CAEN
Tools for Discovery

Digital Pulse Processing For Detector Readout and Physics Applications

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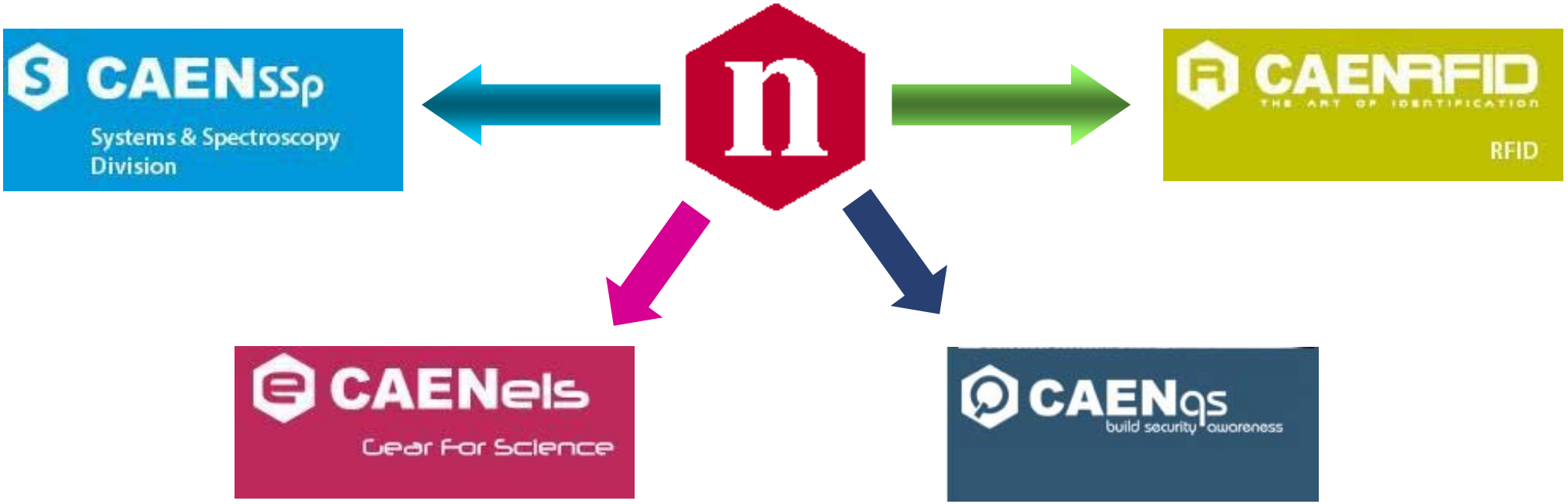
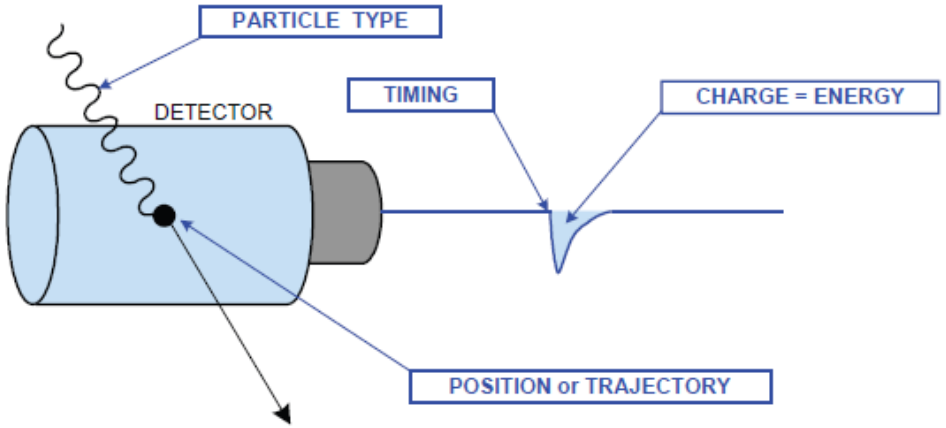
CAEN Network's Companies



- Founded in 1979, CAEN SpA (Costruzioni Appearecchiature Elettroniche Nucleare) is an important industrial spin-off of INFN
- 80 people (assembly not included)
- Core business: Electronic Instrumentation for Particle Physics experiments (world leader)
- Spin-off activities: RFID (2003), CAENels (2010), CAEN SSp (2011), CAENqS (2012)

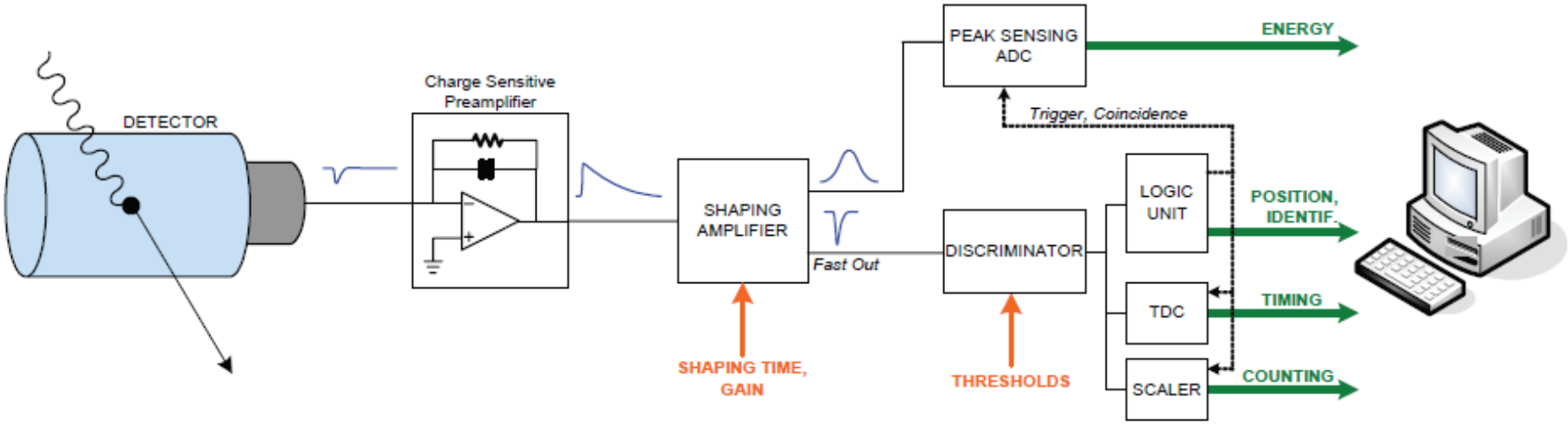
Measurements in Particle Physics

- The function of the Front End electronics for Particle Physics applications is to acquire the electrical charge pulses generated by a radiation detector, to extract the quantities of interest and to convert them into a digital format.
- In some applications, the quantities of interest are the particle energy (proportional to the charge released by the particle in the detector) and the time of arrival
- In some cases the acquisition is restricted to the simple pulse counting, actually a “selective” counting
- In some other cases, it is necessary to discriminate the type of the particle by means of the pulse shape; for example, the γ-n discrimination



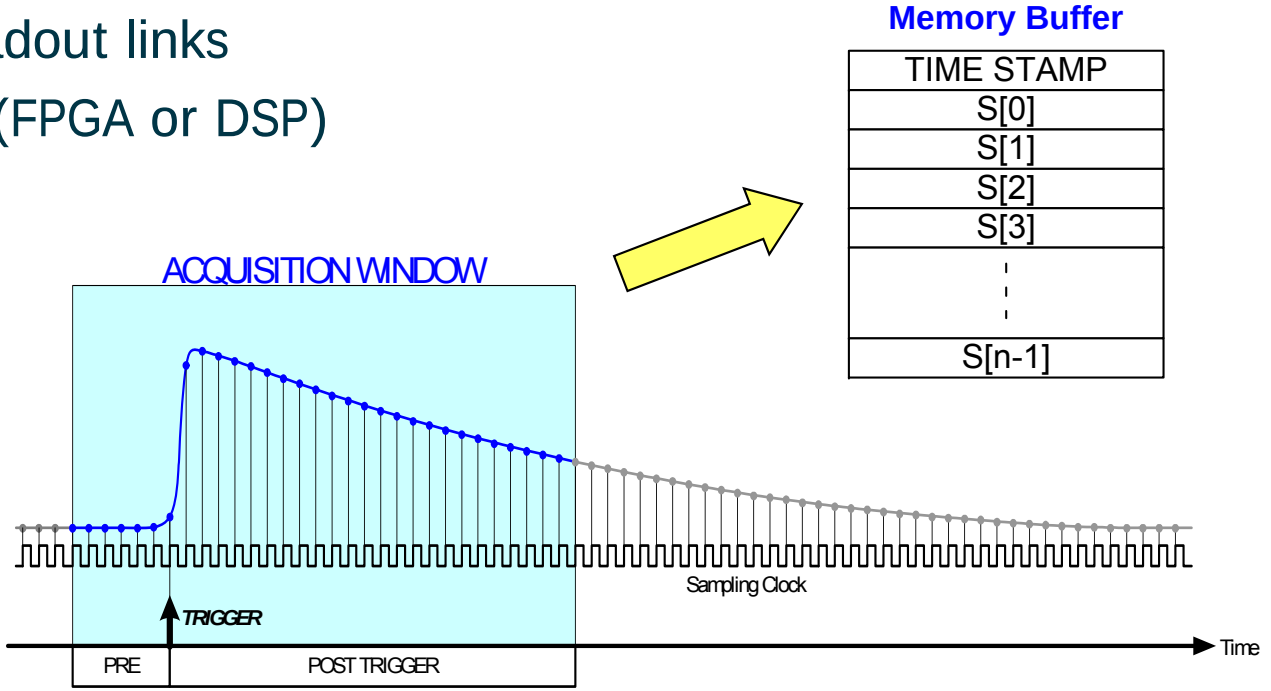
Traditional DAQ Chains

- Traditionally, the electronic readout systems for the particle detectors have been made of almost all-analog chains
- Each block of the chain has a specific function, so that you need to interconnect several blocks in order to make a system able to extract all the quantities of interest.
- With this approach, the A to D conversion is performed at the end of the acquisition chain, just before the readout interface connected to the computer.



Digitizers vs Oscilloscopes

- The principle of operation of a waveform digitizer is the same as the digital oscilloscope: when the trigger occurs, a certain number of samples (acquisition window) is saved into one memory buffer
- However, there are important differences:
  - no dead-time between triggers (Multi Event Memory)
  - multi-board synchronization for system scalability
  - high bandwidth data readout links
  - on-line data processing (FPGA or DSP)



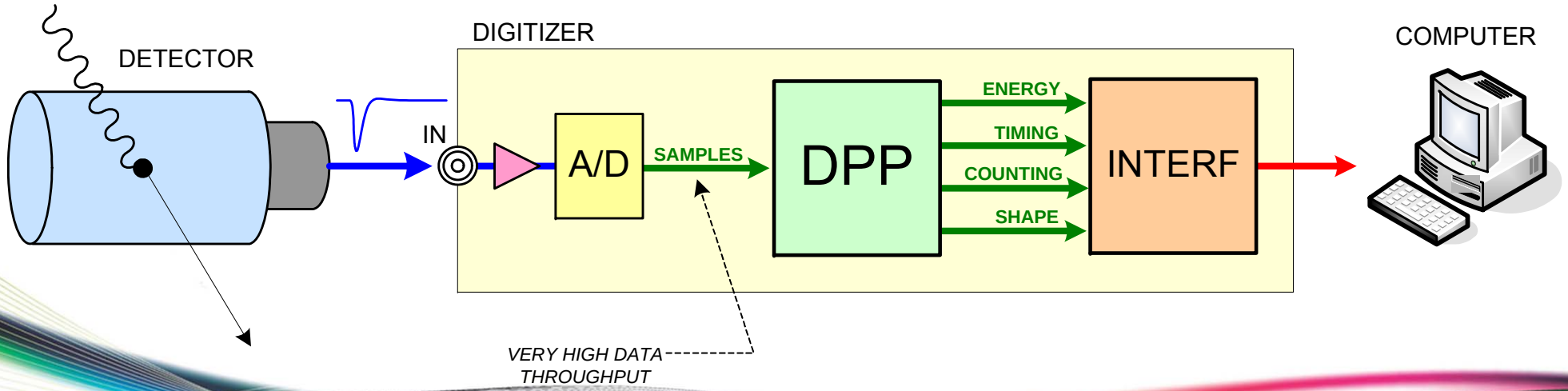
CAEN Digitizers

- From 2 to 64 channels
- Up to 5 GS/s sampling rate - Up to 14 bit
- FPGA firmware for Digital Pulse Processing

- In recent years, CAEN developed a complete family of digitizers
- Beside the use of the digitizers as waveform recorders (“oscilloscope mode”), CAEN offers the possibility to upload special firmware that implement several algorithms for Digital Pulse Processing (DPP)
- Digitizers running DPP firmware represent a complete digital replacement of most traditional acquisition chains

Benefits of digital approach

- One single board can do the job of several analog modules
- Full information preserved: *A/D conversion as early as possible, data reduction as late as possible*
- Reduction in size, cabling, power consumption and cost per channel
- High reliability and reproducibility
- Flexibility (different digital algorithms can be designed and loaded at any time into the same hardware)



Raw waveform mode: Limits

- Using digitizers as waveform recorders can produce a large amount of data to be transferred from the acquisition board to a mass storage devices
- The data throughput can be extremely high: it may be no possible to transfer raw data to computers and make the analysis off-line!
- On-line Digital Pulse Processing is needed to extract only the information of interest reducing the data throughput
- The aim of the DPP is to provide FPGA algorithms able to make in digital the same functions of analog modules such as Shaping Amplifiers, Discriminators, QDCs, etc.
- Three main DPP firmware have been developed so far:

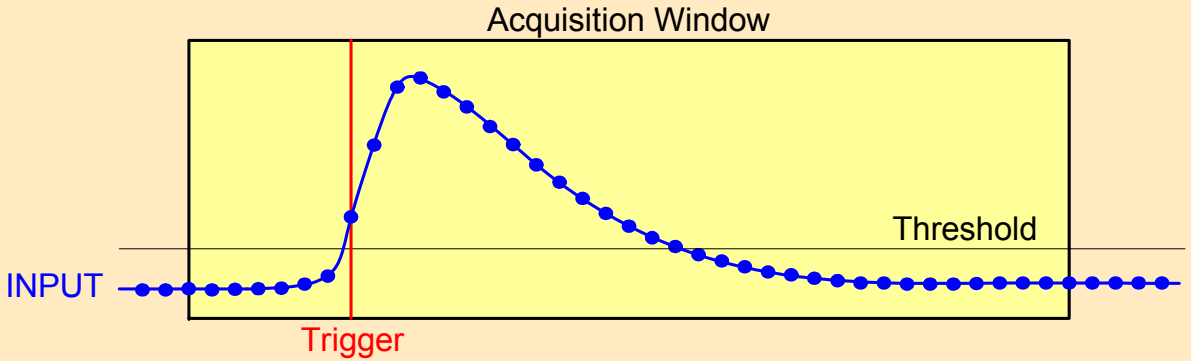
DPP-PHA (Pulse Height Analysis)

DPP-CI (Charge Integration)

DPP-PSD (Pulse Shape Discrimination)

Raw waveform vs DPP

STD FW

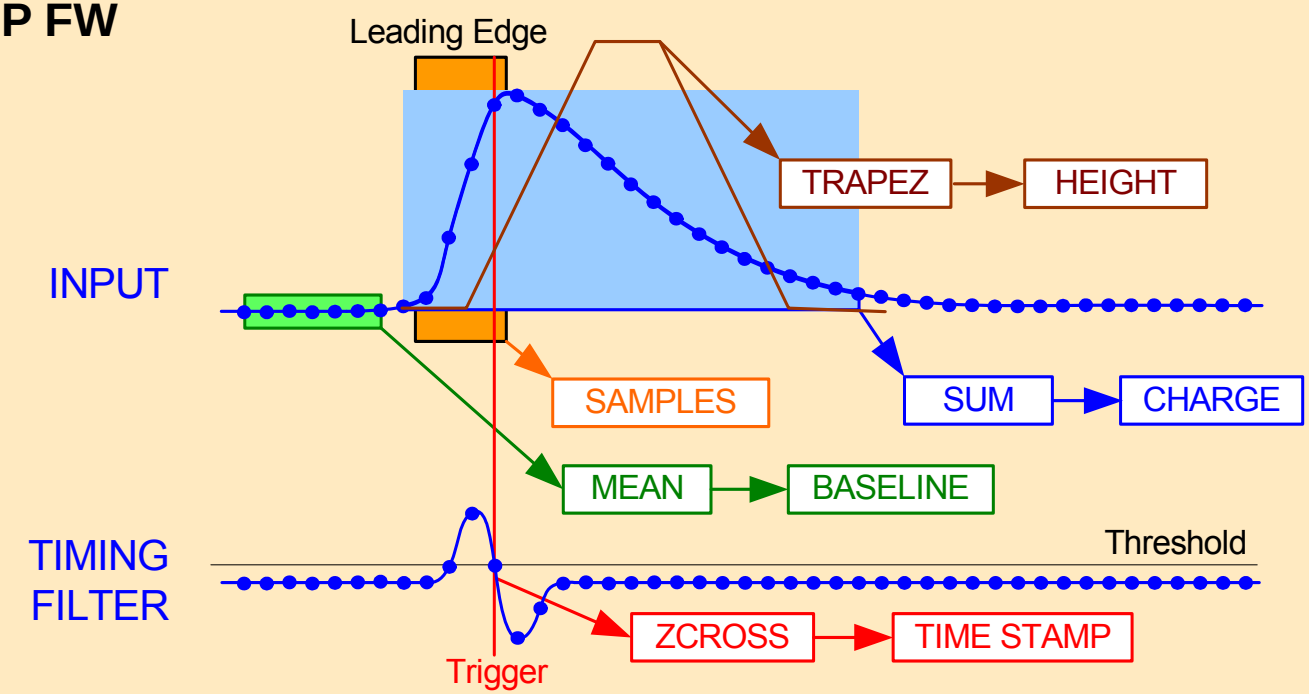


EVENT DATA

S1
S2
S3
S4
S5
S6
S7
Sn

Typ. Nsample > 1K

DPP FW



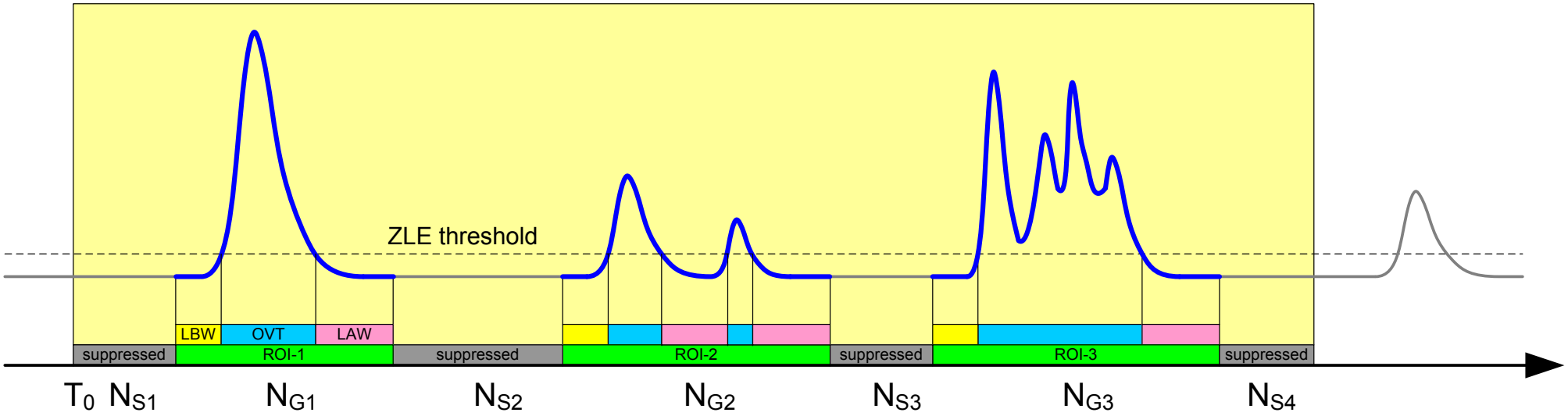
EVENT DATA

TIME STAMP
CHARGE
BASELINE
HEIGHT
S1
S2
S3
S4

Typ. Nsample < 100

ZLE: Zero Length Encoding

Acquisition Window (programmable size with pre and post trigger)



LBW — ***Look Back Window***: programmable size

OVT — ***OverThreshold***: lasts as long as the signal is over threshold

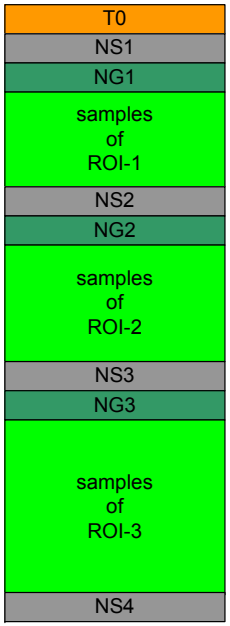
LAW — ***Look Ahead Window***: programmable size; can be retriggered

T_0 — Time Stamp of the first sample of the Acquisition Window

N_S — Number of skipped samples belonging to the suppressed region

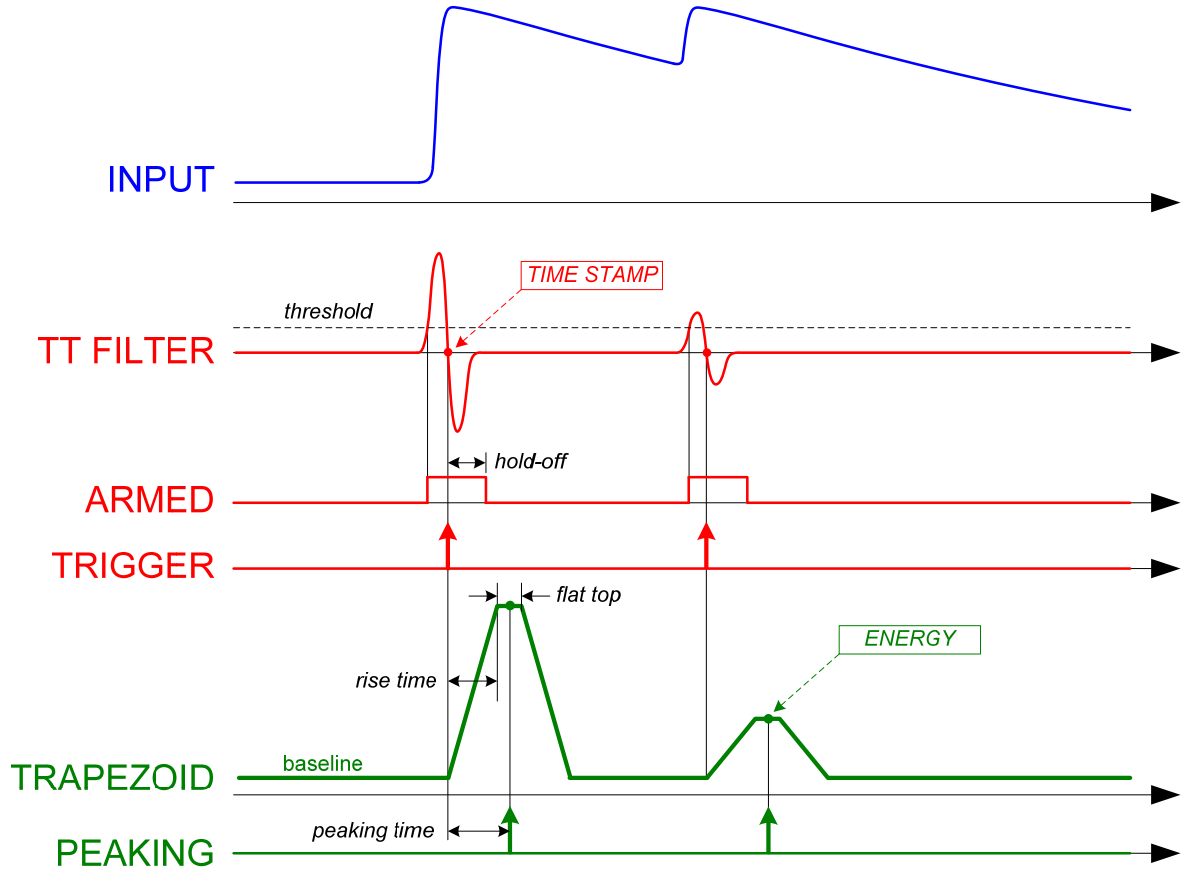
N_G — Number of good samples belonging to the ROI

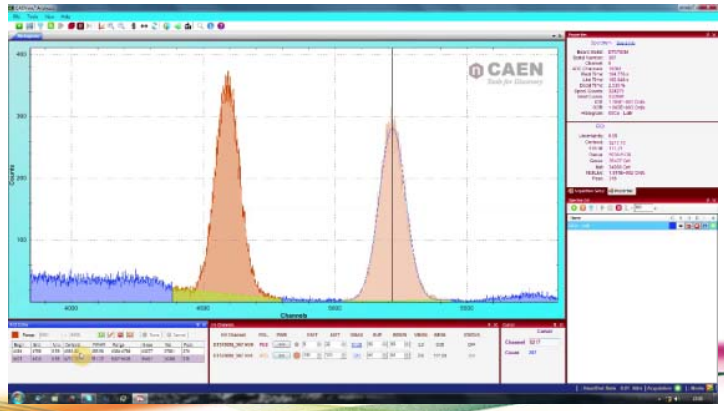
Readout Data



DPP-PHA: Pulse Height Analysis

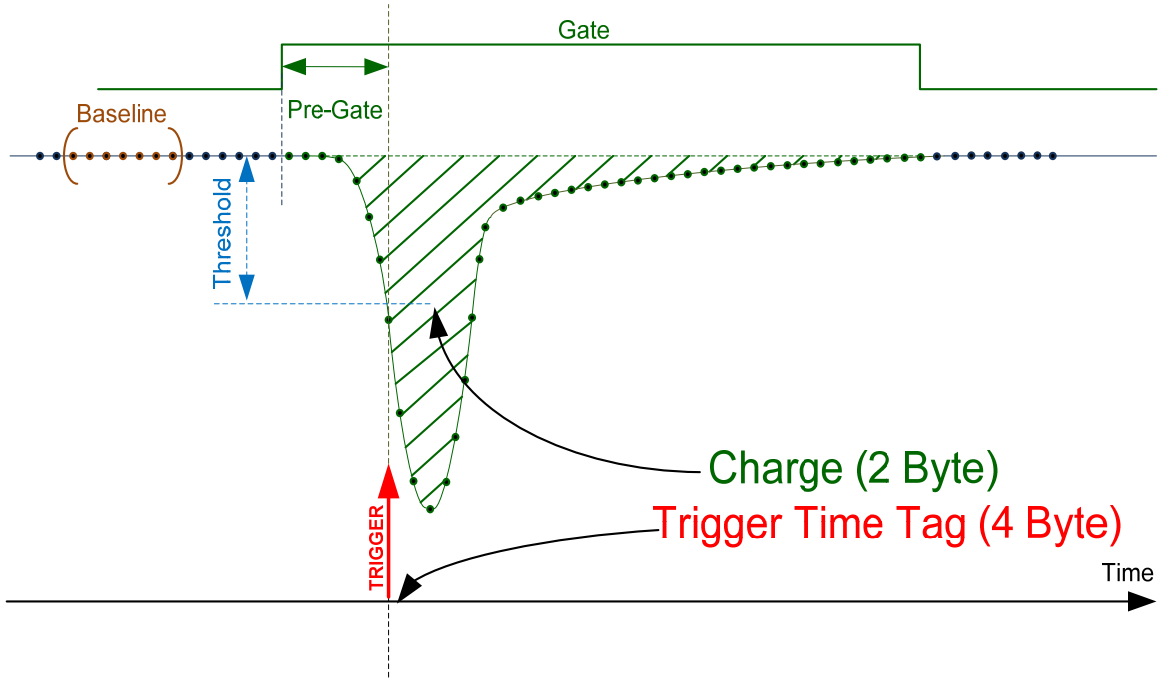
- Digital implementation of the shaping amplifier + peak sensing ADC (Multi-Channel Analyzer)
- Charge Sensitive Preamplifier directly connected to the digitizer
- Pile-up rejection, Baseline restoration, ballistic deficit correction
- Low dead time => high counting rate

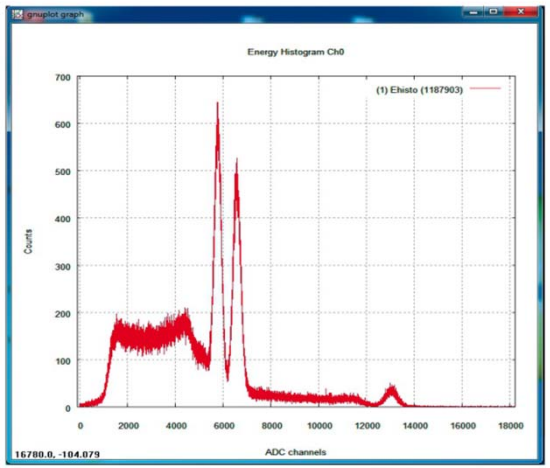




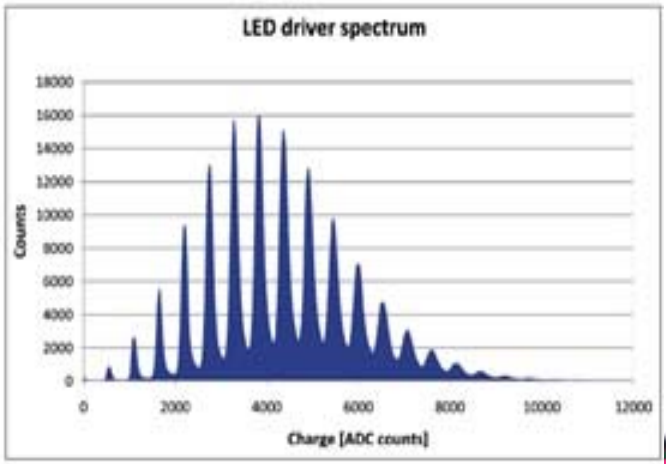
DPP-CI: Charge Integration

- Digital implementation of the QDC + discriminator and gate generator
- Self-gating integration; no delay line to fit the pulse within the gate
- Baseline restoration (pedestal cancellation)
- Extremely high dynamic range
- Dead-timeless acquisition (no conversion time)



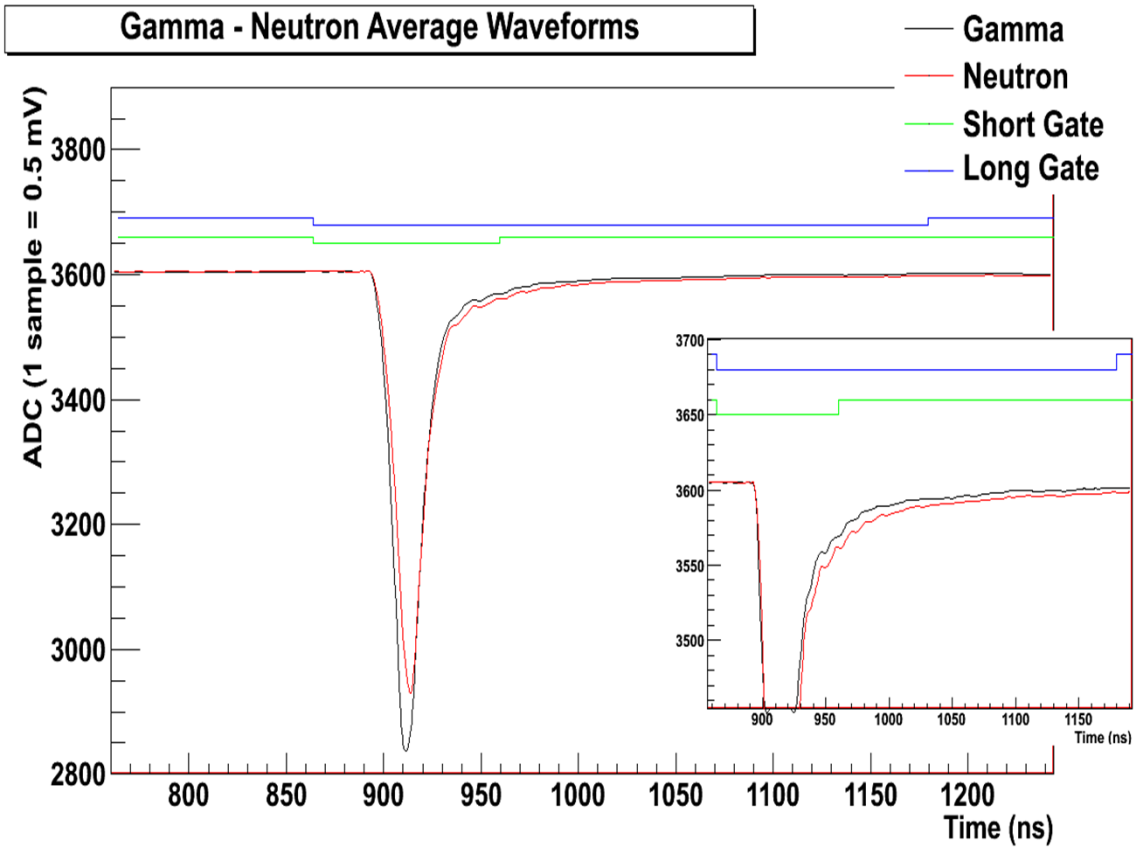


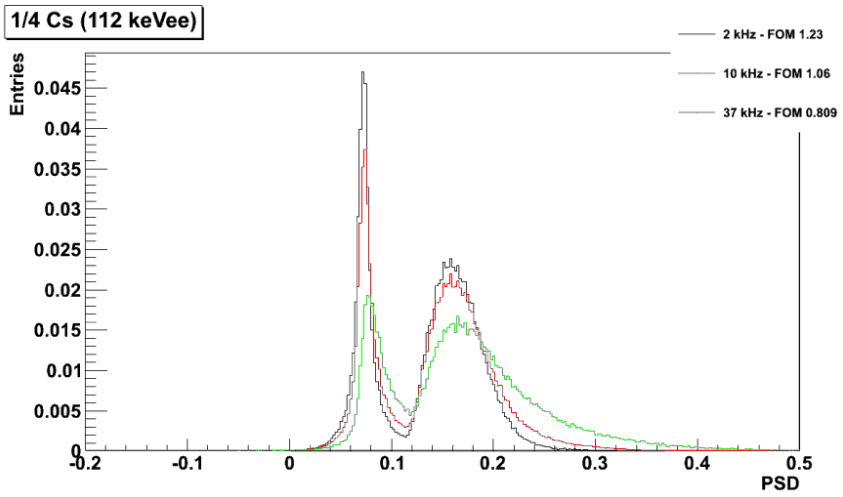
^{60}Co gamma spectrum acquired with NaI detector and DPP-CI

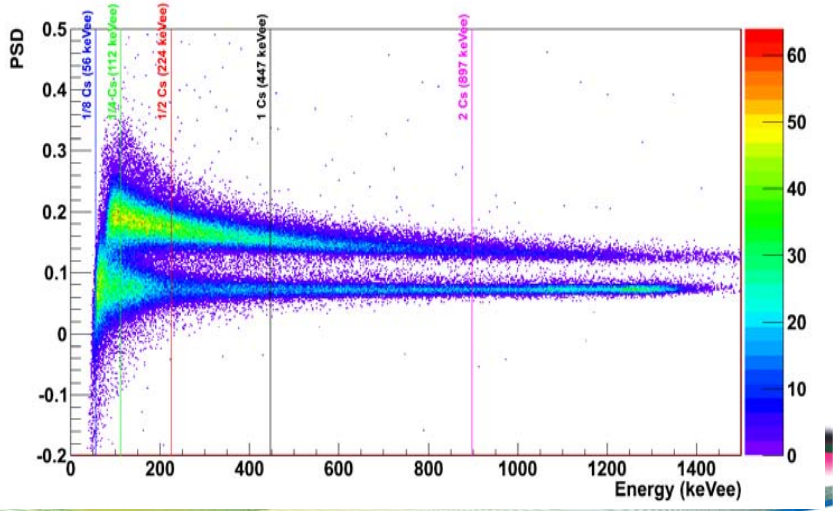


DPP-PSD: Pulse Shape Discrimination

- Digital implementation of the ΔE/E analysis (double gate charge integration)
- PSD = $(Q_{LONG} - Q_{SHORT})/ Q_{LONG}$
- Typically used with organic liquid scintillators (e.g. BC501)
- Dead-timeless acquisition (no conversion time)



