DUNE

Power over Fiber

Meeting Annuale della Collaborazione Nazionale DUNE-Italia
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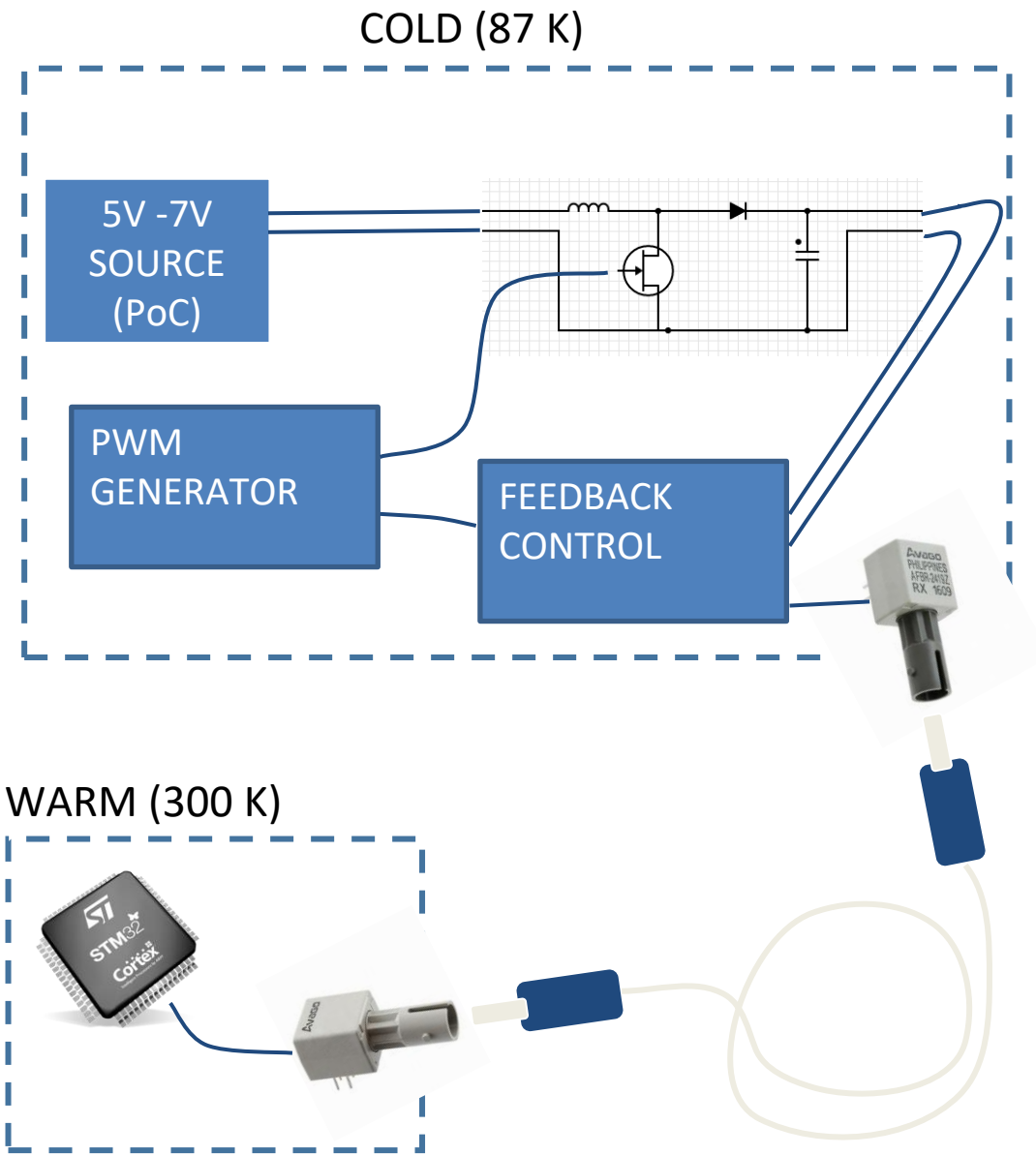
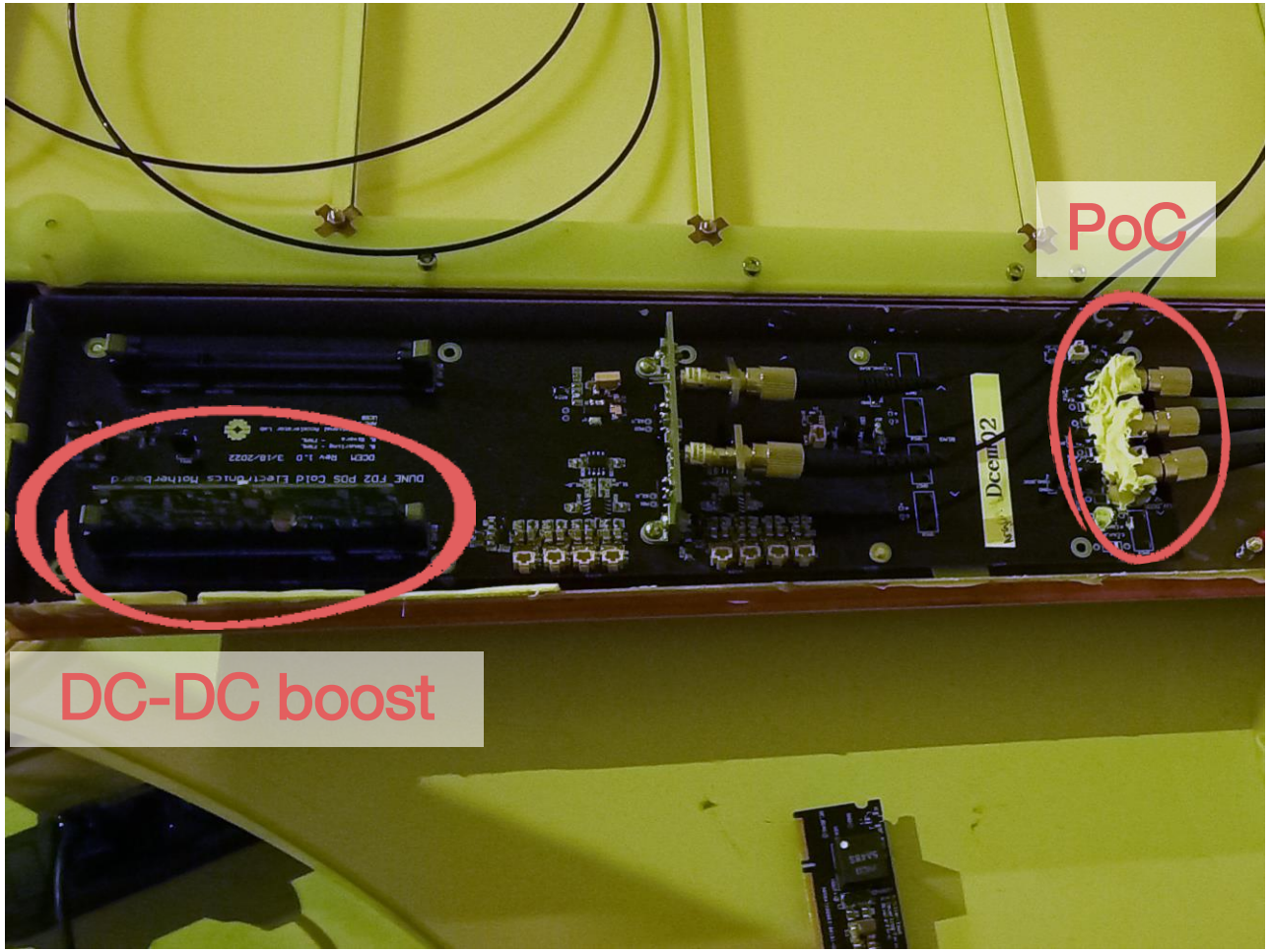
System overview

- **DC-DC boost converter**: HV for SiPM bias at cold
- **Power supply provided by PoC** (Power optical Converter): 5 V to 7 V range
- **PWM generation** with two possible controls:
  - Inner feedback setting output voltage at nominal point (e.g. 48 V)
  - Optical input to change the setting voltage within few volts
- **Analog feedback** control loop circuit

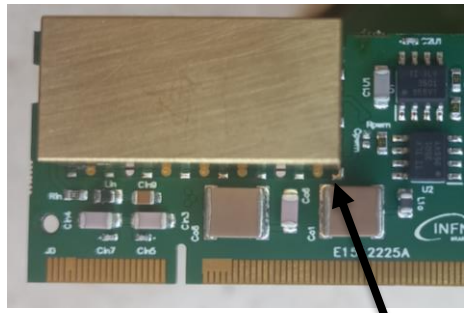


Content

- DC-DC boost design
  - Performance
  - External PWM control
- Control design
- Operational Amplifier characterization for analog feedback control loop
- Conclusions



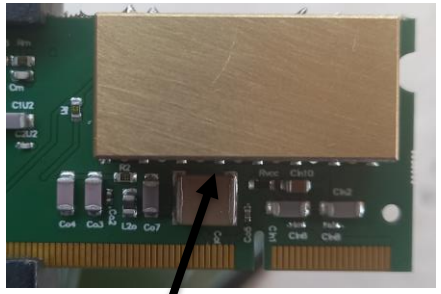
DC-DC boost prototype, version 2

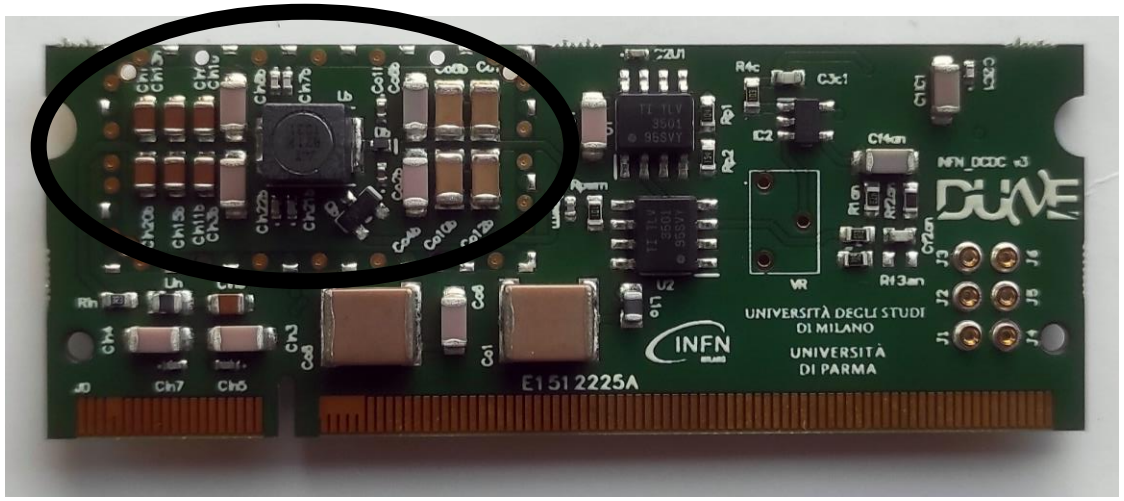


With EMI shield

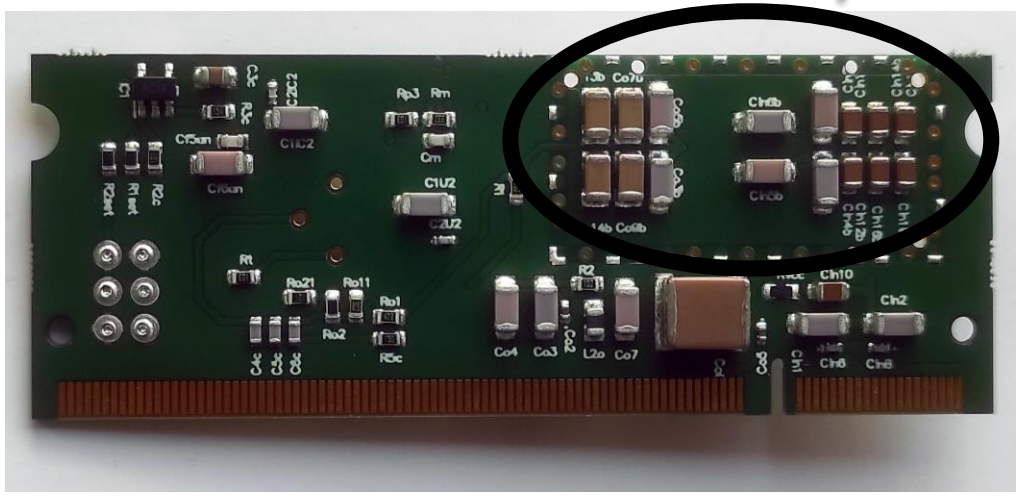
- **Improved** input and output **filters**
- **Optimized** analog feedback **control** circuitry
  - Tests with **external** PWM **control**

With EMI shield





a) DC-DC prototype top layer



b) DC-DC prototype bottom layer

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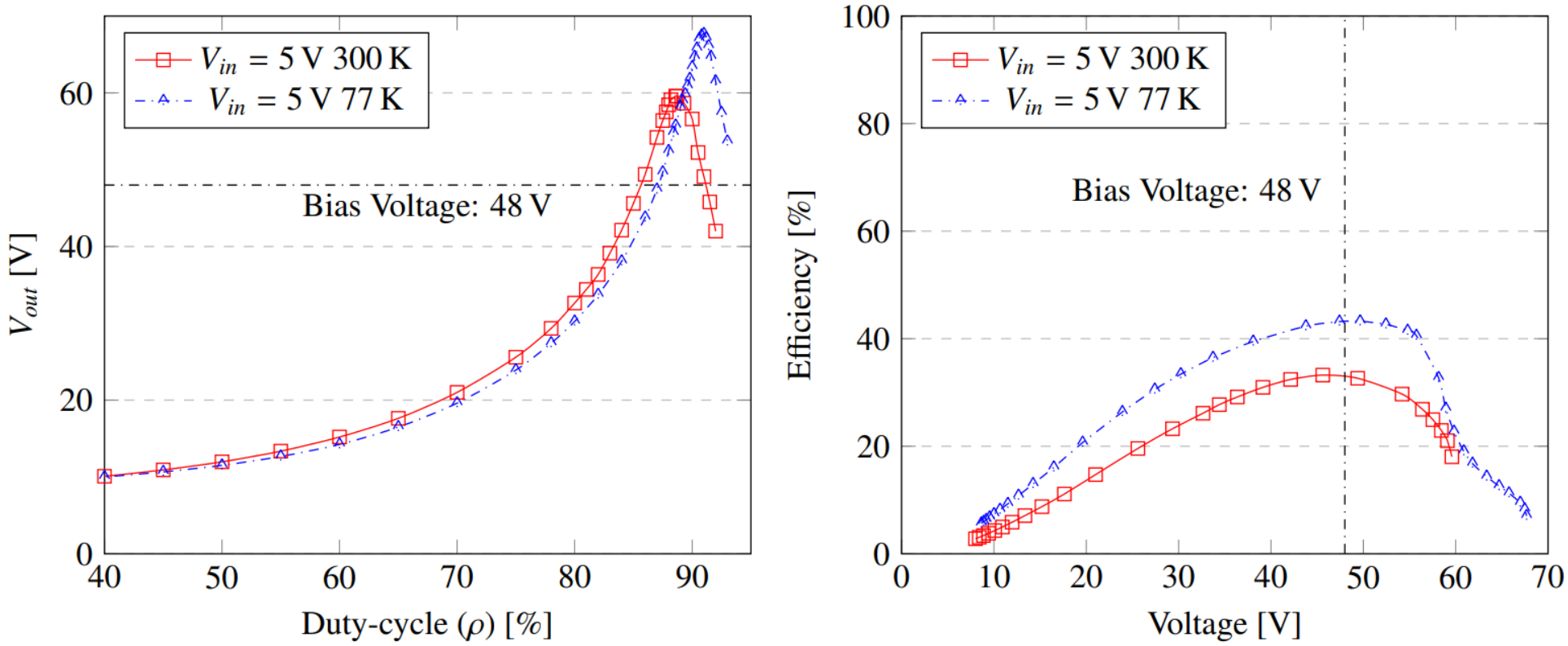
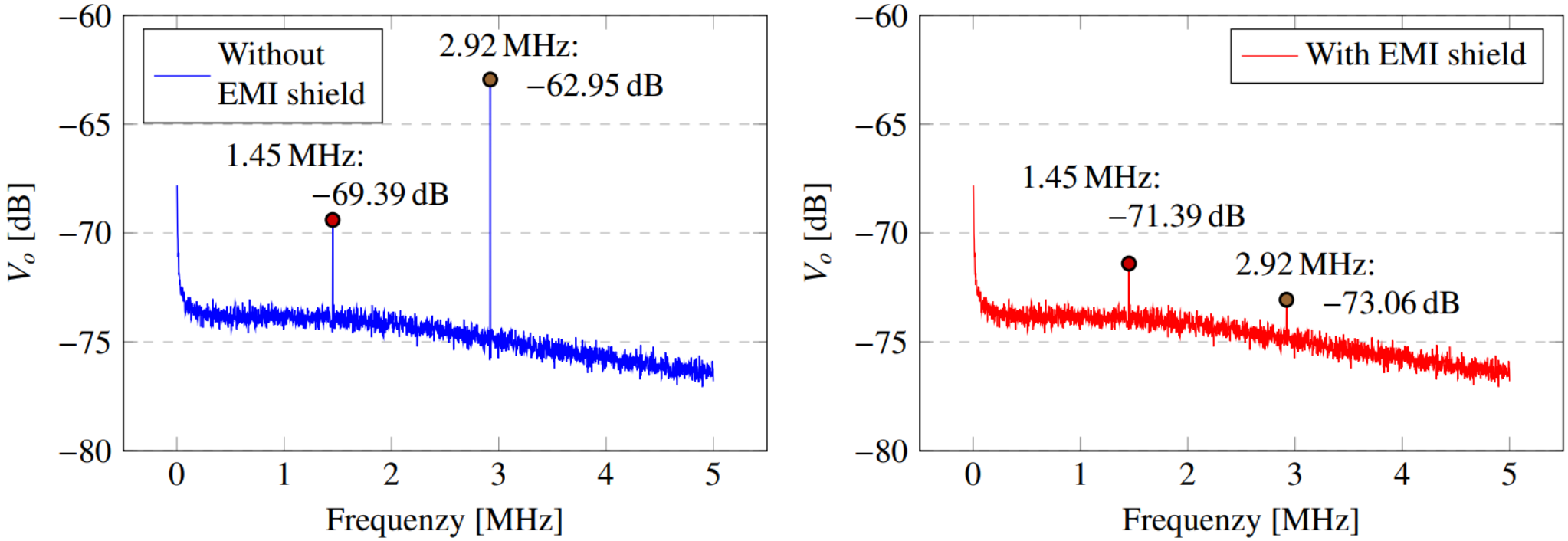
DC-DC prototype results



- **Output voltage** at RoomT limited by the inductor series resistor. At LN2 T, it is possible to reach 68 V at 91% of Duty Cycle
- The **efficiency at LN2** at 48 V is **greater than 40%**

DC-DC prototype results



- Output voltage FFT measurements at 77K without EMI shield (blue) and with EMI shield (red)

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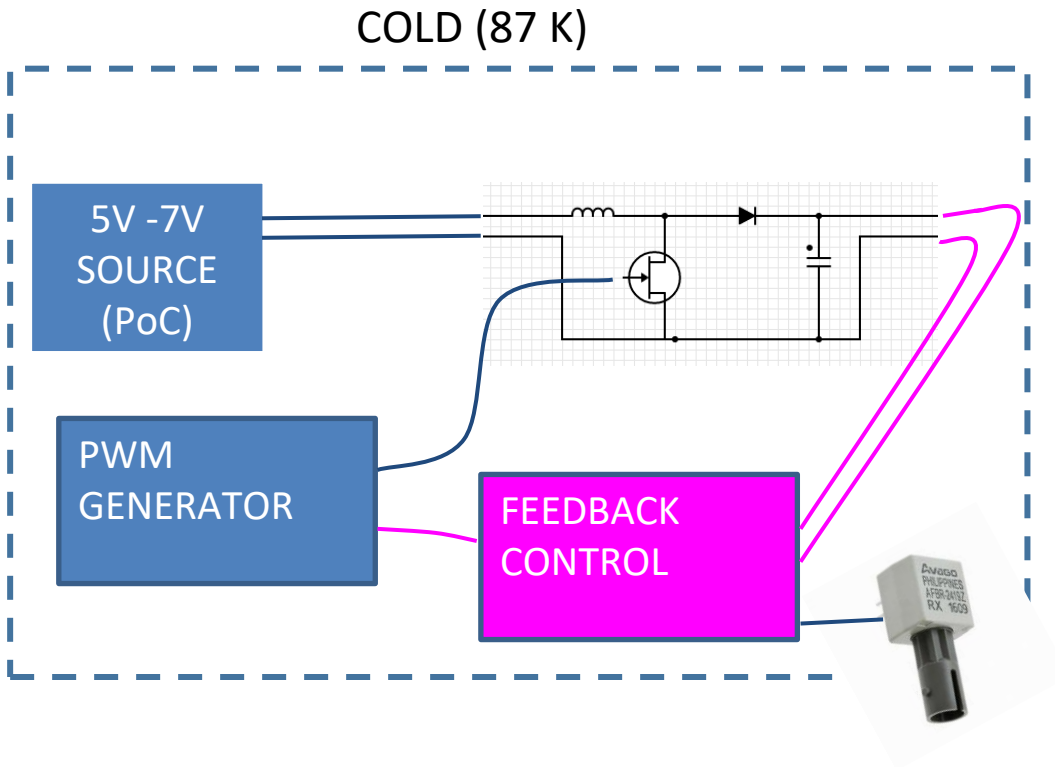
Control design

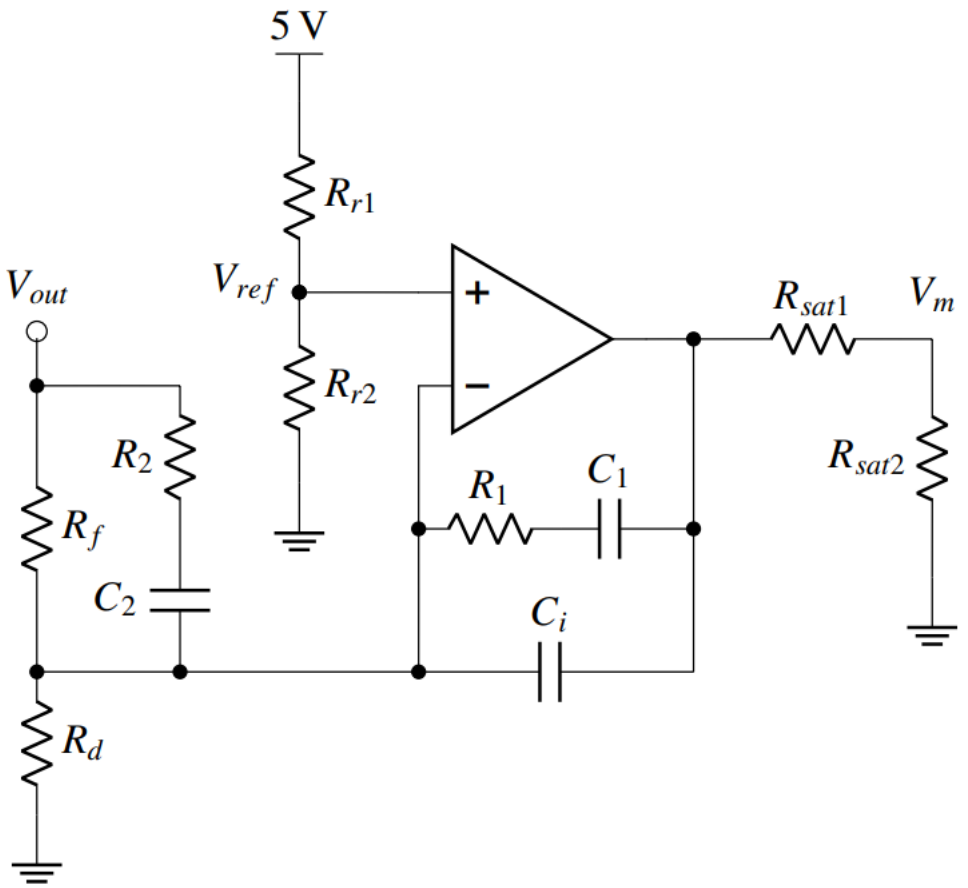
Internal feedback: output voltage control at desired set point

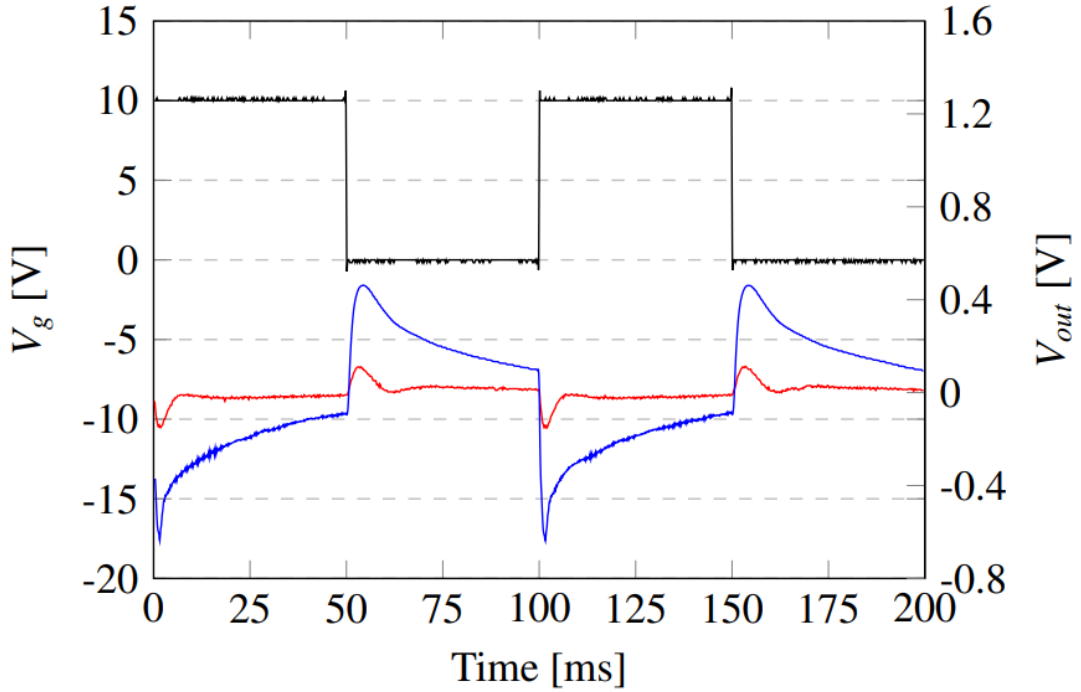
The **set point** can be:

- **Nominal**: set at design stage and fixed throughout the entire run (standalone mode)
- **External**: set point adjusted through external communication (in case of failure, nominal set-point)



Control design: analog feedback circuit





Experimental results of the **output step rejection response**, with a **load change from 50 kΩ to 8.33 kΩ**

Vout = 48 V, Vin = 5 V, output voltage measured with AC coupling at 300 K (red trace) and at 77 K (blue trace)

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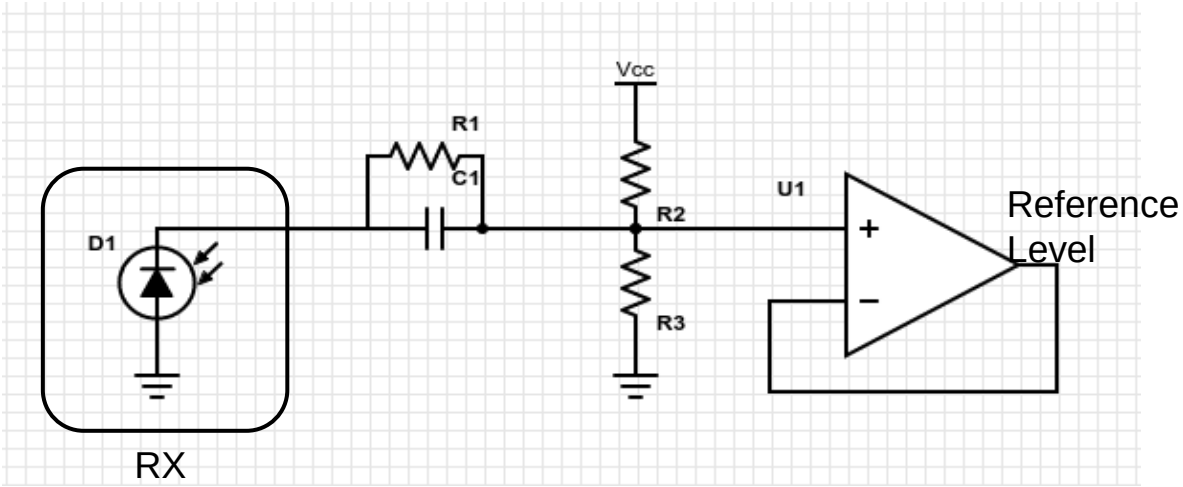
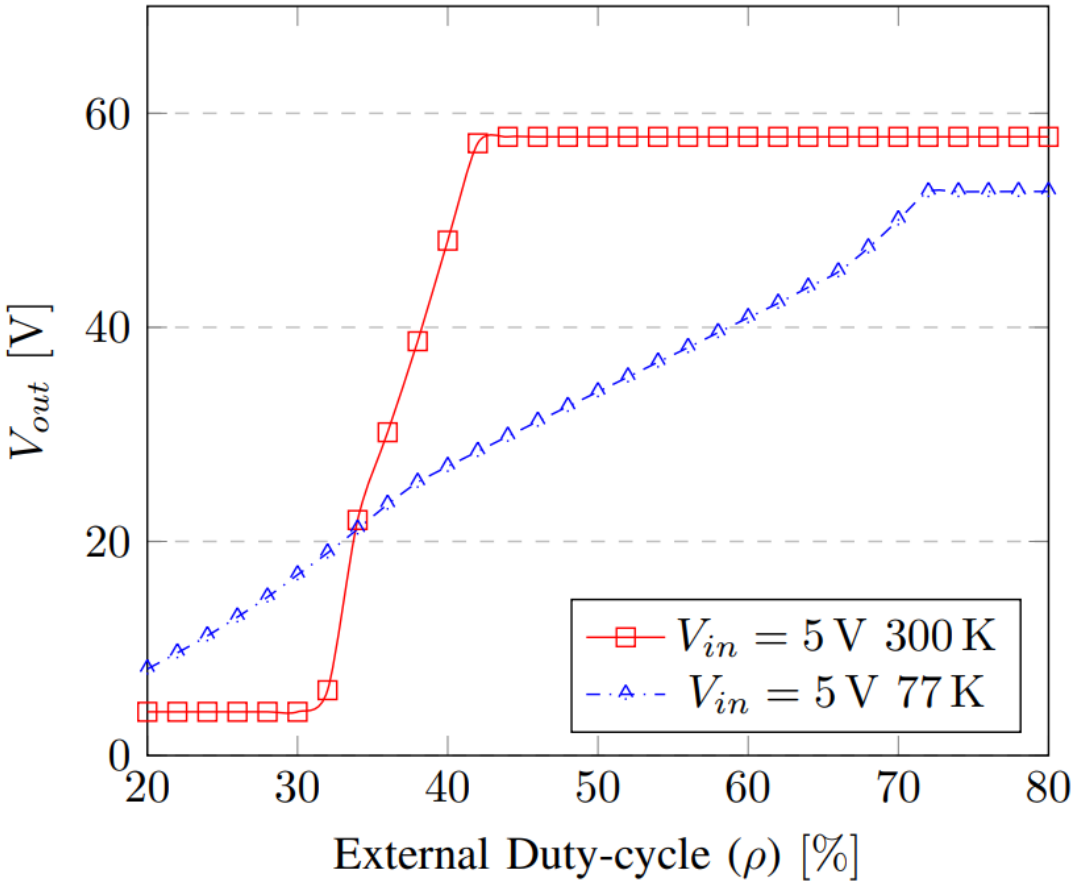
Control design: external set point

- External PWM signal drove through optical fiber: **external set point**
- Reference level changes
- AC-coupling in case of external PWM, otherwise reference set by voltage divider



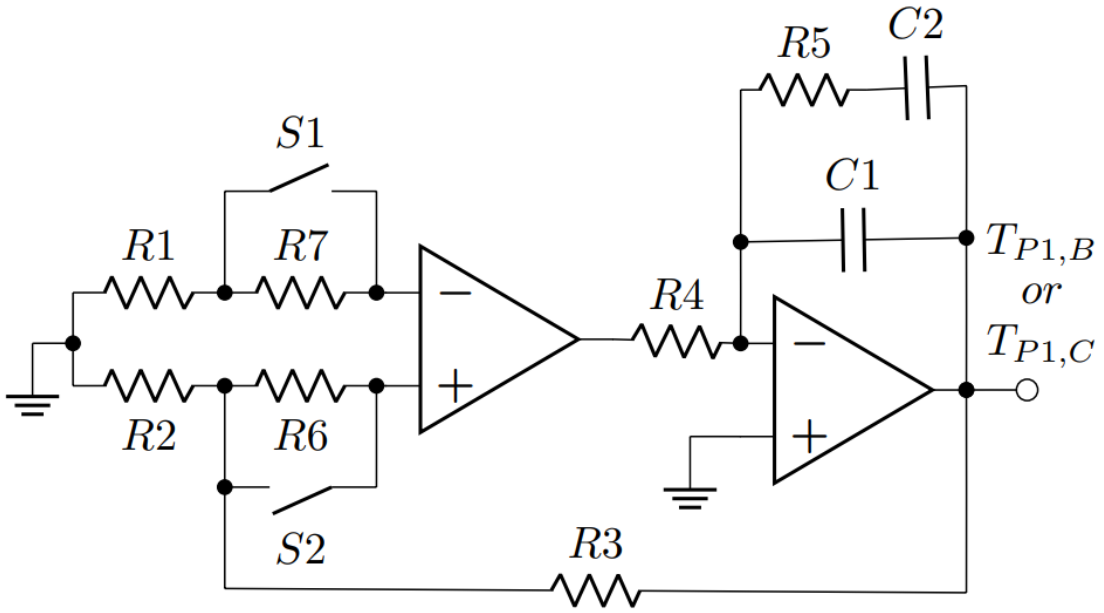


*Test with electrical connection (waveform generator)

