Global decoupling feedback

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1. Overview of eigenmode projection parameters
2. Continuous measurements of global coupling
3. Scheme of global coupling correction in RHIC
4. Other issues

Overview of eigenmode projection parameters

- Coupling is a problem in the linear optics. Single particle model is good enough to explian eigenmode projection parameters.

In the view of instrumentation,

$$\begin{cases} x_n = A_{1,x}\cos[2\pi Q_1(n-1)+\phi_{1,x}] + A_{2,x}\cos[2\pi Q_2(n-1)+\phi_{2,x}] \\ y_n = A_{1,y}\cos[2\pi Q_1(n-1)+\phi_{1,y}] + A_{2,y}\cos[2\pi Q_2(n-1)+\phi_{2,y}] \end{cases}, \tag{10}$$

Besides the two eigentunes Q_1 and Q_2, we define another 2 amplitude ratios

$$\begin{cases} r_1 = |A_{1,y}|/|A_{1,x}| \\ r_2 = |A_{2,x}|/|A_{2,y}| \end{cases}. \tag{11}$$

and two phase difference

$$\begin{cases} \Delta\phi_1 = \phi_{1,y} - \phi_{1,x} \\ \Delta\phi_2 = \phi_{2,x} - \phi_{2,y} \end{cases}. \tag{12}$$

They are measurable from turn-by-turn digital BPMs and PLL pickups.

▪ Analytical expressions to eigenmode projection parameters can be achieved in several linear coupling parameterizations.

For example, with Hamiltonian perturbation theory,

$$C^- = |C^-|e^{i\chi} = \frac{1}{2\pi}\int_0^L \sqrt{\beta_x\beta_y}k_s e^{i[\Psi_x-\Psi_y-2\pi\Delta\cdot s/L]}dl.$$

$$\begin{cases} Q_1 &= Q_{x,0} - \frac{1}{2}\Delta + \frac{1}{2}\sqrt{\Delta^2+|C^-|^2} \\ Q_2 &= Q_{y,0} + \frac{1}{2}\Delta - \frac{1}{2}\sqrt{\Delta^2+|C^-|^2} \end{cases}.$$

$$\begin{cases} r_1 &= \sqrt{\frac{\beta_y}{\beta_x}}\cdot\frac{|C^-|}{2\nu+\Delta} \\ r_2 &= \sqrt{\frac{\beta_x}{\beta_y}}\cdot\frac{|C^-|}{2\nu+\Delta} \end{cases},$$

$$\begin{cases} \Delta\phi_1 &= \chi \\ \Delta\phi_2 &= \pm\pi - \chi \end{cases}.$$

Continuous measurements of global coupling

- Obtain global coupling coefficient from eigenmode projection parameters

$$\begin{cases} Q_1 &= Q_{x,0} - \frac{1}{2}\Delta + \frac{1}{2}\sqrt{\Delta^2 + |C^-|^2} \\ Q_2 &= Q_{y,0} + \frac{1}{2}\Delta - \frac{1}{2}\sqrt{\Delta^2 + |C^-|^2} \end{cases} .$$

$$|C^-| = \frac{2\sqrt{R_I R_{II}}\,|Q_I - Q_{II} - p|}{1 + R_I R_{II}},$$

$$\Delta = \frac{(1 - R_I R_{II})\,|Q_I - Q_{II} - p|}{1 + R_I R_{II}}.$$

$$\begin{cases} r_1 &= \sqrt{\frac{\beta_y}{\beta_x}} \cdot \frac{|C^-|}{2\nu+\Delta} \\ r_2 &= \sqrt{\frac{\beta_x}{\beta_y}} \cdot \frac{|C^-|}{2\nu+\Delta} \end{cases} ,$$

$$\begin{cases} \Delta\phi_1 &= \chi \\ \Delta\phi_2 &= \pm\pi - \chi \end{cases} .$$

amplitude and phase

- The phase-locked loop tune meter is the best tool so far to measure eigenmode projection parameters.

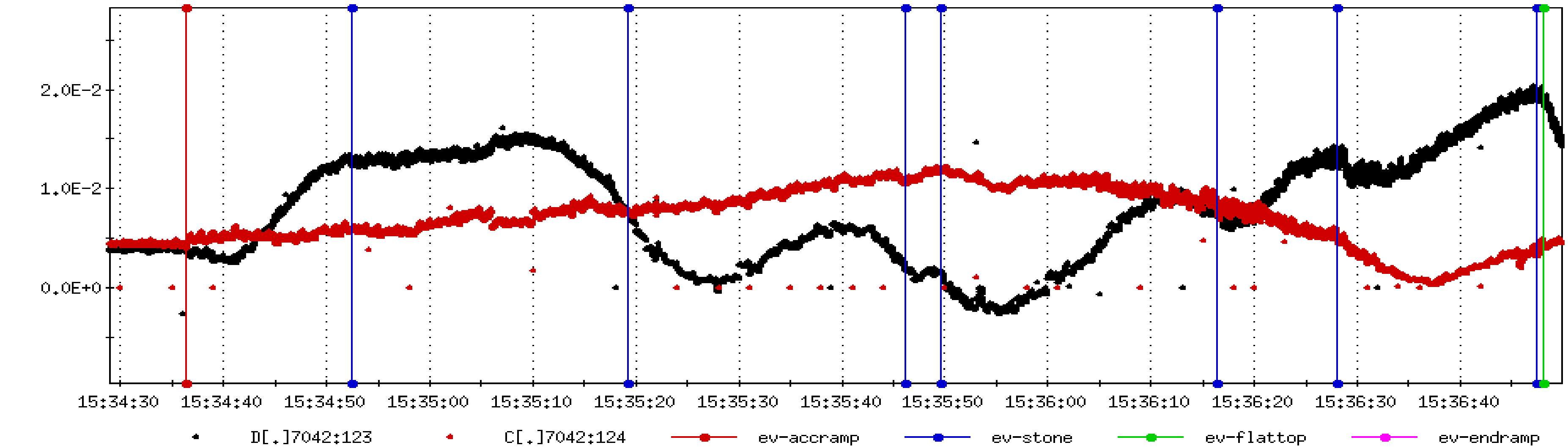
Merits of PLL:

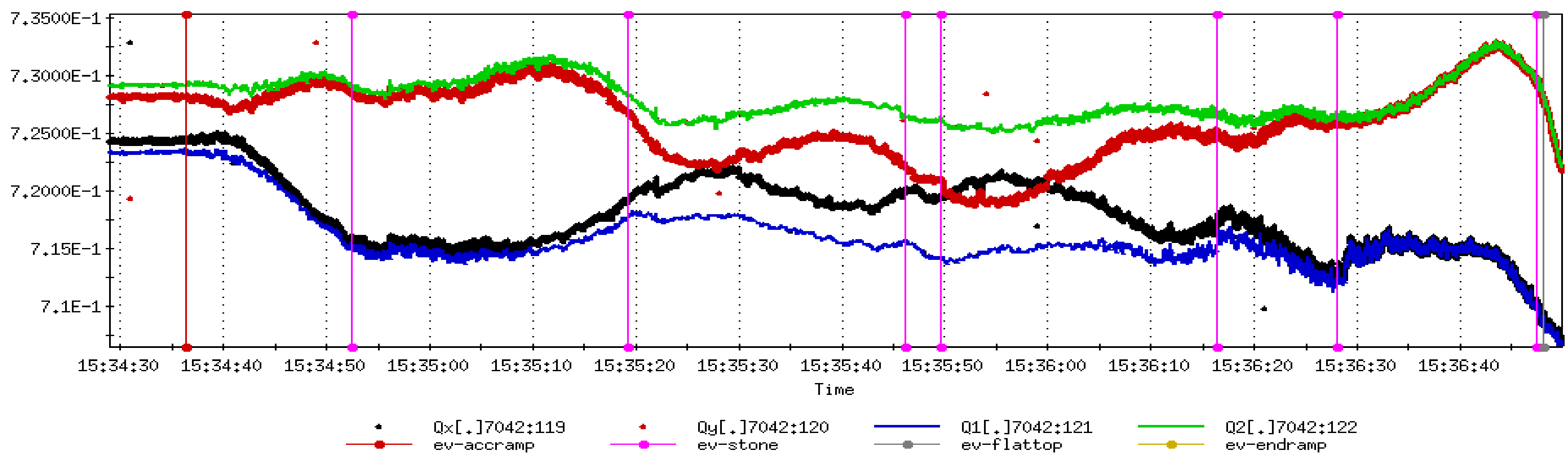
high resolution to detect small motion
robust to be able to work on ramp
continuous to be eligible for feedback

- Eigenmode projection parameters and coupling transfer function

No big difference
transfer function gives spectrum
transfer function reveals more information

- Coupling amplitude is constant along the ring. Not related to the observation location. Without the coupling phase information, we can calculate the set tunes. Coupling phase is related to the location





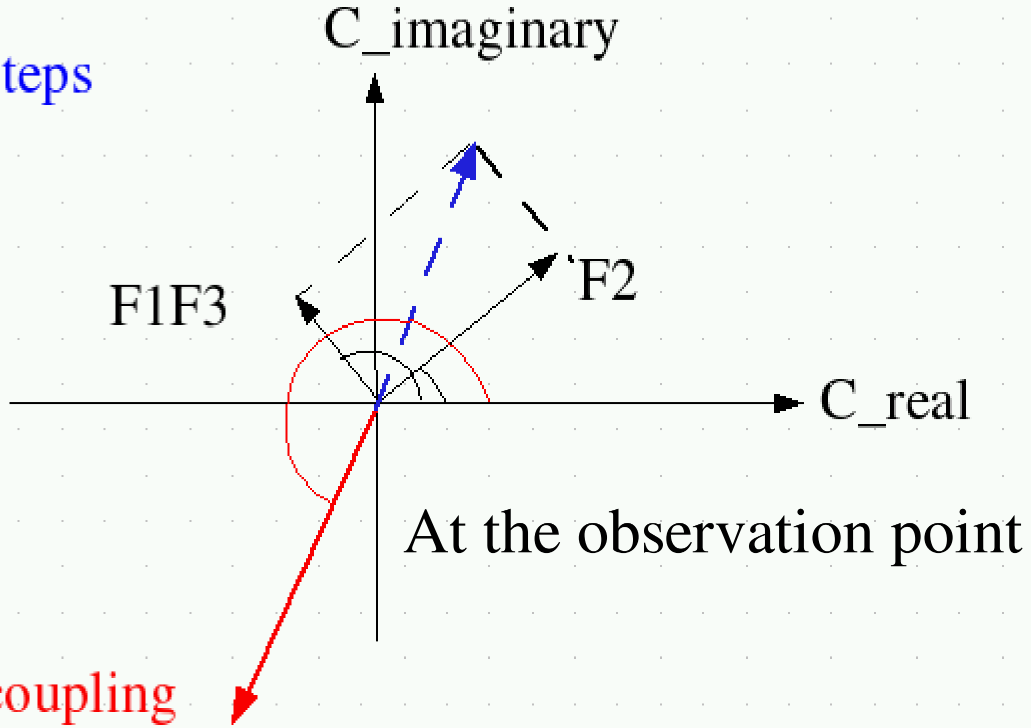
Scheme of global coupling correction in RHIC

- Decoupling: compensate the global coupling coefficient

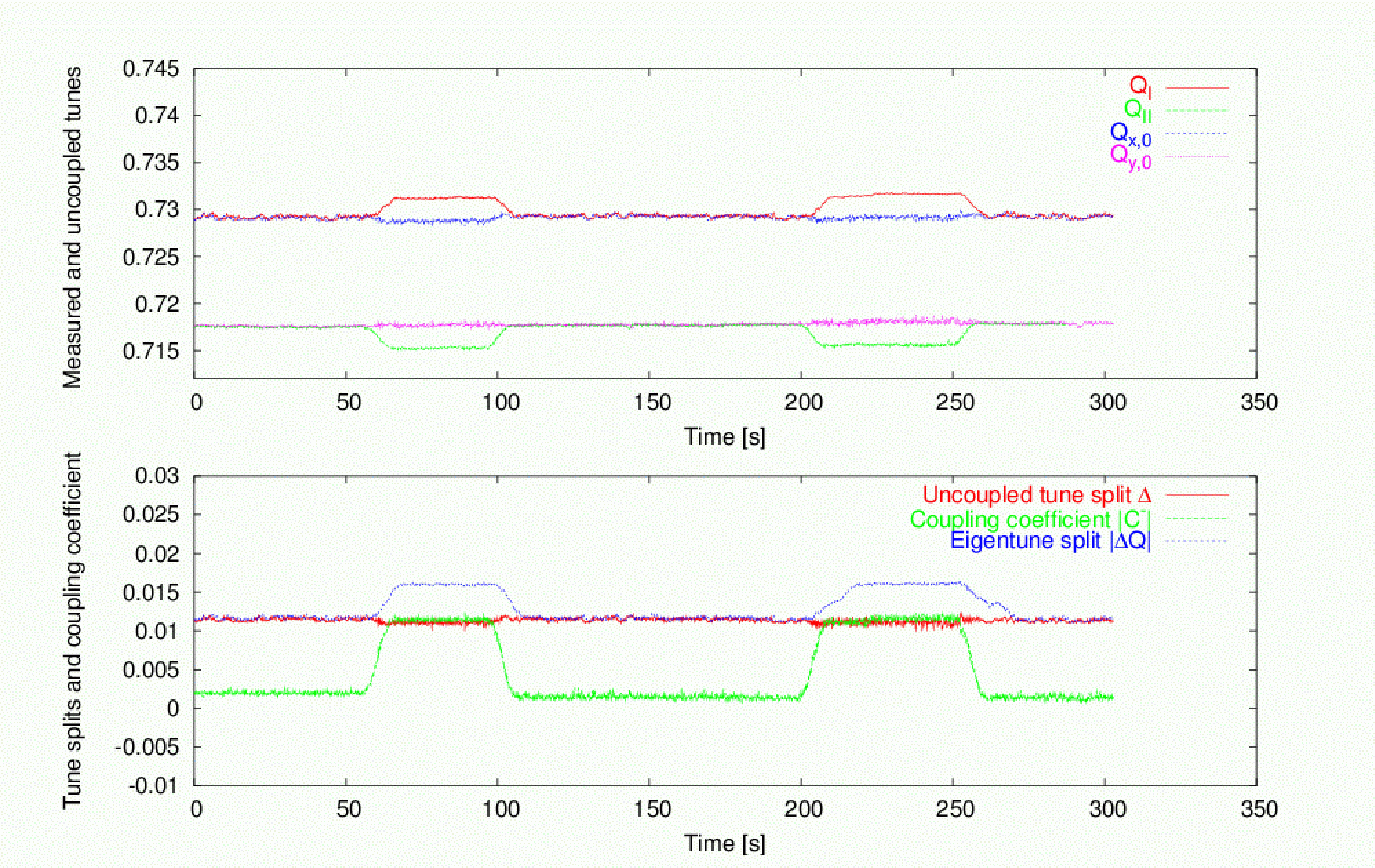
Coupling coefficient

$$C^- = |C^-| e^{i\chi} = \frac{1}{2\pi}\int_0^L \sqrt{\beta_x\beta_y}\, k_s e^{i[\Psi_x-\Psi_y-2\pi\Delta\cdot s/L]} dl.$$

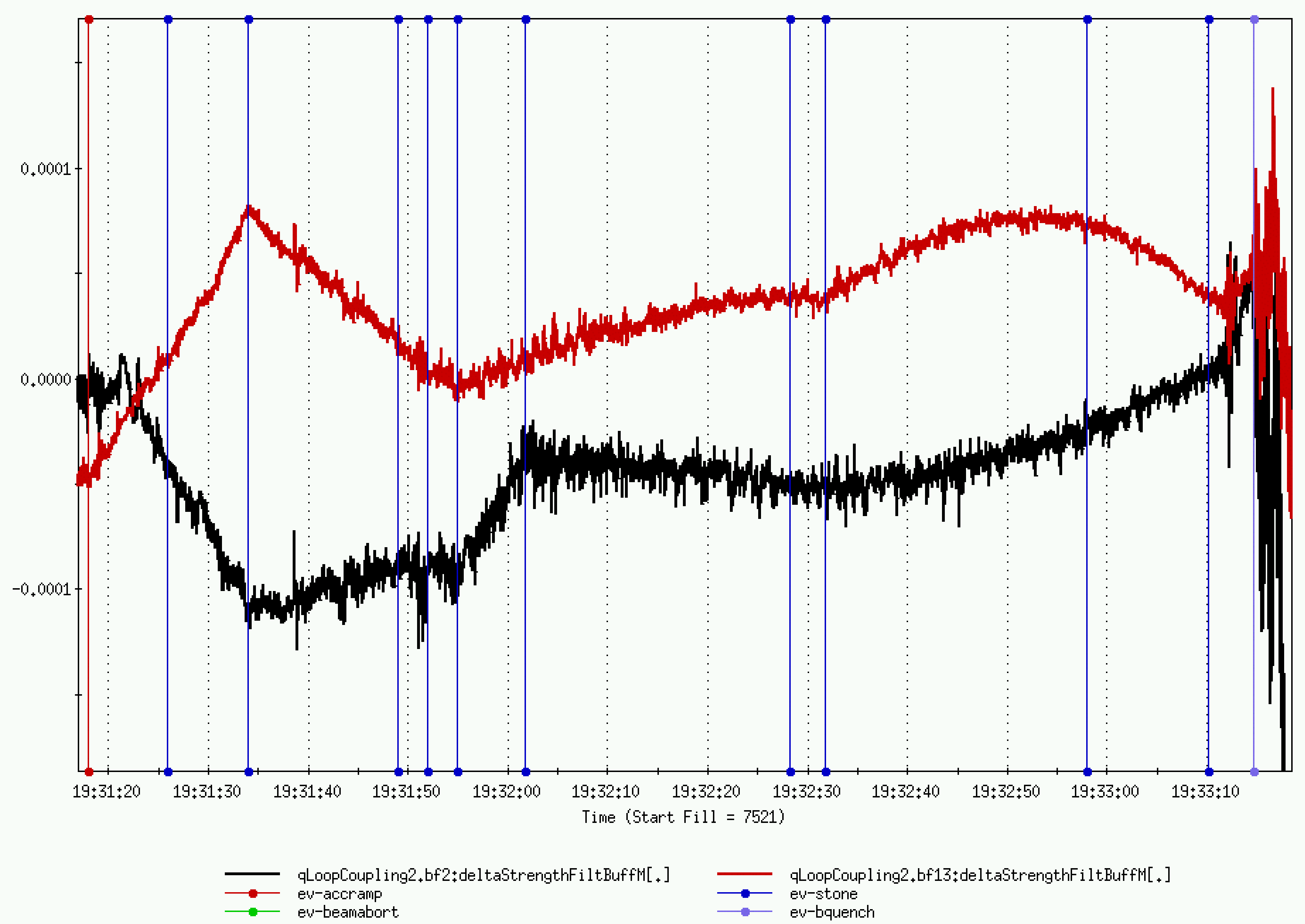
Correction in small steps



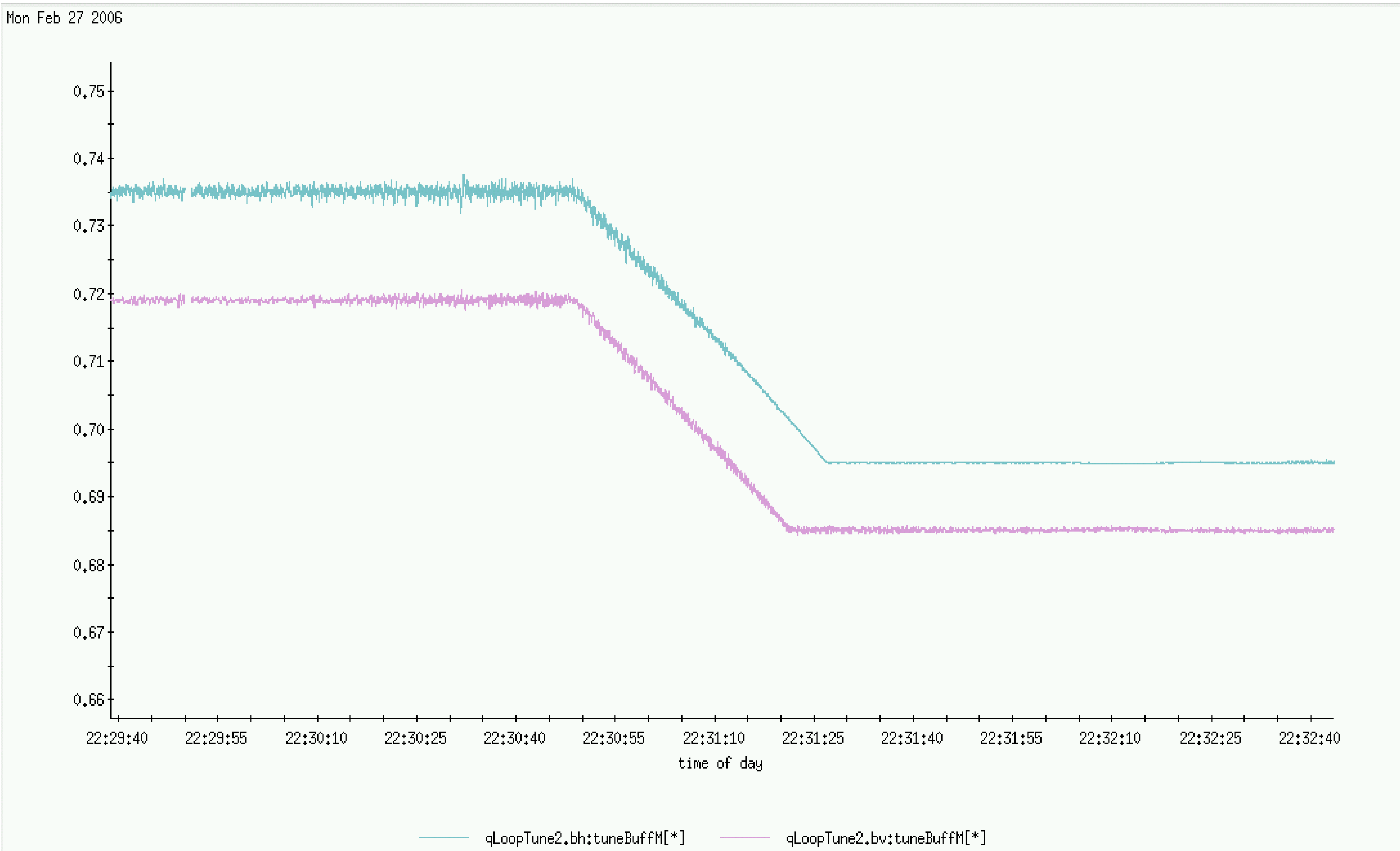
One example: Closing the feedback loop at injection



Another example: Logged decoupling strengths on the ramp

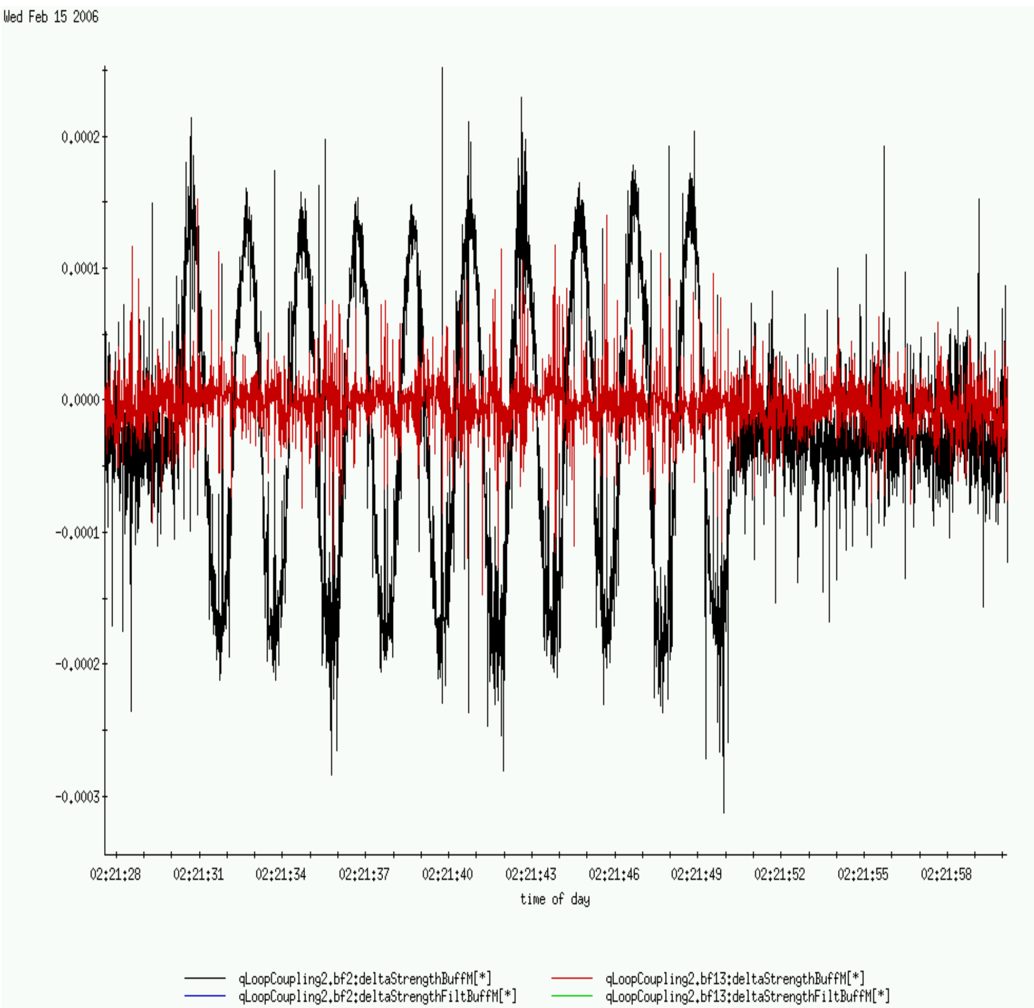


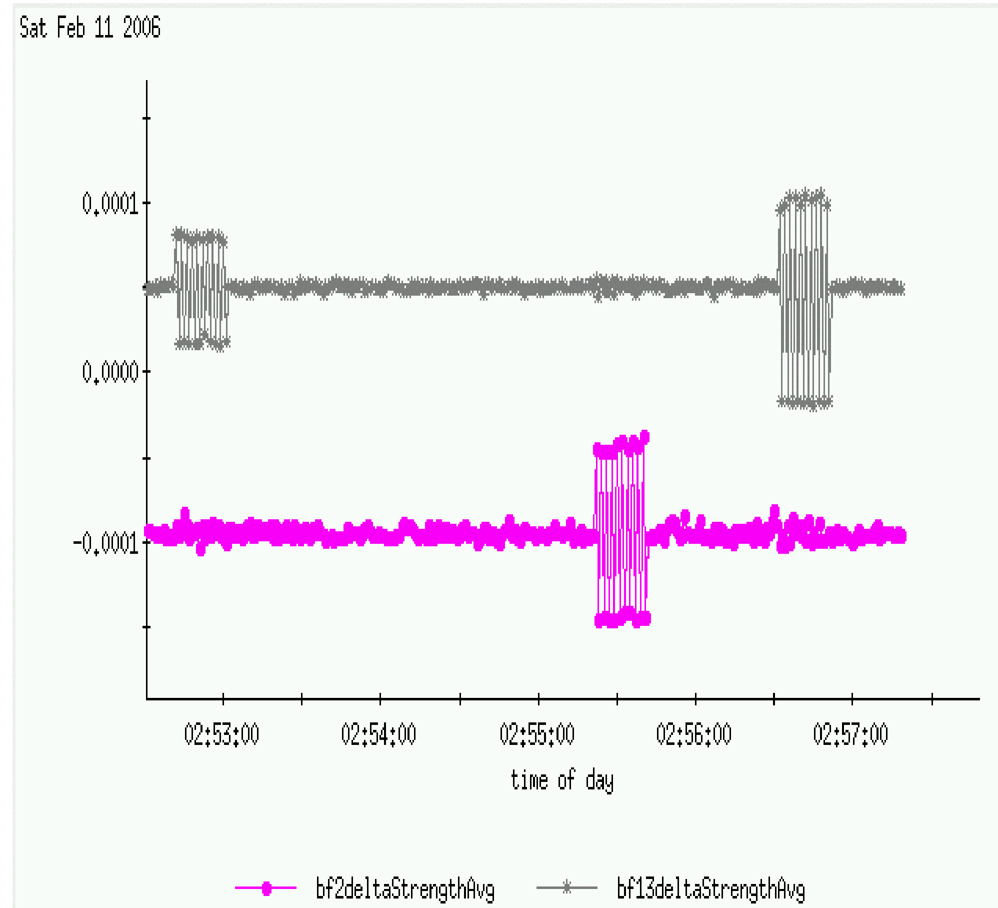
Good example of decoupling and tune feedback



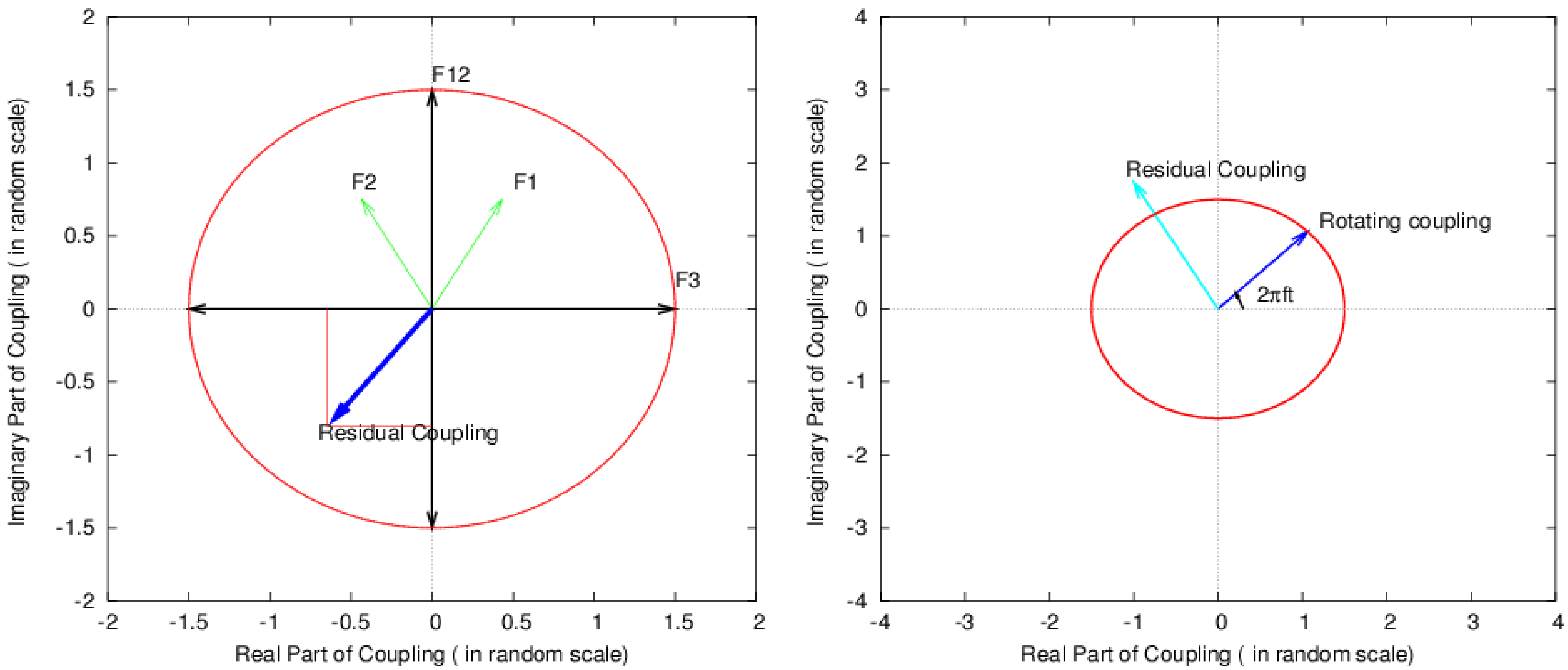
Other issues

- Skew quadrupole modulation is useful for decoupling feedback check.





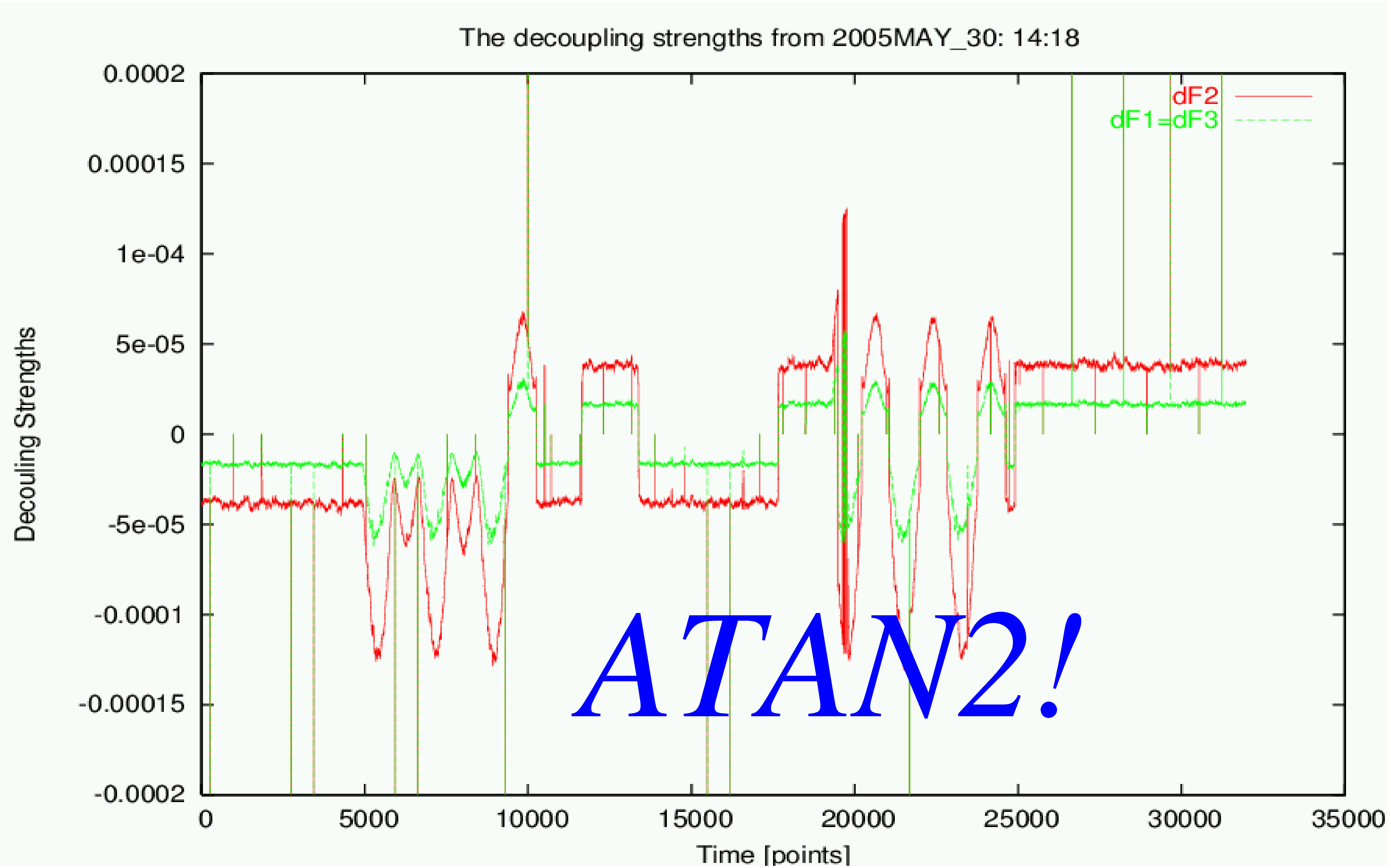
Skew quadrupole modulations



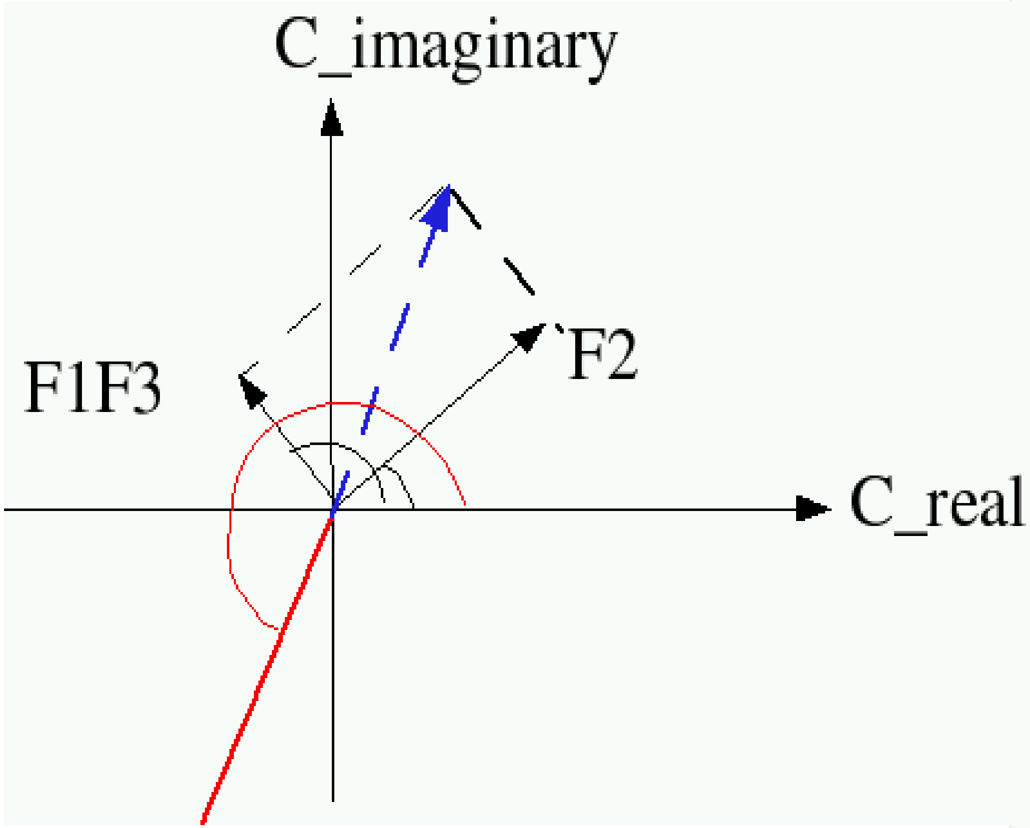
Coupling amplitude modulation

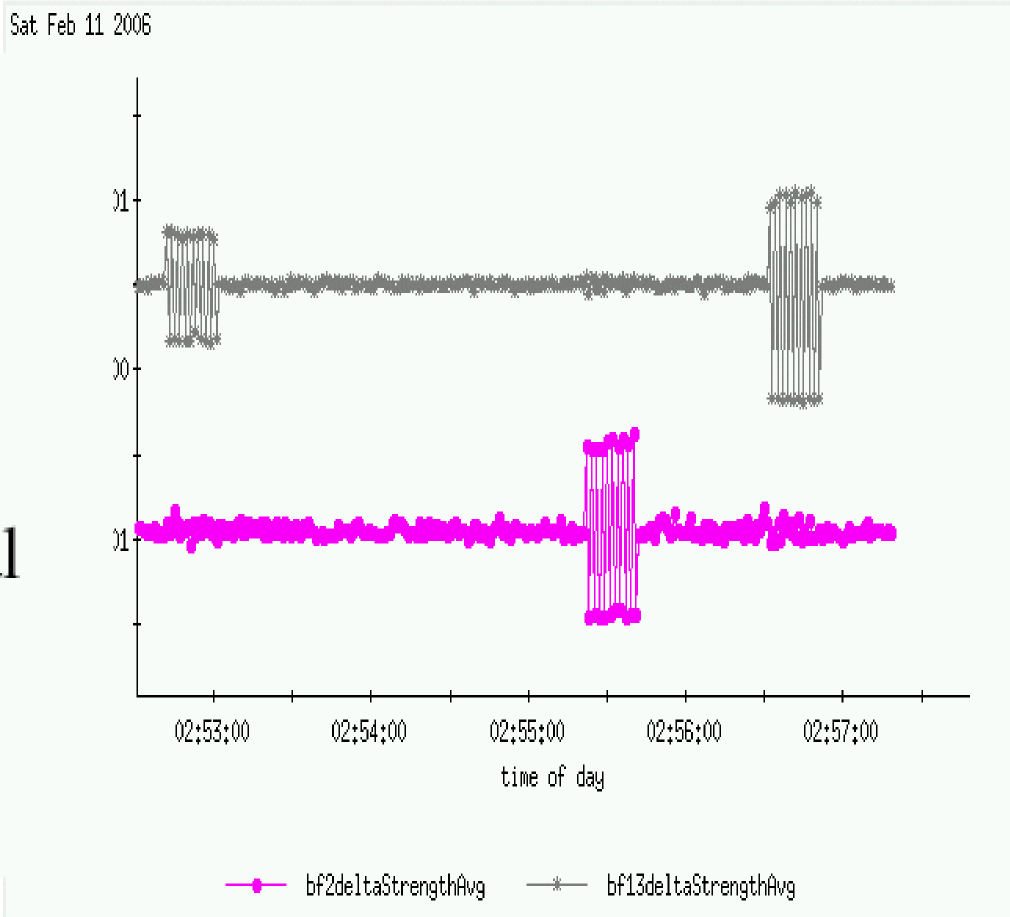
Coupling phase modulation

▪ Using atan2(I,Q) to get correct projection phases



▪ Using two orthogonal skew quadrupole families to simplify problem





- Importance of the coupling contribution angles from correction families

Procedure:

1)Values calculated from the off-line optics model

2) on-line **orthogonal** modulation to adjust them

3) on-line manual decoupling check

4) close the decoupling loop

Number right?

Sign right ?

Wrong signs of couping angles will kill the beam after you close the decoupling loop.

- PLL Tracks on the whole the ramp