Elettra Sincrotrone Trieste

# *Critical Design Review*

# *WS Acquisition System*

# *Software development, EPICS integration*

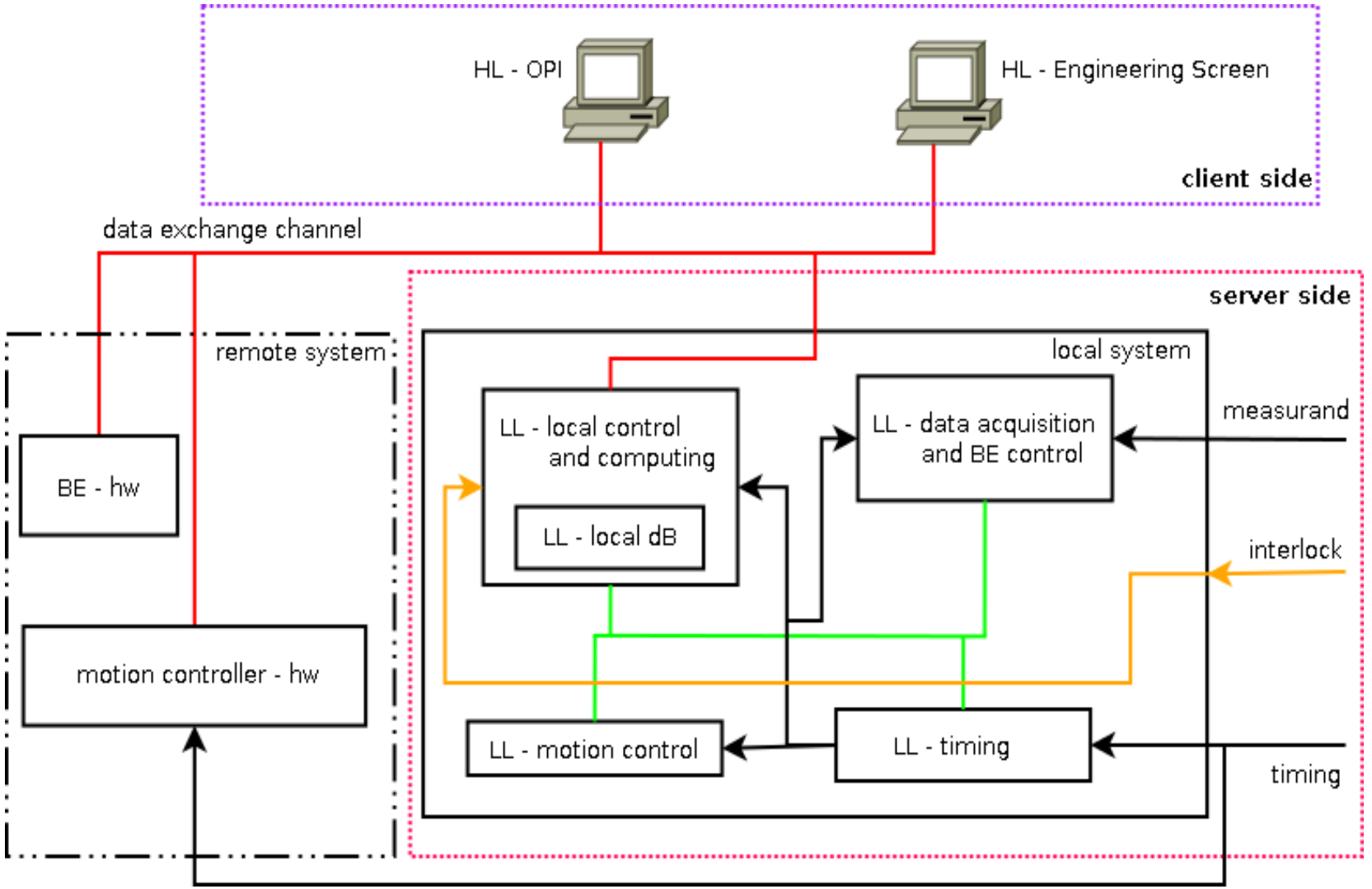
Stefano Cleva

*Elettra Sincrotrone Trieste*

# Intro - 1



**Original plot of the block diagram (PDR2) … something has changed, see next slides**



# Intro - 2



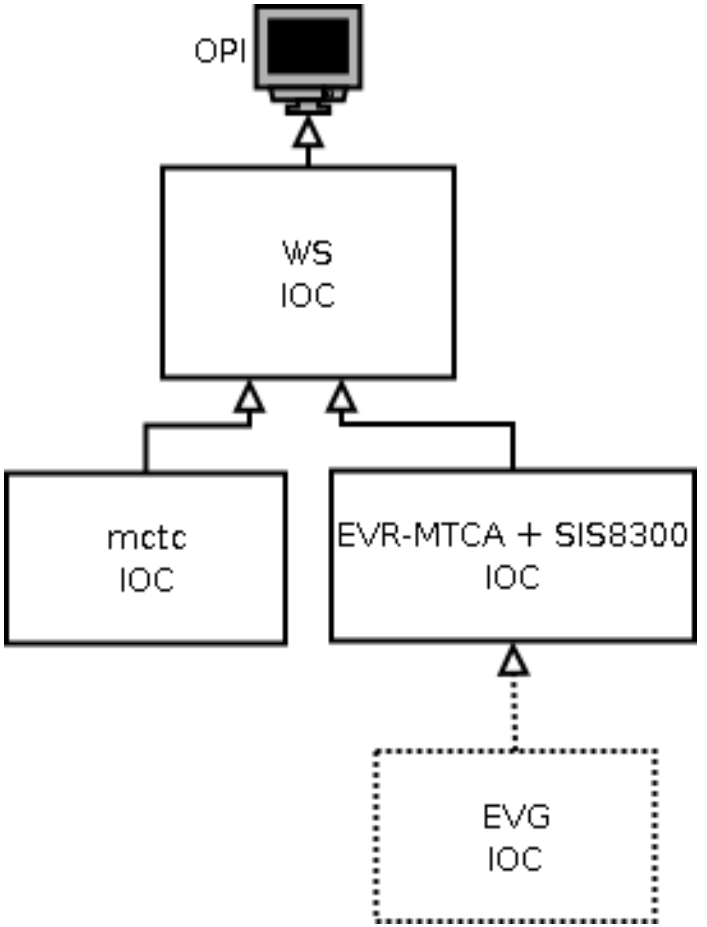
## Two layers SW architecture

- ✓ The High Level Layer (client side) is in charge of human interaction activities;
- ✓ The Low Level Layer (server side) is in charge of all kind of activities/functions strictly related to the WS operation:
  - Motion control: On The Fly and Step By Step trajectory generation;
  - Data acquisition synchronized by/with the timing system;
  - Elaboration of the acquired raw data (raw means buffered by the underlying layer) accordingly to specified algorithms in order to calculate the beam profile;
  - State management (normal operation, alarms, …);
  - User commands checking;
  - BE control;
  - Auto-diagnosis function that checks the sanity of the ancillary equipment, both hardware (BE/AFE/OFE) and software (acquisition/timing/motion control underlying IOC);
- ✓ Constraints:
  - EPICS and CSS based;
  - Motion control (mctc demo) and “ACQ + Timing” (SIS8300 + EVR) sub IOCs are in charge of ESS;

# IOCs Hierarchy

## A hierarchy exists between the IOCs

- ✓ At the bottom level are located the:
  - motion control (mctc) IOC;
  - Acquisition plus Timing IOC (EVR-MTCA + SIS8300);
  - They act as servers for the upper level;
- ✓ At the top level is located the WS-IOC:
  - It is triggered by the timing information by the EVR;
  - It fetches the data buffered by SIS8300 (ADC);
  - It acts on mctc in order to scan the beam;




- ✓ The Operator Interface/Engineer Panel interacts with the WS-IOC by the Channel Access Protocol

