8 Trigger and Data Acquisition System

The trigger event selection and estimated rates are presented, along with the timing synchronization between all of the electronics elements. The processing of the trigger data from the front-end modules through data storage is discussed, along with the detector control system.

8.1 The Trigger System

The trigger system of the Daya Bay experiment makes trigger decisions for the antineutrino and muon detectors to select neutrino-like events, muon-related events, periodic trigger events and calibration trigger events. The following sections will describe the requirements and technical baseline for the trigger system.

8.1.1 Requirements

The signature of a neutrino interaction in the Daya Bay antineutrino detectors is a prompt positron with a minimum energy of 1.022 MeV plus a delayed neutron. About 90% of the neutrons are captured on Gadolinium, giving rise to an 8 MeV gamma cascade with a capture time of 28 μs. The main backgrounds to the signal in the antineutrino detectors are fast neutrons produced by cosmic muon interactions in the rock, ^{8}He/^{9}Li, which are also produced by cosmic muons and accidental coincidences between natural radioactivity and neutrons produced by cosmic muons. All three major backgrounds are related to cosmic muons. The following are the main trigger requirements imposed by the physics goals of the Daya Bay experiment:

1. **Energy threshold:** The trigger is required to independently trigger on both the prompt positron signal of 1.022 MeV and the delayed neutron capture event with a photon cascade of ≈8 MeV with very high efficiency. The threshold level of the trigger is set at 0.7 MeV. This level corresponds to the minimum visible positron energy adjusted for a 3σ energy resolution effect. This low threshold requirement fulfils two trigger goals. For the neutrino signal, it allows the DAQ to record all prompt positron signals produced from the neutrino interactions, enabling a complete energy spectrum analysis that increases the sensitivity to θ_{13}. For background, it allows the DAQ to register enough uncorrelated background events due to either PMT dark noise or low energy natural radioactivity to enable a detailed analysis of backgrounds offline.

2. **Trigger efficiency:** In the early stages of the experiment, the trigger efficiency is required to be as high as possible for signal and background, provided that the event rate is still acceptable and will not introduce any dead time. After an accurate characterization of all the backgrounds present has been achieved, the trigger system can then be modified to have more powerful background rejection without any efficiency loss for the signal. To measure the efficiency variation, the system should provide a random periodic trigger with no requirement on the energy threshold at trigger level. A precise spectrum analysis also requires an energy-independent trigger efficiency for the whole signal energy region.

3. **Time stamp:** Since neutrino events are constructed offline from the time correlation between the prompt positron signal and the neutron capture signal, each front-end (FEE), DAQ and trigger unit must be able to independently time-stamp events with an accuracy better than 1 μs. The trigger boards should provide an independent local system clock and a global time-stamp to all the DAQ and FEE readout boards in the same crate. The trigger boards in each DAQ crate will receive timing signals from a global GPS based master clock system as described in Section 8.2. Events recorded by the antineutrino detectors and muon systems can thus be accurately associated in time offline using the time-stamp.

4. **Flexibility:** The system must be able to easily implement various trigger algorithms using the same basic trigger board design for different purposes such as

(a) Using different energy thresholds to adapt to the possible aging effect of liquid scintillator, or for triggering on calibration source events which have lower energy signatures.

(b) Using different hit multiplicities to increase the rejection power due to the uncorrelated low energy background and for special calibration triggers.

(c) Implementing different pattern recognition for triggering on muon signals in the different muon systems.

(d) Using an OR of the trigger decision of different trigger algorithms to provide a cross-check and cross-calibration of the different algorithms as well as a redundancy to achieve a high trigger efficiency.

5. **Independence:** Separate trigger system modules should be used for each of the antineutrino detectors, and the muon systems. This is to reduce the possibility of introducing correlations between triggers from different detector systems caused by a common hardware failure.

8.1.2 The Antineutrino Detector Trigger System

Neutrino interactions inside a detector module deposit an energy signature that is converted to optical photons which are then detected by a number of the PMTs mounted on the inside of the detector module. Two different types of triggers can be devised to observe this interaction:

1. An energy sum trigger.

2. A multiplicity trigger.

In addition to neutrino interaction triggers, the antineutrino detector trigger system needs to implement several other types of triggers for calibration and monitoring:

3. Calibration triggers of which there are several types:

   (a) Triggers generated by the LED pulsing system that routinely monitors PMT gains and timing.

   (b) Triggers generated by the light sources periodically lowered into the detector volume to monitor spatial uniformity of the detector response and the light attenuation.

   (c) Specialty energy and multiplicity triggers used to test detector response using radioactive sources

4. A periodic trigger to monitor detector stability and random backgrounds.

5. An energy sum and/or multiplicity trigger (with looser threshold and multiplicity requirements) generated in individual antineutrino detector modules which is initiated by a delay trigger from the muon system. This trigger records events to study muon induced backgrounds. This trigger should be able to operate in both tag and veto modes.

A VME module with on-board Field Programmable Gate Arrays (FPGA)s is used to implement the antineutrino detector trigger scheme outlined in Fig. 8.1 based on experiences gained at the Palo Verde [1] and KamLAND experiments. We use an OR of both an energy sum and a multiplicity trigger to signal the presence of neutrino interactions in the antineutrino detector. These two triggers provide a cross-check and cross-calibration of each other.

The multiplicity trigger is implemented with FPGAs which can perform complicated pattern recognition in a very short time. FPGAs are flexible and can be easily reprogrammed should trigger conditions change. In addition, different pattern recognition software can be downloaded remotely during special calibration runs, such as might be needed for detector calibration with sources. The signal from different PMTs is compared

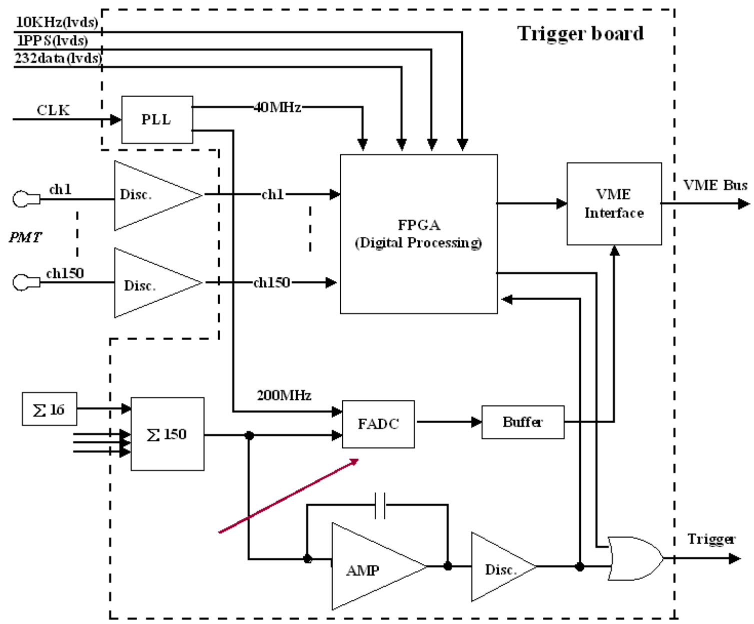

Fig. 8.1. A simplified trigger scheme.

with the threshold on on-board discriminators in the front-end readout cards as described in Section **??**. The output of the PMT discriminators are input into the trigger module FPGA which performs clustering and pattern recognition and generates the multiplicity trigger decision. The dark current rate of the low activity antineutrino detector PMTs is typically around 5 kHz at 15° C. For a detector with N total PMTs, a dark current rate of f Hz, and an integration time of τ ns, the trigger rate R given a multiplicity threshold m is

$$R = \frac{1}{\tau}\sum_{i=m}^{N} iC_N^i(f\tau)^i(1-f\tau)^{N-i}, \quad f\tau << 1 \tag{1}$$

where C_N^i are the binomial coefficients.

To be conservative, we assume a PMT dark current rate of 50 kHz when estimating the dark current event rate from the multiplicity trigger. For the multiplicity trigger, an integration window of 100 ns will be used for the central detector PMTs. The dark current rate calculated using Eq. 1 as a function of the number of PMT coincidences is shown in Fig. 8.2. At a multiplicity of 10 PMTs, the total trigger rate would be of order 1 Hz with a 100 ns integration window.

The energy sum trigger is the sum of charges from all PMTs obtained from the front-end readout boards with a 100 ns integrator and discriminator. The threshold of the discriminator is generated with a programmable DAC which can be set via the VME backplane bus. The energy sum is digitized using a 200 MHz flash ADC (FADC) on the trigger module. We plan to have an energy trigger threshold of 0.7 MeV or less to be compatible with the positron energy of 1.022 MeV within 3σ of the energy resolution. At such low energy thresholds, the trigger will be dominated by two types of background: One is natural radioactivity originating in the surrounding environment which is less than 50 Hz as shown in a Monte Carlo simulation in Section **??**, and the other is from cosmic muons (negligible at the far site). At this threshold, the energy sum trigger rate from the PMT dark current with a 100 ns integration window is negligible.

Tagging antineutrino interactions in the detector requires measuring the time-correlation between different trigger events. The time-correlation will be performed offline, therefore each triggered event needs to be individually timestamped with an accuracy of order of microseconds or better. It may become necessary to have a correlated event trigger in the case the background rate is too high.

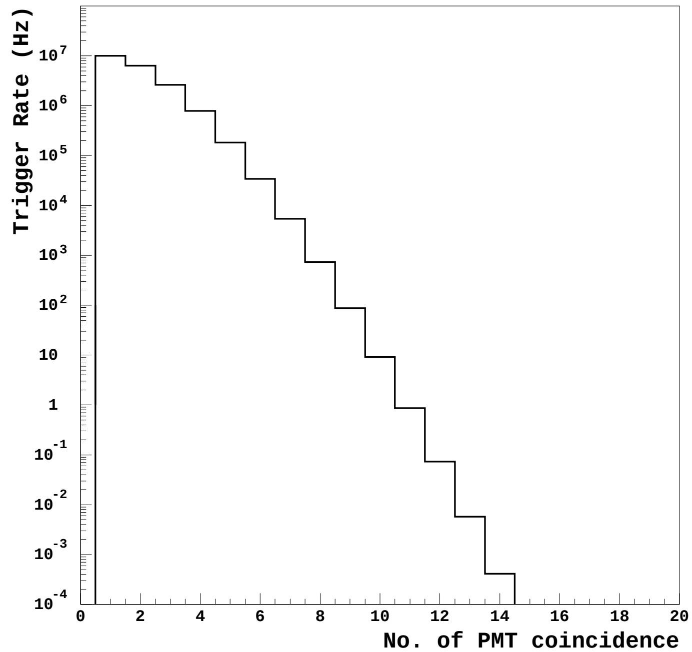

Fig. 8.2. Calculated trigger rates caused by PMT dark current as a function of the multiplicity threshold. The maximum number of PMTs is 200, the PMT dark current rate used is 50k with a 100 ns integration window.

A periodic trigger to monitor the PMT dark-current, the cosmic ray background, and detector stability will be included.

8.1.3 The Muon Trigger System

The muon system will utilize three separate trigger and DAQ VME crates, one for each of the muon detector systems: The water Cherenkov detector, the RPC system and the muon tracker system (scintillators or water trackers).

The presence of a muon which goes through the water Cherenkov detector can be tagged with energy sum and multiplicity triggers using a similar scheme and hardware modules as used for the antineutrino detector. In addition, a more complicated pattern recognition scheme using localized energy and multiplicity information may be used. The trigger rate in the water Cherenkov detector is dominated by the cosmic muon rate which is $<$15 Hz in the far hall and $<$300 Hz in the near halls (see Table 8.1). In addition to the water pool Cherenkov detector trigger, muons will be tagged by a system of RPCs and either water tracker modules or double layers of scintillator strips.

The FPGA logic used for the RPC and scintillator strip detectors forms muon "stubs" from coincident hits in two overlapping layers of scintillator or two out of three layers of RPC. Although the readout electronics of RPC is very different from that of the PMT, the trigger board can still be similar to the other trigger boards. As we discussed before, each FEC of RPC readout electronics can provide a fast OR signal of 16 channels for the trigger. All the fast OR signals will be fed into the trigger board for further decision by FPGA chips. The principal logic is to choose those events with hits in two out of three layers within a time window of 20 ns in a localized region of typically 0.25 m^2. Since the noise rate of a double gap RPC is estimated to be about 1.6 kHz/m^2 (consistent with twice the BES single gap chamber rates), the false trigger rate from noise can then be controlled to be less than 50 Hz in such a scheme. The coincidence rate in the RPC system due to radioactivity is estimated to be 1Hz/m^2 obtained from simulation results based on measurements in the Aberdeen tunnel (see section 7.3.4). This corresponds to a radioactivity trigger rate of about 360 Hz in the far hall.

For the water tracker modules, we need three types of triggers:

1. an AND of the two ends with a threshold of approximately 3 p.e. on each end.
2. A prescaled single ended trigger with a lower threshold.
3. The energy sum of the two ends with a threshold of $\sim$ 20 p.e.

The antineutrino detector trigger board can be used to implement the trigger schemes for the water tracker. The fake trigger rates from radioactivity in the water tracker modules is expected to be negligible.

An alternative to the water tracker modules discussed above, two layers of scintillator strips in the water pool can be used as described in Section **??**. The 0.5 m of water between the water pool walls and the scintillator strips provides some shielding from radioactivity in the rock which generates a rate of 180 Hz of background in the largest plane (bottom of the far detector). The scintillator PMTs noise rate is $<$2 kHz at 15° C. Requiring a coincidence of two hits in overlapping layers with a 100 ns integration window reduces the fake trigger rate from the scintillator strip PMT noise to a negligible level. In principal, the same trigger module design can be used for both RPCs and scintillator strips with different FPGA software to handle the stub formation in the different geometries.

The global muon trigger decision is an OR of the three muon detector trigger systems: RPC, water Cherenkov and muon tracker. The muon trigger decision may be used to launch a higher level delay trigger looking for activity inside the antineutrino detector at lower thresholds and/or multiplicities for background studies.

8.2 The Timing System

The design of the trigger and DAQ system is such that each antineutrino detector and muon detector system has independent DAQ and trigger modules. In this design it is necessary to synchronize the data from the individual DAQ and trigger systems offline. This is particularly important for tagging and understanding the backgrounds from cosmic muons. A single cosmic muon candidate will be reconstructed offline from data originating in three independent systems: the water Cherenkov pool, muon tracker and RPC tracker. Cosmic muon candidates reconstructed in the muon detector systems have to then be time correlated with activity in the antineutrino detector to study muon induced backgrounds. To this end, the Daya Bay timing system is required to provide a global time reference to the entire experiment, including the trigger, DAQ, and front-end boards for each module (LS, water Cherenkov, and tracker) at each site. By providing accurate time-stamps to all components various systematic problems can easily be diagnosed. For instance, common trigger bias, firmware failure, and dead time can all be tracked by looking for time-stamp disagreements in the data output from each component. Furthermore, by having multiple sites synchronized to the same time reference, it will be possible to identify physical phenomena such as supernova bursts or large cosmic-ray air showers.

The timing system can be conceptually divided into four subsystems: the (central) master clock, the local (site) clock, the timing control board, and the timing signal fanout.

8.2.1 Timing Master Clock

The global timing reference can easily be provided by a GPS (Global Positioning System) receiver to provide a UTC (Universal Coordinated Time) reference. Commercially-available units are typically accurate to better than 200 ns relative to UTC [2,3].

This GPS receiver can be placed either at one of the detector sites (most conveniently the mid hall) or in a surface control building. A master clock generator will broadcast the time information to all detector

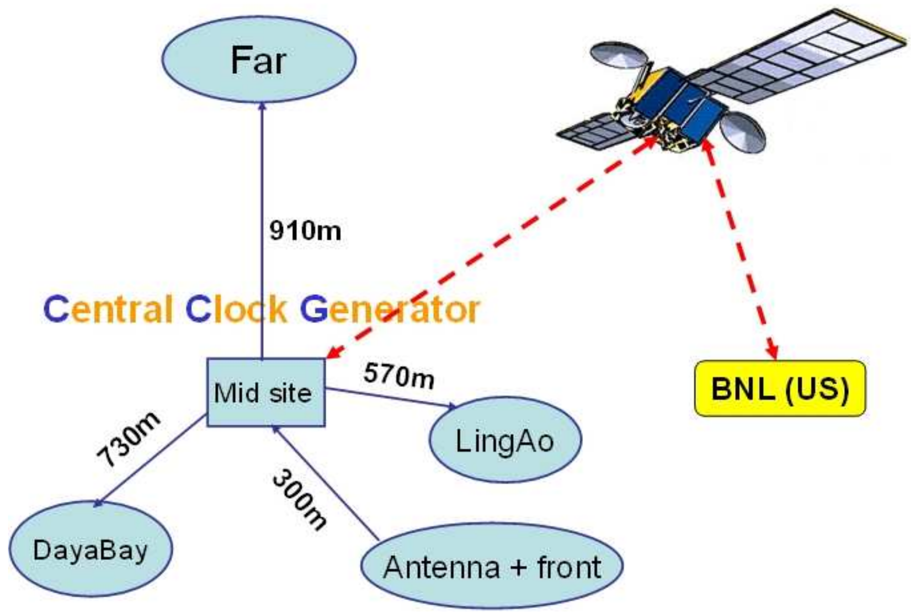

Fig. 8.3. Schematic layout of the global clock.

sites. If the master clock is located underground, the GPS antenna may require an optical fiber connection to the surface, which again is commercially available. One such possibility is illustrated in Fig. 8.3

The master clock will generate a time reference signal consisting of a 10 MHz clock signal, a PPS (Pulse Per Second) signal, and a date and time. These signals can be encoded onto a one-way fiber optic link to be carried to each of the detector halls where they are then fanned-out to individual trigger boards as shown in Fig. 8.4

Additionally, the GPS receiver will be used to synchronize a local computer. This computer can then be used as a Tier-1 network time protocol (NTP) peer for all experiment computers, in particular the DAQ,

Each site will receive the signals from the master clock and use them to synchronize a quartz crystal oscillator via a phase-locked loop. This local clock can then be used as the time reference for that site.

This method allows each site to operate independently of the master clock during commissioning or in the case of hardware failure, but in normal operation provides good time reference. This clock could be used to multiply the 10 MHz time reference to the 40 MHz and 100 MHz required for the front ends. This clock will reproduce the PPS, and 10 (or 40/100) MHz signals and supply them to the timing control board.

8.2.2 Timing Control Board

The timing control board will act to control the local clock operations (i.e. to slave it to the master clock or let it run freely) and to generate any timing signals required by the trigger, DAQ, or front end that need to be synchronously delivered. Typical examples include buffer swap signals, run start/stop markers, and electronic calibration triggers. In addition, this board could be used to generate pulses used by optical calibration sources. This board would be interfaced to the detector control computers.

8.2.3 Timing Signal Fanout

The signals from the timing control board need to be delivered to the individual detector components: every FEE board, DAQ board, and trigger unit. This will allow each component to independently time-stamp events at the level of 25 ns.

This fanout system could work, for example, by encoding various signals by encoding them on a serial bus, such as HOTLink. The trigger board in each FEE and DAQ VME crate could then receive the serial

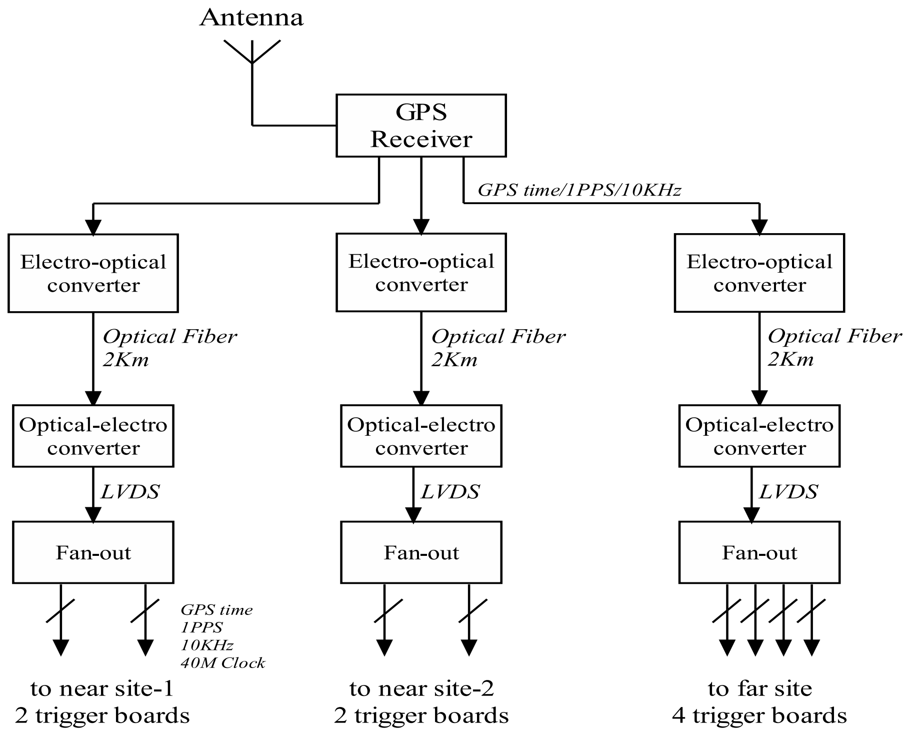

Fig. 8.4. Block diagram of the Daya Bay clock system.

signal and distribute it via the crate backplane. The crate backplanes will then carry the 40 MHz clock (100 MHz clock for RPCs), the PPS signal (to reset the clock counters), and the other timing signals (run start/stop marker, calibration, etc).

Individual components of the trigger, DAQ, and front end can employ counters and latches to count seconds since start of run and clock ticks since start of second. These will provide sufficient data to assemble events and debug the output data streams.

8.3 The Data Acquisition System

The data acquisition (DAQ) system is used to:

1. Read data from the front-end electronics.
2. Concatenate data fragments from all FEE readout into a complete event.
3. Perform fast online processing and event reconstruction for online monitoring and final trigger decisions.
4. Record event data on archival storage.

A brief review of the DAQ design requirements is followed by a discussion of the system architecture, DAQ software, and detector control and monitoring system.

8.3.1 Requirements

The Daya Bay DAQ system requirements are listed in Table 8.1.

1. **Architecture requirements:** The architecture requires separate DAQ systems for the three detector sites. Each antineutrino detector module will have an independent VME readout crate that contains

Detector	Description	Trigger Rates (Hz) DB	LA	Far	Occ	Ch size	data rate (kB/s)
$\bar{\nu}$ module	cosmic-μ	36×2	22×2	1.2×4	100%	228×64 bits	217
	Rad.	50.0×2	50.0×2	50.0×4			730
RPC	Rad. & Noise	260	260	415	10%	$5040/7560 \times 1$ bit	72
	cosmic-μ	186	117	10.5			20
Pool	cosmic-μ	250	160	13.6	50%	$252/340 \times 64$ bits	437
μ-tracker	cosmic-μ	1390	819	57.8	100%	8×64 bits	145
site totals	(kB/s)	683	500	436			1620

Table 8.1. Summary of data rate estimations. kB/s = 1000 bytes per second. The total data throughput rate for all 3 sites is estimated to be 1620 kB/s. The trigger rate for the central detector has substantial components from natural radioactivity and from muons. The trigger rate in the RPCs has, in addition, some trigger rate from noise. The trigger rate in the water pool and μ-tracker comes predominantly from muons.

the trigger and DAQ modules. In addition, the water Cherenkov detector and muon tracking detectors will also have their own VME readout crates. The trigger and DAQ for the antineutrino and muon detector modules are kept separate to minimize correlations between them. The DAQ run-control is designed to be operated both locally in the detector hall during commissioning and remotely in the control room. In addition, run-control will enable independent operation of individual antineutrino and muon detector modules.

2. **Event rates** The trigger event rates at the Daya Bay, Ling Ao and Far site from various sources are summarized in Table 8.1. The rate of cosmic muons coming through the top of a detector are calculated using Table **??**. To turn this into a volumetric rate, we use a MC simulation to calculate the ratio of muon rates entering the top to all muons entering the detector's volume. The total rates from cosmic muons in the different different systems are shown in Table 8.1. At the far site, the trigger rates in the central detectors are dominated by the rates from natural radioactivity ($<$50 Hz/detector) and at the near sites both cosmic and natural radioactivity rates dominate.

   The trigger rate in the water Cerenkov pool is dominated by the cosmic muon rate, the singles rate from PMT noise, gammas and fast neutron backgrounds are negligible.

   The RPC noise rates are taken from the BES chamber measurements in Section **??**. We scale the BES noise rates by a factor of 2 to account for the different geometry of the Daya Bay RPC modules (3 double gap layers). This increases the coincidence rate due to RPC noise by a factor of 4. The singles rates shown in Table 8.1 are the sum of the noise and natural radioactivity rates in the RPC systems at the various sites.

   For the purposes of calculating the overall data throughput for the muon tracker modules, each module is treated as an independent detector and the muon rate through each module is assumed to be its "trigger rate". The occupancy is 100% but only 8 channels are read out. In reality of course muons will tend to hit multiple modules in one full-detector trigger but the entire detector will not be read out. In the end the two methods simply trade trigger rate for # of hit channels and the results should be the same.

   While the trigger rate in the antineutrino detectors at each site is of order a few 100 Hz, an OR of the three muon trigger systems could produce a maximum trigger rate of $<$1 kHz. The Daya Bay trigger and DAQ system will be designed to handle a maximum event rate of 1 kHz. In addition, to trigger on the correlated neutrino and fast neutron signals in the antineutrino detector, the DAQ needs to be able to acquire events that occur 1 μs or more apart.

3. **Bandwidth**

The maximum number of electronics channels for the antineutrino detectors, water Cherenkov pool, and muon tracker PMTs at the far site is estimated to be at most 2000 channels as shown in Table 8.2. We assume that the largest data block needed for each PMT channel is 64 bits or less, provided wave-

Detector Option	Geometry	Approximate number of channels
	PMT channels	
Scint tracker	2 layers	
strip module	side/bottom	
1.2 m $\times$ 5.25 m	water pool	~ 530
OR		
Water tracker	8 PMTs	~ 450
modules	per module	
1 m $\times$ 16 m module	side/bottom	
Water Cherenkov	1 PMT/2 m^2	
pool	4 sides/bottom	~ 350
Antineutrino detector	4 modules	896
Total PMT channels		~ 1900
	RPC channels	
RPC on top	3 layers of	
of water pool	double gap	
2 m $\times$ 2 m module	modules	7560

Table 8.2. Estimated number of readout channels from various detector systems at the far site.

form digitization is not used, the breakdown of the channel data block could be as follows:
Address : 12 bits
Timing(TDC+local time): 32 bits
FADC : 14 bits
For the RPC readout its 1bit/channel + header (12bits) + global time-stamp (64bits) = 1 kBytes maximum.

Assuming zero suppression, and maximum occupancy numbers of 10% for the RPC system, 100% for 1 out of the 4 antineutrino detectors, 10% for the water tracker and 50% for the water Cherenkov (with reflecting surfaces), we estimate the maximum event size at the far will not exceed 10 kBytes/event including DAQ/Trigger header words and global time-stamps. The event sizes at the near sites are smaller than the far site due to a smaller number of channels. The expected data throughput from each site is estimated by combining the number of readout channels with the trigger rates and occupancies as shown in Table 8.1. The site totals in Table 8.1 do not include global header words, trigger words and timestamps which add a small overhead. Therefore, we estimate that the expected data throughput rate is <1 MBytes/second/site. If waveform digitization is used for the PMTs, this could increase the maximum desired data throughput by an order of magnitude to <10 MBytes/second/site.

4. **Dead-time:** The DAQ is required to have a negligible readout dead-time (<0.5%). This requires fast online memory buffers that can hold multiple detector readout snapshots while the highest level DAQ CPUs perform online processing and final trigger decisions and transfer to permanent storage. It may also require some low level pipelines at the level of the PMT FADCs.

8.3.2 The DAQ System Architecture

The main task of the DAQ system is to record antineutrino candidate events observed in the antineutrino detectors. In order to understand the background, other types of events are also recorded, such as cosmic muon events, low energy radiative backgrounds... etc. Therefore, the DAQ must record data from the antineutrino and muon detectors (RPCs, water Cherenkov and Tracker), with precise timing information. Offline analysis will use timing information between continuous events in the antineutrino detector and in both the muon and antineutrino detectors to select antineutrino events from correlated signals or study the muon related background in the antineutrino detectors.

The DAQ architecture design is a multi-level system using advanced commercial computer and network technology as shown in Fig. 8.5. three detector sites. The DAQ system levels shown in Fig. 8.5 are as follows:

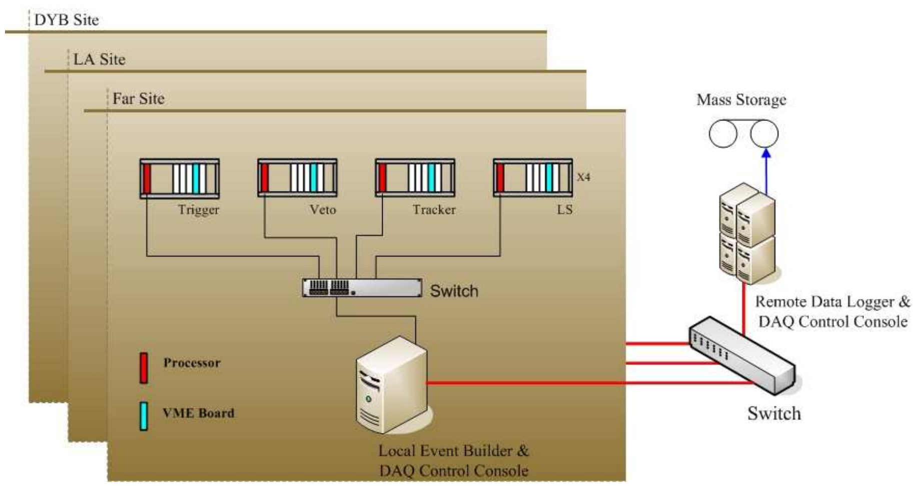

Fig. 8.5. Block diagram of data acquisition system.

1. **VME front-ends:** The lowest level is the VME based front-end readout system. Each VME crate is responsible for one detector or muon system. Each module of the antineutrino detector will have its own independent VME crate. Therefore, The lowest level VME readout system of the far detector hall will consist of the trigger boards for each system, the front-end readout boards from three muon systems, and the four antineutrino detector readout boards. All readout boards are expected to be 9U VME boards.

   The Far and Near detector halls, will have the same DAQ architecture but with different number of VME readout crates to accommodate the different number of readout channels in the Far/Near halls. Each VME crate holds a VME system controller, some front-end readout (FEE) modules and at least one trigger module which supplies the clock signals via the VME backplane to the FEE modules. The VME processor, an embedded single board computer, is used to collect, preprocess, and transfer data. The processor can read data from a FEE board via D8/D16/D32/MBLT 64 transfer mode, allowing a transfer rate up to 80 MB/s per crate which is sufficient to meet the bandwidth requirement. All readout crates of the entire DAQ system at a single site are connected via a fast asynchronous Ethernet switch to a single local event builder computer.

2. **Event Builder and DAQ control:** At each site an Event Builder computer collects the data from the different VME crates for the different detectors and concatenates the FEE readout to form single antineutrino or muon events. The data stream flow can work in two ways, depending on the requirements of offline analysis. One scheme is to send muon events and antineutrino events out into one data stream on the readout computer. Another scheme is that each type of sub-event, muon events, or antineutrino events, have a different data stream and will be recorded as separate data files in permanent storage. The second scheme is simpler from a DAQ design viewpoint and complies with the DAQ system design principal of keeping each detector system completely independent for both hardware and software. The Event Builder computer at each site also allows for local operation and testing of the DAQ system.

3. **Data Storage and Logging:**

   Data from the Event Builder computer at each site are sent via fast optical fiber link through a dedicated switch at a single surface location where it is then transferred to local hard disk arrays. The hard disk arrays act as a buffer to the remote data archival storage or as a large data cache for possible further online processing. Each day will produce about 0.6 Terabyte of data that needs to be archived. Although implementation of data logging has not yet been finalized, there are two obvious options:

   (a) Set up a high bandwidth network link between Daya Bay and the Chinese University of Hong Kong, China, and distribute the data via the GRID (high bandwidth computing network and data distribution applications for high energy physics experiments). This is the preferable scheme.

   (b) Record the data locally on tape. This scheme requires a higher level data filter to reduce data throughput to a manageable level.

   Whichever option is realized, the local disk array should have the capability to store a few days worth of data in the case of temporary failures of the network link or the local tape storage.

Since the DAQ system is required to be dead time free, each DAQ level should have a data buffer capability to handle the random data rate. In addition, both the VME bus and network switches should have enough margin of data bandwidth to deal with the data throughput of the experiment.

The DAQ control and monitoring systems should be able to run both remotely from the surface control room computers and locally on the Event Builder computer in each detector hall. The run control design should be configurable allowing it to run remotely for data taking from all systems and locally. Run control should allow both global operation of all detector systems simultaneously, and local operation of individual detector systems for debugging and commissioning.

8.3.2.1 Buffer and VME Interface

For each trigger, the event information (including the time stamp, trigger type, trigger counter) and the snapshot of the FADC values should be written into a buffer that will be read out via the VME bus for crosscheck.

The global event information which includes absolute time-stamps and trigger decision words will be read out from the trigger board, while individual channel data are read out from the FEE boards. In this case the event synchronization between the DAQ boards and the trigger board is critical, and an independent event counter should be implemented in both the DAQ boards and the trigger boards. The trigger board in each crate provides the clock and synchronization signals for the local counters on each FEE board. The global timing system is designed to enable continuous synchronization of the local clocks in different crates and at different sites.

The event buffers are envisioned to be VME modules that are in the same crates as the FEE boards. Data from the trigger and FEE boards is transfered via the VME bus to the VME buffers. An alternative design is to have the VME buffer modules in separate crates and have data transfered from the FEE modules via fast optical GHz links (GLinks) to the VME buffer modules. We envision VME buffers with enough capacity to store up to 256 events.

8.4 Detector Control and Monitoring

The detector control system (DCS) controls the various devices of the experiment (e.g., high voltage systems, calibration system, etc.), and monitors the environmental parameters and detector conditions (e.g., power supply voltages, temperature/humidity, gas mixtures, radiation, etc.). Some safety systems, such as rack protection and fast interlocks are also included in the DCS.

The DCS will be based on a commercial software package implementing the supervisory, control, and data acquisition (SCADA) standard in order to minimize development costs, and to maximize its maintainability. LabVIEW with Data logging and Supervisory control module is a cost effective choice for the DCS.

The endpoint sensors and read modules should be intelligent, have digitalized output, and conform to industrial communication standard. We will select the minimum number of necessary field bus technologies to be used for communication among the SCADA system and the readout modules.

1. G. Gratta *et al.*, Nucl. Instr. and Meth. A**400**, 54 (1997).
2. Trimble Navigation Ltd. http://www.trimble.com/acutime2000.html.
3. TrueTime Ltd, http://www.truetime.net/software-winsync.html