Component characterization: OpAmps

Characterization circuit for OpAmps

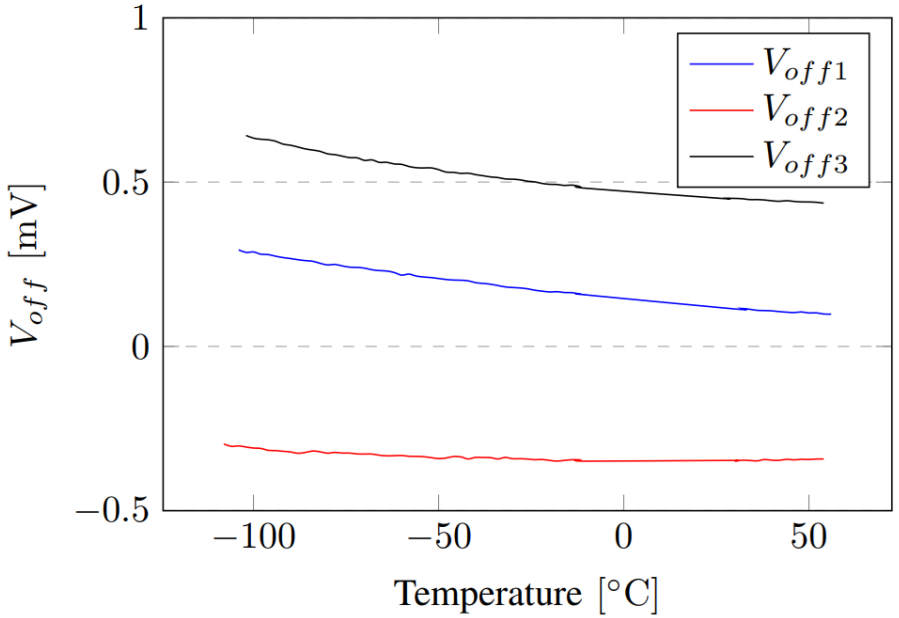
- Offset voltage, quiescent current, offset and bias currents
- First test with DUT: OpAmp LMV321
- Auxiliary OpAmp: OP27G
- DUT in climate chamber with LN2 injection
- Data recovery at each temperature step
- Automatic test bench control

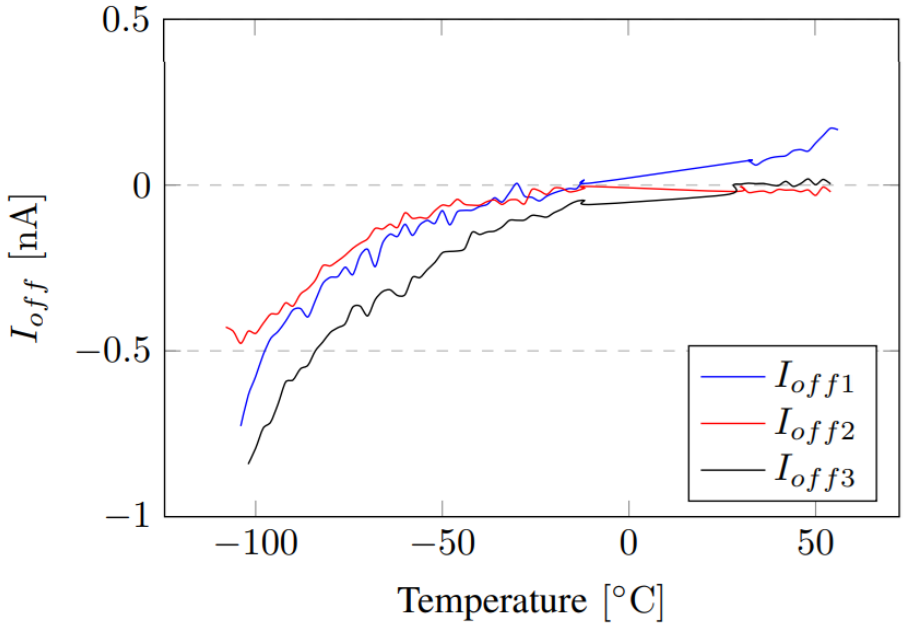


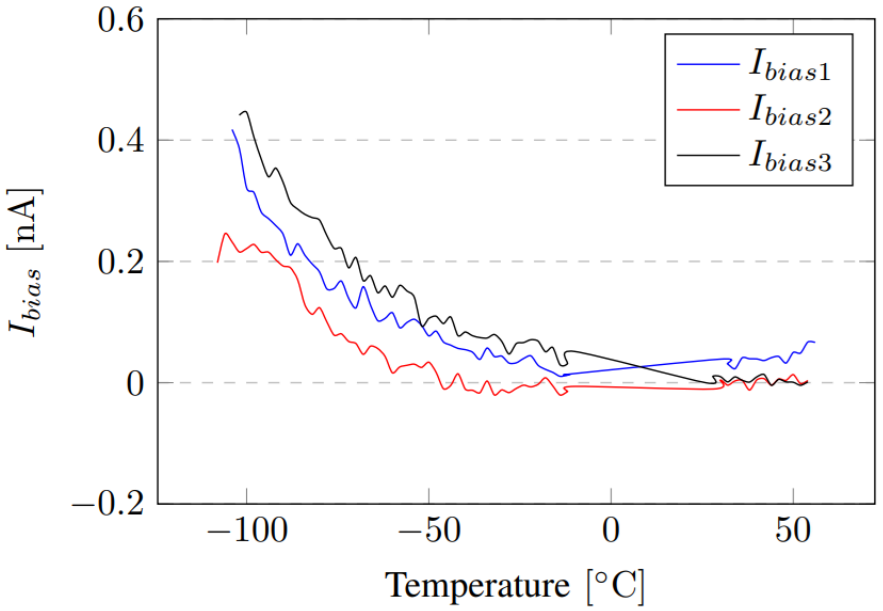
Characterization testbed

- DUT in climate chamber with LN2 injection

Experimental results: OpAmp characterization





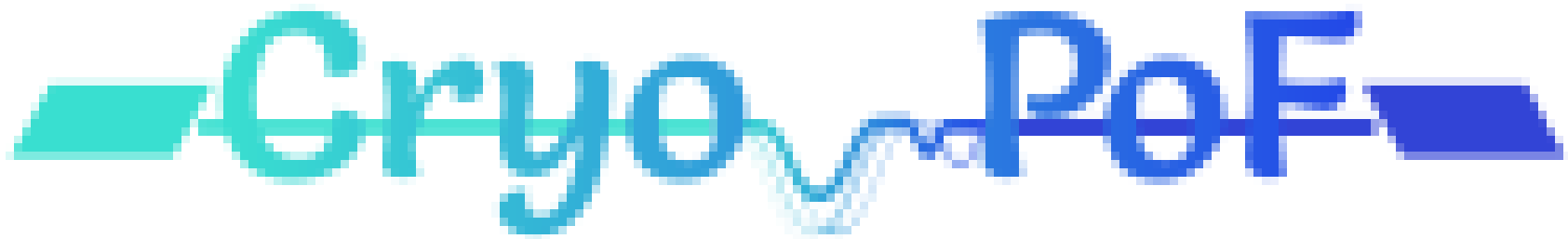


Future developments

- Test of DC-DC externa control through **optical fiber**
- Characterization of **different OpAmps**:
  - MCP6291
  - MCP6N11
  - LMV321
  - TLC271
  - AD8293
- Use of automated test bench for reliability tests for **active and passive devices**

Issues:

- **Dewar** with more capacity necessary
- **High-rate multiplexer** for data acquisition unit necessary



Istituto Nazionale di Fisica Nucleare

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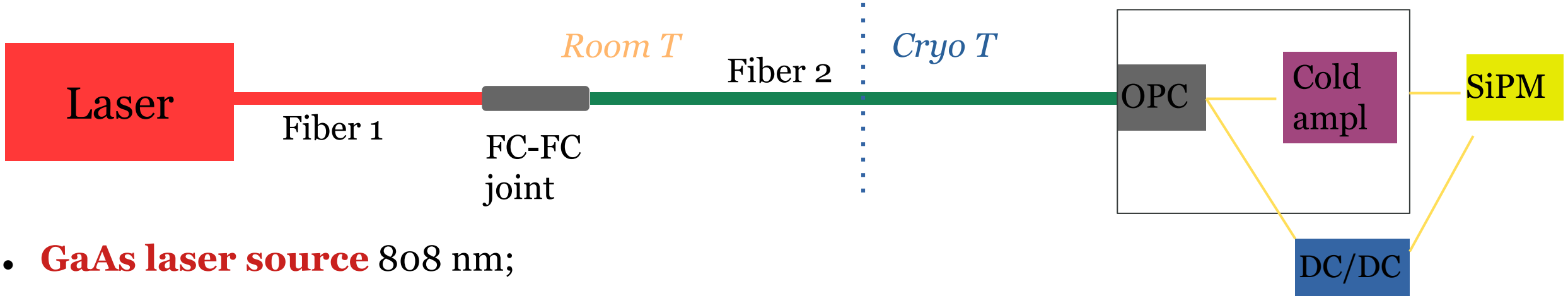
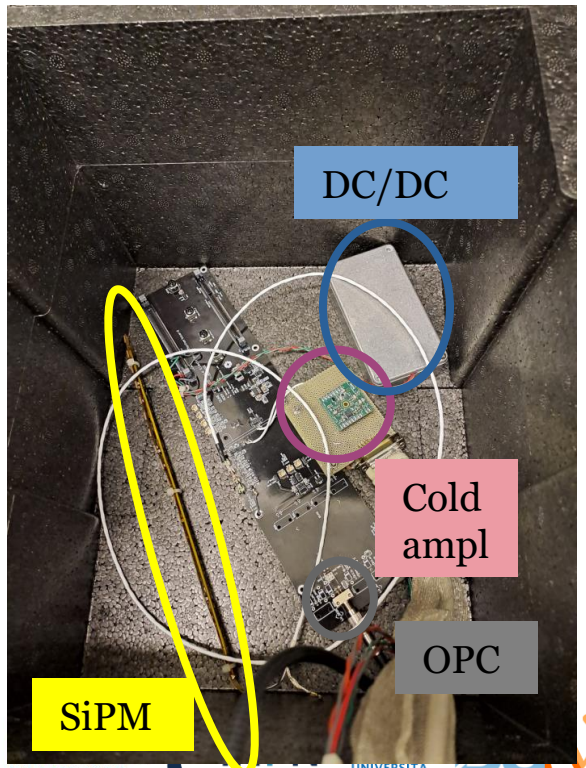
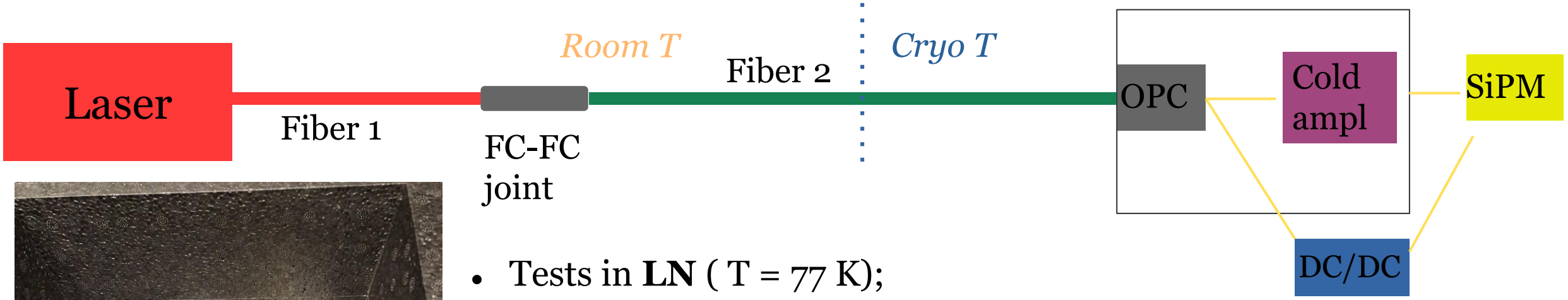
From laser to SiPM – Cryo-PoF setup

