Demonstrating Linear Collider Final Focus Systems in SuperKEKB

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Outline

- Motivation for testing future LC FFS in SuperKEKB.
- Results from initial low β_y^* simulations in SuperKEKB LER.

FFTB and the traditional CCS

- Two separate high dispersive regions, each with two sextupoles, correct horizontal and vertical chromaticity respectively.
- Advantage: easier to tune.
- Tested in the FFTB, where a vertical beam size $\sigma_y^* = 70 \pm 7$nm was achieved[1].

[1] A. Alexandrof et al. "Results of Final Focus Test Beam", IEEE, 4, pp.2742-2746 (1996).

ATF2 and the compact CCS

- Sextupoles for chromaticity correction are interleaved with the FD.
- Shorter FFS.
- Still unsolved discrepancy between experiment and simulations.

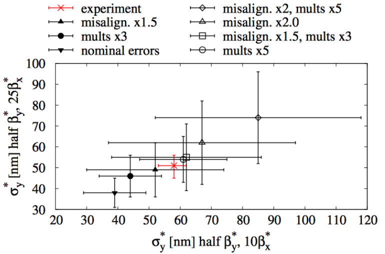


FIG. 11. The IP beam sizes measured in ATF2 (red) and obtained with simulations without the orbit correction (black) for half β_y^*, $10\beta_x^*$ and half β_y^*, $25\beta_x^*$ optics.

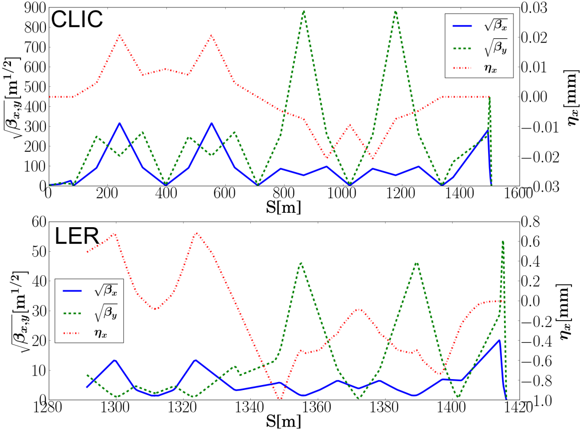
M. Patecki et al. "Probing Half β_y^* Optics in the Accelerator Test Facility 2", 10.1103/PhysRevAccelBeams.19.101001 (2016).

FFS chromaticity comparison

	L^*[m]	$\beta_y^*[\mu m]$	$\xi_y \sim (L^*/\beta_y^*)$
CLIC	3.5	70	50 000
ILC	3.5 /4.5	480	7300 /9400
ATF2	1	100	10 000
FFTB	0.4	100	4 000
SuperKEKB LER	0.935	270	3 460
SuperKEKB HER	1.41	410	3 440

- Nominal SuperKEKB will demonstrate chromaticity correction on same scale as FFTB.
- A factor 3 reduction of β_y^* in SuperKEKB would be on scale with ATF2 and ILC, but with the traditional CCS.

Chromaticity correction optics



- Comparison of FFS optics in SuperKEKB LER and in CLIC with the traditional CCS.

Increasing chromaticity in LER

- SuperKEKB LER lattice matched to reduced β_y^* by a factor 2, 2.5 and 3 using SAD[2].
- Dynamic aperture and Touschek lifetime optimized by varying sextupole strengths.

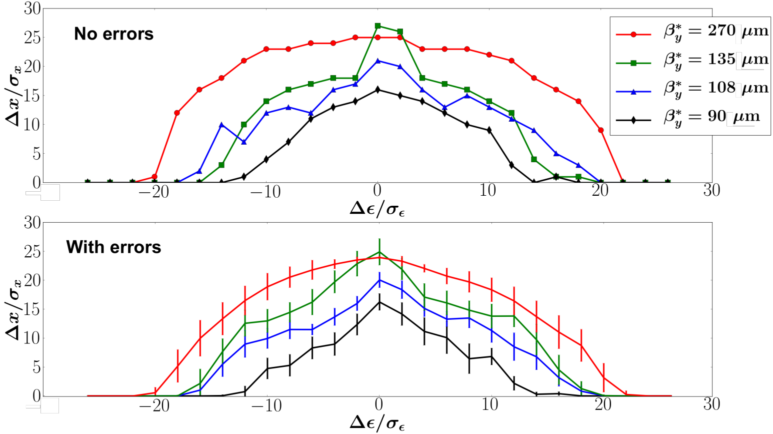
[2] http://acc-physics.kek.jp/SAD/

Effect of machine errors

- Only correction for tune and coupling.
- No errors added in the IR.

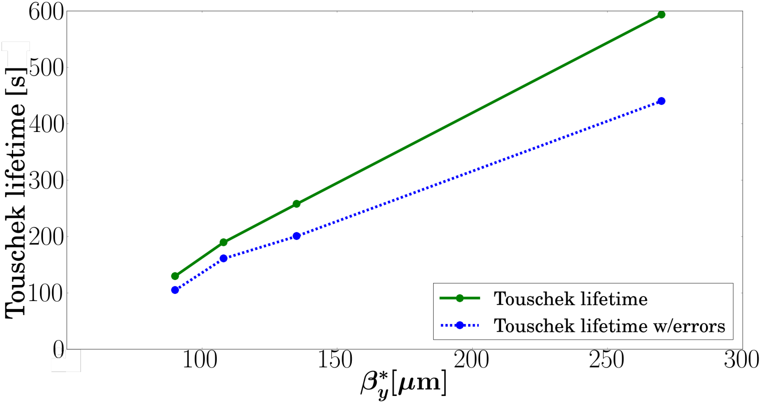
	$\sigma_\theta[\mu\text{rad}]$	$\Delta K/K$
Quadrupoles	100	2.5×10^{-4}
Sextupoles	100	2.5×10^{-4}

Dynamic aperture



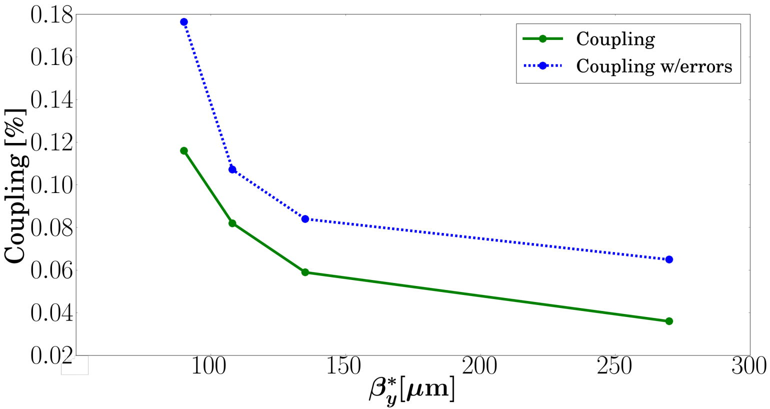
- Dynamic aperture reduction calculated for 110 machines with different lattice errors.
- Single particle tracking for 1000 turns, no beam-beam effect.

Touschek lifetime in LER



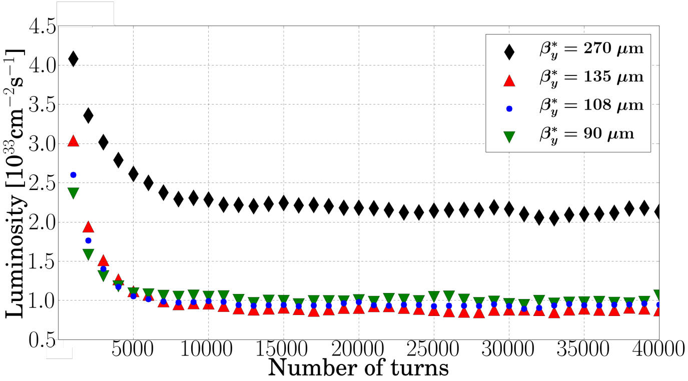
- Touschek lifetime estimated using nominal values for emittance and intensity.
- Errors have less effect on lifetime for lower β_y^* due to larger coupling (next slide).

Coupling



- Remaining emittance coupling ϵ_y/ϵ_x after correction.
- Not including beam-beam interaction. Coupling value for the nominal machine with the beam-beam effect is 0.27%.

Measuring β_y^* using luminosity measurements



- Luminosity estimated using a beam-beam tracking routine in SAD.
- LER intensity reduced by 72% to correspond to single turn injection.
- Important limitation is background in fragile Belle II detector as well as lifetime requirement.

Exploring possibility of using k-modulation

- Using k-modulation to measure β_y^* directly reduces needed intensity, and only needs beam in LER.
- Possibility looked at using a method developed for the LHC, but large fringe fields in the IR require a different approach.

Conclusions

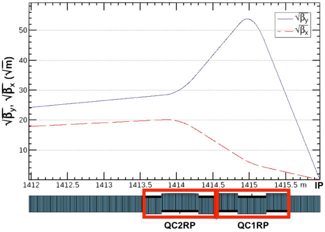
- Preliminary results show a reduction of β_y^* by a factor 3 might be possible in LER, testing the traditional CCS at levels comparable to ATF2 and ILC.
- Further work is needed to determine if k-modulation can be used to measure β_y^*.

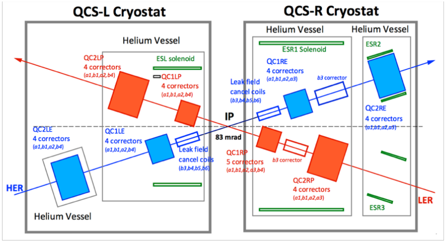
SuperKEKB Machine Parameters

	LER (e^+)	HER (e^-)	Unit
E	4.000	7.007	[GeV]
I	3.6	2.6	[A]
Number of bunches	2 500		
Bunch current	1.44	1.04	[mA]
Circumference	3 016.315		[m]
ϵ_x/ϵ_y	3.2/8.64	4.6/12.9	[nm/pm]
Coupling	0.27	0.28	[%]
β_x^*/β_y^*	32/0.27	25/0.30	[mm]
Crossing angle	83		[mrad]
α_p	3.18×10^{-4}	4.53×10^{-4}	
σ_δ	8.10×10^{-4}	6.37×10^{-4}	
V_c	9.4	15.0	[MV]
σ_z	6.0	5.0	[mm]
ν_s	-0.0244	-0.0280	
ν_x/ν_y	44.53/46.57	45.53/43.57	
U_0	1.86	2.43	[MeV]
$\tau_{x,y}/\tau_z$	43.2/21.6	58.0/29.0	[msec]
ξ_x/ξ_y	0.0028/0.0881	0.0012/0.807	
Luminosity	8×10^{35}		[$cm^{-2}s^{-1}$]

http://www-superkekb.kek.jp

IR in SAD lattice





Y. Funakoshi, Overview of SuperKEKB. Presentation at KEK Nov. 2013.

- IR model consists of 10 mm slices containing magnetic multipole fields for all IR elements.
- Quadrupole field component of focusing magnets are varied while higher order multipole fields are kept constant.