Betatron Tune Feedback

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KEKB Accelerator Review Committee
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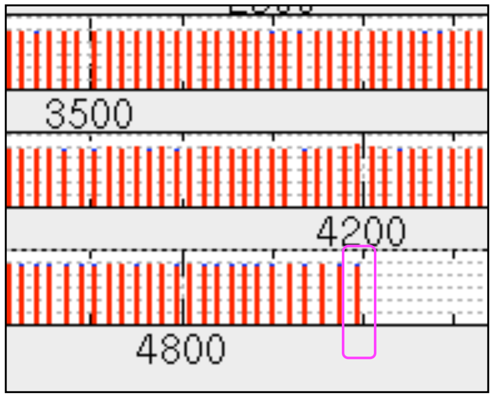
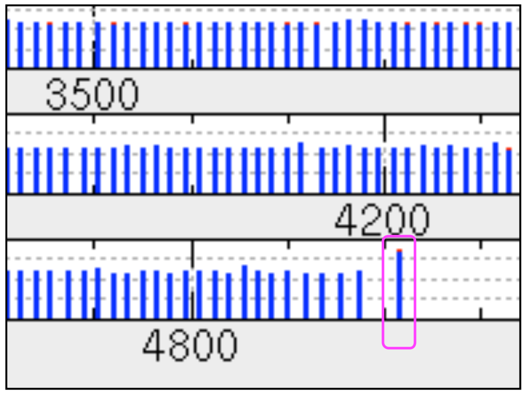
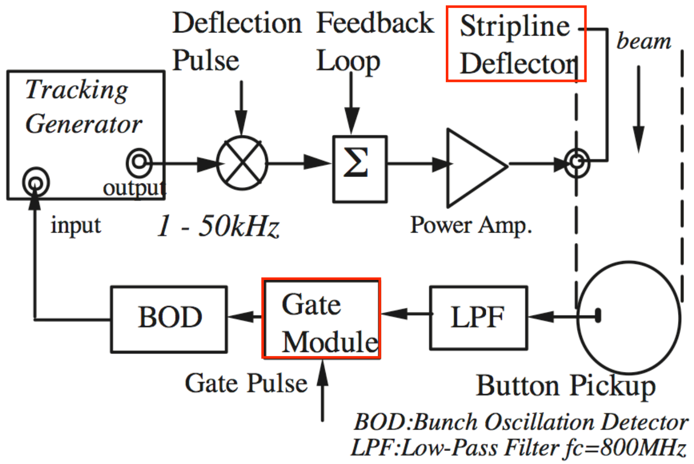
Betatron Tunes of the Pilot Bunch

- The pilot bunch (non-collision bunch)





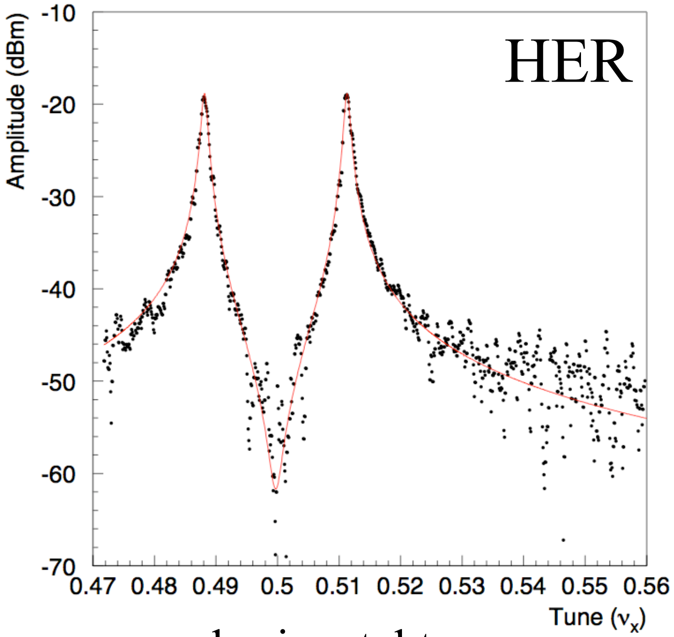
- Betatron tunes are measured with a swept-freuency method using a tracking analyzer and a gate module.



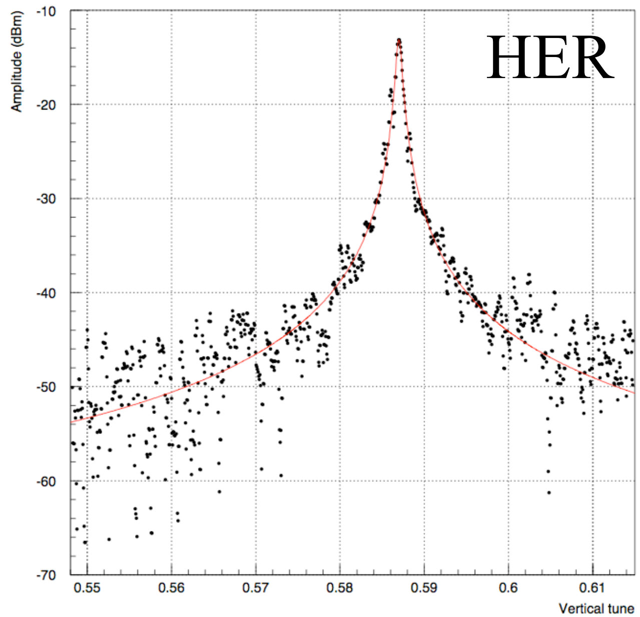
Details will be given by T. Ieiri

Gated Tune Measurement

- Measured horizontal and vertical betatron tunes(HER)



horizontal tune



vertical tune

dot: data
red line: fitted line

Gated Tune Measurement (cont'd)

A betatron oscillation measured by a beam position monitor is

$$x(n) = a\cos(\mu n + \phi_0)e^{-\omega n}, \tag{1}$$

where a is the initial amplitude, $\mu \equiv 2\pi\nu$ is the betatron tune, ϕ_0 is the initial phase advance, ω is the damping rate, and n is the turn number. Two Fourier sums can be defined as follows:

$$\begin{aligned} C(\mu') &= \sum_{n=0}^{\infty} x(n)\cos(\mu' n) \\ &= \frac{a}{2}\left\{\frac{\cos\phi_0 - e^{-\omega}\cos(\phi_0 - \mu - \mu')}{1 - 2e^{-\omega}\cos(\mu+\mu') + e^{2\omega}} + \frac{\cos\phi_0 - e^{-\omega}\cos(\phi_0 - \mu + \mu')}{1 - 2e^{-\omega}\cos(\mu - \mu') + e^{-2\omega}}\right\} \end{aligned} \tag{2}$$

$$\begin{aligned} S(\mu') &= \sum_{n=0}^{\infty} x(n)\sin(\mu' n) \\ &= \frac{a}{2}\left\{\frac{\sin\phi_0 - e^{-\omega}\sin(\phi_0 - \mu - \mu')}{1 - 2e^{-\omega}\cos(\mu+\mu') + e^{2\omega}} - \frac{\sin\phi_0 - e^{-\omega}\sin(\phi_0 - \mu + \mu')}{1 - 2e^{-\omega}\cos(\mu - \mu') + e^{-2\omega}}\right\}. \end{aligned} \tag{3}$$

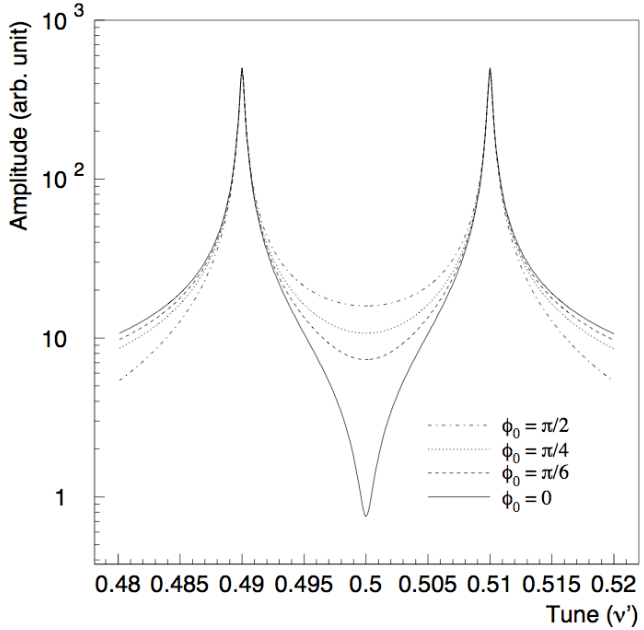
The Fourier spectrum can be calculated by

$$A(\mu') = \sqrt{C^2(\mu') + S^2(\mu')}, \tag{4}$$

where $C(\mu')$ from Eq. (2) and $S(\mu')$ from Eq. (3), then

$$A(\mu') = a\left[\frac{1 + \cos 2\phi_0 - 4e^{-\omega}\cos\phi_0\cos(\phi_0 - \mu)\cos\mu' + e^{-2\omega}\{1 + \cos 2(\phi_0 - \mu)\}}{2\{1 - 2e^{-\omega}\cos(\mu - \mu') + e^{-2\omega}\}\{1 - 2e^{-\omega}\cos(\mu + \mu') + e^{-2\omega}\}}\right]^{\frac{1}{2}}. \tag{5}$$

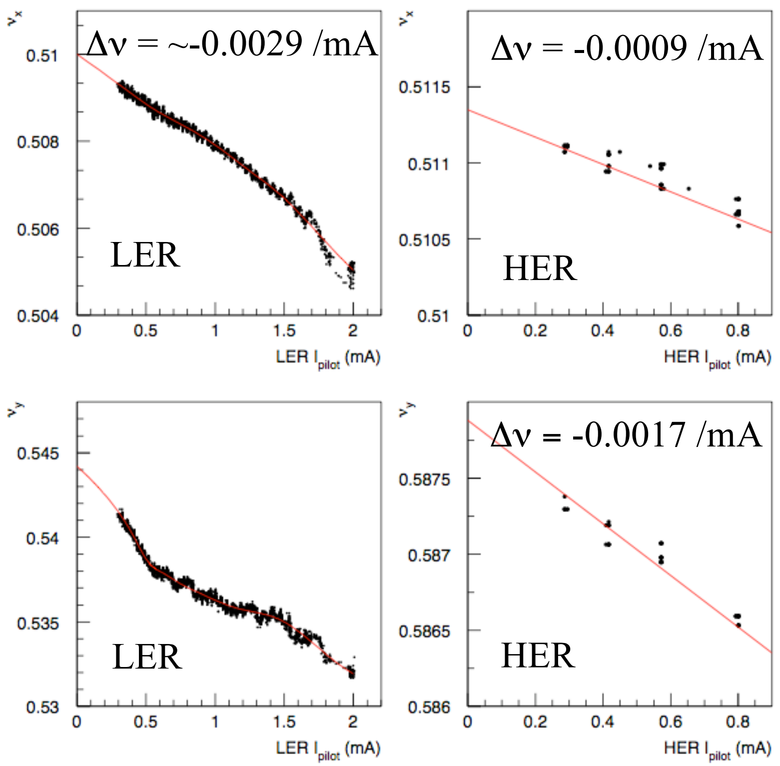
The Fourier spectrum calculated by Eq. (5) is shown in Fig. 1. The betatron tune is $\nu = 0.510$ and the damping rate is $\omega = 0.001$. The several lines indicate the different initial phases, $\phi_0 = 0$, $\pi/6$, $\pi/4$, and $\pi/2$. The analytic formula includes the aliasing effect[1].

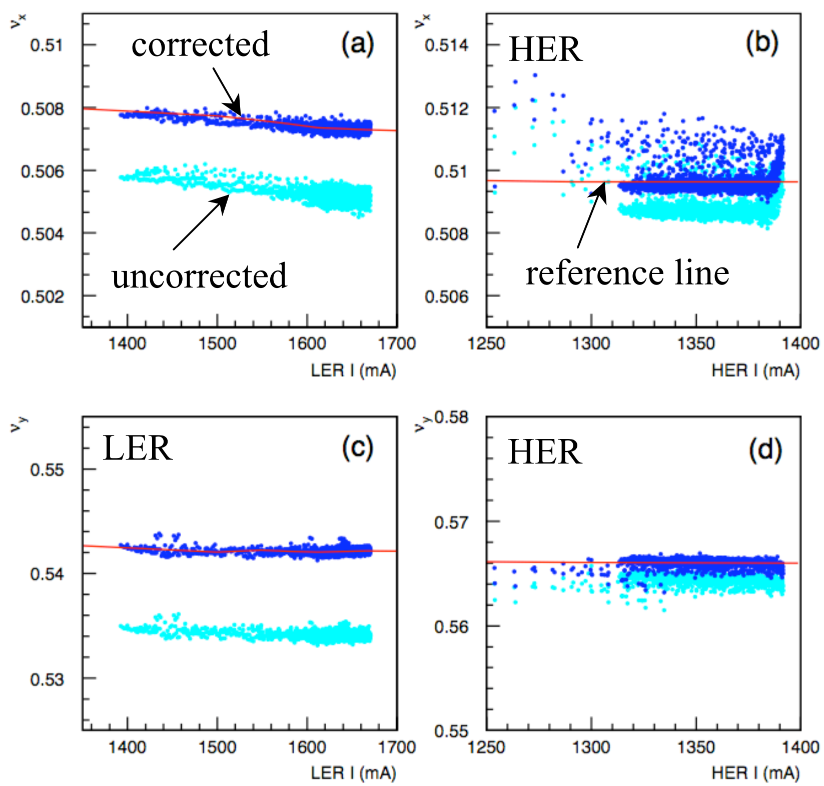


Fourier spectrum calculated by Eq. (5). $\nu = 0.510$ and $\omega = 0.001$.

Dependence of Bunch Current

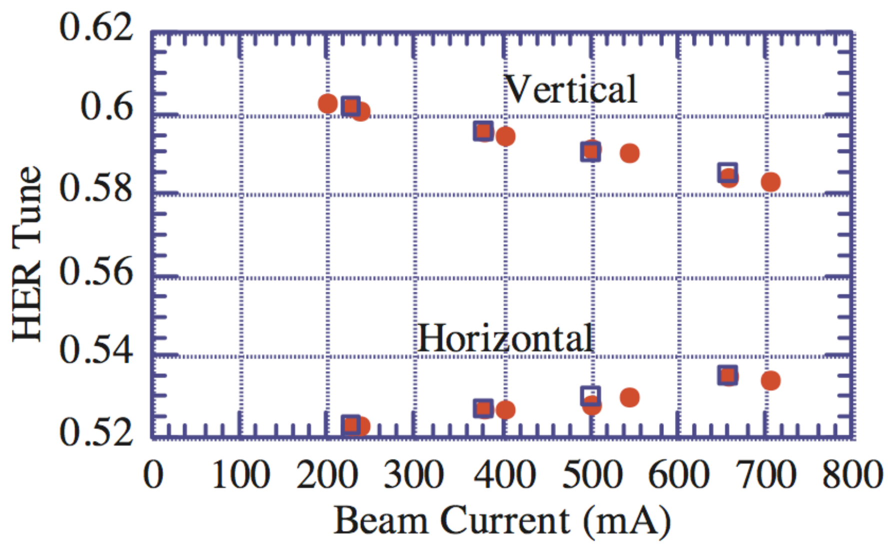
- Tune shift depends on the bunch current.
  - head-tail wake effects, electron cloud effects(only for LER)?
  - Corrected tunes(@zero bunch current) are used for tune FB.





Dependence of Total Beam Current

- Tune shift due to a quadupole field induced by resistive-wall of a chamber in HER. The cross section of the chamber is non-axisymmetric.



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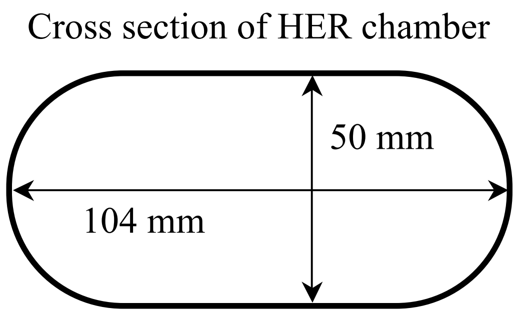
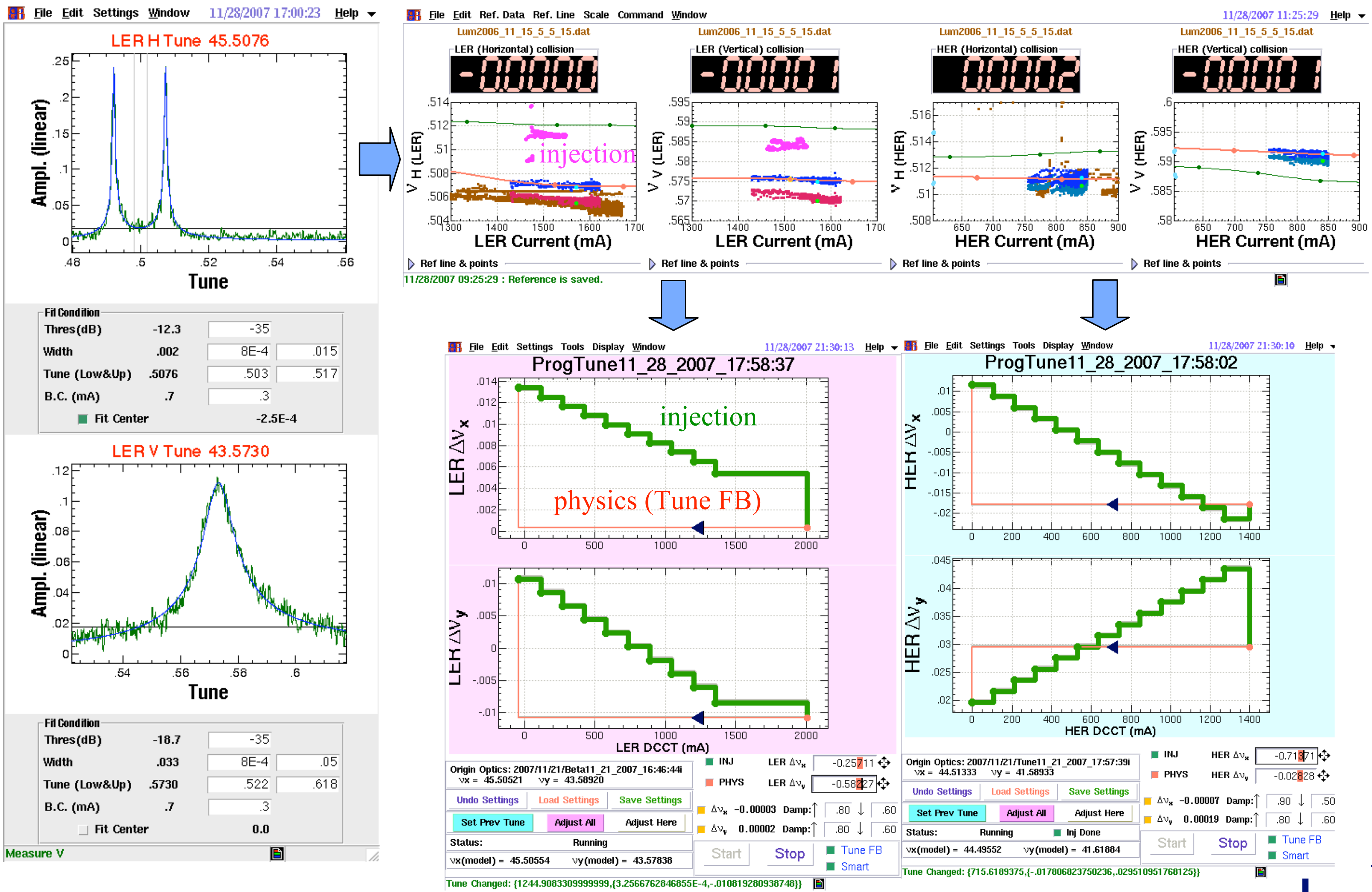


- horizontal tune shift: $\Delta\nu_x$ = +0.026/ A
- vertical tune shift: $\Delta\nu_y$ = -0.037/ A

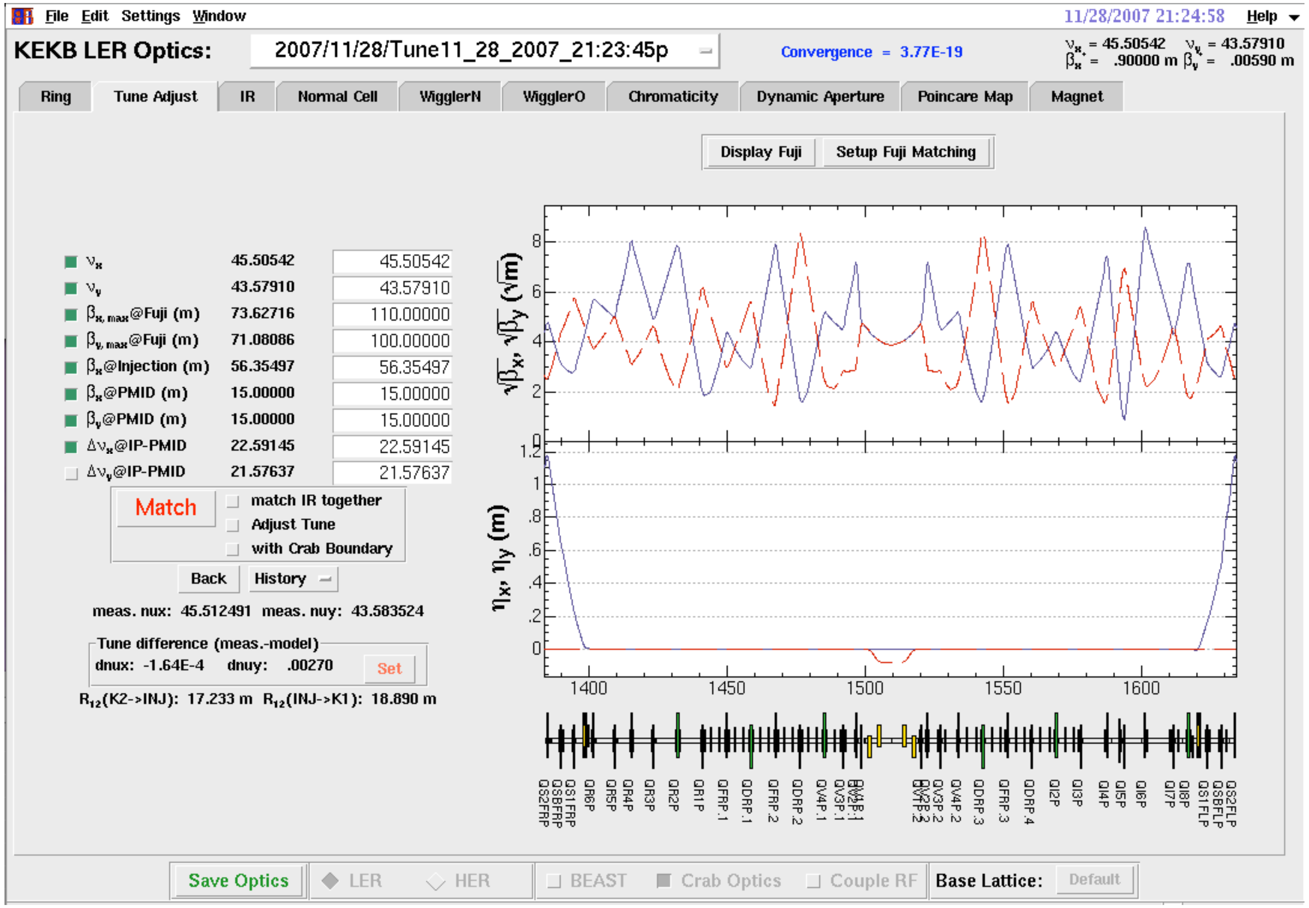
Tune Feedback System (online operation)



LER Tune Matching

QR{123456}, Q{DF}RP, QV{1234}P, QI{2345678}P → Total 19 quadrupole magnets

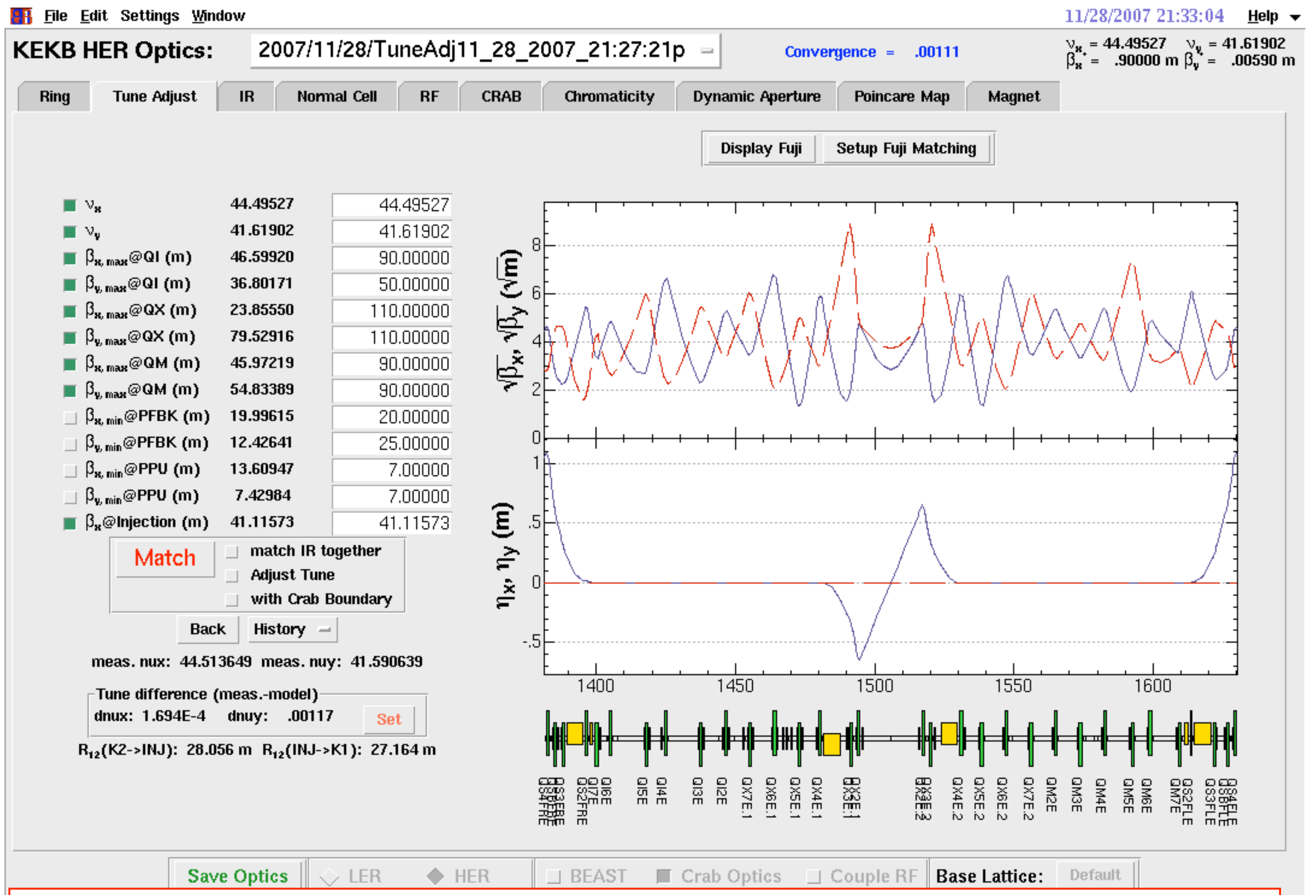
- Arc cell matching condition(α_x, β_x, α_y, β_y at entrance and exit)
- α_x=0, α_y=0 at midpoint,
- phase advance of two injection kickers = 90 deg.
- Tunes(x,y)



HER Tune Matching

QM{234567}E, QX{234567}E, QI{234567}E → Total 18 quadrupole magnets

- Arc cell matching condition(α_x, β_x, α_y, β_y at entrance and exit)
- α_x=0, α_y=0 at midpoint, η_x = 0 at BX2E
- phase advance of two injection kickers = 90 deg.
- phase and beta requirements from the BxB feedback system
- Tunes(x,y)



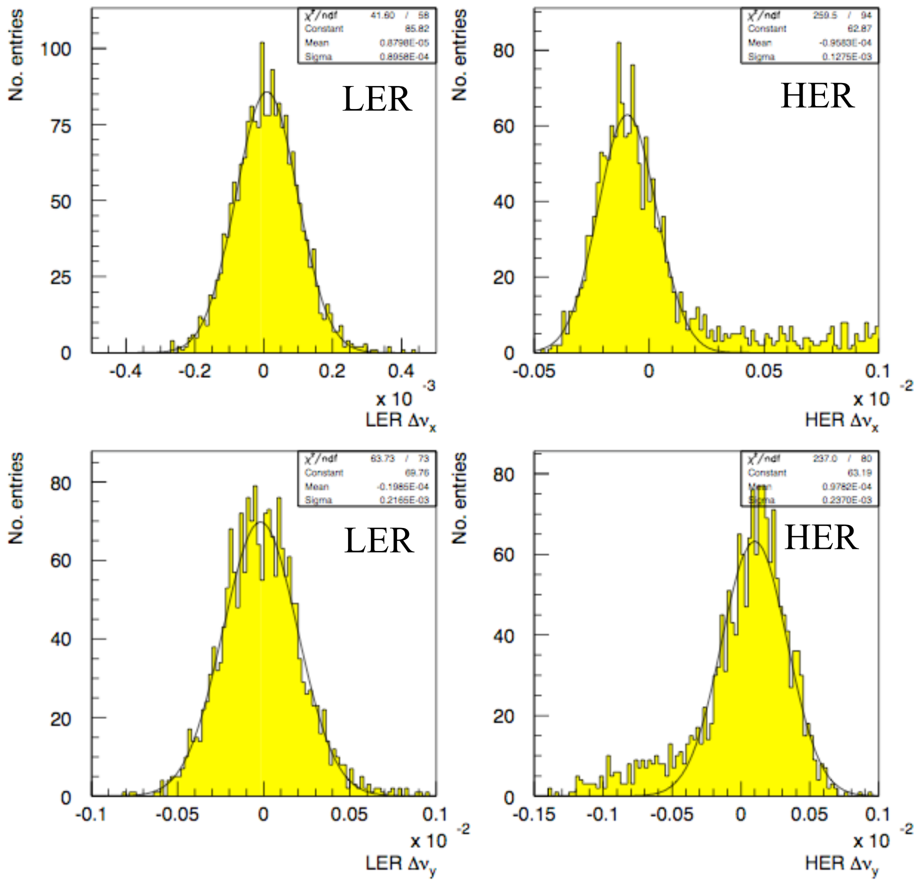
Quadrupoles in the whole ring are used to adjust tunes for the current dependence.

Performance of Tune Feedback

- Residual tunes after the tune feedback

$\sigma_{\nu x}$= 8x10^{-5}

$\sigma_{\nu x}$= 1.3x10^{-4}



$\sigma_{\nu y}$= 2.2x10^{-4}

$\sigma_{\nu y}$= 2.4x10^{-4}

Tune feedback interval is about ~30 sec. Since HER injection rate is large, the tune feedback can not keep the reference completely(see tails).