Proposal for TRIUMF Commitment (5YP 2015-2020)

Date:
September 17, 2012

PROJECT/COMMITMENT TITLE: nEXO – A Search for Neutrino-less Double Beta Decay in Xenon

PROPONENT: David Sinclair **TRIUMF CONTACT:** David Sinclair

PRINCIPAL COLLABORATORS: 16 institutions including Carleton and Laurentian universities in Canada, 8 US Universities, SLAC, ITEP in Russia, IHEP in China, universities in Germany, South Korea, and Switzerland. The PI is G. Gratta, Stanford University. The Canadian PI is D. Sinclair. We very much hope that TRIUMF will become an institutional member of this project.

PROJECT DESCRIPTION:

It is proposed to construct at SNOlab, a detector whose sensitive material is 5 tonnes of liquid xenon enriched to >80% in Xe-136 to search for neutrino-less double beta decay. The xenon is contained in a cryostat which itself is shielded by 4 meters of water from gamma and neutron backgrounds from the rock. It would be located in the Cryopit at a depth of 2 km at SNOlab. All materials of the detector must be made exceptionally clean to control possible backgrounds. The detector design will be based on the very successful EXO-200 detector but even lower backgrounds are required. The scientific objective is to achieve a discovery potential for neutrino-less double beta decay with sensitivity to neutrino masses down to the 'inverted hierarchy'.

If approved, this experiment will be one of the largest at SNOLAB and will require the largest international investment. Triumf has been participating in the EXO-200 project through the scientific efforts of D. Sinclair and the engineering support of V. Strickland. It will be important to have Canada's National Laboratory involved in this international effort and there are many synergies between the needs of the experiment and scientific interests, and technical expertise at TRIUMF. The use of the nucleus as a laboratory for basic science has always been a strong theme of the TRIUMF program and the search for double beta decay is clearly a leading issue in this field. Areas of TRIUMF participation could include mechanical engineering (perhaps centred at Carleton where TRIUMF, SNOLAB, and NSERC engineers form a strong engineering collaboration), sensitive light detection (perhaps in collaboration with the ILIDD facility), detector simulation, trapping and laser tagging of barium ion, and continued scientific leadership. The level of activity proposed here is judged to be the minimum viable. It is hoped that additional TRIUMF scientists will find the science compelling and join the project.

The collaboration plans to complete a full proposal for funding in about 2-3 years at which time the US funding agencies are planning a selection process for a major experiment in this field. It is expected that capital funds will come from several countries including Canada to enable this project to go forward and efforts to secure such support are just beginning. The bulk of the effort is required after the current round of SNOLAB experiments are in the operating phase.

SCIENTIFIC JUSTIFICATION:

The search for neutrino-less double beta decay is one of the most urgent tasks in experimental particle physics. We know from SNO, KamLand and Super-Kamiokande that neutrinos have mass but we do not know how to encompass this within the Standard Model. We know that the masses are very small compared with other elementary particles but we do not know how small. Detection of neutrino-less double beta decay would represent a major advance in this field. It would show that neutrinos are Majorana particles (the only such fermions) and it would show that lepton number is not conserved. Both of these properties could contribute to an understanding of why the universe is made of matter and not equal parts matter and anti-

matter. In the longer term, it may be possible to search for evidence of non-zero phases in the neutrino mixing matrix which are only accessible through double beta decay.

The EXO group has made two significant contributions to this field in the past year. First, the standard model process of two neutrino double beta decay in xenon was observed for the first time. With a measured half life of 2.11×10^{21} years, this is the slowest decay mode ever directly detected. A second run produced a new limit for neutrino-less double beta decay that challenged, for the first time, a prior claim of observation. Testing this claim has been the objective for several experiments. These measurements establish the state of the art in the world and demonstrated the exquisite detection capabilities of xenon.

Xenon is an attractive medium in which to search for this decay because it can be made extremely pure, it has no long lived radioactive isotopes, it can be made into detectors and it offers the prospect of essentially eliminating the background through the ability to tag events with the identification of the barium daughter. Xenon is also the least expensive isotope to produce for double beta decay studies. This is significant as the major cost of the project will be the cost of the isotope.

The possible values for neutrino masses and for the mass parameter entering the double beta decay process are constrained by the SNO, KamLand and Super-Kamiokande measurements. The target for the current experiment is the so called inverted hierarchy or masses down to about 15 meV. It is expected on the basis of the performance of the EXO-200 detector that this level can be reached without the need for barium tagging. If this experiment does not find the double beta decay then a bigger detector with barium tagging is seen as the only way to proceed to the normal hierarchy.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

This experiment would be a major component of the SNOLAB physics program . There are obvious links to other projects using xenon as a detection medium. The laser physics required for the barium identification provides linkages to the atomic physics and trapping community.

BROADER IMPACTS:

Training of HQP is a central component of this project. To date one PhD and 4 MSc degrees have been awarded in Canada on the work. Three further degrees are in progress. Several undergraduate summer students are taken on each year to participate in aspects of the experiment. It is expected that these numbers will grow as the project expands and moves to Canada. Public outreach will continue to form an important part of the program. Several public lectures have been given on the science recently including one at TRIUMF. The SNOLAB staff will be engaged in preparing material suitable for schools on the experiment.

MAJOR MILESTONES:

Description	Date
Submission of full Proposal	2015
Funding approval	2016
Final Design	2016
Construction Complete	2019
First Physics	2020
Final Data Taking	2029

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF	30,000	30,000	30,000	30,000	30,000	150,000
EXTERNAL	600,000	600,000	600,000	600,000	600,000	3,000,000
TOTAL						
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Canadian PI	26	26	26	26	26	130
Physicist light det.	13	13	13	10	10	59
Geant Physicist	10	10	10	10	10	50
Technician	20	20	20	20	20	100
Engineer	26	26	26	26	26	130

EXTERNAL FUNDING INFORMATION:

Current NSERC project grant is $400/a. We anticipate growth as the project expands. Capital cost for the project will include funds for xenon (perhaps $50M) and a few tens of millions for construction. As we have not completed a pre-conceptual design it is not possible to provide an estimate except to judge from similar projects of this scale.

ONGOING OPERATIONAL REQUIREMENTS:

The TRIUMF cost will depend on the number of scientists involved. It is expected that most costs will be covered by NSERC operating awards.

DECOMMISSIONING REQUIREMENT:

Accepted: Date: