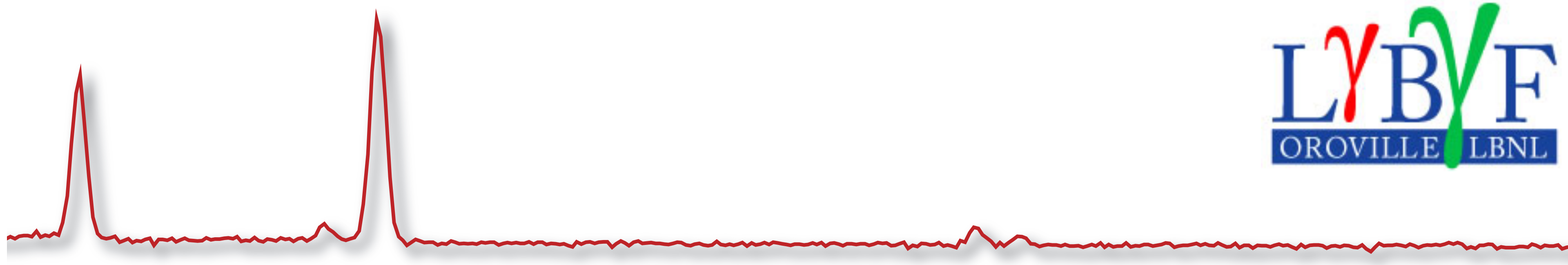


Low Background Counting at the LBNL Low Background Facility

Keenan Thomas
A.R. Smith, Y.D. Chan, E.B. Norman, D.L. Hurley

(and also)

Cosmogenic Activation of TeO_2 in CUORE

for Barbara Wang, E.B. Norman

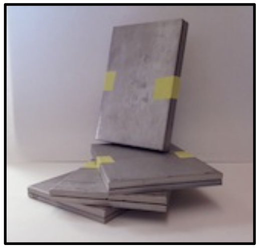
BERKELEY LAB
Lawrence Berkeley National Laboratory

LRT2013 – LNGS – 10 April 2013

services and activities

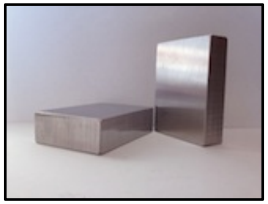
HPGe gamma spectroscopy
115% n-type, 85% p-type, (+others)

- passive assay of U, Th, K (and Co60, Cs137 etc.)
- active assay of trace elements via neutron activation analysis
- Neutron flux measurments (beam characterization via foil activation)
- Low activity NaI and BF3 counting also available, ICPMS via ESD



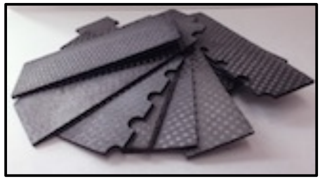
Run by dedicated, expert staff at two facilities.

- Long history of low background counting
- flexible scheduling, fast turn around
- general procedure is for users to contact Al Smith prior to sending sample (arsmith@lbl.gov)
- queue of at least ~several samples in rotation



Long History of Low Background Counting

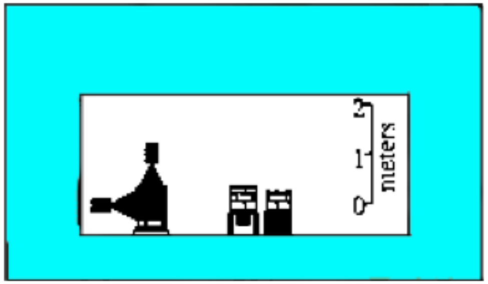
- SNO, KamLAND, CUORE, DoubleCHOOZ, Daya Bay, Majorana, Katrin, Sanford Lab, LUX/LZ

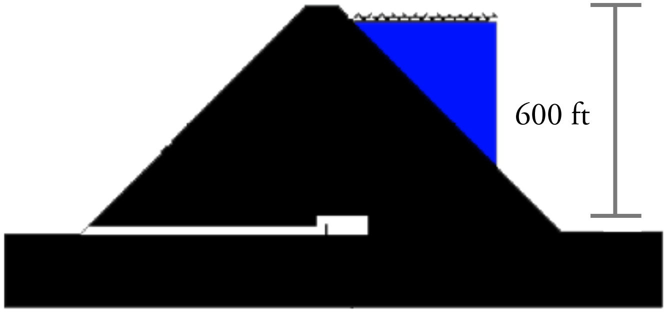


Other Activities:

- LBNL EHS waste characterization
- Environmental monitoring-- air, auto filters; rainwater (Fukushima)

Facilities



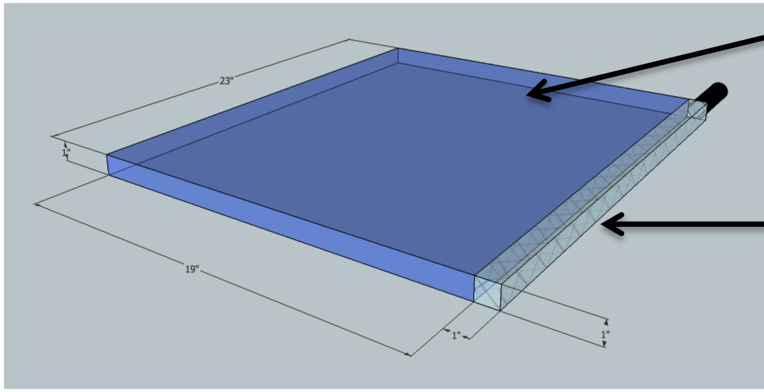


Local Site LBNL	Remote Site Oroville, CA
low activity concrete construction 1.5m minimum thickness	reduction in cosmic rays by 10^3
backgrounds dominated by cosmic ray muons	backgrounds dominated by residual activity in detector and shielding
115% n-type & 85% p-type	85% p-type

Counting Sensitivities [for ~1kg samples]	Berkeley Site [~1 day]	Oroville Site [~1 week]
U series	0.5 ppb (6 mBq/kg)	50 ppt (0.6 mBq/kg)
Th series	2.0 ppb (8 mb/kg)	200 ppt (0.8 mBq/kg)
K	1.0 ppm	100 ppb
Co-60	0.04 pCi/kg	0.004 pCi/kg

Anticoincidence Shielding

for Low Background Counting (Surface LBNL site)



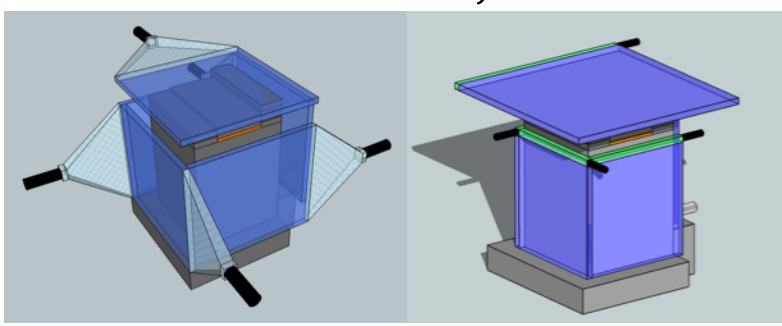
EJ200 scintillator 1 @ (30” x 30” x 1”), 4 @ (17”x18”x1”)

- front edge 'frosted' w/600 grit sand paper
- 0.25mm air gap between PS & WLS
- all other edges diamond milled

EJ280 wavelength shifting plastic 1@(30” x 1 x 1), 4@(17”x1”x1”)

- re-emission in line of sight with PMT
- More compact construction than using typical trapezoidal acrylic light guides

Scintillators Purchased from
Eljen Technologies
Sweetwater, TX



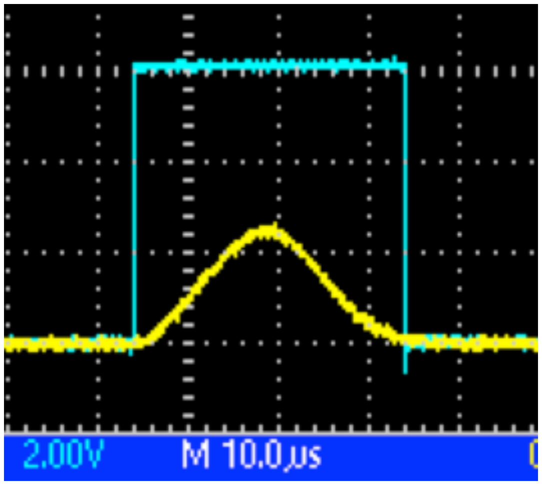
Design Criteria:
--- convenient & non-cumbersome for daily use
--- simple, stable operation

