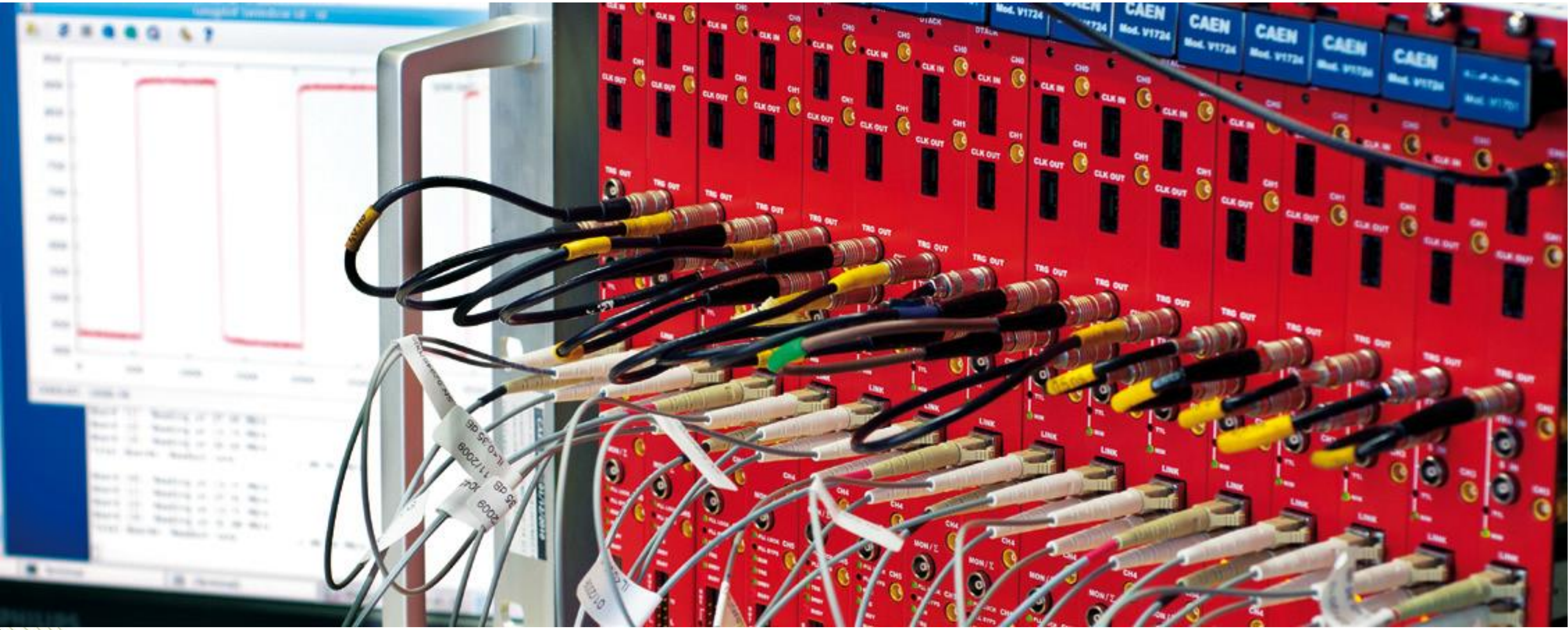


Digital systems for Multi-Parametric analysis in Physics Applications

March 2016 - Carlo Tintori

ISO 9001:2008
CERT. N. 9105.CAEN

CAEN Digitizers Highlights

VME, NIM, Desktop form factors:

- **12, 14** bit flash ADC up to **500 MS/s**
- **10** bit flash ADC up to **4 GS/s**
- **12** bit switched capacitor ADC up to **5 GS/s**

Up to 64 channels in a VME board

On-line Digital Pulse Processing (**DPP**):

- **PHA**: Pulse Height Analysis (MCA)
- **PSD**: Dual Gated integrator (QDC), Pulse Shape Discrimination, CFD + Timing interpolator (TDC)
- **QDC/CI**: Gated integrator (QDC)
- **ZLE**: Waveform Mode with Zero Suppression

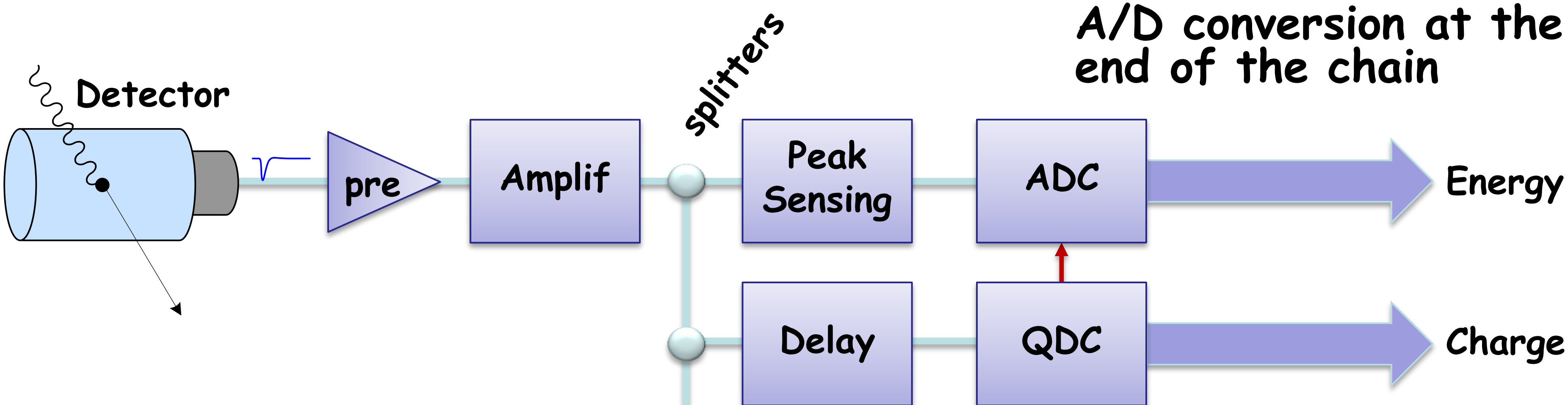
Readout: VME, USB, Optical Link + PCIe (80 MB/s)

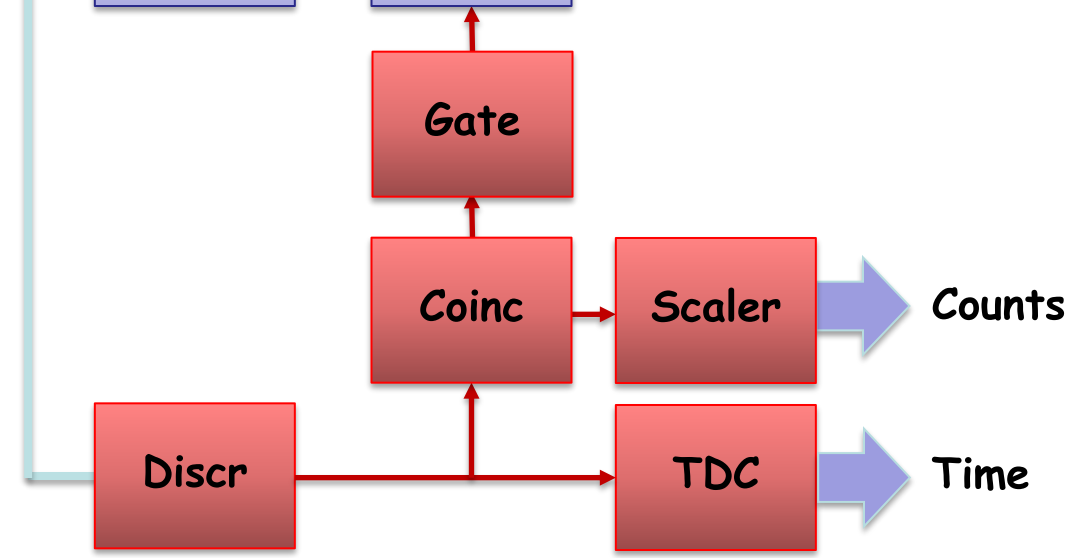
Multi-board synchronization and scalability

Coincidence and majority between channels/boards

Traditional acquisition chain

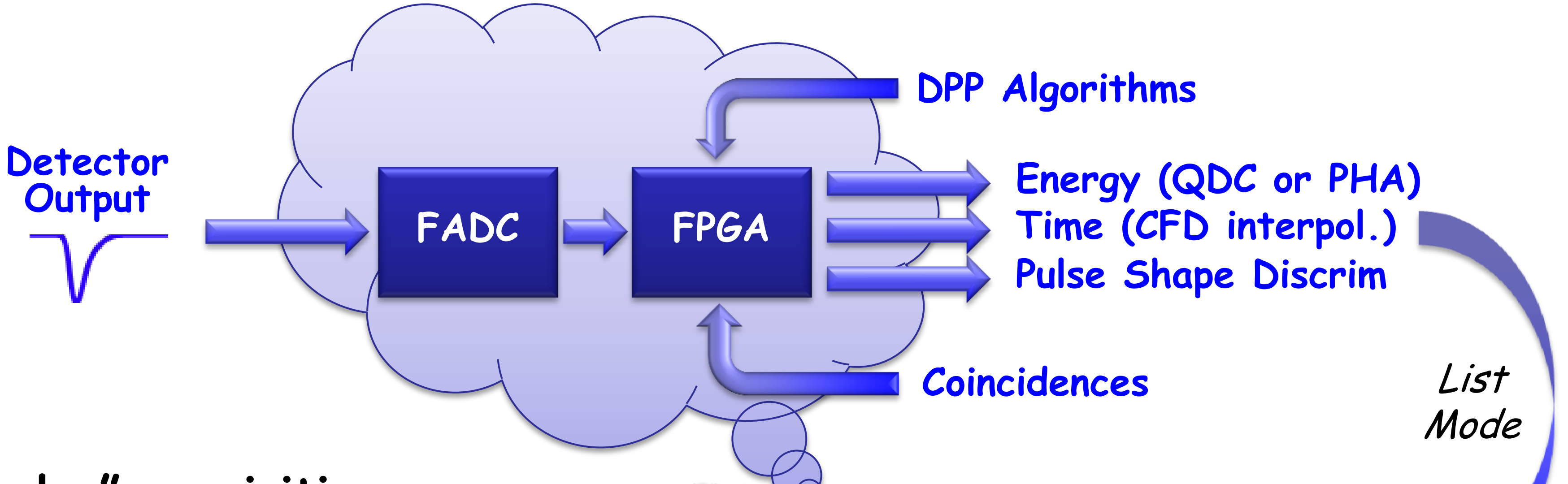
A/D conversion at the end of the chain





Jungle of modules and cables!

Fully digital acquisition chain



"one plug" acquisition

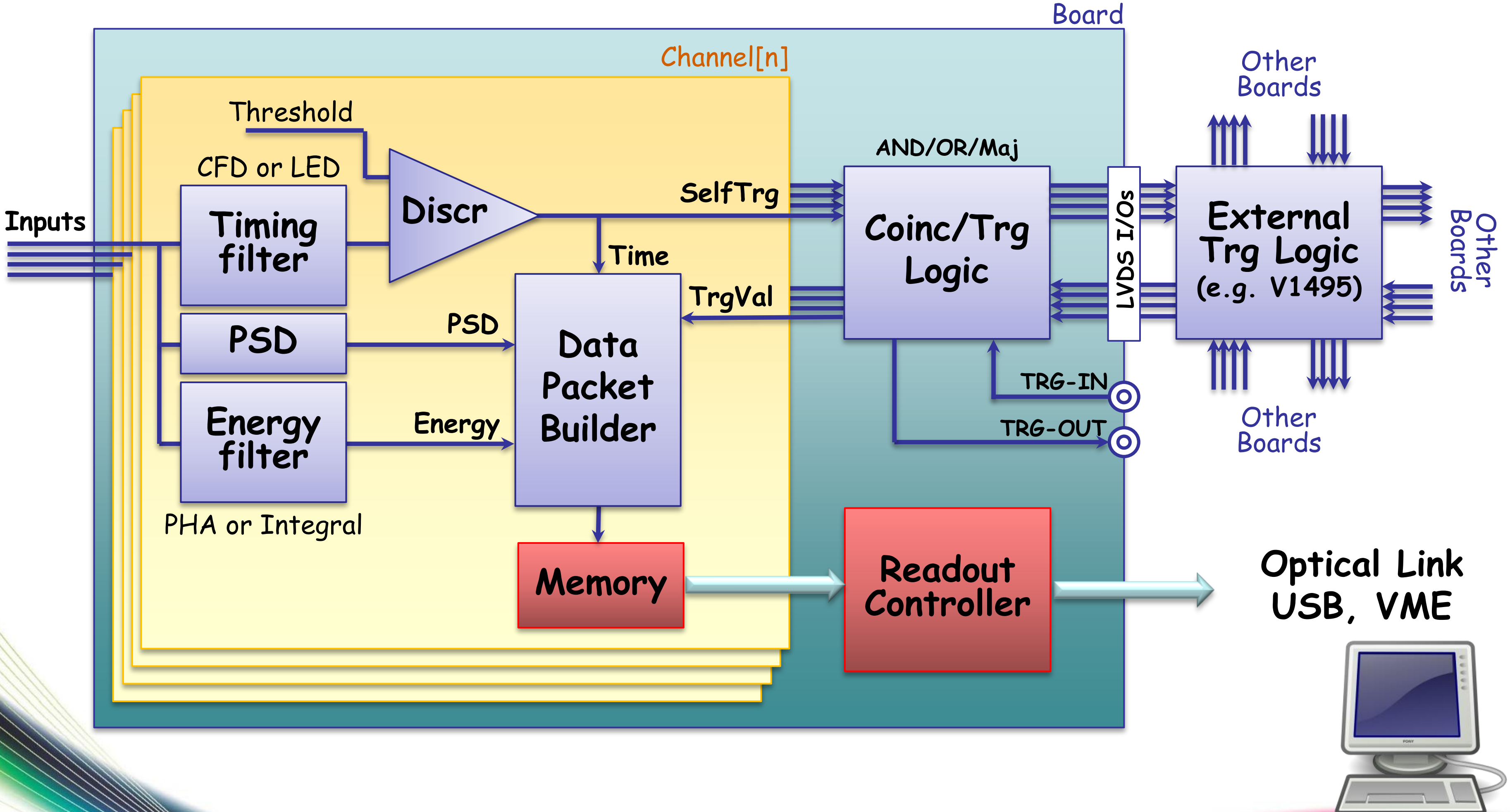
Early A/D conversion.
Preserve information!

CAEN Tools for Discovery

Benefits of the digital approach

- One **single board** can do the job of several analog modules
- A/D conversion as early as possible, data reduction as late as possible: **preserve full information!**
- **multi-parametric analysis**: energy (QDC or PHA), timing (CFD / TDC) and Pulse Shape, all correlated in the same data flow
- 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

System Architecture



CAEN
Tools for Discovery

Digitizers Table

MODEL[1]	Form Factor	# channels	Sampling Frequency (MS/s)	# Bits	Input Dynamic Range (Vpp)	Bandwidth (MHz)	Memory (Msample/ch) *Record Lenght*		DPP firmware[4]
							small	big	
x724	VME	8	100	14	0.5 - 2.25 - 10	40	0.5 *500µs*	4 *4ms*	PHA
	Desktop/NIM	4							
x720	VME	8	250	12	2	125	1.25 *5ms*	10 *40ms*	CI, PSD
	Desktop/NIM	4							
x730	VME	16	500	14	0.5 and 2 [5]	250	1.25 *250µs*	10 *2ms*	PHA, PSD[6]
	Desktop/NIM	8							
x725	VME	16	250	14	0.5 and 2 [5]	125	1.25 *500µs*	10 *4ms*	PHA, PSD[6]
	Desktop/NIM	8							
x731	VME	8/4	500/1000	8	2	250/500	2/4 *2ms*		-
	Desktop/NIM	4/2							
x751	VME	8	1000/2000	10	1	500	1.8/3.6 *1.8ms*	14.4/28.8 *14.4ms*	PSD, ZLE
	Desktop/NIM	4							
x761	VME	2	4000	10	1	1000	7.2 *1.8ms*	57.6 *14.4ms*	-
	Desktop/NIM	1							
x740	VME	64	62.5	12	2 - 10	30	0.19 *3ms*	1.5 *24ms*	QDC
	Desktop/NIM	32							
x742	VME	32+2	5000[2]	12	1	600	0.128[3] *200ns*		-
	Desktop/NIM	16+1							
x743	VME	16	3200[2]	12	2.5	500	0.003[7] *640ns*		CM
	Desktop/NIM	8							

(1) The *x* in the model name is ***V1*** for VME, ***VX1*** for VME64X, ***DT5*** for Desktop and ***N6*** for NIM
(2) Sampling frequency of the analog memory (switched capacitor array); A/D conversion takes place at lower speed (dead-time)
(3) The memory size for the x742 is 128 events of 1024 samples each. Record length can be 200 ns, 500 ns or 1 µs depending on the sampling frequency
(4) DPP-PHA: Pulse Height analysis (Trapezoidal Filters), DPP-CI and CM: Charge Integration (digital QDC); DPP-PSD: n/γ Discrimination (double gate charge)
(5) Input dynamic range with 2 options software selectable
(6) PSD includes also digital CFD with zero cross interpolation for ultra-fine time stamping
(7) The memory size for the x743 is 3 events of 1024 samples each

Application Map

	10 bit	12 bit	14 bit
62.5 MS/s		QDC 740	PHA
100 MS/s			724-780-781
250 MS/s	PSD-QDC	720	725
500 MS/s			730
1 GS/s	751		CFD-TDC
>= 2 GS/s	751 / 761	742 / 743	

Communication: no backplanes!

The digitizers may require a huge readout bandwidth, especially when it is necessary to dump entire waveforms from the input channels

Dislike of DAQ running on special computers sitting on a backplane (SBC)
Software running on “corner shop” computers

CONET: Optical Readout and Control Link that transfers data from/to the front panel of the digitizers directly into the computer via a PCI Express card at ~350 MB/s

The physical interface to the user is standard, performant and widespread: 8 lane PCI Express

One link can manage up to 8 digitizers in daisy chain (~ 90 MB/s per link)

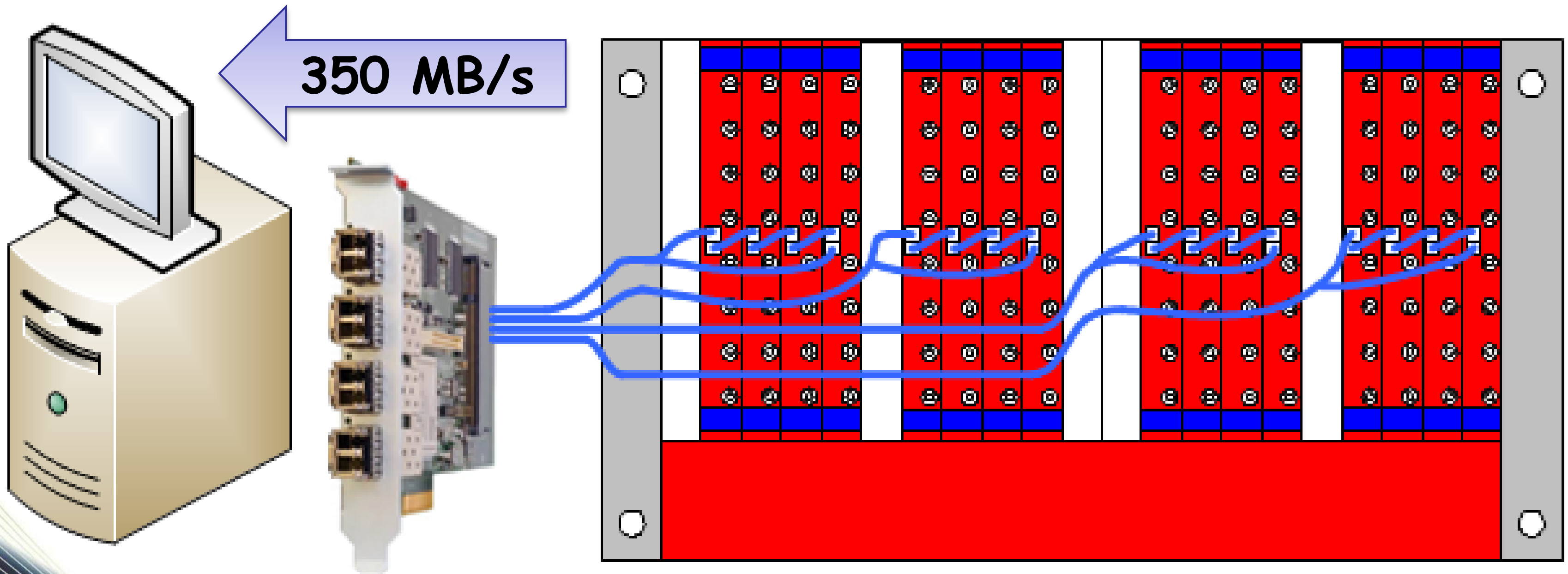
The Front End is form factor independent

Legacy access through the **VME backplane** is still available:
up to 160 MB/s with 2eSST protocol (SBC needed)

USB 2.0 (for desktop and NIM versions): 30 MB/s, no hardware required!

CONET2 readout example

- 16 digitizers in one VME crate read out by 1 computer @ 350 MB/s
- One 4 link A3818 PCIe card. Each link reads 4 digitizers in daisy chain
- ~22 MB/s per digitizer (can be 4 times higher in a P-to-P topology)
- VME crate just for power and mechanics (no backplane communication)

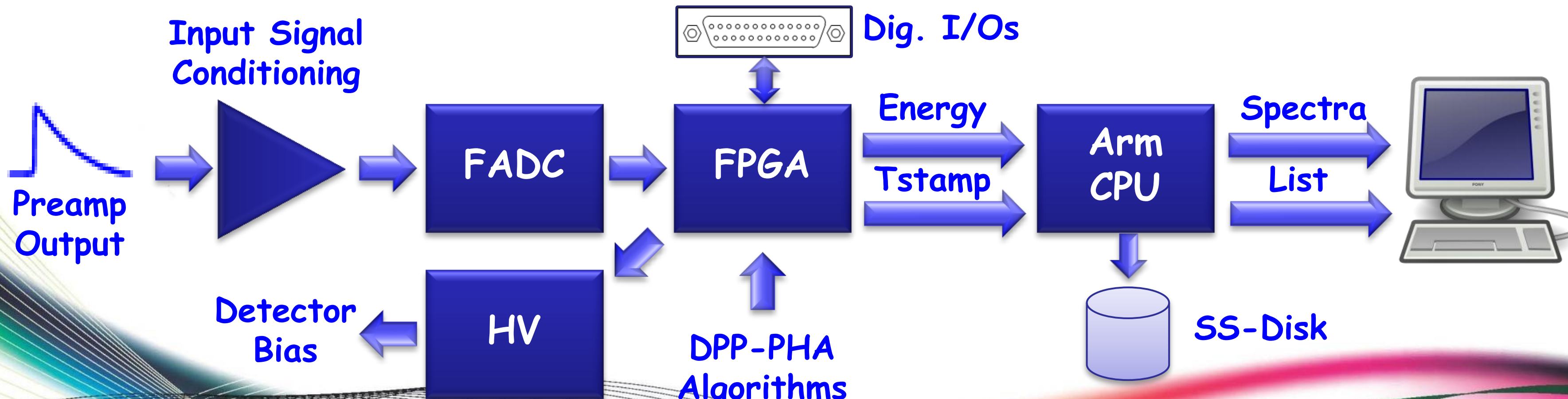


DIGITAL SPECTROSCOPY

From raw waveforms to spectra

From the experience of the waveform digitizers, CAEN has developed digital solutions for Spectroscopy Applications:

- Same core architecture: Flash ADC + FPGA with DPP algorithms
- Input analog stage with DC or AC coupling (PZ comp.) and programmable gains
- Integrated HV and LV for PreAmps
- Digital I/Os (Run start/stop, SCA, ICR, MCS, sample changer, Gate/Veto, Coinc, etc…)
- Embedded Arm CPU (Linux Based) to manage acquisition of Spectra, Counting and Lists
- Local Solid State Disk to store Multiple Spectra
- Possibility of custom software running on-board (unattended operation)



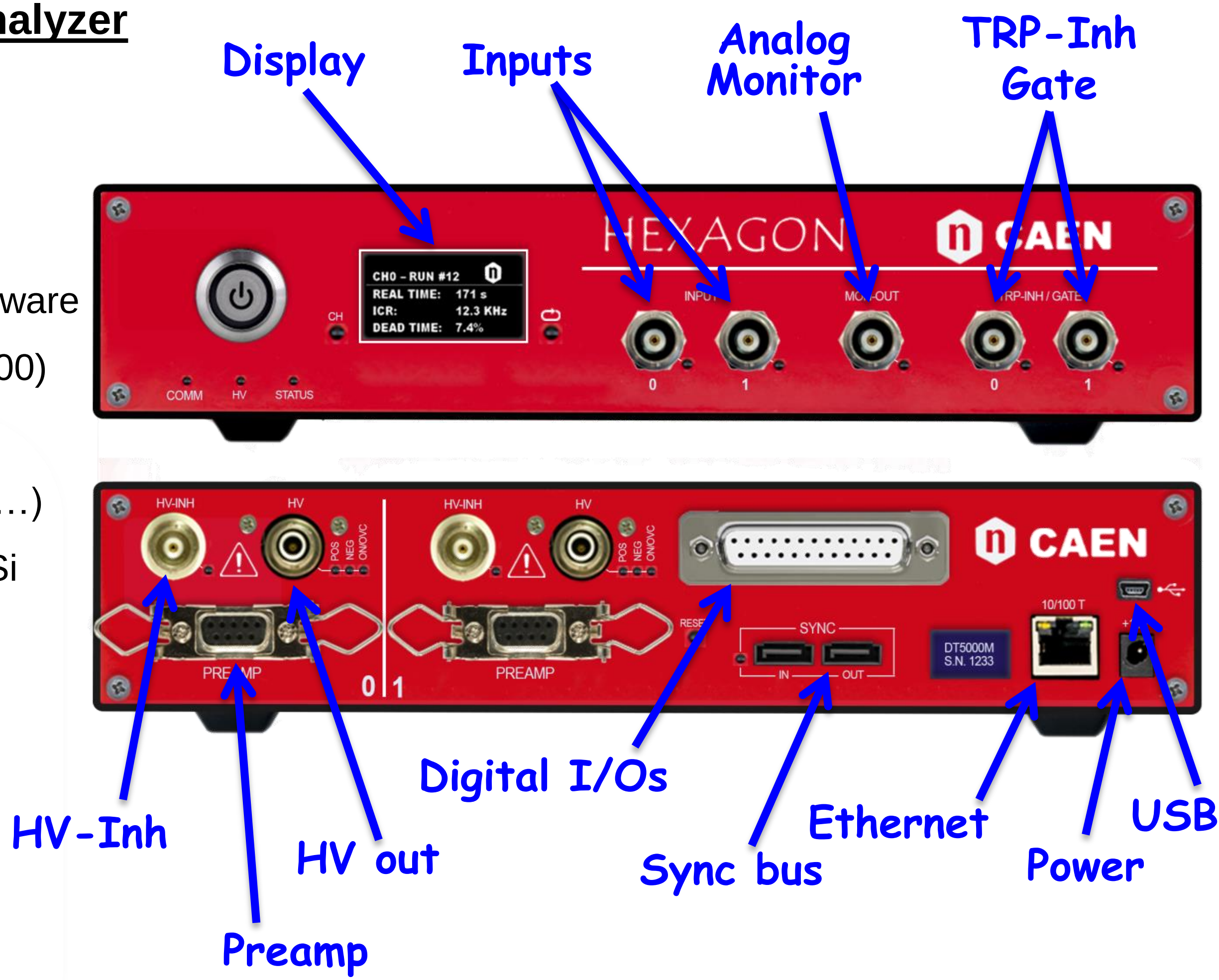
CAEN Tools for Discovery

Hexagon: Dual 32K MCA

Dual Digital 32K Multi Channel Analyzer

- Acquisition Modes:
  - *PHA (Multi-Spectrum SSD storage)*
  - *Time Stamped List Mode*
  - *MCS*
- Signal Inspection: Analog Out and Software
- Progr. Coarse and Fine Gain (up to ~500)
- Two channel Coinc. and Anti-Coinc.

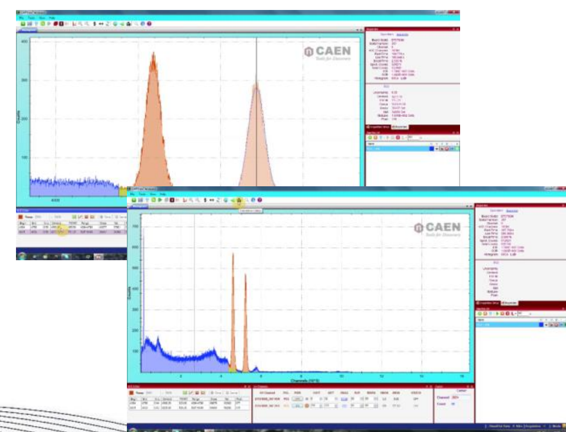
  (Compton Suppression, Cosmic Veto, …)
- Two HV (with Inhibit) for HPGe, PMT, Si
- Front Panel LCD Display
- Sync-bus for Multi-board systems
- Programmable digital I/Os
- Embedded customizable CPU
- Ethernet or USB communication
- MC²Analyzer and SDK software



CAEN Tools for Discovery

γstream: stand-alone tube base MCA

- **Compact, stand-alone, tube base MCA**
  - Compatible with scintillation detectors as NaI(Tl), CsI(Na), and LaBr3(Ce)
  - high voltage power supply (0 to +1600V / 500 µA)
  - PHA and List mode (SCA and MCS on the way)
  - Temperature drift compensation (Gain Stabilizer)
- **On-board battery and data storage** capability for active on-field measurements
- **Embedded ARM based CPU** for unattended operations
- **Wired and wireless connectivity** through USB, Ethernet, Bluetooth and WiFi interfaces
- **Software: MC²** Analyzer for PC, **GammaTouch** for Android (with GPS GeoTagging)



CAEN Tools for Discovery

High channel density digital QDC

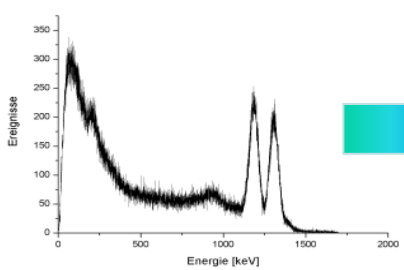
- Based on a 62.5 MS/s, 12 bit waveform digitizer (**x740** series)
- 64 channels is a VME board, 32 channels in a desktop
- **DPP-QDC** firmware: independent, self-gated integrators
- Time stamped list mode
- Signal inspector (digital oscilloscope)
- Best suited for slow scintillation detectors (NaI, CsI)… but also $LaBr_3$
- Perfect solution for air-born spectroscopy systems (light and compact)
- Successfully used with position sensitive ^3He tubes for neutron imaging

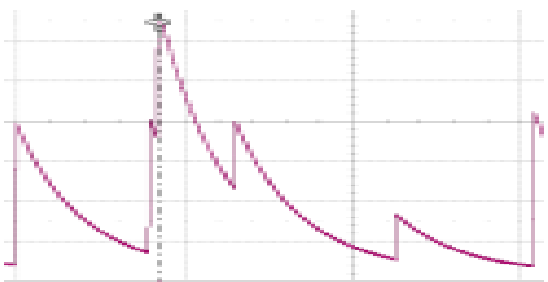
CAEN Tools for Discovery

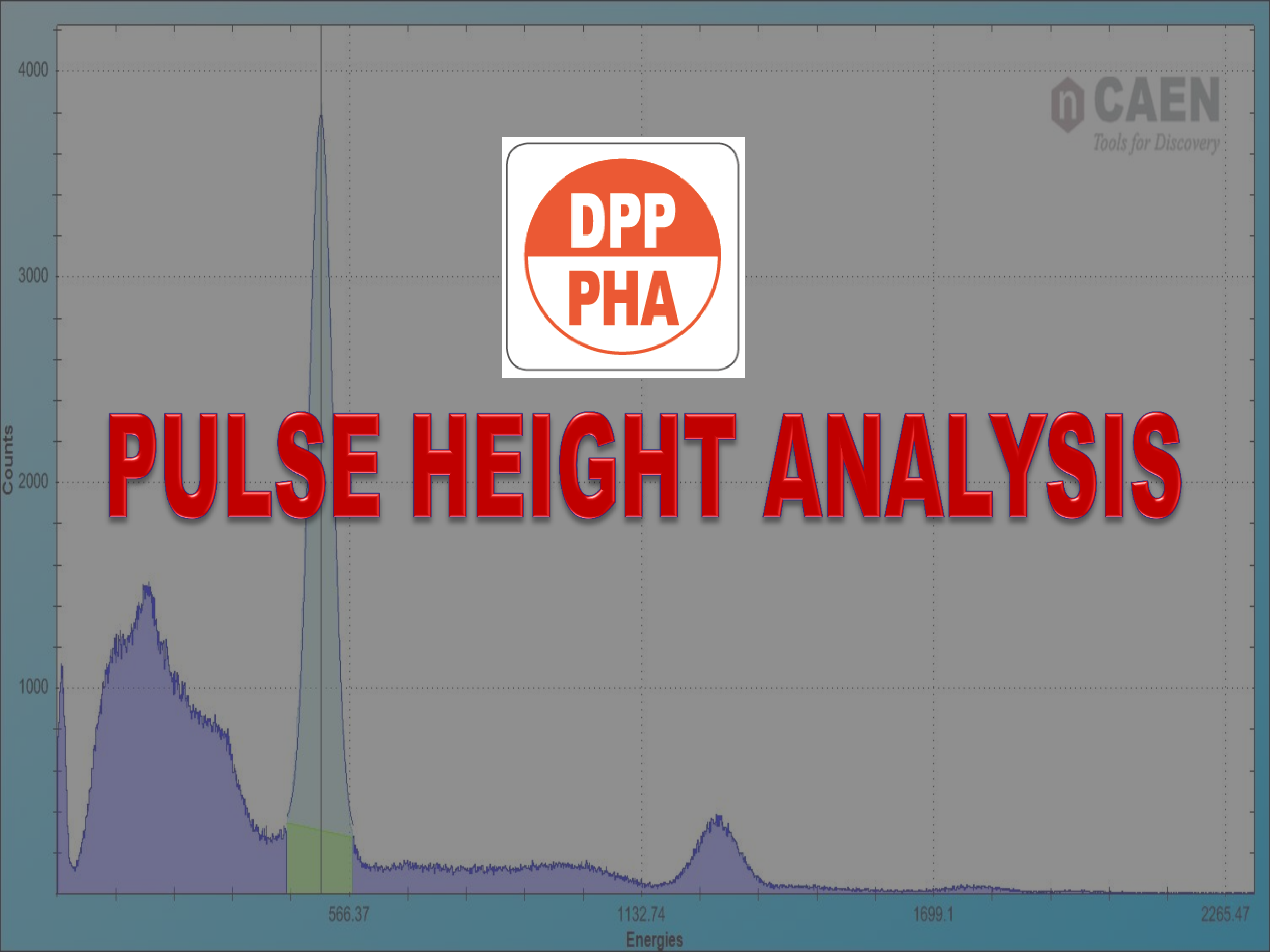
DT5800: Dual Digital Detector Emulator

A synthesizer of true random pulses with programmable shape and statistics emulating a real detector

- Two analog outputs (125MHz, 14bit DAC) + 4 digital I/Os
- Random or periodic **Pulse Generator** emulating a programmable energy spectrum and a poissonian statistic emission with pile-up
- Programmable **Pulse Shape** (synthesized or from recorded files)
- **Noise emulation** (1/f, baseline drift, white noise, interference)
- **Correlated event** emulation (with given energy spectrum and delay in steps of 11 ps) mixed in an uncorrelated background



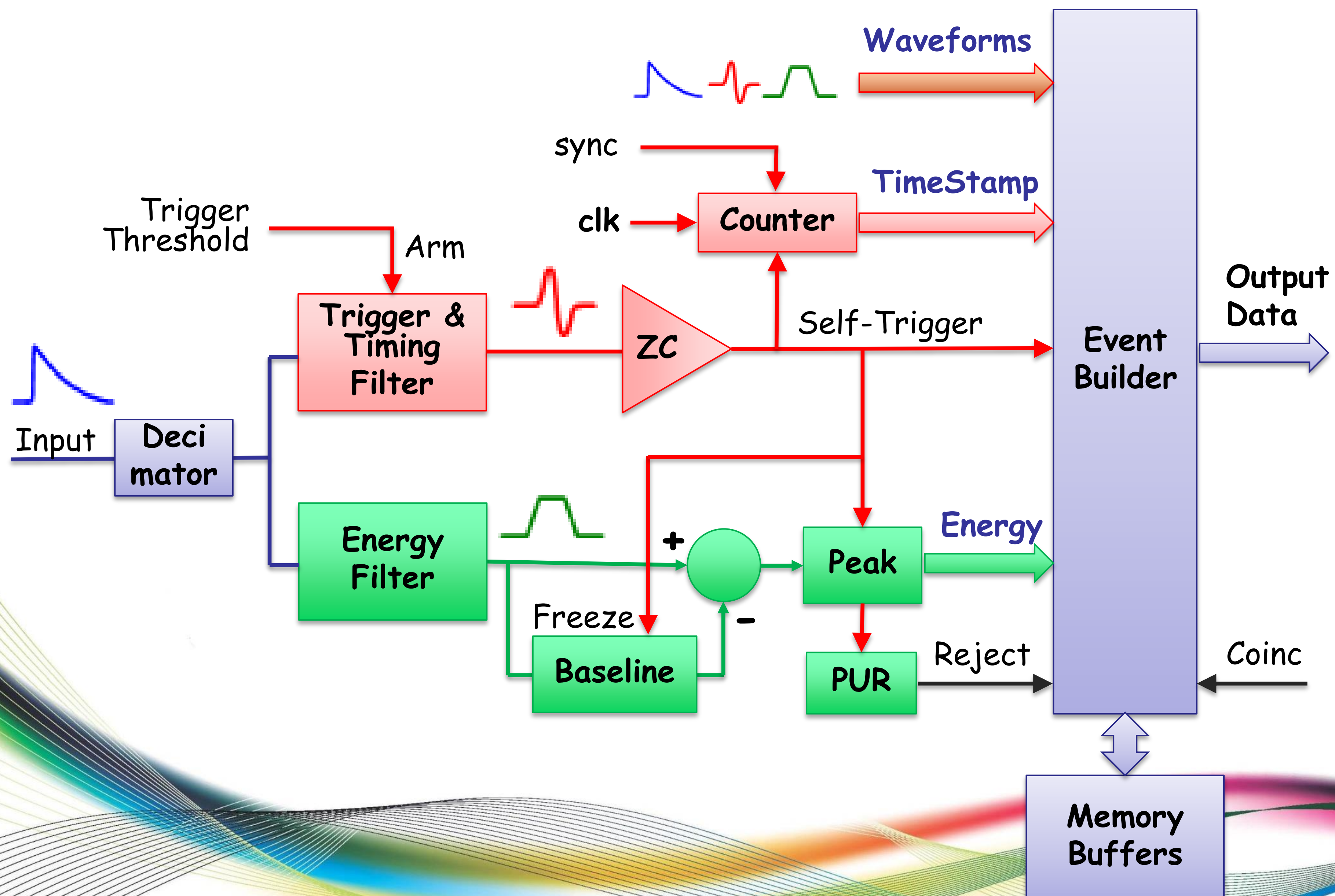



DPP
PHA
PULSE HEIGHT ANALYSIS
CAEN
Tools for Discovery
4000
3000
2000
1000
Counts
566.37
1132.74
1699.1
2265.47
Energies

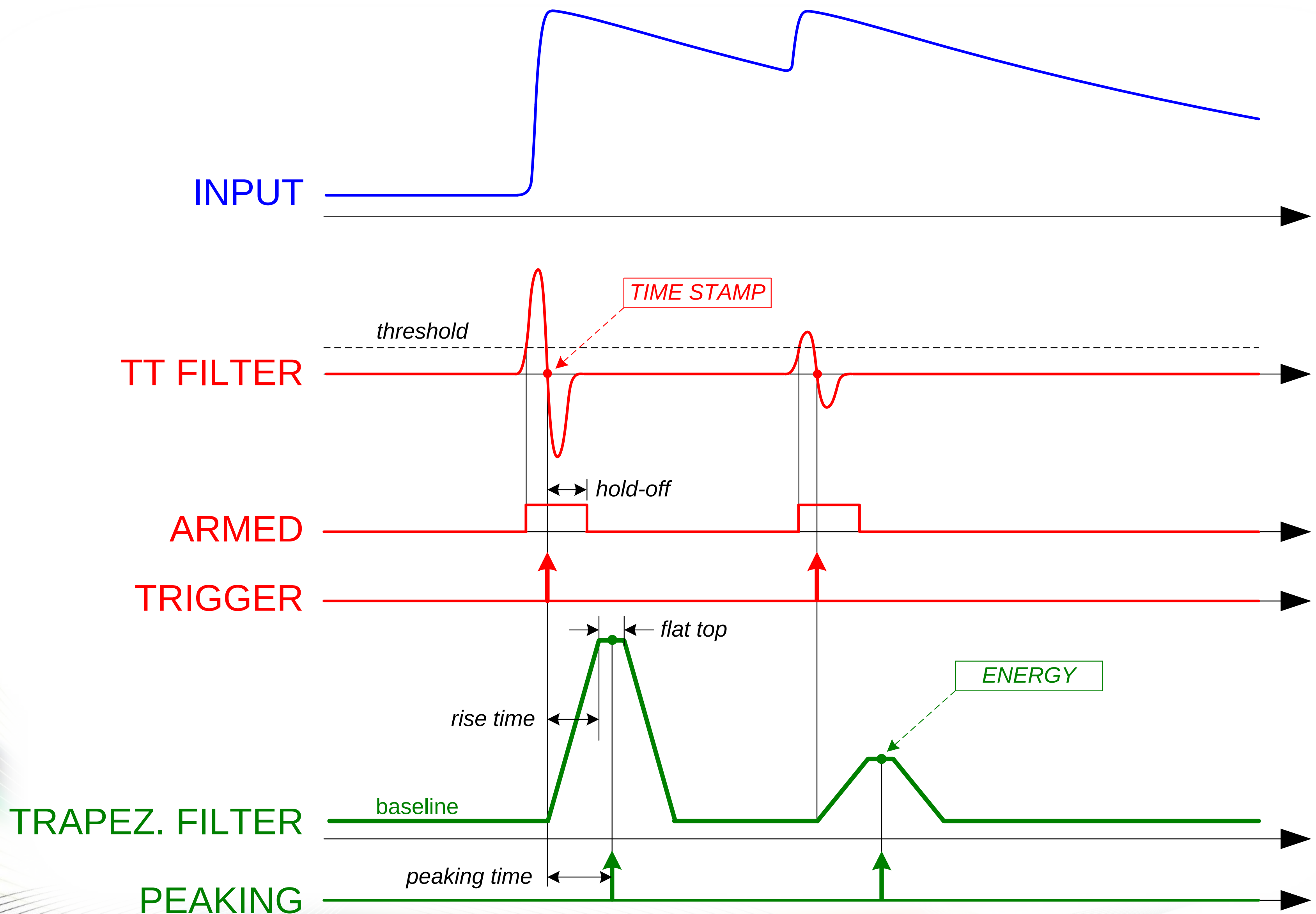
Digital Multi-Channel Analyzer:

- Replaces the analog chain with shaping amplifier + peak sensing ADC
- Directly connected to the Charge Sensitive Preamplifier output
- Implemented in the 14 bit digitizers (100 MS/s, mod. **x724-x781** and 500-250 MS/s, mod. **x730-x725**) as well as in the integrated MCAs (**Hexagon, GammaStream, DT5780**)
- Provides pulse height, time stamp and optionally raw waveforms
- Pile-up rejection, Baseline restoration, ballistic deficit correction
- Best suited for high resolution spectroscopy (HPGe and Si detectors) as well as low cost solutions such as NaI, CsI, etc…
- Multiple channel systems for clover or segmented detectors, compton suppression, cosmic veto, low background spectroscopy, etc…

DPP-PHA Block Diagram

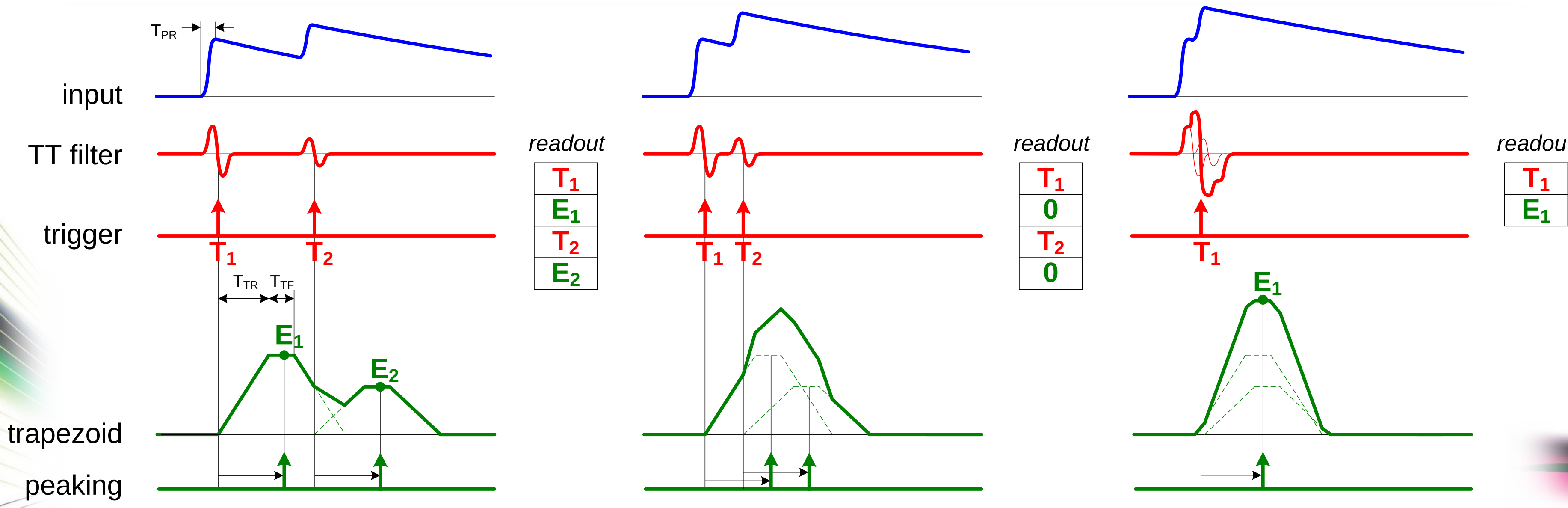


DPP-PHA signals



Pile-up in the Trapezoidal Filter

- **Case 1**: $\Delta T > T_{TR}+T_{TF}$ (2nd trapezoid starts on the falling edge of the 1st one). Both energies are good (no pile-up events)
- **Case 2**: $\sim T_{PR} < \Delta T < T_{TR}+T_{TF}$ (2^{nd} trapezoid starts on the rising edge or flat top of the 1st one). Pulse height calculation is not possible, no energy information is available (pile-up events); still two time stamps.
- **Case 3**: $\Delta T < \sim T_{PR}$ (input pulses piling up on their rising edge). The TT filter doesn't distinguish the double pulse condition. Only one event is recorded (energy sum). The Rise Time Discriminator might mitigate this unwanted effect.



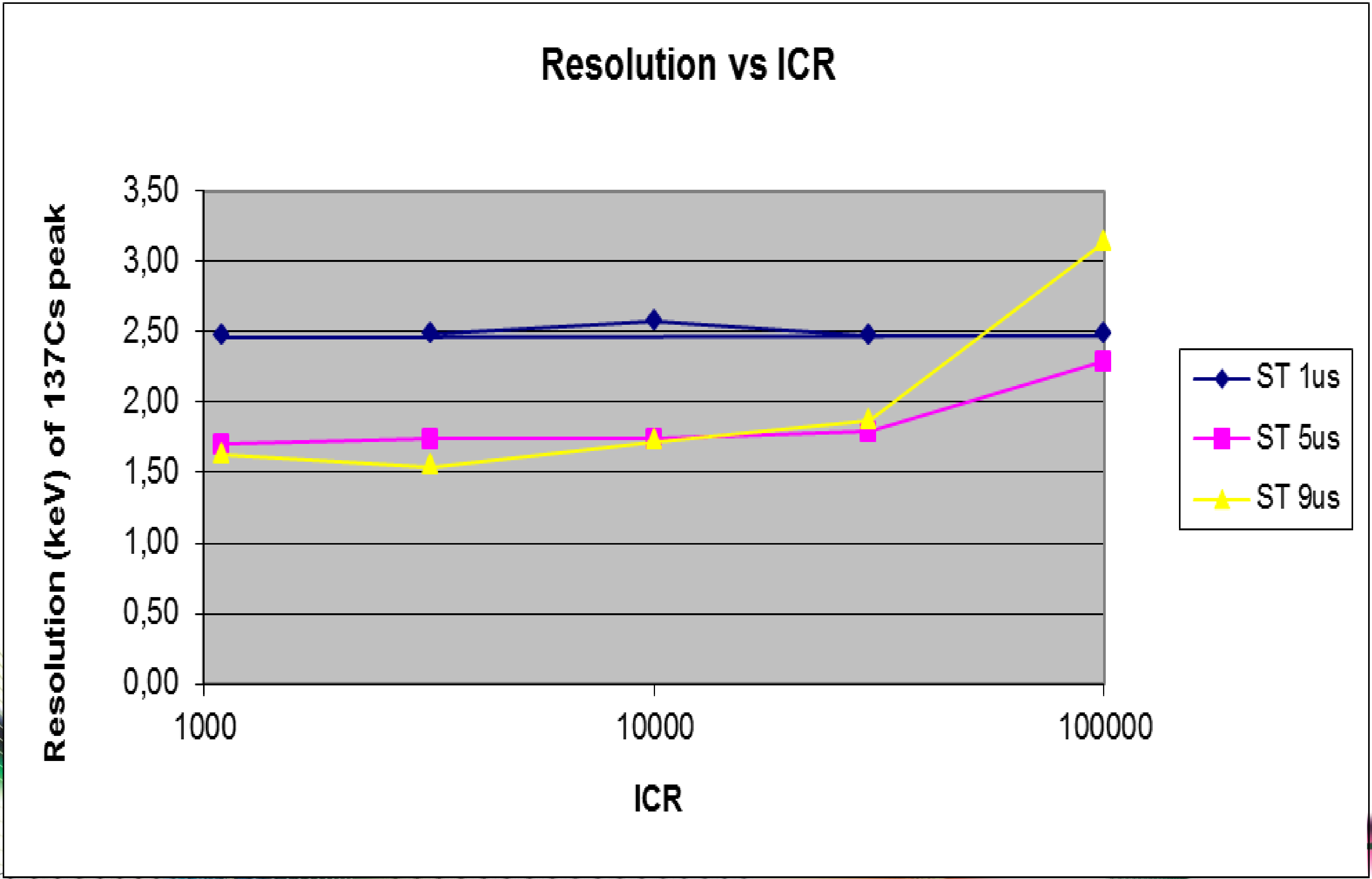
Test Results with HPGe and DT5780

Test Conditions	
MCA	DT5780
Detector	Canberra coaxial HPGe Mod. 7229P
Preamplifier	model 2001
HV bias	4.5 kV
Sources	^{60}Co, ^{137}Cs, ^{241}Am, ^{204}Tl
Counting rate	100 - 500 Hz
Measured Dead time	< 2%

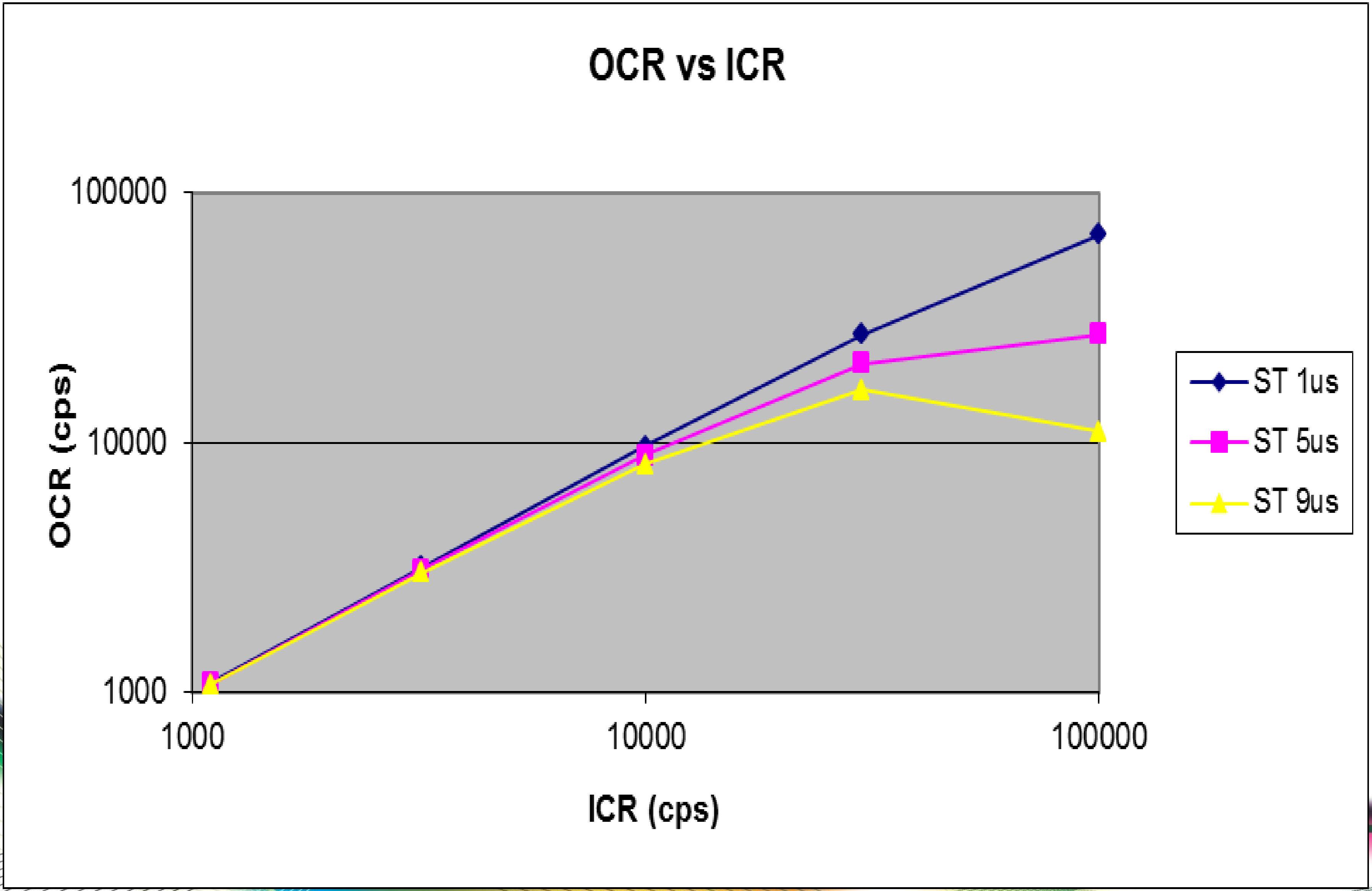
DPP parameter	value
Pole zero time constant	47 µs
# Samples for Baseline	1024
Trapezoid Rise Time	5.0 µs
Trapezoid Flat Top	2.0 µs
Peaking Delay	1.5 µs
Baseline Holdoff	0.1 µs
Peak Holdoff	20.0 µs

Energy (KeV)	Centroid (KeV)	FWHM (KeV)
59.541	59.521 +- 0.004	0.95 +- 0.01
68.895	68.910 +- 0.010	1.04 +- 0.03
70.819	70.809 +- 0.006	0.98 +- 0.01
661.659	661.716 +- 0.008	1.37 +- 0.01
1173.240	1173.233 +- 0.006	1.68 +- 0.01
1332.508	1332.487 +- 0.008	1.77 +- 0.01
1460.822	1460.833 +- 0.033	1.76 +- 0.06

Test Results with HPGe and DT5780

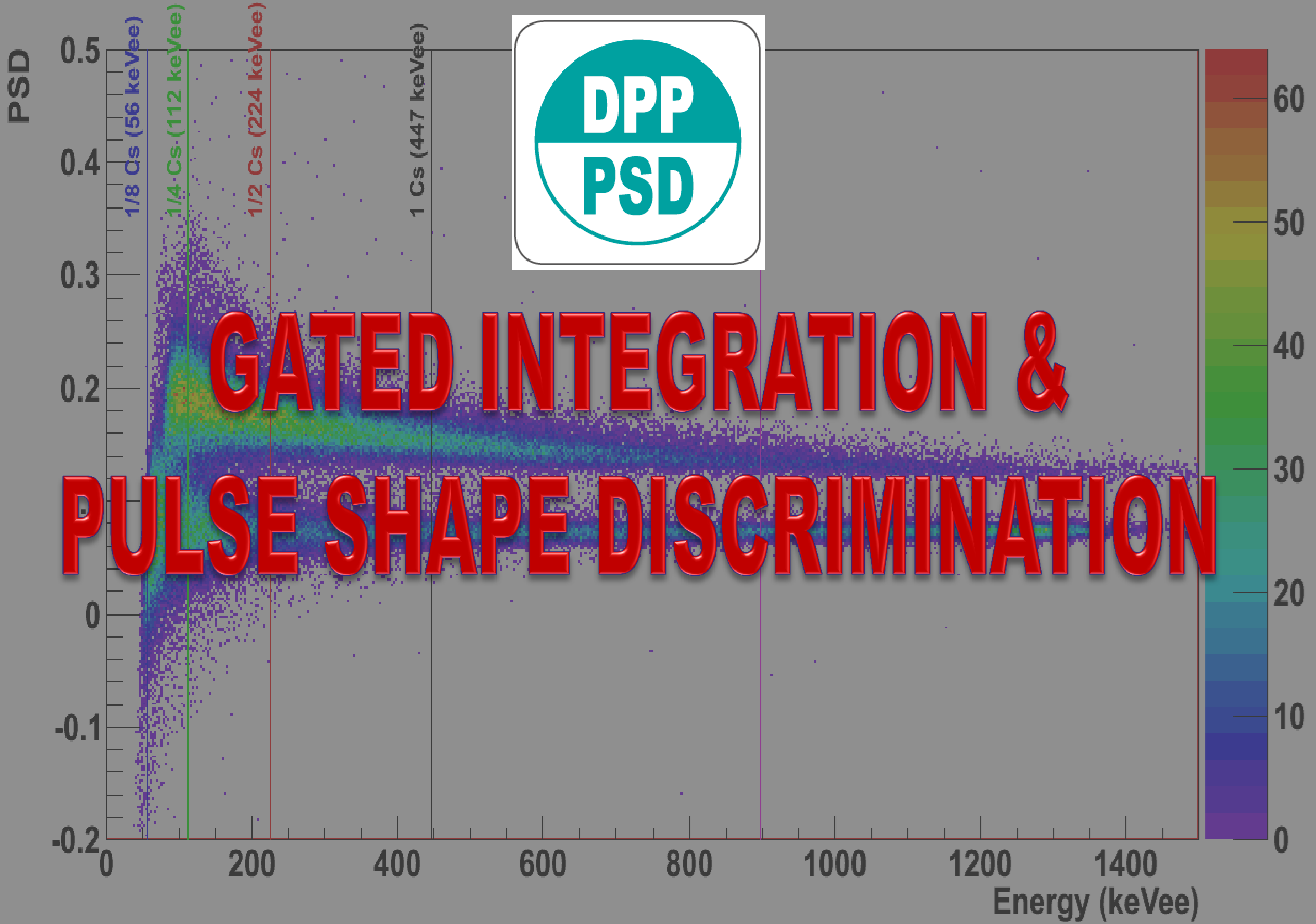


Test Results with HPGe and DT5780



GATED INTEGRATION & PULSE SHAPE DISCRIMINATION

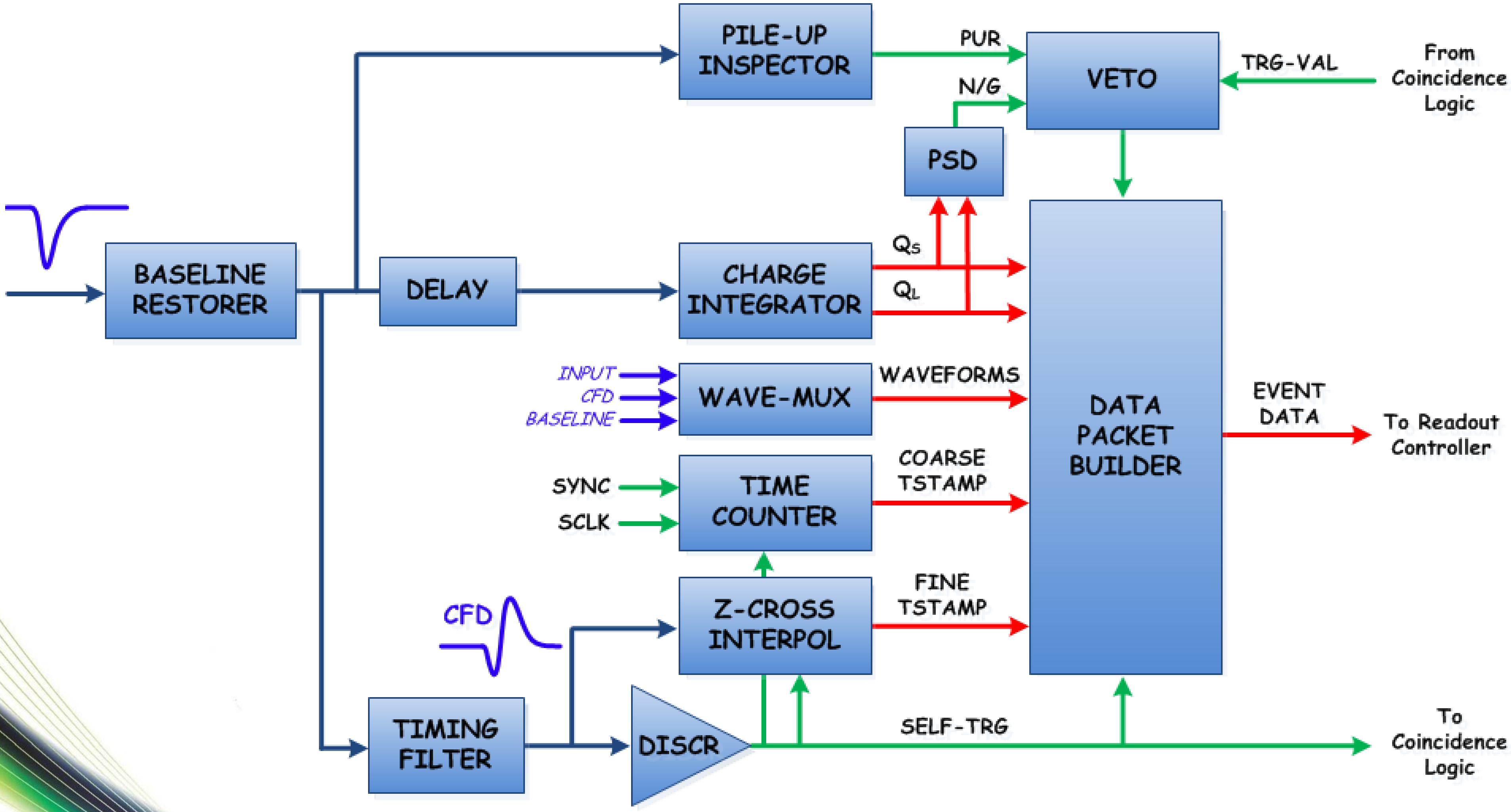
DPP PSD



DPP-QDC/CI/PSD topics

- Digital QDC (gated charge integrator) with self-gating capability
- Typically used with fast pulses from scintillators + PMT/SiPM
- Pulse Shape Discrimination: dual gate to separate fast and slow component (e.g. n-γ separation): **PSD = $(Q_{LONG} - Q_{SHORT})/Q_{LONG}$**
- Available for **x730-x725** (14 bit @ 500-250 MS/s) and **x751** (10 bit @ 1 GS/s). Simplified versions also for **x720** (12 bit @ 250 MS/s) and for the high channel density **x740** (62.5 MS/s, 12 bit)
- Digital CFD and Zero Crossing Interpolation for high resolution timing
- Pile-up rejection, PSD cut (gamma suppression)
- On-board coincidences, majority and trigger propagation
- **All-in-one, multi-parametric acquisition system!**

DPP-PSD Block Diagram

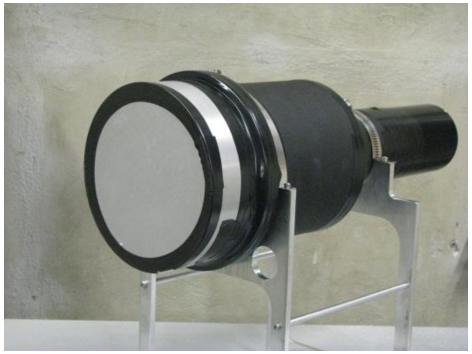


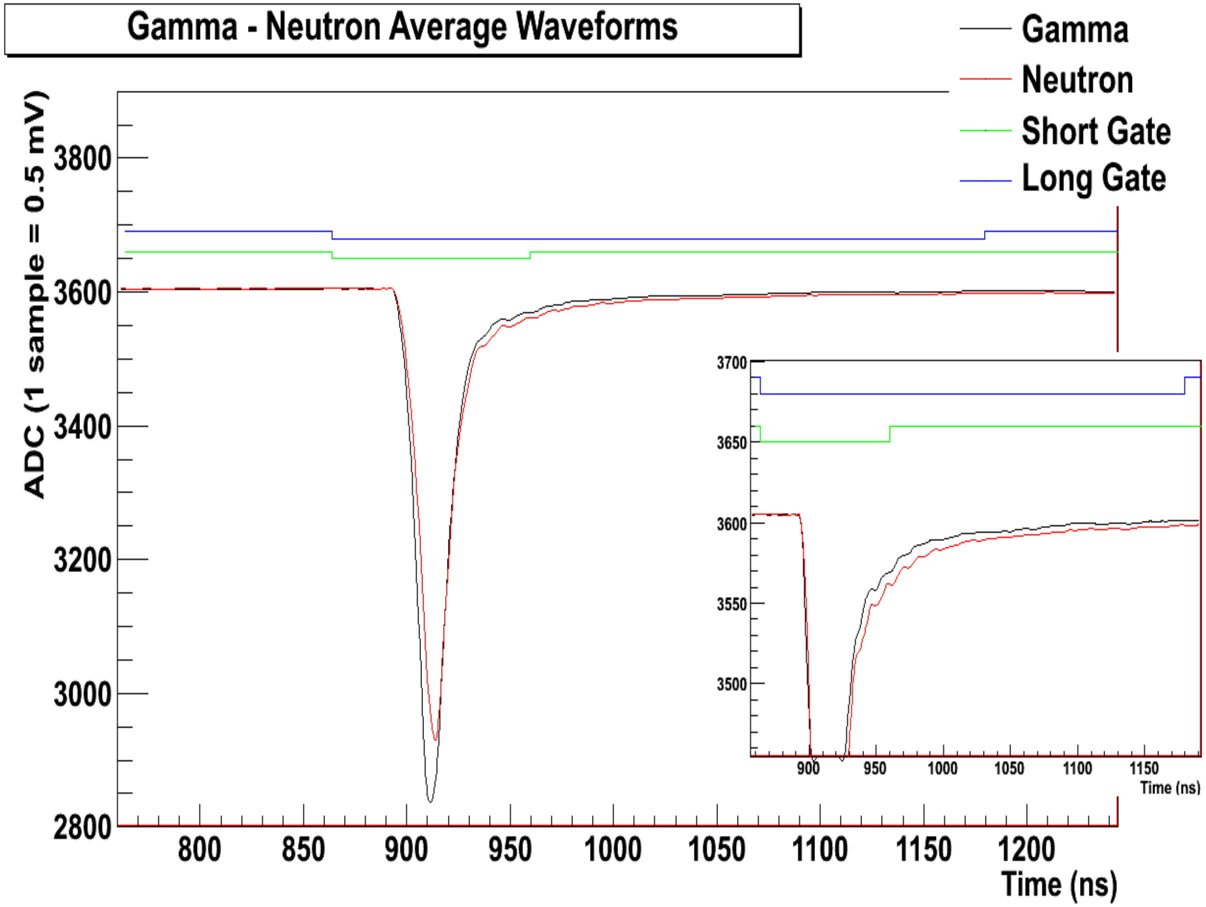
γ-n Discrimination: test results (I)

Detector: BC501A 5x2 inches,

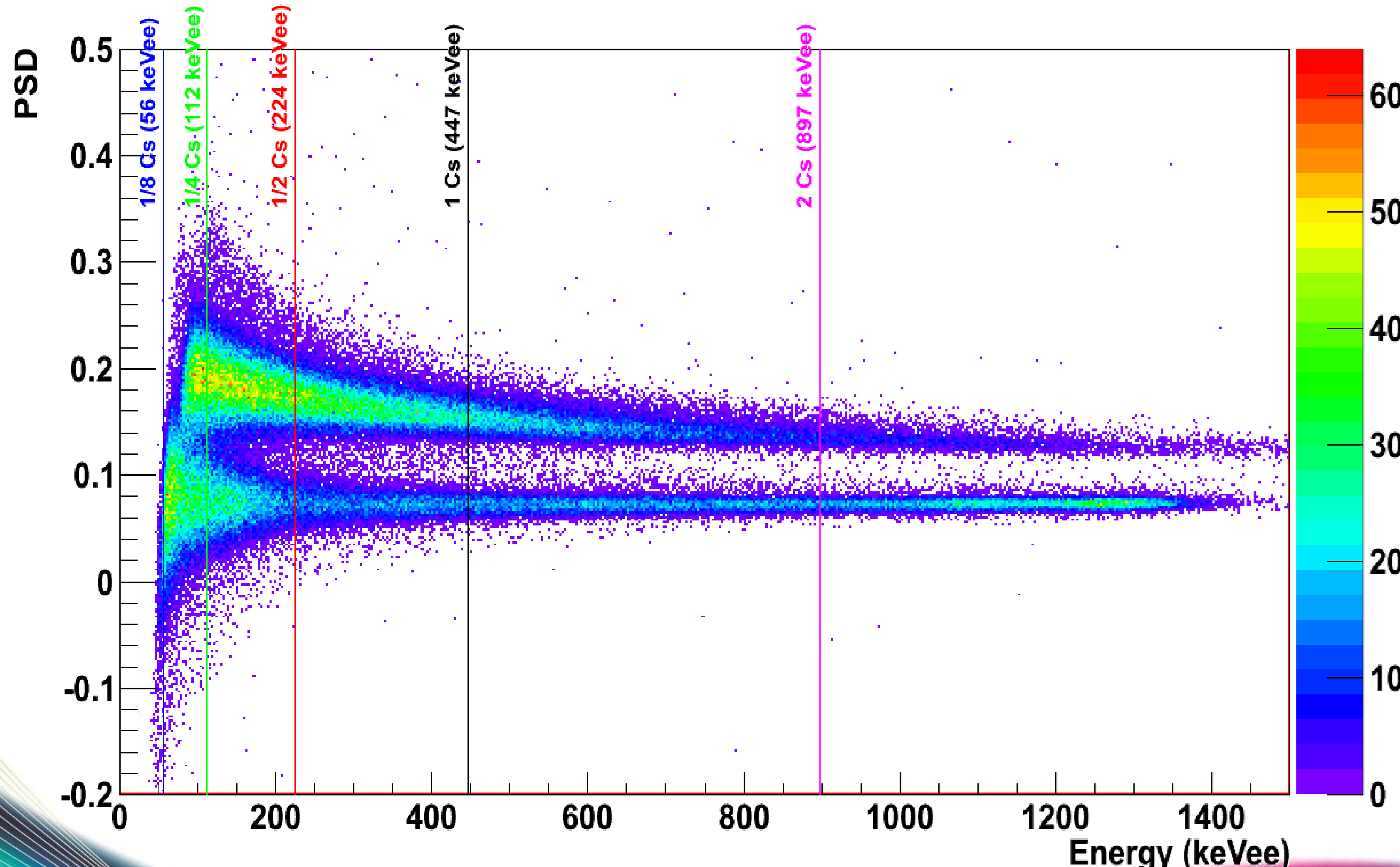
PMT: Hamamatsu R1250

Board: DT5270 with DPP-PSD

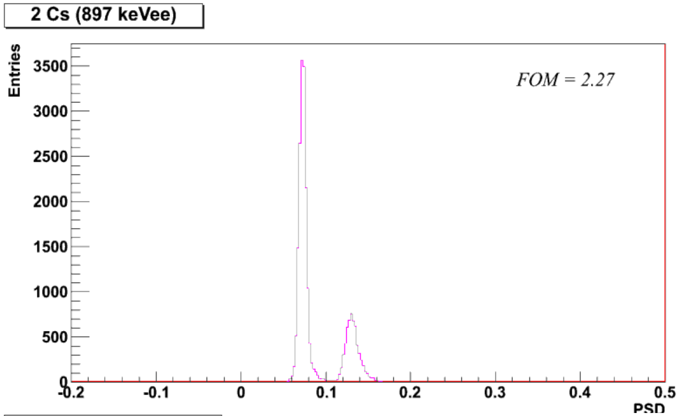


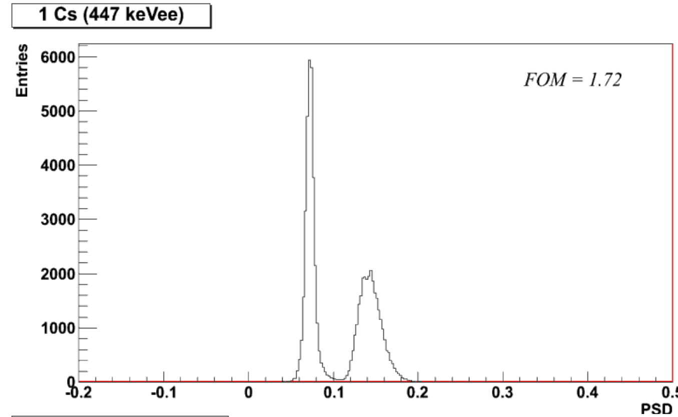


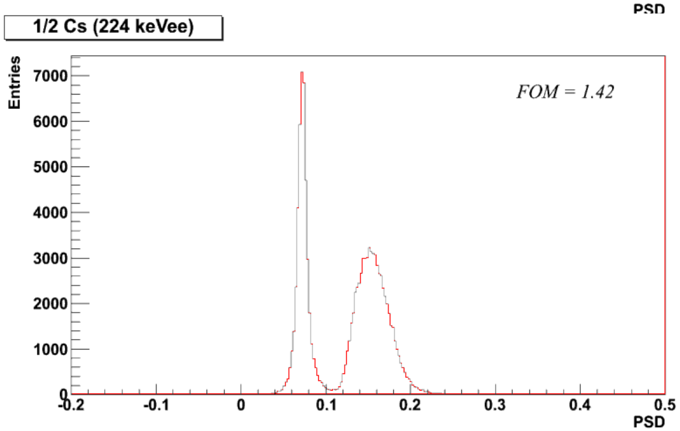
γ-n Discrimination: test results (II)

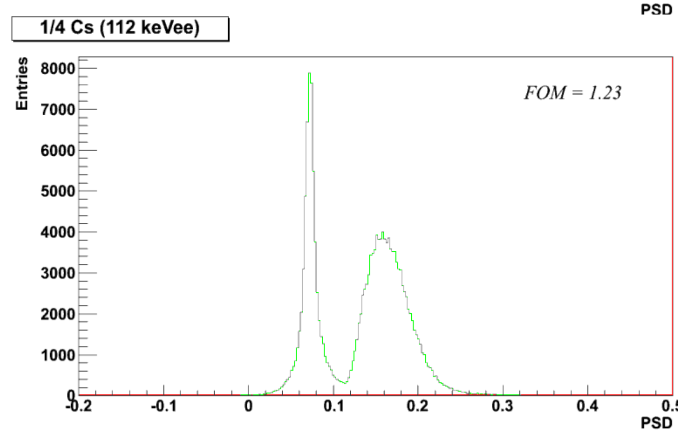


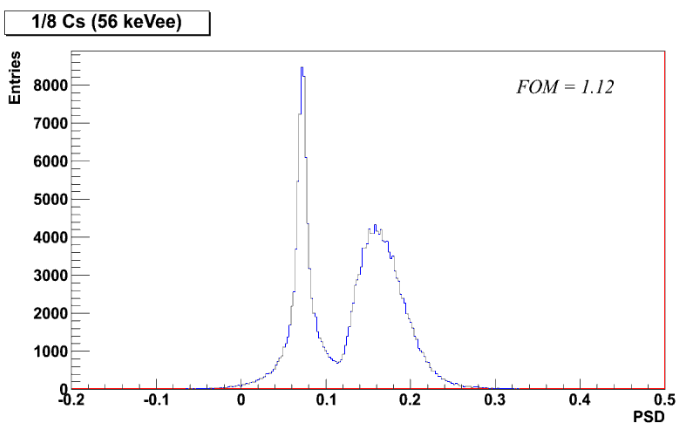
γ-n Discrimination: test results (III)





