ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-MOPML013

PROGRESS ON PRELIMINARY CONCEPTUAL STUDY OF HIEPA, A SUPER TAU-CHARM FACTORY IN CHINA*

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Abstract

As the most successful tau-charm factory of the world, BEPC II will celebrate its 10th birthday this year and will finish its historical mission in the next decade. Because of its very important role in high energy physics study, BEPC II will certainly need a successor, a new tau-charm collider. This paper discusses the feasibility of a greenfield next generation tau-charm collider named HIEPA. The luminosity of this successor is about 5×10^{34} $cm^{-2}s^{-1}$ pilot and $1\times10^{35}cm^{-2}s^{-1}$ nominal, with the electron beam longitudinally polarized at the IP. The general scheme of the accelerators and the beam parameters are shown. Several key technologies such as beam polarization and beam emittance diagnostics are also discussed.

INTRODUCTION

The most successful tau-charm factory of the world in operation is Bejing Electron Positron Collider II (BEPC II), which reached a luminosity of higher than $1\times10^{33}cm^{-2}s^{-1}$ in the year 2016. We believe that the unique collider in China would finish its historical mission in the next decade, maybe around the year 2022 or later. Although many scientists show strong interests in the very ambitious Higgs factory proposal known as CEPC-SPPC in China, it is clear that the Higgs factory will be a long-term plan that will cost a price of several orders higher than a tau charm factory and a period of study and construction of more than 20 years, and require global cooperation. As a transitional choice, a new tau charm collider facility was proposed by high energy physicists in the Collaborative Innovation Center for Particles and Interactions (CICPI, China) [1] to replace BEPC II after its retirement and before the construction of CEPC. The new tau-charm collider was named High Intensity Electron Positron Accelerator (HIEPA) due to its very high luminosity and current. It will be a next generation electron-positron collider operating in the range of center-of-mass energies from 2 to 7 GeV utilize polarized electron beam in collision. The pilot luminosity will be 5×10^{34} $cm^{-2}s^{-1}$ and the nominal luminosity will be $1\times10^{35}cm^{-2}s^{-1}$.

The study and construction of HIEPA will help to maintain China's leading advantage at tau-charm area. In addition, 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. At last, a tau-charm factory would be a good backup plan if the CEPC-SPPC construction cannot begin on time as planned.

* Work supported by National Natural Science Foundation of China 11375178 and the Fundamental Research Funds for the Central Universities, Grant No WK2310000046
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We expect HIEPA to be an important part of Hefei Comprehensive National Science Center. This paper discussed not only the feasibility of the next tau-charm factory, but also several related key technologies needed to be developed in the future 5~10 years. The preliminary study of HIEPA accelerators is now organized by the accelerator division of the National Synchrotron Radiation Laboratory of China.

GENERAL SCHEME AND BEAM PARAMETERS OF THE ACCELERATOR

Last year we reported two possible routes that might lead to a successor of BEPC II [2]. Since IHEP may decommission the collider and reform it to a new light source, the upgrade from BEPC II to BEPC III is then impossible. The plan of HIEPA will be a good choice for a greenfield tau-charm collider.

The whole construction of HIEPA will be divided to three stages: the pilot, the nominal and the future upgrade. During the pilot stage, the main accelerators and detectors will be built and the peak luminosity of the HIEPA will achieve 5×10^{34} $cm^{-2}s^{-1}$. During the nominal stage, the peak luminosity will achieve 10^{35} $cm^{-2}s^{-1}$ and an electron beam with 85% longitudinal polarization will also be deployed and replace the non-polarized electron beam.

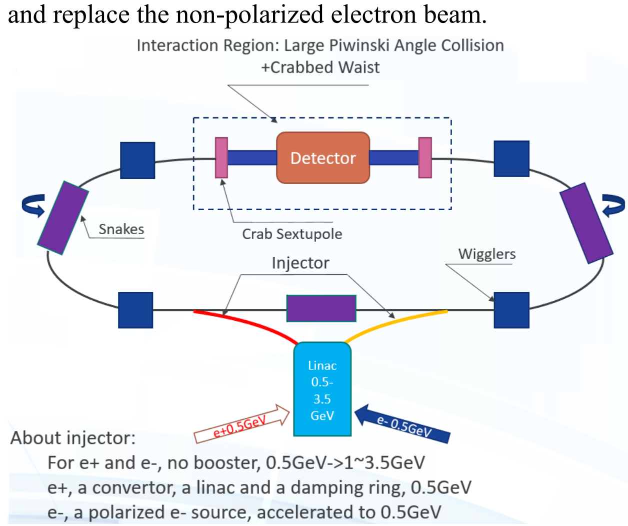

Figure 1: General scheme of HIEPA accelerator.

Figure 1 above shows the general scheme of HIEPA accelerator. The new facility will be a dual-ring collider with symmetric and flat beams and one interaction region. Full energy injection linac is used, so there will be no need to use boosters for injection beams, but a small damping ring for positron beam is still indispensable. The 3.5 GeV full energy linac can also be a good platform for FEL applications, positron annihilation spectroscopy, and γ rays and nuclear physics study.

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For such a collider, the luminosity can be

$$L = \frac{\gamma n_b I_b}{2er_e\beta_y^*}\xi_y H,$$

where γ is relative energy of the beam, n_b is number of the bunches, I_b is current of a single bunch, ξ_y is vertical beam-beam effect parameter, H is hourglass factor, β_y^* is vertical envelope function at IP. Its luminosity is proportional to its current, vertical beam-beam effect parameter and Hourglass factor, and inversely proportional to the vertical envelope function. The future facility should have two long straight sections, one for IP, another set up for injection and beam control.

To avoid the luminosity loss due to hourglass effect, the bunch length should be shorter than β_y^*. Consider the collective effects, the sensible way is use large Piwinski angle collision and crabbed waist scheme, the ξ_y can approach 0.1 while the limit to bunch length can be avoided [3].

The accelerators at stage pilot and stage nominal are set up with parameters specified in Table 1 and Table 2.

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

Table 2: Main Parameters for Accelerators, Nominal

Parameters	Value
Peak Luminosity	1×10^{35} cm^{-2}s^{-1}
Beam Energy	2GeV，1-3.5GeV tunable
Current	2 A
Polarization	>85% (e-)
Beam Emittance $\varepsilon_x/\varepsilon_y$	5/0.05 nm·rad
β_x^*/β_y^*	67/0.6 mm
Crossing Angle	60 mrad
Hourglass factor H	0.8
ξ_y	0.08
Circumference	800-1000m

The general goal of the pilot stage is to finish the frame of the collider, check the whole design of accelerator physics and technologies, and reserve theoretical and physical room for electron beam polarization. The goal of the nominal stage is to suppress the β function at the interaction point, increase the beam current and the ξ_y, and use Siberian snakes to realize the longitudinally polarized electron beam at the IP, while the negative electron affinity photocathode guns will be used as polarized electron sources.

POLARIZED POSITRON BEAM

A long-term plan is to utilize polarized positron in the new collider. The polarized positrons come from circular polarized gamma rays bombarding amorphous targets. Among the three main methods, use circular-polarized gamma rays from helical undulators can achieve the highest yield, but need giant linacs and thus will be extremely expensive. Compton backscattering or direct bombardment method are cheaper, but in China, there is no practical facility yet. On the other hand, polarized positron annihilation spectroscopy plays a unique role in solid state physics and material science, but the traditional positron sources based on radioisotope have achieved their performance bottleneck. The research and development of high performance polarized positron source based on accelerators is then imperative.

The feasibility of a Compton backscattering gamma ray source and polarized positron source based on 3.5 GeV linac will be discussed. As shown in Fig. 2, an ERL loop can also be induced in the facility.

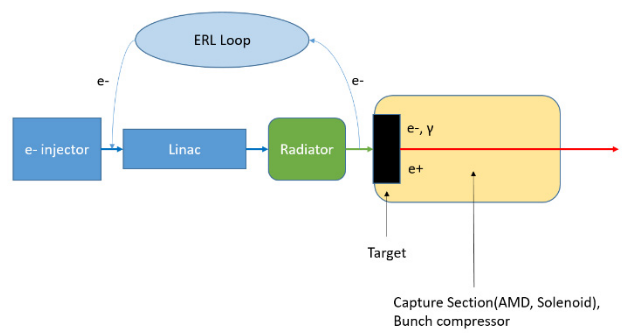

Figure 2: Polarized gamma rays from Compton backscattering.

On the other hand, a plasma wakefield accelerator cell can be used as a super energy and brightness booster for linacs [4]. As shown in Fig. 3, If a plasma cell of Cascaded HTR PWFA is used as a booster for HIEPA 3.5GeV linac, a helical undulator can be installed and generate circular-polarized gamma rays.

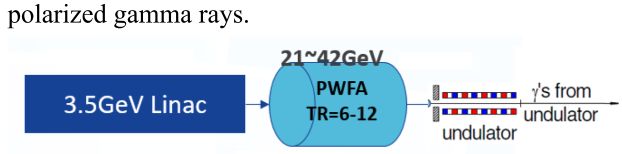

Figure 3: Polarized gamma rays from helical undulators.

ULTRA-LOW EMITTANCE MEASUREMENT

As known, the emittance of a next generation storage ring will be very small, especially for vertical emittance with low coupling. Due to the requirements of on-line measurement, using the SR to obtain the bunch size is an optimal choice. Since the bunch size is very small, the spatial resolution should be of the order of 100pm. Therefore, traditional methods in the third generation light sources are

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not appropriate. Compared to the imaging method, the interference method can measure smaller beam size with better resolution and more reasonable performance price ratio. If work with synchrotron radiation of shorter wavelength, interference method may achieve a resolution of better than 100pm.

To measure the beam emittance and profile precisely, we will design an X-ray interferometer for future HIEPA vertical emittance measurement and give the requirements of the components of the interferometer. We will also use rotating wave-front division method to reconstruct the beam profile. The related study will introduce an international advanced beam diagnostic approach and may lead to a satisfactory answer to the question about how to measure the ultra-low emittance and very small beam size precisely for the diffraction limit storage rings.

FUTURE PLAN AND HEFEI COMPREHENSIVE NATIONAL SCIENCE CENTER

The University of Science and Technology of China has decided to support the HIEPA proposal using First Class Discipline Construction funds from Ministry of Education of China. The first instalment is 10 million RMB. Our next move is to apply for financial and human resource support from Chinese Academy of Sciences.

Meanwhile, a comprehensive national science center is now under construction in Hefei. The local authority has already reserved space for HIEPA, just in the district of national labs and big science facilities (Red area in Fig. 4).

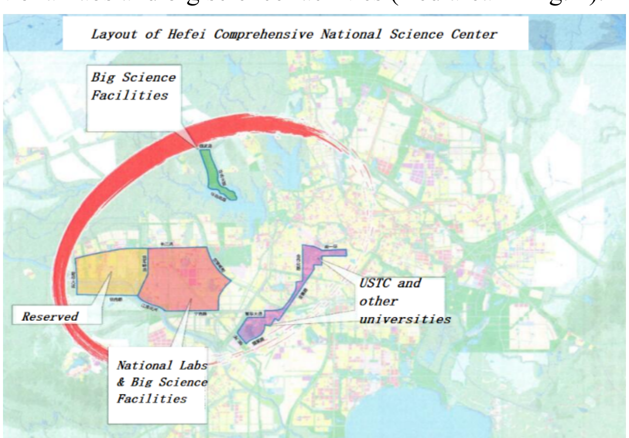

Figure 4: Hefei Comprehensive National Science Center has already reserved space for HIEPA in national labs.

CONCLUSION AND FUTURE WORK

The proposal that construct a super tau-charm collider in Hefei during the 14th and 15th Five-Year Plan sounds attractive, but there is still lots of work to do. We should pay a lot more attention to accelerator physics and key technologies. A preliminary conceptual study project for the new tau charm factory will be beneficial.

Meanwhile, the team is now notably short of hands. Experienced accelerator physicists and engineers are needed all around the world, therefore, besides worldwide recruitment, we should also set up a full system of training and education of accelerator physics and technologies.

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