Sourcing/purifying noble gases

Graham Giovanetti, Wolfgang Lorenzon, David Moore,
Brian Mong, Joseph Zennamo

PRD 3 (Challenges in scaling technologies)

LOIs under this group:

"Kilotonne-scale Xe TPCs for 0vbb searches at 10^{30} yr half-life sensitivity" (contact: David Moore <david.c.moore@yale.edu>)

"DUNE-Beta: searching for neutrinoless double beta decay with a large LArTPC" (contact:Joseph Zennamo <jaz8600@fnal.gov>)

"Charcoal-based radon reduction systems for ultra-clean rare-event detectors" (contact: Wolfgang Lorenzon <lorenzon@umich.edu>)

"Using metal organic frameworks for Krypton and Radon removal in low-background Xenon detectors" (contact: Brian Mong <bung@slac.stanford.edu>)

"Applications for underground Argon" (contact: Graham Giovanetti <gkg1@williams.edu>)

Aria column prototype (^{39}Ar removal)

Instrumentation Requirements

- **Large target masses:**
  - Next-gen detectors for neutrino physics and rare event searches (e.g., dark matter and $0\nu\beta\beta$) will require >tonne to several ktonne scale target masses
- **Ultra high purities:**
  - Internal radiogenic backgrounds, including noble gas impurities (e.g. ^{222}Rn, ^{85}Kr), require further reduction for extremely large rare event detectors
  - Charge drift over >> 1m distances requires reduction of electronegative impurities
- **Isotopic separation:**
  - The dominant intrinsic background in argon-based detectors is due to ^{39}Ar, which is present in argon extracted from the atmosphere at a level of ~1 Bq/kg of liquid argon. Future argon detectors looking for signals below the ^{39}Ar endpoint (565 keV) would greatly benefit from a source of argon depleted in ^{39}Ar.
  - Searches for $0\nu\beta\beta$ employing ^{136}Xe (~9% natural abundance) often benefit from enrichment
  - Detection of solar ν through charged current processes may also favor certain isotopes

Instrumentation Challenges

- **Sourcing noble gases at the required quantities**
  - Next generation Ar-based detectors may require tonnes to ktonnes of depleted Ar
    - Central challenges are the extraction of argon from an underground source, chemical purification of this argon, assay of this argon to verify the ^{39}Ar content, and finally underground storage of the argon.
  - Xenon based $0\nu\beta\beta$ detectors would require >ktonne scale quantities of ^{nat}Xe at 10^{30} yr half-life
    - Main challenge is that existing supply chains not sufficient (current world production 50-100 t/yr) and enrichment cost may not be feasible, requiring use of ^{nat}Xe
- **Removal of Rn and other noble gas impurities**
  - Next-gen detectors will require both lower Rn levels to be reached and higher throughput (>>1000s of SLPM) to continually purify in situ
    - Challenges include developing new, higher throughput techniques and higher specificity materials (e.g. MOFs)

Physics Areas

- Dark matter (e.g. WIMPs):
  - Next-gen liquid argon: DarkSide-20k and Argo
  - Next-gen liquid xenon: G3 Xe detector
- Beam-based coherent neutrino scattering (CEvNS): COHERENT, CCM
- Double-beta decay:
  - Xe based concepts: (nEXO, NEXT, ktonne Xe TPC, doped liquid scintillator (THEIA, JUNO), doped LAr (DUNE-beta)
  - LEGEND (LAr veto)
- Supernova and solar neutrinos: DUNE-like detector, ktonne scale Xe TPC
- Radiometric dating and environmental assay