

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.

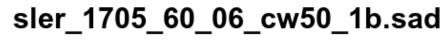
Work supported by KEK via K. Furukawa, Y. Suetsugu, M. Tobiyama, S. Yamaguchi, M. Yamauchi, as well as by FCC-ee via M. Benedikt & F. Zimmermann.

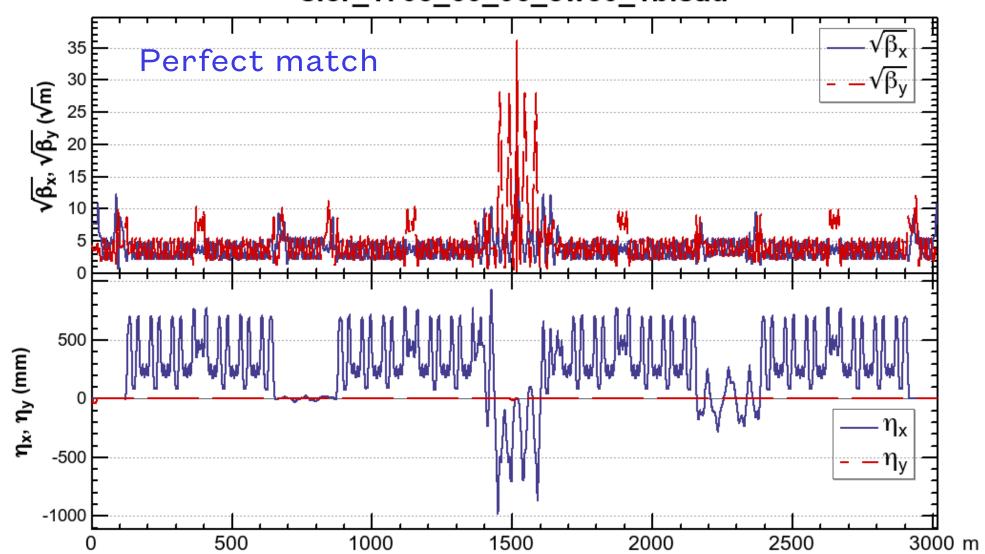
Comparison of beam optics

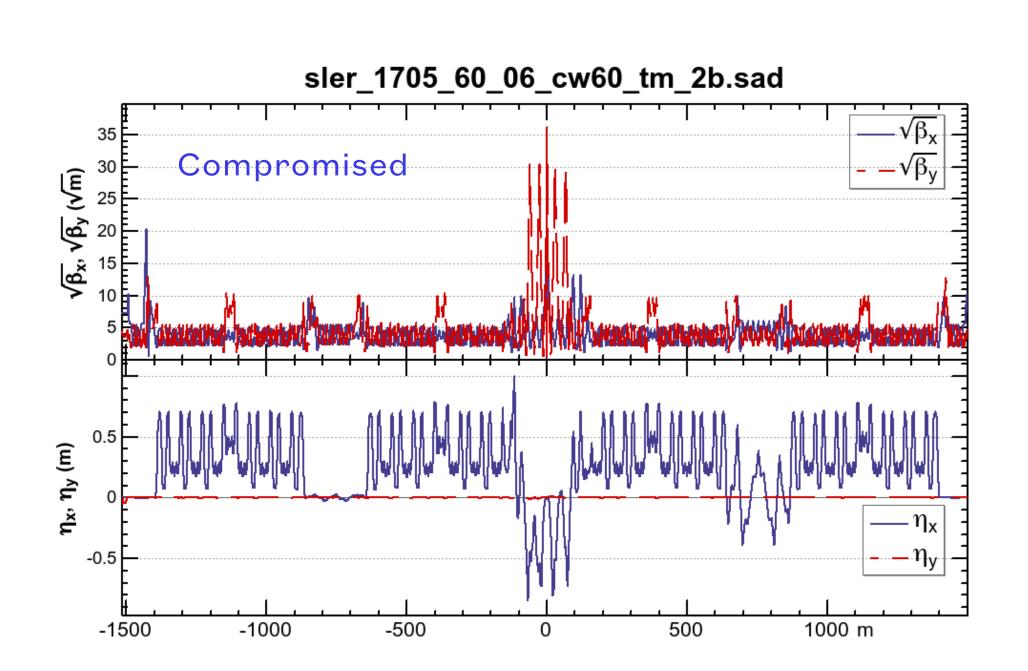


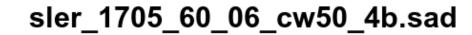
- Three LER optics are examined at $\beta_{x,y}^* = (60,0.6)$ mm for $\mathcal{L} \approx 1 \times 10^{35}$ /cm²s.
 - "Bad OHO": inherited and squeezed from the given optics, having an irregular optics at OHO, which might have been introduced by KO.
 - "perfect": adjusted phases and β s at SLY to be ideal. Also rectified optics all around the ring. Skew components in QLOs 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



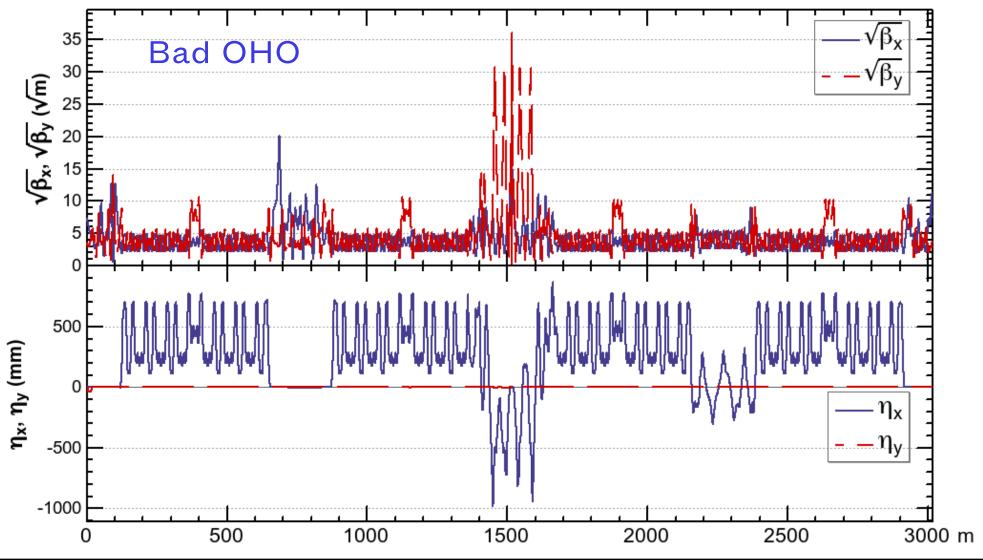






Super

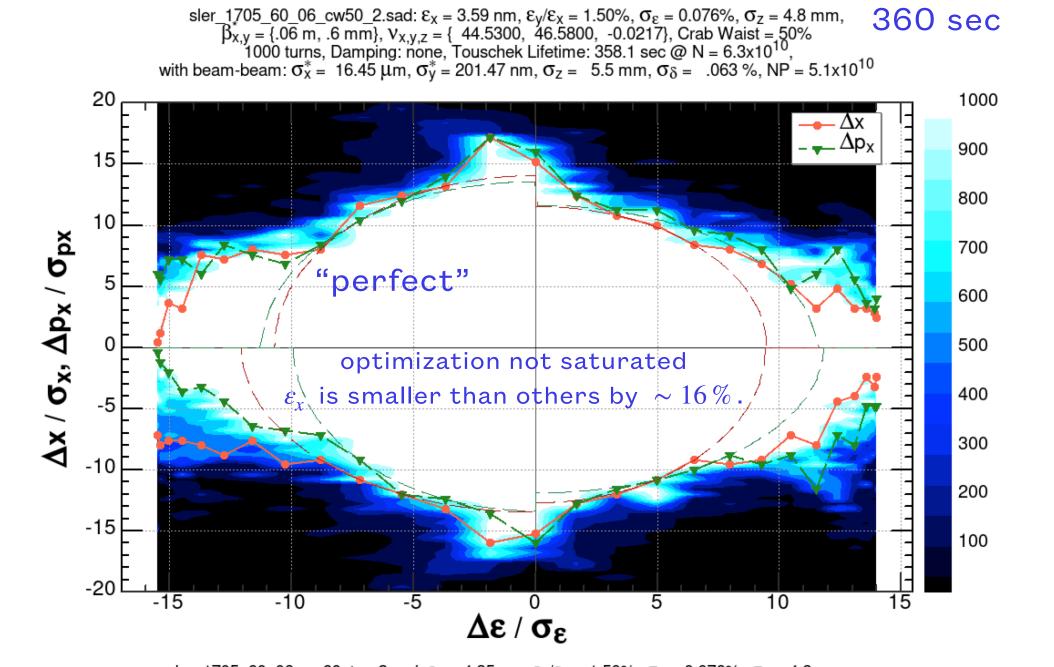
KEKB

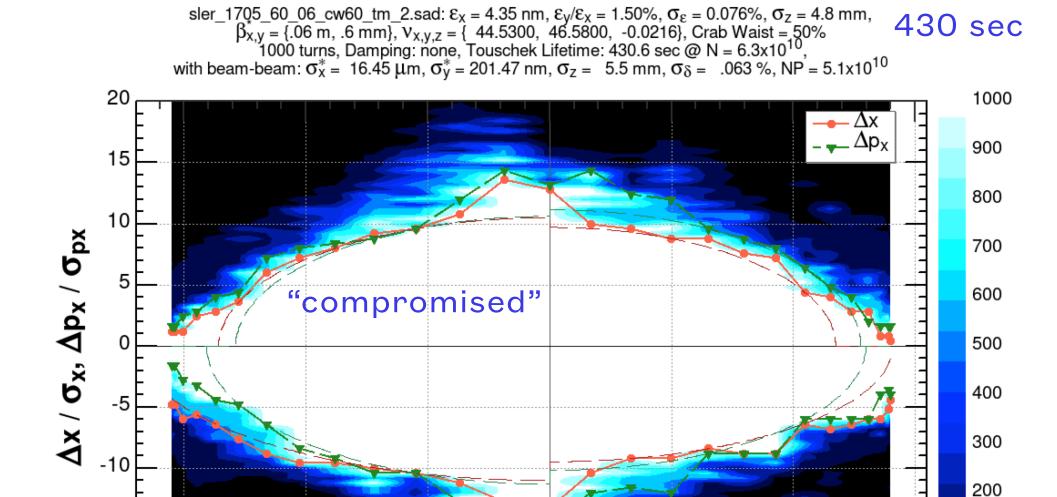


Parameters		"Bad OHO"	"compromised"	"perfect"
β^*x/y , LER=HER	mm		60 / 0.6	
Hor. emittance LER/HER	nm	4.2 / 4.5	$4.4 \; / \; 4.5$	3.6 / 4.5
$\varepsilon_{y0}/\varepsilon_x$, LER=HER	%		1.5	
Bunch current LER/HER	mA	1.0 / 0.81		
Bunches/ring			2200	
Bunch length ¹ LER/HER	mm		$4.8 \; / \; 5.5$	
Energy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

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





 $\Delta \epsilon$ / σ_{ϵ}

5

10

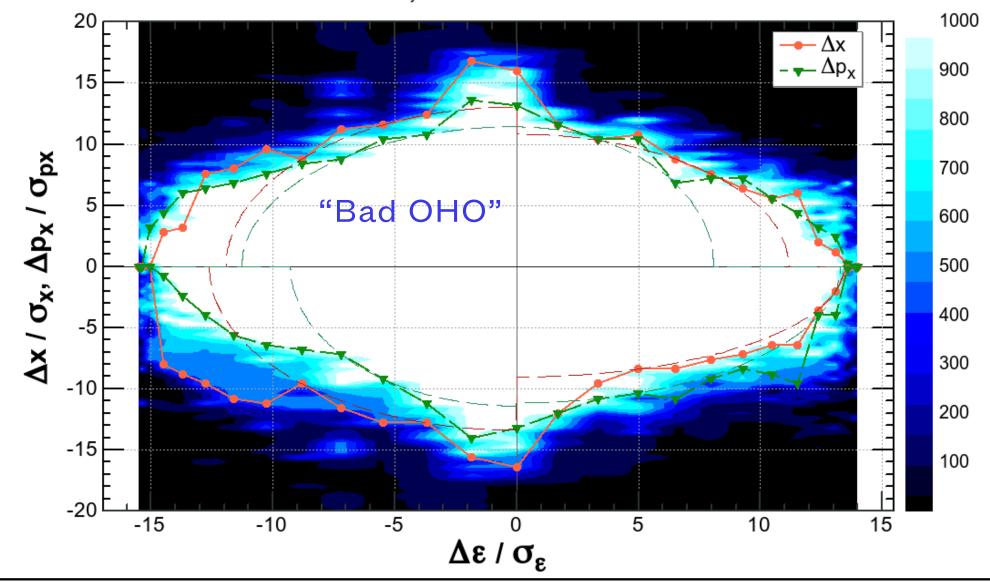
-15 🗀

-10

200

sler_1705_60_06_cw50_4b.sad: $\epsilon_{\rm X}$ = 4.18 nm, $\epsilon_{\rm y}/\epsilon_{\rm X}$ = 1.50%, σ_{ϵ} = 0.076%, $\sigma_{\rm Z}$ = 4.9 mm, $\beta_{\rm X,y}$ = {.06 m, .6 mm}, $\nu_{\rm X,y,Z}$ = { 44.5300, 46.5804, -0.0223}, Crab Waist = 50% 1000 turns, Damping: none, Touschek Lifetime: 418.3 sec @ N = 6.3x10¹⁰, with beam-beam: $\sigma_{\rm X}^*$ = 16.45 μ m, $\sigma_{\rm V}^*$ = 201.47 nm, $\sigma_{\rm Z}$ = 5.5 mm, σ_{δ} = .063 %, NP = 5.1x10¹⁰

420 sec



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	$10^{34}/{\rm cm}^2{\rm s}$	11.4	11.1	12.2
$\Delta\psi_{x,y}/2\pi$ btw. IP & SLY		0.003	0.009	0.001
$\Delta eta/eta$ 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	\mathbf{m}	8×10^{-14}	7×10^{-6}	2×10^{-14}
R_3 @IP	$1/\mathrm{m}$	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}

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Scaling of Lifetime



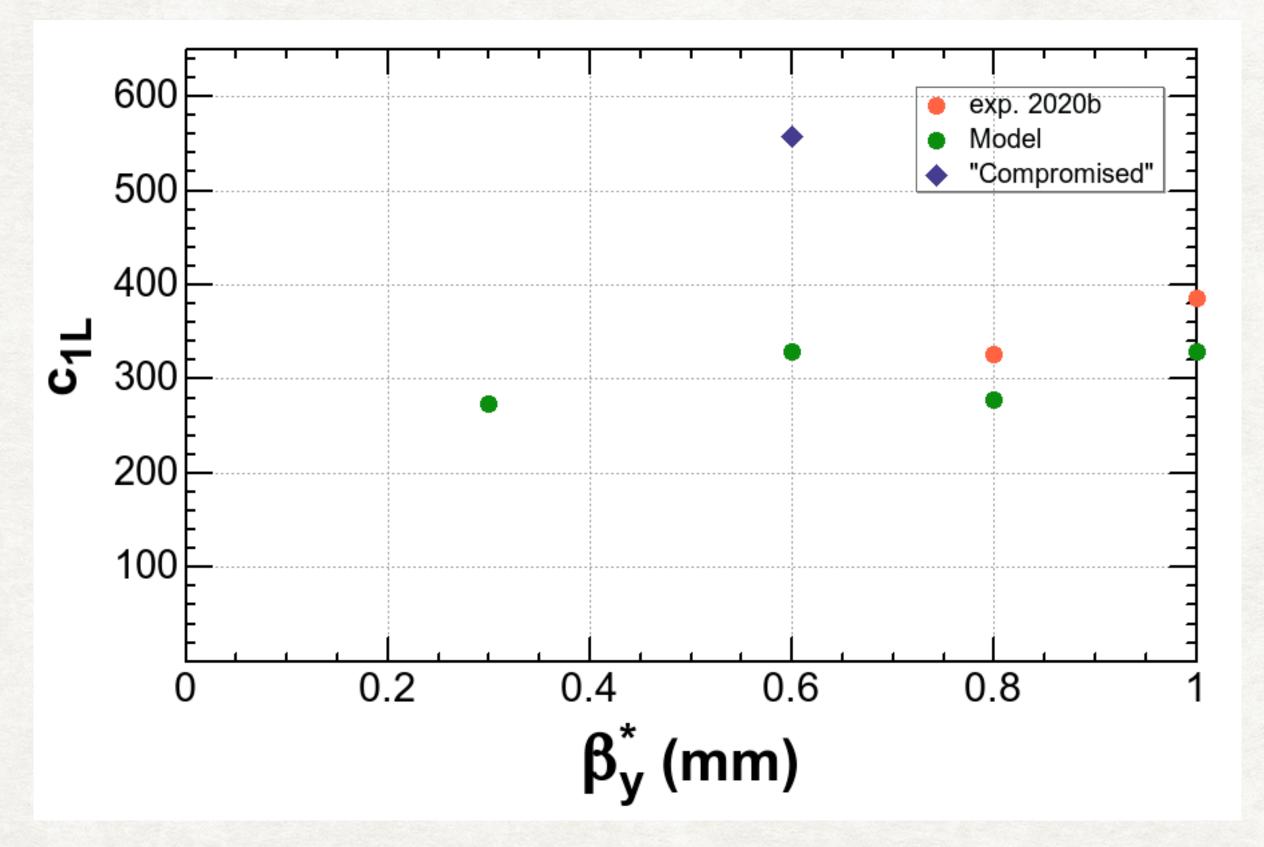
According to these results, the Touschek lifetime is roughly fitted by:

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

with

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

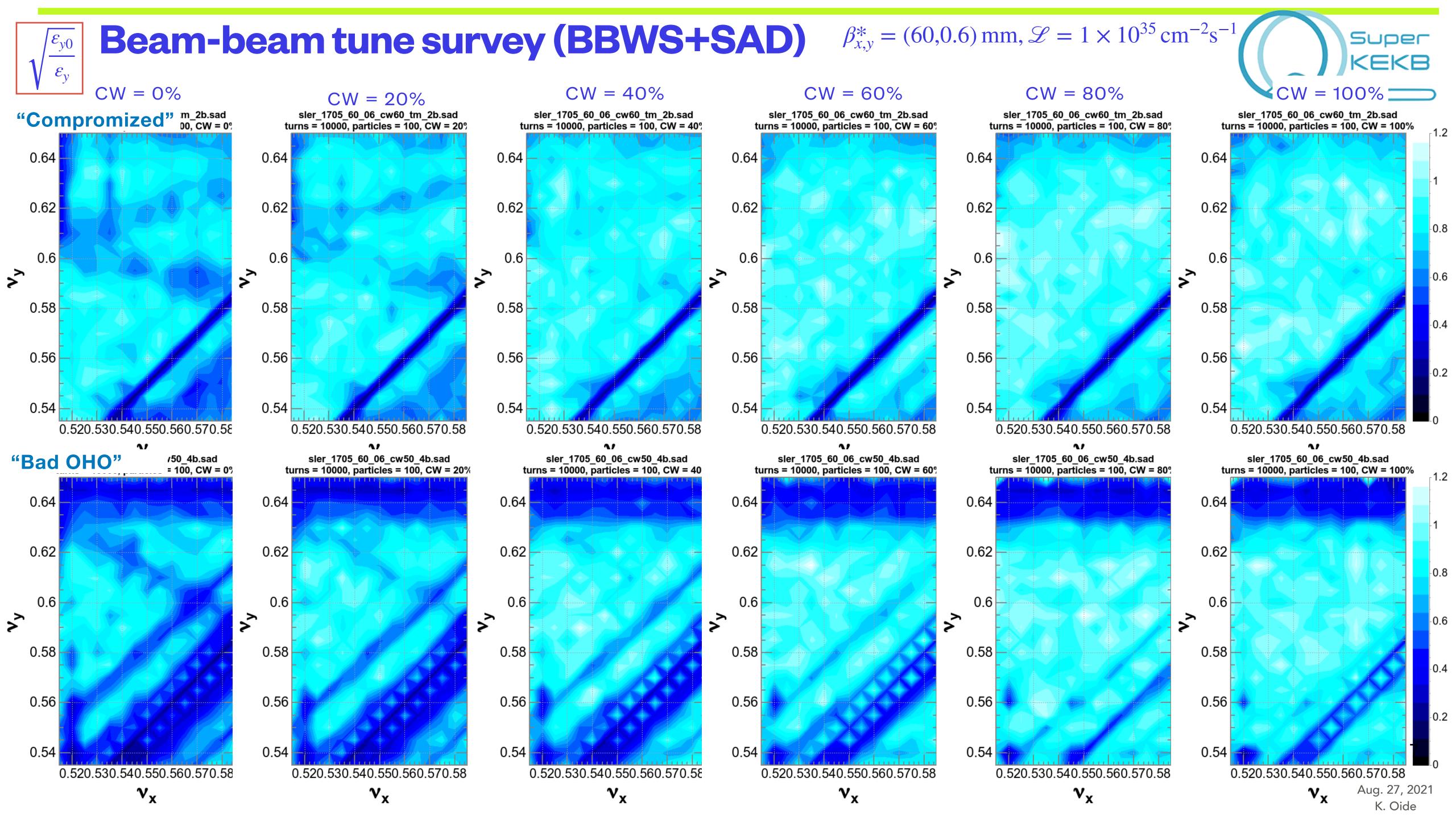
$$c_{1L}(80\%, 4.5 \text{ nm}, 60 \text{ mm}) \approx 560 \text{ sec}$$
, "compromized" optics. (3)

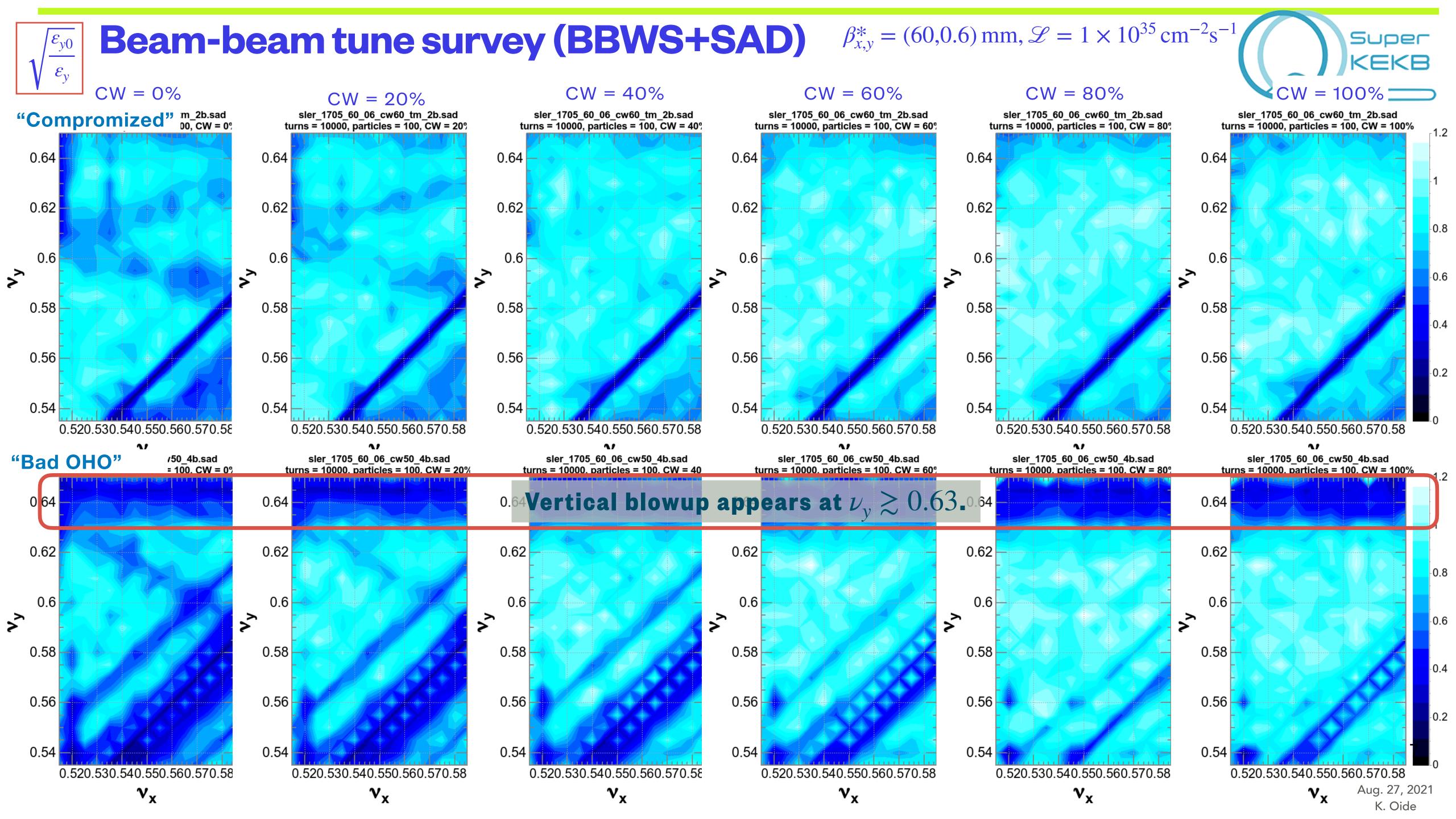


SuperKEKB : June 21, 2020		SuperKEKB:	Unit	
LER	HER	LER	HER	
4.0	4.6	4.0	4.6	nm
712	607	536	530	mA
978		97	978	
0.728	0.621	0.548	0.542	mA
760	1270	600	1177	sec
17.9	16.6	15.5	16.6	μm
0.403		0.3	μm* ¹	
0.285		0.2	μm*²	
44.523 / 46.581	45.531 / 43.577	44.525 / 46.581	45.531 / 43.574	
80 / 1.0	60 / 1.0	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	$cm^{-2}s^{-1}/mA^2$	
2.40 x 10 ³⁴		2.00	cm ⁻² s ⁻¹	

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 $\beta_{x,y}^* = (60,0.6) \,\text{mm}, \mathcal{L} = 1 \times 10^{35} \,\text{cm}^{-2} \text{s}^{-1}$ Beam-beam tune survey (BBWS+SAD) Super CW = 40%CW = 0%CW = 60%CW = 80%CW = 100%CW = 20%Compromized 60_tm_2b.sad = 100, CW = 0% sler_1705_60_06_cw60_tm_2b.sad turns = 10000, particles = 100, CW = 20% sler_1705_60_06_cw60_tm_2b.sad turns = 10000, particles = 100, CW = 80% sler_1705_60_06_cw60_tm_2b.sad turns = 10000, particles = 100, CW = 60% sler_1705_60_06_cw60_tm_2b.sad sler_1705_60_06_cw60_tm_2b.sad turns = 10000, particles = 100, CW = 40% turns = 10000, particles = 100, CW = 100% 0.64 0.64 0.64 0.64 0.64 0.64 0.62 0.62 0.62 0.62 0.62 0.62 0.6 0.6 **~ >** 0.58 0.58 0.58 0.58 0.58 0.58 0.56 0.56 0.56 0.56 0.56 0.56 0.54 0.54 0.54 0.54 0.54 0.54 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 sler_1705_60_06_cw50_1b.sad sler 1705 60 06 cw50 1b.sad "perfect match" turns = 10000, particles = 100, CW = 20% turns = 10000, particles = 100, CW = 40 turns = 10000, particles = 100, CW = 60% turns = 10000, particles = 100, CW = 809 turns = 10000, particles = 100, CW = 100% 0.64 0.64 0.64 0.64 0.64 0.64 0.62 0.62 0.62 0.62 0.62 0.62 0.6 0.6 0.6 0.6 0.6 0.6 0.58 0.58 0.58 0.58 0.58 0.58 0.56 0.56 0.56 0.56 0.56 0.56 0.2 0.54 0.54 0.54 0.54 0.54 0.54 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 0.520.530.540.550.560.570.58 Aug. 27, 2021 ν_{x} v_{x} $\mathbf{v}_{\mathbf{x}}$ v_{x} \mathbf{v}_{x} K. Oide





Summary



- Three LER optics are examined: "perfect", "Bad OHO", "compromised" with $\beta_{x,y}^* = (60,0.6) \, \text{mm}$ for $\mathcal{L} \approx 1 \times 10^{35} \, \text{/cm}^2 s$.
- 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 $\lesssim 0.8 \text{ mA}$.
- Above assumes:
 - chromatic coupling correction by rotating sexts.
 - No impedance.
 - No lattice errors.