Installation, Timing and Gating Details for The Linac Chopper and the BPM's In the Booster

April 21, 2014

Craig Drennan

Table of Contents

Table of Figures

I. Beam Delivery from the Linac to the Booster

Beam accelerated in the Linac is switched into the 400 MeV line, on its way to the Booster by the combination of the 400 MeV Chopper and a Lambertson magnet. A Chopper is a pair of metallic plates, one on either side of the beam aperture, between which an electric field is created to bend the particle beam from its initial trajectory, towards the beam dump. The Lambertson magnet has two apertures. One aperture is simply a hole, the other contains a beam bending dipole field. Initially the Chopper plates are both energized to approximately 55 kV. The electric field is created when one of the plates is shorted to ground creating a sudden difference in potential between the pair. Beam is bent into the dipole aperture of the Lambertson which further direct the beam into the 400 MeV beam line. The signal which triggers the creation of the chopper's electric field is "Chop On". When the Booster has received as much beam from the Linac as it needs, beam is removed from the 400 MeV line by grounding the other plate of the Chopper, removing the difference in potential between the plates and removing the electric field. The signal that triggers this is "400 MeV Chop Off".

There is also a similar chopper at the output of each of the Cockcroft-Walton Generators. These are referred to as the 750 keV Choppers. Another signal from the Booster, "750 keV Chop Off" is used terminate the flow of beam into the Linac just before "400 MeV Chop Off" triggers. This precludes the accelerator from accelerating beam it is not going to send to the Booster, beam that would be directed into the dump and into the metal separating the two apertures of the Lambertson magnet.

It is also worth noting that before the occurrence of Chop On, the first 2 microseconds of Linac beam is allowed to pass on to the dump giving the Linac RF servo loops time to settle to a more stable beam.

II. 200 MHz Beam Position Monitors

Beam coming out of the Linac, through the 400 MeV beam line, into the Booster has a 200 MHz bunch structure. In 2012 new BPM data acquisition modules were designed, built and installed in the Linac and the 400 MeV beam line.

Additionally there are 5 BPM's (10 positions , horizontal and vertical) that are important for seeing the beam position as it is injected into the Booster at Booster period 1. Since these BPMs are used to measure beam position at both injection, when the beam has a 200 MHz structure, and during the Booster acceleration cycle when the structure of the beam sweeps in frequency from 37.9 MHz to 52.8 MHz, the detector signals are split and routed to both the 200 MHz Linac style BPM Modules and the Booster RF Modules.

Figure II.1 shows the approximate location of the BPM's in the 400 MeV beam line. Figure II.2 shows the approximate location of the Booster injection BPM's. There are many more components such as magnets and vacuum pumps not included in the diagrams.

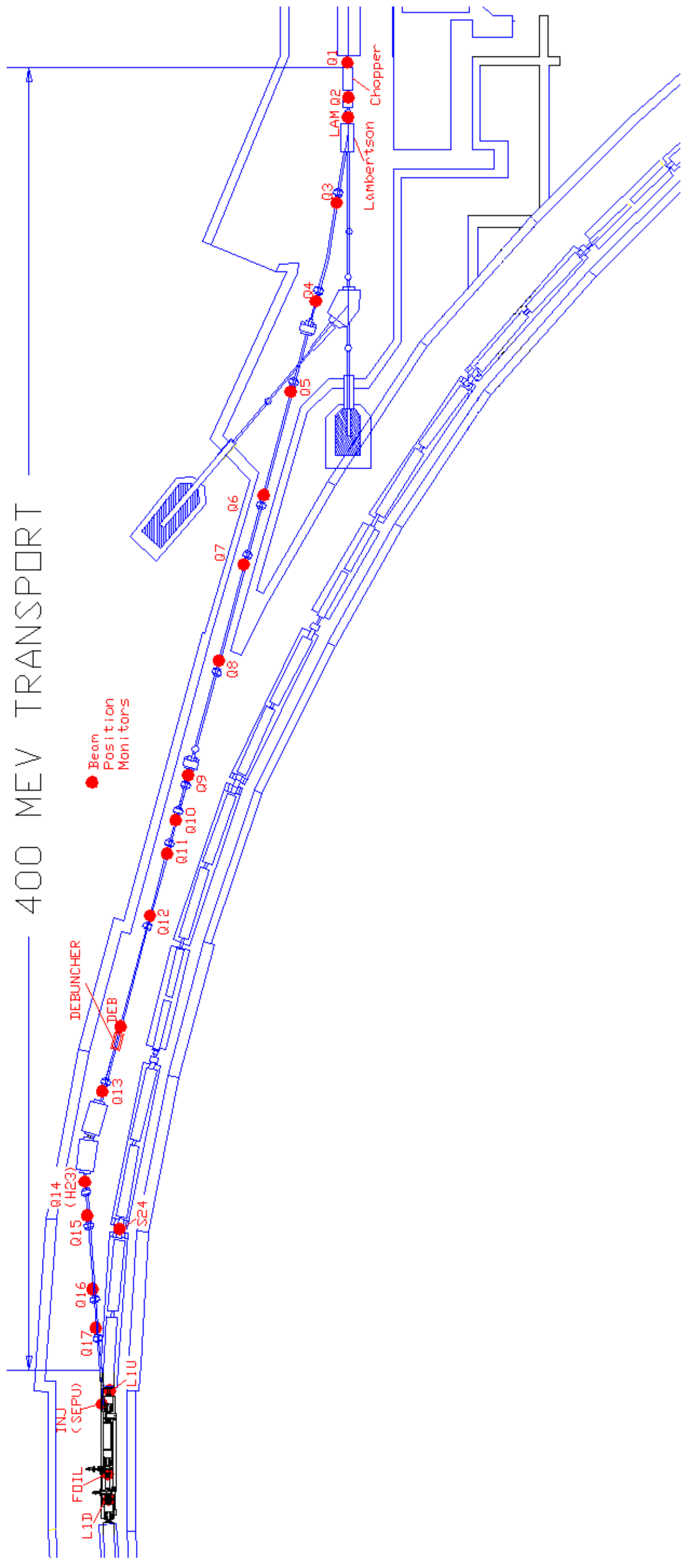

Figure II.1 400 MeV beam line BPM’s

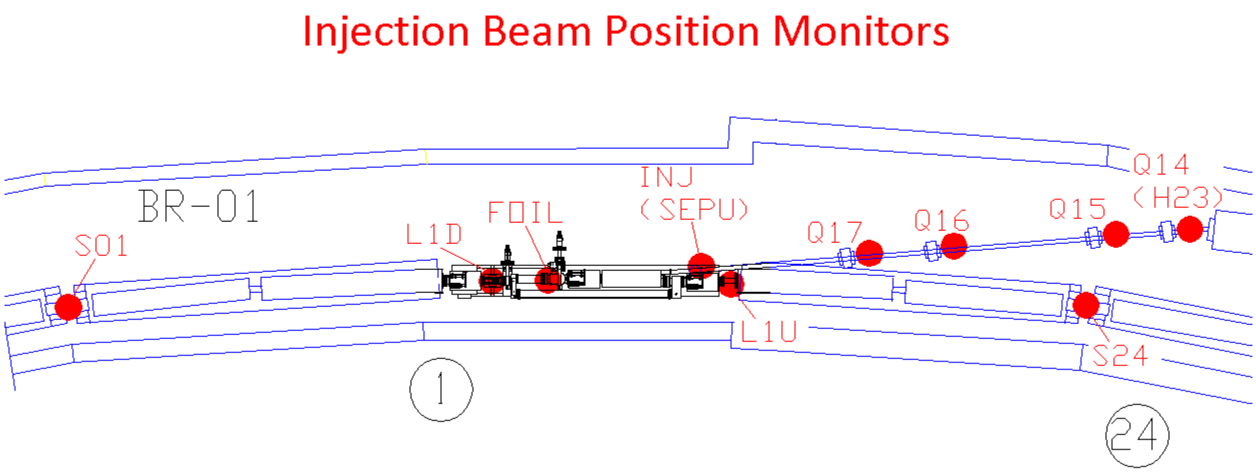

Figure II.2 Booster Injection BPM's

III. Chopper Control and Timing

The timing that controls the Chopper magnets described in Section I. is implemented with a set of modules in racks LG1-RR4-2 in the West Booster Gallery. There are four CAMAC modules that provide operator control of timing pulse inputs and delay variable settings. There is an FPGA programmable logic circuit housed in a NIM module that takes the CAMAC inputs and the Booster RF reference clock, and generates the chopper control signals.

The block diagram in Figure III.1 shows how the logic in the Chopper Controller is laid out. A timing diagram is given in Figure III.2.

The Chop On input signal is synchronized to the Booster RF and then applied to 3 delay timers to produce 3 delayed chopper on signals.

1. **CHOP ON SYNC:** This is the reference for deriving the BPM gates and sampling clock.
2. **DELAYED CHOP ON:** This is the reference for deriving CHOP OFF MEV (400 MeV Chop Off).
3. **CHOP ON KEV:** This is the reference for deriving CHOP OFF KEV (750 keV Chop Off).

Several outputs of this module had controlled the gating and sampling of an older BPM data acquisition system. These signals are greyed-out in the figures.

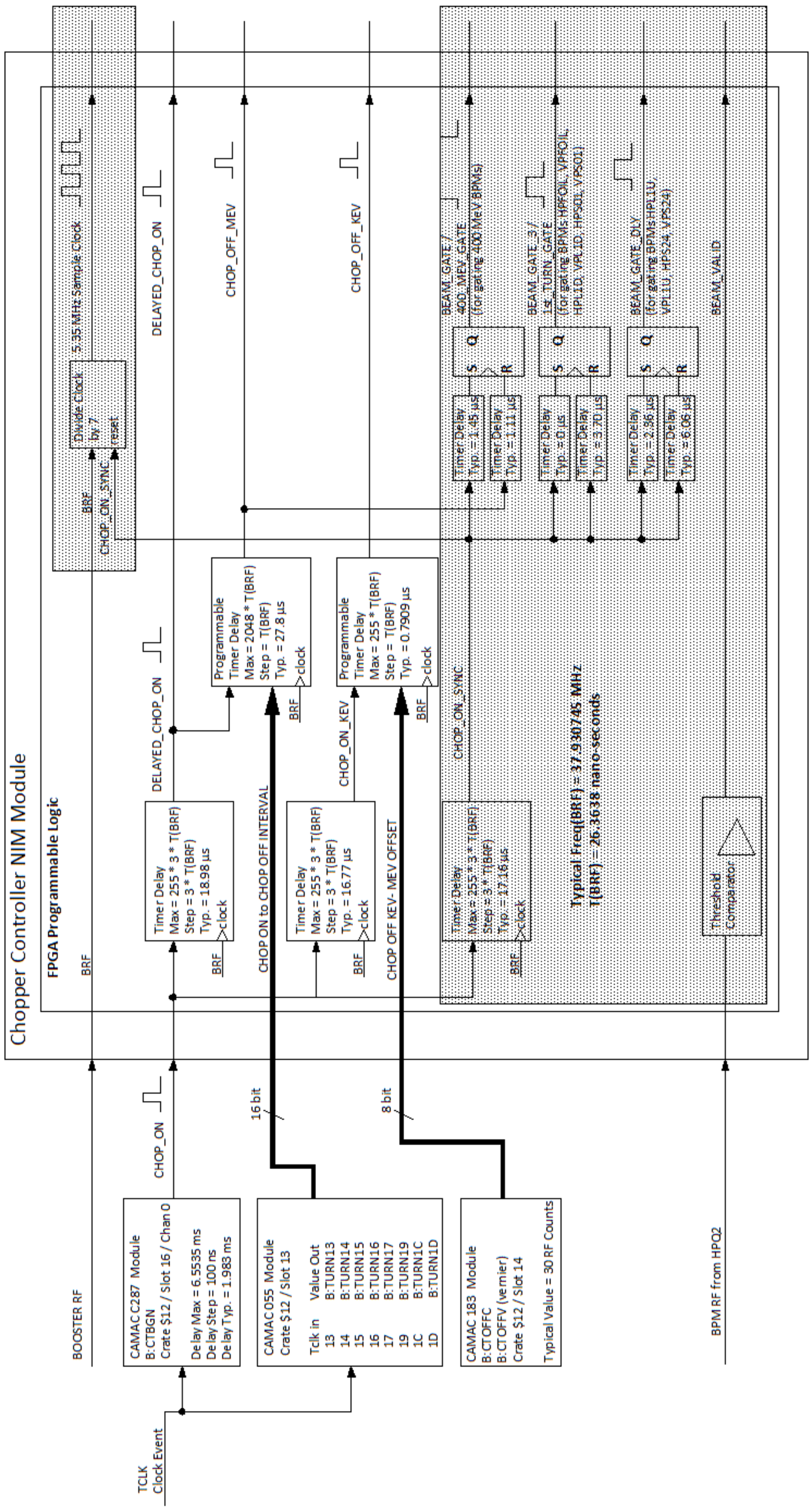

Figure III.1 Block Diagram of the generation of the Chopper control and BPM gating signals

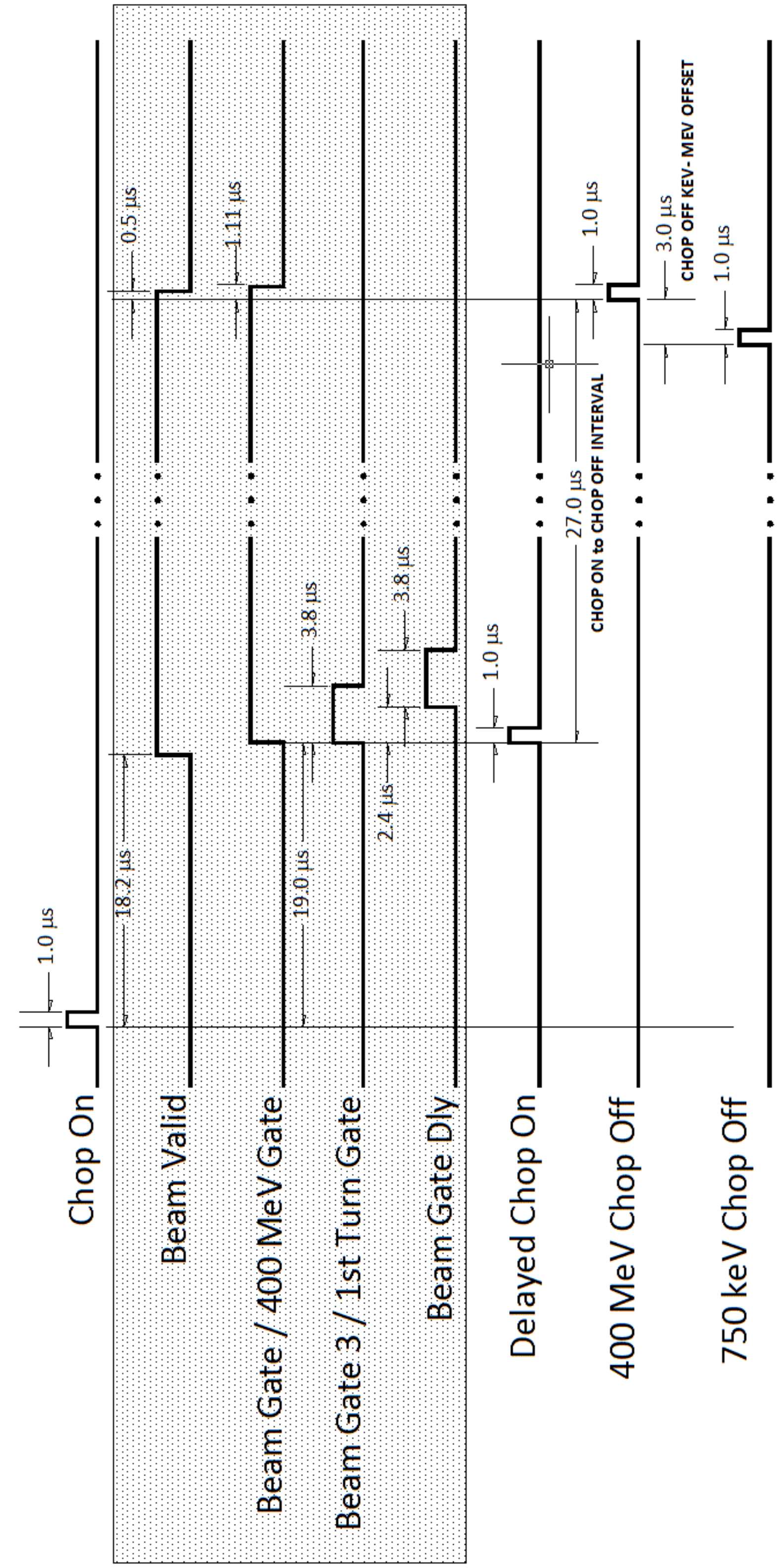

Figure III.2 Timing Diagram of the Chopper control and BPM gating signals

IV. Injection BPM Position Gating and Sampling

When the 200 MHz beam BPM measurements were switched over to the newer Linac style BPM modules, the method of gating the data acquisition changed. Previously, the gating of 400 MeV and 1st Turn Booster Injection BPM's was controlled by the same NIM FPGA module as is still used for the control of the Chopper.

The new 200 MHz Linac style BPM modules receive a TClk signal to which they add an adjusted delay, after which the modules are "armed" and monitoring the beam intensity measured with the BPM detector signals and gate acquisition once the beam intensity is determined to be above a set threshold.

Reference Linac BPM Documentation

DWG 173813 etc.

V. Booster BPM Basics

The Booster is a 75 meter radius rapid cycling synchrotron which accelerates protons from 400 MeV to 8 GeV in approximately 33 ms. The machine lattice is divided into 24 identical periods consisting of an initial "long" straight section followed by the first pair of combined function magnets, a "short" straight section followed by a second pair of combined function magnets. At the upstream end of each pair of combined function magnets there is a Beam Position Monitor detector (BPM). Each BPM provides a measurement of both the horizontal and vertical position of the beam relative to the center of the detector. In summary, there is a horizontal and vertical position measurement at each long and short straight, at each of the 24 periods.

The Booster synchrotron is designed to accelerate the beam with the accelerating RF frequency sweeping from approximately 37.0 MHz to 52.8 MHz and a harmonic number, h = 84. This means a couple things for the BPM measurement. First, the harmonic number of 84 means that the revolution period will be 84 times the RF period throughout the cycle. This fact is used to time the digitizing of the BPM position voltages as explained in a later section.

Second, the RF demodulation of the signals from the BPM detector plates must be accomplished over the 37.0 MHz to 52.8 MHz range. This demodulation is accomplished by generating a frequency offset local oscillator signal along with the Booster RF signal generation. This local oscillator signal is used to mix down the BPM detector signals to a common IF, intermediate frequency used in the RF Modules that derive the position voltages from the BPM detector signals.

There are three signals that are distributed around the Booster gallery to the racks where the BPM positions are processed and digitized. These are the local oscillator signal (BPM LO), the Booster accelerating RF reference signal, and a trigger to begin position sampling, timed with respect to the arrival of the injection of beam into the Booster.

VI. Booster BPM Turn by Turn Gating and Sampling

During the Booster acceleration cycle, beam position voltages are digitized by 4 channel VME modules. Digitization is controlled by a common external gate signal and sampling triggers (in groups of 4). There are several objectives in acquiring the BPM position measurements. First, it is desired to record a position from each vertical and horizontal BPM on each revolution of the beam, each turn. The second objective is for every BPM around the Booster to measure the position of the same portion of the circulating beam. These objectives are achieved with the management of the sampling triggers generated by the Daughter Trigger Generator chassis (DTG). The term “Daughter” refers back to a previous data acquisition system whose digitizing circuits were daughter boards that plug onto a larger module. A single DTG chassis can generate triggers for as many as 6 BPM horizontal and vertical position pairs. That is, one for every 12 BPM positions to be digitized.

The DTG chassis implements a counting function and three distinct trigger delay functions. The counting circuit counts the Booster RF cycles and initiates a sample trigger every 84. This trigger is delayed by a second set of counters that also counts RF cycles to compensate for the beam transit time between BPMs serviced in this location of the Booster gallery. Note that the transit time changes through the Booster cycle as the RF frequency changes. The number of RF cycles the sample triggers are delayed is set by switches in the DTG chassis and is settable between 0 and 7.

Additionally there is a jumper settable fixed delay that is meant to compensate for the differences in cable lengths between the RF Modulator electronics upstairs and each BPM detector in the tunnel. This delay is set according to the difference in cable delay for the particular BPM and the shortest cable delay in the group. This fixed delay is settable between 0 and 200 ns.

The third signal delay function in the DTG chassis is used to time the start of the 84 cycle count. This delay is settable between 200 and 3200 ns, in steps of 40 ns. This delay is used in conjunction with the delay of the cabling that distributes the beam injection sync pulse to the racks around the Booster gallery. It is the timing of this start trigger that anchors the other individual channel delays to accomplish the objective of having the position measurement of every BPM recorded for the same portion of the circulating beam.

The circuit schematic for the Daughter Trigger Generator is drawing number 0803-ED-21837 Rev. B, July 31, 1991. A simplified block diagram is given in Figure V.1.

Note at this point that the 4 channel VME digitizers have one external sample trigger input that controls the sampling of all 4 position voltage inputs. Hence only every other sample trigger output of the DTG chassis is employed.

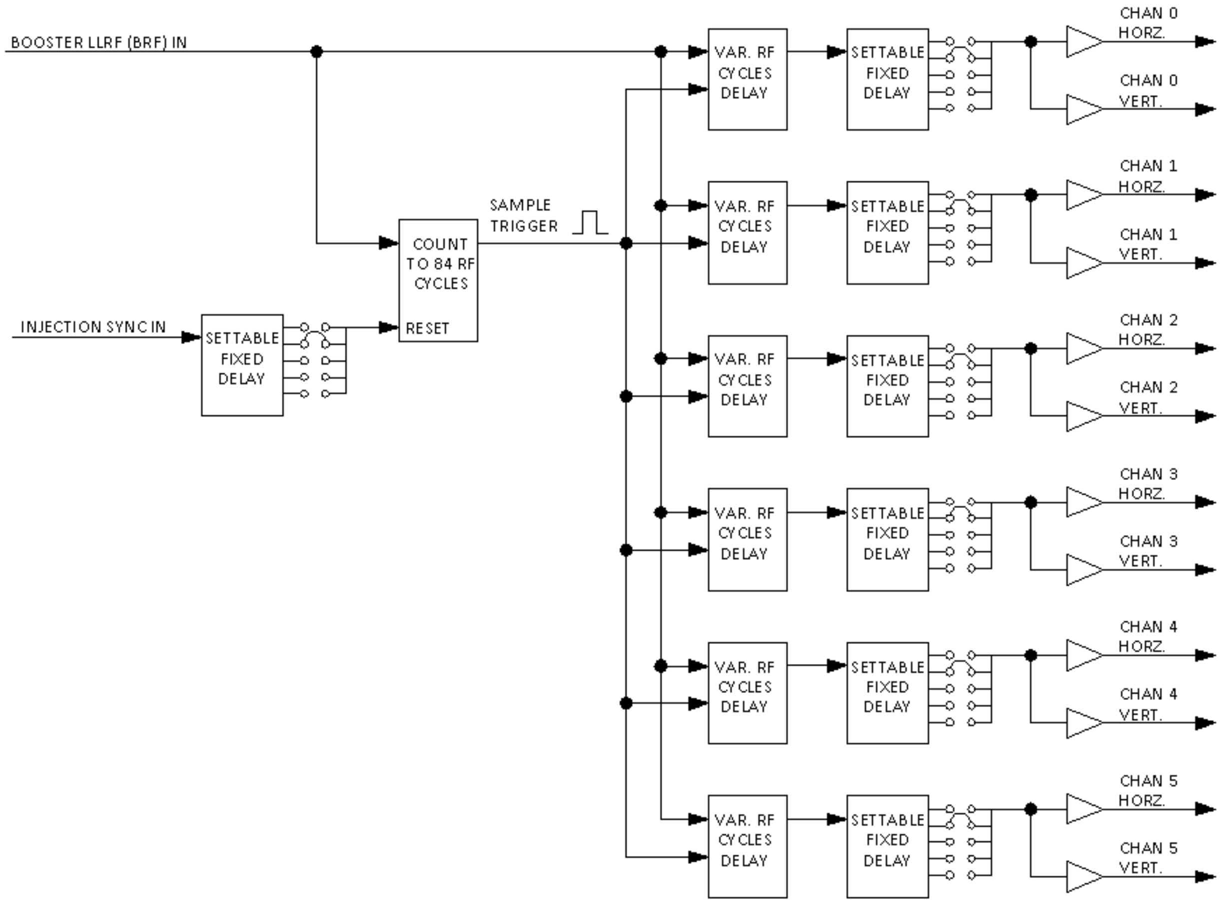

Figure V.1 Simplified block diagram of the Daughter Trigger Generator chassis.

VII. BPM Cabling and Signal Distribution

As mentioned, there are three signals that are distributed around the Booster gallery to the racks where the BPM positions are processed and digitized. These are the local oscillator signal (BPM LO), the Booster accelerating RF reference signal, and a trigger to begin position sampling that is timed with respect to the arrival of the injection of beam into the Booster.

The Booster Low-Level RF reference and the frequency offset BPM local oscillator signal (BPM LO) are generated by the "Digital Frequency Source" VXI module in the Low Level RF room in the East Booster gallery. The naming of the RF reference signal has several aliases since the Booster has evolved over several decades. The names LLRF, BRF, VCO all refer to the Low Level RF reference and will be found on different cable labels, schematics and equipment inputs and outputs.

Figure VI.1 illustrates the routing of the Booster RF reference between the racks in the East and West Booster galleries. Since the RF frequency sweeps it is important to deliver the RF reference signals to each rack with equal phase delay. Loops of cable in each rack are sized to provide the same amount of cable delay for each signal. In the racks there are two functions that use the RF reference as an input. These are the Daughter Trigger Generators that count the RF cycles, and the BPM Test interface Modules used to periodically verifying the calibration of the RF Modules and the BPM Digitizers.

Figure VI.2 illustrates the routing of the BPM local oscillator signal used in the BPM detector signal demodulation in the RF Modules. As seen in the diagram, the BPM LO signals are amplified and then distributed to the RF Modules through special cabling withn the NIM crates and through the NIM module power connection.

Figure VI.3 illustrates the distribution of the Injection Sync signal. The Injection Sync signals are actually copies of the Delayed Chop On signal which switches beam from the LINAC, into the 400 MeV line and into the Booster. The Injection Sync signal is used by the Daughter Trigger Generators, as described earlier, to synchronize the turn by turn sampling of the position voltages. The Injection Sync signal is also used as the start pulse for the Booster Beam Present Gate signal that is applied to the front panel “Ext. Gate” input to the VME digitizer cards.

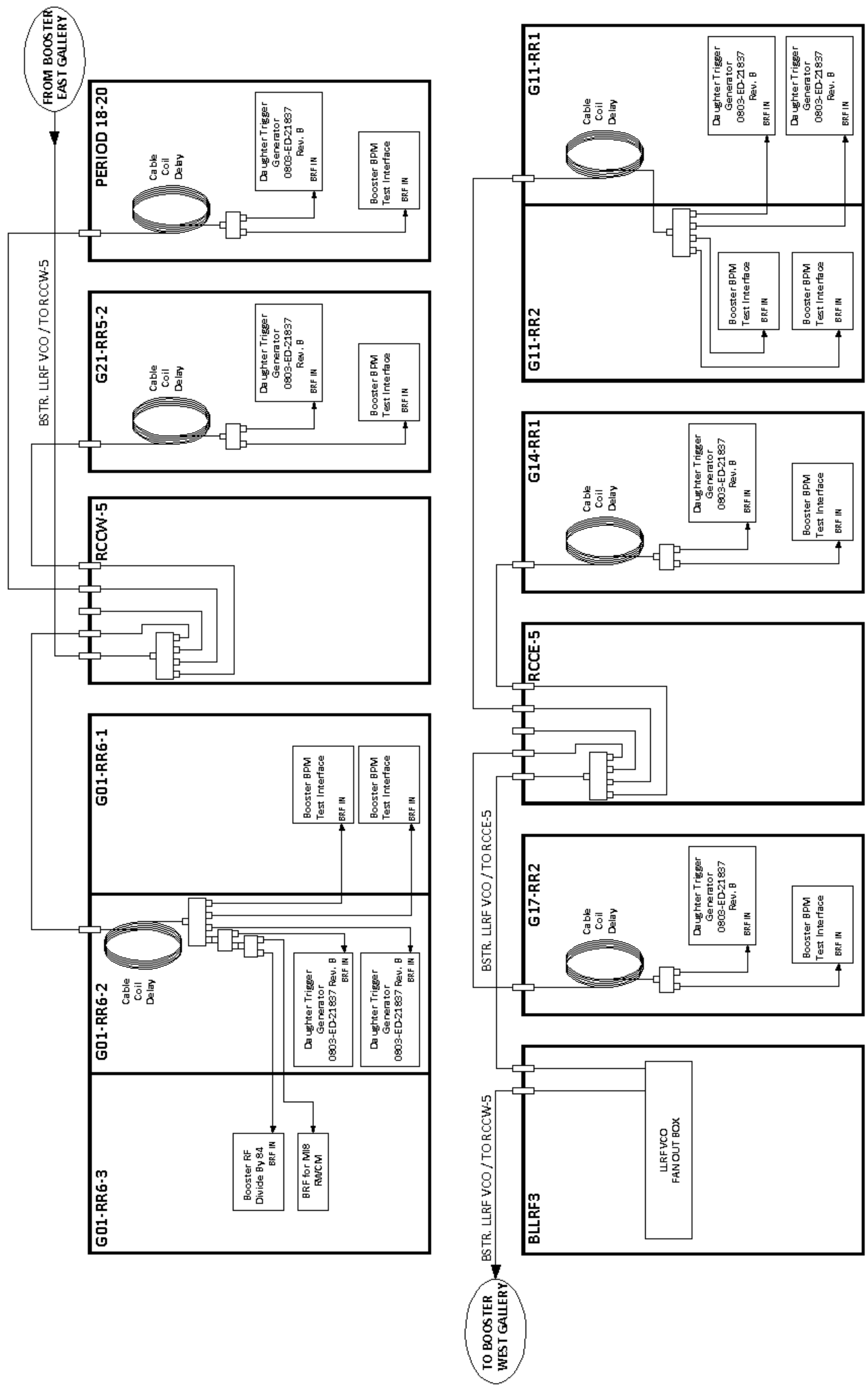

Figure VI.1 Illustration of the routing of the Booster RF Reference signal.

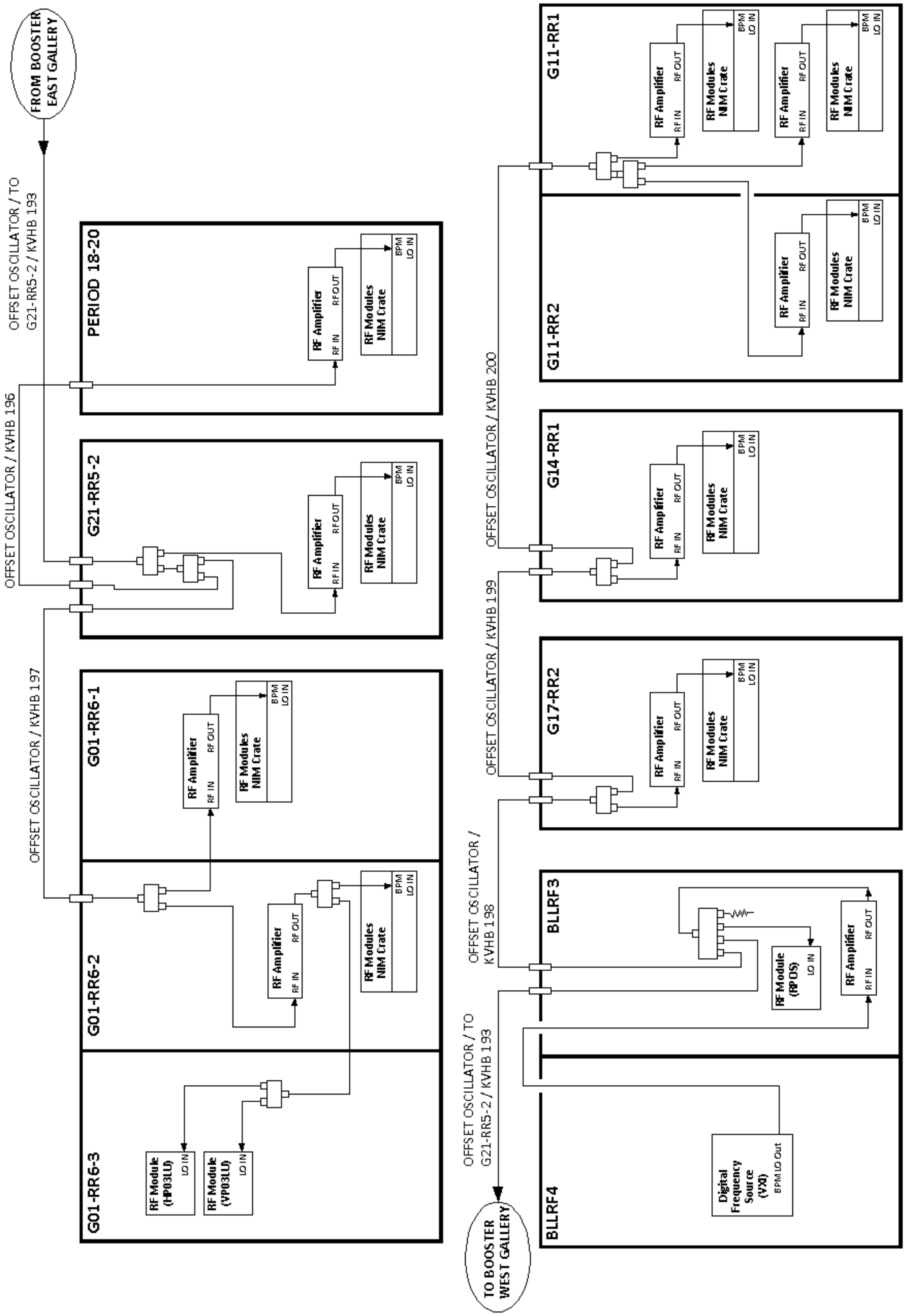

Figure VI.2 Illustration of the BPM local oscillator distribution

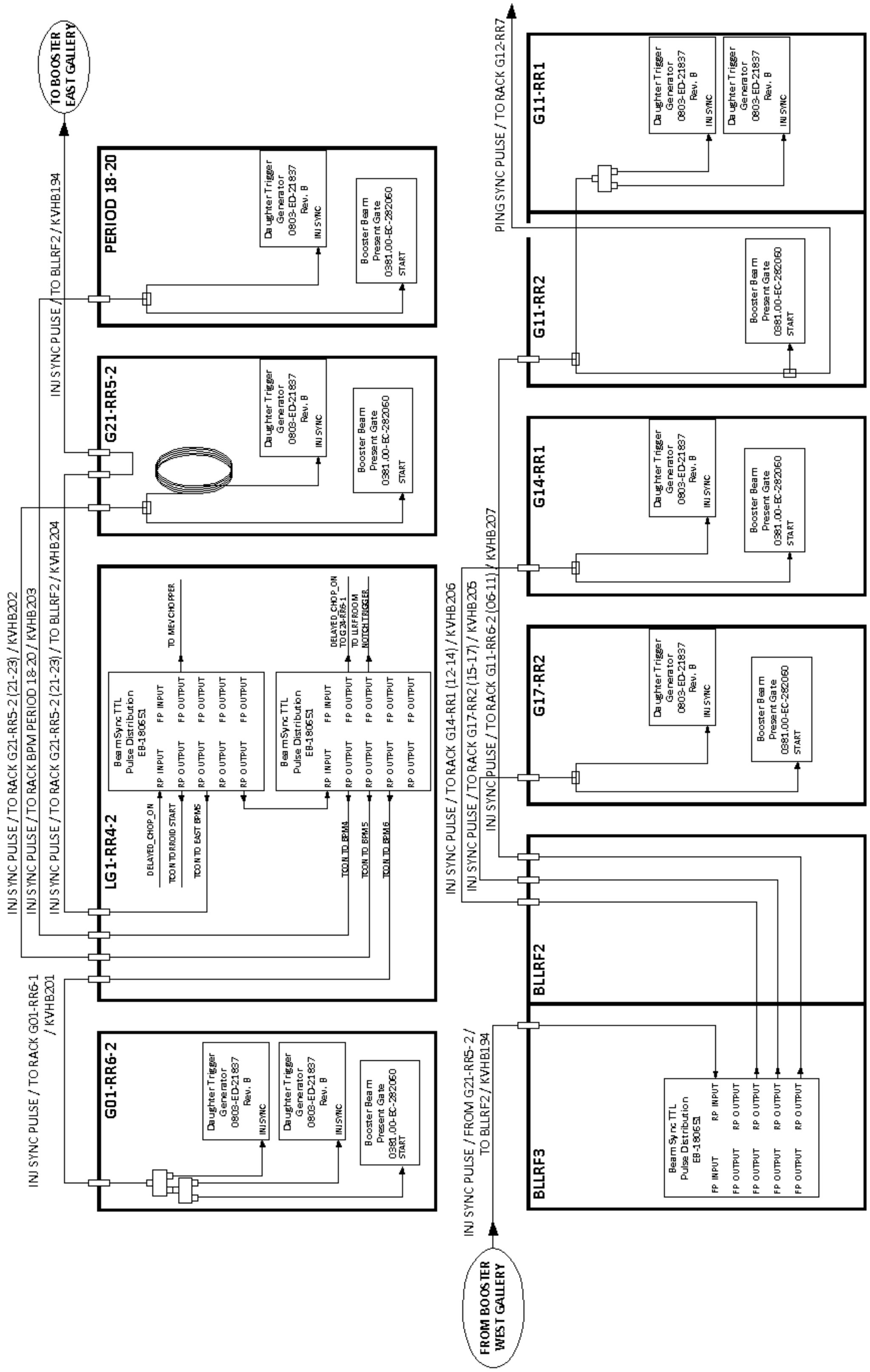

Figure VI.3 Illustration of the Injection Sync trigger distribution

Appendix A: Booster BPM Cable Listing

Table A.1 BPM Cable Listing

BPM	Plate	Channel	KVBH #	Location	Posted Cable Length, ns
H1	IN	A	185	L24	271.1
H1	OUT	B	186	L24	
V1	BOTTOM	A	187	L24	272.4
V1	TOP	B	188	L24	
H2	IN	A	189	S24	241.5
H2	OUT	B	190	S24	
V2	BOTTOM	A	191	S24	242.1
V2	TOP	B	192	S24	
H3	IN	A	001	L1	210.7
H3	OUT	B	002	L1	
V3	BOTTOM	A	003	L1	212.3
V3	TOP	B	004	L1	
H4	IN	A	005	S1	164.8
H4	OUT	B	006	S1	
V4	BOTTOM	A	007	S1	165.4
V4	TOP	B	008	S1	
H5	IN	A	009	L2	109.5
H5	OUT	B	010	L2	
V5	BOTTOM	A	011	L2	109.5
V5	TOP	B	012	L2	
H6	IN	A	013	S2	80.2
H6	OUT	B	014	S2	
V6	BOTTOM	A	015	S2	80.7
V6	TOP	B	016	S2	
H1	IN	A	017	L03	115.9
H1	OUT	B	018	L03	
V1	BOTTOM	A	019	L03	114.9
V1	TOP	B	020	L03	
H2	IN	A	021	S03	146.9
H2	OUT	B	022	S03	
V2	BOTTOM	A	023	S03	146.1
V2	TOP	B	024	S03	
H3	IN	A	025	L04	197.9
H3	OUT	B	026	L04	
V3	BOTTOM	A	027	L04	197.9
V3	TOP	B	028	L04	

