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

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ESI - 17 May 2011

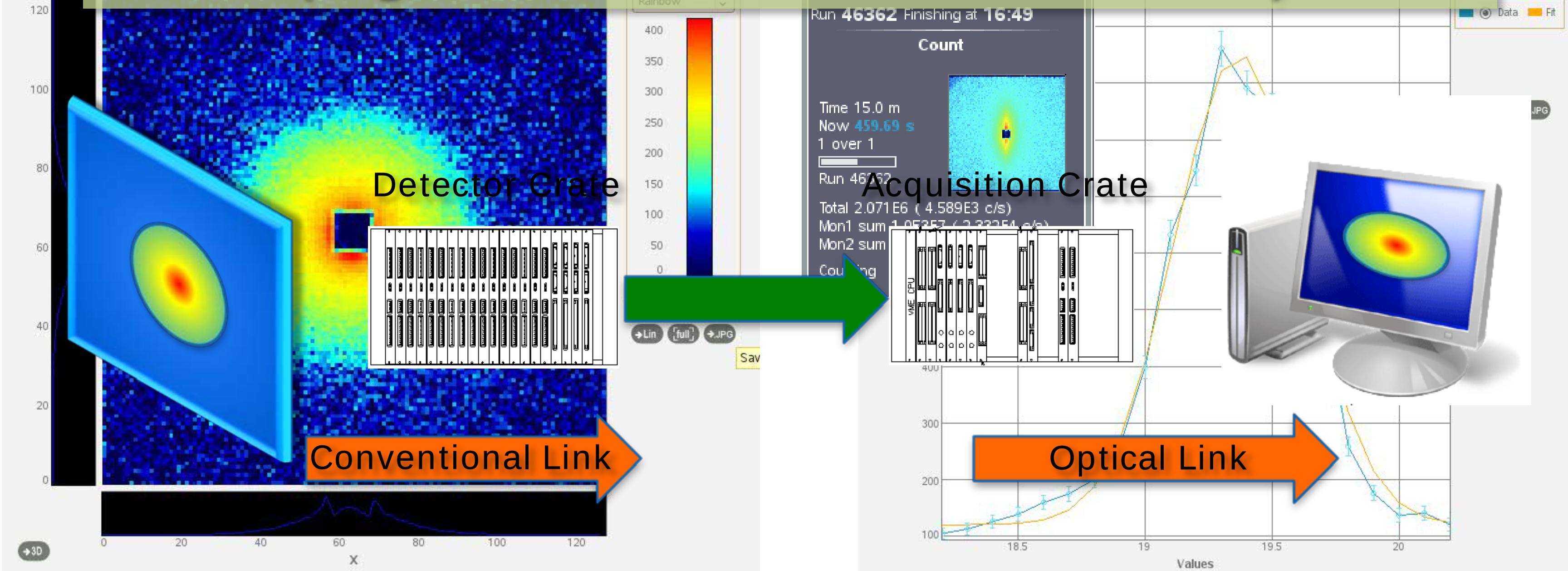
Outline

- 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

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

Signals

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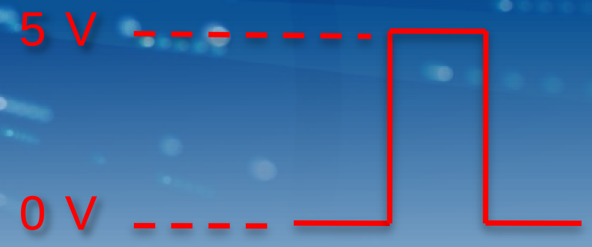
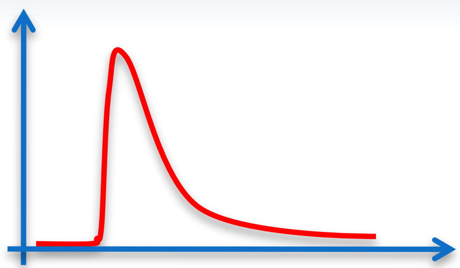
- **Digital**
  - **TTL:**

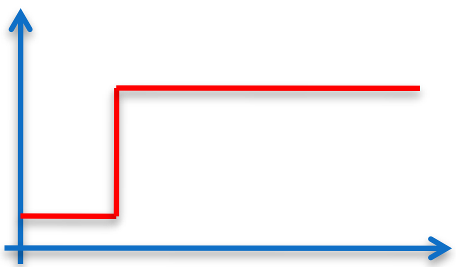


  - **Address:** 0x7f66

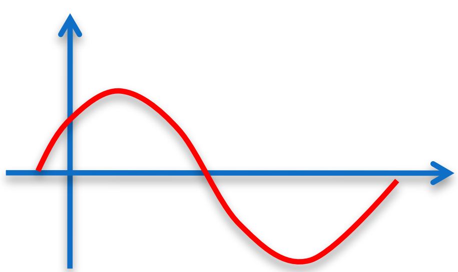
- **Analog**
  - **Pulse-Shape:**



  - **Current/Voltage:**



  - **Phase:**



Signals' Acquisition

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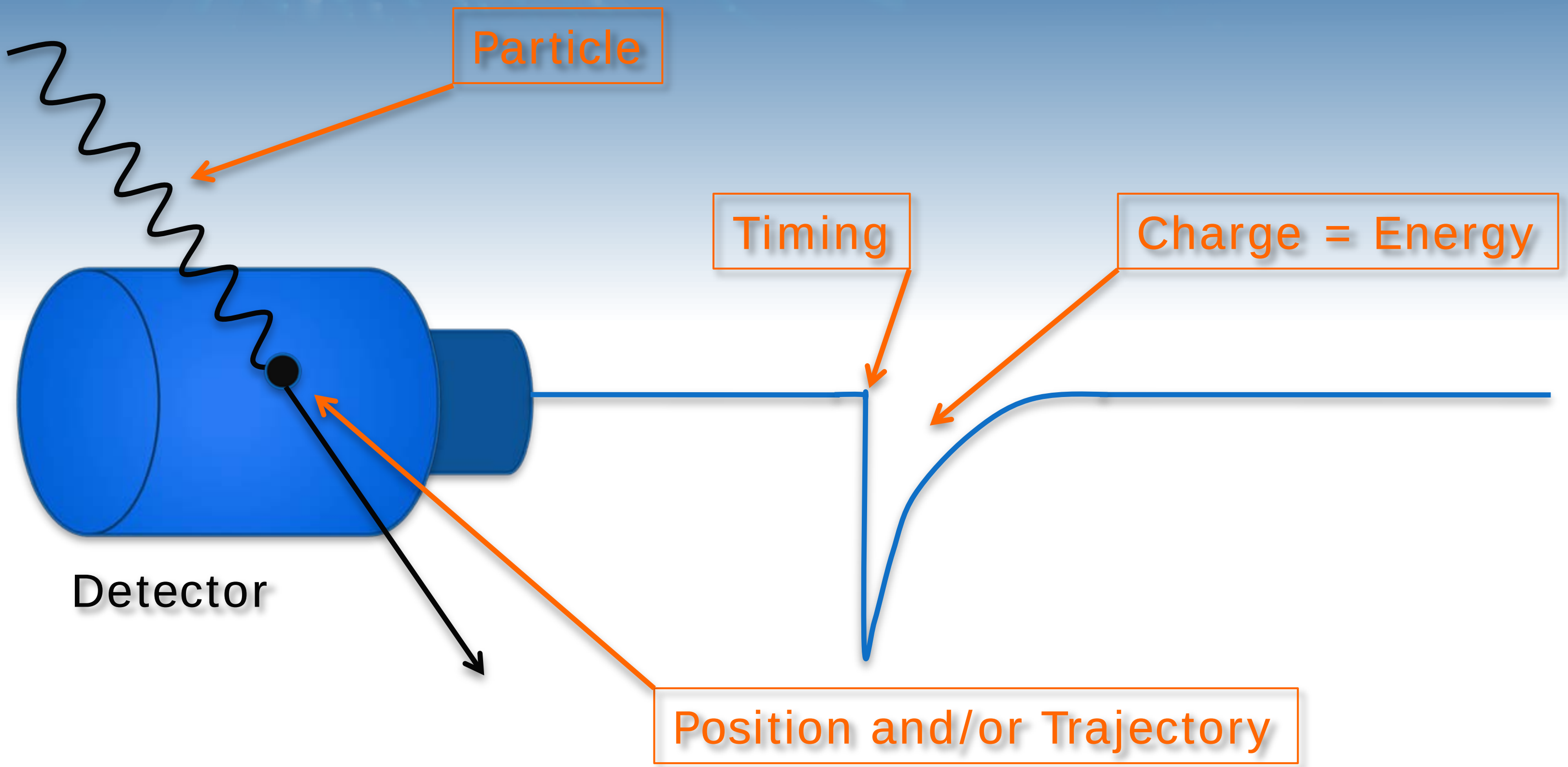
- **Digital**
  - Scalers
  - Digital I/O

- **Analog**
  - Sampling ADC
  - Peak-Sensing ADC
  - Digitizers
  - Multi-Channels Analyzers

