Comparison of commercial Hamamatsu SiPM with the new custom samples

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ePIC-dRICH meeting
04/06/2025

Hamamatsu UVE SiPM prototypes

2024 test samples

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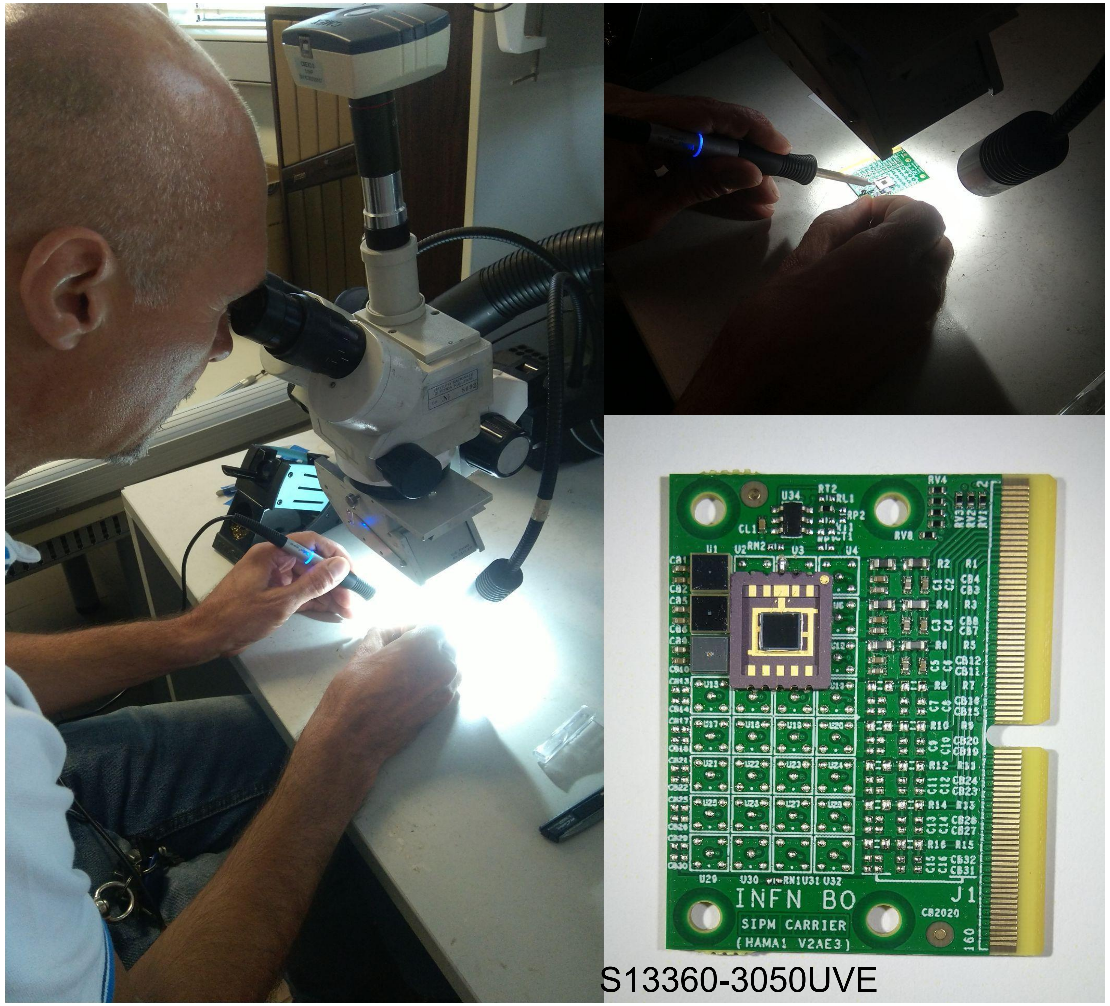


S13360-3050UVE

newly-developed Hamamatsu SiPM sensors

based on S13360 series

few samples of 50 μm and 75 μm SPAD sensors

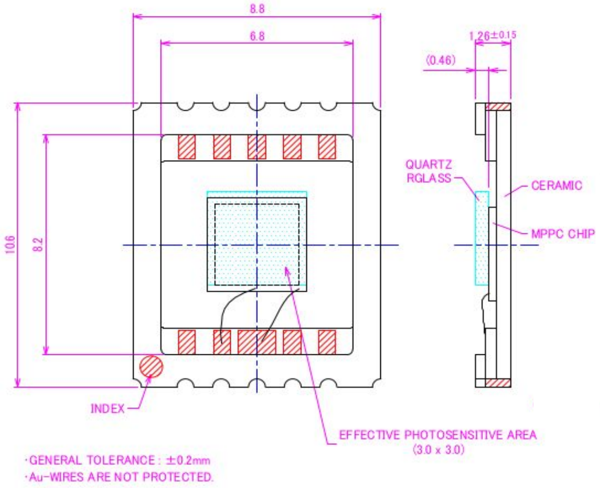
on paper they look VERY promising

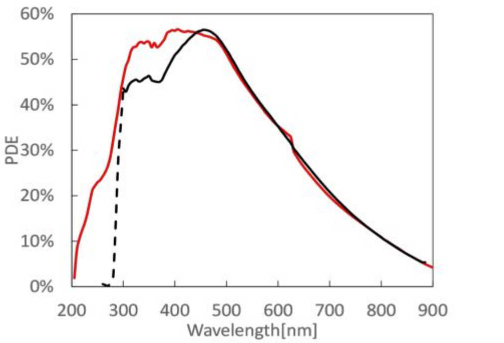
- improved NUV sensitivity
- improved signal shape
- improved recharge time

mounted on EIC SiPM test boards

characterised and tested them

irradiation, annealing, laser, …





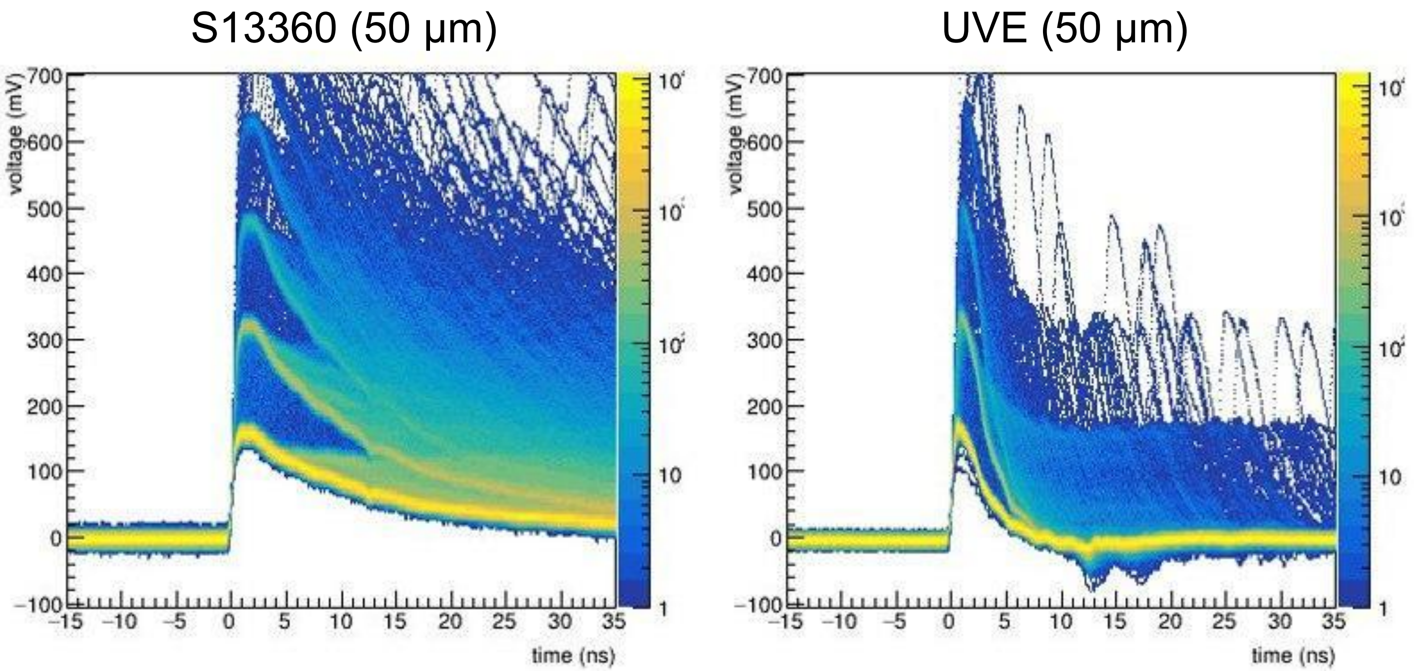
Prototype：based on S13360 series (75μm)

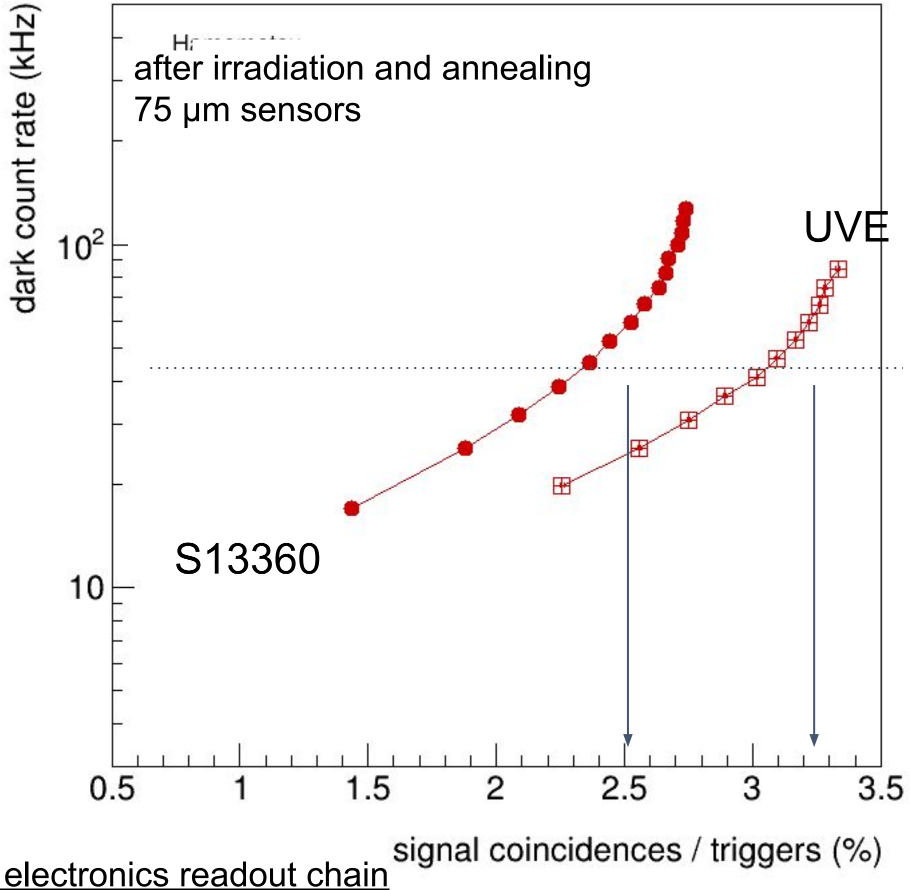
Conventional：S14520 series (75μm)

