CAEN Digitizer setup in ePIC-Lab Irnerio

Riccardo Ricci[1], Edoardo Rovati[2]

[1]INFN Bologna

[2]University and INFN, Bologna

ALICE-ePIC meeting

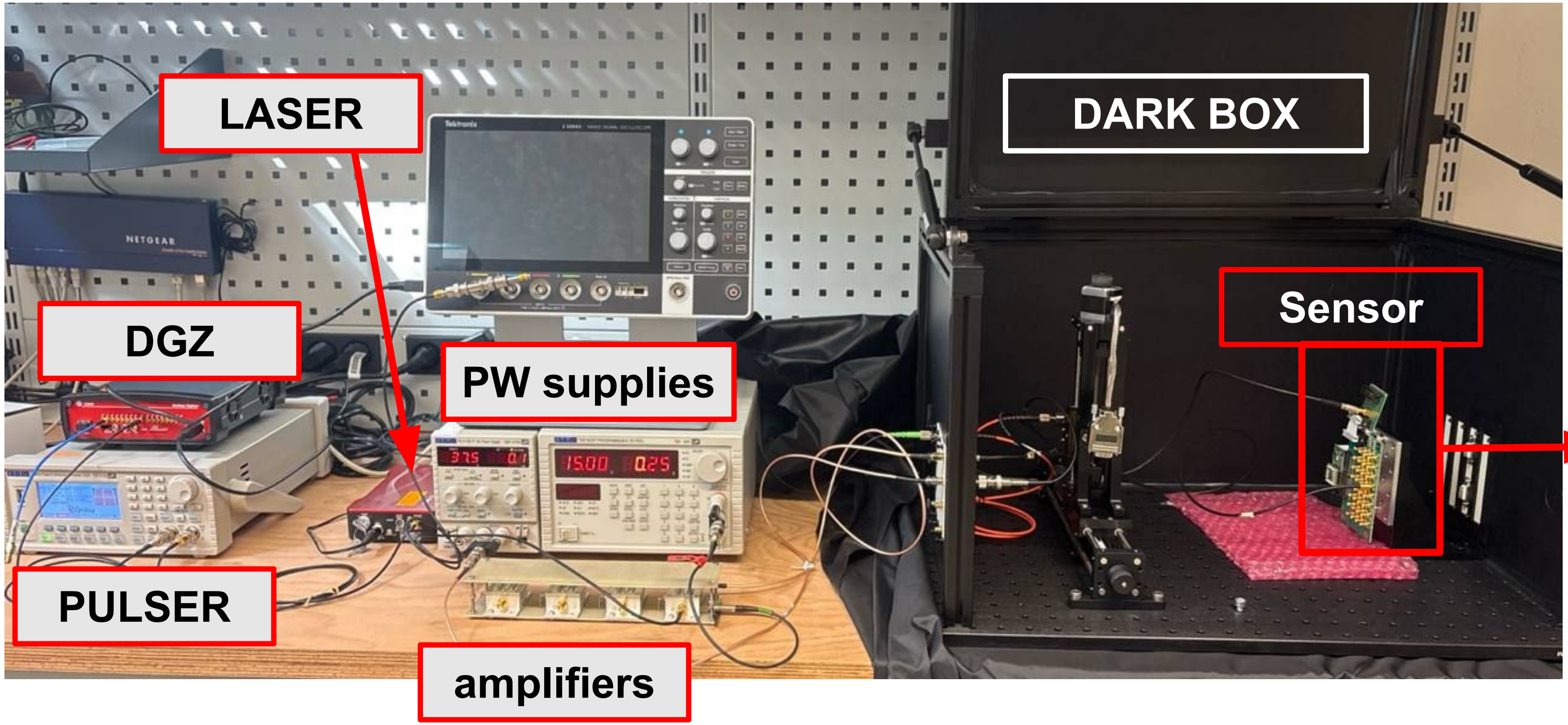
28/05/2025

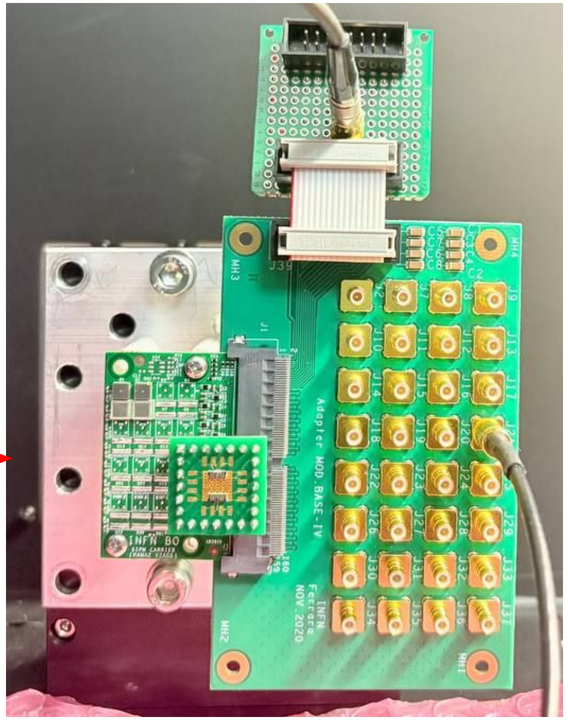
Resume - CAEN-DT572B

- A digitizer converts analog signals into digital data for processing and analysis
- The CAEN DT5742B is a 12-bit, 5 GS/s digitizer based on a DRS4 (Domino Ring Sampler) chip
- Designed for fast waveform acquisition, equipped with 16+1 channels for digitization (1 can be used as fast trigger) + **external trigger (NIM)**
- Light-weight solution which can become useful in different environments
- Full Scale Range: 1 Vpp
- It comes from CAEN with dedicated C Libraries
- Now in ePIC-Lab Irnerio

Riccardo Ricci | INFN Bologna

Setup





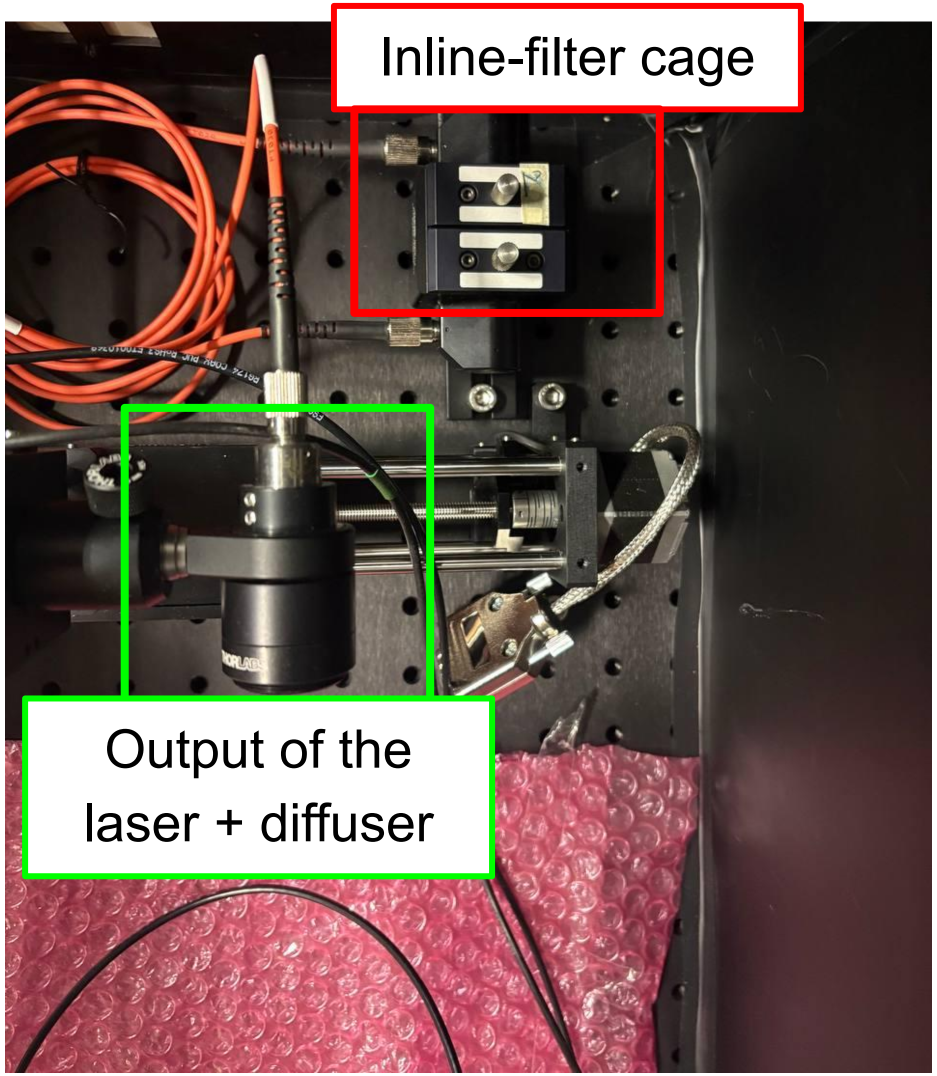
- CAEN Digitizer
- Pulser (provides NIM trg to the DGZ + trg to the laser)
- 2 pw supplies (providing bias and powering the amplifier)
- Amplifier (Mini-circuits ZFL1000LN+)
- Linux desktop PC → controls digitizer, pw supplies, pulser

DARK BOX:

- SiPM + carrier + adapter board
- Laser **GSL45A - 450 nm**

Laser & filter

Riccardo Ricci | INFN Bologna

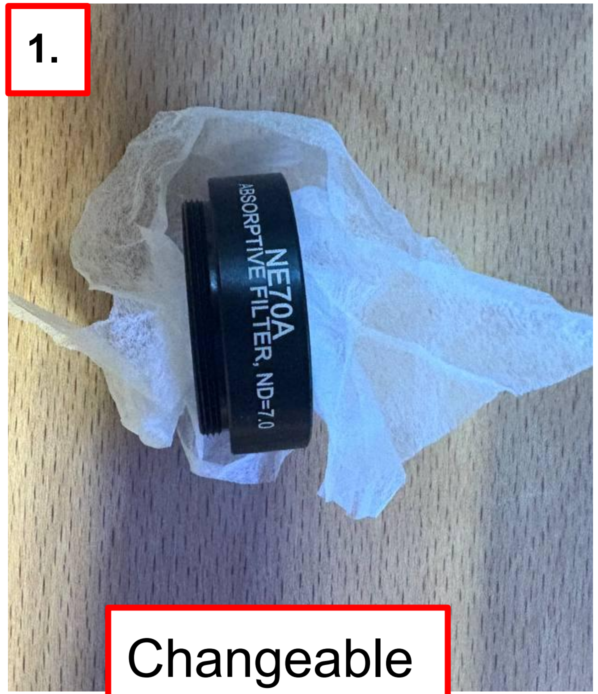


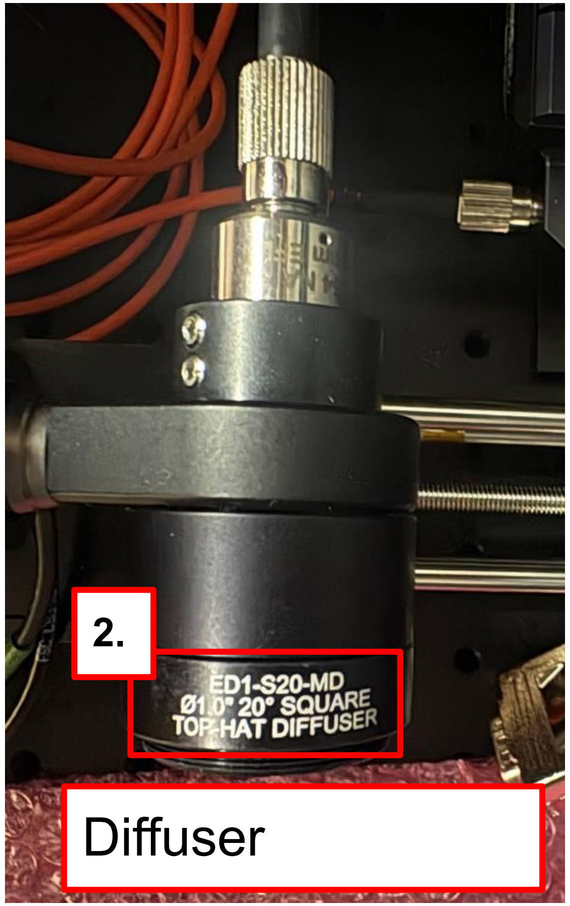
Thorlabs laser (class B) used in laboratory:

- 450±10 nm Gain-Switched Laser
- Repetition rates: 200 kHz-200 MHz
- Pulse duration < 90 ps

Laser & filter

1. NE70A (Thorlab) - Ø25 mm Absorptive ND Filter, SM1-Threaded Mount, Optical Density: [1.0 - 8.0]
2. ED1-S20-MD - Ø1" SM1-Mounted Polymer Engineered Diffuser, 20° Square Pattern



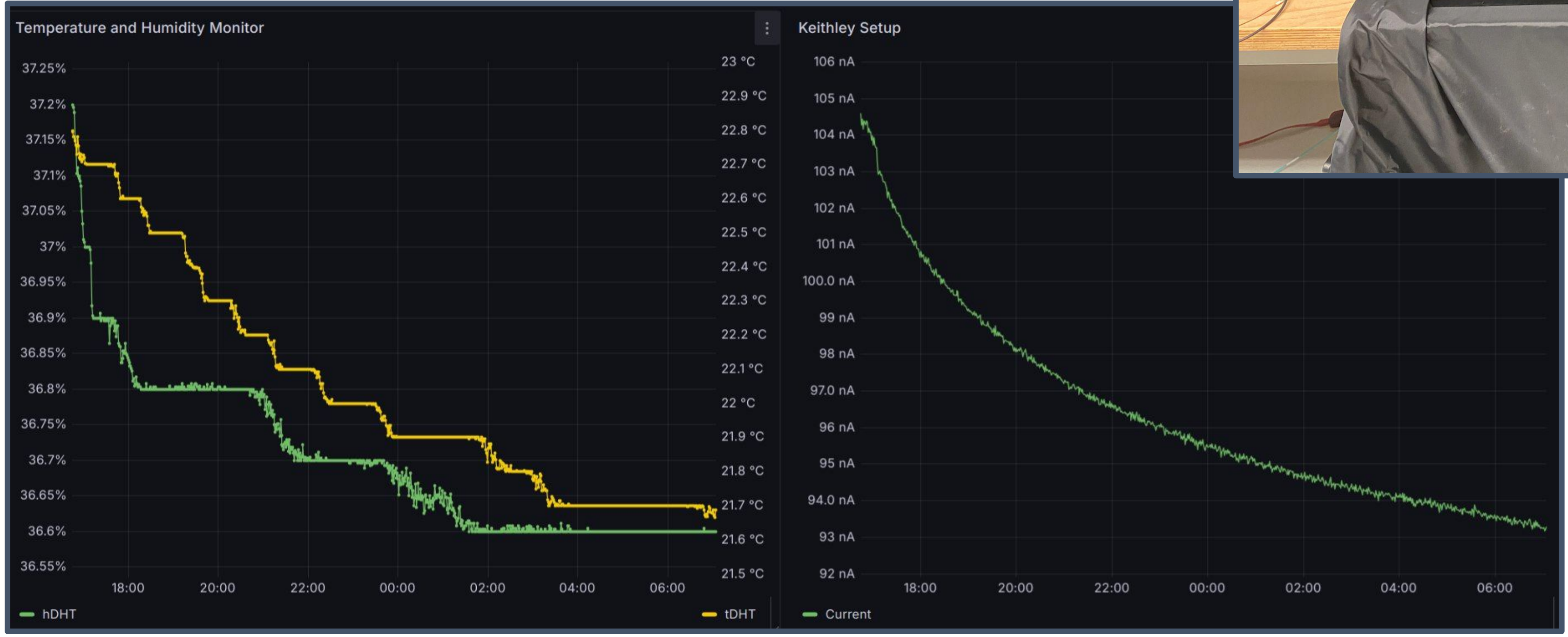


Dark box

- **Thorlabs XE25C11D -** Aluminum Enclosure with Hinged Door
- Not completely dark, needed some adjustments with black tape + black cloth
- SMA and light fiber port
- Contains: sensor+board, double-axis mover, laser system

Dark box

- **Thorlabs XE25C11D -** Aluminum Enclosure with Hinged Door and optical plane
- Not completely dark, needed some adjustments with black tape + black cloth
  → adjustments done monitoring the current variation during the night



Riccardo Ricci | INFN Bologna

Trigger system

- Pulser and CAEN DGZ both handled remotely by lab PC
- Trg provided by Pulser TGP3152
  → 200 kHz NIM signal from Pulser_CH1 to DGZ-NIM TRG (LEMO port)
  → 200 kHz 3 V signal from Pulser_CH1 to LASER

Trigger signals sync between the two channels is handled by pulser

DGZ-NIM TRG

PULSER

200 kHz NIM

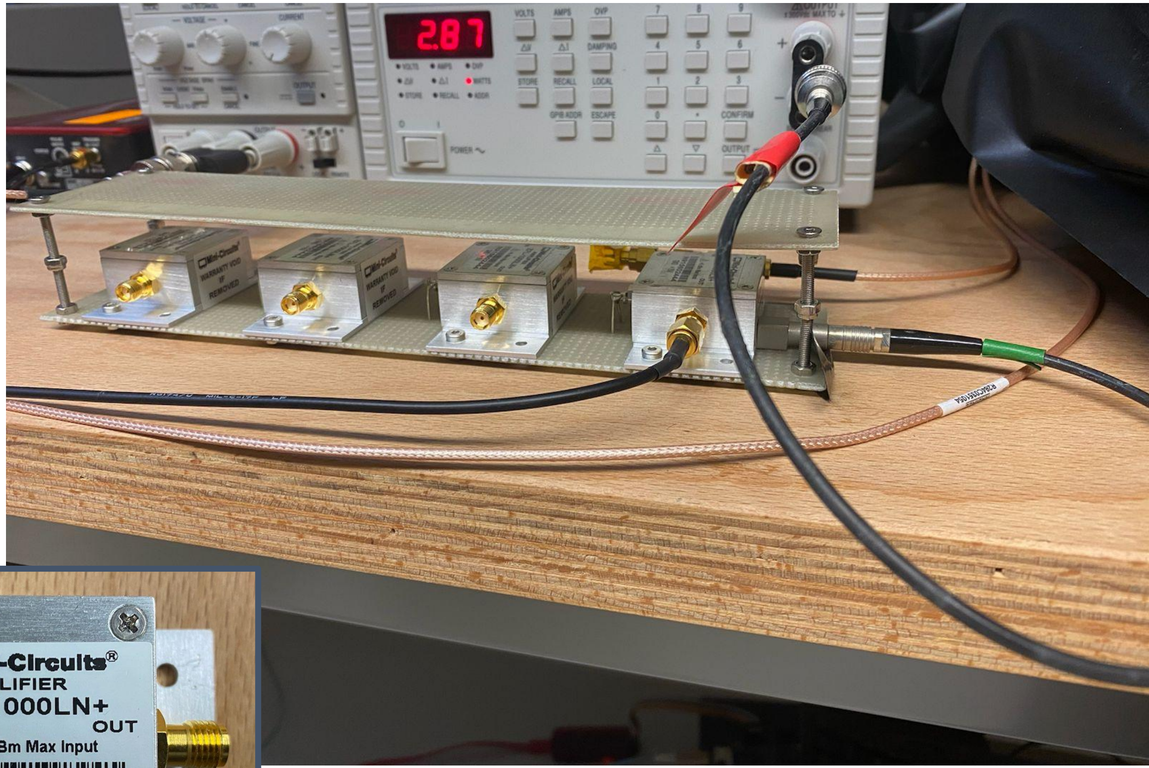
200 kHz 3 V

LASER

Signal amplification

- Amplifier: Mini-circuits ZFL-1000LN+
- Low-noise, operational range 0.1 - 1000 MHz
- Powering at 15 V
- Now using a prototype array (thanks Daniele!) providing 4 amplifiers in parallel, in a single structure

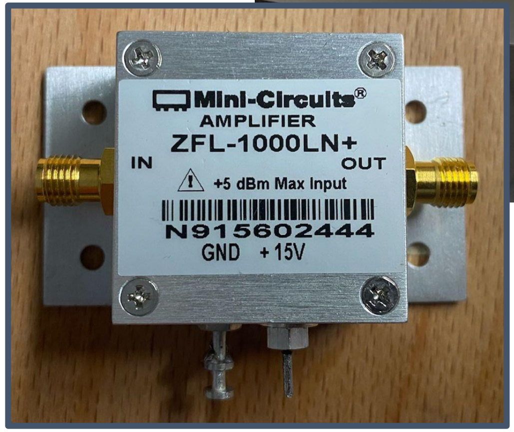
- full array available for future measurements with multiple channels at once



Maximum Ratings

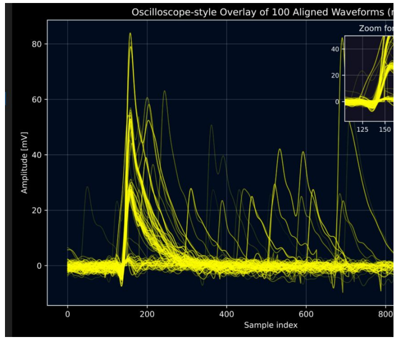
Parameter	Ratings
Operating Temperature	-20°C to 71°C
Storage Temperature	-55°C to 100°C
DC Voltage	17V
Input RF Power (no damage)	+5 dBm

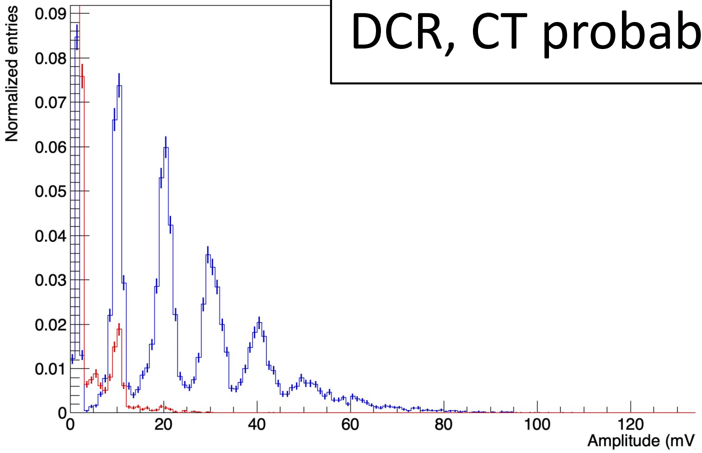
Permanent damage may occur if any of these limits are exceeded.



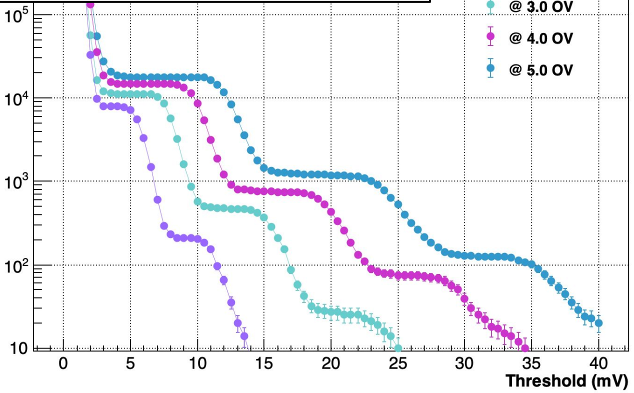
Data acquisition and analysis

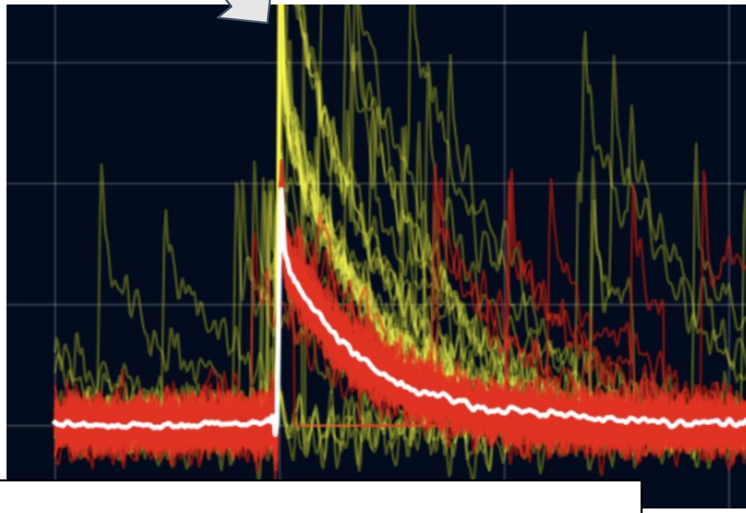
CAEN DGZ → Waveforms → Pre-processing → .npz files → ONLINE and OFFLINE analysis





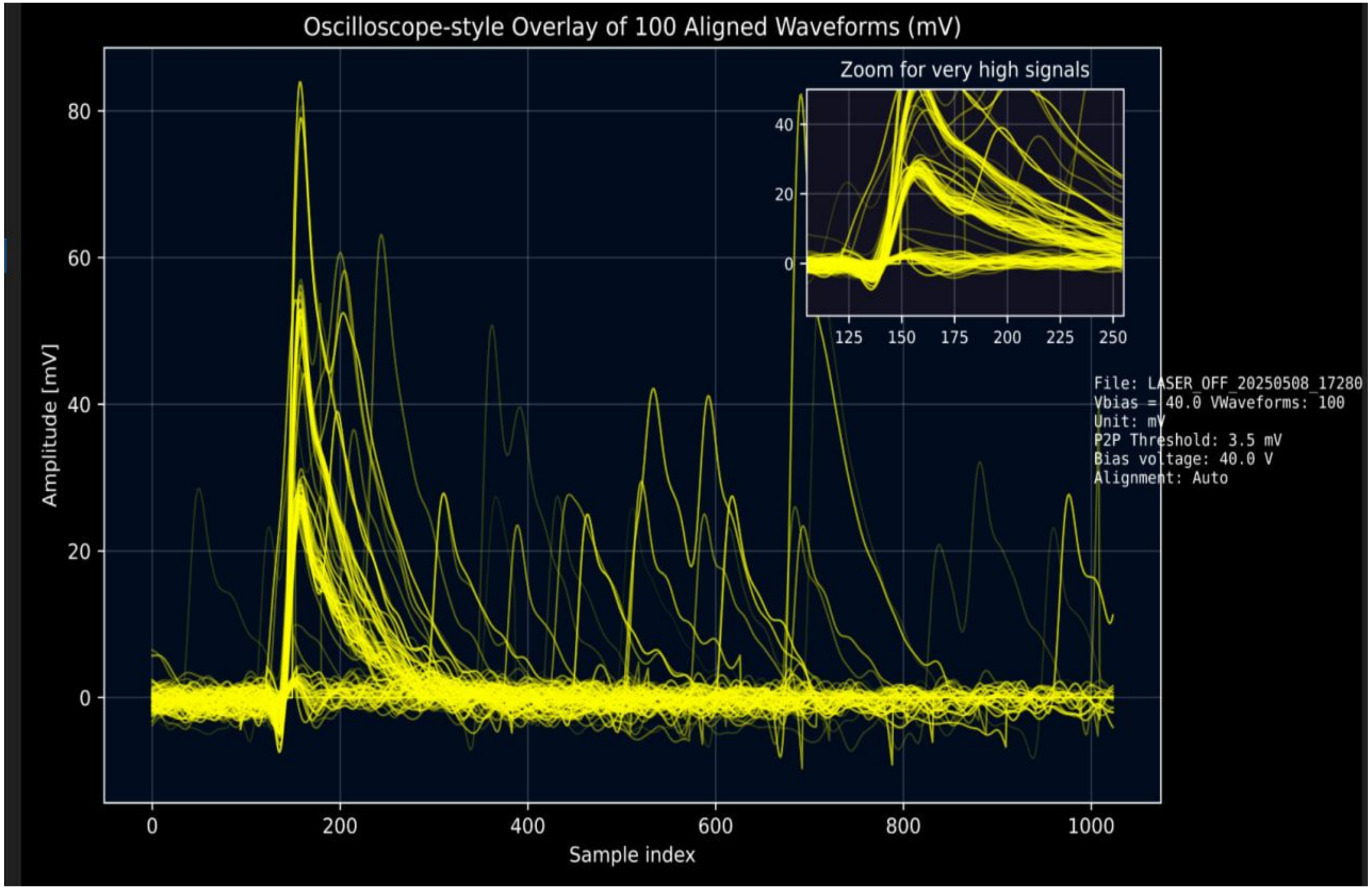
DCR, CT probability, amplitude...





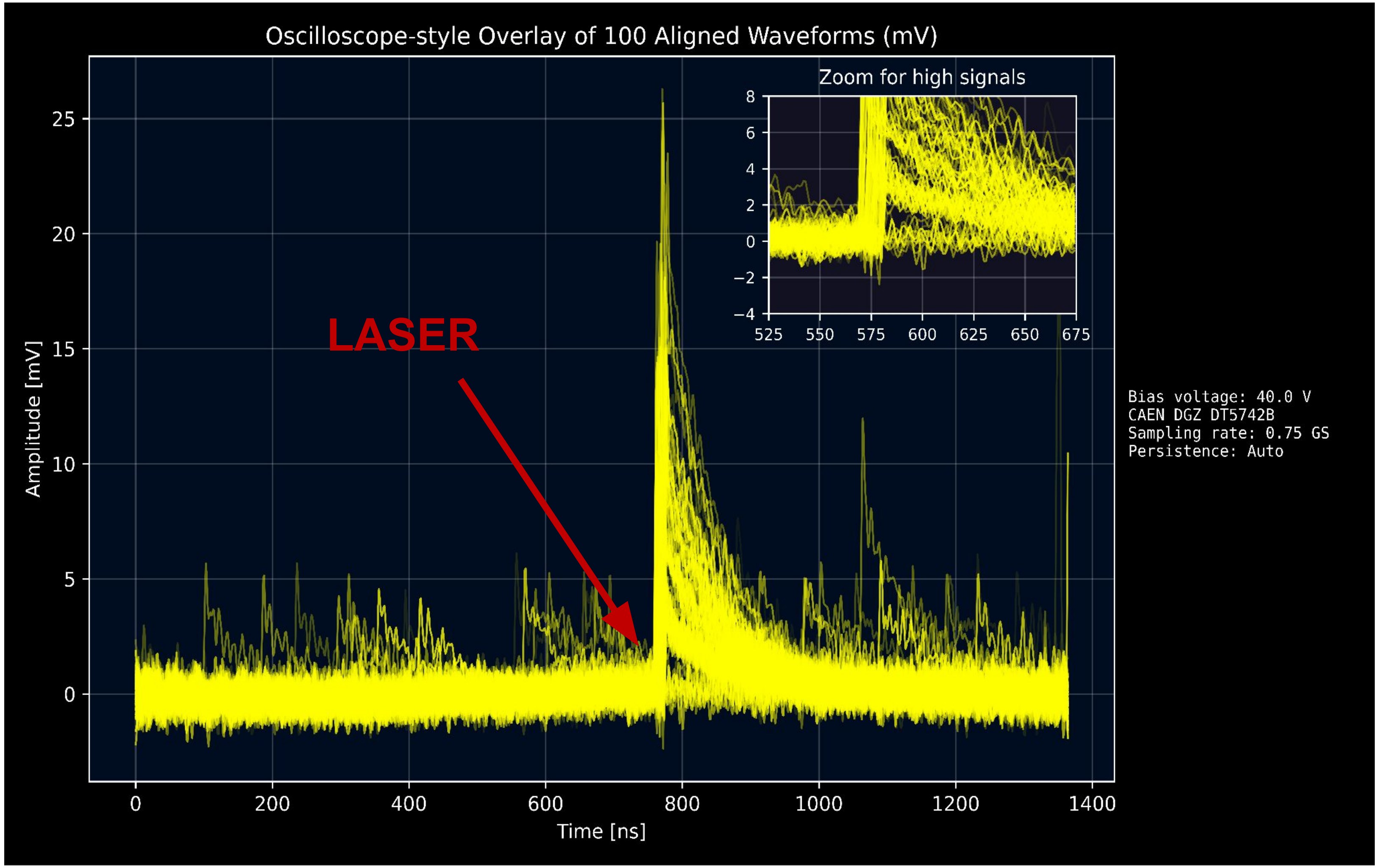
Signal visualization & analysis

Signal analysis with DGZ - persistence



- Only good waveforms selected (with p2p or threshold in amplitude)
- Peaks are identified and collected, then aligned at the rising edge
- to be perfectioned the individuation of the single-pe peak (needed for other analysis)

