

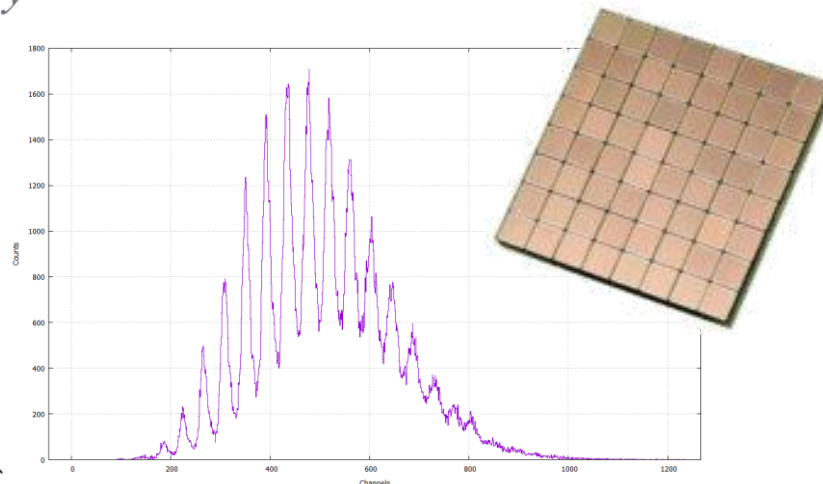
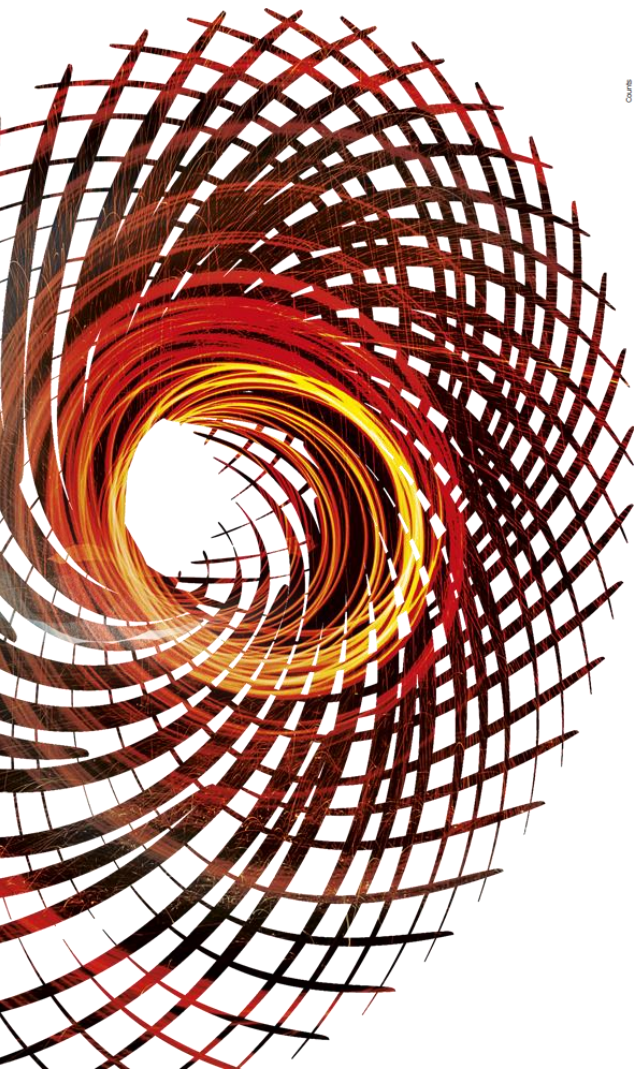


CAEN
Tools for Discovery



NI Nuclear
Instruments

Electronic Instrumentation

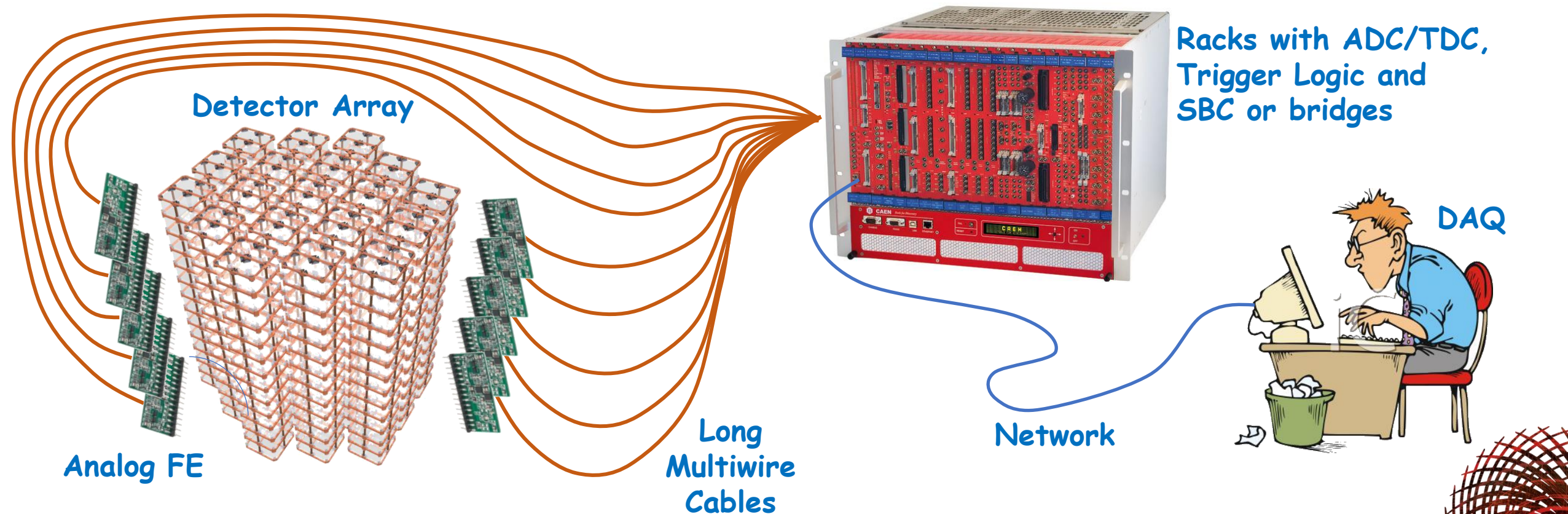


FERS: a distributed Front End Readout System for multi-detector arrays

Carlo Tintori

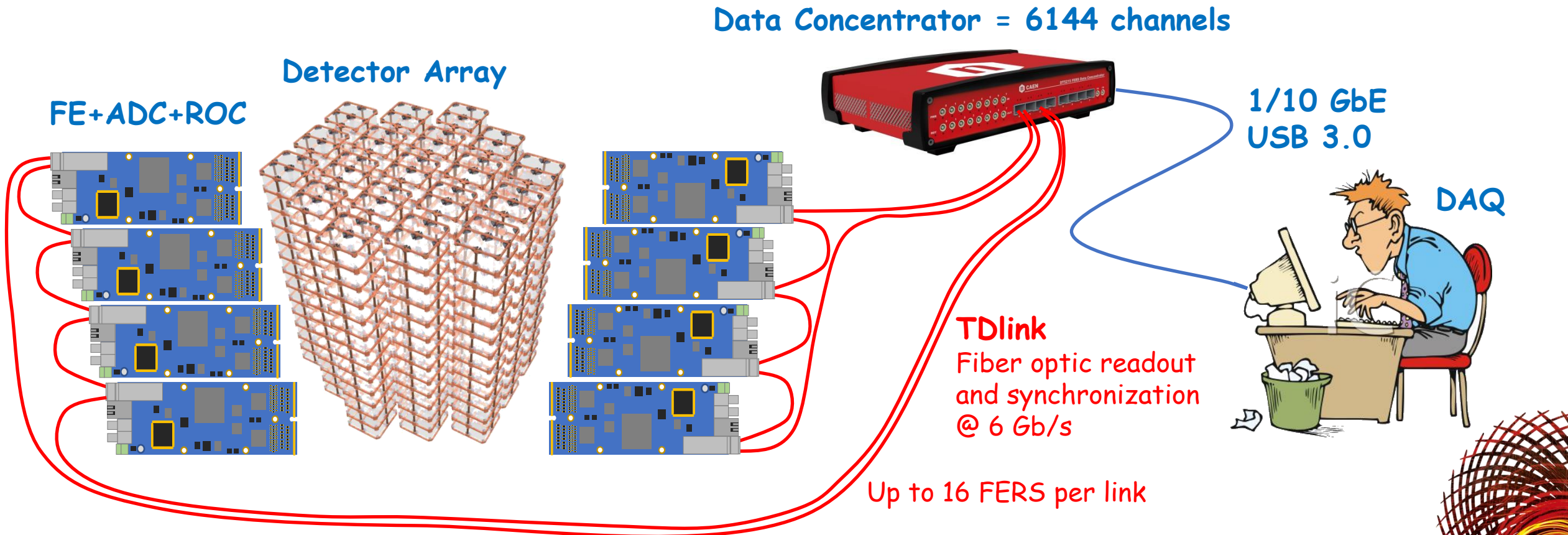
SoLID Collaboration Meeting– 8/9 Jun 2020

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



Distributed Front End Readout System

- Front End Preamplifiers, A/D conversion and data processing/readout in small **FE card**
- **TDlink**: single optical ring connection for synchronization, readout and slow control
- Data Concentrator: provides global synch, trigger logic, event data building and storage
- Easy scalable and deployable: 6144 channels per Data Concentrator

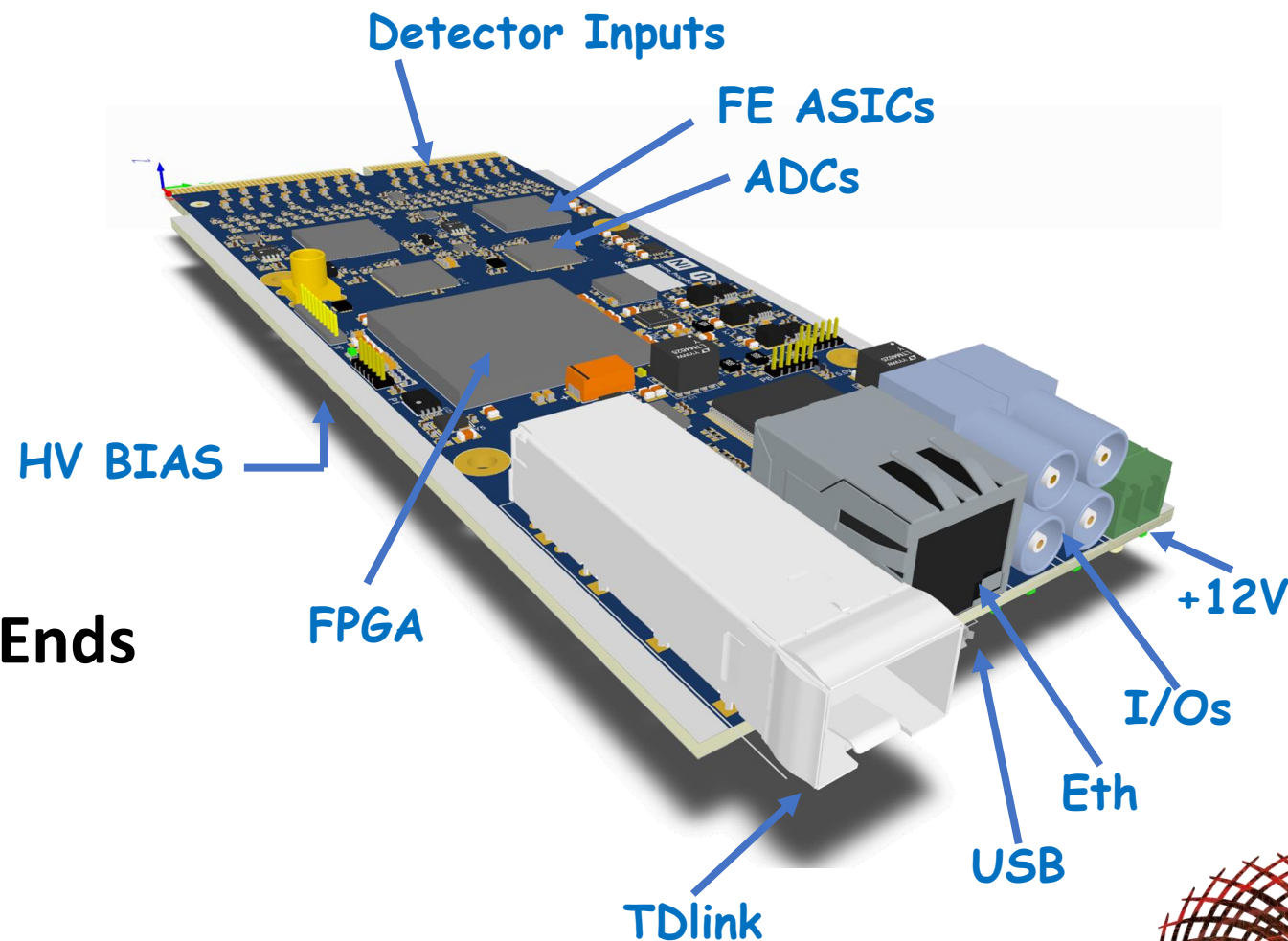


A new line of FE and readout electronics for:

- SiPM
- PMTs and MA-PMTs
- Gas Detector, wire chambers
- GEM
- Micromegas
- Silicon Strip Detectors
- Segmented HPGe detectors

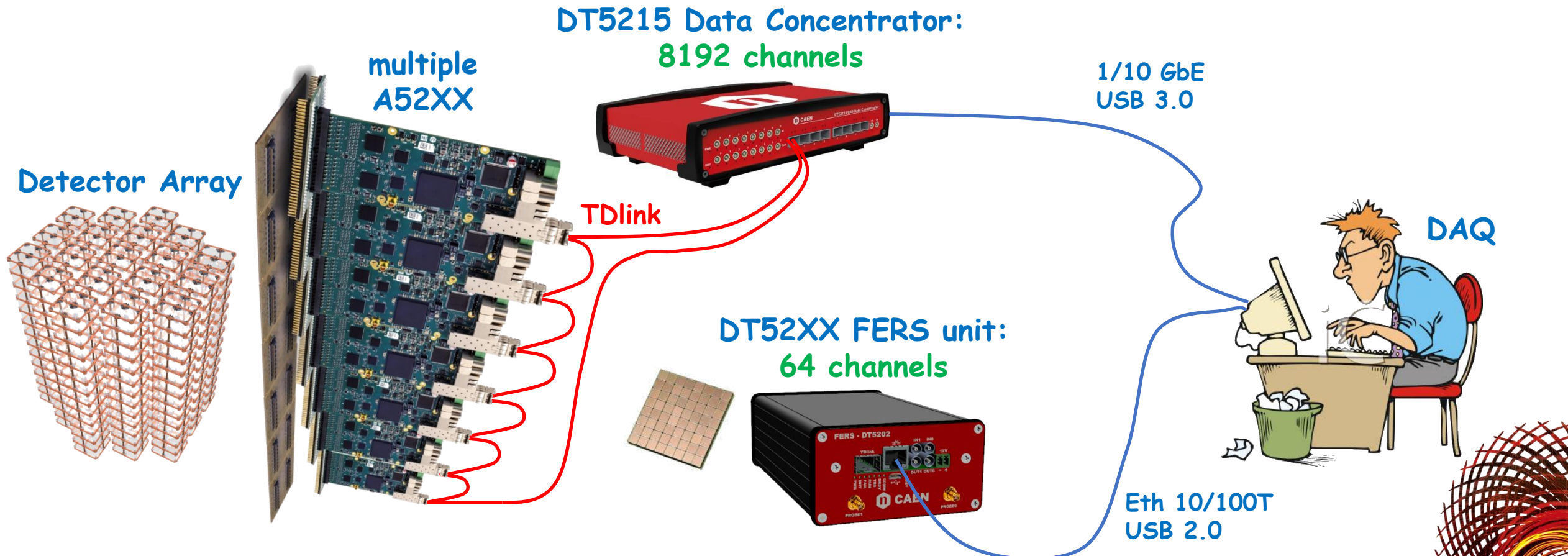
Same Infrastructure, different Front Ends

Quick integration of different ASICs



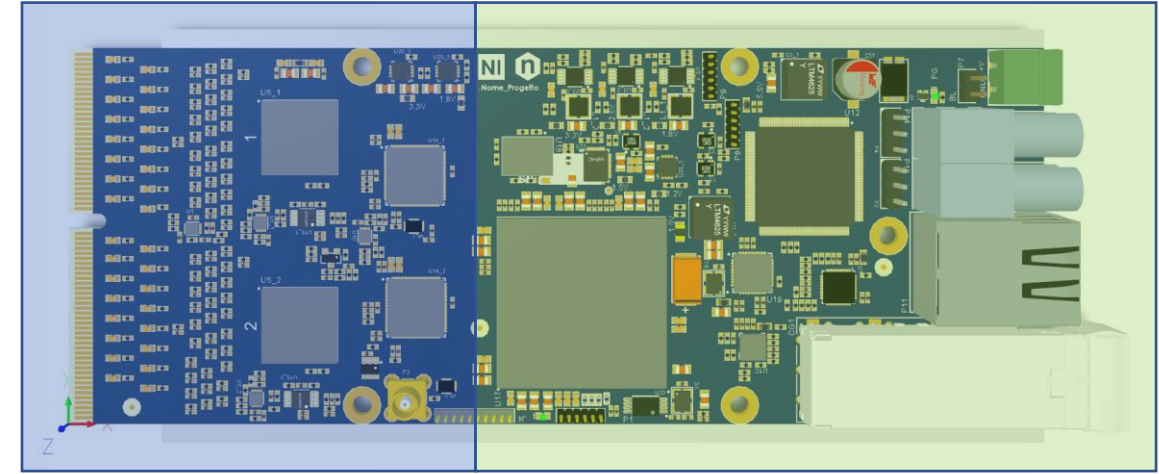
From evaluation to large experiments

- One FERS unit can be used stand-alone in a desktop form factor, directly connection to PC (USB or Ethernet). No additional hardware required!
- Naked FERS units can be arranged in custom backplanes/mechanics to build large systems, keeping the same user interface (SW, libraries, etc.) and the same electronics



FERS flavors (possible future implementations)

- **Citiroc:** SiPM Spectroscopy (Weeroc)
- **Petiroc:** SiPM timing (Weeroc)
- **Maroc:** MA-PMT (Weeroc)
- **Skiroc:** Silicon Detector (Weeroc)
- **Gemroc:** Gem Detector (Weeroc)
- **VMM3:** Micromegas, Gem (BNL)
- **Sampic:** 10 GS/s SCA waveform digitizer and ps TDC (LaL)
- **AARDVARC / ASOC:** 13 GS/s and 3.2 GS/s SCA waveform digitizer and ps TDC (Nalu Scientific)
- **picoTDC:** 5 ps TDC (CERN)
- **Hybrid Solutions:** FE in separate box, plug-in FERS with flash ADCs (e.g. 16 channel, 100 MS/s, 14 bit)
 - **A1442:** 16/32 channel preamp for Silicon Strip Detectors
 - **PADIFF:** 32 channel preamp for Neutron Detector
 - Detached FE-ASIC for cryogenic applications