Hamamatsu UVE SiPM prototypes

2024 test samples

we compared the standard commercial Hamamatsu S13360 sensors with the UVE sample devices





measured with the oscilloscope and a broadband amplifier

UVE sensors have > 5x faster recharge time with the same signal amplitude

→ lower pile-up probability at high DCR

measured with the ALCOR electronics readout chain

UVE sensors have > 30% higher PDE at the same DCR of 50 kHz

note: this is measured with a 400 nm laser and the prototype have a quartz protective window

check with Hamamatsu for custom devices with silicone protective window

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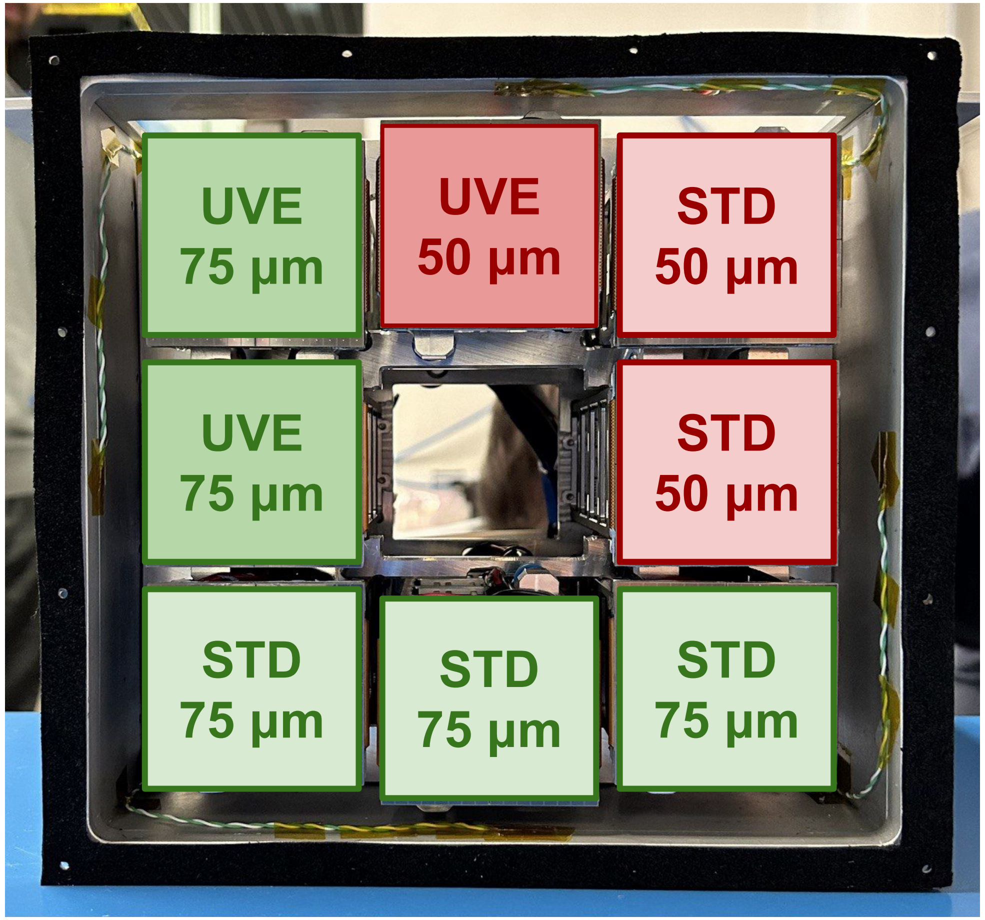
Hamamatsu UV-Enhanced SiPM optimisation

2025 test samples

aim at a the next dRICH beam test to evaluate them with Cherenkov light



possible layout on the present prototype readout box

- **meeting with Hamamatsu engineers**
  - productive meeting in September 2024
  - can provide what we want, namely
    - SiPM matrices 8x8 with UVE sensors
    - SMD mounting
    - silicone resin window
- **purchased and received**
  - 4x matrices with 50 µm SPADs
  - 12x matrices with 75 µm SPADs
  - several single-SiPM sensors

this presentation

- **goal**
  - assemble few new PDUs
  - use them in the next beam test
  - evaluate expected PDE improvement

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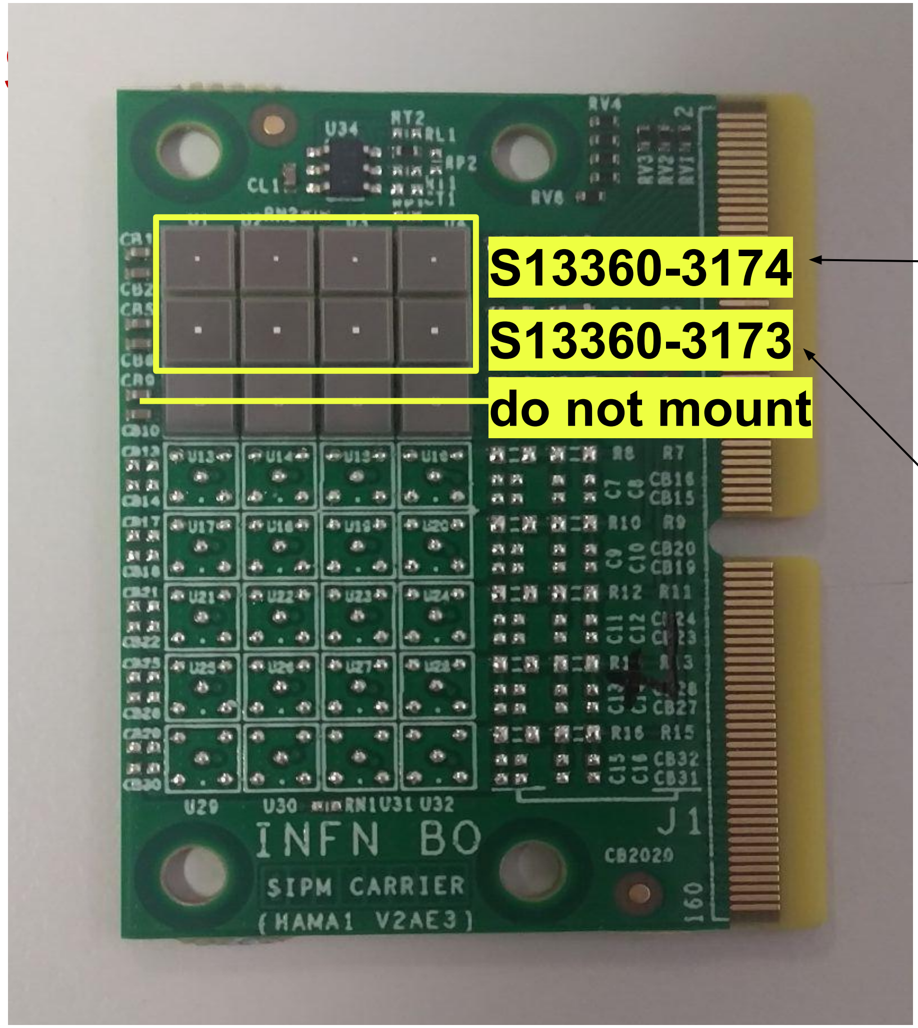
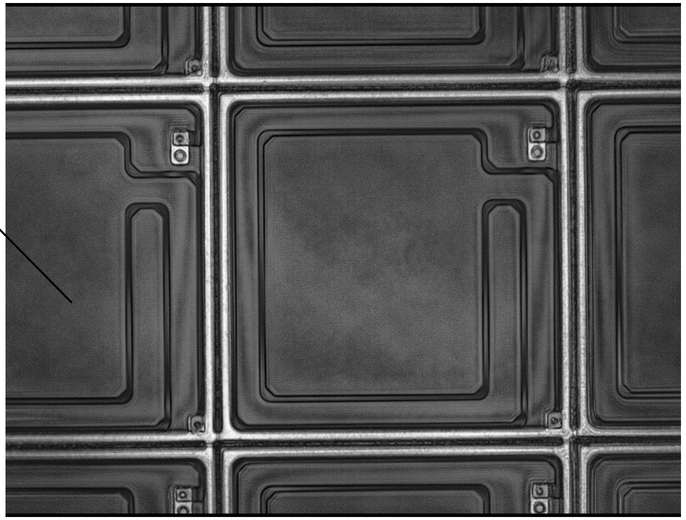
SiPM test boards with new UVE Hamamatsu



2025 test samples

50 µm



75 µm

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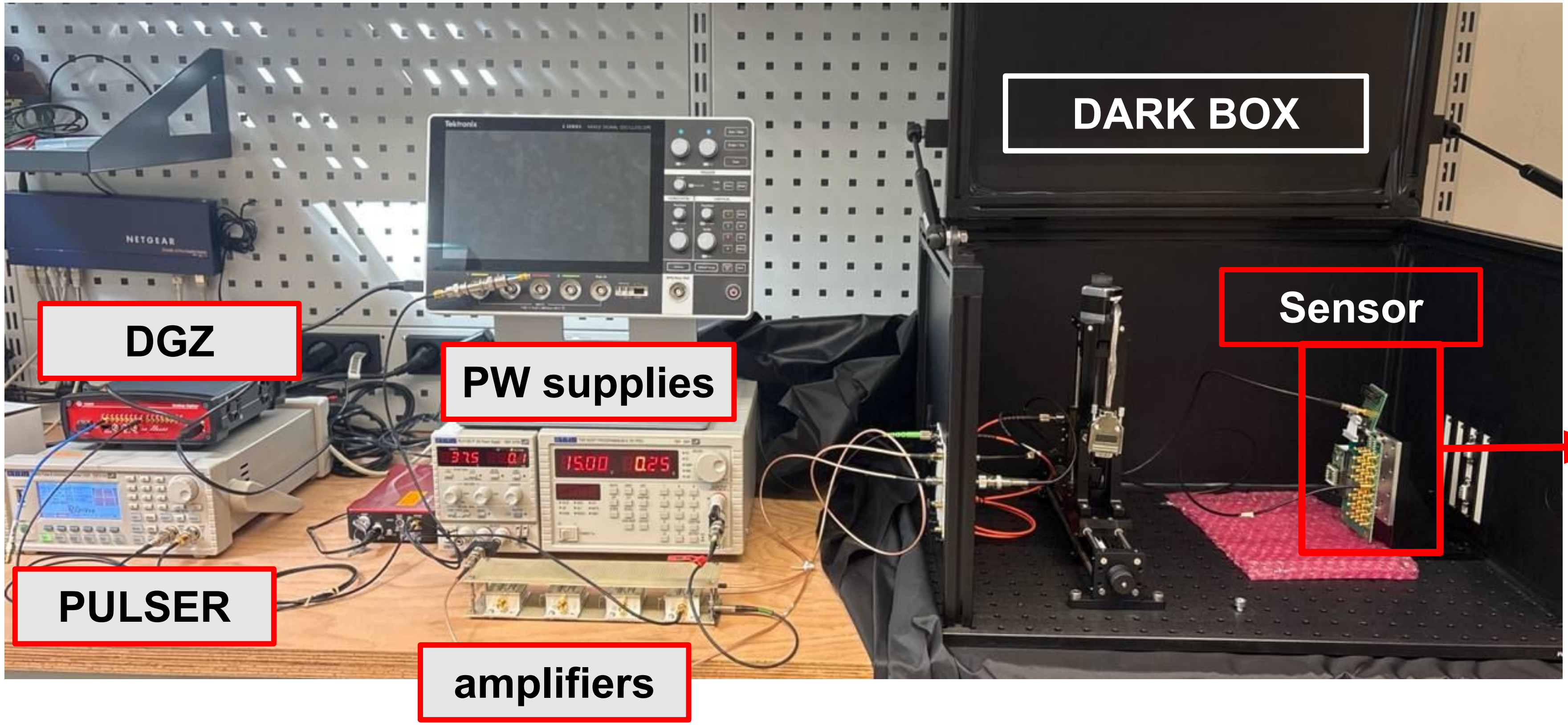
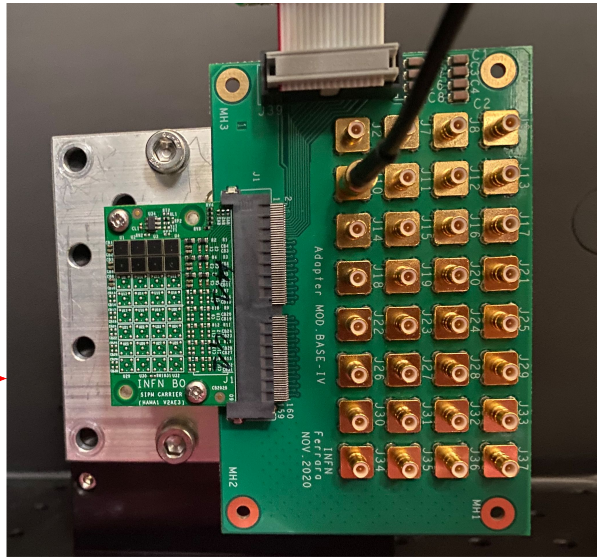
Setup





- CAEN Digitizer DT5742B
- 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

Setup - digitizer CAEN DT5742B

- CAEN DT5742B: 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)**
- Full Scale Range: 1 Vpp
- It comes from CAEN with dedicated C Libraries

ANALOG INPUTS	**Number of Channels** 16 1 special channel (TR0) Single ended **Full Scale Range (FSR)** 1 V_{pp} (default) 2 V_{pp} (by customization) **Absolute max analog input voltage (for any DAC offset)** @1V_{pp} = 3 V_{pp} (with V_{rail} max +3V or -3V) @2V_{pp} = 6 V_{pp} (with V_{rail} max +6V or -6V)	**Impedance** Z_{in} = 50 Ω **DC Offset** Programmable 16-bit DAC for DC Offset adjustment on each channel. Range: ± 1 V
DIGITAL CONVERSION	**Resolution** 12 bits **Switched Capacitor Array** Domino Ring Sampler chip (DRS4), 8+1 channels with 1024 storage cells each	**Sampling Rate** 5 GS/s - 2.5 GS/s - 1 GS/s - 0.75 GS/s SW selectable, simultaneously on each channel

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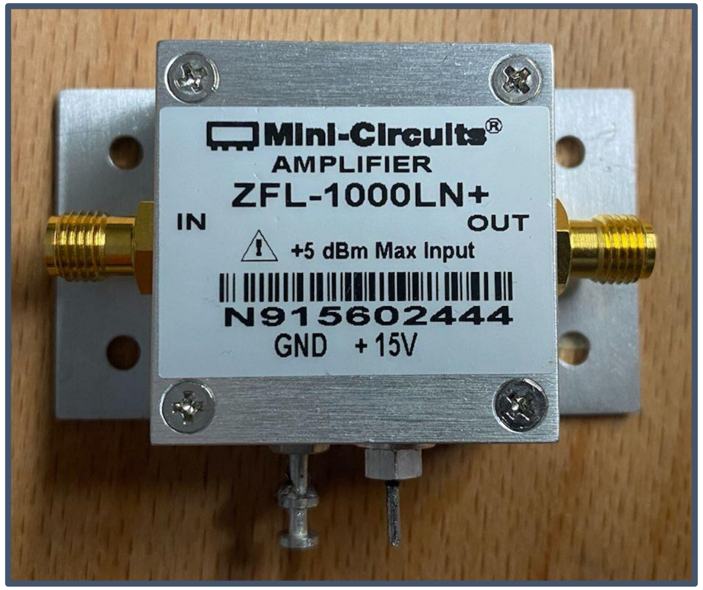
Signal amplification

- Amplifier: Mini-circuits ZFL-1000LN+
- Low-noise, operational range 0.1 - 1000 MHz
- Powered at 15 V
- 4-amplifier 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.

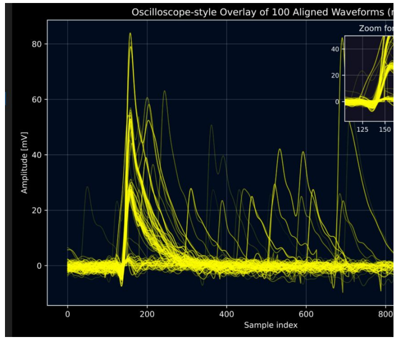
Data acquisition and analysis

CAEN DGZ

Waveforms acquisition 2.5 GS/s

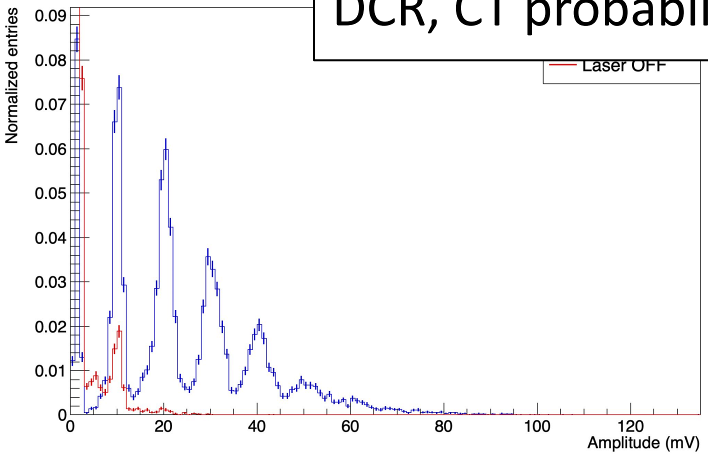
Pre-processing

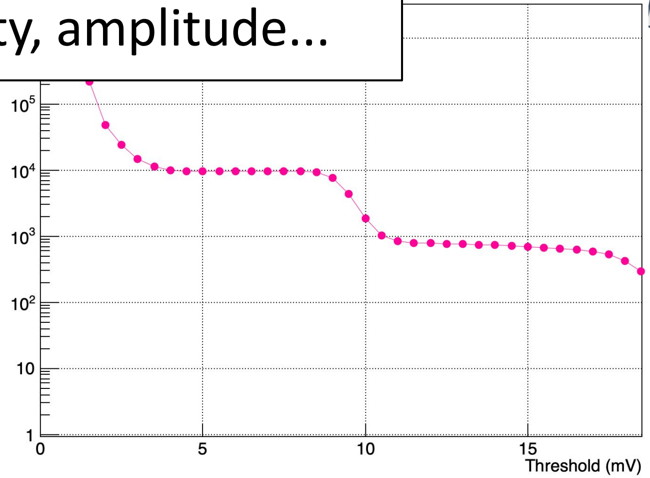
.npz files

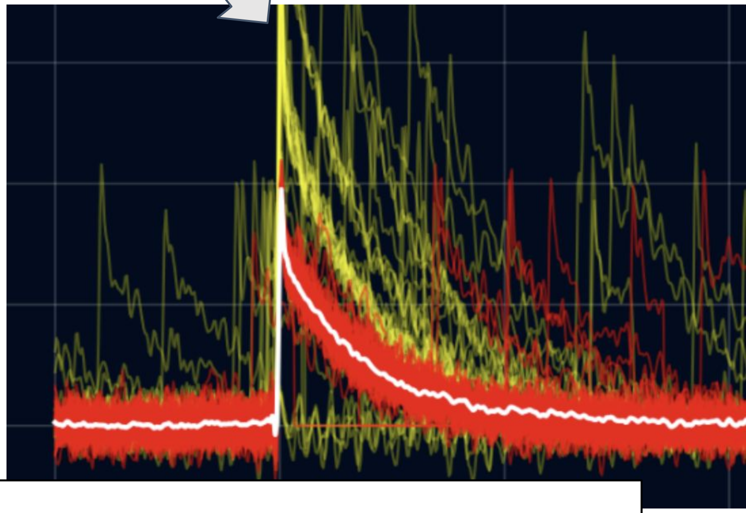


ONLINE and OFFLINE analysis

DCR, CT probability, amplitude...

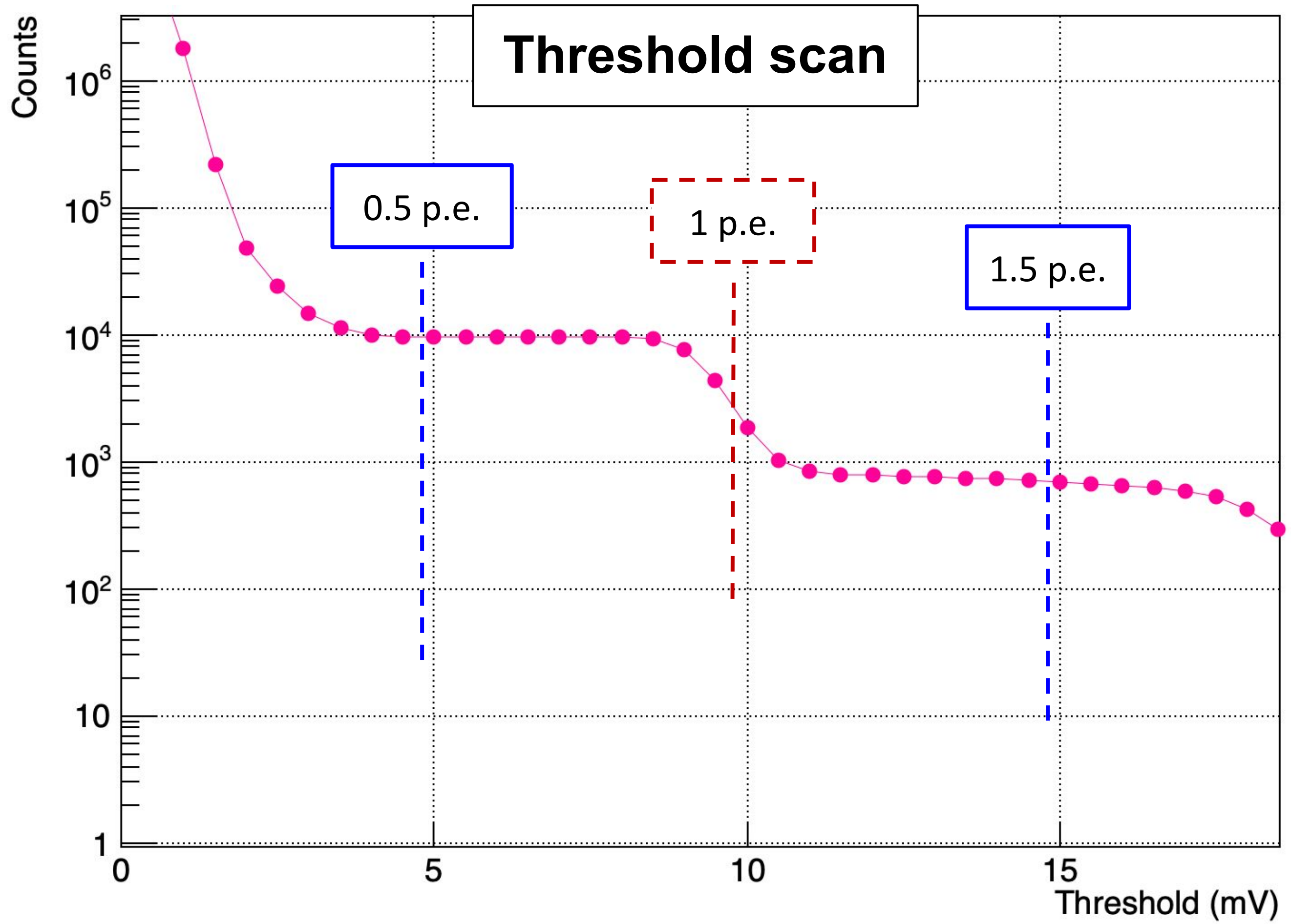






Signal visualization & analysis

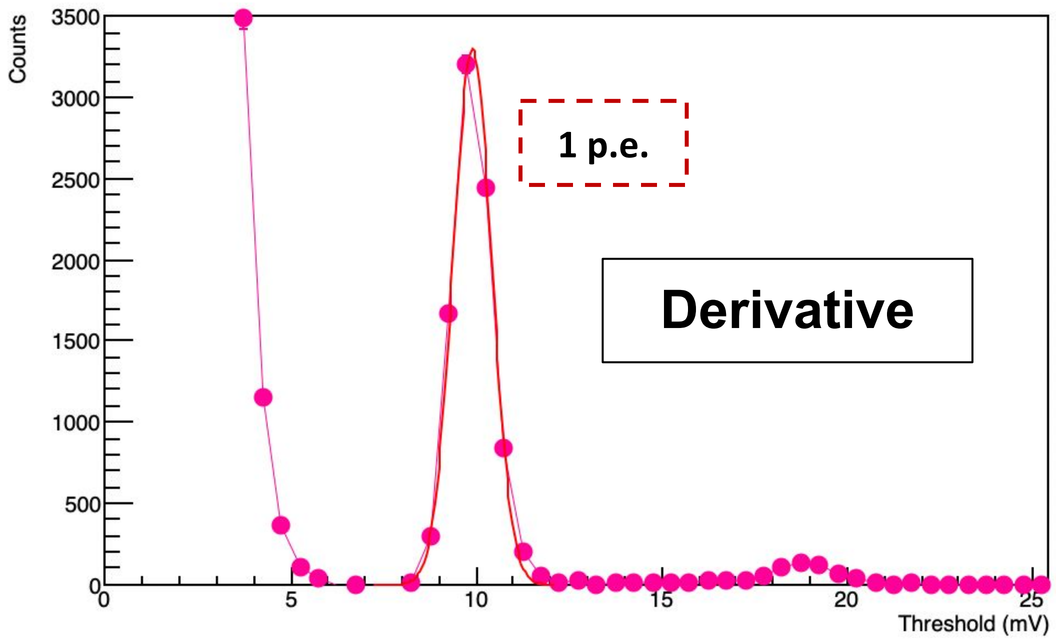
Dark analysis recipe



Example: sn31-A1 @54.5 V

Our recipe:

- Threshold scan
- Derivative: gaussian fit on 1 p.e.
- DCR is defined at 0.5 p.e.
- CT is defined as ratio of the amplitude at 1.5 and 0.5 p.e.



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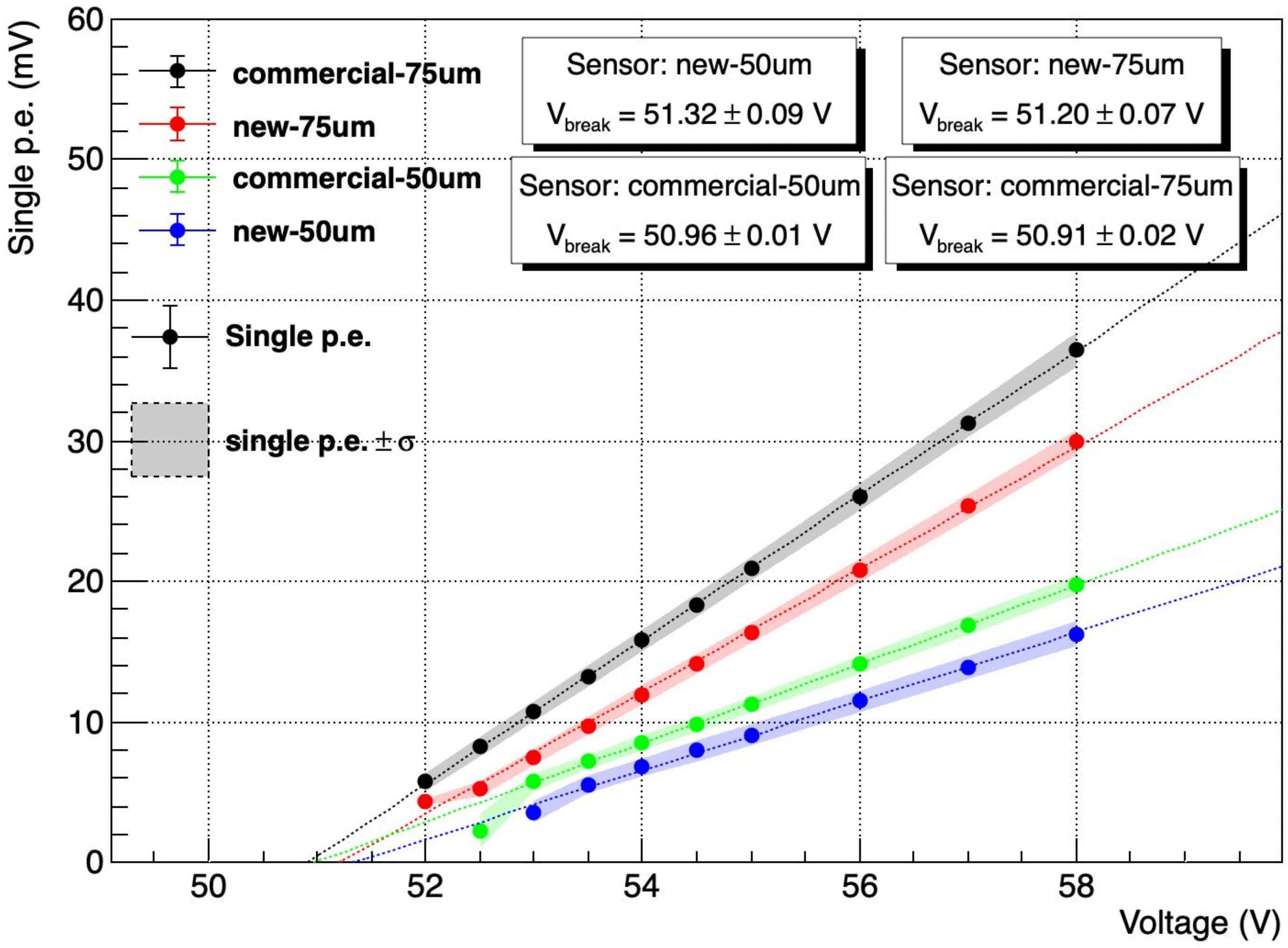
Results of dark analysis



