Decoupling on the ramp

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1. General considerations

2. Decoupling scheme candidates

3. PLL tune jump

4. Near-term work plan

The role of coupling on the ramp

Coupling plays an imporatnt role on the LHC ramp.

1) Coupling shifts the design tunes.

Tune feedback couldn't work well without decoupling.

2) Coupling enlarges the design tune split.

Too large coupling will push the tunes to resonance lines.

3) Coupling also plays important role in other issues.

Why is decoupling on ramp difficult

1. Non-stop energy acceleration.

2. Beam optics evolves on the ramp.

   such as snapback, beta squeezing, different separation bumps.

3. Movements of the closed orbit on the ramp.

   Vertical orbit in sextupoles produces coupling

Therefore, **FAST** and **ROBUST** decoupling scheme and instrumentation are required.

Decoupling mode choosing

Feed-forward or Feedback ?

Considering optics has more or less change from ramp to ramp and decoupling feedback ensures the tune feedback, **decoupling in feedback mode is preferred.**

Decouping in feedback mode is still in research phase, not yet demonstrated on real machine.

Decoupling in feed-forward mode with skew quadupole modulations has been verified at the RHIC.
Feed-forward mode needs several ramp iterations.

Instrumentation choosing

1. **BPM** ?

BPM data from the kicked beam, which causes the emittance blowup.
Beam dynamics of kicked beam is complicated, coupling, nonlinear, and decoherence all play roles.
Another important concern is the quality of BPM data.
Data anlysis is not staright-forwards, fitting is always needed.

2. **Phase Lock Loop (PLL)?**

PLL has less perturbation to the beam
Coherent kicking
Outputs are straight-forward.

Therefore, PLL is preferred for the decoupling on ramp.

Decoupling Scheme Candidates

1. Decouple with BPM data

Decouple the 4*4 transfer matrix

Turn-by-turn BPM data from the kicked beam or injected beam.
Succeeded at theRHIC injection.
(W. Fischer, Phys. Rev. ST Accel. Beams **5** 54001, 2002)

Compensate the coupling coefficient

Extract coulpling coefficients from the kicked beam.
Decouple through a 4*4 orbit response matrix.
(V. Ziemann, Part. Accel. V **51**, 1995. Simulation work done.)

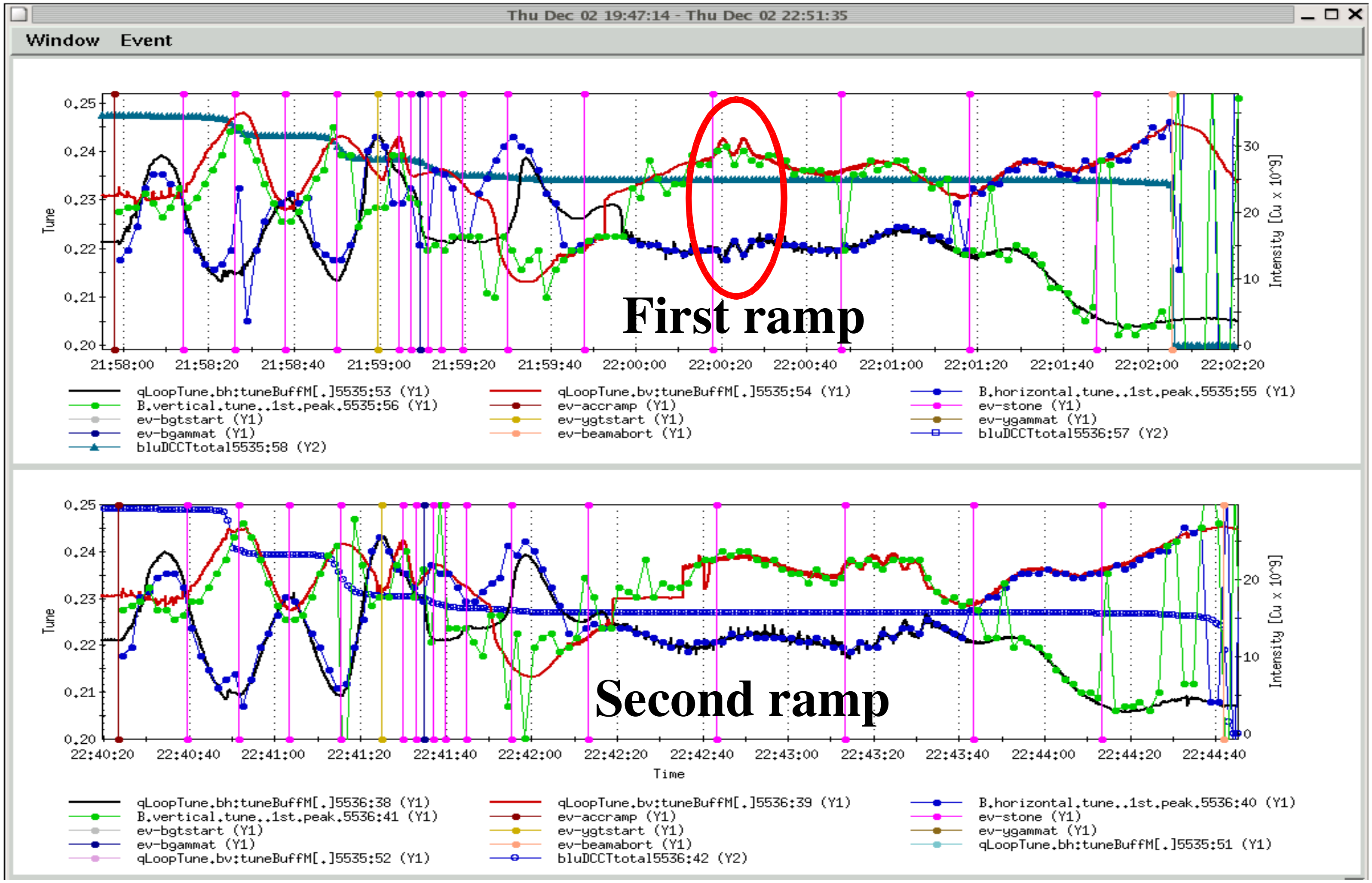
Decoupling Scheme Candidates

2 Skew quadrupole modulations (Y. Luo)

Modulate the skew quadrople families on the ramp
Correction strengths are obtained from tune modulation.
PLL system is used here for the fast tune tracking.

- Coupling angle modluation is simple and straight-forward.
- Fast and robust, verified on RHIC ramps.
- Less connection with the optics.
- Better used in Feed forward mode.
- However, it perturbs the beam.
- And it suffers PLL tune jump under some coupling situations.

One example of coupling angle modulation at RHIC



Decoupling Scheme Candidates

3 **Amplitude ratio / phase difference** decouping loops (Y.Luo)

In the view of instrumentation,

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

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

$$\left\{ \begin{array}{lcl} r_1 & = & |A_{1,y}|/|A_{1,x}| \\ r_2 & = & |A_{2,x}|/|A_{2,y}| \end{array} \right. . \tag{11}$$

and two phase difference

$$\left\{ \begin{array}{lcl} \Delta\phi_1 & = & \phi_{1,y} - \phi_{1,x} \\ \Delta\phi_2 & = & \phi_{2,x} - \phi_{2,y} \end{array} \right. . \tag{12}$$

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

Simulation of decouping 2-D scan

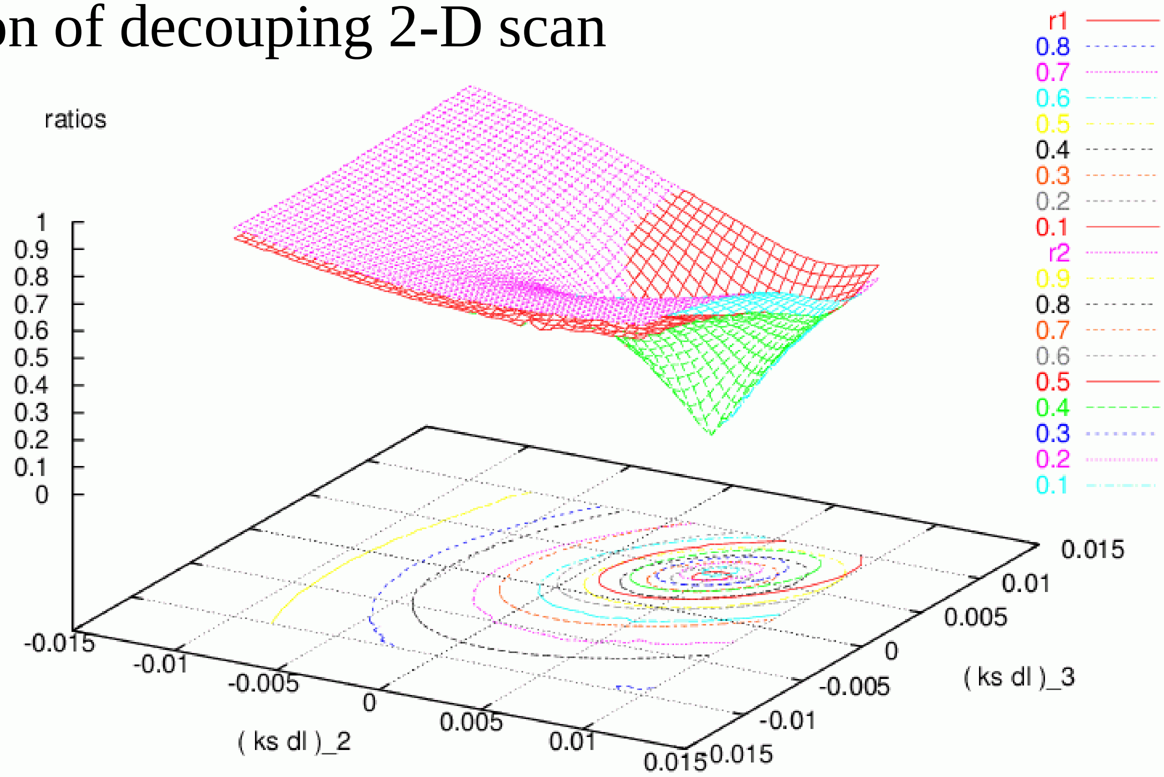


Figure 6: The amplitude ratios $r_{1,2}$ in the 2-D decoupling scan.

Amplitude ratio is more sensitive than tune split near the uncoupled point.

Simulation of decouping 2-D scan

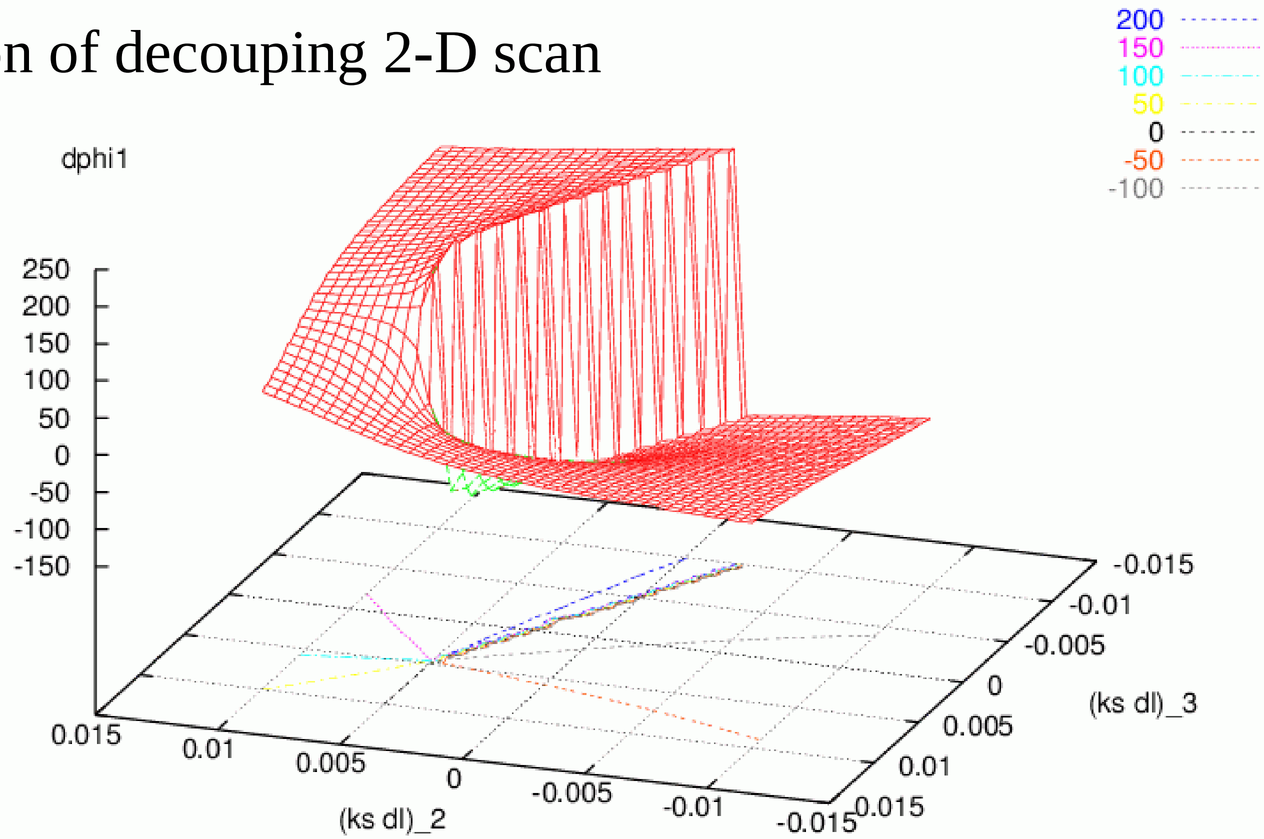
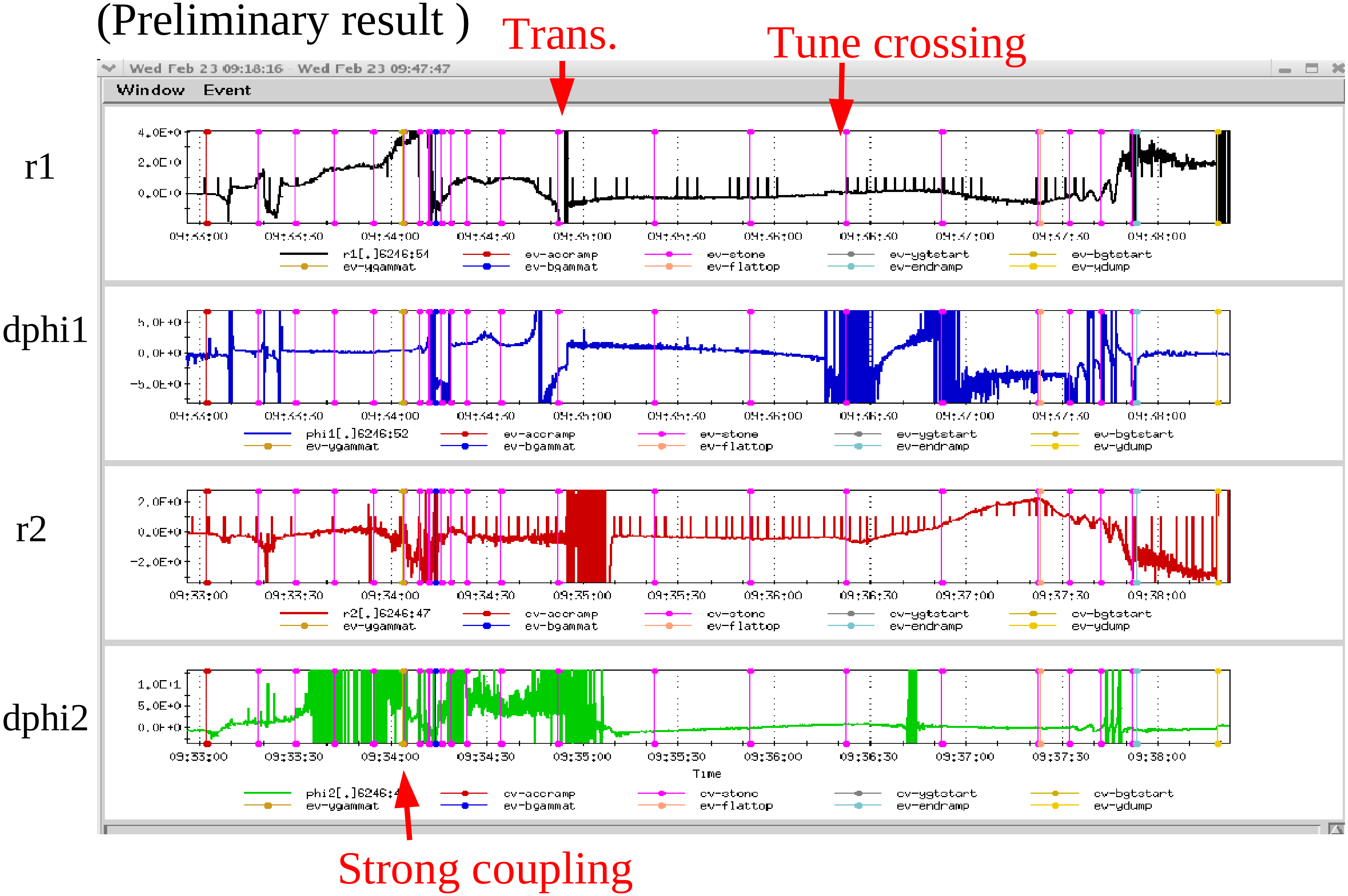


Figure 7: The phase differences $\Delta\phi_1$ in the 2-D decoupling scan.

The phase differences tells the global decoupling direction.

Measuerment on the ramp at RHIC with PLL system
(Preliminary result)



PLL tune jump under coupling

1. PLL is a powerful tool for the decoupling purpose.

2. PLL suffers tune jump under some coupling situation.

3. The solutions to PLL losing lock:

- Possible PLL improvement
- Combining coupling feedback and tune feedback

PLL tune jump example

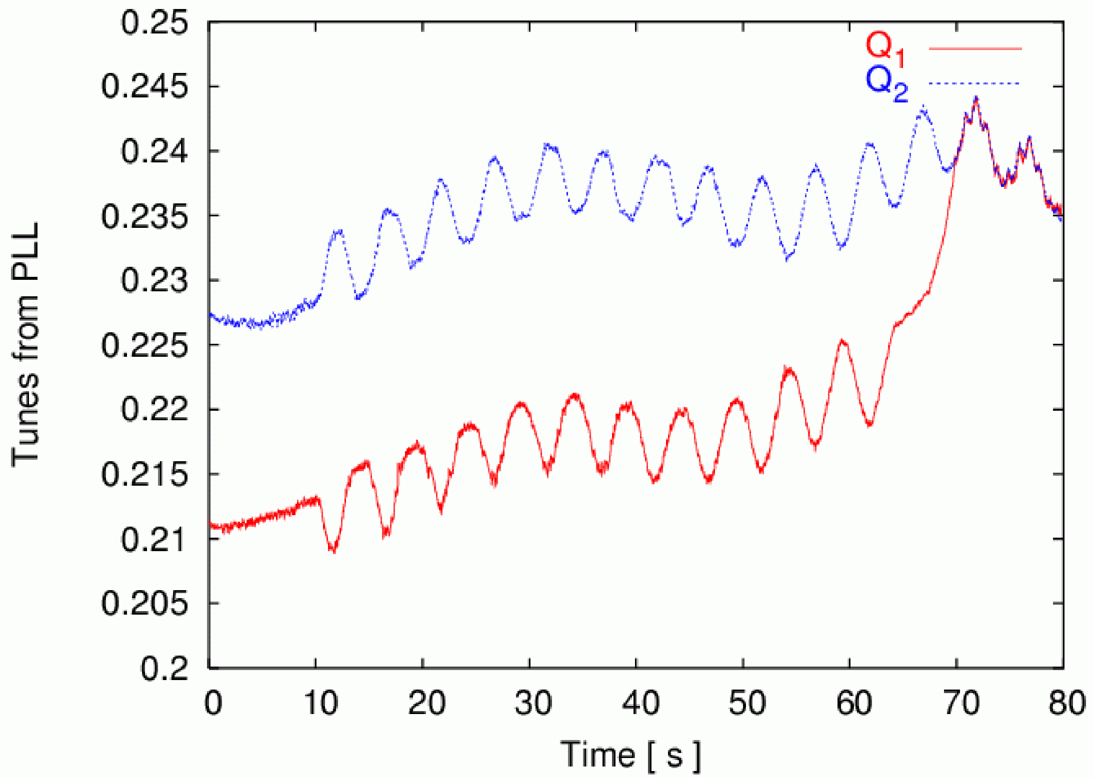


FIG. 6: An example of measurement on the ramp.

Notice : this happens not only in the skew quadrupole modulation, but also in chromaticity measuremetn and normal operation.

Work plan for decoupling feedback

1. Beam experiment at RHIC

   test the 6 coupling parameter measurment on ramp
   test the amplitude ratio and phase difference decoupling loops

2. PLL problems to be addressed

   robust PLLsystem to be able to avoid the PLL tune jump
   obtain valid 6 parameter data, get rid of the hairs and spikes

3. If we succeed at RHIC, apply to the LHC decouping on ramp