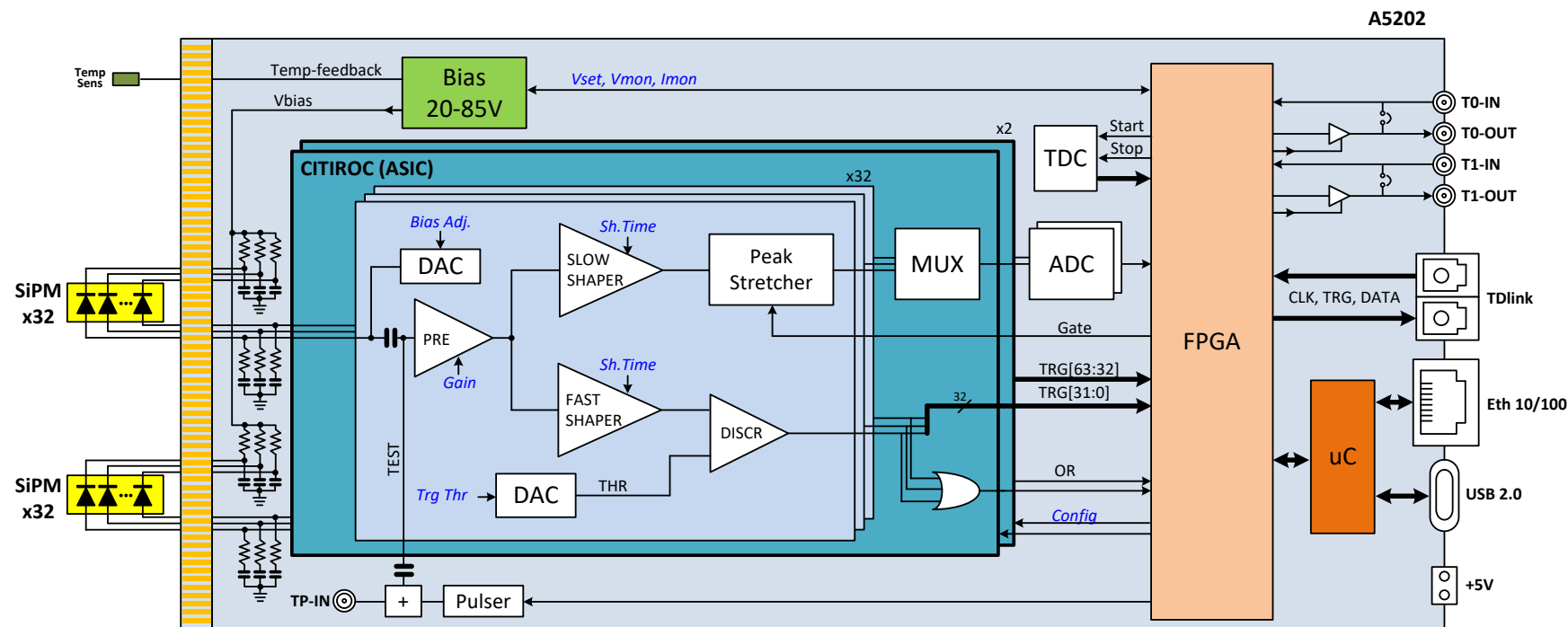
DETECTOR SPECIFIC

COMMON INFRASTRUCTURE

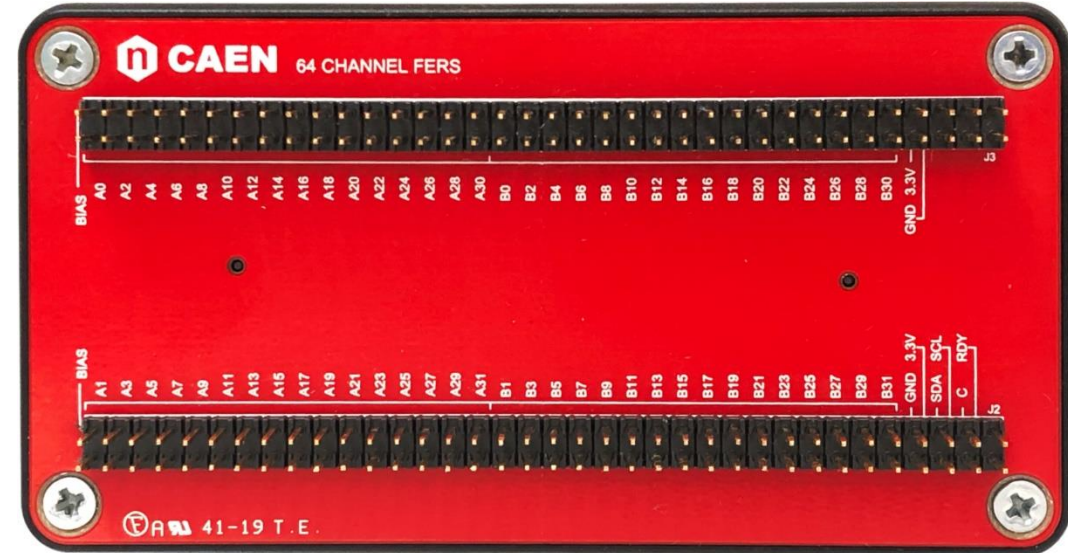


A5202: 64 channel SiPM readout (Citiroc 1A)

- Based on two ASICs **Citiroc 1A** (Weeroc): 64 channel SiPM readout
- Embedded HV bias (20-85V) with temperature feedback. Individual DACs for HV adjust (per channel)
- 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 rate counting (20 Mcps), Time stamping (0.5 ns) and ToT (low res PHA)
- 50 ps TDC for high resolution time stamping of OR trigger (to an external time reference signal)
- Acquisition modes: photon counting, spectroscopy mode (PHA), list mode (channel ID + Tstamp + ToT)



The image shows a red CAEN 64 Channel FERS module. It features a large black sensor array in the center, surrounded by a complex network of red circuit traces. The module is secured with four screws at the corners. On the right side, there is a P1 connector with a 2x8 pin configuration. The text "CAEN 64 CHANNEL FERS" is printed in white at the top left, and "19 T.E." is printed at the bottom left.