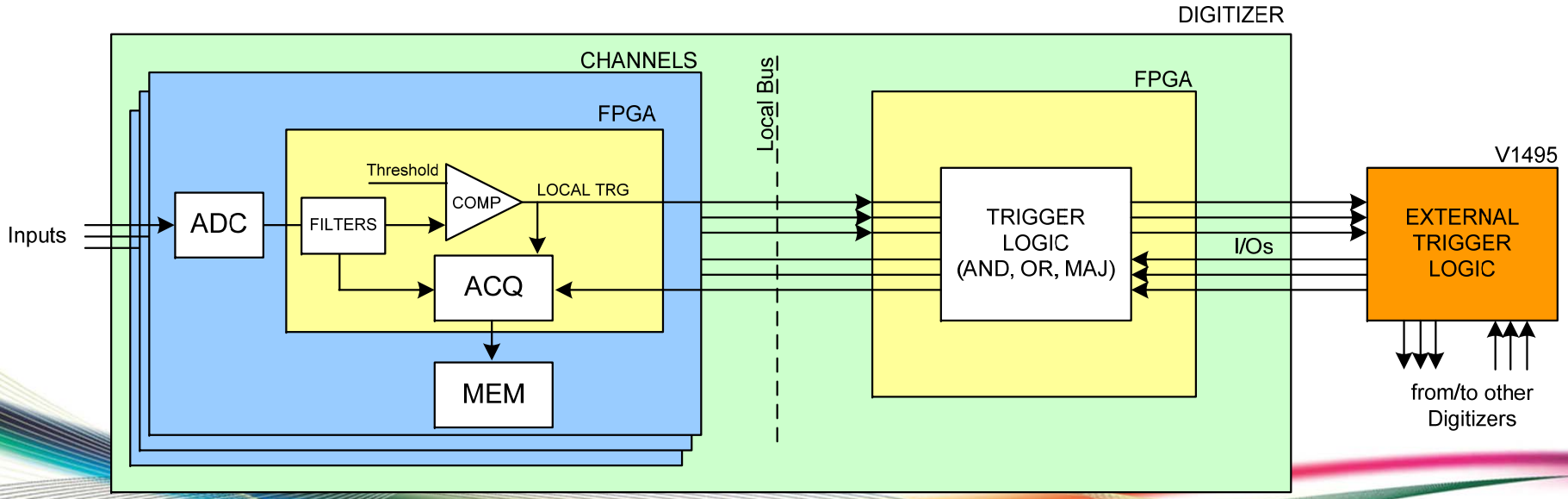




Event correlation (HW)

Hardware approach

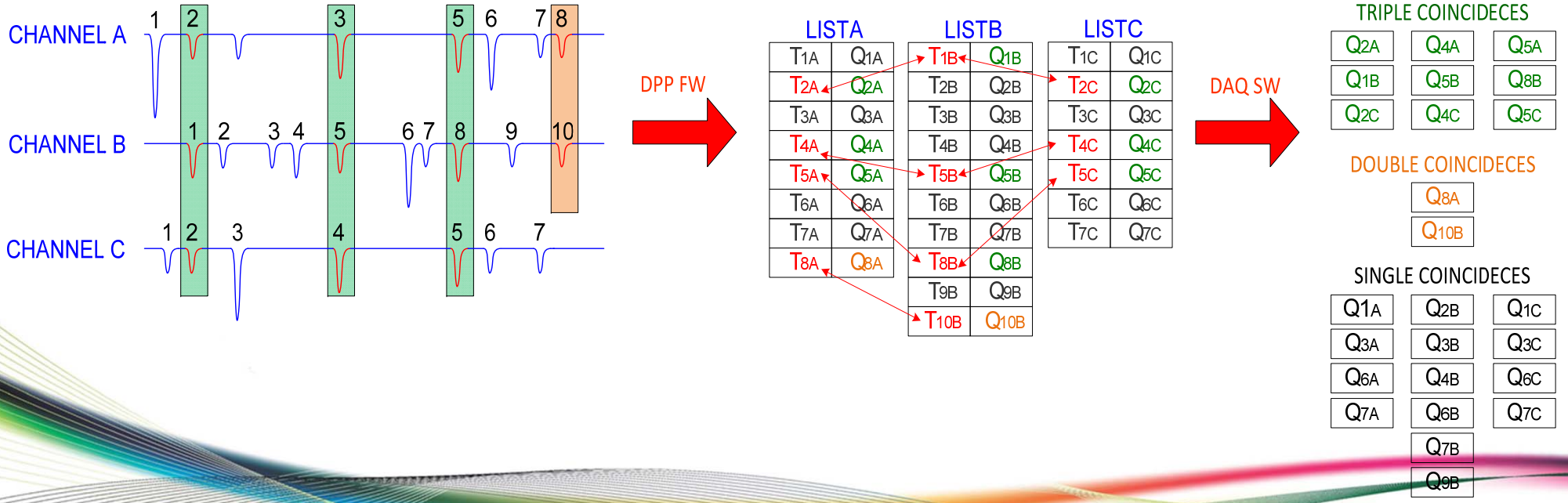
- Propagate local triggers from each channel to the others within the board
- TR-TV mode: triggers from other channels (trigger requests) can be used as trigger validation
- Apply individual trigger masks and simple combinatorial logics on board (AND, OR, Majority)
- Use GPIOs on the front panel to propagate individual trigger inputs/outputs from/to external logic boards (e.g. V1495)



Event correlation (SW)

Software approach

- Read all events as long as you have enough bandwidth (i.e. make data suppression as late as you can): **preserve the information**!
- In list mode, the bandwidth requirement is very low (e.g. 8 bytes per event). Example: 8 channels at 100 KHz trigger rate gives 6.4 MB/s.
- Time stamped events allow for easy and flexible software coincidence, anticoincidence, correlation, etc.



CAEN Digitizers for LIDAR?

- ARCADE collaboration is testing a CAEN Desktop Digitizer for its Raman LIDAR
- DT5751 – 10 bit, 1/2 GSps, 4/2 input channels
- To our knowledge, first time a CAEN digitizer has been used in LIDAR application
- Some firmware/software customization needed?
- Tests are on the way...stay tuned!

ARCADE
PROJECT

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Thank you!

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