Neganov-Luke assisted Light Sensors

LLD (Luke Light Detector) for his friends

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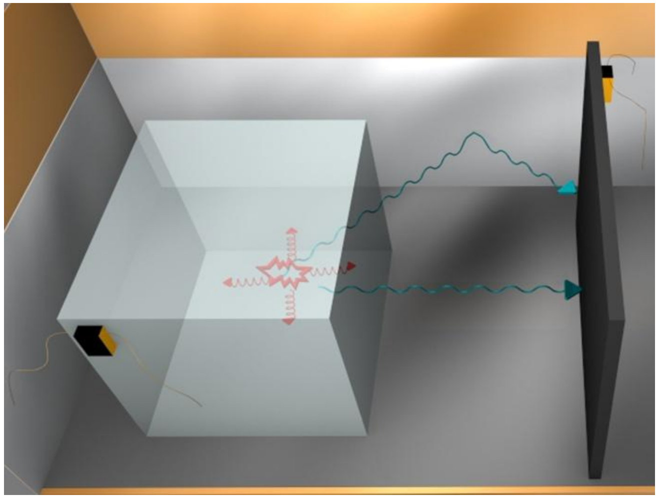
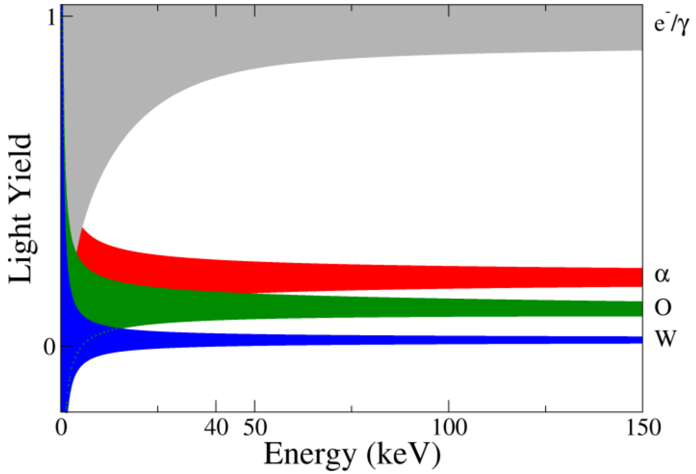
Motivation



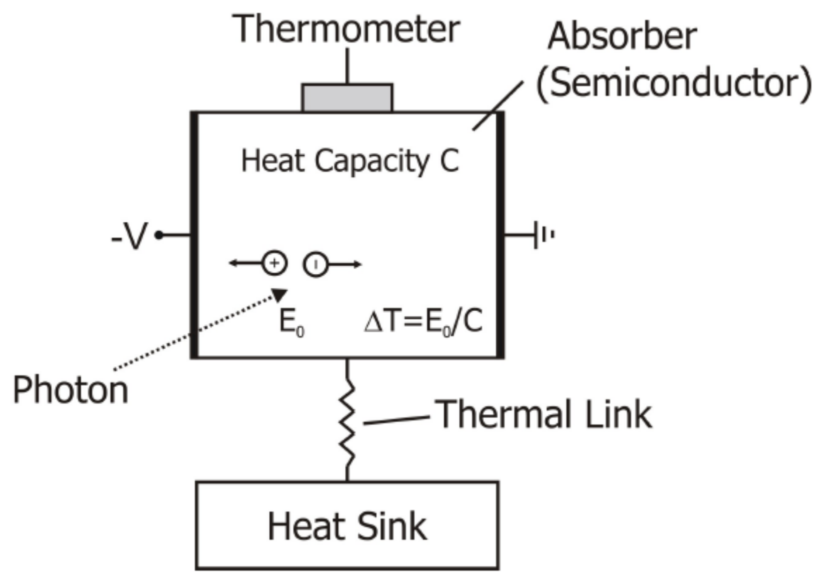
$$LY_{\beta/\gamma} \neq LY_{\alpha} \neq LY_{nuc-rec}$$

The simultaneous detection of heat and light allows to separate γ and β particles form α particles and nuclear recoils



Increasing the sensitivity of the light detector allows to disentangle the different bands at lower energy.
→ Crucial for DM and solar axion searches
→ Detection of Cherenkov light from non scintillating crystal

