Proposal for TRIUMF Commitment (5YP 2015-2020)

Date:
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PROJECT/COMMITMENT TITLE: Ultracold Neutrons (UCN)

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PROJECT DESCRIPTION:

The aim of the project is to create the world's highest density ultracold neutron (UCN) source, and use it to conduct the best measurement of the neutron electric dipole moment (nEDM). The project leverages expertise from Japanese collaborators who constructed a world competitive UCN source at RCNP Osaka at 1 μA beam current. A prototype nEDM apparatus has also been operated at the source, and has produced key R&D milestones relevant to the experiment. The project is supported by CFI and TRIUMF in Canada, and by JSPS, KEK, and RCNP Osaka in Japan. An MOU for the project detailing completion of construction phase through 2016 has been signed by TRIUMF, Winnipeg, KEK, and RCNP, with terms of validity to 2020 providing experimental priority for the nEDM experiment. Experiments and a user facility beyond the nEDM experiment are also envisioned at TRIUMF.

The UCN source and prototype nEDM experiment are presently being completed and tested at RCNP Osaka. The source and experiment will be operated at RCNP Osaka until late 2014, and then moved to TRIUMF in 2015 for installation. Meanwhile the Canadian group will be constructing the new beamline and spallation target, and developing key elements of the nEDM experiment. Operations at TRIUMF and experiments on the nEDM will commence in 2016.

In 2015-2020 we propose to complete the UCN facility and the helium liquefier facility for full current, operate and maintain the UCN facility, complete the nEDM experiment, and upgrade the facility enabling higher UCN density and greater flexibility. In 2015-16, we will complete the initial UCN facility, and thereby the CFI NIF project. Personnel requirements are specified in the MOU, and are available detailed form in Microsoft Project. They relate primarily to engineering, design, and technicians for beamline, shielding, target, remote handling, and services. A first liquefier to support CMMS is planned to be in place by 2015; we require support in the next 5YP to bring it to full capacity for UCN ($100k in 2015), and to upgrade with a second liquefier for full intensity operation of the UCN source ($1M in 2016). We also require support for acquisition of helium-3 for the UCN source itself ($150k in 2015). Ongoing operations, maintenance, and technical support will be provided by CFI IOF. We require support for the nEDM experiment in the form of lab space for development and testing of magnetometers, magnetic shielding, and high voltage systems, and DAQ support.

In upgrades to the UCN facility we consider beamline magnet power supply upgrades ($200k in 2017), an additional UCN port for detector and UCN guide testing ($100k in 2017), radiation shielding for higher intensity operation ($500k in 2018). We anticipate writing a CFI grant to support an upgrade of the cold moderator of the UCN source to liquid D_2, resulting in a projected factor five increase in UCN density ($1.5M in 2018). We anticipate upgrading the nEDM experiment's magnetic shielding in order to reach the ultimate experimental sensitivity to 1×10^{-28} e-cm, in either a CFI or NSERC request ($2M in 2017). We require stable operation of BL1A, for which significant repairs to the M11 and T2 target would be required; we therefore support such proposals which we anticipate are covered elsewhere.

SCIENTIFIC JUSTIFICATION:

New sources of CP violation are believed to be required to explain the observed predominance of matter over antimatter, the baryon asymmetry, of our universe. Extensions to the standard model predict such new sources,

together with values for the nEDM within the reach of our experiment. So this effort will play a major role in testing such extensions and their possible role in explaining this fundamental problem in cosmology. The TRIUMF project aims to measure the nEDM to the 10^{-27} e-cm level by 2017. The experiment has the potential to deliver measurements to the 10^{-28} e-cm level in 2018-2020. This is more than two orders of magnitude better than the present best experimental upper bound, which is 2.9×10^{-26} e-cm.

Experiments on the neutron lifetime, gravitational levels, beta decay, nnbar oscillations, and neutron-ion interactions have been discussed as possible future experiments. In the next five-year plan, we could begin to develop plans for other experiments after the successful completion of the nEDM experiment.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

The project represents a new research thrust in subatomic physics in Canada: fundamental physics with UCN. It will represent a new core capability for the TRIUMF facility with its own user base. The project has complementary research goals to fundamental symmetries experiments at ISAC, and e.g. PiENu and ALPHA.

The project is strongly supported in the Canadian research community. The UCN source is supported by a CFI NIF to U. Winnipeg in 2009. Manitoba industry involvement is matched by a smaller grant from the Manitoba Research and Innovation Fund. Other Canadian matching is in-kind support from TRIUMF.

The project has been supported by NSERC for research towards the nEDM experiment through both project grants and RTI's. The project is also supported by additional CFI grants for R&D infrastructure at the universities. The most recent example of this, the Polarized Xe Lab for Fundamental Physics at U. Winnipeg, is now under completion and will serve as a test-bed for Xe comagnetometry for the nEDM experiment. A new CFI NIF request from UBC (Momose) is pending at this time, where a portion of the request would support a high-power XUV laser to be used as either a pump or probe laser for the Xe comagnetometer, and another new CFI LOF request from Winnipeg (Jamieson) for detector fabrication and testing infrastructure is also pending. Furthermore, the project proponent in Canada (J.W. Martin) was recently promoted to a CRC (Tier 1) position. Two new grant-eligible members joined the team this year (R. Mammei and J. Mammei), and a new staff member at TRIUMF, dedicated to the project, will be appointed in fall 2012. Additional requests for joint faculty positions with universities would aim to attract more of the excellent talent seen in recent competitions, making an even stronger connection with the university community.

The project has a number of competitors worldwide. Neutron EDM projects are presently running at PSI, and ILL, and are planned at ILL, SNS, Munich FRM-II, PNPI, and J-PARC. Our project is competitive with these experiments in both the experimental goals and timescales. Comparing to the PSI experiment, our strategy is similar in that we pursue a traditional room-temperature nEDM experiment. However, it is unique in that we pursue a Xe-129 comagnetometer as opposed to Hg-199. The measurement cell size is kept small to minimize systematic effects, better making use of increased UCN densities, and to ease the problem of magnetic shielding and homogeneity. Our UCN source uses He-II in the UCN production volume, allowing a lower intensity beam to accumulate UCN with lower instantaneous heat load (PSI uses solid D_2, necessitating a short pulse followed by a long beam off period – in all the average beam power is comparable). Our strategy is also similar to PSI in that we are building from proven technologies, many of which we are prototyping already in Japan or in bench tests in Canada.

BROADER IMPACTS:

The project is supported by CFI, which also evaluates benefits to Canada, often described by Canada's S&T priorities ("advantages"). The project supports the people advantage by: attracting world-class researchers from abroad to Canada through usership, and development of a skilled work force through training in basic research. Trainees have already completed projects in: beamline design, target thermal design, neutron physics, neutron and radiation detectors, cryogenics, low-field NMR, laser physics, data-acquisition systems, and computer simulation. More projects of these kinds are expected; the project trained eight undergraduates this year, and supports three grad students and five postdocs/RA's. The project supports a knowledge advantage through a strong relationship to technology used in medical MRI's, cryogenics, laser technology, and quantum computation, and several listed collaborators work in these fields. Relating to the entrepreneurial advantage, we are partnered with Acsion Industries (Pinawa, MB) who support the project with an in-kind contribution, and who conduct simulations of heat deposition, neutron transport, and radiation shielding and dose calculations related to personnel safety. This collaboration has already spawned other industrial

collaborations between Acsion Industries and U. Winnipeg. We are also interested in the development of diamond-like carbon coatings in collaboration with TRIUMF's Advanced Applied Physics Solutions.

MAJOR MILESTONES:

Description	Date
Completion of UCN facility construction, first commissioning	2015-2016
Operation of nEDM experiment	2016-2017
Installation and commissioning of additional liquefier	2016
Upgrades for long-term operation, increased UCN density, additional experiments	2017-2020
Completion of next phase of nEDM experiment	2017-2020

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF	$0.25M	$1.0M	$0.3M	$0.5M		$2.05M
EXTERNAL			$2.0M	$1.5M		$3.5M+below
TOTAL						
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Eng/Design/Tech						
(fac. completion)	6 FTE yr	3 FTE yr				9 FTE yr
Eng/Design/Tech						
(upgrades)			3 FTE yr	3 FTE yr	3 FTE yr	9 FTE yr
DAQ support	0.25 FTE yr	0.25 FTE yr	0.25 FTE yr	0.25 FTE yr	0.25 FTE yr	1.25 FTE yr
Beamline tech.	1 FTE yr	0.25 FTE yr	0.25 FTE yr	0.25 FTE yr	0.25 FTE yr	2 FTE yr
Science div.	not estimated					
Beam time		5 months	8 months	8 months	8 months	30 months
Lab space	500 s.f.	500 s.f.	500 s.f.	500 s.f.	500 s.f.	Lab per year

EXTERNAL FUNDING INFORMATION:
Not included in table: Remaining CFI NIF (secured), CFI IOF $1.3M (secured), NSERC anticipated $500k/yr, CRC anticipated $100k/yr. Included in table: CFI or NSERC magnetic shielding $2.0M, CFI cold moderator upgrade to LD_2 $1.5M.

ONGOING OPERATIONAL REQUIREMENTS:
Technical support for cryogenics and other operation, maintenance, and repairs, to be covered by CFI IOF.

DECOMMISSIONING REQUIREMENT:
None in this time period. The facility will be operational beyond 2020. Beyond the facility lifetime, the decommissioning requirement would be similar to that of decommissioning the TNF.

Accepted: Date: