UNIVERSITY OF MANITOBA

CANADA FOUNDATION FOR INNOVATION
Innovation Fund

15-9

Notice of Intent

1. Completed NOIs must be submitted by the Associate Dean (Research)/Research Liaison Officer of the "Lead" Unit to the Office of Research Services to: Birtukan.Gebretsadik@umanitoba.ca by May 15, 2018.

Proposed name of project: The MOLLER integrating electron detector array: Searching for new physics between electrons at the zeptometer scale	**Estimated Total Project Costs:** 5,000,000

Designated Project Leader/Faculty/Dept: **Michael Gericke/Science/Physics** **CV:** x

List Principal Users/Faculty/Dept:

1.	J. Birchall/Science/Physics	CV: x	
2.	J. Mammei/Science/Physics	CV: x	
3.	W.T.H. van Oers/Science/Physics	CV: x	
4.	R. Mammei/U. of Winnipeg/Physics	CV: x	(adjunct)
5.	J. Martin/U. of Winnipeg/Physics	CV: x	(adjunct)
6.	A. Aleksejevs/Memorial U./Physics	CV: x	
7.	S. Barkanova/ Memorial U./Physics	CV: x	
8.	E. Korkmaz/UNBC/Physics	CV: x	
9.	C. Gal/Science/Physics	CV: x	(or other new faculty; finalizing hire)
10.	S. Park/Science/Physics	CV: x	(tentative)

'Lead' Unit ADR/RLO:

Name:

Proposed Research and Innovation: The infrastructure proposed here will be a key contribution to a new particle physics experiment called MOLLER[1] (Measurement Of a Lepton-Lepton Electro-Weak Reaction – leptons are a family of particles, including electrons and neutrinos). The experiment aims to measure the interaction between pairs of electrons down to separation distances of 10^{-21} meter (roughly a million times smaller than the size of the smallest atomic nucleus) to unprecedented accuracy, unlikely to be matched by any other experiment over the next several decades. It is widely expected that completely new interactions may be found at such small distance scales, including those that couple to dark matter, and may explain some of the deepest unanswered questions in particle physics and cosmology (such as the large matter – antimatter asymmetry). The existence of dark matter (so-called because it does not emit photons and is not detectable at large distance scales) is the leading explanation for astrophysical phenomena, such as galactic rotation speeds. The search for dark matter, and new physics that couples to it, is currently at the forefront of the worldwide research effort in subatomic physics. The most innovative aspects of the proposed project are encapsulated in our technical solutions to the extreme challenges involved in making a clean measurement to the proposed accuracy. The MOLLER experiment will be a cornerstone of the scientific program at the recently upgraded Thomas Jefferson National Accelerator Facility JLab[2], a premier electron beam accelerator laboratory located in Newport News, USA, funded by the US Department of Energy (DOE). The experiment is an international effort involving collaborators from the USA and Canada (the lead countries), as well as Germany, Italy, France, and Mexico. The lead institutions for this project are Stony Brook University, the University of Manitoba, the Virginia Institute of Technology, and the University of Virginia. **Benefits to Canada:** The primary benefits of fundamental research like this are the generation of new knowledge and understanding about nature, the international visibility that high profile efforts like this create for Canada (ref. our recent Nature publication and international attention for the QWeak experiment), possible spin-off technologies, and the unique training of highly qualified personnel for the technology sector. **New knowledge:** New physics discoveries often have profound and transformative effects on human life. For example, quantum mechanics is the foundation for developing novel materials and processes at the nanometer scale, and the strong and weak interactions of nuclear physics have had a profound influence on the energy and medical sectors. In the long run, no truly new technology can be developed without new fundamental knowledge about nature. For example, the discovery and study of dark matter could have profound implications for the energy sector. As an analogy, the photoelectric effect was discovered in the early 20th century – a hundred years later, the replacement of fossil fuels by solar cells for energy generation is becoming a reality, but the development of this technology was only possible because of the discovery of the underlying physics process. **Possible technology spin-off:** Some of the proposed detectors will have a new type of photosensitive readout device that combines modern day microchip technology with precision low noise analog electronics into a single detector unit. These devices could eventually be marketable in the medical diagnostic sector or for personal radiation monitoring. **Training of HQP:** This is a large project with a high capacity for training of HQP from several fields of study even beyond physics, including engineering, and computer science. Students and postdocs on this project will acquire a broad set of skills, both on the design and the practical side, including working with sensors, micro-electronics, mechanical assemblies, high vacuum systems, large scale programming, and large data set analysis. These people will have the skill set to be invaluable employees or entrepreneurs in many different sectors, including but not limited to the, information technology, medical, energy, financial, or public sectors.

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[1] The MOLLER Experiment: An Ultra-Precise Measurement of the Weak Mixing Angle Using Møller Scattering, http://arxiv.org/abs/1411.4088

[2] http://www.jlab.org

Proposed Infrastructure: In order to do this measurement, the experiment must develop ultrasensitive new particle detector technology to meet its very challenging physics goals. The team represented by this proposal is requesting funding to build a large subset of the overall detector package, which is at the heart of the experiment. The apparatus consists of an electron beam colliding with target electrons; the scattered electrons travel through a magnetic spectrometer system and then traverse a highly sensitive detector array that measures changes in the electron properties. The detector array will consist of about 300 separate detectors (and associated data acquisition electronics) that each must make measurements of part per billion differences in the number or detected particles in a high radiation environment. The detectors require a very particular design, and the development of hardware that is highly customized. The proposed equipment will include about 300 pieces of ultrapure laboratory grown quartz, 300 photosensitive devices (photon detectors- either to be custom build or purchased if they are available to our specifications), and 600 channels of custom made front-end electronics that will be used to amplify and digitize the signal the particles make.

The prototyping of the detectors will use several facilities at the University of Manitoba: We will make use of the clean room in Dr. Juliette Mammei's lab, recently financed through a LOF CFI, to assemble the detectors in a clean environment. A significant complement of readout electronics will be needed for prototype testing and final commissioning. Most of this is already on hand in the labs of Michael Gericke and Juliette Mammei (largely funded through CFI grants), but we will develop and purchase additional, specialized equipment (specifically electronics) to facilitate this part of the project. This equipment would stay at the university and would be available for use by other researchers, after the MOLLER construction project is completed. The detectors and electronics will also return to the University after the completion of the MOLLER experiment and can be reused for future experiments.

Excellence of the team and Collaborations: The MOLLER experiment builds on more than two decades of research by the University of Manitoba group at JLab on precision measurements using polarized electron scattering. Most recently, our work on a similar high profile experiment, the QWeak experiment, in which this team had strong leadership roles, was published in the journal Nature and received significant international media attention. We are recognized worldwide as experts in the design and construction of such experiments, and the University of Manitoba is known, within the subatomic physics community, for this work. The collaborations with international facilities such as JLab and TRIUMF are of strategic importance and leverage key resources in support of these efforts, reaching far beyond what is available at the university. The DOE requires a well-defined management structure consisting of leaders of all of the individual major subsystems. Within this structure, the U of M has two researchers in key positions of the MOLLER collaboration. Juliette Mammei is the Canadian representative on the Executive Board, which is the leadership body of the experiment. She is also the Work Package Leader and DOE Level 2 Manager for the magnetic spectrometer. Michael Gericke is the Work Package Leader and DOE Level 2 Manager for the integrating detector package. These two packages comprise the largest and most critical subsystems of the apparatus. Drs. Gericke and Mammei have naturally risen to leadership roles in these areas by virtue of their expertise and proven track record in high-precision electron scattering experiments at JLab.

Funding partners: The proposed integrating electron detector set is estimated to cost roughly CAD 2.0M, and this is the amount that would be requested from CFI (from the University of Manitoba cap). The overall detector and spectrometer system (which cannot function independently) is expected to cost about CAD 5.0M. The overall capital cost for the experiment is estimated to be USD 25M and is will be financed for the most part through a US DOE MIE (Major Installation Equipment) grant program. The required 60% matching funds (CAD 3M) would come from the DOE budget for the experiment, in the form of the spectrometer. Alternatively, we may request in-kind funding through the province of Manitoba, but this is not necessary. We will request in-kind matching from companies that supply the quartz detector material (Heraeus) and the photosensitive devices.