FACET-II LEM Overview

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September 16, 2024

LEM (LINAC energy management) consists of two main computations: (1) estimating the live momentum profile $p_z(s)$ and (2) calculating the correct magnet strengths, B_{LEM} for a given momentum profile.

1 Calculating $p_z(s)$

The live beam momentum profile is a monotonically increasing function of s, and is determined by the current complement of klystrons, and klystron/subbooster phases. At the position s, the beam momentum is approximated by:

$$P_z(s) \approx \sum_{i}^{N_k(s)} E_i cos(\phi_k + \phi_s)$$

where $N_k(s)$ counts the number of klystrons up to the position s_i, ϕ_k and ϕ_s are the klystron and subbooster phases, respectively and E_i is the klystron ENLD in MeV(MV).

Due to inaccuracies in measured ENLD values and phase errors in the linac, $P_z(s)$ will not add up exactly to the correct beam energy. To correct this error we can compare $P_z(s)$ to the design momentum $p_{0z}(s)$ at points in the accelerator where the beam energy is known, and determined by bend magnet settings.

For a given LEM region (i.e. regions of the beamline where the beam is accelerated from a know starting energy to a known final energy), we'll calculate a "fudge factor", K_{LEM} that is just the ratio of the actual:estimated energy. This fudge factor scales the estimated profile to match the extant acclerator.

$$K_{LEM} = \frac{p_{0z}(s_{end})}{p_z(s_{end})} \quad \rightarrow \quad p_z(s) = K_{LEM} P_z(s)$$

As a side effect, the set of fudge values, K_{LEM} also characterize phase coherence & ENLD measurement accuracy. To maximize the accuracy of LEM calculations, ENLD data and linac phase scans should be current.

2 Calculating B_{LEM}

2.1 From extant settings

In principle, when the acceleration profile of the beam changes, magnet settings can be adjusted simply by scaling magnet BDES values relative to their current (extant) setting.

$$B_{LEM} = \frac{p_z(s)}{p_{z,old}(s)} BDES$$

In practice, this extant scaling is usually only applied to matching/corrector magnets. It also has a "bootstrapping" problem, where $p_{z,old}(s)$ may not be known. In these cases we must use design lattice data.

2.2 From design settings

We can also compute the needed magnet settings directly using the design model. The first step is to calculate the beam rigidity at each point. This calculation can be made simply using the following useful formula: (from Wiedemann)

$$B\rho(s) \approx \frac{1}{0.29979} \beta p_z(s)(GeV)$$

β here refers to the relativistic velocity v/c, and not the Twiss function. To calculate the field strength needed at each magnet, we can use the design multipole coefficients k_n for each magnet (i.e. k_0 for dipoles, k_1 for quadrupoles etc.). The required field is then calculated as:

$$B_{LEM} = (B\rho) k_n l_{eff}$$

where l_{eff} is the magnet's "effective length". Using this method we set each quad to achieve the design focusing strength directly, and make no reference to the current BDES value.

2.3 LEM regions

Region Name	$p_{0z}(s_{end})$ (MeV)	Model start element	Model end element
L0	125	L0AFEND	ENDDL10
L1	335	BEGL1F	ENDBC11_2
L2	4500	BEFL2F	ENDBC14_2
L3	10000	BEGL3F_2	ENDBC20

Table 1: FACET-II LEM region definitions

LEM calculations are defined for a given "region" of the accelerator. Specifically that means region with a known start and end p_z. We can determine the total accelerating voltage (amplitude) of a given linac by comparing the design momentum $p_{0z}(s)$ at the start and end of each region (Alternately, these milestone energies can also be extracted from the extant bend magnet settings is each spectometer region). Region definitions for FACET-II are shown in Table 1.

It's important to note that the LEM regions *do not* span the full beamline. The L0 region starts from an injector simulation "treat-point", defined as the end of L0-A. Since $p_z(s)$ is fixed up to L0-B anyways, LEM would not have anything to do from the cathode to L0-A. Additionally, the L3 region ends at the end of BC20, and *does not* include the final focus/spectrometer or dump. Magnet setting in that region is the repsonsibility of the Sector 20 config code, and $p_z(s)$ is flat in BC20 and downstream anyhow.