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DESIGN OF A HYBRID SEVEN-BEND-ACHROMAT-BASED LATTICE FOR A SUPER TAU CHARM FACILITY

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Abstract

Super Tau Charm Facility (STCF) proposed in China, is a future electron-positron collider project with symmetric double ring. It's designed to be operated in the center of mass energy (CME) range between 2 GeV and 7 GeV. The goal luminosity is beyond $0.5 \times 10^{35} cm^{-2}s^{-1}$. Hybrid multi-bend-achromat (HMBA) concept, proposed to develop low emittance lattices with large dynamic aperture, has been adopted in some diffraction-limited storage ring (DLSR) designs. In this paper, we will show a lattice with hybrid 7BA arcs for STCF. On the basis of last published lattice version, we optimize the interaction region, arc as well as technique region, add the damping wigglers and construct the geometry of double-ring.

INTRODUCTION

Super Tau Charm Facility (STCF) [1] proposed in China, is a future electron-positron collider project with symmetric double ring, a linear injector of full energy, and a particle spectrometer. It's designed to be operated in the center of mass energy (CME) range between 2 and 7 GeV. The goal luminosity is beyond $0.5 \times 10^{35} cm^{-2}s^{-1}$, which is about 2 orders higher than that of BEPC-II (Beijing Electron-Positron Collider, China) [2]. It also leaves the potential for upgrading to higher luminosity and implementing the longitudinal polarized electron beams in the future [1]. Now the Anhui local authority and the University of Science and Technology of China have approved a key R&D program of 420M RMB (about 62M dollars) for STCF.

To achieve such a high luminosity, several advanced techniques, such as large Piwinski angle collision and crab waist scheme [3] are adopted in the interaction region (IR). Although some work has been done on the concept design [4], there are still many problems to solve. In this paper, we redesign the IR, arc and technique section, add the damping wigglers and take the layout of double-ring (Fig. 1) into consideration. The main parameters are shown in Table 1.

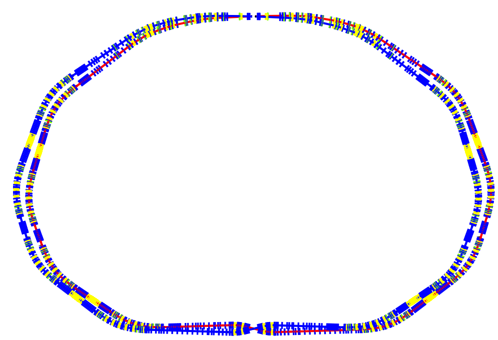

Figure 1: Geometry of STCF double ring. Red line means electron ring and blue positron one.

ARC REGION

The arc optics consists of 8 hybrid multi-bend achromat (HMBA) [5] cells, each of which is the hybrid seven-bend achromat structure shown in Fig. 2 and has a total bending angle of 36°. The horizontal and vertical phase advances between two dispersion bumps in a cell are $(1.5\pi, 0.5\pi)$, which form a -I transformation. A pair of sextupoles are placed at the peaks of bumps to correct the horizontal chromaticity. Another two pairs, placed at the upstream and downstream of the horizontal pairs respectively, are used to correct the vertical chromaticity. Magnet strength has been taken into consideration for the working mode of 2×3.5 GeV.

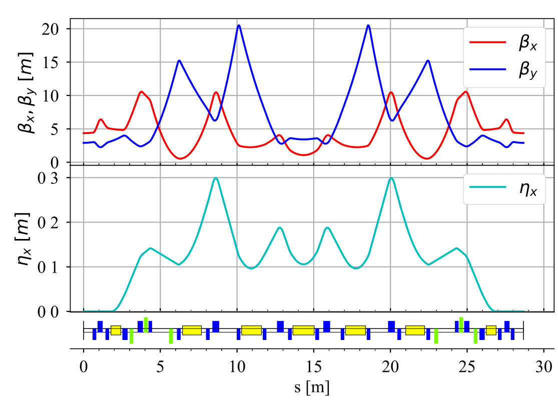

Figure 2: Optics of a hybrid 7BA arc cell.

INTERACTION REGION

Fig. 3 shows the optics of the IR for $\beta_x^* = 40mm$, $\beta_y^* = 0.6mm$, which are the beta functions at IP. It consists of final telescope (FT), chromaticity correction for vertical plane (CCY), chromaticity correction for horizontal plane (CCX),

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Table 1: Main Parameters of STCF

Parameters	Values
Optimize energy E $[GeV]$	2.0
Circumference $[m]$	616.76
2θ $[mrad]$	60
$\varepsilon_y/\varepsilon_x$ $[\%]$	0.5
Beta function @ IP β_x^*/β_y^* $[mm]$	40/0.6
Total current I $[A]$	2.0
particles per bunch $N_{e/bunch}$ $\left[10^{10}\right]$	5.02
Compact factor α_c $\left[10^{-4}\right]$	10.29
Damping time τ_x/τ_s $[ms]$	60.5/20.2
V_{RF} $[MV]$	1.2
Betatron tunes ν_x/ν_y	31.552/24.571
Synchrotron tune ν_s	0.0095
U_0 (SR/IBS+WG) $[keV/turn]$	135.8/409.9
σ_e (SR/IBS+WG) $\left[10^{-3}\right]$	0.52/0.92
σ_s @IP (SR/IBS+WG) $[mm]$	5.22/9.7
ε_x @IP (SR/IBS+WG) $[nm \bullet rad]$	5.4/3.7
Hor. beam-beam parameter ξ_x	0.0027
Ver. beam-beam parameter ξ_y	0.113
$\tau_{Touschek}$ $[s]$	72
Hour-glass factor F_h	0.9329
Peak luminosity L $\left[cm^{-2}s^{-1}\right]$	1.52×10^{35}

crab waist sextupole (CWS) and matching transformer (MT). To compensate the generated chromaticity from FT, two pairs of sextupoles separated by -I transformation are used to correct 1st order chromaticity locally. A pair of sextupoles with opposite strength at each side of IP respectively are needed to compose crab waist at the IP.

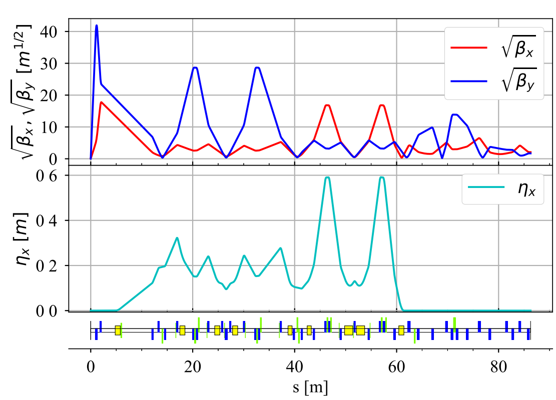

Figure 3: Optics of half interaction region.

OTHER REGIONS

There are some other regions such as the wiggler region and the technique region. The optics of the wiggler region, at the center of which is a wiggler of 2 m, are shown in the Fig. 4. the double rings are separated by two short wiggler regions in the inner half ring and another two long ones in the outer double ring. Injection and rf cavities are placed at the technique region, which also connect the inner and outer half ring, see Fig. 5.

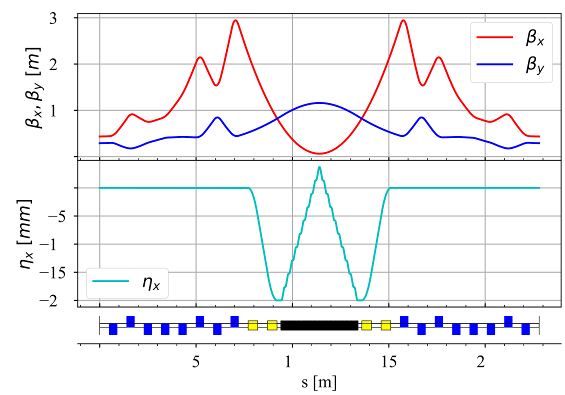

Figure 4: Optics of outer wiggler region.

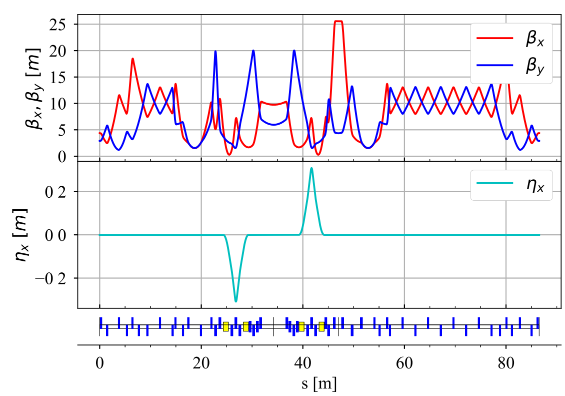

Figure 5: Optics of technique region.

