SNO-STR-93-017

# The MERLIN II Detector: Initial Operation at Oroville

Alan R. Smith, Donna L. Hurley, and Eric B. Norman
Lawrence Berkeley Laboratory
April 27, 1993

The Merlin II detector, a very large "low-background" high-purity n-type germanium semiconductor detector, was delivered to LBL from ORTEC in late December, 1992. The crystal in this detector is 8.03-cm in diameter and 8.55-cm long, thus containing more than 2.3 kg of germanium. It's nominal efficiency as compared to that of a 3"x3" NaI detector is quoted by ORTEC to be 115%. After a thorough checkout at LBL by Norm Madden and Chris Cork of our electronics group, it was installed at Oroville on Jan. 28, 1993. The crucial first measurement, urgently needed by the SNO Collaboration, was to determine whether any of the candidate "rope" materials has low enough concentration of Thorium for use to suspend the acrylic vessel containing the heavy water. All effort to date with MERLIN II has been directed to this end.

We have accomplished the following:

1. Background (BKG) data for 23970 min, two runs of 12688 min and 11383 min, respectively.

2. Vectran (metal filtered), two runs of 8185 min and 16667 min, respectively

3. Detection efficiency determination for U,Th, and K, using a previously "calibrated" vermiculite sample.

4. Kevlar, an ongoing run which will have counted about 14000 min at analysis time on 4/28/93: results to be phoned to Rick Norman at SNO Meeting.

The detector BKG is unexpectedly high at energies up to about 800 keV, but quite satisfactorily low at higher energies. The high BKG at low energies is understood and will be remedied at the first opportunity following completion of the crucial "rope" runs. The remedy will likely require the detector's return to ORTEC; hence,its unavailability for (probably) several weeks.

The "rope" samples are a two-piece assembly, and represent about the largest volume of material that can be put into MERLIN's present shield: a 7"OD by 4"ID annulus that is 8" long, and a 7"diam. by 2" thick disc. The annulus fits around the detector housing, while the disc fits against the top of the housing. The"rope" filaments are wound from the stock spools into the sample shapes - - not an easy task!! The Vectran sample weighs 2644 grams; the Kevlar sample weighs 3356 grams. It is worth noting that a sample of NaCl (granular) of this same volume would weigh about 7000 grams - - which translates into outstanding sensitivity for measuring potassium ($^{40}K$).

The vermiculite (expanded mica) sample is also a two-piece assembly, allowing the same sample shape and volume as for the"rope" samples. The vermiculite sample weighs 710 grams; it contains 2.6 ppm U, 4.9 ppm Th, and 4.6% K by weight. These assays were done with the LBF S7 NaI(Tl) scintillation crystal gamma-spectrometer system, a system whose calibrations have been maintained continuously since 1967. The calibrations are based on USAEC New Brunswick Laboratory standard materials which contain known quantities of U-ore and Th-ore, on CP grade KCL, and on an IAEA $^{137}Cs$ calibration source.

Detector "efficiencies" obtained from the Vermiculite sample for the peaks used to determine radionuclide concentrations are expressed in the following terms. Uranium series members are given in terms of the quantity of uranium present at secular equillibrium; thorium series members are expressed in the same way. Potassium is given as the quantity of elemental potassium present for the normal isotopic ratio. All "efficiency" values are given in terms of counts/min per gram of uranium, thorium, or potassium.

| Element | Peak | "Efficiency" |
|---|---|---|
| Thorium | 238 keV | 3744 c/min-g |
| | 583 keV | 1307 c/min-g |
| | 911 keV | 782 c/min-g |
| | 2614 keV | 557 c/min-g |
| Uranium | 352 keV | 9243 c/min-g |
| | 609 keV | 7519 c/min-g |
| Potassium | 1461 keV | 2.42 c/min-g |

The capability of MERLIN II for setting upper limits on the (U,Th,K) concentrations in samples of the "rope" size has been estimated for several peaks commonly used in assay for these radionuclides, using the Vermiculite data and the current summation of BKG data. In this listing of "least detectable" concentrations,values are calculated from the single Standard Deviations on the BKG data combined with weights appropriate to our Vectran and Kevlar samples, and are expressed in parts per trillion (ppt). Additional values are given for Th (ppt) and K (ppb) in a same-size, but much heavier sample of NaCl (7000 grams), where self-absorption of the high-energy gamma-rays in the sample material has been neglected.

| ELEMENT | PEAK | BKG in C/MIN | LEAST DETECTABLE CONCENTRATION |
|---|---|---|---|
| Thorium | 238 keV | 0.0526±0.0023 | 230 ppt (Vectran)<br>181 ppt (Kevlar) |
| | 583 keV | 0.0131±0.0011 | 320 ppt (Vectran)<br>252 ppt (Kevlar) |
| | 911 keV | 0.0087±0.0008 | 387 ppt (Vectran)<br>305 ppt (Kevlar) |
| | 2614 keV | 0.0074±0.0006 | 407 ppt (Vectran)<br>320 ppt (Kevlar)<br>154 ppt (NaCl) |
| Uranium | 352 keV | 0.0098±0.0014 | 57 ppt (Vectran)<br>45 ppt (Kevlar) |
| | 609 keV | 0.0112±0.00098 | 49 ppt (Vectran)<br>39 ppt (Kevlar) |
| Potassium | 1461 keV | 0.0058±0.0006 | 93 ppb (Vectran)<br>73 ppb (Kevlar)<br>35 ppb (NaCl) |

The Vectran filament was counted twice, in the sequence: BKG/Vectran/Bkg/Vectran. The first Vectran run(8185 min) showed a positive signal from the Th-series at the 238 keV peak, indicating a Th-concentration of 1920±400 ppt. (This is a higher value than was reported to Jan Wouters by phone, prior to running the Vermiculite calibration sample.) The second Vectran run (16667 min) showed no signal above BKG at the 238 keV peak, and indicated an upper limit on

Th-concentration of 360 ppt. Both results are probably valid, and herein lies a severe warning: approximately twice the time elapsed before starting the second run as was allowed before starting the first run - - three days in the second case. Even at the Oroville site, a relatively low-radon(and thoron) environment, extreme care must be exercised to guard against such interference in the most critical measurements. Storage of these samples (especially non-conducting materials) in sealed mylar bags is indicated.

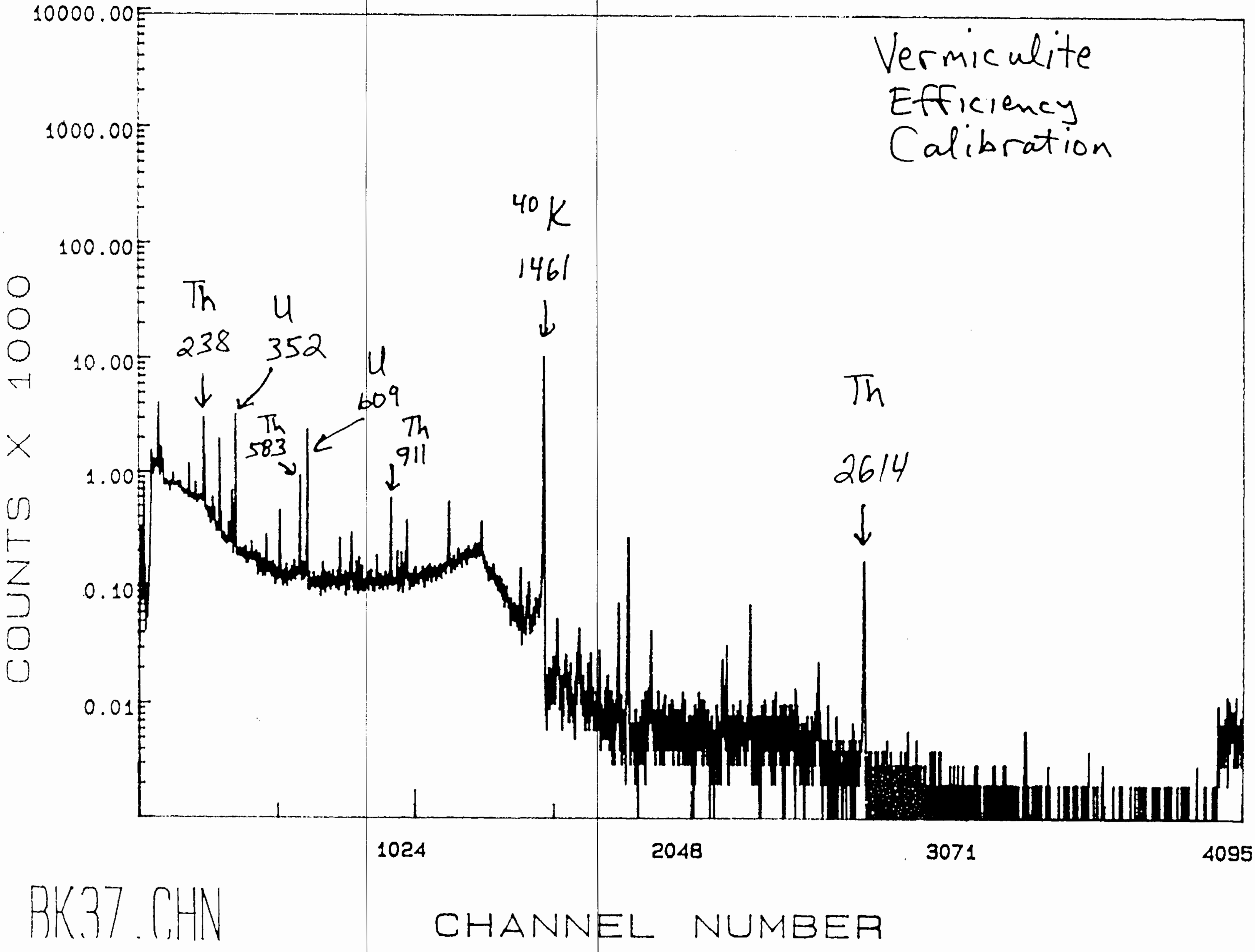
Results from the second count of the Vectran sample are summarized as follows, where count rates in the selected peaks aregiven as NET rates "above" BKG, along with appropriate Standard Deviations. The listed CONCENTRATIONS have the BKG statistics incorporated in their values.

| ELEMENT | PEAK | NET C/MIN | CONCENTRATION |
|---|---|---|---|
| Thorium | 238 keV | -0.0053±0.0036 | < 360 ppt |
| | 583 keV | -0.0004±0.0016 | < 460 ppt |
| | 911 keV | 0.0026±0.0014 | 1260± 680 ppt |
| | 2614 keV | -0.0002±0.0009 | < 611 ppt |
| Uranium | 352 keV | 0.0007±0.0022 | < 90 ppt |
| | 609 keV | -0.0011±0.0015 | < 75 ppt |
| Potassium | 1461 keV | 0.244 ±0.004 | 38100± 600 ppb |

Late members of the Th-series have not been detected in this Vectran sample, at an upper limit of about 300 ppt. There is a suggestion that early members of the Th-series may be present, as indicated by the positive net rate in the 911 keV peak ($^{228}$Ac), at a level close to 1000 ppt. (Life is hardly ever simple.) There is no evidence for presence of the U-series, as indicated by the absence of $^{226}$Ra daughter gamma-rays, giving anupper limit of about 100 ppt. Our Vectran does have a significant potassium content, which appears truly monumental in low-BKG spectral data, although the concentration of potassium is only 38 ppm (38100 ppb). Perhaps this amount of potassium is significant to the project?

