Compact and Scalable Electronics for Sub-10 ps Timing in Particle Physics and Medical Imaging

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on behalf of

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DeSyT-2025 – Catania 24-26 Feb 2025

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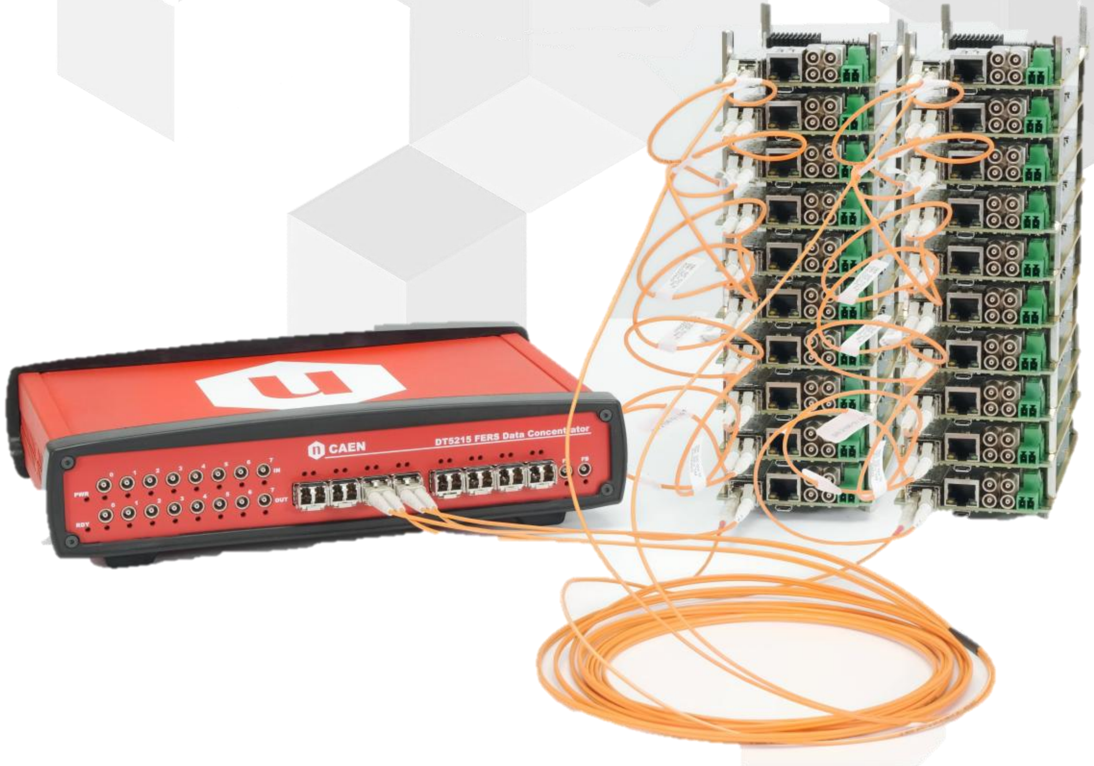
Outline

- FERS-5200 family: project core and architecture
- X5203: picoTDC timing unit
- Timing performances
- Feasibility study for SAND
- X5203 PET application: the Provision scanner
- Conclusions



Front End Readout System 5200: The Core Idea

Compact and Scalable Multi-channel Readout Electronics

High-granularity Detectors with Thousands of Channels

Cost-effective Readout Systems

CERN
weeroc
NALU SCIENTIFIC

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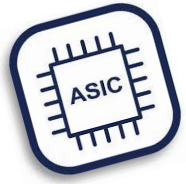
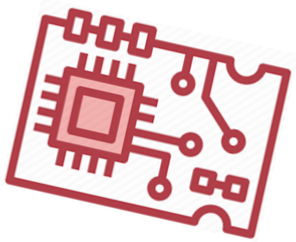
NI Nuclear Instruments

Off-the-shelf **front-end ASIC** for scientific instrumentation

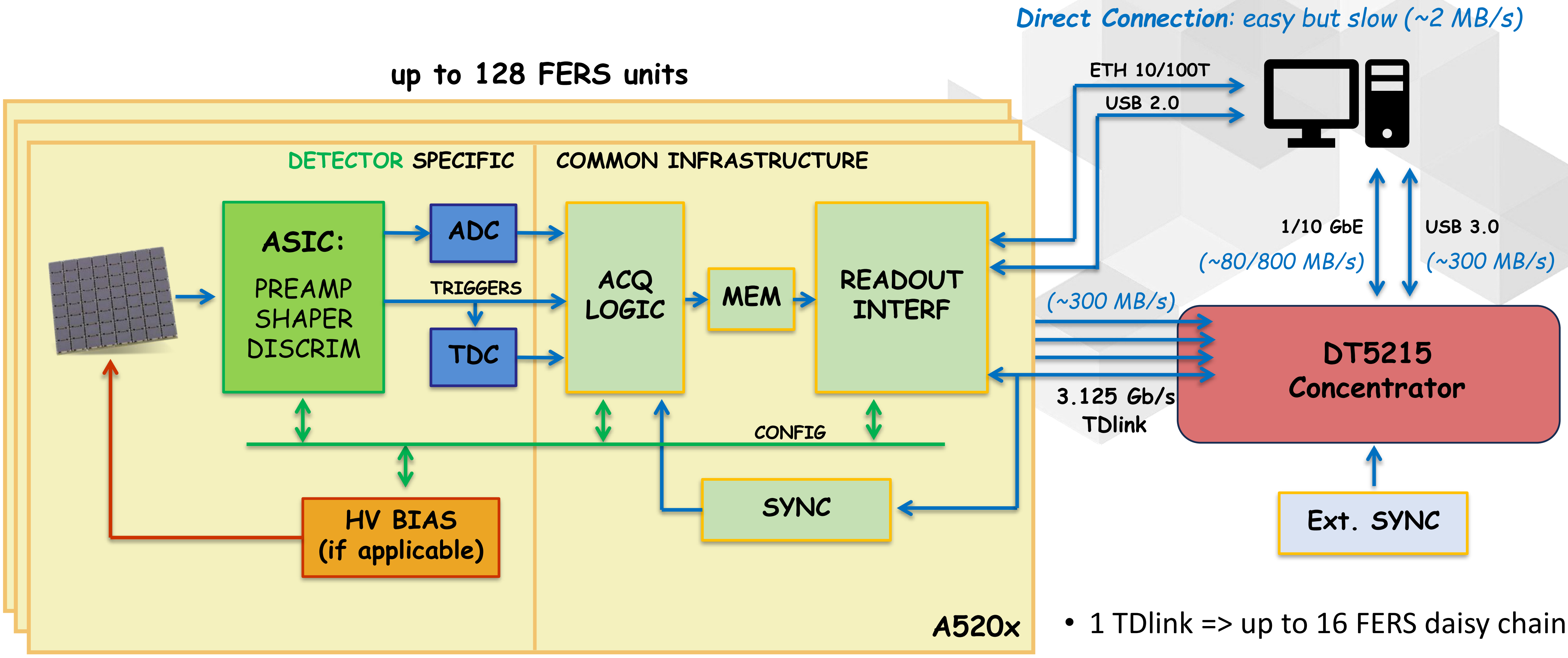
Design of **Readout Electronics and Power Supply** for NP and HEP





FERS-5200: block diagram

FERS-5200



- 1 TDlink => up to 16 FERS daisy chain
- 1 DT5215 => 128 FERS = 8k/16k ch
- Sync to ext. GPS

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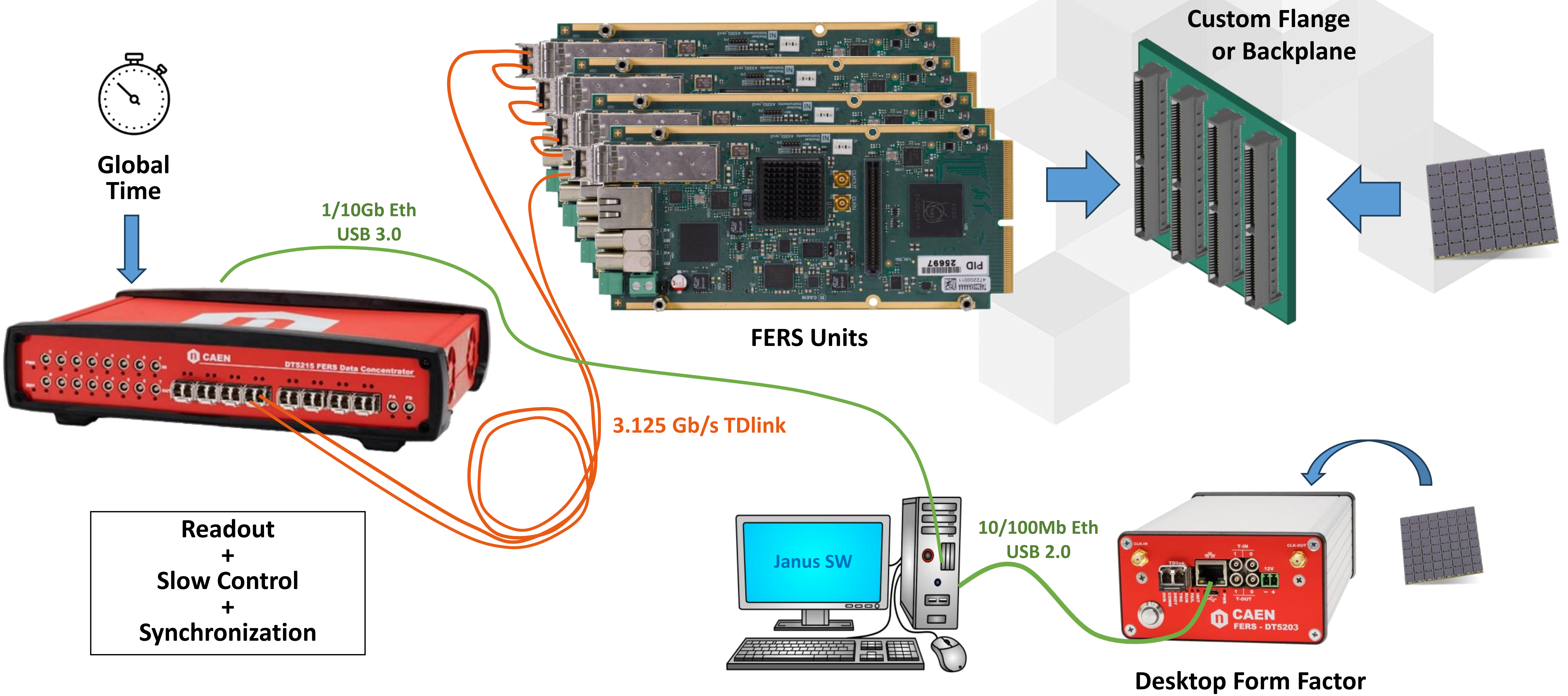
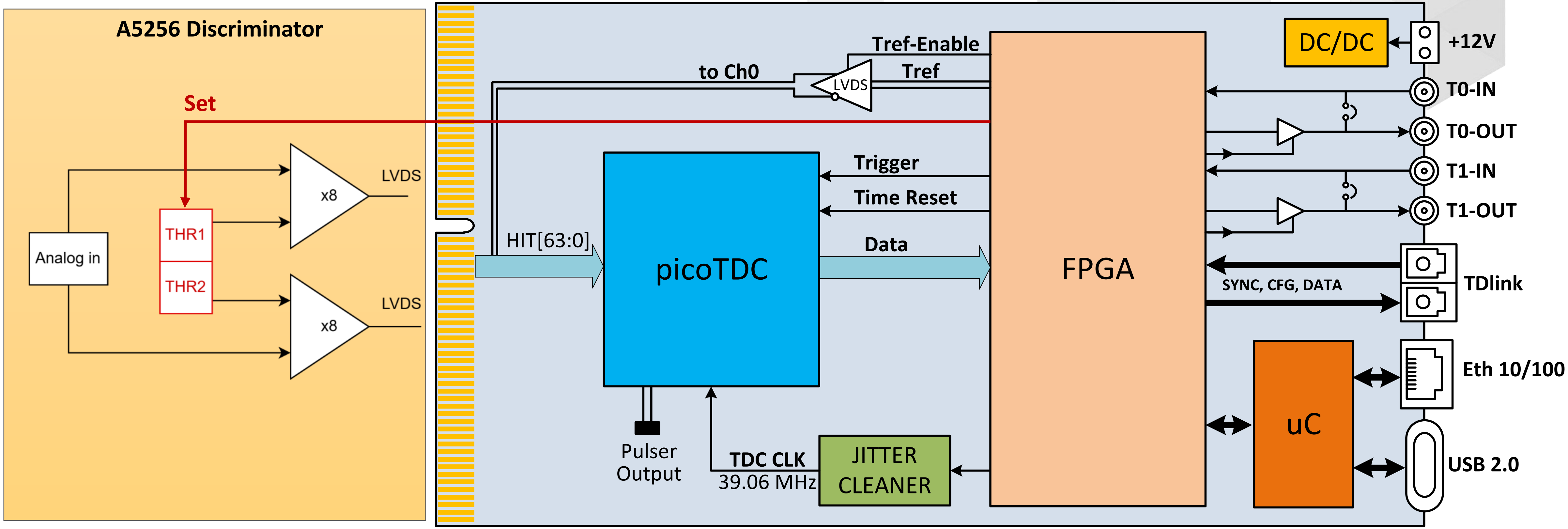
FERS-5200 architecture



