Optics matching for LER

Aug. 27, 2021

K. Oide @ SuperKEKB Long-term Planning Meeting

Many thanks to H. Koiso, Y. Suetsugu, and the SuperKEKB/Belle II teams.

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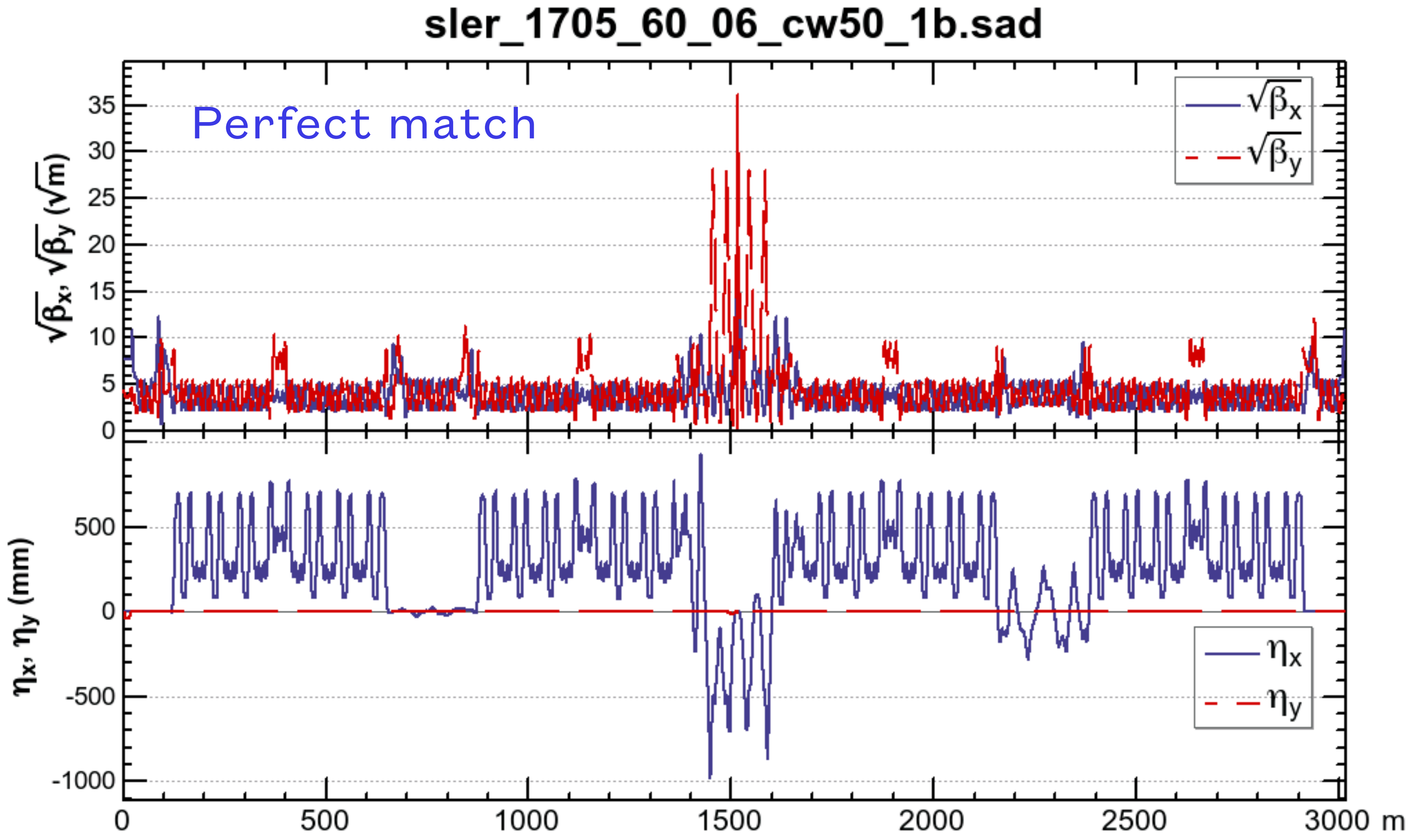
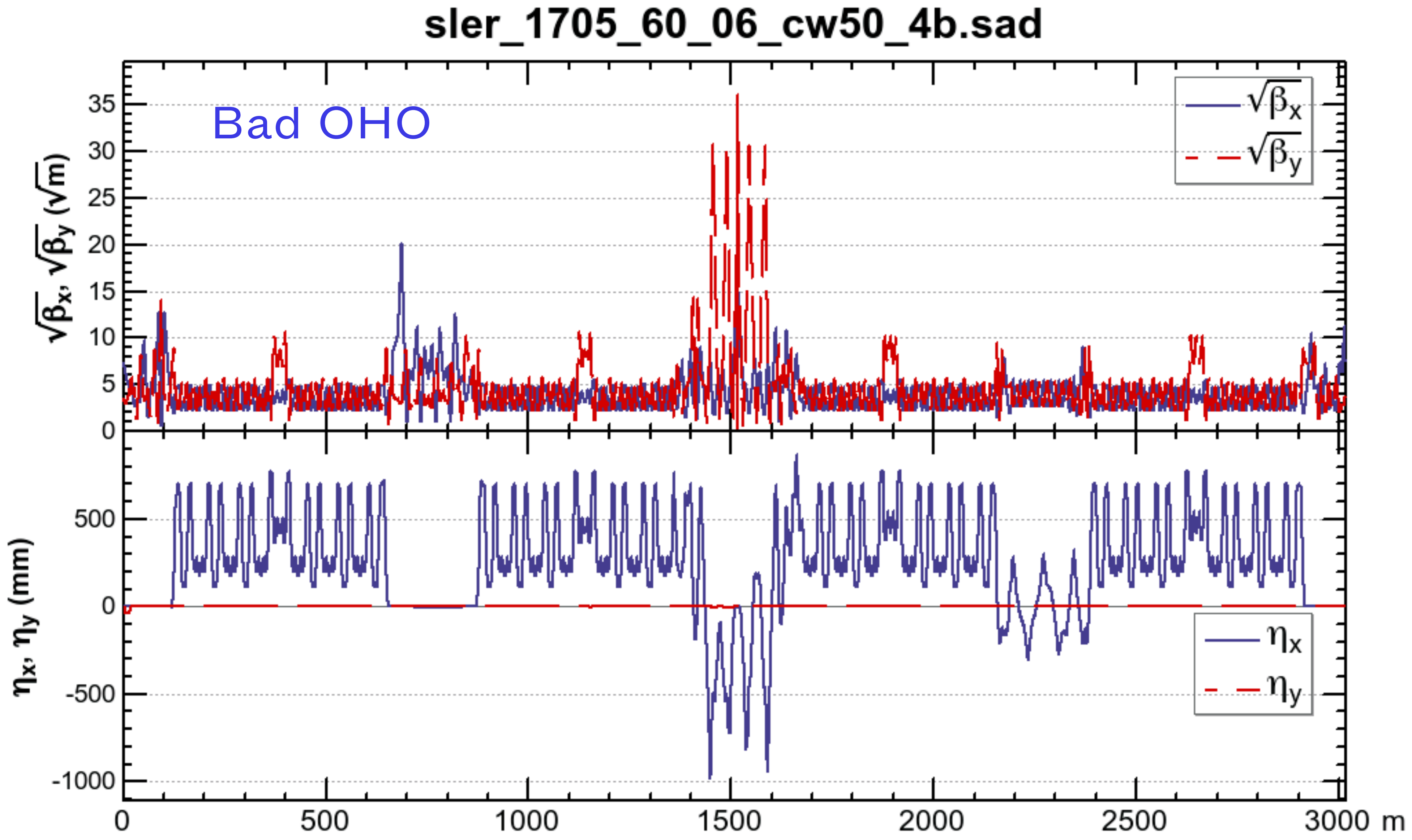
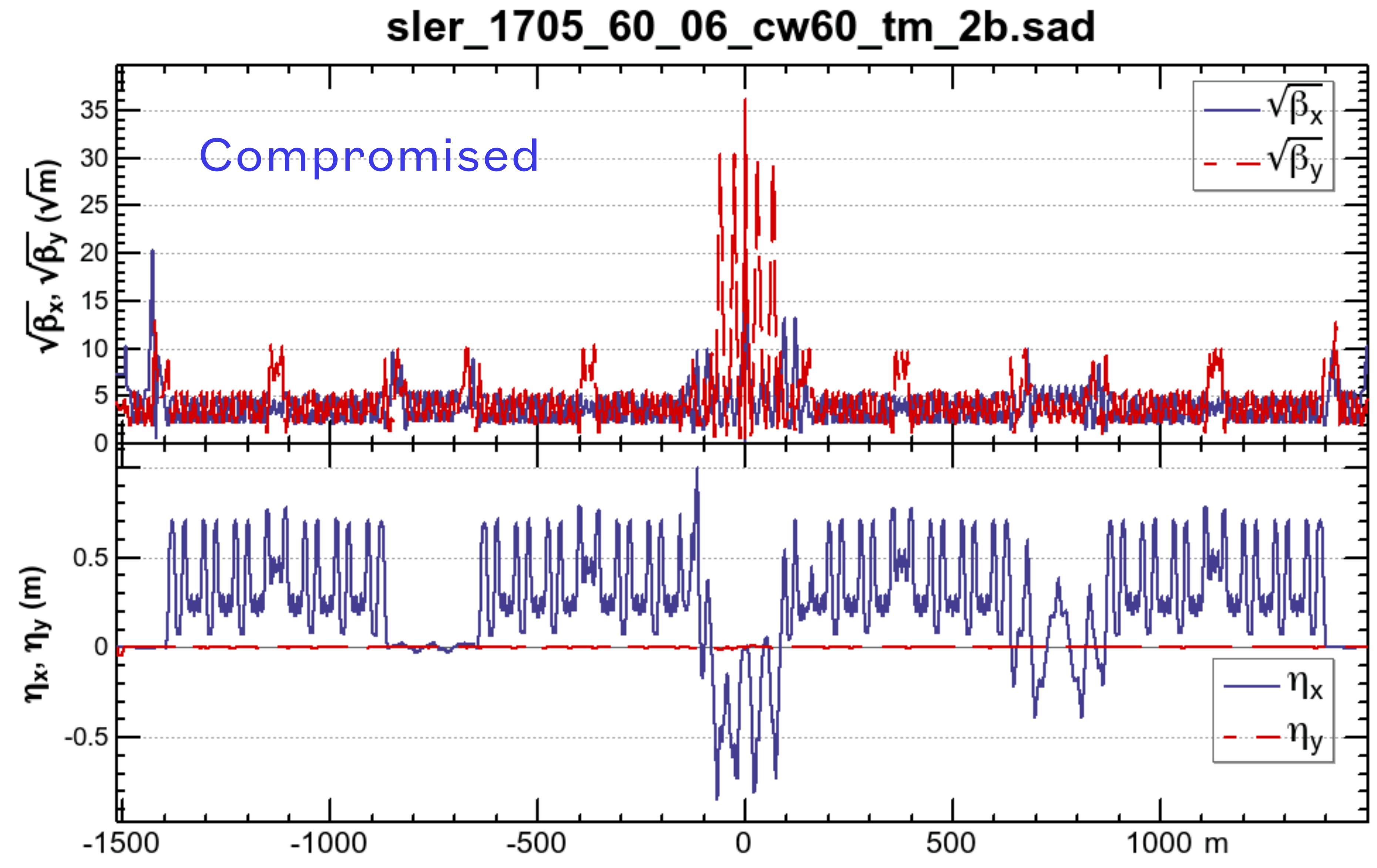
Comparison of beam optics

