Measurements of influence of temperature on ABCD1 and ABCD2 chips.

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1 Introduction

It was observed during the summer beam test of modules with ABCD1 chips that the electronics had to be re-tuned when modules were moved from the laboratory into the test beam. The operating point, defined by the bias and shaper currents and by the delay of the calibration pulse, was different in the lab and in the test beam. The modules were cooled in the test beam and they were not cooled in the lab, so the influence of the temperature was suspected. There were other potential factors however, such as much longer cables in test beam. The single module readout system in the SCT system test area offered the possibility to study the influence of temperature directly in laboratory conditions. This informal note describes the performance of several modules with ABCD1 and ABCD2 chips measured at different temperatures.

2 The setup

The single module readout system in Building 186 consists of:

- a box for mounting and cooling modules previously used at the test beam,
- a VME crate with the DSP based readout block and the BC96 bias card for controlled powering of the tested modules,
- a stand-alone power supply for detector biasing,
- a PC-VME interface and a PC running the DAQ system.

The DAQ was written by Peter Phillips using Labview and is documented on his web page. Janusz Godlewski has made the cooling system. A detailed documentation of the setup has been written by Simon Peeters and is available from him on request.

The cooler uses a mixture of alcohol and water. This cooling liquid can be kept at a predefined temperature with an accuracy of ~ 0.1 degree C. The liquid passes through an aluminium bar inside a thermally insulated box where tested modules can be mounted. The modules are cooled thanks to thermal conductance to the bar, as

place	Temperature [^{o}C]	
	warm	cold
Cooling liquid	$+25 \pm 1$	-15.0 ± 0.1
Cooled aluminium bar	$+25 \pm 1$	-14.1 ± 0.2
Wall of module box	$+25 \pm 1$	-3 ± 1
Ceramic back of module	$+36 \pm 1$	$+5 \pm 1$
Corner of the hybrid	$+46 \pm 1$	$+8 \pm 1$

Table 1: Temperatures in various points of the setup for "warm" and "cold" operating conditions.

well as by the flow of cooled nitrogen. The nitrogen is cooled when it passes through copper tubes attached to the bar.

Over the course of the measurements reported here a variety of temperature sensors were installed in various points of test the setup and on modules themselves. The measured temperatures are summarised in Table 1. The temperatures varied within the specified approximate errors, showing correlation with the ambient temperature. For example, with cooling running continuously, the temperature at the wall of a module box would be -4^oC at night, -3^oC in the morning and late evening and -2^oC during a day.

The results reported in this write-up were taken either at "warm" conditions, with cooling switched off, or with cooling liquid kept at -15^oC. It was taking about four hours for the setup to cool to the state described by the "cold" column in Table 1, after which the the temperatures were not dropping any further. Both "warm" and "cold" measurements were taken at stable temperatures.

The alcohol content of the cooling liquid was measured to be 24% in volume. With the cooling liquid upgraded to 40% alcohol it would be possible to reduce the temperature of the cooling liquid by another 5 degrees, down to -20^oC. However already the setup running with the liquid at -15^0C offered a reduction of temperature by almost 40 degrees, as measured on the hybrid (see table 1).

2.1 The tested modules

The following modules were tested:

Modules 1 and 2 - each one resembling one side of a barrel module, equipped with ABCD1 chips; used in last summer beam tests;

Hybrid 3 - non-metallized ABCD2 chips, no detector;

Module M1 - metallized ABCD2 chips but not thinned down, complete side of barrel module.

In all four cases the ABCD chips were mounted on a beryllia hybrid ("Oslo" hybrid).

2.2 The plots and the chip settings

The modules were tested mainly by means of calibration threshold scans. A calibration pulse was injected to every channel and the probability of each channel responding was measured as a function of the threshold. The resulting S-curves, integrals of Gaussian distributions, can be characterised by two parameters: 50% point and sigma of the distribution, which is a measure of the output noise. Both these parameters are expressed in mV. For a few channels an occupancy plateau at low threshold values was below 1.0[1] It was therefore necessary to introduce the third parameter of the S-curve fit, the plateau level.

By comparing S-curves measured for different magnitudes of the calibration pulse it is possible to measure the gain of the front-end amplifier, expressed in mV/fC. The equivalent noise charge (ENC), expressed in electrons, is calculated from the gain and from the measured noise.

The plots are available as */afs/cern.ch/user/g/gadomski/abcd/note/plots.ps* at the *atlas.cern.ch* unix cluster. Three modules and one hybrid were tested, as listed above, each at "warm" and "cold" conditions. Because the hybrid was tested at two different settings, that gives a total of 10 data "points". Performance of each module/hybrid at each setting and temperature is summarised in a concise way on two pages of plots. First 20 pages of the 25 page long plot file contain those summaries, labelled by titles. The last 5 pages show changes in the measured gain between "warm" and "cold" conditions.

The settings of the ABCD chips on modules are listed in tables 2, 3 and 4. It should be noted that the FE bias and FE shaper currents are internally generated on ABCD chips by DAC converters. The FE bias current can be changed in steps of 9.2 mA. The nominal values are ~ 210 mA. The FE shaper current can be changed in steps of ~ 1.2 mA and the reasonable values lie between ~ 15 and ~ 26 mA.

2.3 The modules with ABCD1

The modules with ABCD1 chips need to be tuned carefully. For each chip there exists just one value of FE bias that is good for the majority of channels. We have found that an independent search for optimum conditions done at different setups, namely the setup of Daniela Macina and Andras Zsenei in building 161 and the one used for

[1]Its is a known problem for ABCD chips, some channels show inefficiency independent of the threshold. A fault in the pipeline is suspected.

this study, give the same result. The optimum operating point to which a module should be tuned is not setup dependent.

The optimum points for ABCD1 chips depend on temperature however. That both explains and confirms the behaviour seen for modules 1 and 2 at the test beam. The modules with ABCD1 chips show no systematic change of gain with temperature. The optimum setting however, even after careful tuning done separately for every chip, are not not good for all the channels at once. In the distribution of gains the number of channels that populate the low-end tail varies. This causes small changes of the average measured gain. The average gain appeared to drop by 4% when module 1 was cooled while for module 2 it rose by 7%.

2.4 The hybrid and the module with ABCD2

The hybrid and the module with ABCD2 were both getting into an oscillating state when the bias current was close to what should be its optimum value. An oscillating state is recognised, because the response of each channel to a threshold scan does not resemble an S-curve. The modules were operated at the highest values of the bias current that were still below the oscillation region. In order to get the bias current as close as possible to the nominal values the shaper current was also kept fairly high. In particular for hybrid 3 Andras Zsenei and Jason Ward have found before that for the shaper current of 25.2 mA the highest value of the bias current below the oscillation region is 165.6 mA. This set of values is named here "uniform settings" (Table 3). The performance of hybrid 3 was studied for this set of parameters in warm and cold conditions. There were much smaller channel to channel variations compared to the ABCD1. The average gain was lower however, and it also to dropped by 20% when the hybrid was cooled.

It was observed in case of hybrid 3 that tuning FE bias currents individually on all chips enables going to higher values without getting into oscillation. The tuning was done separately for warm and cold operation. The values make the setting named "max. FE bias" on the plots, also documented in table 3. It turned out NOT to be advantageous for the measured gain to go to those higher FE bias values, especially when cold.

On module M1 the highest value of the bias current at which the electronics is still not oscillating was found to be 165.6 mA, uniform for all the chips. This confirms the observations done by Andras and Jason using another test setup. It was of interest to establish whether the stability region is not larger when the electronics is cooled. It was observed that the highest bias current for stable operation remains the same when the module is cooled. Module M1 was then tested, both warm and cold, using the same set of parameters, uniform for all the chips. The parameters are listed in Table 4. The measured gain dropped by 44% on average.

Simulations of the most recent design of ABCD chips were done for different temperatures. A rise in measured gain is expected when the temperature drops. The new design is slightly different from that of the tested modules. More importantly however, none of the tested ABCD2 modules, neither hybrid 3 nor module M1, could be operated at nominal conditions.

Both hybrid 3 and module M1 had large noise in the first chip, the master chip. The same effect was visible on module 1 after cooling. The cause of this noise is not known. In addition module M1 has higher noise in all channels (except for channels 600 to 640, which were not bonded to the detector), compared to its performance at the other readout system. This noise is reduced when the module is cooled.

3 Conclusions

The observations and measurements described in the previous section can be summarised in the following way:

- The results are well reproducible at different readout setups. Neither the optimum settings nor the behaviour of modules seem to be setup dependent. There seem to be additional noise sources in the setup used for this study, particularly affecting the first chip. There is no explanation yet.
- The ABCD1 chips need individual tuning. They also need to be re-tuned once cooled. No systematic change of gain between cold and warm is observed. There is a small change of average gain because of large channel to channel variations and the presence of large low end tail in the distributions of gains.
- The ABCD2 chips could not be operated at nominal settings because of the oscillation problem. The cooling does not affect the values of settings at which the chips start to oscillate. The measured gain drops significantly when the electronics is cooled.

4 Acknowledgements

I would like to thank Simon Peeters for allowing me to use his test setup in building 186. Janusz Godlewski and Marcin Wolter have contributed by preparing the cooling system. I should also tank Peter Phillips for the user-friendly and documented DAQ software he makes available.

Module 1 warm	
FE bias	211.6, 211.6, 220.8, 211.6, 220.8, 220.8 mA
FE shaper	18.0 mA
Cal delay	17 bits

Module 1 cooled	
FE bias	202.4, 202.4, 211.6, 202.4, 211.6, 211.6 mA
FE shaper	13.2 mA
Cal delay	17 bits

Module 2 warm	
FE bias	202.4, 211.6, 211.6, 211.6, 211.6, 211.6 mA
FE shaper	18.0 mA
Cal delay	23 bits

Module 2 cooled	
FE bias	193.2, 202.4, 202.4, 211.6, 202.4, 202.4 mA
FE shaper	15.6 mA
Cal delay	21 bits

Table 2: Settings of 6 ABCD1 chips on modules 1 and 2. Settings appear in order of rising chip index: 0 to 5. A single number means the same setting for all.

Hybrid 3, uniform settings, warm and cold	
FE bias	165.6 mA
FE shaper	25.2 mA
Cal delay	21 bits

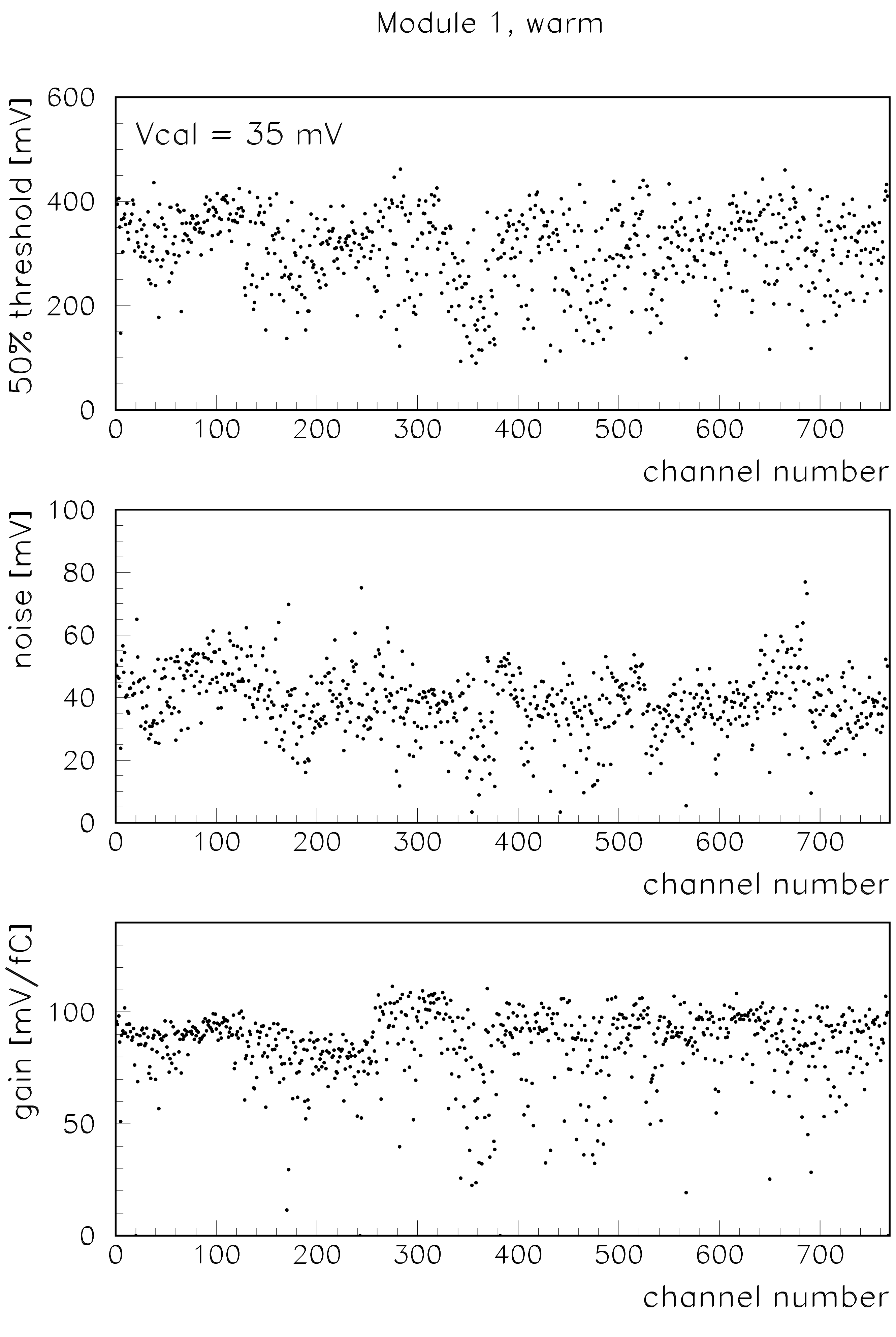
Hybrid 3, max. FE bias, warm	
FE bias	202.4, 202.4, 184.0, 211.6, 211.6, 211.6 mA
FE shaper	25.2 mA
Cal delay	21 bits

Hybrid 3, max. FE bias, cold	
FE bias	211.6, 211.6, 193.2, 220.8, 220.8, 220.8 mA
FE shaper	25.2 mA
Cal delay	21 bits

Table 3: Settings of 6 ABCD2 chips on hybrid 3. Settings appear in order of rising chip index: 0 to 5. A single number means the same setting for all.

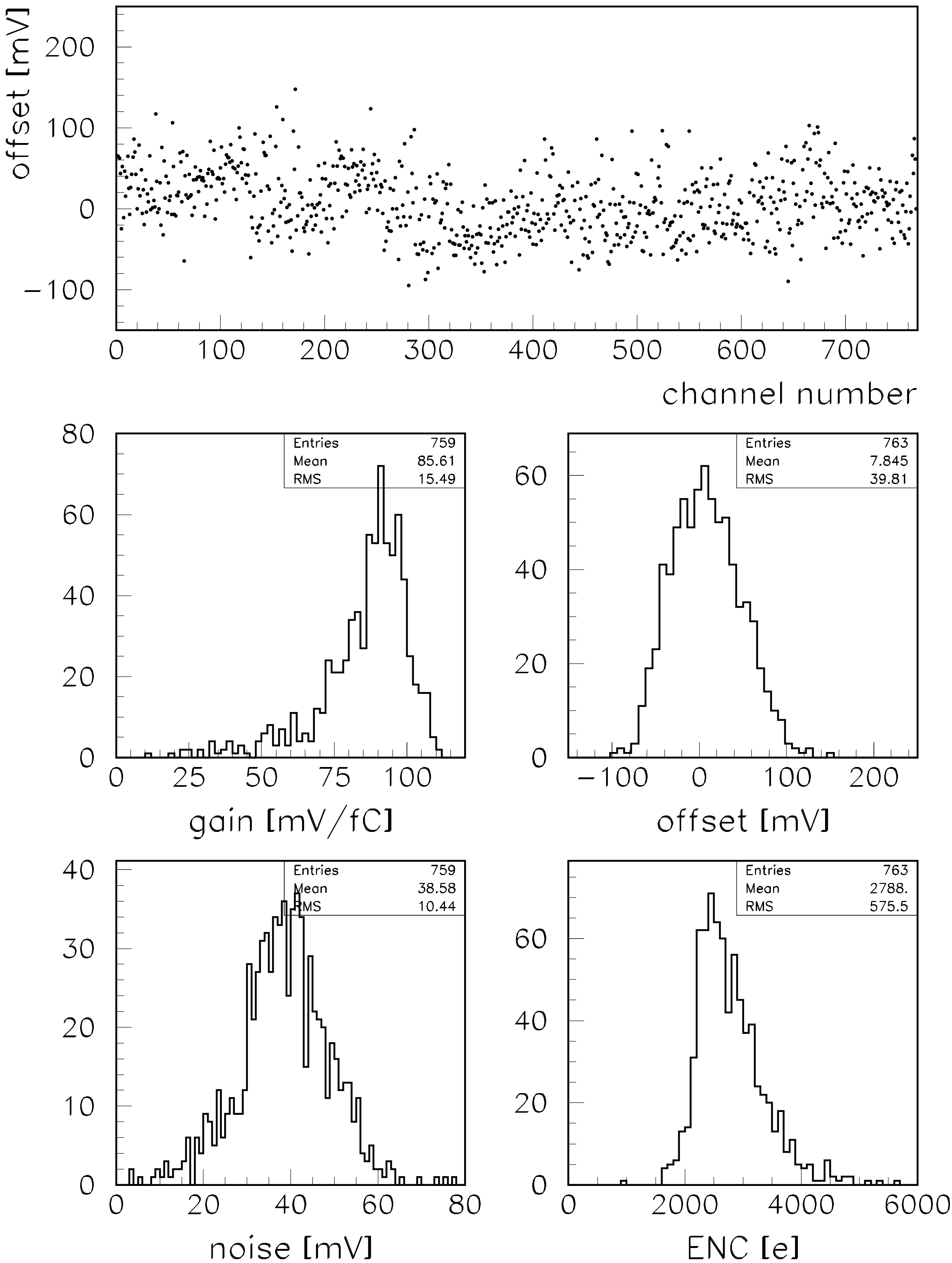
Module M1, warm and cold	
FE bias	165.6 mA
FE shaper	22.8 mA
Cal delay	21 bits

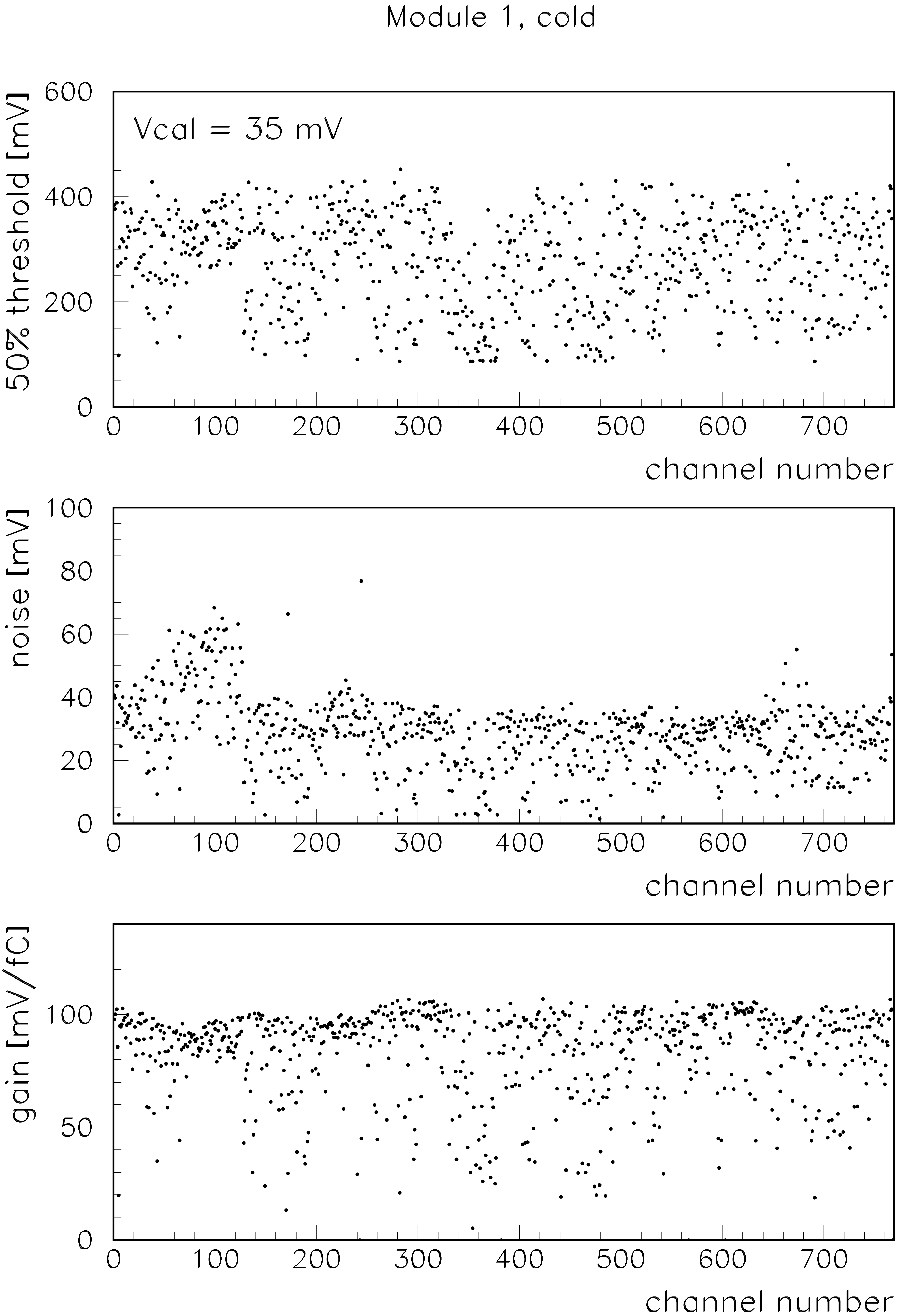
Table 4: Settings of 6 ABCD2 chips on module M1.

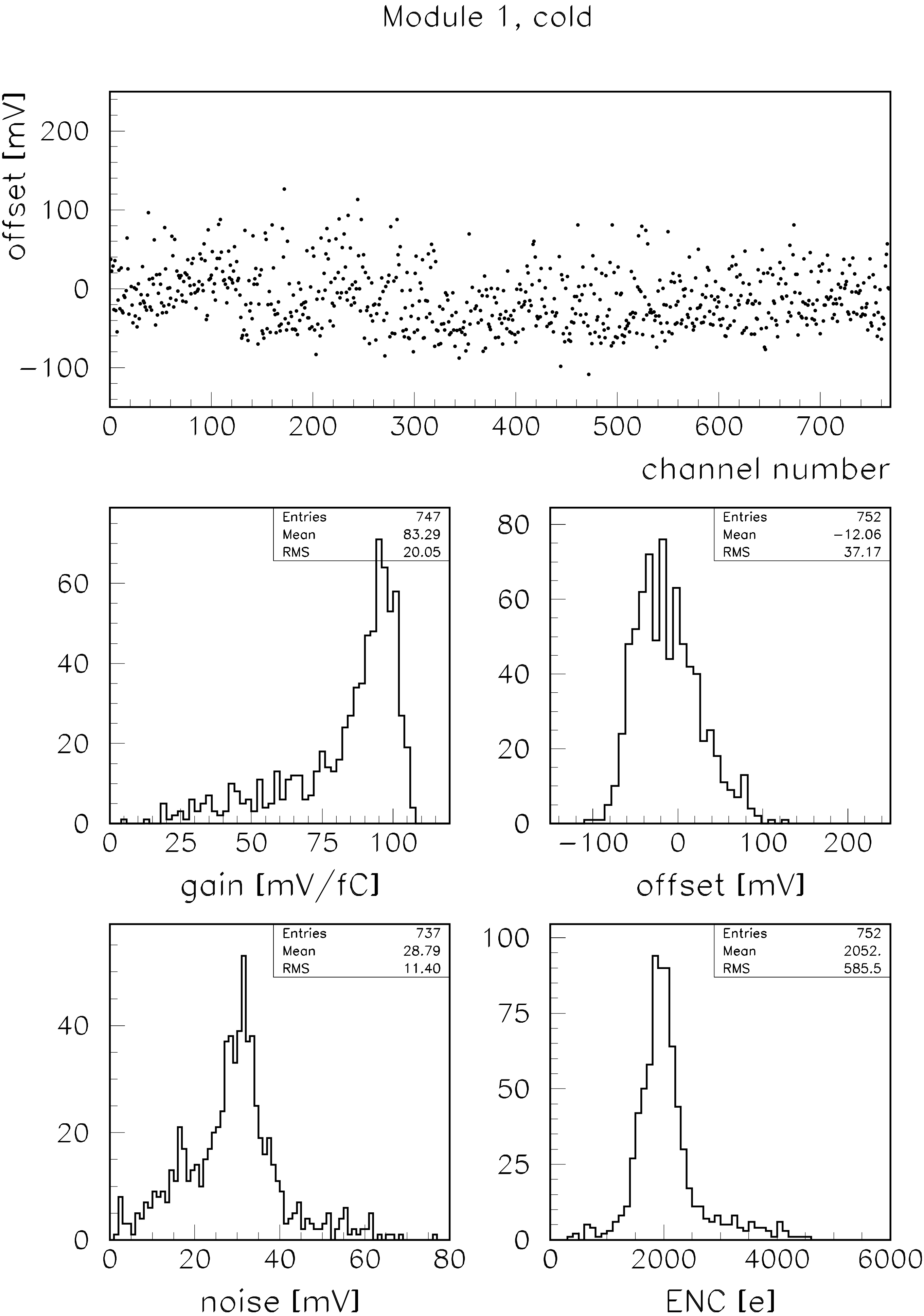


Module 1, warm
Vcal = 35 mV
50% threshold [mV]
600
400
200
0
0
100
200
300
400
500
600
700
channel number
noise [mV]
100
80
60
40
20
0
0
100
200
300
400
500
600
700
channel number
gain [mV/fC]
100
50
0
0
100
200
300
400
500
600
700
channel number

