PRELIMINARY CONCEPT AND KEY TECHNOLOGIES OF HIEPA ACCELERATOR *

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Abstract

High energy physicists proposed a new collider: super tau-charm factory. The name of the project is high intensity electron positron accelerator facility. As high intensity electron positron collider, it runs in an energy range of 2-7 GeV. As an advanced light source, it can also provide high quality synchrotron radiation from VUV to soft X-ray. The facility will be a symmetrical two-ring collider located at Hefei. This paper discusses the preliminary concept and the key technologies of HIEPA Accelerator.

INTRODUCTIONS

A super tau-charm factory is a next generation electron-positron collider operating in the range of center-of-mass energies from 2 to 7 GeV with a high luminosity of about 5×10^{34} cm^{-2}s^{-1}. The Collaborative Innovation Center for Particles and Interactions (CICPI, China) proposed this plan [1] to explore the frontier of high energy physics and give it a name "High Intensity Electron Positron Accelerator (HIEPA)" due to its very high luminosity and current. Nation Synchrotron Radiation Laboratory, for decades, have run the Hefei Light Source and developed useful technologies for huge accelerator facilities.

It is only natural for us to work together and propose a novel facility that solve puzzles in high energy physics when provides high quality synchrotron radiation. The problems are:

Which kind of machine it will be? How much does it cost? What technologies do we need?

This paper wants to discuss those questions and show what we can do in the future.

SIGNIFICANCES OF HIEPA FACILITY

The Feature of 2-7GeV Energy Region

- Rich of resonances: charmonium states, such as J/ψ, ψ(2S), ψ(3770) and particles are copiously produced at/around production threshold, providing a clear and unique laboratory to study the physics with charm quarks, and for the search of the existence of the new form of matter/hadron, including exotic hadrons, multi-quark states hybrids and glue balls.
- Threshold characteristics: Pairs of τ lepton, charmed mesons and charmed baryons can be directly produced at their production thresholds, which leads to a better handling of backgrounds for the study of CP violation from the decays of tau and charmed mesons, as well as for the search for lepton number violating process from the tau decays.
- Transition between smooth and resonances, perturbative and non-perturbative QCD. It is also the energy region where exotic hadron, hybrid, glueballs are located.

The Significances of the Physics for HIEPA

Therefore the significances of the physics for HIEPA are:

- Search for new forms of matter/hadron and study their properties.
- Measurement of the nucleon electromagnetic form factor.
- Search for new physics.

Advanced Light Source at 2GeV

HIEPA is designed to also supply synchrotron radiation. The beamlines can be fully operated when there are no collision, while scientists and engineers plan to work on optimization design to make sure as many beamlines as possible can still work while the facility is collect collision data.

Energy of electron beam determines the best spectrum range for synchrotron radiation [2]. The major wavelength range of the HIEPA light source is from VUV to soft X-ray.

Table 1 compares the brightness of HIEPA light source and SSRF from 5eV to 1keV, the latter is now the leading synchrotron light source in China. Here W means wiggler, U means undulator and B means bending magnet. It is easy to find out that low energy light source supplies much brighter VUV to soft X-ray light than mid energy synchrotrons.

Table 1: Comparison of the Room Temperature Insertion Device Brightness for HIEPA Light Source and SSRF

	5 eV	10 eV	100 eV	1keV	5keV
HIEPA	5×10^{17} (W/U)	5×10^{18} (W/U)	1×10^{20} (U)	5×10^{21} (U)	2.6×10^{20} (U)
SSRF	1×10^{14} (B)	5×10^{15} (W)	5×10^{18} (U)	5×10^{19} (U)	9.9×10^{19} (U)

In this range, the light source can provide a wonderful set of tools for both atom and electron scale. The future light source will be a boost in biology, chemistry, material science and many other frontier fields in China.

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GENERAL SKETCH OF THE FUTURE ACCELERATOR

Collider Scheme

HIEPA is a dual-ring collider with symmetric and flat beams and one interaction region. The most important performance index of HIEPA is the luminosity of the collider. For a symmetric machine and flat beam, the luminosity can be

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

Here 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.

So for a collider optimized at a certain energy range, 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. The concept map of the positron/electron ring is showed in Figure 1.

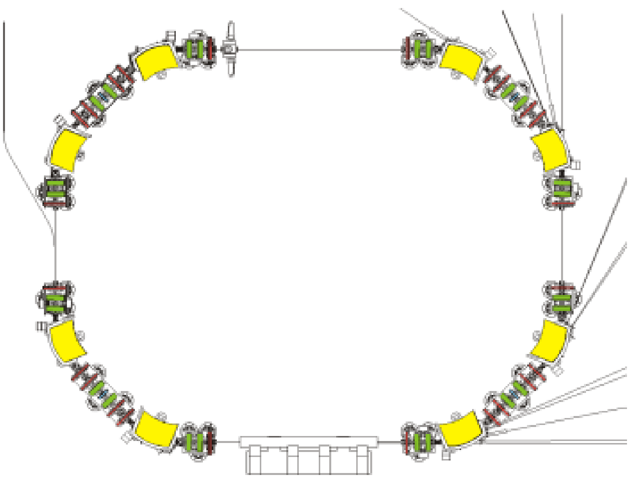

Figure 1: Schematic drawing of one of the rings with beamlines

Light Source Scheme

The second important performance index of HIEPA is its light source brightness. Since generally speaking the brightness of a synchrotron is inversely proportional to the square of horizontal emittance, there's brightness limit due to the priority of the luminosity of the collider. When emittance is too low, the collective effect such as IBS will be too severe and beam quality will worsen very quickly.

A 3rd generation light source with an average level of emittance is then expected. The design goal of the horizontal emittance is 1nm·rad with IBS, which is about the half of the ALS emittance at LBNL. Super tau-charm factory at INFN-LNF has an emittance of 5.13nm·rad [3], HIEPA is a similar plan with stronger focus and close to double circumstance.

Set Main Parameters

Table 2: Main Parameters for Accelerators

Design goals	value
Peak Luminosity	$5\times10^{34}/(\mathrm{cm}^2\cdot\mathrm{s})$
Brightness of Light Source	$10^{17}\sim10^{21}$ Ph./s mm^2 mrad^2 0.1%BW
Beam Energy （1/2 Collision Energy）	2GeV，1-3.5GeV tunable
Current	2A
Electron Horizontal Beam Emittance	~1nm·rad
Lattice	DBA like
Collision Method	Large Crossing Angle +Crabbed Waist
Circumstance	~600m

Table 2 shows the main parameters of HIEPA accelerators. The interaction region uses large Piwinksi angel collision and crabbed waist scheme.

The peak luminosity is $5\times10^{34}/(\mathrm{cm}^2\cdot\mathrm{s})$, about 50 times as it is at BEPC II. To achieve the luminosity, assume ξ_y is 0.04, β_y^* should be compressed to 0.3-0.4mm. There are two long-term plan for HIEPA: to upgrade to a peak luminosity of $10^{35}/(\mathrm{cm}^2\cdot\mathrm{s})$ and to utilize polarization positron beam in collision

After service life of high energy physics experiment, the facility will be modified to a 4th generation light source with a horizontal emittance of 50 pm·rad (with IBS).

KEY TECHNOLOGIES REQUIRED

To build this new facility, new study has to be done and key technologies will be developed in next few years. They are:

Accelerator Physics for High Intensity, Small Dimension and Low Emittance Beam

Among the options of the next generation colliders, compared to HIEPA, higgs factory like CEPC has an energy about 100 fold and much lower current about 16.6mA, energy of super B factory is also higher. This means the facility will face more serious collective effect.

Serious collective effects result in emittance growth, lifetime loss and beam instabilities. Beam loss and beam quality depravation restrict the peak luminosity, so this is the most important accelerator physics problem.

Meanwhile, the lattice and interaction region design is another key point. The high current and strong focus induce strong nonlinearity, result in very small dynamic aperture. Nonlinearity optimization requires further work and also new technologies for injection.

Superconducting Magnets

HIEPA requires several kinds of superconducting magnets. The magnets to be designed are listed in Table 3.

Table 3: Superconducting Magnets in HIEPA

Type	quantity	Maximum Magnetic Field
Anti-solenoid	2	4.5 Tesla
Defocusing quadrupole	2	1.07Tesla/cm
Focusing quadrupole	2	0.66 Tesla /cm
Damping wigglers	4	4.5 Tesla
Siberian snake solenoids	10	6 Tesla

Superconducting Undulator

Table 4: Brightness of One of the Superconducting Undulators @K_{max}

Harmonic	Photon Energy (eV)	Brightness	Spectral flux
1	562	8.16×10^{20}	1.12×10^{18}
3	1690	1.01×10^{21}	8.16×10^{17}
5	2815	9.64×10^{20}	6.34×10^{17}
7	3940	8.30×10^{20}	4.86×10^{17}
9	5065	7.00×10^{20}	3.80×10^{17}

To supply high brightness synchrotron radiation light, HIEPA use superconducting undulators. Superconducting undulators can reach shorter period and supply brighter synchrotron with shorter wavelength. Table 4 shows that it is possible to supply 5 keV high brightness soft X-ray with superconducting undulator.

CONCLUSION AND FUTURE WORK

HIEPA facility, as next generation electron-positron collider, is a very attractive option for the successor of the BEPC II tau-charm factory after 5-10 years. Meanwhile, HIEPA is also possible to provide a 3rd generation light source at VUV-soft X-ray range.

There are still lots of work to do to make sure the concept design is feasible and the beam dynamics is optimal. Scientists and engineers will also pay attention to new method of accelerator physics and key technologies of superconducting magnets and insertion devices. This future work will be beneficial to both next generation colliders and 4th generation light source.

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