High speed Tune Measurement using Phase Following on Multi-Bunch Feedback

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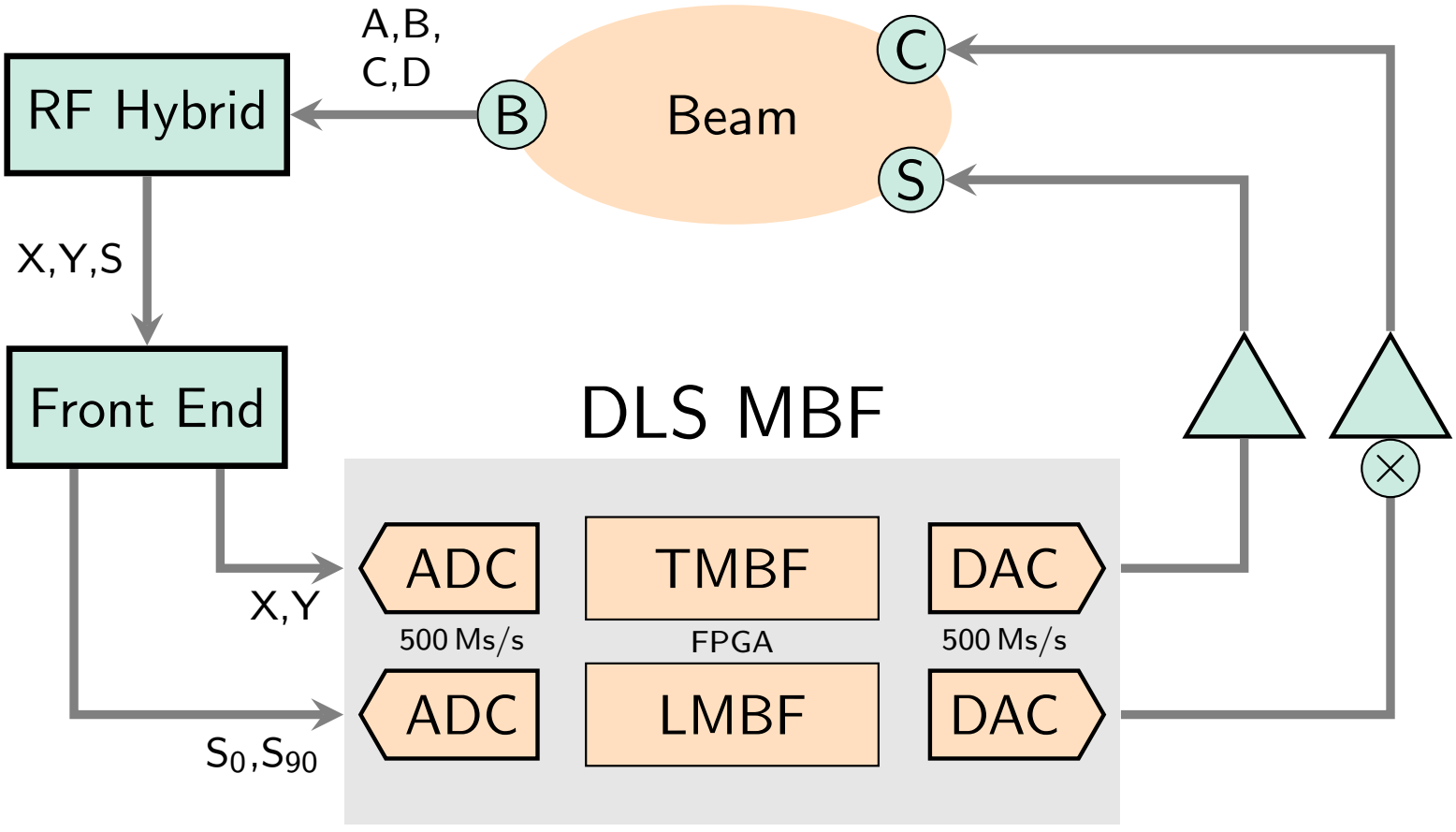
Diamond Light Source

