Proposal for TRIUMF Commitment (5YP 2015-2020)

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PROJECT/COMMITMENT TITLE: Data Acquisition/SiPM readout for SuperCDMS-SNOLAB

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Other institutions: California Institute of Technology, Massachussetts Institute of Technology, Santa Clara University, SLAC, Southern Methodist University, Stanford University, Syracuse University, Texas A&M University, U. Autónoma de Madrid, UC Berkeley, UC Santa Barbara, UC Denver, University of Evansville, University of Florida, University of Minnesota

PROJECT DESCRIPTION:

SuperCDMS-SNOLAB is a proposed direct dark matter detection experiment that uses superconducting transition edge sensors and charge-collecting electrodes coupled to germanium crystals. These detect phonons and ionization resulting from nuclear recoils produced by the interaction of a dark matter particle in the crystal. Over the past decade, several generations of CDMS technology have provided increasing, often world-leading, sensitivity to potential dark matter signals. SuperCDMS-SNOLAB is the latest in this progression and will improve upon the previous generation in several ways. First, an improved charge collection ("iZIP") scheme will significantly enhance discrimination of "surface" background, where beta rays from contamination on the surface of the detector result in incomplete charge collection, mimicking the WIMP-nuclear recoil signal. Second, larger detectors will allow up to 200 kg of detector mass to be deployed, compared to the 10 kg currently used. The larger detectors will also have larger signal/background rates due to a smaller surface/volume ratio. Finally, the experiment will be situated at SNOLAB, where the 6000 meter water-equivalent overburden will reduce cosmogenic background by about two orders of magnitude compared to the current site in the Soudan mine in Minnesota.
Canadian groups will be responsible for the cryogenic infrastructure and shielding at SNOLAB. The collaboration has recently expressed interest in transitioning to a MIDAS-based data acquisition system
The project described here is the development and maintenance of a MIDAS-based data acquisition system for the experiment that will allow a common and scalable platform to be used by the main experiment at SNOLAB and various test setups. The collaboration is also exploring the development of an active neutron veto using SiPM readout. Based on our experience from the T2K Fine Grained Detector, TRIUMF is in a strong position to contribute expertise to the readout and operation of such devices. Decisions on both items are pending in the collaboration and are expected within 2013.

SCIENTIFIC JUSTIFICATION:

Numerous astrophysical and cosmological observations indicate that nearly a quarter of the energy content of the universe is in the form of a non-luminous matter that cannot be explained by known particles. This so-called "dark matter" problem is one of the most pressing issues in physics today. The most compelling explanation consistent with the observations is that the dark matter is composed of a heretofore unidentified weakly interacting massive particle (WIMP) produced in the Big Bang. At the same time, many favoured extensions of the Standard Model of Particle Physics, such as Supersymmetry, naturally furnish particles which can serve as WIMPs. The direct detection of primordial WIMPs, whatever their nature, would solve this puzzle.

CDMS, which detects WIMPs via phonon and ionization signals produced by WIMP-nucleus interactions in germanium crystals, has been at the forefront of this field for many years. CDMS II results from 2009 set the most stringent limits on WIMP-nucleon cross sections (7×10^{-44} cm^2 for a 70 GeV/c^2 WIMP) at the time. It has also weighed in on a few purported claims of evidence for direct dark matter detection, in particular low-mass signals reported by DAMA, CoGeNT and CRESST, rejecting most of the allowed region of WIMP mass and cross section inferred from these claims.

In the meanwhile, R&D effort has led to a new detector configuration ("iZIP") where interlaced electrodes on both sides of the detector provide a large improvement in discrimination against surface contamination, as well as larger detectors that provide more detector mass (hence sensitivity) and further reduce the impact of surface contamination. Fifteen new "SuperCDMS" detectors with a total mass of ~10 kg are currently deployed in the Soudan mine in Minnesota. The proposed next phase, "SuperCDMS-SNOLAB" will scale the mass to 200 kg using larger detectors with the aim of achieving sensitivity to WIMP-nucleon cross sections of ~10^{-46} cm^2, comparable to projected sensitivities from other methods such as those using liquid argon and xenon, and covering a large fraction of the WIMP masses and cross sections predicted by extensions to the Standard Model.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

Through SNOLAB, Canada has made an enormous investment in underground science which has resulted in a world class facility to conduct experiments that require shielding from backgrounds induced by cosmic rays. Direct dark matter detection searches such as SuperCDMS, along with neutrinoless double beta decay experiments, are the most important component of this scientific program, and thus SNOLAB is striving to foster a leading program in dark matter experiments. To this end, DEAP, COUPP, Picasso and SuperCDMS have been approved for or are already in operation in SNOLAB.

The Canadian SuperCDMS group has been involved in detector R&D, background studies, data analysis, the development of the SuperCDMS infrastructure, and now with the participation of UBC, brings experience in MIDAS-based data acquisition and SiPM readout gained from T2K and ND280. With currently ten members, Canadian collaborators now comprise approximately10% of the collaboration and will play a leading role in deploying the experiment at SNOLAB.

In relation to the other proposed dark matter searches at SNOLAB, SuperCDMS brings a proven technology that is known to be scalable with additional detectors, whereas DEAP and COUPP are still demonstrating their scalability to ~tonne scale detectors, the former making one leap from a kg-scale prototype to 1 tonne, the latter now transitioning from a 4 kg detector to a 60 kg detector. PICASSO is likewise in an R&D phase that may significantly change their approach to achieving tonne-scale mass.

MIDAS has established itself as a standard platform for particle physics data acquisition systems. With extensive experience with MIDAS-based systems on many scales (ISAC experiments, T2K ND280, etc.) TRIUMF expertise is well-matched towards helping the UBC SuperCDMS group in developing a MIDAS-based solution for SuperCDMS-SNOLAB. Likewise, with the experience of developing and building the MPPC readout electronics for the T2K Fine Grained Detectors, TRIUMF is in a strong position to help develop a solution for an active neutron veto system using SiPM technology.

BROADER IMPACTS:

We anticipate that the projects described here (MIDAS-based data acquisition and SiPM readout) will offer many opportunities for the training of highly qualified personnel at all levels (undergraduate, co-operative, graduate, postdoctoral) in computing and detector design, construction and operations.

Starting with the first large scale application of MPPCs in T2K, SiPM technology has become a generic cheaper and smaller alternative to photomultipliers in many applications both inside and outside of particle physics. The application of SiPMs in the neutron veto offers yet another opportunity to explore SiPM applications in particle physics which may spur additional applications.

MAJOR MILESTONES:

Description	Date
Demonstration of MIDAS-based DAQ with single board	Winter 2012
Demonstration of full MIDAS-DAQ and decision	Spring 2013
Design and construction of active neutron veto prototype and decision on SiPMT	Spring 2013
CFI funding decision for SuperCDMS-SNOLAB infrastructure.	Fall 2012
US funding decisions	Winter 2013

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF	0	0	0	0	0	0
EXTERNAL	$0.2M	$0.2M	$0.2M	$0.2M	$0.2M	$1M
TOTAL	$0.2M	$0.2M	$0.2M	$0.2M	$0.2M	$1M
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
IT/DAQ	20	20	20	20	20	100

EXTERNAL FUNDING INFORMATION:

The SuperCDMS effort in Canada is currently supported by an NSERC SAP operating grant of $120k/year. A renewal which reflects the expansion of the group to include UBC is being submitted this year. A CFI-LEF request for $4.2 million for cryogenic and shielding infrastructure at SNOLAB was recently submitted, with a funding decision expected in Fall 2012. The total anticipated cost for SuperCDMS-SNOLAB is approximately $29 million. The remaining $25 million is expected from the US DOE and NSF with a funding decision expected at the end of 2013, with the project phase extending from 2014-2016.

ONGOING OPERATIONAL REQUIREMENTS:

Assuming successful funding, SuperCDMS-SNOLAB operations are expected to start by 2015 and last for three to four years. The MIDAS-based DAQ will be maintained primarily by the collaboration, but support will be needed to handle more difficult issues and upgrades.

DECOMMISSIONING REQUIREMENT:

No significant decommissioning requirements are expected for the MIDAS-based DAQ.

Accepted: Date: