Tune Measurement from Transverse Feedback Signals in LHC

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Abstract

We show how bunch-by-bunch position data from the LHC transverse feedback system can be used to determine the transverse tunes. Results from machine development experiments are presented and compared with theoretical predictions. In the absence of external beam excitations the tune is visible in the spectra of the position data with the feedback loop as a dip, while with external excitation a peak is visible. Both options, observation with and without excitation, are demonstrated to be complementary. Periodic excitation and observation of the free oscillation can also be used to determine the damping time of the feedback in addition to the coherent tune. Plans are outlined for hardware upgrades of the LHC transverse feedback system that will enable fast online processing of bunch-by-bunch, turn-by-turn data using Graphical Processing Units (GPU). By using GPUs we gain the ability to compute and store the spectrum of all bunches in real-time and the possibility to reconfigure test and deploy algorithms. This data acquisition and analysis architecture also allows changes to be made without disturbing the operation.

Measurement principles

A Fourier analysis of the time domain data sampled at every turn yields the tune of the beam.

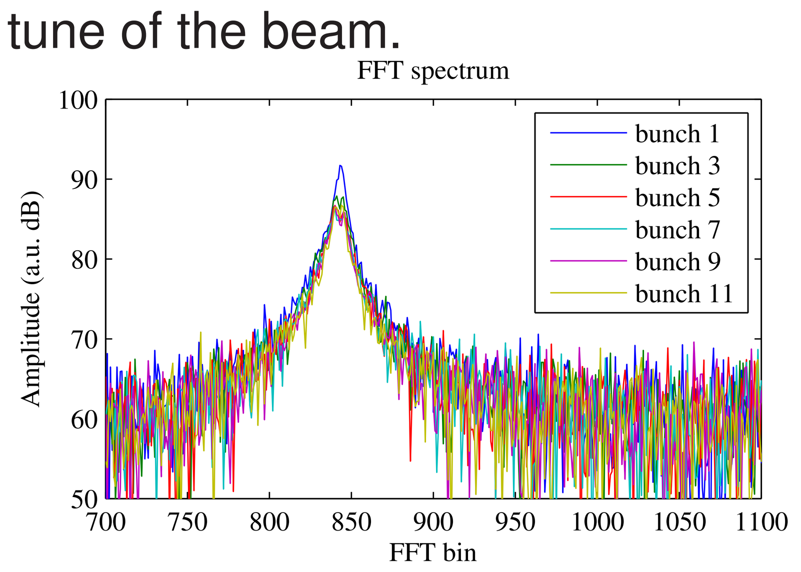

Fig. 1. Spectra for individual bunches.

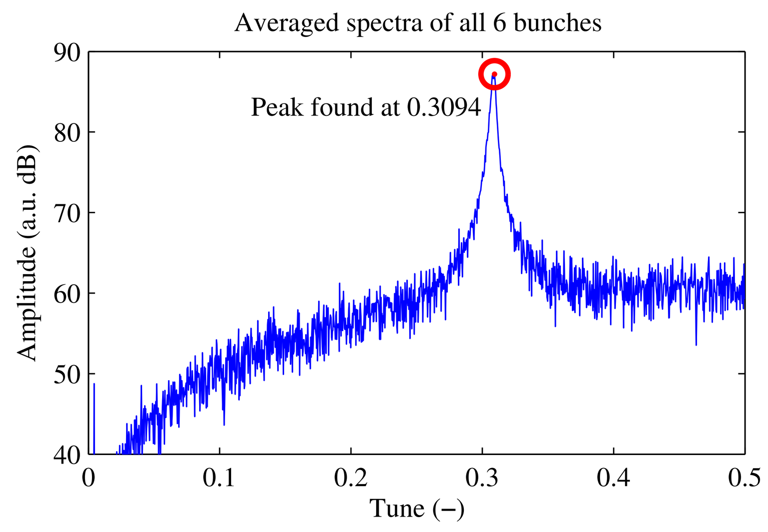

Fig. 2. Average Spectra over 6 bunches.

Active excitation can be use to drive the beam and make the tune line grow above the measurement background noise, but usually this is at the expense of emittance blow-up.

