Single Knob Scan

The optical functions at the IP are adjusted locally in various ways
to optimize the luminosity during physics runs.
In this tuning, the following optical parameters are adjusted.

- Vertical waist
- Tilt(xy-coupling) and vertical dispersion
- Horizontal dispersion

In KEKB operation panels,
blue and red colors are usually used
as HER and LER.
Because positron means "sun-electron" in Japanese.

•Vertical Waist

-The waist of the vertical β-function in each ring is adjusted independently by changing the fudge factors of the final-focus quadrupoles on both sides of the IP, QCSs and QC1s(only for the HER)

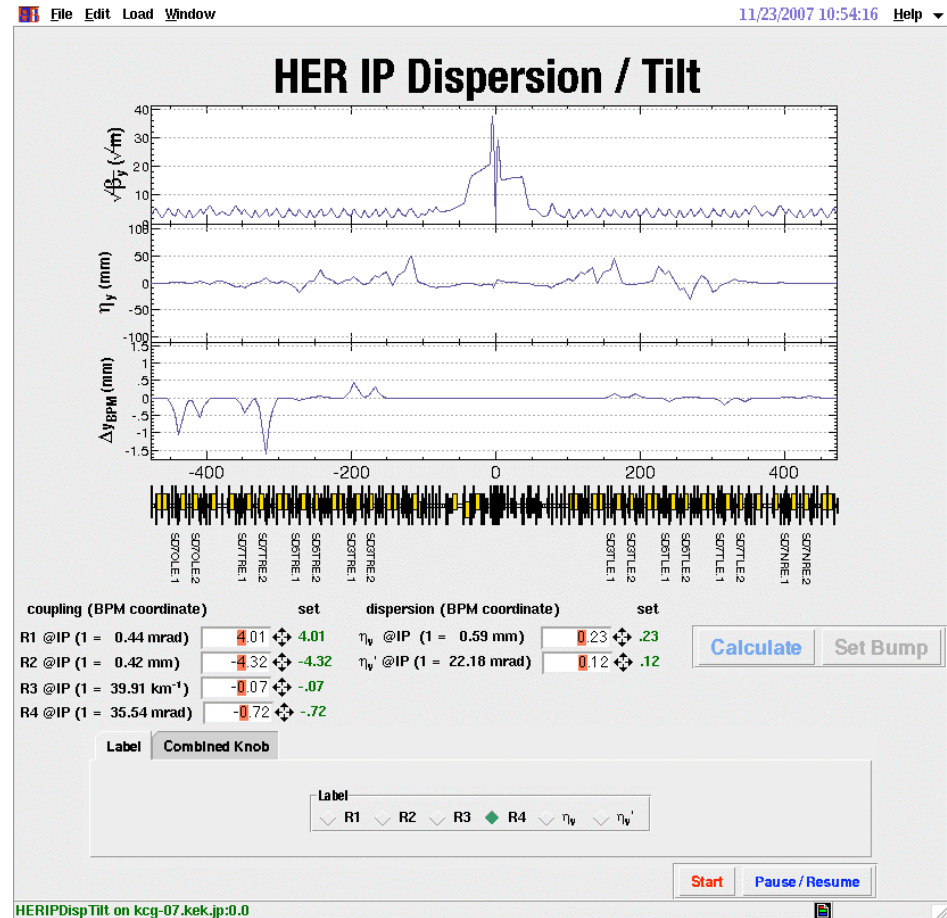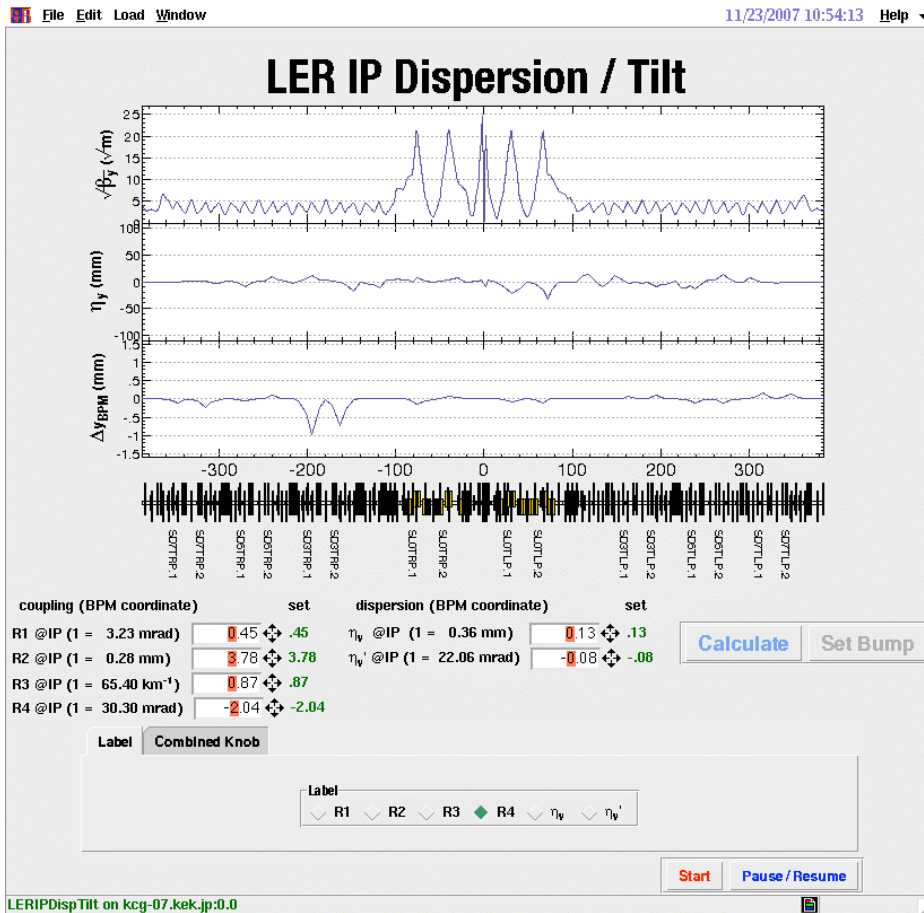-HER: The vertical waist is changed by QC1{LR}E.

-LER: The vertical waist is changed by QCS{LR} and
     that of HER is compensated by QC1{LR}E.
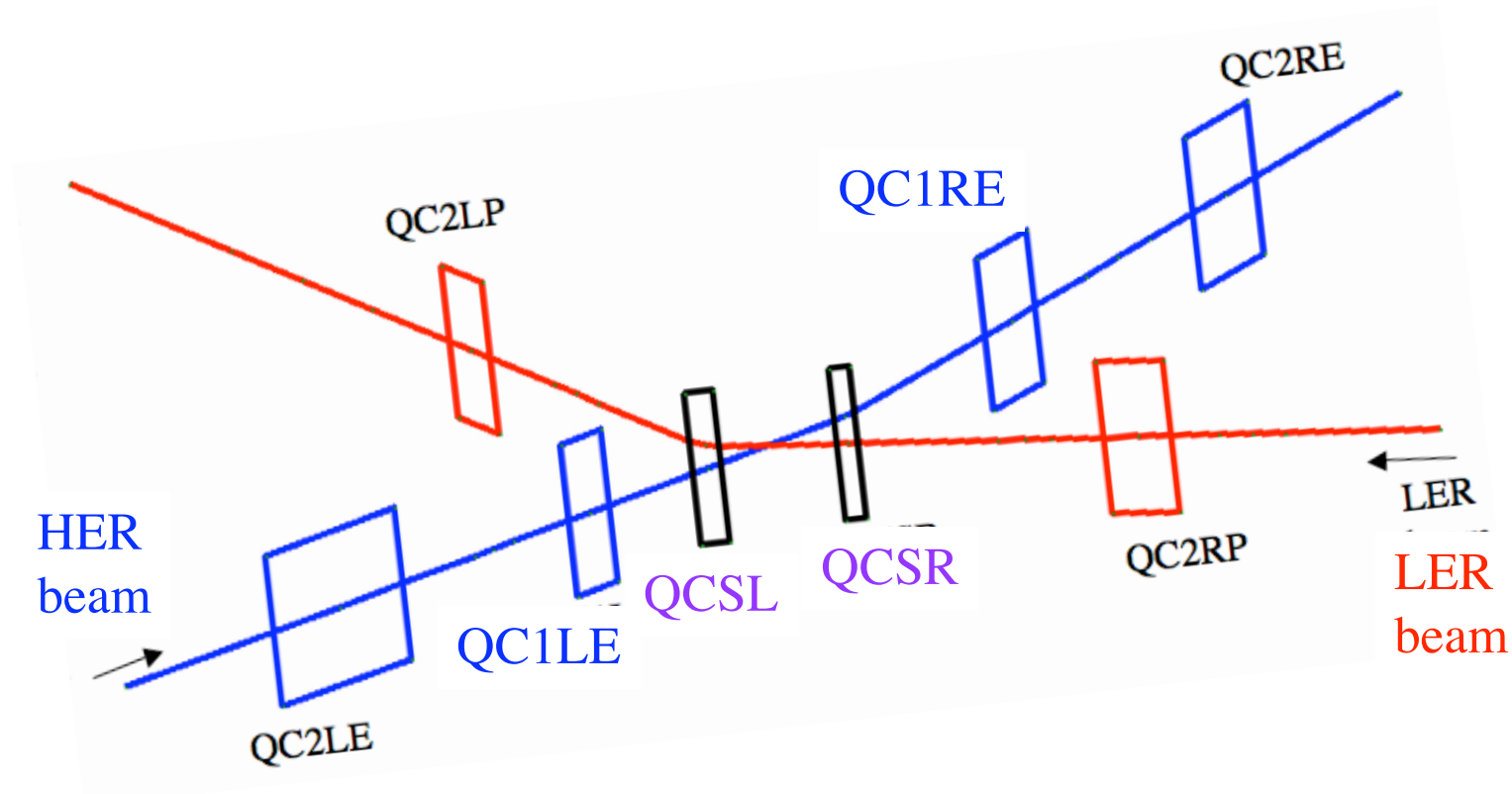
• **Tilts(xy-coupling) and Vertical Dispersion**

    -Tilt(xy-coupling:R1*~R4*), the vertical dispersion function and its slope (η_y * and η'_y*) at the IP are adjusted by making vertical bumps at sextupoles.

    -16 bumps of sextupoles are used to adjust 12 parameters in each ring.

    -The bumps are enough as free parameters.

LER IP Dispersion / Tilt

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coupling (BPM coordinate)   set   dispersion (BPM coordinate)   set

R1 @IP (1 = 3.23 mrad)   0.45   .45 η_y @IP (1 = 0.36 mm)   0.13   .13

R2 @IP (1 = 0.28 mm)   3.78   3.78 η_y' @IP (1 = 22.06 mrad)   -0.08   -.08

R3 @IP (1 = 65.40 km⁻¹)   0.87   .87

R4 @IP (1 = 30.30 mrad)   -2.04   -2.04

Label   Combined Knob

Label   R1   R2   R3   ◆ R4 η_y η_y'

Calculate   Set Bump

Start   Pause/Resume

LERIPDispTilt on kcg-07.kek.jp:0.0

HER IP Dispersion / Tilt

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coupling (BPM coordinate)   set   dispersion (BPM coordinate)   set

R1 @IP (1 = 0.44 mrad)   4.01   4.01 η_y @IP (1 = 0.59 mm)   0.23   .23

R2 @IP (1 = 0.42 mm)   -4.32   -4.32 η_y' @IP (1 = 22.18 mrad)   0.12   .12

R3 @IP (1 = 39.91 km⁻¹)   -0.07   -.07

R4 @IP (1 = 35.54 mrad)   -0.72   -.72

Label   Combined Knob

Label   R1   R2   R3   ◆ R4 η_y η_y'

Calculate   Set Bump

Start   Pause/Resume

HERIPDispTilt on kcg-07.kek.jp:0.0

The definition of xy-coupling parameters and dispersion functions

In the normal coordinate
(no xy-coupling space)

In the the physical coordinate
(real space)

$$\begin{pmatrix} X \\ p_X \\ Y \\ p_Y \end{pmatrix} + \begin{pmatrix} \eta_X \\ \eta'_X \\ \eta_Y \\ \eta'_Y \end{pmatrix} \delta = \begin{pmatrix} \mu & 0 & -R_4 & R_2 \\ 0 & \mu & R_3 & -R_1 \\ R_1 & R_2 & \mu & 0 \\ R_3 & R_4 & 0 & \mu \end{pmatrix} \begin{pmatrix} x \\ p_x \\ y \\ p_y \end{pmatrix}$$

$$\mu^2 + (R_1 R_4 - R_2 R_3) = 1$$
$$\delta = \Delta p / p.$$

$$\begin{pmatrix} \eta_X \\ \eta'_X \\ \eta_Y \\ \eta'_Y \end{pmatrix} = \begin{pmatrix} \mu & 0 & -R_4 & R_2 \\ 0 & \mu & R_3 & -R_1 \\ R_1 & R_2 & \mu & 0 \\ R_3 & R_4 & 0 & \mu \end{pmatrix} \begin{pmatrix} \eta_x \\ \eta'_x \\ \eta_y \\ \eta'_y \end{pmatrix}$$

We scan the xy-coulping parameters, R1~R4 and the
dispersion functions, η and η' at the IP(Interaction Point).

How to obtain the bump heights

Number of parameters

- $R_1{}^* \sim R_4{}^*$ at IP $\longrightarrow$ Scan   4
- η^*_y and $\eta'_y{}^*$ at IP $\longrightarrow$ Scan   2
- $R_1{}^E \sim R_4{}^E$ at the exit of knob region $\longrightarrow 0$ 4
- η^E_y and $\eta'_y{}^E$ at the exit of knob region $\longrightarrow 0$ 2

12

$$
\begin{pmatrix}
R_1{}^* \\
R_2{}^* \\
R_3{}^* \\
R_4{}^* \\
\eta_y{}^* \\
\eta'_y{}^* \\
R_1{}^C \\
R_1{}^C \\
R_1{}^C \\
R_1{}^C \\
\eta_y{}^C \\
\eta'_y{}^C
\end{pmatrix}
= M
\begin{pmatrix}
h_1 \\
h_2 \\
h_3 \\
h_4 \\
h_5 \\
h_6 \\
h_7 \\
h_8 \\
h_9 \\
h_{10} \\
h_{11} \\
h_{12} \\
h_{13} \\
h_{14} \\
h_{15} \\
h_{16}
\end{pmatrix}
$$

- h_n is the bump height at sextupoles.
- M is a 16x12 matrix that is simulated by SAD computer code in advance.
- 16 bump heights are obtained with the Singular Value Decomposition (SVD) method.

Panel of the LER IP Vertical Dispersion and xy-coupling
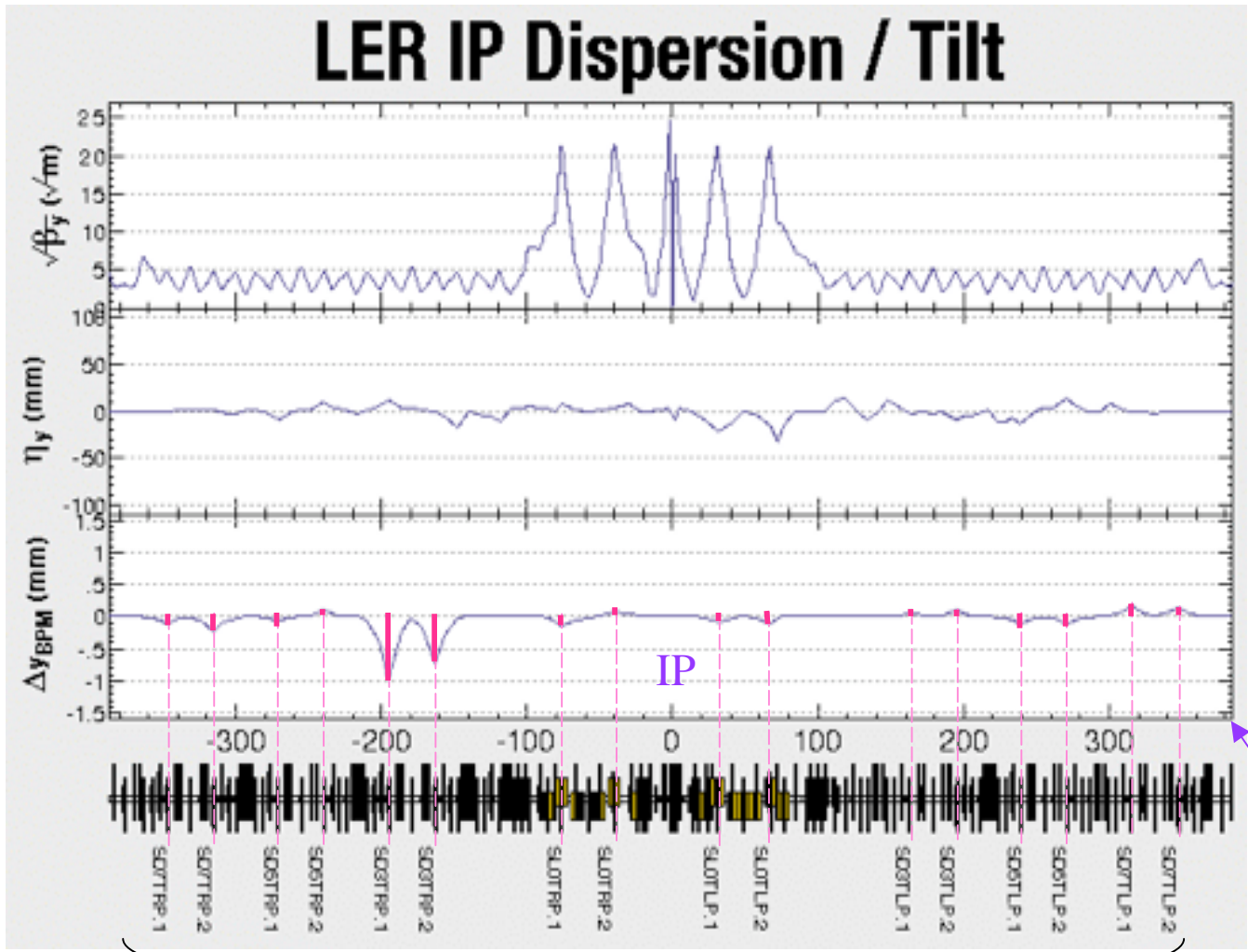
•Horizontal Dispersion

-The horizontal dispersion function and its slope (η_x and η'_x) at the IP are adjusted by making asymmetric horizontal bumps at non-interleaved sextupoles.

-We use 8 sextupole pairs of the closest to the IP in each rings for tuning.
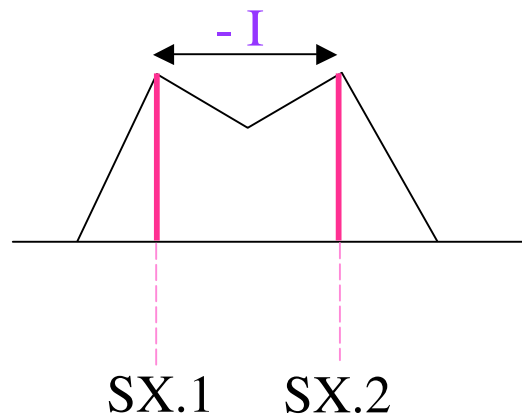
-We can fit 4 parameters using enough free parameters .

LER IP Horizontal Dispersion

$|$: Bump Height

IP

The exit of knob region

8 pairs of sextupoles
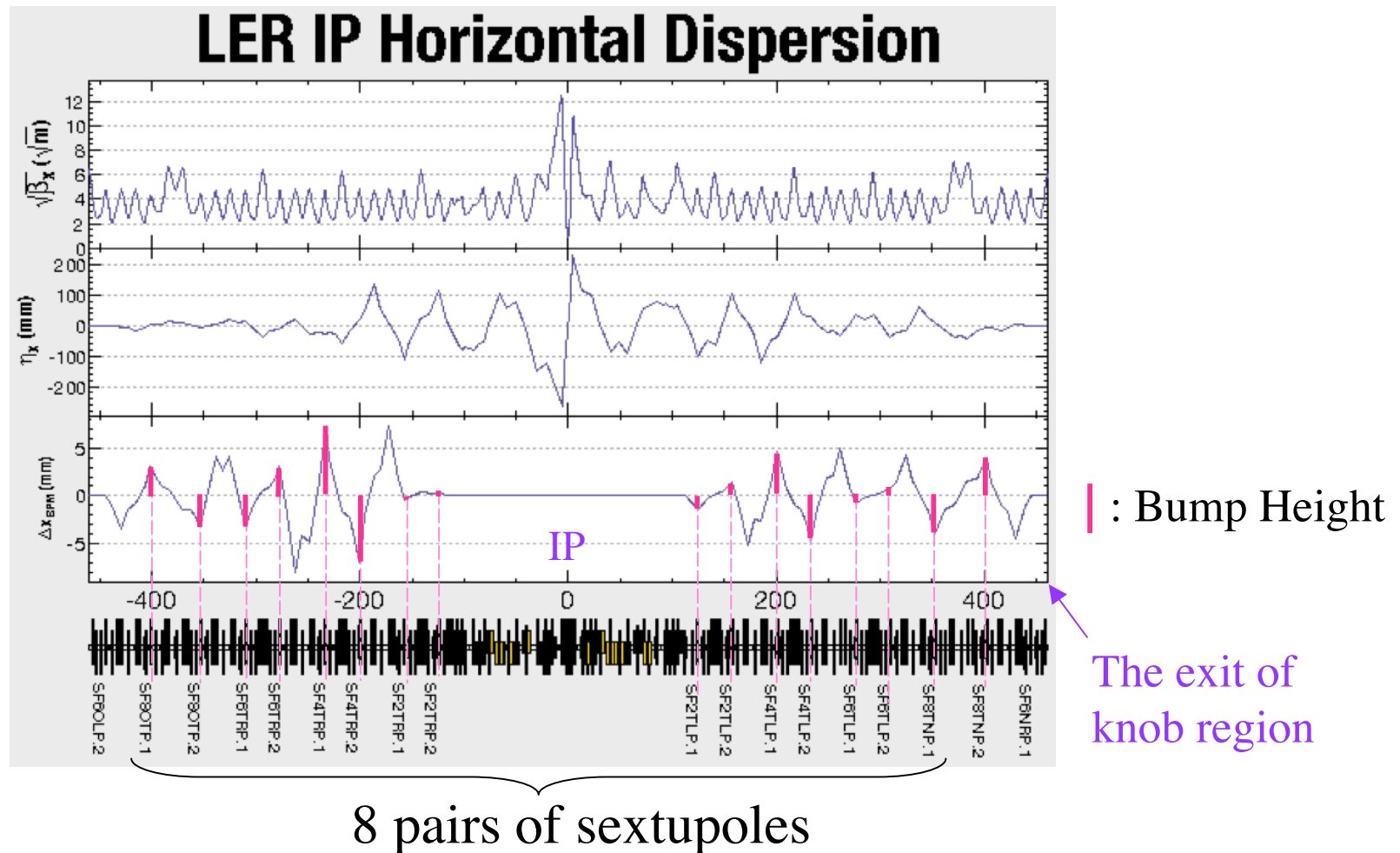
Bumps on non-interleaved sextupoles

