Fermi National Accelerator Laboratory

Fermilab

PIP-II Medium Energy Beam Transport (MEBT) Functional Requirements Specification

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Document Approval

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Revision History

Revision	Date of Release	Description of Change
-	11/10/2014	Initial release
A	November 2021	This revision replaces the original FRS, which was initially written under different guidelines and format. The content of the original FRS is now part of ED0014432 MEBT TRS and has been updated.

Table of Contents

1. Purpose

An FRS describes the project needs and/or requested behavior of a system or component. The document typically outlines what is needed by the end user as well as the requirements and requested properties of inputs and outputs. The FRS specifies the functions that a system or component must perform and establishes consensus among stakeholders on what the system is expected to provide.

2. Scope

The PIP-II MEBT is a set of elements between the exit of the RFQ and entrance of the SRF linac. The MEBT includes components providing transverse and longitudinal focusing and steering of the beam, preparation of the necessary bunch structure with a chopping system, manipulation of the beam transverse tails with scrapers, beam diagnostic, and proper vacuum. This FRS addresses the functional requirements of the PIP-II MEBT.

3. Acronyms

FESHM	Fermilab ES&H Manual
FRCM	Fermilab Radiological Control Manual
FRS	Functional Requirements Specification
HWR	Half-Wave Resonator
MEBT	Medium Energy Beam Transport
MPS	Machine Protection System
PIP-II	Proton Improvement Plan II Project
RF	Radio Frequency
RFQ	Radio-Frequency Quadrupole
SRF	Superconducting Radio-Frequency
TC	Teamcenter
UHV	Ultra-High vacuum

4. Reference

#	**Reference**	**Document #**
1	PIP-II MEBT EPDM	ED0001228
2	Fermilab Engineering Manual	NA
3	Fermilab Environmental Safety and Health Manual	NA
4	Fermilab Radiological Control Manual	NA
5	PIP-II PRD	ED0010216

5. Key Assumptions

The beam exiting the RFQ and entering the MEBT has a 162.5 MHz bunch structure in 0.55 ms-long pulses (formed by the LEBT chopper) at 20 Hz with a nominal average beam current during the pulse of 5 mA and a beam energy of 2.1 MeV ±1% [5].
If deemed rational in the context of the PIP-II Project, MEBT components can be designed to perform at duty factors exceeding the one required for providing beam to the LBNF/DUNE experiment and be compatible with future increases of the PIP-II beam power.

6. Functional Requirements

The MEBT manipulates the beam coming out of the RFQ, preparing its bunch structure and bunch parameters for injection into the linac. Requirements are listed in Table 6-1.

Table 6-1. MEBT General Requirements

Requirement #	Requirement Statement
F-ED0001303-A001	The beam transport in the MEBT shall be compatible with low losses and low emittance growth.
F-ED0001303-A002	The MEBT shall provide optical matching to the RFQ and the HWR in all planes.
F-ED0001303-A003	The average pulse current of the beam to be injected into the HWR shall not exceed 2 mA.
F-ED0001303-A004	The MEBT shall include a chopping system capable to let pass or remove any of the 162.5 MHz bunches delivered by the RFQ according to a pre-programmed pattern.
F-ED0001303-A005	The MEBT shall include a scraping system to remove the beam transverse tails and intercept the beam in the case of unexpected changes in beam focusing or steering.
F-ED0001303-A006	In Diagnostic mode with short pulses, each scraper paddle shall be capable of intercepting the entire beam pulse.
F-ED0001303-A007	In Diagnostic mode with short pulses, the scraper system shall be capable of creating a pencil beam for initial tuning of the linac.
F-ED0001303-A008	The MEBT shall include beam diagnostics to measure the following beam characteristics: transverse position and phase, transverse distribution, rms bunch length, bunch pattern, and beam current at the entrance and exit of MEBT.
F-ED0001303-A009	The MEBT vacuum system shall be compatible with a low-loss beam transport, a low gas load to the HWR cryomodule, and reliable operation of bunching cavities.
F-ED0001303-A010	The MEBT vacuum system shall have the section closest to the HWR particle free and UHV.
F-ED0001303-A011	The vacuum system shall include a fast vacuum protection scheme of the HWR in the case of a vacuum accident in the MEBT.

F-ED0001303-A012	Some MEBT components shall provide signals to the MPS to ensure that the beam is interrupted if conditions where a beam-induced damage may occur are detected.
F-ED0001303-A013	For the purpose of commissioning, the MEBT shall be configurable to a setup where the beam can propagate through the chopping system but cannot be injected into the HWR.
F-ED0001303-A014	The MEBT design shall include a section accommodating a wall shielding the WFE from radiation from the SRF linac.
F-ED0001303-A015	Ionization radiation levels at the High-Bay Building balcony related to MEBT's regular operation or for accidental conditions shall be compatible with short visits of the general public.

7. Safety Requirements

The system shall abide by all Fermilab ES&H (FESHM) and all Fermilab Radiological Control Manual (FRCM) requirements including but not limited to:

Pressure and Cryogenic Safety
• FESHM Chapter 5031 Pressure Vessels
• FESHM Chapter 5031.1 Piping Systems
• FESHM Chapter 5031.5 Low Pressure Vessels and Fluid Containment
• FESHM Chapter 5031.6 Dressed Niobium SRF Cavity Pressure Safety
• FESHM Chapter 5032 Cryogenic System Review
• FESHM Chapter 5033 Vacuum Vessel Safety
Electrical Safety
• FESHM Chapter 9110 Electrical Utilization Equipment Safety
• FESHM Chapter 9160 Low Voltage, High Current Power Distribution Systems
• FESHM Chapter 9190 Grounding Requirements for Electrical Distribution and Utilization Equipment
Radiation Safety
• FRCM Chapter 8 ALARA Management of Accelerator Radiation Shielding
• FRCM Chapter 10 Radiation Safety Interlock Systems
• FRCM Chapter 11 Environmental Radiation Monitoring and Control
General Safety
• FESHM Chapter 2000 Planning for Safe Operations

Any changes in the applicability or adherence to these standards and requirements require the approval and authorization of the PIP-II Technical Director or designee.

In addition, the following codes and standards in their latest edition shall be applied to the engineering, design, fabrication, assembly, and tests of the given system:

ASME B31.3 Process Piping
ASME Boiler and Pressure Vessel Code (BPVC)
CGA S-1.3 Pressure Relief Standards
NFPA 70 – National Electrical Code
IEC Standards for Electrical Components

In cases where International Codes and Standards are used the system shall follow FESHM Chapter 2110 Ensuring Equivalent Safety Performance when Using International Codes and Standards and requires the approval and authorization of the PIP-II Technical Director or designee.

Additional Safety Requirements that are not listed in the general list above shall be included in the Requirements table in the Functional Requirements section.