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VALIDATION OF THE HALBACH FFAG CELL OF CORNELL-BNL ENERGY RECOVERY LINAC *

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Abstract

The Cornell-BNL Electron Test Accelerator (CBETA), a 150 MeV energy recovery linac (ERL) now in construction at Cornell, employs a fixed-field alternating gradient optics return loop: a single beam line comprised of FFAG cells, which accepts four recirculated energies. CBETA FFAG cell uses Halbach permanent magnet technology, its design studies have covered an extended period of time supported by extensive particle dynamics simulations using computed 3-D field map models. This approach is discussed, and illustrated here, based on the final stage in these beam dynamics studies, namely the validation of a ultimate, optimized design of the Halbach cell. This work is published in NIM A (2018)

INTRODUCTION

The Cornell Laboratory of Accelerator-based Sciences and Education (CLASSE) and the Collider Accelerator Department (BNL-CAD) are developing a multi-turn energy recovery linac (ERL).

CBETA (Cornell-BNL ERL Test Accelerator) will carry out accelerator science and enable research in nuclear physics, materials science, and industrial applications. Initially it will prototype components and evaluate concepts that are essential in validating a Linac-Ring based Electron-Ion Collider (EIC), comprised of a multi-turn 21 GeV ERL built along BNL's RHIC heavy ion collider and using FFAG return arcs.

CBETA is based on Cornell's 1.3 GHz superconducting linac operated at 36 MeV, and on a Non-Scaling Fixed Field Alternating Gradient (NS-FFAG) return loop using Halbach permanent magnet quadrupole technology.

THE HALBACH FFAG CELL

Main aspects are commented in Figs. 1-5 and their captions, and in Table 1.

This work is published in NIM A (2018), 20 pages of detailed ray-tracing outcomes and comments can be found there [1]

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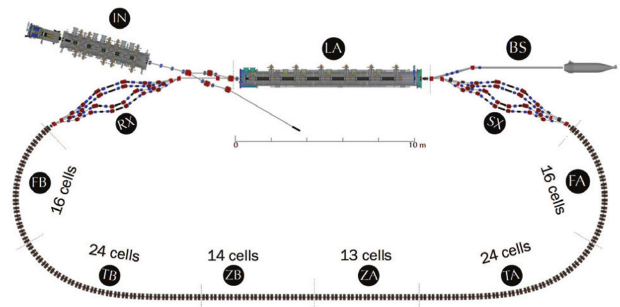

Figure 1: CBETA 150 MeV, 4-pass, 79 m circumference ERL, based on a 36 MeV superconducting linac and on a 107 cell NS-FFAG return loop using Halbach permanent magnet quadrupole technology. The return loop accepts the 4 recirculated energies in a single channel: 42, 78, 114 and 150 MeV.

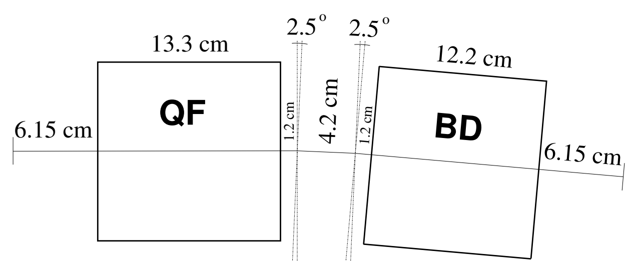

Figure 2: A synoptic of CBETA 5-degree bend, 44.4 cm long arc cell. QF is a pure quadrupole, focusing, BD is a combined function dipole, defocusing. The optical axis coincides with the bore axis in the Halbach magnets.

Table 1: Normalized horizontal (col. 2) and vertical (col. 3) dynamical admittances of a 300-cell beam line (3 times CBETA channel length, for safety margin), observed from the start of the line. This is the transverse initial emittances of the 4-D bunch of mono-energetic particles that have survived the transport through the line. Momentum spread in the bunch has marginal effect on these data.

γmc^2 (MeV)	A_x/π (mm)	A_y/π (mm)
150	19	37
114	70	154
78	22	52
42	5	9

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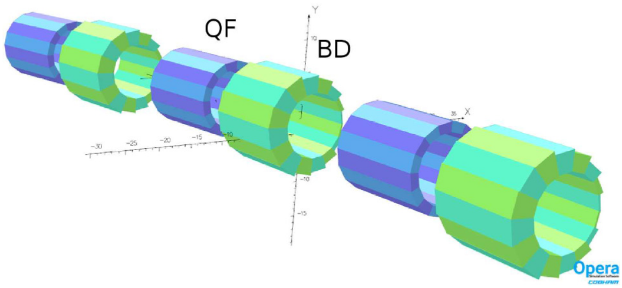

Figure 3: A 3-cell model in OPERA, with its quadrupoles QF, BD realized using the Halbach permanent magnet technology. The central (QF,BD) doublet field map can be used in the beam dynamics studies, or otherwise two independent field maps, one for QF and one for BD. The latter case offers flexibility, for instance it allows tuning fields independently, or moving the magnets relatively to one another.

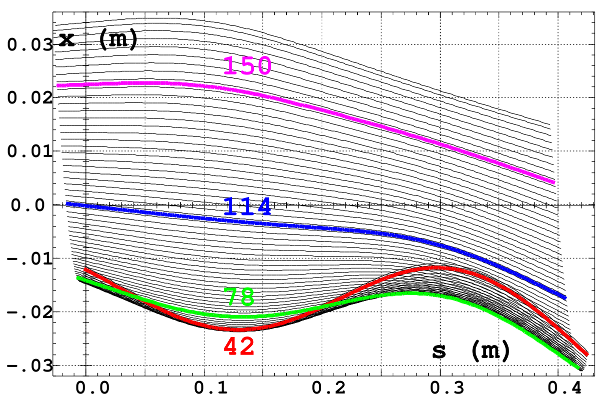

Figure 4: A scan in energy of periodic orbits across the 3-D full-cell map, 64 different energies over a 40-166 MeV range, the 4 design energies are thicker, colored curves. The 42 and 150 MeV orbit excursions reach ∓ 2.33 cm respectively, *wrt* QF bore axis. Nominal beam envelopes extend a fraction of a millimeter about these orbits.

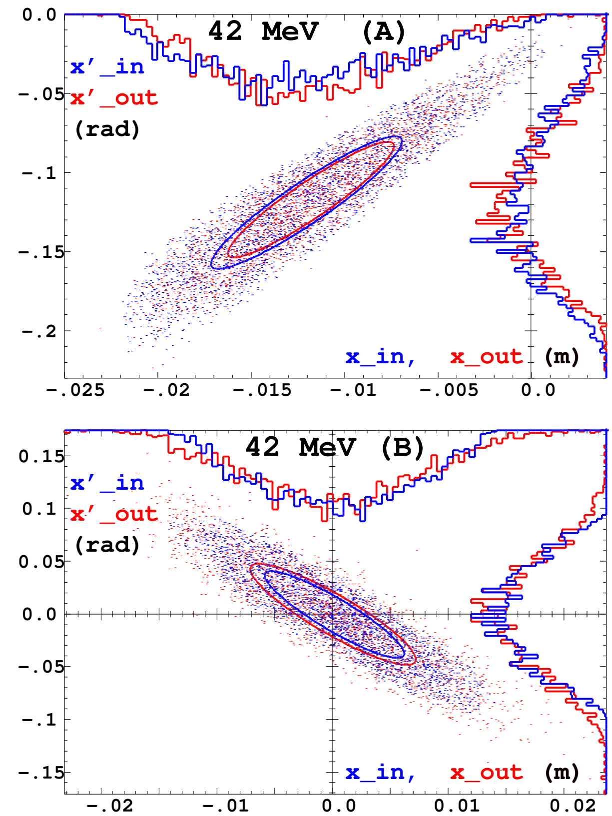

Figure 5: Horizontal (A) and vertical (B) initial (blue) and final (red) phase space coordinates, of the particles that make it through the 300-cell line, 42 MeV case. The blue and red ellipses are the *rms* matched ellipses, with surfaces respectively $60\pi\mu$m, $110\pi\mu$m.

REFERENCES

[1] F. Méot, N. Tsoupas, S. Brooks, D. Trbojevic, Beam dynamics validation of the Halbach Technology FFAG Cell for Cornell-BNL Energy Recovery Linac, NIM A, 2018.