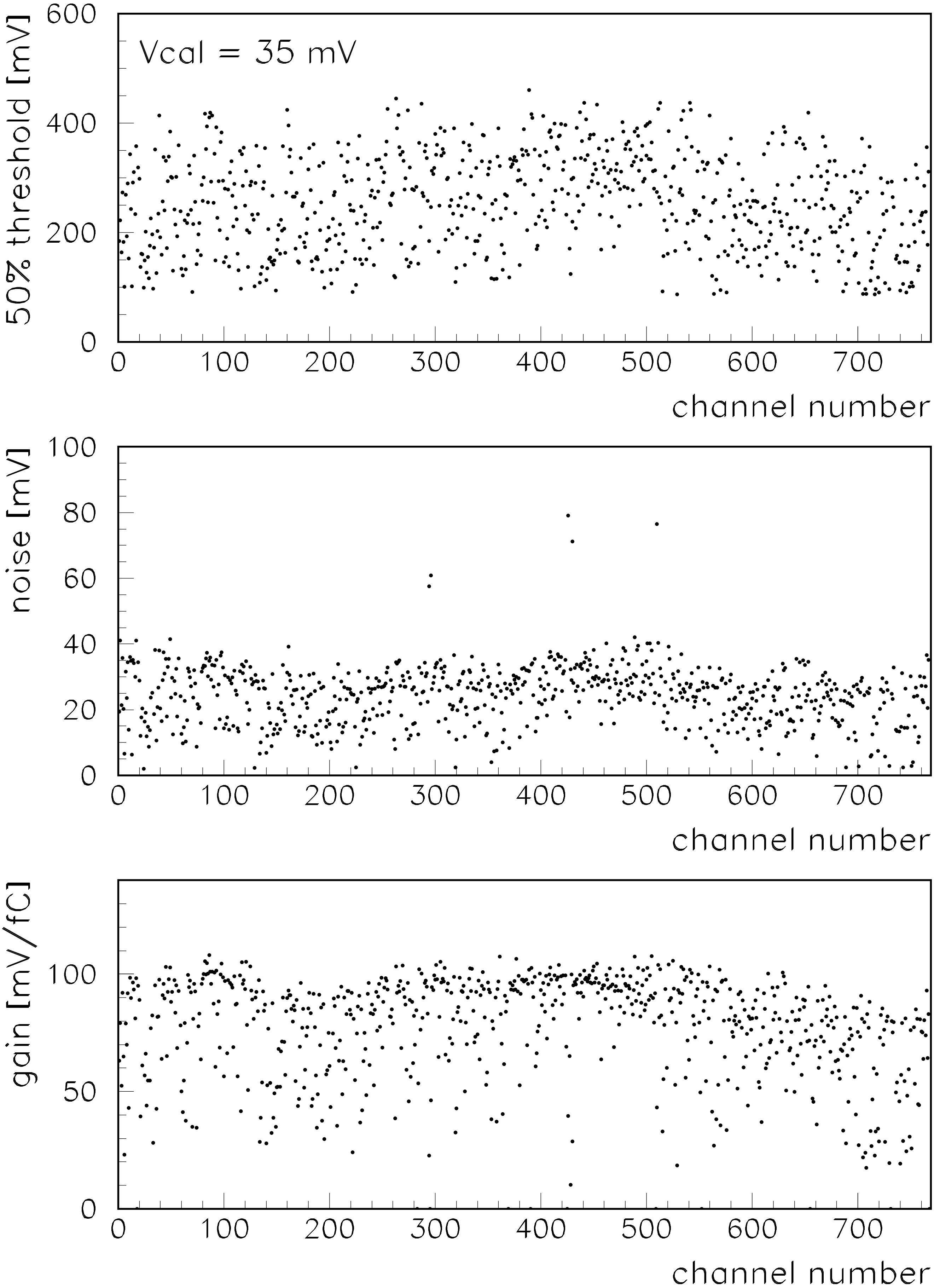
Module 1, warm



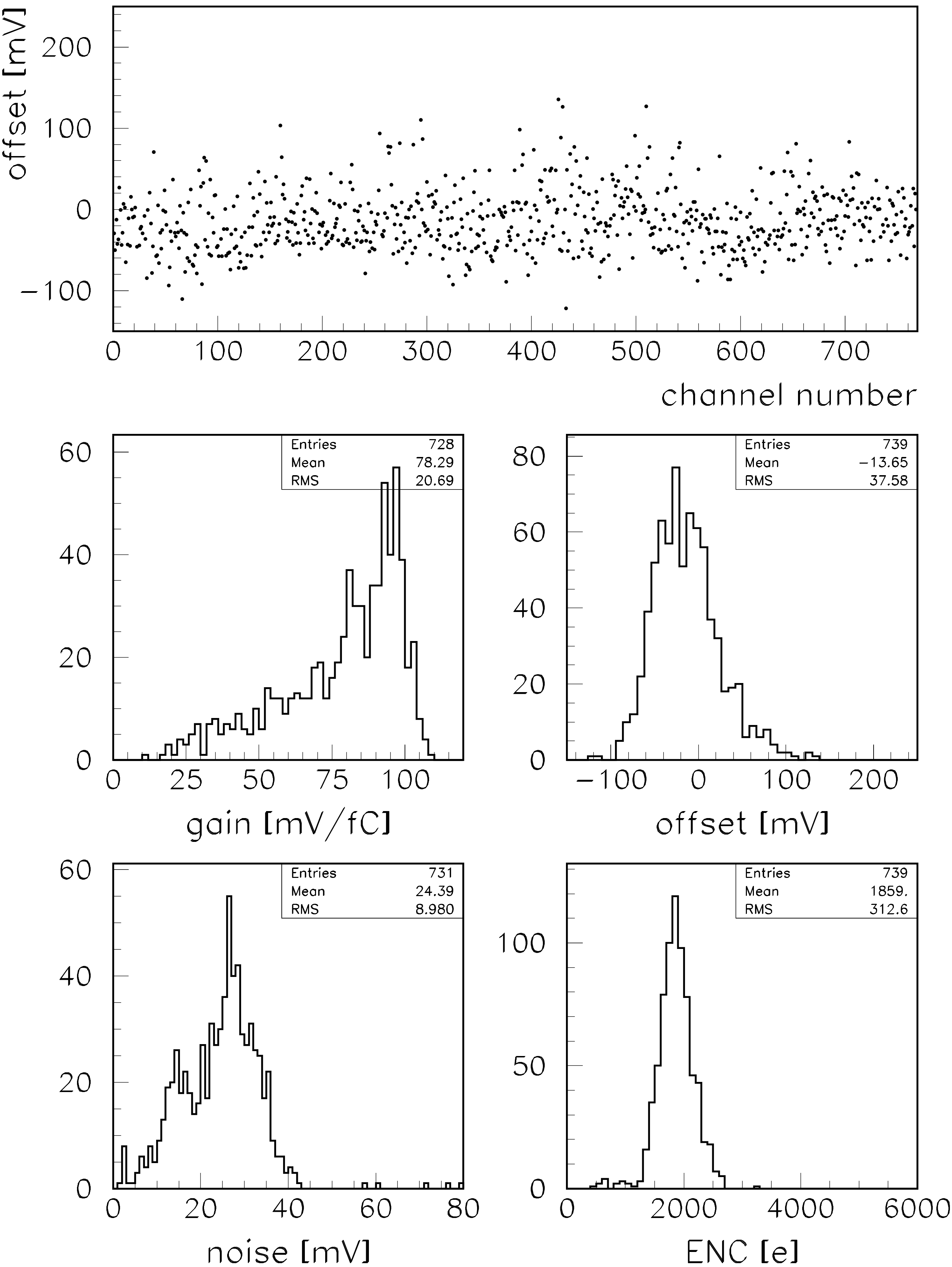

Module 1, cold
Vcal = 35 mV
50% threshold [mV]
0
200
400
600
0
100
200
300
400
500
600
700
channel number
noise [mV]
0
20
40
60
80
100
channel number
gain [mV/fC]
0
50
100
channel number


Module 1, cold
offset [mV]
channel number
Entries 747
Mean 83.29
RMS 20.05
gain [mV/fC]
Entries 752
Mean −12.06
RMS 37.17
offset [mV]
Entries 737
Mean 28.79
RMS 11.40
noise [mV]
Entries 752
Mean 2052.
RMS 585.5
ENC [e]