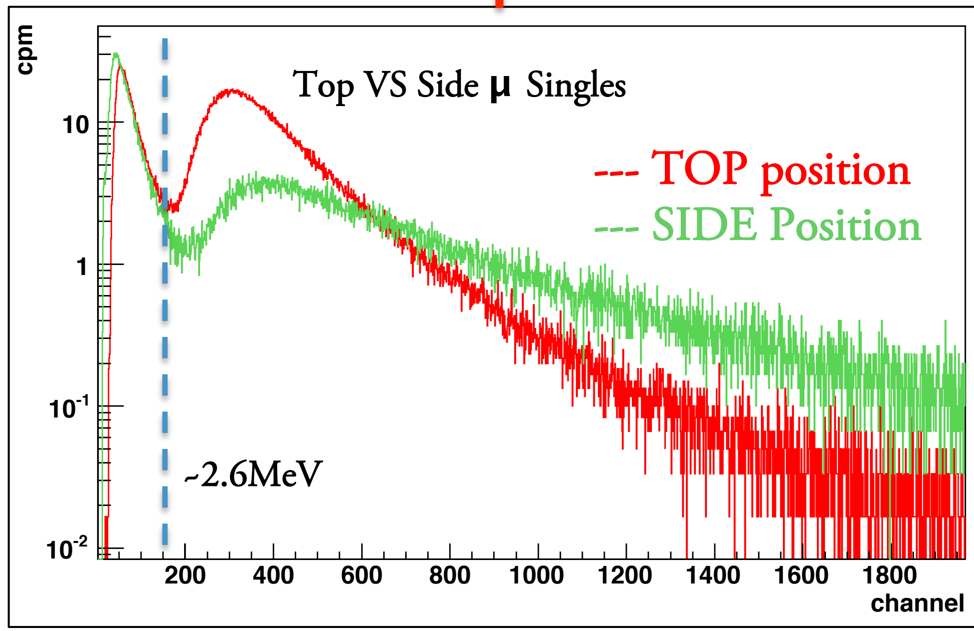
1" Hamamatsu PMT (R1924A)

Electronics and Operation

ORTEC 919 MCA ← Gate in ← ORTEC 516A Gate and Delay — ORTEC 551 TSCA — ORTEC 572 Spec. Amp ← All 5 PMT's

ORTEC 672 Spec. Amp → Signal in → ORTEC 919 MCA



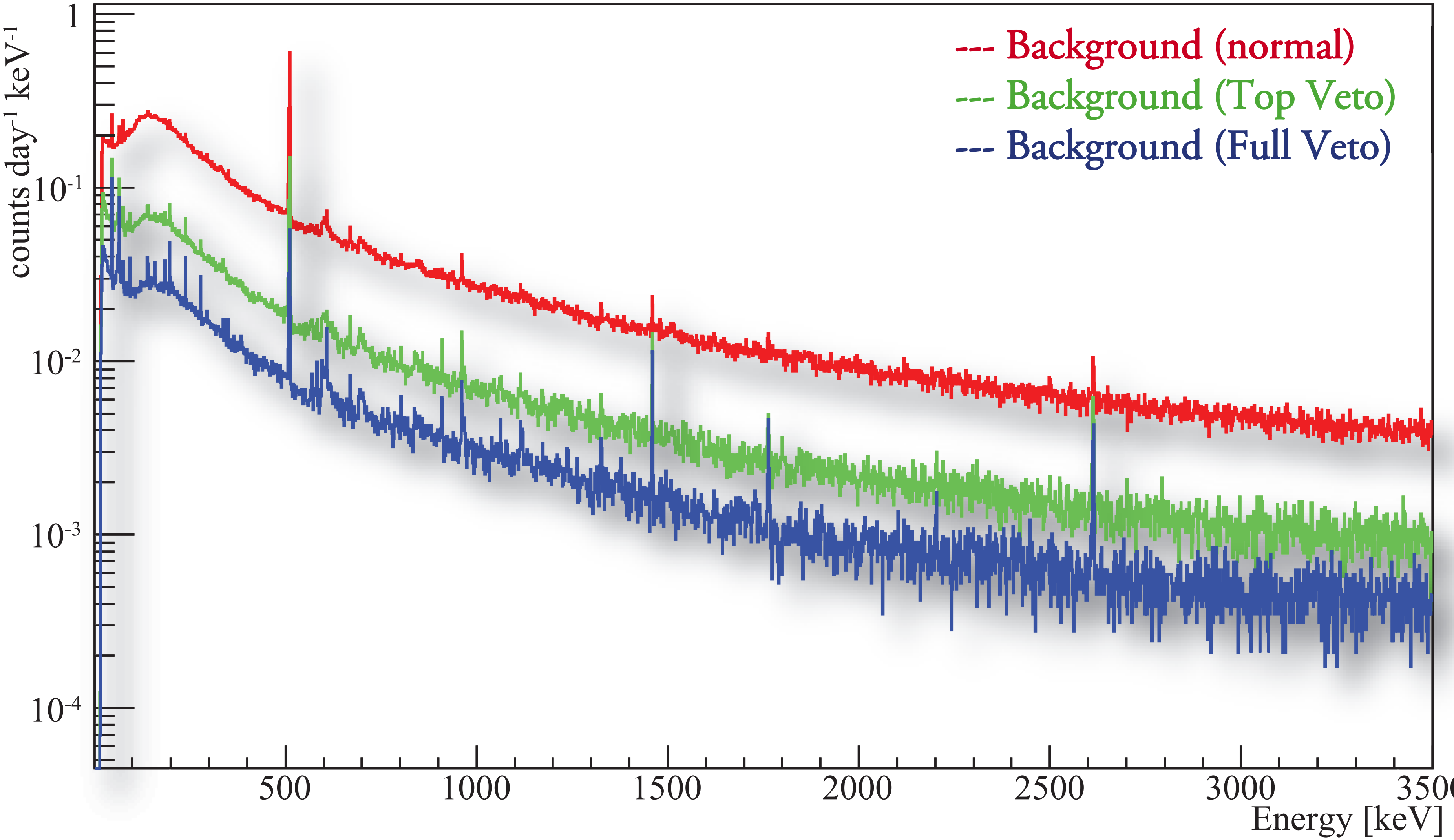


Threshold set by separation of gamma and muon separation in scintillator energy spectrum. (set somewhat lower)

Signals over SCA threshold generate logic that is stretched by the Gate & Delay NIM unit to create veto gate to indicate that the MCA should not record HPGe data during that period.

