

# On a new RPC read out

RPC 2026 Rio de Janeiro

17 Sep 2026

C. Casentini<sup>1</sup>, L. Conti<sup>4</sup>, L. Di Stante<sup>2</sup>, B. Liberti<sup>2</sup>, E. Pastori<sup>2</sup>, G. Piano<sup>1</sup>,  
G.D. Piccolo<sup>2</sup>, G. Rodriguez<sup>1,2</sup>, R. Santonico<sup>2</sup>, M. Tavani<sup>1</sup>, M. Vallocchia<sup>3,4</sup>

By R. Santonico

(1)INAF (2)INFN (3)INGV (4)Uninettuno

# Strip vs squared pad read-out

- The purpose of this talk is to optimize the RPC read-out in cases requiring a **very large number of channels with a relatively modest space-time accuracy**, such as nanoseconds x tens of centimeters
- Strip RO: Capacitance-free; long distance propagation with modest amplitude loss; very good space resolution in the transversal direction; BUT longitudinal position needed to eliminate the transmission time jitter
  - Orthogonal X and Y read out panels faced to the same gap. Submillimeter XY accuracy achievable with the charge partition method
  - OR two FE circuits at both ends of the strip to interpolate the longitudinal coordinate

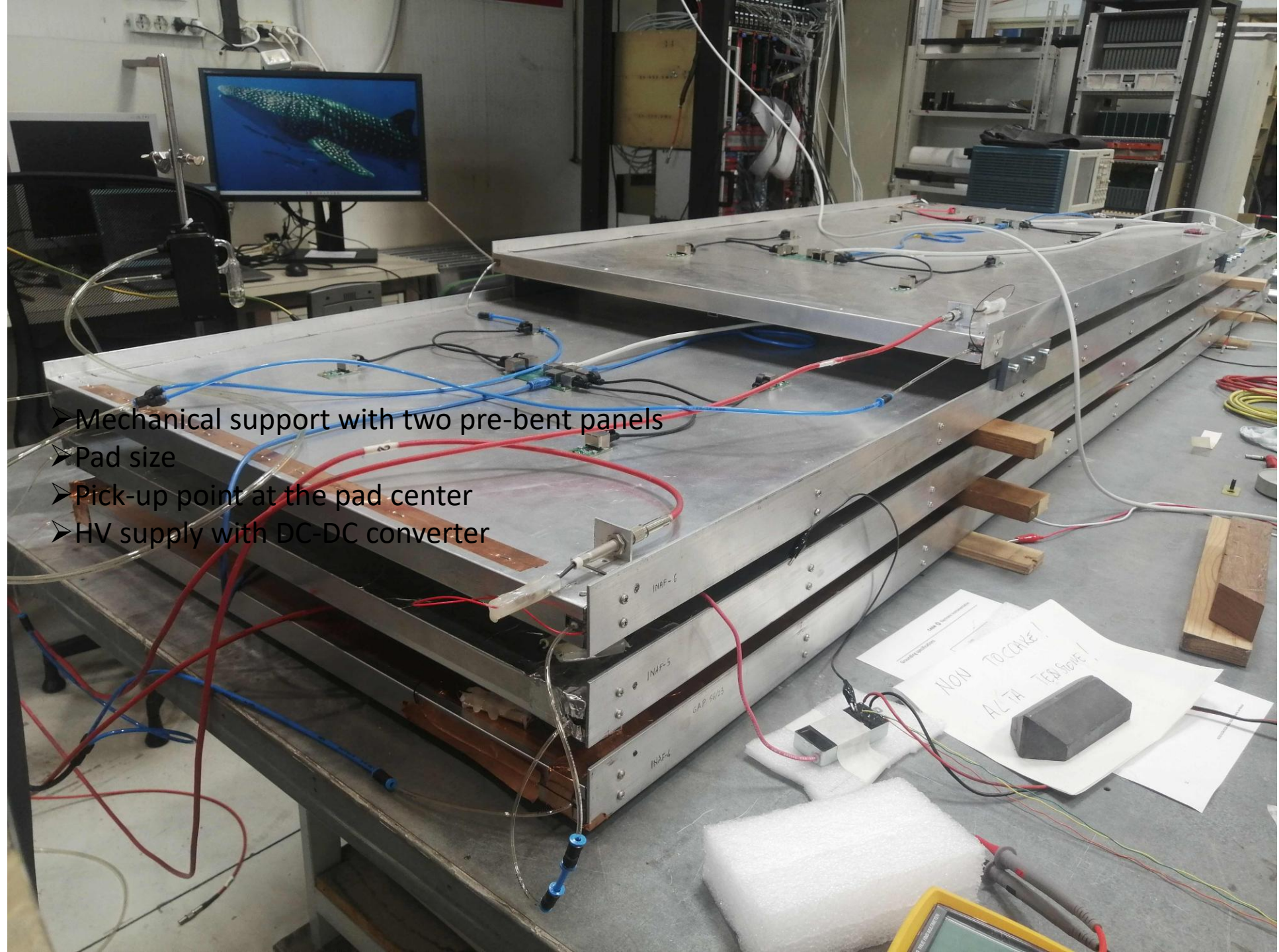
# Strip vs squared pad read-out (2)

- PAD RO: both coordinates measured within the uncertainty due to the pad sizes; good solution when relatively modest space resolution needed; modest time jitter due to signal propagation inside the pad; capacitance effect could be relevant
- Problem not at all irrelevant: in the next future the cost will more and more discriminate between feasible and unfeasible experiments
- A natural and relevant application of the pad RO is the mapping a CR shower at ground
- This talk is an extensive study of the RPC performance when equipped with the pad RO

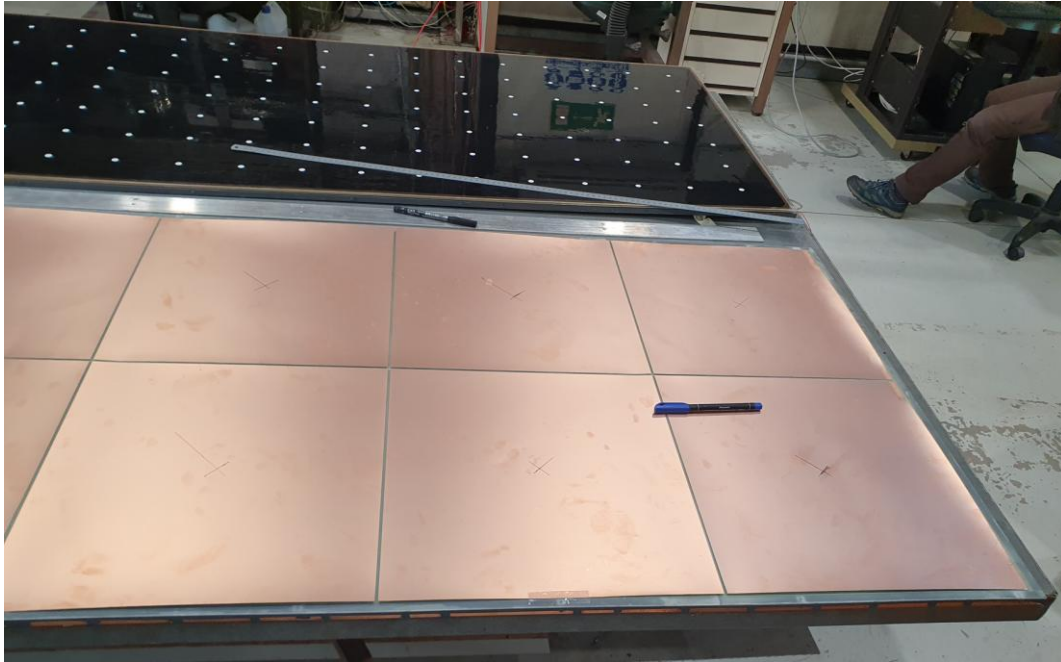
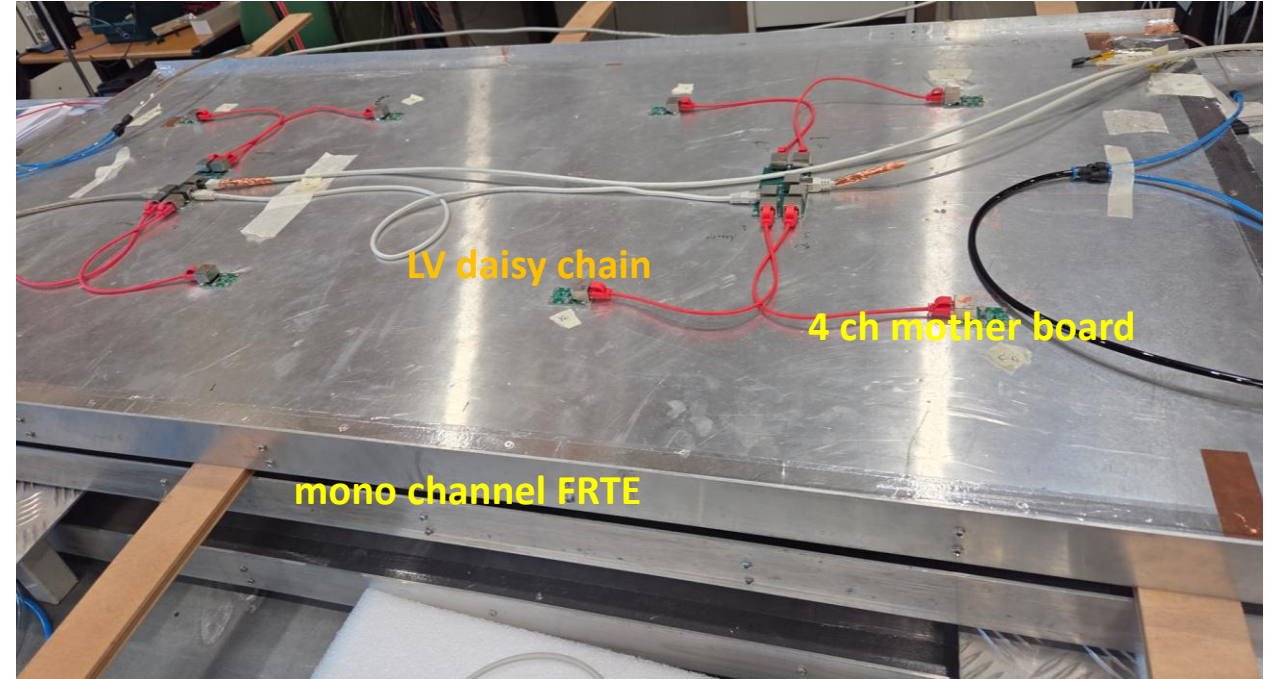
# Further improvements

- HV supply by DC-DC converter
- New lay-out → gas pipes inserted in the gas gap; HV cables 10 kV 1 mm diameter; General layout
- FE circuit connected at the center of the pad → perforating the mechanical support panel
- → improved shielding hermeticity with respect to external em noise

- Chamber size 2.8 x 0.80 m<sup>2</sup>
- Mechanical support with two pre-bent panels
- Pad size ~35x40 cm<sup>2</sup> with **Pick-up point at the pad center**
- HV supply with DC-DC converter **NO HV connectors**
- All 4 chambers tested with CR using as **trigger signal** the triple coincidence excluding the chamber under test



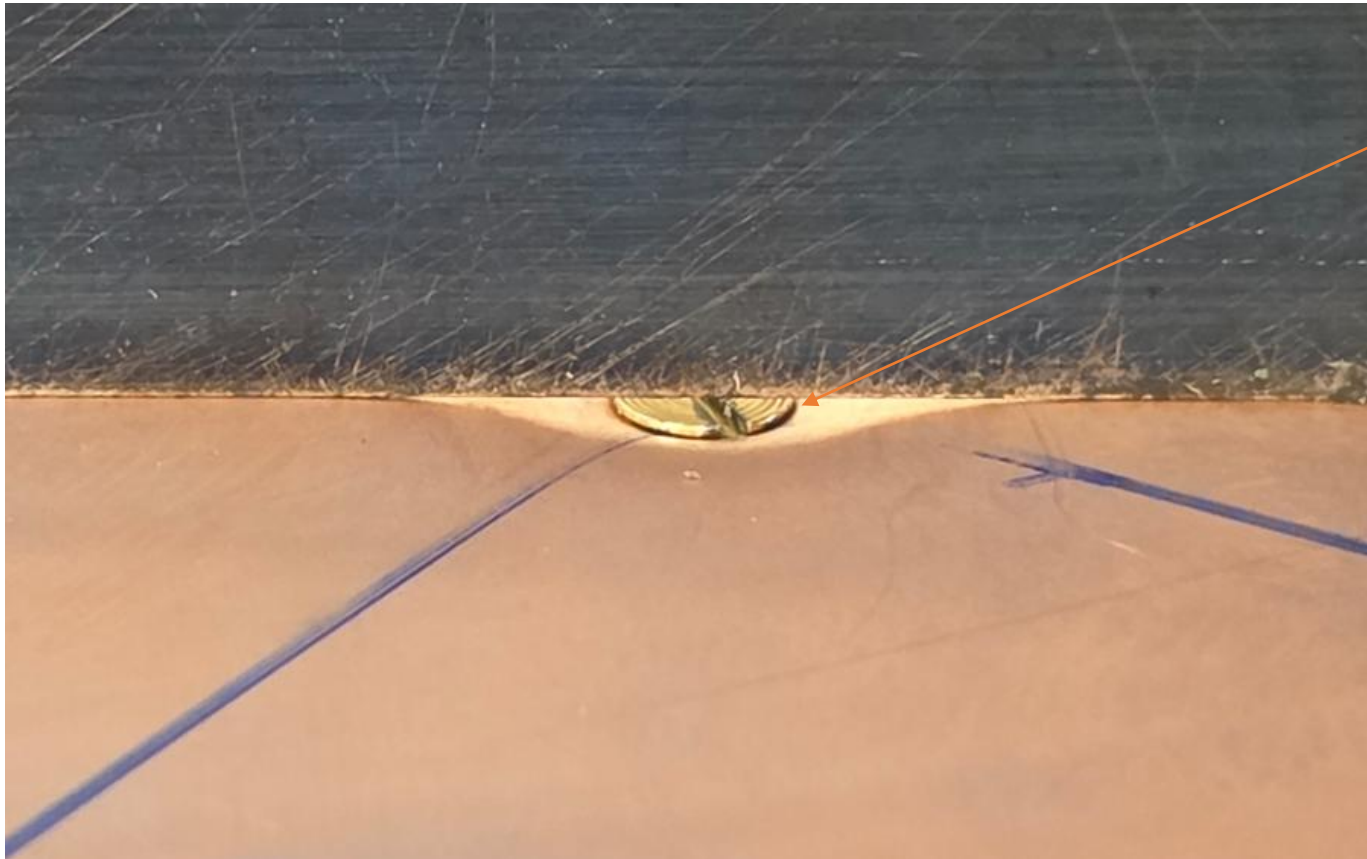
# Front-end and chamber integration



The mono channel FRTE is **installed without welding at center of each PAD** with a single screw for the signal. The board is grounded outside the chamber faraday cage and connected to a 4 channels motherboard. All the connections both for the LV and the signal are made through standard LAN patch cords with RJ45 connectors. For the signal the cat 6a LAN type assures about 450 MHz of bandwidth and it is possible to send the LVDS signal for about 10 m without any significant signal degradation. **The measured system time skew between channel after 10 m of standard cable is about 1ns without any calibration.**