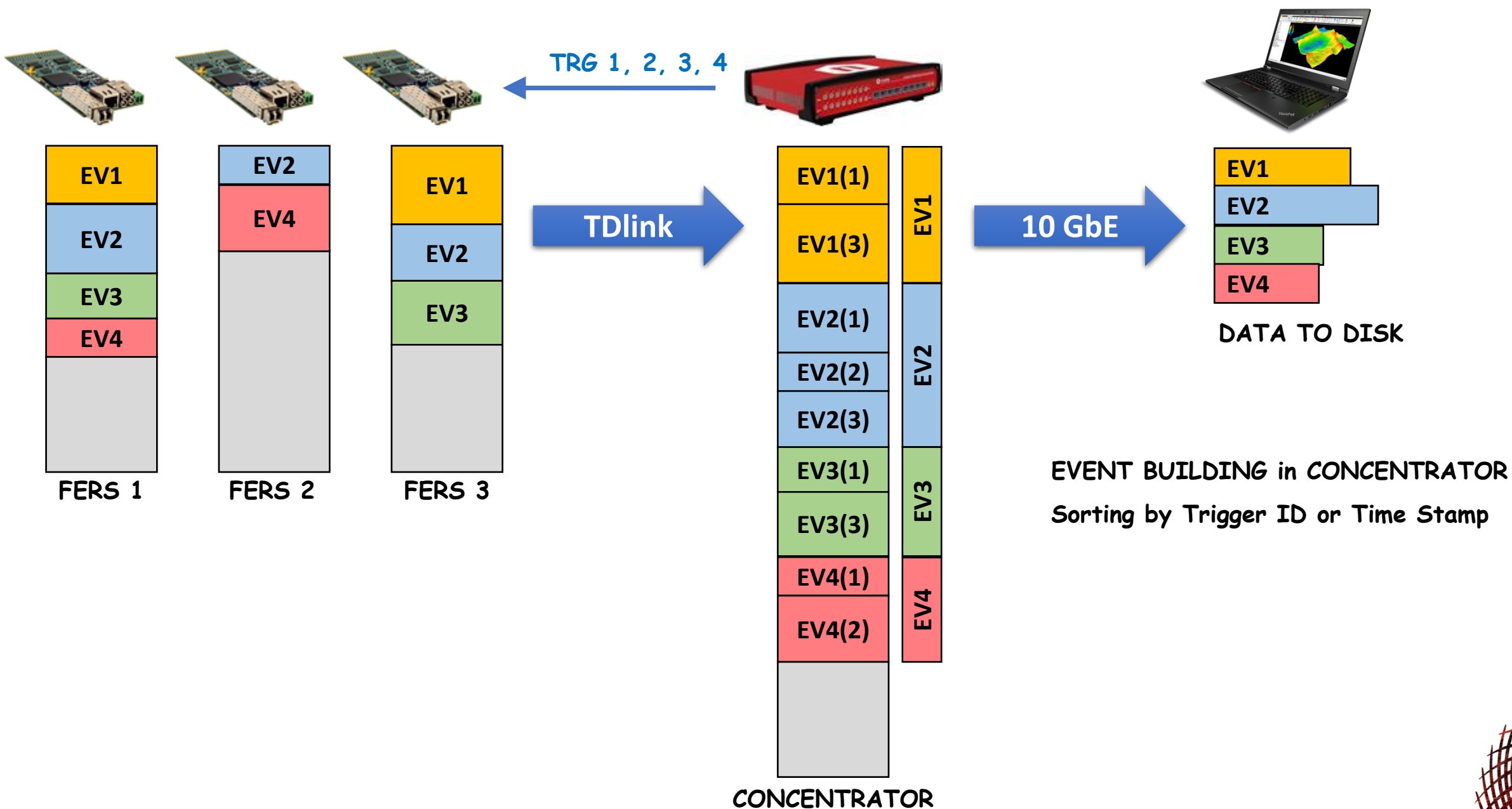
- **Spectroscopy Mode (PHA):**
 - A/D conversion of the pulse height (preamp + shaper + peak hold + mux + 14 bit ADC)
 - Common trigger (int. or ext.)
 - Zero suppression with programmable thresholds (read fired channels only)
 - Max trigger rate = 100 KHz (dead time = $\sim 10 \mu\text{s}$ per trigger)
- **Counting Mode** (e.g. photon counting in SiPMs):
 - Counters fed by fast discriminator signals
 - Simultaneous latched at programmable time frames and saved to memory (MCS mode)
 - Counting rate up to $\sim 20 \text{ Mcps/ch}$
- **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 (T-ref signal from LEMO input)
 - Gating mode (coincidence with external gate)
 - Optionally, **ToT** (0.5 ns) provided for low resolution PHA: Charge Resolution = 1.5%
 - Max total hit rate = $\sim 50 \text{ Mcps/board}$
- **Waveform Mode:**
 - Signal inspection: mux output waveform and control signals



- **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**
 - Triggers produce formatted data packets in the FERS units. Little local data buffering.
 - Data Concentrator reads data fragments belonging to the same event from FERS units (using Tstamp or Trigger-ID)
 - **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
 - Data aggregated in small packets in FERS units, then bigger packets in Data Concentrator
 - 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

