SiPM temperature characterization for AHCAL adaptive power supply

Uni Bergen: G. Eigen, E. van der Kraaij
FZU Prague: J. Cvach, J. Kvasnička, I. Polák

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AIDA

Introduction

Goal:

- Adaptive power supply for the SiPM bias voltage, regulating V_{bias} with varying temperature as to keep the gain constant.

To develop this, we need:

- To characterize SiPM gain as function of temperature.
  - Define voltage function (dV/dT) to obtain constant gain.

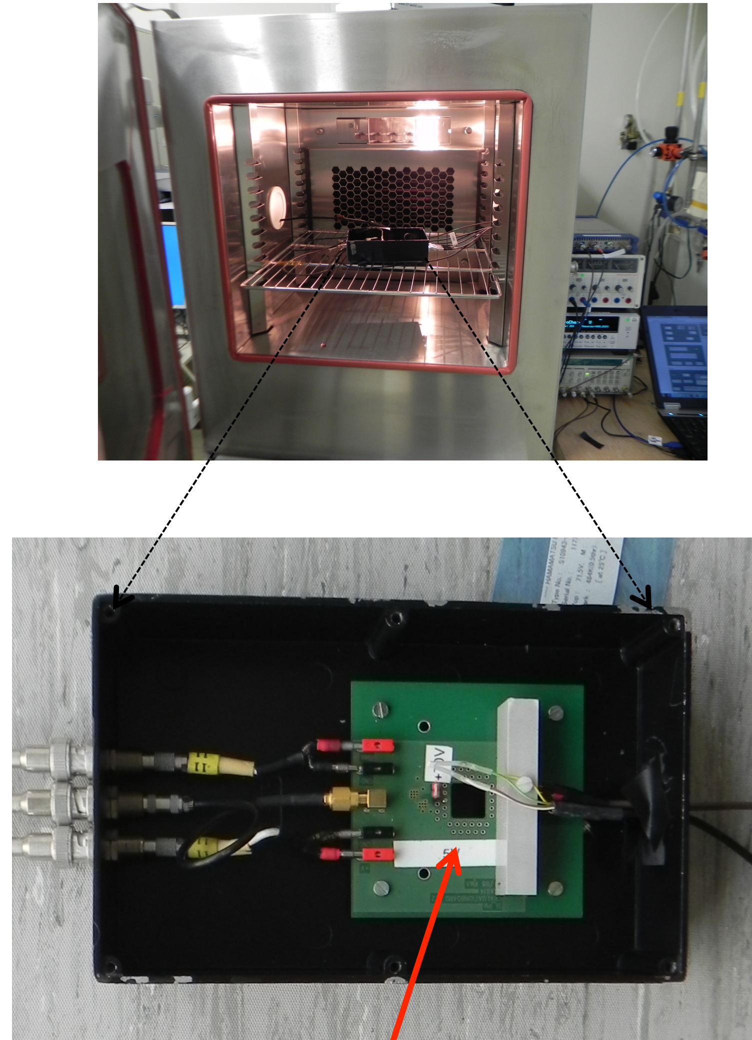
→ At the CERN LCD's lab for ECAL scintillator tile studies, set up equipment
  - Using PCB with preamp from MPI München T3B group & T3B DAQ.

→ Move equipment to CERN Climate Chamber

This talk, characterization of:

- Hamamatsu MPPCs (50 um pitch)
- CPTA SiPMs (40 um pitch)

Setup

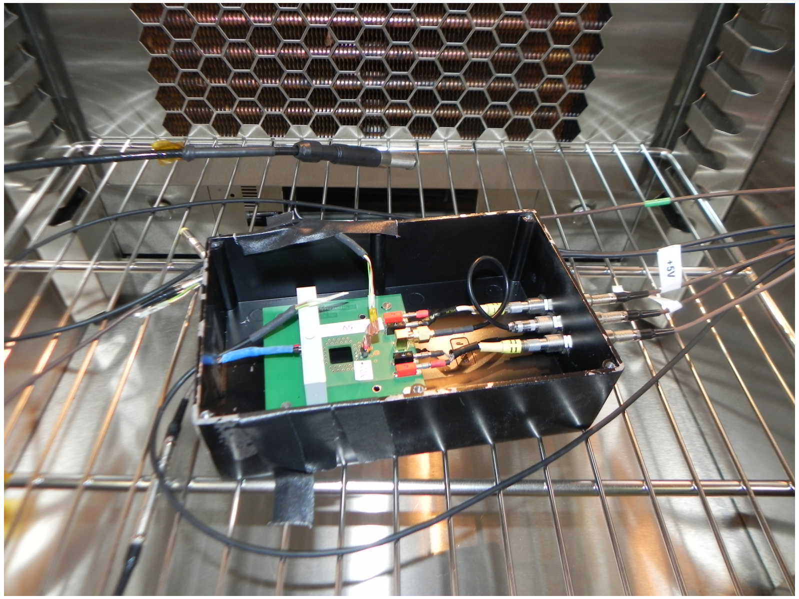


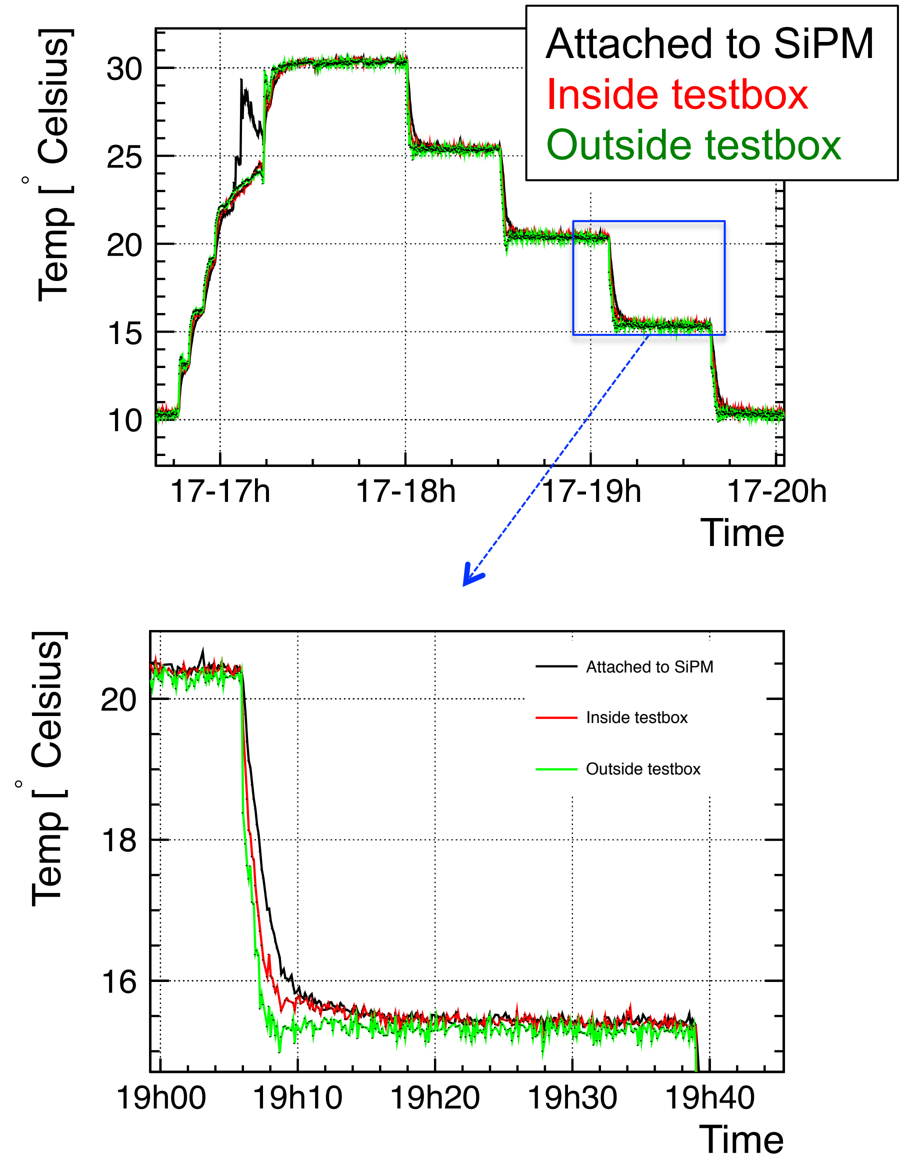
SiPM + preamp + T-sensor + LED

- 'Climate Chamber'
  (Used for stress tests in CERN bondinglab)
  - Accurate to 0.1C.

- Digital oscilloscope readout by laptop
- LV and bias voltage supply
- Pulse generator for LED

Temperature measurement





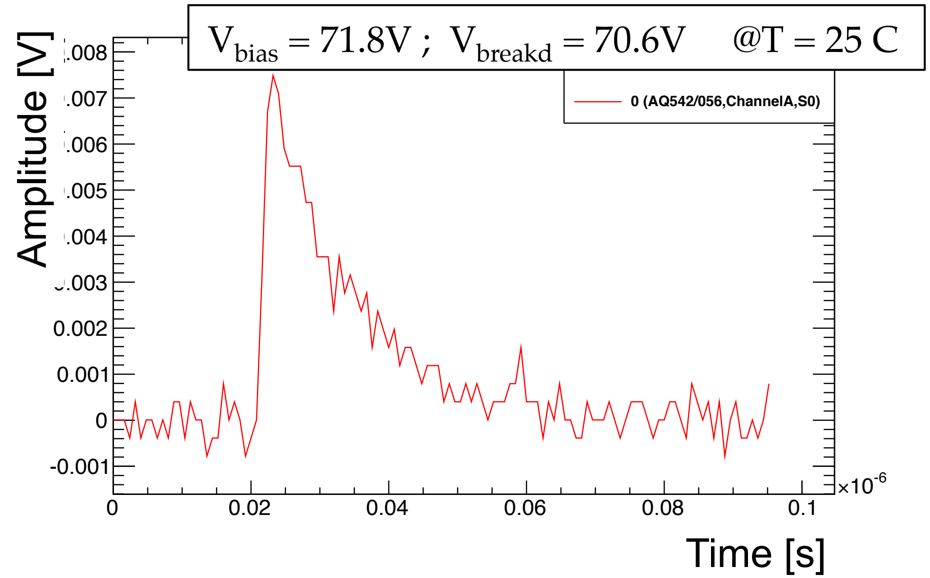
- 3 Pt1000 sensors:
  1. Coppertaped to backside of SiPM
  2. Inside black testbox
  3. Outside black testbox

- T set to 10, 15, 20, 25 & 30C.
  - $T_{SiPM} \sim T_{SET} + 0.4C$
  - Offset consistent over full range.

Obtaining photon spectrum – Hamatsu MPPC

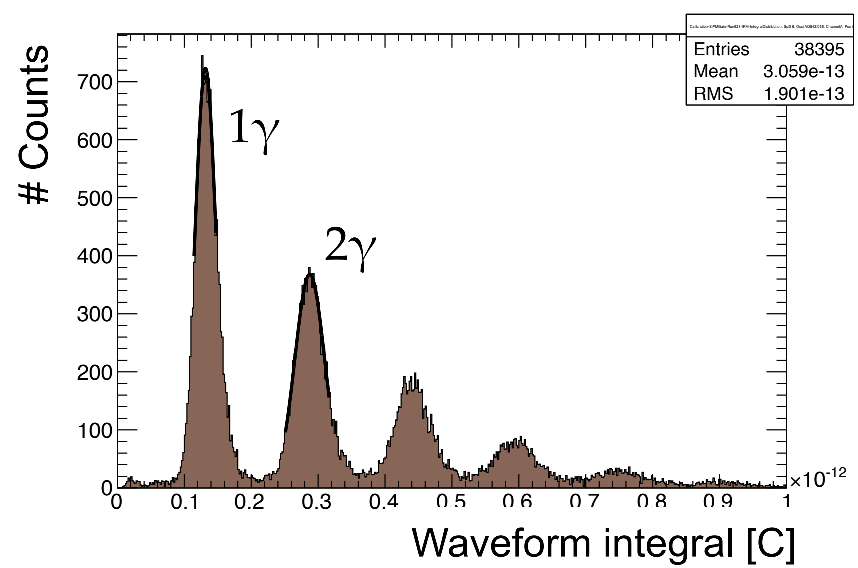
- 8bit ADC
- Sampling / 800ps
- Trigger on LED signal

- Using T3B analysis framework, integrate waveform

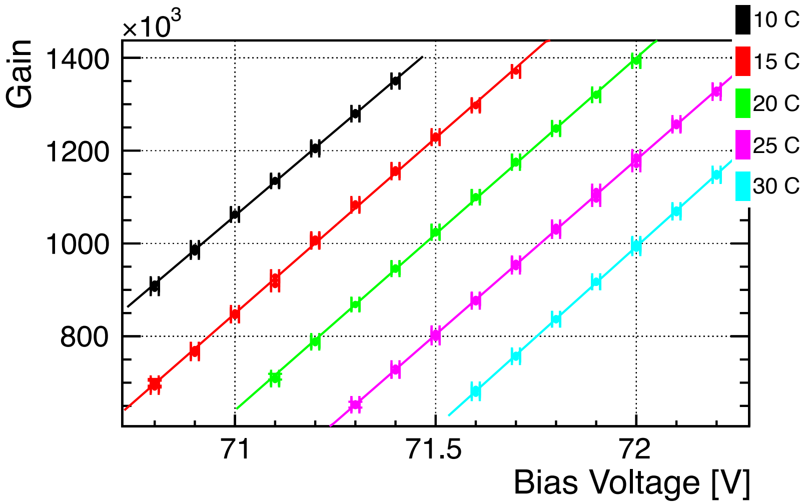


From 50k triggers:

- Waveforms integrated
  → wf identified by rising edge at 2.5 mV and falling edge at 0.4 mV.
- Fit each peak with gaussian dist.
- Extract gain from 2γ - 1γ peak to ~1% accuracy.
  (Pedestal is subtracted in analysis)



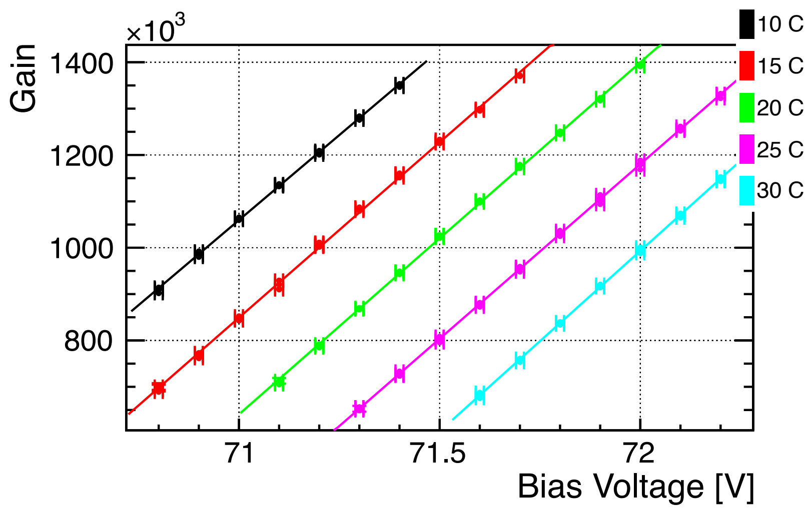
Gain vs voltage for different temperatures - MPPC (#11759)



- Each entry is the gain extracted from 50k waveforms
- Uncertainty on gain calculation is from the uncertainty on the gauss' means.

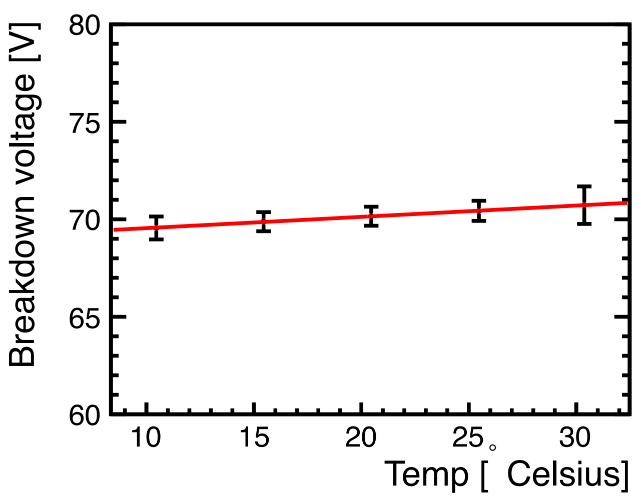
- Measured at 5 different temperatures:
  - 10-30C, in steps of 5C.
- At each temperature, varied bias voltage in steps of 0.1V:
  - range varied, assuming dV/dT ~50 mV/K (for constant gain)

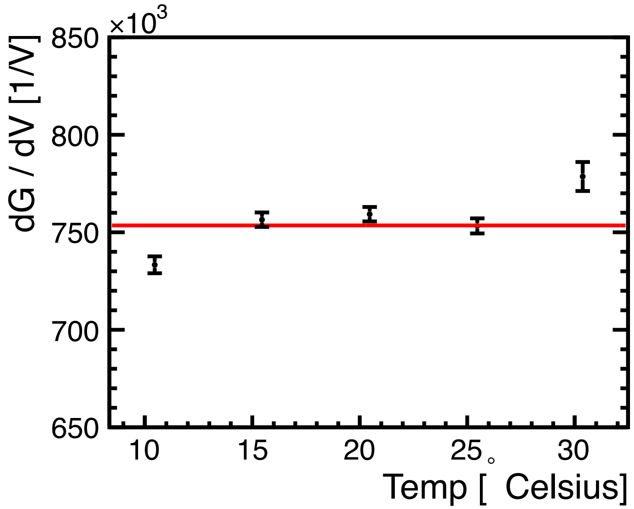
- Took at least 5 measurements at each temperature and V point.



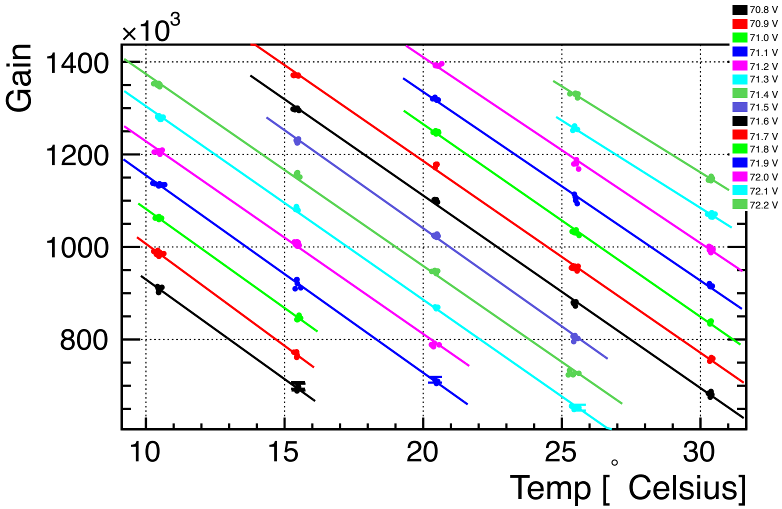
Assuming a linear dependency for Gain on V:

- Breakdown voltage increases linearly with temperature, as expected.
- Capacitance (=dG/dV) should be independent of temperature: systematic effect is visible.





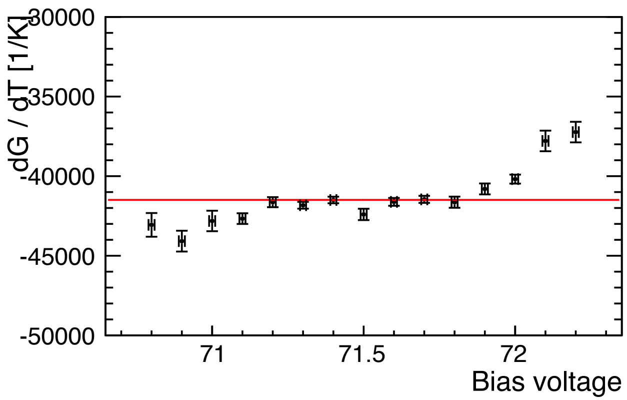
Gain vs temperature for different V - MPPC (#11759)



← Same data as previous slide

- For highest and lowest V_{bias}, accuracy of slopes decreases.

Different fitted slopes



For a constant gain, need dV / dT:

- Averaging the fitted slopes, and assuming as uncertainty the spread of slopes:
- dV/dT = - av (dG/dT) / av(dG/dV)

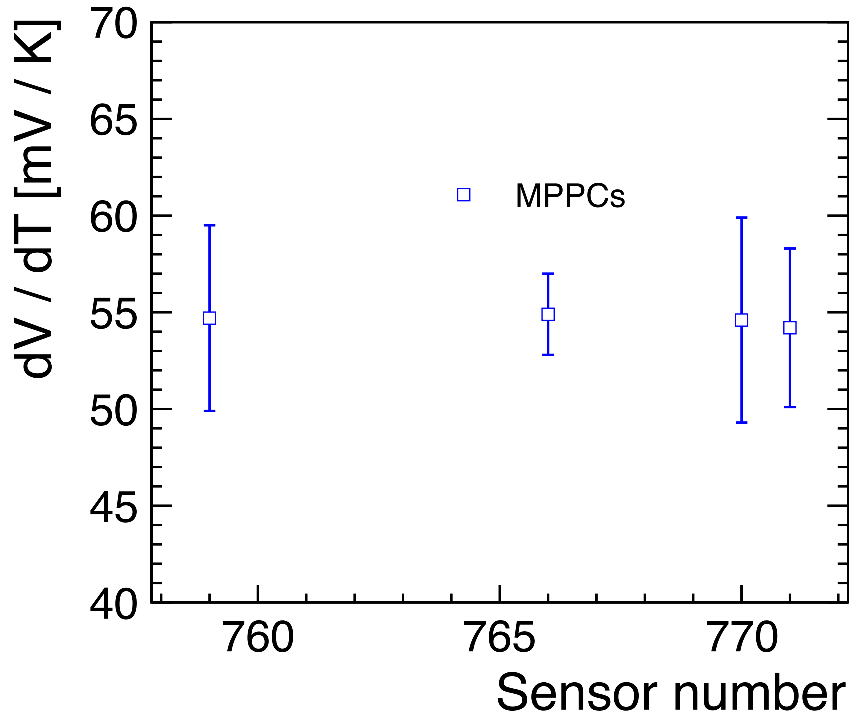
= 54.7 +- 4.8 mV / K

Results for several Hamamatsu MPPCs

Tested 4 MPPCs

- Determine for each
  - average dG/dT
  - average dG/dV
    (See backup slides)

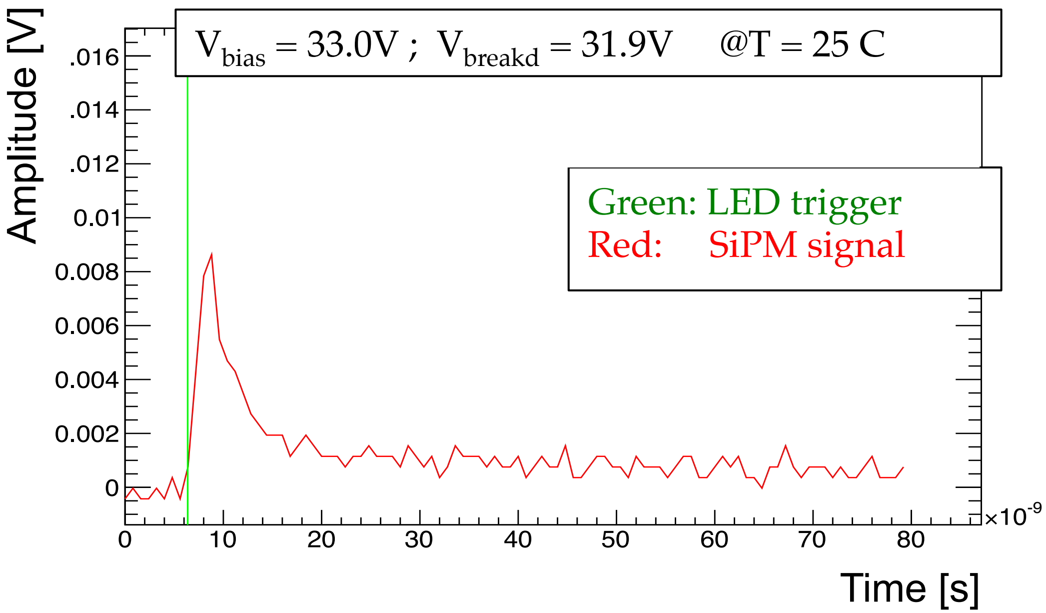
- Calculate the voltage-temperature dependency for a constant gain →



- Results for all 4 sensors vary less than 1%.
  - Individual uncertainties are large as I have simply taken the spread in slopes as uncertainty.

Photon spectrum for CPTA SiPM

- The same setup, now with CPTA SiPM
  - These come attached to tile
    (same sensor+tile as used in 2nd generation CALICE AHCAL prototype)
  - Wrapped in aluminum foil, LED shines at small hole in foil near SiPM



Signal is different than Hamamatsu MPPC

- Longer tail
- Decomposition into single photon waveforms does not work.

→ Integrate over full 80ns.

Fitting p.d.f. to spectrum

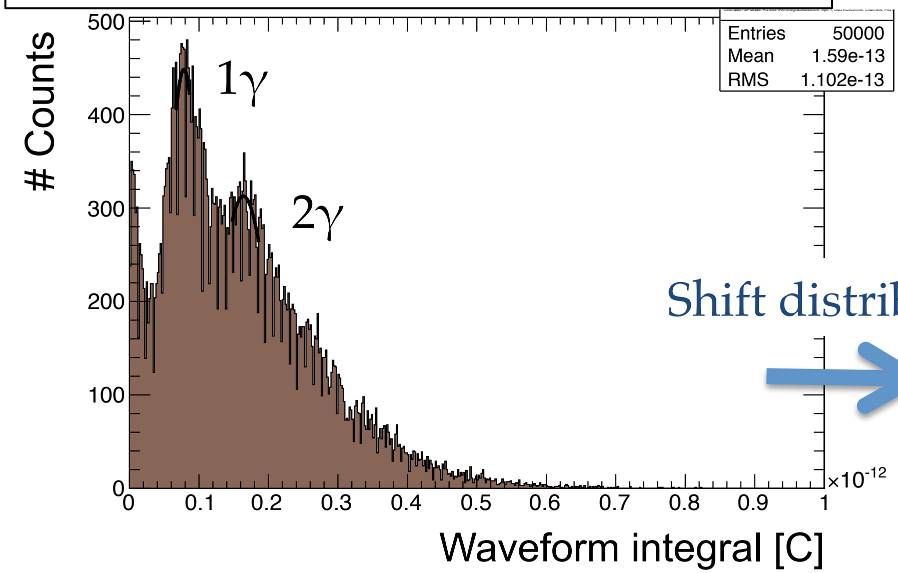
Unfortunately the 2γ peak is not always clear.

→ Extract the gain by measuring the distance from pedestal peak to 1γ peak.

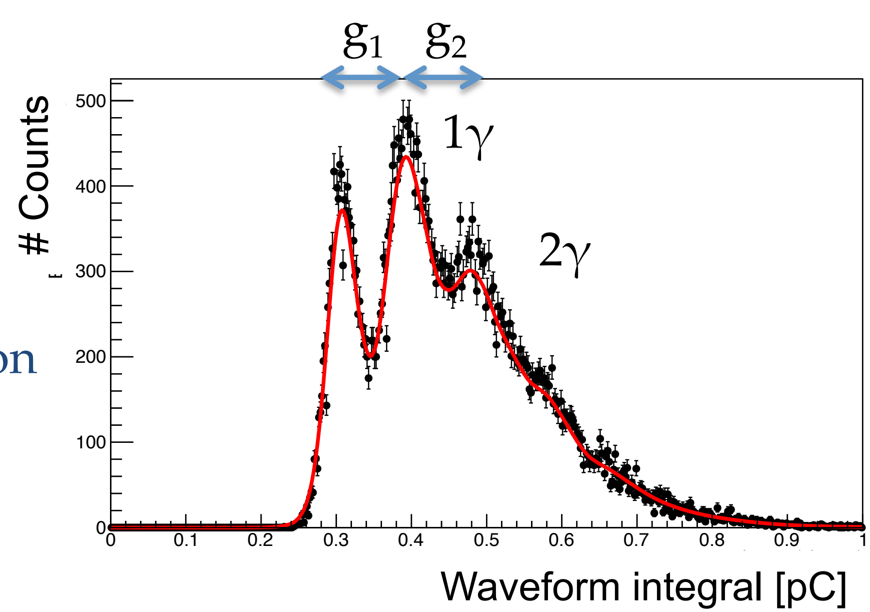
→ Use RooFit p.d.f.: models the distribution as a superposition of gaussians.

- Only include measurements which result in at least 3 peaks.
- Define uncertainty on gain to be difference between g_1 and g_2.
- Only include measurements with gain uncertainty < 4%.

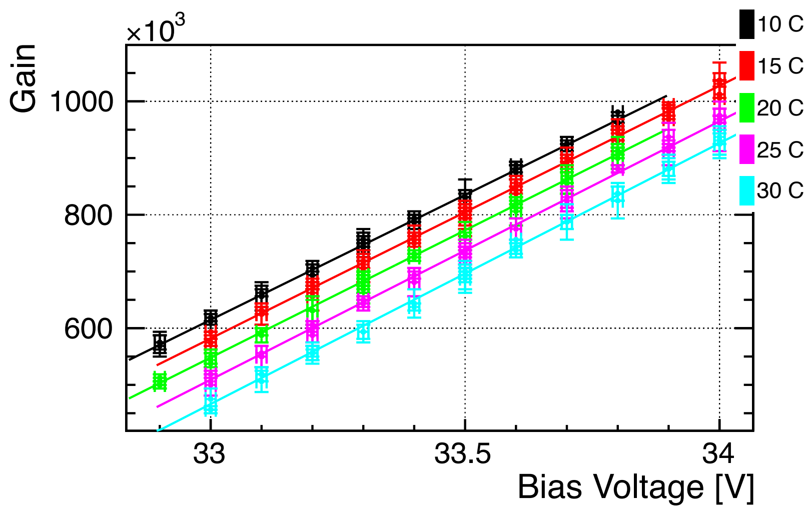
V_{bias} = 33.0V ; V_{breakd} = 31.9V @T = 25 C



Shift distribution

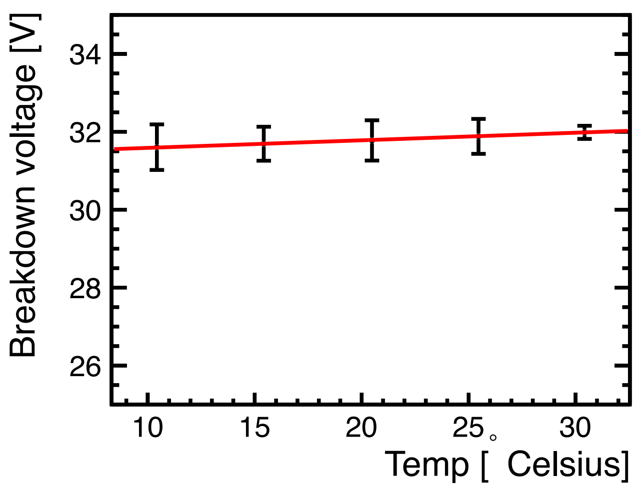


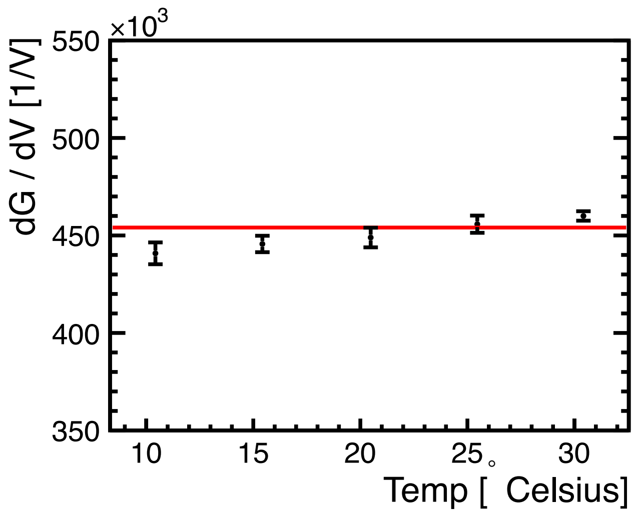
Gain distribution – CPTA SiPM (#857)



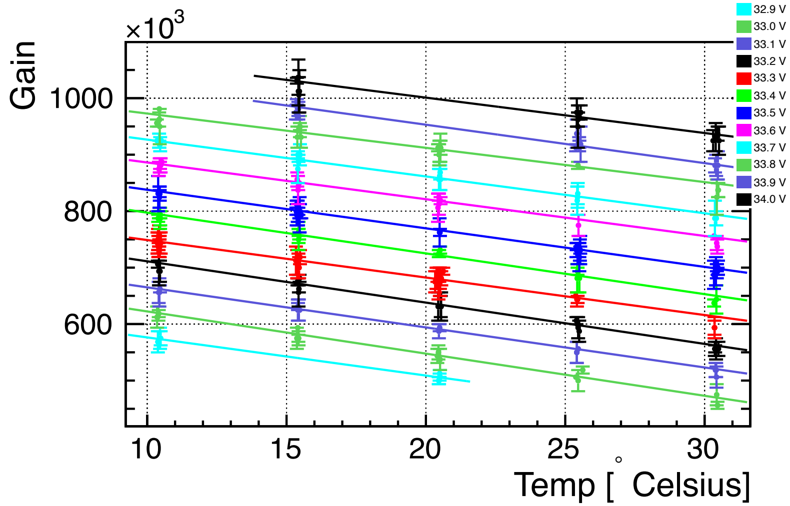
- Each entry is the gain extracted from 50k waveforms
- At 5 different temperatures, with varying bias V in steps of 0.1V
  - At least 5 measurements at each temperature and V point.

