Fermi National Accelerator Laboratory

Fermilab

PIP-II Injector Test (PIP2IT)
Functional Requirements Specification

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Document Approval

Signatures Required	Date Approved
Originator: Fernanda G. Garcia, Linac Installation and Commissioning Level 2 Manager Paul Derwent, PIP-II Project Scientist	
Approver: Marc Kaducak, PIP-II Project Manager	
Approver: Lia Merminga, PIP-II Project Director	
Approver: Arkadiy Klebaner PIP-II Technical Director	
Approver: Allan Rowe, Project Engineer	
Approver: Benjamin J. Hansen, PIP-II Cryogenic Engineer	
Approver: Jerry Leibfritz, Test Infrastructure L3 Manager	

Revision History

Revision	Date of Release	Description of Change
0	11/18/11	Initial Draft Release.
1	02/03/12	Initial Release
ED0001223 Rev -	02/11/13	Draft Update
A	12/10/15	Realignment to PIP-II goals
B	05/31/18	Realignment to pulsed beam operation only
C	06/22/2018	Comply with new PIP-II FRS guidelines and template

Table of Contents

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 PIP-II Injector Test.

PIP2IT is an integrated system test for the PIP-II front end which is part of the broader program of research and development aimed at key components of PIP-II. The successful completion of this test will validate the concept for the PIP-II front end, thereby minimizing an important technical risk element within PIP-II.

The PIP2IT accelerator will include the following seven subsystems shown in Figure 1 and listed below:

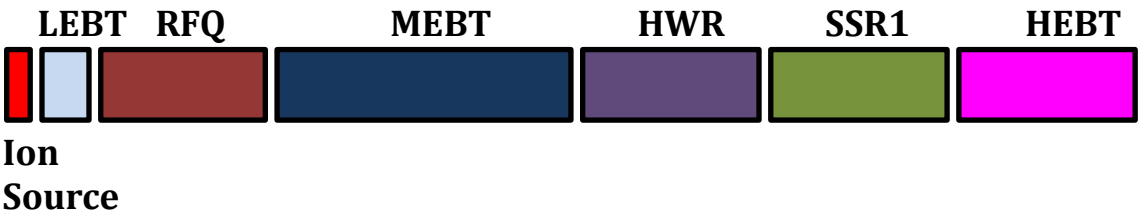

Figure 1: PIP2IT major sub-systems.

- A DC H^- ion source [3].
- A Low Energy Beam Transport (LEBT) section with beam pre-chopping [4].
- A CW Radio Frequency Quadrupole (RFQ) [5].
- A Medium Energy Beam Transport (MEBT) section with integrated fast programmable wideband beam chopper capable of generating arbitrary bunch pattern and a beam absorber [6].
- Two low-beta superconducting cryomodules (HWR and SSR1) [7,8]
- A High Energy Beam Transport (HEBT) section [9], which consists of a beam diagnostic section, capable of measuring particle distribution including tail distributions and the extinction ratio of removed bunches, and a beam dump.

These accelerator components will be installed inside a radiation shielding cave assembled from existing concrete shielding blocks.

3. Acronyms

CMTF	Cryomodule Test Facility
CMTS-1	Cryomodule Test Stand #1
CTL	Cryogenic Transfer Line

FESHM	Fermilab ES&H Manual
FRCM	Fermilab Radiological Control Manual
FRS	Functional Requirements Specification
HWR	Half-Wave Resonator
IS	Ion Source
LCW	Low Conductivity Water
LEBT	Low Energy Beam Transport
MEBT	Medium Energy Beam Transport
MPS	Machine Protection System
PIP2IT	PIP-II Injector Test
PIP-II	Proton Improvement Plan II Project
RFQ	Radio Frequency Quadrupole
SC	Super Conducting
SCD	System Configuration Document
SRF	Superconducting Radio Frequency
SSR	Single-Spoke Resonator
TC	Teamcenter
WBS	Work Breakdown Structure
WFE	Warm Front End

4. Reference

#	**Reference**	**Document #**
1	XXXX EPDM	ED000XXXX
2	*L2 System Configuration Document (SCD) shall be included here*	ED000xxxx
3	PIP2IT Ion Source Functional Requirements Specifications	ED0001288
4	PIP2IT LEBT Functional Requirements Specification	ED0001289
5	PIP2IT RFQ Functional Requirements Specification	ED0001300
6	PIP2IT MEBT Functional Requirements Specification	ED0001303
7	PIP2IT HWR Cryomodule Functional Requirements Specification	ED0001313
8	PIP2IT SSR1 Cryomodule Functional Requirements Specification	ED0001316
9	PIP2IT HEBT Functional Requirements Specification	YYYYYY
10	Fermilab Engineering Manual	N/A

11	Fermilab Environmental Safety and Health Manual	N/A
12	Fermilab Radiological Control Manual	N/A

5. Key Assumptions

- The PIP2IT linac is situated in the Cryomodule Test Facility (CMTF) building.
- All necessary utilities such as electrical power, HVAC, cooling water (LCW & chilled), compressed air, cryogenics, hydrogen gas, networking are provided by the facility, except for the LCW for the ion source

6. Functional Requirements

Requirement #	Requirement Statement
F-PIP2IT-001	PIP2IT shall provide a platform for demonstrating operations of PIP-II front end components such as IS, LEBT, RFQ, MEBT, HWR & SSR1.
F-PIP2IT-002	PIP2IT shall achieve the same beam parameters (e.g. current, emittance) as required for PIP-II nominal operation.
F-PIP2IT-003	PIP2IT shall be capable of reproducing the PIP-II pulsed mode of operation and bunch pattern for Booster injection.
F-PIP2IT-004	PIP2IT shall include a dump capable of collecting the entire beam at nominal beam parameters (e.g. power).
F-PIP2IT-005	The PIP2IT enclosure shall be sized to accommodate all beam line elements and a personnel access aisle in accordance with fire safety regulations.
F-PIP2IT-006	The PIP2IT enclosure shall be expandable by adding concrete blocks as necessary to accommodate extension of the beam line when new components are available.
F-PIP2IT-007	The PIP2IT enclosure roof shall be removable for easy installation, reconfiguration and servicing of the machine components.
F-PIP2IT-008	Radiation shielding shall be sufficient for an unlimited occupancy designation, as defined by FESHM, outside the PIP2IT enclosure.
F-PIP2IT-009	The PIP2IT enclosure shall be outfitted for Controlled Access.
F-PIP2IT-010	Appropriate diagnostic systems shall be developed, installed and commissioned to verify and quantify all PIP2IT requirements.
F-PIP2IT-011	Appropriate Machine Protection System shall be developed and commissioned for the sole purpose of protecting the PIP2IT equipment. It may or may not constitute the basis for the PIP-II MPS.
F-PIP2IT-012	PIP2IT engineering design shall follow the process detailed in the Fermilab Engineering Manual.
F-PIP2IT-013	PIP2IT shall adhere to the Fermilab ES&H manual always.
F-PIP2IT-014	The PIP2IT cryogenic system shall support independent modes of operation of each cryomodule (HWR and SSR1).
F-PIP2IT-015	PIP2IT cryomodules shall be able to operate independently of other activities in CTMF.
F-PIP2IT-016	PIP2IT shall allow for local and remote operations.

F-PIP2IT-019	PIP2IT shall allow for the development of procedures for cleaning, certification and assembly of beamline vacuum components.
F-PIP2IT-020	PIP2IT shall demonstrate adequate vacuum management at transitions between sections with different vacuum requirements (e.g. warm-to-cold transition)
F-PIP2IT-021	PIP2IT shall provide a self-contained LCW cooling system to operate the ion source.

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.