Cavity BPM: Multi-bunch analysis

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System information

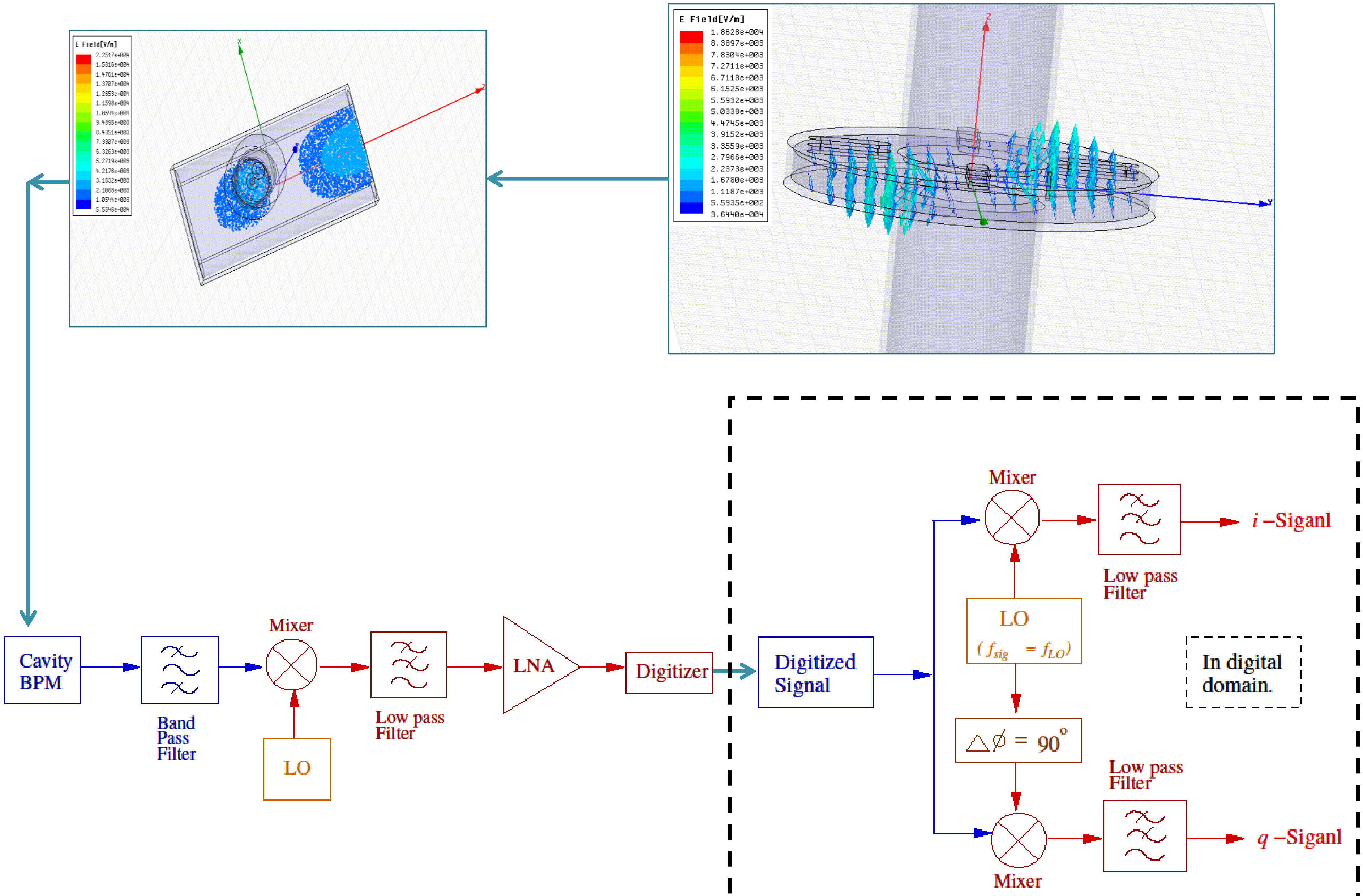
- Data was acquired during the machine operation in multi bunch(train) mode for FONT shift in December 2010.
  - Bunch separation, Δt_b : 154 ns
  - Number of bunches, n : 3

- Cavity parameters

Parameter	**Dipole cavity**	**Reference cavity**
Cavity used for calculation	QM13FF	REF1
Direction	Y	
IF frequency (GHz)	6.423586	6.4223
Decay time constant τ (ns)	305.49	300.66

