ABSTRACT

In preparation for a future Large Hadron electron Collider (LHeC) at CERN, an ERL test facility is foreseen as a test bed for SRF development, cryogenics, and advanced beam instrumentation, as well as for studies of ERL-specific beam dynamics. The CERN ERL test facility would comprise two linacs, each ultimately consisting of 4 superconducting 5-cell cavities at ~802 MHz, and two return arcs on either side; a final electron energy of about 300 MeV is reached. The average beam current should be about 6 mA to explore the parameter range of the future LHeC. In this paper we present a preliminary optics layout.

LHeC Recirculator with ER

The LHeC is a proposed new machine at CERN which will collide the 7-TeV protons circulating in the Large Hadron Collider (LHC) with a high-energy lepton beam at a single collision point [1].

The LHeC ERL approach allows a comparable or even higher machine performance as compared to the LHeC Ring-Ring option.

An LHeC ERL Test Facility at CERN

The main purposes are:

• confirming the feasibility of the LHeC ERL design by demonstrating stable intense electron beams with the intended parameters (current, bunch spacing, bunch length);
• testing novel components such as a (polarized) DCS electron gun, superconducting RF cavities, cryomodule design and feedback diagnostics;
• experimental studies of the lattice dependence of stability criteria.

System architecture

1. A 5 MeV in-line injector with an injection chicane;
2. Superconducting linacs consisting of two (or one) cryomodules in total eight 5-cell SC structures operating at 802 MHz [2];
3. optics transport lines including spreader regions at the exit of each linac to separate and direct the beams via vertical bending, and recombiner sections to merge the beams and to match them for acceleration through the next linac;
4. Beam dump at 5 MeV.

Overall layout:

• A 0.5 GeV injector with an injection chicane;
• Two SRF linacs (Energy gain of 10 GeV per pass);
• Six 180° arcs, for each arc one re-accelerating station that compensates the SR emitted;
• Switching stations to combine/distribute the beams over different arcs;
• An extraction dump at 0.5 GeV.

LHeC ERL main parameters

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARTICLE PER BUNCH</td>
<td>3 MeV</td>
</tr>
<tr>
<td>INITIAL HORIZONTAL EMITTANCE</td>
<td>10 µm</td>
</tr>
<tr>
<td>INITIAL VERTICAL EMITTANCE</td>
<td>10 µm</td>
</tr>
<tr>
<td>MAXIMUM IP SIZE</td>
<td>1 µm</td>
</tr>
<tr>
<td>NORMALIZED TRANSVERSE EMITTANCE AT IP</td>
<td>50 µm</td>
</tr>
<tr>
<td>MAXIMUM CURRENT</td>
<td>50 mA</td>
</tr>
<tr>
<td>COMMISSIONING CURRENT</td>
<td>30 mA</td>
</tr>
<tr>
<td>MINIMUM OPERATING CURRENT</td>
<td>10 mA</td>
</tr>
<tr>
<td>MAXIMUM POWER COUPLING COEFFICIENT</td>
<td>-100%</td>
</tr>
</tbody>
</table>

Optics choice:

Arc-to-Linac Synchronization | Quasi-isochronous lattices
Arc optics | Emittance preserving lattices | Variation of Flexible momentum compaction cells (Imaginary Y, Double-Bend Achromat [DBA], Theoretical Emittance Minimum [TEM]).

Transport optics

Appropriate recirculation optics are of fundamental concern in a multi-pass machine to preserve beam quality. The design comprises three different regions, the linac optics, the recirculation optics and the merger optics. The focusing strength of the quadrupoles along the linac needs to be set to transport two co-propagating beams of different energy and to support a large number of passes. Disturbing effects on the beam phase-space such as cumulative emittance and momentum growth have to be counteracted through a pertinent choice of the basic optics cell.

For beams with non-zero energy spread, one would like to employ a quasi-isochronous arc to limit bunch lengthening in the subsequent linac and the synchronous condition can by defined in terms of a tolerable RF phase delay for a given momentum acceptance. Diverse plausible optics layouts are taken into consideration:

• FMC cell;
• 6-cell FODO lattice (with 60° horizontal phase advance and 90° vertical phase advance per cell) perturbed by a closed dispersion bump to control Mz;
• compact FODO arc also based on 90°/60° horizontal/vertical phase advance per cell.

CONCLUSIONS

An ERL based collider in which a newly provided electron beam collides with the intense hadron beams of the LHC represents a major opportunity for progress in particle physics. A proposal for a scientific and technical R&D facility preparing to LHC is now under active development. Here we have described the CERN ERL test facility purposes and specific requirements along with two conceivable layout schematics. The ultimate goal is a design that operates on a multiple operating points in order to allow for a comprehensive validation testing of the key concepts for the final LHeC.

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REFERENCES