Proposal for TRIUMF Commitment (5YP 2015-2020)

Date: September 17, 2012

PROJECT/COMMITMENT TITLE: T2K and future long-baseline neutrino experiments

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PRINCIPAL COLLABORATORS: D. Karlen (UVic); H. Tanaka, C. Hearty (UBC); F. Retière, R. Helmer, S. Yen, A. Miller, J.-M. Poutissou, R. Poutissou (TRIUMF); T. Mathie, R. Tacik, M. Barbi (Regina); B. Jamieson (Winnipeg); S. Bhadra (York); J. Martin (Toronto); + international partners in Japan, the US, UK, France, Switzerland, Spain, Poland, Italy, Germany, Russia.

PROJECT DESCRIPTION: The T2K experiment is an ongoing long-baseline neutrino experiment designed to study oscillation of a ~0.7GeV ν_μ beam across a 295 km baseline. Its primary physics goal is to measure the rate of $\nu_\mu \rightarrow \nu_e$ oscillation. This oscillation is sensitive to the neutrino mixing angle θ_{13} and the Dirac CP phase δ_{CP}. TRIUMF has made among the largest contributions of any international partner to the T2K experiment. These include time projection chambers and fine-grained scintillator detectors for T2K's near detector, an optical transition radiation monitor and remote handling systems for the neutrino beamline, and computing, DAQ, and slow controls support. TRIUMF hosts the CFI-funded T2K Tier 1 data centre for the Western hemisphere. T2K will operate for an undetermined length of time (at least until 2018) and probably will be operational through 2020.

A next-generation experiment called Hyper-Kamiokande is planned to search for differences in the ν_e appearance probability for neutrinos vs. antineutrinos, which is a distinctive signature of CP violation in the leptonic sector. Hyper-K will require the construction of a huge water Cherenkov detector with a fiducial volume of ~0.5Mtonne in order to collect sufficient statistics to establish neutrino CP violation. The Hyper-K proto-collaboration is forming presently with Canadian involvement, and a formal proposal to the Japanese funding agencies is expected before 2015. It is one of the two highest-ranked projects for particle physics in Japan. We anticipate approval and start of construction in the 2015-2020 period.

We request continued support from TRIUMF for its previous T2K contributions (detector facility, DAQ, computing/website support). These include maintenance for TRIUMF-built detectors and beam hardware, support for the T2K websites hosted at TRIUMF, and DAQ/slow controls support. We also request R&D support for Hyper-K work in the first part of the 2015-2020 period (especially detector facility, GEANT4 simulation, computing, DAQ), anticipating that this will evolve into a Canadian hardware contribution to calibration systems and photosensors during the construction phase. The hiring of one or more TRIUMF staff scientists (essentially replacing recent retirements, and possibly done through joint positions with IPMU) would allow TRIUMF to maintain leadership in long-baseline neutrinos through the next 5-year plan. We also request increased computing support for the T2K Tier 1 data centre and for T2K grid computing. This would include support for the Tier 1 data centre hardware and dCache software, as well as network support and scientific computing (operating system upgrade/installation & tools like ROOT and GEANT).

SCIENTIFIC JUSTIFICATION: The structure of the PMNS neutrino mixing matrix has only recently been determined. The value of the mixing angle θ_{13} was for a long time uncertain until initial results from T2K in 2011 suggested that it was relatively large, an indication that was confirmed at high significance by reactor neutrino experiments in early 2012. T2K has recently reported a >3σ signal for ν_e appearance, demonstrating the viability of using this channel to search for CP violation by

neutrinos. CP violation by neutrinos would be the first indication of a new source of CP violation beyond the Standard Model CKM matrix, and can be related to the cosmological matter-antimatter asymmetry in a leptogenesis model. T2K will also provide the world's most precise measurement of the neutrino mixing parameters Δm^2_{23} and θ_{23}. Current measurements of θ_{23} are consistent with 45°, suggesting a symmetry in the PMNS matrix, making precision measurements of any deviation from 45° particularly important. The very large far detector required to achieve sufficient statistics for CP-violation studies naturally will yield an order of magnitude improvement in the proton decay lifetime. Proton decay is one of very few experimental probes of GUT-scale physics, and the ability to study it with the same detector that is needed for CP violation measurements is a fortuitous efficiency.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY: T2K-Canada, at ~40 members, is the largest neutrino experiment in the Canadian subatomic physics community, with participation at seven universities. The Canadian group is among the largest international partners in the T2K experiment, and has established a worldwide profile for Canada and for TRIUMF in the long-baseline neutrino community. The physics questions addressed by T2K complement those addressed by SNOLAB experiments, and there is increasing overlap between T2K and SNOLAB researchers, particularly in R&D for future experiments such as Hyper-K and next-generation SNOLAB experiments.

Since the start of T2K, TRIUMF has been a focal point of activity, and the local TRIUMF/UBC group is among the largest in the collaboration. TRIUMF has hosted several T2K workshops and meetings, as well as visiting T2K scientists on sabbatical, and hopes to continue this in the next 5 years. T2K has particularly showcased the abilities of TRIUMF's detector facility, remote handling, and DAQ groups. Continued TRIUMF involvement in Hyper-K will not only allow the lab to maintain a leadership role in long-baseline neutrinos, but also may yield R&D synergies with other efforts in Canada with interests in large-area photosensor development, such as IceCube/PINGU, EXO, or DEAP.

T2K is currently leading the world in measurements of ν_e appearance in long-baseline experiments. The NOνA experiment, using the NuMI beam at Fermilab, will turn on in 2013, and is the most direct competitor for T2K itself. NOνA is expected to confirm the ν_e appearance results from T2K, and its longer baseline and higher beam energy may allow it to determine the sign of the neutrino mass hierarchy. However the NOνA technology does not scale to the megaton size needed for CP violation studies, and the future US long-baseline neutrino programme is heavily invested in the LBNE proposal, which would build a new beamline and a detector near Homestake, SD. The LBNE project has been severely descoped due to budgetary pressures in the US, and it is reasonable to expect that Hyper-K, if approved, will more quickly reach good sensitivity to CP violation in the neutrino sector.

BROADER IMPACTS: T2K maintains a vigorous HQP effort, with many graduate and coop students resident at TRIUMF forming a critical mass for analysis, making TRIUMF the most attractive place in the collaboration to work on T2K analysis. TRIUMF's contributions to the experiment have featured novel technologies such as pixelated avalanche photodiode sensors, large-volume time projection chambers with micropatterned readout, and optical transition radiation beam monitors, that are now finding many new applications. The anticipated R&D programme for Hyper-K will focus on large-area photosensor development and calibration systems that will allow TRIUMF to develop in-house expertise in next-generation technologies for future projects. The success of this effort depends upon replacement of retiring T2K group members (with 3 TRIUMF staff scientists on T2K having retired in 2012).

MAJOR MILESTONES:

Description	Date
Installation of TRIUMF-built T2K near detector components	Fall 2009
Start of T2K data-taking	Spring 2010
First oscillation results from T2K (2.5σ indication of ν_e appearance)	June 2011
Updated oscillation results from T2K (3.2σ indication of ν_e appearance)	June 2012
J-PARC LINAC energy upgrade (beam intensity upgrade)	2nd half of 2013
Completion of approved T2K running at JPARC (approved for $5x10^7$ s x 750kW)	~2018-2020

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS

\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF	0	0	0	0	0	0
EXTERNAL	$1.8M	$1.8M	$1.8M	$3.3M	$3.3M	$12M
TOTAL	$1.8M	$1.8M	$1.8M	$3.3M	$3.3M	$12M

TRIUMF NON-CASH RESOURCES

\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Physics / Particle (staff physicists)	180	180	180	180	180	Unknown
Physics / Detector	15	15	15	15	15	Unknown
IT / DAQ	10	10	10	10	10	Unknown
IT / sysadmin	6	6	6	6	6	Unknown
Physics / Experimental / Grid computing	8	8	8	8	8	40
Engineering/Electronics	3	3	3	3	3	Unknown
HK: Physics/Detector	15	20	50	100	100	285
HK: Engineering/Mechanical	0	20	30	30	20	100
HK: Technical/Mechanical Designer	0	10	20	40	40	110
HK: Mechanical/CNC machining	0	0	20	60	60	140
HK: IT / DAQ programming	0	10	10	20	30	70
HK: IT/DAQ/simulation	15	15	10	5	5	50

EXTERNAL FUNDING INFORMATION: Existing funding from NSERC at $1.7M/year. We assume a ~$3M capital contribution for Hyper-K construction in the last two years of the 5-year plan, to be funded by either CFI or NSERC.

ONGOING OPERATIONAL REQUIREMENTS: Listed in the above table, these include ongoing analysis and management activities by staff physicists, support from the detector facility to maintain T2K near detector components, support from the DAQ group to maintain certain slow controls and DAQ systems, electronics repair assistance by electronics engineers, and help with scientific computing, our storage array, and grid computing tools/infrastructure. New resource requests for Hyper-K listed separately. Totals for years predating TRIUMF's current accounting system are not available and listed as "unknown".

DECOMMISSIONING REQUIREMENT: Past TRIUMF hardware contributions to T2K were donated to KEK, which thereby assumed the decommissioning liability. We do not anticipate any decommissioning activities in this 5-year period, and we anticipate that any hardware contributions to Hyper-K will similarly be donated to a Japanese host laboratory and will not result in decommissioning requirements.

Accepted: Date: