Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

Stirling Hall 302 C, 64 Bader Lane,
Queen's University
Kingston, ON K7L 3N6
www.McDonaldInstitute.ca
Tel: 613-533-6961

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Alignment with the McDonald Institute Research Strategy

This document provides guidelines to help interpret the vision and scientific goals for the McDonald Institute (MI) research program. Historically a focus for MI has been on research capacity building such that the Canadian researcher community has the capacity to lead on major international projects destined for the SNOLAB facility, and where this community are leading efforts in the development of the theories underpinning the experimental pursuits. With new funding received in 2024, the MI continues to support many programs in partnership with SNOLAB but also supports new programs in astroparticle physics that build on the community's expertise in neutrino and dark matter physics, detector development, and rare search technologies. The 2026 Long-Range Planning exercise for Canadian Subatomic Physics led to community consultation across the Canadian Astroparticle Physics Community and informed a more focused set of scientific priorities for the McDonald Institute going forward, outlined below. This document was created to assist in assessing funding levels for astroparticle physics programs and personnel appointments for any McDonald Institute-supported researchers (faculty, postdoctoral fellows, graduate and undergraduate students), engineering and technical staff, and as well will be used to check the alignment of new proposals for research support.

Note, this document is to be revisited at least annually, allowing for the opportunity to respond to new opportunities and changing priorities.

General Guiding Principles:

The overall scientific objectives of the McDonald Institute are as follows:

- Expand on the scientific culture at Queen's University and its partner institutions by building a powerful and integrated team working on all aspects of astroparticle physics including the experimental program (at SNOLAB or where there is strong Canadian leadership), astroparticle and astrophysics theory, related observational astrophysics, cosmology, detector development and low background techniques.
- Equip the Canadian research community with engineering and technical resources, such that the community may undertake major responsibilities on new projects and lead the next generation of increasingly challenging experiments. This will attract international scientists and technology along with the capital and operational funding necessary to allow one or more global-scale next-generation detectors to be hosted at SNOLAB. It will also enable the community to be leaders on emerging new programs, at other facilities within Canada, and internationally
- Maximize the scientific output from the suite of experiments that are currently operational or under development at SNOLAB or other Canadian facilities by hiring key additional highly qualified personnel, strengthening international collaborations, and engaging the broader scientific community in the undertaking.

Hence, when considering alignment, it is important to keep in mind that we want to build the community in such a way that this will contribute to making the SNOLAB and Canadian astroparticle physics program a success. This does not imply that only experiments currently planned for Canadian facilities are relevant. However, research taking place on other projects should be developing the technology or expertise with a clear long-term goal of preparing for potential future benefit to the Canadian program.

These physics topics include working on experiments in dark matter, supernovae monitoring, neutrinoless double beta decay, solar/geo-neutrino physics experiments, neutrino oscillations, and other physics pursuits that benefit from the advantages of a deep underground laboratory or the Ocean Networks Canada underwater infrastructure.

It also includes research programs which are developing the technologies that are required for an identified or potential future experimental program. Some examples of these include:

- Working on the technology for or contributing directly to any of the current or planned astroparticle physics programs supported by the McDonald Institute,

  and/or,

- Working on experiments or technology developments currently outside of Canadian facilities but where the overarching goal is to gain expertise and develop the technology for a future program for which there is the potential for a future generation version to take place within Canadian facilities.

  and/or,

- Detector development, which could include the development of quantum sensors for astroparticle physics, semiconductor devices at cryogenic temperatures, the development of SiPM and other novel light detection technologies, and their applications in commercial opportunities, medical physics or astroparticle physics. This area of alignment could include technology development programs advantageous to both non-McDonald Institute related offshore programs (e.g. accelerator based, short/long baseline, or underwater/under-ice detectors) and identifiable components of the McDonald Institute program.

In the case of research taking place in cross-disciplinary research areas, such as radio-analytic chemistry, these activities need to add value to both parties and provide identifiable benefit to the Canadian astroparticle physics programs.

While the above informs the general scientific objectives of the McDonald Institute, we are at a crucial time where resources are limited, and where the community has recognized the benefits of coalescence around a small number of priority projects while still fostering some research breadth across different astroparticle physics focuses. Therefore, the McDonald Institute is prioritizing specific efforts. In alphabetical order, the top priorities are:

- **DarkSide-20k:** In the context of dark matter detection with liquid argon, the McDonald Institute is prioritizing completion of the DarkSide-20k experiment and Canada's ability to

take on leadership roles in that collaboration. This prioritization is with the goal of fully developing this technology and extracting the maximal scientific output first, while recognizing the potential, if successful, for bringing a next generation detector to SNOLAB.

- **SNO+**: In the context of the detection of neutrinoless double beta decay searches, a priority is the completion of the SNO+ experiment, and the technological advances required for the deployment of tellurium.

- **SuperCDMS:** In the context of solid state and cryogenic detectors for studying lower mass dark matter, the McDonald Institute will prioritize the activities of Canadians in commissioning and operations of SuperCDMS.

- **XLZD:** In the context of neutrinoless double beta decay and dark matter searches with liquid xenon, the McDonald Institute will continue to prioritize a singular liquid xenon flagship experiment that is the focus of the Canadian XLZD collaboration. (with the Canadian nEXO collaboration recently joining the XLZD collaboration).

The above four experimental focuses are the McDonald Institute's highest scientific priorities.

P-ONE: The next, near top priority is the installation and commissioning of the initial set of demonstrator strings of the P-ONE neutrino observatory in the Pacific Ocean, and its multi-messenger context.

NEWS-G, PICO, SBC: Finally, recognizing the importance of additional breadth, the McDonald Institute would prioritize at a lower level the operations of the NEWS-G dark matter detector, the commissioning of SBC, and the completion of the PICO programs.

Other priorities of the McDonald Institute receive modest funding support but include projects with strong Canadian leadership, which are the Hyper-Kamiokanda accelerator-based neutrino experiment in Japan, and broader multi-messenger programs in the context of gravitational waves.

In general, support for theorical research is somewhat broader in scope as the research interests are not necessarily tied to a particular experimental program. However, the clear intent is support for research personnel where these individuals would work closely with the broader Canadian astroparticle physics community to help guide the development of the experimental research programs, the interpretation of model dependent results, and to bring theoretical insight into topics of interest to the astroparticle physics community in areas such as neutrino physics, dark matter, neutrinoless double beta decay, and similar, and potentially, how these relate to the field of astronomy/cosmology. Similarly, multi-messenger astroparticle physics research can be broader in scope, but the clear intent for these research areas is that the researchers would work closely with the community to engage with data that supports theoretical or experimental work relevant to the Canadian astroparticle physics program.

There may also be positions in cross-disciplinary areas where for example, the focus may be to develop new analytical tools and chemical procedures required by the next generation of astroparticle physics experiments to measure radioactivity at extremely low levels, and to purify complex materials of radio-impurities and other sources of backgrounds. It may also include the development of means to produce or purify detector materials such that they meet a variety of other experimental requirements, such as optical transparency, light output, or isotopic content. Other contribution areas could be the

development of instrumentation for low-background studies, or detector development and characterization. This includes the development of quasi mono-energetic neutron beams ideal for the calibration of dark matter detectors, the measurement of detector thresholds, the production of special short-lived radioactive calibration sources peculiar to the needs of astroparticle physics experiments, the development and testing of sensitive neutron spectrometers, and the training of students with hands on experience in accelerator and nuclear physics.