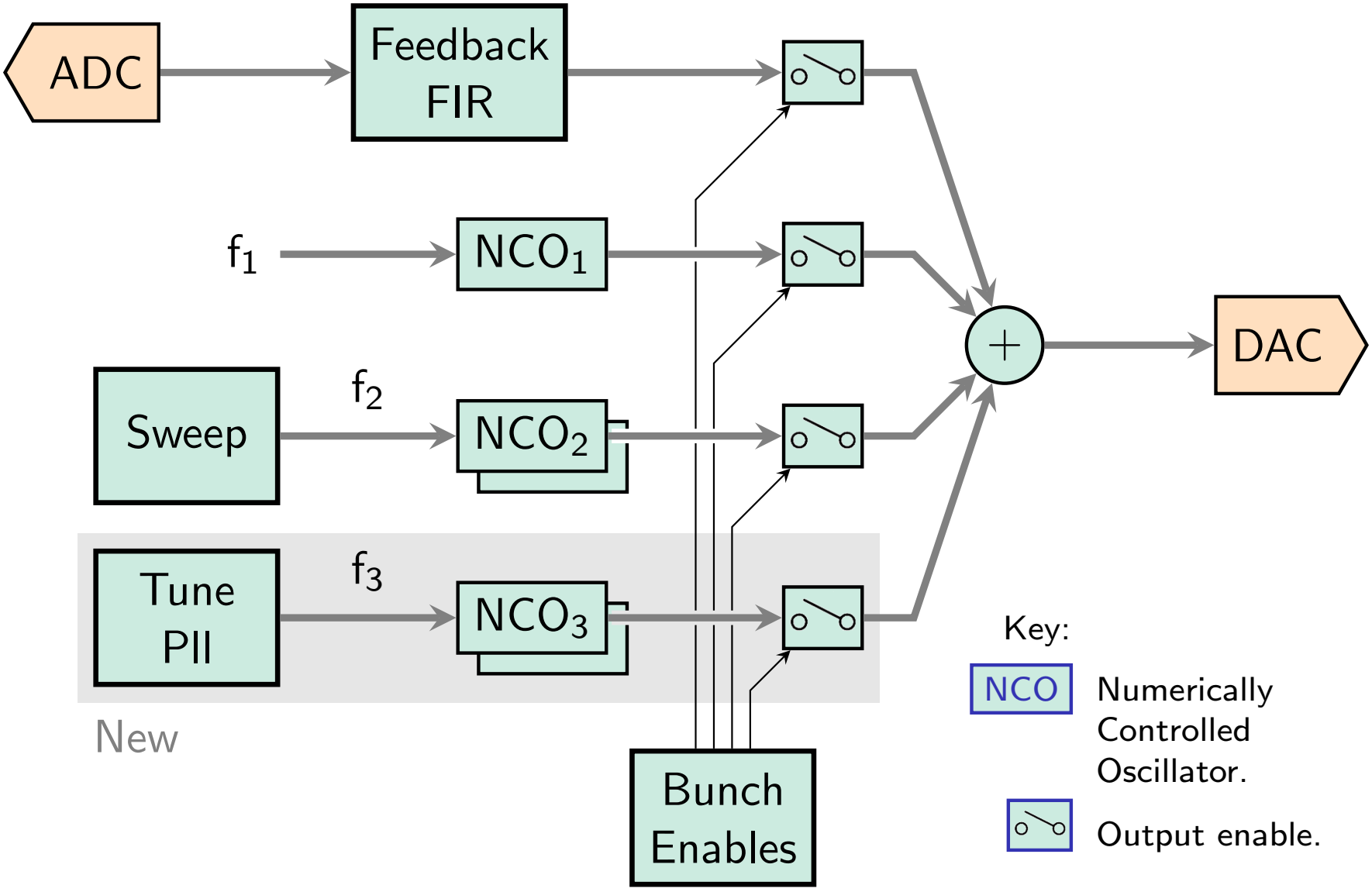
Tuesday 4th June 2019

TMBF and LMBF at Diamond Light Source

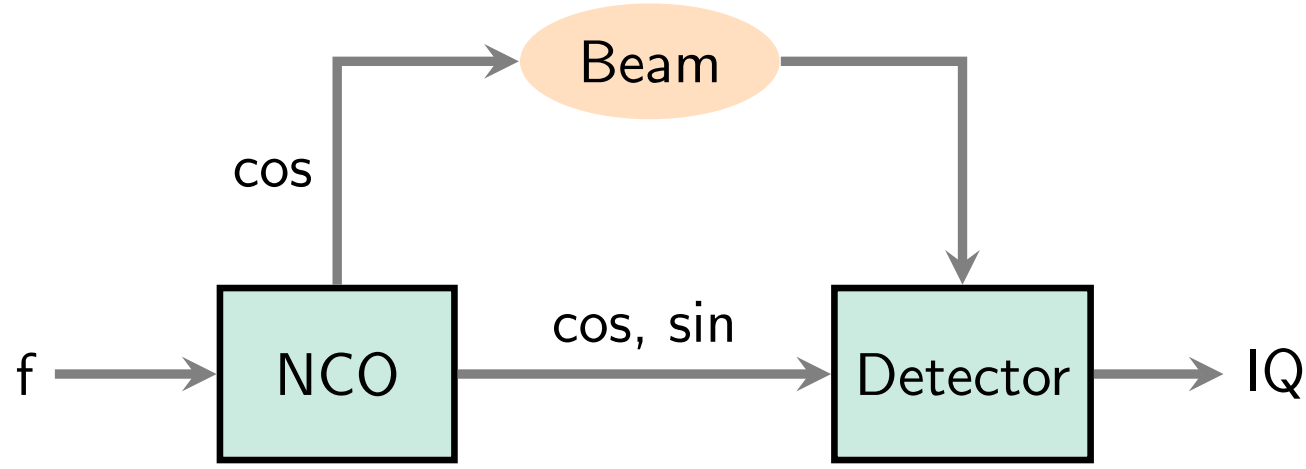


(B) EBPM pickup; (C) Longitudinal cavity; (S) Transverse striplines.

