Overview of Commissioning in 2021c - 2022b

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The 26th KEKB Accelerator Review Committee

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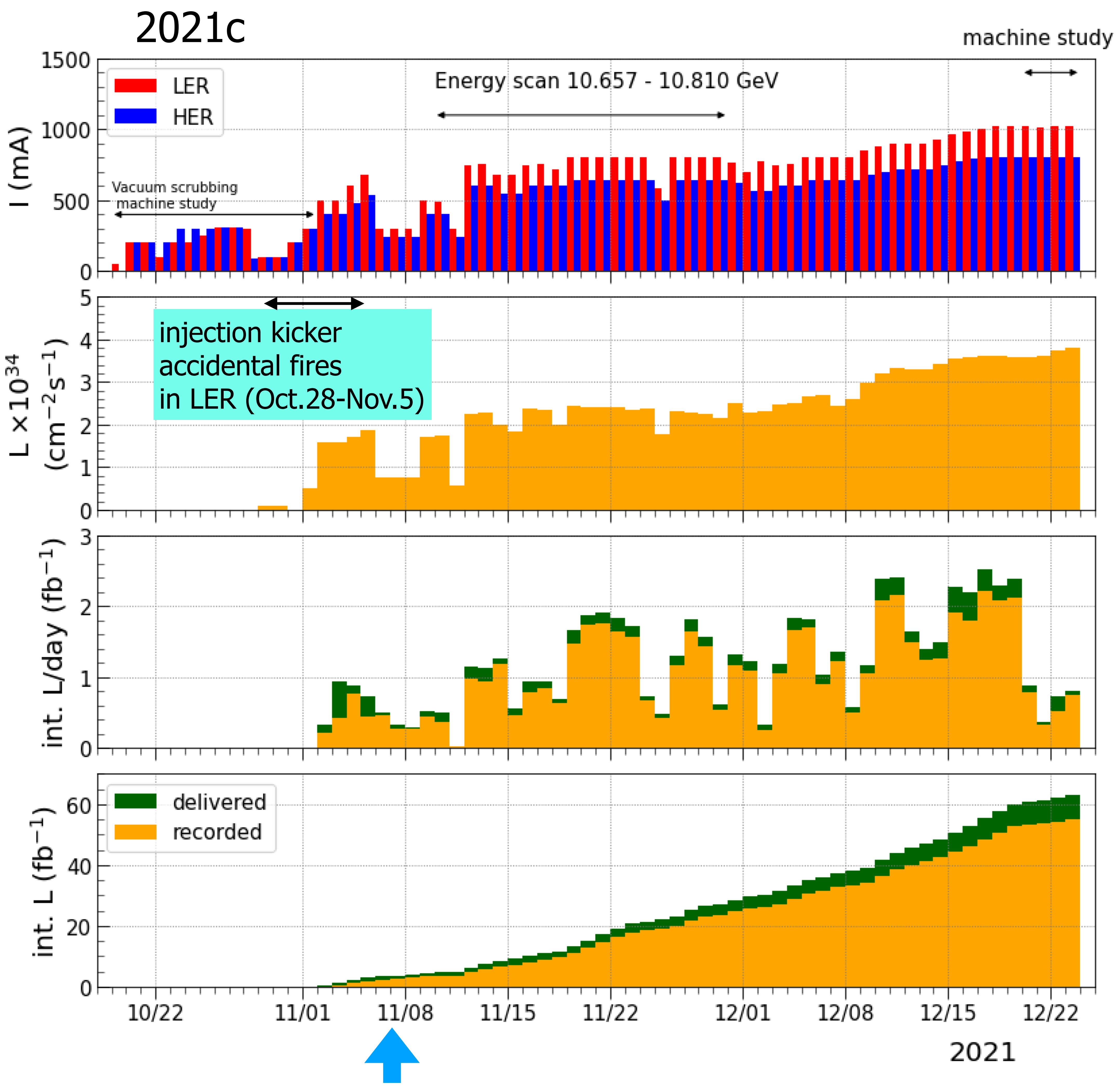
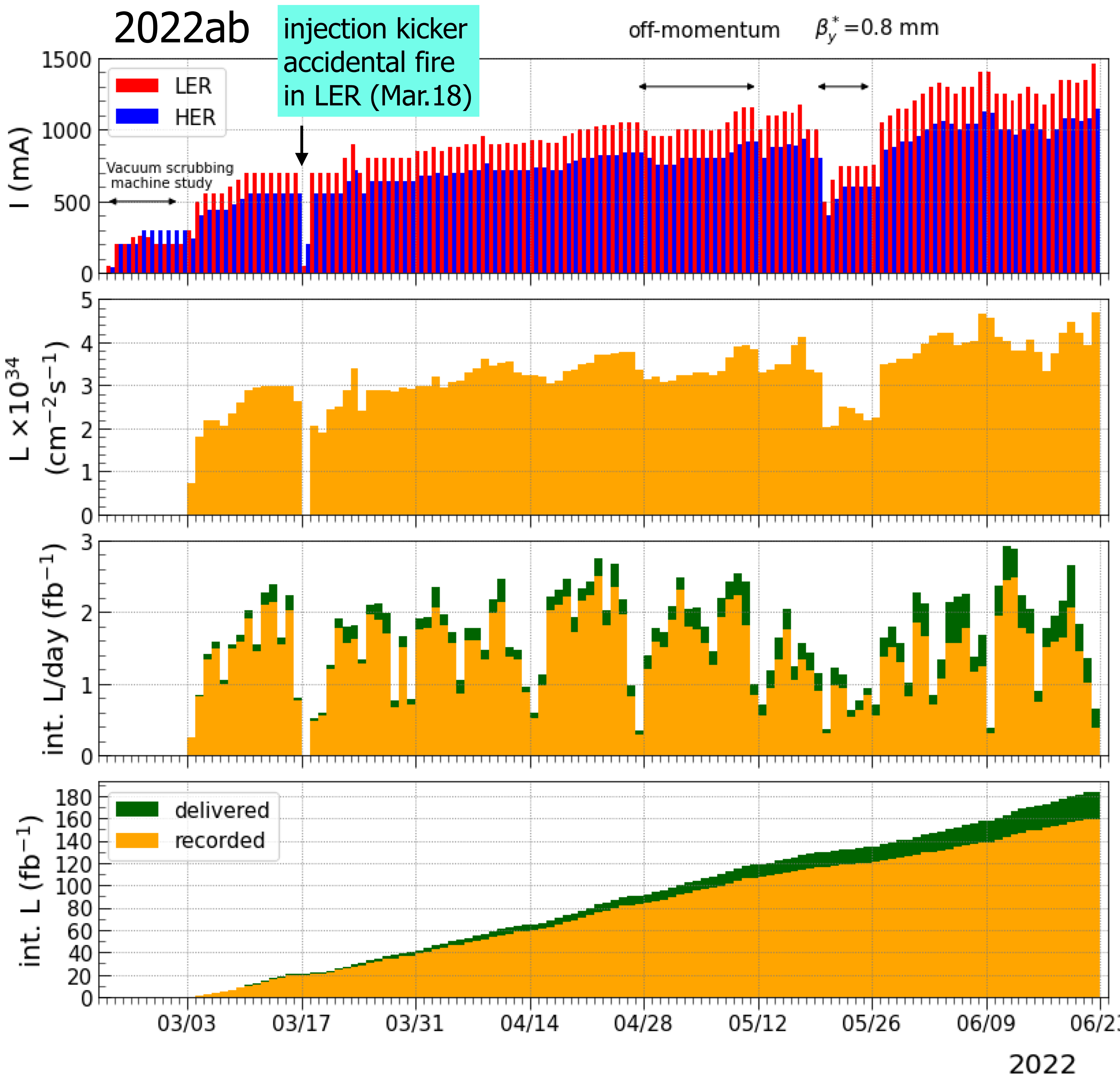
2021c and 2022ab Run



We reduced beam currents
after replacing the thyratrons
for their conditioning.



Integrated luminosity	Recorded	Date	Delivered	Date
Shift (pb^{-1})	958.1	April 24, swing, 2022	1035.9	April 22, swing, 2022
1 days (fb^{-1})	2.503	April 22, 2022	2.912	June 11, 2022
7 days (fb^{-1})	15.001	April 18 - April 24, 2022	16.599	April 18 - April 24, 2022

Machine Parameters : 2021c - 2022b

	Dec. 23, 2021c		June 8, 2022b		May 22, 2022b		Unit
Ring	LER	HER	LER	HER	LER	HER	
Emittance	4.0	4.6	4.0	4.6	4.0	4.6	nm
Beam Current	1015	797	1321	1099	744	600	mA
Number of bunches	1370		2249		1565		
Bunch current	0.741	0.582	0.587	0.489	0.475	0.383	mA
Horizontal size σ_x*	17.6	16.6	17.9	16.6	17.9	16.6	μm
Vertical cap sigma Σ_y*	0.339		0.303		0.250		μm *1
Vertical size σ_y*	0.240		0.215		0.177		μm *2
Betatron tunes ν_x / ν_y	44.524 / 46.589	45.530 / 43.572	44.525 / 46.589	45.532 / 43.573	44.525 / 46.589	45.532 / 43.574	
β_x* / β_y*	80 / 1.0	60 / 1.0	80 / 1.0	60 / 1.0	80 / 0.8	60 / 0.8	mm
Piwinski angle	10.7	12.7	10.7	12.7	10.7	12.7	
Crab waist ratio	80	40	80	40	80	40	%
Beam-Beam parameter ξ	0.0433	0.0315	0.0407	0.0279	0.0309	0.0219	
Specific luminosity	6.45×10^{31}		7.21×10^{31}		8.74×10^{31}		$cm^{-2}s^{-1}/mA^2$
Luminosity	3.81×10^{34}		4.65×10^{34}		2.49×10^{34}		$cm^{-2}s^{-1}$

*1) estimated by luminosity with assuming design bunch length

*2) divide *1 by $\sqrt{2}$

Achievements until 2022 (1)

- Peak luminosity : 4.65 x 10^{34} $cm^{-2}s^{-1}$ (4.71 x 10^{34} $cm^{-2}s^{-1}$ w/o Belle II data taking and HV OFF)
- Integrated luminosity : 424 fb^{-1} (491 fb^{-1})
- Peak currents : 1.46 A (LER) / 1.14 A (HER), 2346 bunches (2-bucket spacing)
- β_y^* : 1 mm (0.8 mm) << bunch length ~6 mm → proof of the nano-beam scheme
- Crab waist scheme has been applied (80 % in the LER, 40 % in the HER). → luminosity improvement
- Beam-Beam parameter : 0.035 at 0.7 mA (0.045 at 1.1 mA for small number of bunches as machine study)
- Bunch-by-bunch FB tuning (gain, noise reduction) in the HER → luminosity improvements
- Bunch-by-bunch FB tuning (number of taps) in the LER → suppress single bunch blowup, luminosity improvements
- Chromatic X-Y coupling correction with rotatable sextupoles in the LER → luminosity improvements

Achievements until 2022 (2)

- Long-term drift of QCS magnetic field (beta-beat) ← reduced by new QCS initialization procedure
- Orbit deviation due to IP knob tuning (beta-beat) ← suppressed with QCS corrector (ZHQC2RP)
- Increase of positron charge for the LER injection : 3 nC at the end of e^+ beam transport line
- 2-bunch injection for the LER and HER → improve injection efficiency (Bunch equalization is difficult.)
- Adjustment of injection orbit in the HER (septum, kicker) → improve injection efficiency (not enough)
- Leakage orbit from injection kickers ← reduced by 60 % with additional inductance for the coils

What Limits Luminosity Performance ?

Classification		Remarks	Items
A	A1	Single-beam causes. Luminosity becomes lower as increasing bunch current. (single-bunch)	-1 mode instability
	A2	Single-beam causes. Luminosity becomes lower as increasing total current. (multi-bunch)	coupled-bunch, degradation of optics (linear parameters) due to beamline deformation
B		Single-beam causes, but interference of beam-beam interaction makes luminosity lower.	lattice nonlinearity (QCS fringe, chromatic X-Y couplings, etc.)
C		Pure beam-beam interaction limits luminosity. Beam-Beam limit, etc.	crab-waist, resonances, coherent beam-beam head-tail instability, parasitic collision

Obstacles to Luminosity Improvement

- Beam blowup in the LER (single beam, non-collision) : "-1 mode instability" (A1)
- Sudden beam loss (both rings, more serious in the LER) → "fireball hypothesis"
  - Damage of collimator head and/or QCS quench if large beam loss
- Optics degradation due to beam current dependence of beam orbit (A2)
  - Orbit deviation at strong sextupoles is caused by beam line deformation due to intense SR heating.
- Lower beam-beam parameter: 0.035 at 0.7 mA for physics run (0.045 at 1.1 mA) (B)
- Short beam lifetime (dynamic aperture, physical aperture) : LER 8 min(1.25 A) / HER 25 min(1 A) n_b=2346
- Beam related background (optimization of collimators, QCS aperture and IR orbit)
- Beam injection (small physical aperture of injection region, emittance growth in the beam transport line)
- Earthquake : The beam aborts invariably. The ε_y becomes large in the HER. The optics correction is needed.
- Lower online luminosity monitor during LER injection (Beam backgrounds affect the measured value.)

Executive Summary from the 25th KEKB ARC Report

The most important challenges are:

- Top-up injection efficiency and injection stability, including HER beam blow up in the transfer line, mitigating the consequences of accidental kicker-pulser misfiring, problematic HER two-bunch injection, septum drifts, etc.
- Collimation and machine protection strategy, including overcoming the present bunch intensity limitations due to TMCI → -1 mode instability; developing a strategy for safe beam current increase; and understanding and avoiding the as yet unexplained sudden large beam losses in the LER.
- Medium and long-term planning including possible upgrade paths; with an overall plan of increasing the beam currents, increasing the number of bunches, and lowering β_y^* to maximize the luminosity.

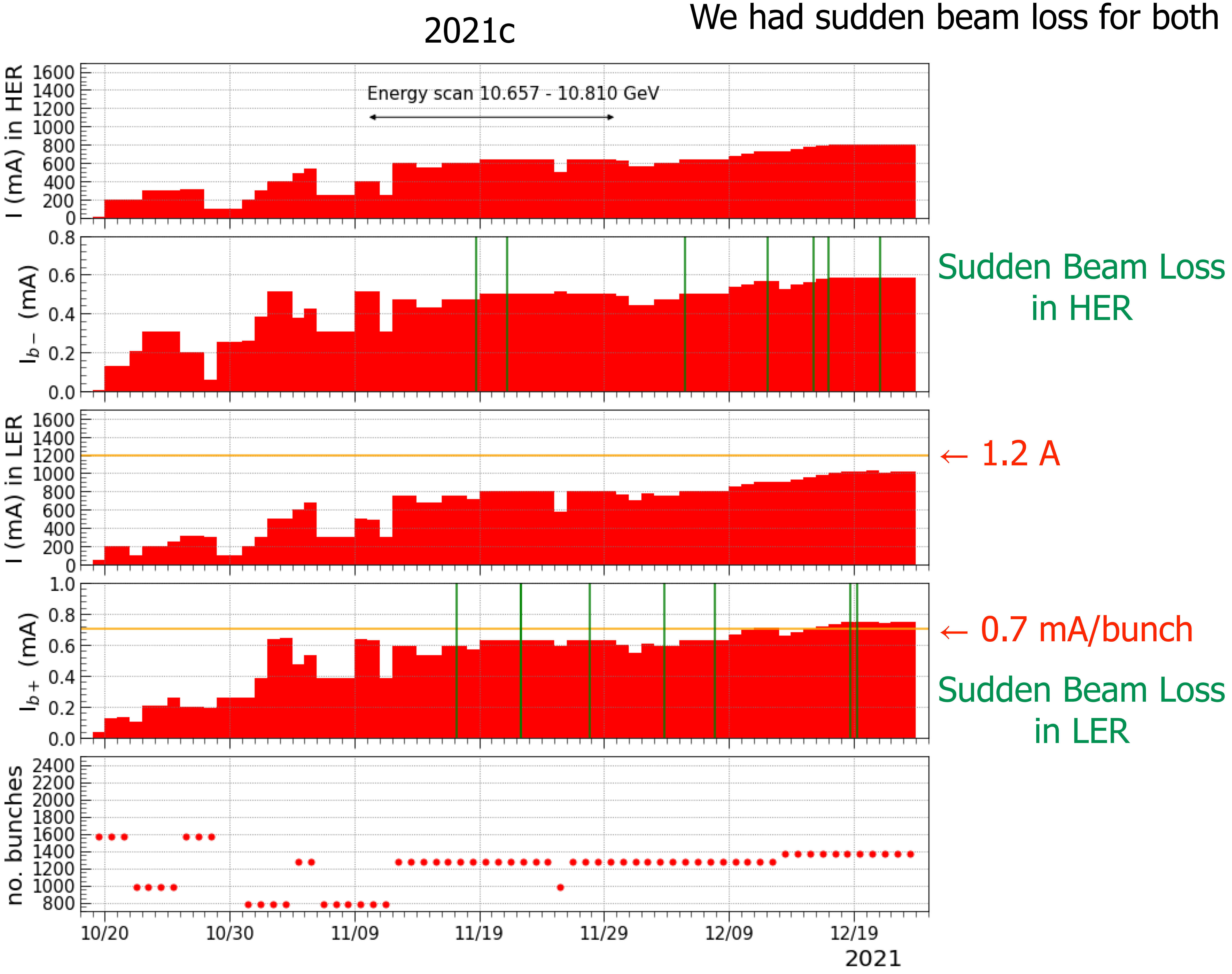
Accidental Fire of Injection Kicker in LER

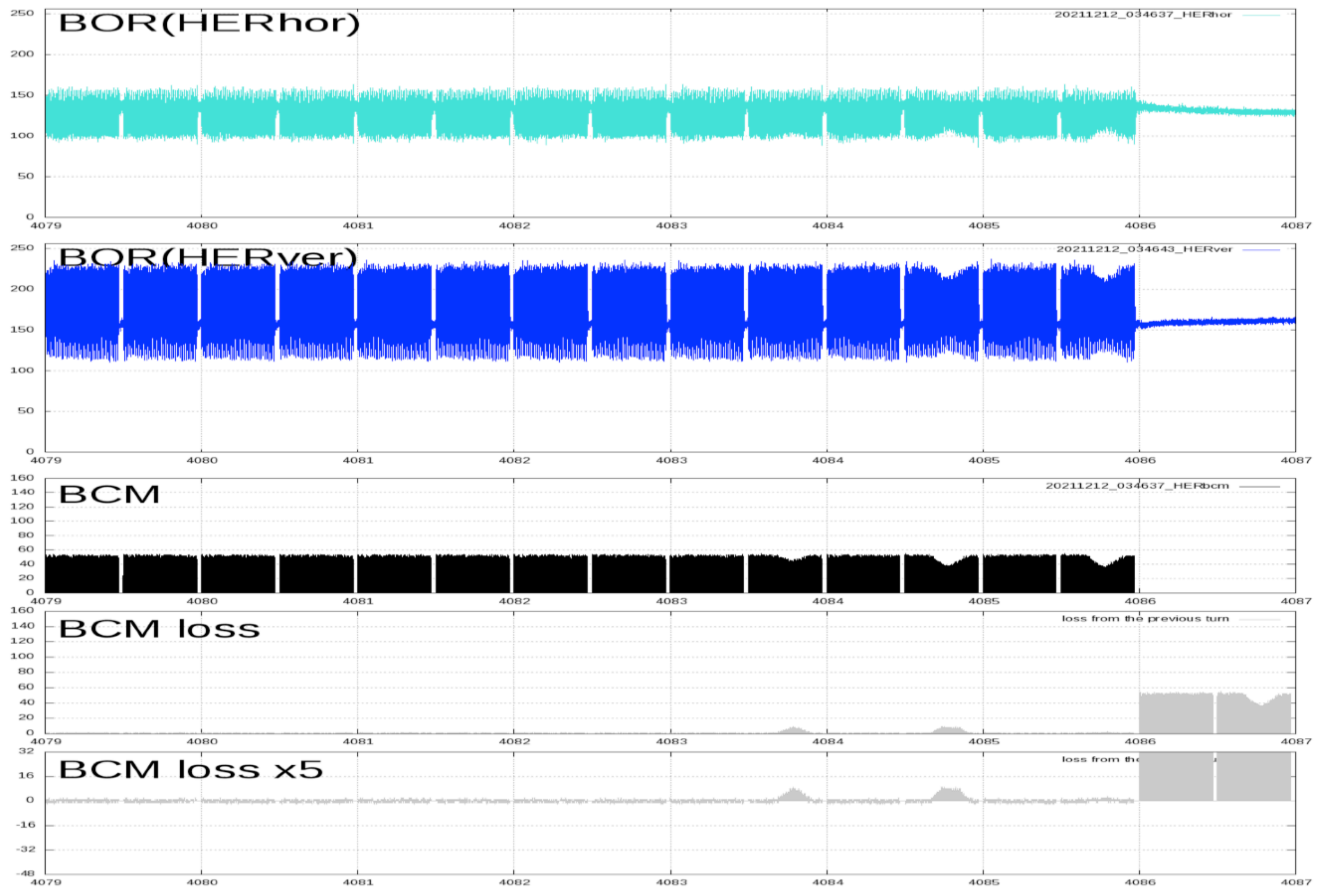
- 2021c: We got several accidental fires in the LER at the early commissioning (Oct.28, Oct.30, Nov. 5). There is no accidental fire after the replacement of thyratrons and further conditioning.
- Before starting 2022a, the thyratrons were rearranged and replaced with new one.
- 2022a: We observed large beam loss in the LER on March 18 due to accidental fire of injection kicker in the LER. Then, the collimator head of D06H3 was damaged (broken). The thyratron was replaced and conditioned.
- 2022b: No accidental fire of the injection kickers
- Accidental fire of injection kicker is caused by a lack of the thyratron conditioning or early failure.
- If we use a well conditioned thyratron, there will be no accidental fire.
- There is no accidental fire in the HER even though the applied voltage is higher than the LER. The thyratrons in the HER are well conditioned.

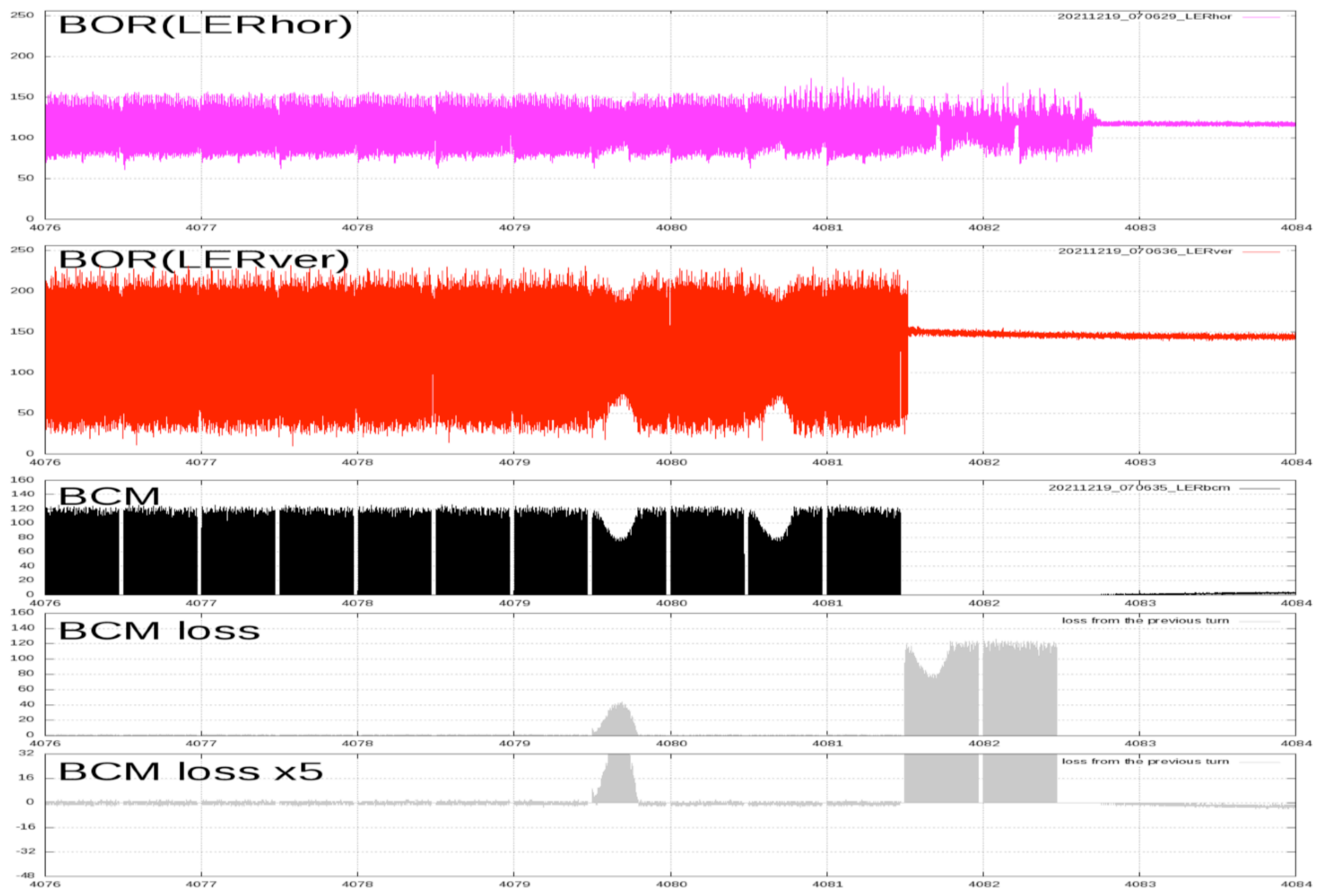
Robust Low-Z (C) head is installed into D06H3 collimator during LS1. (used as the spoiler)
D06H1 on the upstream side is moved to the downstream side (D06H4) to collimate beam scattered by D06H3.

No Fatal Accident due to Large Sudden Beam Loss in 2021c

We had sudden beam loss for both rings.

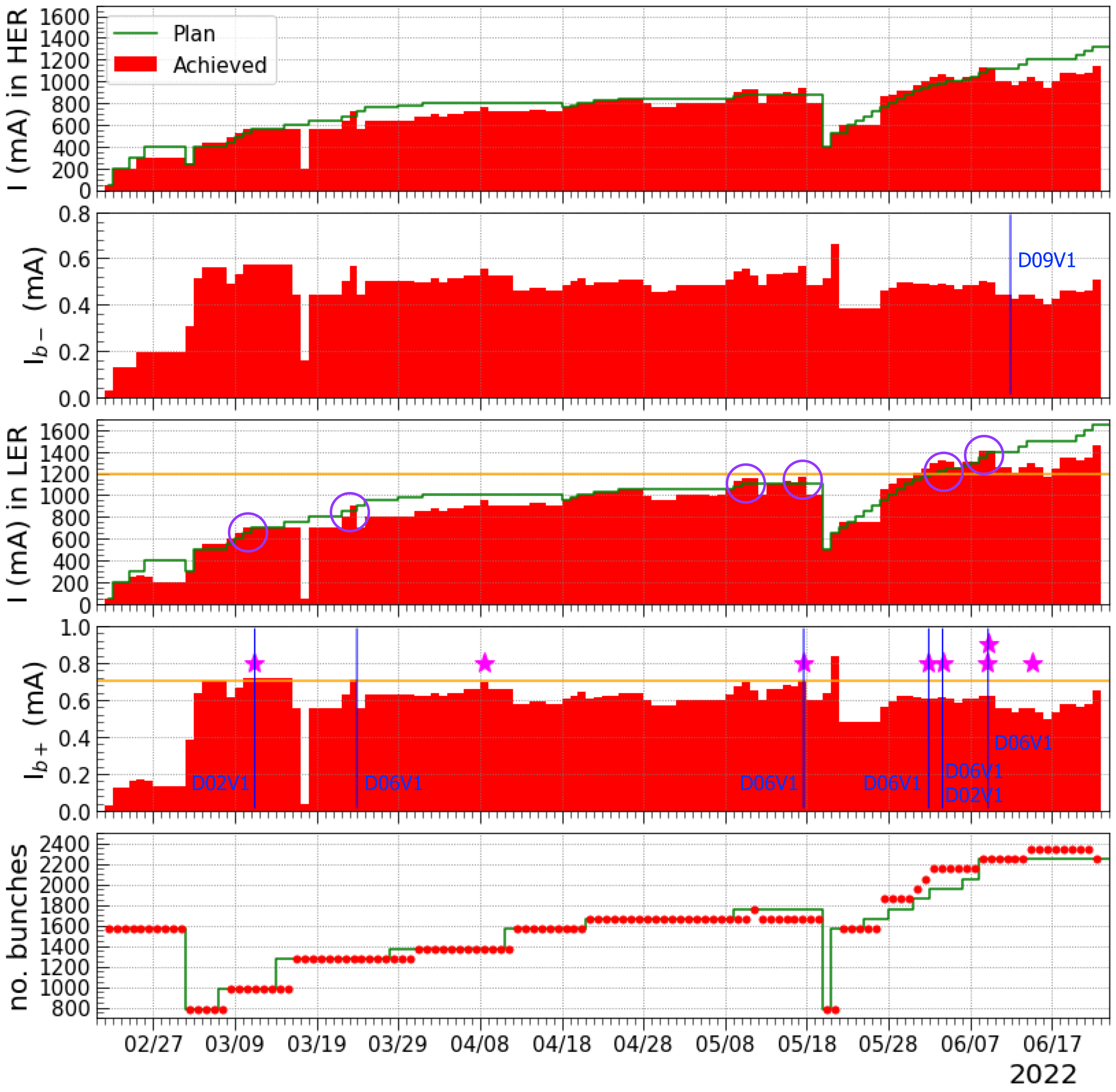




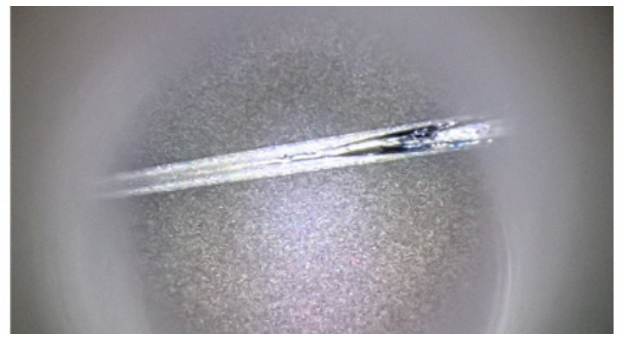


QCS Quench and Collimator Damage due to Sudden Beam Loss in 2022ab

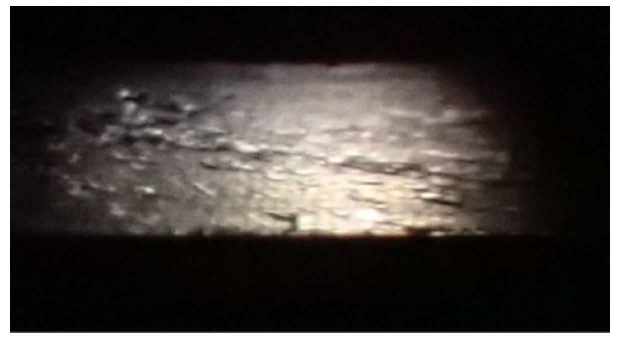
2022ab

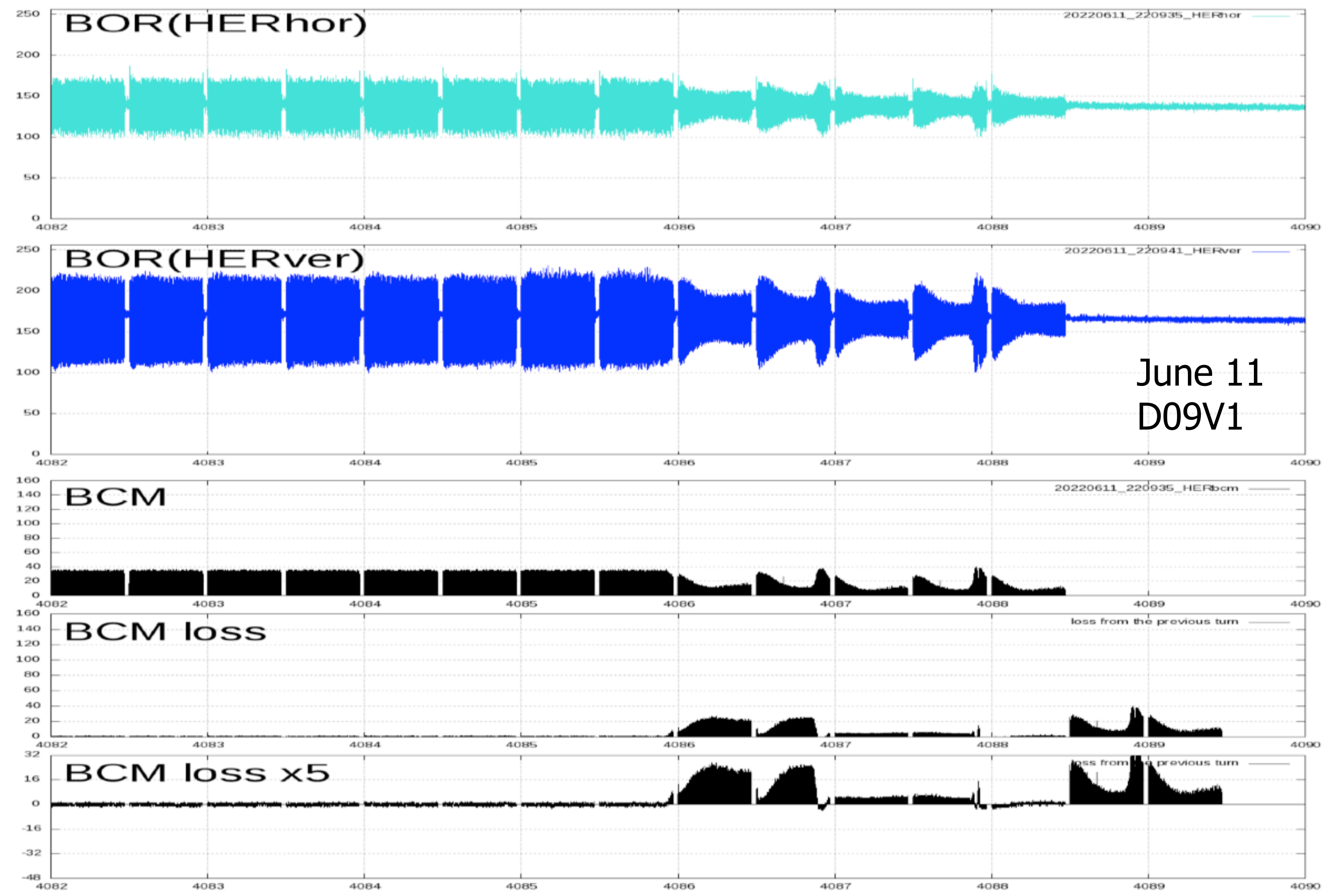


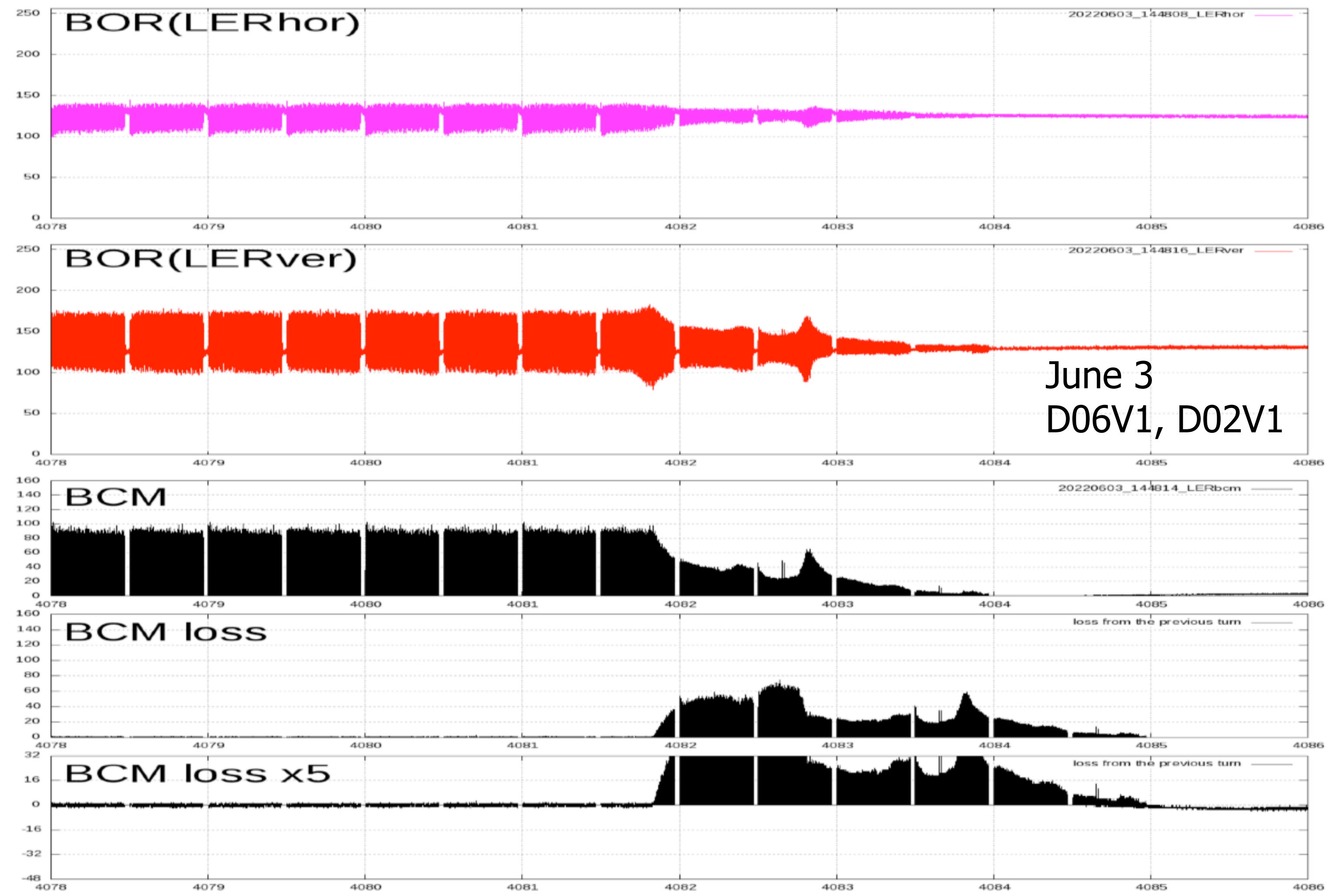
D09V1



D06V1







← 1.2 A

deviation from plan

← 0.7 mA/bunch

QCS (LER) quench

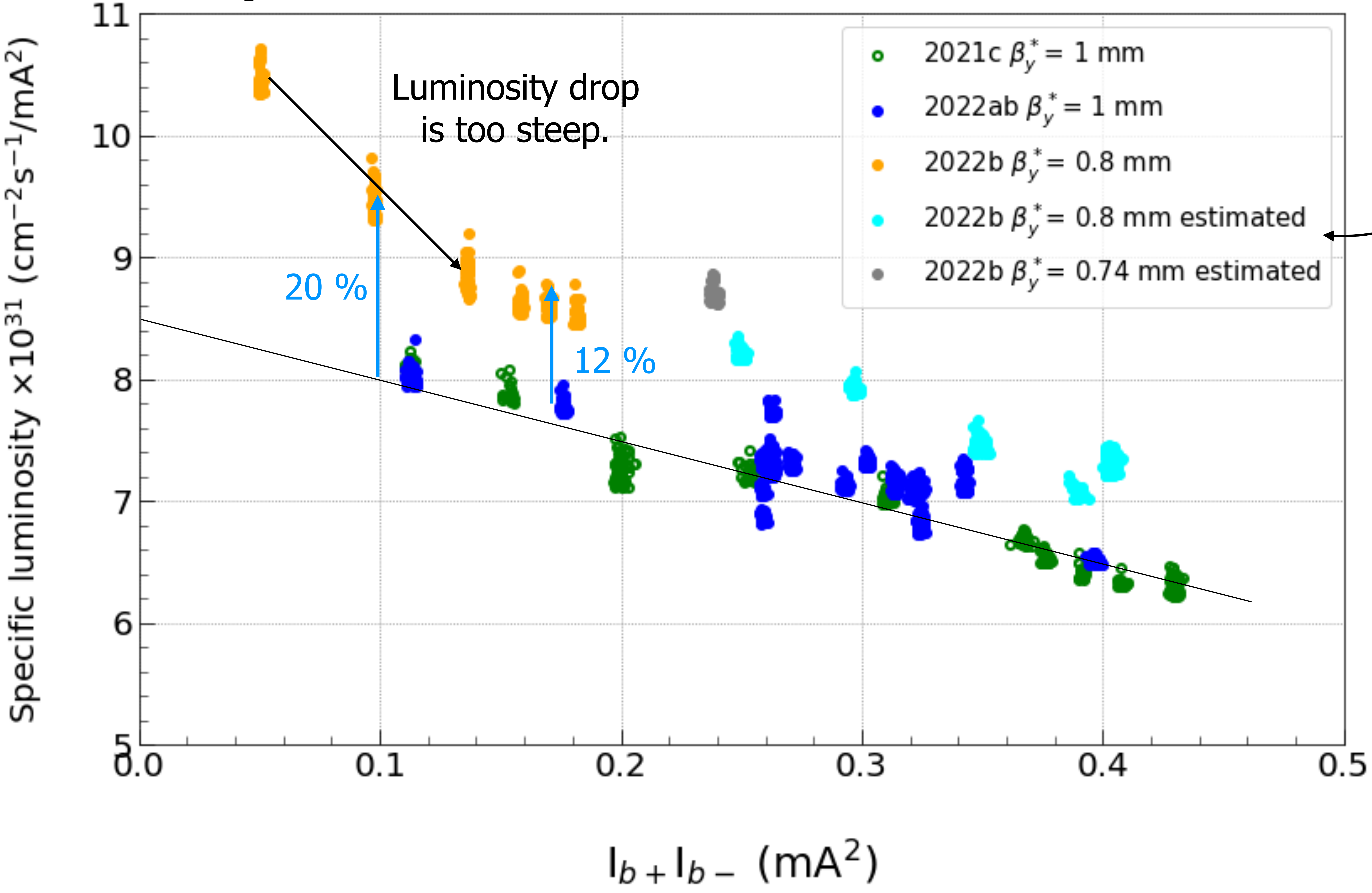
collimator damage

We introduced Matsuoka Limit $I_{b+} < 0.7\ mA$ to avoid sudden large beam loss which causes QCS quench and collimator damages as much as possible.
Sudden beam loss becomes a serious problem to increase total beam current.

Luminosity Performance

The geometrical luminosity is good.

"estimated" means β_y^* is calculated by the horizontal orbit deviation at SLY(strong sextupoles) in HER due to beam-line deformation.



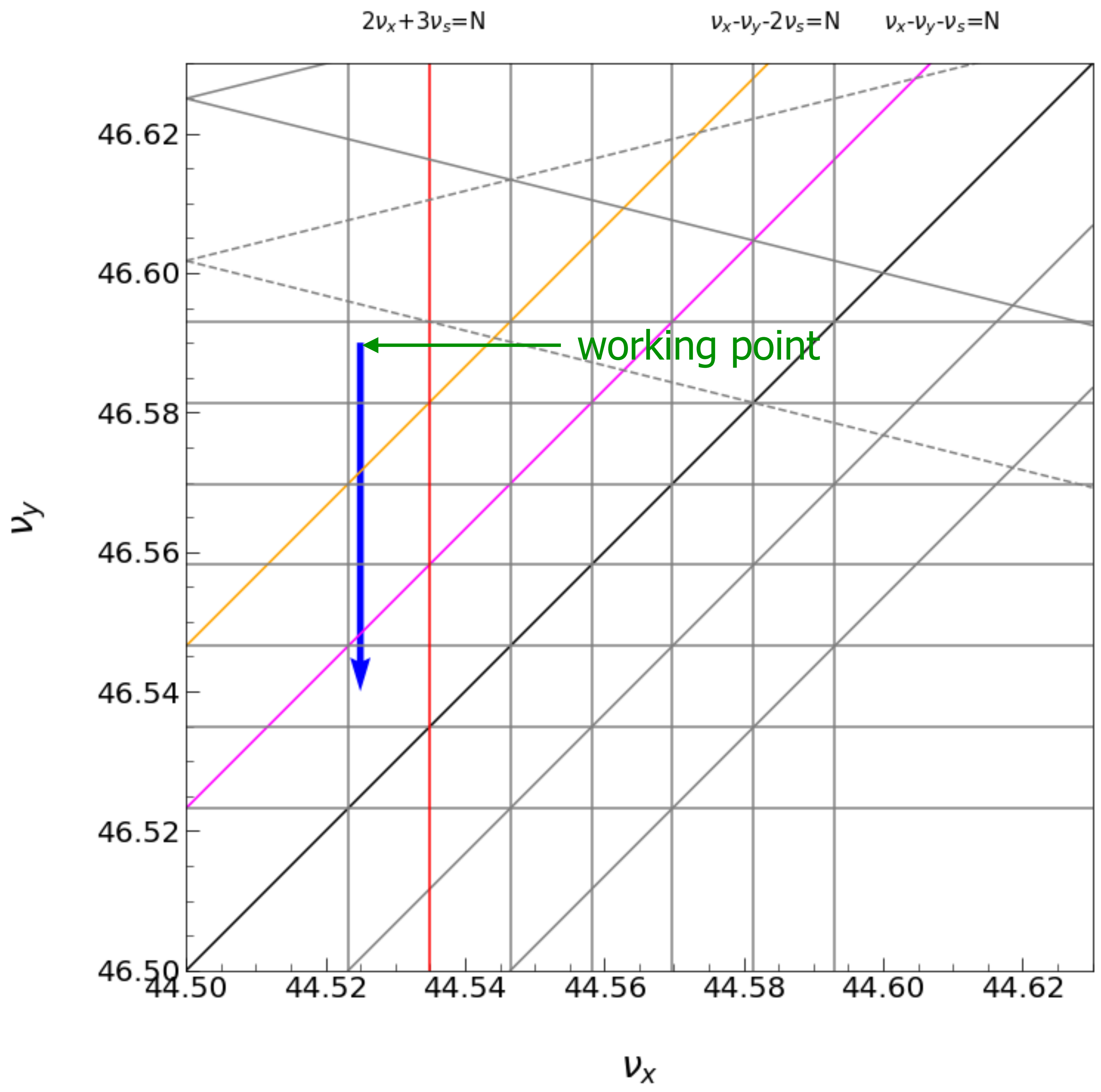
Specific Luminosity

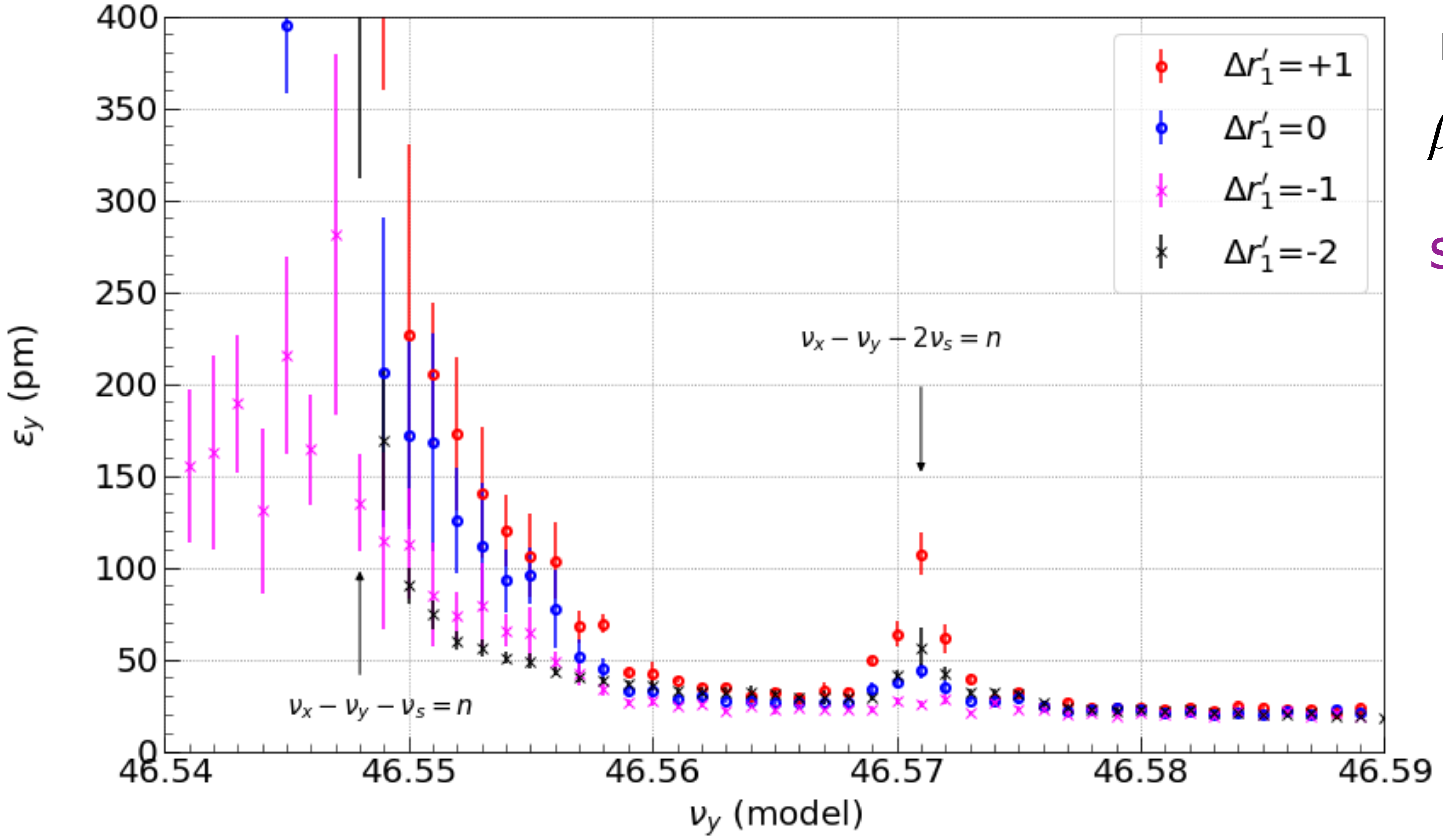
- The definition of specific luminosity:

$$L_{sp} = \frac{L}{n_b I_{b+} I_{b-}} \propto \frac{1}{\Sigma_z \Sigma_y^*}$$

- It was found that even if the setting is 1 mm, β_y^* can be shifted due to beta-beat caused by a deviation of the horizontal beam orbit at the strong sextupoles in the local chromaticity correction.
  - The orbit deviation is caused by beam line deformation due to intense SR heating.
  - This effect is more significant for the HER rather than the LER.
- Higher specific luminosity for β_y^* = 0.8 mm is obtained at a bunch current product of 0.05 mA^2, but the specific luminosity rapidly decreases around 0.1 mA^2.
  - L_{sp} for β_y^* = 0.8 mm is about 20 % higher than 1 mm at 0.05 mA^2 and decreases to about 12 % at 0.1 mA^2 and above.
- This implies that the corrections of the chromatic X-Y coupling and other parameters are not optimized yet for β_y^* = 0.8 mm which affect beam-beam blowup.

Chromatic X-Y Coupling Correction with Rotatable Sextupoles in LER

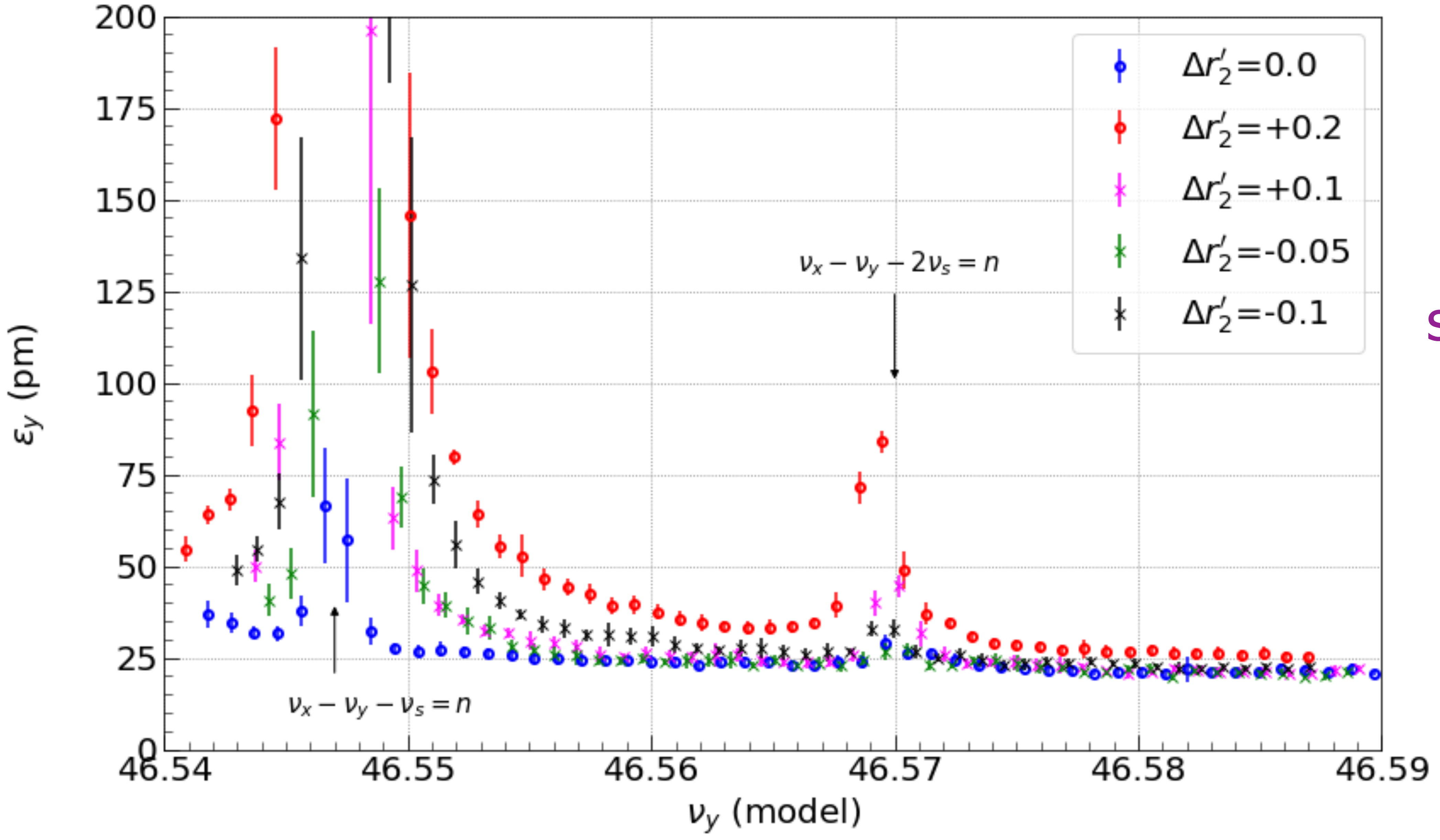




Dec. 20, 2021

$\beta_y^* = 1\ mm$

single beam



March 14, 2022

$\beta_y^* = 1\ mm$

$\Delta r_1' = -1$

single beam

$\Delta r_2' = 0$
is optimal.

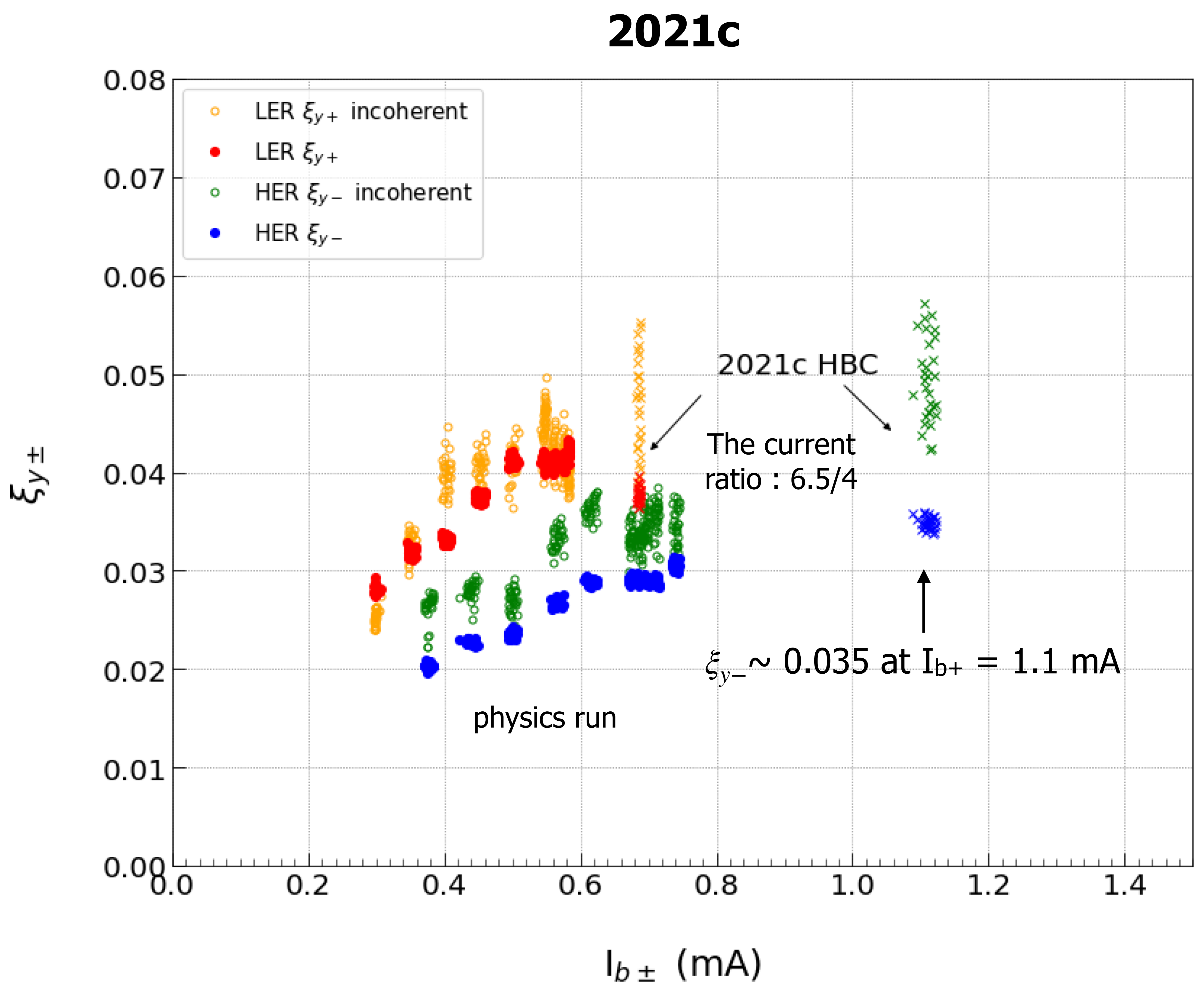
The rotatable sextupoles (6 families for right and left side of IP) are used to make the first synchro-beta coupling resonance weak together with the second resonance.

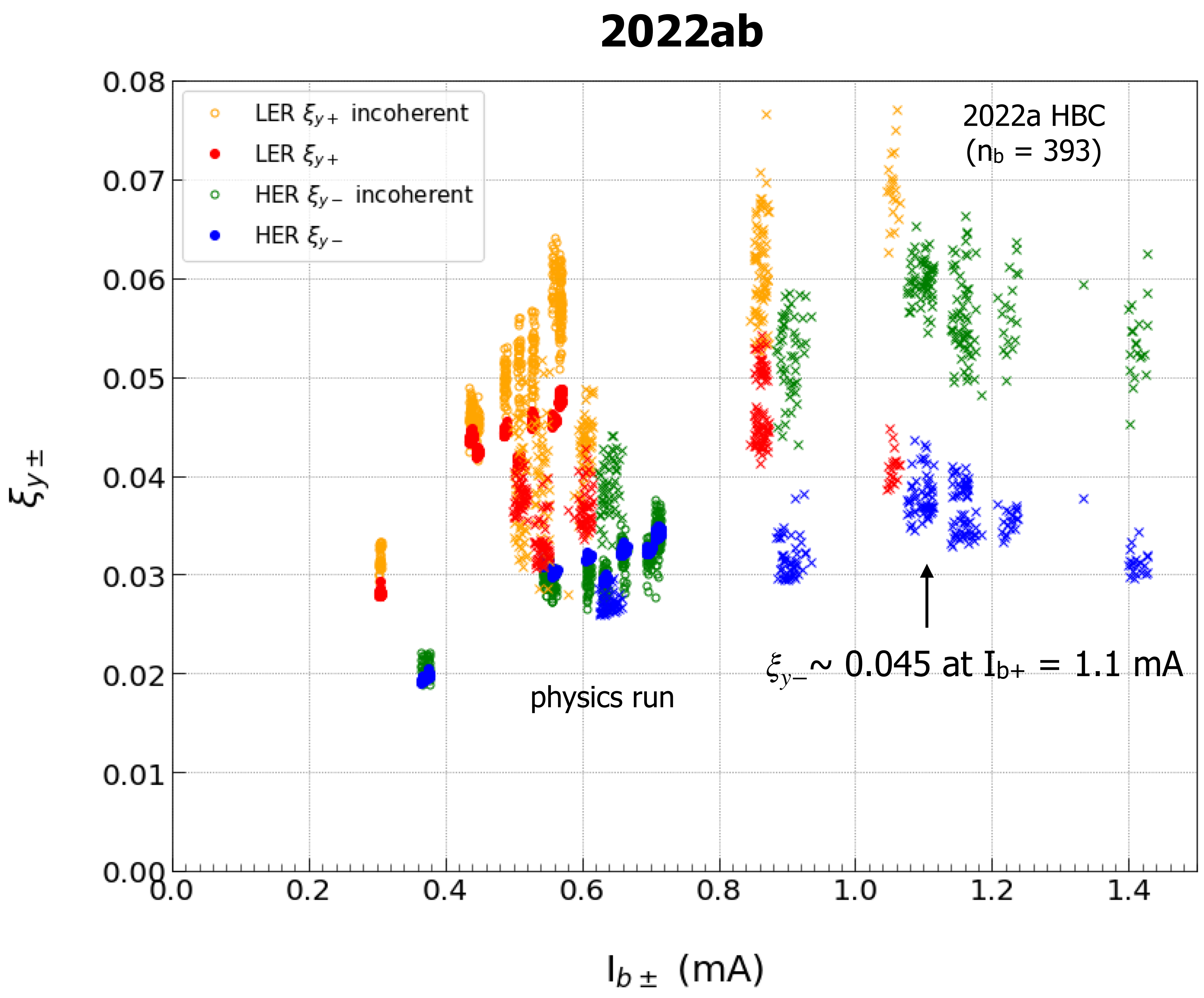
SLYTLPs and SLYTRPs were not used here.

