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PROGRESS OF CONCEPTUAL STUDY FOR THE ACCELERATORS OF A 2-7 GeV SUPER TAU CHARM FACILITY AT CHINA

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Abstract

This paper shows the progress of the conceptual study for the accelerators of a super tau charm facility in China. Since the BEPCII will finish its historical mission in 5~10 years and its upgrade plan will only achieve a luminosity gain of 3~5 times as it is now, a new next generation tau-charm collider will play an irreplaceable role in future high energy physics study. The luminosity of this successor is about 5×10^{34} cm^{-2}s^{-1} pilot and 1×10^{35} cm^{-2}s^{-1} nominal, 100 times as BEPCII, also with the electron beam longitudinally polarized at the IP. The general scheme of the accelerators and the beam parameters are shown.

INTRODUCTION

Bejing Electron Positron Collider II (BEPC II), the most successful tau-charm factory of the world in operation, reached its design goal of luminosity of 1×10^{33}cm^{-2}s^{-1} in the year 2016. Although IHEP is now planning to upgrade the collider to large crossing angle with crabbed waist collision, the luminosity enhancement of the future upgrade project will be 3~5 times as it is now, due to the limited final focus section space and small total circumference. We believe that BEPCII would finish its historical mission in the next decade. The very ambitious CEPC-SPPC proposal, which will cost a price of several orders higher than a tau charm factory and a study and construction period of more than 15 years, will be a long-term plan that requires global cooperation. As a transitional choice before the construction of CEPC, a new tau charm collider facility was proposed [1] as BEPCII's successor. It would also be a good backup plan if the CEPC-SPPC construction cannot begin on time as planned.

The new super tau charm facility was first named as High Intensity Electron Positron Accelerator (HIEPA) due to the intention to combine the collider and a 3rd /4th generation synchrotron radiation light source together [2]. Then the accelerator physicists realized it is very hard to achieve a perfect performance for different users respectively, because of the strong nonlinear effect and limited lifetime of the beam. After that we make a decision that the new facility will be a collider only. This new collider, operating in the range of center-of-mass energies from 2 to 7 GeV, will have a luminosity of 5×10^{34} cm^{-2}s^{-1} for pilot operation, and a luminosity of 1×10^{35}cm^{-2}s^{-1} with longitudinal polarized electron beam at the collision point for nominal operation.

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The conceptual study of the STCF is now listed in future plan of the Hefei Comprehensive National Science Center, supported by the Collaborative Innovation Center for Particles and Interactions (CICPI, USTC) and the accelerator division of the National Synchrotron Radiation Laboratory (NSRL, USTC). At this stage, many common technologies which are useful for both CEPC-SPPC and tau charm factory will be developed and a strong team of scientists will be trained.

THE EVOLUTION OF THE GENERAL SCHEME AND BEAM PARAMETERS

The first STCF idea in the year 2015 was a dual-purpose facility that compatible with a 3rd/4th generation light source [1]. But this idea is not feasible for three reasons. First, the nonlinear effects from the final focus section of the colliders and the arc sections of the ring light sources are both very strong, therefore the dynamic aperture will be too small. Second, the small bunches of the 4th generation light source will induce ultra-strong collective effects, and then degrade the whole performance of the facility. Finally, the beam lifetime of the super tau charm factory is about the order of magnitude of 1000 seconds, unable to meet the need of stability that the light source users requires.

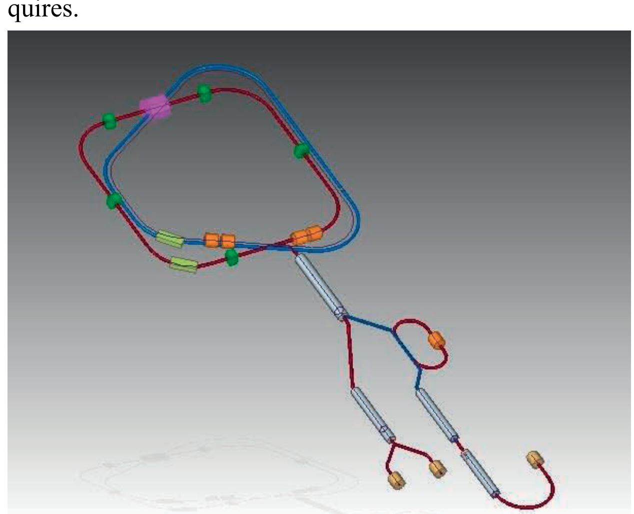

Figure 1: General sketch of the STCF accelerators.

Figure 1 shows the sketch of the STCF accelerators. The new facility will be a dual-ring collider with symmetric and flat beams. In Fig. 1 the two rings are not identical only because we want to show there should be snakes in the electron ring.

Last year we reported that the whole construction of the Chinese STCF will be divided into three stages: the pilot,

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the nominal and the future upgrade [3]. At the pilot stage, the main accelerators and detectors will be built and the peak luminosity will achieve $5\times10^{34}cm^{-2}s^{-1}$. At the nominal stage, the peak luminosity will achieve $10^{35}cm^{-2}s^{-1}$ and an electron beam that longitudinal polarized at the collision point will be deployed and replace the non-polarized electron beam. After the latest discussion between high energy physicists and accelerator physicists, we believe that the economic and time cost can be cut down, and lower polarization is acceptable. In the latest version, the 3rd stage was removed, and the goal of the polarization was changed from 85% to 75%.

The design goal for the beam parameters at stage pilot is listed in Table 1.

Table 1: Main Parameters for Accelerators, Pilot

Parameters	Value
Peak Luminosity	5×10^{34} $cm^{-2}s^{-1}$
Beam Energy	2GeV，1-3.5GeV tunable
Current	1.5 A
Beam Emittance $\varepsilon_x/\varepsilon_y$	5/0.05 nm·rad
β_x^*/β_y^*	100/0.9 mm
Crossing Angle	60 mrad
Hourglass factor H	0.8
ξ_y	0.06
Circumference	800-1000m

THE BEAM OPTICS DESIGN STATUS

The rings have six straight sections. Two of them are very long, one for IP, another set up for injection and beam control. The other four are shorter, reserved for three Siberian snakes and a damping wiggler. In the final focus section, the collider uses large Piwinski angle collision and crabbed waist scheme, the ξy can approach higher than 0.08 while the limit to bunch length can be avoided [4]. Full energy injection linac is used, so there will be no boosters but a small damping ring for positron beam. If the beam dynamic performance was not good enough, boosters with swap-out injection method would be a backup plan. At present, we have achieved a sketchy design.

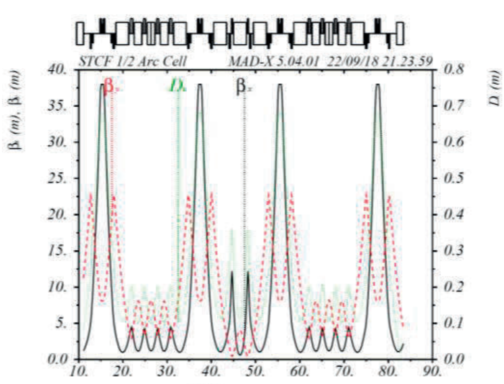

Figure 2: Sketchy design of the STCF 1/2 arc section.

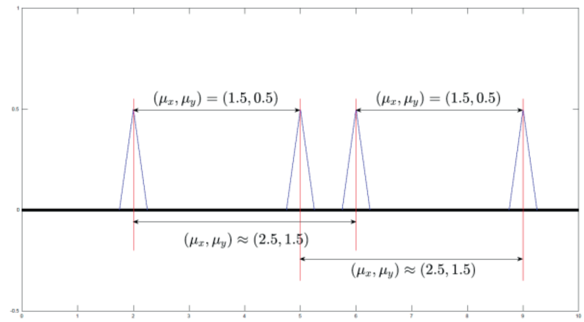

Figure 3: Phase advances for the STCF arc section.

To get a low emittance, an MBA-based arc design from the Italian TCF (tau charm factory) [4] is transplanted and modified, showed in Figs. 2 and 3. Instead of one QF in the original lattice, we use one more combined bending magnet, 2 QDs and 2 QFs, induce more nonlinear cancellation and allows to get better dynamic aperture with even smaller emittance.

The final focus section, showed in Figs. 4 and 5, has a total length of 257.318m (without dispersion suppression section). The traditional scheme for chromatic correction [5] is employed. The chromaticity is compensated in dedicated sections separately (CCY and CCX). A pair of sextupoles are placed in symmetrical high β function in each section, each pair is in phase with the final doublet. The geometric aberrations and the second order dispersion aberration are cancelled in each pair.

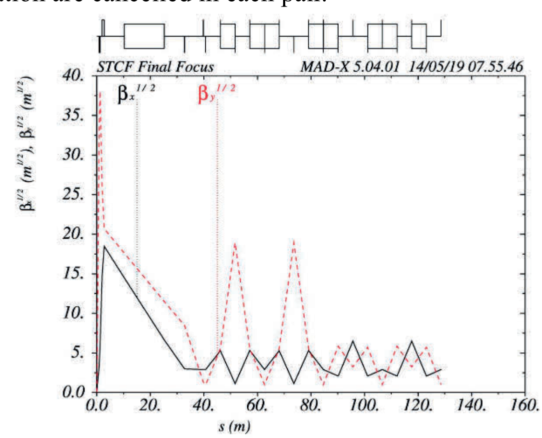

Figure 4: β function of 1/2 final focus section.

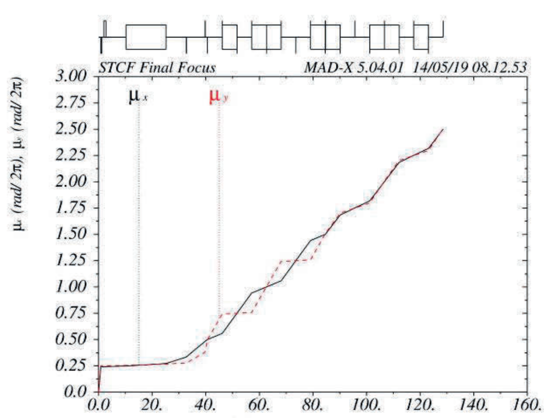

Figure 5: Phase advances of 1/2 final focus section.

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Table 2 shows the rough and estimated machine parameters that we achieve at present. The nonlinear optimization is in progress while the study of the collective effects and beam-beam effect has not started yet, so the whole design may be greatly adjusted in future.

Table 2: Rough Results of Parameters

Parameters	**Value**
Peak Luminosity	0.5~0.8×10^{35} $cm^{-2}s^{-1}$(estimated)
Beam Energy	2GeV，1-3.5GeV tunable
Current	1.5 A
Beam Emittance $\varepsilon_x/\varepsilon_y$	2.4/0.03 nm·rad
β_x^*/β_y^*	60/0.6 mm
Crossing Angle	60 mrad
Hourglass factor H	0.8(estimated)
ξ_y	0.04~0.06(estimated)
Circumference	540m

CONCLUSION AND FUTURE WORK

Based on the raw results, one can see that the project is feasible, and much more work on accelerator physics, such as nonlinear optimization, collective effect and beam-beam, is needed.

The STCF steering committee will apply for funds to construct a super tau-charm collider in China during the 15th Five-Year Plan. There is still lots of work to do. We should put a lot more effort in accelerator physics and key technologies. A preliminary conceptual study project for the new tau charm factory will be beneficial.

We have already established a new computational accelerator physics lab, with a high performance computing cluster and up-to-date software such as CST studio, ANSYS, VSIM and OPERA. Meanwhile, our team is now notably short of hands. Experienced accelerator physicists and engineers are needed all around the world, therefore, besides world-wide recruitment, we will also set up a full system of training and education of accelerator physics and technologies.

ACKNOWLEDGEMENTS

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