Trigger and DAQ for the Daya Bay Neutrino Experiment

for the Daya Bay Collaboration

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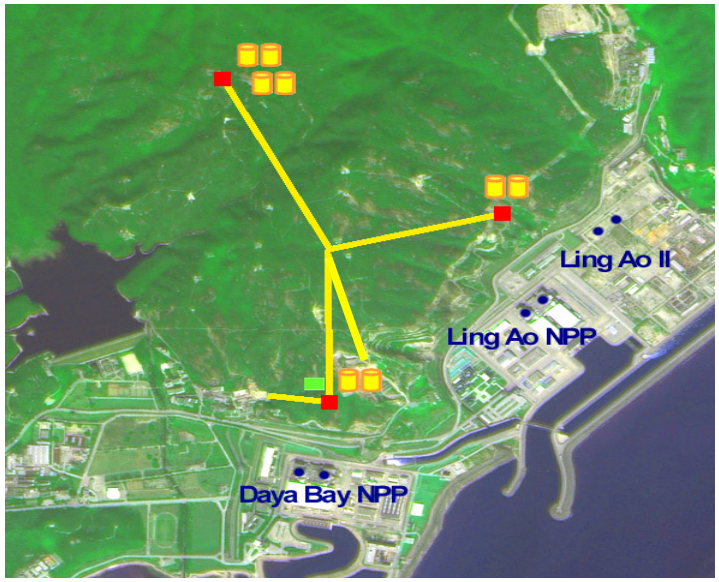
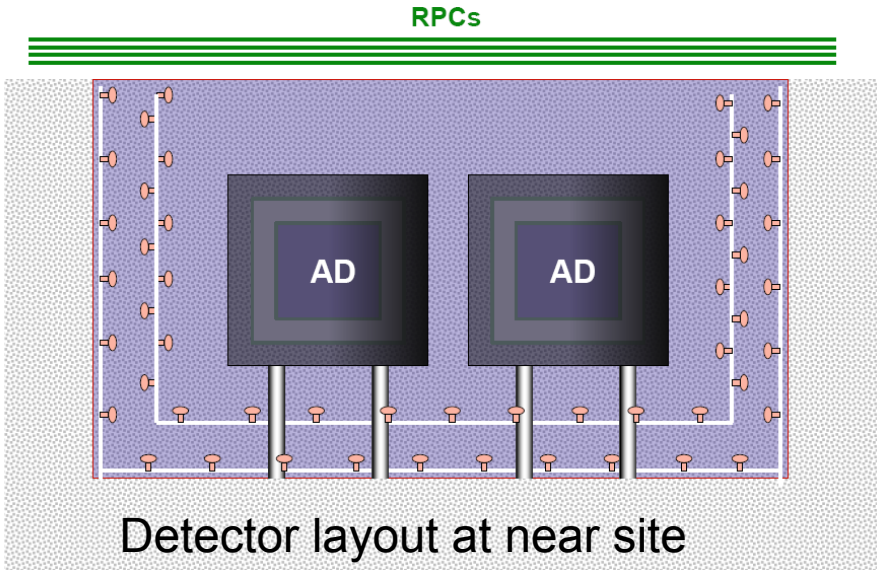
The Daya Bay Collaboration

Outline

- Introduction to the Daya Bay experiment
- PMT & RPC readout systems
- Trigger & DAQ requirements
- Trigger details
- DAQ details
- Summary

The Experiment





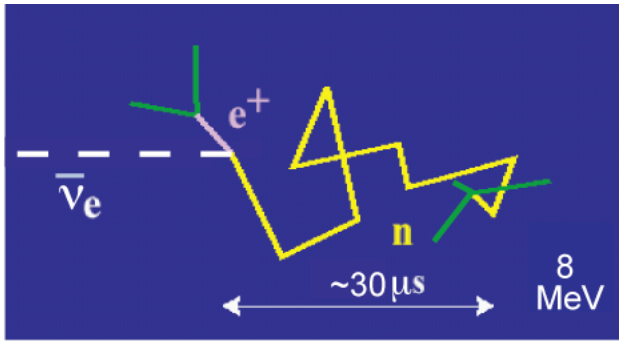
- A precision counting experiment (the number of $\overline{\nu}_e$ interactions)
- Anti-neutrino Detectors are calorimeters (count photo-electrons)
- Near-far relative measurement to cancel correlated errors
- Multiple neutrino detector modules at each site to cross check and reduce uncorrelated systematic errors
- Multiple muon-veto to reduce background-related systematic errors

Detecting Antineutrinos

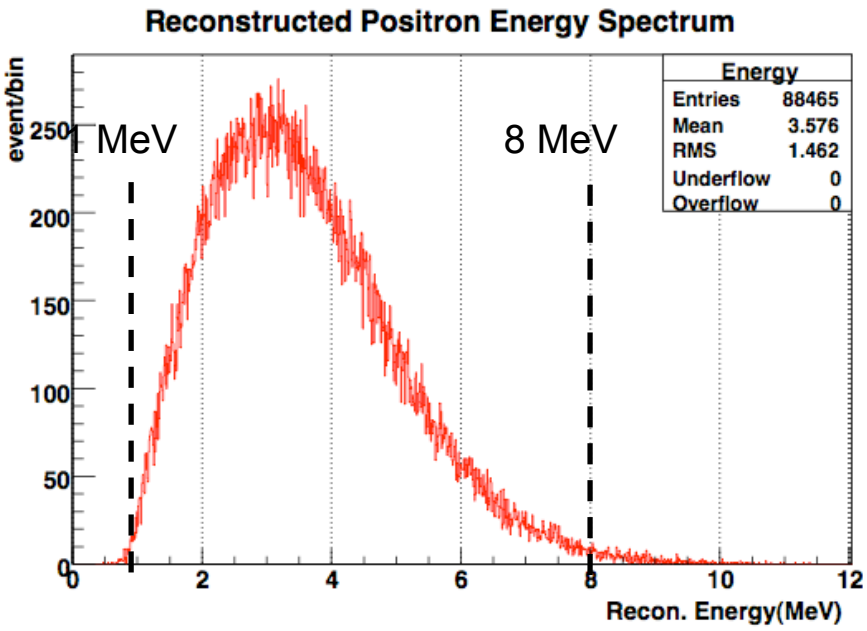
$\bar{\nu}_e + p \rightarrow e^+ + n$

0.3 b → + p → D + γ (2.2 MeV) (delayed)

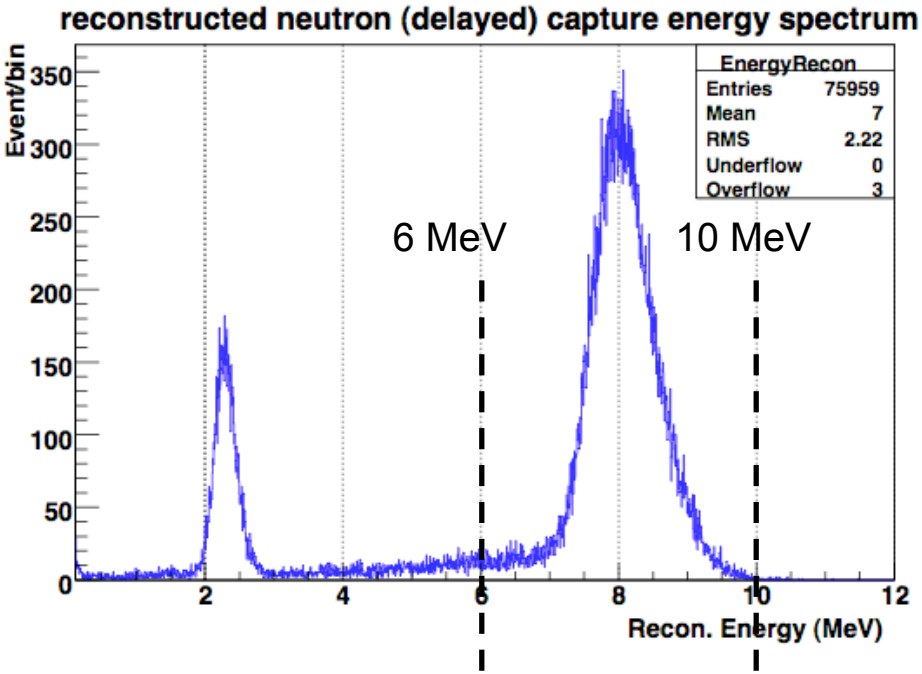
49,000 b → + Gd → Gd* → Gd + γ's (8 MeV) (delayed)



