Determining the energy dependence of the α band in $CaWO_4$

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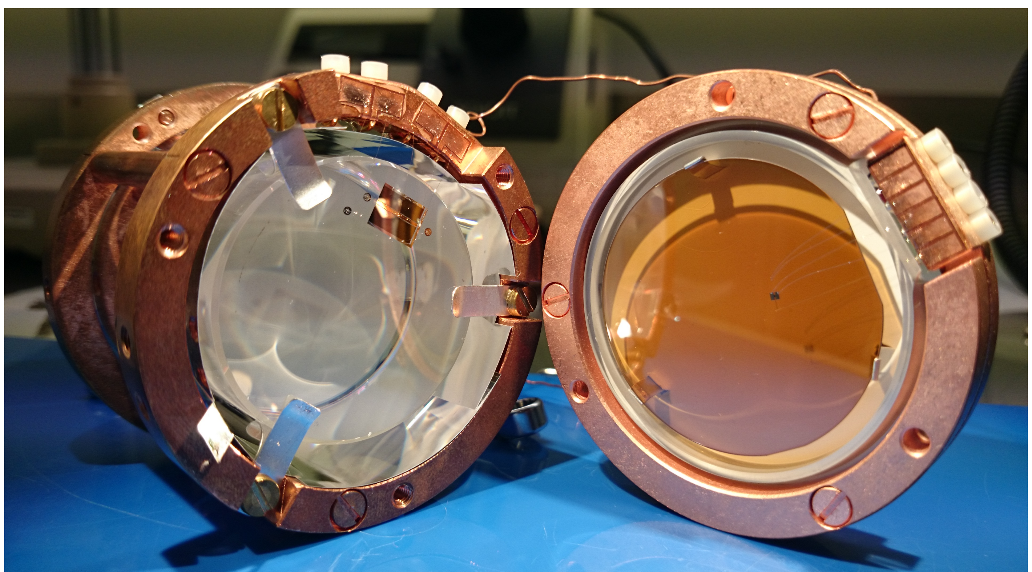
Detector Basics

- Particles deposit phonons and scintillation light in the $CaWO_4$ crystal.
- Phonons heat the crystal. Photons are absorbed by a silicon-on-sapphire disc, converting them into phonons in the disc.
- Two transition edge sensors (TES) vary their resistance with the resulting temperature changes. SQUIDs measure the change in current.
- The crystal is kept at 8mK, and the TES are heated to remain at the correct operating point.



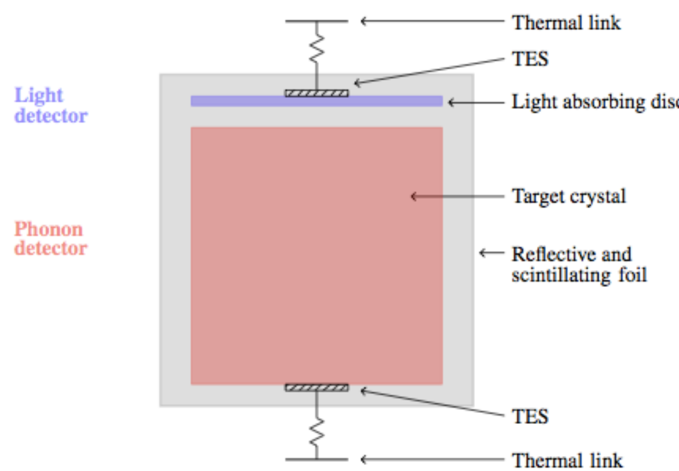
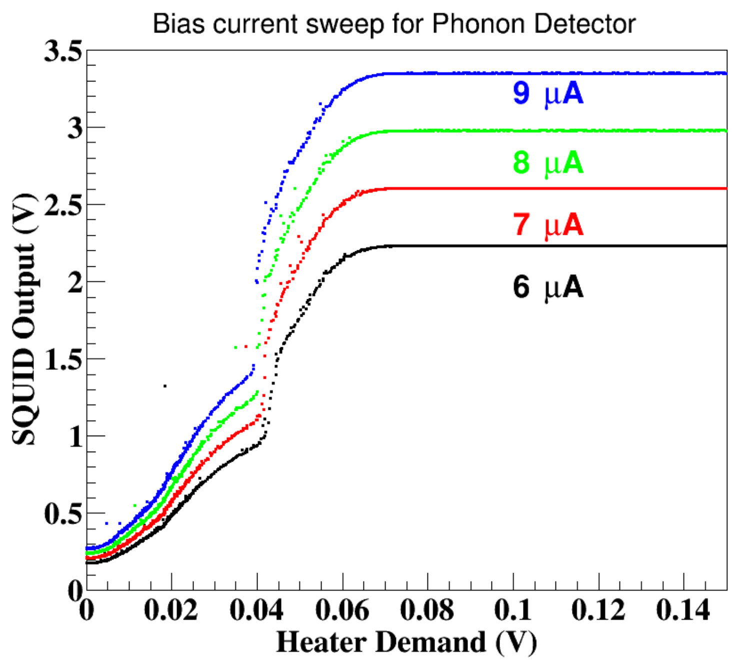
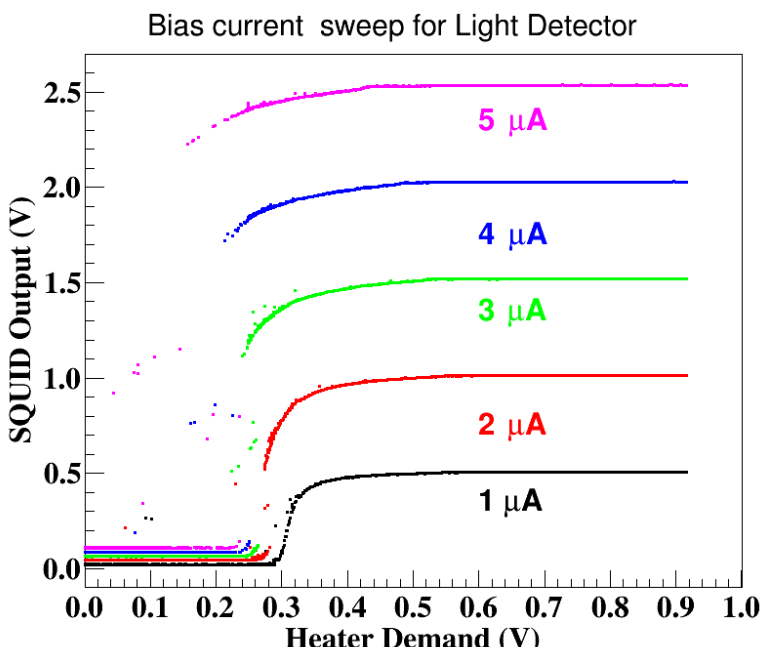


Figure 2.7. – Schematic drawing of a CRESST detector module.

Mounting and Sources

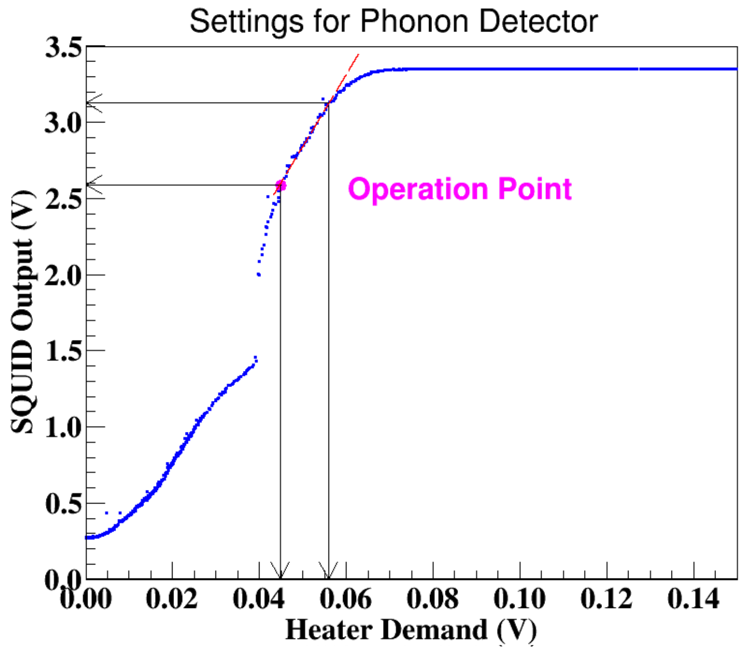
- The detector is mounted in a way that minimizes high frequency vibrations, which create noise.
- The goal of the measurements is to examine the detector response to alpha particles at low energies.
- Sources used:
  - U-238 (4.3 MeV α emitter), in solution, with teflon sheet to smear energies to lower values.
  - Sm-147 (2.3 MeV α emitter), in bulk, with gold foil to prevent recoil nuclei from reaching detector.
  - Am-241 (59.5 keV γ emitter)

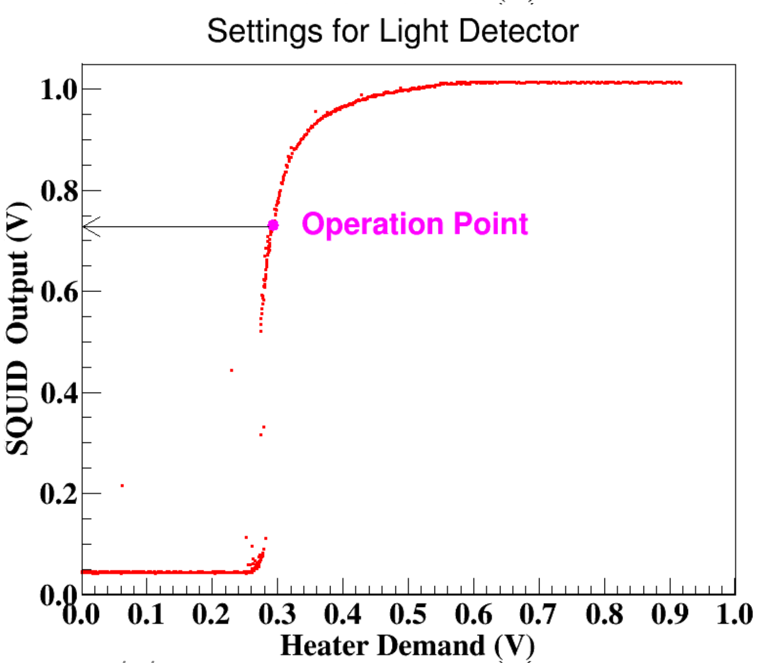




Tuning the TES

- The TES transition region isn't perfect– its slope can vary.
- Want to operate the detector at the point with:
  - the largest possible linear region, so dynamic range is maximized.
  - the highest possible slope, so sensitivity is maximized.
- To maintain stability, artificial heater pulses are injected. Heater demand is tuned to keep its amplitude stable.





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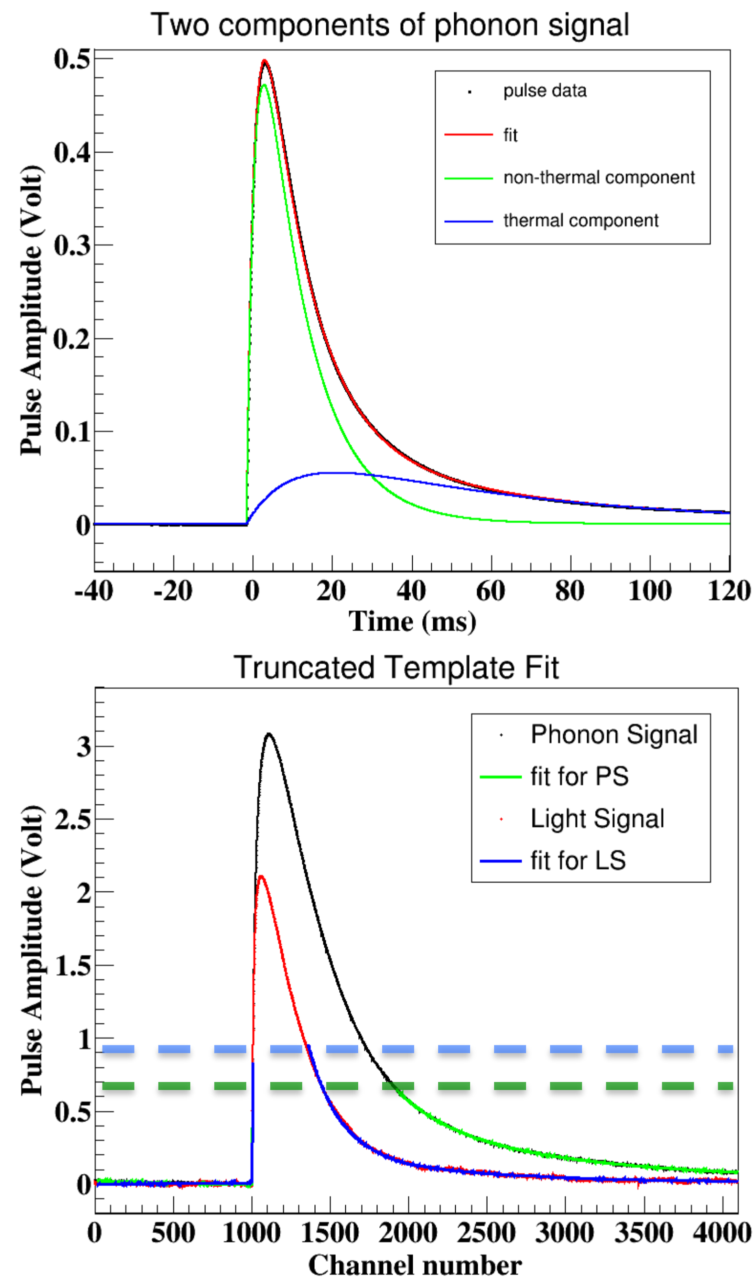
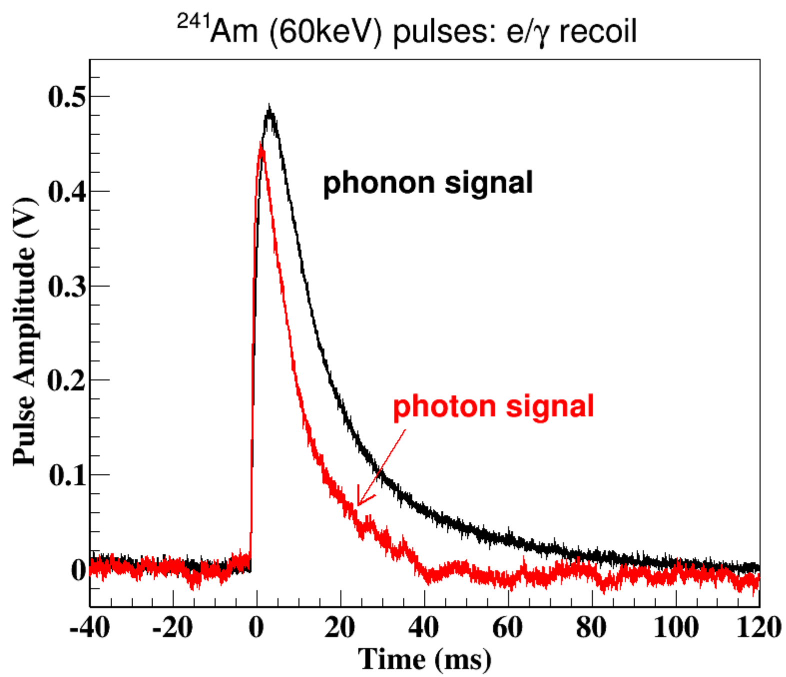
Pulse Shapes

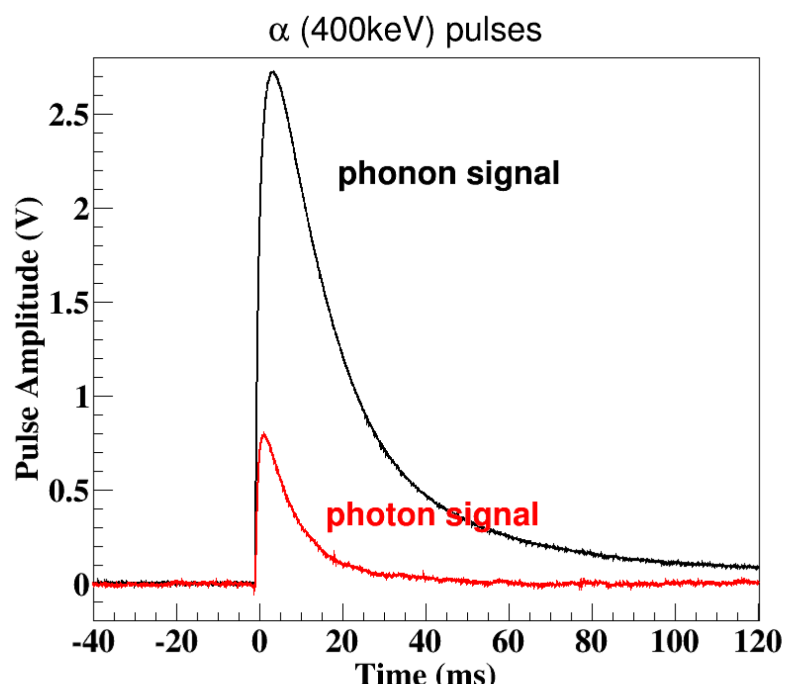
- Pulses are made up of a non-thermal fast component and a thermal slower-decaying component.
- Over the linear part of the TES transition, pulse amplitude correlates with energy deposited. For large pulses though, amplitude underestimates energy.
- Therefore, to find the energy of large pulses, we truncate the fit at some amplitude. Then we use a fitted template to estimate what the amplitude of those pulses would be if the TES transition were linear for that range.



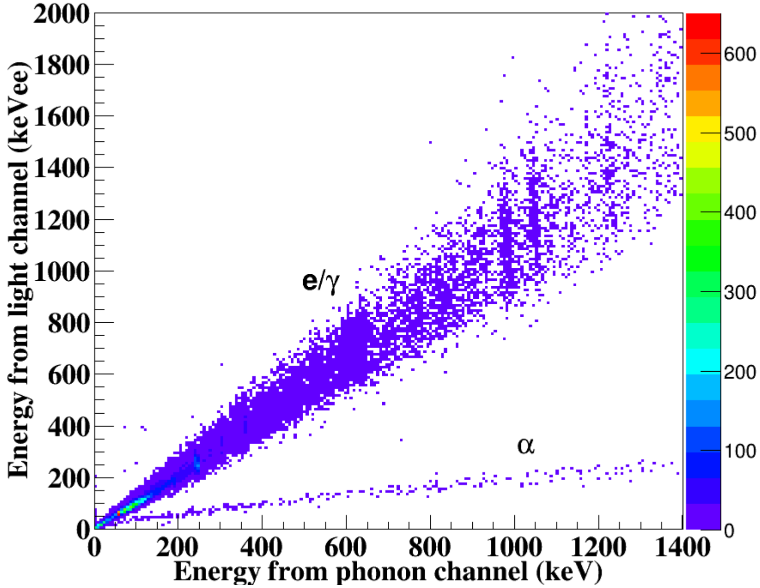
Light yield

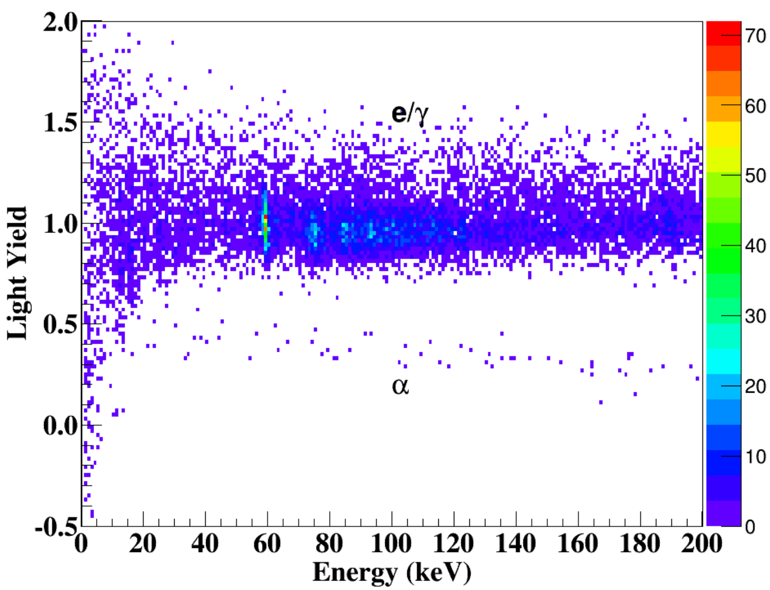
- Using the 59.5 keV peak from Am-241, we normalize the scintillation photon to phonon yield to 1 for electron and gamma interactions.
- Alpha particles and nuclear recoils yield about ¼th as much scintillation light.





Preliminary Data:





The α band

- Since WIMP signals are nuclear recoils, understanding where the e/ϒ and α bands lie is vital to understanding backgrounds for WIMP searches.
- In past analyses, α bands were extrapolated from high-energy quenching factors assuming a constant light yield ratio.
- Work by Karoline Schäffner (our tutor) showed that this wasn't the case– low energy α particles deposit more light than expected.
- More measurements like this one will help determine the α band energy dependence and set stronger bounds on WIMP interactions.

Acknowledgements

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