Infrastructure Requirements For the European XFEL Beam Position Monitor and Intra-Bunchtrain Feedback Electronics

1 Revision History

1.1	29/04/2009	B. Keil	Typos fixed. Units added. Table 3-3 line 14-15 baud rate changed. Fig. 1, Tables 3-2 and 4-1: front-to-back air flow for MBU and all 19" racks.
1.2	04/06/2009	B. Keil	Table 4-2: Rack heights for IBFB racks changed from 32 to 26HE.
1.3	15/07/2009	B. Keil	Figure 1 updated. Requirements for re-entrant BPMs as defined by C. Simon added & updated.
1.4	22/10/2009	B. Keil	Reference Frequency Clock Requirements for CEA updated according to information from S. Simon (100MHz instead of 10MHz)
1.5	25/02/2010	B. Keil	Reference frequency in tables 3-4 & 3-5 changed from 100MHz to 216MHz.
1.6	15/04/2010	B. Keil	Added missing table 3-4.
1.7	09/06/2010	B. Keil	Added beam arrival time jitter & drift relative to reference clock to table 3-4. Added table 3-6 (button BPM cable RF properties). Added spare fiber optic cables to tables 3-3 and 4-3, re-phrased text. Changed fiber optic cable necessity betw een SASE BPMs & IBFB from optional to mandatory.
1.8	15/06/2010	C.Simon	Changed table 3.5
1.9	16/06/2010	D.M. Treyer	Changed Table 3-3 items 1, 9, 11, 12. Added Tables 3-7 and 3-8. Added comments regarding cabling of button BPMs to Section "3.2 Cabling Requirements". Changed button BPM cable size and patch panel requirements.
1.10	23/06/2010	B. Keil	Added bunch spacing requirement to Table 3-4.
1.11	26/10/2010	B. Keil	Fixed w rong line number reference at end of section 3 (reference to Table 3-3 line 9). Fixed w rong units in Table 3-5 (reference clock phase noise) at request of C. Simon. Added air humidity requirements for BPMs (table 3-2) and IBFB
1.12	22/03/2011	B. Keil	Corrected typo in table 3-4 (w rong unit GHz, should be MHz).
1.13	04/04/2011	B. Keil	Clarified fiber optic cable types e.g. in Table 3-3.
1.14	17/08/2011	B. Keil	Table 3-2: MBU pow er requirement for button BPMs changed from 200W to 400W (MBU for 4 button pickups). Pow er tolerance for cavity & re-entrant MBU pow er added. Changed air flow volume in Table 3-2 from typ. to max. 1500 l/s.
1.15	24/08/2011	B. Keil	Table 3-2: Updated button MBU pow er consumption, at request of DESY, to typical (not w orst case) values, based on detailed estimate (on chip level) for present RFFE design & GPAC firmw are. Assumed 10% tolerance / safety margin (for final design).
1.16	06/10/2011	C. Simon, B. Keil	Table 3-5: Updated phase noise and signal level for re-entrant BPMs. Table 3-3 line 18 and Table 4-4 line 29-35: Changed fiber optic cable type betw een IBFB and undulator BPMs from multimode to singlemode, w ith new baud rate range (5-10Gbps).
1.17	26/01/2012	B. Keil	Updated Table 3-3 and Table 4-4.: Clarified that one MBU need three full-duplex fiber connections for operation. Added fiber optic transceiver and related cable specifications. Changed MBU maintenance interface from fiber optic 1000-Base- to CAT6 1000-Base-T in both tables at request of D. Nölle. Specified baud rates more precisely.
1.18	02/02/2012	B. Keil	Modified Table 3-4 (reference clock requirements) at request of M. Stadler and D. Lipka.
1.19	06/02/2012	C. Simon	Table 3-3 and 3-5 updated
1.20	07/02/2012	B. Keil	Added line 35 to Table 4-4 (IBFB fiber link to dispersive BPM).
1.21	03/05/2012	B. Keil	Added Table 4-5 w ith IBFB rack locations (longitudinal coordinates). Added Table 4-6 w ith IBFB BPM pickup and kicker magnet locations.
1.22	19/12/2012	B. Keil	Correcte max. allow ed depth of IBFB rack components from 620mm to 600mm, according to latest information from DESY / W. Decking. Updated IBFB component Table 4-6 (z-locations changed, BPM no. 1&2 X-Y sw apped, optics changed).
1.23	09/01/2013	B. Keil	Updated name/location of dispersive BPM used by IBFB in Table 4-4 row 35.
1.24	21/01/2013	M. Stadler	Modified Table 3-3: Added Patchpanel-to-RFFE cable for cavity pickups. Changed comment in text below Table 3-2.
1.25	19/03/2013	D. Treyer	Changed No. 20 in Table 3.2. Changed No. 8, 10, 12 in Table 3.3. Changed Tables 3.6 and 3.7
1.26	28/05/2015	B. Keil	Updated IBFB component locations according to E-XFEL component list 8.4.5 .
1.27	17/02/2016	B. Keil	Updated IBFB cabling and rack specifications and rack installation scheme. Removed copper-cable based BPM timing system interface (now only fiber). Various smaller updates. Air temperature at MBU air inlet speficied as 30°C max. (previoiusly 40°C max.)
1.28	19/02/2016	B. Keil	Added 2nd Ethernet interface to MBU and IBFB crate for remote crate monitoring and control (independent of GPAC).
1.29	28/04/2016	C. Simon	Table 3-3 updated and Figure 2

2 Introduction

This document defines some general infrastructure requirements for the installation and operation of the beam position monitor (BPM, WP17) and Intra-Bunchtrain Feedback (IBFB, WP16) electronics that are being developed by PSI as the Swiss in-kind contribution to the European XFEL (E-XFEL). Additionally, the requirements for the BPM electronics delivered by CEA as French contribution to WP17 are also included, since this electronics will be integrated into the overall BPM electronics infrastructure provided by PSI. The requirements include rack space, cooling, temperature stability, power, and cabling, using worst-case values that are based on the present designs and performance specifications for BPMs and IBFB.

3 BPMs

Table 3-1 contains the BPM types in E-XFEL and the quantities for which PSI will deliver BPM electronics as an E-XFEL in-kind contribution (as agreed in the In-Kind Contribution Agreement IKCA).

The cavity BPM (CBPM) pickups in the warm beamlines also include nine BPMs used by the IBFB: Four so-called upstream and four downstream BPMs close to the IBFB, and a dispersive BPM near the end of the collimator that allows the IBFB to measure the beam energy. It should be noted that the electronics for all warm cavity BPMs is identical. The only difference is an additional attenuator at the RFFE inputs of the standard 40.5mm CBPMs, in order to achieve a larger position measurement range at high bunch charges (at the expense of less resolution at low charge) compared to the 40.5mm IBFB and 10mm undulator CBPMs that have no additional attenuators.

The following sections define the requirements for all BPMs except the IBFB, for which additional requirements are defined in chapter 4.

Table 3-1:

Machine Section	*BPM Type*	*Aperture [mm]*	*#*	*Pickup*	*RF Front-End*	*Digital Back-End Electronics*
Cold	Re-entrant	78	31	CEA/France	CEA/France	PSI
Cold	Button	78	73	DESY	PSI	PSI
Warm Beamlines	Button	40.5, ...	228	DESY	PSI	PSI
Warm Beamlines	Cavity (Standard)	40.5	10	DESY	PSI	PSI
Warm Beamlines	Cavity (IBFB)	40.5	9	DESY	PSI	PSI
Warm Undulator	Cavity	10	117	DESY	PSI	PSI

3.1 Space, Power and Cooling Requirements

The E-XFEL BPM electronics consists of compact units called MBU (Modular BPM Unit). One MBU contains the complete BPM electronics for either four button BPMs or two Re-entrant BPMs or two cavity BPMs (or 1-2 buttons and either a normal or re-entrant cavity). Figure 1 shows an MBU for two undulator cavity BPMs.

Figure 1: Modular BPM Unit (Air Flow Front-to-Back)

The electronics consists of RF front-ends (RFFEs) that are different for each BPM type, a common digital back-end (GPAC = Generic PSI ADC Carrier Board) for all BPM types, with a common housing with power supply, fans, trigger I/Os and additional (optional) SFP fiber optics transceivers. The GPAC is a digital carrier board that has two mezzanine modules with ADCs. The RFFEs and GPAC with their coaxial connectors for BPM pickups and RF reference clock are plugged into the MBU from the front side, their mechanical form factor is compatible to VME64x. One button BPM RFFE occupies one MBU front side slot, one re-entrant or cavity RFFEs two slots, with four slots overall for RFFEs per MBU. It is possible to mix different RFFE types in one MBU, e.g. two (or one) button RFFEs with either one cavity or re-entrant RFFE. Two additional front-side slots in the MBU are foreseen for the GPAC with its ADC mezzanines. In addition to two SFP transceivers at the GPAC front, four additional (optional) SFP transceivers as well as trigger IOs (connected to the GPAC via the MBU backplane) and the power supply module with its 230V power connector are located at the rear side of the MBU. While RFFEs and GPAC can also be plugged into normal VME64x crates for testing and development purposes, the power, grounding, mechanical and thermal concept of the cost-efficient and compact MBU is required to achieve the desired BPM performance. Table 3-2 contains a list of power, cooling and space requirements and specifications of the MBU.

The MBU height specified in Table 3-2 is the height of the MBU housing. In order to more easily be able to access cables at the MBU rear side (or to connect cables from other systems from the rear rack side to the MBU front or vice versa), it is recommended to leave sufficient free space above and/or below the MBUs, such that one can reach the MBU rear side from the rack front by hand.

Table 3-2: E-XFEL Modular BPM Unit (MBU) Specifications and Requirements

No.	*MBU Specification/Requirement*	*Min.*	*Typ.*	*Max.*	*Unit*	*BPM Type*	*Comment*
1	BPMs per MBU, Option 1			4		Button	
2	Option 2			2		Re-entrant	
3	Option 3			2		Cavity	
4	AC Line Power	-10%	230	+10%	V	All	
5			50		Hz	All	
6			300	+10%	W	Cavity & Re-Entrant	MBU tries to regulate its power dissipation
7			330	+10%	W	Button BPMs	digitally to ~const. value (-> stable temp.)
8	Air Flow Direction					All	Front-to-back
9	Air Flow Volume (By MBU Fans)			1.5	m^3/min	All	For MBU in free air
10	Air Temperature @ Cooling Air Inlet	10		30	°C	All	
11	Air Temperature Drift (Peak-Peak)			0.1	°C/hour	Undulator Cavity	Causes position drift, should be minimized
12				1	°C/week	Undulator Cavity	
13				1	°C/hour	All Others	
14				10	°C/week	All Others	
15	Air Humidity			90	%	All	Non-condensing.
16	Height			3	HE	All	1HE =44.45mm
17	Width		19		Inch	All	Standard 19" width (482.6mm)
18	Depth			450	mm	All	Worst case
19	Free Space Behind MBU	150			mm	All	For back side cables & connectors, cooling air outlet
20	Free Space In Front of MBU	150			mm	All	For front side cables & connectors, cooling air inlet

3.2 Cabling Requirements

Table 3-3: MBU Cable Connections

Signal	*Cable*	*#Cables*	*From*	*To*	*BPM Type*	*Connector/Comment*
Button BPM Pickup	Coax 1/2"	4/BPM	Patch Panel at Cryostat	Patch Panel Near MBU	Button	N to N. Length tolerance 15mm peak-peak between 4 cables of a pickup.
	Coax 1/4"		Patch Panel Near MBU	MBU Front		SMA to SMA. Length tolerance 5mm peak-peak between 4 cables of a pickup.
Re-Entrant BPM Pickup	Cryo	4/BPM	Pickup	Patch Panel 1	Re-entrant	SMA to N (cryo cable, short) +/- 1° phase between the 4 cables of a pickup, same length
	Coax		Patch Panel 1	Hybrid Box		N to SMA (short length < 1m)
Re-Entrant BPM Hybrid Box	Coax 1/2"	3/BPM	Hybrid Box	Patch Panel 2		N toN (LCF12-50 series cable, long)
	Coax 1/4"		Patch Panel 2	MBU Front		SMA to SMA (short length)
Undulator Cavity Pickup	Coax 1/4"	3/BPM	Pickup	Patch Panel	Cavity Undul.	N to N (Length < 6m, cable RFS SCF14-50). Length tolerance 5mm peak-peak between 3 cables of a pickup.
	Coax		Patch Panel	MBU Front		N to SMA (Length: <1m, Cable: H&S Multiflex 141)*****
Other Cavity Pickup	Coax 1/2"		Pickup	Patch Panel	Cavity Other	N to N. Length tolerance 5mm peak-peak between 3 cables of a pickup.
	Coax		Patch Panel	MBU Front		N to SMA (Length: <1m, Cable: H&S Multiflex 141)*****
Machine Ref. Clock	Coax	1/MBU	Master Osc.	MBU Front	Cavity + Re-entrant	SMA (see Tables 3-4 and 3-5 for details)
Line Power	230V	1/MBU	Rack	MBU Back	All	Standard ("Kaltgerätestecker")
Digital Timing Interface	Twin Fiber* (Full Duplex)	2/MBU	Timing Sys.	MBU Back (COM SYS1)	All	LC Duplex (850nm multimode 1.3 Gbps 8b/10b Rocket IO). 1 full duplex cable for operation, 1 spare cable.
DOOCS Interface	Twin Fiber** (Full Duplex)	2/MBU	Control Sys.	MBU Front (GPAC SFP2)	All	LC Duplex (850nm multimode 2.5 Gbps 8b/10b Rocket IO) 1 full duplex cable for operation, 1 spare cable.
Maintenance Interface	CAT6 Ethernet	2/MBU	Ethernet	MBU Front (GPAC SFP1) and GPAC Rear (Crate Monitor MMC2)	All	RJ45 (1000-Base-T Ethernet) at front, RJ45 (100-Base-T Ethernet) at rear side.******
Machine Interlock	Multi-pole	1/MBU	MBU Back	Interl.sys.	All	
Beam Positions in SASE Undulators	Twin Fiber*** , Single-mode (Full Duplex)	2/MBU	MBU Back (COM BPM1 of the first MBU and COM BPM2 of the last MBU)	IBFB Digital Electronics	1st (upstream) & last (downstream) cavity BPM MBU in each SASE undulator	LC Duplex (1310nm single-mode 5-10.3 Gbps 8b/10b). 1 full duplex cable for operation, 1 spare cable.
Beam Positions in SASE Undulators	Twin Fiber**** 850nm Multimode (Full Duplex)	2/MBU	MBU Back (COM BPM2)	Adjacent downstreamMBU Back (COM BPM1)	Cavity BPM MBUs in SASE undulators	IBFB feedback network (one network per SASE undulator): LC Duplex (850nm 2-10.3 Gbps 8b/10b). 1 full duplex cable for operation, 1 spare cable.

* Type, length and overall attenuation (e.g. patch panels) of fiber optic connections should allow the use of the following transceiver type(s): AFBR-57J5APZ (transceiver supports 0.614-3.072 Gbps, operation typ. at 1.3Gbps).
** Type, length and overall attenuation (e.g. patch panels) of fiber optic connections should allow the use of the following transceiver type(s): AFBR-57D9AMZ (transceiver supports 2.125-8.5 Gbps, operation typ. at 2.5Gbps)
*** Type, length and overall attenuation (e.g. patch panels) of fiber optic connections should allow the use of the following transceiver type(s): can be used: AFCT-57D5ATPZ, AFCT-57D3ATMZ, FTLF1428P2BNV (transceivers support 2.125-8.5 Gbps, operation typ. at 2.5-5Gbps)
**** Type, length and overall attenuation (e.g. patch panels) of fiber optic connections should allow the use of the following transceiver type(s): AFBR-57D9AMZ (transceiver supports 2.125-8.5 Gbps, operation typ. at 2.5-5Gbps)
***** Loss 0.77dB/m.
****** The nominal performance of BPM and IBFB only has to be reached with disconnected maintenance interface. However, during operation the maintenance interface will be connected. DESY is responsible to ensure that nominal performance is also reached with connected maintenance interface (suppression ground loop noise caused by the maintenance interface cable etc.).

Table 3-3 contains the cable connections required for an MBU. For fiber optic cables, the cable quantities in column 4 of the table are the number of full duplex cables consisting of two fibers each (one transmit, one receive fiber). Since many BPMs are expected to be necessary for the operation of the E-XFEL, all fiber optic cables in

Table 3-3 are redundant (i.e. 50% of the cables in the table are spares): One full duplex cable for operation for each purpose, one full duplex spare cable that is not connected unless the one for operation breaks.

All coaxial cable end connectors are of male type, unless specified otherwise in the table. The cables from a BPM pickup to the electronics of the pickup should have matched lengths (tolerance: see Table 3-3 and Table 3-6).

The cables for undulator cavity BPMs are expected to have ¼" thickness. Thicker cables could be used instead, reducing loss at the price of increased bending radius. All cables must be chosen and equipped with connectors such that they can be easily attached/screwed to the MBUs.

Button BPMs will have coax ½" from pickup to patch panel at electronics rack, both sides N connectors, and coax ¼" from patch panel to MBU, with SMA on both ends.

For the cold reentrant BPMs, the four pickup signal cables that come out of the cryostat go to SMA-to-SMA patch panel no. 1 that is mounted onto the cryo-module (Figure 2, left hand side). From this patch panel, four SMA cables go to a box mounted at the side of the cryo-module. This box contains hybrids that generate a sum and two difference signals from the four raw pickup signals (Figure 2, right hand side). From the hybrid box (with three SMA-to-N adaptors attached to its outputs via a mechanical frame and short rigid SMA cables), three ½’’ cables with N connectors at both sides go to the 19’’ rack with the MBU. These cables cannot be connected directly to the re-entrant RF front end (RFFE) in the MBU since they are too thick. Therefore another N-to-SMA connector patch panel (no. 2) is required close to the MBU, with three ¼’’ SMA cables from this panel to the re-entrant RFFE in the MBU.

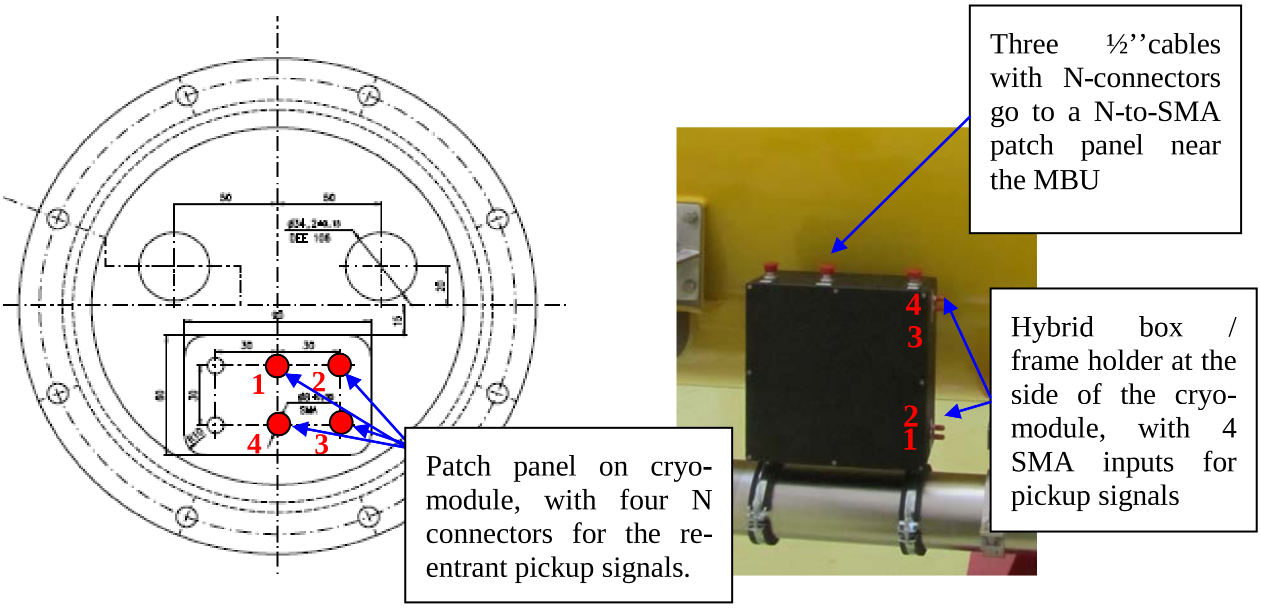

Figure 2: Re-entrant pickup signal patch panels. Left: 1st Patch panel (4x SMA-to-SMA) for pickup signals mounted on cryo-module. Right: Hybrid box with attached N-connector cables to MBU.

As shown in Table 3-3, all cavity BPM MBUs in each SASE undulator are connected via digital multi-gigabit fiber optic links in a daisy chain (see chapter 4), with the first and last MBU of the chain both being connected to the IBFB digital electronics rack (one daisy chain per SASE undulator). This allows the IBFB to acquire the beam positions of all undulator BPMs, and to use their position readings for feedback and adaptive feed-forward algorithms. The fiber optic cables between the MBUs and from MBUs to IBFB should be as short as possible in order to minimize the delay of the feedback loop, and thus to maximize the correction bandwidth and related beam stability.

Table 3-4 shows the requirements for the cavity BPM RFFE reference clock (see Table 3-3) which is to be provided by the E-XFEL accelerator RF reference clock distribution infrastructure. Table 3-5 shows the respective requirements for the re-entrant BPMs that also need such a reference clock, however with different requirements.

Table 3-6 shows the RF properties/requirements that the cables for the cold and warm button BPMs (cables provided by DESY) must fulfill.

Table 3-4: Machine Reference Clock & Beam Timing Requirements for Cavity BPM RFFE

No.	Property	Min.	Typ.	Max.	Unit	Comment
1	Phase Noise @ 10Hz			-95	dBc/Hz	
2	Phase Noise @ 100Hz			-115	dBc/Hz	
3	Phase Noise @ 1kHz			-135	dBc/Hz	
4	Phase Noise @ 10kHz-10MHz			-140	dBc/Hz	
5	Amplitude Noise @1Hz-10MHz			-133	dBc/Hz	
6	Signal Level	0	3	8	dBm	
7	Frequency		216,666667		MHz	
8	Harmonics			-40	dBc	
9	total non-harmonic content @1Hz-10MHz			-70	dBc	
10	non-harmonic content @>10MHz			-50	dBc	
11	Peak-Peak Frequency Drift (Short & Long Term)			30	ppm	
12	Beam Arrival Time Jitter & Drift Relative To Reference Clock			400	fs rms	1Hz-10MHz
13	Bunch Spacing		N*48		Ref. clock periods	N=Integer
14	Connector Type @ MBU		SMA			

Table 3-5: Machine Reference Clock Requirements for Reentrant BPM RFFE

No.	Property	Min.	Typ.	Max.	Unit
1	Phase Noise @ 1kHz		-95		dBc/Hz
2	Phase Noise @ 10kHz		-115		dBc/Hz
4	Phase Noise @ 100kHz		-135		dBc/Hz
5	Phase Noise @ 1Mhz		-150		dBc/Hz
6	Phase Stability		10		ps
7	Signal Level		7		dBm
8	Frequency		216,666667		MHz
9	Peak-Peak Frequency Drift (Short & Long Term)			30	ppm
10	Connector Type @ MBU		SMA		

Table 3-6 shows the RF properties/requirements that the cables for the cold and warm button BPMs (cabled provided by DESY) must fulfill.

Table 3-6: Button BPM Pickup Cable Requirements

No.	Property	Frequency [GHz]	Min.	Max.	Unit	Comment
1	Attenuation	1		6	dB	
2	Attenuation Mismatch of 4 buttons	1		0.17	dB RMS	For 0.1 mm offset at max. pickup sensitivity 1.7 dB/mm.
3	Delay Mismatch of 4 Buttons	0.3 – 1.2		200	ps	See Table 3-3 comments to No. 1 and 2.
4	Echo Separation from Main Pulses	0.3 – 1.2	50		ns	Applies only if echoes exceed –50 dB, relative to main pulses.
5	Interference and noise	0.3 – 1.2		0.2	%	Peak interference and noise voltage relative to weakest signal pulse.
		>1.2		2	%	
6	Return Loss	0.3 – 1.2	26		dB	

4 IBFB

Figure 3 shows the location of the IBFB in the E-XFEL tunnel, Figure 4 the topology for the final IBFB version. The IBFB components for each plane (horizontal and vertical) consist of two so-called upstream BPMs (cavity type, 40.5mm aperture) followed by two kicker magnets, followed by two so-called downstream BPMs (same type). The eight IBFB BPMs (four per plane) and four kicker magnets (two per plane) are connected to the IBFB electronics that is located in several 19’’ racks near the IBFB beam line components (see rack overview in Table 4-1). The electronics consists of cavity BPM MBUs to obtain the beam positions, digital signal processing electronics to calculate beam trajectory corrections, RF power amplifiers that drive the kicker magnets which kick and thus correct the beam position, and DAC/ADC electronics (controlled by the digital electronics) that drive and monitor the power amplifiers. The digital IBFB electronics is also connected via fiber optics to all undulator cavity BPM MBUs (as already defined in Table 3-3), in order to monitor and correct the beam position directly in the undulators, since the actual IBFB upstream and downstream BPMs are quite far away from the undulators (see Figure 3).

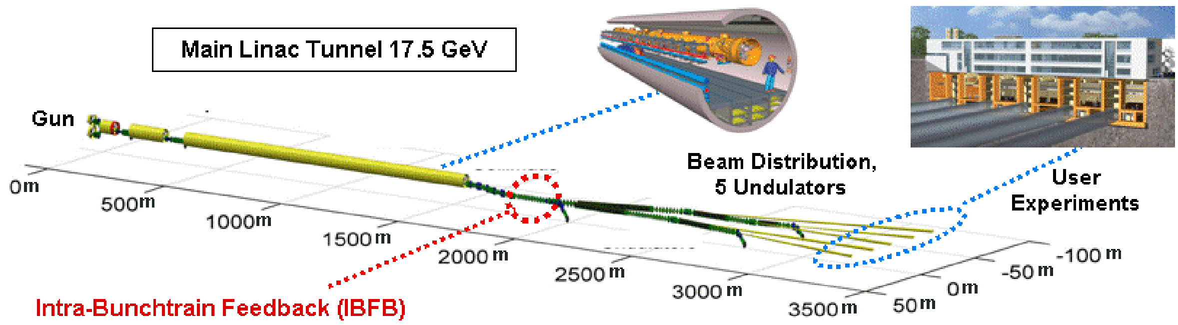

Figure 3: Location of the IBFB

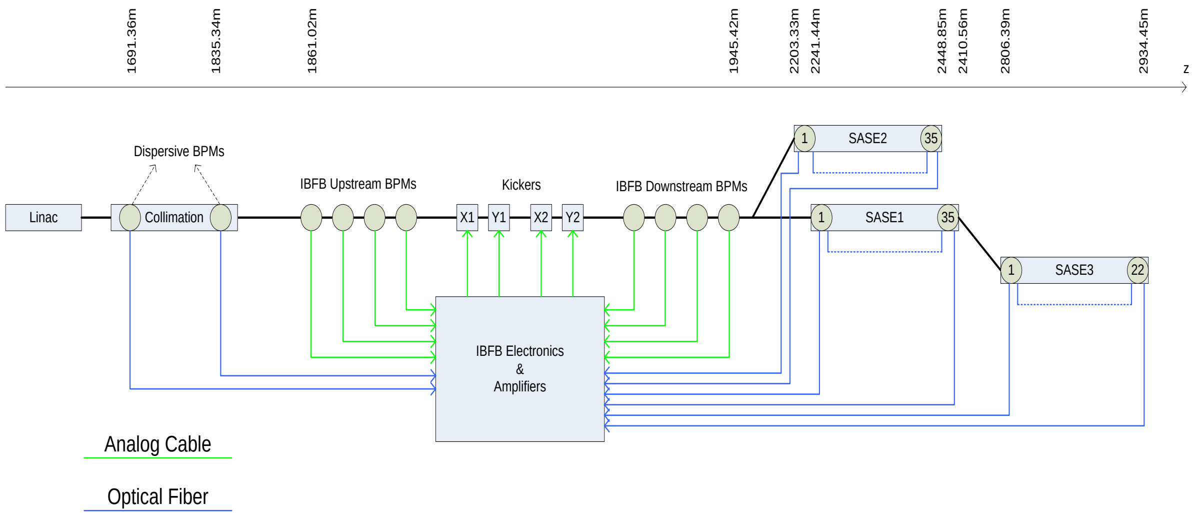

Figure 4: Topology of the IBFB.

Table 4-1 contains the longitudinal tunnel coordinates of the IBFB racks. The coordinate of each rack refers to the center of mass (i.e. middle) of the rack, not the upstream side of the rack.

Table 4-1: Longitudinal Positions of IBFB Electronics Racks

No.	Rack Contents	Longitudinal Position z[m]
1	IBFB Kicker V1-1 Amplifier IBFB Kicker V1-2 Amplifier	1894.5
2	IBFB Kicker V2-1 Amplifier IBFB Kicker V2-2 Amplifier	1895.5
3	Analog IBFB Electronics	1900.7
4	Digital IBFB Electronics	1901.7
5	IBFB Kicker H1-1 Amplifier IBFB Kicker H1-2 Amplifier	1909.5
6	IBFB Kicker H2-1 Amplifier IBFB Kicker H2-2 Amplifier	1910.5

* The longitudinal coordinate “z” is based on the coordinate system in the Excel Table “XFEL Component List Version 8.4.5” by W. Decking, table sheet “LONGLIST”, table column “P”.

Table 4-2 contains the locations of the IBFB BPM pickups and kicker magnets in the beam pipe. The longitudinal coordinate “z” refers to the center of the component.

Table 4-2: Longitudinal IBFB BPM Pickup and Kicker Magnet Positions in the Beam Pipe

No.	Official (E-XFEL) Component Name*	Informal (PSI) Name	Longitudinal Position z[m]	Comment
1	BPMI.1860.TL	BPM1-Y	1860.922845	1st Upstream BPM for vertical (Y) plane
2	BPMI.1863.TL	BPM1-X	1863.702845	1st Upstream BPM for horizontal (X) plane
3	BPMI.1878.TL	BPM2-Y	1878.877844	2nd Upstream BPM for vertical (Y) plane
4	KFBY.1880.TL	KICKER1A-Y	1880.355343	Vertical Kicker 1, 1st of 2 chained elements
5	KFBY.1883.TL	KICKER1B-Y	1883.355343	Vertical Kicker 1, 2nd of 2 chained elements
8	BPMI.1889.TL	BPM2-X	1889.077843	2nd Upstream BPM for horizontal (X) plane
9	KFBX.1890.TL	KICKER1A-X	1890.555343	Horizontal Kicker 1, 1st of 2 chained elements
10	KFBX.1893.TL	KICKER1B-X	1893.555343	Horizontal Kicker 1, 2nd of 2 chained elements
13	KFBY.1905.TL	KICKER2A-Y	1905.555342	Vertical Kicker 2, 1st of 2 chained elements
14	KFBY.1908.TL	KICKER2B-Y	1908.555342	Vertical Kicker 2, 2nd of 2 chained elements
17	BPMI.1910.TL	BPM3-Y	1910.032842	1st Dow nstream BPM for vertical (Y) plane
18	KFBX.1920.TL	KICKER2A-X	1920.555341	Horizontal Kicker 2, 1st of 2 chained elements
19	KFBX.1923.TL	KICKER2B-X	1923.555341	Horizontal Kicker 2, 2nd of 2 chained elements
22	BPMI.1925.TL	BPM3-X	1925.032841	1st Dow nstream BPM for horizontal (X) plane
23	BPMI.1930.TL	BPM4-Y	1930.332840	2nd Dow nstream BPM for vertical (Y) plane
24	BPMI.1939.TL	BPM4-X	1939.077840	2nd Dow nstream BPM for horizontal (X) plane

* The longitudinal coordinate “z” is based on the coordinate system in the Excel Table “XFEL Component List Version 8.4.5” by W. Decking, table sheet “LONGLIST”, table column “P”. Please note that the IBFB is also connected via fiber optic cables to one dispersive BPM in the collimator (see Table 4-6) for energy measurements and to the undulator BPMs (see also Table 4-6) for fine-tuning of undulator beam positions.

4.1 Space, Power and Cooling Requirements

Table 4-3 and Table 4-4 contain the main infrastructure requirements of the IBFB and its electronics components with respect to cooling, power and rack space. All electronics modules in the racks as well as the kicker amplifiers have internal fans. The air temperature range and drift specified in the tables is related to the air inlets of the electronics modules in their cooled racks.

Table 4-3: Temperature, Cooling and Power Requirements of IBFB Electronics Racks. Analog and Digital IBFB Electronics have one rack each. The power amplifiers are installed in four racks, with two amplifiers per rack.

No.	*Rack Contents*	*Location*	*Line Power*	*Cooling Power Typ.*	*Max.*	*Air Flow Direction*	*Air Temperature Range*	*Drift*	*# 230V Conn.*
1	IBFB Kicker V1-1 Amplifier	Tunnel, Room 39	4kW	1.5kW	2kW	front-to-back	15-30°C	1°C/day	5
	IBFB Kicker V1-2 Amplifier	Tunnel, Room 39							
2	IBFB Kicker V2-1 Amplifier	Tunnel, Room 39	4kW	1.5kW	2kW	front-to-back	15-30°C	1°C/day	5
	IBFB Kicker V2-2 Amplifier	Tunnel, Room 39							
3	Analog IBFB Electronics	Tunnel, Room 39	2kW	1.2kW	2kW	front-to-back	15-30°C	0.1°C/day	5
4	Digital IBFB Electronics	Tunnel, Room 39	2kW	1kW	2kW	front-to-back	15-30°C	0.1°C/day	5
5	IBFB Kicker H1-1 Amplifier	Tunnel, Room 39	4kW	1.5kW	2kW	front-to-back	15-30°C	1°C/day	5
	IBFB Kicker H1-2 Amplifier	Tunnel, Room 39							
6	IBFB Kicker H2-1 Amplifier	Tunnel, Room 39	4kW	1.5kW	2kW	front-to-back	15-30°C	1°C/day	5
	IBFB Kicker H2-2 Amplifier	Tunnel, Room 39							

Table 4-4: Space Requirements of IBFB Electronics Racks

No.	*Rack Contents*	*Rack Height*	*Electronics Depth (Net)*	*Additional Free Space(Min.) Front*	*Back*	*Left*	*Right*
1	IBFB Kicker V1-1 Amplifier	26HE	600mm	150mm	150mm	0mm	0mm
	IBFB Kicker V1-2 Amplifier						
2	IBFB Kicker V2-1 Amplifier	26HE	600mm	150mm	150mm	0mm	0mm
	IBFB Kicker V2-2 Amplifier						
3	Analog IBFB Electronics	26HE	450mm	150mm	150mm	150mm	150mm
4	Digital IBFB Electronics	26HE	450mm	150mm	150mm	0mm	0mm
5	IBFB Kicker H1-1 Amplifier	26HE	600mm	150mm	150mm	0mm	0mm
	IBFB Kicker H1-2 Amplifier						
6	IBFB Kicker H2-1 Amplifier	26HE	600mm	150mm	150mm	0mm	0mm
	IBFB Kicker H2-2 Amplifier						

The rack for the analog electronics contains the IBFB BPM electronics (MBUs). The digital electronics rack contains electronics e.g. for IBFB digital signal processing (incl. fast DACs driving the kicker RF power amplifiers), kicker RF power amplifier control and monitoring. The remaining four racks contain the RF power amplifiers for the IBFB kicker magnets (two amplifiers per stripline kicker magnet)

Table 4-5: Air Humidity Requirements of IBFB Electronics Racks

No.	*Rack Contents*	*Location*	*Air Humidity*
1	IBFB Kicker V1-1 Amplifier	Tunnel, Room 39	<90% non-condensing
	IBFB Kicker V1-2 Amplifier		
2	IBFB Kicker V2-1 Amplifier	Tunnel, Room 39	<90% non-condensing
	IBFB Kicker V2-2 Amplifier		
3	Analog IBFB Electronics	Tunnel, Room 39	<90% non-condensing
4	Digital IBFB Electronics	Tunnel, Room 39	<90% non-condensing
5	IBFB Kicker H1-1 Amplifier	Tunnel, Room 39	<90% non-condensing
	IBFB Kicker H1-2 Amplifier		
6	IBFB Kicker H2-1 Amplifier	Tunnel, Room 39	<90% non-condensing
	IBFB Kicker H2-2 Amplifier		

4.2 Cabling Requirements

Table 4-6 contains a list of cable connections for the different IBFB electronic racks. As already mentioned, the IBFB uses the same BPM electronics as the other cavity BPMs, and the cabling requirements are the same (see Table 3-3). However, the cables from CBPM pickups to IBFB BPM electronics (MBUs) should be as short as possible in order to maximize the signal level (and thus BPM resolution) and to minimize the delay (latency) of the feedback loop. The cables from the RF power amplifiers to the IBFB kicker magnets should also be length-matched (per kicker magnet, tolerance 5mm) and as short as possible. The fiber optic cables that connect the analog with the digital IBFB electronics rack should also be length-matched (tolerance 10mm) and as short as possible. All coaxial cable end connectors are of male type, unless specified otherwise in the table. Since the IBFB is expected to be necessary for the operation of the E-XFEL, all fiber optic cables in Table 4-6 are redundant (i.e. 50% of the cables in the table are spares): One cable for operation for each purpose, one spare cable that is not connected unless the one for operation breaks. Since broken short patch cables in the racks can easily be replaced, spares are only specified in the table for the long cables to other racks or components outside the racks.

Table 4-6: IBFB Cable Connections

No.	Signal	Cable	#	From	To	Connector/Comment
1	BPM Pickup Signals	1/2" Coax Sucofeed	40 (5/BPM)	8 IBFB Cavity BPM Pickups	Analog IBFB electronics rack, patch panel at front	N to N. Length tolerance 10mm peak-peak between 5 cables of a pickup.
2		Coax	40 (5/BPM)	Analog IBFB electronics rack, patch panel at front	Analog IBFB electronics rack, MBU front	N to SMA (Length: <1m, Cable: H&S Multiflex_141)*****
3	Machine Ref. Clock	1/4" Coax	8	E-XFEL machine ref. clock distribution system	Analog IBFB electronics rack, patch panel at front	SMA (same spec as MBU). Cables to rack include 50% spares.
4			4 (1/MBU)	Analog IBFB electronics rack, patch panel at front	Analog IBFB electronics rack, MBU front	
5	Digital Timing Interface	Twin Fiber* (Full Duplex, OM3 LWL-Multi Mode 50/125 µm)	8 (2/MBU)	E-XFEL timing system	Analog IBFB electronics rack, patch panel at front	LC Duplex (same as MBU). Cables to rack include 50% spares.
6			4 (1/MBU)	Analog IBFB electronics rack, patch panel at front	Analog IBFB electronics rack, MBU rear (COM SYS 1)	
7	DOOCS Interface		8 (2/MBU)	E-XFEL control system	Analog IBFB electronics rack, patch panel at front	
8			4 (1/MBU)	Analog IBFB electronics rack, patch panel at front	Analog IBFB electronics rack, MBU front (GPAC SFP 2)	
9	Maintenance Interface	CAT6 Ethernet *	16 (4/MBU)	E-XFEL Ethernet	Analog IBFB electronics rack, patch panel at front	RJ45 (1000-Base-T Ethernet) at front and RJ45 (100-Base-T Ethernet) at rear side (same as MBU). Cables to rack include 50% spares.
10			8(2/MBU)	Analog IBFB electronics rack, patch panel at front	Analog IBFB electronics rack, feedback electronics front (GPAC SFP 1) and rear (crate monitor MMC2)	
11	Machine Interlock	Digital multi-pole	4 (1/MBU)	Analog IBFB electronics rack, MBU rear side	E-XFEL machine interlock system	Same as BPM system
12	Digital BPM data	Twin Fiber* (Full Duplex, OM3 LWL-Multi Mode 50/125 µm)	8 (2/MBU)	Analog IBFB electronics rack, MBU rear (COM BPM1 / BPM 2)	Analog IBFB electronics rack, patch panel at front	LC Duplex.
13				Analog IBFB electronics rack, patch panel at front	Digital IBFB electronics rack, patch panel at front	
14				Digital IBFB electronics rack, patch panel at front	Digital IBFB electronics rack, rear side of digital IBFB crate	
15	Machine Ref. Clock	Coax	8	E-XFEL machine ref. clock distribution system	Digital IBFB electronics rack, patch panel at front	SMA. Cables to rack include 50% spares.
16			4	Digital IBFB electronics rack, patch panel at front	Digital IBFB electronics rack, feedback electronics front (2 DAC + 2 ADC boards)	
17	Digital Timing Interface	Twin Fiber* (Full Duplex, OM3 LWL-Multi Mode 50/125 µm)	8	E-XFEL timing system	Digital IBFB electronics rack, patch panel at front	LC Duplex (same as MBU). Cables to rack include 50% spares.
18			4	Digital IBFB electronics rack, patch panel at front	Digital IBFB electronics rack, feedback electronics rear side (GPAC SYS1)	
19	DOOCS Interface		8	E-XFEL control system	Digital IBFB electronics rack, patch panel at front	
20			4	Digital IBFB electronics rack, patch panel at front	Digital IBFB electronics rack, feedback electronics front (GPAC SFP 2)	
21	Maintenance Interface	CAT6 Ethernet *	16	E-XFEL Ethernet	Digital IBFB electronics rack, patch panel at front	RJ45 (1000-Base-T Ethernet) at front and RJ45 (100-Base-T Ethernet) at rear side. Cables to rack include 50% spares.
22			8	Digital IBFB electronics rack, patch panel at front	Digital IBFB electronics rack, feedback electronics front (GPAC SFP 1) and rear (crate monitor)	
23	Machine Interlock	Digital multi-pole	4	Digital IBFB electronics rack, MBU rear side	E-XFEL machine interlock system	Same as BPM system
24	Kicker Amplitude Drive	Coax	16 (2/Amp).	Digital IBFB electronics rack, DAC boards	Digital IBFB electronics rack, patch panel at front	Radiall-to-SMA cables provided by PSI.
25		Coax 1/4"		Digital IBFB electronics rack, patch panel at front	Kicker amplifier rack, patch panel	SMA double-shielded cables. The two cables of an amplifier must be length matched to <10mm (pseudo-differential).
26				Kicker amplifier rack, patch panel	Kicker amplifier rack, diff to single-ended converter	
27			8(1/Amp).	Kicker amplifier rack, diff to single-ended converter	Kicker amplifier, back	SMA double-shielded cables.
28	Amplifier. Control/Status	CAT6	8(1/Amp).	Digital IBFB electronics rack, IBFB electronics rear side	Digital IBFB electronics rack, patch panel at front	RJ45
29				Digital IBFB electronics rack, patch panel at front	Kicker amplifier rack, patch panel	
30				Kicker amplifier rack, patch panel	Kicker amplifier, Back	
31	Amplifier 2nd Gate (For Test)	Coax 1/4"	8(1/Amp).	Digital IBFB electronics rack, patch panel at front	Kicker amplifier rack, patch panel	SMA. Optional gate signal from digital IBFB rack to amplifier racks for amplifier testing. Terminate with 50ohm when unused.
32		Coax 1/4"		Kicker amplifier rack, patch panel	Kicker amplifier, back (coax gate input)	
33	Amplifier Monitor (Amplit Measurem.)	Coax 1/4"	8 (1/Amp).	Kicker amplifier back	Kicker amplifier rack, single-ended to differential converter	SMA double-shielded cables
34			16 (2/Amp).	Kicker amplifier rack, single-ended to differential converter	Kicker amplifier rack, patch panel	SMA double-shielded cables. The two cables of an amplifier must be length matched to <10mm (pseudo-differential).
35				Kicker amplifier rack, patch panel	Digital IBFB electronics rack, patch panel at front	
36		Coax		Digital IBFB electronics rack, patch panel at front	Digital IBFB electronics rack, front (ADC boards)	SMA-to-Radiall cables provided by PSI.
37	Kicker Output Amplitude Monitor (Measurem.)	Coax 1/2" Sucofeed	8 (2/Kicker)	Each BFB Kicker (Outp. Port)	Digital IBFB electronics rack, patch panel at front	HN (magnet) to 7/16" (patch panel)
38				Digital IBFB electronics rack, patch panel at front	Digital IBFB electronics rack, front (attenuator + differential converter)	7/16" (patch panel) to 7/16" (attenuator)
39		Coax	16 (4/Kicker)	Digital IBFB electronics rack, front (attenuator + differential converter)	Digital IBFB electronics rack, front (ADC boards)	SMA-to-Radiall cables provided by PSI.
40	Kicker Power/Drive Signals	Coax 1/2" Sucofeed	1	IBFB Kicker H1-1 Amplifier, Back	IBFB Kicker Magnet H1 (Left Port)	HN (magnet) to 7-16 female (amplifier). Length tolerance between the two cables of one kicker <10mm.
41			1	IBFB Kicker H1-2 Amplifier, Back	IBFB Kicker Magnet H1 (Right Port)	
42			1	IBFB Kicker H2-1 Amplifier, Back	IBFB Kicker Magnet H2 (Left Port)	
43			1	IBFB Kicker H2-2 Amplifier, Back	IBFB Kicker Magnet H2 (Right Port)	
44			1	IBFB Kicker V1-1 Amplifier, Back	IBFB Kicker Magnet V1 (Top Port)	
45			1	IBFB Kicker V1-2 Amplifier, Back	IBFB Kicker Magnet V1 (Bott. Port)	
46			1	IBFB Kicker V2-1 Amplifier, Back	IBFB Kicker Magnet V2 (Top Port)	
47			1	IBFB Kicker V2-2 Amplifier, Back	IBFB Kicker Magnet V2 (Bott. Port)	
48	SASE1 Beam Positions	Twin Fiber* , Single-mode (Full Duplex)	2	1st cavity BPM MBU in SASE1	Digital IBFB Electronics, GPAC front (QSFP mezzanine) via patch panel	LC Duplex, 5-10.3Gbps, 1310nm Single-mode. 1 cable for operation, 1 spare cable.
49			2	Last cavity BPM MBU in SASE1		
50	SASE2 Beam Positions		2	1st cavity BPM MBU in SASE2		
51			2	Last cavity BPM MBU in SASE2		
52	SASE3 Beam Positions		2	1st cavity BPM MBU in SASE3		
53			2	Last cavity BPM MBU in SASE3		
54	Dispersive collimator BPM data		2	Rear side of MBU for BPM "BPMI.1835.CL"	Digital IBFB Electronics, Back	

* See Table 3-3 and footnotes for details.

The cable specified from the dispersive BPM to the IBFB electronics at the end of Table 4-6 allows the IBFB to measure the beam energy autonomously and apply energy-dependent corrections e.g. to the kick strength.

Table 4-7: IBFB Rack Component Installation Overview (PP = Patch Panel for Cables, Followed by Signal Type)

<table>
<tr><td></td><td>Rack No.</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td></td><td>z Pos. [m]</td><td>1894.5</td><td>1895.5</td><td>1900.7</td><td>1901.7</td><td>1909.5</td><td>1910.5</td></tr>
<tr><td>H[cm]</td><td>HU No.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>120.0</td><td>1</td><td>Fire Exting./ Reserve</td><td>Fire Exting./ Reserve</td><td>Fire Exting./ Reserve</td><td>Fire Exting./ Reserve</td><td>Fire Exting./ Reserve</td><td>Fire Exting./ Reserve</td></tr>
<tr><td>115.6</td><td>2</td><td rowspan="2">PP (Kicker Power/Drive Signal, 7/16")</td><td rowspan="2">PP (Kicker Power/Drive Signal, 7/16")</td><td rowspan="2">PP (BPM Pickup Signal Cables, 5 Per Pickup, 8 Pickups)</td><td rowspan="2">PP (Kicker and Tomco Amp Output Monitoring)</td><td rowspan="2">PP (Kicker Power/Drive Signal, 7/16")</td><td rowspan="2">PP (Kicker Power/Drive Signal, 7/16")</td></tr>
<tr><td>111.1</td><td>3</td></tr>
<tr><td>106.7</td><td>4</td><td>PP (Amplif. Control/ Status + Gate*) 2xRJ45 + 2xSMA</td><td>PP (Amplif. Control/ Status + Gate*) 2xRJ45 + 2xSMA</td><td rowspan="2">PP (Maintenance, RefClock, Fibers for Timing/Doocs/ Feedback/BPM Data)</td><td rowspan="2">PP (Maintenance, RefClock, Fibers for Timing/Doocs/ Feedback/BPM Data)</td><td>PP (Amplif. Control/ Status + Gate*) 2xRJ45 + 2xSMA</td><td>PP (Amplif. Control/ Status + Gate*) 2xRJ45 + 2xSMA</td></tr>
<tr><td>102.2</td><td>5</td><td>PP (Amplif. Monitor Signal) 4x SMA</td><td>PP (Amplif. Monitor Signal) 4x SMA</td><td>PP (Amplif. Monitor Signal) 4x SMA</td><td>PP (Amplif. Monitor Signal) 4x SMA</td></tr>
<tr><td>97.8</td><td>6</td><td>PP (Amplif. Drive Signal) 4x SMA</td><td>PP (Amplif. Drive Signal) 4x SMA</td><td></td><td></td><td>PP (Amplif. Drive Signal) 4x SMA</td><td>PP (Amplif. Drive Signal) 4x SMA</td></tr>
<tr><td>93.3</td><td>7</td><td></td><td></td><td rowspan="3">MBU (BPM Electronics) BPM1-X & BPM2-X (Horiz. Upstr. CBPMs)</td><td rowspan="6">Digital IBFB Electronics Crate (DACs + ADCs + SFP Interfaces)</td><td></td><td></td></tr>
<tr><td>88.9</td><td>8</td><td>Diff <-> Single Ended Converter (Amp Drive & Monitor Sig.)</td><td>Diff <-> Single Ended Converter (Amp Drive & Monitor Sig.)</td><td>Diff <-> Single Ended Converter (Amp Drive & Monitor Sig.)</td><td>Diff <-> Single Ended Converter (Amp Drive & Monitor Sig.)</td></tr>
<tr><td>84.5</td><td>9</td><td></td><td></td><td></td><td></td></tr>
<tr><td>80.0</td><td>10</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>75.6</td><td>11</td><td rowspan="5">Tomco IBFB Kicker Amplif. V1-1 (1st Vert. Kicker) (Height: 5 HU)</td><td rowspan="5">Tomco IBFB Kicker Amplif. V2-1 (2nd Vert. Kicker) (Height: 5 HU)</td><td></td><td rowspan="5">Tomco IBFB Kicker Amplif. H1-1 (1st Hor. Kicker) (Height: 5 HU)</td><td rowspan="5">Tomco IBFB Kicker Amplif. H2-1 (2nd Hor. Kicker) (Height: 5 HU)</td></tr>
<tr><td>71.1</td><td>12</td><td rowspan="3">MBU (BPM Electronics) BPM3-X & BPM4-X (Horizontal Downstr. CBPMs)</td></tr>
<tr><td>66.7</td><td>13</td><td></td></tr>
<tr><td>62.2</td><td>14</td><td></td></tr>
<tr><td>57.8</td><td>15</td><td></td><td rowspan="4">Attenuators & Single Ended To Diff Converters for Kicker Output Monitoring</td></tr>
<tr><td>53.3</td><td>16</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>48.9</td><td>17</td><td></td><td></td><td rowspan="3">MBU (BPM Electronics) BPM1-Y & BPM2-Y (Vertical Upstr. CBPMs)</td><td></td><td></td></tr>
<tr><td>44.5</td><td>18</td><td></td><td></td><td></td><td></td></tr>
<tr><td>40.0</td><td>19</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>35.6</td><td>20</td><td rowspan="5">Tomco IBFB Kicker Amplif. V1-2 (1nd Vert. Kicker) (Height: 5 HU)</td><td rowspan="5">Tomco IBFB Kicker Amplif. V2-2 (2nd Vert. Kicker) (Height: 5 HU)</td><td></td><td></td><td rowspan="5">Tomco IBFB Kicker Amplif. H1-2 (1nd Horiz. Kicker) (Height: 5 HU)</td><td rowspan="5">Tomco IBFB Kicker Amplif. H2-2 (2nd Horiz. Kicker) (Height: 5 HU)</td></tr>
<tr><td>31.1</td><td>21</td><td></td><td></td></tr>
<tr><td>26.7</td><td>22</td><td rowspan="3">MBU (BPM Electronics) BPM3-Y & BPM4-Y (Vertical Downstr. CBPMs)</td><td></td></tr>
<tr><td>22.2</td><td>23</td><td></td></tr>
<tr><td>17.8</td><td>24</td><td></td></tr>
<tr><td>13.3</td><td>25</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8.9</td><td>26</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4.4</td><td>27</td><td>Reserved (For Tool Box Etc)</td><td>Reserved (For Tool Box Etc)</td><td>Reserved (For Tool Box Etc)</td><td>Reserved (For Tool Box Etc)</td><td>Reserved (For Tool Box Etc)</td><td>Reserved (For Tool Box Etc)</td></tr>
</table>

* The gate signal is presently transmitted via the CAT6/RJ45 digital serial link cable from IBFB digital electronics to amplifier, but analog (coaxial) SMA gate signal cables from digital IBFB electronics rack to each amplifier rack (one per amplifier) should be foreseen as optional alternative (e.g. for testing of the amplifiers from the digital electronics rack via function generators).

Table 4-7 shows the components in the different IBFB racks (see Table 4-6 for a detailed list of cables for the patch panels – not show in detail in the rack drawing). In order to simplify the cabling, all coaxial, fiber and CAT6 (network and kicker control) and fiber optic signals connected to components outside a rack should be connected to patch panels in each racks (rather than directly to the components in the racks).

Signals coming from outside of the racks shall be connected to the rear side of the patch panels, such that the front side can be patched to the components in the rack, either directly (for components that have the connector at the front side), or also via patch panel (for components in the rack with connectors at the rear side, where cables from these components also go to the rear side of a patch panel, thus allowing easy access from the rack front side during operation).

The digital IBFB electronics has DACs that drive the Tomco kicker amplifiers via differential output signals going to the amplifier racks, using two separate coaxial cables for each differential signal, rather than special differential coaxial cables. In the amplifier racks, differential-to-single-ended converters transform these signals to single-ended signals driving the Tomco amplifiers. Using long differential and short single-ended cables minimizes interference noise on the cables (where differential cables are usually ~10x less sensitive) that may otherwise cause unwanted kicks of the beam and thus affect the beam stability.

Each Tomco amplifier has a single ended monitor output that is an attenuated and filtered version of its high power output signal which drives the kicker magnets. The monitor output is converted from single-ended to differential signal level in the amplifier rack and then goes via coax cables (two per differential signal) to the digital IBFB electronics rack, where the signals are sampled by fast ADCs (with differential coaxial inputs) to monitor the kicker amplifier output directly.

The high power kicker magnet output signals are also monitored. The noise-insensitive high power output signal of each kicker output port goes - without attenuation - via coaxial cable (single-ended) to the digital IBFB electronics rack, where the signal is attenuated, converted from single-ended to differential, and then connected to fast ADC boards with differential coaxial inputs in order to measure the kicker output signal shape, amplitude and timing.