DAQ of KEK-PS E362

A.Sakai

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Chapter 1

Overview

The detectors of the long baseline neutrino experiment (KEK-PS E362) consist of the Front-detector and the Super-Kamiokande detector. In this report, we describe front detectector DAQ, beam channel DAQ, relation of these DAQ and data storage.

1.1 Generals

The purpose of the KEK-PS E362 experiment is to search for neutrino oscillation by accelerator beam. Fig.1.1 shows schematic view of the E362 beamline. The primary proton beam is transported from KEK 12GeV Proton Synchrotron (PS) to the target station (Horn). At the target station, the primary proton collide the target and generate mesons (pions and kaons). Mesons are focused by Horn. Then, mesons are decaying in the decay pipes and generates neutrino. The neutrino go through the Front Detector (FD) and Super-Kamiokande (SK).

The experimental group monitors Front Detector (FD) signals, muon monitor signals and horn signals. The requirement of near detector and beam line monitor is to measure the neutrino flux accurately. In this report we describe following items:

- the method of synchronization between beam-channel monitor with the front detector and the Super-Kamiokande .
- the front detector DAQ.
- the beam-channel monitor.
- the material which we need in this experiment and data size of this experiment.

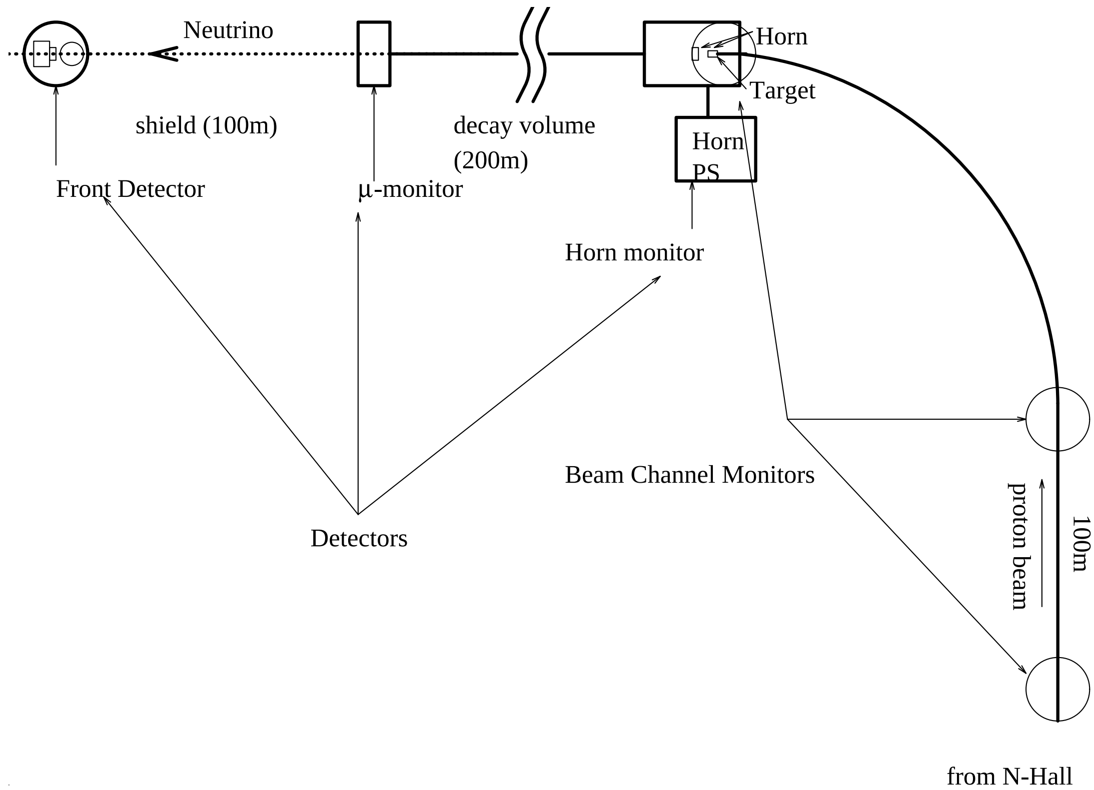

Figure 1.1: Schematic view of the E362 beamline.

Chapter 2

Front Detector

The front detector is composed of following modules (see Fig.2.1):

- 1-kton water Čerenkov detector.
- water SCIFI detector.
- Lead-Glass counter.
- μ chamber and its trigger counter.
- veto counter.

We call "*fine-grained detector*" as front detector except the 1-kton water Čerenkov detector. The detail of fig. 2.1 will be described in this sections. This section describes the experimental hall, each detector components, its trigger scheme and expected data size.

2.1 Experimental Hall

Figs.2.2 and 2.3 show the planned experimental hall. We set up electronics system in two places. One is the electronics hut on the ground-level, the other is the electronics rack in the underground-level. The main work of the electronics hut is to digitize the 1-kton detector and combine the front detector signals. The electronics rack is to digitize the data of the fine-grained detector. Each electronics hut & rack monitor the trigger time difference from the beam spill signal ,each detector component information and store event number (For more detail see 2.8). Table 2.1 shows the experimental hall parameters.

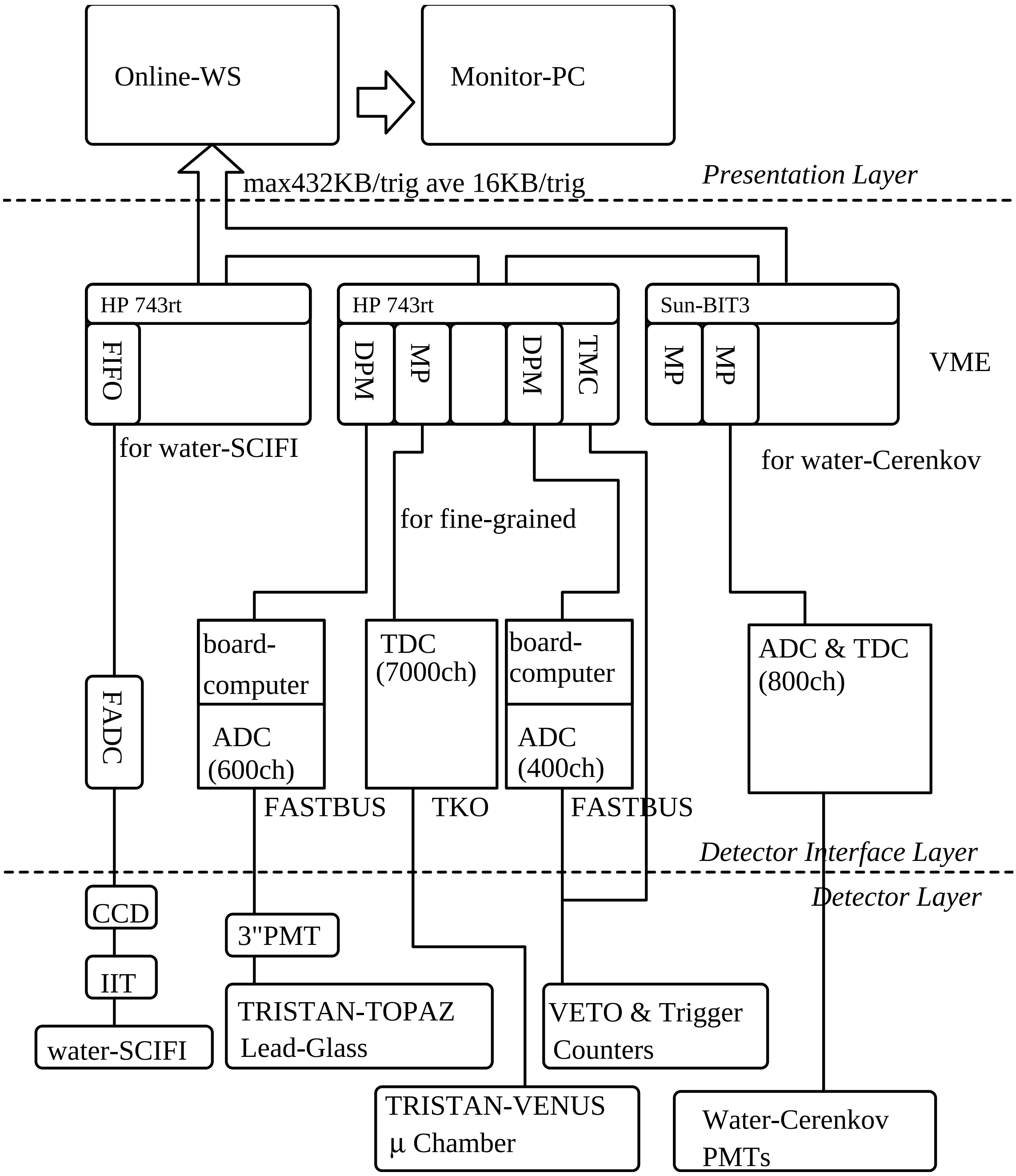

Figure 2.1: Schematic view of E362 front detector DAQ.

Height	:	17.4 (m)
Floor size	:	24 ϕ (m)

Table 2.1: Basic parameters of experimental hall

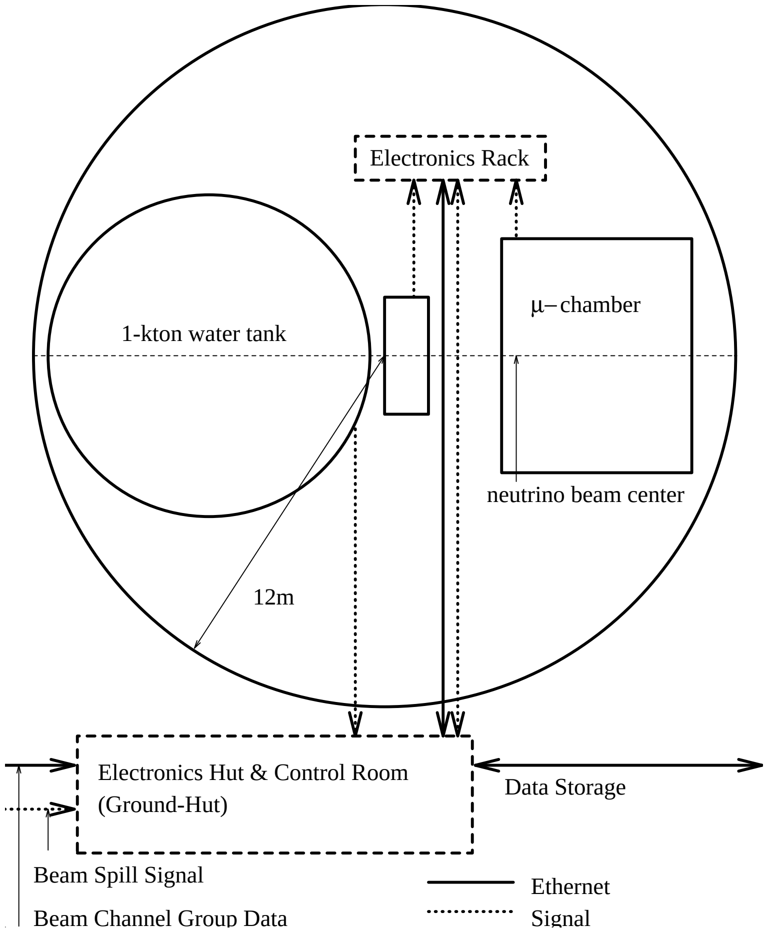

Figure 2.2: Top view of experimental hall. The dotted lines are signal line. The solid lines are data transfer line (Ethernet). The dashed line is the center of neutrino beam. The electronics-hut and the detectors are also shown.

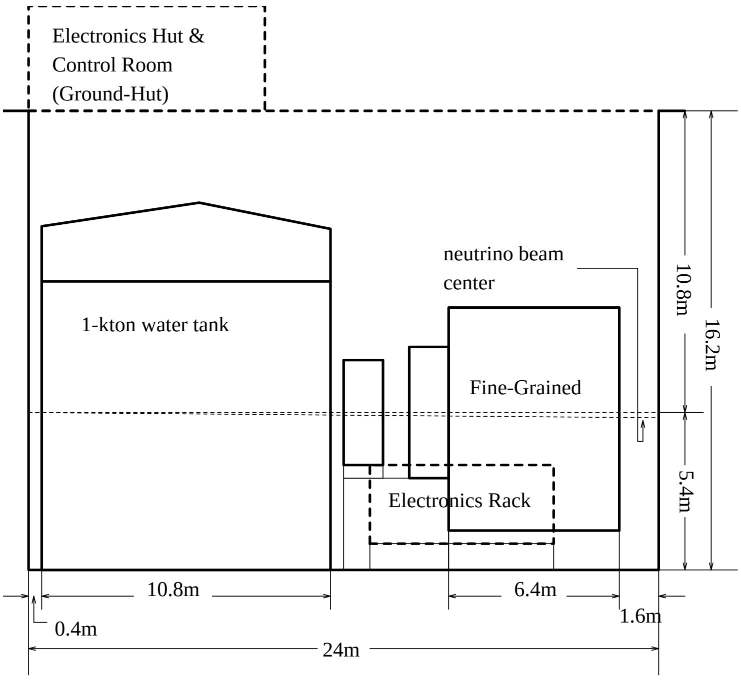

Figure 2.3: Side view of experimental hall. The detectors and electronics hut are shown in this figure. The center of the neutrino beam is also shown (-1.07° to the underground).

2.2 The 1-kton water Čerenkov detector

The 1-kton water Čerenkov detector is located most upstream of the experimental hall. We set up same detector system which is used in Super-Kamiokande (see Table 2.2). The detector size is same as the E261a experiment (see Fig.2.4).

Number of PMT	:	760
Number of ATM	:	64
Number of GONG	:	4
Number of SCH	:	4
Number of MP	:	4

Table 2.2: Basic parameters of water Čerenkov detector

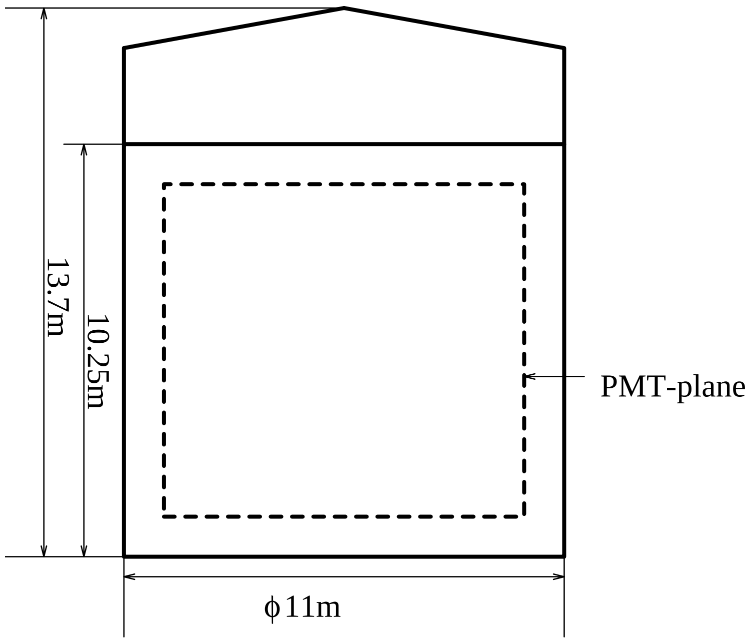

Figure 2.4: Schematic view of water Čerenkov detector

2.3 Water SCIFI detector

Fig.2.5 shows the Block diagram of Water SCIFI signal digitization. Image intensifier (IIT) is accumurate and multiplied water SCIFI signals. CCD change the photon intensity to electric current with position information. FADC digitize the CCD-information. Trigger logic supplies the trigger to the Clock & Coordinates Generator. Clock & Coordinates Generator generates H-coordinate (10bits) and V-coordinate (10bits) information to the VME-FIFO module VME-FIFO store the digitized CCD informations. VME-Computer store the VME-FIFO informations.

The current connection plan of SCIFI and IIT is shown in Fig.2.6.

The number of required rack is 5 (see Table 2.4). We need 3 racks for HV Power Supplies, 1 rack for VME and NIM crates and 1 rack for Calibration modules.

2.4 veto counters

Regrettably, the water SCIFI can only get charge information. For this reason, we need to get time information for rejecting backgrounds. We planed to set up veto counters

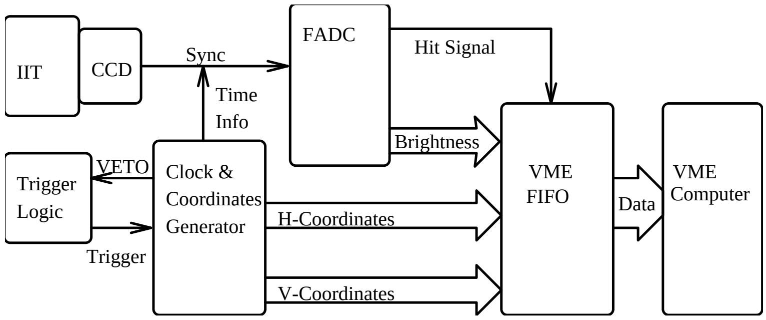

Figure 2.5: Block diagram of Water SCIFI Signal Digitization.

Number of IIT	:	22
Number of FADC	:	11
Number of Clock & Coordinate Generator	:	2
Number of VME-FIFO	:	11
H-coordinates address width	:	10bits
V-coordinates address width	:	10bits
FADC digitized resolution	:	8bits (6bits for FIFO storage)
FIFO memory size	:	32bits $\times$ 8192
CCD-pixel/fibre	:	80

Table 2.3: Planned specification of water-SCIFI.

VME crate	:	1
NIM bin	:	2
HV Power Suppy	:	24

Table 2.4: Required crates and bins for SCIFI tracker

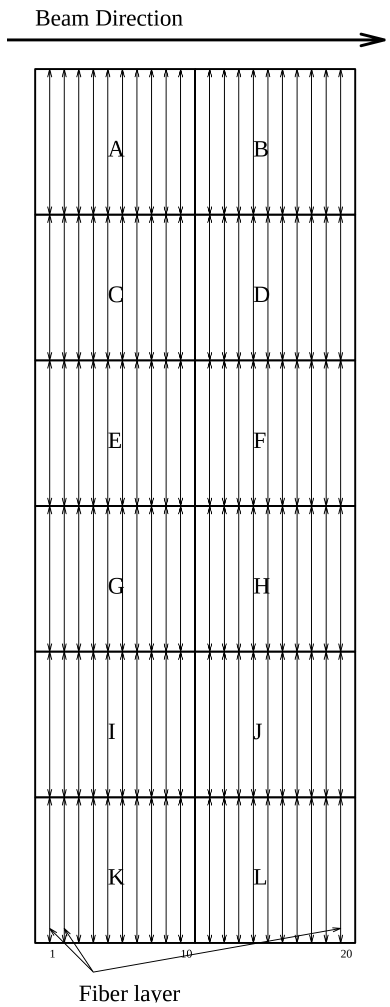

Figure 2.6: Connection plan of SCIFI and IIT. The arrow corresponds SCIFI layer. The A – L corresponds IIT. This figure only shows the XX plane. YY plane is sams as this figure.

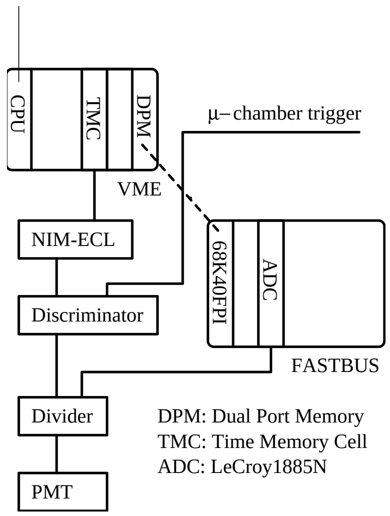

Figure 2.7: Schematic view of veto-counter electronics.

Number of Scinti	:	150
Number of PMT	:	300
Number of TMC	:	4
Number of ADC	:	10
Number of SCH	:	1
Number of GONG	:	1
Number of MP	:	1

Table 2.5: Basic parameters of veto & trigger counters

around water-SCIFI to get time information.

Also, we plan to set up μ-trigger counters in front of the μ-ranger. Figs. 2.7 and 2.8 shows the schematic view of DAQ system.

The number of required rack is 1 (see Table 2.6). Power Supplies are as same size as NIM bin. The size of heat bath is as same as that of the rack.

2.5 Lead-Glass detector

It is important to confirm the $\nu_e$contaminations in the neutrino beam, because of searching for small mixing angle region. To improve the capability of particle identification for

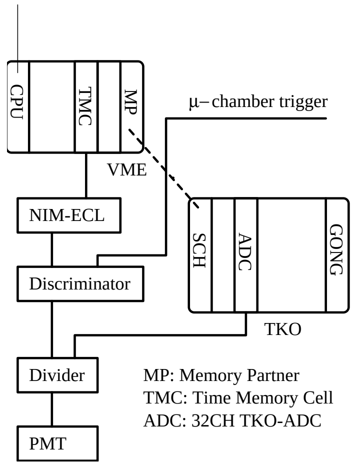

Figure 2.8: Schematic view of veto-counter electronics.

TKO crate	:	1
TKO Power Supply	:	1
VME crate	:	1
NIM bin	:	1
HV Power Suppy	:	1
HV distributor	:	1

Table 2.6: Required crates and bins for veto-counters

Number of Lead Glass	:	600
Number of TKO-ADC	:	19
Number of GONG	:	1
Number of SCH	:	1
Number of MP	:	1

Table 2.7: Basic parameters of Lead glass detector (TKO-case)

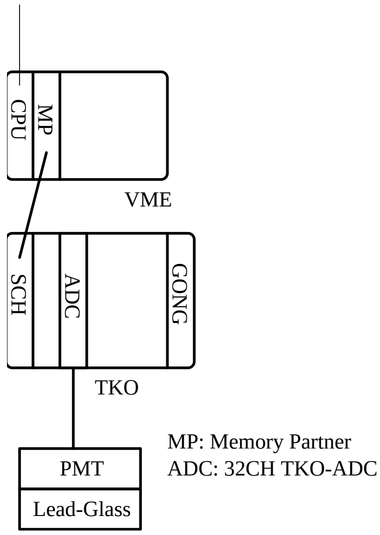

Figure 2.9: Schematic view of Lead-Glass counter electronics.

electrons, we set up lead-glass detector. We plan to use the Lead-Glass detector which was used in TRISTAN-TOPAZ. We detect the signal by 3" PMT. Currently we consider two options of electronics systems after the PMT. One is to use TKO as the electronics system or to use FASTBUS.

