Functional Requirement Specification

PXIE MEBT Kicker

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Revision History

Revision	Date	Section No.	Revision Description
0	02/11/2013	All	Initial signed release.

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1. Introduction:

The PXIE Medium Energy Beam Transport (MEBT) [1] will test the concept of the bunch by bunch selection required for the Project X. This selection will be made by a chopping system consisting of two travelling- wave, broadband kickers working in sync, and an absorber. In the nominal operation mode, for 80% of the time bunches are directed to the absorber, and the remaining part (1 mA) of initially 5 mA, 162.5 MHz CW beam is sent to the linac. This specification describes functional requirements for the MEBT kicker.

2. Scope:

The PXIE MEBT beam optics scheme assumes 2 travelling-wave kicker assemblies working in sync. The kicker electric field is generated by applying equal and opposite polarity voltage to the two opposing electrodes of each kicker assembly. The difference in the angular beam deflection for bunches assigned for removal or passing is 7.4 mrad per the kicker assembly. Below this requirement is translated into electrode voltages.

3. Key Assumptions, Interfaces & Constraints:

Typical beam parameters at the kicker location, which are used for this specification, are listed in Table 1.

Table 1. Typical beam parameters

	Ion type	H-
	Beam energy	2.1 (+/-1%) MeV
	Velocity (beta)	0.0668
	Frequency of bunches (CW)	162.5 MHz
	Beam current , nominal/range	5/(1 – 10) mA
	Nominal charge per bunch	30 pC
	Relative residual charge of removed bunches	$< 10^{-4}$
	Beam loss of pass through bunches	< 5%
	Bunch size, 6-sigma X/Y (horizontal/vertical)	16/12 mm
	Bunch length, , 6-sigma	1.3 ns

Each kicker assembly is contained between two quadrupole triplets. Physical length of the assembly is 650 mm (flange to flange).
The MEBT kicker will conform to FNAL Engineering [3] and ES&H Standards [4].

4. Requirements

Dimensions:

Effective electric length	500 mm
Minimum distance between opposite plates	16 mm

The kick is in the vertical direction.

Pulse:

Two drive schemes are being considered:

Drive Scheme A: A unipolar drive scheme. The voltage is applied to kicker electrodes to kick the beam out. Zero electric field is generated for bunches intended to pass through.

Drive Scheme B: A bipolar drive scheme. The voltage is applied to kick the beam out, and the opposite polarity is applied to kick beam in and allow it to pass through. The magnitude of the voltage applied to each kicker side is half that of Scheme A.

1. Any bunch of the 162.5 MHz CW train can either pass or be removed.
2. Flattop voltage to kick the beam is defined by two parameters being met simultaneously:
    a. A minimum voltage to kick the bunch by a specified amount.
    b. A minimum length of time of ±0.65 ns with respect to the bunch center.
3. Minimum flattop voltage for kicking the beam out (for the kicker gap of 16 mm):
    a. Drive scheme A: 500 V on each plate.
    b. Drive scheme B: 250 V on each plate.
4. Voltage tolerance for bunches passing through:
    a. Drive scheme A: 0 V ±25 V on each electrode.
    b. Drive scheme B: flattop voltage ±25 V on each electrode for the duration of the flattop.
5. The voltages specified above are for the ideal case of two long parallel plates. Any reduction of the integral kicker strength caused by gaps between the kicker electrodes is to be compensated by increasing the applied voltage by the corresponding amount.
6. Any difference between kicker phase velocity and beam velocity is to be corrected by widening the flattop width by a corresponding amount. For example, for a rectangular pulse, a 1% of the velocity error should be compensated by increasing the pulse width by 0.25 ns.
7. Uniformity of the kicker electric field in the horizontal direction shall be adequate
    a. Drive scheme A: to kick beam out as specified above. Any reduction of the integral kicker strength due to field non-linearity at the periphery of the horizontal beam size $\Delta X=\pm 8$ mm is to be compensated for by increasing the applied voltage by the corresponding amount.
    b. Drive scheme B: such that the kick applied to the particles within 6 sigma of the bunch, i.e. over the horizontal beam size $\Delta X=\pm 8$ mm, should not differ by more than 5%.
8. The required pattern of kicker pulses is determined by a cyclical buffer. Transition from one pattern to another should be less than 0.5 ms (the expected time of switching the magnet for injection into the Recycler).
9. If necessary, additional limitations can be applied:
    a. Beam removal for longer than 200 ns is made by LEBT kicker
    b. During ~1 μs element of periodicity of the pulse structure, the total number of alterations (pass-> remove) or (remove->pass) is not more than $(2\cdot 162.5/5) = 65$, i.e. the maximum average frequency of switching cycles is 33 MHz.

Beam irradiation resistance:

1. The kicker electrodes should withstand a steady-state heat load from the beam of 40W and an accidental loss of 20 J per one assembly. It can be assumed evenly distributed along all electrodes of one kicker side.
2. The kicker structure should not deteriorate from a steady-state radiation by 20 μA tails of the H- beam per one assembly.
3. The kicker assembly incorporates two electrically isolated plates for protecting the kicker from accidental beam scraping. The plates are mounted one at each end of the kicker structure within the assembly physical length of 650 mm (flange to flange). Each plate has a slit for beam passage of 13 mm in Y and at least 20 mm in X.

Vacuum:

Typical operational vacuum - $2 \cdot 10^{-7}$ Torr.
Outgassing of the kicker assembly at operational conditions - $\leq 1 \cdot 10^{-6}$ l·Torr/s

5. References:

Documents with reference numbers listed are in the Project X DocDB:
http://projectx-docdb.fnal.gov

[1] Project X and PXIE MEBT Functional Requirements Specification
Document #: Project-X-doc-938

[2] Fermilab Engineering Manual
http://www.fnal.gov/directorate/documents/FNAL_Engineering_Manual_REVISED_070810.pdf

[3] Fermilab ES&H Manual
http://www-esh.fnal.gov/pls/default/esh_home_page.page?this_page=15053