LHC Injection Tunes
(first experiences)

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Summary

Motivation to study LHC tunes at injections:

- understand the machine and our models.

Motivation of this talk:

- getting precise tunes at injection is not as straightforward
- we want to share the experience and give feedback for next run to improve measurements and data taking.

Summary

- Review of harmonic fit
- LHC available data
- Some initial results
- Systematic effects being studied

Harmonic fit

Given a discrete signal in the form:

$$x(N) = A_{xx}\cos(2\pi Q_x N + \Phi_{xx}) + A_{xy}\cos(2\pi Q_y N + \Phi_{xy}) + \xi_x(N)$$
$$y(N) = A_{yx}\cos(2\pi Q_x N + \Phi_{yx}) + A_{yy}\cos(2\pi Q_y N + \Phi_{yy}) + \xi_y(N)$$

Estimate the coefficients Q, A, Φ, despite the noise ξ. For kicked beams also A is function of N, e.g.:

$$A(N) = Ae^{-N/\tau}$$
$$A(N) = A + B\,N + C\,N^2$$

There are several methods [1,…] and depending on N, the noise and data themselves, they can be more or less effective.

Some reference:

[1] R. Bartolini et al., Algorithms for a precise determination of the betatron tune (1996) and reference therein…

[...] Many other papers and methods also outside the accelerator domain

Methods

Methods Families:

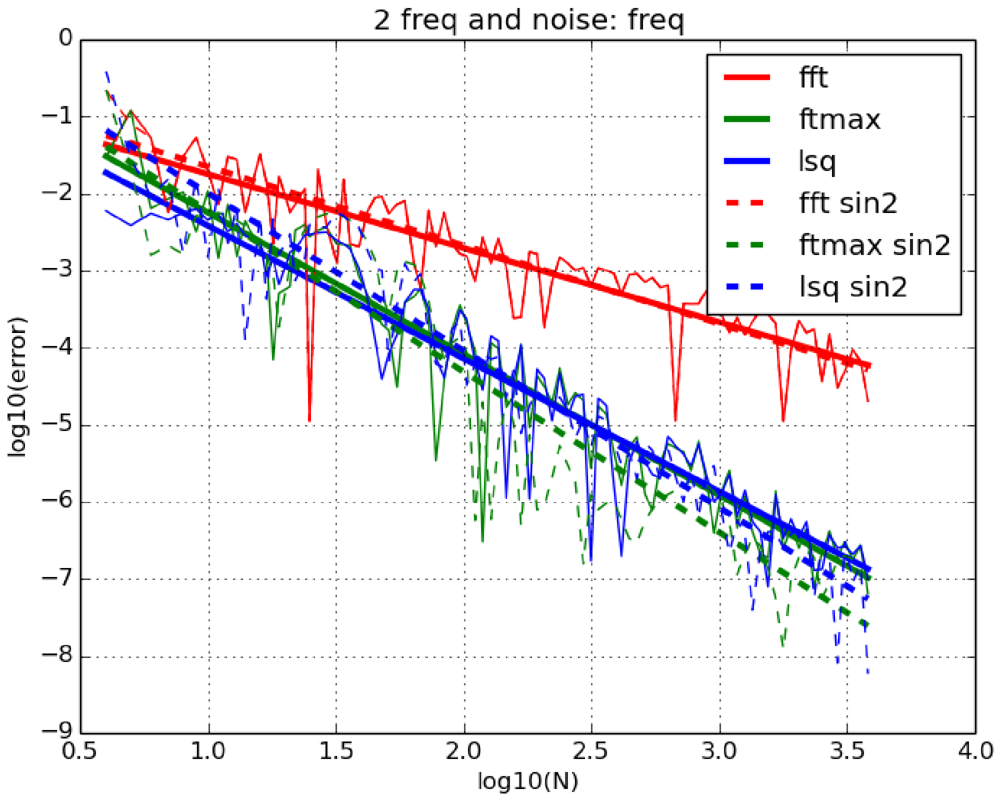
- Max FFT: fast, coarse, model independent.
- Max FFT with interpolation: fast, precise, model dependent, closed formulas not always available.
- Max FT: slower, precise, model independent, easy to implement.
- Least square fitting: slowest, very precise for small N, small noise, model dependent, easy to adapt.

