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Technical review report on the ND280

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1. Preface

As is stated in the minutes of the first J-PARC program advisory committee (PAC) meeting in 2006, it recommended the stage-2 approval to the T2K experiment. But due to the limited information and time available at the PAC meeting, a technical review by the PAC of the complex near detector system, ND280, was not possible. Therefore the PAC requested to the T2K group detailed documentation on the design with simulations and justifications including the status of the funding, group responsibility, and schedule for each sub-component. The PAC also requested IPNS to set up a technical review committee to examine the near detector system. Responding to the request, the director of IPNS formed the J-PARC neutrino experiment review committee (JNRC). It will serve as an advisory committee to the director, not an ad hoc, on technical aspects of the T2K experiment. Its current task is to examine the technical feasibility of the near detector system.

Detailed technical review meeting on ND280 was held on November 27 and 28, 2006. A technical design report (TDR) was distributed beforehand. The committee was impressed and thanked the T2K group on the well prepared documentation and the presentations. In this report, the committee gives a summary of the feasibility study based on the information and direct communication afterwards with the T2K group.

2. ND280

The major roles of the ND280 detector are to measure the ν_μ and ν_e fluxes and their energy spectrum through charge current (CC) quasi-elastic (QE) processes, $\nu_\mu n \rightarrow \mu^- p$ and $\nu_e n \rightarrow e^- p$. Since the ν_e contamination is about 1% of the ν_μ flux, good electron identification with muon rejection factor of about 1,000 is required. Other important role is to measure one-pion-production cross- sections on water target, which will be basic data to estimate backgrounds at the far detector, the

Super-Kamiokande III. Among others, key processes are one-pion-productions with neutral current (NC), $\nu_\mu p \rightarrow \nu_\mu \pi^+ n$, $\nu_\mu n \rightarrow \nu_\mu \pi^- p$, and with charged current (CC), $\nu_\mu N \rightarrow \mu^- \pi^+ N$ for the ν_μ disappearance measurement, and NC one-pion-production, $\nu_\mu p \rightarrow \nu_\mu \pi^0 p$ for the ν_e appearance measurement. Required errors are 10% levels, while much better precisions are expected to be achieved.

2.1 ND280 detector

The ND280 consists of two systems. One is the on-axis neutrino monitor (INGRID), and the other is the off-axis neutrino detector. The INGRID provides direct measurement of the neutrino beam profile, flux, and the direction. The detector guarantees the neutrino beam quality day-by-day basis. The required uncertainty of the direction measurement is 1 mrad, which can be achievable with 15 modules.

The prime functionality of the off-axis detector is the tracking of charged particles, and identifications of μ, e, p, charged π, π^0, and photon. The tracking part consists of the UA1 magnet, fine-grained detector (FGD), and time projection chamber (TPC). With the help of the tracking, the electromagnetic calorimeter (ECAL) serves to separate e/μ and μ^-/π^-, and to measure photon and π^0. The side muon range detector (SMRD) serves to identify muons and veto accidental events from outside. The π^0 detector (P0D) is to detect π^0s for the neutral current one-π^0 production study with high statistics.

2.2 Construction plan

Construction organization

The T2K group is a fully international collaboration, and the construction sharing is world-wide: Canada, France, Germany, Italy, Japan, Korea, Poland, Russia, Spain, Switzerland, UK, and US. The construction organization and responsibility are well defined.

Schedule

The first neutrino beam will be available in April 2009. The construction of ND280 is scheduled to meet with the beam delivery. However, due to the tight schedule and broad budget profile, the integration will be done with three stages. The INGRID, magnet, FGD, TPC, and part of SMRD will be installed in spring 2009; the rest of the SMRD and P0D will be installed in 2009; then ECAL will be finally installed in the end of 2009.

3. Review on the feasibility of the ND280

The committee investigated feasibility of the ND280 from two aspects. One is detector technologies themselves, and the other is related to external constraints. The former is straightforward and the committee has relatively firm confidence. While, the latter includes J-PARC schedule, ND280 budget profile, organization, manpower, and infra-structures and services available for ND280 in the Tokai site. The committee has been trying to grasp an overall picture on these constraints. But it is still far from completeness. Therefore statements for the feasibility from the second aspect should be understood as interim.

3.1 Detector technologies

Multi-pixel Geiger mode avalanche photodiode

Combination of scintillation counters and photo-sensors are used for both INGRID and sub-detectors in the off-axis neutrino detector except for TPC. The T2K group chose multi-pixel Geiger mode avalanche photo-diode (APD) after extensive R&D studies as the photo-sensor. In general, the technology itself is in a matured level. The sensor is relatively cheap and compact; it can be operational at room temperature and in a magnetic field. Du to these excellent properties it makes possible for many experiments to implement and readout fine-grained scintillator bars or fibers in limited spaces. Requirements on the sensors for ND280 are similar for all the sub-systems: FGD, P0D, SMRD, ECAL and INGRID. Pixels per sensor should be more than 400; efficiency for green light should be more than 10%; dark-noise rate should be less than 1.5 MHz; and the gain should be $0.5\text{-}1\times10^6$. There are two promising candidates which are commercially procurable. One is Metal-Register-Semiconductor (MRS) APD of Center of Perspective Technologies and Apparatus (CPTA) in Russia. The other is Multi-Pixel Photon Counter (MPPC) of Hamamatsu Photonics in Japan. Most parameters are already satisfactory for ND280. On the other hand, as theses sensors are new and have not been used for real experiments for long period, remaining would-be concerns are long-term stability and life time. These studies are ongoing. The committee considers the MRS-APD and MPPC for ND280 are feasible.

Micromegas

As the TPC is three-dimensional tracking detector, it is superior in pattern recognition to other tracking detectors. It also has a capability of particle identification by the dE/dx measurement. Many TPCs have been constructed and operated since the pioneering PEP4-TPC for more than two decades. So far, the multi-wire proportional chamber is used for the gas amplification device in actual experiments. As new generation detectors, not necessarily for TPC, many micro-pattern gaseous detectors generically have been invented and developed. The Micromegas is one of such devices. It consists of two gas regions: drift region and amplification region. The amplification region is based on a narrow, about 50 to 100 μm, parallel electrode structure. One is a very-fine mesh or grid through which drift electrons can go into the amplification gap. The other is an anode readout plane. The technology has reached maturity and been or was used for several experiments. So far, the COMPASS experiment at CERN used the largest quantity of the device. Twelve 40x40 cm^2 Micromegas detectors were operated successfully. While the active area of the ND280 Micromegas is the similar size, 34x36 cm^2, the ND280 group will use 72 detectors. It is six times more detectors, but some of the members who developed the COMPASS Micromegas are also joining in the ND280-TPC. The committee considers the Micromegas for ND280 is feasible.

3.2 Schedule and budget

The committee worries the tightness of the integration schedule. The ND280 building is only available in January 2009. The integration of INGRID, magnet system, FDG and TPC have to be completed within three months. It might be possible, but a dedicated integration team should be well prepared and organized. Also the commissioning strategy must be well prepared in advance. As quality assurance test of each component is foreseen, reasonable working area as well as storage area should be kept near the ND280 building.

Budgets for INGRID and the tracking part except for the UA1 magnet and part of SMRD are already secured. While those for the magnet, the rest of SMRD, P0D and ECAL will be approved soon. The committee cannot scrutiny the correctness of the budget for ND280 construction because it strongly depends on construction site or country, and how subsystems will be built. However, as the construction responsibility is well defined, it is assumed that each institute has requested necessary budget to its funding agency accordingly. The committee considers it is important for the collaboration to have firm consensus that the construction responsibility is obligatory.

4. Summary and comments

The committee considers the simulation studies are reasonably progressing at this stage, and the results show feasibility of the ND280 system for the physics requirements of T2K. Both of the detector technologies, multi-pixel Geiger mode avalanche photodiode for the photo-sensor and Micromegas for the TPC gas amplification device, reached to maturity. In addition, there are many collaborators in the T2K group who have experience in those technologies in intensive R&D studies and/or the past experiments. Therefore, the committee considers the ND280 detector is feasible from a viewpoint of technologies themselves chosen by the group.

Nevertheless, here are some comments on ND280, which the committee thinks worth to be mentioned.

1) Simulation studies of the ND280 performance as a whole detector system should be improved. The tracking part is relatively advanced, but the ECAL, P0D and SMRD should be also included.
   - Muon rejection factor of better than 1,000 should be demonstrated in the ν_e flux measurement.
   - Quantitative studies on the μ^-/π^- separation should be shown.
   - Algorithm for the π^0 identification should be improved.
   - Systematic errors on the measurements of the one-pion-production cross-sections on the water target should be studies.
2) Multi-pixel Geiger mode avalanche photodiodes which will be used for ND280 are new to the market. Therefore, the studies on long-term stability and life time should be continued. Also the acceptable failure rate in the detector should be studied with simulation.
3) The TPC plays the key role in momentum measurement and particle identification. In order to get good dE/dx resolution, the gain uniformity is essential. Therefore it is mandatory to establish the gain calibration method in-situ.
4) The construction organization and responsibility are well defined for the main part of the subsystems. They should also be clearly defined in each stage: quality assurance, installation, integration of services, commissioning, maintenance and operation. The collaboration should take the responsibility to be obligatory.
5) The progress of the construction should be regularly monitored.