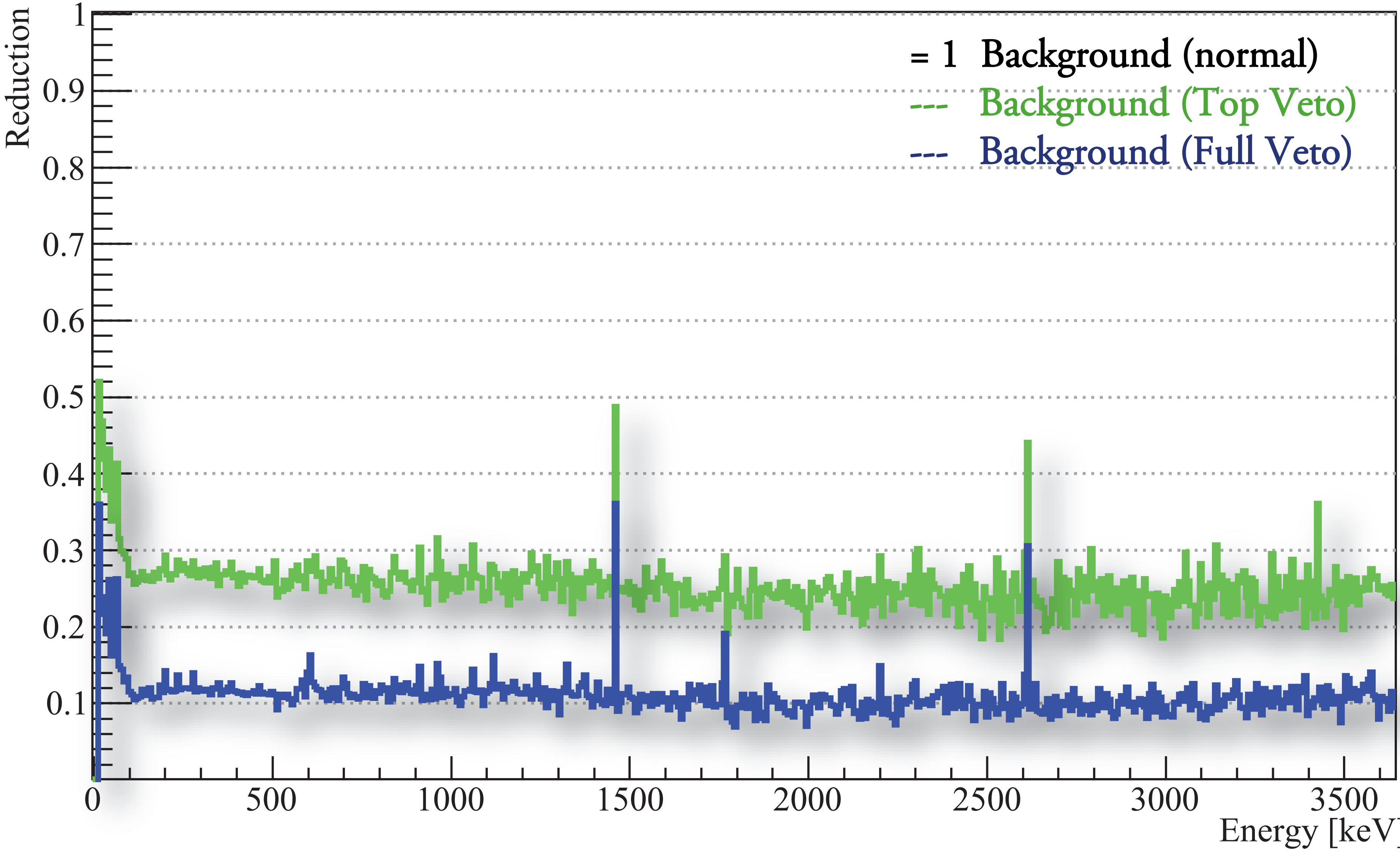
- Veto rate is stable regardless of threshold and gate length settings, and has a very simple operation.
- Low external gamma background in LBF counting lab makes this very easy-- false coincidences aren't an issue even if the threshold is set a little low.

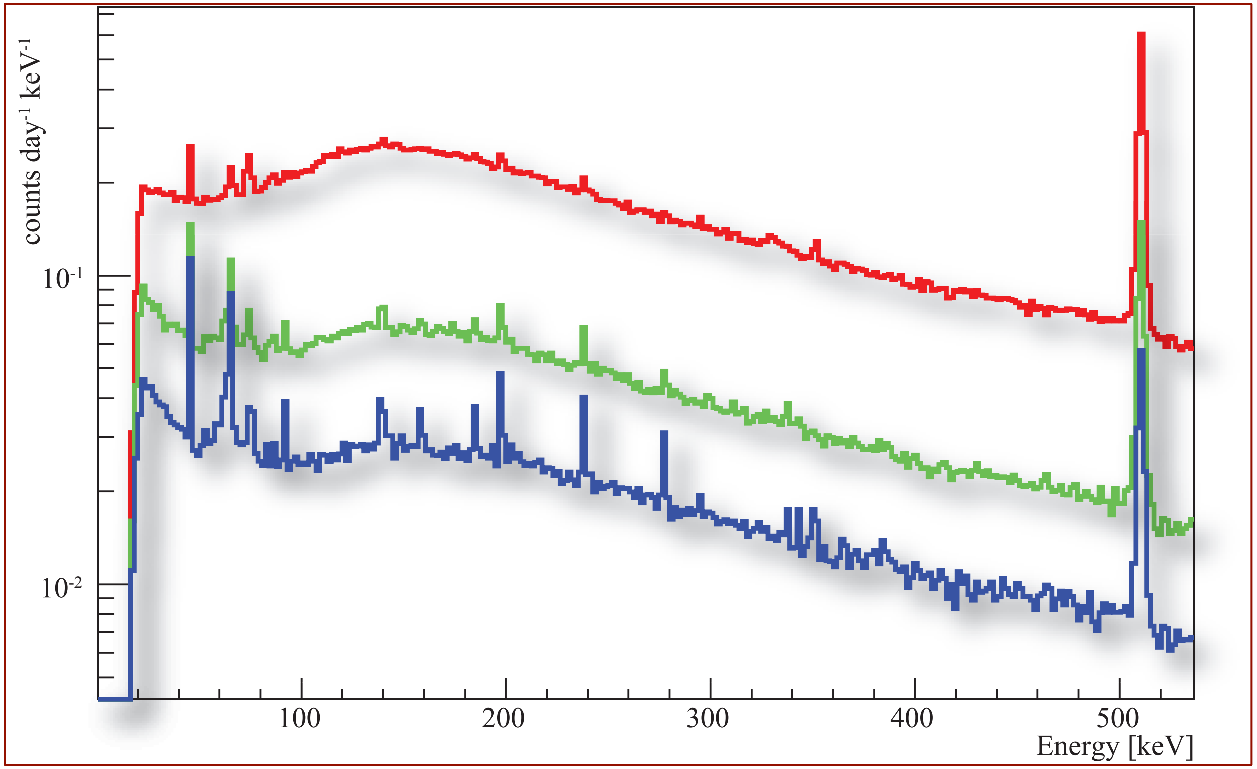
Background Reduction



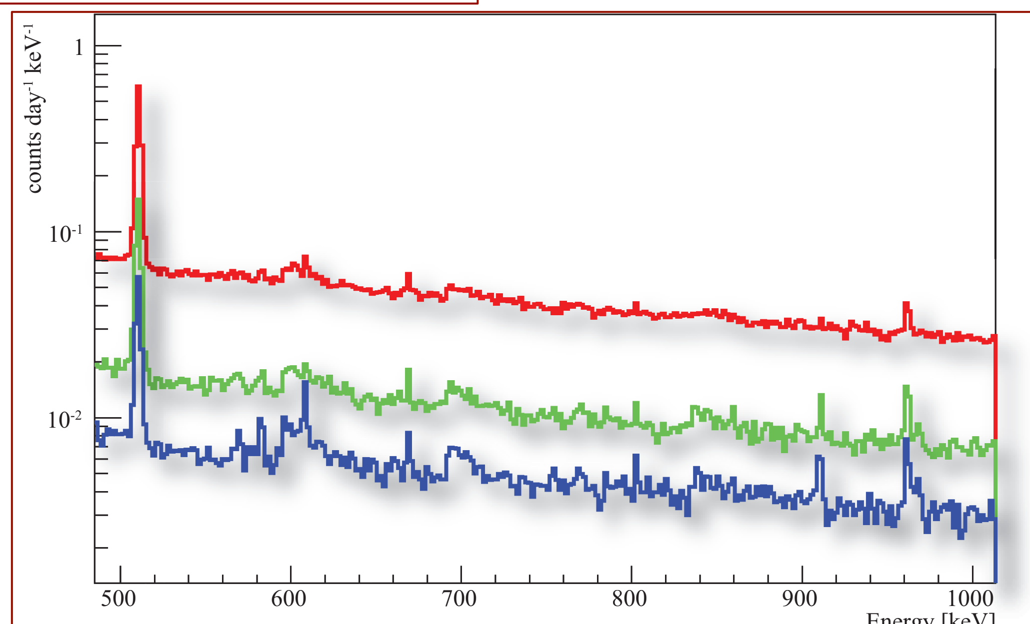
Total Reduction across entire spectrum: by factor of 8, but reaches up to a factor of 10.