Single p.e. amplitude (mV) vs V_{bias}:

- Hint of a V_{Break} greater for custom sensors compared for commercial one
- The amplitude of commercial Hamamatsu sensors is greater compared to the customs

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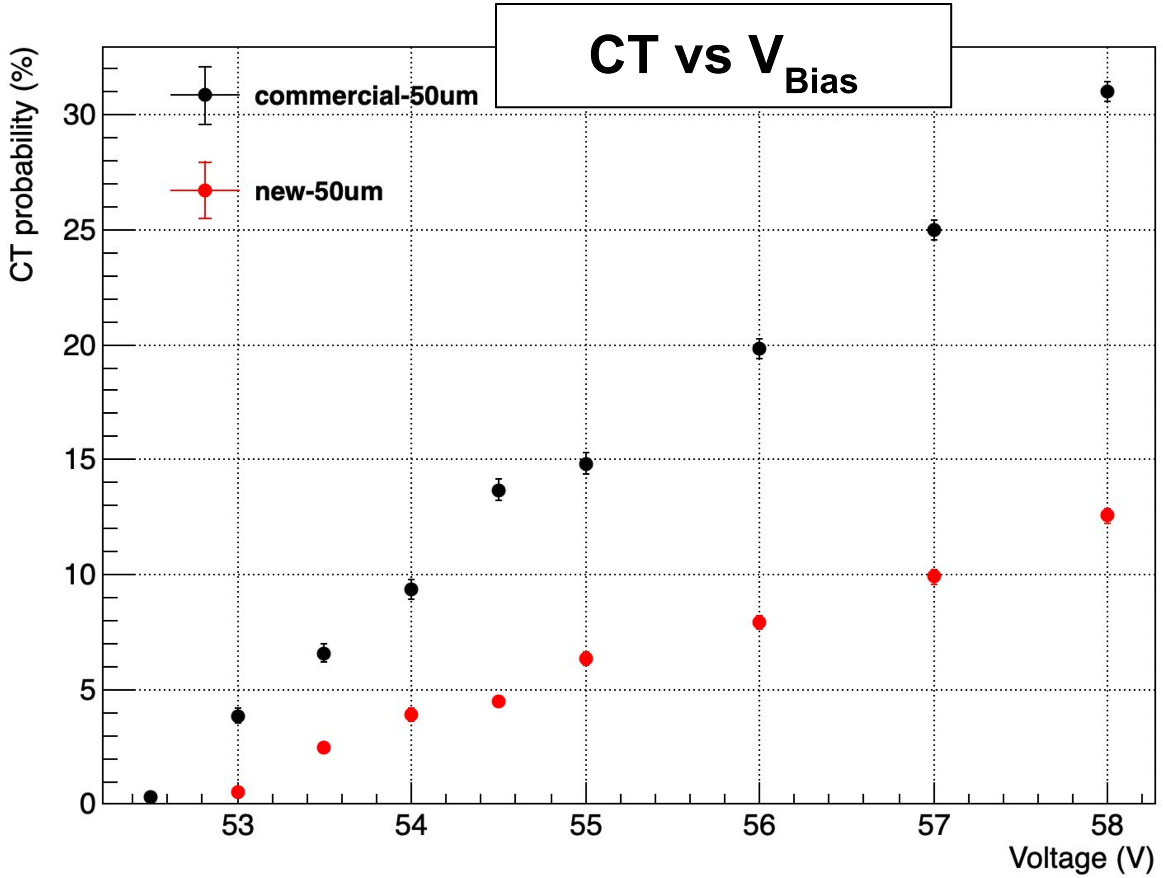
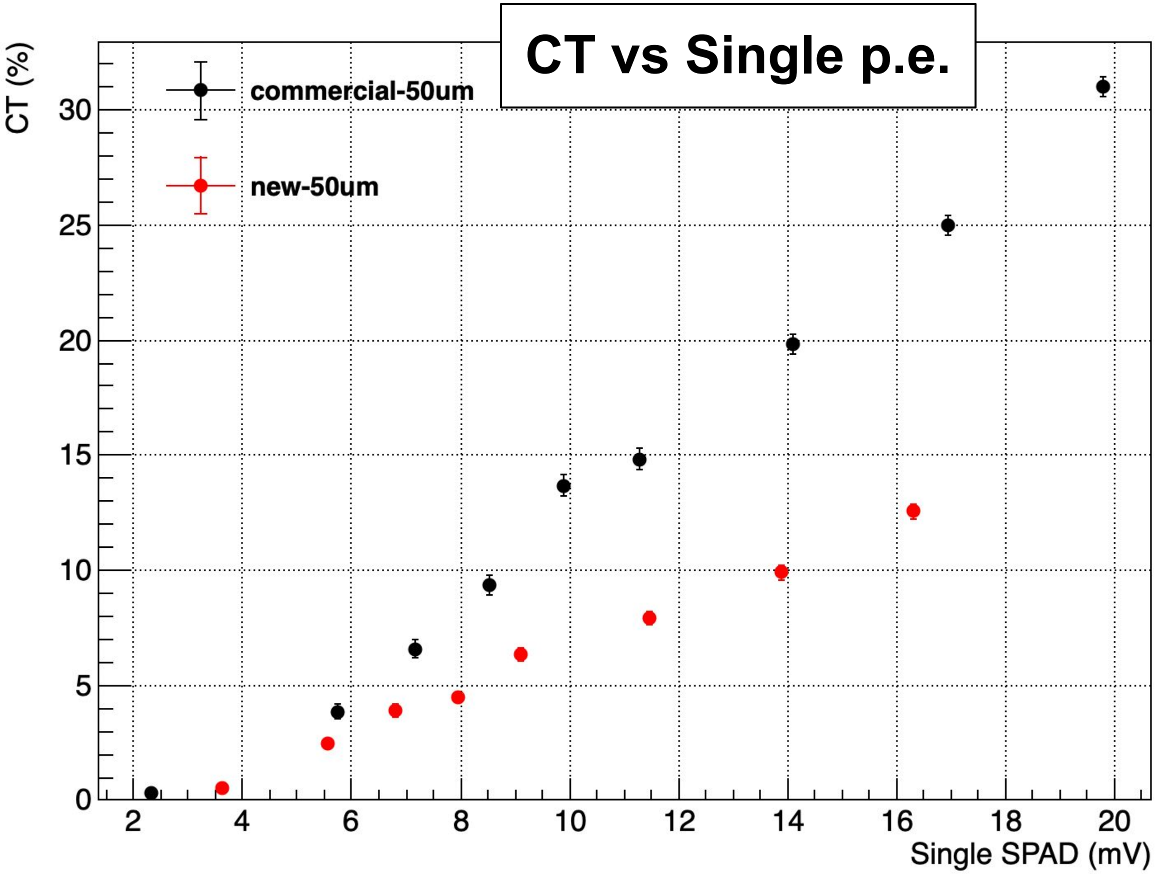
Results of dark analysis [50μm]

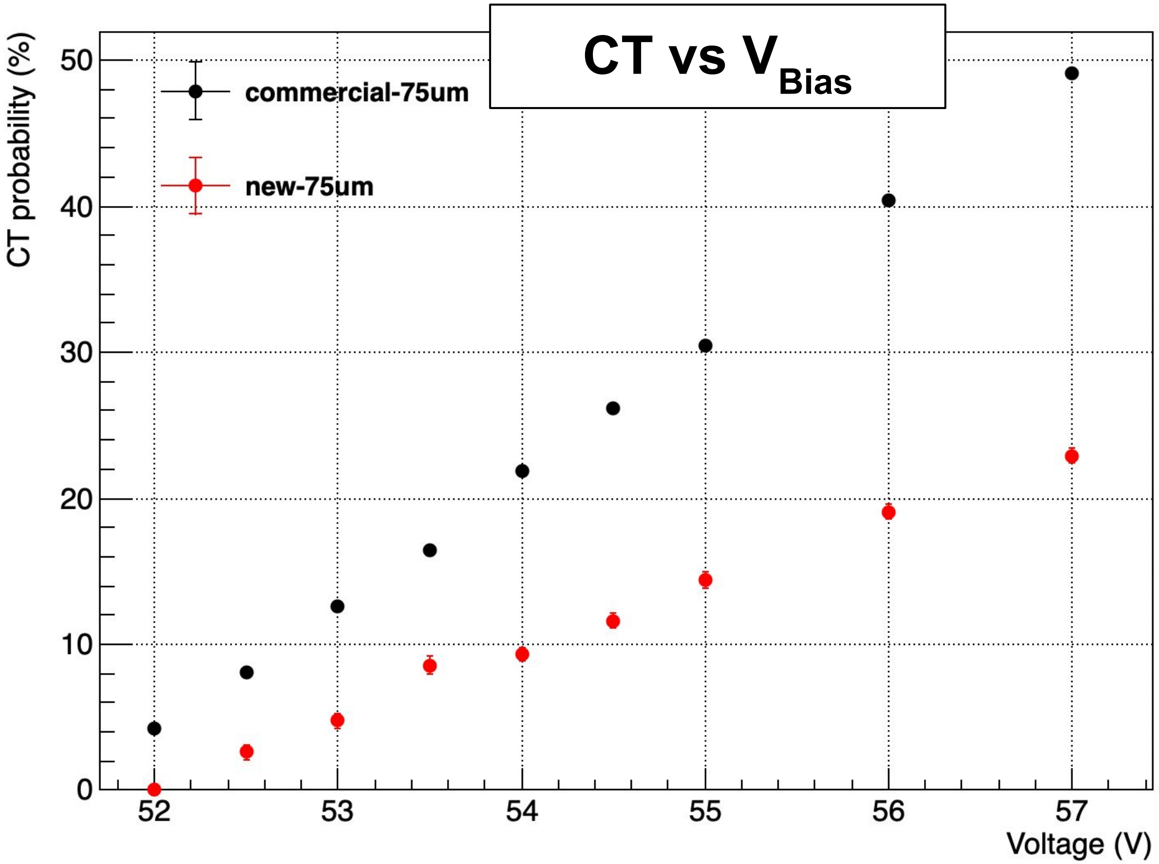
- General improvements in CT results
- Need to have a precise temperature stabilization

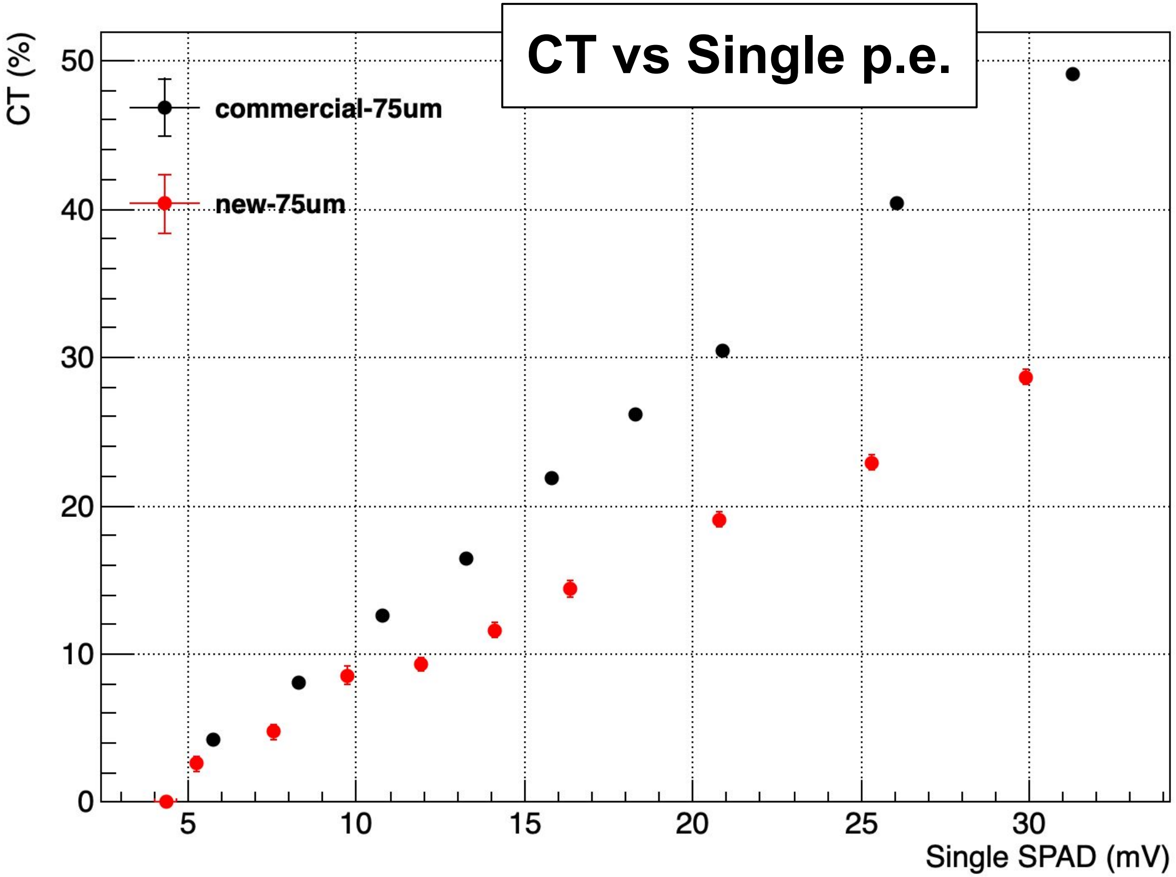




Results of dark analysis [75μm]

- General improvements in CT results
- Need to have a precise temperature stabilization





Persistence

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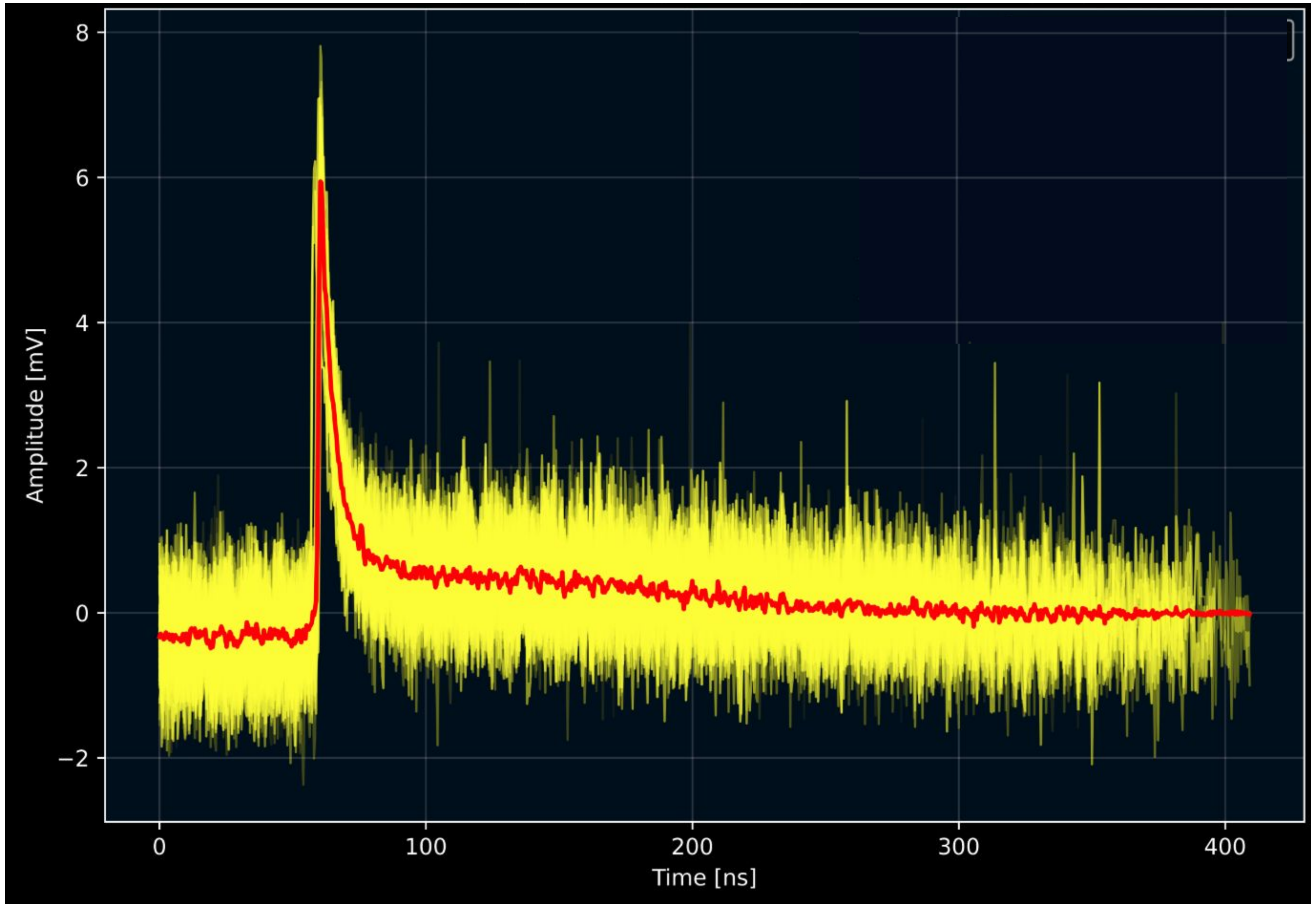
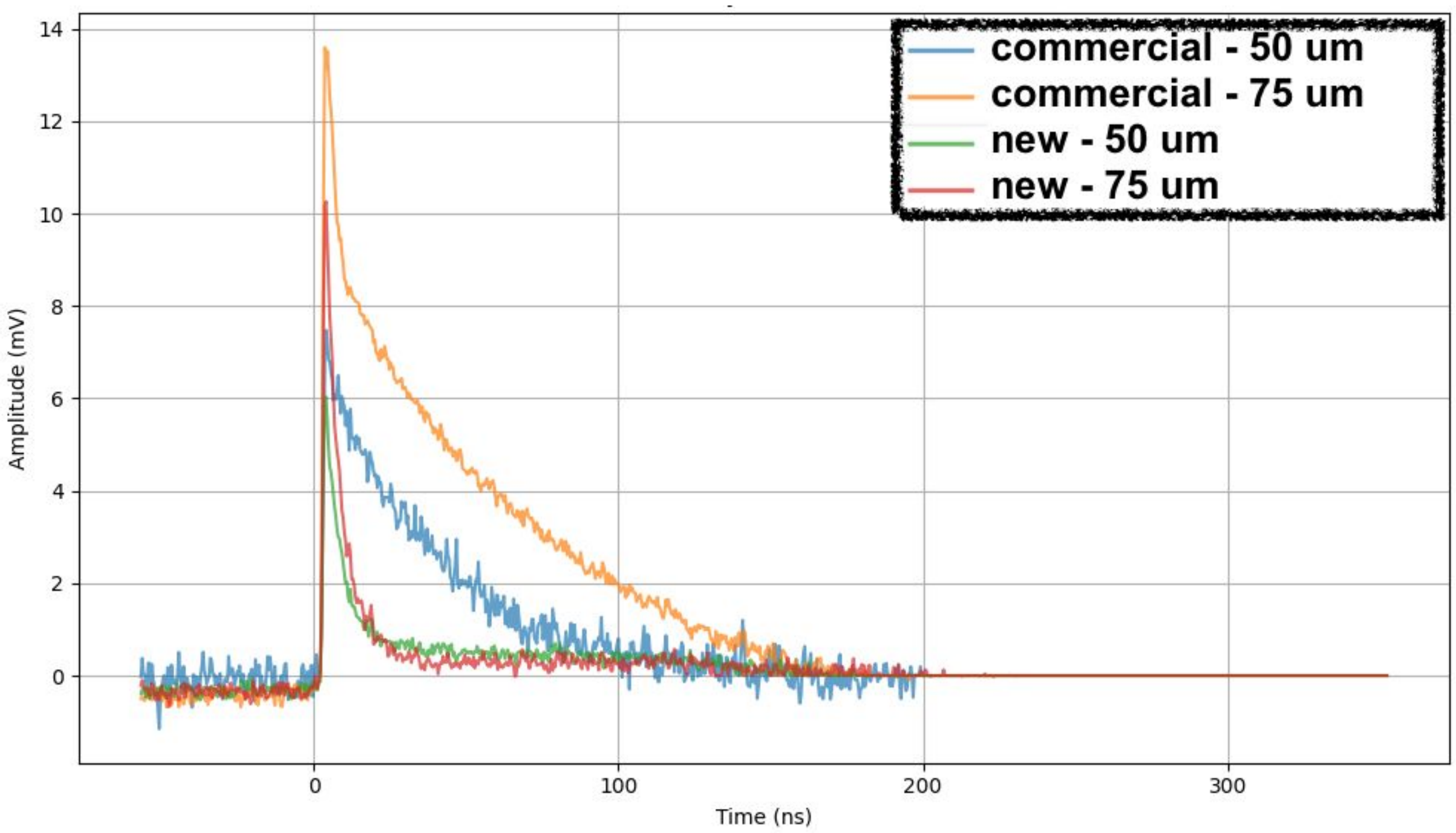


