CHARACTERIZATION OF LIGHT DETECTORS IN LNGS

F.ORIO - INFN ROMA

ON BEHALF OF

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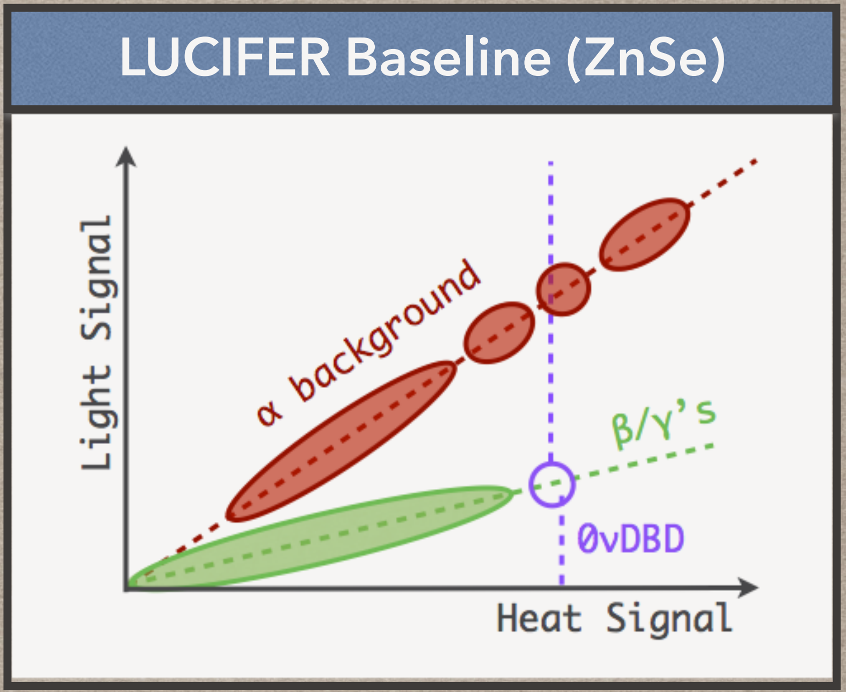
THE IMPORTANCE OF LIGHT DETECTORS

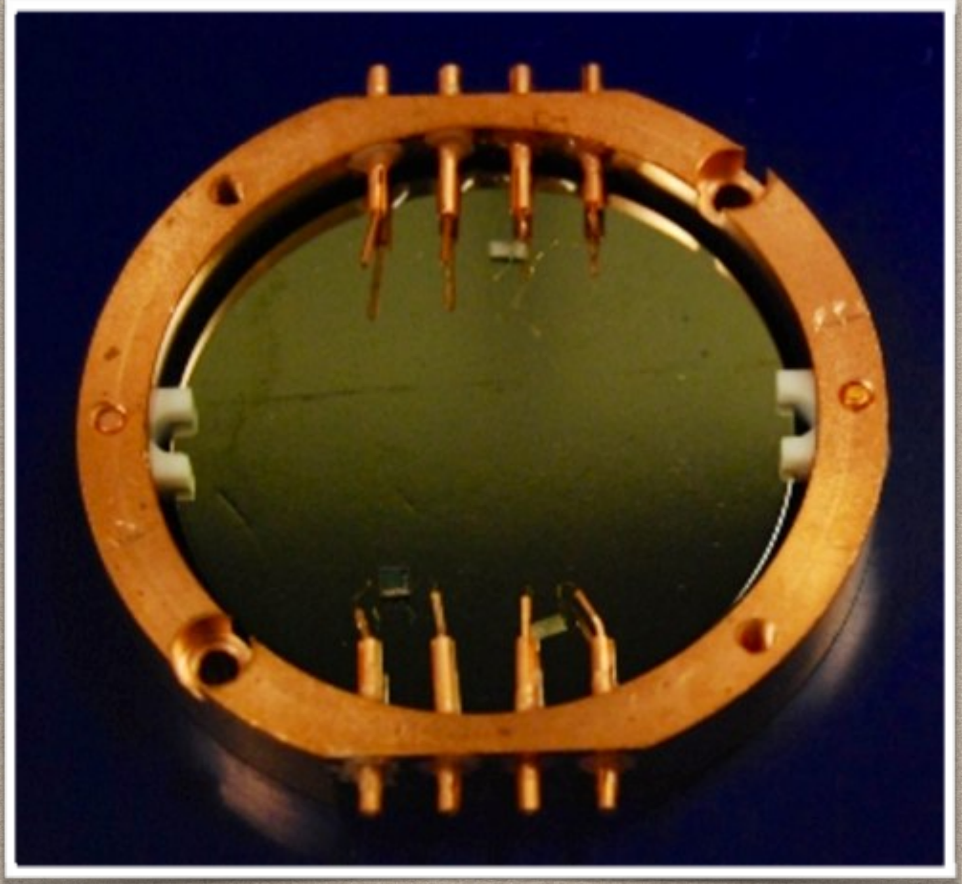
- Scintillating bolometers allow to reject α background, thanks to the different light signal with respect to β/γs, leading to "zero-background" experiments.



- In order to increase as much as possible this background rejection, an optimization of the light detectors in terms of resolution and absolute light yield is mandatory.

THE LIGHT DETECTOR

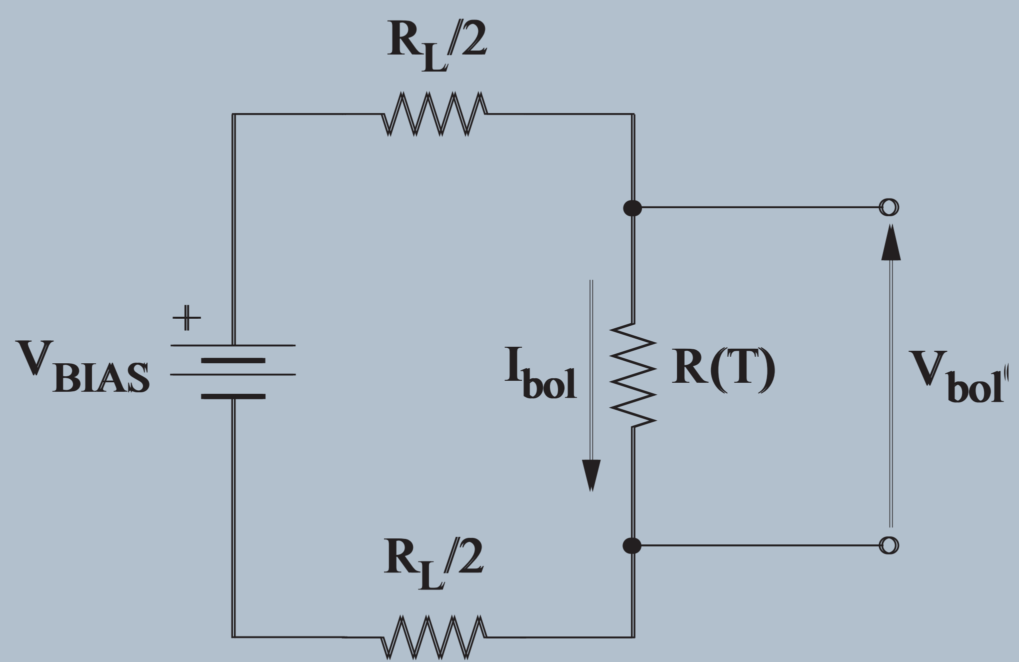
- We operated several light detectors, obtaining compatible results. In this talk I will focus on the one presented in Beeman et al 2013 JINST 8 P07021.



- Pure Ge disk (⌀50 mm×300 μm) produced by UMICORE
- Equipped with NTD sensor (3×1.5×0.4 mm^3) via 6 epoxidic glue spots of ≈ 600 μm diameter and ≈ 50 μm height.
- Held in place by PTFE clamps

THE READOUT ELECTRONICS

Polarization circuit



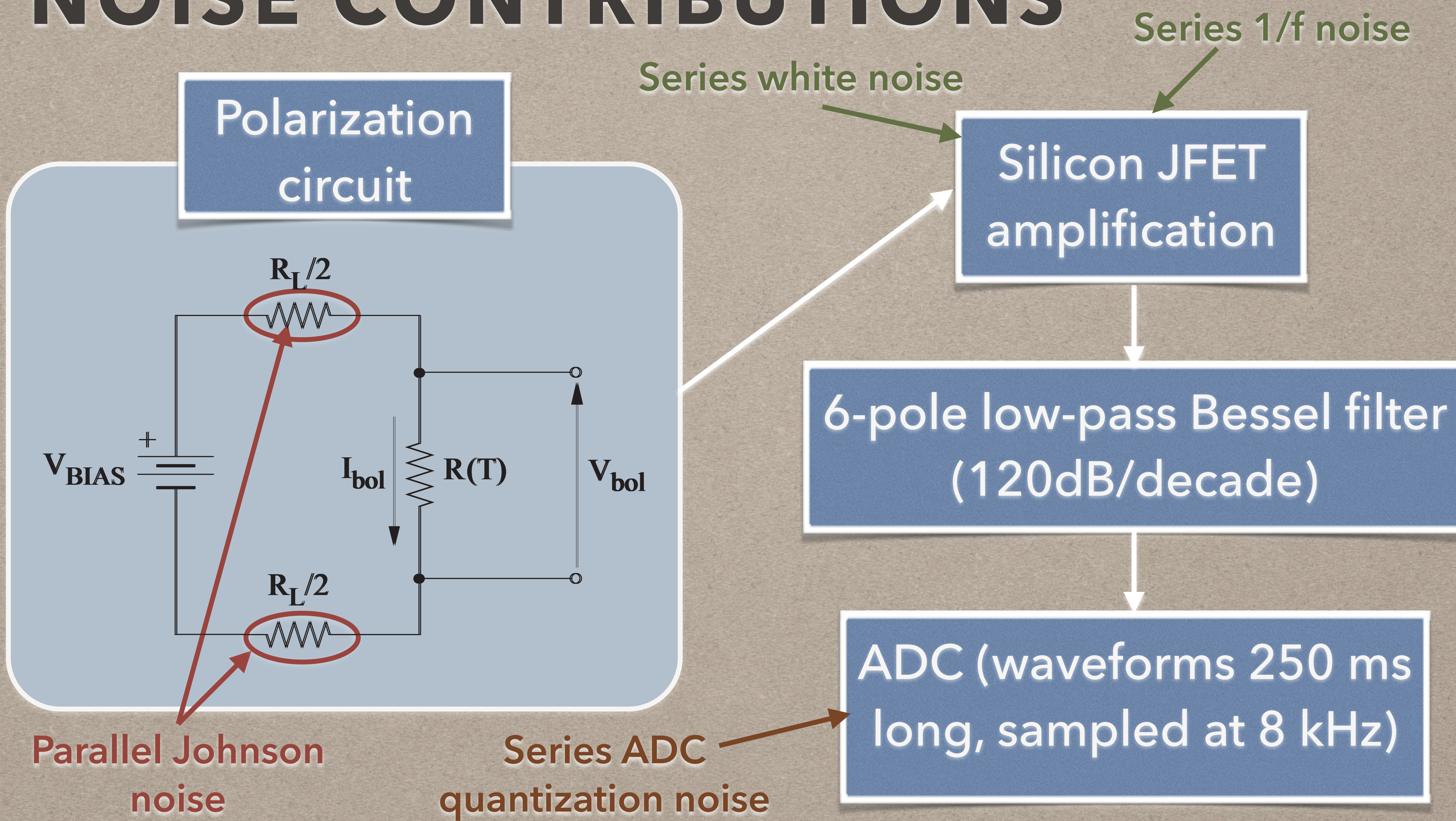
Silicon JFET amplification

6-pole low-pass Bessel filter (120dB/decade)

ADC (waveforms 250 ms long, sampled at 8 kHz)

To maximize the signal to noise ratio, waveforms are processed offline with the optimum filter algorithm.

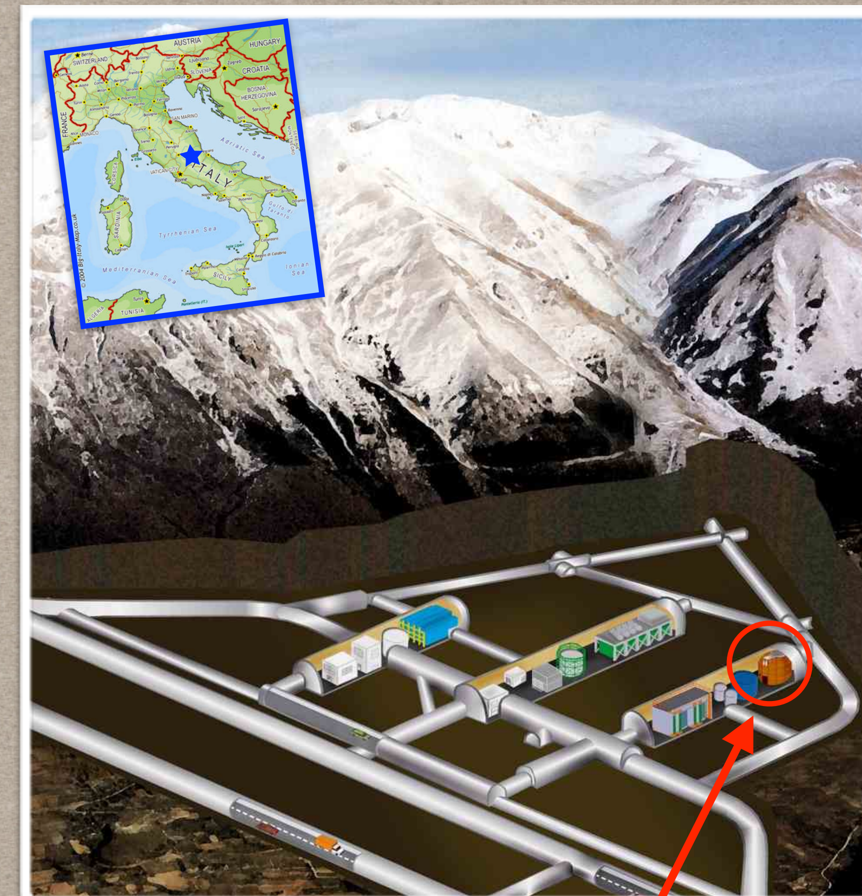
NOISE CONTRIBUTIONS



Mechanical vibrations of the cryogenic apparatus, propagated to LD and wires, represent the dominant contributions.

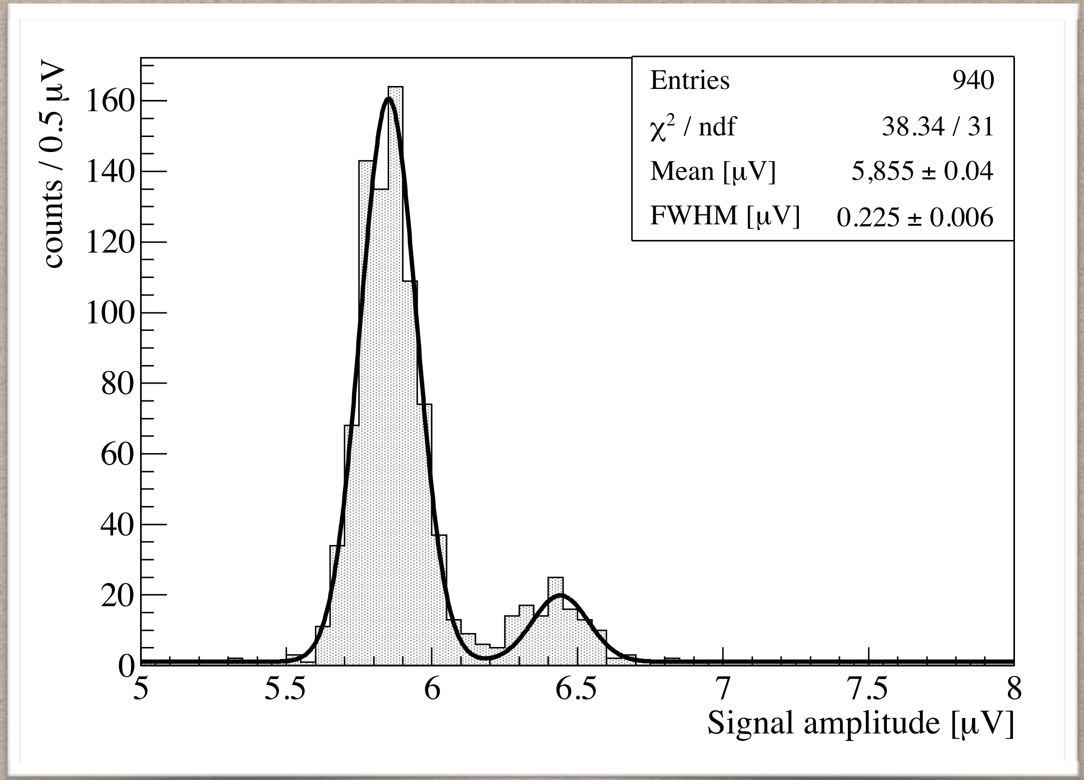
THE DATA TAKING @LNGS

- Operated in Oxford 200 $^{3}He/^{4}He$ dilution refrigerator
- Many short-lasting runs, varying bias voltage, load resistances, Bessel cutoff frequencies
- Data taken at different cryostat temperatures (in the range 10-20 mK)
- About 500 hours of data collected



THE CALIBRATION SOURCE

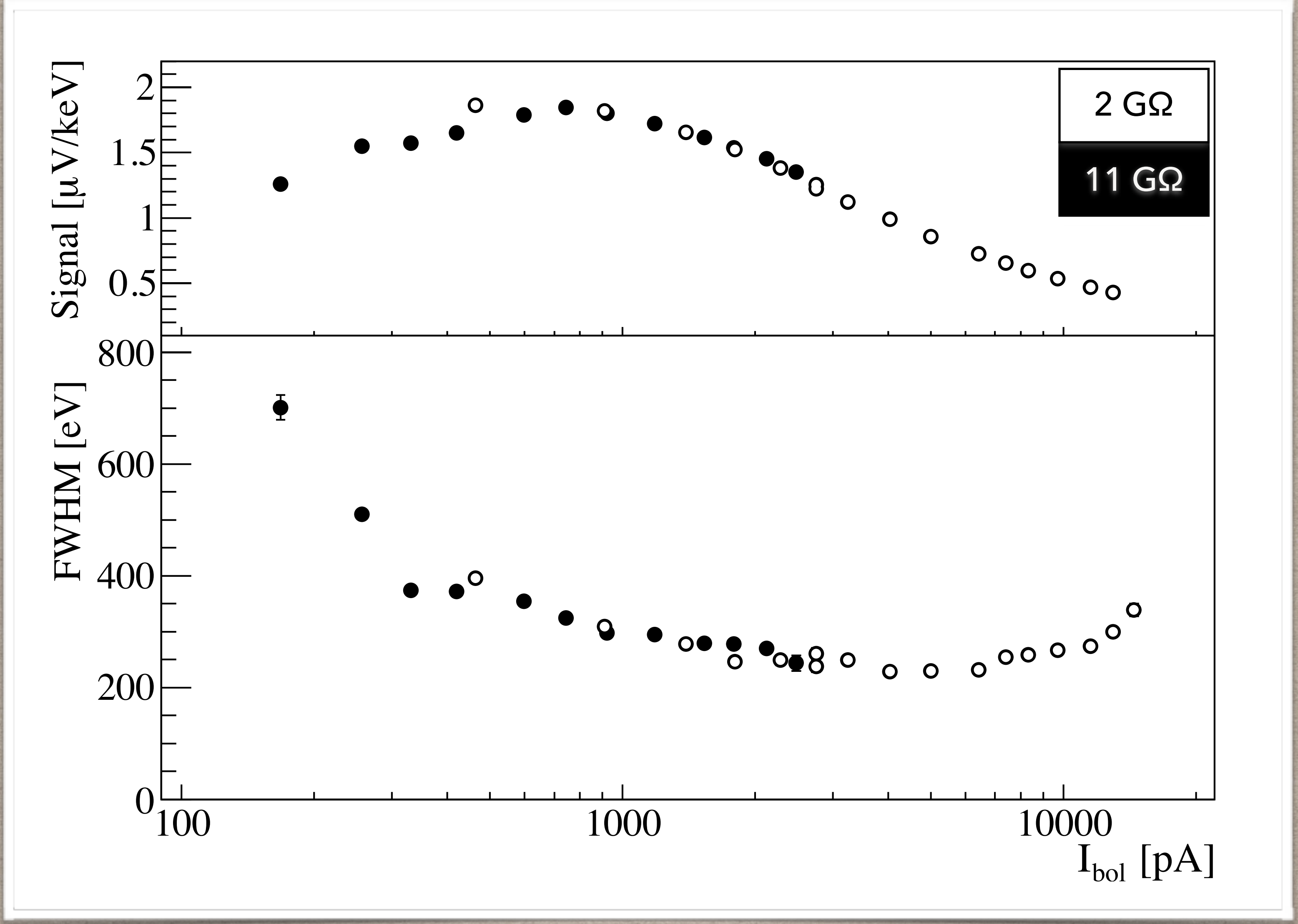
- ^{55}Fe source faced to the light detector
- X-rays at 5.9 and 6.5 keV



We used events belonging to these lines to measure signal yield, energy resolution and signal time development

BIAS CURRENT VARIATION (I)

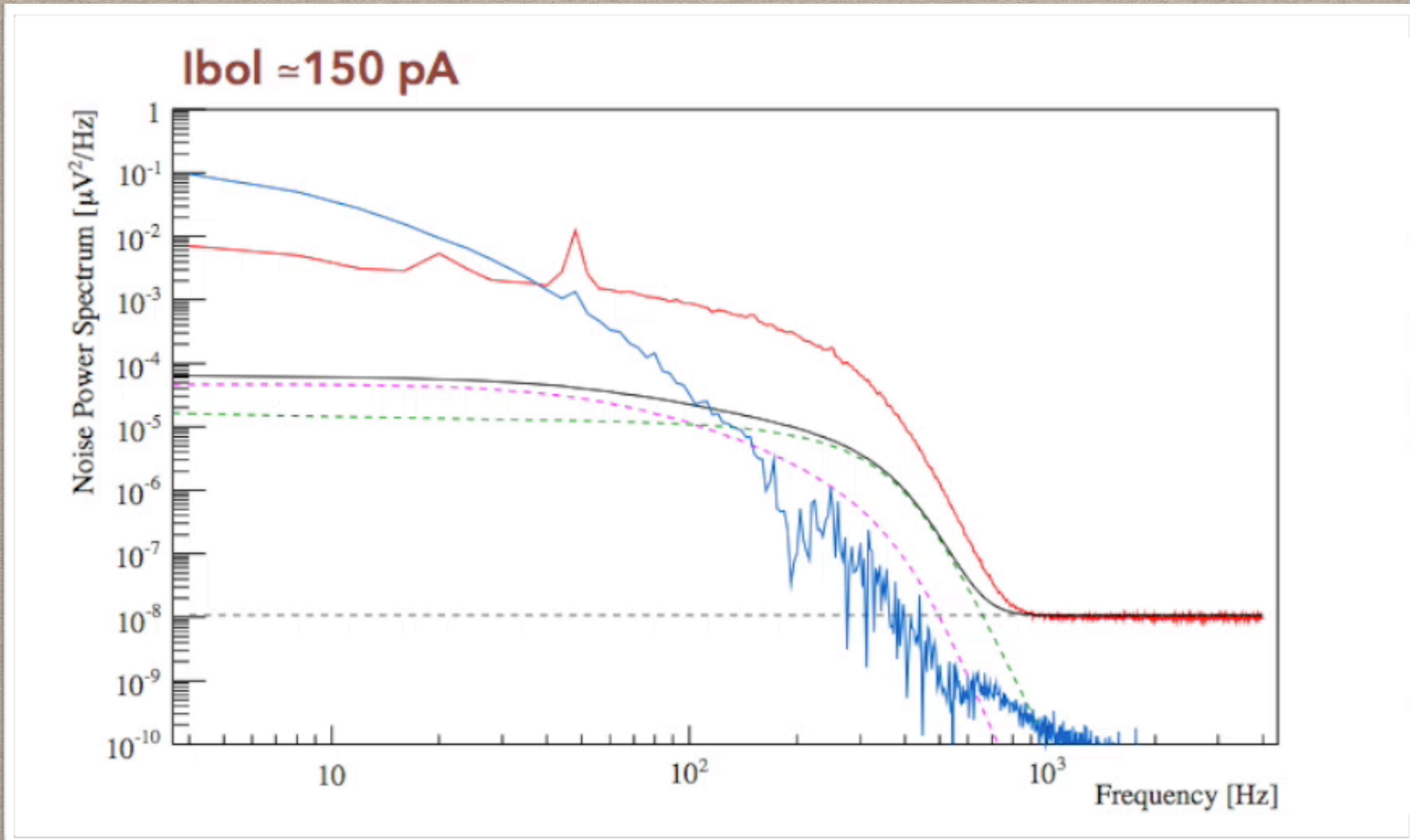
- V_{BIAS} ranging from 1 to 30 V
- Two different R_L: 2 or 11GΩ
- Bessel cutoff: 200 Hz
- Working temperature: 20 mK

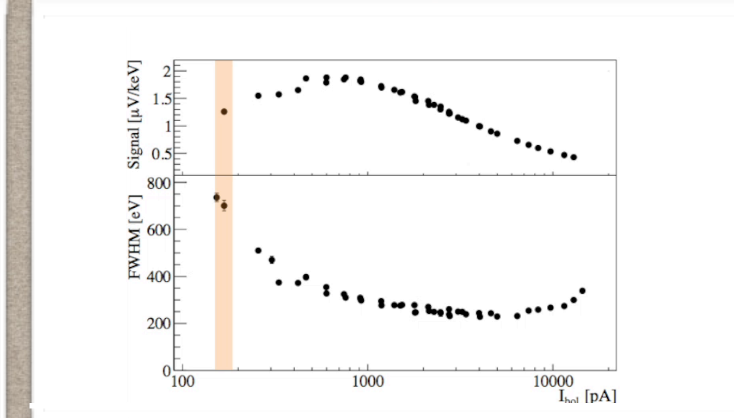


Best resolution does not coincide with the maximum of signal yield

At highest bias currents, after a quite large plateaux, the resolution gets worse

BIAS CURRENT VARIATION (II)



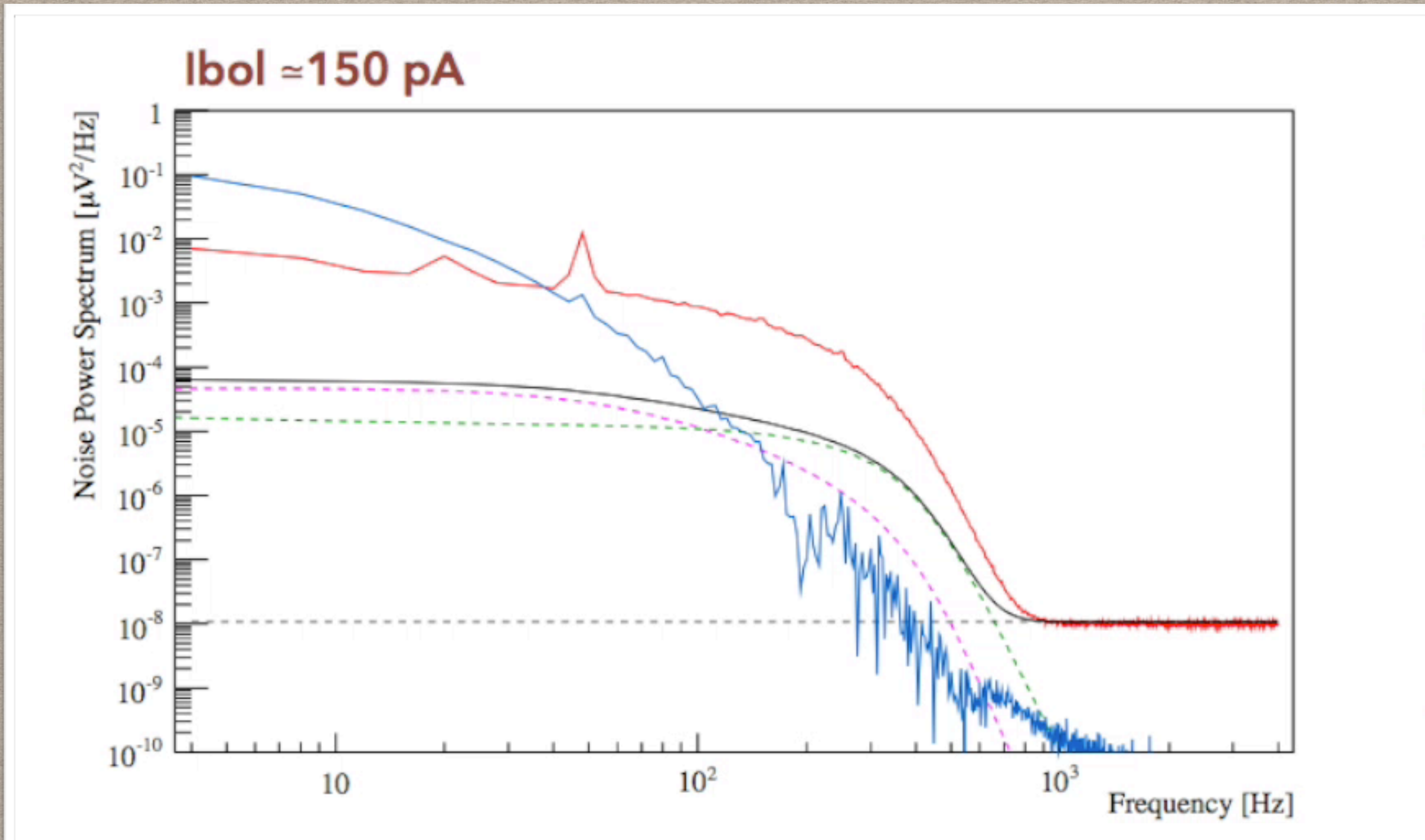


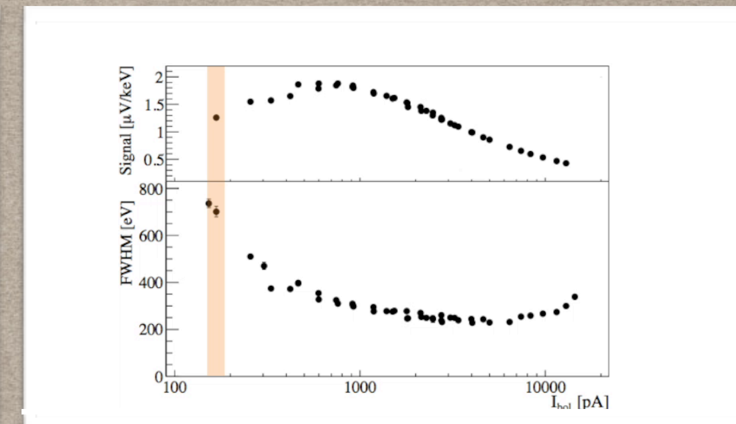
Measured signal
Measured NPS

JFET
Load resistances
ADC quantization
Resulting noise

All the noise contributions decrease as bias current increases, except for series JFET that gives a constant contribution of ~ 50 nV rms.

BIAS CURRENT VARIATION (II)





Measured signal
Measured NPS

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Load resistances
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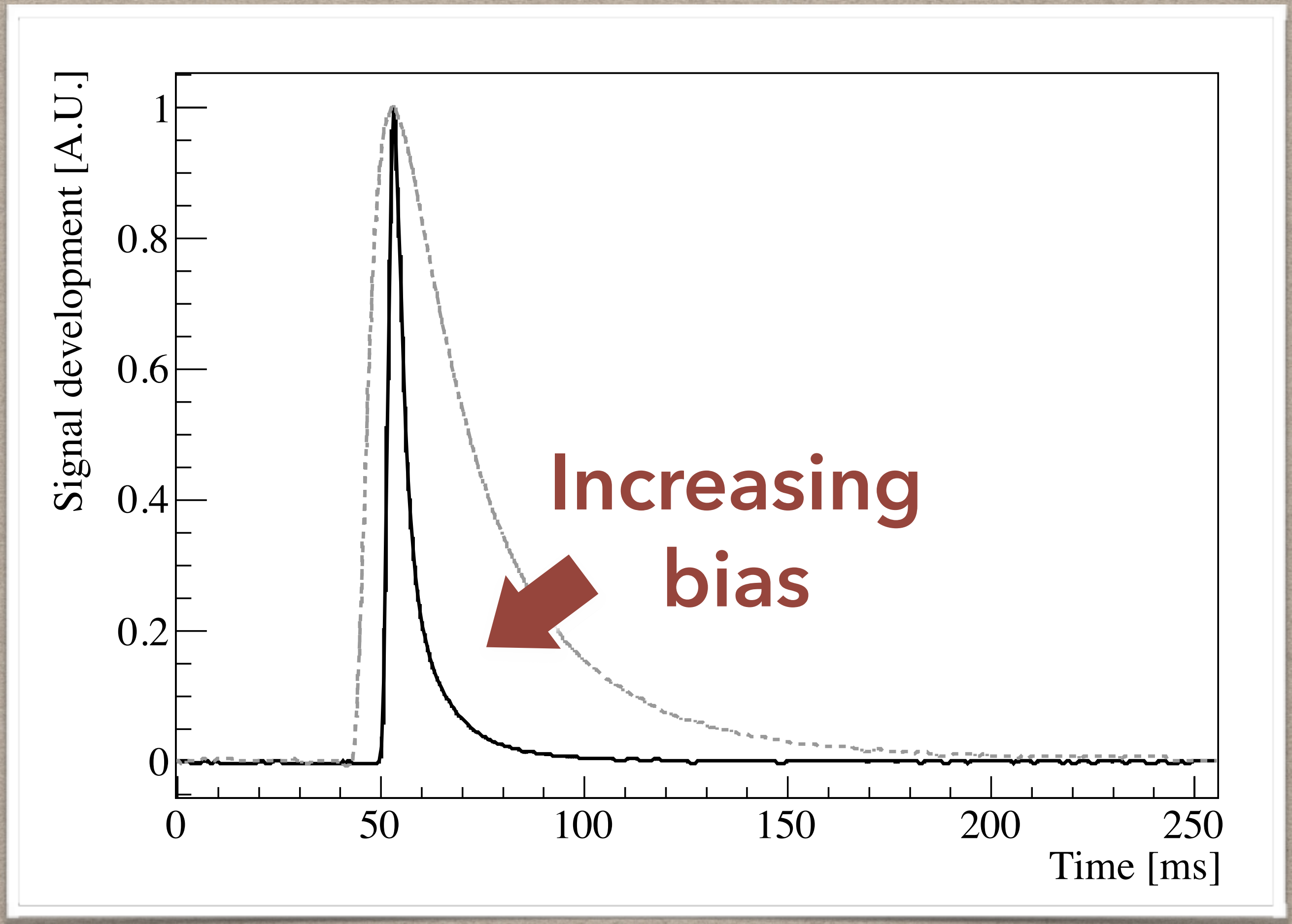
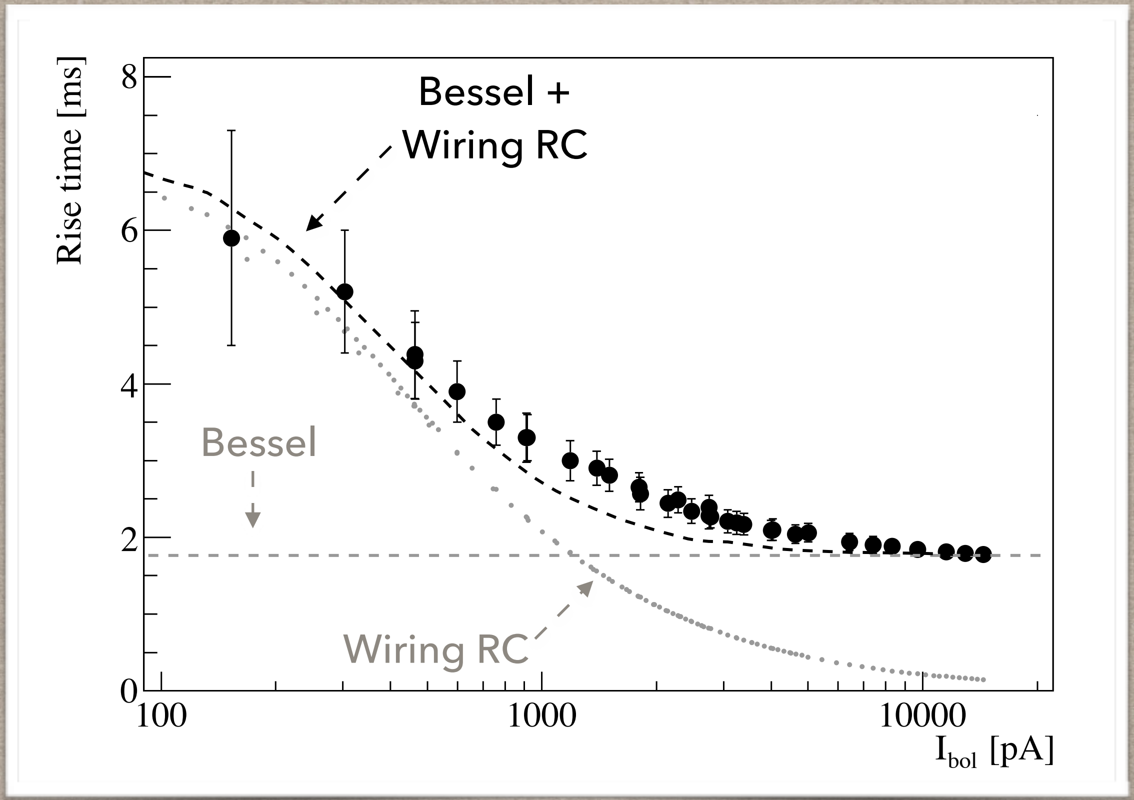
All the noise contributions decrease as bias current increases, except for series JFET that gives a constant contribution of ~ 50 nV rms.

BIAS CURRENT VARIATION (III)

- Signal development becomes faster as the bias increases, both on rise and decay.

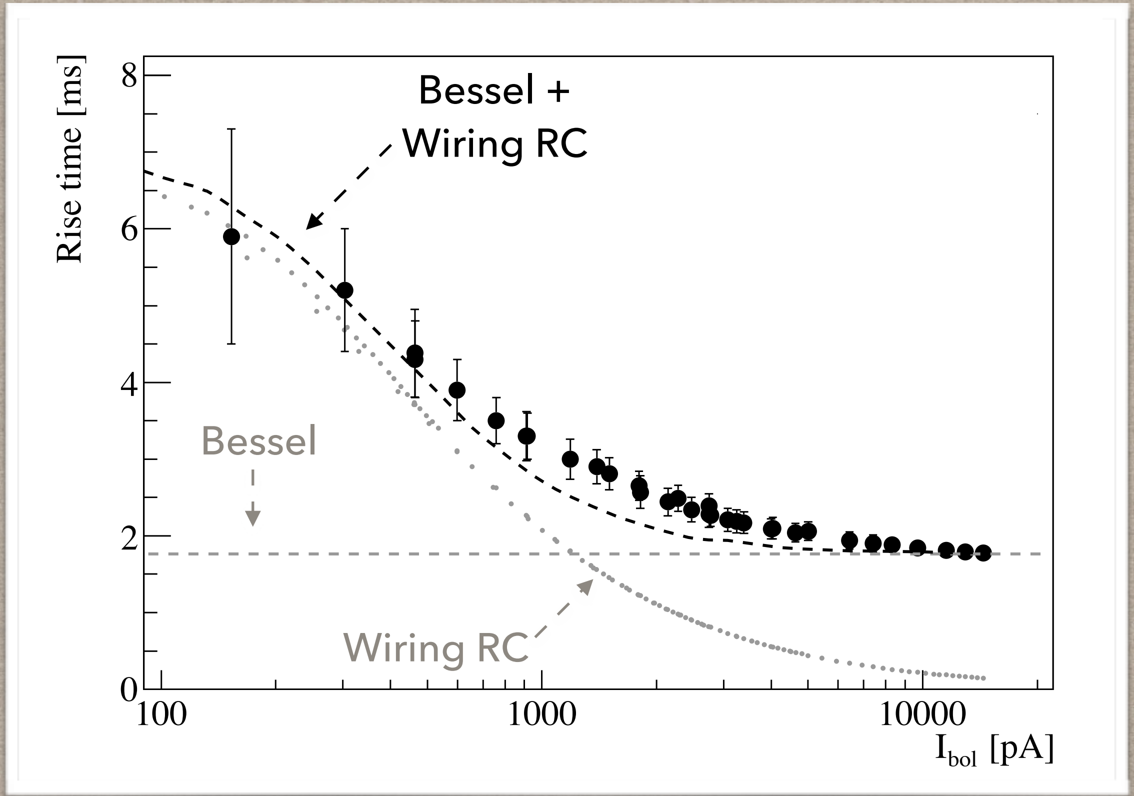


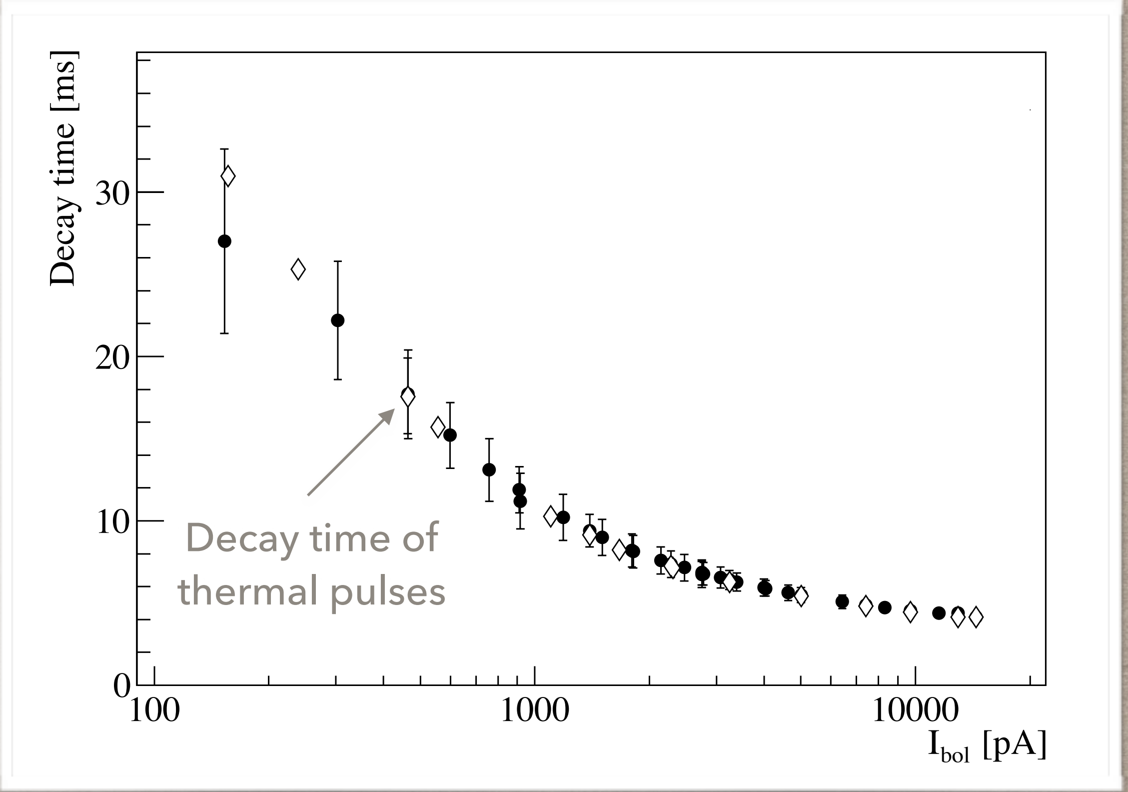
BIAS CURRENT VARIATION (IV)



- Rise time variation is due to the combination of the constant term given by the Bessel filter and the variable contribution given by the RC of the wiring (thermistor dynamic impedance depends on the bias).