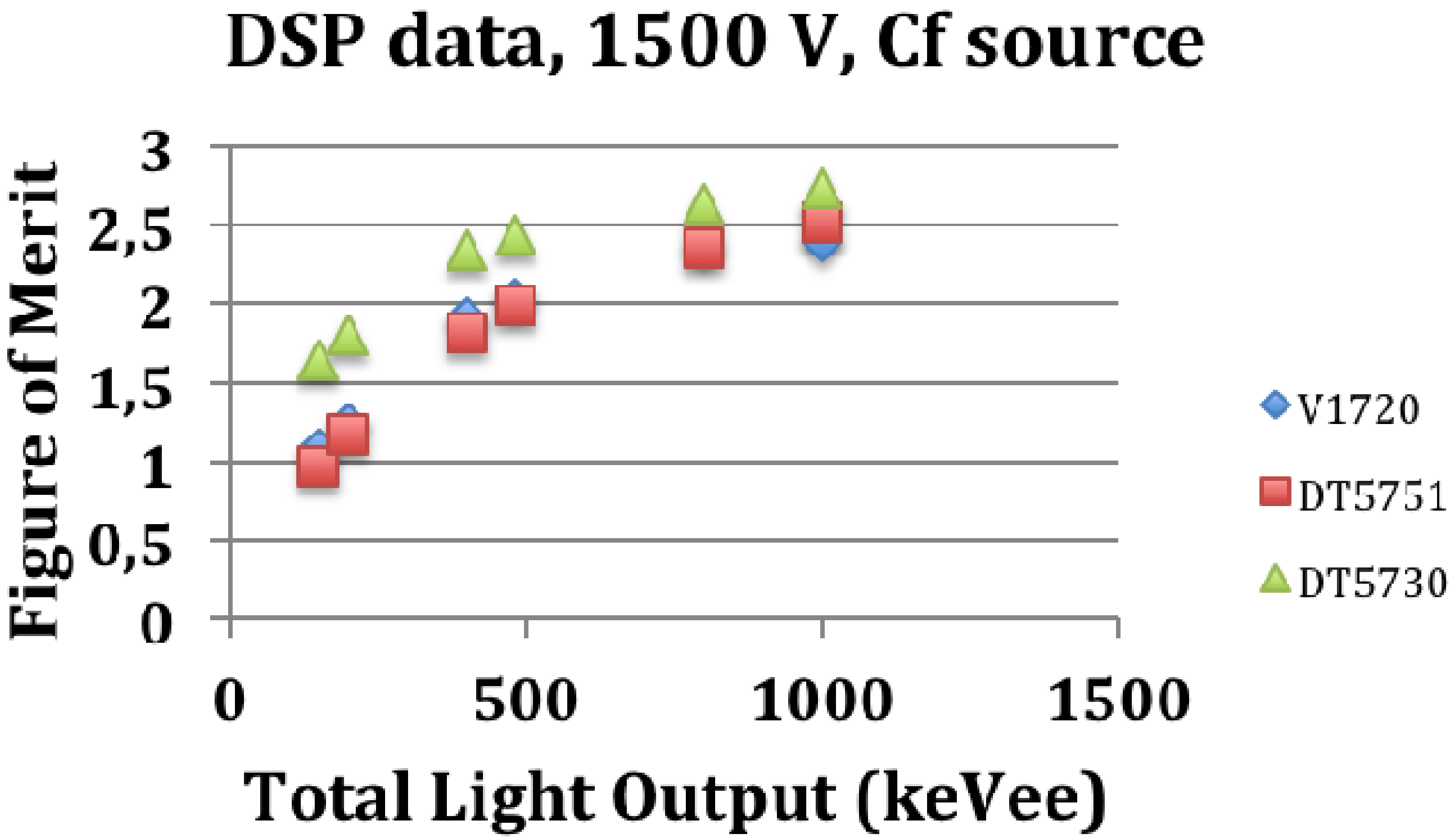




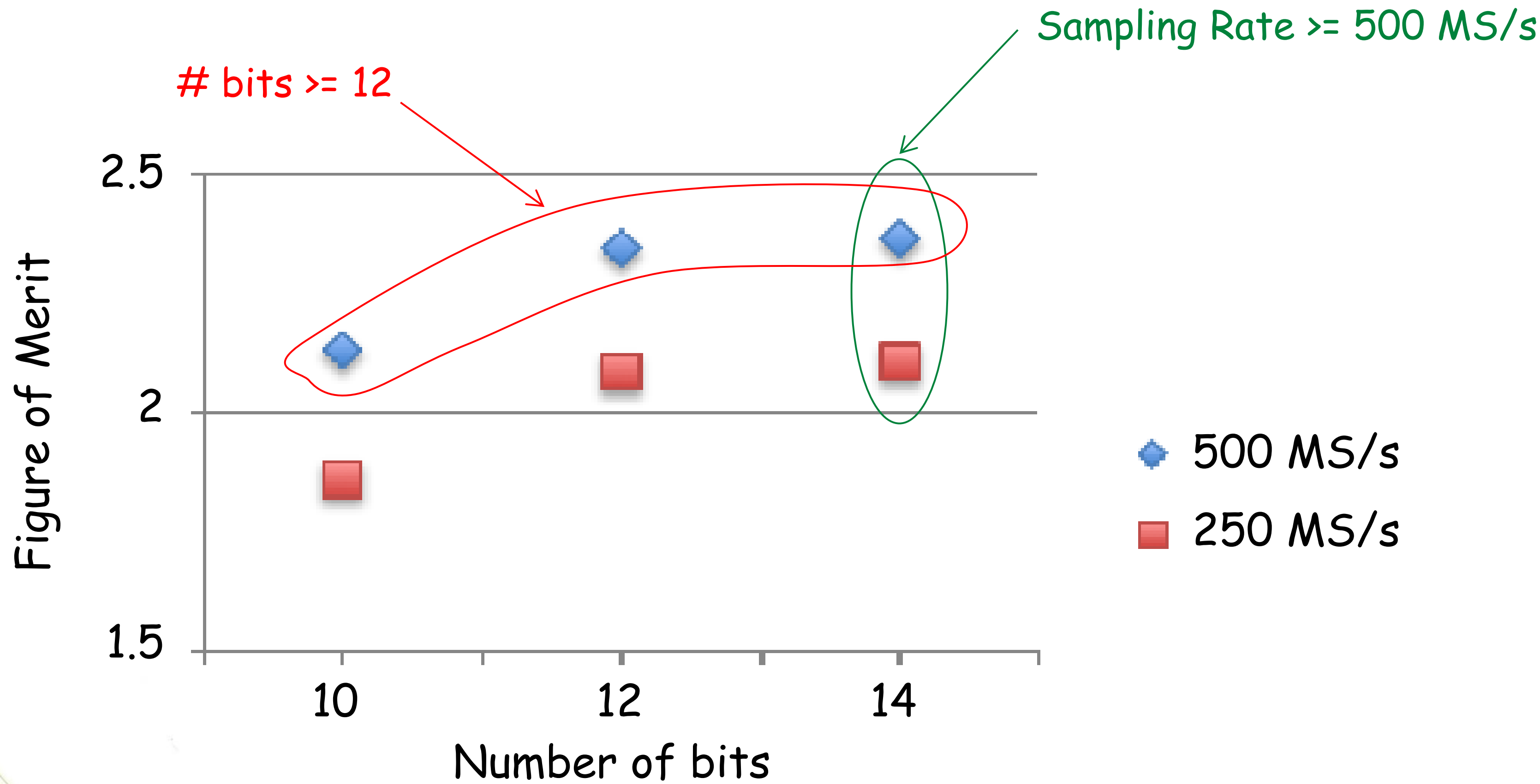


$$FOM = \frac{\Delta PEAK}{FWHM_{\gamma} + FWHM_{n}}$$

γ-n Discrimination: Comparing boards

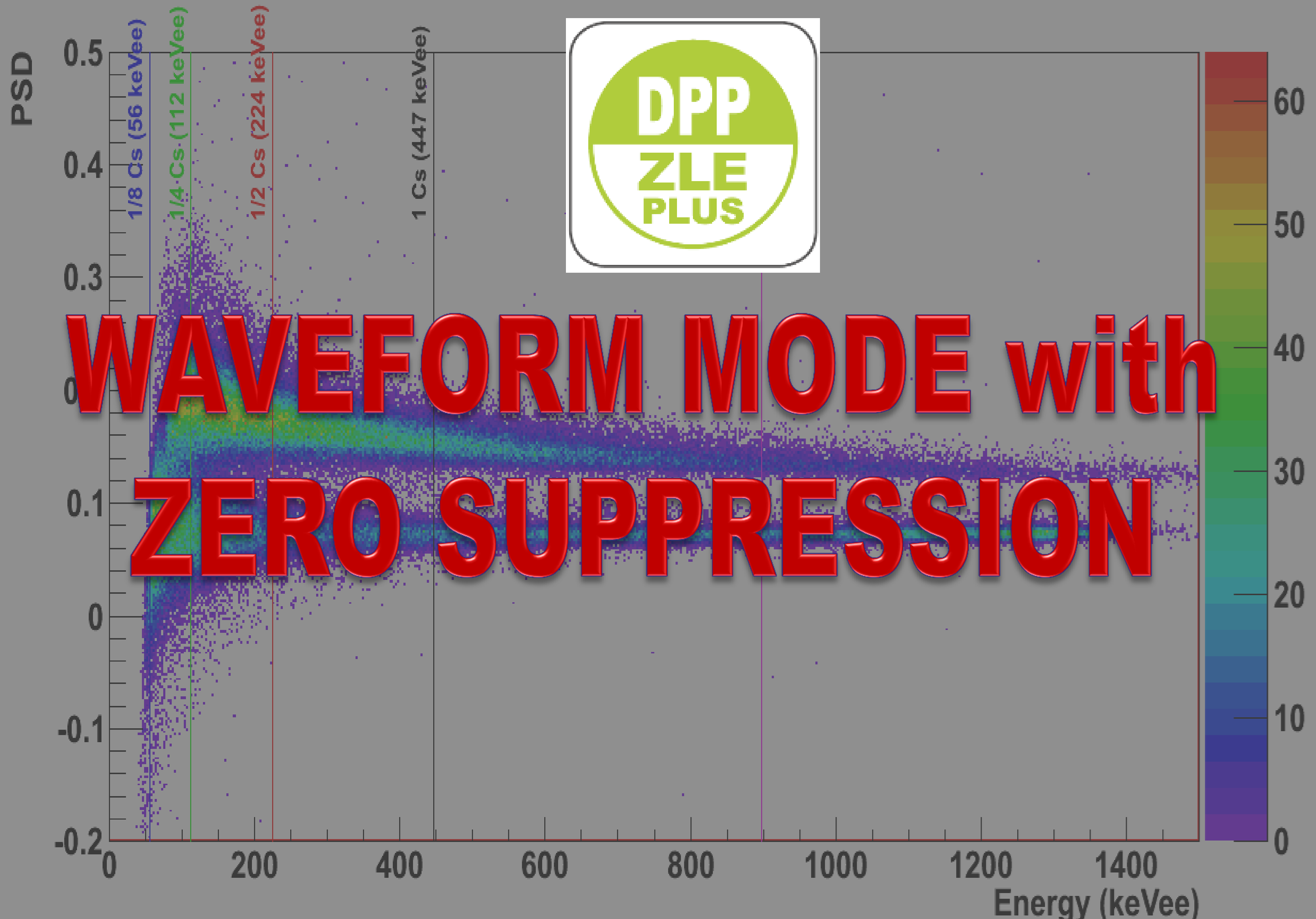


PSD FoM vs bits and sampling rate



WAVEFORM MODE with ZERO SUPPRESSION

DPP ZLE PLUS



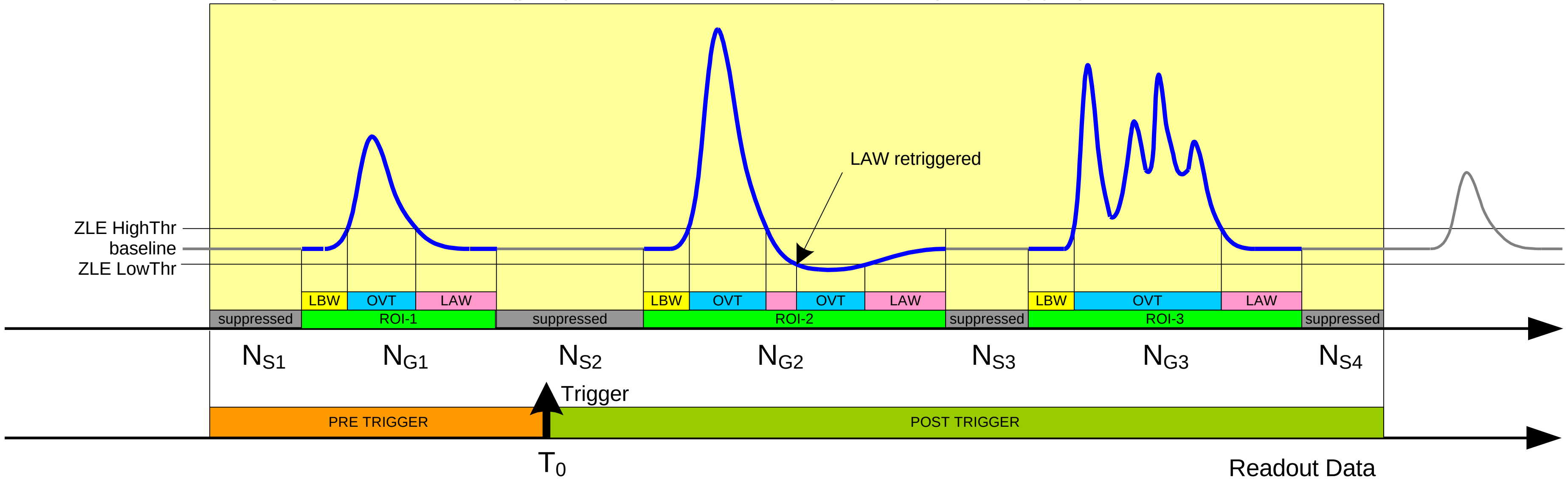
ZLE topics

- The zero suppression (**Zero Length Encoding**) in a waveform digitizer consists in removing from the acquisition window the parts or the waveform that don't contain useful information
- DPP used for the pulse identification (Region Of Interest) and baseline calculation, not to extract physical quantities from the waveforms
- Typically used in beam experiments where the **trigger is common** to all channels, but only few of them contains events
- Available for x724, x720, x721, x731 (1) and x751 (2).
  Coming soon for x730 (2)

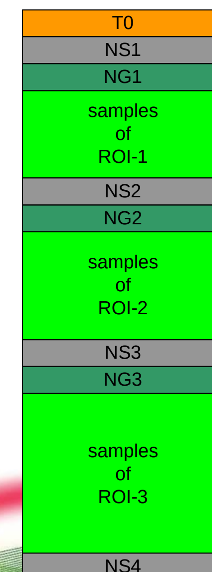
(1) The ZLE version for the x724, x720, x721 and x731 is free of charge (available in the standard firmware) but has less features and suffers from a readout bandwidth reduction

(2) License required

Acquisition Window (programmable size with pre and post trigger)



Readout Data



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

OVT — ***Over/UnderThreshold***: lasts as long as the signal is over/under threshold

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

ROI — ***Region of Interest***: size varies from ROI to ROI

T_0 — Trigger Time Stamp

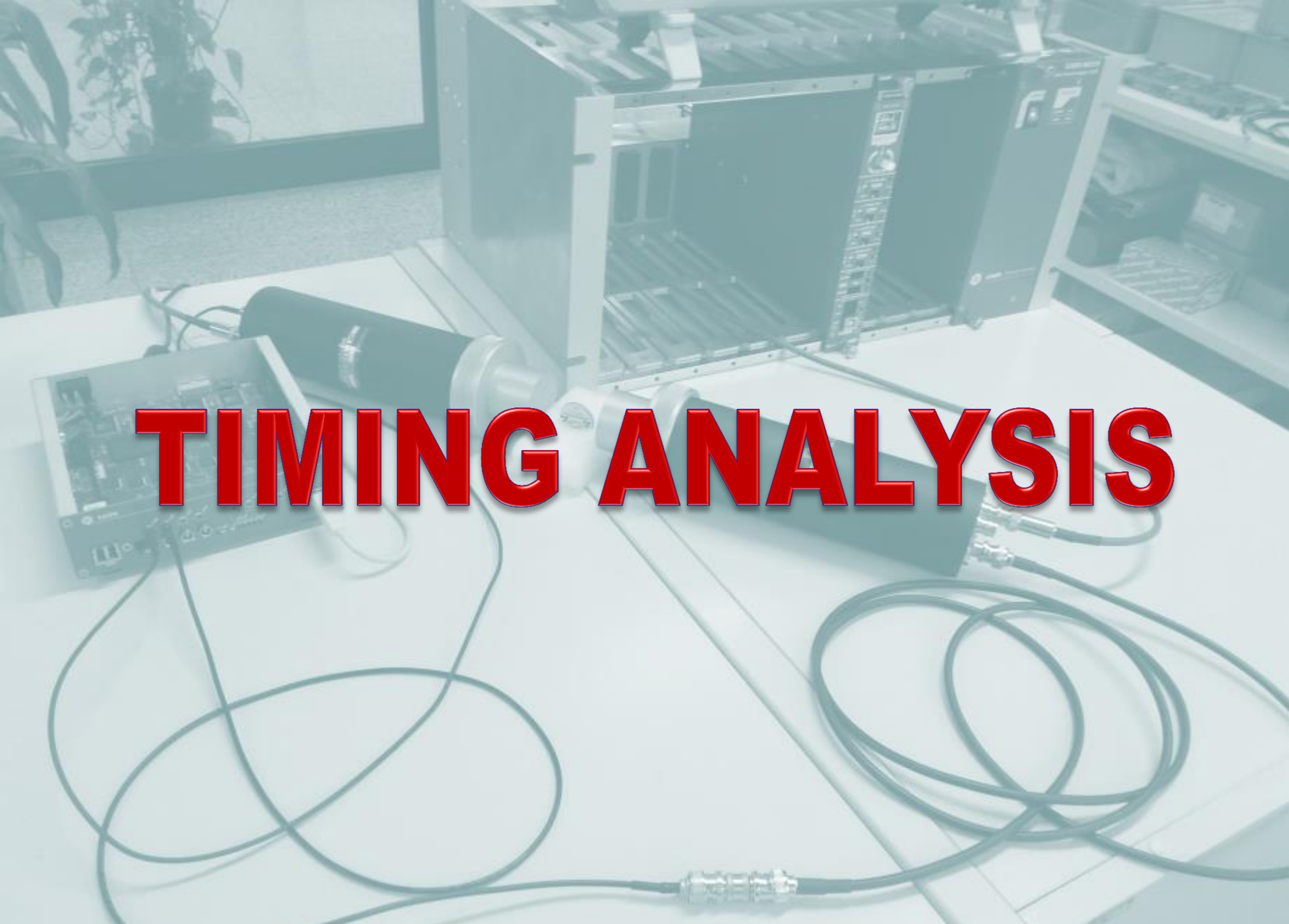
N_{Sn} — Number of skipped samples belonging to the n^{th} suppressed region

N_{Gn} — Number of good samples belonging to the n^{th} ROI

Acquired waveform

Suppressed Waveform

TIMING ANALYSIS



Conventional TDCs vs Digitizers

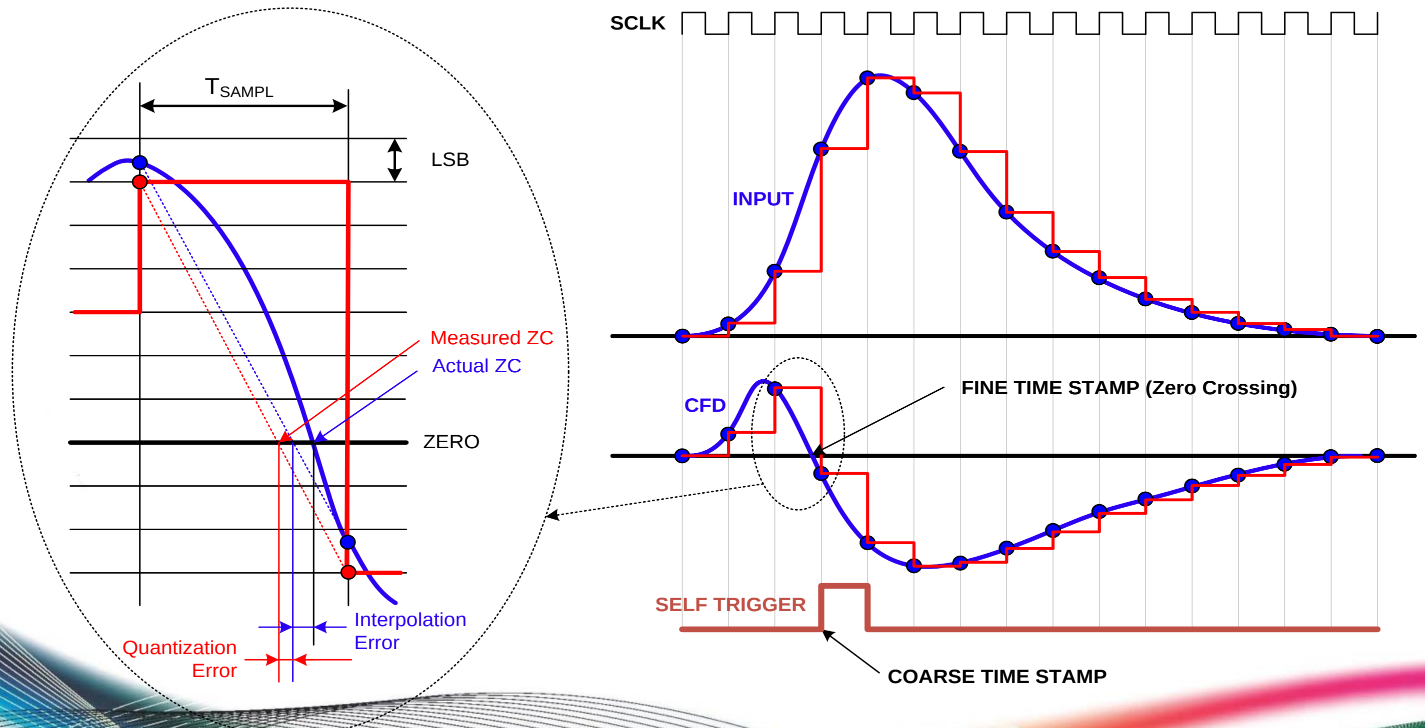
- Conventional TDC boards:
  - **V1190**: 128 channel, 100 ps Multi-Hit TDC
  - **V1290**: 32 channel, 25 ps Multi-Hit TDC
  - **V775**: 32 channel, 35 ps Start-Stop TDC

external
CFD required!

- The TDCs based on waveform digitizers can't compete in terms of density and cost, but there are cases where they are profitable:
  - Applications requiring an excellent timing resolution (< 10 ps); the conventional chain (CFD+TDC) shows its limits
  - Simultaneous acquisition of Timing and Energy: the digitizer can manage multi-parametric analysis and acquire both T and E in a single board
  - Bursts of very close pulses: the digitizer can operate without dead time
  - Direct connection from detector to digitizer (no discriminators!). Less cables, less distortion… eventually less cost!

Algorithms for the Time Measurements

- **Digital CFD**: $S_{CFD}(n) = A*S_{IN}(n) - S_{IN}(n-D)$, A=Attenuation, D=Delay
- Self-trigger on the 1st sample after the ZC: Coarse Time Stamp with sampling clock granularity
- On-board Linear Interpolation to get the Fine Time Stamp (Zero Crossing within the clock bin)
- **Rule of thumb**: 3-5 samples on the leading edge to have a good timing resolution and minimize the artificial effects of the interpolation error
- For faster edges, low pass analog filters (signal shaping) and/or the digital smoothing help!



Timing Measurements: Test Setup

Test n 1: Pulse generators

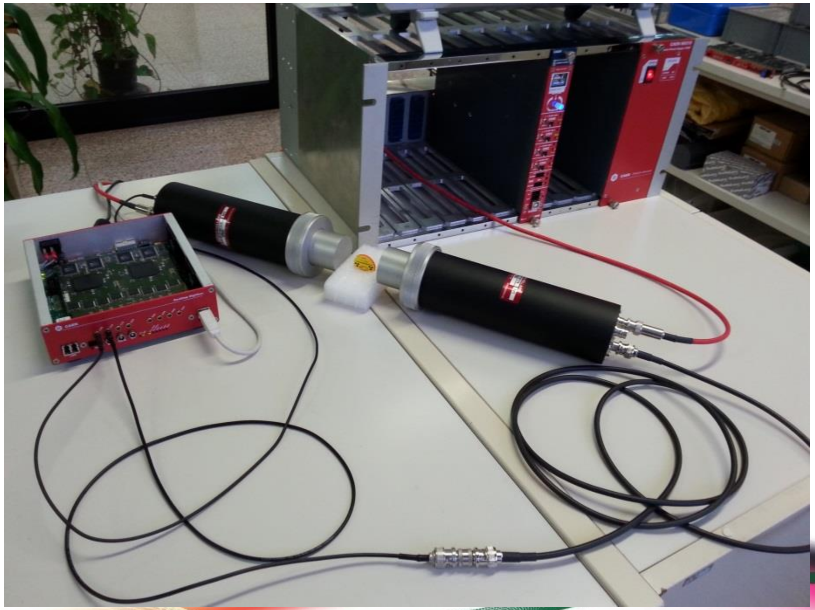
- Agilent 81110A and Tektronix AFG3252 to generate pulses with different rising edges (1, 2.5, 5, 10 and 20 ns)
- Passive splitter + cable delay to make a start-stop measurement (self timing)
- HP Step Attenuator (10, 20, 30, 40 dB) on the stop signal to measure the walk

Test n 2: Self-timing of $LaBr_3$ and BaF_2 detectors

- Single detector output, passive splitter and cable delay (~11 ns)
- **BaF_2:** 1" mod. *Scionix 38A38/2M-E1-BAF-X-N (PMT: Hamamatsu H3378-51)*
- **$LaBr_3$:** 2" mod. *Saint Gobain Brilliance 380 (PMT: R6231)*
- **^{22}Na** source
- ROI @ 511 keV peak

Test n 3: TOF between to BaF_2 detectors

- Two BaF2 detectors (same mod. as test 2)
- Gamma-gamma coincidence
- ROI @ 511 keV peak



All tests with DT5730 + DPP-PSD (digital CFD with interpolation)

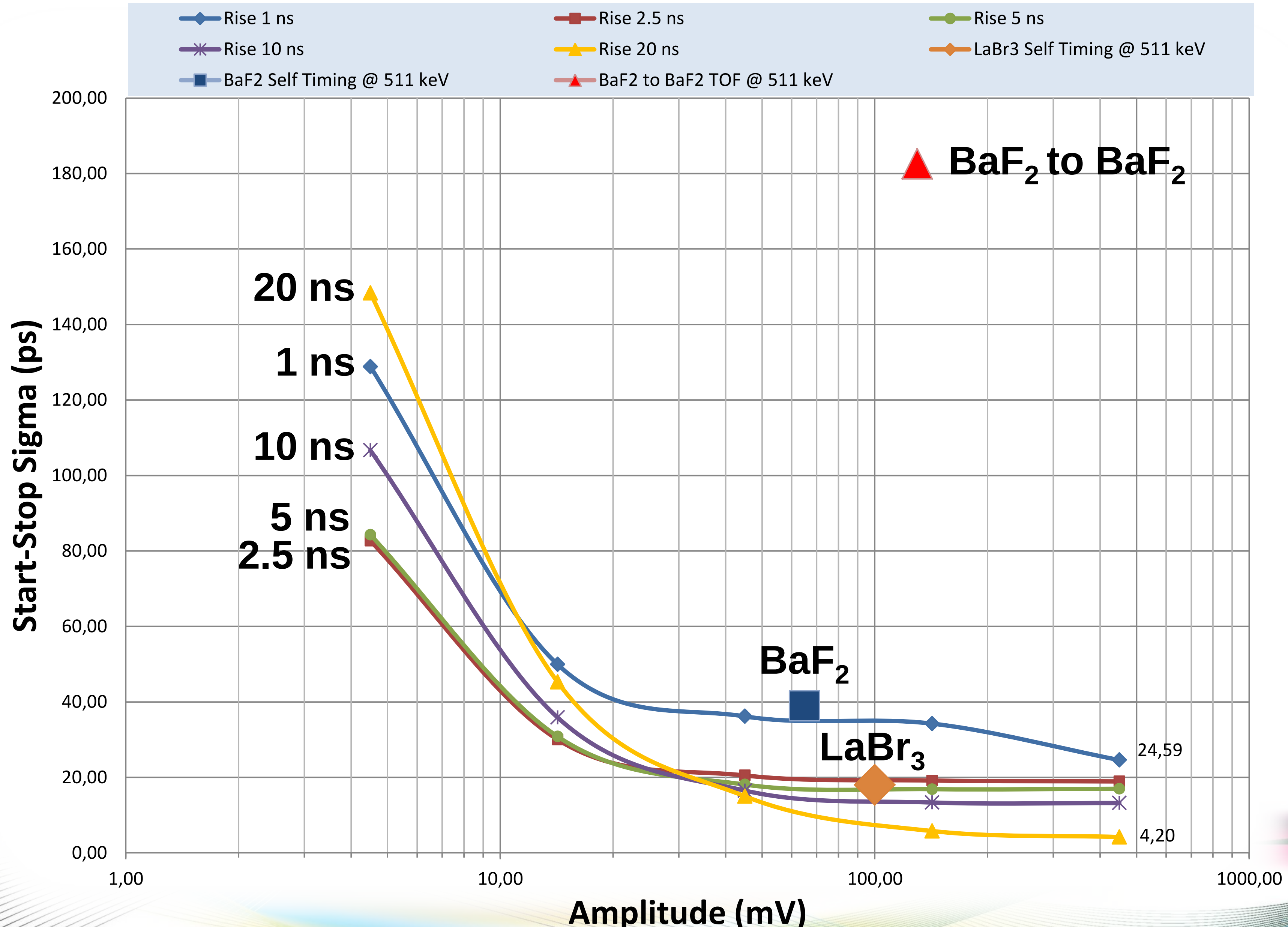
CFD settings and results

- 11 ns delay cable on the stop signal
- Start and Stop from passive splitter with pulsers and detector Self Timing
- True Time of Flight (@ 511 keV) for BaF_2 to BaF_2 measurement

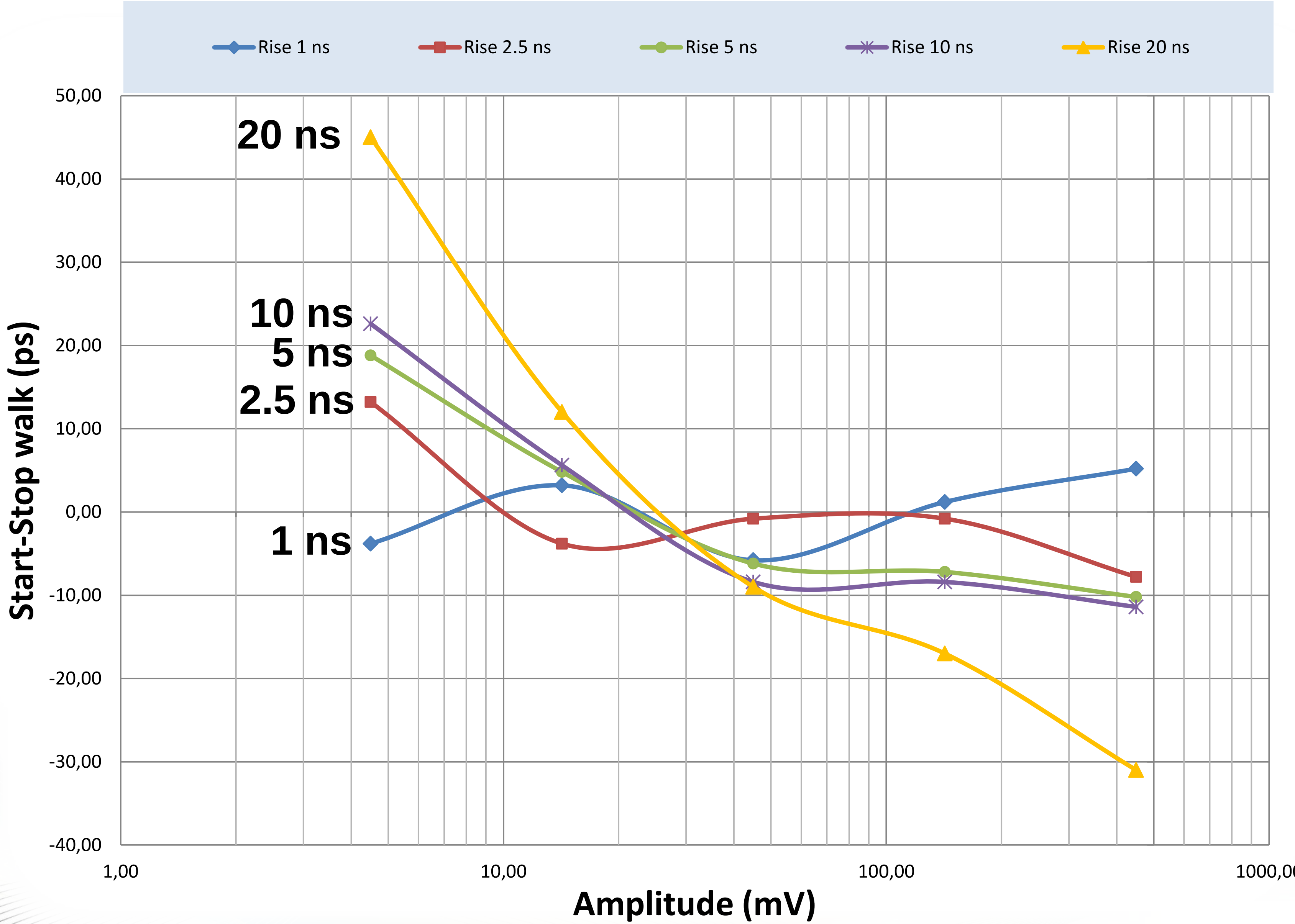
Rise Time	Ampl	Smoothing	CFD Delay	CFD Fraction	ΔT Sigma
1 ns pulser	450 mV	8 smp	8 ns	100 %	25 ps
2.5 ns pulser	450 mV	4 smp	6 ns	75 %	19 ps
5 ns pulser	450 mV	4 smp	10 ns	75 %	17 ps
10 ns pulser	450 mV	4 smp	16 ns	75 %	13 ps
20 ns pulser	450 mV	4 smp	20 ns	75 %	4 ps
Self $LaBr_3$	100 mV	4 smp	20 ns	75 %	18 ps
Self BaF_2	65 mV	4 smp	6 ns	75 %	39 ps
BaF_2 to BaF_2	130 mV	4 smp	6 ns	75 %	182 ps

CAEN
Tools for Discovery

TOF Timing Resolution

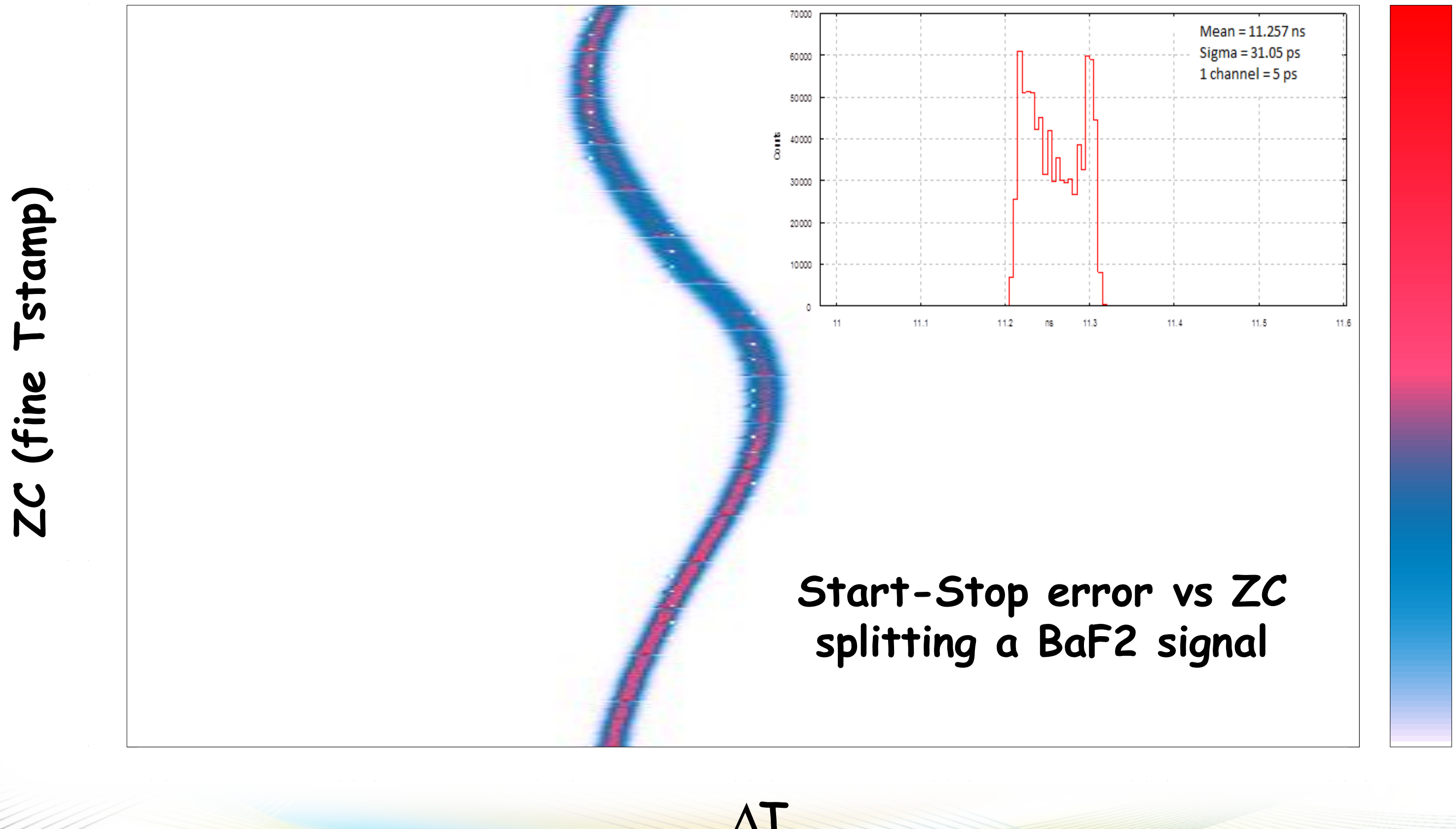


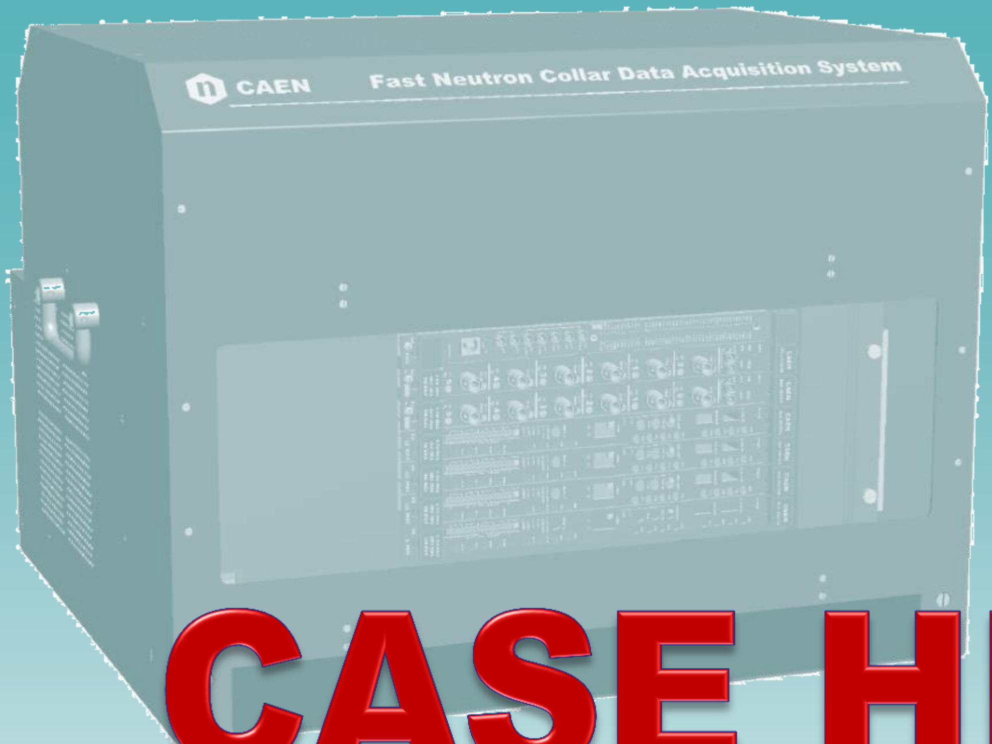
TOF Timing Walk

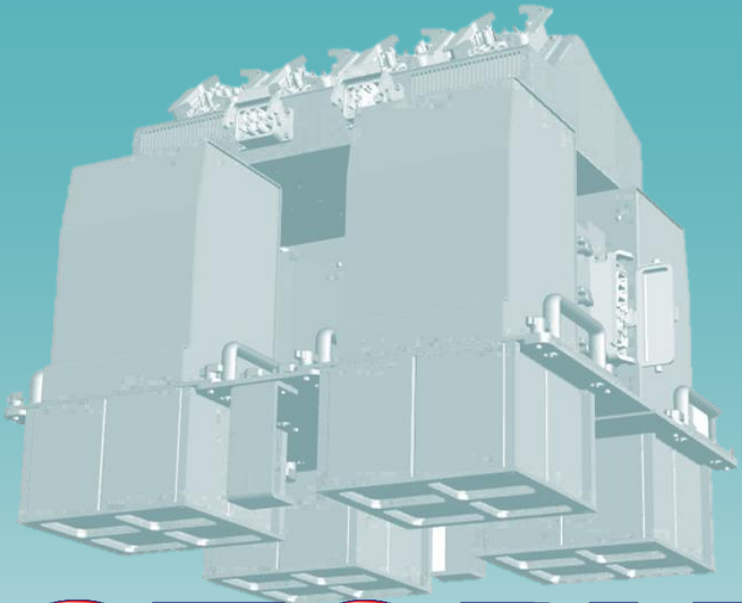


Further Optimization…

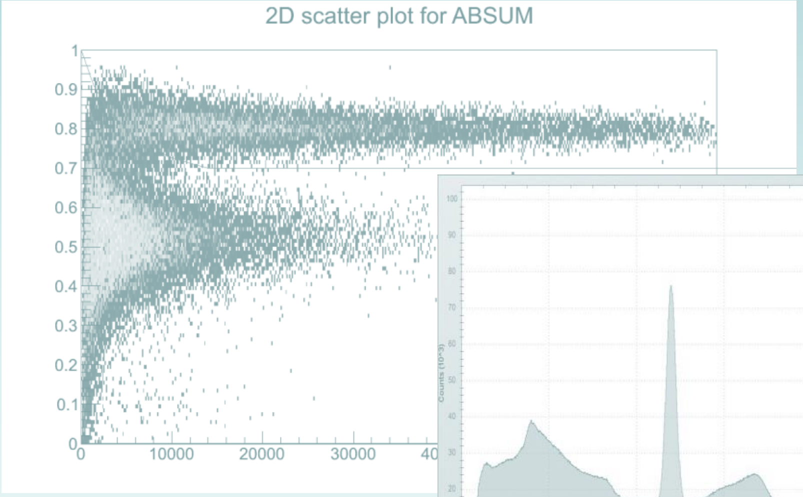
- Like in analog CFDs, a low fraction (e.g. 25%) reduces the jitter due to the statistical distribution of the photons and so gives better timing resolution
- However, in digital CFDs, smaller fractions cause higher interpolation error
- The interpolation error is function of the zero crossing within the sampling clock, thus it is possible to compensate it with a calibrated function or LUT (under study…)

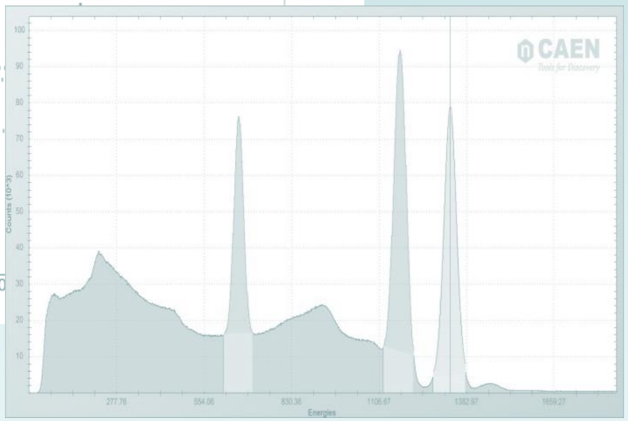






CASE HISTORY





Physics Experiments

- **XMASS (Kamioka)**: 85 V1751 (ZLE)
- **ELI-NP (Romania)**: 36 V1725 (PHA) + 2 V1730 (PSD)
- **Dance (LANL)**: 12 V1730 (PSD, PHA)
- **Xenon (LNGS)**: 25 V1724 (Custom FW)
- **Deap (Snolab)**: 32 V1720 + 5 V1740 (Raw Waveforms)
- **Mini Clean (Snolab)**: 8 V1720 (Raw Waveforms)
- **DHRUVA (BARC)**: 4 V1724 (PHA) + 1 V1720 (CI) + 1 V1730 (PSD)
- **Exill (ILL)**: 10 V1724 (PHA) + V1751
- **Dark Side (LNGS)**: V1720 (Raw Waveforms)

and more…

Tagged Neutron Inspection Systems

- A neutron generator (with alpha tracker) activates materials inside the container
- Activated materials emit gamma rays with a specific energy spectrum
- An array of 48 gamma detectors (NaI) on the other side of the container collect energy and time of flight spectra
- one VME crate with four V1730 reading signals from the alpha tracker and NaI detectors. Readout through one A3818.
- DPP-PSD firmware running in list mode
- Coincidences between Alphas (TOF start) and Gammas done in software
- Correlated Energy and TOF spectra

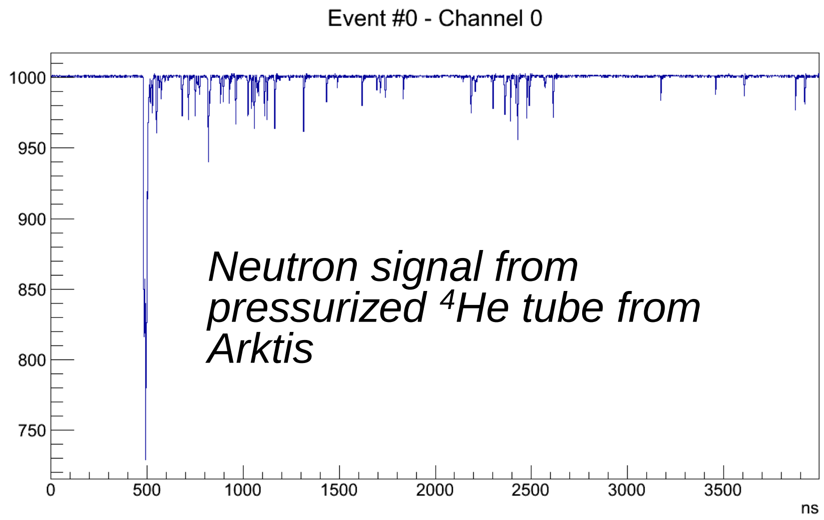
Fast neutron counting in fresh fuel bars

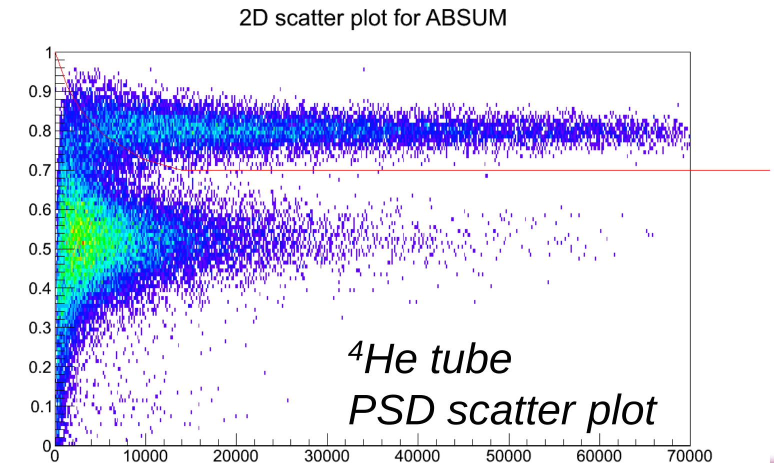
- Fully integrated bias and readout system with embedded PC
- 12 liquid scintillators read by 4 V1730 (3 channels each)
- DPP-PSD firmware, 1 Mcps/ch
- Waveform readout (typ. 100 ns)
- Sustained throughput: 340 MB/s
- Custom software:
  - PSD filter for Gamma rejection
  - Pile-up rejection
  - n-n coincidence
  - Total neutron counting
  - Figure of merit of the n/g discrim

Detection of illicit radioactive material

Aim: Readout of different gamma-ray and neutron detectors for the identification of illicit radioactive materials inside volumes tagged as "suspect" by conventional surveys as X-ray scans.

- Two projects: SLIMPORT (SMANDRA), MODES-SNM
- Different types of detectors:
  - **LaBr, NaI(Tl), pressurized Xe tubes** for gamma spectroscopy
  - **Liquid scintillators (NE213), ^{3}He, pressurised ^{4}He tubes** for neutrons
- DT5730 (or DT5790) with DPP-PSD for spectroscopy and n-γ discrimination





Phoswich detectors (PARIS Experiment)

- Phoswich detectors require Pulse Shape Discrimination to separate events that interact in one or in the other crystal
- PARIS detectors: 2"x2"x2" LaBr3 / 2"x2"x6" NaI
- Wide energy dynamic range (40KeV to 40MeV)
- Test performed in July 2015 at IFJ (Krakow): 5 detectors (4 phoswich + 1 reference 3"x3" pure $LaBr_3$) read by one DT5730 (500 MS/s, 14 bit) with DPP-PSD

RESULTS:

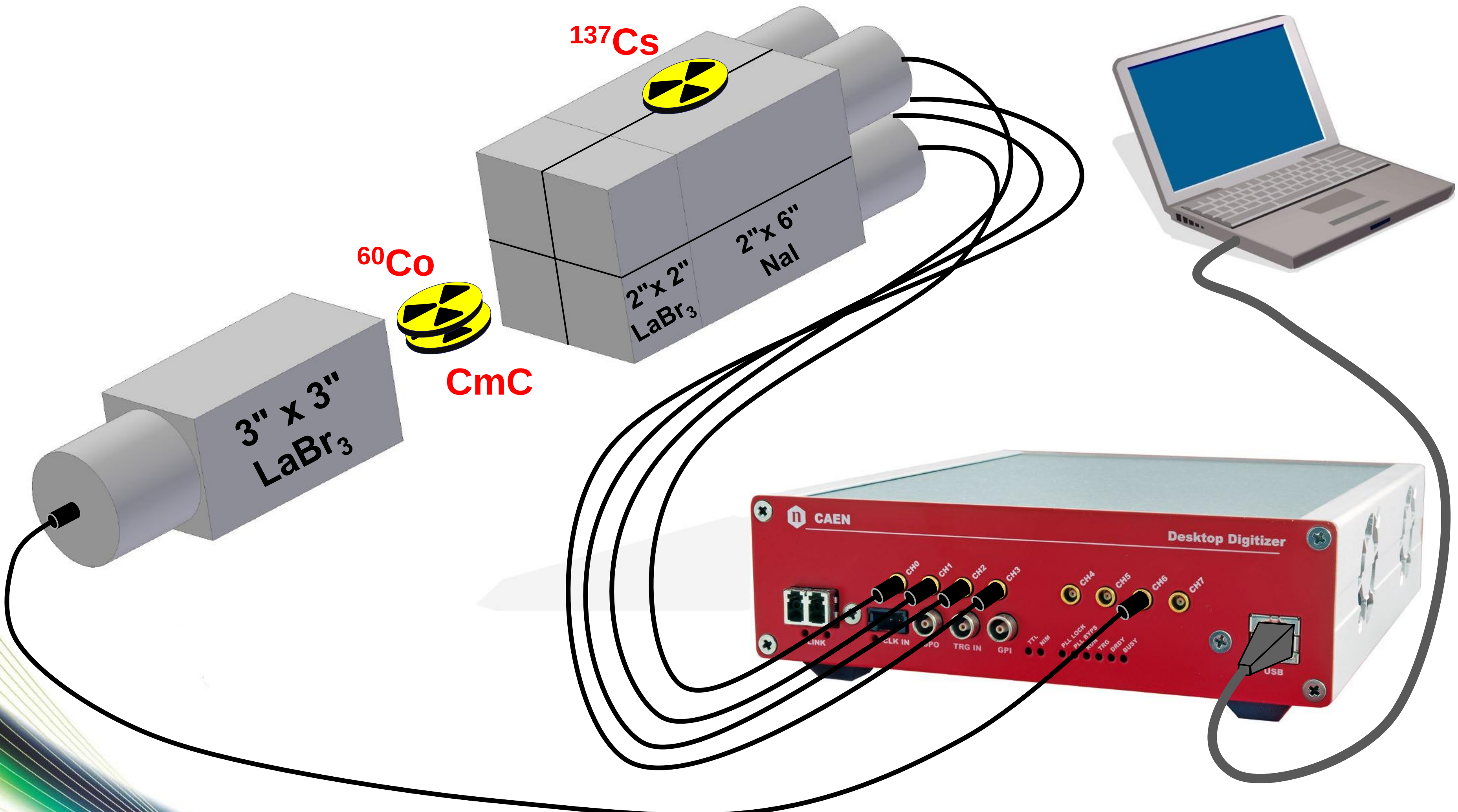
Excellent PSD separation of NaI and $LaBr_3$ events

Throughput: ~15 Kcps, almost deadtime free (10 times better than analog chain)

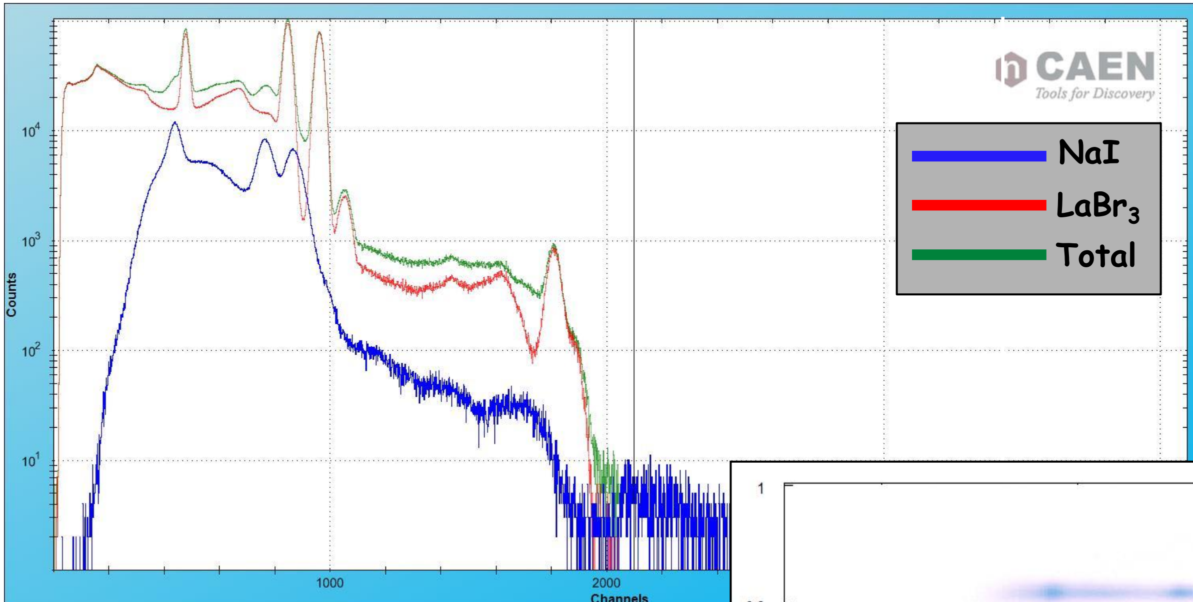
TOF Resolution (Start = pure $Labr_3$, Stop = phoswich $LaBr_3$): 700 ps FWHM combined

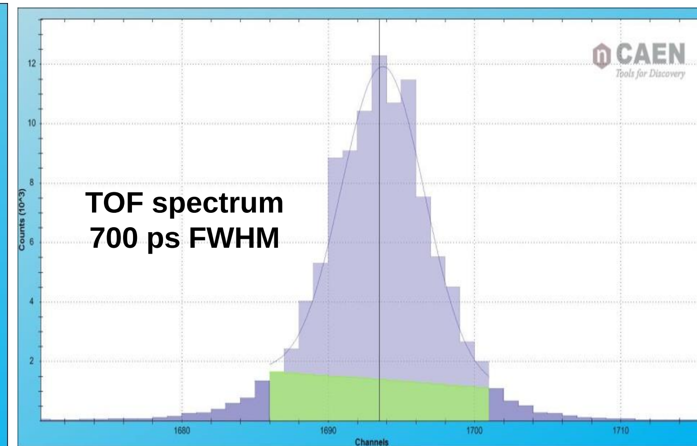
Energy Resolution (17 MeV FSR):	pure $Labr_3$	phoswich $LaBr_3$
@662 keV	2.7 %	5.0 %
@1173 keV	2.1 %	3.4 %
@1332 keV	2.0 %	3.2 %

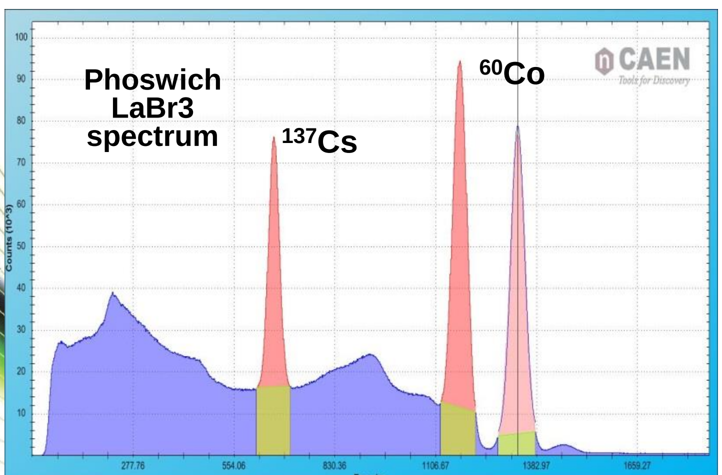
PARIS Test Setup

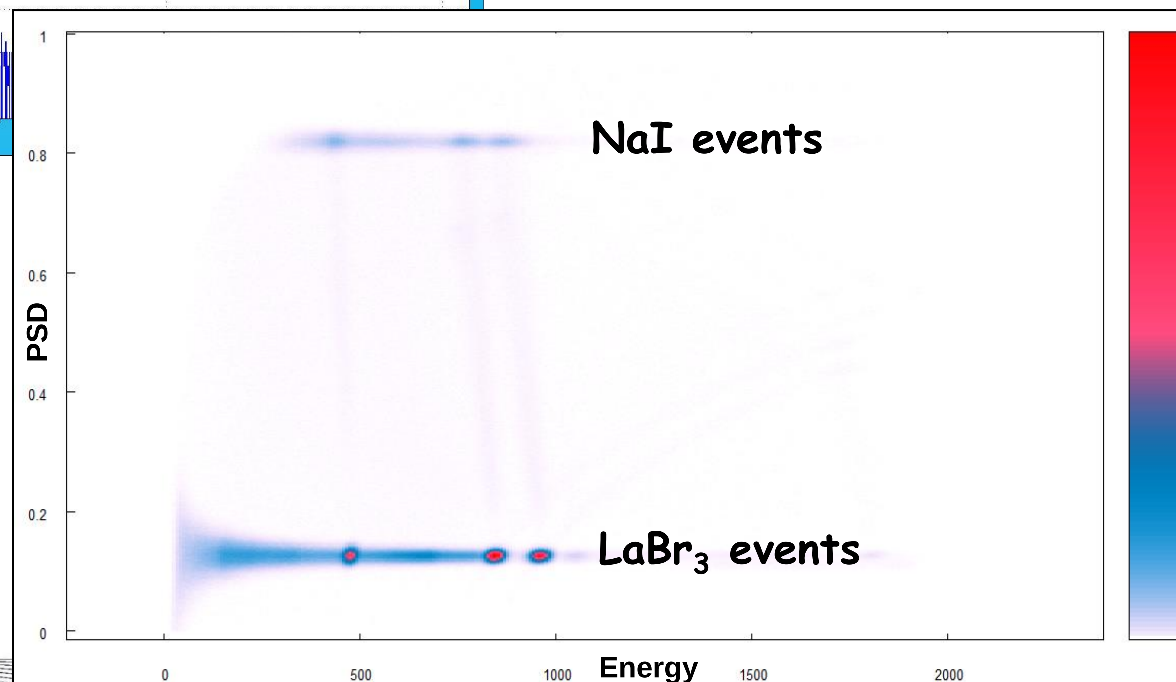


PARIS Test Results (spectra)









CAEN Tools for Discovery

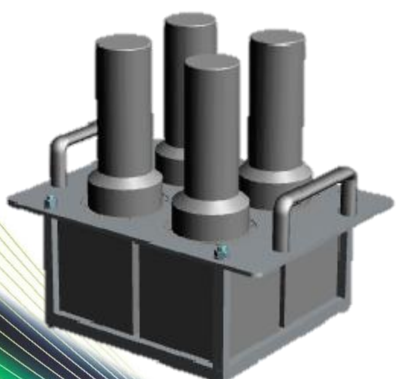
GammaFly: airborn Gamma Spectroscopy

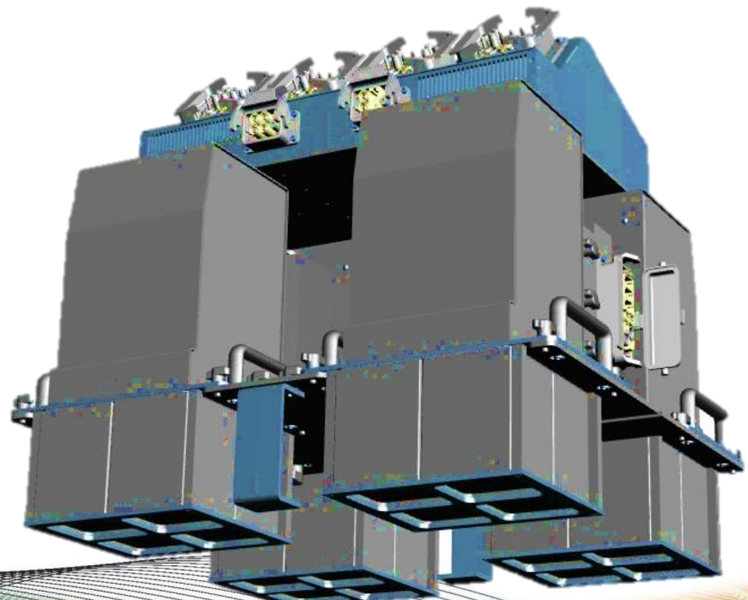
Airborn Spectroscopy used for:

- Geological and soil mapping
- Uranium and mineral exploration
- Environmental radioactivity monitoring

System:

- 4x4 array of 1 liter NaI detectors
- One DT5740 with DPP-QDC (self-gated charge integration)
- Four DT55xx, 4 ch High Voltage Desktop Module



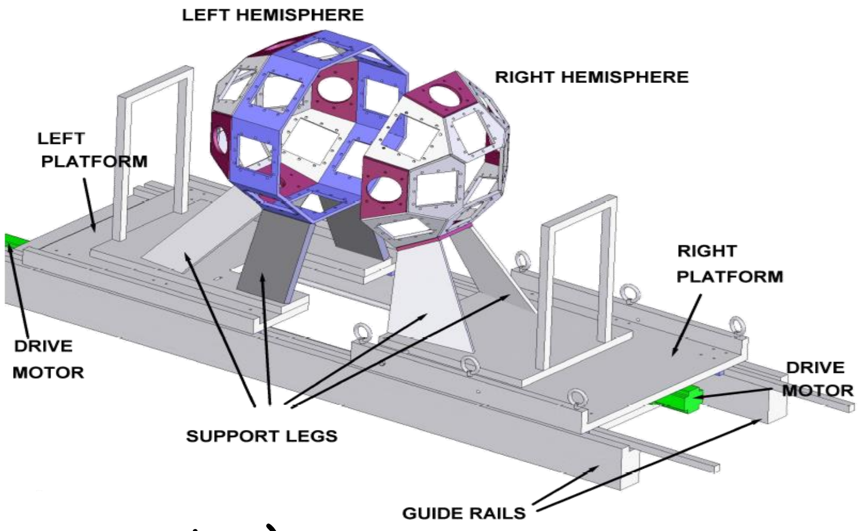


GammaFly: airborn Gamma Spectroscopy

DHRUVA @ BARC (Clovers + $LaBr_3$)

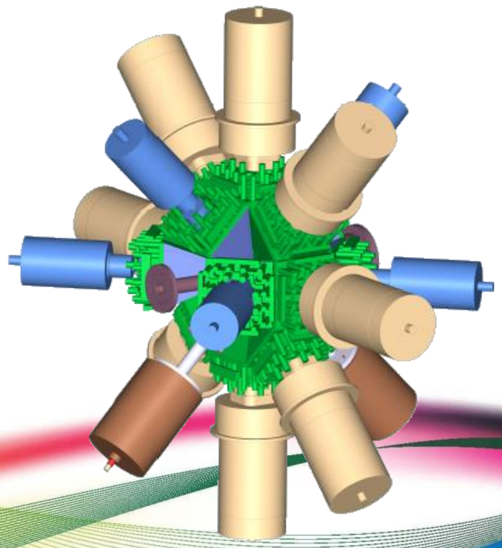
gamma-ray spectroscopy of fission fragment nuclei

- 8 clovers (32 channels)
- BGO for Anti Compton Shield
- 16 $LaBr_3$



System

- 4 x V1724 /w DPP-PHA (Clovers)
- 1 x V1720 for the ACS (BGO)
- 1 x V1730 /w DPP-PSD ($LaBr_3$)
- 1 x A3818 for the data readout (to computer)
- ACS suppression in hardware (veto signals)
- Trigger-less acquisition (raw sorted list to disk)
- Off-line event building: Clover calibration and add-back, 1+1, 1+2, 2+2 coincidences
- Custom software with GUI and post-processor

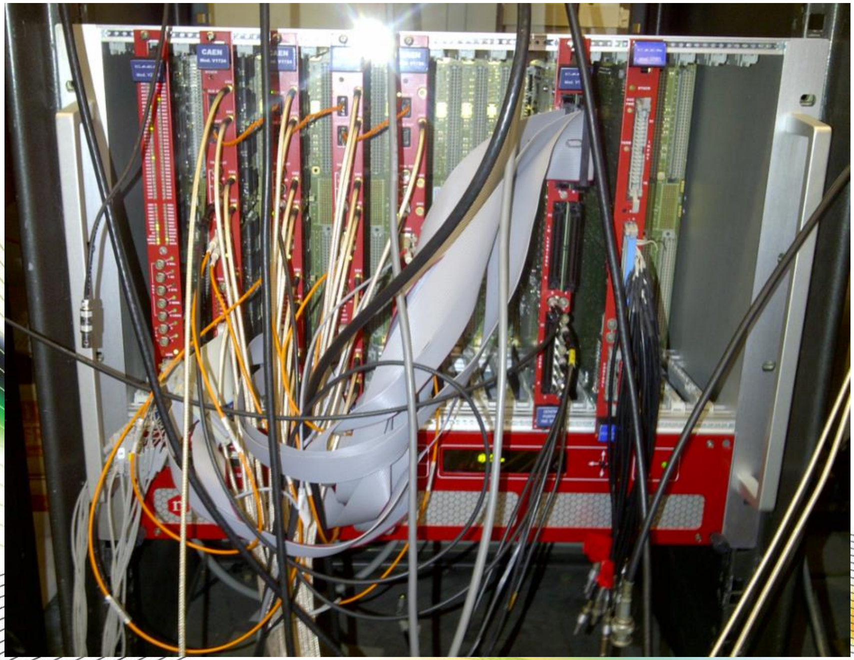


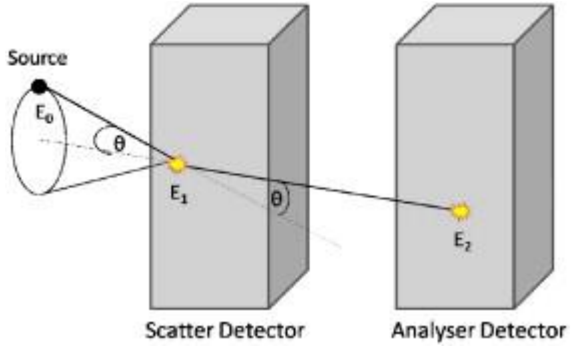
CAEN Tools for Discovery

Medical Imaging (ProSPECTus)

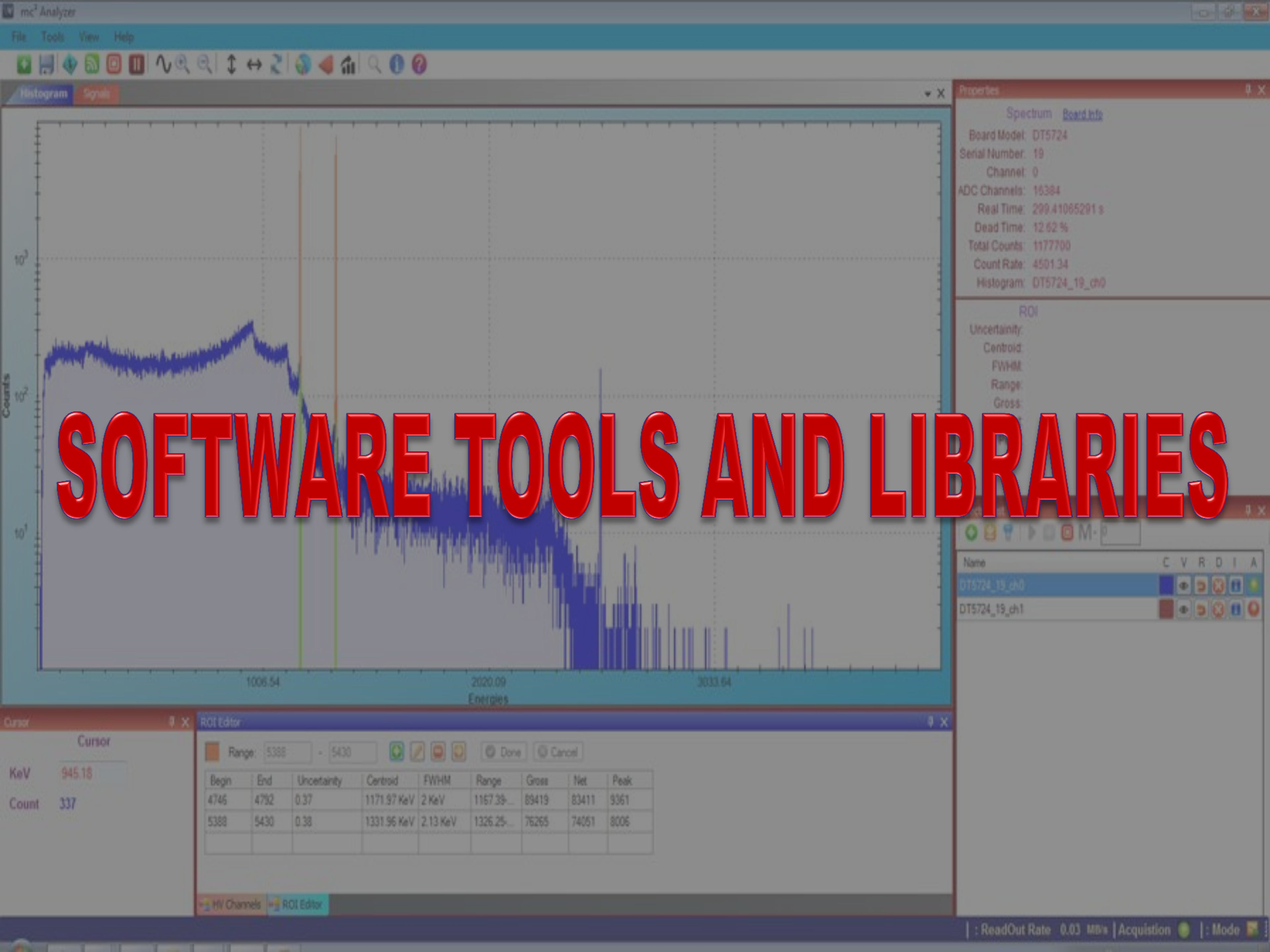
Single Photon Emission Computed Tomography: SPECT
Localization of a gamma-ray source through the reconstruction of interaction sequences in position and energy sensitive strip detectors

- 32 channel orthogonal strip HPGe planar detector
- 1 VME crate with 4 V1724 + DPP_PHA
- 1 V1495 for the trigger logic (neighbour strip trigger propagation)
- List Mode (Pulse Height + Time Tstamp) + waveform of the rising edge for off-line analysis (improve spatial resolution)





SOFTWARE TOOLS AND LIBRARIES

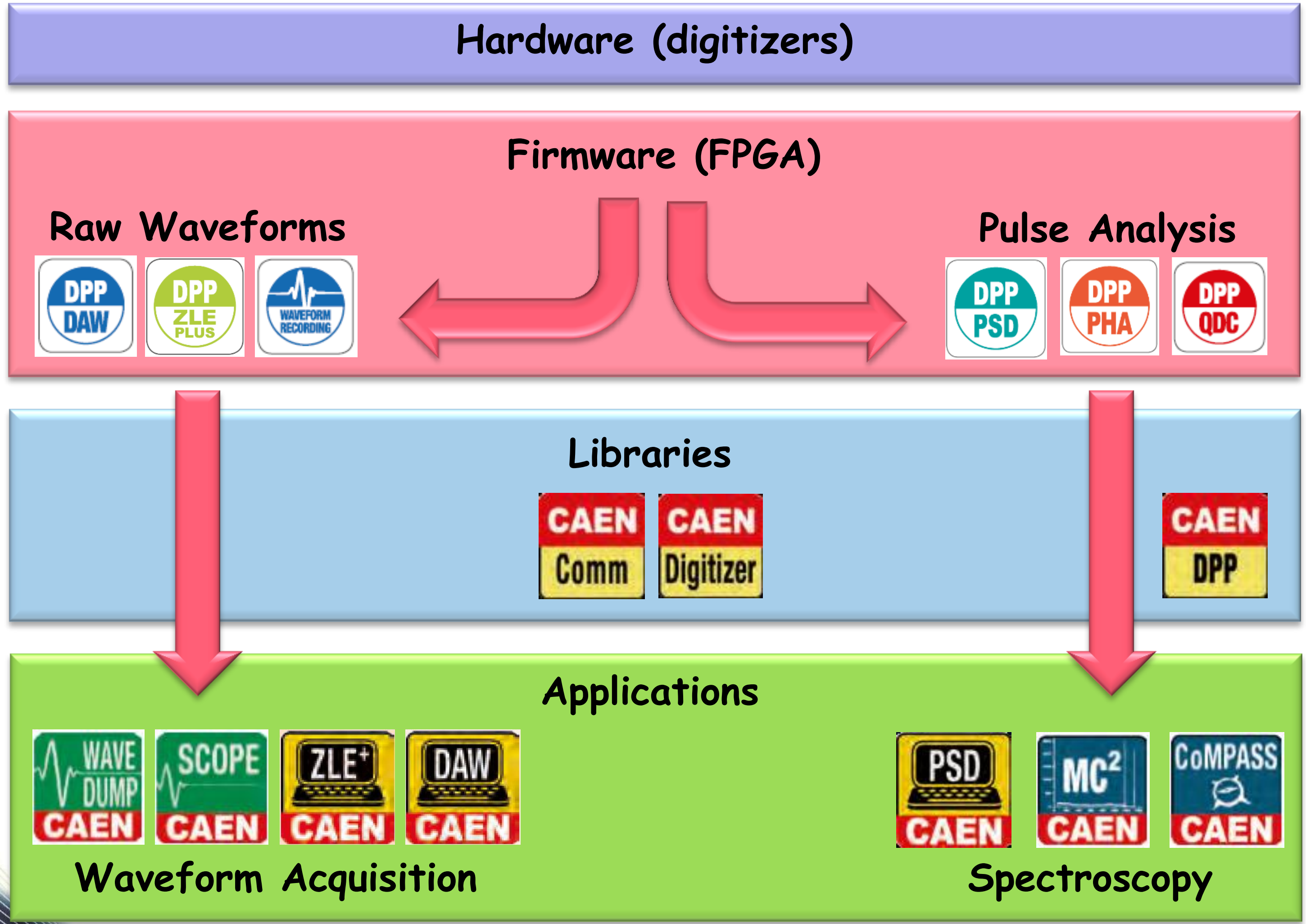


CAEN Tools for Discovery

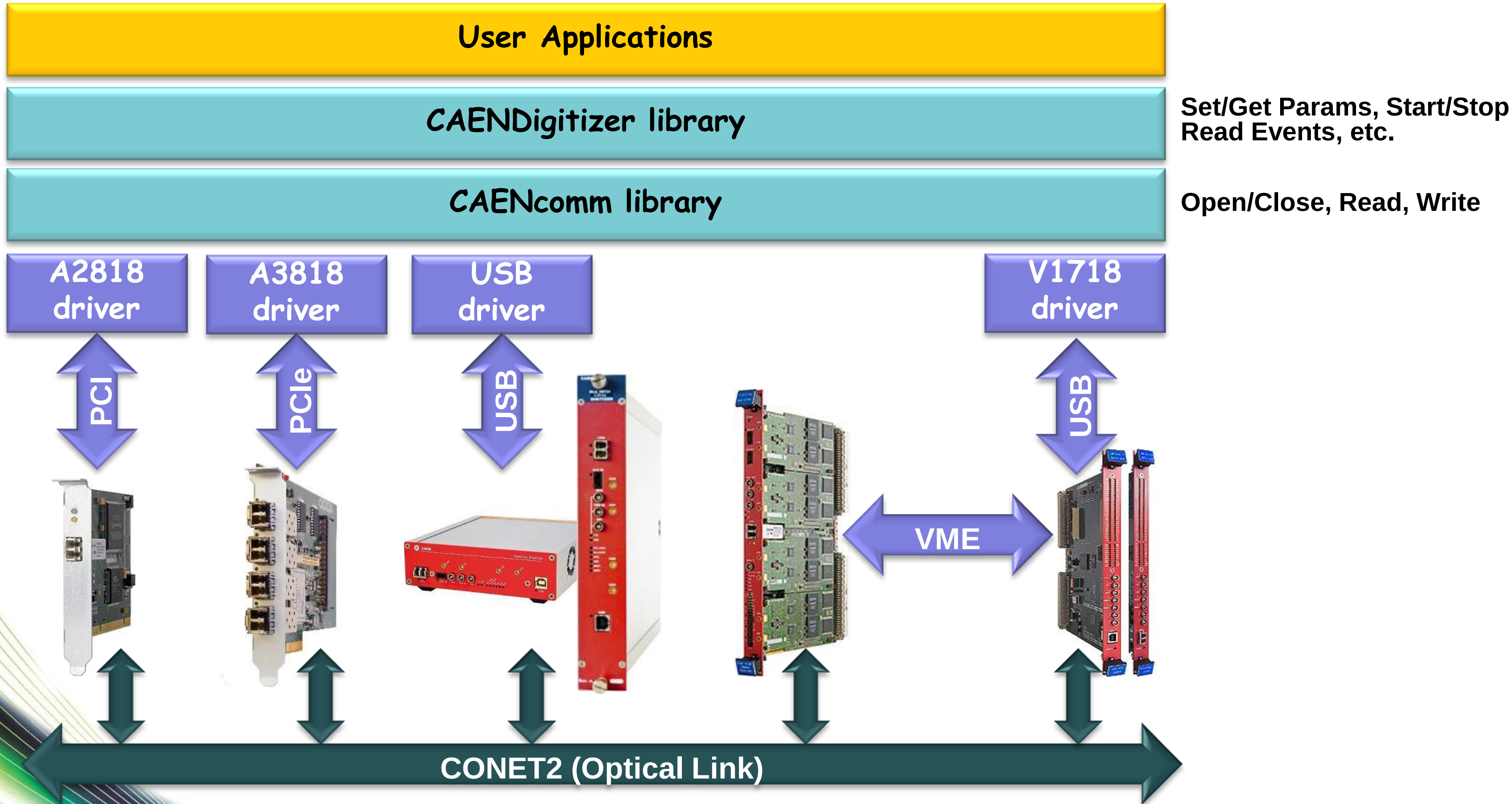
Software for the digitizers

- **Drivers** for USB and PCI/PCIe cards (optical links) for Windows and Linux
- C and LabView **Libraries**:
  - CAENComm (low level data transfer)
  - CAENDigitizer (functions to manage configuration, run and data readout)
  - CAENdpp (acquisition of spectra and lists; for PHA firmware only)
- **CAENupgrader**: tools for firmware upgrade, licensing, PLL configuration, etc…
- **CAENscope**: graphical digital oscilloscope (standard FW, non DPP)
- **WaveDump**: open source waveform recorder for developers
- **DPP PSD Control Software**: Java GUI for a DPP-PSD basic acquisition
- **MC²Analizer**: Basic Spectroscopy software (for PHA only)
- **Compass**: Multi-parametric DAQ software for Physics Application (coming soon)
- **digiTES**: unsupported open source program, distributed "as is" in the hope that it can be useful to the users. It is a forerunner of Compass

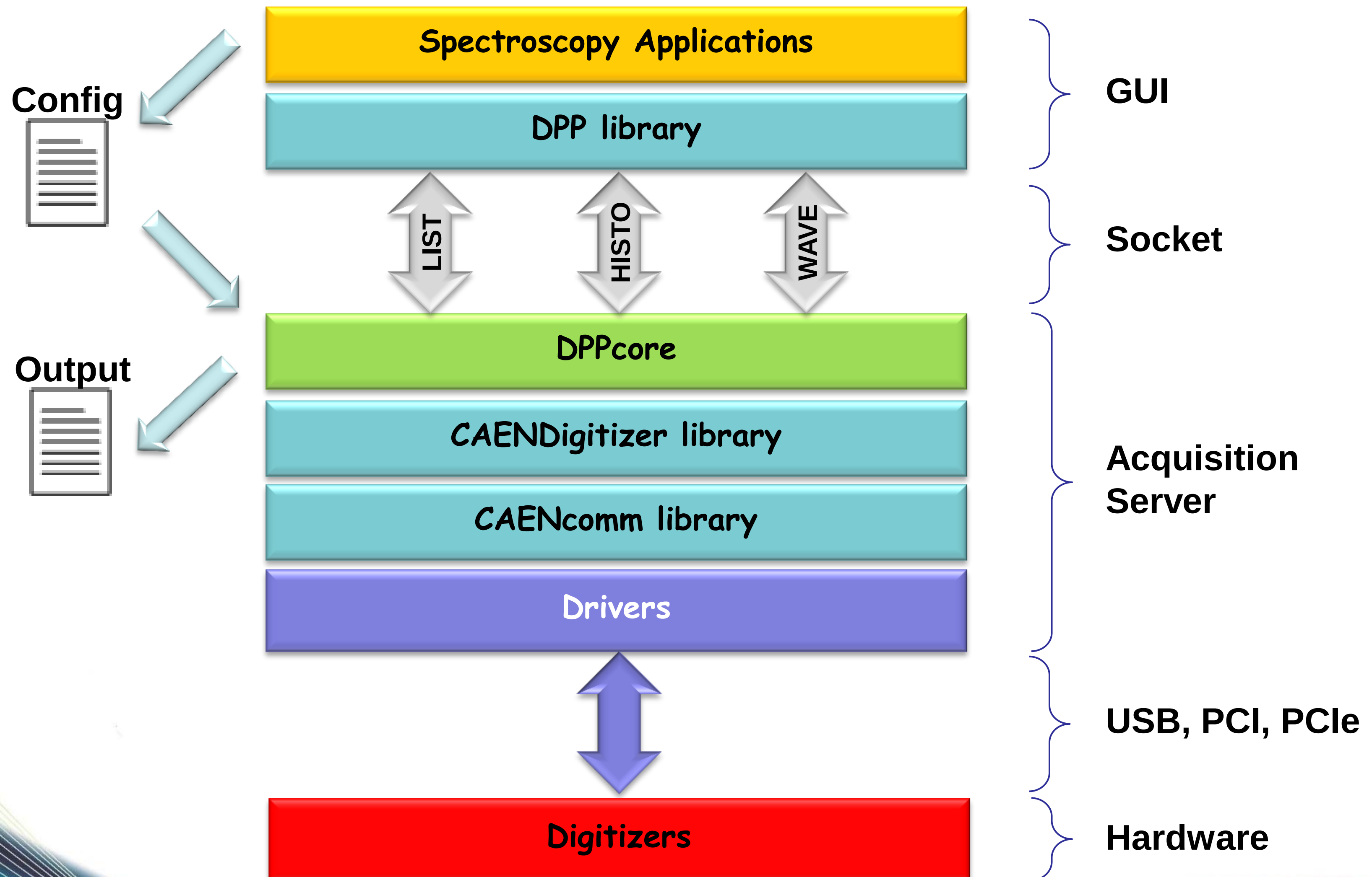
Software for the digitizers



Libraries and drivers

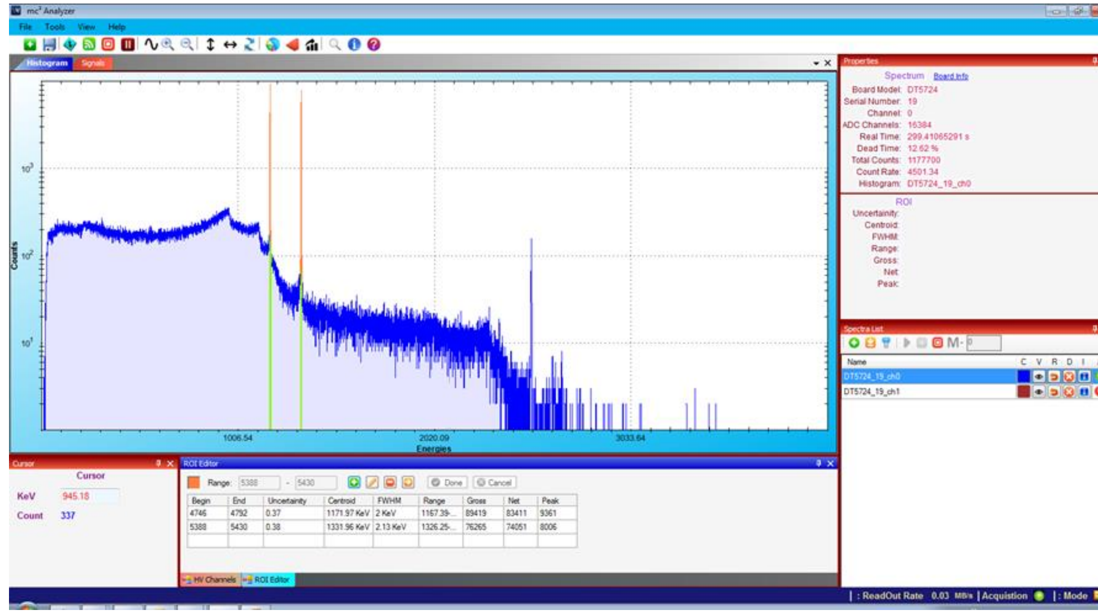


DPP libraries for spectroscopy software



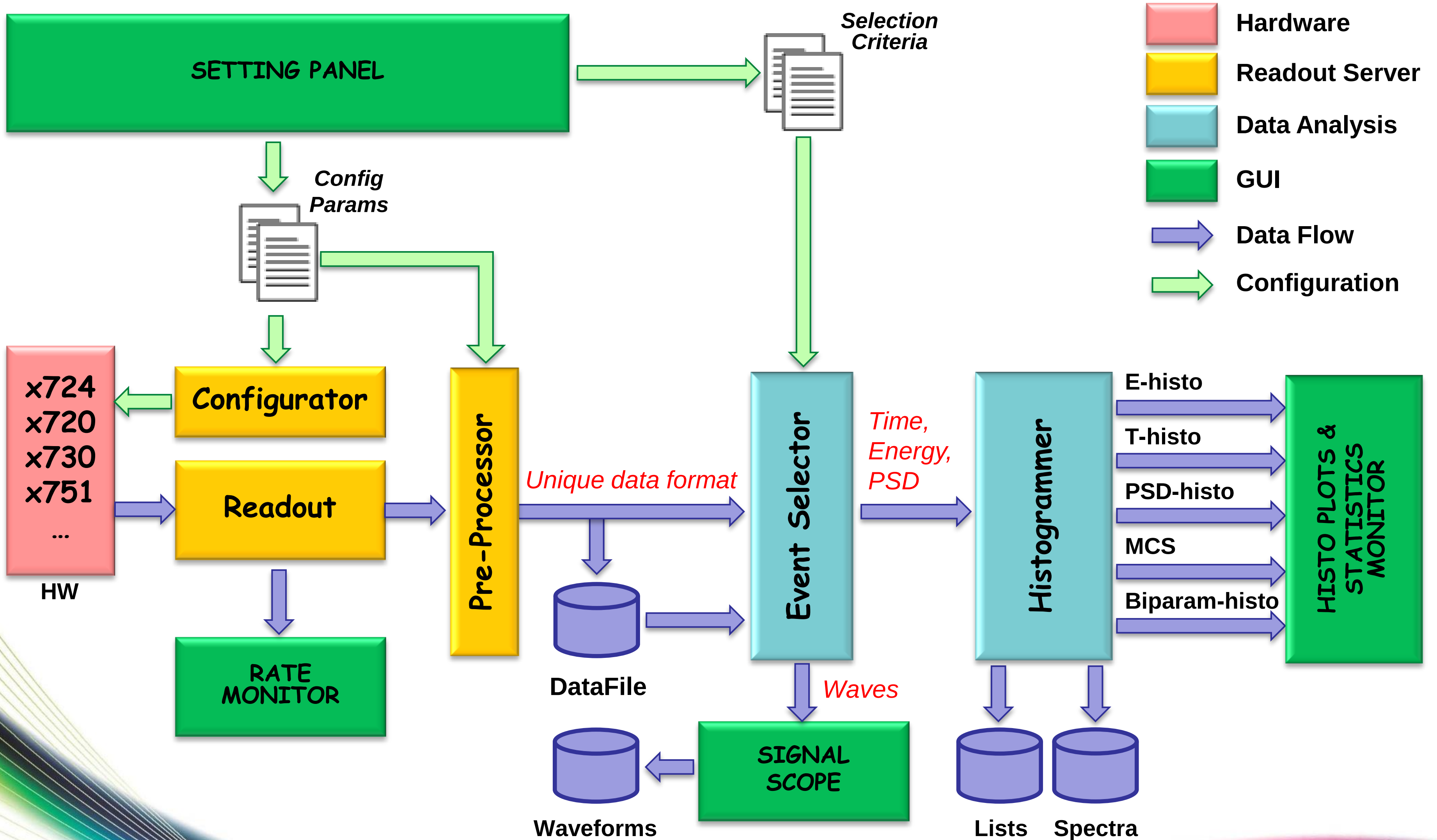
MC^{2}Analyzer

- Spectroscopy Software for MCAs (Hexagon, Gamma Stream, DT5780/81, x724)
- Basic operations
  - run control
  - spectra and list saving/loading
  - ROIs
  - peak search, fit, FWHM
  - Background, net/gross count
  - Energy Calibration
  - Dead/Real time
  - Coincidence/Anti-coincidence
  - Rebinning
  - Etc…



- Multiple channels/boards
- Signal Inspector: live display of waveforms

Architecture of digiTES (and Compass)



Cooming soon: Compass

- Similar architecture of digiTES (event oriented readout)
- Event Packet = Time, Energy, Shape (waveform optional)
- Multiple channels/boards with synchronization
- Channel correlation and Energy/PSD filters
- Acquired events populate a ***Root*** T-tree
- E, T, PSD Spectra built, saved and plotted with ***Root***
- Java configuration GUI, parameters saved as a Data-Base