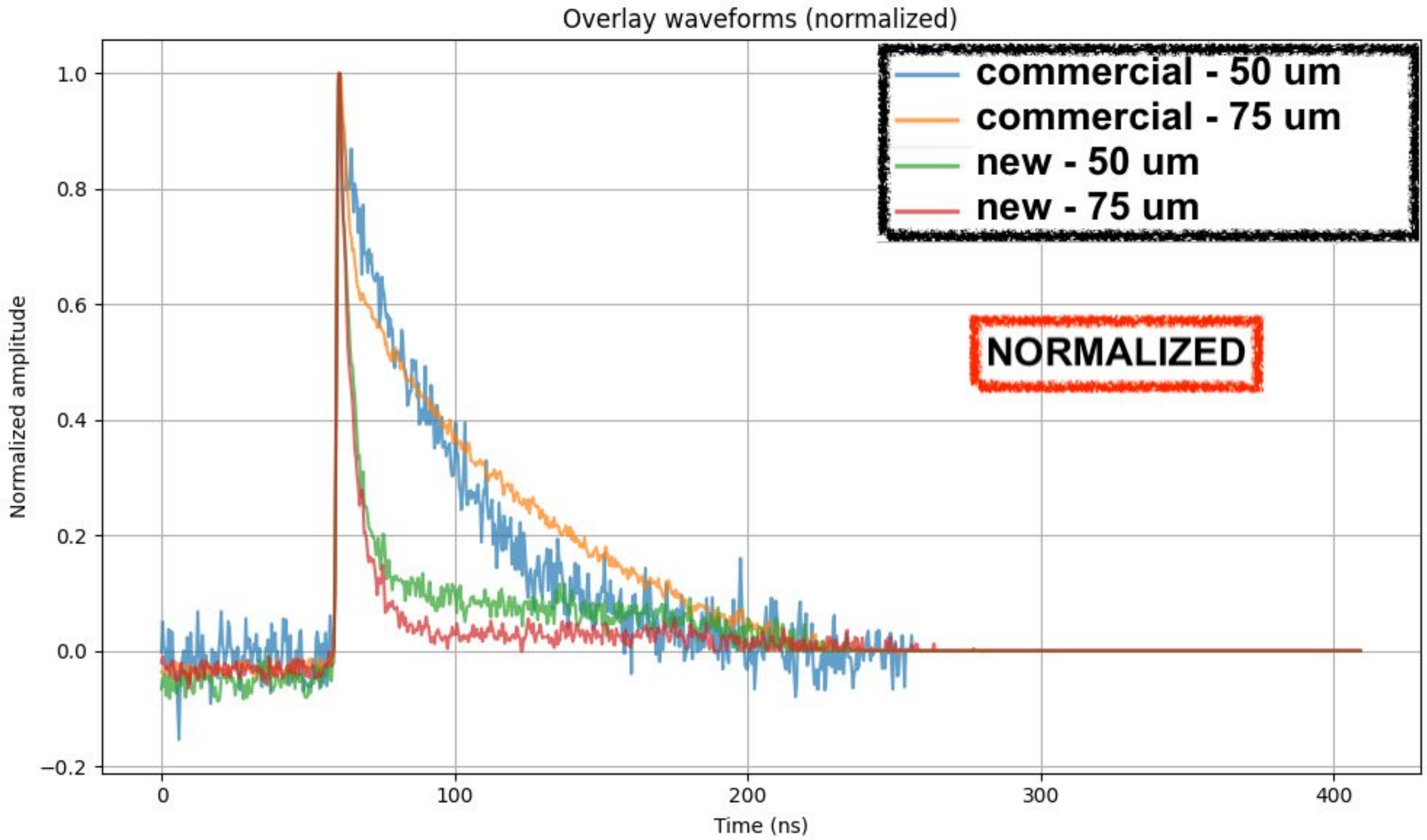
- Only good waveforms selected (using threshold in amplitude)
- Peaks are identified and collected, then aligned at the rising edge
- to be perfectioned the individuation of the single-pe peak and exclusion of after-pulses
- the median waveform is used as input for a direct tau estimation

Persistence - sensor comparison



- measured at constant bias voltage: **54 V**
- **waveform selection:** waveform over threshold, single pe, no double peaks
- **after selection → median**
- Breakdown voltage differs slightly between sensors → new sensors (**board 41)** may show lower signals than those on **board 31 due to** different **overvoltage** levels i.e. not the same operating point
- Same considerations applies to the next plots

Persistence - sensor comparison



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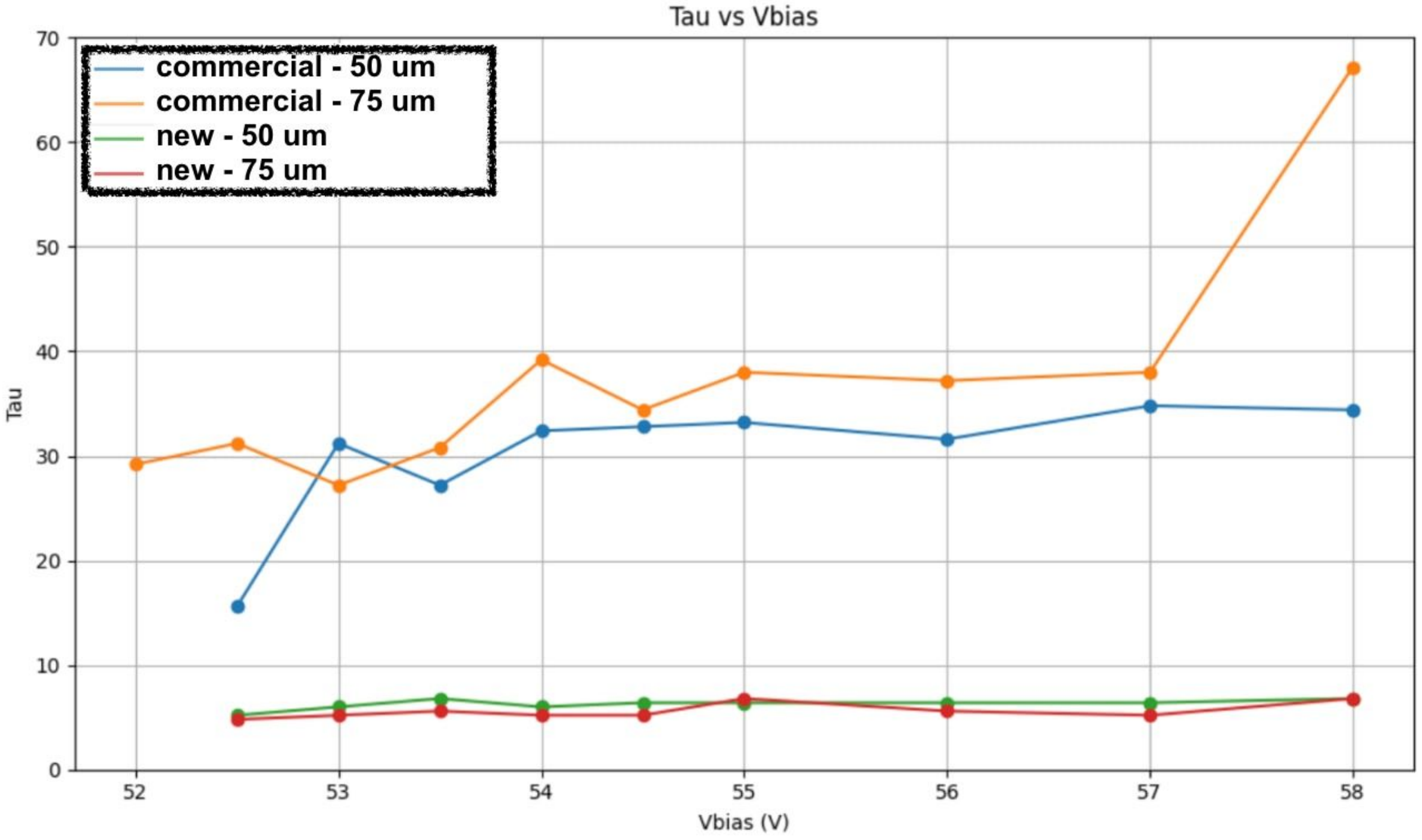
Measurement of the tau



- **waveform selection:** waveform over threshold, single pe, no double peaks
- **after selection:**
  → median (waveforms)
  → decay constant
  (direct estimation)

$$\tau = t_{1/e} - t_{peak}$$

PRELIMINARY

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Summary and conclusions

- Preliminary comparison among commercial and new-custom Hamamatsu using a setup with CAEN digitizer DT5742B
- The system now is equipped with a server to take/download data + first version of a **online** analysis framework (work in progress)
- First results from the new sensors (custom) looks promising compared to the commercial ones

- These are the first measurements taken with a completely **new setup**
- The setup currently lacks any **temperature stabilization**
- In the upcoming weeks, we will work to improve and stabilize the system and the analysis

Backup

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.

