DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

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Note: **CD-14**

Trajectory Measurements in the DAΦNE Transfer Line using log Amplifier

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Abstract

The diagnostic system realized to measure beam trajectory in the DAΦNE transfer line is based on BPM detection electronics using demodulating logarithmic amplifiers. The design and layout of the whole system is reported, together with measurements performed to characterize accuracy, resolution, sensitivity, dynamic range and acquisition time.

Introduction

To reconstruct the trajectory of the beam, 23 beam position monitors (BPMs) are available along the lines (TL) which interconnect Linac, Accumulator and Main Rings (Fig. 1).

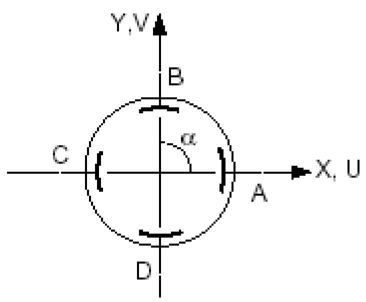
The BPMs consist of 50Ω strip-line electrodes, with 0.15 m length and 30 degrees angular width, short circuited at one end inside the vacuum chamber of 37 mm radius.

The low repetition rate, ≤50 Hz from the Linac to the Damping Ring and ≤2 Hz for the injection in the Main Rings, requires a single shot detection system to measure the beam position.

The new system replaces the former trajectory acquisition system [1] based on multiplexed track & hold circuits. The core of the present diagnostic system is built around several BERGOZ LR-BPM [2] detection boards using demodulating logarithmic amplifiers.

Log-Ratio detection electronics

In this method of detection the beam position is extracted from the ratio of signals coming from the electrodes. Since the logarithm of the ratio of two signals is equal to the difference of the logarithm, the signals can be converted by logarithmic amplifiers to give the normalized signal as the difference of the outputs.



The LR-BPM board manufactured by Bergoz Instrumentation [2], processes simultaneously the signals from the pickup electrodes (A,B,C,D) through four independent channels.

Each channel consists of an input band-pass filter, followed by an amplification chain with logarithmic response.

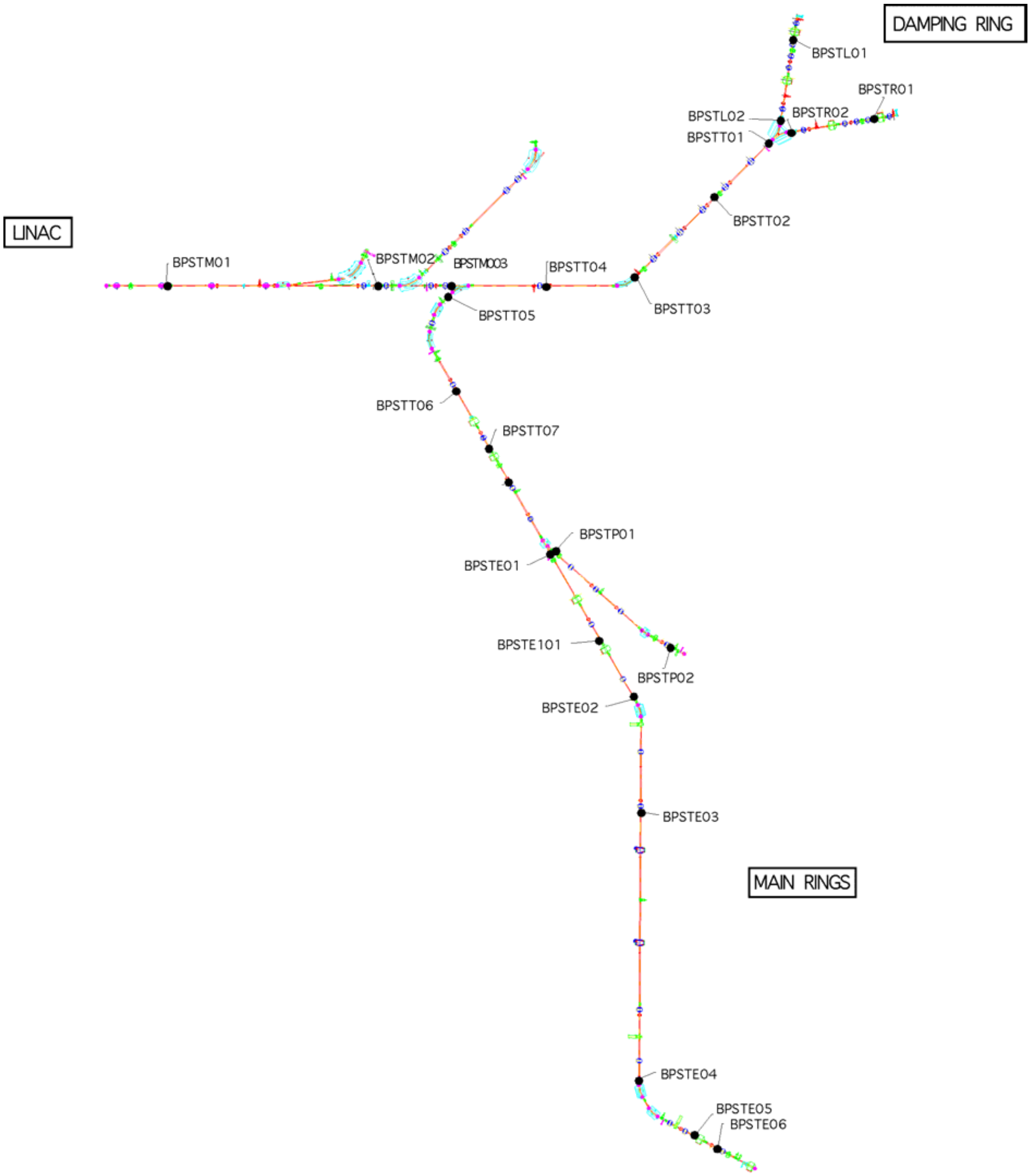


Figure 1: BPMs along the Transfer Line.

When a single short pulse is applied to the band-pass filter, it will oscillate at its own resonant frequency for about 250 ns, allowing enough time for the Analog Devices (AD8307) logarithmic amplifiers to recover the envelope of the band pass filter output.

Each amplifying chain produces a signal whose peak amplitude is proportional to the log of the input signal.

A differential amplifier produces a signal proportional to the difference of the logarithmic outputs which is equivalent to the log-ratio of the two input signals.

The two differential amplifiers output signals ($X_v.Y_v$):

$$X_v = G_x \cdot Log\left(\frac{A}{D}\right) \qquad Y_v = G_y \cdot Log\left(\frac{B}{C}\right) \tag{1}$$

are, at a first order, proportional to the beam position.

The gain $G_{x,y}$ is provided by an amplifier with adjustable gain.

Beam Position Reconstruction

Beam position (X,Y) is deduced processing the two outputs (X_v,Y_v) of the Log board, so that one can get:

$$X = K_x \cdot \frac{X_v}{G_x} \qquad Y = K_y \cdot \frac{Y_v}{G_y} \tag{2}$$

where $G_{x,y}$ are the electronic gains and Kx, Ky are characteristic of the BPM..

The K_x, K_y for the DAΦNE TL are obtained from existing calibration measurements:

K_x=20.83 mm $\qquad$ K_y=20.66 mm

At large beam offset from the center, the electrodes response to the beam position is not linear, accuracy is improved by using a non-linear fit to reconstruct beam position starting from the log ratio of the electrodes signals. In this case the maximum error in absolute beam position in the half vacuum chamber area is 0.04 mm.

Bergoz LR-BPM Board

Bench Tests

Bench measurements have been performed to characterize transfer response and resolution of the detection electronics and to calibrate the board to extend as much as possible the dynamic range for the case of the extraction branch of the TL.

A pulse generator provided to the board the input pulses with 0.75ns width and variable amplitude to simulate the beam induced signals. Beam offset has been simulated with variable attenuators to measure the characteristics function X_v vs *log(A/C)* .

The gain G, defined in Eq.(1), has been measured with the test setup in Fig. 2 and re-adjusted to extend the linear response zone of the electronics to provide a full scale output (±2Volt) for a beam offset of 20 mm, taking as reference the DAΦNE BPMs calibration measurements.

Figure 3 reports the transfer characteristic Xout vs Log(A/C) as measured on the LR-BPM.

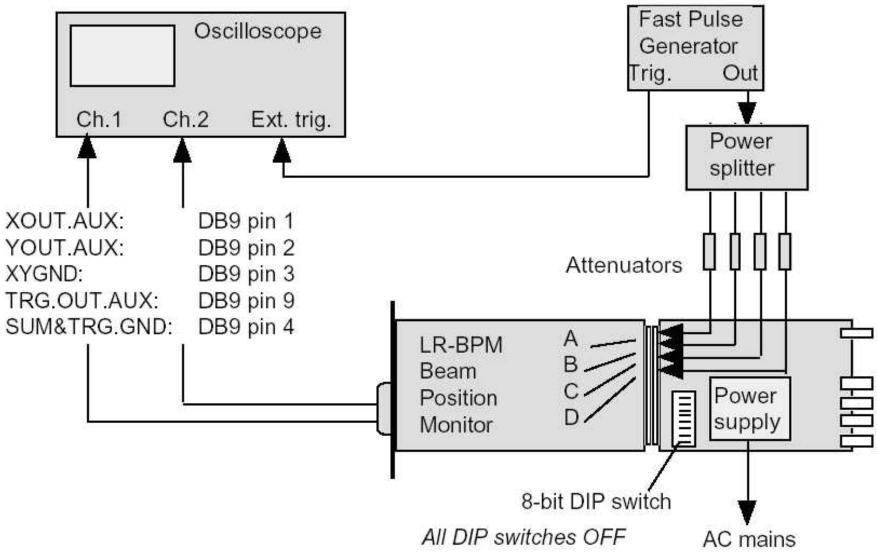


Figure 2: Test setup [2].

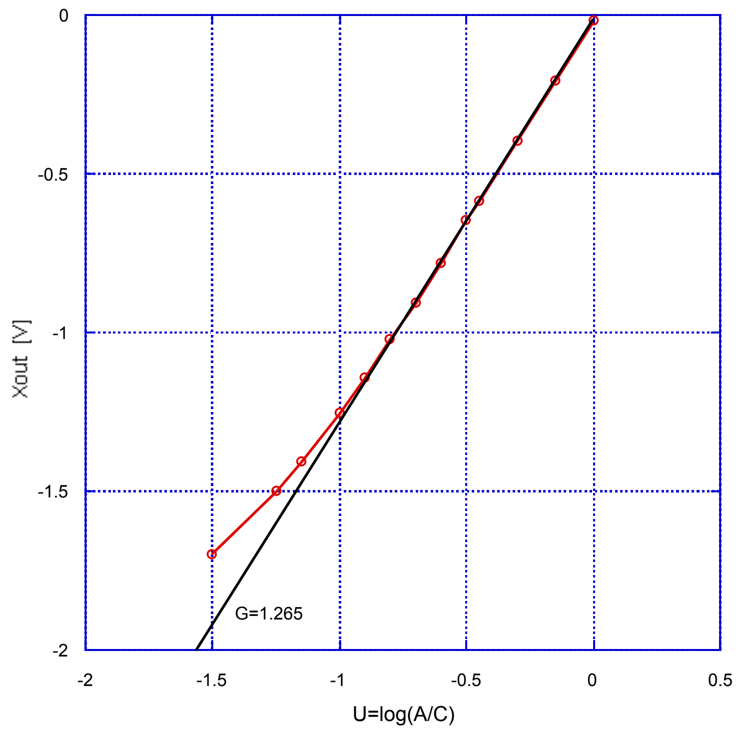


Figure 3: LR-BPM board gain.

In Fig. 4 is reported the peak to peak noise voltage introduced by the log board for different pulse amplitudes (i.e. simulating beams with different charge), in the right vertical scale the same data are converted to mm with Eq.[2], to estimate the resolution obtainable with the DAΦNE striplines.

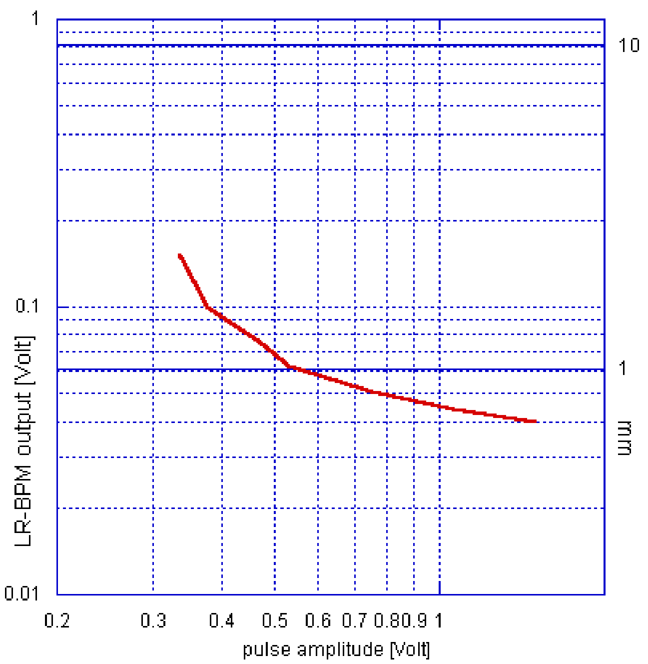


Figure 4: Noise error vs pulse amplitude.

System Layout

A total of 20 BPMs of the extraction line from the Accumulator to the Main Rings have been connected to the Bergoz boards. For the trajectory reconstruction 16 BPMs are used in the e- line while 11 BPMs in the e+ line. Eight BPMs, not common for both e+ and e-, are selected, according to the injection timing, for connection to the detection electronics through the use of RF multiplexer.

The block diagram for the complete trajectory acquisition system is reported in Fig. 5.

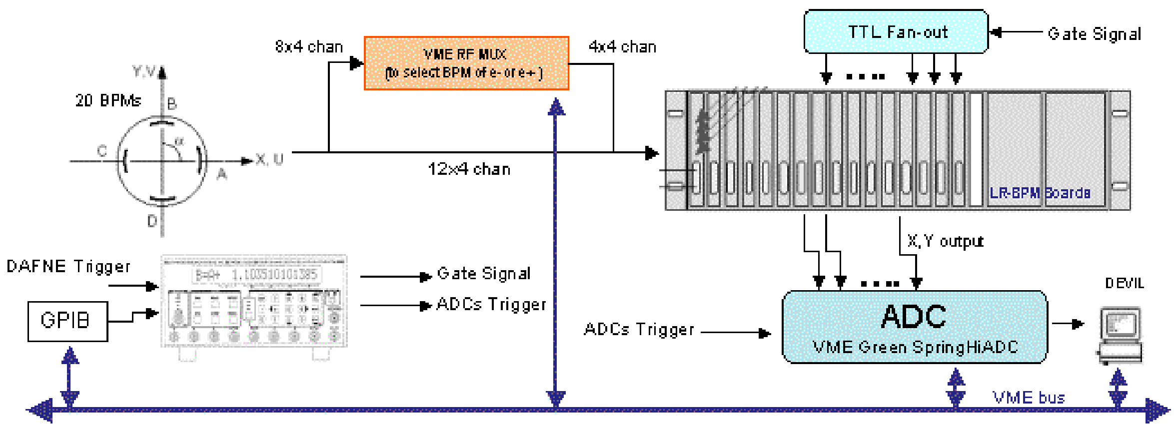


Figure 5: Block diagram of the trajectory acquisition system.

Each board is equipped with a sampling stage which allows single shot measurements.

Log ratio output of the differential amplifier are available for acquisition after 450ns from internal trigger switching through the use of a Track/Hold amplifier (SPT9101), which *holds* the signal for the subsequent ADCs stage up to 100ms (Fig. 6).

A Stanford DG535, sinchronized with the extraction trigger provided by the DAΦNE timing system, distributes triggers and TTL signals to all the logarithmic boards and the ADCs.

LR-BPM boards output signals (X_v,Y_v) must be processed to extract beam position. They are acquired by externally triggered 12 bit ADC VME multichannel boards (Green Spring mod. HiADC) for a total of 32 channels, through a dedicated LabView software running on a DEVIL CPU. The latter is also in charge of converting voltage output to beam position, controlling the DG535 with a VME GPIB board, switching the RF-MUX (HP1366 boards), and collecting data for subsequent transfer to the console level of the DAΦNE control system.

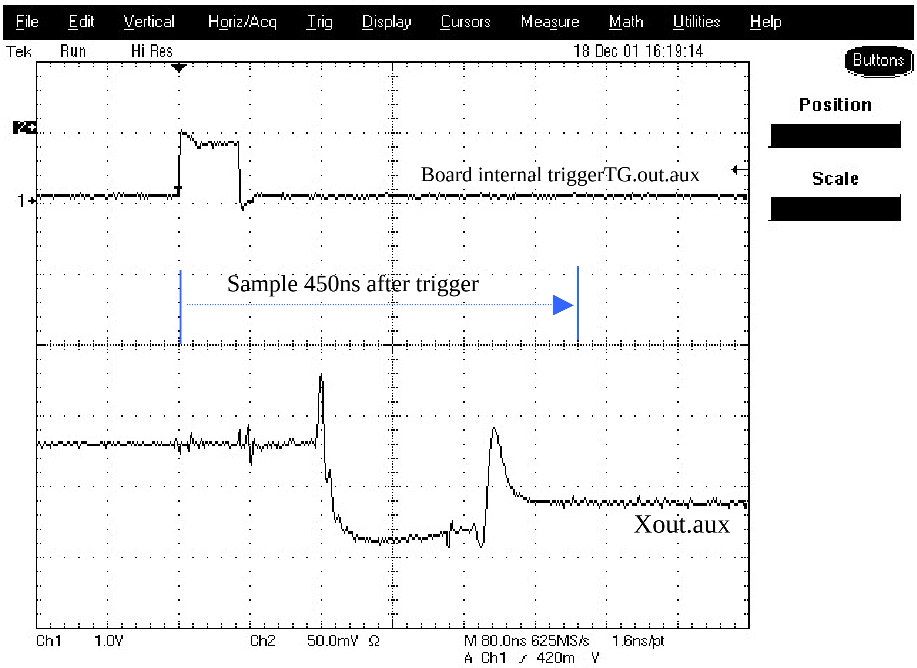


Figure 6: Typical Log board output signals

Beam Tests

Measurements refer to the beam extracted from the Damping Ring, where the bipolar pulses induced by the beam have a typical width of 1ns and maximum amplitude of 10V as seen at the end of a ≈40m long coaxial cable.

First tests with beams showed an improper behaviour later explained as due to multiple reflections of the beam signals on narrowband input impedance of LR-BPM and pickup's short circuited impedance [3]. Two solutions have been adopted to avoid this:

- the dynamic range of the beam trigger has been reduced to avoid multiple switching in correspondence of signal reflections, at the price of increasing the minimum pulse charge needed. The minimum D.R. current to lock detection electronics is now 10 mA.
- a TTL gate signal, triggered by the beam passage, has been implemented to prevent spurious switching up to the following beam passage.

Insertion of active high speed OP-Amp buffers is foreseen in order to match the impedance between BPM electrodes and the detection electronics to eliminate the cause of these reflections.

In the following pictures (Figs. 7a, 7b), beam position data are reported for two different BPMs in a typical injection sequence from the Damping ring to the Main Rings.

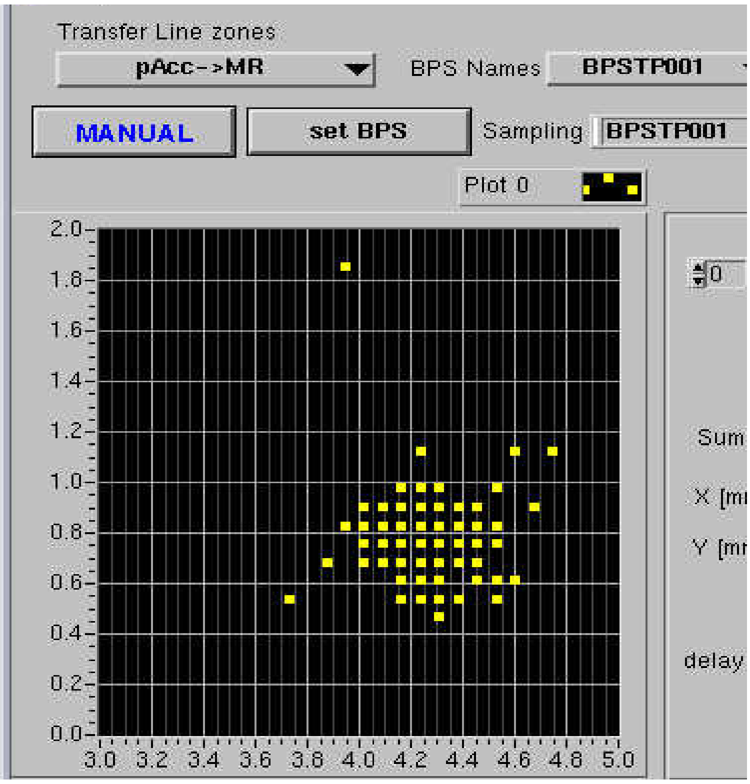


Figure 7a: Data acquisition at different beam passages for BPSTP001 (axis scale in σ_x ~ 0.20 mm, σ_y ~ 0.20 mm @ DR current I = 25 mA).

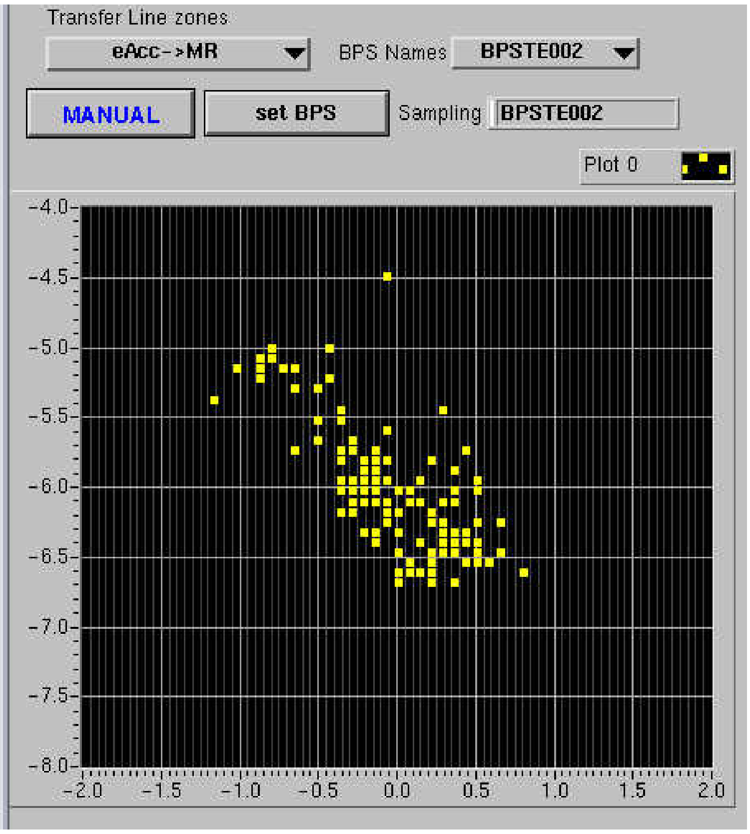


Figure 7b: Data acquisition at different beam passages for BPSTE002 (axis scale in σ_x ~ 0.25 mm, σ_y ~ 0.25 mm @ DR current I = 20 mA).

References

[1] A. Stella, C. Milardi, M. Serio: “Trajectory measurements in the DAΦNE Transfer Lines”, Proc. European Workshop On Beam Diagnostic and Instrumentation for Particle Accelerators (DIPAC 99), Chester (UK) 1999.

[2] Bergoz Instrumentation: “Log-ratio Beam Position Monitor User’s Manual Rev.2.0.2”.

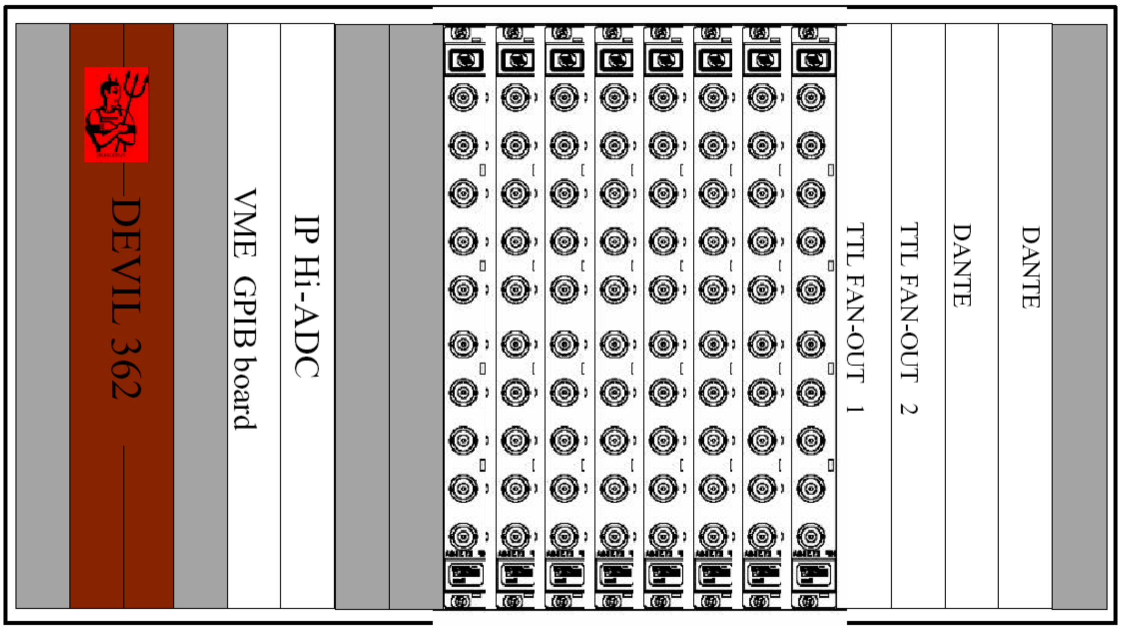
[3] A. Kalinine, Bergoz Instrumentation: private communication .

Acknowledgments

The authors would like to thank Umberto Frasacco and Donato Pellegrini for the invaluable technical support.

APPENDIX A

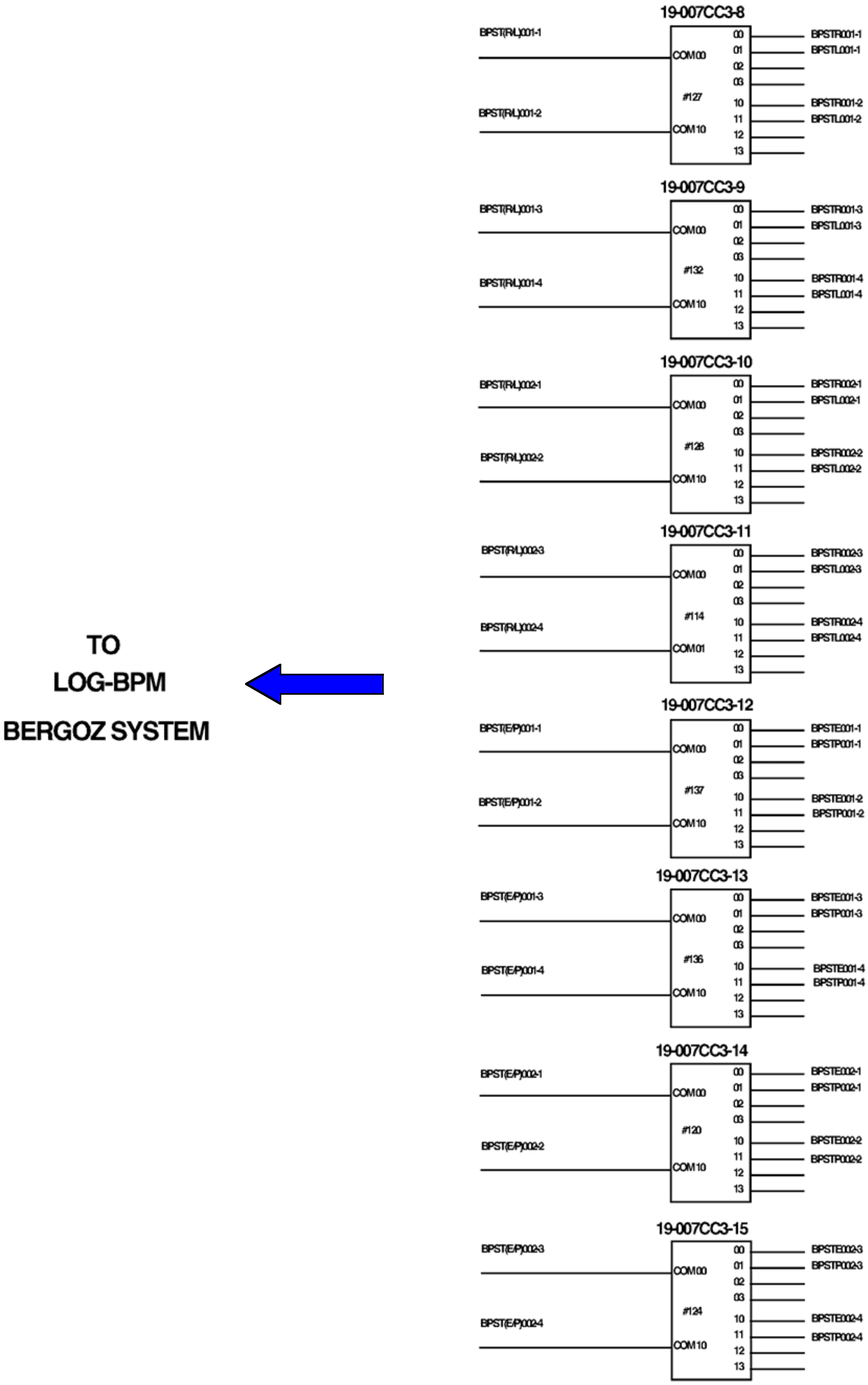
Layout of the VME crate (19-007CC3) equipped with the hardware assigned to the LR-BPM boards control and acquisition.



Board	**Type**	**Address**	
HP 1366	RF MUX	Log.Add. 127	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 132	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 128	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 114	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 137	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 136	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 120	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 124	Base Add. E3FF0000
TTL Fan-OUT			
TTL Fan-OUT			
Green Spring Hi-ADC	16 channels ADC	Base Add. E3FF6000	Slot A
Green Spring Hi-ADC	16 channels ADC	Base Add. E3FF6000	Slot B
GPIB Board	VME GPIB Board	Base Add. E3FF3000	DMA Area Add E0901000 board GPIB Add 0 device GPIB Add 15 (Stanford DG535)

Connections between VME ADC channels and LR-BPM outputs.

ADC 1 slot A	e- mode	e+ mode
Chan 1	BPS TR 001, X	BPS TL 001, X
Chan 2	BPS TR 001, Y	BPS TL 001, Y
Chan 3	BPS TR 001, X	BPS TL 001, X
Chan 4	BPS TR 001, Y	BPS TL 001, Y
Chan 5	BPB TT 001, X	
Chan 6	BPB TT 001, Y	
Chan 7	BPB TT 002, X	
Chan 8	BPB TT 002, Y	
Chan 9	BPB TT 003, X	
Chan 10	BPB TT 003, Y	
Chan 11	BPB TT 004, X	
Chan 12	BPB TT 004, Y	
Chan 13	BPB TT 005, X	
Chan 14	BPB TT 005, Y	
Chan 15	BPB TT 006, X	
Chan 16	BPB TT 006, Y	
ADC 2 slot B	**e- mode**	**e+ mode**
Chan 1	BPS TT 007, X	
Chan 2	BPS TT 007, Y	
Chan 3	BPS TE 001, X	BPS TP 001, X
Chan 4	BPS TE 001, Y	BPS TP 001, Y
Chan 5	BPS TE 002, X	BPS TP 002, X
Chan 6	BPS TE 002, Y	BPS TP 002, Y
Chan 7	BPS TE 003, X	
Chan 8	BPS TE 003, Y	
Chan 9	BPS TE 004, X	
Chan 10	BPS TE 004, Y	
Chan 11	BPS TE 101, X	
Chan 12	BPS TE 101, Y	
Chan 13	BPS TE 005, X	
Chan 14	BPS TE 005, Y	
Chan 15	BPS TE 006, X	
Chan 16	BPS TE 006, Y	


TO
LOG-BPM
BERGOZ SYSTEM
19-007CC3-8
BPST(R/L)001-1
BPST(R/L)001-2
COM00
COM10
#127
00 01 02 03 10 11 12 13
BPSTR001-1
BPSTL001-1
BPSTR001-2
BPSTL001-2
19-007CC3-9
BPST(R/L)001-3
BPST(R/L)001-4
COM00
COM10
#132
00 01 02 03 10 11 12 13
BPSTR001-3
BPSTL001-3
BPSTR001-4
BPSTL001-4
19-007CC3-10
BPST(R/L)002-1
BPST(R/L)002-2
COM00
COM10
#128
00 01 02 03 10 11 12 13
BPSTR002-1
BPSTL002-1
BPSTR002-2
BPSTL002-2
19-007CC3-11
BPST(R/L)002-3
BPST(R/L)002-4
COM00
COM01
#114
00 01 02 03 10 11 12 13
BPSTR002-3
BPSTL002-3
BPSTR002-4
BPSTL002-4
19-007CC3-12
BPST(E/P)001-1
BPST(E/P)001-2
COM00
COM10
#137
00 01 02 03 10 11 12 13
BPSTE001-1
BPSTP001-1
BPSTE001-2
BPSTP001-2
19-007CC3-13
BPST(E/P)001-3
BPST(E/P)001-4
COM00
COM10
#136
00 01 02 03 10 11 12 13
BPSTE001-3
BPSTP001-3
BPSTE001-4
BPSTP001-4
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BPST(E/P)002-1
BPST(E/P)002-2
COM00
COM10
#120
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BPSTE002-1
BPSTP002-1
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BPST(E/P)002-3
BPST(E/P)002-4
COM00
COM10
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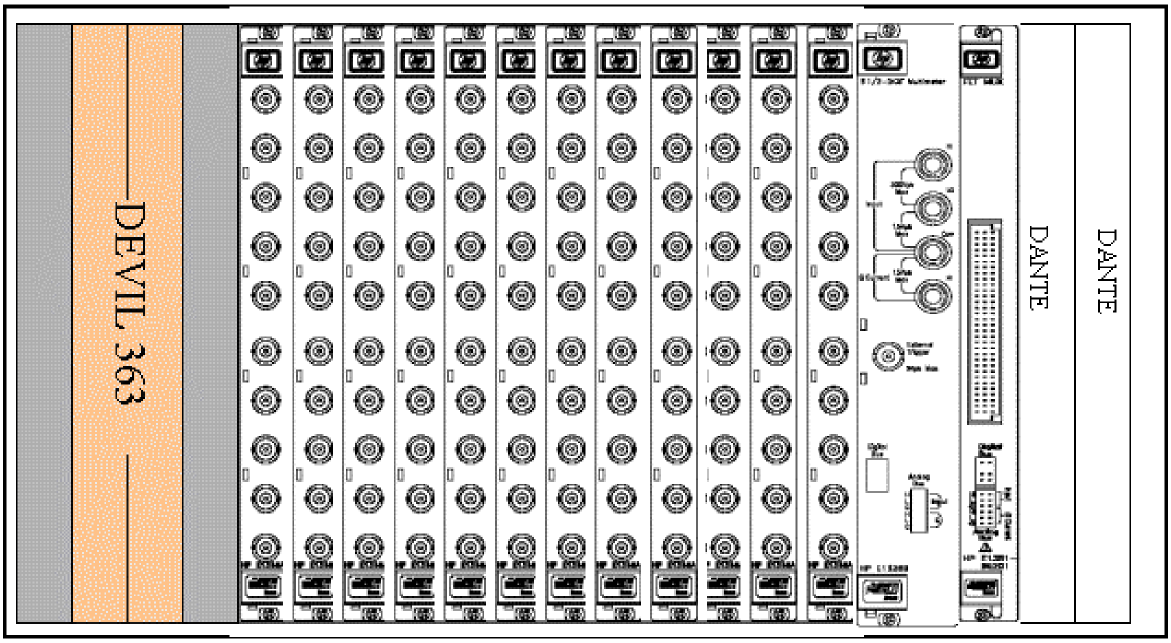
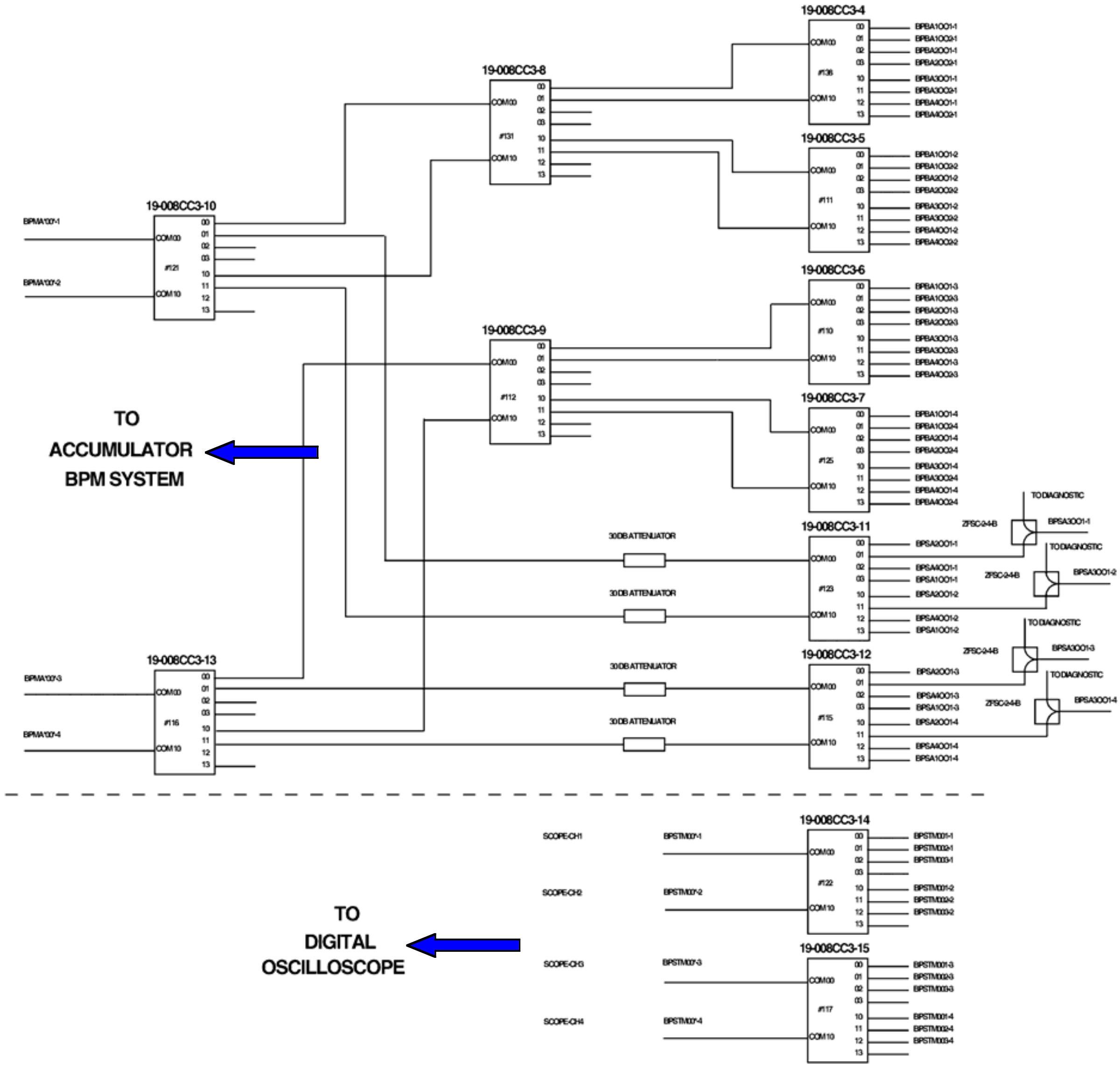
00 01 02 03 10 11 12 13
BPSTE002-3
BPSTP002-3
BPSTE002-4
BPSTP002-4

Layout of the VME crate (19-008CC3) equipped with the hardware assigned to the Damping Ring orbit acquisition system and BPMs not connected to the LR-BPM boards.



Board	Type	Address	
HP 1366	RF MUX	Log.Add. 138	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 111	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 110	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 125	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 123	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 115	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 122	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 117	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 112	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 131	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 121	Base Add. E3FF0000
HP 1366	RF MUX	Log.Add. 116	Base Add. E3FF0000
HP 1326	DVM	Log.Add. 24	Base Add. E3FFC000
HP 1351	FET MUX	Log.Add. 112	Base Add. E3FF0000


19-008CC3-4
19-008CC3-8
19-008CC3-5
19-008CC3-10
19-008CC3-6
19-008CC3-9
19-008CC3-7
TO
ACCUMULATOR
BPM SYSTEM
19-008CC3-11
19-008CC3-12
19-008CC3-13
TO DIAGNOSTIC
ZFSC-2-4-B
30DB ATTENUATOR
19-008CC3-14
19-008CC3-15
TO
DIGITAL
OSCILLOSCOPE

APPENDIX B

Dedicated Labview software, to be executed on the DEVIL cpu, has been developed to perform the low level tasks and to test all the devices installed in the diagnostic system.

- data acquisition from ADCs

Name	Path	Input	Output	Comment
DAQ_LOG.vi.vi	DFMD/DANTE/oclasses/ TRJ/CTRL	BaseAdd1 I32 BaseAdd2 I32	Error TF Voltage DBL Xmm DBL Ymm DBL	Collects Xv , Yv voltages from externally triggered ADCs , reconstruct beam position @ each BPM. Max acquisition rate is 10 Hz
ReadMultiCh_trj.vi	DFMD/DANTE/oclasses/ TRJ/CTRL	BaseAddress I32 Loop/Single TF	Error TF ReadOuts DBL Volts DBL	Reads all externally triggered ADC channels and convert data to voltage

- hardware initialization and setup recall of the devices

Name	Path	Input	Output	Comment
RESET_DG535.vi	DFMD/DANTE/oclasses/ TRJ/InitHW	GPIB1014Add Device Add	Error code CDB	DG535 initialization
INIT_DG535.vi	DFMD/DANTE/oclasses/ TRJ/InitHW	GPIB1014Add Device Add	Error code CDB	DG535 setup with proper triggering, signals level and delays
HiADC_init_trj.vi	DFMD/DANTE/oclasses/ TRJ/InitHW	Base address I32 Module Num I32 Range I16 Ext Strobe I16	Error code CDB	init ADCs: set range, external trigger, correction coefficients
SWITCH_e_p.vi	DFMD/DANTE/oclasses/ TRJ/CTRL	e-/e+ TF	Error Code CDB	Switches RF multiplexer to connect e- / e+ BPMs

- reconstruct beam position

Name	Path	Input	Output	Comment
Posizione_strip_log.vi	DFMD/DANTE/oclasses/ TRJ/CTRL	Xv DBL Yv DBL	Xmm DBL Ymm DBL	Reconstructs beam position with non linear fit . Contains BPM coefficients , board gains and offsets