Fast Beam Current Transformer Software for the CERN Injector Complex

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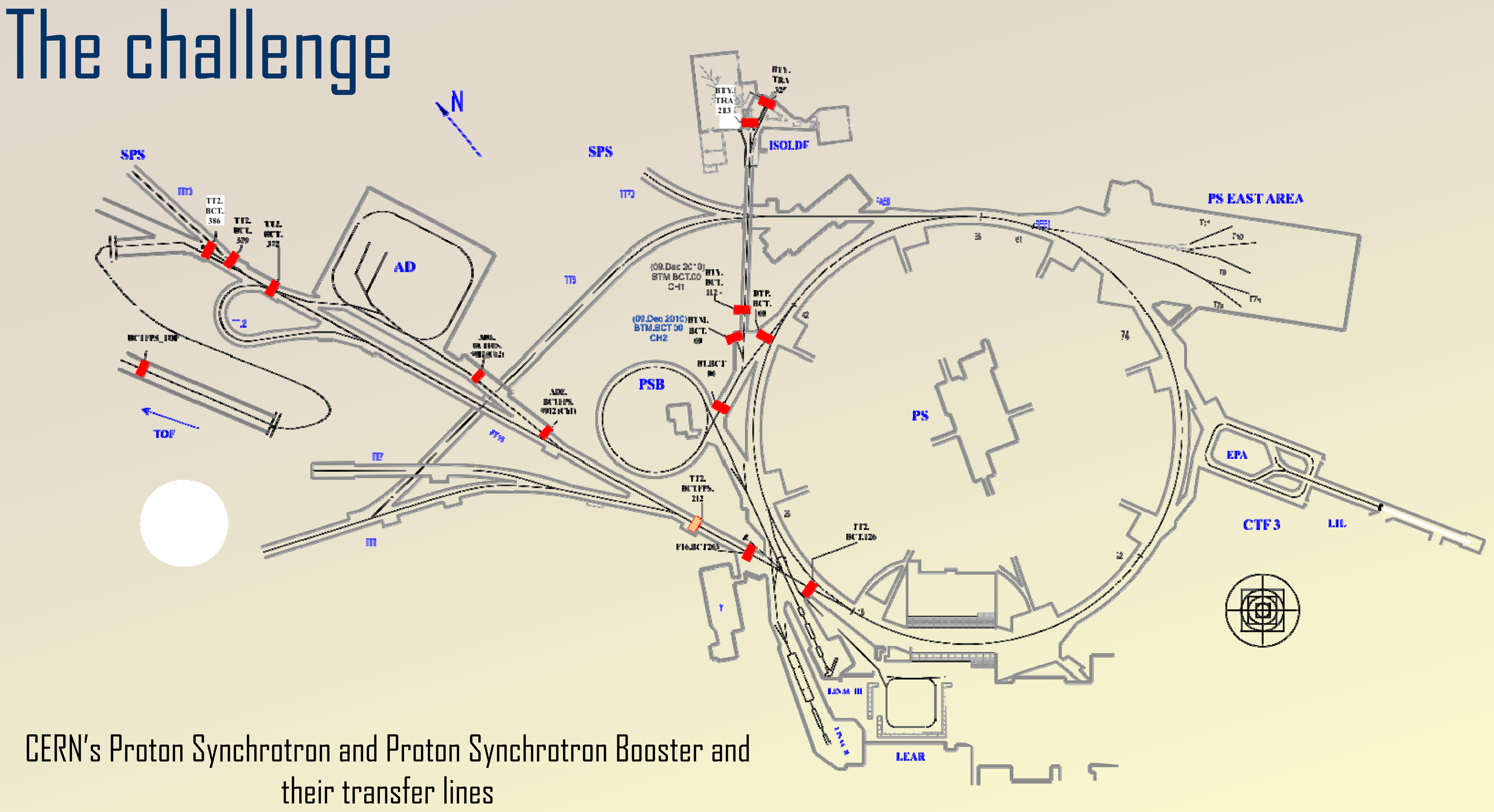
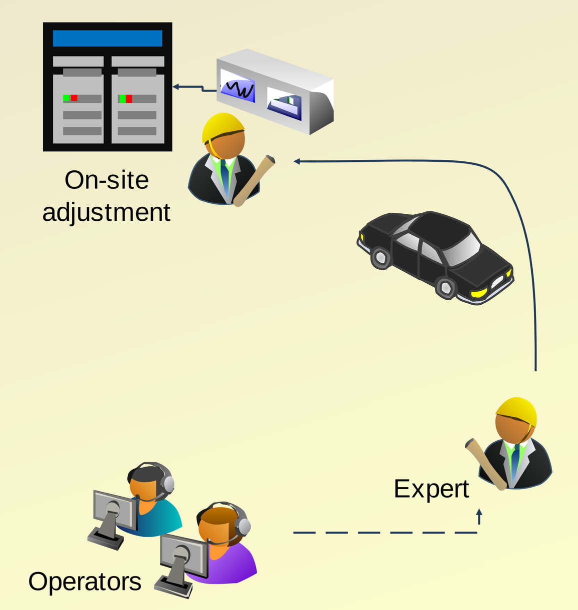
The challenge



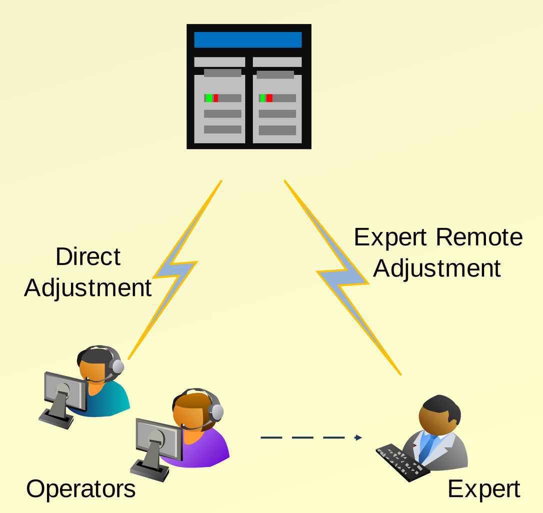
CERN's Proton Synchrotron and Proton Synchrotron Booster and their transfer lines

The older system from 90's suffered from:

1. No ability to precisely limit acquisition gate to the beam signal giving way to more absolute error
2. No ability to perform calibration upon remote request and limited remote diagnostics in general
3. No possibility to discern and measure multiple isolated beam bunches and multi-ejections
4. Parameters such as measurement gains had to be changed on-site using analogue dials and screwdriver
5. No remote diagnostics for hardware based beam-loss interlock.

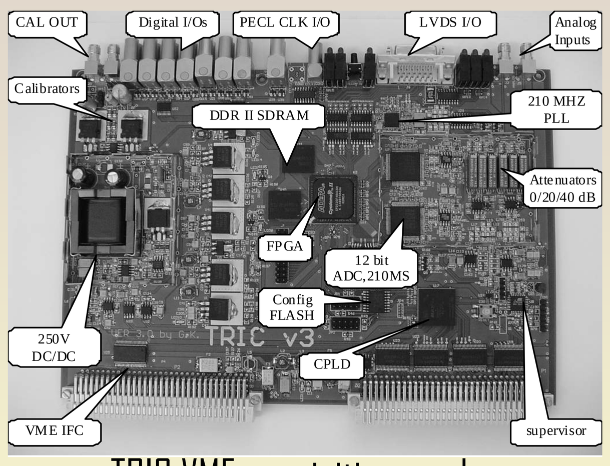


Interaction with older fast BCT system

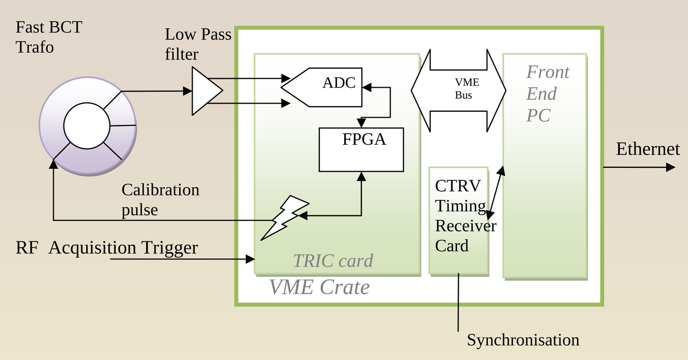


Interaction with new system

Hardware



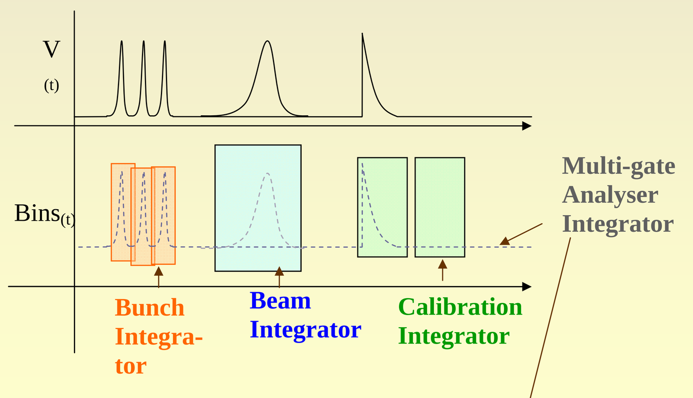
TRIC VME acquisition card



HW block diagram

TRIC (TRansformer Integrator Card)

1. CERN's custom FPGA based digital integrator solution.
2. Contains several independent integration modes.
3. Built-in high-voltage or constant-current calibrator circuit
4. Large degree in-firmware post processing
5. Multiple attenuation choices



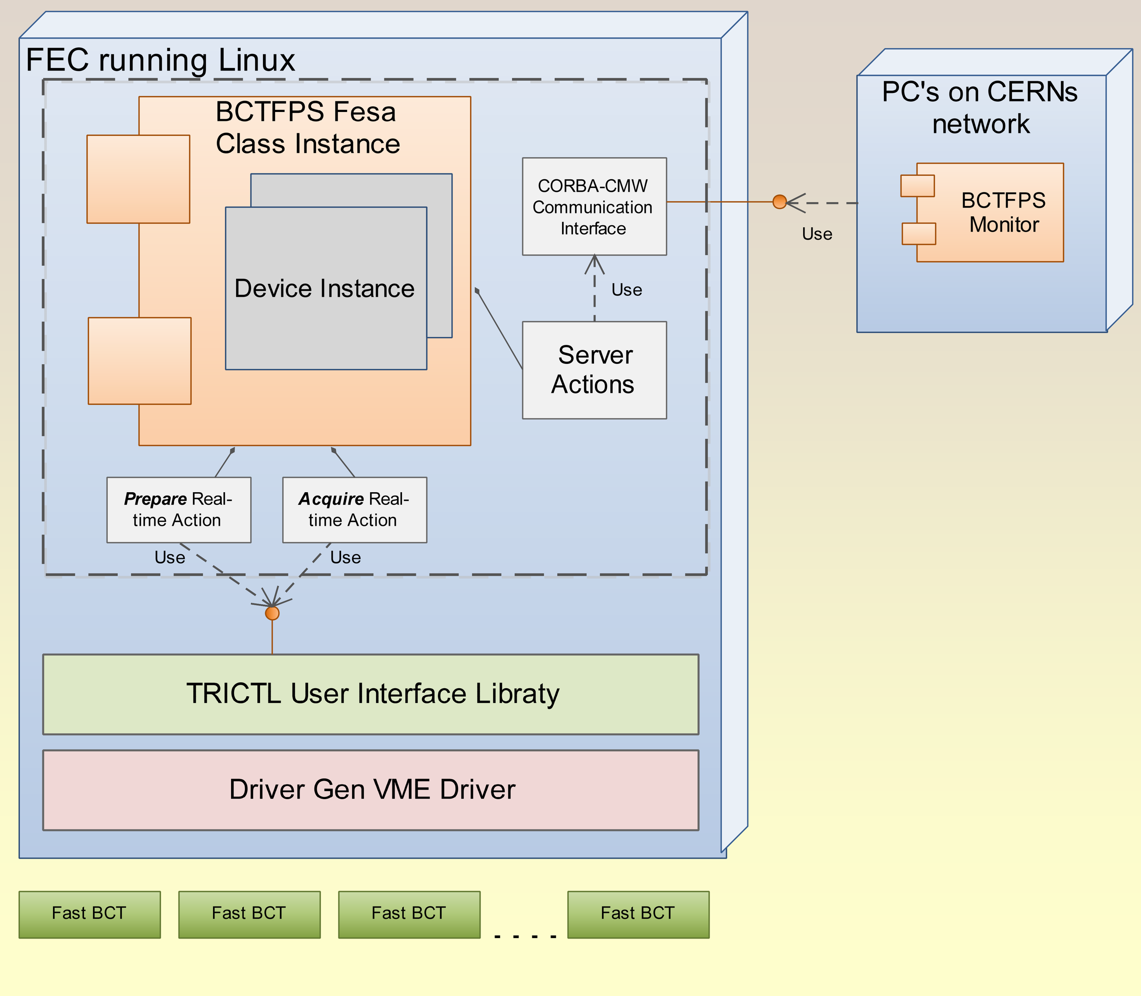
Signal integration modes

Software

BCTFPS

Real time server running CERN standard **FESA** class handles real time scheduling, beam-cycle synchronisation. Settings and acquisition are handled via Server Actions using standard CERN RDA/CMW.

Prepare and **Acquire** are real-time actions to set up and acquire integration results on cycle to cycle basis. The signals for RT-execution events originate from the acceleration timing domain.



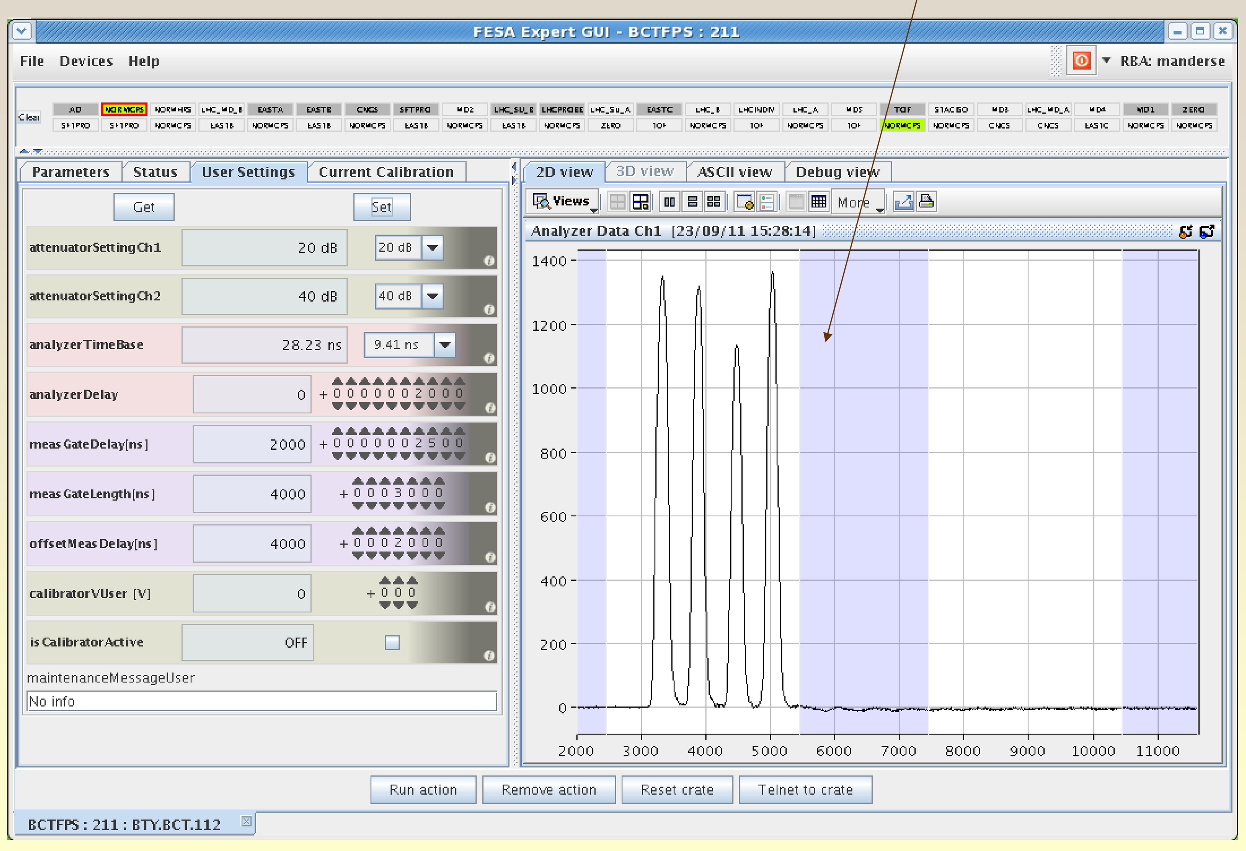
Software structure diagram

Expert GUI

BCTFPS_Monitor

The *BCTFPS_Monitor* application is built for the adjustment of the integration and calibration gates as well as electrical and logic parameter for the low level BCTFPS acquisition server. It is coded using *BI-SW* framework for Expert GUI s

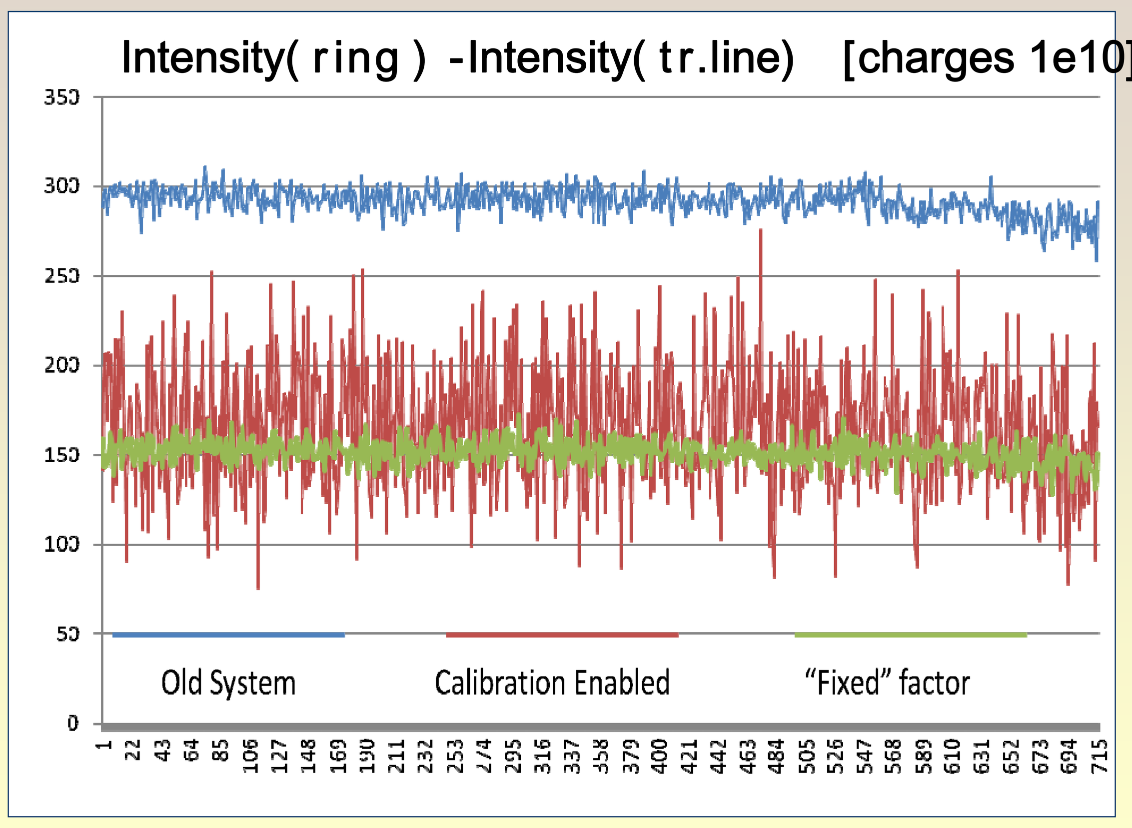
The main part of the GUI is a large graph showing acquisition data from the *multi-gate* integrator's 1024 data points. The graph refreshes at each beam cycle. The beam acquisition and calibration pulse are superimposed on the acquisition gates using background colour regions.



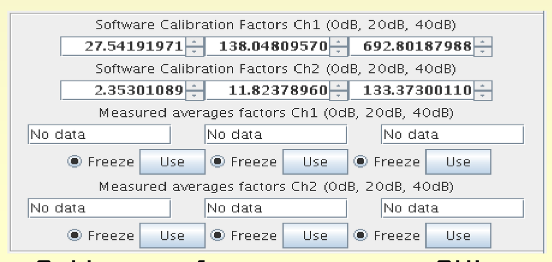
Screenshot of the full application

Relative error

The variation in total intensity measured by old and new system was analysed by taking difference of intensity measured in the PSB Ring and the Fast BCT of the ejection line. The relative error variation proved to be bigger than that for the old system, if calibration factor was found at every measurement.
It was decided to abandon "maintenance-free" calibration at every shot to reduce relative error. A measurement scheme with fixed calibration factor computed using running average proved to reduce the error considerably.

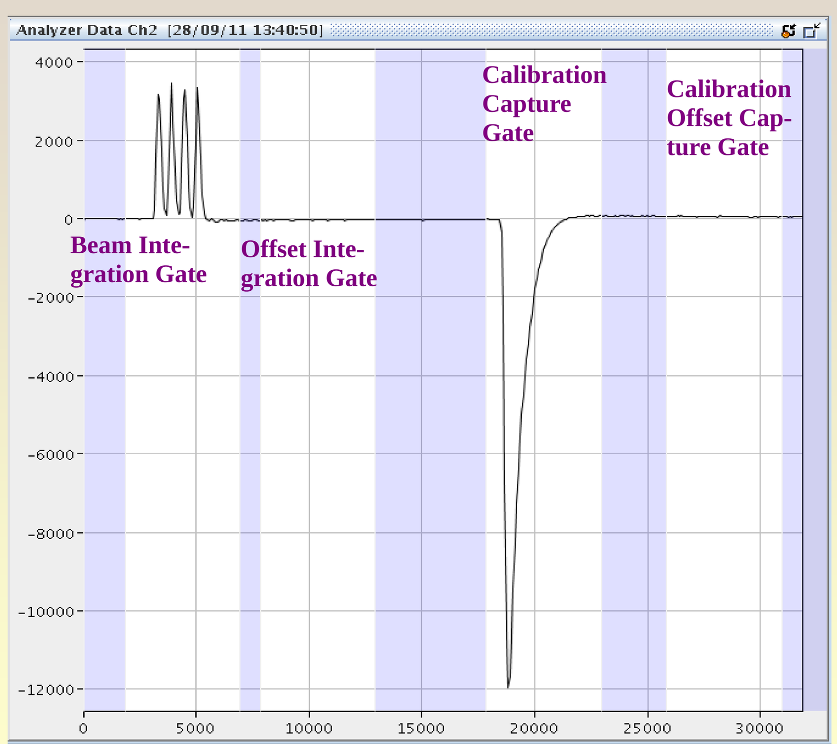


Comparison of cycle-to cycle measurement noise with active calibration and fixed calibration factor

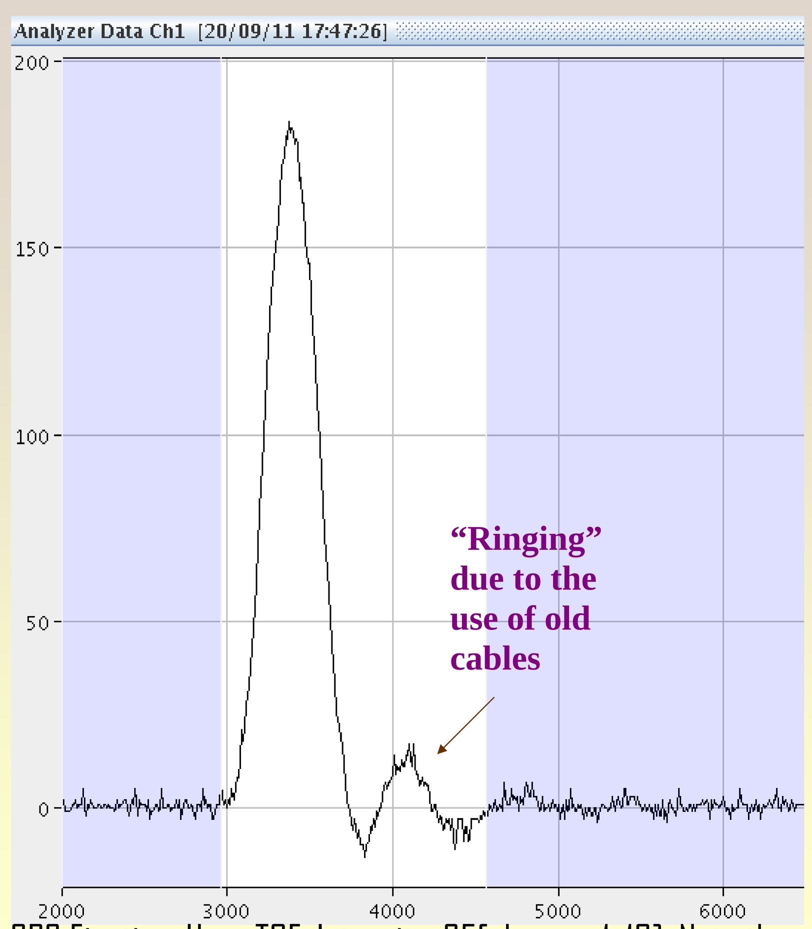


Calibration factor averaging GUI

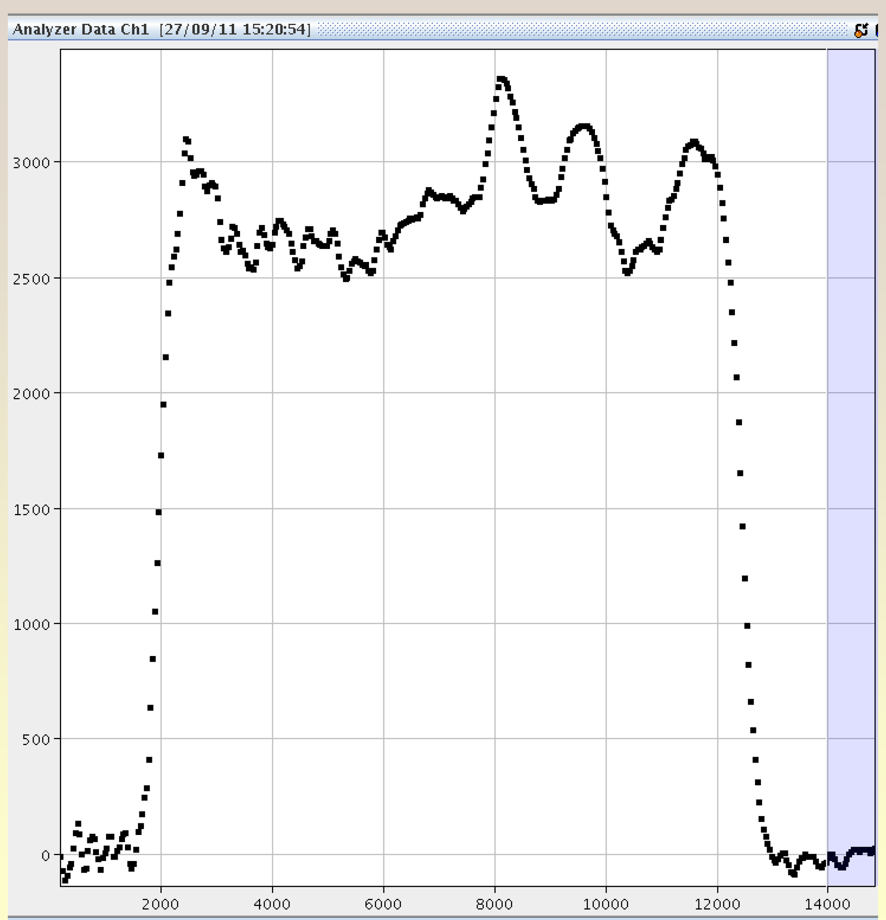
Example Cases



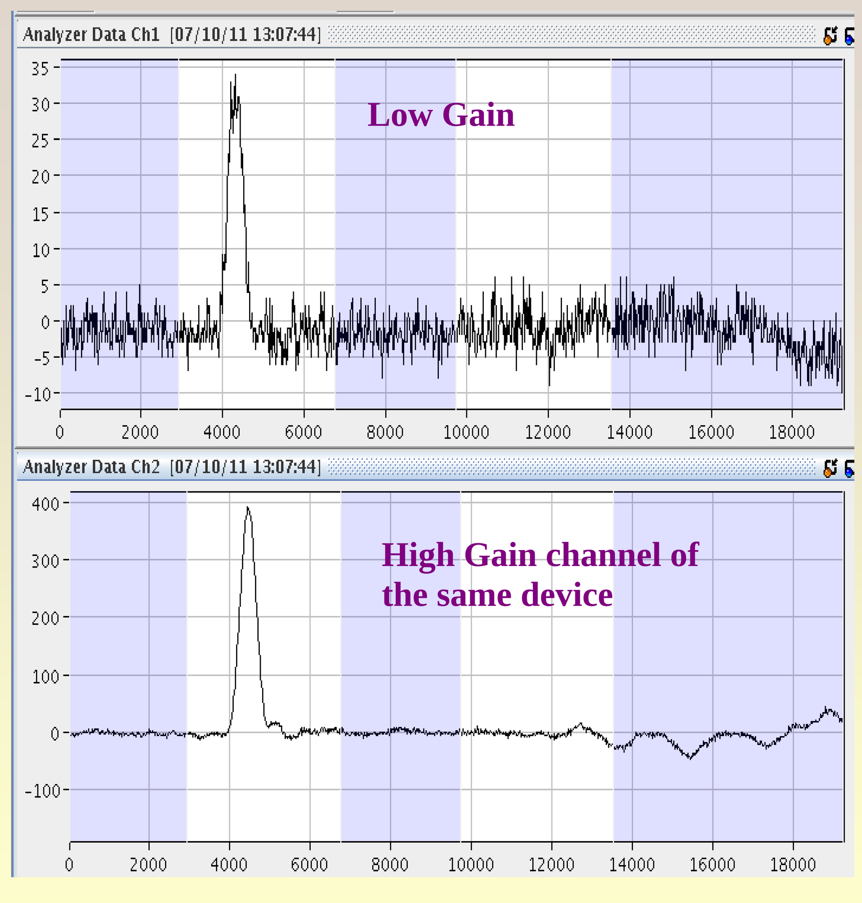
PSB Ejection; User EAST_A; Intensity 31.4 [charges 1e10]; 20dB attenuation. Note individual integration gates adjusted for the beam, the offsets and the calibration high-voltage pulse (negative)



CPS Ejection; User TOF; Intensity: 95[charges 1e10]. Note the acquisition is suffering from signal "ringing" distortion caused by sub-optimal cables, and transfer impedance mismatch.



CPS Ejection; User SFTPRO; Intensity: 2300 [charges 1e10]. Note the longer beam duration is captured using 37 ns time resolution



CPS Ejection; User I_LHC_SU; Intensity: [3.5 charges 1e10] Note noise to signal ratio difference for low intensity beam as measured by two channels of the same device.