Background Reduction



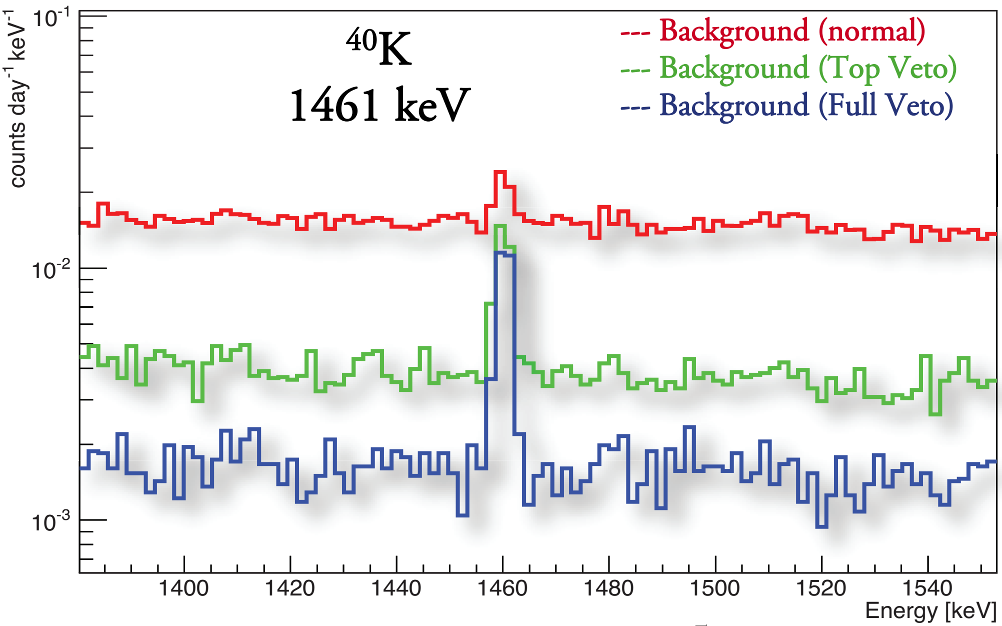


--- Background (normal)
--- Background (Top Veto)
--- Background (Full Veto)



Dramatic improvement of signal to background across the entire spectrum, as demonstrated here by background peaks.

Counting Rate Validations



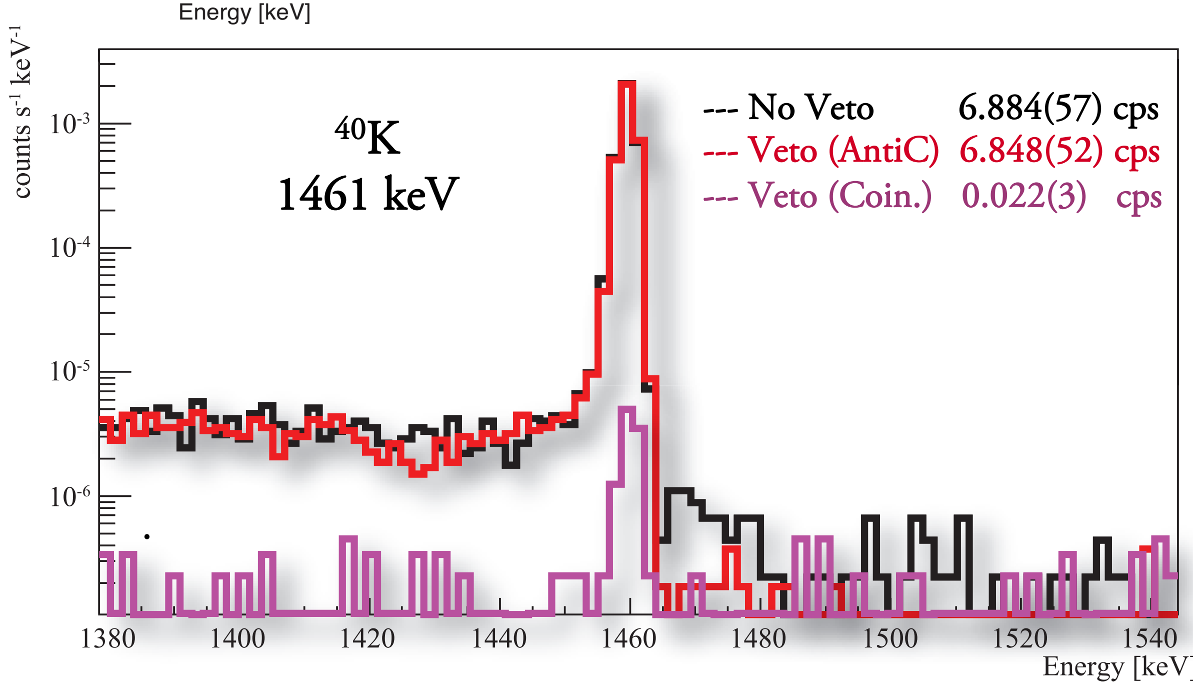
K-40 Background peak counting rate stays the same (~0.03 cpm) on each spectra, but much clearly defined in BKG-vetoed spectra (BKG reduced by 10 here)

*Very useful for low activity samples.

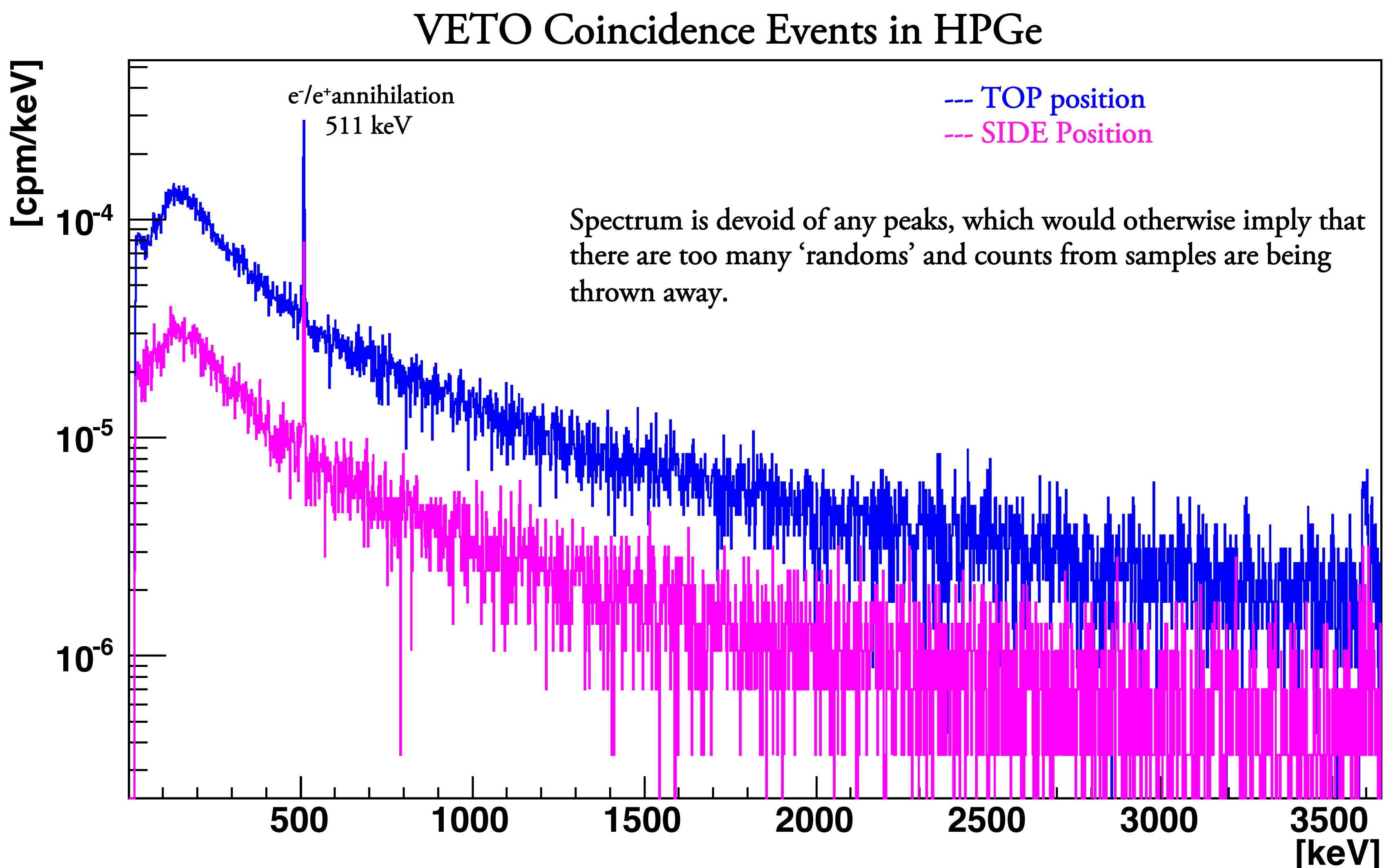
*Achieve equivalent statistics in ~1/3 the time

Comparison repeated at a higher count rate using a 'hotter' source – ~140 grams KCL.

Still no significant losses in count rate due to random coincidences.



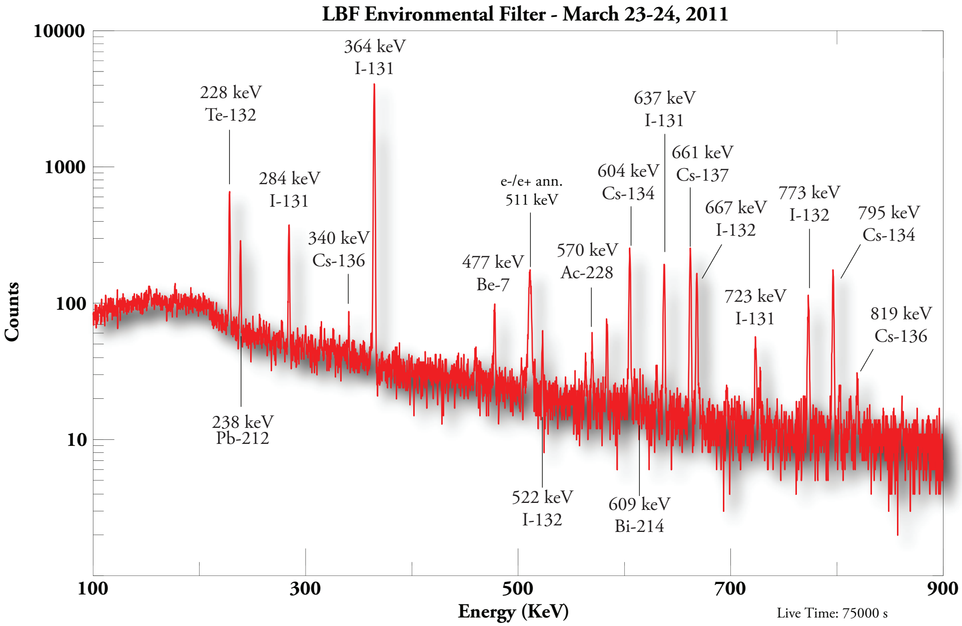
Vetoed Energy Spectrum



Only peak present is 511 keV from e^+/e^- annihilation, created by cosmic ray muon-related processes in the shielding/detector.

(single) Side to Top Ratio is ~ 24.5% consistent with $\cos^2\boldsymbol{\theta}$ prediction

Fukushima: LBF Air Station

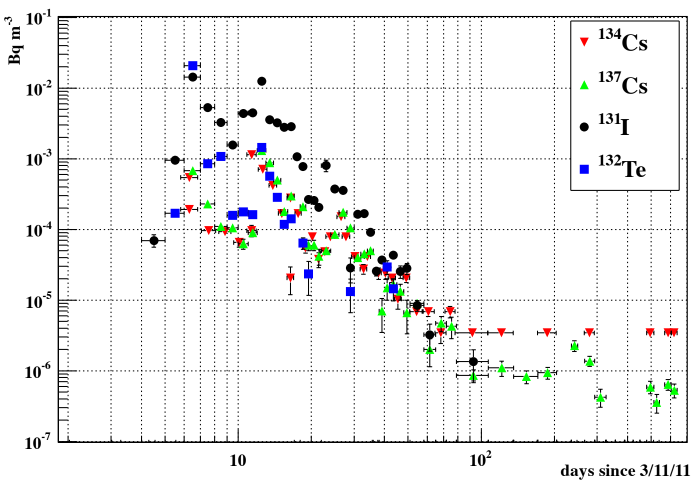


6 ft^3/min
245 m^3/day
4” HEPA

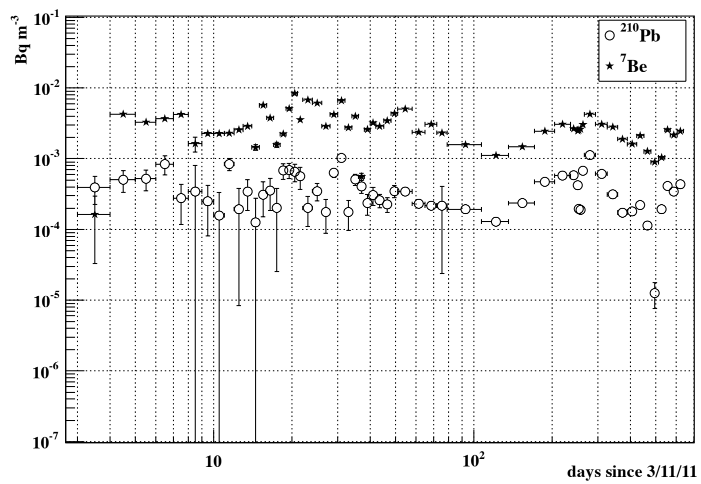
Detected in HEPA filters:
^{131}I, ^{132}I, ^{132}Te, ^{134}Cs, ^{136}Cs, ^{137}Cs

First detection of fallout was the 364 keV peak for ^{131}I on March 15-16, 2011. Arrival of ^{131}I with a companion fission product, ^{132}Te, on the following day officially confirmed its arrival, since ^{131}I is sometimes produced from local sources such as hospitals.