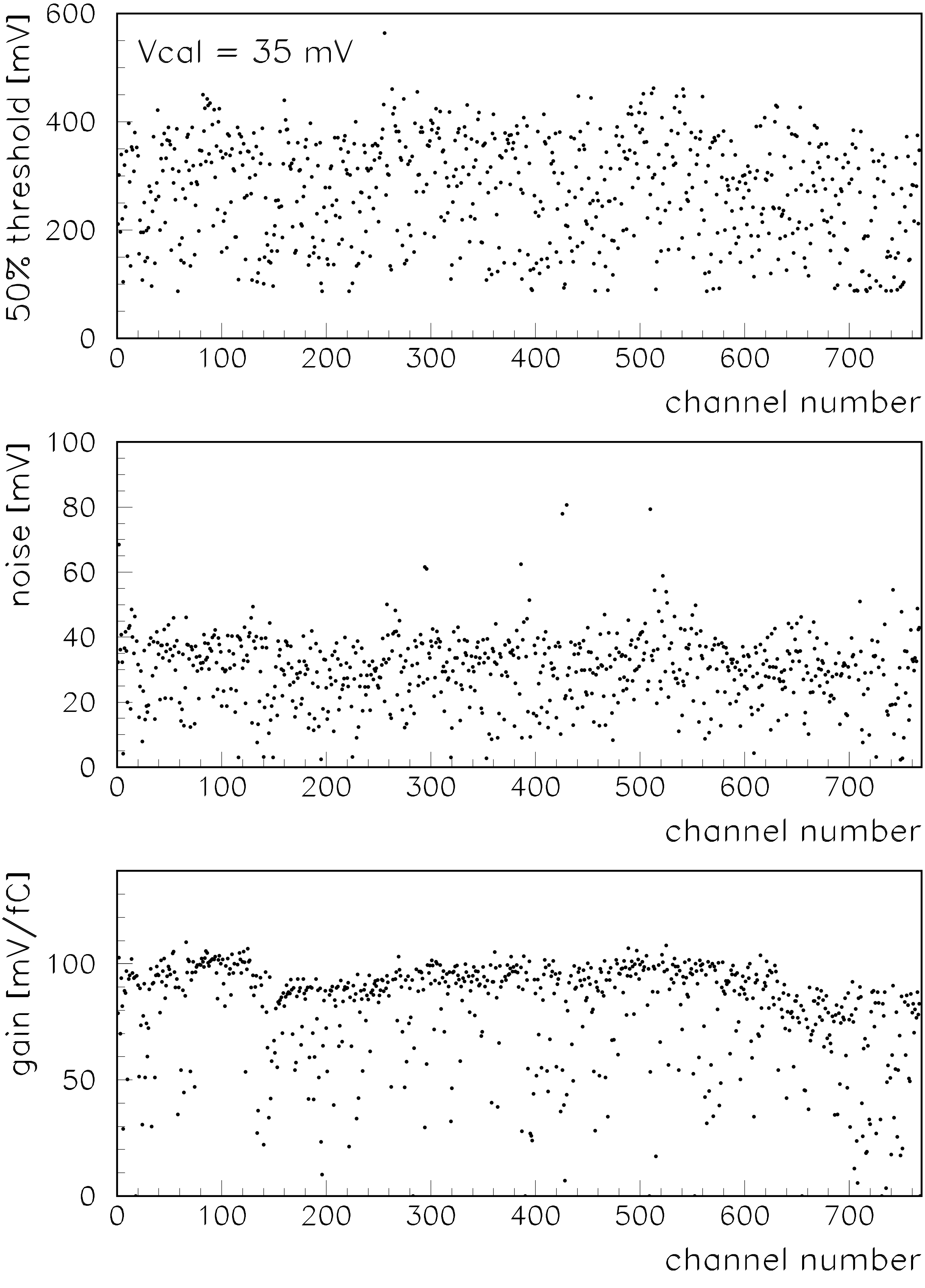
Module 2, warm



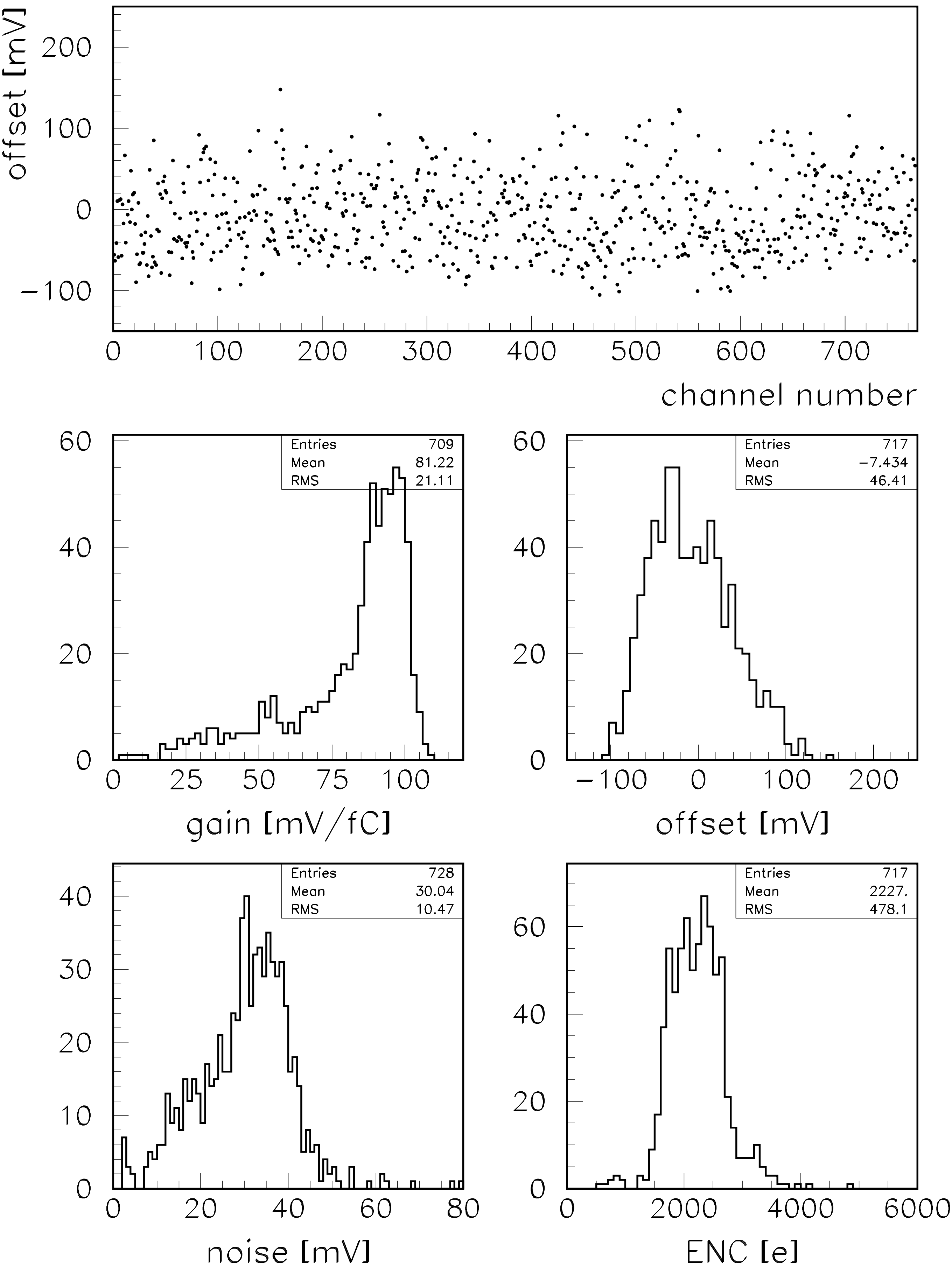
Module 2, warm

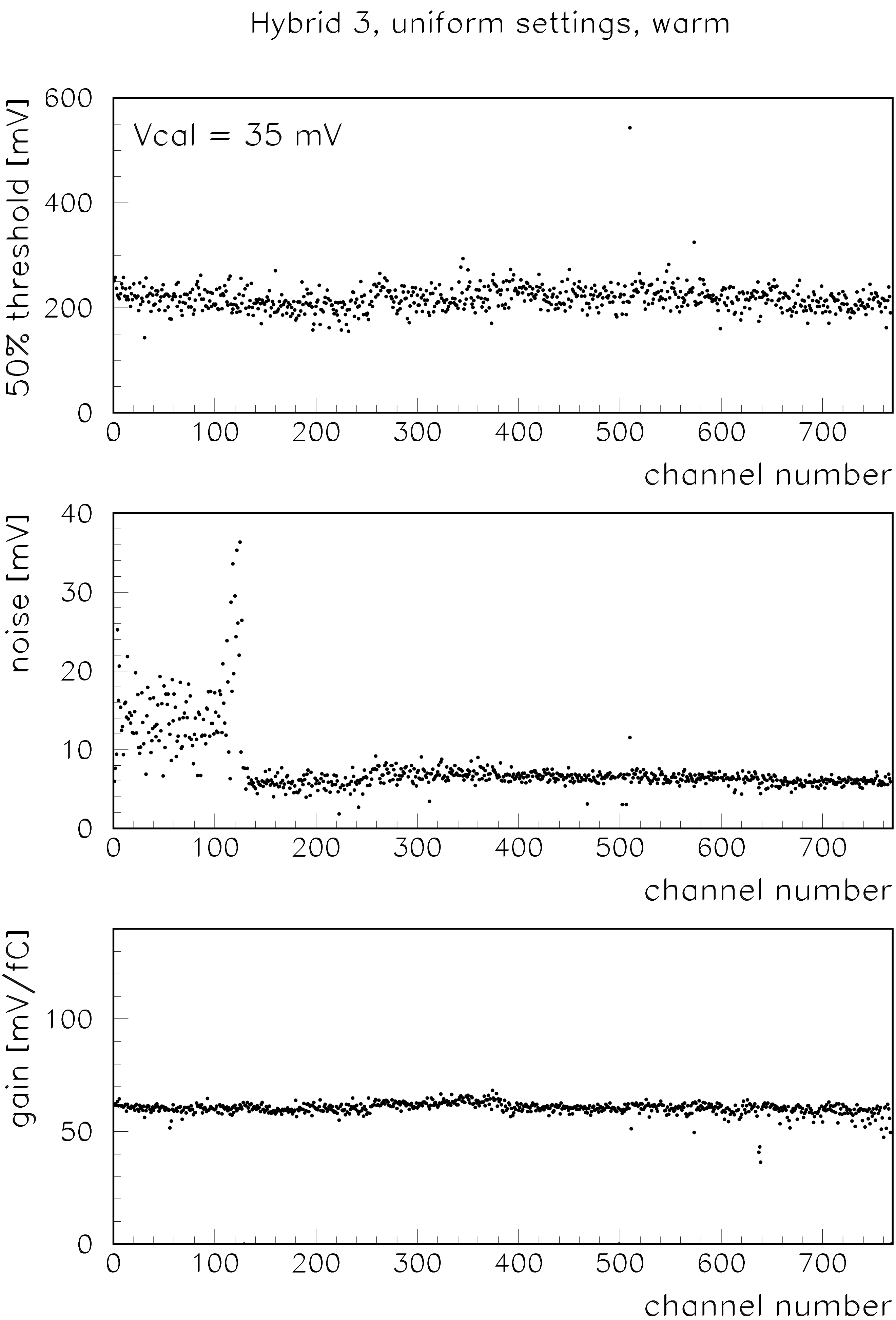


Module 2, cold

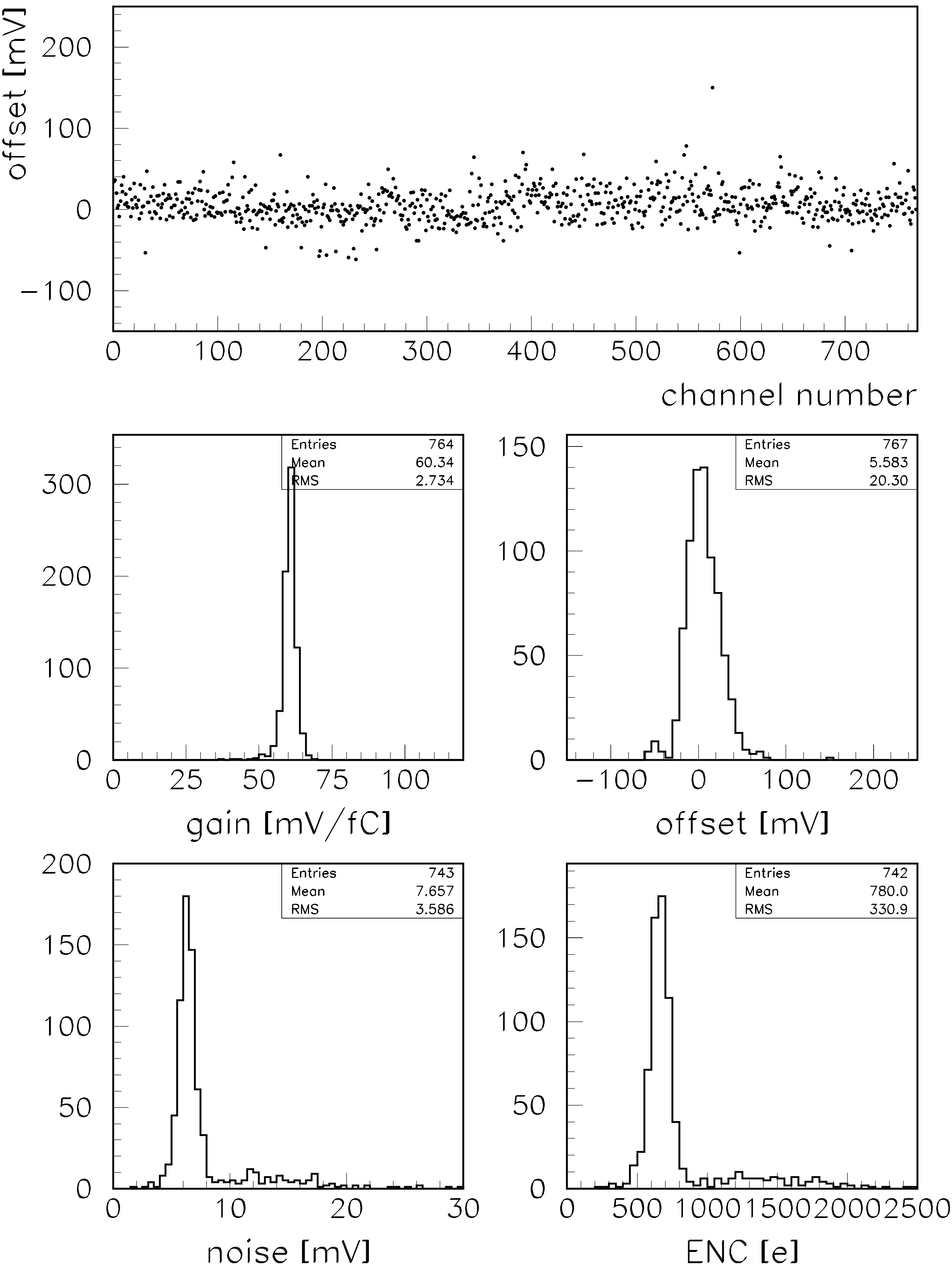


Module 2, cold

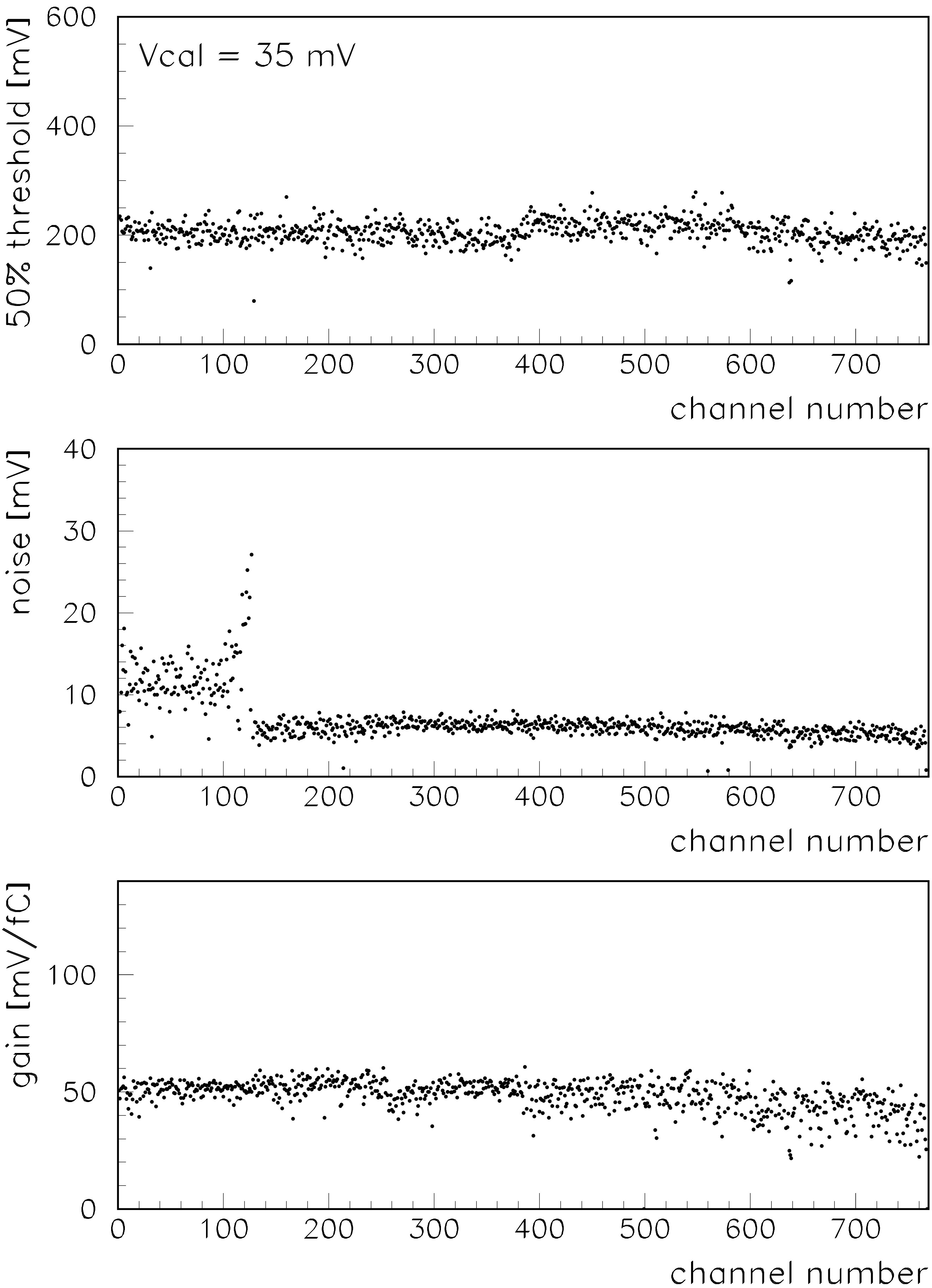



Hybrid 3, uniform settings, warm
Vcal = 35 mV
50% threshold [mV]
0
200
400
600
0
100
200
300
400
500
600
700
channel number
noise [mV]
0
10
20
30
40
0
100
200
300
400
500
600
700
channel number
gain [mV/fC]
0
50
100
0
100
200
300
400
500
600
700
channel number