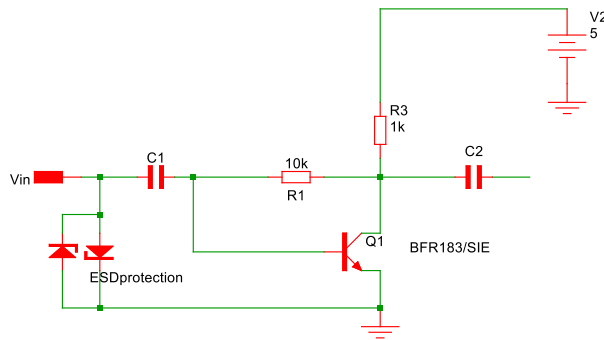
# Connecting the pad to the FE circuit



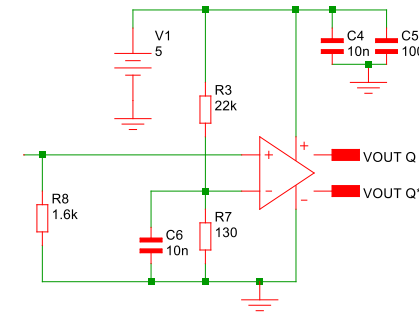
2 mm screen with 4 mm  
head not touching the  
gas gap

# New FRTE for RPC PAD readout

Based on single Bjt transimpedance amplifier (TIA) first proposed for RPC strips readout by **Roberto Cardarelli** + High-Speed commercial comparator with LVDS Output



**The first-stage** characteristics depend on the transistor and biasing chosen. In this application, **stability and robustness are stressed more than sensitivity and speed**. The main advantages of this configuration is the high pulse amplification, low noise (typical  $A=1$  mV/fQ with 1-2 mV of noise floor for the typical RPC pulse), intrinsic stability.



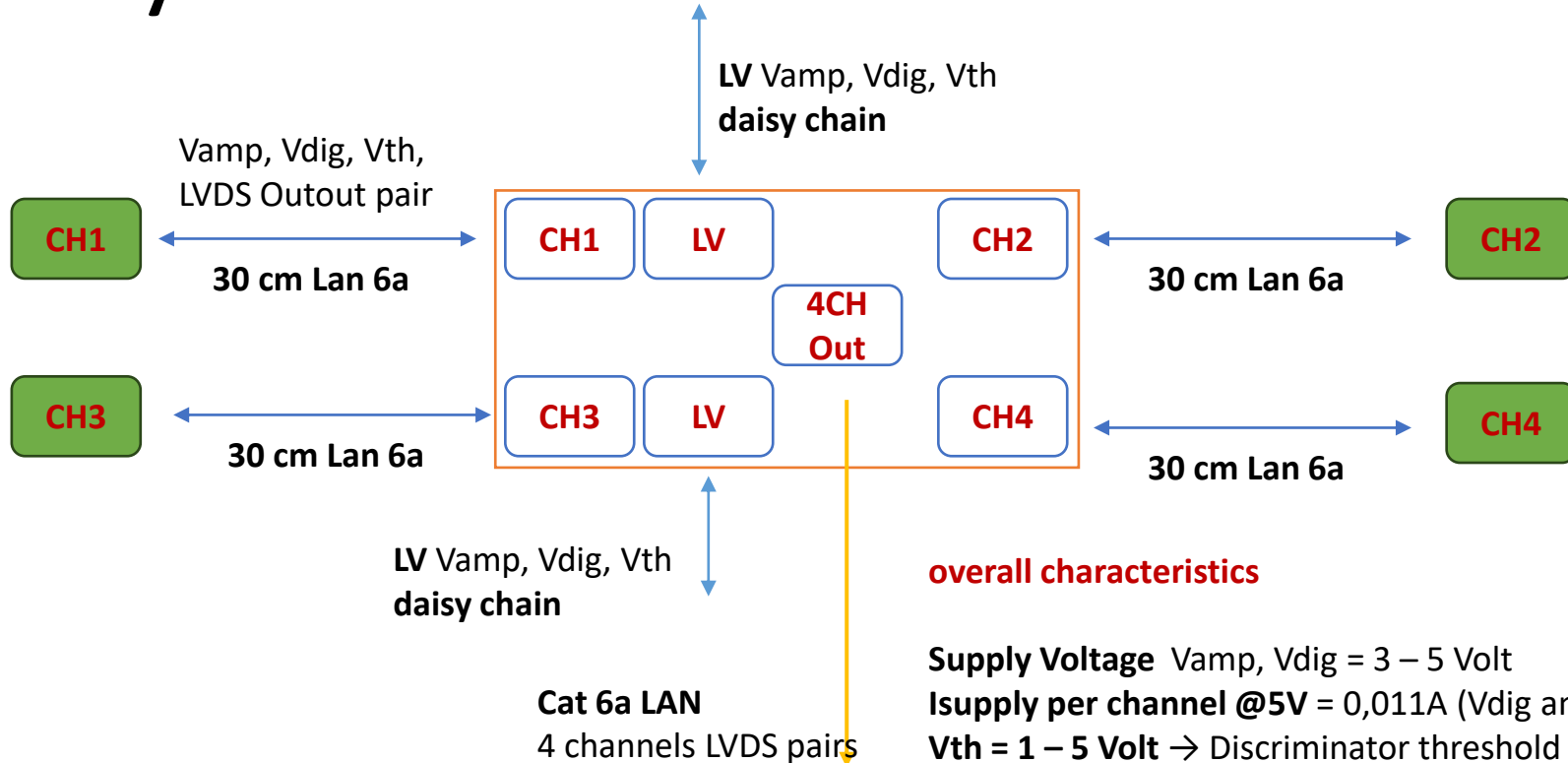
**The second stage** is a discriminator made with a standard catalogue fast comparator (Texas TLV3604) typically used for LIDAR application.

The main interesting characteristic of this COTS are:

- Low cost and low consumption
- Low overdrive dispersion: 350 ps
- Low input offset voltage:  $\pm 5$  mV
- Adjustable Hysteresis
- True differential LVDS output ( no external polarization voltage needed)
- Input common-mode range extends 200 mV beyond both rails

(it is possible to discriminate both input pulse polarity simply using a negative  $V_{th}$  with the same circuit)

# System schematic and characteristics



## overall characteristics

**Supply Voltage** Vamp, Vdig = 3 – 5 Volt

**Isupply per channel @5V** = 0,011A (Vdig and Vamp connected) → about 50mW/ch

**Vth = 1 – 5 Volt** → Discriminator threshold 5 -28 mV

**Peaking time** = 2 ns

**Outputs** = standard RJ45 connectors: LVDS output , Vdig, Vamp, Vth

**Minimum Input detectable signal** = **0.05 pC** (test pulse rise time 2ns fall= 5ns R=50 Ohm)

**Maximum system time skew** between channel 1ns

**No measurable hysteresis** lowering the threshold to noise floor

**The minimum usable discriminator threshold** depends on the chamber shielding and is, in general, far from the theoretical best performance of the FRTE. In this project, the configuration with Front boards fully installed outside the chamber ground frame and connected only through a small hole to the PAD has shown a clear advantage in RF external noise rejection and input-to-output coupling reduction.

Gas pipe inserted and  
glued directly into the gas  
gap

- Improved gas tightness
- Improved gas inlets
- Minimal leakages in a closed  
loop



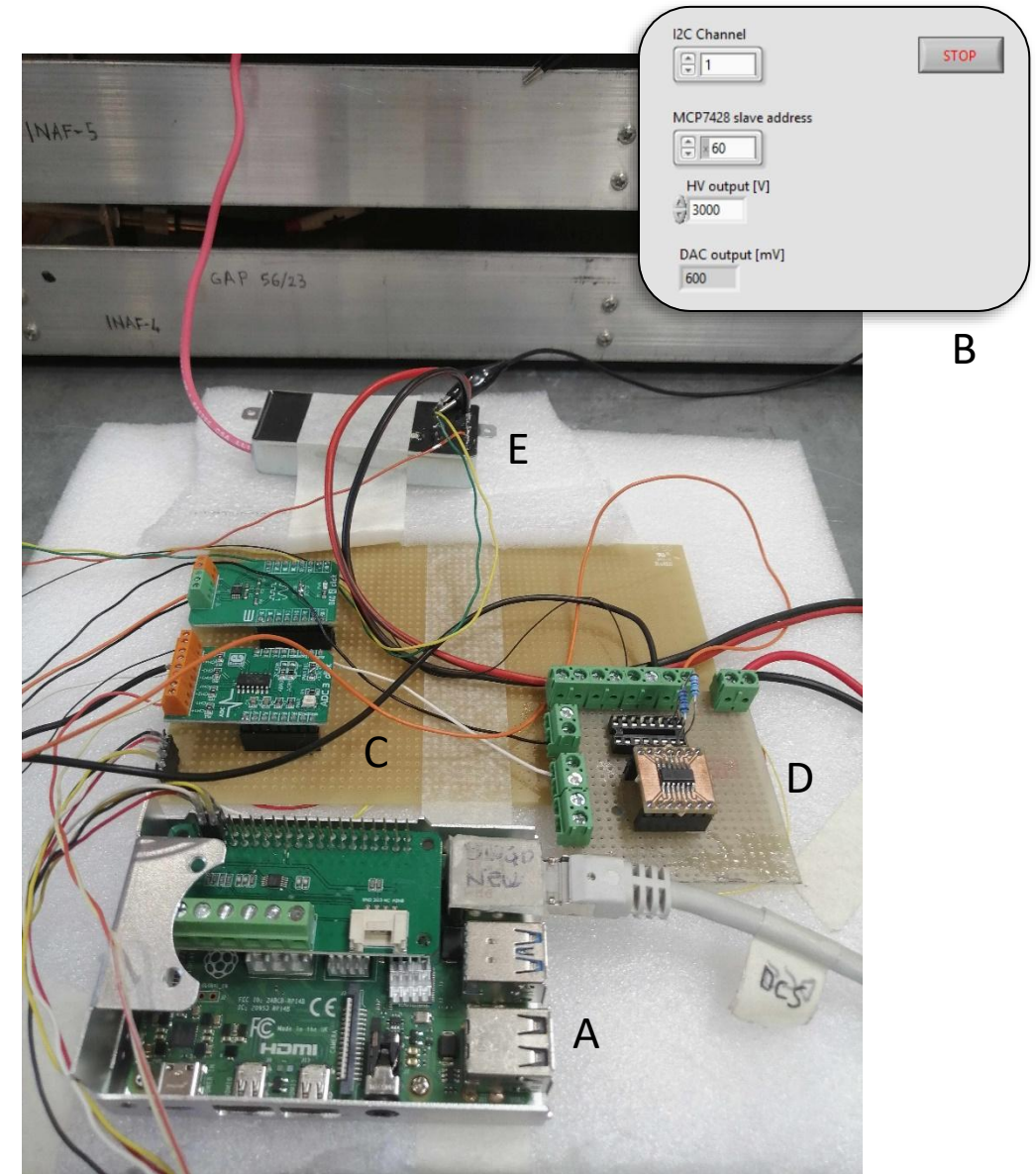
# DC-HVDC converter

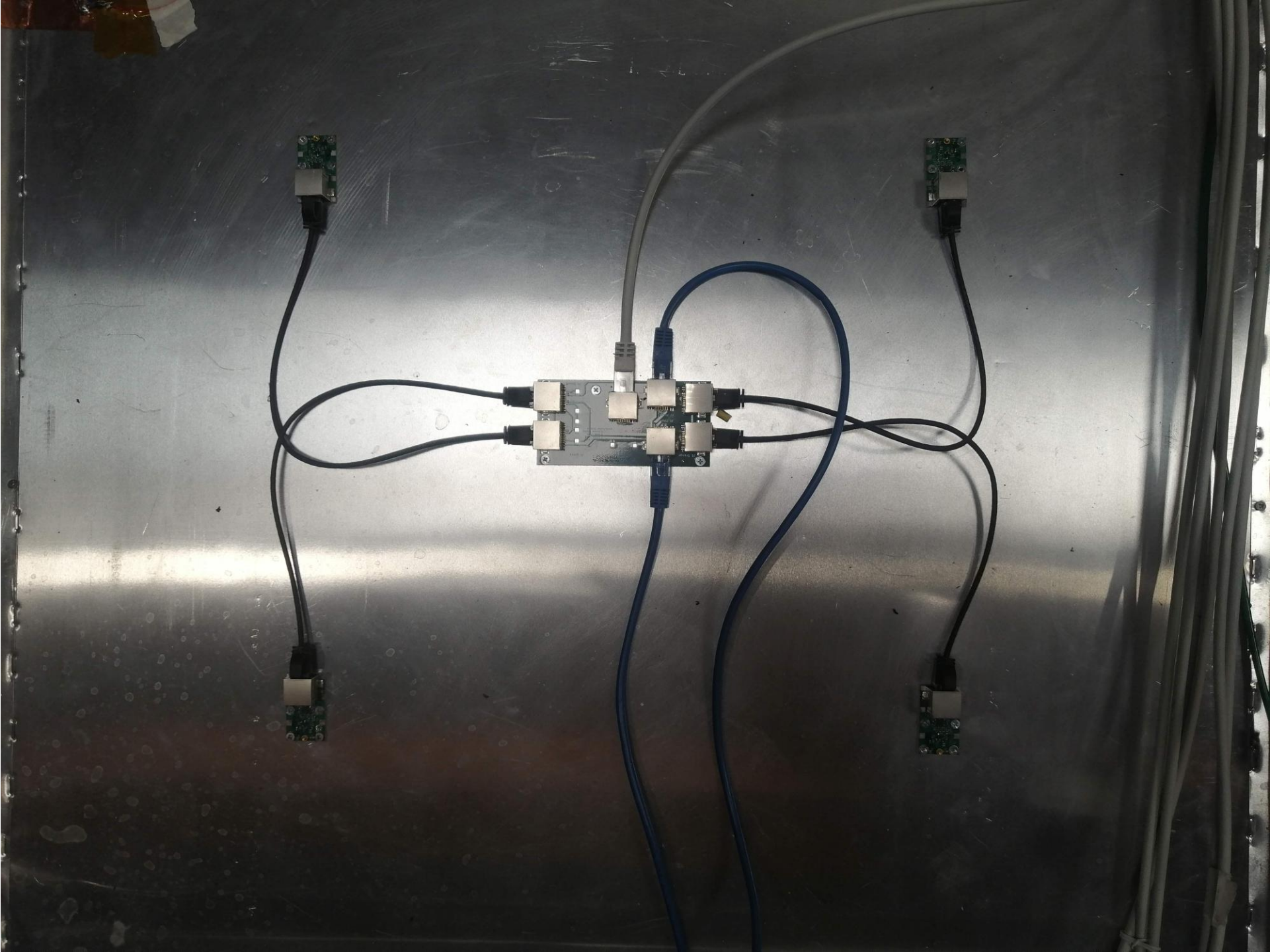
- LV input 0-5 V
  - HV output 0-10 kV;
  - max current 100  $\mu$ A
  - Located on chamber
- 
- 2-4 gaps can be connected to the same converter



# HV generation through a DC/DC converter

- A Raspberry Pi (A), software controlled (B), via network sends the chosen voltage values to the Digital to Analog Converter (DAC) (C), whose output range is 0-2 V
- The amplifier (D) multiplies the DAC generated voltages by a factor 2.5 so that the output voltage range is 0-5 V
- The CD-CD converter (E) transforms the 0-5 V input into the 0-10 kV output
- The 10 kV output is directly connected to the gas gap.
- **No HV connector is used**

