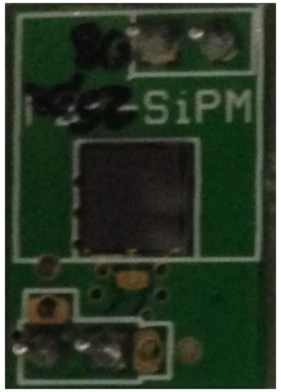
Temperature Dependence of Resistance and Breakdown Voltage For Silicon Photomultipliers (SiPM)



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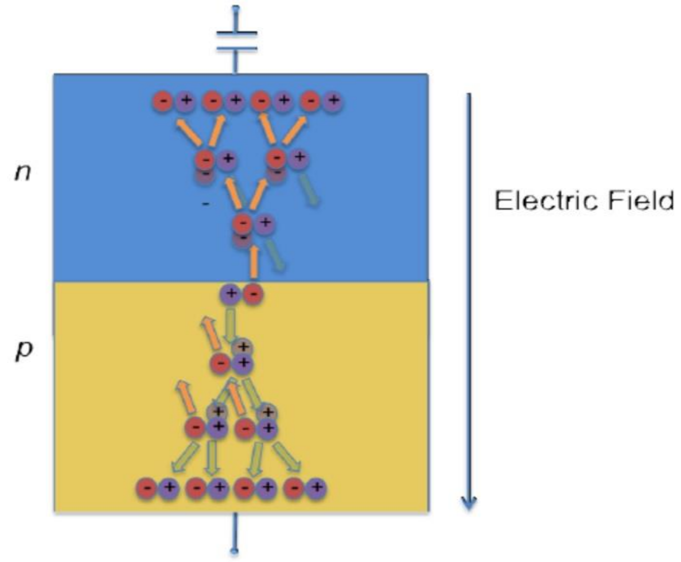
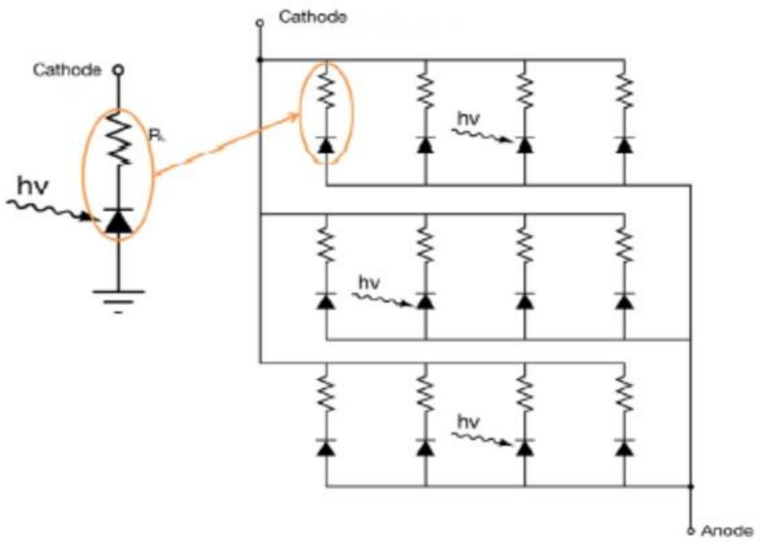
Basics of Geiger Mode SiPMs



SiPMs are made by doping Silicon wafers to create a pn-junction type of diode. In Geiger mode, the device is operated above the breakdown voltage. When a photon is absorbed it creates an electron-hole pair. The electrons and holes are accelerated by the electric field with enough energy to make more electron-hole pairs and trigger a discharge.

The signal from a cascade is of the same amplitude, no matter how many photons are absorbed. To regain proportionality, SiPMs are composed of individual electrically and optically isolated pixels. Each pixel (or microcell) has its own quenching resistor to stop the discharge. The signals from all the microcells are summed to give a signal proportional to the number of microcells triggered.



*Figures from Sensl “Introduction to the SPM Technical Note”

Pros and Cons of SiPMs in Geiger Mode

Advantages

- On par with PMTs for low level light detection (single photon counting)
- High gain ($10^5 – 10^7$)
- Low intrinsic background
- Small mass
- Possibilities for mass production
- High PDE (per area)
- Low operating voltage and power consumption
- Insensitivity to magnetic fields
- Nuclear counter effect is negligible

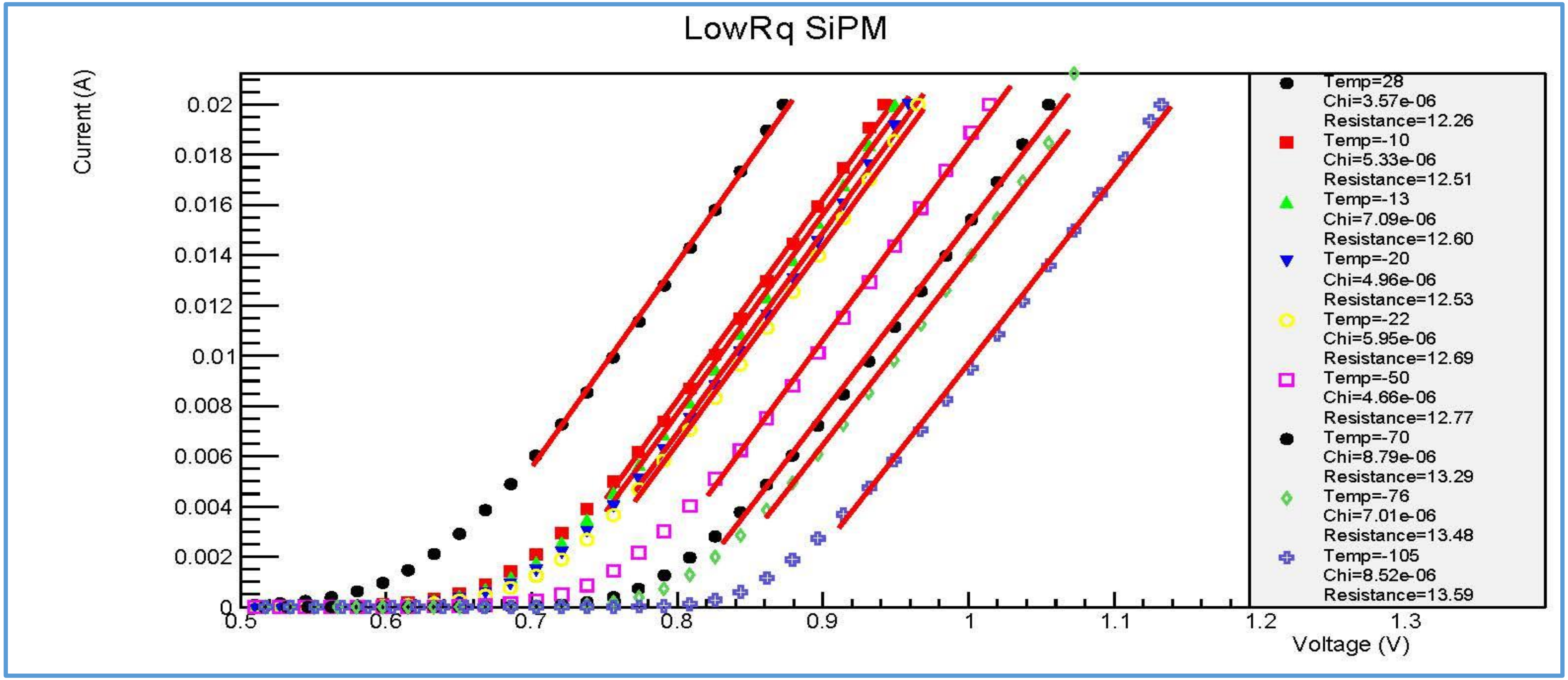
Difficulties

- **Temperature dependence of quenching resistor, breakdown voltage**, gain and darkrate
- PDE and gain depend sensitively on overvoltage
- Parasitic capacitance increases rise time
- Readout becomes complicated for arrays
- High dark rate at room temperature
- Small surface area (currently)
- Dead space needed between pixels for optical/electrical isolation
- Afterpulsing
- Optical crosstalk

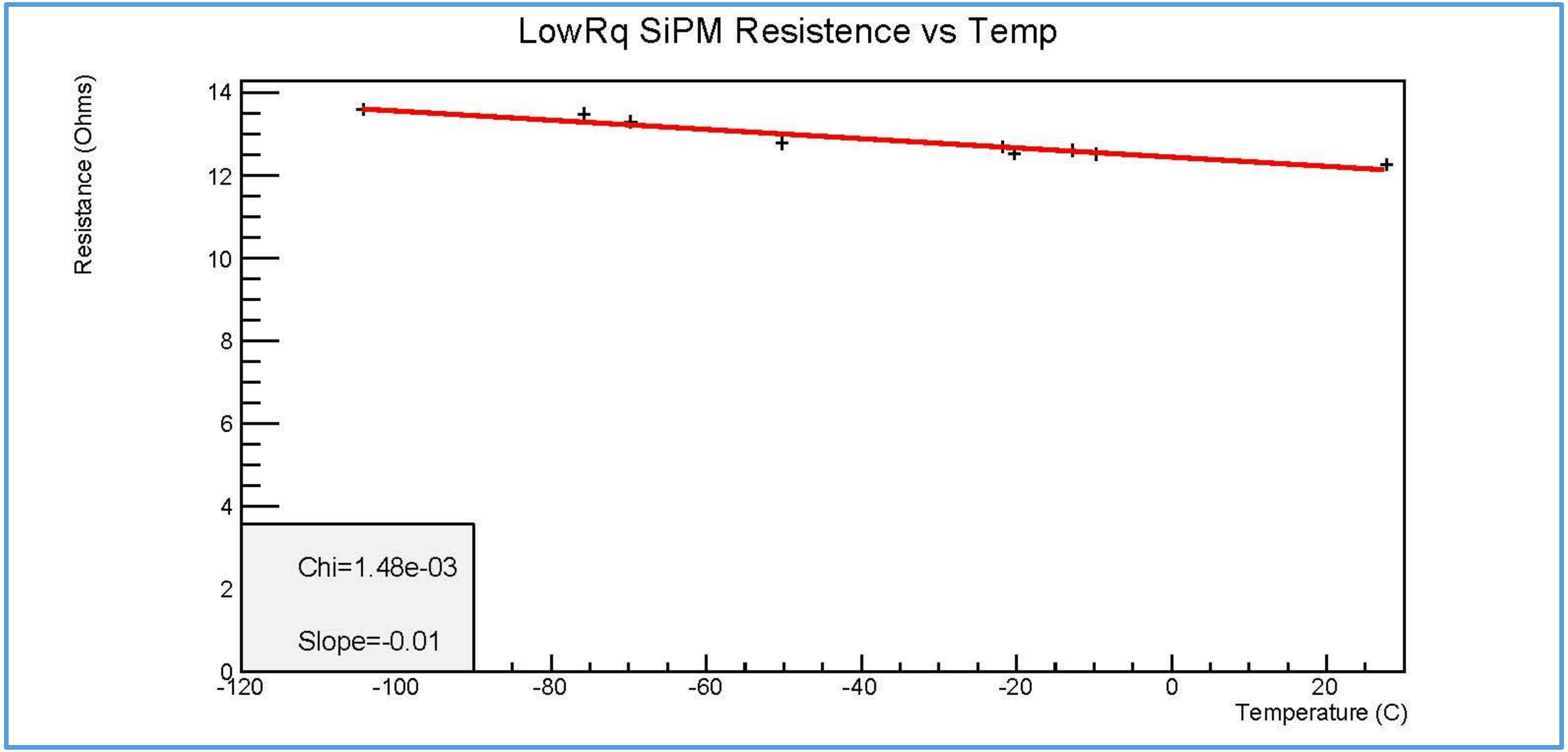
Testing Temperature Dependence of Resistance and Breakdown Voltage

- The SiPM was placed in a light tight box with a PT-100 sensor to monitor temperature. A Keithley 2450 SourceMeter was used to provide the Bias Voltage to the SiPM and readout the current. The box was flushed with Nitrogen to decrease the temperature.
- For testing the resistance, the SiPM was set up for forward bias and the Keithley SourceMeter was programmed to scan from ~0 to 3.5 V
- For testing the breakdown voltage, the SiPM was set up for reverse bias and and scanned from ~20-27 V depending on the SiPM

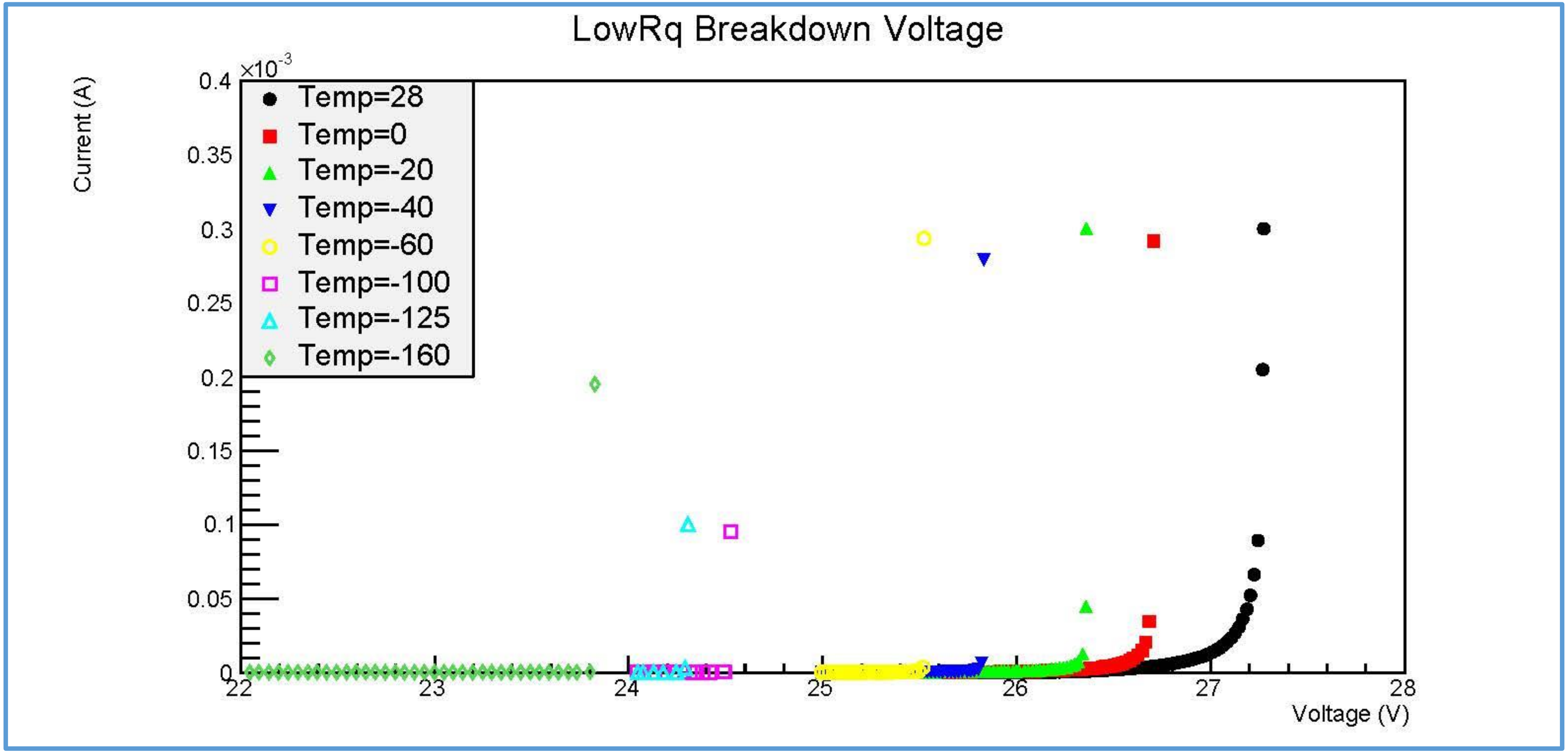
Results for Resistance



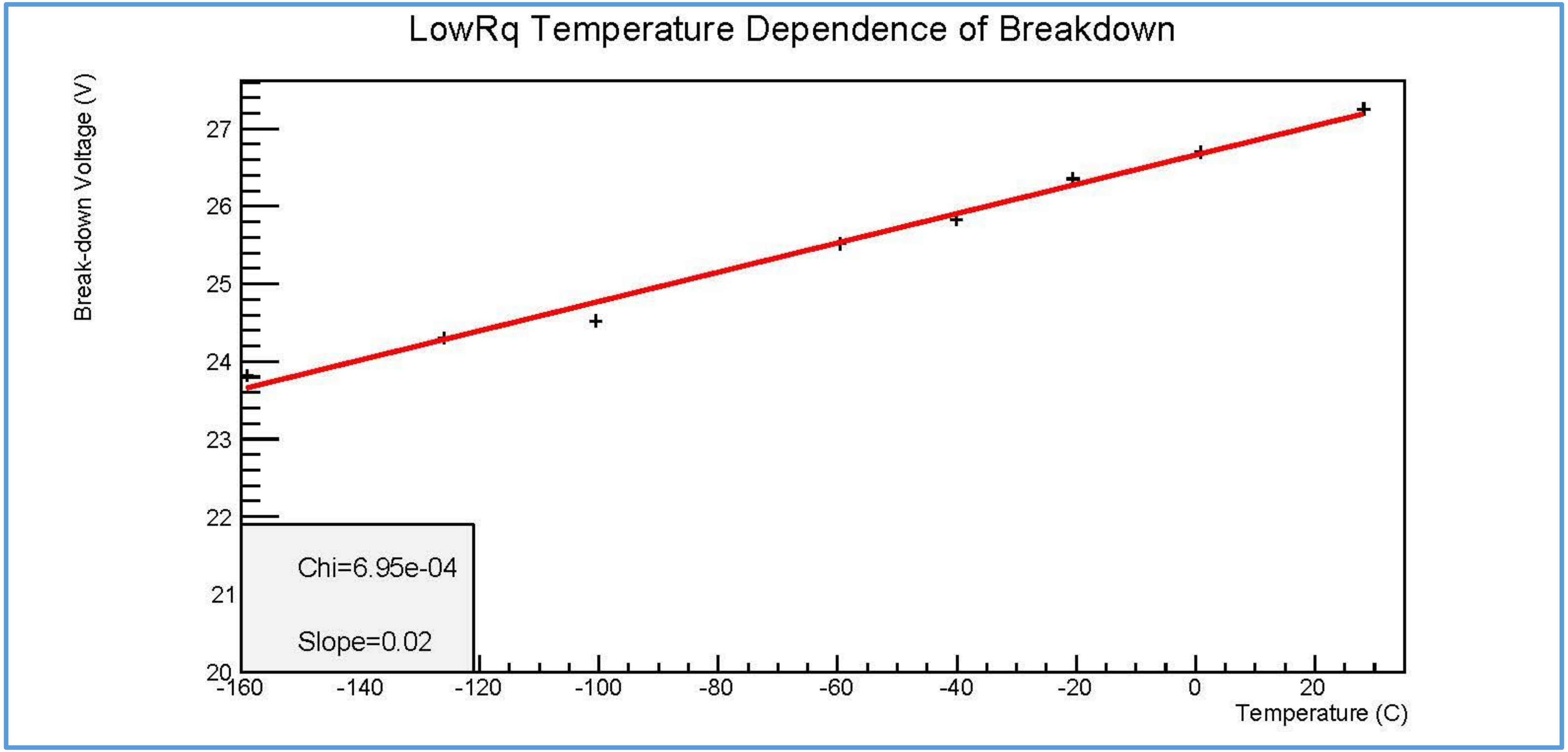
Results for Resistance



Results for Breakdown Voltage



Results for Breakdown Voltage



Conclusions

- For the LowRq SiPM, the resistance of the quenching resistor showed a linear dependence on the temperature of -0.01 Ohms/C
- The breakdown voltage showed a linear dependence on temperature of 0.02 V/C
- Four other SiPMs were tested in the same manner and the analysis of their data is pending
- Temperature dependence of other factors such as dark rate, afterpulsing, sensitivity spectrum, and PDE should be tested in the future

References

- Sensl *Introduction to the SPM Technical Note*
- D. Renker and E Lorenz, *Advances in Solid State Photon Detectors*, Jinst 4 (2009) 4004.
- V. Chepel, H. Araujo, *Liquid noble gas detectors for low energy particle physics,* arXiv:1207.2292v2