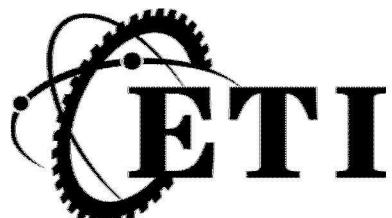


Virtual Summer Meeting for Young Researchers

Characterizing the Temperature Dependence of Silicon Photomultipliers and Scintillators

Melinda Sweany, Erik Brubaker, **Kyle Weinfurther**, Peter Marleau, Ben Maestas

Sandia National Laboratories
July 7, 2020



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.



Biography

- B.S.E. and M.S.E. from the University of Michigan in Nuclear Engineering
- Ph.D. from North Carolina State University in Nuclear Engineering on neutron scatter camera imaging
- Four internships at Sandia National Laboratories during undergraduate and graduate school
- Postdoctoral researcher at Sandia National Laboratories in Livermore, CA



NC STATE UNIVERSITY

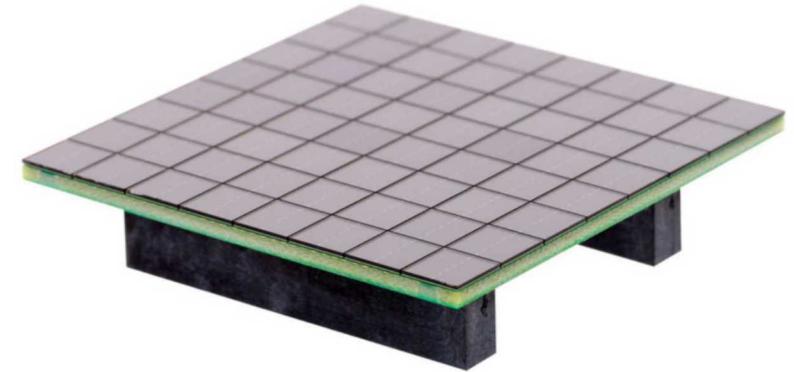


Sandia National Laboratories

Why silicon photomultipliers?

- Compared to traditional photomultiplier tubes (PMTs)
 - Small form factor
 - Low operating voltage
 - Magnetic field insensitivity
 - Negligible cost differences for comparable photo-sensitive area
 - Gain and dark current
 - Higher photon detection efficiency
- Temperature affects the amount of dark current from thermal production of charge carriers and the breakdown voltage

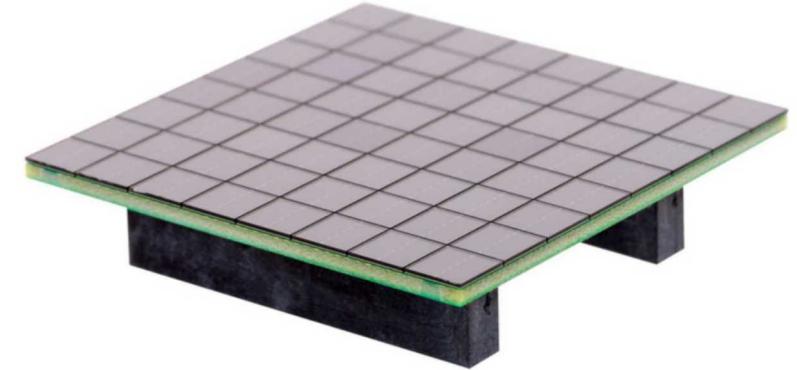
ON Semiconductor ArrayJ Series SiPMs



Why silicon photomultipliers?

- How does temperature affect
 - Resolution
 - Pulse shape discrimination (PSD) figure-of-merit (FOM)
 - Dark current
 - Others...
- Primary interest in summed response of the 8x8 SiPM array coupled to a 2" x 2" cylinder scintillator
- Investigate individual pixel response to help understand summed array response

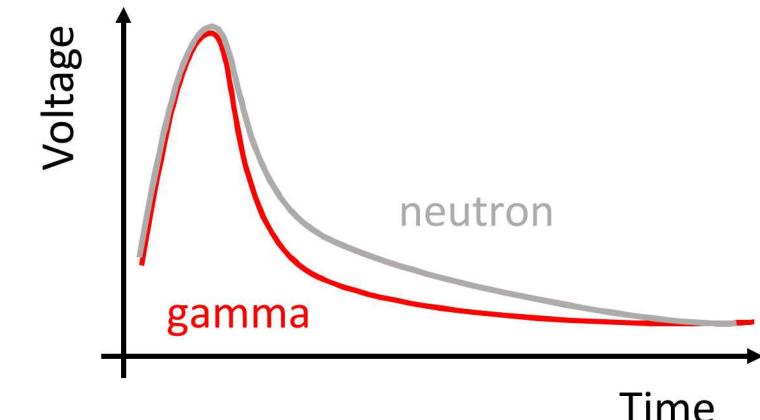
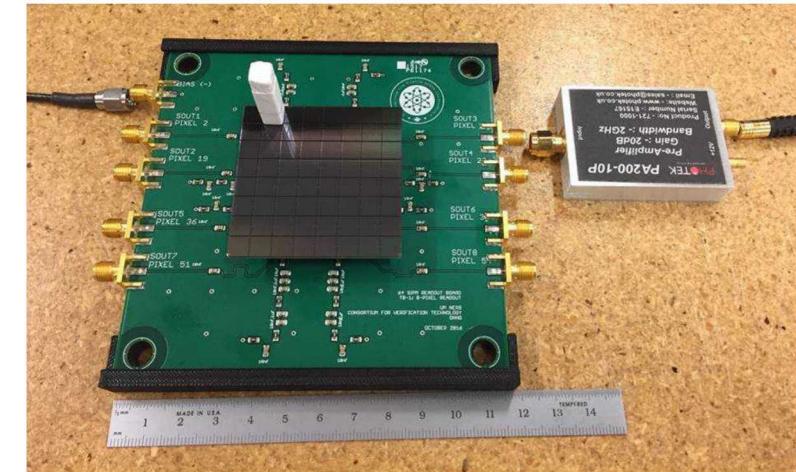
ON Semiconductor ArrayJ Series SiPMs



Single SiPM Pixel Experimental Setup

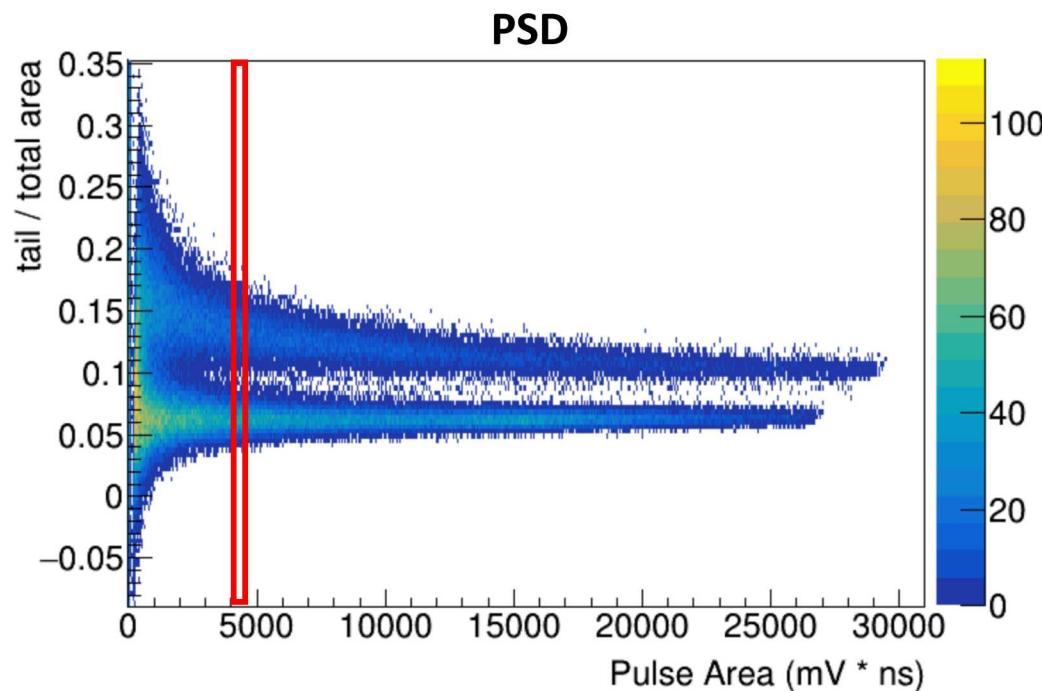
- J-series SiPM array
- CAEN DT5730 500 MHz, 14-bit digitizer
- Digitized four channels
 - Two channels with coupled to organic EJ-299 scintillator pillars
 - Two uncoupled channels with 10x amplification
- Temperature chamber
- Sources: AmBe, Cs-137

J-Series SiPM Array

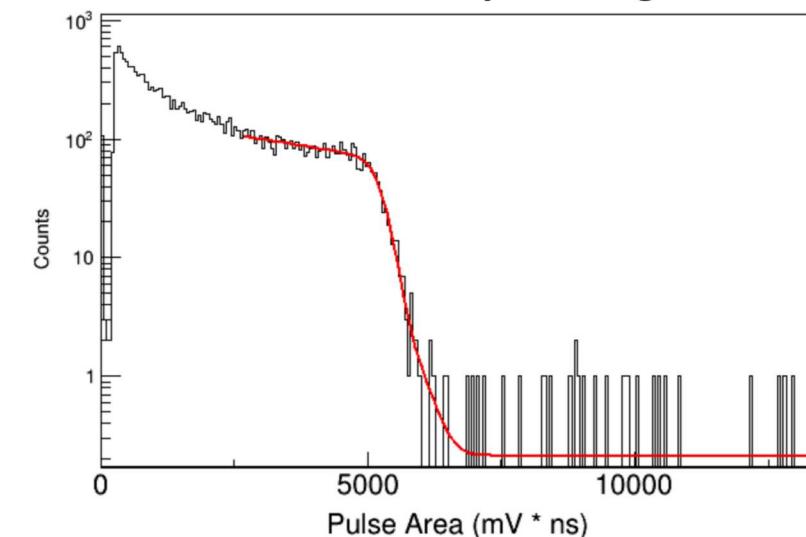


Pulse Shape Discrimination

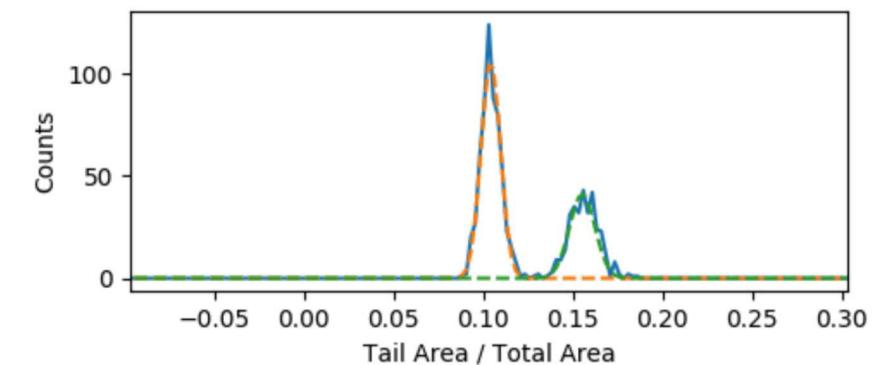
- Estimate the Cs-137 Compton edge location
- Take a vertical slice on 2D PSD plot
- Fit slice with a double Gaussian to calculate FOM



Cs-137 Compton Edge

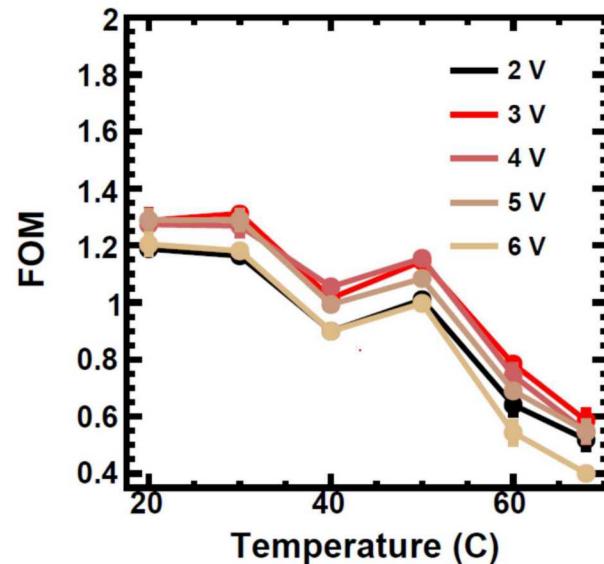
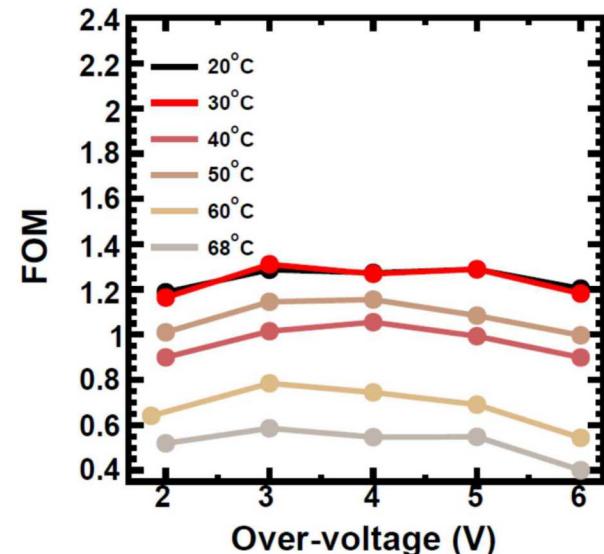


