Daya Bay Reactor Neutrino Experiment Operations Plan

Prepared and maintained by the Daya Bay Operations Office

December 2011
Revision 1

Operations Plan
Change Log

Revision No.	Date	Change Description	Sections Changed
1	1/8/12	Signed Version	

CONCURRENCES:

_______________________________ Date: 5 JAN. 2012

David Nygren
Acting Division Director, Physics Division, Lawrence Berkeley National Laboratory (LBNL)

_______________________________ Date: 25 Jan. 2012

Steven Vigdor
Associate Laboratory Director, Nuclear and Particle Physics, Brookhaven National Laboratory (BNL)

_______________________________ Date: Dec. 30, 2011

Hesheng Chen
Institute for High Energy Physics (IHEP)

APPROVED:

______________________________ Date: 1/7/12
Yifang Wang
China Operations Manager and Co-Spokesperson, EB member

______________________________ Date: 1/7/12
Kam-Biu Luk
Co-Spokesperson, EB member

______________________________ Date: 1/7/12
Steve Kettell
U.S. Chief Scientist, EB member

______________________________ Date: 1/7/12
Bill Edwards
U.S. Operations Manager, EB member

______________________________ Date: 1/7/12
Jun Cao
EB member

______________________________ Date: 1/8/12
Shaomin Chen
EB member

______________________________ Date: 1/7/12
Ming-Chung Chu
EB member

______________________________ Date: 1/7/12
Karsten Heeger
EB member

______________________________ Date: 1/8/12
Bob Hsiung
EB member

______________________________ Date: 1/7/12
Bob McKeown
EB member

______________________________ Date: 1/7/12
Changgen Yang
EB member

Table of Contents

1 Introduction

Recent discoveries in neutrino physics have shown that the Standard Model of particle physics is incomplete since it assumes massless neutrinos. The observations of neutrino oscillation have unequivocally demonstrated that neutrino masses are nonzero. There are three “flavors” of neutrinos, with mass eigenstates that are distinct from their flavor eigenstates, such that neutrinos oscillate from one flavor to another. Every neutrino is a mixture of the three mass states, and the probability of finding a given flavor at a certain distance from its source depends on the values of the mixing angles (θ_{12}, θ_{23} and θ_{13} as parameterized in the PMNS mixing matrix), the mass splittings and the neutrino energy. These mixing angles express the proportion of each mass eigenstate (1, 2 and 3) in each neutrino flavor. The first two of these mixing angles have been measured with reasonable precision and are relatively large. The third mixing angle (θ_{13}) has not yet been observed but is known to be small and could be zero. The current experimental bound, from the Chooz experiment, is $\sin^2 2\theta_{13}<0.16$ at 90% confidence level for the most probable mass splitting of $\Delta m^2_{31}=2.3\times10^{-3}eV^2$. It is important to measure this angle to provide further insight on how to extend the Standard Model to accommodate massive neutrinos. It is also important to measure the value of this angle to design a new generation of experiments to search for Charge-Parity (CP) violation in the neutrino sector. CP violation may occur in the neutrino sector and its discovery would be a major addition to our understanding of the universe. CP violation is required to explain why matter dominates over antimatter in the universe; however, the level of observed CP violation in the quark sector is too small to explain the matter-antimatter asymmetry of the universe. Measurement of neutrino CP violation in the PMNS framework will, however, only be possible if the presently unknown neutrino mixing angle θ_{13} is not zero. Therefore, the first step to determine the feasibility of measuring CP violation in the neutrino sector is to determine the magnitude of the neutrino mixing angle θ_{13}. The Daya Bay experiment will have the greatest sensitivity to $\sin^2 2\theta_{13}$, to a level of better than 0.01. Determining whether the value of $\sin^2 2\theta_{13}$ is less than or greater than 0.01 will have significant implications for the design of experiments to observe CP violation in neutrinos. A reactor-based determination of $\sin^2 2\theta_{13}$ is vital to resolving the neutrino-mass hierarchy and future measurements of CP violation in the lepton sector because this technique cleanly separates θ_{13} from CP violation and effects of neutrino propagation in the earth, unlike accelerator-based experiments that are sensitive to all three effects. A reactor-based determination of $\sin^2 2\theta_{13}$ provides important information needed to untangle the multiple effects seen in accelerator-based experiments.

2 Daya Bay Project

The International Daya Bay Project was formed under the auspices of the International Daya Bay Memorandum of Understanding (MOU) between Brookhaven National Laboratory (BNL), the Institute of High Energy Physics (IHEP) of the Chinese Academy of Science (CAS) and Lawrence Berkeley National Laboratory (LBNL) dated 1/29/08 to build and operate the Daya Bay experiment. It was formed to build a detector to perform a precision measurement of the θ_{13} mixing angle by searching for the disappearance of electron antineutrinos from the nuclear reactor complex in Daya Bay, China. The goal of the Daya Bay experiment is to reach a sensitivity of 0.01 or better in $\sin^2 2\theta_{13}$ at the 90% confidence level (CL). This Operations Plan, among other purposes, is intended to serve as addendum to the MOU to cover the operations phase of the experiment. The Daya Bay collaboration was formed to build, operate, analyze data from and publish results from the Daya Bay experiment. The Daya Bay collaboration operates under guidelines of the Daya Bay MOU and the Collaboration By-laws. The Daya Bay Operations Program is described in this document.

The Daya Bay nuclear power complex is one of the most prolific sources of antineutrinos in the world. The site is located adjacent to mountainous terrain, ideal for underground detector laboratories that are well shielded from cosmogenic backgrounds. This site is exceptional for a precision determination of $\sin^2 2\theta_{13}$ through measurement of the relative rates and energy spectra of reactor antineutrinos at different baselines.

The Daya Bay experiment consists of three underground experimental halls, one far from and two near the reactors. Eight identical detectors, consisting of three nested cylindrical zones, will be deployed to detect antineutrinos via the inverse beta-decay reaction. To maximize sensitivity four detectors are deployed in the far hall at the first oscillation maximum.

The rate and energy distribution of antineutrinos from the reactors are monitored with two detectors in each near hall at relatively short baselines from their respective reactor cores, reducing the systematic uncertainty in $\sin^2 2\theta_{13}$ due to uncertainties in the reactor power levels to about 0.1%. Each detector will have 20 metric tons of 0.1% Gadolinium (Gd)-doped liquid scintillator in the inner-most, antineutrino target zone. A second zone, separated from the target and outer buffer zones by transparent acrylic vessels, will be filled with undoped liquid scintillator for capturing gamma rays that escape from the target thereby improving the antineutrino detection efficiency. A total of 192 photomultiplier tubes (PMTs) are arranged along the circumference of the stainless steel tank in the outer-most zone, which contains mineral oil to attenuate gamma rays from trace radioactivity in the PMT glass and nearby materials including the outer tank. With reflective surfaces at the top and bottom of the detector the energy resolution of the detector is about 12% at 1 MeV. To suppress backgrounds from interactions of cosmic ray muons the detectors are situated under the mountains adjacent to the Daya Bay nuclear power plant. To further suppress these backgrounds and study them the detector is surrounded by a Muon System, consisting of an instrumented water shield (detecting Cherenkov light from muons) and a Resistive Plate Counter (RPC) system.

With three years of running at the estimated signal and background rates and systematic uncertainties, the sensitivity of Daya Bay for $\sin^2 2\theta_{13}$ is 0.01 or better, relatively independent of the value of Δm^2_{31} within its currently allowed range.

2.1 Project Scope

The International Daya Bay Project scope is described in the Daya Bay MOU and includes civil construction of the experimental facility as well as detector construction — Antineutrino Detectors, Muon System, Calibration System, Electronics and Offline. Crucial to all of these activities are the project integration elements — Installation, Integration and Project Management. The Work Breakdown Structure (WBS) is described in the TDR and detailed in the WBS Dictionary. The US and Chinese project scope is further documented in Appendix A of the Daya Bay MOU, where the Chinese scope includes the scope of other countries and regions.

The scientific goal of the Daya Bay experiment is to measure $\sin^2 2\theta_{13}$ to a sensitivity of 0.01 or better at 90% confidence level. In order to reach this goal the experiment must achieve several objectives, including requirements on the systematic and statistical uncertainties. The experimental requirements are thoroughly described in the Technical Design Report (TDR); key system requirements for the relative signal in near and far detectors are listed in Table 1.

Item	Requirement
Sensitivity to $\sin^2 2\theta_{13}$ at 90% C.L.	≤ 0.01
Standard error on $\sin^2 2\theta_{13}$	0.006
Far detector baseline	~2 km
Statistical uncertainty	0.05%
Detector systematic uncertainty	0.38% per module
Reactor power uncertainty	0.13%
Background uncertainty	0.3%

Table 1 – Functional Requirements

2.2 Project Organization

This section overviews the international project organization. While there is oversight by many agencies, the primary international oversight is the Laboratory Oversight Group (LOG).

The Project is organized into project offices in the U.S. and PRC that report to their respective national funding agencies and the LOG. The Project is advised on technical issues by a Technical Board (TB) consisting of the Project Managers, Chief Scientist and L2 subsystem managers from the U.S. and China and on safety issues by the U.S. and Chinese Safety Officers and their ESSH committee. Each subsystem has two Subsystem Managers who work together to ensure that the subsystem is designed, constructed and installed in a safe and efficient manner at the Daya Bay Site.

The LOG members are the Brookhaven National Laboratory Associate Director for Nuclear and Particle Physics, the Institute of High Energy Physics (China) Director and the Lawrence Berkeley National Laboratory Acting Division Director for the Physics Division. These are currently Steve Vigdor, Hesheng Chen and Dave Nygren. They meet regularly with Daya Bay Collaboration leadership and Project Offices to assess progress and plans. They report to the DOE, Chinese Academy of Sciences (CAS) and other Chinese and international funding agencies.

The International Finance Committee (IFC) consists of representatives from the international funding agencies and meets as appropriate, usually in conjunction with the annual U.S.-China meeting, to review financial status and plans and resolve funding issues as needed.

3 Daya Bay Operations Program

This section provides an overview of the international Daya Bay Operations Program which includes the technical effort supported by the Daya Bay Operations Office (OO) and the scientific effort supported by the Collaboration. The operations program is governed by this Operations Plan. The Collaboration is responsible for the scientific direction and output of the experiment and provides direction to the Operations Office, whereas the Operations Office is responsible for the safe and efficient operations of the experiment. The Operations Office is responsible to the funding agencies. Both the Collaboration and Operations Office operate under the guidelines of the Daya Bay MOU and by-laws. The primary decision making body is the Executive Board. The current expectation by the collaboration and funding agencies is that the Daya Bay experiment will be operated jointly for approximately five years after construction is completed (2012–2016) to measure θ_{13}. Depending on the scientific results obtained, possible detector upgrades or other factors, the planned duration of operations may change. The Chinese side of the collaboration currently expects that the Daya Bay site will continue operations beyond five years, perhaps for other physics.

The international organization of the Daya Bay Operations Program is shown in Fig. 1.

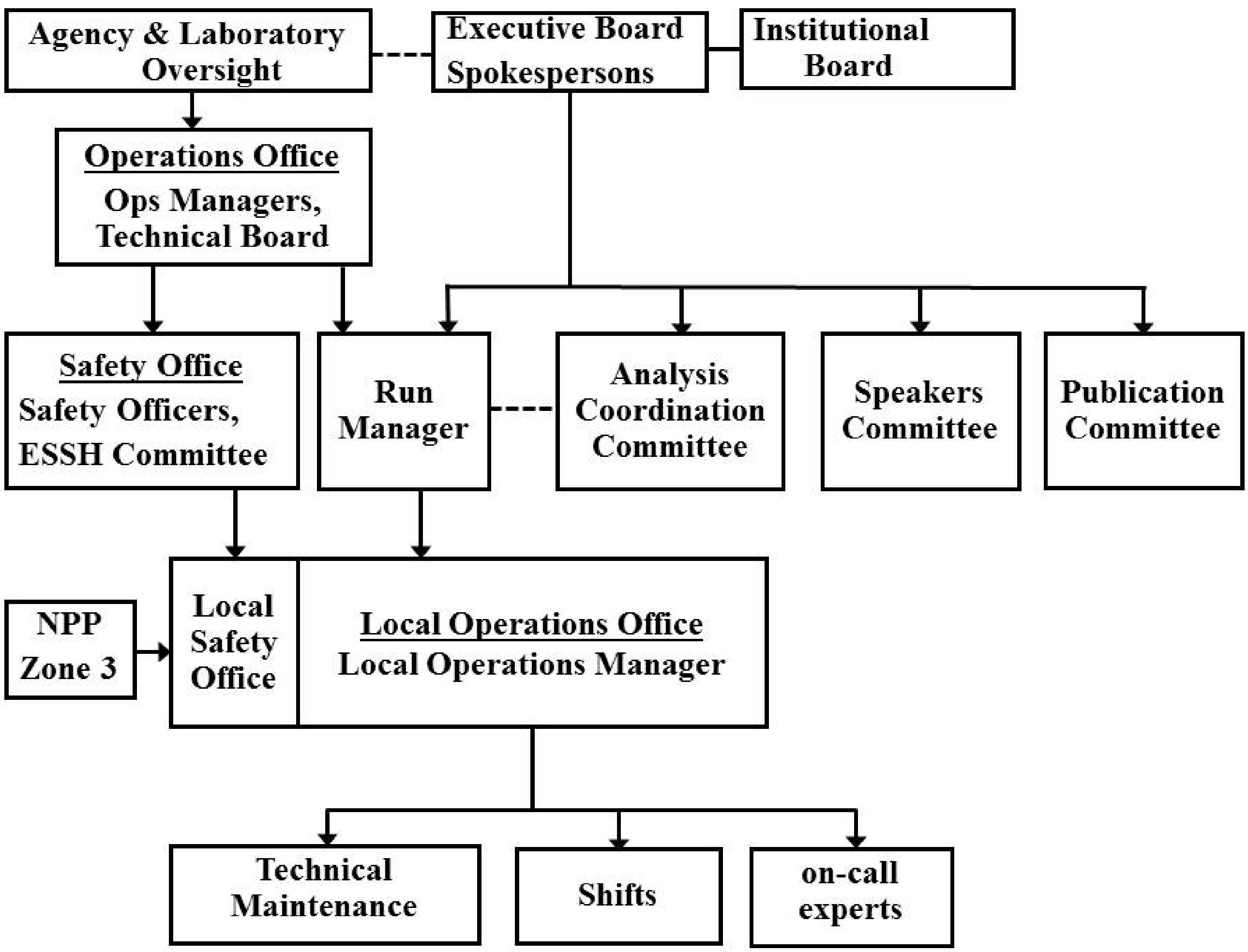

Figure 1 - Daya Bay Operations Organization

The Operations program retains many of the same advisory bodies as the Project. These include the LOG (including its Program Advisory Panel or PAP), IFC, TB and ESSH Committee. The Operations Office and Run Manager are advised on technical issues by the TB and on safety issues by the two Safety officers. The Operations Office is advised on scientific issues by the Run Manager and the collaboration's Executive Board (EB) and is tightly coupled to the EB, with the Operations officers serving as ex-officio members of the EB. The Operations Office is responsible for the support of the technical labor, travel and equipment to maintain safe and efficient operations of the experiment, including appointment of the Local Operations Manager, management of the Common Fund (supporting the Local Operations Office, consumables and site maintenance) and Subsystem maintenance and operations (supporting each country's deliverables) (M&O). The LOG and IFC aid the funding agencies in oversight of the Daya Bay Operations Program.

3.1 Executive Board (EB)

The collaboration's Executive Board is responsible for the overall operation of the experiment, some collaboration management (shared with IB as described in the by-laws), physics analysis and publication of data from the experiment. The EB consists of the following ex-officio members: the co-spokespersons, the Operations Managers and the Chief Scientist. These are currently Yifang Wang, Kam-Biu Luk, Bill Edwards and Steve Kettell. The other seven members are elected as described in the by-laws. The current elected members are: Ming-Chung Chu, Jun Cao, Shaomin Chen, Changgen Yang, Bob Hsiung, Karsten Heeger and Bob McKeown. The EB is responsible to review funding issues in each country, review and approve the annual Common Fund budget and expenditures and review and approve Operations Management appointments.

The EB appoints the Run Manager (RM), who is responsible for data collection by the experiment. The RM is responsible for data collection policy and works with the Local Operations Manager to assure that the policy is implemented. This includes direction to shift personnel, filling of shifts, assuring the availability of on-call experts, calibration data collection (in consultation with the Calibration L2 managers and Calibration Working Group) or other special runs, oversight of data quality in consultation with the Data Quality Working Group, decisions about stopping data collection in order to make repairs. The RM works with the Operations Office and LOM to assure appropriate technical support and maintenance of the detector and facility. The RM reports to the EB and OO quarterly or as needed/requested. The RM may appoint a deputy RM, who will serve as Shift Manager.

The Analysis Coordination Committee is appointed by the EB and is responsible for the overall analysis of experimental data, for verification of analysis results to be published and for the collaboration manpower effort to perform the analysis, as described in the by-laws. They are responsible to develop and enforce analysis policy.

The Speakers Committee is appointed by the EB and is responsible for recruiting conference talks for Daya Bay and for assigning speakers from the collaboration as described in the by-laws.

The Publication Committee is appointed by the EB and is responsible for reviewing and approving collaboration publications as described in the by-laws.

3.2 Institutional Board (IB)

The IB is responsible for the Collaboration By-laws and membership and other duties as described in the by-laws. The collaboration's Institutional Board consists of one representative from each institution. The current members are: David Jaffe (BNL), Guo Xinheng (BNU), Bob McKeown (Caltech), Lin Yanchang (CDUT), Rupert Leitner (Charles University), Ruan Xichao (CIAE), Ming-Chung Chu (CUHK), Yang Lei (DGUT), Olshevski Alexandr (Dubna), John Leung (HKU), Wang Yifang (IHEP), Chris White (IIT), Bing-Lin Young (ISU), Vladimir Vyrodov (Kurchatov), Xu Ye (Nankai University), Xubo Ma (NCEPU), Guey-Lin Lin (NCTU), Qi Ming (NJU), Chung-Hsiang Wang (NUU), Yee Bob Hsiung (NTU), Kirk McDonald (Princeton), Jim Napolitano (RPI), Huang Xingtao (SDU), John Cummings (Siena), Jianglai Liu (SJTU), Chen Yu (Shenzhen University), Shaomin Chen (Tsinghua University), Randy Johnson (University of Cincinnati), Kam-Biu Luk (Berkeley), Huanzhong Huang (UCLA), Kwong Lau (Houston), Jen-Chieh Peng (UIUC), Zhang Ziping (USTC), Jonathan Link (Virginia Tech), Wei Wang (William & Mary), Karsten M. Heeger (Wisconsin), Zhibing Li (ZSU).

The Daya Bay International project currently has 39 collaborating Institutions from the U.S., the Peoples' Republic of China (PRC), Hong Kong, Taiwan, Russia and the Czech Republic. The list of collaborating institutions and members is the responsibility of the IB, following the by-laws. The current participating institutions are listed below:

Beijing Normal University
Brookhaven National Lab
California Institute of Technology
Chengdu University of Technology
China Guangdong Nuclear Power Group
Charles University
China Institute of Atomic Energy
Chinese University of Hong Kong
Dongguan Institute of Technology
Illinois Institute of Technology
Institute of High Energy Physics
Iowa State University
Joint Institute for Nuclear Research
Kurchatov Institute
Lawrence Berkeley National Lab
Nanjing University
Nankai University
National Chiao-Tung University
National Taiwan University
National United University
North China Electric Power University
Princeton University
Rensselaer Polytechnic Institute
Shandong University
Shanghai Jiao Tong University
Shenzhen University
Siena College
Tsinghua University
University of California at Berkeley
University of California at Los Angeles
University of Cincinnati
University of Hong Kong
University of Houston
University of Illinois at Urbana-Champaign

University of Science and Technology of China
University of Wisconsin – Madison
Virginia Polytechnic Institute and State University
College of William and Mary
Zhongshan University

3.3 Operations Office (OO)

The operations office (OO) is responsible for the financial oversight and management of experimental operations and support and oversight of the local operations office. They are responsible for staffing, planning and financial oversight of the common fund and subsystem M&O, for onsite safety and for technical and engineering support for maintenance and repair of the experiment. The subsystem M&O responsibility of each country and region is based on the equipment they supplied, as described in the Daya Bay MOU. The organization of the Operations office, including the Technical Board, is shown graphically in Fig. 2.

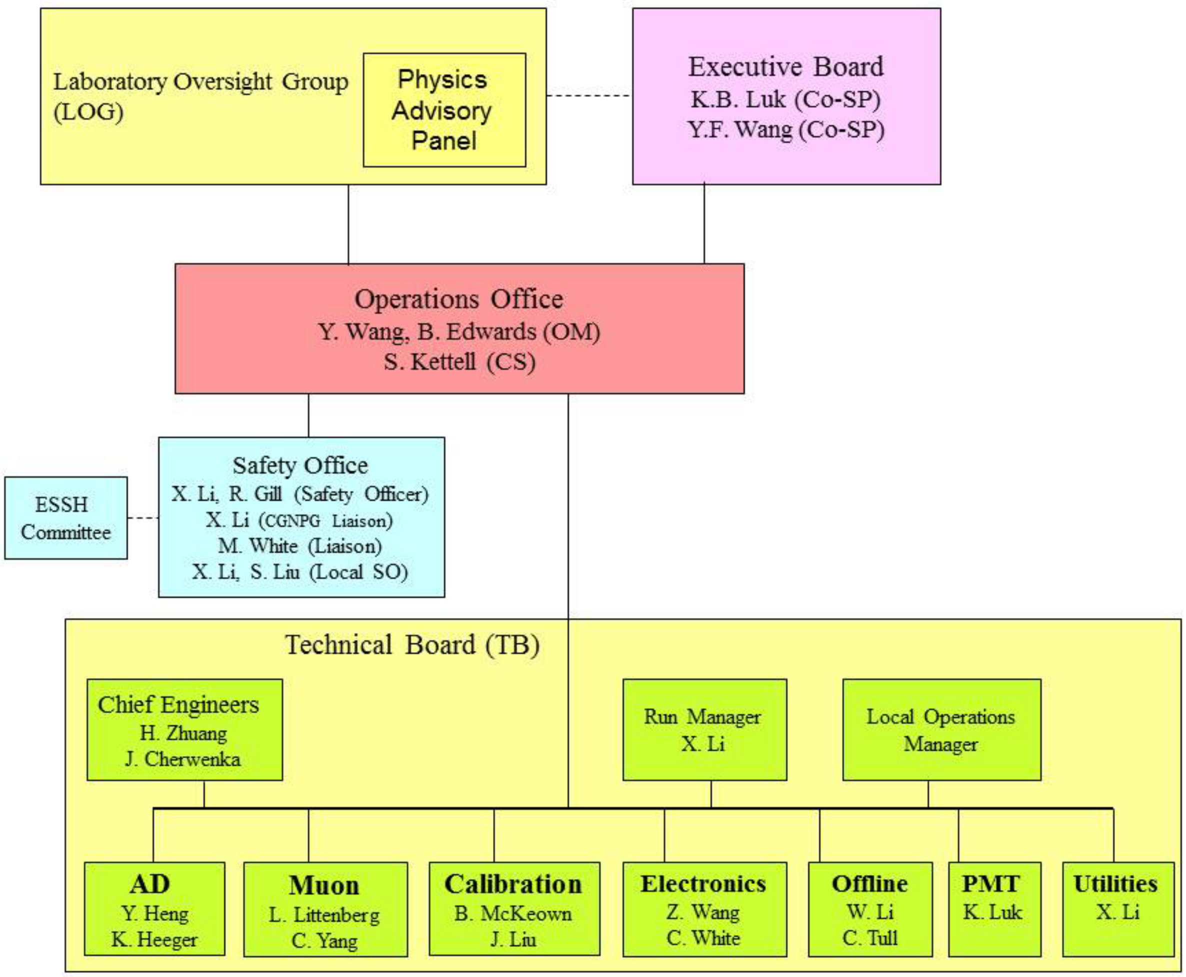

Figure 2 - Daya Bay Operations Organization

The Technical Board (TB) is responsible for subsystem M&O and advises the OO on M&O issues. The TB is also responsible for evaluation of detector upgrades or swaps. The TB provides expertise in detector subsystems, utilities and infrastructure. The TB is appointed and chaired by the Operations Managers and Chief Scientist. The technical board consists of Subsystem Managers from each subsystem. The Level 2 (L2) Subsystem Managers for the Daya Bay operations program are given in Table 2.

Subsystem	Co-L2	
AD	K. Heeger	Y. Heng
Muon	L. Littenberg	C. Yang
Calibration	R. McKeown	J. Liu
Electronics	C. White	Z. Wang
Offline	C. Tull	M. Wang
PMT	K. Luk	N/A
Utilities	N/A	X. Li

Table 2 – Subsystem Managers

The Safety Officers (SO) are responsible for safety at Daya Bay and report to the Operations Managers, the LOG and the funding agencies. They Chair the ESSH Committee, which serves as an advisory body to them and the Operations Managers. They oversee the onsite Safety Office and have delegated day to day safety responsibility to the Local Safety Officer (LSO). The LSO reports to the Daya Bay Safety Officers and the Zone 3 Safety Officer. The LSO is responsible for the safety of all personnel onsite. The Task Control and Equipment Acceptance processes are the responsibility of the Safety Officers or their designees. They are also responsible for review of any upgrades or design changes, along with the Chief Engineers. They are responsible for oversight and review of onsite safety systems, with support from the utility experts.

3.4 Local Operations Office (LOO)

The Local Operations Manager (LOM) is appointed by and reports to the Operations Office and reports to the Run Manager. The LOM is responsible for the Local Operations Office staff, including administrative support for collaboration logistics onsite, technical support of all maintenance and operations of the experiment, contracted maintenance and any other work performed onsite. The LOM holds a weekly video/phone meeting with the RM, OO and other interested parties to discuss operations and data collection.

The onsite scientific operation of the Daya Bay experiment is overseen by the Run Manager and includes the scientific team from the Daya Bay collaboration:

1) The scientific staff on shift.
2) Subsystem and data collection experts that may be on-call either onsite or remote.
3) A run manager or his designee responsible for overall optimization of physics data collection. The Run Manager is appointed by and responsible to the EB.

The onsite technical operation of the experiment and technical team reporting to the Operations Office:

1) The Local Operations Manager, responsible for facility M&O and technical aspects of detector M&O, management of onsite technical resources and reports to the Operations Office. Responsible for efficient and safe operations of the detector in support of the run plan provided by the Run Manager. This is

envisioned to be a full time onsite position for someone with a technical background.

   a. The organization and execution of repairs, preventative maintenance and scheduling of detector upgrades.
   b. Responsible for a quarterly report to the Operations Office.

2) The Local Safety Officer is responsible for safety onsite and reports to the Safety Officers. This is envisioned to be a full time onsite position for someone with a safety background and an understanding of the key elements of both Chinese and U.S. safety policies & procedures. Responsible for timely reporting of incidents and accidents to local authorities and the Operations Office (China and U.S.). Responsible for providing a quarterly safety report to the SO.
   a. Provide safety oversight, identify safety problems and assist with their resolution.
   b. Conduct periodic safety walkthrough inspections of the Daya Bay workplace areas. Walkthrough findings will be documented and reported to the Safety Officers. Assist with timely resolutions.
   c. Participate in meetings with maintenance contractors. Communicate with onsite maintenance groups to understand operational status.
   d. Act as a single point of contact on site for safety information. Provide Daya Bay safety briefings. Verify personnel training compliance.
   e. Facilitate communication between the NPP Zone 3 Safety Office, Daya Bay operations office, collaboration, LOG and funding agencies on safety issues. Report ES&H incidents and near-misses to the U.S. Project Management. Communicate safety issues and information as required to all parties involved in the activities on site. Assist with the resolutions.
   f. Maintain inventory records of restricted materials such as flammable liquids. Oversee the maintenance and calibration of safety equipment or systems. Coordinate emergency response.
3) Technical facility support from the contracted fire watch, security, ventilation watch and contracted facility maintenance and in-house technical support.
   a. Daya Bay engineering and technical staff to oversee contracted maintenance, plan preventive maintenance, implement detector upgrades and support detector maintenance.
   b. Contract maintenance for fire maintenance/watch, utilities maintenance/watch, mine rescue, mine maintenance, cleaning, gas/liquid delivery.

3.5 Laboratory Oversight Group (LOG)

The LOG advises the Operations Office and periodically reviews cost, management, safety and scientific direction of the Operations Office and Collaboration. Representing the three laboratories signatory to the Daya Bay MOU, they oversee operations and science and review resource needs to ensure that the laboratories are responsive to the needs of the Operations Office. They initiate reviews of the operations and science programs through a Program Advisory Panel (PAP) as needed.

3.6 Environmental, Safety and Health

The Integrated Safety Management (ISM) policy for the experiment requires full commitment to safety by the collaboration and operations management team. Principles of ISM are incorporated into planning and execution following the guidelines described in the Daya Bay MOU, ISM and Safety Plans.

3.6.1 Environment

Work at Daya Bay will follow the appropriate Chinese environmental rules and regulations following the Daya Bay MOU, ISM, Safety Plan and policies and procedures.

3.7 Operations Budget

The operations budget for Daya Bay is the responsibility of the Operations Office and consists of two major components:

1) Common Fund
2) Subsystem M&O

Scientific labor and travel is the responsibility of each institution through their base research grants. This includes their shift responsibility as well as scientific oversight of any repair or maintenance work.

3.7.1 Common Fund

The common fund supports consumables, such as gas, water and power; infrastructure support, such as cleaning, waste removal, security and facility maintenance contracts; and the Daya Net computing network. The Common Fund supports the costs associated with running the local Operations office. The local Operations office includes administrative staff to support housing, transportation and related needs and may include technical staff to interface with contracted maintenance support. The local Operations office serves as the point of contact for various maintenance contracts: fire watch, gate guard, cleaning, mine rescue, utilities maintenance, water system maintenance and tunnel maintenance. The technical aspects and costs of the Common Fund supported activities are reviewed by the TB. The annual budget is reviewed and approved by the EB. Annual expenditures are also reviewed and approved by the EB semi-annually. The share of common fund costs assigned to each country is based on the number of collaborators established by the Institutional Board (IB) as described in the by-laws.

3.7.2 Subsystem M&O

Subsystem M&O supports technical labor, travel and spare parts for the repair, maintenance and operation of each detector subsystem. These are the responsibility of each country for the equipment they provided as described in the Daya Bay MOU.

3.8 Decommissioning

Decommissioning scope and costs are currently unknown, although an initial estimate is O($100k). It is expected that China will continue to operate Daya Bay beyond the expected end of joint operations in 2016. Other countries and regions will provide their share of this decommissioning cost on or before the decommissioning of the detectors.

3.9 Data Policy

Raw data will be made available to all collaborators in all countries and regions. Processed reactor data will be made available to all collaborators in all countries and regions.

3.10 Daya Bay Computing Model

The Daya Bay computing model is based on the following key requirements.

1. All data, software and services relevant to the analysis of data and understanding of detectors and physics will be available to all collaborators in all countries and regions through servers at IHEP and LBNL.
2. All non-reproducible data and information will be backed up on tape at IHEP and LBNL.
3. All processed reactor data needed for analysis of the data will be available to all collaborators in all countries and regions.

We estimate that Daya Bay will generate approximately 150 TB of data each year (raw data, simulated data, derived data and all ancillary information and calibrations needed for analysis).

We anticipate processing the full data set at least twice each year in addition to real-time calibration, reconstruction and data quality monitoring. Production processing at PDSF and IHEP will take maximum advantage of aggregate resources. Early production runs (such as P11A in November 2011) will process 100% of data on both PDSF and IHEP clusters, allowing us cross checks and determination of the analysis throughput at the 2 sites. For larger production runs as we accrue more data, we will process ~55% of data on each cluster, using the ~10% overlap for validation and cross check purposes and exchange data files so that each site has all production data. The U.S. will site and backup to HPSS 100% of raw data (DAQ format) as well as backups of code, database, and other non-reproducible info. We will also host 100% of production reconstructed data (ROOT format) and ~50% of simulation data. U.S. scientists will generate analysis data files (ROOT Trees/Ntuples) which are treated as temporary (i.e. reproducible), and hence not backed up to HPSS. All production data files (raw and reconstructed) available at PDSF are recorded in our queryable data catalog. Two physical files are treated as the same logical file only if they are bitwise identical. As of December 2011, the only tape-based backup of Daya Bay raw data files and production reconstructed files is at PDSF on HPSS. The U.S. Daya Bay Tier 1 at NERSC will keep a complete set of raw data backed up on tape for the duration of the experiment, and 100% of the most recent reconstructed data available on spinning disk for efficient analysis by U.S. scientists.

3.10.1 Hardware Resources:

Network connectivity to the outside world (DayaNet) is over 1 Gbps fabric between the onsite computer room and IHEP and bandwidth limited by CSTNet. Initially, DayaNet bandwidth was provisioned at 45 Mbps. As of December 2, 2011, DayaNet bandwidth was increased to 150 Mbps. Daya Bay pays a flat monthly rate for network connectivity based upon bandwidth. The cost for 150 Mbps is 85,000 RMB/month in Fiscal Year 2012. Because our connection is over 1 Gbps fabric, we can upgrade our network connectivity to higher bandwidths for higher fees with ~1 month notice. The current fee of 1,020,000 RMB per year is a guaranteed rate, though we are in constant contact with CSTNet and will take advantage of any cost savings available. The DayaNet costs are split among collaborating institutions as part of the Common Fund. Onsite networking and online computing is a Chinese responsibility.

The Daya Bay computing model has three officially supported offsite computing clusters at IHEP, LBNL and BNL. The offsite clusters are designed to scale with increasing data volume so that they can hold all raw and derived data on spinning disk for random access by all collaborators. In the U.S., the PDSF Cluster at LBNL (NERSC) and the RACF Cluster at BNL will be used for CPU and disk resources. Both clusters implement a buy-in business model where Daya Bay purchases CPU shares of the overall system (PDSF) or individual machines (RACF) as well as purchasing explicit disk space. As usual, cluster hardware (CPU and disk) will be replaced on a 3 year time scale. Disk space will be increased to keep pace with aggregate data volume. CPU will grow to track data volume as well so that full processing of all data maintains constant wall-clock time.

Original estimates of data rates (TDR) predicted that at full production running, Daya Bay would be producing approximately 150 TB of raw, production processed, and simulation data each year. Subsequent experience with EH1 data indicates that the true data rate will be at least twice as much raw data per year. Daya Bay stores all data and backups on the NERSC HPSS tape system at LBNL and will soon start storing on the Castor system at IHEP.

As of January 2012, we have 300 TB of storage quota on HPSS and will increase our allocation each year to keep pace with our data rates. Because NERSC's HPSS is a DOE allocated national resource managed by the Office of Advanced Scientific Computing Research (ASCR), there are no operations cost to Daya Bay for archival hardware. As of December 2011, IHEP's Castor system is not yet in use. IHEP plans to purchase tape media to keep pace with Daya Bay data rates starting in early 2012 (N.B. IHEP Daya Bay funds are not spent on tape drives, robots or manpower).

We have developed a system for automated software distribution and building at IHEP, LBNL and BNL and tools for building and installing from source or binaries for local clusters, desktops and laptops. Institutional clusters can be utilized as simulation engines or as analysis engines pushing simulation data or pulling experimental data from the main data repositories at LBNL, BNL and IHEP, provided the institution supplies manpower needed to locally configure and maintain the software build system and to manage jobs and the associated databases.

3.10.2 Data Transfer & Archiving:

The network bandwidth from Daya Bay to IHEP and LBNL is sufficient to deliver 200% of the DAQ data rate. This allows sufficient overhead to recover from reasonable network outages. Current performance of the data migration system (Spade/Ingest) delivers Raw Data Files (RDFs) to IHEP within 15 minutes and LBNL within 30 minutes of data taking. RDFs are immediately available on disk, archived on magnetic tape and entered into the Data Warehouse database. Collaborators can access the Data Warehouse through a web interface, query the underlying database and define and/or access collections of files and/or runs via datasets.

3.10.3 Real-Time Processing:

Upon arrival at IHEP and LBNL, RDFs are immediately scanned and analyzed to produce a set of standard monitoring and diagnostics plots. These plots are available to all scientists in realtime via a web interface. During physics data-taking, this same mechanism will be used to trigger the first pass of calibration and reconstruction of the data which will produce our Data Summary Tapes (DSTs).

Past experience has shown that access to the entire dataset on spinning disk is vital to effective analysis of data. Once processed, the raw data and calibrated/reconstructed data are available on disk for further processing and analysis by scientists at IHEP and LBNL and the DSTs and some portion of the RDFs will be copied to BNL where additional resources are available. All production data files can be queried through the Data Warehouse and accessed by collaborators, either by logging into the main PDSF (NERSC computing cluster at LBNL available to Daya Bay) or RACF (BNL RHIC and ATLAS Computing Farm) cluster or copying manually to local disk.

3.10.4 Simulation:

As of January 2011 we have conducted 5 Mock Data Challenges (MDCs) which involved coordinated, large scale simulation runs on clusters in the U.S. and China. We anticipate continued simulation using this model throughout the experiment. Experience has shown that although the tools exist for building the NuWa software on local machines, a critical element to the success of these MDCs are dedicated local scientists and computer support personnel who can configure the local cluster, manage the jobs, and interface with the MDC coordinator. The 3 main clusters at IHEP, LBNL and BNL will be fully involved in every simulation run throughout the experiment. We will utilize institutional resources as they are available and when those local scientists and support personnel can participate.

3.11 Analysis Plan and Organization

The Daya Bay experiment Analysis Coordination Committee (ACC) was appointed by the EB (Fig. 1) to oversee and manage the Daya Bay analysis effort. It consists of four members (two from China and two from the U.S.) and is responsible for developing the overall analysis plan, which is outlined in Fig. 3. The ACC is responsible for implementing this plan through the direction of collaboration resources to complete the various analysis tasks and for the review, verification and approval of the results of those tasks prior to any publication.

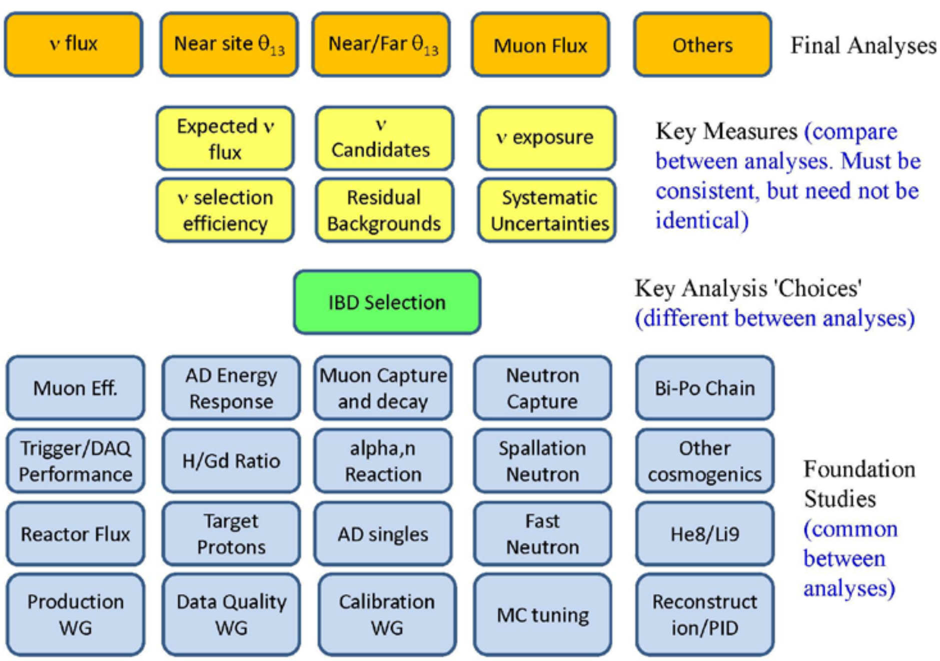

Figure 3 - Daya Bay analysis plan

3.12 Education and Outreach

The Daya Bay experiment offers excellent outreach/education opportunities:

1. The subject of neutrino physics is both important and fascinating. As one of the fundamental building blocks of the universe, neutrino plays an important role in particle physics, nuclear physics, cosmology, astrophysics and the search for new physics. The neutrino is one of the most abundant known particles in the universe, yet it hardly interacts with matters and can only be detected with sophisticated devices and enormous effort. Many outstanding questions regarding the true nature of neutrinos remain to be answered. This is a perfect subject for arousing the curiosity and enthusiasm of the general public in physics as well as sciences in general.
2. The Daya Bay experiment is aiming to answer some of the most fundamental questions in neutrino physics. Significant progress has been made and first results from the Daya Bay experiment are expected very soon. It is timely to devote a significant effort in the areas of outreach/education since many interesting aspects about the experiment can now be presented to the general public.
3. The Daya Bay experiment is performed by a large international collaboration including crucial contributions from many scientists from China and the United States. It is the first major collaborative effort between the United States and China on Particle Physics experiment. It serves as a brilliant example of how scientists from diversified backgrounds can collaborate effectively towards a common scientific goal.

Since its inception, the Daya Bay reactor neutrino experiment has been a component of popular science talks given by collaborators at IHEP and collaboration Chinese universities. The following are some of the activities that have taken place:

1. For several years lectures on neutrinos have been given by Daya Bay collaborators at IHEP’s annual "Open Day" to the general public. Many high school and college students in Beijing and nearby cities attend the lectures and visit research facilities at IHEP. Daya Bay is a centerpiece of the activity.
2. Seminars and Lectures on Daya Bay have been given to undergraduate and graduate students at many universities throughout China, in particular, in Beijing.
3. Daya Bay collaborators at IHEP have participated in blogs on the discussion of neutrino physics research carried out worldwide.
4. IHEP is considering the establishment of an exhibition room on the Daya Bay site, with videos, posters, models, etc. to serve a permanent science educational base for the Shenzhen area. U.S. collaborators are invited to join its organization and operation.

We propose the following Daya Bay outreach/education activities in the United States:

1. We will generate a webpage under the Daya Bay website dedicated to outreach/education. It will contain information on progress of the experiment that may be interesting to the general public, photos and videos of the underground laboratory and detector construction, files of public talks given by collaborators, relevant education materials and links to many of the outreach website worldwide, such as the Interactions.org which provides further links to web sites of various

aspects focused on education/outreach activities that are interesting to students and teachers, as well as individual outreach web sites, such as Quarknet, Particle physics in the UK, CERN Recourses, webpages at DESY, etc. Mirror sites will be established in U.S. institutions.

2. We will encourage members of the Daya Bay collaboration to actively participate in giving lectures on neutrino physics aimed at the general public. These talks will be collected and made available on the Daya Bay website for high-school and college teachers and students.
3. In anticipation of the announcement of the major physics results from the Daya Bay experiment during the next few years, we plan to collect material (photos, videos, articles) suitable for distribution to news media (Newspaper, magazines, radios, TV programs). We will also cooperate with news media interested in featuring the Daya Bay experiment for the general public.
4. Many of Daya Bay's outreach and educational activities will understandably take place in China and the U.S. collaboration can contribute to aspects of the activities, including, for instance design of the on-site exhibition hall mentioned above, participation in lecture tours in the local area schools by interested individual U.S. physicists, etc., drawing from extensive experience of long established outreach programs at the various U.S. collaborating universities and national laboratories.
5. The collaborative effort of the outreach and education program can obviously benefit the U.S. side. The materials developed will be shared by both the U.S. and Chinese institutions. Internet links will enhance this sharing experience. U.S. collaborators, if interested can participate in the outreach activities in Shenzhen. The materials developed and approaches taken by our Chinese collaborators can provide a different, fresh perspective to the subject which will enrich the U.S. effort.