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An Estimate of the Gamma Flux in the East Counting Room of the Davis Cavern

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1. Introduction

This document provides a brief estimate of the gamma ray flux measured with a HPGe detector, MAEVE, while setting up the Berkeley Low Background Facility (BLBF) counting station in the East Counting Room of the Davis Cavern. A gamma ray spectrum was taken while testing the detector, external of a Pb shield, after cooling it down for the first time since its relocation from Oroville, CA. The detector was resting on the floor in the location shown in Figure A.1, with the HPGe crystal approximately 1 foot from the floor and perhaps 2 feet from the shotcrete-coated cavern wall. The initial purpose of this spectrum was really for making relative comparisons with the shielded spectrum, to show the effectiveness of Pb shielding, nitrogen purging, etc. (which is shown in Figure A.2, the top curve being the curve of interest for this note.)

Understanding the efficiency of the detector from a 4π source - the room in this case, is critical to making estimates of the gamma flux. Unfortunately, no tests with calibrated sources were made with MAEVE during this setup, since only diagnostic measurements were being made at the time. However, the room background that was taken during testing is useful for making some rudimentary estimates of the flux if some basic understanding of the efficiency is known. At LBNL, the BLBF also operates a sister detector of MAEVE, that has a very similar HPGe crystal (in size and type)– this detector is known as POP1. Coincidentally, this other detector was used to make fairly extensive flux measurements recently, so this calibration information should serve as a reasonable proxy for MAEVE.

2. Methods

The efficiency information used to estimate the gamma flux was adapted from previous work on MAEVE's sister detector POP1 (soon to be MORGAN). POP1 was recently used to perform a series of flux measurements in the San Francisco Bay Area in the aftermath of Fukushima. Undergraduates Boris Lo and Krzysztof Brozek, post-doc Chris Angell, and Prof. Eric Norman of the Nuclear Engineering Department at UC Berkeley took unshielded environmental spectra all over the Bay Area to measure the fallout in the weeks after the Fukushima Daiichi nuclear power plant accident and presented at the APS-DNP conference in 2011[1].

The following calibration procedure used on POP1 was described in [1]:
For taking environmental flux measurements, the detector POP1 was calibrated by placing a 50 μCi

^{60}Co source at various angles 1 meter away from the center of the detector to obtain an efficiency at 1173 keV averaged over the angle of incidence of the gamma ray. Six different 1μCi sources were then placed one foot in front of the detector in succession to obtain the efficiency as a function of energy. These data were then used to convert the observed count rate into a flux by using the formula:

$$\varphi_{field} = \frac{CR_{field}}{CR_{ref}} \varphi_{ref} \frac{\epsilon(E_{ref})}{\epsilon(E_{field})} \quad (1)$$

where:
φ_{field}: is the gamma-ray flux observed during field measurements.
φ_{ref}: is the reference gamma-ray flux that is known from calibrated source at 1173 keV.
CR_{field}: is the net count rate observed during field measurements for a given energy peak.
CR_{ref}: is the net count rate observed in the reference setting for 1173 keV.
$\epsilon(E_{ref})$: is the efficiency of the detector at 1173 keV in the reference setting.
$\epsilon(E_{field})$: is the efficiency of the detector at given energy in the field measurements.

The efficiency values prepared by B. Lo, et. al. [1] were then directly applied to the count rates taken by MAEVE in peaks of interest from the unshielded spectrum taken underground in the East Counting Room by MAEVE in May 2014– shown as the top curve in Figure A.2. Since the two detectors, POP1 and MAEVE, have nearly identical crystal sizes, it is assumed that the calibration information developed for making flux measurements with POP1 is a reasonable proxy for MAEVE– especially for higher energy gamma rays such as those at 1460, 1764, and 2614 keV from ^{40}K, ^{214}Bi, and ^{208}Tl; respectively. In reality, the detector response is probably within 50% for two detectors such as these, but conservative uncertainties of a factor of 2-5 may be warranted.

3. Flux Values

The estimated flux values obtained by converting the net count rates from the unshielded spectrum in Figure A.2 using the proxy calibration information are provided in the table below. Note that since calibration data was substituted by a completely separate detector in lieu of actual data on MAEVE, very conservative error bars to account for systematic data are appropriate. Therefore, this data should not be relied upon for better than perhaps a factor of 2 of the listed value, and are intended for use in 'order of magnitude' estimations. The data is shown as both net peak fluxes and some estimates of integrated flux from the continuum. The net peak values can be used to estimate the flux from other portions of the U and Th chains not listed by taking simple ratios of branching intensities.

Table 1: Flux estimates obtained from the East Counting Room of the Davis Campus on the 4850L of the Sanford Underground Research Facility. Uncertainties are statistical only and although the two detectors likely would behave within ~50-100% of each other, an additional conservative uncertainty of perhaps a factor of 2 may be warranted due to differences between POP1 and MAEVE. More confidence is placed on the higher energy peaks than the lower, since variations between the two detectors are likely to be less dramatic at higher energies. The peak fluxes listed here are likely useful for estimating other high energy U and Th series lines by taking simple ratios of branching intensities relative to the 1764 and 2614 keV peaks, for example. Integrated flux values for the regions listed at the bottom portion of the table were estimated by calculating flux in 100 keV bins, then integrating together. Note, these include Compton scattered events in the detector as well as gammas that were already 'pre-scattered' in the rock walls in the room, for instance, before getting added to the continuum – so these integrated rates are *overestimates* of the total flux in these regions. Based on some crude estimates of peak to continuum ratios, the true total flux is likely 2 to 5 times lower that what is listed here so this may be useful as an upper limit of sorts.

Isotope (series)	**γ ray**	**flux cm^{-2} s^{-1}**
^{212}Bi (^{232}Th series)	238 keV	2.3E-02 ± 2.3E-04
^{214}Pb (^{238}U series)	295 keV	3.2E-02 ± 2.4E-04
^{214}Pb (^{238}U series)	352 keV	7.1E-02 ± 3.0E-04
^{208}Tl (^{232}Th series)	583 keV	2.8E-02 ± 2.6E-04
^{214}Bi (^{238}U series)	609 keV	1.2E-01 ± 4.0E-04
^{228}Ac (^{232}Th series)	911 keV	2.9E-02 ± 2.8E-04
^{214}Bi (^{238}U series)	1120 keV	5.0E-02 ± 3.4E-04
^{40}K	1460 keV	3.6E-01 ± 8.1E-04
^{214}Bi (^{238}U series)	1764 keV	5.9E-02 ± 3.4E-04
^{208}Tl (^{232}Th series)	2614 keV	5.6E-02 ± 3.4E-04
Integrated Regions:		
	1.0 - 2.0 MeV	1.95E+00
	2.0 - 2.7 MeV	2.35E-01
	1.0 - 2.7 MeV	**2.19E+00**

4. Acknowledgements

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References

[1] B. Lo, K. Bro ek, C. Angell, E. Norman, Measurements of gamma radiation levels and spectra in the San Francisco Bay Area, APS-DNP 2011 Poster Presentation, Abstract ID: BAPS.2011.DNP.EA.77. http://meetings.aps.org/link/BAPS.2011.DNP.EA.77.

A. Figures

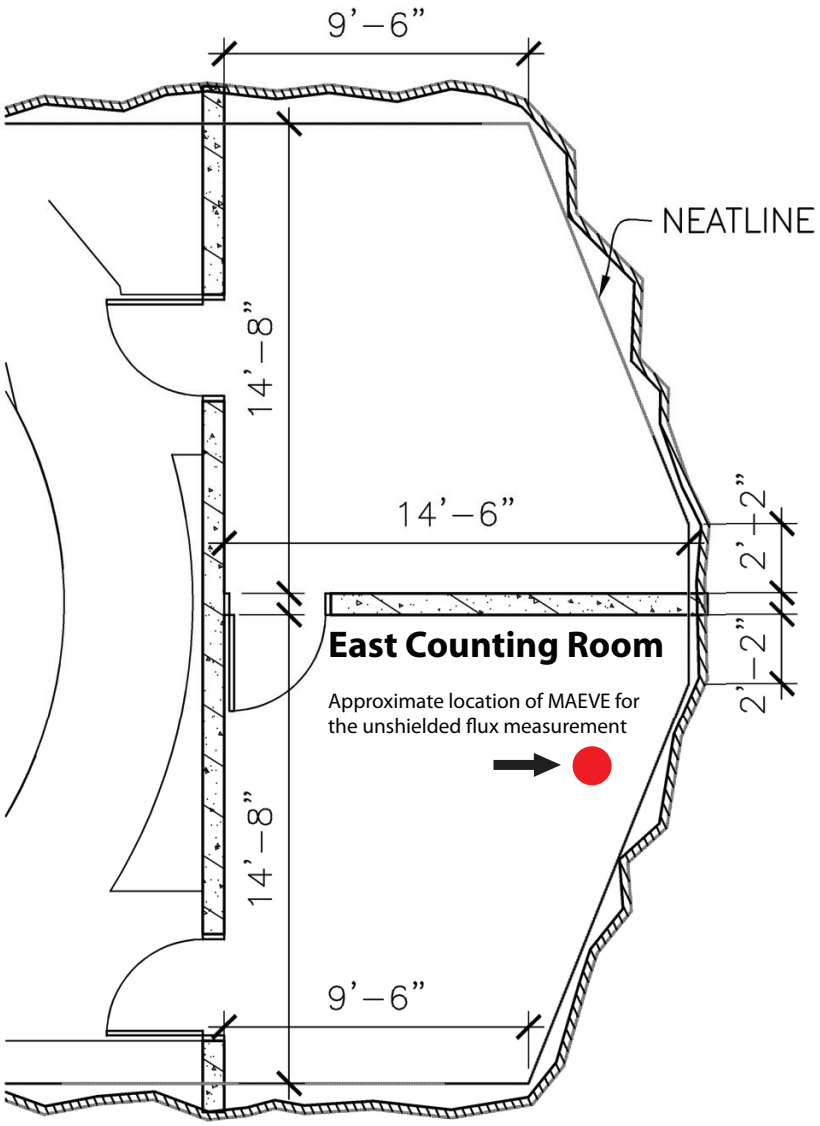

Figure A.1: Approximate location of MAEVE in the East Counting Room when the unshielded flux measurement was made in May of 2014.

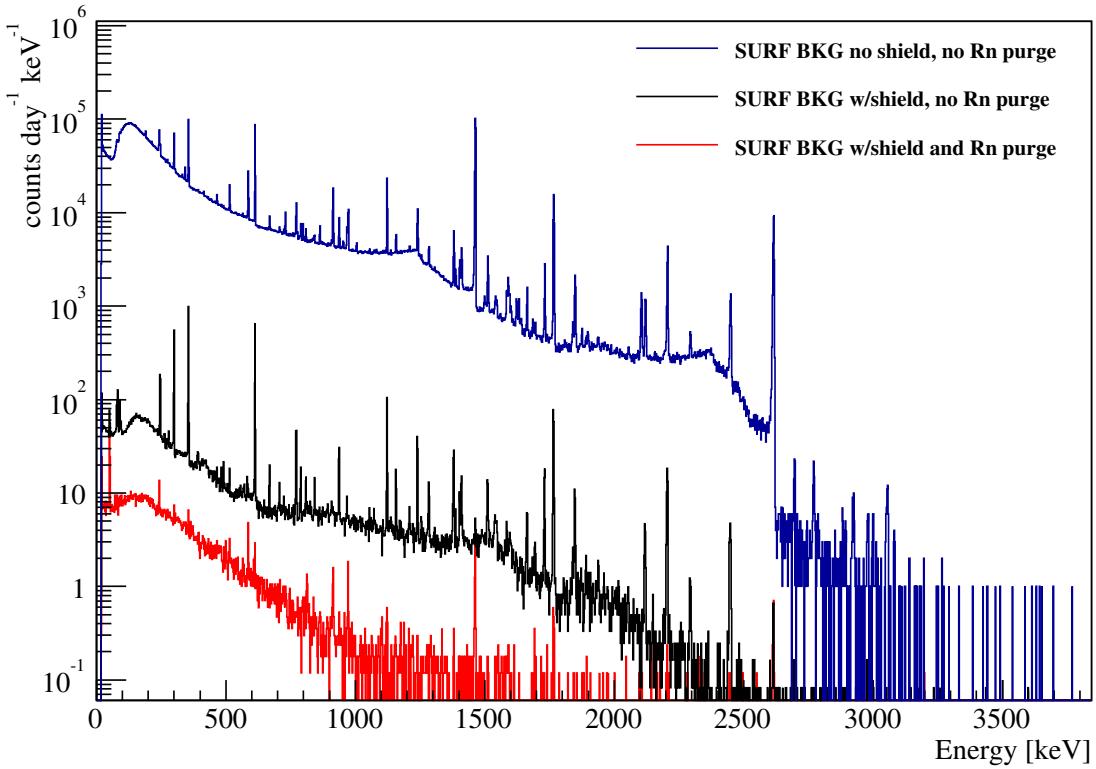

Figure A.2: Detector backgrounds in the BLBF East Counting Room of the Davis Cavern without shielding (top), with shielding (middle), and with the nitrogen radon purge running (bottom). The top curve is the one from which the flux estimates are being made.

Figure A.3: Boris Lo and Krzysztof Brozek taking spectra with POP1/MORGAN in Alameda across from the Oakland Port.