Functional Requirement Specification

Project X and PXIE Medium Energy Beam Transport System

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Revision History

Revision	Date	Section No.	Revision Description
0	02/13/2013	All	Initial signed release.

TABLE OF CONTENTS

1. Introduction:

Project X is a high intensity proton facility conceived to support a world-leading physics program at Fermilab [1]. Project X will provide high intensity beams for neutrino, kaon, muon, and nuclei based experiments and for studies supporting energy applications. The Project X Injector Experiment (PXIE) [2] will be an integrated systems test for the Project X front end that will validate its concept thereby minimizing the technical risks within Project X.

The PXIE Medium Energy Beam Transport (MEBT) system accepts the ion beam at 2.1 MeV as it exits the RFQ [3], prepares the required bunch structure by chopping out the unwanted bunches, and matches the beam envelopes to the Half Wave Resonator (HWR) Cryomodule [4]. This specification, identical for Project X and PXIE, includes the beam physics requirements for the MEBT section.

2. Scope:

The PXIE MEBT includes all of the beam line components necessary to transport, chop, match, and control the beam from the exit of the RFQ to the entrance of the HWR. The overall schematic of the PXIE components is shown in Figure 1.

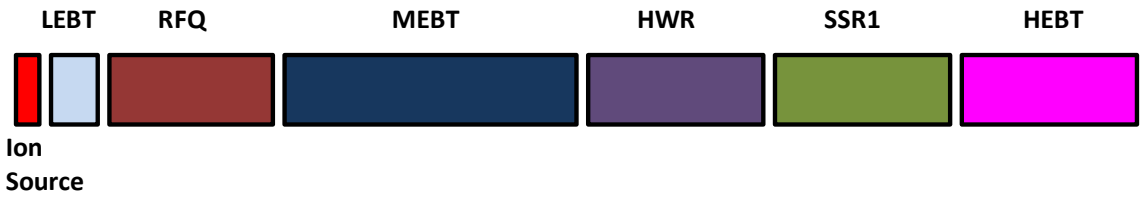

FIGURE 1: Major Subsystem in the PXIE Linac

The MEBT creates the final time structure of the PXIE beam, chopping ~ 80% of the beam with a wideband chopper. The chopper allows for bunch by bunch selection, using a programmable cyclical buffer. The MEBT matches, both transversely and longitudinally, the beam envelopes to RFQ and HWR, includes scrapers for beam halo removal, and is equipped with proper instrumentation for beam diagnostics.

3. Key Assumptions, Interfaces & Constraints:

The MEBT will be included in the overall layout of PXIE, and will conform to FNAL Engineering [5] and ES&H Standards [6]. All interfaces (e.g. power, instrumentation, vacuum, personnel protection, etc…) are described in separate Functional Requirement Specification documents.

4. Requirements

Table 1. MEBT Requirements

	Beam line height from the floor	1.3m
	Ion type	H-
	Input beam energy	2.1 (+/-1%) MeV
	Nominal output energy (kinetic)	2.1 (+/- 1%) MeV
	Maximum frequency of bunches	162.5 MHz
	Nominal input beam current	5 mA
	Beam current operating range	1- 10 mA
	Nominal output beam current	1 mA
	Nominal charge per bunch	30 pC
	Relative residual charge of removed bunches	$< 10^{-4}$
	Beam loss of pass through bunches	< 5%
	Nominal transverse emittance, norm, rms*	0.27 mm mrad
	Nominal longitudinal emittance, rms&	0.8 eV-μs
	Longitudinal emittance tolerance	<10% increase over input
	Transverse emittance tolerance	<10% increase over input
	Beam displacement at exit	< 0.5mm
	Beam angle at exit	< 0.5 mrad
	Scraping to transverse emittance (n, rms, pulsed mode for 10W avg beam power)	<0.05 mm mrad

* The rms emittance is defined using the moments of the particle distribution in phase space (e.g. $x - x'$) as follows: $\varepsilon_x = \left(\overline{x^2}\,\overline{x'^2} - \overline{xx'}^2 \right)^{1/2}$. In modeling, it is based on 100% of particles; in experiments, it may be based on a truncated number of particles (95-100%) to reduce the effect of far tails on the calculated emittance value.

& To express the longitudinal rms emittance in mm-mrad, multiply it by $(M_p c)^{-1}$, 0.32 mm-mrad/(μs-eV) for protons and H^- ions.

5. References:

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

[1] Project X Functional Requirements Specification
Document #: Project-X-doc-658

[2] Project X Injector Experiment Functional Requirements Specification
Document #: Project-X-doc-980

[3] PXIE RFQ Functional Requirements Specification
Document #: Project-X-doc-894

[4] PXIE HWR Functional Requirements Specification

Document #: Project-X-doc-967

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

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