Rotatable sextupoles:
M. Masuzawa, T. Kawamoto et al.

Beam-Beam Parameter

$\beta_y^* = 1\ mm$





Beam-Beam parameter has been improved compared to the 2021c run for higher bunch currents.

The chromatic X-Y couplings (r_1' and r_2') are corrected in the LER.

HBC = High Bunch current Collision

Beam-Beam Interaction

Vertical beam-beam parameter (from luminosity)

$$\xi_{y\pm} = 2er_e \frac{\beta^*_{y\pm} L}{\gamma_\pm I_\pm}$$

Vertical beam-beam parameter (incoherent)

$$\xi_{y\pm} = \frac{r_e}{2\pi\gamma_\pm} \left(\frac{I_{b\mp}}{ef_0}\right) \frac{\beta^*_{y\pm}}{\phi_x \sigma_{z\mp} \sigma^*_{y\mp}}$$

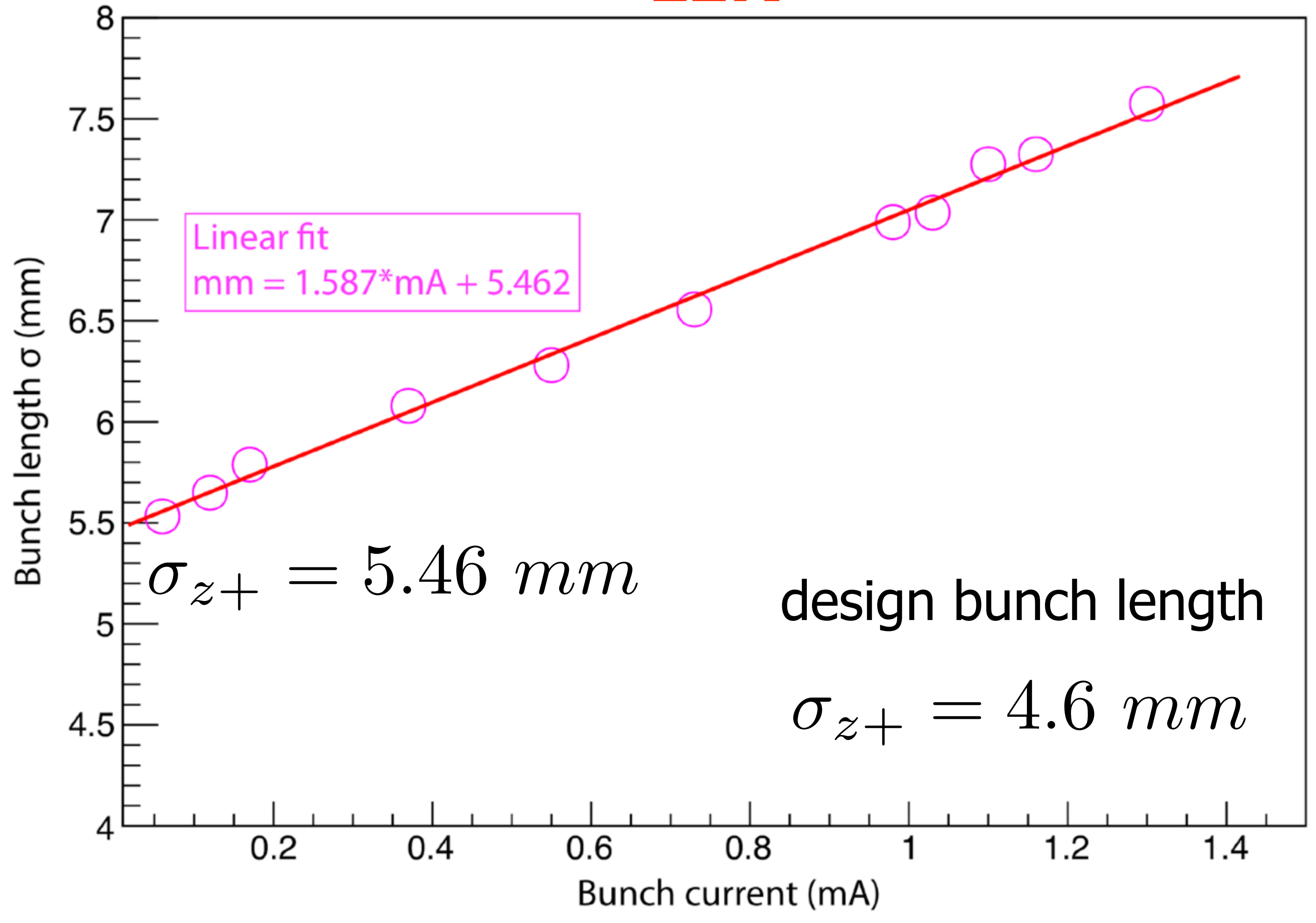
nominal bunch length

$$\sigma_{z+} = 4.6\ mm$$
$$\sigma_{z-} = 5.1\ mm$$

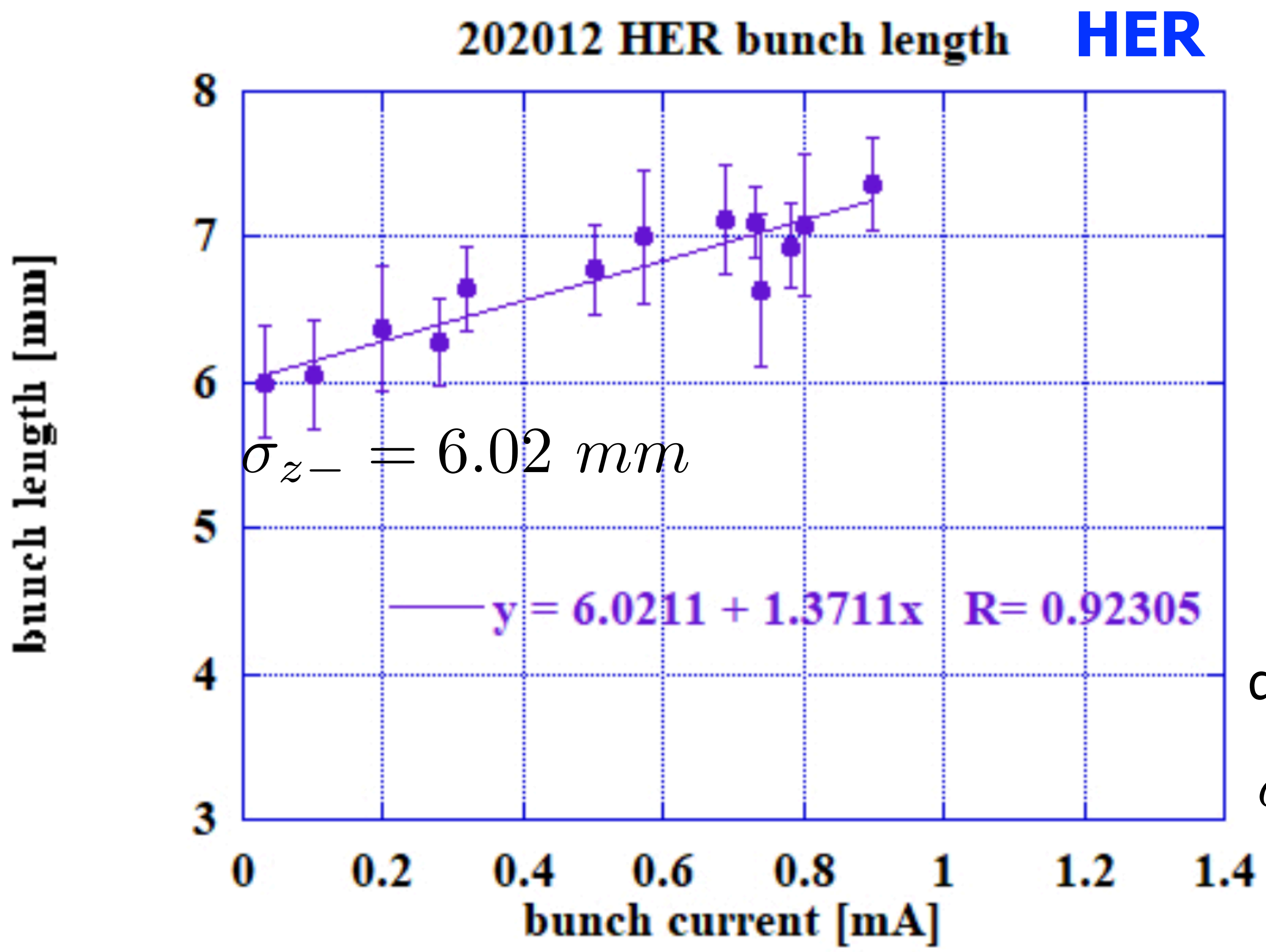
- Lower beam current in the HER tends to cause beam blowup.
- This means that the HER beam size is more easy to blow-up when the beam current of the HER decreases.
- The beam current of the HER is larger than the energy ratio (4 GeV / 7 GeV). $\boxed{\gamma_+ I_+ < \gamma_- I_-}$
- The optimum ratio of LER to HER beam current is 5:4 from luminosity tuning.
- The beam-beam parameter of the LER are larger than that of the HER.
- The current ratio is kept constant for daily operation in principle.
- The beam-beam parameter is sluggish with LER beam currents of around 0.6 ~ 0.8 mA.

Contribution from Bunch Length

LER

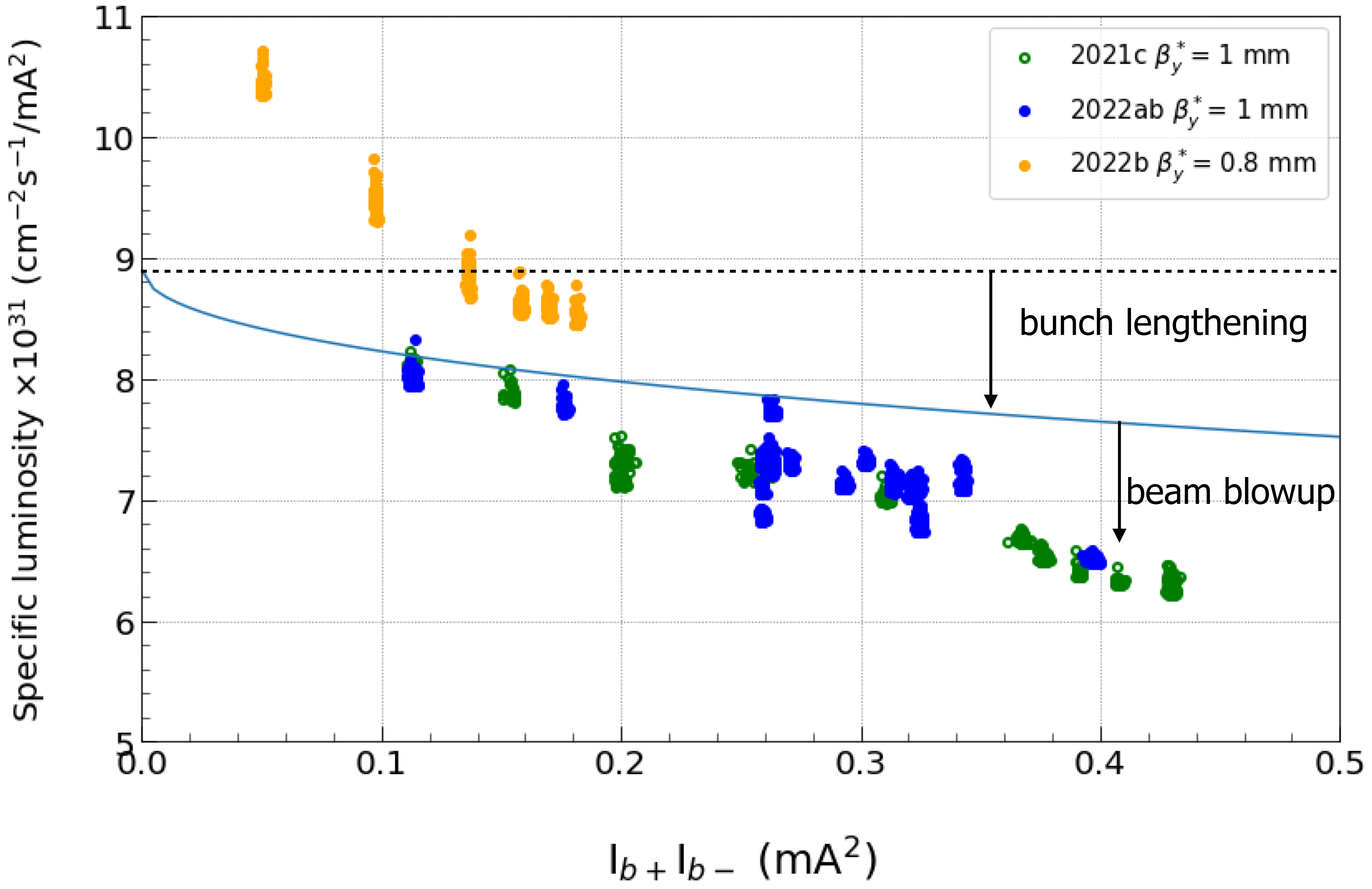


HER



design bunch length

$\sigma_{z-} = 5.1\ mm$



$$L_{sp} = L_{sp}^0 \frac{\sqrt{(\sigma_{z+}(0))^2 + (\sigma_{z-}(0))^2}}{\sqrt{(\sigma_{z+}(I_{b+}))^2 + (\sigma_{z-}(I_{b-}))^2}}$$

$$\sigma_{z+}(I_{b+}) = 5.46 + 1.587 \cdot I_{b+}\ (mm)$$
$$\sigma_{z-}(I_{b-}) = 6.02 + 1.371 \cdot I_{b-}\ (mm)$$

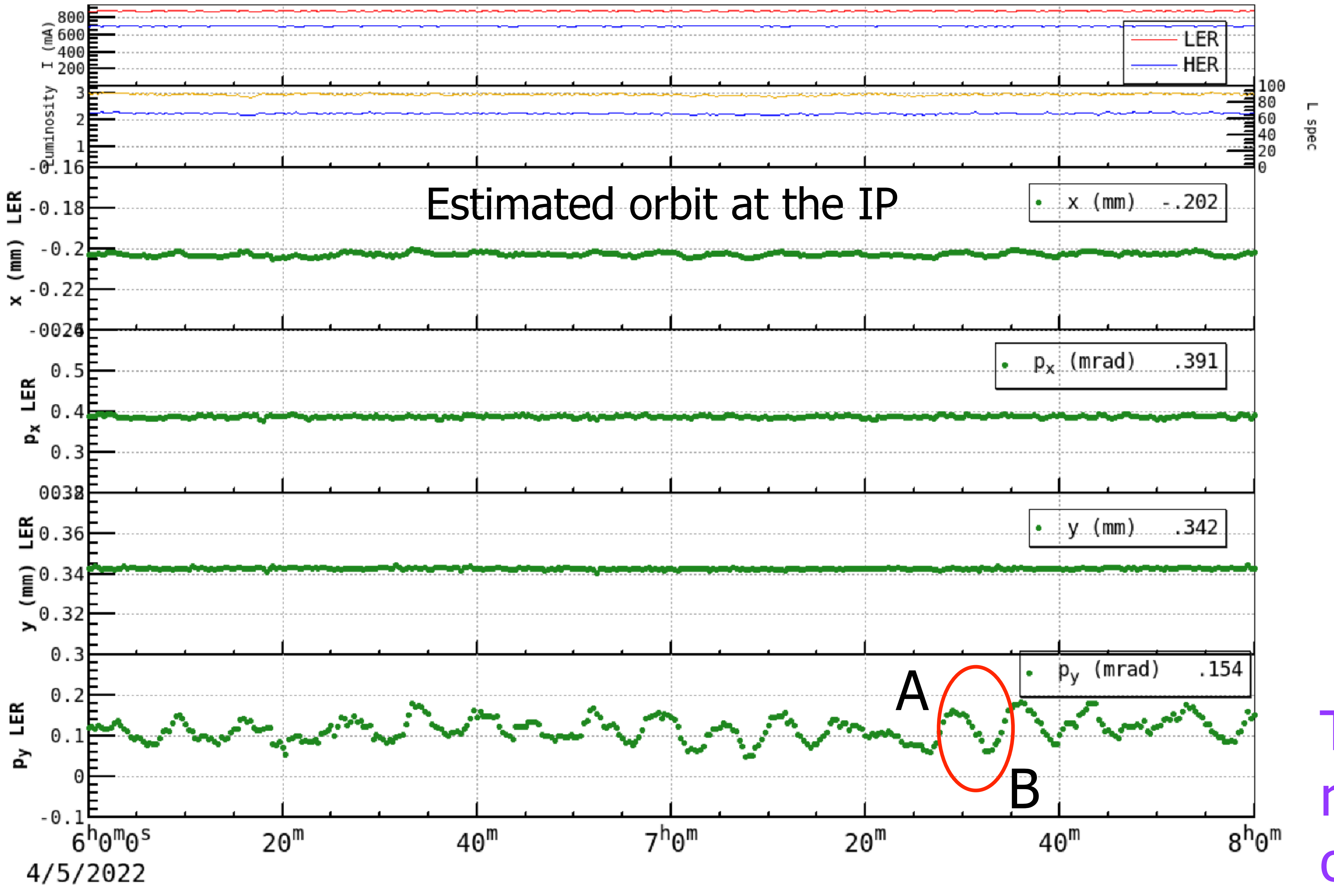
$I_{b+} : I_{b-} = 5 : 4$

Stability of Machine

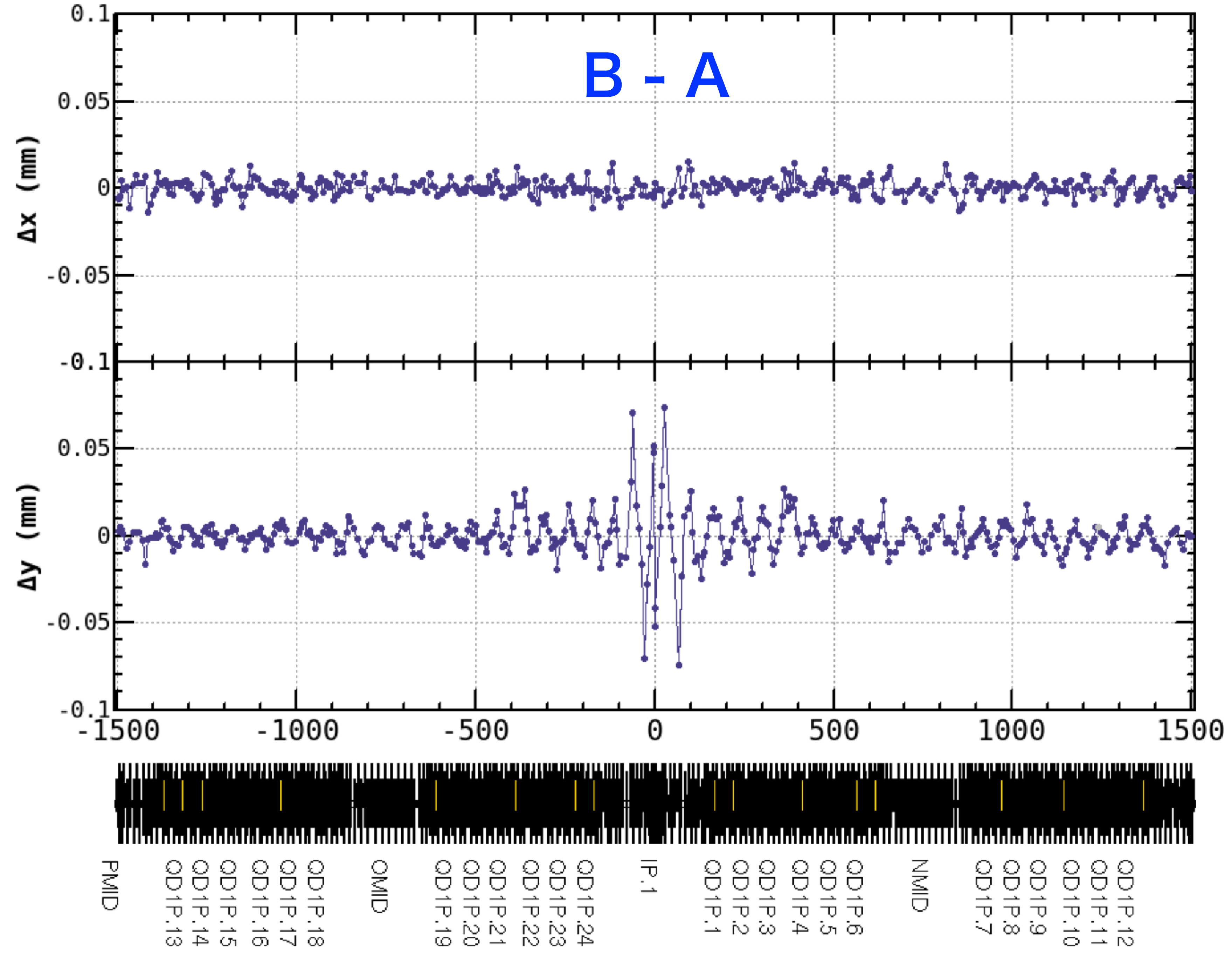
Stability of Beam Orbit

- Control of beam orbit as well as stability is very important.
- The beam orbit cannot be considered in isolation from the beam optics.
- BPM gain calibration is performed before optics correction, Quad-BPM (BBA) is sometimes performed if necessary (after cabling work of BPMs).
- Optics correction is scheduled every two weeks (maintenance day) or when we found luminosity degradation. Magnet initialization is performed every maintenance.
- We set the reference orbit, so called "GOLD orbit" when the optics correction is performed. But it is difficult to adjust a measured orbit to the GOLD orbit in several days after the registration.
  - Residual of measured orbit from GOLD orbit is typically 30 μm. This is not enough to keep optics stable.
  - Beam position at the strong sextupole is important to correct X-Y couplings and vertical dispersions.
  - Degradation of consistency, beam-line deformation, change of BPM cable length due to temperature at day and night, etc.
- There are many sources to induce orbit fluctuation. Cooling water cycle, all environment as well as earthquake
- Moreover, SR becomes intense and the heating might deform the beam-line. Difficulties arise how to treat of the orbit.
- Orbit in the vicinity of the IP is not well understood as well as QCS magnetic field.

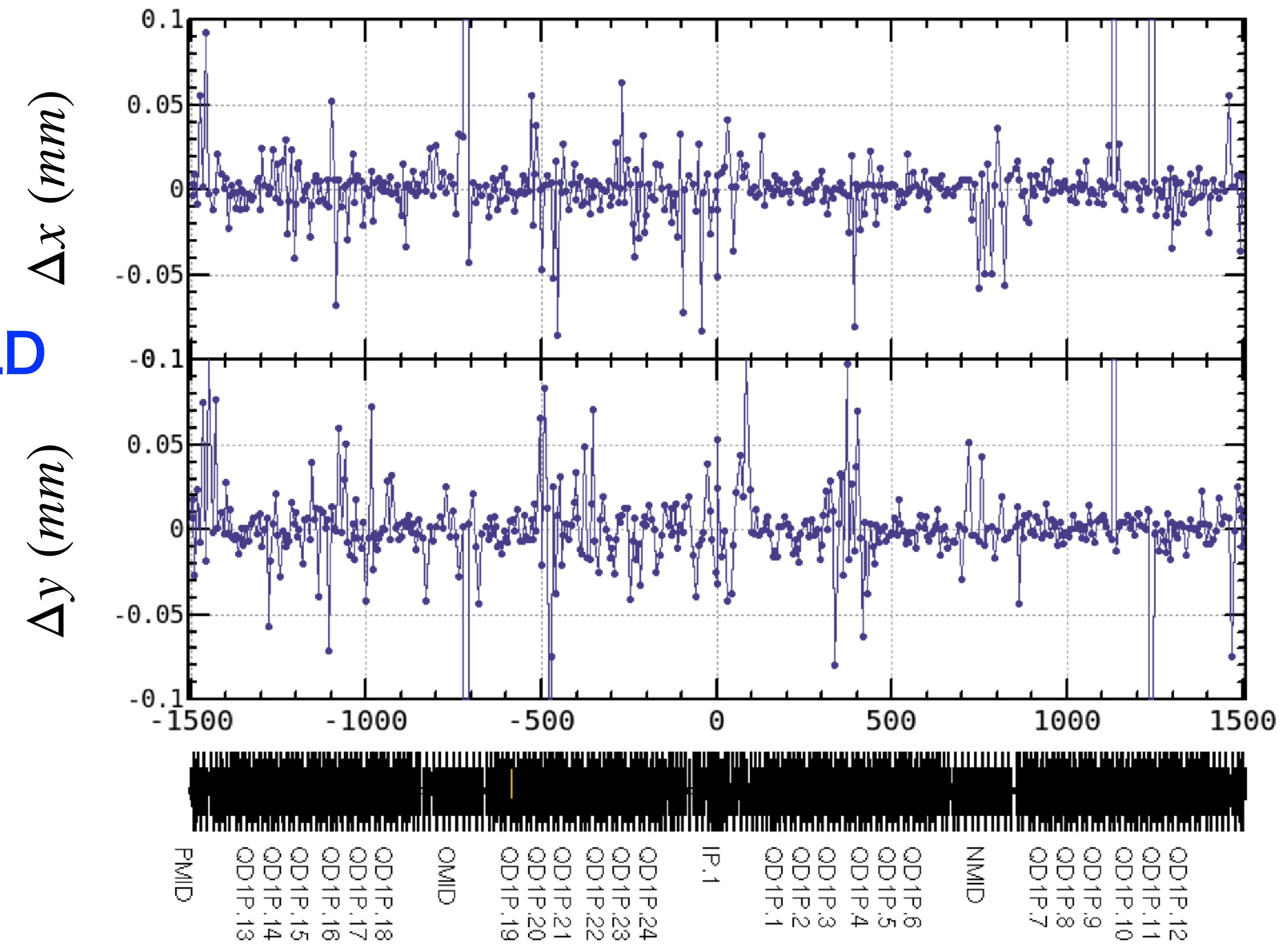
LER



Set 2-1: 04/05/2022 07:32:30 - 04/05/2022 07:29:00

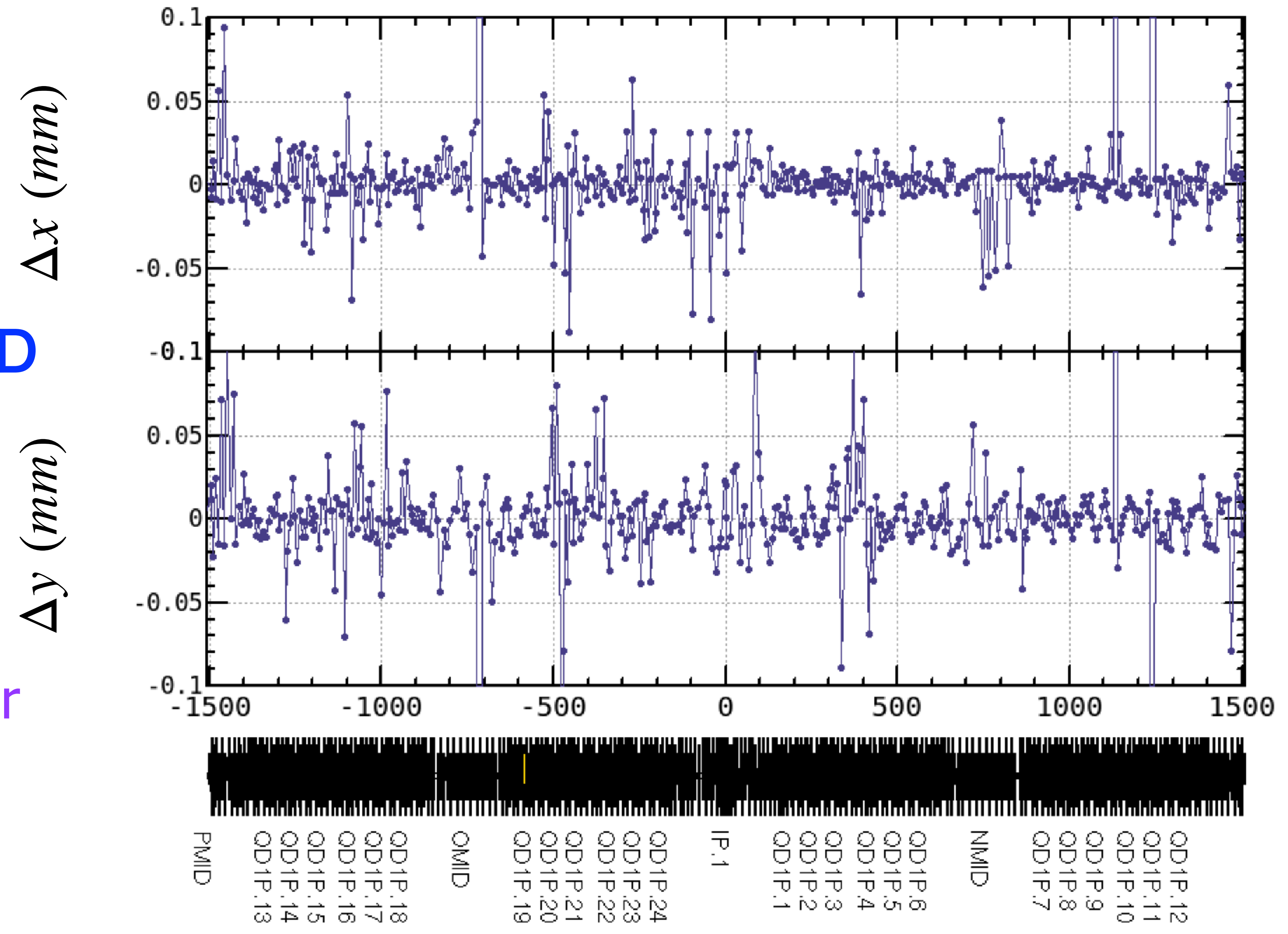


A - GOLD



The difference between the measured orbit and the GOLD orbit becomes large in several days after optics corrections.

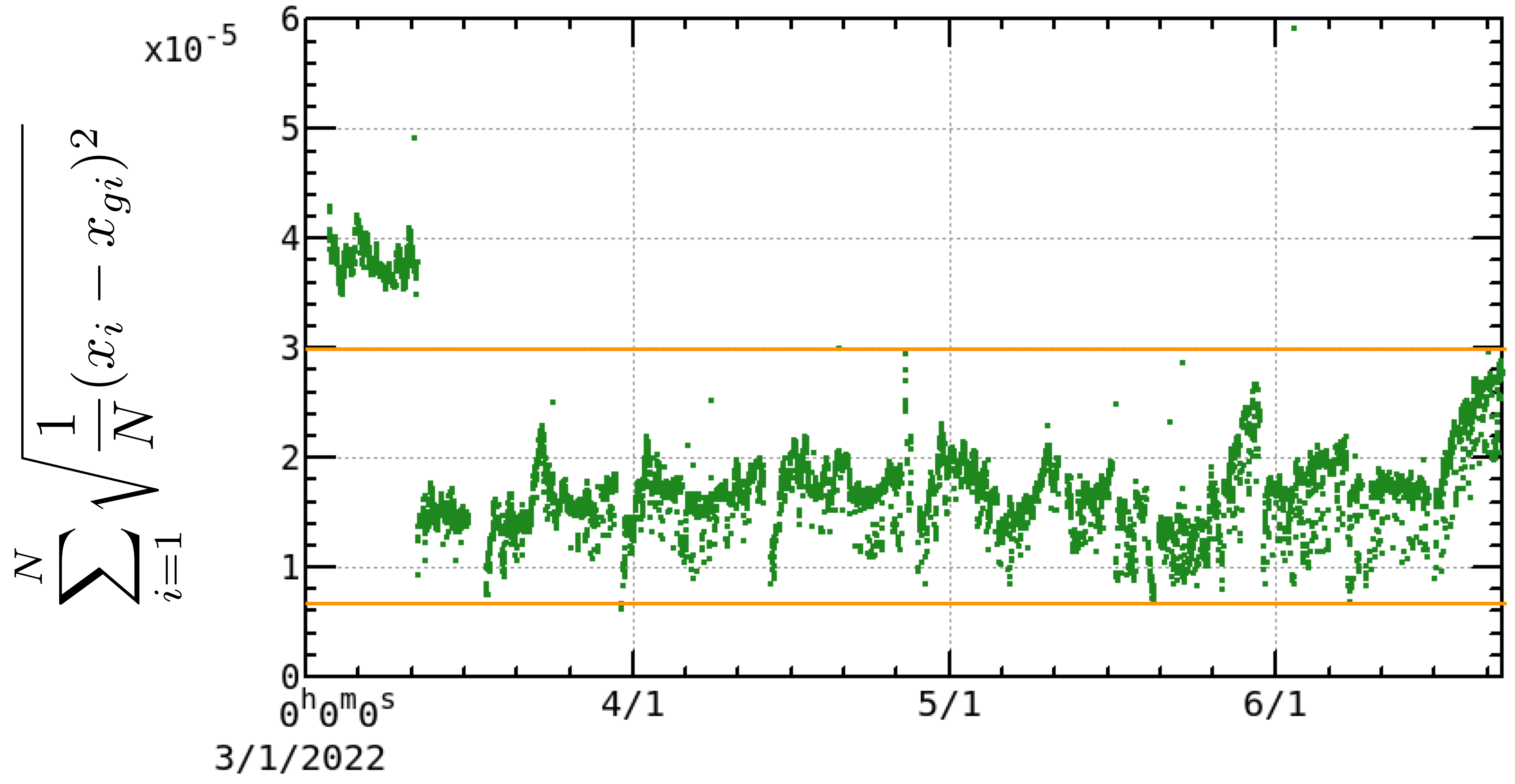
B - GOLD



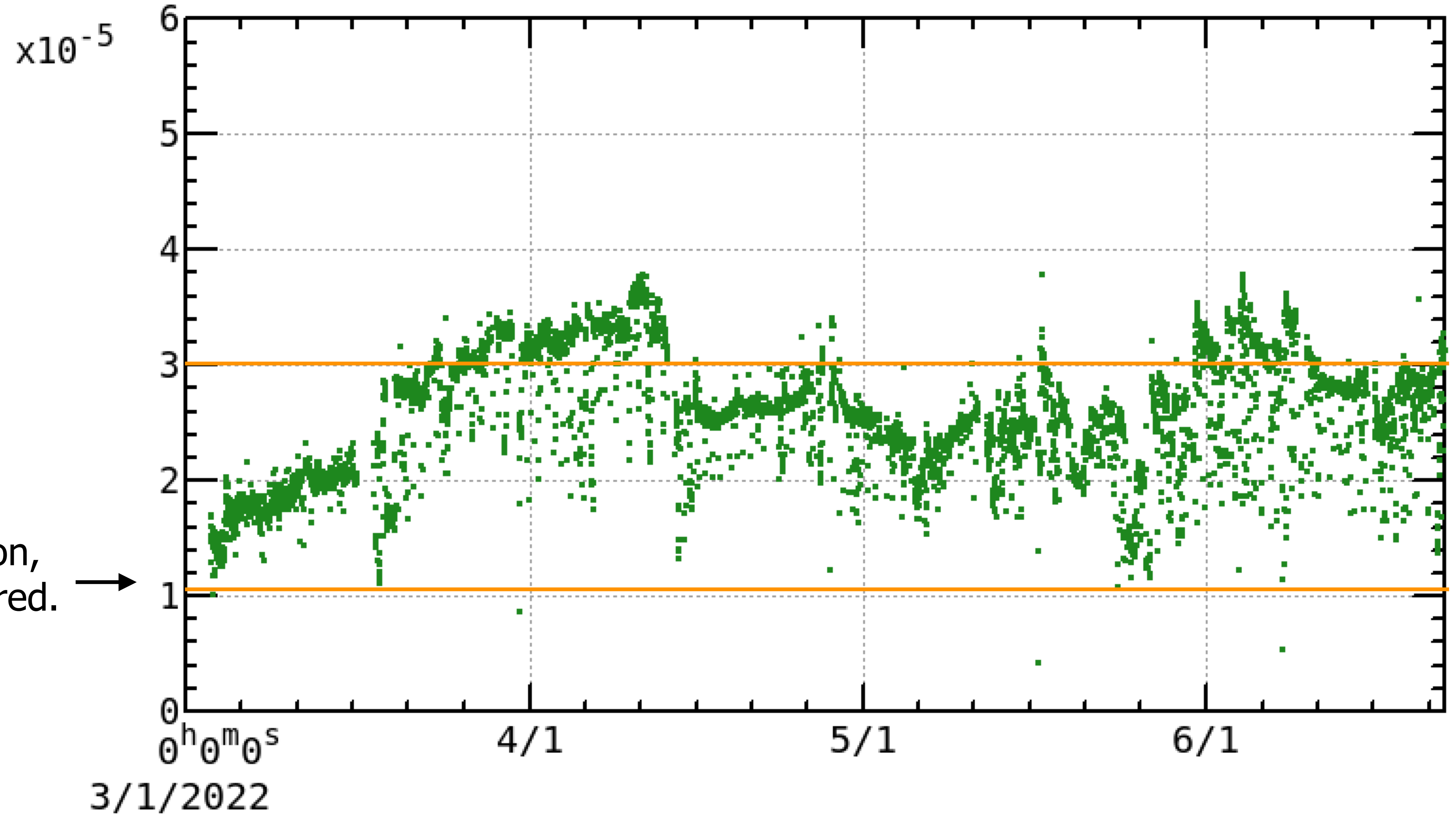
We can correct B-A, but neither A-GOLD nor B-GOLD can be corrected.

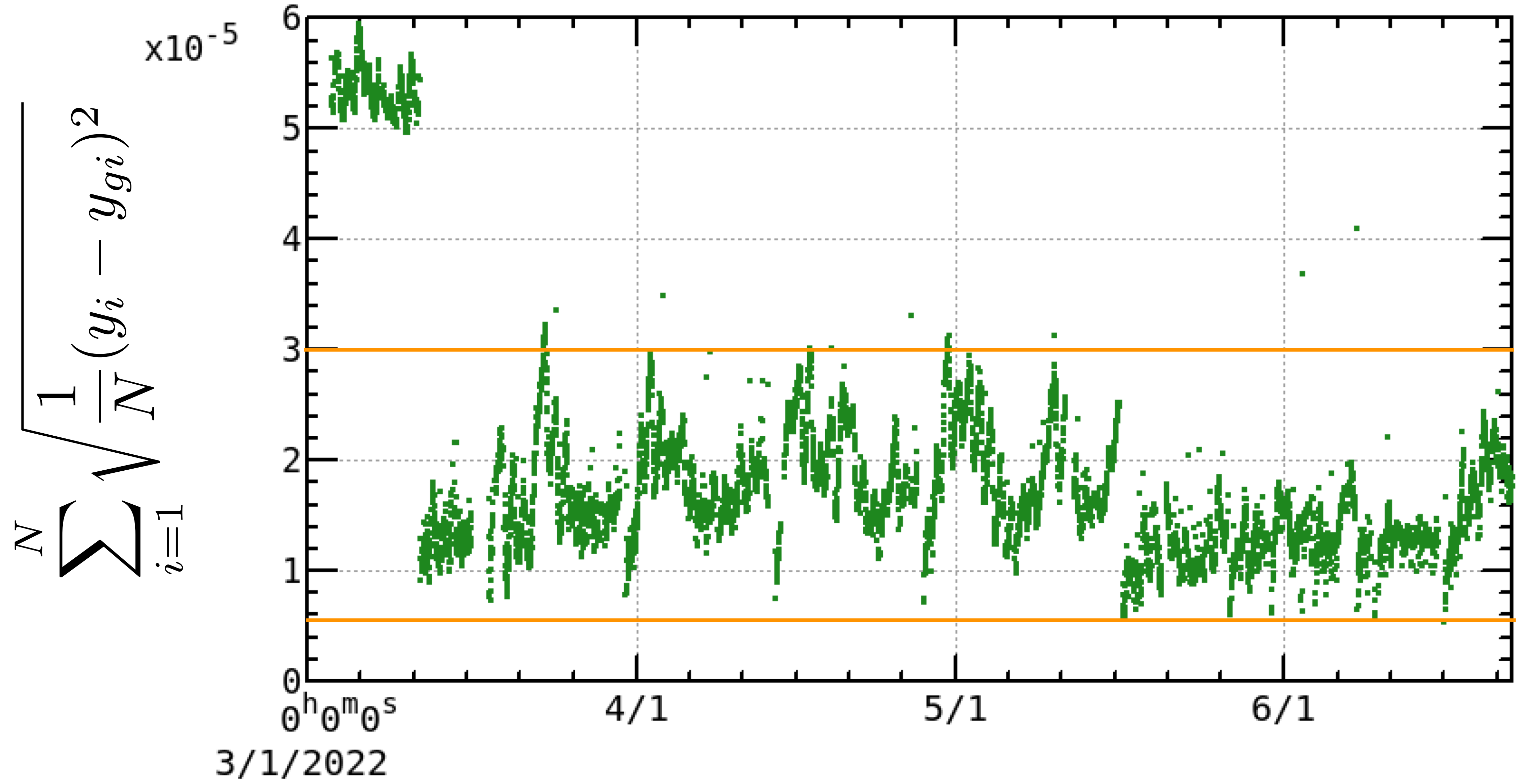
Residual of Measured Orbit from GOLD Orbit in 2022ab

LER | **HER**

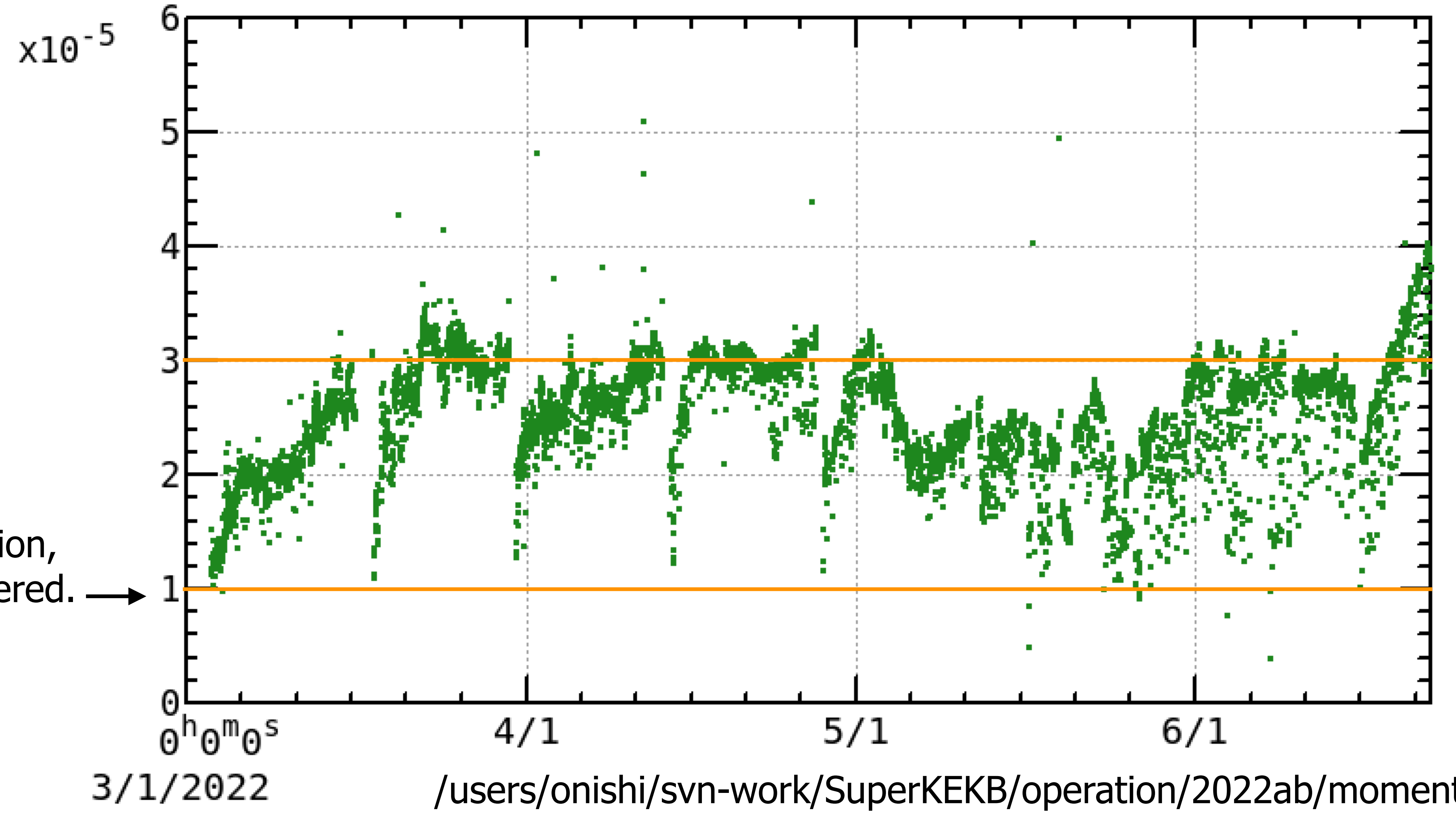


optics correction,
GOLD is registered.





optics correction,
GOLD is registered.



/users/onishi/svn-work/SuperKEKB/operation/2022ab/momentum

Beam Lifetime and Dynamic Aperture

Lifetime Evaluations in LER

2021c

We tested three different kinds of sextupole settings in the LER. (Original, proposed by Y. Cai, B2)

Assuming constant gas pressure and beam emittances during the measurements, the fitting out lifetimes (w/ bunch current of 1 mA) are

Optics parameters (I= 50 mA, 1370 bunches)

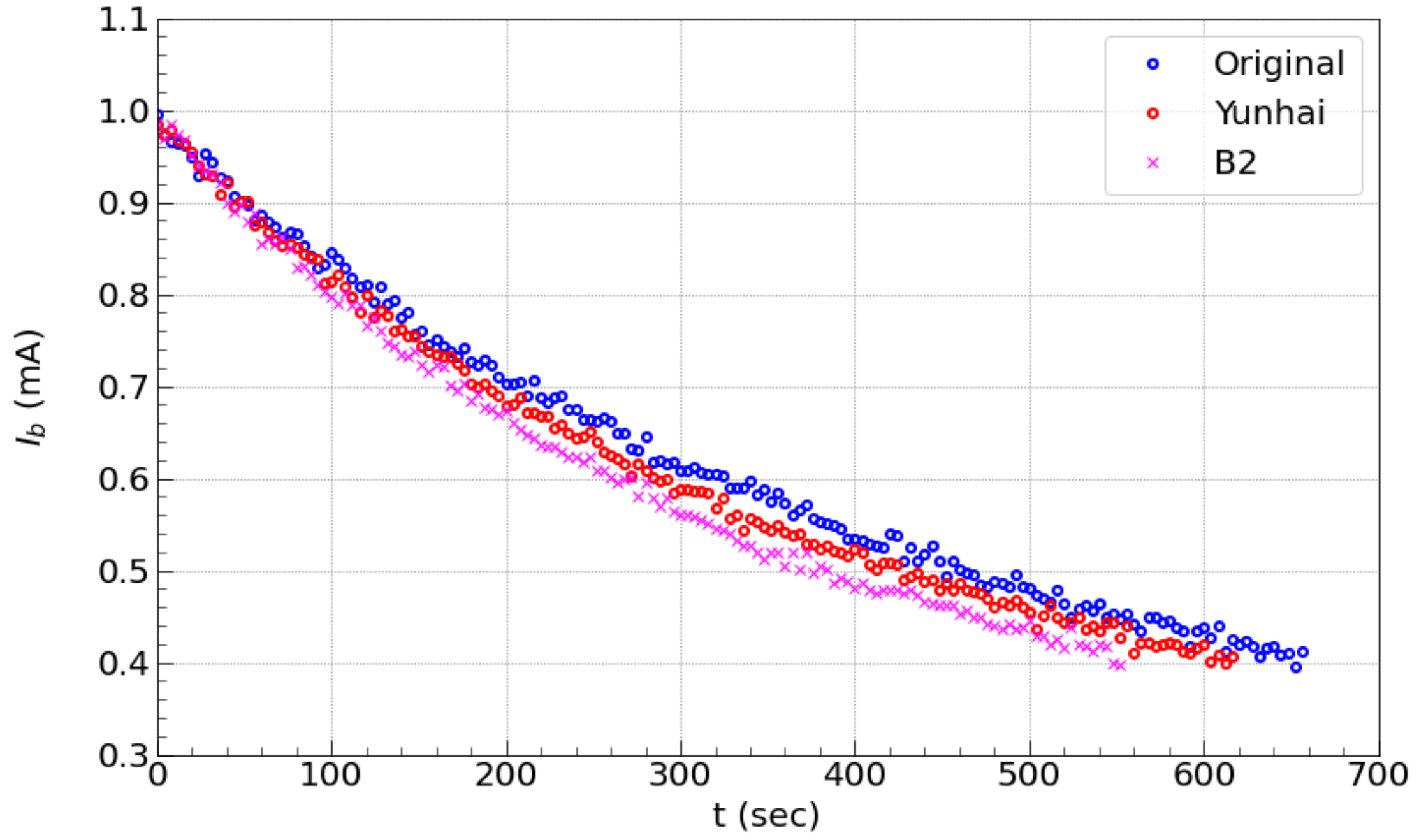
	$(\Delta\beta/\beta)_y$ [%]	$\Delta\eta_y$ [mm]	ε_y [pm]	$\xi_{x/y}$	IP knobs
original	4.2	4.5	~20	-1.24/3.58	≠0
Yunhai	5.3	3.7	~20	-1.24/3.66	0
B2	6.5	7.9	~20	0.1/1.9	0

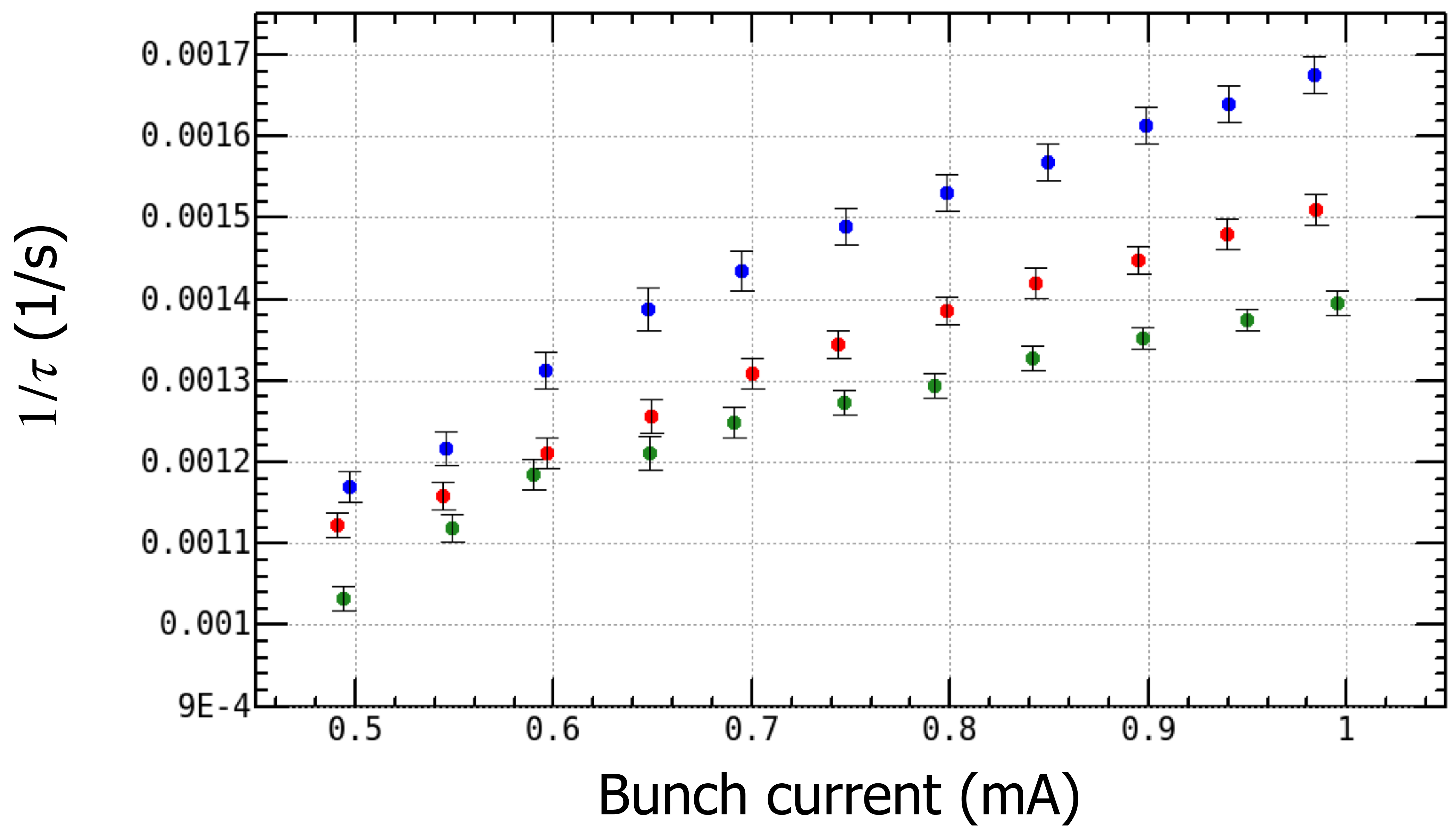
Lifetime (sec)

	I_b = 0.6 mA	I_b = 1 mA
original	843 ± 14	716 ± 7
Yunhai	825 ± 14	662 ± 8
B2	761 ± 13	596 ± 8

$1/\tau$ is not a straight line, it is different between lower and higher than 0.6~0.7 mA.

$$\frac{1}{\tau_T} = c_T I_{b+}$$





Single bunch current was measured by DCCT.
No information of beam size from XRM.

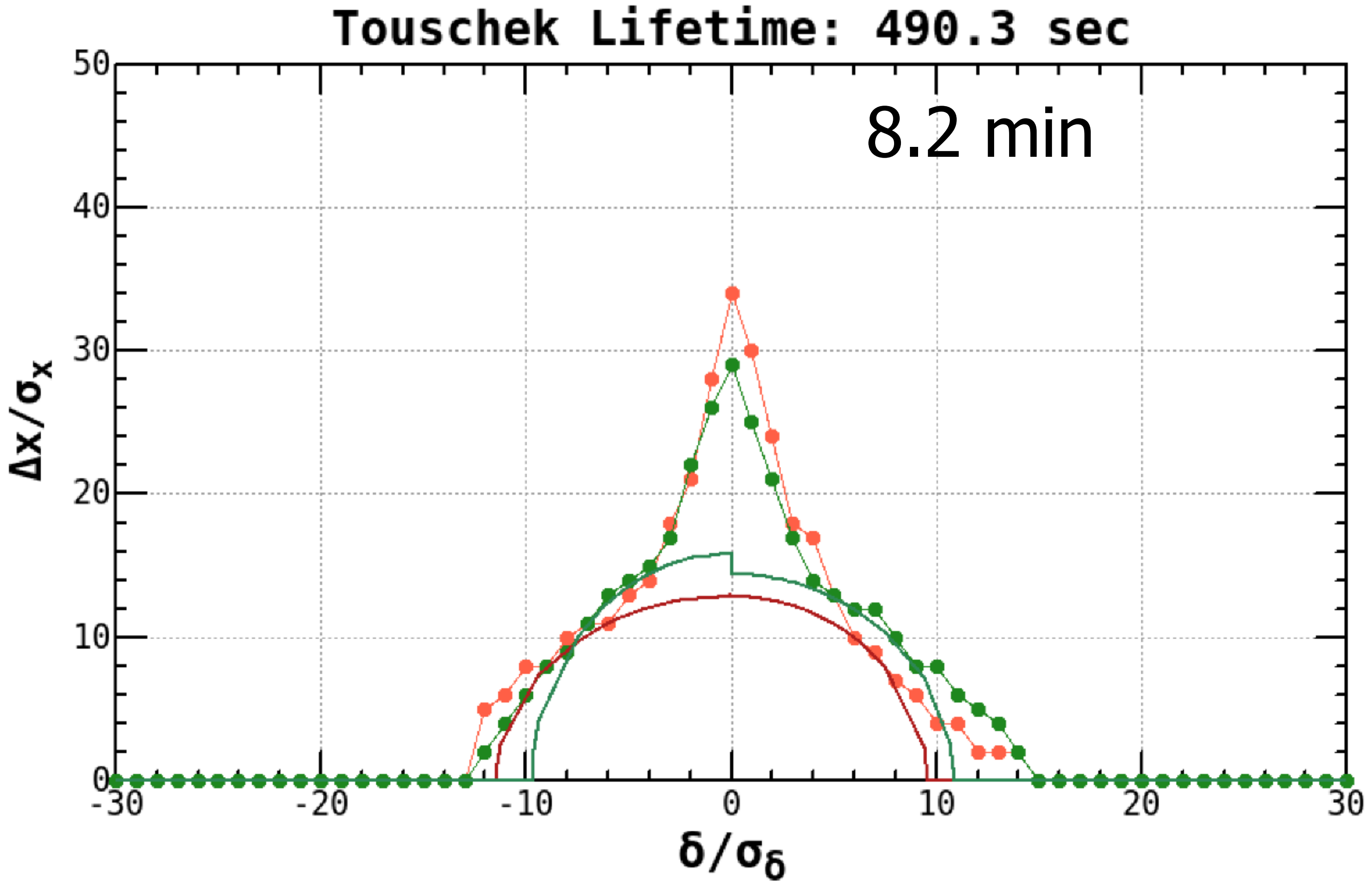
Vertical emittance is uncertain at high bunch current due to beam blowup (-1 mode instability).

Simulation of Dynamic Aperture in the LER

Crab-Waist : 80 % Emittance: $\varepsilon_x = 4\ nm / \varepsilon_y = 20\ pm$ $I_{b+} = 0.6\ mA$ without collimator aperture (QCS only)

initial phase = 0, $\pi/2$

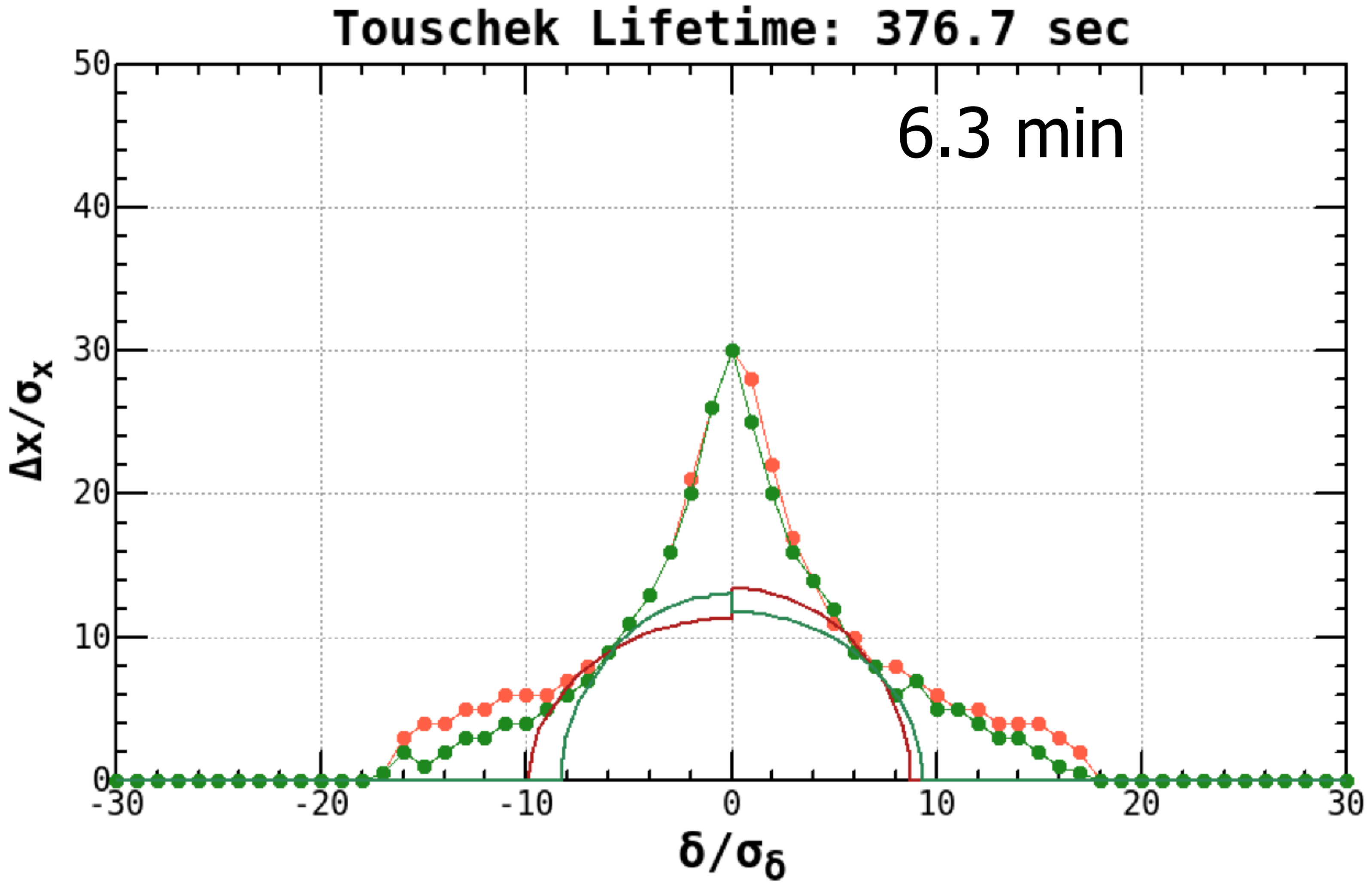
Original 300 sec @ 1 mA



a11: 11.47 b11: 12.91 a12: 9.53 b12: 12.87 (453.2 sec)
a21: 9.71 b21: 15.86 a22: 10.82 b22: 14.42 (533.9 sec)

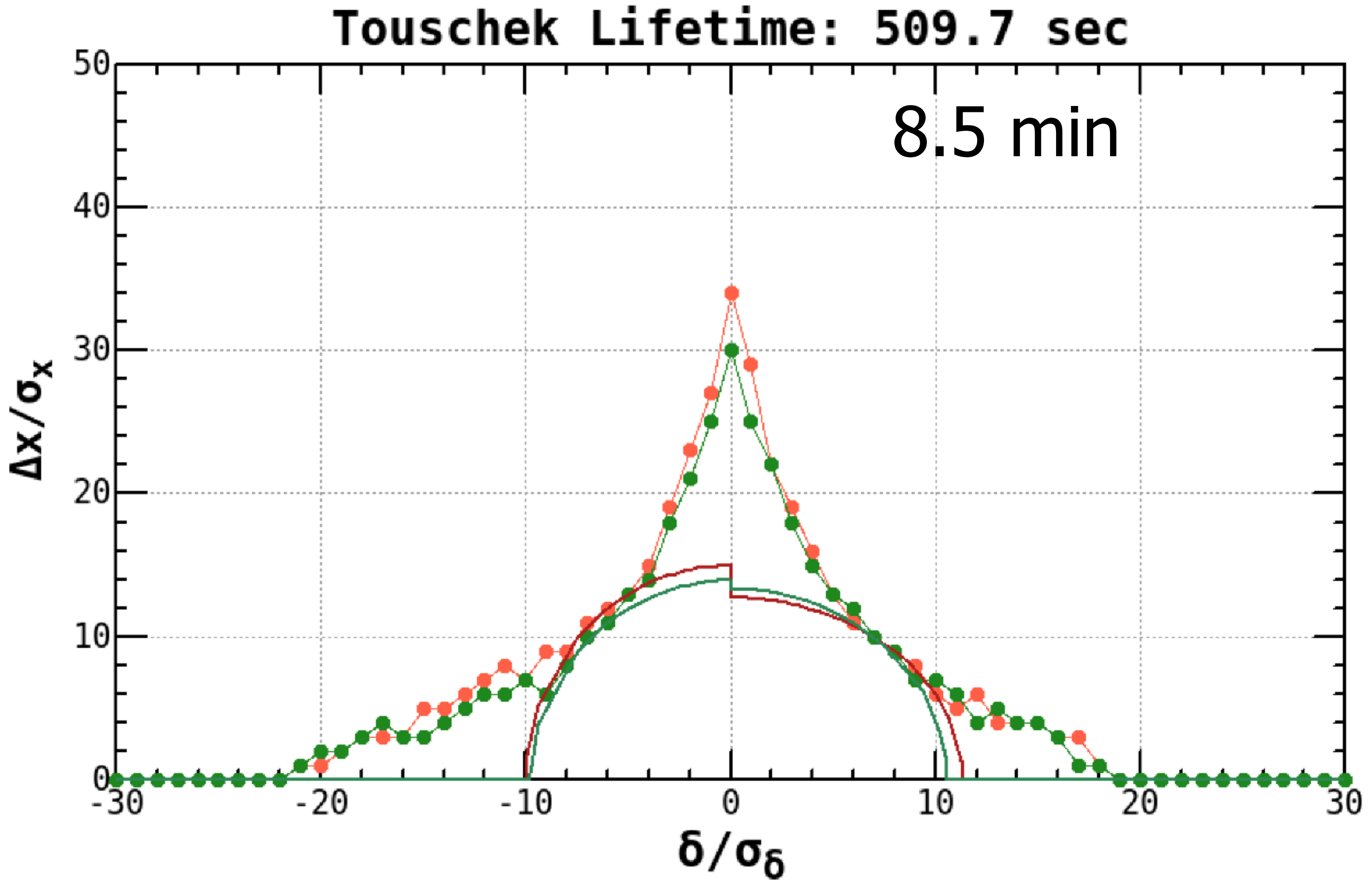
Yunhai

larger momentum acceptance than original



a11: 9.90 b11: 11.32 a12: 8.71 b12: 13.43 (388.1 sec)
a21: 8.30 b21: 13.02 a22: 9.30 b22: 11.78 (365.8 sec)

B2



a11: 10.00 b11: 15.00 a12: 11.31 b12: 12.73 (525.9 sec)
a21: 9.77 b21: 13.94 a22: 10.57 b22: 13.35 (494.5 sec)

The Touschek lifetime is evaluated by an ellipse inscribed in the dynamic aperture (stable region). → too short lifetime

There are various methods of evaluation and lifetime depends on the method from DA.

