



# Temperature Readout for the FOOT calorimeter: a proposal

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# Outline

- Requirements for temperature monitoring of calo crystals + SiPM's
- NTC sensors
- Readout concept
- Prototyping results
- Next steps



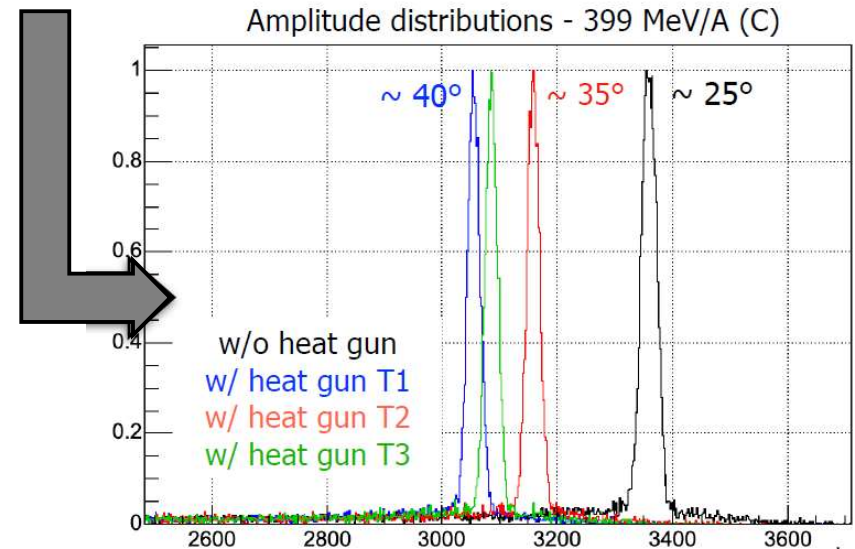
This talk is based on the work towards a B.Sc. degree in Computer Science by R. Patera and A. Scalogna

# Requirements for temperature monitoring



- BGO L3 crystals\*: **tempco = -1.55 % / °C @ 25 °C**
- SiPM gain also has a **negative tempco**
- Offline correction works
- Need temperature monitoring:
  - for up to 320 crystals
  - with 0.5 °C resolution (or better)
  - readout of temperatures every ~ 1-5 min

L. Scavarda, VIII Coll. Meeting




\* NIM A 280 (1989) 25 - test beam (10 GeV e<sup>-</sup>) results

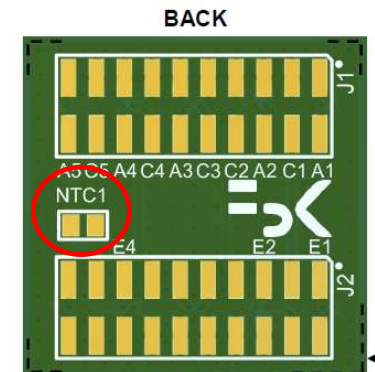


# NTC sensors

- Main features of the Negative Temperature Coefficient sensors:

 mounted on each SiPM tile

Part number:	<b>B57471V2103J062</b>	B57164K0103J000	B57861S0103J040
Form factor	<b>SMD size 0805</b>	disk	miniature
B coefficient	<b>4480 K</b>	4300 K	3988 K
R <sub>R</sub> tolerance	<b>±5 %</b>	±5 %	±5 %
Cooling time constant	<b>10 s</b>	20 s	15 s
Heat capacity	<b>35 mJ/K</b>	150 mJ/K	22.5 mJ/K



