Fermi National Accelerator Laboratory

Fermilab

PIP-II Parameters
Physics Requirement Document (PRD)

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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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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 overall PIP-II Project. Also, it describes the layout of the accelerator components and documents their quantities.

3. Acronyms

ACCT	AC Current Transformer
BAL	Beam Absorber Line
BTL	Beam Transfer Line
CM	Cryomodule
CW	Continuous Wave
DCCT	DC Current Transformer
DC	Direct Current
DPI	Differential Pumping Insert
EID	Electrically Isolated Diaphragm
FFC	Fast Faraday Cup
FRS	Functional Requirements Specification
GRD	Global Requirements Document
HB	High Beta
HWR	Half Wave Resonator
L2	WBS Level 2 System
L2M	WBS Level 2 Manager
L3	WBS Level 3 System
L3M	WBS Level 3 Manager
LB	Low Beta
LBNF	Long Baseline Neutrino Facility

LEBT	Low Energy Beam Transport
MEBT	Medium Energy Beam Transport
PIP-II	Proton Improvement Plan II Project
PRD	Physics Requirements Document
RF	Radio Frequency
RFQ	Radio Frequency Quadrupole
RMS	Root Mean Square
RT	Room Temperature
SC	Superconducting
SSR	Single Spoke Resonator
TRS	Technical Requirements Specification
WFE	Warm Front End

4. Overview

Figure 6-1 shows the PIP-II accelerator layout with the three main accelerator areas highlighted; Warm Front End (WFE), superconducting Linac, and Beam Transfer Line (BTL). The following sections describe these main accelerator areas along with a listing of the main components for each as well as the main beam parameters.

5. Beam Parameters

The evolution of beam parameters along the accelerator is shown in Table 6-1. The parameters are given for the LBNF bunch pattern after fast chopping and an average beam current of 2 mA after chopping and collimation in the MEBT. The bunch intensity after chopping still corresponds to 5 mA@162.5 MHz.

Beam commissioning will be conducted with reduced intensity. The pulse length will be decreased to 5 to 10 microseconds and the peak intensity can be decreased to 0.2 to 0.4 mA after chopping. The beam quality and beam sizes are expected to be similar to those at nominal beam parameters.

The rms emittance is defined using the second moments of the particle distribution in phase space (e.g.: $f(x,x')$) as follows: $\varepsilon_x = \sqrt{\langle x^2\rangle\langle x'^2\rangle - \langle xx'\rangle^2}$ where $\langle x^2\rangle = \frac{\int x^2 f(x,x')dx}{\iint f(x,x')dxdx'}$ (continuous distribution) and similarly for the other variables (this assumes the first moments to be zero or already subtracted out). The longitudinal emittance is expressed in μm (or equivalently mm mrad). To express it in keV ns, the emittance value is multiplied by ($M_p c$), where M_p is the mass of the proton/H^- ion and c the speed of light in vacuum (i.e. 3.125 keV ns/μm). The normalized emittance is simply $\beta\gamma\cdot\varepsilon_i$.

6. Pictogram Symbol Table

Pictograms that show the lattice arrangement for a given beam line which were created for each major area (WFE, Linac and BTL) and will be displayed in the following sections. Figure 6-2 shows the pictogram legend used to graphically identify the main lattice components for the PIP-II accelerator.

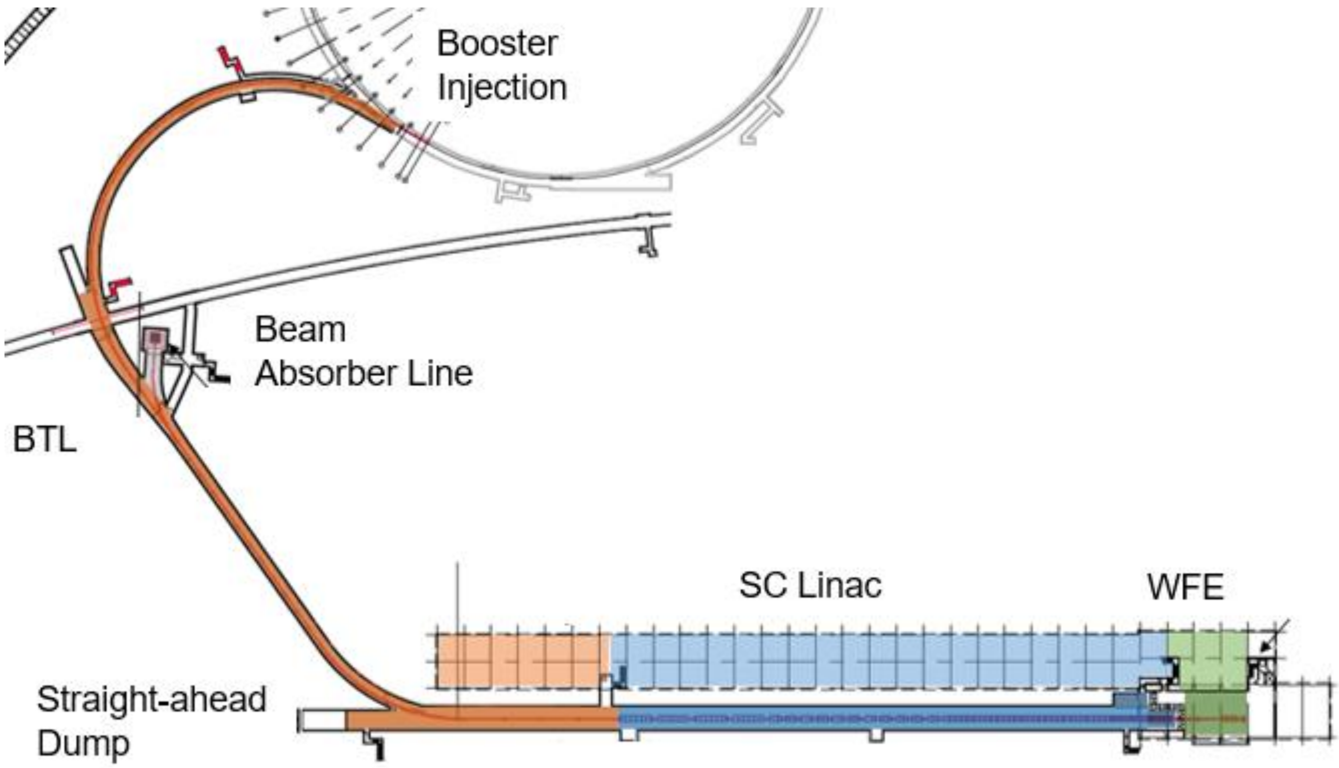

Figure 6-1. PIP-II Layout

Table 6-1. Beam Parameters for nominal operational mode. The parameters are shown for the LBNF bunch patter with chopping and average beam current of 2 mA after chopping and collimation in MEBT. The bunch intensity after chopping still corresponds to 5 mA@162.5 MHz.

Position	**Current, mA**	**Beam Energy (MeV)**	**Velocity $\beta = v/c$**	**Emittance, H/V, norm (μm)**		**Emittance, Long.,norm, (μm)**		**Beam Size, H/V,Trans., typ., mm**	**Beam length,** deg@162.5 **MHz**	**Energy spread, (%)**
				rms	99.99%	rms	99.99%	rms	rms	rms
LEBT	5.2	0.03	0.008	0.18	1.2	NA	NA	5	NA	NA
RFQ Exit	5	2.1	0.067	0.21/0.21	3.87/4.0	0.34	6.0	1/0.5	7.1	0.4
MEBT output	2	2.1	0.067	0.21/0.2	2.95/2.68	0.35	7.35	1.89/1.84	7.71	0.6
HWR output	2	10	0.145	0.24/0.24	6.06/6.15	0.33	8.0	1.31/1.23	1.93	0.3
SSR1 output	2	32	0.256	0.25/0.25	4.91/4.43	0.33	11.12	1.65/1.61	1.07	0.18
SSR2 output	2	177	0.541	0.23/0.27	5.23/6.61	0.33	12.13	1.64/1.72	0.61	0.06
LB650 output	2	516	0.764	0.24/0.27	6.54/6.73	0.32	12.89	1.68/2.17	0.3	0.04
HB650 output	2	833*	0.848	0.24/0.27	6.49/7.02	0.32	12.18	1.56/2.09	0.25	0.03
BTL	2	800*	0.842	0.24/27	6.49/7.02	0.32	12.18	1.3/1.3	4.5	0.03

Figure 6-2. Pictogram symbols.

7. Warm Front End

The PIP-II Warm Front End (WFE) consists of two ion sources, a LEBT, an RFQ, and a MEBT. The H- beam originates from a DC ion source and is transported through the LEBT to a CW normal-conducting RFQ, where it is bunched and accelerated to 2.1 MeV. The MEBT transports and matches the beam to the first SRF cryomodule. In the MEBT, a fast, bunch-by-bunch chopper provides the required bunch patterns, removing 60-80% of the bunches according to a pre-programmed timeline. The pictogram of the WFE is shown in Figure 7-1.

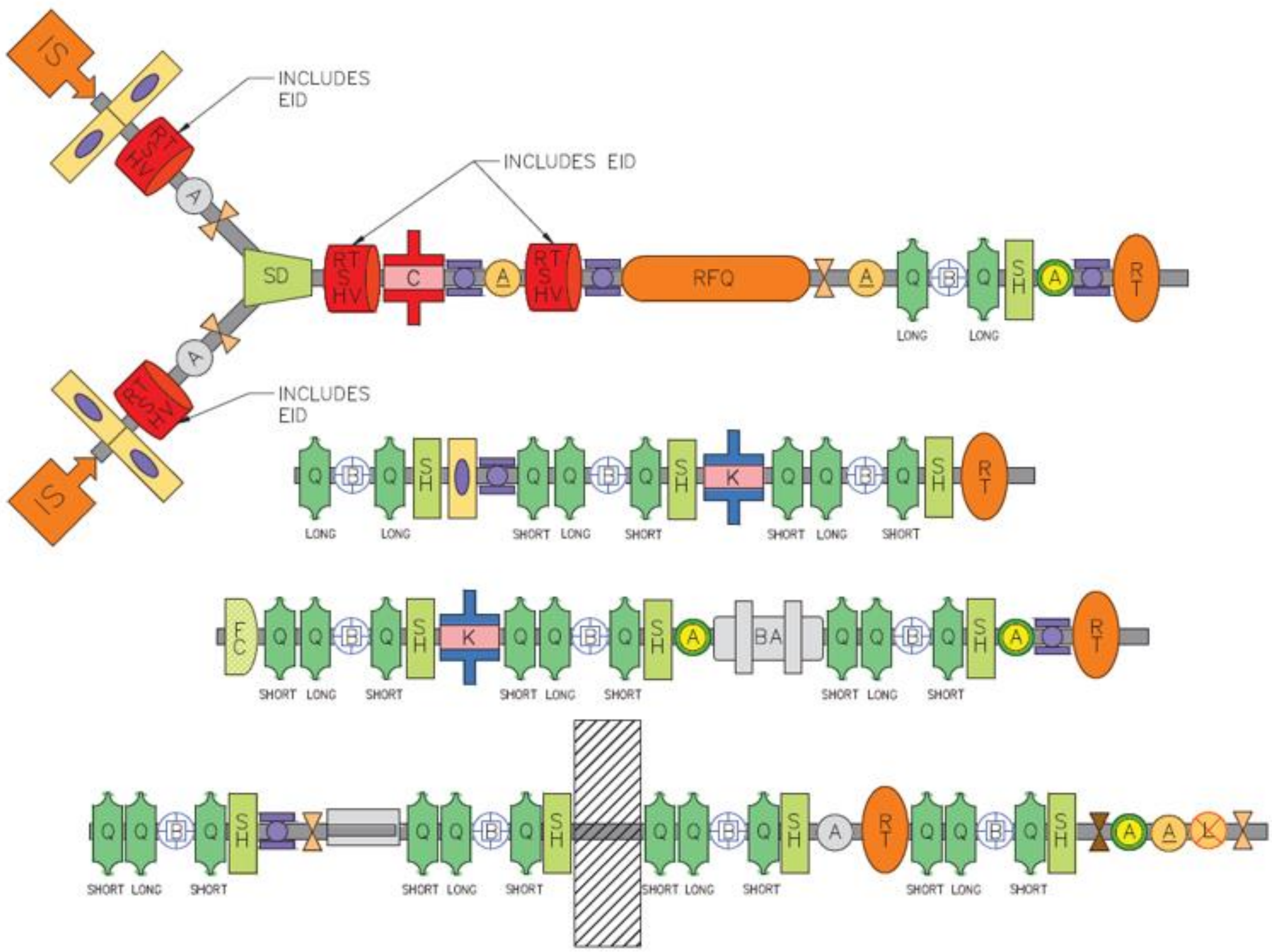

Figure 7-1. WFE Pictogram.

Table 7-1 lists the beam line components that form the ion source and the LEBT. Figure 7-2 shows the beam horizontal envelope (±2.5σ) for the partially un-neutralized LEBT optics solution simulated with TraceWin for the nominal beam current of 5 mA.

Table 7-1. Ion Source and LEBT Components List

Parameter	Count	Comment
Ion source assembly	2	-
Solenoid with integrated dipole correctors	4	Additional information in ED0001295
Switching dipole magnet	1	Additional information in ED0001293 / ED0002843
Chopper assembly	1	Additional information in ED0001291 / ED0002239 / ED0004984 / ED0006567
Electrically Isolated Diaphragm (EID)	4	-
Movable electrode assembly	1	Just upstream of the RFQ entrance, additional information in ED0001290
DCCT	2	1 per leg
ACCT	1	After chopper
Turbo pump (backed with scroll pumps)	7	3 per ion source, 1 on the chopper
Vacuum valve (pneumatic)	2	1 per leg

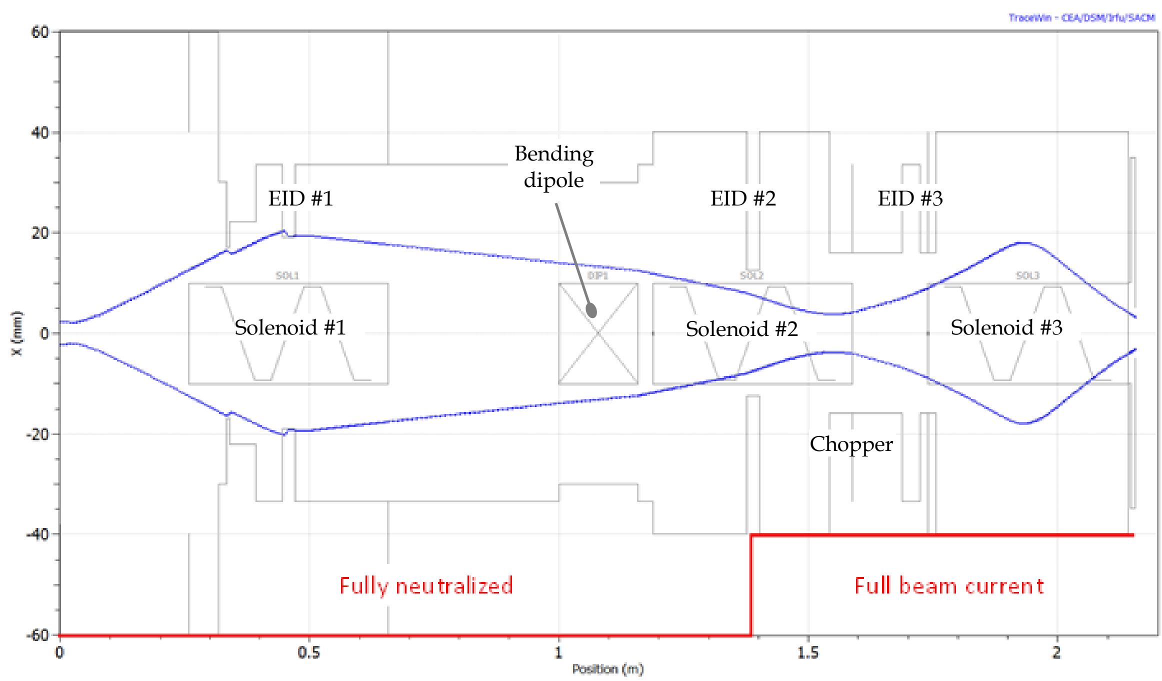

Figure 7-2. Beam horizontal envelope (2.5σ) for the partially un-neutralized LEBT optics solution simulated with TraceWin. The grey lines show aperture limitations. The red line indicates the level of neutralization (from fully neutralized to full beam current of 5 mA).

Table 7-2 summarizes the main components of the RFQ structure and Table 7-3 summarizes the beam operational parameters, as well as the main characteristics of the RFQ design and configuration.

Table 7-2. RFQ Components List

Parameter	Count	Comment
Module/section	4	-
Vacuum ports	4	One per module
RF coupler	2	Forced air cooled
RF coupler bias power supply	1	-
RF power amplifiers	2	Solid-state
RF circulators	2	-
Pi-mode rods	32	Water cooled
Slug tuners	80	Fixed
Water cooling circuit	2	Vanes and walls

Table 7-3. Beam Parameters and RFQ Design Characteristics (in parentheses, Teamcenter document number for the corresponding FRS/TRS and/or RFP)

Parameter	Units	Value	Comment
Beam			
Input energy	keV	30	-
Output energy	MeV	2.1	-
Nominal pulse length	ms	0.55	-
Output bunch frequency	MHz	162.5	Over the pulse length
Nominal beam current	mA	5	Possible range: 1-10 mA
Transmission (1-10 mA)	%	> 95%	-
Output transverse emittance	mm mrad	0.2	At 5 mA
Output longitudinal emittance	keV ns (mm mrad)	0.9 (0.28)	At 5 mA
RF (ED0001651)			
Center frequency	MHz	162.5	-
Duty factor (nominal)	%	100	Pulsing capability
Vane tip-to-vane tip nominal voltage	kV	60	-
Total power for resistive losses and beam loading	kW	< 130	-

Parameter	Units	Value	Comment
Power amplifiers (ED0003671/ED0002015)			Solid-state
RF frequency	MHz	162.5	-
Maximum power output at saturation	kW	75	CW
Couplers (ED0000541/ED0001301)			
RF power rating (max)	kW	75	Full reflection capability
Duty factor (nominal)	%	100	-
Bias power supply (DC)	kV	5	-
Circulators (ED0002016)			
RF power rating (max)	kW	75	CW
Minimum bandwidth	MHz	1	-
Operating temperature	°F	86	Water cooled
Water cooling system			
Nominal temperature	°C	30	i.e. 86°F
Water temperature stability (rms)	°C	≤ 0.1	Steady state
Vacuum (ED0001651)			
Operating pressure	torr	$< 5\times10^{-7}$	-

Table 7-4 lists the beam line components that form the MEBT.

Table 7-4. MEBT Components List

Component	Count	Comment
Quadrupole doublets	2	2 Long/F quads per doublet, Additional information in ED0001312 / ED0003467
Quadrupole triplets	9	2 Short/D quads and 1 Long/F quad per triplet
Steering dipoles assemblies	11	Both horizontal and vertical per assembly, ED0003467 / ED0001307
Bunching cavities	4	Additional information in ED0001307
BPM (1.25”)	11	-
ACCT	2	-
DCCT	1	-
Ring Pick Up (RPU)	4	2 upstream of the absorber and 2 downstream
Emittance scanner (Allison-type)	1	Two heads: 1 horizontal and 1 vertical

Component	Count	Comment
Fast Faraday Cup (FFC)	1	-
Scraper vacuum chambers	4	4 independently controlled scrapers per chamber (left, right, top, bottom)
Scrapers	16	Electrically isolated, ED0001304
Wire scanner	4	Located in the scraper vacuum chambers (diagonal port)
Kicker assemblies	2	Travelling wave, 200-Ohm structure, ED0001305 / ED0002305 / ED0008094
Absorber assembly	1	Electrically isolated, ED0001304
Differential Pumping Insert (DPI)	1	Electrically isolated
Slow vacuum valves	1	Valves at both ends of the MEBT belongs to the RFQ and HWR systems, respectively
Fast Acting Valve	1	-

Figure 7-3 shows the design envelopes (and trajectories) when the kickers are off (top 3 frames) and bunches are transported to the end of the MEBT, and when the kickers are energized (bottom frame) and the bunches are directed onto the beam absorber. It should be noted that one of the challenges for the MEBT optics is the presence of several tight apertures (kickers, DPI). As such, the “S” trajectory (vertical) around the absorber when the kickers are off has been chosen to maximize the use of the kickers’ apertures (i.e. maximum separation between kickers on and off trajectories).

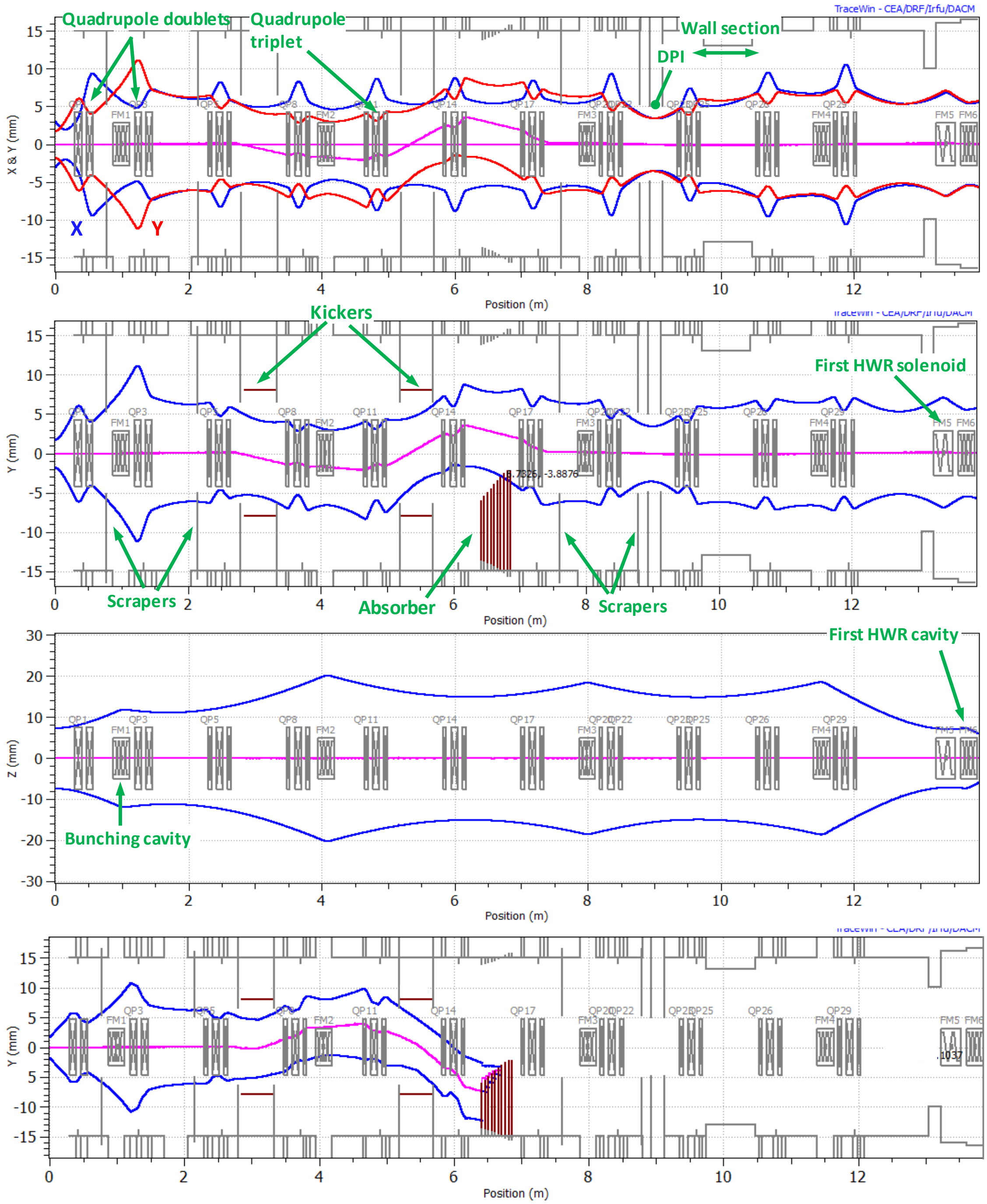

Figure 7-3. ±3σ beam envelopes of the transmitted bunches for 5 mA in the horizontal (x), vertical (y) and longitudinal (z) planes, and of the chopped-out bunches (vertical plane only) simulated with TraceWin. For the 2nd frame from the top, the voltages of all kicker plates are set to zero. For the last frame, the top and bottom plates' voltages of the first kicker are +500 V and -500 V, correspondingly, and opposite for the second kicker, (-500V, +500V).

8. Superconducting Linac

The PIP-II Linac is required to deliver H- ions beam with a final kinetic energy of 800 MeV and an average beam-current of 2 mA with a special and flexible time structure to satisfy diverse experimental needs. The actual Linac design documented in this PRD is capable of accelerating the beam to 833 MeV to provide an operational energy margin.

The Linac consists of five different types of cavities and cryomodules:

- HWR – half-wave resonator cavities operating at 162.5 MHZ
- SSR1 – single-spoke resonator, type 1, cavities operating at 325 MHz
- SSR2 – single-spoke resonator, type 2, cavities operating at 325 MHz
- LB650 – low-beta elliptical resonator cavities operating at 650 MHz
- HB650 – high-beta elliptical resonators cavities operating at 650 MHz

The number of cryomodules (CM) and their configurations in each section are summarized in Table 8-1. Note that superconducting solenoids are used in HWR, SSR1 and SSR2 sections while warm quadrupole doublets are utilized in LB650 and HB650 sections. The quadrupoles are located in the room temperature sections between cryomodules. Figure 8-1 and Figure 8-2 depict the lattice pictograms of the HWR/SSR1/SSR2 and LB650/HB650 cryomodule strings, respectively.

Table 8-1. Numbers of elements and energy range in each section of the PIP-II SRF Linac.

Section	CM Qty	Cav/Mag per CM	Energy (MeV)
HWR	1	8 / 8	2.1 – 10
SSR1	2	8 / 4	10 – 32
SSR2	7	5 / 3	32 – 177
LB	9	4 / 0 (2*)	177 – 516
HB	4	6 / 0 (2*)	516 – 833

* Warm quadrupole doublets are external to the LB650 and HB650 CMs

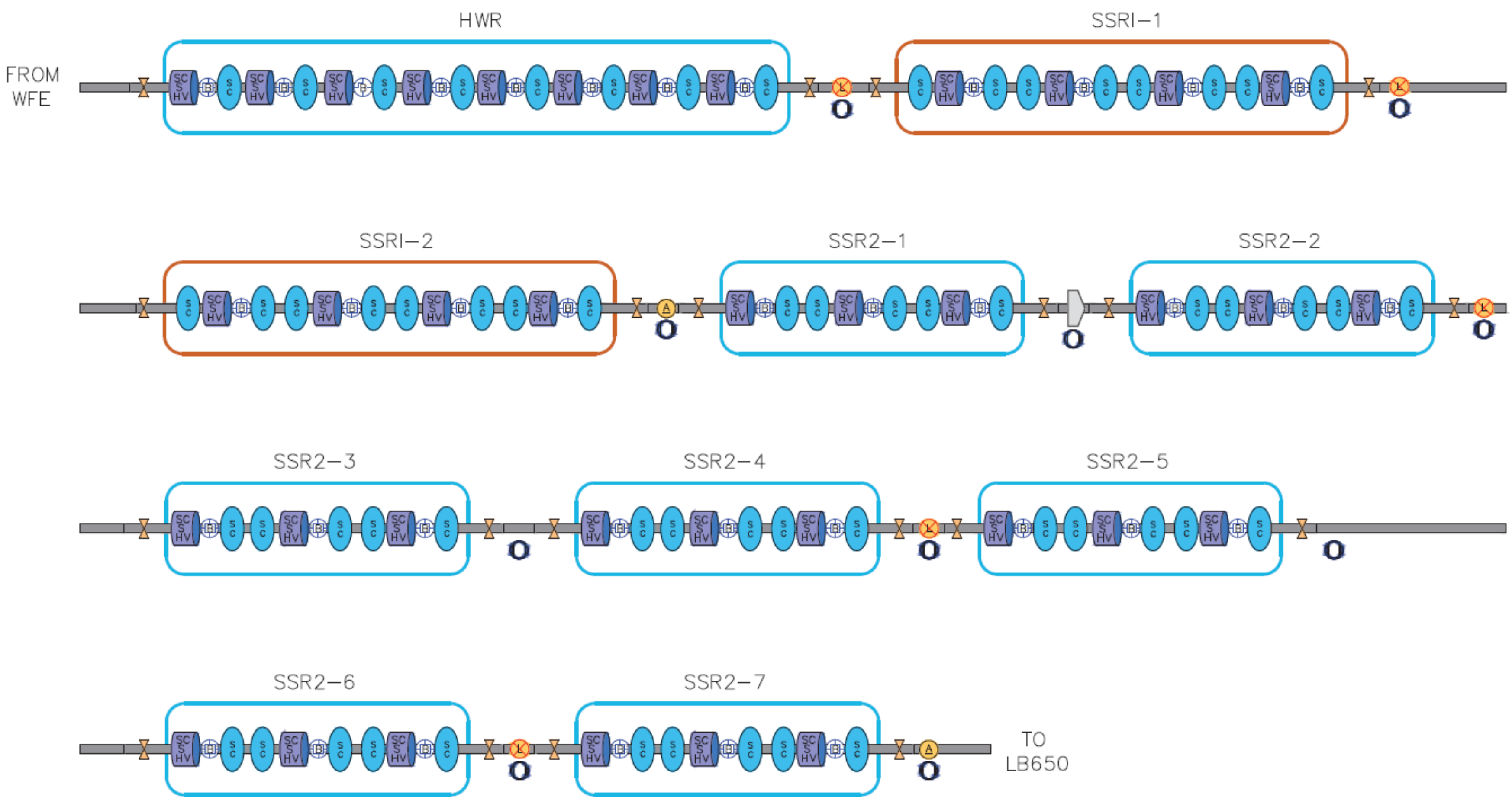

Figure 8-1. HWR and SSR Pictogram.

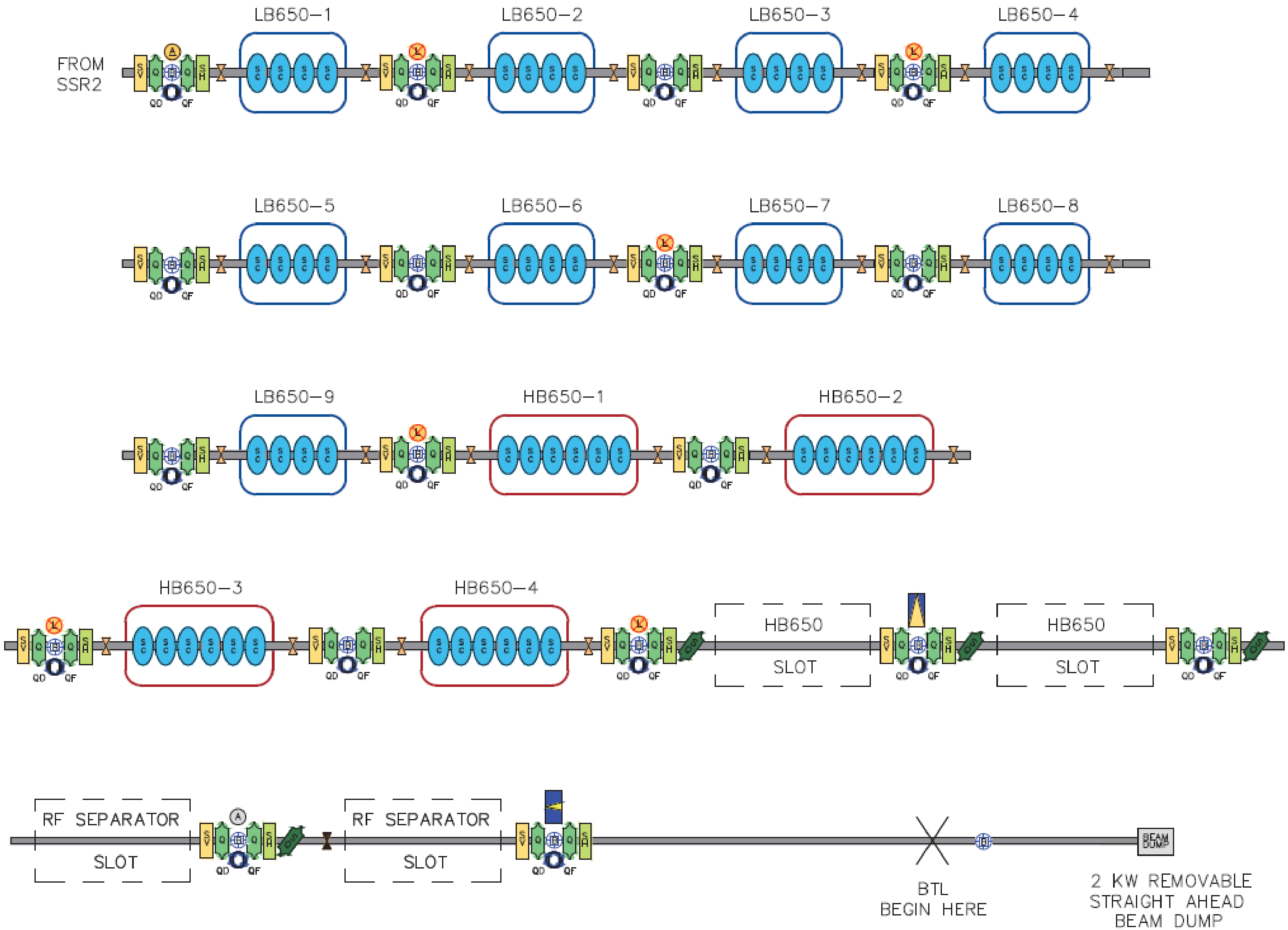

Figure 8-2. LB650 and HB650 Pictogram.

9. Cryomodule configuration

Figure 9-1, Figure 9-2 and Figure 9-3 show schematics of the HWR, SSR1 and SSR2 cryomodules, respectively. Cryomodule outer dimensions are given gate valve to gate valve using outer surfaces of the gate valves.

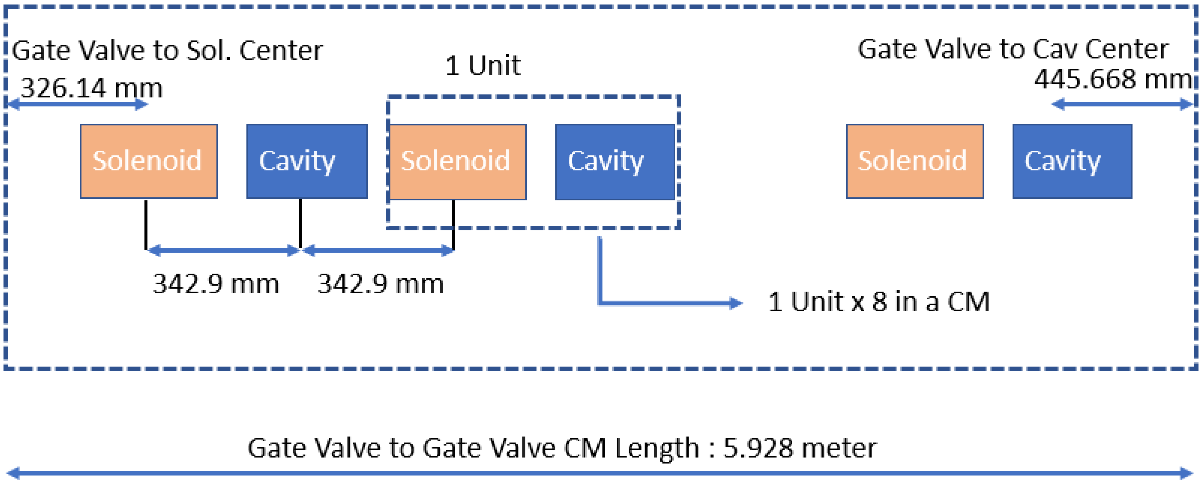

Figure 9-1. Schematic of the HWR cryomodule. The cryomodule configuration is S-C x 8 where S and C are acronym for the solenoid and cavity respectively.

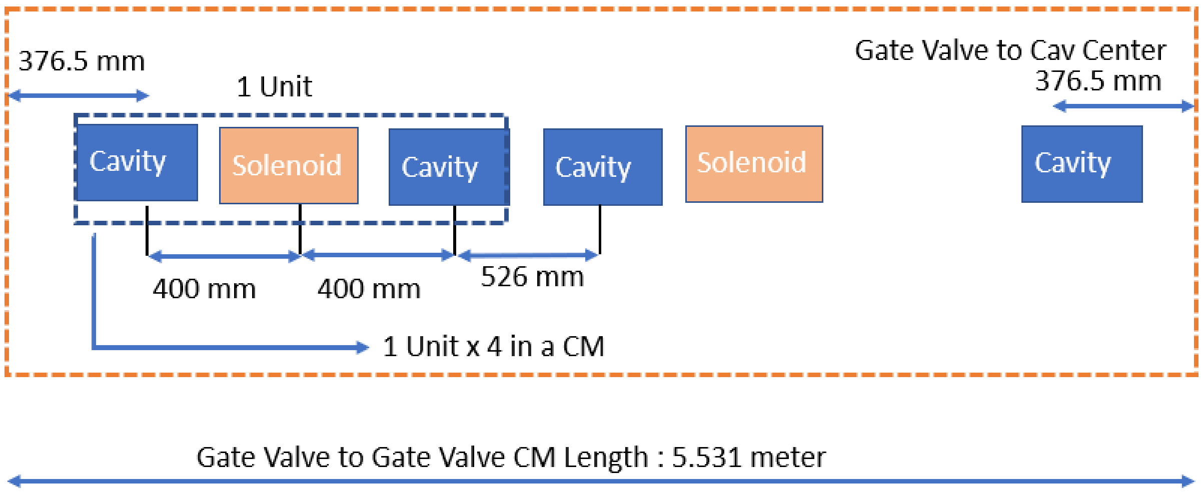

Figure 9-2. Schematic of the SSR1 cryomodule. The cryomodule configuration is C-S-C x 4 where S and C are acronyms for the solenoid and cavity respectively.

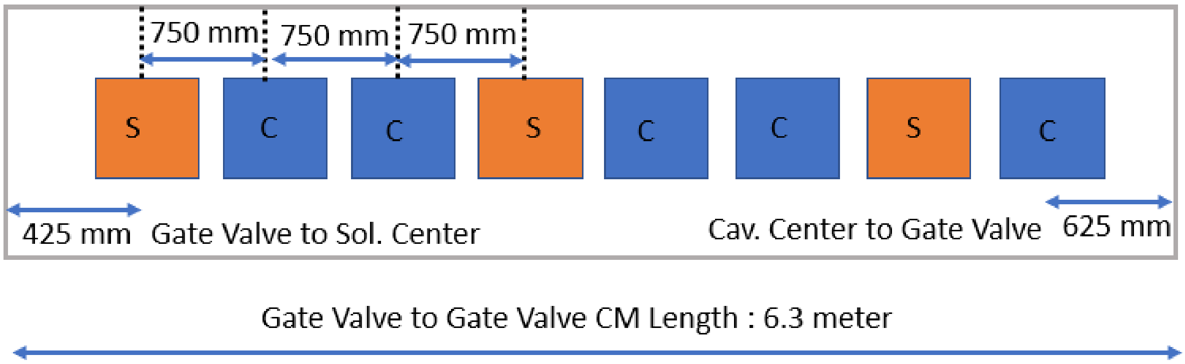

Figure 9-3. Schematic of the SSR2 cryomodule. The cryomodule configuration is S-C-C-S-C-C-S-C where S and C are acronym for the solenoid and cavity respectively.

A schematic of the LB650 cryomodule is shown in Figure 9-4. It houses four 5-cell LB650 cavities. The warm quadrupoles arranged in the doublet configuration (vertical focusing and horizontal focusing) makes transverse optics in this LB650 section. A space of 1.3 m (flange to flange) is allocated for the doublet assembly outside the cryomodule.

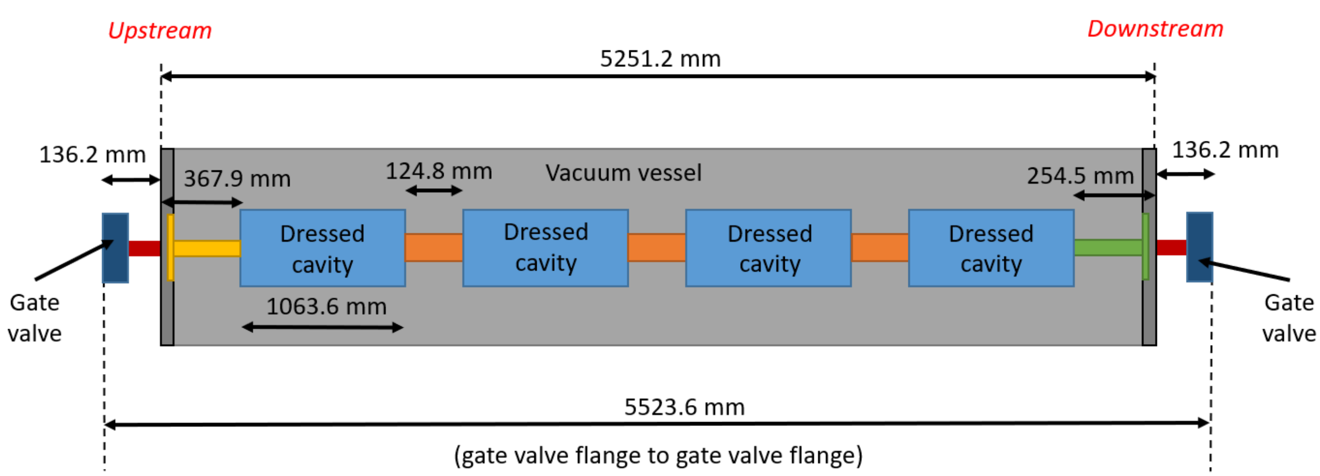

Figure 9-4. Schematic of LB650 cryomodule. Each cryomodule consists of four LB650 cavities.

The HB650 cryomodule comprises six HB650 superconducting cavities. Figure 9-5 showed a layout of the cryomodule. Like LB650 section, transverse optics in HB650 section is made of the warm quadrupole doublet. Note that quadruples of same type are utilized for both LB650 and HB650 sections.

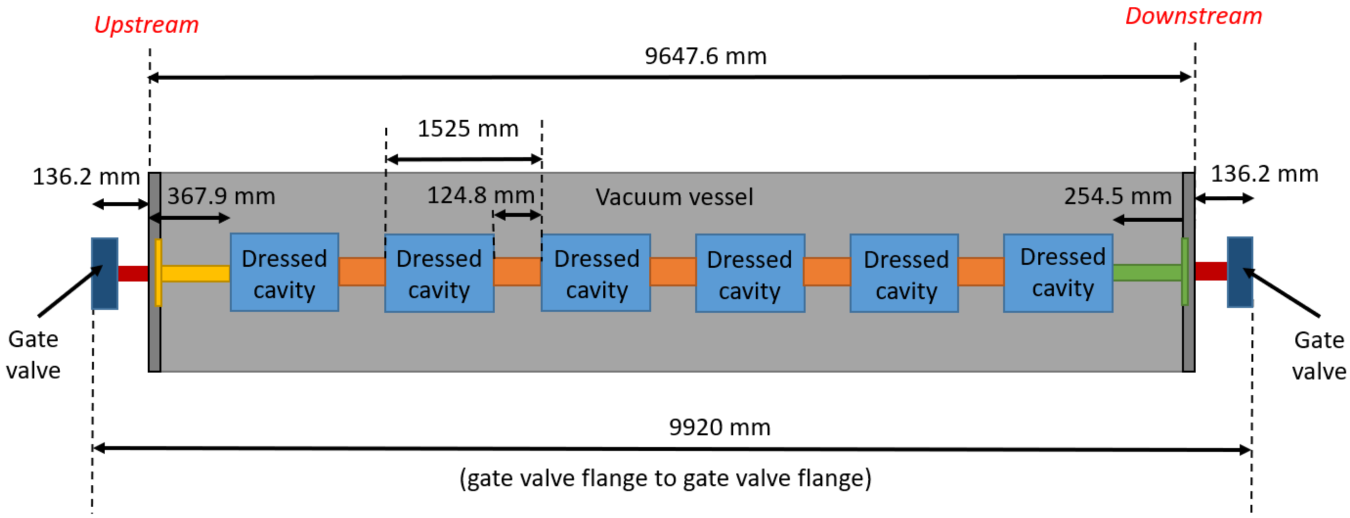

Figure 9-5. Schematic of HB650 cryomodule. Each cryomodule consists of six HB650 type cavities.

10. Linac components and parameters

Table 10-1, Table 10-2, Table 10-3, Table 10-4 and Table 10-5 list the parameters and components in the HWR, SSR1, SSR2, LB650 and HB650 cryomodules and adjacent areas, respectively.

Table 10-1. List of parameters and components in the HWR section.

Parameter	Value	Units	Comment
General			
Area definition	From the end of MEBT to the beginning of SSR1-1, includes RT section between HWR and SSR1-1		
Input Energy	2.1	MeV	-
Output energy	10	MeV	-
SRF and Cryomodule			
Number of HWR Cryomodules	1	-	-
Length of HWR CM	5.928	m	Argonne design model
Number of HWR cavities per CM	8	-	-
Number of HWR type solenoids per CM	8	-	-
Total number of SC correctors	16	-	Two per solenoid, one x and one y
Cold BPMs	8	-	One unit with x and y capability per SC solenoid
Room Temperature Section Between HWR and SSR1			

Length of RT section between HWR and SSR1 CM for instrumentation	0.25	m	Distance is between HWR GV and SSR1 GV
Beam loss monitors	0	-	-
Beam Profile Monitors	1	-	Laser Wire between HWR and SSR1
Vacuum pumps	1	-	Between HWR and SSR1-1

Table 10-2. List of parameters and components in the SSR1 section.

Parameter	Value	Units	Comment
General			
Area definition	From the beginning of SSR1-1 to the beginning of SSR2-1, includes RT section between SSR1-2 and SSR2-1		
Input Energy	10	MeV	-
Output energy	32	MeV	-
SRF and Cryomodule			
Number of SSR1 Cryomodules	2	-	-
Length of SSR1 CM	5.531	m	-
Number of cavities per CM	8	-	-
Total number of SSR1 cavities in SSR1 section	16	-	-
Number of SSR1 type solenoids per CM	4	-	-
Total number of SSR1 type solenoids in SSR1 section	8	-	-
Number of SC dipole correctors per solenoid	2	-	Two per solenoid, one x and one y
Total number of SC correctors	16	-	-
Cold BPMs per CM	4	-	On unit with x and y capability per SC solenoid
Total number of cold BPMs	8	-	
Room Temperature Sections			
Length of RT section between SSR1-SSR1 CM for instrumentation	0.45	m	-
Length of RT section between SSR1-SSR2 CM for instrumentation	0.40	m	-
ACCTs	1	-	-
Beam loss monitors	0	-	-
Beam Profile Monitors	1	-	Laser Wire Monitors
Ion pumps in SSR1 section	2	-	One per RT section

Table 10-3. List of parameters and components in the SSR2 section.

Parameter	Value	Units	Comment
General			
Area definition	From the beginning of SSR2-1 to the end of SSR2-7, does not include RT section between SSR2-7 and LB650-1		
Input Energy	32	MeV	-
Output energy	177	MeV	-
SRF and Cryomodule			
Number of SSR2 Cryomodules	7	-	-
Length of SSR2 CM	6.3	m	Conceptual design
Number of cavities per CM	5	-	-
Total number of SSR2 cavities in Linac	35	-	-
Number of SSR2 type solenoids per CM	3	-	-
Total number of SSR2 type solenoids	21	-	-
Number of SC dipole correctors per solenoid	2	-	-
Total number of SC correctors	42	-	-
Cold BPMs per CM	3	-	On unit with x and y capability per SC solenoid
Total number of cold BPMs	21	-	
Room Temperature Sections			
Length of RT section between SSR2-SSR2 CM for instrumentation	0.65	m	-
ACCTs	1	-	-
Low-power beam stop	1	-	After first SSR2 CM
Beam loss monitors	0	-	-
Beam Profile Monitors	2	-	-
Ion pumps in SSR2 Section	6	-	-

Table 10-4. List of parameters and components in the LB650 section.

Parameter	Value	Units	Comment
General			
Area definition	From the end of SSR2-7 to the beginning of HB650-1, includes the RT section between SSR2-7 and LB650-1 and the section between LB650-9 and HB650-1		

Input Energy	177	MeV	-
Output energy	516	MeV	-
SRF and Cryomodule			
Number of LB650 Cryomodules	9	-	-
Length of LB650 CM	5.5236	M	Conceptual design
Number of cavities per CM	4	-	-
Total number of LB650 cavities in Linac	36	-	-
Room Temperature Sections			
Length of RT section between SSR2-LB650 CM for instrumentation	1.8	m	-
Length of RT section between LB-LB CM for instrumentation	1.3	m	-
Length of RT section between LB-HB CM for instrumentation	1.3	m	-
Number of RT Quadrupoles per RT section	2	-	One quadrupole-doublet between CM
Total number of Quadrupoles in LB650 section	20	-	-
Number of dipole correctors per quad. doublet	2	-	X corrector in horizontally focusing quad, Y corrector in vertically focusing quad
Total number of correctors in LB650 section	20	-	-
Total BPMs in LB650 section	10	-	One per quadrupole doublet
ACCT	1	-	Between SSR2-7 and LB650-1
Beam loss monitors	0	-	-
Beam Profile Monitors	4	-	-
Ion pumps in LB650 RT sections	10	-	-

Table 10-5. List of parameters and components in the HB650 section to the straight-ahead dump.

Parameter	Value	Units	Comment
General			
Ara definition	From the beginning of HB650-1 to the straight-ahead dump at the end of the linac		
Input Energy	516	MeV	-
Output energy	833	MeV	Design provides margin over required 800 MeV.
SRF and Cryomodule			

Number of HB650 Cryomodules	4	-	-
Length of HB650 CM	9.9194	m	-
Number of cavities per CM	6	-	-
Total number of HB650 cavities in Linac	24	-	-
Room Temperature Sections			
Length of RT section between HB-HB CM for instrumentation	1.3	m	-
Number of Quadrupoles per RT section	2	-	One quadrupole-doublet between CM
Number of Skew-Quadrupoles	4	-	-
Total number of Quadrupoles in HB650 section	16	-	-
Number of dipole correctors per quad. doublet	2	-	X corrector in horizontally focusing quad, Y corrector in vertically focusing quad
Total number of correctors in HB650 section	16	-	-
ACCTs	1	-	At HB650 end
Total BPMs in HB650 section	9	-	One per quadrupole doublet
Beam loss monitors	0	-	-
Beam Profile Monitors	2	-	-
DCCT	1	-	-
Bunch Length Monitor	1	-	-
Resistive Wall Current Monitor (RWCM)	1	-	-
Ion pumps in HB650 section	8	-	-

Figure 10-1 shows the evolution of 1σ beam envelopes along the SC Linac for a nominal setting of the beamline elements. It can be observed that the transverse rms beam sizes change comparatively little along the Linac, and do not exceed over 3 mm over the course of the entire acceleration. This weak dependence of beam sizes on the acceleration implies that the adiabatic reduction of beam transverse emittances with beam acceleration is compensated by a corresponding increase in the beta-functions. The full transverse beam size is approximately $\pm 3\sigma$.

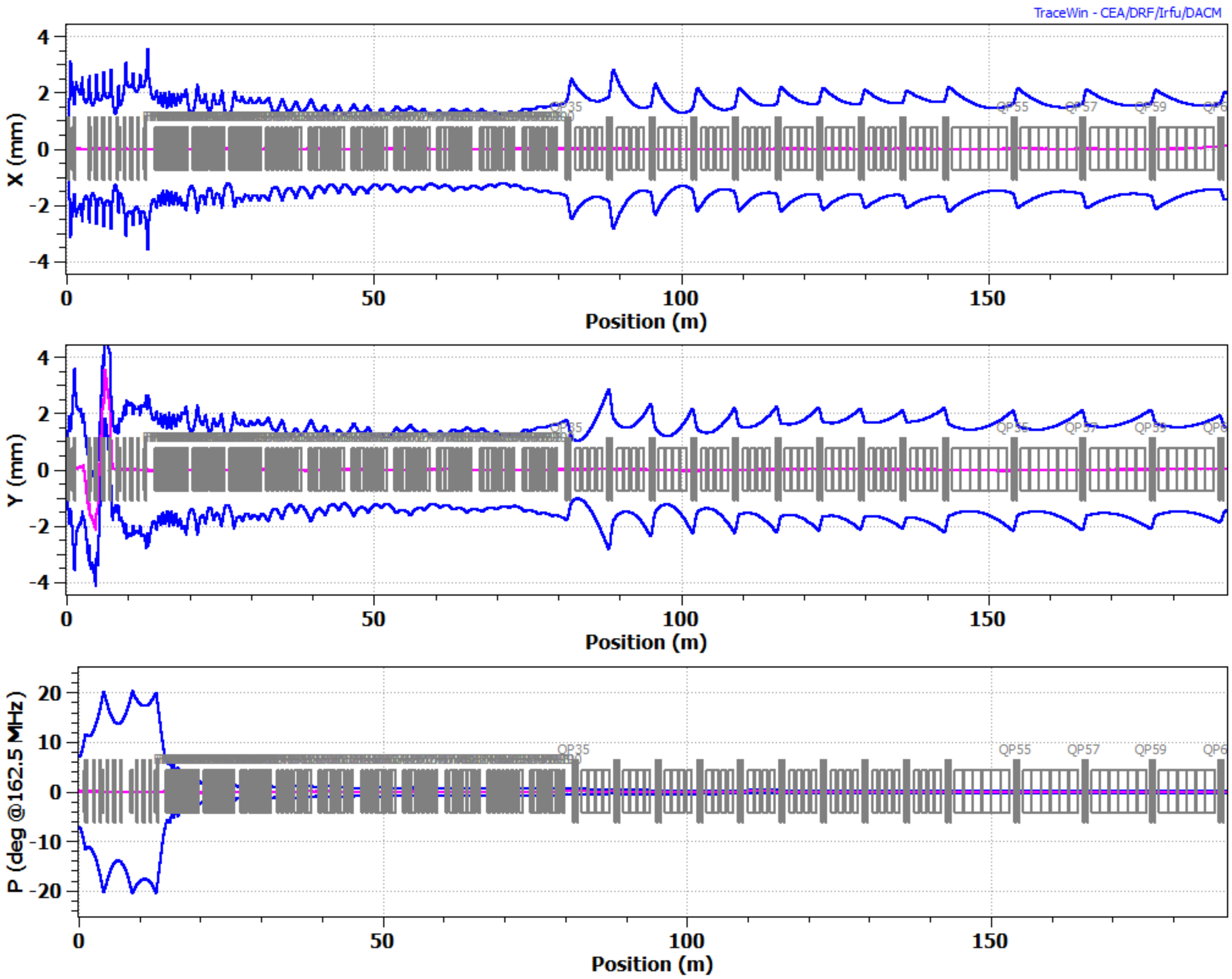

Figure 10-1. Horizontal (top) and vertical (center) rms bunch envelopes and rms bunch length (bottom) along the entire Linac (from the beginning of the MEBT to the end of the 0.83 GeV Linac); bunch population corresponds to the RFQ beam current of 5 mA. Magenta lines show displacements of the bunch centroid.

Figure 10-2 shows the beam phase advances in longitudinal, horizontal and vertical planes along the Linac corresponding to the optics shown in Figure 10-1.

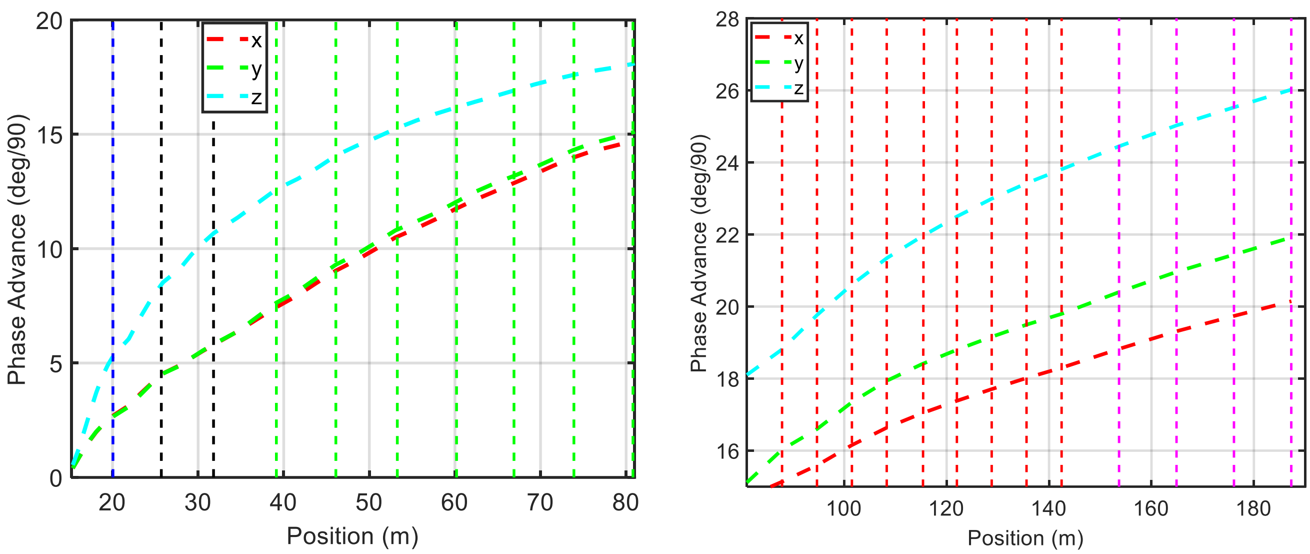

Figure 10-2. Beam phase advance in all planes for 5 mA beam current along the PIP-II Linac. (left) the beginning of the HWR to the exit of the SSR2 section and (right) LB650 to HB650 sections. Each vertical line represents the exit of cryomodule in the respective sections.

11. Beam Transfer Line

The Linac-to-Booster Transfer Line (BTL) transports the beam from the exit of the SC Linac to the injection girder of the Booster. The transport line has two arcs and a straight section connecting them. In this straight section the Booster line splits into two additional lines. One goes to the Linac beam dump and the other one goes to the Mu2e experiment which in a future upgrade is expected to receive 800 MeV beam from the SC Linac. Table 11-1 lists the main components in the BTL and their quantities. Figure 11-1 shows the lattice pictogram for the BTL Arc 1, Straight Section and BAL while Figure 11-2 shows the lattice pictograms for the BTL Arc 2. Figure 11-3 shows the lattice functions (βx, βy, Dx, Dy) from the entrance of the BTL to the foil at the Booster and Figure 11-4 shows the lattice functions (βx, βy, Dx, Dy) from the entrance of the Fast Corrector (Switch magnet) to the septum in the BTL and then to the end of the absorber line (the corn of the beam absorber). Figures 11-5 and 11-6 show the RMS beam size in BTL and BAL respectively.

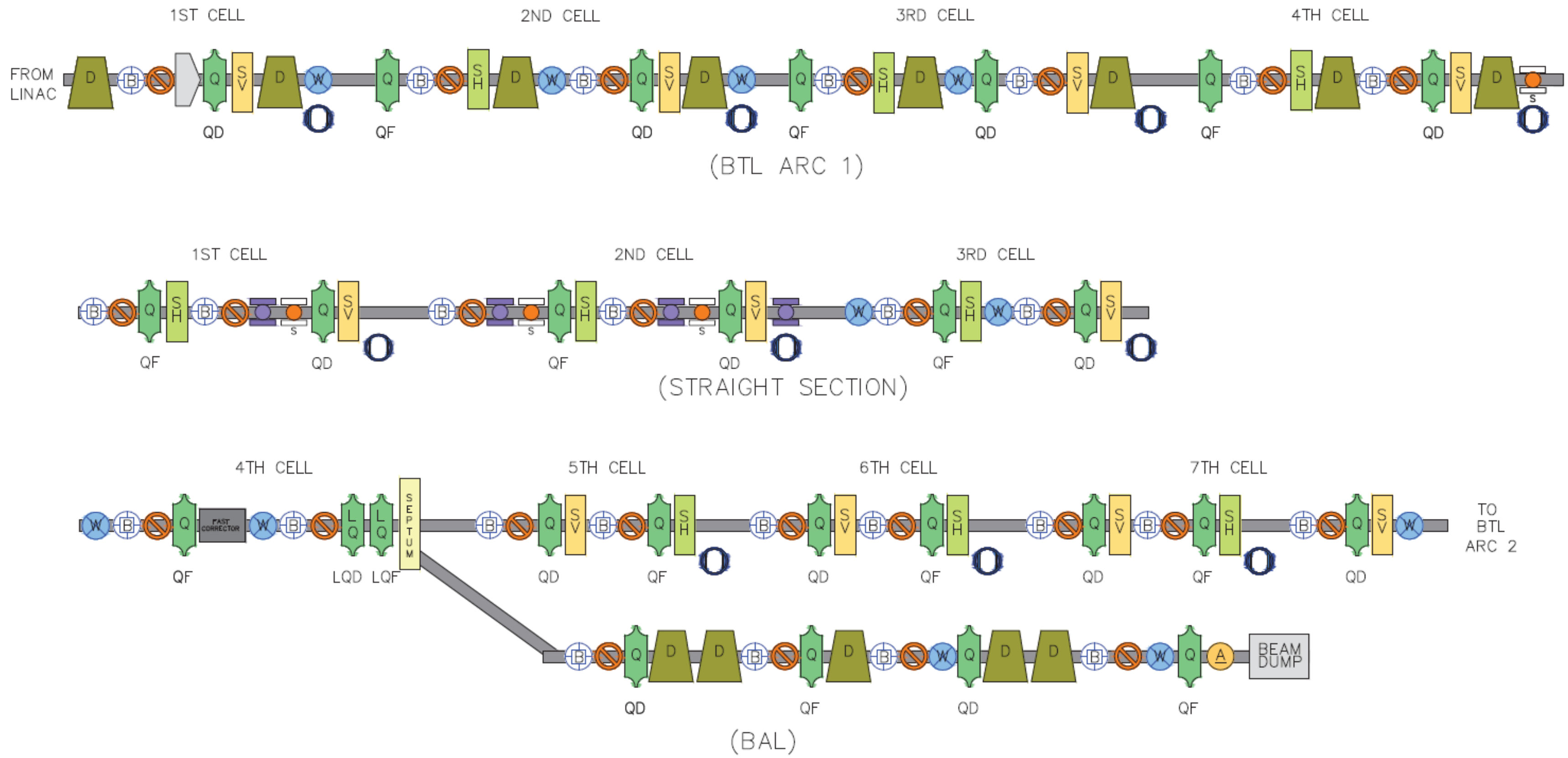

Figure 11-1. BTL Arc 1, Straight Section and BAL Pictogram

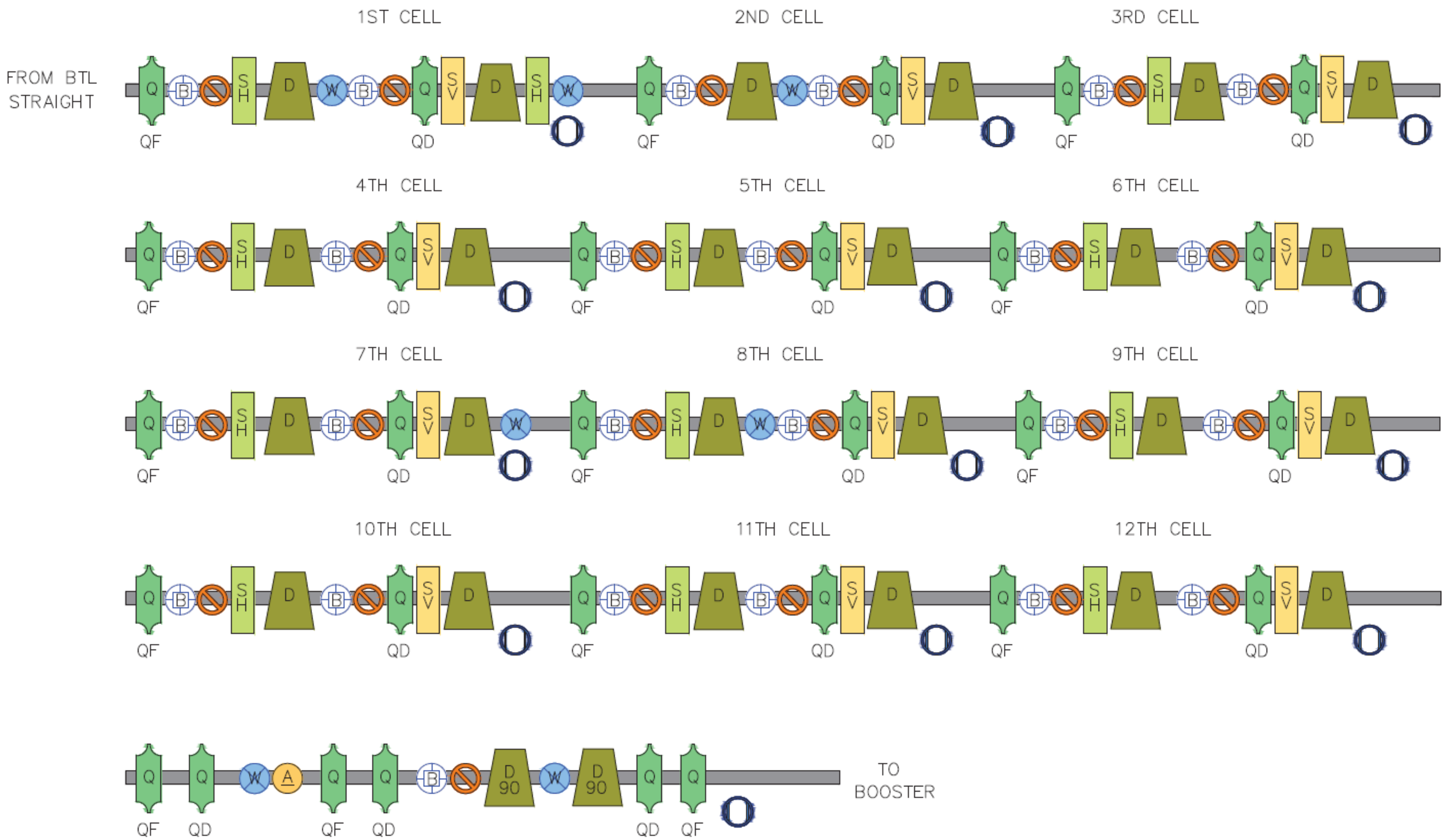

Figure 11-2. BTL Arc 2 Pictogram

Table 11-1. BTL Components

Parameter	Quantity	Comments
General		
Beam Energy	Up to 1 Gev	Booster injection designed up to 800 MeV
Magnets		
Dipole magnets in BTL	32	-
Dipole magnets in BAL	5	Same dipoles magnets as in BTL
Quads in BTL	45	-
Quads in BAL	4	Same quads as in BTL
EOL Quads	6	-
Large Aperture Quads	2	-
Number of correctors	56	-
3-Way Septum	1	-
Fast Sweep Magnet	1	-
Diagnostics		
ACCTs	2	-
BPMs (2”)	58	-
BPM (large aperture)	1	-
Beam loss monitors	65	-
Vacuum		
Ion pumps	23	-

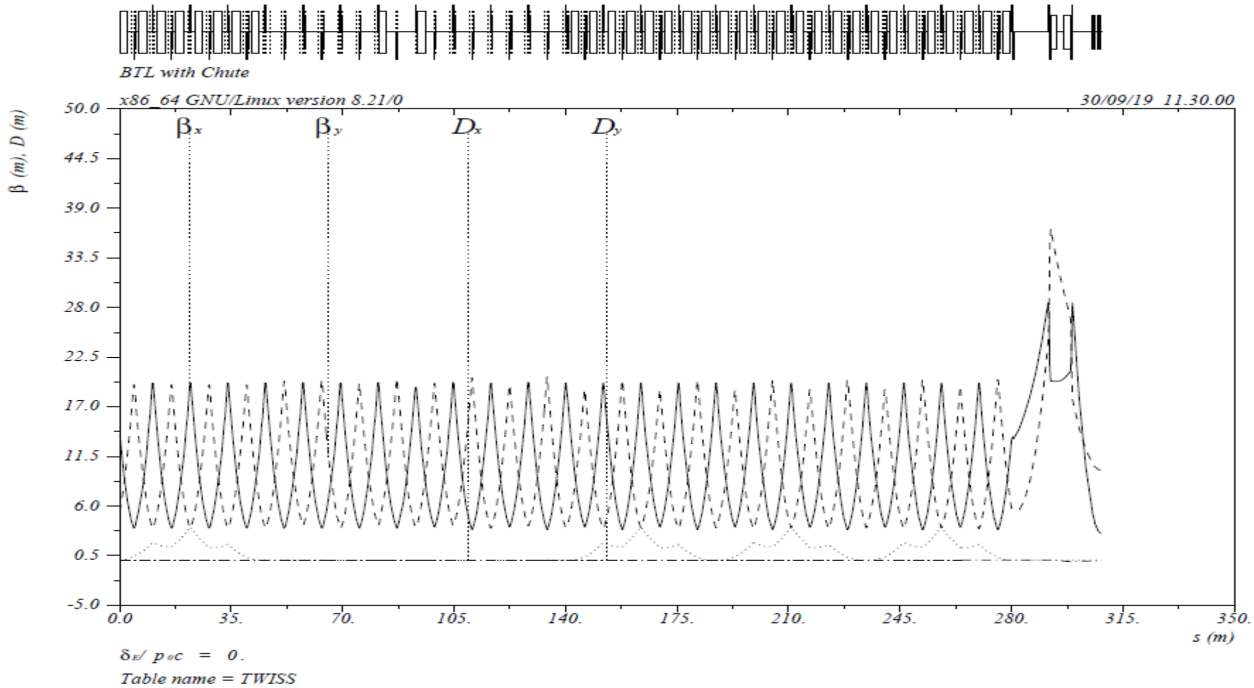

Figure 11-3. Optical Functions along the BTL

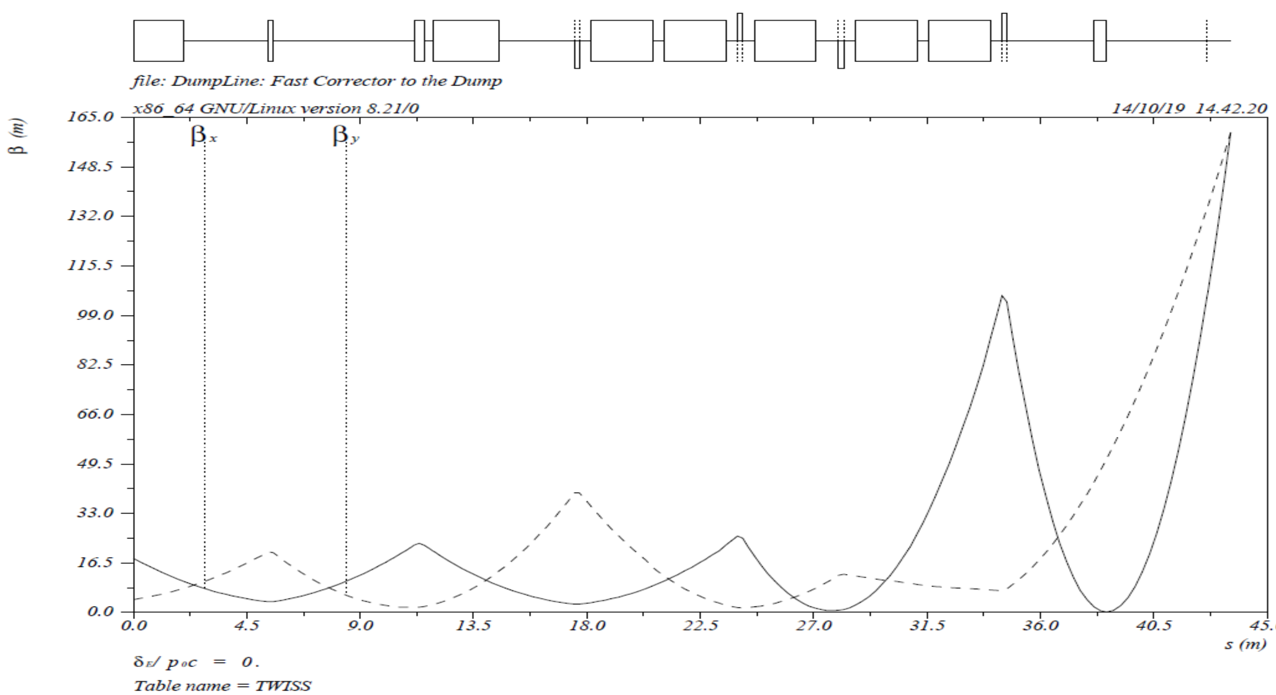

Figure 11-4. Optical Functions along the BTL and Absorber

Figure 11-5 shows the RMS beam size along BTL.

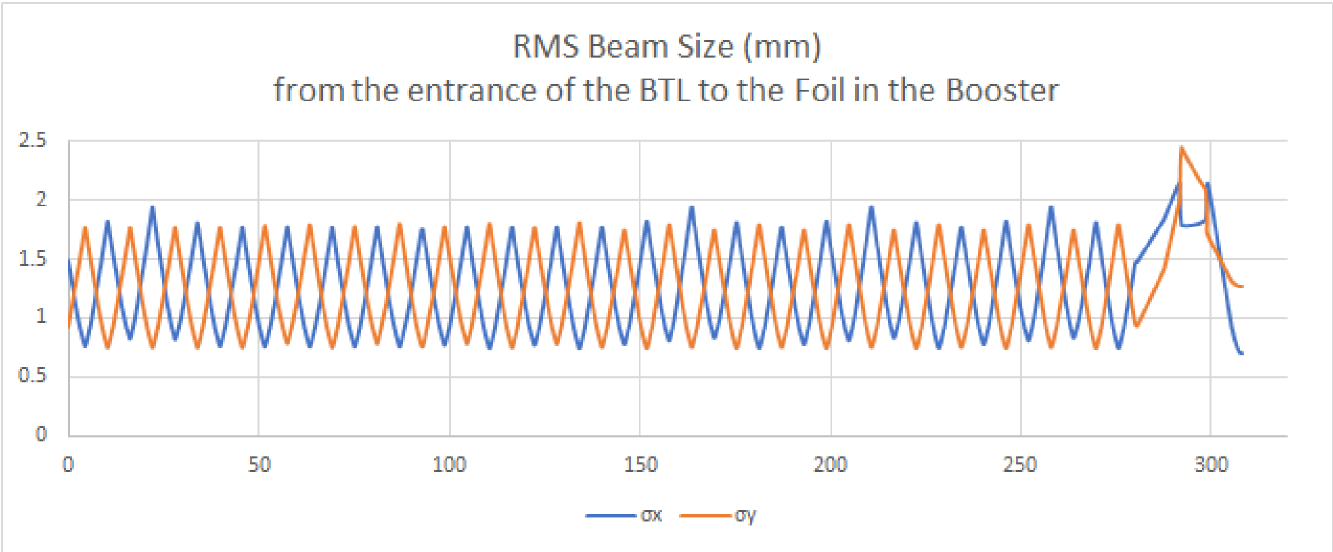

Figure 11-5. RMS Beam Size along the BTL

Figure 11-6 shows the RMS beam size along BTL to absorber.

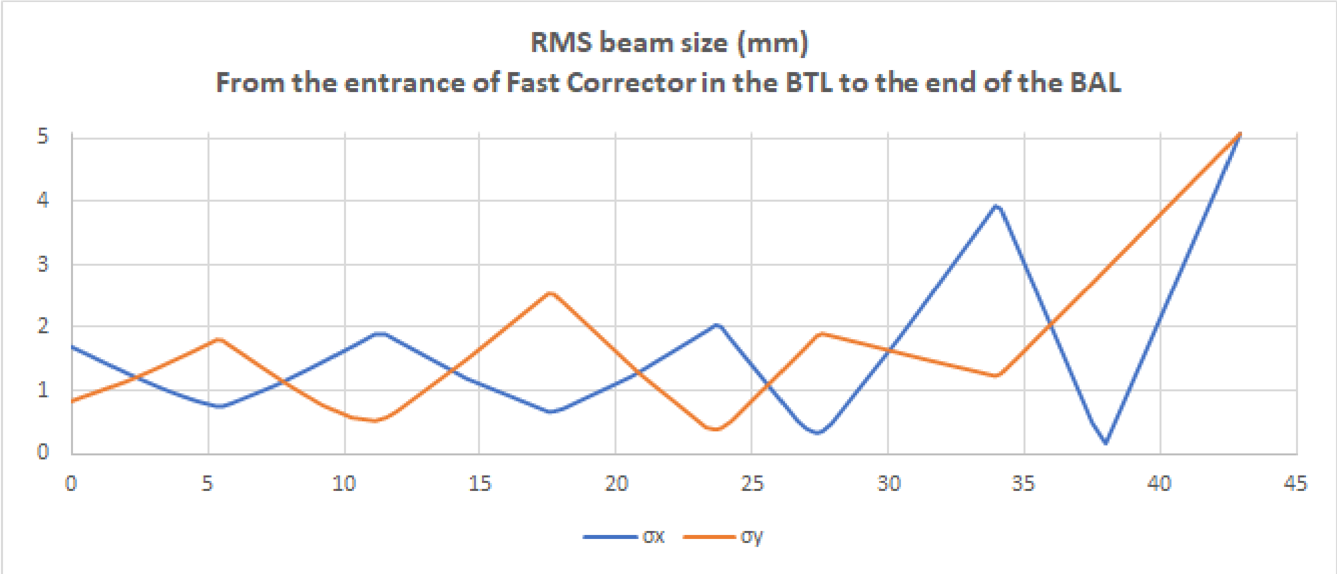

Figure 11-6. RMS Beam Size along the BTL and Absorber

12. Diagnostics Summary

Table 12-1 lists the type of diagnostics with their quantities at a given location.

Table 12-1. Diagnostic Distribution Totals by Location

Instrument	WFE	Linac (to SA dump)	BTL	Totals
DCCT	3	1	0	4
ACCT	3	3	2	8
RWCM	1	1	0	2
BPM – warm, 1.25”	11	0	0	11
BPM – cold	0	37	0	37
BPM – warm, 2”	0	20	58	78
BPM – large aperture	0	0	1	1
Laser Wire	1	12	0	13
Wire Scanner	2	2	22	26
Emittance Scanner – Allison	6	0	0	6
Emittance Scanner – Laser	0	0	1	1
Scraper – paddles	16	0	0	16
EID – non-ring	14	0	0	14
EID – ring pickups	4	0	0	4
Longitudinal – Feschenko	0	1	0	1
Longitudinal – Laser	1	0	0	1
BLM – ion	0	54	58	112
BLM – PMT	8	63	0	71
BLM – neutron	4	48	0	52
Multiwire	0	1	1	2
Halo Ring	0	1	1	2

13. Magnets Summary

Table 13-1 lists the magnet type and quantity.

Table 13-1. Magnet Quantities

Magnet Type	Quantity	Comments
MEBT Long Quads	12	-
MEBT Short Quads	20	-
MEBT Correctors	13	-
HWR Solenoids	8	-
HWR Correctors	16	-
SSR1 and SSR2 Solenoids	29	-
SSR1 and SSR2 Correctors	116	-
650 MHz Warm Quads	40	Including 4 skew quads
650 MHz Warm Correctors	36	-
BTL Regular Dipoles	37	-
Vertical Booster Injection Dipoles	2	-
Regular BTL Quads	49	-
Large Aperture BTL Quads	2	-
EOL BTL Quads	6	-
BTL Correctors	56	-
3-way Septum	1	-
Fast Switch Magnet	1	-
Booster Injection C-magnet	1	-

14. Reference Documents

#	Reference	Document #
1	PIP-II Global Requirements Document (GRD)	ED0001222