The Relevant Quantities



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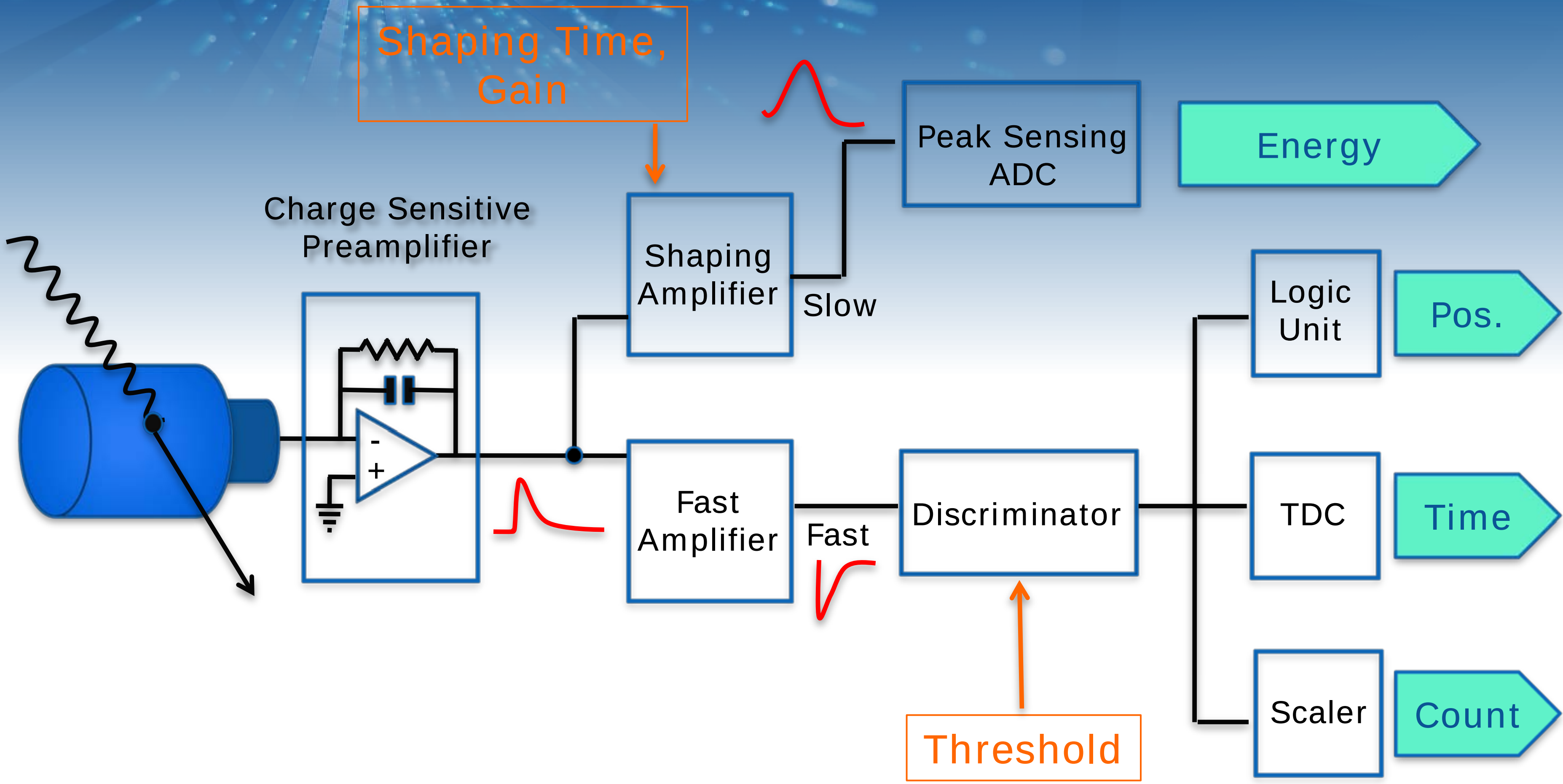
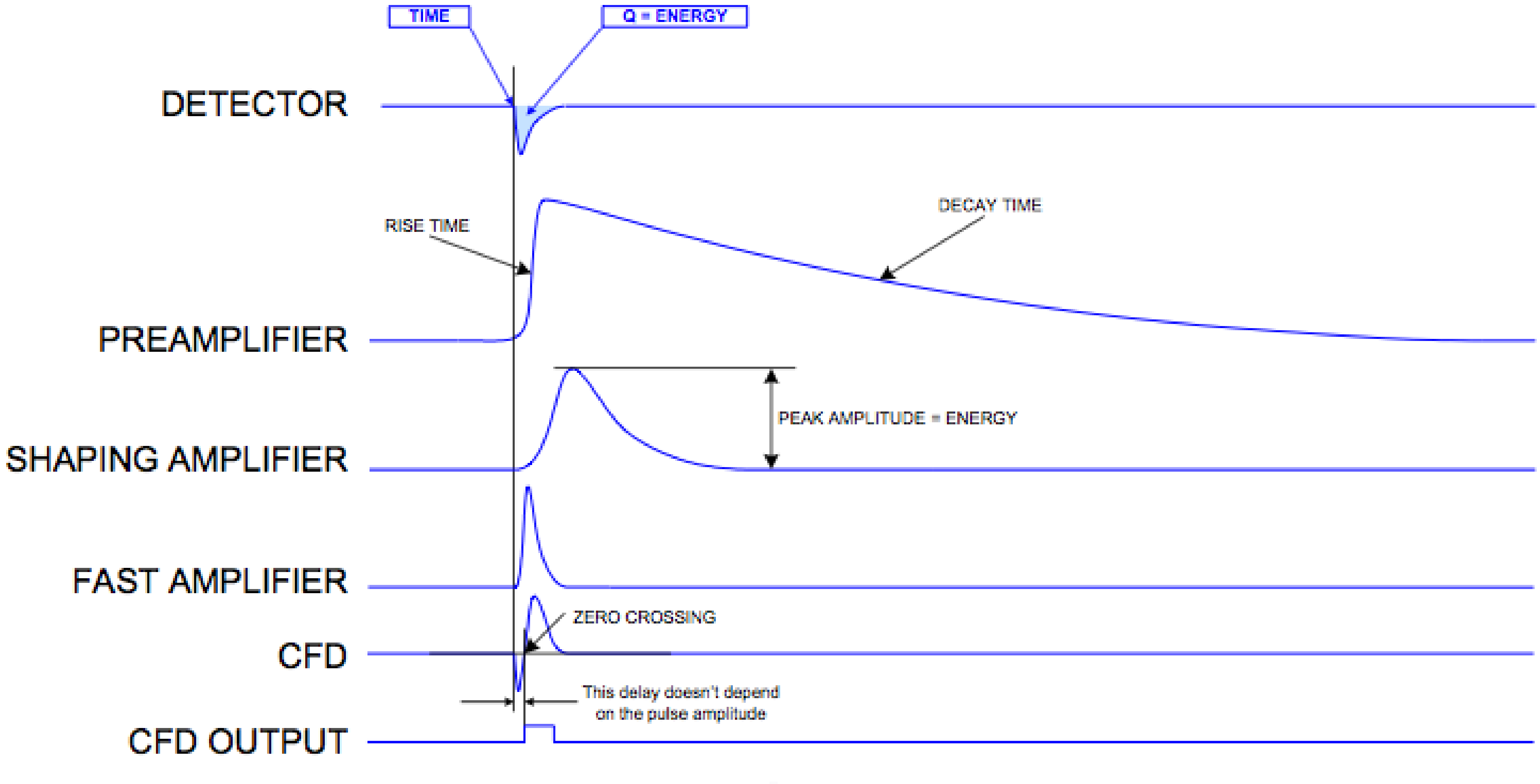
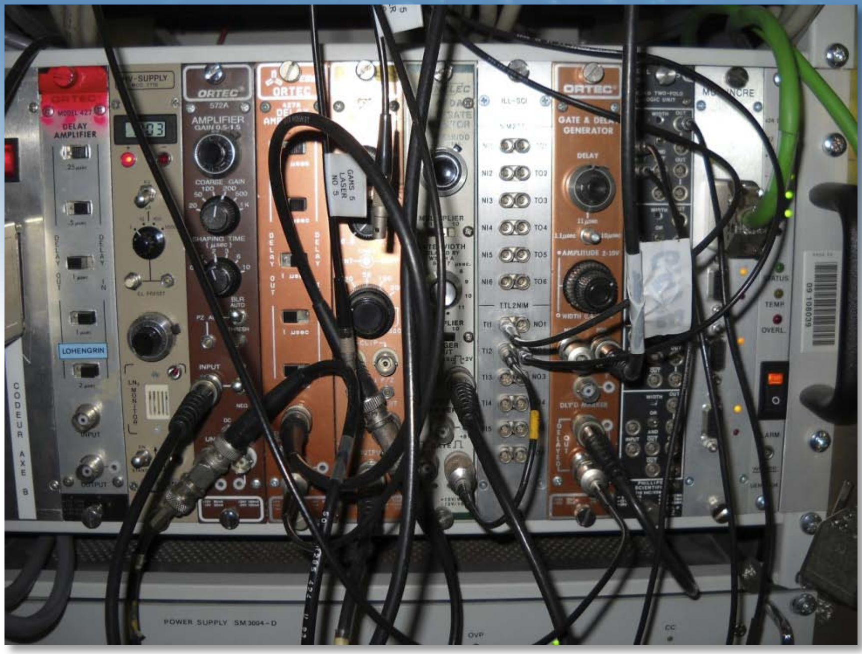
Traditional Analogue Chain



Analog Signals

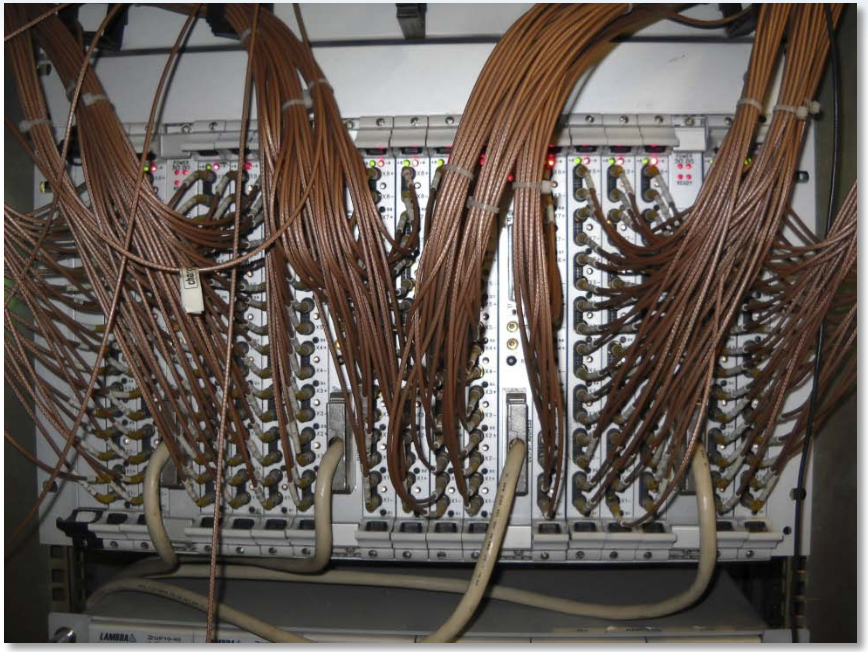


Analog Acquisition



One channel energy-time

256 x 128 pixels



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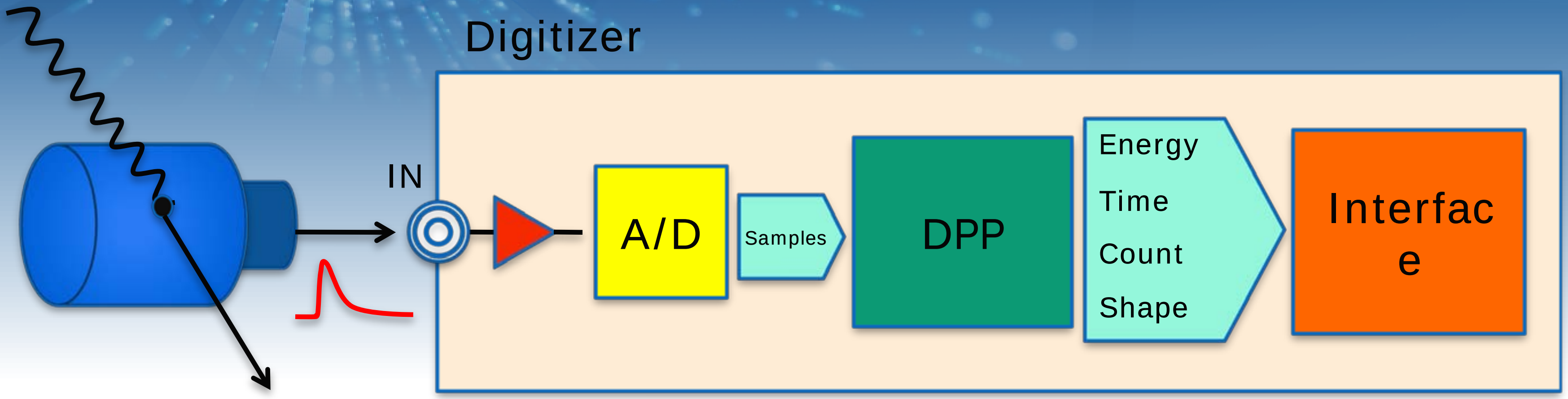
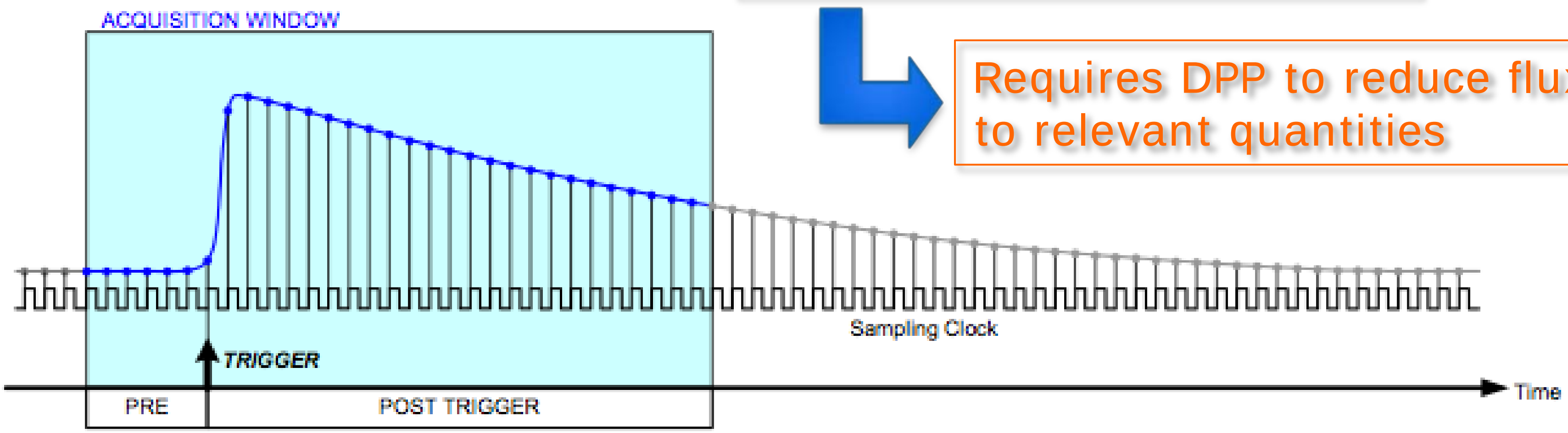
Digital Chain



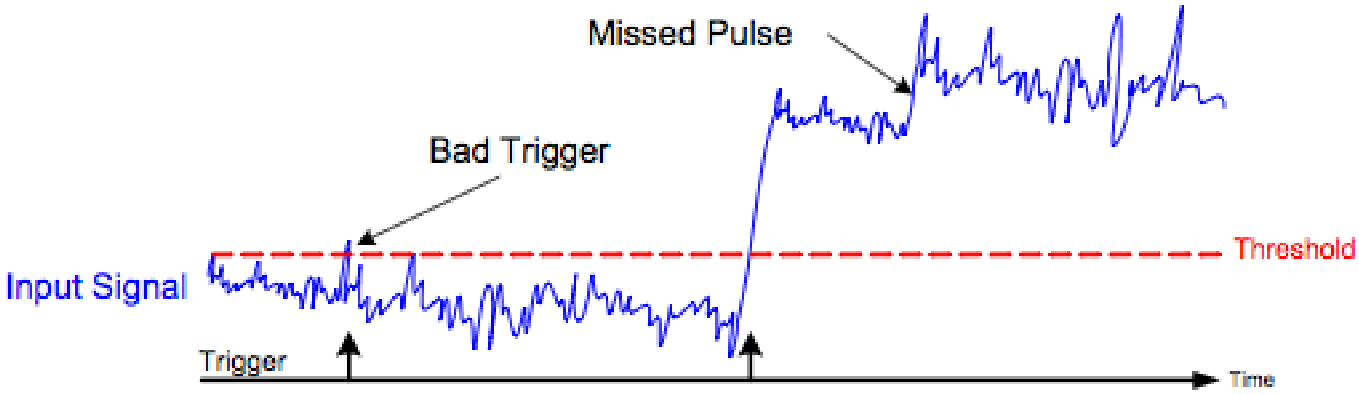
Very high throughput of data

Requires DPP to reduce flux to relevant quantities



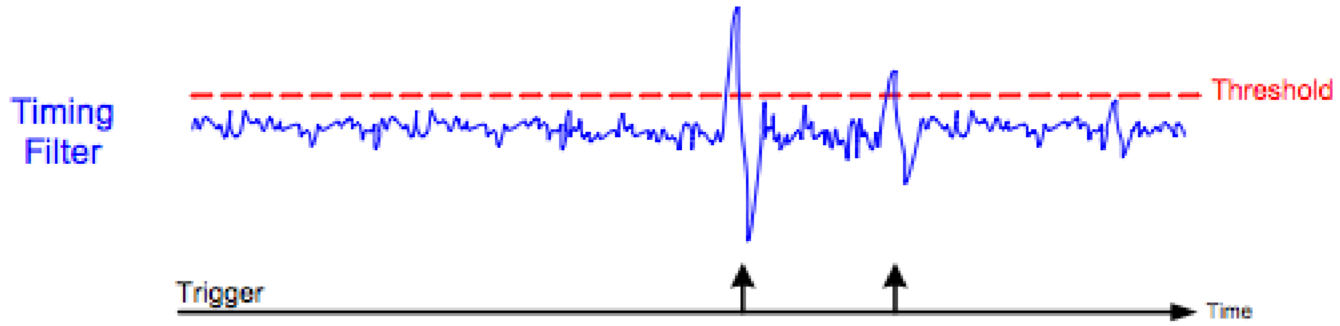
Trigger and Timing Filter

- 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

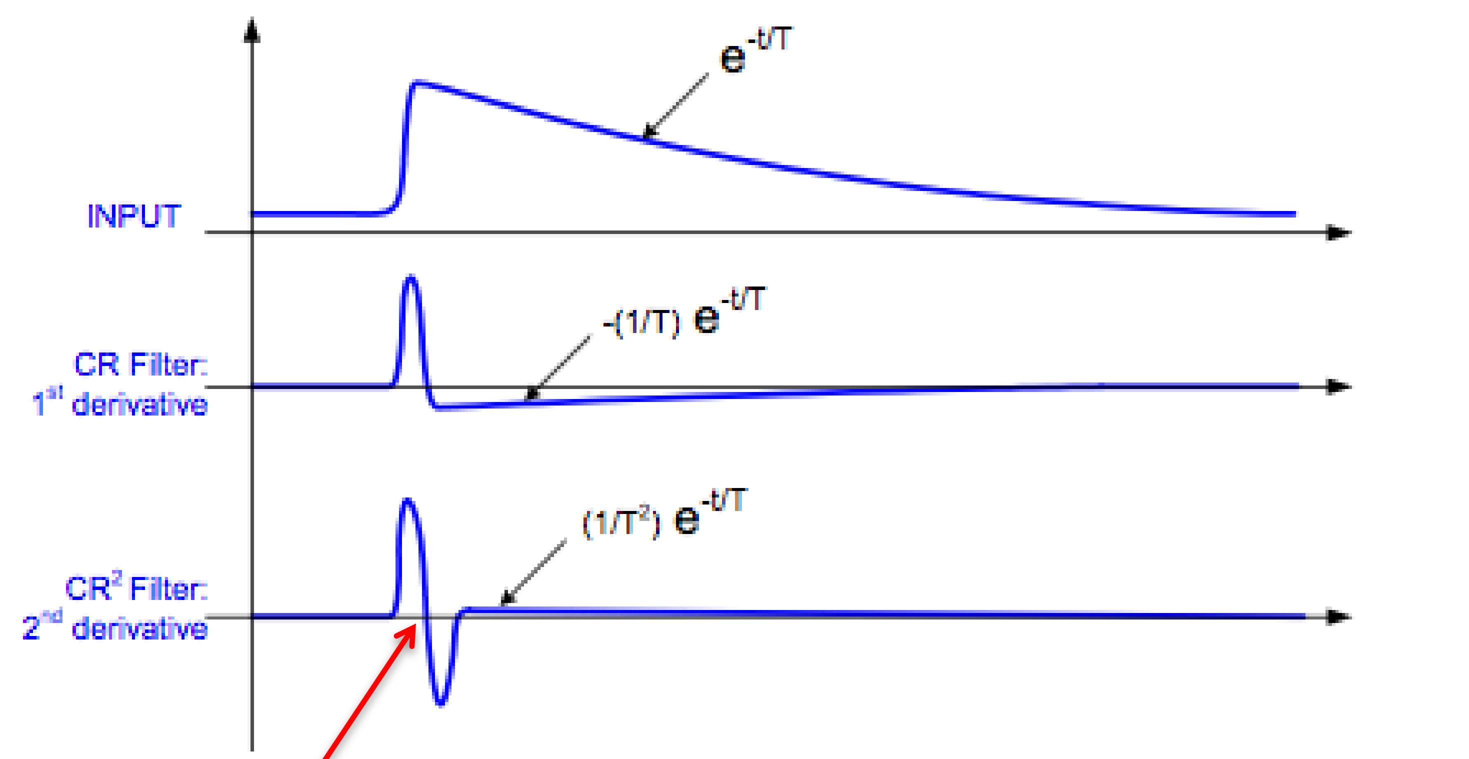


Trigger and Timing Filter

- 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)

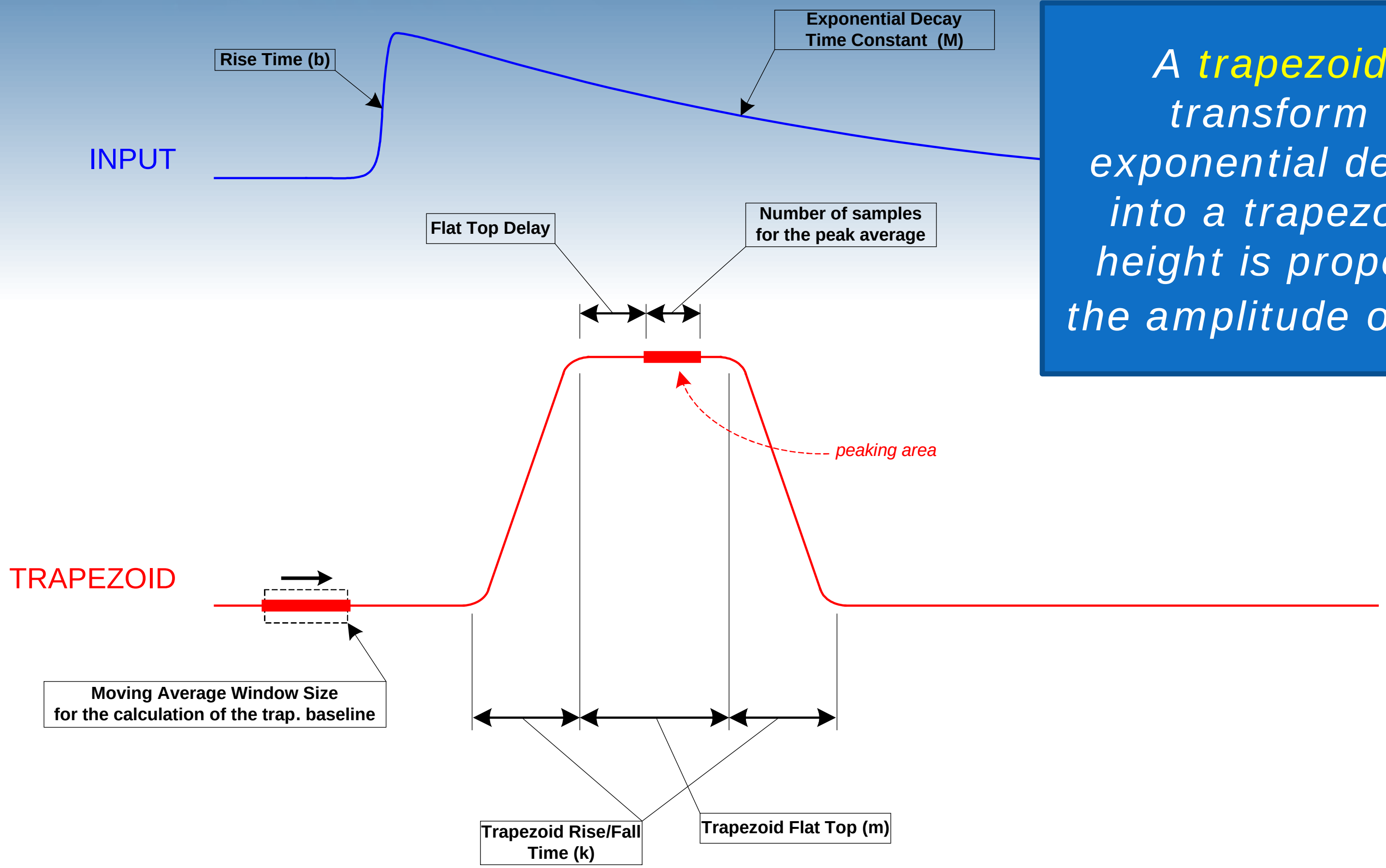


Digital Signals



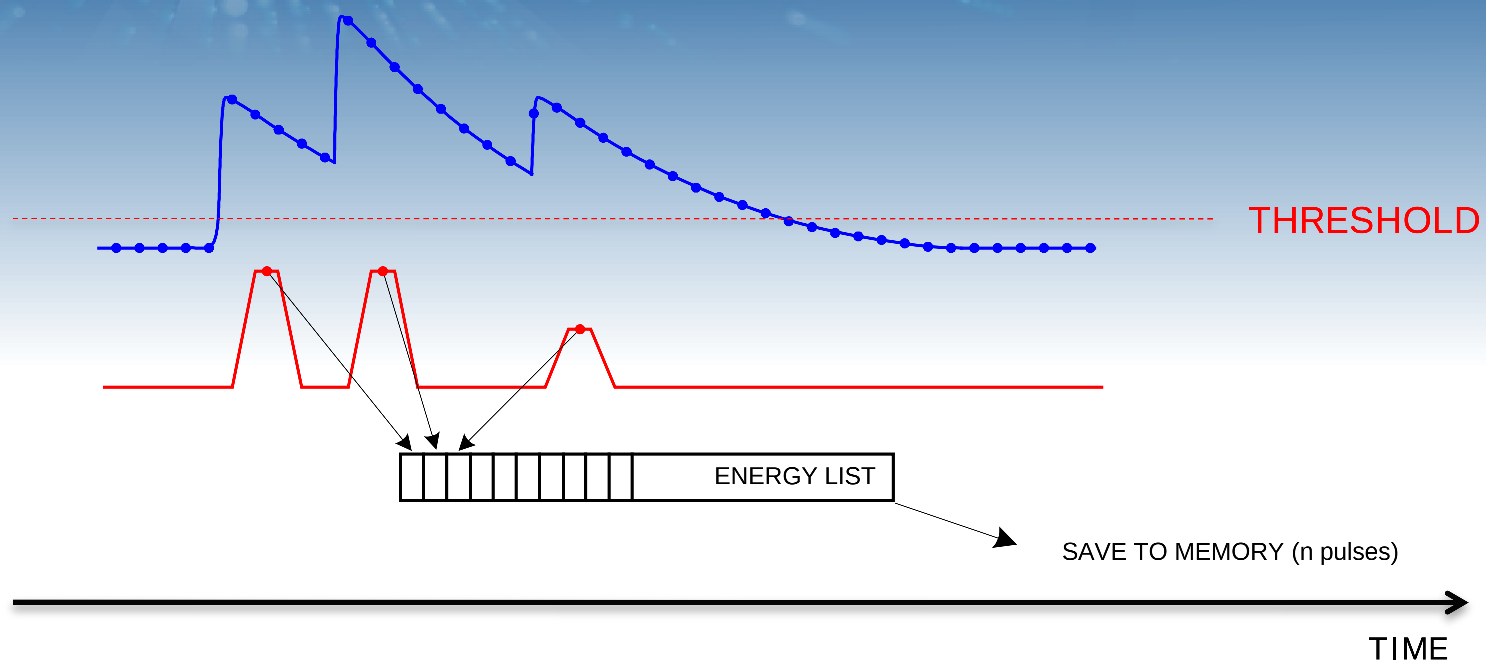
Precise time determination independent from pulse height

Pulse Height Analysis



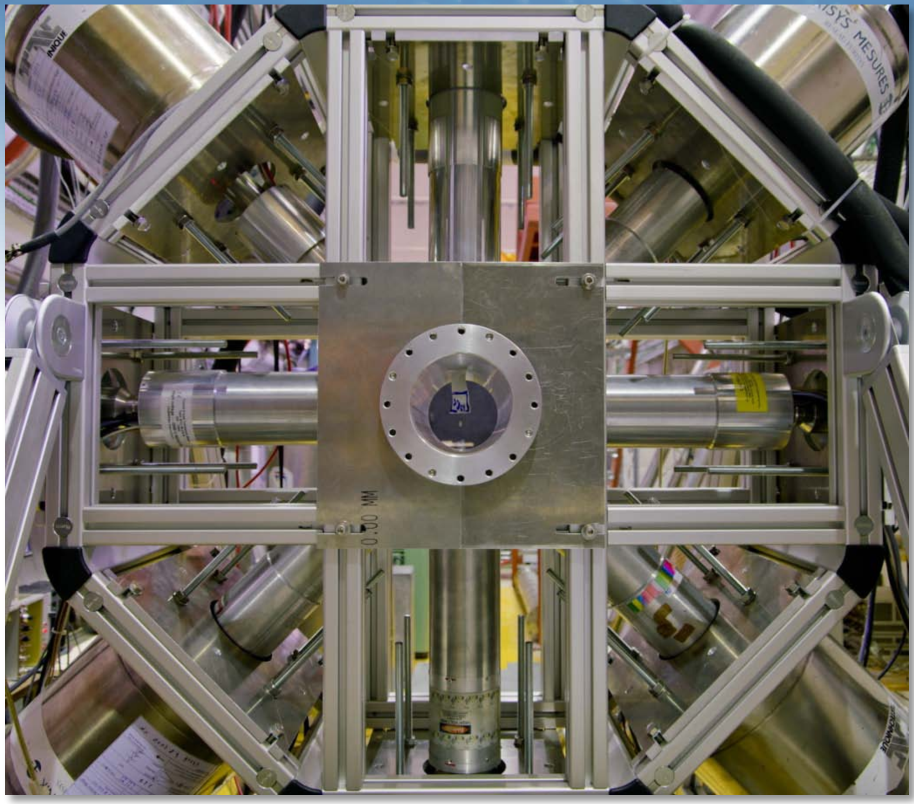
A trapezoidal filter transform typical exponential decay signal into a trapezoid whose height is proportional to the amplitude of the pulse

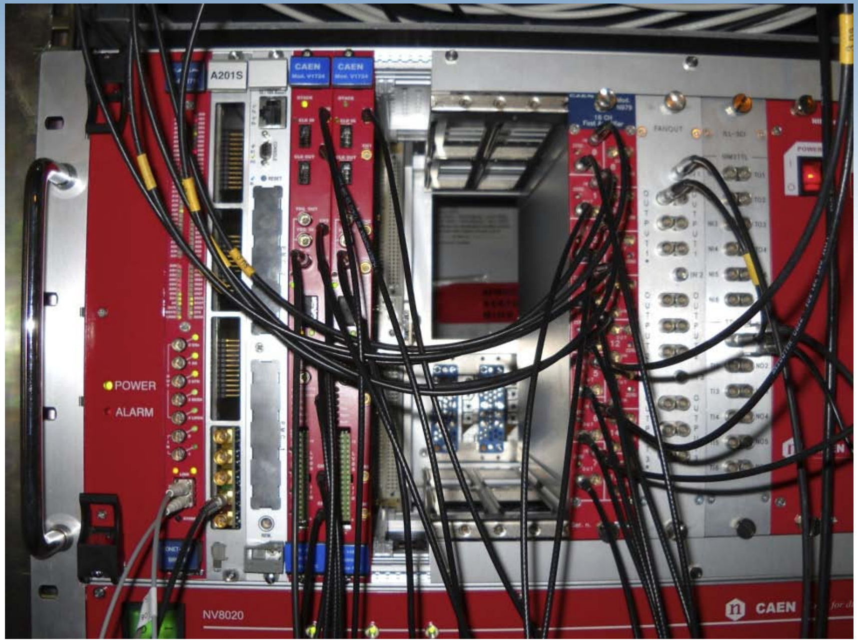
Reduced Pile-Up



- 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

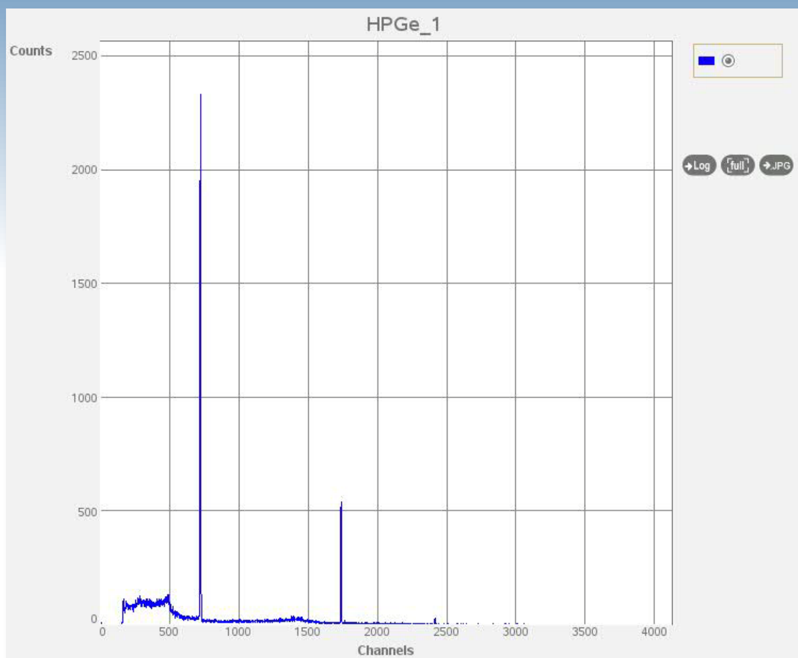
- One single board can do energy, timing and pulse shape analysis.
- Low cost per channel and reliability.
- Low dead-time in the acquisition.
- Synchronization and correlation among several channels (coincidence).
- All in FPGA, flexibility in tuning and calibration.

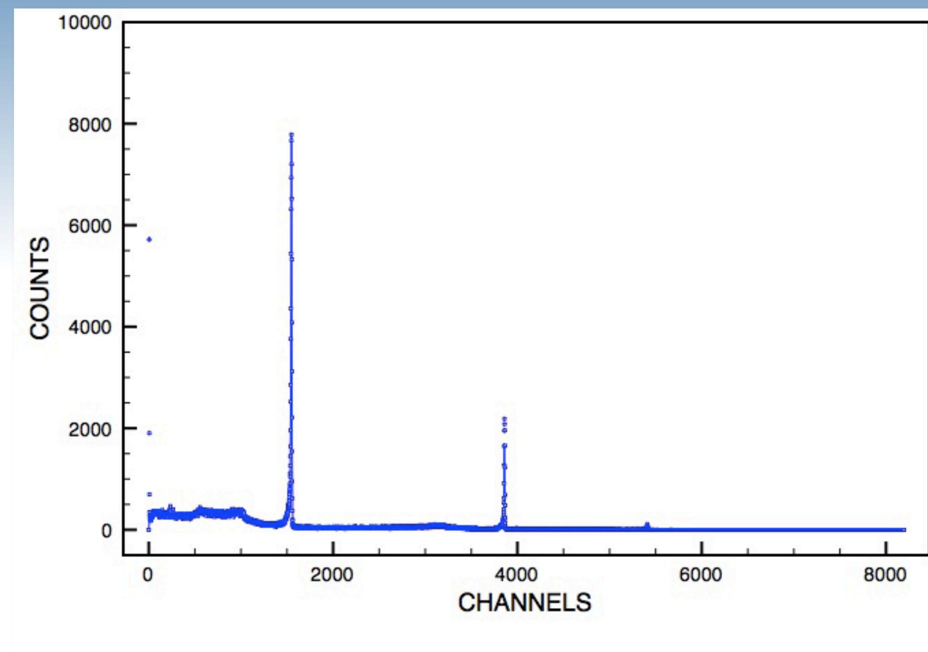
DISADVANTAGES

- 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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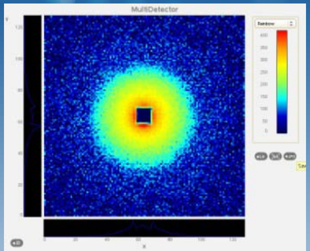
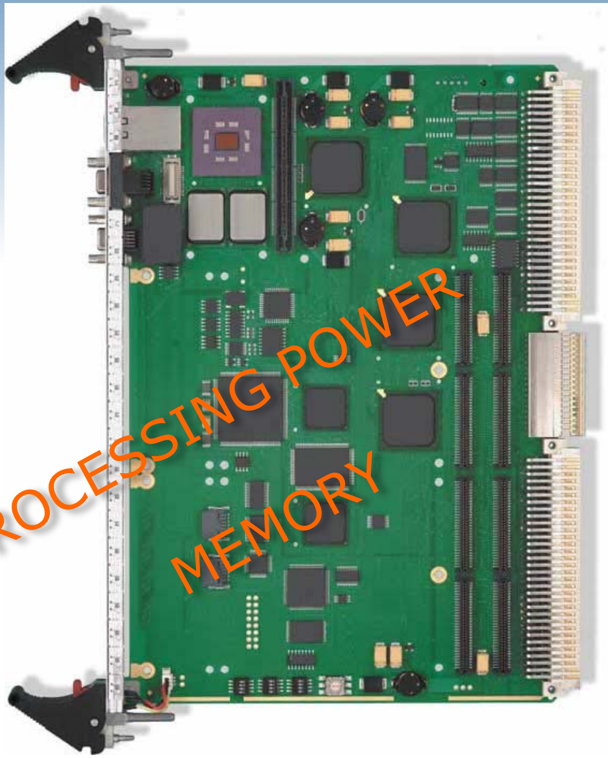
The Acquisition Card

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



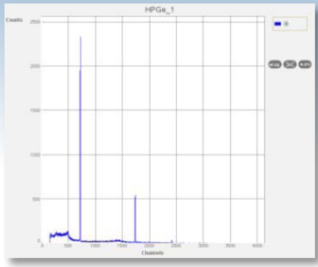
RAW DATA FROM DETECTOR



PROCESSING POWER

MEMORY

LIVE DISPLAY



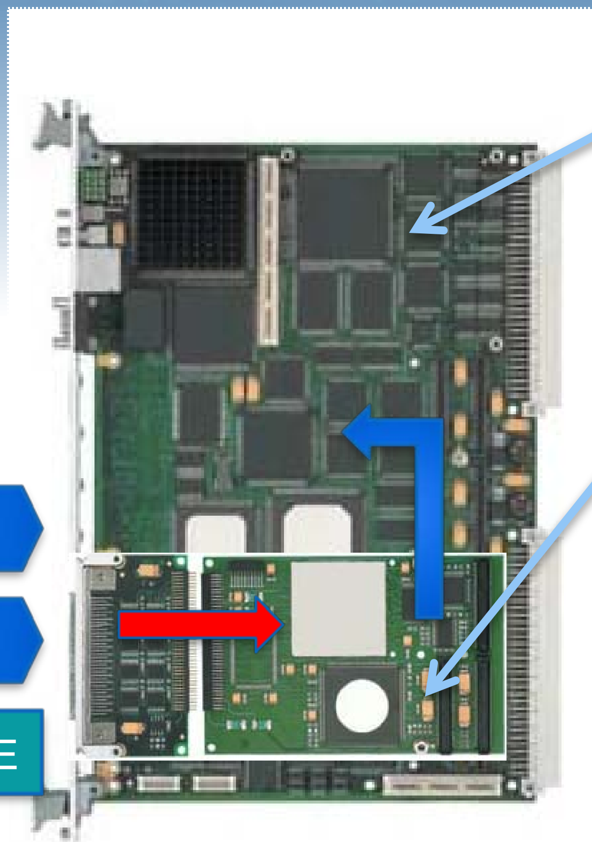
STORAGE

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 μs 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



DATA

STROBE

ACKNOLEDGE

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

Data from detector

Readout from FIFO (PCI) and storage in RAM

The RIO3 Family

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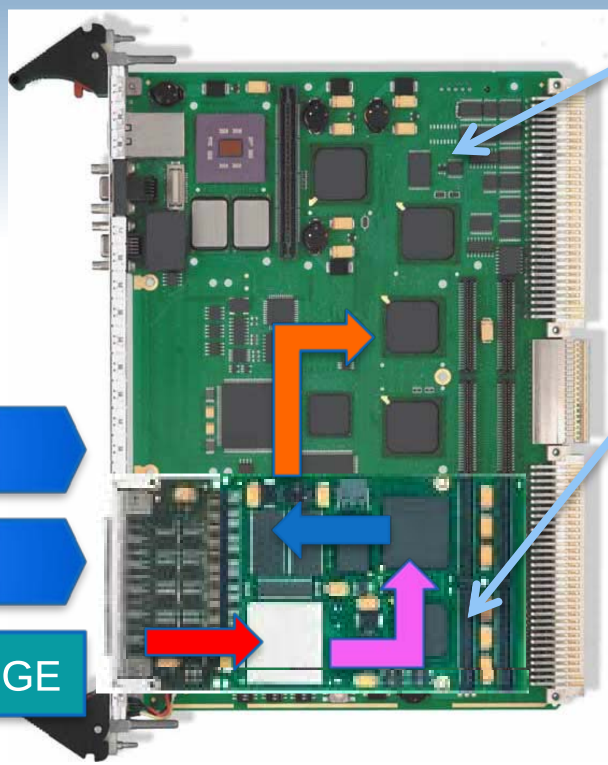
- Motherboard: RIO3 - 8064
- Clock: 400 MHz
- Memory: 256 Mb
- PMC: MFCC 8443 (128 Mb)



DATA

STROBE

ACKNOLEDGE

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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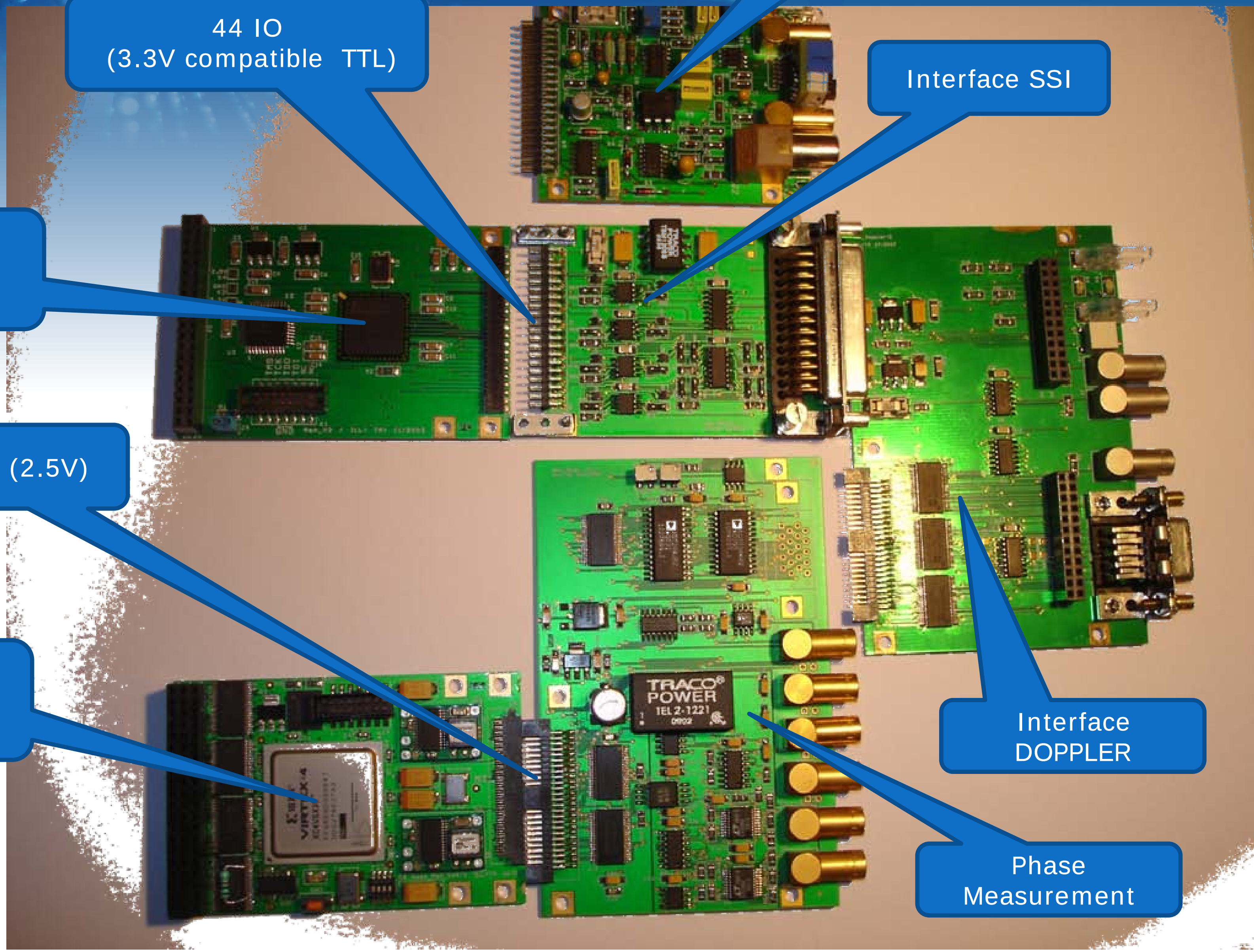

