LAWRENCE LIVERMORE NATIONAL LABORATORY

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MagMicro with Ultra-High Energy Resolution (Report Q1 FY19)

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Quarterly Progress Report: Q1 FY19 – September to December 2018

Project:	MagMicro with Ultra-High Energy Resolution
Project Number:	LL16-MagMicro-PD2La
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HQ Project Manager:	Chris Ramos
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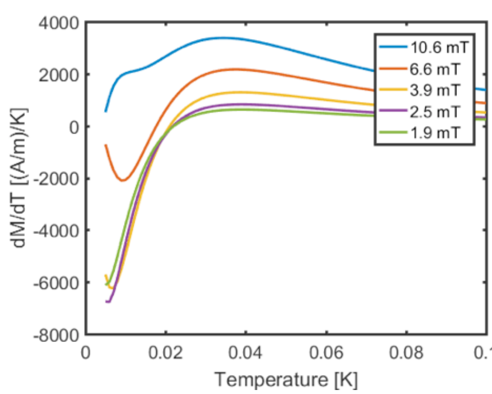
Progress this quarter

Task 15 (Fabricate 32-pixel Ag:Er MMC Arrays):

We have continued to simulate the response of the MMC detector response to optimize their energy resolution, detection efficiency and count rate based on the data we took in FY17/18. Unfortunately, the simulations, which were done at the Supercomputing Center of the University of New Mexico, are taking significantly longer than expected. The difficulty is due to the fact that the magnetic response (Figure 1) and the resulting signals (Figure 2) depend sensitively and non-linearly on the device parameters and the detector geometry, which affect the magnetic coupling between the sensor and the SQUID preamplifier. The detector optimization is therefore a complicated iterative process constrained by photolithographic capabilities. If we push the design parameters too far, say by making the features too small or an insulating layer too thin, we risk device failure that would make the entire detector non-functional. There are therefore many design trade-offs that need to be considered and simulated.



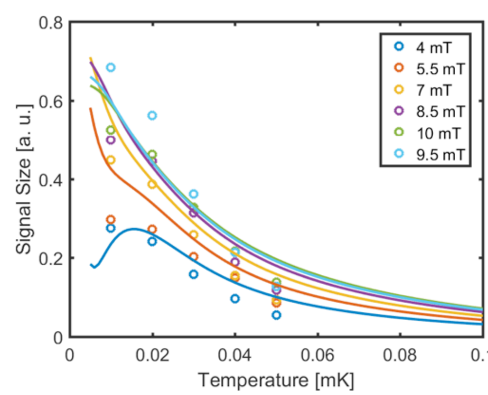


Figure 1 (left): Simulations for a particular MMC geometry illustrate that the magnetic sensor response to gamma-ray heating (dM/dT) depends sensitively on temperature and applied magnetic field (different colors). Detector optimization is therefore a complicated iterative process constrained by photolithographic capabilities. Figure 2 (right): Simulations of the signal size for different operating conditions, compared to experimental values measured in FY17/18.

Task 16 (Demonstrate energy resolution <50 eV FWHM):

Since we have already achieved an energy resolution of 38 eV FWHM in FY17, we will not focus on this task until the optimized MMC arrays are available.

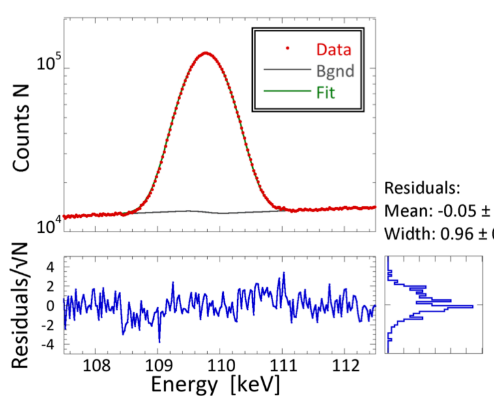
Task 17 (Integrate Compton Veto with MMC in Dilution Refrigerator): Abandoned ×

The Compton veto will unfortunately not be completed in this project due to insurmountable problems with electromagnetic pickup due to poor grounding and limited shielding of the current setup. It is still an excellent idea and should be re-addressed in a future LCP.

Task 18 (Operate 32-MMC array in LLNL dilution refrigerator): Not yet started

Task 19 (Acquire Gamma Spectrum from Safeguards-Relevant Sample): Completed ✓

Our earlier experiments on $^{233}U/^{239}Pu$ had shown that the accuracy of our MMC measurements is limited by the literature values of the available calibration sources. We have therefore generated ^{169}Yb, whose gamma emissions are known with exquisitely high accuracy, through the reaction $^{169}Tm(d,2n)^{169}Yb$ by irradiating two 100 µm thick Tm foils with 15 MeV deuterons at the 88" Cyclotron at LBL, because it is not commercially available. We have then tried to reproduce traditional nuclear data measurements using the best modern Ge detectors currently available at LLNL (hand-selected by Ortec), whose response function has no low-energy tail that likely introduced small systematic errors in earlier measurements (Figure 3). In this context we (re-)discovered that the exact same data captured simultaneously by two different multi-channel analyzers (MCAs) produce inconsistent results (Figure 4), with residuals differing by up to 10 eV (!). This suggests that even modern MCAs may introduce errors that affect the accuracy of gamma-ray measurements. We will repeat the Yb-169 experiments with our MMC gamma detectors next to better understand the source of these inconsistencies.



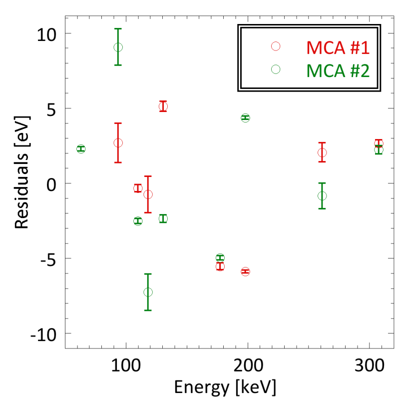


Figure 3 (left): Line shape of the 109 keV gamma-ray from Yb-169 measured with a modern high-quality Ge detector. The low energy tail due to charge loss at the detector edges is completely suppressed when a collimator shields the detector edges, so that the shape can be fit by a pure Gaussian function on a Complementary Error Function (erfc) background with the statistical accuracy. Figure 4 (center): The residuals of the Yb-169 centroids (which are known to an accuracy <0.1 eV) to a linear energy calibration of the *exact same data* differ (!) when the data are captured with two different multi-channel analyzers (MCAs). This suggests that the accuracy of the MCA limits the measurement of gamma-ray energies in this experiment.

Task 20 (Present paper at INMM and report to NA-22): Completed ✓

Outlook

With the dilution refrigerator fixed, we will repeat the MMC characterization with Yb-169 with ultra-high energy resolution.

Publications

Our paper on "Magnetic Microcalorimeter Gamma Detectors for high-accuracy nuclear decay data" has been submitted to INMM Proceedings. These proceedings are not reviewed, so the paper will be published as-is.

Lab Program Manager Comments [optional]: