Tune Shift Along the Batch at 6.5TeV

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Acknowledgements: M. Giovanozzi, B. Salvant, G. Iadarola, X. Buffat

Overview

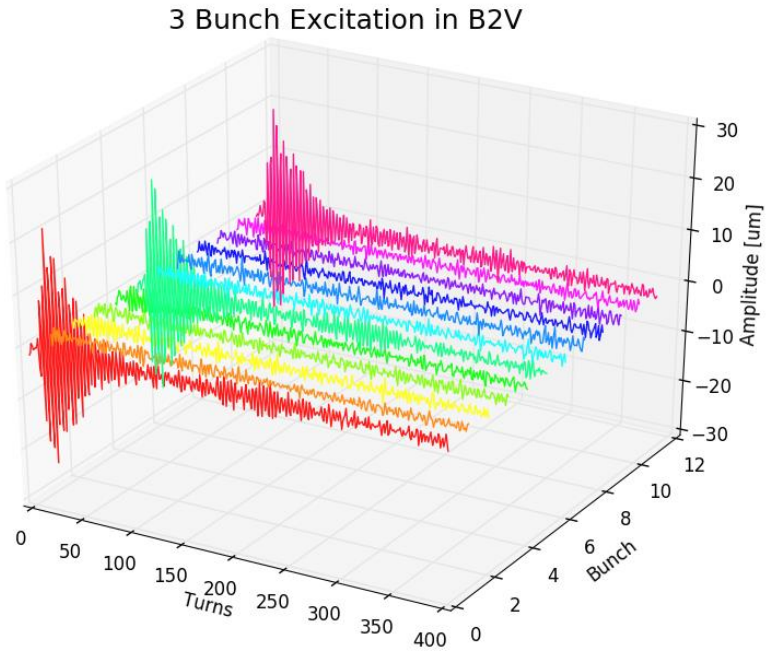
- In order to measure bunch by bunch tunes at flat top. Need to provide an excitation to provide some oscillation amplitude.

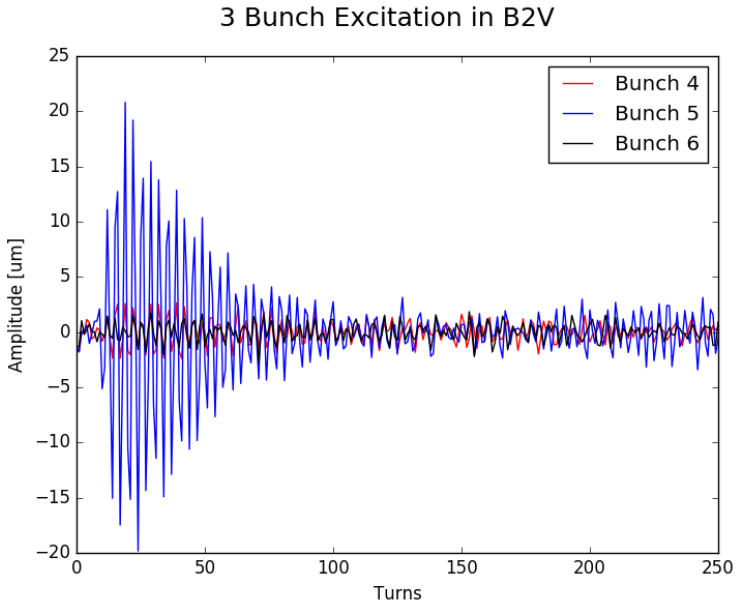
- We would like to get one measurement this year as input for simulations, but can refine the techniques next year during the intensity ramp up, but of course this provides a serious machine protection issue.

- After discussions with MPP, the compromise was that we can only excite one bunch at a time (in a full 2220b physics beam), and that the excitation settings have to be tested at injection and as an EOF MD.

Test of Excitation at Injection (Fill 5440)

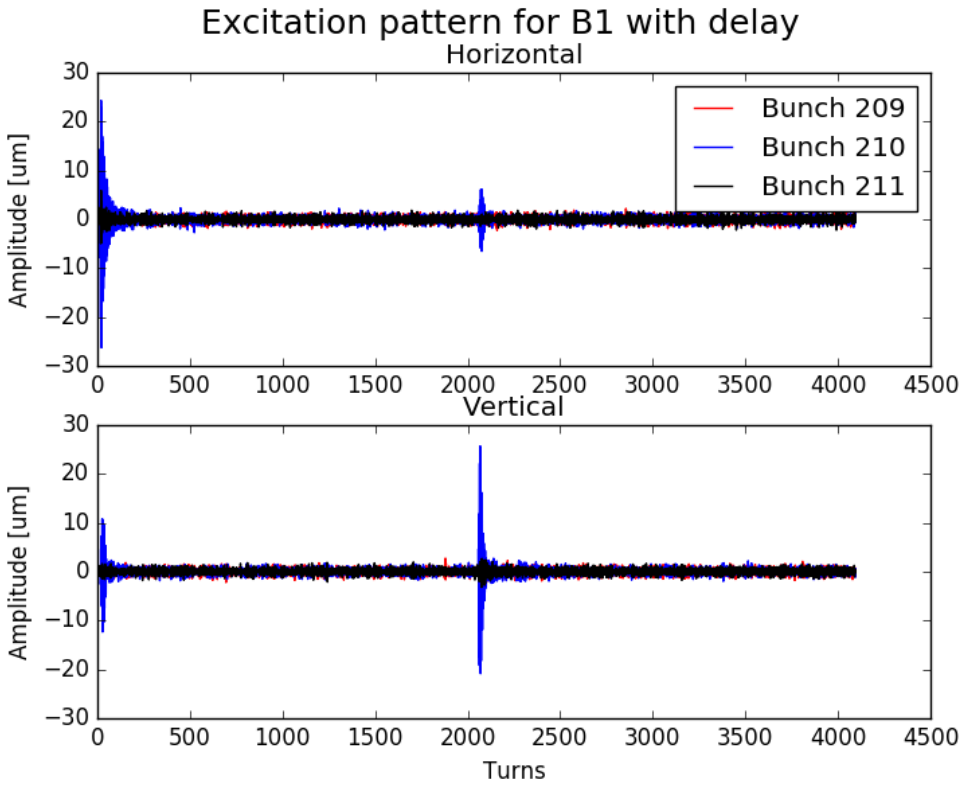
- After much refinement of the ADT excitation settings, we were able to kick any specified bunches at any point in the train without affecting its neighbours.
- Also tested bunch windowing and verified the single bunch excitation for bunches further along the train. Each time it behaved as expected, with minimal impact on the neighbours.
- Excellent process control.

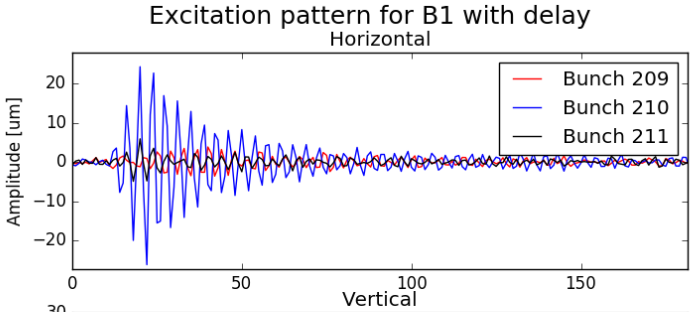


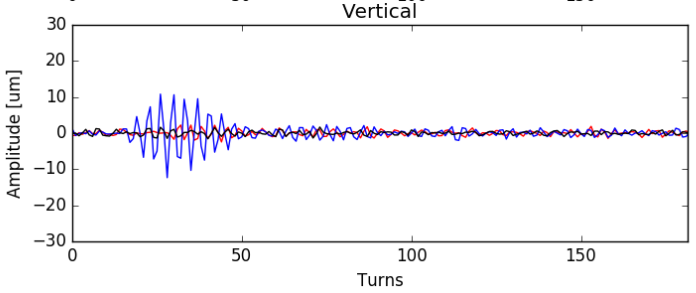


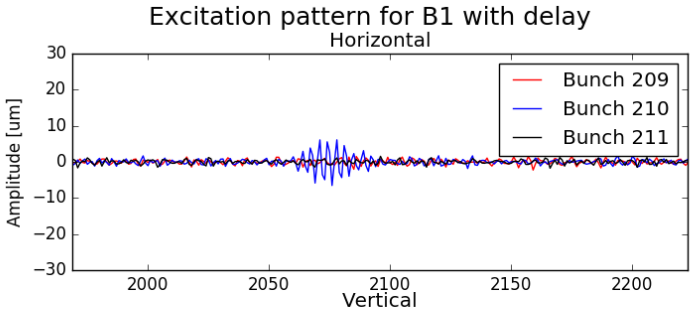
Test of Excitation at Injection (Fill 5440)

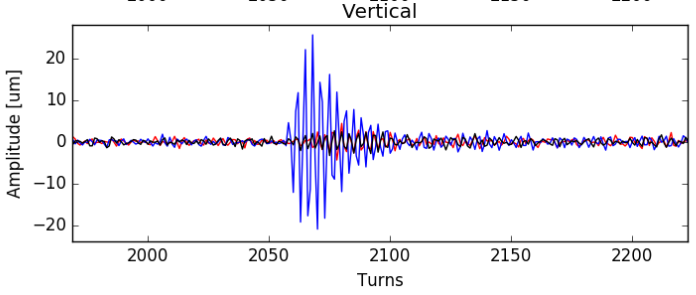
- The excitation pattern that will be used will kick in H followed by V with a delay of ~2000 turns.





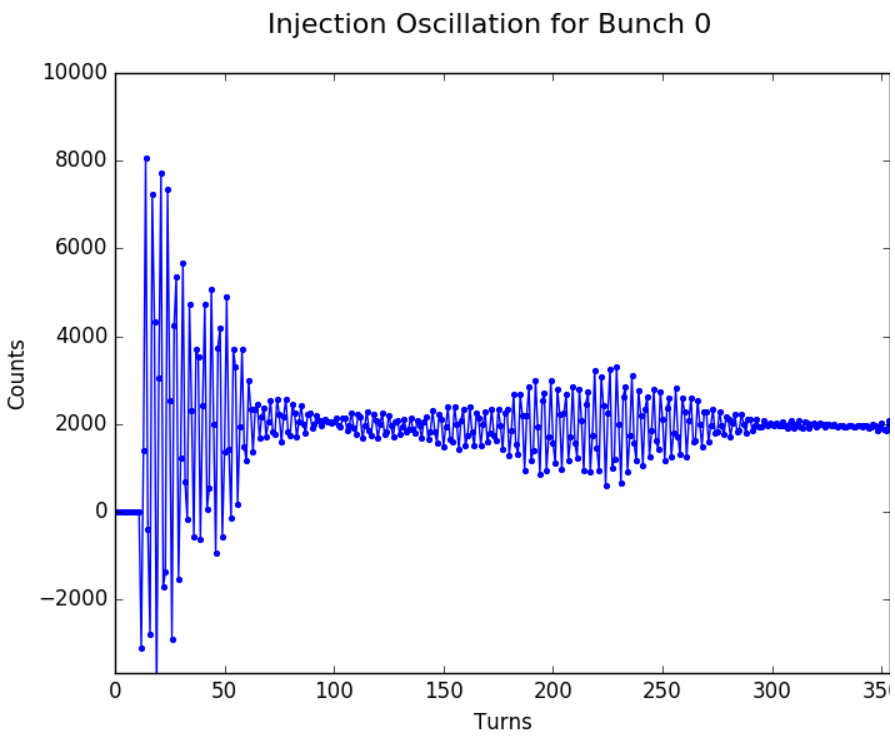


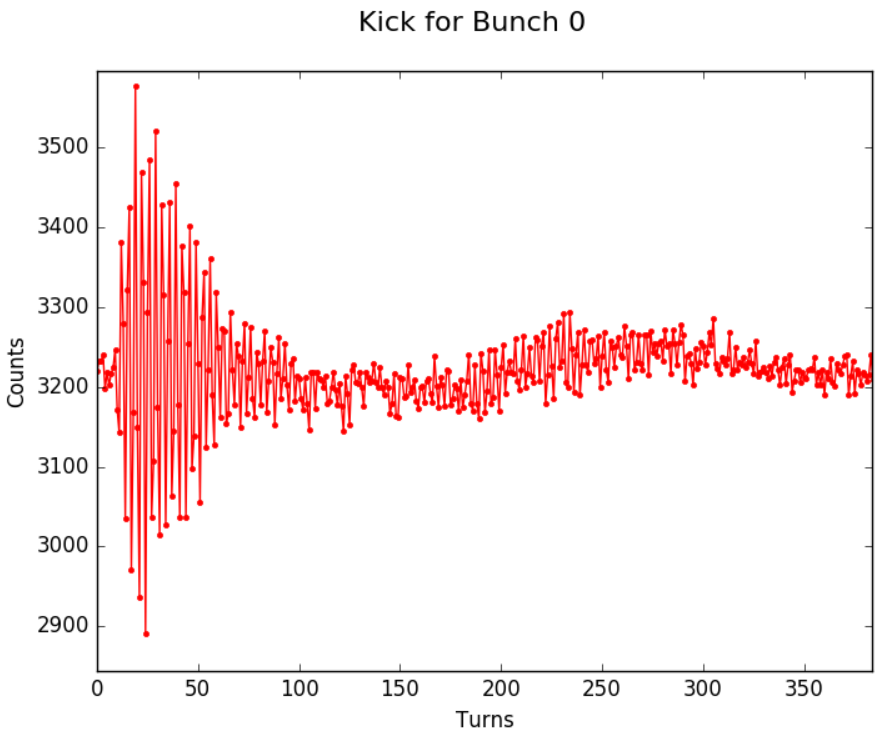




Kick vs Injection Oscillation

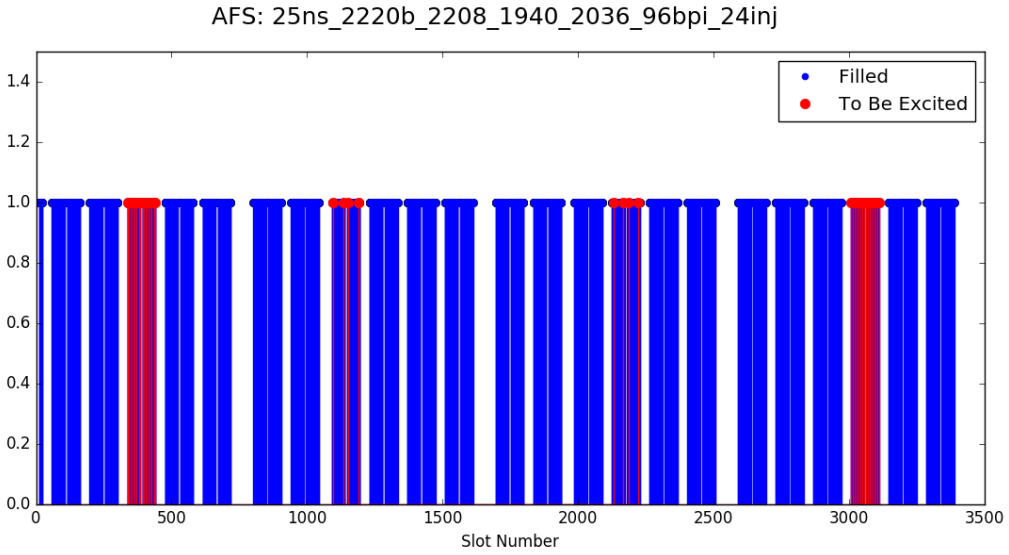
- Most of the kicks done at injection were on the 12 bunches in the ADT witness region.
- Can compare oscillation data from kicks to injection oscillations to see if it is possible to acquire a cleaner tune measurement.
- However, did not systematically kick along the batch so cannot obtain tune shift measurements (this could be implemented in the future and be performed during heat load validation).
- Have also setup PyHT notebook to understand analysis weaknesses better.

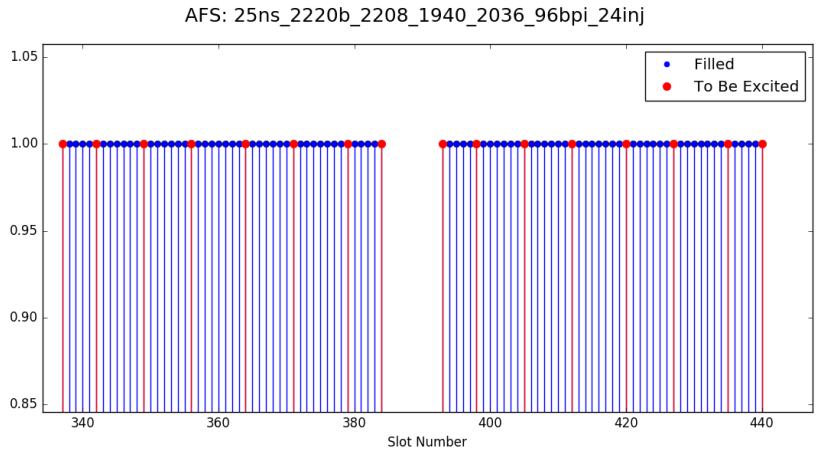


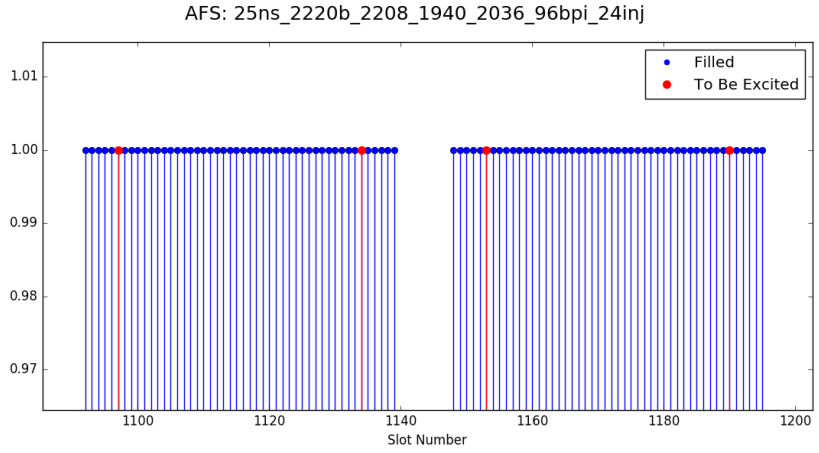


EOF MD (Fill 5442)

- 40 bunches have been selected to be excited in order to adequately sample the internal structure of the electron cloud build up. These can be seen below.

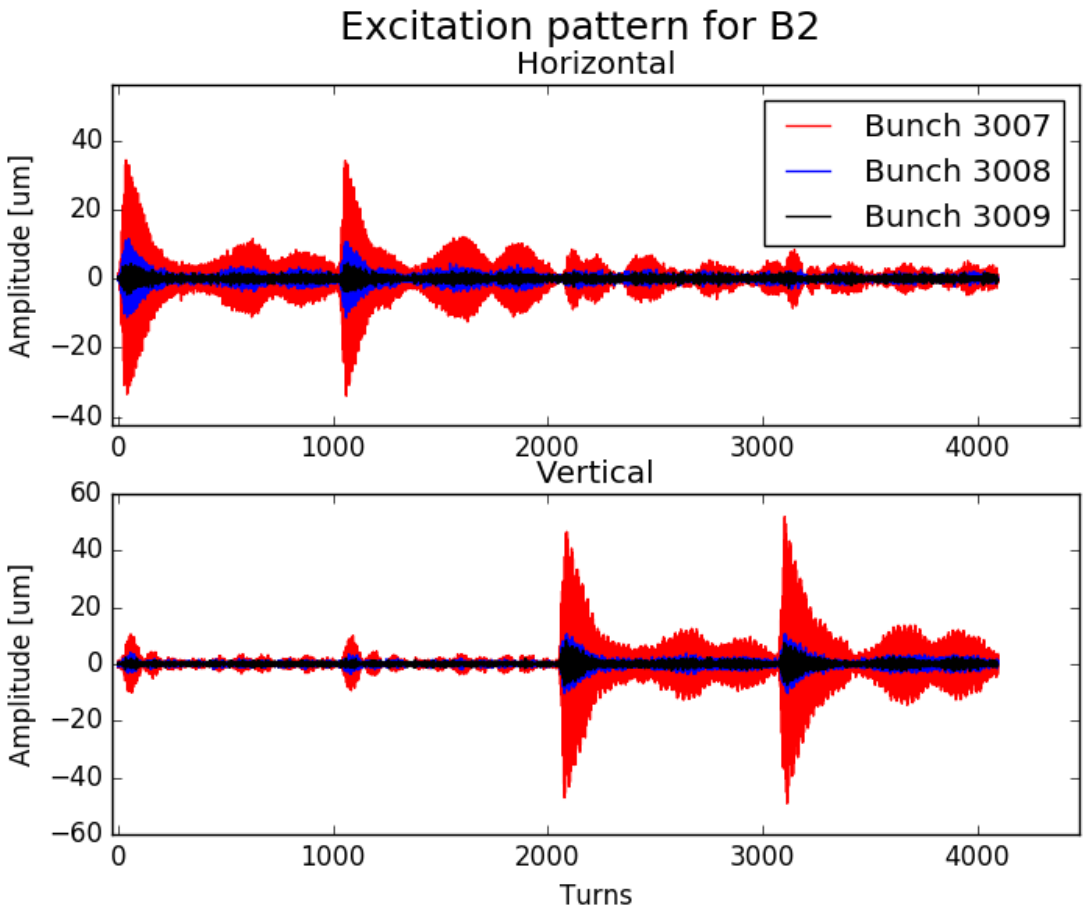






EOF MD (Fill 5442)

- The typical excitation pattern that was used can be seen below. Two kicks in H followed by 2 kicks in V.