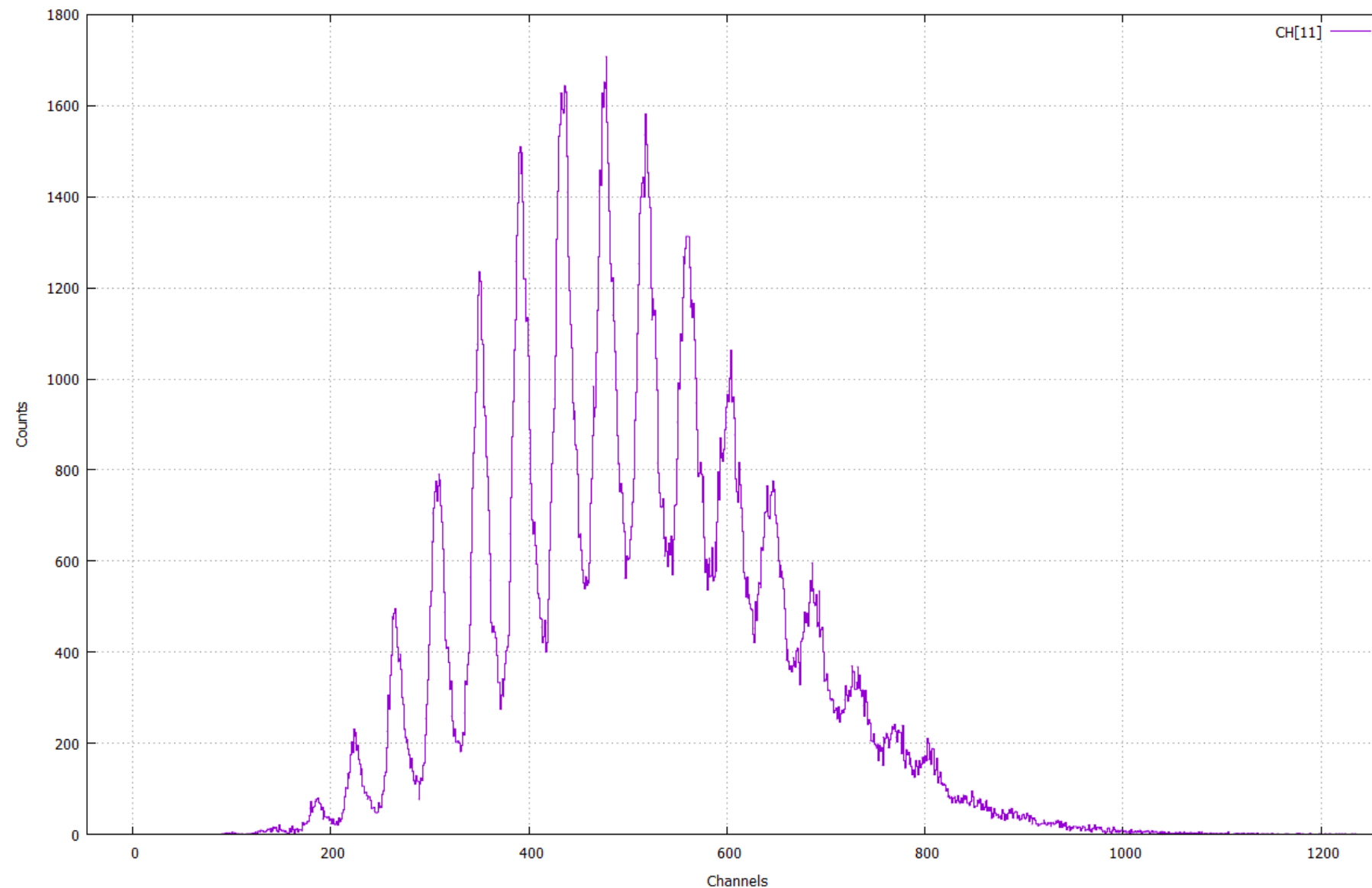


In-built sparse event readout



Some preliminary results with 8x8 SiPM matrix

High Gain Ch 11: Cnt = 363505, Mean = 509.26, Rms = 140.09



Spectroscopy Mode:

Single Photon Spectrum of Ch11

Matrix illuminated by LED pulser

Trigger from pulser

High Gain = 51

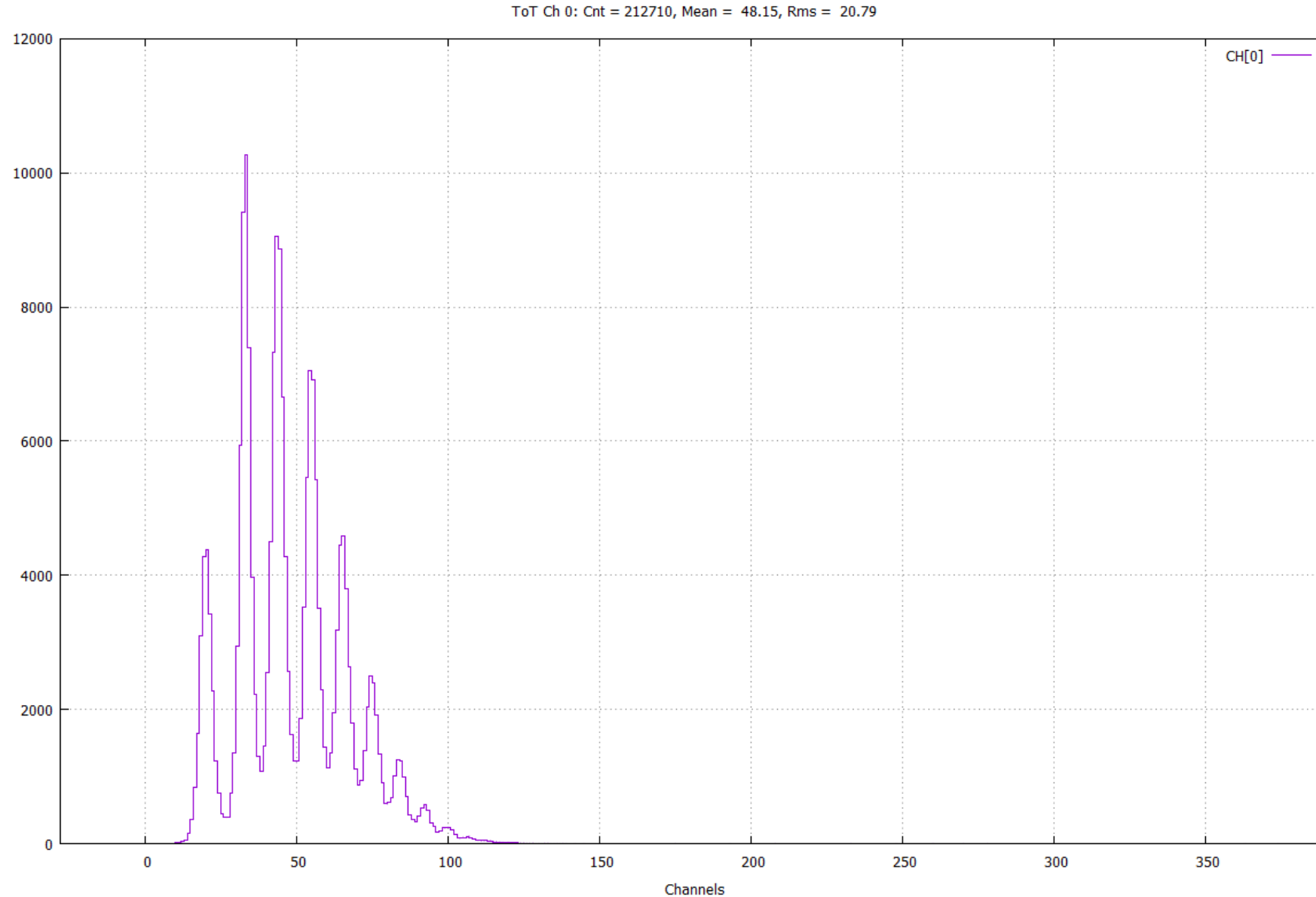
Shaping Time = 25 ns

HV Bias = 56 V

Matrix: hamamatsu S13361-3050AE-08



Some preliminary results with 8x8 SiPM matrix



Timing Mode (ToT):

Single Photon Spectrum of Ch0

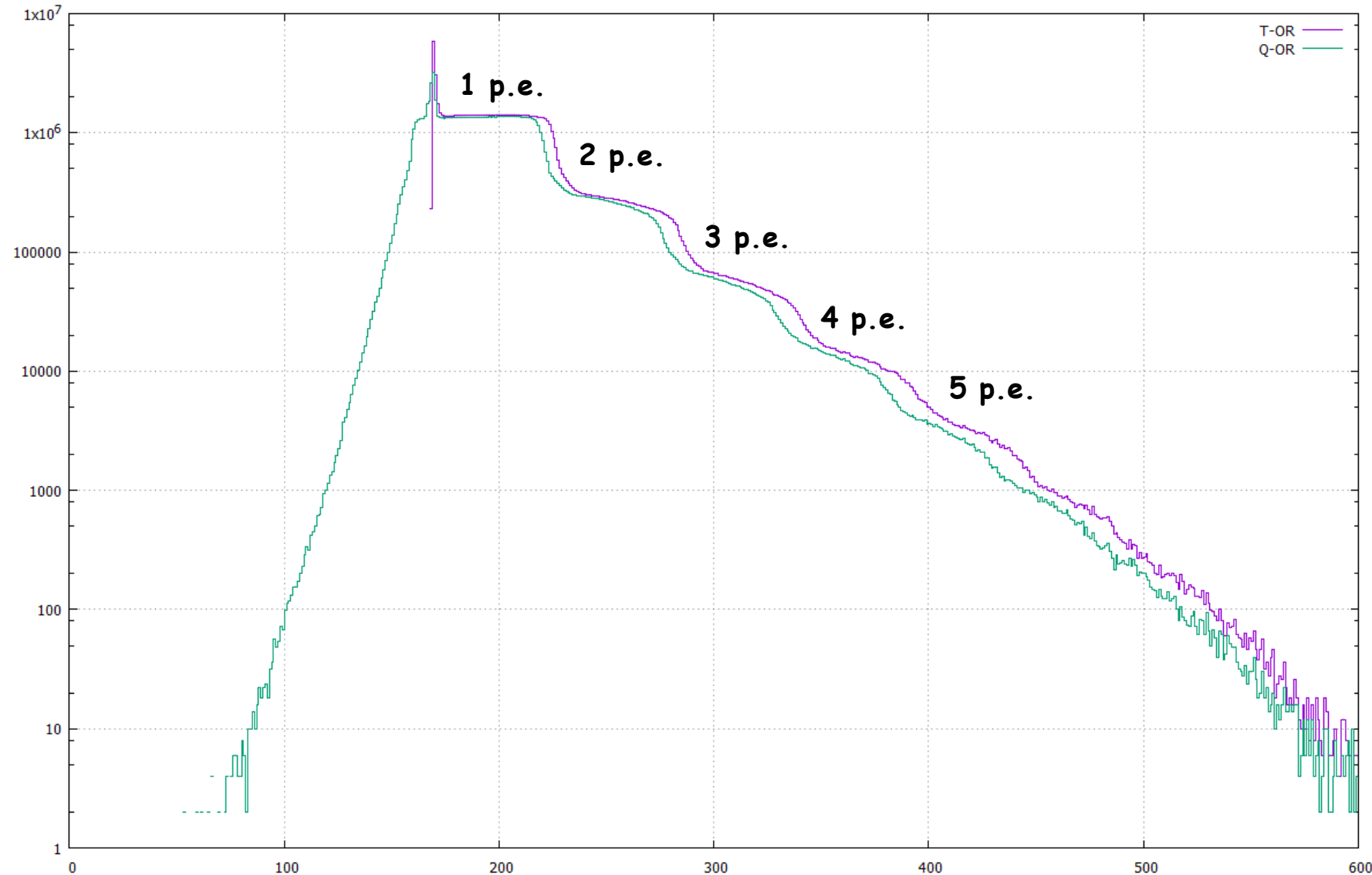
Matrix illuminated by LED pulser

Trigger from internal discriminator

Matrix: hamamatsu S13361-3050AE-08



Some preliminary results with 8x8 SiPM matrix



Staircase:

Trigger rate vs Threshold

T-OR = fast shaping discriminators

Q-OR = slow shaping discriminators

Matrix: hamamatsu S13361-3050AE-08





Thank You