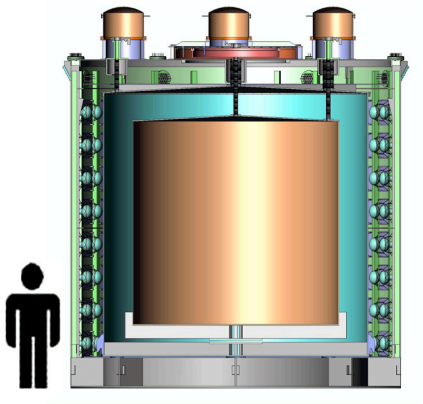
Prompt Energy Signal



Delayed Energy Signal



Detectors and Electronics each site

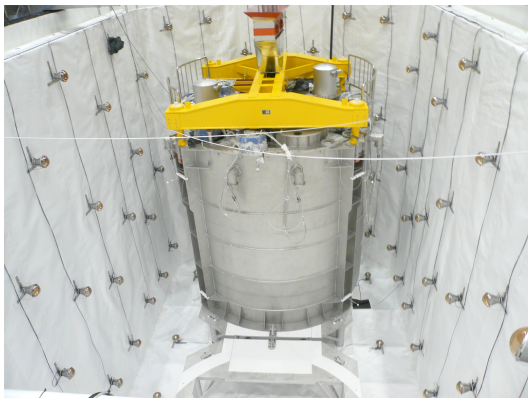


Antineutrino Detector

(192 8”PMTs)

x2 near site
x4 far site

2 or 4 PMT readout systems

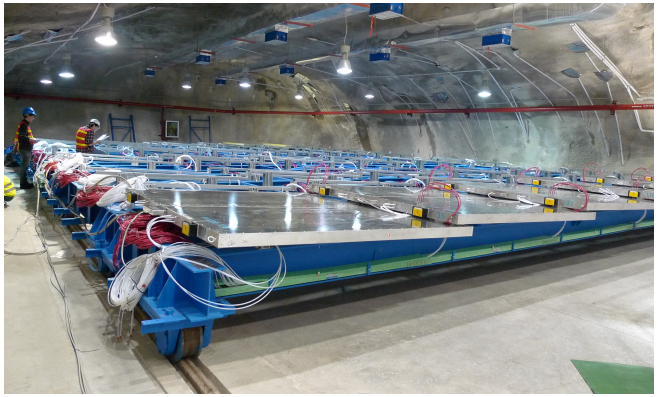


Inner and outer Water Cherenkov Detectors

(289 or 392 8”PMTs)

289 near site
392 far site

2 PMT readout systems



RPC Detector

(1728 or 2592 readout strips)

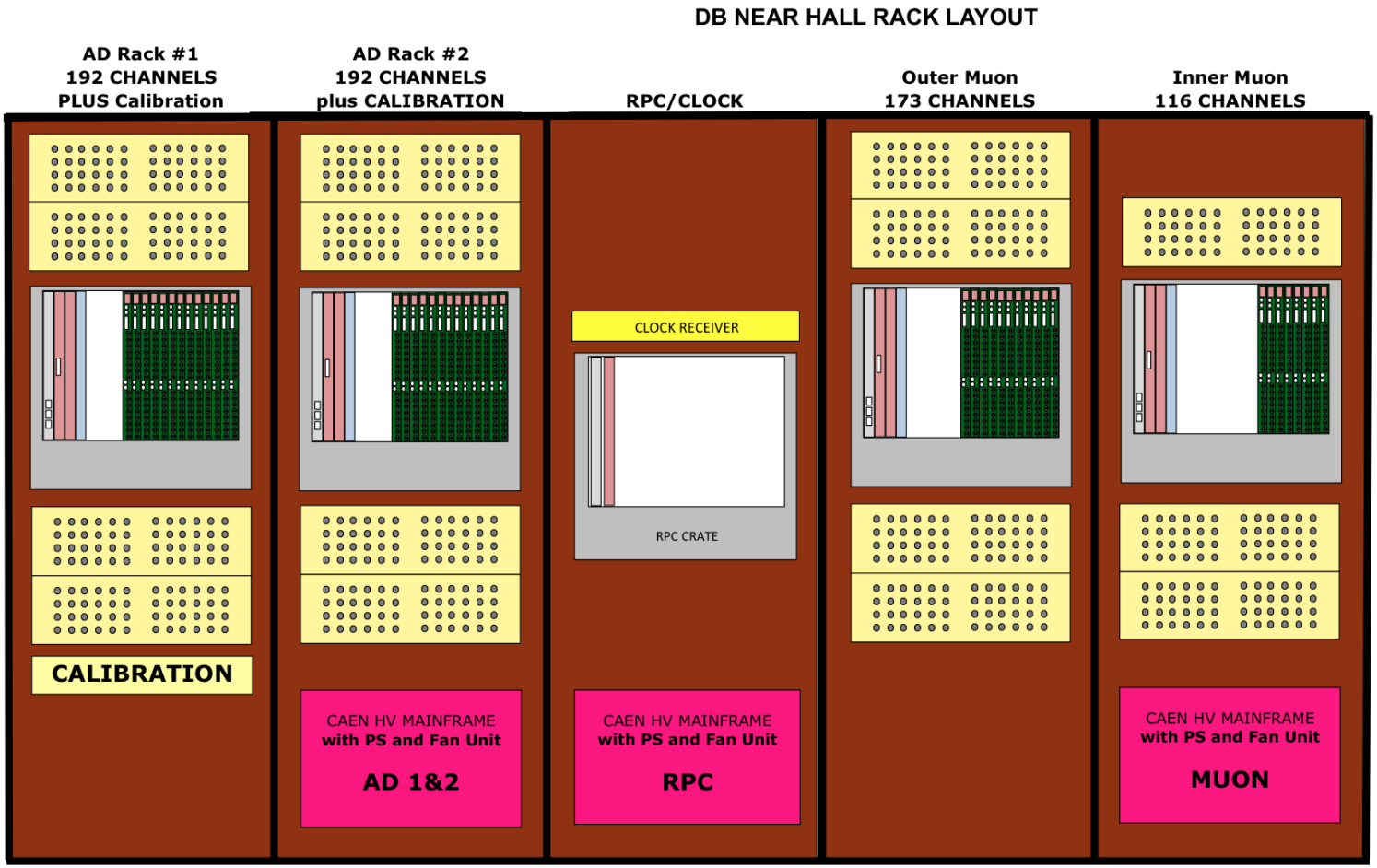
1 RPC readout system

Electronic system

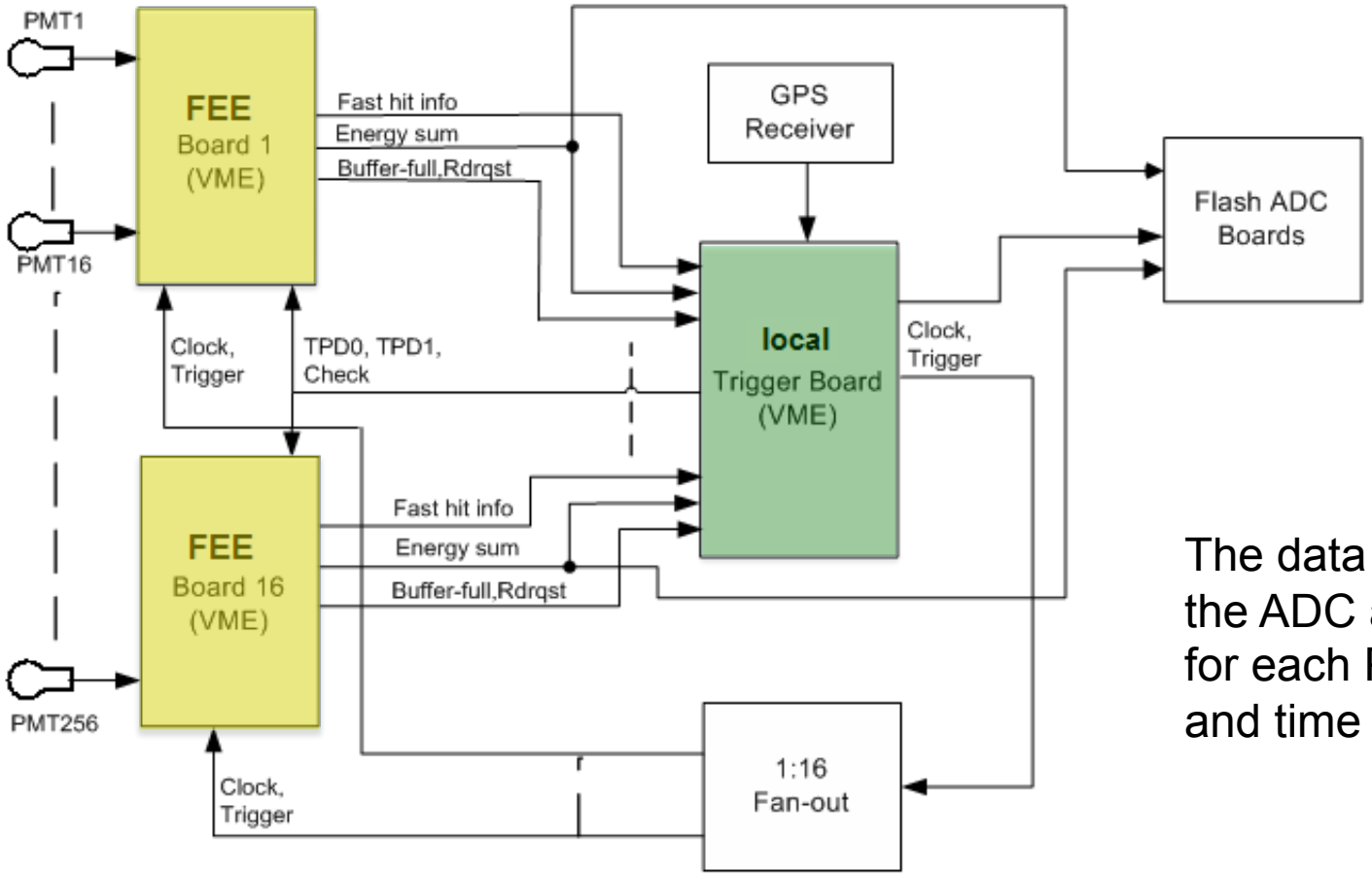
Each detector has a separate standalone electronic readout system housed in a 9U VME crate. The DAQ is configurable to run individual crates, or multiple crates.