DYNAMIC APERTURE & TOUSCHEK LIFETIME

In the above STCF lattice, we get a estimated luminosity of $1.52 \times 10^{35} cm^{-2}s^{-1}$, which has met the requirement we mentioned. Many attempts [6,7] have beam tried to increase the dynamic aperture and touschek lifetime. With two pairs of sextupoles separated by -I transformation and four additional sextupoles, the momentum bandwidth of $\pm 1.5\%$ and on-momentum dynamic aperture of 6mm×1mm are achieved. Fig. 6 and Fig. 7 show the frequency map analysis (FMA) of DA tracked at the injection point for 1024 turns using elegant code 8, where the blue color means stable particle motion and red is chaos one. We can see that the horizontal DA is larger than 6 mm and there is no dangerous resonance inside the DA. As shown in Fig. 8, the tune footprints are truncated by the integer and half-integer resonance, and the local momentum aperture (MA)(Fig. 9) at injection point is about $\pm 1.1\%$. Then the touschek lifetime is estimated to be 72s, which is larger than the last published version but still does not meet the requirement of 300s.

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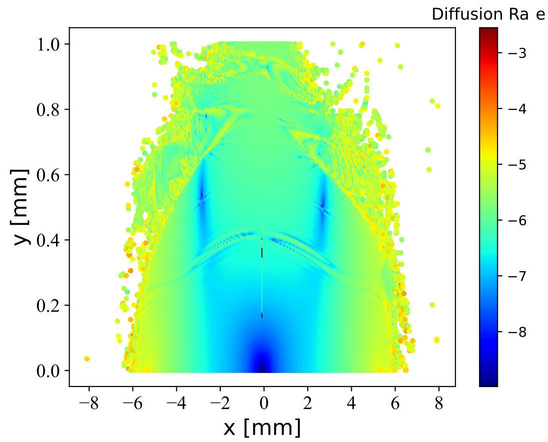

Figure 6: FMA of DA in x-y space.

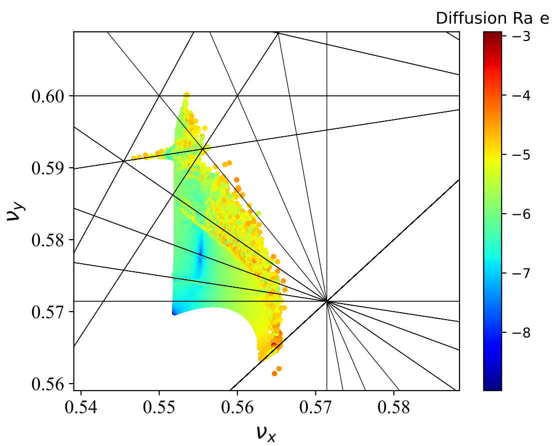

Figure 7: FMA of DA in tune space.

CONCLUSION

We optimized the IR and arc region, added the wiggler regions and constructed the geometry of double ring for the STCF. Including the synchrotron radiation, damping wiggler and intra-beam scatter effect without error, the DA is $6mm \times 1mm$ and the touschek lifetime is 72s, while 300s is required. In the future, we will optimize the strength and phase advances of sextupoles to increase the off-momentum DA and touschek lifetime. The identity local chromaticity correction FODO in IR will also be further studied to enlarge the momentum aperture.

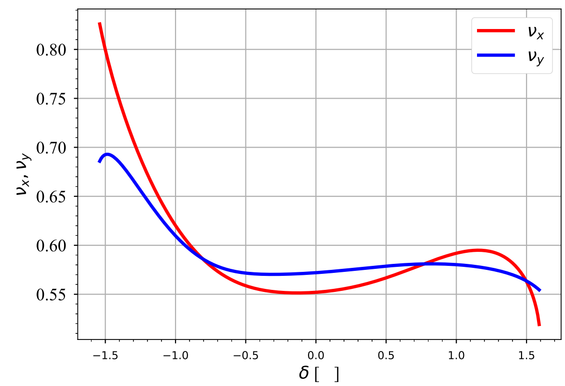

Figure 8: Momentum dependent tune footprints.

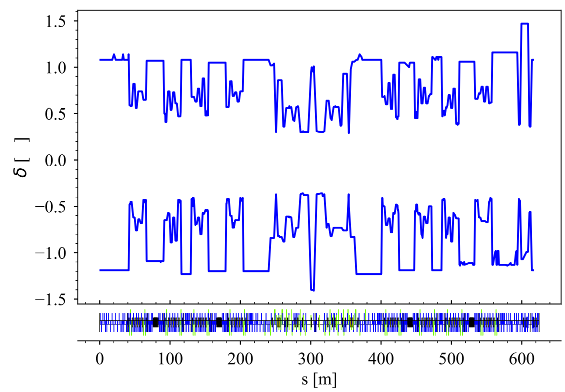

Figure 9: Local MA along the ring, tracked for 1024 turns.

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