

Fast Data Acquisition, Signal Processing and Its Integration Within Instrument Control

Paolo Mutti

ESI - 17 May 2011

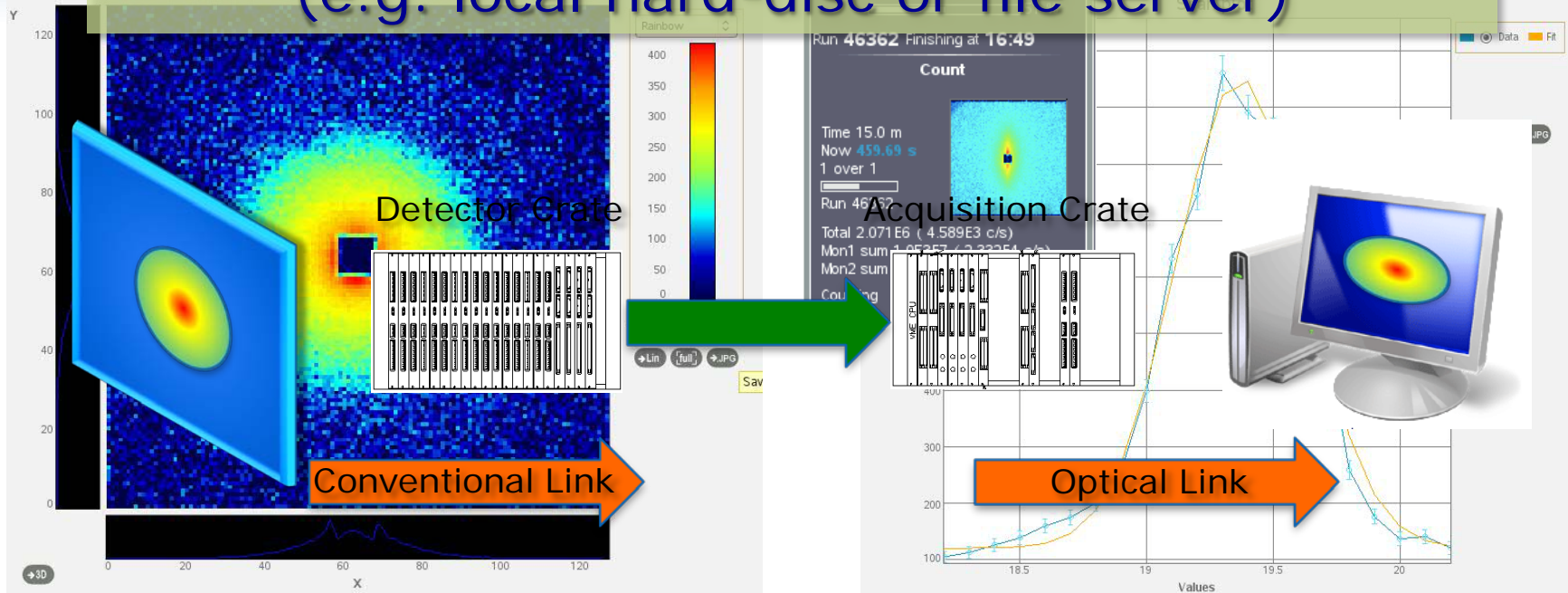
Outline

- Basics of signal detection
- Analog approach
- Digital approach
- Acquisition modes
- Integration within the sequencer

Acquisition - The Goal

Obtain a numerical or graphical representation of the events arriving at the detector

Store the data on a non volatile support (e.g. local hard-disc or file server)



Acquisition – Requirements

- Handle High Event Rate
- Minimize Dead-Time
- Accurate Timing
- High Data Throughput
- Synchronization With Other Operations

Signals

◆ Digital

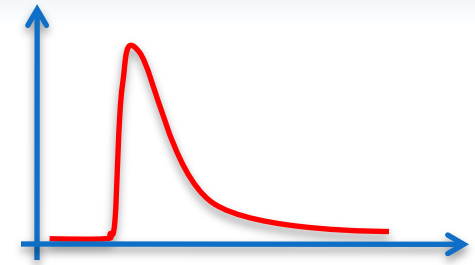
TTL:



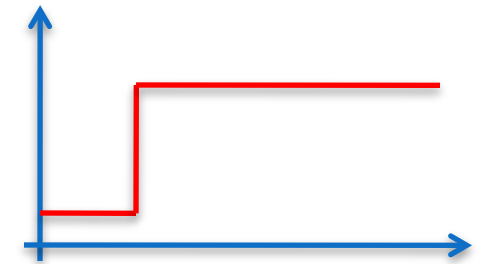
Address: 0x7f66

◆ Analog

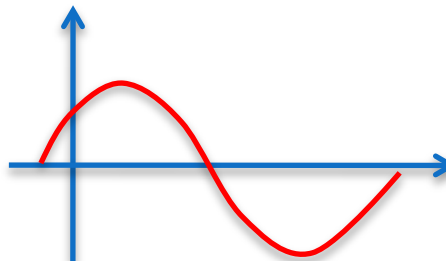
Pulse-Shape:



Current/Voltage:



Phase:



Signals' Acquisition

◆ Digital

Scalers

Digital I/O

◆ Analog

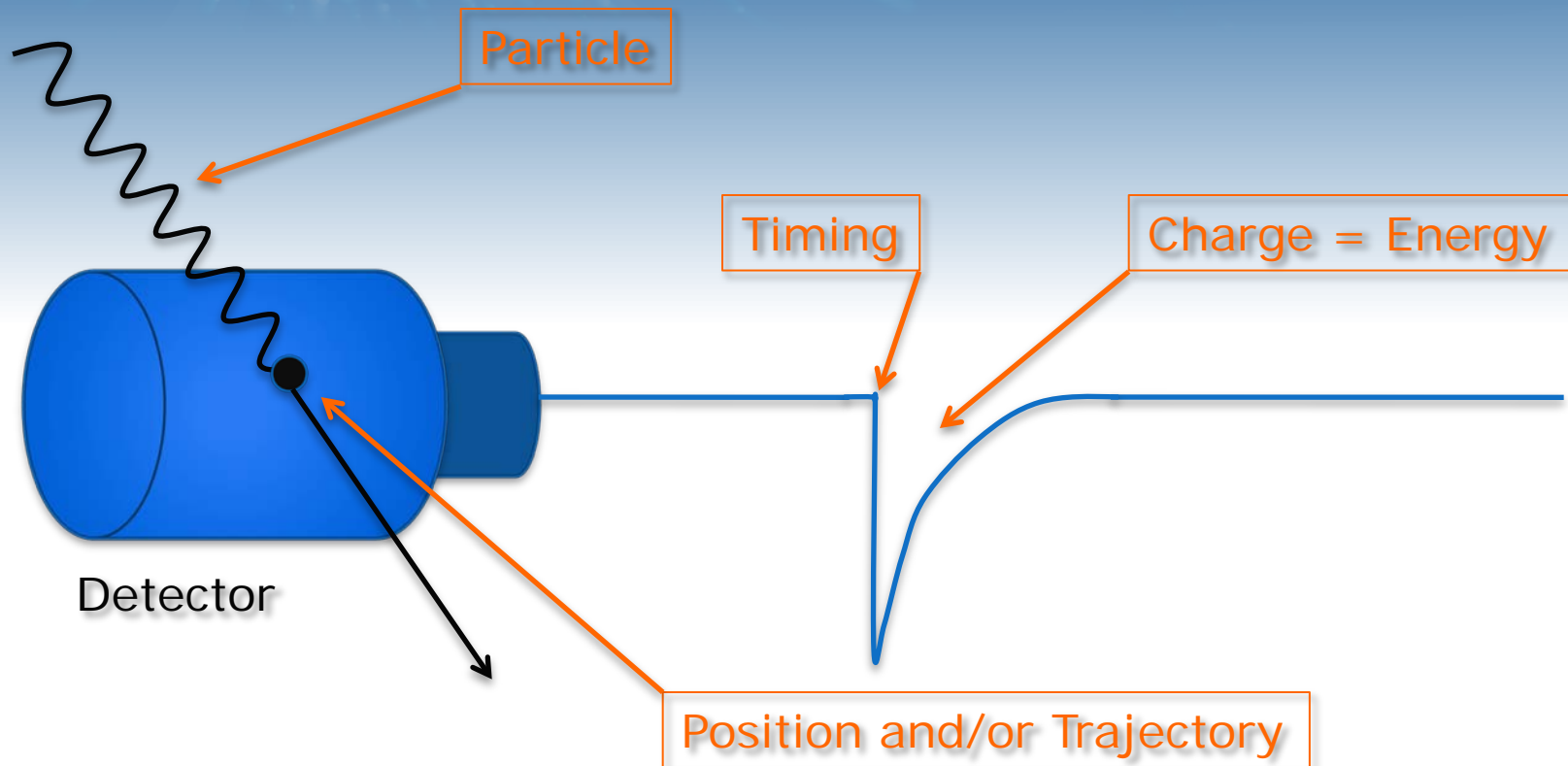
Sampling ADC

Peak-Sensing ADC

Digitizers

Multi-Channels Analyzers

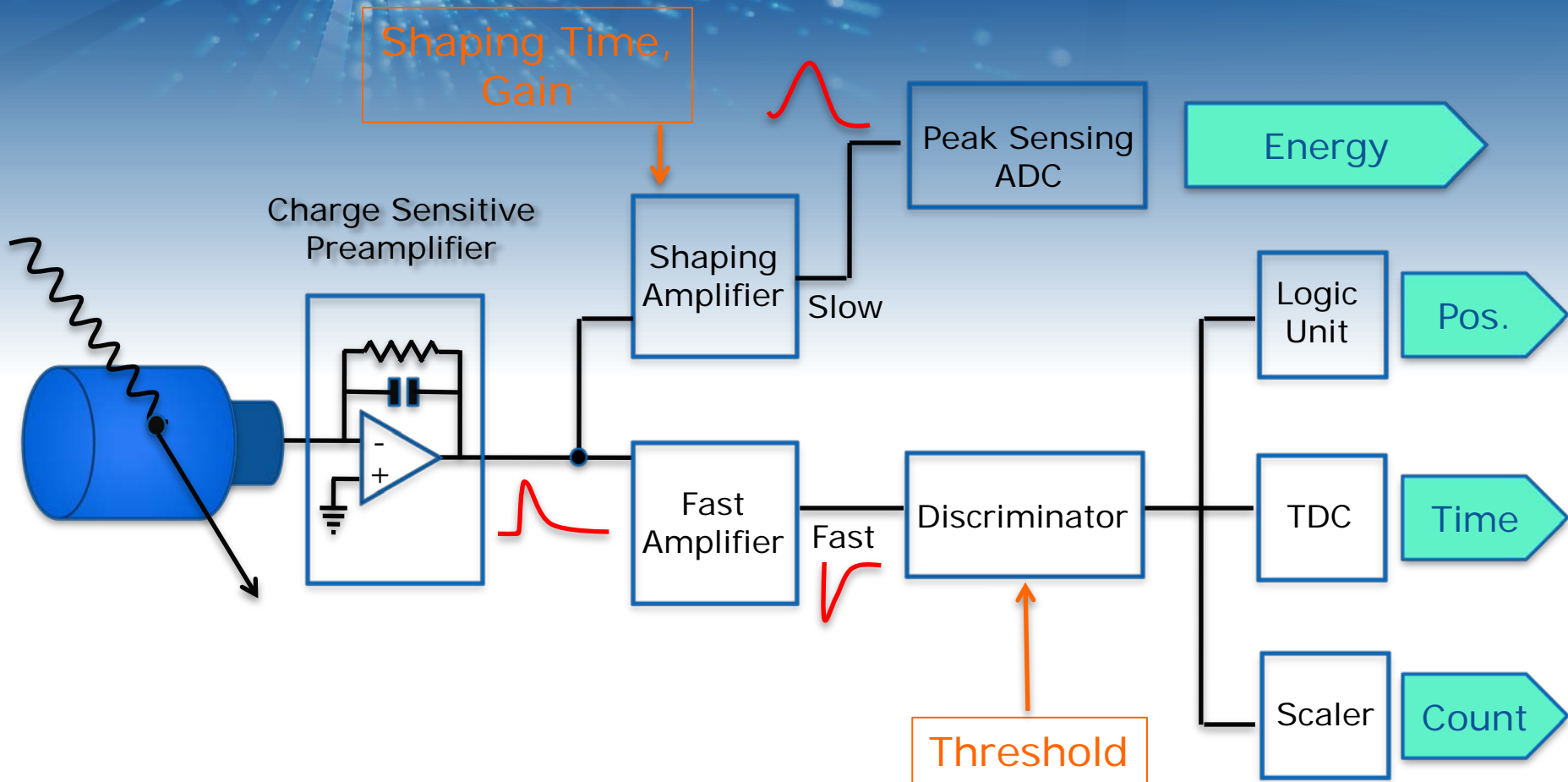
The Relevant Quantities



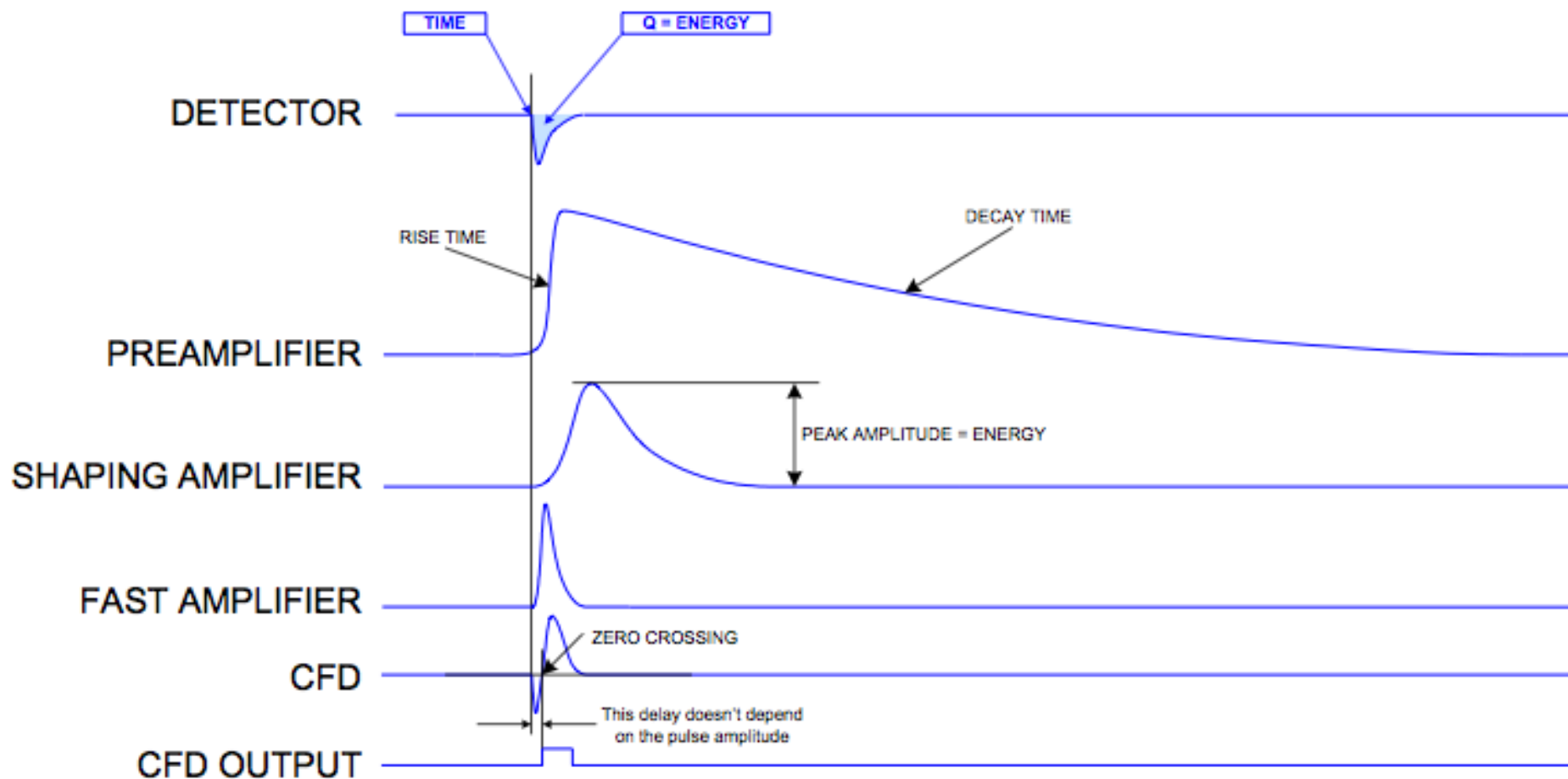
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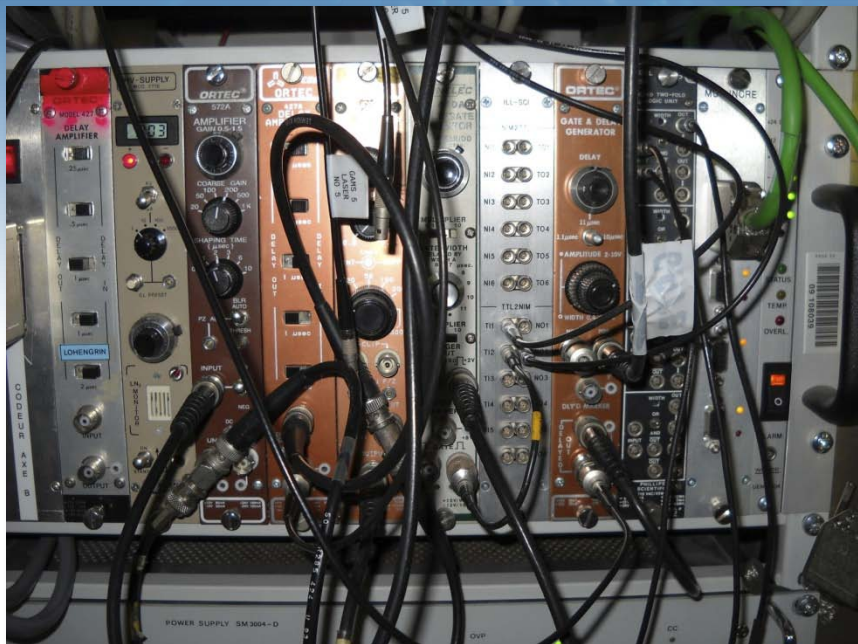
Traditional Analogue Chain



Analog Signals

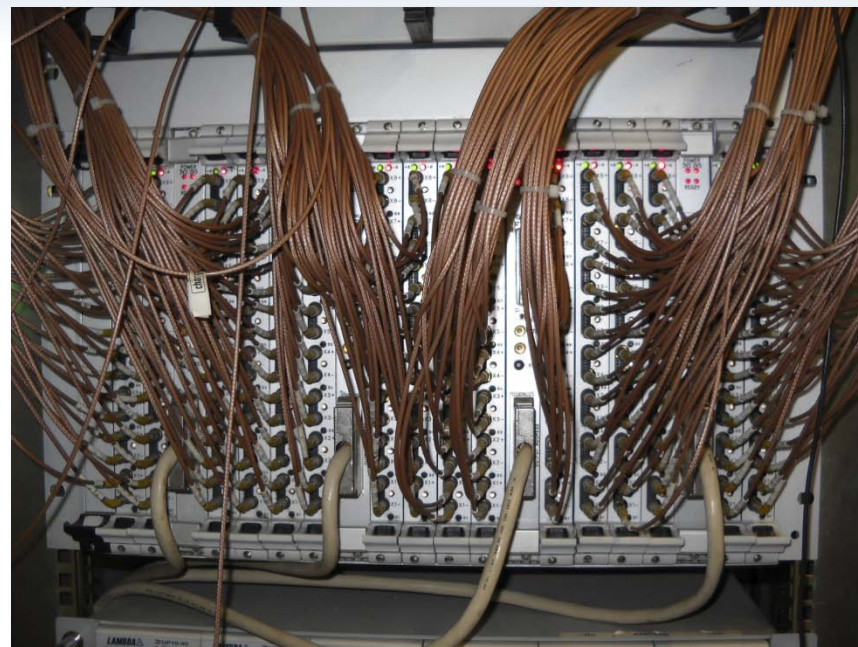


Analog Acquisition



256 x 128 pixels

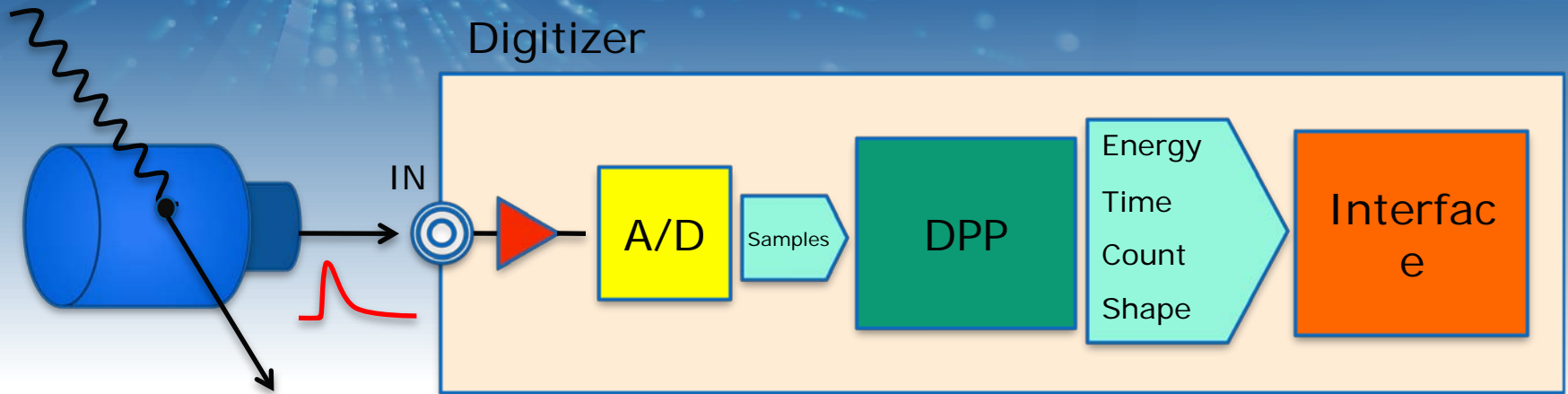
One channel energy-time



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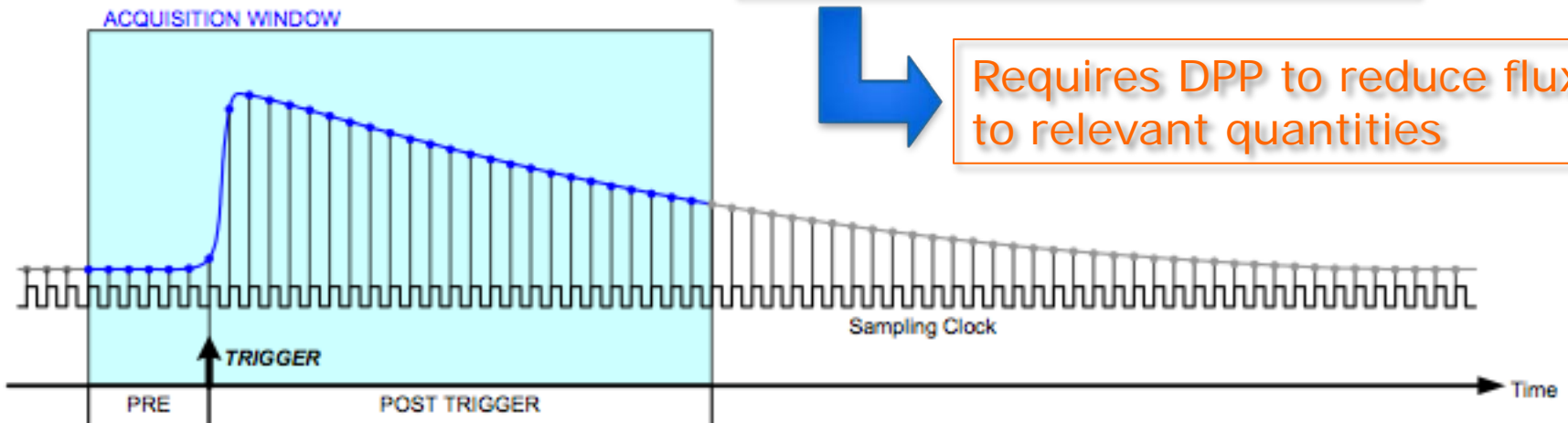
Digital Chain



Very high throughput of data

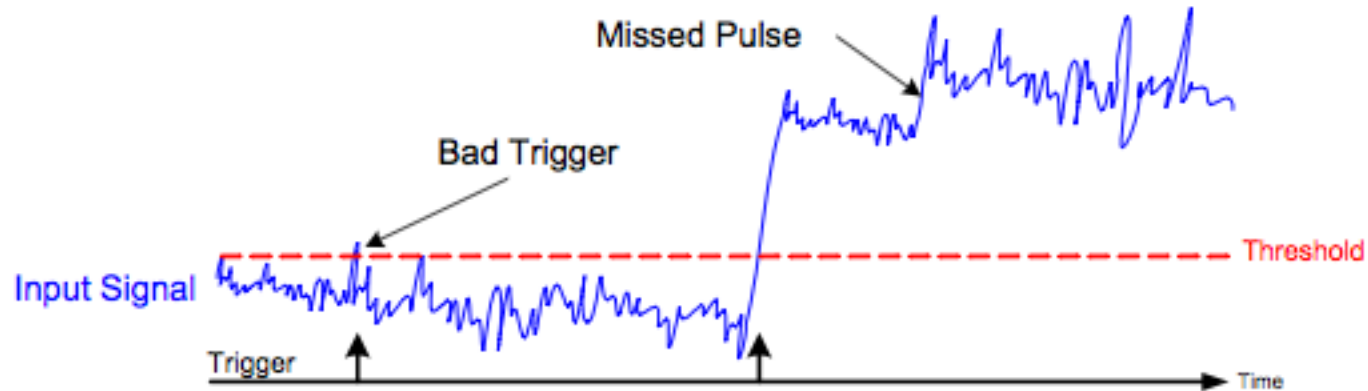


Requires DPP to reduce flux to relevant quantities



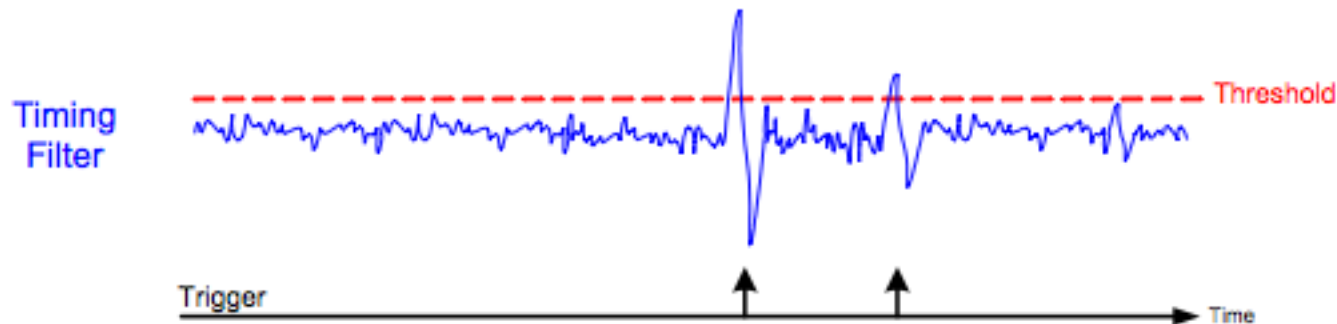
Trigger and Timing Filter

- A trigger is generated as soon as the signal cross the threshold
 - Noise and base-line variation can generate bad triggers
 - Loss of pulses due to pile-up

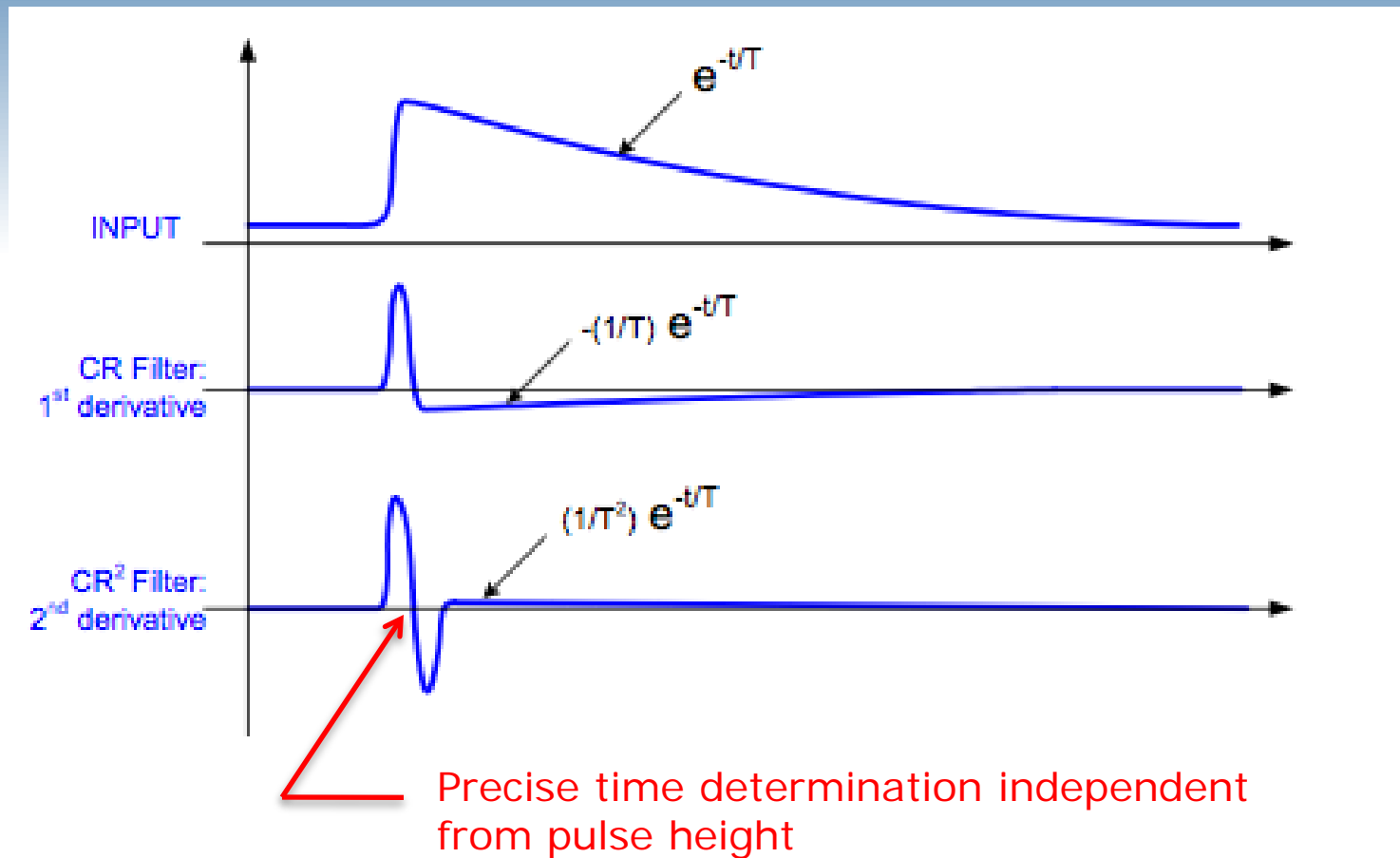


Trigger and Timing Filter

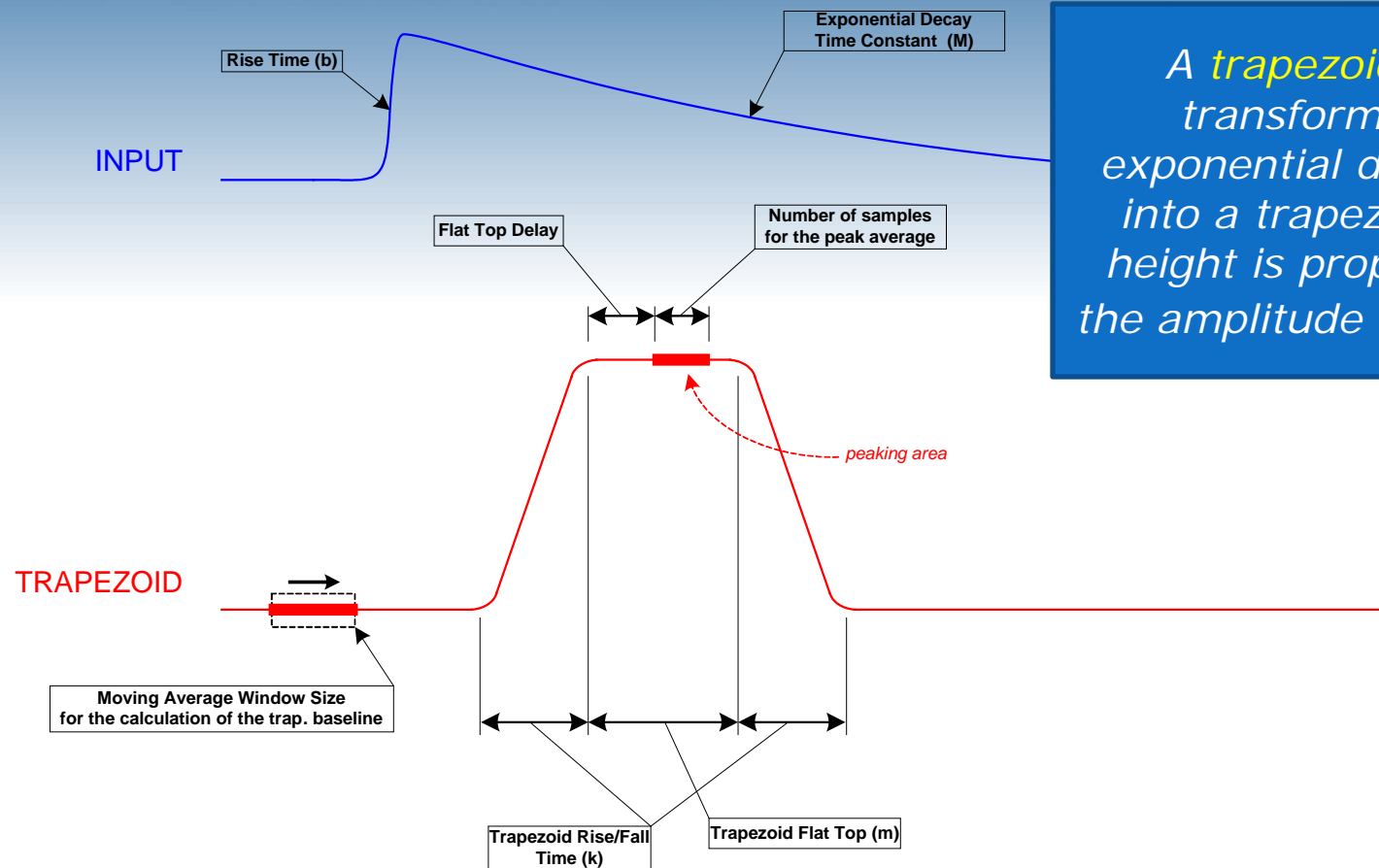
- Digital filters are able to reject the noise and restore the base-line
 - + RC filter (mean) for high frequency noise
 - + CR^N filter (derivative) for low frequency noise
 - + Transform signal in bipolar for better timing (zero crossing)



Digital Signals

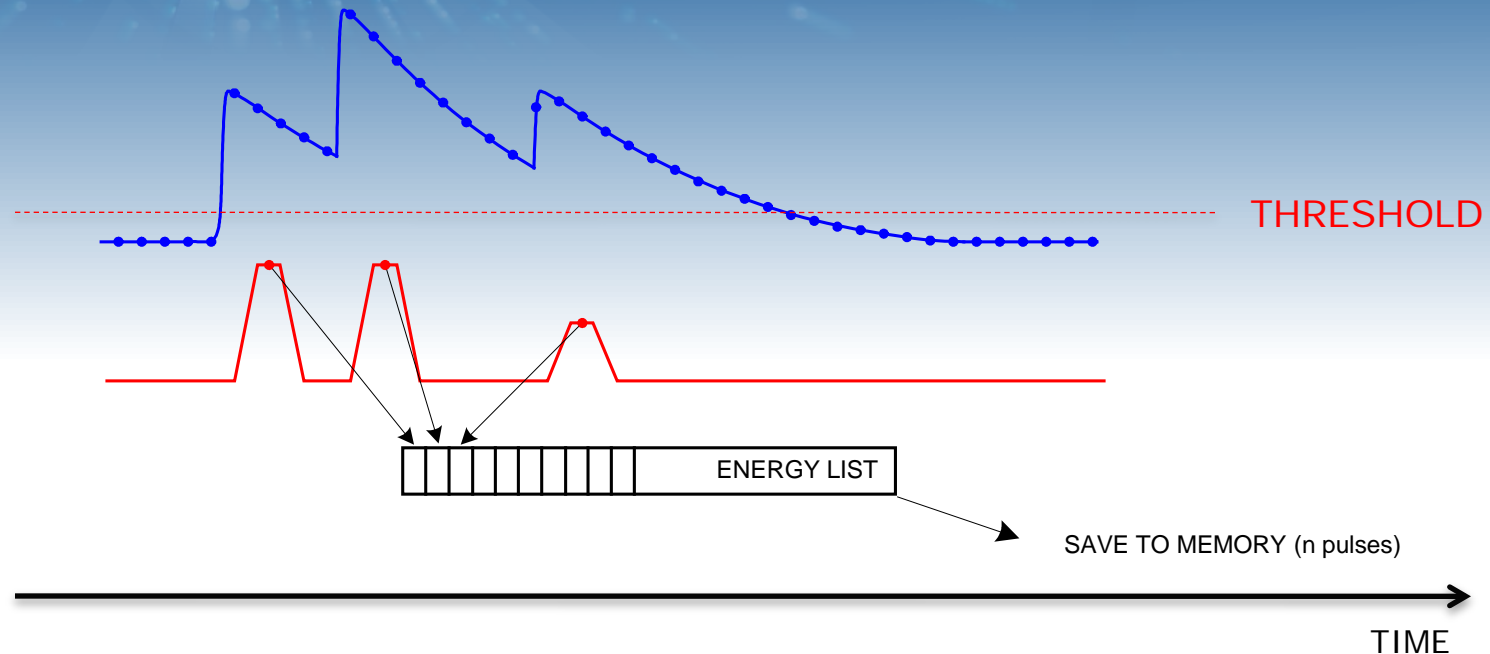


Pulse Height Analysis



A *trapezoidal filter* transform typical exponential decay signal into a trapezoid whose height is proportional to the amplitude of the pulse

Reduced Pile-Up

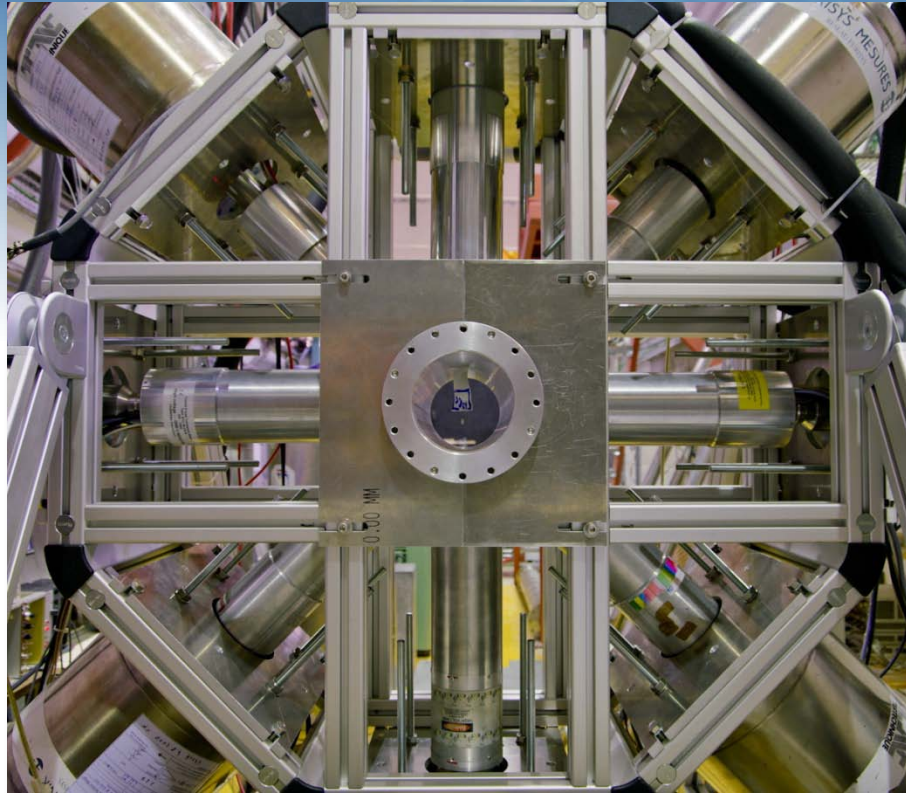


Classical approach would count only one pulse



Digital approach separates pulses as far as trapezoids do not overlap

Digital Acquisition



Detection System



Acquisition System

A/D Comparison

ADVANTAGES

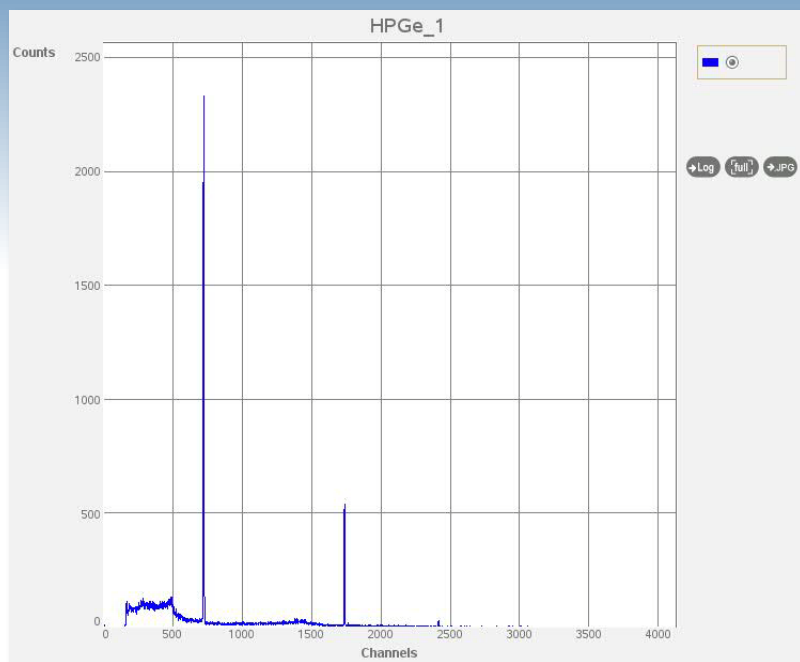
- ✖ One single board can do energy, timing and pulse shape analysis.
- ✖ Low cost per channel and reliability.
- ✖ Low dead-time in the acquisition.
- ✖ Synchronization and correlation among several channels (coincidence).
- ✖ All in FPGA, flexibility in tuning and calibration.

DISADVANTAGES

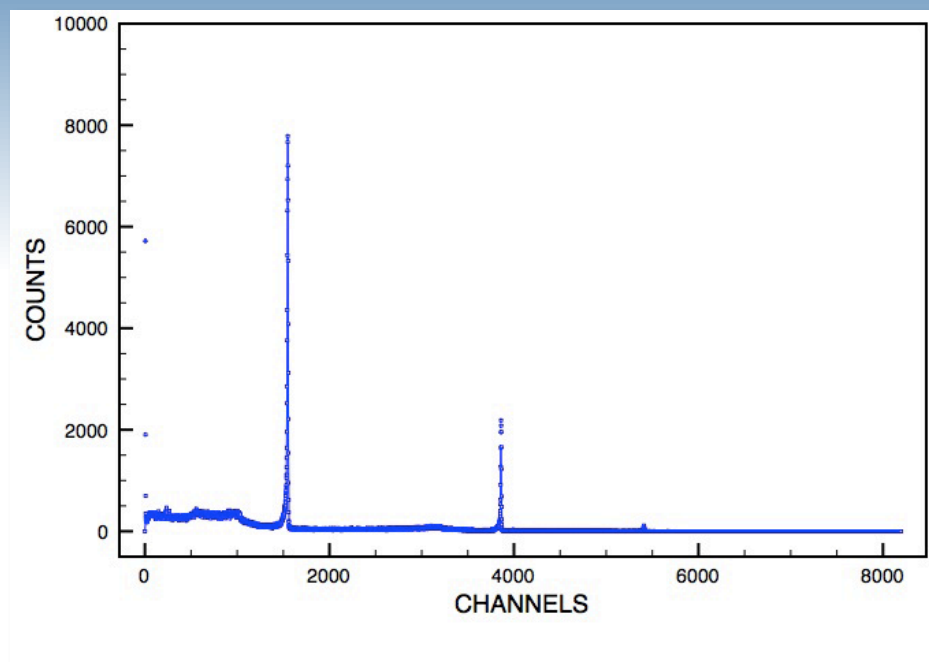
- ✖ Setting up the system requires time and a knowledge of the relevant parameters.
- ✖ Loss of resolution with fast signals. We are limited by the bit number and sampling rate.

A/D Comparison

NA SOURCE (511 + 1274 KEV GAMMAS)



12 bit resolution
2300 counts/sec



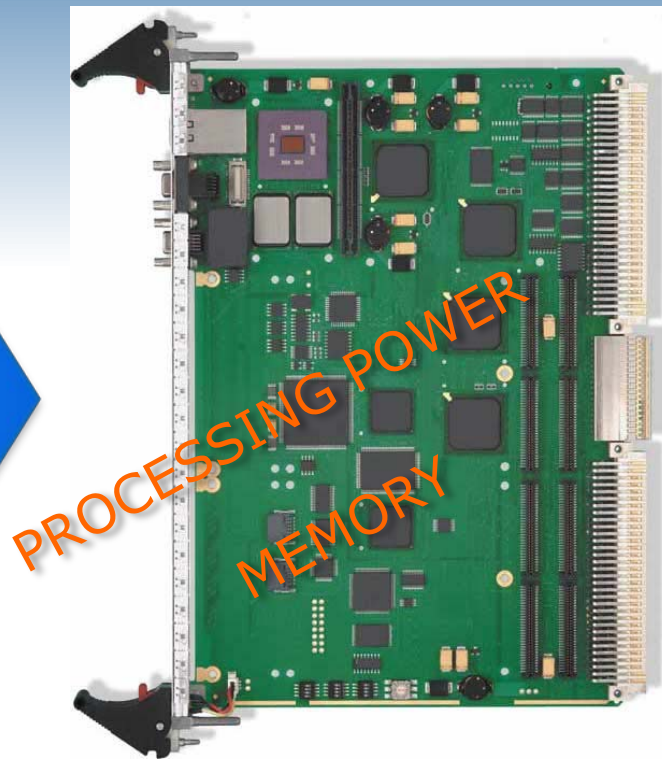
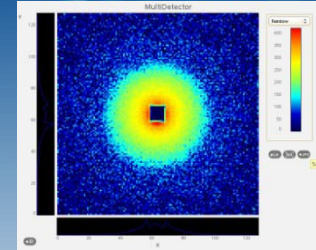
14 bit resolution
3400 counts/sec

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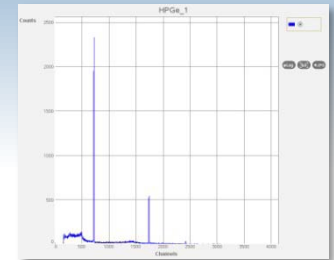
The Acquisition Card

PowerPC VME based cards using PMC or MFCC modules for multi-detector acquisition



RAW DATA
FROM
DETECTOR

LIVE
DISPLAY



STORAGE

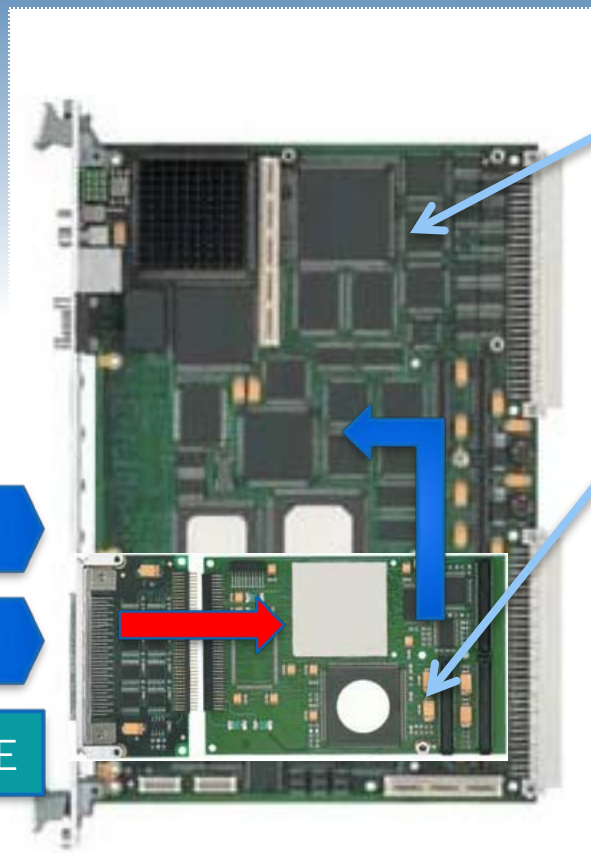


Its main role is to rearrange the data according to the user's need before the final storage

Requirements

- Total event rate up to 5 *MHz* per MFCC (Digital)
- Event rate up to 1 *MHz* (Analog)
- 20 different acquisition modes
- 100 *ns* up to 100 *ms* channel width in ToF mode
- 10 μ *s* up to 100 *s* channel width in Kinetic mode
- 40 *ms* dead time between consecutive acquisitions
- List-mode storage with no additional dead-time

The RIO2 Family



- Motherboard: RIO2 - 8062
- Clock: 400 MHz
- Memory: 32 Mb
- PMC: GPIO 8405

DATA

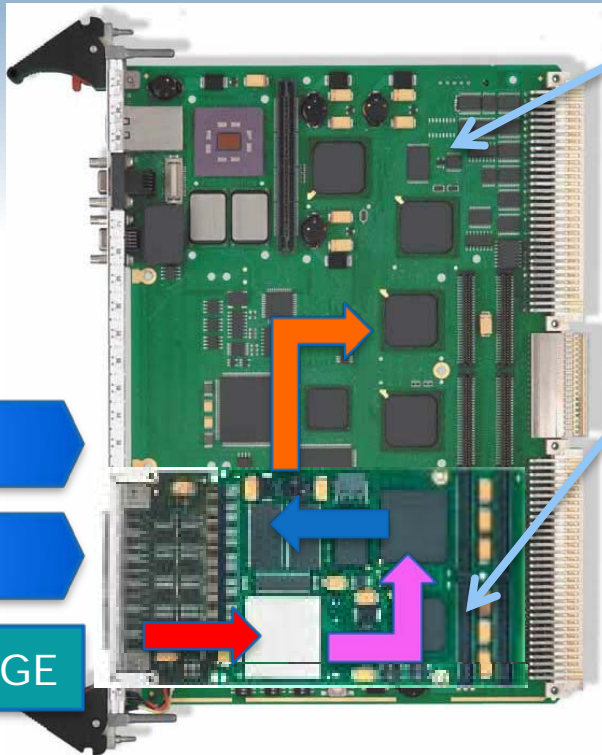
STROBE

ACKNOWLEDGE

Data from detector

Readout from FIFO
(PCI) and storage
in RAM

The RIO3 Family



- Motherboard: RIO3 - 8064
- Clock: 400 MHz
- Memory: 256 Mb
- PMC: MFCC 8443 (128 Mb)

DATA

STROBE

ACKNOWLEDGE

-  Data from detector
-  Transfer FIFO -> cache
-  Transfer cache -> RAM
-  DMA MFCC -> RIO3

Acquisition Modes

- Simple Count

Simple image of the detector, with or without a pixel binning mask

- Time-of-Flight

Events are arranged as a function of the travel time from the source to the detector in channels from 100ns to 100ms

- Kinetic

Events are arranged as a f of time from an initial TOP in channels from 100ms to 100s

- ToF - Kinetic

For each Kinetic time slice the events are arranged in ToF

- ToF - Extern

Events are arranged in ToF and a number of slices are generated by an external signal

- Doppler

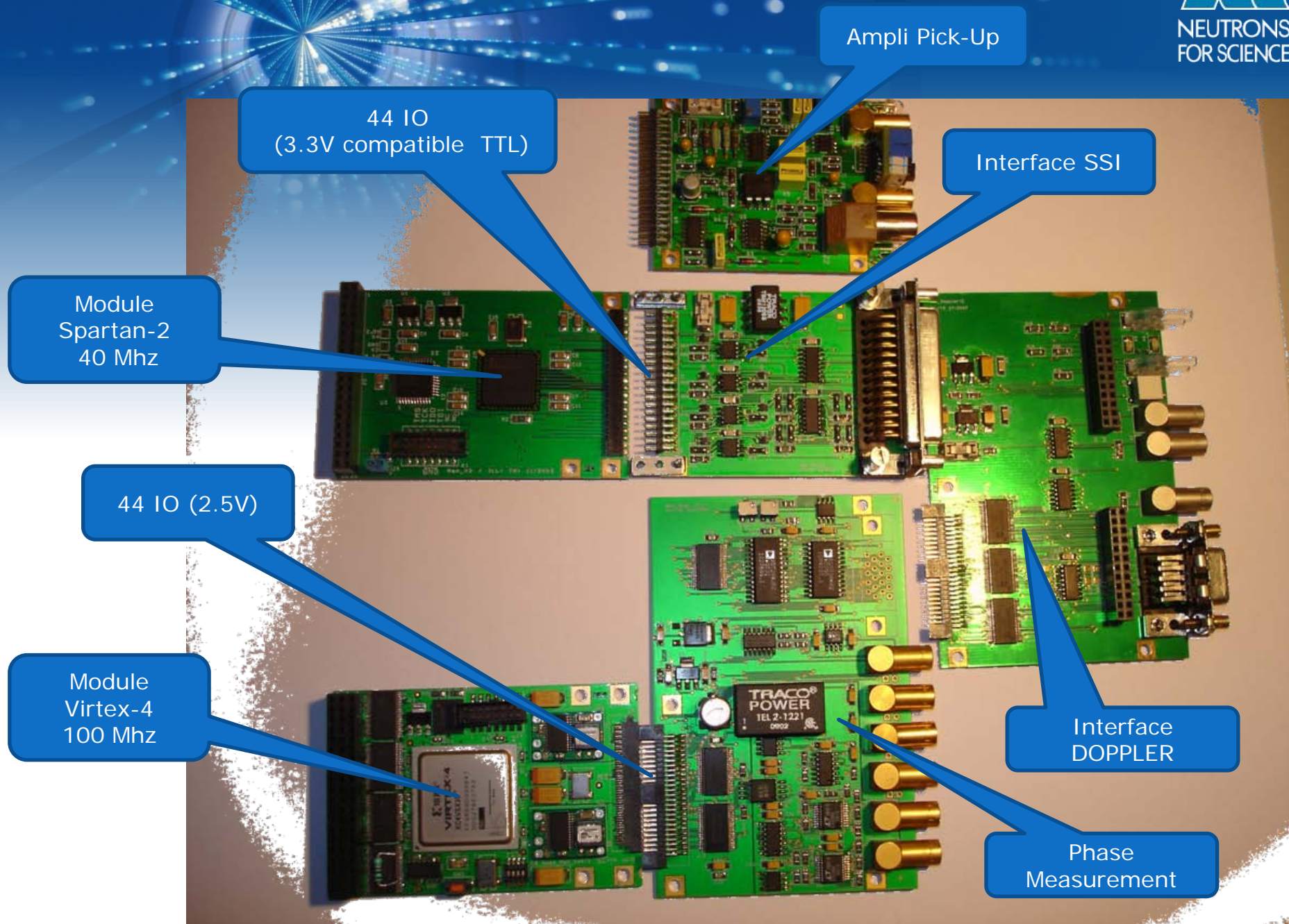
Events are arranged in speed slices according to the information delivered by the Doppler drive

- Energy

Acquires energy spectra from peak-sensing ADCs

- DPP

Full digital acquisition, energy and time are recorded in list-mode



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Digitizer Tuning

Nomad

File Edit View Hardware Command Help

Hardware Settings

Devices

- Bit3_617_1
 - A201st [ch. 3]
 - Rio2Acq_H [ch. 5]
 - Rio3DPP_H [ch. 6]**

Rio3DPP_H

Global parameters

Version 6.41b

Nb. of channels

Listmode size Events

☐ List Mode ☐ Inverse polarity

ADC resolution ☐ Scope mode

Plot

Post trigger samples %

Input DC offset %

Histogram

Signals

Channel parameters

Active channel

Threshold ch

Rise time ns

Decay time ns

Average window

Baseline average

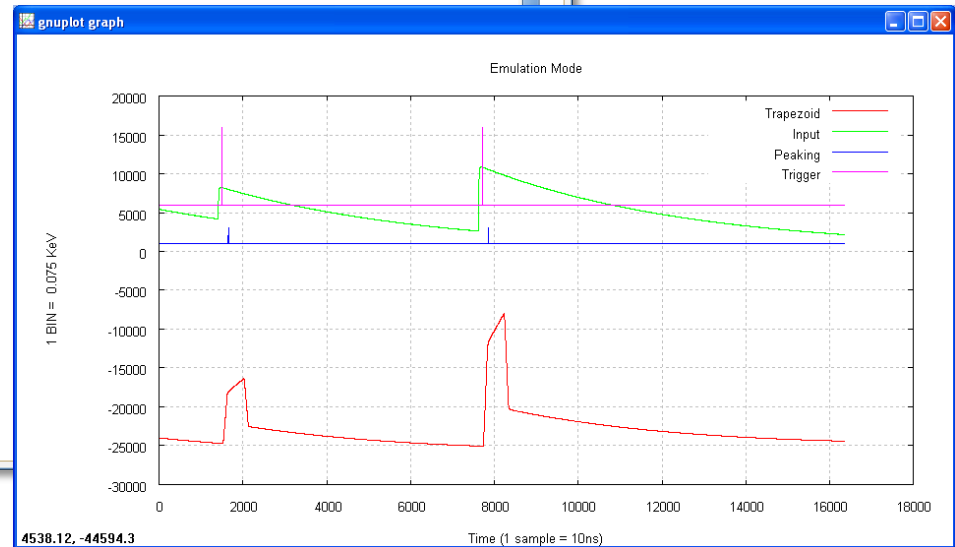
Peak average

Trapezoid rise/decay ns

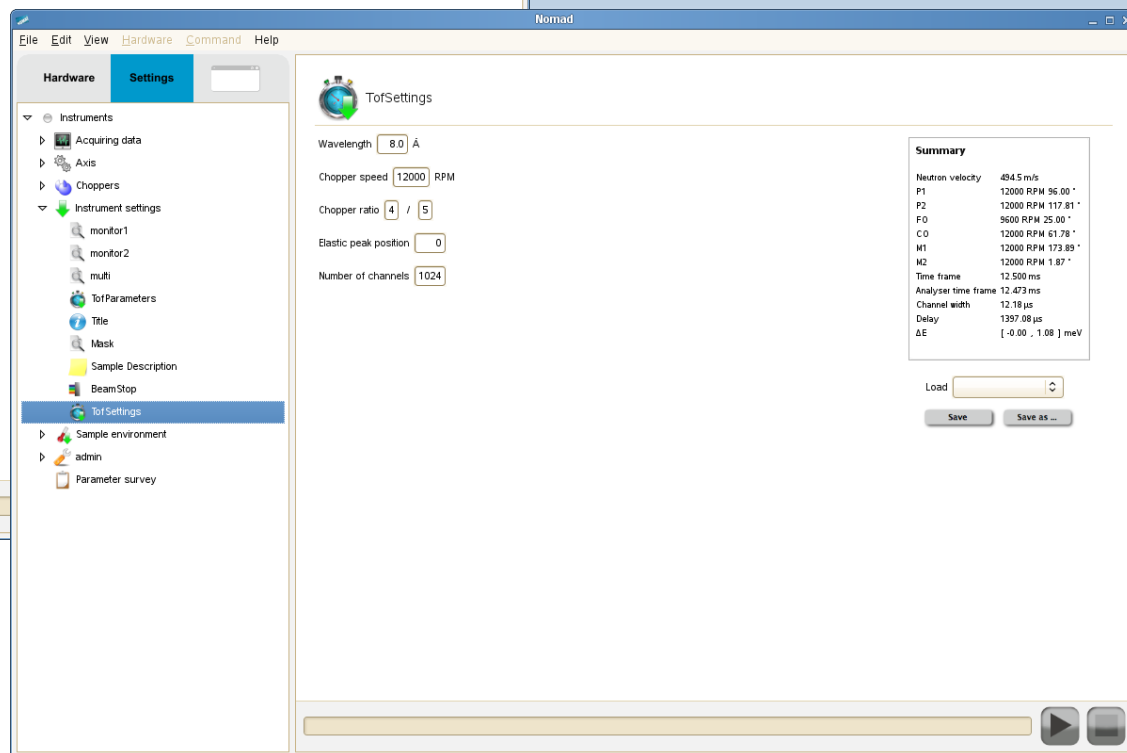
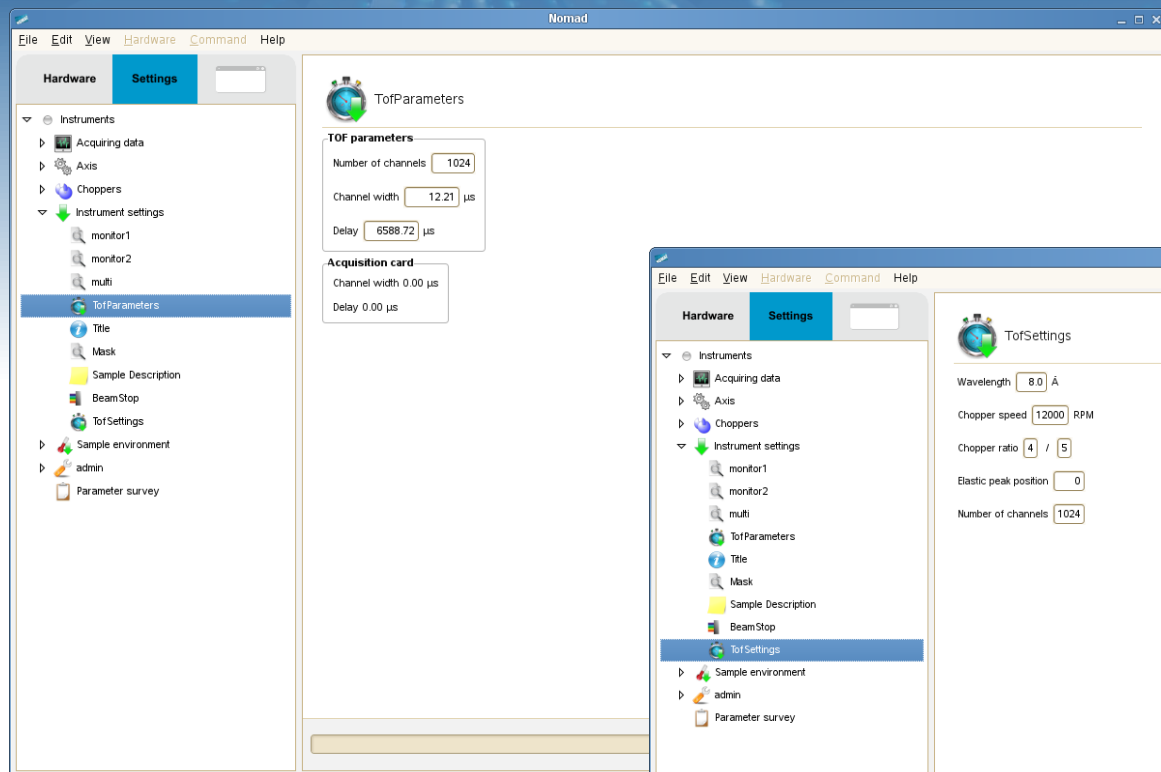
Trapezoid flat top ns

Flat top delay ns

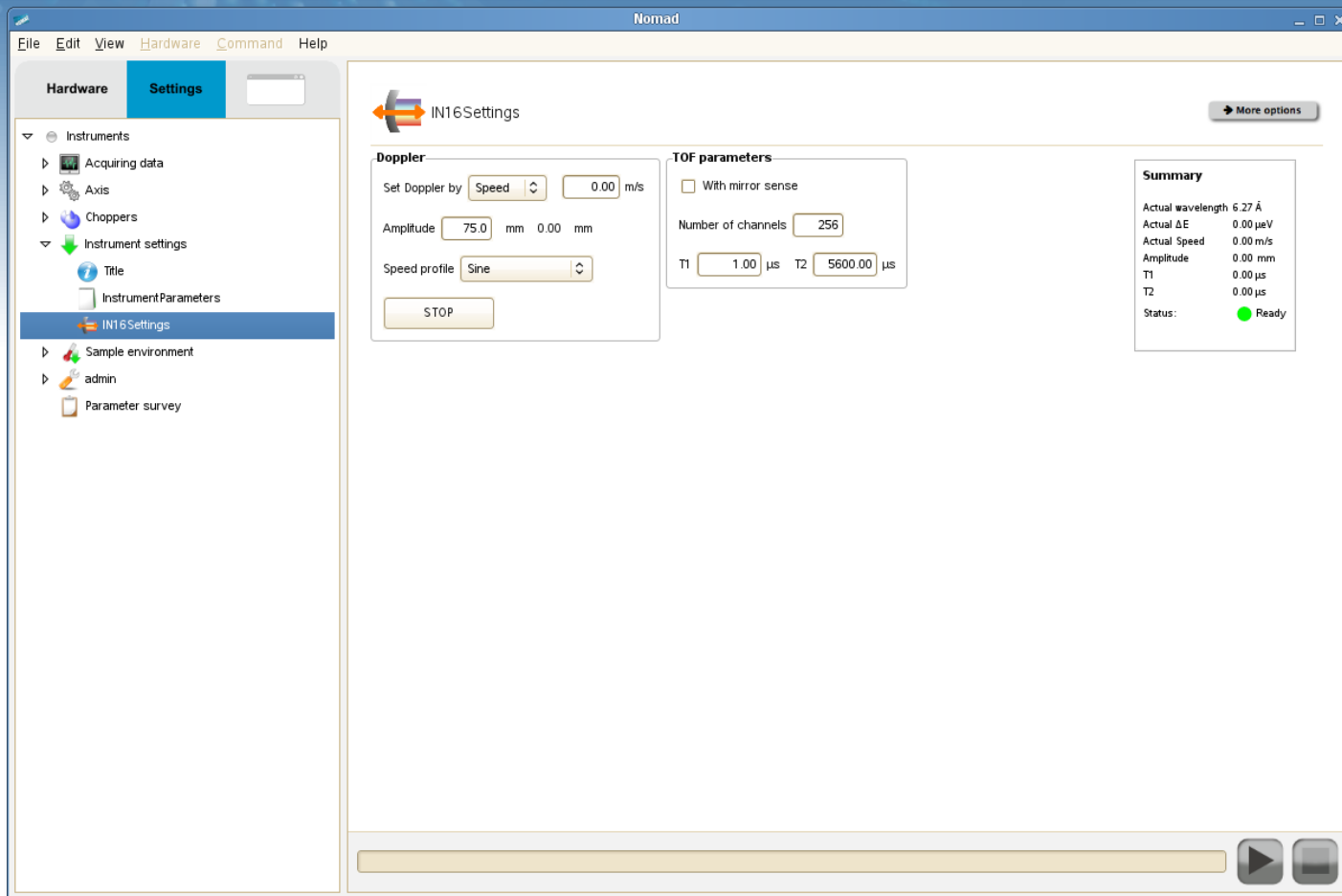
Sampling time ns



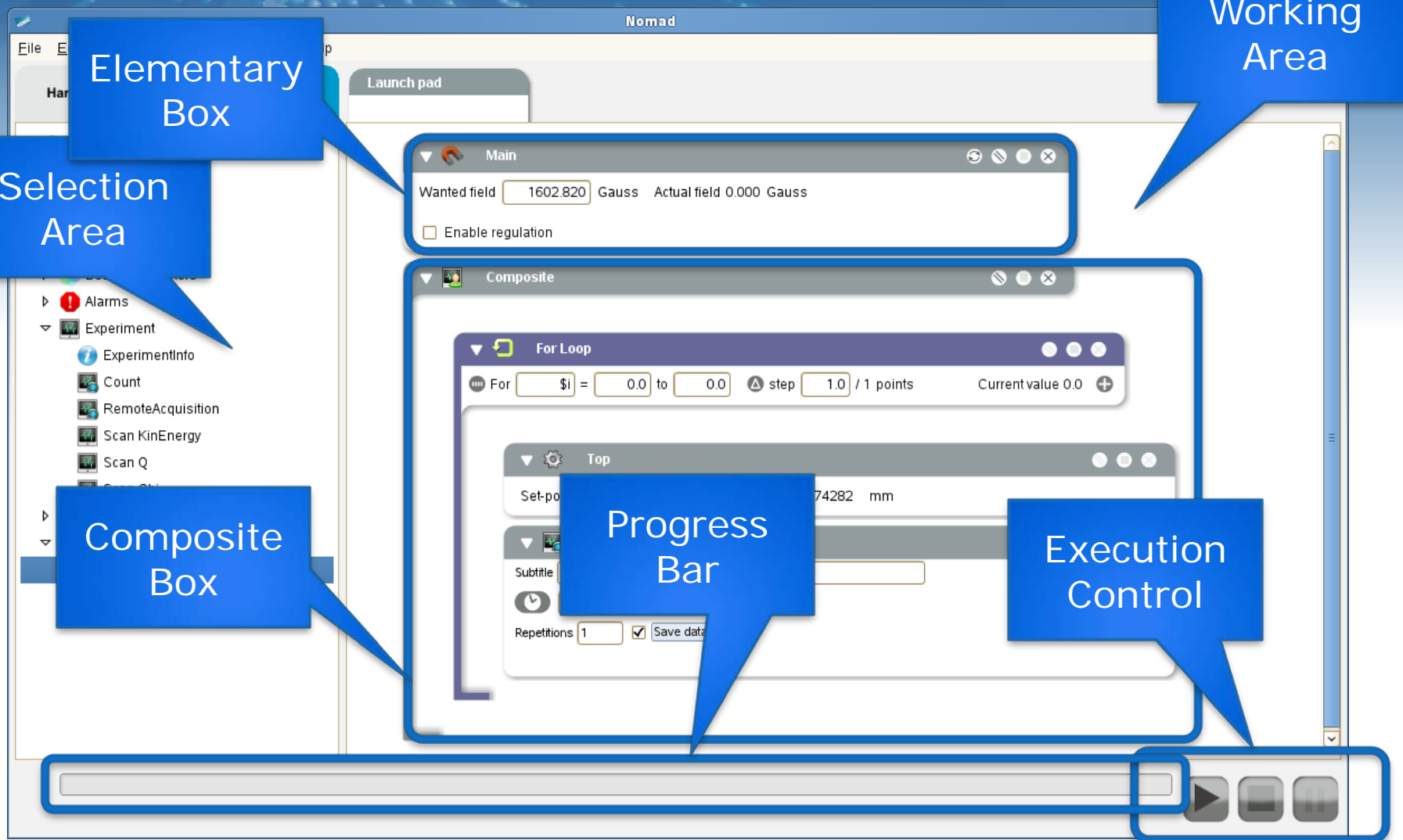
ToF Tuning



Doppler Tuning



A Graphical Control



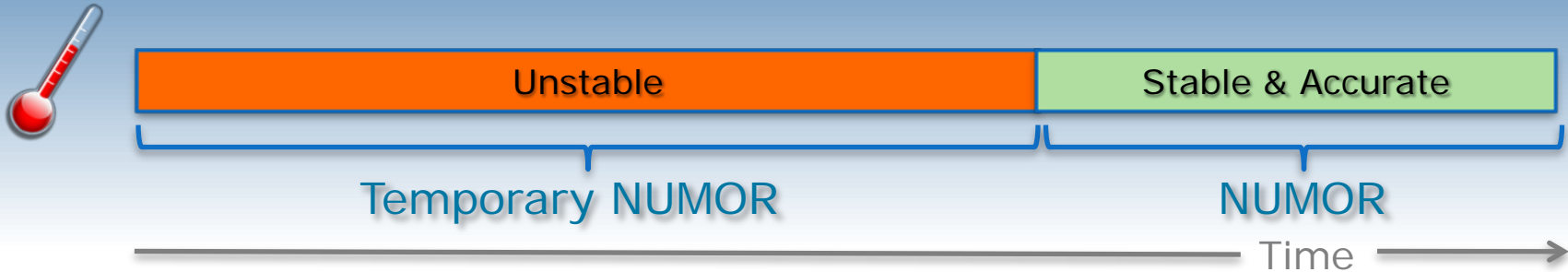
The image shows a screenshot of the Nomad graphical control interface. The interface is divided into several sections, each highlighted by a blue callout box:

- Elementary Box:** Points to the 'Main' control window, which displays 'Wanted field 1602.820 Gauss' and 'Actual field 0.000 Gauss', along with an 'Enable regulation' checkbox.
- Selection Area:** Points to the left sidebar containing a tree view of the experiment structure, including 'Alarms', 'Experiment', 'ExperimentInfo', 'Count', 'RemoteAcquisition', 'Scan KinEnergy', and 'Scan Q'.
- Composite Box:** Points to the 'Composite' control window, which contains a 'For Loop' control element.
- Progress Bar:** Points to the 'Top' control window, which displays 'Set-point 74282 mm' and a progress bar.
- Execution Control:** Points to the 'Execution Control' window, which displays 'Repetitions 1' and a 'Save data' checkbox.
- Working Area:** Points to the main workspace area where the control elements are displayed.

The interface also features a 'Launch pad' button at the top left and a status bar at the bottom with a play button and other controls.

Software – Hardware Integration

● Temperature Watchdog



● Double Buffering

- Reduce the dead-time between successive acquisitions
- Allow high data throughput from acquisition electronics to the final storage
- Necessary for list-mode (up to 1Tb per day)

Summary

- ◆ Comparison between analog and digital acquisitions. Which is the best?
- ◆ Examples of ILL's acquisitions
- ◆ Implementation of acquisition functionalities within the control software

Thanks for your attention