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Suppression of the internal Conversion Decay of Th-229m (FY19Q1 report)

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Disclaimer

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Progress Report:	Q1 FY19 – October to December 2018
Project:	Suppression of the Internal Conversion Decay of ^{229m}Th
Project Number:	SCW-1661
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Project Goal

To measure the decay energy of metastable Th-229m, we had proposed to modify an existing experiment by placing a MgF_2 crystal between our U-233 source and a high-resolution STJ photon detector. Metastable Th-229m nuclei produced in the decay of U-233 would be absorbed in the MgF_2, but since the MgF_2 bandgap of ~10eV exceeds the energy of the metastable state, decay by internal conversion is expected to be suppressed. Th-229m can then only decay by gamma emission, and the ~7.8 eV gamma energy can be transmitted through the MgF_2 and detected by the STJ detector. The spectra are calibrated with a pulsed 355 nm laser.

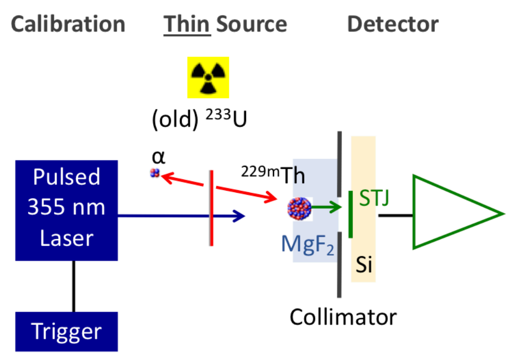
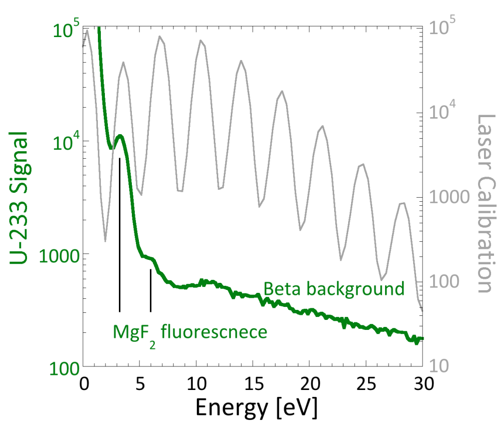


Figure 1: Experimental setup

Progress this Quarter

We have mounted a small 1.5 x 1.5 x 0.1 mm^2 MgF_2 crystal in front of our detector chip with several STJs of different sizes and exposed it to an existing U-233 source (Figure 1). The detectors worked very well,



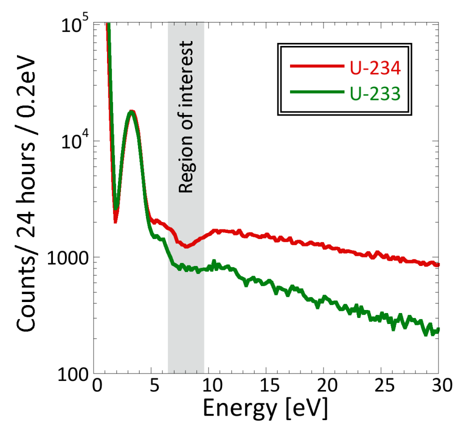


Figure 2 (left): U-233 sum spectrum for several detector pixels (green). The laser calibration (grey) shows peaks corresponding to an integer number of 3.5 eV photons. Figure 3 (right): Comparison of a U-233 and a U-234 spectrum for the detector with highest energy resolution, scaled to the same MgF_2 peak intensity.

with a resolution of ~1 eV for the smaller pixels (Figure 2, grey line). As expected, the spectrum also shows MgF_2 fluorescence at ~3 and ~5.5 eV that has been excited by the U-233 source (green). Unfortunately, no peak is visible in the region of interest around ~7.8 eV that may correspond to a Th-229m decay. The primary reason is a broad background that extends to well over 400 eV, the maximum range in our MCA.

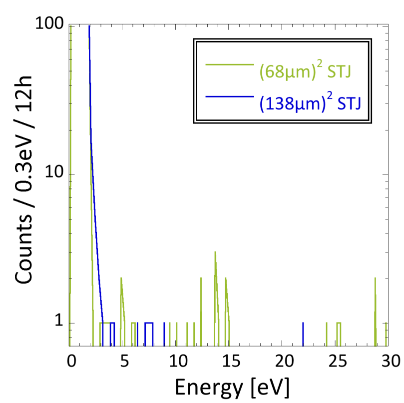
This background is most likely due to high-energy beta particles from the U-233 daughter products, especially Bi-213 whose betas have an average energy of 435 keV and can therefore easily penetrate the 100 µm thick Si collimator in front of the STJs. High-energy betas absorbed in the Si substrate will generate high-energy phonons that propagate to the STJ detectors and generate a signal whose magnitude depends on the beta energy and the absorption location. This background must be suppressed to increase the sensitivity to detect a Th-229m signal at ~7.8eV.

We have also exposed the same STJ detectors to a U-234 source that does not produce any Th-229m signal (Figure 3). This experiment will be an important control experiment in case we detect a tentative Th-229m signal from the U-233 source.

Outlook

While the initial experiment did not produce a signal from the decay of Th-229m, it suggests a few simple changes to increase the sensitivity. Most importantly, a fresh U-233 source should be prepared and measured before the daughter nuclei have grown in that are responsible for the high-energy beta emissions. This will reduce the background in the region of interest significantly, especially since the background without a source in our current setup is low (Figure 4). If this source is placed in close vicinity to the STJ detectors, it can have a ~100x lower activity than than the ~7200 Bq of our current U-233 source. This will reduce the fluorescence background from the MgF_2 accordingly by a factor of 100. Close placement can be accomplished by depositing ~100 Bq of freshly-separated U-233 directly onto a thin MgF_2 crystal in front of the STJ detector. This will be our next experiment (Figure 5).

In addition, we will measure the fluorescence of the MgF_2 crystals we are using in our experiment to ensure that they do not have any emissions in the region of interest around ~7.8 eV. Published UV fluorescence spectra of MgF_2 do not show any lines in that region, but it is important to confirm this for our MgF_2 crystals. Since the $(1.5mm)^2$ crystals used in our experiment are too small for characterization in our UV spectrometer, we have bought a larger MgF_2 crystal from the same boule for these tests.



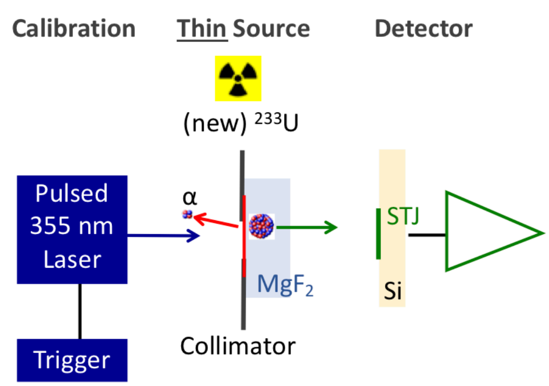


Figure 4 (left): The background spectrum from two STJs over a period of 12 hours shows few counts in the region of interest around ~7.8eV. Figure 5 (right): Modified experimental setup for upcoming experiments with increased sensitivity (not to scale – the 100 µm thick MgF_2 will be mounted very close to the STJ).