PROGRESS IN TUNE, COUPLING, AND CHROMATICITY MEASUREMENT AND FEEDBACK DURING RHIC RUN 7

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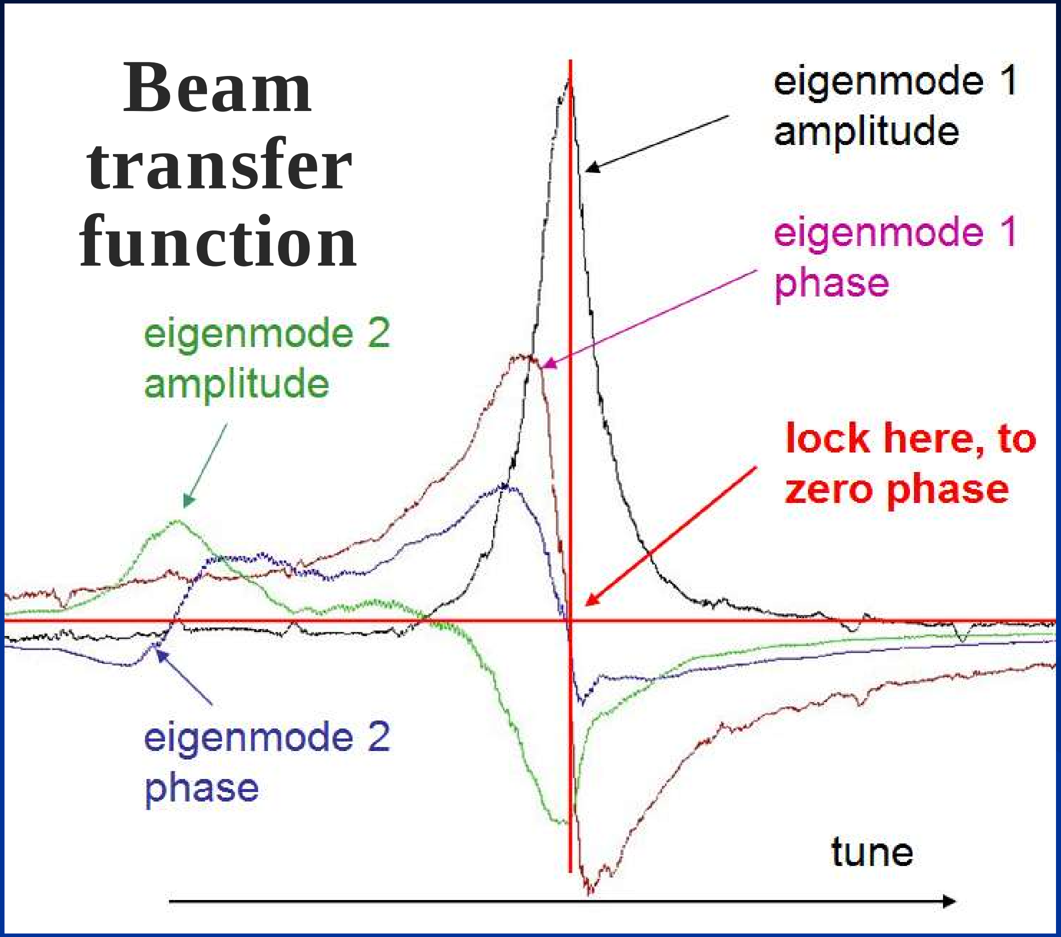
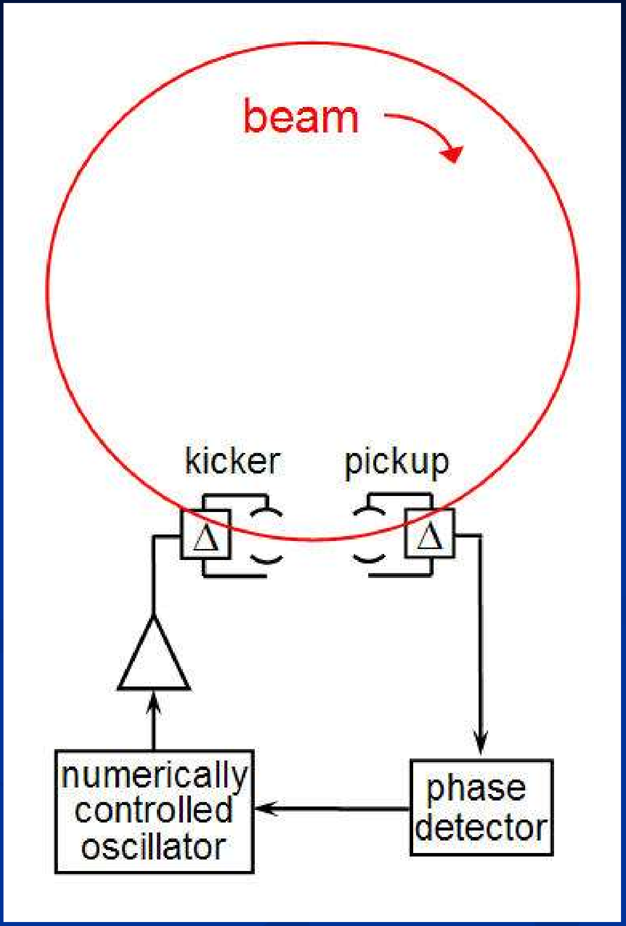
Outline

- Basic principle, block diagram
- Obstacles to be overcome
  - Coupling
  - Dynamic range
  - Mains harmonics
- Results from Run 6
- New problems in Run 7
  - Anomalous beam response at injection
  - Tune scalloping

Basic principle, block diagram





A phase-locked tune tracker comprises a continuous beam transfer function measurement at a single frequency

The first obstacle - Coupling

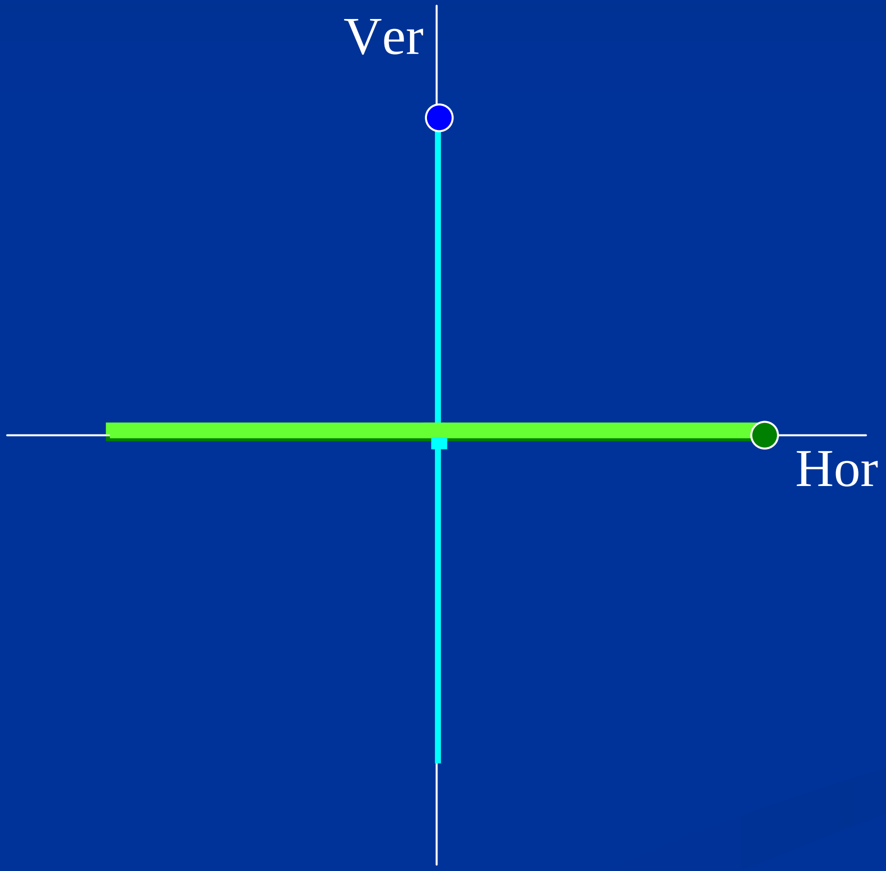
Coupling rotates the eigenmodes away from the horizontal and vertical measurement planes

When this rotation is >45 degrees, the tune correction is applied to the wrong quadrupole plane, and the tune feedback loop runs away

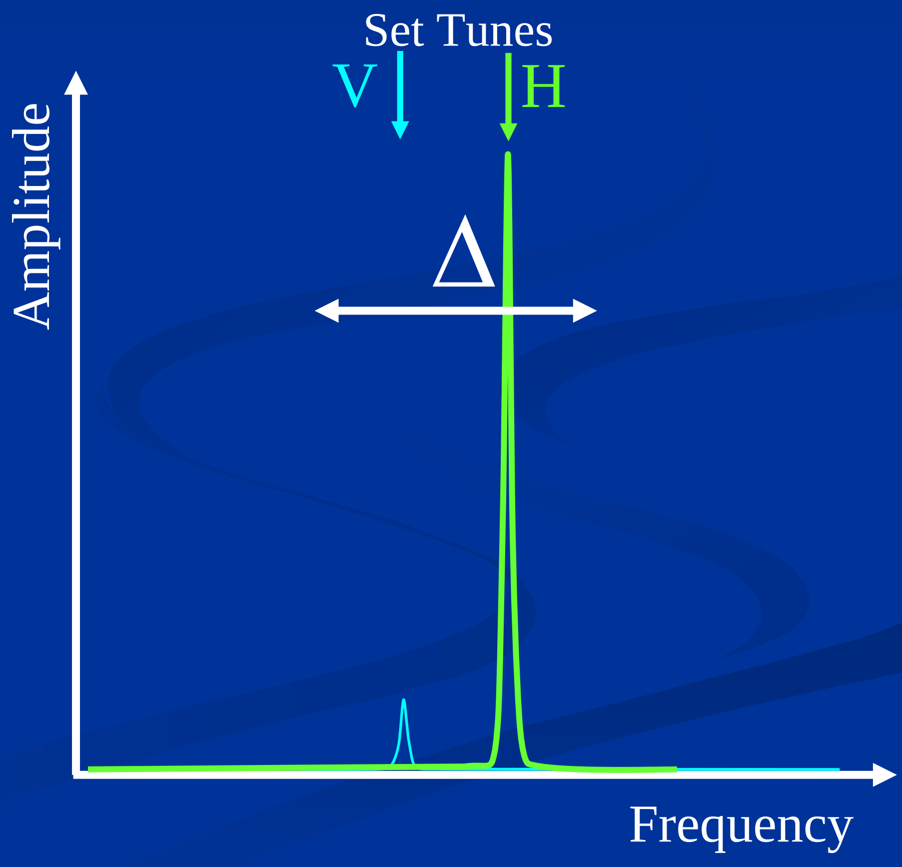
Measurement of Coupling using a PLL Tune Tracker

Start with decoupled machine → Only horizontal tune shows up in horizontal FFT
Gradually increase coupling → Vertical mode shows up & frequencies shift

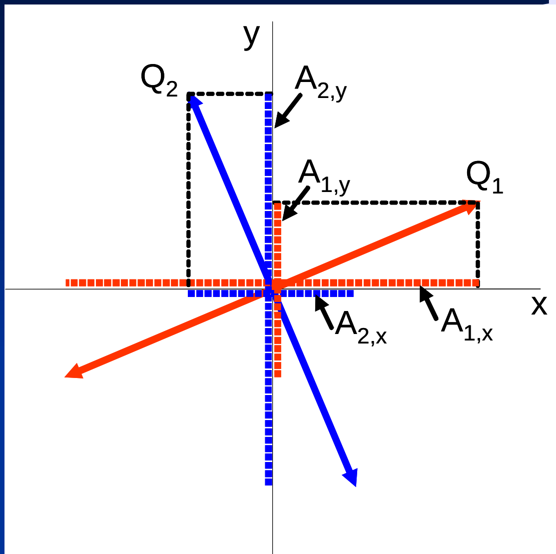
Fully coupled machine: $\Delta = |C^-|$

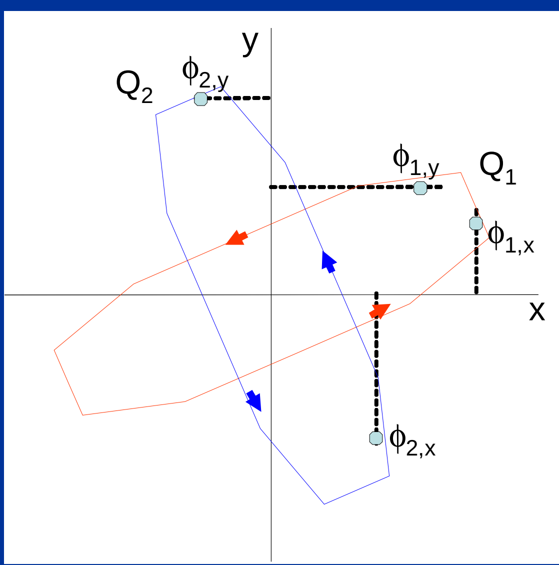


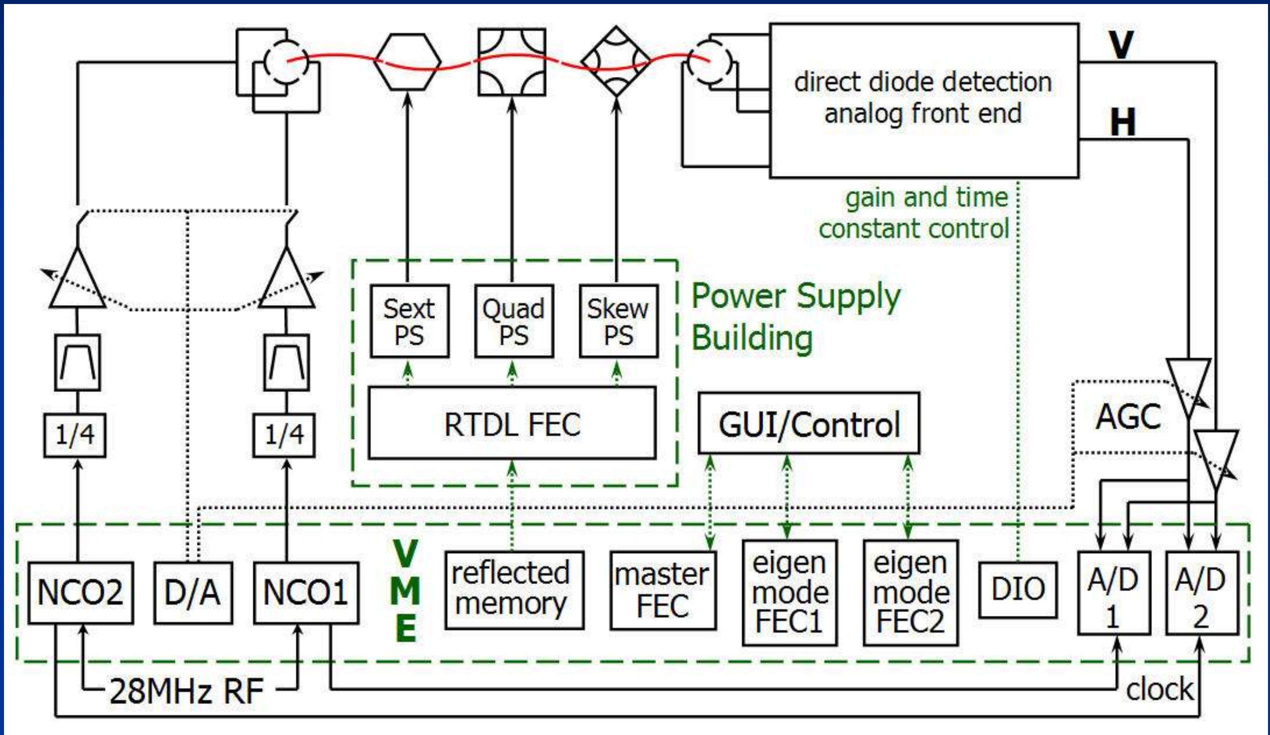
FFT of Horizontal Acquisition Plane



Measurement of Coupling using a PLL Tune Tracker

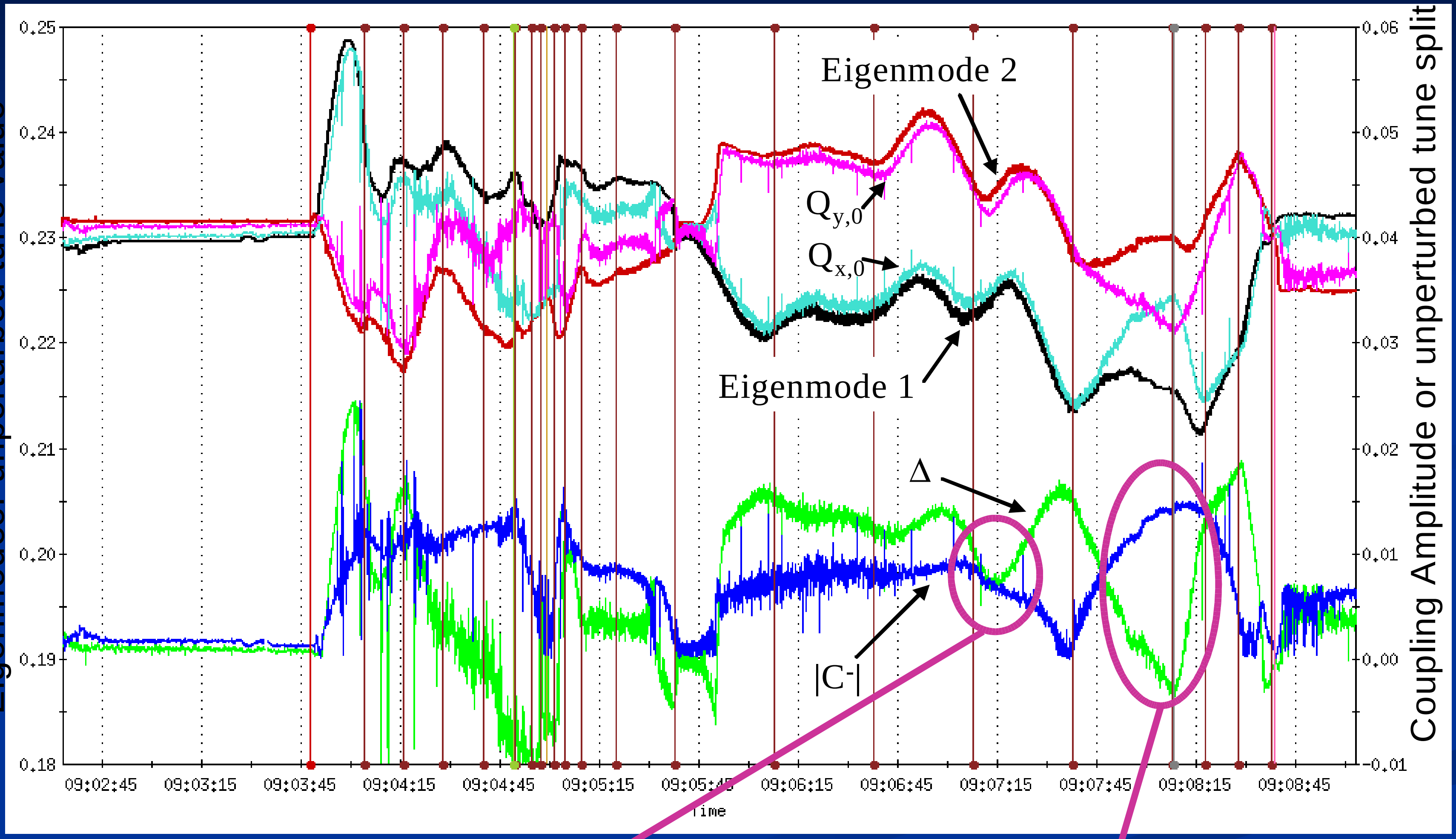






Tracking the vertical mode in the horizontal plane & vice-versa allows the coupling parameters to be calcul

Measurement of Coupling using a PLL Tune Tracker



Fully coupled

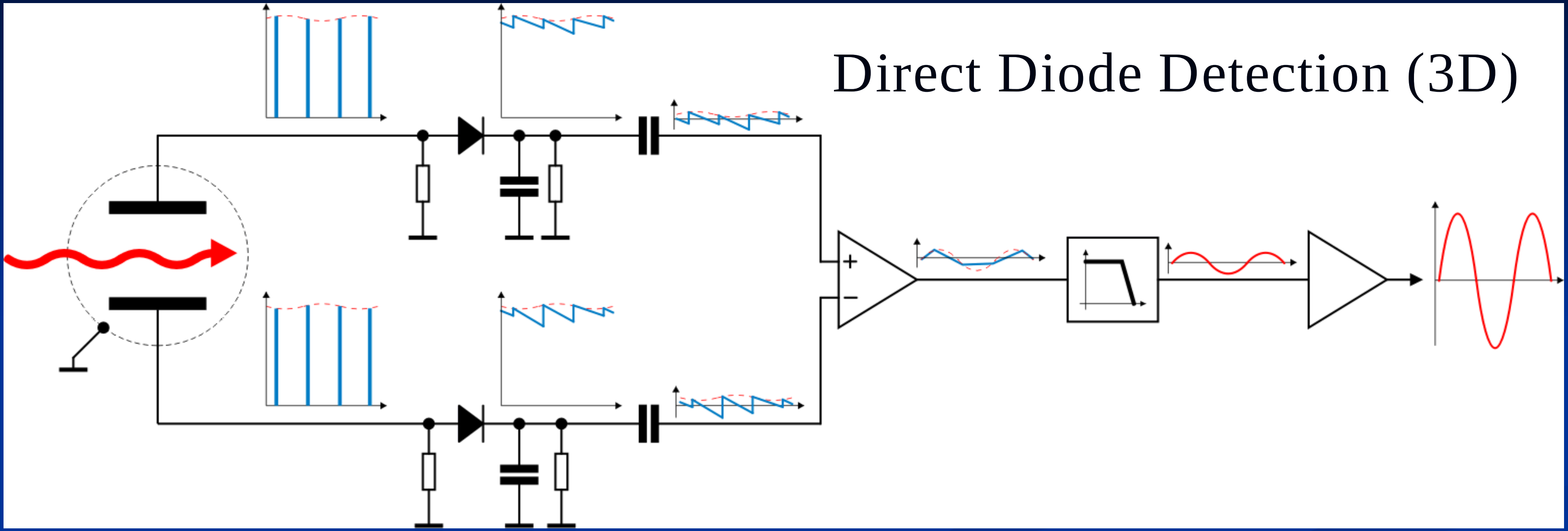
Tunes entirely defined by coupling – tune feedback would break here

Fig. 3. Continuous coupling amplitude measurement using the PLL tune tracker during a RHIC ramp.

The next obstacle – Dynamic Range

- Pickup response is nil at low frequencies
- At higher frequencies (10’s to 100’s of MHz) relative separation between revolution and betatron lines is small, filtering out the rev line is very difficult
- Desired beam excitation by tune tracker i
  micron
  - Have to allow some bits for resolution
- Beam offset can easily be 1mm or mo
- Needed dynamic range is >100dB

Measuring Tune with Little or No Excitation – The Base Band Q Measurement (BBQ) System

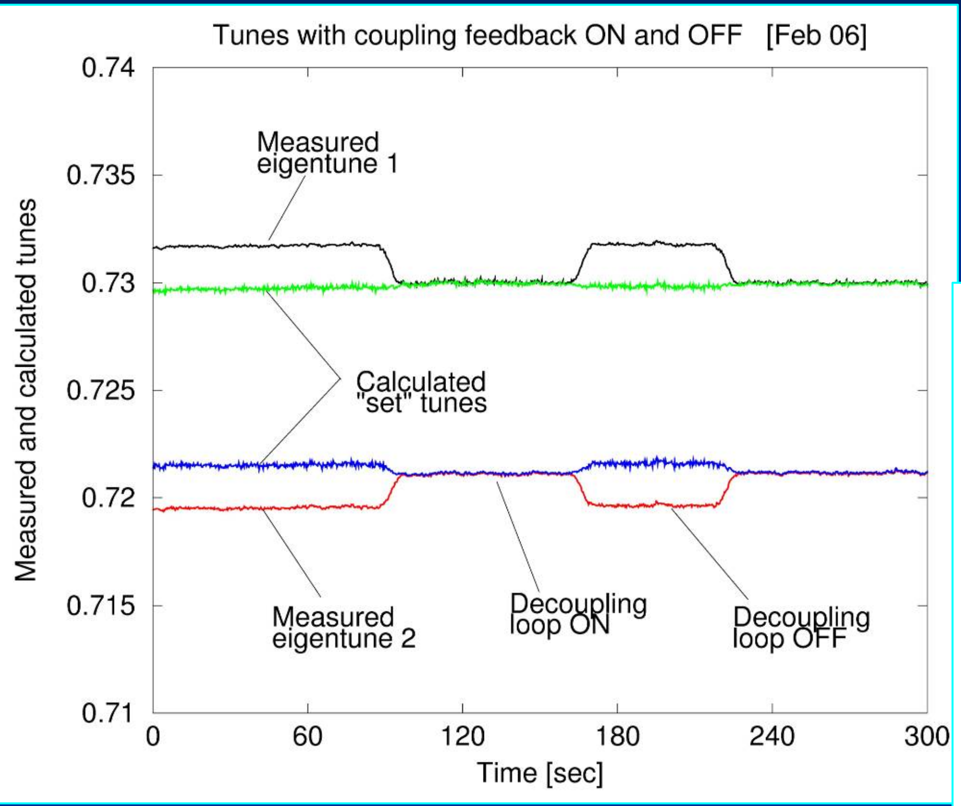


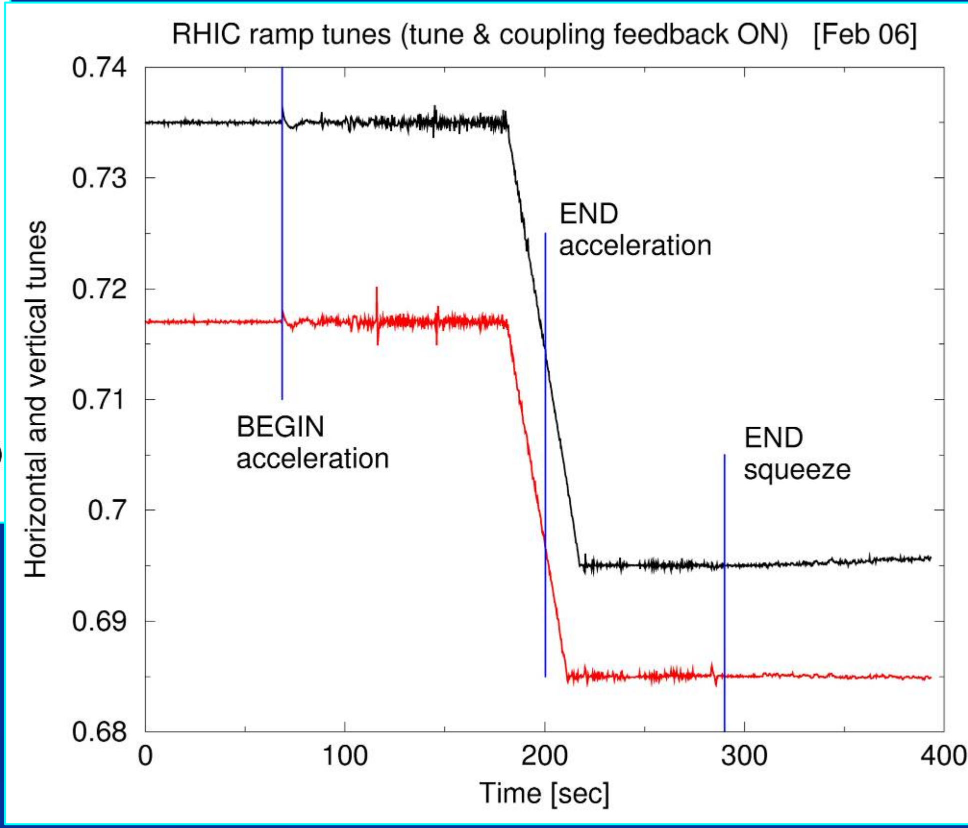
Advantages of the 3D AFE

- Sensitivity (noise floor in the 10 nm range)
- Virtually impossible to saturate
- ~160dB suppression of the revolution line
- Simplicity and low cost
- Base band operation
  - Excellent 24 bit audio ADCs available
  - Signal conditioning / processing is easy
- Independent of the machine filling pattern

Systems now installed in the SPS, PS, LEIR, RHIC & Tevatron

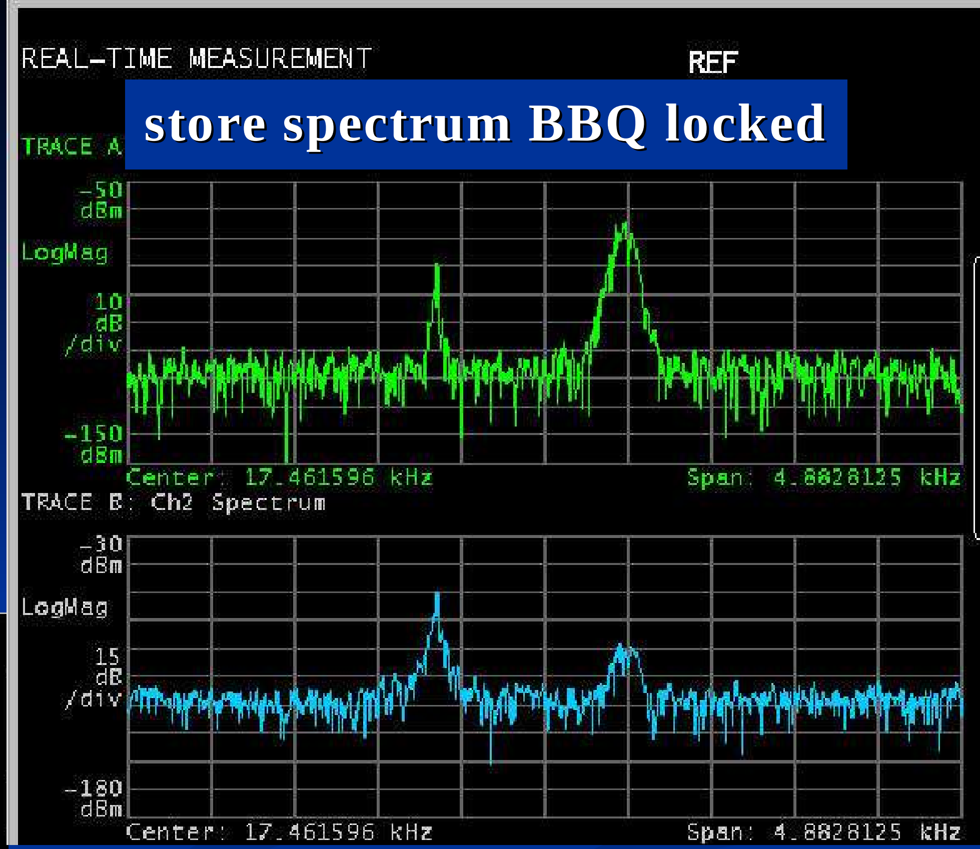
Tune & Coupling Feedback at RHIC during Run 6

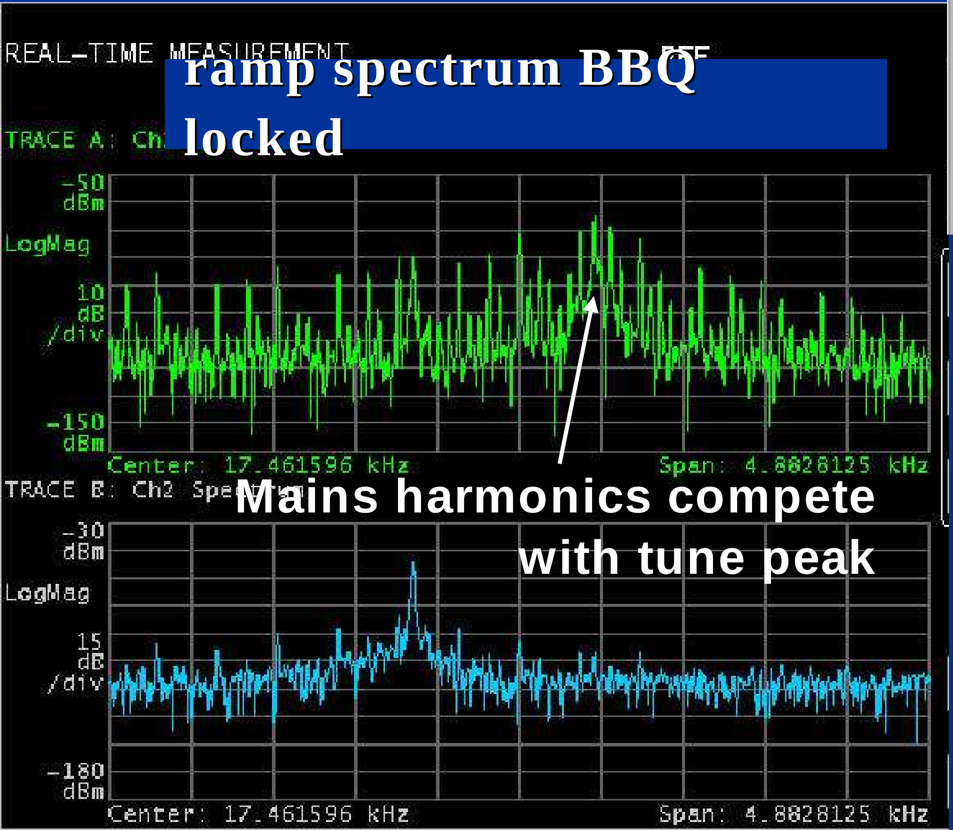




The third obstacle – Mains harmonics

Betatron resonance is **directly** excited by high harmonics of the power line frequency





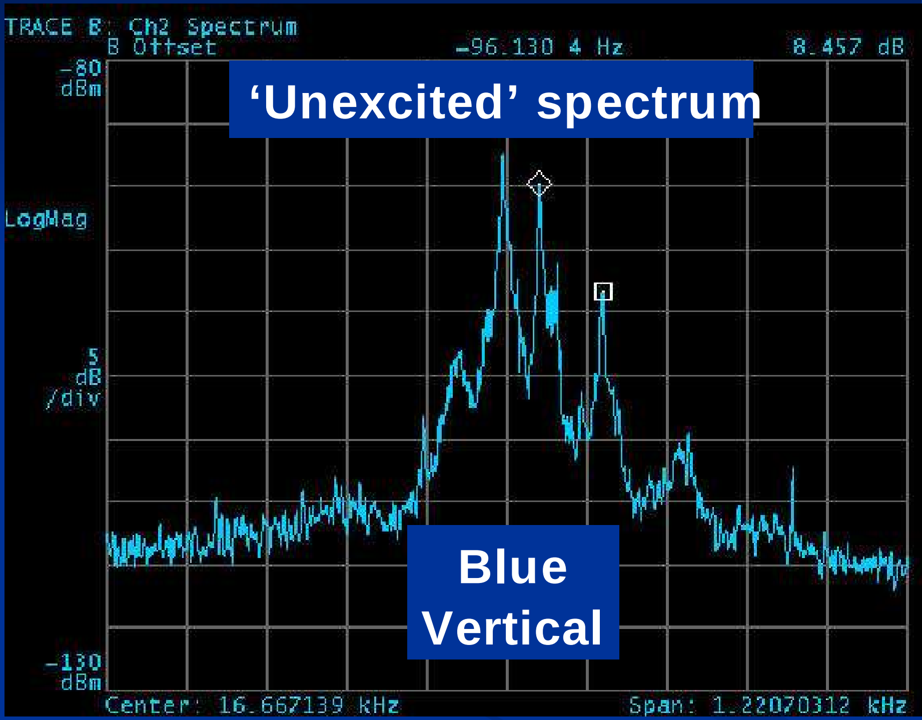
Mains harmonics remain the most serious obstacle to feedbacks

- ~70dB above noise floor on ramp
- dictates excessive beam excitation
  - causes emittance growth
  - contributes to 'tune scalloping'
  - makes chrom measurement difficult
- no significant progress on this

New problems in Run 7

Anomalous beam response at injection

- tunes separated and well decoupled
- not power line, synchrotron freqs
- similar in all 4 planes
- serious obstacle to acquiring lock
- serious contributor to 'noise'
- not seen in previous years
- disappeared with start of ramp
- not understood – speculation on power supply regulation at low current



New problems in Run 7

<u>'Tune Scalloping'</u>

- BBQ very precisely drives a slice up out of the tune distribution
- tune shifts as amplitude increases
- the slice depopulates as amplitude increases
- BBQ falls off that slice, locks back in the center of the distribution
- the process repeats

<u>Contributing factors</u>

- large kicker excitation
- large loop gains
- small chromaticity

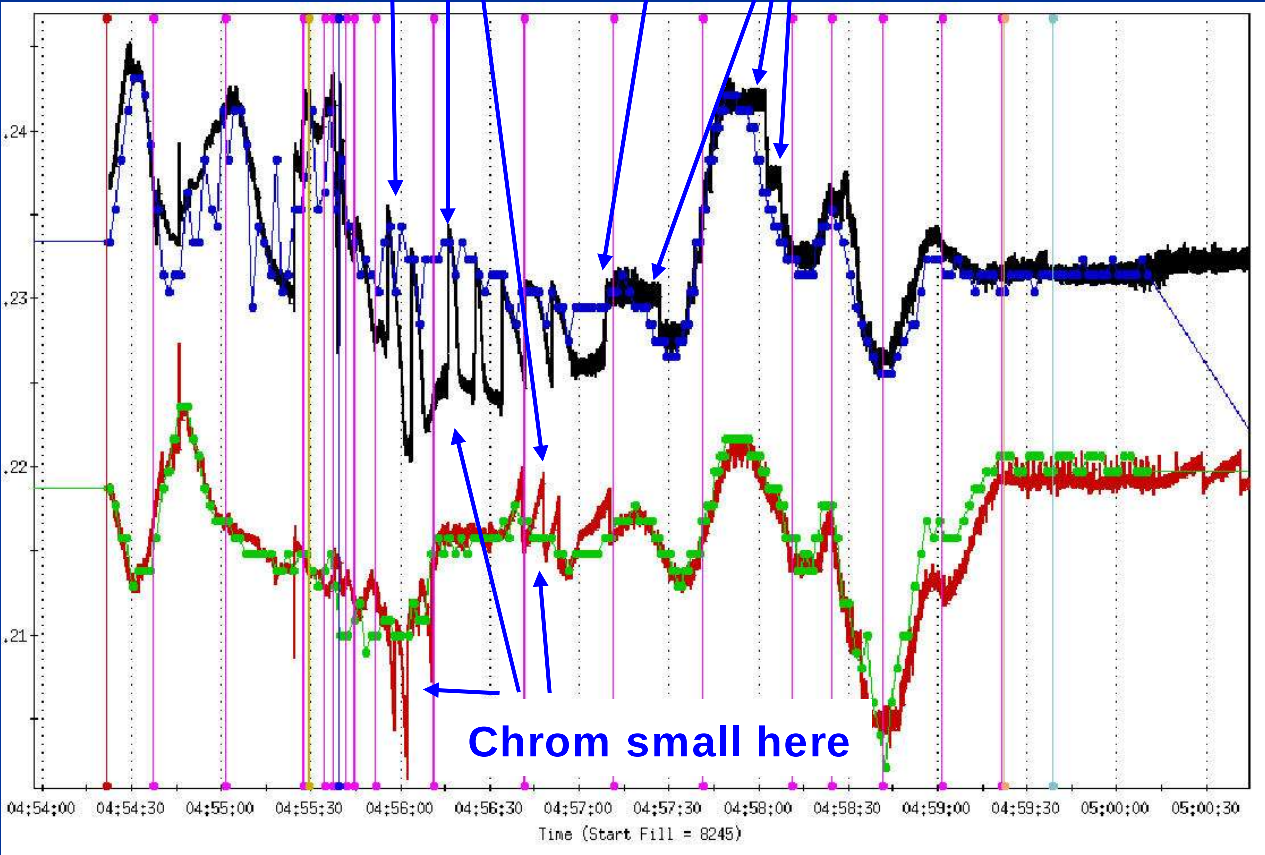
<u>Makes for a tight 'box'</u>

- need large kicker excitation because of mains harmonics
- need large loop gains for reliable tracking of fast tune changes
- chromaticity feedback not yet implemented – chrom control is not particularly good

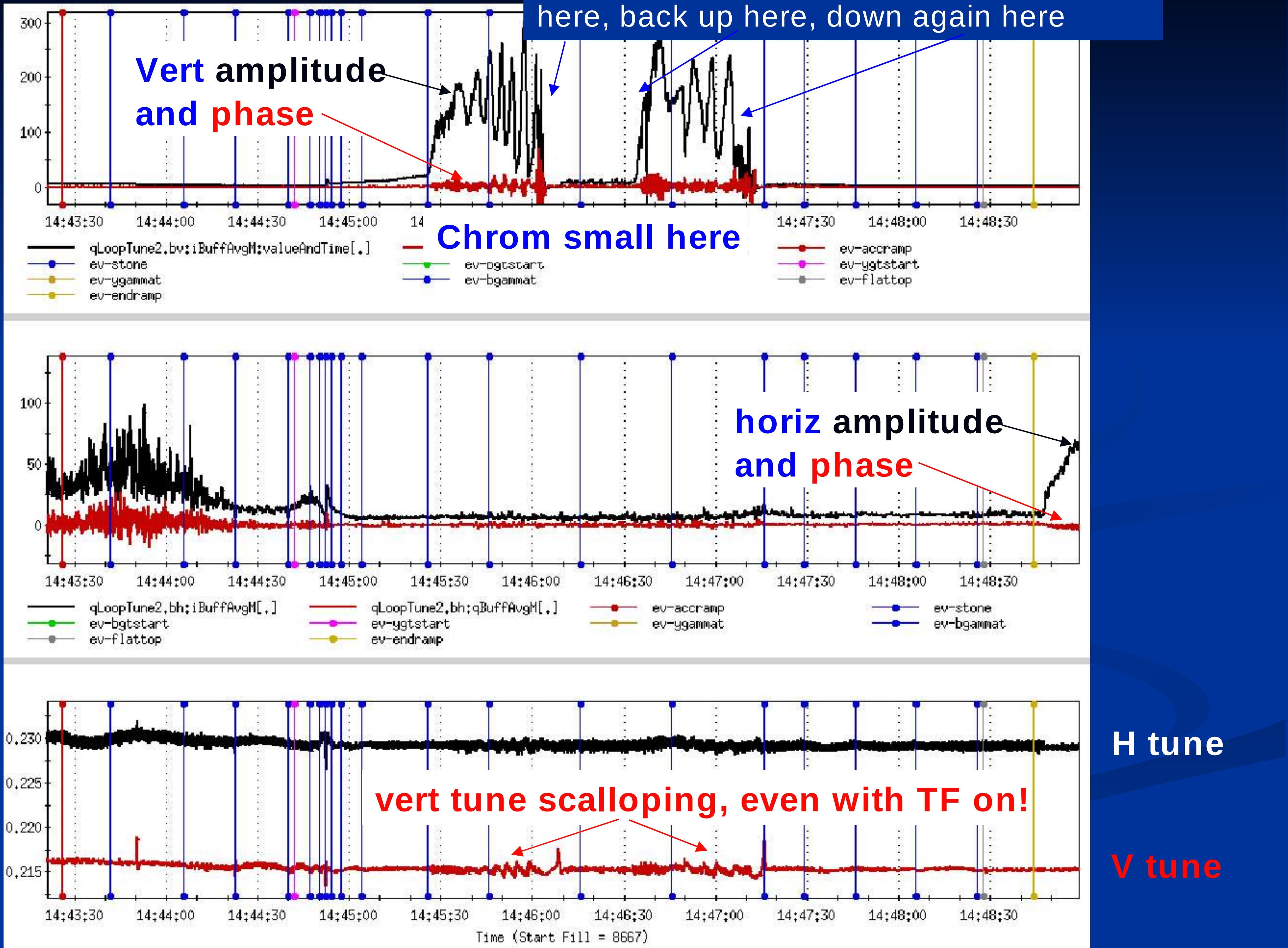
<u>A delicate balance to tune the tracking</u>

Kicker turned down here, then started locking on mains harmonics

scalloping



Scalloping with TF loops closed



Despite all this, there was good success