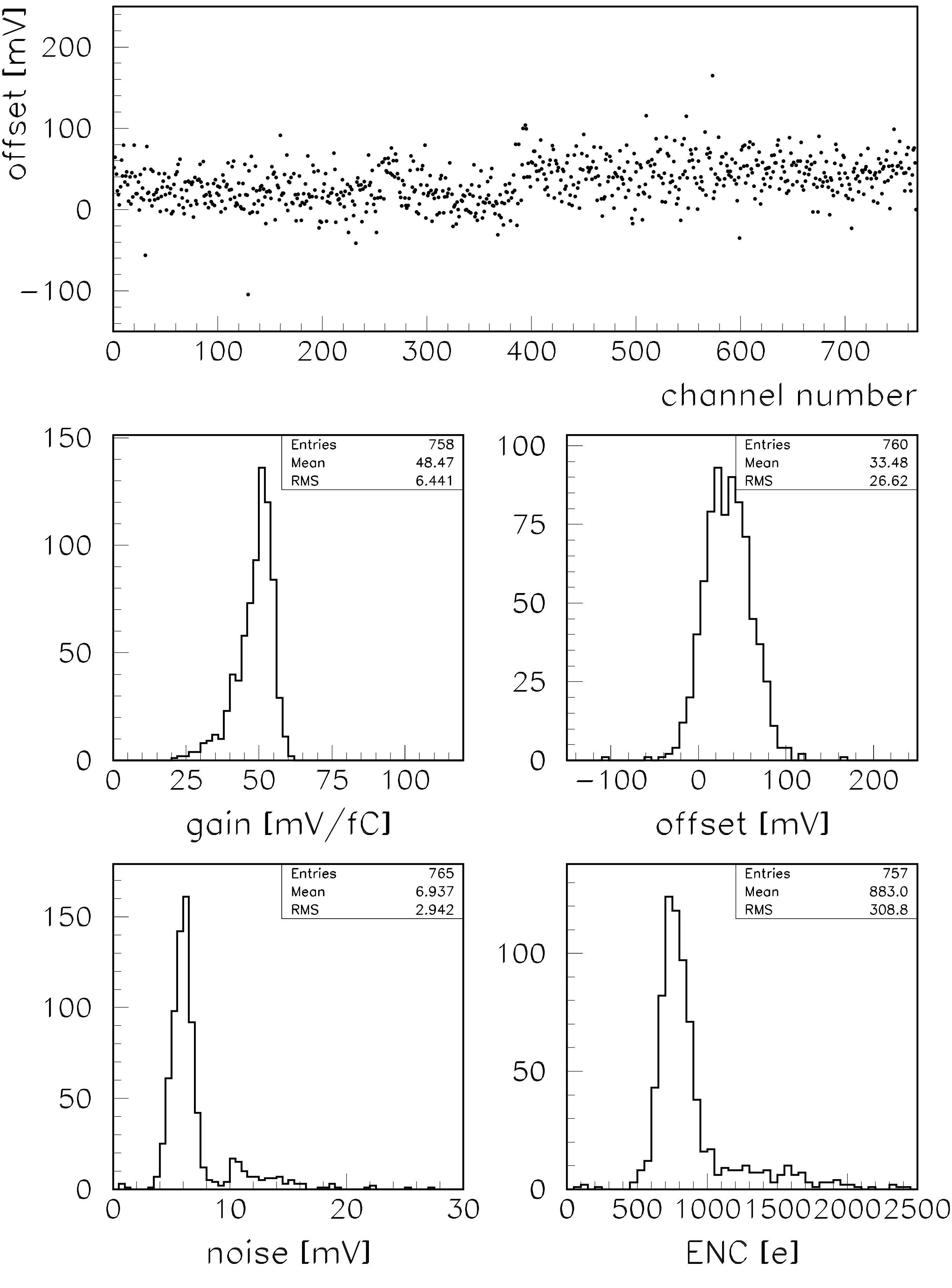
Hybrid 3, uniform settings, warm



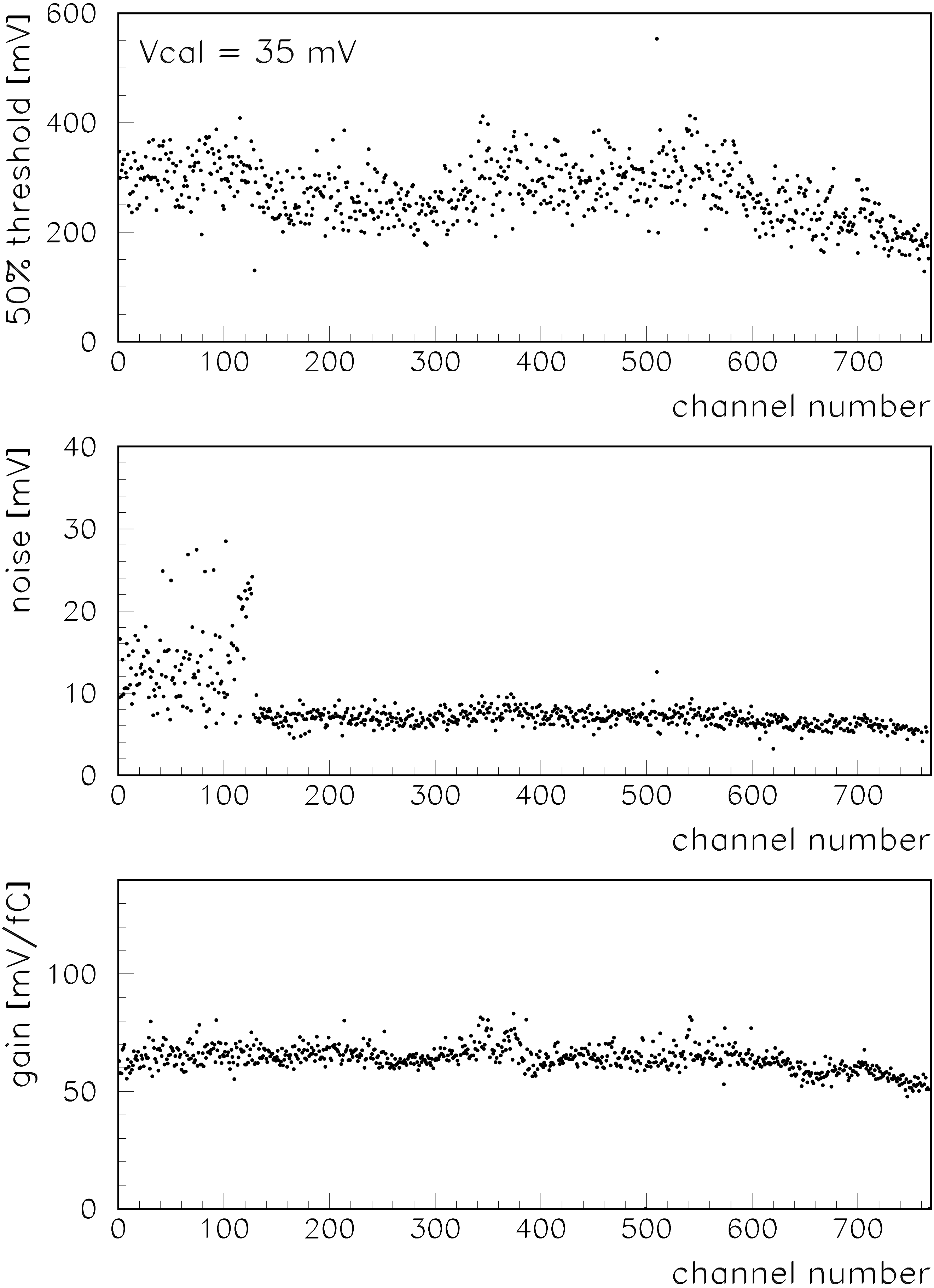
Hybrid 3, uniform settings, cold



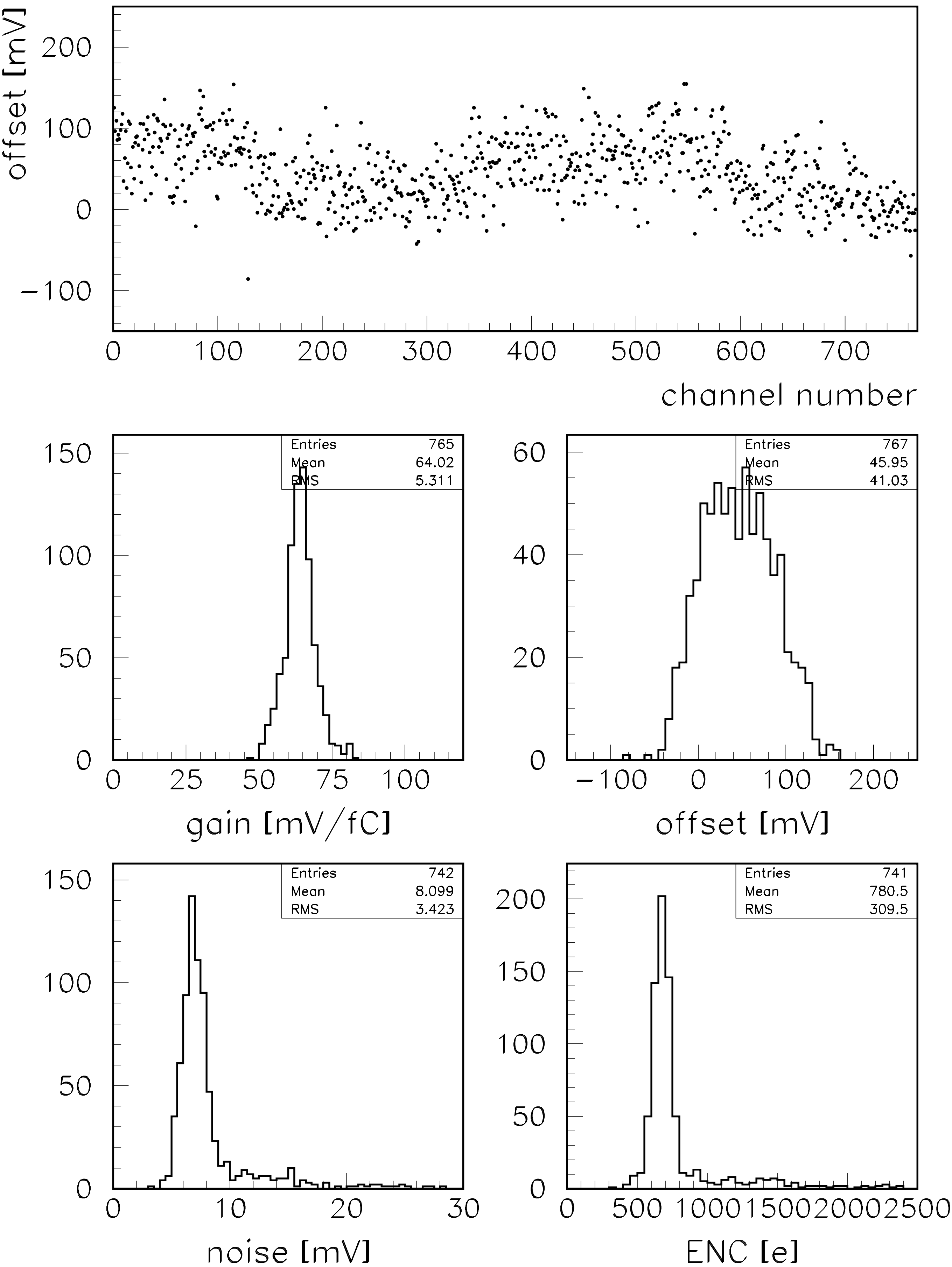
Hybrid 3, uniform settings, cold



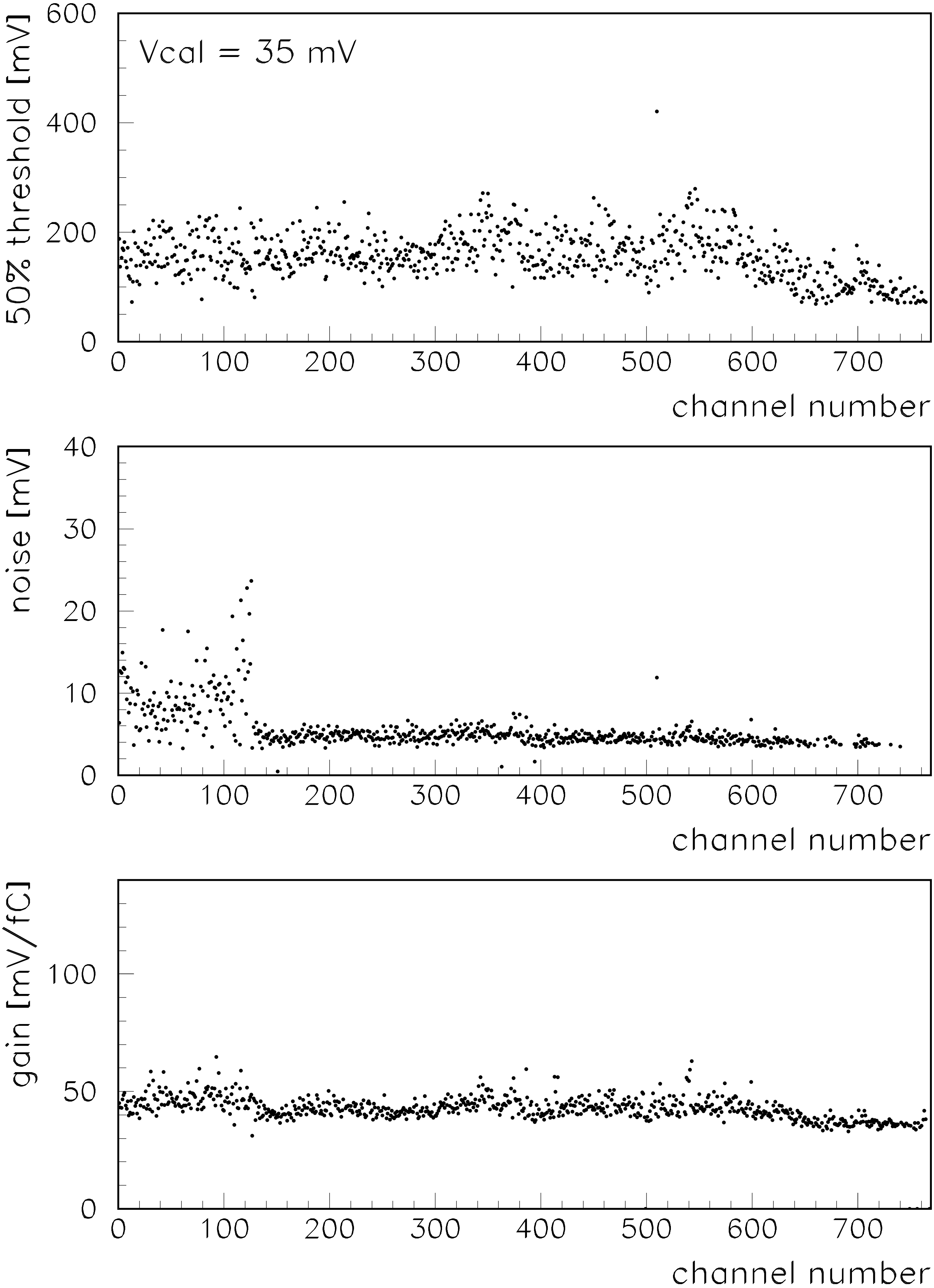
Hybrid 3, max. FE bias, warm



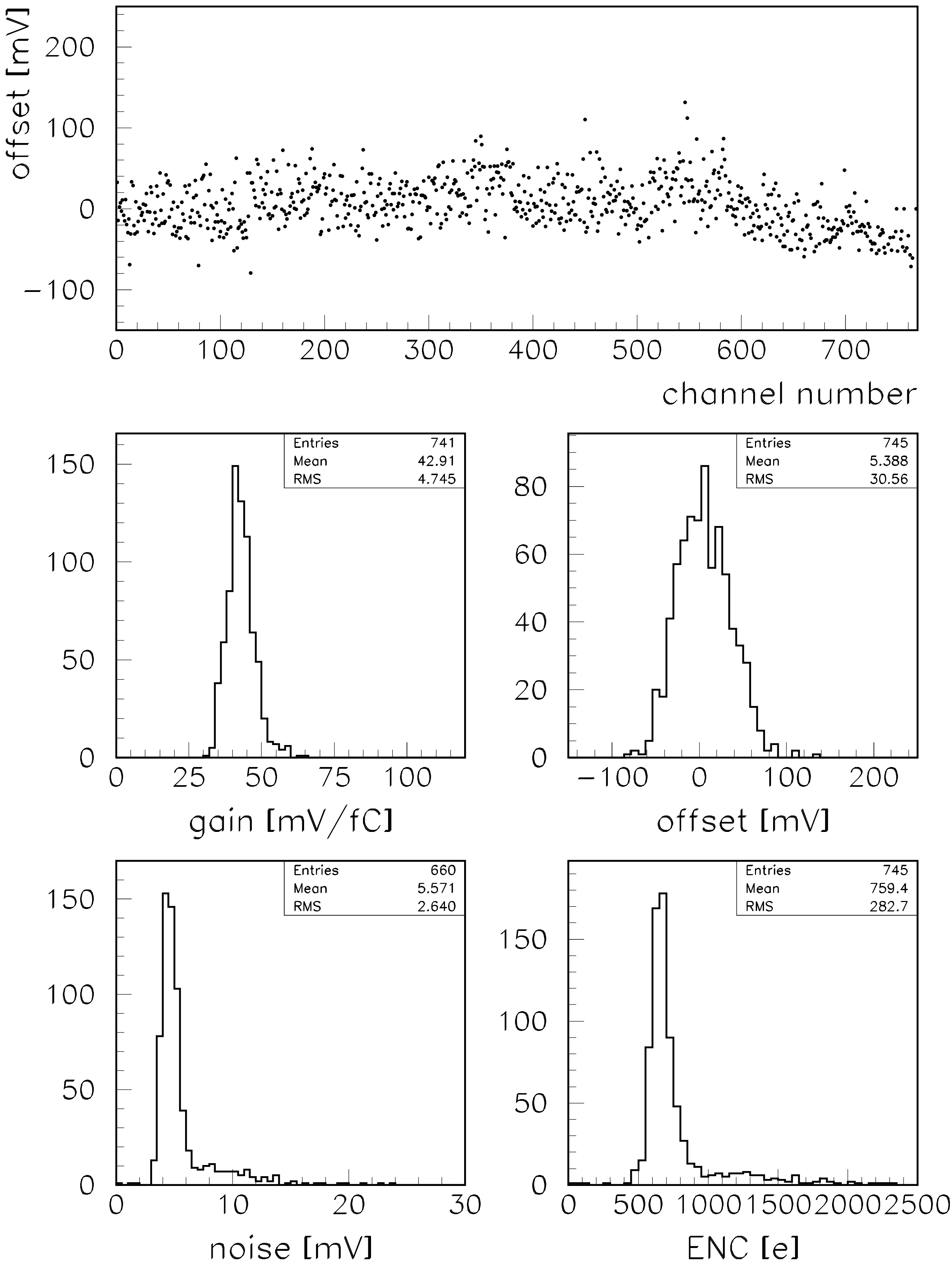