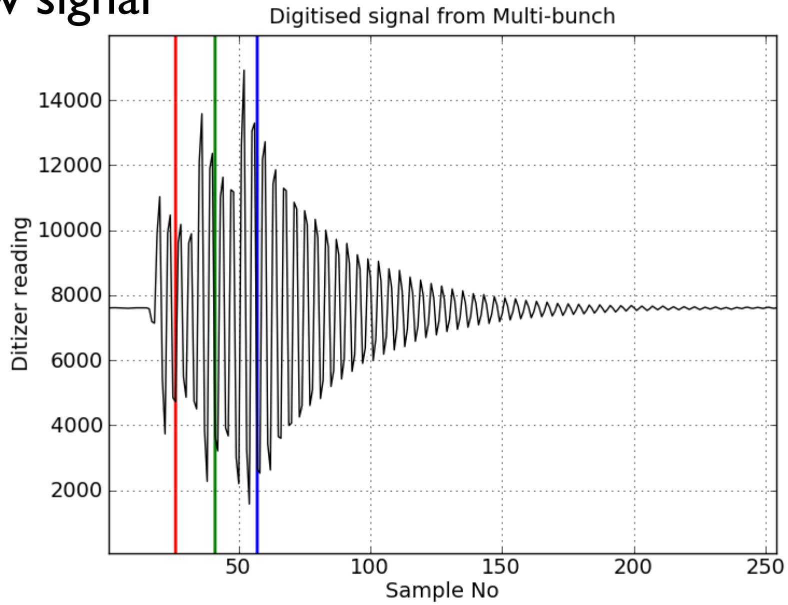
- Only one mover scan was recorded to minimize any disturbance in on going operation.

Block diagram : Process flow



Signal Processing

Raw signal



Colour convention:

Bunch1

Bunch2

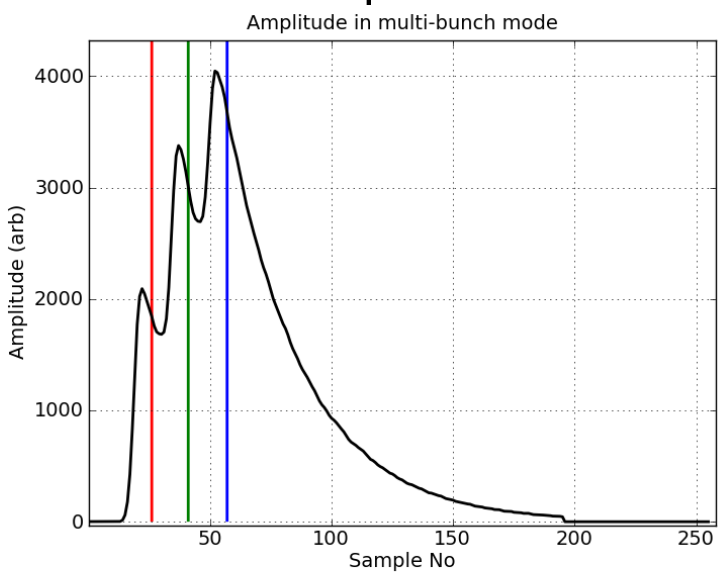
Bunch3

Normalization:

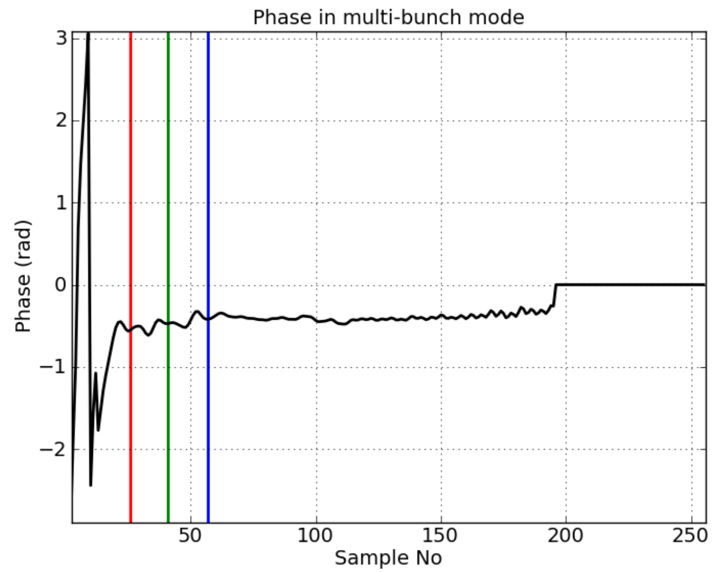
$$I(n) = \frac{A_{BPM}}{A_{REF}} \cos\left(\phi_{BPM} - \phi_{REF}\right)$$