- Three LER optics are examined at $\beta^*_{x,y} = (60,0.6)$ mm for $\mathscr{L} \approx 1 \times 10^{35}\,/\mathrm{cm}^2 s$.
  - "Bad OHO": inherited and squeezed from the given optics, having an irregular optics at OHO, which might have been introduced by KO.
  - "perfect": adjusted phases and βs at SLY to be ideal. Also rectified optics all around the ring. Skew components in QLCs and QKs, which do not exist, are introduced.
  - "compromised": Relaxed the conditions for SLC and the IP from "perfect", by *using only existing magnets*. Rest of the ring optics is basically same as "perfect".

Comparison of optics



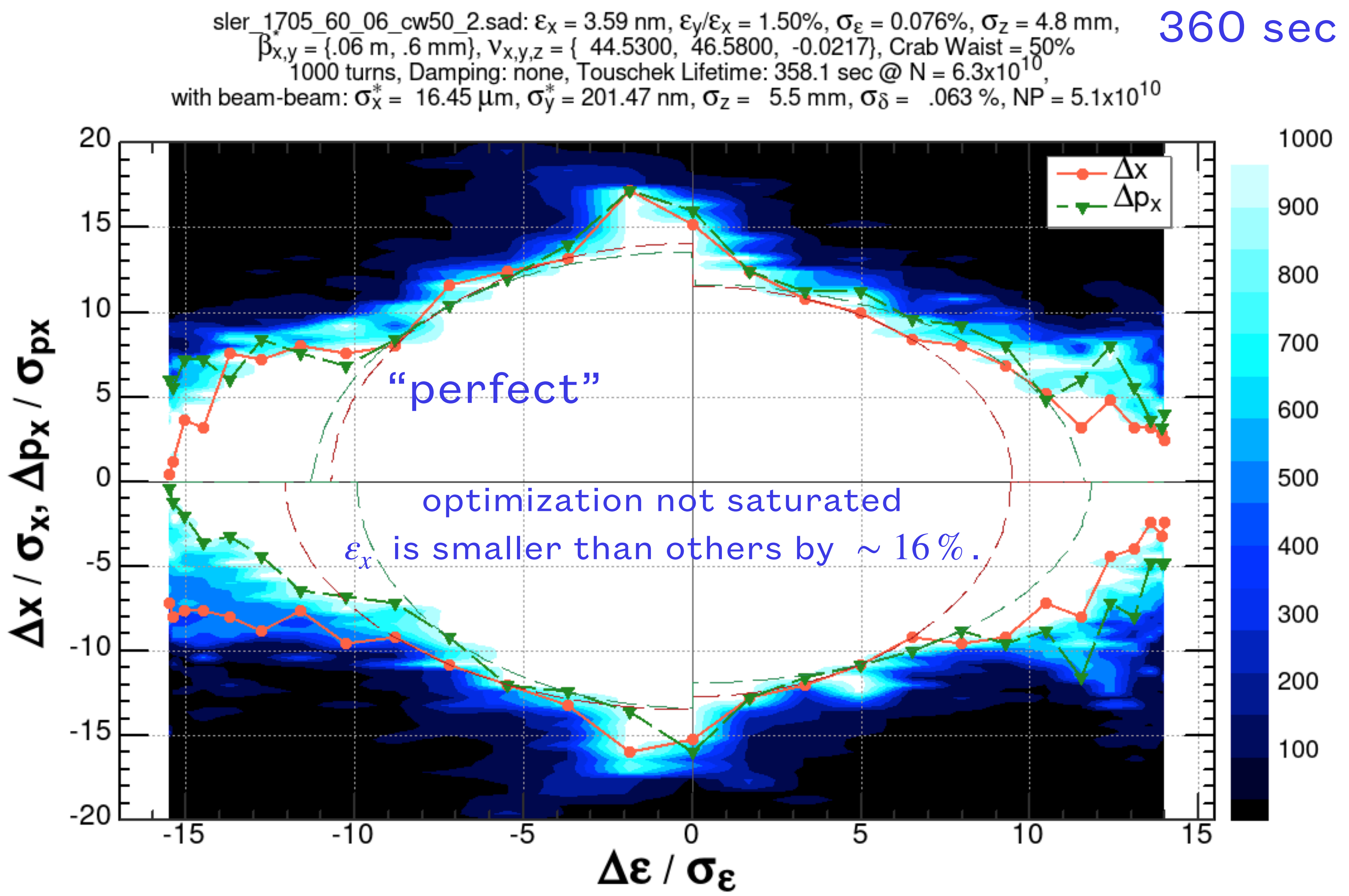


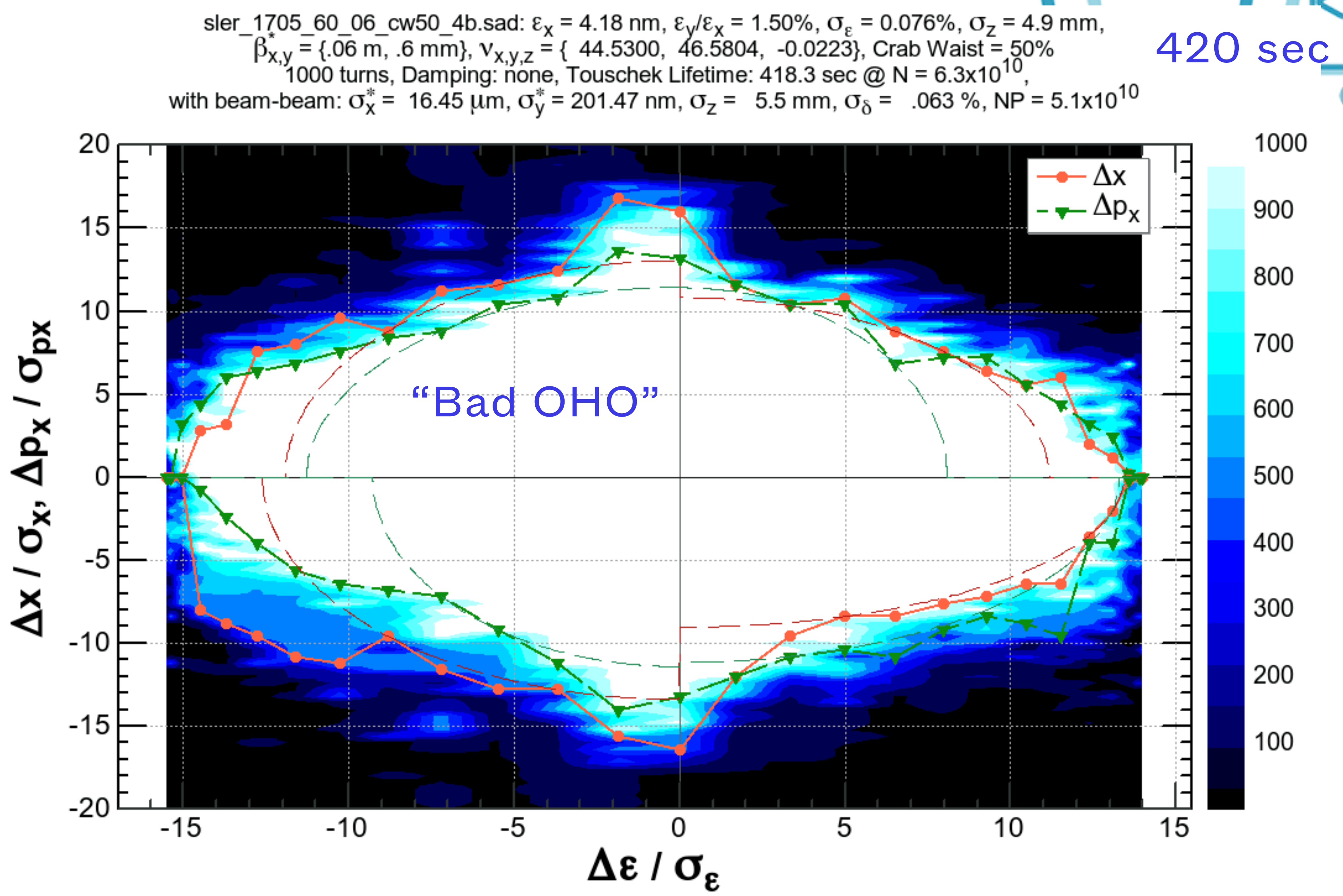


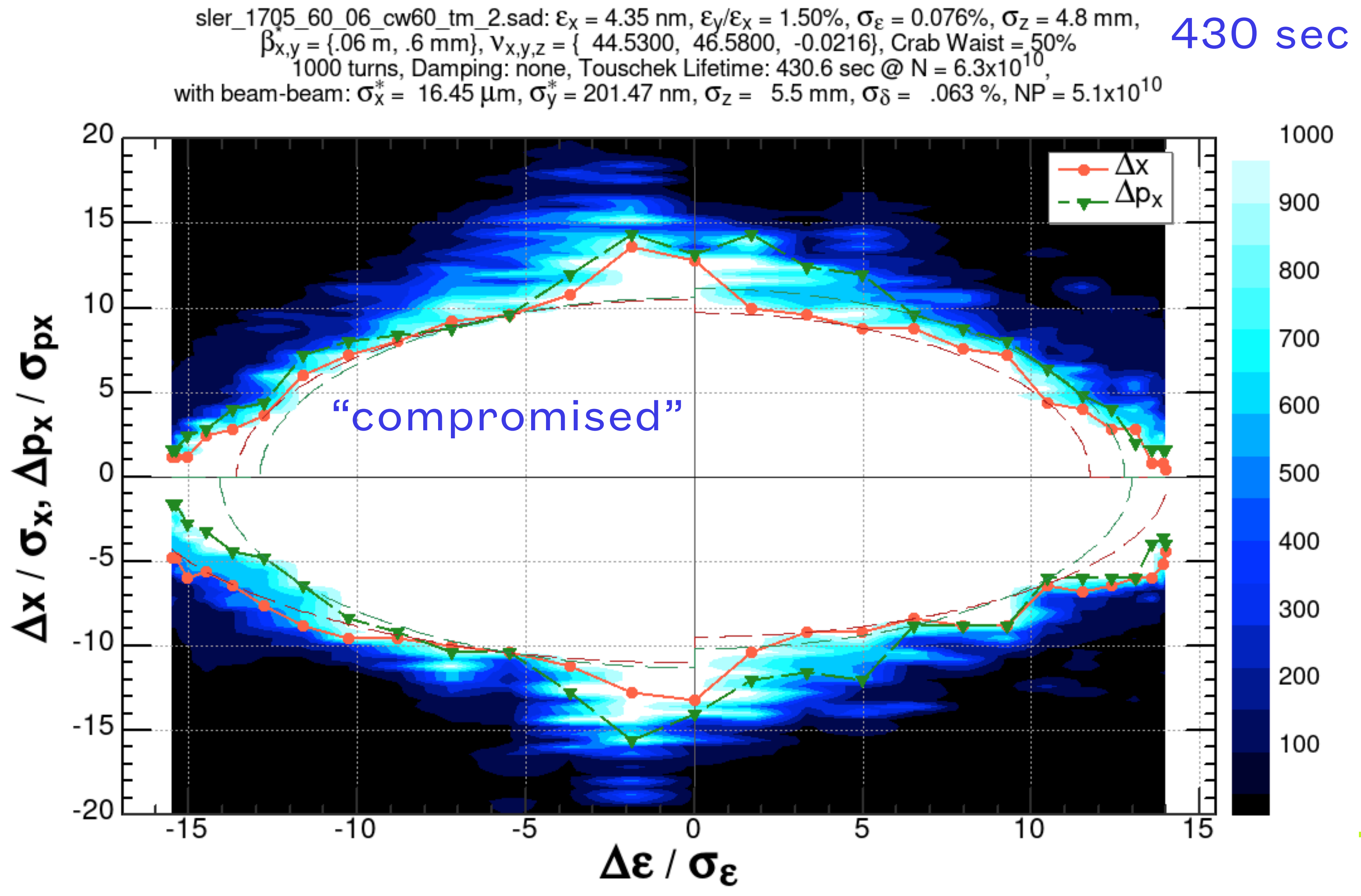
Parameters		"Bad OHO"	"compromised"	"perfect"
$\beta^* x/y$, LER=HER	mm		60 / 0.6	
Hor. emittance LER/HER	nm	4.2 / 4.5	4.4 / 4.5	3.6 / 4.5
$\varepsilon_{y0}/\varepsilon_x$, LER=HER	%		1.5	
Bunch current LER/HER	mA		1.0 / 0.81	
Bunches/ring			2200	
Bunch length[1] LER/HER	mm		4.8 / 5.5	
Energy spread[1] LER/HER	10^{-4}		7.6 / 6.3	
Luminosity	$10^{34}/\mathrm{cm}^2\mathrm{s}$	11.4	11.1	12.2
$\Delta\psi_{x,y}/2\pi$ btw. IP & SLY		0.003	0.009	0.001
$\Delta\beta/\beta$ btw. SLY	%	0.13	3.6	0.011
$\Delta\eta_{px}$ @PQLY1C		0.01	0.01	0.0002
R_1, R_4 @IP		1×10^{-8}	0.012	1×10^{-10}
R_2 @IP	m	8×10^{-14}	7×10^{-6}	2×10^{-14}
R_3 @IP	1/m	5×10^{-6}	0.21	3×10^{-10}
η_y @IP	m	1×10^{-14}	2×10^{-6}	5×10^{-15}
η_{py} @IP		3×10^{-14}	1×10^{-5}	6×10^{-13}

[1] @zero impedance

Dynamic aperture (with beam-beam, CW = 50%)







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Scaling of Lifetime

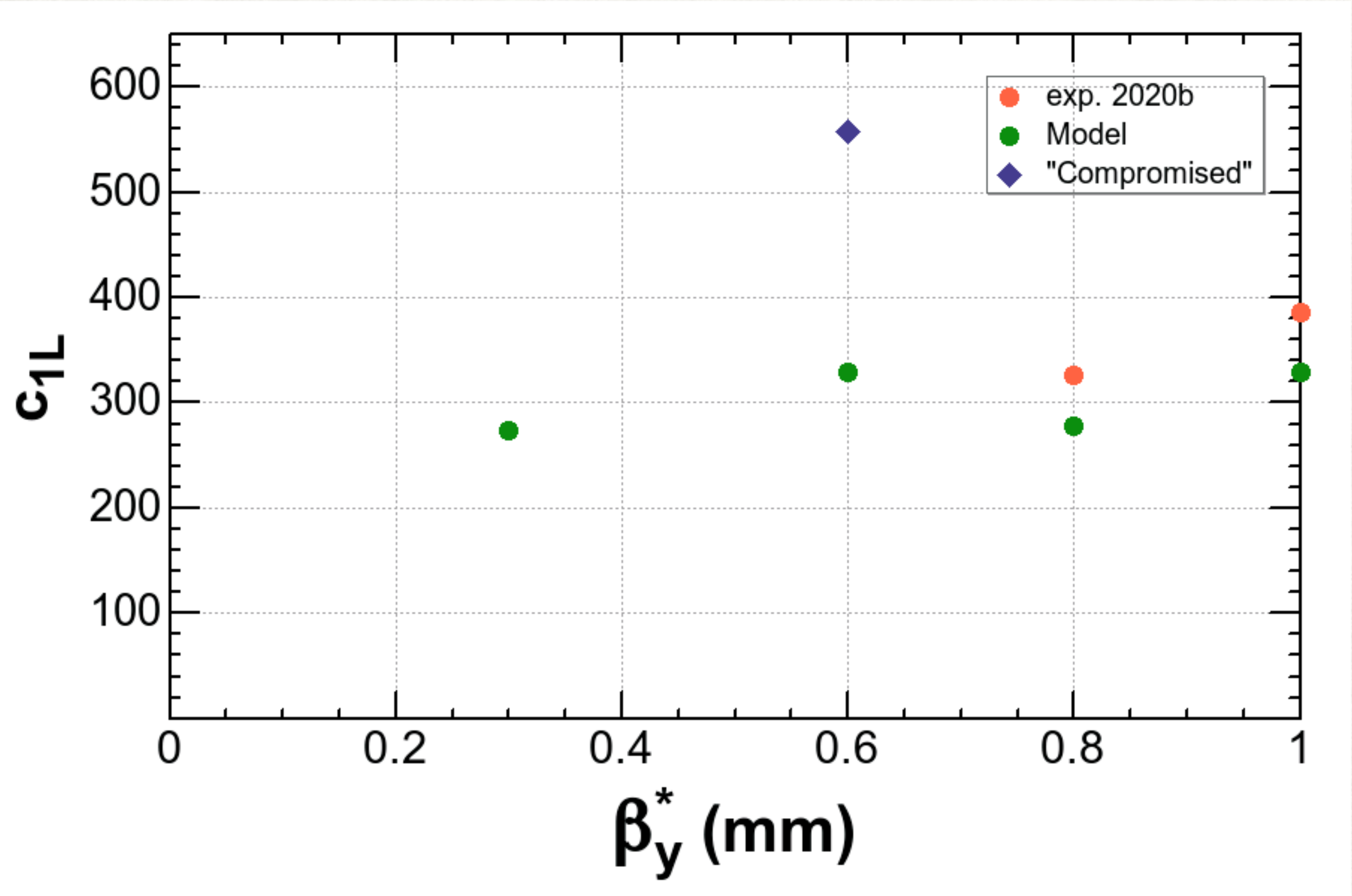
According to these results, the Touschek lifetime is roughly fitted by:

$$\tau \approx c_{1L}(CW, \varepsilon_x, \beta_x^*, \dots) \left(\frac{\beta_y^*}{\text{mm}}\right) \left(\frac{\varepsilon_y}{\text{pm}}\right)^{1/2} \left(\frac{N}{10^{10}}\right)^{-1} \quad (1)$$

with

$$c_{1L}(80\%, 4.5\ \text{nm}, 60\ \text{mm}) \approx 300\ \text{sec}, 2020\ \text{optics}\,, \quad (2)$$

$$c_{1L}(80\%, 4.5\ \text{nm}, 60\ \text{mm}) \approx 560\ \text{sec}, \text{“compromized” optics}\,. \quad (3)$$



SuperKEKB : June 21, 2020		SuperKEKB : July 1, 2020		Unit
LER	HER	LER	HER	
4.0	4.6	4.0	4.6	nm
712	607	536	530	mA
978		978		
0.728	0.621	0.548	0.542	mA
760	1270	600	1177	sec
17.9	16.6	15.5	16.6	μm
0.403		0.317		μm*1
0.285		0.224		μm*2
44.523 / 46.581	45.531 / 43.577	44.525 / 46.581	45.531 / 43.574	
80 / 1.0	60 / 1.0	60 / 0.8	60 / 0.8	mm
10.7	12.7	12.3	12.7	
80	40	80	40	%
0.0389	0.0261	0.0345	0.0199	
5.43 x 10^{31}		6.90 x 10^{31}		$cm^{-2}s^{-1}/mA^2$
2.40 x 10^{34}		2.00 x 10^{34}		$cm^{-2}s^{-1}$

Y. Ohnishi @KEKB-ARC 2020

Beam-beam tune survey (BBWS+SAD)

$\sqrt{\frac{\varepsilon_{y0}}{\varepsilon_y}}$

$\beta^*_{x,y} = (60,0.6)\,\mathrm{mm},\ \mathscr{L} = 1\times10^{35}\,\mathrm{cm^{-2}s^{-1}}$

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Summary

- Three LER optics are examined: “perfect”, “Bad OHO”, “compromised” with $\beta^*_{x,y} = (60,0.6)$ mm for $\mathscr{L} \approx 1 \times 10^{35}\,/\mathrm{cm}^2 s$.
- The dynamic aperture and the lifetime look insensitive to these optics.
- The luminosity performance is somewhat worse for “Bad OHO”.
- The “compromised” optics using only existing magnets looks OK for the lifetime and the luminosity. This optics can be tried immediately in the next run.
- CW = 50% is also OK up to the HER bunch current $\lesssim 0.8\,\mathrm{mA}$.
- Above assumes:
  - chromatic coupling correction by rotating sexts.
  - No impedance.
  - No lattice errors.