

## **B1. Low Level Counting, Radon control, ultra-pure materials, and Homeland Security Cross-Cutting Working Group**

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### **Supporting Science at DUSEL**

Many of the science opportunities that will be pursued in the initial suite of experiments at DUSEL will require detectors to be constructed from materials having ultra-low levels of radioimpurities. The *Low Level Counting, Radon control, ultra-pure materials, and Homeland Security* cross-cutting working group collected information from the science disciplinary working groups on the technologies and capabilities needed to produce and/or certify ultra low-background materials and the environments necessary for carrying out the DUSEL science missions. Although the DUSEL science needs are both broad and disparate, there are commonalities in the production and assay of low-background materials that argue for cost-effective facilities centered at DUSEL.

The cross-cutting group also made an initial assessment of existing facilities within North America, collected preliminary estimates on assay needs and throughput for the initial suite of experiments at DUSEL, and identified a set of core technical capabilities that are recommended for implementation in a low-background assay and materials preparation facility at DUSEL.

### **Needs as defined by the Disciplinary Working Groups**

All of the eight disciplinary science working groups as well as the Other Uses cross-cutting group were polled to ascertain their low-background assay needs, required sensitivities, and any special material or environmental demands. Based on their responses, the groups can be approximately divide into two categories based on their low-background assay and ultra-pure material requirements:

#### *Significant needs.*

- Solar/Geo/Supernova neutrinos (A1)
- Neutrinoless double beta decay (A2)
- Dark matter and other rare searches (A4)

#### *Modest or limited needs.*

- Long Baseline Neutrinos, Nucleon Decay and N-NBar Oscillations (A3)
- Underground Accelerator Laboratory for Nuclear Astrophysics (A5)
- Biology (A6)
- Earth Sciences, (A7)
- Geo-Engineering (A8)
- Homeland security (B2)

Groups A1, A2, and A4 have both extremely demanding technical requirements as well as significant assay throughput needs. They require an array of assay techniques including radiometric (gamma) counting, inductively-coupled plasma mass spectrometry (ICP-MS), neutron activation analysis (NAA), radiochemistry-NAA (RNAA), alpha and beta counting, and radon emanation measurements. The proposed experiments in these areas will each require the counting of many hundreds of samples and materials. All require the identification and in

several cases production of materials with extremely low levels of U and Th (less than microBq/kg). Many require substantial reduction of cosmogenic induced activities, by either storing materials underground to allow for the decay of these impurities or producing the material underground using processes that selectively eliminate unwanted radioactive isotopes.

A common need for groups A1, A2, and A4 includes low background shielding - which is often a combination of lead and/or copper, and hydrogenous materials such as polyurethane and/or water. Gamma screening using high purity germanium (HPGe) detectors will be sufficient for screening many of the samples of the shielding materials, with the exception of the innermost lead and copper which is closest to the detectors serving as either shielding or detector construction materials. Achieving the necessary purity levels for this inner copper requires electroforming production facilities underground and enhanced sensitivity ICP-MS assay techniques. The anticipated need for a large amounts of copper shielding requires early installation of DUSEL facilities with the sufficient production, storage, and assay capabilities. R&D is necessary to develop the enhanced ICP-MS sensitivities to U and Th at the sub-microBq/kg level. An ultra-low background ICP-MS radiochemistry lab, based on the latest technology, should be implemented at DUSEL as part of the suite of assay systems.

Electroformed copper may be able to meet demands for pure inner shielding if started early, but there are other options that should be initiated for general shielding materials, such as a program of stockpiling copper or other materials in existing underground storage locations, which over time allows much of the cosmogenic activities to decay. There is also the option of acquiring ancient lead. It is increasingly hard to find and can be expensive, but a concerted effort at collecting this for DUSEL may be useful. A water shield is an inexpensive way to build large scale hydrogenous shields. The purification required can be achieved by commercial systems (except for the ultra-sensitive, whole body counter envisioned for the deep campus).

Most passive shielding will not be able to stop high energy cosmic muon-induced neutrons, and as one moves deeper, this neutron spectrum becomes even harder. Thus, it has become very important to develop active neutron shielding, as well as the simulation tools necessary to predict punch-through rates, production of fission neutrons, and neutron producing radioactive isotopes in the material around the detectors. Resulting nuclear recoils in the detectors will become the irreducible background for even the deepest WIMP searches. R&D into enhanced neutron shielding for example via the addition of Gd-loaded scintillator or Cerenkov systems is one avenue to consider pursuing.

Radon reduction and cleanliness techniques are also important for detectors being designed to search for rare decays or interactions. Some dark matter experiments, for example bubble chamber types, cannot distinguish WIMPs from above-threshold energy depositions from alphas. For other experiments, the push toward ever-increasing sensitivity means that every part in the device must be protected from radon plate-out which deposits radioactive daughters into surfaces. This, in turn, places greater restrictions on the amount of radon anywhere. These needs support the continued development of cost effective radon reduction techniques for livable spaces, such as pioneered by NEMO and Borexino. The DUSEL assay capabilities should include devices capable of measuring radon emanation from materials, as well as surface alphas and betas.

The proposed experiments include various structural components and detector parts made from a variety of materials. Initial assay of many of these materials can be done via production HPGe detector gamma screening. Here an issue will be the sheer volume, as opposed to the sensitivity. In Figure 1 is a previous estimate of the number of samples to be counted as a function of year that was compiled by the DUSEL Solicitation-1 low-background working group. The consensus of the B1 working group attendees is that this is an underestimate, in particular when considering the number of ultra-low activity measurements.

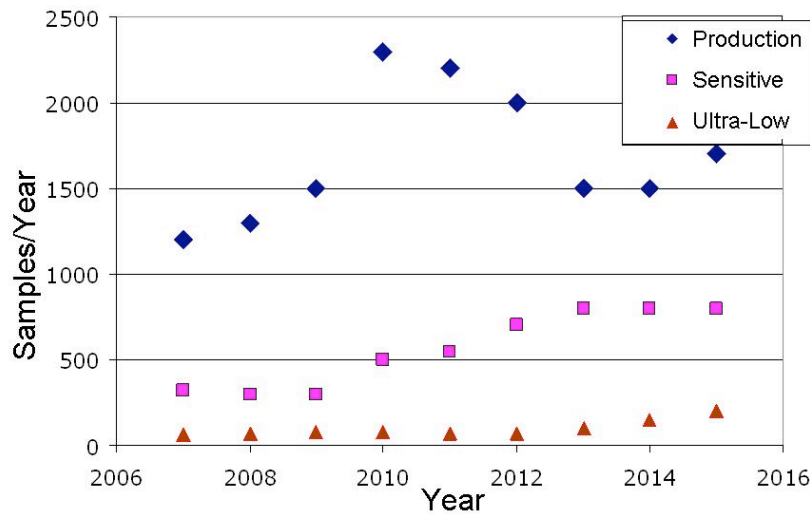


Figure 1. Estimated Assay Needs from the Solicitation 1 Working Group

Assay of some small parts and materials will require enhanced sensitivity and assay methods other than radiometric gamma counting, such as ICP-MS or NAA. NAA is complementary to ICPMS; materials not readily dissolved for ICPMS, in many cases can be effectively assayed via NAA and visa versa. For these NAA measurements, a separate radiochemistry and handling infrastructure will be required, including the need for separate, dedicated HPGe detectors that can be used for counting activated materials so that one does not risk contaminating the more sensitive HPGe counters used for screening low-background non-activated materials.

Groups A3, A5-8, and B2 that identified only modest assay or material purity requirements will still require access to reasonable sensitivity screening facilities. For instance, the long baseline neutrino group (A3) identified only modest ultra purity goals, such as purification of water and argon, and low activity concrete. Likewise the underground accelerator facility (A5) aims to measure extremely low cross-sections requiring modest amounts of low-background shielding materials, but has no extreme ultra-purity requirements. Microbiologists are interested in developing radiotracer detectors with several micron scale spatial resolution, as well as DNA microarrays which look at minute amounts of uptake from those tracers. Isotope dating will be needed by geologists, hydrologists, and biologists, and this often requires sensitive beta counting. These efforts will not push assay sensitivity capabilities, but will require use and access to the production screening facilities. Homeland security tasks will also add to the total number of samples requiring production screening of gammas, alpha, and betas, but these needs are likely

to be met using current technologies and sensitivities. Many of these groups may eventually require specialized facilities or capabilities that could be developed in conjunction with the overall low-background assay and materials facilities at DUSEL.

### **Existing Facilities and Programs**

There are a number of existing UG facilities in North America that are currently providing material assay screening to the community. These sites were surveyed to determine what resources currently exist. Given the anticipated needs for materials screening, these facilities will continue to provide important complementary capabilities, even after the DUSEL low-background facilities start operation.

- *Kimballton* - In 2007, a Va Tech, NCSU, UNC collaboration received DUSEL R&D funding to provide both HPGe gamma screening at a facility located at 1450 meter water equivalent (mwe) depth at the Kimballton Mine as well as access to a GEMPI-type HPGe detector located at Gran Sasso. At Kimballton, they expect to have the NIST 'Melissa' HPGe detector and a VT-1 ORTEC Ge counter operational by spring 2008. They anticipate being able to provide screening access to interested users.
- *Oroville Facility* - LBNL operates a HPGe counter at the Oroville Dam at a depth of 180 mwe. Recent groups utilizing the screening facility include CUORE, Daya Bay, DoubleCHOOZ, KamLAND, KATRIN, LUX, Sanford Lab, and MAJORANA. In addition to the Oroville counter, they have a low-background concrete shielded lab at Berkeley to provide initial screening, where they have moderate sensitivity HPGe, as well as NaI, and BF<sub>3</sub> detectors.
- *Sanford Lab* - A group at the University of South Dakota is leading an effort at the Sanford Laboratory at the Homestake Mine for an early implementation of a low background counting facility at the 300 and 4850 foot levels. The instrumentation is expected to be funded through an EPSCoR grant. By 2009 there should be 2 HPGe detectors available for screening for the user community. It is anticipated that several additional HPGe detectors will be installed during 2010-2012. For this latter stage, work may begin on laser isotope separation and development of ICP-MS/NAA radiochemistry labs. By 2012 there may also be alpha/beta counting devices.
- *SNOLab* - At 6060 mwe SNOLab has a HPGe counter currently being used at the 100% level for their planned experiments: SNO+, EXO, PICASSO, and DEAP/CLEAN. They also have a Rn emanation chamber and a bank of 8 electrostatic counters also used for detecting Rn emanation from components. Users can apply for to these screening facilities. For ICP-MS measurements, they established have close ties with the NRC facility in Ottawa.
- *Soudan* - A low-background facility at a depth of 2100 mwe is located in a large experimental hall previously used for the original proton decay experiment at the Soudan Laboratory. The facility, which has ample room for additional users, is enclosed by proportional tubes that have been refurbished to make an active muon veto shield and is configured to provide easy user access to this trigger and timing information. In a different hall, there is the SOLO installation which includes a 0.5 kg HPGe detector (heavily used by XENON) and a new 1.2 kg HPGe detector is planned for installation in January 2008. Two new alpha/beta counters are being developed at the facility: a beta cage (DUSEL R&D) for use primarily by CDMS collaboration should be in operation by early 2009 and a new device by XIA for use by CDMS and COUPP experiments will be available spring 2008.

- *WIPP* - A LANL group maintains a low-background facility at 1700 mwe at WIPP. The lab is dedicated to carrying out MAJORANA collaboration R&D activities, but is open to negotiated shared use for another user. There are currently several HPGe detectors in this facility.

In addition to the underground facilities, there are currently laboratories at PNNL being used to develop ultra-sensitive ICP-MS measurements needed by MAJORANA. There is also a screening facility at the University of Alabama that has been used for KamLAND and EXO related NAA measurements.

### **Roadmap for the Future**

The clear consensus of the working group was that DUSEL must have world class facilities capable of providing assay and ultra-clean materials support for the initial suite of science experiments. Any such facility also will require a local staff with the requisite expertise. The expectation would be that this staff would provide state-of-the-art assay and materials preparation and eventually would also help lead and direct future R&D efforts to develop enhanced sensitivities.

The ideal implementation plan would be to have a fully equipped low background screening facility at DUSEL very early, with the capacity ramping up fast enough to keep up with the needs as the first suite of experiments are constructed. Common technical capabilities identified as needed by many of the initial suite of experiments anticipated for DUSEL include:

- *Gamma screening* - HPGe detectors of varying sensitivity and segmentation. Includes both systems at the 300' level for pre-screening as well as sensitive systems located at the 4850' level.
- *Alpha, Beta, and Rn counting* - Both commercial pre-screeners and more sensitive new technology that is currently being developed. Radon emanation chambers and systems.
- *ICP-MS facility* - A dedicated ICP-MS machine capable of reaching sensitivities at the sub-microBq/kg level. Requires ultra-clean reagents and wet-lab facilities.
- *NAA and RNAA screening* - The ability to facilitate and conduct neutron activation and radiochemistry NAA measurements. The RNAA measurements require wet lab capabilities.
- *Large liquid scintillation counter* - A longer term facility, providing whole body counting capabilities for large samples or materials.
- *Underground storage of ultra-pure materials* - Storage at appropriate levels of clean materials such as cryogenics, water, noble liquids and gases, copper, lead and germanium.
- *Underground ultra-pure material production facilities* - Expected materials include electroformed copper, Kr removal, and potentially Ge crystal growth. Also includes access to a clean machine shop, and special fabrication tools such as EDM machines and laser welders.

The preliminary space requirements and analysis of what this low background counting lab might look like can be found in the Solicitativo-1 low-background working group white paper and the S1 DUSEL infrastructure matrix (see [http://www.deepscience.org/docs\\_reports/](http://www.deepscience.org/docs_reports/)).

Important R&D activities that were identified during the workshop include enhanced beta screening, capabilities to measure the energy of the ambient neutron background, development of low radiation photodetectors, production of ultra-pure electroformed Cu, enhanced ICP-MS sensitivity, <sup>39</sup>Ar removal, and Kr removal.

Finally, during the workshop, the community agreed that it would be best if a single S4 proposal would be submitted by the community that articulates the integrated program that defines the necessary technologies and capabilities available as DUSEL starts operations and specifies the R&D program needed to develop technologies providing enhanced sensitivities. The proposal will start the transition from the current loosely organized community into a cohesive DUSEL focused group. A possible model to consider will be the European ILIAS JRA-1 organization (see <http://www.unizar.es/ilias/JRA1/05.htm>) that joins together the institutions and facilities interested in low-level counting and ultra-clean materials in a cooperative manner. It is expected that as part of the early S4 efforts, an open database will be developed that provides Web based access to information on material radiopurities as well as assay capabilities and facilities. It is clear that for the immediate future, the S4 process is the ideal route to provide resources to help unite and coordinate the separate groups and institutions as the community develops an integrated program centered at DUSEL.

#### **Appendix - Workshop**

The B1 cross cutting working group was attended by ~40 scientists with good representation from the disciplinary science working groups. Talks on the various facilities and assay technologies can be found at

[http://cosmology.berkeley.edu/DUSEL/Town\\_meeting\\_DC07/working\\_groups.html](http://cosmology.berkeley.edu/DUSEL/Town_meeting_DC07/working_groups.html)