FOM



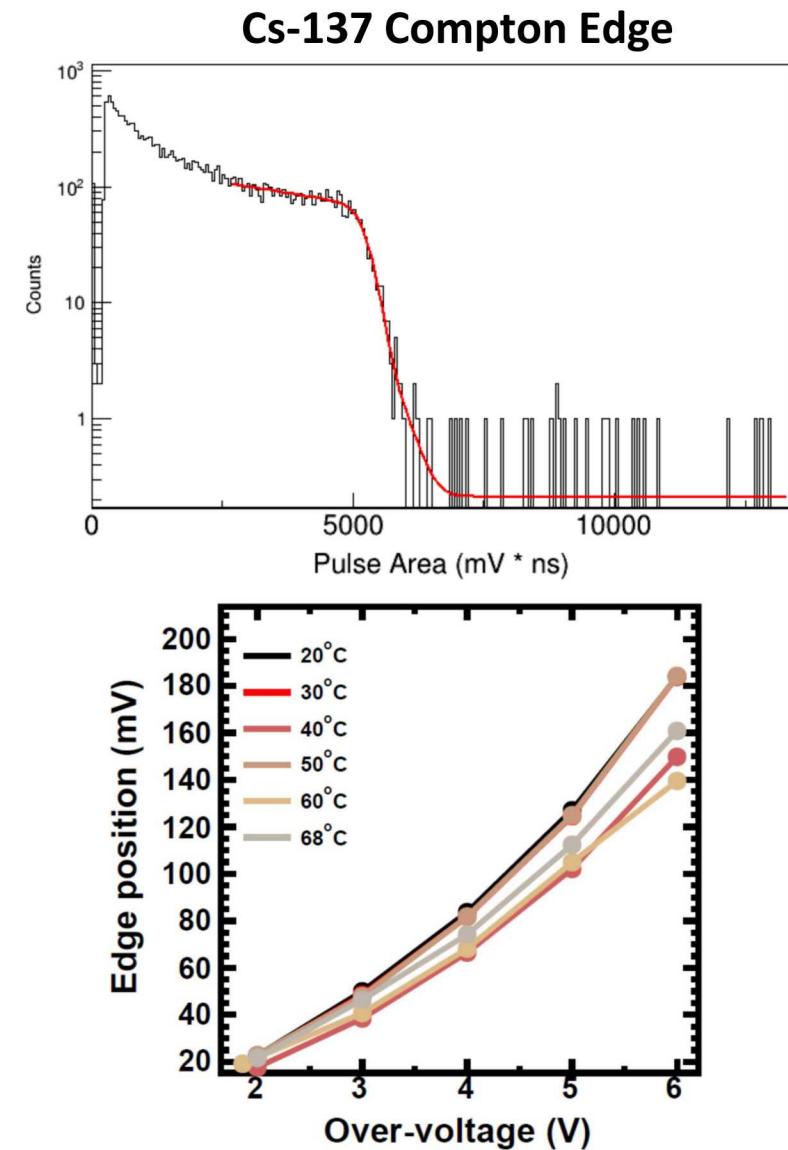
Temperature Response Results PSD and FOM

- Majority of the figure of merit degradation occurs above at 50°C
- Optical coupling issues may be the cause for a portion of the reduction in FOM
- FOM is relatively constant as over-voltage increases
- Discrimination of neutrons and gamma-rays becomes problematic at high temperatures
- FOM decreases as temperature increases



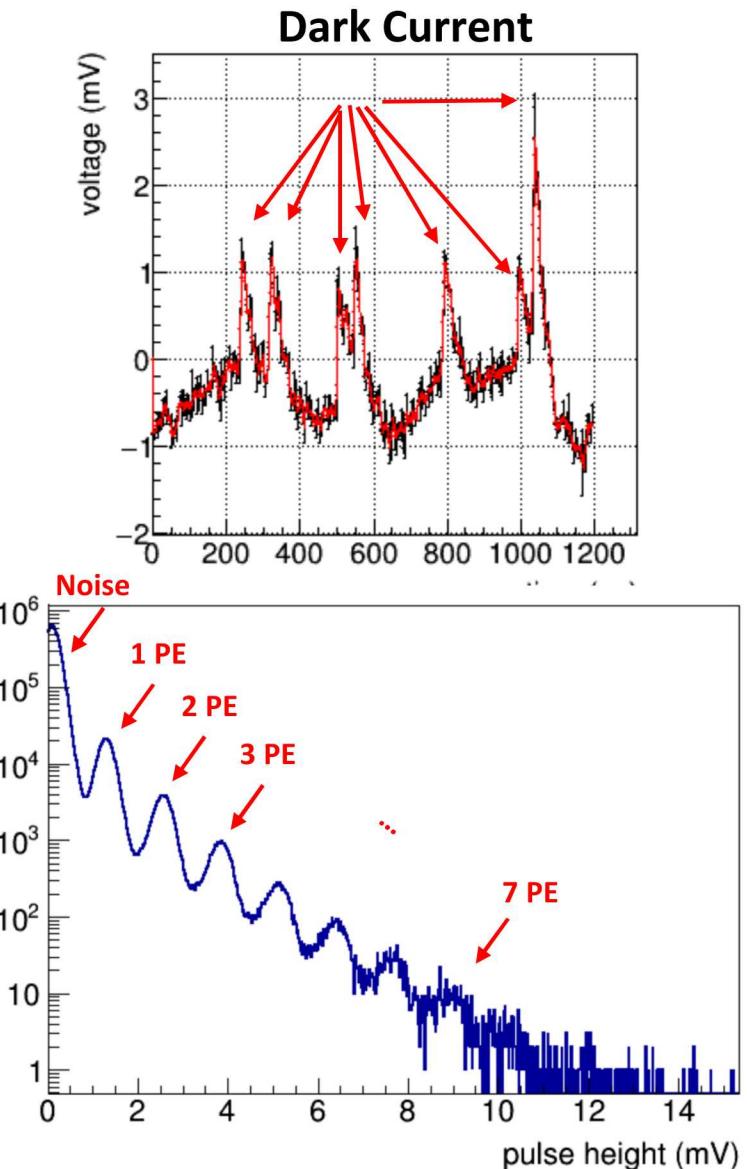
Compton Edge Position

- Fit the pulse height distribution with a convolved Gaussian and Heaviside step function to estimate the Compton edge position and
- Estimated edge position varies slightly at higher temperatures
- Edge position increases as expected at higher over-voltages due to increased gain



