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[Functional Specifications]

BDI FRONT END SOFTWARE FUNCTIONAL SPECIFICATIONS FOR THE LEIR ORBIT MEASUREMENT SYSTEM [BPNCO]

Abstract

As part of the Beam Instrumentation Software Common Tools and Interfaces project (BISCoTI) [1], this document presents and explains the LEIR Orbit Front End Software Functional Specifications defined and implemented using FESA [2] (BPNCO class) following the standard interface for beam position measurements (BdiStdPosition) [3] and the document "Guidelines and conventions for defining interfaces of equipment developed using FESA" [4].

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History of Changes

Rev. No.	*Date*	*Pages*	*Description of Changes*
1.0.0	19.08.05	All	Initial Submission
	14.09.05	12, 14, 16	Updated figure 6 "Real-time behaviour", table of PU coefficients and figure 8 "Calibration guideline".

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1. INTRODUCTION

As part of the Beam Instrumentation Software Common Tools and Interfaces project (BISCoTI) [1], this document presents and explains the LEIR Orbit Front End Software Functional Specifications defined and implemented using FESA [2] (BPNCO class).

Every BDI instrument interfaces will inherit from 'virtual' interfaces corresponding to its main measured beam observable. The considered observables are the following:

- Beam Position [3],
- Beam Intensity,
- Beam Profile,
- Beam Losses,
- Tune & Chromaticity,
- …

These virtual interfaces will themselves implement some standard custom types, properties and property fields relevant to every observable. These items will be grouped in the 'BDI standard interface' that will be inherited by every 'virtual' interface.

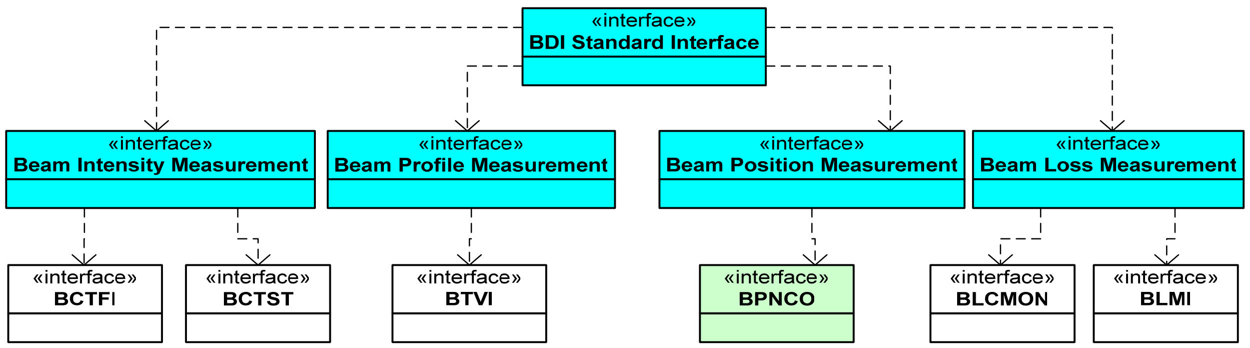

Figure 1: Inheritance Tree. Blue Boxes represent 'Virtual' interfaces. Green Box represents BPNCO interface.

The interface documentation for BPNCO class is published in "BDI Front End Software Interface for the LEIR Orbit Measurement System [BPNCO]" document.

The present document will provide:

- The instrument hardware and software responsible.
- An overview of the instrument functionality.
- An overview of the instrument timings.
- The instrument hardware layout.
- A description of its real time behaviour with respect to machine events.
- An overview of the instrument calibration.

2. COMMUNICATION PARTNERS

Inside AB/BDI:	Hardware specialists:	L Soby	LEIR HW instrument specialist.
	AB-BDI-SW:	M Ludwig D Korchagin A Guerrero	Coordination, SW instrument specialist. SW instrument specialist. BDI-SW LEIR SW coordination.
With AB/CO	AB-CO-FC:	F di Maio N de Metz-Noblat	Section leader, main entry point for feedback & problems FEC & communication related. FEC System and exploitation, infrastructure, network specialist, body, senior expert.
	AB-CO-HW:	M Vanden Eynden I Kozsar J Lewis	Section leader, low-level specialist for standard HW. CO timing implementation specialist. CO timing, exploitation, infrastructure, senior expert.
	AB-CO-AP:	M Gouber	CO applications.
With AB/OP	AB-OP:	J Wenninger	Orbit GUI.

3. FUNCTIONALITY

In LEIR 8 horizontal, 8 vertical and 8 combined (horizontal and vertical) PU are installed including the 2 PUs in the electron cooler [5]. The 2 (H+V) electrons cooler PU are included in the orbit measurement for the ions, but are also used to measure the trajectory of the electrons. Two different types of PUs are installed in the ring. 16 PUs (8H+8V) are installed inside the bending magnets and consist of 4 metalized, ceramic rectangular plates, on which diagonal cuts have been made. Eight combined horizontal and vertical cylindrical PUs are installed in the 4 straight sections and from which 2 are installed inside the electron cooler. They consist of metalized ceramic tubes on which semi-sinusoidal cuts have been made on the inside.

The beam position is digitized by the MPV908 module. The front-end software has to read the digitised values (MPV908) from the normalizer and to compute the 32 positions using scaling factors and offsets measured in the calibration mode:

$$Pos. = unitFactor \cdot \left(k \cdot (V_{Norm.} - Cal_0) + offset\right)$$

where

offset = electrical offset (a0) + mechanical offset,

Cal_0 is normalizer output voltage when LEIR Orbit is in calibration zero mode.

A control module interfaces with the control system, in order to allow remote control of clearing voltage, gains and calibrations. The following NON-PPM (non pulse-to-pulse (=cycle) modulation) controls are foreseen:

- Gain: hi (HG), medium (MG) or low (LG). The gain is chosen by the operator according to an intensity.
- Mode: beam or calibration.
- Clearing voltage (a voltage applied to each electrode per PU): ON / OFF.

There are three types of “machine cycles” to be processed:

- standard (max 3.6 seconds, 1 user is used to inject, electron cool, accelerate and eject the beam to the PS machine),
- MD (can be more than 3.6 seconds, 3 different users are combined in order to generate the “machine cycles”, which can be as long as 26 basic periods),
- no beam (one value per pickup/channel at predefined time by communication action).

Data for all types is retrieved continuously during regular acquisition with data synchronization each 0.2 seconds (20 position values per channel, 640 position values for 32 channels) and is published during a publish action at the end of a cycle. The data can be acquired without any inter-users delay by cycled continuous mode of MPV908 (PS/CO/Note98-24). If there is no beam, there is a possibility to retrieve position (noise) of all pickups at predefined time (one value per pickup/channel). The information about gain and additional conditions can be retrieved by VMOD I/O with 8 (9 in the future) acquisition bits and can be changed by 5 control bits.

Following real-time actions are implemented:

- acquire (C-train each 200 ms),
- publish.

Status bits about data processing (too small, too big) are available in the acqState (AQN_STATUS). For hardware experts LEIR orbit hardware calibration procedure is implemented.

4. TIMINGS

4.1 HARDWARE TRIGGERS AVAILABLE ON THE FRONT PANELS

User name & usage	Timing name assigned	Description	PPM	Train	Special	Timing module, channel
start_trigger	EX.STRIG-RIPU	100Hz train derived from the c-train. (ADC conversion pulse train.) Goes directly to the MPV908. It is a burst of 32 pulses separated by 10us each 10ms.	no	yes	no	7282, 1
trigger	EX.TRIG-RIPU		no	yes	no	7283, 2
end_trigger	EX.ETRIG-RIPU		no	yes	no	7284, 3

4.2 INTERRUPTS FOR REAL-TIME SOFTWARE

User name & usage	Timing name assigned	Description	PPM	Train	Special	Timing module, channel
acquire	EX.ACQ-RIPU	5Hz (200ms) train derived from the c-train.	no	yes	no	7285, 4
publish	EX.PUB-RIPU	Comes out once at the end of each cycle (not at each basic period). Generated from EX.WCY200-MTG with delay 200.	yes	no	no	7281, 5

4.3 TIMING CONDITIONED BY BEAM BUNCHING

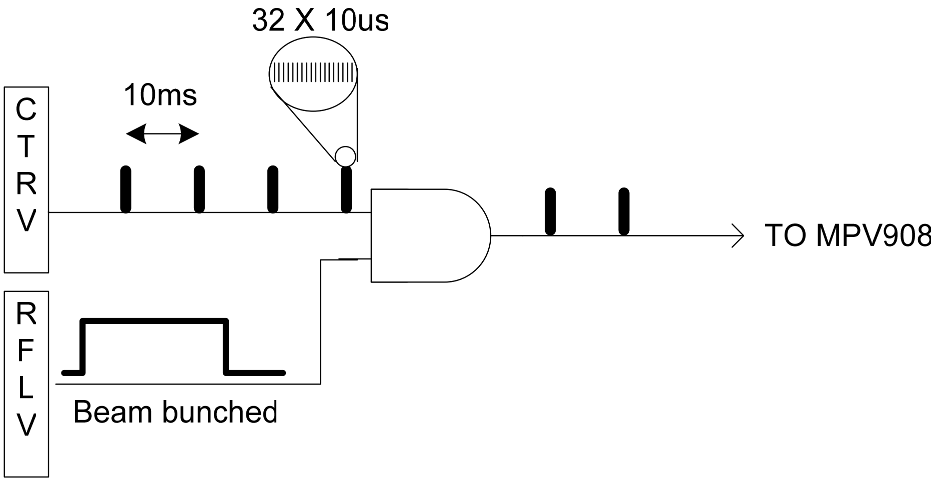

Figure 2: Timing conditioned by beam bunching.

5. FEC & HARDWARE

The instrument BPNCO is deployed on **dleiripu** in 363/R-020 RAF031 and uses following hardware modules:

- 1 x MPV908;
- 1 x VMOD TTL (8 acquisition bits & 5 control bits)
  (can be upgraded to 2 x VMOD TTL (9 acquisition bits & 5 control bits)).

The FEC **dleiripu** is also used for LEIR Q measurement.

IOCONFIG Information for **dleiripu** (from rc.local file) is showed below:

```
ln mln bus mtno module-type lu W AM DPsz basaddr1 range1 W AM DPsz basaddr2   range2
                                                                  testoff sz sl ss
 1   0 VME   76 SIS3300BASE   0 N EX DP32 30400000 400000 Y EX DP32 30000000   210000
                                                                        4  0 11 -1
 2   0 VME   90 CTRV          0 N ST DP32   c00000  10000 N SH DP16      100      100
                                                                        0  0  3 -1
 3   0 VME  186 RIO3-8064RD   0 N -- DP16        0      0 N -- ----        0        0
                                                                        0  0  1 -1
 4   1 VME   77 SIS3300CHBNK 0 Y EX DP32 30400000  20000 N -- ----        0        0
                                                                        0  0 11  0
 5   1 VME   77 SIS3300CHBNK 1 Y EX DP32 30480000  20000 N -- ----        0        0
                                                                        0  0 11  1
 6   1 VME   77 SIS3300CHBNK 2 Y EX DP32 30500000  20000 N -- ----        0        0
                                                                        0  0 11  2
 7   1 VME   77 SIS3300CHBNK 3 Y EX DP32 30580000  20000 N -- ----        0        0
                                                                        0  0 11  3
 8   1 VME   77 SIS3300CHBNK 4 Y EX DP32 30600000  20000 N -- ----        0        0
                                                                        0  0 11  4
 9   1 VME   77 SIS3300CHBNK 5 Y EX DP32 30680000  20000 N -- ----        0        0
                                                                        0  0 11  5
10   1 VME   77 SIS3300CHBNK 6 Y EX DP32 30700000  20000 N -- ----        0        0
                                                                        0  0 11  6
11   1 VME   77 SIS3300CHBNK 7 Y EX DP32 30780000  20000 N -- ----        0        0
                                                                        0  0 11  7
12   0 VME   13 VMOD-TTL      0 Y SH DP16     6000    200 N -- ----        0        0
                                                                        0  2  7  0
13   0 VME   41 VMODIO        0 N SH DP16     6000    800 N -- ----        0        0
                                                                        0  0  7 -1
14   0 VME   41 VMODIO        1 N SH DP16     6800    800 N -- ----        0        0
                                                                        0  0 13 -1
15   0 VME   41 VMODIO        2 N SH DP16     7000    800 N -- ----        0        0
                                                                        0  0 17 -1
16   0 VME    8 MPV908        0 N SH DP16     4000    100 Y ST DP16   600000    20000
                                                                        0  2  9 -1


ln sln bus mtno module-type lu evno  subaddr    A1  F1     D1     A2  F2      D2
17   2 EVT   90 CTRV          0    1     7285
```

6. HARDWARE LAYOUT AND MAPPING

6.1 HARDWARE LAYOUT

The following scheme shows layout of hardware devices:

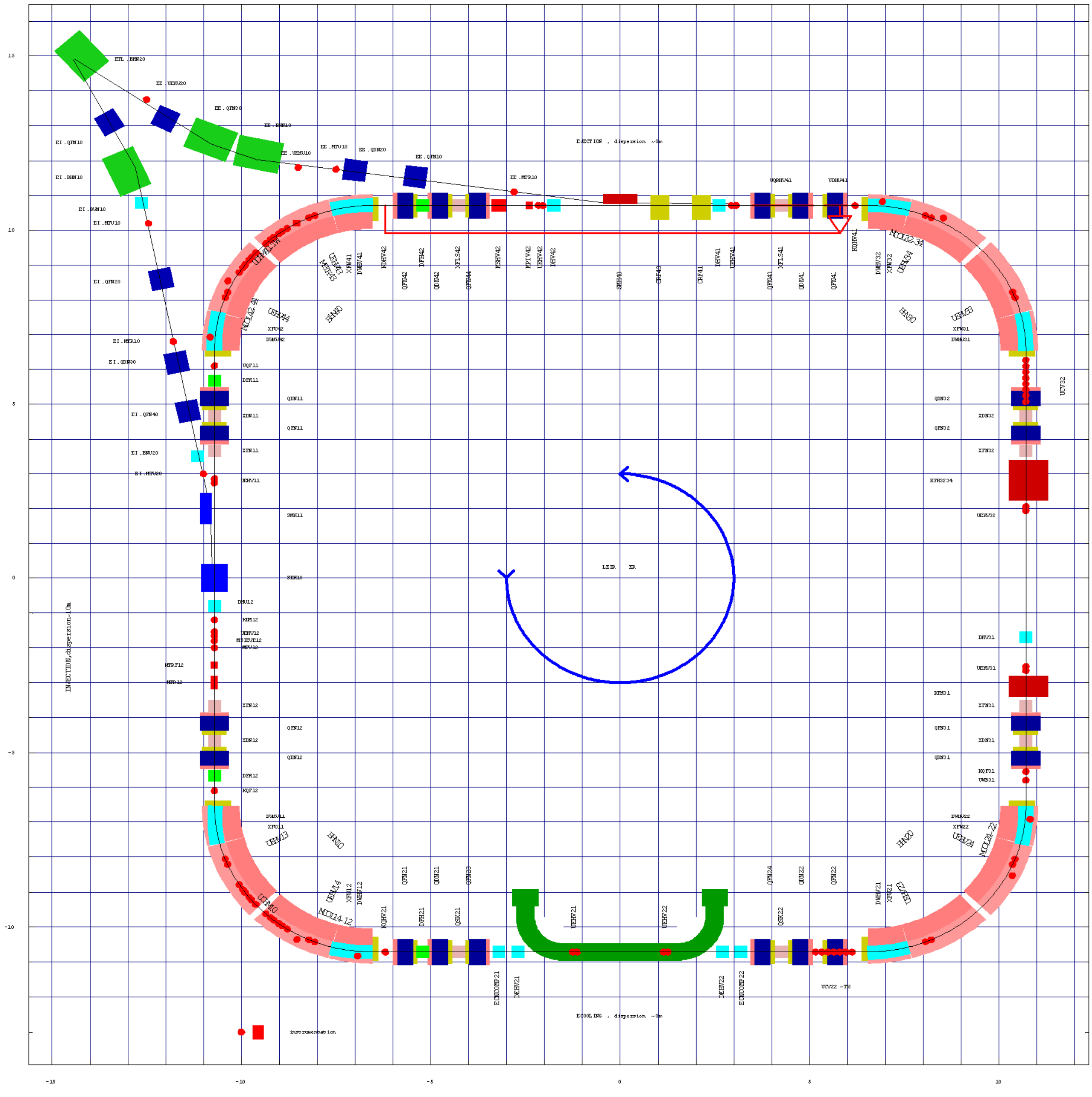

Figure 3: Hardware layout (http://chanel.home.cern.ch/chanel/leir.html).

6.2 SW DEVICE MAPPING

The following scheme shows the dependency between ADC channels, VMOD TTL and software device (PUs are connected to ADC channels as 1:1):

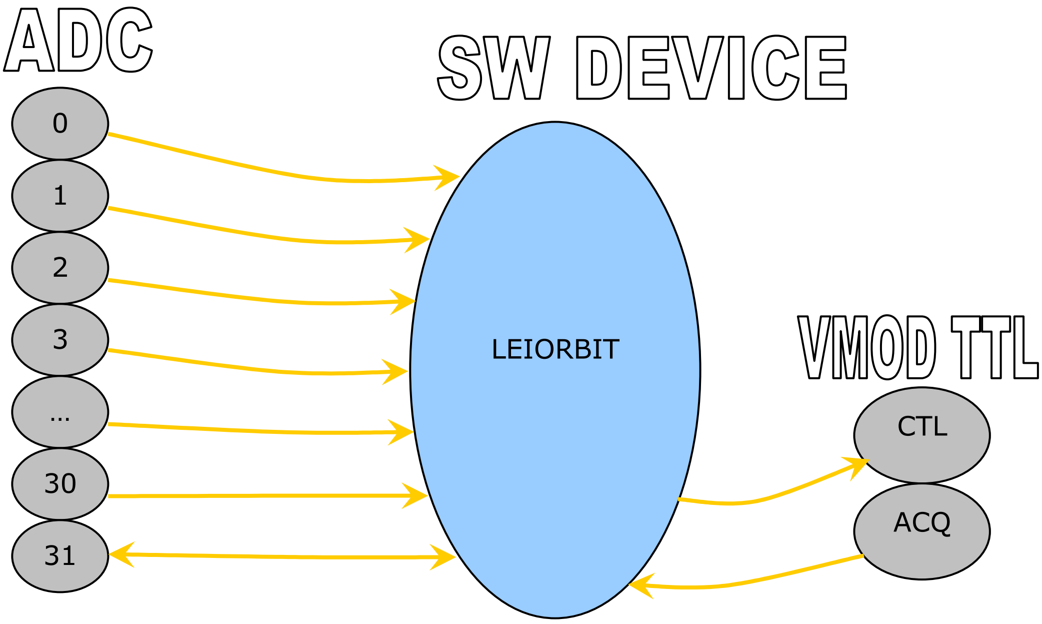

Figure 4: SW device mapping.

Channels' names corresponding to the PUs are showed in the table below:

Device name	MPV 908 Ch.	Device name	MPV 908 Ch.
ER.UEH11	1	ER.UEV11	17
ER.UEH12	2	ER.UEV12	18
ER.UEH13	3	ER.UEV13	19
ER.UEH14	4	ER.UEV14	20
ER.UEH21	5	ER.UEV21	21
ER.UEH22	6	ER.UEV22	22
ER.UEH23	7	ER.UEV23	23
ER.UEH24	8	ER.UEV24	24
ER.UEH31	9	ER.UEV31	25
ER.UEH32	10	ER.UEV32	26
ER.UEH33	11	ER.UEV33	27
ER.UEH34	12	ER.UEV34	28
ER.UEH41	13	ER.UEV41	29
ER.UEH42	14	ER.UEV42	30
ER.UEH43	15	ER.UEV43	31
ER.UEH44	16	ER.UEV44	32

7. REAL-TIME BEHAVIOUR

BPNCO Instrument publishes its result at the end of its measurement.

The ADC scanning starts automatically, when the FEC and BPNCO RT process are restarted and ADC memory is initially tagged (it is enough just tag the last channel).

Data is acquired continuously to MPV908 memory in cyclic mode (PS/CO/Note98-24) each 10 ms with data synchronization between ADC memory and the internal software NON-PPM buffer (retrieving and tagging just arrived data) each 0.2 seconds (20 position values per channel, 640 position values for 32 channels, ~1.4 ms of processor time) and at the end of each cycle (figure 5). Data synchronization is triggered inside Acquire and Publish real-time actions with semaphore inside.

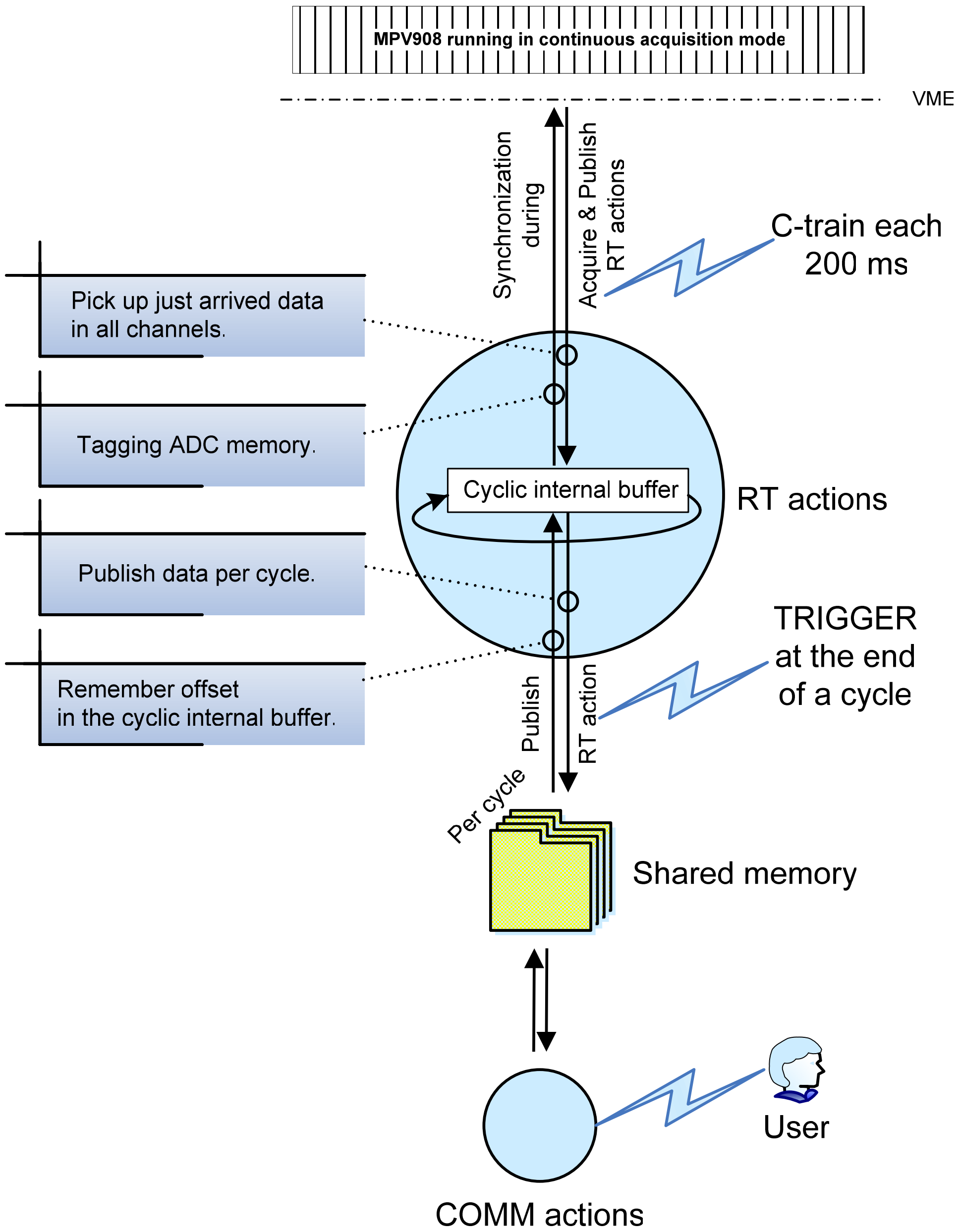

Figure 5: Dataflow in real-time behaviour.

Data publishing is realized inside the Publish real-time action by taking necessary data from the internal software buffer (2D array, NB_OF_CHANNELS x 2*MAX_NB_OF_MEAS) and putting them to PPM shared memory (2D array, NB_OF_CHANNELS x MAX_NB_OF_MEAS). In worse case (32x360 values must be published) the Publish action takes ~6.5 ms of processor time. No other real-time actions are implemented and used.

The figure 6 shows the real-time behaviour for one ADC channel:

- Acquire action is triggered each 0.2 seconds (10 us before a burst of 32 pulses separated by 10 us);
- Publish action is triggered at the end of each cycle (1.2, 2.4 and 3.6 seconds).

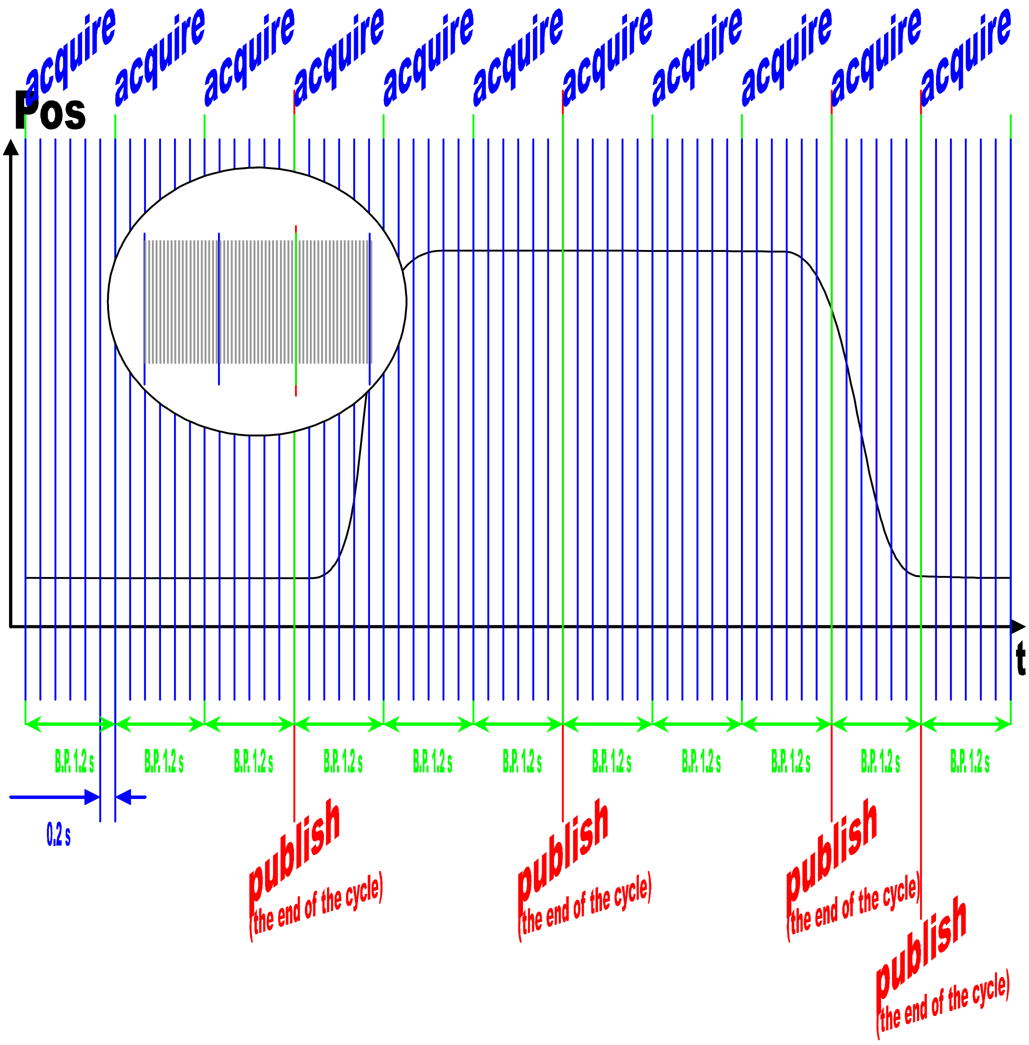

Figure 6: Real-time behaviour.

8. EXPERT CALIBRATION

8.1 EXPERT CALIBRATION DESCRIPTION

The calibration mode is used to calculate automatically new calibration factors for centered beam and scaling factors.

On the figure 6 a sine wave generator connected to the input of the head amplifier is used to simulate the beam.

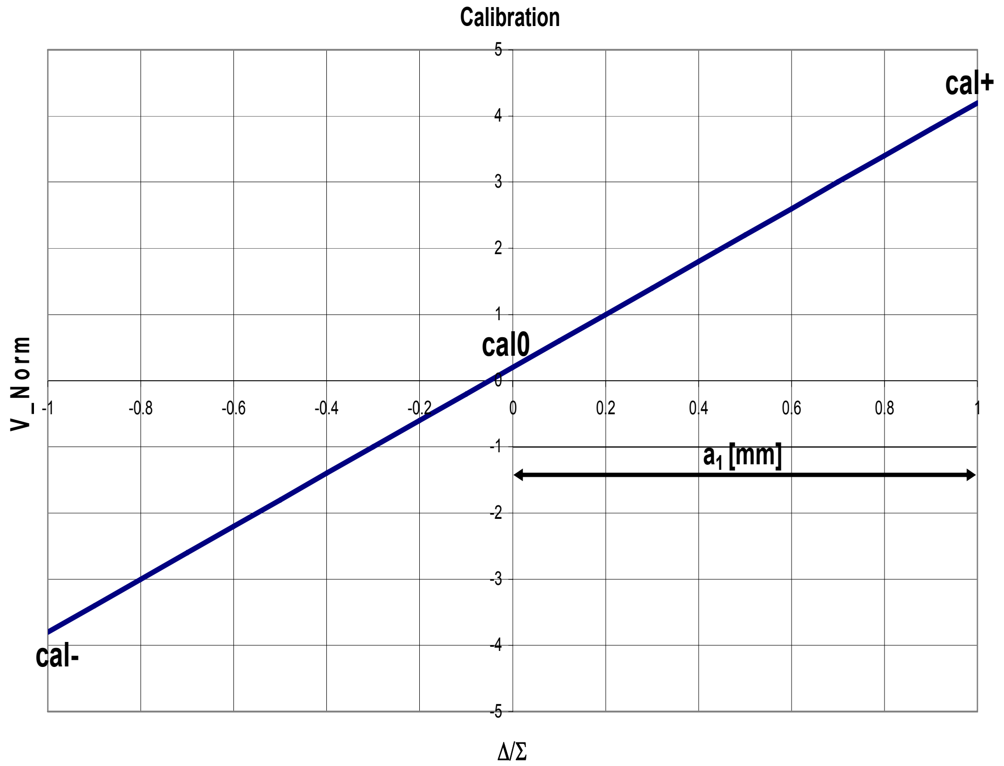

Figure 7: Calibration beam.

Cal_+: Simulates the maximum positive beam displacement.

Cal_0: Simulates a centered beam.

Cal_-: Simulates the maximum negative beam displacement.

The slope of the line, which is determined by the $\Delta_{Gain} / \Sigma_{Gain}$ and the normalizer transfer function, will be used to normalise the beam position measurements such that:

$$k = \frac{2 * a_1}{V_{Norm}(cal_+) - V_{Norm}(cal_-)} \text{ [mm/V]},$$

where a_1 is the PU sensitivity.

Every PU has been measured on a test bench and its electrical offset (a_0) and sensitivity (a_1) are known (these coefficients are persistent and can be changed in the feature):

PU	Ch nb	Offset a0	LG a1	MGa1	HG a1
UEH11	1	-1.3	103.8	108.8	108.8
UEH12	2	-0.4	105.6	110.3	110.3
UEH13	3	0	111.4	117.8	117.8
UEH14	4	0	111.4	116.5	116.5
UEH21	5	1.6	79.6	82.7	82.7
UEH22	6	-1.1	79	82.6	82.6
UEH23	7	0	111.2	116.4	116.4
UEH24	8	0	112.2	117.4	117.4
UEH31	9	-1.4	101.3	106	106
UEH32	10	-0.9	102.4	107.3	107.3
UEH33	11	0	107.9	116.5	116.5
UEH34	12	0	112.1	116.8	116.8
UEH41	13	-1.3	103.3	108.4	108.4
UEH42	14	1.2	105.4	110.1	110.1
UEH43	15	0	113.7	118.5	118.5
UEH44	16	0	107.3	116.2	116.2
UEV11	17	1	109	114	114
UEV12	18	-1	105.6	110.4	110.4
UEV13	19	0	23	24.5	24.5
UEV14	20	0	23	24.3	24.3
UEV21	21	0	75.1	78.3	78.3
UEV22	22	-0.3	75.3	78.7	78.7
UEV23	23	0	22.9	24.3	24.3
UEV24	24	0	23.1	24.4	24.4
UEV31	25	1	106.6	111.5	111.5
UEV32	26	0.7	106.6	111.1	111.1
UEV33	27	0	23.1	24.3	24.3
UEV34	28	0	23.1	24.4	24.4
UEV41	29	1.7	104.3	109.5	109.5
UEV42	30	0	104.9	109.9	109.9
UEV43	31	0	23.4	24.7	24.7
UEV44	32	0	23.1	24.3	24.3

8.2 EXPERT CALIBRATION MODES

The calibration can be done in manual, semi-automatic and automatic modes (ExpertSetting property / set):

- In automatic mode HW specialist can retrieve acquired calibration factors and scales for all gains, verify (ExpertCalibration property / get) and store (ExpertCalibration property / set) them.
- In semi-automatic mode HW specialist can retrieve acquired calibration factors and scales for chosen gain, verify (ExpertCalibration property / get) and store (ExpertCalibration property / set) them.
- In manual mode HW specialist needs to define manually when it is maximum positive beam, maximum negative beam and centered beam, afterwards he can verify (ExpertCalibration property / get) and store (ExpertCalibration property / set) acquired values.

In the table below you can see summered fields processing in different calibration modes:

	NO_CALIBRATION	POSITIVE_BEAM	CENTERED_BEAM	NEGATIVE_BEAM	SEMIAUTOMATIC	AUTOMATIC
calibratingFactorZero						
calibratingFactorMinus						
scalingFactor						
calibratingFactorPlus						
offset						
sensitivityPU						

Manual mode.
User can put values by himself using ExpertSettings.set().

Semi-automatic / automatic mode.
User needs:

- to specify gain (only for semi-automatic mode) & calibration mode using ExpertSettings.set();
- to wait until calibrationMode becomes NO_CALIBRATION (up to several seconds);
- to verify acquired factors using ExpertCalibration.get();
- to admit acquired factors using ExpertCalibration.set().

8.3 EXPERT CALIBRATION GUIDELINE

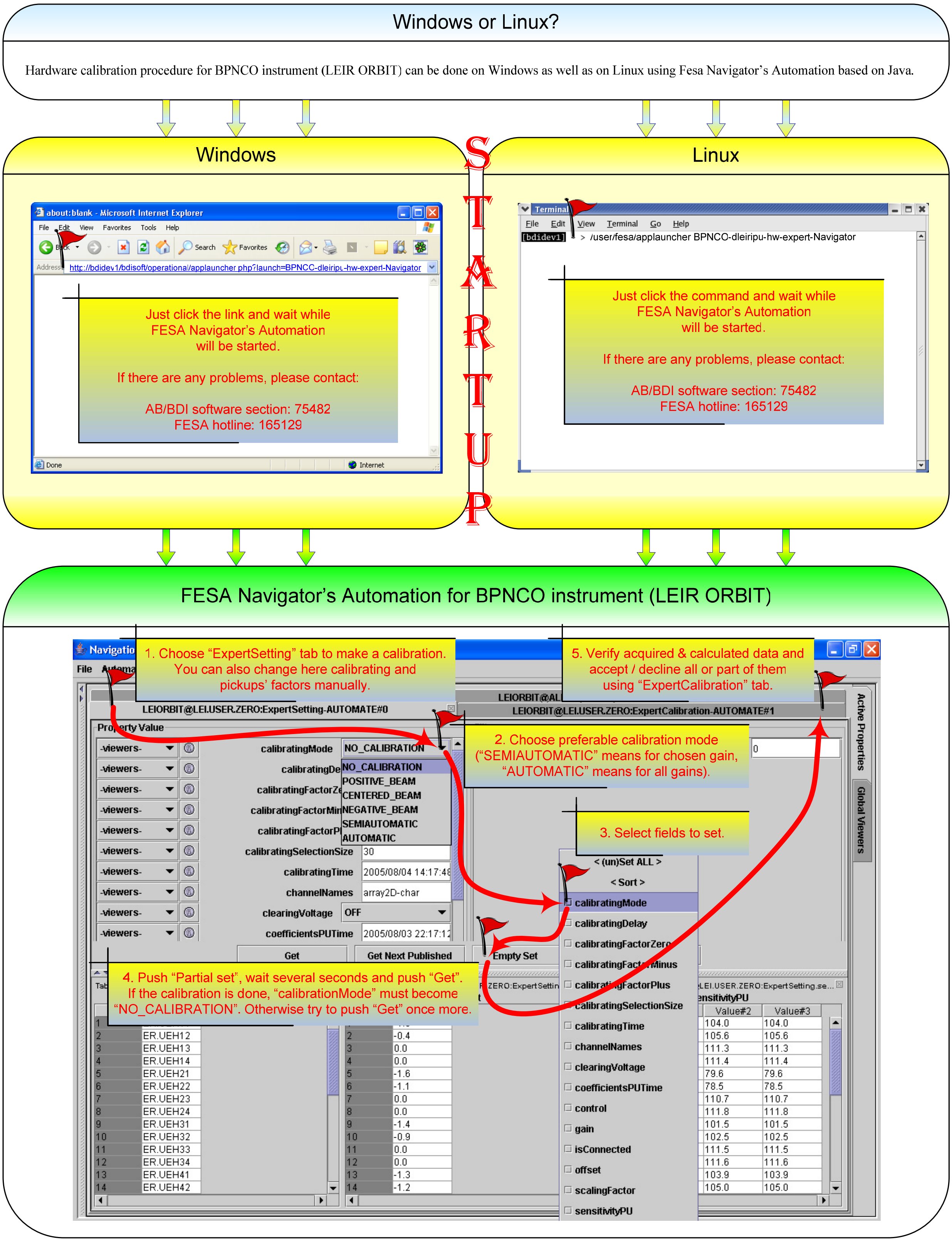

Figure 8: Calibration guideline
(Windows: http://bdidev1/bdisoft/operational/applauncher.php?launch=BPNCO-dleiripu-hw-expert-Navigator ,
Linux: ">/user/fesa/applauncher BPNCO-dleiripu-hw-expert-Navigator").

9. REFERENCES

[1] **B**eam **I**nstrumentation **S**oftware **Co**mmon **T**ools and **I**nterfaces Web Site [http://project-biscoti.web.cern.ch/project-biscoti]

[2] Front End Software Architecture Web Site [http://project-fesa.web.cern.ch/project-fesa]

[3] BDI front end software Standard interface For Beam position Measurements [EDMS: 630857]

[4] Guidelines and conventions for defining interfaces of equipment developed using FESA [EDMS: 581892]

[5] LEIR Closed Orbit Measurement proposal [AB-Note-2004-049 BDI]