Basic principle



Photons
→ creates e-h pairs
→ e-h pairs are drifted by electric field

→ Phonon emission while e-h pairs drift

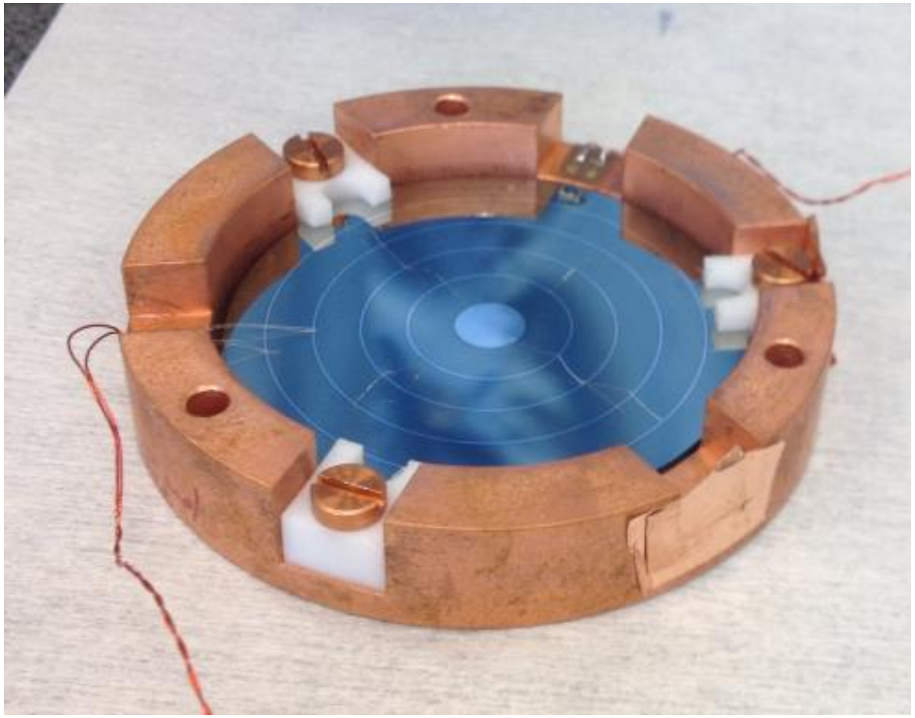
→ Amplification

$$W_{gen} = Q\int_{o}^{d} \vec{E} \cdot d\vec{l}$$

$$E_{heat} = E(1+\frac{qV}{\varepsilon})$$

The detector

The Neganov-Luke assisted photon sensor was developed at CSNSM, France.
The aluminum elecrodes were deposited on bare Ge by evaporation using a shadow mask

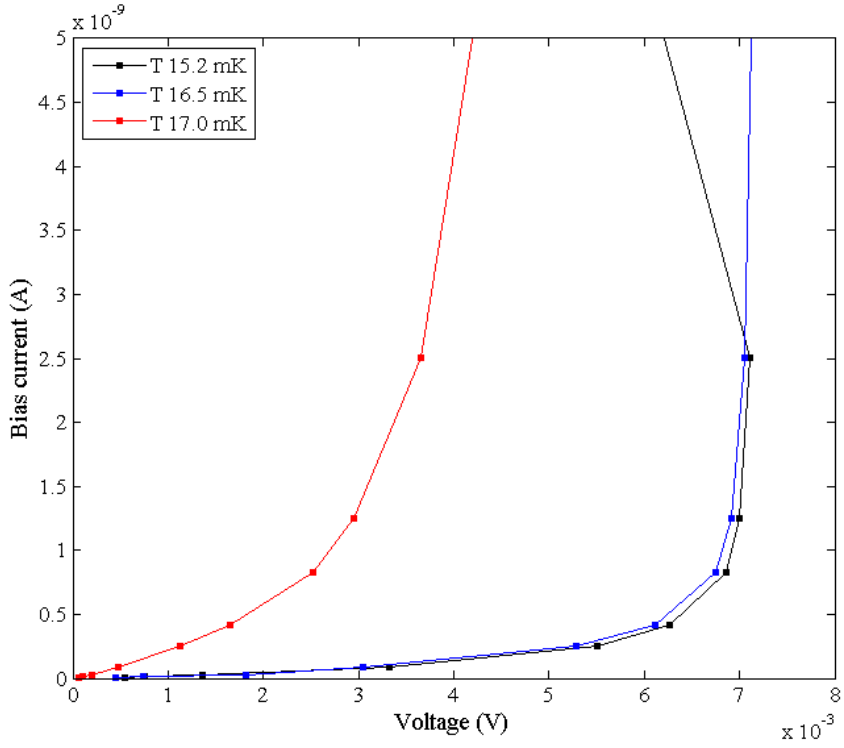


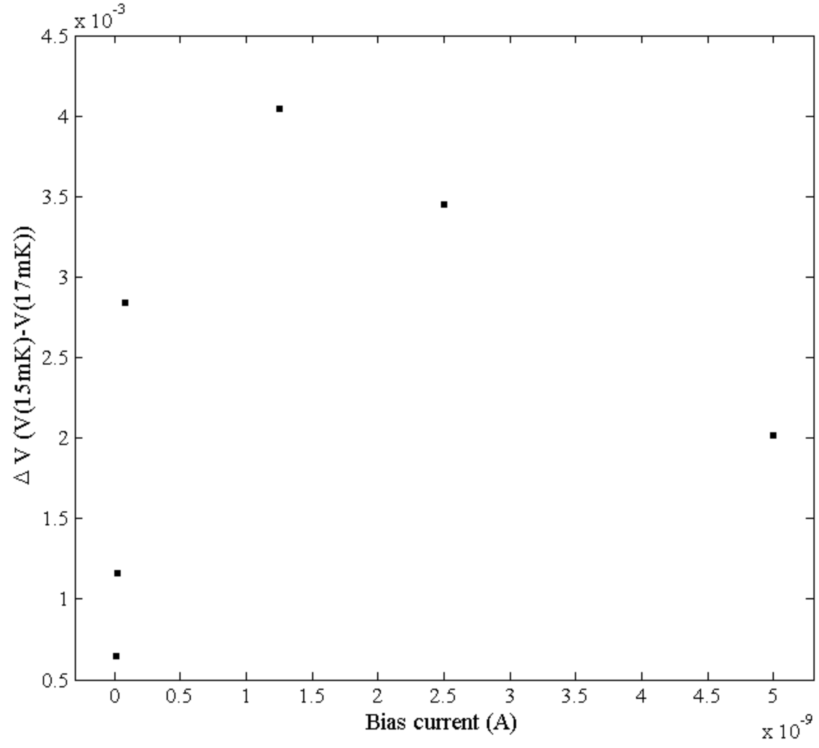
- Copper holder
- High-purity Ge plate with size of ∅50 x0.20mm^3
- Mechanical coupling is provided by teflon clamps
- The readout was made by 3x1.5x0.6 mm^3 NTD Ge thermistors
- ^{55}Fe source was used to stabilize the detector response and to compare the results from different runs
- Hamamatsu LED provides the light signals for the characterization

Even and odd aluminum annular electrodes respectively connected by bonding aluminum wires. V_{bias} is applied within the two sets.

