

Snowmass2021 - Letter of Interest

Applications for Underground Argon

Thematic Areas: (check all that apply ☐/☒)

- ☐ IF1: Quantum Sensors
- ☐ IF2: Photon Detectors
- ☐ IF3: Solid State Detectors and Tracking
- ☐ IF4: Trigger and DAQ
- ☐ IF5: Micro Pattern Gas Detectors (MPGDs)
- ☐ IF6: Calorimetry
- ☐ IF7: Electronics/ASICs
- ☒ IF8: Noble Elements
- ☒ IF9: Cross Cutting and Systems Integration
- ☐ (Other) *[Please specify frontier/topical group]*

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Abstract: The Global Argon Dark Matter Collaboration (GADMC) is developing facilities for the extraction and purification of underground argon (UAr), which is depleted in ^{39}Ar . The use of ultra-pure UAr is central to the GADMC dark matter search program and has potential broader application within the particle physics community, including its use in detectors for measuring coherent neutrino scattering, environmental assay, neutrinoless double-beta decay, and large DUNE-like detectors.

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(The Global Argon Dark Matter Collaboration)

(The LEGEND Collaboration)

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The dominant background in LAr detectors for rare events is from ^{39}Ar β -decays, which are present in atmospheric argon (AAr) at an activity of 1 Bq/kg [1]. While pulse shape discrimination (PSD) heavily suppresses electronic recoil backgrounds in LAr detectors [2], reducing ^{39}Ar below the AAr rate is necessary when operating large detectors or when studying low-energy electronic or nuclear recoils below the 565 keV endpoint.

The Global Argon Dark Matter Collaboration (GADMC) will procure high-purity LAr using three facilities: (1) Urania: a facility for extracting underground argon (UAr) that is significantly depleted in ^{39}Ar ; (2) Aria: a distillation column that will chemically purify and further deplete UAr; and (3) DArT: a facility for measuring the ^{39}Ar activity in UAr. The ultra-pure UAr produced by these facilities is critical for the GADMC program (see dedicated LoI) and has broader application within the particle physics community, as described below.

COHERENT NEUTRINO SCATTERING

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Liquid argon experiments searching for low-energy beam-related processes, such as coherent elastic neutrino nucleus scattering (CEvNS) [3, 4] and the production of dark matter particles in a proton beam [5] could benefit from the reduction of ^{39}Ar provided with the use of UAr. Specific examples are the liquid argon detectors employed by COHERENT at the ORNL SNS [6] and by CCM at LANL Lujan center [7]. In both of these scintillation-only detectors, both electron/gamma identification and the use of a pulsed beam greatly reduces the steady-state ^{39}Ar background [8]. However, it is still the dominant steady-state background, and the use of UAr with a ^{39}Ar suppression factor of O(x100-x1000) would substantially improve the statistical precision of the resulting measurements [9].

DUNE-LIKE DETECTOR

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A multi-kiloton liquid argon time projection chamber would have unique sensitivity to the electron neutrino component of a core-collapse supernova burst, via the dominant charged-current (CC) interaction $\nu_e + {}^{40}\text{Ar} \rightarrow e^- + {}^{40}\text{K}^*$ [10]. The dominant radiological background is ^{39}Ar , the presence of which degrades event reconstruction quality and presents a challenge for DAQ and trigger design. The background is furthermore a serious impediment to potential detection of the “CEvNS glow” of a supernova burst [11] and will impede other ambitious attempts to extract information from very low energy physics signals [12]. Obtaining quantities of UAr sufficient to fill a DUNE-like detector will be challenging, but potentially still interesting to explore, perhaps for a single module.

ENVIRONMENTAL ASSAY

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Radiometric age dating using ^{39}Ar covers an intermediate age range not achievable with other naturally occurring radioisotopes [13] and is used in fields such as ground water age dating to understand the recharge rate of the California Central Valley Aquifer system [14], ocean ventilation [15], and others. A handful of groups around the globe have developed technologies for measuring trace amounts of ^{39}Ar [14, 16–18]. These technologies will benefit greatly from a supply of argon free of ^{39}Ar for detection limit determination and to avoid the introduction of modern argon (which is ^{39}Ar rich) into the detection systems.

LEGEND

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The Large Enriched Germanium Experiment for Neutrinoless double beta Decay (LEGEND-1000, see dedicated LoI) is proposed to search for neutrinoless double beta decay ($0\nu\beta\beta$) of ^{76}Ge . The experiment will probe the $0\nu\beta\beta$ decay of ^{76}Ge with a 3σ discovery potential of a half-life $> 10^{28}$ yr corresponding to a limit on the effective neutrino mass of < 17 meV. The Ge detectors will be distributed among four 250-kg modules to allow commissioning of the array in stages and independent operation. In each module, the detector strings are immersed within a liquid argon active shield, sourced from radiopure UAr. It is expected that ^{42}Ar will be greatly reduced within underground Ar, as is the case for ^{39}Ar . Hence, this UAr will provide direct reduction of background from the decay of ^{42}K , a daughter of ^{42}Ar . Alternative mitigation strategies have been developed if UAr is unavailable.

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