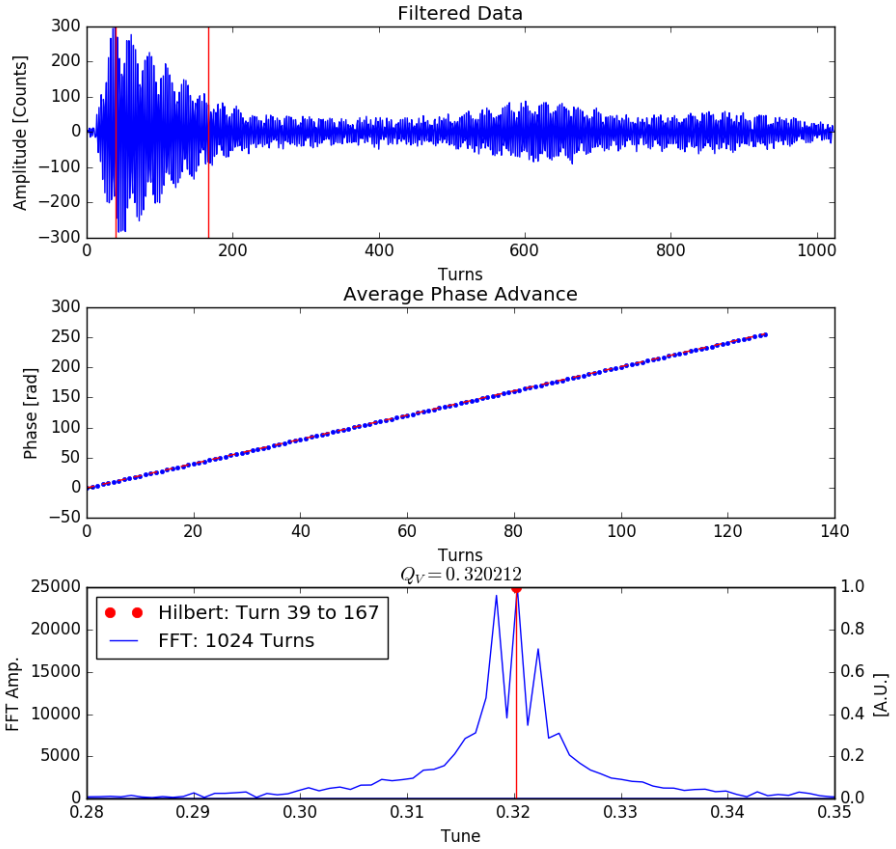
Measurements at Flat Top – Fill 5443 & Fill 5451

Techniques (1/2)

- Attempting to calculate the tune with several different methods. Standard tools like:

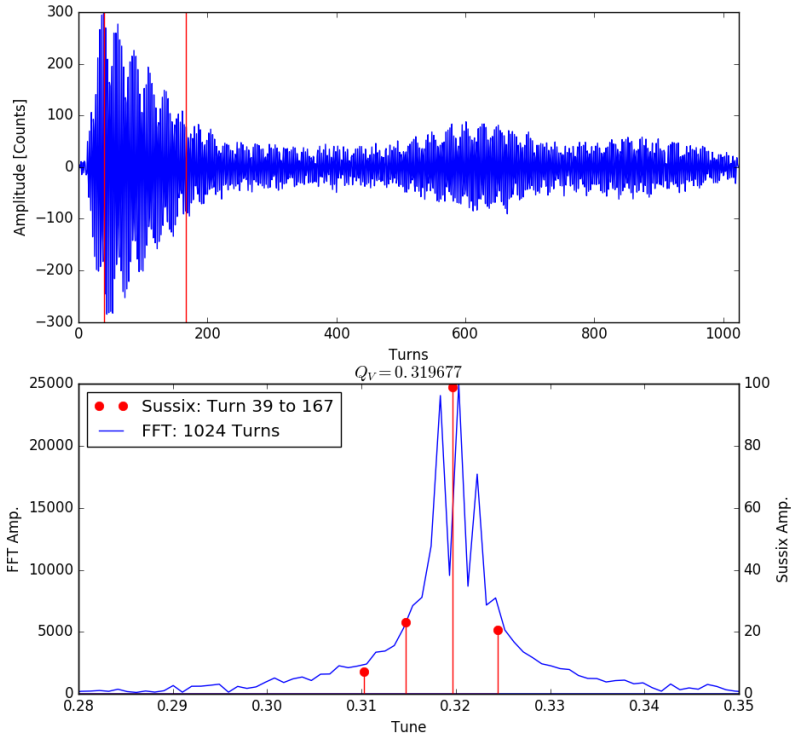
Average phase advance per turn via Hilbert Transform

Plane: B1V, Bunch 3007, Pickup: 7, Excitation: 1, Time: 101404



Sussix

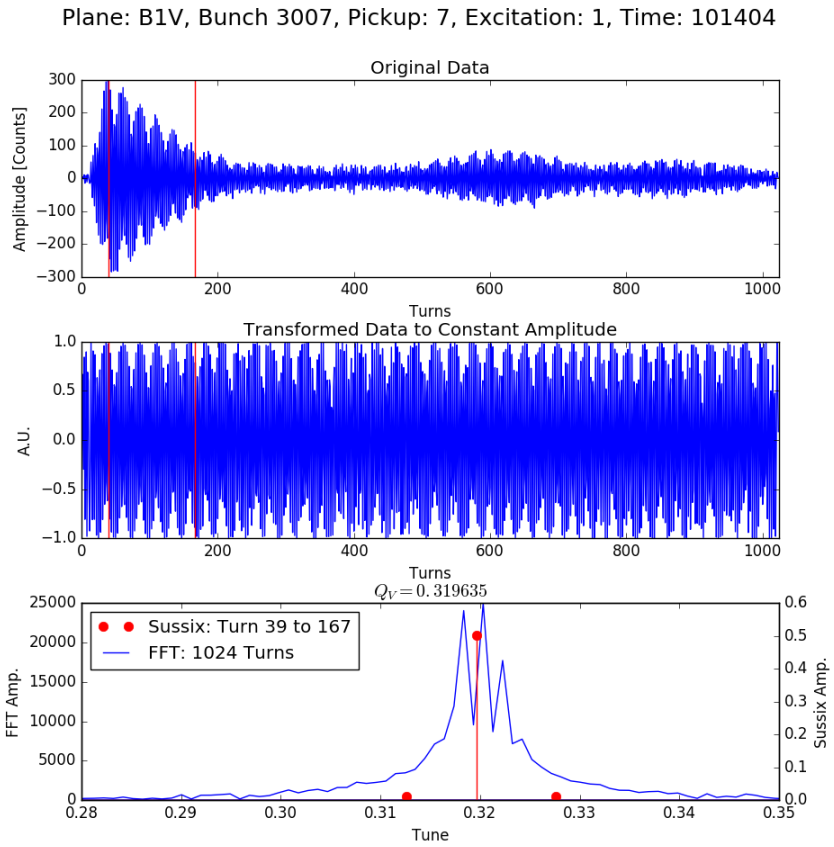
Plane: B1V, Bunch 3007, Pickup: 7, Excitation: 1, Time: 101404



Techniques (2/2)

- Some untested methods are also being explored, such as

Normalise original signal to its envelope and use Sussix



Interpolated Sussix for exponentially decreasing amplitude

Ongoing

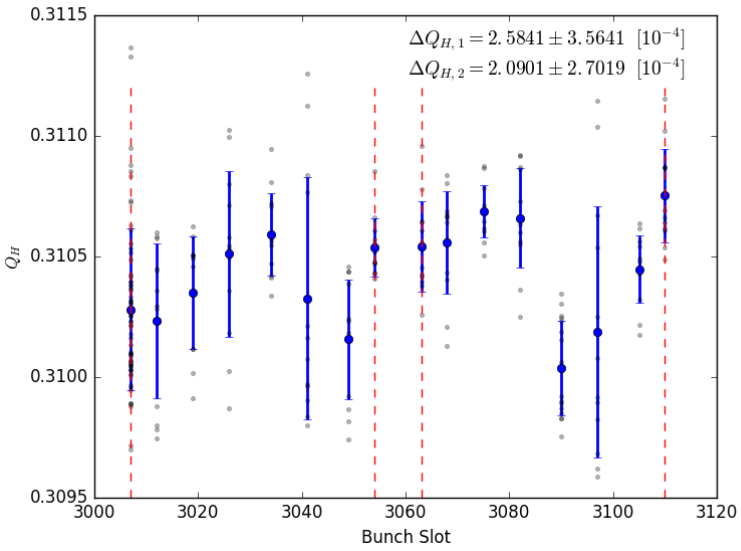
Use the data from Q7 and Q9 and reconstruct the complex signal for the analysis

Ongoing

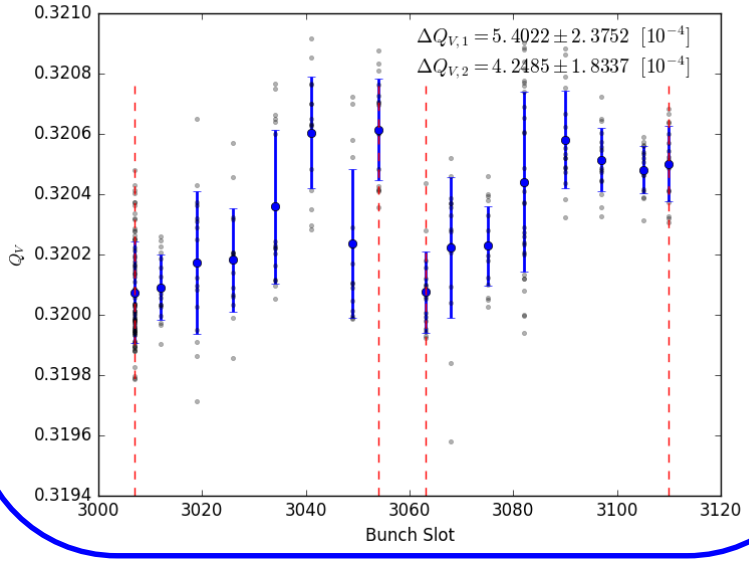
Hilbert Transform

B1

Tunes from Hilbert Transform along 96b batch for B1H

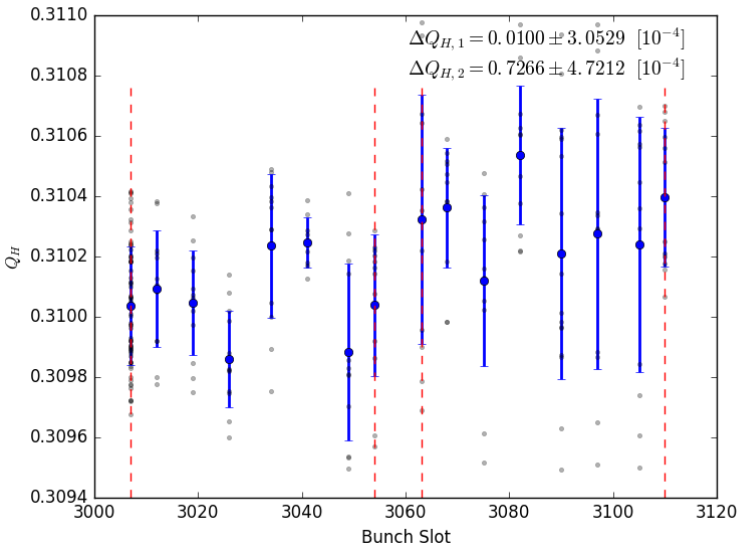


Tunes from Hilbert Transform along 96b batch for B1V

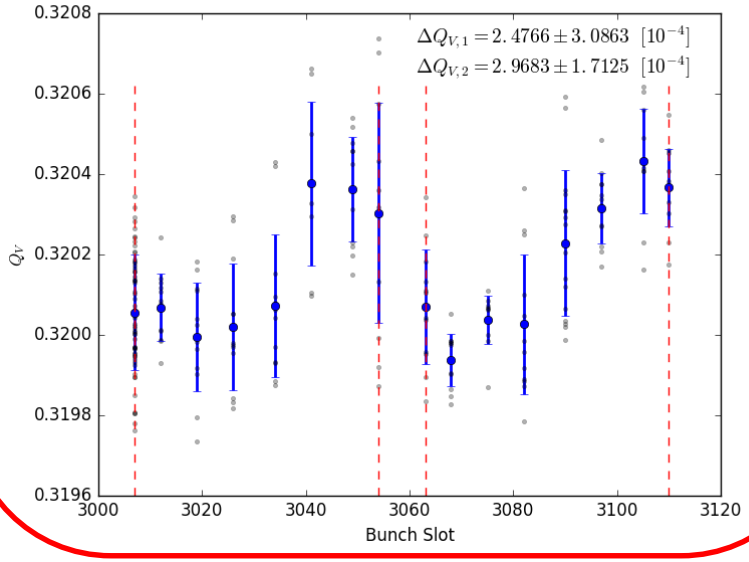


B2

Tunes from Hilbert Transform along 96b batch for B2H

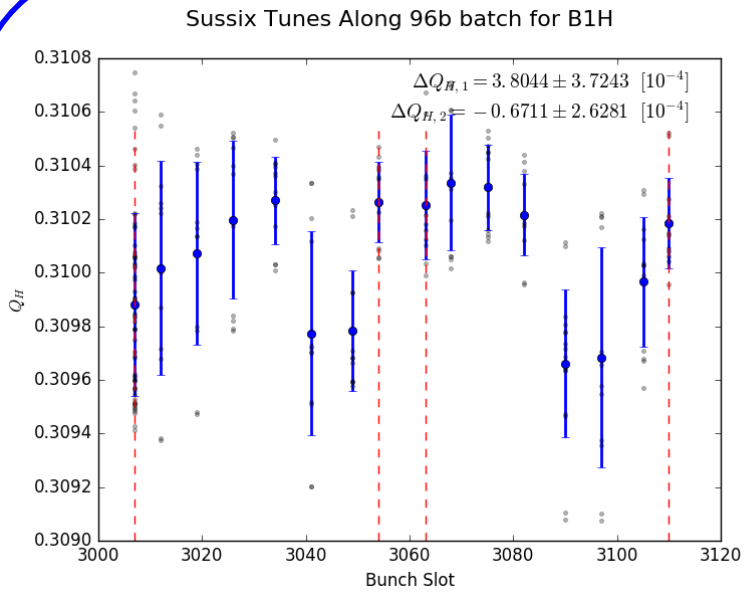


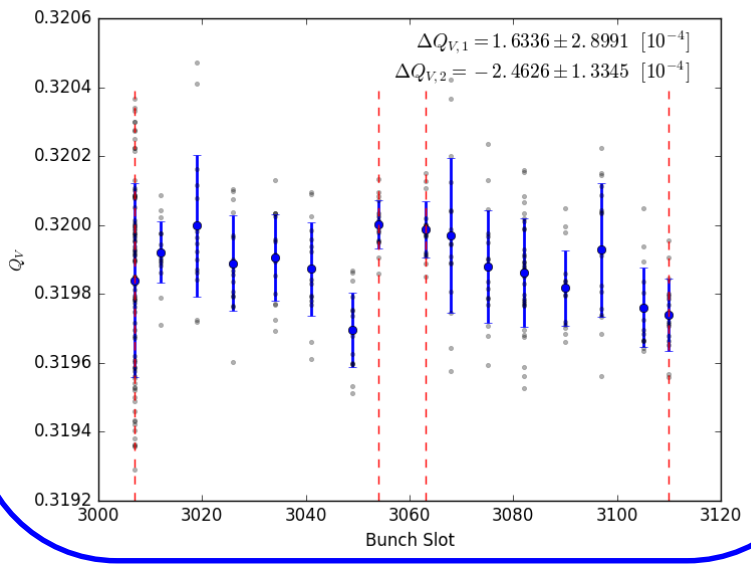
Tunes from Hilbert Transform along 96b batch for B2V



