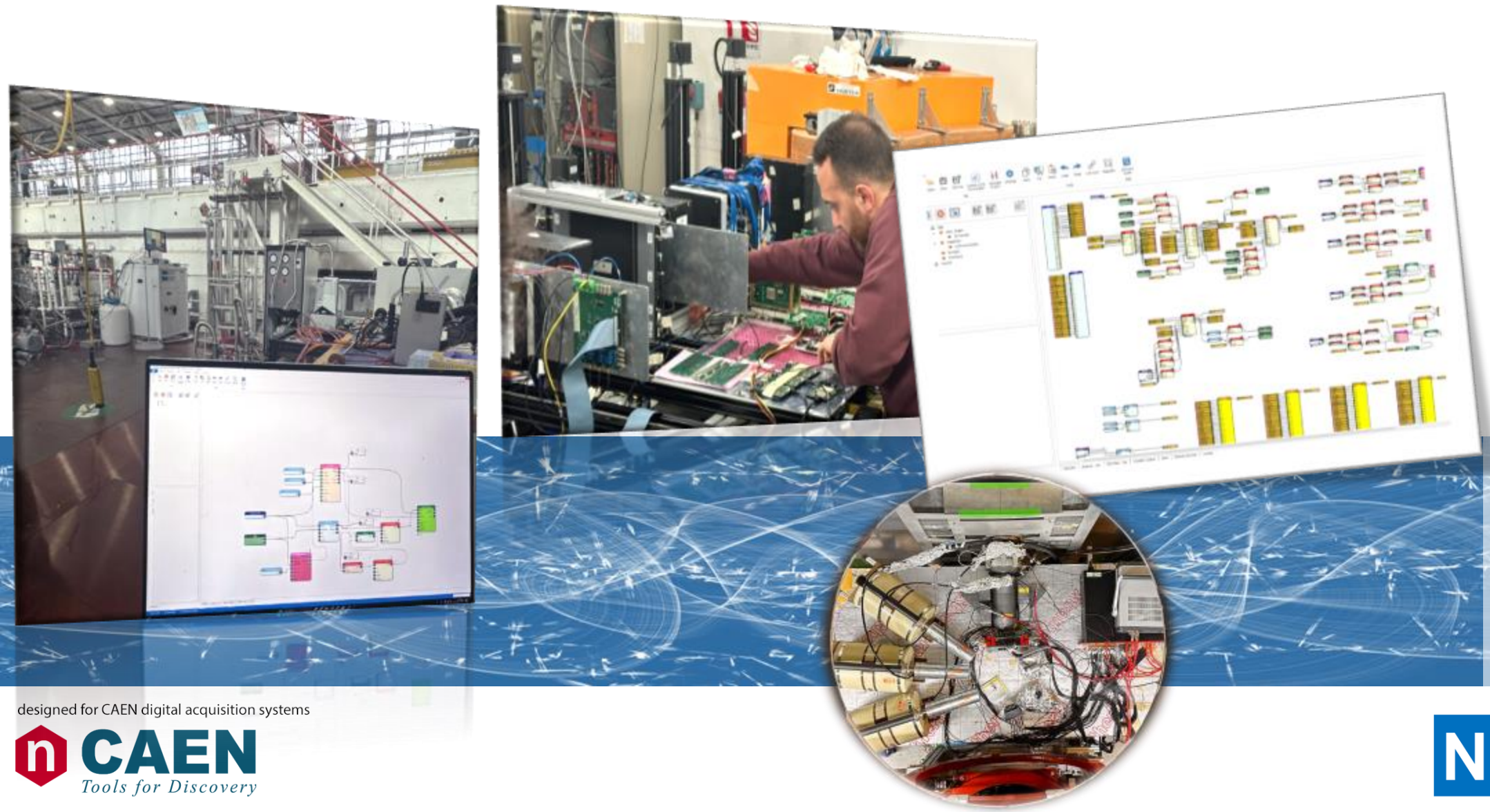
SCI-COMPILER

Sci-Compiler: A Flexible Tool for Designing Complex Multi-Channel Readout Systems



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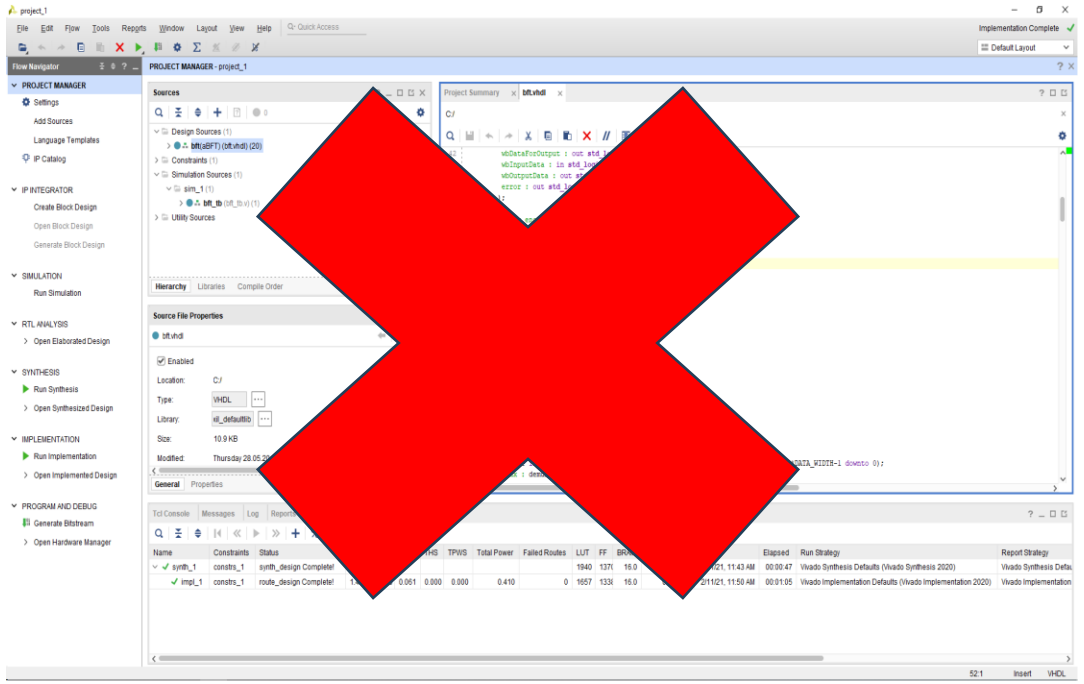
designed for CAEN digital acquisition systems

CAEN
Tools for Discovery

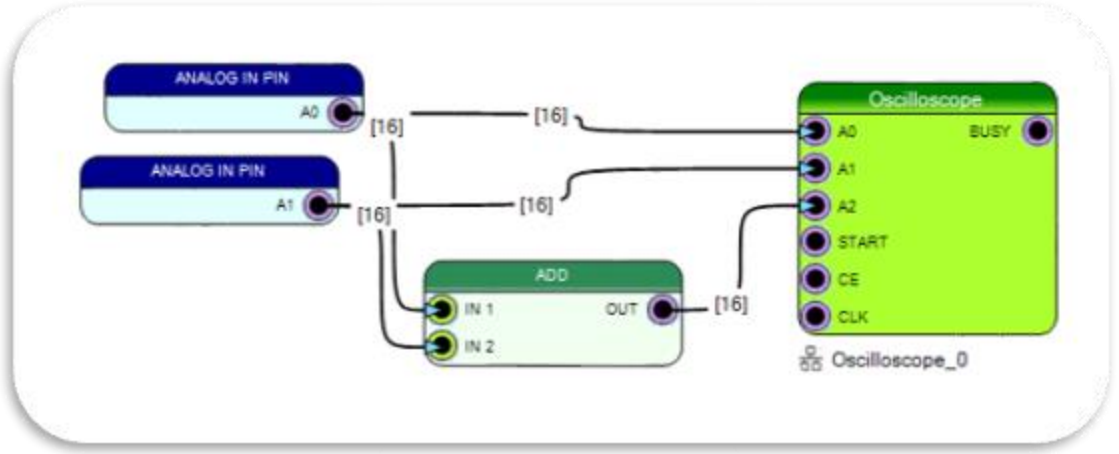
Nuclear Instruments

From Concept to Creation: SciCompiler Brings Your Ideas to Life

Design as easily as sketching your ideas – no need to learn complex languages like VHDL or Verilog; SciCompiler takes care of it for you.

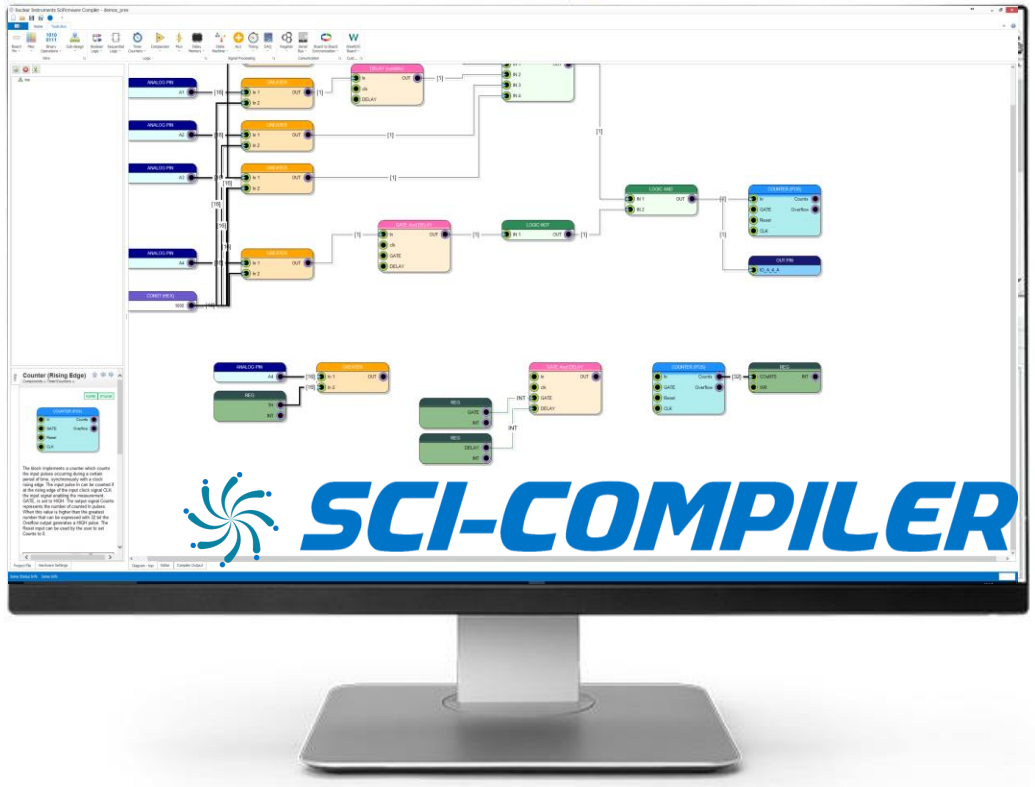


Develop with block diagram



SCI-COMPILER

NI/CAEN Solution: OpenFPGA digitizers + SciCompiler firmware generator

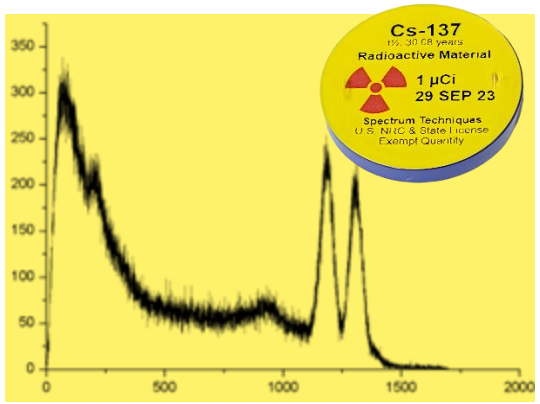


DAQ 121 / DAQ 122

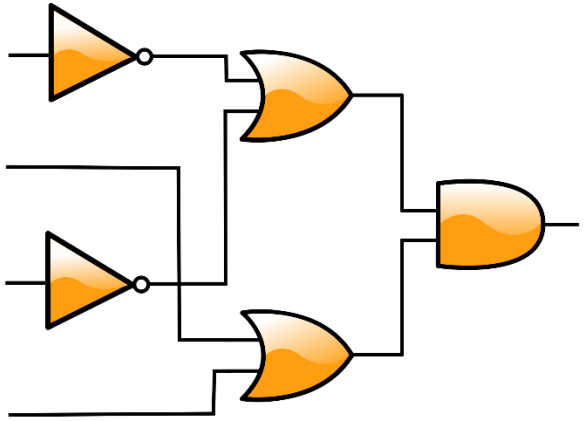
12/14 bit – 1 Gsps

32 channels

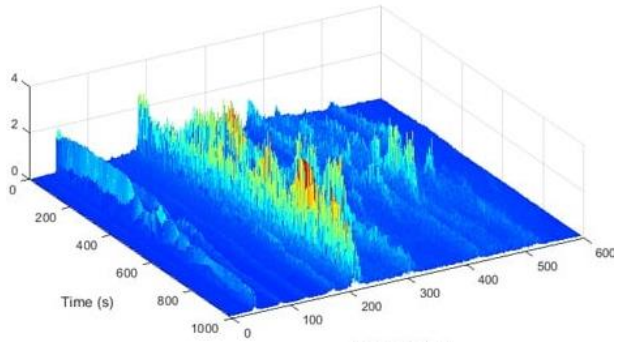
Examples of what you can do with Sci-Compiler



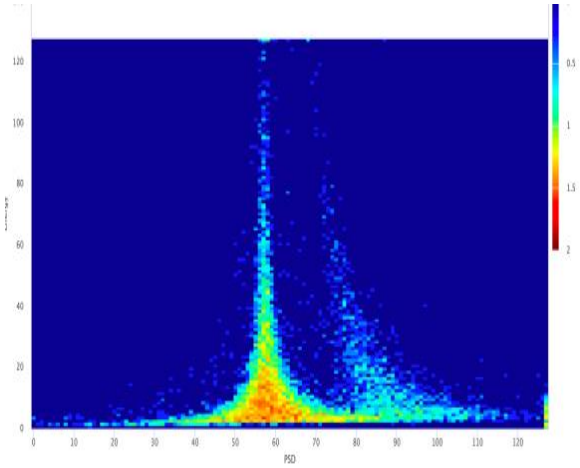
PHA



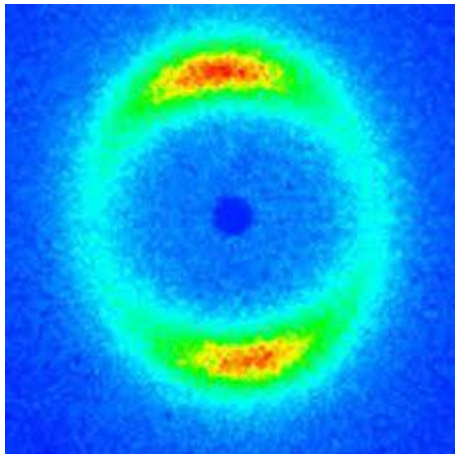
COMPLEX TRIGGER LOGIC



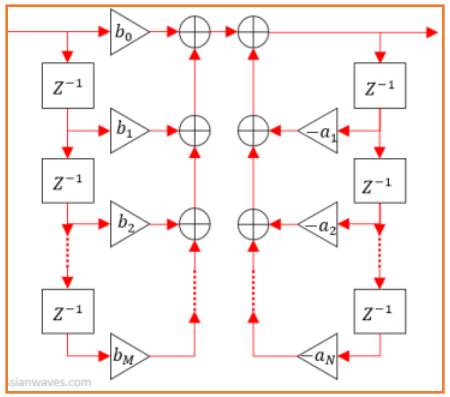
REALTIME FFT



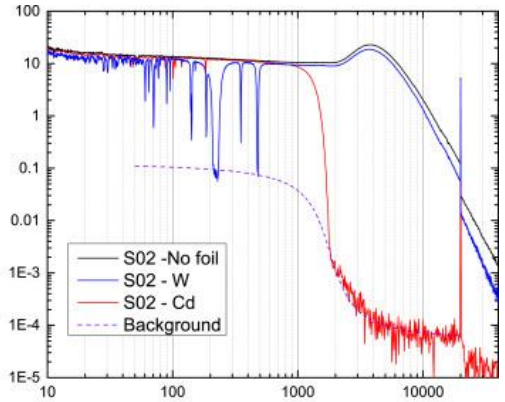
PSD



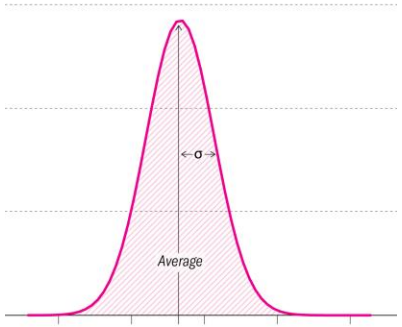
NEUTRON IMAGING



REALTIME IIR-FIR FILTER



SUB-ns TOF TDC



REALTIME STATISTICS

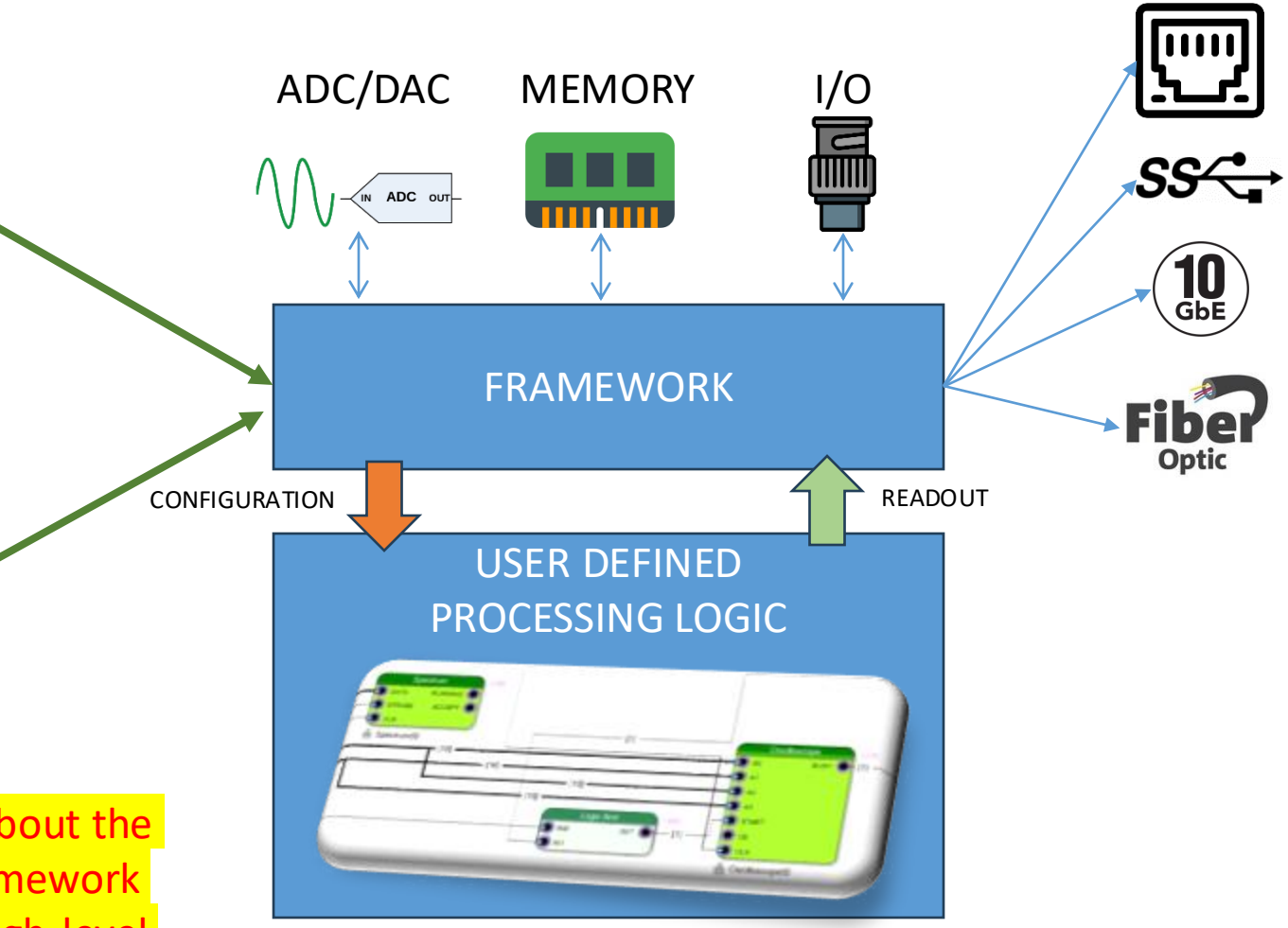
Open-FPGA Board architecture

Primary function of a firmware:

Control the board acquisition process

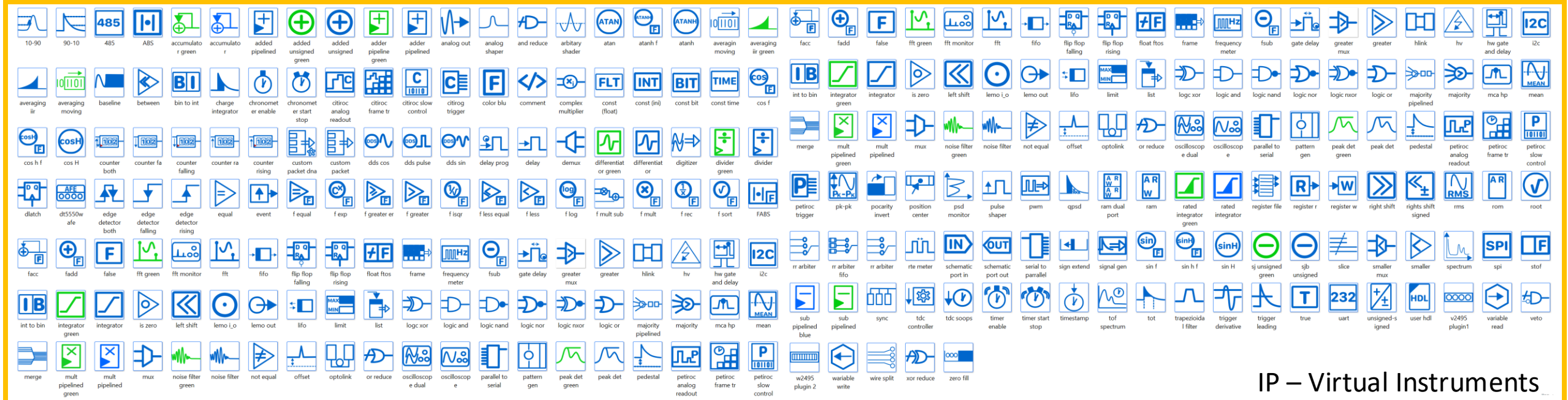
Processing data

Transfer data to and from readout PC/Server

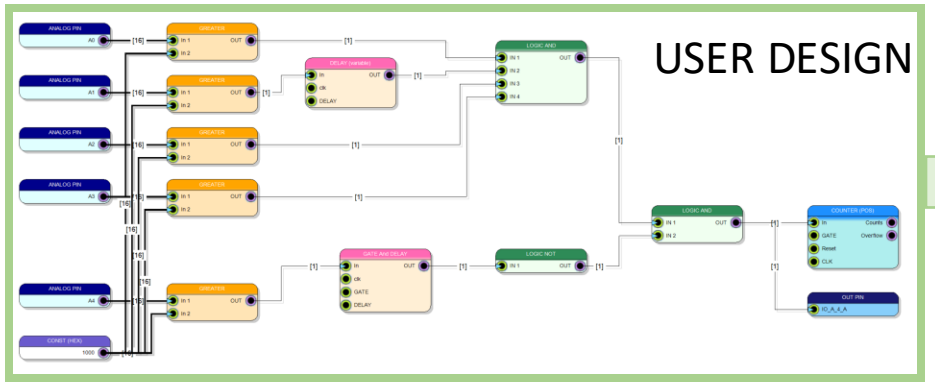


Sci-Compiler lets the developer think only about the core algorithm — everything else, from framework to readout, is handled automatically with high-level abstraction blocks.

SciCompiler: ip integrator software



IP – Virtual Instruments



USER DESIGN

BUILDER ENGINE

```
architecture Counter_Arch of AAC2M2P1 is begin

    count_proc : process(CP,SR,PE,CEP,CET) begin

        if (SR='0') then Q <= "0000";

        elsif rising_edge(CP) then

            if PE = '0' then Q <= P; --Load

            elsif CET = '1' and CEP = '1' then Q <= Q+1; -- count

            end if;

            if CET = '1' and Q = "1111" then TC <= '1'; -- Terminal count

            else TC <= '0';

            end if;

        end if;

    end process count_proc;
```

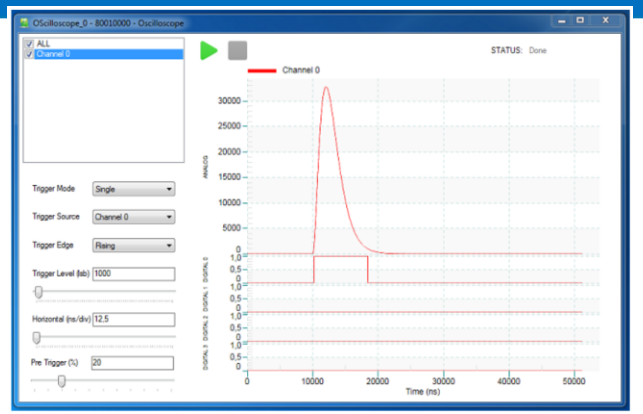
Nuclear Instruments

CAEN Tools for Discovery

www.sci-compiler.com

Sci-Compiler generate for you firmware and software

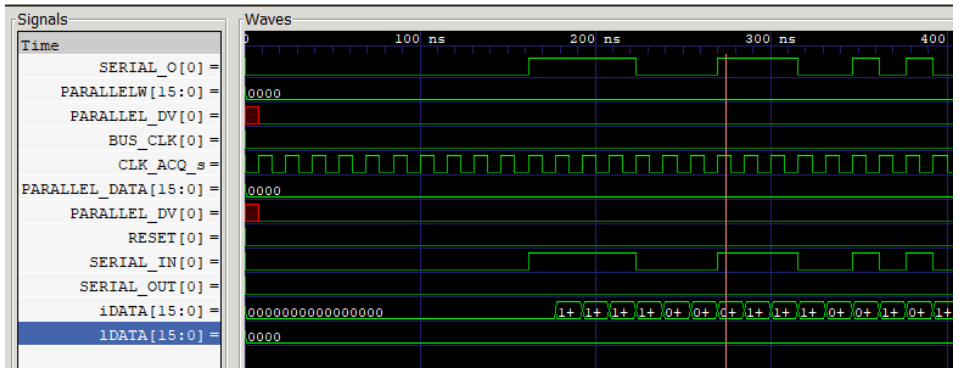
FIRMWARE



READOUT UI

SCI-COMPILER

SIMULATE

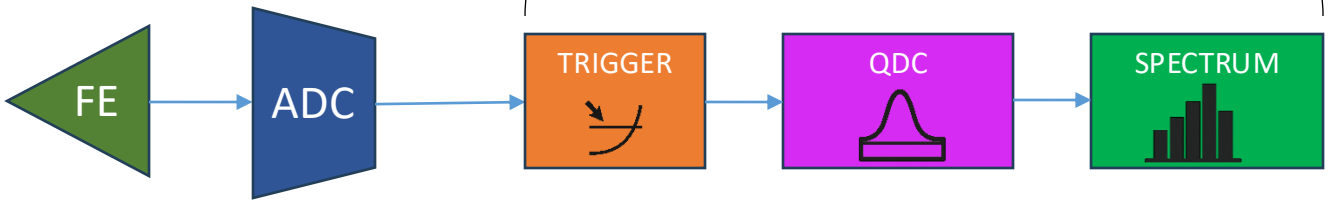


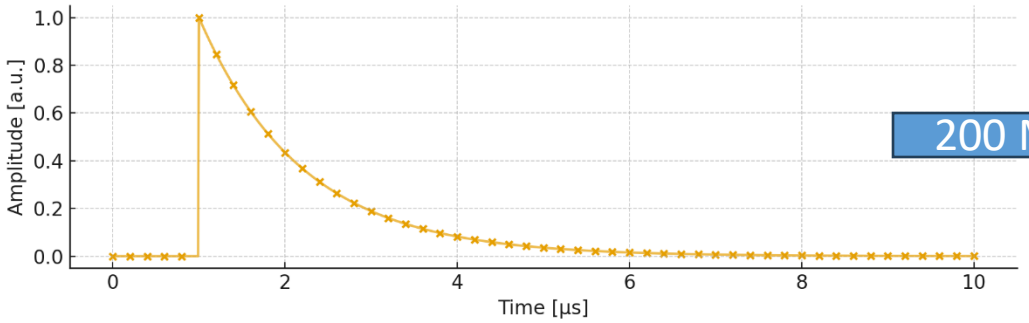
SDK Software Development Kit

WINDOWS AND LINUX SDK

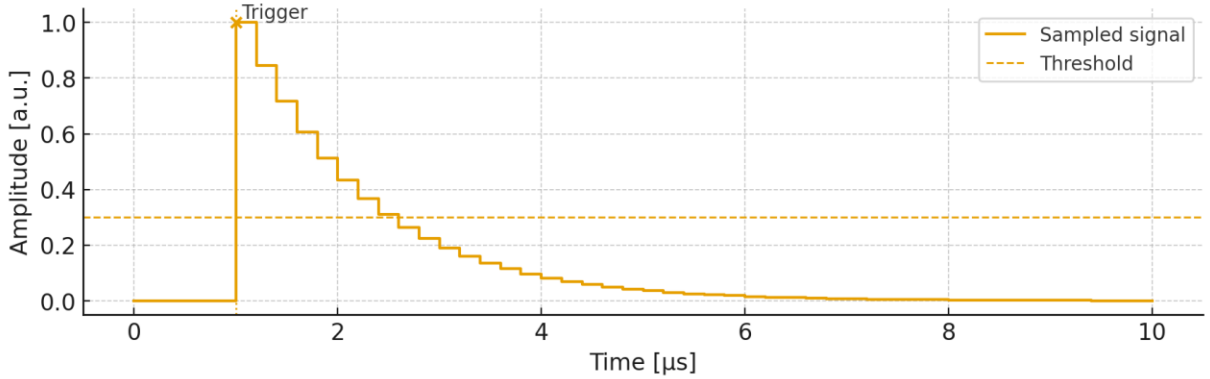
High Speed Digitizer (up to 200 MSPS)

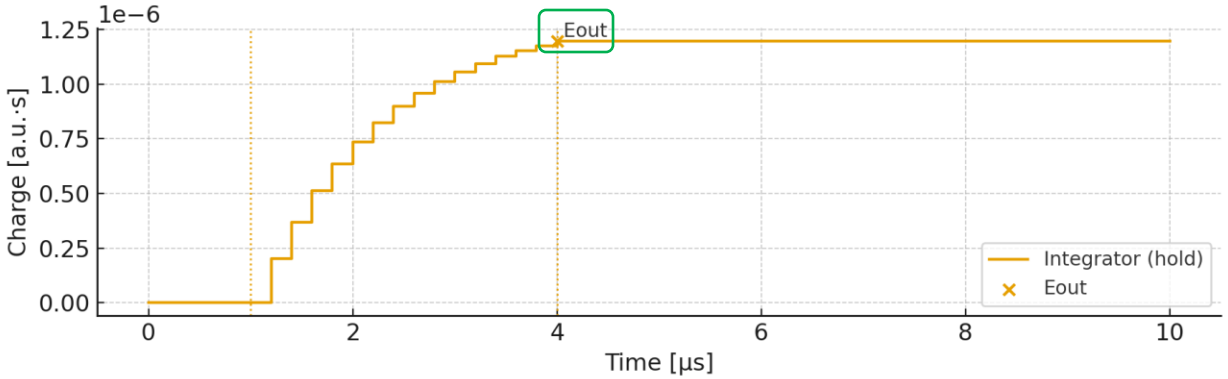
DT5571



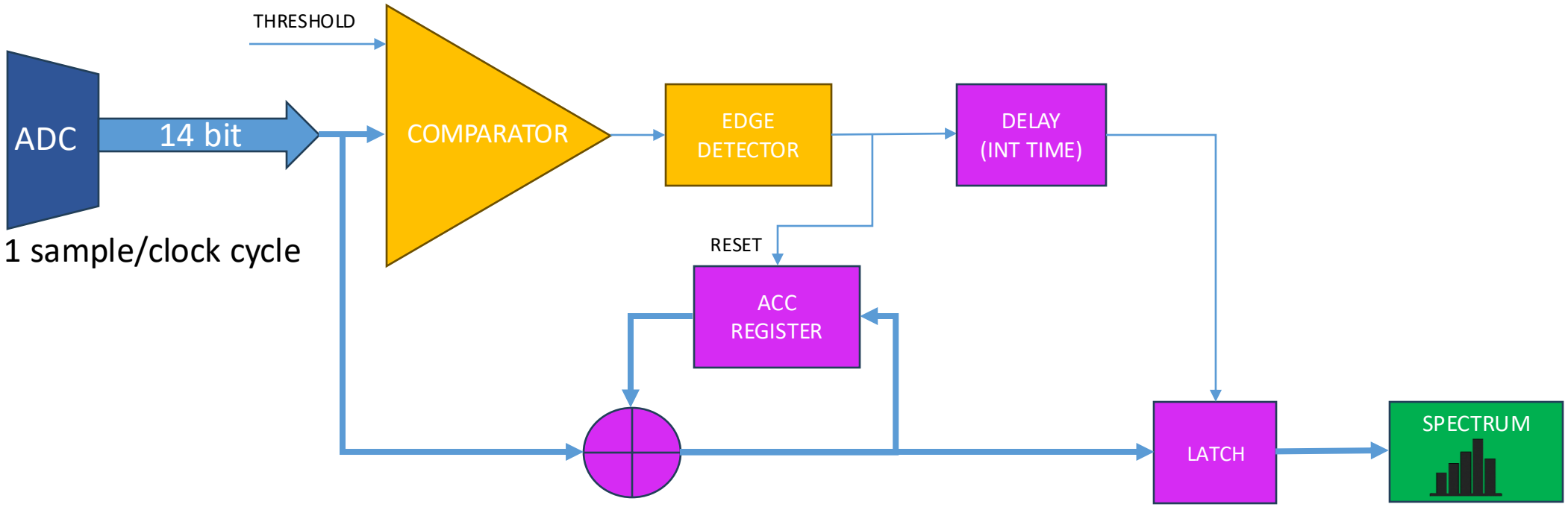


200 Msps





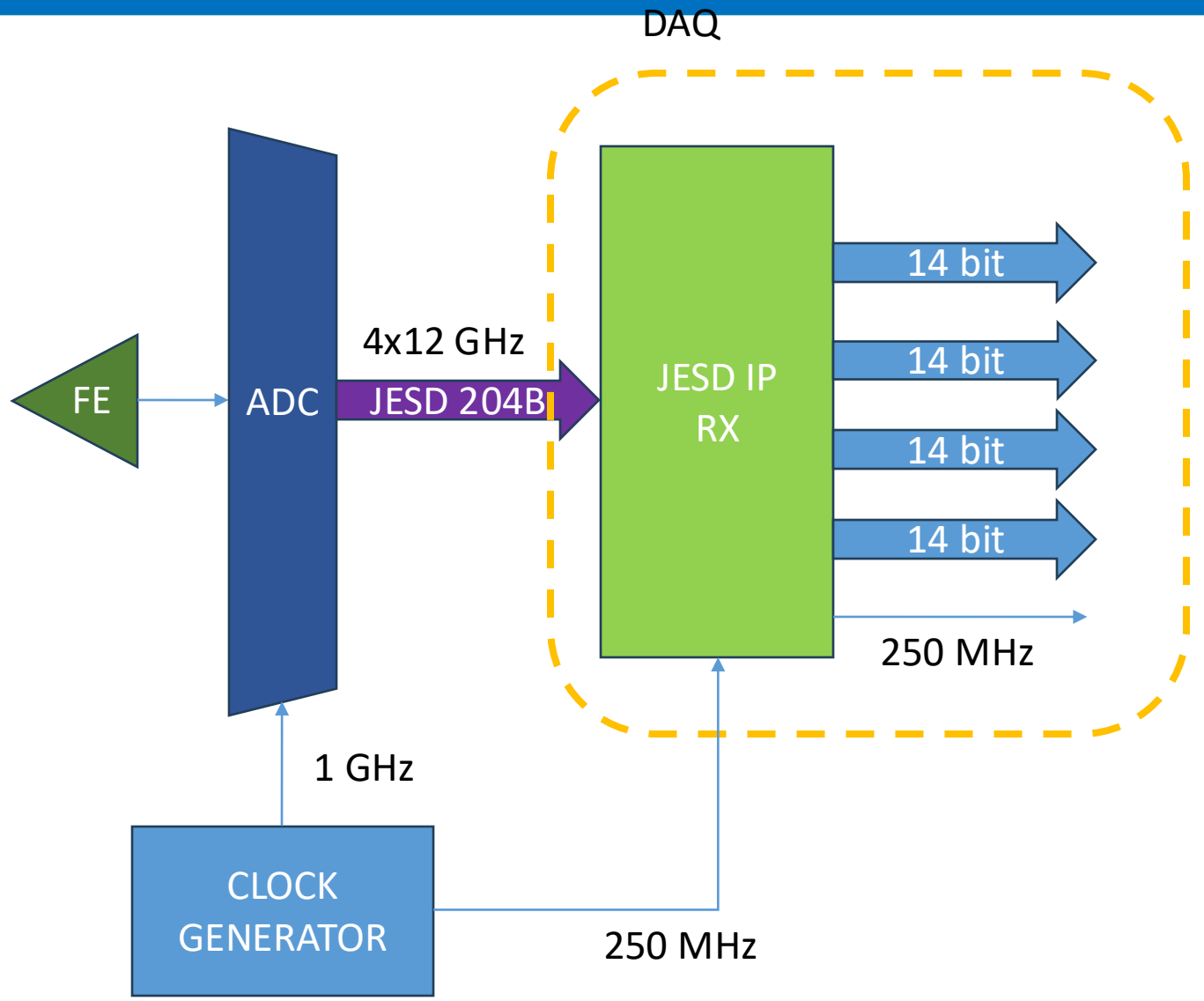
High Speed Digitizer (up to 200 MSPS)



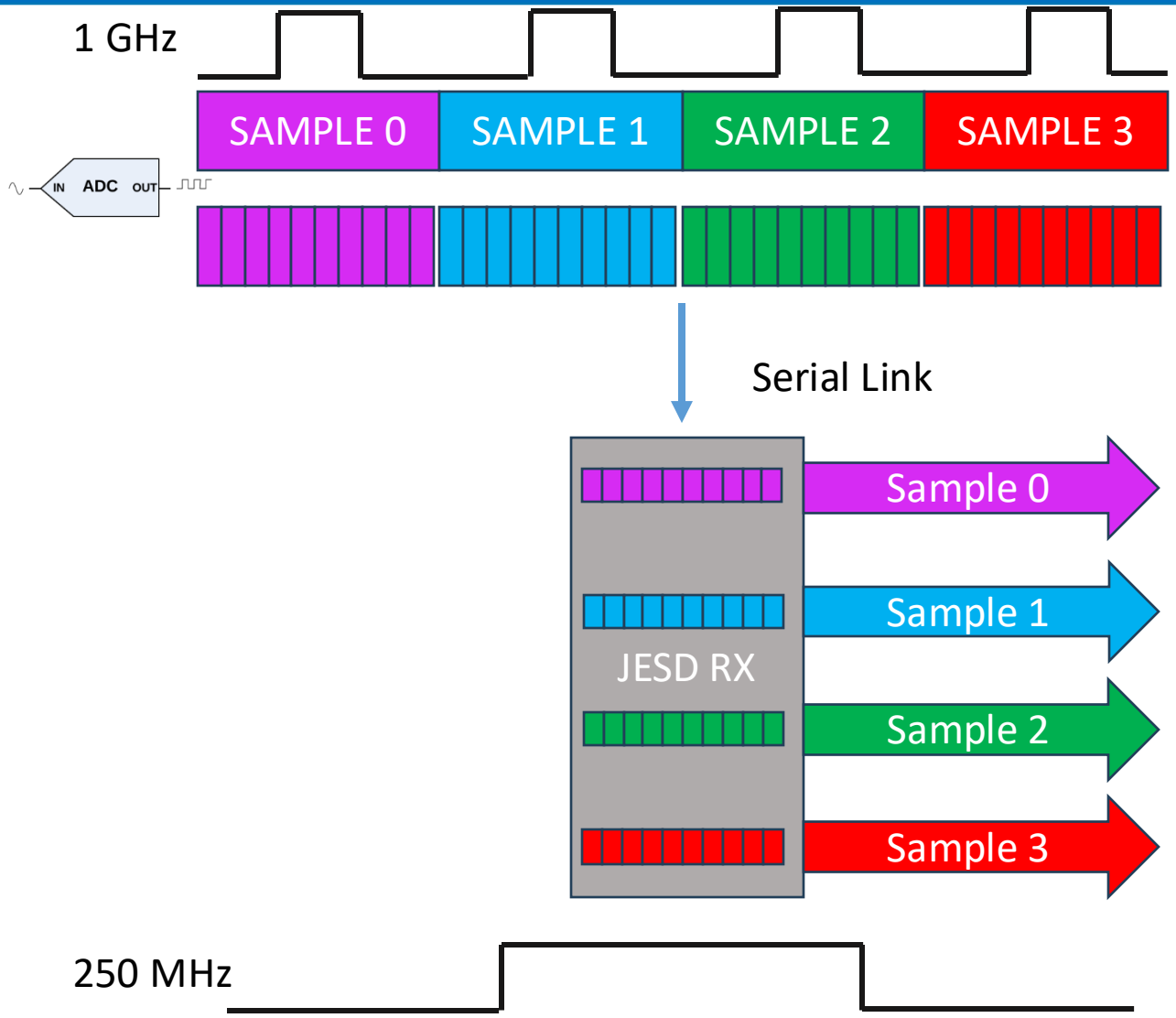
Ultra-High Speed Digitizer

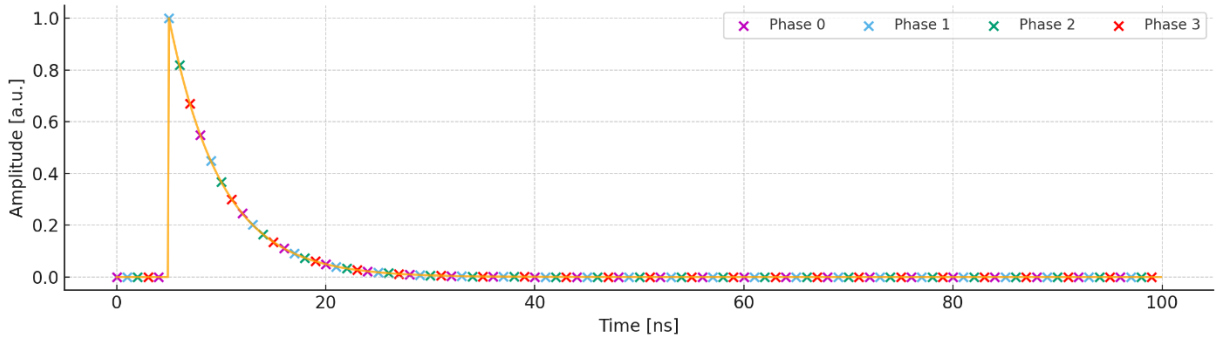
Nuclear Instruments
DAQ 121 - DAQ 141
1 Gsps, 32 channel, 12/14 bit

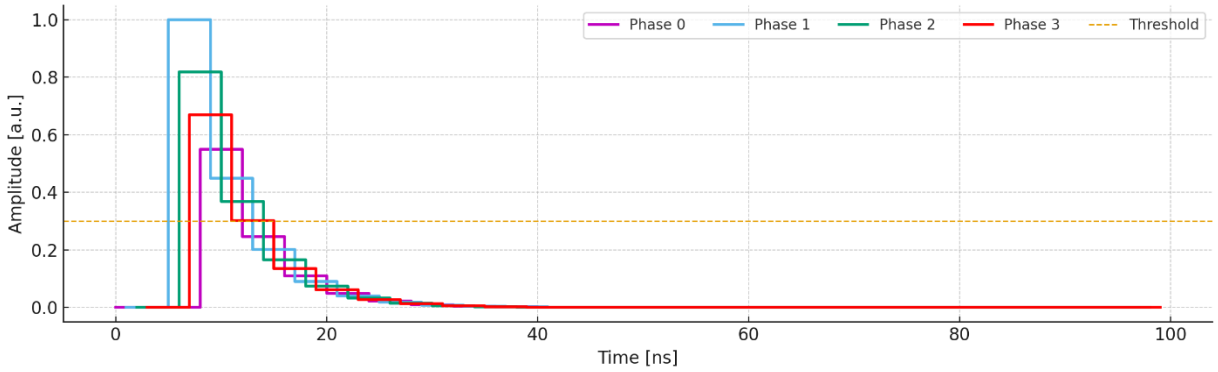
CAEN V2730 - 500 Msps, 32 channel, 14 bit
CAEN V2751 - 1 Gsps, 16 channel, 14 bit



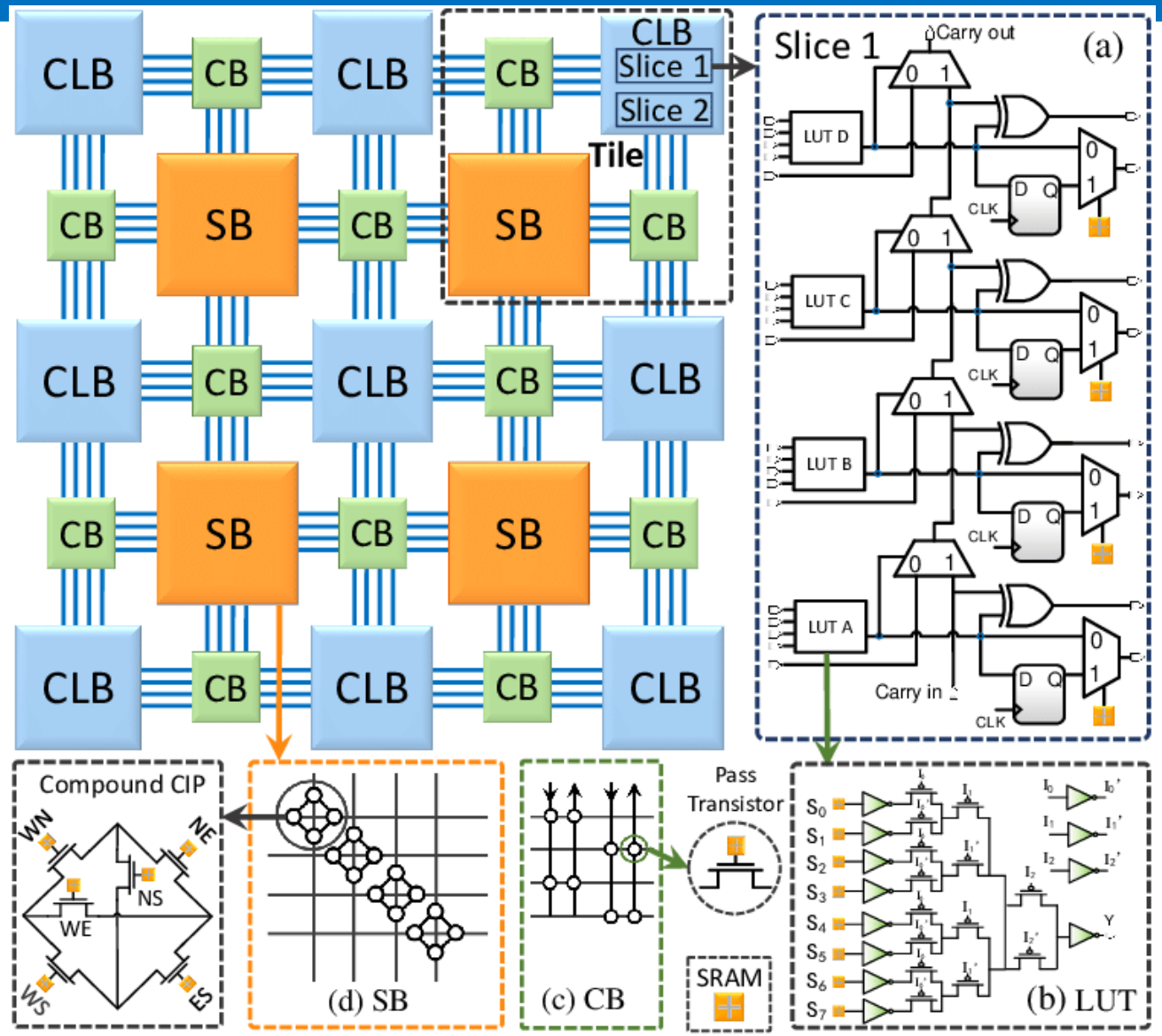
Ultra-High Speed Digitizer: Parallel data decoding







Ultra-High Speed Digitizer: FPGA clock speed limit

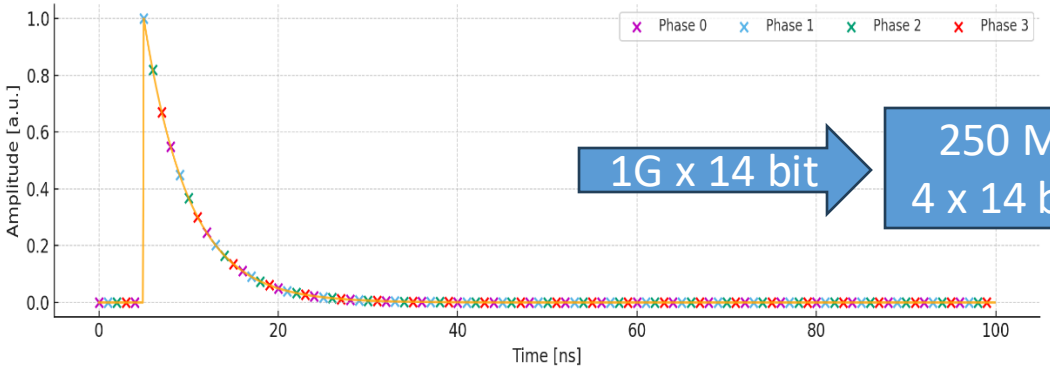


- Programmable FPGA architecture limits maximum clock speed
- Modern FPGA optimized designed may operate in the range 250 – 400 MHz
- Congestion in the device reduce maximum speed
- Safe margin must be considered for “open hardware” configurable application

Parallel QDC implementation

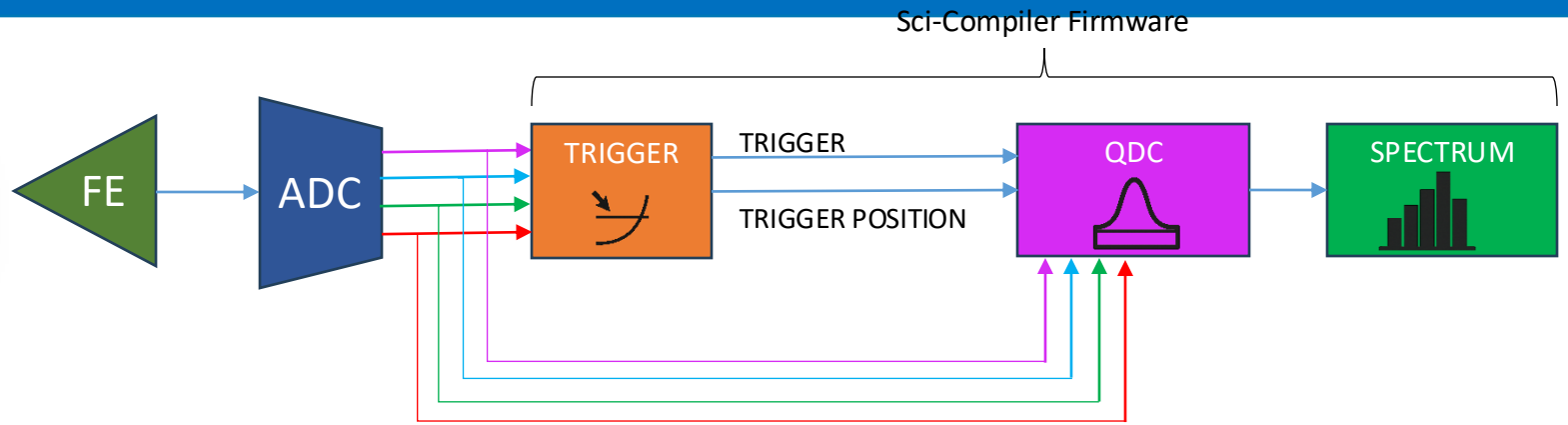
NI-DAQ 121/141

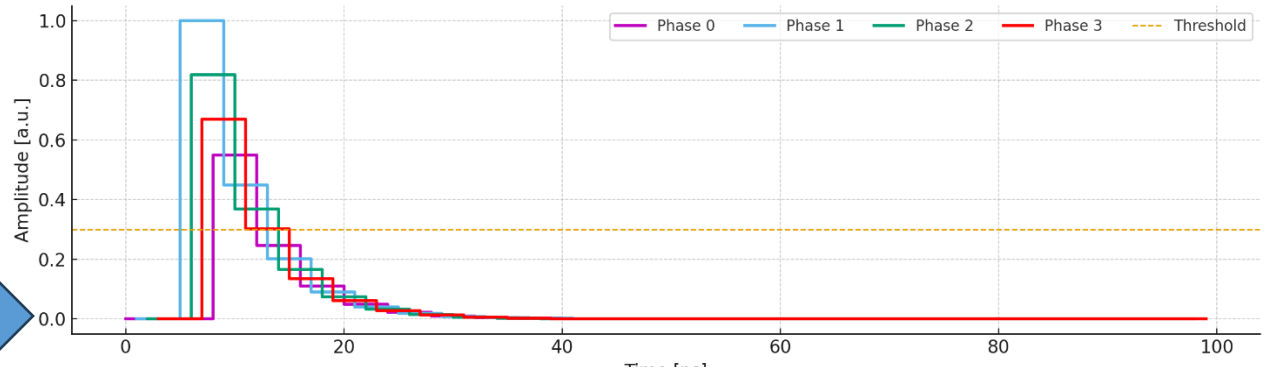
CAEN DT2730

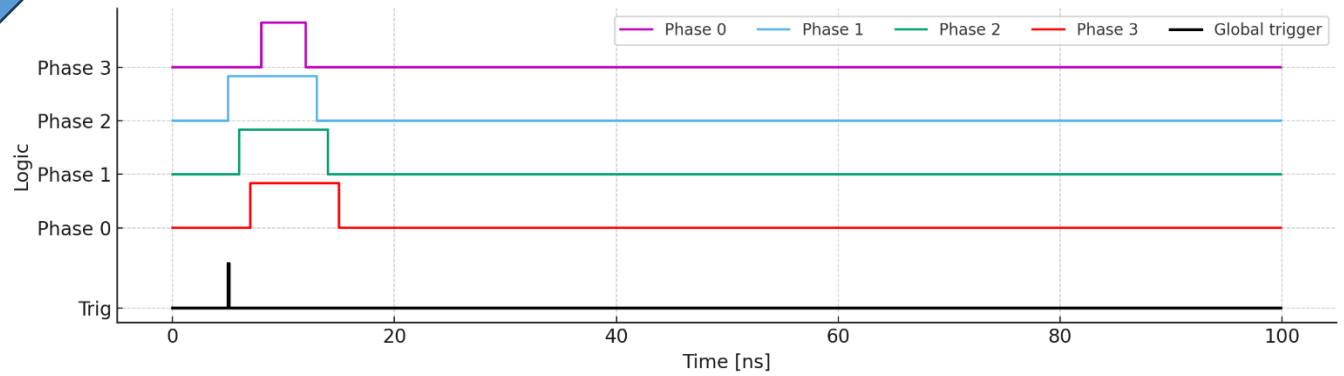


1G x 14 bit

250 M
4 x 14 bit



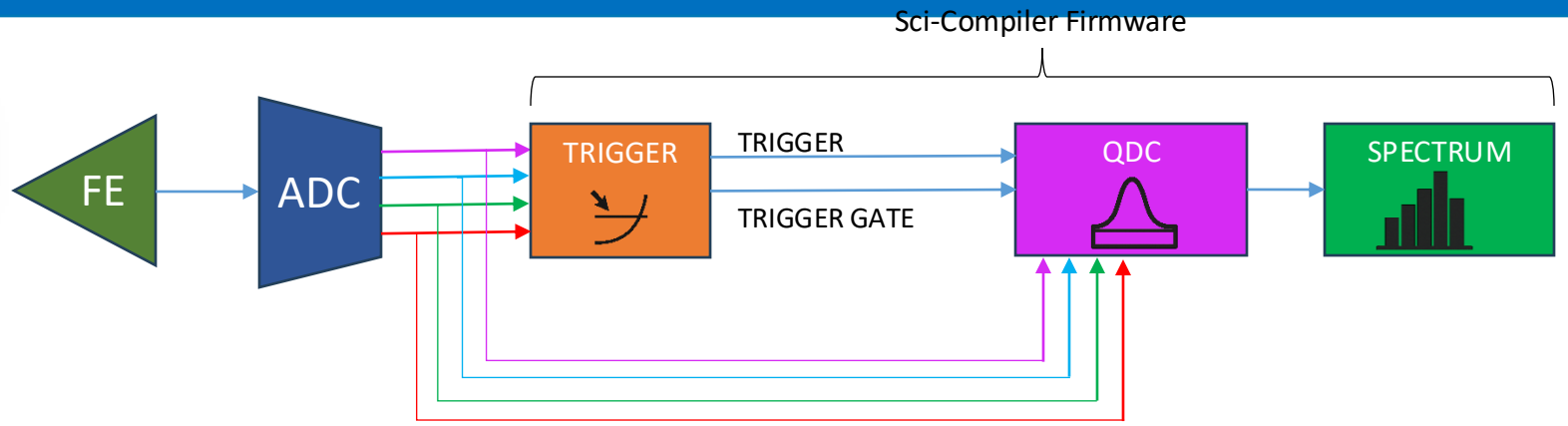


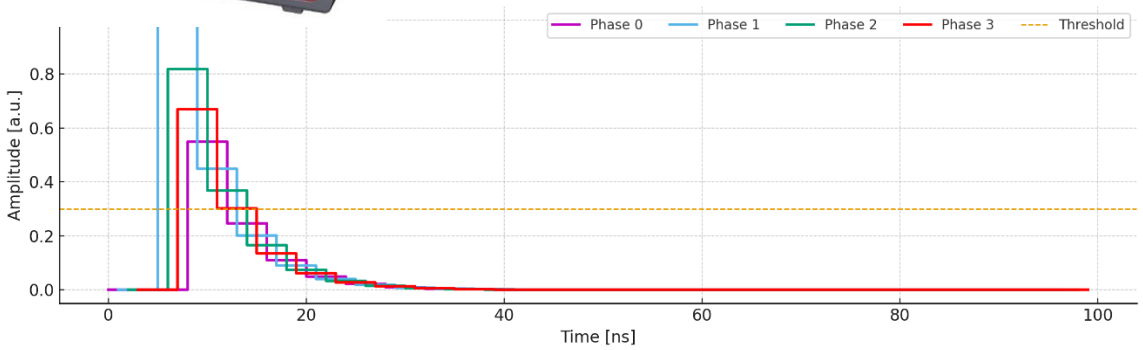


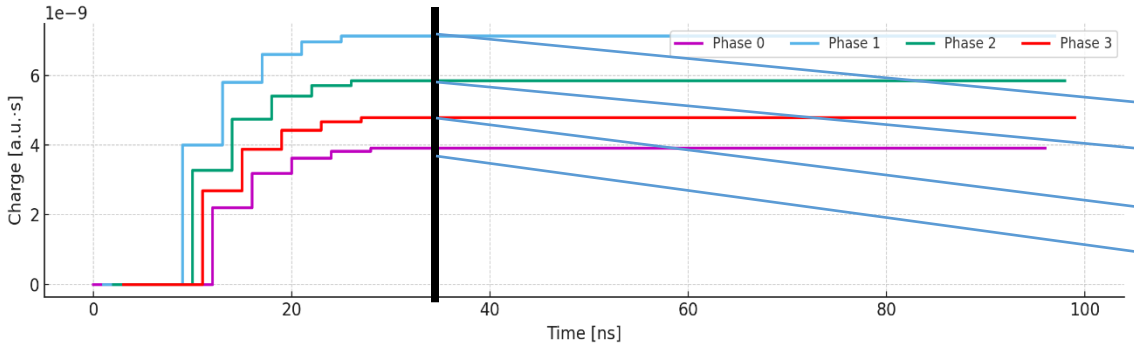
Ultra-High Speed Digitizer: Parallel QDC implementation

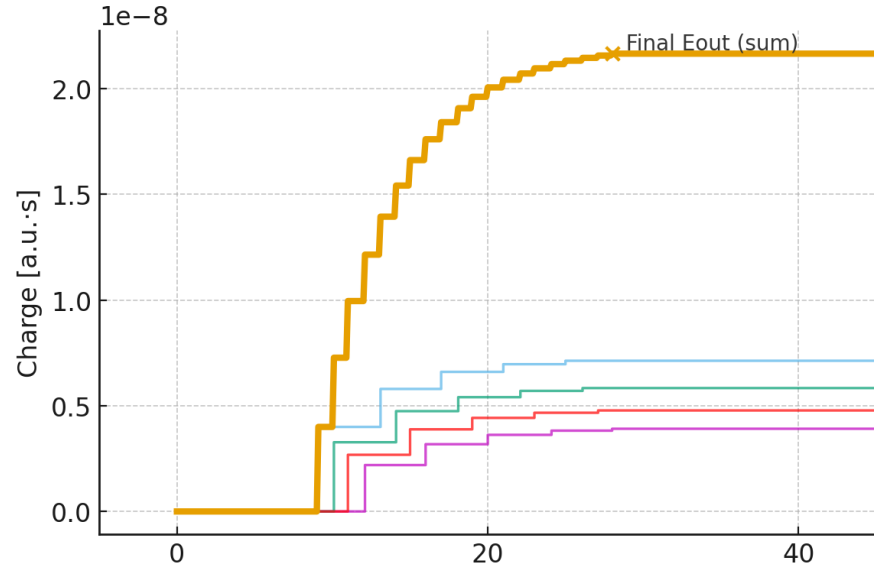
NI-DAQ 121/141

CAEN DT2730

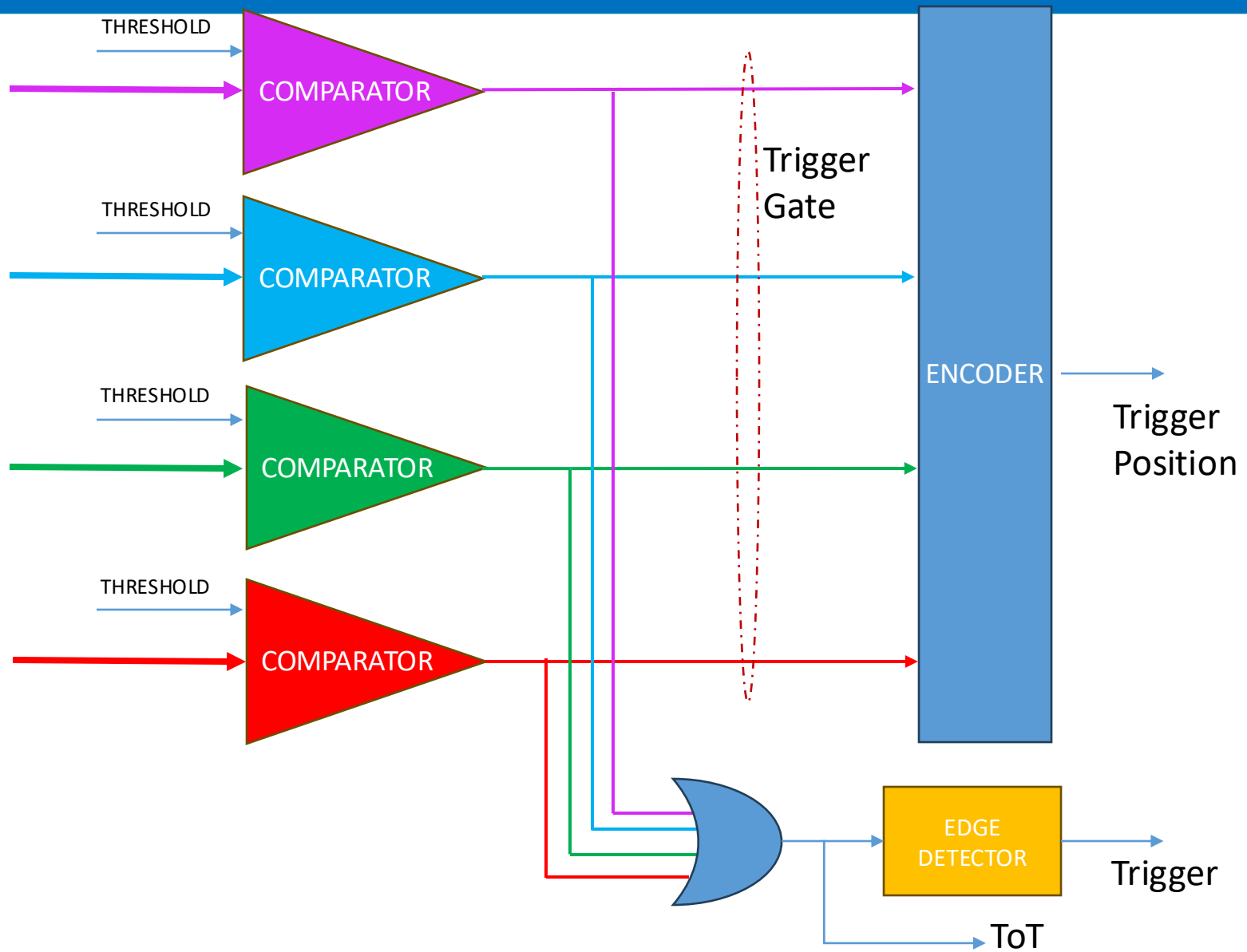




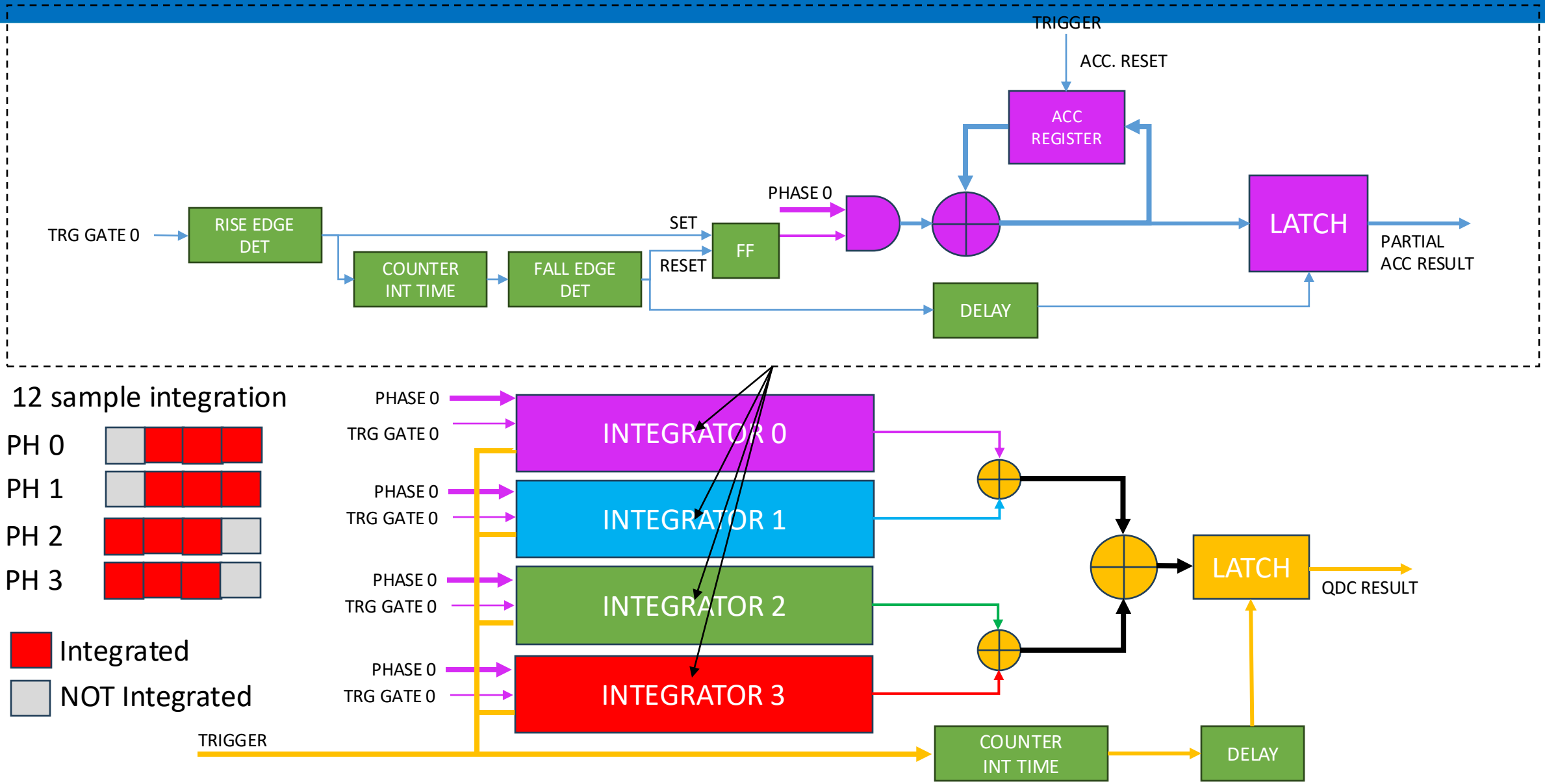




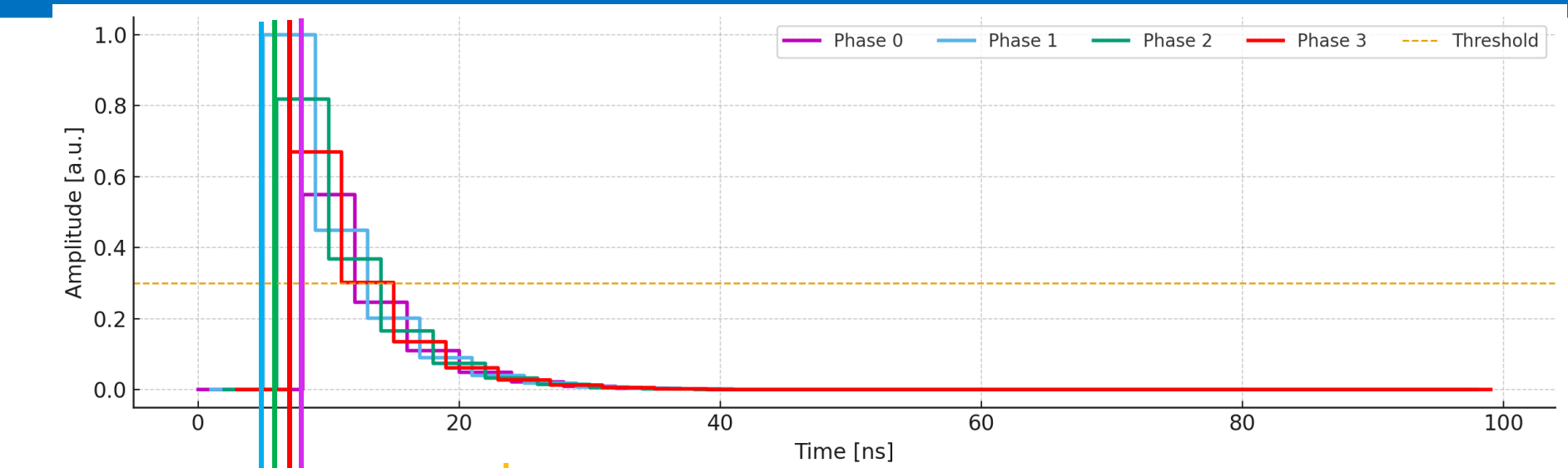
Parallel QDC implementation

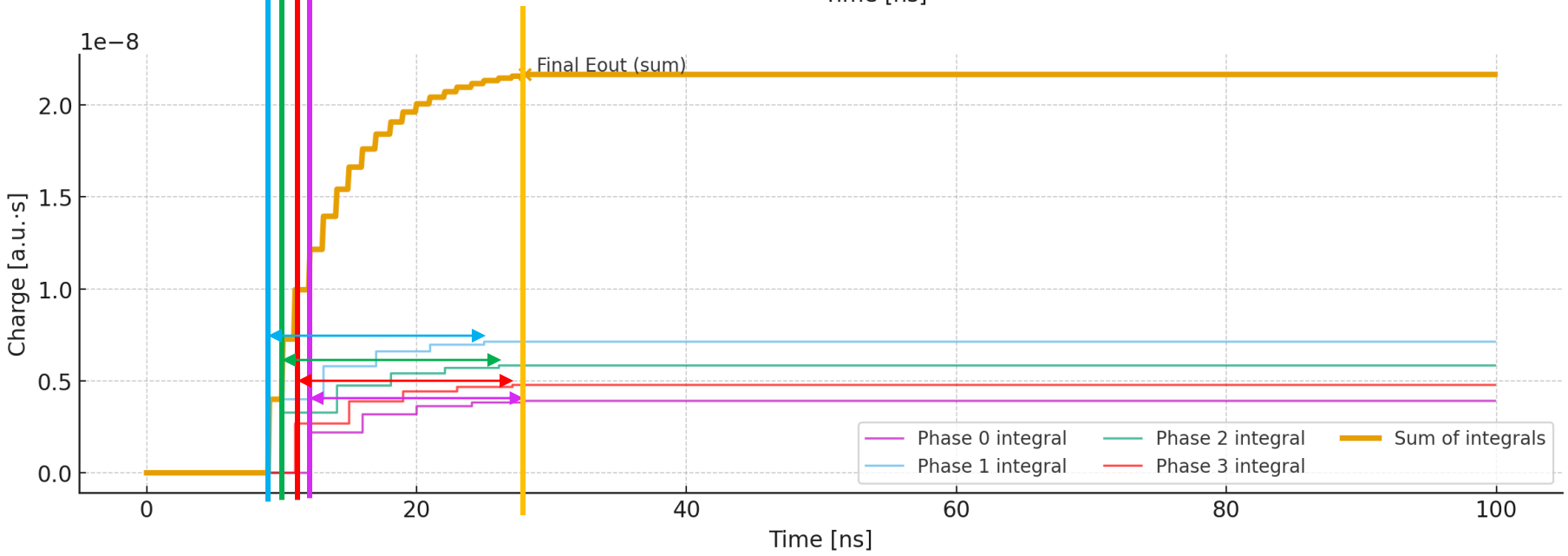


Parallel QDC implementation



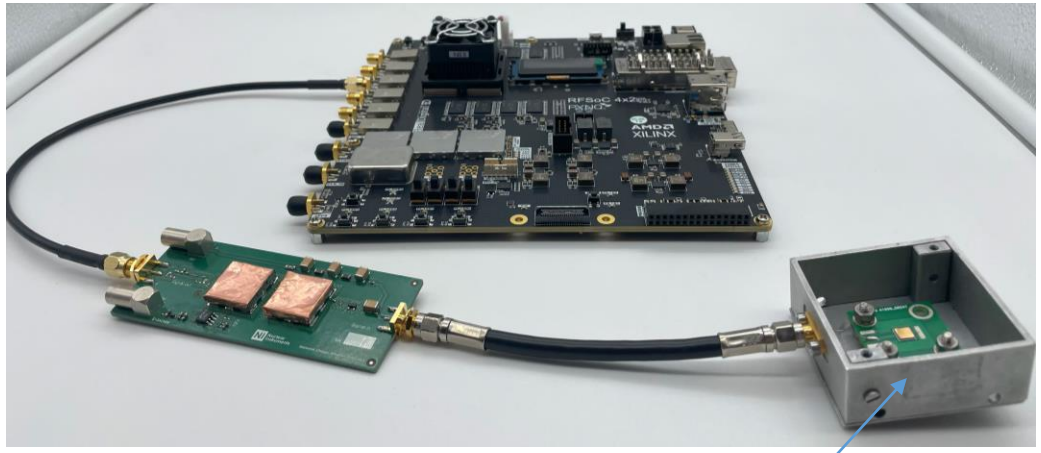
Parallel QDC implementation

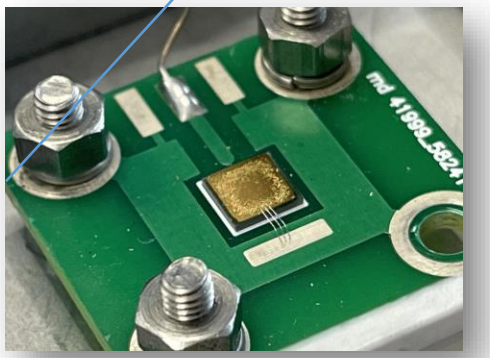




Parallel trapezoidal implementation

DT9000 → 5 Gsps
upcoming digitizer family





Diamond Detector

High-Energy Physics
•Particle tracking in collider experiments
•Radiation-hard sensors for extreme environments.

Nuclear Physics & Fusion
•Neutron detection and spectroscopy.
•Monitoring of intense radiation fields in fusion reactors.

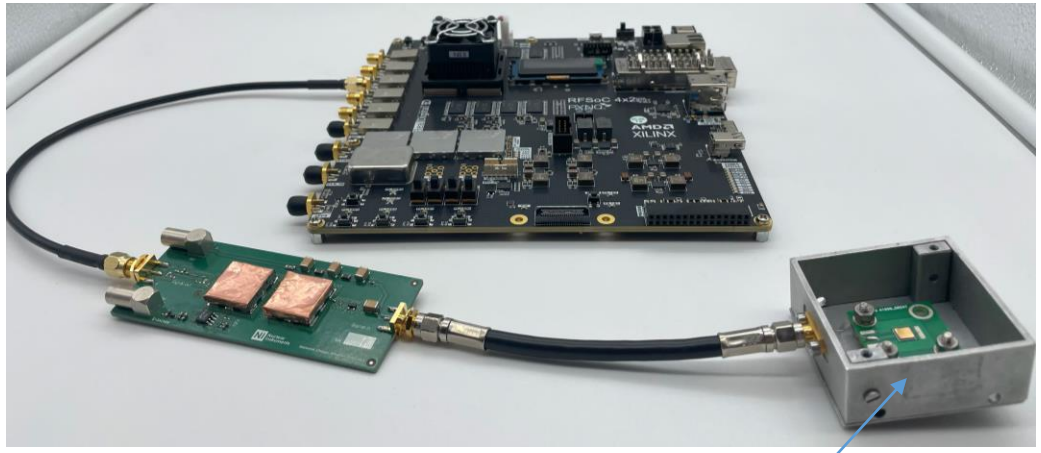
Medical Physics
•Dosimetry for radiotherapy and proton therapy (high precision and radiation hardness).
•Real-time monitoring of therapeutic beams.

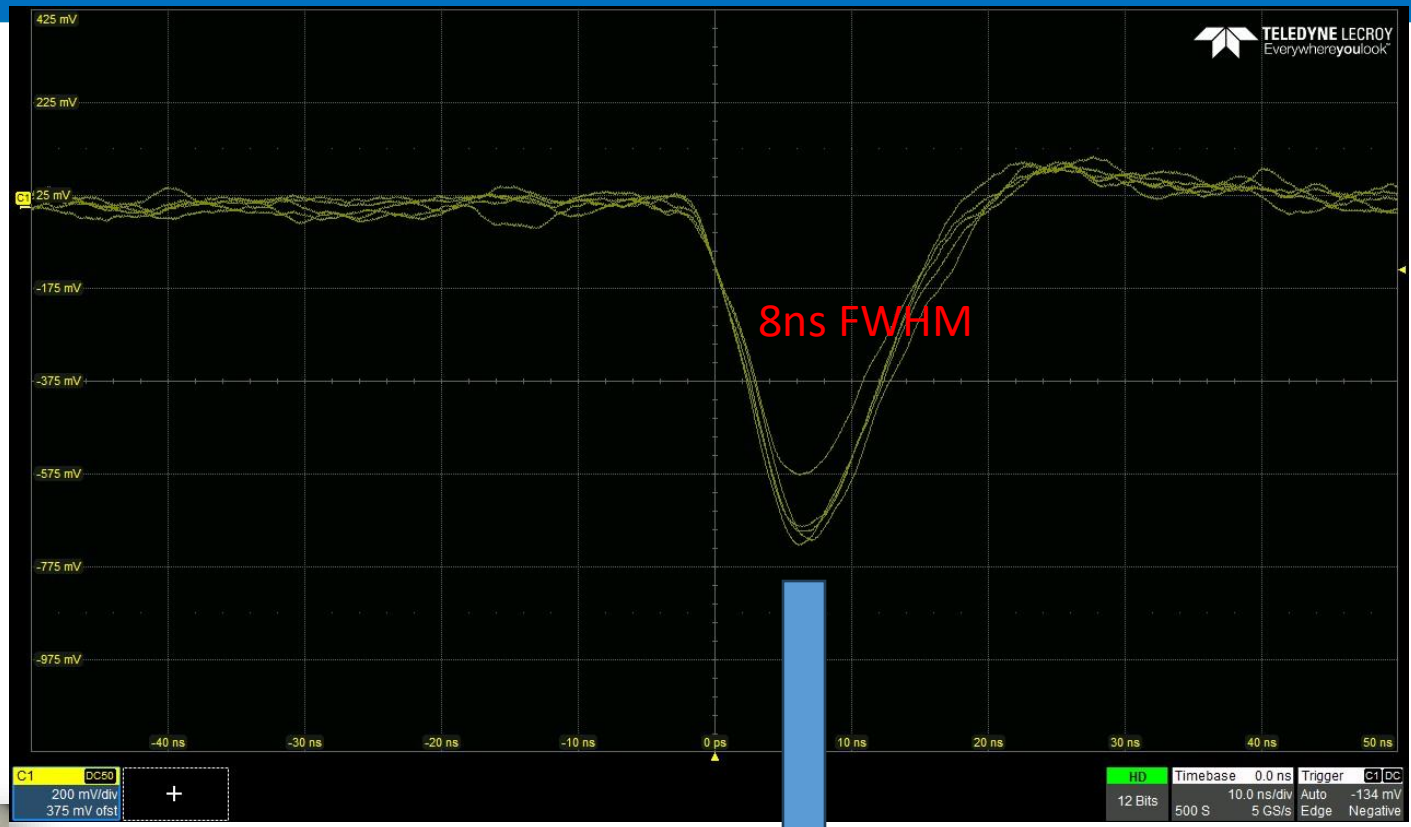
Space & Astrophysics
•Radiation monitoring in satellites and space missions.
•Detection of cosmic rays and solar particle events.

Industrial & Security Applications
•Beam diagnostics in accelerators and synchrotrons.
•Non-destructive testing using radiation.
•Radiation monitoring in nuclear facilities.

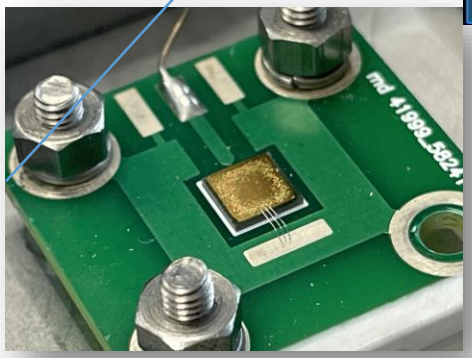
Parallel trapezoidal implementation

DT9000 → 5 Gsps upcoming digitizer family





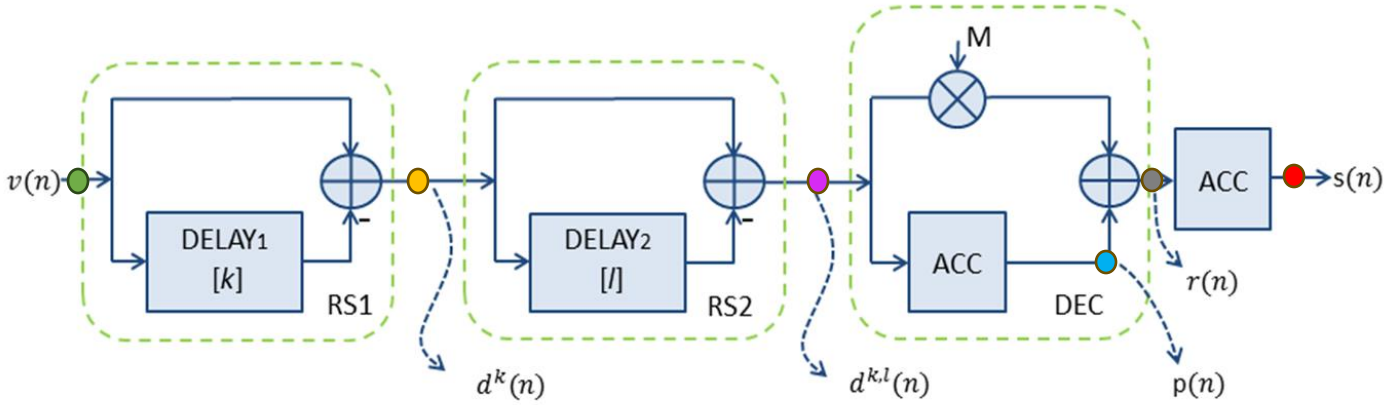
Diamond Detector

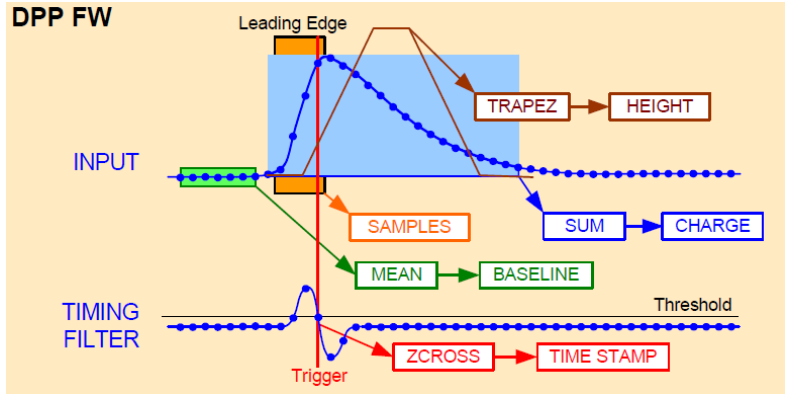


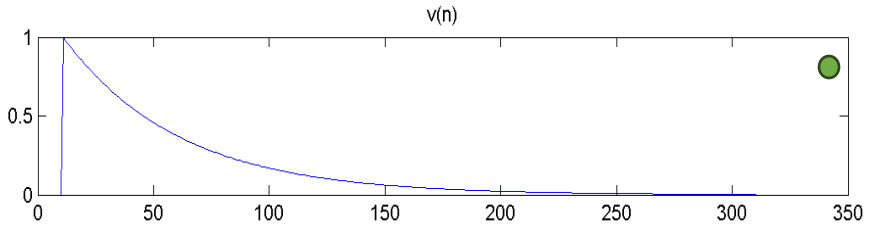
Ultra Fast signal response

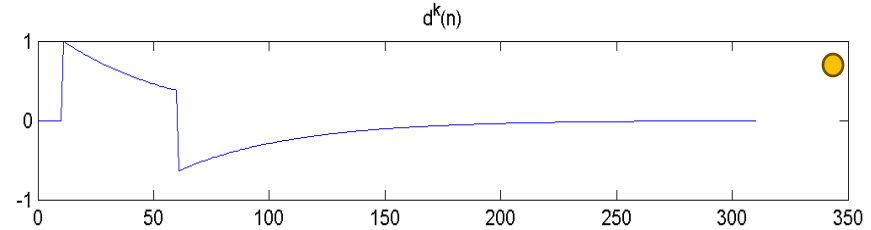
Fast digitizer and new processing algorithms

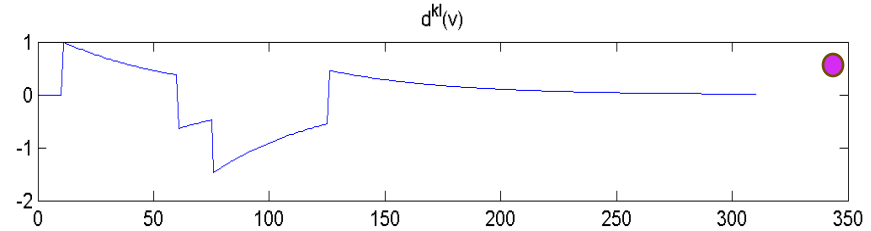
Parallel trapezoidal implementation

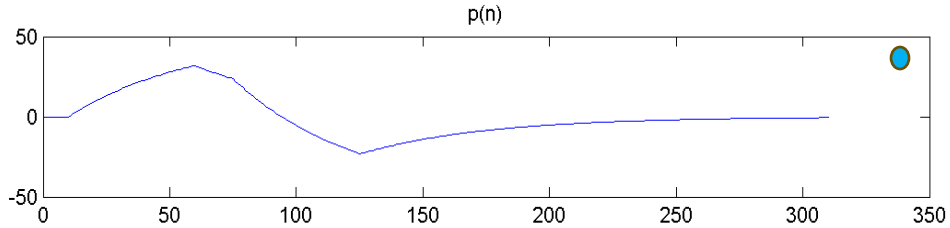


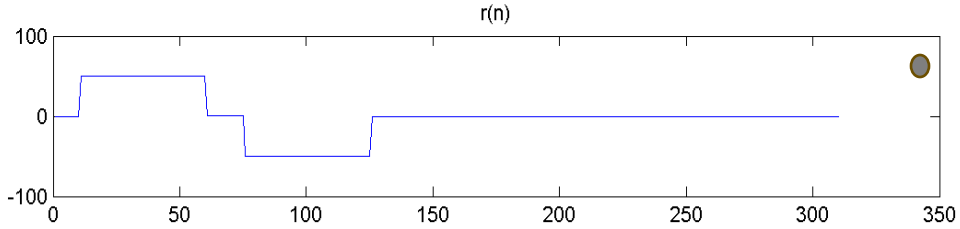


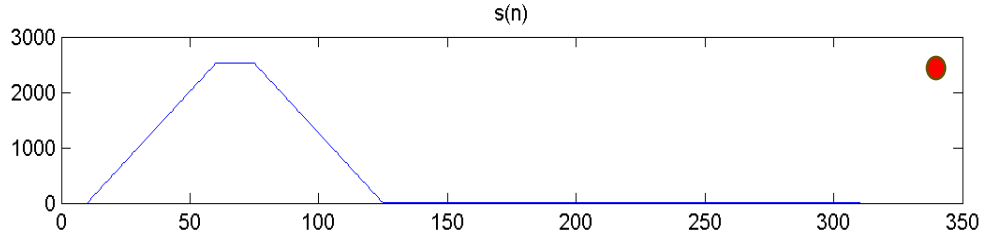




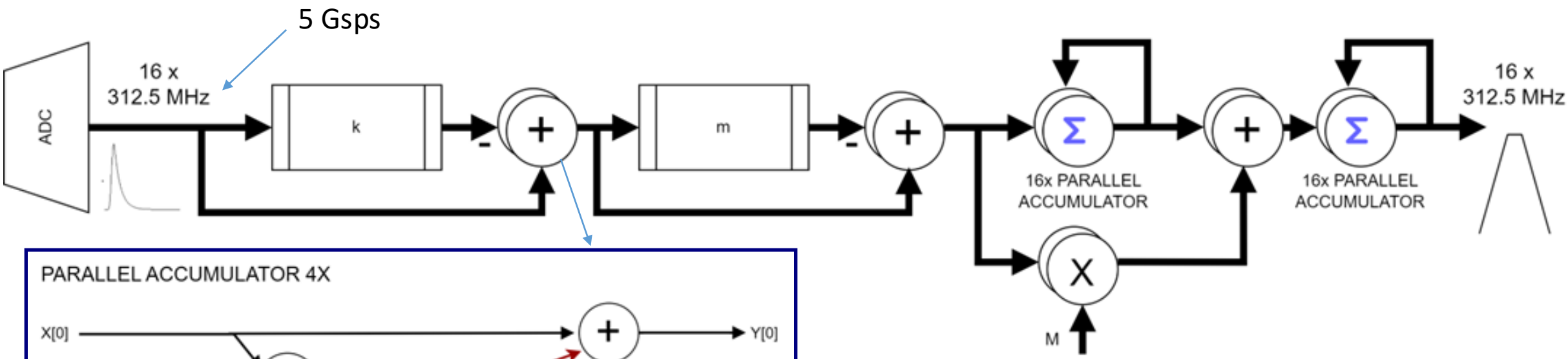


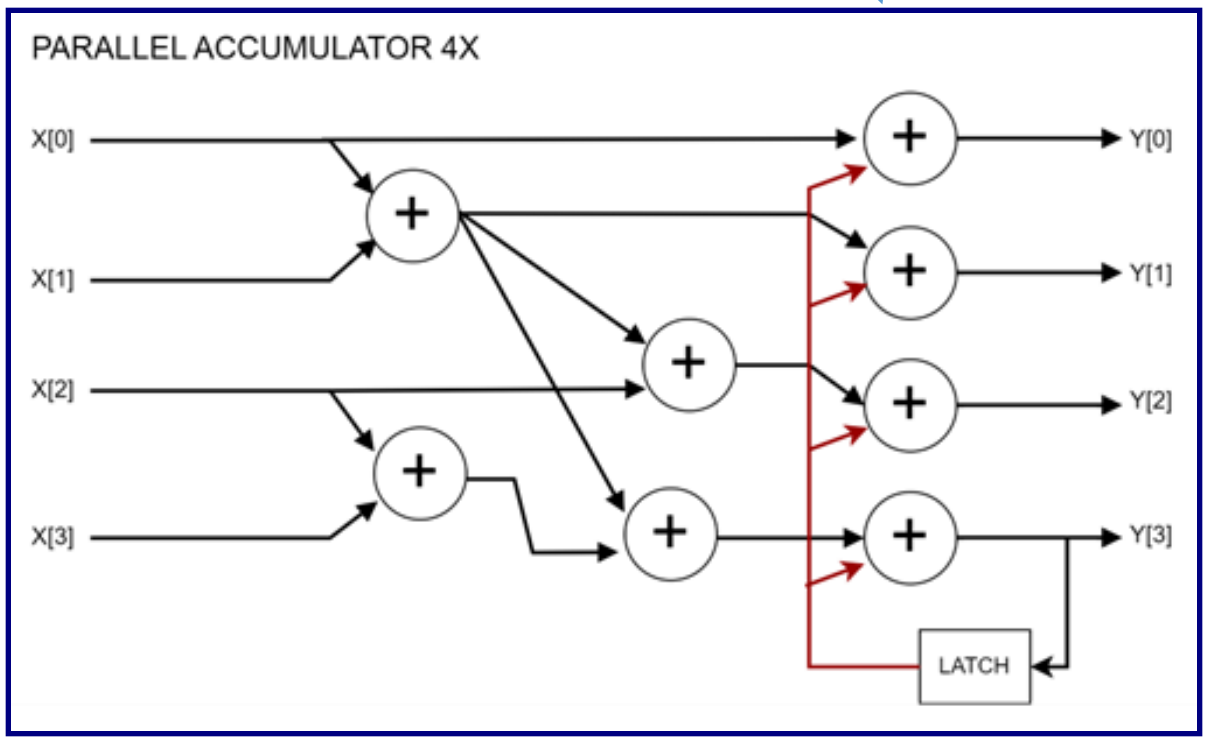






Parallel trapezoidal implementation

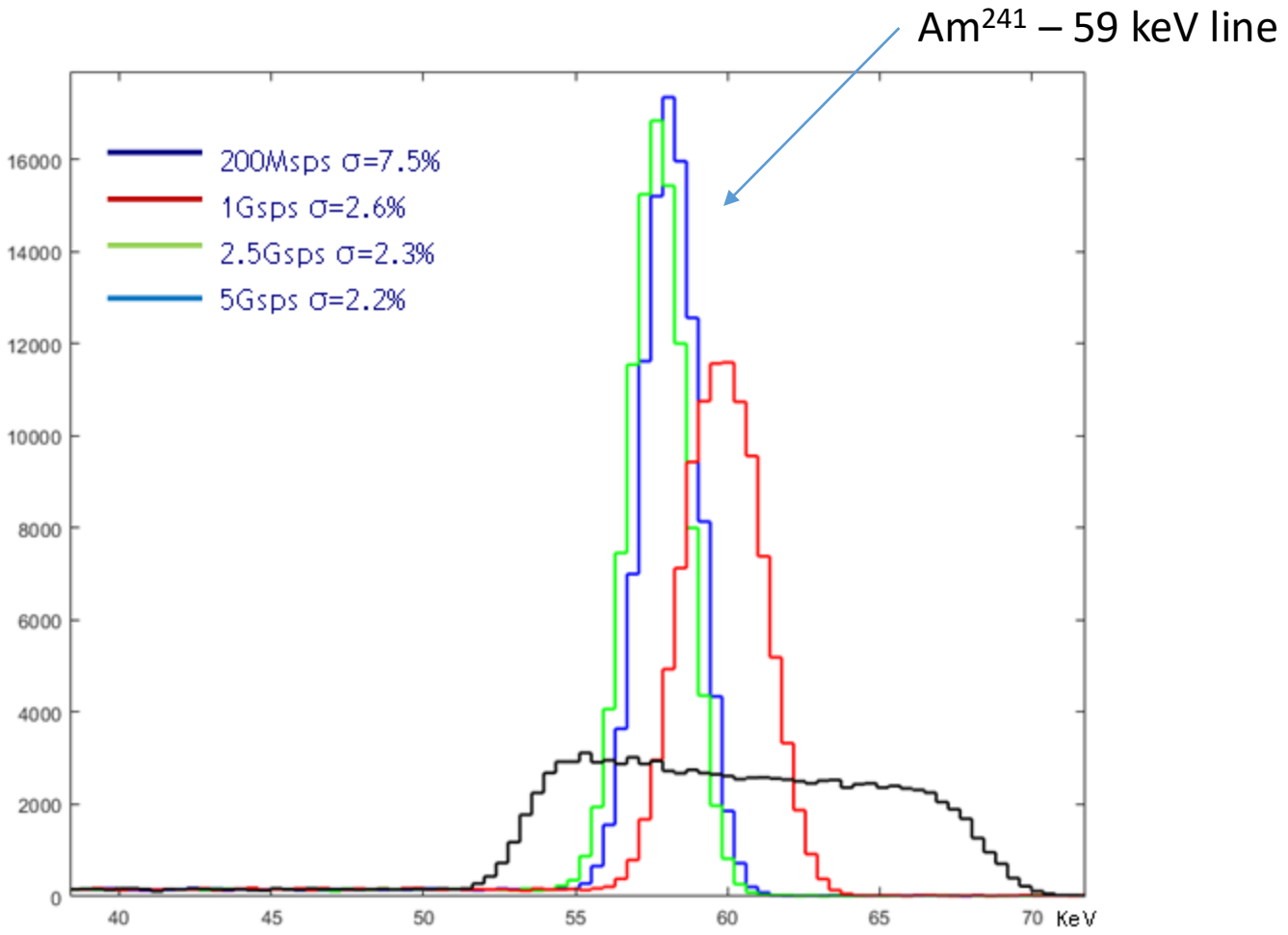




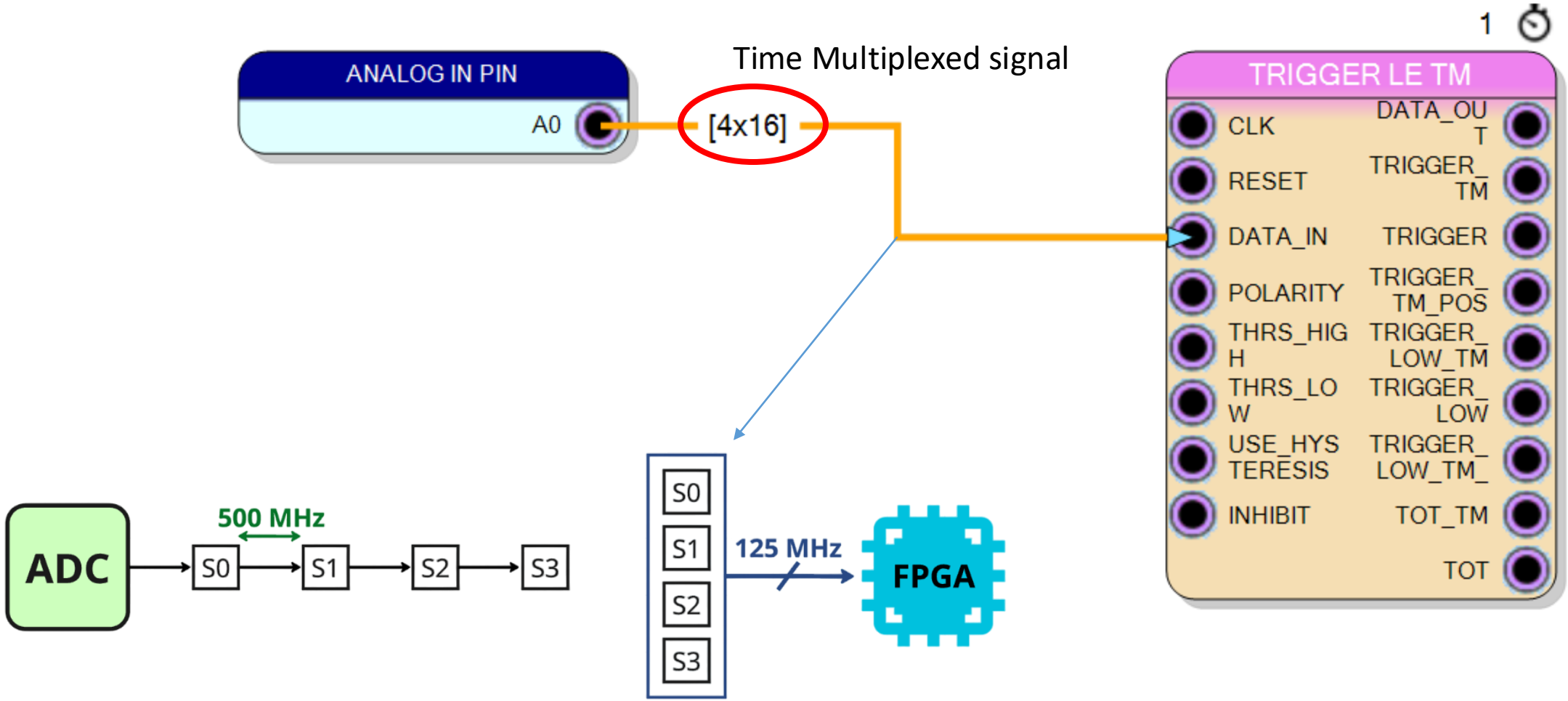
$$Y_0(n) = Y_0(n-1) + X_0(n); \quad Y_1(n) = Y_1(n-1) + s_0(n);$$
$$Y_2(n) = Y_2(n-1) + s_1(n); \quad Y_3(n) = Y_3(n-1) + s_4(n);$$
$$s_1(n) = X_0(n) + X_1(n); \quad s_2(n) = s_1(n) + X_2(n);$$
$$s_3(n) = X_2(n) + X_3(n); \quad s_4 = s_1(n) + s_3(n)$$

Parallel trapezoidal implementation

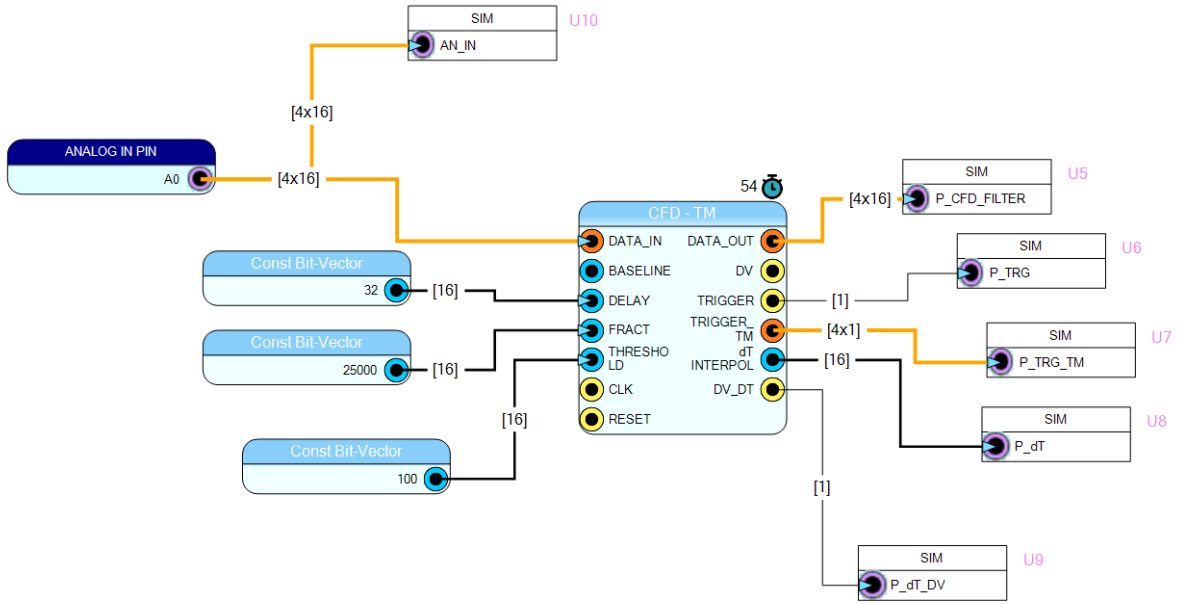
Resolution comparison at different sampling rate and constant shaping time for 20ns decay signal from diamond detector

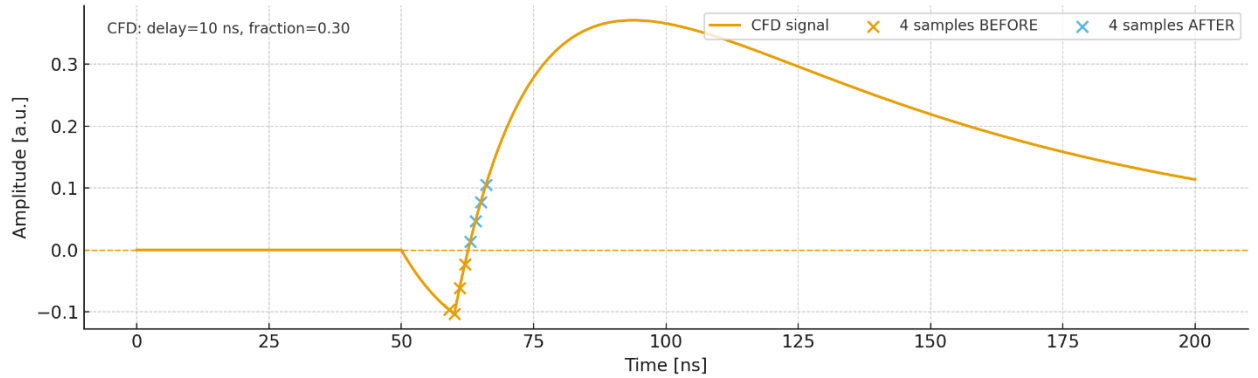


Sci-Compiler TM signals

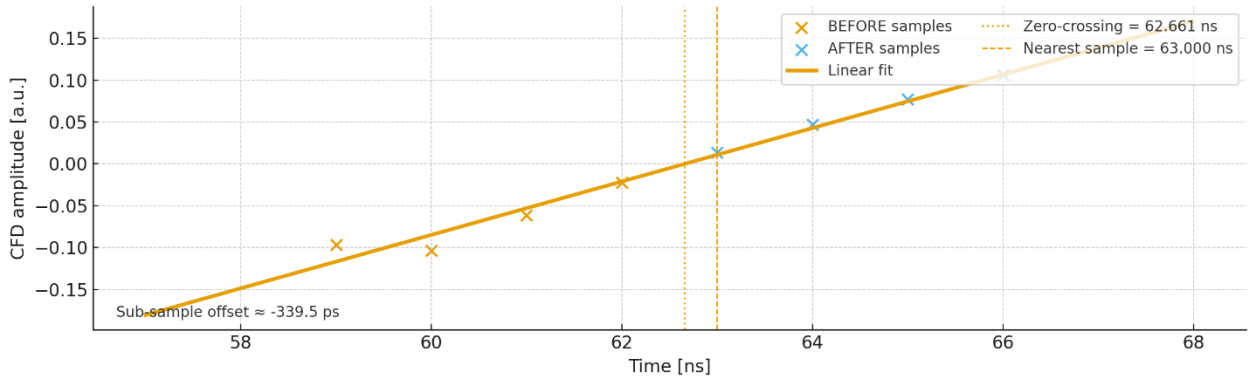


Sci-Compiler TM signals

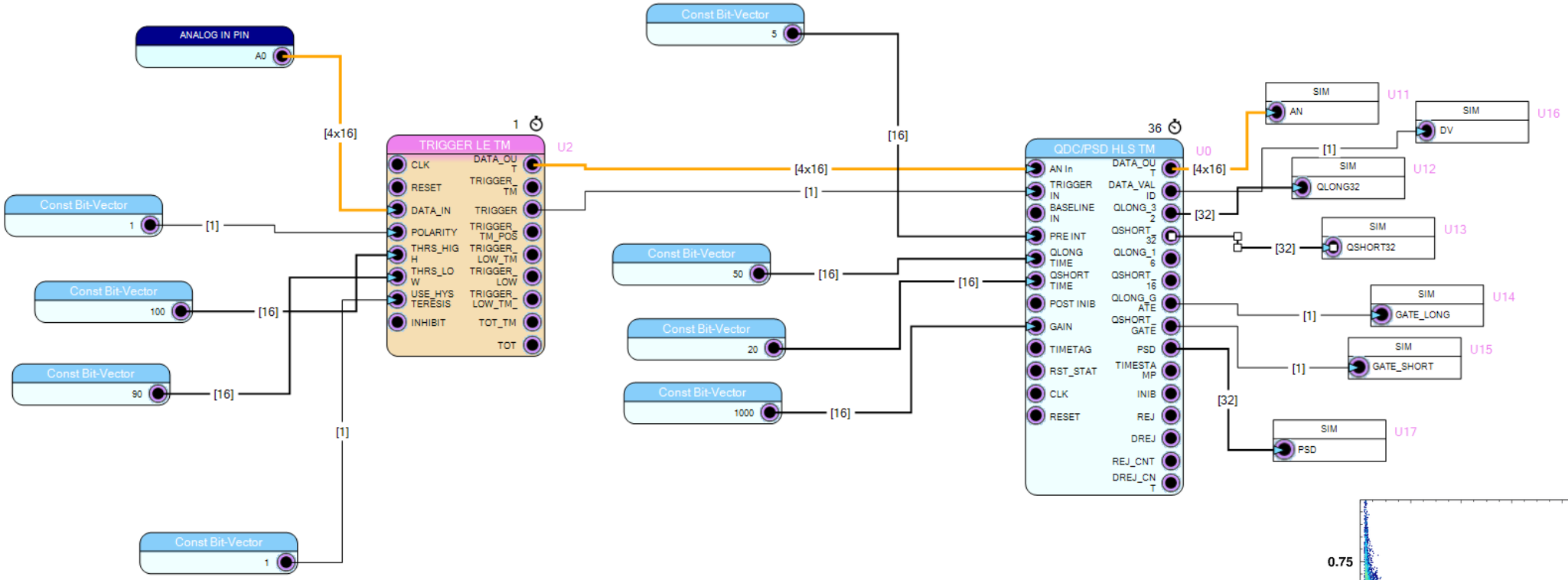


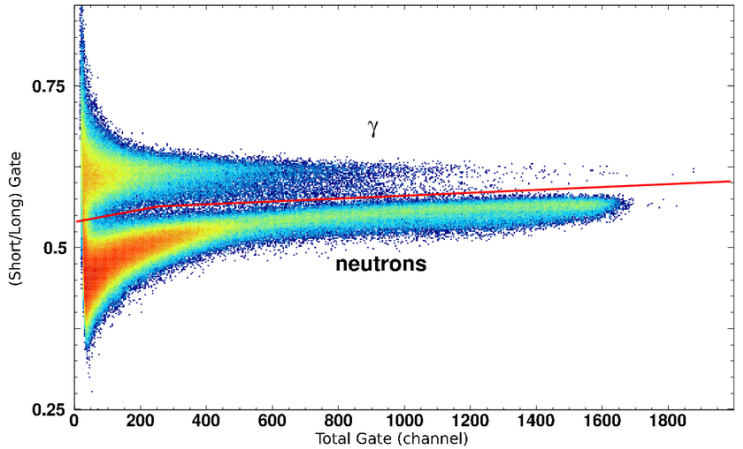


Sub-sample interpolator

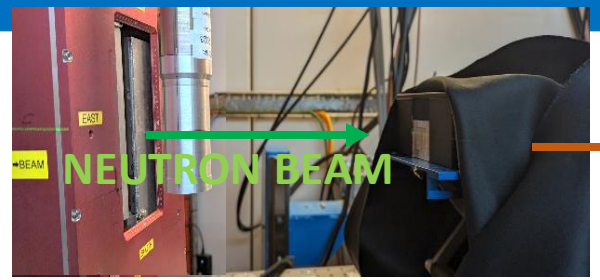


Sci-Compiler TM signals





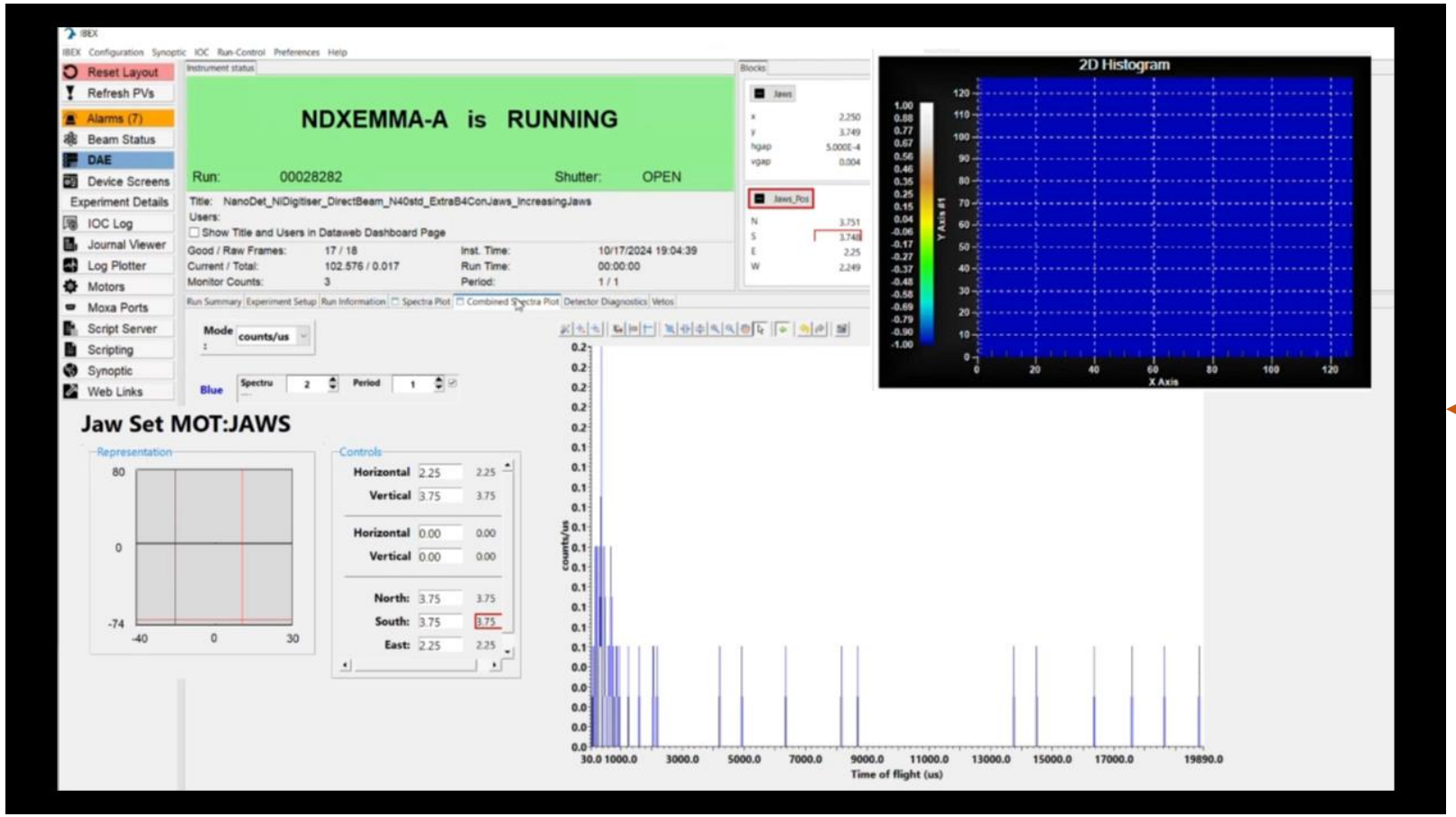
(ISIS) Realtime PSD on GS20 scintillator and Nanoparticles detectors



DAQ 121 Real Time Processor

220 ns Latency
Up to 50 Mcps

ISIS DAE



Science and Technology Facilities Council

Years of ISIS Neutron and Muon Source

University of BRISTOL

Nuclear Instruments

Fission Fragment Gamma Spectroscopy

Combination of different Gamma detector arrays:

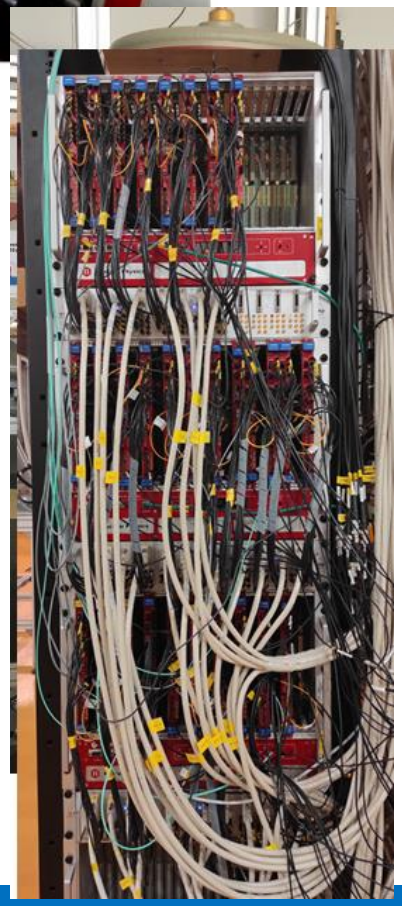
- HPGe (Clover) for high energy resolution
- BGO for Anti-Compton Shield
- $LaBr_3$ for fast timing information (prompt gamma coincidences)

Several installations with similar requirements:

- **VENUS** @ VECC (Kalkata)
- **ROSPHERE** Array @ ELI-NP (Romania)

Readout Modes:

- BGO: 250/500 MS/s, 14 bits, QDC algorithm (gated charge integration)
- $LaBr_3$: 500 MS/s, 14 bits, QDC + CFD algorithms (charge integration + high resolution timing interpolation)
- LVDS I/Os for sync/trigger/inhibit distribution among the boards



RFX (Padova) Neutron Monitor

Scientific Goals

- **Neutron measurement** as a direct indicator of fusion reaction rate and fusion power.
- Requires **accurate neutron/gamma discrimination (PSD)**.

Detector Setup

- **Three scintillator-based detectors** installed below the vacuum vessel.

Scintillators:

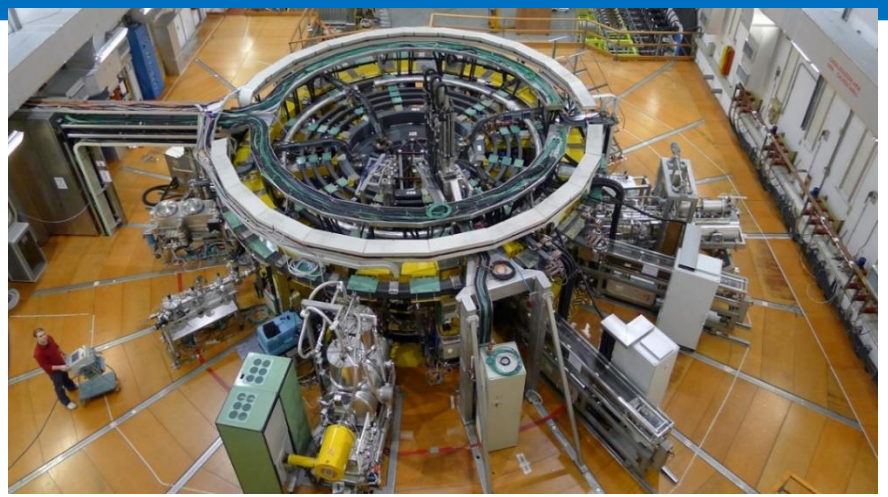
- **EJ276D (25×25×100 mm, plastic):** fast response, excellent n/γ discrimination, efficient for fast neutrons (no spectral info).
- **$LaCl_3$ (Ø1" × 1"):** provides spectral information (discrete peaks), fast (~50 ns) but poor n/γ discrimination → needs advanced algorithms.

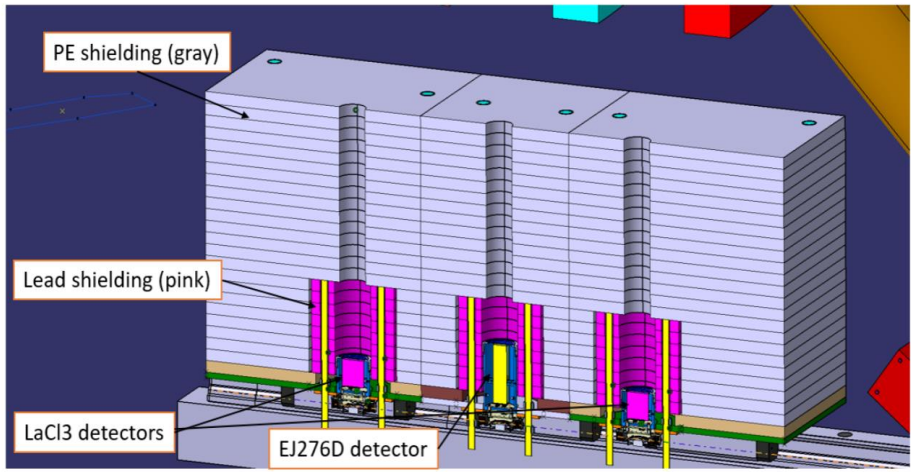
Readout & Acquisition

- All crystals coupled to **SiPM arrays (4×4)**, grouped and summed analogically.
- Signals sampled by **NI DAQ121** with **full waveform**
- **Typical discharge:** ~1 s, average ~1 kHz, bursts (100 µs–1 ms) from magnetic reconnection events.

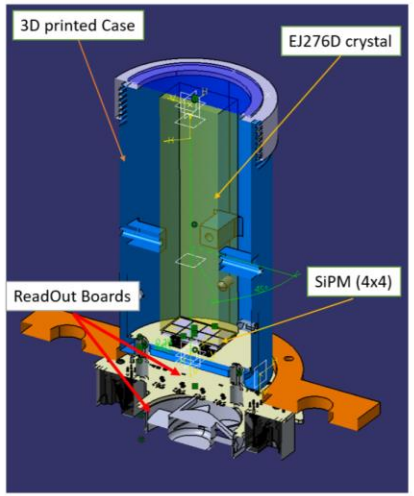
PSD Methods

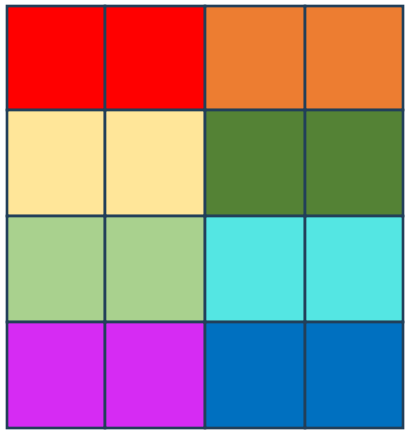
- Standard PSD effective for EJ276D but **ineffective for $LaCl_3$**.
- **FFT-based approach:** compute FFT for each event and evaluate amplitude ratio → **improves neutron/gamma separation**.

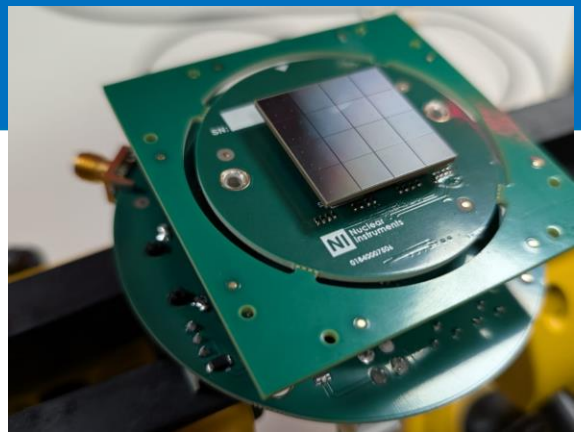


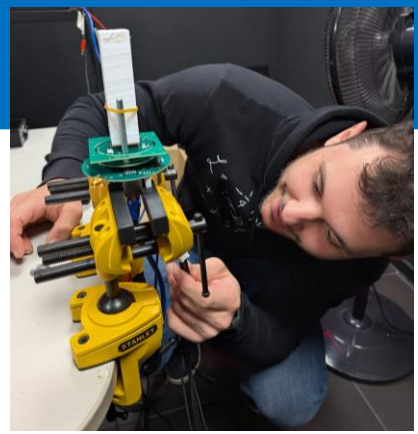


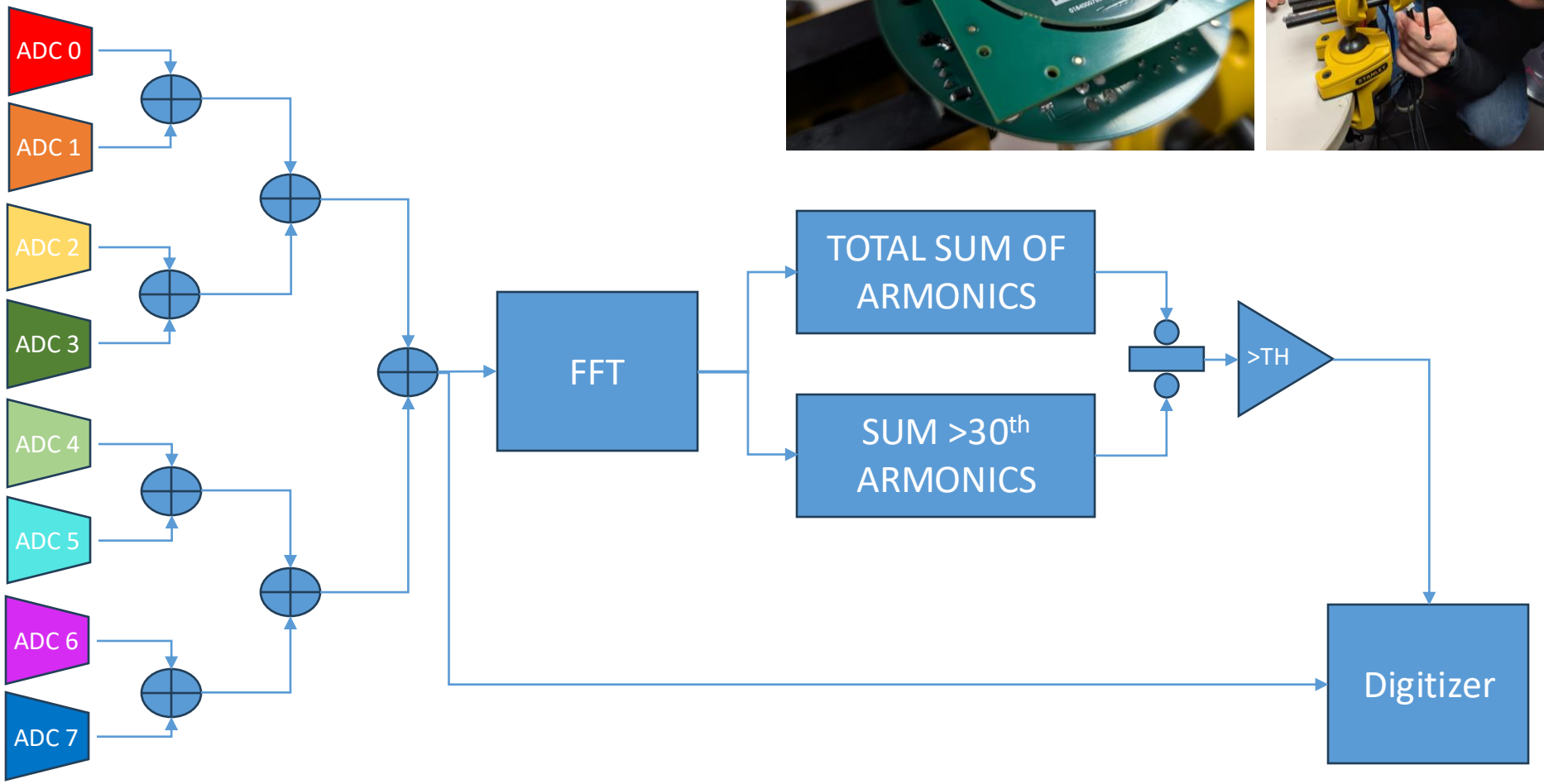
RFX (Padova) Neutron Monitor: Firmware





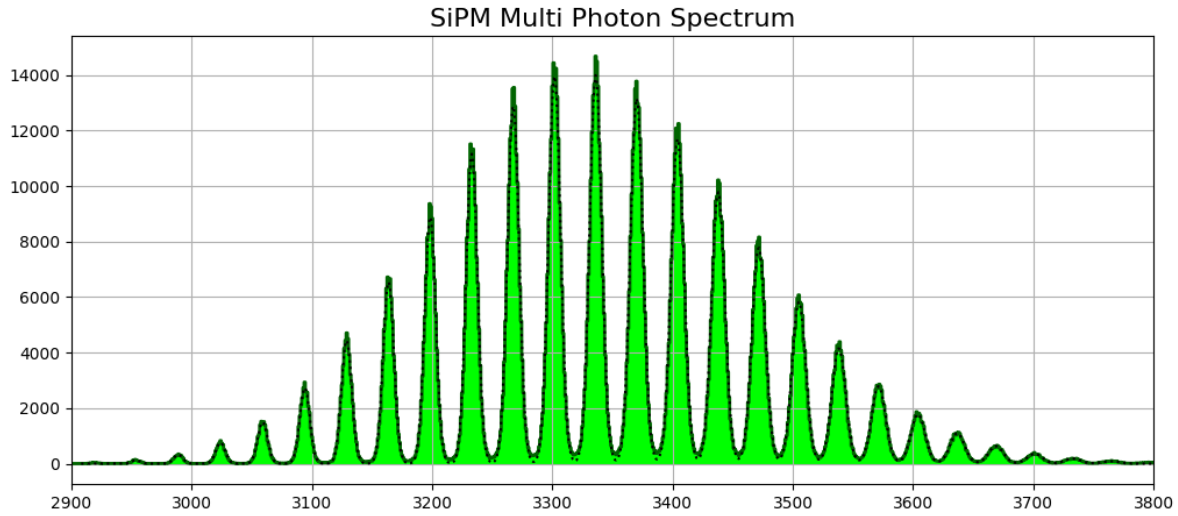




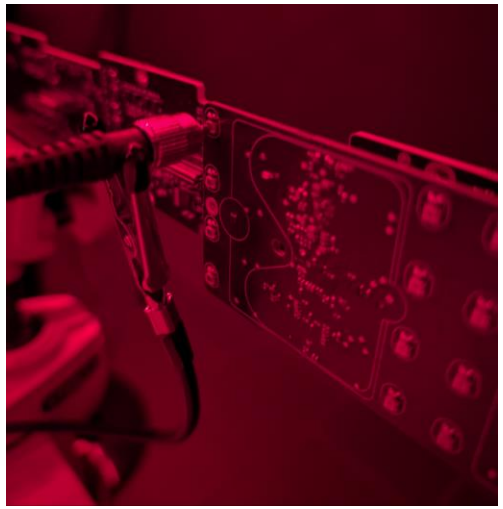


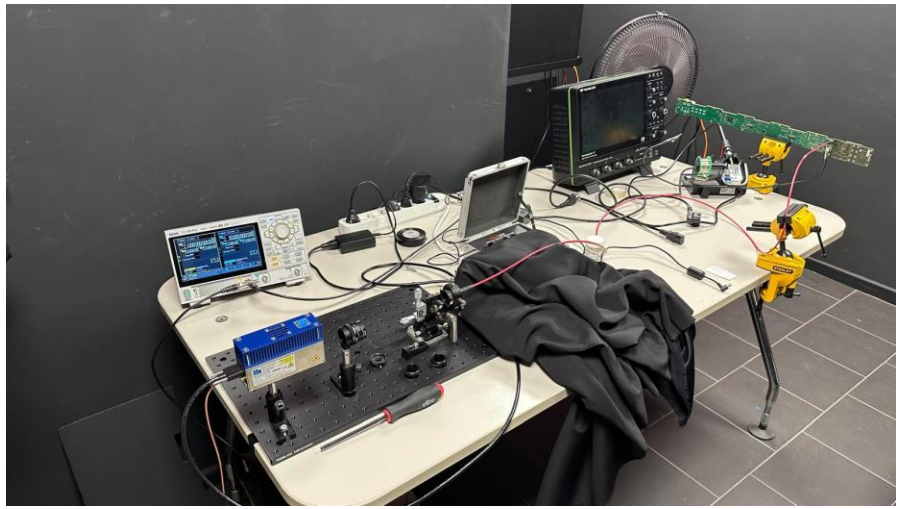
Quantum optics and quantum computing

- Measurement of quantum correlation in optical states
- Very Low noise < Shot Noise
- Quantum Entangled states
- Single photon counting
- Hamamatsu S13360 MPPC
- 1 Gsps 14 bit Nuclear Instruments Digitizer with real-time pulse processing.



Hamamatsu S13360-1325





FAST DIGITIZER WITH TM SUPPORT

Nuclear Instruments

DAQ121 – 1 Gsps 32 channels – 12 bit
DAQ122 – 1 Gsps 32 channels – 14 bit
(differential input)
(COMPATIBLE WITH ESS & ISIS READOUT)

CAEN V2730 – 500 Msps 32 channels – 14 bit
CAEN V2751 – 1 Gsps 16 channels – 14 bit
(single ended input)