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Very short summary of FOA proposal 235252

Contents

Abstract

In January 2018 three institutions – BNL, Cornell and JLab – jointly submitted a proposal for CBETA research and development titled "High Intensity Tests for Electron Cooling" in response to DOE Funding Opportunity Announcement (FOA) LAB-18-1858 [1]. Although it reviewed positively in most ways, proposal number 235252 was nonetheless rejected. This note quickly summarizes the research topics that were suggested in the FOA proposal, in preparation for the discussions that will take place at the one-day satellite workshop, "EIC ERL Accelerator Physics", to be held in November 2018 at JLab [2].

The proposal breaks down into the five tasks that are sumarized in turn, below. The *Potential Impact of the [Proposal]* states that: "Successful performance of these tasks would increase CBETA intensities to best-in-class values, with enhanced understanding of the leading physical and technological issues that dominate in the trend toward ever higher performance ERLs. This would enable more reliable designs for higher performance electron-ion colliders, and would have the spin-off effect of making ERL accelerators more useful in general applications." Most of the text, below, is quoted directly from the proposal document.

1 Simulations

1.1 Beam loss

Goal: Develop halo-simulations to compare loss mechanisms, including ghost pulses from the laser, field emission at the cathode and in cavities, and Touschek (residual gas) scattering.

1.2 High-bunch-charge

Goal: Simulate bunch-charge limits for CBETA, including coherent synchrotron radiation, microbunching, longitudinal space charge, and wakes.

1.3 Magnetized beam-transport

One of the most critical features of JLEIC is the luminosity, which requires cooling the ion beams. In the proposed design, this is achieved when an electron beam and ion beam of the same average velocity but different temperatures co-propagate. The cooling rate such an interaction achieves can be improved by approximately two orders of magnitude if the interaction occurs within an appropriate solenoid field [3].

1.4 Nonlinear dynamics

Maintaining a high-quality longitudinal distribution is important for avoiding particle loss and maintaining energy recovery efficiency.

The very high chromaticity of CBETA may have an impact on transverse instabilities. This will also be studied, for comparison with beam studies experiments.

2 Diagnostics

2.1 Halo diagnostics

A High Dynamic Range (HDR) transverse beam profile monitor was developed for both the Jefferson Lab FEL and for the running of the Dark Light experiment at JLab FEL [4]. A version of this device is proposed to image the tails of the core beam by having it pass through a hole in the center of the Optical Transition Radiation (OTR) and only image the halo.

2.2 Coherent synchrotron radiation and microbunching

ERL beams start with very bright beams, which are very susceptible to microbunching.

The best way to see microbunching is to look for the coherent radiation enhancement at short wavelengths.

The CSR effects can be imaged CW with synchrotron light, the effect is seen and the electron beam begins to separate out to distinct filaments. Passing the signal into a visible/near IR spectrometer can quantize the effect.

2.3 Time-resolved beam-loss diagnostics for machine protection

The problem of determining the cause of the beam loss can be aided by first fault capability in the machine protection system logic chain, but it can be determined even more sensitively by monitoring some key parameters with sampling scopes and triggering on a loss event. One can then look back to the time before the trip to see what led to the event.

3 Low Level RF

3.1 RF stability in the injector and main linac cryomodules

Ramping the DC current up to the maximum value will present important problems with beam scraping and halo, as well as with beam loading. The approach used at JLab in their moderate current ERL was to first tune with a pulsed beam of 2 Hz 250 μs beam, then to change the pulse repetition rate from 2 Hz to 60 Hz, and finally to increase the pulse width until achieving good transport without tripping the beam loss monitor system. Additionally, JLab had a vernier control on the micro pulse repetition rate.

The proposal is to develop a beam mode table that defines all of the required time structures and bunch charge parameters. This is necessary to define the machine protection system and to understand the RF drive requirements.

4 Commissioning to high-intensity

4.1 1 nC bunch charge at a reduced repetition rate

Previously, the Cornell photoinjector has produced low emittance bunches with charges up to 2 nC per bunch at about 9.5 MeV.

The emittance scales like $Q^{1/2}$ at low charges, and roughly linear with Q at higher charges. A charge of about $Q = 0.3$ nC separates the two regimes.

The 95% and 100% emittances at 1 nC are 1.6 and 2.3 microns (consistent with CBETA design specification), with the formation of large halo tails that become even larger with 2 nC bunches [5].

4.2 1-pass energy recovery at 42 MeV

The highest average current in superconducting ERLs achieved to date is 9.1 mA, demonstrated at the JLab IRFEL-DEMO [6]. CBETA is uniquely poised to explore the regime of higher average currents, with CW currents of more than 50 mA already demonstrated in the Cornell photoinjector.

The permanent magnet arcs require a properly matched beam to achieve a transport that will not degrade the beam parameters to the point where they significantly affect the energy recovery efficiency. Initial experiments will be performed at a very low duty factor using the diagnostic line.

Finally, the largest impediment to high current is likely to be beam loss both from halo and incompletely energy-recovered beam (i.e. temporal tails). We detect these two effects using local radiation monitors and a network of scintillating fibers connected to PMTs around the recirculating arc. Understanding and mitigating beam losses will require guidance from the simulations as discussed elsewhere.

4.3 4-pass energy recovery at 150 MeV

Multi-pass high average current operation is significantly more complicated than single-pass operation, due not only to the complexity of beam diagnostics that must work simultaneously on overlapping beams, but also to the inherent challenges in controlling orbits, energies, and beam halo losses of each individual beam when using a shared control system that affects them all. Our goal is to explore the challenges posed by multimode operation with as many as 4 passes, and to identify average current limitations.

5 Extraction design

CBETA could be used for EIC R&D or other purposes in a configuration in which beam is extracted at 150 MeV, and also returned for subsequent energy recovery. A number of concepts have been proposed for high-energy beam extraction, but none of them have been developed far enough to evaluate their performance and practicality. The goal of this topic is to develop these concepts further, supported where possible by preliminary beam studies.

References

[1] *FY 2018 Research and Development for Next Generation Nuclear Physics Accelerator Facilities*, FOA LAB-18-1858; *High Intensity Tests for Electron Cooling*, proposal 23525. Neither document is publicly available.

[2] *EIC ERL Accelerator Physics*, workshop to be held on November 2, 2018, https://www.jlab.org/conferences/erl-2018 .

[3] *Magnetization effects in electron cooling*, Ya. Derbenev and A. Skrinsky, Fiz. Plazmy 4, 492 (1978) [Sov. J. Plasma Phys. 4, 273 (1978)].

[4] *Large dynamic range beam diagnostics for high average current electron linacs*, P. Evtushenko, IPAC14, (2014).

[5] *Operational experience with nanocoulomb bunch charges in the Cornell photoinjector*, A. Bartnik et al, Phys. Rev. ST Accel. Beams 18, 083401, (2015).

[6] *Performance and modeling of the JLab IR-FEL upgrade injector*, C.H.G. Hernandez-Garcia et al., FEL04, (2004).