TOUSCHEK EFFECT IN SUPER CHARM TAU FACTORY

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Abstract

Super Charm Tau Factory (SCTF) is a proposed electron-positron double ring collider with a crab waist collision scheme. It is designed to operate within a wide beam energy range from 1.5 GeV to 3.5 GeV, with a peak luminosity of 10^{35} $cm^{-2}s^{-1}$. The work describes studies of the Touschek effect in SCTF, in addition to the results of a simulation of Touschek scattering, MOGA optimisation of local momentum acceptance, and an investigation into the dependence of the dynamic aperture and Touschek lifetime on the average orbit error.

INTRODUCTION

The primary challenges of Super Charm Tau Factory (SCTF) are small dynamic aperture and the Touschek lifetime at required beam parameters for achieving peak luminosity of 10^{35} $cm^{-2}s^{-1}$ [1]. In this work we use 68 version of SCTF lattice. Table 1 shows the SCTF parameters for the mode with the required peak luminosity (Set 1) and with a minimum satisfactory lifetime of more than 300 seconds (Set 2). It can be seen that for the required peak luminosity, the lifetime is three times lower than the minimum satisfactory lifetime. We used multi-objective genetic algorithm (MOGA) to optimize energy aperture and consequently the Touschek lifetime.

Touschek scattering simulation was performed to verify that the calculation of the lifetime is correct, and also to find out in what places of the collider the largest number of particles is lost per unit time.

Since the magnetic elements of the collider can be manifactured and installed with a finite accuracy, which will not be ideal, it is of particular interest to study the effect of various errors on the dynamic aperture area and the lifetime of the beams. For simplicity, in this work the quantities of interest are calculated for sets of quadrupole lenses transverse misalignment errors for which the rms orbit error is up to 40 mkm.

Table 1: SCTF Parameters at 1.5 GeV (v.68)

Set	**1**	**2**
E(MeV)	1500	
Π(m)	935.874	
f_{RF} (MHz)	350	
2θ (mrad)	60	
β_x^*/β_y^* (mm)	100/1	
ϵ_y/ϵ_x (%)	0.5	
I (A)	2.9	0.65
$N_{e/bunch}\times 10^{-10}$	6	1.3
N_b/q	941/1093	983/1093
$U_0(keV)/V_{RF}(kV)$	91/1500	
ν_s	0.0153	
δ_{RF} (%)	1.98	
$\sigma_e\times 10^3$ (SR/IBS+WG)	0.27/1.1	0.27/0.9
σ_s (mm) (SR/IBS+WG)	3.6/14	3.6/12
ϵ_x (nm) (SR/IBS+WG)	2/6.4	2/3.9
$L_{HG}\times 10^{-35}$ $(cm^{-2}s^{-1})$	1	0.075
ξ_x/ξ_y	0.005/0.12	0.001/0.04
$\tau_{Touschek}$ (s)	125	312
$\tau_{Luminosity}$ (s)	3500	10000

OPTIMIZATION OF TOUSCHEK BEAM LIFETIME

Optimization of Touschek lifetime can be done by optimizing local momentum aperture (LMA) along the ring. LMA can be found in tracking using code ELEGANT [2, 3] for accelerator design. We chose “MOGA optimizer for rings” code [4] distributed together with the ELEGANT for LMA optimization. Optimization goals are X-Y dynamic aperture area, the lifetime calculated by LMA at critical locations in the lattice (non-zero Courant-Snyder invariant, large changes in optical functions), and betatron tune chromaticities. The working point was kept constant as it was chosen considering space-charge effects and beam-beam effects to obtain high peak luminosity. Strength of sextupole and octupole lenses combined in -I pairs were chosen as variables for optimizer. Figure 1 shows that LMA has been optimized along the ring. From Figs. 2 and 3, it can be seen that the increase in LMA and energy aperture (EA) came at the expense of a decrease in dynamic aperture (DA). The lifetime for the optimized structure with beam parameters selected to obtain a luminosity of 10^{35} $cm^{-2}s^{-1}$ is 218 seconds, which is still less than minimum required lifetime of 300 seconds.

SIMULATION OF TOUSCHEK SCATTERING

The simulation of Touschek scattering was performed using the code ELEGANT, in which such simulation is implemented in touschek_scatter module. Simulation is done using Monte Carlo method for generation of scattered particles distributions between special elements TSCATTER [5, 6]. We chose to insert these elements after each magnetic element, as well as in places of rapid change of optical functions

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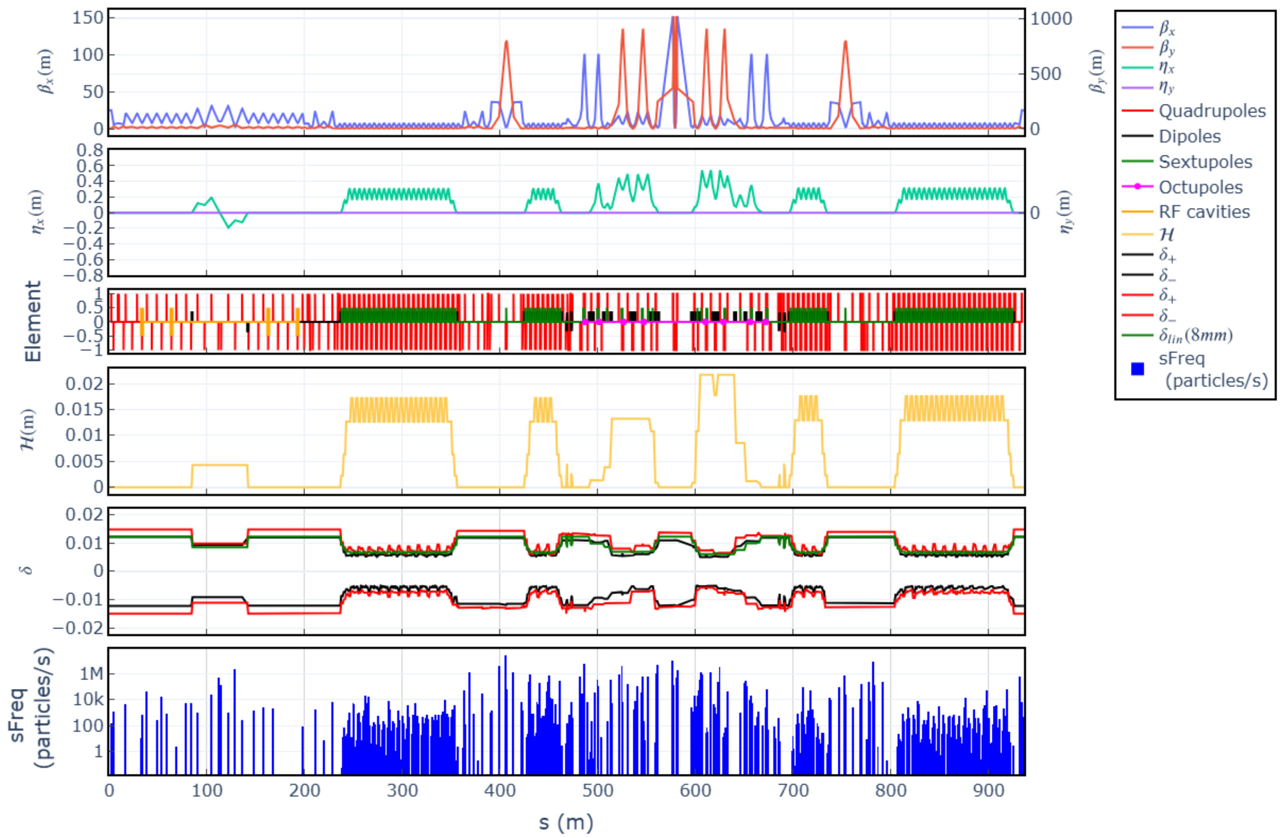

Figure 1: Betatron functions ($\beta_{x,y}$), dispertion functions ($\eta_{x,y}$), elements layout, Courant-Snyder invariant ($\mathscr{H}$), momentum aperture (δ, black - before optimization, red - optimized, green - linear approximation), particle losses (sFreq).

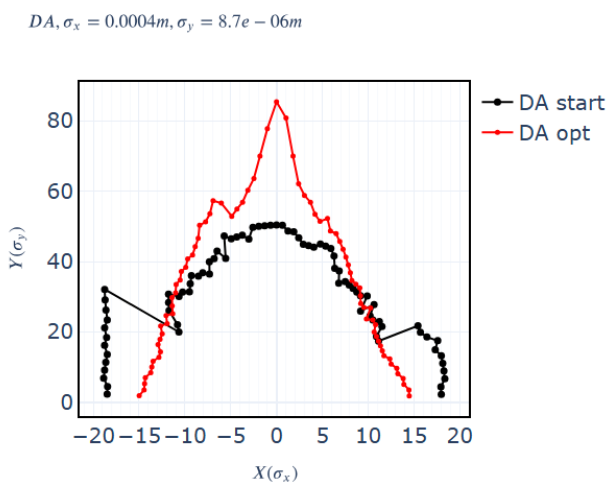

Figure 2: Dynamic aperture (DA) before and after MOGA optimization.

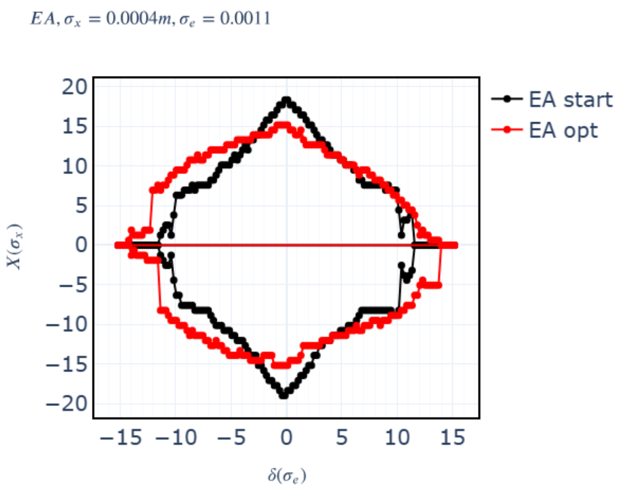

Figure 3: Energy aperure (EA) before and after MOGA optimization.

depending on azimuth. LMA along the entire ring is calculated in advance and used in particle distribution generation. In accordance with the Touschek effect theory, a particle is deemed to be lost if it exceeds the momentum aperture. We chose to observe particles with momentum deviation more than 0.8δ. For each TSCATTER element 5 million particles are simulated. Those particles are filtered by their contribution to scattering rate. For the purpose of tracking particles that contribute 95% of scattering rate are chosen. Anticipated margin of error is approximately 10%. The most significant particle losses have been observed to occur in locations characterised by both a small LMA and a large $\mathscr{H}$ invariant. The result of simulation for sets 1 and 2 is presented in Table 2.

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Table 2: Calculated Lifetime vs Simulated

Set	**1**	**2**
Calculated lifetime (s)	125	312
Simulated lifetime (s)	141	359

DEPENDANCE OF TOUSCHEK LIFETIME AND DYNAMIC APERTURE AREA ON AVERAGE ORBIT ERROR

Previous sections considered ideal lattice, but in reality there are many sources of errors which will influence beam dynamics and parameters of the collider. It is of interest to check the sensitivity of the lattice to small transverse misalignments of quadrupole lenses, which are sufficient to cause a RMS error of a closed orbit up to 40 mkm. This is not a full-fledged study of the effect of various errors on the beam dynamics, but it provides insight into the effect of small errors on lifetime and DA under near-operational conditions when the errors are compensated by correctors.

As seen from Fig. 4, for a 40 µm RMS closed orbit error, the lifetime reduction is about 40%, while the dynamic aperture area is reduced by 15% (but has a larger error).

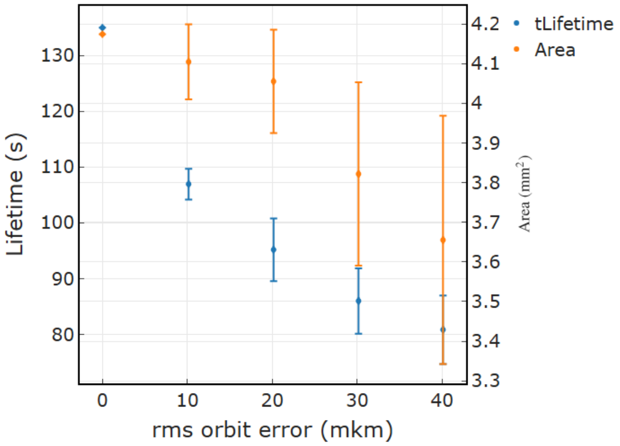

Figure 4: Touschek lifetime (blue) and DA area (yellow) vs RMS orbit error.

CONCLUSION

As a result of optimization, the lifetime was increased from 125 seconds to 218 seconds, this did not reach the target of 300 seconds.

Touschek scattering is simulated using Mone Carlo method and tracking in ELEGANT. Results are in good agreement with calculation.

Sensitivity of lattice is checked with introduction of small transverce misalignments to quadrupole lenses.

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