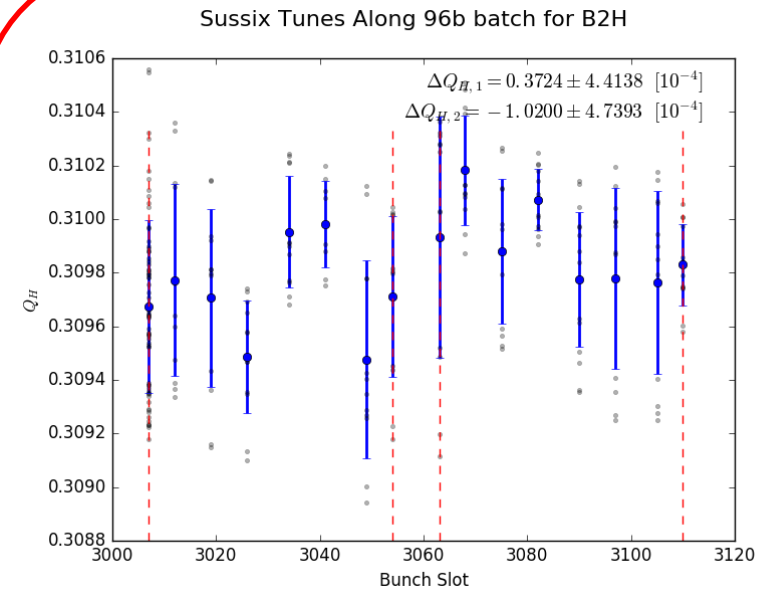
Sussix

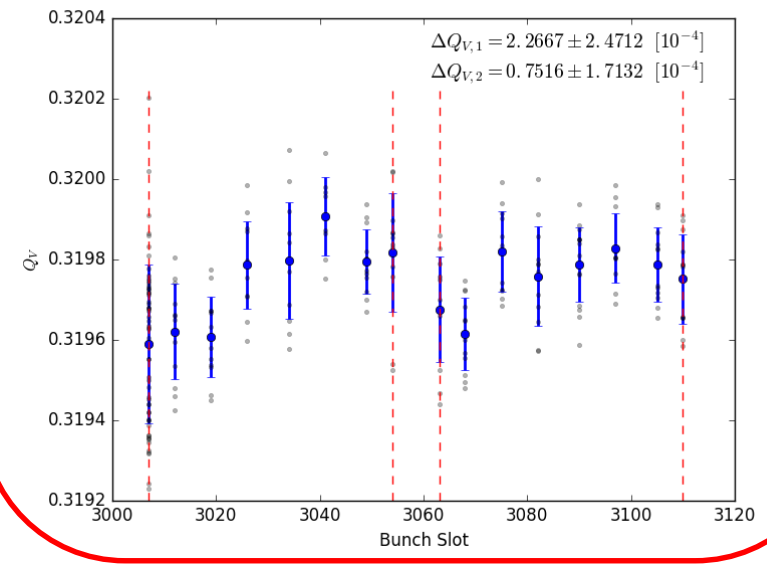
B1


Sussix Tunes Along 96b batch for B1H
$\Delta Q_{H,1} = 3.8044 \pm 3.7243$ $[10^{-4}]$
$\Delta Q_{H,2} = -0.6711 \pm 2.6281$ $[10^{-4}]$
Q_H
Bunch Slot


Sussix Tunes Along 96b batch for B1V
$\Delta Q_{V,1} = 1.6336 \pm 2.8991$ $[10^{-4}]$
$\Delta Q_{V,2} = -2.4626 \pm 1.3345$ $[10^{-4}]$
Q_V
Bunch Slot

B2


Sussix Tunes Along 96b batch for B2H
$\Delta Q_{H,1} = 0.3724 \pm 4.4138$ $[10^{-4}]$
$\Delta Q_{H,2} = -1.0200 \pm 4.7393$ $[10^{-4}]$
Q_H
Bunch Slot


Sussix Tunes Along 96b batch for B2V
$\Delta Q_{V,1} = 2.2667 \pm 2.4712$ $[10^{-4}]$
$\Delta Q_{V,2} = 0.7516 \pm 1.7132$ $[10^{-4}]$
Q_V
Bunch Slot

Conclusions

- Some hint of a tune shift in the vertical plane that is larger for B1 than B2 but is not seen consistently over different calculation techniques.
- Some time now needs to be spent to understand the data and also to compare with simulations in PyECLOUD with the same parameters.
- The fact that we successfully kicked a single bunch at flat top with a full beam in the machine is already a huge achievement.
- Will be able to kick more aggressively with both single bunches and full batches next year where it can be tested during the intensity ramp up.