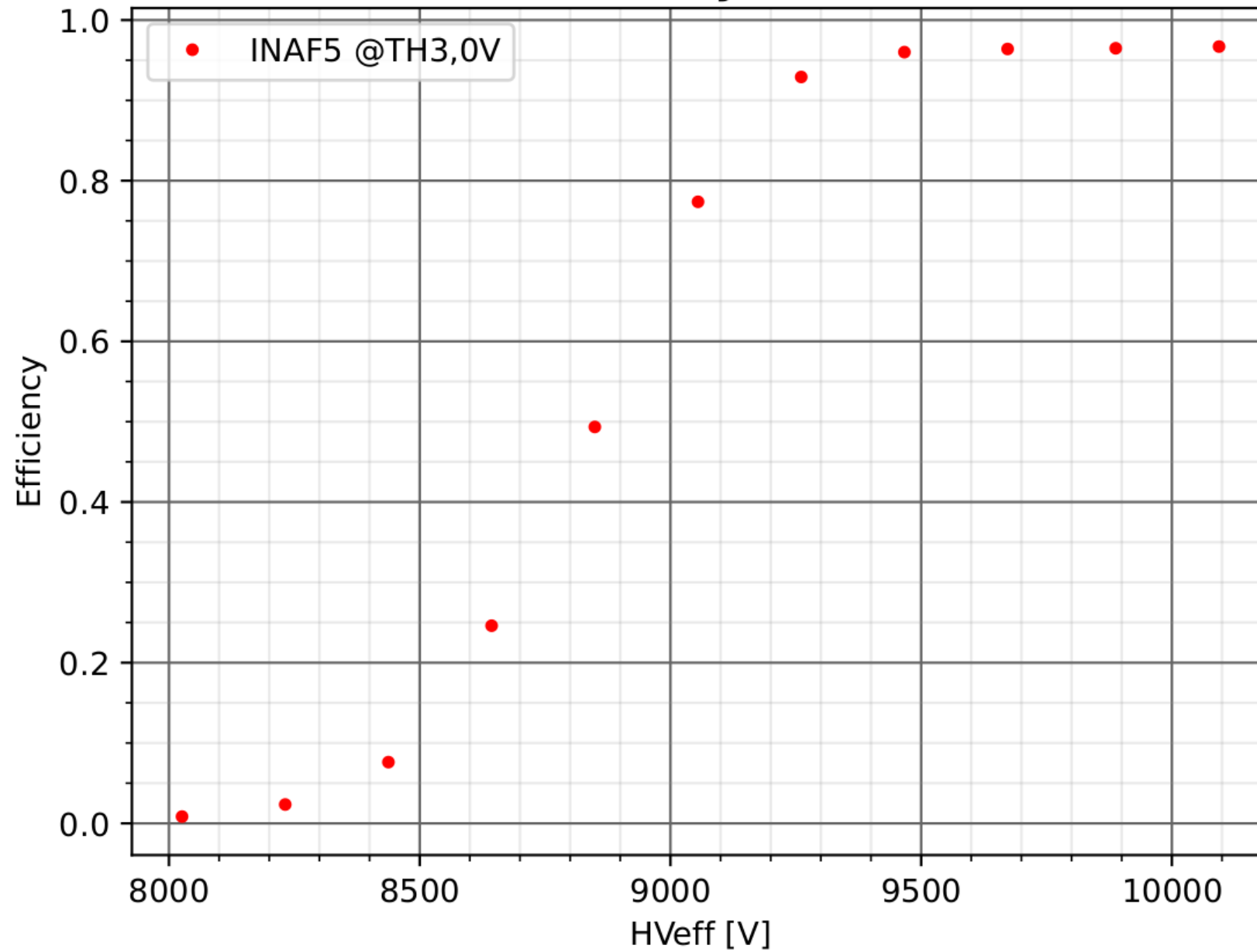




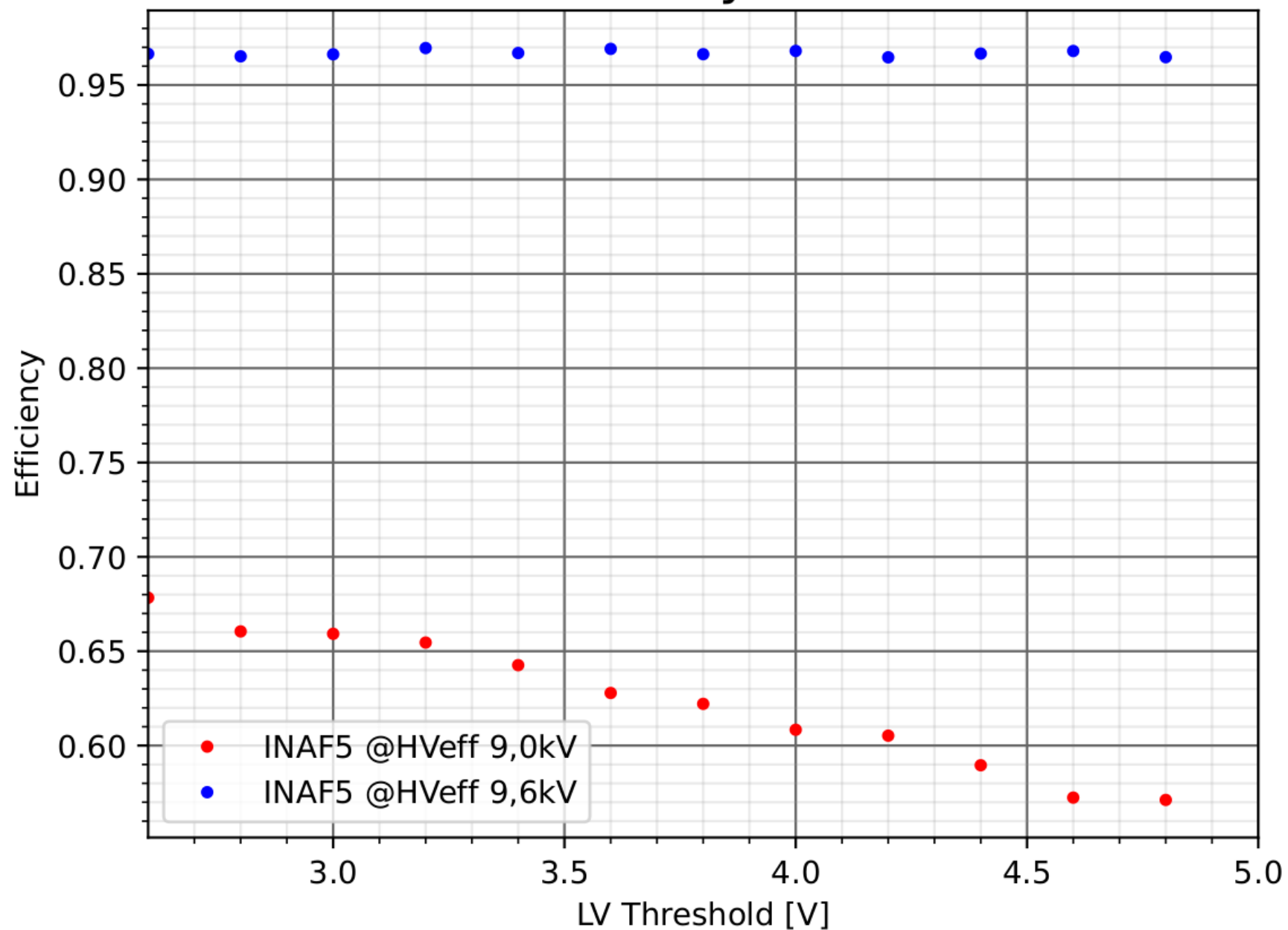
# Test results

- 4 chambers tested: INAF4, INAF5, INASF6, INAF7
- Trigger logic: triple coincidence of 3 chambers with the chamber under test not included in the trigger
  - Eff vs HV at fixed threshold
  - Eff vs threshold at fixed HV
  - Single rate vs HV and thresh
  - Cluster size
  - Time resolution

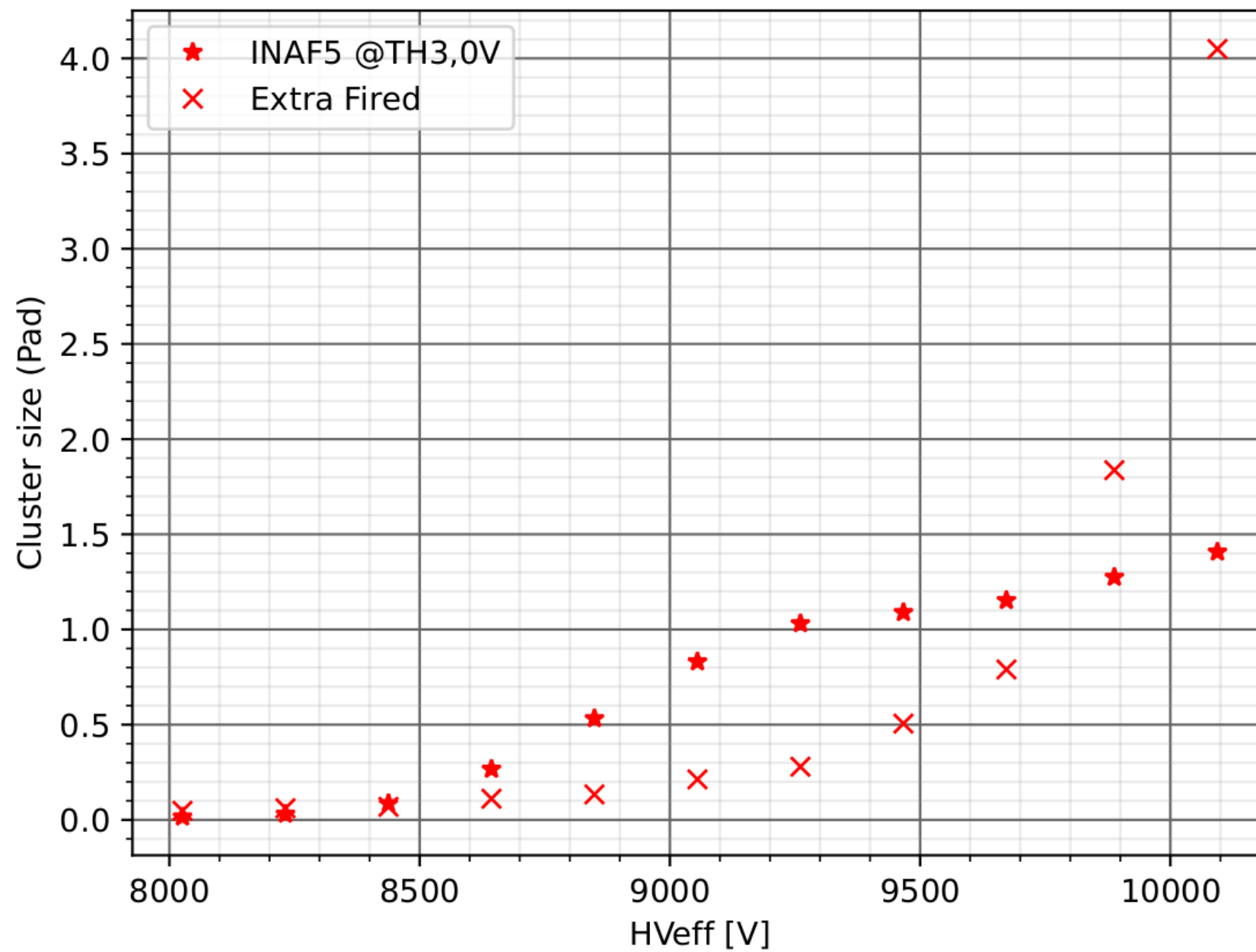
# Efficiency vs HV



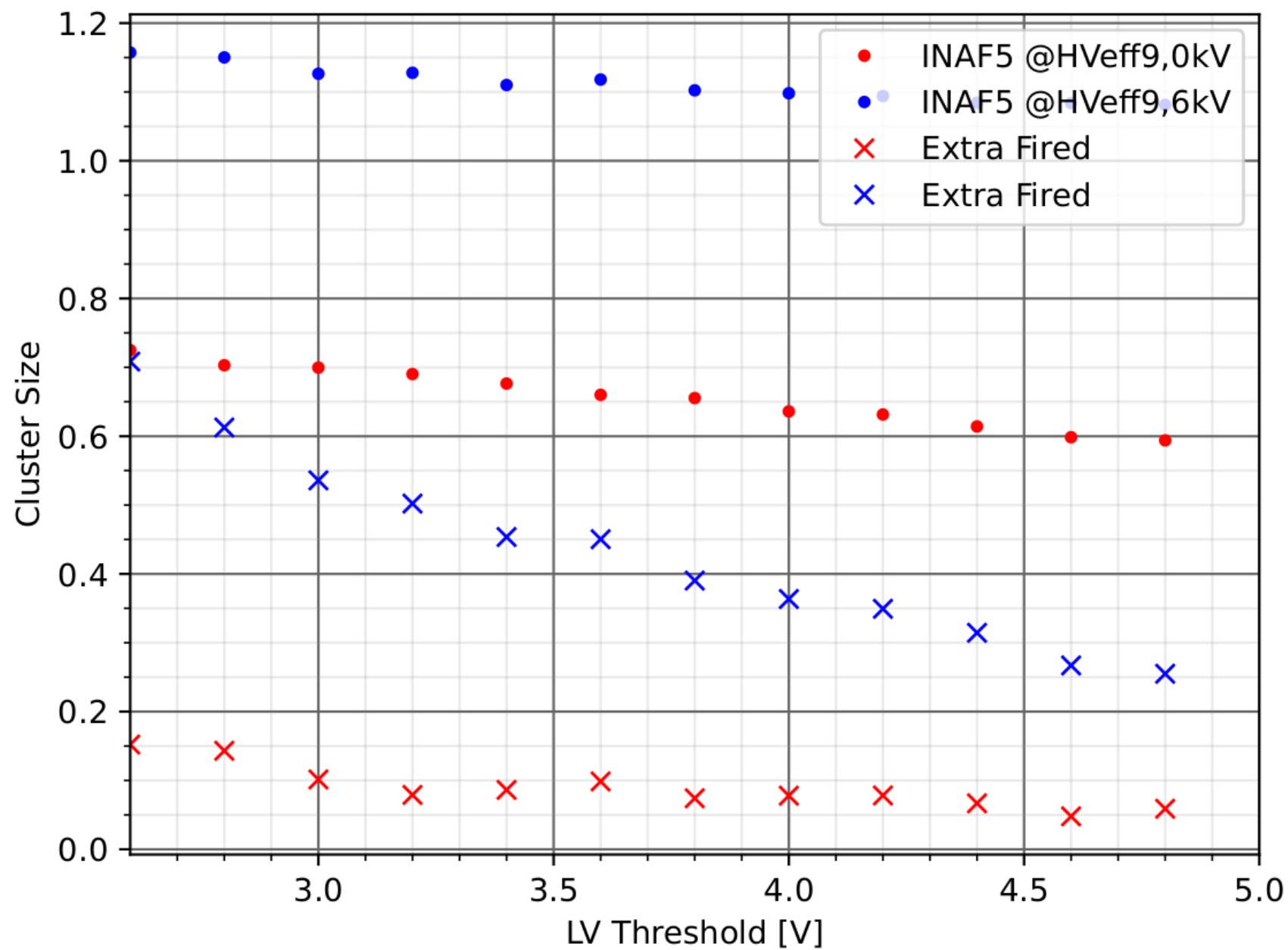
# Efficiency vs TH



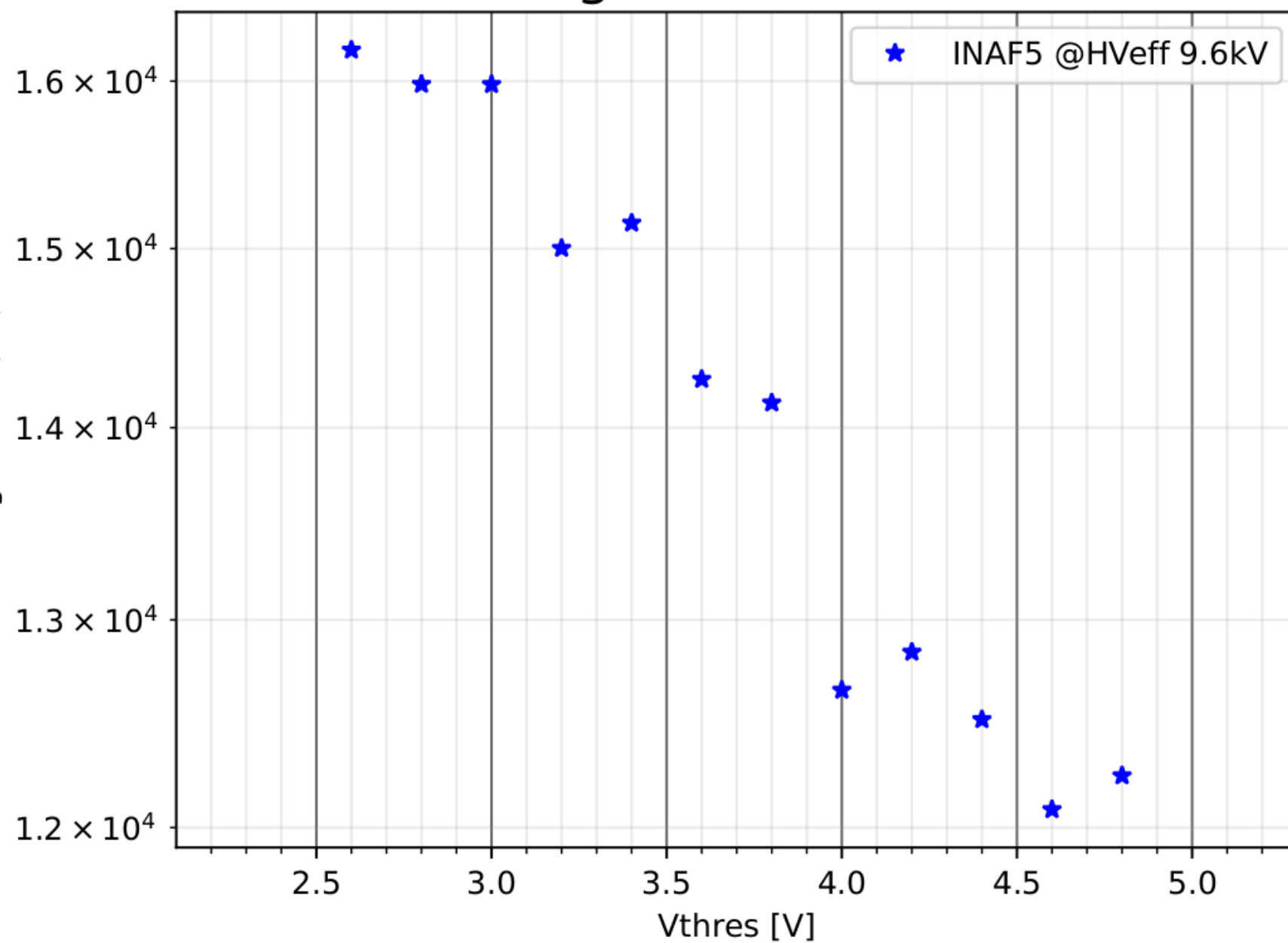
# Cluster size vs HV



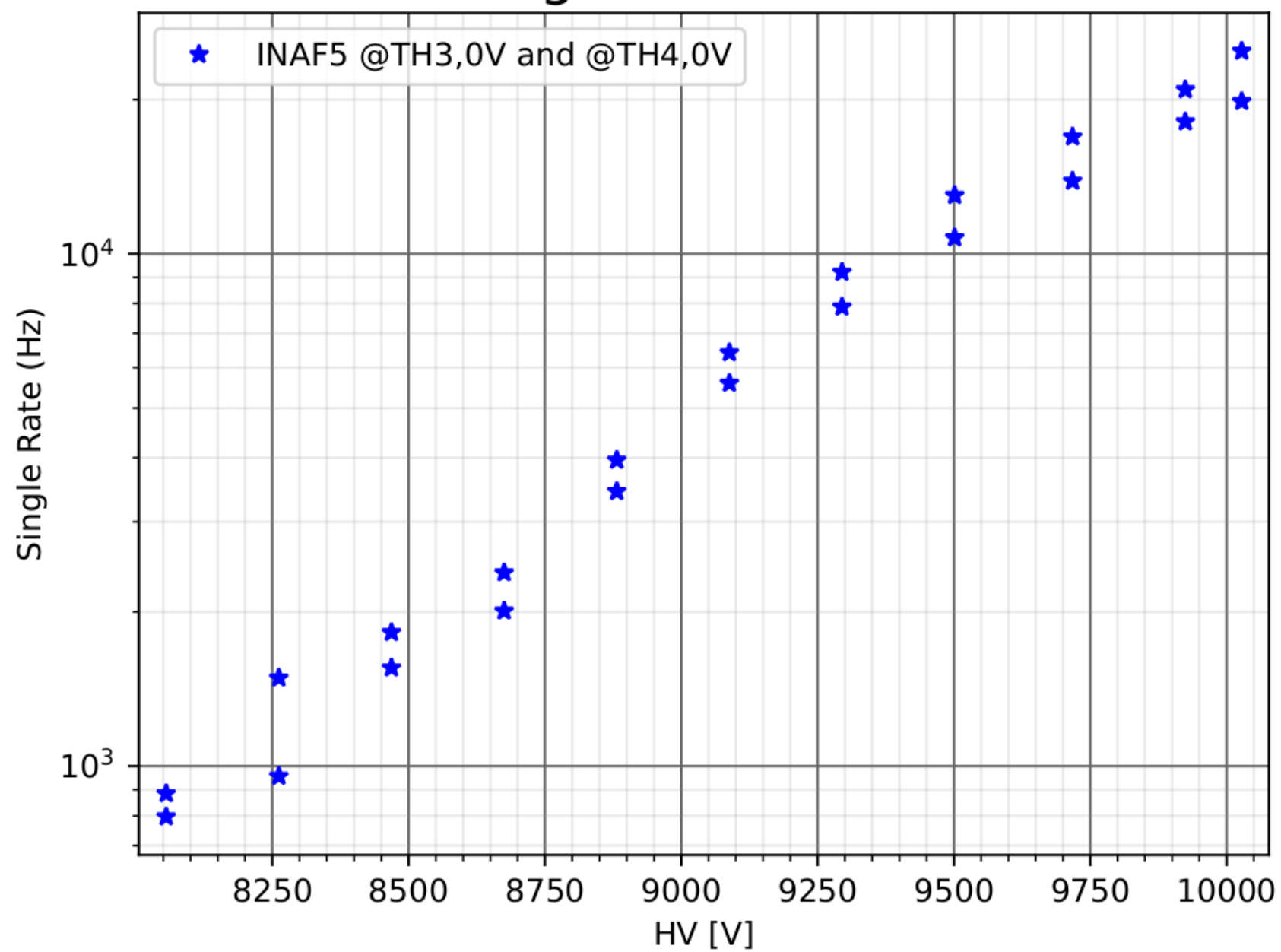
# Cluster Size vs TH

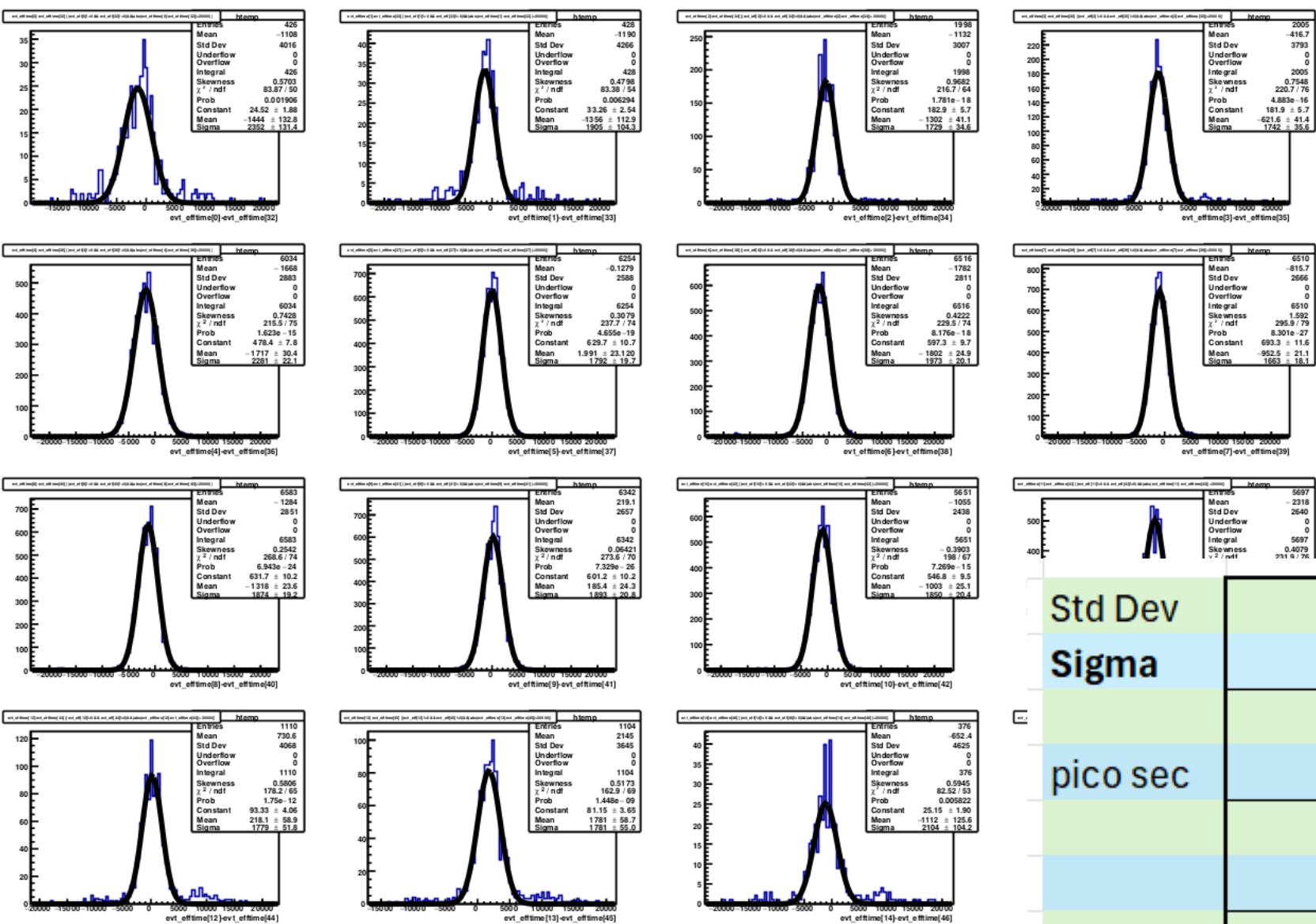


# Single Rate vs TH



# Single Rate vs HV





|          |      |      |      |      |
|----------|------|------|------|------|
| Std Dev  | 4016 | 4266 | 3007 | 3793 |
| Sigma    | 2352 | 1905 | 1729 | 1742 |
| pico sec | 2883 | 2588 | 2811 | 2666 |
|          | 2281 | 1792 | 1973 | 1663 |
|          | 2851 | 2657 | 2438 | 2640 |
|          | 1874 | 1893 | 1850 | 2016 |
|          | 4068 | 3645 | 4625 | 4186 |
|          | 1779 | 1781 | 2104 | 1899 |

# How does the signal propagate in two dimensions?

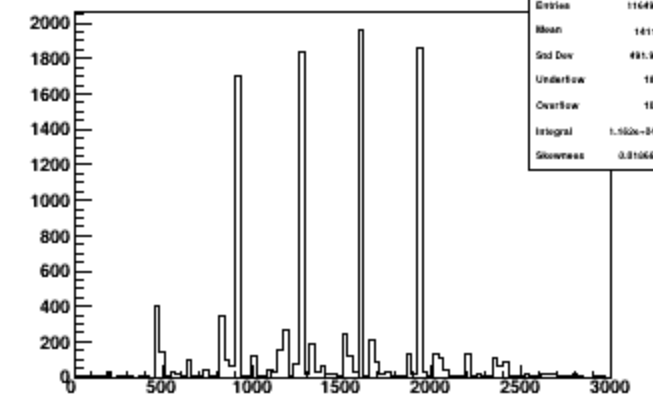
- Model needed
- A circular wave around the avalanche position point?
- The signal delay compatible with propagation at  $v=c/n$  velocity

# Conclusions

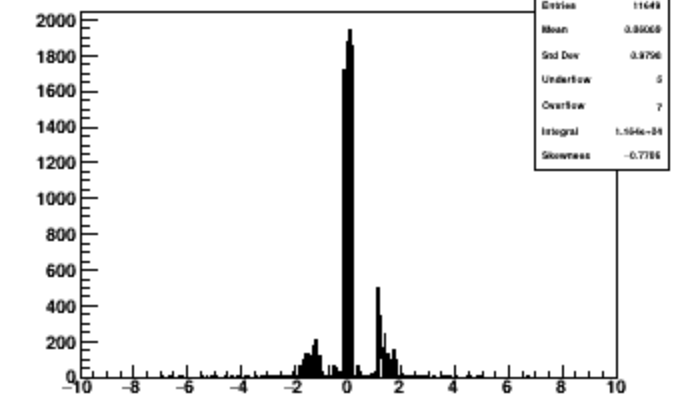
- The test performed show that for applications requiring space and time resolution of *few tens of centimeters*  $\times$   $\sim 1$  ns the pad read-out gives results compatible with the strip read-out
- This represents a relevant advantage, with respect to a pad segmented in 8 strips (like in Argo), for very large area applications requiring the above resolutions
- Particularly suitable for mapping the particles of a cosmic shower
- More work required for optimizing the prototypes
- About 20 chambers will be available for *tests in situ*

Bck up

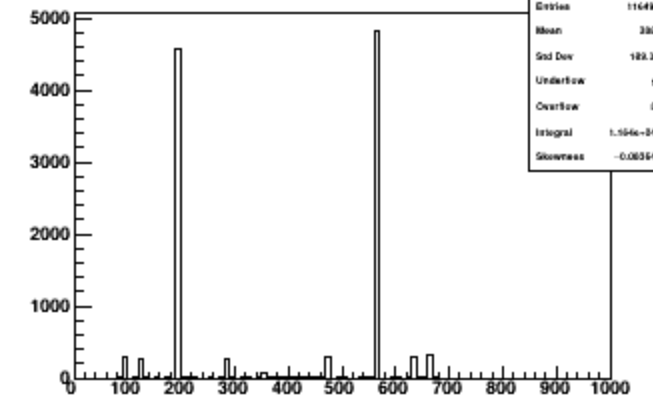
Intercetta Tracce su Piano XZ



Pendenza Tracce su Piano XZ



Intercetta Tracce su Piano YZ



Pendenza Tracce su Piano YZ