Fallout Radionuclides



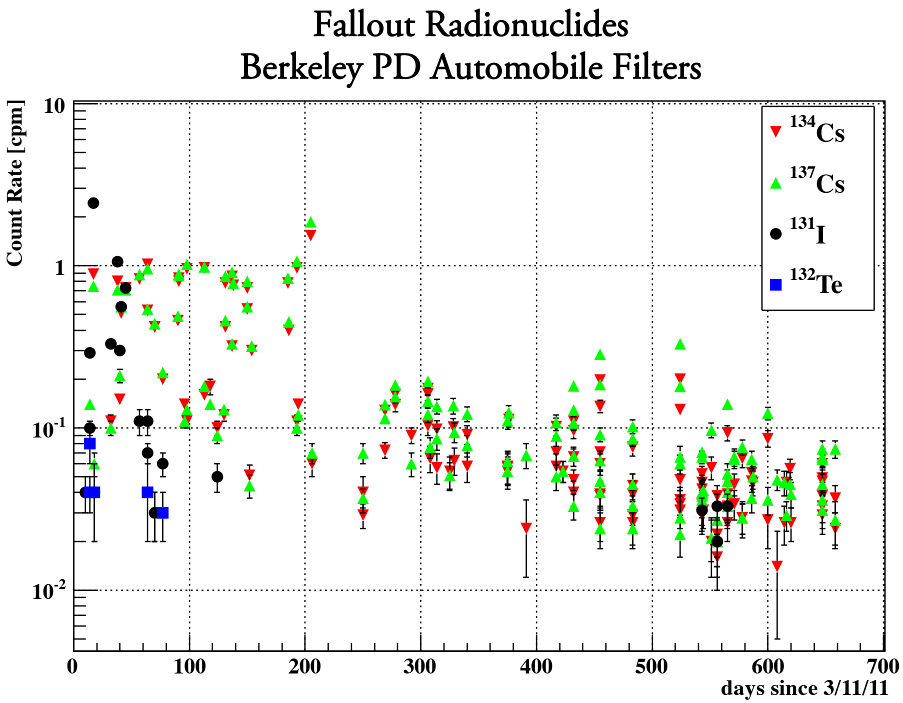
Natural Radionuclides*

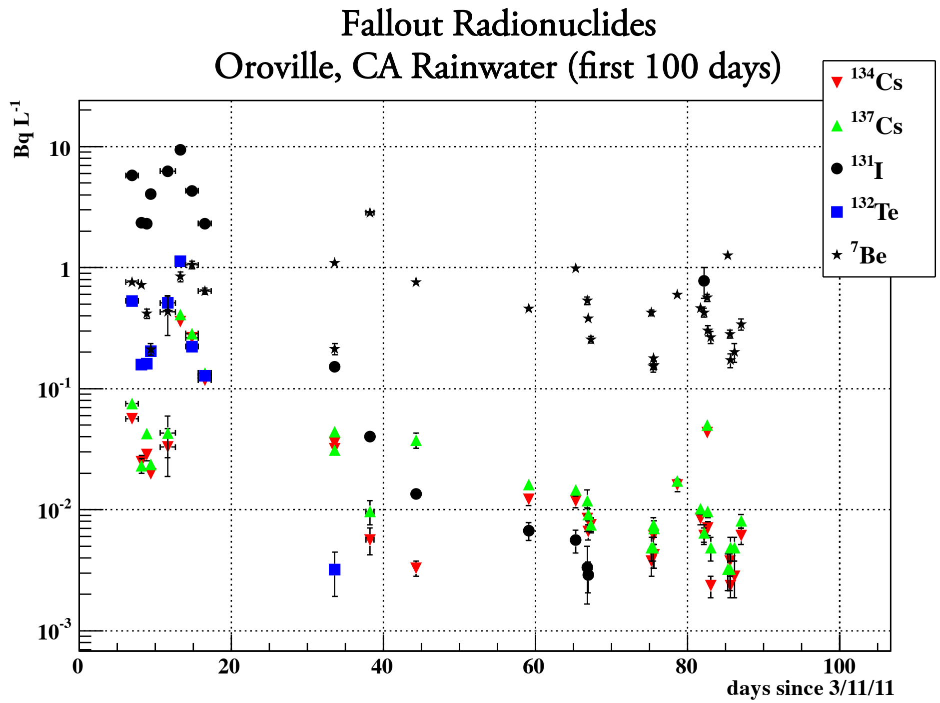


*Data for 134Cs, 137Cs out to end of 2012.

(note: Horizontal error bars signify filter exposure period. If error bars are not visible, then they are smaller than the data marker.)

Fukushima: Auto filters, Rain





Over 1200 automobile filters counted since 2002 with no trace of man-made radioactivity before Fukushima. The Fukushima Incident provided a proof-of-principle for monitoring method.

Document Summarizing all monitoring of Fuckushima Fallout: Air Filter, Auto Filter, Rainwater, Soil and Sediments, etc. is in preparation.

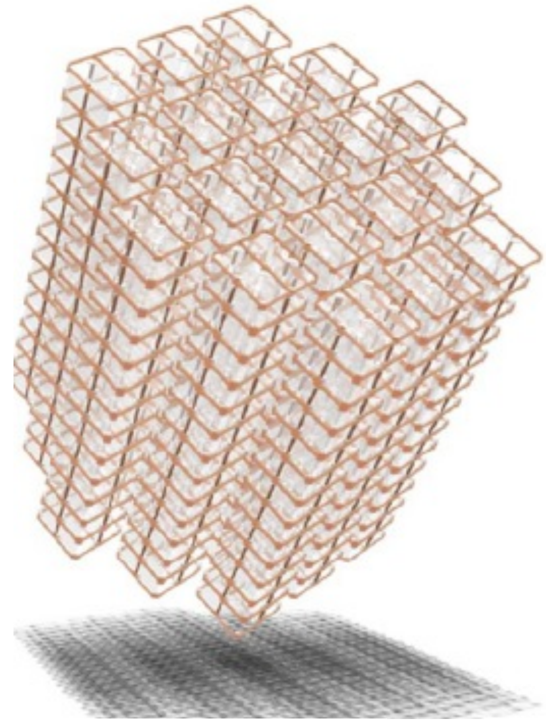
(note: Horizontal error bars signify filter exposure period. If error bars are not visible, then they are smaller than the data marker.)

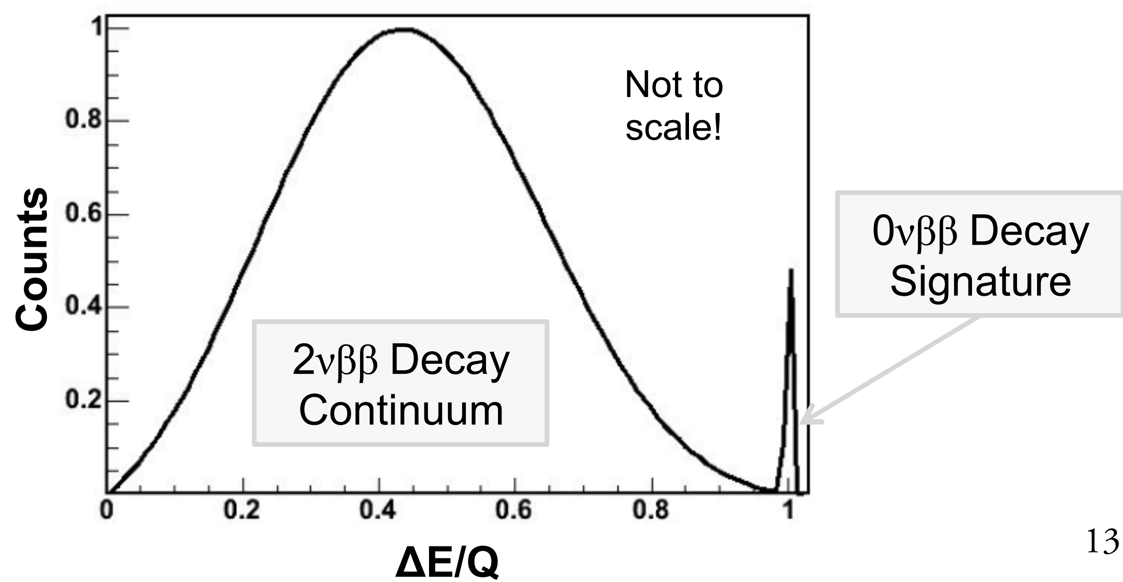
Cosmogenic Activation of TeO_2 in the 0νββ Decay Experiment CUORE

Barbara Wang

CUORE:

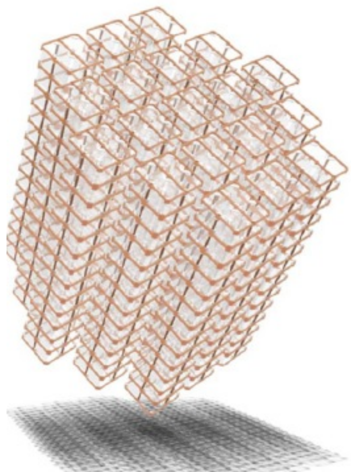
- Will search for 0νββ decay:
  $^{130}Te \rightarrow {}^{130}Xe + 2e^-$
  Q = 2527 keV
- Comprised of 988 high resolution, low background TeO_2 bolometers.
- **Goal background at 2527 keV:**
  0.001 - 0.01 counts/kg/keV/y
- **Half-life sensitivity:**
  1.6×10^{26} y
  (for background of 0.01 counts/kg/keV/y)

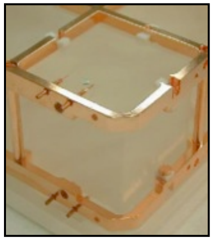




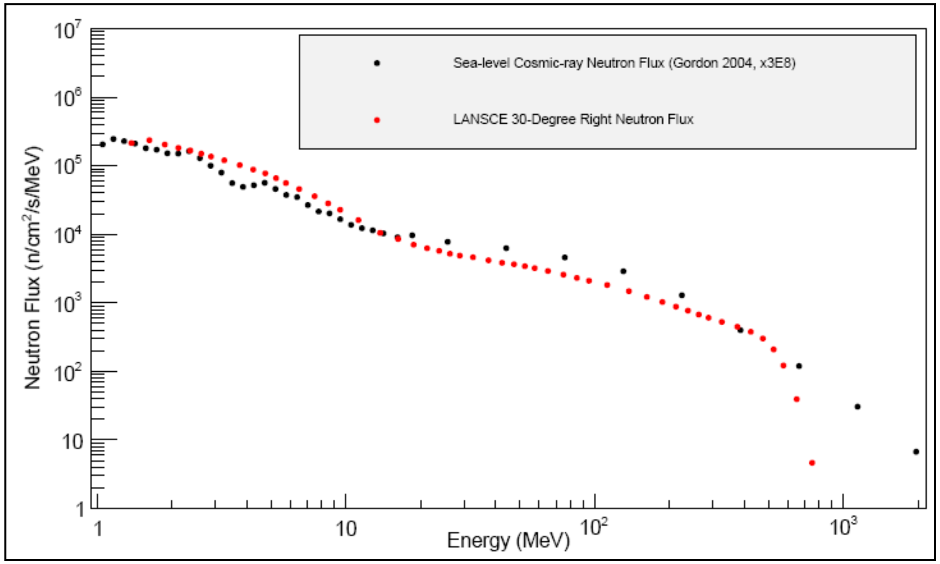
Cosmogenic Activation of TeO_2 in the 0νββ Decay Experiment CUORE

