FCC-ee BINP studies review

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BINP potential for FCC

BINP is a well-known lab dealing with HEP experiments, accelerator science and technology and colliders. Mainly we specialize in e+e- colliders, but some issues related to the protons/ions are also developed rather well (ion sources, electron cooling, charge exchange injection, etc.). BINP strong points:

- beam optics and dynamics simulation,
- luminosity and BB,
- linear accelerator systems,
- electron/positron sources,
- magnets (normal- and SC),
- vacuum system, RF systems (NC),
- PS,
- beam instrumentation and control.

Not whole BINP potential is now in demand for the FCC study.

Pre-FCC (TLEP) studies

BINP joined the FCC study (TLEP) at an early stage.

- V.Telnov first has pointed out that the TLEP luminosity at high energy is limited by a **single** beamstrahlung (the effect which is well-known in linear e+e- colliders)

- A.Bogomyagkov, E.Levichev and D.Shatilov have shown that at the TLEP low energy a **multipole** beamstrahlung determines the energy spread and bunch length and also influences the luminosity.

(Touschek effect and IBS is the analogy.)

PROCEEDINGS OF SCIENCE

Limitation on the luminosity of e^+e^- storage rings due to beamstrahlung

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Particle loss due to the emission of single energetic beamstrahlung photons in beam collisions is shown to impose a fundamental limit on storage-ring luminosities at energies greater than $2E_0 \sim 140$ GeV for head-on collisions and $2E_0 \sim 40$ GeV for crab-waist collisions. Above these threshold energies, the suppression factor due to beamstrahlung scales as $1/E_0^{4/3}$, and for a fixed power of synchrotron radiation, the luminosity $\mathscr{L} \propto R/E_0^{13/3}$, where R is the collider radius. For $2E_0 \gtrsim 150$ GeV, both collision schemes have similar luminosity limits. The luminosities attainable at storage-ring and linear-collider (LC) $2E_0 \sim 240$ GeV Higgs factories are comparable; at higher energies, LCs are preferable. This conference paper is based on my recent PRL publication [1]
ers with

Beam-beam effects investigation and parameters optimization for a circular e+e- collider TLEP to study the Higgs boson

PS: 29.20

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(Dated: November 8, 2013)

Abstract

Several proposals exist for future circular electron-positron colliders designed for precise measurements of the Higgs boson characteristics and electroweak processes. At very high energies, synchrotron radiation of the particles in a strong electromagnetic field of the oncoming bunch (*beamstrahlung*) becomes extremely important, because of degradation of the beam lifetime and luminosity. We present theoretical calculations of beamstrahlung (including the beam lifetime reduction and the energy spread increase) which are benchmarked against quasi strong-strong computer simulation. Calculation results are used to optimize TLEP project (CERN).

BINP and FCC officiality

Memorandum of Understanding for the Future Circular Collider (FCC) has signed by CERN and BINP on July 2014. According to that, BINP is responsible for the following three chapters of the FCC-ee CDR:

- BB effects and luminosity (D.Shatilov)
- IR and FF arrangement (A.Bogomyagkov)
- Polarization and energy calibration (I.Koop)

Final solutions need closed optics so we should study (together with our CERN colleagues) the optics of the rest ring (S.Sinyatkin) and nonlinear beam dynamics (P.Piminov). Presently we focus of the CW option but according to our responsibility we shall (must) study and discuss in our CDR chapter any other collision options.

Work Units	
Identifier	**Title**
BINP-EE-1	Interaction regions optics studies for FCC-ee
BINP-FE-2	Beam-beam studies for FCC-ee
BINP-EE-3	Polarization studies for FCC-ee

Deliverables	
Identifier	**Title**
BINP-EE-1.1	Evaluation of IR optics for different scenarios
BINP-EE-1.2	CDR section on IR optics design
BINP-EE-2.1	Evaluation of beam-beam issues for different scenarios
BINP-EE-2.2	CDR section on beam-beam issues and optimization
BINP-EE-3.1	Evaluation of polarization for different energies
BINP-EE-3.2	CDR section on polarization scenarios

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MoU attachment scan

BINP talks at the ICFA Workshop HF2014 in Beijing, October 2014

- Dmitry Shatilov - Beam-beam effects in high-energy colliders: crab waist vs. head-on
- Ivan Koop - Polarization issues and schemes for energy calibration
- Anton Bogomyagkov - Crab waist interaction region
- Eugene Levichev - Choice of L* II: IR optics and dynamic aperture
- Ivan Koop - Maintaining polarization in synchrotrons
- Ivan Koop - Longitudinal polarization and acceleration of polarized beams
- Nikolay Muchnoi - FCC-ee beam energy measurement suggestion
- Sergei Nikitin - Possible applications of wave-beam interaction for energy measurement and obtaining of polarization at FCCe+e-

Beam-beam studies for FCC-ee

Main contributor is Dmitry Shatilov

- Parameters optimization and comparative analysis of different collision schemes is now performing with the use of more accurate models and techniques.
- There is much synergy between the head-on and crab waist lattice parameters and requirements, especially at high energies.
- At the top energy (175 GeV) the luminosity of the baseline and crab waist schemes are almost equal.
- At 120 GeV crab waist has an advantage ~ 50% growing with lowering the energy. At 45.5 GeV the advantage may reach about factor of 10.
- When the real nonlinear lattice is ready, more reliable beam-beam simulations will be possible.

IR optics studies for FCC-ee

Main contributor is Anton Bogomyagkov

What is done?

1. Interaction region matched to arc v-16.
2. Phase advances over IR and Straight sections is fixed to integer of 2π.
3. Global tune is defined by arc cell.
4. At the end of IR the distance between the beams is 0.72 m.
5. Energy acceptance [-2.5%;+2%].
6. Geometry of the IR provides straight tunnel 3 m wide.

Polarization studies for FCC-ee

Main contributor is Ivan Koop

- Methods of the energy calibration based on polarization are considered. Free precession approach could provide extremely fast method of spin frequency measurement. FCC-ee beam parameters satisfy this requirement at energies below 120 GeV, assuming $v_s < 0.2$.

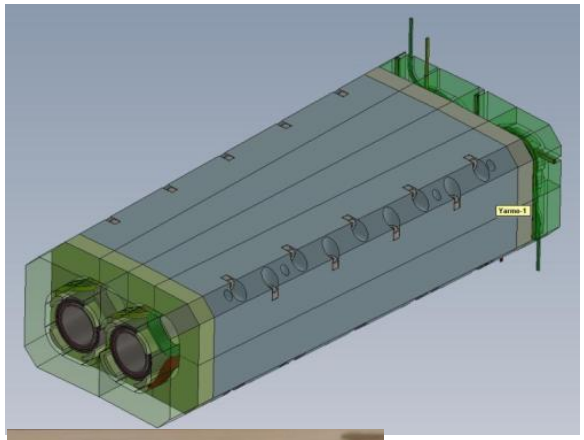
- Methods of the energy calibration based on alternative technique (CBS) are also discussed.

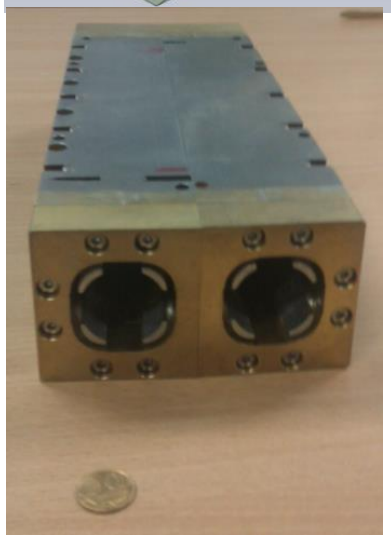
- FCC-ee orbital kinks which do not disturb the spin motion and vertical emittance are proposed and studied.

SC final focus quadrupole

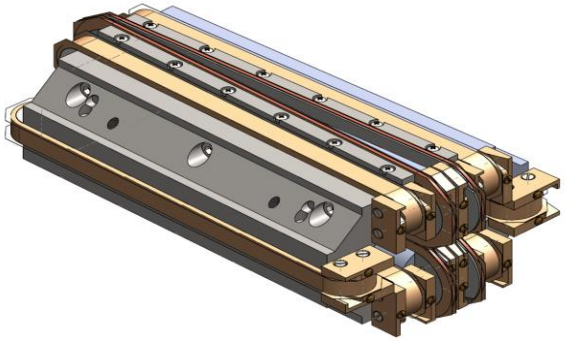
Main contributors are Ivan Okunev and Pavel Vobly

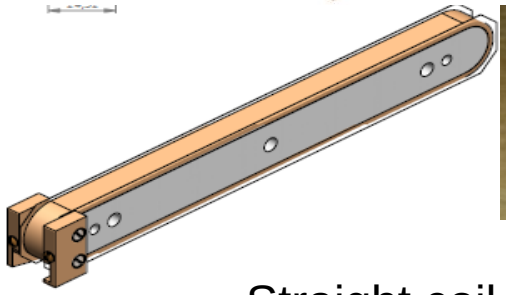
Two versions of the FF twin-aperture iron yoke quad prototype with 2 cm aperture and 100 T/m gradient are in production.





Saddle-shaped coils, complicated in production, the first coil failed. New winding device is in development.





Straight coil, successfully wound and tested (650 A instead of the nominal 400 A)

The work has low priority and small contract with CERN would help

Preliminary study of the IR solenoids

Main contributor is Sergey Sinyatkin

Placement of anti-solenoids inside the FF quad doublet (close to the IP) seems the simplest way to compensate influence of the main solenoid field to the remaining lattice. A disadvantage is the vertical emittance excitation by the fringe fields (especially at 45 GeV for our model Ey/Ex = 75%, Ey=60 pm). Possible cures: (1) rectangular cross-section anti-solenoid (horizontally wide but vertically narrow), horizontal field at the edges is suppressed, (2) more precise optimization of the fringe transition region.

A scheme with anti-solenoids located outside the FF quads does not contain strong solenoid fringe fields but requires complicated coupling correction with skew-quads in the area of chromatic sextupoles and bending magnets. Now the highest value of the vertical emittance is Ey = 1.7/3.6 pm at 45 GeV. Influence to the dynamic aperture and momentum acceptance is expected and careful study is necessary.

Nonlinear beam dynamics

Main contributor is Pavel Piminov

- Arc FODO cell is optimized and does not limit both DA (~$\pm 150\sigma_x$ x $\pm 3000\sigma_y$) and MA ($\pm 2\%$). Only 2 sextupole families are used so further optimization with several families is available
- Strong IR chromatic sextupoles reduce the DA to ~$\pm 50\sigma_x$ x $\pm 450\sigma_y$ and MA to $\pm 1.6\%$
- Crab sextupoles reduce it additionally to ~$\pm 15\sigma_x$ x $\pm 120\sigma_y$ at dp/p = 0% and to unacceptable ~$\pm 2\sigma_x$ x $\pm 20\sigma_y$ at dp/p = $\pm 1\%$
- No quad fringes, kinematics, etc. Additional optimization is necessary

Background FCC activities at BINP

- Detector region magnet field simulation including the main, compensating and screening solenoids, FF quadrupoles, correction coils, etc.
- FF quadrupole full scale prototype design and production.
- Low field magnets (a short prototype was built for LHeC).
- SR background calculation and mitigation.
- Compton backscattering polarimeter.
- Compton backscattering energy calibration.
- Experiment on the free spin precession approach to measure the FCC-ee beam energy is now under way at VEPP-4 collider.

Conclusion

Present status of Budker INP activity with respect to the FCC project is discussed shortly.

Thank you.