CAEN Electronic Instrumentation

Tools for Discovery

Advanced Technologies for Detector Readout in Nuclear and Particle Physics

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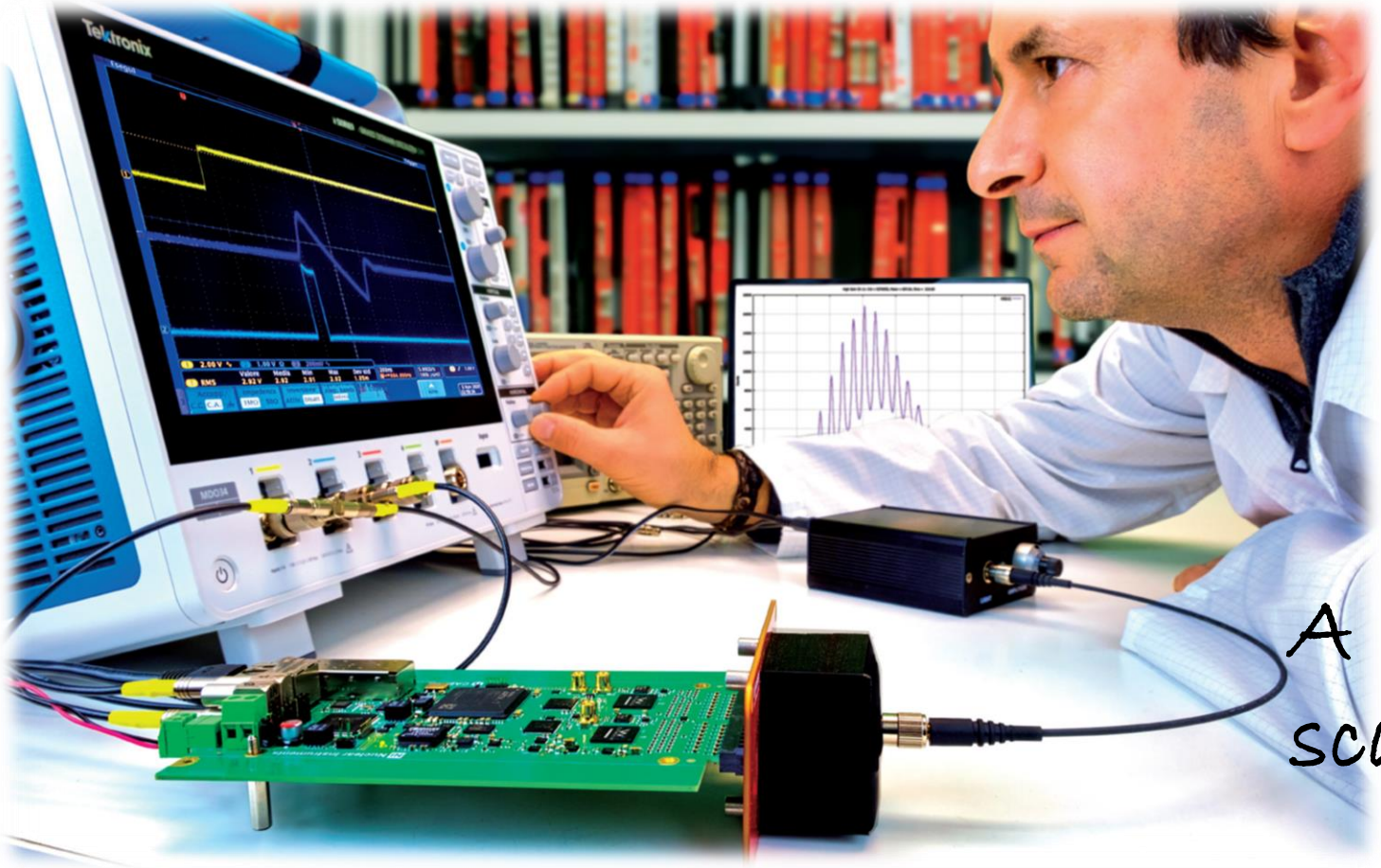
Workshop VIII on Streaming Readout – Apr 28-30th, 2021

Summary

- **FERS-5200 Readout Platform for large detector arrays**
  - General concept
  - A5202/DT5202 with CITIROC ASIC
  - Measurements with SiPMs
  - DT5215 Concentrator Board
- **Digitizers 2.0 : VX2740 and next steps**
  - General concept
  - New generation overview
  - Software

FERS-5200

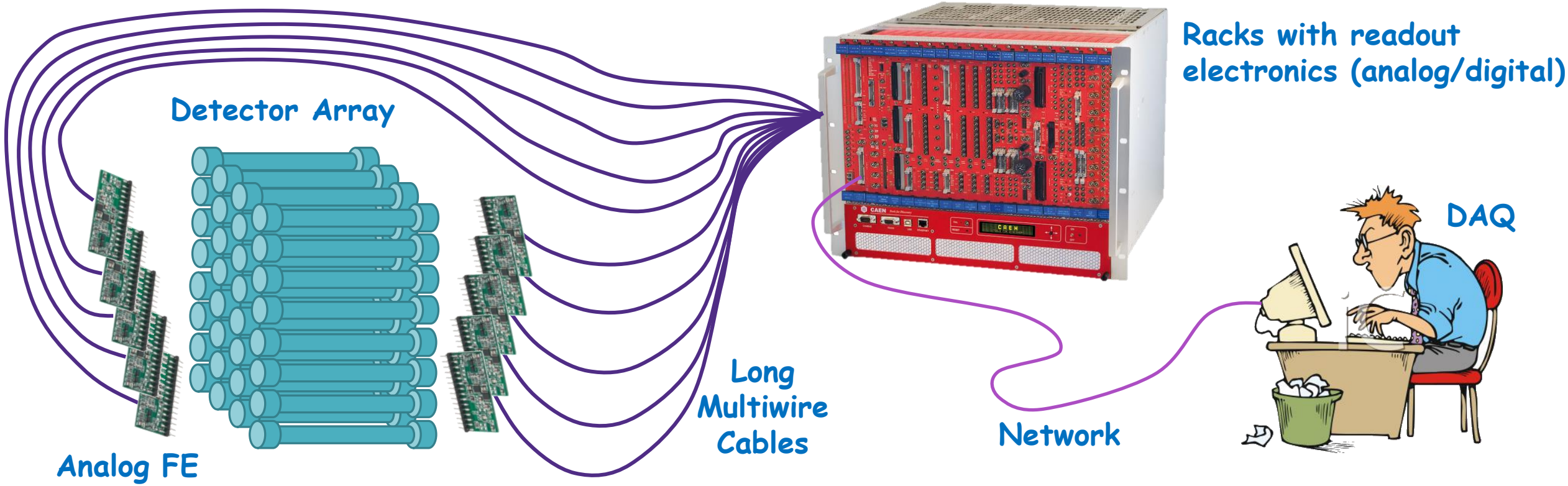


A modular, flexible and scalable Readout System

How to readout a gigantic detector?

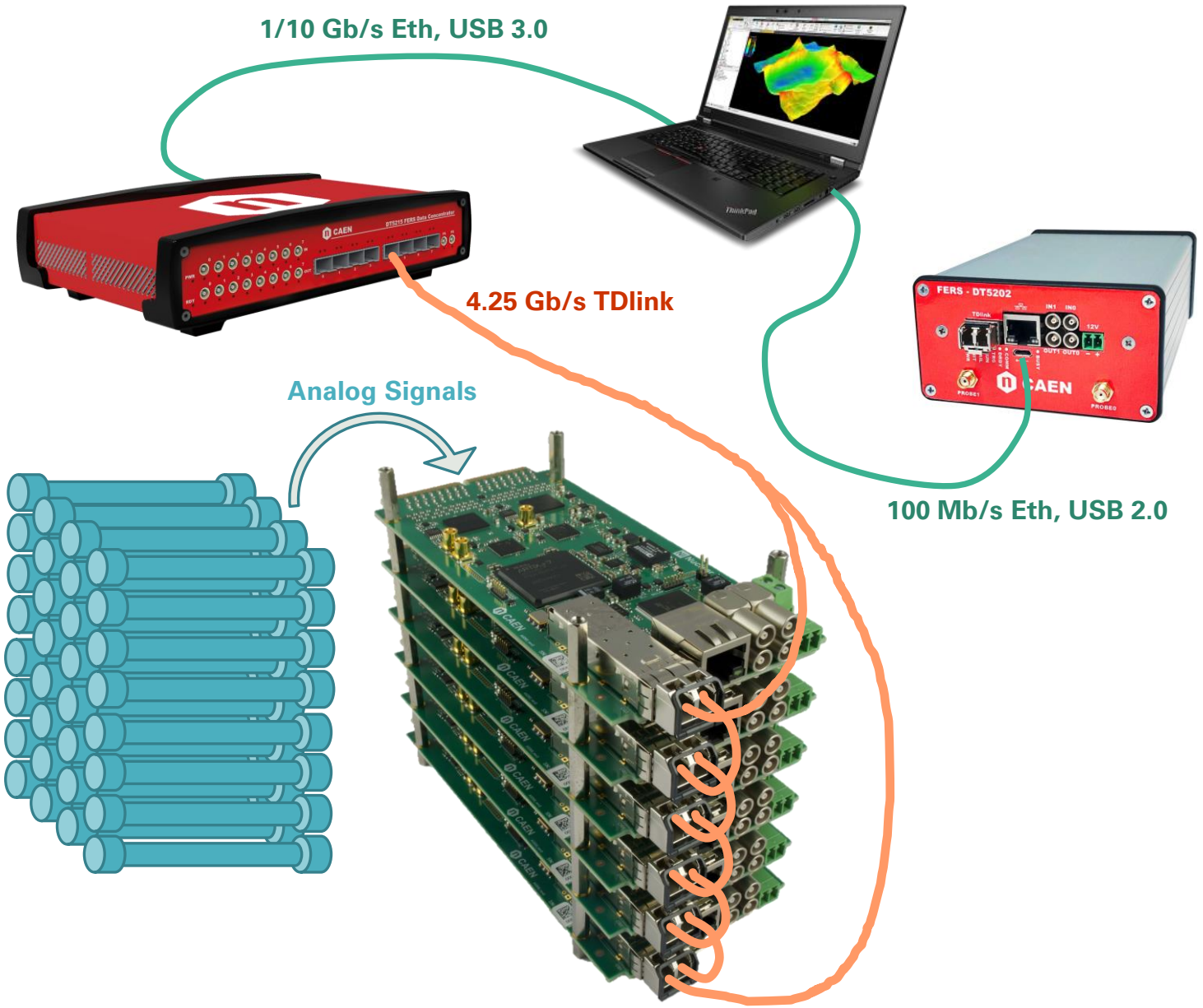
The old way: rack electronics

- Front End Preamplifiers close to the detectors
- Long cables bring analog signals to readout electronics (ADC, TDC, etc.) in racks
- **PROBLEMS**: Signal attenuation, noise pick-up, ground loops, cost of cables, geometry constraints



The new way: FERS-5200

- **Modular** readout of large arrays of detectors
- **Compact** FERS units: front-end + digital (standalone)
- **TDlink**: 4.25 GB/s Optical link providing Readout, Slow Control, Synchronization
- **Easy-scalability:**
  1 FERS unit = 64/128 ch
  1 Concentrator = 8k/16k channels
- Stand Alone version for **Evaluation** => scale up to 10k/100k channels with same electronics



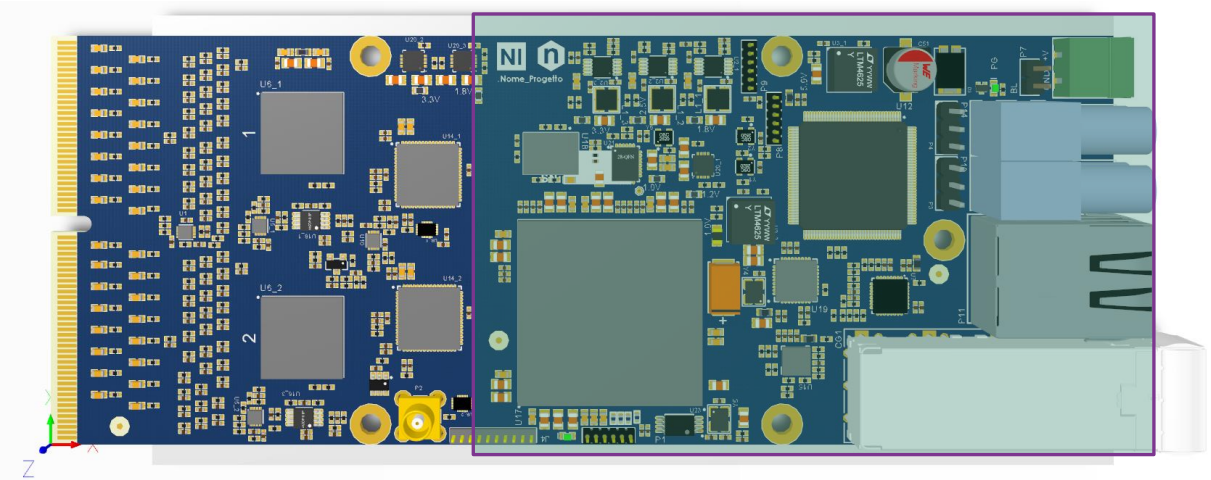
FERS units

A **flexible architecture** for a wide range of potential applications:

- SiPM – **CURRENTLY AVAILABLE**
- General purpose ps timing with **picoTDC** ASIC – **COMING SOON**
- PMTs and MA-PMTs
- Gas Detector, wire chambers
- GEM
- Micromegas
- Silicon Strip Detectors
- Segmented HPGe detectors

Same Infrastructure, different Front Ends

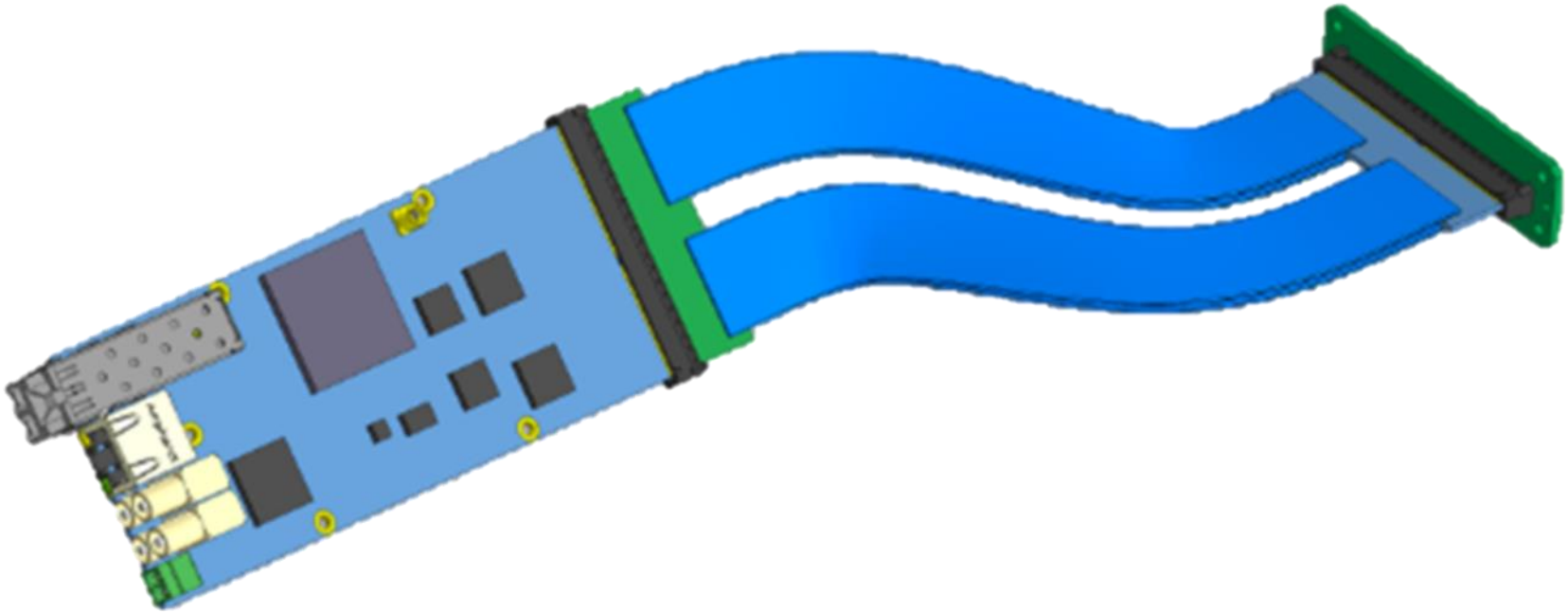
Quick integration of different ASICs



DETECTOR SPECIFIC COMMON INFRASTRUCTURE

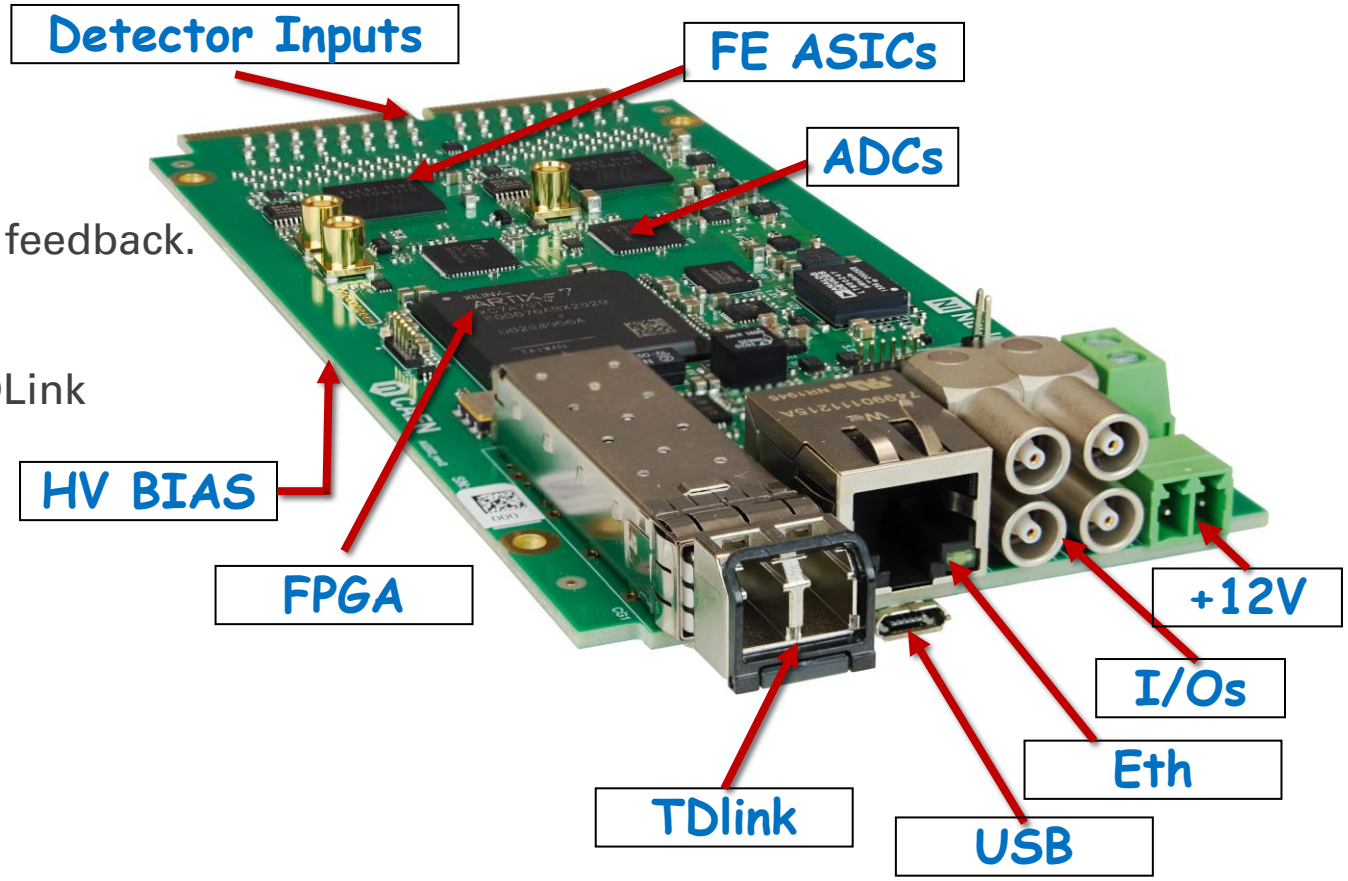
Connectors and Cables

- **Micro coaxial cable assembly:** no significant signal degradation up to 2-3 m
- **Same connector mating:** no need of adapters
- Easy fitting of **geometrical constraints**
- Detached electronics simplifies the connection to **cold detectors**
- **Edge connector**: optimal fit for feed-through **flanges**



NEW A5202: 64 channel SiPM readout

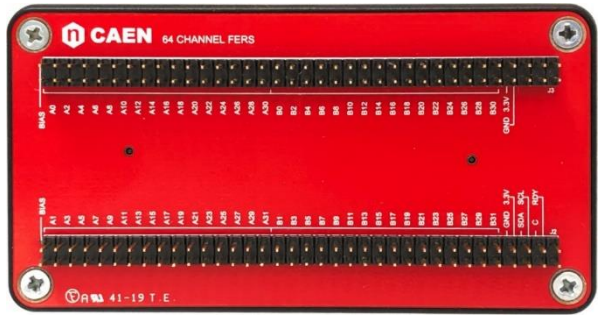
- Based on two ASICs **Citiroc 1A** (by Weeroc)
- A5202 is nearly the **size of your smartphone**!
- Embedded **HV bias** (20-85V) with temperature feedback.
- Different readout protocols: USB, Ethernet, TDLink



NEW DT5202: 64 channel SiPM readout

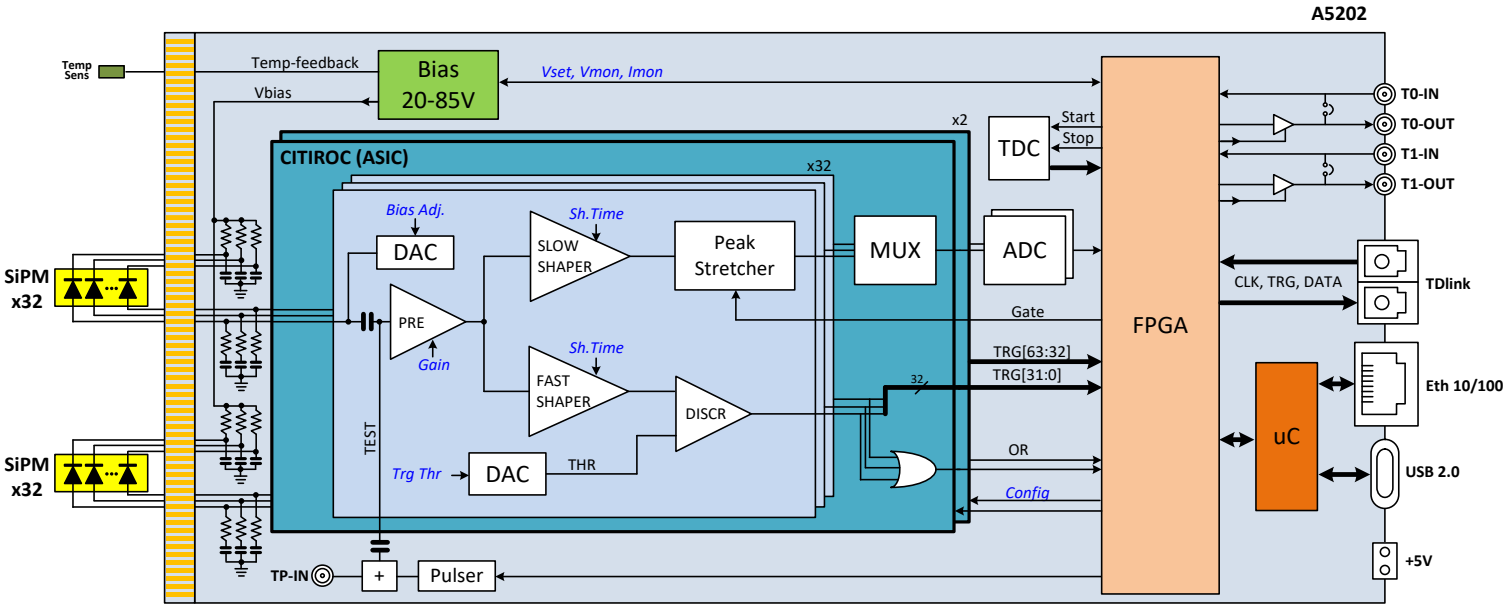
- Goes standalone on your desk via Ethernet/USB connection
- Ideal for prototyping phase

FRONT PANEL :
EXCHANGABLE AND CUSTOMIZABLE



x5202: 64 channel SiPM readout

- Programmable gain and shaping time for High Res PHA (Multiplexed A/D, max Trg Rate = 100 Kcps)
- Individual discriminator thresholds: down to 1/3 p.e.
- Discriminator outputs for high counting rate (20 Mcps), Time stamping (0.5 ns) and ToT (low res PHA)
- Acquisition modes: photon counting, spectroscopy mode (PHA), timing mode (channel ID + Tstamp + ToT



x5202: acquisition modes

- **Spectroscopy Mode (PHA)**:
  - A/D conversion of the pulse height (preamp + shaper + peak hold + mux + 14 bit ADC)
  - Common trigger (int. or ext.)
  - Zero suppression with programmable thresholds
  - Max trigger rate = 100 kHz (dead time = ~10 μs per trigger)
- **Counting Mode** (e.g. photon counting in SiPMs):
  - Counters fed by fast discriminator signals
  - Simultaneously latched at programmable time frames and saved to memory (MCS mode)
  - Counting rate up to ~20 Mcps/ch

x5202: acquisition modes

- **Timing Mode** (List of Tstamps and/or Time over Threshold):
  - Independent hit recording: channel ID + timing (0.5 ns resolution)
  - Common start or common stop (int/ext T-ref signal)
  - Gating mode
  - Optionally, **ToT** (0.5 ns resolution) provided for low resolution PHA: Charge Resolution = 1.5%
  - Max total hit rate = ~50 Mcps/board

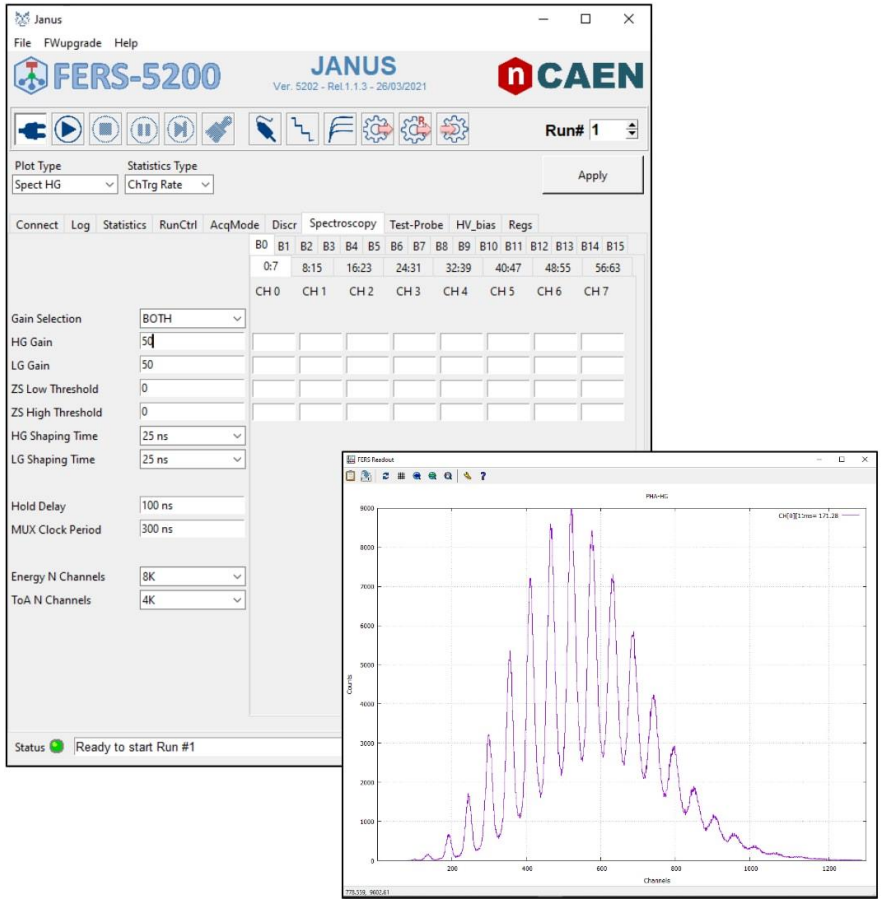
- **Spectroscopy and Timing mode** (List of PHA + Tstamps and/or ToT)

COMING SOON

SiPM readout with x5202 - Janus Software

CAEN **Janus software** is free and available for A5202/DT5202 multi-board control and data acquisition:

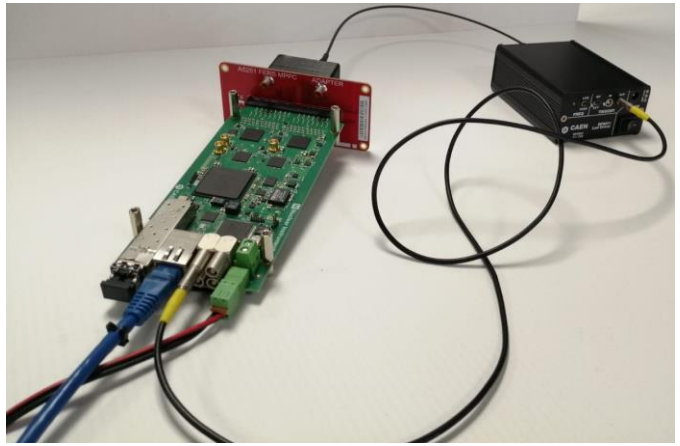
- GUI available for a quick and easy start
- **Open-Source** for user customization
- SiPM HV fully controllable by the software
- Management of the acquisition parameters of all connected boards
- Special runs (staircase, parameter sweeps) for SiPM characterization
- Multi parametric Jobs and Runs with time or counts preset
- Data saving of lists in **.bin**, **.txt** format
- Statistics and Spectra visualization

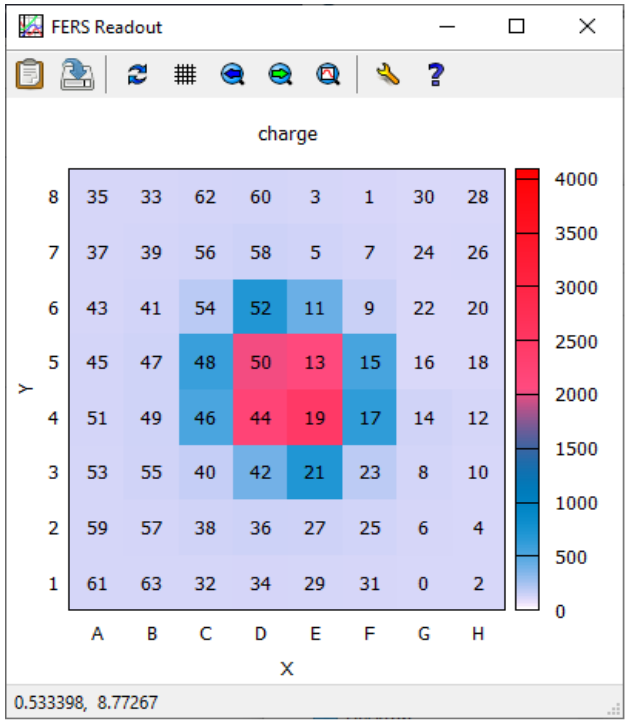


SiPM readout with A5202 – Energy Spectra

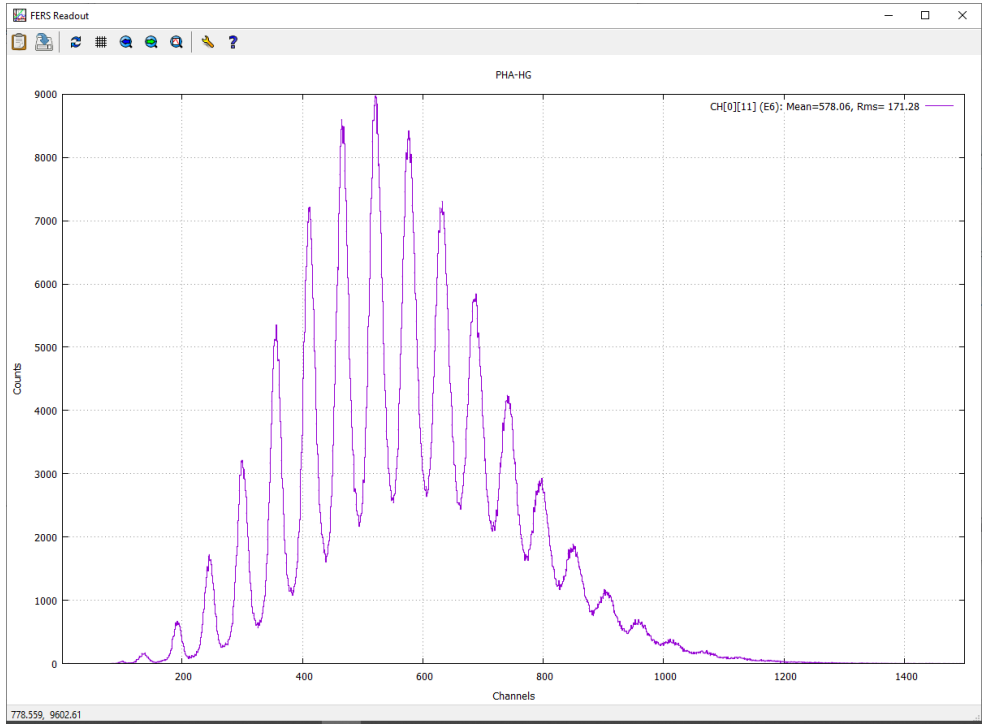
Example of energy spectra acquired with:

- One A5202 board
- SiPM Matrix Hamamatsu S13361-3050AE-08
- SP5601 LED Driver





2D energy reconstruction for imaging applications

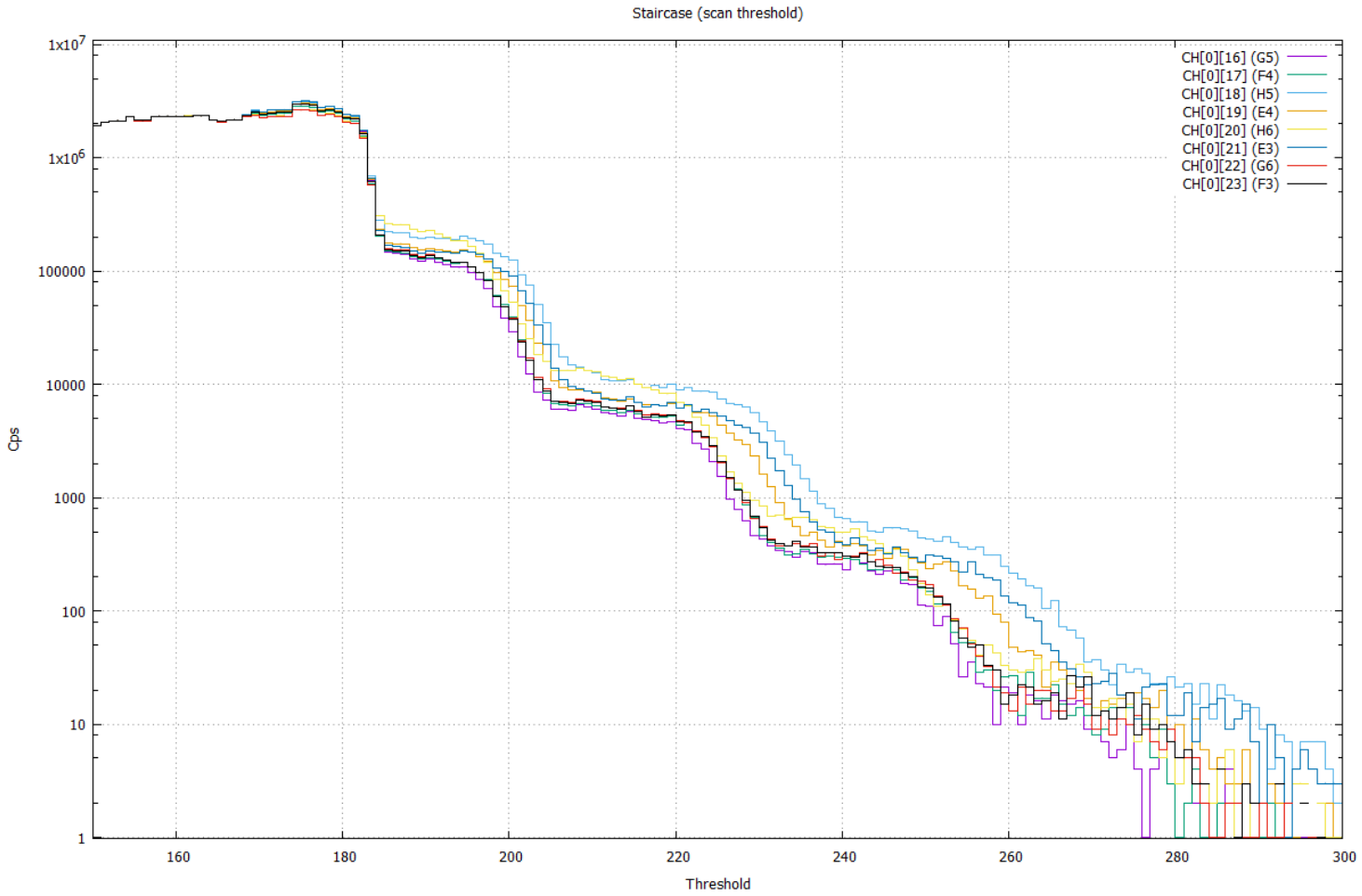


SiPM pulse height spectrum with the clearly visible photopeaks

SiPM readout with A5202 – Staircase

Example for the trend of the number of events triggered as a function of the threshold:

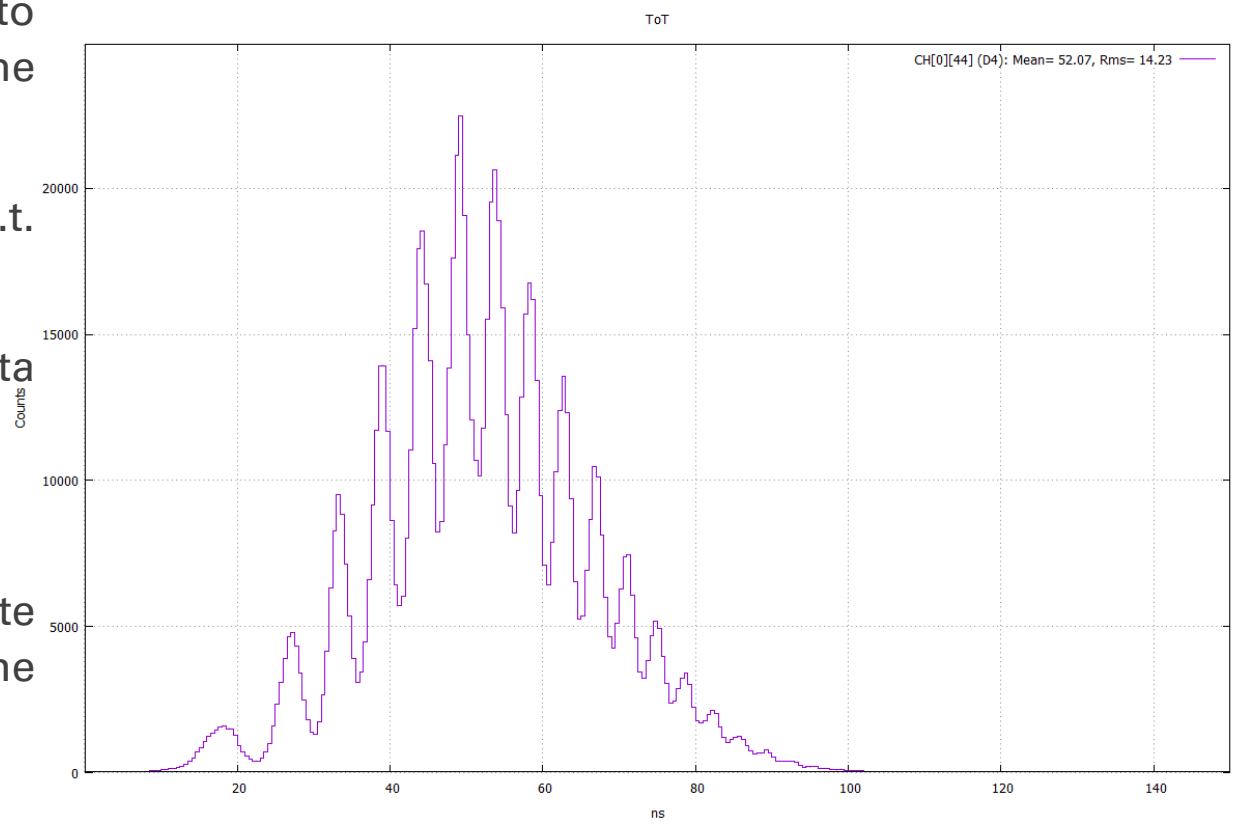
- No LED Driver used → Dark Count Rate only
- Each stair correspond to a different number of photoelectrons triggered



SiPM readout with A5202 – ToT

The Time over Threshold (ToT) of the pulse allows to reconstruct the energy information as well with some advantages:

- Greater dynamics to higher amplitude signals w.r.t. PHA
- Independent channel acquisition (trigger-less data streaming)
- Lower dead time ⟶ Higher acquisition Rate
- Photopeaks clearly visible and well resolved despite the lower resolution (~ 1/3) w.r.t. PHA using the same setup

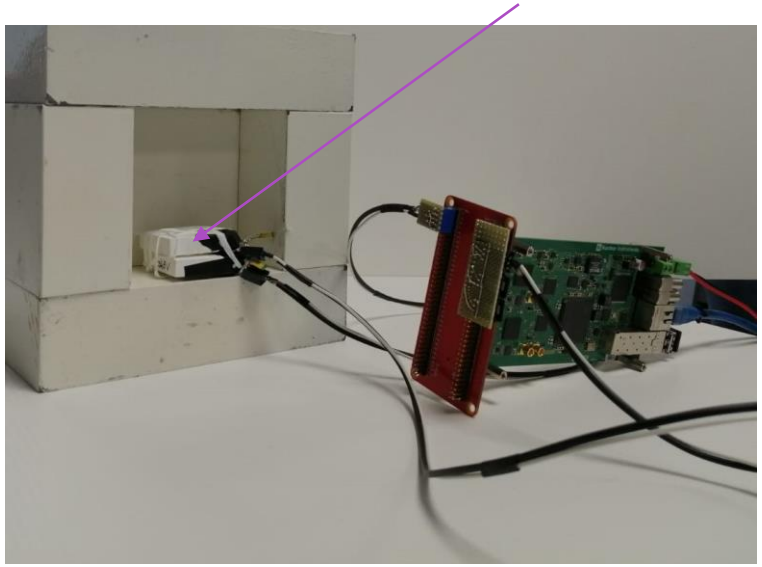


SiPM ToT spectrum with the clearly visible photopeaks

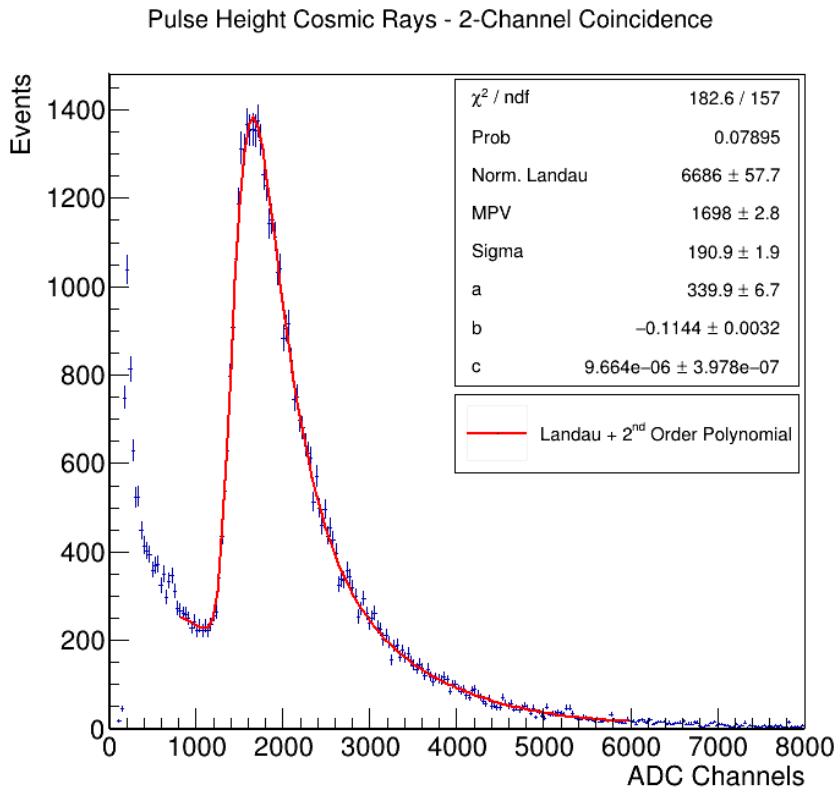
Measurement of Cosmic Ray Energy Loss

Preliminary measurements with one A5202 board. Setup:

- Two 4.8 cm x 4.8 cm x 1 cm plastic scintillators, each one coupled to a Hamamatsu S13360-6050CS SiPM

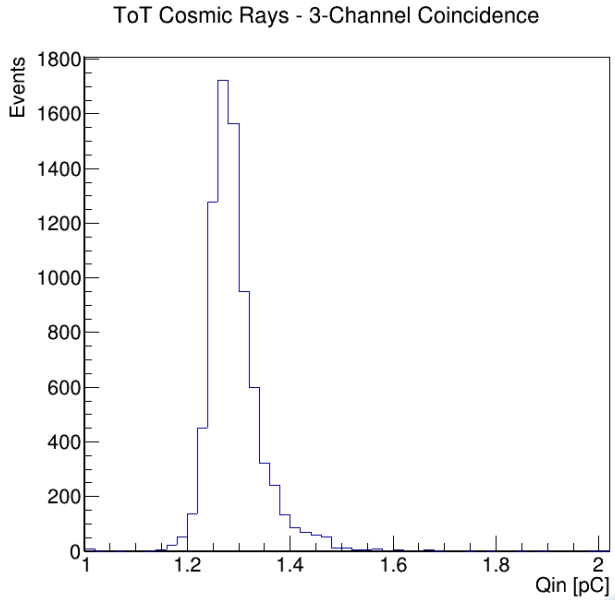


- Two channel coincidence (implemented at firmware level) used as trigger for PHA acquisition

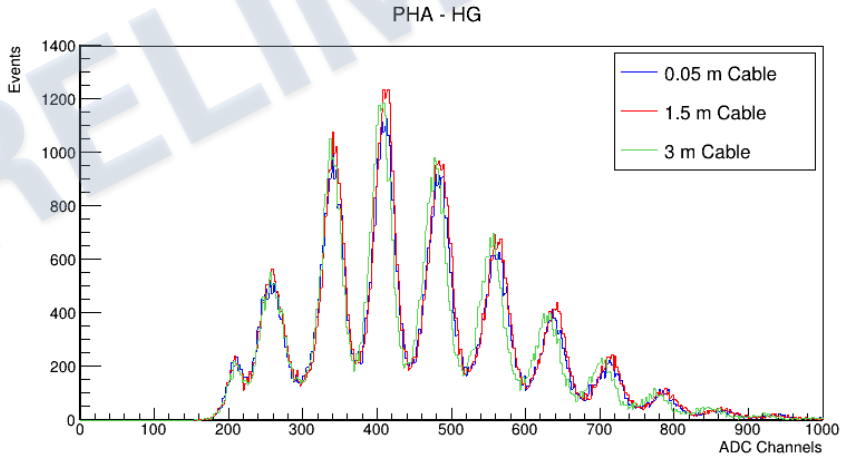


Landau from relativistic muons loss of energy clearly visible

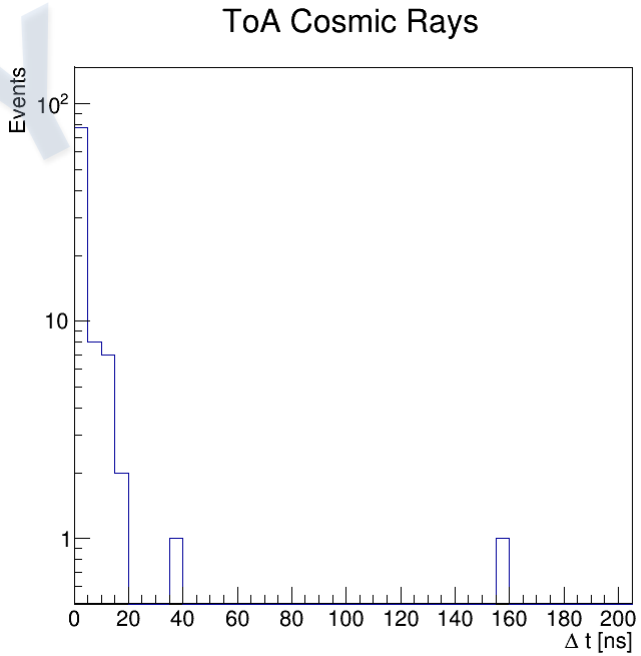
Work in progress



Landau distribution of
Cosmic Rays in ToT mode

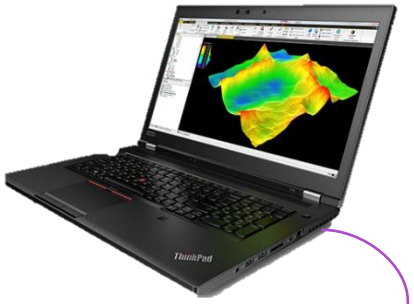


Energy loss along a cable with remote SiPM



Muon lifetime with plastic scintillators

COMING SOON DT5215 – Concentrator Board



Readout Interface
- 10 Gbps Ethernet
- 1 Gbps Ethernet
- USB-3.0

Zynq Ultrascale + SoC

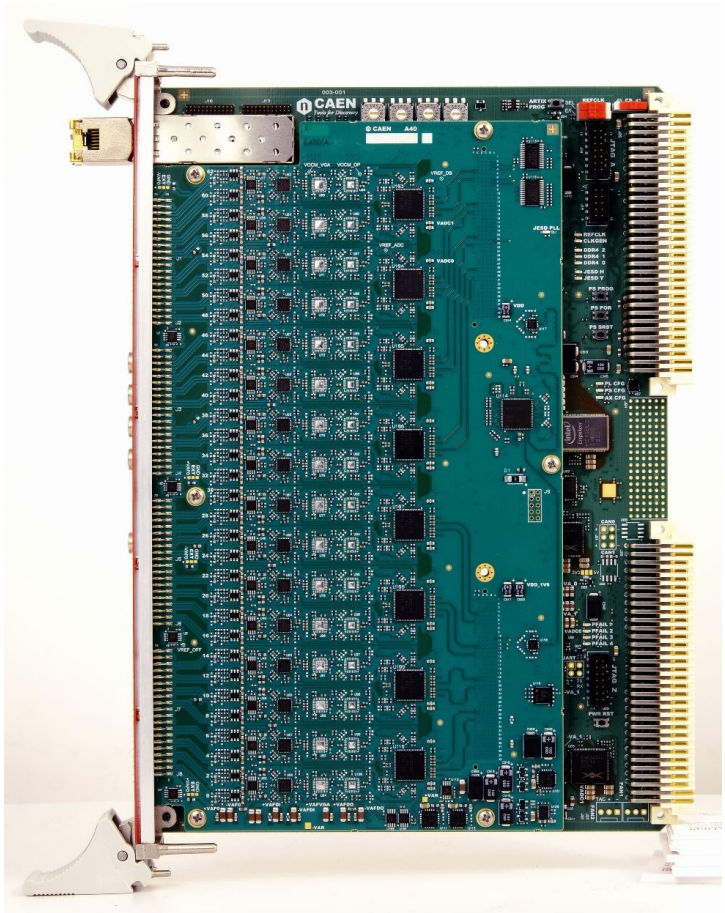
4 core @ 1.2 GHz processor
- Readout process management
- Event sorting
- Event Building

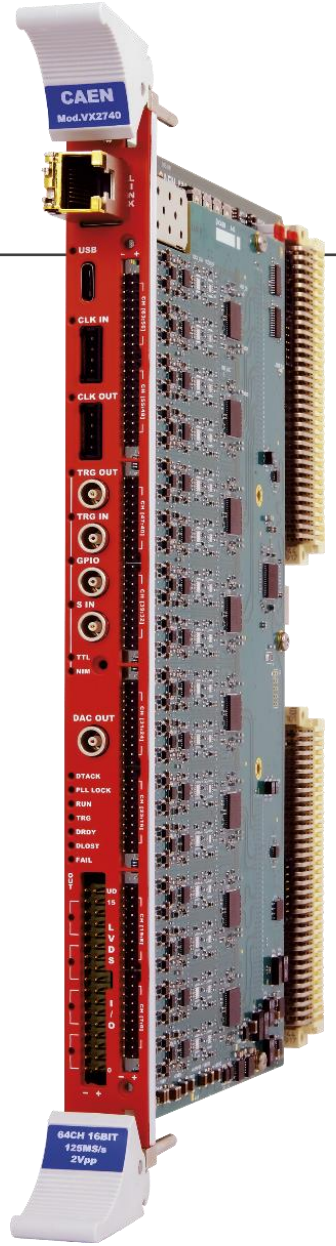
GPIO (x16)

8 x Tdlink @ 4.25 Gbps

Up to 16 FERS units/link

Digitizers 2.0





The new generation is coming ...

New hardware

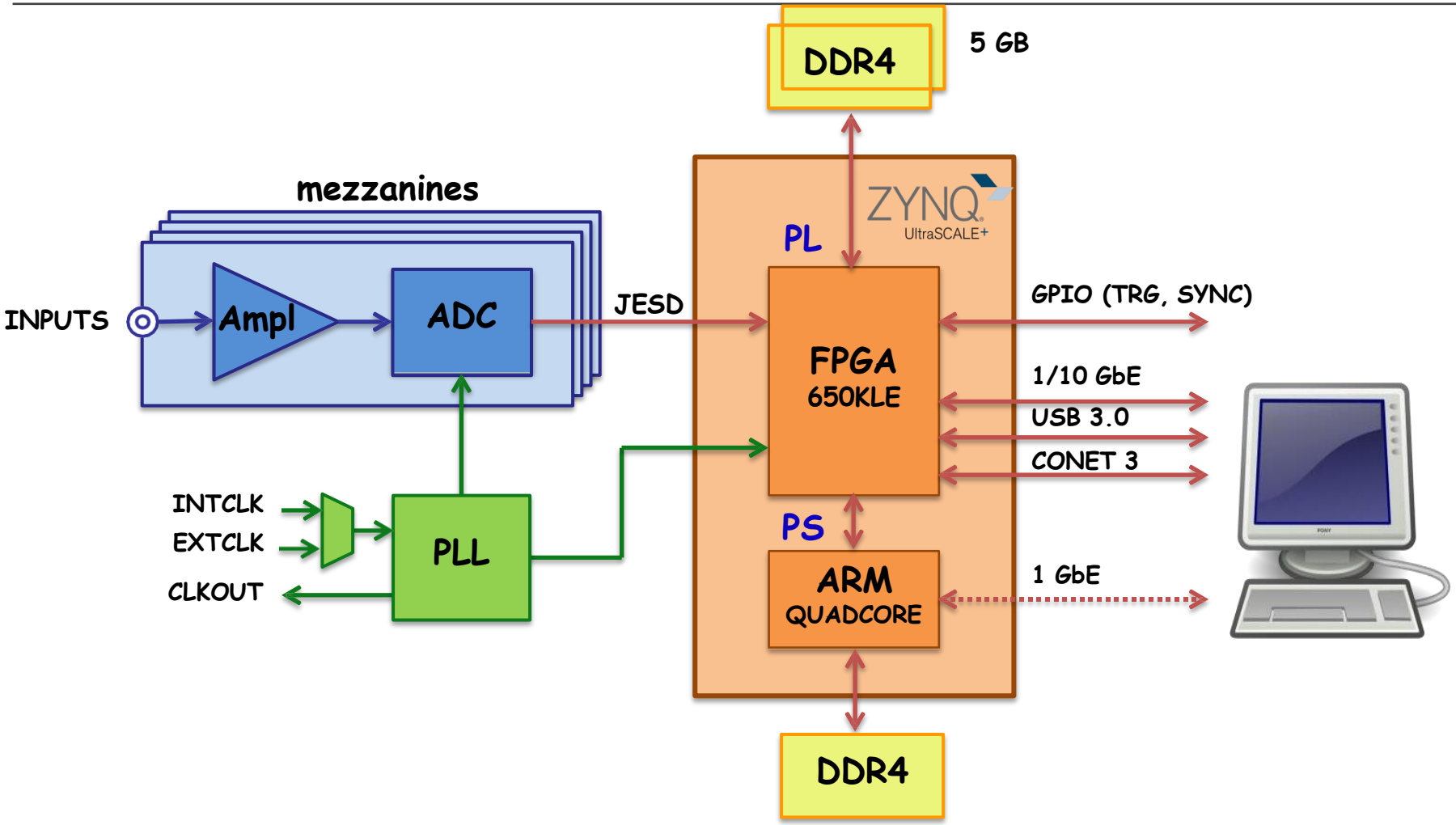
CAEN **always drives to develop** new hardware and to improve its products with new firmware and software tools.

During the last years, a major project was pursued that is going to influence the years ahead: the **new digitizers**.

The new digitizers have better performance across the board:

- more channels for denser systems,
- faster communication links,
- from MB to GB on-board memory,
- improved FPGA with embedded ARM and OpenFPGA.

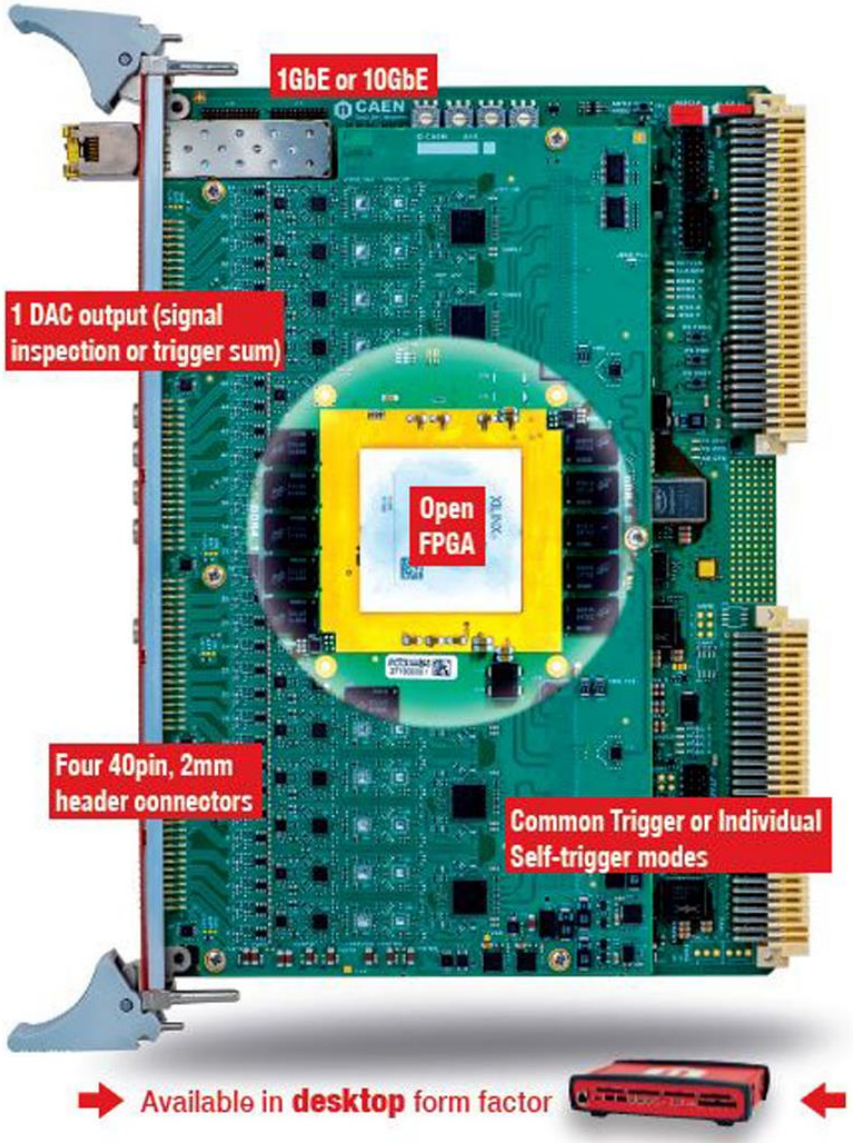
The architecture



VX2740: the first of a kind

64 channel, 125 MS/s, 16 - bit waveform digitizer

- High channel density spectroscopy
- Good fit for Neutrino and Dark Matter experiment
- **Open FPGA**: SCI-Compiler tool for beginners (**COMING SOON**) or advanced firmware template
- Four 40-pin, 2 mm header connectors with DIFF or SE inputs
- **1 GbE**, **10 GbE**, **USB 3.0** and CONET 2.0 (optional) connectivity
- Common Trigger (waveforms) or Individual Self-trigger modes
- **DPP options**: PHA, QDC, PSD, CFD
- Advanced Waveform Readout modes: ZLE, DAW
- DT2740, 64 channels in Desktop form factor (**COMING SOON**)



Model	# channels	MS/s	# bit	Applications
x2740	64	125	16	64 MCAs for high channel density spectroscopy Good fit for Neutrino and Dark Matter exp.
x2745 Advanced version of x2740	64	125	16	Variable gain input stage Designed for Si detectors readout
x2725/x2730	32	250/500	14	Medium-fast detectors Sub-ns timing combined with high energy resolution Optimal trade off between cost and performances
x2751	16	1000	14	Ultra-fast detectors (diamond, MPCs, SiPMs) with ps timing applications Potential upgrade to higher sampling rate
x2724	32	125	16	Spectroscopy & MCA Advanced Front-End (gain, shaping, AC/DC coupling …) Semiconductor detector (HPGe, Clover, SDD ,…) Typically connected to charge Sensitive Preamplifier

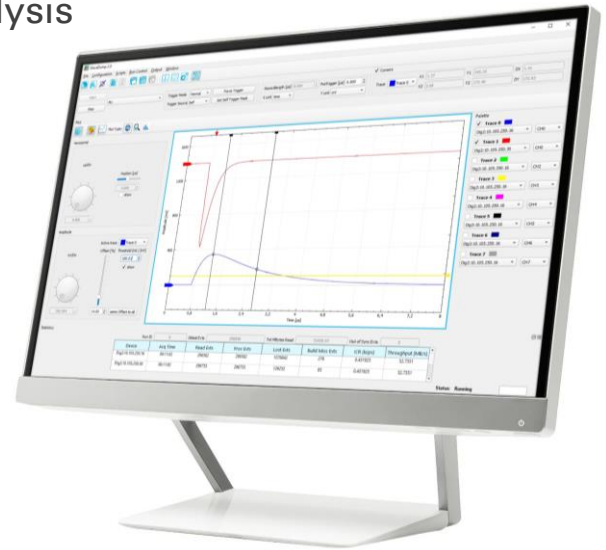
Currently available

COMING SOON

Birdseye view – what's coming

WaveDump2

- **Multi-board management**
- Simultaneous plot of waveform from up to 8 input channels
- Flexible and easy configuration channel and trigger settings
- Import/Export of configuration presets
- FFT analysis



CoMPASS

- Support to all the **CAEN Digitizer** running **DPP FW**
- **Multi-board management**
- Simultaneous plot of waveform, energy, time, PSD, and TOF spectra
- ROI management and energy calibration
- Selectable filters on energy, PSD and Time Correlation
- Several options for **data saving**, including **ROOT**, **.csv**, **.bin**, **.n42.**

Thank you for your attention

Any question/curiosity?

Backup slides

A5202: readout modes

- **Common Trigger Mode**
  - **FERS units**: generate a trigger request (typically OR of channel discriminators)
  - **Data Concentrators**: receive and combine requests from all units and generate the **Global Trigger**
  - **Event Building** and data reduction takes place in the ARM processor of the Data Concentrator
- **Trigger-less Mode (independent channel acquisition)**
  - **FERS units**: each channel pushes data asynchronously, typically at different rates
  - No trigger and data correlation in HW. Events reconstruction in DAQ.
- ARM processor running **Linux** and local DDR memory available in Data Concentrator
- High throughput data transfer to host computers via 10 GbE or USB 3.0
- Users can run custom routines for data handling in the embedded ARM

In-built sparse event readout