Readout system	Antineutrino Detector	Water Cherenkov Detector	RPC detector	Site subtotal
Daya Bay near site	2	2	1	5
Ling Ao near site	2	2	1	5
Far site	4	2	1	7
Detector subtotal	8	6	3	17

Electronic system for DB near site



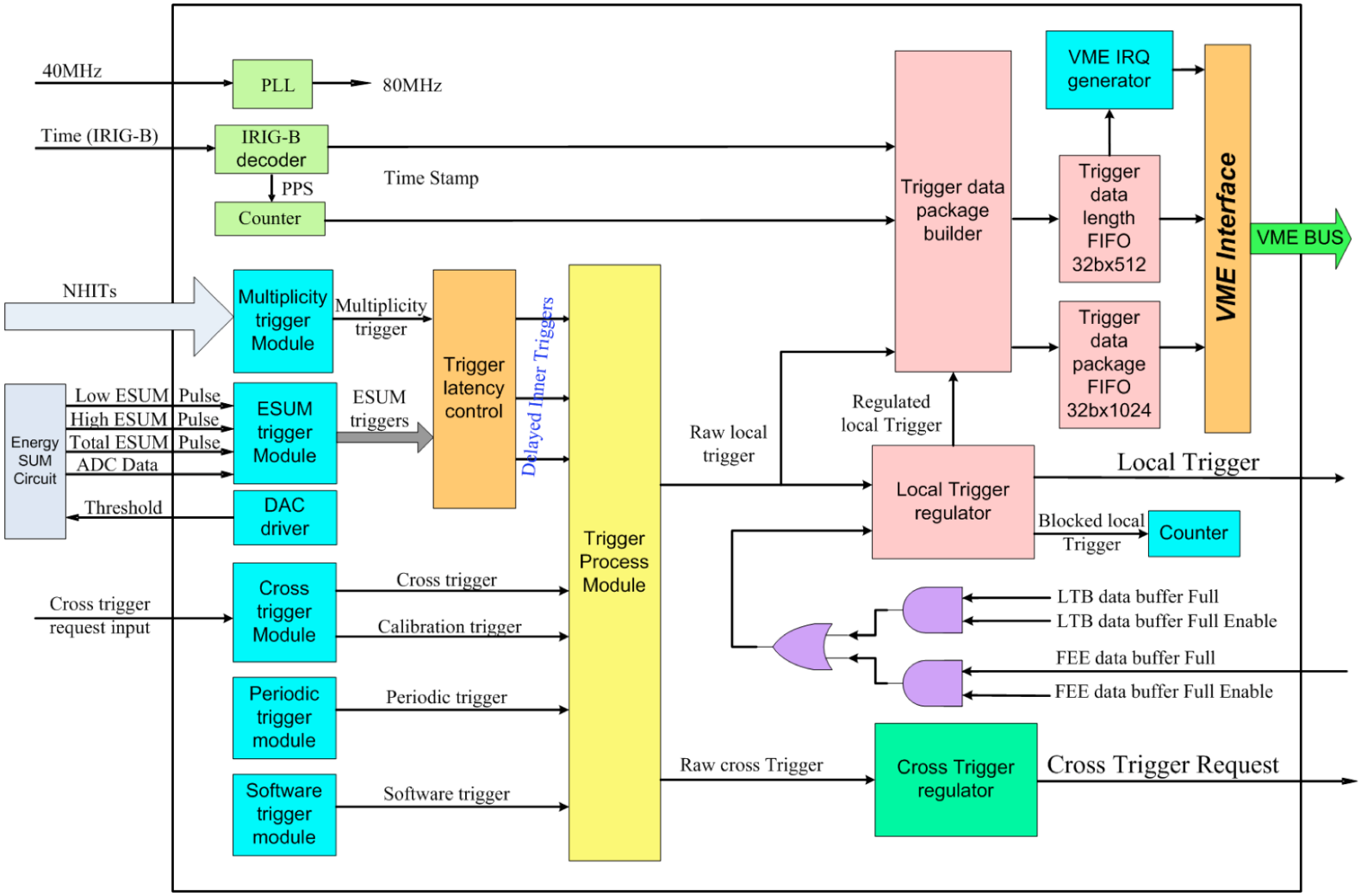
PMT Electronic System



The data stream includes the ADC and TDC values for each PMT, plus trigger and time information.

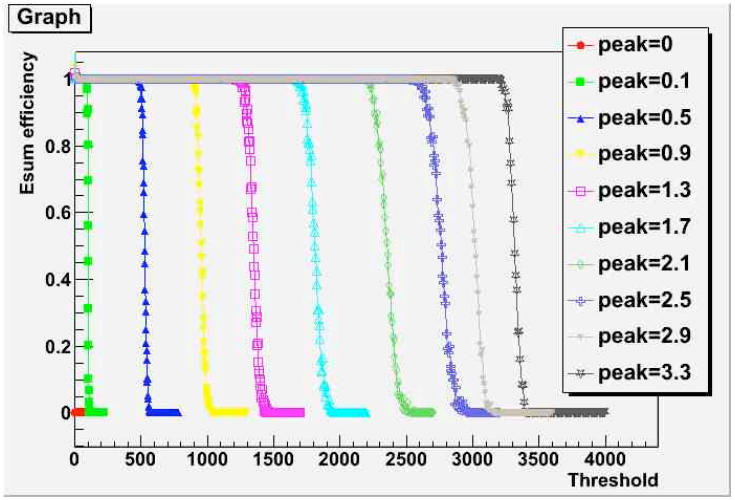
Each PMT electronic system sits in single 9U VME crate

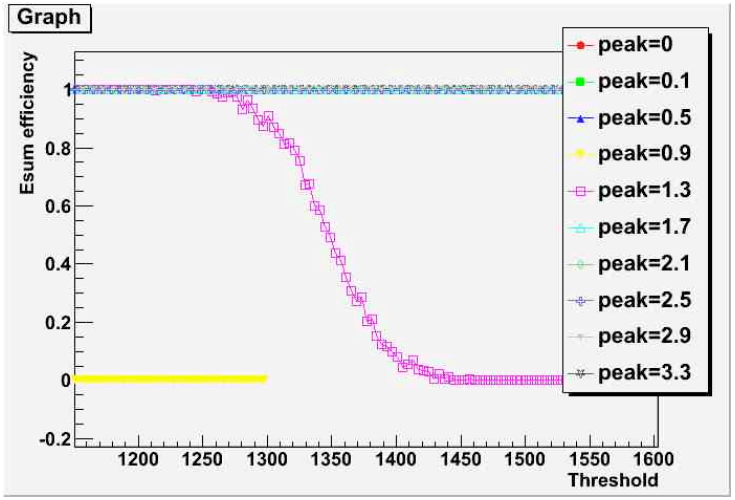
PMT Trigger Logic

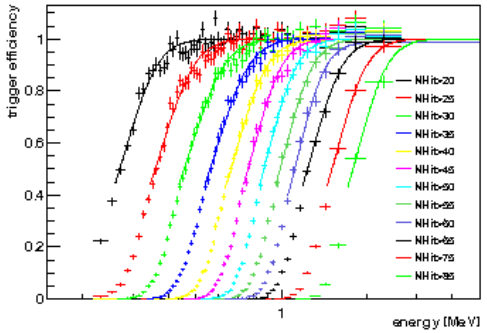


Bench Test Results

LTB performance achieves the design requirements







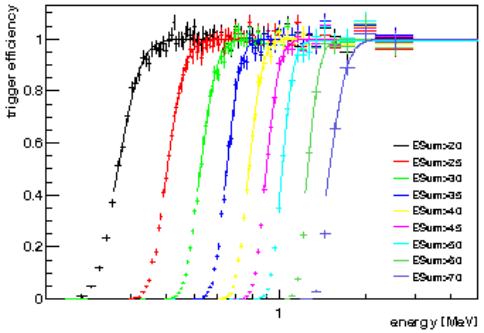
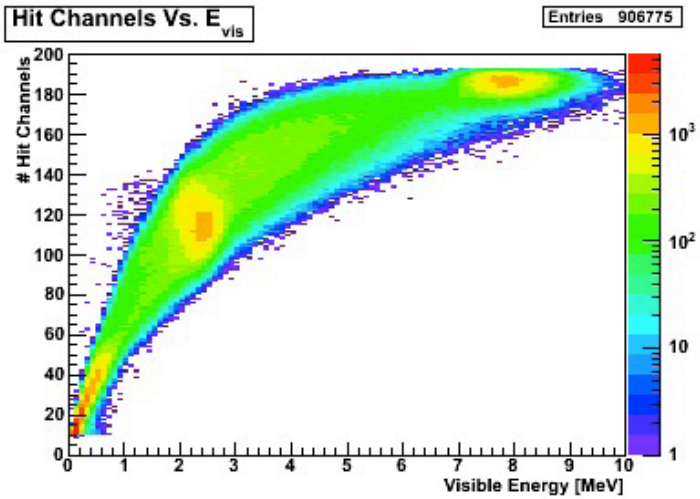
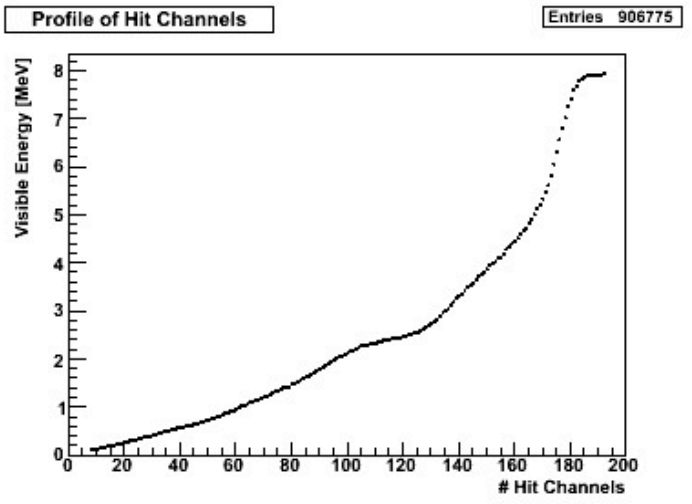
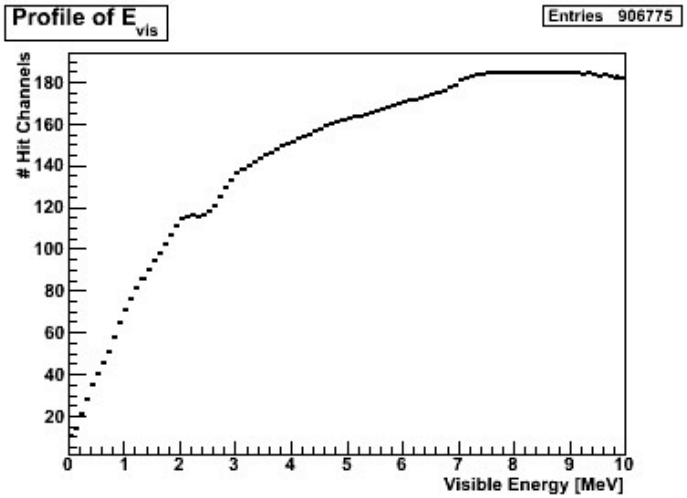


Figure 1: Relative trigger efficiencies from AD1 Dry Run data

Multiplicity Trigger Simulations



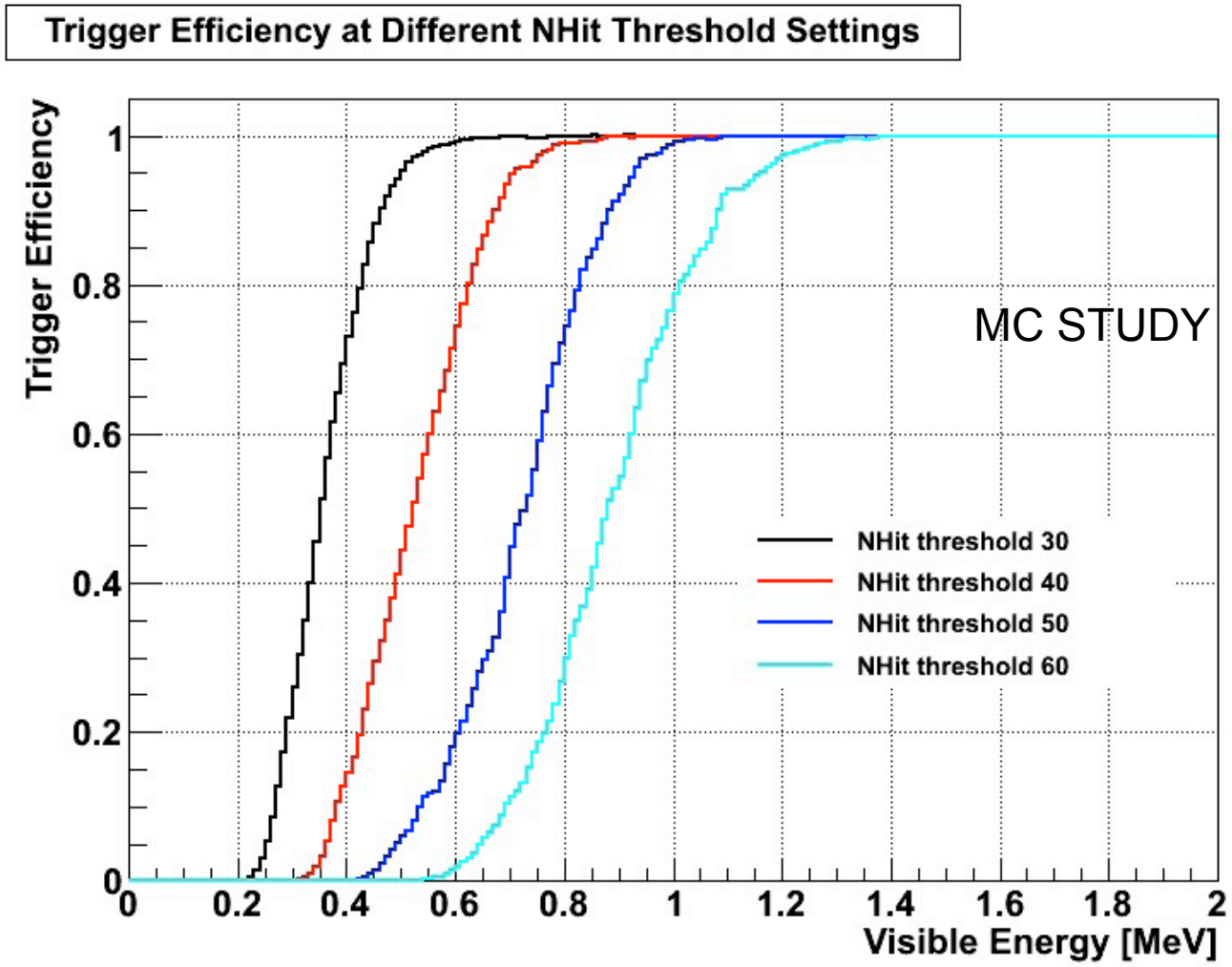




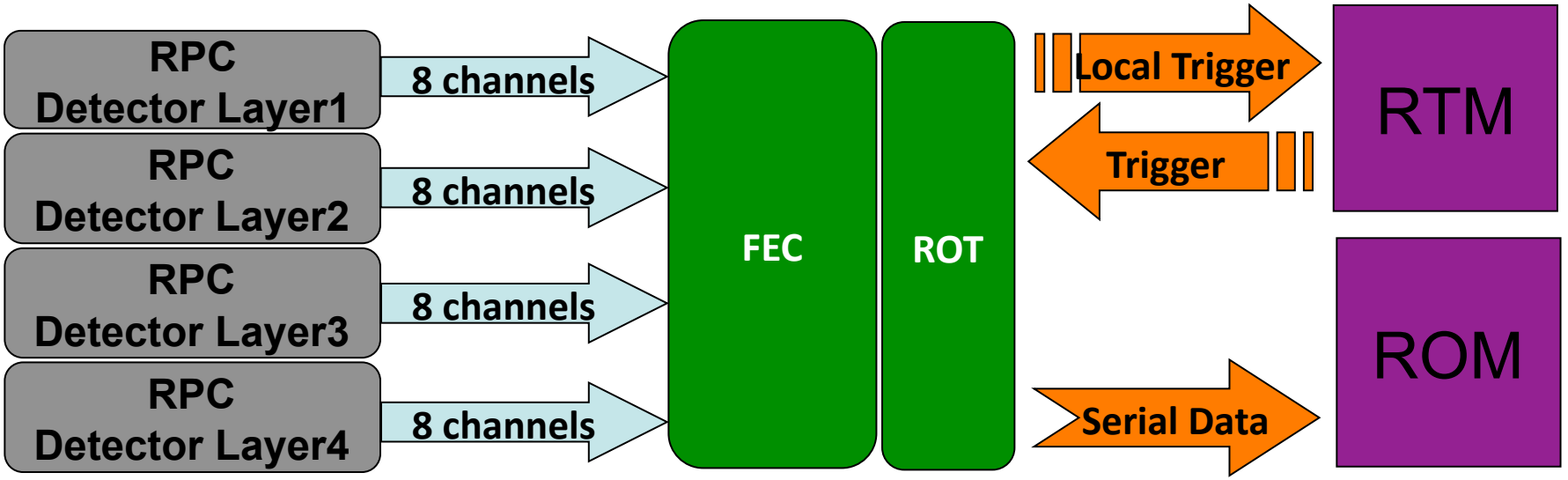
What value to use for NHIT threshold?