# WS-IOC and AFE/OFE



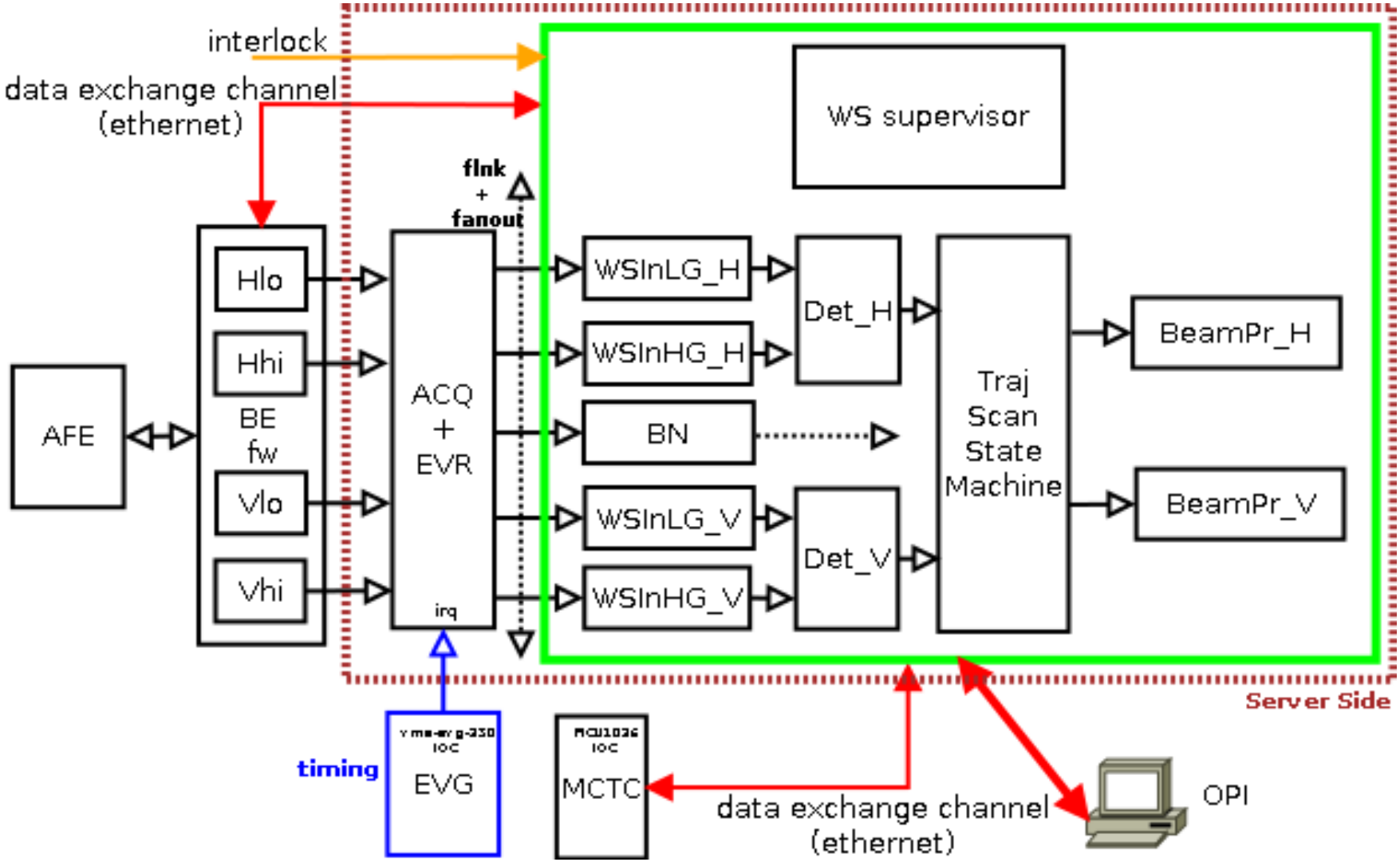
## AFE/OFE and WS-IOC

- ✓ Two kind of Front End have to be managed:
  - AFE: electrically connected to the scanning wires;
  - OFE: optically connected to the optical fibers of the scintillators;
- ✓ The amplifying hardware is different, so different solutions must be implemented in the data elaboration;
- ✓ At moment only the AFE case has been fully validated;
- ✓ The data elaboration of the OFE case is simpler than the one of the AFE;

# Simplified Block Diagram - AFE



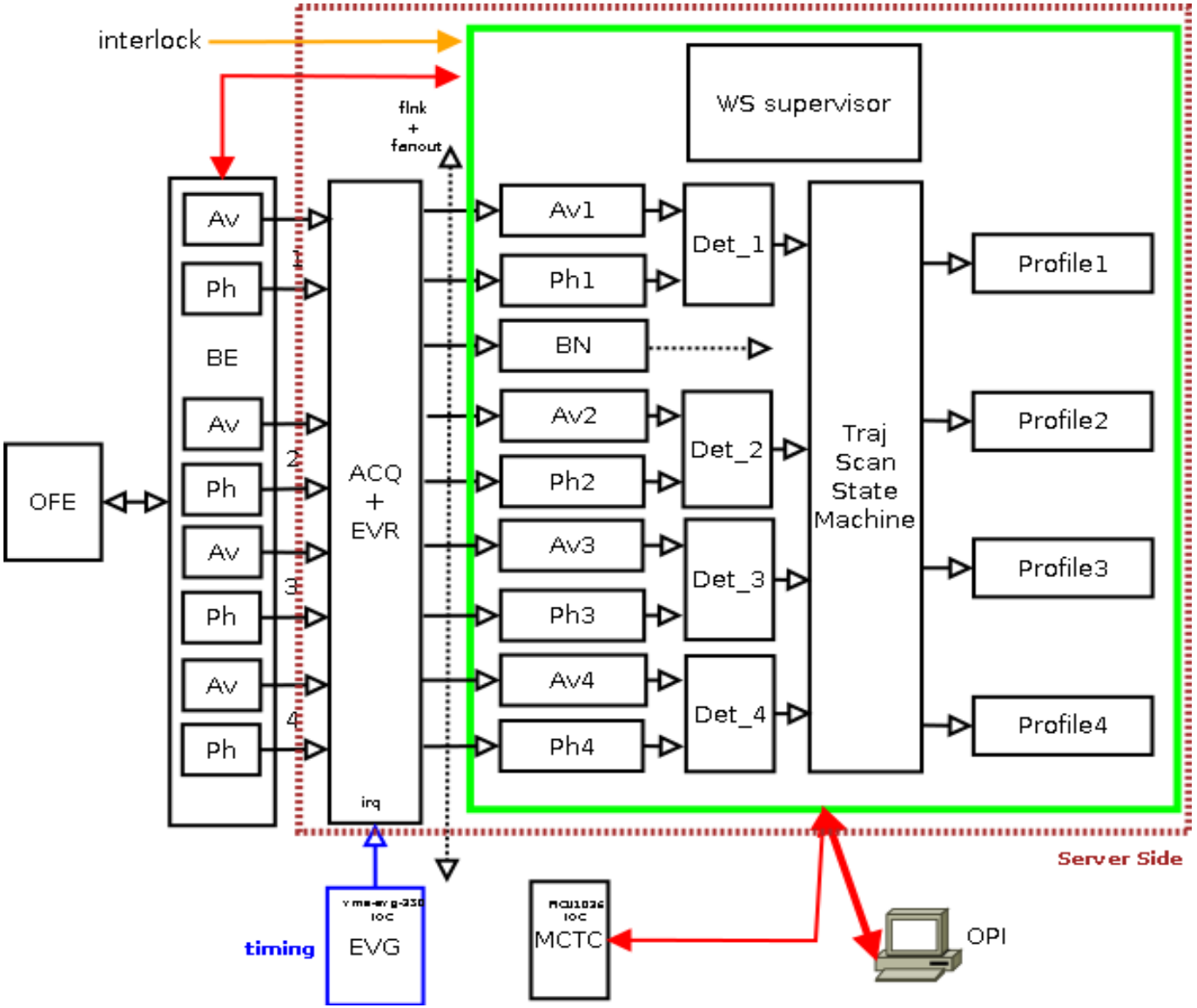
## Server Side (WS-IOC – AFE) simplified block diagram



# Simplified Block Diagram - OFE



## Server Side (WS-IOC – OFE) simplified block diagram

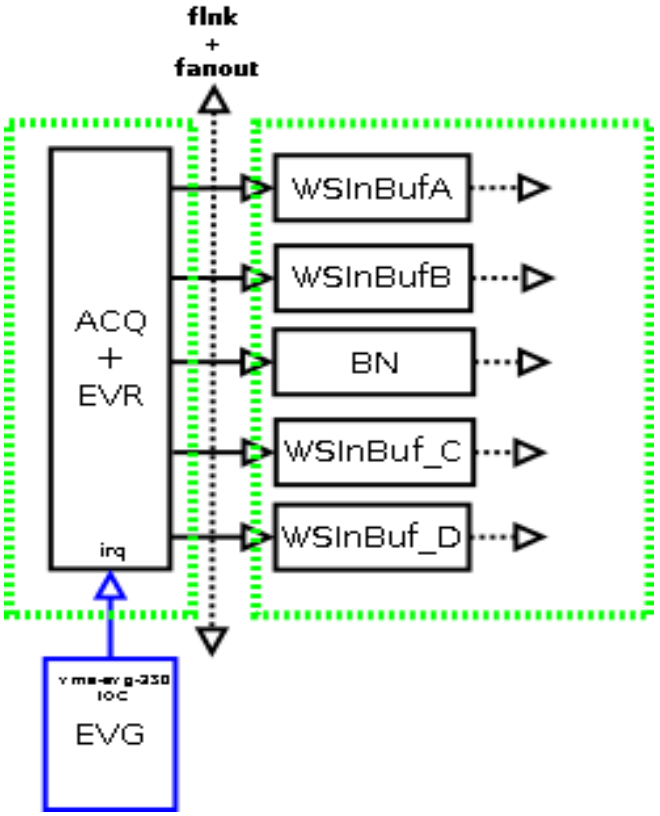


# WS-IOC details - 1



## Signal Processing Chain (data processing pipeline)

- ✓ The sequence of operations required to obtain the beam shape have been split in a “pipeline” manner;
- ✓ Each stage of the pipeline performs a simple action;
- ✓ Any stage is triggered by the previous one and triggers the next stage;
- ✓ A state machine has been introduced in order to manage the “out of pipeline” (e.g. asynchronous) operations (trajectory scan);
- ✓ This model fits the EPICS “scan passive” concept;
- ✓ A set of forward links triggers the data flow;
- ✓ Periodic actions like IOC supervision are performed by periodic tasks (periodically scanned records);




- ✓ The primary trigger source is the event generated by the EVR in “EVR-MTCA” IOC;
- ✓ The event generates an IRQ that triggers the ADC acquisition (ACQ) in “SIS8300” IOC;
- ✓ Once ACQ buffers are available a CA forward link triggers the WS-IOC pipeline;

# WS-IOC details - 2



## Pipeline Stages (AFE)

- ✓ 1st: triggered by the “xxx:PropagateHWtriggerHV.PROC” CA FLNK, it processes a fanout record that triggers the following data fetching:
  - SIS8300 buffers (Ai* → WSInBuf*);
  - EVR-MTCA event counter (Event-X-Cnt-I → TrigSeqNum);

  When WSInLG_H and WSInLG_V records processing ends two FLNK are triggered:
  - DetectSaturationAndSelectArray_H: H data path processing;
  - DetectSaturationAndSelectArray_V: V data path processing;
- ✓ 2nd: it is the most critical because it must:
  - detect saturation effects in the input arrays. If both High Gain and Low Gain arrays are saturated a warning flag is set;
  - rescale the input signals according to the AFE analog parameters (offset and gain);
  - recalculate the LG channel array if the HG one is saturated;
  - select which array must be propagated (HG, LG or LG “gray zone”);

  When this stage ends two FLNK are triggered to process:
  - DetectProfile_H;
  - DetectProfile_V;

# WS-IOC details - 3



## Pipeline Stages (AFE)

- ✓ 3st: this stage calculates the significative parameters of the previously processed arrays, basically areas selected by settable markers. A number of algorithms are available (RMS, mean, ABS, background subtraction) to assess the (3) selected portions of the input signal. When this stage ends the BuildProfile record is triggered.
- ✓ 4nd: this stage put together the measured signal amplitudes with the scanned positions. Depending on the state of the Trajectory Scanning State Machine, the record that collects the data necessary to build the beam profile can be:
  - Enabled if operating in OtF mode, and the state machine only manages the trajectory scan (“trigger event driven” task);
  - Disabled if operating in SbS mode, and the state machine manages both the trajectory scan and the data gathering (“position driven” task);

  In both cases the H and V arrays containing the beam shape are filled sample by sample.

# WS-IOC details - 4



## Pipeline Stages (OFE)

- ✓ Conceptually the same as the AFE but simpler because the array rescaling stage is not required;

## Other notes about OFE

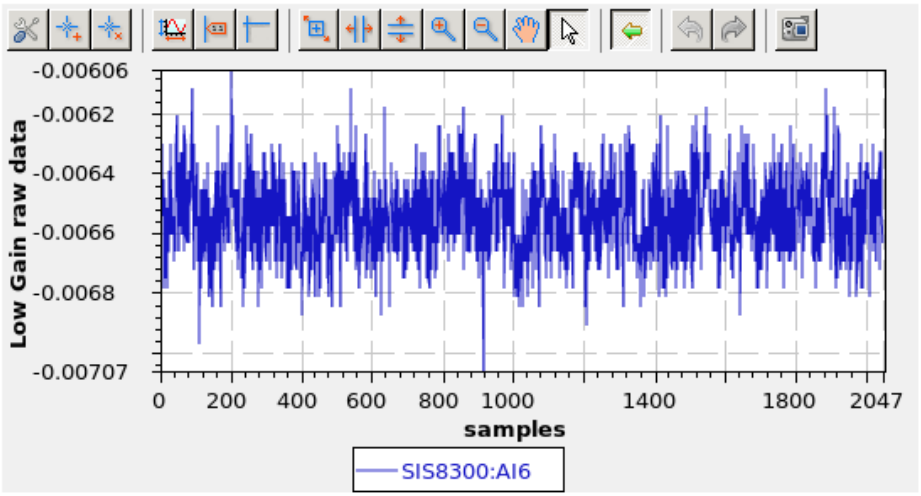
- ✓ At moment it is under development;
- ✓ A greater number of signals are required, but this doesn't affect the SW architecture;
- ✓ The HW difference between AFE and OFE can easily be taken in account;
- ✓ It could be difficult to maintain inside the same IOC the AFE and OFE data path differences;

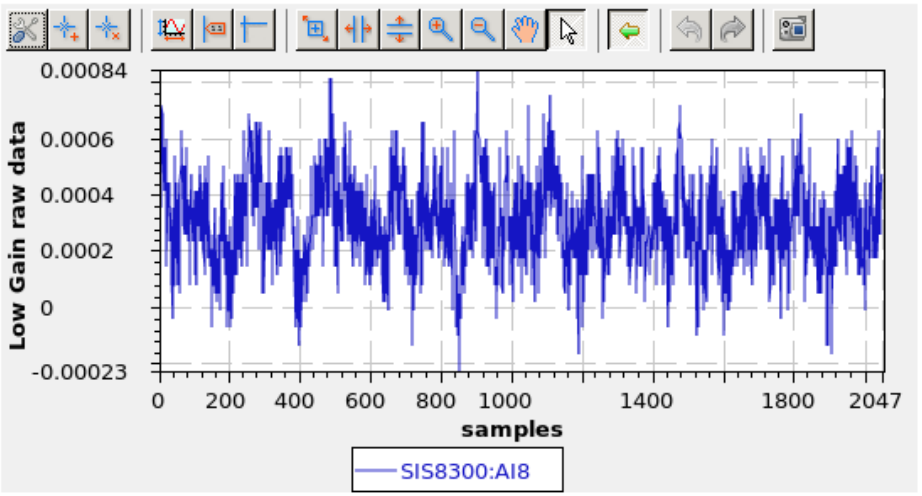
# OPI/EngPanel - 1

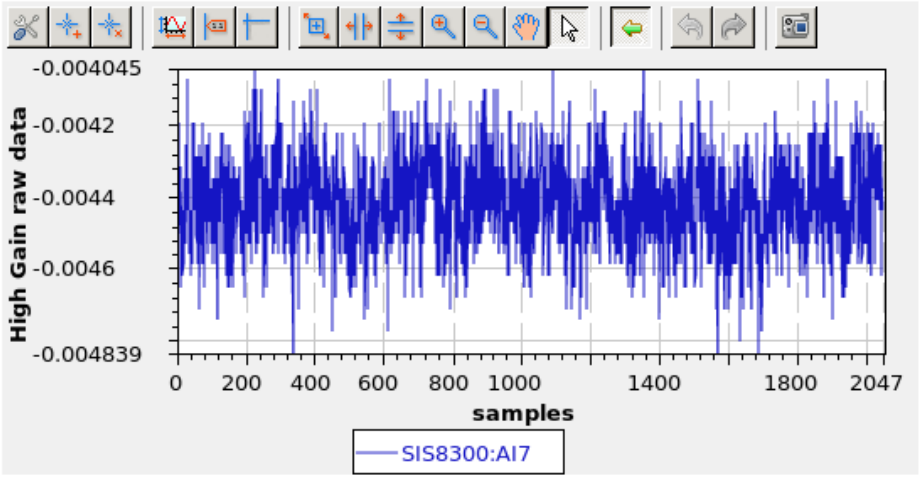


## ADC IN channels

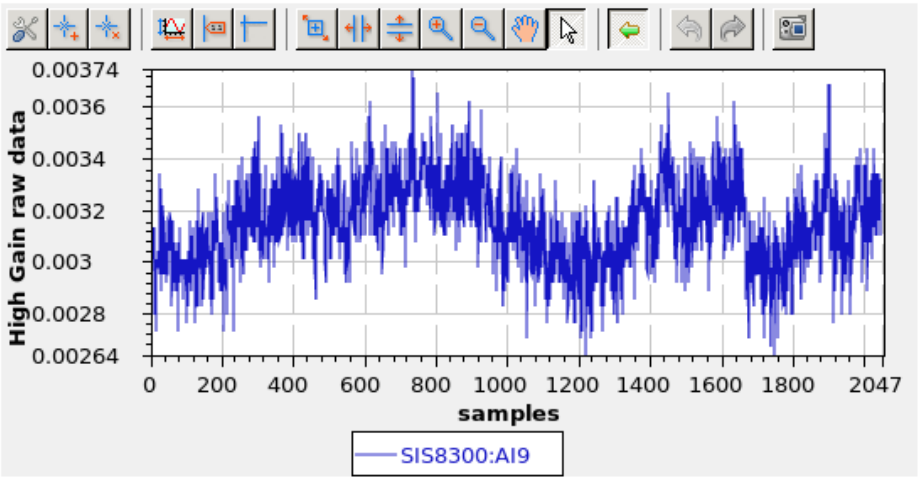
ADC in channels | WS IN channels | markers | beam | motion | Back End | log




H




V

## WS IN channels

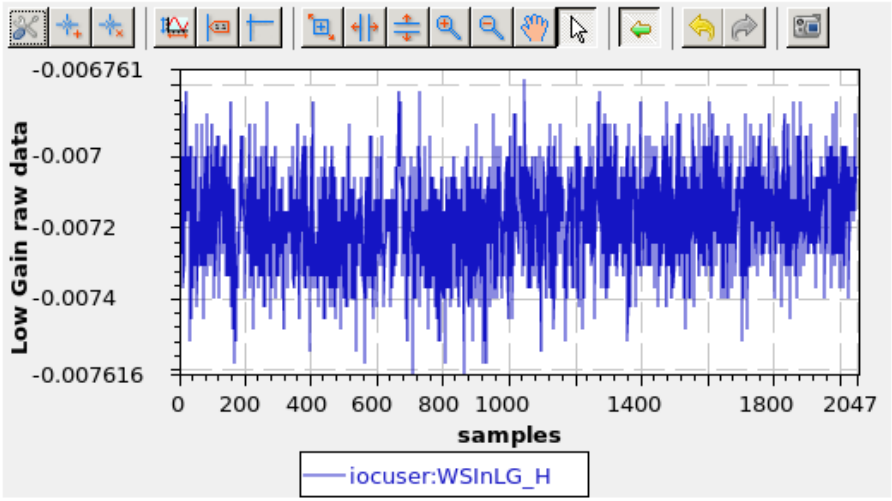
ADC in channels | WS IN channels | markers | beam | motion | Back End | OFEver | log

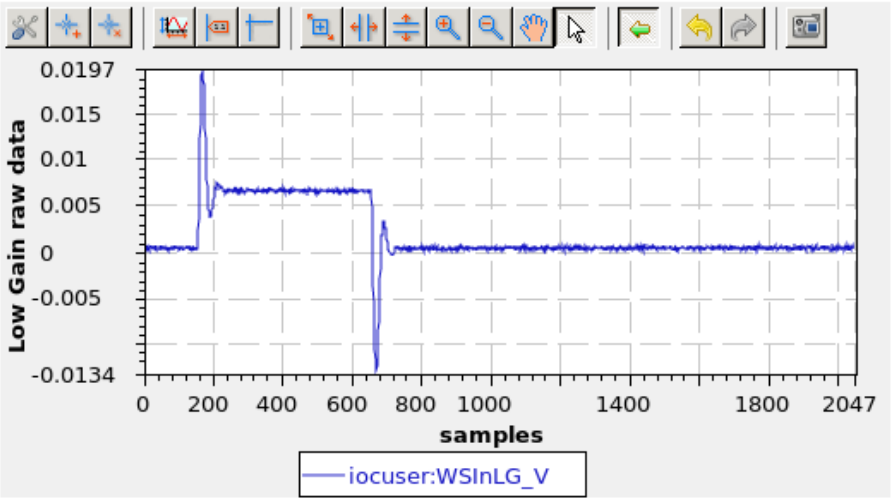
TrigDelay
-140
TrigDelayRBV
-140

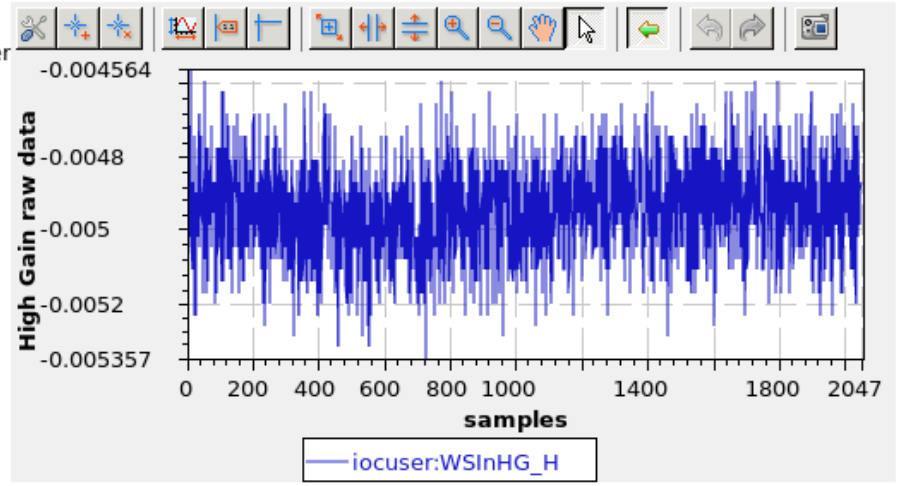
Trigger Status
Beam Permit

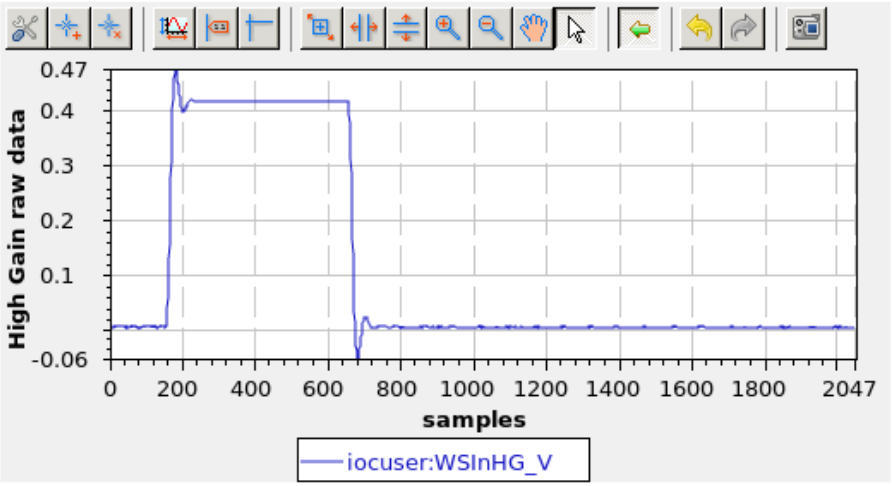
HiSaturationThreshold
0.9000
LoSaturationThreshold
-0.9000
SaturationLenghtPercer
10.00