The number of required rack is 2 (see Table 2.8). Power Supplies are as same size as NIM bin. The size of heat bath is as same as that of the rack.

2.6 Muon Chamber

Fig.2.10 shows the schematic view of muon chamber electronics. One front board monitor the eight muon chambers. The muon chamber signals are digitized in front board. The

TKO crate	:	1
TKO Power Supply	:	1
CAMAC crate	:	1
NIM bin	:	1
HV Power Suppy	:	3
HV distributor	:	3
Heat Bath (for Xe lamp)	:	1

Table 2.8: Required crates and bins for lead glass counters

Number of Chamber	:	7400
Number of Front Board	:	925
Number of Module Address Generator	:	116
Number of Main Address Generator	:	15
Number of TKO-Memory Buffer	:	15
Number of SCH	:	1
Number of GONG	:	1
Number of MP	:	1

Table 2.9: Basic parameters of muon chamber

front board make 6-bit TDC information and 3-bit Address information per channel. The module address generator add 3-bit per channel. The main address generator add more 3-bit per channel. In total 15-bit datas are generated. For this 4-bytes of data are generated per channel.

The number of required rack is 2 (see Table 2.10). Power Supplies are as same size as NIM bin.

2.7 Estimation of the number of the rack

We estimate the number of the rack at the front detector.

At experimental hall, there exists following 4 components:

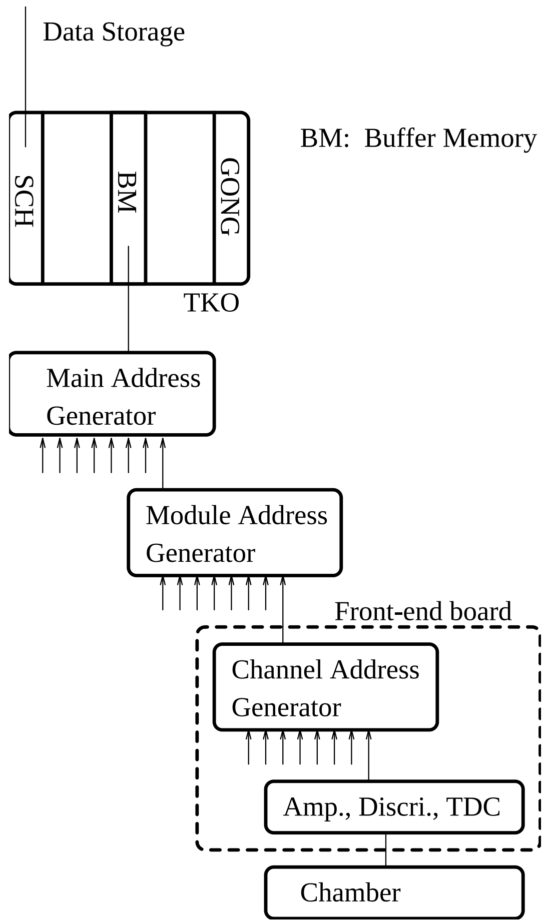

Figure 2.10: Schematic view of Muon Chamber Electronics.

TKO crate	:	1
TKO Power Supply	:	1
NIM bin	:	2
+8V Power Suppy (450A)	:	4
-8V Power Suppy (450A)	:	4

Table 2.10: Required crates and bins for muon-chamber

SCIFI tracker	2
Veto counter	1
Lead glass counter	2
Muon chamber	2
Trigger logic	1
Downstairs sum	8
1-kton water Čerenkov	4
Trigger logic	1
Upstairs sum	5
Total sum	13

Table 2.11: Required racks for KEK PS-E362 Front Detector

- SCIFI tracker
- Veto counter
- Lead Glass counter
- muon chamber

SCIFI tracker uses 2 rack (see Table 2.4). Veto counter uses 1 rack (see Table 2.6). Lead Glass counter uses 2 racks and 1 rack space (see Table 2.8). Muon chamber uses 2 racks (see Table 2.10). We need trigger distribution rack (1 rack).

At the upstears of the experimental hall, we measure the 1-kton detector. The 1-kton detector uses 4 racks. We also need trigger rack (1 rack).

In total, we need 8 rack-space for the downstairs of the experimental hall and 5 rack space for the upstairs (see Table 2.11).

2.8 Trigger Scheme

In this subsection we describe the trigger scheme of each detector components. Fig.2.11 shows the relation of the trigger time information. The type of trigger scheme is grouped into two types. One is triggered by beam-spill information only. The other is triggered

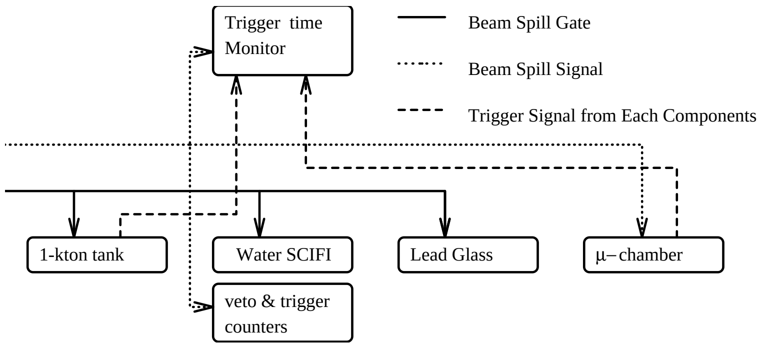

Figure 2.11: Schematic view of trigger

by the coincidence of beam-spill information and self trigger signal. As shown in fig.2.12, we are only taken the data within beam-spill gate.

In a realistic the 1-kton detector is triggered by hit sum and beam-spill information, the μ chamber is triggered by the coincidence of trigger counter (front of μ-chamber) and beam-spill information. Other electronics uses gate by beam-spill signal, because some of these detectors are taken charge information only (water SCIFI and Lead glass), and another detectors only needs the time difference from the beam spill.

The time difference of the 1-kton detector and μ chamber from beam-spill is also monitored.

In electronics Hut, we measure the following signals:

- the 1-kton PMT (TDC and ADC)
- 1-kton trigger (TDC-B) (see Fig.2.12 t_{1-kton})

where TDC is the time difference between trigger and hit, TDC-B is the time difference between beam spill signal and hit, ADC is the charge information.

In electronics rack, we measure the following signals:

- water SCIFI (ADC)
- veto counter (TDC-B) (see Fig.2.12 t_{veto})
- Lead Glass (ADC)
- μ-chamber (TDC-B)

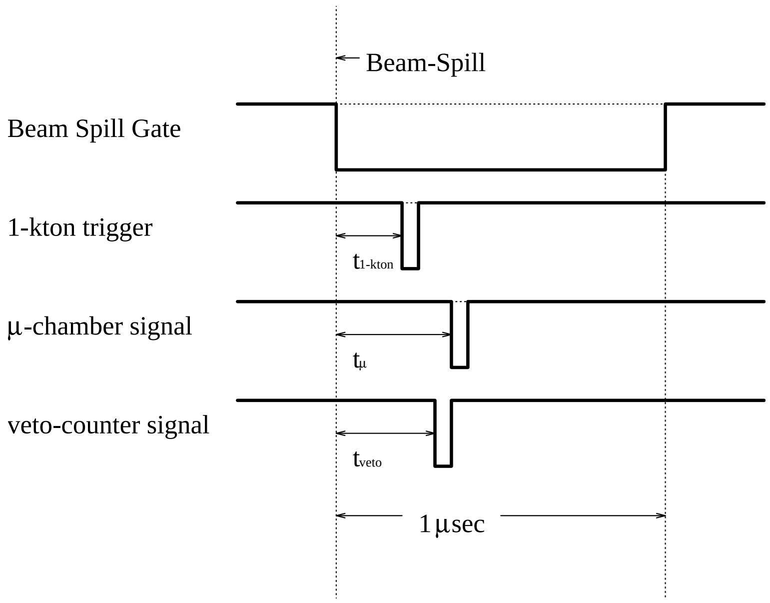

Figure 2.12: Schematic view of trigger timing

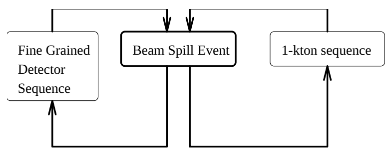

Figure 2.13: Schematic view of DAQ sequence.

2.9 Data Aqusition Sequence

The planned data acquisition sequence is as shown in Fig.2.13. The event structure is shown in Table.2.12. Beam Spill Event is a neutrino events. C.R. 1-kton is a cosmic ray event in the 1-kton detector. C.R. Fine Grained Detector (FGD) is a cosmic ray event in the fine grained detector. Lead Glass (Xe) is a calibration by Xe. Above them, we plan to take Beam Spill Event, C.R. 1-kton for each spill.

2.10 Software Structure of DAQ

Figs.2.14 – 2.17 show the planned software structure. These 3 types of computers are connected by control. data, and message in software. Control path controls all the

	1-kton	SCIFI	veto	PbG	μ-chamber
Beam	○	○	○	○	○
Pedestal(1-kton)	○				
Cosmic Ray (1-kton)	○				
Pedestal (PbG)				○	
Xe flush (PbG)				○	
Cosmic Ray (FGD)		○	○	○	○
Fiber Pos (SCIFI)		○			
Pedestal (SCIFI)		○			

Table 2.12: Planned view of Event Structure.

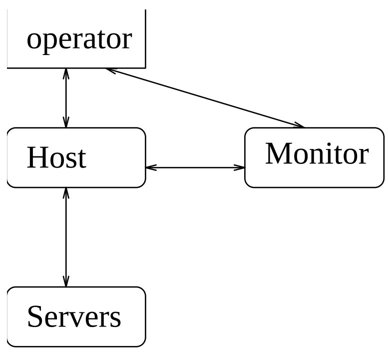

Figure 2.14: Global view of the DAQ software structure.

processes. Data path transfers all the data. Message path transfers all the message generated by the processes.

We plan to use following application software for online.

- Nova (Buffer management)
- NetNova (Buffer management (Network))
- Network Time Protocol (NTP) [3]

2.11 Requirements for the E362 DAQ

We list up the requirements of the E362 DAQ.

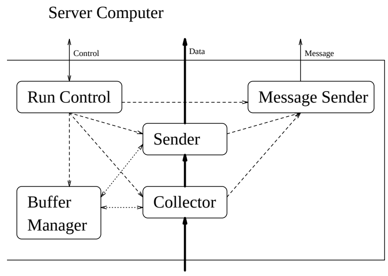

Figure 2.15: Software structure of the server process.

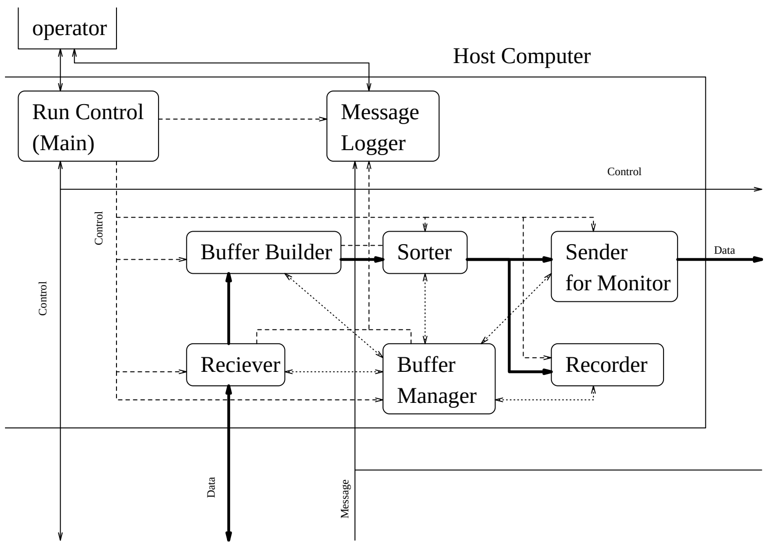

Figure 2.16: Software structure of the host process.

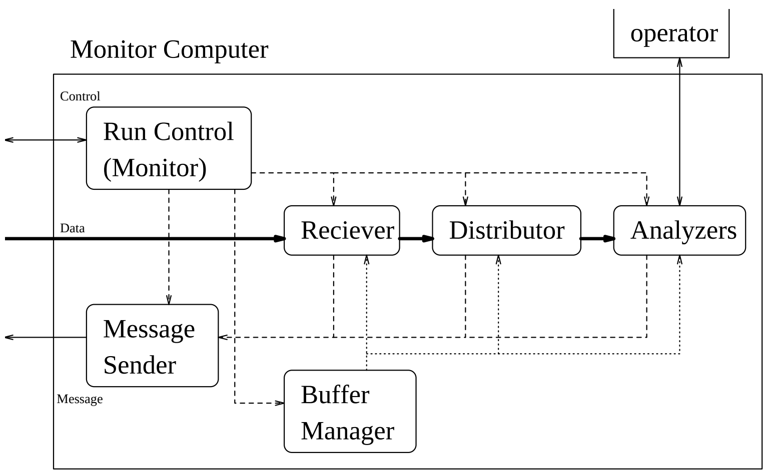

Figure 2.17: Software structure of the monitor computer.

2.11.1 Front Detector

- The DAQ system should run without stopping in 90 days (our run period).
- The system can change the run number between off-spill (2-sec).
- Every crates should recieve spill number contiuously.
- The DAQ system should support complex data aquisition sequence.
- Reset of the Hardware should be completed within 2 seconds.
- Reset of the Software should be completed nearly 2 seconds.

2.11.2 Beam Monitor

- The DAQ system should be running without stopping in 90 days (our run period).
- The precision of the clock should be less than 1μ sec.
- The spill number shoud be distributed to each crates contiuously.
- Reset of the Hardware should be completed within 2 seconds.
- Reset of the Software should be completed nearly 2 seconds.

2.11.3 Super-Kamiokande

- The precision of the clock should be less than 1μ sec.
- Hopefully the system should be dead time free.

Chapter 3

Beam-Channel Monitor

It is important to monitor the muon intensity after the decay pipe and the primary proton intensity for determining the integrated neutrino flux for Super-Kamiokande and the front detector. Fig.3.1 shows the planned beam-channel DAQ. Two monitor systems are exist in this configuration. Since one monitor located near the horn, the other monitor located near the muon monitor(200m downstream of the horn). The exact location of these two monitor system is under consideration.

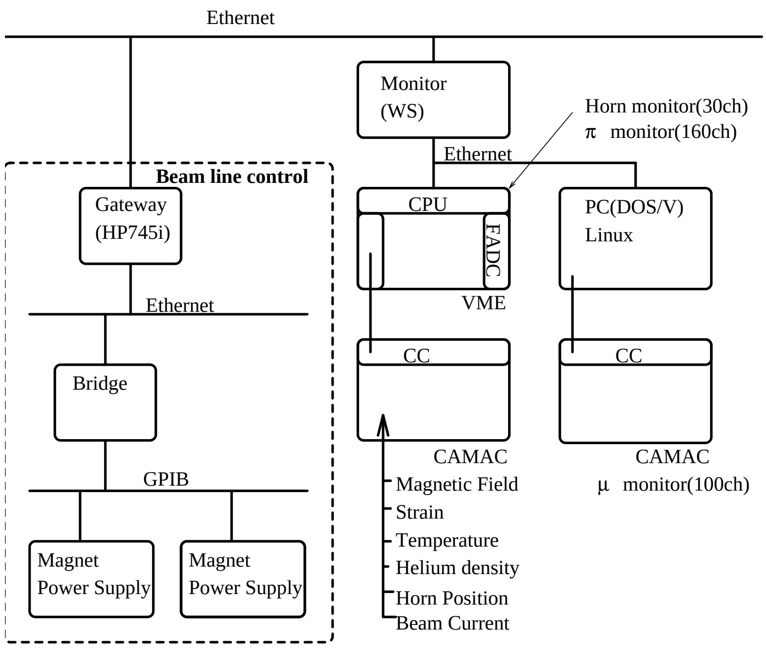

Figure 3.1: Schematic plan view of Beam-Channel DAQ system.

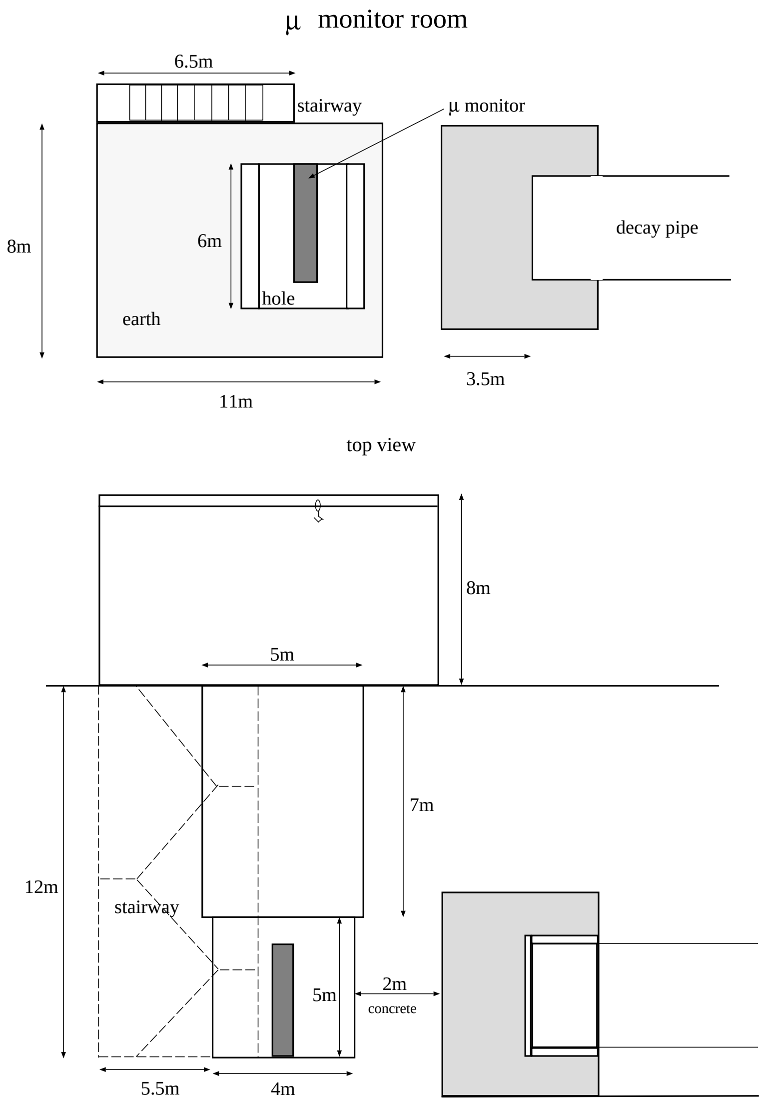

Figure 3.2: Schematic view of μ monitor room.

Chapter 4

Various properties of DAQ

4.1 Synchronization of each detector

It is important to derive total neutrino flux for Super-Kamiokande (ϕ_{SK}) and the front detector (ϕ_{FD}). For this purpose we need to synchronize the beam-channel monitor between Super-Kamiokande and the front detector. For synchronization with Super-Kamiokande we need to record the beam spill time information by GPS system and compare the event time information of Super-Kamiokande . For the front detector we transfer the spill number information to the front detector and record it. To make a confirmation of synchronization we run network time protocol (NTP) on DAQ computers. Fig. 4.1 show the planned view of the spill synchronization with Beam Channel and Front Detector. The spill number is generated in the VME-TRG module. The number is distributed by 8 or 16 NIM signals. Each crate gets a spill number using Input Registers.

4.2 Calibration of each detector

We describe the calibration of each detector at experimental hall.

4.2.1 1-kton water Čerenkov detector

Currently we planned 3 types of calibration as follows:

- Absolute Gain Calibration
- Relative Gain Calibration

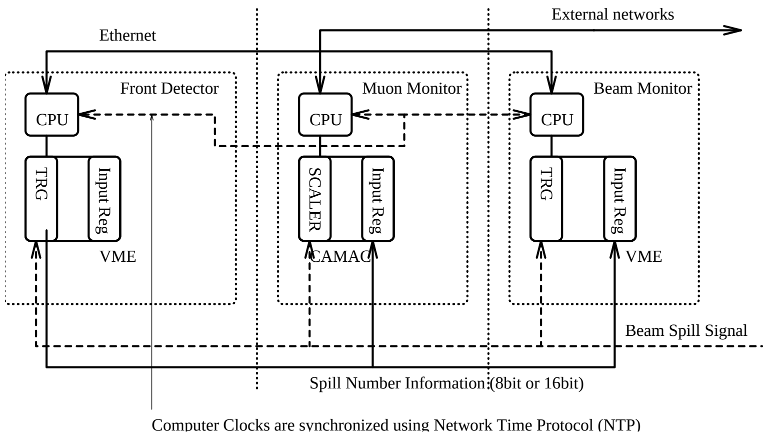

Figure 4.1: Schematic view of synchronization between BC-DAQ and FD-DAQ. The event are directly connected to cables (Spill Number). For making redundancy we use network time protocol (NTP).

- Time Calibration

We perform the absolute gain calibration by going-through Cosmic Ray muons. The relative gain calibration by scintillation-ball. The time calibration of the each PMT is performed by laser calibration. For more details of 1-kton calibration you must see the note written by Y.Itow (ICRR).

4.2.2 Water SCIFI

Currently we planned 2 types of calibration as follows:

- Scintillation fiber position calibration
- Scintillation fiber gain calibration

For position calibration, we atatch LED to each 5 fiber. And we flush these LEDs within the interval of the beam spill.

For gain calibration, we plan to use Cosmic Ray and Beam events.

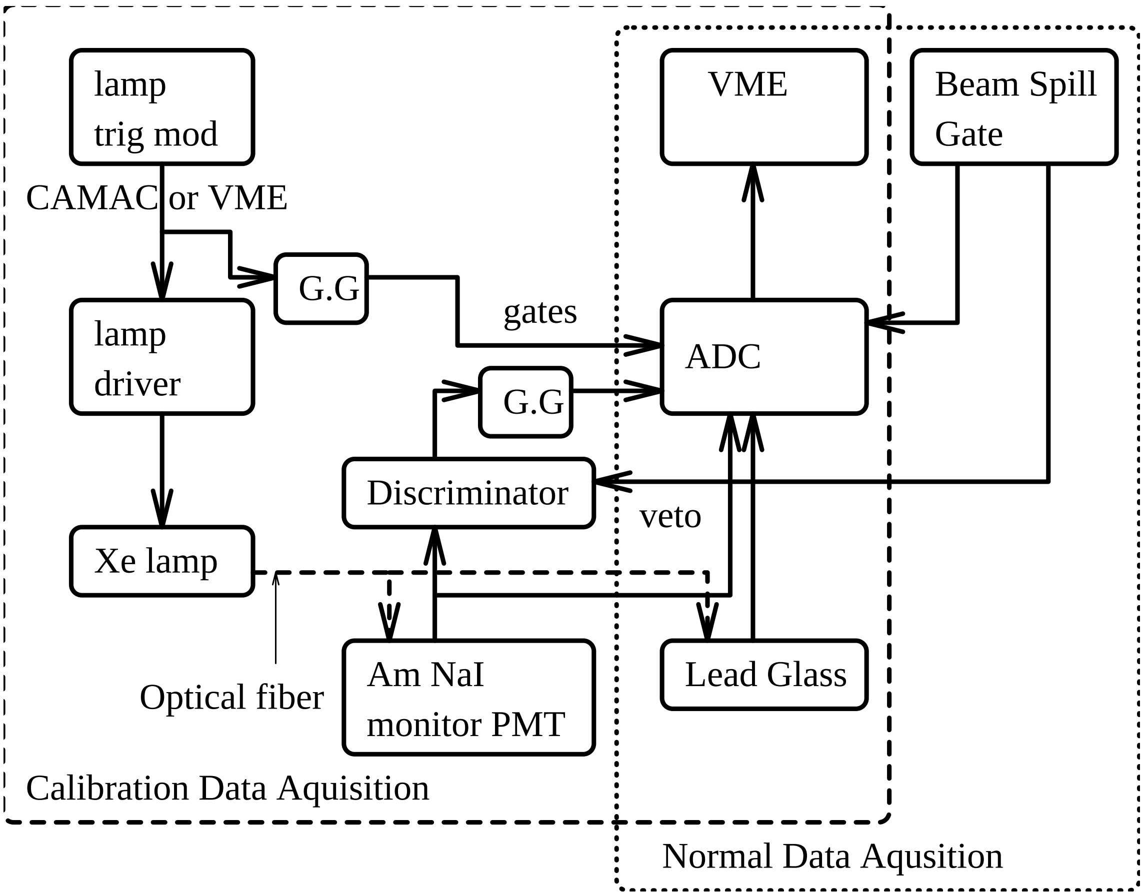

Figure 4.2: Schematic view of the lead glass calibration

4.2.3 veto counters

4.2.4 Lead Glass counters

Fig.4.2 shows the schematic view of the lead glass calibration. All channels of lead glass detector is opened when beam spill on, because of monitoring each channel pedestal. The gain of each chennel was monitored by Xe calibration system (see Fig.4.2).

4.2.5 μ-chambers

(from Ishii's report) We plan to monitor the μ-chambers by beam associated background μ.

The event rate at the front row chambers is (from calculation of T.Kobayasi):

$$0.1\mu/\text{spill}/\text{plane} \approx 40\mu/\text{day}/\text{wire} \tag{4.1}$$

The event rate after 20cm-iron down stream is:

$$0.5\mu/\text{spill}/\text{plane} \approx 200\mu/\text{day}/\text{wire} \tag{4.2}$$

From these values we can monitor the wires are alive or not within a day.

Now we consider the method of precise calibration (t_0 etc.) .

We also planned to calibrate the test pulse run at the off-beam period (before and after on-beam). The purpose is to measure the TDC linearity, threshold and efficiency.

4.3 Data size estimation

In this section, we estimate the generated data size in the E362 experiment.

Table4.1 shows the averaged data size for the E362 experiment. We assumed 1-track μ event going-through whole detectors in averaged data size estimation. In this case, the 1-kton water Čerenkov detector hits all PMTs. Since a hit in water Čerenkov detector corresponds to 2 bytes $\times$ 3 (cable number, charge, time), total data size is 5Kbytes (760 $\times$ 6 bytes). For the water-SCIFI detector, 20 (layers) $\times$ 2 (hits/layers) $\times$ 2 is expected (last 2 corresponds to X-axis and Y-axis). This corresponds to 6KB. For the Lead-Glass counters, one-cell is expected to hit. This corresponds to 4bytes. For the Muon-chambers, 13 (layers) $\times$ 2 (hits/layers) $\times$ 2 is expected (last 2 corresponds to X-axis and Y-axis). This corresponds to 200bytes.

But, Water SCIFI group[4] calculates more realistic value. Here we describe From the source test of 2-layer SCIFI with IIT, we get following value:

Event	93 pixel-hits/event
Noise	46 pixel-hits/event

In a realistic configuration of SCIFI with IIT (see Fig.2.6), 10 XX-layer of SCIFI generates lights per IIT. The data size of 1-IIT for 1-track is:

$$93 \times 10 + 46 = 976\text{pixel-hits} \tag{4.3}$$

Next, we calculate the total data size. To estimate realistic data size (XX and YY plane), we assume that 3-tracks of particles are running on average.

$$930 \times 6 \times 2 + 46 \times 24 = 12.3K\text{pixel-hits} \tag{4.4}$$

Detector	Data size	Max data size
1-kton water Čerenkov	5KB	5KB
Water SCIFI	6KB	384KB
Lead glass	3KB	3KB
Muon chamber	0.2KB	30KB
Trigger & veto counter	8B	2KB
Total (Front Detector)	14KB	424KB
horn monitor	0.1KB	2KB
π monitor	1KB	1KB
μ monitor	1KB	1KB
Total (Beam Channel)	2KB	4KB
Total	16KB	432KB

Table 4.1: Summary of the data size of the E362 experiment.

For no hit case,

$$46 \times 24 = 1.1K\text{pixel-hits} \tag{4.5}$$

From above equations we can calculate averaged data size. From T.Kobayashi calculation, the background rate from the wall is 0.025event/spill. And neutrino interaction at SCIFI itself is about 0.01event/spill

$$0.035 \times 12.3K + 0.965 \times 1.1K = 1.5K\text{pixel-hits} \tag{4.6}$$

Then we get averaged data size is 6KB/spill.

We also estimate the beam-channel data size. We only use π monitor for early period to study π momentum distribution. For this reason, we can neglect the data size of π monitor. Horn monitor includes the monitor of the primary proton intensity in the beam line. We plan to monitor 30channels of ADC. And, VME-FADC can take two-types of data, one is the precise time distribution (32KB), the other is the summary of the horn current data (4B). μ monitor generates 400bytes.

The results are shown in Table 4.1.

Number of Period	:	7
Run time/Period (day)	:	90
Beam Spill Interval (sec)	:	2.2
Number of Total Spill	:	2.5×10^7
Expected Raw-Data Size	:	400GB

Table 4.2: Basic Parameters of the E362 experiment.

4.4 Data Acquisition material list

We estimate the properties which we need in the E362 experiment DAQ. The following list (Tables 4.3 and 4.4) is temporary. We welcome comments and discussions about this list.

4.4.1 Front Detector DAQ items

Table 4.3 shows the current required list of the front detector. Online & Monitor-Computer are planned to use PC/AT (in japan we call DOS/V[1]) machines. VME-Computer is already decided to use Hewlett Packard 743rt with HP-RT (Real Time OS). This computer is supported by KEK ONLINE group. VME-Crate is a standard model of KEK (modified version of schroff).

For water SCIFI, NIM-Clock and Coordinate Generator (CCG) and NIM-FlashADC (FADC) are assembled by S.Aoki (Kobe-U). NIM-CCG and NIM-FADC are an upgraded version of CHORUS group. VME-FIFO are supplied by GND Co. VME-FIFO are designed by Y.Itow (ICRR).

TKO-SCH, GONG, TKO-ADC and VME-MP are supplied by KEK Electonics shop. TKO-GONG for 1-kton tank is supplied by ICRR. Other modules are mainly purchased by neutrino experiment groups.

4.4.2 Beam Channel DAQ items

Table 4.4 shows the list of materials. Online & Monitor-Computers are planned to use PC/AT machine. VME-Computer is HP 743rt. VME-FlashADC (FADC) was designed

[1] DOS with VGA

Material	Number	Supplyer	Purpose
Online &	2	to be	Event Build &
Monitor-Computer		determined	Monitor
VME-Computer	3	HP 743rt (2)	
		Sun-Bit3 (1)	
VME-Crate	3	Schroff (3)	
NIM-CCG	2	Aoki (KOBE)	for water SCIFI
NIM-FADC	11	Aoki (KOBE)	
VME-FIFO	11	Itow (ICRR)	
TKO-SCH	1	KEK	for lead glass
TKO-GONG	1		
VME-MP	1		
TKO-SCH	1	KEK	for muon chamber
TKO-GONG	1		
VME-MP	1		
VME-TMC	10	KEK-E362	for veto & trigger
NIM-ECL converter	20		counter
Discriminator	20		
Divider	40		
TKO-ADC	10	KEK	
TKO-SCH	1		
TKO-GONG	1		
VME-MP	1		

Table 4.3: Materials in E362 Front Detector DAQ

Material	Number	Supplyer	Purpose
Online &	2	to be	Event Build &
Monitor-Computer		determined	Monitor
VME-Computer	1	HP 743rt (1)	
VME-Crate	1	Schroff (1)	
CAMAC-VME interface	1	KEK-E362	for Horn monitor
CAMAC-CC	1		
CAMAC-ADC (12ch)	3	KEK	
CAMAC-ADC (32ch)	10		
VME-FADC	1	Kohama (KOBE)	
CAMAC-interface (for PC)	1	KEK-E362	for muon monitor
CAMAC-ADC (12ch)	10	KEK	

Table 4.4: Materials in E362 Beam-Channel DAQ

by M.Kohama (Kobe-U). CAMAC-ADCs are lend from KEK Electornics shop. Other items are purchased by the neutrino experiment group.

Chapter 5

Slow control

We need to monitor various parameters. Here we describe the slow-control monitor.

5.0.3 μ-chambers

We need to monitor the High Voltage (HV), Gas and enviroment.

- High Voltage monitor
  - Voltage
  - Current
- Gas monitor
  - Flow
  - Pressure
  - Concentration of O_2
  - Concentration of CH_4
- Enviroment
  - Temperature
  - Pressure

Chapter 6

Job assignment

We list up DAQ Jobs to be done. The schedule of following jobs is shown in Fig.6.1.

- Component check
  - HP-RT installation and check
  - PC-CAMAC installation and check
  - GPS module installation
  - FASTBUS installation
- Monitors and Interface to the offline
  - Event Display
  - Histgramming
  - Sorting Process (for Reformat and Monitor)
- Trigger and Electronics and Collection
  - Trigger Logic
  - Event Synchronization
  - Data Acquisition Sequence
  - Event Building
- Beam Channel and Slow Control Monitors
  - Determine the frame work of data acquisition

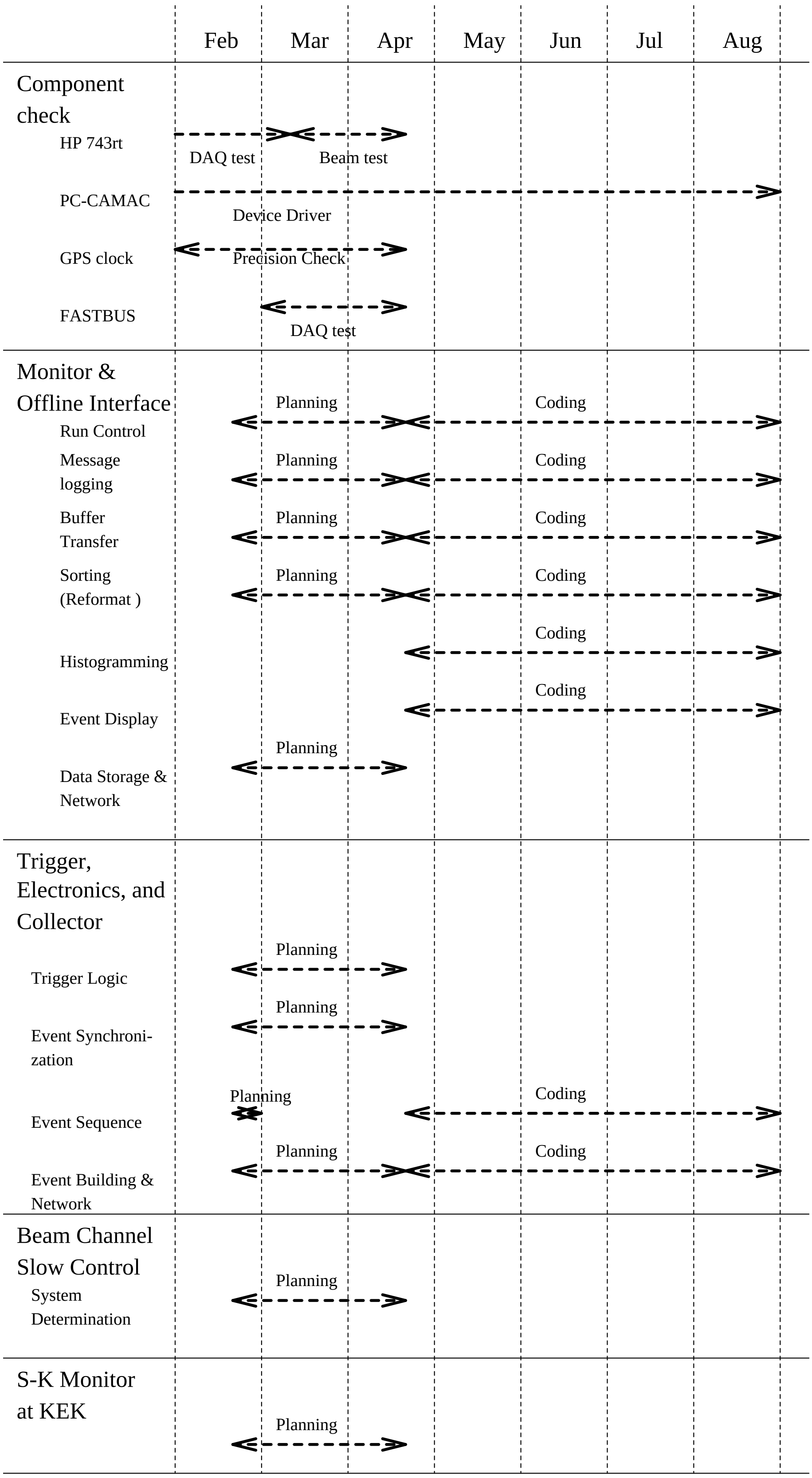

Figure 6.1: Schedule of the E362 DAQ.

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