TRIUMF Neutrino Program

by Dean Karlen

The Canadian effort in the Tokai-to-Kamiokande (T2K) experiment at the Japanese Hadron Facility (JHF), now known as the Japan Proton Accelerator Research Complex (J-PARC), was initiated by TRIUMF scientist, Akira Konaka. He was the only contributor outside Japan on the Letter of Intent (LOI) for the "JHF-Kamioka neutrino project" released in June 2001. The proposal was to build a neutrino beamline at the new proton accelerator facility under construction in Tokai to produce an intense neutrino beam directed towards the Super-Kamiokande detector, 295 km away. The discovery of oscillation of atmospheric and solar neutrinos by earlier experiments (in particular Super-Kamiokande and Sudbury Neutrino Observatory, recognized by the 2015 Nobel Prize in Physics) provided the physics justification. The distance between Tokai and Super-Kamiokande happened to be ideal for fully exploring the oscillation of muon neutrinos and muon anti-neutrinos. The highly ambitious LOI concluded with the statement, "The first phase experiment is planned to start in 2007."

The project would require significant international participation to be a success. Akira Konaka convinced several TRIUMF scientists to join the effort, forming a nucleus that attracted many other scientists from across Canada. In 2003, 20 Canadian scientists signed the pre-collaboration LOI, with 45 from Japan and 80 from other nations, and later that year the Japanese government approved the proposal.

TRIUMF had a significant impact on the neutrino beamline design, including the deliberate misdirection by a few degrees from the Super-Kamiokande direction, to improve beam properties for oscillation studies. The latter "off-axis beam" concept was first investigated by a (then) undergraduate student working at TRIUMF, Jared Anderson. TRIUMF contributed to the beam kicker, beamline optics, hot cell, and the beamline technical advisory committee. The hot cell has been invaluable in repairing equipment impossible to access directly due to radioactivity. TRIUMF proposed to use an optical transition radiation (OTR) detector to monitor the proton beam properties immediately in front of the neutrino production target. The OTR system was successfully completed by Canadian collaborators at York University and University of Toronto. Former T2K spokesperson, Takashi Kobayashi remarked "Without the collaboration with TRIUMF, the T2K beam facility would not have been completed".

A complex of near detectors was necessary to measure the neutrino beam properties prior to their oscillation. TRIUMF's technical resources and experience in detector design led to the Canadian group taking responsibility for the most critical elements of the near detectors, the Fine Grained Detectors (see Fig. 1) and the Time Projection Chambers (see Fig. 2). Following a period of 5 years to design, prototype, construct, and test, the detector systems were installed in Japan in 2009. These systems were completed as a collaboration between TRIUMF, UBC, University of Victoria, University of Regina, and international partners.

The far detector, Super-Kamiokande (SK), was in operation prior to the formation of T2K. Some members of the

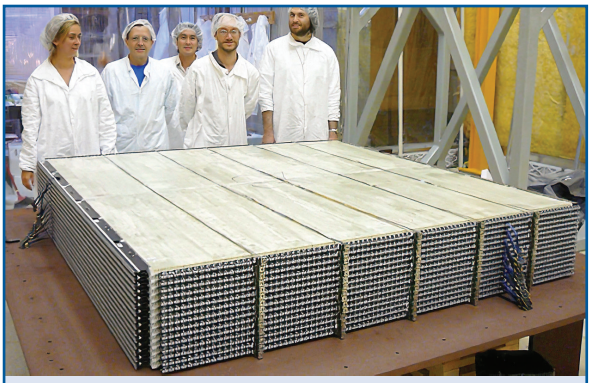

Fig. 1 Fine grained detectors under construction in the cleanroom at TRIUMF. From left to right: Joanna Zalipska (NCBJ, Warsaw), Robert Henderson (TRIUMF), Hiro Tanaka (SLAC), Scott Oser (UBC), Daniel Brook-Roberge (Rival Tech).

Summary

A brief history of the T2K project in Canada, a pillar of Canada's involvement in global neutrino physics, as presented at the TRIUMF 50th Anniversary Science Symposium.

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Fig. 2 Time projection chamber under construction in clean-room at TRIUMF under the watchful eye of Robert Henderson (TRIUMF).

Fig. 3 Canadian group members visiting J-PARC during neutrino beamline construction. From left to right: Akira Konaka (TRIUMF), Peter Kitching (TRIUMF and U Alberta, ret.), John Martin (IPP and U Toronto, ret.), Richard Helmer (TRIUMF, ret.), Dean Karlen (UVic and TRIUMF), Jean-Michel Poutissou (TRIUMF, ret.), Slavic Galymov (IPN Lyon), Thomas Kutter (LSU)

Canadian group joined the SK group and introduced new methods to analyze SK data, significantly improving the detector performance. Under Akira's leadership, Canada had significant involvement in all aspects of the T2K experiment (see Fig. 3).

A special seminar was scheduled for March 11, 2011, at 3:00 pm, at the Japanese laboratory, KEK, to reveal the first results from the T2K experiment. At 2:46 pm, a magnitude 9 earthquake struck Japan, followed by devastating tsunami waves on the east coast. At the J-PARC laboratory, 200 km from the epicentre, there was significant upheaval of roads, but the buildings and accelerator were not severely damaged. The accelerator was brought back into operation before the end of 2011, and the T2K experiment was collecting data again within one year of the earthquake. The data collected by 2011 showed evidence (at the 3-sigma level) that all three types of neutrino oscillation occur. One additional year of data was required to make that conclusion definitive (i.e., more than 5 sigma), during which time the observation was confirmed by other experiments studying the oscillation of neutrinos from reactors. For this discovery, T2K shared the 2016 Breakthrough Prize in Fundamental Physics with 5 other collaborations. The experiment continues to collect data to measure possible difference between neutrino and anti-neutrino oscillation and to determine the mass ordering of the neutrino mass states.

T2K has been a great training ground for the future scientists in Canada and around the world. There have been more than 120 Canadians involved since its inception, and several students and postdocs now hold faculty positions in Canada, the US, and abroad.

Canadian participation in T2K has been a tremendous success. Only with a laboratory like TRIUMF could a large group be established and accomplish so much in such a short time. The combination of excellent technical resources and highly knowledgeable and enthusiastic staff at TRIUMF allows Canadian scientists to come together and lead major international projects at the forefront of science.

The former T2K spokesperson, Takashi Kobayashi, asked to summarize the role of TRIUMF in T2K said, "Long and extremely fruitful collaboration with TRIUMF has been essential for the success of the T2K experiment. We really appreciate the essential contribution from TRIUMF on many aspects of the T2K experiment and we would like to continue and further strengthen our collaboration toward the next generation experiment, Hyper-Kamiokande."