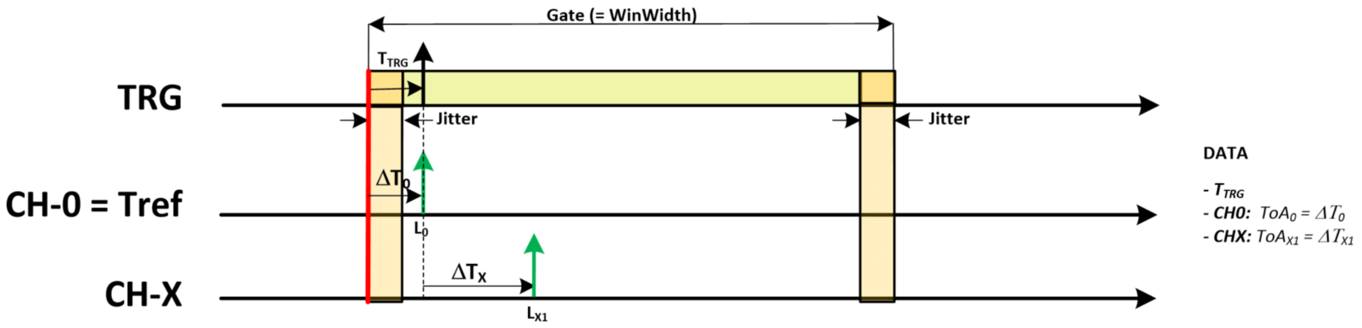
x5203: 64/128 channel 3.125 ps TDC

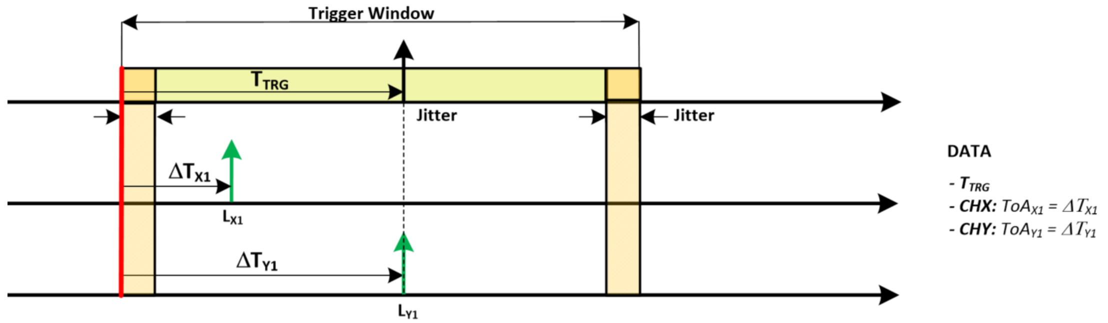
- **TDC**: 64/128 channels (1 picoTDC = 64 ch), LSB = 3.125 ps, dynamic range = 56 bit (extended by FPGA)
- **Inputs:** digital, LVDS → **A5256 Front-End** (= 16-ch discriminators)
- **Output Data:** Time of Arrival (ToA), Time over Threshold (ToT)
- **Data throughput:** up to ~**64 Mcps/board**



X5203 performances

Acquisition modes: Common Start/Stop (Tref=Ch0), Trigger Matching, Streaming





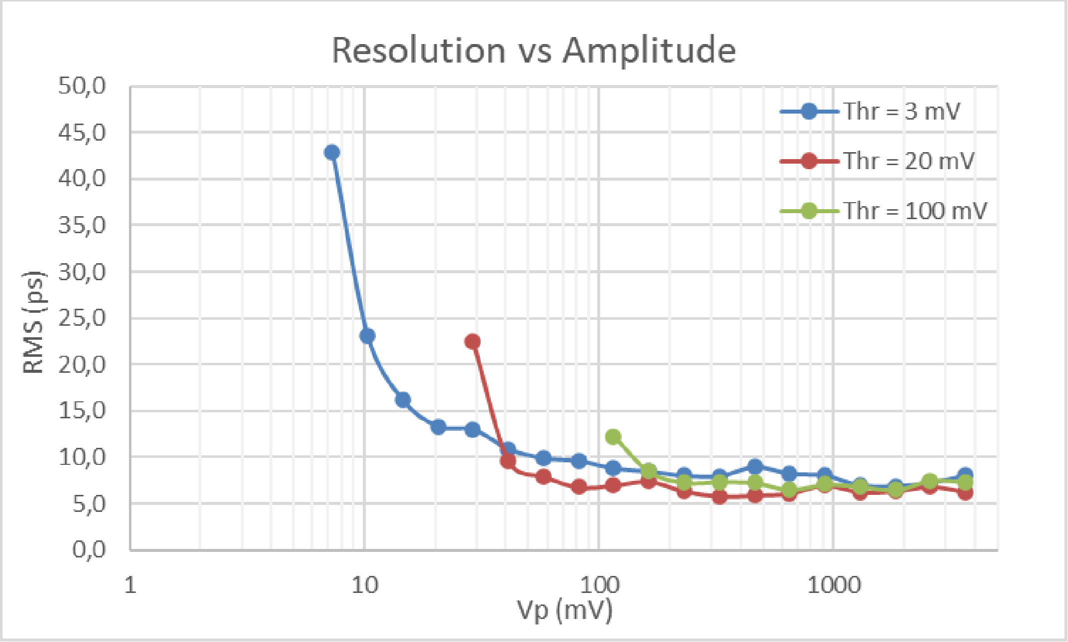
DeltaT Resolution (*) :

- Same board: **typ 5 ps RMS**
- Board to board: **~20 ps RMS** → **Precision of the TDLink sync**

  synchronized by DT5215 Concentrator Board via TDlink
- Board to board: **~8 ps RMS**

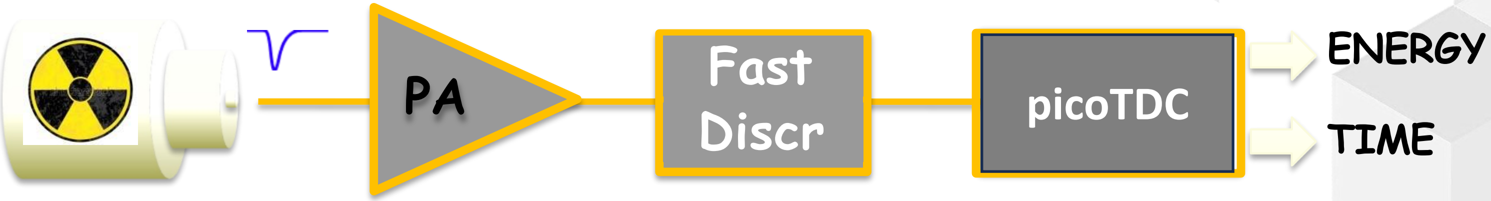
  synchronized by DT5215 Concentrator Board via TDlink
  with auxiliary daisy chain/fan out clock cables

(*) Tested with CAEN A5256 discriminator. Pulse: 0.5 Vpp, 0.8 ns rise time



Energy reconstruction

x5203 Pros	x5203 Cons
• high timing resolution (~ 5 ps), high channel density, almost no dead time • provides ToA and ToT in one word	• ToA affected by walk effect • No energy information (PHA) acquired -> need for a separate ADC readout chain



=> energy by ToT with 2 or more thresholds not to worsen energy resol. Time walk correction needed

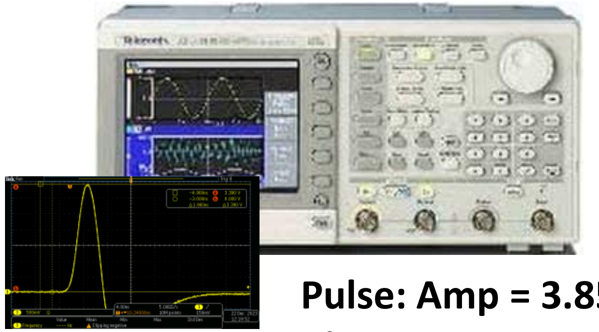
-> ToT-Based Analysis: Walk correction and PHA

- **ToT** can be used **to correct for time walk** => no need of Constant Fraction Discriminator in hardware
- **ToT** can be used **to reconstruct pulse amplitude**: ToT – PHA curve is not linear => need calibration (pulse shape dependent)
- **FPGA ToT filter**: rejects pulses if **ToT < LowCut** or **ToT > HighCut** (remove noise, DCR, saturation…)

ToT Analysis Setup

FERS-5200

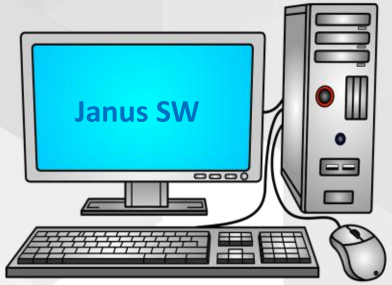
AFG 3252



Pulse: Amp = 3.85 V
Rise = ~2.5 ns

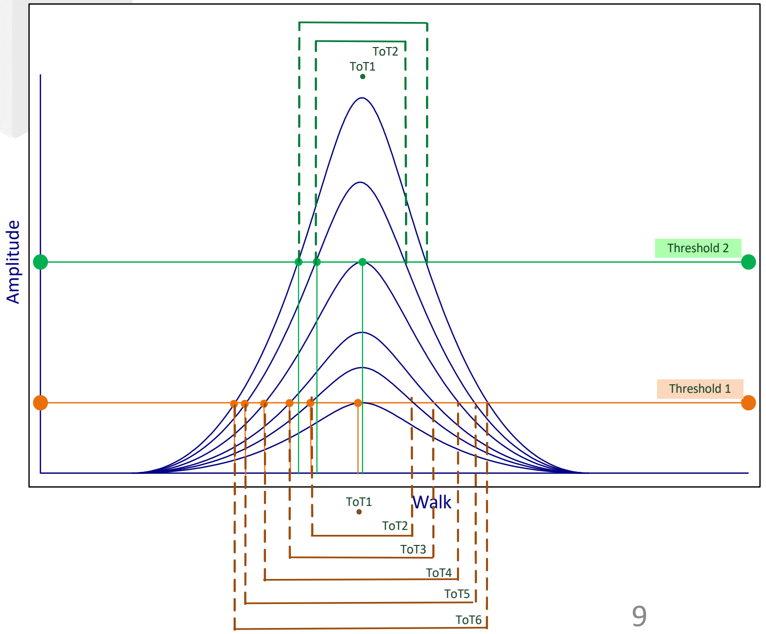
Step Attenuator

DT5203+A5256



Common Start Acquisition: start on Ch0 with fixed amplitude, stop on Ch1 and Ch2 (dual threshold) with variable amplitude (max = 3.85 V). Delay = 13 ns

1. **Sweep**: acquire **ToT** and **ΔT (ToA)** at different amplitudes (from 0 to 54 dB, 3 dB step)
2. Fit points and build **ToT-Walk (ToA)** and **ToT-Ampl** curves
3. Use curves to **correct Walk** from ToT (replace CFD)
4. Use curves to **get Amplitude** from ToT (make ADC from TDC)



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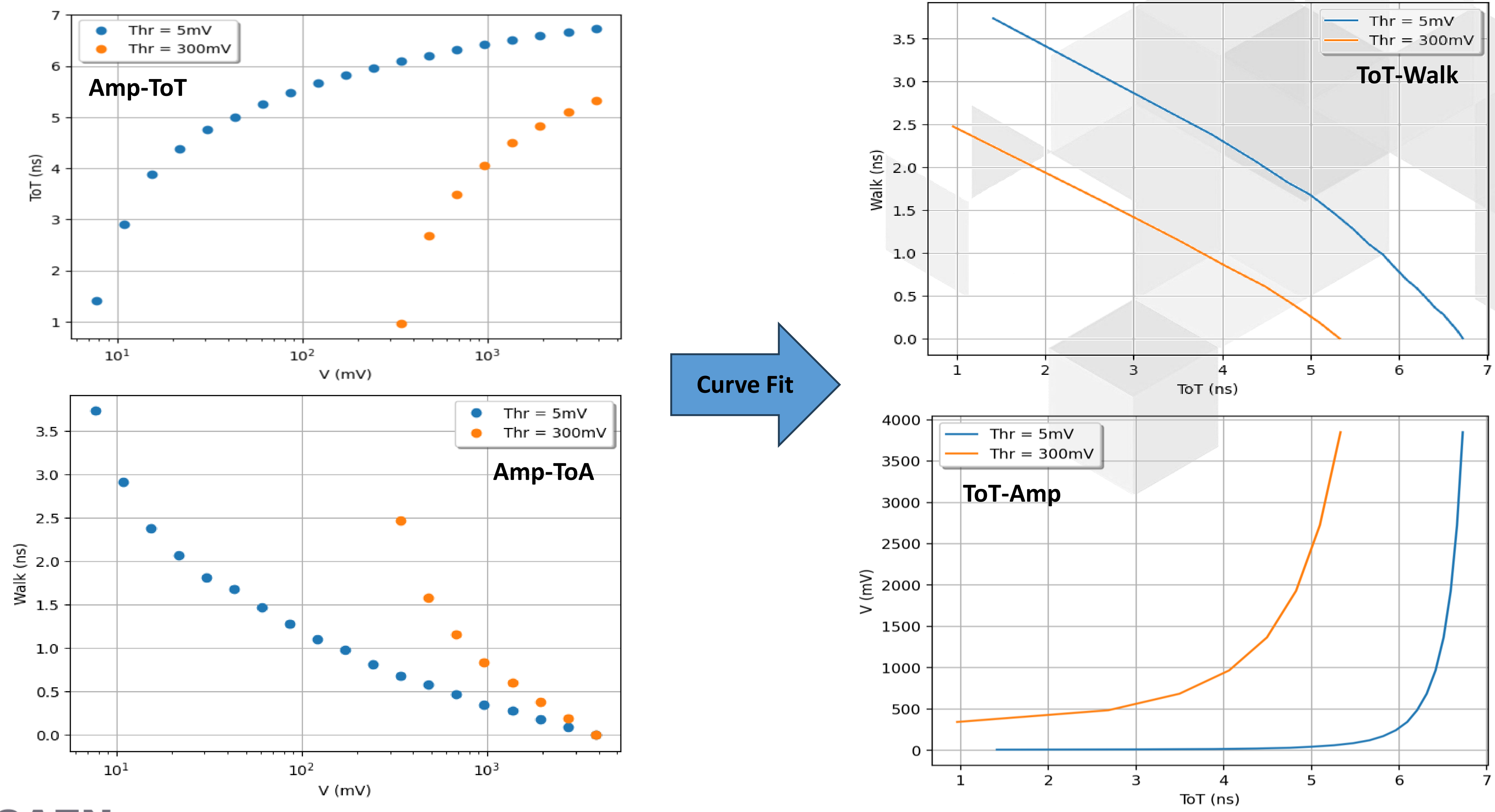
ToT calibration curves (double threshold)



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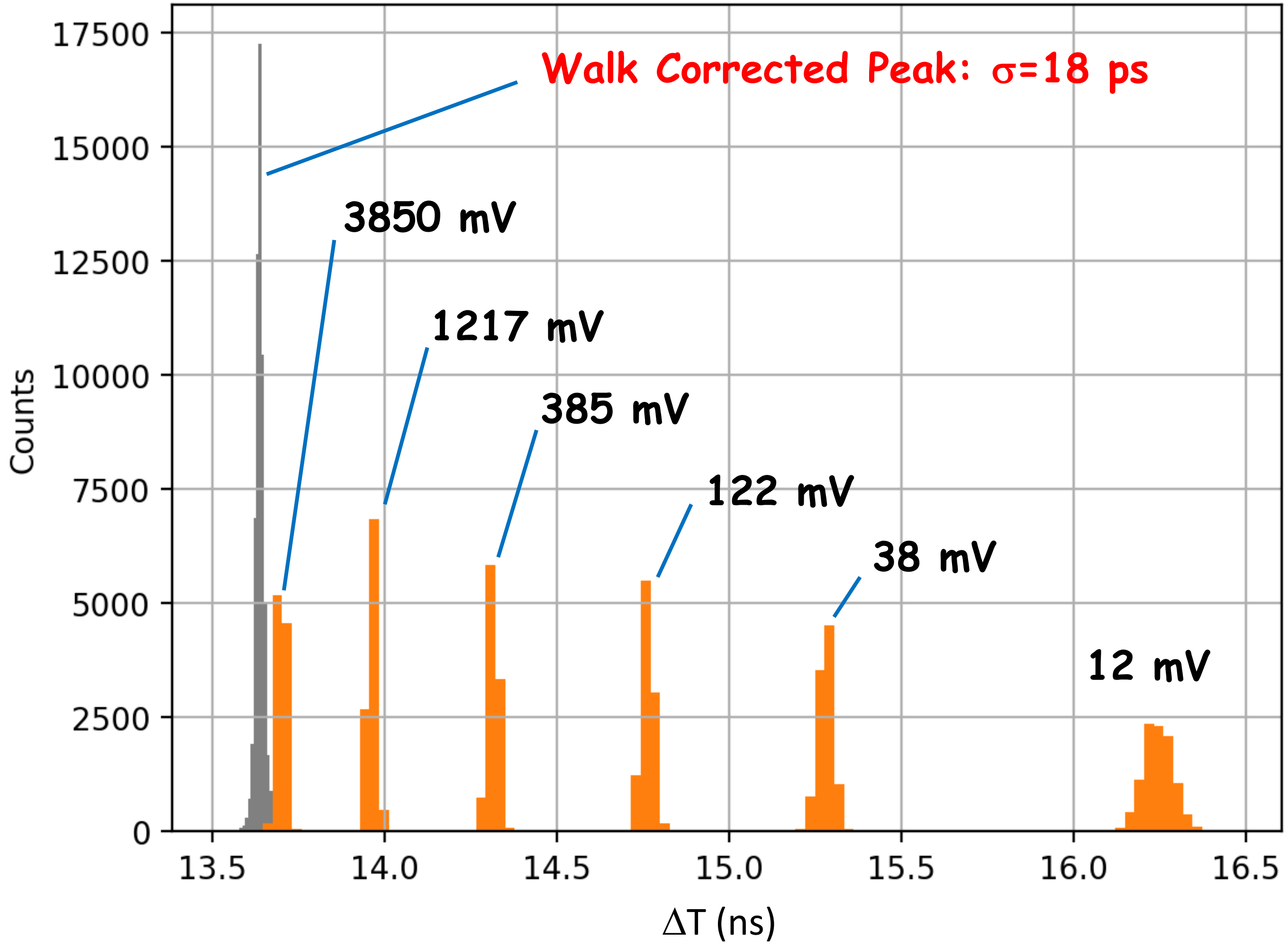
Walk Correction



- Pulses at 6 different amplitudes over a 50 dB dynamic range
- ~2 ns spread on ΔT (ToA) caused by the walk effect: 6 separate peaks !!

  ➔ timing resolution totally destroyed
- ΔT corrected by ToT using a 5th order polynomial fit of the **ToT-Walk** points taken at threshold = 5 mV
- Corrected ΔT histogram presents one single peak:

  18 ps RMS over 50 dB dynamic range

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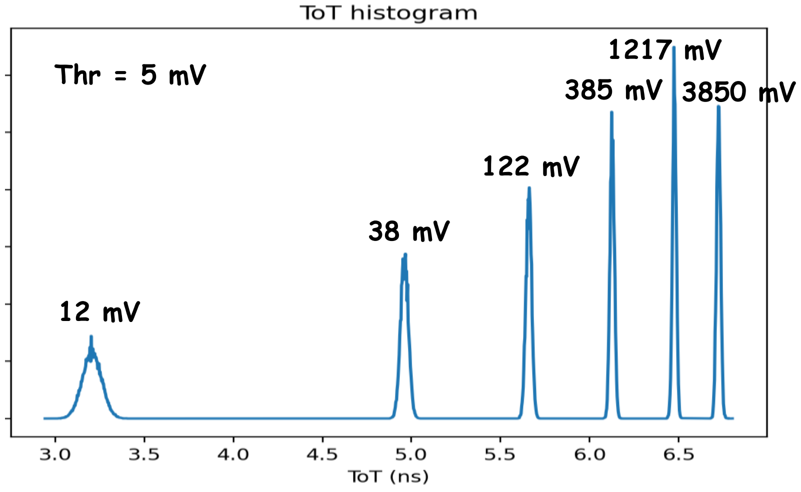
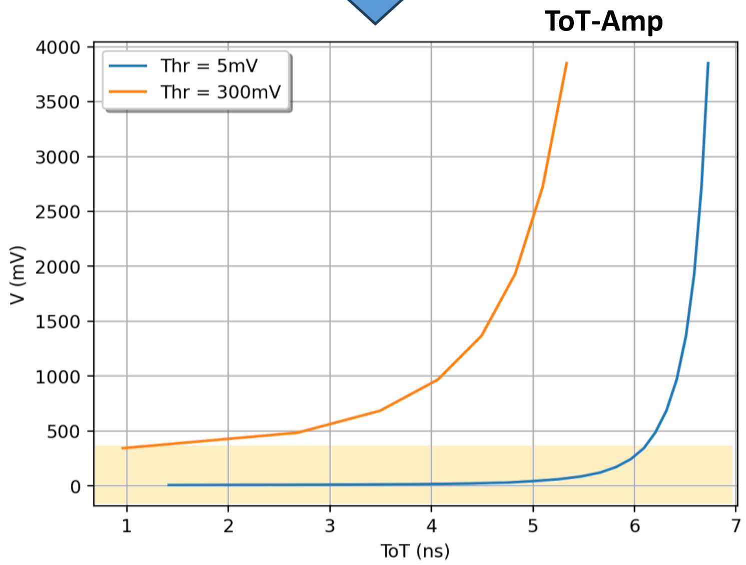
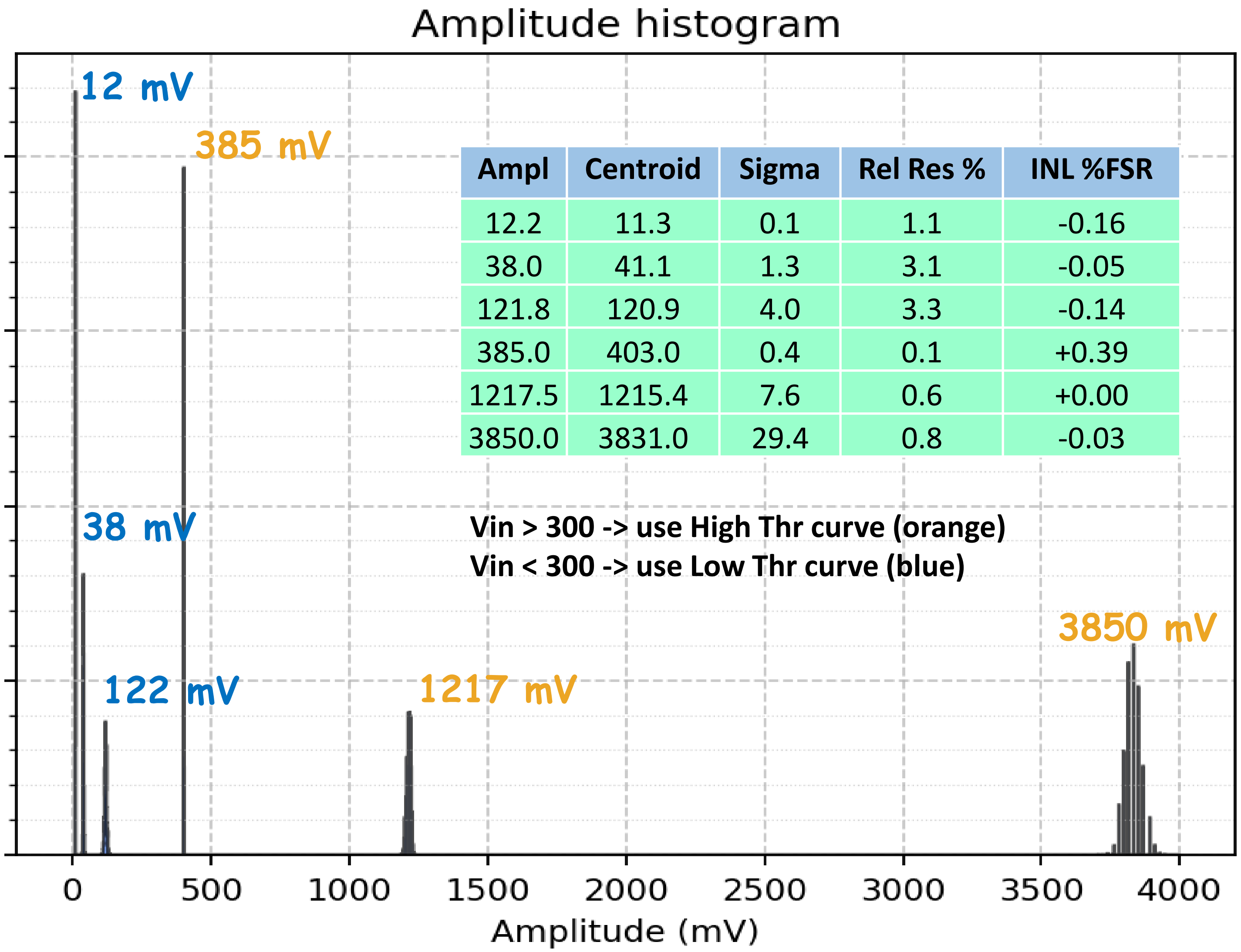
Amplitude Reconstruction

FERS-5200







Ampl	Centroid	Sigma	Rel Res %	INL %FSR
12.2	11.3	0.1	1.1	-0.16
38.0	41.1	1.3	3.1	-0.05
121.8	120.9	4.0	3.3	-0.14
385.0	403.0	0.4	0.1	+0.39
1217.5	1215.4	7.6	0.6	+0.00
3850.0	3831.0	29.4	0.8	-0.03

Vin > 300 -> use High Thr curve (orange)
Vin < 300 -> use Low Thr curve (blue)

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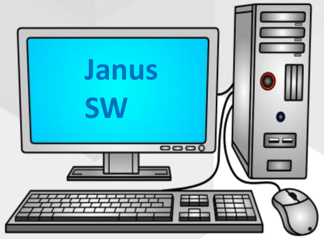
Feasibility study for SAND calorimeter

FERS-5200

PMTs + Led Driver

Step Attenuator

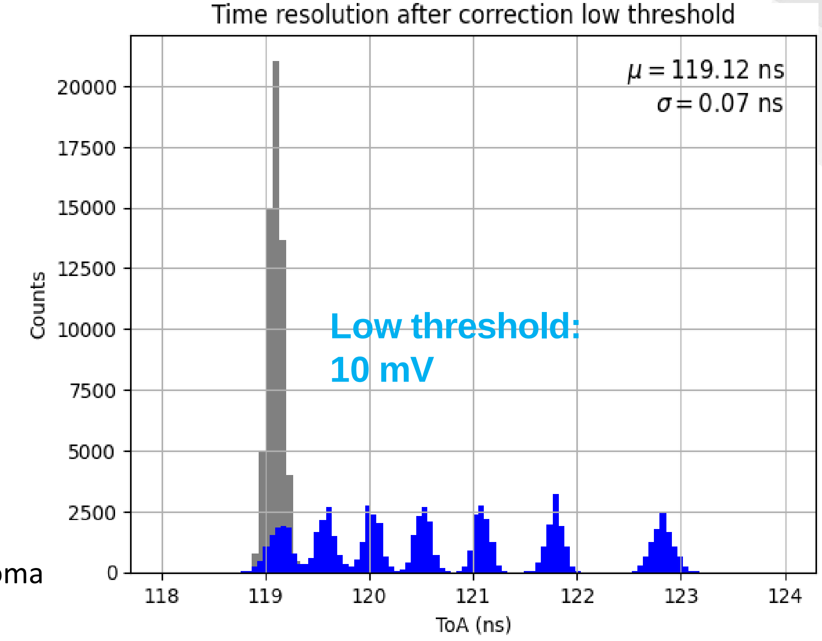
DT5203+A5256

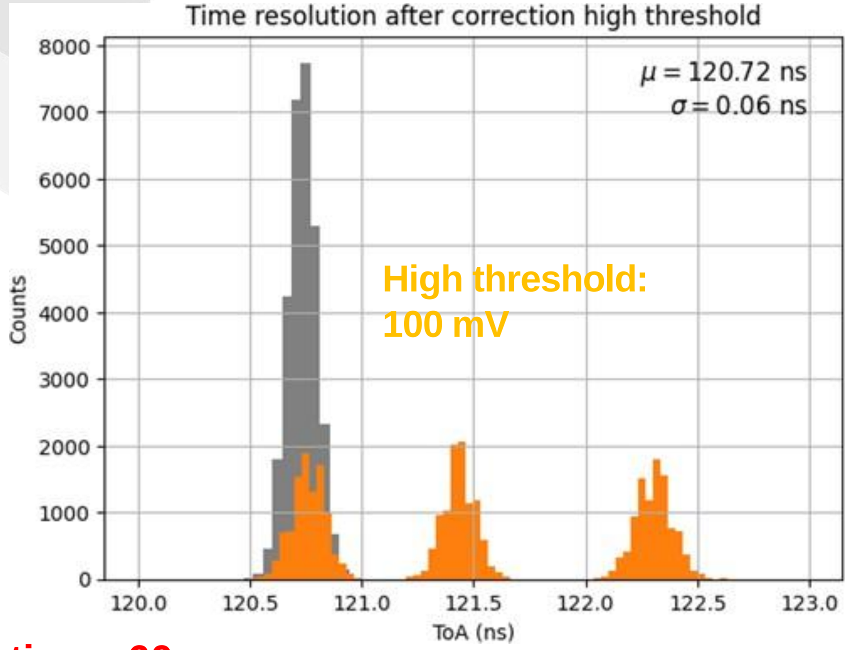


Ongoing feasibility study of the ToT technique for the readout of **5000 PMTs** in SAND (DUNE)

- Led Driver CAEN SP5601 (λ~400 nm) + fiber splitter
- PMT signal → variable amplitude
- DT5203 + A5256 → dual threshold

Courtesy of A. Di Domenico, V. Di Silvestre, P. Gauzzi - INFN Roma





Time Resolution ~ 60 ps

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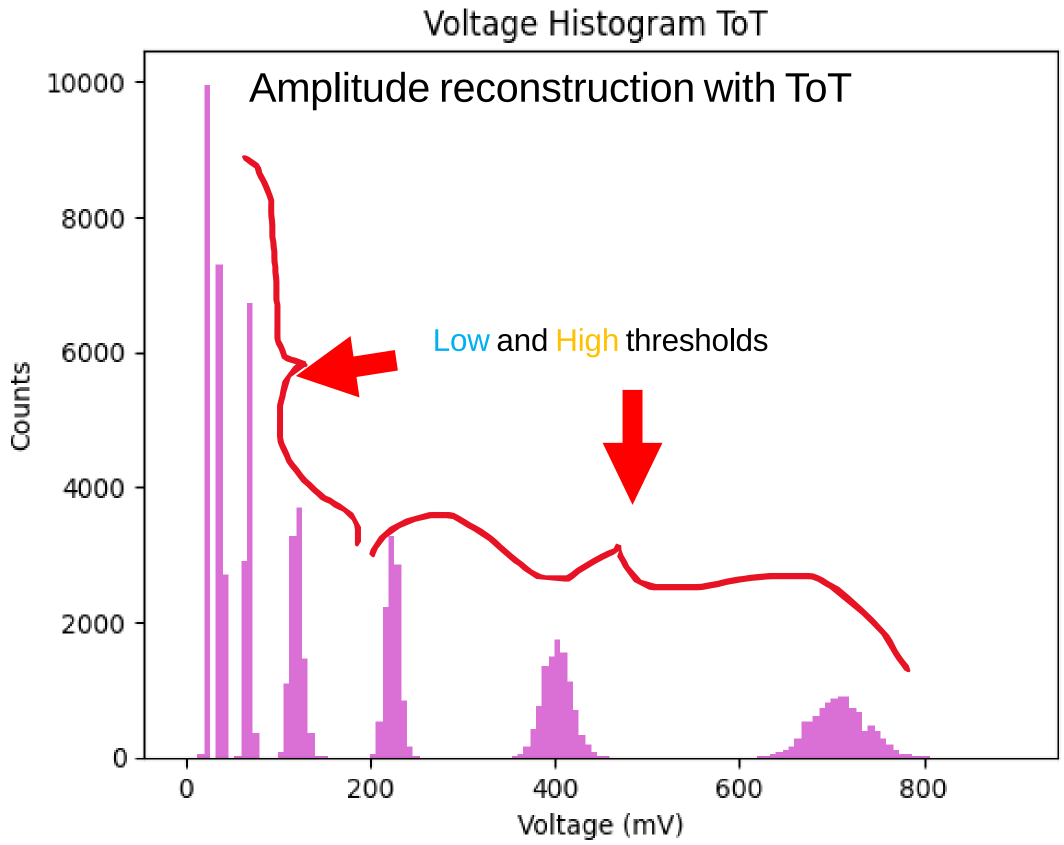
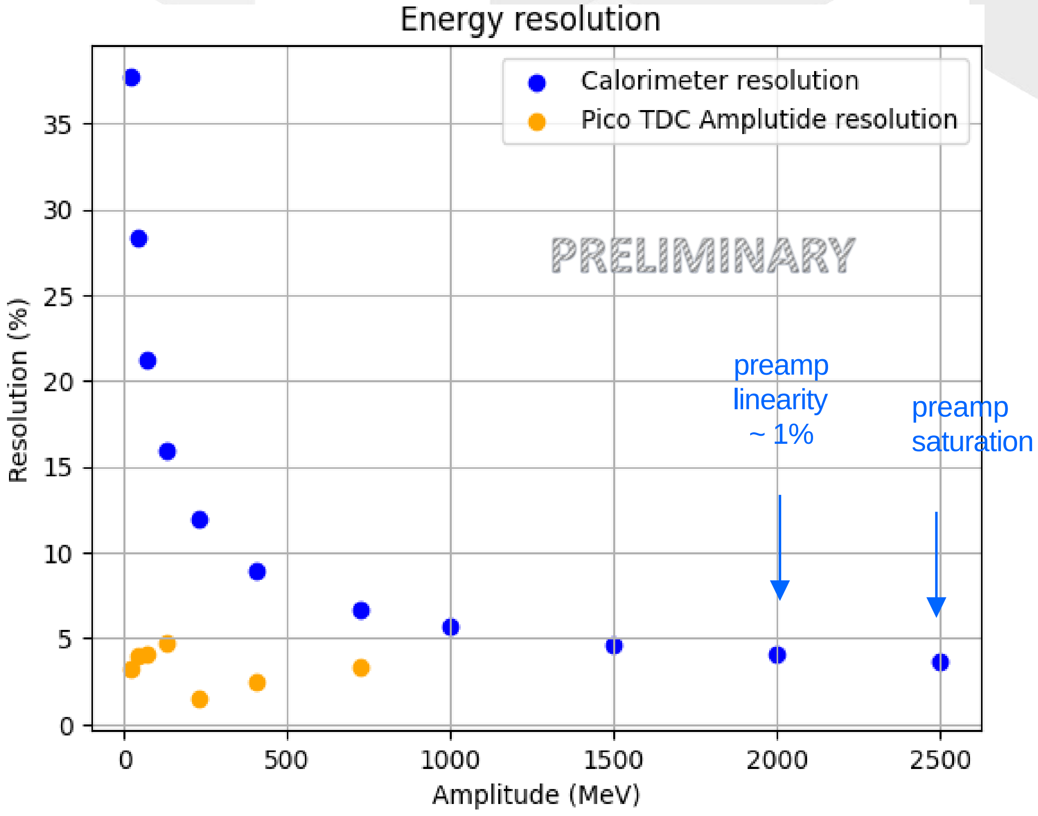
Feasibility study for SAND calorimeter

FERS-5200



Amplitude resolution obtained from ToT is compared with the intrinsic calorimeter resolution (assuming PMT gain 1 mV = 1 p.e. = 1 MeV => 1 V = 1 GeV)

to be done: optimization of the thresholds for the best perfomance in the whole expected dynamic range (2.5-2000 mV)



comparison with calorimeter resolution

($\sigma_E/E \sim 5.7\%/\sqrt{E}$)

Courtesy of A. Di Domenico, V. Di Silvestre, P. Gauzzi - INFN Roma

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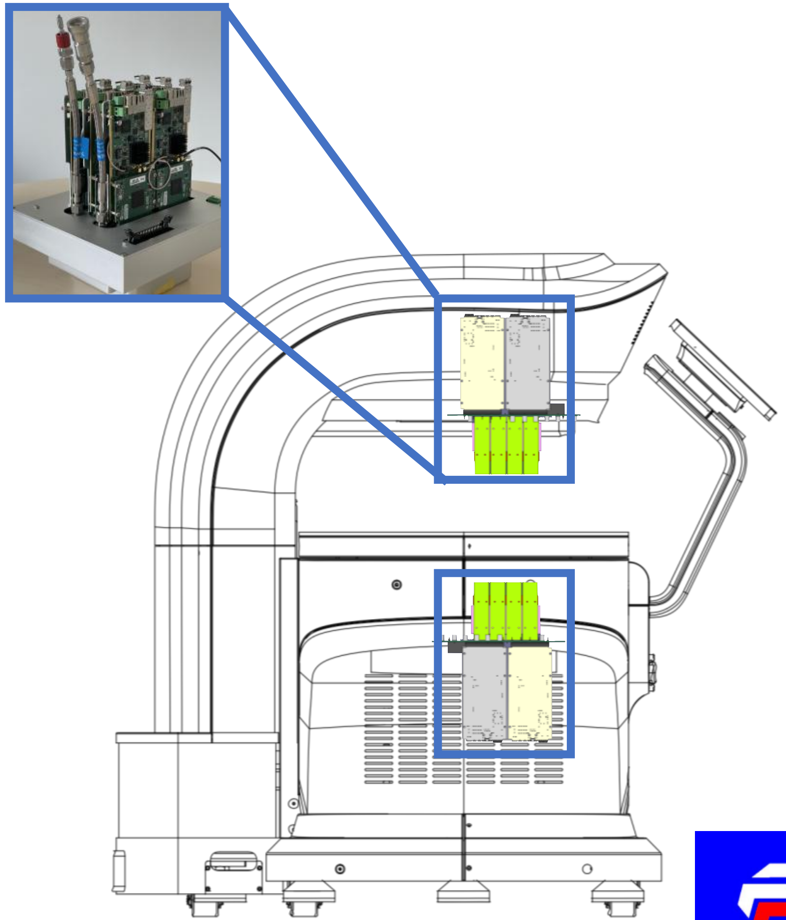
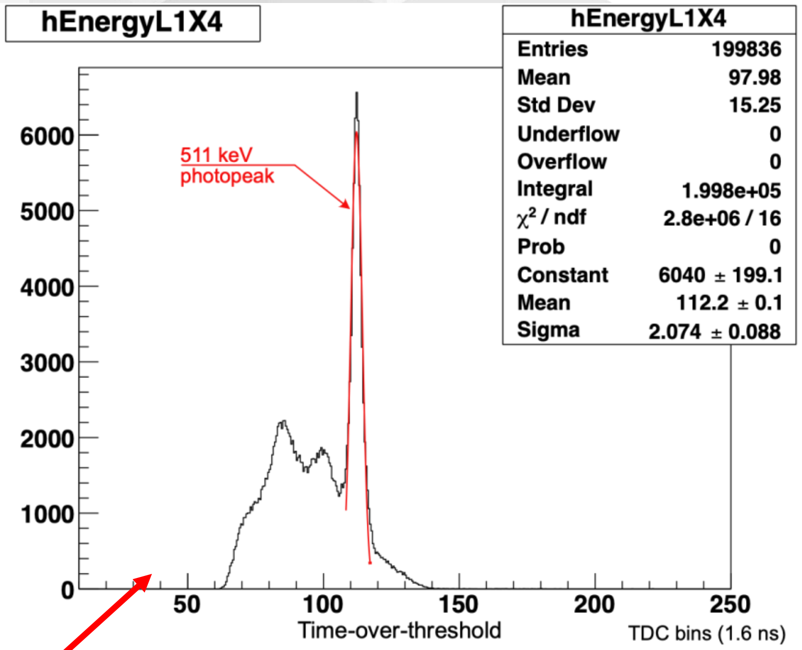
The Provision PET Scanner

FERS-5200

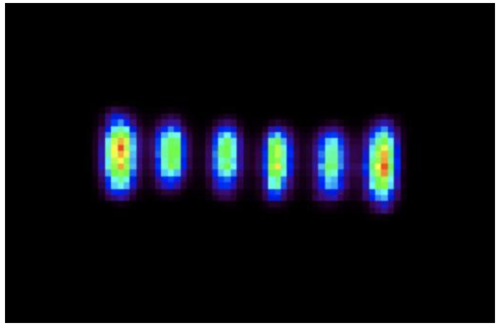


- 2x768 SiPM channels
- 2x6 A5203Bs (128 ch TDC)
- 1 DT5215 Concentrator
- Precise timing and TOT measurement
- High throughput – almost zero deadtime
- ToT cut for Dark Count and noise suppression

Picotech



'Empty' region thanks to TOT filter



Courtesy of C. Williams

Conclusions

FERS-5200

- **ToA and ToT** measurements with a resolution of **5 ps RMS**
- **Walk correction** (mimic CFD) possible with single or double threshold:
  18 ps RMS on a 50 dB dynamic range
- **Amplitude reconstruction** (mimic ADC) requires at least 2 thresholds (2 TDC channels).
  Linearity = ~0.4%. Resolution = ~3%. Possible improvement with a more accurate threshold setting
- Optimal results in the Provision PET scanner: **few mm size radioactive sources easily detectable thanks to the excellent x5203 time resolution**
- Challenge: build ToA vs.ToT calibration curves in a real data acquisition case

  ➔ Machine learning ???

- New FERS Units embedding the picoTDC + → Radioroc chip: **SiPM**
  → Psiroc chip: **GEMs, Si strip**

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Thank you!

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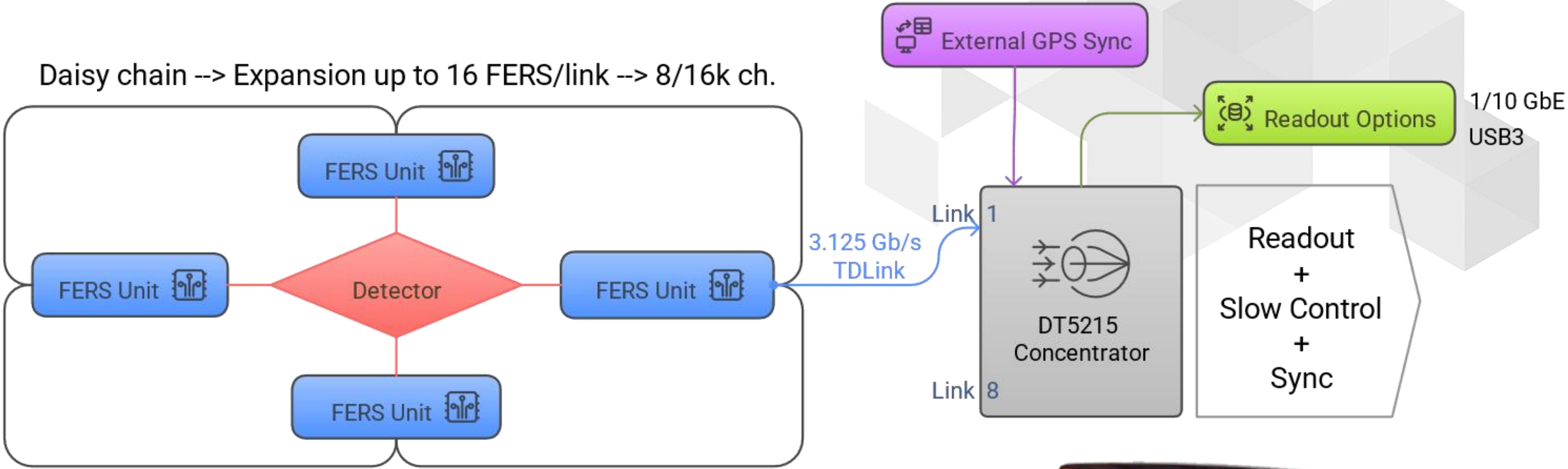
Back-up slides

FERS-5200 architecture

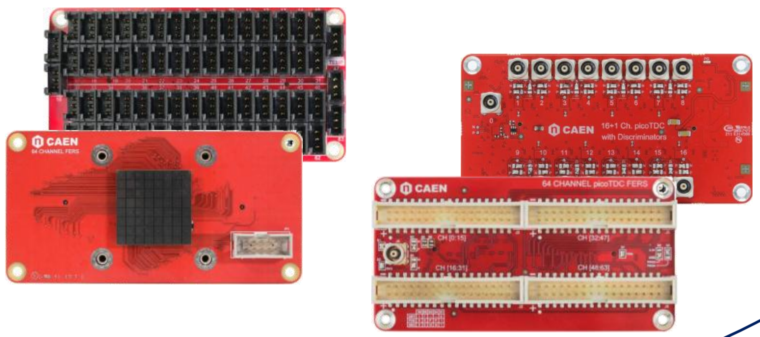


FERS-5200 Family

FERS-5200 Units

DT5215 Concentrator Board

Adapters



Remotization Cables & Accessories

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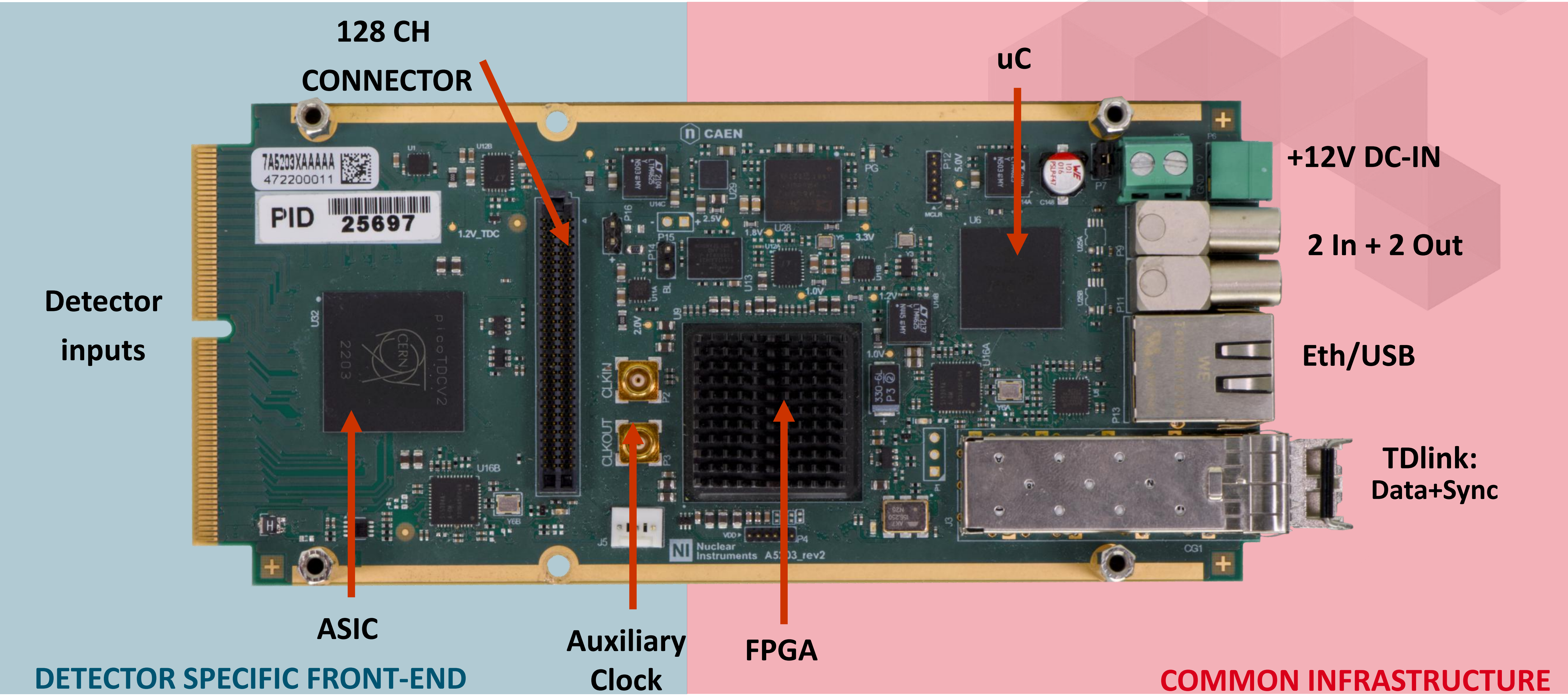
FERS A5203: 64/128 channel Readout



FERS Units: A520X(naked)/DT520X(boxed)

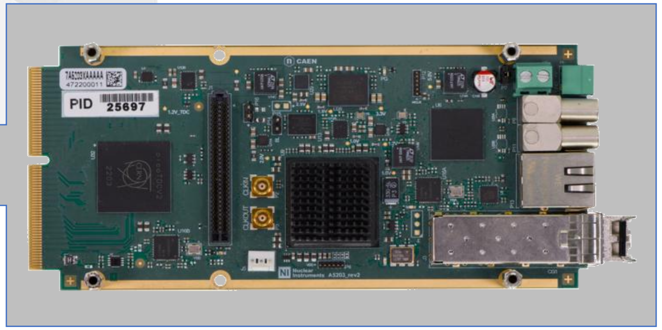
A5205
64 ch – Psiroc+picoTDC

COMING SOON

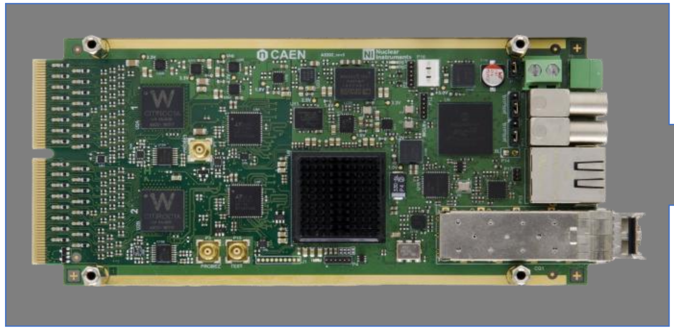
A5204
64 ch – Radioroc+picoTDC

- **MPPC bias**
- **Spectroscopy (PHA)**
- **Timing**

A5203
64/128 ch - picoTDC



- **Time Measurements (ToA & ToT)**
- **Amplitude Estimation**



A5202
64 ch – Citiroc 1A

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Technical Specifications A5204 & A5205

COMING SOON

A5204: 64 channel SiPM Readout based on Citiroc/Radioroc+picoTDC

- Analog inputs (charge, not voltage)
- All-in-one readout: Preamp + Shaper + Discr + ADC + TDC + HV Bias (20-80 V)
- Dynamic Range: 1 to 2500 p.e.
- Single photon detection (threshold at 1/3 p.e.)
- Timing resolution = 55 ps FWHM (A5204 only)
- **Acquisition Modes:Counting, Spectroscopy (PHA), Timing (ToA + ToT) , Mixed (PHA + ToA)**

A5205: 64 channel SSD, GEM, PIN diode readout based on Psiroc + picoTDC

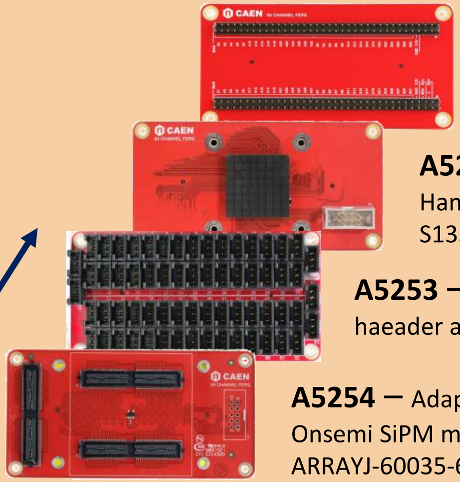
- Pos/Neg inputs. Dynamic range up to 5 pC with PHA, 100 pC with ToT
- Programmable gain: 125 mV/pC up to 4 V/pC. Min trigger threshold = 0.5 fC
- Linearized ToT

Different combos for all customers' needs

FERS-5200

A5202

A5204

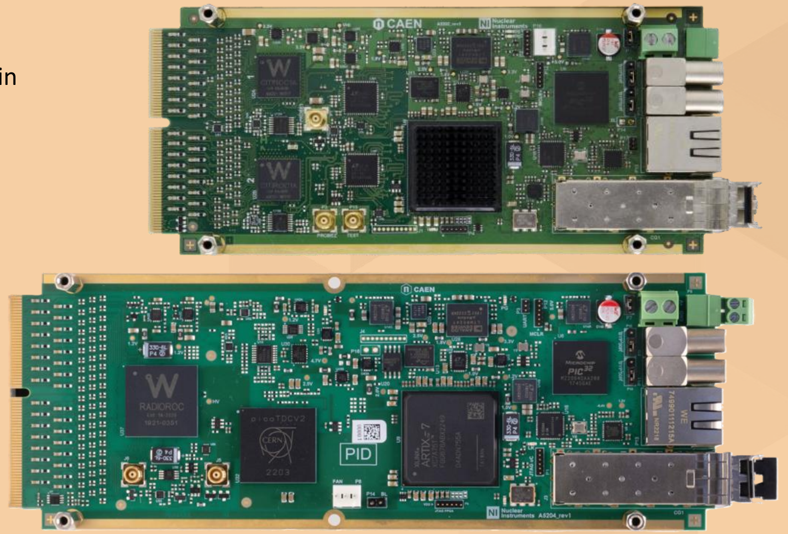


A5250 – 2.54 mm pin header adapter

A5251 – Adapter for Hamamatsu SiPM matrix S13361-3050AE-08

A5253 – 3-pin connectors haeader adapter

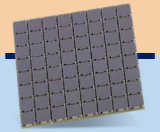
A5254 – Adapter for Onsemi SiPM matrices ARRAYJ-60035-64P-PCB, ARRAYC-60035-64P-PCB

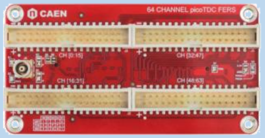


64 CHANNELS:

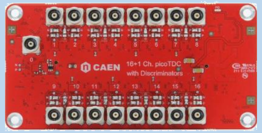
- ➡ **MPPC bias**
- ➡ **Spectroscopy (PHA)**
- ➡ **Timing**

Detector



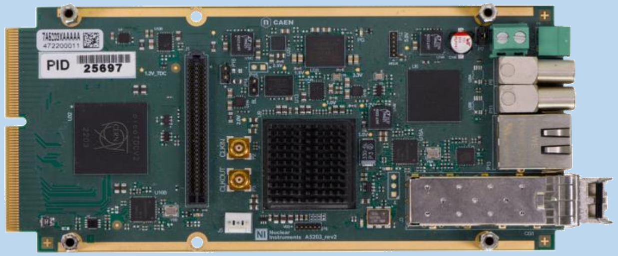


A5255 – 4x17 2.54 mm pin header connectors adapter



A5256 – 16+1 channel single threshold, 8+1 channel dual threshold edge discriminator adapter

CUSTOM



64/128 CHANNELS:

- ➡ **Time Measurements (ToA & ToT)**
- ➡ **Amplitude Estimation**

A5203

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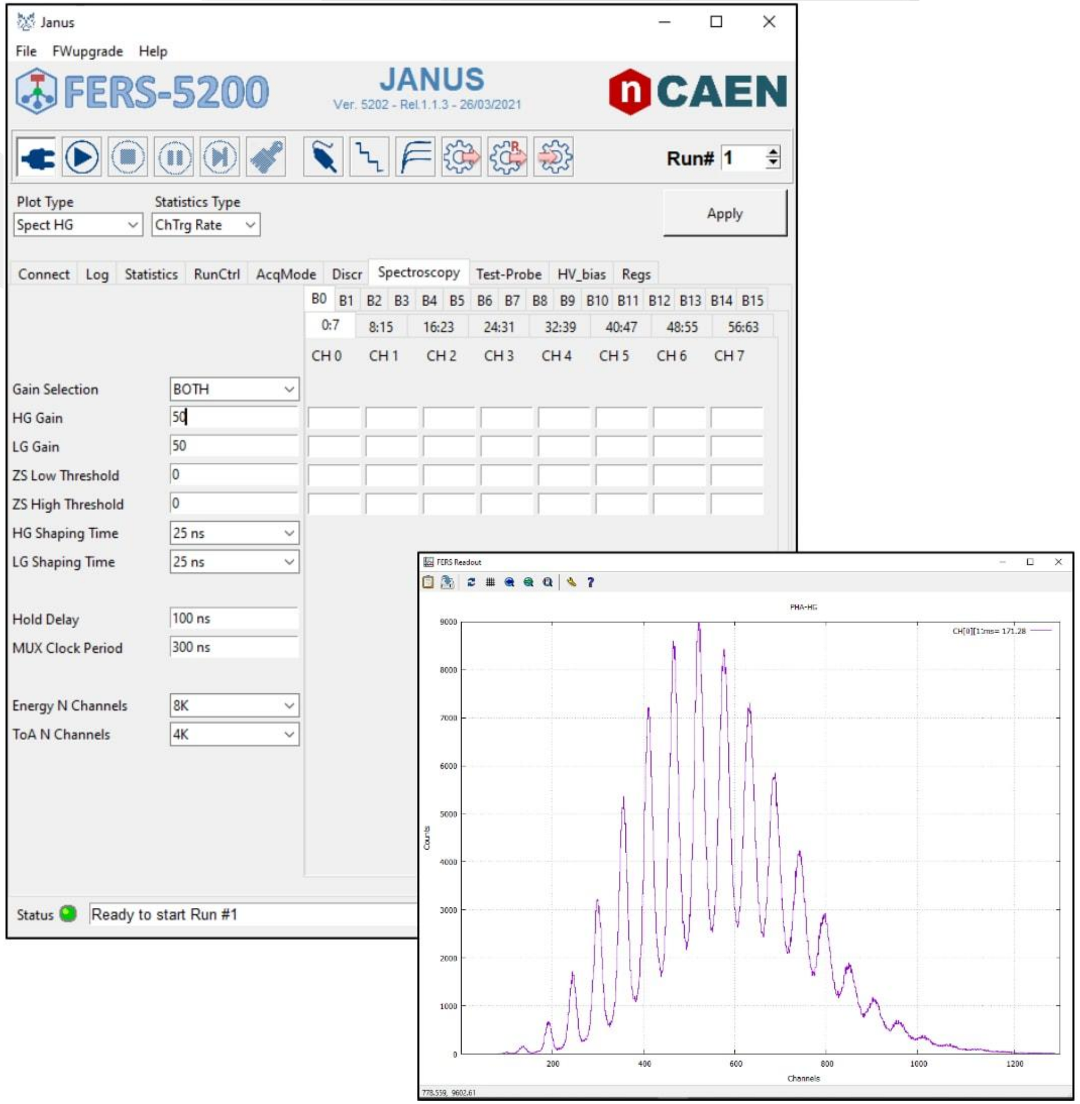
Janus Software

FERS-5200

- **Open source** software for multi-board configuration and data readout
- Specific Janus version for each FERS unit (Janus 5202, Janus 5203, …) with common FERSlib library
- **SDK** for user customization (lib + demo) **[COMING SOON]**
- **GUI (Python) and console mode** – based on C/C++ readout programs
- Multi parametric Jobs and Runs with time or counts preset
- Output files: lists in **.bin** or **.csv** format, spectra, raw data
- Off-line runs for Post-processing and Event Building
- Live plots (with gnuplot) and statistics monitor
- Up to 300 MB/s data throughput (with DT5215 Concentrator via USB 3.0 or 10 Gb Eth)



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A5203 Technical Specification Table (1)

FERS-5200

MECHANICAL	**Weight** 40 g (A5203 with spacers mounted); 163 g (A5203B with spacers mounted) **Dimension** 73.0 W x 30.0 H x 174.5 L mm^3 73.0 W x 25.0 H x 174.5 L mm^3
TDC INPUT	**A5203:** 64 channels (1 edge connector type HSEC8-170) **A5203B:** 128 channels (2 edge connectors type HSEC8-170) • Mating connector: Samtec HSEC8-170-01-S-DV • Input Type: reduced LVDS • Input voltage: Min = -40 mV Max = +1450 mV • Common Mode: Min = +70 mV Max = +1200 mV • Differential voltage: Min = +140 mV Max = +450 mV • Input Termination: 100 Ω
TIMING RESOLUTION	LSB = 3.125 ps • ΔT_{RMS} = ~5 ps. Tested with LVDS signals, two passive splitters and delay cables • ΔT_{RMS} = ~7 ps. Tested with pulse generator (1 Vpp, 0.8 ns rise/fall), passive splitter and 5 ns cable delay • ΔT_{RMS} = ~20 ps with variable amplitude pulses (30 mV to 1 V) and walk correction by ToT
DYNAMIC RANGE	Time measurement dynamic range in picoTDC: • Leading Edge only: T_{LEAD} = 24 bits (FSR = ~ 52 μs)* • Leading + Trailing Edge: T_{LEAD} / T_{TRAIL} = 24 bits (FSR = ~ 52 μs)* • Leading + ToT8: T_{LEAD} = 19 bits, T_{TOT} = 8 bits (LSB size and FSR can be programmed) • Leading + ToT11: T_{LEAD} = 16 bits, T_{TOT} = 11 bits (LSB size and FSR can be programmed) Coarse time stamp in FPGA (56 bits @ 12.6 ns) con be combined with picoTDC data to extend the full scale range of the time measurement to a maximum dynamic of 64 bit (streaming acquisition mode). * 26bits (FSR = ~ 210 μs) optional
ACQUISITION MODES	**Common Start:** TDC ch0 is the common start that opens the acquisition gate and represents the time reference. All other channels provide ΔT time measurements: $T_{LEAD} = \Delta T_N = T_N - T_0$. The gate width is programmable by software. Any hit falling outside the gate will be discarded. Output Data: T_{LEAD} or T_{LEAD} + ToT **Common Stop:** Same as common start, but ch0 is used as a common stop that closes the acquisition gate: $\Delta T_N = T_0 - T_N$. Output Data: T_{LEAD} or T_{LEAD} + ToT **Trigger Matching:** The trigger signal (typ. from T0/T1 inputs) defines an acquisition window with programmable width and offset. All hits falling into the window will be recorded. Multi-hit acquisition is supported. All time measurements are referred to the Coarse Trigger Time Stamp (LSB = 25.6 ns), while the relative time between the hits keeps the TDC timing resolution (minimum LSB = 3.125 ps). Output Data: T_{LEAD} or $T_{LEAD}+T_{TRAIL}$ or T_{LEAD}+ToT **Streaming:** Continuous hit recording, without any gate or trigger windowing. All hit time measurements are expressed as 64 bit time stamps (minimum LSB = 3.125 ps) and saved in the form of a sorted list. Output Data: T_{LEAD} or $T_{LEAD}+T_{TRAIL}$ (or T_{LEAD}+ToT , **COMING SOON**)

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A5203 Technical Specification Table (2)

FERS-5200

FPGA TRIGGER TIME STAMP	• 56-bit counter, 25,6 ns step • up to 128 boards can be synchronized with the DT5215 FERS-CB by sending a time stamp reset signal via TDlink
FRONT PANEL I/Os	• **T0-IN, T1-IN**: LEMO-00 connector, NIM or TTL (terminated to 50 Ω) • **T0-OUT, T1-OUT**: LEMO-00 connector, TTL (50 Ω termination required) Jumpers for IN-OUT bypass and termination removal (daisy chaining). **Functions (SW programmable):** Trigger, Acquisition Start/Stop, Sync, Busy, Veto, Signal inspection, etc ... T0/T1 inputs can be used to drive TDC – Ch0 = Tref (possible degradation of the resolution because of the FPGA temperature dependence)
FRONT PANEL LEDs	• GREEN: Power-ON, Init-Done, Run, Trigger, Data Ready, T0-IN, T1-IN • ORANGE: Event Overrun (rejected triggers because received while busy) • RED: Failure (missing clock, over-temperature, etc...)
INTERNAL PULSER	Fast reduced-LVDS output (one signal only) with programmable frequency and width, for debug purposes
COMMUNICATION INTERFACES	**USB** • USB2.0: microUSB connector • Bandwidth = ~ 3 MB/s **Ethernet** • Ethernet connector, type Rj-45. Supports 10/100 Mbit/s connection to a PC • Bandwidth = ~ 2.5 MB/s **Optical Link** • Small Form Factor Pluggable (SFP+) transceiver component for optical connection (3.125 Gbit/s). TDlink CAEN proprietary protocol allows for multi-board synchronization, slow control and data readout • Data Concentrator DT5215 required
FIRMWARE	• Firmware of FPGA upgrade via USB or Ethernet (or TDlink **COMING SOON**) • Firmware of µC upgrade via Ethernet only
SOFTWARE	**Readout SW** Fully controlled by the Janus 5203 open source software for Windows® and Linux®. It can run in console mode (C program, with console commands and gnuplot display for plots) or connected to a GUI (Python) that implements user friendly configuration panels and run controls. Janus 5203 can acquire, plot and save output files with ToA, ToT histograms, as well as list files (trigger timestamp, ToA and ToT for each channel). **Web Interface** Board information and monitoring, Ethernet configuration.
POWER REQUIREMENTS	Single power supply: +12 V. Accepted voltage range: MIN +7 V, MAX +15 V (110 V/220 V AC/DC converter provided with Desktop version only)
POWER CONSUMPTIONS	700 mA @ +12 V, i.e ~ 8.4 W (A5203 – 64 channels) tbd (A5203B – 128 channels)

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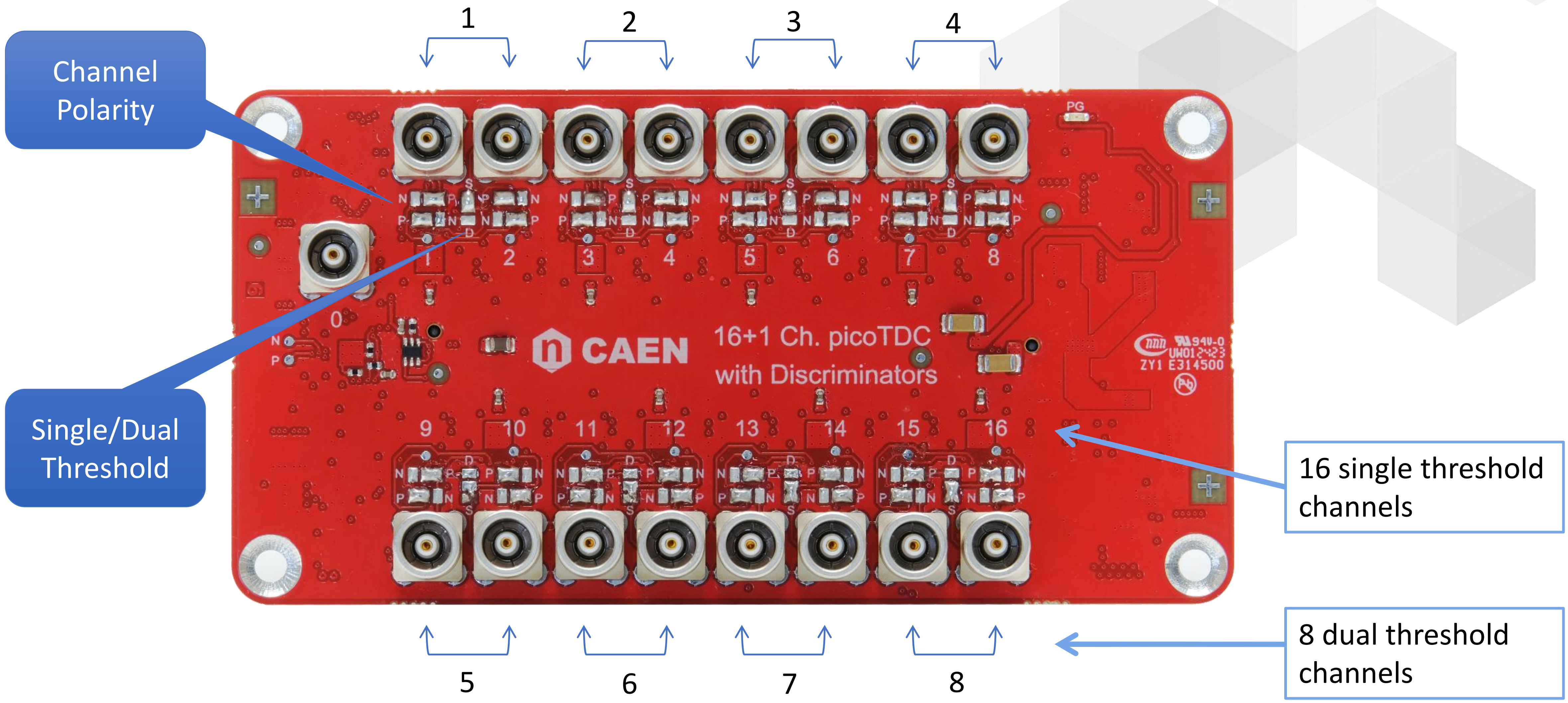
A5256 Focus

A5256 Hardware Configuration

FERS-5200



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A5256 Technical Specification Table

FERS-5200

Inputs	Single Threshold: 16+1 inputs positive/negative polarity, 50 Ω impedance Double Threshold: 8+1 inputs positive/negative polarity, 50 Ω impedance
Min/Max Input Voltage	- 4 V / +3 V
Min Detectable Signal	1.5 mV
Threshold Range	-1.2 V / +1.2 V
Threshold Step	0.61 mV
Timing Resolution	A5256 mounted on A5203: ΔT_{RMS} = ~7 ps. Tested with a pulse generator (1 Vpp, 0.8 ns rise/fall pulses), one passive splitter and delay cables. ΔT_{RMS} = ~20 ps. with variable amplitude pulses (30 mV to 1V) and walk correction by ToT.
Non-Linearity	≤ 0.18 % typ.
Efficiency	<2 mV typ. (3 mV max) Measured with 150 mV signal, with 1.6 ns rise time

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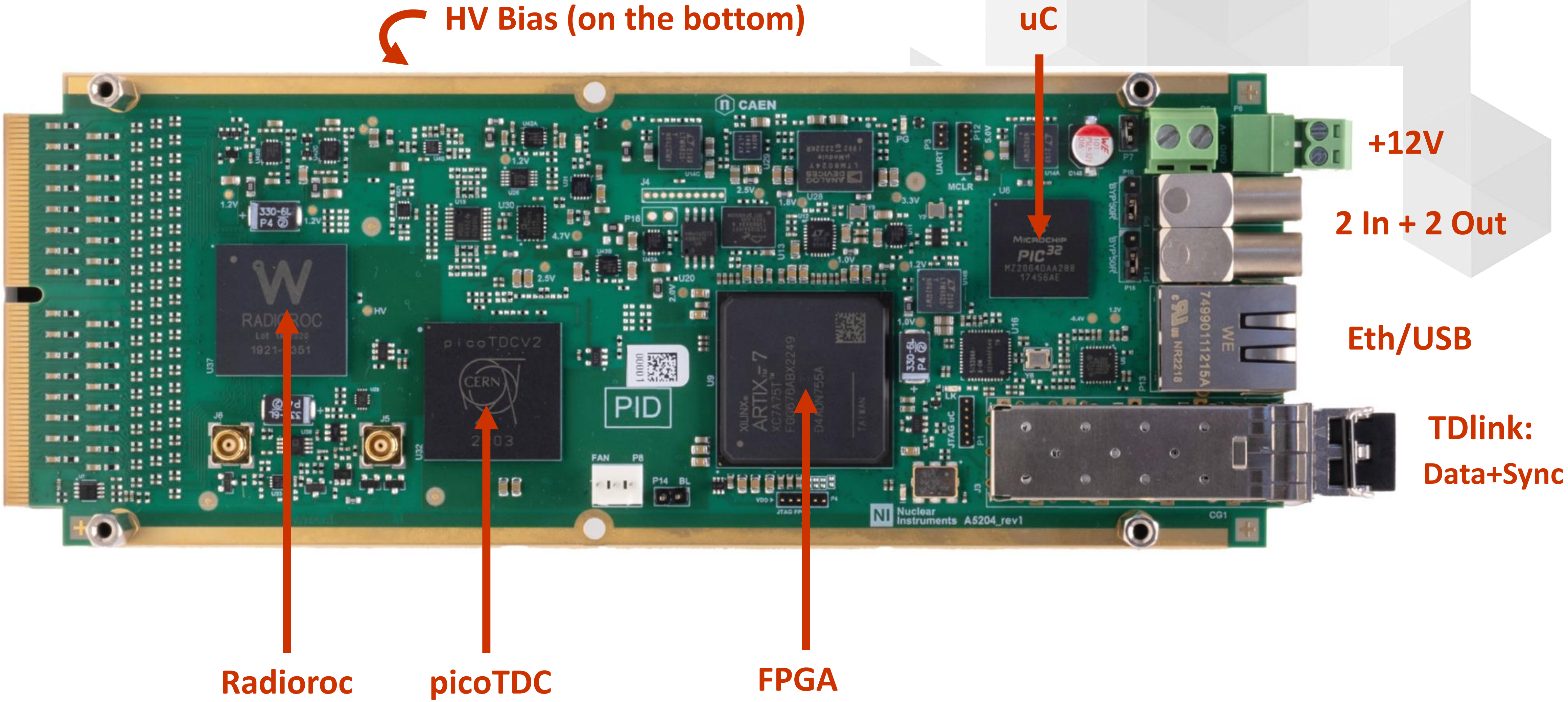
A5204 Focus

FERS A5204: 64 channel SiPM Readout

FERS-5200



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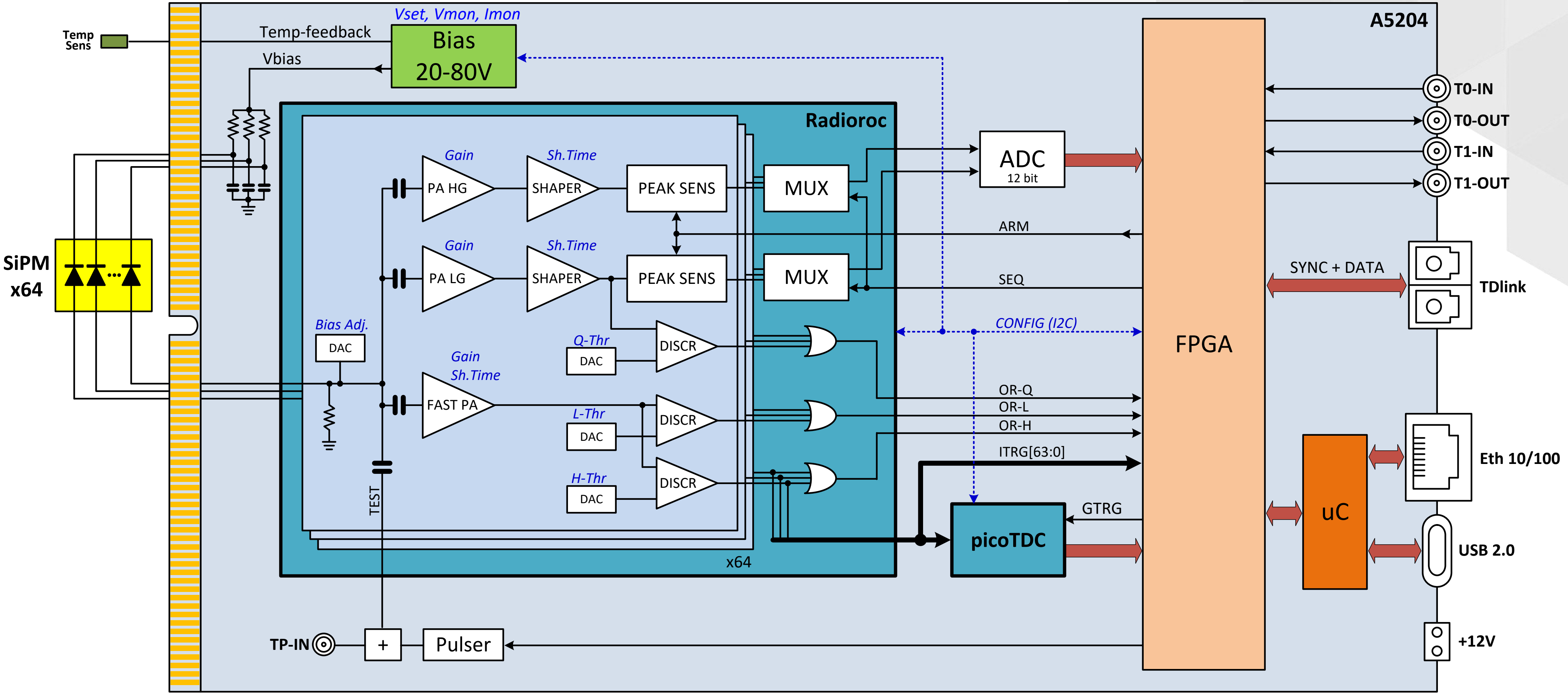
A5204: block diagram

FERS-5200



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A5204 Technical Specification Table (1)

MECHANICAL	**Weight** 161 g (A5204 with spacers mounted); **Dimension** 72.8 W x 22.0 H x 208.5 L mm^3
INPUTS	64 channels Input edge connector type Samtec HSEC8-170 Mating connector: Samtec HSEC8-170-01-S-DV Signal polarity: Positive Each SiPM input has two pins: • Cathode with HV bias (min = +20V, max = +80V) • Anode closed to -100 ohm, feeding the Radioroc inputs
HIGH VOLTAGE (SiPM Bias)	HV module for SiPM biasing (A7585D) HV Range: +20V/+80V, Max 10 mA Individual bias adjustment on channel basis (8 bit DACs, LSB = -2 mV, adjust range = 550 mV) Automatic temperature feedback for SiPM gain stabilization
ACQUISITION MODES	**Spectroscopy:** The common trigger initiates the peak sensing detection and A/D conversion (12 bit) on all channels simultaneously. Conversion time = -10 µs. Output Data: Trigger time stamp, Trigger ID, PHA (Low and/or High Gain). Zero suppression with programmable threshold. **Counting:** 32 bit counters, up to 200 MHz. Common trigger defines dwell time (i.e. counting window). No dead-time between subsequent windows. Internal period trigger from 16 ns to -34 s. Output Data: Trigger time stamp, Trigger ID, channel counts. Zero suppression available. Counters are automatically reset after each trigger. **Timing (Common Start):** The Tref signal (T0, T1 inputs) is a common start that opens the acquisition gate with programmable width. Channel self-triggers are acquired as ▯T from Tref and, optionally, as ToT for PHA estimation. Output Data: Trigger (=Tref) time stamp, Trigger ID, ▯T or ▯T+ToT **Timing (Common Stop):** Same as common start, with Tref used as a common stop that closes the acquisition gate. Acquired events are those ones arrived before the trigger (look back acquisition). **Timing (Trigger Matching):** The common trigger signal defines an acquisition window with programmable width and offset. All hits falling into the window will be recorded. Multi-hit acquisition is supported. Output Data: Trigger time stamp, Trigger ID, ToA or ToA+ToT **Timing (Streaming):** Continuous hit recording, without any gate or trigger windowing. All hit time measurements are expressed as 64 bit time stamps and saved in the form of a sorted list. Output Data: ToA or ToA+ToT
SENSITIVITY (GAIN) - SPECTROSCOPY	**High Gain:** Min = 5, Max = 80, 16 steps (1 step = 5) **Low Gain:** Min = 0.5, Max = 8, 16 steps (1 step = 0.5)
SHAPING TIME - SPECTROSCOPY	**Short Range:** Min = 20 ns, Max = 300 ns, 16 steps (1 step = 20 ns) **Long Range:** Min = 80 ns, Max = 1200 ns, 16 steps (1 step = 80 ns)

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A5204 Technical Specification Table (2)

FERS-5200

DYNAMIC RANGE - SPECTROSCOPY	Up to 2000 photo-electrons @ 10^6 SiPM gain
SELF TRIGGERS - TIMING & COUNTING	Dedicated fast preamps + discriminator for SiPM pulse detection. Trigger down to 1/3 p.e. **Fast Preamp Gain:** Min = 15 (BW = 480 MHz), Max = 100 (BW = 55 MHz), 32 steps **Discriminator Dual Threshold:** Range = 278 mV; 1024 steps, 1 step = 0.27 mV
TIMING RESOLUTION - TIMING & COUNTING	55 ps FWHM on a single p.e. Time Stamp Range: 64 bit Intrinsic timing resolution of picoTDC = 3.125 ps LSB
ToT - TIMING & COUNTING	Time over Threshold (ToT): 1% linearity energy measurement up to 2000 p.e.
COUNTING - TIMING & COUNTING	Photon counting up to 200 Mcps per channel MCS mode with programmable dwell time: from 16 ns to ~34 s
TRIGGER LOGIC	Global trigger common to 64 channels: used in Spectroscopy mode to start Peak acquisition, in Timing mode to generate the acquisition windows (Gate). Trigger-less acquisition only in Streaming mode. Global Trigger Sources: • OR of self-triggers = OR(0..63) • Plane coincidence: OR(0..31) AND OR(32..63) • Paired channels: AND(0..1) OR AND(2..3) ... OR AND(62..63) • Majority with programmable threshold • External trigger (T0-IN, T1-IN, LEMO, TTL/NIM) • Internal periodic trigger with programmable frequency
TIME STAMP & SYNCHRONIZATION	Acquisition Trigger Time Stamp: 56 bit, step = 8 ns Two synchronization modes: • T0 or T1 IN-OUT daisy chain: max jitter = 100 ns • fiber optic (TDlink) and DT5215 Concentrator: up to 128 boards, max jitter 50 ps
FRONT PANEL I/Os	**T0-IN, T1-IN:** LEMO-00 connector, NIM or TTL (terminated to 50 Ω) **T0-OUT, T1-OUT:** LEMO-00 connector, TTL (50 Ω termination required) SW selectable IN-OUT bypass and termination removal for daisy chaining **Functions** (SW programmable): Trigger, Acquisition Start/Stop, Sync, Busy, Veto, Signal inspection, etc...
FRONT PANEL LEDs	GREEN: Power-ON, Init-Done, Run, Trigger, Data Ready, T0-IN, T1-IN ORANGE: Event Overrun (rejected triggers because received while busy) RED: Failure (missing clock, over-temperature, etc...)

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A5204 Technical Specification Table (3)

FERS-5200

INTERNAL PULSER	Radioroc provides a test input pin that can be internally connected to the pre-amplifier inputs, channel by channel. The test signal can come from an external signal (MCX connector on the PCB) or generated by an internal pulser with programmable amplitude. The internal pulser can be trigger by T0/T1 IN or by the internal periodic trigger.
COMMUNICATION INTERFACES	**USB** USB2.0: microUSB connector Bandwidth = ~ 3 MB/s **Ethernet** Ethernet connector, type Rj-45. Supports 10/100 Mbit/s connection to a PC Bandwidth = ~ 2.5 MB/s **Optical Link** Small Form Factor Pluggable (SFP+) transceiver component for optical connection (3.125 Gbit/s). TDlink CAEN proprietary protocol allows for multi-board synchronization, slow control and data readout Data Concentrator DT5215 required
FIRMWARE	Firmware of FPGA be upgraded via USB or Ethernet Firmware of μC can be upgraded via Ethernet only
SOFTWARE	**Readout SW** Fully controlled by the Janus 5204 open source software for Windows® and Linux®. It can run in console mode (C program, with console commands and gnuplot display for plots) or connected to a GUI (Python) that implements user friendly configuration panels and run controls. Janus 5204 can perform multiple board acquisition of PHA energy spectrum (Low and High Gain). ToT spectrum (represents PHA in timing mode) DT spectrum, with event building based on trigger ID or time stamp. Live Display: channel hit count and rate, trigger rate, lost triggers, data throughput, acq. time, etc... Plots: PHA, DT, ToT, hit rate, 2-D heat map with channel hit rates or PHA. Output Files: histograms (spectra), list files (PHA, ToA, ToT, DT), Run Info, Sync file. **Web Interface** Board information and monitoring, Ethernet configuration.
POWER REQUIREMENTS	Single power supply (+12 V). Regularly working in a range between +7 V and +15 V 110V/220V AC/DC converter provided with Desktop version only.
POWER CONSUMPTIONS	t.b.d.

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