Data conditioning:

- Windowing (e.g. Hanning): increase frequency accuracy at the cost of larger errors from close frequencies (not good when amplitude information is needed and to use with care with tune modulation).
- Hilbert transform normalization: remove amplitude modulation (to use with care when SNR drops).
- Reject 50Hz harmonics (if N is sufficiently large).

Benchmark

$$Q_x = 0.28 \; Q_v = 0.31 \; A_{xx} = 1 \;\; A_{xv} = 0.3 \; |\xi_x| < 0.1$$



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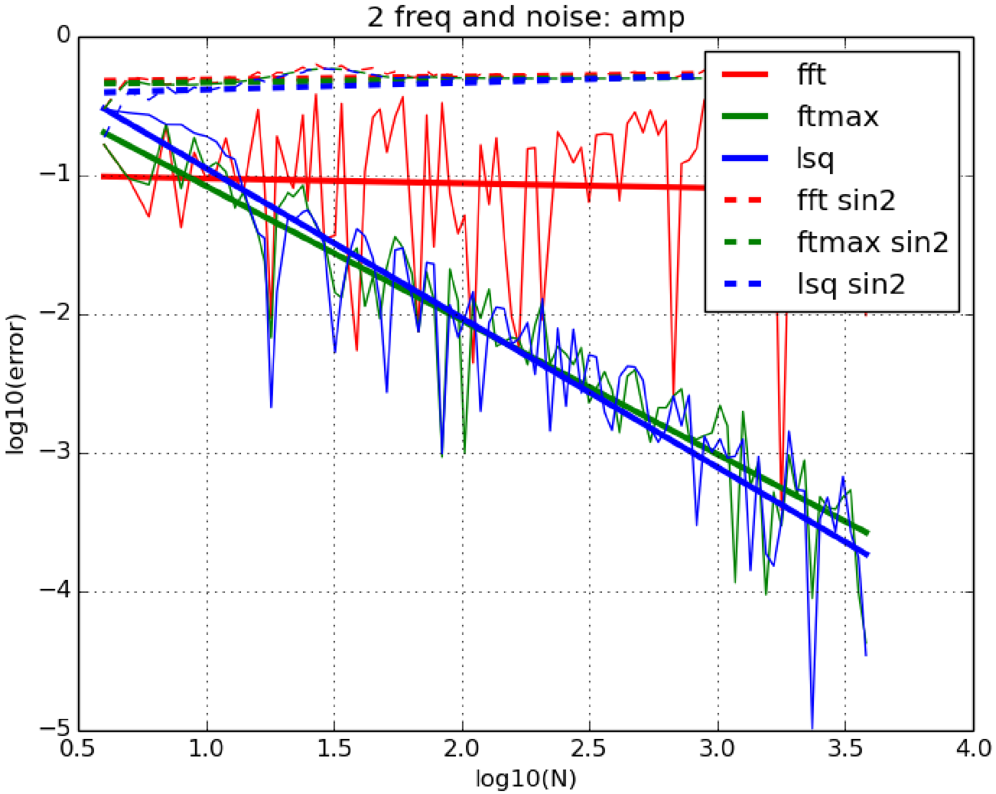


