Tune modulation on the PS injection bump

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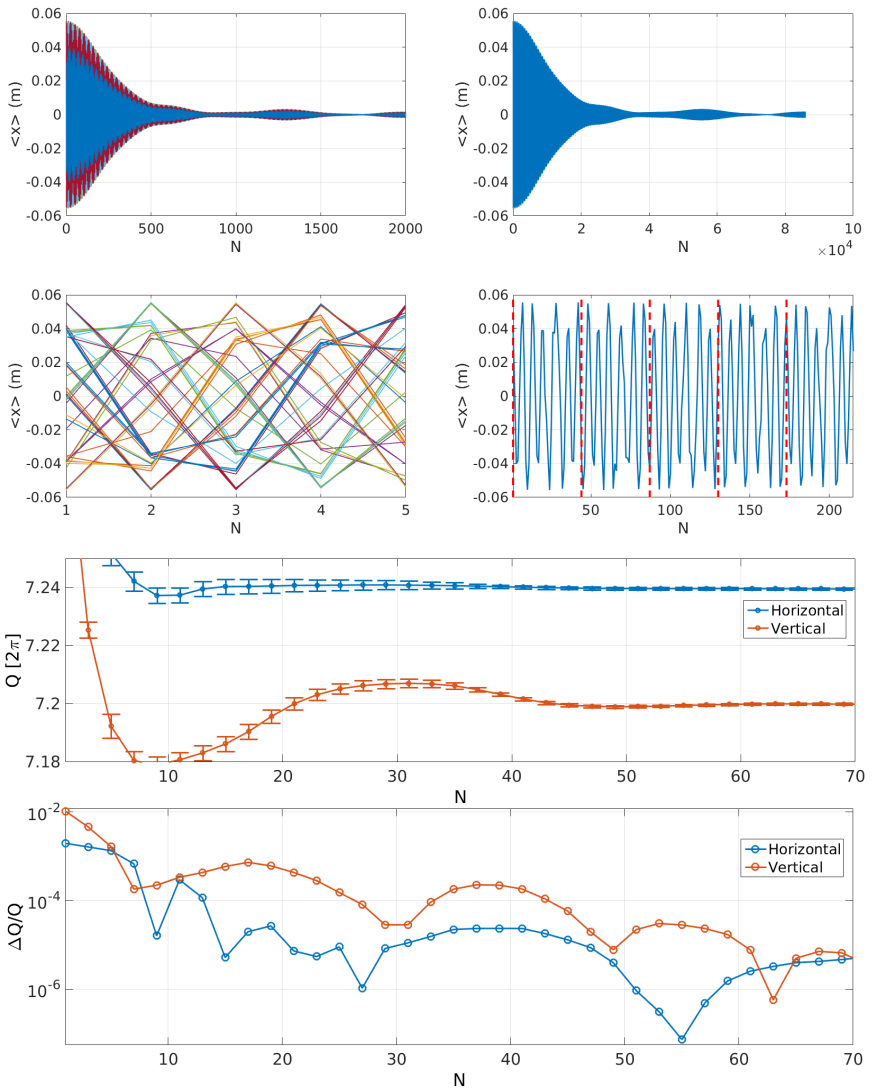
Outline

- A novel method to measure the tune
- MD Results 1/2
- (Preliminary) MD Results 2/2
- Conclusions

A novel method to measure the tunes

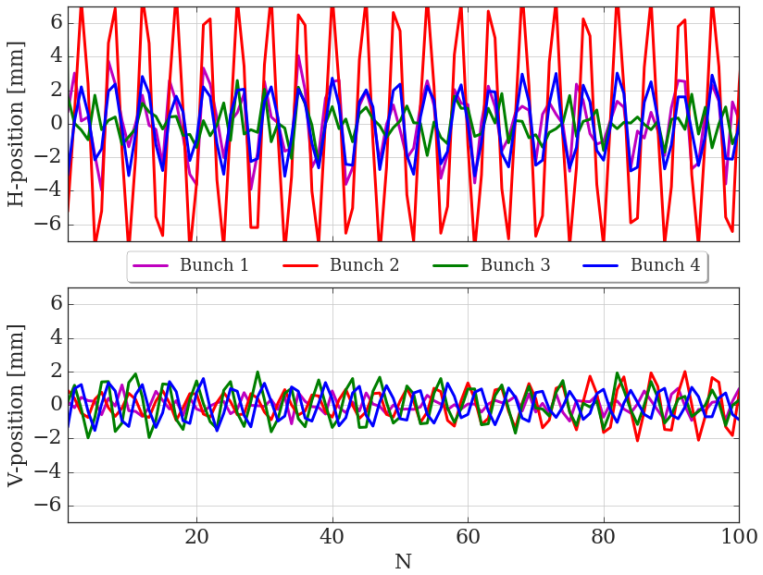
- Refined Fourier analysis with NAFF for precise tune measurements.
- Theoretical convergence of NAFF: $\omega-\omega^T \sim 1/N^4$, N number of turns.
- Convergence can be further accelerated by mixing all the BPM data together [1]: $\omega-\omega^T \sim (1/\mathbf{M}^3N^4) + \delta(M)$, M number of BPMs, $\delta(M)$ is the sampling error.
- As a by-product the integer part of the tune can be also recovered.

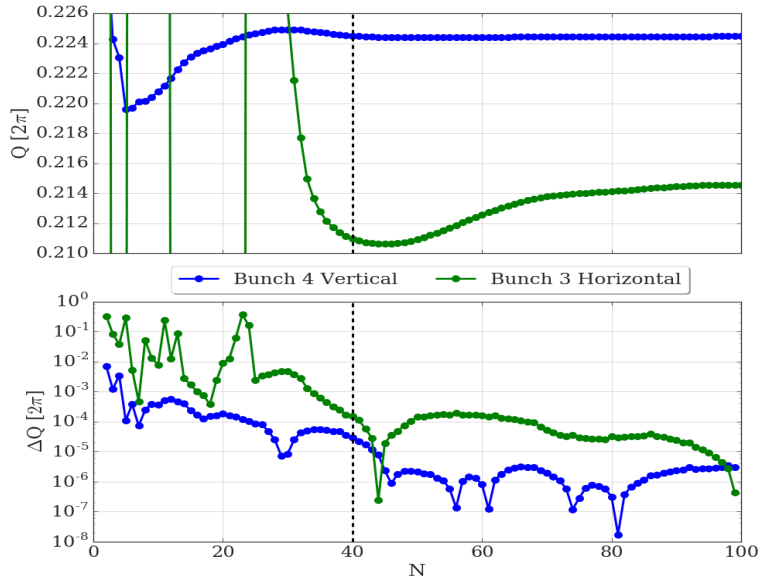


[1] P. Zisopoulos "Beta-beating at the PS", 16th MSWG Meeting, 11/11/2016 (https://indico.cern.ch/event/587300/)

Benchmarking the method at the PS

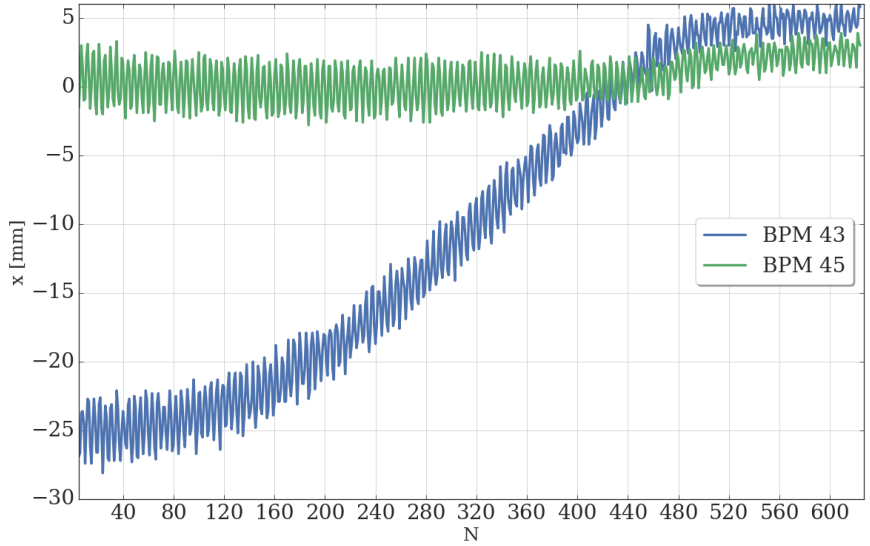
- An MD was performed in 2016 to benchmark the method as a potential on line frequency analysis tool.
- It can provide bunch by bunch tune information for a very small number of turns.
- For that MD, LHCINDIV beam was used with 4 bunches at injection energy. Bunch by bunch turn by turn data ~ 600 turns at 43 BPMs
- The 4 bunches have different oscillation amplitudes due to ring-by-ring injection differences from the PSB.
- For the worst case scenario (Bunch 3 horizontal) the tune is recovered at around 40 turns.

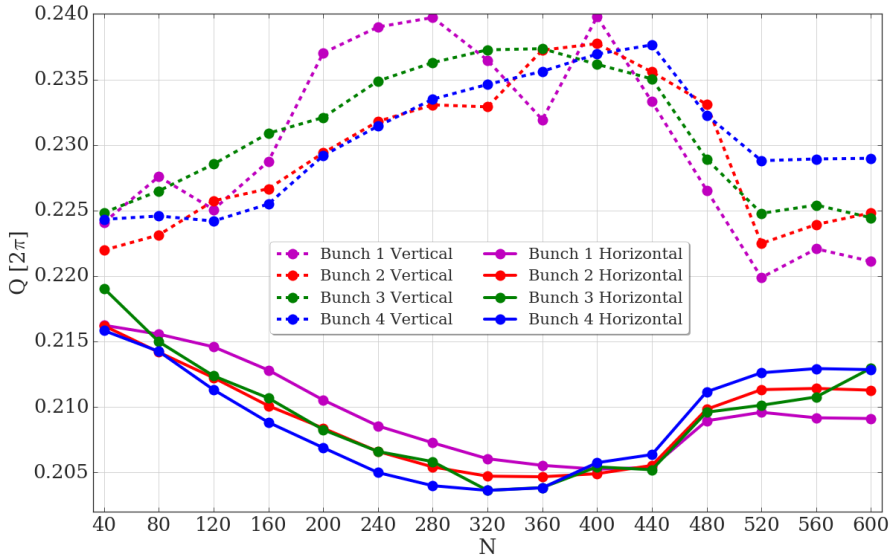




MD Results 1/2: Tune modulation from the injection bump

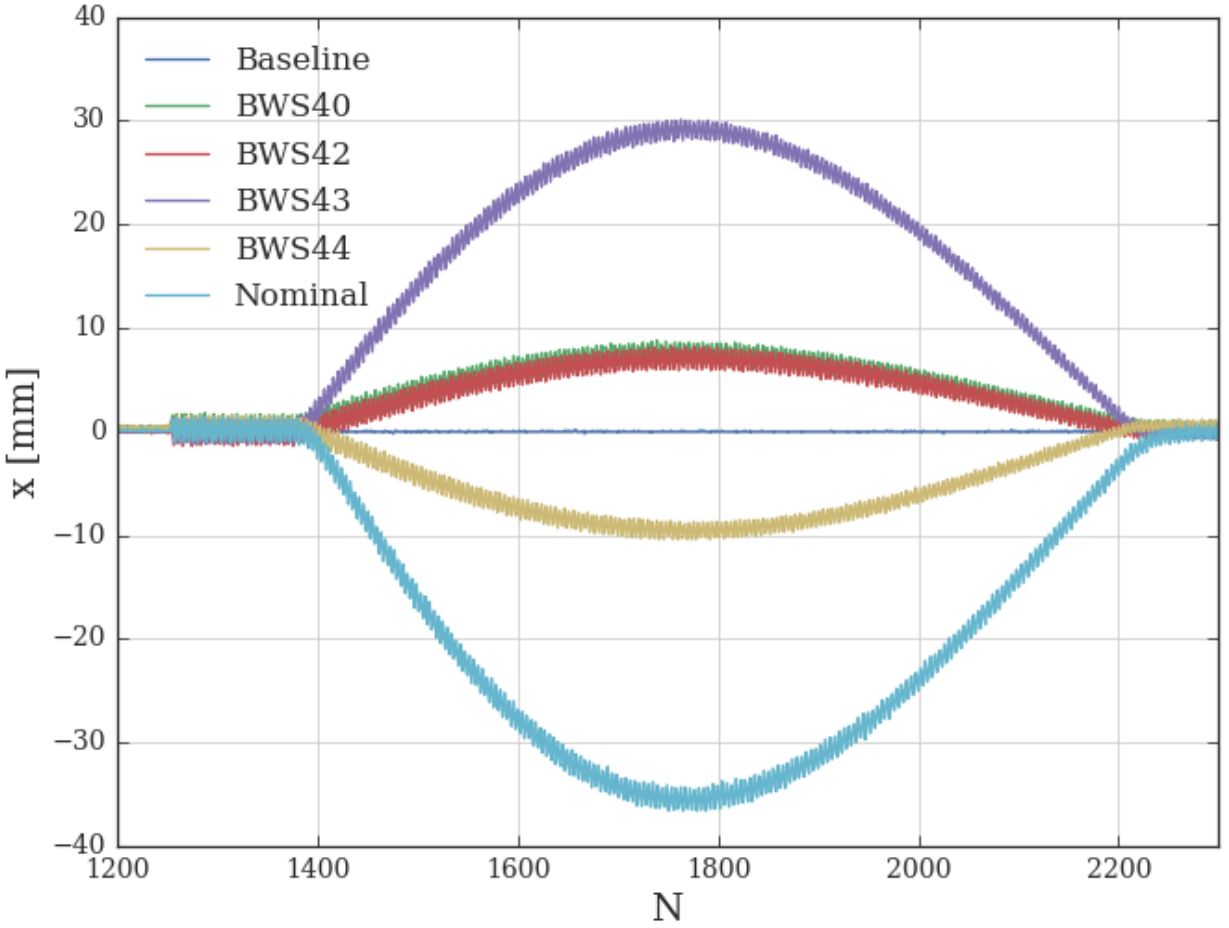
- Large orbit displacement at the injection region.
- A scanning window of 40 turns was used for tune estimation along the turn by turn data
- The results provided with very precise measurements, revealing a tune modulation and tune-shift of **10^{-2}**
- Maximum tune-shift: Horizontal tune reveals chromatic effects as well (injection errors)
- Modulation appears to be related to the B dot (eddy currents on the chamber?)





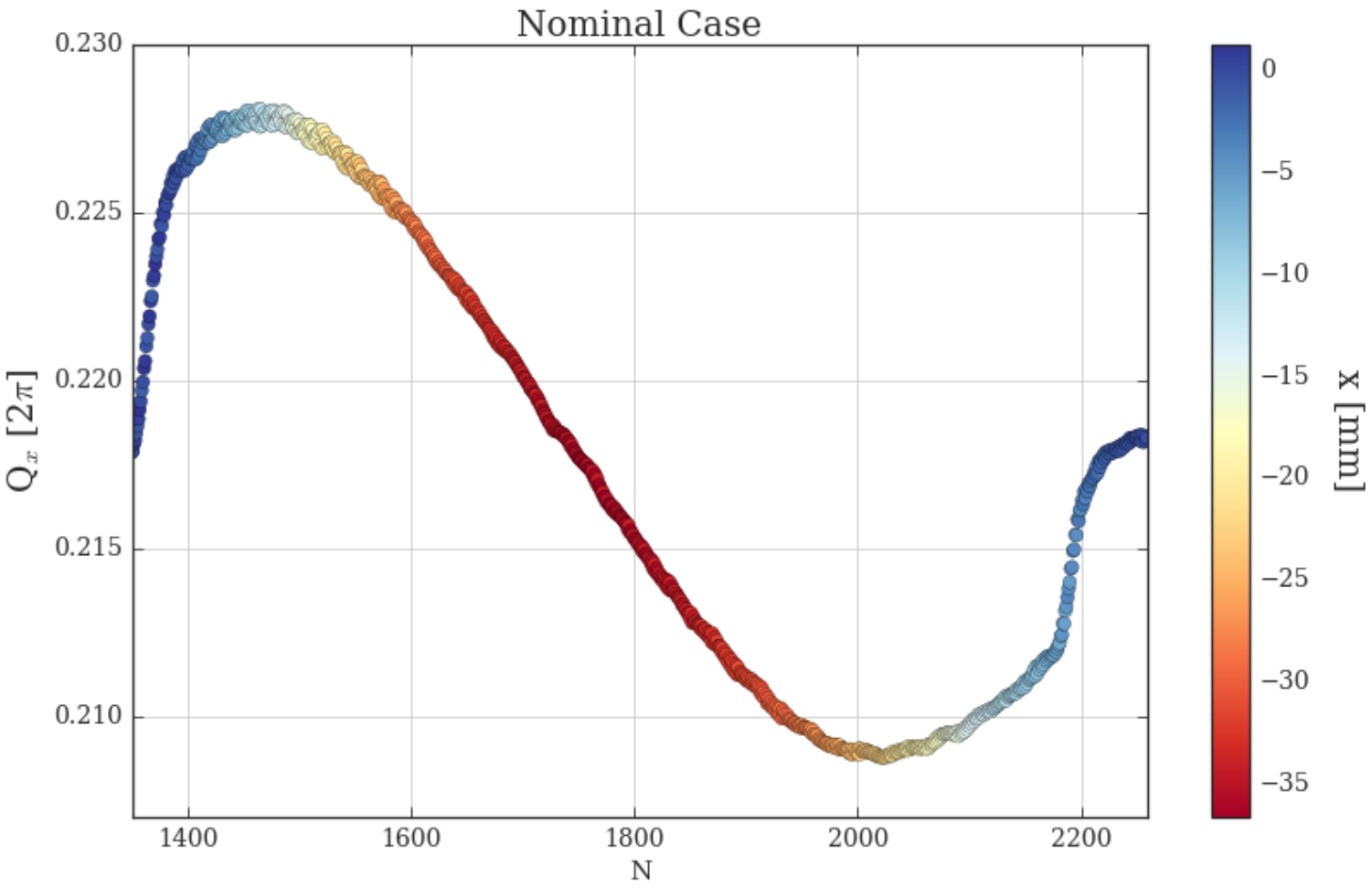
MD 2/2: Preliminary results with BCMS

- In order to investigate the tune modulation an MD was scheduled for tune measurements with turn by turn data.
- Measurements with BCMS beam gated at a single bunch at the second batch of injection.
- Data were taken for:
  - All bumps on (nominal case)
  - All bumps off (baseline)
  - Firing the bumpers separately
- Each case was also taken for :
  - With and without excitation from the tune kicker
  - With and without the radial loop
  - With and without the septum



Orbit at BPM 43 in the injection bump

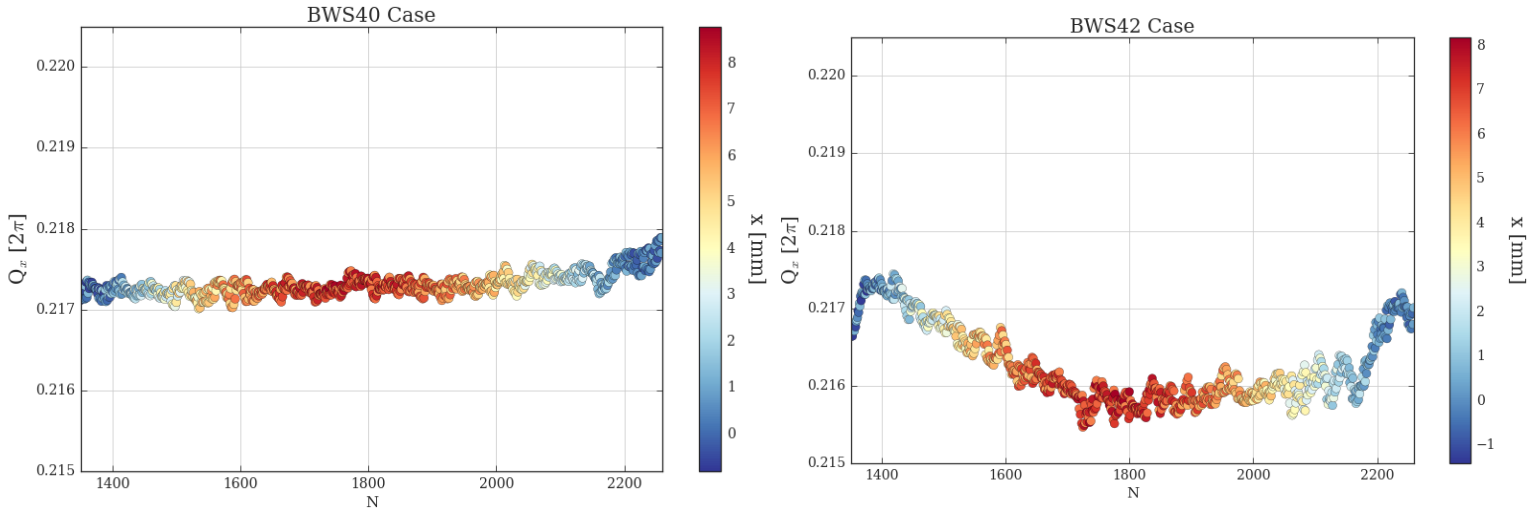
Tune Scan of 40 turns for Nominal case



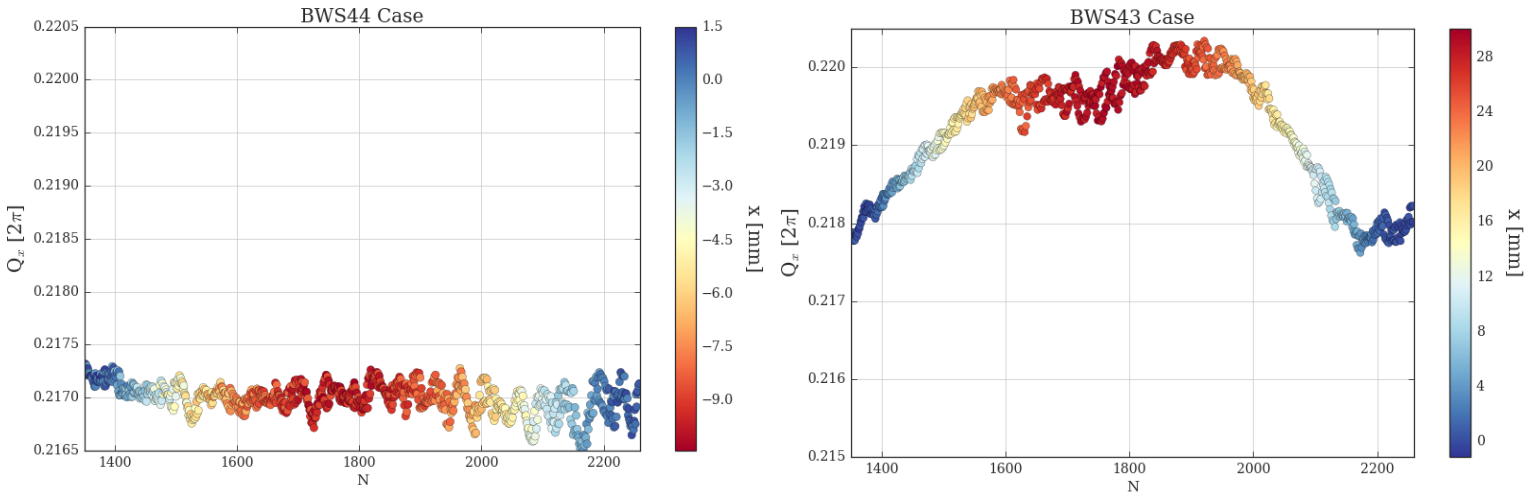
- The color bar is the orbit amplitude measured at BPM 43 (Injection region)

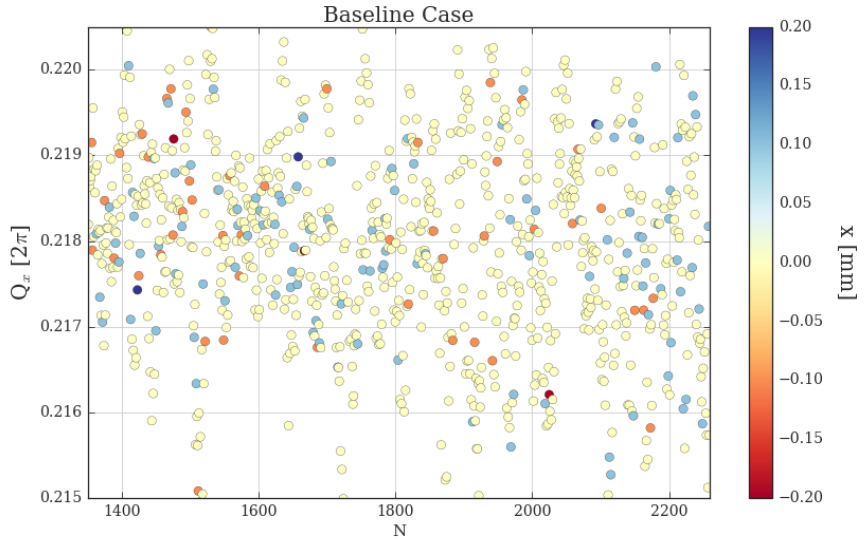
Bumper	Current [kA]
BWS40	1.07
BWS42	3.95
BWS43	3.10
BWS44	1.19

Tune scan of 40 turns for separate bumpers and Baseline case



Bumper	Current [kA]
BWS40	0.17
BWS42	0.59
BWS43	0.49
BWS44	0.18





Conclusions

- Precise tune measurements are possible using the mixed BPM method and PyNAFF even without exciting the beam. Fast quadrupolar shifts can be detected, even without beam excitation!
- A tune modulation at injection is reported that can lead a tune-shift of 10^{-2}.
- LIU-PS 2 GeV injection bump: Need to understand this phenomenon with the old bump first!
- A series of MDs concentrated on the injection bump are taking place and the preliminary results have been showed.
- In the preliminary results the tune-shift is explored , leading to conclusion that multipoles in the machine cause feed-down effects due to eddy – currents . (Any more possible scenarios?)
- Work in progress! : Need to reproduce measurements in simulations, post process all the data etc.