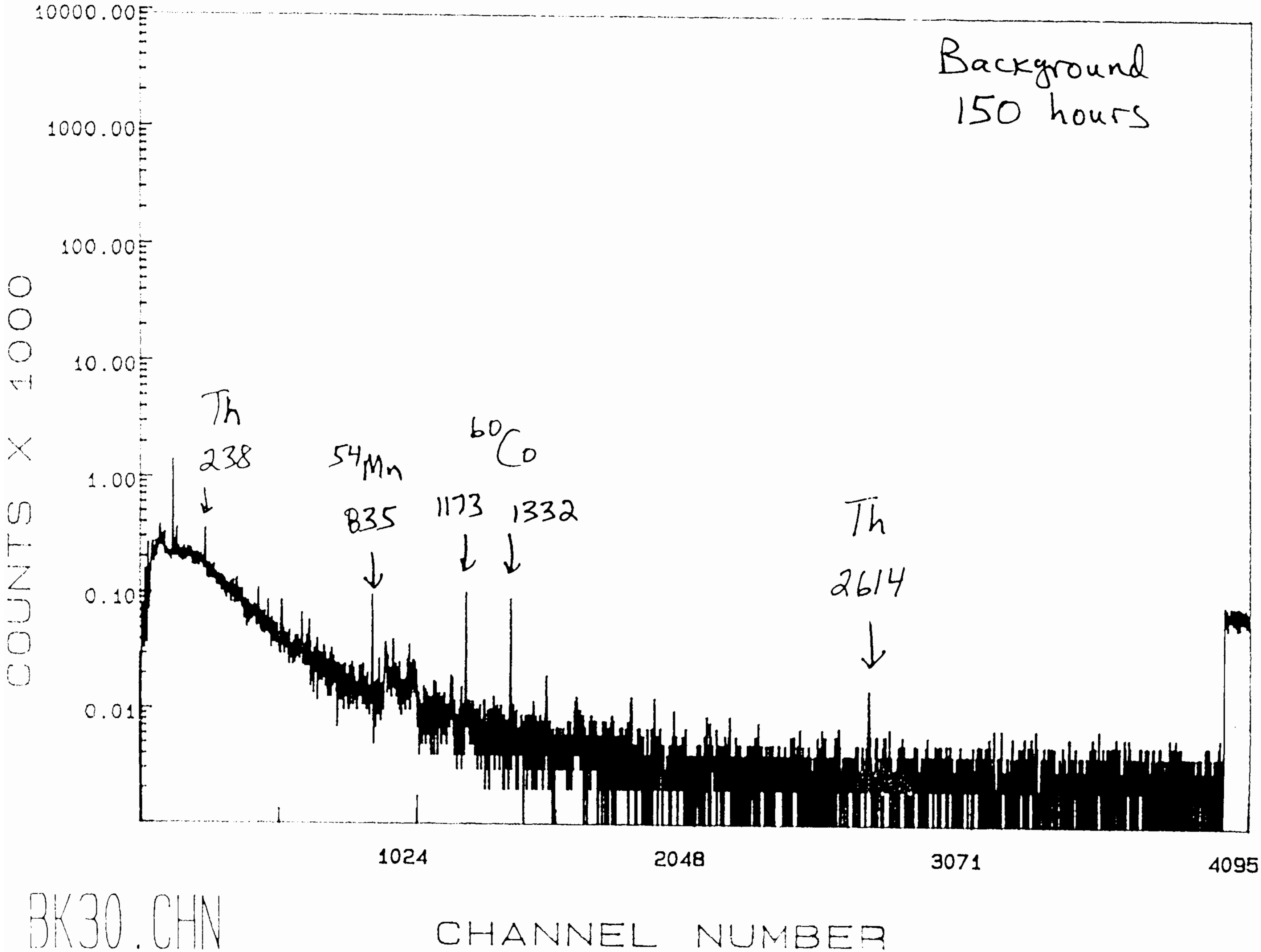
Improvements are presently planned for the MERLIN II detector. We expect the BKG below about 800 keV to be drastically reduced after fixing the "high- BKG" situation, at which time the BKG standard deviations for the 238 keV and 352 keV peaks should be reduced two-fold. When this improvement is implemented, data from run times employed to date should bring our lower limit on Thorium (238 keV) to about 100 ppt. An external Cosmic Ray veto (an overhead scintillator paddle) should lower the continuum at least a factor of two at energies above 1500 keV, permitting use of a large interval below the 2614 KeV peak as an indicator for Thorium. A significant increase in Th-detection sensitivity is potentially available here, in cases where ONLY the Th-series is present. It is still possible to realize an increase in sensitivity from these low-Z sample materials by increasing the sample size. At least a 50% increase should be attainable. We are studying how to provide MERLIN with a shield which has a much larger cavity.