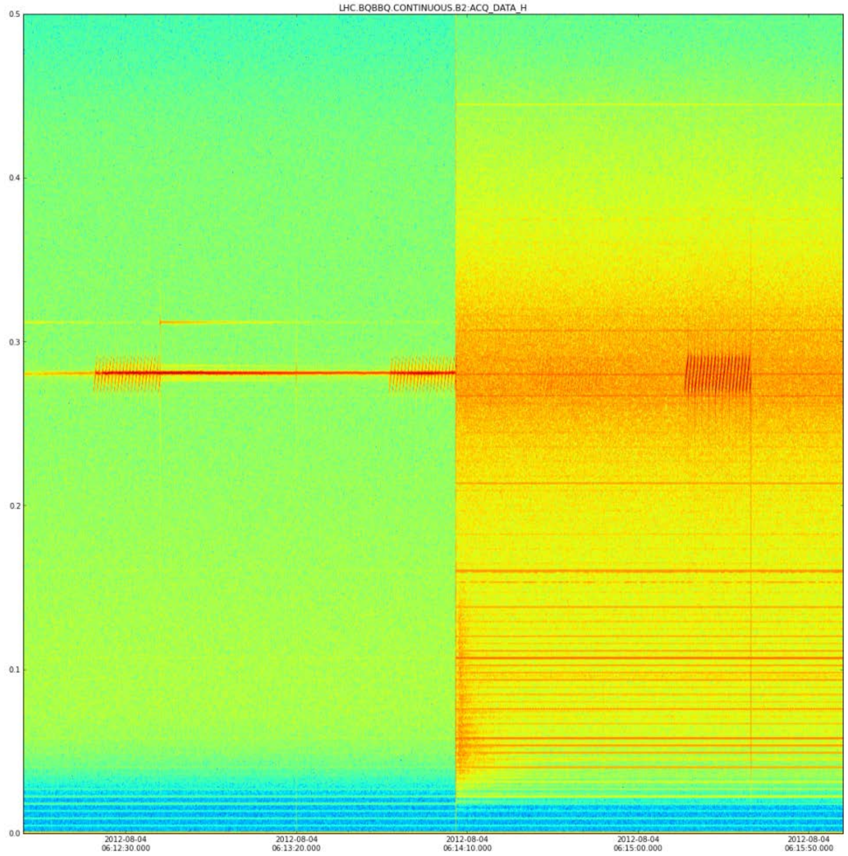
LHC available data

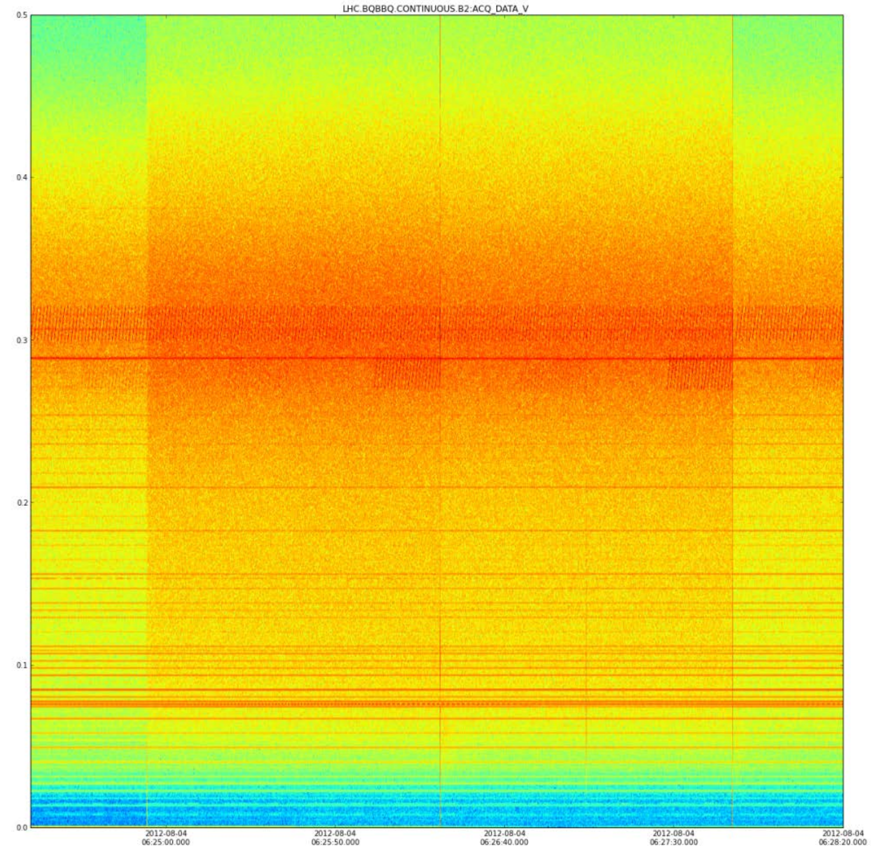
- BBQ: BSFU tunes, BBQ tunes, FFT data, raw data in Logging DB and locally saved data. Available for almost all run I but, gated BBQ data after Oct 2012 “lost” in change Logging DB names, signal source not logged, (sparse private datasets are available).

- Normal BPM: turn-by-turn bunch-by-bunch of the last injected batch at injection. Data nfs fill_data repository, perhaps more data in the IQC. Beam1: 17 BPM odd arc 3-4 50 turns (noisy from about 25th turn). Beam2 only 10 turns from 5 BPM in IR5.

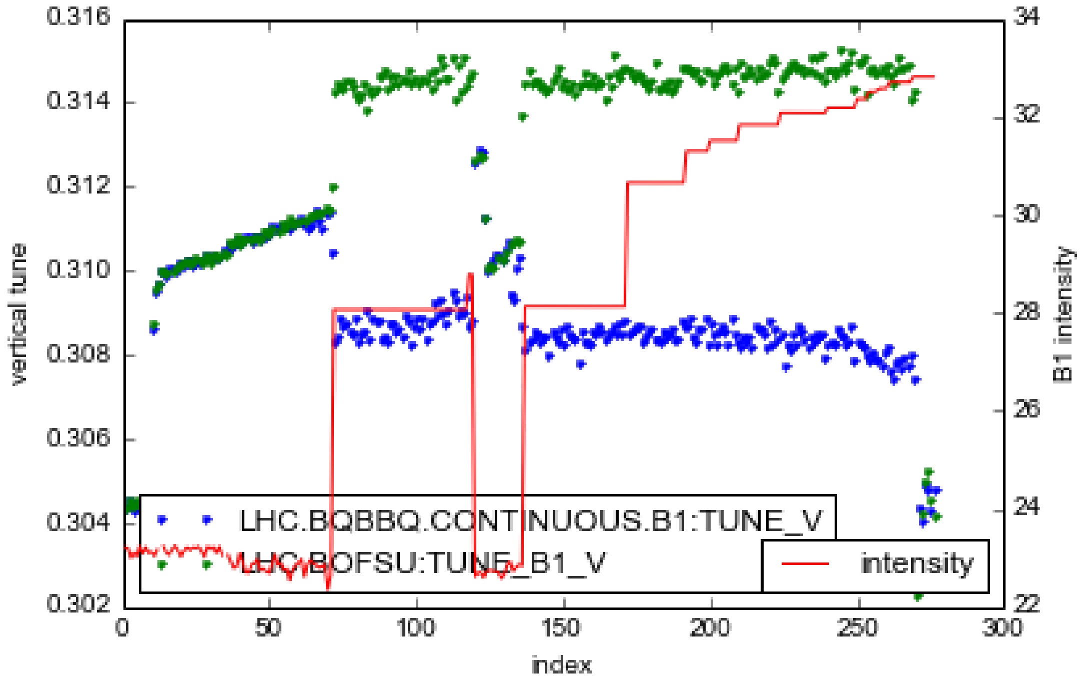
- ADT BPM: turn-by-turn first bunch of the last injected batch in LDB. Q7 and Q9 in IR4 are available for 1024 turns (damping time 50 turns)

BBQ Freq data

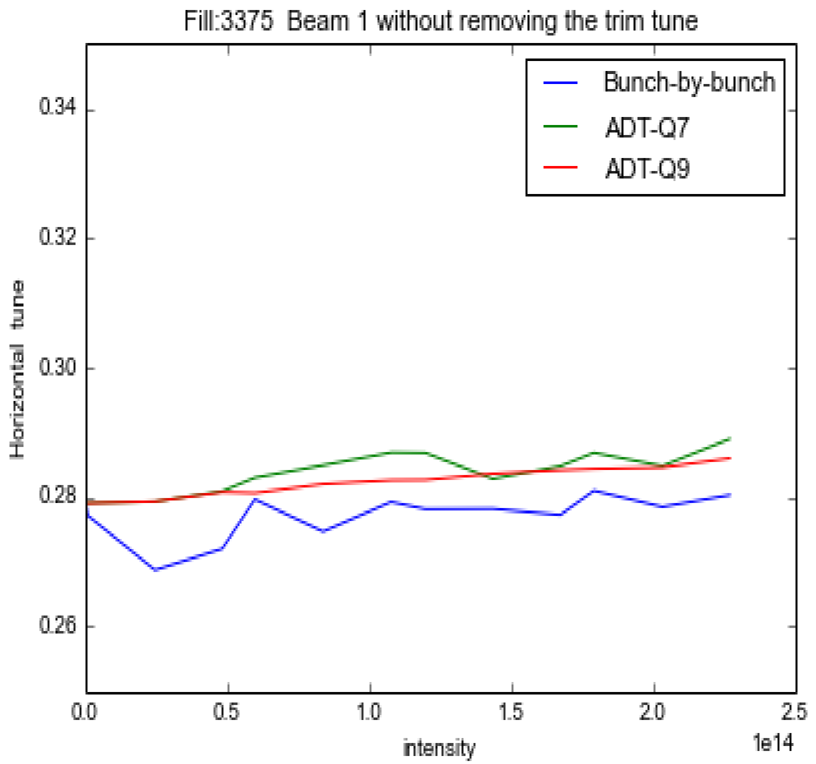


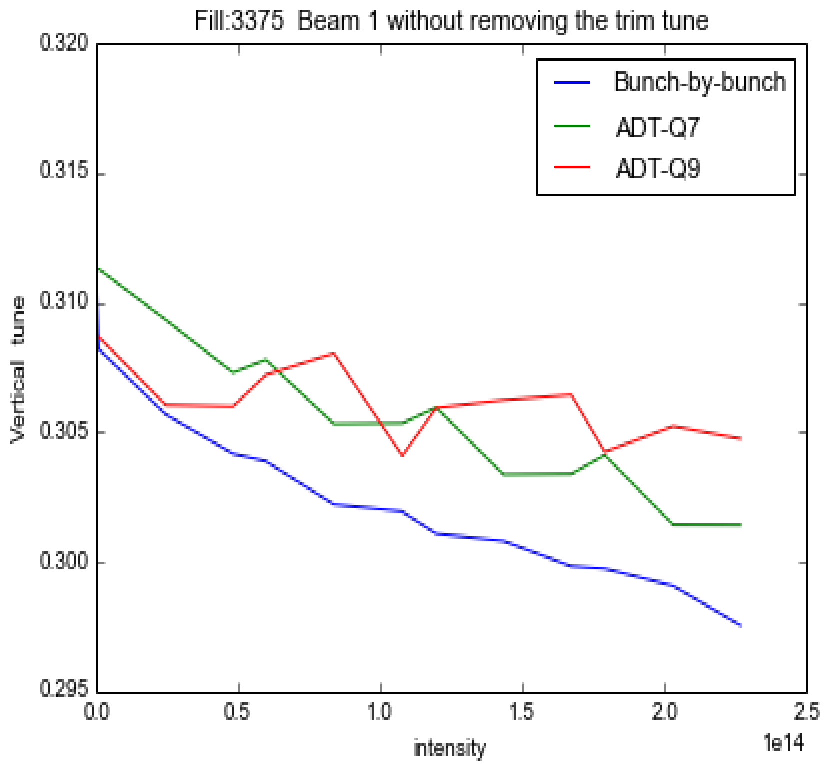


Tune data used extracted for the feedback

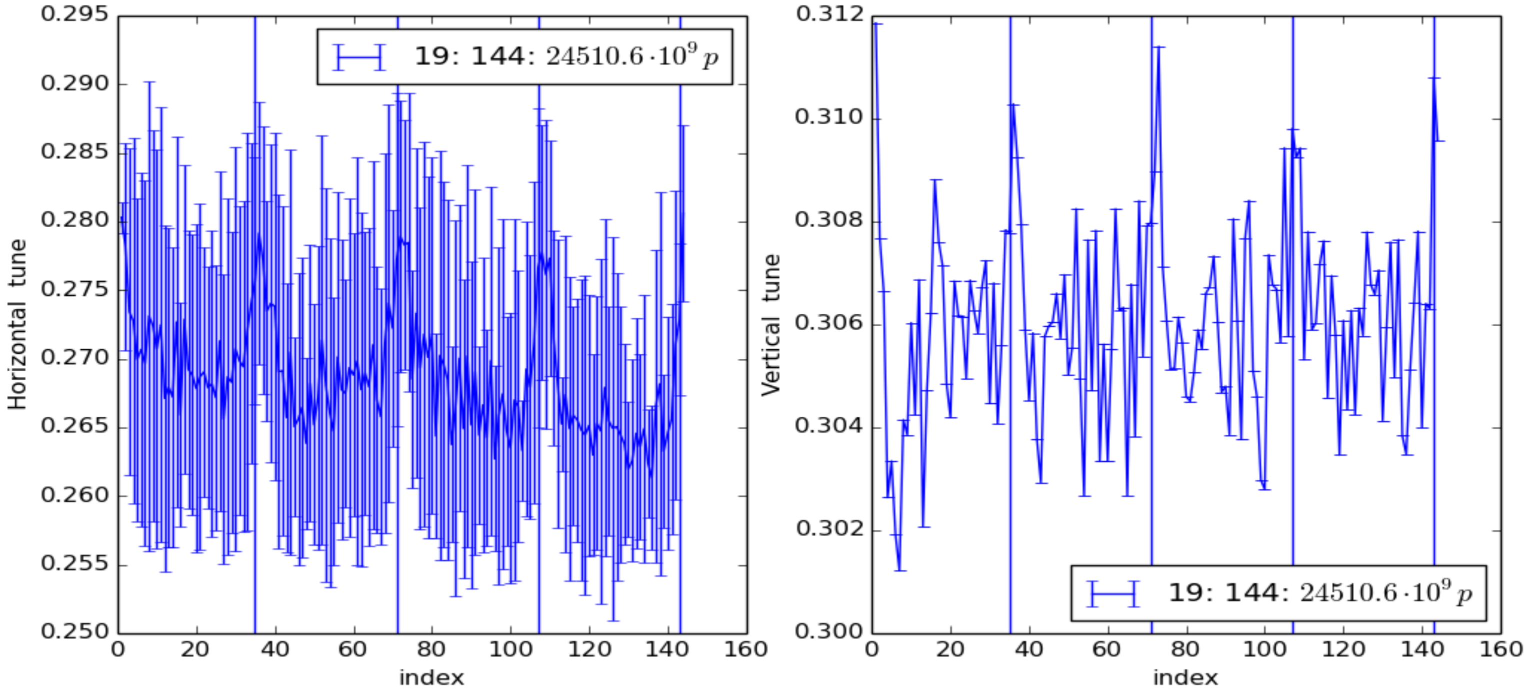


ADT and BPM data

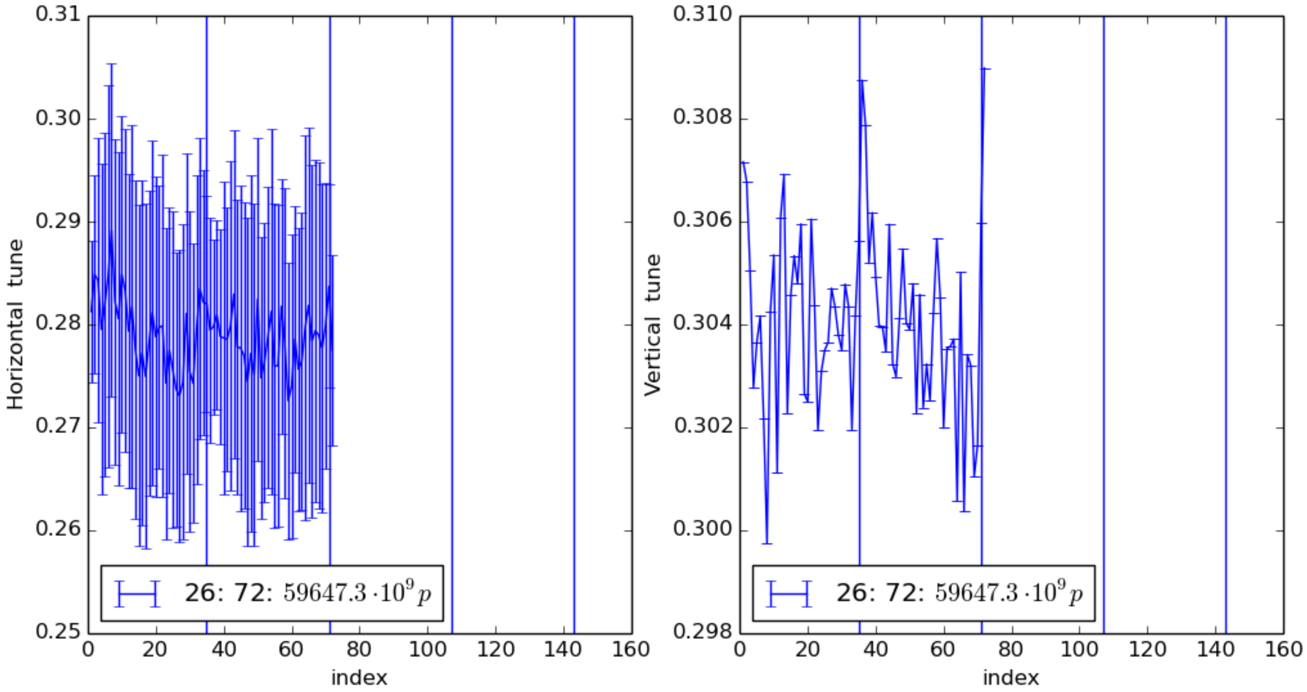




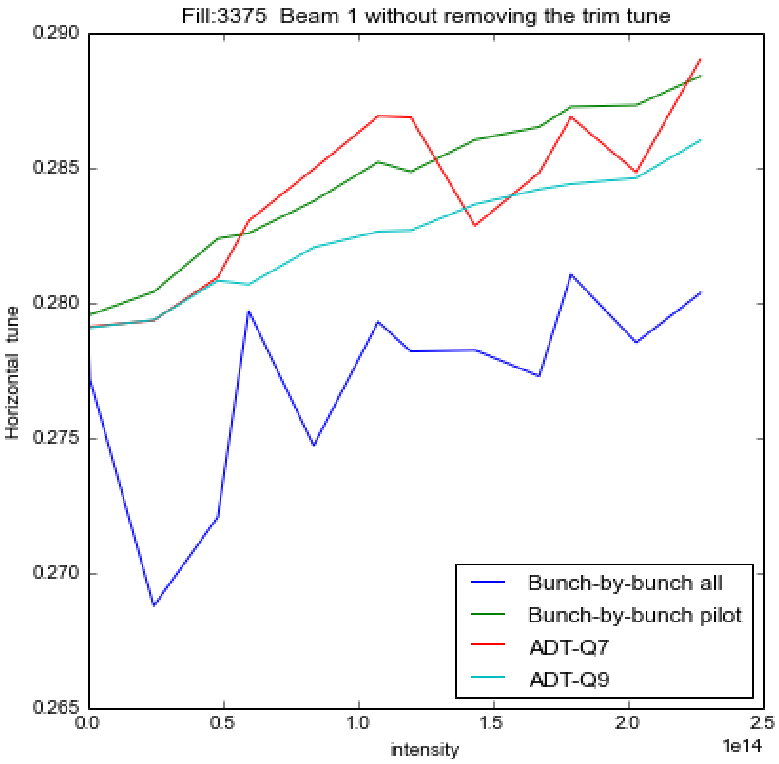
BPM Data bunch-by-bunch

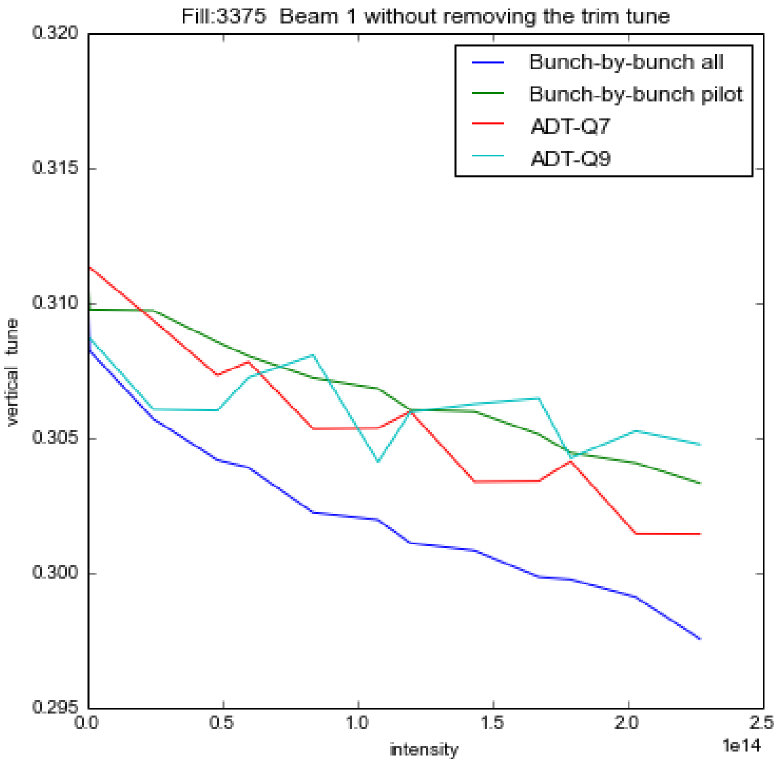


BPM Data bunch-by-bunch



ADT and BPM


Fill:3375 Beam 1 without removing the trim tune
Horizontal tune
intensity
1e14
0.290
0.285
0.280
0.275
0.270
0.265
0.0
0.5
1.0
1.5
2.0
2.5
Bunch-by-bunch all
Bunch-by-bunch pilot
ADT-Q7
ADT-Q9


Fill:3375 Beam 1 without removing the trim tune
vertical tune
intensity
1e14
0.320
0.315
0.310
0.305
0.300
0.295
0.0
0.5
1.0
1.5
2.0
2.5
Bunch-by-bunch all
Bunch-by-bunch pilot
ADT-Q7
ADT-Q9

Systematic effects

- Tune Decay
- Tune Feedback
- ADT detuning due to phase errors [1]
- Space charge effects
- Other intensity dependent effects

For injected data:

- Damper transient [1]
- Beam-beam and non-linearities (MS, MO, b3 MB etc…) detuning with amplitude.

[1] W. Hofle et al., LHC Transverse damper observations versus expectations. In proceedings of Evian, 2010.