→ Systematic effect of dG/dV with temperature again visible



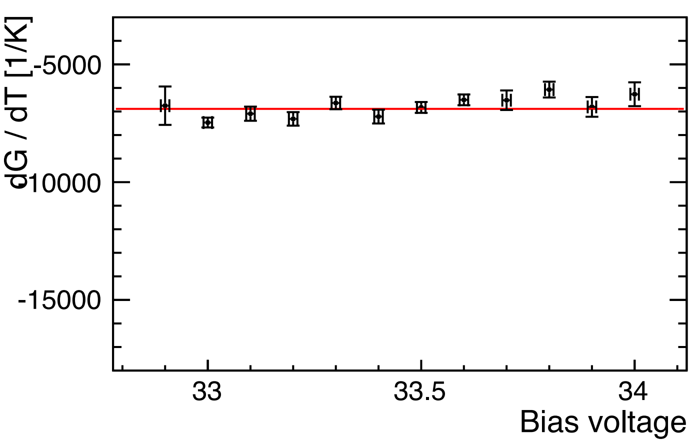


Gain distribution – CPTA SiPM (#857)



← Same data, plotted as Gain vs T, for the different bias voltages set.

Different fitted slopes



For a constant gain, need dV / dT:

- Averaging the fitted slopes, and assuming as uncertainty the spread of slopes:
- dV/dT = - av (dG/dT) / av(dG/dV)

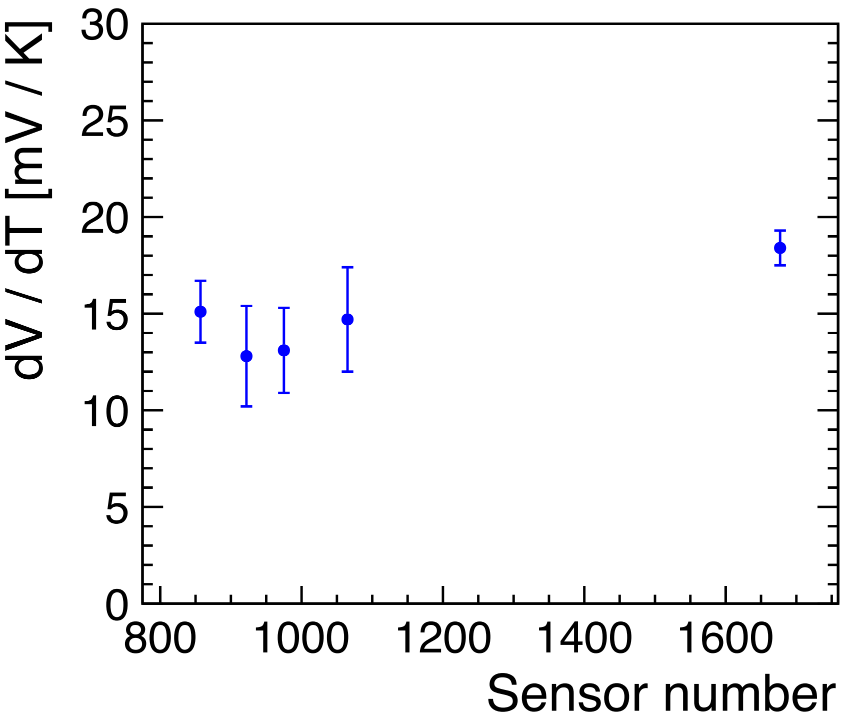
  = 15.1 +- 1.6 mV / K

Results for several CPTA SiPMs

- Repeated the measurements on 5 different SiPM+tile
  - 4 are similar in gain
  - 1 (#1677) is different and has ~ 2x higher gain.
  - See backup slides for individual measurements.

- Variation between 4 similar SiPM is ~10%

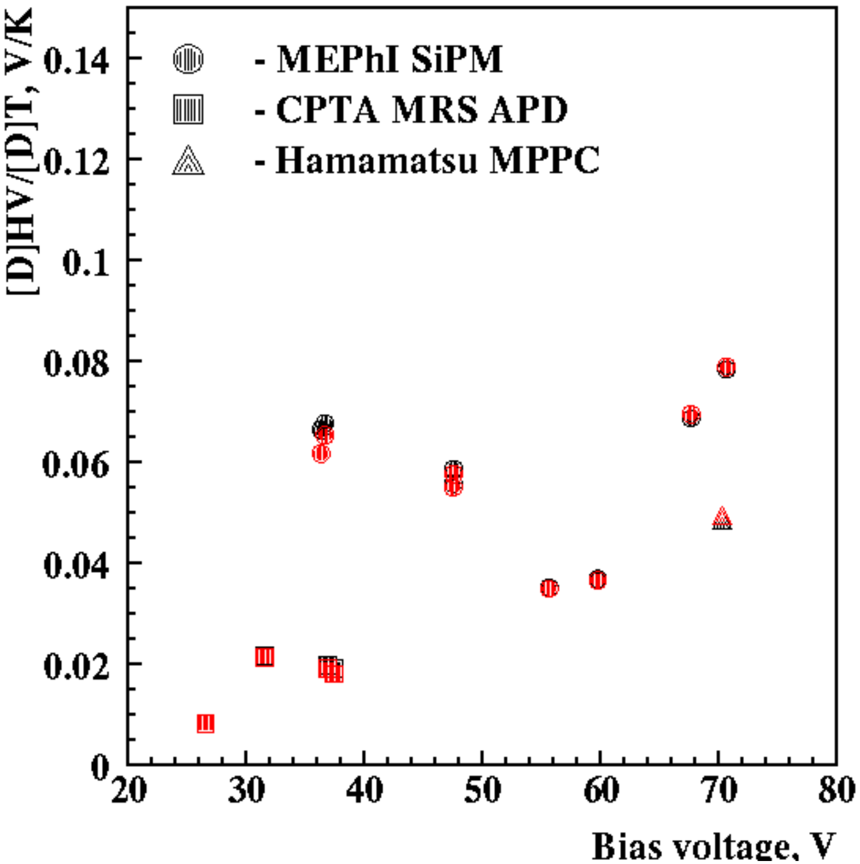
- #1677 is easier to characterize, thanks to its higher gain.

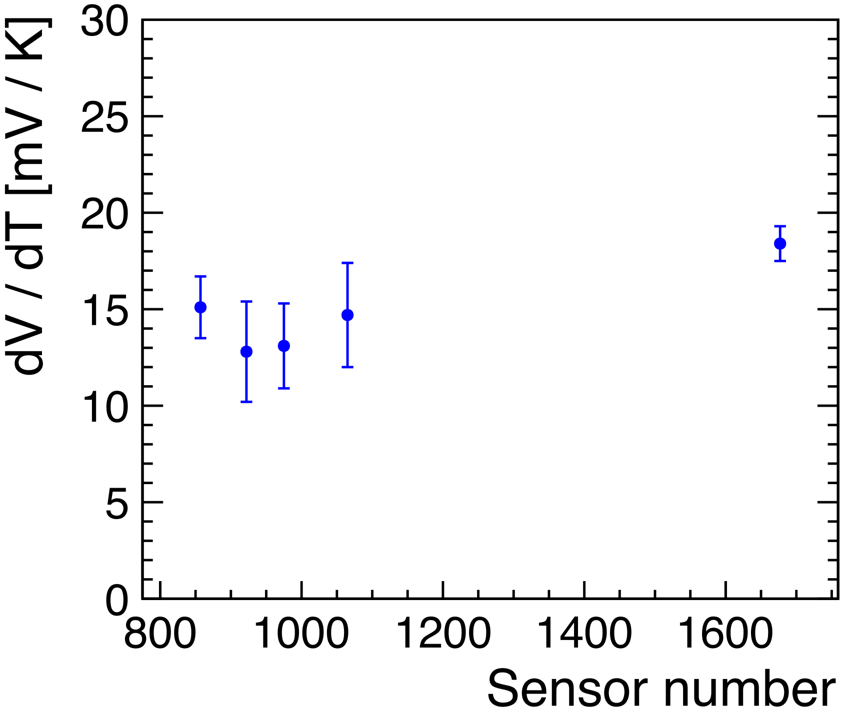


Results for several CPTA SiPMs

Results are in agreement with what can be expected.

- From Evgueny Tarkovsky:





Conclusion

Have a working setup to characterize gain-temperature dependence

- Works (almost) out of the box for the Hamamatsu MPPCs using T3B DAQ & analysis.
  - Gain defined by distance between 1γ- and 2γ peak
- CPTA SiPMs have different / longer signals
  - Gain can be determined using distance between pedestal and 1γ peak
  - dV/dT can be measured to ~10%.

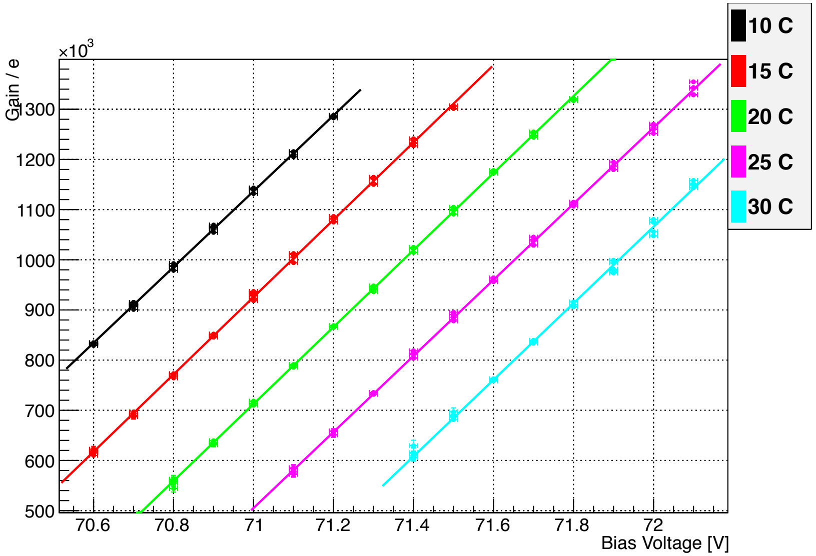
- Small dependency of capacitance on temperature
  - Need to figure out its origin.

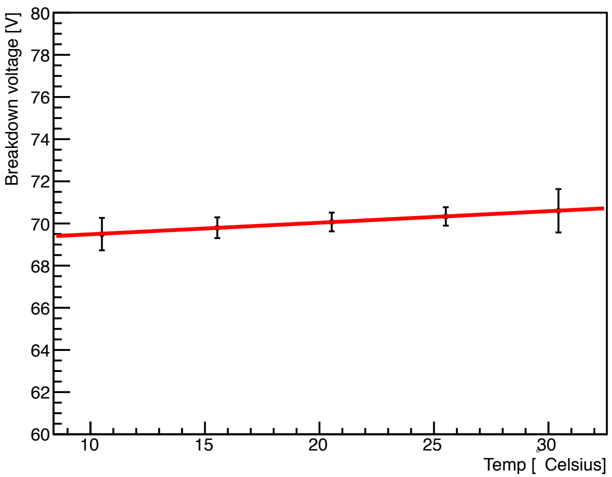
Many thanks to:

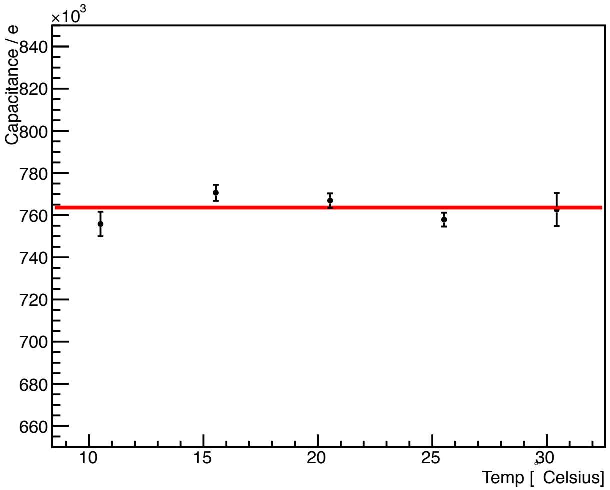
T3B: C. Soldner, L. Weuste, M. Szalay

LCD group: especially M. Benoit and S. Arfaoui

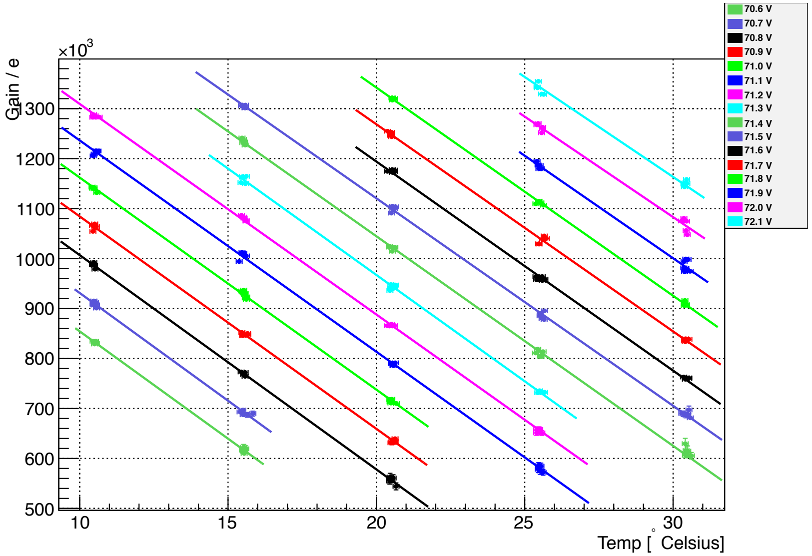
Backup

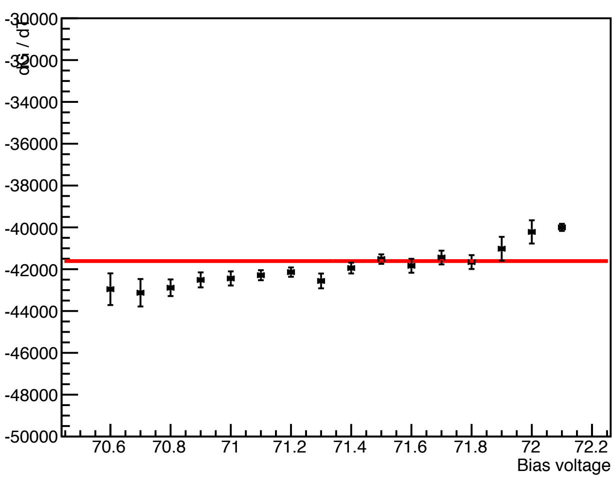

10 C
15 C
20 C
25 C
30 C
×10³
Gain / e
1300
1200
1100
1000
900
800
700
600
500
70.6
70.8
71
71.2
71.4
71.6
71.8
72
Bias Voltage [V]


Breakdown voltage [V]
80
78
76
74
72
70
68
66
64
62
60
10
15
20
25
30
Temp [Celsius]


×10³
Capacitance / e
840
820
800
780
760
740
720
700
680
660
10
15
20
25
30
Temp [Celsius]

Gain distribution - Hamamatsu MPPC (#11766)



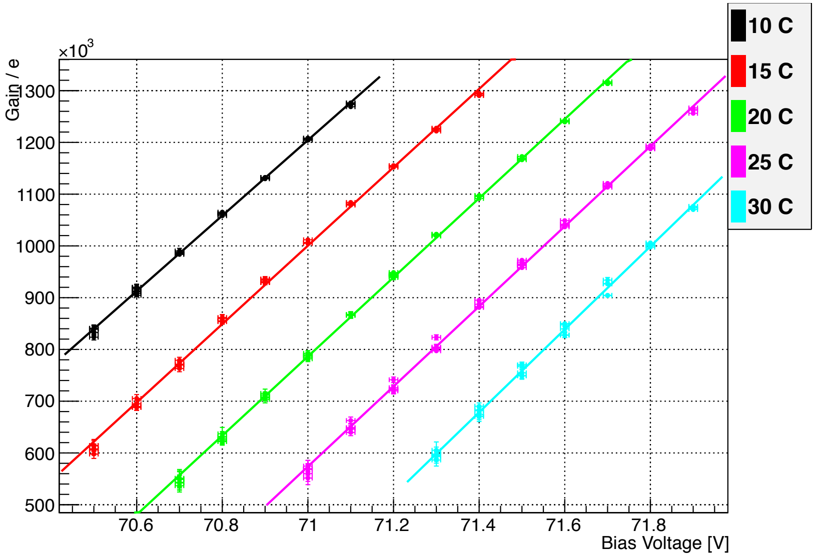


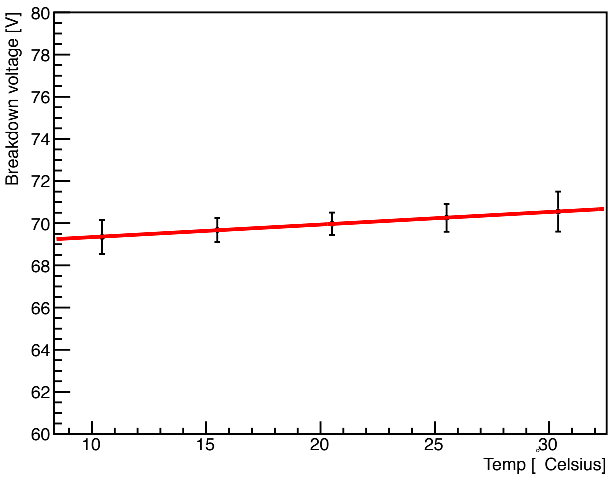
For a constant gain, need dV / dT:

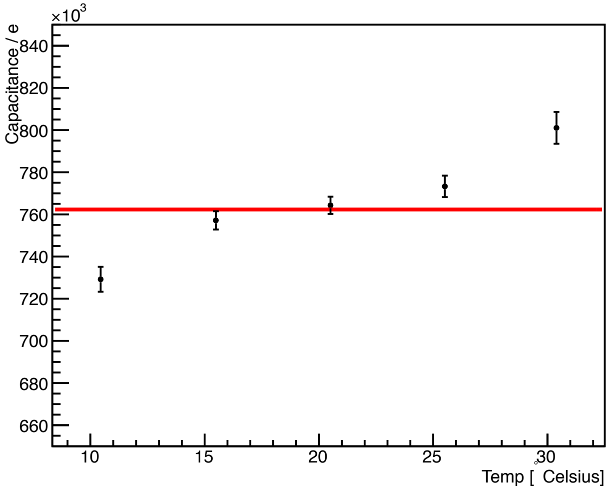
- Averaging the fitted slopes, and assuming as uncertainty the spread of slopes:
- av (dV/dT) = - av (dG/dT) / av(dG/dV)

  = 54.9 +- 2.1 mV / K

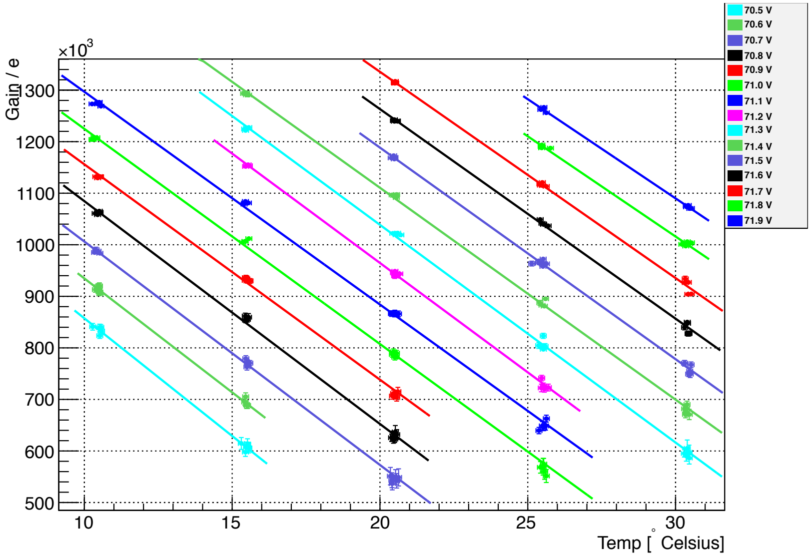
Gain distribution - Hamamatsu MPPC (#11770)

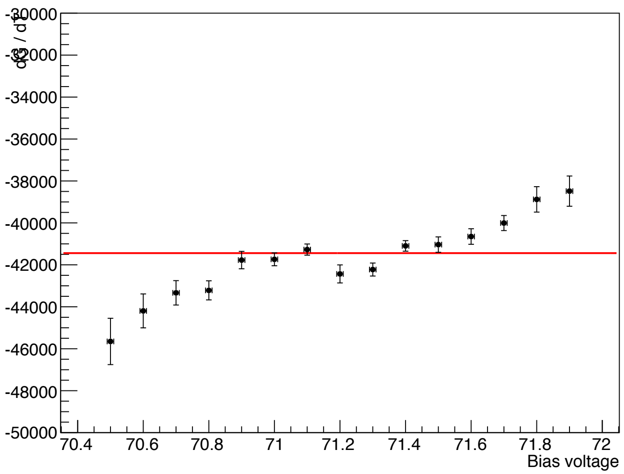






Gain distribution - Hamamatsu MPPC (#11770)



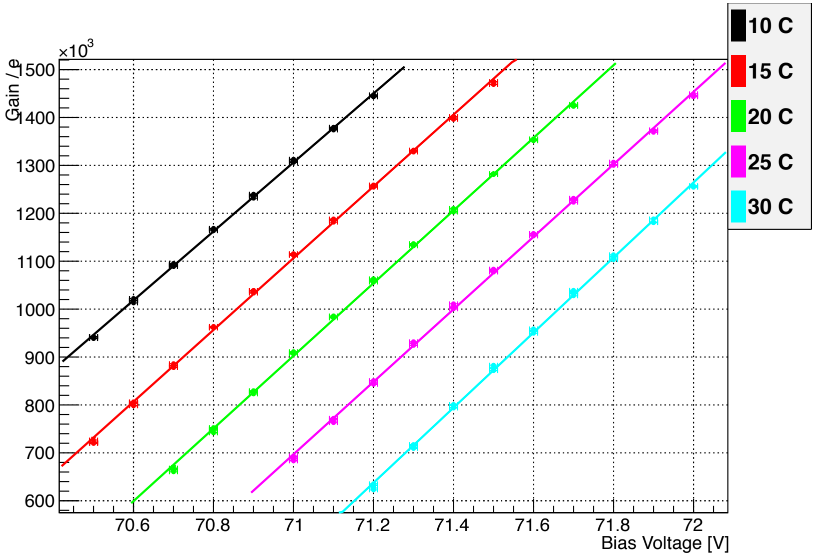


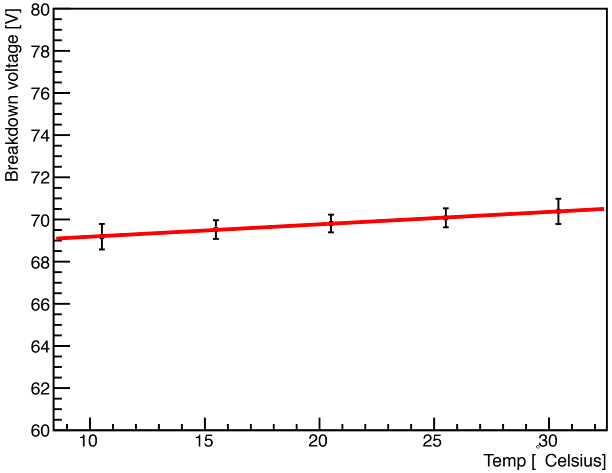
For a constant gain, need dV / dT:

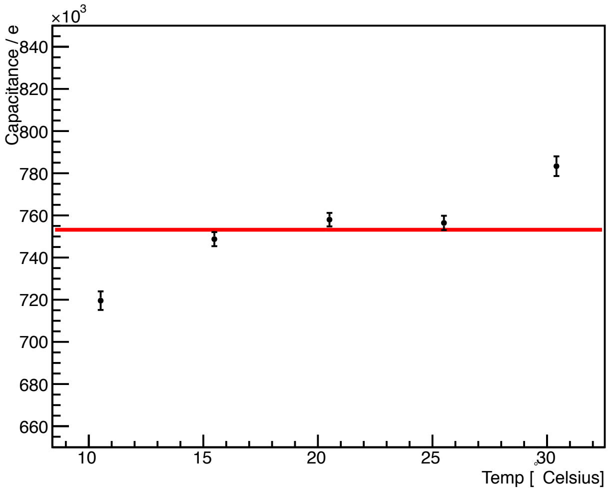
- Averaging the fitted slopes, and assuming as uncertainty the spread of slopes:
- av (dV/dT) = - av (dG/dT) / av(dG/dV)

  = 54.6 +- 5.3 mV / K

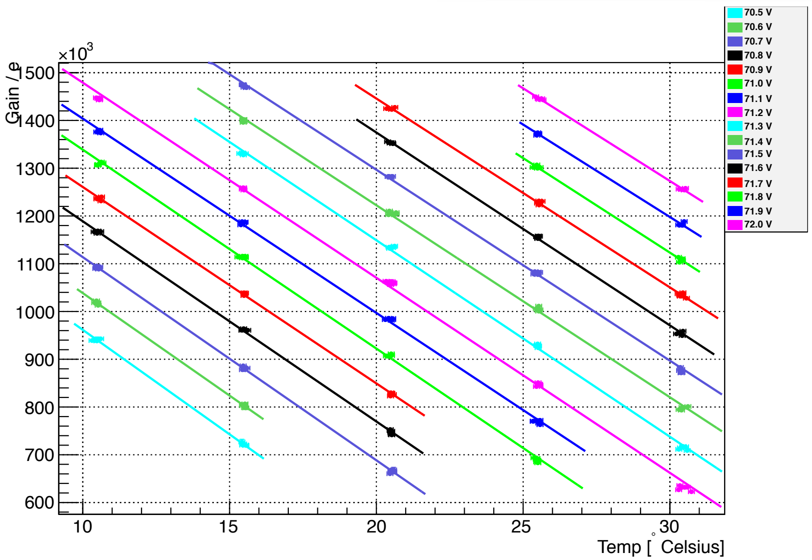
Gain distribution - Hamamatsu MPPC (#11771)

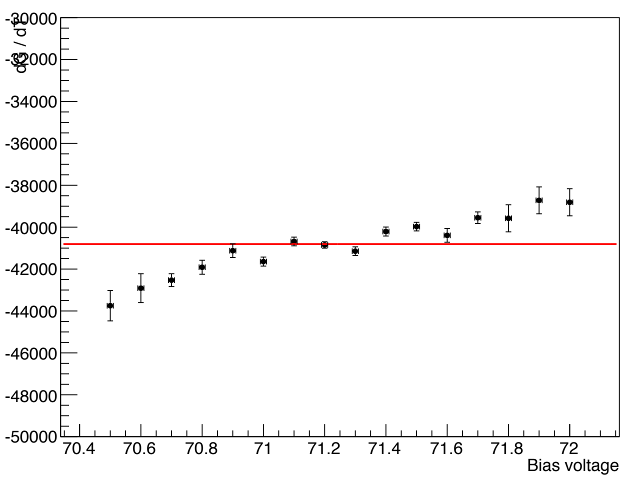






Gain distribution - Hamamatsu MPPC (#11771)



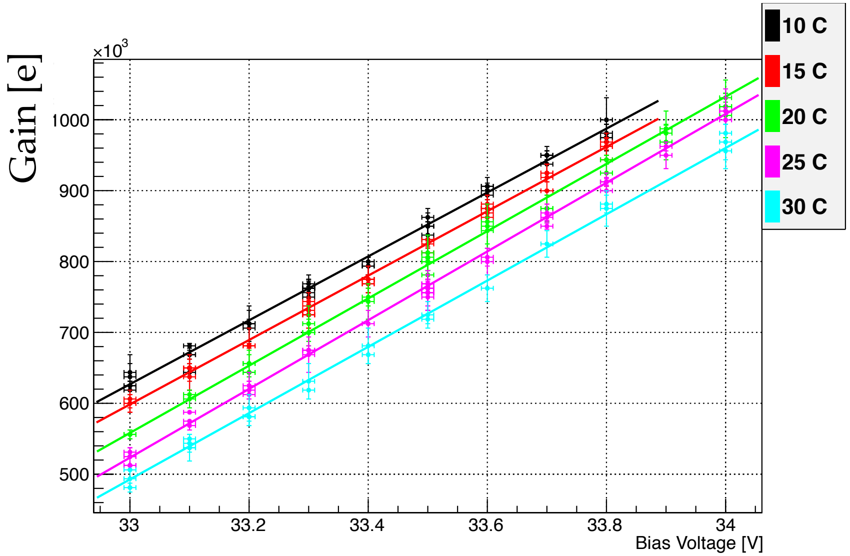


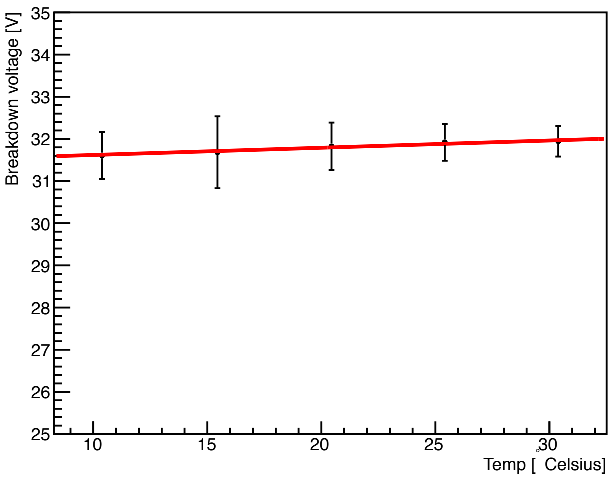
For a constant gain, need dV / dT:

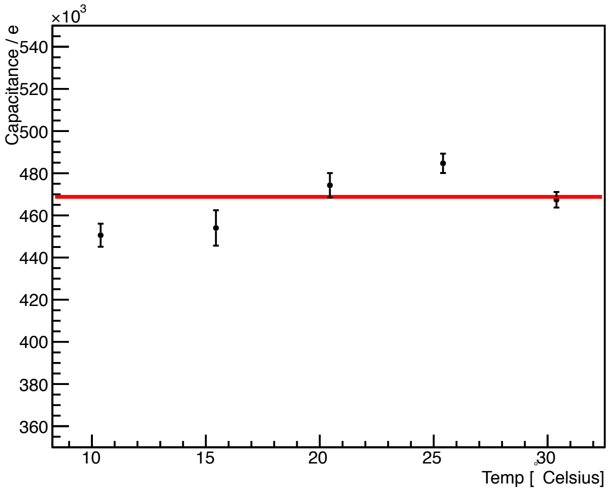
- Averaging the fitted slopes, and assuming as uncertainty the spread of slopes:
- av (dV/dT) = - av (dG/dT) / av(dG/dV)