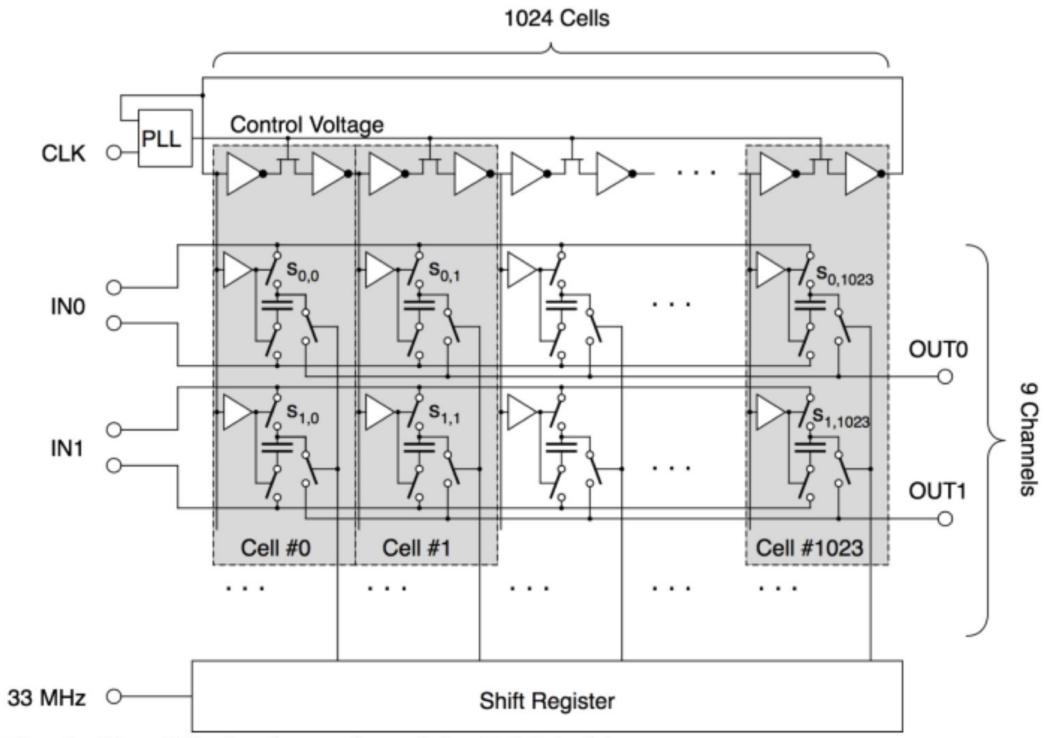
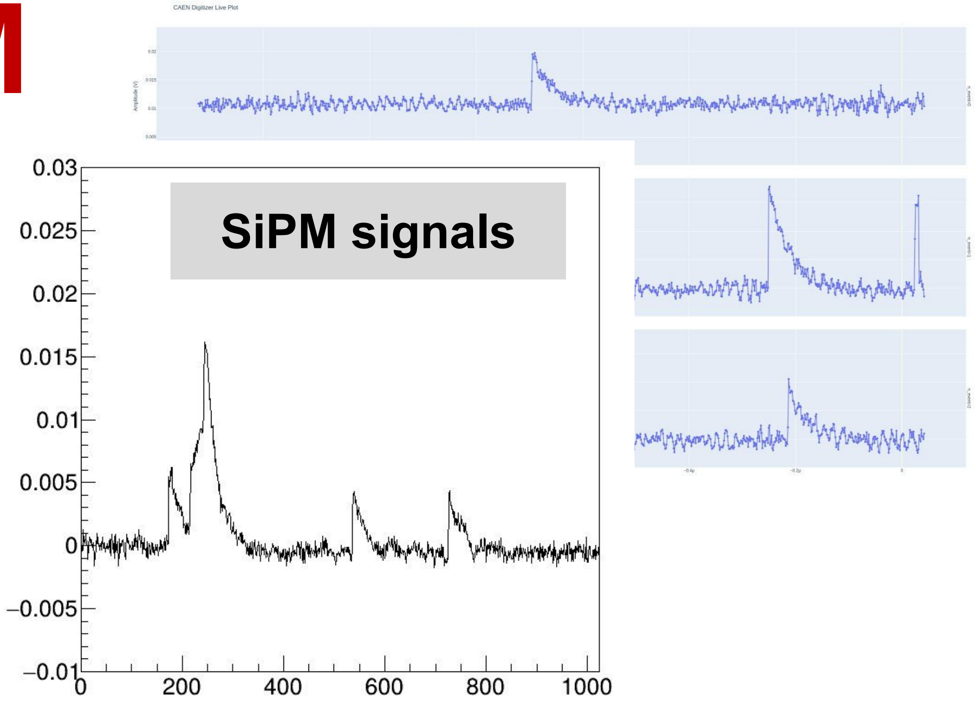


Fig. 1: Simplified schematics of the DRS4 chip.

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

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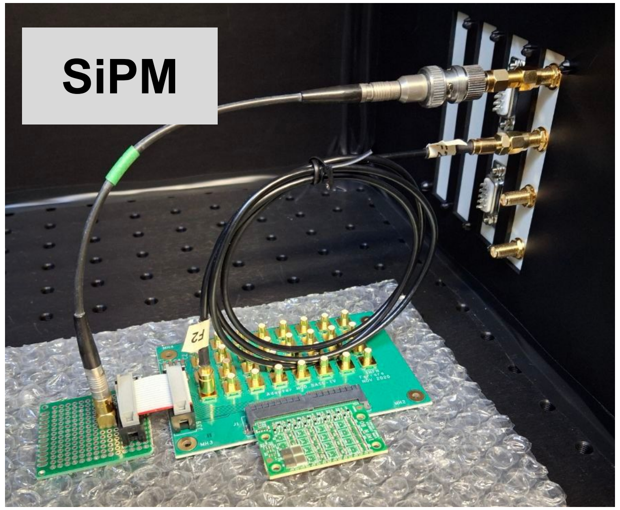

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Digitizer

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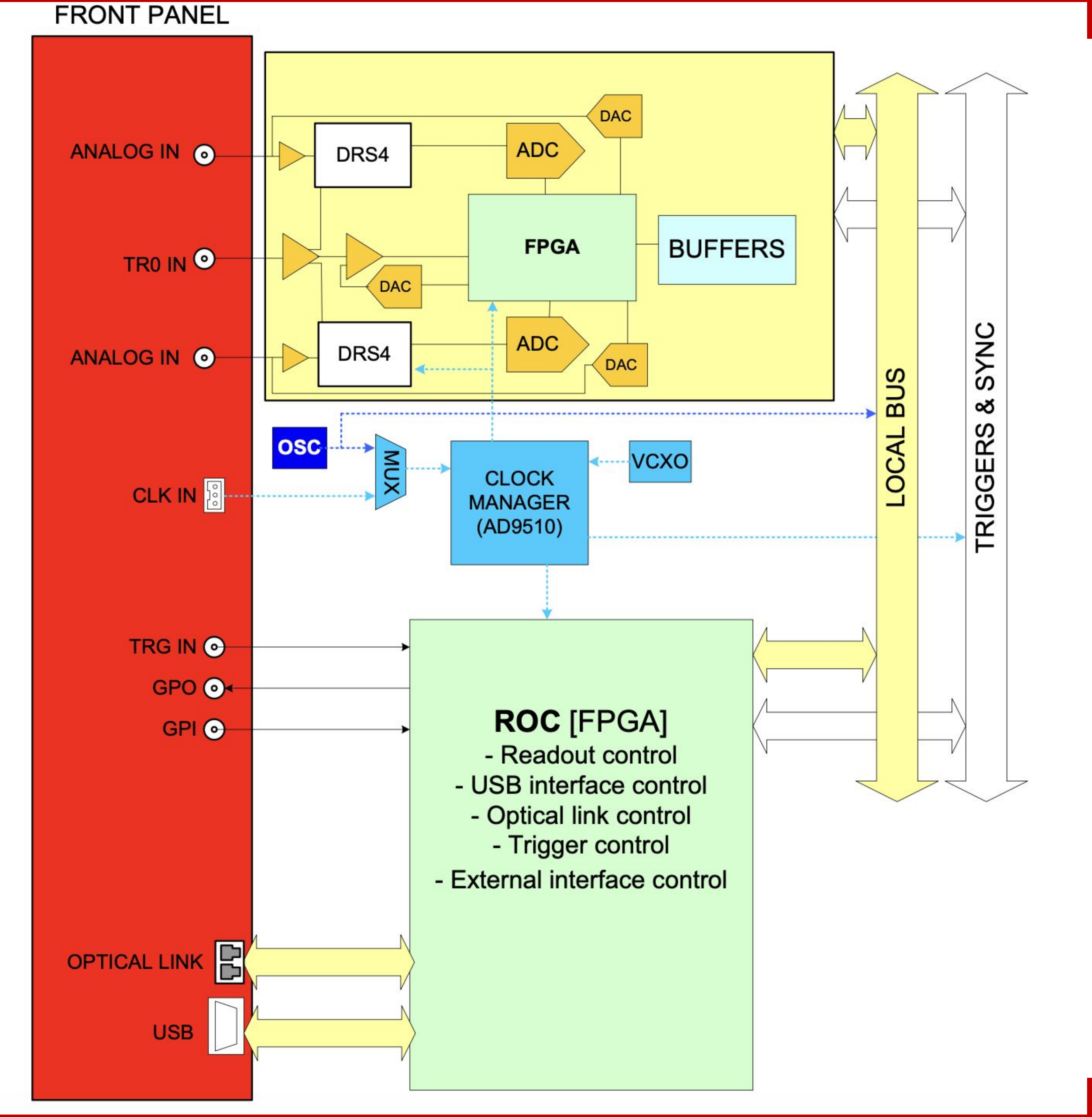
DGZ Scheme



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Aimtti pulser specs

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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