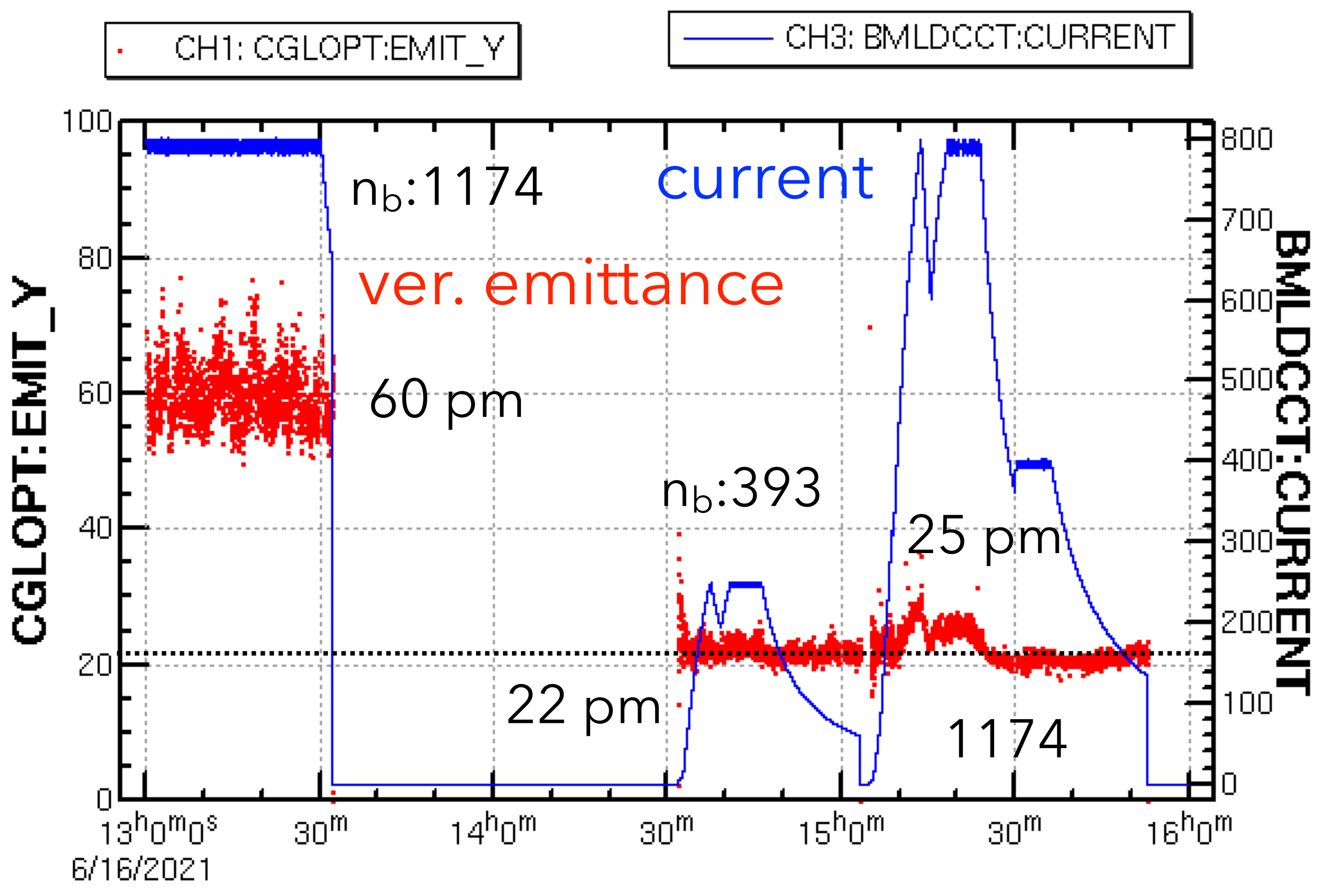
Vertical emittance is uncertain at 1 mA bunch current (larger than 20 pm or bunch lengthening).

Lifetime (sec)

	I_b = 0.6 mA	I_b = 1 mA
original	843 ± 14	716 ± 7
Yunhai	825 ± 14	662 ± 8
B2	761 ± 13	596 ± 8

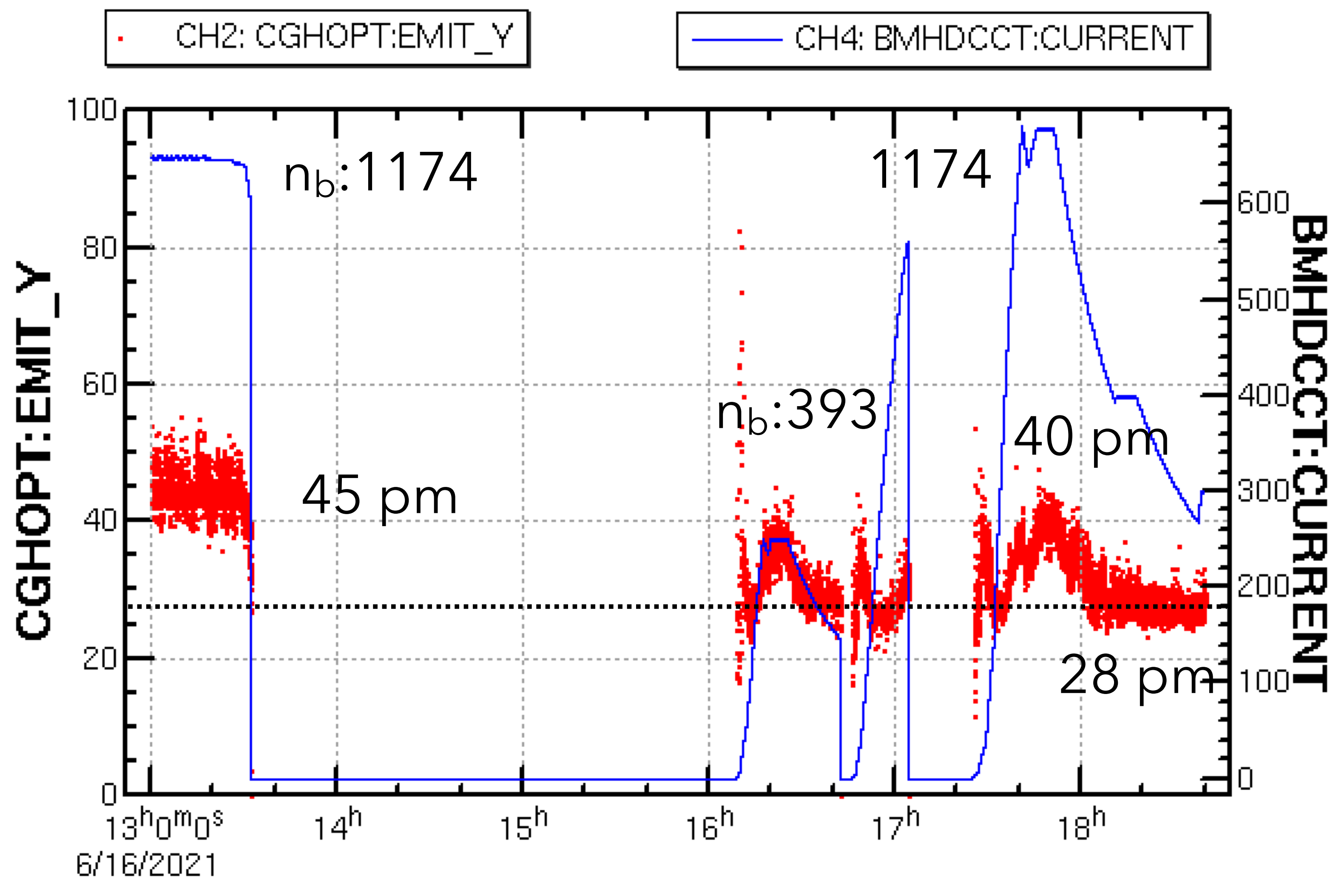
Beam Lifetime and Vertical Emittance

LER



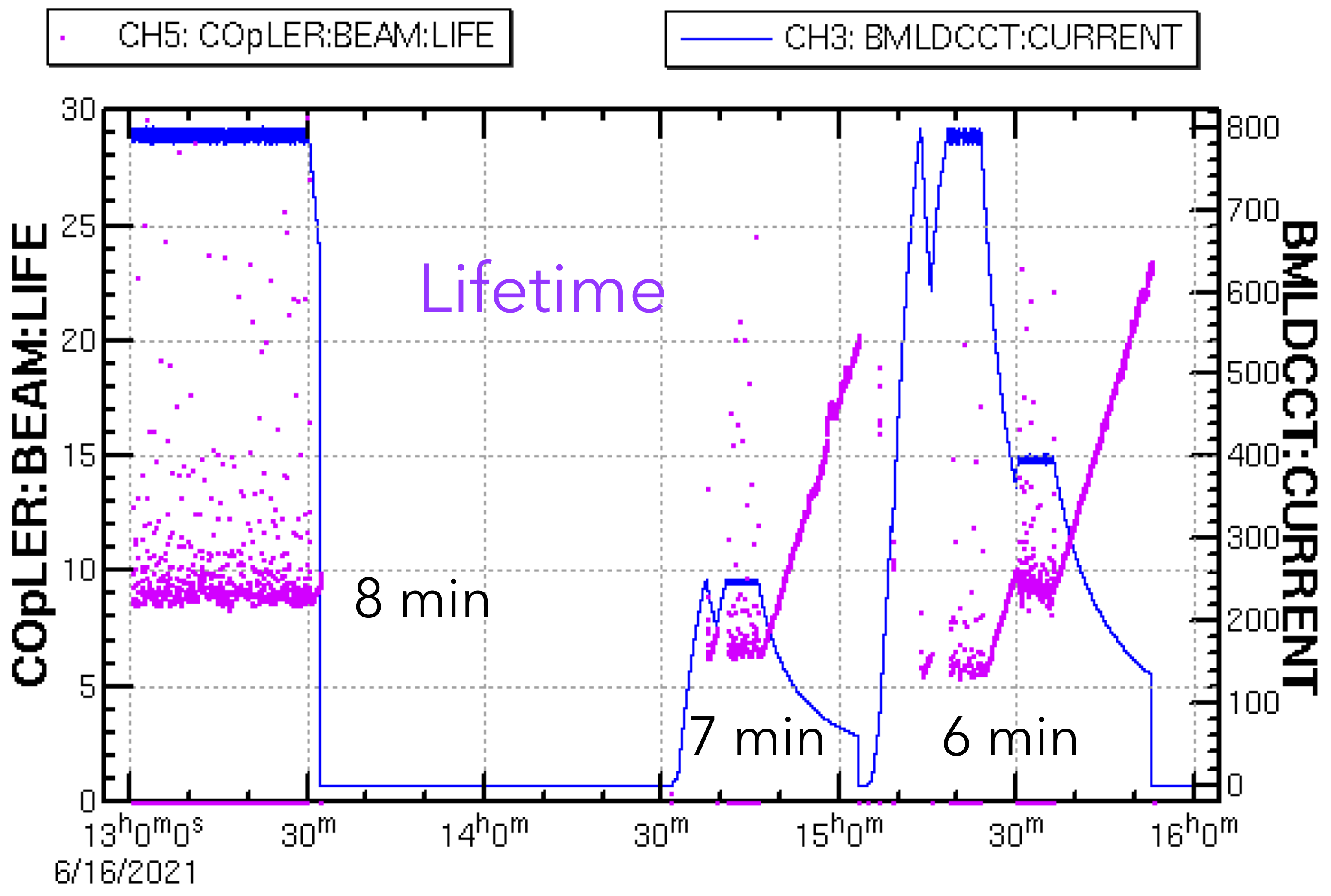
collision single beam

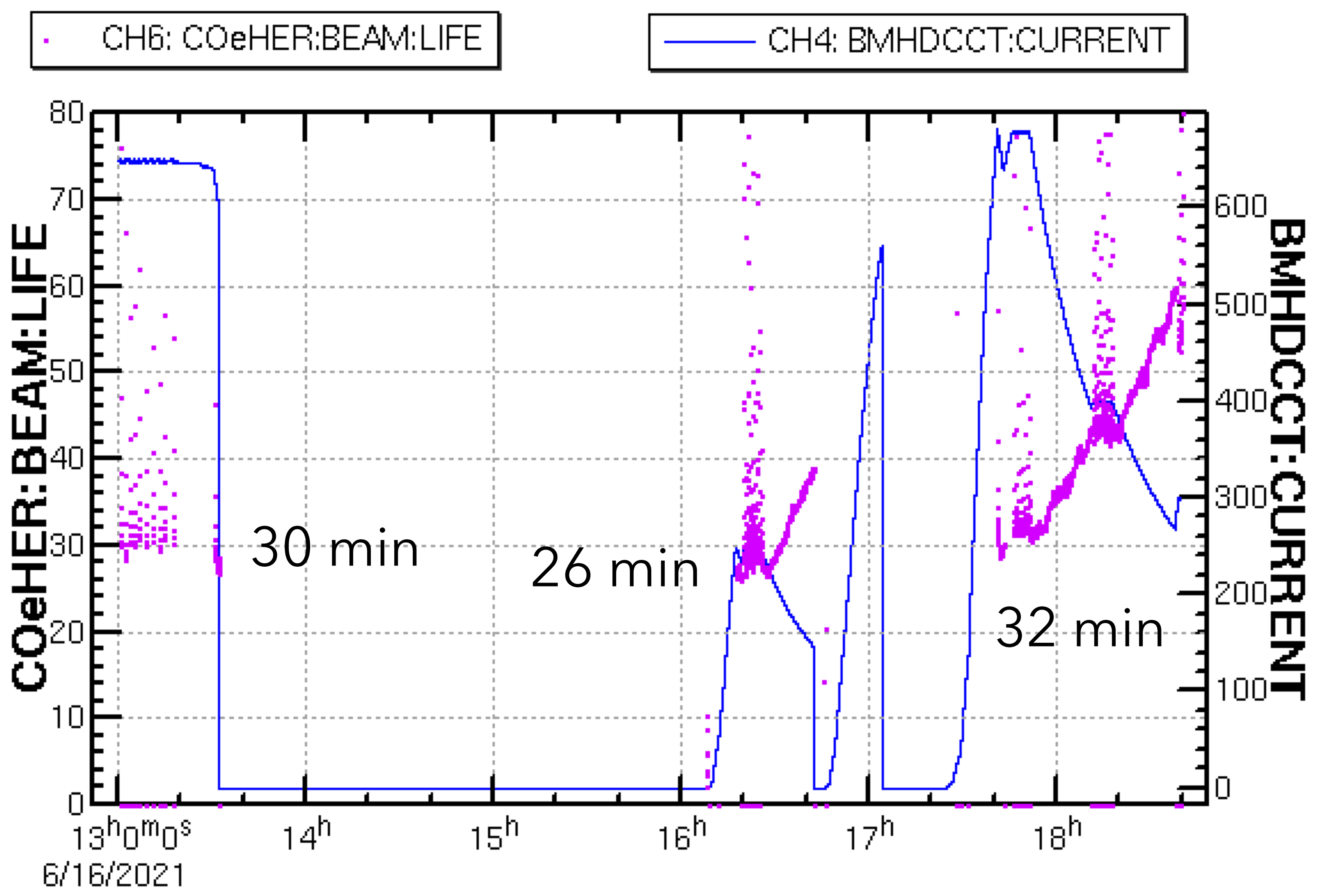
HER



collision single beam

ε_y depends on bunch current.





2021b

	LER	HER
β_x^*	80 mm	60 mm
β_y^*	1 mm	1 mm
I	800 mA	650 mA
n_b	1174	1174
I_b	0.681 mA	0.545 mA
ε_y collision	60 pm	45 pm
ε_y single	25 pm	40 pm
life collision	8 min	30 min
life single	6 min	32 min

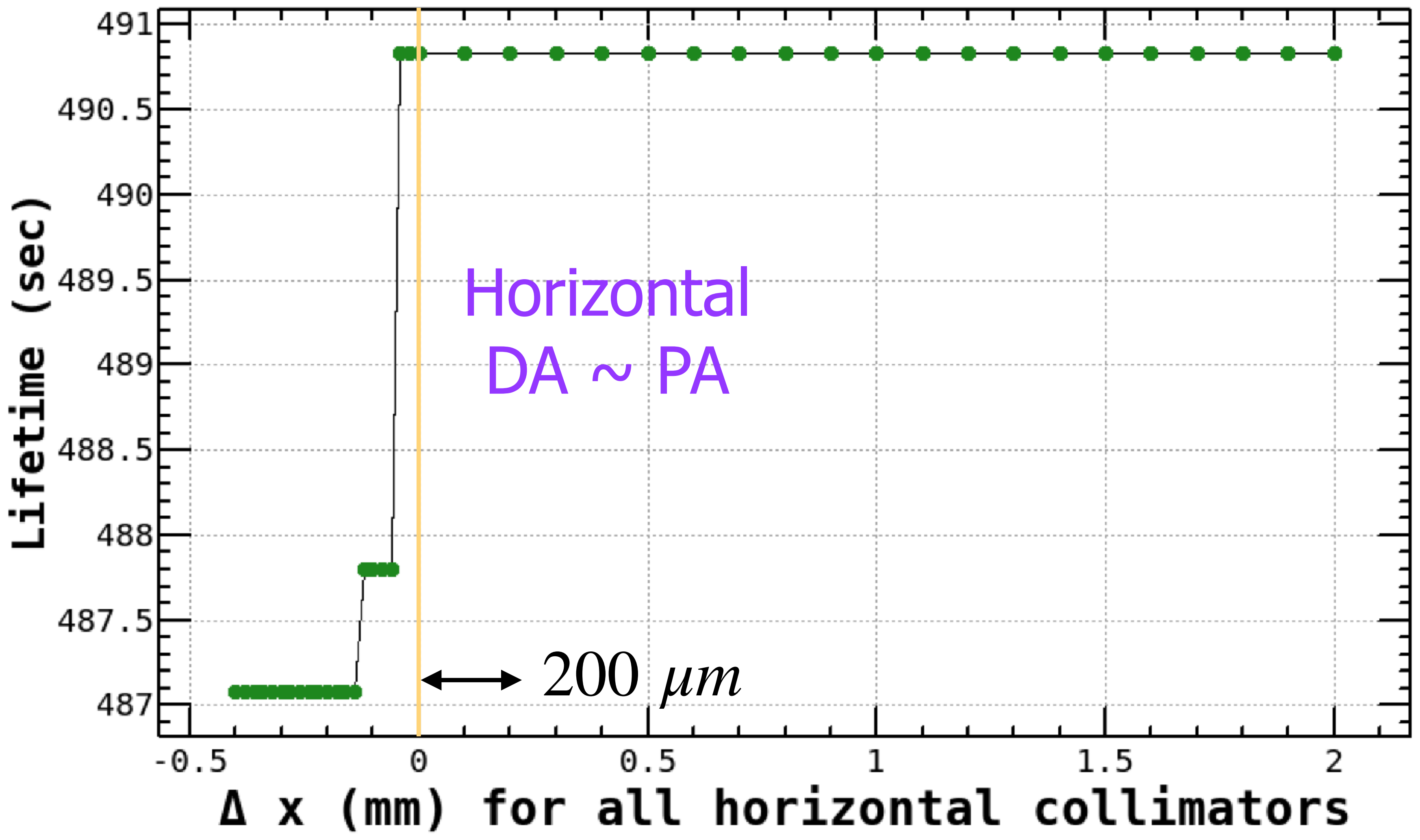
e^+_{inj}: 2.3 nC x 2 x 12.5 Hz x 80 %
I_{max}= 1.5 A for lifetime: 8 min

Simulation of Dynamic Aperture and Lifetime

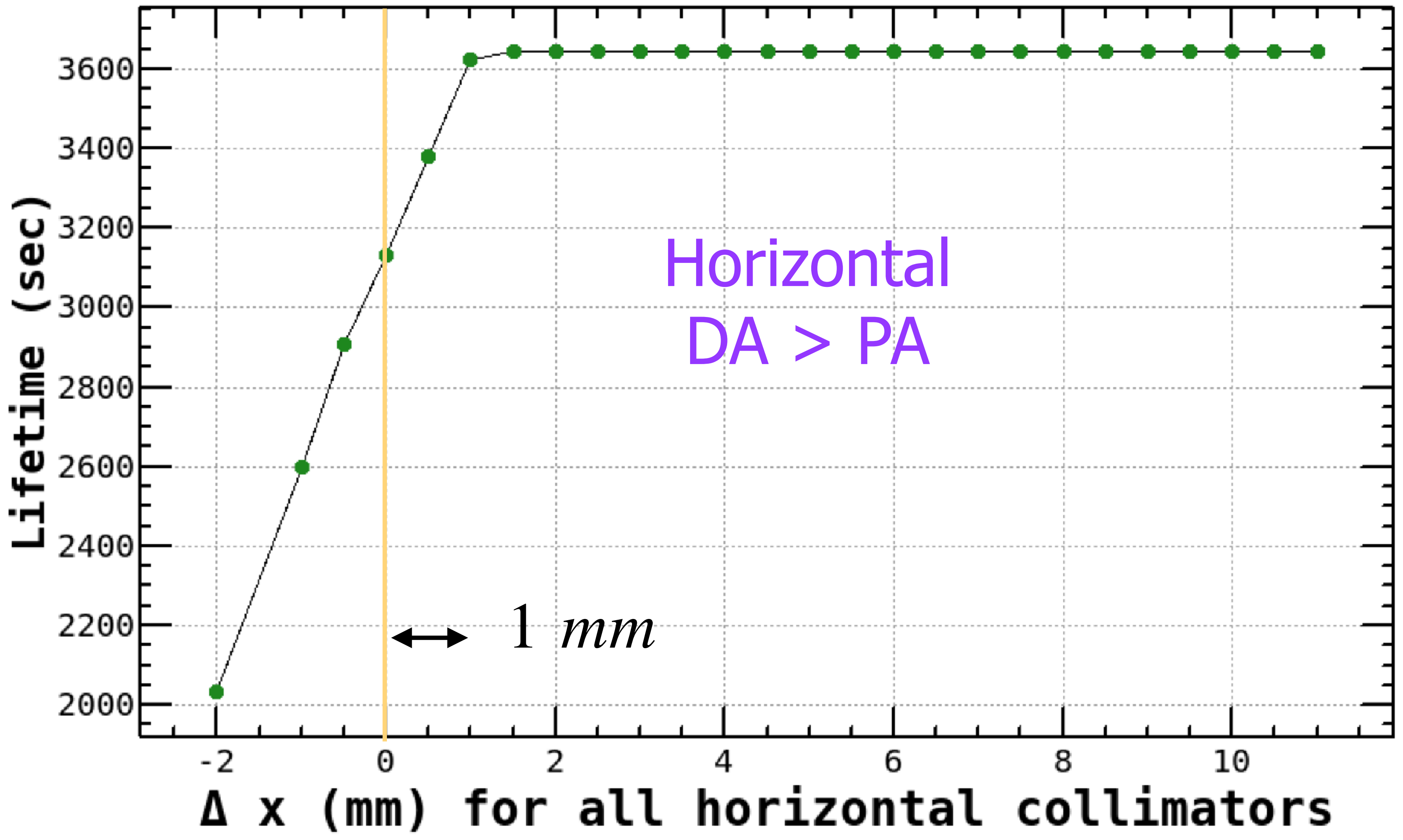
Open and close the collimator uniformly from the nominal setting to examine the change in lifetime.

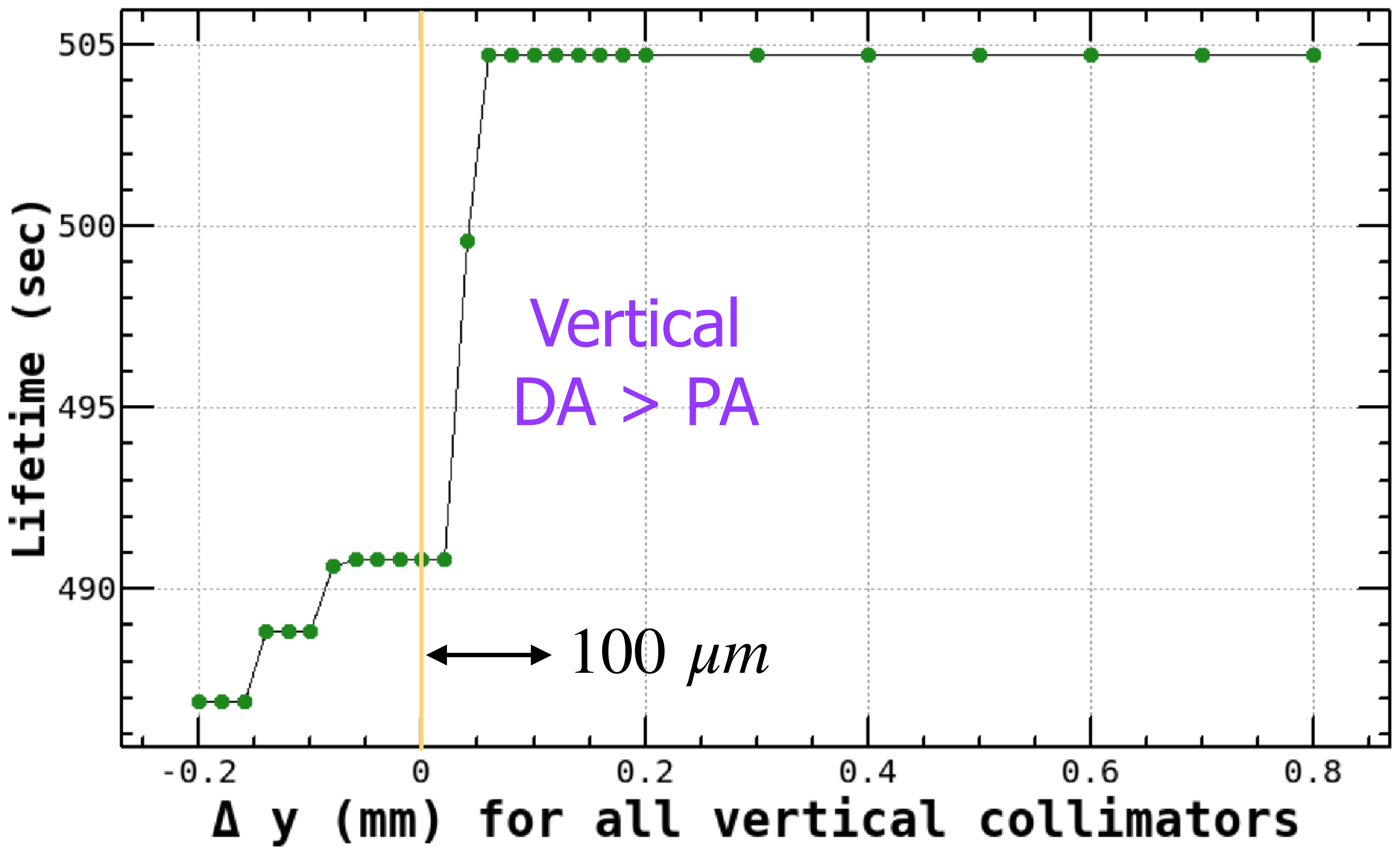
Zero means the nominal setting for the collimators.