  = 54.2 +- 4.1 mV / K

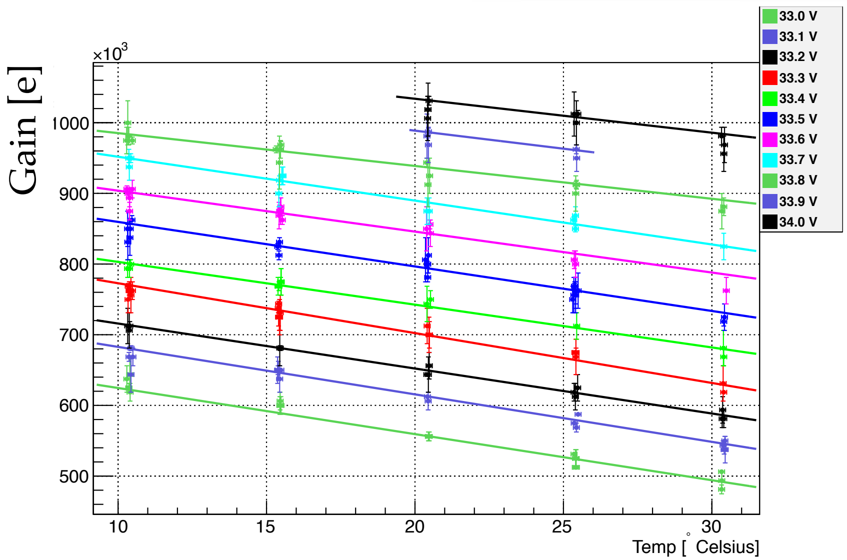
Gain distribution - SiPM (#922)





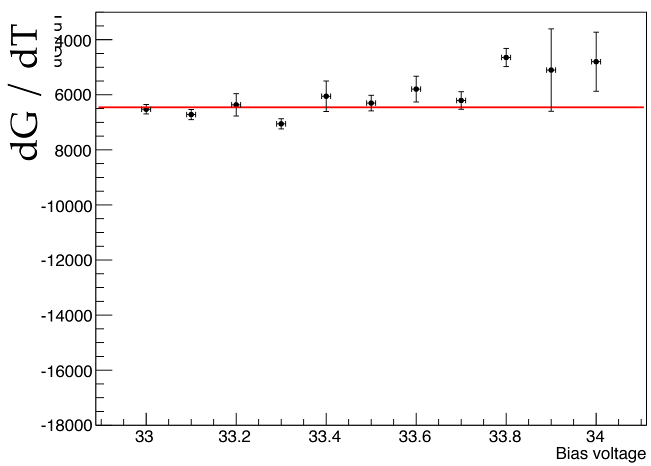


Gain distribution - SiPM (#922)



← Same data, plotted as Gain vs T, for the different bias voltages set.

Different fitted slopes

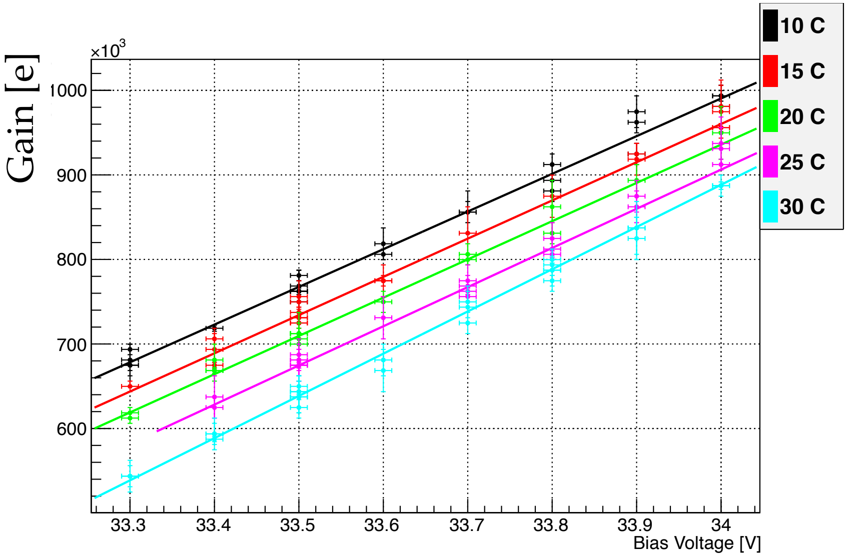


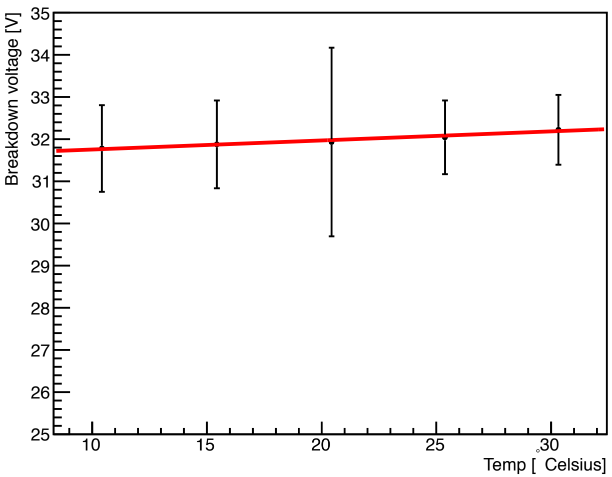
For a constant gain, need dV / dT:

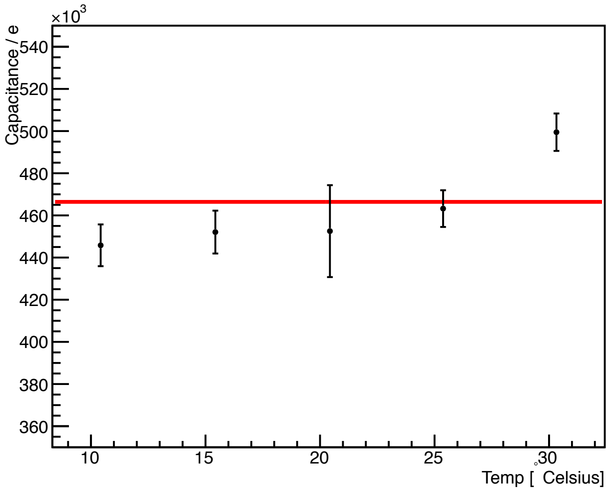
- Averaging the fitted slopes, and assuming as uncertainty the <u>spread of slopes</u>:
- dV/dT = - av (dG/dT) / av(dG/dV)

  = 12.8 +- 2.6 mV / K

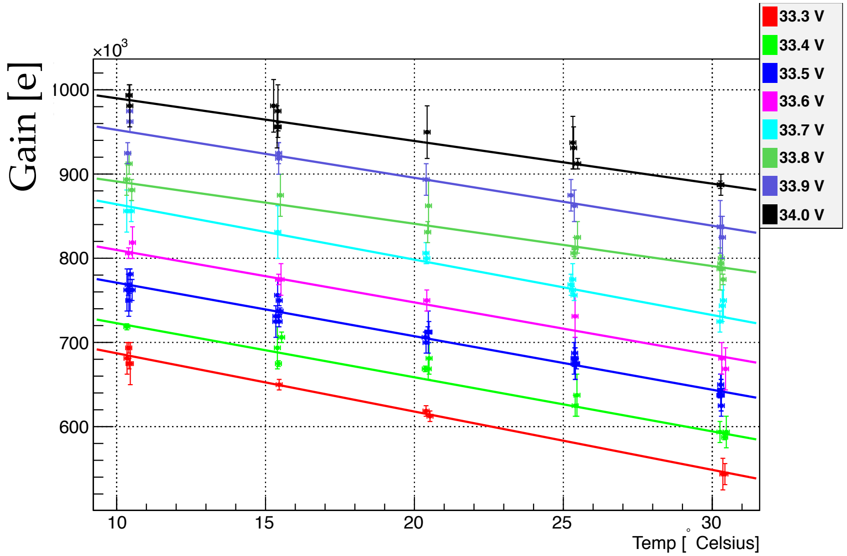
Gain distribution - SiPM (#975)





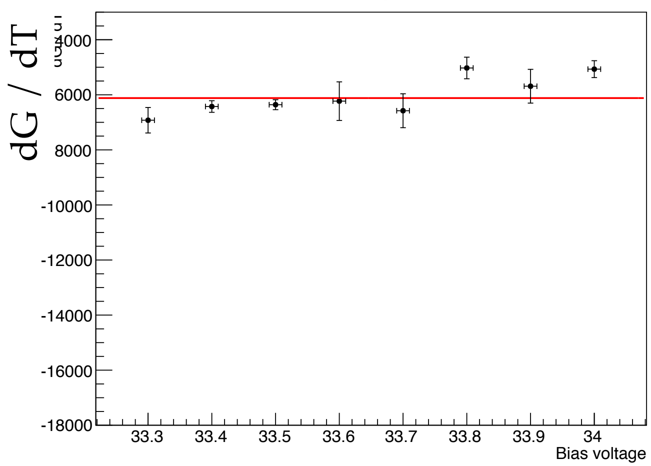


Gain distribution - SiPM (#975)



← Same data, plotted as Gain vs T, for the different bias voltages set.

↓ Different fitted slopes ↓

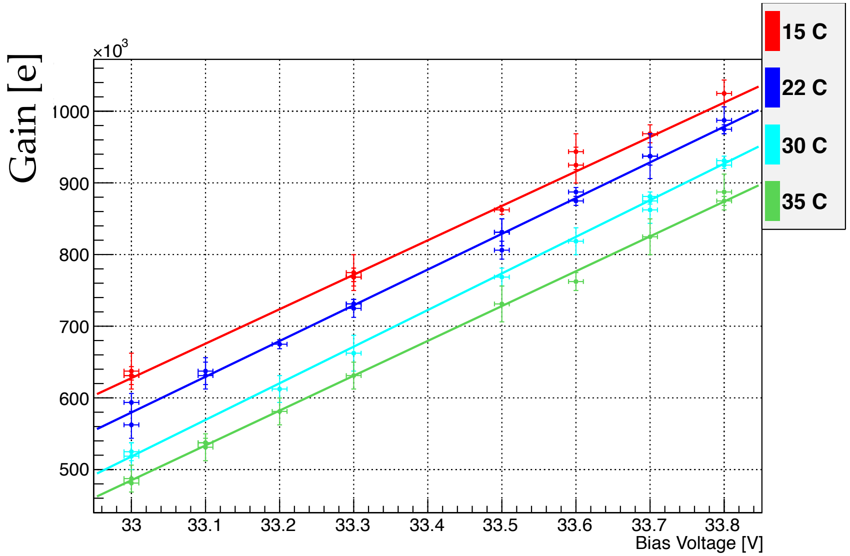


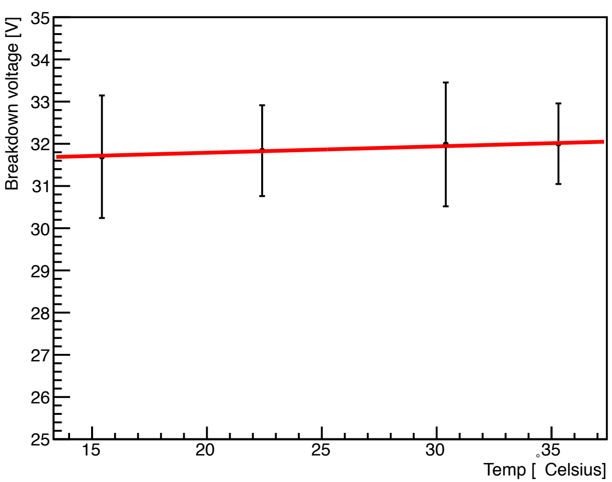
For a constant gain, need dV / dT:

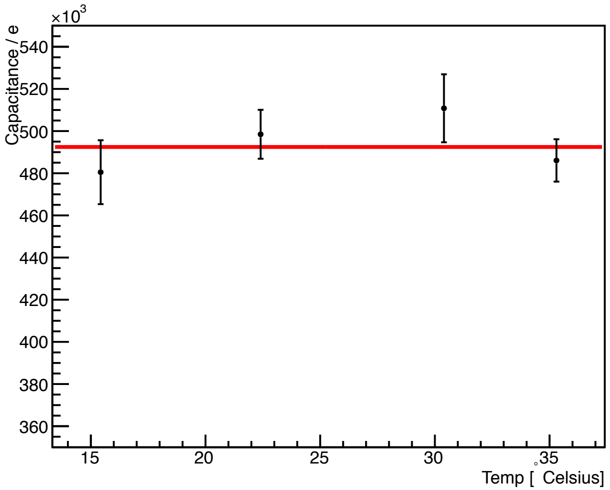
- Averaging the fitted slopes, and assuming as uncertainty the spread of slopes:
- dV/dT = - av (dG/dT) / av(dG/dV)

  = 13.1 +- 2.2 mV / K

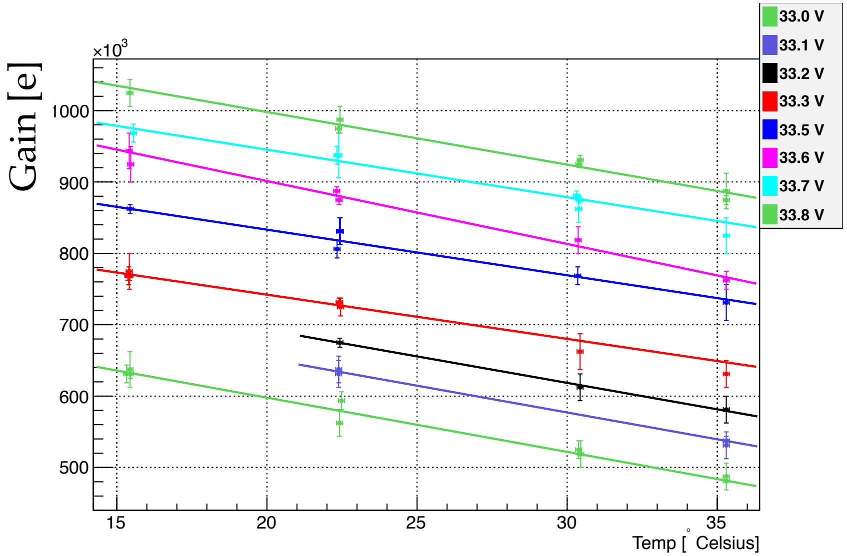
Gain distribution - SiPM (#1065)





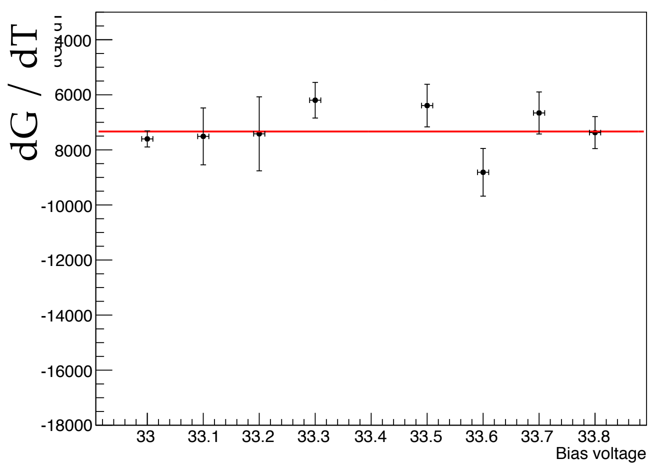


Gain distribution - SiPM (#1065)



← Same data, plotted as Gain vs T, for the different bias voltages set.

Different fitted slopes

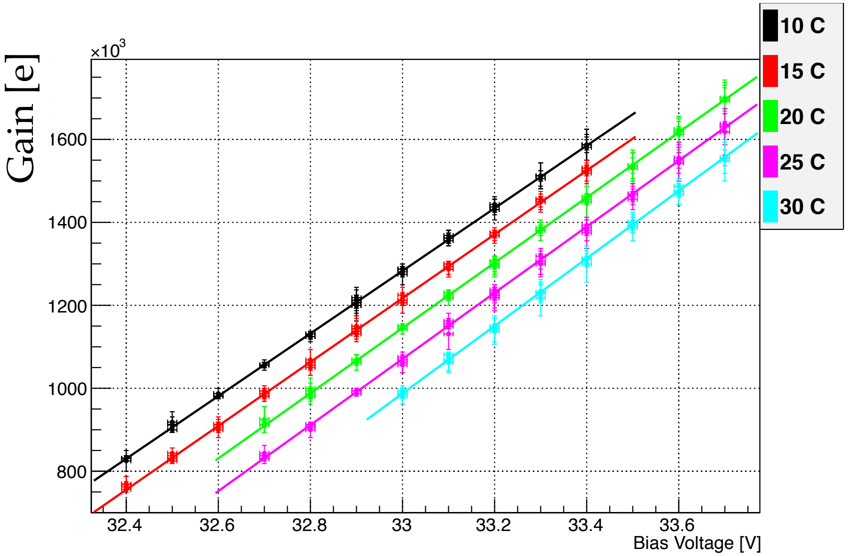


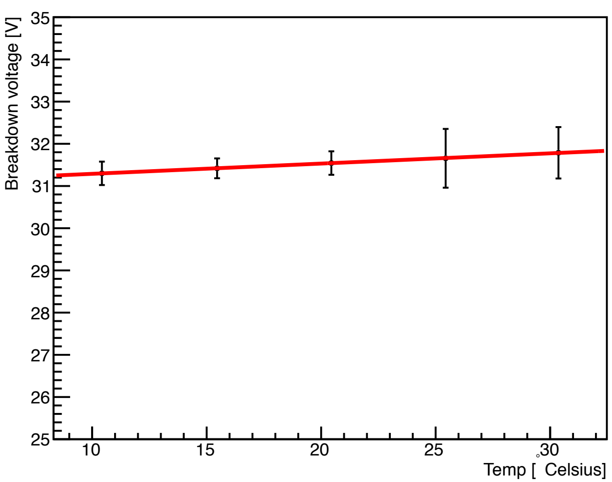
For a constant gain, need dV / dT:

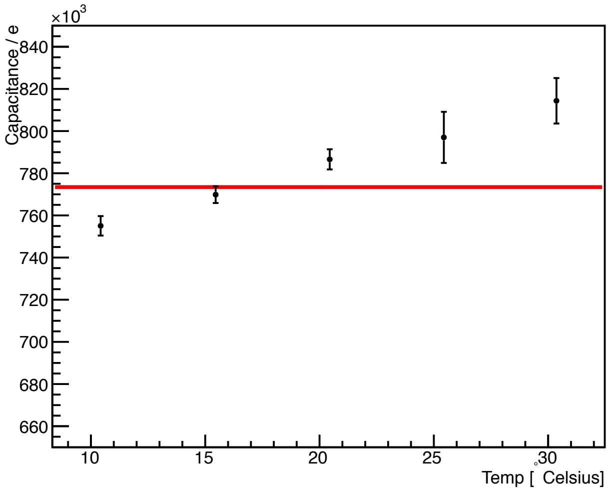
- Averaging the fitted slopes, and assuming as uncertainty the spread of slopes:
- dV/dT = - av (dG/dT) / av(dG/dV)

  = 14.7 +- 2.7 mV / K

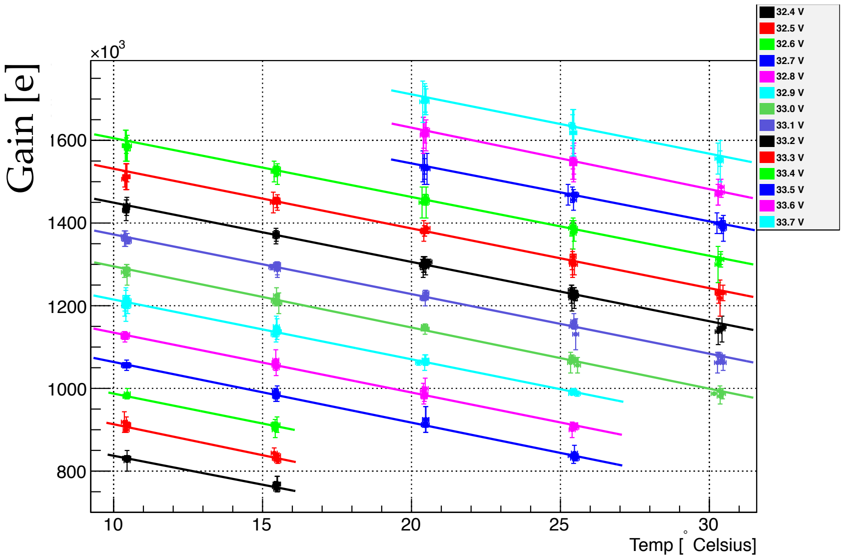
Gain distribution - SiPM (#1677)





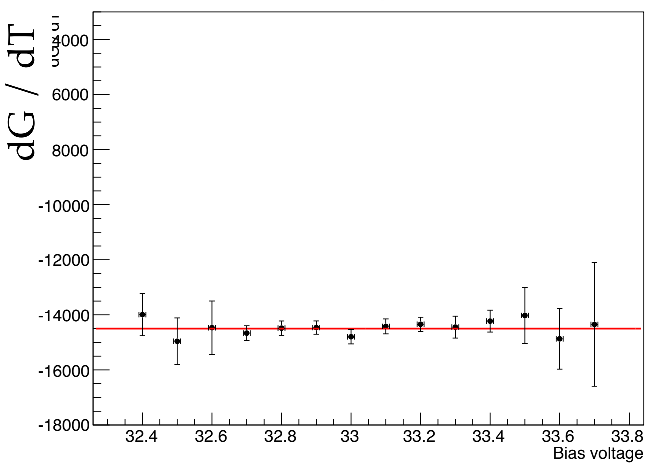


Gain distribution - SiPM (#1677)



← Same data, plotted as Gain vs T, for the different bias voltages set.

Different fitted slopes



For a constant gain, need dV / dT:

- Averaging the fitted slopes, and assuming as uncertainty the <u>spread of slopes</u>:

- dV/dT = - av (dG/dT) / av(dG/dV)

  = 18.4 +- 0.9 mV / K