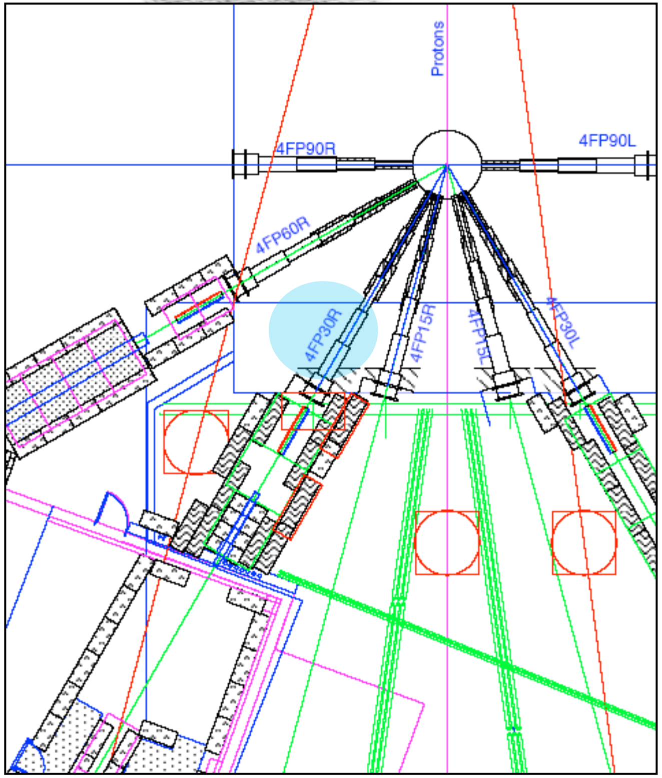
Barbara Wang





- Cosmogenic activation during transportation at sea-level results in intrinsic radioactivity in CUORE TeO_2 crystals.
- This background source poorly characterized because experimental cross-sections for radioisotope production in TeO_2 sparse.
- **Cosmogenic activation experiment:**
  - **Location:** Los Alamos Neutron Science Center (LANSCE)
  - **Target: 272 g TeO_2 powder** (Al, Au, and Cd foils used to track neutrons through target.)
  - **Irradiation time:** 42 hours
  - **Neutron flux:** 1.4E6 n/cm^2/s

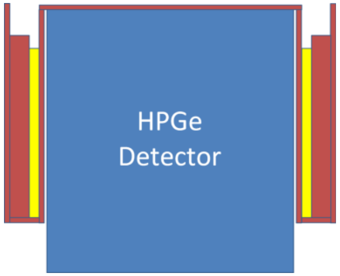


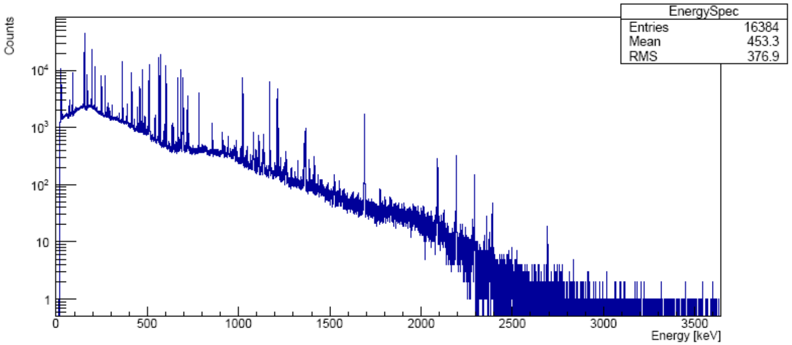


Cosmogenic Activation of TeO_2 in the $0\nu\beta\beta$ Decay Experiment CUORE

Barbara Wang

- TeO_2 powder gamma-counted after irradiation.





- Isotopes activated in powder that may be problematic for CUORE:

Isotope	Half-life	Mode of Decay	Q-value of Decay (keV)
Sb-124	60.2 d	Beta minus	2904
Ag-110 (Ag-110m parent)	24.6 s	Beta minus	2892
Ag-110m	249.8 d	Beta minus	3010

- Data from gamma spectra used to estimate background present in CUORE from cosmogenic activation of TeO_2

	Background Rate in 0ν DBD Region (c/keV/kg/y)
Sb-124	$(1.0\pm0.2)\times10^{-5}$
Ag-110m	$(8\pm1)\times10^{-5}$
TOTAL	$(9\pm1)\times10^{-5}$
CUORE Goal Bkg	$10^{-3} - 10^{-2}$

Summary

Other active projects in addition to LBC

– NAA (trace element), n-measurements, environmental measurements
– Fukushima monitoring summary coming soon
– Assistance with SUL/USD counting

Recent Upgrades!

- Muon Veto System – BKG reduced by factor of 8-10
- New ORTEC MCA, NIM electronics, networking equip., scope
- Upgraded remote-cloud based data sync to Oroville
- Re-smelt of existing supply of Old Pb (in evaluation/progress)

LBNL very active-- always eager to collaborate on new projects

Thank You

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arsmith@lbl.gov
ebnorman@lbl.gov
barbara.s.wang@gmail.com

