PIP-II Magnets
Physics Requirement Document (PRD)

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Document Approval

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Revision History

Revision	Date of Release	Description of Change
-	11/4/2019	Initial Release.
A	August 2024	General edits to clarify text Section 5: operating range definition added. Section 6: 6.1 - Clarification added for good field region Table 6-1, LEBT Solenoid parameters updated: • Beam aperture diameter changed to 80mm • Maximum field changed to 0.6T • Maximum integrated corrector strength changed to 0.5 mT-m 6.1.2 - Updated to reflect consolidation of performance parameters for SSR1 & SSR2 as approved in DCR-2019-0089. Table 6-2 SSR Linac Solenoid and Steering Corrector parameters updated: • Combined the requirements for both SSR1 and SSR2 solenoids/correctors, except for their integrated strengths • Removed the “maximum field on axis” parameter • SSR beam aperture changed to 40 mm • Solenoid integrated focusing strength for SSR changed to 3.2 & 4.5 T^2m • Solenoid strength operating range for SSR changed to 5-100% • Solenoid ramp rate updated to <20 s for HWR and <5 min for SSR • Corrector ramp rate updated to <30 s for HWR and SSR • Effective length updated to 0.185 m from 0.167/0.223 m • Corrector field uniformity updated from 1% to 5% • HWR Integrated steering corrector requirement updated from “NA” to “x and y independent” • Requirement on HWR and SSR steering corrector ramp rates added. Corrector integrated strength changed from >6 mT-m to >4.5 mT-m & >6.0 mT-m 6.2 – Clarification of definition of quadrupole field uniformity. Table 6-5 Linac RT Quad Operating Range lower limit changed from 48% to 40%. Table 6-6 Linac RT Steering Corrector parameters updated: • Steering direction changed to one plane Integrated dipole strength updated to +- 10 mT-m Table 6-7 BTL RT Regular Quad & Table 6-8 BTL RT Large Aperture Quad Operating Range lower limit changed from 60% to 50%.

		• Table 6-8 BTL RT Large Aperture Quad parameters updated: Operating range changed to 50-100% • Good field region changed to 24 x 150 mm Table 6-9 BTL RT EOL Quad parameters changed: • Maximum integrated quad strength changed to 2.5 T • Maximum field at pole tip changed to 0.325 T • Operating range changed to 50-100% Table 6-10 BTL Steering Orbit Corrector integrated steering strength changed to +-10 mT-m Table 6-11 LEBT Dipole nominal bend angle changed to 30 deg Table 6-12 Beam Transport Line Dipole Parameters updated: • Nominal field integral changed from 0.71 T-m to 0.56 T-m • Nominal magnetic field changed to .229 T • Field uniformity changed from .02% to .1% Table 6-13 EOL Dipole Parameters updated: • Bending angle changed from .091 rad to .03970 • Max Field Integral changed to 0.292 T-m • Max field changed to 0.162 T • Field uniformity changed to 0.1% Table 6-14 BTL 3-Way Septum parameters updated: • Septum thickness changed to <17 mm • Field free region field changed to <5e-6 T • Nominal bend angle changed to 0.074 rad • Nominal field integral changed to 0.36 T-m • Nominal magnetic field changed to 0.139 T • Field free region radius changed to 25 mm Table 6-15 Fast Switch Magnet parameters updated: • Nominal bend angle changed to 0.00385 rad • Ramp up/down time requirement added, 40 ms Table 6-16 Sweep Magnet parameters updated: • Added requirement for Nominal integrated field, .01244 T-m • Sweep angle changed to .00255 rad • Nominal field changed to .0245 T • Added requirement for Operational frequency, 11 Hz Table 7-1 Max Power Supply Design Current and Field Stability Requirements updated: • Description updated to note the maximum current parameters are for power supplies. • Requirements combined for SSR1 and SSR2 • Max current for SSR Solenoids changed to 75 A • Max current for Fast Switch magnet changed to 11 A • Max current for BTL Sweep magnet changed to 5 A • Max current for SSR Correctors changed to 12 A

		Other general updates to parameters include post CD-3 updates made to reflect changes from Conceptual to Final Design requirements. Nominal vs Maximum parameters specified where needed. Document Approval Block updated to add missing stakeholders. Requirements IDs assigned.

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Table of Contents

1. Purpose

Physics Requirement Documents (PRDs) contain the summary parameters and configuration definitions for systems, sub-systems, and devices that impact higher-level requirements established in the PIP-II Global Requirements Document (GRD) [1]. PRDs establish a traceable link to lower-level requirements (FRSs, TRSs) that affect the PIP-II beam or machine performance. In the aggregate, the PRDs for the PIP-II Project contain the essential parameters and configuration developed through the preliminary design phase to enable completion of the PIP-II accelerator and complex design.

2. Scope

This document describes the high-level parameters for the magnets of the PIP-II Project.

3. Acronyms

BTL	Beam Transfer Line
CM	Cryomodule
DC	Direct Current
EOL	End of Line
FRS	Functional Requirements Specification
GRD	Global Requirements Document
HWR	Half Wave Resonator
L2	WBS Level 2 System
L3	WBS Level 3 System
LEBT	Low Energy Beam Transport
MEBT	Medium Energy Beam Transport
PIP-II	Proton Improvement Plan II Project
PRD	Physics Requirements Document
RT	Room Temperature
SRF	Superconducting Radio Frequency
SSR	Single Spoke Resonator
TRS	Technical Requirements Specification

4. Overview

This document details high level requirements for PIP-II magnets:

1. Low Energy Beam Transport (LEBT)
2. Medium Energy Beam Transport (MEBT)

3. SRF Linac
4. Beam Transport Line (BTL)

The diagrams with element location in the project lattice and total element counts can be found in the PIP-II Parameters PRD [2]. Exact locations of the beam line optical elements are listed in the PIP-II Expanded Lattice File [3].

The maximum strength of BTL magnets and Linac quadrupoles is compatible with the upgrade beam energy of 1 GeV.

Section 7 specifies the design current corresponding to the maximum field strength. The design current is an important optimization parameter that affects the selection of the current conductor, the cooling scheme, and power supply requirements. Magnet designers shall use the requirement as a guidance for the magnet design. Power supplies shall be specified based on magnet technical requirements documented in corresponding Technical Requirements Specification (TRS).

Section 7 also specifies required field stability caused by power supply current ripple. The field stability requirements were obtained based on multiparticle simulations of the beam mismatch caused by random, uncorrected field errors [4]

These accelerator physics requirements will be used as input into optical element design. The field uniformity requirements and extent of the good field region serve as guidance for the magnet design and are preliminary and will be finalized during the final design.

The required accuracy of placement of magnets in the beam line is listed in PIP-II Alignment PRD [5].

5. General Definitions

Following general definitions are used in the tables below:

- The strength of magnets defines the maximum strength that will be required to tune the machine. That is, the required strength includes a tuning margin and can be higher than the nominal operational strength in the accelerator model. If an engineering margin is required to operate power supplies and magnets reliably and safely, it shall be added on top of the numbers shown in the tables.
- The tables define the operating range in relation to the maximum strength. The operating range is the typical operating field range in which the field uniformity and other requirements have to be met.
- Beam aperture is the full aperture available to the beam. That is, the magnet bore shall be larger than the shown number to accommodate the vacuum chamber and provide sufficient space to

install and align the vacuum chamber. The size of the magnet steel bore aperture will be defined in a corresponding TRS document.

- x is the horizontal plane and y is the vertical plane

6. Magnet Requirements

6.1. Solenoids with Steering Correctors

Definitions specific for solenoids:

- The Integrated solenoid focusing strength is given by the integral: $I_2 = \int B_z^2 dz$ where B_z is axial magnetic field in a solenoid. The field integral is given by the integral $I_1 = \int B_z dz$.
- Approximate effective length is given by the $L_{eff} = I_1^2/I_2$. The effective field of the solenoid is defined as $B_{eff} = I_2/I_1$. For the hard-edge approximation, the effective length is equal to the length of the solenoid and the effective field is equal to the field of the solenoid.
- Integrated strength of a steering corrector is $I_1 = \int B_t dz$
- Corrector field uniformity is given by $\frac{\int B_t dz}{\int B_t dz_{x,y=0}} - 1$, where the integral $\int B_t dz_{x,y=0}$ is taken on the beam axis. The requirements specify the good field region in which the uniformity requirements must be met.
- Skew quad correctors are generated from the dipole correctors by powering corrector coils independently.
- The requirements for superconducting solenoids include the expected beam loss to inform the design of possible heat load due to beam loss.

6.1.1. Low Energy Beam Transport (LEBT) Solenoids with Steering Correctors

Table 6-1. LEBT Solenoid Parameters

Parameter	Units	LEBT Solenoids	Requirement ID#
Location	-	LEBT	P-ED0010226-T6-1-001
Beam aperture, diameter	mm	80	P-ED0010226-T6-1-002
Maximum field	T	0.6	P-ED0010226-T6-1-003
Maximum Integrated Strength	T^2.m	0.03	P-ED0010226-T6-1-004
Approx. effective length	mm	140	P-ED0010226-T6-1-005
Operating range	%	0 – +100	P-ED0010226-T6-1-006
Operational regime	-	DC	P-ED0010226-T6-1-007
Integrated steering correctors	-	x and y	P-ED0010226-T6-1-008
Maximum Integrated corrector strength	mT.m	0.5	P-ED0010226-T6-1-009

Corrector field uniformity	%	5	P-ED0010226-T6-1-010
Corrector field operating range	%	-100 – +100	P-ED0010226-T6-1-011
Corrector good field region (diameter)	mm	10	P-ED0010226-T6-1-012

6.1.2. Linac Superconducting Solenoids with Steering Correctors

Table 6-2. Superconducting Linac Solenoid and Steering Corrector Parameters

Parameter	Units	HWR Solenoid	Requirement ID#	SSR Solenoid	Requirement ID#
Location	-	HWR Cryomodules	P-ED0010226-T6-2-001	SSR1 & SSR2 Cryomodules	P-ED0010226-T6-2-016
Beam aperture, diameter	mm	33	P-ED0010226-T6-2-002	40	P-ED0010226-T6-2-017
Solenoid integrated focusing strength	T^2.m	2	P-ED0010226-T6-2-003	3.2 & 4.5	P-ED0010226-T6-2-018
Solenoid effective length (approximate)	m	0.159	P-ED0010226-T6-2-004	0.185	P-ED0010226-T6-2-019
Solenoid strength operating range	%	12 – 100	P-ED0010226-T6-2-005	5 – 100	P-ED0010226-T6-2-020
Solenoid ramp time to maximum current	-	< 20 s	P-ED0010226-T6-2-006	< 5 min	P-ED0010226-T6-2-021
Beam loss	W	≤1	P-ED0010226-T6-2-007	≤1	P-ED0010226-T6-2-022
Integrated steering correctors	-	x and y	P-ED0010226-T6-2-008	x and y	P-ED0010226-T6-2-023
All 4 corrector coils powered independently	-	No	P-ED0010226-T6-2-009	Yes	P-ED0010226-T6-2-024
Corrector integrated strength	mT.m	>2.5	P-ED0010226-T6-2-010	≥4.5 & ≥6.0	P-ED0010226-T6-2-025
Corrector field good field region (diameter)	mm	24	P-ED0010226-T6-2-011	24	P-ED0010226-T6-2-026
Corrector field uniformity	%	±5	P-ED0010226-T6-2-012	±5	P-ED0010226-T6-2-027
Corrector field operating range	%	-100 – +100	P-ED0010226-T6-2-013	-100 – +100	P-ED0010226-T6-2-028
Corrector operational regime	-	DC	P-ED0010226-T6-2-014	DC	P-ED0010226-T6-2-029
Corrector ramp time to maximum current	-	< 30 s	P-ED0010226-T6-2-015	< 30 s	P-ED0010226-T6-2-030

6.2. Room Temperature Quadrupoles and Steering Corrector Magnets

Definitions specific for quadrupoles:

- Integrated quadrupole strength is given by the integral $\int G\, dz$, where G is the field gradient on the beam axis
- Field uniformity, in percent, at the reference radius (good field radius) is defined as

$$Uniformity\ [\%] = \frac{1}{100}\sum_{n=3}^{n=8}\sqrt{a_n^2 + b_n^2}$$

  where a_n and b_n are normalized skew and normal multipole field coefficients defined by

  $B_y(z) + iB_x(z) = 10^{-4}B_2 \sum_{n\geq 3}(b_n + ia_n)\left(\frac{z}{R_{\mathrm{ref}}}\right)^{n-1}$ with $z = x + iy$

  where B_2 is the amplitude of the quadrupole field on a circle of the reference radius R_{ref}.
- Corrector field uniformity is given by $\frac{\int B_t dz}{\int B_t dz_{x,y=0}} - 1$, where the integral $\int B_t dz_{x,y=0}$ is taken on the beam axis.
- Design of all warm Linac magnets must minimize heat dissipation to the air.

6.2.1. Medium Energy Beam Transport (MEBT) Room Temperature Quadrupoles and Steering Corrector Magnets

MEBT houses two types of quadrupoles named QF and QD. Requirements for each type of quadrupoles are summarized in following table:

Table 6-3. MEBT Room Temperature Quadrupole

Parameter	Units	MEBT RT QF Quad	Requirement ID#	MEBT RT QD Quad	Requirement ID#
Location	-	MEBT	P-ED0010226-T6-3-001	MEBT	P-ED0010226-T6-3-009
Beam aperture, diameter	mm	30	P-ED0010226-T6-3-002	30	P-ED0010226-T6-3-010
Maximum Integrated strength	T	1.5	P-ED0010226-T6-3-003	0.85	P-ED0010226-T6-3-011
Approx. effective length	mm	100	P-ED0010226-T6-3-004	50	P-ED0010226-T6-3-012
Good field region (diameter)	mm	23	P-ED0010226-T6-3-005	23	P-ED0010226-T6-3-013
Field uniformity within good field region	%	1	P-ED0010226-T6-3-006	1	P-ED0010226-T6-3-014
Operating range	%	40 – 100	P-ED0010226-T6-3-007	40 – 100	P-ED0010226-T6-3-015
Operational regime	-	DC	P-ED0010226-T6-3-008	DC	P-ED0010226-T6-3-016

Table 6-4. MEBT Room Temperature Steering Correctors

Parameter	Units	MEBT RT Correctors	Requirement ID#
Location	-	MEBT	P-ED0010226-T6-4-001
Beam aperture, diameter	mm	30	P-ED0010226-T6-4-002
Maximum Integrated strength	mT.m	2.1	P-ED0010226-T6-4-003
Good field region (diameter)	mm	23	P-ED0010226-T6-4-004
Field uniformity within good field region	%	5	P-ED0010226-T6-4-005
Operating range	%	-100 – +100	P-ED0010226-T6-4-006
Operational regime	-	DC	P-ED0010226-T6-4-007

6.2.2. Linac Room Temperature Quadrupoles and Steering Corrector Magnets

Table 6-5. Linac Room Temperature Quadrupole Parameters

Parameter	Units	Linac RT Quad	Requirement ID#
Location	-	LB and HB CMs	P-ED0010226-T6-5-001
Beam aperture, diameter	mm	46	P-ED0010226-T6-5-002
Maximum Integrated quad strength	T	3	P-ED0010226-T6-5-003
Approx. effective length	m	0.2	P-ED0010226-T6-5-004
Maximum field at pole tip	T	0.35	P-ED0010226-T6-5-005
Good field region (diameter)	mm	26	P-ED0010226-T6-5-006
Field uniformity within good field region	%	0.1	P-ED0010226-T6-5-007
Operating range	%	40 – 100	P-ED0010226-T6-5-008
Operational regime	-	DC	P-ED0010226-T6-5-009

Table 6-6. Linac Room Temperature Steering Corrector Parameters

Parameter	Units	Linac RT Steering Correctors	Requirement ID#
Location	-	LB and HB Section	P-ED0010226-T6-6-001
Steering direction	-	One plane. Magnets will be installed at 90 deg. to provide x and y steering.	P-ED0010226-T6-6-002
Beam aperture, diameter	mm	46	P-ED0010226-T6-6-003
Integrated dipole strength	mT.m	+/- 10	P-ED0010226-T6-6-004

Approx. effective length	m	0.1	P-ED0010226-T6-6-005
Maximum field	mT	100	P-ED0010226-T6-6-006
Good field region (diameter)	mm	26	P-ED0010226-T6-6-007
Field uniformity within good field region	%	1	P-ED0010226-T6-6-008
Operating range	%	-100 – +100	P-ED0010226-T6-6-009
Operational regime	-	DC	P-ED0010226-T6-6-010

6.2.3. BTL Room Temperature Quadrupoles and Steering Corrector Magnets

The BTL section is comprised of three families of quadrupoles which are named here, regular BTL quads, End of Line (EOL) quads and large aperture quads. Requirements for each type are listed in following table.

Table 6-7. BTL Room Temperature Regular Quadrupole Parameters

Parameter	Units	Regular BTL Quad	Requirement ID#
Location	-	BTL	P-ED0010226-T6-7-001
Beam aperture, diameter	mm	46	P-ED0010226-T6-7-002
Maximum Integrated quad strength	T	2	P-ED0010226-T6-7-003
Approx. effective length	m	0.2	P-ED0010226-T6-7-004
Maximum field at pole tip	T	0.26	P-ED0010226-T6-7-005
Good field region (diameter)	mm	24	P-ED0010226-T6-7-006
Field uniformity within good field region	%	0.1	P-ED0010226-T6-7-007
Operating range	%	50 – 100	P-ED0010226-T6-7-008
Operational regime	-	DC	P-ED0010226-T6-7-009

Table 6-8. BTL Room Temperature Large Aperture Quadrupole Parameters

Parameter	Units	Large aperture Quad	Requirement ID#
Location	-	BTL	P-ED0010226-T6-8-001
Beam aperture (y/x)	mm	80 x 200	P-ED0010226-T6-8-002
Maximum Integrated quad strength	T	2	P-ED0010226-T6-8-003
Approx. effective length	m	0.4	P-ED0010226-T6-8-004

Maximum field at the pole tip	T	0.2	P-ED0010226-T6-8-005
Good field region	mm	24 x 150	P-ED0010226-T6-8-006
Field uniformity within good field region	%	0.1	P-ED0010226-T6-8-007
Operating range	%	50 – 100	P-ED0010226-T6-8-008
Operational regime	-	DC	P-ED0010226-T6-8-009

Table 6-9. BTL Room Temperature EOL Quadrupole Parameters

Parameter	**Units**	**Regular BTL Quad**	**Requirement ID#**
Location	-	BTL	P-ED0010226-T6-9-001
Beam aperture, diameter	mm	46	P-ED0010226-T6-9-002
Maximum Integrated quad strength	T	2.5	P-ED0010226-T6-9-003
Approx. effective length	m	0.2	P-ED0010226-T6-9-004
Maximum field at pole tip	T	0.325	P-ED0010226-T6-9-005
Good field region (diameter)	mm	24	P-ED0010226-T6-9-006
Field uniformity within good field region	%	0.1	P-ED0010226-T6-9-007
Operating range	%	50 – 100	P-ED0010226-T6-9-008
Operational regime	-	DC	P-ED0010226-T6-9-009

Table 6-10. BTL Steering Orbit Corrector Parameters

Parameter	**Units**	**Steering Corrector**	**Requirement ID#**
Location	-	BTL	P-ED0010226-T6-10-001
Steering direction	-	One plane	P-ED0010226-T6-10-002
Beam aperture, diameter	mm	46	P-ED0010226-T6-10-003
Integrated steering strength	mT.m	+/- 10	P-ED0010226-T6-10-004
Approx. effective length	mm	100	P-ED0010226-T6-10-005
Maximum magnetic field	T	0.1	P-ED0010226-T6-10-006
Good field region(radius)	mm	24	P-ED0010226-T6-10-007