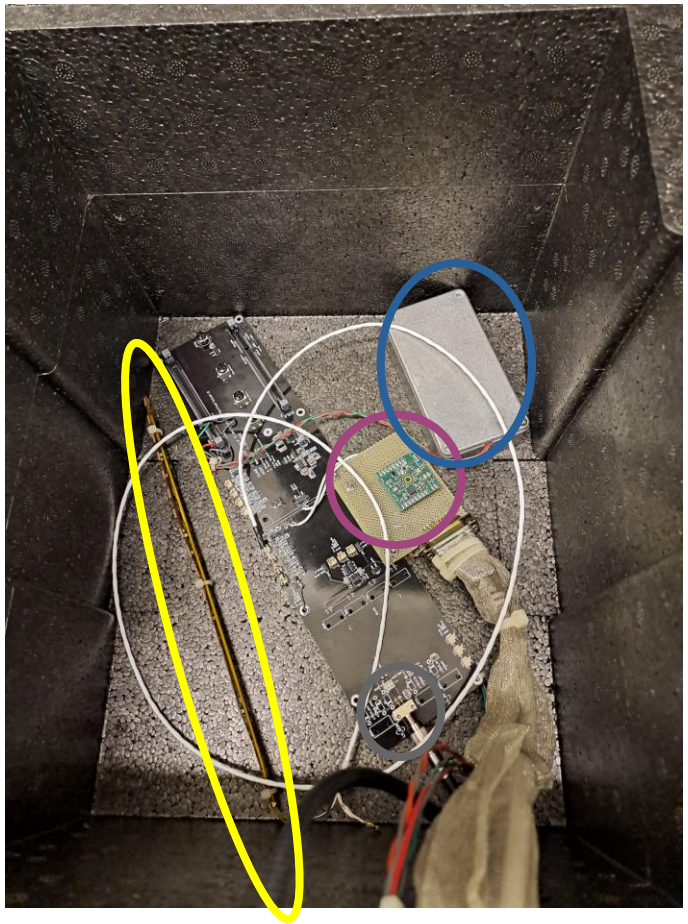


- **GaAs laser source** 808 nm;
- **Graded index multi mode optical fiber** with black plastic sheath;
- **Optical power converter,** V_{max} = 6 V, 30% efficiency in LN;
- **Cold amplifier** MiB for DUNE HD, V_{in} = 3.3 V;
- **DC/DC** boost converter **V1** INFN Mi → placed in a metallic box to reduce noise, possibility to tune SiPM bias as a function of laser power;
- **Hamamatsu SiPM,** 1 flexi board with **20 SiPMs** in parallel.



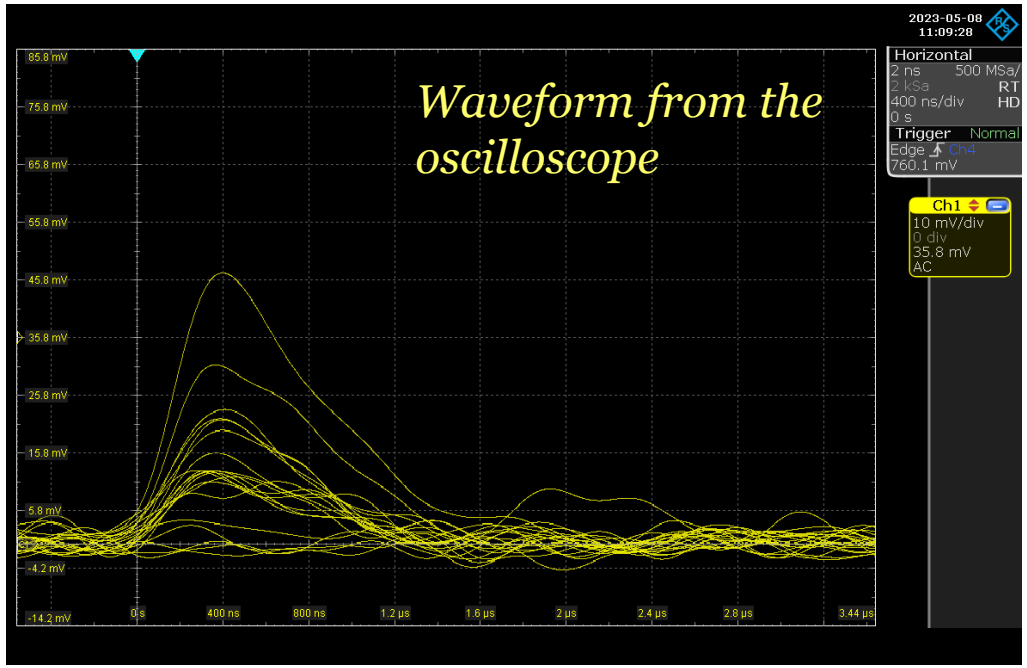
From laser to SiPM - Results





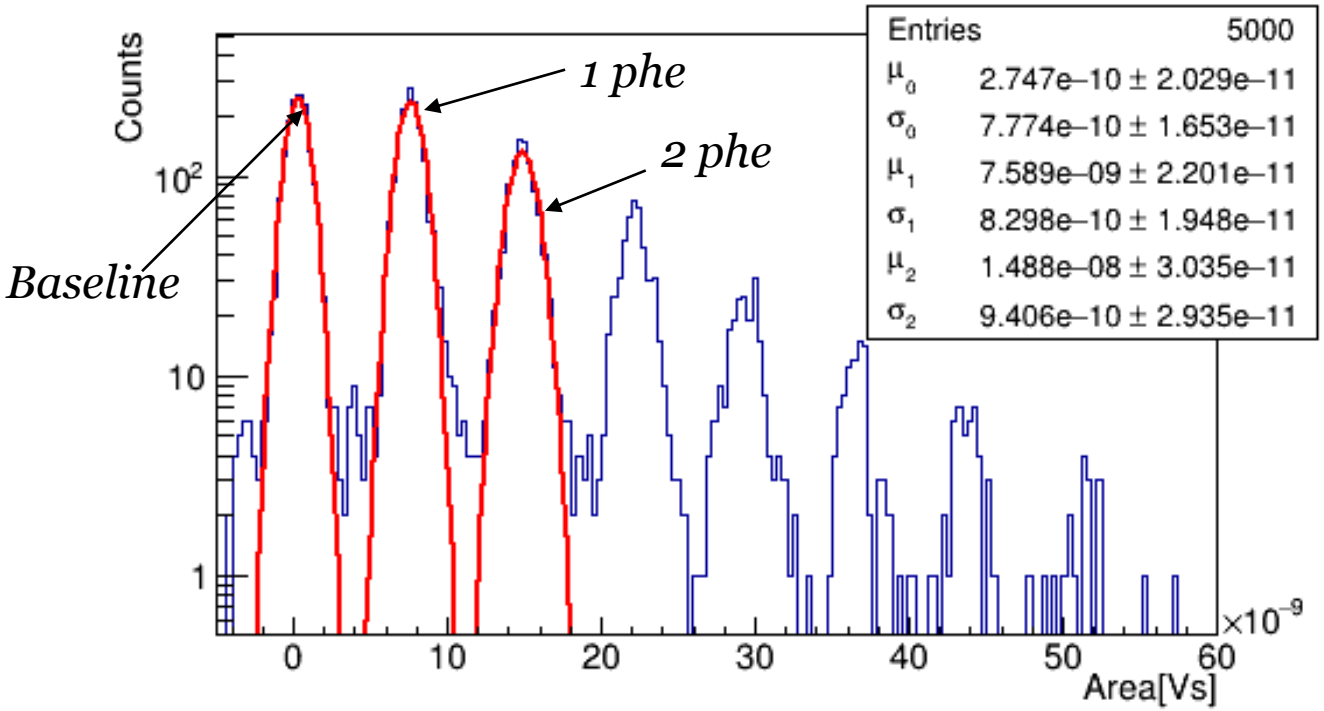
- Tests in **LN** (T = 77 K);
- **20 SiPMs** in parallel (1 flexi board);
- **three SiPM bias** tested : 45 V, 46 V, 47 V (3, 4, 5 V ov);
- evaluation of the **Signal to Noise Ratio** (SNR);
- comparison of the results: PoF vs copper line.

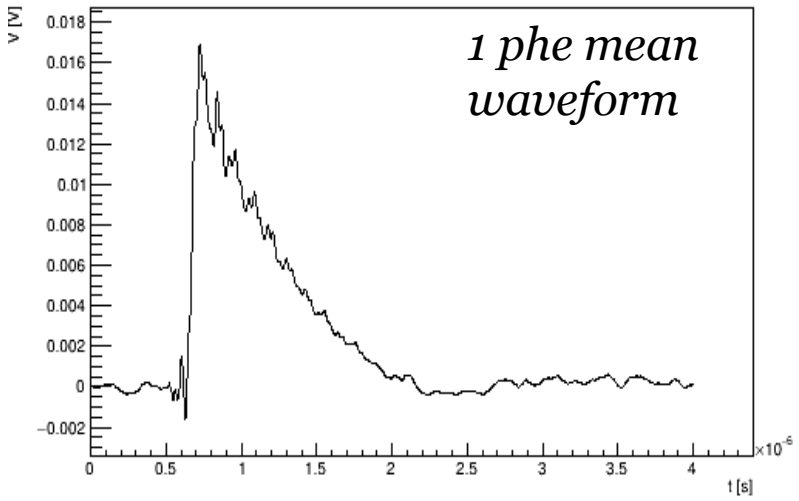
From laser to SiPM – PoF Results



V_{in} laser = -2.83 V
V_{bias} = 46 V – 4 V ov

Charge integral





SNR = 9.409

PoF vs copper cable – SNR results

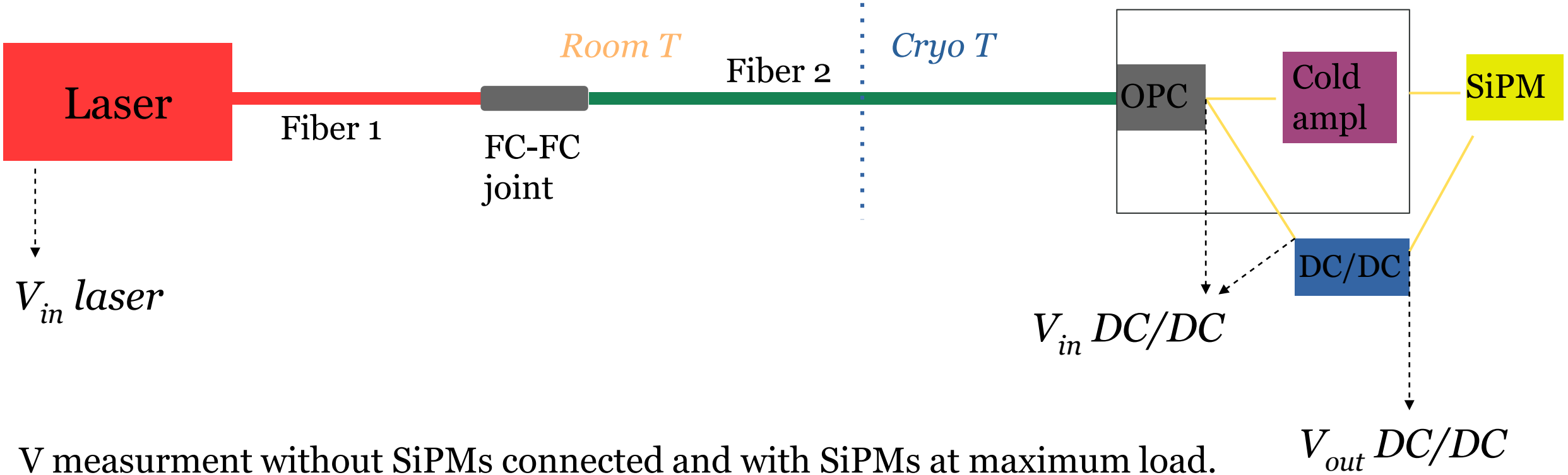
SNR is calculated for each SiPM bias tested.