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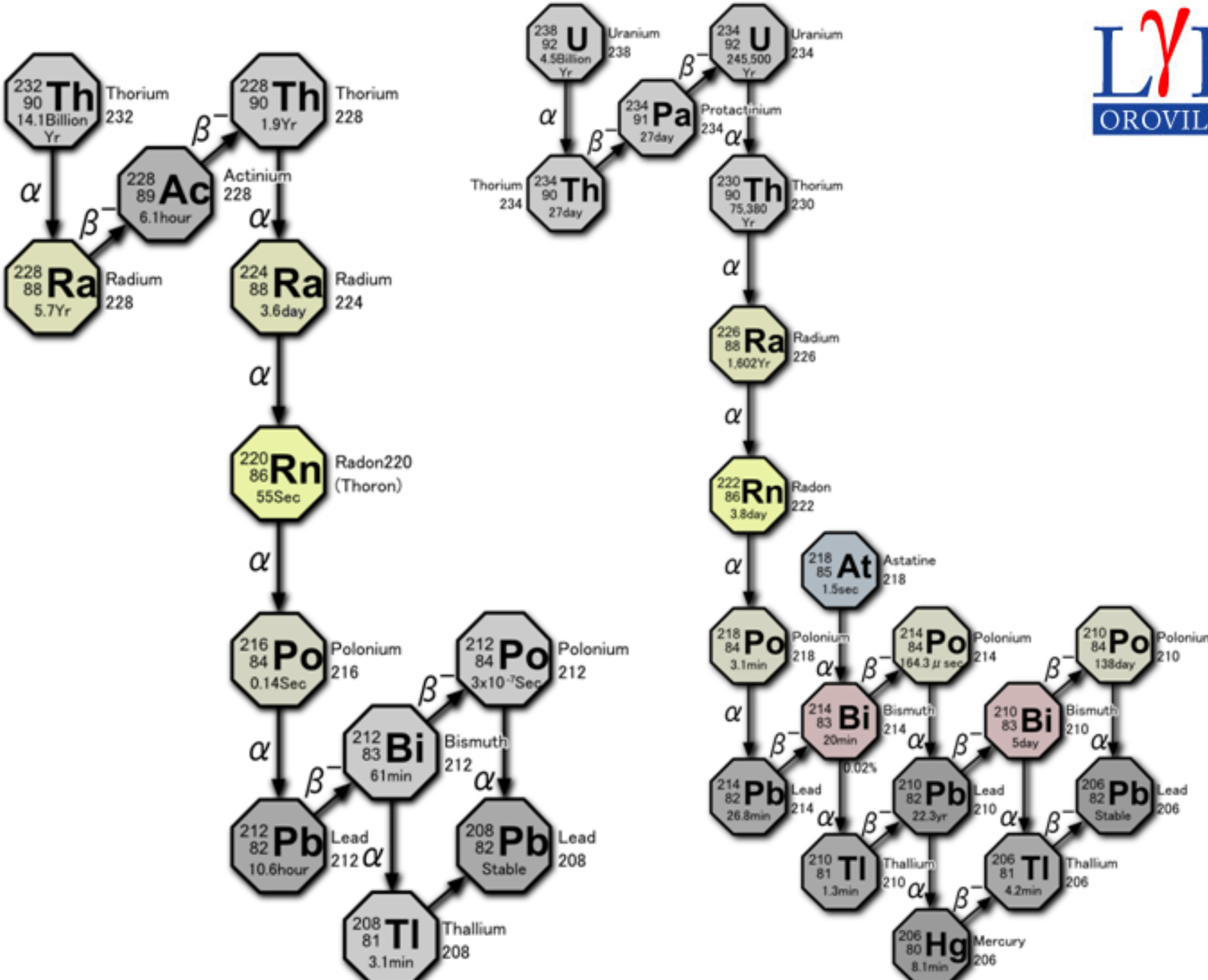
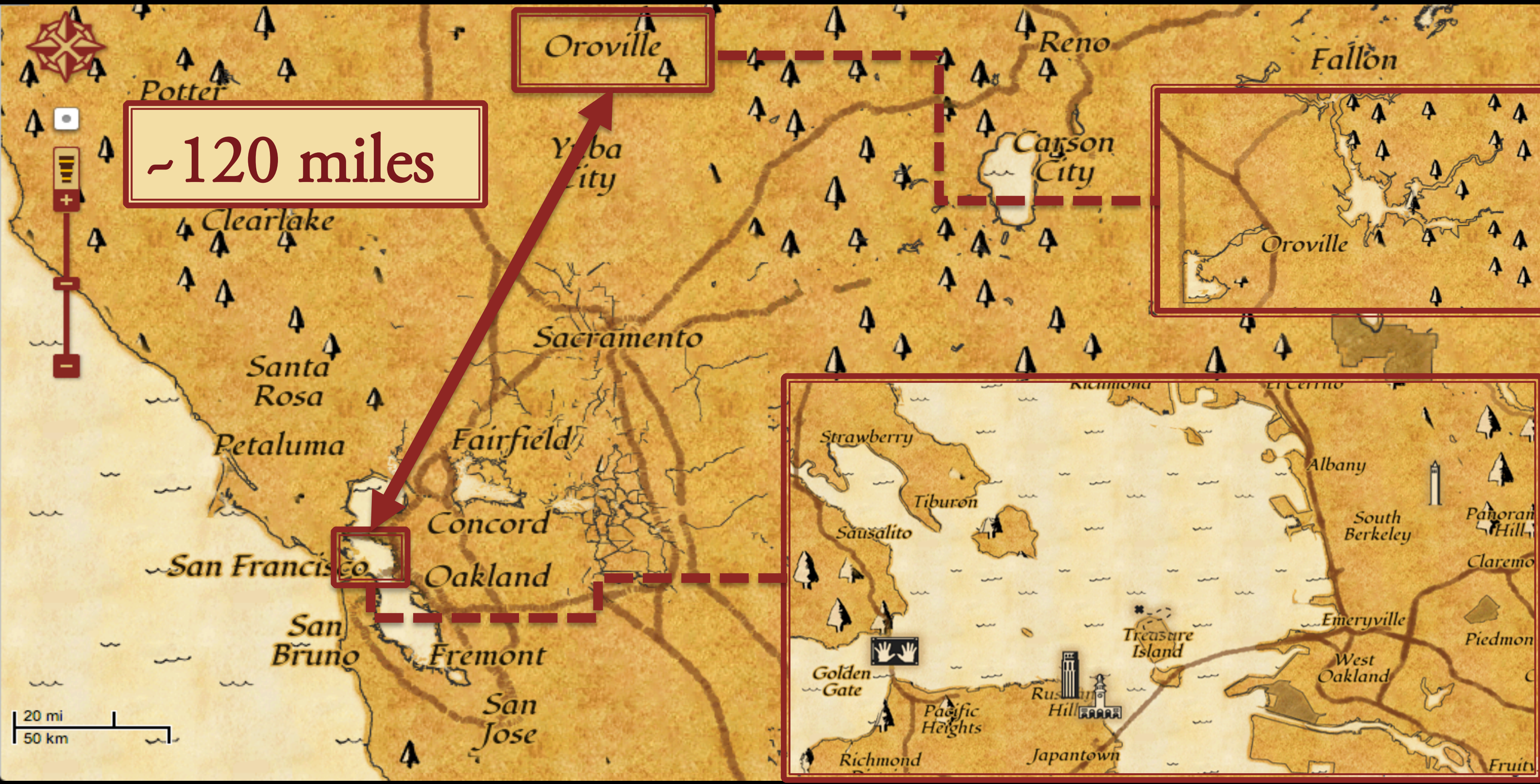
Extras

Background Reduction

(keV)	(keV)	BKG CPM	veto Top CPM	Full veto CPM	Reduction
25	50	4.0	1.6	0.9	4.6
50	100	7.8	2.5	1.3	6.2
100	150	9.8	2.6	1.1	9.0
150	200	9.8	2.6	1.1	8.6
200	300	14.1	3.8	1.7	8.3
300	400	9.3	2.5	1.1	8.5
400	511	6.9	1.8	0.8	8.8
	511	1.5	0.4	0.1	10.9
511	600	3.9	1.0	0.4	8.8
600	700	4.1	1.1	0.5	8.3
700	800	3.2	0.8	0.4	8.8
800	900	2.7	0.7	0.3	8.5
900	1000	2.3	0.6	0.3	8.4
1000	1100	2.0	0.5	0.2	8.8
1100	1200	1.8	0.5	0.2	8.2
1200	1300	1.5	0.4	0.2	8.8
1300	1400	1.4	0.3	0.2	8.6
1400	1460	0.7	0.2	0.1	9.2
1460	1500	0.4	0.1	0.0	9.2
1500	1600	1.1	0.3	0.1	9.6
1600	1700	1.0	0.2	0.1	9.5
1700	1800	0.9	0.2	0.1	9.3
1800	1900	0.8	0.2	0.1	10.2
1900	2000	0.8	0.2	0.1	10.5
2000	2100	0.7	0.2	0.1	9.8
2100	2200	0.6	0.2	0.1	10.2
2200	2300	0.6	0.2	0.1	9.9
2300	2400	0.6	0.1	0.1	9.4
2400	2500	0.5	0.1	0.1	9.6
2500	2600	0.5	0.1	0.1	10.1
2600	3575	3.5	0.8	0.4	9.8



LγBγF
OROVILLE LBNL


~120 miles
Oroville
Potter
Yuba City
Clearlake
Reno
Fallon
Carson City
Sacramento
Santa Rosa
Petaluma
Fairfield
Concord
San Francisco
Oakland
San Bruno
Fremont
San Jose
20 mi
50 km
Strawberry
Tiburon
Sausalito
Albany
South Berkeley
Emeryville
Treasure Island
Golden Gate
Pacific Heights
Japantown
West Oakland
Piedmont
Richmond

Deadtime

The deadtime introduced to our system by the generation of gates in anticoincidence is calculated as:

$$T_D(\%) = r_g \times l_g \times 100\%$$

which is necessary to check manually, since the 919 MCB we currently use does not automatically account for deadtime introduced by its gate input, only the conversion time it uses measuring pulses.

For this system we have ~6200 cpm for through going muons and use a 30us gate length, so it only generates ~0.3% deadtime (which is quite negligible).

The low activity concrete in the LBF really allows for our settings for threshold/gate length to be quite flexible, compared to conventional construction.