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MAGNET DESIGN FOR THE SPLITTER/COMBINER REGIONS OF CBETA, THE CORNELL-BROOKHAVEN ENERGY-RECOVERY-LINAC TEST ACCELERATOR

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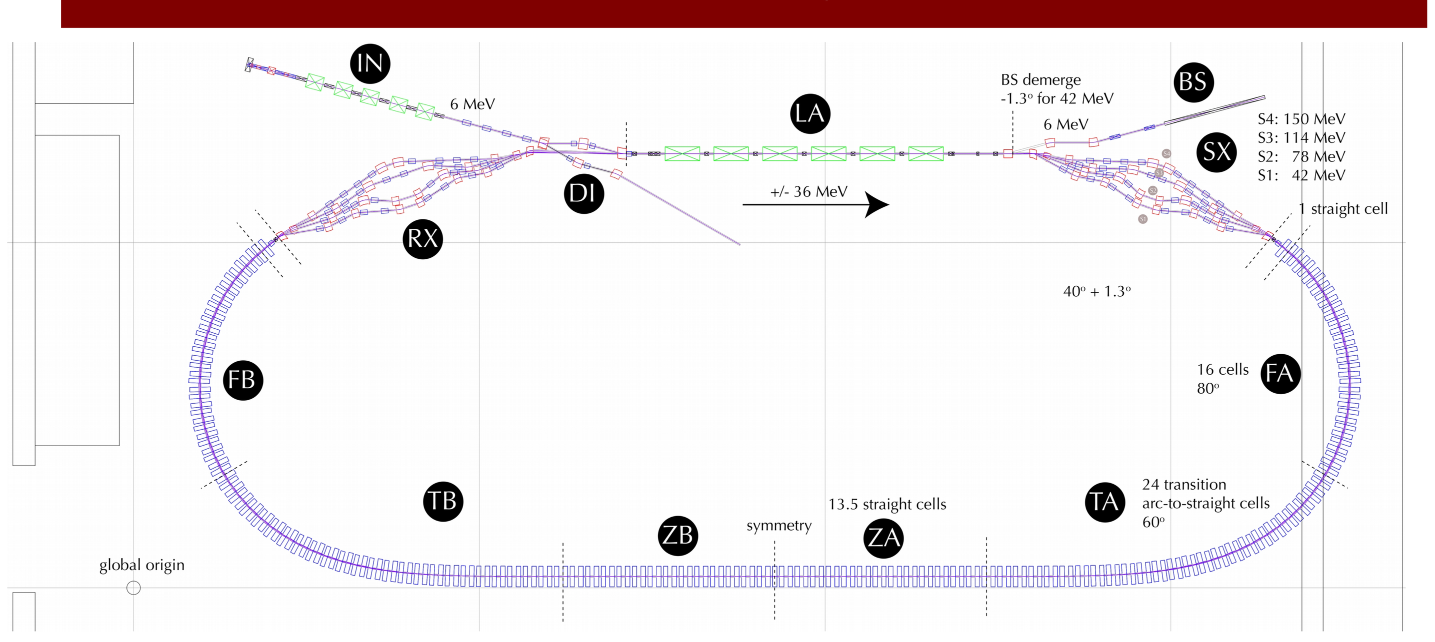
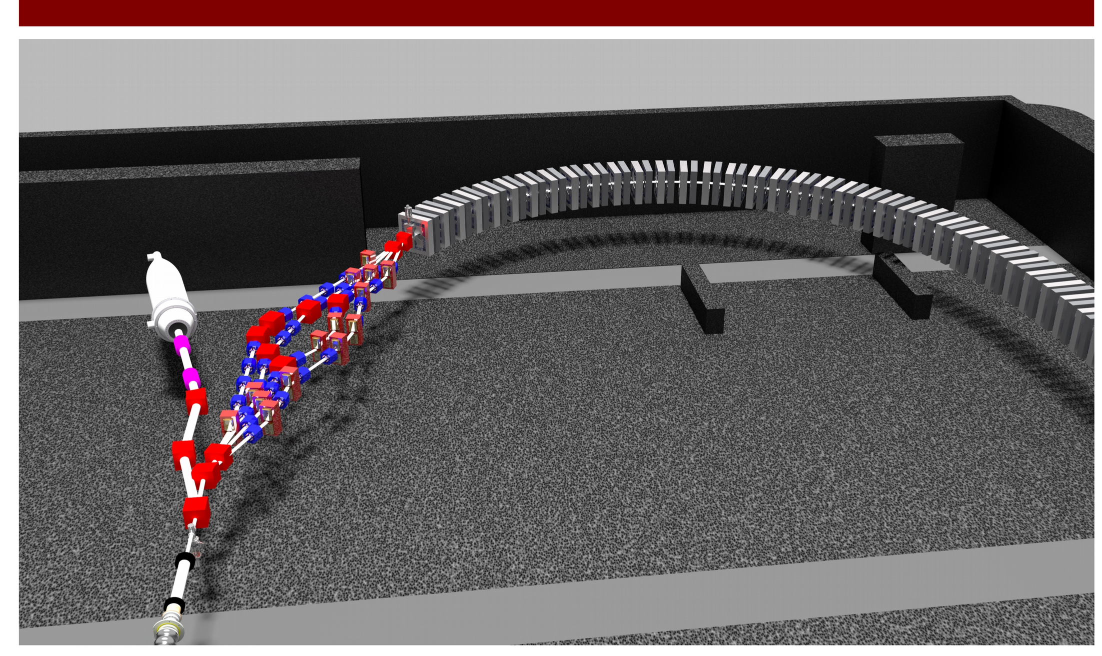
The Cornell-Brookhaven Energy-Recovery-Linac Test Accelerator (CBETA) will provide a 150-MeV electron beam using four acceleration and four deceleration passes through the Cornell Main Linac Cryomodule housing six 1.3-GHz superconducting RF cavities. The return path of this 76-m-circumference accelerator will be provided by 106 fixed-field alternating-gradient (FFAG) cells which carry the four beams of 42, 78, 114 and 150-MeV. Here we describe magnet designs for the splitter and combiner regions which serve to match the on-axis linac beam to the off-axis beams in the FFAG cells, providing the path-length adjustment necessary to energy recovery for each of the four beams. The path lengths of the four beamlines in each of the splitter and combiner regions are designed to be adapted to 1-, 2-, 3-,and 4-pass staged operations. Design specifications and modeling for the 24 dipole and 32 quadrupole electromagnets in each region are presented. The CBETA project will serve as the first demonstration of multi-pass energy recovery using superconducting RF cavities with FFAG cell optics for the return loop.

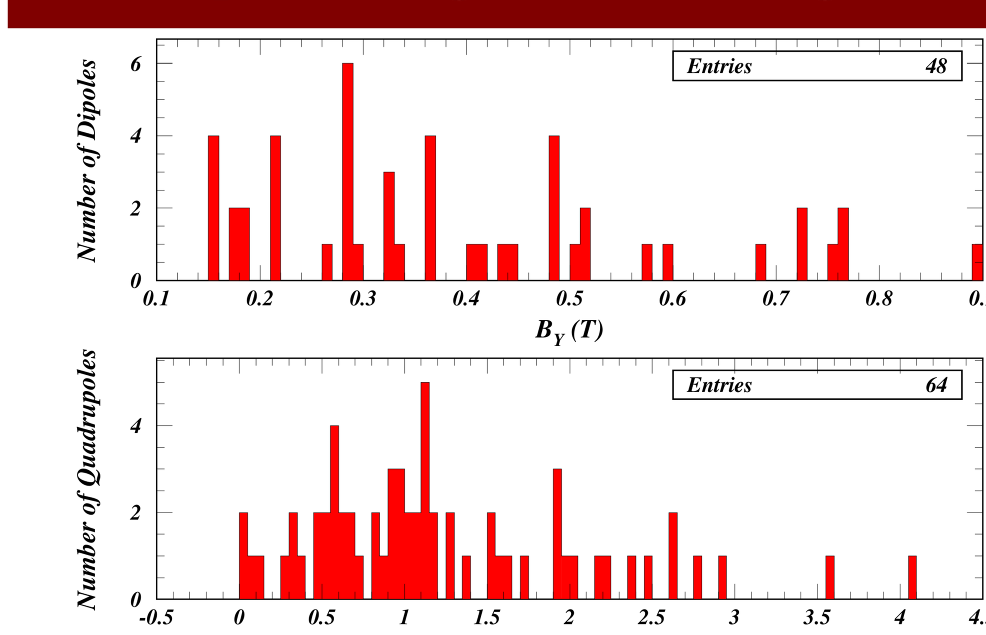
CBETA Layout



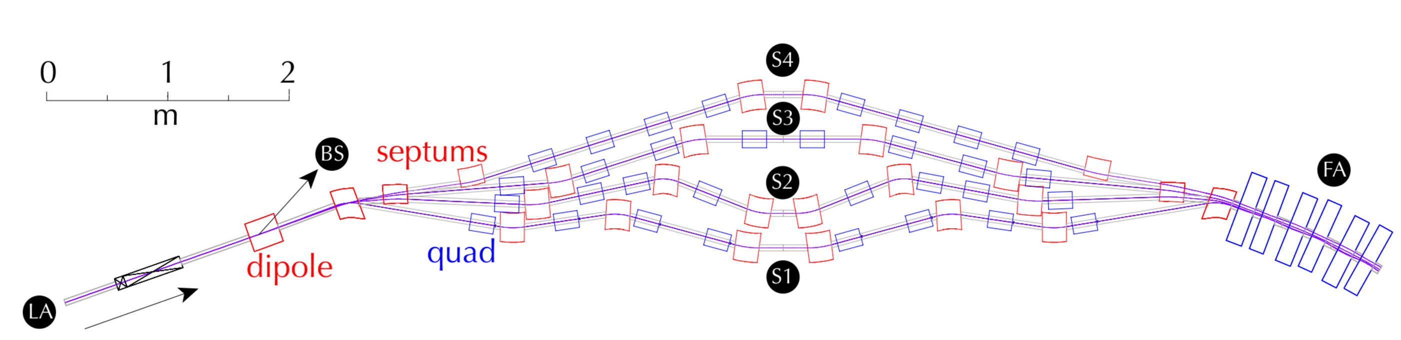
Splitter & Beam dump & FFAG return loop



Splitter Magnet Field Strengths

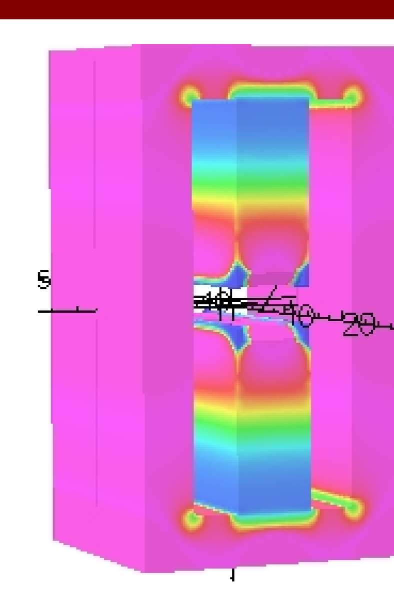


Splitter Layout



Dipole surface contours of B/H

Saturation contours show flux leakage from central pole resulting in 1% non-linearity at 6 kG excitation



Quadrupole surface contours of B

Nonlinearity less than 0.1% at the maximum excitation of 4.0 T/m

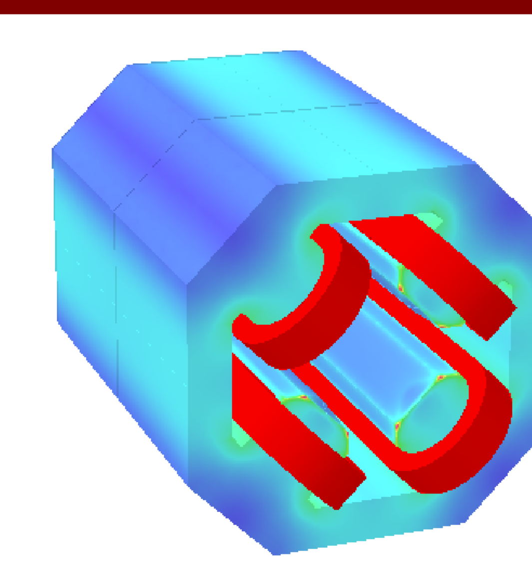
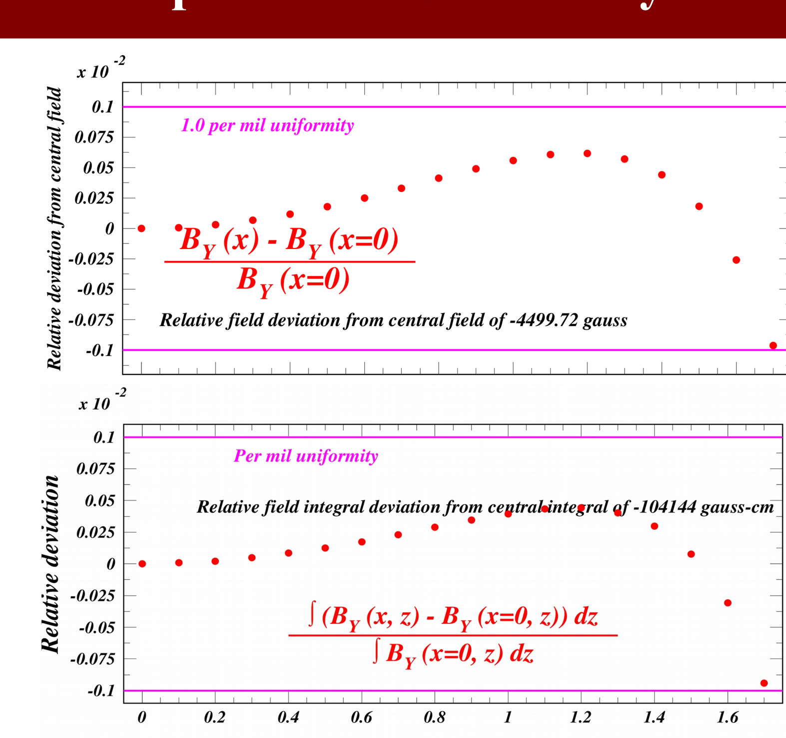


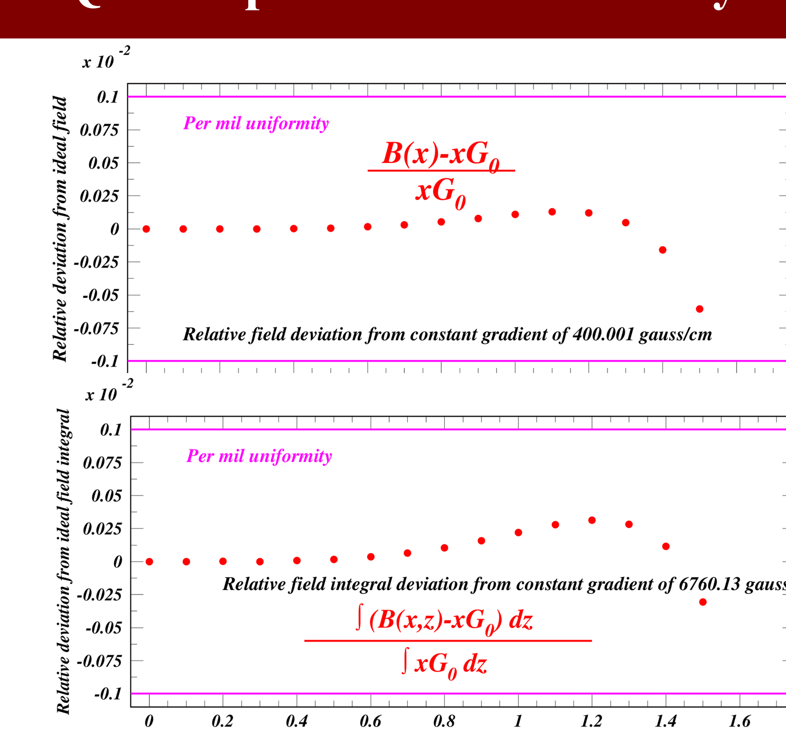
Table of Electrical and Thermal Operational Parameters

Parameter	H-Dipole 21x39x20	H-Dipole 21x39x20	H-Dipole 21x39x30	Quadrupole 12x12x15
Gap or Bore (cm)	3.0	3.0	3.0	4.0
Steel height (cm)	39.0	39.0	39.0	12.3
Steel width (cm)	21.0	21.0	21.0	12.3
Steel length (cm)	20	20	30	15
Pole width (cm)	6.0	6.0	6.0	3.1
Field (G)/Gradient (G/cm)	5936	4500	5977	400
NI (Amp-turns)	7166	5375	7166	637
Turns per coil	5x20	5x20	5x20	2x4
Coil cross section (cm x cm)	3.4x13.7	3.4x13.7	3.4x13.7	1.0x2.0
Conductor straight length (cm)	20	20	30	15
Coil inner corner radius (cm)	1.0	1.0	1.0	1.53
Conductor length per turn, avg (cm)	65.1	65.1	85.1	41.2
R_{coil} (Ω)	0.0323	0.0323	0.0422	0.00263
Power supply current (A)	71.7	53.8	71.7	80.0
Current density (A/mm^2)	1.78	1.33	1.8	3.2
Voltage drop for two (four) coils (V)	4.6	1.7	6.1	0.8
Power/coil (W)	165	45	219	17
Water flow/coil @Δp=45 psi (Gal/min)	0.11	0.11	0.09	0.31
Coil temperature rise (°C)	6.0	3.4	8.9	0.2

Dipole Field Uniformity



Quadrupole Field Uniformity



Summary

We present a first-pass design study for the magnets required for the splitter and combiner regions of the Cornell-Brookhaven ERL Test Accelerator CBETA. Stringent space and cooling constraints and a wide range of field strengths have been accommodated by a design featuring a single transverse cross section for all dipoles and for all quadrupoles. Modeling has shown that the per-mil field uniformity specifications are satisfied. This feasibility study will serve as the basis for near-term value engineering development.

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