Functional Requirement Specification

Project X Low Energy Beam Transport Section

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Revision History

Revision	Date	Section No.	Revision Description
0	1/3/2012	All	Initial Release.

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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) will be a prototype Front End linear accelerator,[2] that will validate the concept for the Project X front end, thereby minimizing a large portion of the technical risk within Project X.

The PXIE Low Energy Beam Transport (LEBT) Section accepts the beam as it exits the Ion Source and chops it to PXIE specifications before delivering the chopped beam to the RFQ. This specification includes the beam physics, vacuum, chopper, machine protection requirements and interfaces to interconnecting equipment and adjacent beam line elements.

2. Scope:

The PXIE LEBT includes all of the beamline components necessary to transport, chop, and control the beam from the exit of the Ion Source to the entrance of the RFQ. The overall layout of the PXIE components is shown in Figure 1.

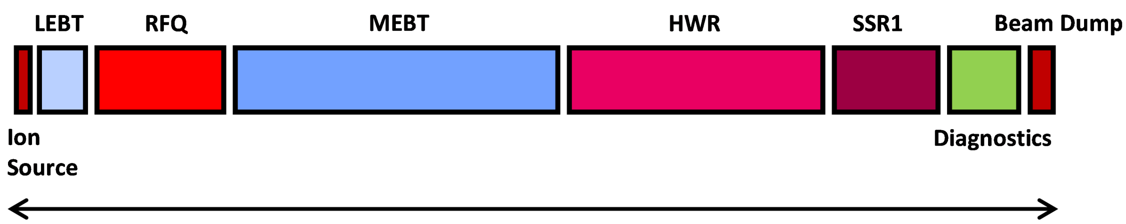

FIGURE 1: Major Subsystem in the PXIE Linac

The LEBT can accommodate two ion sources (not running concurrently). Although this is not a requirement for PXIE, the PXIE beam line will still include the anticipated switching dipole magnet. The LEBT will allow chopping the beam before the RFQ (up to 1 MHz). The final time structure of the beam is realized in the Medium Energy Beam Transport (MEBT). In the LEBT, the H^- beam is fully neutralized before the chopper. The beam neutralization varies afterwards from completely un-neutralized within the chopper to some level of neutralization at the RFQ entrance depending of the final design. The LEBT also includes various diagnostics to characterize and tune the beam. Finally, it serves as the primary sub-system where machine protection takes place. Beam loss and emittance growth should be marginal.

3. Key Assumptions, Interfaces & Constraints:

The LEBT will be installed initially in the PXIE facility at NML. The LEBT will be included in the overall layout, and will conform to FNAL Engineering[5] and ES&H Standards.[6] All interfaces (e.g. power, instrumentation, vacuum) will be further discussed and agreed upon by the PXIE Project Scientist.

4. Requirements

Table 2. LEBT Requirements

Beam		
	Ion type	H^-
	Input kinetic energy	30 keV
	Output kinetic energy	30 keV
	Kinetic energy stability	0.5% RMS
	Nominal beam current	5 mA
	Maximum beam current	10 mA
	Beam current stability [for frequencies $f > 1$ Hz (ripples)]	±5%
	Duty factor	100%
	Input transverse emittance** over 1-10 mA current range	< 0.2 mm mrad
	Output transverse emittance** over 1-10 mA current range	< 0.25 mm mrad
	Neutralization time	< 50 µs
	Beam loss outside gaps (i.e. un-chopped beam)	< 10%
	Steering capability	±3 mm
Uptime		
	Turn-on time (after source switch e.g.: tuning)	< 2 hours
Chopper		
	Extinction ratio at 6σ	<0.001
	Rise/fall time (10% - 90%)	< 100 nsec
	Beam cut off time	100 nsec* - DC‡
	Single pulse length# (> 90% of maximum intensity)	1 µsec - DC
	Maximum pulsing frequency^E	10 Hz†
		1 MHz
Machine protection		
	Beam shut-off time	< 1 ms
	Beam stop	1 sec
Vacuum		
	Base pressure (i.e. beam off)	$\leq 10^{-7}$ torr
	Operating pressure (i.e. beam on)	$\leq 10^{-6}$ torr
	Gate valve before the switching magnet	

* To accommodate 3 GeV program and relax MEBT chopper requirements; concurrent to 1 MHz chopper frequency

‡ "DC" ≡ a few seconds for machine protection purposes

Primarily for commissioning and troubleshooting

† Initial requirement for pulsed linac injection

E A pulsing frequency of 60 Hz for duration from 4 to 100 µsec will be used for machine tuning.

** 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.

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-xxx

[3] PXIE Ion Source Functional Requirements Specification
Document #: Project-X-doc-968

[4] PXIE RFQ Functional Requirements Specification
Document #: Project-X-doc-968

[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