MBF Signal Processing Chain



Measuring Beam Frequency Response

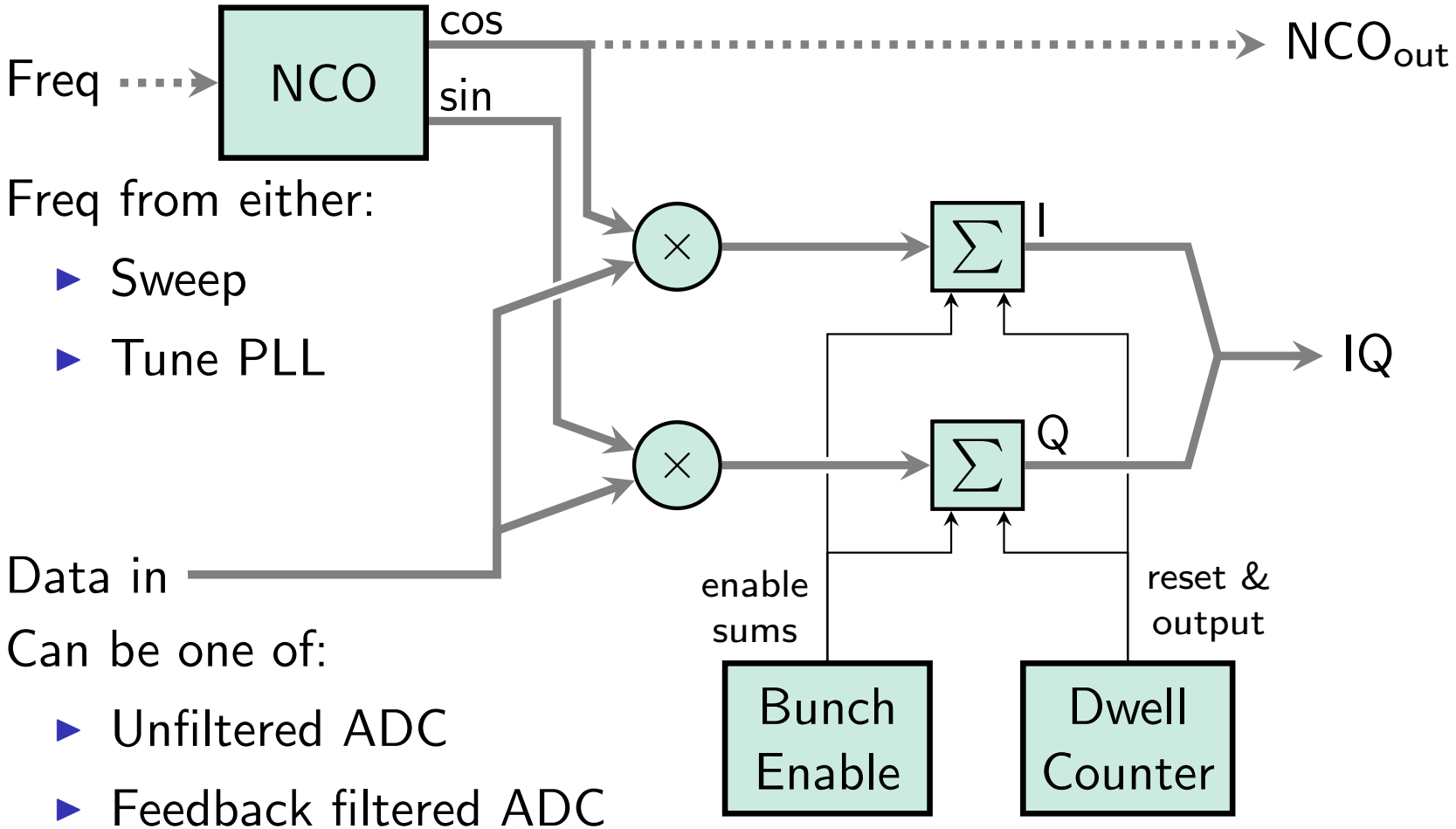


By exciting the beam at a selected frequency f and measuring the response of the beam at that frequency, we compute the *transfer function* of the machine at the selected frequency.

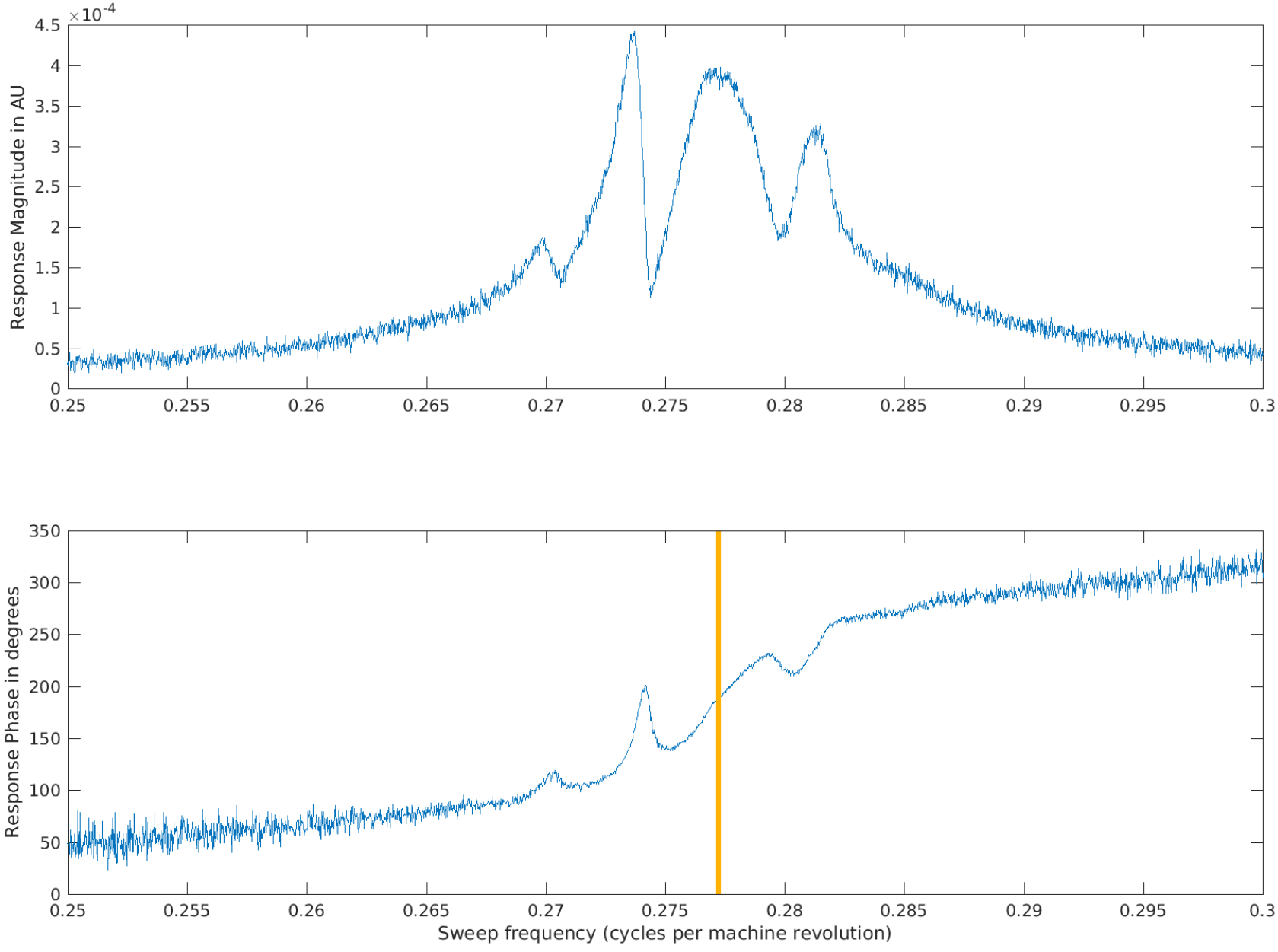
$$R(f) = \sum_{t \in \text{dwell}} e^{2\pi i f t} x_t$$

This can be expressed as phase and magnitude, or equivalently as a complex number, or in digital processing terms as a pair (I,Q).

