T2K ECAL Test–beam Proposal

T2K Collaboration
Recognised Experiment RE13
Spokesperson : Prof. David Wark

October 27, 2008

A. Grant, A. Muir

STFC Daresbury Laboratory, Daresbury, WA4 4AD, UK

P. Guzowski, M. Malek, M. Noy, M. Raymond, I. Taylor, Y. Uchida, A. Vacheret, F. van Schalkwyk, J. Walding, D. Wark, M. Wascko

Imperial College London, SW7 2AZ, London, UK

I. Bertram, A. Chilingarov, G. Davies, A. Finch, A. Hatzikoutelis, L. Kormos, T. Maryon, P. Ratoff

Lancaster University, Lancaster LA1 4YB, UK

C. Chavez, L. Kellett, N. McCauley, D. Payne, P. Sutcliffe, C. Touramanis

The University of Liverpool, Oliver Lodge Laboratory L69 7ZE, Liverpool, UK

G. Barr, R. Smith, N. West

The University of Oxford, Clarendon Laboratory OX1 3PU, Oxford, UK

M. George, A. Hyndman, F.Di Lodovico, R.A. Owen, R. Sacco, R. Terri

Queen Mary, University of London, London E1 4NS, UK

C. Andreopoulos, T. Durkin, C. Metelko, T.C. Nicholls, G.F. Pearce, T.M. Raufer, M. Rooney, M. Thorpe, A. Weber, M.L. Woodward

STFC Rutherford Appleton Laboratory, Harwell Science and Innovation Campus, Didcot, OX11 0QX, UK

S.L. Cartwright, R. Salih, B. Still, L.F. Thompson, O. Veledar, G. Ward, M. Ward

University of Sheffield, Sheffield S3 7RH, UK

G.J. Barker, S. Boyd, A. Carver, P. Litchfield, M. Haigh, L. Whitehead

Warwick University, Coventry, CV4 7AL,UK

CERN-SPSC-2008-025 / SPSC-P-336
27/10/2008

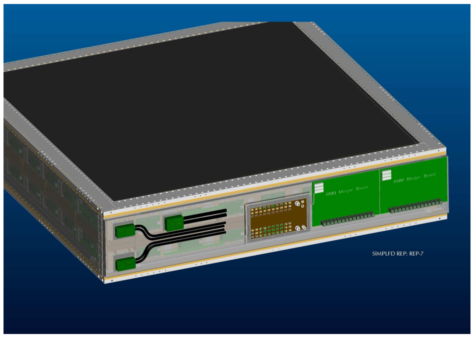
1 Introduction

A combination of experiments worldwide have now demonstrated that neutrinos have mass and oscillate, which is the first confirmed evidence for physics beyond the Standard Model. Critical questions remain to be answered, however, with the next major target being the measurement of the third mixing angle θ_{13}. A non-zero value for $sin^2\theta_{13}$ is a prerequisite for any terrestrial demonstration of CP violation in the lepton sector, which is the ultimate goal of oscillation physics (and the principle justification for building a Neutrino Factory). The T2K experiment will represent a very substantial step forward in our ability to probe neutrino oscillations. The most intense artificial neutrino beam ever constructed will be produced at the newly built J-PARC facility on the east coast of Japan, and directed 295 km underground to the Super-Kamiokande detector, which is being refurbished for this experiment. Phase I of the experiment, with a proton beam now expected to exceed 0.75 MW combined with the Super-Kamiokande detector, will extend our sensitivity to θ_{13} by an order of magnitude.

The accuracy and reliability of the experiment depends crucially on detectors close to the beam origin which characterise the beam before any oscillations take place, and perform detailed studies of the interactions of neutrinos at these energies. The UK group has designed and built a tracking calorimeter which will be vital to our understanding of neutrino interactions in this beam. The calorimeter uses Multipixel Photon Counters (MPPC), a relatively new type of photosensor which requires somewhat different calibration techniques than are commonly utilised in detectors using photomultiplier tubes. A test–beam run is crucial to our understanding of this calibration procedure before the the detector is positioned within the near detector suite in-beam and, more importantly, offers the only opportunity before installation to measure the absolute electromagnetic and hadronic energy scale.

In addition to calibration work, the test–beam will provide a library of clean data on hadronic and electromagnetic shower profiles at energies below 1 GeV. It is well known that Monte Carlo models do not model such interactions well. Test–beam data will be useful in tuning our understanding of these interactions and in testing our reconstruction and particle identification techniques using real, rather than simulated, data.

Lastly, it is extremely important that the entire ECAL system, including the hardware, data acquisition and detector control subsystems, is tested and debugged before installation in the ND280m detector in Japan. A test–beam represents a unique opportunity to operate the detector under standard operating conditions and will provide a valuable opportunity to test the system.



(a) Engineering design drawing of the first ECAL module type. The external design of the module, including all external services, is shown.

(b) Photograph of the module under construction to provide a sense of scale.

2 Electromagnetic Calorimeter Design

There will be two distinct types of calorimeter modules employed in the T2K near detector. Both are sampling calorimeters utilising layers of 1 cm thick, 4 cm wide plastic scintillator bars. They differ in the number of active layers, and their sampling fractions.

The main module that we wish to install in a beam consists of 34 active layers, separated by 1.75 mm of lead sheet comprising a total effective thickness of 11 radiation lengths. The active area of the module transverse to the beam direction is 204 cm by 204 cm and it is 50 cm deep. Including the support and shipping frame, in which the module will remain during the test, the cross sectional area is approximately 270 cm by 280 cm. The total weight, including all services, is 7.0 tonnes. The module is self-contained with all readout electronics, power distribution systems, cooling systems located within the module itself, making the interface to external services particularly simple. A photograph of this module under construction is shown in 1(b). This module has already been assembled.

A second module type will also be used in the experiment. This is of a coarser design than the one just described, with 6 active layers of scintillator separated by lead sheets that are 4 mm thick, a total effective thickness of 4.5 X_0 and a total weight of 4.0 tonnes. The active area of this module type transverse to the beam direction is 280 cm by 280 cm (346 cm by 356 cm including the support structure) and it is also 50 cm deep. The different sampling fraction implies significantly different properties than those of the more fine-grained module, and so we also wish to expose this module to the same beam. However, we believe that, if necessary, the main aims of the beam test can be achieved with the first, already assembled, module.

The temperature in each module will be stabilised by chilled water flowing in an external cooling circuit.

3 DAQ and Event rates

The front end readout boards are installed within the modules and are not accessible. These boards supply individually-controlled bias voltages of about 70 V to each photosensor , configure and control the front end readout chip, contain charge injection circuitry and generate trigger primitives for the cosmic ray trigger. These front end boards are controlled by the DAQ PC's via the Readout Merger Module (RMM) boards, which are installed on the external surface of the module. The boards read out to the DAQ PC at around 40 Hz. We estimate a data rate of about 1 Mb/sec. We will provide all DAQ PCs, all data storage disks and personal PCs. We request that CERN provide network access and support for data archival to our off-site data repository at KEK, expert access to the DAQ from the UK and general internet access by T2K staff whilst at CERN.

4 Test–beam Request

4.1 General Considerations

Single particle pion energies in T2K range between 300 MeV and approximately 1 GeV. Electron energies fron ν_e interactions range from 500 MeV to 5 GeV. The test–beams should, as much as possible, cover these energy regimes. In addition to electrons and pions, muons are also required for calibration purposes - either from cosmic ray interactions or from the beam. The beam energies should stay within 1-2% of nominal settings. At T2K, the particles will enter the ECAL modules at different angles and position, so we plan to position the modules at three different angles incident to the beam and at two different positions on the module face. The nominal run plan requests a total of 5×10^5 events.

After discussion with the East Area co-ordinator, and taking into account the known experimental constraints, we feel that the T9 beamline in East Area Hall is best suited to our needs, although T7 would also be acceptable. We understand that, currently, T9 receives one spill every 48 seconds. Assuming a 40 Hz event readout rate, and taking a conservative estimate of 50% for the run inefficiency incurred from module movement and reconfiguration and other unknown delays into account, we calculate that the total event sample would be collected in approximately 30 days of beam. In addition we believe that we will require 2 weeks of setup and commissioning and 1 week of decommissioning time. We would prefer the setup and decommissioning to be carried out within the experimental enclosure, but, if required, it is possible that it could take place in any secure staging area outside the enclosure close to the counting room.

4.2 Requirements

We have surveyed the T9 enclosure and are confident that it is large enough for the ECAL modules. Their (minimal) attendant electronics will be contained in one rack, positioned within the enclosure, which we will provide.

We request the use of the two Cerenkov counters currently installed in the T9 beamline for hadron/electron discrimination. We will also require the use of a time-of-flight system which we will supply. We ask CERN for the provision of network access, including access to an external data archiving facility at KEK. We require a supply of de-ionised water which will be cooled in a chiller we will provide. In addition we require electrical power, a gas supply for the Cerenkov counters and technical support for installation and movement of the modules during the run. We need a temporary counting room and office space.

4.3 Timing

After test–beam the modules will be shipped to Japan directly from CERN for installation in the ND280 detector. We plan to send them by air, but feel that the installation schedule would best be supported by running the test–beam as early in the year as possible. We request that, if possible, the T2K ECAL be the first in-beam in 2009. This will allow us to ship the modules to CERN before the beam switches on and setup within the enclosure whilst waiting for beam. We estimate that early June is the latest we could go into beam and still maintain our installation schedule.