H4	IN	A	029	S04	224.4
H4	OUT	B	030	S04	
V4	BOTTOM	A	031	S04	224.4
V4	TOP	B	032	S04	
H5	IN	A	033	L05	273.9
H5	OUT	B	034	L05	
V5	BOTTOM	A	035	L05	272.0
V5	TOP	B	036	L05	
H6	IN	A	037	S05	303.5
H6	OUT	B	038	S05	
V6	BOTTOM	A	039	S05	303.8
V6	TOP	B	040	S05	
H1	IN	A	041	L06	493.2
H1	OUT	B	042	L06	
V1	BOTTOM	A	043	L06	495.2
V1	TOP	B	044	L06	
H2	IN	A	045	S06	462.7
H2	OUT	B	046	S06	
V2	BOTTOM	A	047	S06	464.9
V2	TOP	B	048	S06	
H3	IN	A	049	L07	415.2
H3	OUT	B	050	L07	
V3	BOTTOM	A	051	L07	414.7
V3	TOP	B	052	L07	
H4	IN	A	053	S07	382.2
H4	OUT	B	054	S07	
V4	BOTTOM	A	055	S07	383.7
V4	TOP	B	056	S07	
H5	IN	A	057	L08	330.9
H5	OUT	B	058	L08	
V5	BOTTOM	A	059	L08	331.9
V5	TOP	B	060	L08	
H6	IN	A	061	S08	301.7
H6	OUT	B	062	S08	
V6	BOTTOM	A	063	S08	303.2
V6	TOP	B	064	S08	
H1	IN	A	065	L09	255.7
H1	OUT	B	066	L09	
V1	BOTTOM	A	067	L09	257.2
V1	TOP	B	068	L09	
H2	IN	A	069	S09	227.2
H2	OUT	B	070	S09	
V2	BOTTOM	A	071	S09	227.4

V2	TOP	B	072	S09	
H3	IN	A	073	L10	176.4
H3	OUT	B	074	L10	
V3	BOTTOM	A	075	L10	177.2
V3	TOP	B	076	L10	
H4	IN	A	077	S10	145.9
H4	OUT	B	078	S10	
V4	BOTTOM	A	079	S10	146.9
V4	TOP	B	080	S10	
H5	IN	A	081	L11	115.7
H5	OUT	B	082	L11	
V5	BOTTOM	A	083	L11	116.7
V5	TOP	B	084	L11	
H6	IN	A	085	S11	145.2
H6	OUT	B	086	S11	
V6	BOTTOM	A	087	S11	146.2
V6	TOP	B	088	S11	
H1	IN	A	089	L12	215.0
H1	OUT	B	090	L12	
V1	BOTTOM	A	091	L12	215.8
V1	TOP	B	092	L12	
H2	IN	A	093	S12	186.7
H2	OUT	B	094	S12	
V2	BOTTOM	A	095	S12	189.1
V2	TOP	B	096	S12	
H3	IN	A	097	L13	136.0
H3	OUT	B	098	L13	
V3	BOTTOM	A	099	L13	137.1
V3	TOP	B	100	L13	
H4	IN	A	101	S13	106.4
H4	OUT	B	102	S13	
V4	BOTTOM	A	103	S13	106.4
V4	TOP	B	104	S13	
H5	IN	A	105	L14	58.4
H5	OUT	B	106	L14	
V5	BOTTOM	A	107	L14	57.9
V5	TOP	B	108	L14	
H6	IN	A	109	S14	79.7
H6	OUT	B	110	S14	
V6	BOTTOM	A	111	S14	79.9
V6	TOP	B	112	S14	
H1	IN	A	113	L15	187.0
H1	OUT	B	114	L15	

V1	BOTTOM	A	115	L15	188.0
V1	TOP	B	116	L15	
H2	IN	A	117	S15	155.8
H2	OUT	B	118	S15	
V2	BOTTOM	A	119	S15	156.7
V2	TOP	B	120	S15	
H3	IN	A	121	L16	107.1
H3	OUT	B	122	L16	
V3	BOTTOM	A	123	L16	106.3
V3	TOP	B	124	L16	
H4	IN	A	125	S16	76.9
H4	OUT	B	126	S16	
V4	BOTTOM	A	127	S16	77.2
V4	TOP	B	128	S16	
H5	IN	A	129	L17	78.5
H5	OUT	B	130	L17	
V5	BOTTOM	A	131	L17	79.0
V5	TOP	B	132	L17	
H6	IN	A	133	S17	107.9
H6	OUT	B	134	S17	
V6	BOTTOM	A	135	S17	108.4
V6	TOP	B	136	S17	
H1	IN	A	137	L18	256.3
H1	OUT	B	138	L18	
V1	BOTTOM	A	139	L18	254.8
V1	TOP	B	140	L18	
H2	IN	A	141	S18	225.5
H2	OUT	B	142	S18	
V2	BOTTOM	A	143	S18	223.7
V2	TOP	B	144	S18	
H3	IN	A	145	L19	174.9
H3	OUT	B	146	L19	
V3	BOTTOM	A	147	L19	175.0
V3	TOP	B	148	L19	
H4	IN	A	149	S19	144.0
H4	OUT	B	150	S19	
V4	BOTTOM	A	151	S19	143.9
V4	TOP	B	152	S19	
H5	IN	A	153	L20	92.2
H5	OUT	B	154	L20	
V5	BOTTOM	A	155	L20	92.1
V5	TOP	B	156	L20	
H6	IN	A	157	S20	73.7

H6	OUT	B	158	S20	
V6	BOTTOM	A	159	S20	73.8
V6	TOP	B	160	S20	
H1	IN	A	161	L21	106.3
H1	OUT	B	162	L21	
V1	BOTTOM	A	163	L21	106.9
V1	TOP	B	164	L21	
H2	IN	A	165	S21	77.7
H2	OUT	B	166	S21	
V2	BOTTOM	A	167	S21	77.7
V2	TOP	B	168	S21	
H3	IN	A	169	L22	77.8
H3	OUT	B	170	L22	
V3	BOTTOM	A	171	L22	77.8
V3	TOP	B	172	L22	
H4	IN	A	173	S22	108.3
H4	OUT	B	174	S22	
V4	BOTTOM	A	175	S22	108.4
V4	TOP	B	176	S22	
H5	IN	A	177	L23	158.4
H5	OUT	B	178	L23	
V5	BOTTOM	A	179	L23	158.4
V5	TOP	B	180	L23	
H6	IN	A	181	S23	188.5
H6	OUT	B	182	S23	
V6	BOTTOM	A	183	S23	188.5
V6	TOP	B	184	S23	

Appendix B: Booster BPM Electronics Listing

VME Crate: BBPM24

Name	Period	Demod Rack #	VME alias	VME MOD	VME CHAN
HL24	24	G01-RR6-1	HP24L	0	0
VL24	24	G01-RR6-1	VP24L	0	1
HS24	24	G01-RR6-1	HP24S	0	2
VS24	24	G01-RR6-1	VP24S	0	3
HL1	1	G01-RR6-1	HP01L	1	0
VL1	1	G01-RR6-1	VP01L	1	1
HS1	1	G01-RR6-1	HP01S	1	2
VS1	1	G01-RR6-1	VP01S	1	3
HL2	2	G01-RR6-1	HP02L	2	0
VL2	2	G01-RR6-1	VP02L	2	1
HS2	2	G01-RR6-1	HP02S	2	2
VS2	2	G01-RR6-1	VP02S	2	3
HL3	3	G01-RR6-2	HP03L	3	0
VL3	3	G01-RR6-2	VP03L	3	1
HS3	3	G01-RR6-2	HP03S	3	2
VS3	3	G01-RR6-2	VP03S	3	3
HL4	4	G01-RR6-2	HP04L	4	0
VL4	4	G01-RR6-2	VP04L	4	1
HS4	4	G01-RR6-2	HP04S	4	2
VS4	4	G01-RR6-2	VP04S	4	3
HL5	5	G01-RR6-2	HP05L	5	0
VL5	5	G01-RR6-2	VP05L	5	1
HS5	5	G01-RR6-2	HP05S	5	2
VS5	5	G01-RR6-2	VP05S	5	3
HP03LU	3	G01-RR6-3	HP03LU	7	2
VP03LU	3	G01-RR6-3	VP03LU	7	3
		G01-RR6-1			
		G01-RR6-1			
		G01-RR6-1			
		G01-RR6-1			
		G01-RR6-1			
		G01-RR6-1			

VME Crate: BBPM21

Name	Period	Demod Rack #	VME alias	VME MOD	VME CHAN
HL21	21	G21-RR5-2	HP21L	0	0
VL21	21	G21-RR5-2	VP21L	0	1
HS21	21	G21-RR5-2	HP21S	0	2
VS21	21	G21-RR5-2	VP21S	0	3
HL22	21	G21-RR5-2	HP22L	1	0
VL22	21	G21-RR5-2	VP22L	1	1
HS22	21	G21-RR5-2	HP22S	1	2
VS22	21	G21-RR5-2	VP22S	1	3
HL23	21	G21-RR5-2	HP23L	2	0
VL23	21	G21-RR5-2	VP23L	2	1
HS23	21	G21-RR5-2	HP23S	2	2
VS23	21	G21-RR5-2	VP23S	2	3

VME Crate: BBPM18

Name	Period	Demod Rack #	VME alias	VME MOD	VME CHAN
HL18	18	P. 18-20 (BGW-North)	HP18L	0	0
VL18	18	P. 18-20 (BGW-North)	VP18L	0	1
HS18	18	P. 18-20 (BGW-North)	HP18S	0	2
VS18	18	P. 18-20 (BGW-North)	VP18S	0	3
HL19	18	P. 18-20 (BGW-North)	HP19L	1	0
VL19	18	P. 18-20 (BGW-North)	VP19L	1	1
HS19	18	P. 18-20 (BGW-North)	HP19S	1	2
VS19	18	P. 18-20 (BGW-North)	VP19S	1	3
HL20	18	P. 18-20 (BGW-North)	HP20L	2	0
VL20	18	P. 18-20 (BGW-North)	VP20L	2	1
HS20	18	P. 18-20 (BGW-North)	HP20S	2	2
VS20	18	P. 18-20 (BGW-North)	VP20S	2	3

VME Crate: BBPM15

Name	Period	Demod Rack #	VME alias	VME MOD	VME CHAN
HL15	17	G17-RR2	HP15L	0	0
VL15	17	G17-RR2	VP15L	0	1
HS15	17	G17-RR2	HP15S	0	2
VS15	17	G17-RR2	VP15S	0	3
HL16	17	G17-RR2	HP16L	1	0
VL16	17	G17-RR2	VP16L	1	1
HS16	17	G17-RR2	HP16S	1	2
VS16	17	G17-RR2	VP16S	1	3
HL17	17	G17-RR2	HP17L	2	0
VL17	17	G17-RR2	VP17L	2	1
HS17	17	G17-RR2	HP17S	2	2
VS17	17	G17-RR2	VP17S	2	3

VME Crate: BBPM12

Name	Period	Demod Rack #	VME alias	VME MOD	VME CHAN
HL12	14	G14-RR1	HP12L	0	0
VL12	14	G14-RR1	VP12L	0	1
HS12	14	G14-RR1	HP12S	0	2
VS12	14	G14-RR1	VP12S	0	3
HL13	14	G14-RR1	HP13L	1	0
VL13	14	G14-RR1	VP13L	1	1
HS13	14	G14-RR1	HP13S	1	2
VS13	14	G14-RR1	VP13S	1	3
HL14	14	G14-RR1	HP14L	2	0
VL14	14	G14-RR1	VP14L	2	1
HS14	14	G14-RR1	HP14S	2	2
VS14	14	G14-RR1	VP14S	2	3

VME Crate: BBPM06

Name	Period	Demod Rack #	VME alias	VME MOD	VME CHAN
HL6	11	G11-RR6-2	HP06L	0	0
VL6	11	G11-RR6-2	VP06L	0	1
HS6	11	G11-RR6-2	HP06S	0	2
VS6	11	G11-RR6-2	VP06S	0	3
HL7	11	G11-RR6-2	HP07L	1	0
VL7	11	G11-RR6-2	VP07L	1	1
HS7	11	G11-RR6-2	HP07S	1	2
VS7	11	G11-RR6-2	VP07S	1	3
HL8	11	G11-RR6-2	HP08L	2	0
VL8	11	G11-RR6-2	VP08L	2	1
HS8	11	G11-RR6-2	HP08S	2	2
VS8	11	G11-RR6-2	VP08S	2	3
HL9	11	G11-RR6-1	HP09L	3	0
VL9	11	G11-RR6-1	VP09L	3	1
HS9	11	G11-RR6-1	HP09S	3	2
VS9	11	G11-RR6-1	VP09S	3	3
HL10	11	G11-RR6-1	HP10L	4	0
VL10	11	G11-RR6-1	VP10L	4	1
HS10	11	G11-RR6-1	HP10S	4	2
VS10	11	G11-RR6-1	VP10S	4	3
HL11	11	G11-RR6-1	HP11L	5	0
VL11	11	G11-RR6-1	VP11L	5	1
HS11	11	G11-RR6-1	HP11S	5	2
VS11	11	G11-RR6-1	VP11S	5	3
HUL6	11	G11-RR6-3	HP06LU	7	0
VUL6	11	G11-RR6-3	VP06LU	7	1
HUL7	11	G11-RR6-3	HP07LU	7	2
VUL7	11	G11-RR6-3	VP07LU	7	3