Snowmass2021 - Letter of Interest

An Ultralow Background Facility to Support Next Generation Rare Event Physics Experiments

UF Topical Groups: (check all that apply □/■)
■ (UF01) Underground Facilities for Neutrinos
■ (UF02) Underground Facilities for Cosmic Frontier
■ (UF03) Underground Detectors
■ (UF04) Supporting Capabilities
■ (UF05) Synergistic Research
■ (UF06) An Integrated Strategy for Underground Facilities and Infrastructure
Other Topical Groups:
■ (CF1) Dark Matter: Particle-like
■ (NF04) Neutrinos from natural sources
■ (NF05) Neutrino properties
■ (NF10) Neutrino Detectors
■ (IF9) Cross Cutting and Systems Integration

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Abstract:

Next-generation ultralow background experiments will require significant and collaborative efforts to achieve target radioactivity levels in order to reach required sensitivity. We list some of the significant challenges facing these experiments from a materials and assay perspective and propose a collaborative ultralow background facility to address them.

1 Introduction

Future generation experiments for dark matter, neutrinoless double beta decay and low-energy neutrino detection will have increasingly stringent radiopurity requirements while growing vastly in size to the 10 Ton to 100 kTon scale. While these rare-event fundamental physics experiments grow in scale, sophistication and sensitivity, so, too, will the materials and assays needs that are bedrock to their design and construction. This Letter Of Interest emphasizes areas of concern in meeting next-generation challenges and advocates for a unified approach to enable these experimental searches to succeed through funding consistent and coordinated research efforts in the field.

We believe an "*a la carte*" approach to developing materials and assays is not a successful, practical, or efficient approach to take in supporting next-generation experiments. The materials and assay capabilities needed for future experiments requires significant time, effort, and expertise to be developed and maintained in order to meet the evermore stringent radiopurity requirements. An overarching supported program to address the many efforts of ultralow background (ULB) physics from a materials and assay perspective will allow for a more holistic advancement of these fields, and ULB physics overall. In order to meet future materials and assay challenges we propose the creation of an "Ultra Low Background Facility" to address these issues. The Facility will be composed of an interdisciplinary group of expert scientists (e.g., dark matter physicists, neutrino physicists, analytical chemists, radiochemists, material scientists, mechanical and electrical engineers) across multiple institutions with capabilities in identifying, sourcing, creating, and verifying (through assay) ultralow background materials. The Facility could follow a "hub and spoke" model, with a centralized management "hub" enabling collaboration, whereas the "spokes" would be institutions with unique capabilities that will be leveraged (*e.g.*, ULB underground High Purity Germanium (HPGe) counting). The Facility would focus on addressing some of the concerns described in the following sections.

2 Next Generation Assay Techniques

Large scale assays – The next generation experiments will require unprecedented numbers of assays (likely numbering in the 1000s) to ensure all components background contributions are well characterized. This will require a number of innovations, such as: dedicated ultrasensitive assay facilities; automation of fast batch techniques such as inductively coupled plasma mass spectrometry (ICP-MS); shared distribution and calibration of techniques requiring longer measurements such as HPGe counting or radon emanation; and, statistical tools to sample materials in a representative manner when it is inconceivable to assay everything.

New backgrounds of interest – As the energy thresholds of detectors are lowered or larger more obvious backgrounds are removed, newer second-order backgrounds will become significant. These will require the development of novel assay techniques to control. Examples include ^{42}Ar, ^{226}Ra, ^{222}Rn, ^{32}Si, ^{3}H, ^{210}Pb, ^{87}Rb, ^{40}K, ^{110m}Ag, ^{190}Pt, *etc*.

Cataloguing and Sharing – More efficient sharing and recording of assay results through community-wide tools such as radiopurity.org are required so each experiment does not spend time "reinventing the wheel" and gives collaborations a starting point for material sourcing and investigation.

Understanding and Measuring Secular Disequilibrium – Due to limited sensitivity in HPGe counting techniques to measure target sensitivity levels in many materials, many assay techniques (e.g., ICP-MS, NAA) rely on measurements of the top of ^{238}U or ^{232}Th decay chains and an assumption of secular equilibrium. This may not be true, with radon being an obvious example of where secular disequilibrium can (and oftentimes does) occur. Improved assay and analysis techniques are required to understand full decay chain background contributions.

Next-generation radon assays – Larger emanation volumes taking into account operating temperatures and the target materials that components are immersed in (for example cryogens, water or scintillators) are required.

3 Improved Radiopurity Materials for Detectors

New detector bulk materials – Next generation experiments may have radiopurity demands on structural materials beyond what is achievable in commercial-off-the-shelf materials. New materials, such as ultrapure metals (e.g., copper alloys) or novel radiopure polymers, are required to meet these demands. New radon mitigation strategies through surface treatments or coatings are required to reduce large scale emanation effects.

Detector components – The increased sensitivity will require further emphasis on engineered components such as cables, connectors and electronics. Such ultrapure components could be shared across multiple collaborations and physics experiments so that each project is not independently performing the same research and development activities (*i.e.*, one single coordinated program is more effective and efficient than ten activities each funded at 1/10 of the level). Significant collaboration between Facility scientists and industry partners will be required to iteratively investigate the sourcing of radiopure materials and development of ultraclean, non-contaminating fabrication processes. From experience, the devil is in the details; the small components and composite materials that make a minor fraction of the total mass of the detector oftentimes can very easily be a dominant background contributor.

Long-term development – The timeline for advanced materials and improved assay technique development is now exceeding the typical time scales representing the R&D portion of low background experiments. So a mechanism that stretches beyond the limitation of project starts and stops is essential to provide notable materials and assay advancements. We believe setting up a Facility addressed this problem.

4 Cleaning and Handling

Surface contamination – With increasingly stringent material radiopurity requirements, surface contamination represents a significant issue. Accumulation of contaminants on extremely pure material surfaces occur during machining, transportation, handling and installation of detector parts. Dust is also a limiting contribution to material surface contamination. Exposure to dust particulate takes place even in cleanrooms.

Background control and mitigation - Surface contamination processes are not yet fully understood. Handling and cleaning protocols are oftentimes based on “best practice” procedures and/or estimates from accepted models. Quantitative determinations and informed procedures are required.

5 Conclusion

In order to meet a number of future materials and assay challenges across multiple experiments and physics topics we propose the creation of an “Ultra Low Background Facility” to address these issues.