LER



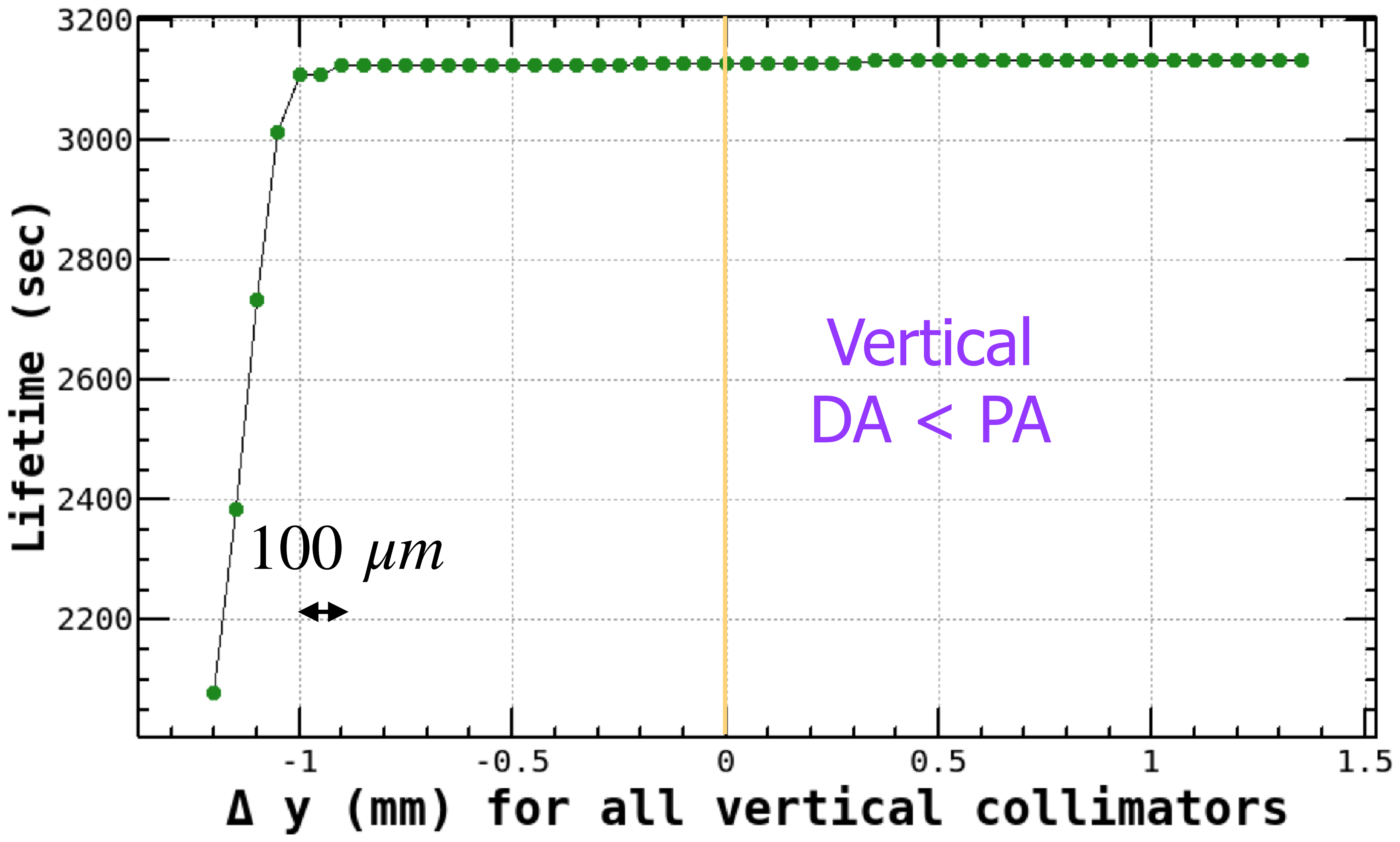
HER





τ = 8 min
(meas. 6 min,
vac. lifetime inc.)

The simulation is almost consistent with measurement.



τ = 52 min
(meas. 32 min,
vac. lifetime inc.)

Dynamic aperture is smaller than what we expected ?

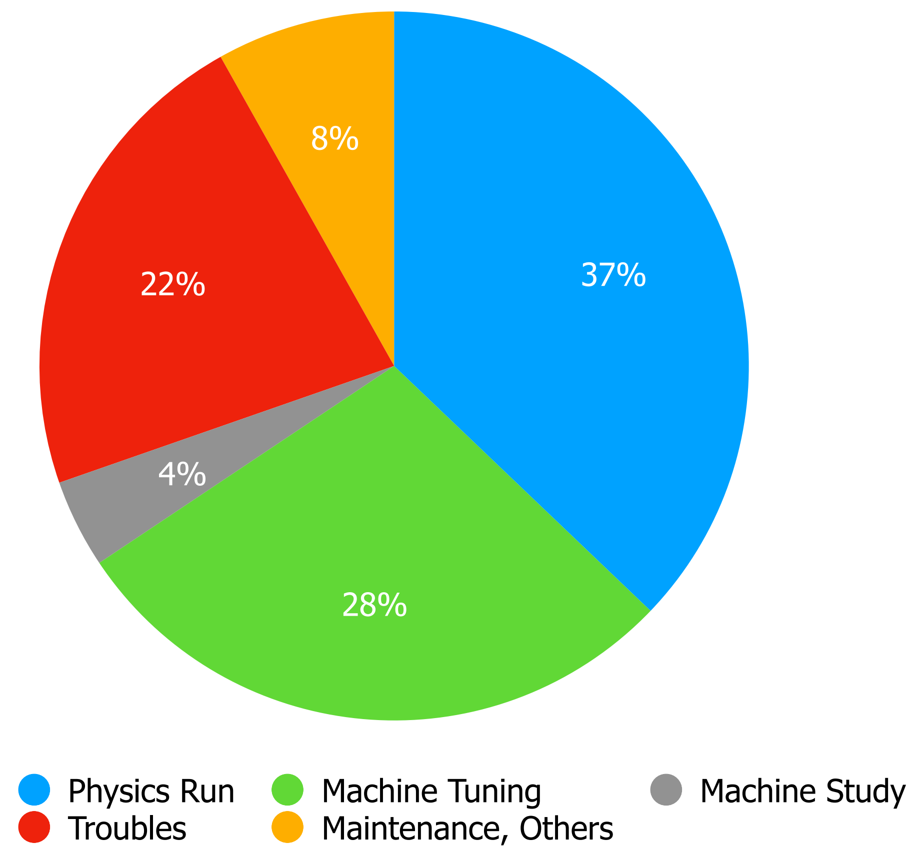
Or machine error ?

No Summary

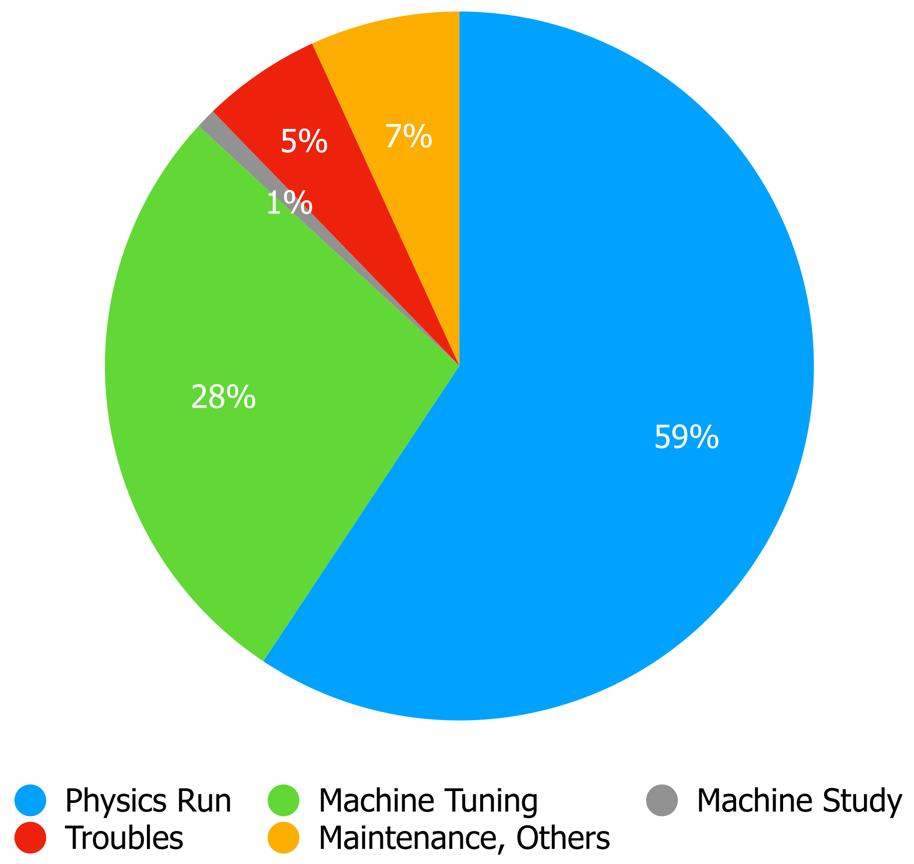
-1 mode instability	K.Ohmi	"Impedance issues (BxB FB, etc.)"	Dec. 14
Sudden beam loss	H. Ikeda	"Sudden Beam Loss"	Dec. 14
Optics degradation and others	H. Sugimoto	"Optics issues"	Dec. 14
Beam-Beam simulations, interference of lattice nonlinear, etc.	D. Zhou	"Beam-Beam, comparison of Beam-Beam interaction between simulations and experiments"	Dec. 14
Collimators	T. Ishibashi	"Collimator issues"	Dec. 14
Issues of beam injection	N. Iida	"Injection"	Dec. 13

Appendix

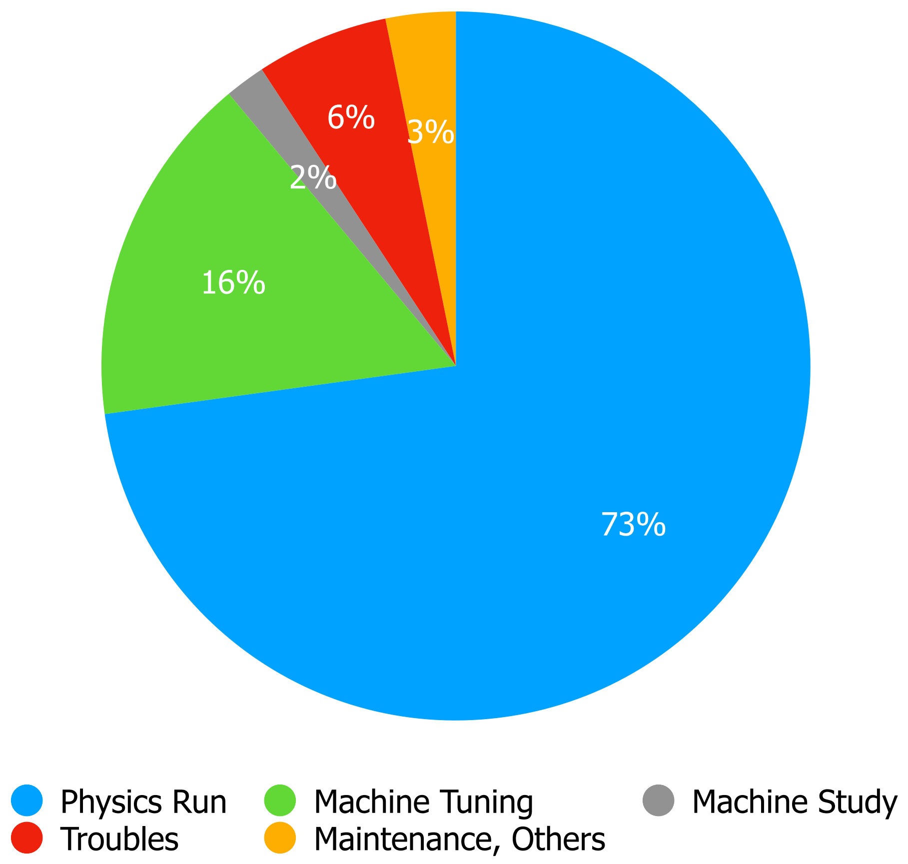
2019 a/b



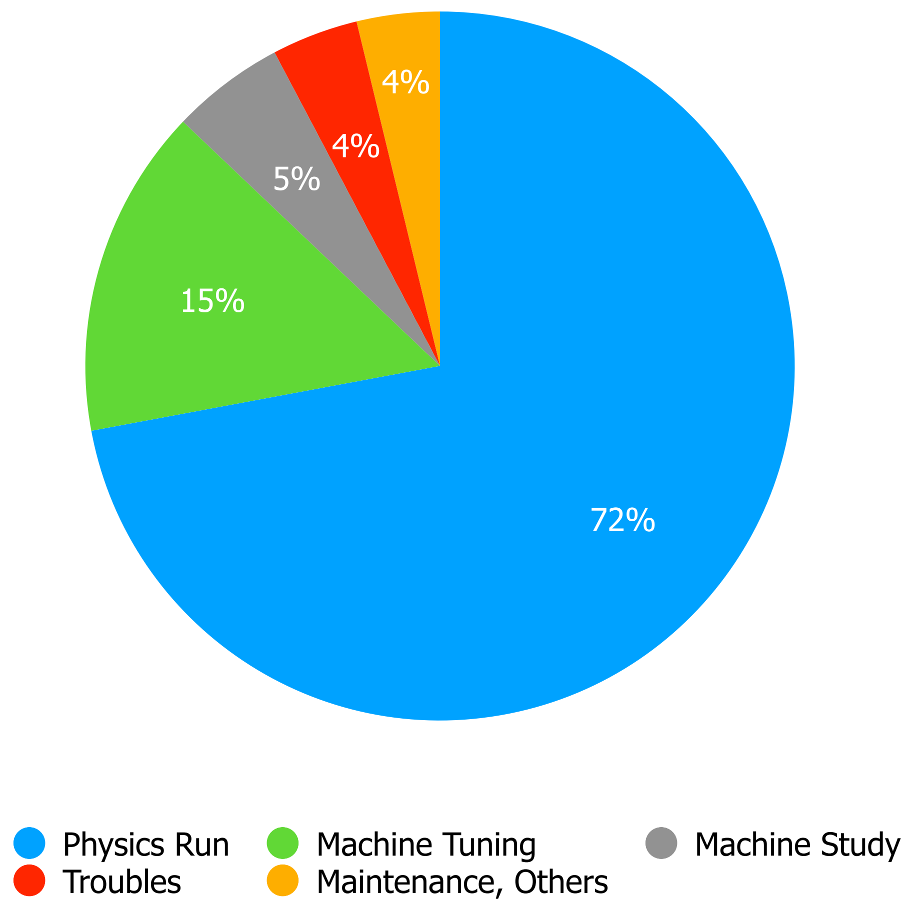
2020 a/b



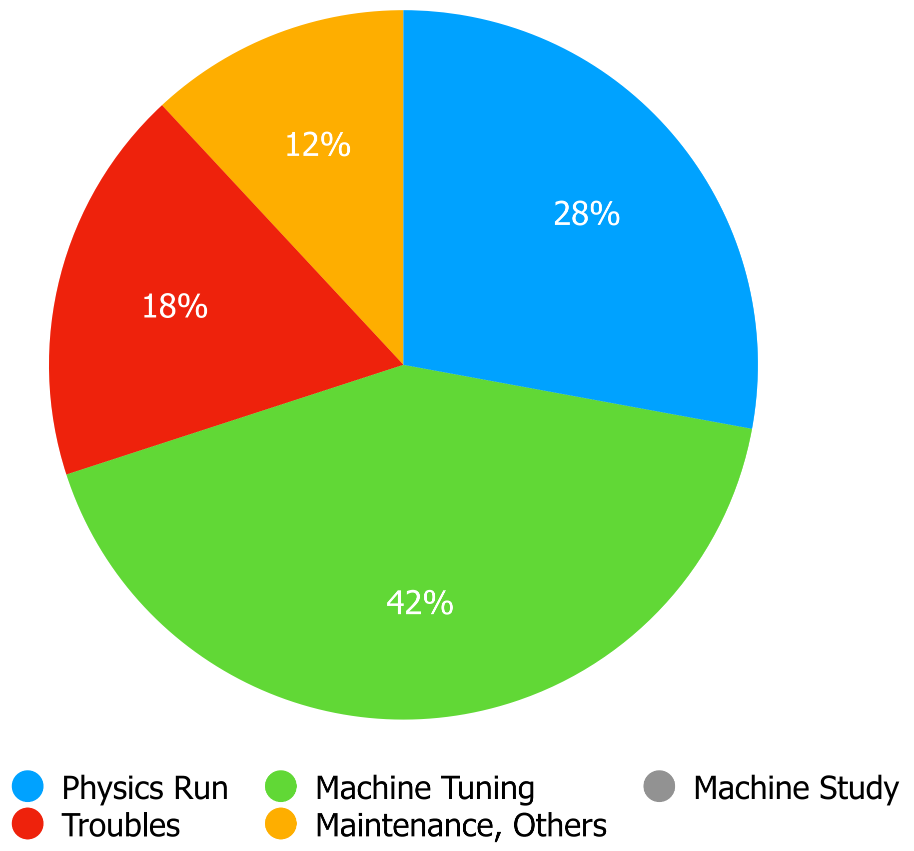
2021a/b



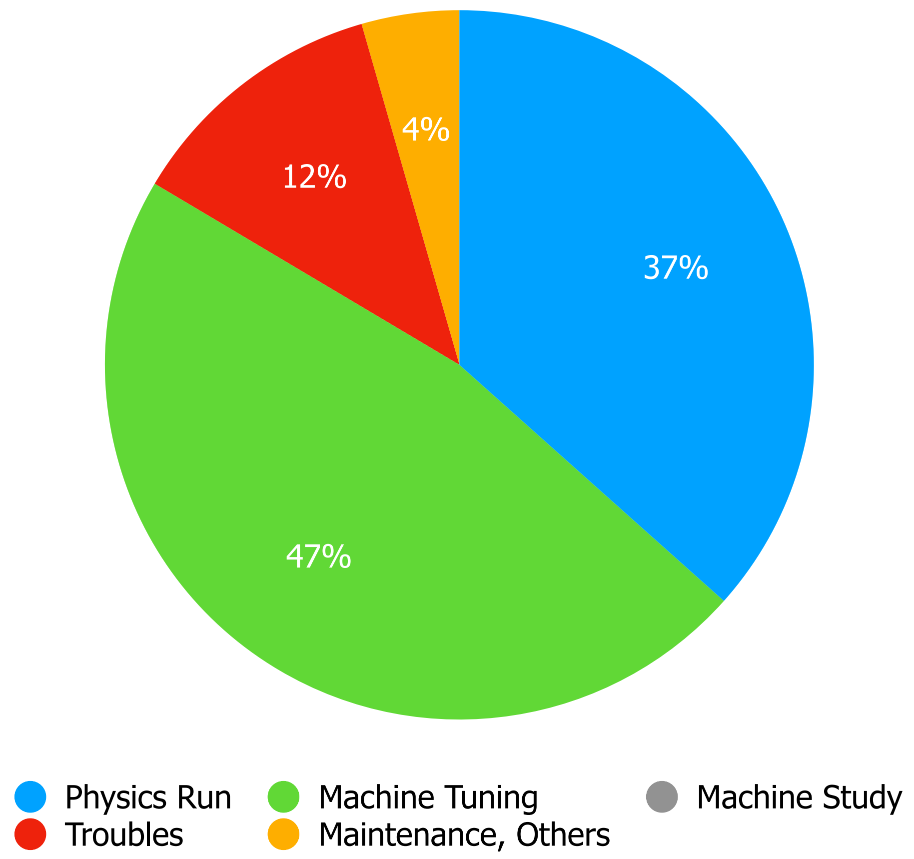
2022a/b



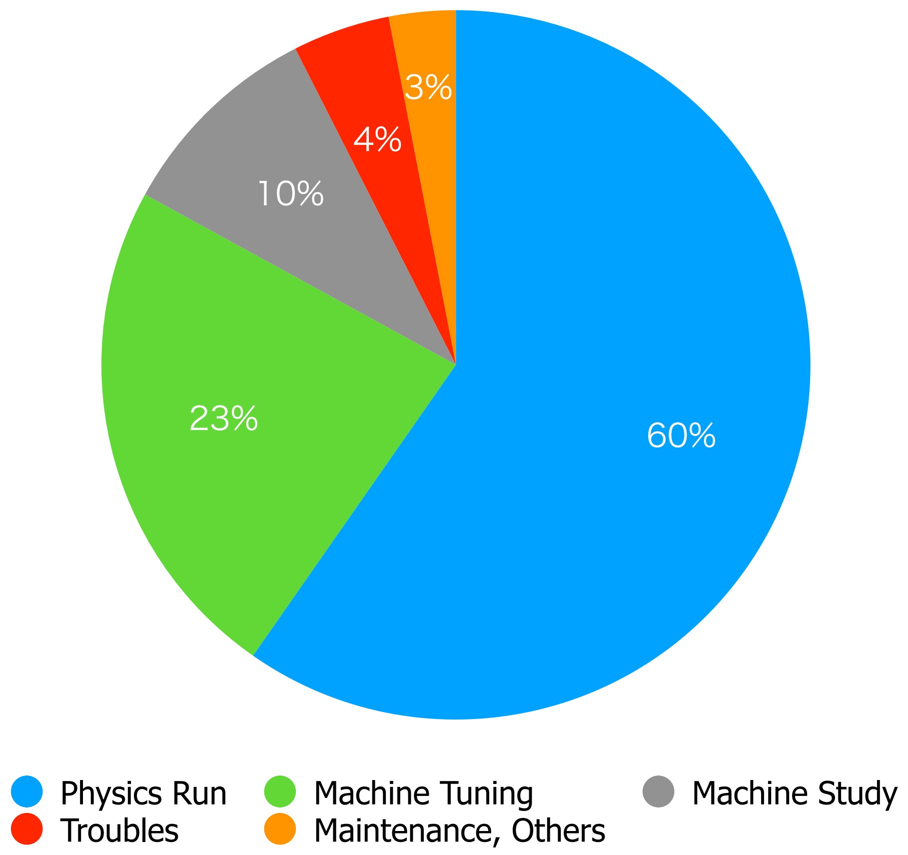
2019 c



2020c



2021 c



Operation statistics 2019 -2022

Vertical Beam Size at IP

$$\sigma_y^{*2} = \mu^2 \varepsilon_y \left(\beta_y^* + \frac{\Delta s^2}{\beta_y^*} \right) + (\eta_y^* \sigma_\delta)^2 + \frac{\varepsilon_x}{\beta_x^*} (r_2^* + r_4^* \Delta s)^2 + \varepsilon_x \beta_x^* (r_1^* + r_3^* \Delta s)^2$$

$$= \mu^2 \varepsilon_y \beta_y^* + (\eta_y^* \sigma_\delta)^2 + \frac{\varepsilon_x}{\beta_x^*} r_2^{*2} + \varepsilon_x \beta_x^* r_1^{*2}$$

X-Y couplings

normal coordinate
(decoupled coordinate)

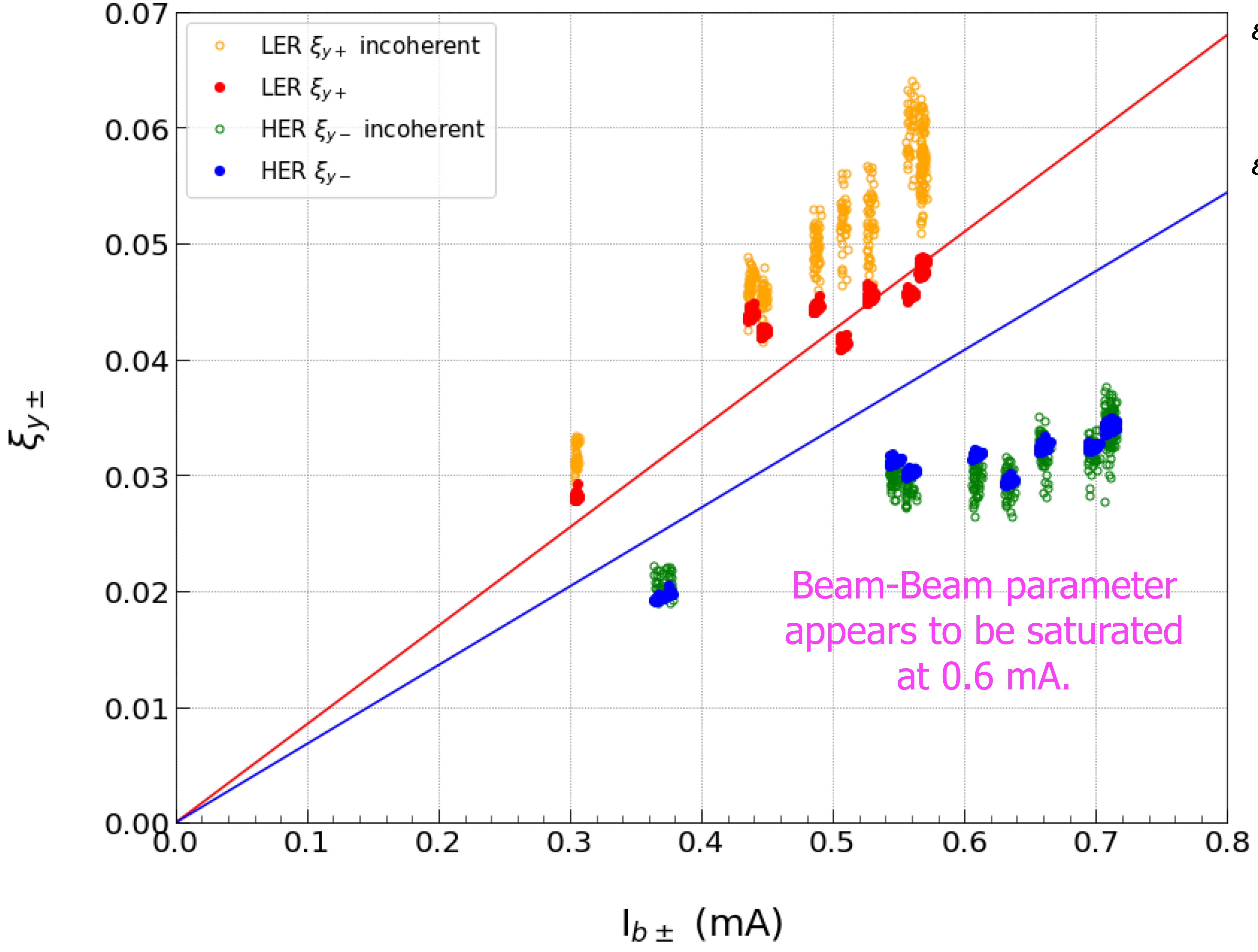
physical coordinate

$$\begin{pmatrix} u \\ p_u \\ v \\ p_v \end{pmatrix} + \begin{pmatrix} \eta_u \\ \eta_{p_u} \\ \eta_v \\ \eta_{p_v} \end{pmatrix} \delta = \begin{pmatrix} \mu & 0 & -r_4 & r_2 \\ 0 & \mu & r_3 & -r_1 \\ r_1 & r_2 & \mu & 0 \\ r_3 & r_4 & 0 & \mu \end{pmatrix} \begin{pmatrix} x \\ p_x \\ y \\ p_y \end{pmatrix}$$

$$\begin{pmatrix} \eta_u \\ \eta_{p_u} \\ \eta_v \\ \eta_{p_v} \end{pmatrix} = \begin{pmatrix} \mu & 0 & -r_4 & r_2 \\ 0 & \mu & r_3 & -r_1 \\ r_1 & r_2 & \mu & 0 \\ r_3 & r_4 & 0 & \mu \end{pmatrix} \begin{pmatrix} \eta_x \\ \eta_{p_x} \\ \eta_y \\ \eta_{p_y} \end{pmatrix}$$

Vertical emittance, vertical dispersion, coupling parameters r_1 and r_2 at the IP are fundamental parameters for luminosity performance.

2022ab $\beta_y^* = 1\ mm$



single beam emittance

$\varepsilon_{y-}^0 = 40\ pm$

$\varepsilon_{y+}^0 = 25\ pm$

Vertical beam-beam parameter

$$\xi_{y\pm} = 2er_e \frac{\beta_{y\pm}^* L}{\gamma_\pm I_\pm}$$

Vertical beam-beam parameter (incoherent)

$$\xi_{y\pm} = \frac{r_e}{2\pi\gamma_\pm}\left(\frac{I_{b\mp}}{ef_0}\right)\frac{\beta_{y\pm}^*}{\phi_x\sigma_{z\mp}\sigma_{y\mp}^*} \propto I_{b\mp}\sqrt{\frac{\beta_{y\pm}^*}{\varepsilon_{y\mp}}}$$

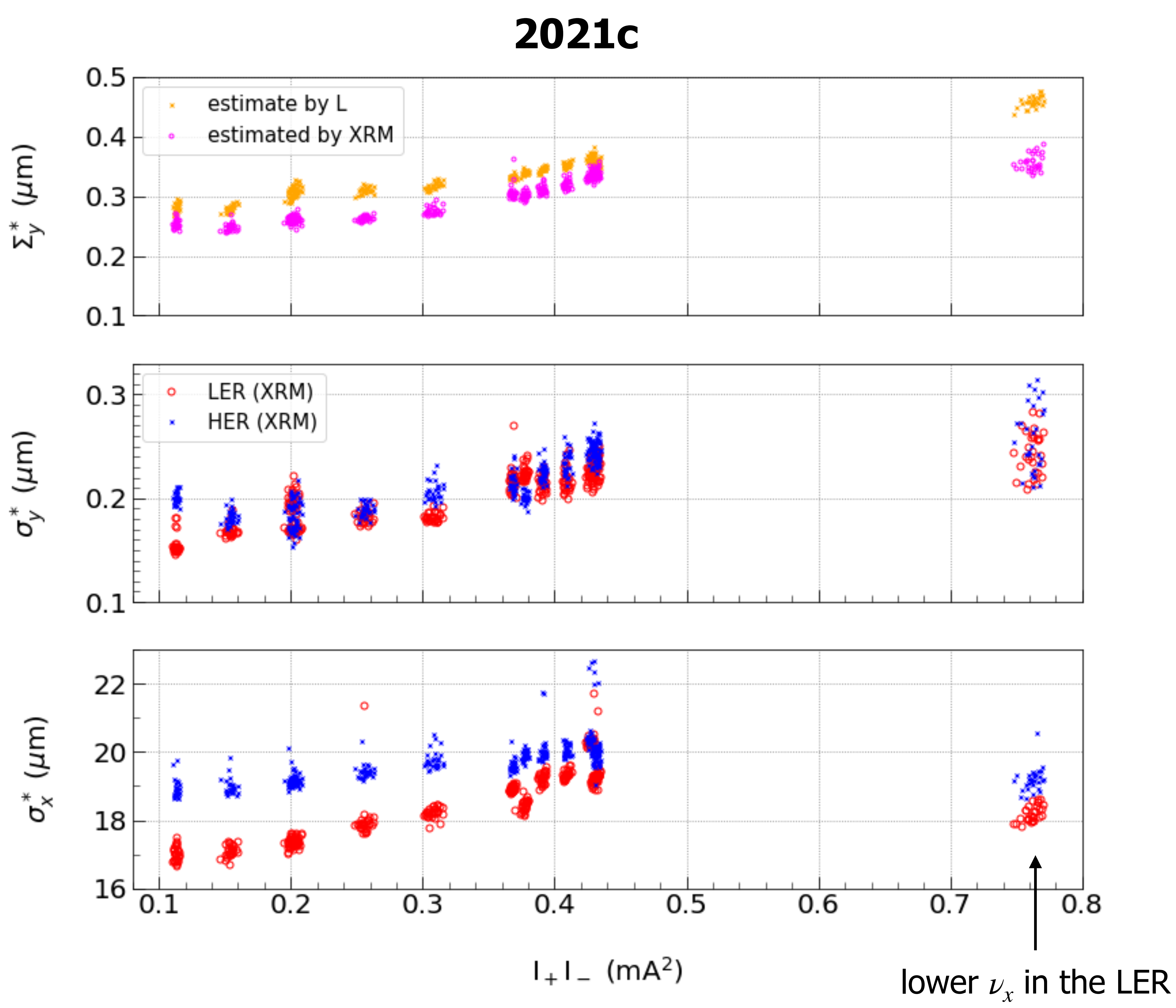
Here, the nominal bunch length is used.