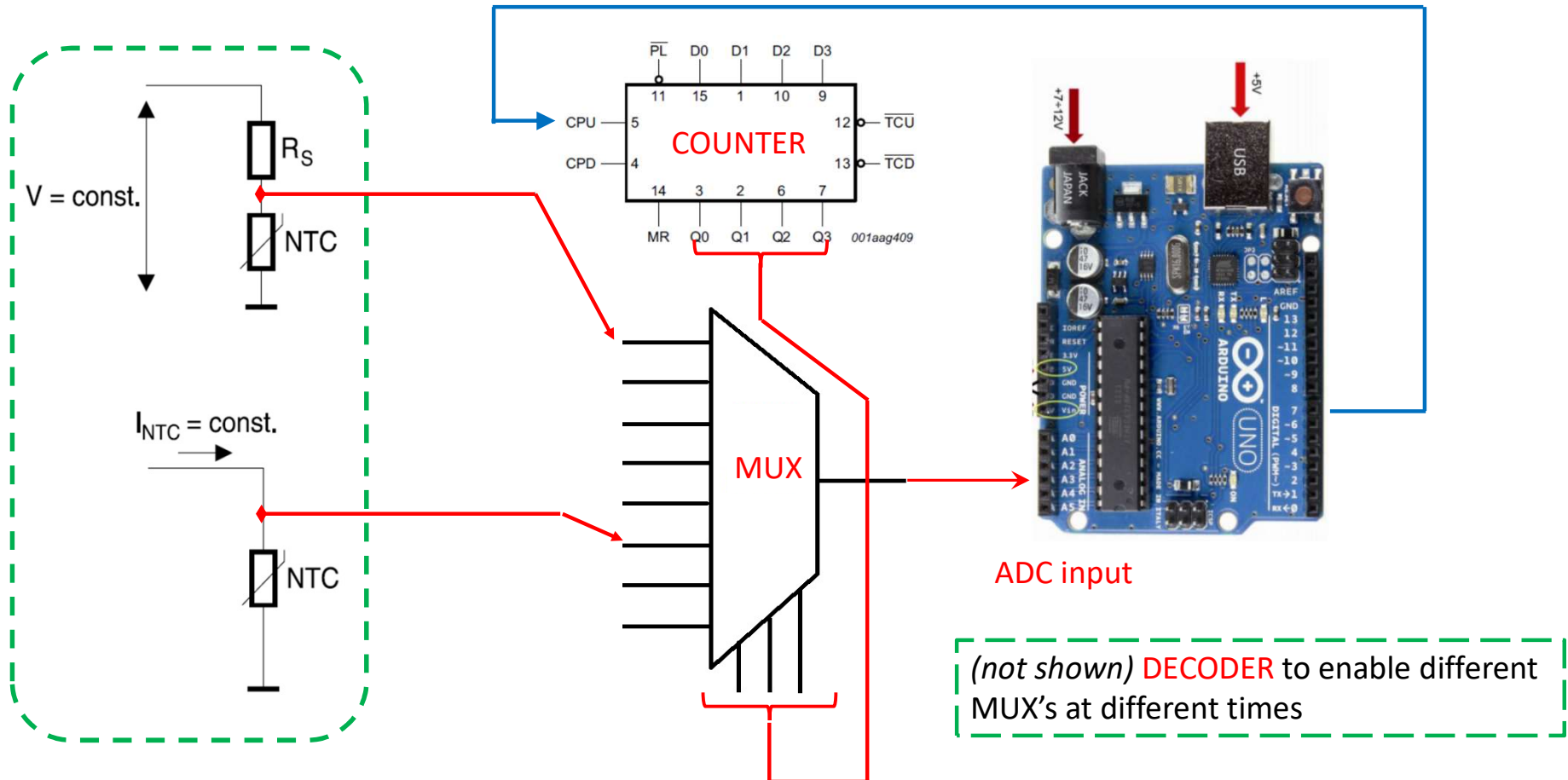
Common features:  $R_R = 10 \text{ k}\Omega$  @  $T_R = 25 \text{ }^\circ\text{C}$  (298.15 K)

$$R_T = R_R e^{B \left( \frac{1}{T} - \frac{1}{T_R} \right)}$$

approximate two-parameter (B, R<sub>R</sub>) formula for R(T)



# Readout concept (1)



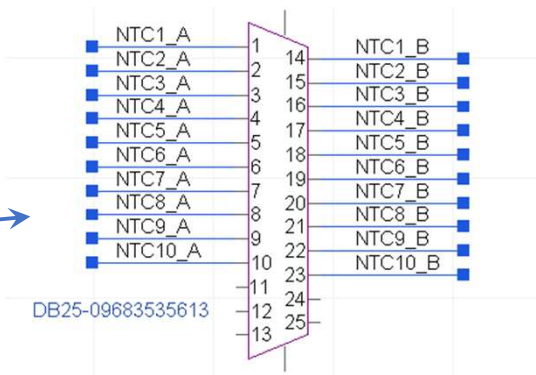


# Readout concept (2)

- Components needed for reading out *all* 320 NTC sensors:

Component	Model used for prototype	Possible choice for final system	Number needed
Multiplexer 16:1	ADG506A	ADG406	20
Counter	74HCT193 (4 bit)	<i>same</i>	4
Decoder 3 → 8	not used	74HC238	4
VME board (6U)	breadboard	custom board	4
Arduino	UNO / Mega	...	1

VME board: 2 slots wide, to accommodate 8 DB25 connectors, together bringing 80 wire pairs from NTC's



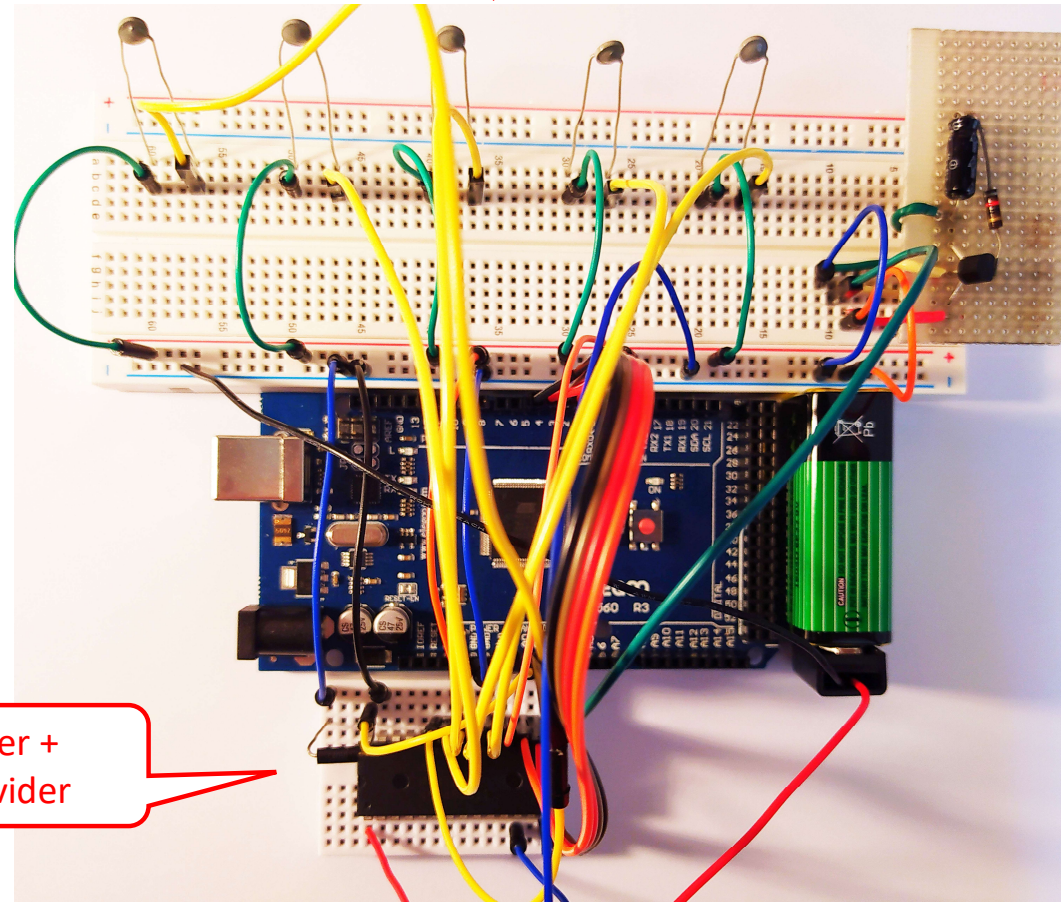
# Prototyping



5 m cable



5 disk-type NTC sensors



LM35 temperature reference

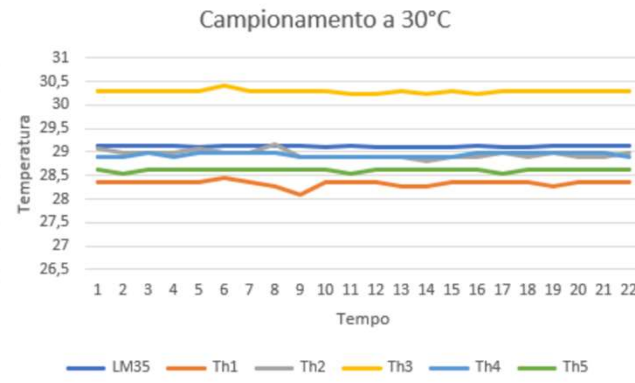
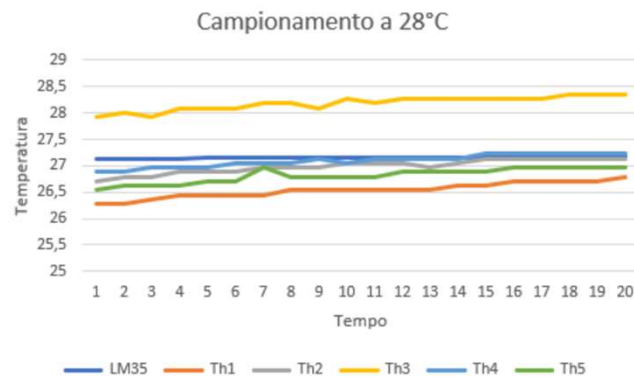
Multiplexer + voltage divider



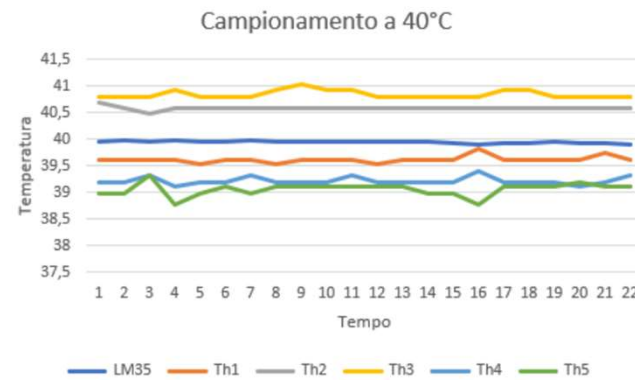
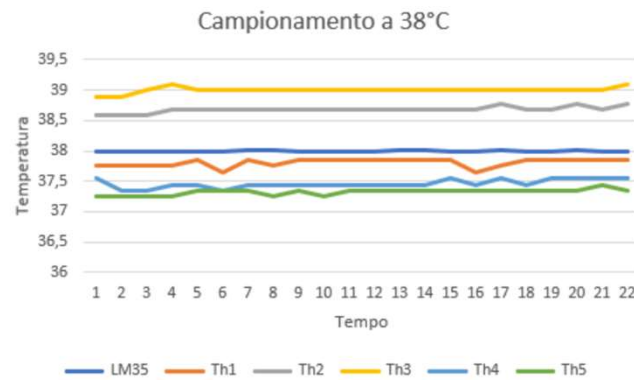


# Results (1)

Temperatures from 5 *disk* NTC's with *voltage divider* biasing (10 kΩ fixed resistor)



Reference T from LM35



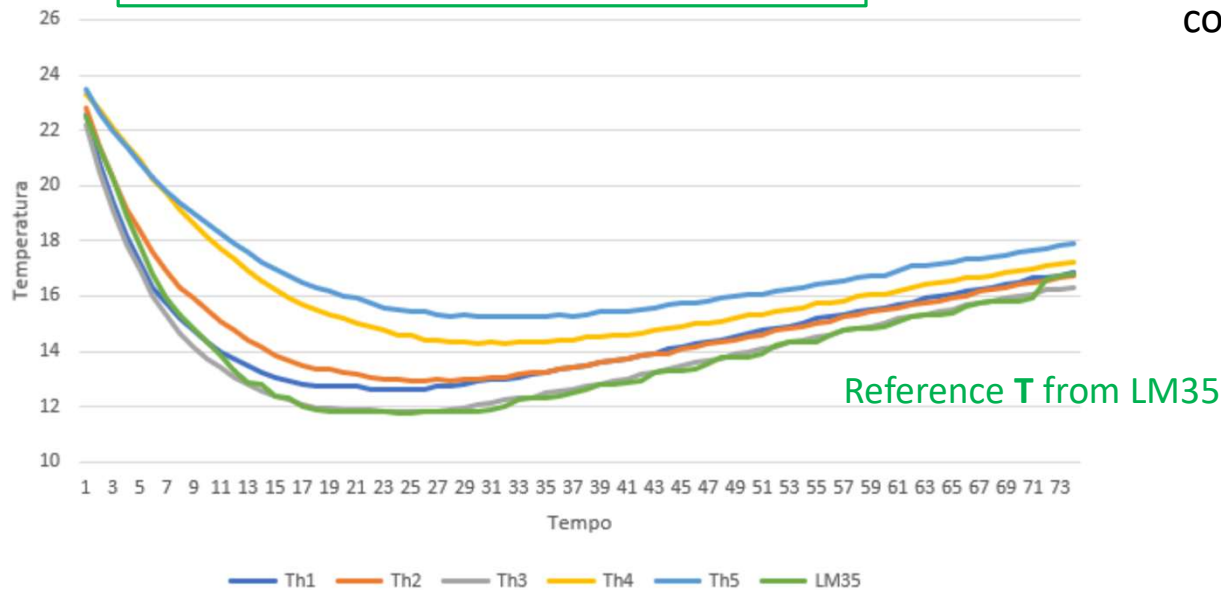
- Expected systematic effects:
- $\pm 1.25\text{ }^\circ\text{C}$  from tolerances
  - $+ 0.1\text{ }^\circ\text{C}$  from self-heating





# Results (2)

Temperatures from 5 *disk* NTC's with *voltage divider* biasing



Most NTC's show higher temperatures compared to reference

Expected systematic effects in the 10 - 25 °C range:

- $\pm 1.25$  °C from tolerances
- + 0.1 °C from self-heating

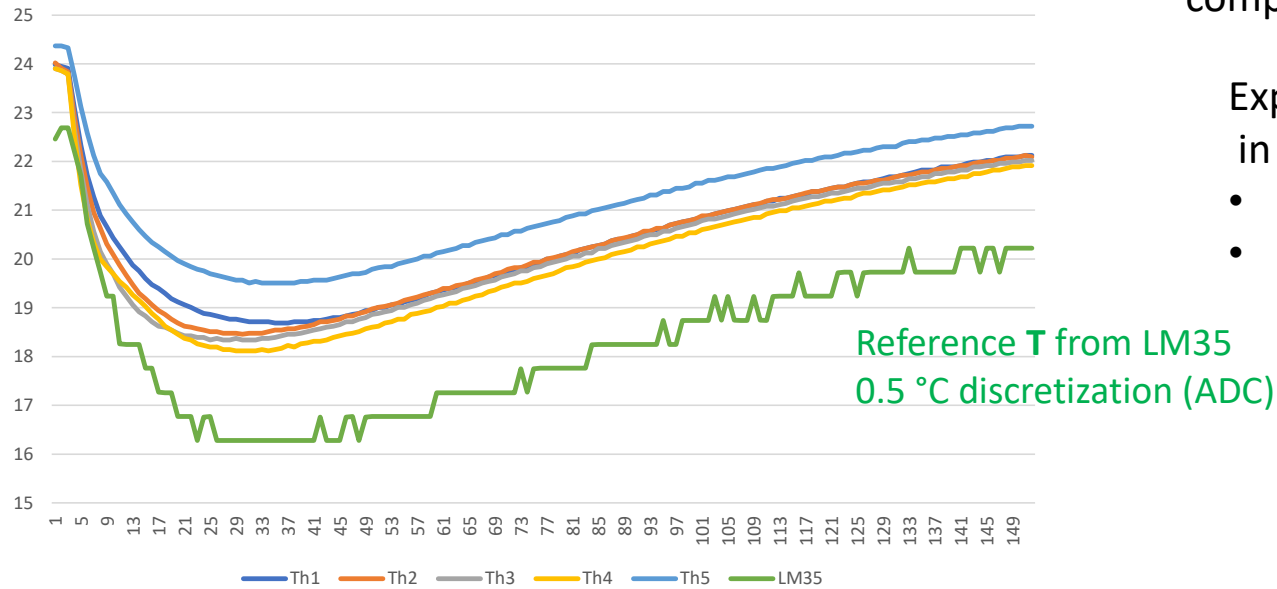
Warning: probably, there was a non-uniform temperature distribution inside the test box

Readout every 30 seconds



# Results (3)

Temperatures from 5 *miniature* NTC's with *current source* biasing



All NTC's show higher temperatures compared to reference

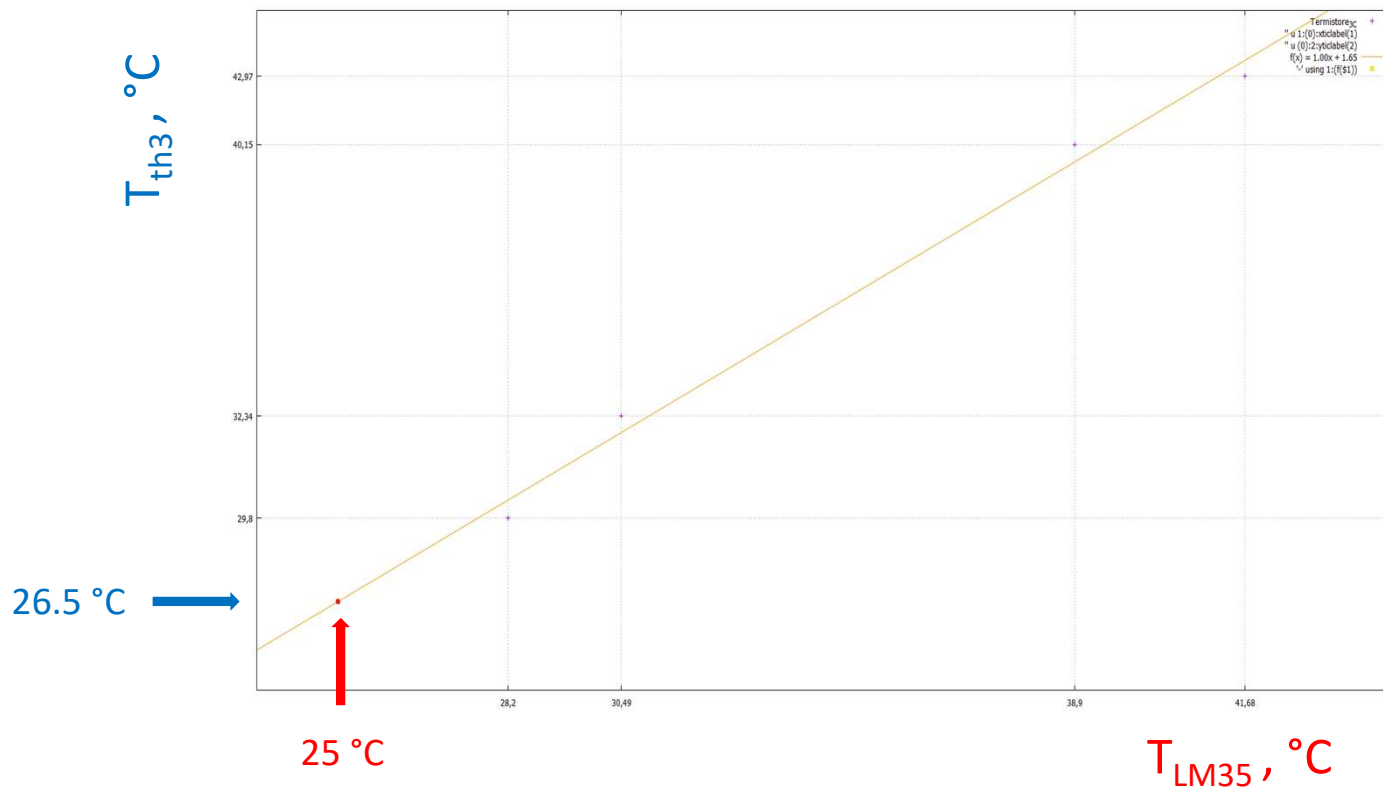
- Expected systematic effects in the 15 - 25 °C range:
- $\pm 1.1$  °C from tolerances
  - + 0.9 °C from self-heating

Readout every 30 seconds



# Results (4)

Example of linearity for a *miniature* NTC





# Next steps

- More accurate calibration with a climatic chamber
  - in a few weeks, both for single crystal and 3x3 crystal module
- Improving the parameterization of  $R(T)$
- Design of the readout card
- Production & test of the readout card
- Integration with DAQ
  - preliminary idea discussed with Mauro Villa