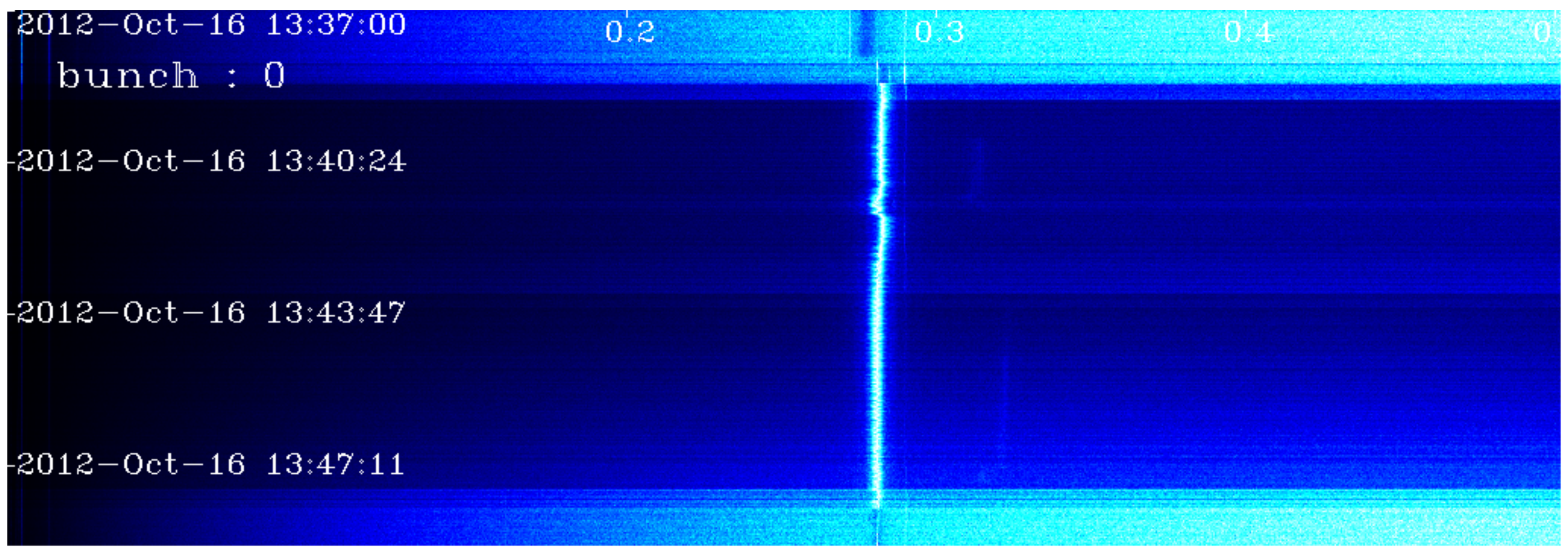

Fig 3. Spectrogram (non-invasive) with low damper gain.

Passive observation can also be used, without any additional excitation. With feedback on a "trench" at the tune develops and we have to search for a minimum in order to determine the tune value.

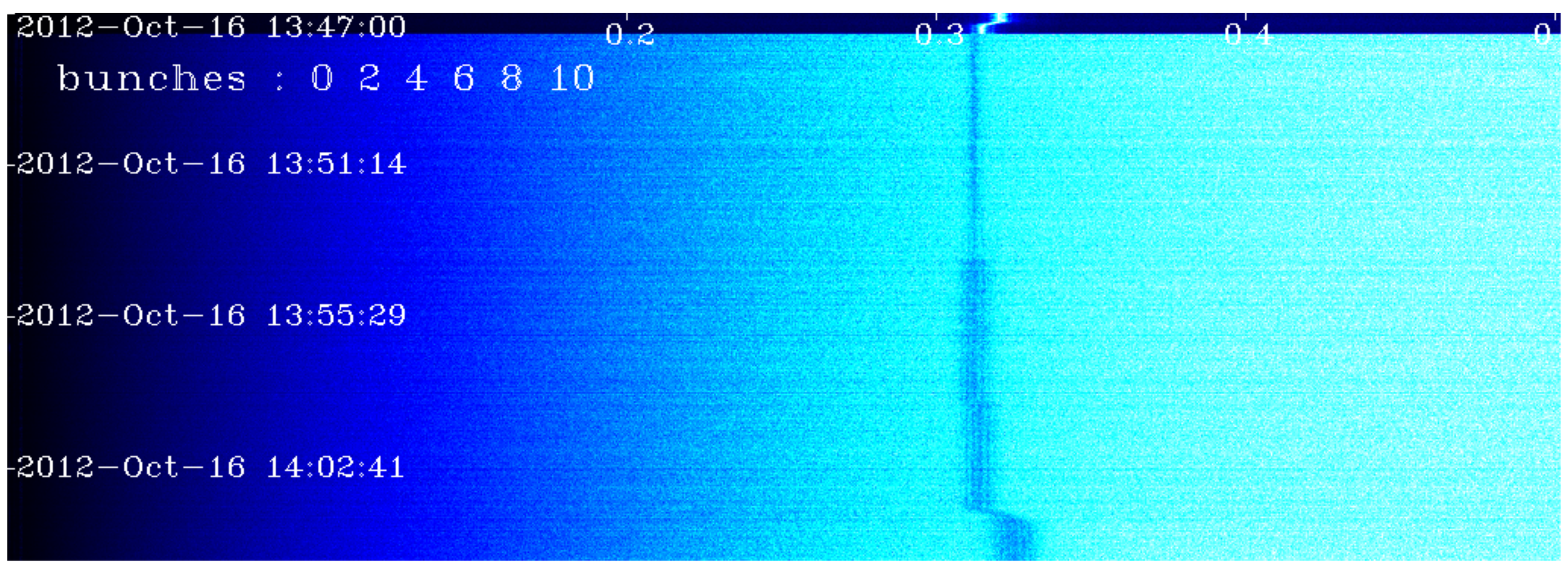

Fig 4. Spectrogram (non-invasive) with high damper gain.

Results and discussion

- Tune Measurement with selective excitation
  - limited bunches
  - spurious in the spectra
  - dedicated bunches to be excited
- Non-invasive tune measurement from transverse feedback
  - passive no excitation needed
  - acquisition per bunch all the bunch can be monitored
  - lots of FFTs to be done
  - tune is less visible
  - more acquisitions for in depth analysis

Algorithm on GPU using experimental data

To compute the tune in real time the data has to pass through different steps in a time constrain frame. Using conventional Central Processing Units (CPUs) as shown on Table we are over the acquisition speed (around 100 ms).

Table : Speed for 3000 acquisitions of 2048 points

Device	Type	Threads	Speed [GHz]	Pipeline	Time [ms]
Xeon X5650	FFTW	12	2.67	N/A	291
Xeon X5650	OpenCL	12	2.67	enable	284
Xeon X5650	OpenCL	12	2.67	disable	288
i7-3720QM	FFTW	8	2.6	N/A	310
i7-3720QM	OpenCL	8	2.6	enable	272
i7-3720QM	OpenCL	8	2.6	disable	273
Tesla M2090	OpenCL	512	1.3	enable	35
Tesla M2090	OpenCL	512	1.3	disable	37
GeForce 650M	OpenCL	384	0.9	enable	355
GeForce 650M	OpenCL	384	0.9	disable	365

This showed we can compute the tune FFTs for each individual bunch at acquisition speed only using a GPU.

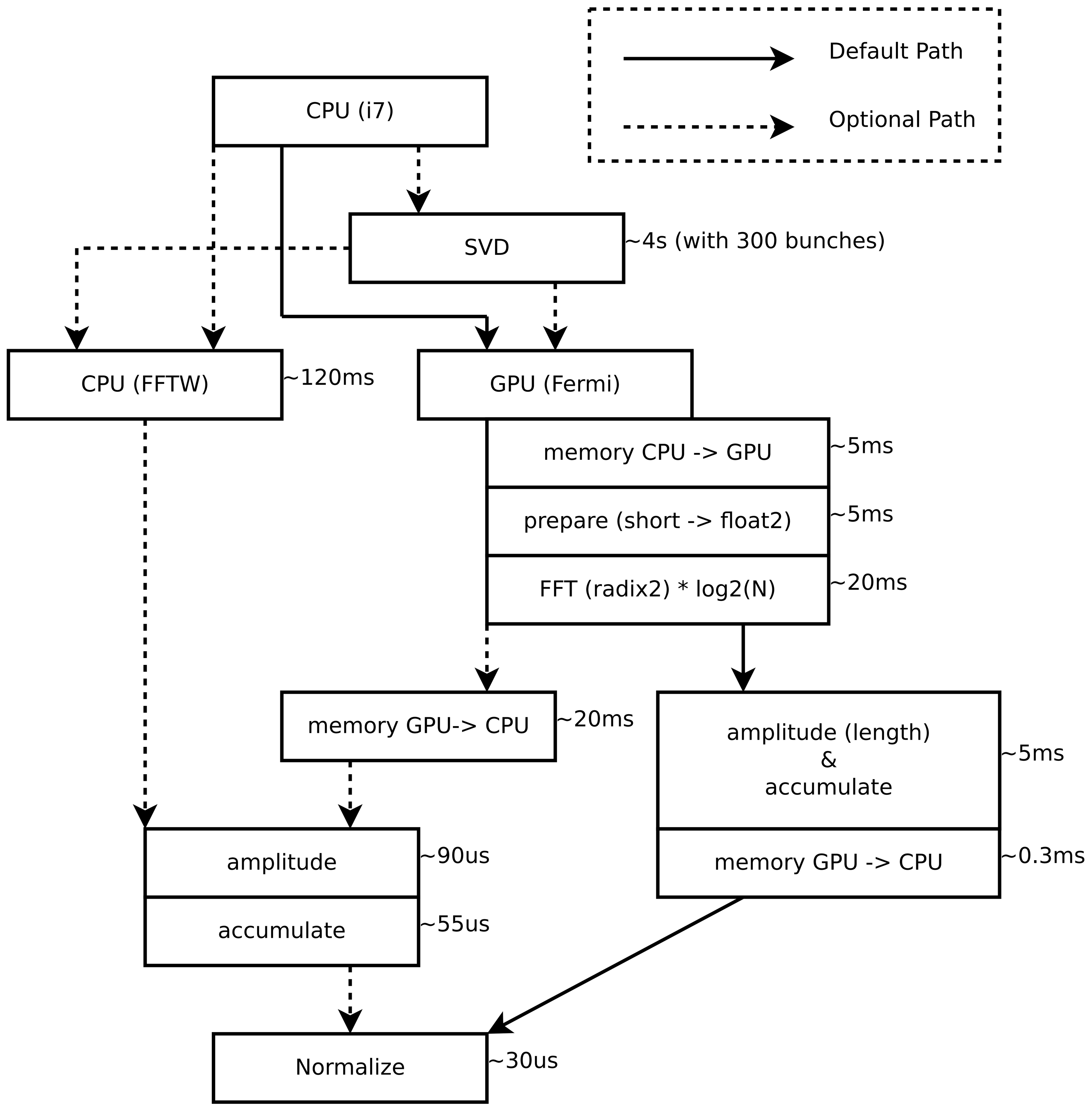

Fig 5. Different algorithms used with impact on time.

Parallelization of FFTs on GPU is done by distributing all the twiddling and multiplication between the available cores so in our case we have a maximum optimization possible of 2880 times 1024 that is 3 order of magnitude bigger than the number of core even on last generation GPUs.

Architecture for a future online operational system

The tune measurement and observation from the operation of the transverse feedback system will be streamed out of the feedback system over fiber to a dedicated sampling box based on a PC platform. By selecting an external solution, based on off the shelf PC hardware, we can easily upgrade the sampling boxes provide extra capacity in terms of storage space and GPU processing power without disrupting the operation of the transverse feedback system.

References

[1] M. Gasior, DIPAC'11, Hamburg, May 2011, pp. 445–447.
[2] R. J. Steinhagen, PAC'11, (2011), pp. 1399–1403.
[3] W. Höfle et al., EPAC'08, Genoa, May 2008, pp. 3266–3268.
[4] W. Höfle, IPAC'13, Shanghai, May 2013, pp. 3990–3994.
[5] C. H. Kuo et al., IPAC'11, (2011), San Sebastián, September 2011, pp. 514–516.
[6] C.-Y. Yao et al., IPAC'13, Shanghai, May 2013, pp. 3058–3060.
[7] F. Dubouchet, "Betatron tune measurement with the LHC damper using a GPU", CERN Thesis (unpublished), 2013.
[8] M. Scarpino, OpenCL in Action, (Manning Publications, 2011).
[9] M. Frigo and S.G. Johnson, "The Design and Implementation of FFTW3", Proceedings of the IEEE, February 2005, IEEE93, p. 216-231, 0018-9219
[10] http://www.ohwr.org/projects/spec

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