Signal analysis with DGZ - laser signal



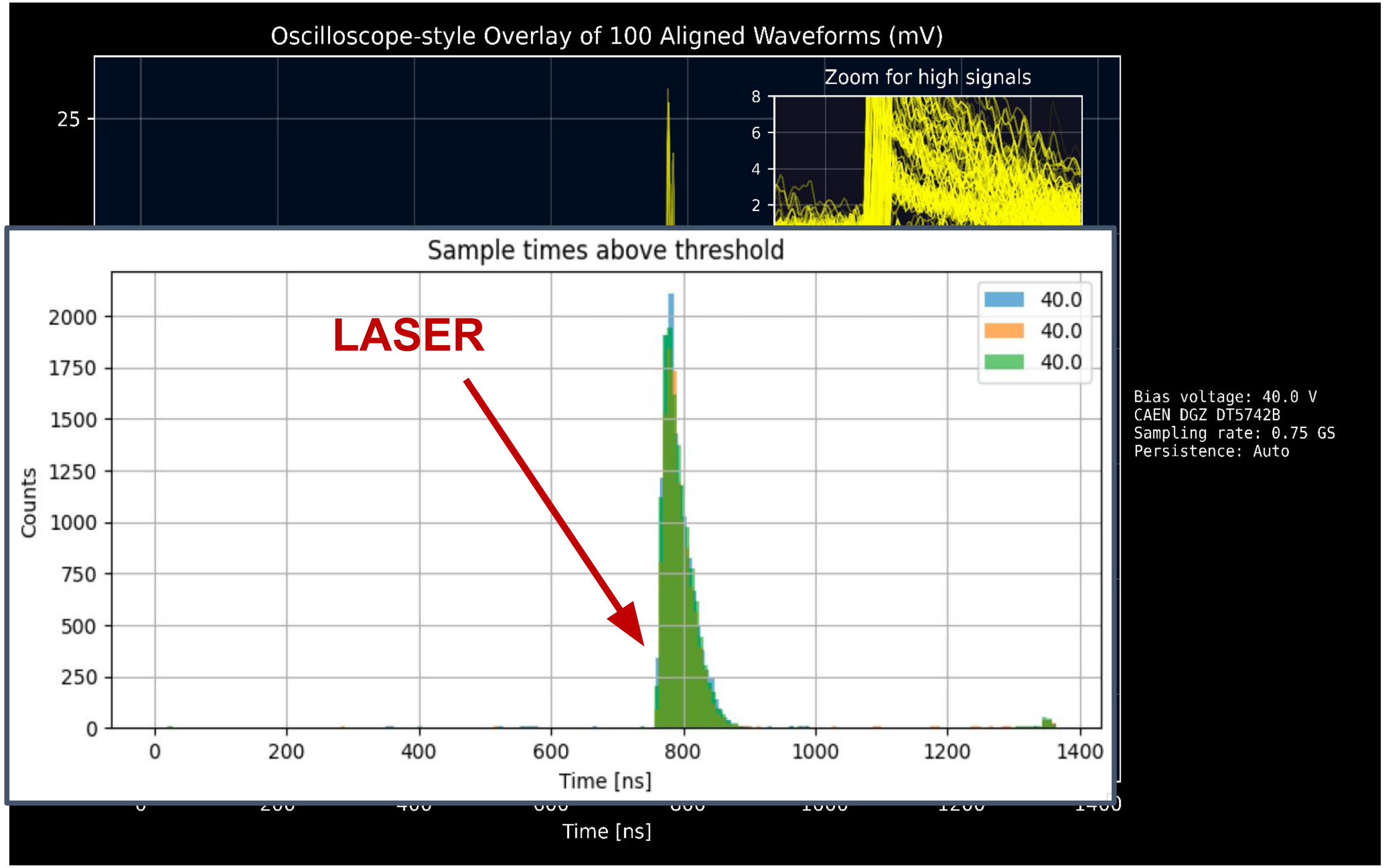
Pulser provides:

- NIM trigger to the DGZ
- trigger to the laser

Persistence is **auto-disabled** if a certain number of good signals (i.e. cluster of rising edges) is reached within a certain window wrt to the whole acquisition window

Laser signal has to be shifted accordingly (especially for shorter time-acquisition windows)

Signal analysis with DGZ - laser signal



Pulser provides:

- NIM trigger to the DGZ
- trigger to the laser
- channels alignment in time

Persistence is **auto-disabled** if a certain number of good signals (i.e. cluster of rising edges) is reached within a certain window wrt to the whole acquisition window

Laser signal has to be shifted accordingly (especially for shorter time-acquisition windows)

Summary and conclusions

Riccardo Ricci | INFN Bologna

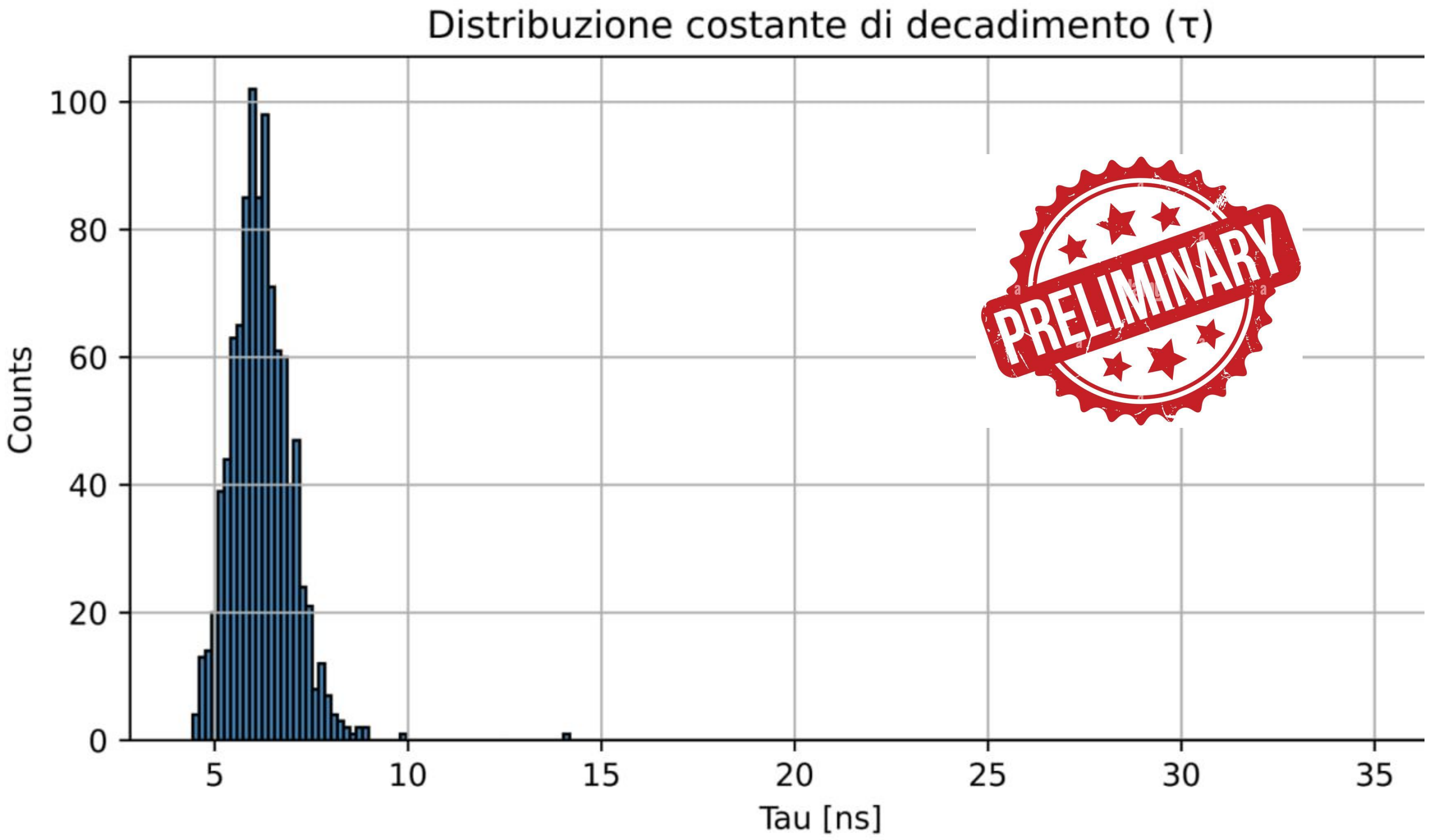
- CAEN Desktop Digitizer DT5742B now installed and operating in ePIC Lab Irnerio with dark box, laser setup and pulser-driven trg system
- Prepared an 4-amplifier array for future measurements with multiple channels at once
- The system now is equipped with a server to take/download data + first version of a **online** analysis framework (work in progress)
- First set of results shows the adaptability of this system for different kind of studies (still perfectioning)

Next steps:

- Finalize data with new Hamamatsu sensor (50 and 75 um - DCR, tau..)
- Studies with laser on/off
- studies with back-side illuminated SiPMs

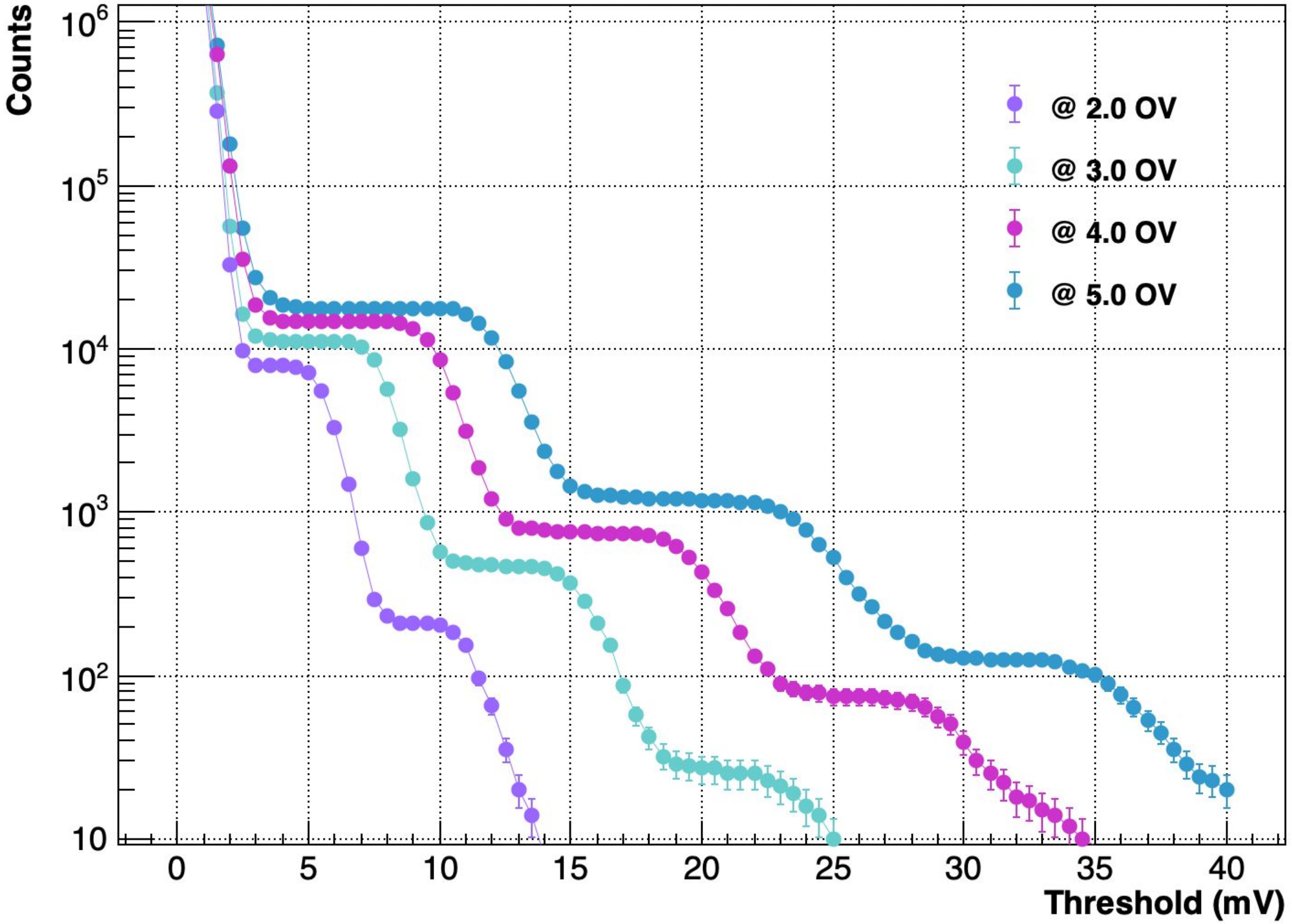
Backup

Measurement of the decay constant



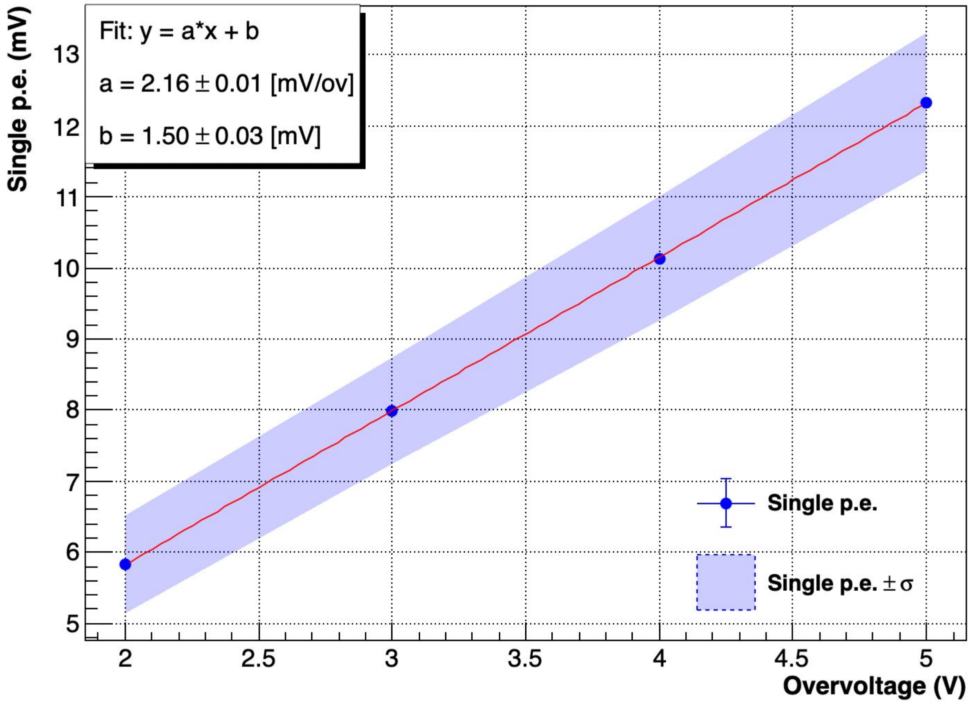
- Waveforms with good signals are fitted and tau+fit parameters extracted and saved
- Code has to be perfectioned to consider only signals from 1 photoelectron (WIP)

