ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-MOPRB098

AN INCREASED EXTRACTION ENERGY BOOSTER COMPLEX FOR THE JEFFERSON LAB ELECTRON ION COLLIDER*

E. Nissen†, Jefferson Lab, Newport News, VA, USA

Abstract

The proposed Jefferson Lab Electron Ion Collider (JLEIC) envisions an ion complex composed of an ion linac, two booster synchrotrons and a collider ring. The evolving design of the JLEIC booster required an increase in the extraction energy of the booster from 8 to 12.1 GeV kinetic energy, necessitating two machines instead of one. The decision was also made to switch to warm magnets, thus increasing the total radius of the 8 GeV booster. The second booster is now the same size as the collider rings. In this work we present the new designs for JLEIC's Low Energy Booster (LEB) and High Energy Booster (HEB).

REQUIREMENTS

As the design of the Jefferson Lab Electron Ion Collider (JLEIC) has evolved, an increase in the extraction energy of the booster complex was required. This was due to the increase in the top energy of the collider ring from 100 GeV to 200 GeV [1], and the need to keep the energy reach within reasonable bounds. In order to accommodate this switch to warm magnets and avoid transition crossing throughout the complex, the machine was split into two. The booster complex now goes from the source, through a linac, a Low Energy Booster (LEB) a High Energy Booster (HEB) and finally into the collider ring. The LEB now goes from 150 MeV to 8 GeV kinetic energy, and the HEB goes from 8 GeV to 12.101 GeV kinetic energy (13 GeV/c momentum) for protons or ions of equivalent rigidity.

LOW ENERGY BOOSTER DESIGN

The low energy booster needs to take protons (or ion equivalents) from 150 MeV to 8 GeV kinetic energy without crossing transition. A decision was made to switch to warm magnets from superconducting, necessitating an increase in size to a 604 m circumference. The figure-8 shape is again used to preserve spin polarization. This increase in size allows us to use FODO cells in the arc while still keeping the transition energy above the maximum extraction energy. The γ_t is 10.6, a 10% overhead on the extraction gamma for protons. In order to provide a simple superperiod for the chromaticity correction, the phase advance in the arcs is 108° per cell. Dispersion suppression is accomplished via differential bending in the two cells on either end of the arcs. The optical functions of the LEB are shown in Fig. 1, while the physical layout is shown in Fig. 2. The magnets and their strengths are shown in Table 1. The straights are each composed of five pairs of FODO cells, any working point changes will be performed in the straights which must also make room for electron cooling, RF, injection and extraction. Each straight FODO cell has an overall length of 4.4 m.

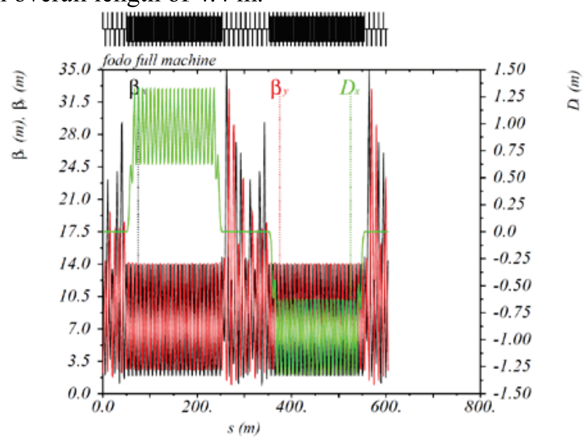

Figure 1: These are the lattice functions for the LEB.

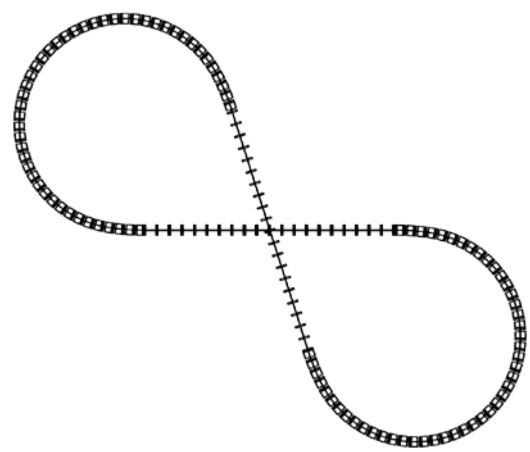

Figure 2: This is the physical layout of the LEB.

Table 1: Magnets and their Strengths for the LEB

Element	L (m)	Number	T (max)	T/m (max)	T/m^2 (max)
Dipole	2.5	96	1.19	-	-
Quadrupole	0.6	136	-	19.7012	-

HIGH ENERGY BOOSTER DESIGN

The high energy booster needs to take the beam from 8 GeV to 12.101 GeV kinetic energy in a footprint that fits in the tunnel provided for the ion and electron collider rings (2341 m). We matched the geometry of the electron collider ring, but used 2 FODO cells for every 3 in the collider ring's arcs. The electron collider ring also includes spin rotators which perform part of the bending, so these needed to be matched in the HEB. Once again, a 108° phase advance per cell is used, giving a γ_t of 14.745. The ends of

* Authored by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177. The U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce this manuscript for U.S. Government purposes.
† nissen@jlab.org

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-MOPRB098

the arcs have reduced bending to match the geometry of the electron collider ring. The electron collider ring uses differential bending to suppress dispersion. However, since the cell length is longer in the HEB, the dispersion is not completely suppressed, combined with the bending in the spin rotator, we used the quadrupoles in that section to suppress the dispersion. The lattice functions of the HEB are Shown in Fig. 3, and the physical layout is shown in Fig. 4. A detailed view of the spin rotator matching section is shown in Fig. 5. Its magnet parameters are shown in Table 2.

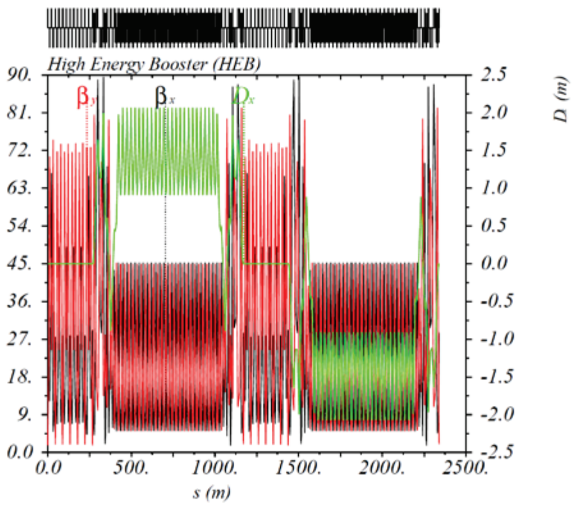

Figure 3: The optics functions of the HEB.

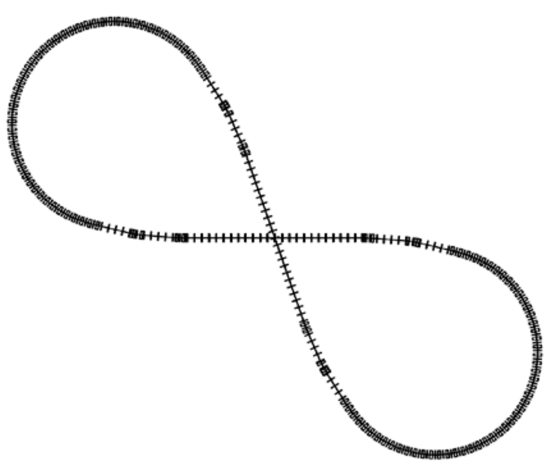

Figure 4: The physical layout of the HEB.

Table 2: Magnets and their Strengths in the HEB

Element	L (m)	Number	T (max)	T/m (max)	T/m^2 (max)
Dipole	4.0	104	0.857	-	-
Dipole	3.6	20	0.925	-	-
Quadrupole	0.6	202	-	12.19	-
Sextupole	0.2	80	-	-	113.7

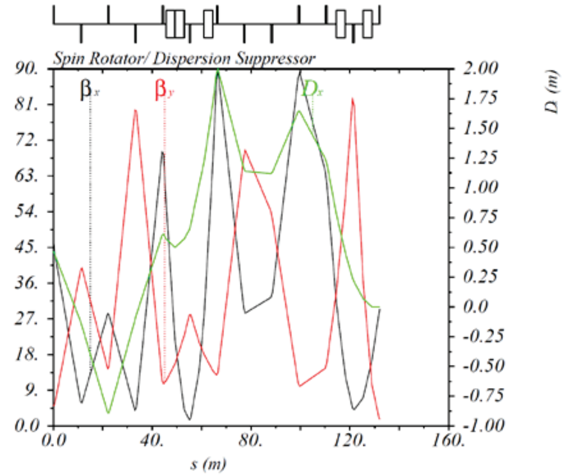

Figure 5: This is an overview of the spin rotator/dispersion suppressor section in the HEB.

CONCLUSIONS AND FURTHER WORK

The new designs for the boosters in JLEIC will allow the project to increase its top extraction energy to allow for a higher center of mass energy in the collider ring of JLEIC. The increased size requirements mean that a FODO lattice can be used in the arcs while still avoiding transition crossing. Issues like finding and optimizing the working point, and designing the transfer lines to and from the LEB and from the HEB still need to be done.

REFERENCES

[1] Y. Zhang, "JLEIC: A High Luminosity Polarized Electron-Ion Collider at Jefferson Lab", presented at the 10th Int. Particle Accelerator Conf. (IPAC'19), Melbourne, Australia, May 2019, paper MOPRB114, this conference.