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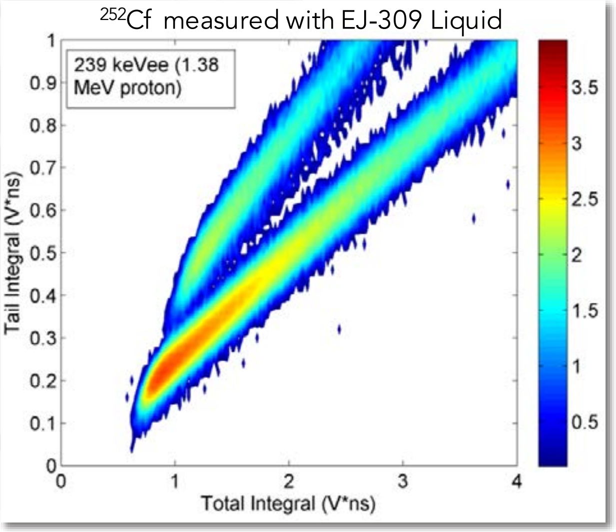
TEMPERATURE DEPENDENCE OF ORGANIC SCINTILLATOR RESPONSE

Motivation

- Versatility and robustness in radiation detection capabilities and equipment are priorities across the field of nuclear engineering
- Detection equipment encounters temperature gradients as it is transported or as the surrounding environment changes
- How do changes in temperature affect the performance of detection equipment?

Focus: Organic scintillator Detectors

- Three main components:
  - Organic scintillator (active volume)
  - Photomultiplier tube (PMT), or other photosensor
  - Voltage divider
- The shape of pulses can be analyzed to classify detected particles as photons or neutrons
- Each component of the detector has a distinct dependence on temperature; this analysis considers the temperature dependence of the system as a whole



Experimental Procedure

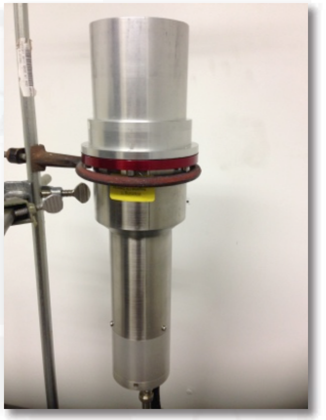
<u>Objectives:</u>

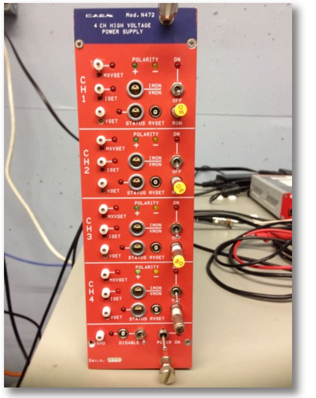
1. Characterize the calibration stability of a liquid scintillator with changes in temperature
2. Characterize the pulse shape discrimination (PSD) stability of a liquid scintillator with changes in temperature

- Measure radiation sources at various controlled temperatures: room temperature, 30°C, 40°C
- Investigate pulse integral distribution, energy resolution, and pulse shape discrimination at each temperature

Equipment

- EJ-309 liquid scintillator detector
  - Cylindrical active volume: 3'' diameter x 3'' height
  - ORTEC embedded PMT
- CAEN DT5720 digitizer
  - 4 analog input channels
  - 2 V dynamic range
  - 4 ns time resolution

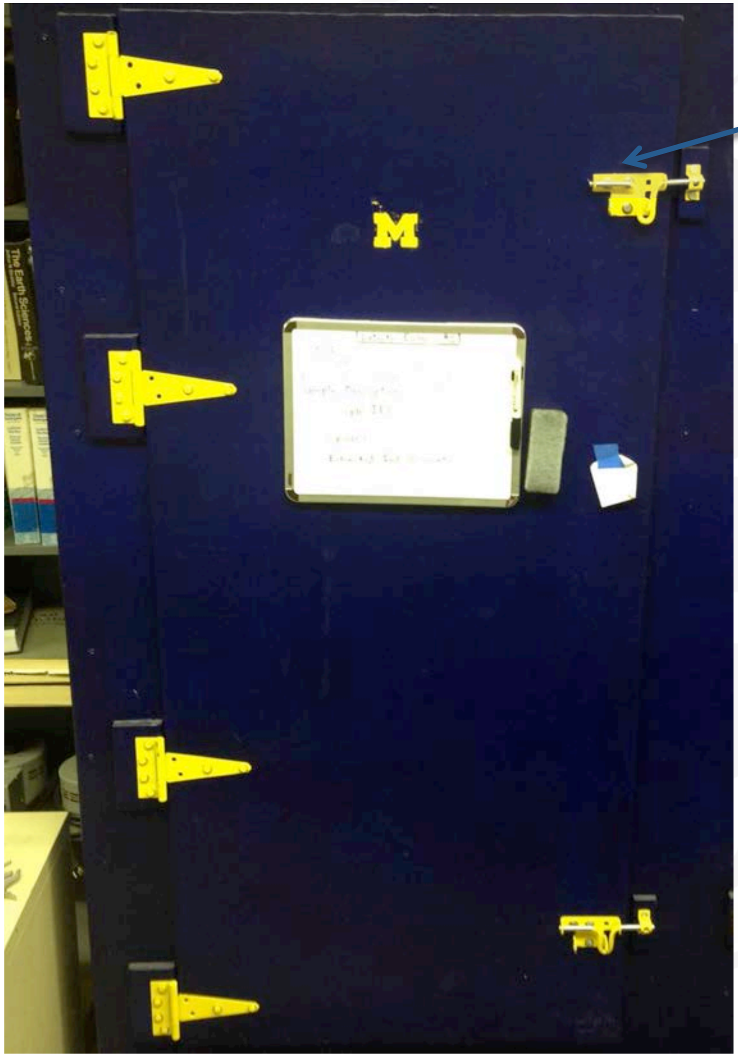




- CAEN N472 4-channel high voltage power supply
  - Selectable polarity
  - ±3 kV at 3 mA; ±6 kV at 1 mA
- EXTECH SD 700 Pressure/ Humidity/ Temperature Datalogger
  - Variable sampling rate (set to .033 Hz)
  - Working temperature range: 0°C – 50°C
  - Temperature measurement uncertainty of ±0.8°C (1 SD)

- Thermal chamber controlled by JULABO FL601 recirculating cooler
  - Chamber dimensions: 34'' x 24'' x 84''
  - Working temperature range: -20°C – 40°C

Thermal Chamber and Cooler



Thermal Chamber

FL601 Recirculating Cooler

Experimental Setup

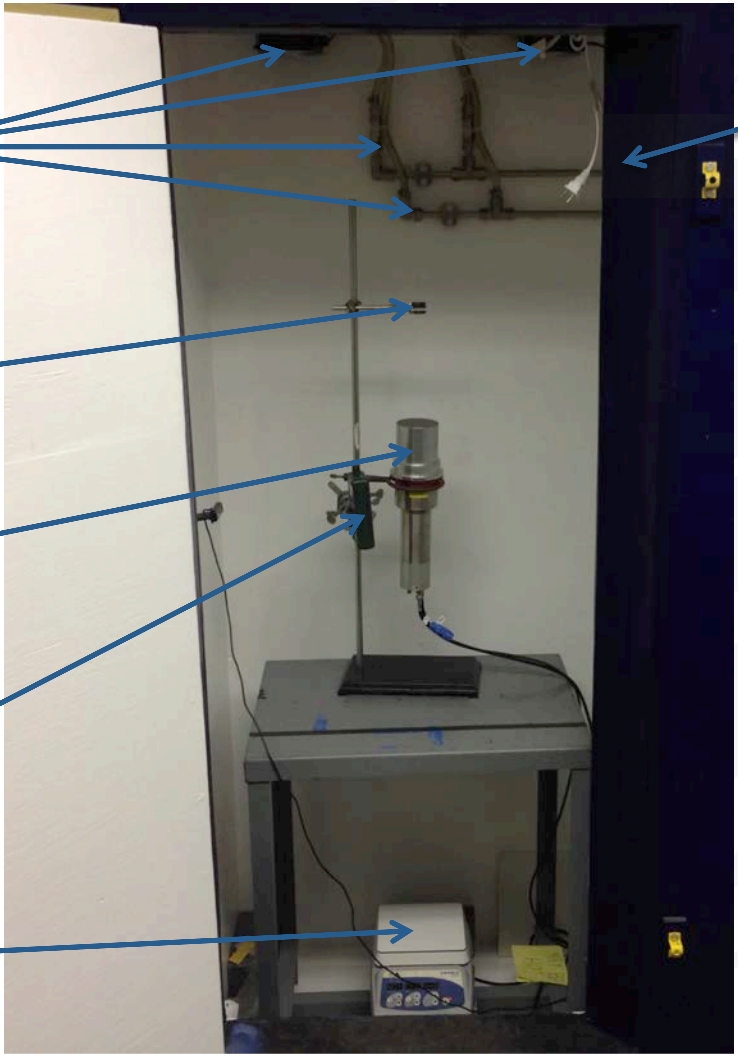
Fans and pipes for temperature control

Source

EJ-309 Detector

SD700 Datalogger

Hot plate

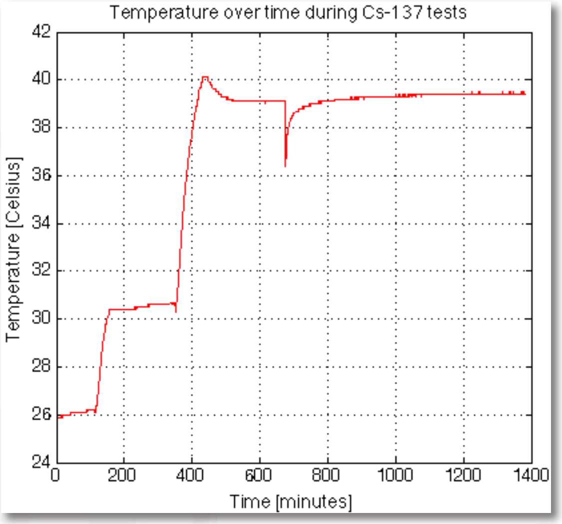


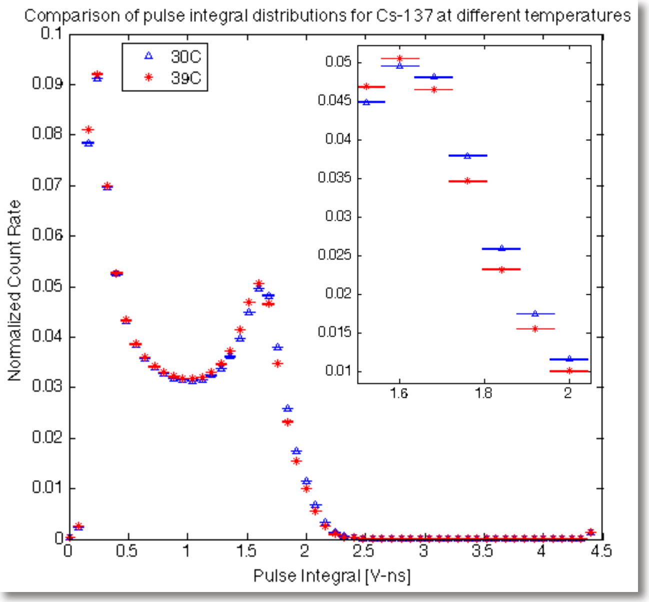
Thermal Chamber

FL601 Recirculating Cooler

Calibration Stability
Approach

- Cs-137
  - Emits gamma rays of a single energy
  - Compton edge provides a fixed reference for calibration
- Steady state temperatures
  - 26°C, 30°C, 39°C
- Method
  - The Compton edge is defined at 80% of the max of the falling edge of the Compton continuum
  - The energy resolution is the FWHM of the Gaussian fit of the falling edge of the Compton continuum



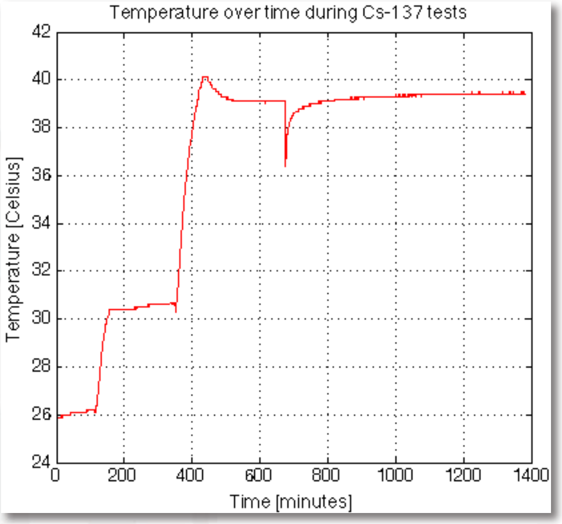


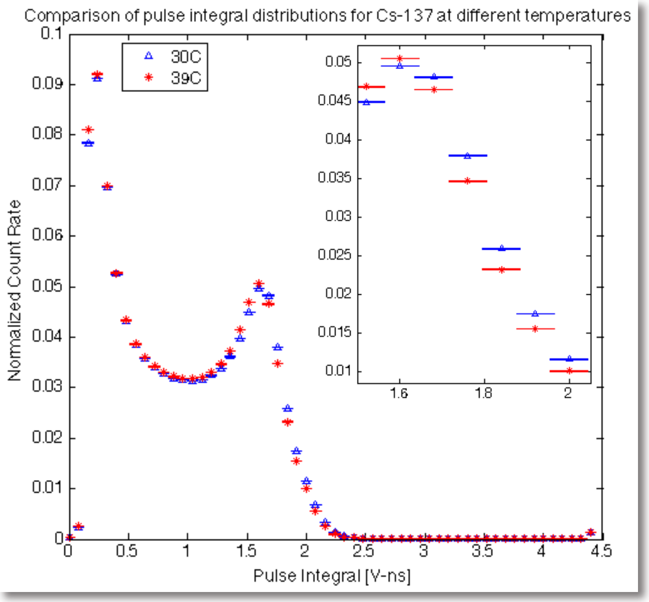
Calibration Stability

Results

Temperature [°C]	Compton Edge [V-ns]	Energy Resolution [%]
30	1.75 ± 1.93e-3	48.5
39	1.72 ± 2.06e-3	44.3

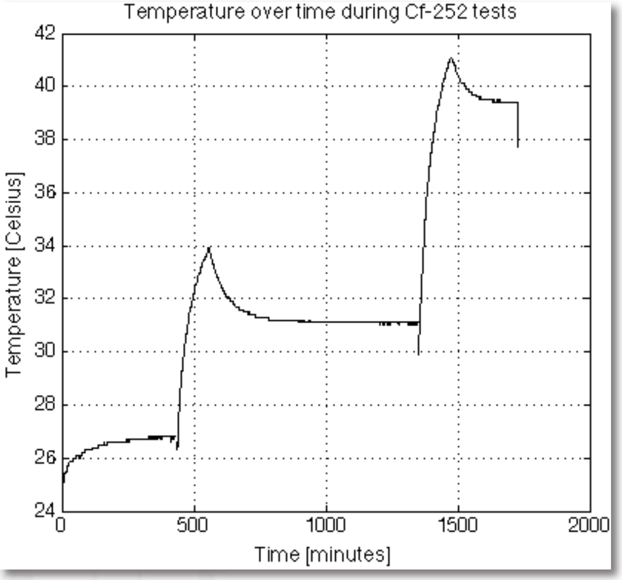
As temperature increases, the Compton edge shifts towards lower pulse integral values, which corresponds to a decrease in gain.

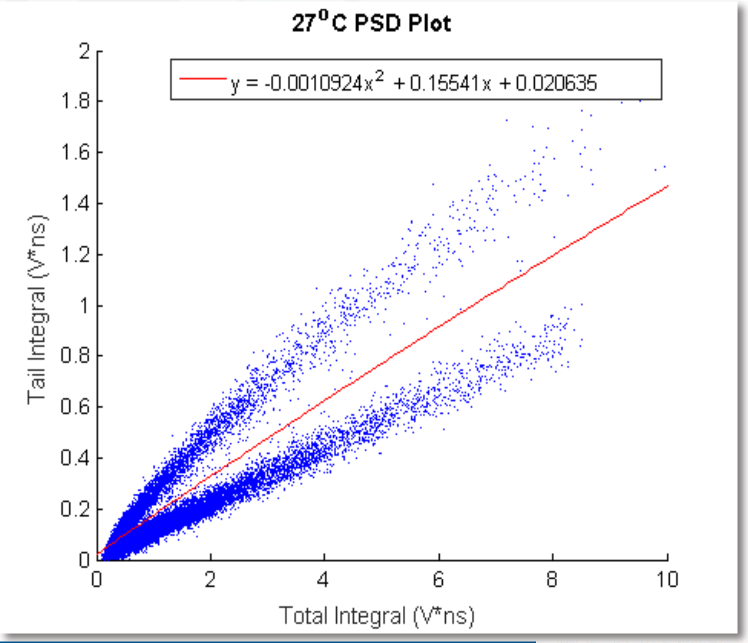




PSD Stability
Approach

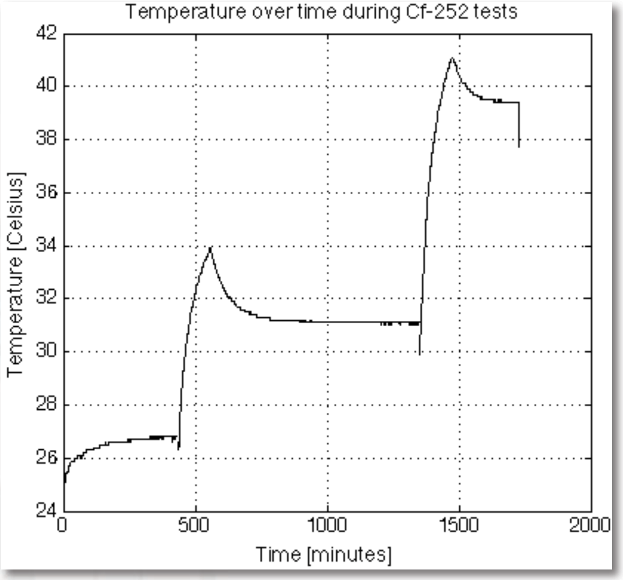
- Cf-252
  - Spontaneous fission source: produces gamma rays and neutrons
- Steady state temperatures
  - 27°C, 31°C, 39°C
- Method
  - Optimize PSD parameters
  - Fit a quadratic as the gamma-neutron discrimination line

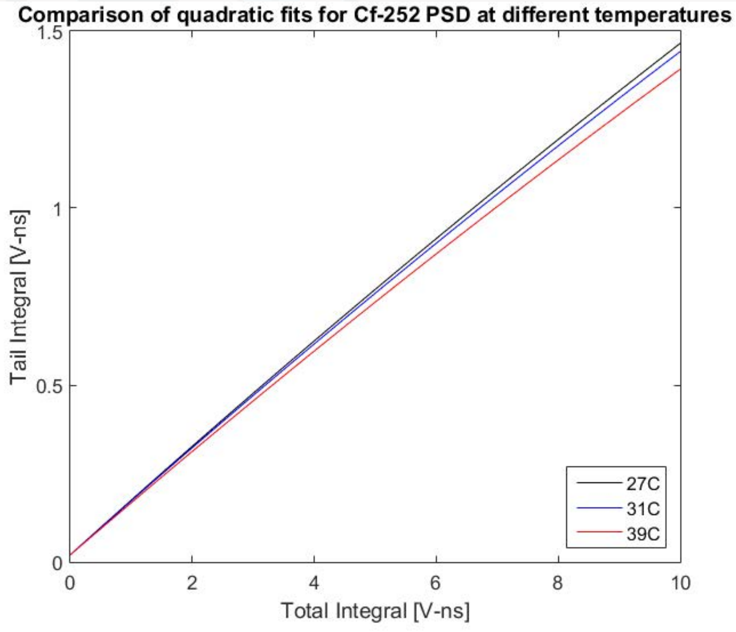




PSD Stability
Results

- Cf-252
  - Spontaneous fission source: produces gamma rays and neutrons
- Steady state temperatures
  - 27°C, 31°C, 39°C
- Method
  - Optimize PSD parameters
  - Fit a quadratic as the gamma-neutron discrimination line
  - Quantify temperature effects using the gamma:neutron ratio





PSD Stability

Results

Temperature	y = Ax^2 + Bx + C			Gamma:neutron
°C	A	B	C	Using 27°C PSD coefficients
27	**-1.09e-3**	**0.155**	**2.06e-2**	4.57
31	-1.12e-3	0.153	2.07e-2	4.59
39	-1.13e-3	0.149	2.01e-2	4.63

As temperature increases, the PSD clouds shift towards lower tail integral values.

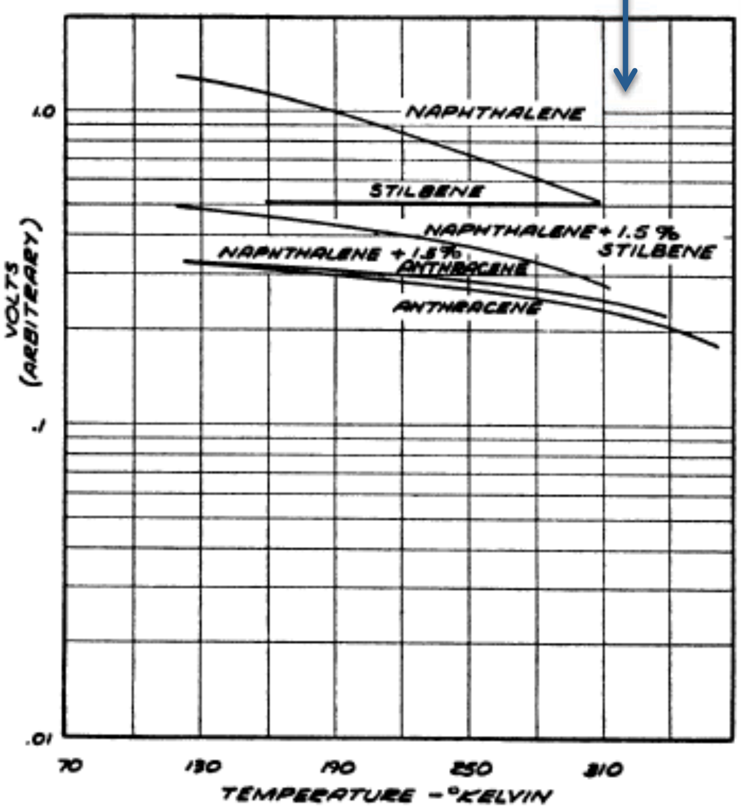
Conclusions

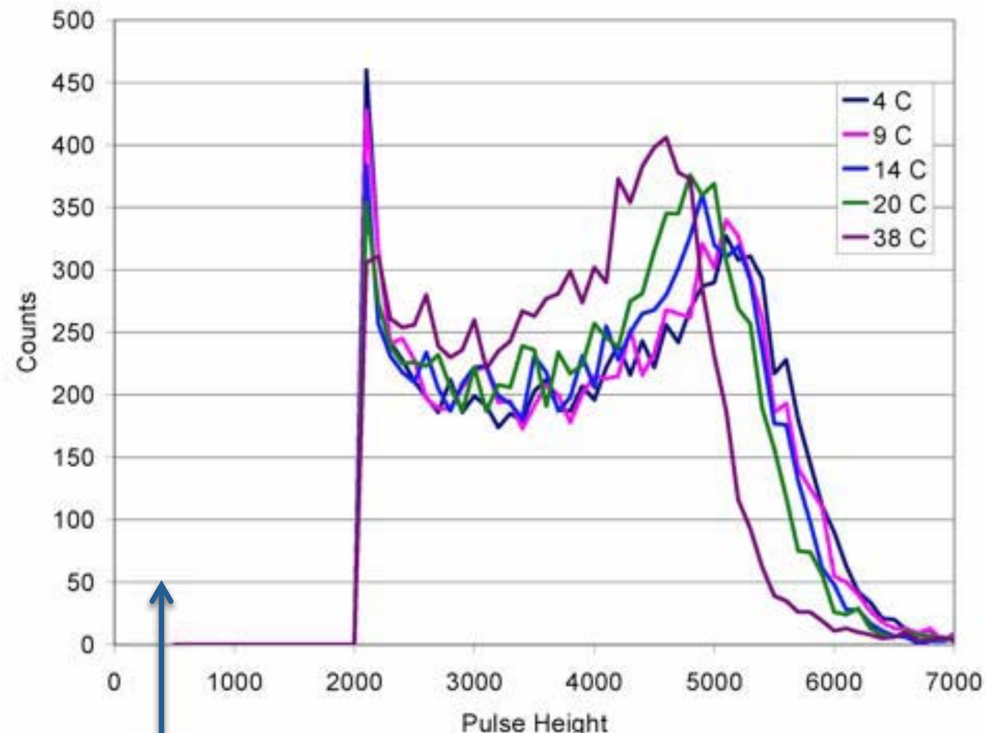
- With increasing temperature:
  - Compton edge shifts towards lower pulse integral values
  - PSD clouds shift towards lower tail integral values
- Future work:
  - Re-run room temperature Cs-137 experiment
  - Test PMT with LED-driver to de-couple temperature dependences
  - Transient temperature experiments

QUESTIONS?