TYPE = -1 MCA # 1 SEGMENT # 1
REALTIME = 30015.88 SECONDS, LIVETIME = 30001.18 SECONDS
DATA COLLECTED AT 05:06:00 ON 15-APR-93



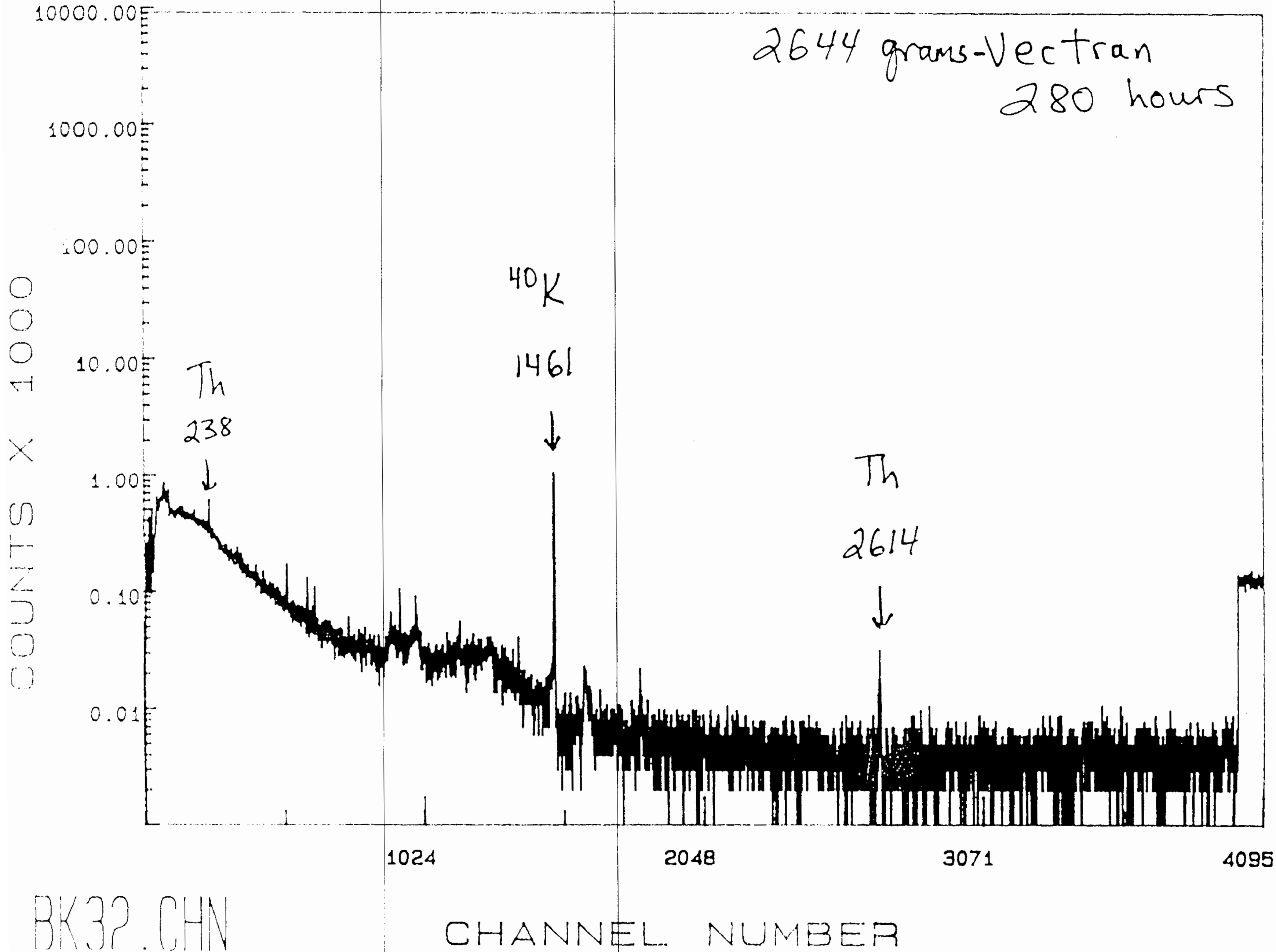

RK37.CHN

TYPE = -1 MCA # 1 SEGMENT # 1
REALTIME = 539007.60 SECONDS, LIVETIME = 539002.80 SECONDS
DATA COLLECTED AT 12:06:00 ON 25-MAR-93




BK30.CHN

TYPE = -1 MCA # 1 SEGMENT # 1
REALTIME = 1007109.00 SECONDS, LIVETIME = 1007100.00 SECONDS
DATA COLLECTED AT 23:50:00 ON 02-APR-93




BK32.CHN