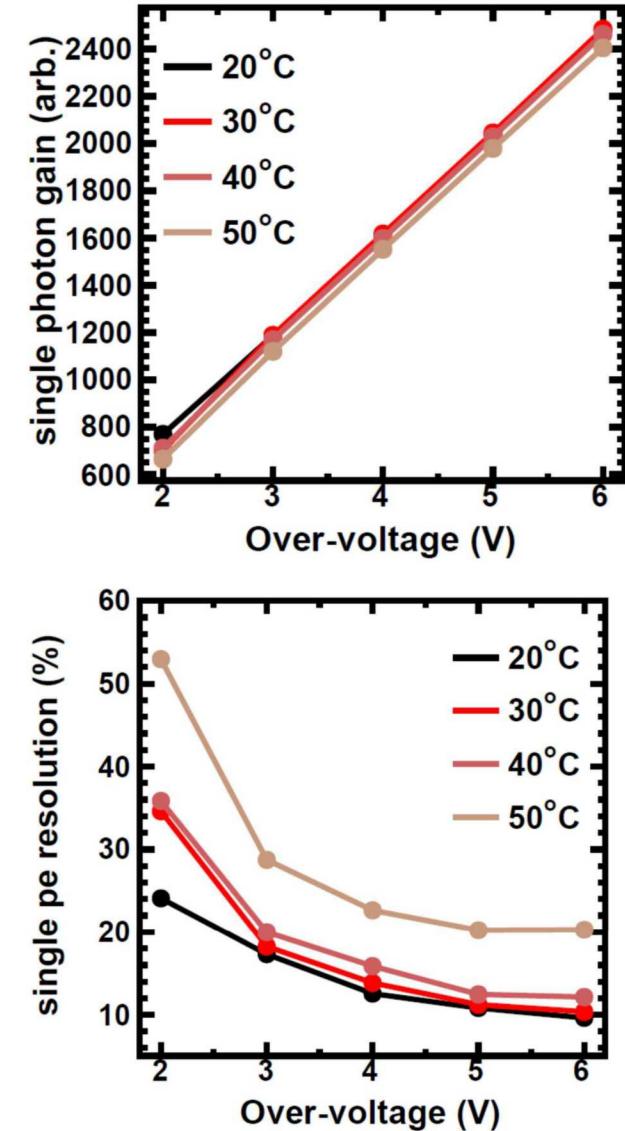
Dark Current

- Investigated dark current using the amplified uncoupled SiPM channels
- Estimated pulse height of dark current waveforms with a trapezoidal filter
- Subtracted noise peak by fitting a Gaussian to isolate single photo-electron peak



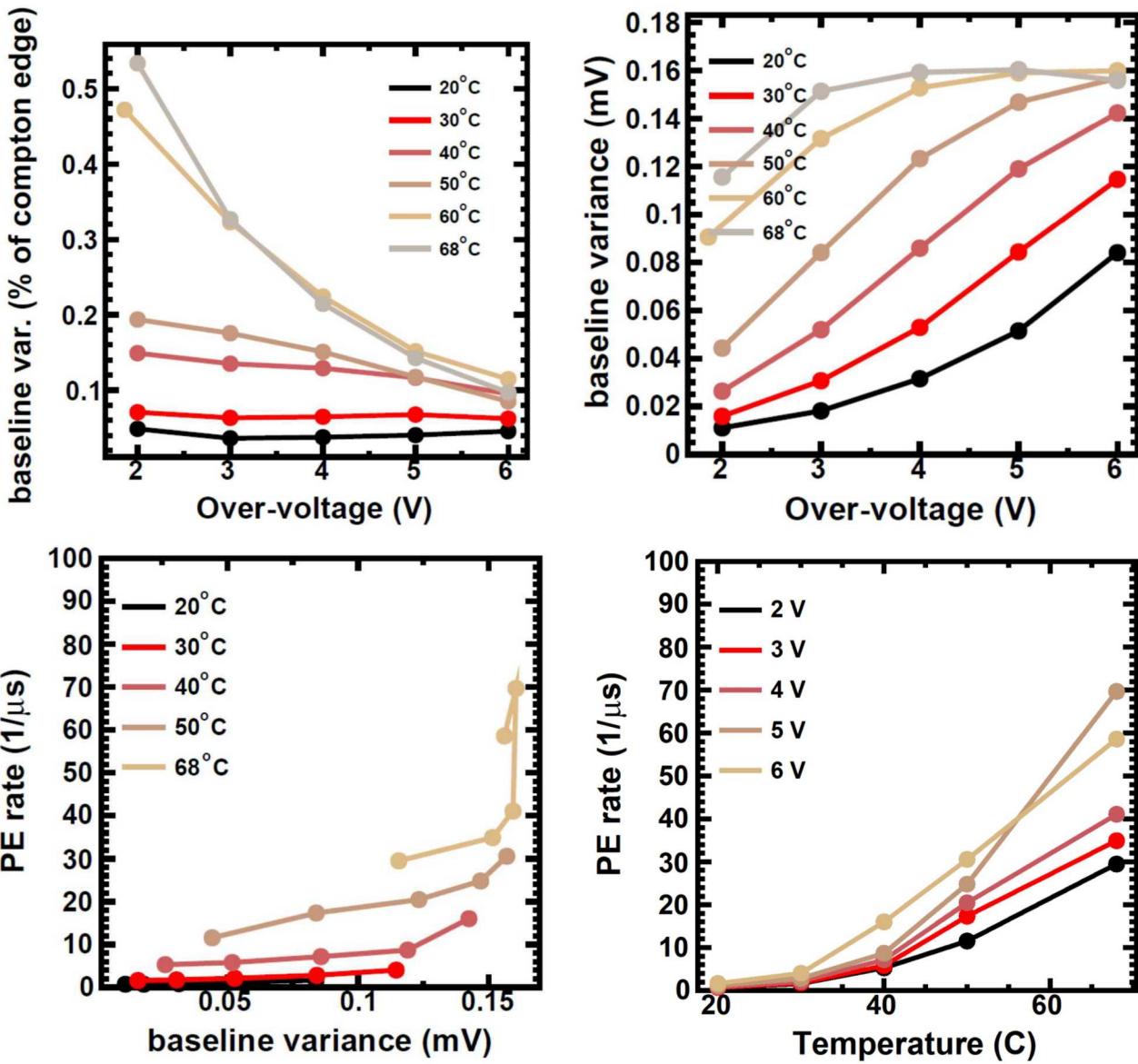
Single PE Gain and Resolution

- Results at 60°C and 68°C not shown due to no observable single PE responses
- Single PE gain not dependent on temperature and behaves as expected
- Break-down voltage correction supplied by the manufacturer retained comparable gain for all temperatures measured
- Single PE resolution decreases as over-voltage increases due to higher gain and photon detection efficiency
- Higher temperatures result in worse single PE resolution



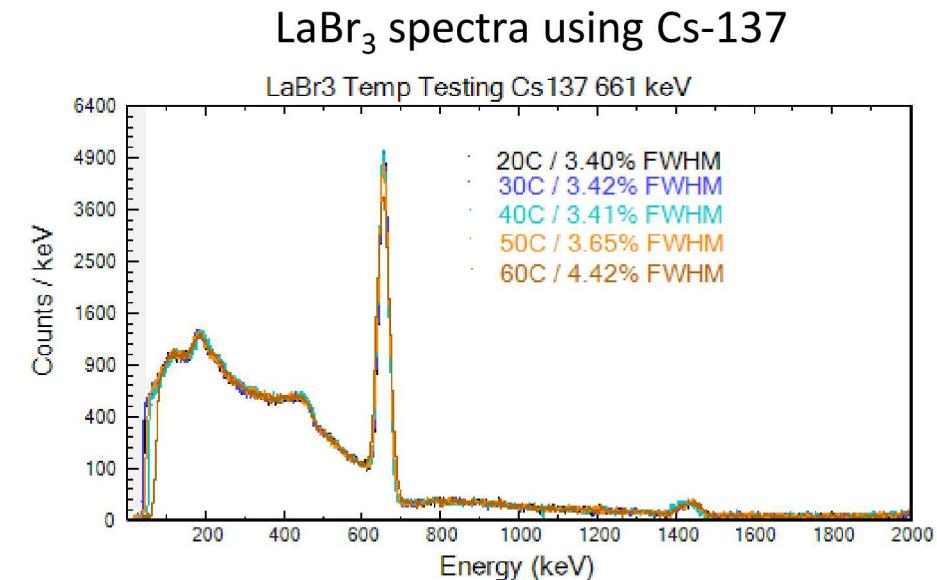
Experimental Setup

- Temperature and over-voltage both increase dark count rate as expected
- Baseline variance is based on the overall PE rate



Current/Future Work

- Expand testing to a summed 8 x 8 SiPM array
- Use 2" x 2" cylindrical organic and inorganic scintillators
- Automate measurements for minimal human interaction needed
- Acquire detector response functions for each scintillator/SiPM combination for simulation campaign



Conclusions

- Measured PSD capable plastic scintillator EJ-299 from 2V – 6V over-voltage and at temperatures from 20°C to 68°C
- Particle discrimination capability is possible at all temperatures tested
 - Degraded PSD above 50°C
- Manufacturer recommended breakdown voltage corrections worked
- Possible loss of low energy events due to larger baseline variations at high temperatures
- Summed 8 x 8 arrays
 - Linear increase in PE rate
 - Quadrature increase of baseline variance



Kyle Weinfurther
kjweinf@sandia.gov