Temperature variation of the Integrated light output 'Excluding' the PMT

PRL Liebson and Keller 1950

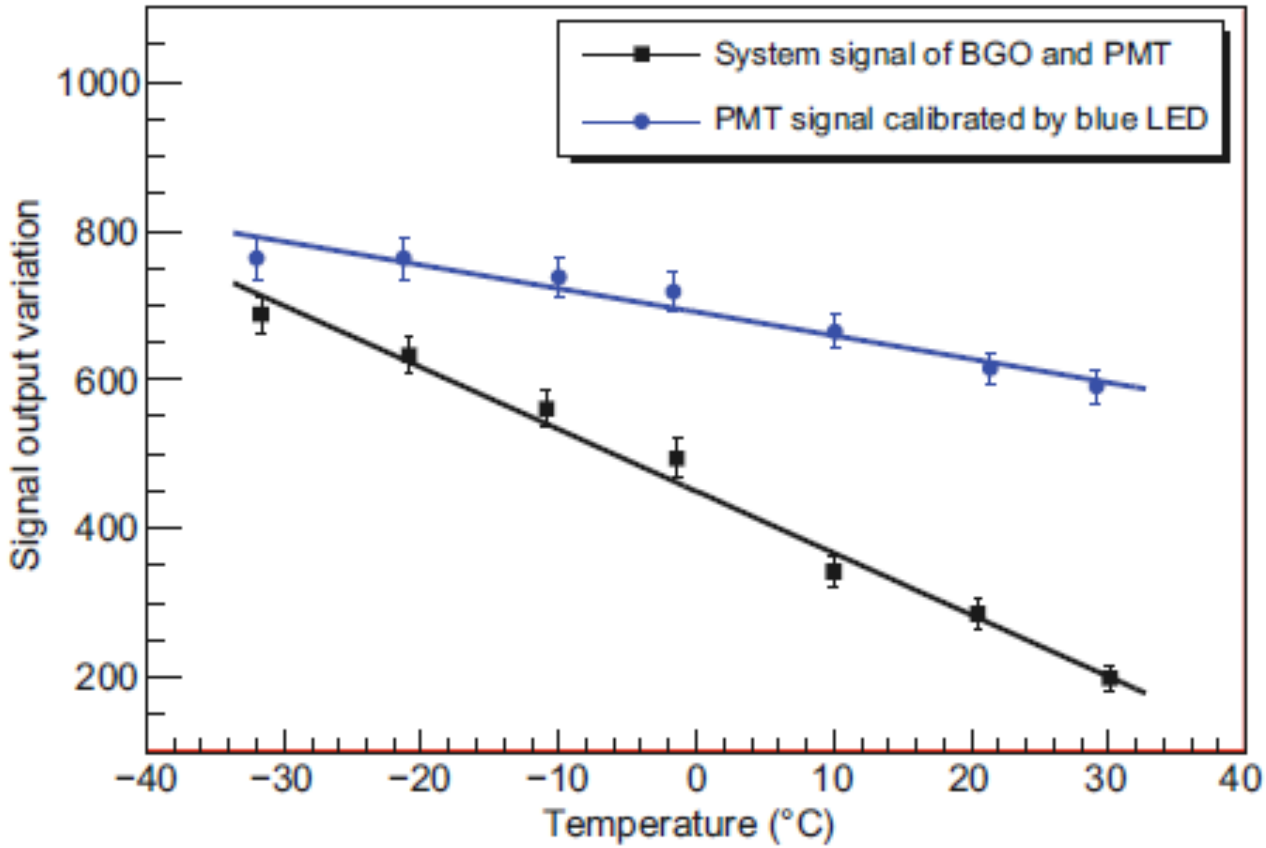


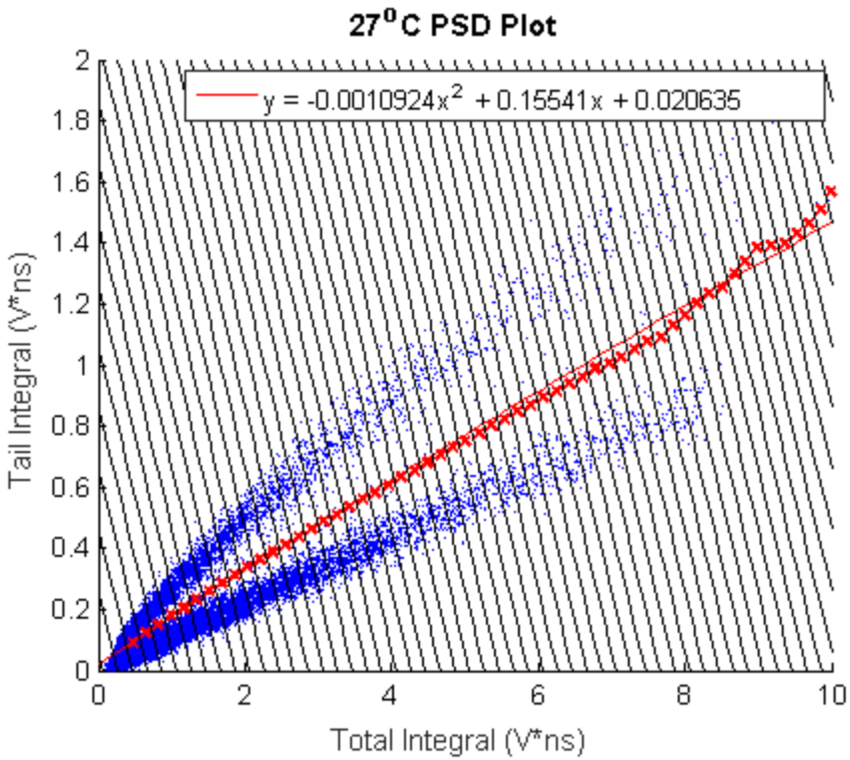


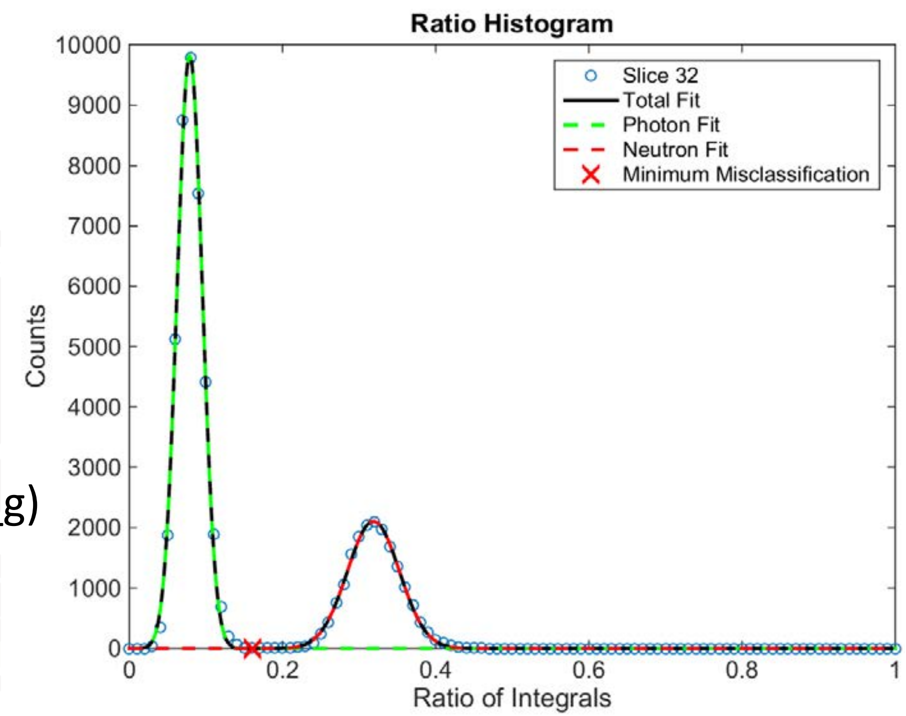
Temperature Dependency Analysis of Light Output from an EJ-301 Liquid Scintillator

Gehman et al. IEEE 2007

The temperature dependence of the BGO-PMT system and the PMT itself.
Wang P L, *et al. Sci China-Phys Mech Astron* October (2014) Vol. 57 No. 10







FOM = (peak separation) / (FWHM_n + FWHM_g)

PSD Figure of Merit

Temperature	Figure of Merit	
°C	Low Energy	High Energy
27	0.81	1.73
31	0.83	1.76
39	0.84	1.77

PSD Integrals