Collision Tuning Dithering system

KEK

R. Ueki, Y. Funakoshi, T. Kawamoto, M. Masuzawa, S. Nakamura, T. Oki, M. Tobiyama, S. Uehara

SLAC

A. S. Fisher, M.K. Sullivan, D. Brown

ANL

U. Wienands

LAL

P. Bambade, S. Di Carlo, D. Jehanno, C. Pang

CERN

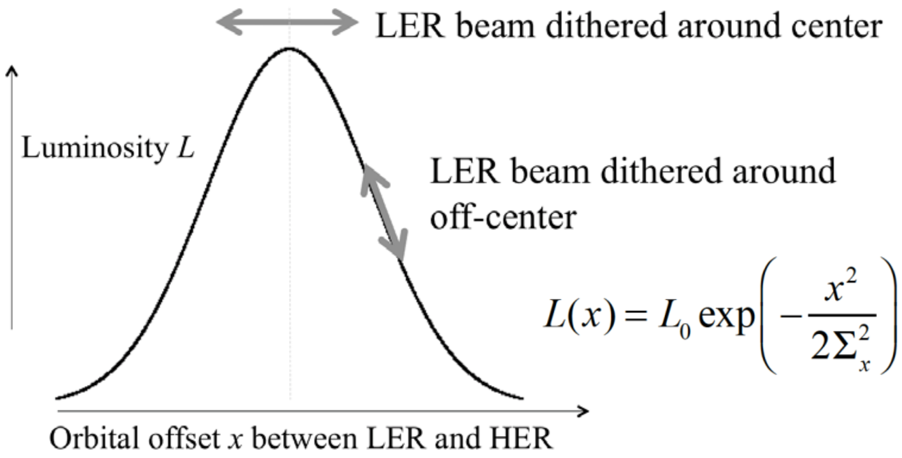
D.El Khechen

Contents

Dithering system

Beam-beam parameter

ξy	0.0881	0.0807	Beam-beam deflection
ξx	0.0028	0.0012	Dithering feedback



Dithering feedback system was used at SLAC for PEP-Ⅱ

By dithering LER beam,
luminosity is modulated at dithering frequency

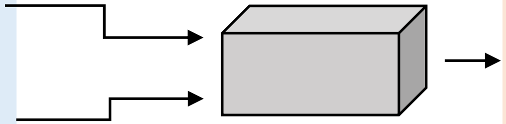
Input

Reference signal

$A\cos(wt)$

$B\cos(wt+\alpha)$

Modulated luminosity signal

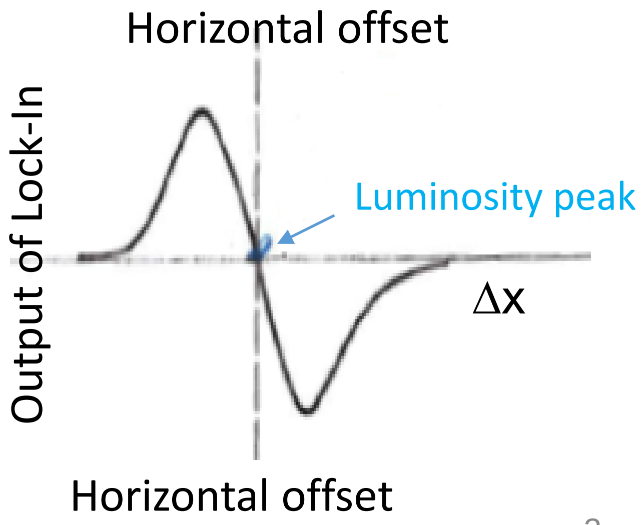


Lock-in Amp

Output

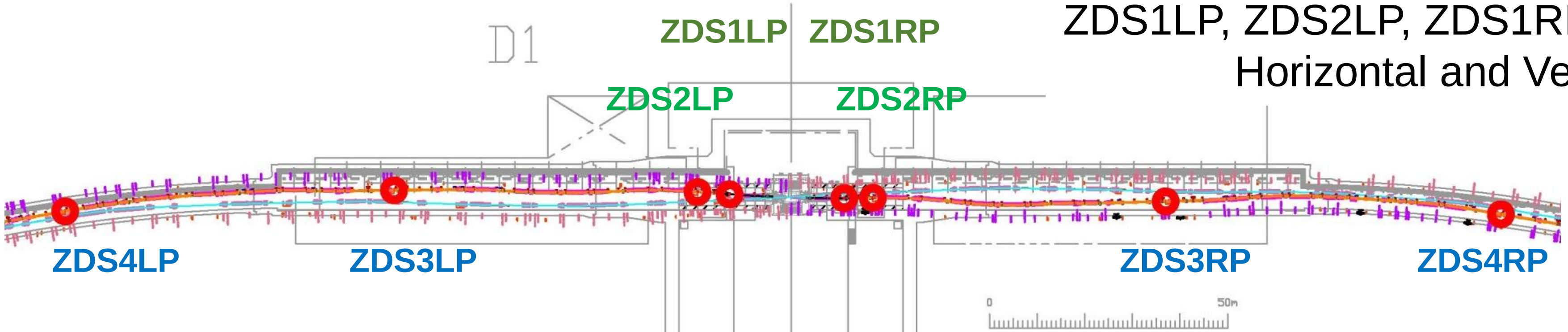
$$\frac{AB}{2} * \cos(C\alpha) + \cos(2wt+\alpha)$$

- Magnitude (Voltage) proportional to B
- Phase difference (α) reference and luminosity



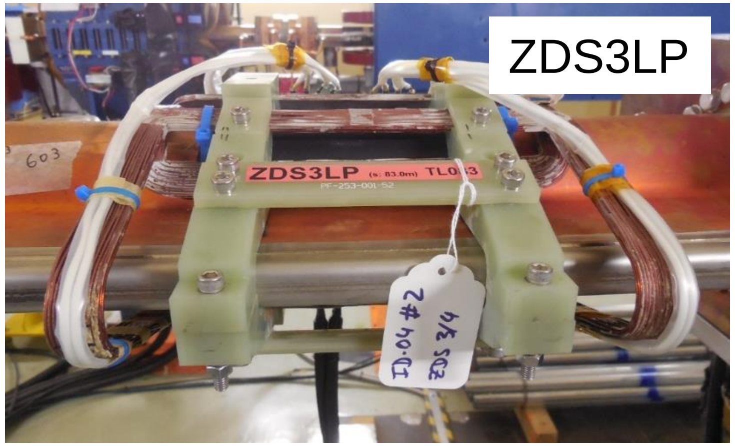
Hardware of dithering system

- 8 sets of Helmholtz coils designed and fabricated at SLAC as dithering coil
- The coils were installed in LER beam line



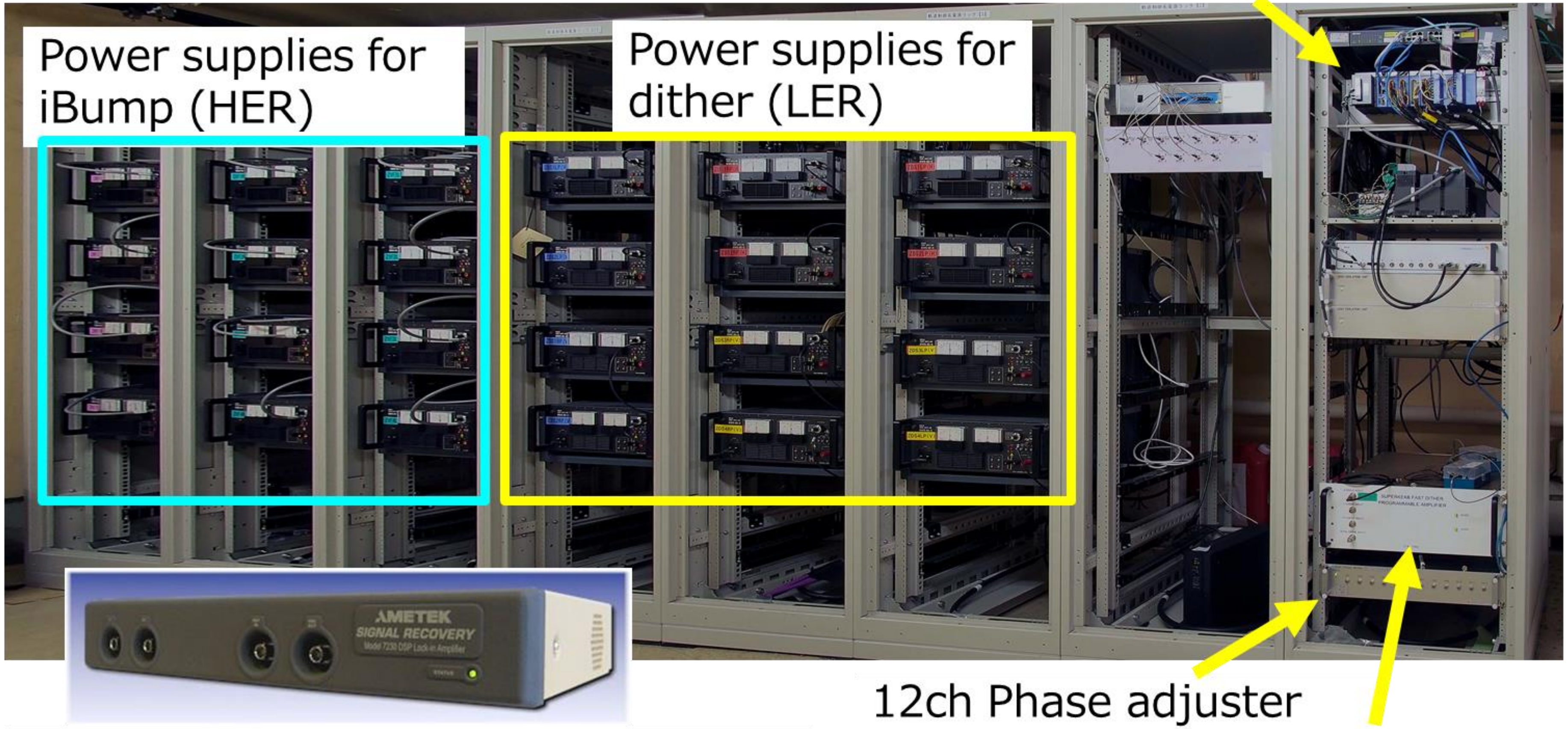
ZDS1LP, ZDS2LP, ZDS1RP, ZDS2RP
Horizontal and Vertical dither coils

ZDS3LP, ZDS4LP, ZDS3RP, ZDS4RP
Vertical dither coils



Other hardware

TsukubaB4 control room

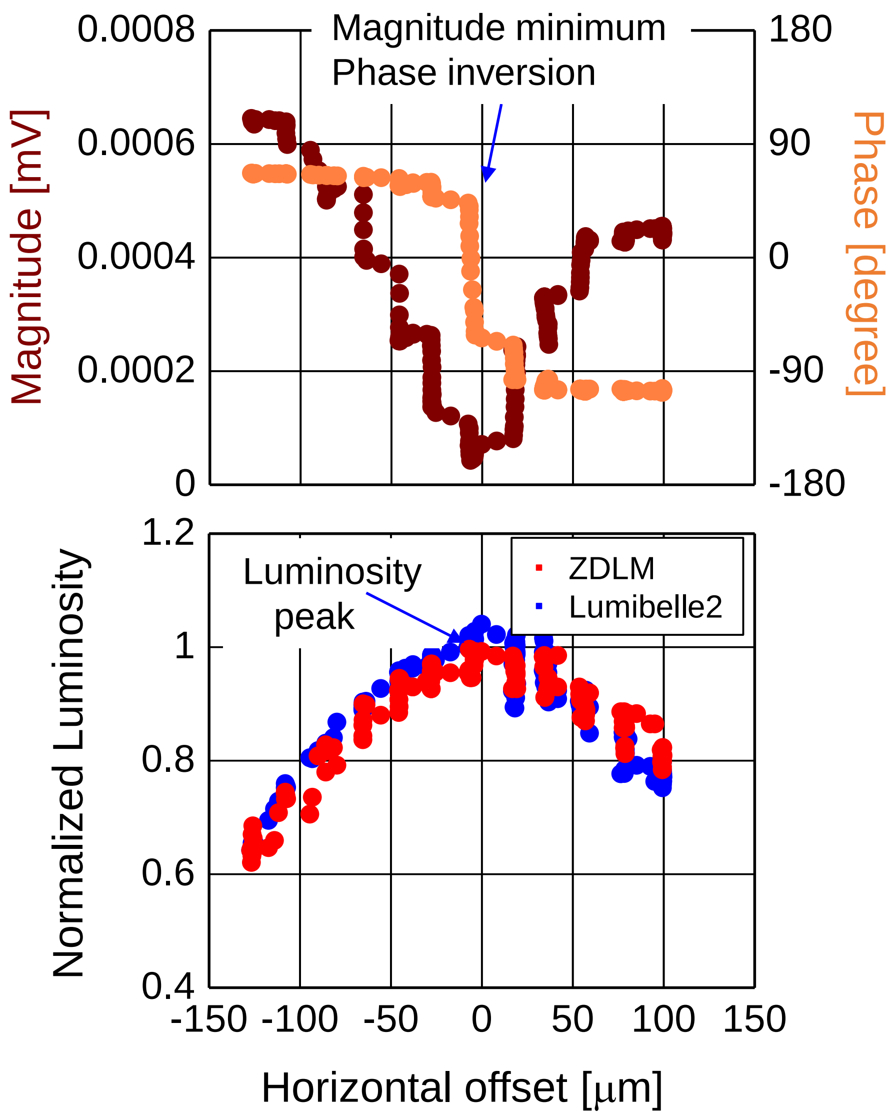


Luminosity scan in the Horizontal direction

- We checked the response of the lock-in amplifier
- Using local bump system at HER, horizontal offset was changed from -120 to 100 um
- measuring magnitude, phase and luminosity during horizontal scan

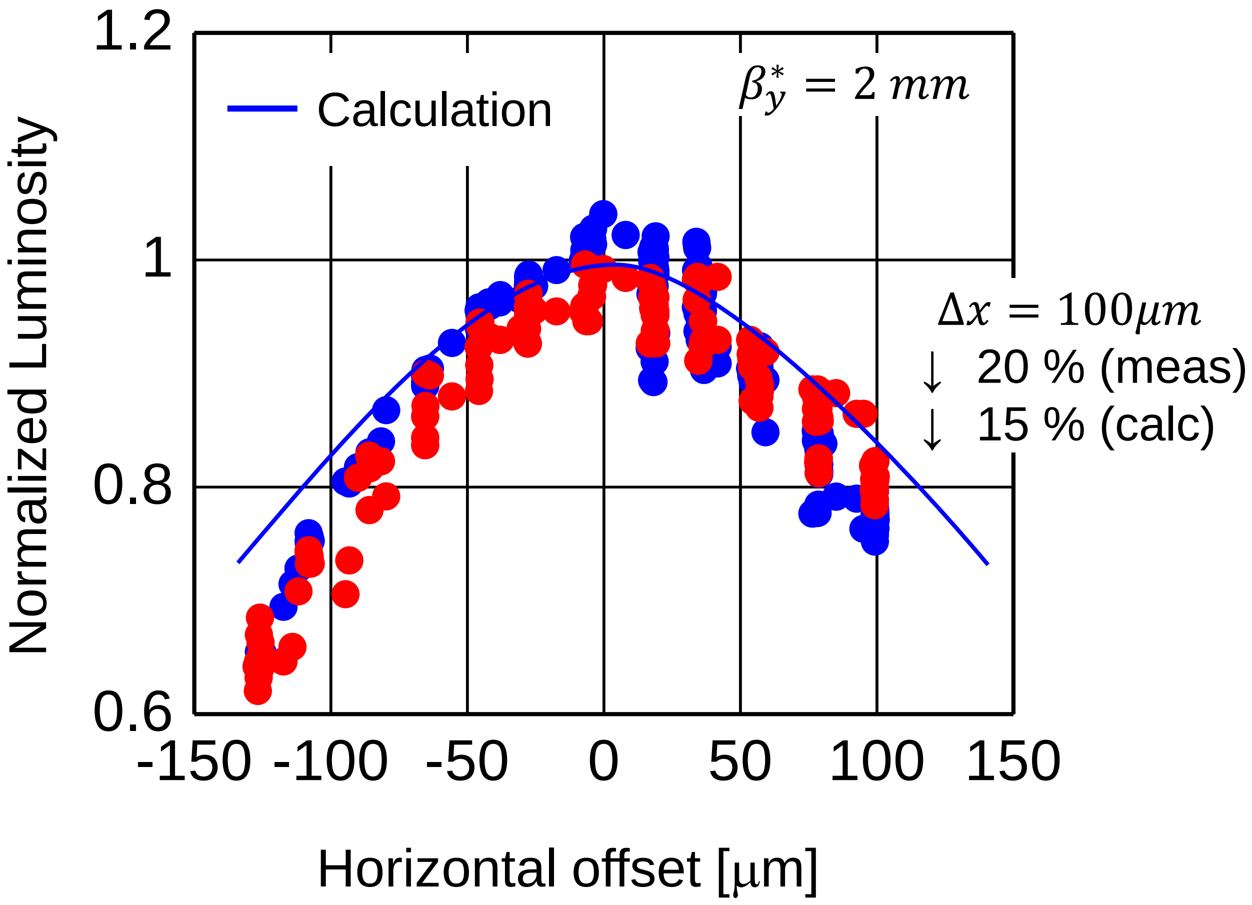
Condition	
By*	2 mm
luminosity	2.8×10^{33} cm^{-2}s^{-1}
Dither Amp	20 um
Freq	79 Hz
Scan range	-120 um → 100 um

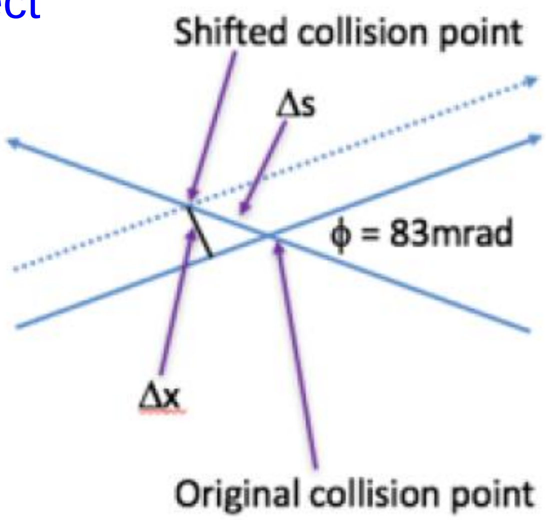
Luminosity peaked at the point of magnitude minimum and phase inversion

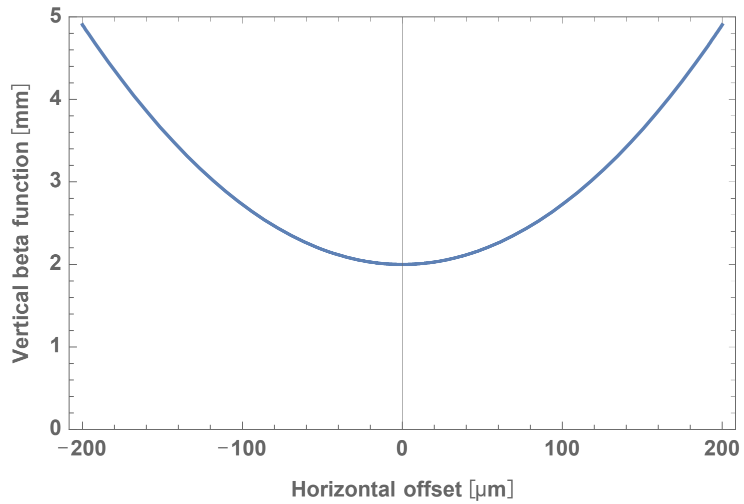


Luminosity degradation by hourglass effect

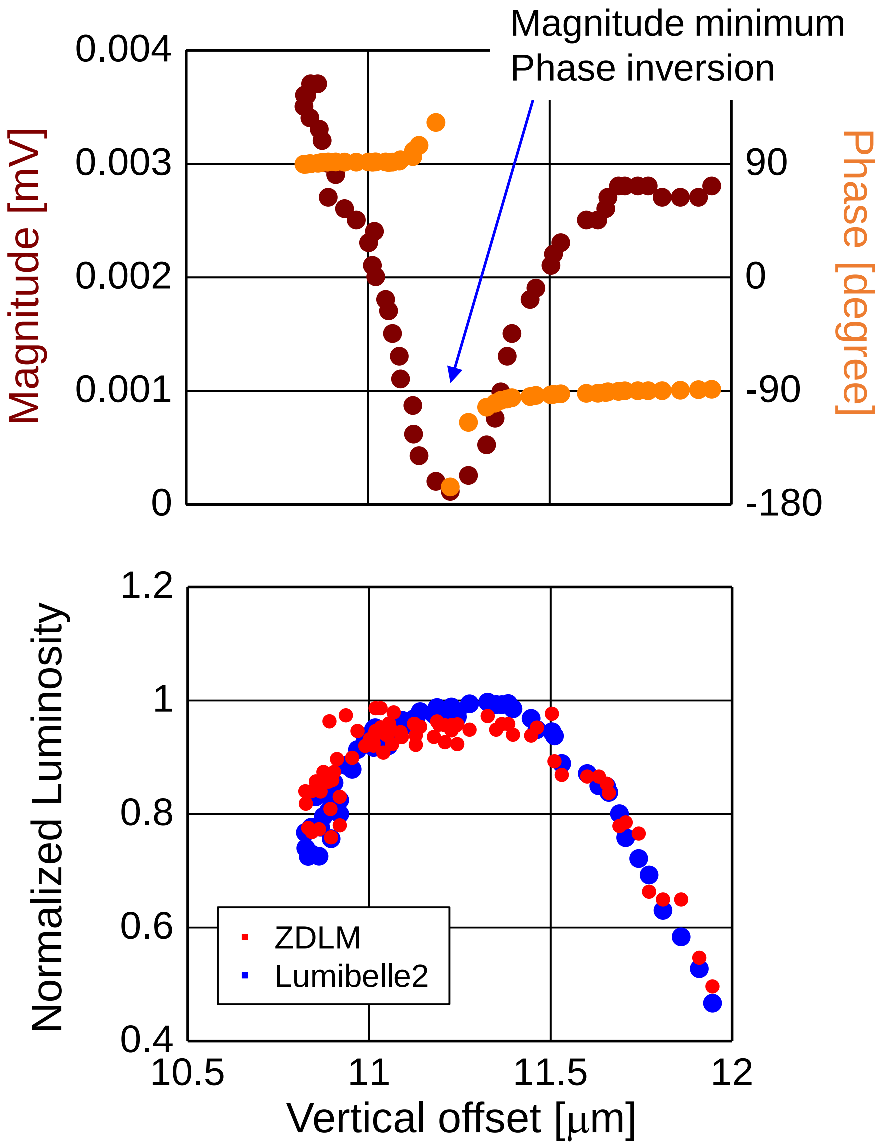
Luminosity degradation due to horizontal offset through hourglass effect







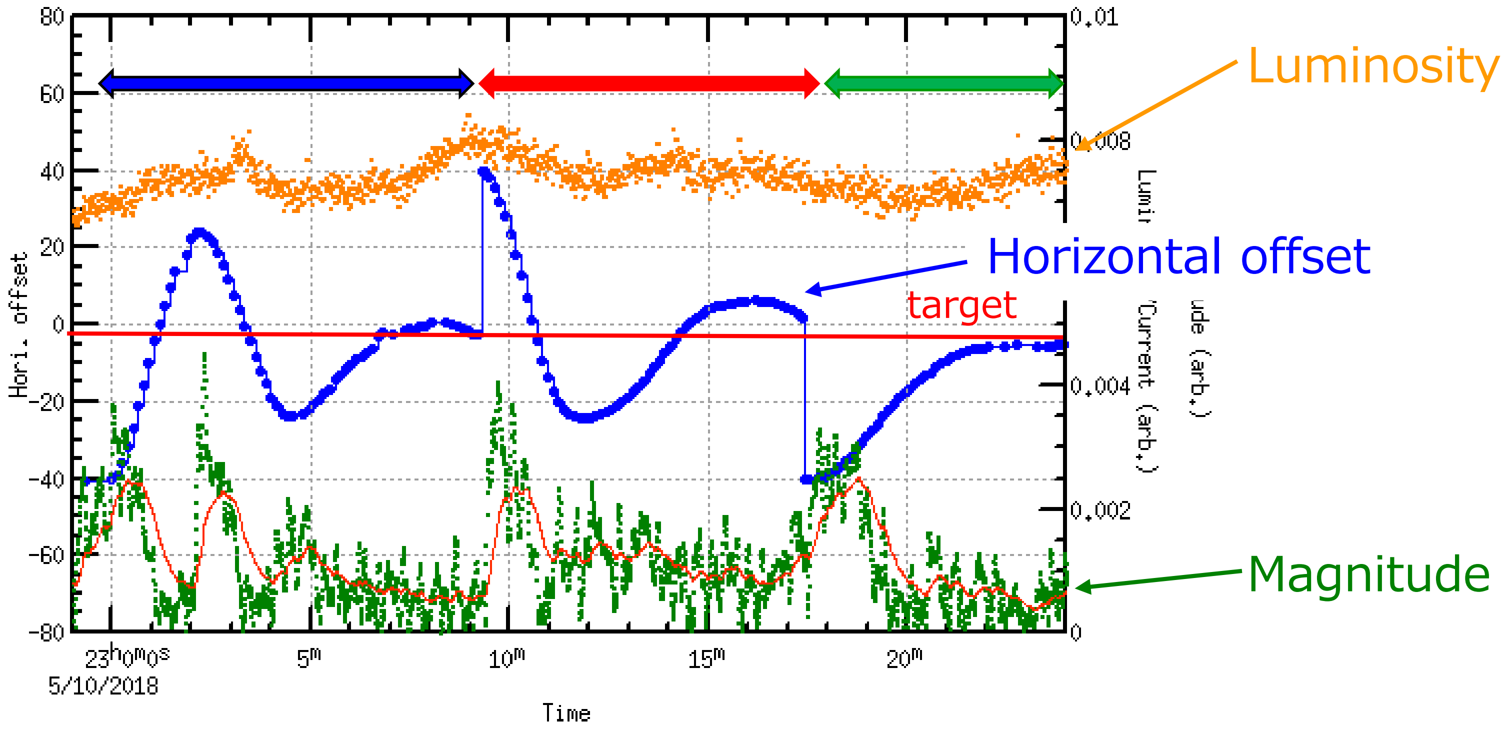
Coupling in the vertical direction



- Horizontal dither is coupling vertically
- In rough estimation, vertical dither amplitude due to coupling is ~ 0.02 um
- Possible cause is x-y coupling at IP
  - when vertical offset of two beams is small, vertical dither does not affect horizontal feedback
  - if vertical offset large, minimum point of the lock-in amp magnitude does not coincide with luminosity peak
- It would be possible to cancel coupling component applying additional vertical dither intentionally or adjusting x-y coupling parameter (R1)
- Vertical dither feedback may be useful for beam tuning

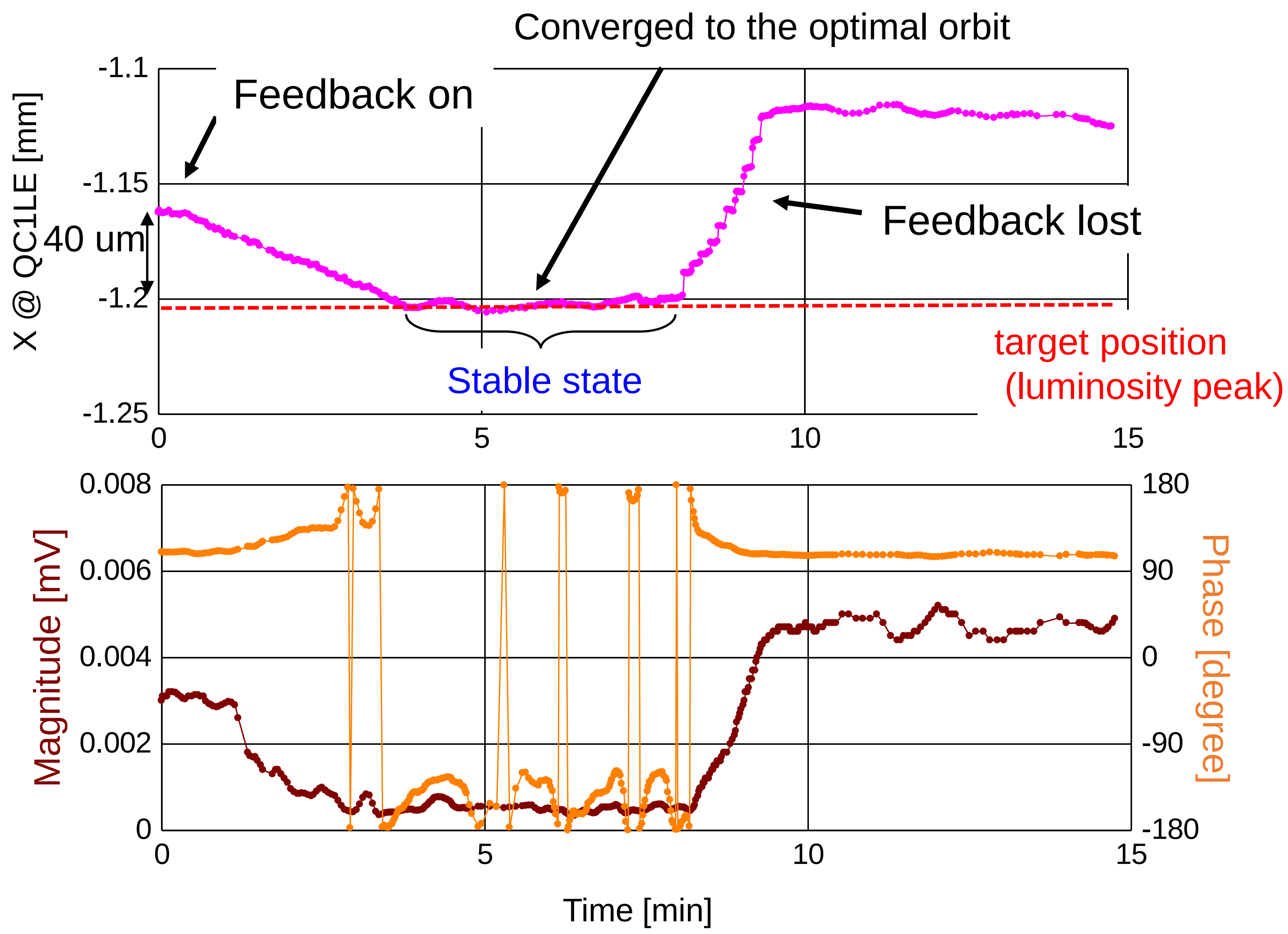
Feedback test - parameter optimization -

Dithering feedback algorism is based on PI control
→ To need optimize the feedback gain
We did 3 feedback tests changing the integral gain



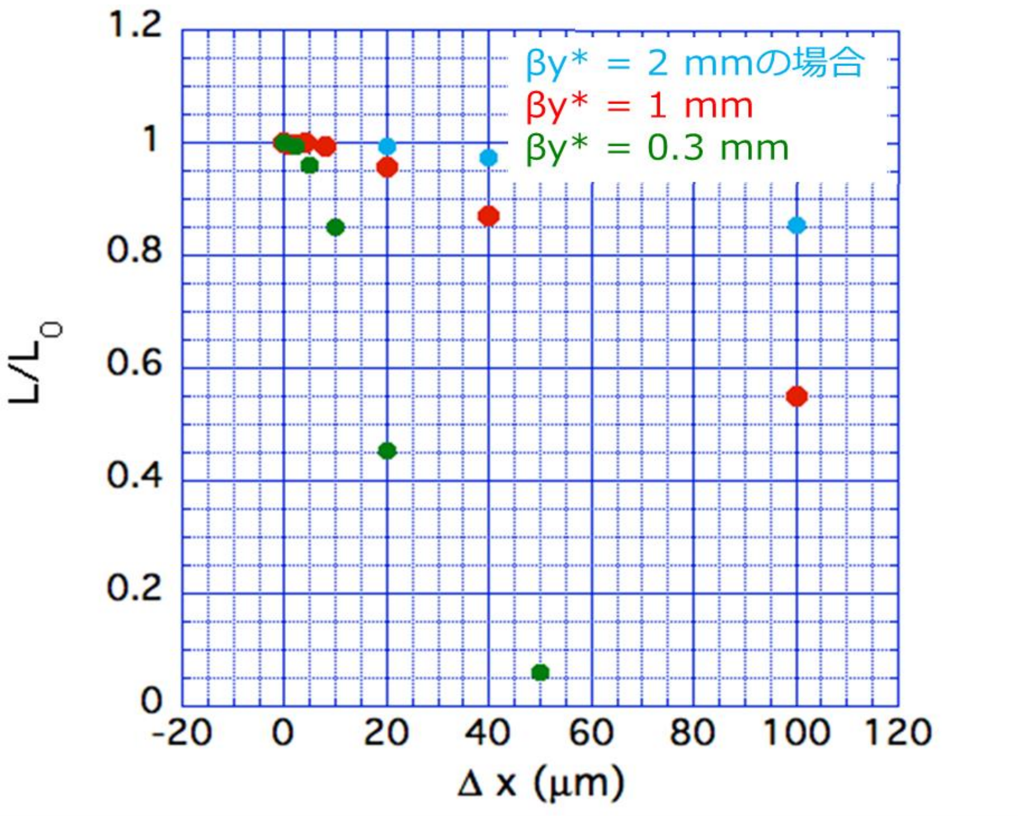
・As a result of adjusting the integral gain,
Horizontal offset approached to target position without large overshoot.

Feedback Test - stability of feedback -



- The cause is not understood yet
- We are checking algorism of system

Luminosity degradation due to offset at each beta y*



Simulation of luminosity degradation
by Ohmi-san

$\beta_y^* = 2\ mm$ (Phase3 spring commissioning)

$\Delta x = \pm 20\ \mu m$

degradation is small

$\beta_y^* = 1\ mm$ (next step)

$\Delta x = \pm 20\ \mu m$

↓ 5 %

$\beta_y^* = 0.3\ mm$ (design)

$\Delta x = \pm 20\ \mu m$

↓ more 50 %

Summary

・All components of dithering system were prepared before Phase-2 commissioning

・We checked lock-in amplifier response and did dithering feedback test

Luminosity scan

・We successful found Luminosity peak from magnitude and phase of Lock-in Amp

・Horizontal dither is coupling vertically

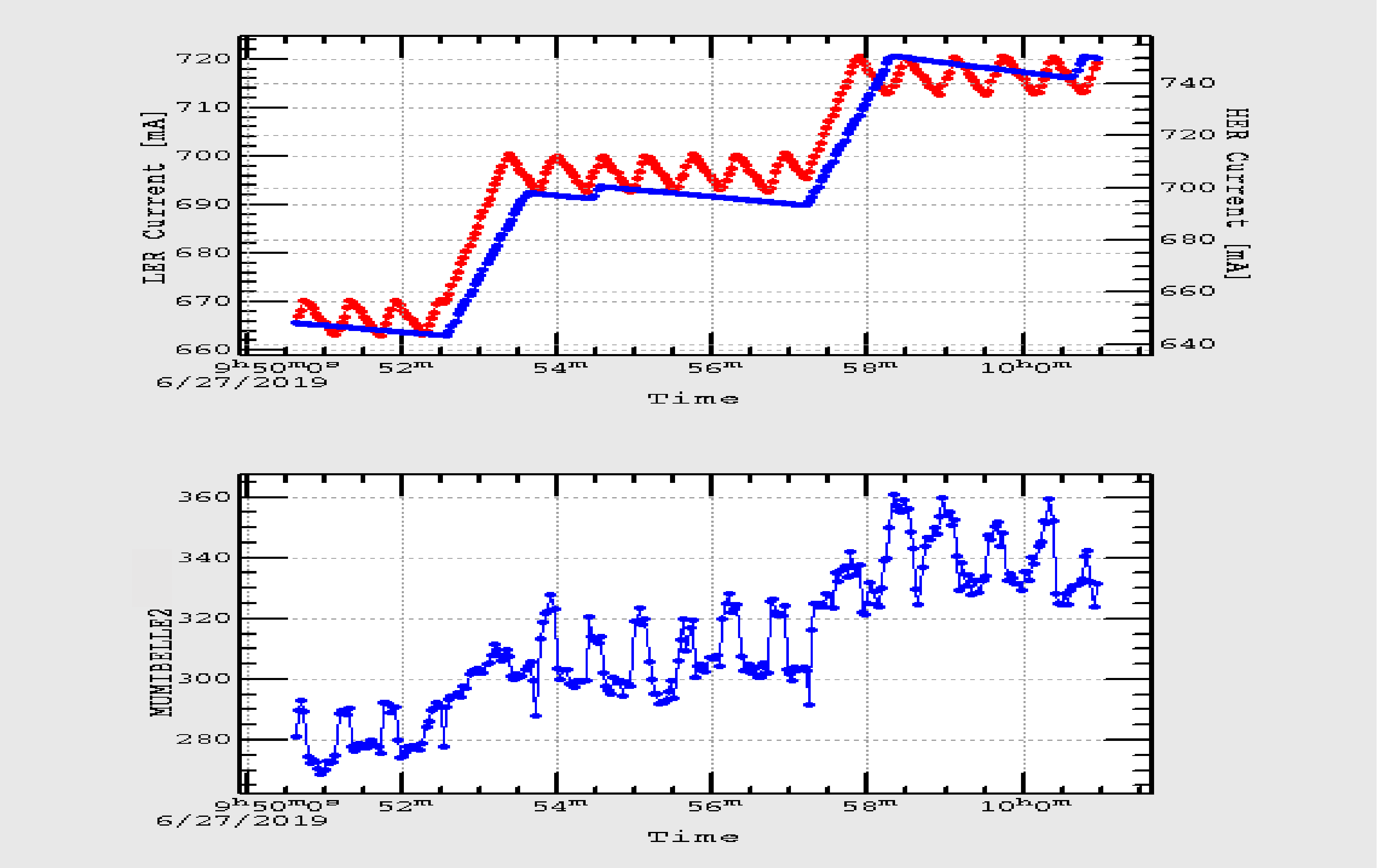
Feedback test

・by adjustment of integral gain, horizontal orbit converged to the optimal orbit

・Dithering feedback system does not operate now.

・When beta is squeezed and luminosity degradation due to horizontal offset become remarkable, dithering system will be needed in order to keep high luminosity

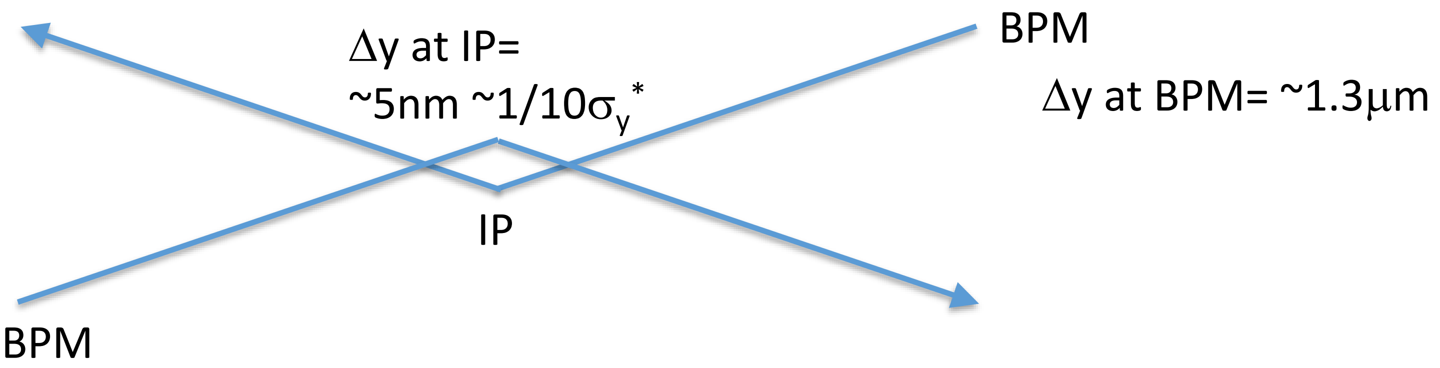
Trend graph of current and luminosity



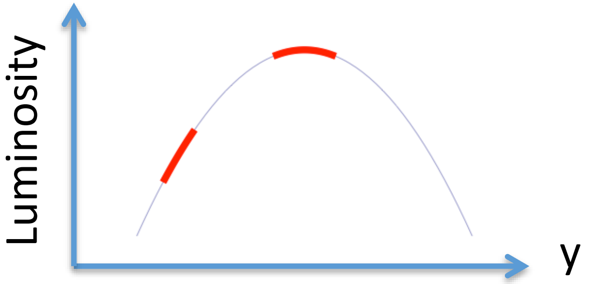
Feedback algorism

- Beam-beam deflection (SLC, KEKB vertical)

	LER	HER
垂直（ξy）	0.0881	0.0807
水平（ξx）	0.0028	0.0012

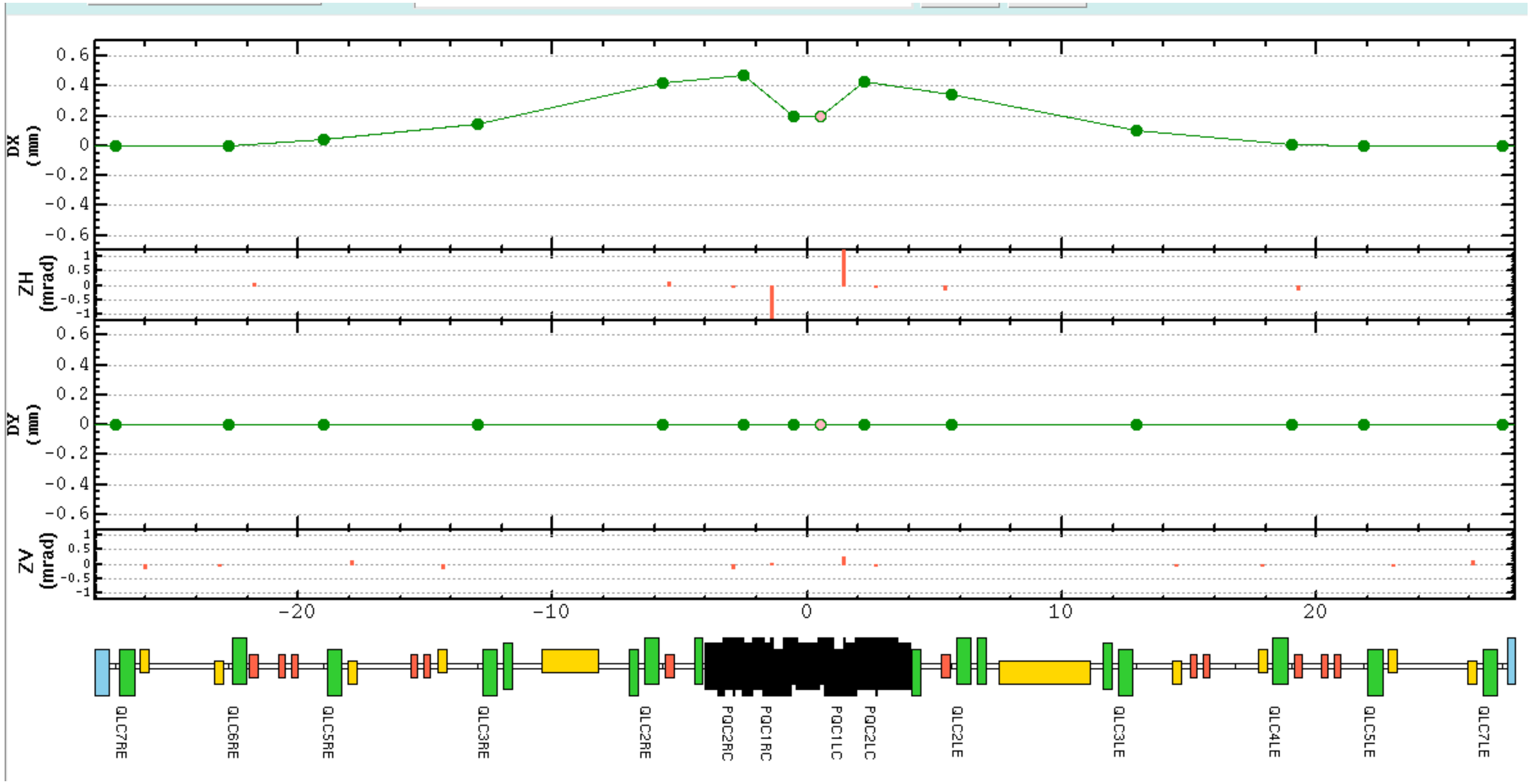


- Luminosity feedback (dithering)(PEP-II)



When we shake the beam at around the peak of the luminosity (dithering), the dithering frequency in the luminosity is minimized and there appears twice of the the dithering frequency.

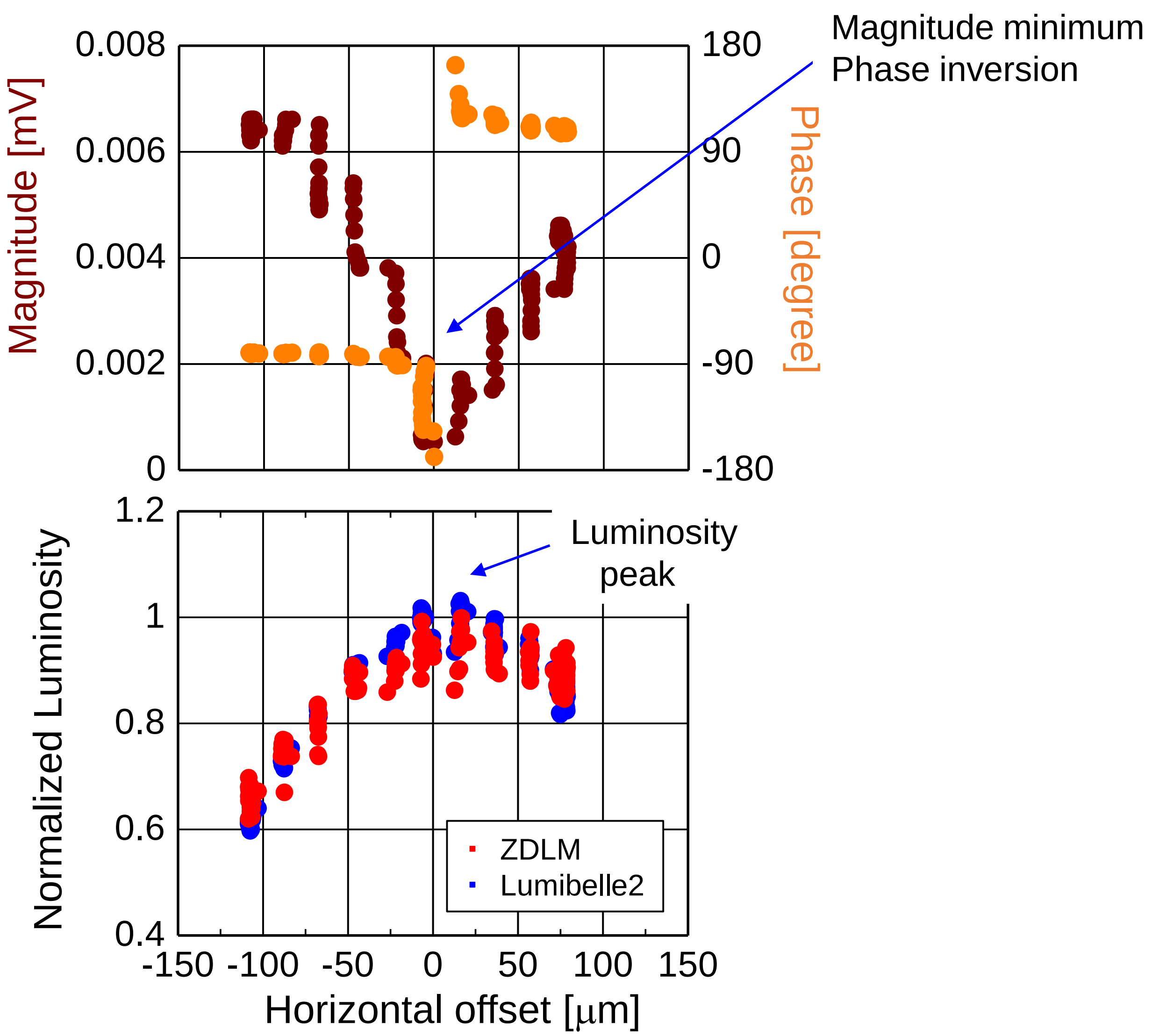
Horizontal bump



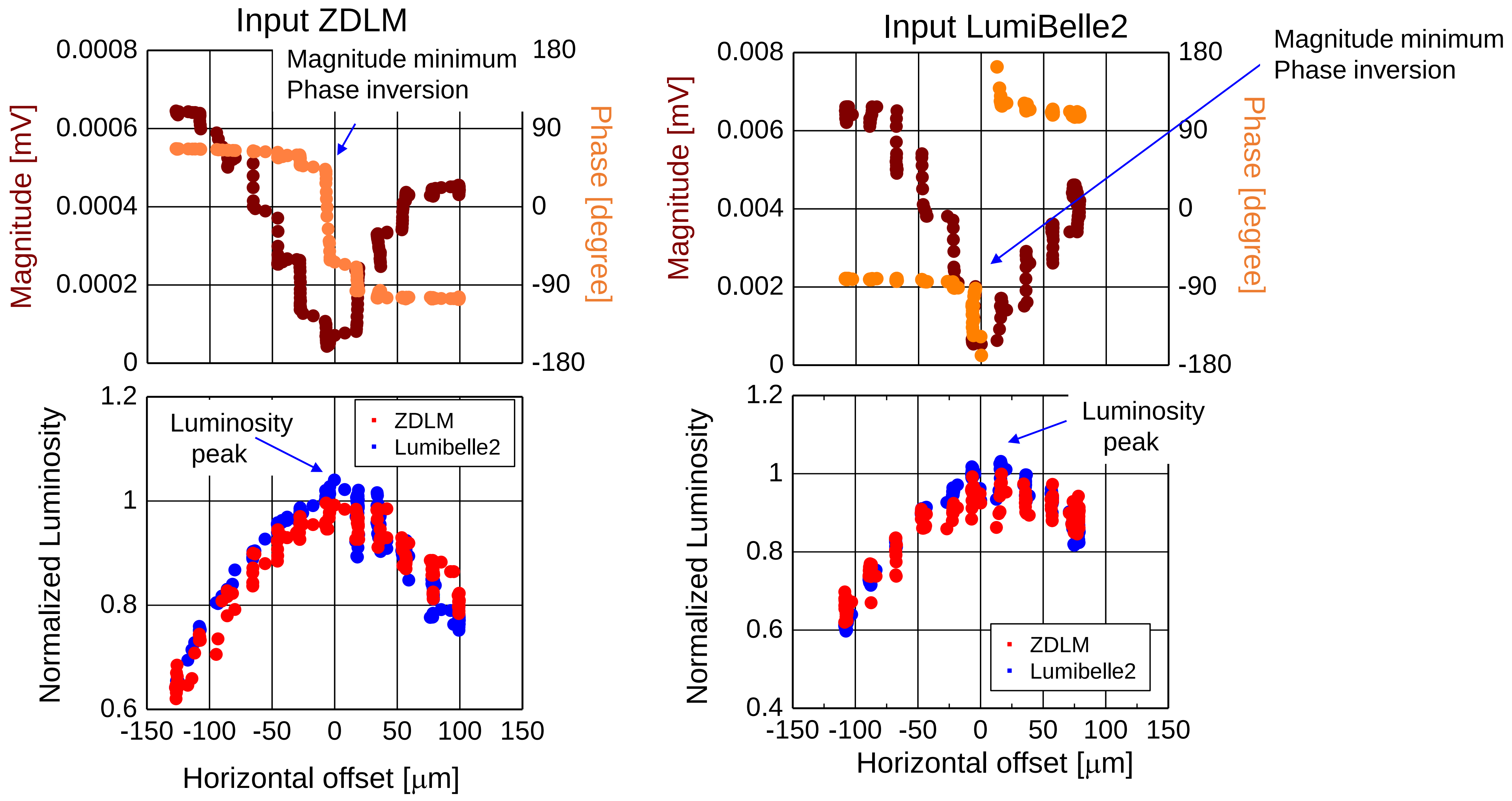
Luminosity scan in the horizontal direction (LumiBelle2)

Condition	
By*	2 mm
luminosity	2.8×10^{33} cm^{-2}s^{-1}
Dither Amp	20 um
Freq	79 Hz
Scan range	-120 um → 80 um

Luminosity peaked at the point of magnitude minimum and phase inversion

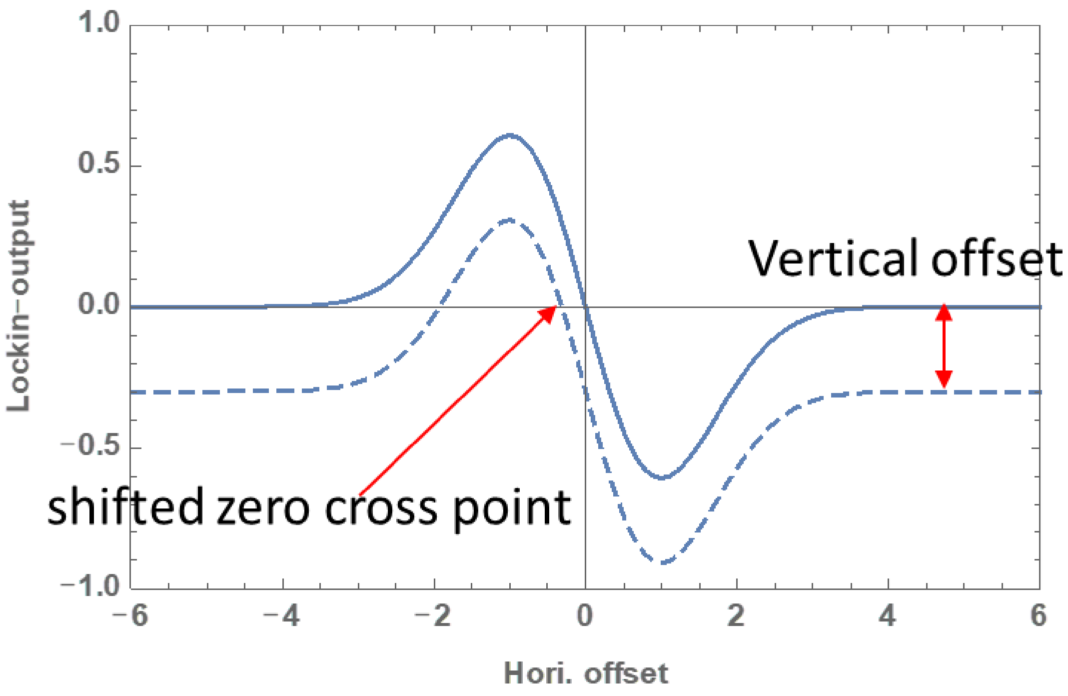


Luminosity scan to Horizontal direction



Lock-in output with vertical offset

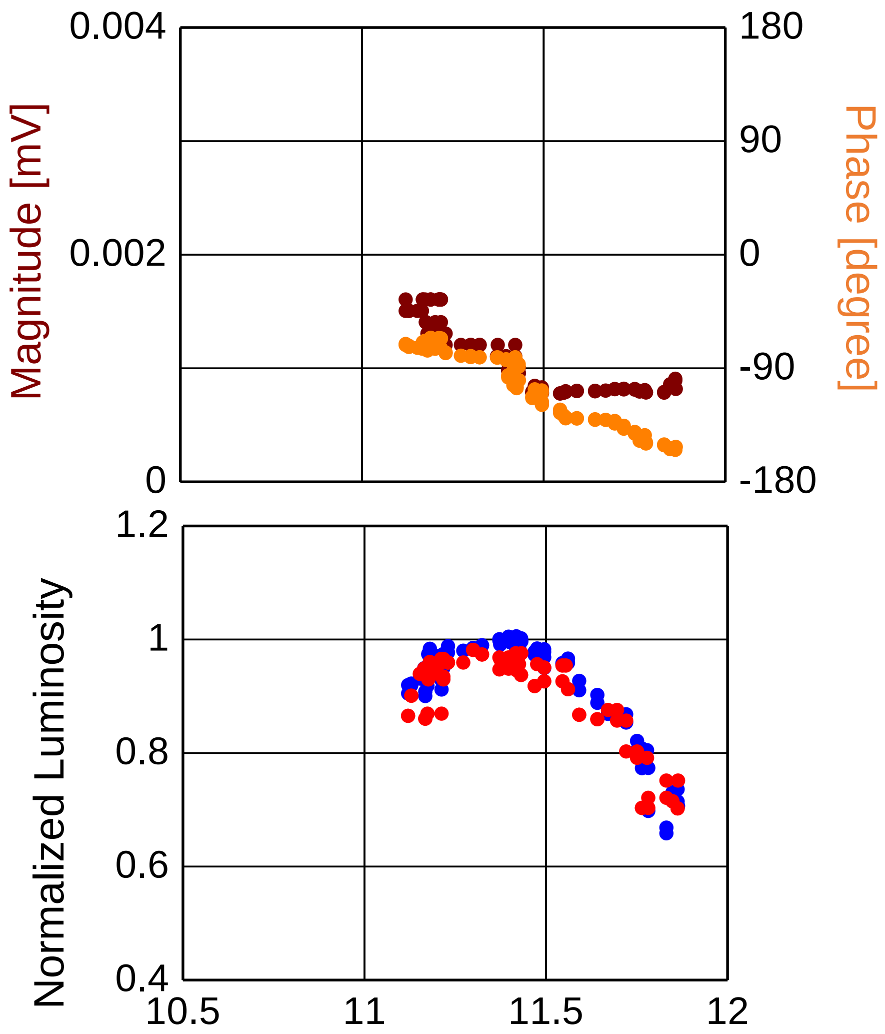
Vertical offset of LER and HER beam
→ The point of magnitude minimum and phase inversion shift from luminosity peak
→ Horizontal feedback dose not work properly



- It's important to maintain good vertical collision point for accurate horizontal feedback

- High frequency fluctuation can be not collected,
- Slow drift during long time can be collected using vertical dither

Luminosity scan to Vertical direction

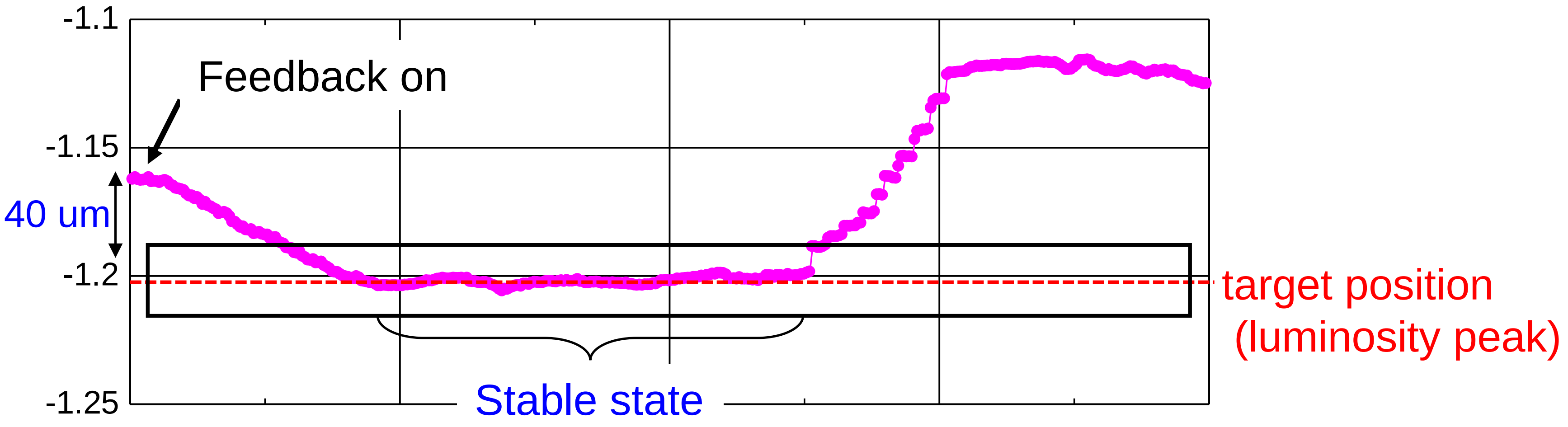


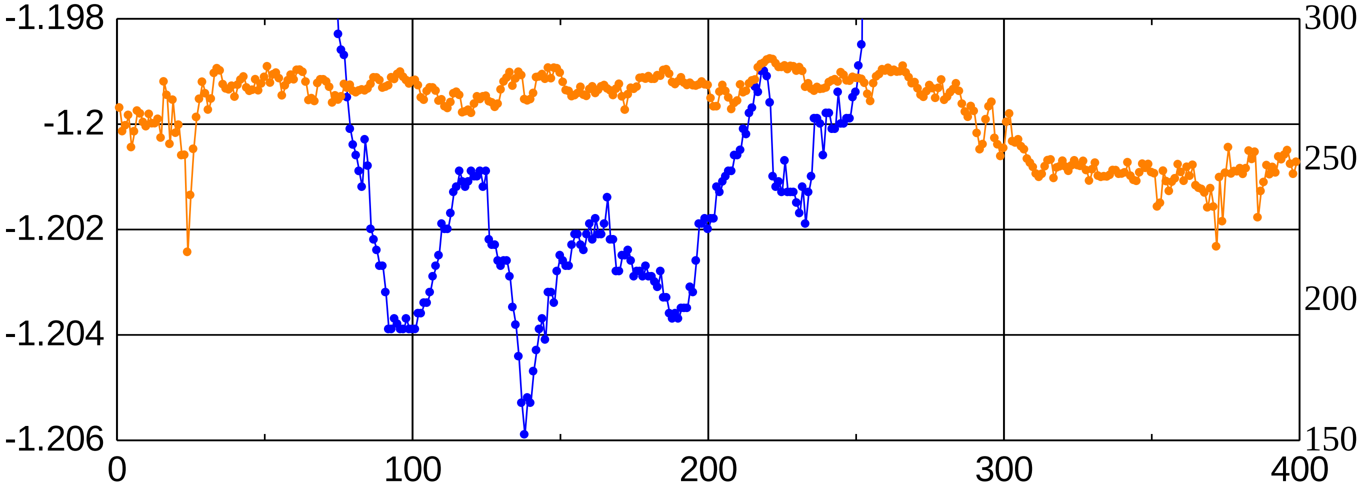
Input	LumiBelle2
Dither Amp	20 um
Freq	79 Hz

Vertical Dither ON

Dither Amp	0.07 um

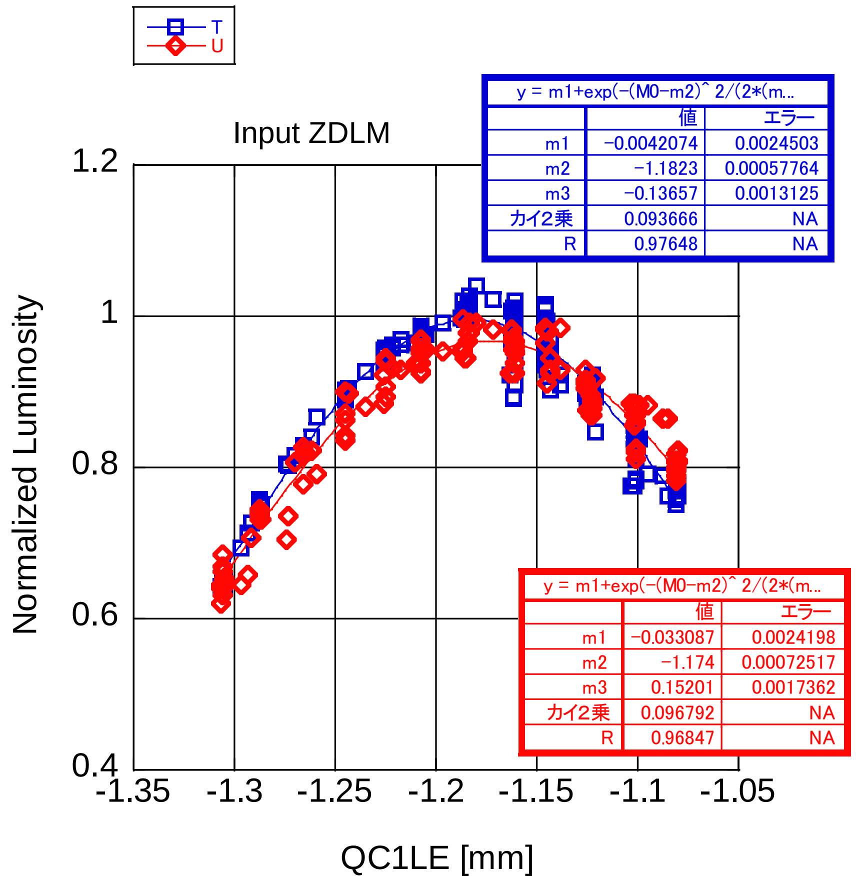
Feedback test





Luminosity degradation by horizontal offset

Continuous Injection mode	
HER	250 mA (-1% Auto injection)
LER	250 mA (-1.5% Auto injection)
Fill pattern	6.12 spacing 1train, 789 bunches



$$L(x)/L_0 = \exp(-\frac{\Delta x^2}{2\Sigma_x^2})$$

$$\Sigma_x^2 = \sigma_{x+}^{*eff2} + \sigma_{x-}^{*eff2}$$

$$\sigma_{x\pm}^{*eff} = \sigma_z \sin\emptyset_c$$

By fitting parameter

Σ_x
0.13657
0.15201

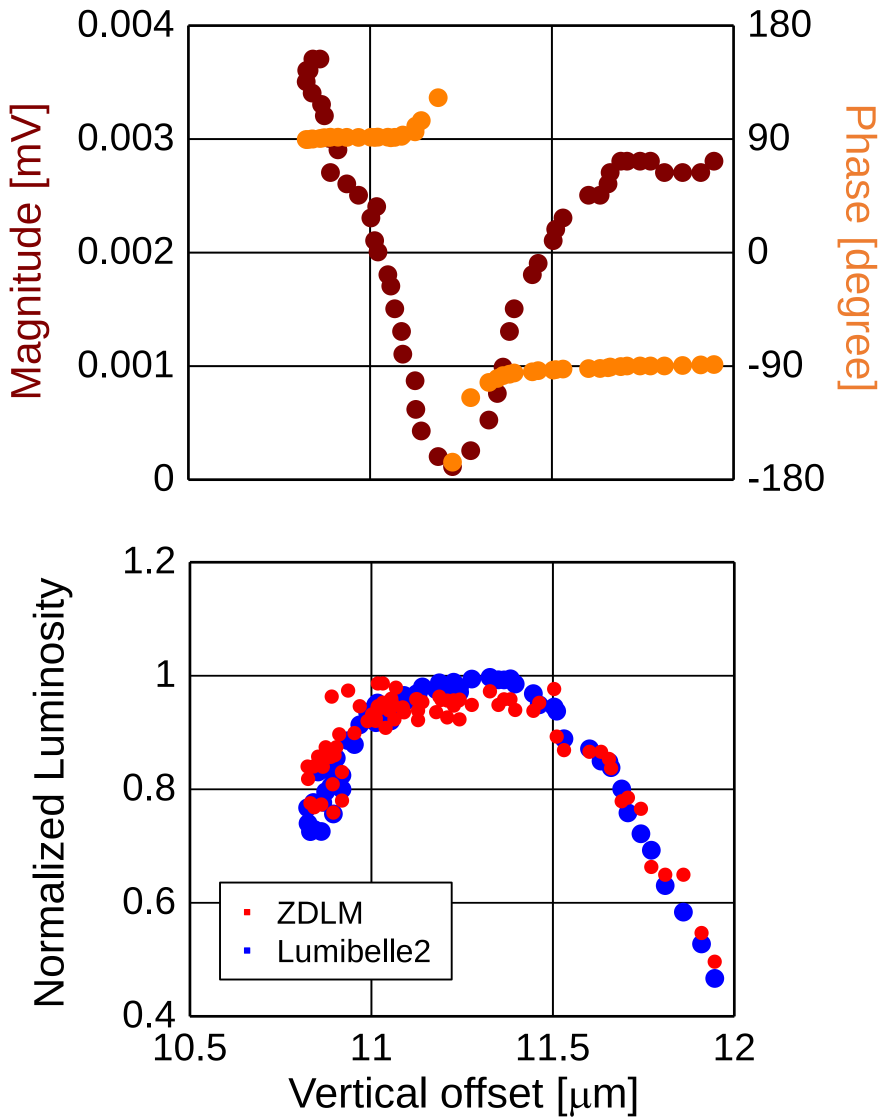
$$\Delta x = 100\ \mu m$$

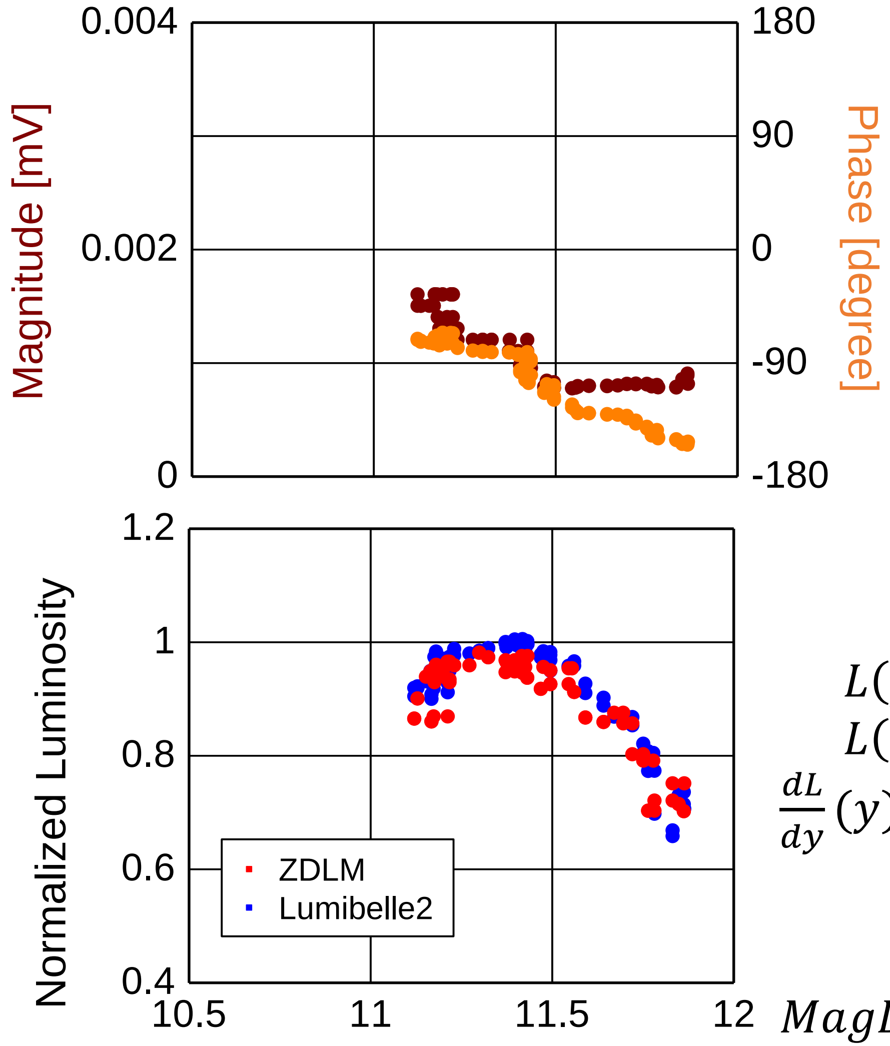
$$\rightarrow \frac{L(x)}{L_0} = 20\ \%$$

By bunch length and half crossing angles

σ_{z-}	σ_{z+}	Σ_x
5.64 mm	4.99 mm	0.312

$$\Delta x = 100\ \mu m \rightarrow \frac{L(x)}{L_0} = 5\ \%$$





$$L(y) = 1 - a(y - 11.3)^2$$

$$L(11.7) = 0.8 \rightarrow a = 1.25$$

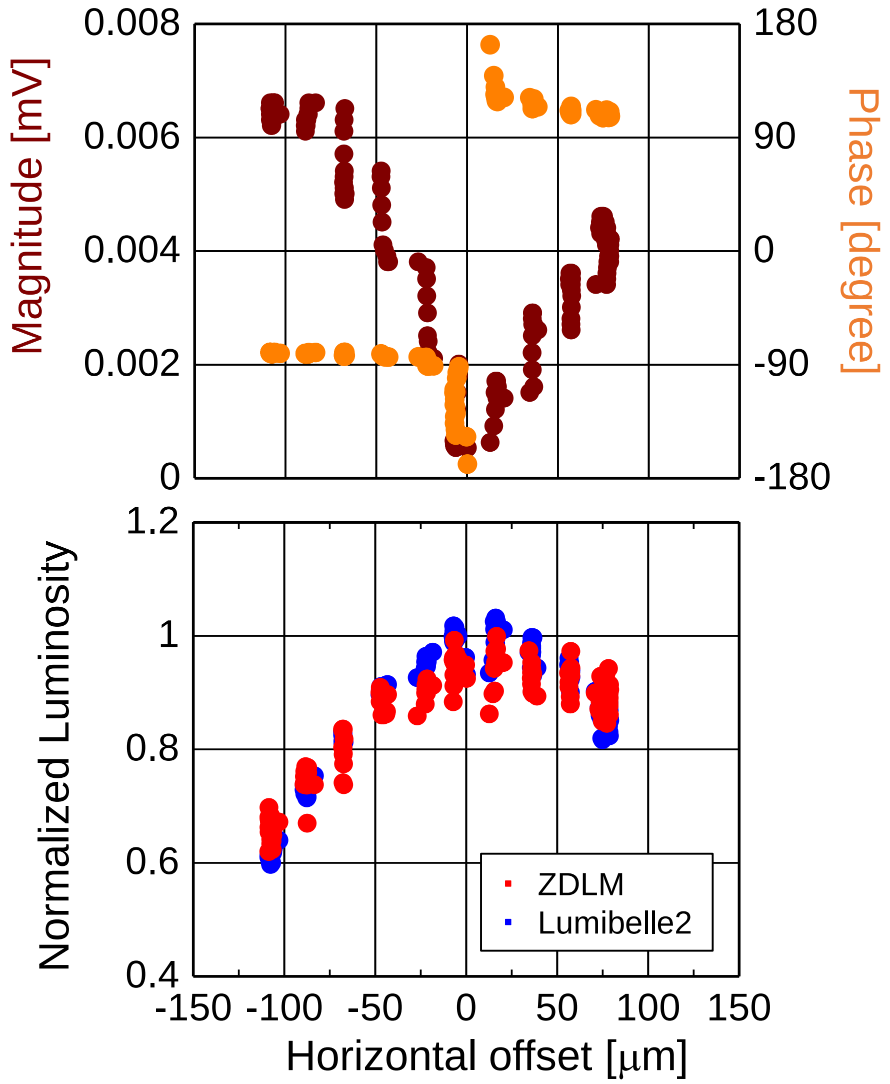
$$\frac{dL}{dy}(y) = -2.5\ (y - 11.3)$$

$$\frac{dL}{dy}(11.7) = -1.0$$

$$MagDithery(y) = \frac{dL}{dy}(y) \times \Delta y$$

$$MagDithery(11.7) = -1.0 \times \Delta y$$

Luminosity scan to Horizontal direction (LumiBelle2)



Input	LumiBelle2
Dither Amp	20 um
Freq	79 Hz
CCC	ON
iBump FB	ON

$$L(x) = 1 - b(x-20)^2$$

$$L(-75) = 0.8 \rightarrow b = 2.2 \times 10^{-5}$$

$$\frac{dL}{dx}(x) = -4.4 \times 10^{-5}(x-20)$$

$$\frac{dL}{dy}(50) = -1.3 \times 10^{-5}$$

$$MagDitherx(x) = \frac{dL}{dx}(x) \times \Delta x$$

$$MagDithery(50) = -1.3 \times 10^{-3} \times \Delta x$$

$$MagDithery(11.7) = -1.0 \times \Delta y$$

$$MagDithery(50) = MagDithery(11.7)$$

$$-1.0 \times \Delta y = 1.3 \times 10^{-3} \times 20\mu m -> \Delta y = 0.026\ \mu m$$