		SNR	
SiPM bias	**Overvoltage**	*Copper cable*	*PoF*
45 V	3 V	7.830	7.520
46 V	4 V	10.665	9.409
47 V	5 V	13.004	11.070

The performances of the PoF are comparable with the copper cable ones.

Back up

DC/DC boost converter



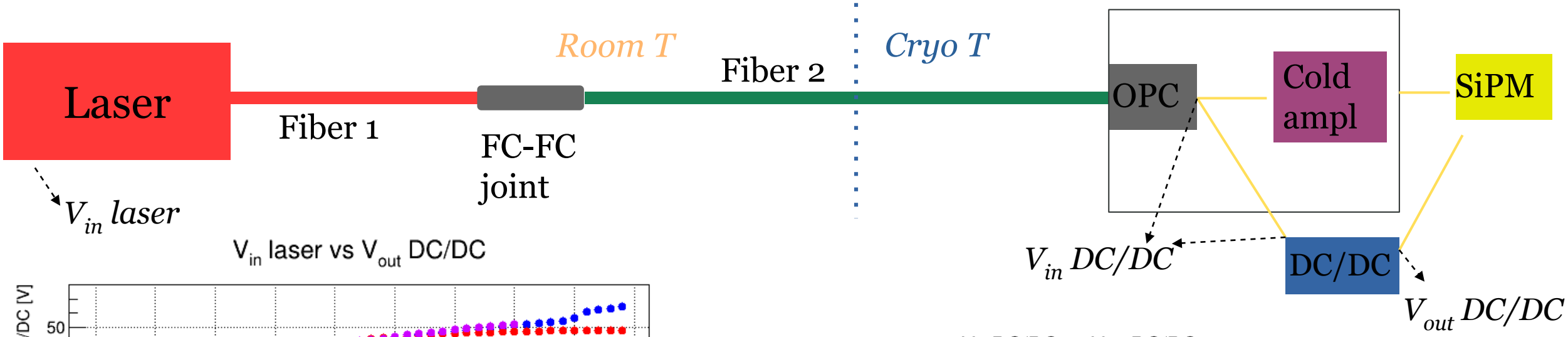
V measurment without SiPMs connected and with SiPMs at maximum load.

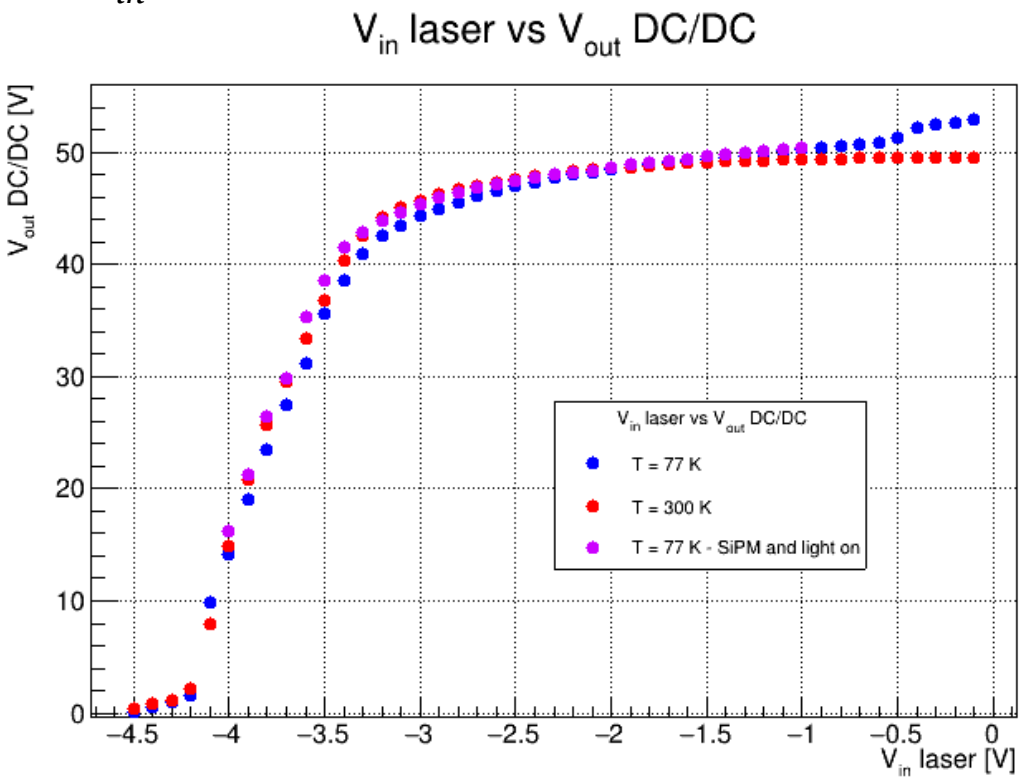
V_{in} laser → V laser source input, proportional to the laser power;

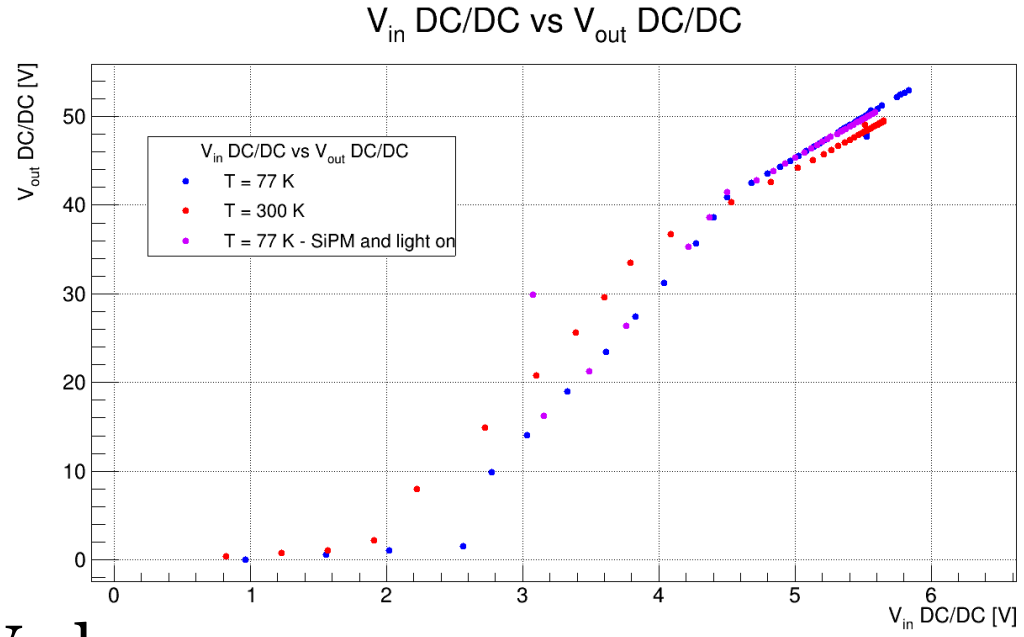
V_{in} DC/DC → V output from the OPC, that is the DC/DC input ;

V_{out} DC/DC → V output from the DC/DC, that is the SiPMs bias voltage.

DC/DC boost converter



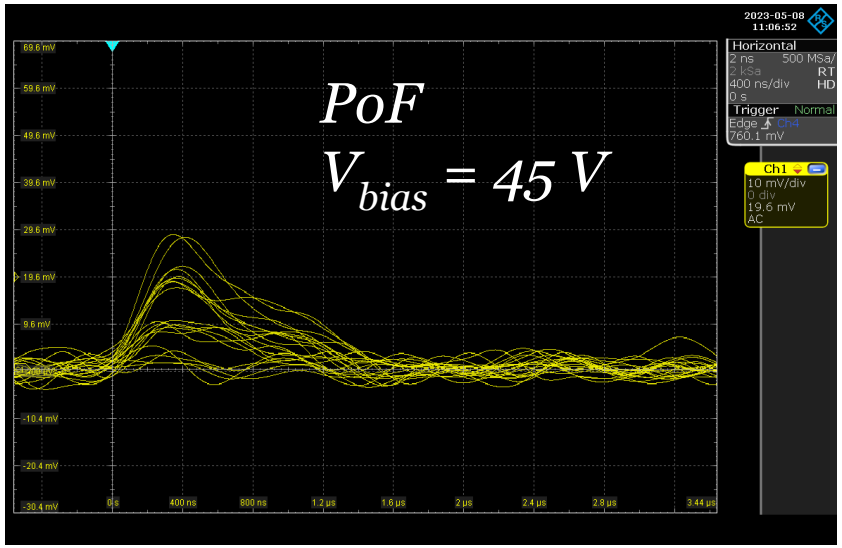


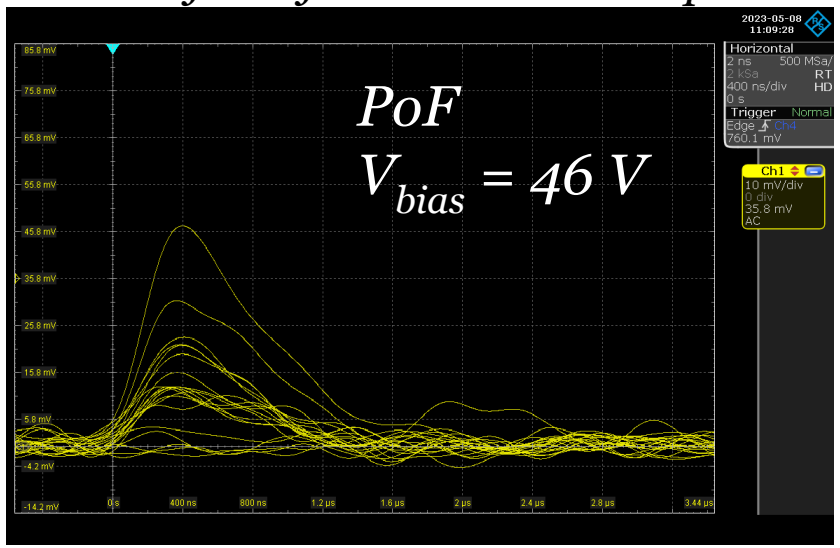


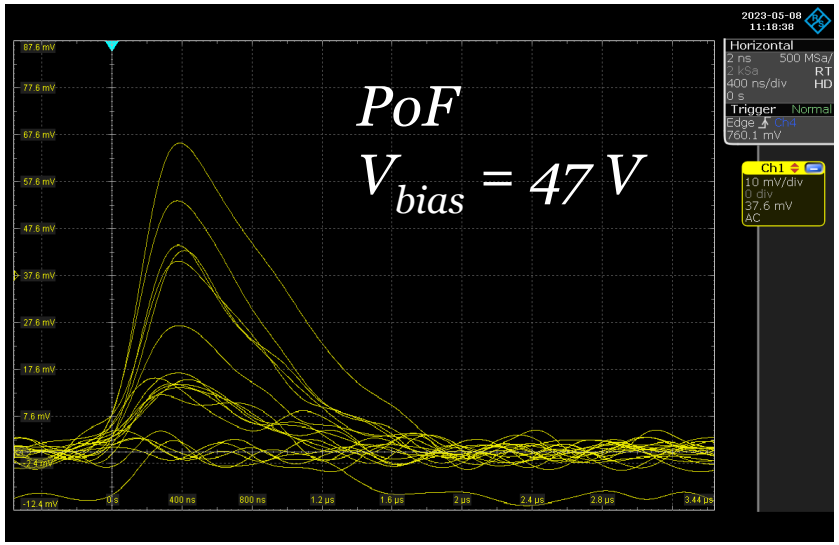
V_{out} DC/DC increases as a function of V_{in} laser.

