



The University of South Dakota

Update on External Background Characterization of Homestake Mine for Sanford Lab and DUSEL

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AARM Collaboration Meeting --- LEAD, Nov 12, 2010

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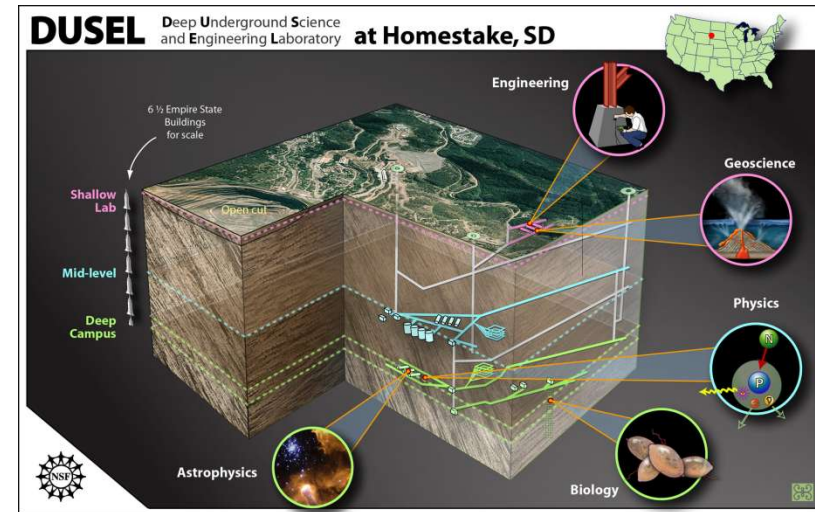
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External Backgrounds at Homestake

- Measuring external sources of radioactivity at the DUSEL site is key to success in low-energy neutrino and dark matter (WIMP searches) experiments
 - Shielding design, radon mitigation, and active veto
- **The Sources of External Background**
 - Radioactivity in the rock
 - Gamma-rays, (alpha, n) neutrons, radon
 - Muon-induced processes
 - Muon-induced neutrons
 - Muon bremsstrahlung
- **How the measurements are being pursued**
 - NaI detectors for measuring gamma-rays
 - Plastic scintillators for measuring muons
 - Liquid scintillators for measuring neutrons
 - RAD 7 and AlphaGuard for measuring radon levels

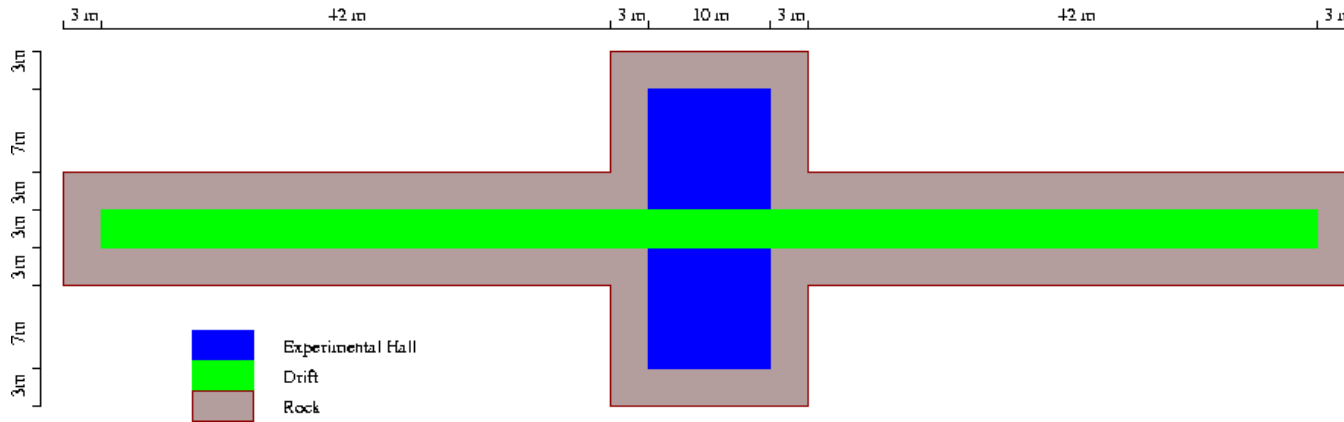


Rock Composition

Produced primarily through the radioactive decay processes of U^{238} , Th^{232} , and K^{40} present in the host rock.

Sample	Core #	Note	U (ppm)	Th (ppm)	K (%)
HST-05A	15532	7300-7450L, Poorman	0.080	0.25	0.104
HST-05B	15532	7300-7450L, Poorman	0.085	0.25	0.125
HST-06	11537	4850L, Poorman/Yates	0.160	0.20	0.154
HST-07	15532	4850L, Poorman	0.55	0.30	2.12
HST-12	11553-352	4850L, Yates	0.21	0.30	1.12
HST-13	11553-218	4850L, Yates	0.19	0.19	0.920
HST-14	18627-3461	7400L, Yates	0.18	0.24	1.01
HST-15	18627-3461	7400L, Yates	0.49	0.20	0.57
HST-08	15680-820	4850L vicinity (Rhyolite)	9.4	12.2	3.98
HST-09	17581-822	7400L vicinity (Rhyolite)	8.3	10.1	3.31
HST-10	11553-059	4850L vicinity (Rhyolite)	8.0	8.6	2.80
HST-11	11537-180	4850L vicinity (Rhyolite)	8.6	12.2	1.69
HST-16		1250L Pump Rm.(Rhyolite)	8.71	10.9	6.86

Background Simulation



Rock Component (Sample 278-2)	Composition (% weight)
SiO_2	43.7
TiO_2	1.22
Al_2O_3	13.6
FeO	12.7
MnO	0.13
MgO	7.0
CaO	7.9
Na_2O	2.87
K_2O	0.21
P_2O_5	0.07
H_2O	10.7
$^{232}Th(\alpha, n)$ Yield	0.34/g/ppm/y
$^{238}U(\alpha, n)$ Yield	0.86/g/ppm/y

<http://neutronyield.usd.edu>

NIM A 606(2009)651-660 (arXiv:0812.4307)



★ We developed a web database to calculate (α,n) neutron yield in all possible element/compound/mixture.

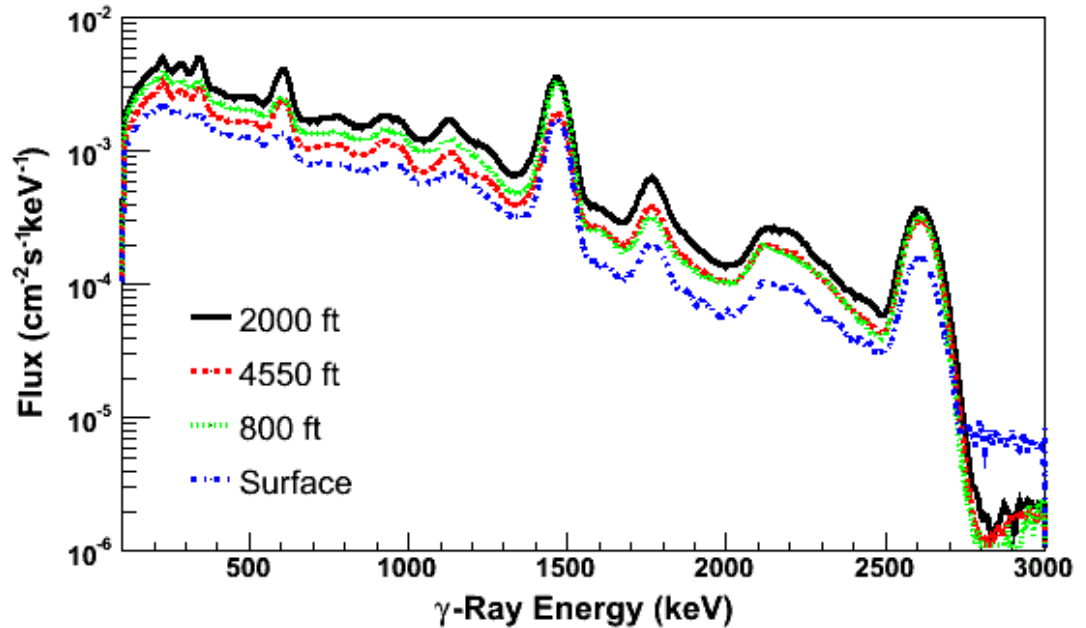
★ The result of neutron energy spectrum is taken as an input for MC simulation.

Table 1: The equilibrium yields from ^{238}U , ^{232}Th and Samarium ($E_n > 0.1MeV$).

Element	^{232}Th ($n \cdot ppm^{-1} \cdot g^{-1} \cdot y^{-1}$)	^{238}U ($n \cdot ppm^{-1} \cdot g^{-1} \cdot y^{-1}$)	Samarium ($n \cdot ppm^{-1} \cdot g^{-1} \cdot y^{-1}$)
Boron	1.32e+01	5.00e+01	8.32e-03
Carbon	1.13e-01	3.78e-01	
Oxygen	4.53e-02	1.45e-01	2.57e-06
Neon	1.65e+00	5.02e+00	
Sodium	1.75e+00	5.43e+00	
magnesium	1.47e+00	4.14e+00	
Aluminum	2.04e+00	4.95e+00	
Silicon	2.12e-01	5.54e-01	1.49e-08
Phosphorus	2.01e-06	5.63e-07	
Argon	3.06e+00	6.12e+00	
Potassium	2.84e-02	5.36e-02	
Calcium	1.90e-02	3.54e-02	
Titanium	8.60e-01	1.38e+00	
Manganese	4.03e-01	4.61e-01	
Iron	1.71e-01	1.61e-01	
Copper	3.77e-02	1.77e-02	
Xeon	6.07e-07	1.33e-08	

Gamma Ray Background

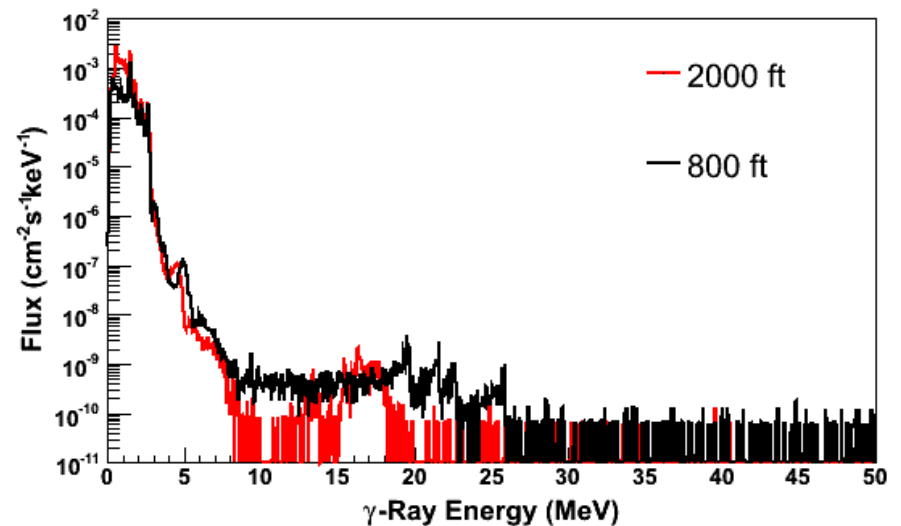
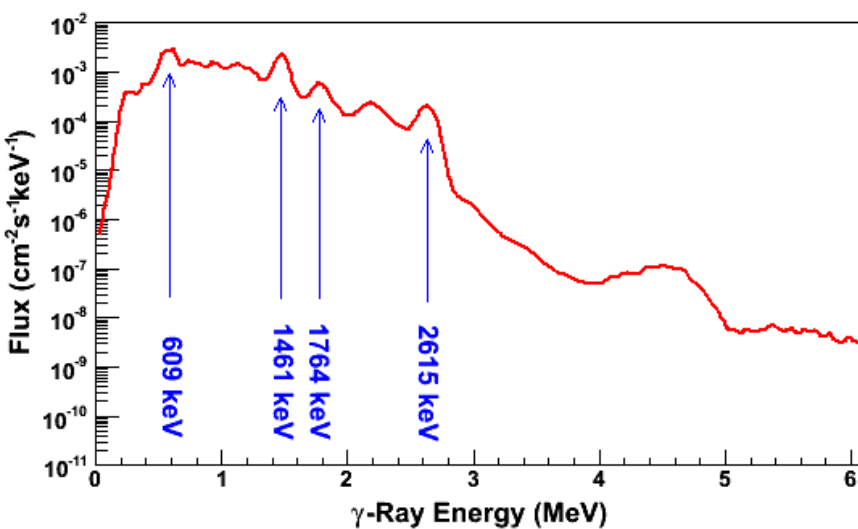
arXiv:0912.0211



- Levels surveyed so far include locations on the surface, 800L, 2000L, and 4550L.
- Results depend most upon local geology. More measurements are planned for the 4850L soon when appropriate areas become available.

Gamma Ray Background

Long-term measurements are being conducted in an effort to characterize the higher energy gamma ray flux, as a result of muon bremsstrahlung. This has been done on the 800L and it is currently operating on the 2000L with plans to relocate to the 4850L soon.

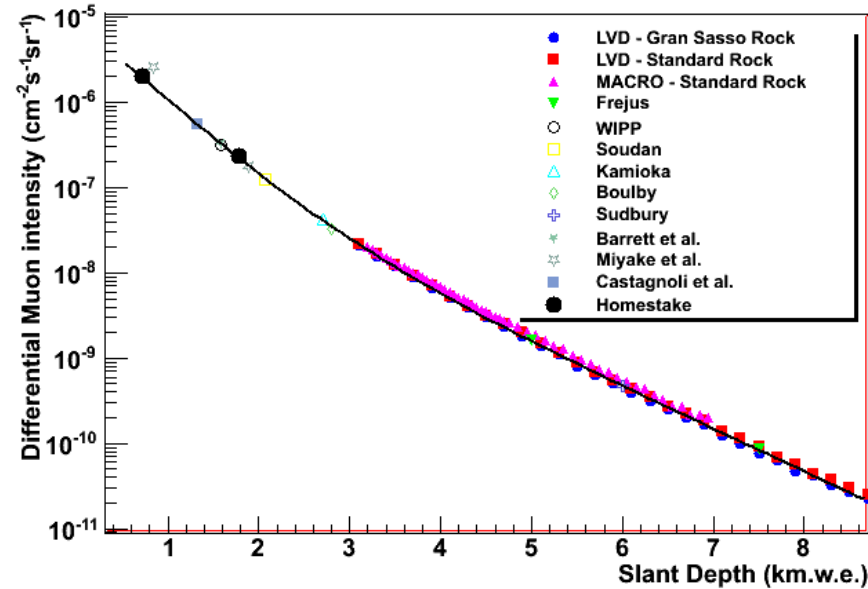


~ 2 months data collected.

Muons



Muon detector system on the 2000L



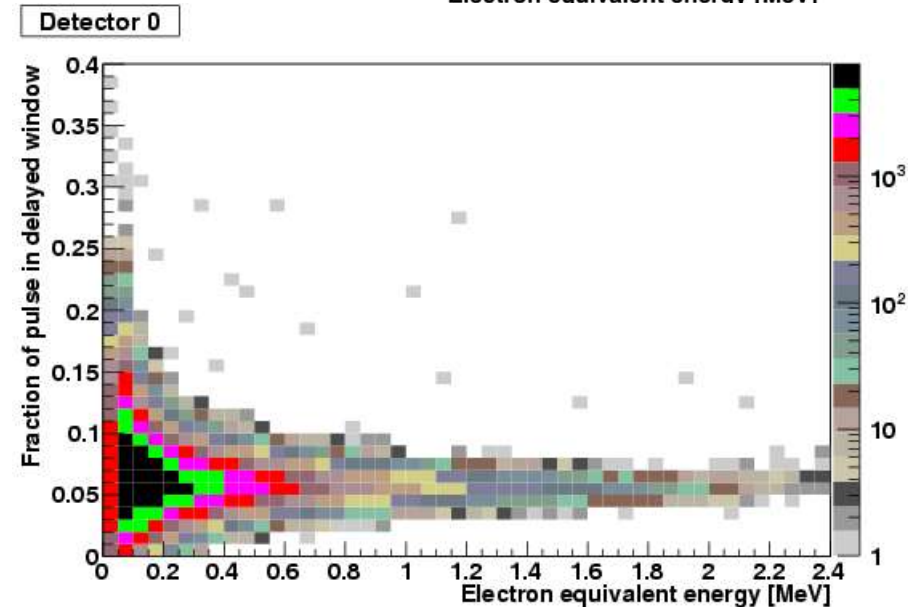
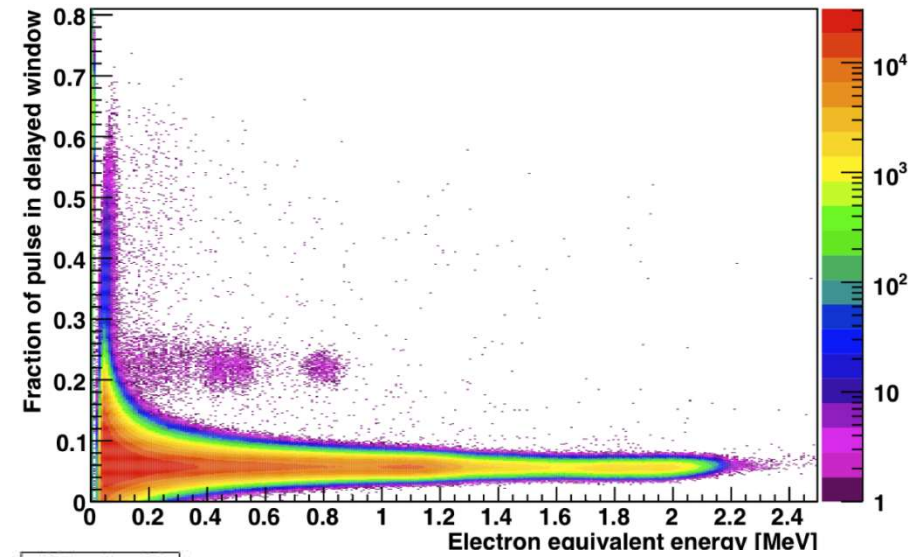
Muon measurements conducted thus far have been consistent with what was predicted in Mei & Hime's paper: PRD 73, 053004 (2006)

[arXiv:1007.1921\[nucl-ex\]](https://arxiv.org/abs/1007.1921)

Surface	$(1.15 \pm 0.01) \times 10^{-6} \text{ s}^{-1} \text{ cm}^{-2} \text{ sr}^{-1}$
800L	$(2.67 \pm 0.06) \times 10^{-6} \text{ s}^{-1} \text{ cm}^{-2} \text{ sr}^{-1}$
2000L	$(3.05 \pm 0.34) \times 10^{-7} \text{ s}^{-1} \text{ cm}^{-2} \text{ sr}^{-1}$

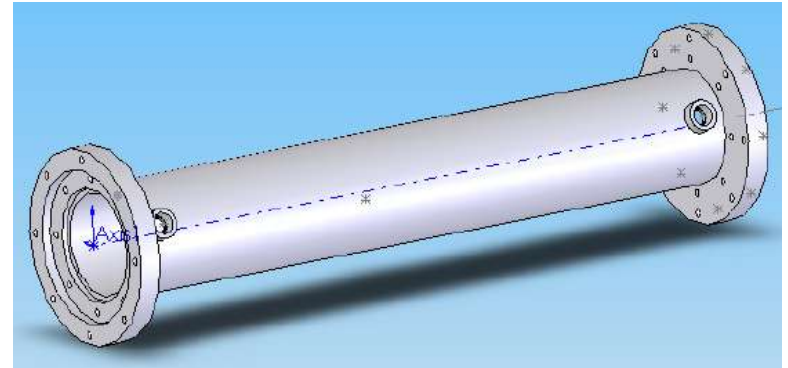
Neutrons

- ★ Neutrons are produced in rock through (a, n) reactions, spontaneous fission, and muon-induced process.
- ★ Current measurements are being conducted with approximately a 1L scintillation cell containing Eljen Technologies EJ301 Liquid Scintillator, chosen for its pulse shape discrimination.
- ★ Alpha backgrounds in the small scintillator are dominant, so that we will need a coincidence technique.

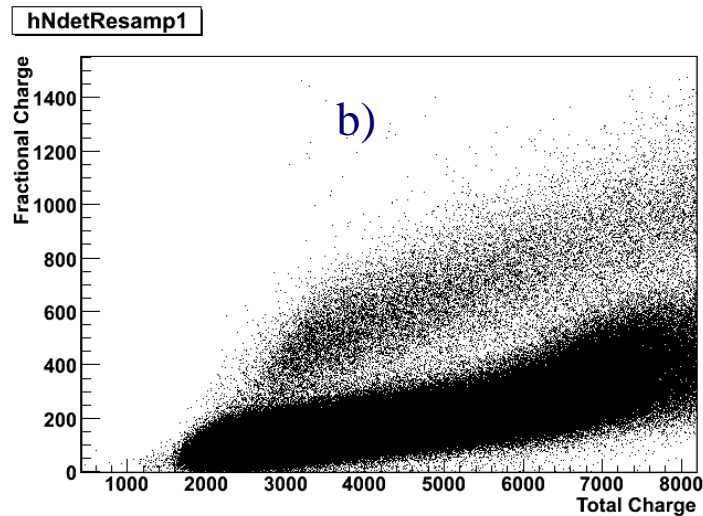
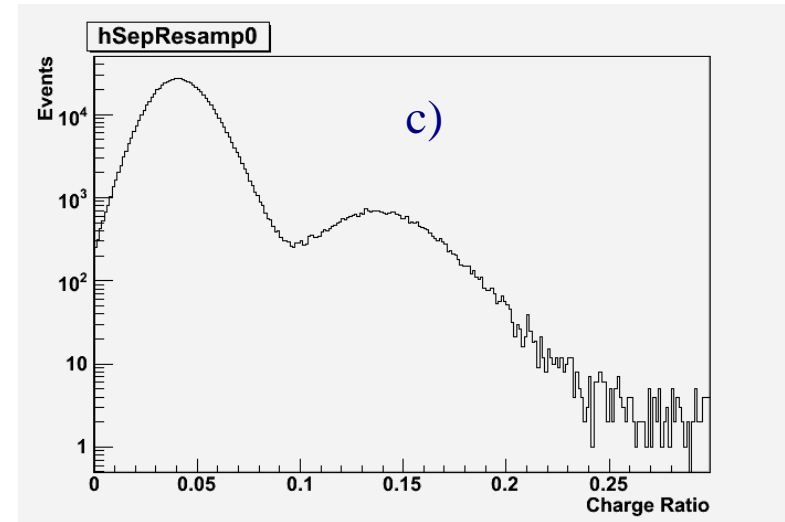
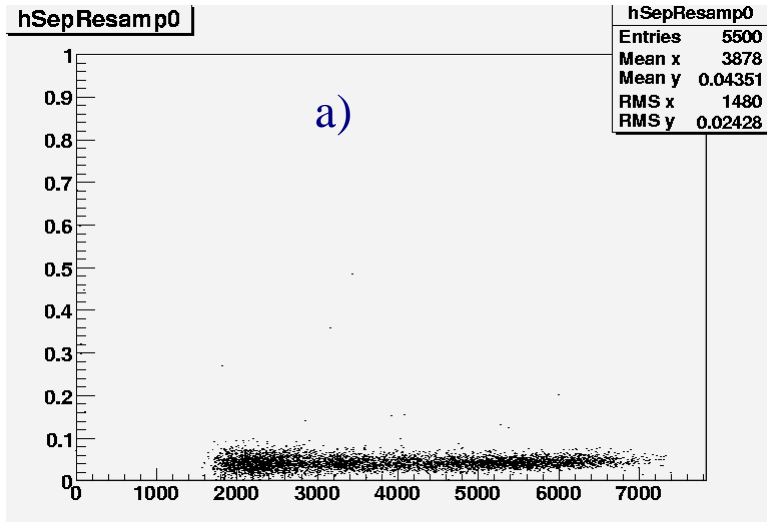


Big Neutron Detector

- ★ A 10L liquid scintillation counter has been built and tested in the lab.
- ★ it's a 5" in diameter, 1 meter in length Aluminum tube filled with EJ-305 liquid scintillators. EJ-520 reflective paint is uniformly painted on the inner surface of the tube.
- ★ Two PMTs (R4144 , hamamatsu) installed at the both ends of the counter.



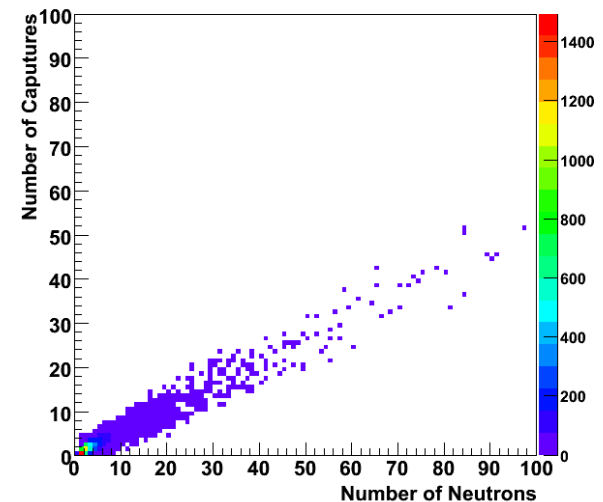
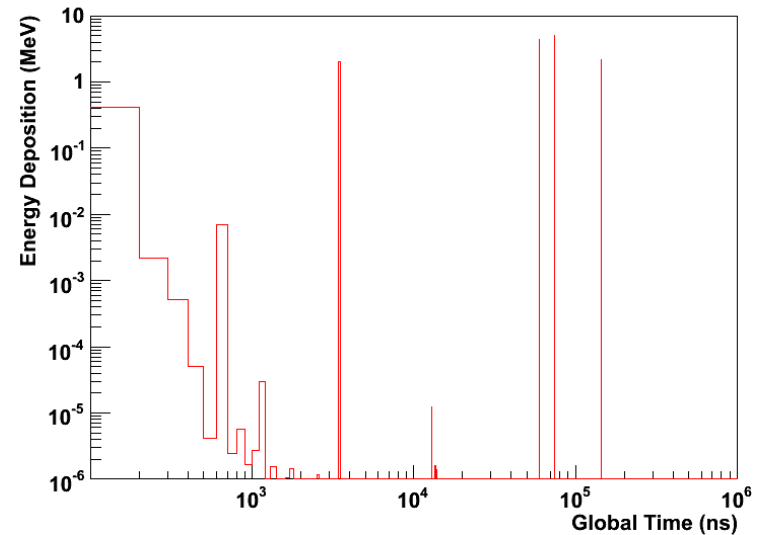
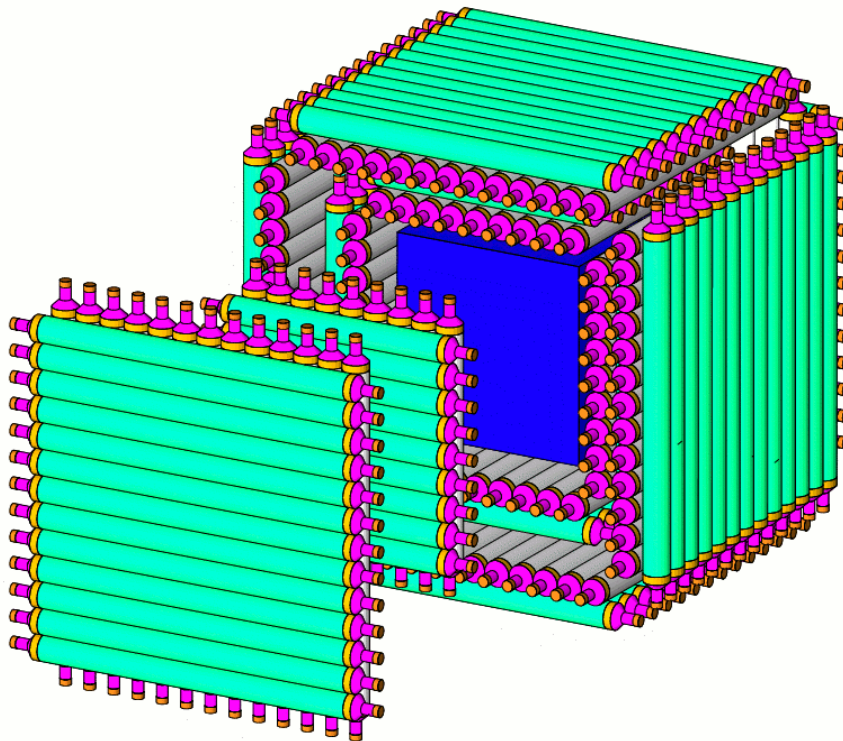
Big Neutron Detector



- a) ^{60}Co source.
- b) AmBe source.
- c) Pulse shape discriminations.

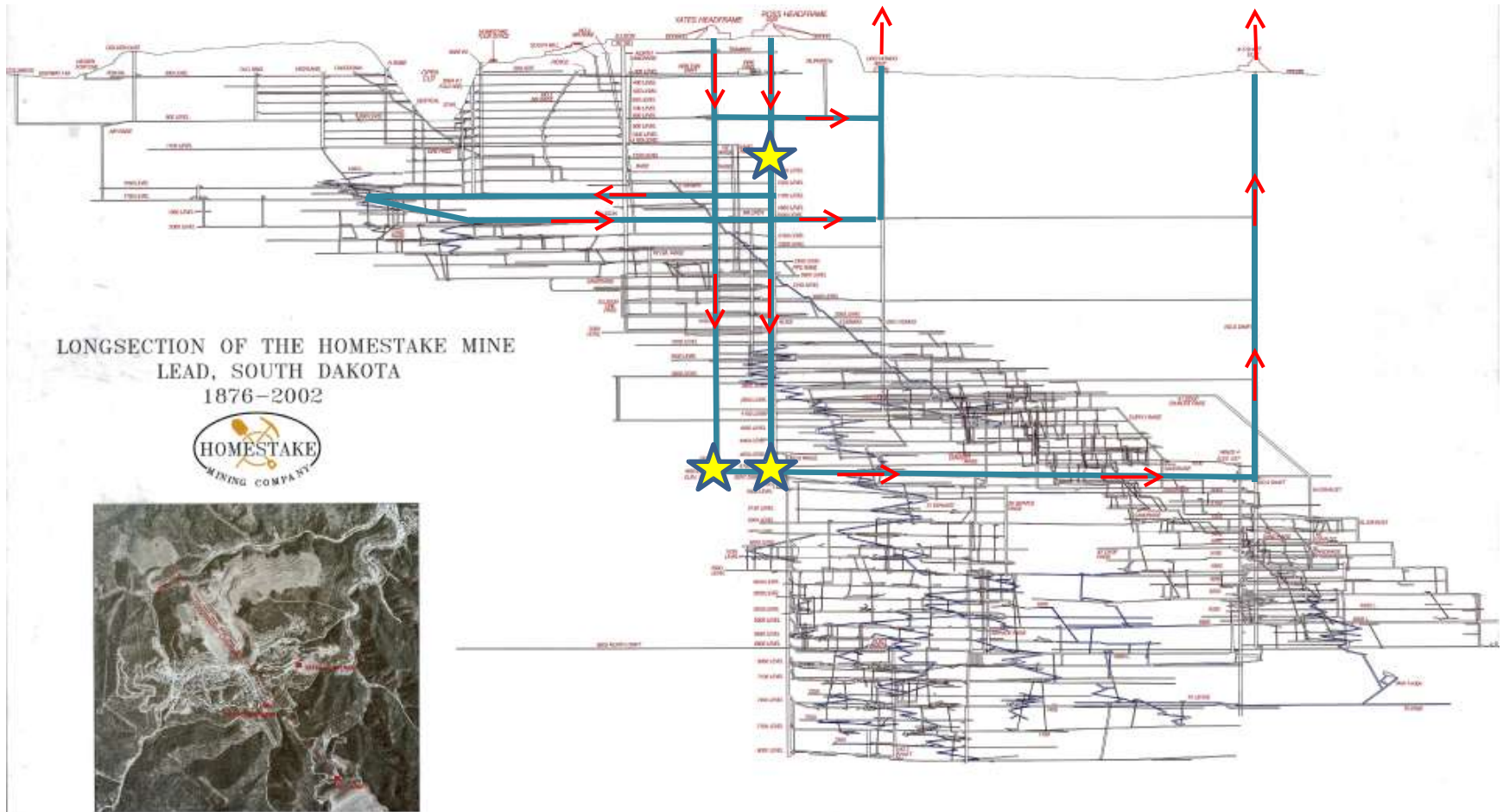
Big Neutron Detector

- ★ Phase I: this 10L liquid scintillation counter will be deployed at 2000 ft level underground for test soon.
- ★ Phase II: a detector system which surrounds inner and outer four layers liquid scintillators / water doped Gd counters together with the muon tracking detectors above and below the target will be replaced.



Radon

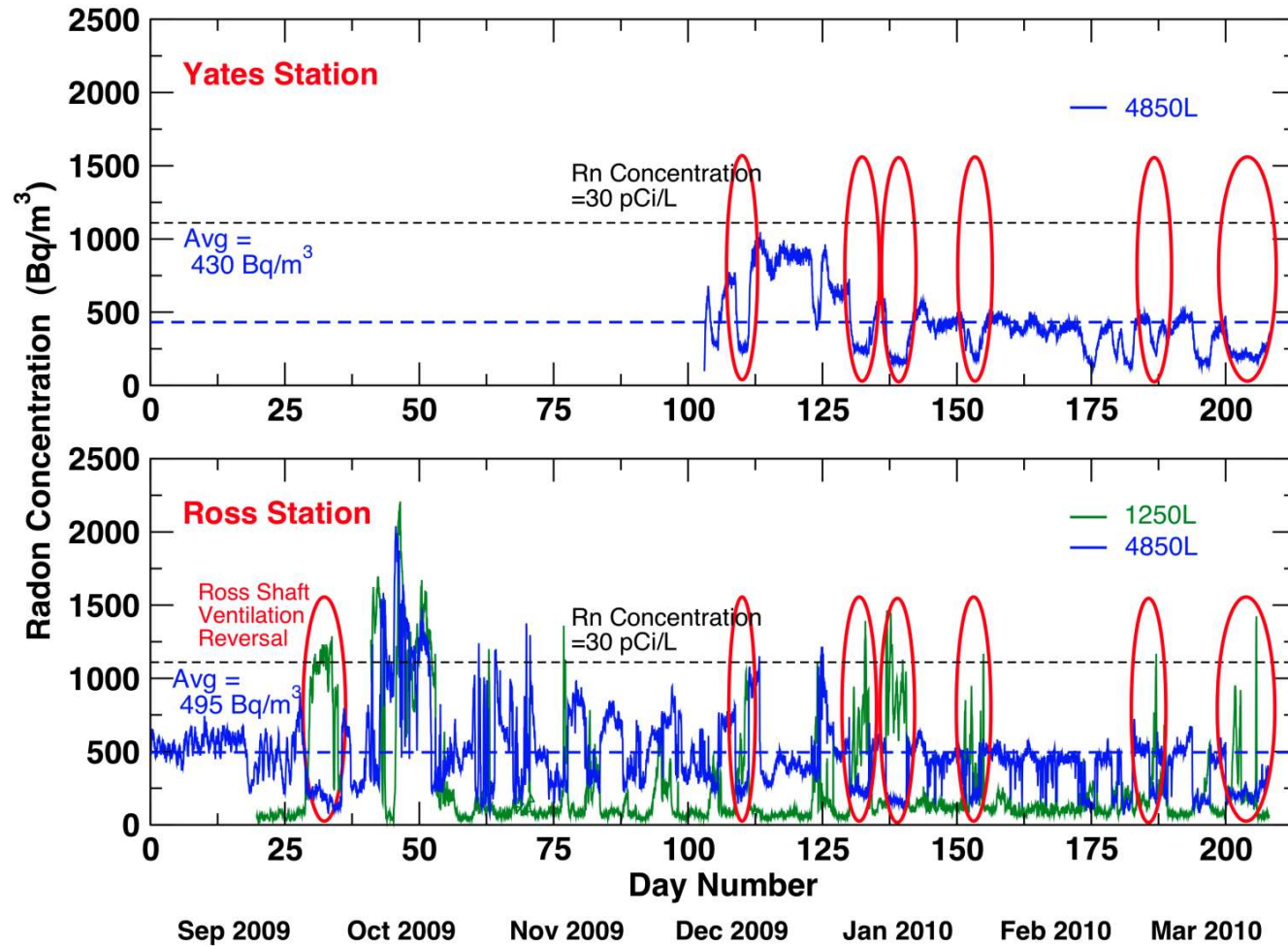
Only 30-50% of Historical Capacity. (and very dynamic)



Radon

Sanford Lab Underground Radon Concentration

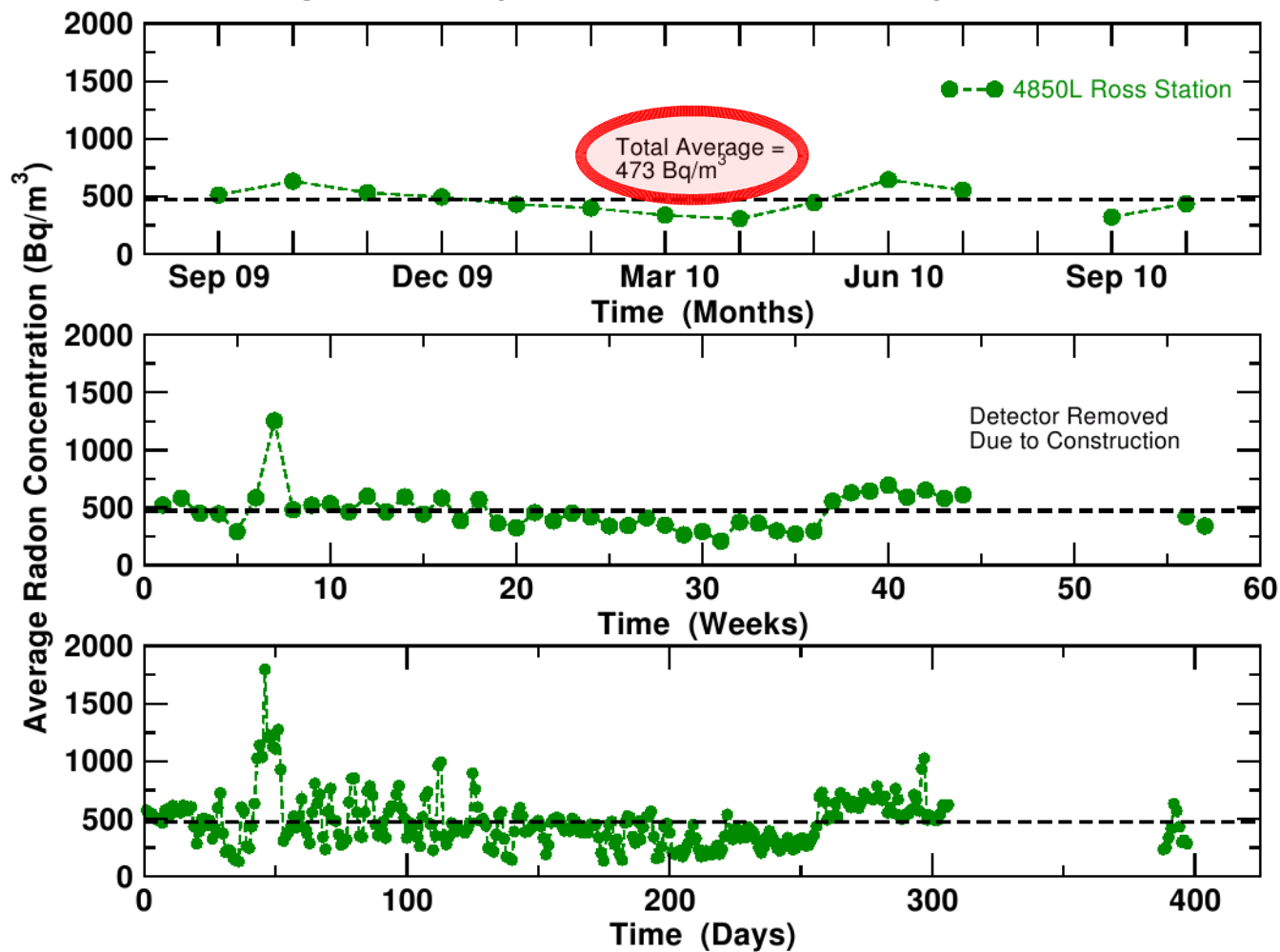
Using Genitron AlphaGuard detectors since September 3, 2009



Radon

Sanford Lab Underground Radon Concentration

Using Genitron AlphaGuard detectors since September 3, 2009



Radon

SDSTA Iron Oxide Sludge 3/11/10-2

^{234}Th	U(early)	1.3	ppm
$^{226}\text{Ra}\downarrow$	U(late)	14	ppm
$^{228}\text{Ra}/\text{Ac}$	Th(early)	44	ppm
$^{228}\text{Th}\downarrow$	Th(late)	11	ppm



- Preliminary results from sample taken from water filtration system on surface (3/11/10) and sent to Al Smith for counting at LBNL.

In comparison:

Homestake Country Rock Homestake Rhyolite

U	0.08-0.2	ppm
Th	0.2-0.3	ppm

U	8-10	ppm
Th	8-12	ppm

Both U series, Th series *not in equilibrium*; in particular due to enrichment of Radium in the iron oxide (not because of Radon).

- Rn emanation: 8 pCi/g
- Fine iron oxide dust underground can pose source of contamination in clean room transitions, for example.



Status

- Gamma flux measured on surface, 800L, 2000L, and 4550L.
- High energy gamma's are being measured right now underground on the 2000ft level. System will be relocated to the 4850L soon.
- Muon measurements have been made on the surface, 800L and 2000L. Results agree with predictions/measurements taken in past. The setup will relocate soon to the 4850L.
- Neutrons are currently being measured on the 800L, and will soon incorporate a 10L detector.
- The simulation results agree with the measured results on muons and gamma rays pretty well. Prediction can be done for levels/areas temporarily inaccessible.
- Continuing multiple-site monitoring in terms of radon level, to understand ventilation changes/improvements from the radon mitigation. 2-3 long term monitors will be added at new sites soon for additional radon comparison.