Implementation of Detector



Typical Tune Sweep Response

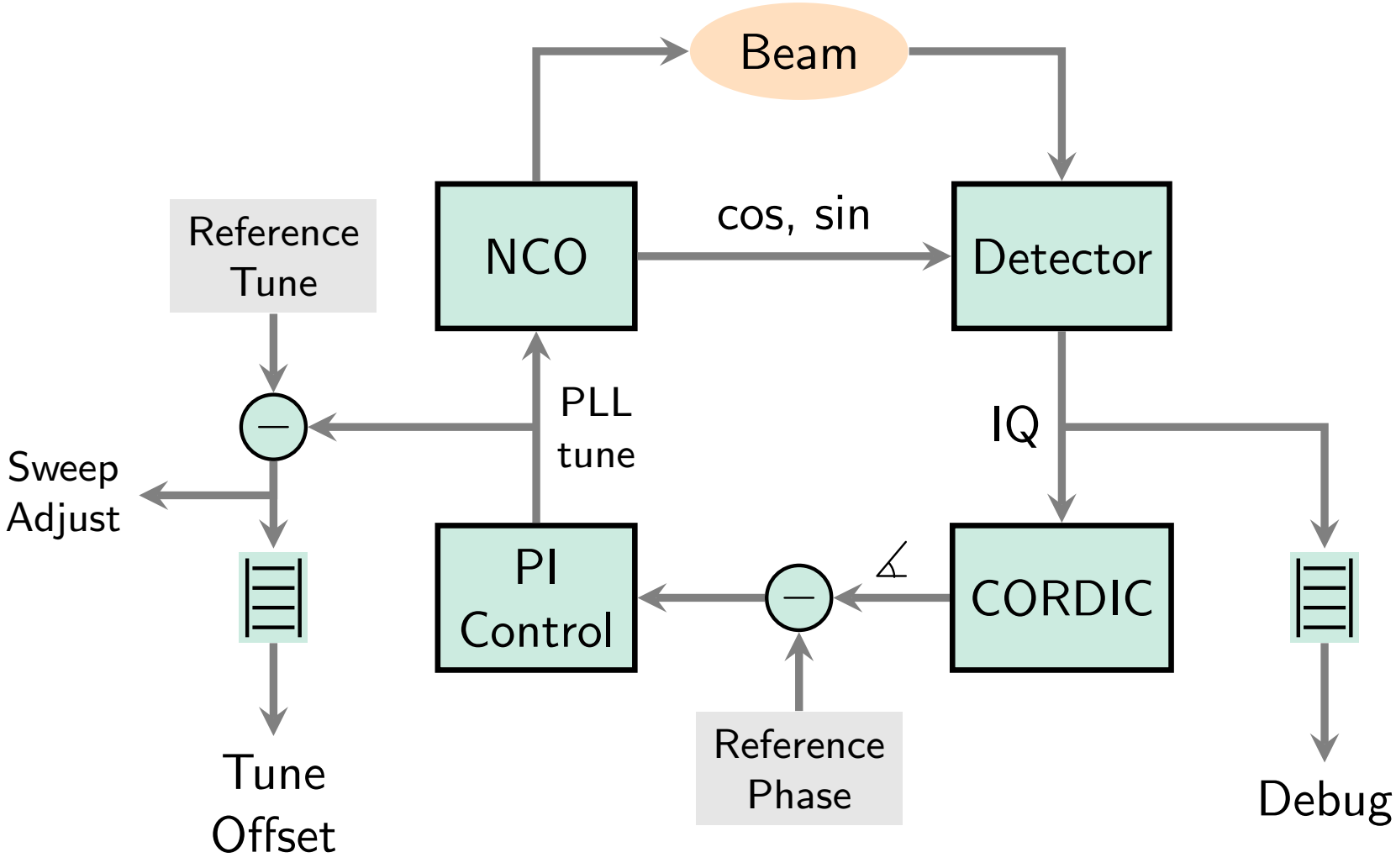


Measuring Tune by Tracking Phase

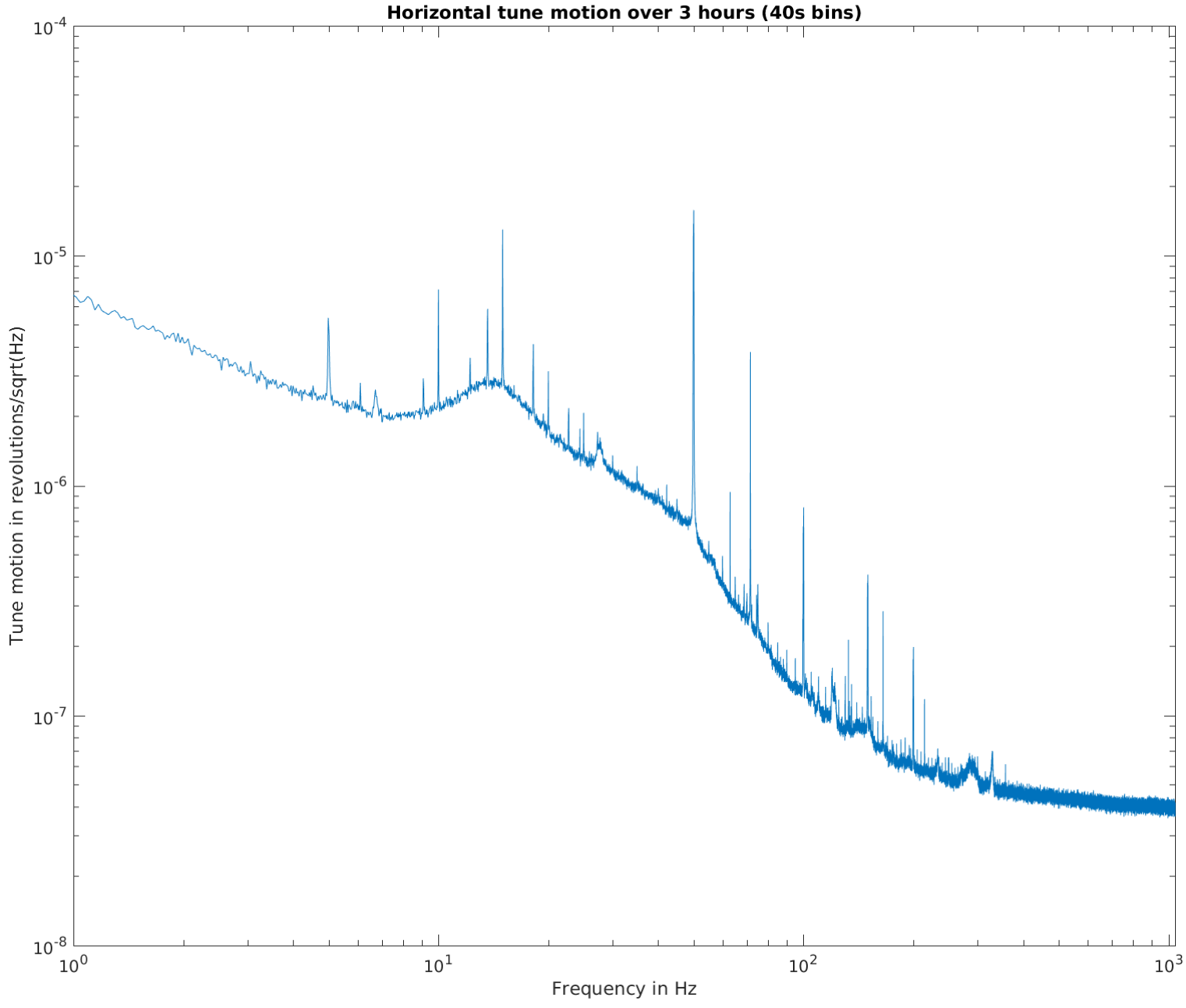
- Define desired target phase response (eg, 180°).
- Excite selected region of beam with Tune PLL NCO at selected single frequency.
- Measure phase response at this frequency.
- Use difference between measured and target phase to update frequency (a simple PI controller is sufficient).
- Repeat.

This is implemented on the FPGA, and can run at more than 100 kHz; however most tune motion seems to be concentrated between 10^2 and 10^{-2} Hz, and a sensible rate is around 2 kHz.

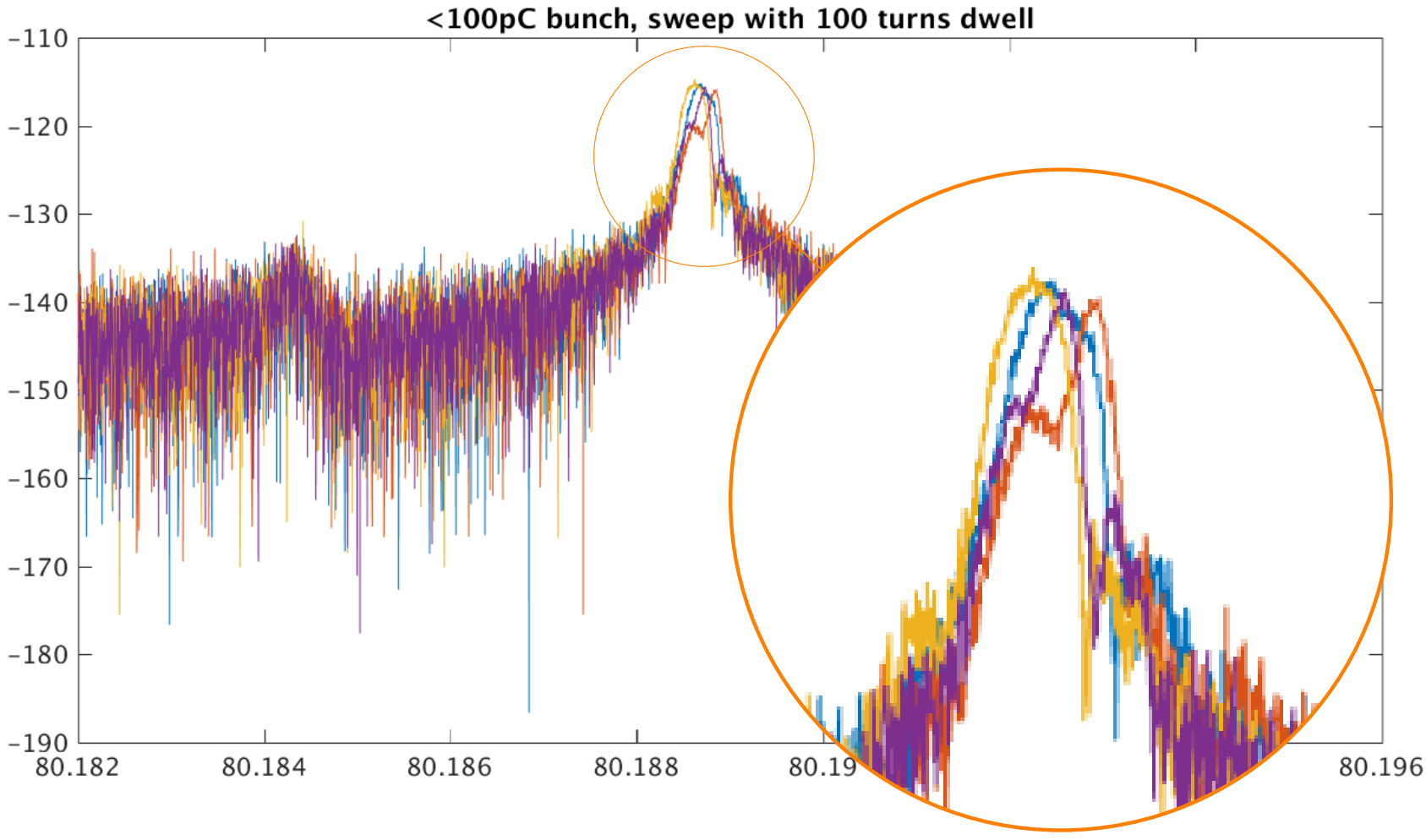
Tune PLL Implementation



High Resolution Tune Measurement

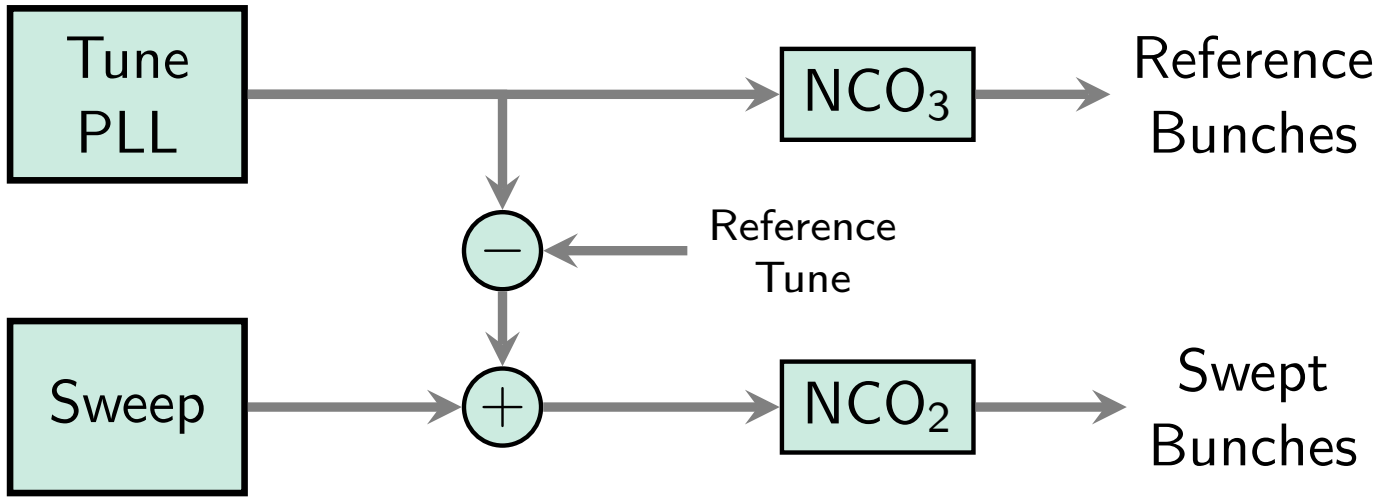


Disturbance to Tune Sweeps



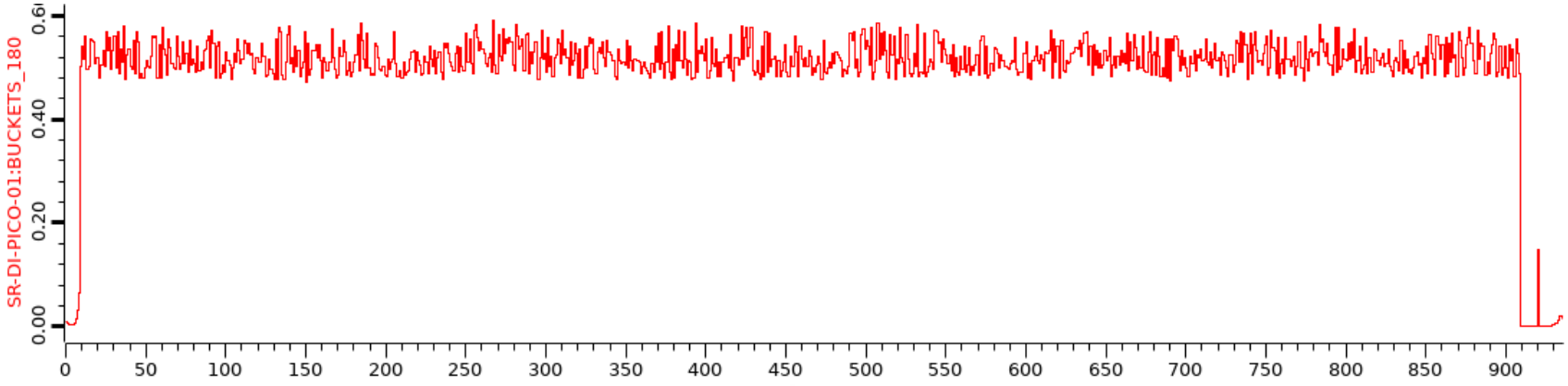
Compensating for Tune motion

- Tune disturbance is global (all bunches see the same disturbance).
- Can use PLL to track tune on part of fill.
- Tune offset then dynamically compensates tune sweep.
- Can now perform very long sweeps on low current parts of fill.

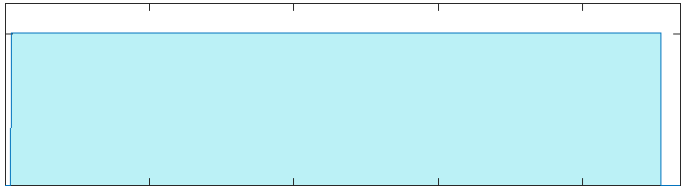


Using Bunch Enables

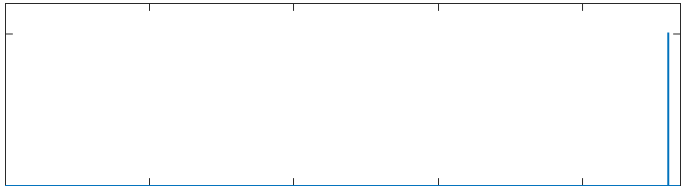
Machine fill pattern



FIR (feedback) output enable,
Tune PLL (NCO_3) output enable,
Tune PLL detector enable.

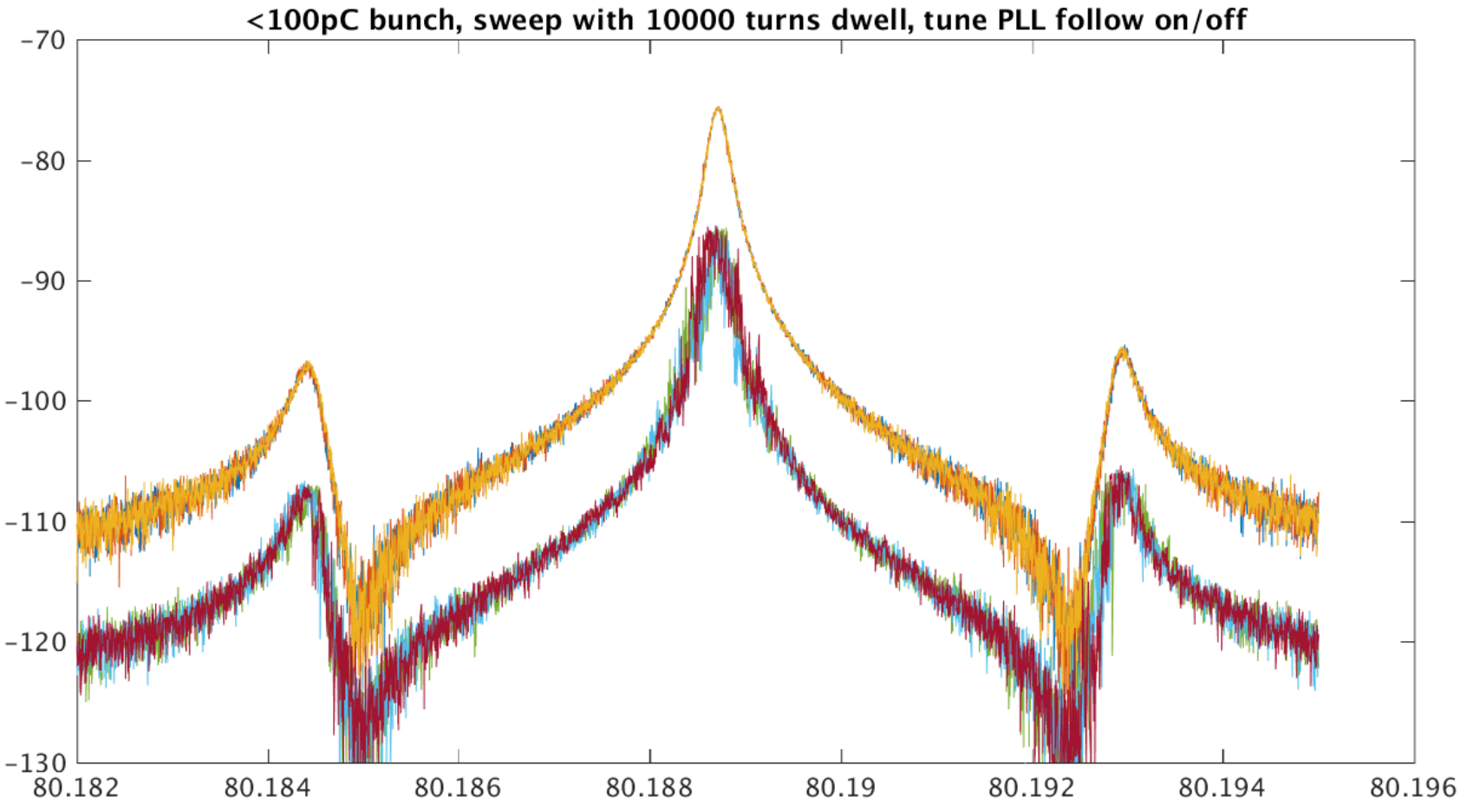


Sweep (NCO_2) output enable,
Sweep detector enable.



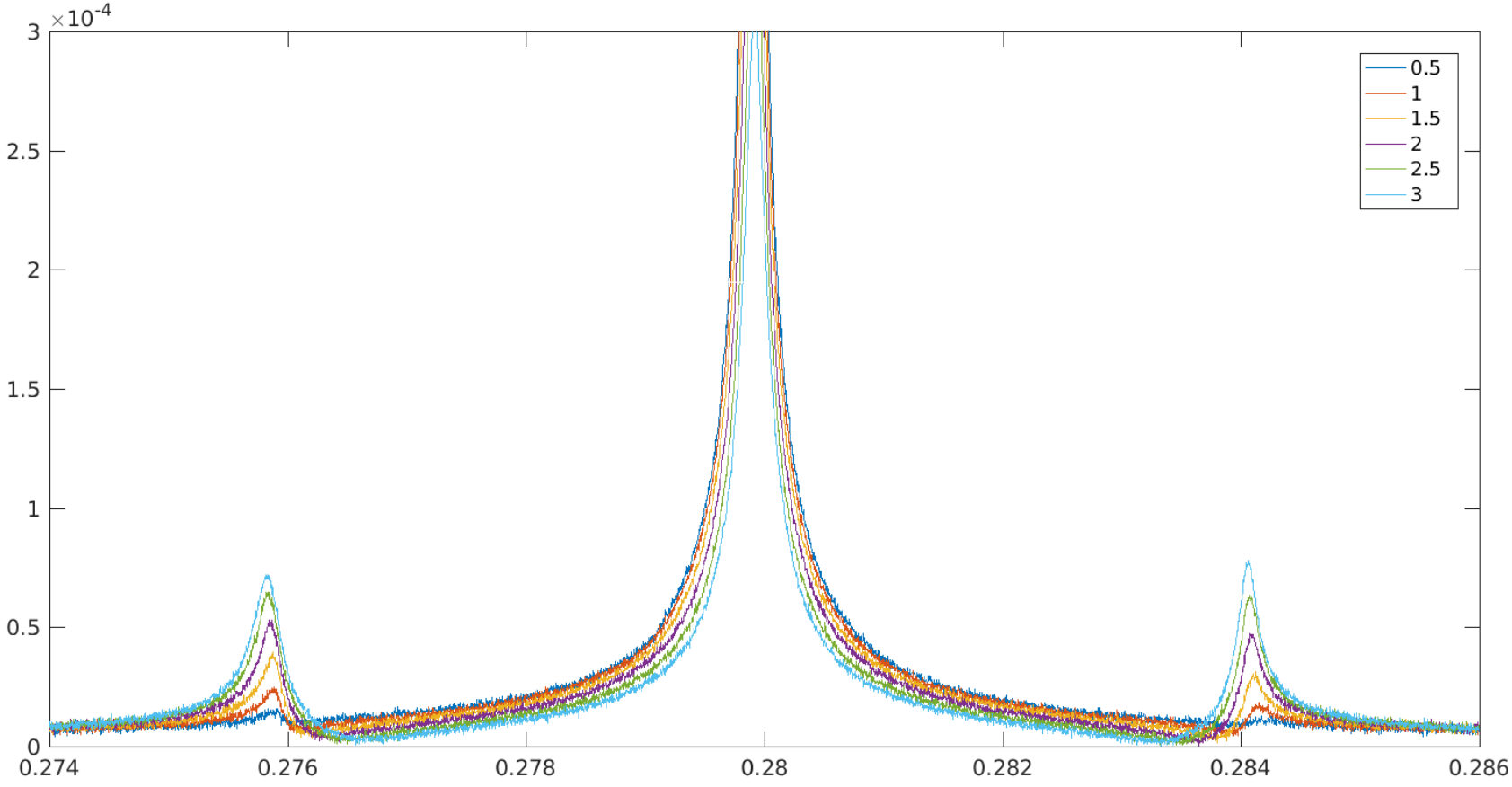
With this setup we can do long slow sweeps on the single bunch.

Compensated vs Uncompensated Tune Sweeps



High resolution slow sweeps

Slow tune sweeps of 50 pC single bunch with varying chromaticity.



Now ready to investigate inference of machine chromaticity from high resolution tune sweep.

Fin

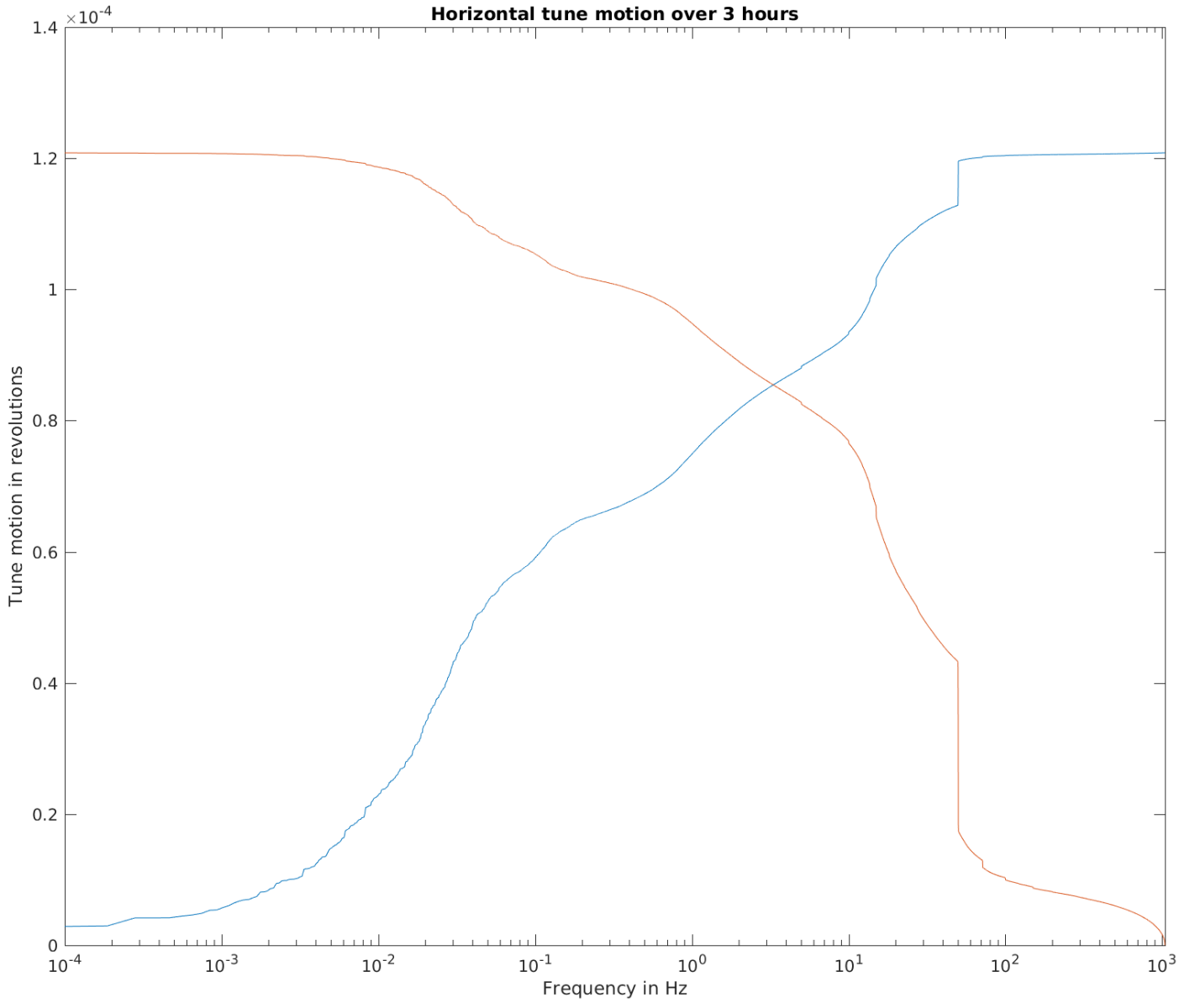
Some extra slides follow.

Equation for Detector Operation

$$\mathrm{iq}_n = \sum_{t=nDT}^{(n+1)DT-1} e^{2\pi i \frac{f_n}{T} t} \cdot B(t \bmod T) \cdot x_t$$

n	Number of captured dwell
D	Dwell time in turns
f_n	Excitation frequency in cycles per machine revolution (T ticks)
T	Number of bunches per turn (936 at DLS)
t	Time in bunch clock ticks
$B(b)$	Bunch enable for selected bunch b
x_t	Sample at time t

Tune PLL 3 hour Cumulative Sum



Feedback Residual

How much noise is the feedback loop introducing?