BIAS CURRENT VARIATION (IV)

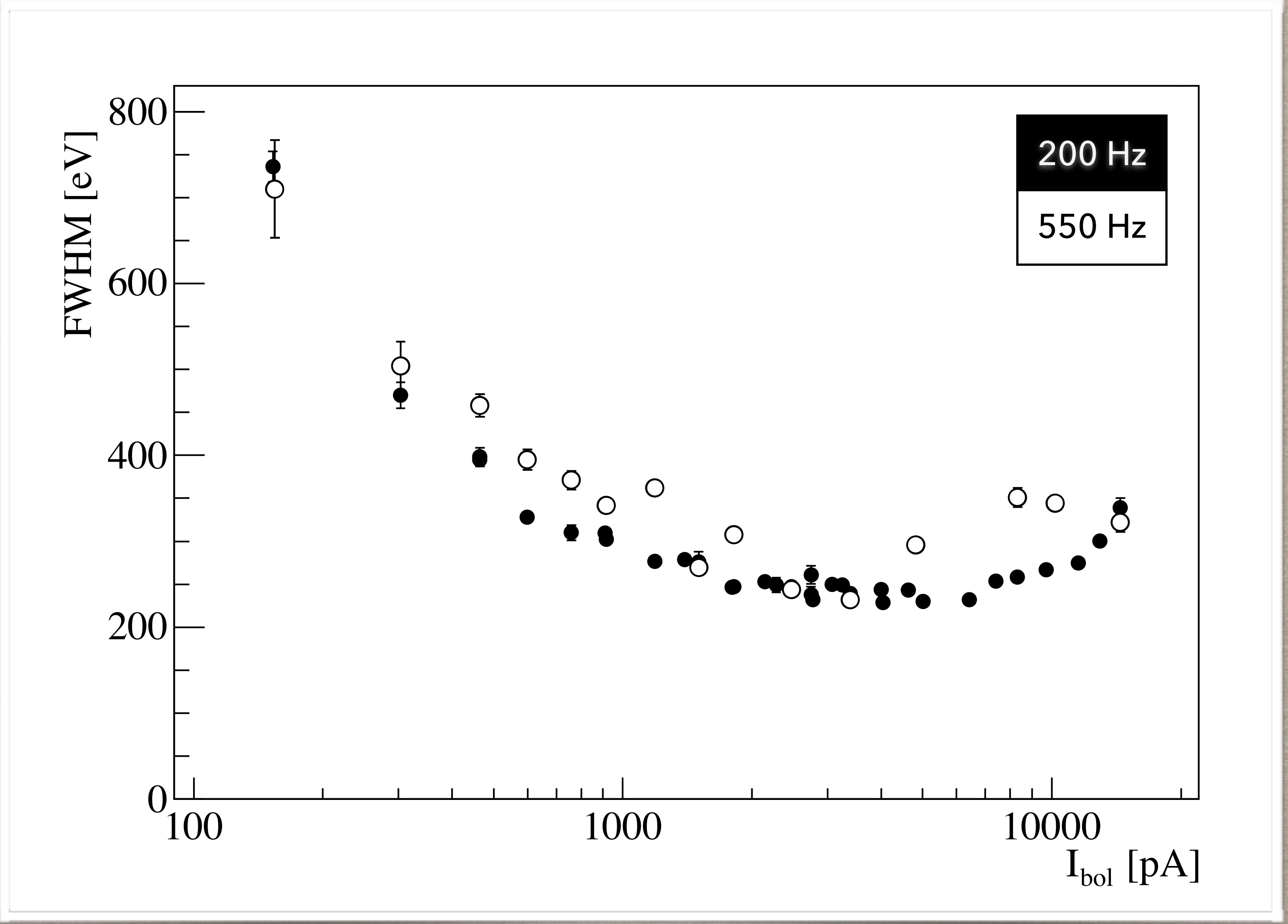




- Rise time variation is due to the combination of the constant term given by the Bessel filter and the variable contribution given by the RC of the wiring (thermistor dynamic impedance depends on the bias).
- Both these contributions are negligible in the decay time, whose variation is due only to the thermal response of the absorber (the light detector itself).

BESSEL CUTOFF VARIATION (I)

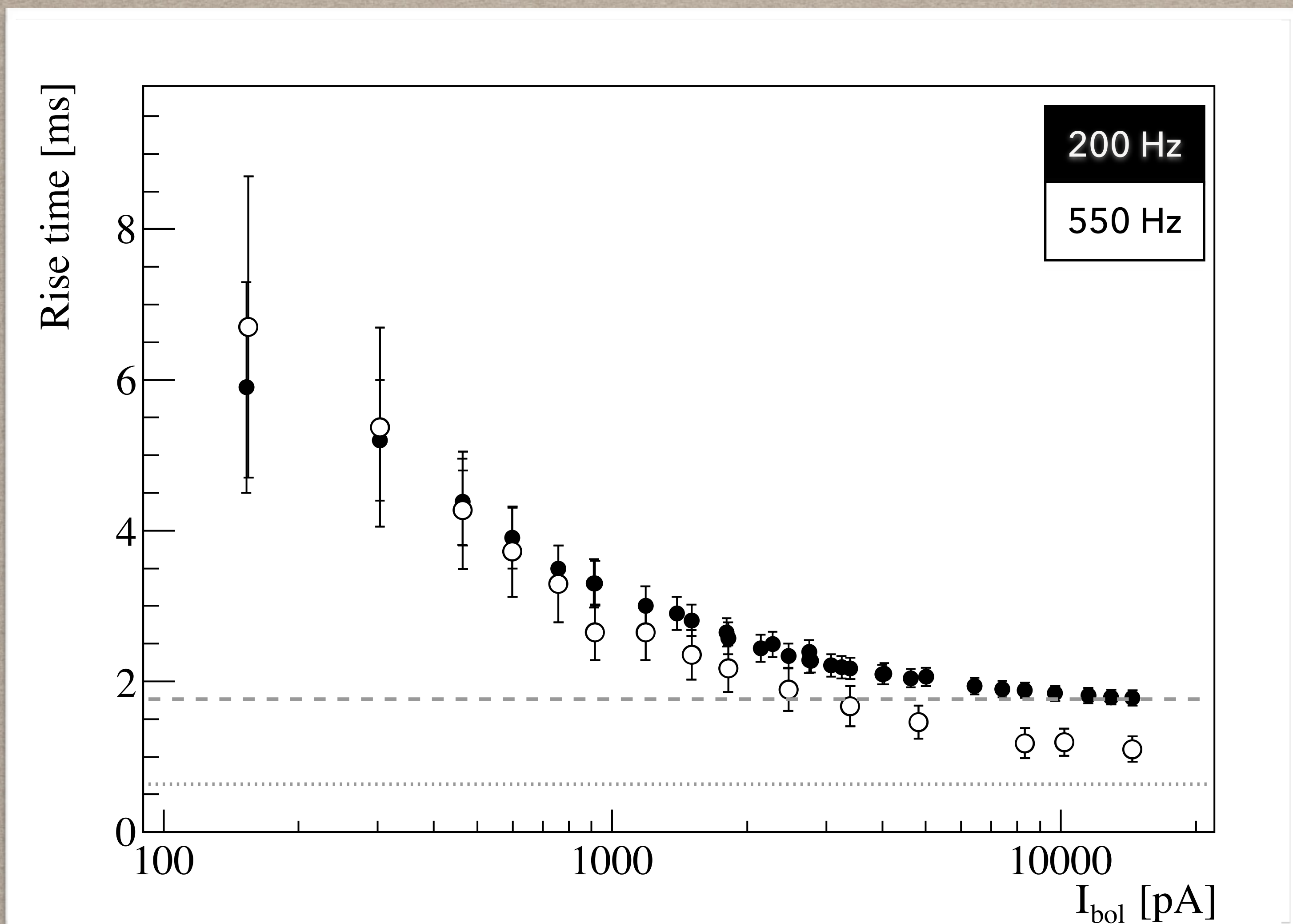
- V_{BIAS} ranging from 1 to 30 V
- Two different R_L: 2 or 11GΩ
- Bessel cutoffs: 200 or 550Hz
- Working temperature: 20 mK



Increasing the Bessel cutoff frequency leads to a general worsening of the resolution

The best resolution is, however, still the same (~250 eV FWHM)

BESSEL CUTOFF VARIATION (II)



- For low bias currents, RC contribution is dominant and both the datasets show the same rise time.
- For higher bias currents, higher cutoffs mean faster rise times.

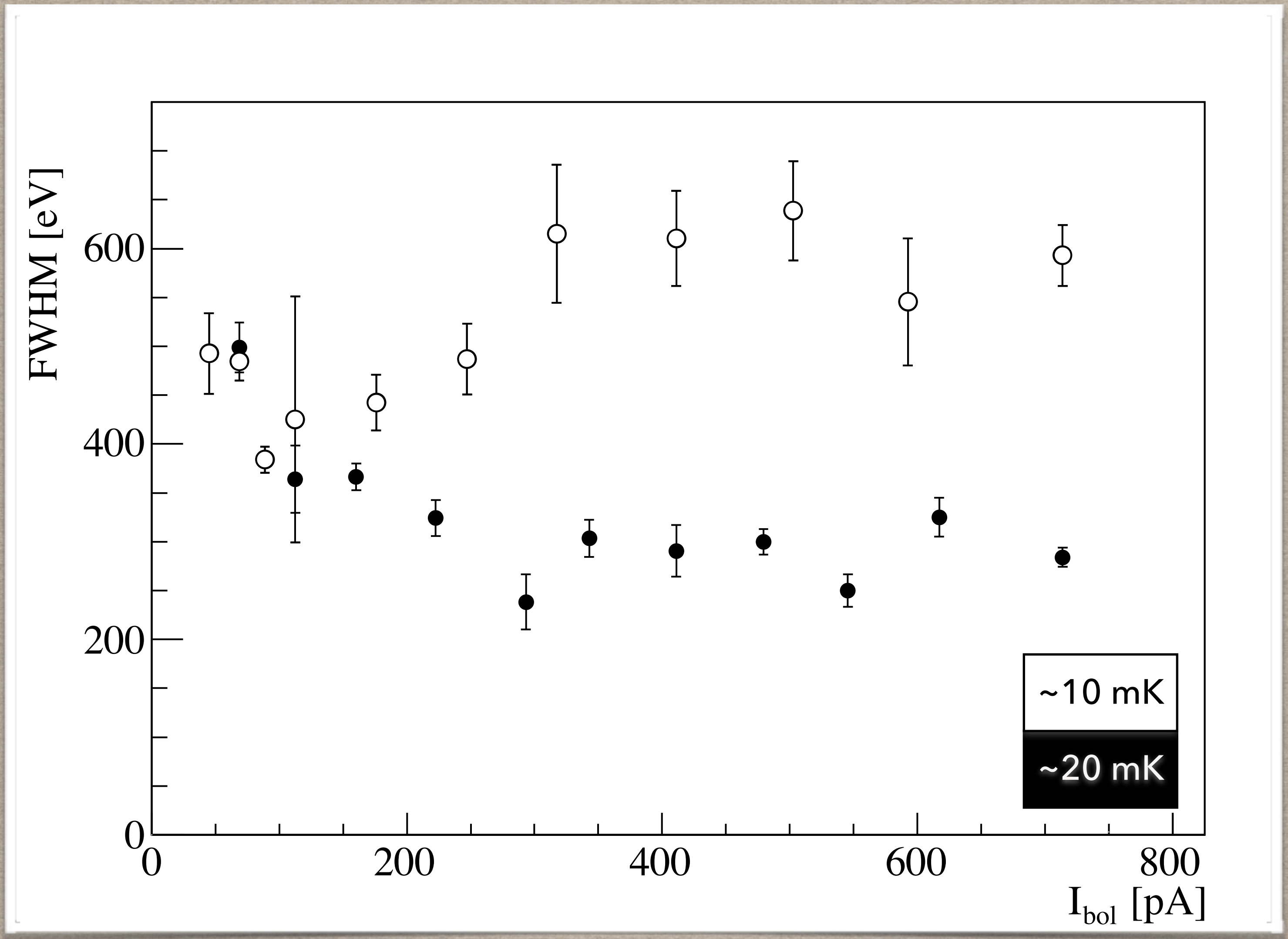
As explained previously, decay time does not depend on Bessel cutoff frequency choice

WORKING TEMPERATURE VARIATION (I)

- During last year we operated and tested several light detectors.
- Unfortunately we had the possibility of varying the working temperature only in few of the runs.
- Among them, we chose to present the case in which we had the biggest difference of working temperatures, i.e. ~10 and ~20 mK.

In this run, the detector was not the previously shown one, but it has the same shame and compatible performances @ 20 mK

WORKING TEMPERATURE VARIATION(II)



GENERAL WORSENING OF THE ENERGY RESOLUTION

Cooling down to 10 mK, we observe mild alterations in the signal shape while the NPS in the lowest frequencies region (0 – 50 Hz) increases.

CONCLUSIONS

- We investigated the performances of Ge bolometric light detectors in terms of signal amplitude, energy resolution and signal time development.
- Data show a clear dependence on the applied bias current, favoring values around 2 – 7 nA.
- The value of the load resistance has no influence on the signal amplitude and the energy resolution
- Different choices of the Bessel-Thomson filter cutoff frequency do not critically change the light detector behavior
- LD performances at ~ 20 mK are significantly better with respect to the ones observed at ~ 10 mK, the standard working temperature of bolometers for rare events searches.

BACKUP

THERMAL PULSE DECAY TIME ESTIMATION (I)

- Based on thermal model response
    - M.Carrettoni and M.Vignati,JINST6 (2011) P08007, [arXiv:1106.3902]
    - M. Vignati, J. Appl. Phys. 108 (2010) 084903, [arXiv:1006.4043]
- We performed a fit to the average detector response for a given bias current, in order to extract the decay time of the thermal component alone.
    - Ingredients: sampling frequency, gain, Bessel-Thomson cutoff frequency, bias voltage, baseline voltage, working resistance, load resistance and capacitance.

THERMAL PULSE DECAY TIME ESTIMATION (I)

- For each working point we estimated the thermal component of the pulse