Systematic studies of a sapphire bolometer at 10-100 mK

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Introduction

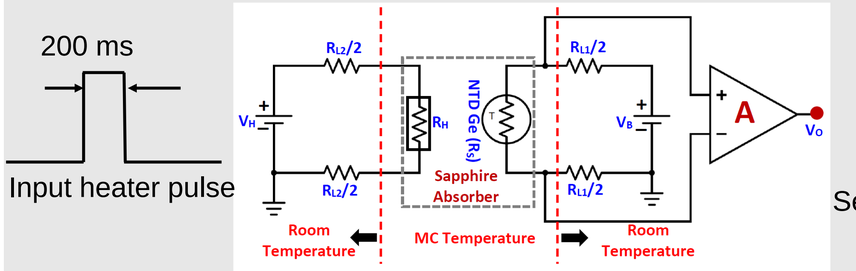
- Tin based cryogenic bolometer is being developed to study NDBD in ^{124}Sn in the upcoming underground facility, India-based neutrino observatory in India [1].
  $^{124}Sn \rightarrow {}^{124}Te^{*}$ $T_{1/2} > (0.8 - 1.2) \times 10^{21} y$ [2]

✓ Moderate $Q_{\beta\beta}$ = 2292.62 ± 0.39 keV, Moderate Isotopic abundance = 5.79 %
✓ Sn becomes super conducting at 3.7 K
✓ Can be made into a bolometer (T<100 mK) with excellent energy resolution

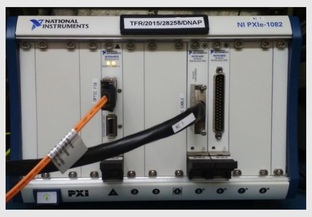
- A sapphire bolometer test setup is made with the indigenously made NTD Ge sensor to understand various systematics affecting the performance a bolometer.
- Very low specific heat (20 fJ/K/g at 10 mK) for sapphire, $\theta_D \sim 1042$ K [3].
- Sapphire tested at temperature as high as 1.5 K as a bolometer [4].
- An understanding of the systematics is essential to study superconducting tin bolometer.

Experimental setup and DAQ

- Low temperature measurements were carried out in a custom designed high cooling power Cryogen Free Dilution Refrigerator (CFDR) [5].
- **A sapphire bolometer consisting of indigenously developed NTD Ge thermistors [6,7] and a heater.**

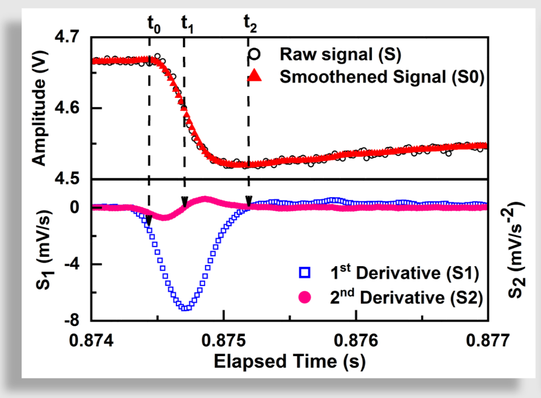


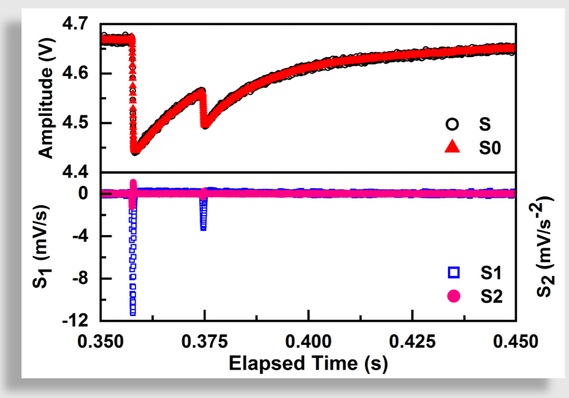
- PXI-6281: 2 single ended 16 bit DAC output channels and 8 differential 18 bit ADC input channels.
- The amplifier output is recorded in an ADC input channel with a sampling rate of 50 kS/s.



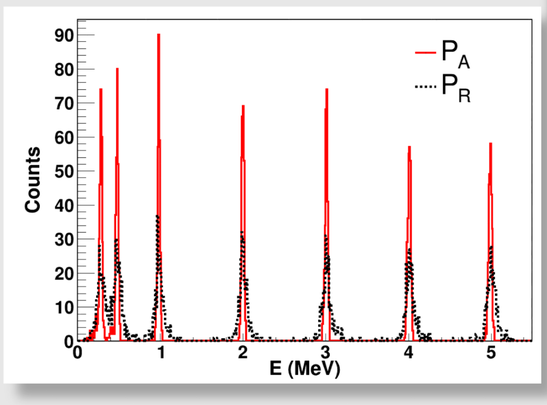
Pulse height analysis technique

- **A ROOT based C++ program is developed for off-line pulse shape analysis of the bolometer signal using Savitzky-Golay technique [8]**





Parameter	Definition
P_R	Height of S0 pulse
P_H	Height of S1 pulse
P_A	Area under S1
t_r (= t_1-t_0)	Rise time
t_p (= t_2-t_0)	Peaking time
t_d (= t_3-t_2)	Decay time

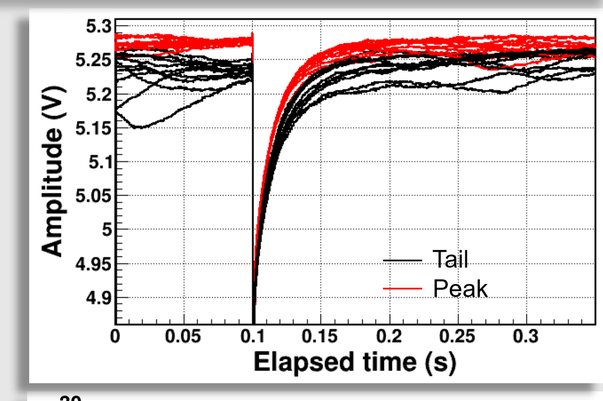


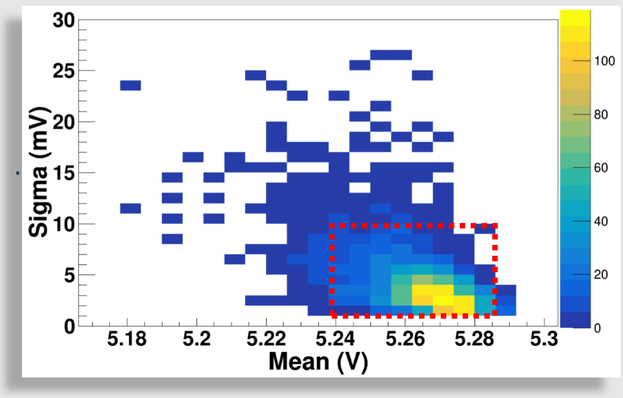
E (MeV)	$\frac{\sigma_R \sim \sigma_H}{\sigma_R}$ (%)	$\frac{\sigma_R \sim \sigma_A}{\sigma_R}$ (%)
1	49	68
2	54	66
5	53	62

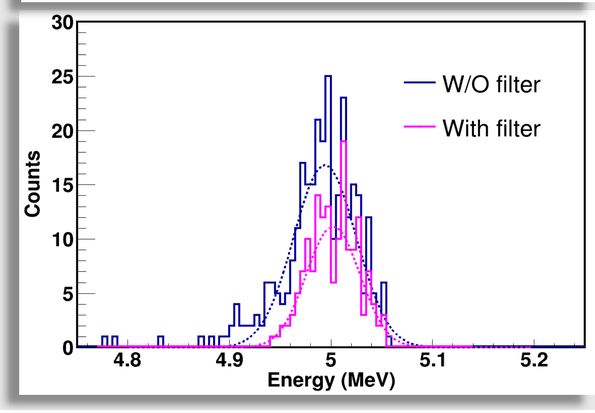
Effect of unstable baseline

- Pulse height depends on average baseline.
- Baseline drifts can significantly deteriorate energy resolution.
- Pulses with unstable baseline needs to be rejected.

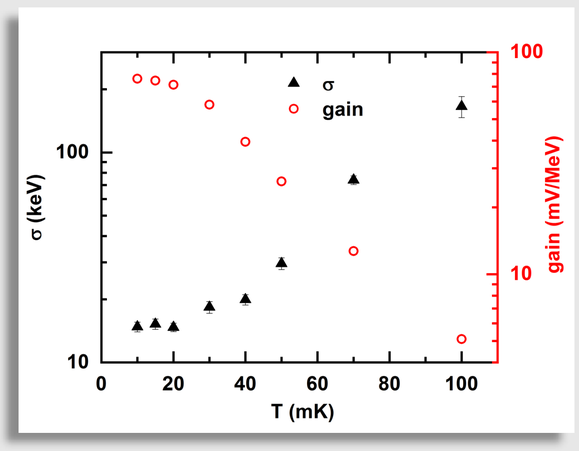
- A rectangular gate is applied on the 2D distribution between mean and sigma of the baseline of 99 ms for rejecting pulses with unstable or drifted baseline.

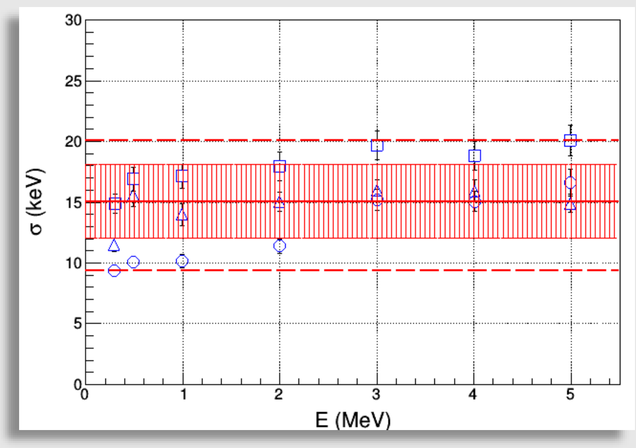




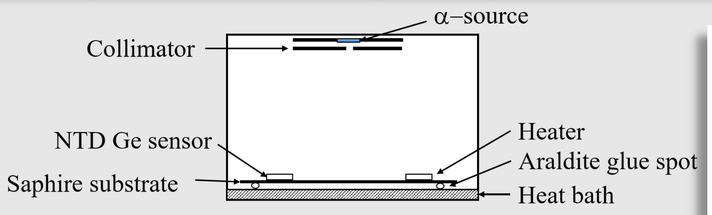


Response to heater pulses

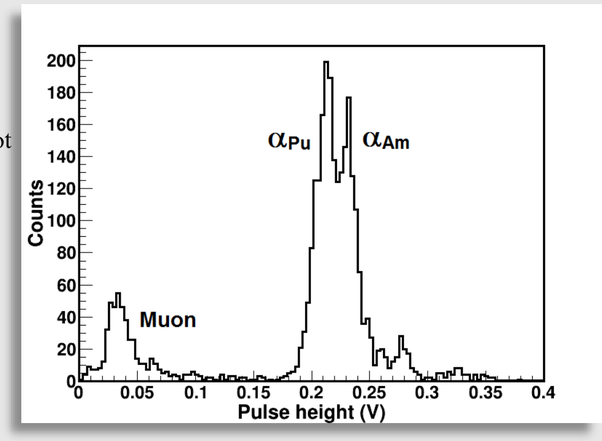




Response to alpha pulses



Isotope	E (keV)	I (%)
^{239}Pu	5105.5	11.94
	5156.59	**70.77**
	5144.3	17.11
^{241}Am	5442.8	13.1
	5485.56	**84.8**



Summary

- A pulse height analysis program implementing Savitzky-Golay filter technique is demonstrated.
- Response of the sapphire bolometer is studied with heater pulses at 10-100 mK.
- The energy resolution is found to be improving with lowering the temperature down to ~ 25 mK but it is nearly constant (15 keV ± 3 keV) below 25 mK.
- About a factor of 5 improvement in the energy resolution is needed to achieve the design goal.
- Response of the sapphire bolometer with an alpha source is shown.

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