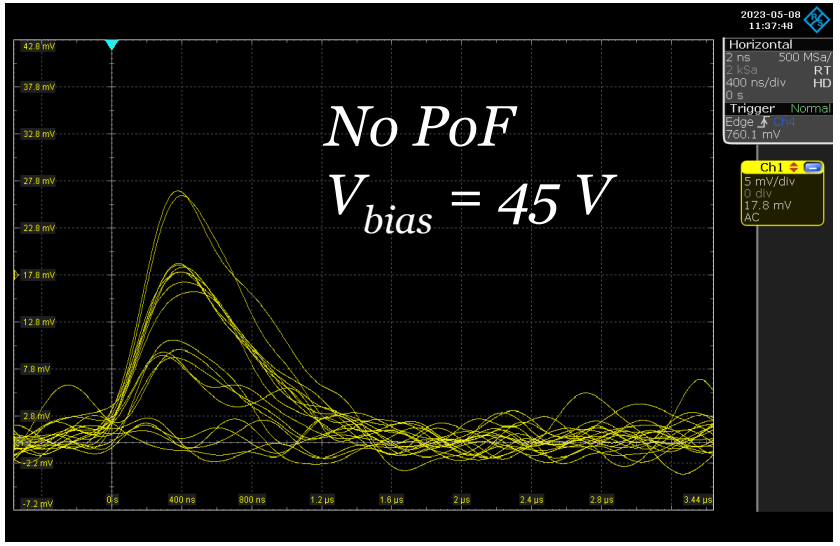
Results

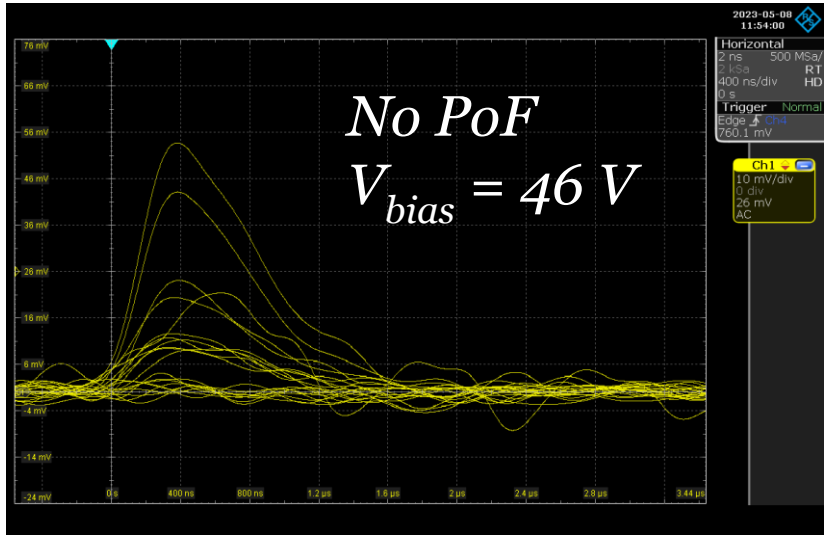
Waveform from the oscilloscope

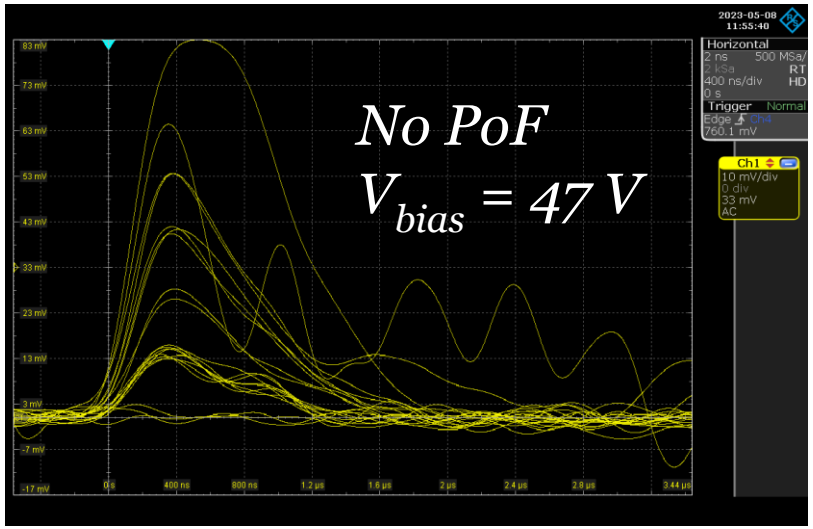






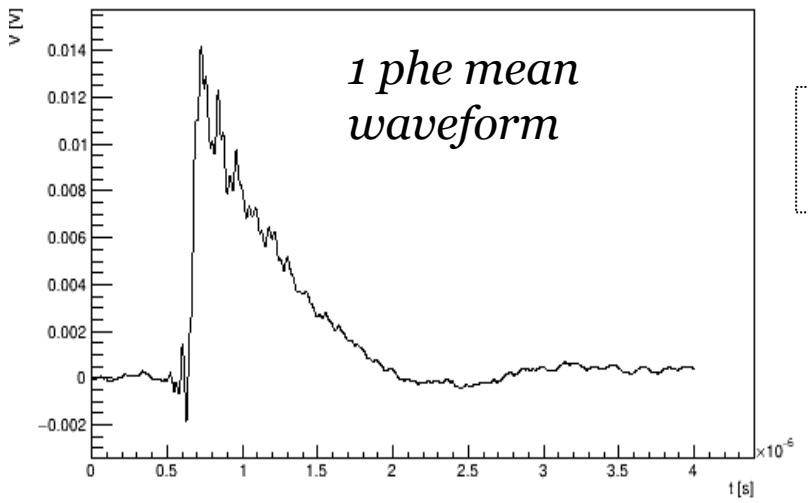






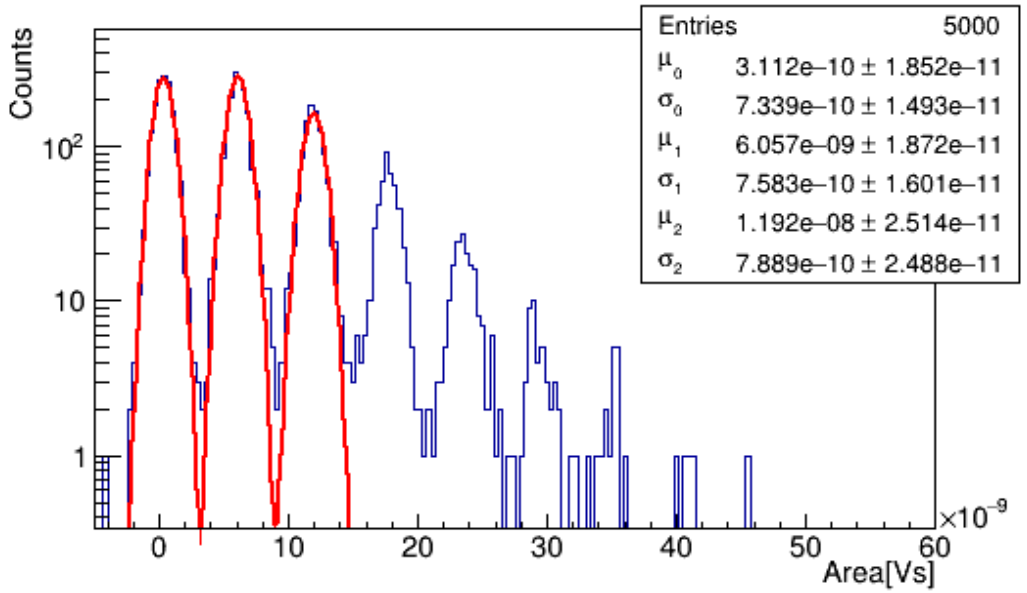
Results

Copper cable

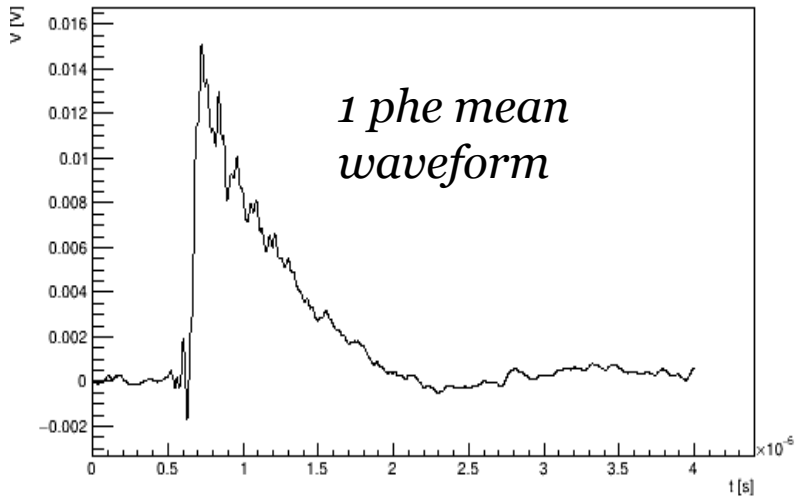


V_{bias} = 45 V – 3 V ov

SNR = 7.830

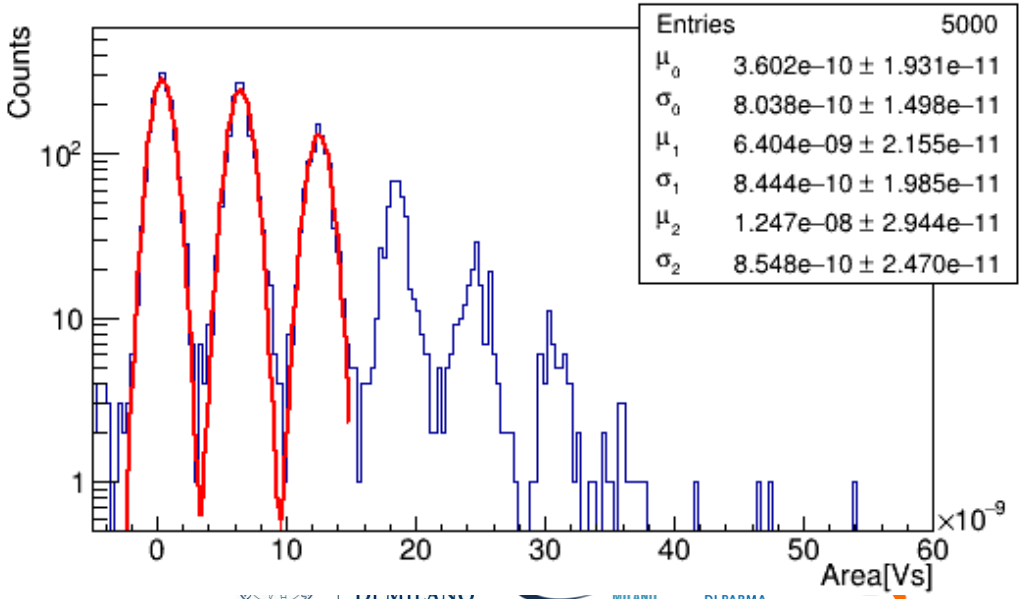


PoF



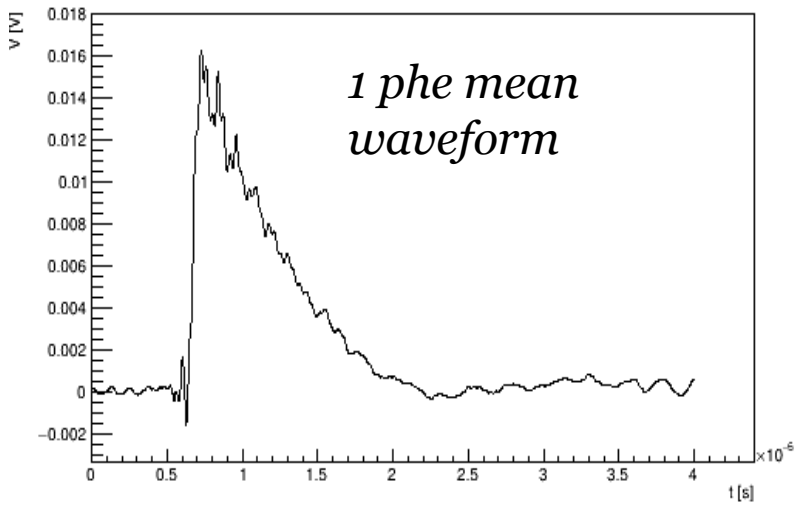
V_{in} laser = -2.97 V
V_{bias} = 45 V – 3 V ov

SNR = 7.520



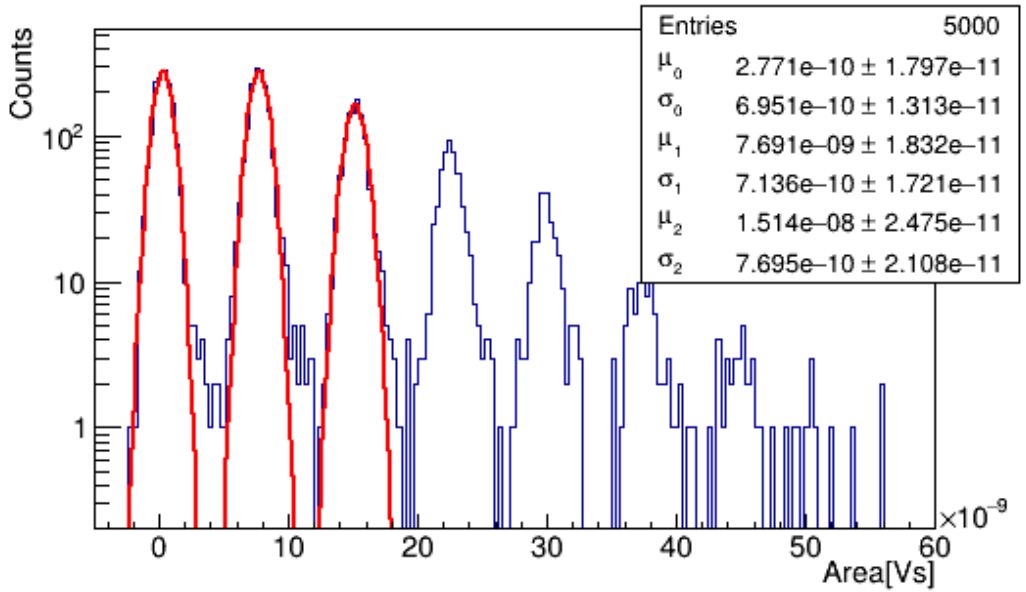
Results

Copper cable

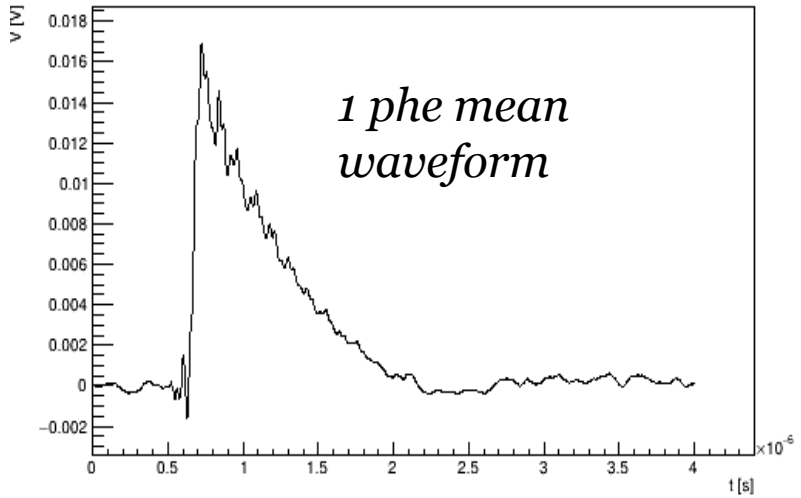


V_{bias} = 46 V – 4 V ov

SNR = 10.665

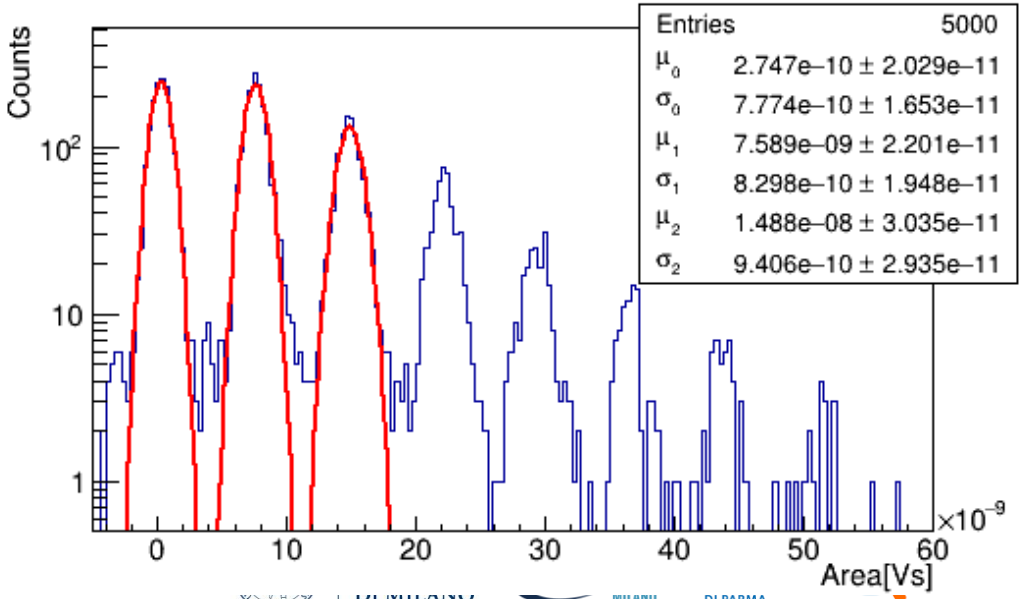


PoF



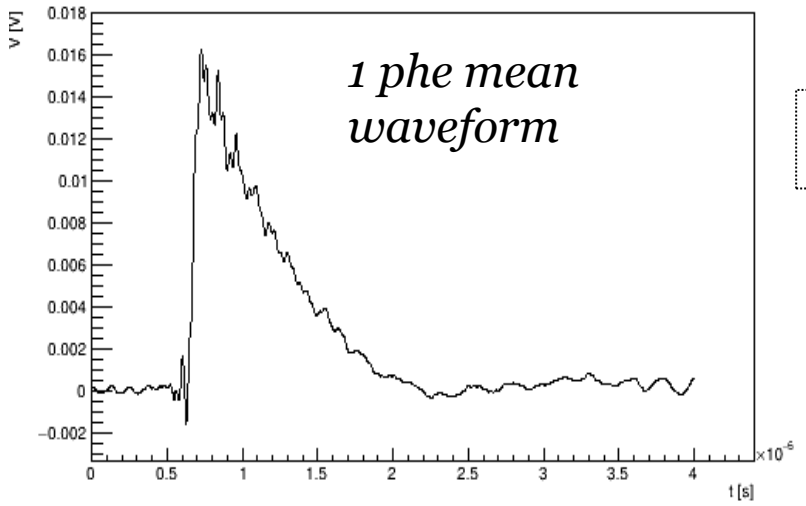
V_{in} laser = -2.83 V
V_{bias} = 46 V – 4 V ov

SNR = 9.409



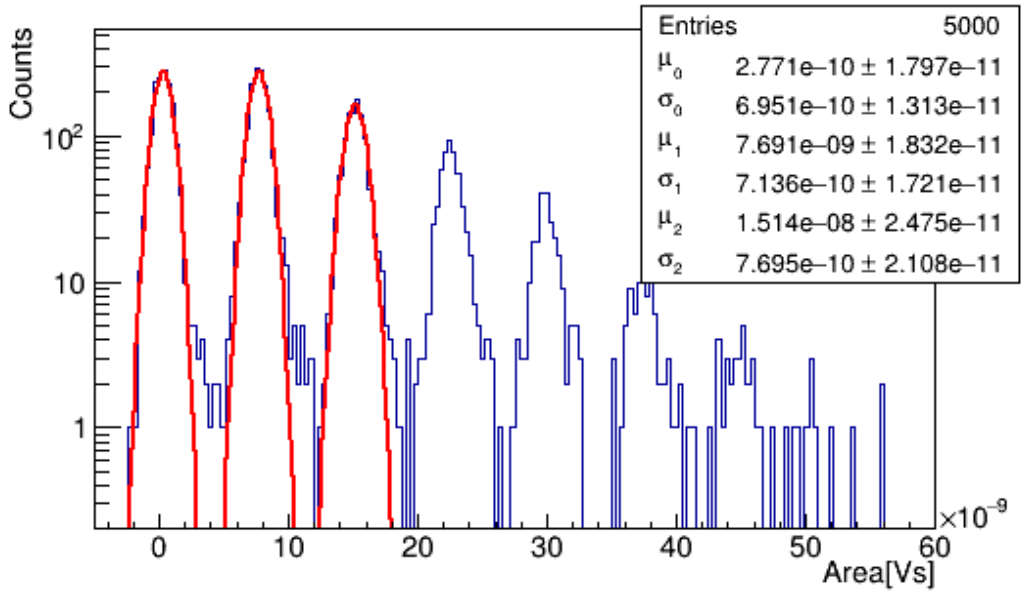
Results

Copper cable

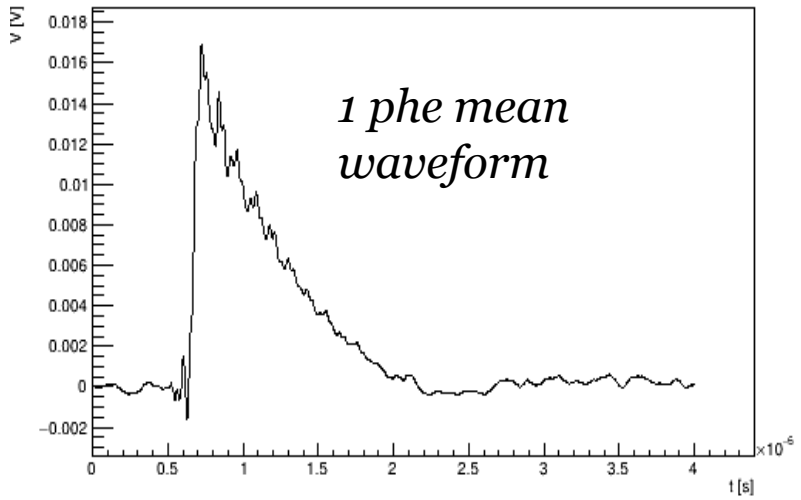


V_{bias} = 47 V – 5 V ov

SNR = 13.004



PoF



V_{in} laser = -2.61 V
V_{bias} = 47 V – 5 V ov

SNR = 11.070