Cooling down

The bolometric response was studied in the range of 15-17 mK





Final working point was selected as:
Temperature: 16.7mK
Acqusition Rate: 20000 Hz
Voltage range: -1.0 to +1.0

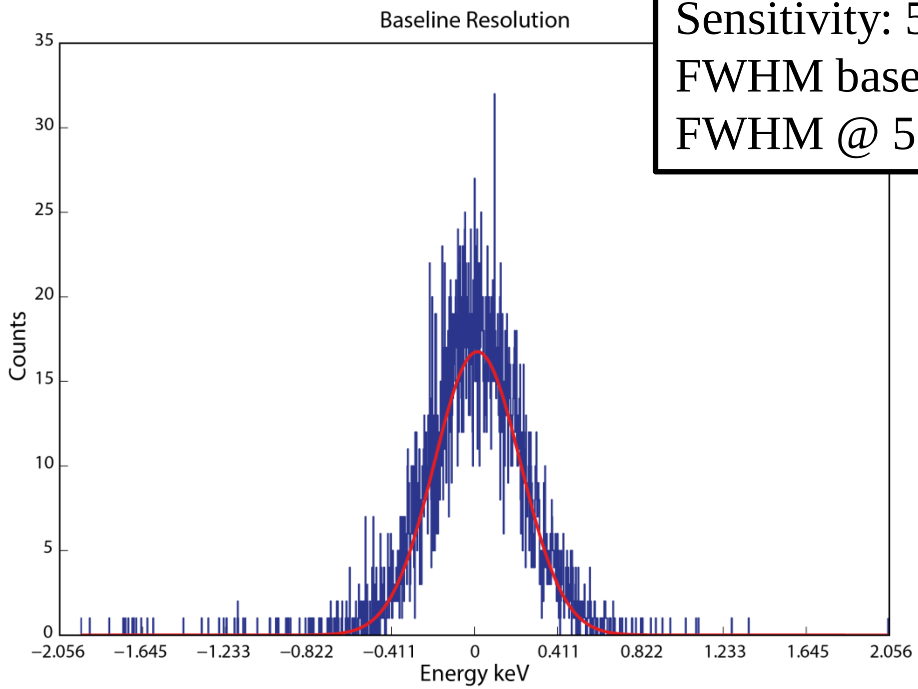
Applied Bias : 5.000 V
Load Resistor : 1.000 Gohm
Applied Gain : 1403.000 V/V
Besset cut-freq : 675.000 Hz

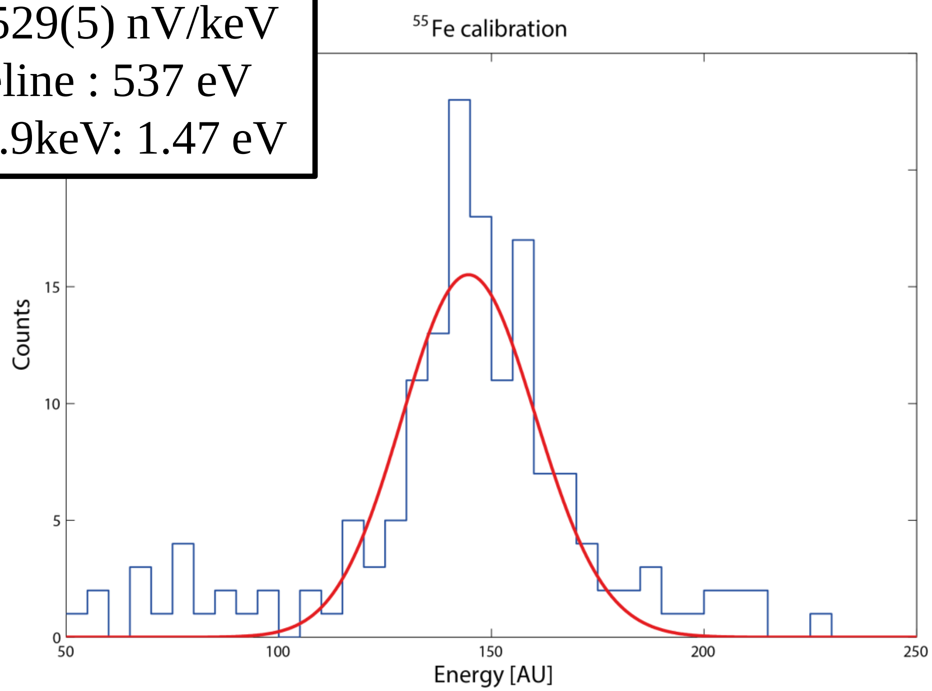
Measurements

We have only 2-3 days to perform the detector characterization

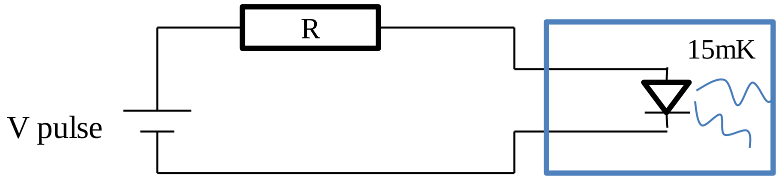
- Iron calibration
- Study LED pulse
- Study of Luke effect
- Study the reduction of amplification due to space-charge trapping
- Cherenkov light measurement 53V with TeO_2 bolometer

Sensitivity: 529(5) nV/keV
FWHM baseline : 537 eV
FWHM @ 5.9keV: 1.47 eV



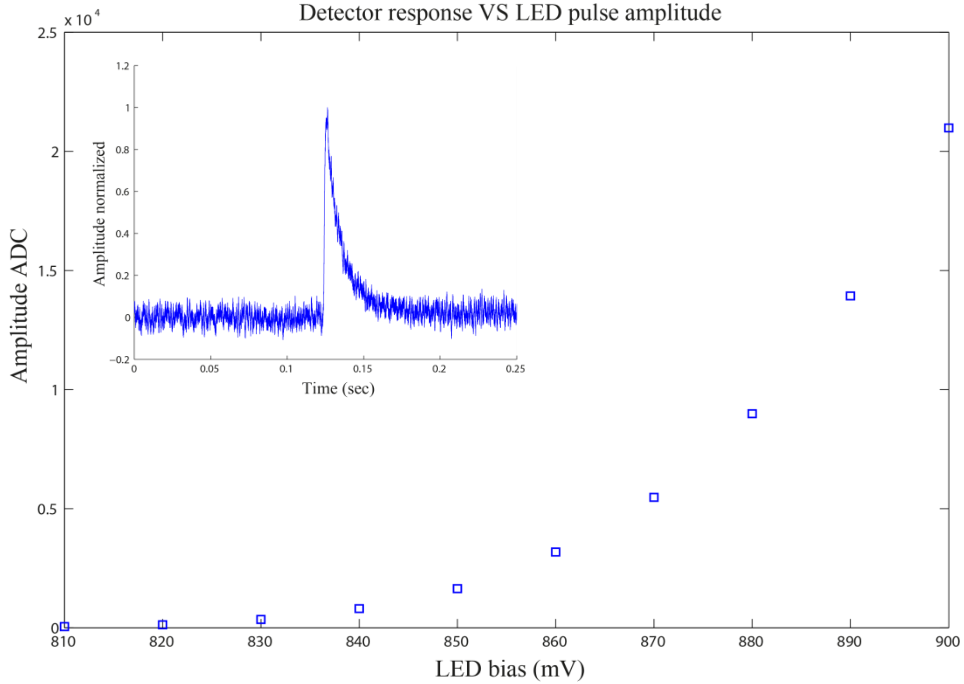


Study the detector response of LED pulses



LED Bias = 810 – 900 mV
R = 1 kΩ
pulse width = 1 ms

The purpose was to use the energy resolution at different LED bias to obtain the number of photon emitted for certain bias



The total σ is given by:

$$\sigma_{tot}^2 = \sigma_{ph}^2 + \sigma_0^2$$

Where σ_{ph} is:

$$\sigma_{ph} = a\sigma_N = a\sqrt{N} = \sqrt{ax}$$

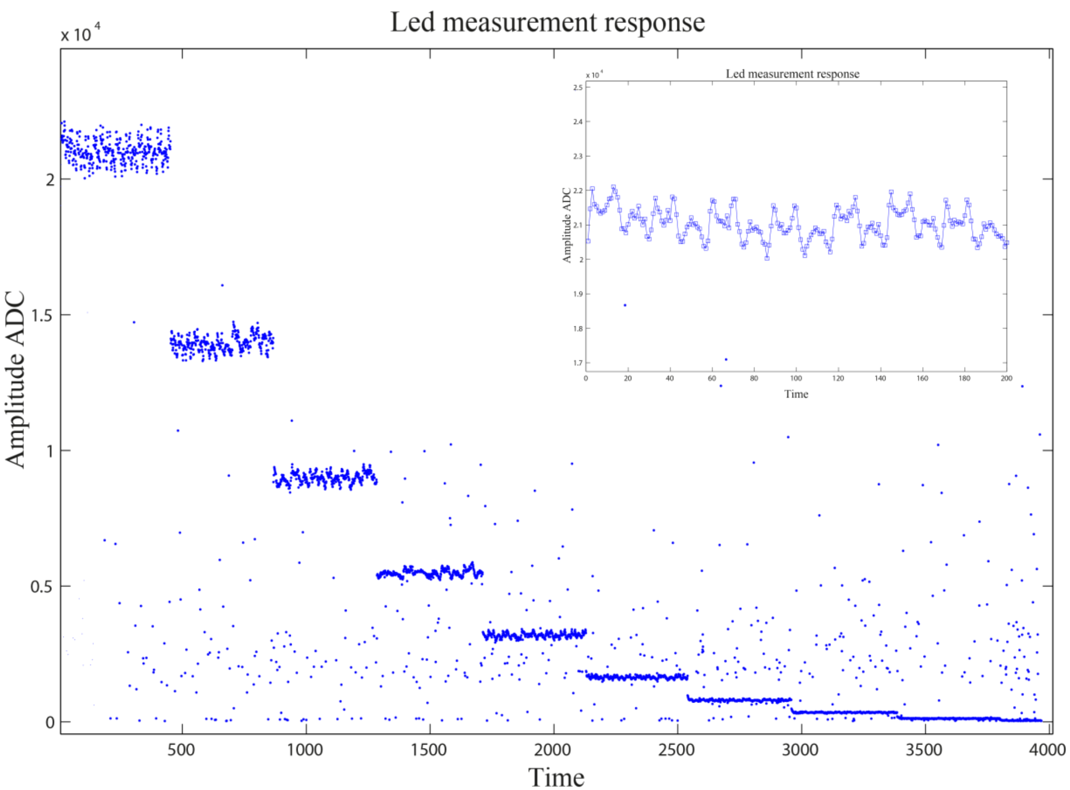
x is the signal amplitude and a is equal to *sensitivity* x E_{ph}

$$x = aN$$

Study the detector response of LED pulses

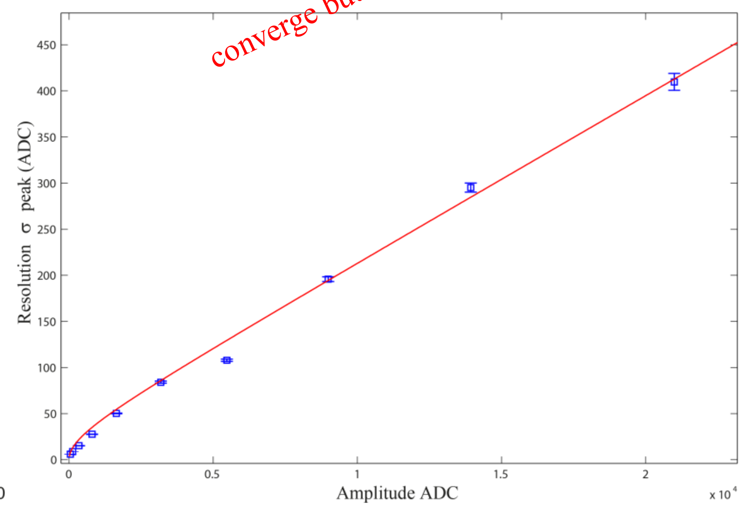
- The signals provided by LED+pulser show a clear dispersion with a well defined pattern.

Impossible to reconstruct the number of photons in function of bias ⇨ In the future tests we planed to introduce an optic fiber in the system



f(x) = sqrt(a*x+sigma^2+(b*x)^2)
a = 1.275 ± 0.3978
sigma = 0.0001018 ± 1.8255e+6
b = 0.01805 ± 7.8726e-4
rsquare: 0.9957

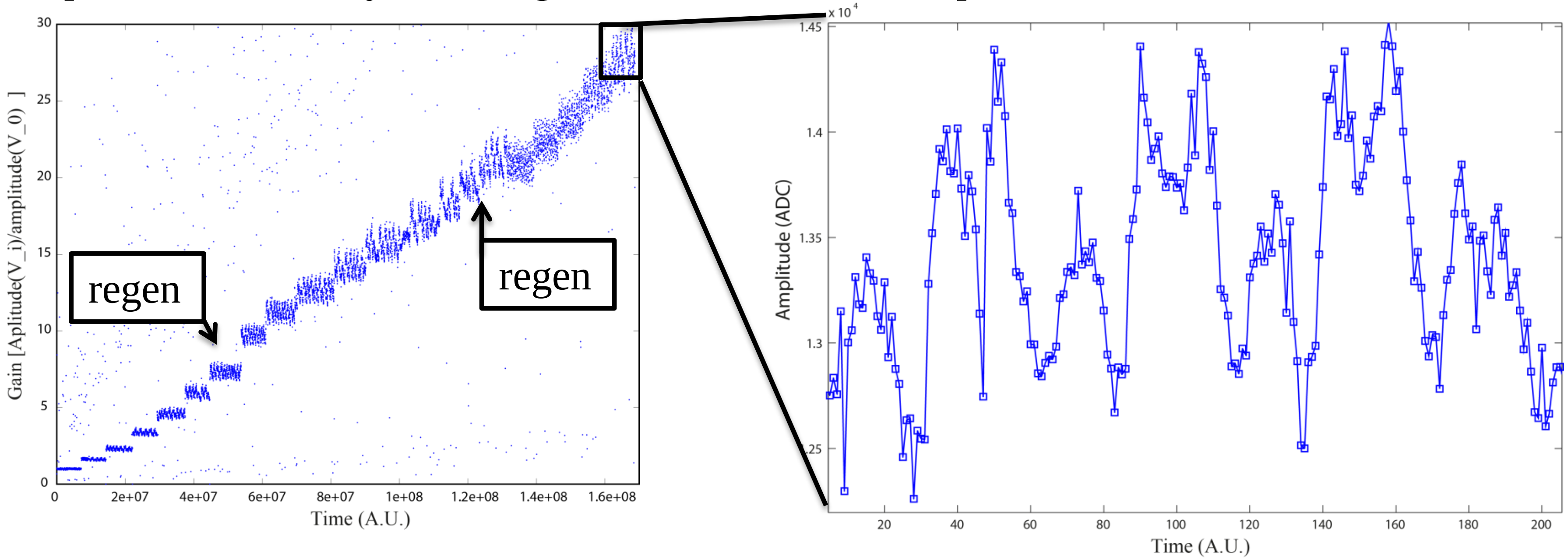
converge but the parameters has no sense



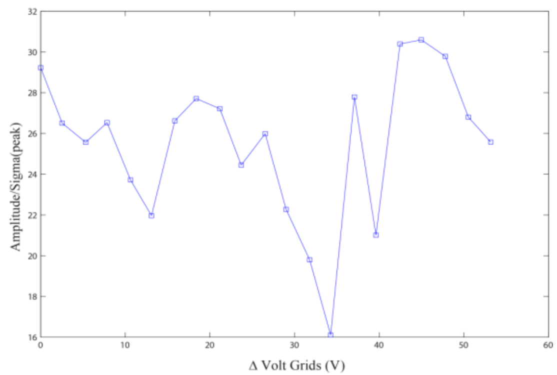
- …But we can use this defect of the LED for a first test of the amplification capability of the detector.

Amplification by drifting charges

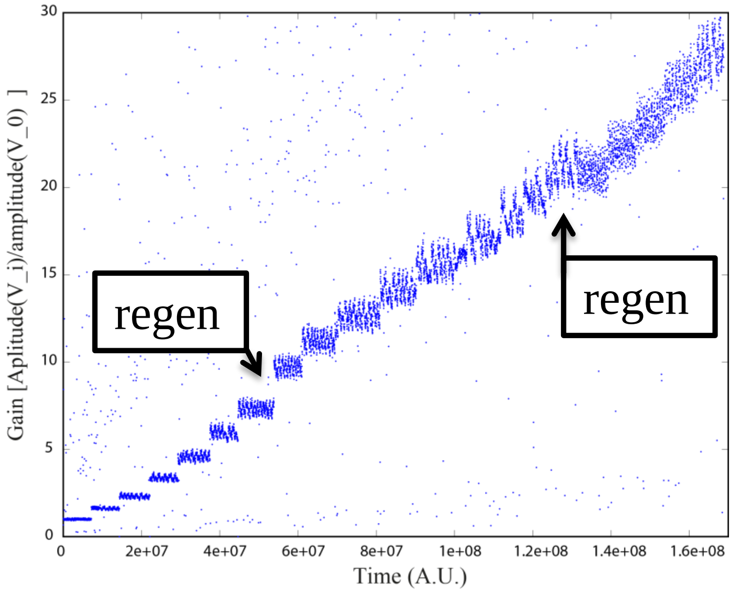
By applying on the grids different biases in the range 0-53 V it is possible to see the amplification not only of the signal but also of the LED pattern.

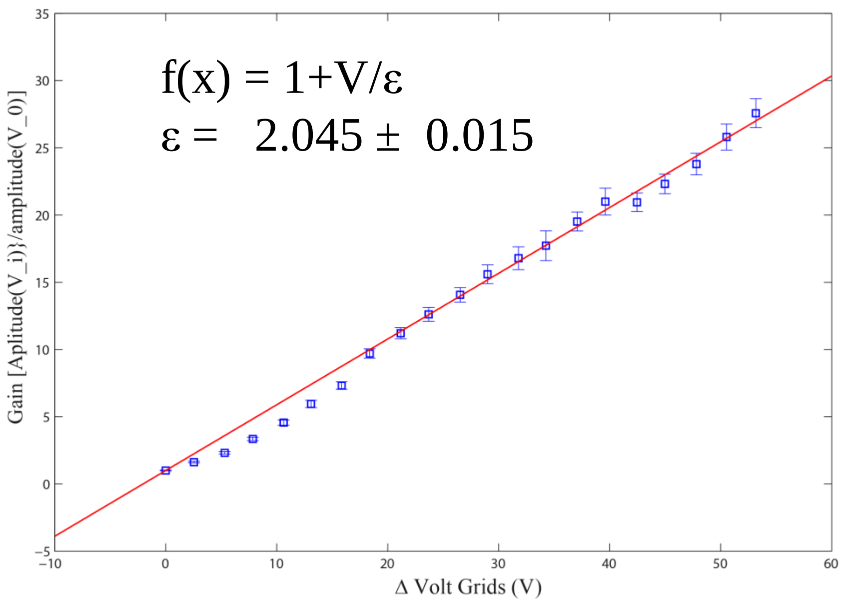


- Moreover the LED response is not so reproducible as as expected.
- The signal/σ_{tot} for those reasons does not improve.



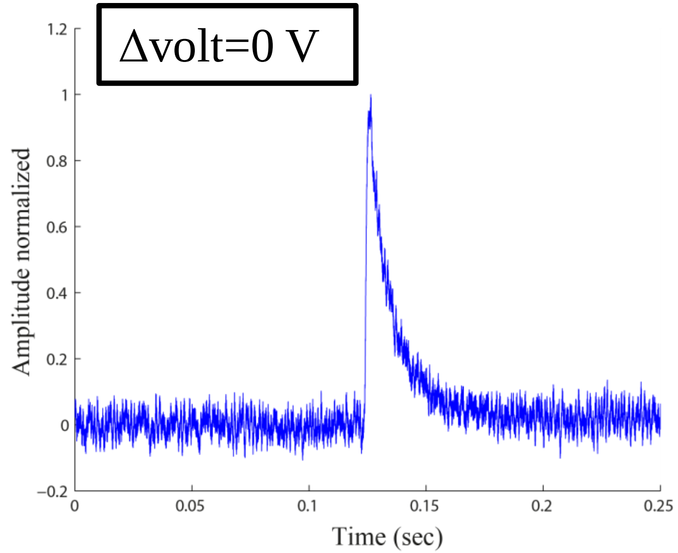
Amplification by drifting charges

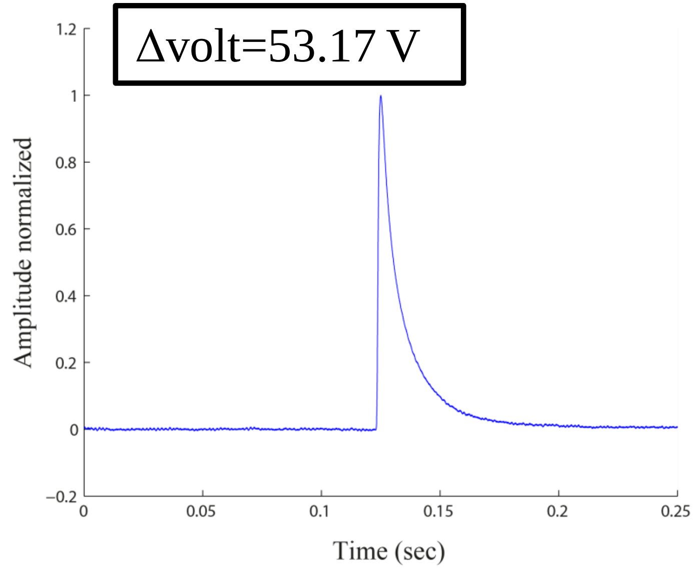




➢Despite these problems it is possible to verify that the detector behaves compatibly with the Neganov-Luke theory.

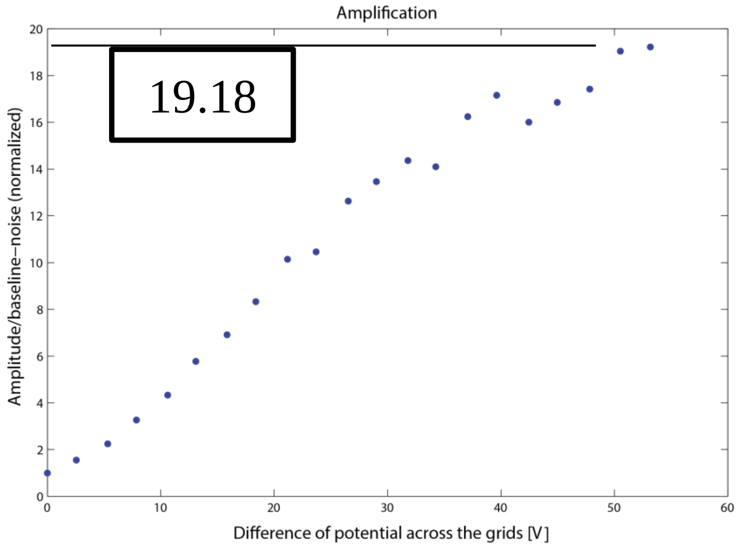
Gain over noise





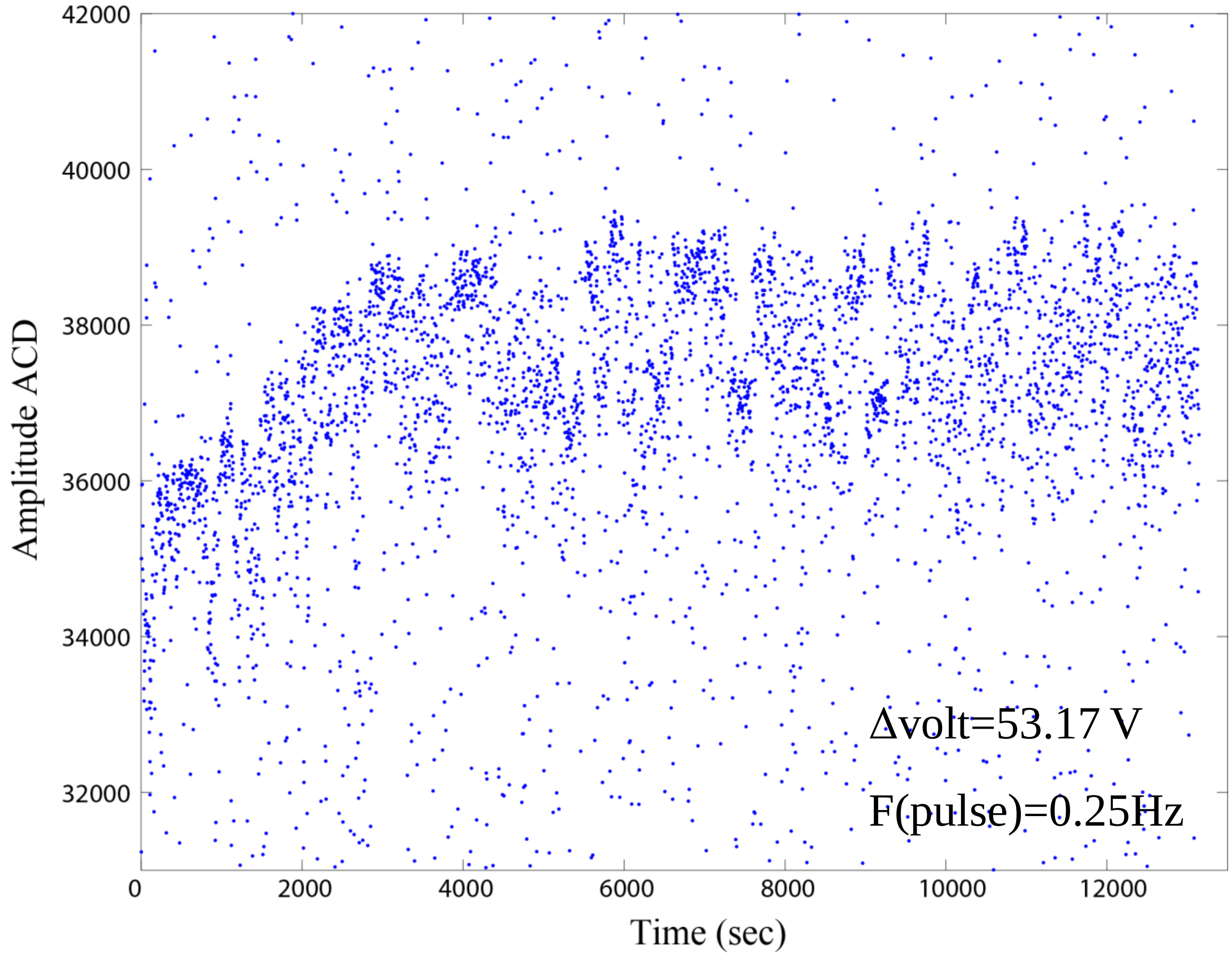
It is possible to evaluate the amplification capability of the detector by evaluating the gain over noise ratio at different biases:

$$\frac{\langle Amplitude \rangle}{RMS_{baseline}}$$

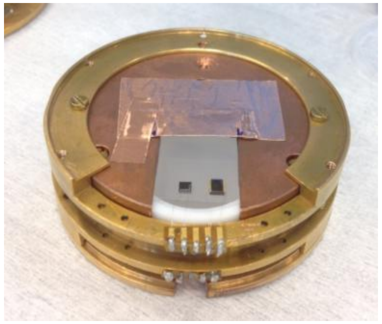


Titolo

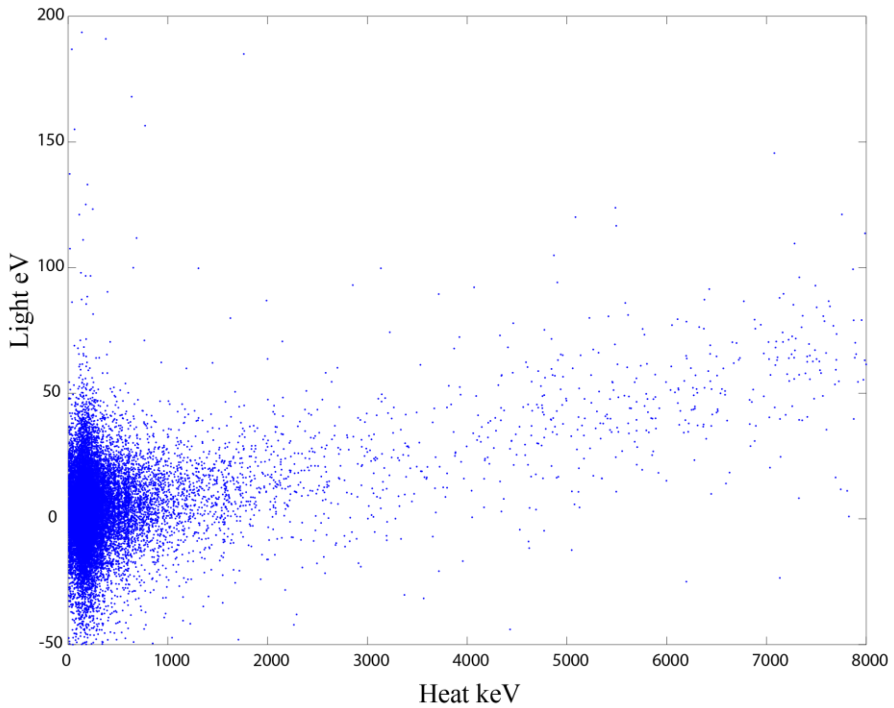
No apreciable degradation in amplitute after more then 3 hours at 53.17 V

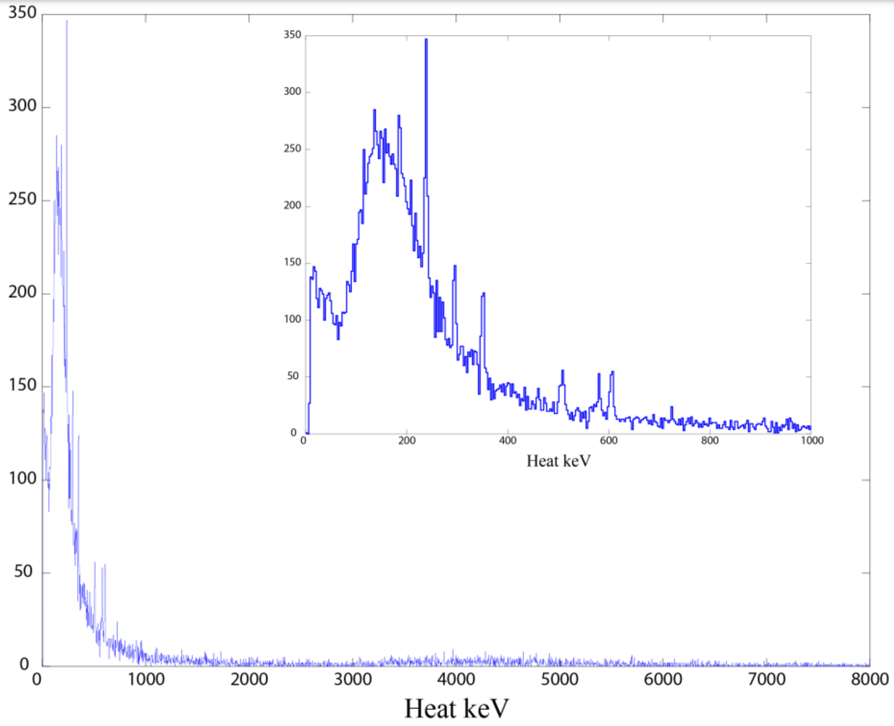


Cherenkov measurement



- A small bolometer of TeO_2 was coupled to the LLD.
- The detector was calibrated with a Th souce





The scatter plot shows the light signal recorded in coincidence with the events occurend in the TeO_2

A Cherenkov measurement with a TeO_2 crystal is ongoing at the LNGS.

Conclusions and prespectives

Conclusion

The Neganov-Luke assisted photon sensor was developed at CSNSM, France .
A low-temperature test was performed at ~ 16 mK in an aboveground pulse-tube cryostat housing a high-power dilution refrigerator.

- Excellent performance in agreement with the theory.
- A gain over noise ratio of ~ 19 was achieved with a bias of 53.17 V.
- No appreciable degradation in amplitute due to space charge trapping after more then 3 hours with 53V was observed.

Perspective

In the future tests we planed to introduce an optic fiber in the system

A Cherenkov measurement with a TeO_2 crystal is ongoing at the LNGS.