Self-absorption and Phonon Pulse Shape Discrimination (PSD) in Scintillating Bolometers

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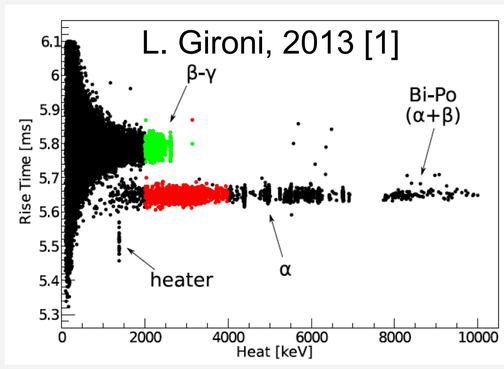
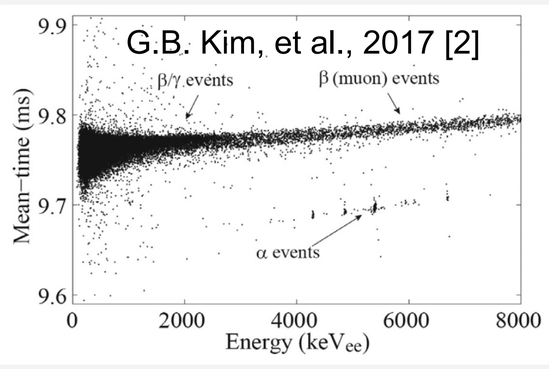
Abstract

Here we show that self-absorption of photons in scintillating bolometers differentiates phonon pulse shapes between α and β signals, and discuss novel particle detectors with single phonon readout and maximized self-absorption for sub-keV particle discrimination.

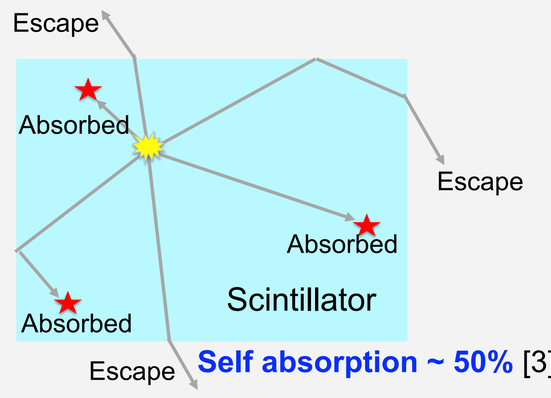
Phonon Pulse Shape Discrimination

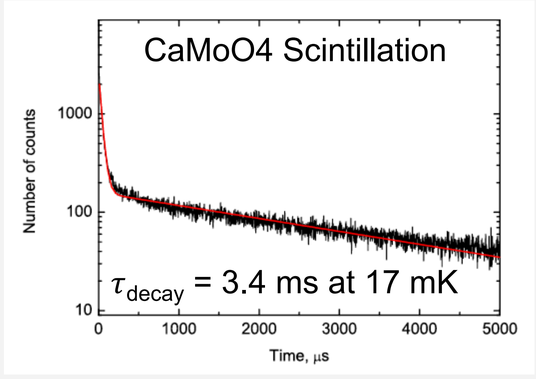




- ✓ Using pulse shape differences in phonon signals.
- ✓ Often stronger than particle discrimination using heat/light ratio
- ✓ Origin is not fully understood yet.

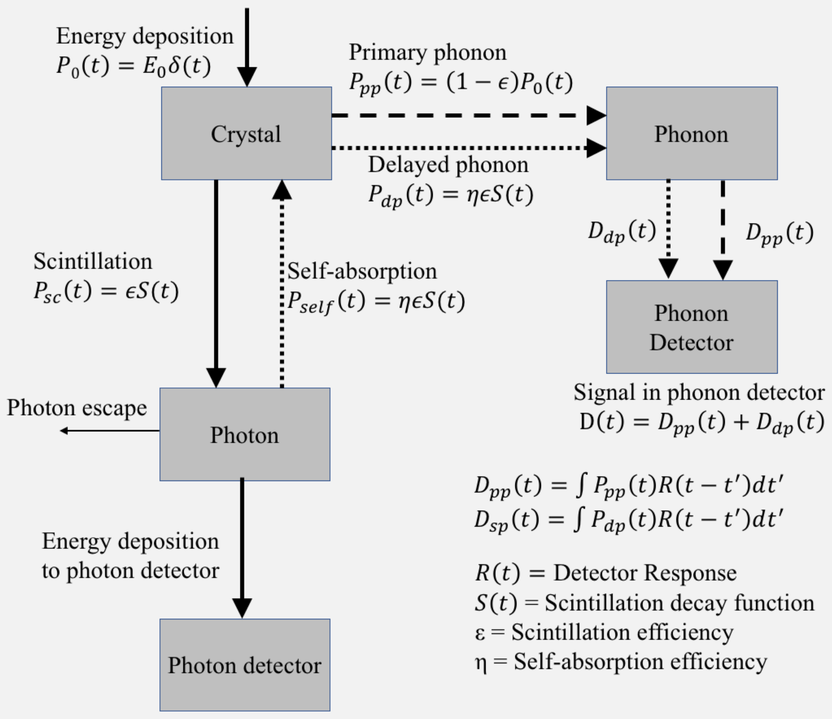
Self-absorption in Scintillating Bolometers





- ✓ Self-absorption in slow scintillators produces delayed phonons
- ✓ Delayed phonons add up to primary phonon signals and slow it down
- ✓ Amount of delayed phonons determines final phonon pulse shapes.

Detector Model



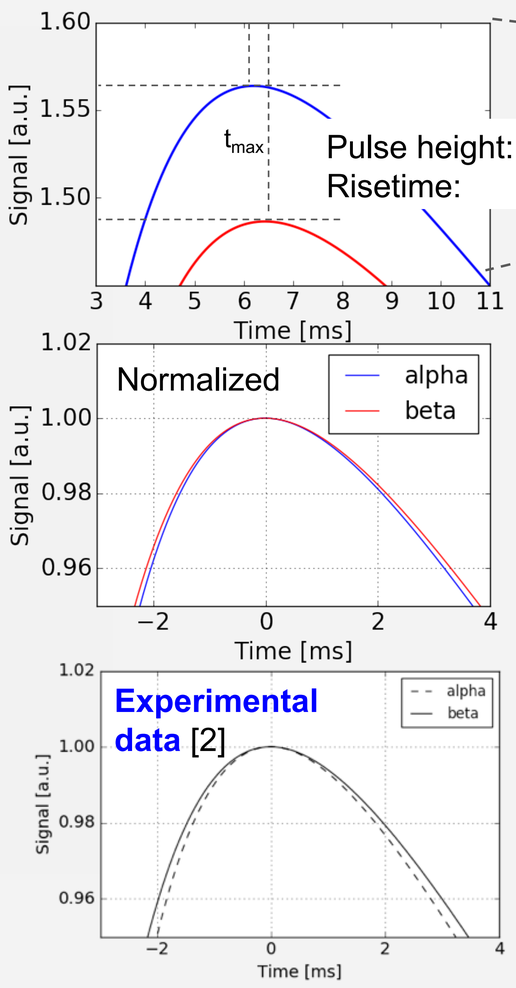
$D_{pp}(t) = \int P_{pp}(t)R(t-t')dt'$
$D_{sp}(t) = \int P_{dp}(t)R(t-t')dt'$

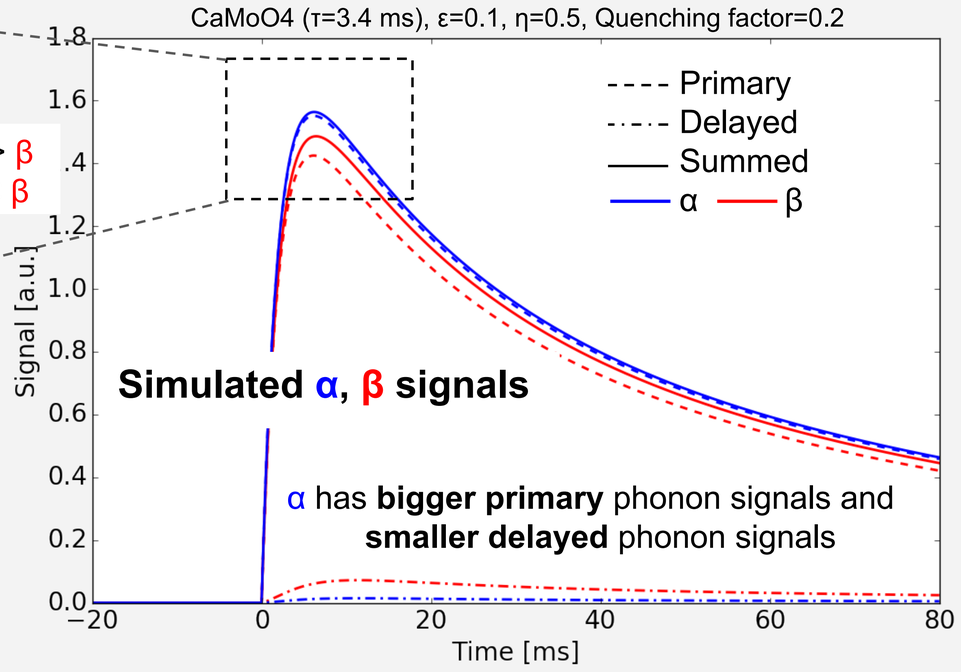
$R(t)$ = Detector Response
$S(t)$ = Scintillation decay function
ε = Scintillation efficiency
η = Self-absorption efficiency

Two phonon components:

1) Primary phonons instantly produced

2) Delayed phonons by slow self-absorption



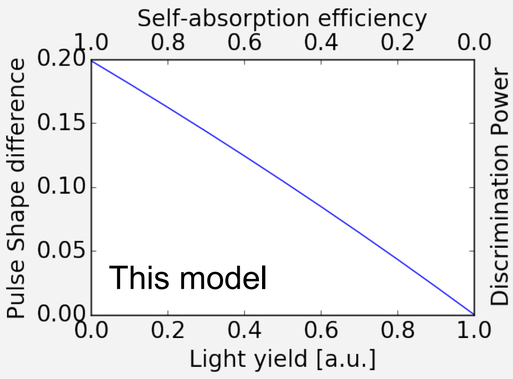


Quenching in α signals
⇒ Lower scintillation efficiency
⇒ Smaller amount of self-absorption
⇒ Smaller amount of delayed phonons
⇒ **Faster than β signal** that has bigger delayed phonon signal

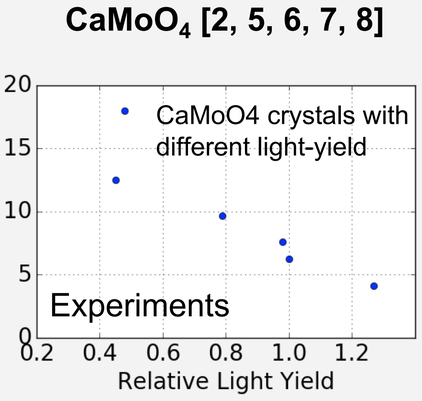
α has **faster rise, faster decay, bigger pulse height** in the model
⇒ **Consistent with experimental results**

Comparison with Experimental Results

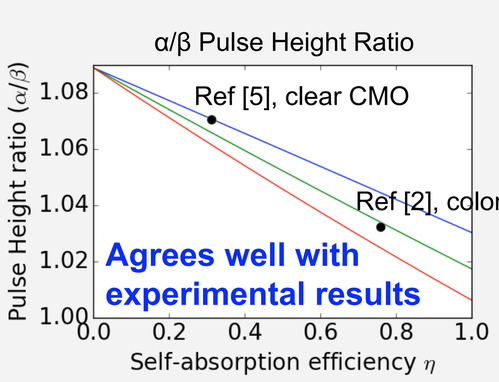
$CaMoO_4$ [2, 5, 6, 7, 8]



1) Pulse shape differences for different light yields



2) PSD powers of $CaMoO_4$ detectors with different light yields



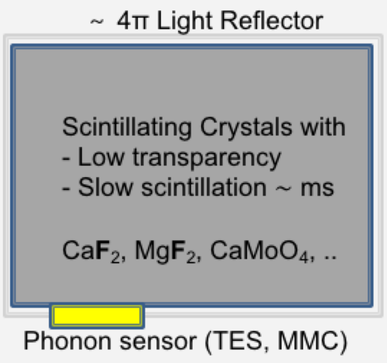
3) Pulse height ratios in the model and experiments

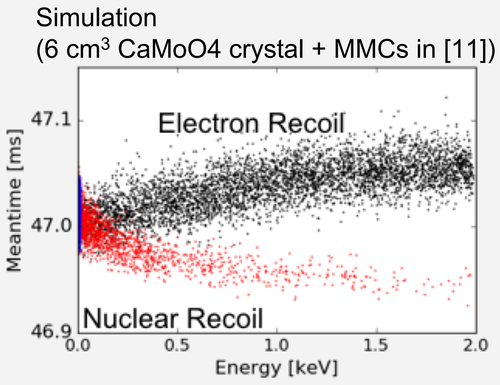
$ZnMoO_4$ [9, 10]

	Small ZnMoO4 [9]	Large ZnMoO4 [10]
Relative light yield	**1**	**1.4**
PSD power	**20**	**16**
Discrimination Power (heat/light)	8	19

Lower light yield → Higher self-absorption → Higher PSD power

Novel Scintillating Bolometers for Rare Event Searches





- ✓ Simple design and reduced number of readouts
  ⇒ Easier to scale up
- ✓ Strong PSD with maximized self-absorption
- ✓ Optimizing sensitivity of phonon readout
  ⇒ Will improve both energy threshold and PSD power with reduced noise

References

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