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Digitizer Tuning

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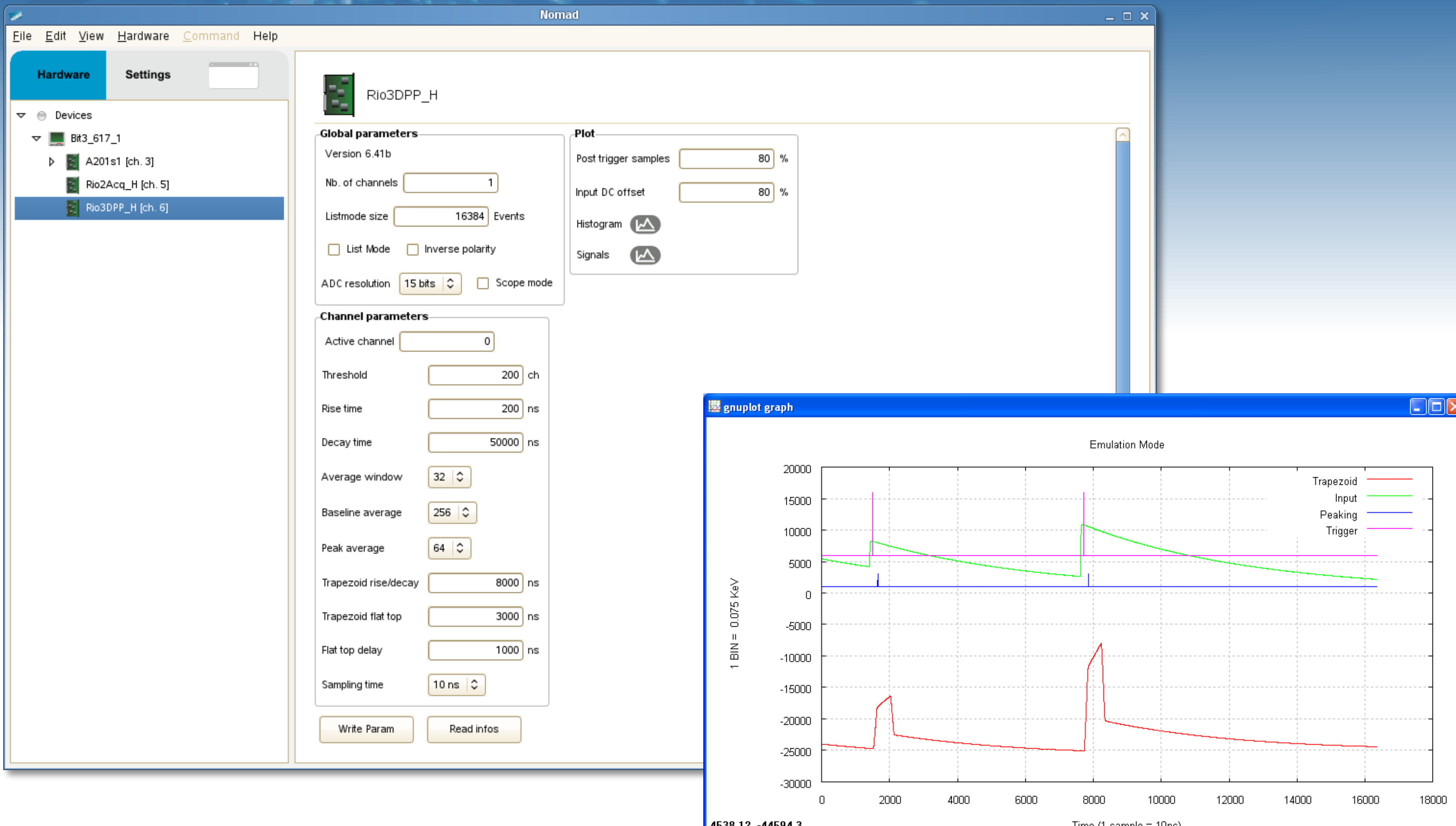
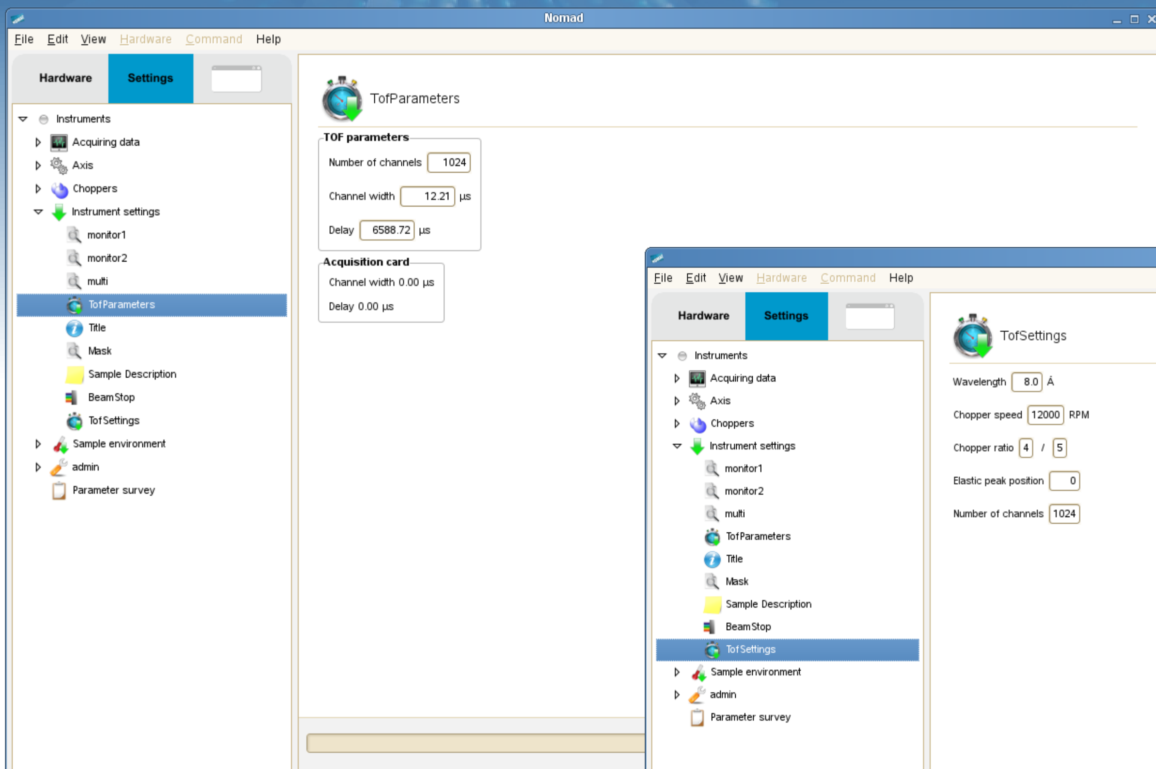
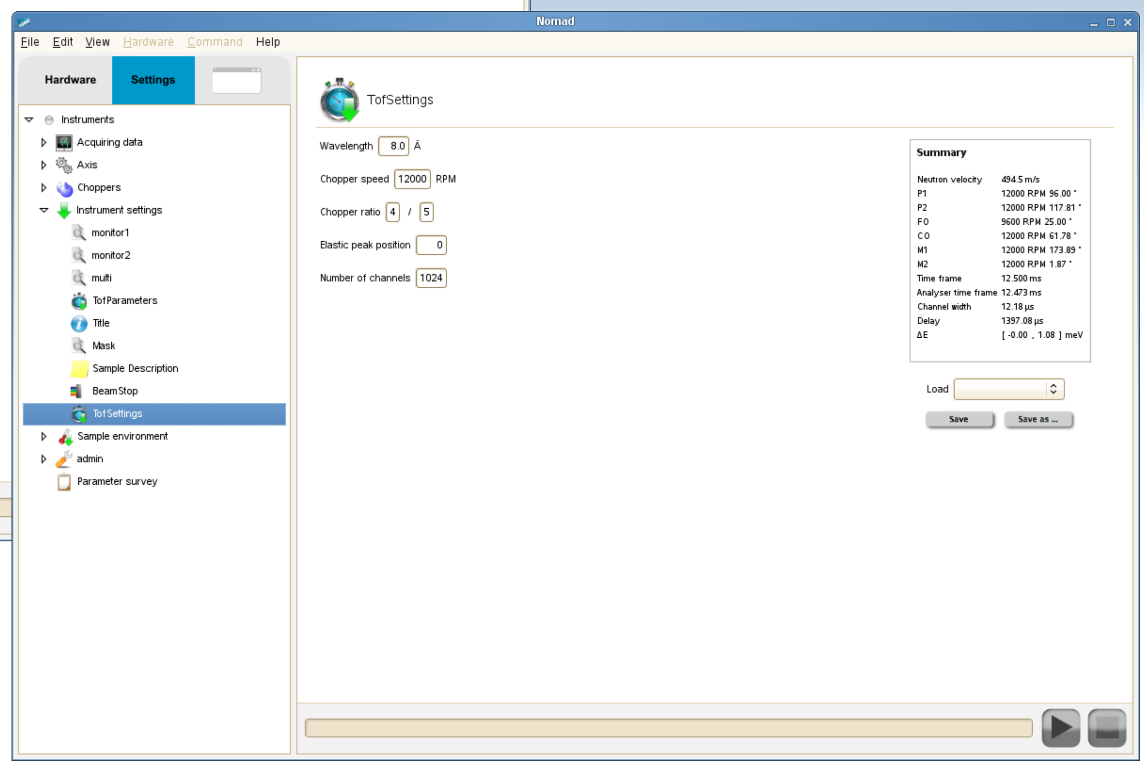


ToF Tuning





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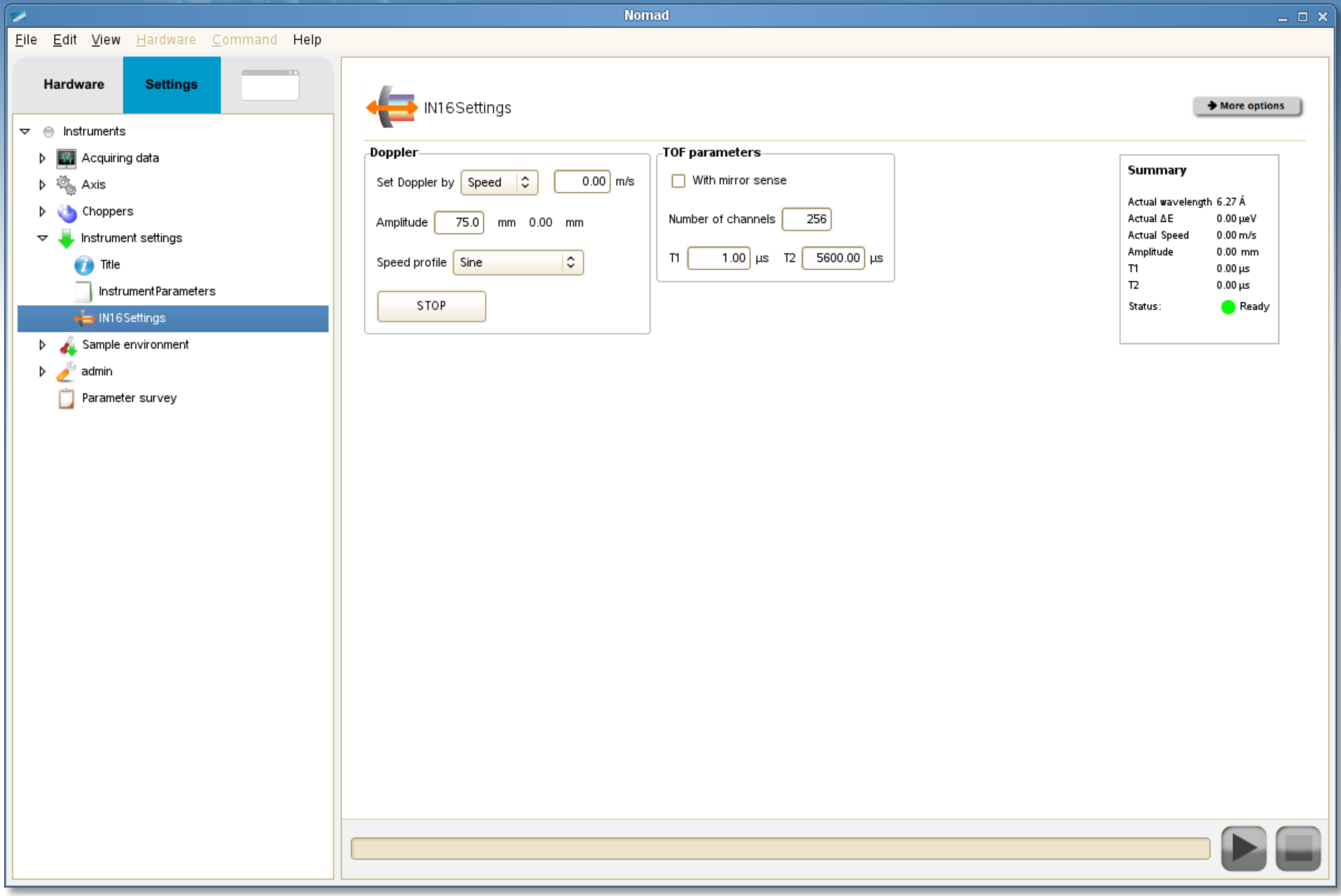
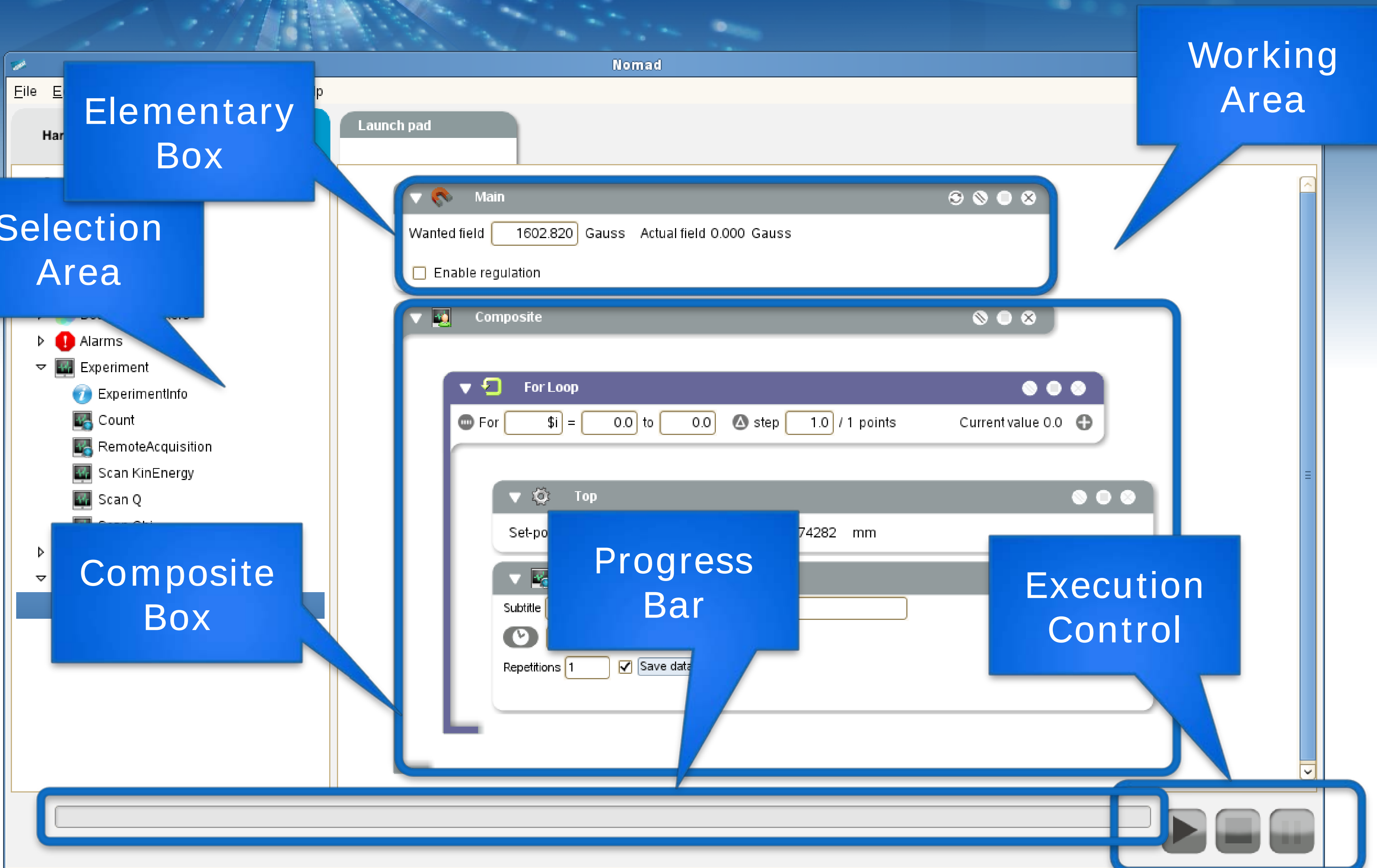
Doppler Tuning



A Graphical Control



Software – Hardware Integration

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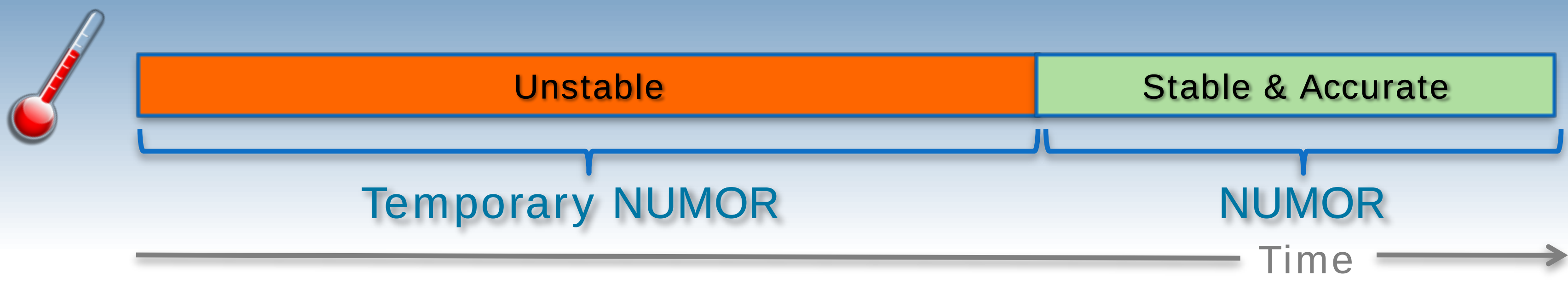
Temperature Watchdog



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