Competing interests –
Low trigger rates vs high efficiency

Multiplicity Trigger Simulations



RPC Electronic System



FEC: Front-End Card – mounted on RPC chamber
ROT: Read Out Transceiver – mounted on RPC frame
RTM: RPC Trigger Module – VME crate in electronics hall
ROM: RPC Output Module – VME crate in electronics hall

RPC data consists of timing information along with a list of channels over threshold.

RPC Trigger Logic

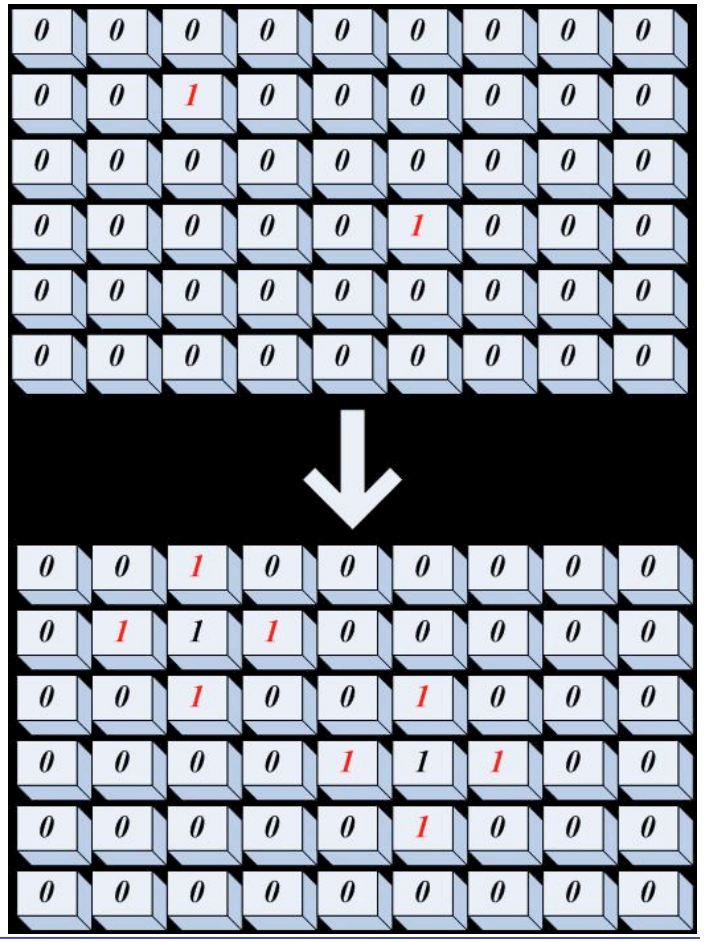
Input: 2/4 Local Trigger
Output: RTM issues trigger to adjacent modules

Input: 3/4 Local Trigger
Output: RTM issues trigger to all modules, or same as 2/4. RTM also sends signal to PMT readout system.

For an external trigger, readout all modules

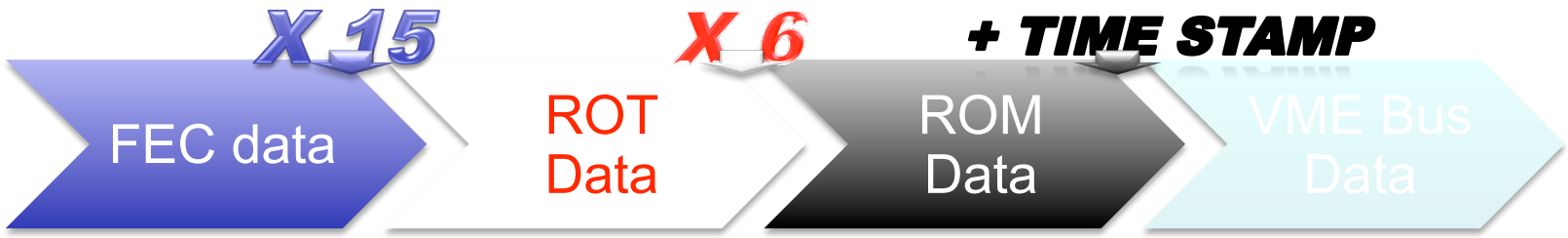
For a random trigger, readout all modules

Trigger time window is programmable.



Dataflow

- RPC dataflow is organized by RPC Module. Each data package contains one module's hit map, with time information and module ID , trigger information maybe included also.
- Usually 1 local trigger 2/4 will result 5 neighbor RPC data package with same time information, except that when the module gives out local trigger is on edge or corner.
- If a ¾ local trigger arose or cross trigger arrived, all FECs will be readout, then the dataflow may contains 54 or 81 data package with same time information.

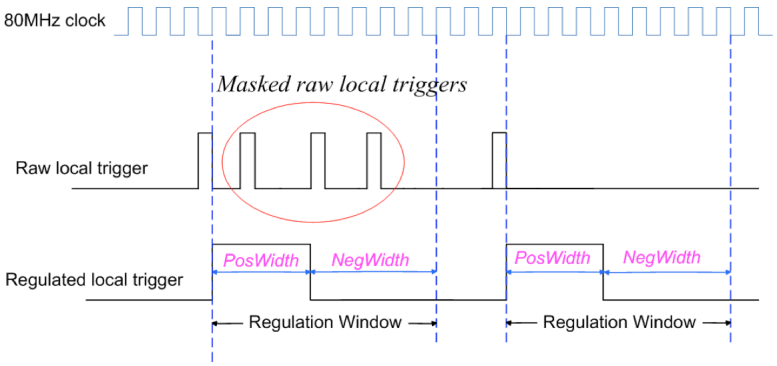


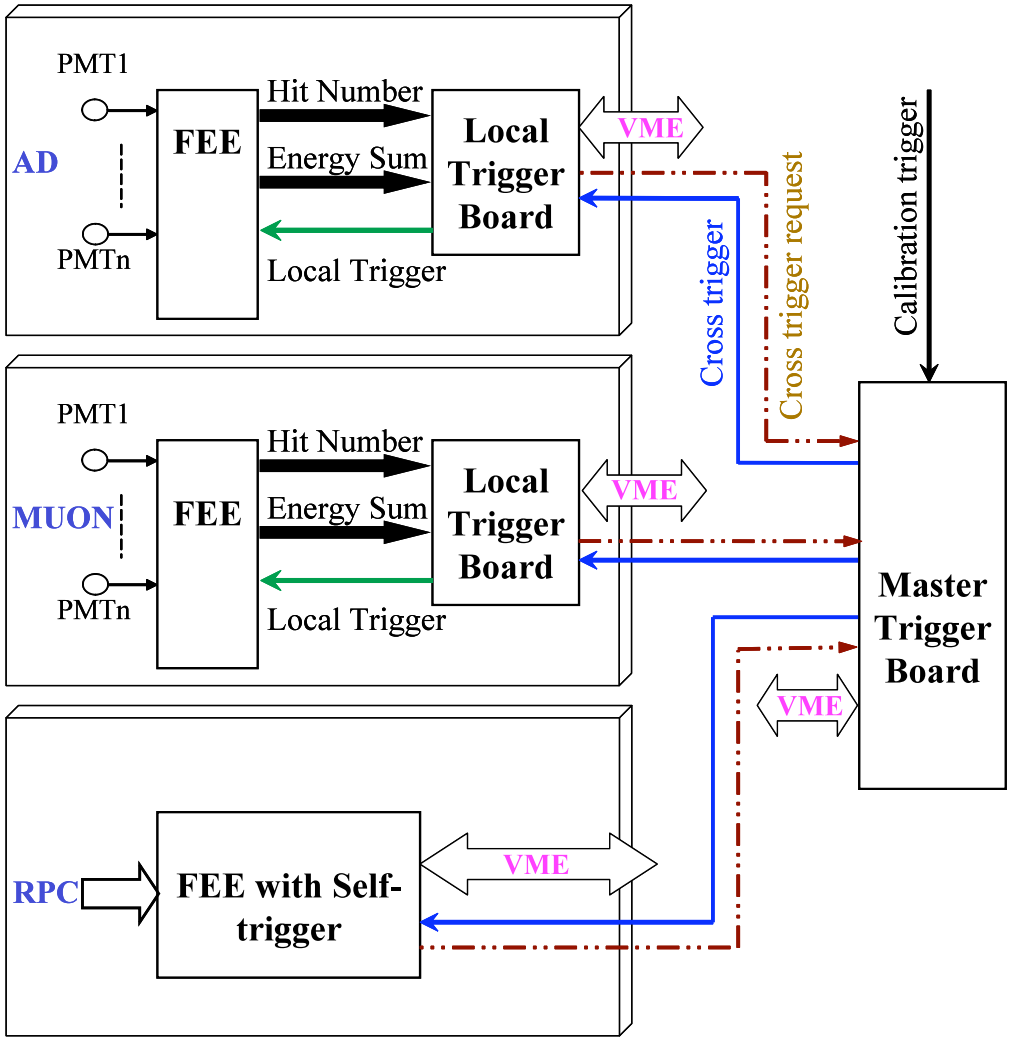
Master Trigger Board

The MTB coordinates triggers between the detector subsystems

Cross-Triggers initiate readout of any or all sub-systems

Look Back Triggers initiate a readout of over threshold PMT channels going back 200 μs for systematic studies.

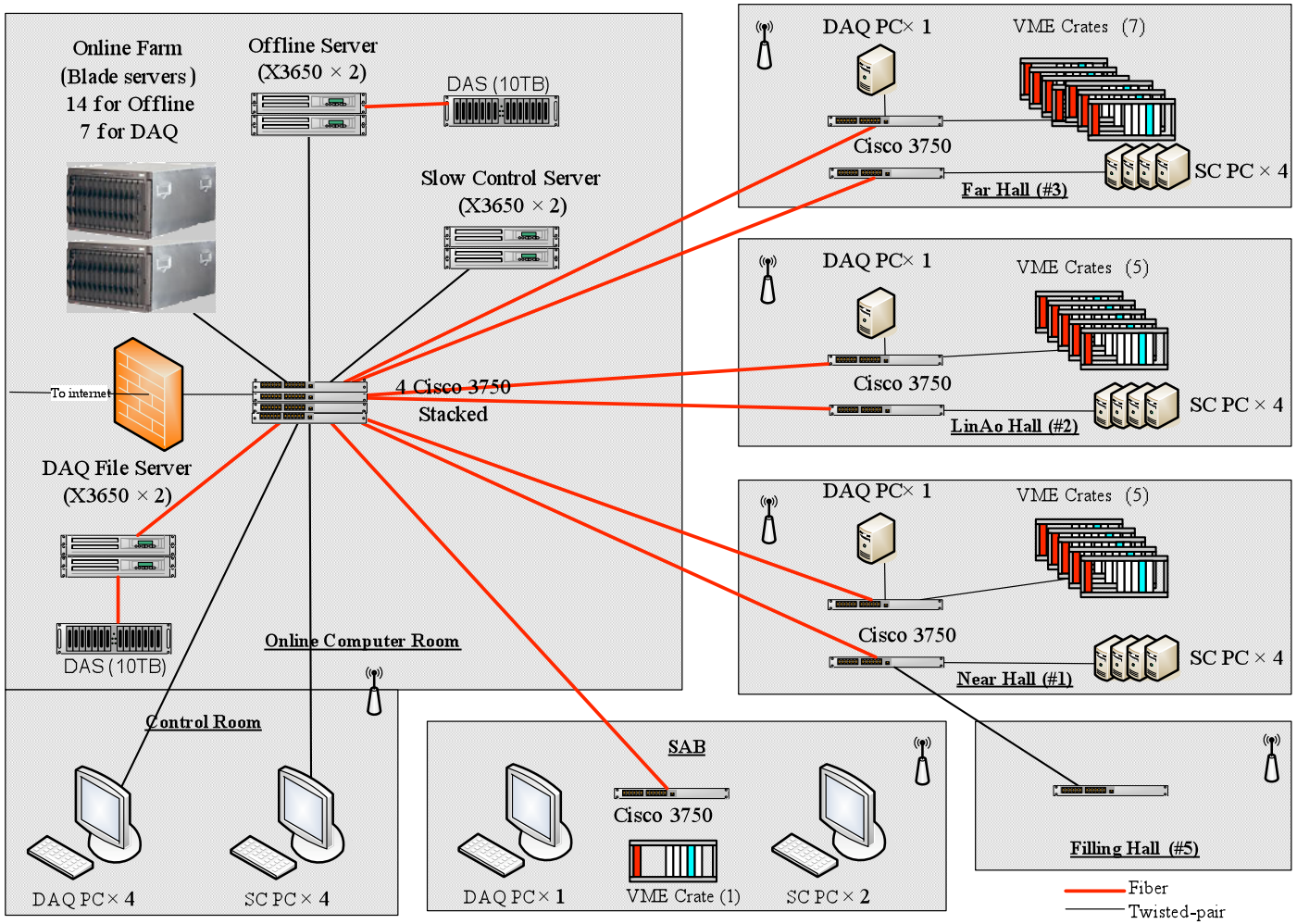




DAQ Architecture Requirements

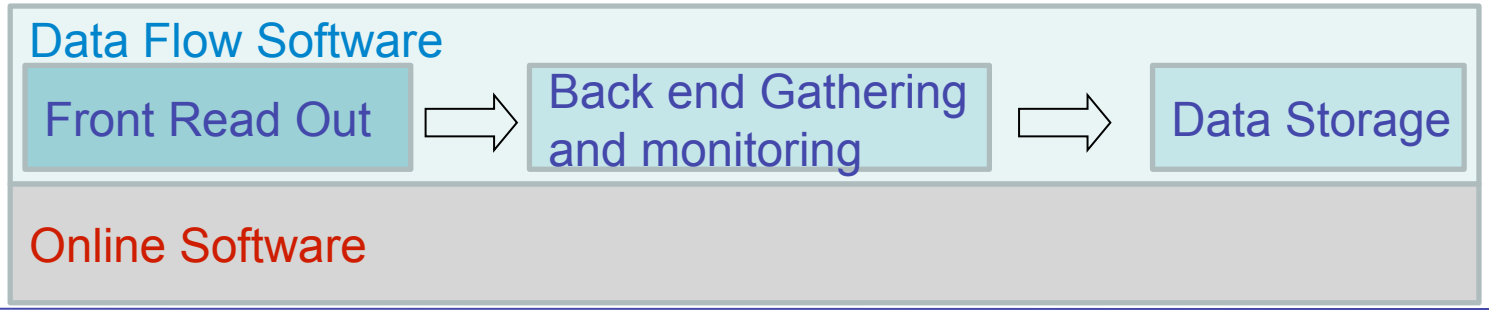
- Independent front-end read out subsystems for 17 detectors in three experiment sites.
  - AD modules (8 VME crates)
  - The inner and outer water shield detectors (6 VME crates)
  - RPC detectors (3 VME crates)
  - Event building in each crate, stream merging thereafter
- Running and run control requirements
  - Multi subsystems can run independently or as a group
    - The participants can be configurable.
    - Each subsystem can be a individual group
  - Different groups can be run and controlled separately
  - Several external system (Calibration systems)

Hardware Deployment

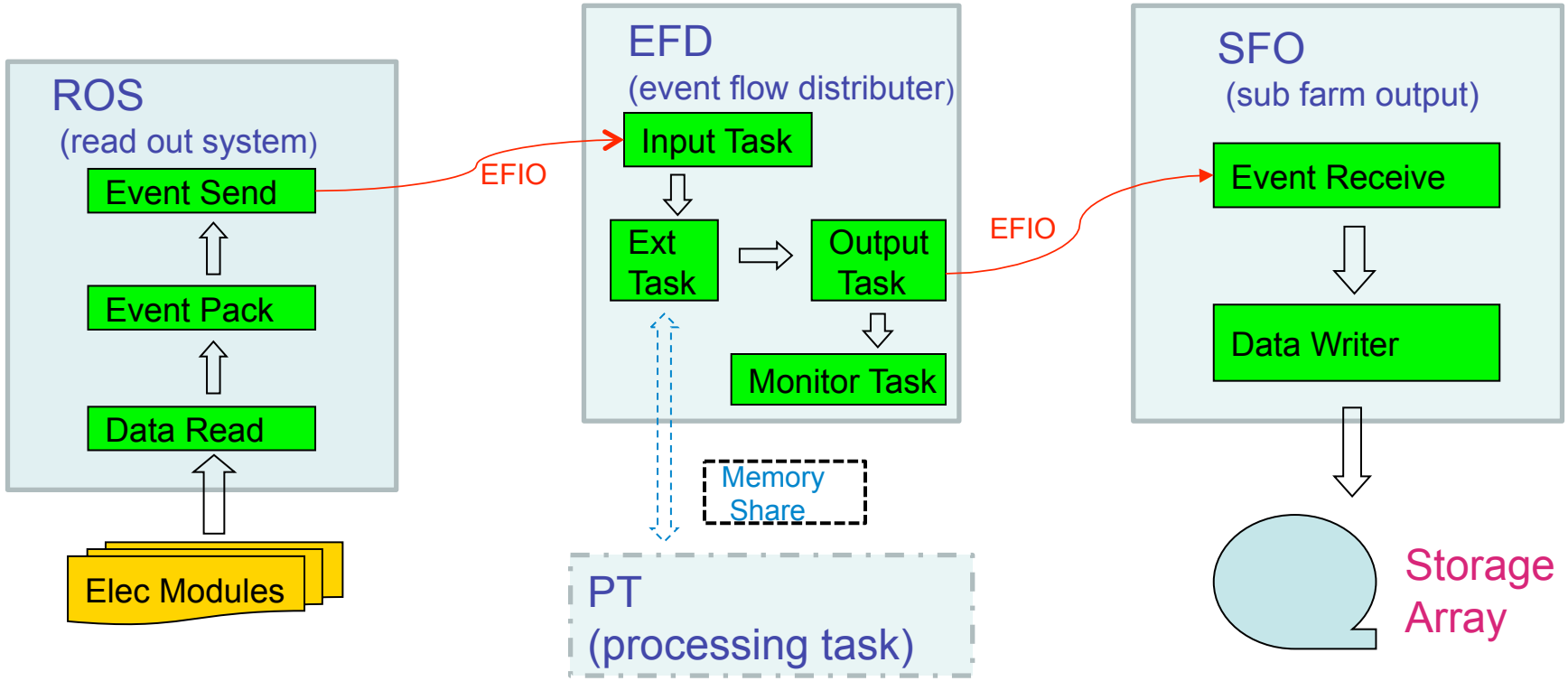


DAQ Software Architecture

- Based on the framework of ATLAS TDAQ and BESIII DAQ, divided into two parts
  - Online software (almost reuse ATLAS)
    - Configure, control, and monitor the DAQ system
    - Provide services to data flow
  - Data flow software (ATLAS+BES+DYB)
    - Responsible for all the processing and transportation of physics data

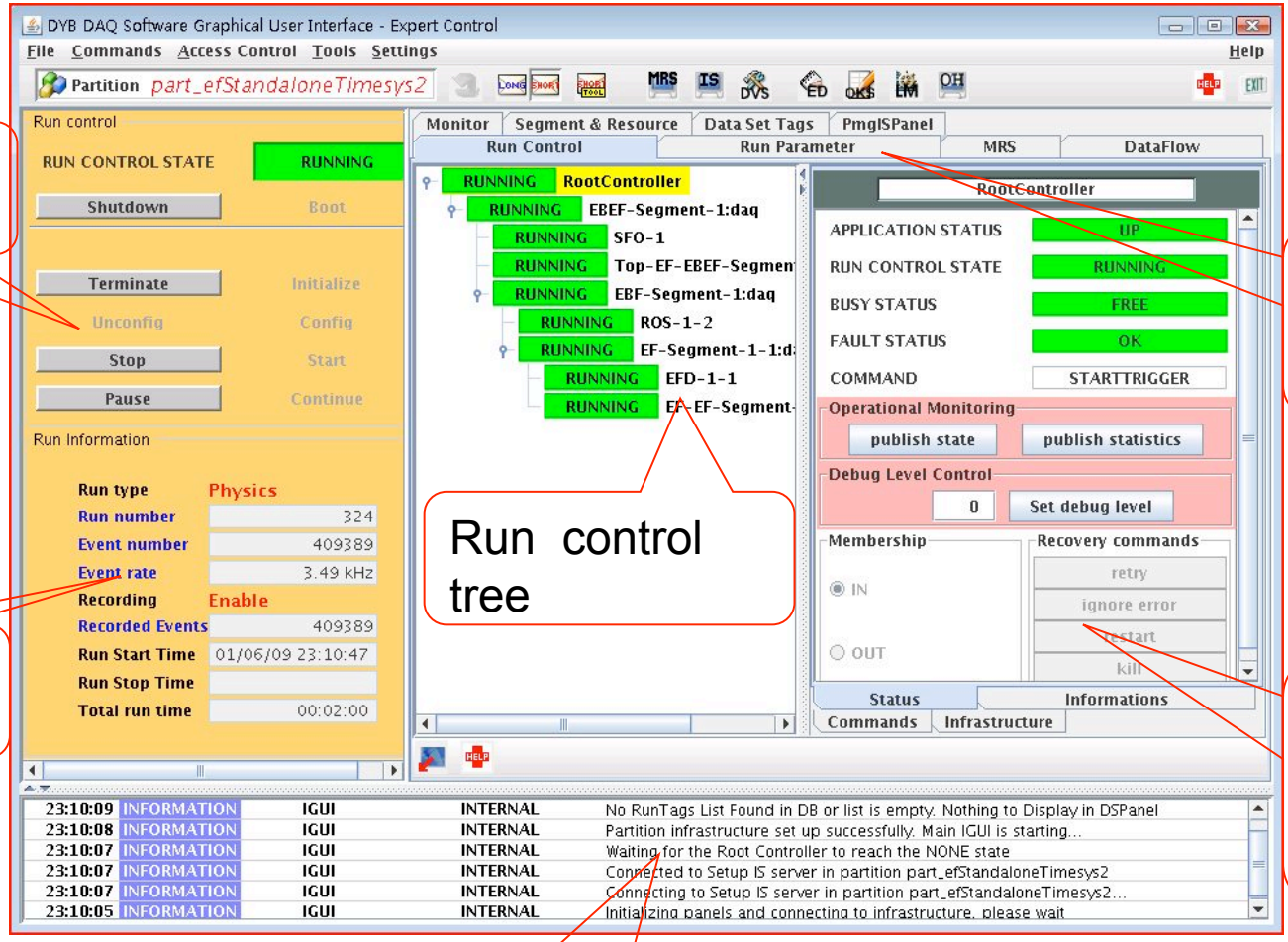


Data flow scheme



- ROSs run on PowerPC/Timesys RT Linux
- Others run on X86/SLC4

Graphic Interface



Run control panel

Running status

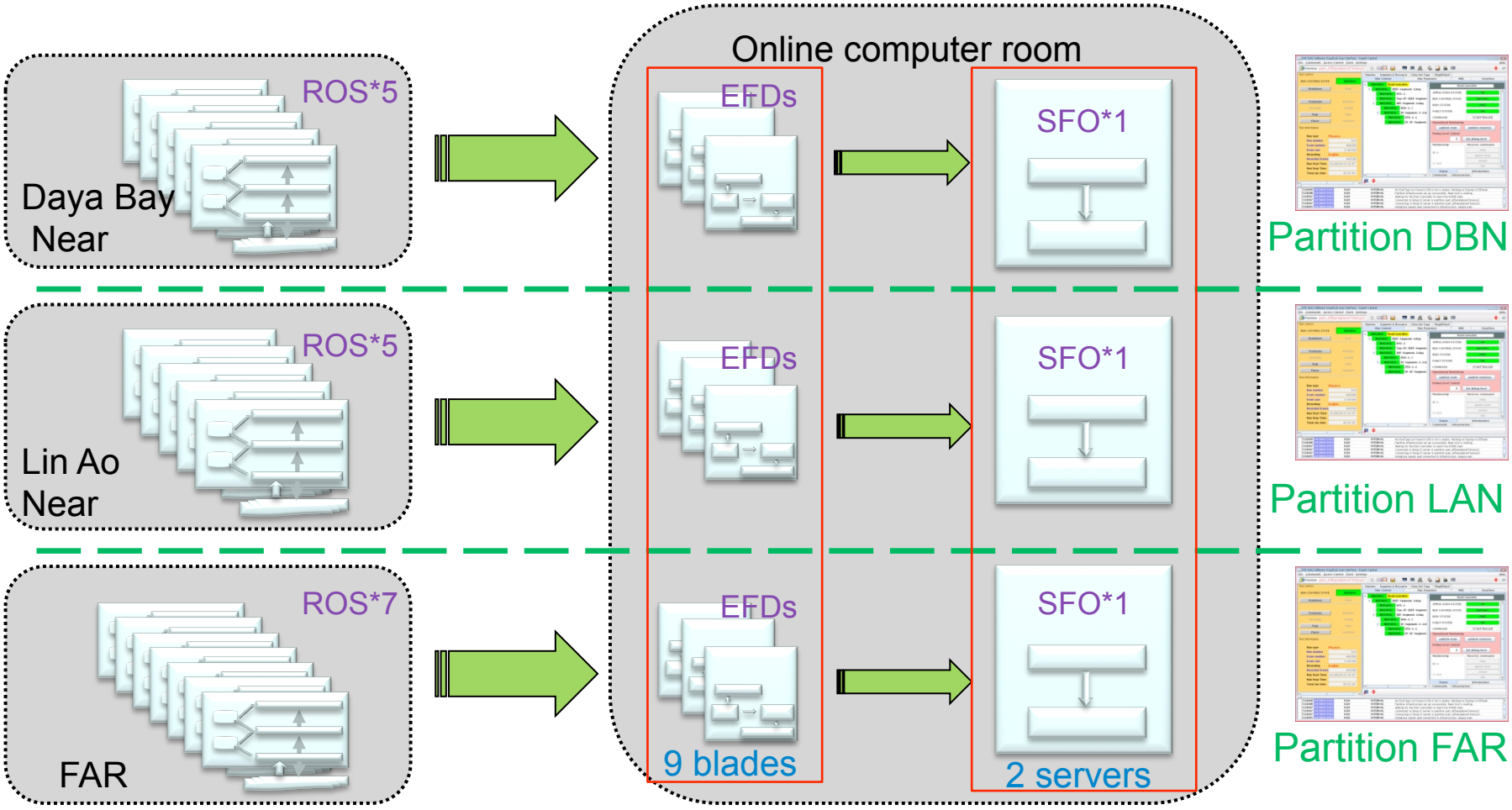
Run control tree

Run parameter panel

Individual controller control panel

Message report panel

Software Deployment Scheme



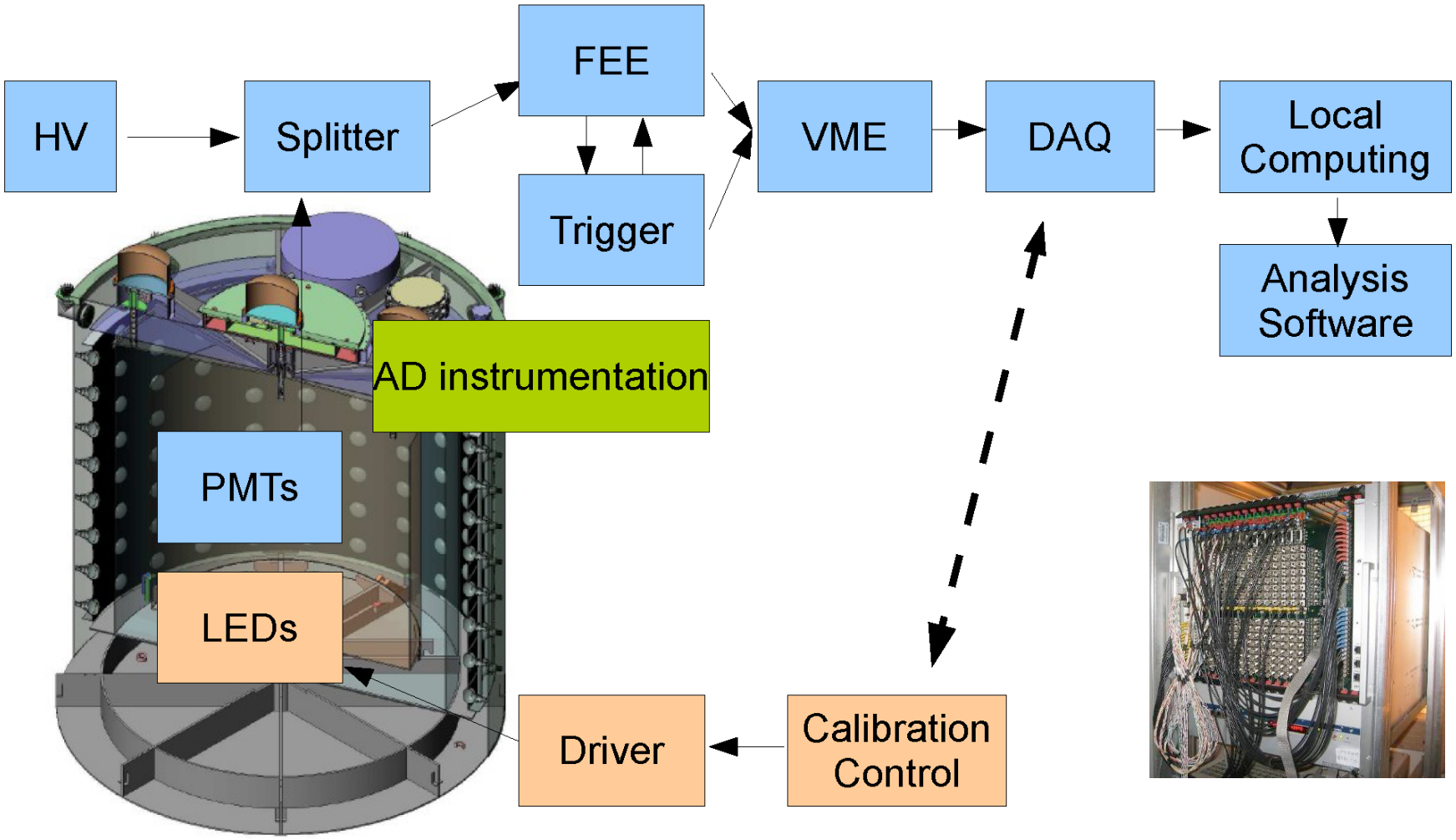
Deployment can be configurable for different experiment requirements

Data Stream Merging

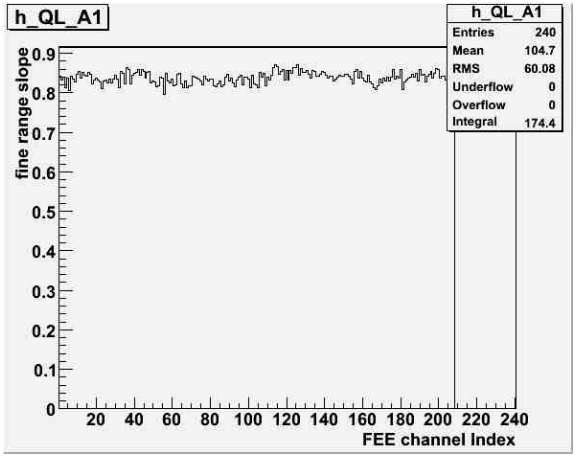
- Each independent DAQ subsystems/detectors may run standalone.
  - Each one is a stream (17)
- Which streams merge together
  - All of one site together (3)
  - All of three site together (1)
  - Configurable to switch merging or not
- Merged stream sorting by trigger time stamp
  - Some data will not be time ordered when some streams block too long for some troubles.
    - These data should be written to files before all buffers are full.
    - A timeout sorting flag will set to the header of these events.

Dry-Run

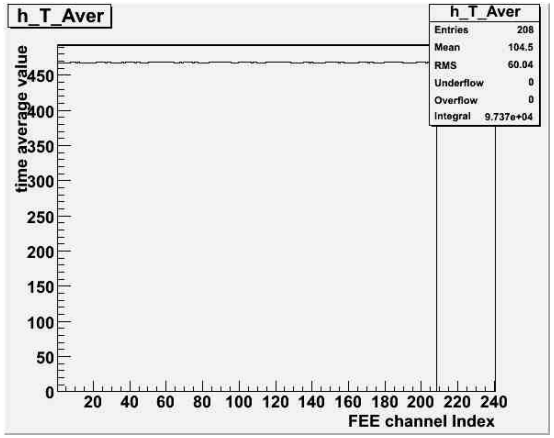
Integrated test of complete AD system



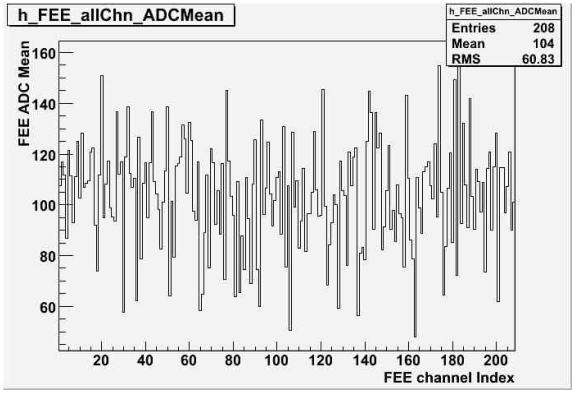
Performance of PMT electronics



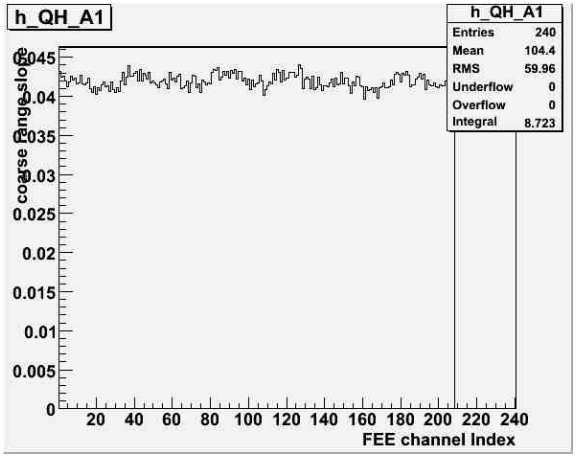
ADC fine range slope



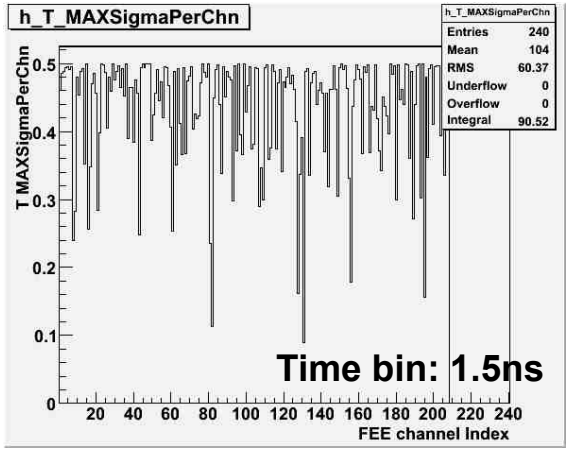
Time average



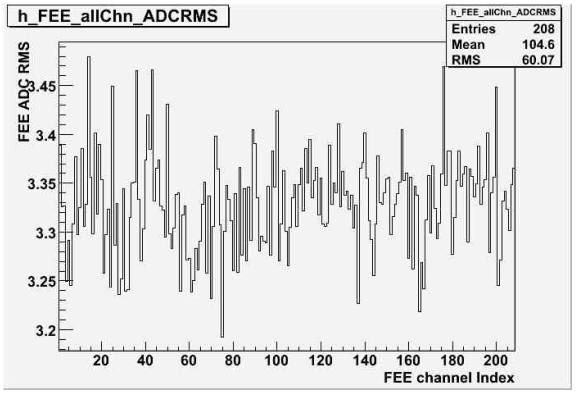
ADC pedestal



ADC coarse range slope



Time RMS



ADC RMS

System installation and test

Summary

- PMT trigger system has been demonstrated to work
  - Multiplicity Trigger works as designed
  - Energy Sum Trigger works as designed
  - External and Calibration Triggers work as designed
- RPC trigger system working
  - 2/4 trigger employed for now
  - Integration with MTB pending further integration
- DAQ system working well
  - Dry-run data taking is reliable
  - Multi-crate operations work, more development to come

Thank you.