Detector Microphysics/Characterization

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Executive Summary (Bulleted Lists)

Instrumentation requirements to achieve physics goals

- Lower detector energy thresholds to pursue measurements of interest, both in the bulk liquid and at the liquid-gas interface for two-phase technology
- Accurate measurement of charge and light from both electron recoils and sub-keV nuclear recoils in xenon and argon
- Establishing measurements of noble liquid properties (e.g. diffusion, electron-ion recombination), including those leading to self-organized criticality (SOC), to sufficient levels, prior to running large, next-generation noble liquid detectors
- High event statistics to improve determination of detector response over a wide range of energies
- Flexible user facilities (not tied to any particular group nor experiment) with fast turnaround time to promote noble element property measurements in cases where *in situ* measurements are insufficient
- Prototyping calibration equipment meant for large detectors using smaller test beds with both charge and light readout
- Improve understanding of dynamic effects at low energies arising from the interplay of condensed matter and chemical interactions in noble liquid detectors, such as accumulations and releases of excitation energy and Wigner crystallization, which are potential backgrounds in rare event searches

Significant instrumentation challenges

- Increasing light collection and quantum efficiencies well beyond current levels, in order to lower energy thresholds and improve energy resolution, is a difficult problem

- Significant current uncertainties concerning how non-linear detector response becomes at the lowest recoil energies relevant to low-mass dark matter particles and coherent neutrino observations
- Improvements needed in light and charge collection efficiencies in liquid argon and in liquid xenon such as impurity modeling, improved purification methods, mitigating and accounting for material degassing, and estimating electron attachment rates for impurities
- Toward developing atom-level simulations of charge and light yields to improve modeling for noble element detectors, need better particle and detector models to extract more information from data
- Greater background reduction at lower energies is a significant challenge
- Additional expertise needed for calibration of large noble element detectors as they come online
- Rapid development of smaller test beds for measuring noble element properties and prototyping calibration equipment in advance of running of large noble liquid detectors
- Need to significantly increase interest from the HEP areas of funding agencies for the understanding of the “condensed matter” effects in noble liquid detectors

Relevant physics areas

- Dark matter searches (especially for sub-GeV-scale WIMPs and/or involving sub-keV interactions)
- Coherent elastic neutrino-nucleus scattering experiments
- Neutrinoless double beta decay searches
- Neutrino oscillation experiments (neutrinos in MeV-TeV range from a variety of sources)
- Experiments investigating supernova/solar neutrinos
- Experiments investigating nucleon decay and other searches for baryon number violation

Relevant cross-connections

- Neutrino Frontier (e.g. NF02, NF03, NF05, NF06, NF10) for connections to neutrino experiments using liquid noble detectors
- Cosmic Frontier (e.g. CF01, CF03, CF07) for connections to dark matter searches using liquid noble detectors
- BES/NP for cross-cutting work on condensed matter physics and nuclear physics topics that manifest in noble liquid detectors

Further reading

[WORK IN PROGRESS]