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

Processed Amplitude

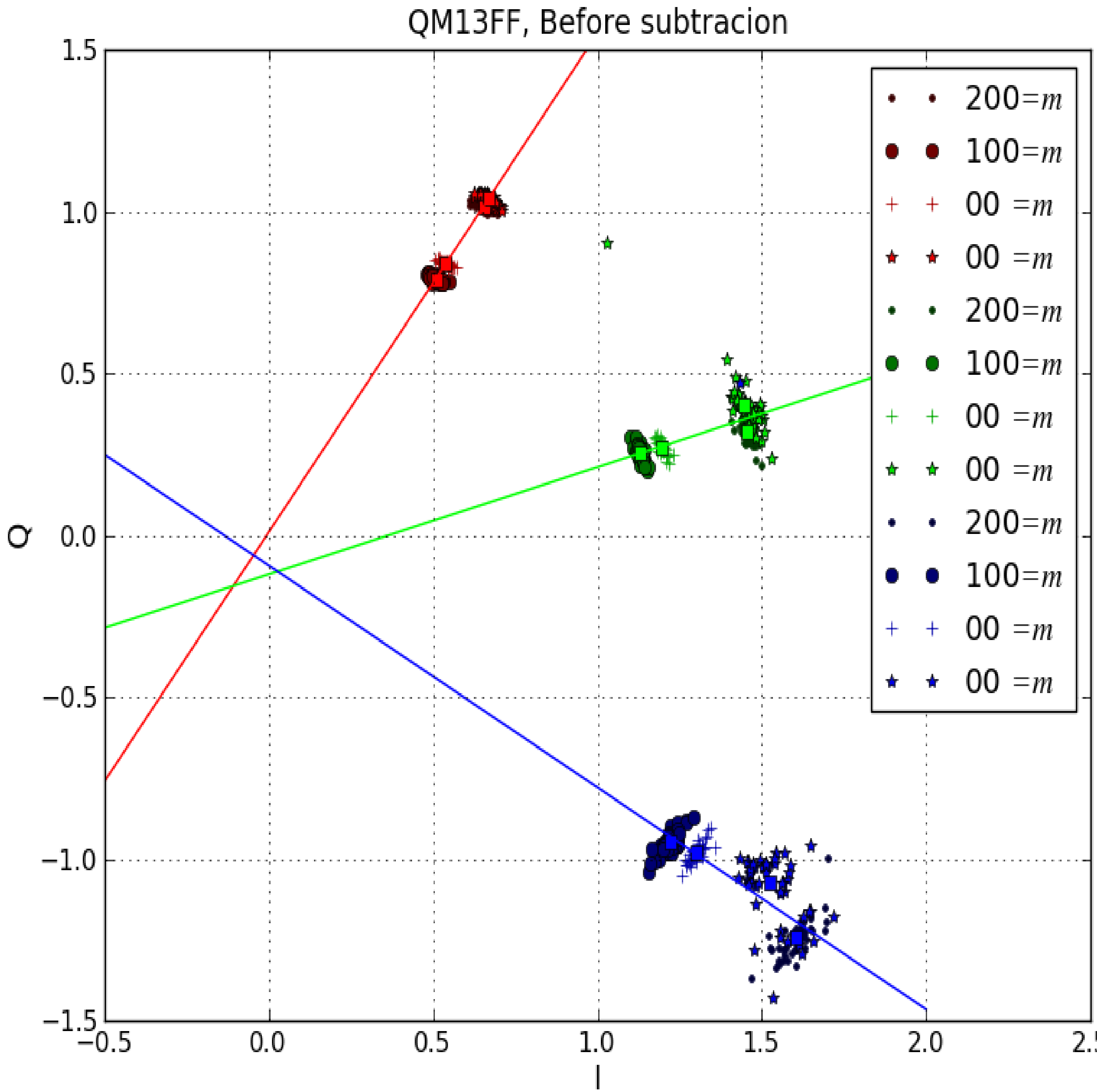


Processed Phase



IQ : Without bunch subtraction

- BPM is moved along Y axis at 200, 100, 0, 0μm positions respectively.
- 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.



Rotation Angle:

Bunch No	ϕ (rad)	$\lvert\Delta\phi\rvert$ (rad)
1	0.98778	
2	0.32898	0.65883
3	-0.59777	0.92671

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.

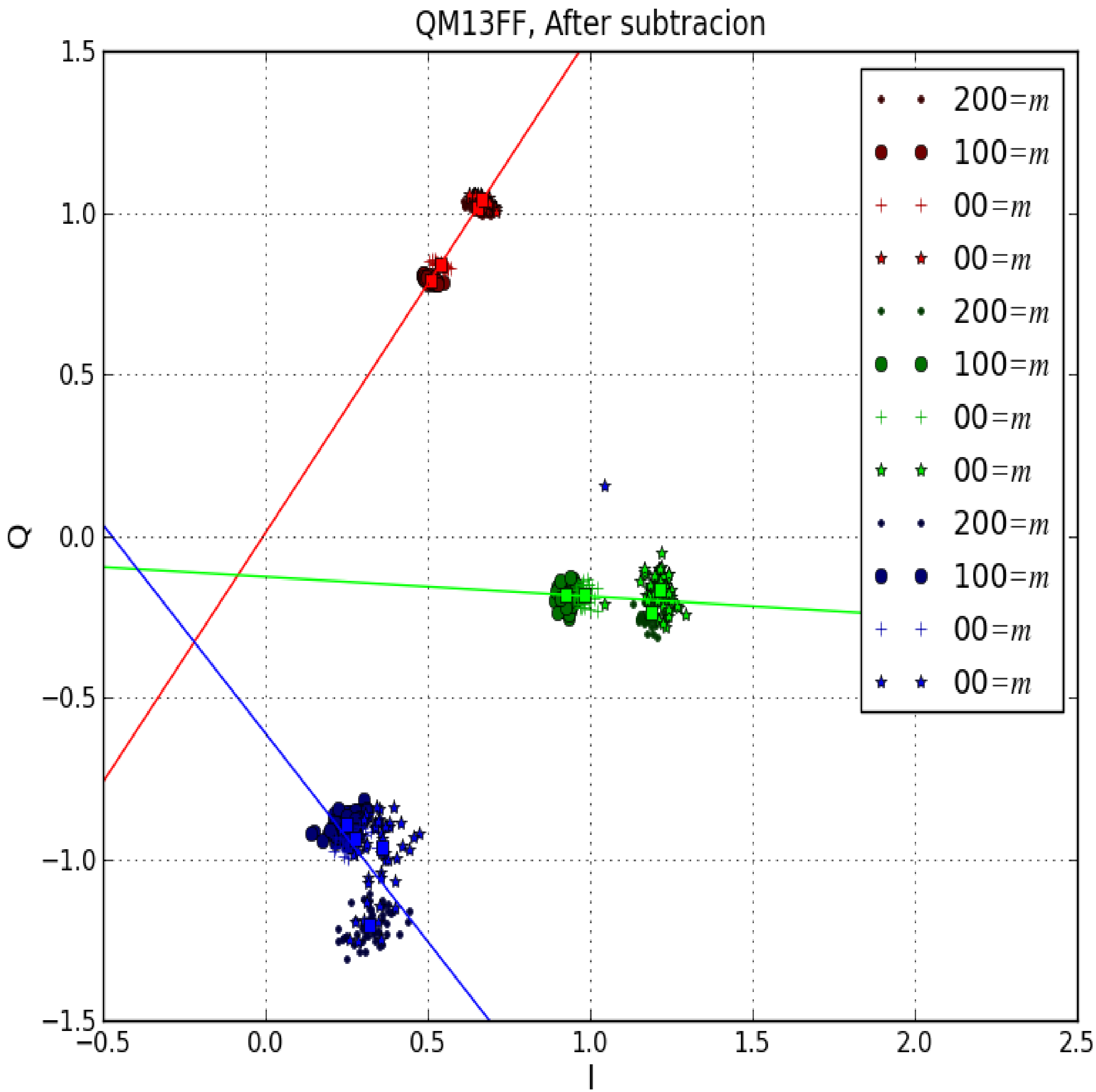
$$i_s(n) = i(n) - i(n-1)e^{\frac{-\Delta t_b}{\tau}}$$

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

- Subtracted signal is then normalized.
- Phase difference between bunches becomes even.

Rotation Angle:

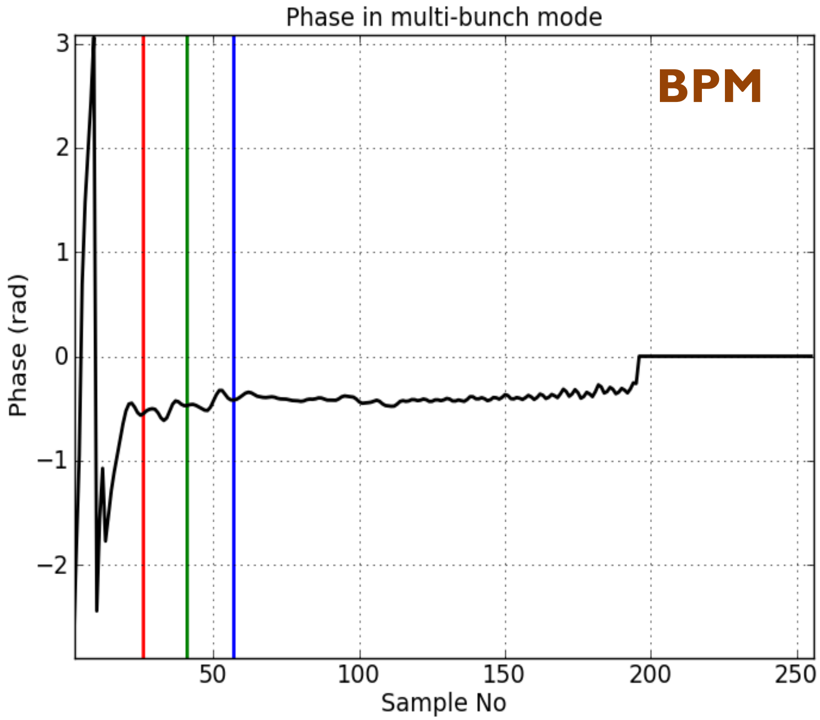
Bunch No	ϕ (rad)	$\lvert\Delta\phi\rvert$ (rad)
1	0.98778	
2	-0.04182	1.029609
3	-0.96794	0.926120

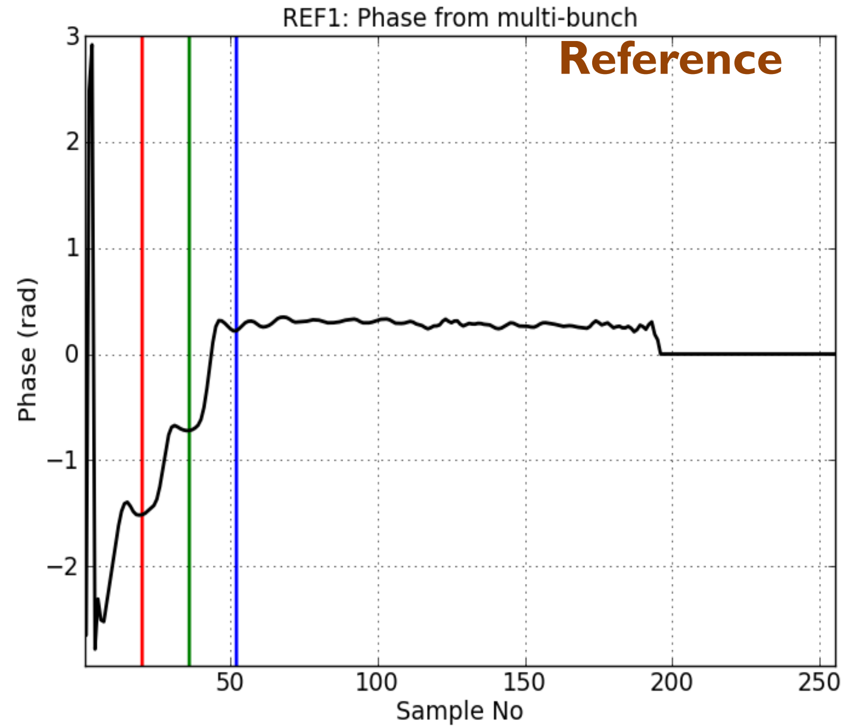


Phase difference between bunches

- 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 *1.2MHz., t*he bunch separation of 154ns will generate phase difference of 1.1611 rad, which agrees with observation.
- If BPM and reference cavities have different frequency and decay constant, then their effects can be removed by normalizing with following general equation.

$$I(/Q) = \frac{A_{BPM}}{A_{REF}} e^{-\left(\frac{1}{\tau_{BPM}} - \frac{1}{\tau_{REF}}\right)\Delta t_b} \times e^{i[(\phi_{BPM} - \phi_{REF}) - (\omega_{BPM} - \omega_{REF})\Delta t_b]}$$

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

- More data will be recorded for different BPMs over different position range.
- Jump in IQ phase between bunches is being studied.
- Results will be scanned over range of parameters, such as the digital filter bandwidth and data extraction sample points.
- Ultimate goal is to make BPM system online in multi-bunch mode as well.

Thank you