Hybrid 3, max. FE bias, warm



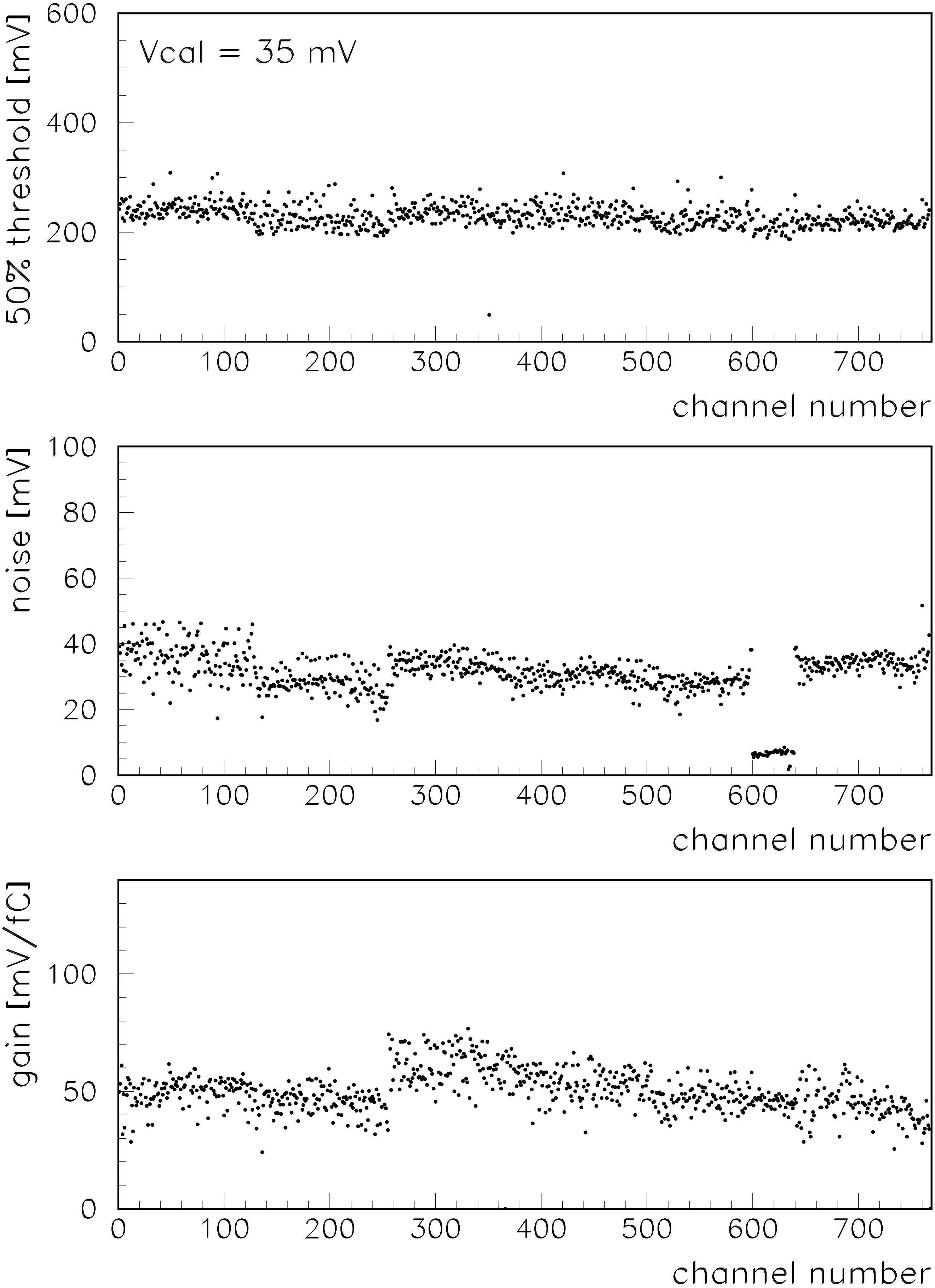
Hybrid 3, max. FE bias, cold



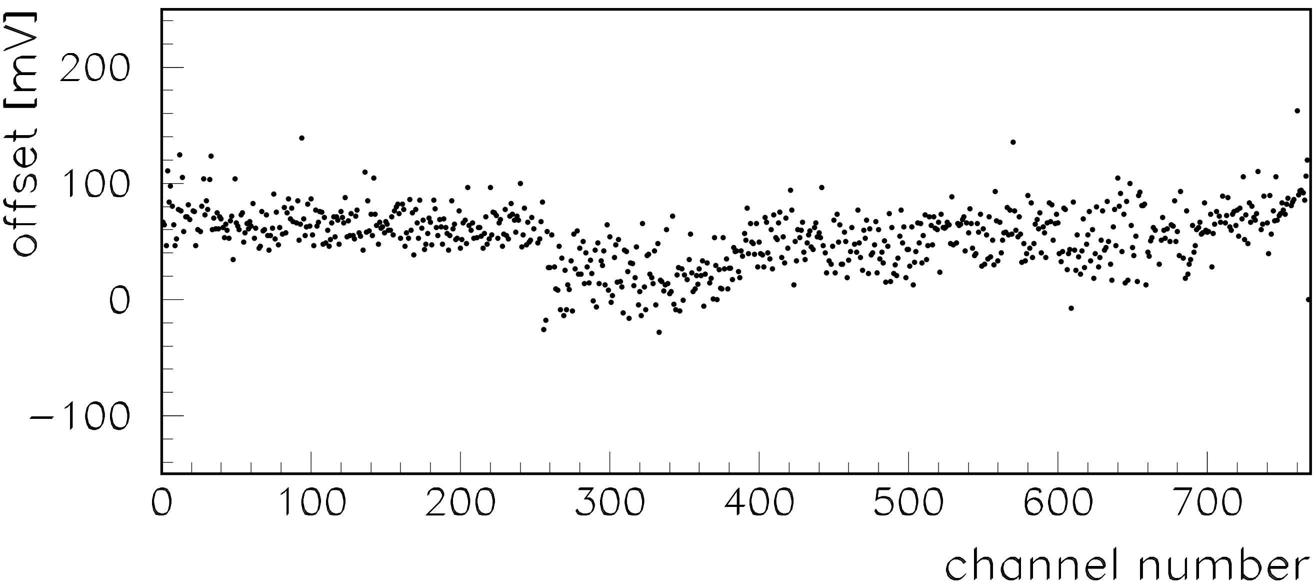
Hybrid 3, max. FE bias, cold

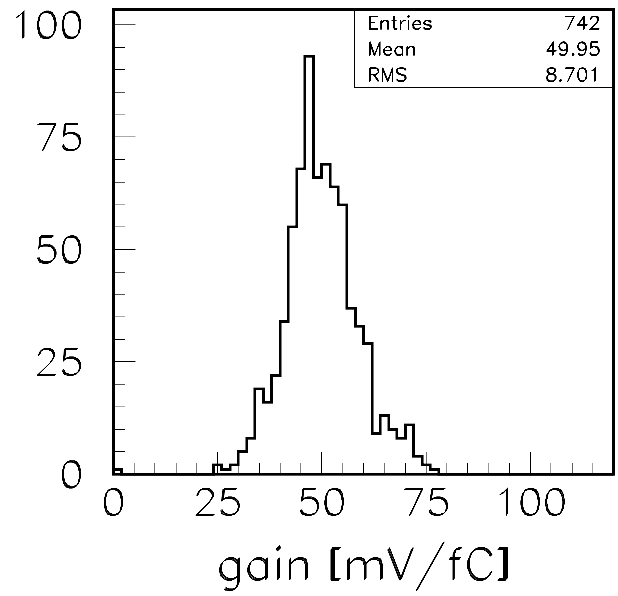


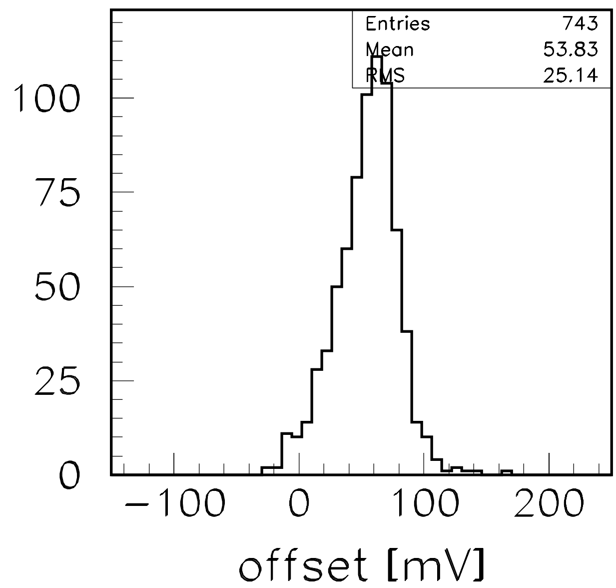
Module M1, warm

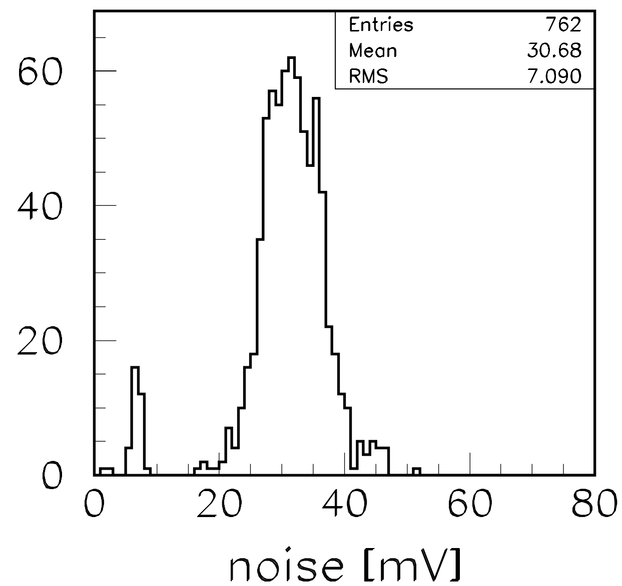


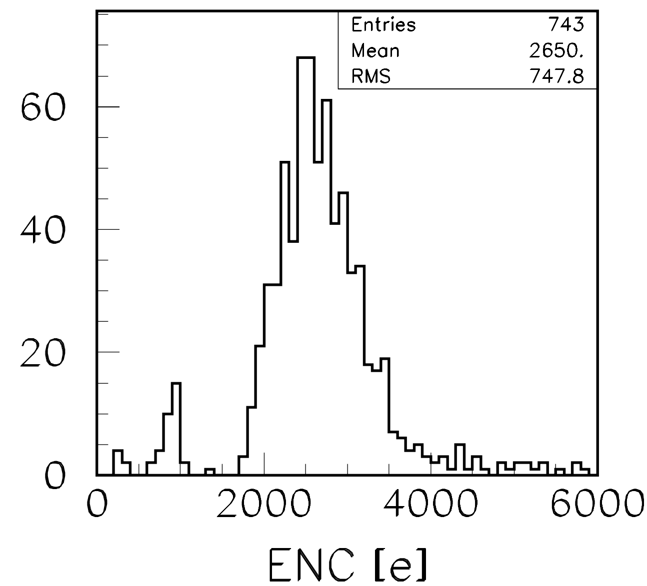
Module M1, warm



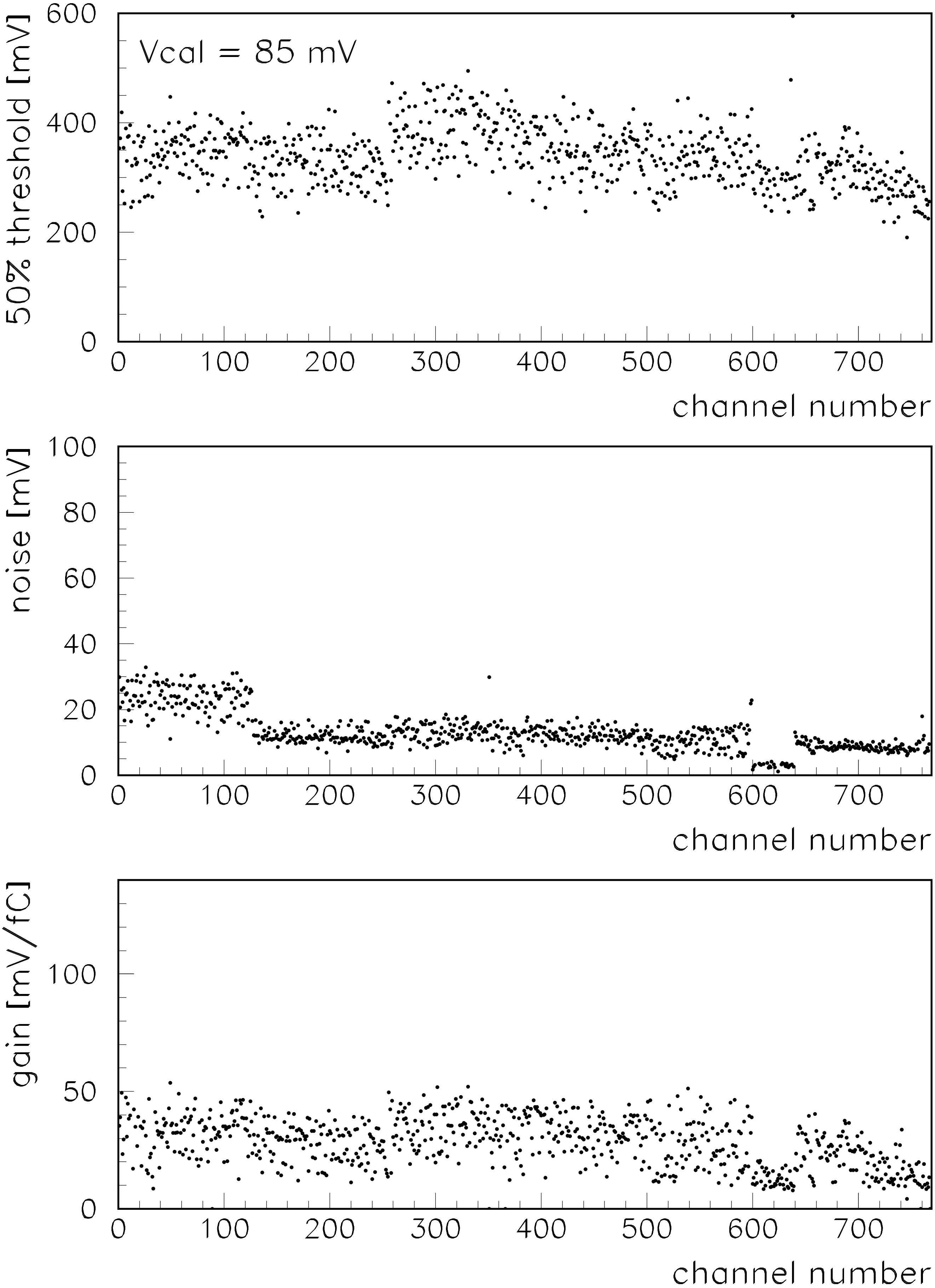




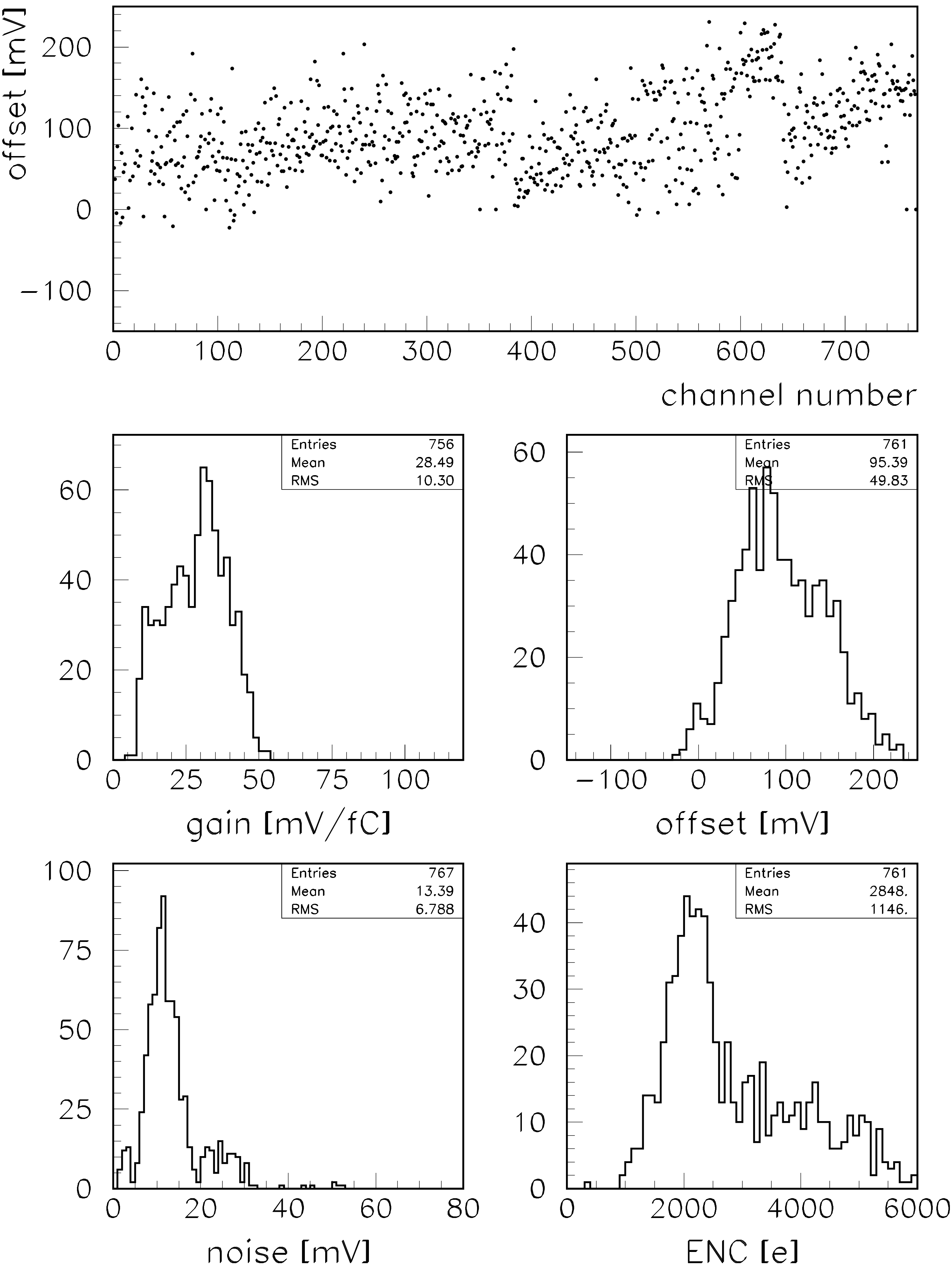




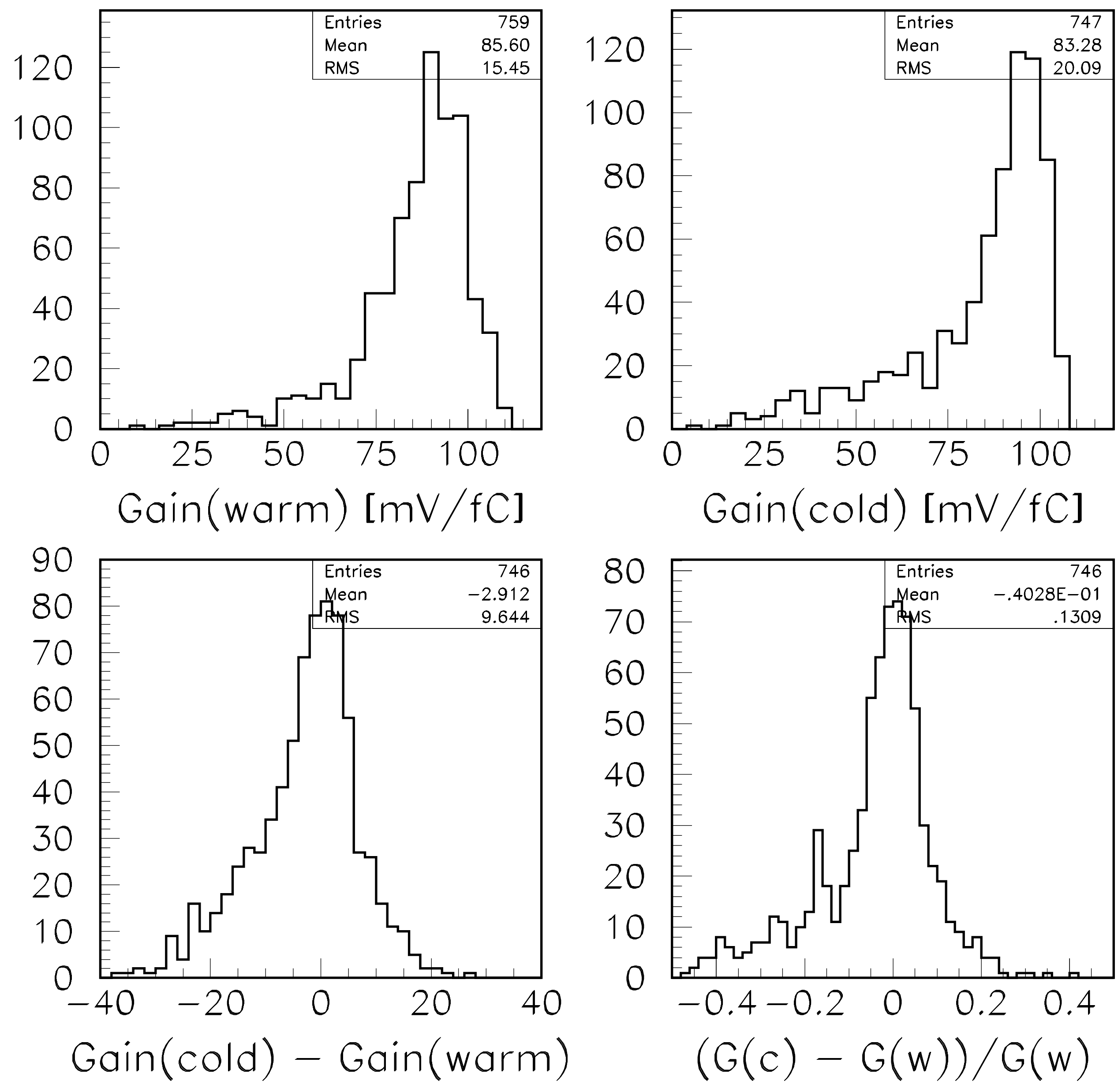
Module M1, cold



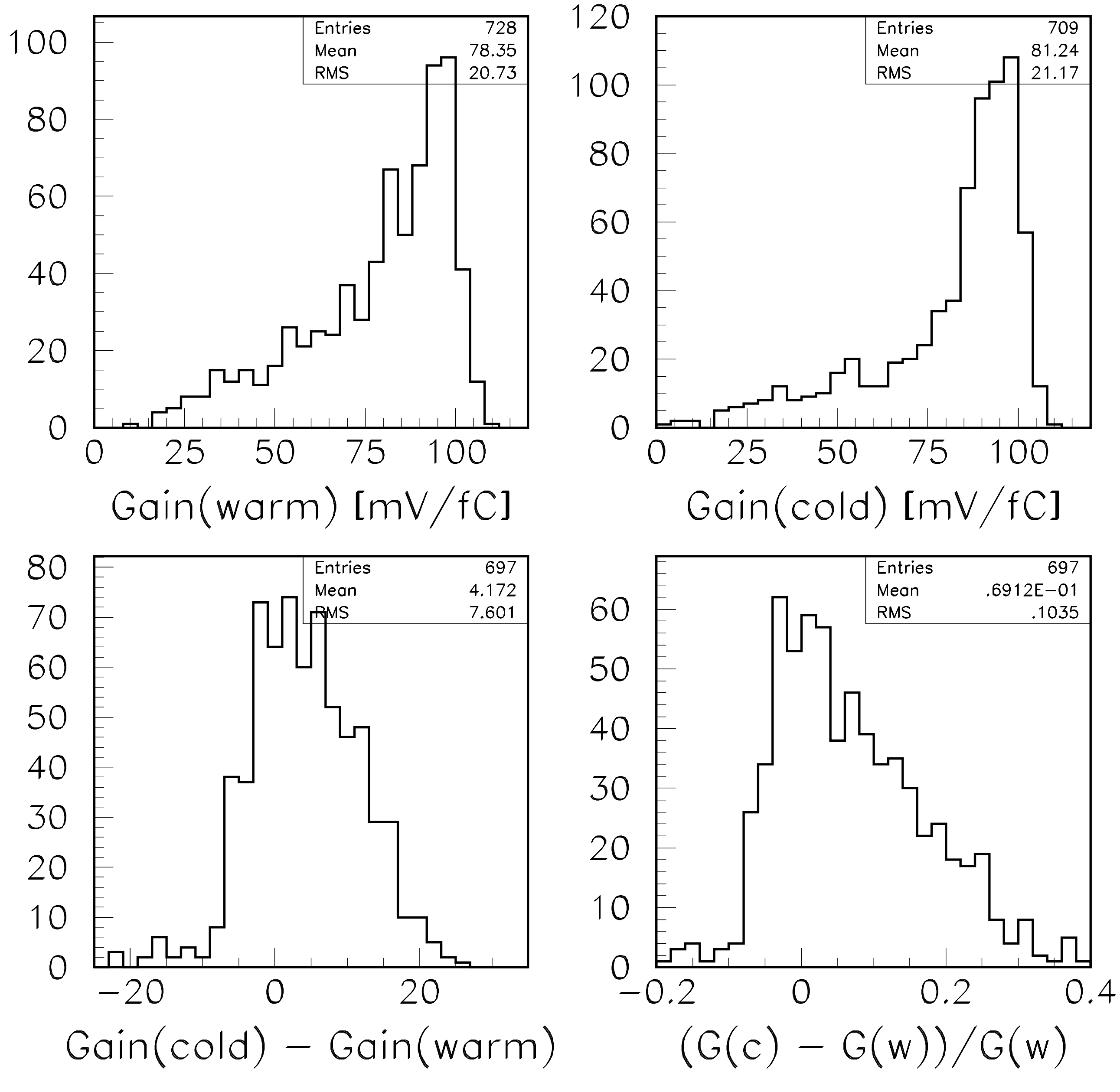
Module M1, cold

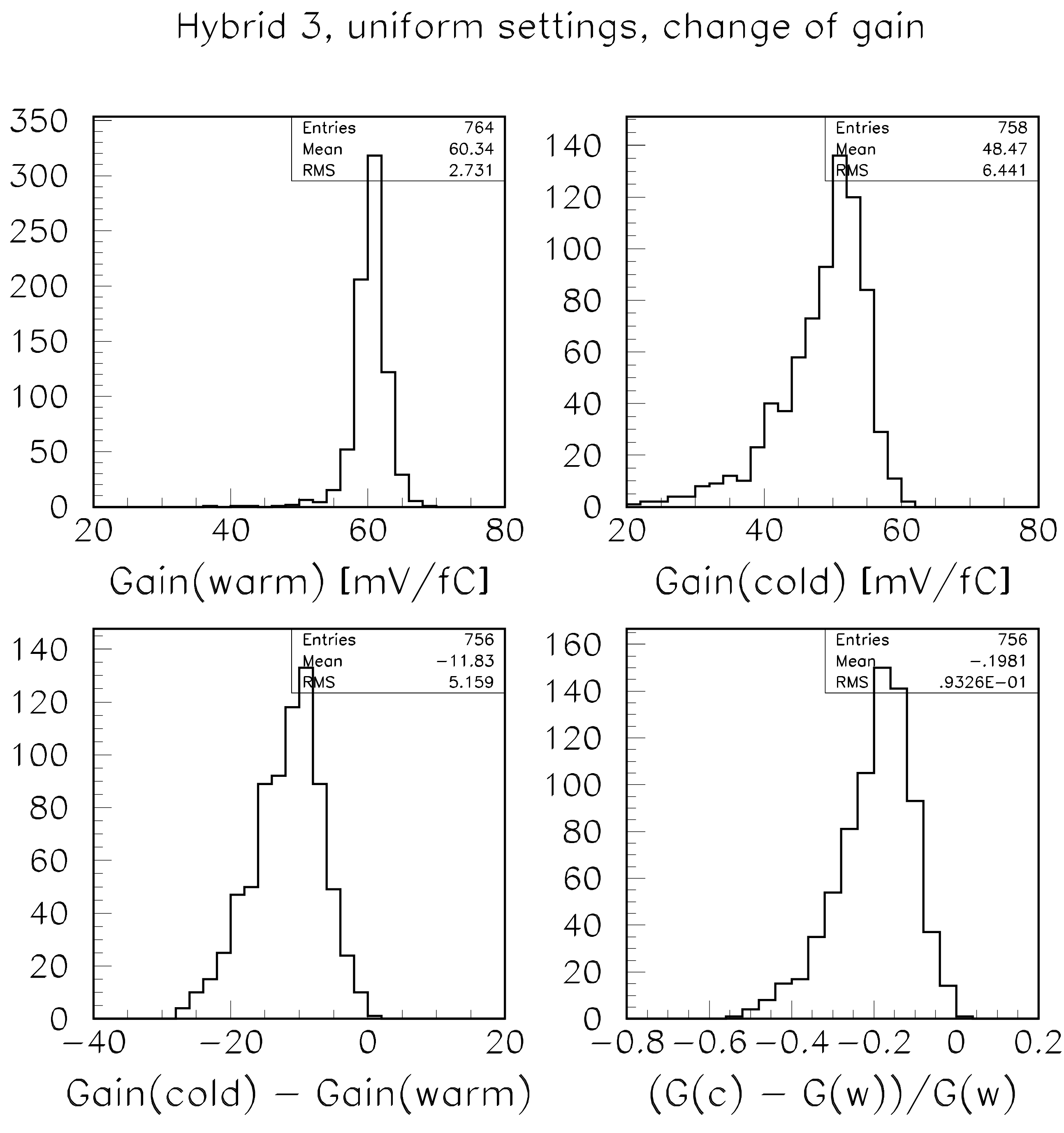


Module 1, change of gain

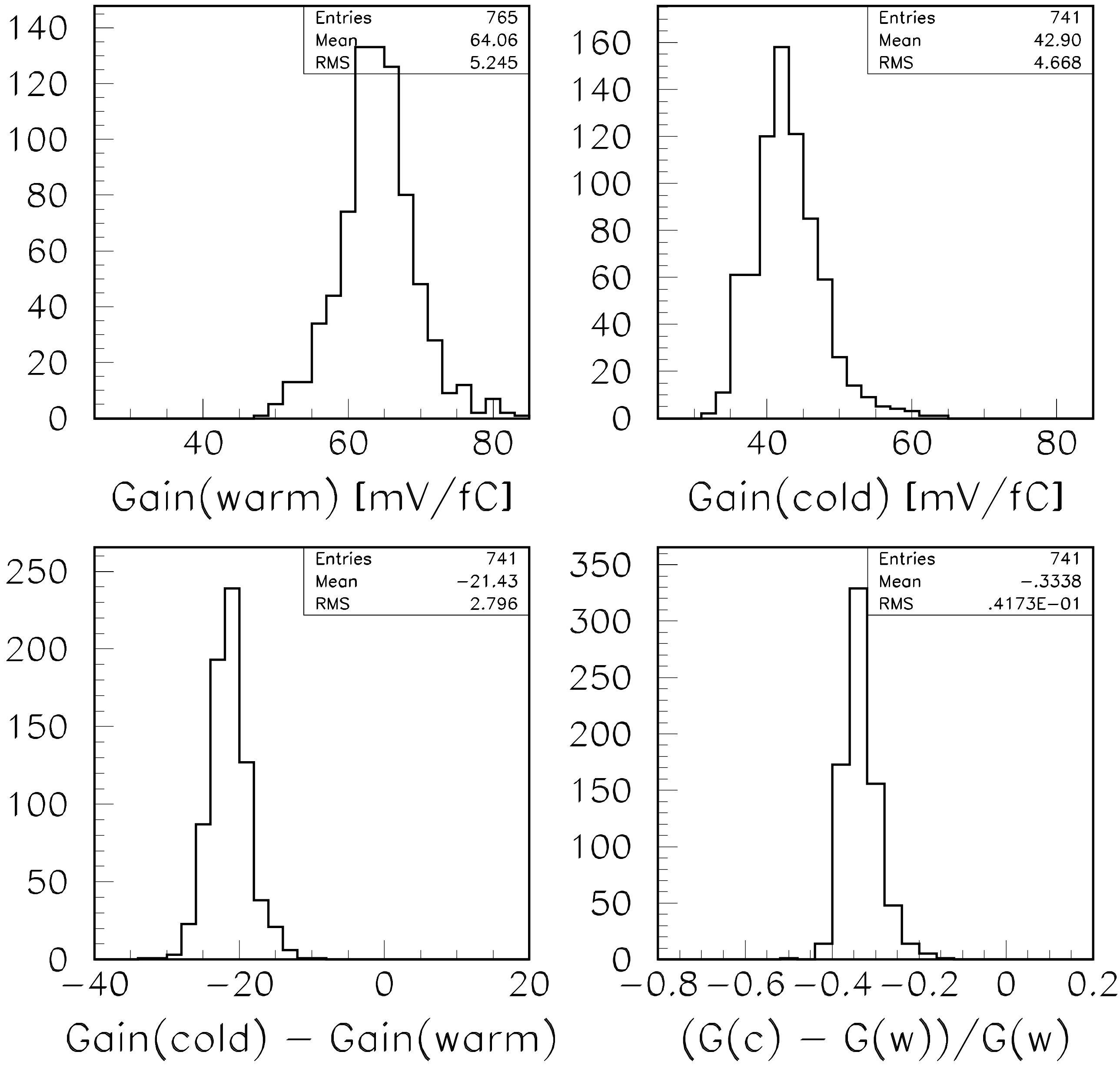


Module 2, change of gain




Hybrid 3, uniform settings, change of gain
Entries 764
Mean 60.34
RMS 2.731
Gain(warm) [mV/fC]
Entries 758
Mean 48.47
RMS 6.441
Gain(cold) [mV/fC]
Entries 756
Mean −11.83
RMS 5.159
Gain(cold) − Gain(warm)
Entries 756
Mean −.1981
RMS .9326E−01
(G(c) − G(w))/G(w)

Hybrid 3, max. FE bias, change of gain



Module M1, change of gain