Field uniformity within good field region	%	1	P-ED0010226-T6-10-008
Operating range	%	-100 – +100	P-ED0010226-T6-10-009
Operational regime	-	DC	P-ED0010226-T6-10-010

6.3. Room Temperature Dipole Magnets

Definitions specific to dipoles:

- Edge angle: Magnet face tilt with respect to the line perpendicular to the beam reference trajectory at entrance or exit of the magnet (as shown in Figure 6-1).
- Positive edge angle: Positive edge angle (α in Figure 6-1 below) is tilt toward the center of the magnet w.r.t the line perpendicular to the beam reference trajectory.
- Field Index: n = $-\left[\frac{\rho}{B_0}\frac{\partial B_r}{\partial r}\right]_{r=0}$ where ρ is reference particle bending radius, B_0 is component of the magnetic field strength and $\frac{\partial B_r}{\partial r}$ is variation in magnetic field.
- Design of all warm magnets must minimize heat dissipation to the air

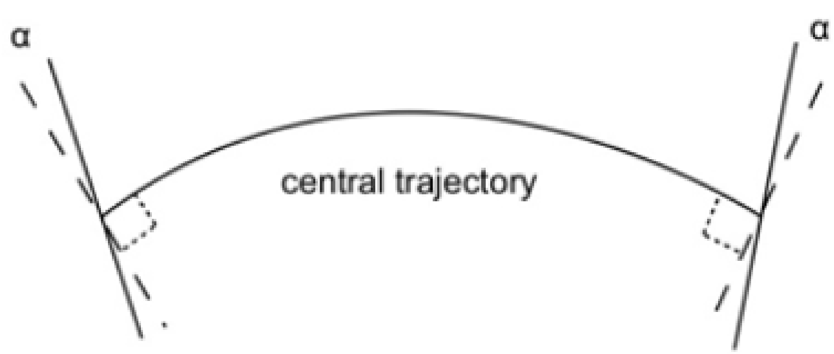

Figure 6-1. Edge angle in a magnet

6.3.1. Normal Conducting Low Energy Beam Transport (LEBT) Dipole Magnets

Table 6-11. LEBT Dipole Magnet Parameters

Parameter	**Units**	**LEBT Dipole**	**Requirement ID#**
Location	-	LEBT	P-ED0010226-T6-11-001
Beam aperture, diameter around reference orbit	mm	44	P-ED0010226-T6-11-002
Nominal Bending angle	deg	30	P-ED0010226-T6-11-003
Nominal Field integral	T.m	0.016	P-ED0010226-T6-11-004

Effective length	m	0.16	P-ED0010226-T6-11-005
Nominal Magnetic field	T	0.083	P-ED0010226-T6-11-006
Field Index	-	0	P-ED0010226-T6-11-007
Good field region diameter	mm	25	P-ED0010226-T6-11-008
Edge angle (entrance/exit)	deg	30 / 0	P-ED0010226-T6-11-009
Field uniformity within good field region	%	0.3	P-ED0010226-T6-11-010
Operating range	%	-100 – +100	P-ED0010226-T6-11-011
Operational regime	-	DC	P-ED0010226-T6-11-012

6.3.2. Beam Transfer Line Dipole Magnets

Table 6-12. Beam Transport Line Dipole Parameters

Parameter	Units	BTL Dipoles	Requirement ID#
Location	-	BTL	P-ED0010226-T6-12-001
Beam aperture (v x h) around reference orbit	mm	46 x 46	P-ED0010226-T6-12-002
Bending angle	rad	0.1146	P-ED0010226-T6-12-003
Nominal Field integral	T.m	0.56	P-ED0010226-T6-12-004
Effective length	m	2.45	P-ED0010226-T6-12-005
Nominal Magnetic field	T	0.229	P-ED0010226-T6-12-006
Field Index	-	0	P-ED0010226-T6-12-007
Good field region diameter (around beam trajectory)	mm	24	P-ED0010226-T6-12-008
Edge angle (entrance/exit)	deg	0 / 0*	P-ED0010226-T6-12-009
Field uniformity within good field region	%	0.1	P-ED0010226-T6-12-010
Operating range	%	60 – 100	P-ED0010226-T6-12-011
Operational regime	-	DC	P-ED0010226-T6-12-012

* - the edge angle can be changed to optimize the magnet design

Table 6-13. End of Line (Booster Injection magnets) Dipole Parameters

Parameter	Units	BTL Dipoles	Requirement ID#
Location	-	Booster	P-ED0010226-T6-13-001
Beam aperture (v x h) around reference orbit	mm	46 x 46	P-ED0010226-T6-13-002

Bending angle	rad	0.0397	P-ED0010226-T6-13-003
Effective length	m	1.05	P-ED0010226-T6-13-004
Maximum Field Integral	T.m	0.3029	P-ED0010226-T6-13-005
Maximum field	T	0.2885	P-ED0010226-T6-13-006
Field Index	-	0	P-ED0010226-T6-13-007
Good field region diameter	mm	24	P-ED0010226-T6-13-008
Edge angle (entrance/exit)	deg	0 / 0	P-ED0010226-T6-13-009
Field uniformity within good field region	%	0.1	P-ED0010226-T6-13-010
Operating range	%	50 – 100	P-ED0010226-T6-13-011
Operational regime	-	DC	P-ED0010226-T6-13-012

6.4. Special Magnets

Table 6-14. BTL 3-way Septum Magnet Parameters

Parameter	**Units**	**BTL 3 Way Septum**	**Requirement ID#**
Location	-	BTL	P-ED0010226-T6-14-001
Beam aperture, diameter	mm	40	P-ED0010226-T6-14-002
Width	mm	140	P-ED0010226-T6-14-003
Septum thickness	mm	< 17	P-ED0010226-T6-14-004
Field Free Region field	T	$< 5\ 10^{-6}$	P-ED0010226-T6-14-005
Field Free Region radius	mm	25	P-ED0010226-T6-14-006
Nominal Bending angle	rad	0.074	P-ED0010226-T6-14-007
Nominal Field integral	T.m	0.36	P-ED0010226-T6-14-008
Effective length	m	2.6	P-ED0010226-T6-14-009
Nominal Magnetic field	T	0.139	P-ED0010226-T6-14-010
Field Index	-	0	P-ED0010226-T6-14-011
Good field region diameter	mm	30	P-ED0010226-T6-14-012
Edge angle (entrance/exit)	rad	.007 / .067	P-ED0010226-T6-14-013
Field uniformity within good field region	%	0.2	P-ED0010226-T6-14-014
Operating range	%	-100 – +100	P-ED0010226-T6-14-015
Operational regime	-	DC	P-ED0010226-T6-14-016

Table 6-15. Fast Switch Magnet Parameters

Parameter	Units	Fast Switch Magnet	Requirement ID#
Location	-	BTL	P-ED0010226-T6-15-001
Beam aperture, diameter	mm	46	P-ED0010226-T6-15-002
Nominal Bending angle	rad	0.00385	P-ED0010226-T6-15-003
Effective length	m	0.5	P-ED0010226-T6-15-004
Nominal Magnetic field	T	0.01	P-ED0010226-T6-15-005
Nominal Field Integral	T.m	0.02	P-ED0010226-T6-15-006
Field Index	-	0	P-ED0010226-T6-15-007
Good field region diameter	mm	24	P-ED0010226-T6-15-008
Edge angle (entrance/exit)	rad	0	P-ED0010226-T6-15-009
Field uniformity within good field region	%	1	P-ED0010226-T6-15-010
Operating range	%	-100 – +100	P-ED0010226-T6-15-011
Operational regime	-	Pulsed	P-ED0010226-T6-15-012
Ramp up/ down time	ms	40	P-ED0010226-T6-15-013

Table 6-16. Sweep Magnet Parameters

Parameter	Units	Beam Sweep Magnets	Requirement ID#
Location	-	BTL	P-ED0010226-T6-16-001
Beam aperture, diameter	mm	46	P-ED0010226-T6-16-002
Nominal Bending angle	rad	0.00255	P-ED0010226-T6-16-003
Effective length	m	0.5	P-ED0010226-T6-16-004
Nominal Magnetic field	T	0.0245	P-ED0010226-T6-16-005
Nominal Field integrated	T.m	0.01244	P-ED0010226-T6-16-006
Field Index	-	0	P-ED0010226-T6-16-007
Good field region diameter	mm	24	P-ED0010226-T6-16-008
Edge angle (entrance/exit)	rad	0.0	P-ED0010226-T6-16-009
Field uniformity within good field region	%	1	P-ED0010226-T6-16-010
Operating range	%	-100 - +100	P-ED0010226-T6-16-011
Operational regime	-	AC	P-ED0010226-T6-16-012
Operational Frequency	Hz	11	P-ED0010226-T6-16-013

7. Maximum Current and Field Stability Requirements

Table 7-1 defines the power supply maximum current and field stability needed to achieve the Magnet Requirements described in Section 6.

Table 7-1. Maximum Power Supply Design Current and Field Stability Requirements for PIP-II Magnets

Magnet Type	Max. Current (A)	Requirement ID#	Field Stability (%)	Requirement ID#
LEBT Dipole	15	P-ED0010226-T7-1-001	0.1	P-ED0010226-T7-1-022
LEBT Solenoids	300	P-ED0010226-T7-1-002	0.1	P-ED0010226-T7-1-023
LEBT Correctors	12	P-ED0010226-T7-1-003	0.1	P-ED0010226-T7-1-024
MEBT QFs	10	P-ED0010226-T7-1-004	0.1	P-ED0010226-T7-1-025
MEBT QDs	10	P-ED0010226-T7-1-005	0.1	P-ED0010226-T7-1-026
MEBT Correctors	4	P-ED0010226-T7-1-006	0.1	P-ED0010226-T7-1-027
HWR Solenoids	70	P-ED0010226-T7-1-007	0.1	P-ED0010226-T7-1-028
HWR Correctors (x,y)	10	P-ED0010226-T7-1-008	0.1	P-ED0010226-T7-1-029
SSR Solenoids	75	P-ED0010226-T7-1-009	0.1	P-ED0010226-T7-1-030
SSR Correctors	12	P-ED0010226-T7-1-010	0.1	P-ED0010226-T7-1-031
Warm Unit Linac quads	100	P-ED0010226-T7-1-011	0.1	P-ED0010226-T7-1-032
Warm Unit Linac correctors	10	P-ED0010226-T7-1-012	0.1	P-ED0010226-T7-1-033
BTL regular dipoles	500	P-ED0010226-T7-1-013	0.01	P-ED0010226-T7-1-034
EOL Dipole Magnet	500	P-ED0010226-T7-1-014	0.02	P-ED0010226-T7-1-035
3-way septum	1350	P-ED0010226-T7-1-015	0.2	P-ED0010226-T7-1-036
Regular BTL quads	100	P-ED0010226-T7-1-016	0.1	P-ED0010226-T7-1-037
Large aperture BTL quads	100	P-ED0010226-T7-1-017	0.1	P-ED0010226-T7-1-038
EOL BTL quads	150	P-ED0010226-T7-1-018	0.1	P-ED0010226-T7-1-039
Dipole correctors	10	P-ED0010226-T7-1-019	1	P-ED0010226-T7-1-040
Fast switch Magnet	11	P-ED0010226-T7-1-020	0.1	P-ED0010226-T7-1-041
BTL Sweep Magnet	5	P-ED0010226-T7-1-021	0.5	P-ED0010226-T7-1-042

8. Reference Documents

#	Reference	Document #
1	PIP-II Global Requirements Document (GRD)	ED0001222
2	PIP-II Parameters PRD	ED0010216
3	PIP-II Lattice File	PIP-II DocDB# 119
4	Beam Dynamics Studies of Misalignments and RF Errors for PIP2	PIP-II DocDB# 4083
5	PIP-II Alignment PRD	ED0010231