$\sigma_{z+} = 4.6\ mm$

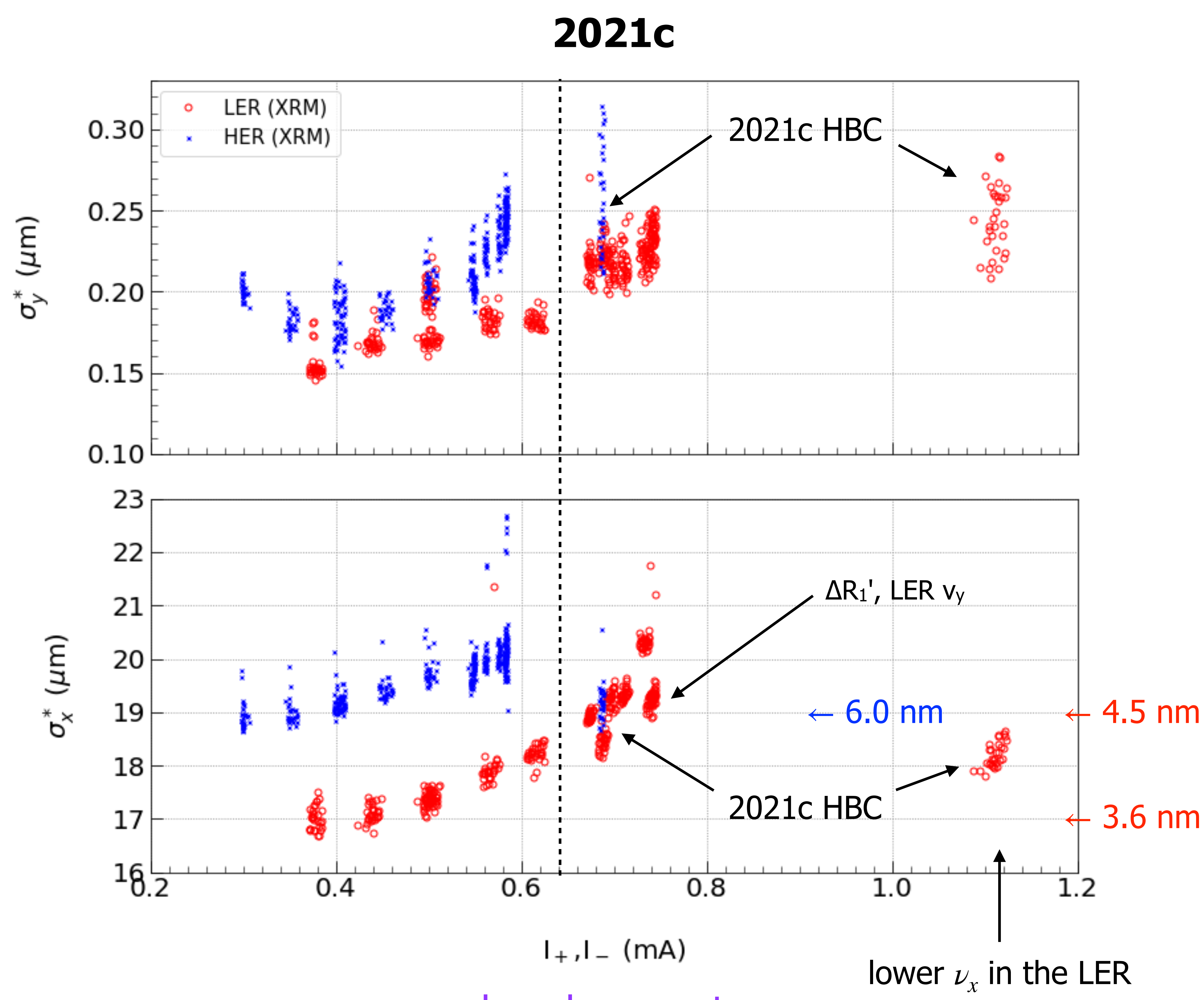
$\sigma_{z-} = 5.1\ mm$

Bunch lengthening is important parameter.

Beam Size in 2021c



bunch current product

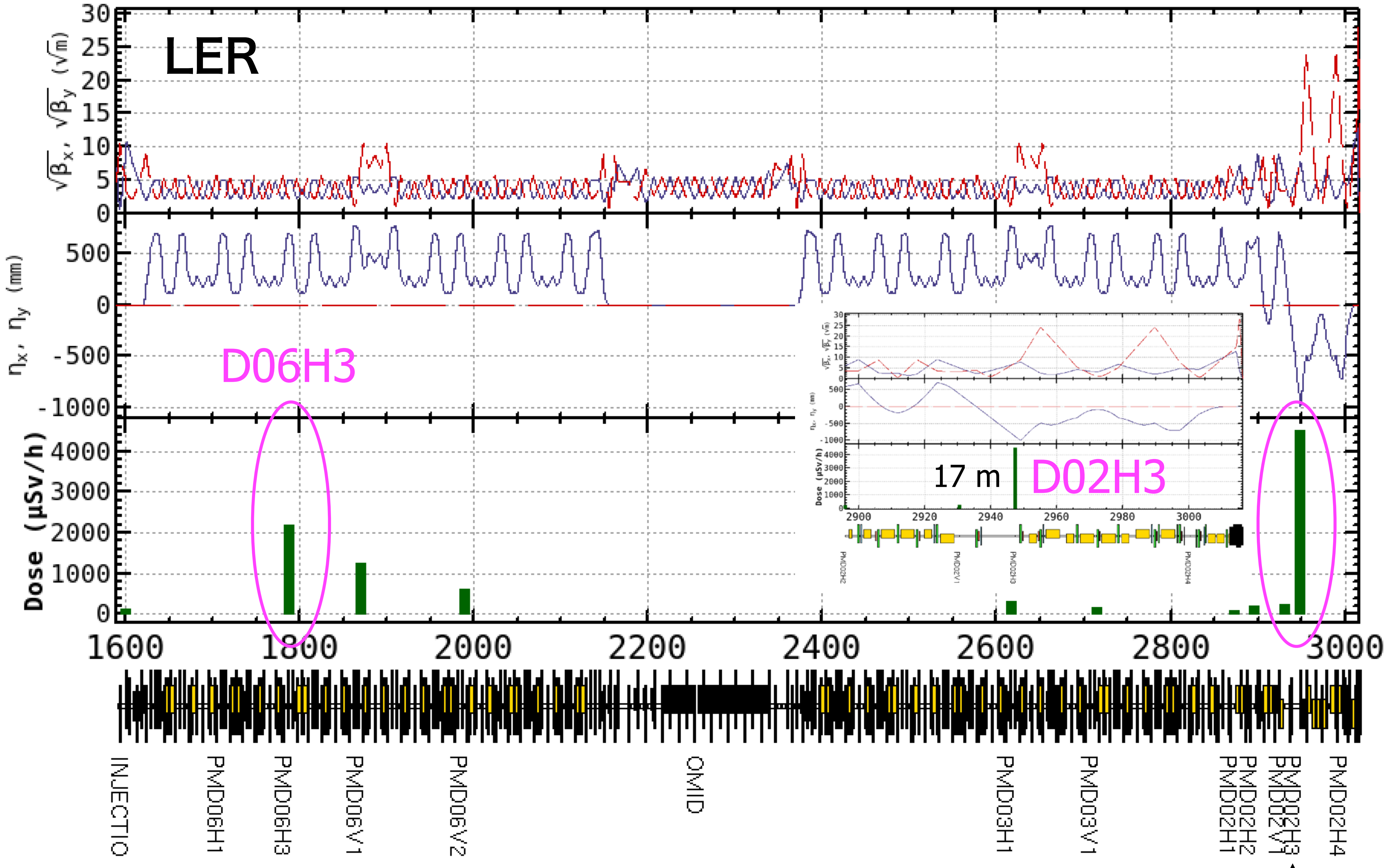


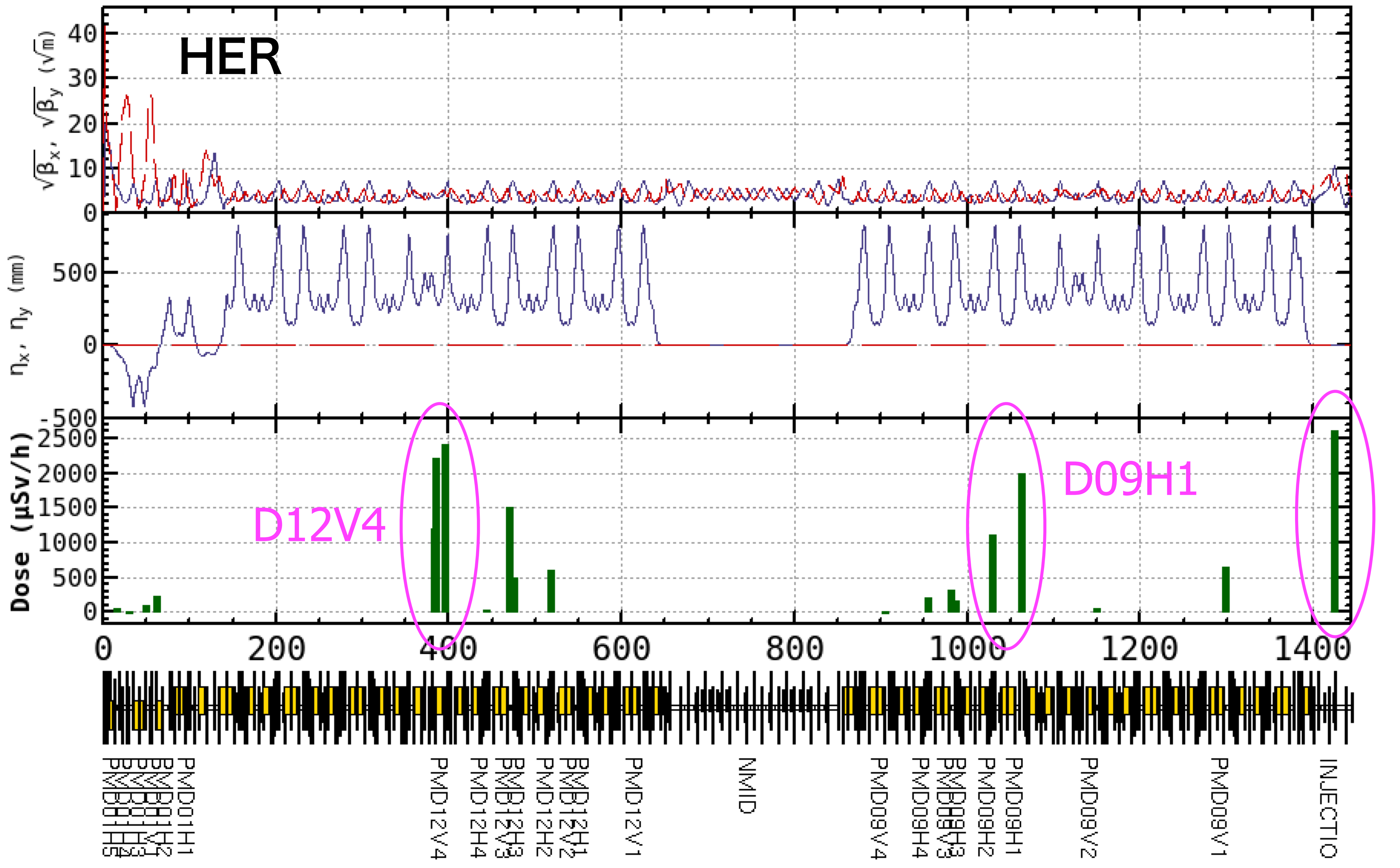
bunch current

Location of Movable Collimators

Collimators and Radiation Dose (measured on June 22, 2022)

measured by Radiation Safety Group





Injection Point

e^+

IP

e^-

Injection Point

D06H3 damaged
due to accidental fire of
injection kicker on March 18

D02H3 is 17 m downstream of D02V1
which is damaged on March 11.

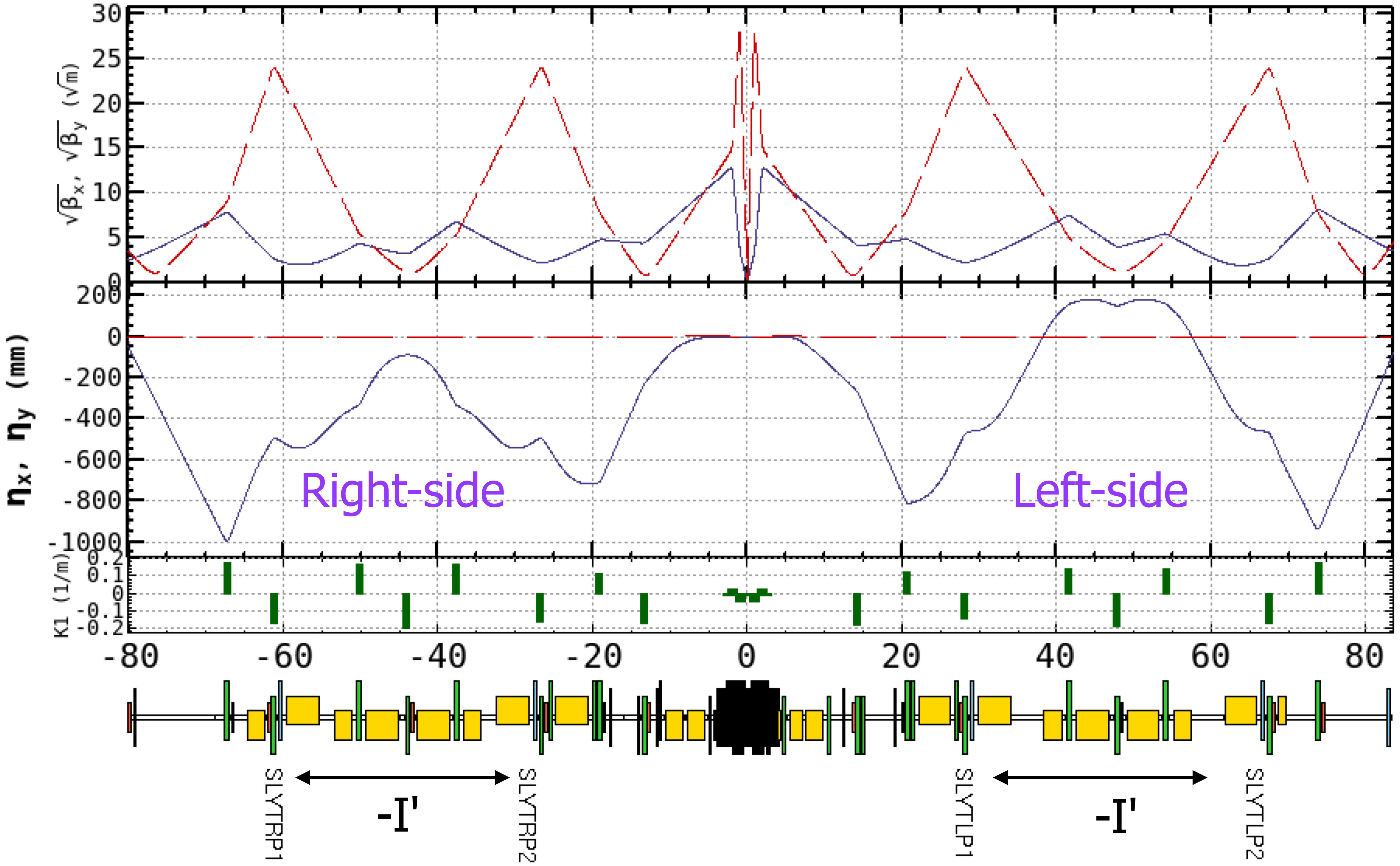
The radiation dose at the injection point is very high in HER.

The bottom jaw of D06V1 was opened from the usual setting due to damage of the collimator head. In stead of D06V1, D06V2 was used to protect D02V1 and QCS from mid. of June.

Local Chromaticity Correction: Strong Sextupoles (SLY)

$\beta_y^* = 1\ mm$

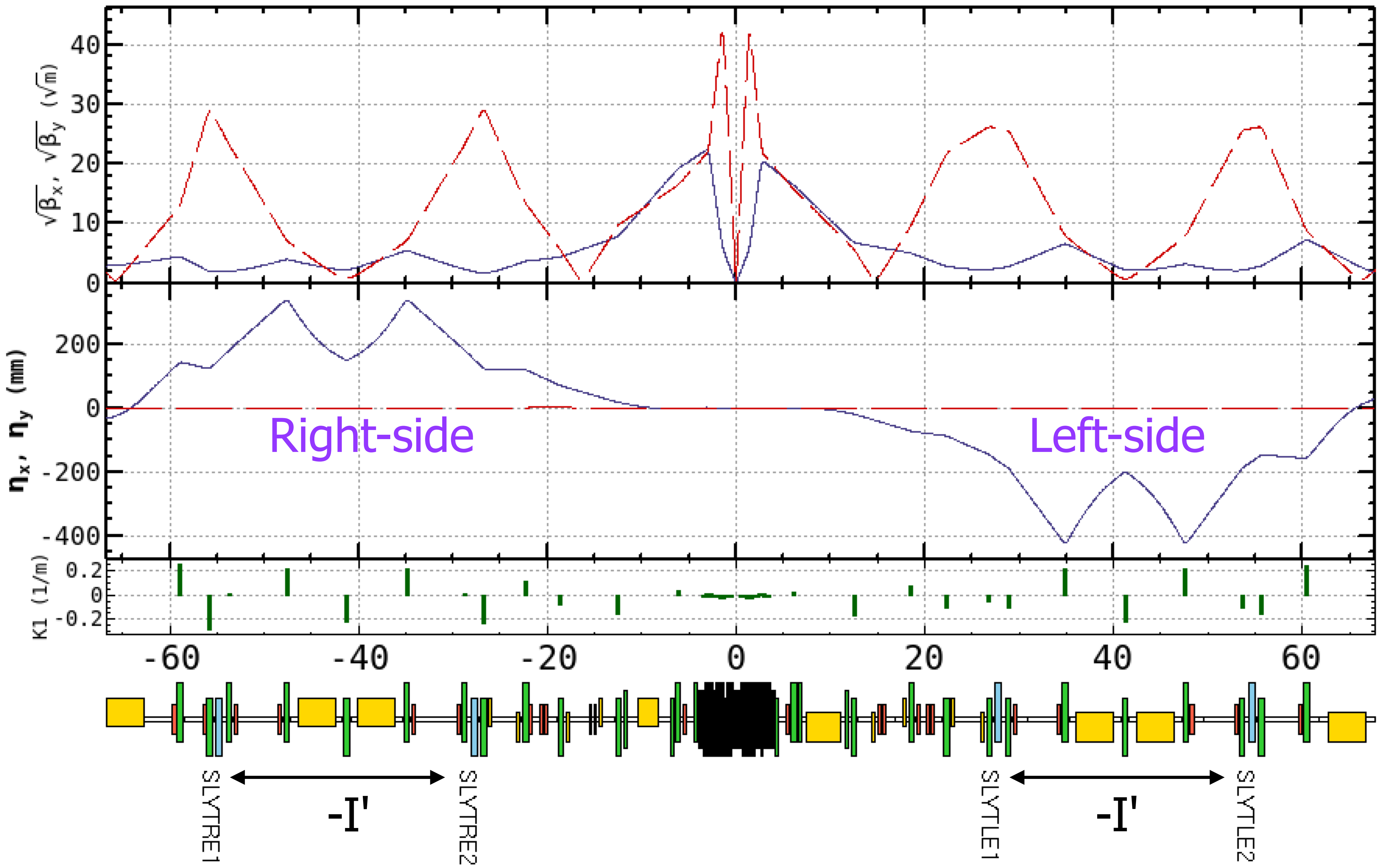
LER



K2: 1.23 1/m² K2: 3.48 1/m² K2: 1.33 1/m² K2: 3.53 1/m²

$\beta_y = 521\ m$ $\beta_y = 525\ m$

HER



K2: -8.76 1/m² K2: -9.62 1/m² K2: 8.36 1/m² K2: 7.66 1/m²

$\beta_y = 702\ m$ $\beta_y = 675\ m$

$\Delta\nu_y = \frac{\beta_y}{4\pi} K_2 \Delta x$ ~0.0028 for $\Delta x = 20\ \mu m$

Horizontal tune shift can be ignored.

Horizontal orbit in-phase for each pair induces large beta-beat which changes β_y^*.

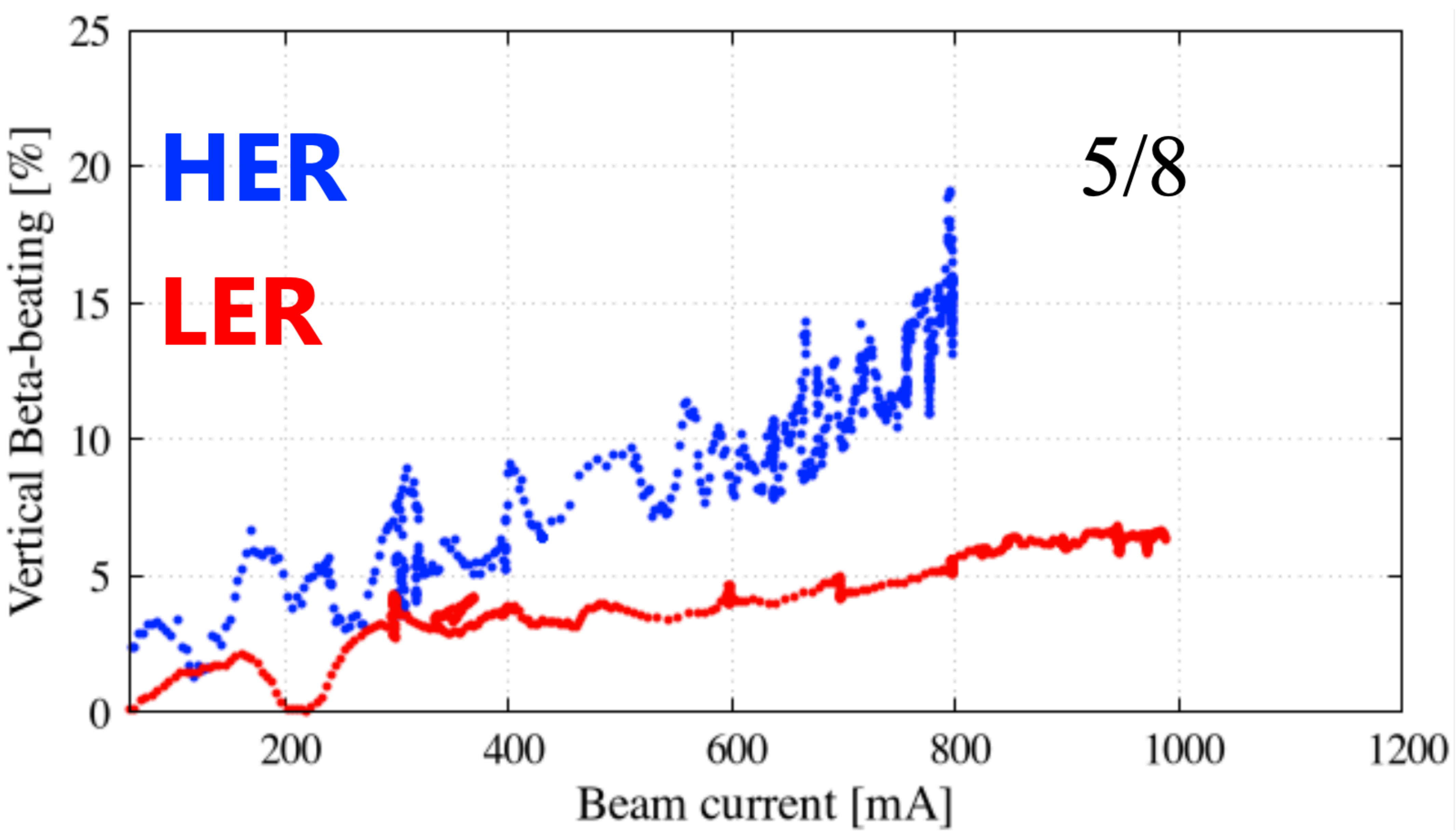
$\Delta\nu_y$ ~0.01 for $\Delta x = 20\ \mu m$

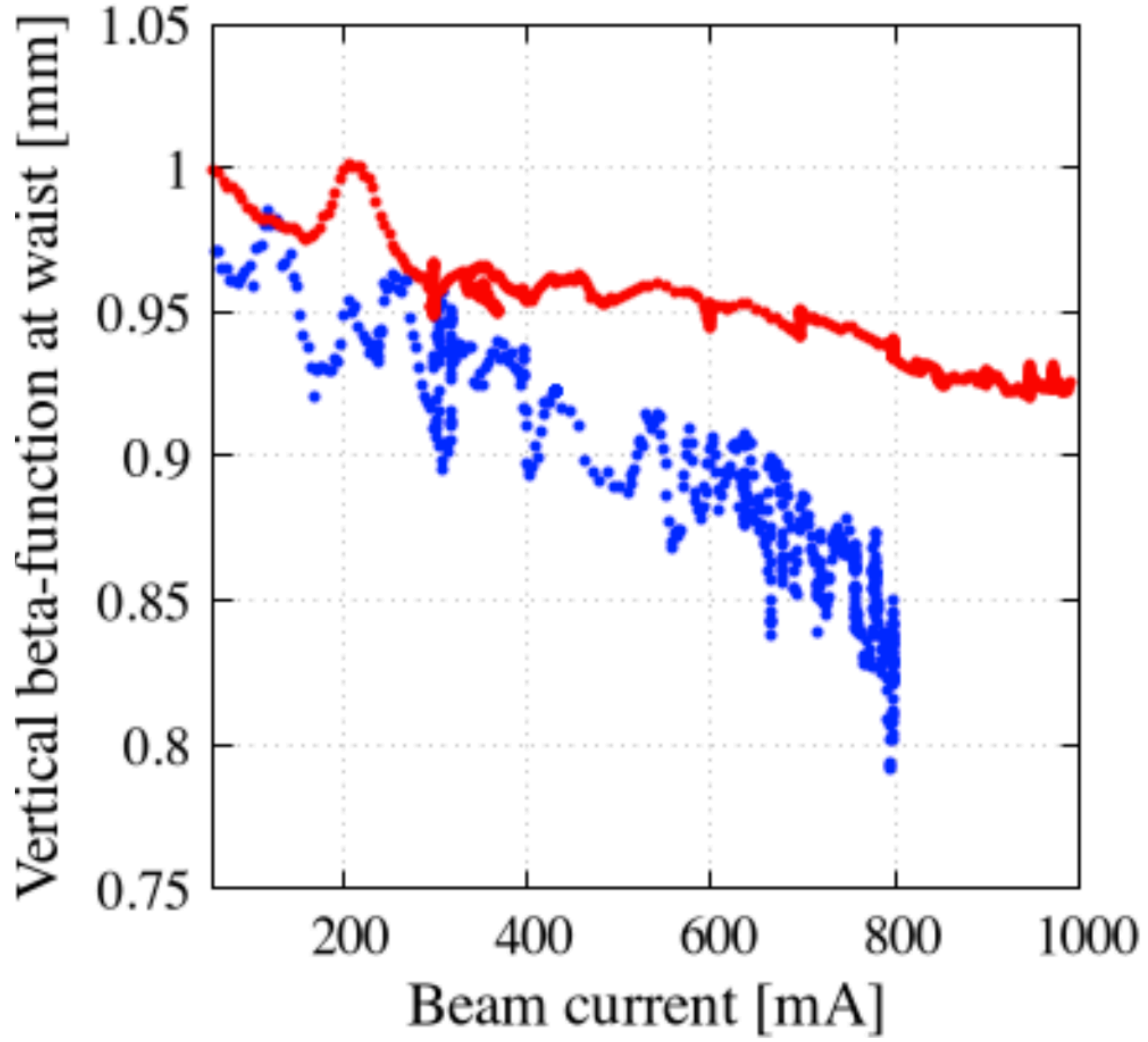
3.6 times larger than LER

Beta-Beat due to Orbit Deviation

H. Sugimoto, 2022ab Summary Meeting

The SR heating deforms the beam line.
The horizontal orbit deviation induces tune shift and beta-beat. As the result, β_y^* also changes.
The orbit deviation in the local chromaticity correction (SLY) is always in the outward direction of the ring.
This implies a squeezing of β_y^*.
The HER is larger effects rather than the LER.
In order to reduce optics degradation, the local bumps correct the orbit at the strong sextupoles.
(Horizontal bump for beta-beat and vertical bump for X-Y couplings)

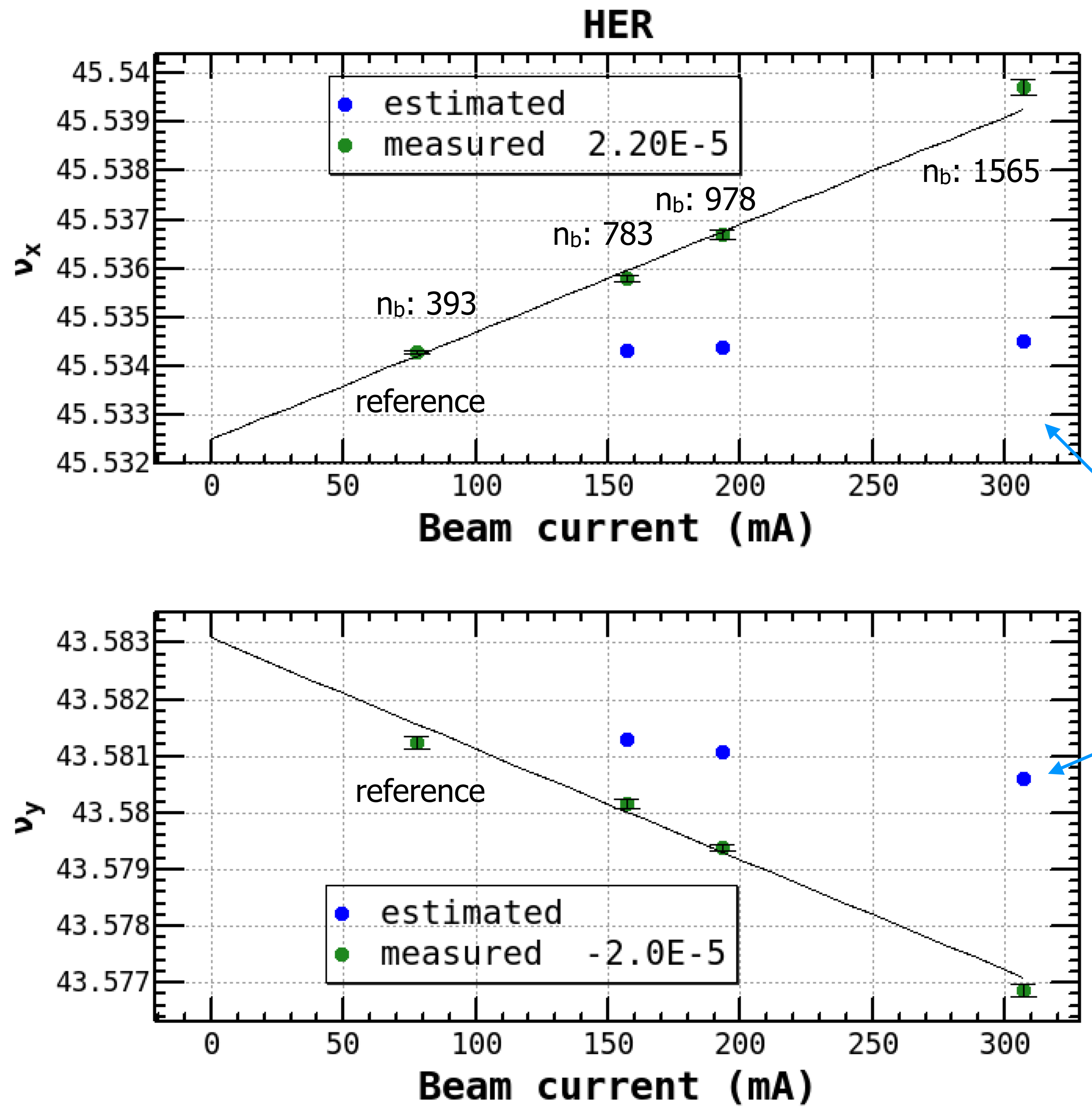


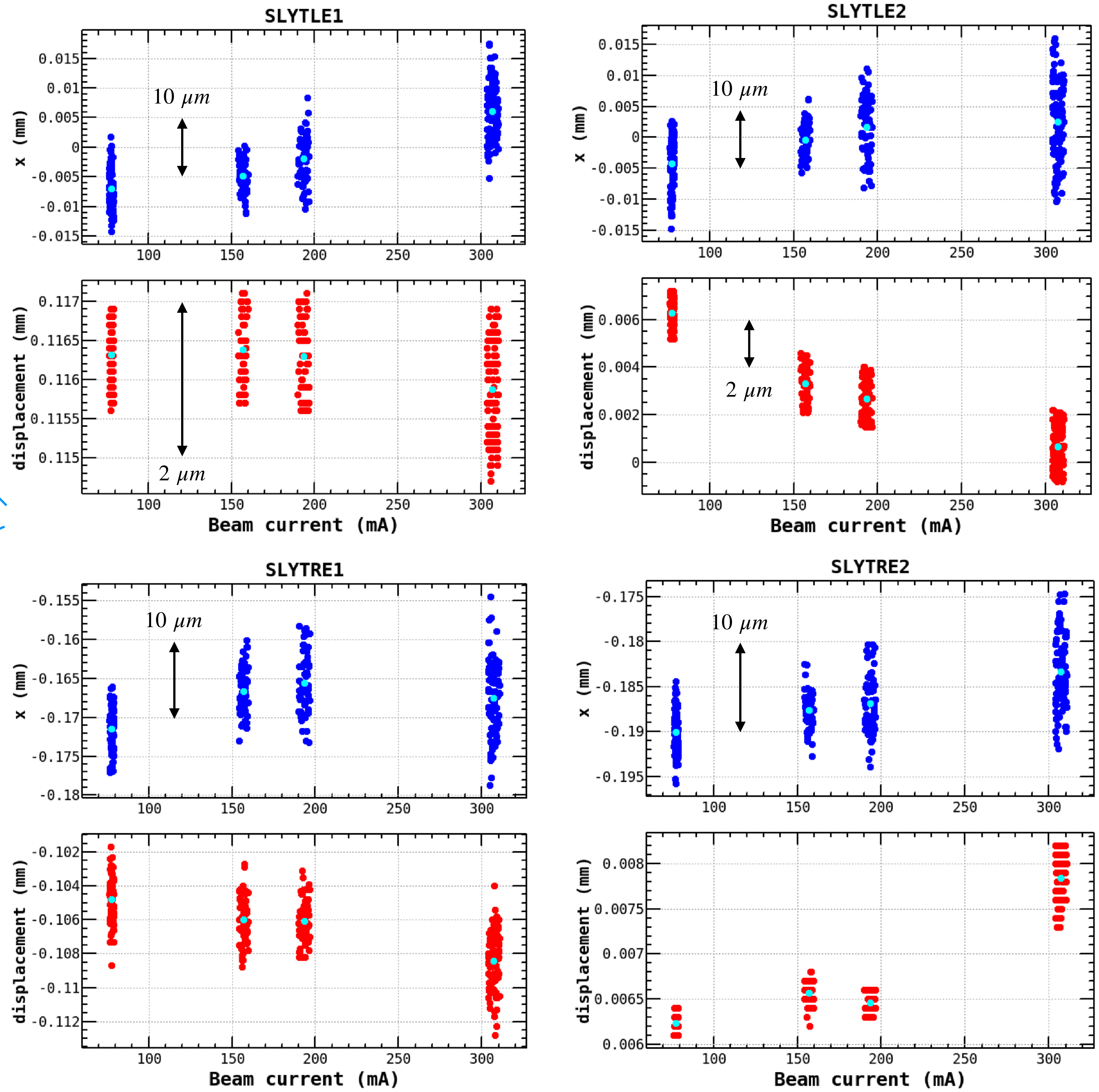


Measurement of Resistive-Wall Tune Shift

$\beta_x^*/\beta_y^* = 200\ mm/8\ mm$ (no crab waist) **HER**

The bunch current is fixed to be 0.2 mA.





tune shift due to resistive wall impedance:

$$\Delta\nu_x/I = +2.2\times10^{-5}\ (1/mA)$$

$$\Delta\nu_y/I = -2.0\times10^{-5}\ (1/mA)$$

$$\rightarrow -1.64\times10^{-5}\ (1/mA)$$

corrected value

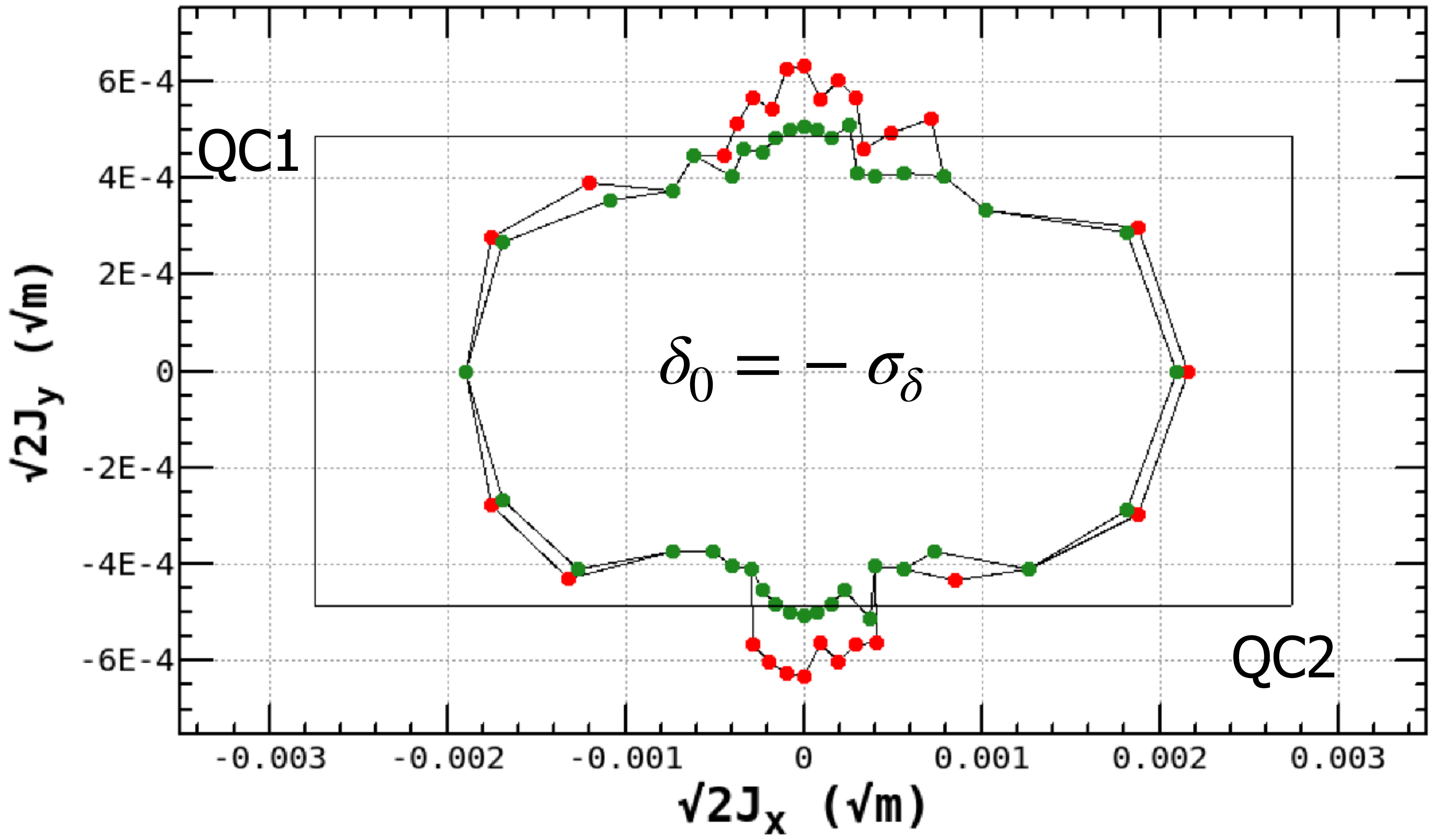
18:50 - 23:10, October 26, 2021

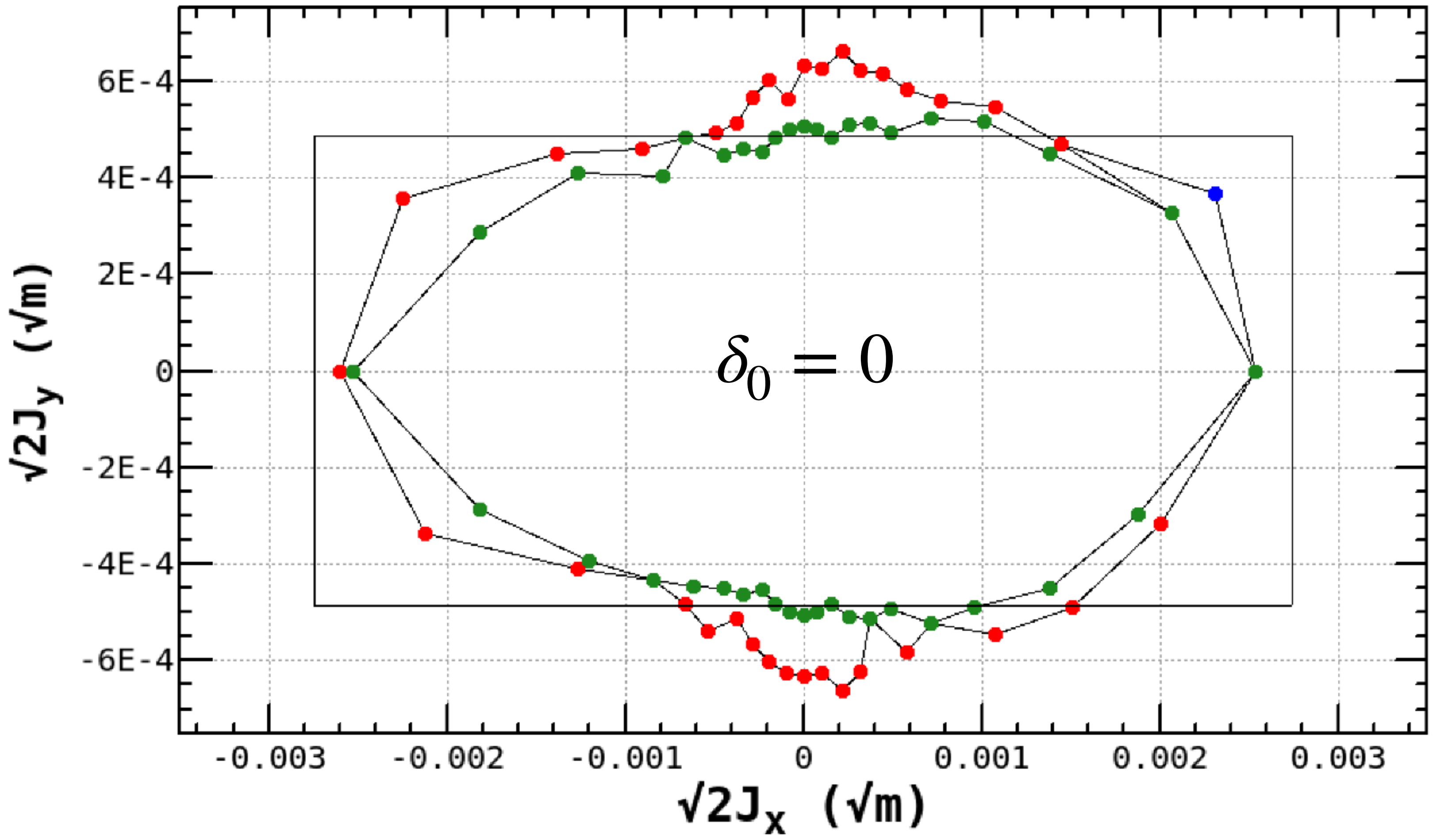
Dynamic Aperture in the LER

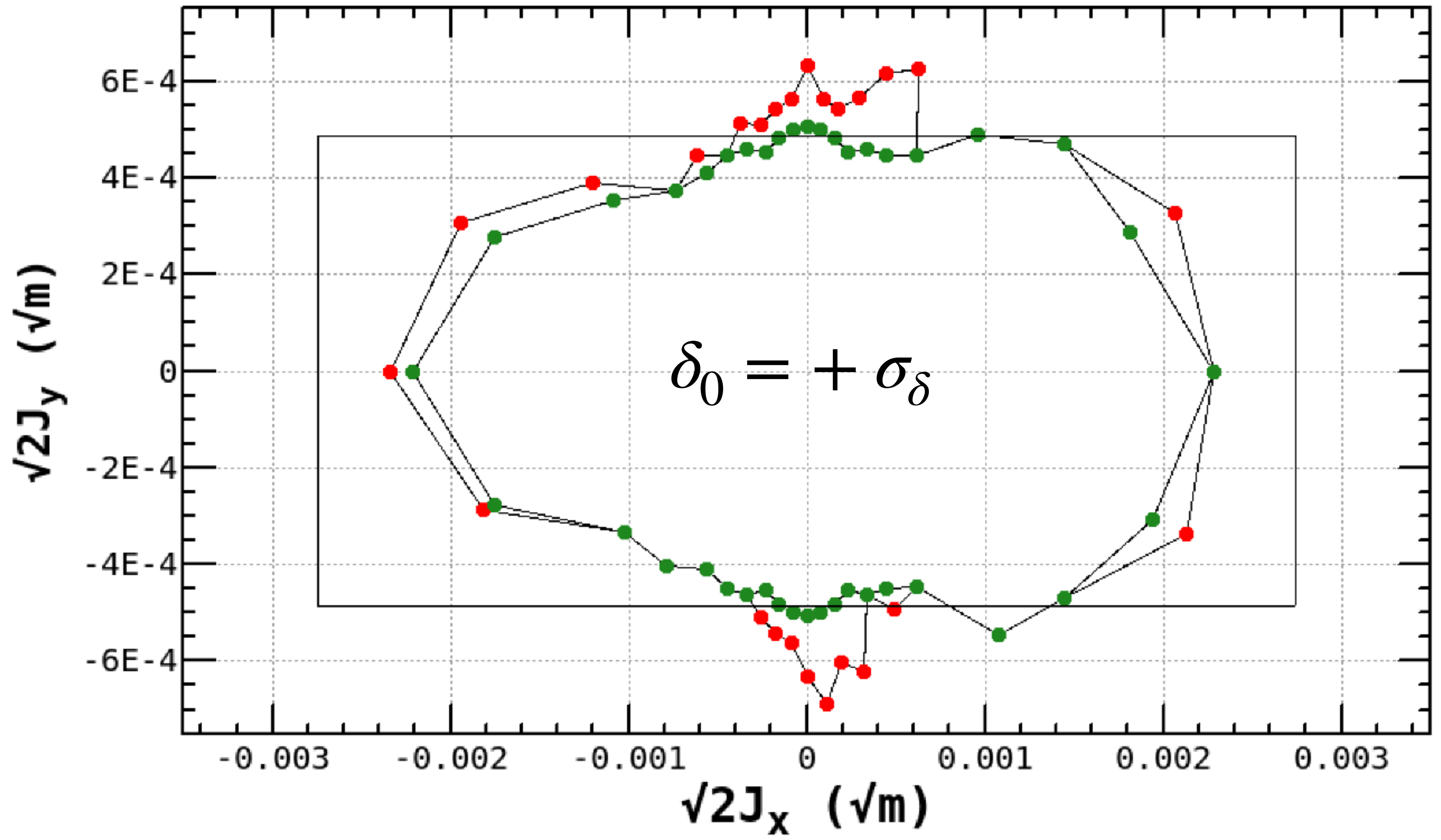
initial amplitude at injection point

CW 80 %

Collimators : full open, QCS aperture only







AQC1: AY =20.0 mm
AQC1: AY =18.0 mm
AQC1: AY =13.5 mm

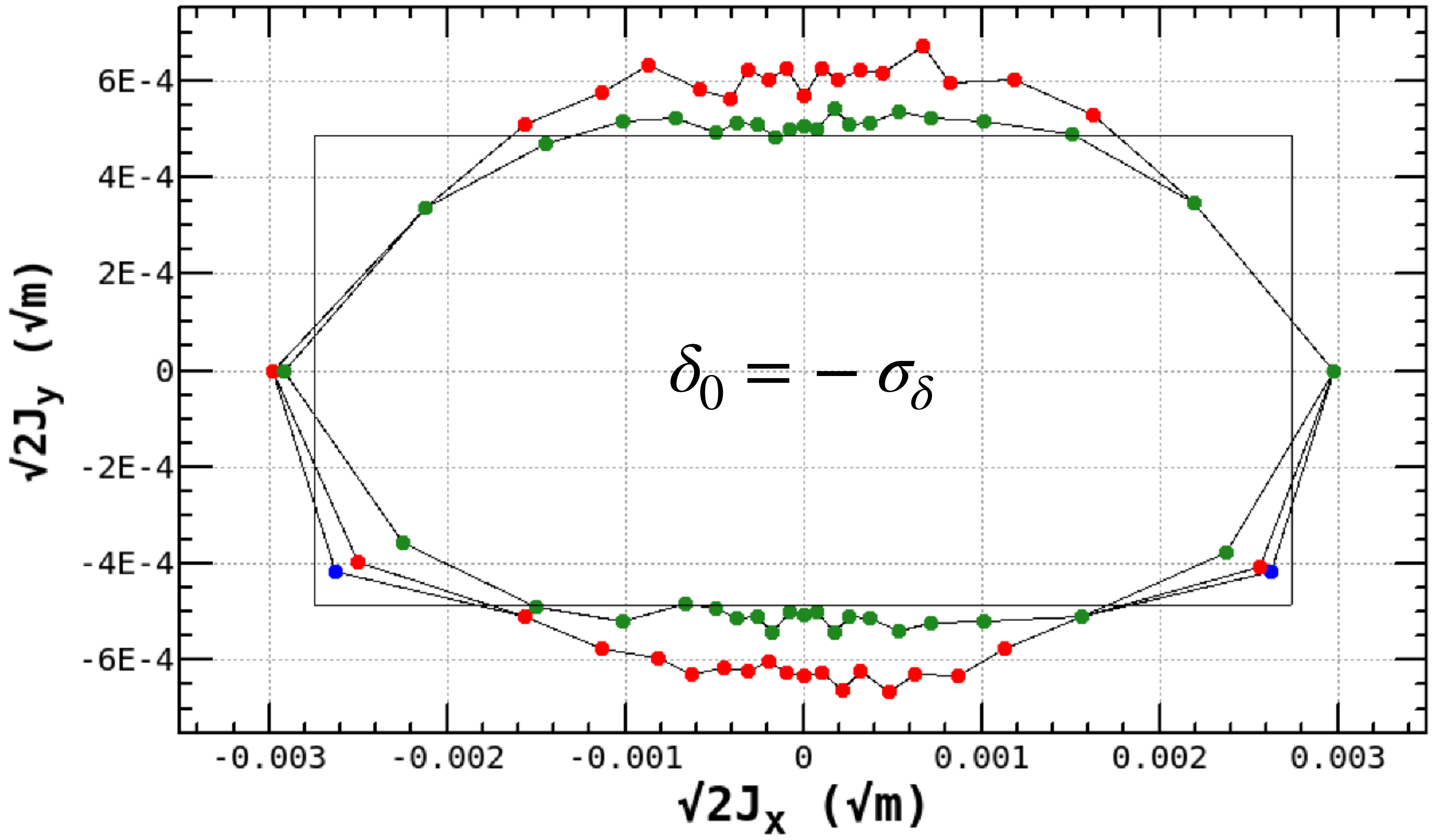
Tested three different vertical apertures for QC1

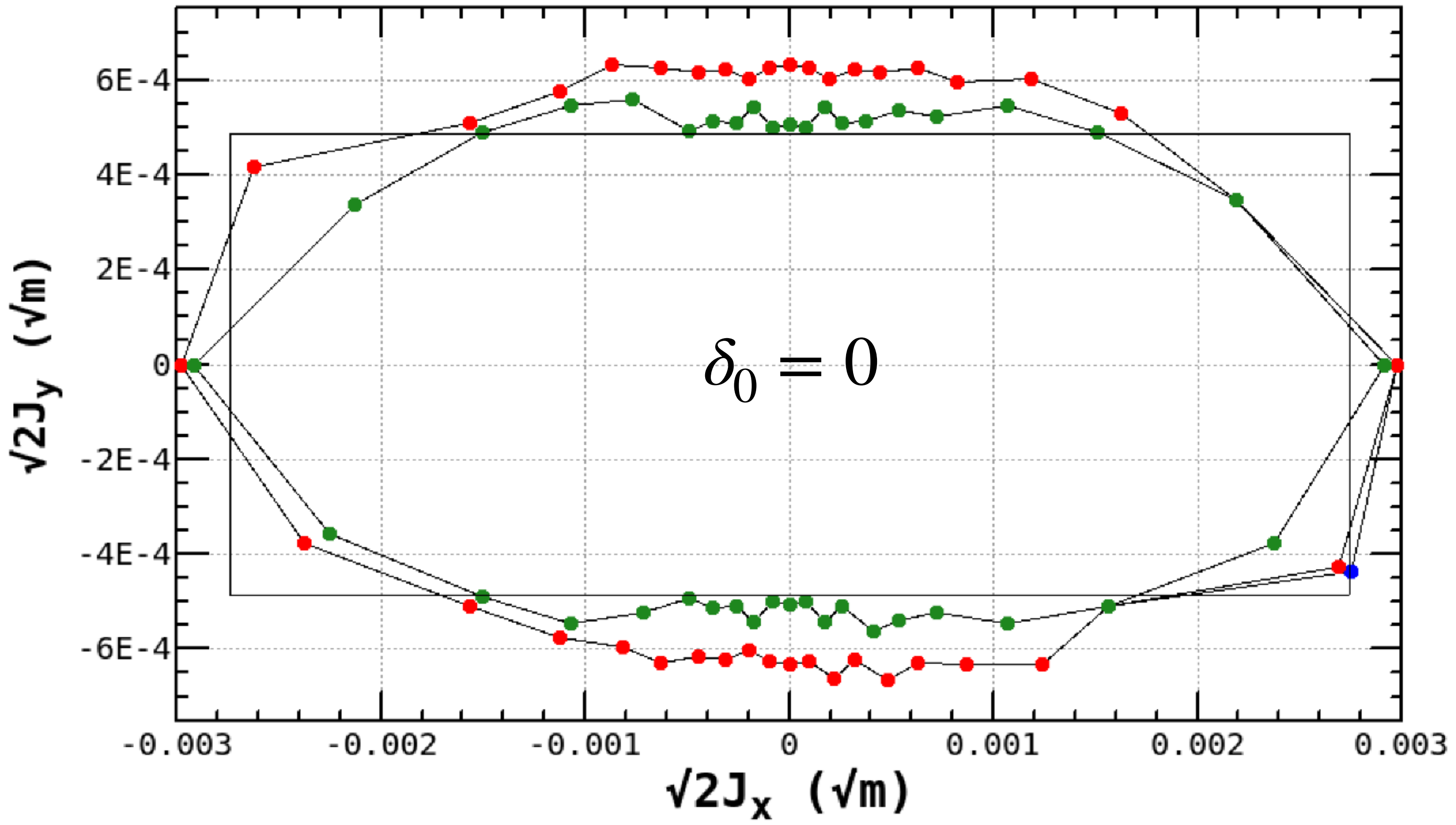
is determined by the physical aperture of QC1 and QC2

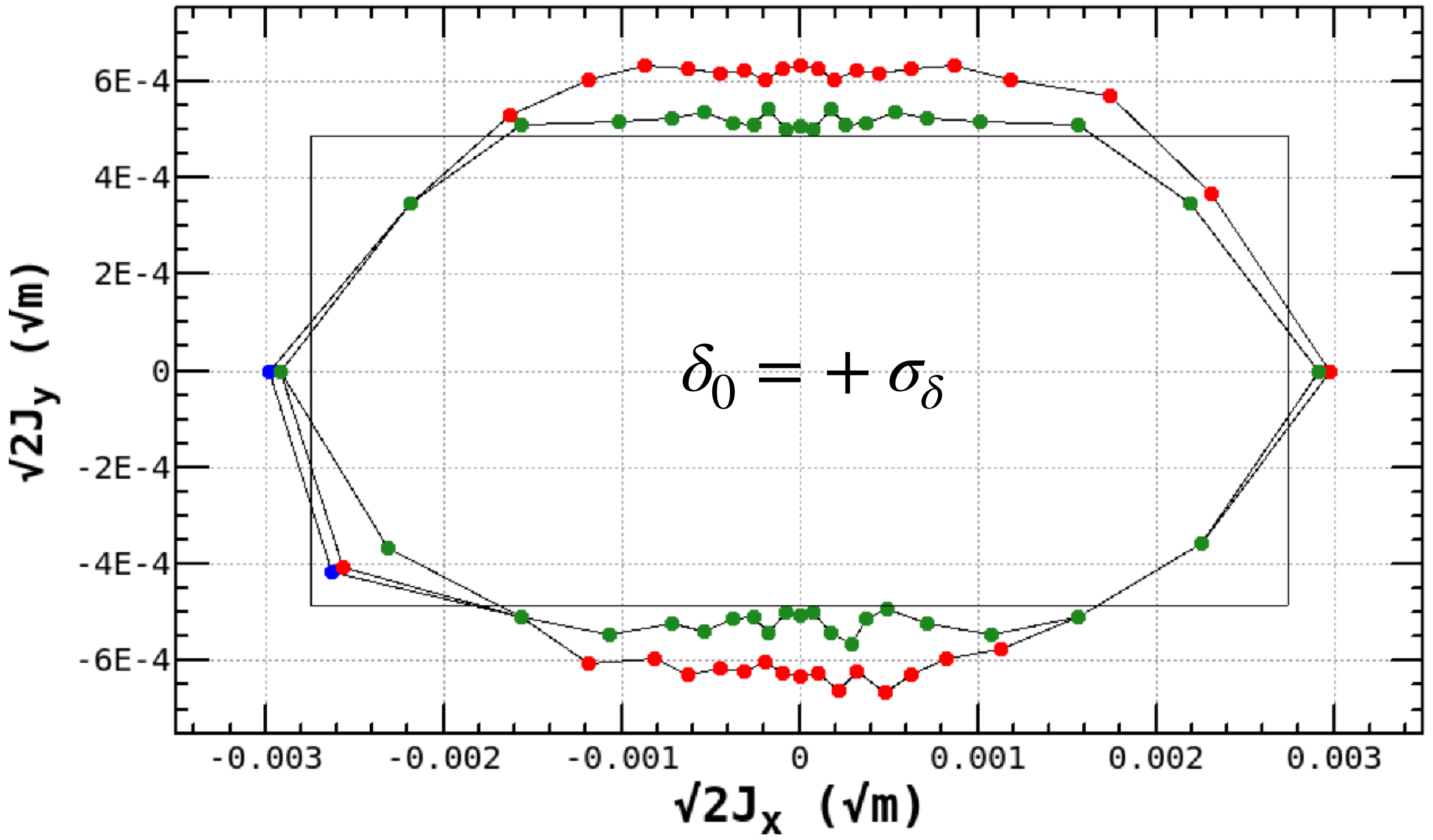
Horizontal dynamic aperture is reduced by the crab waist scheme.

If the vertical physical aperture of QC1P is increased to 17 mm, the stable region is extended in the small horizontal amplitude. (Above 17 mm is limited by the dynamic aperture.)

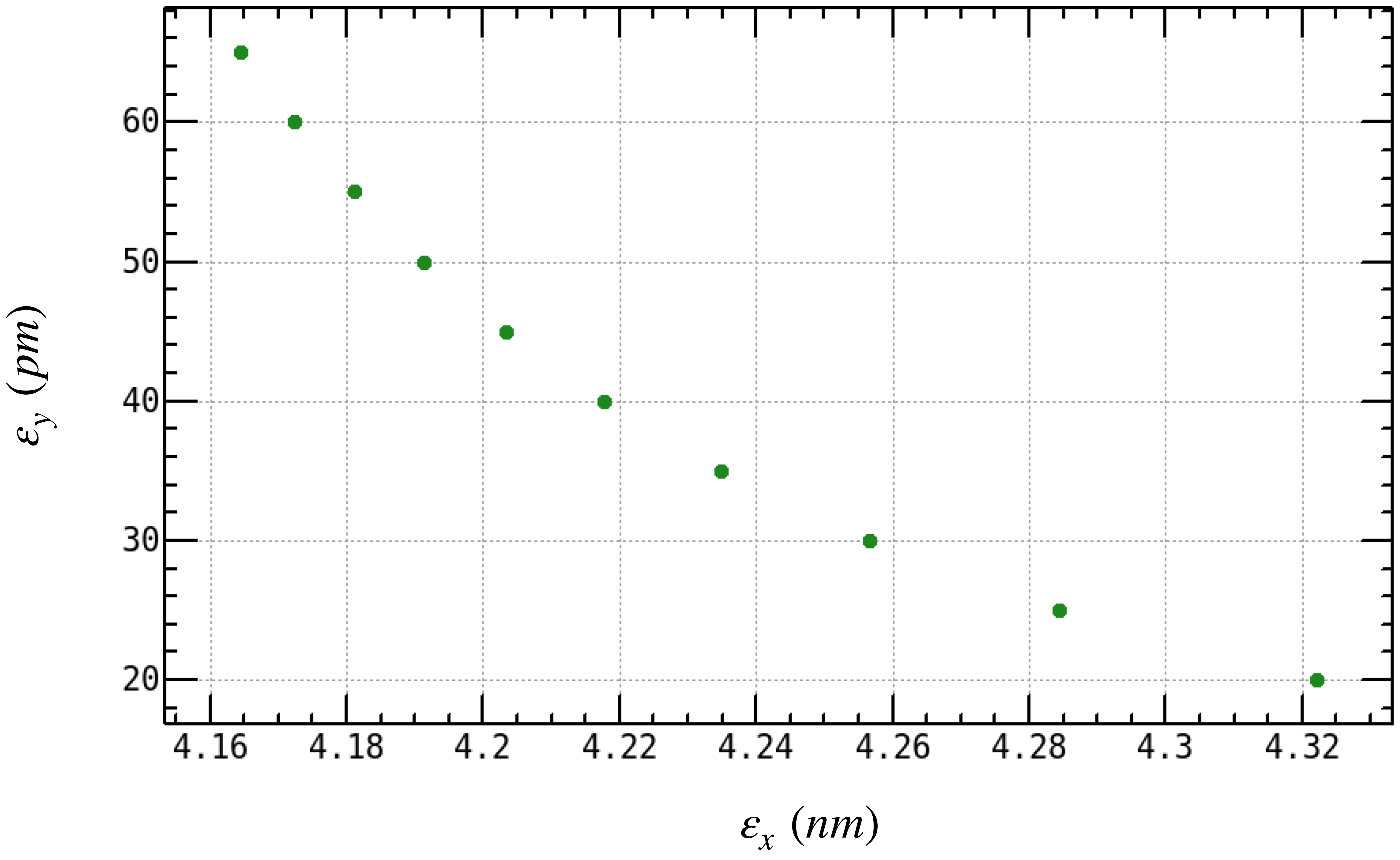
CW 0 %







I_b = 0.6 mA


60
50
40
30
20
4.16
4.18
4.2
4.22
4.24
4.26
4.28
4.3
4.32
ε_y (pm)
ε_x (nm)