Phase advance:

- I

SX.1   SX.2
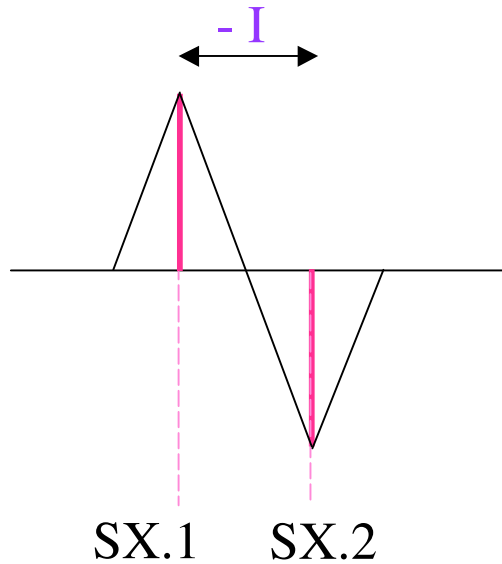
•Asymmetric bump
   -dispersion function:
      leaks around the ring
   -xy-coupling:
      localizes in the sextupole pair

Phase advance:

- I

SX.1   SX.2

•Symmetric bump
   -dispersion function:
      localizes in the sextupole pair
   -xy-coupling:
      leaks around the ring

LER IP Horizontal Dispersion
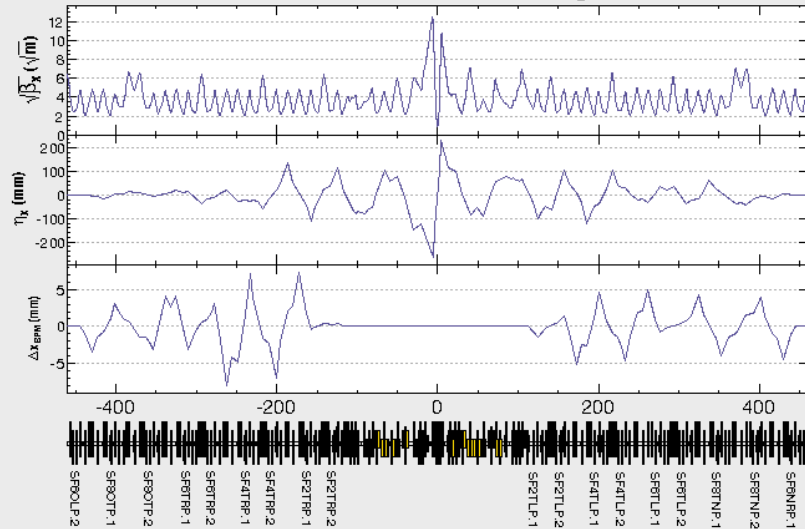
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dispersion (BPM coordinate)

η_{lx} @IP (1 = 0.64 mm)   3.18 ✛ 3.18

η_{lx}' @IP (1 = 0.39 mrad)   70.00 ✛ 70

Label   EX ◆ EPX   Start   Pause / Resume

Calculate   Set Bump

LERIPXDispersion on :0.0

HER IP Horizontal Dispersion

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dispersion (BPM coordinate)

η_{lx} @IP (1 = 0.89 mm)   -1.00 ✛ -1

η_{lx}' @IP (1 = 0.74 mrad)   6.50 ✛ 6.5

Label   EX ◆ EPX   Start   Pause / Resume

Calculate   Set Bump
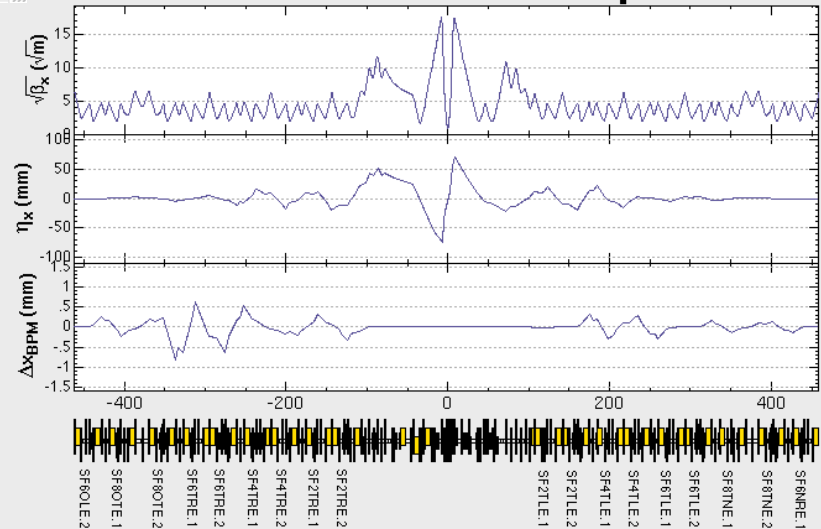
HERIPXDispersion on :0.0

Number of parameters

- η^*_x and $\eta'_x{}^*$ at IP $\longrightarrow$ Scan   2
- η^E_x and $\eta'_x{}^E$ at the exit of knob region $\longrightarrow$ 0   2 $\Big\}$ 4

$$\begin{pmatrix} \eta_x{}^* \\ \eta'_x{}^* \\ \eta_x{}^E \\ \eta'_x{}^E \end{pmatrix} = M \begin{pmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \\ h_5 \\ h_6 \\ h_7 \\ h_8 \end{pmatrix}$$

- h_n (n=1~8) is the asymmetric bump height at non-interleaved sextupoles.
- M is a 8x4 matrix that is simulated by SAD computer code in advance.
- 8 bumps are obtained with the Singular Value Decomposition (SVD) method.

Scans in Operation -1-

The position of luminosity peak coincides with that of the minimum vertical beam size being scanned.

position of HER beam size peak

position of Luminosity peak

original value

Data taking

Each data are taken at the same current ratio as possible.
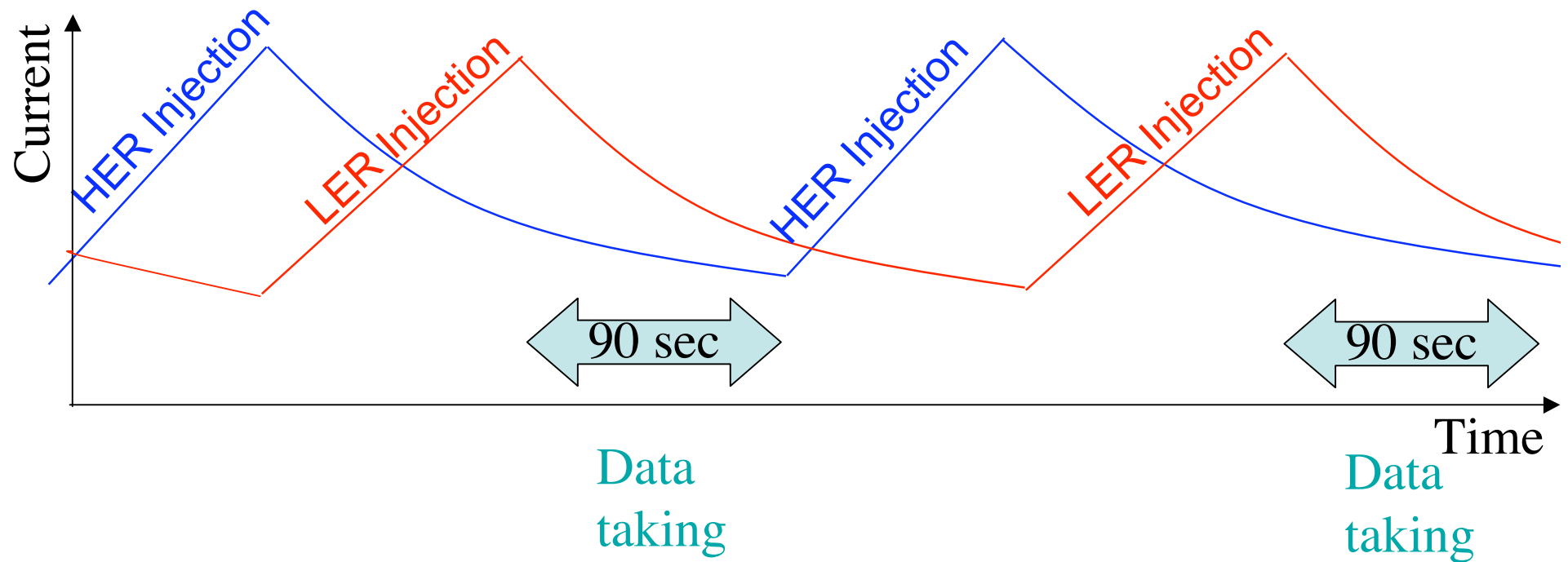
Scans in Operation -2-

• Typical scan (good example)
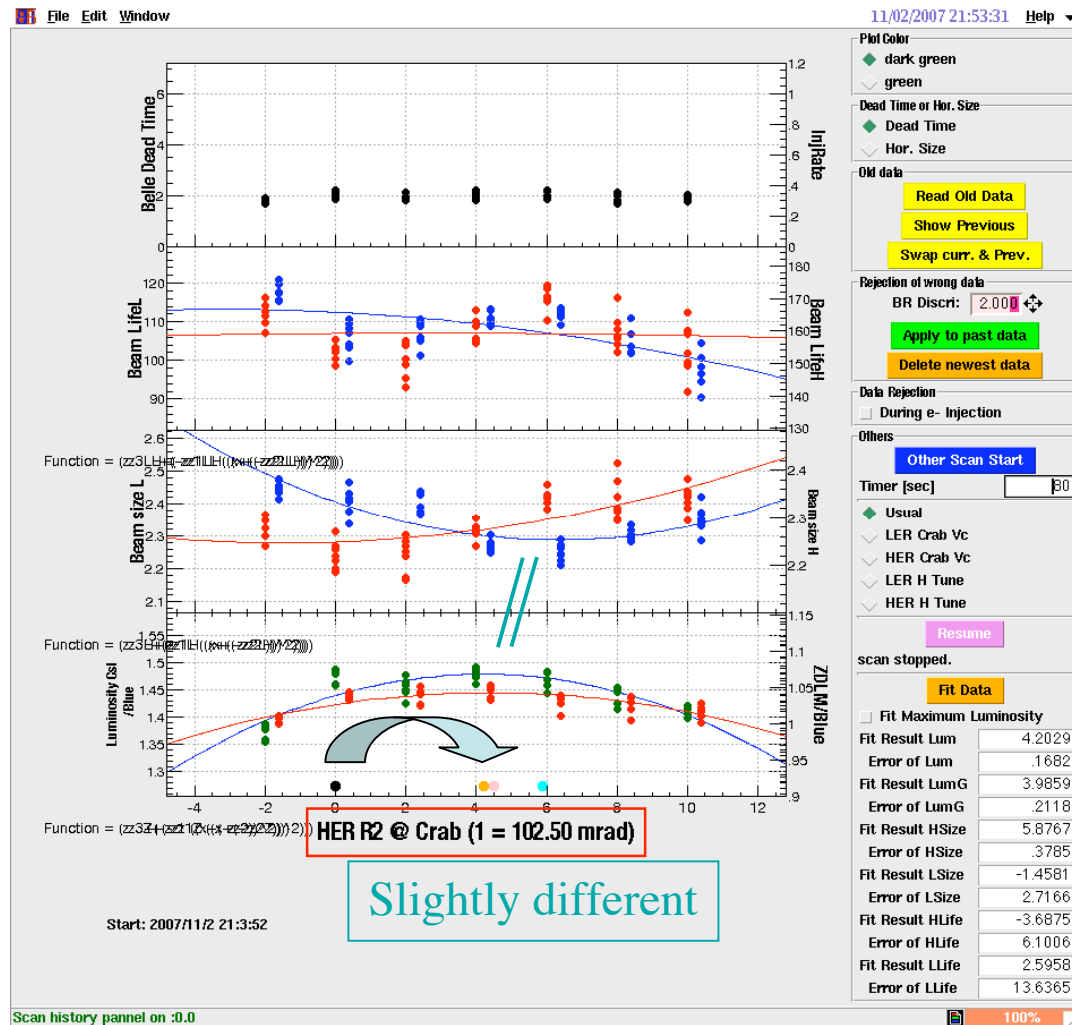
The position of luminosity peak coincides with that of the minimum vertical beam size being scanned.

Scans in Operation -3-

• Typical scan in bad life time situation
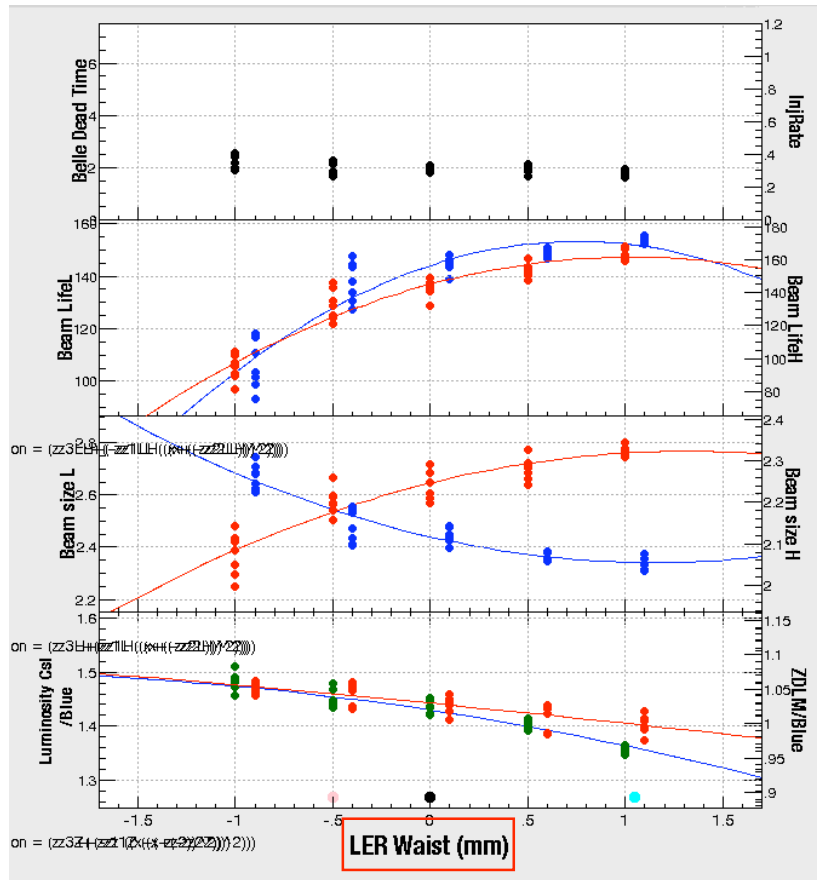
The position of luminosity peak coincides with that of the minimum vertical beam size being scanned.

But unfortunately, both beam lives are shortened at better luminosity.

We give up the highest luminosity and set tolerable life time.

Scans in Operation -4-

- Examples with a "cross shape" of beam sizes
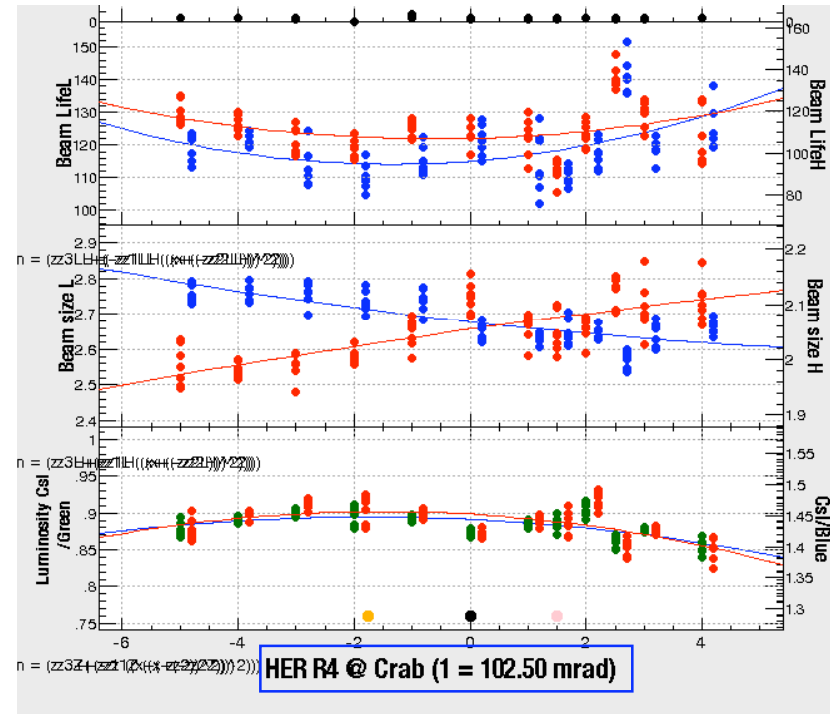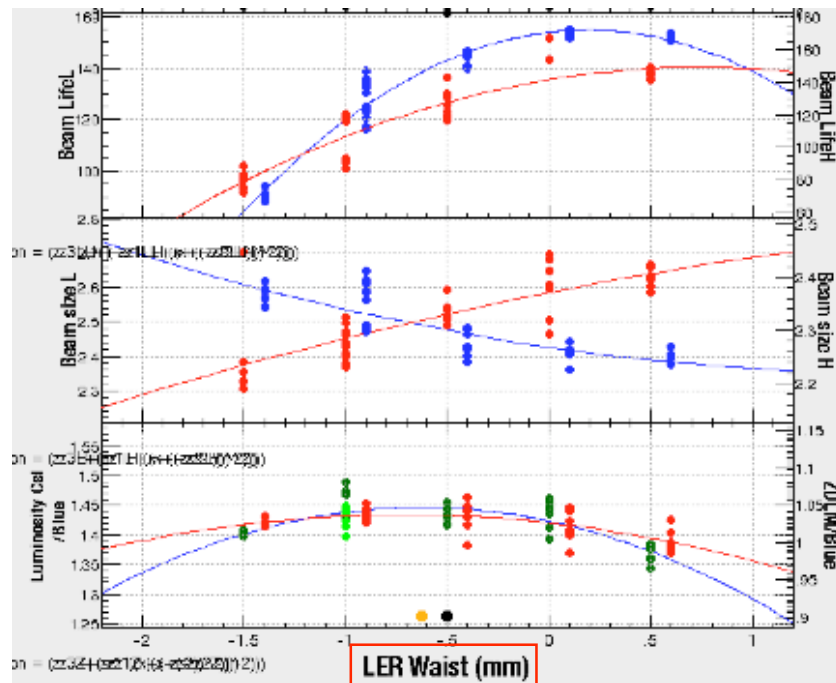
- The beam sizes are in inverse proportion to each other.

- The shape of the two beam sizes is like a "cross shape".

- The peak of luminosity is found around the cross point.

Scans in Operation -5-

•Two peak shape
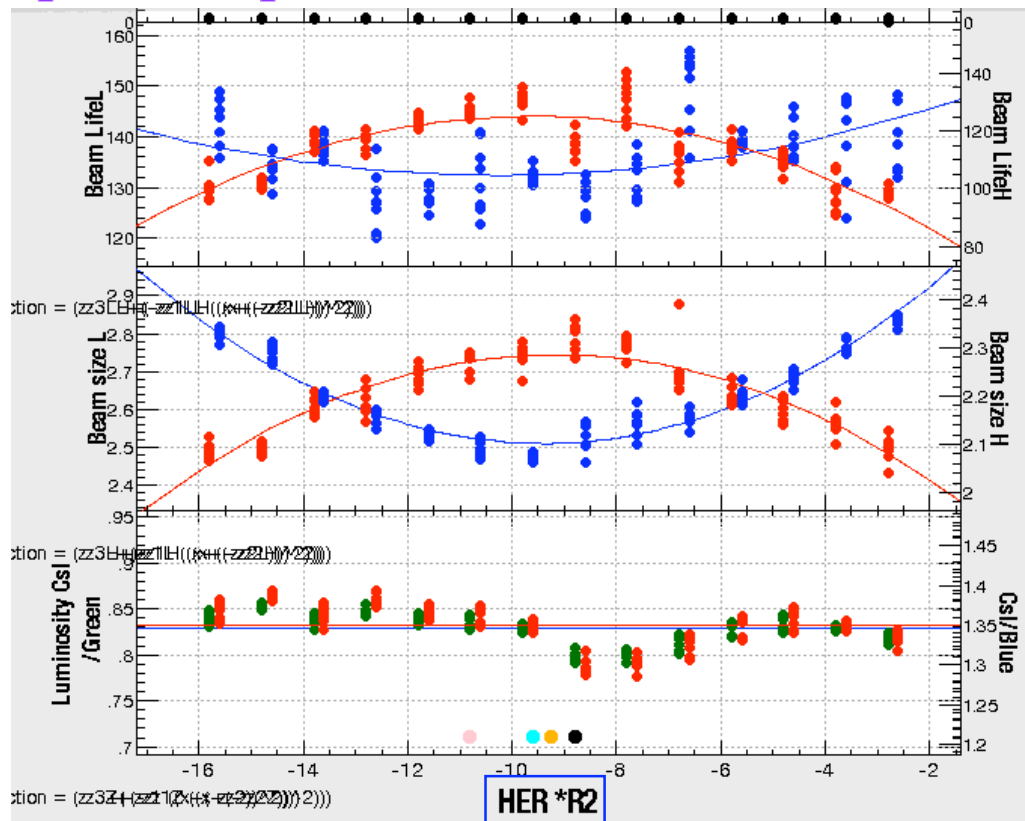
•The luminosity has two peaks with scanning.

•At the position of the minimum beam size in scan, the luminosity is also minimum.

Simulation of Scan in Operation -5-

by M.Tawada

•Two peak shape

Typical example

- HER beam size
- LER beam size
- sgy [μm]
- Lum [10^{30}/cm^2/sec]
- HER ey [mm]
- Luminosity
- HER r4 [mrad]
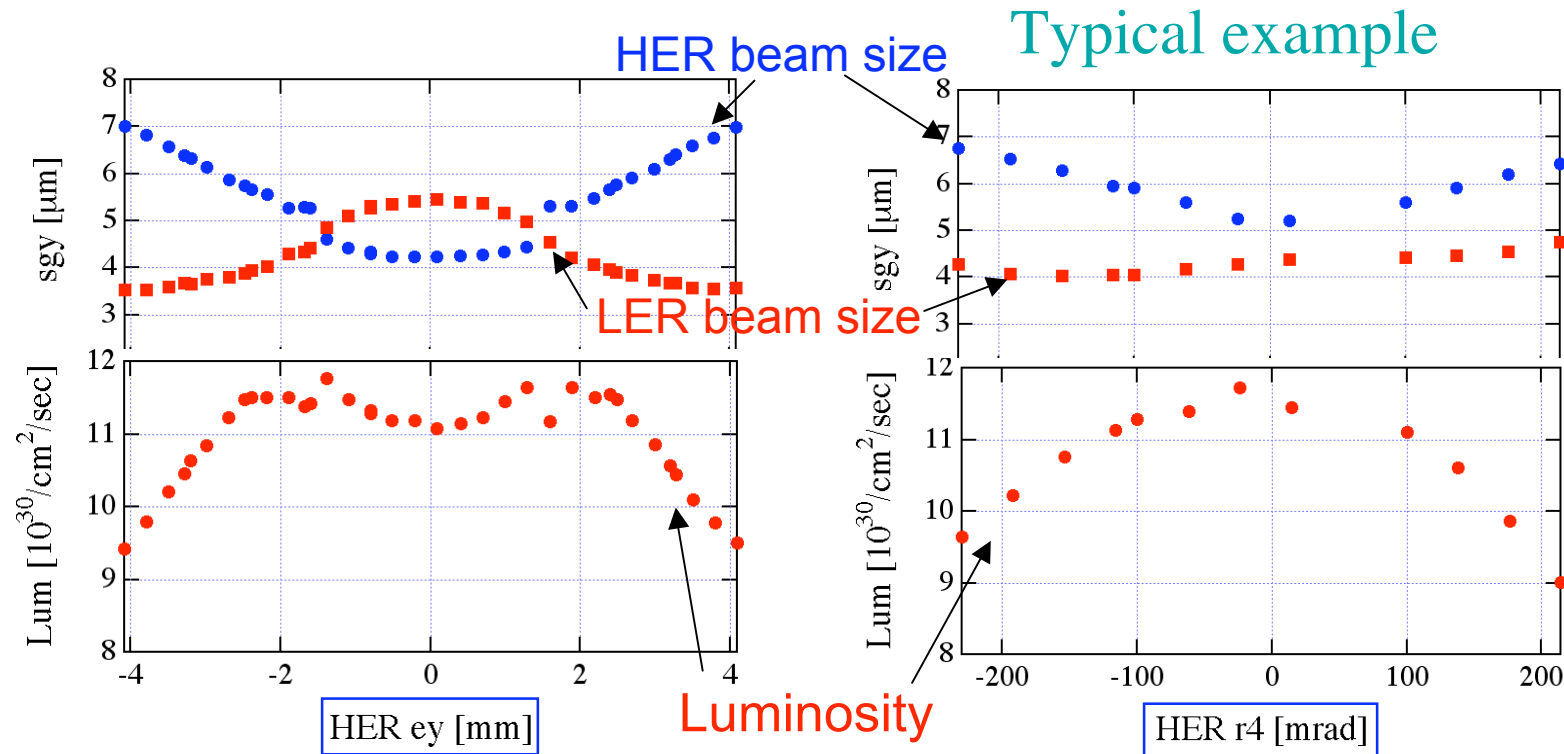
•In almost cases, the shape is like the typical example.

•The "cross shape" is included in this "two peak" case.

Scans in Operation -6-

•Bad examples with same shape of the beam size as luminosity
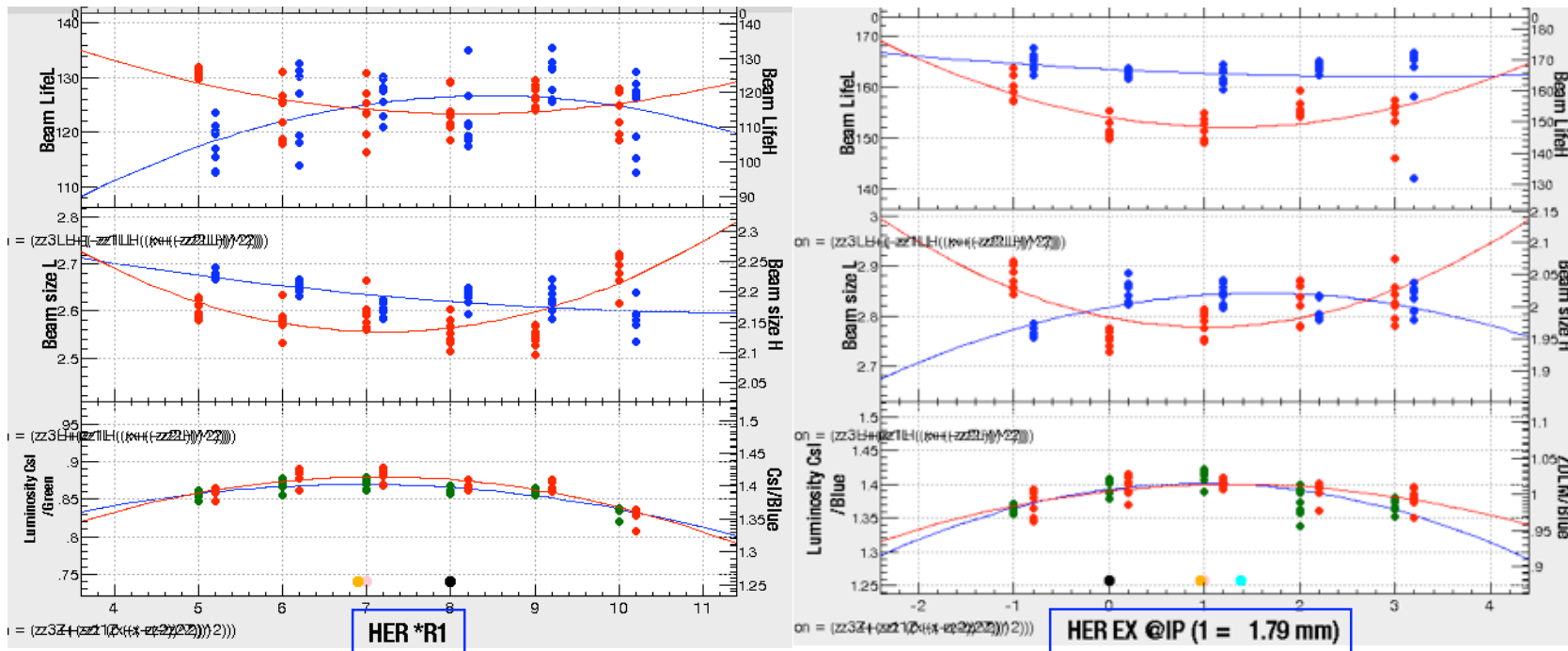
•The position of Luminosity peak is the same as the beam size of the other ring.

•In worst case, the shapes of luminosity and that of the beam size in scanning ring are like mountains.

Scans in Operation -7-
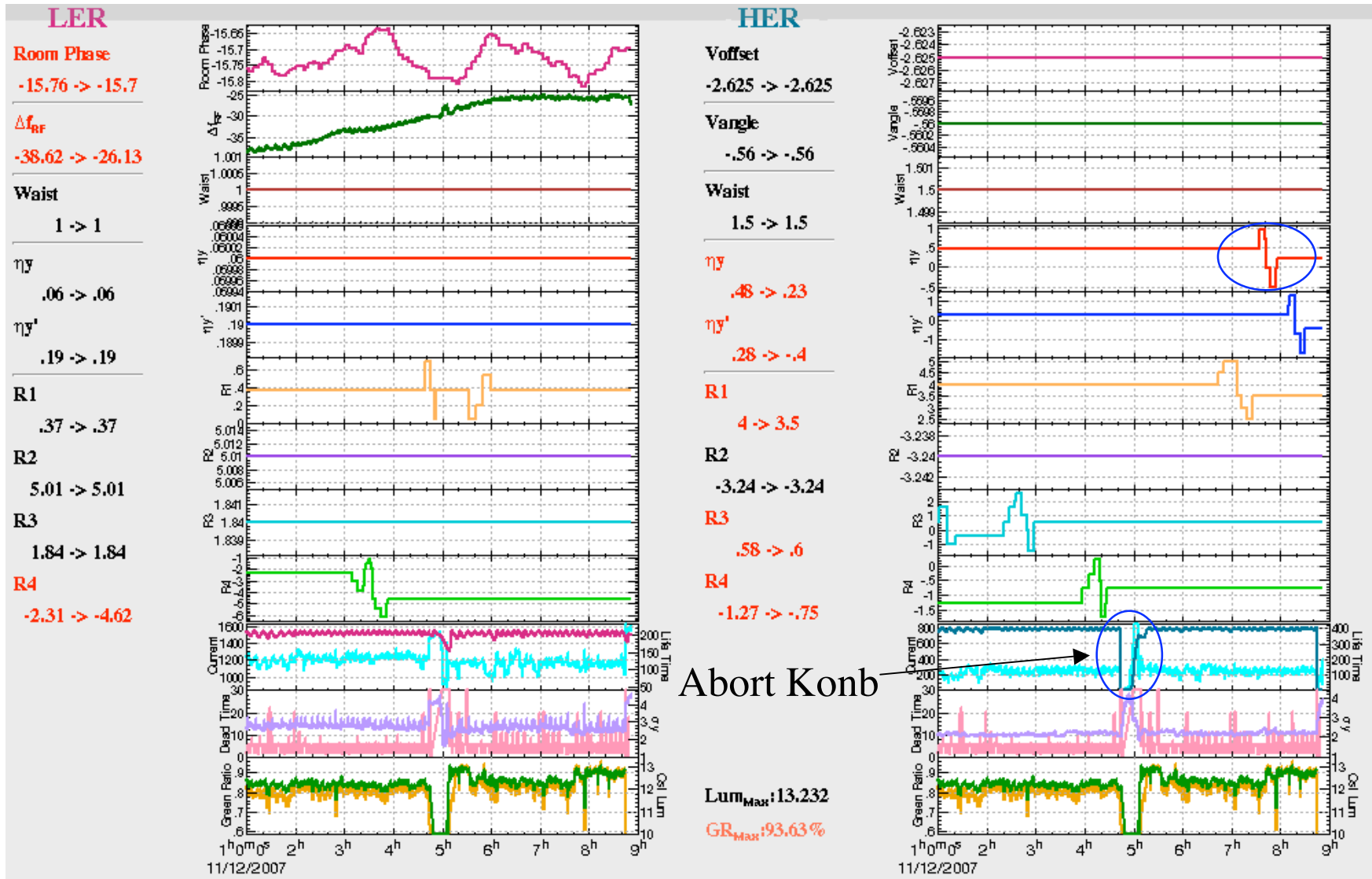
• Situlation sometimes changes.
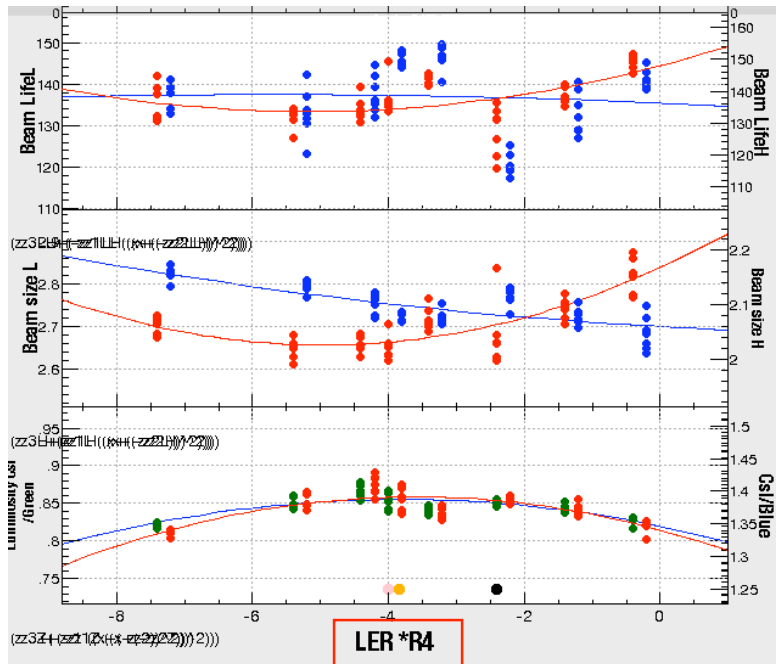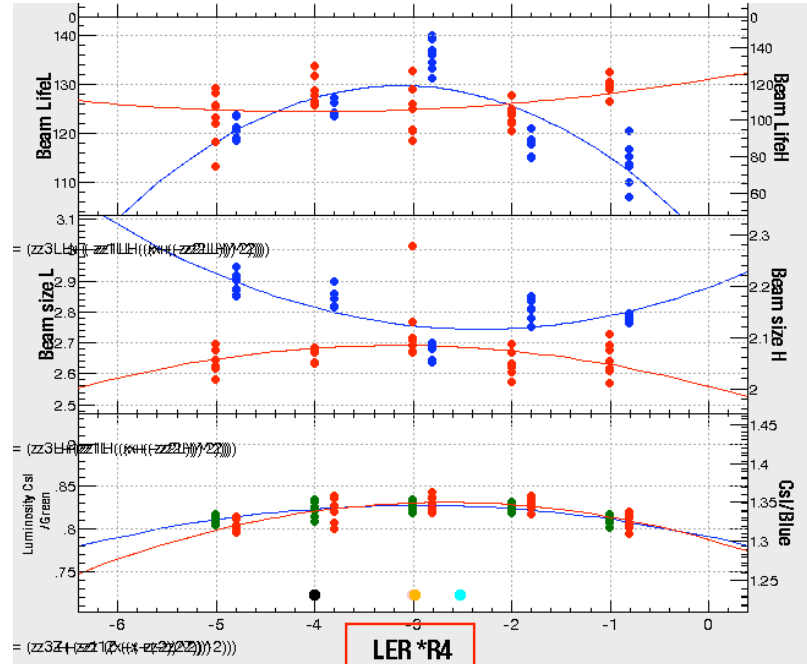
day shift （10:00） evening shift （21:00）

Same day

- Shift Report Panel
    - We can check which knob is effective.

Knob 1

Knob 3