DCR measurements



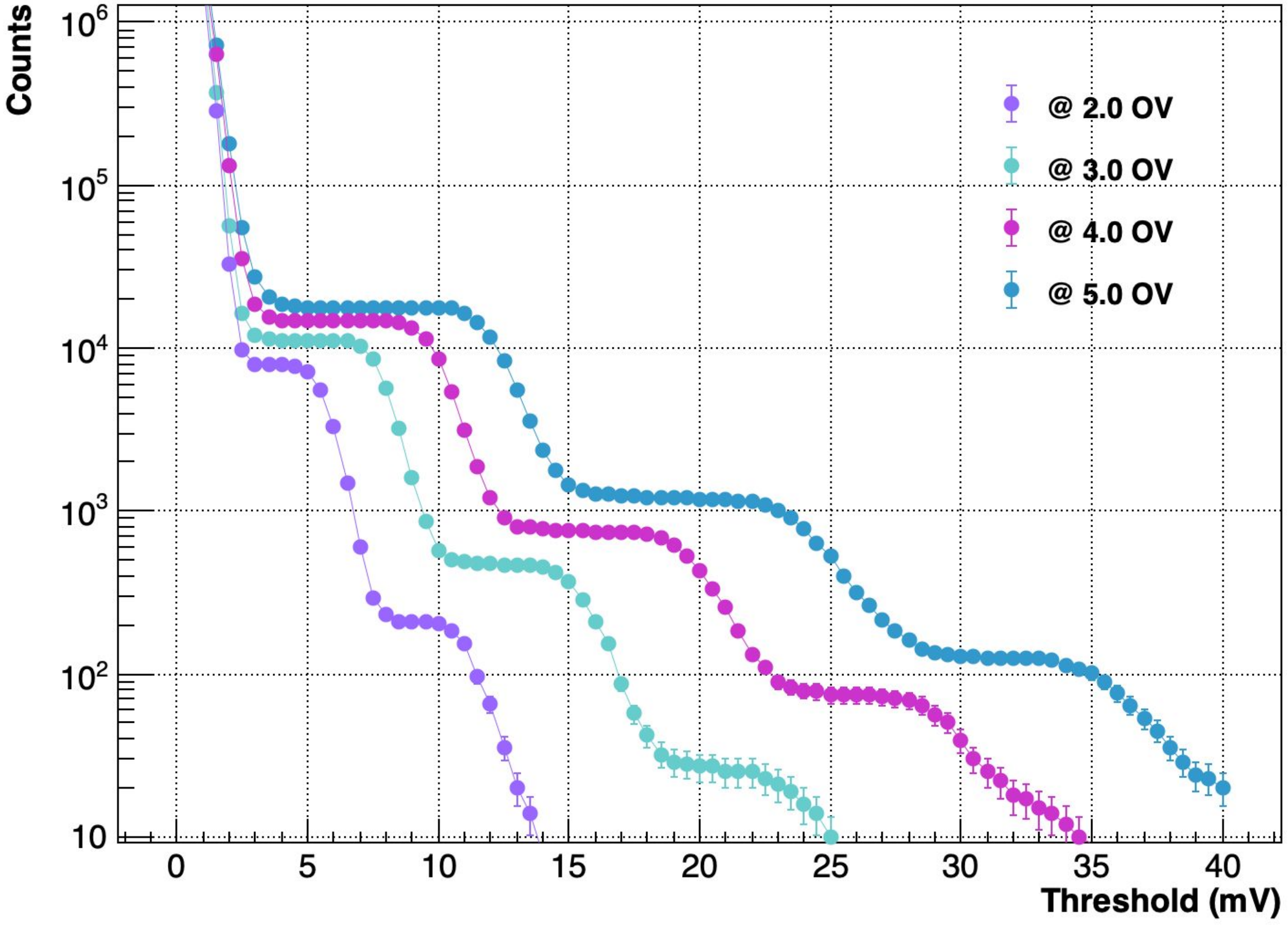
Using a recipe we are able to do **dark measurements**:

- Single SPAD values
- DCR values
- CT probabilities



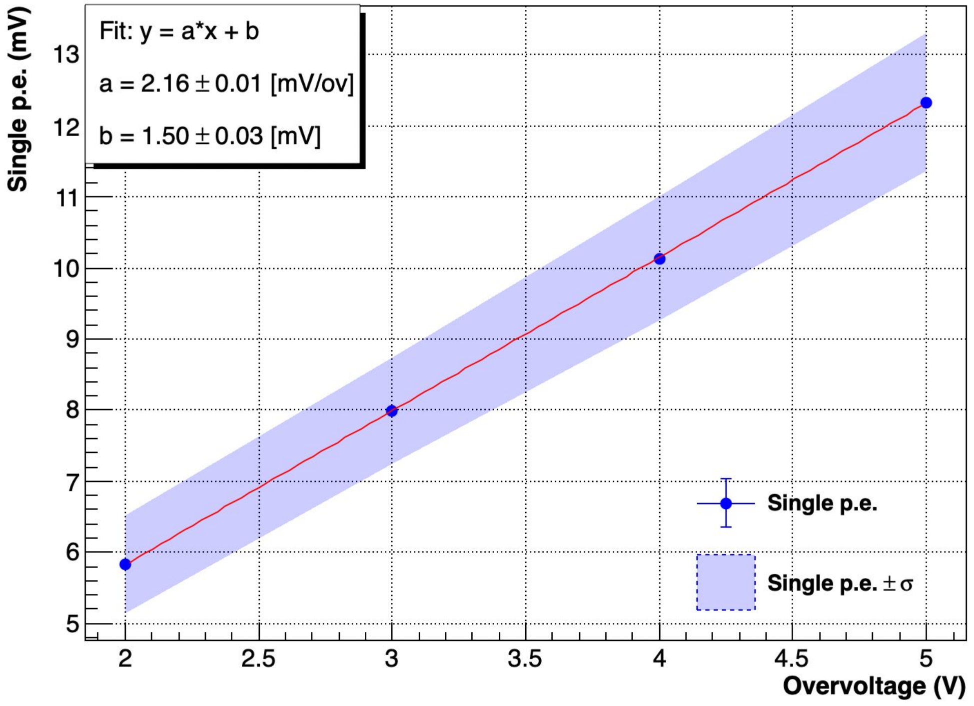
Riccardo Ricci | INFN Bologna

DCR measurements



Using a recipe we are able to do **dark measurements**:

- Single SPAD values
- DCR values
- CT probabilities



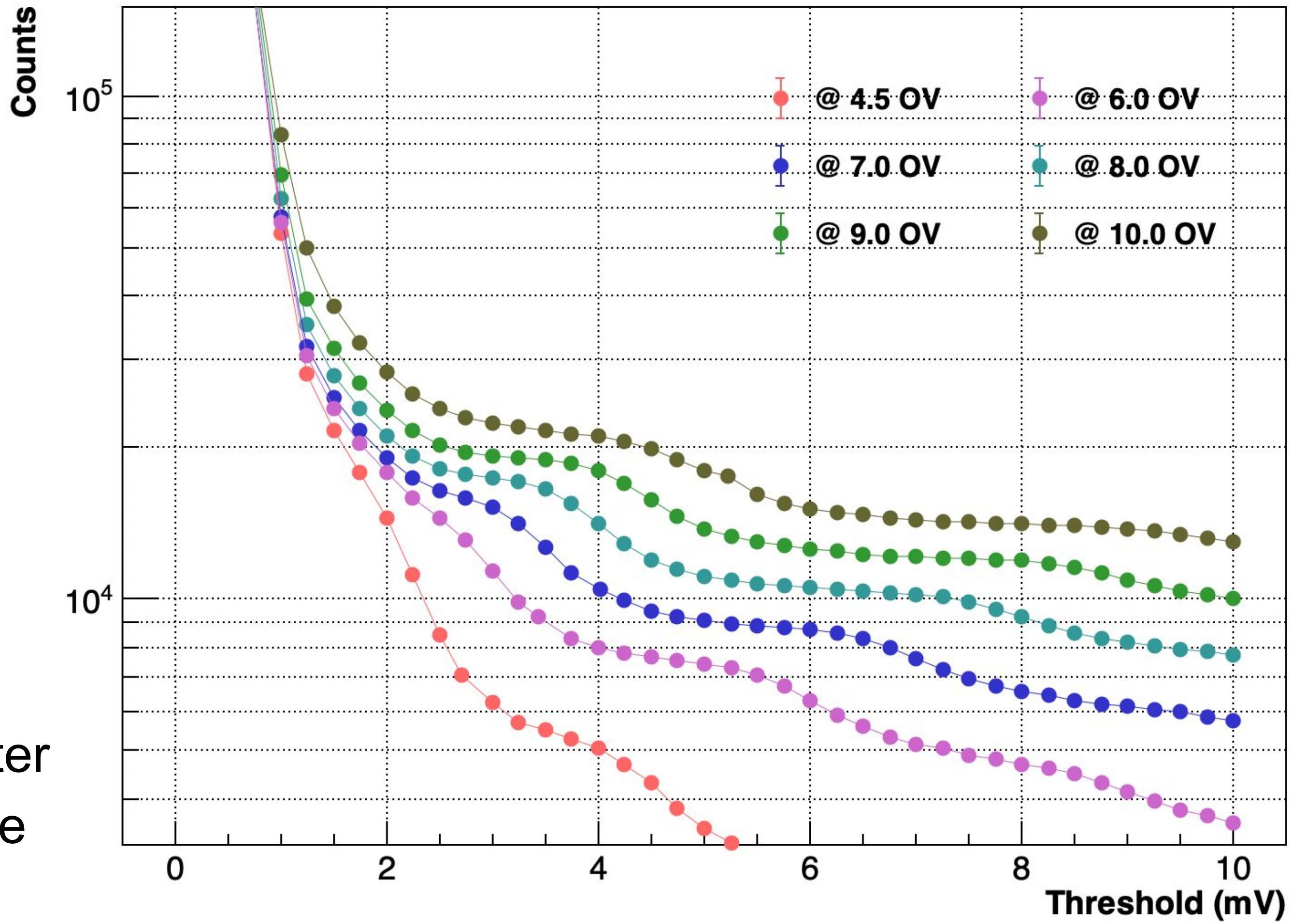
Riccardo Ricci | INFN Bologna

DCR measurements

We can test also BSI devices, taking into account that:

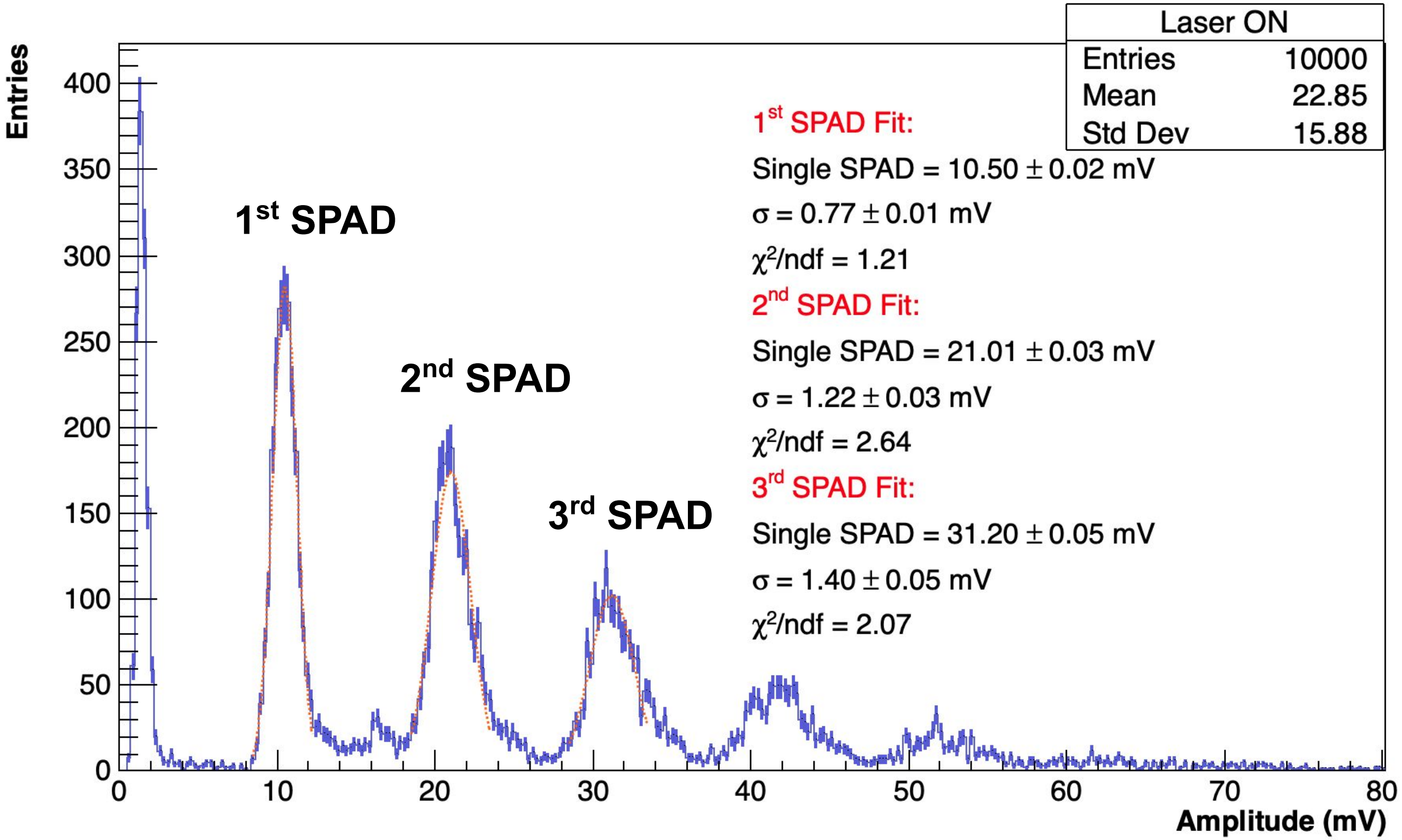
- BSI has very **small signal**
- **5-6 OV** required to “see” clearly a signal
- High OV = **high CT probability**

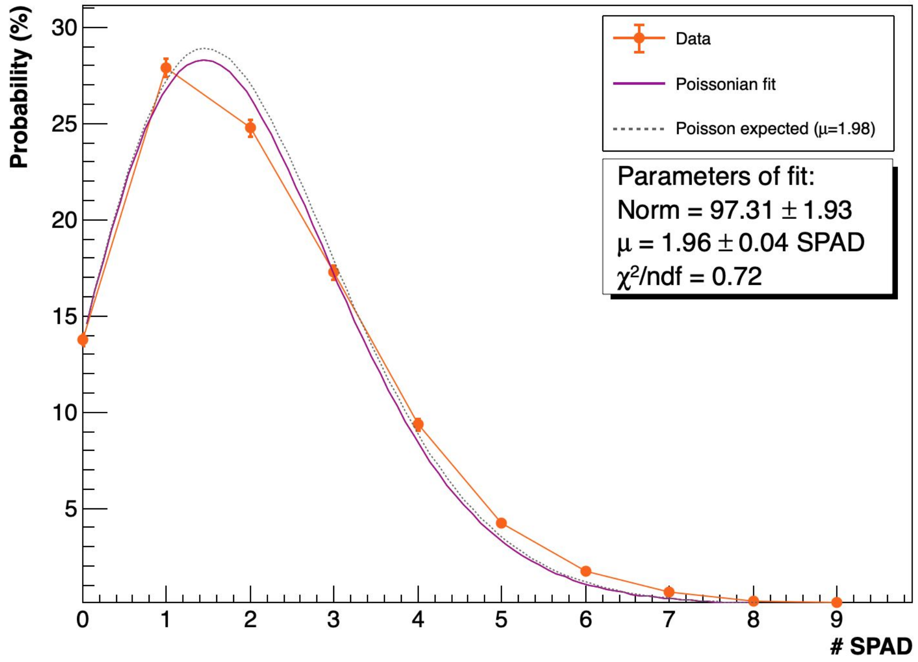
A possible solution is a low pass filter @20 MHz but it changes real amplitude



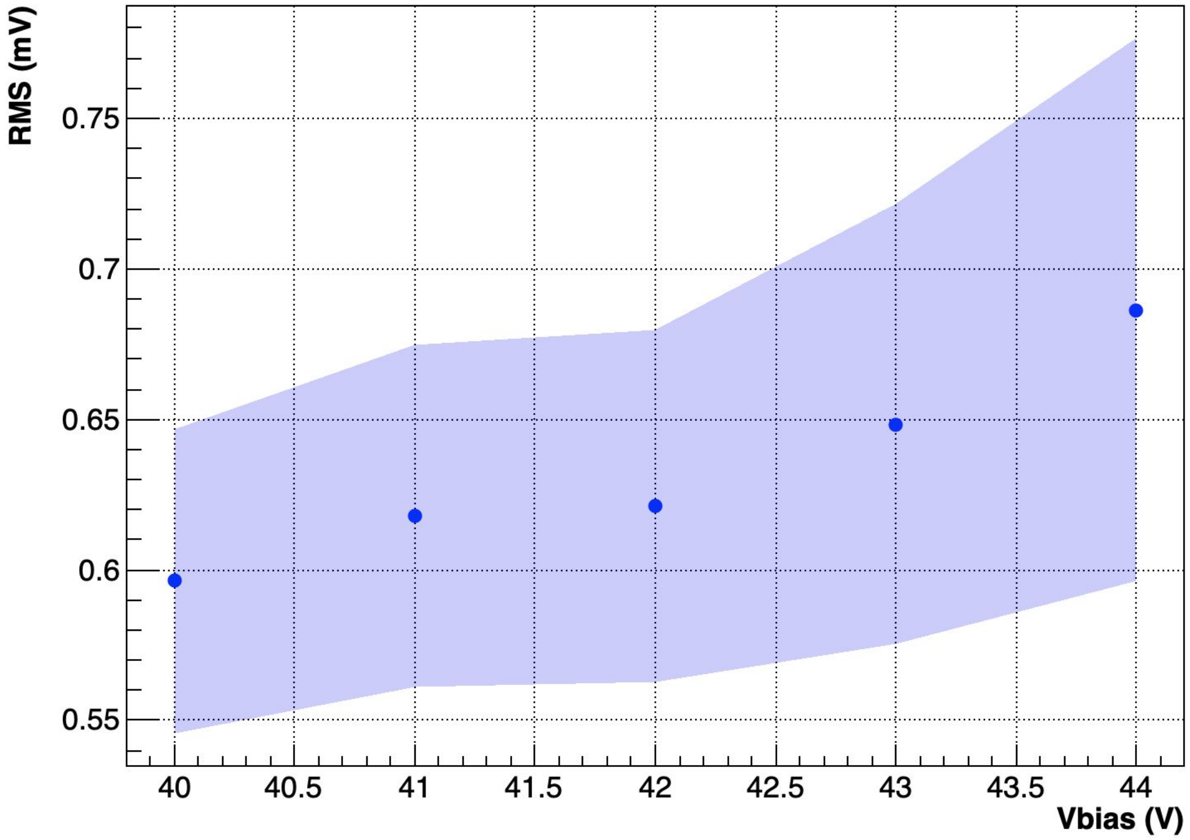
Preliminary laser measurements:

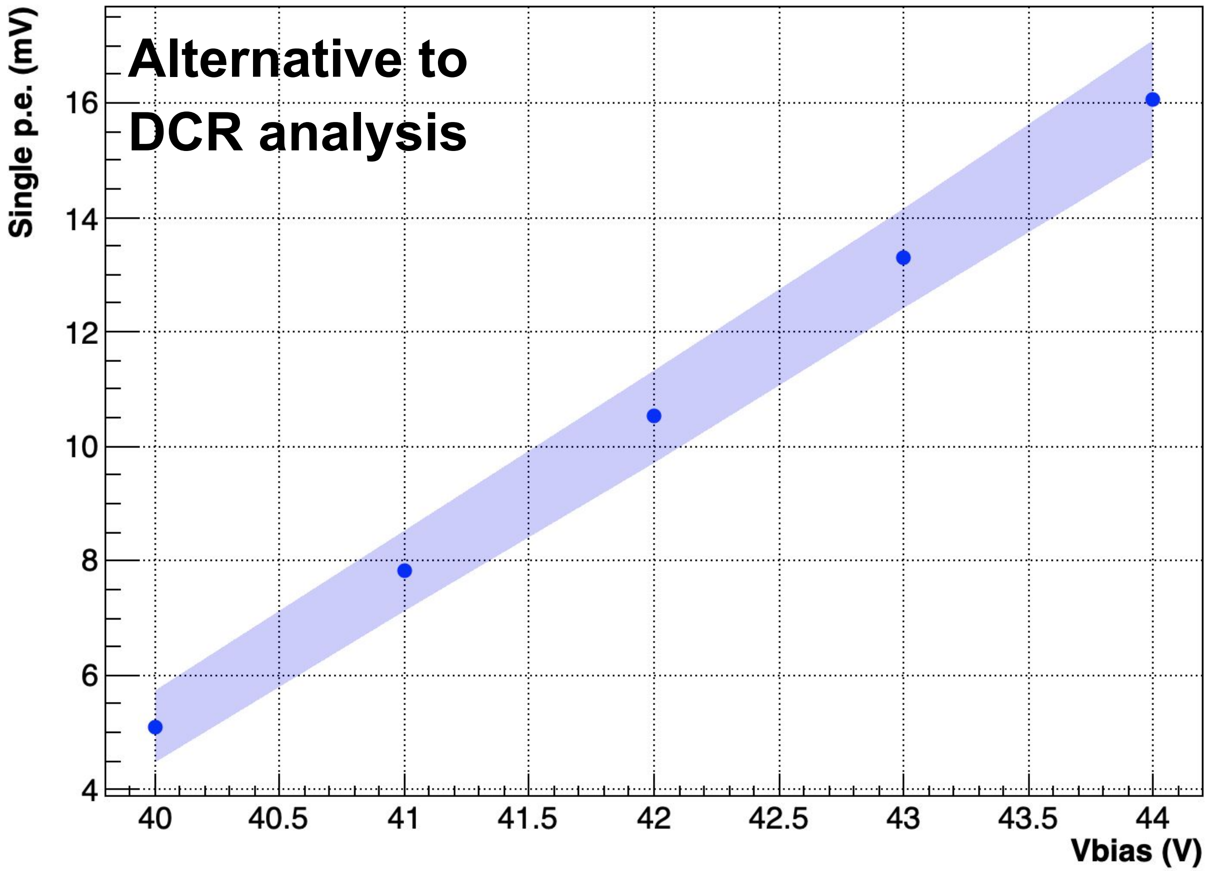
- Example with an Hamatsu sensors @42V
- measurements of amplitude distribution
- RMS + SNRs
- Poissonian distribution
- Integrated charge





Preliminary laser measurements





Introduction

- A digitizer converts analog signals into digital data for processing and analysis
- The CAEN DT5742B is a 12-bit, 5 GS/s digitizer based on a DRS4 (Domino Ring Sampler) chip
- Designed for fast waveform acquisition, equipped with 16+1 channels for digitization (1 can be used as fast trigger) + external trigger (NIM)
- Light-weight solution which can become useful in different environments
- Full Scale Range: 1 Vpp
- It comes from CAEN with dedicated C Libraries
- Now in ePIC-Lab Irnerio

DRS4 chip

- The DRS4 (Domino Ring Sampling 4) is the 4th generation of an ASIC chip designed for high-speed digitization of signals.
- Based on a **switched-capacitor array**, where analog voltages are temporarily stored in capacitors before being digitized.
- Each channel has **1024 storage cells** acting as a circular buffer. A fast sequence of write pulses allows the recording of analog waveforms in the capacitors at high frequency, which can later be read out and digitised via ADCs at a much lower speed
- Sampling speed up to **5 GS/s** (minimum 750 MS/s)
- Requires **calibration** to correct **non-uniformities** and **offsets** introduced by variations in capacitor properties and charge injection effects.

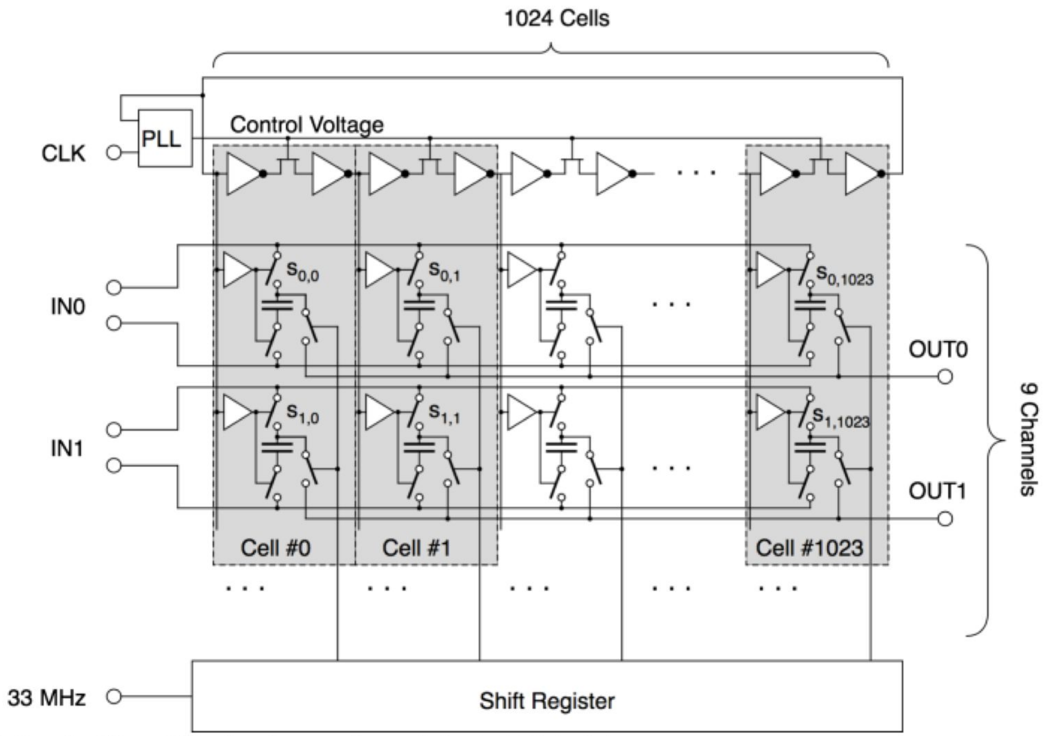
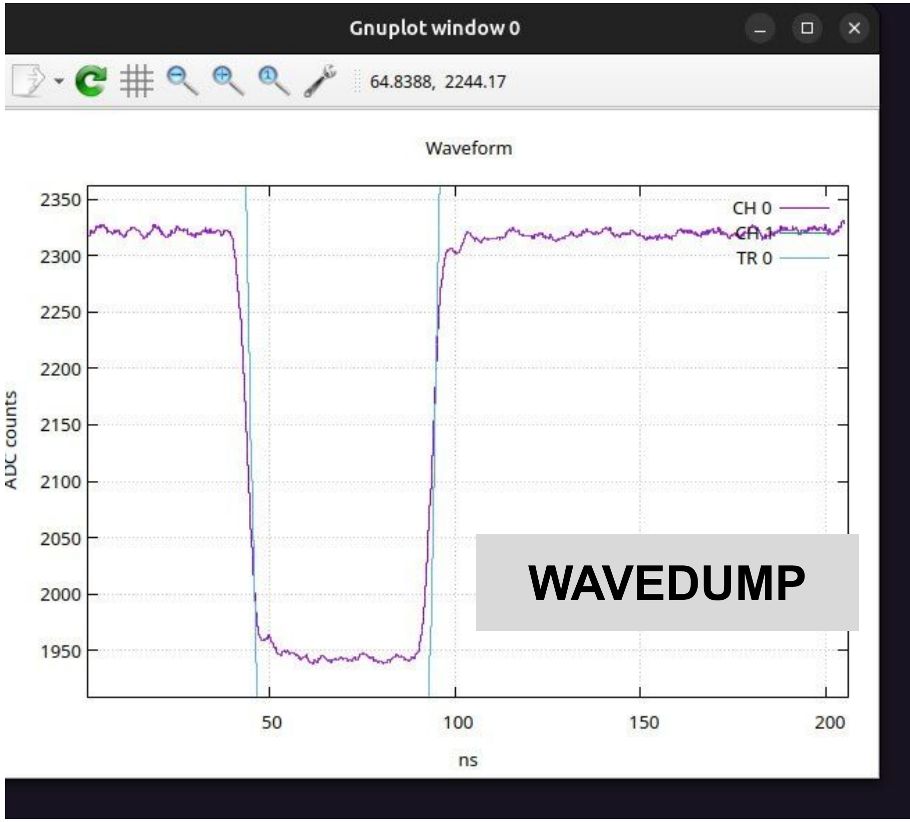


Fig. 1: Simplified schematics of the DRS4 chip.

Example setup and first tests

Minimal setup:

- CAEN Digitizer DT5742 (connected to Linux PC via USB)
- AimTTi 2-channel pulse generator
  (one ch connected as fast trigger*, the other ch as signal)
- Data visualization: CAEN *Wavedump* program to check if the DGZ was working properly

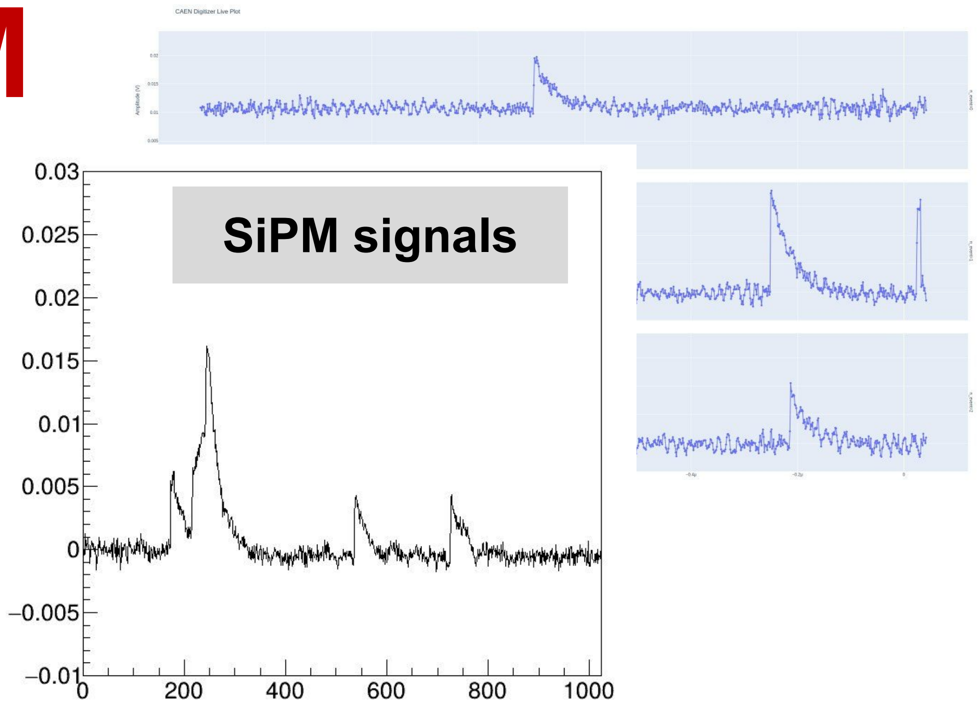


*trg channel which is also being digitized

First signal from a SiPM

SiPM setup:

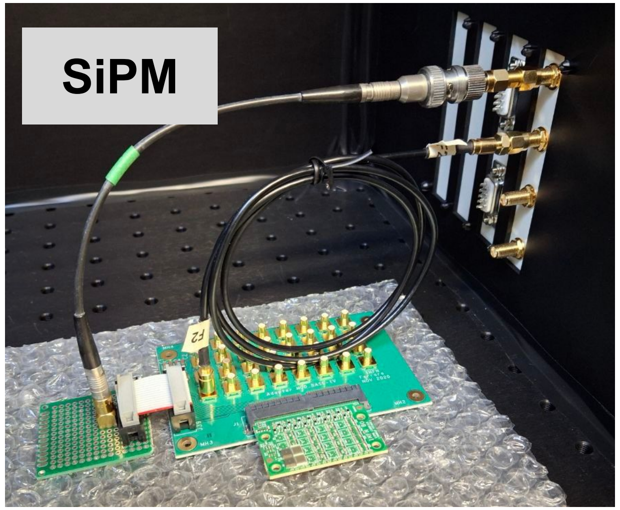
- CAEN Digitizer DT5742 (connected to Linux PC via USB)
- AimTTi 2-channel pulse generator to provide trigger signal*
- SiPM and related setup (AimTTi PW supplies to provide bias to the sensor an power to the amplifier)
- Data visualization: python code working with CAEN Libraries or a modified (rewritten version) of wavedump



Pulser

+

SiPM



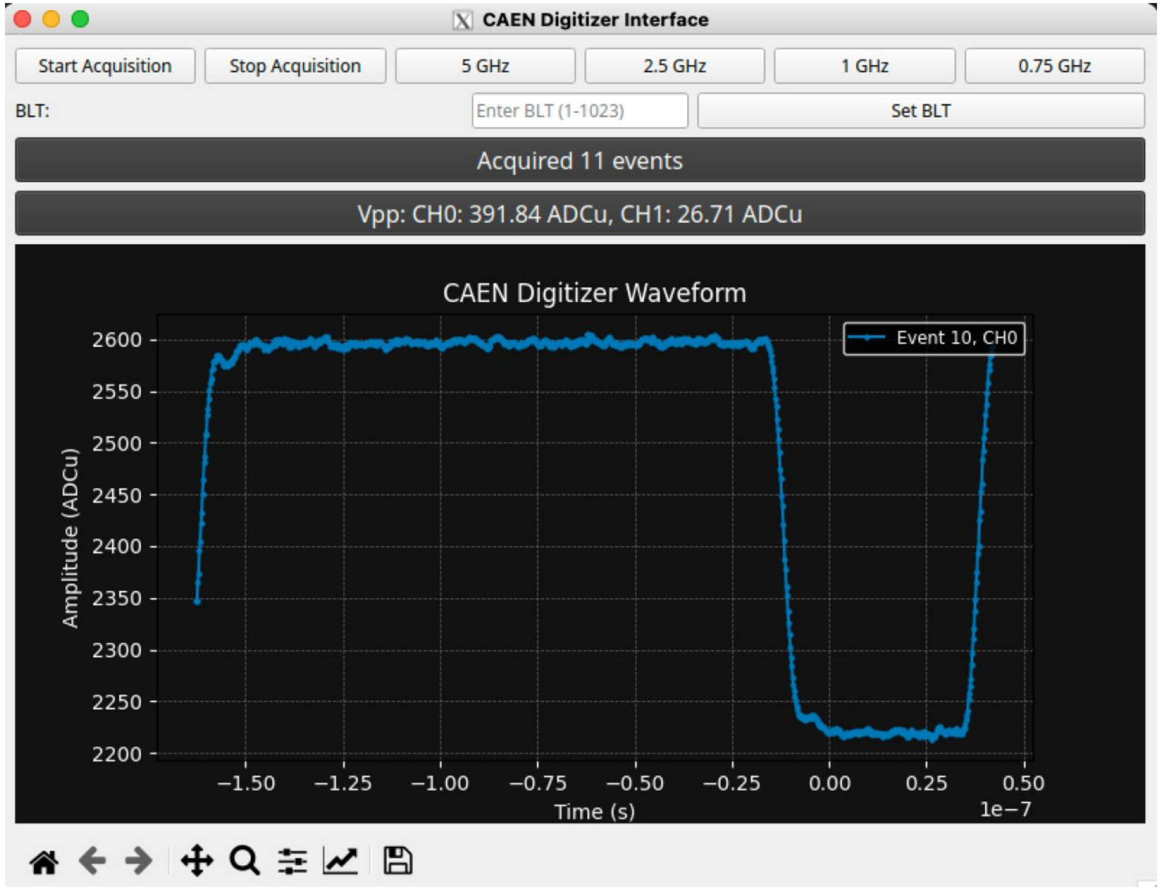
+

Digitizer

GUI

“Oscilloscope”- like Graphical User Interface

- Possible using few Python libraries to treat data as “live” by updating the plot at each N events/waveforms
- Progressing (now priority given to calibration)
- Trigger: software or sent from pulser



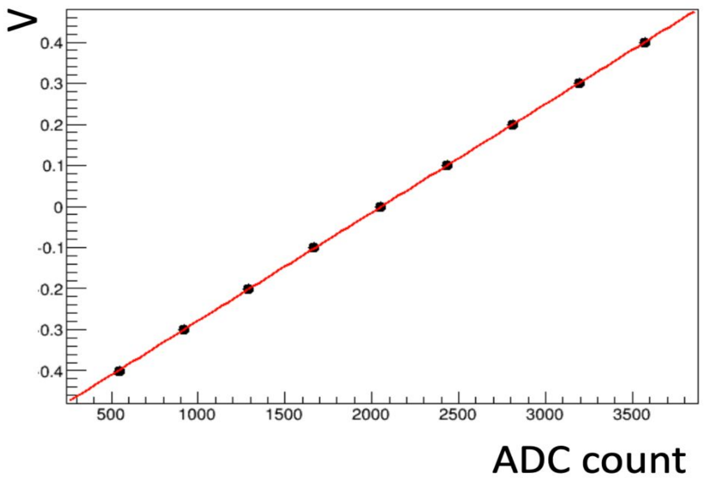
Pulser signal

DRS4 Calibration

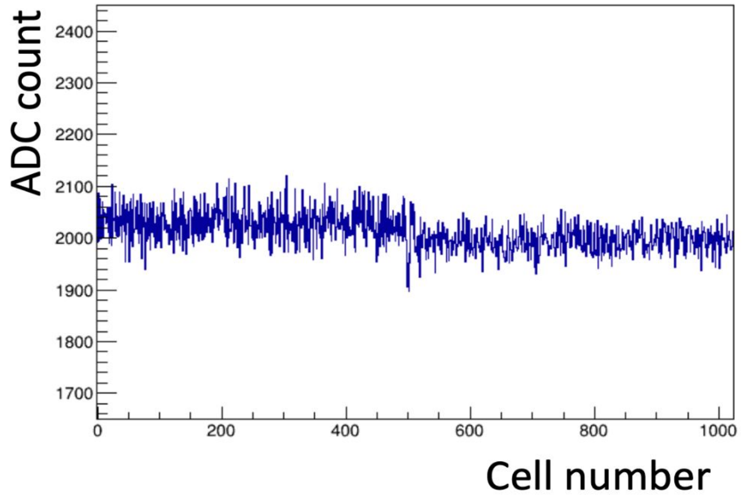
- The digitizer has pre-loaded calibration done by CAEN in its flash memory, but a more fine tuning is needed
- The ADCs should be calibrated:
    a. as a function of the input voltage, given a known source
    b. also some time-dependent calibration has to be done
- To properly calibrate the data, it is probably needed to keep track of the index of the first read cell (first cell != cell_0, due to the ring sampling structure).
- This approach should allow event-by-event reconstruction of the correct cell index, ensuring accurate time alignment.
- Attempting calibration with **pulser** (ongoing) but **might not be enough** (see backup). Checks ongoing!

→ we are observing some strange DC offsets at 0 depending on pulser ON or OFF state. Thus we should take into account for once doing/applying calibration

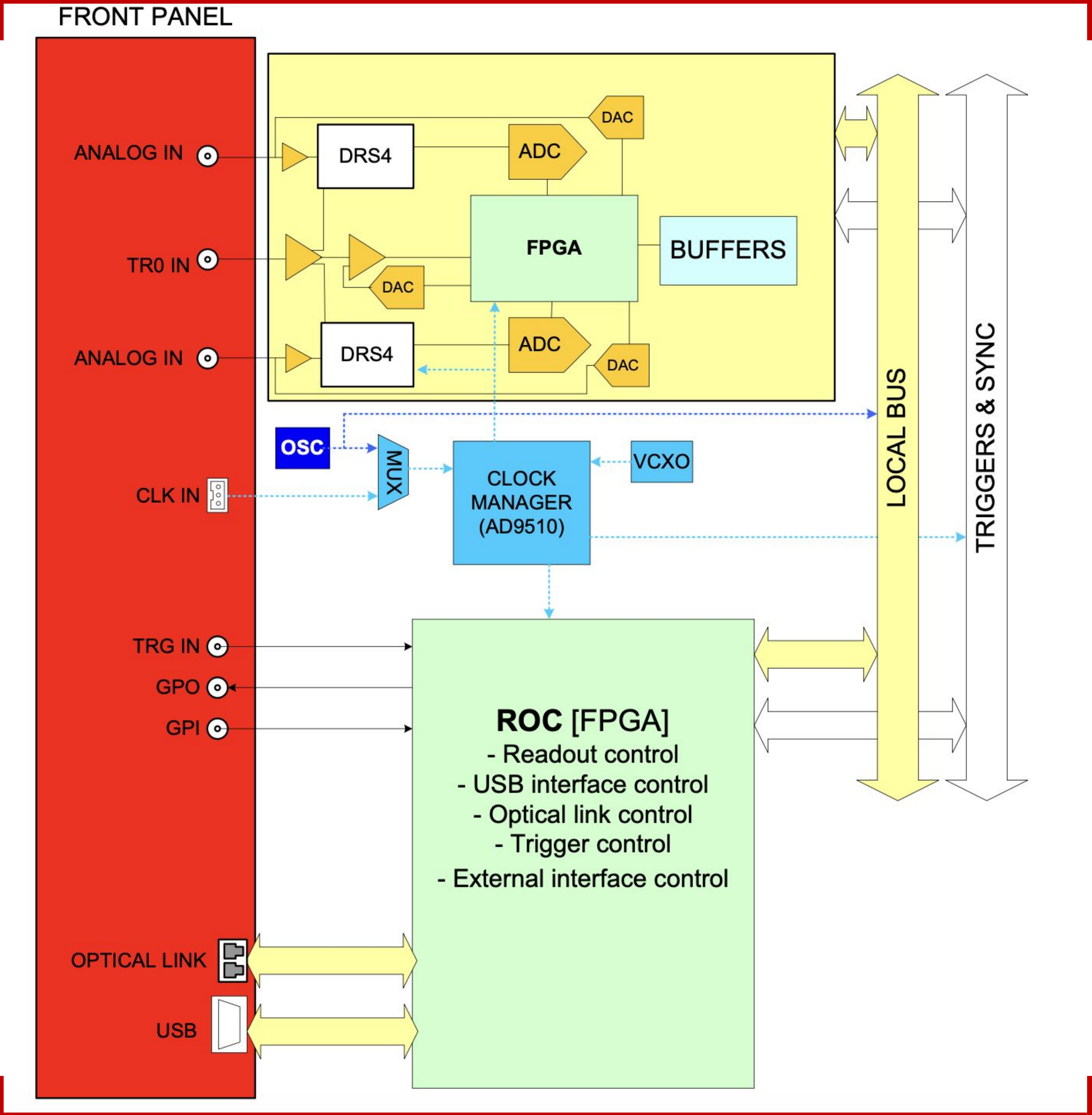
Calibration fit for one cell



Typical 0V line before calibration



DGZ Scheme



FRONT PANEL
ANALOG IN
TR0 IN
ANALOG IN
CLK IN
TRG IN
GPO
GPI
OPTICAL LINK
USB
DRS4
DRS4
ADC
ADC
DAC
DAC
DAC
FPGA
BUFFERS
OSC
MUX
CLOCK MANAGER (AD9510)
VCXO
ROC [FPGA]
- Readout control
- USB interface control
- Optical link control
- Trigger control
- External interface control
LOCAL BUS
TRIGGERS & SYNC

ADCs Calibration - pulser specs

24.8 Outputs

24.8.1 Main Output

Amplitude:	100mVpp to 10Vpp 50Ω into 50Ω 200mVpp to 20Vpp 5Ω into 50Ω or 50Ω into open circuit
Amplitude Accuracy:	1.5% ±5mV at 1kHz 50Ω into 50Ω
DC Offset Range:	±5V. DC offset plus signal peak limited to ±5V from 50Ω into 50Ω
	±10V. DC offset plus signal peak limited to ±5V from 5Ω into 50Ω or 50Ω into open circuit
DC Offset Accuracy:	Typically 1% ±50mV.
Resolution:	3 digits or 1mV for both Amplitude and DC Offset.
Source Impedance	5Ω or 50Ω selectable

DRS4 Calibration

- ADC value of a channel plotted as a function of the delay between each triggers
- The function describing this behaviour could be (to be verified)

f = p0 - p1 * exp(x /p2)