Saturation
Bunch Number
568579




H V

# A brief note on switching



## Select&Rescale input signal – AFE only

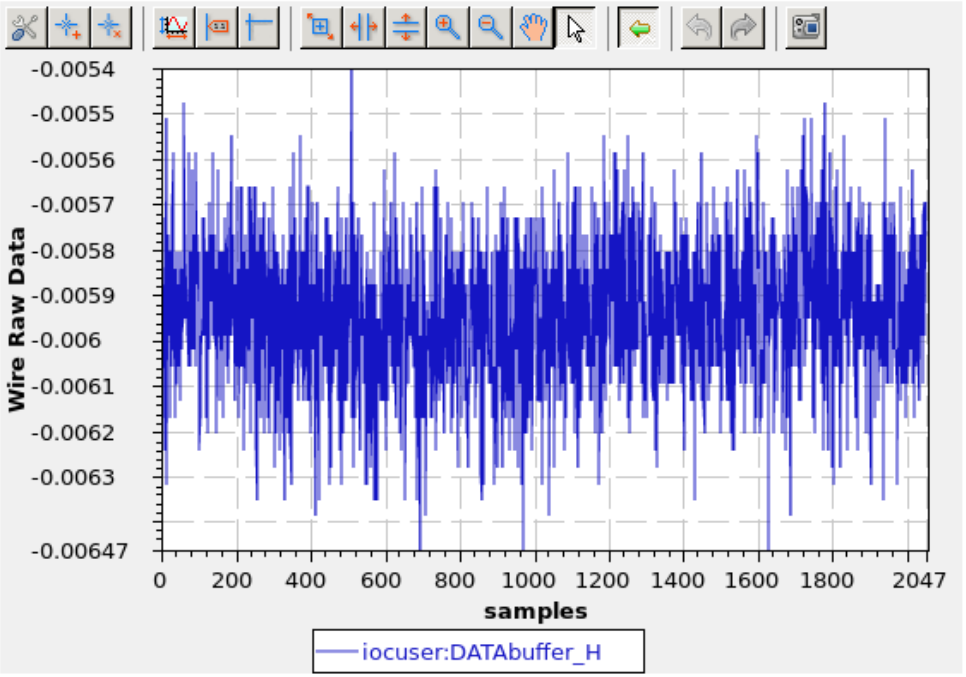
- ✓ Two signals are acquired per plane: WSInLG_H, WSInHG_H (H plane), and WSInLG_V, WSInHG_V (V plane)
- ✓ It is mandatory to compensate the gain change of the LG amplifier when HG amplifier saturates
- ✓ Saturation is detected when the portion of the signal inside the ROI exceedes the following thresholds:
  - field(INPC, "$(user):HiSaturationThreshold_V NPP")
  - field(INPD, "$(user):LoSaturationThreshold_V NPP")
  - field(INPE, "$(user):SaturationLenghtPercentage_V NPP")
- ✓ The following compensation is adopted when:
  - HGsignal= (HG -HG OFFS) * HG GAIN – HG is not saturated at all;
  - LGsignal = (LG - L_OFFS) * LG_GAIN – HG is not saturated inside ROI;
  - LGsignal =((LG - L_OFFS) * LG_GAIN_HI) + LG_OFFS_HI – HG is saturated inside the ROI;

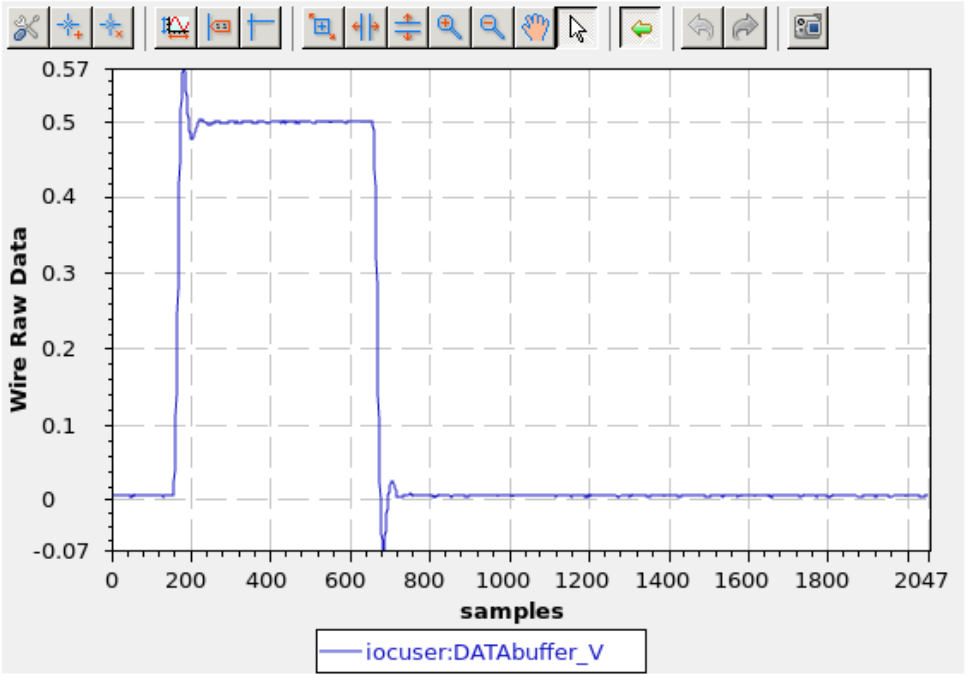
# OPI/EngPanel - 3



## Markers

ADC in channels | WS IN channels | markers | beam | motion | Back End | OFEver | log




H

pre pulse lo: 10
pre pulse hi: 50 → -0.00592949
ROI lo: 600
ROI hi: 1000 → -0.00598231
post pulse lo: 1700
post pulse hi: 400 → 0.00000000
algorithm: 0

Bunch Number: 568796

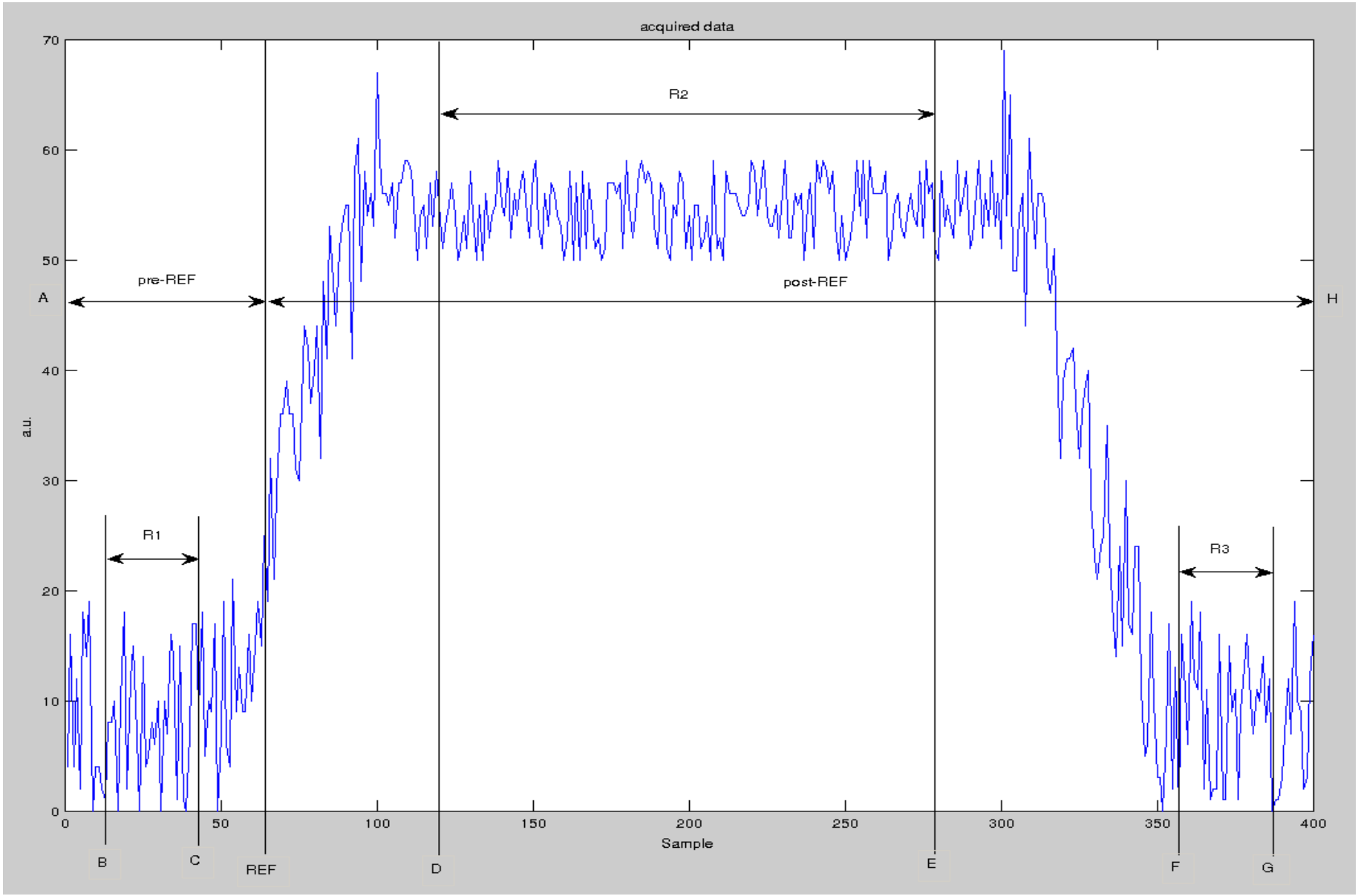
save wfm M

V

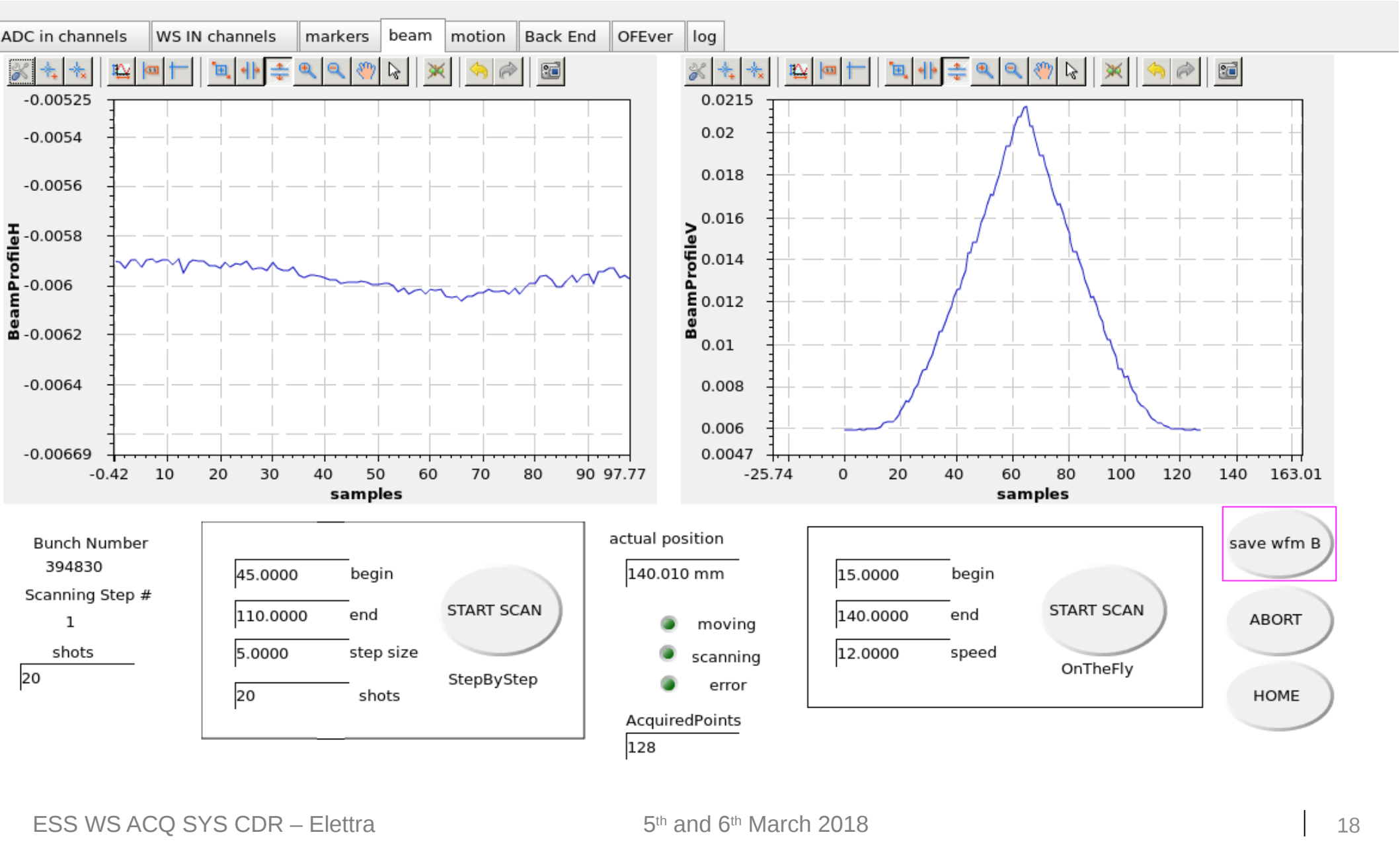
pre pulse lo: 10
pre pulse hi: 50 → 0.00424321
ROI lo: 400
ROI hi: 600 → 0.49725908
post pulse lo: 1700
post pulse hi: 1800 → 0.00385129
algorithm: 0

# A brief review (PDR2)

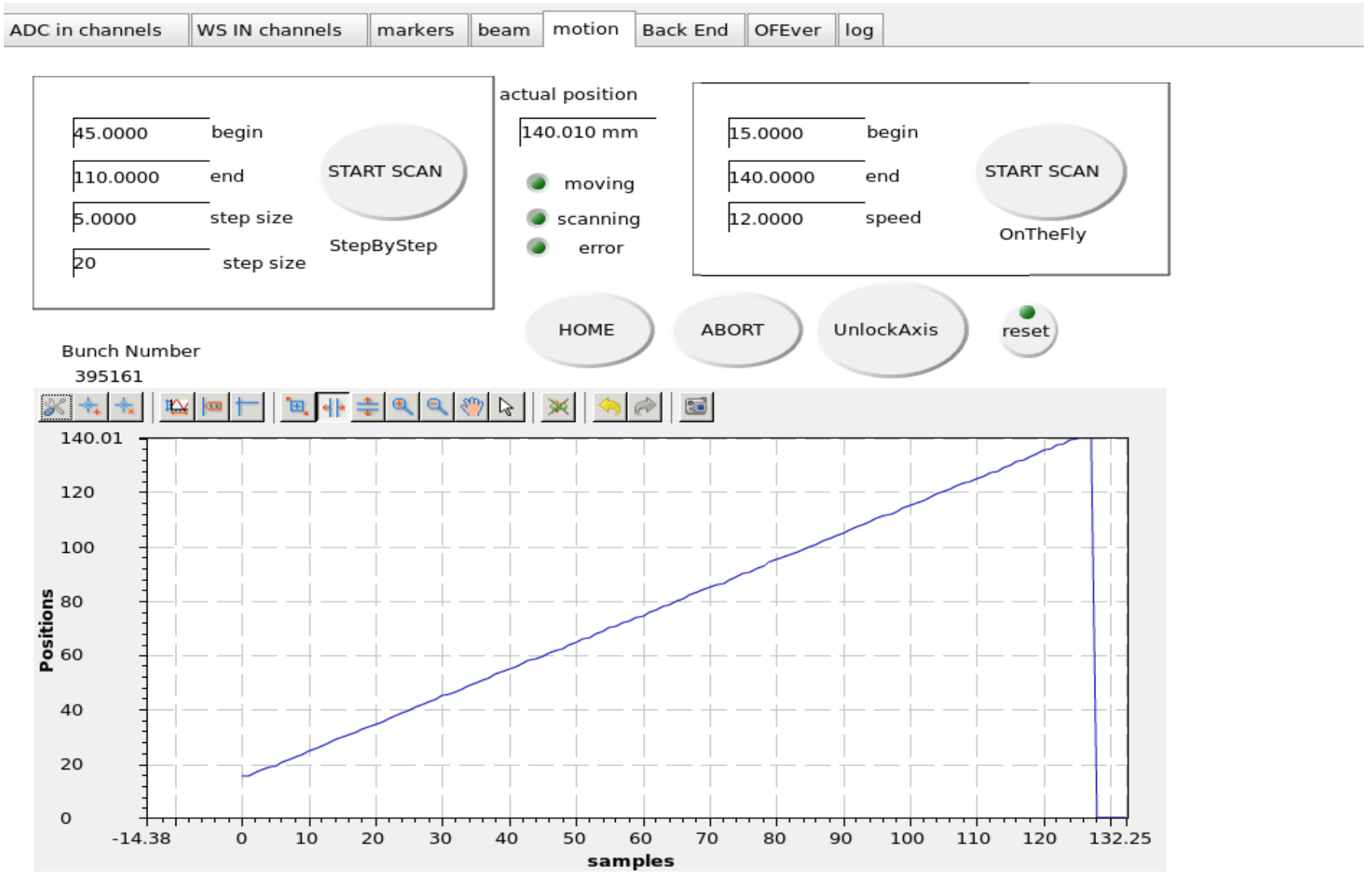




## Beam


ADC in channels
WS IN channels
markers
beam
motion
Back End
OFEver
log
BeamProfileH
-0.00525
-0.0054
-0.0056
-0.0058
-0.006
-0.0062
-0.0064
-0.00669
-0.42
10
20
30
40
50
60
70
80
90
97.77
samples
BeamProfileV
0.0215
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.0047
-25.74
0
20
40
60
80
100
120
140
163.01
samples
Bunch Number
394830
Scanning Step #
1
shots
20
45.0000
begin
110.0000
end
5.0000
step size
20
shots
START SCAN
StepBySteP
actual position
140.010 mm
moving
scanning
error
AcquiredPoints
128
15.0000
begin
140.0000
end
12.0000
speed
START SCAN
OnTheFly
save wfm B
ABORT
HOME

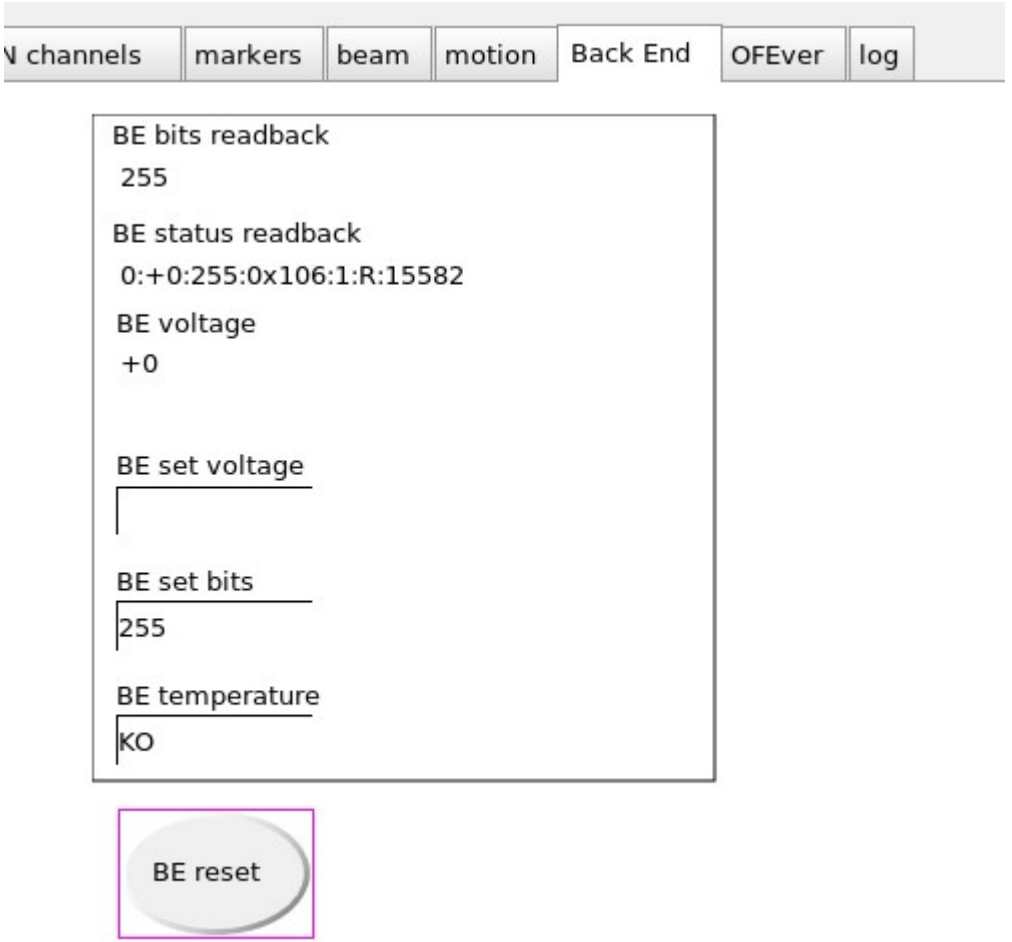
## Motion


ADC in channels
WS IN channels
markers
beam
motion
Back End
OFEver
log
45.0000
begin
110.0000
end
5.0000
step size
20
step size
START SCAN
StepByStep
actual position
140.010 mm
moving
scanning
error
15.0000
begin
140.0000
end
12.0000
speed
START SCAN
OnTheFly
HOME
ABORT
UnlockAxis
reset
Bunch Number
395161
140.01
120
100
80
60
40
20
0
Positions
-14.38
0
10
20
30
40
50
60
70
80
90
100
110
120
132.25
samples

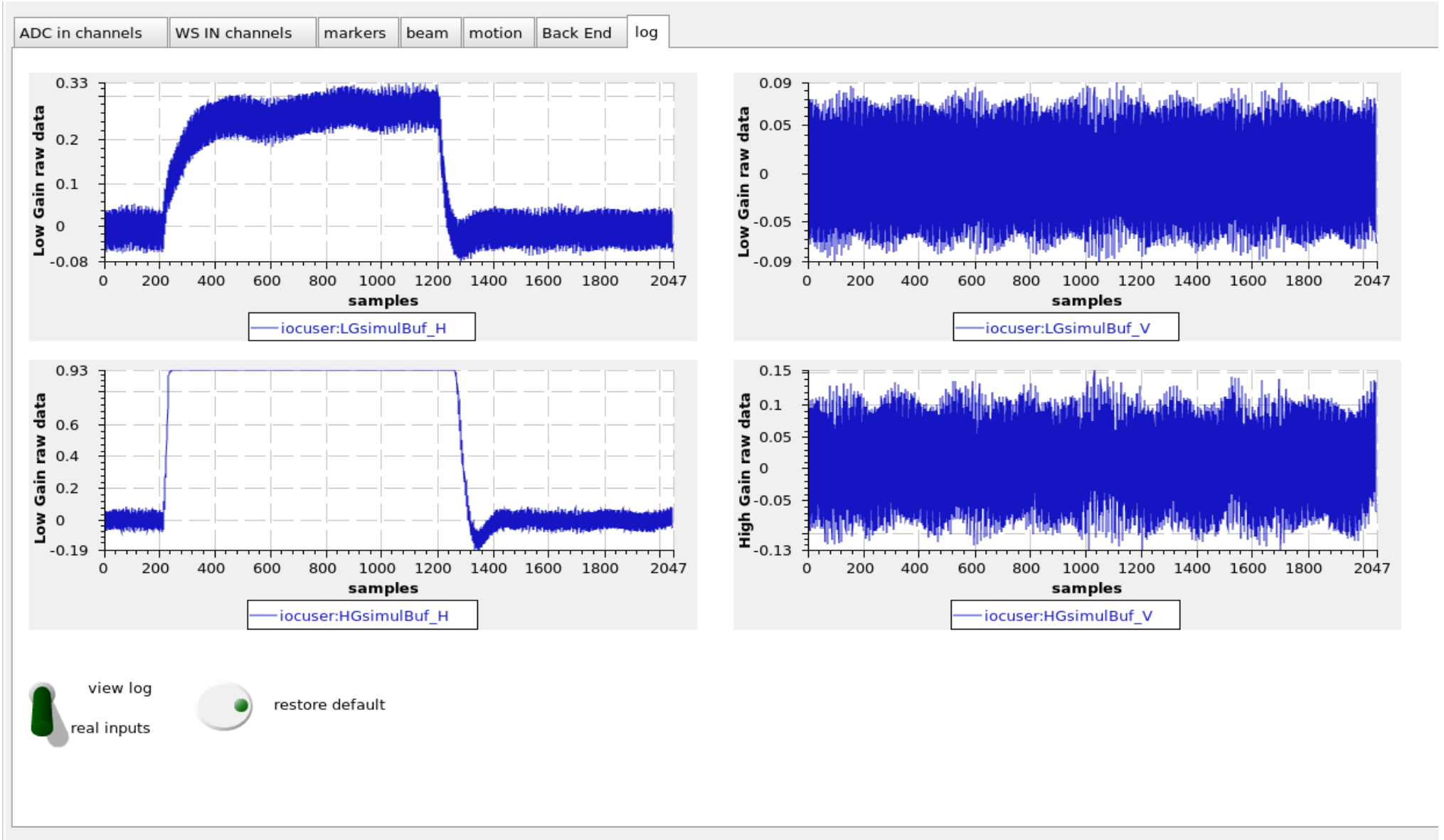
# OPI/EngPanel - 6



## BE



## Log – (CERN, Linac4)



# Some Tests Performed



## CERN - Linac4

- ✓ Data Acquisition ability: PASS
- ✓ Pipeline mechanism: PASS
- ✓ Detecting and switching algorithms: PASS
- ✓ BE control: PASS
- ✓ Log mode: PASS (this feature is used only for E-ST debug, it will be removed soon)
- ✓ Beam Profile Building algorithm: NA (motion controller not available, only post processing could be done)

## E-ST labo

- ✓ Trigger frequency increased to 20 Hz: PASS (! mctc warning)
- ✓ Trajectory scan both OtF and SbS: PASS
- ✓ Full beam scan simulation: PASS (! 1Hz repetition rate)
- ✓ WARNING: it seems that the maximum CA refresh frequency (camonitor) of the motion controller IOC is 5 Hz, see next slides

# camonitor x:Positions -#10

- iocuser:Positions 2018-03-02 20:54:19.163954 10 15 0 0 0 0 0 0 0 0 0
- iocuser:Positions 2018-03-02 20:54:19.213752 10 15 15 0 0 0 0 0 0 0 0
- iocuser:Positions 2018-03-02 20:54:19.263757 10 15 15 15 0 0 0 0 0 0 0
- iocuser:Positions 2018-03-02 20:54:19.313626 10 15 15 15 15 0 0 0 0 0 0
- iocuser:Positions 2018-03-02 20:54:19.363777 10 15 15 15 15 15 0 0 0 0 0
- iocuser:Positions 2018-03-02 20:54:19.413019 10 15 15 15 15 15 15 0 0 0 0
- iocuser:Positions 2018-03-02 20:54:19.463545 10 15 15 15 15 15 15 15 0 0 0
- iocuser:Positions 2018-03-02 20:54:19.513234 10 15 15 15 15 15 15 15 15 0 0
- iocuser:Positions 2018-03-02 20:54:19.563448 10 15 15 15 15 15 15 15 15 15 0
- iocuser:Positions 2018-03-02 20:54:19.613874 10 15 15 15 15 15 15 15 15 15 15.3

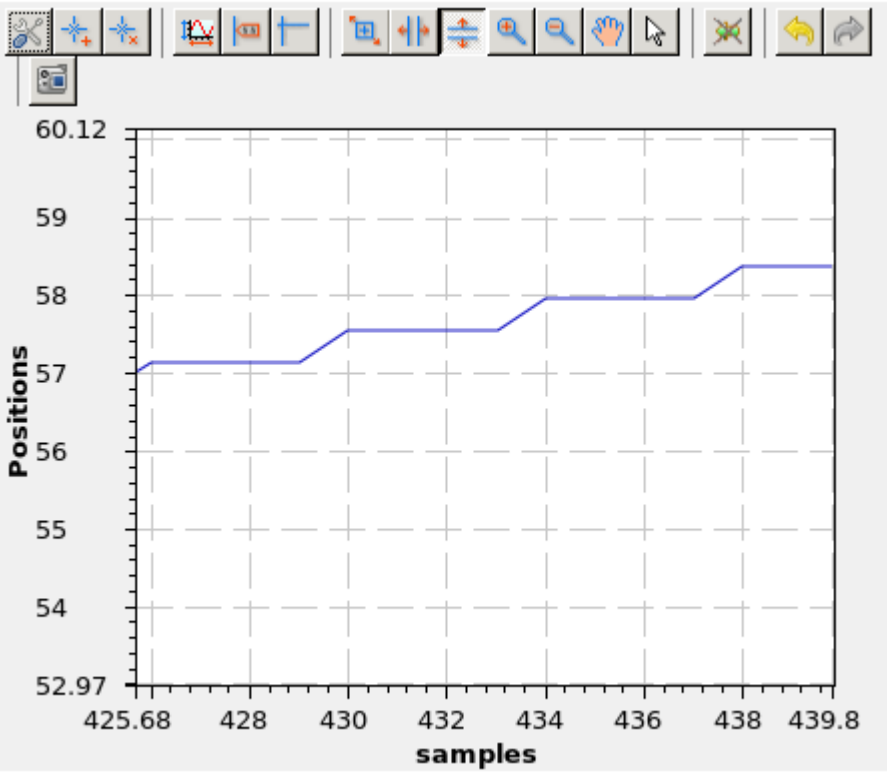
0.05 s period – 20 Hz, the EVG Trigger frequency: OK!

- caget: iocuser:Positions 2048 15 15 15 15 15 15 15 15 15 15.3 15.3 15.3 15.3 15.72 15.72 15.72 15.72 16.11 16.11 16.11 16.11 16.5 16.5 16.5 16.5 16.92 16.92 16.92 16.92 17.31

# MCTC limitation?

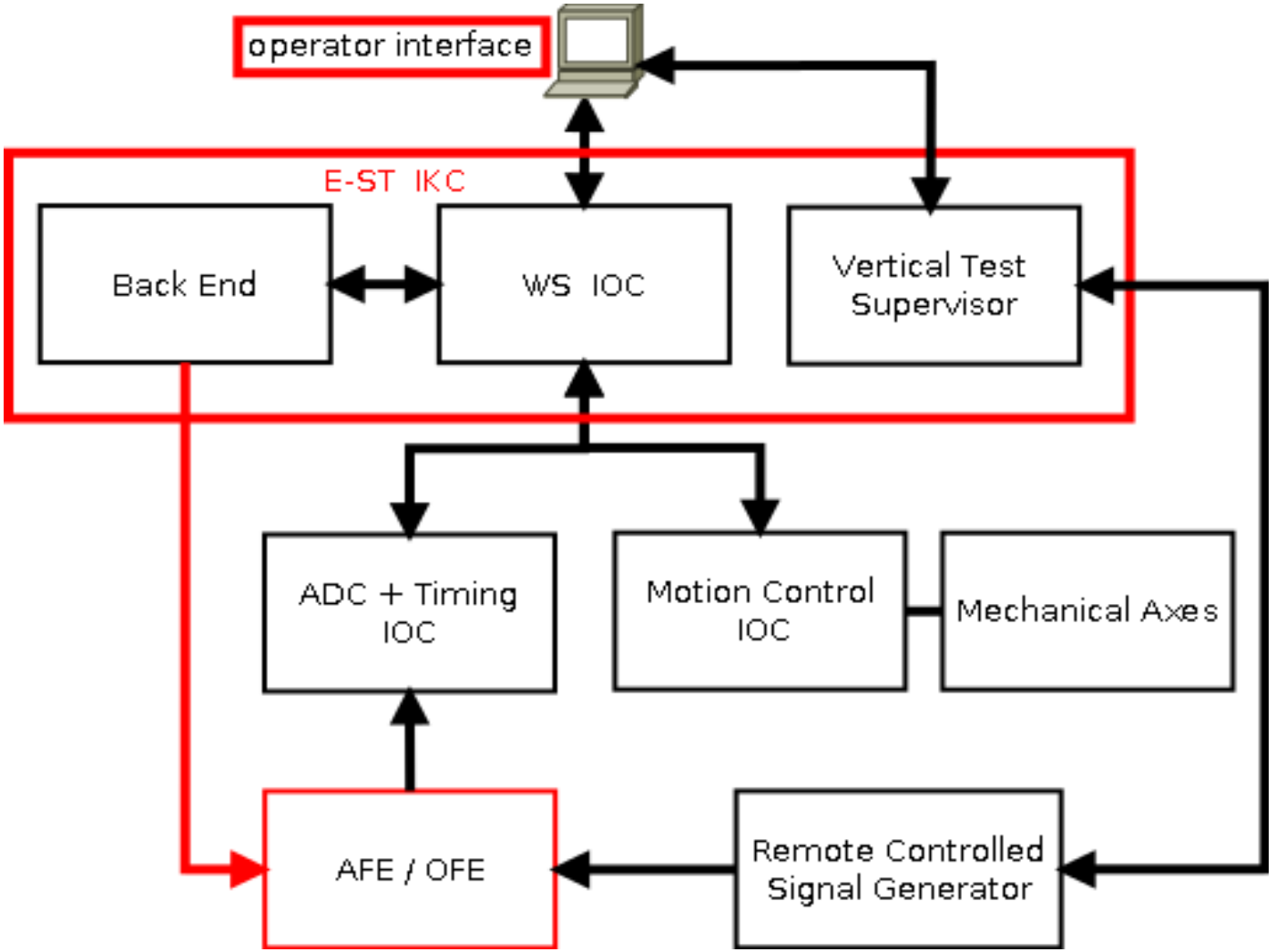
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:01.812140 20.94
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:02.012988 21.36
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:02.213861 21.75
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:02.414765 22.14
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:02.615534 22.56
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:02.816206 22.98
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:03.016924 23.37
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:03.217634 23.79
- ✓ IOC_WS:Axis1.RBV 2018-03-02 20:48:03.418367 24.18

- ✓ 0.2 s period – 5 Hz



# Vertical Integration Test





# Final Notes

- ✓ The actual release of the WS IOC is able to work fine enough in labo ...

  … but the real environment is quite different ! (nooo, really?) …

  … and some aspects need to be improved (engineering panel? OPI?). So?
- ✓ The next stages of the WS-IOC evolution are:
  - move from the labo environment to the real one (real mechanical axis, archiver, ...);
  - develop a full set of tests aimed at finding and managing all (!) the possible error conditions;
  - complete the OFE version;
  - start the definition of the procedure needed for the vertical integration test;
  - … your suggestions are welcome!!!

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