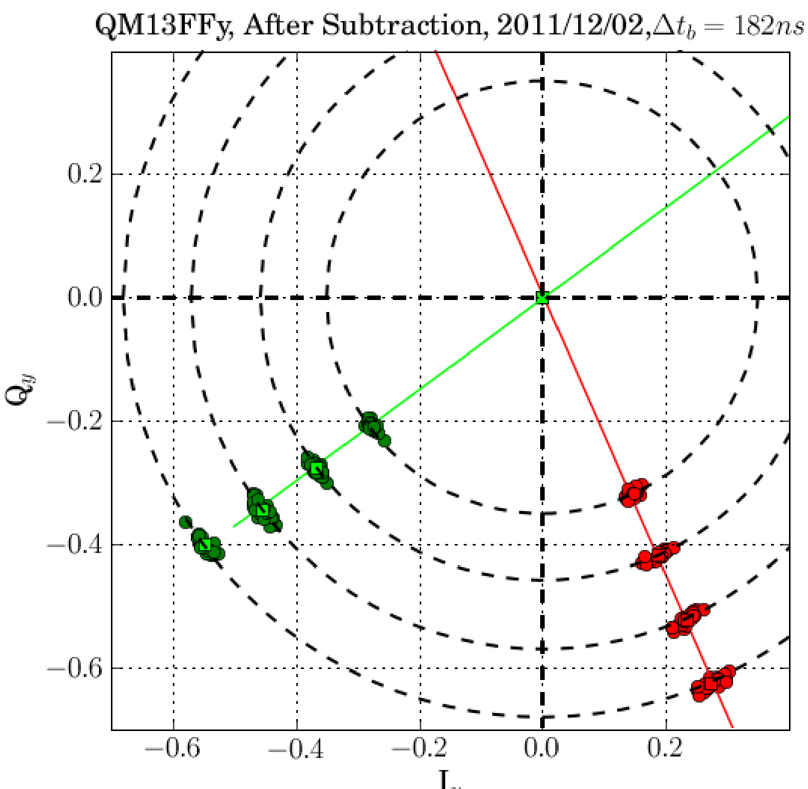
Phase difference dependence on bunch separation

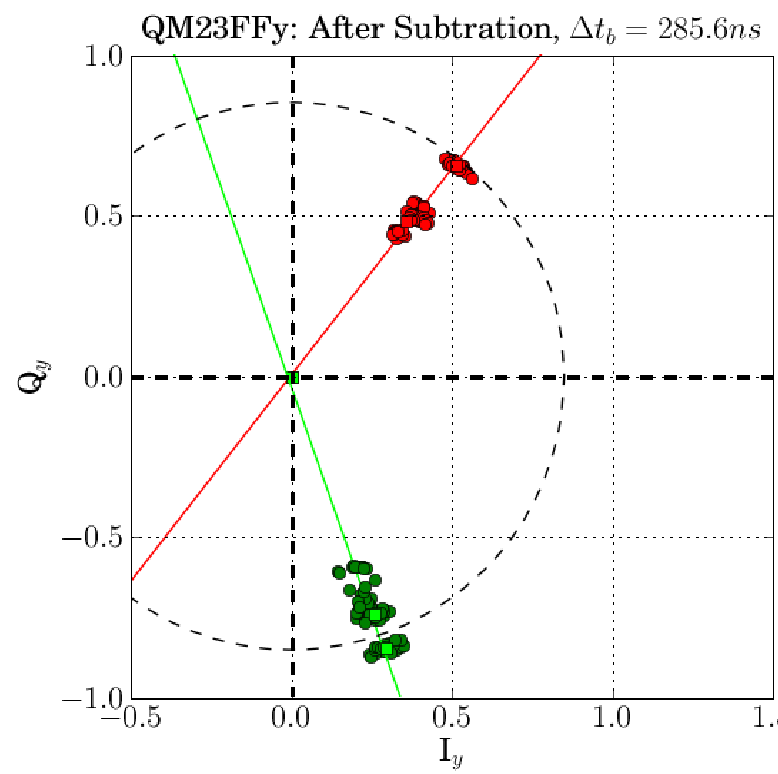
- One of the reason can be the difference in frequency between BPM and reference cavity. It will generate certain phase difference over a period of time.

$$\Delta\phi = \Delta\omega \times \Delta t_b$$

- The difference in frequency is *1.249MHz. For two different bunch separation. The phase difference is*

Bunch Separation Δt_b (ns)	**Phase difference between bunches $\Delta\phi$ (rad)**	
	Theoretical	Experimental
182	1.382	1.375
285.6	2.16	2.14





Conclusions

- Position scan was recorded for BPM during multi-bunch operation mode.
- IQ plots, for each bunch, point towards a single point in plane. That indicates that the system is working as a beam position monitor in multi-bunch mode as well.
- Observed difference in phase, between bunches, is in agreement with its theoretical explanation derived till date.

Future work

- Effect of process parameters, such as the digital filter bandwidth and data extraction sample points, are being studied with current data set.
- Some calibration data with different bunch spacing, which could not be acquired due to limited shift time, will be more helpful.
- Ultimate goal is to make BPM system online in multi-bunch mode as well.

Thank
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