Fermi National Accelerator Laboratory

Fermilab

PIP-II Warm Front End
Functional Requirements Specification

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Document Approval

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Revision History

Revision	Date of Release	Description of Change
-		Initial release

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1. Purpose

An FRS describes the programmatic or 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

This FRS addresses the functional requirements of the Linac Warm Front End. The WFE generates a beam of H^- ions, accelerates and bunches that beam, and transports it to the first SRF cryomodule. A beam chopping system removes bunches as driven by the Low-Level RF system to create the appropriate time structure for injection into the Booster and possibly other experiments. The WFE is also where beam-inhibiting devices are located both for Machine Protection and for Personnel Protection.
The scope of this FRS is limited to the beam line considered to be an independent system, and does not include functional requirements for sub-systems such as Low-Level and High-Level RF, RFPI, Resonance Control, Personnel and Machine Protection, Controls, etc.

3. Acronyms

FESHM	Fermilab ES&H Manual
FRCM	Fermilab Radiological Control Manual
FRS	Functional Requirements Specification
HLRF	High Level Radio Frequency
HVAC	Heating, Ventilation and Air Conditioning
HWR	Half-Wave Resonator
L2	WBS Level 2
L3	WBS Level 3
LCW	Low Conductivity Water
LLRF	Low Level Radio Frequency
MPS	Machine Protection System
PIP-II	Proton Improvement Plan II Project
RF	Radio Frequency
RFPI	Radio Frequency Protection Interlocks
SCD	System Configuration Document
SRF	Superconducting Radio Frequency
TC	Teamcenter
WBS	Work Breakdown Structure
WFE	Warm Front End

4. Reference

#	Reference	Document #
1	Warm Front End EPDM	ED0007864
2	Fermilab Engineering Manual (FEM)	-
3	Fermilab Environmental Safety and Health Manual (FESHM)	-
4	Fermilab Radiological Control Manual (FRCM)	-

5. Key Assumptions

All necessary support systems such as electrical power, HVAC, Low Conductivity and cooling water, compressed air, HLRF, LLRF, Controls and Safety Systems are provided. There will be high-level applications to operate the machine. Automation of repetitive tasks and/or certain procedures as well as control and monitoring of key parameters is expected.
The SRF cryomodules, to which the WFE delivers the beam, will be driven at a harmonic of 162.5 MHz.
The SRF cavity power systems will be able to handle an average beam current of no more than 2 mA with the average calculated over a 1 μs duration.
The SRF cryomodule includes an isolation gate valve at its entrance. The warm-to-cold transition takes place downstream of the isolation valve.

6. Functional Requirements

Requirement #	Requirement Statement
F-121.4.02-001	The WFE shall deliver a beam of H^- ions to the first SRF cryomodule (HWR).
F-121.4.02-002	The WFE shall include two ion sources.
F-121.4.02-003	The WFE shall deliver the beam as ensembles/batches of bunches.
F-121.4.02-004	The maximum frequency of the WFE's bunches shall match the frequency of the HWR cryomodule RF drive.
F-121.4.02-005	The WFE shall be able to deliver bunches with the time structure that allows bucket-to-bucket injection into the Booster.
F-121.4.02-006	The WFE shall interrupt the beam when prompted by the MPS including when fault conditions originate from within the WFE.
F-121.4.02-007	The WFE shall passively protect downstream components from uncontrolled beam.
F-121.4.02-008	The WFE shall limit the beam current delivered to the SRF cavities to below their beam current handling specifications.
F-121.4.02-009	The WFE shall permit beam commissioning activities at a largely reduced average power with respect to nominal in order to protect the equipment.
F-121.4.02-010	The WFE shall provide the capability to steer the beam.

F-121.4.02-011	The WFE's output beam energy shall match the acceptance energy of the SRF HWR.
F-121.4.02-012	The WFE shall include transverse focusing elements to transport the beam up to the first SRF cryomodule.
F-121.4.02-013	No component within the WFE shall present residual radiation once the beam is turned off, allowing for immediate access.
F-121.4.02-014	The WFE shall include devices that allow monitoring the beam current at several locations along its beam line, including at its exit.
F-121.4.02-015	The WFE shall include devices that allow measuring and/or monitoring the beam trajectories.
F-121.4.02-016	The WFE shall include devices that allow measuring the beam profile (transverse and longitudinal).
F-121.4.02-017	The WFE shall include devices that allow measuring the beam emittance.
F-121.4.02-018	The WFE shall include devices that allow monitoring beam losses.
F-121.4.02-019	The WFE shall include a beam absorber capable of safely accepting full nominal beam power.
F-121.4.02-020	The WFE shall include beam inhibiting Critical Devices that satisfy Fermilab's safety requirements for Controlled Accesses.
F-121.4.02-021	The WFE design shall allow access to the lowest energy section of the accelerator to qualified personnel while still delivering beam to the SC linac.
F-121.4.02-022	The WFE shall provide an Ultra-high-vacuum/low-particulate section adjacent to the first SRF cryomodule.

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.