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# A New Data Acquisition System for $4\pi$ EM Calorimeter FOREST

H. Fujimura[1], R. Hashimoto[1], T. Ishikawa[1], J. Kasagi[1], A. Kawano[2], S. Kuwasaki[1], K. Maeda[3], Y. Okada[1], Y. Sakamoto[2], M. Sato[1], H. Shimizu[1], K. Suzuki[1], Y. Tajima[4], and H. Yamazaki[1]

[1]*Laboratory of Nuclear Science, Tohoku University, Sendai 982-0826*
[2]*Department of Information Science, Tohoku Gakuin University, Sendai 980-8511*
[3]*Department of Physics, Tohoku University, Sendai 980-8578*
[4]*Networking and Computing Service Center, Yamagata University, Yamagata 990-8560*

We have developed a data acquisition (DAQ) system for a $4\pi$ electro-magnetic (EM) calorimeter complex, FOREST [1, 2]. The FOREST consists of three EM calorimeters and front-end electronics of different parts comply with different standards. The number of detectors to be read out is extremely increased as compared with that of SCISSORS II. Since FOREST has been constructed step by step over 3 years, we added and reconfigured the front-end electronics at every stage. Therefore, our requirements on the DAQ software are scalability and flexibility as well as capability of high speed up to 2 kHz trigger rate. The new DAQ system has been introduced to the FOREST experiment since early June 2008. The DAQ efficiencies have been achieved to be 88% and 76% for 1 kHz and 2 kHz trigger rate, respectively.

## §1. Framework of DAQ System

The DAQ software framework consists of collector, event builder, and recorder processes based on the C++ language [3]. Figure 1 shows the dataflow of the DAQ system. Event data transfer and command communication between different subsystem processes are handled via the Transmission Control Protocol/Internet Protocol (TCP/IP). Each TCP/IP communication uses a different port number.

The collector is a readout process which gathers the data from the front-end electronics and converts the data coming from different modules to a single output stream. The output stream is built with a basic information including a run number, an event sequential number and a collector ID number, and is sent to the event builder process. In general, more than one collector is used at the same time. The event builder process receives the data of event fragments from collectors, and unifies a complete event. The incoming data fragment is strictly combined according to an event sequential number and is attached with a basic information. The output stream is sent to the recorder process to be stored in a data file on a hard disk. The recorder process attaches a basic run information to the event data, which contains a time stamp, the number of events stored and comments to the data file.

This framework is easy to add and replace the collector processes and to allow the development of the reconfigurable hardware. Usually we use more than one collector in order to handle different

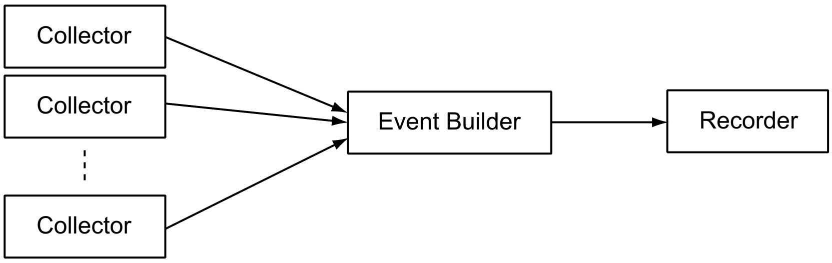


Fig.1. The dataflow of the DAQ system. The data are gathered by collector processes from the front-end electronics. An event builder process receives the data of event fragments from the collectors and builds a single output stream which is stored in a data file by the recorder process.

electronics standards. Since the main part of the DAQ dead time is caused by readout processes of the front-end electronics, parallel readout of adequate number of collector systems achieves high trigger rate and high DAQ efficiency.

## §2. Subsystem Configuration of the FOREST Experiment

All the subsystem processes work on different computers in order to reduce the load level. The data communication between the collectors and the event builder uses a private gigabit Ethernet network dedicated to the DAQ system. An event trigger signal is distributed to each collector and is read in a polling mode through a REPIC Interrupt & I/O Register RPV-130 in a VME system. Figure 2 shows the DAQ configuration. We have employed 5 collectors described as follows:

- **TKO-SMP collector**

  The front-end module is a REPIC TDC RPT-140 in a TRISTAN/KEK Online (TKO) system. The timing signals from SCISSORS III [1, 4] are measured in this collector system. The digitized data are collected and stored with Super Memory Partner (SMP) modules in a VME system through Super Controller Head (SCH) modules in the TKO systems. All the digitized data in the SMP buffer are finally accumulated in a Sanritz PC/AT compatible VME module SVA041 single board computer through the VMEbus.

  Since SMP has two data buffers, it is possible to send the data from the TKO system to SMP during the data transfer from SMP to SVA041. After a module conversion time of 80 $\mu$sec, SMP receives a signal to ask SCH to execute a sparse-data-scan. A SMP busy signal is released and a trigger signal is sent to the TKO-SMP collector through a RPV-130 after the sparse-data-scan. The collector asks SMP to switch the recording buffer to the other one and releases the event veto signal. Then SMP is ready to receive the next data from the TKO system. This buffer switching is occurred event by event. The dead time of this collector process is about 110 $\mu$sec. This is caused by conversion, sparse-data-scan, and data transfer from the TKO system to SMP.

- **FERA-UIO collector**

  The energy deposited in the Backward Gamma (BG) detector [5] is digitized by a LeCroy 4300B Fast Encoding and Readout ADC (FERA) in a CAMAC system. The data are collected from a

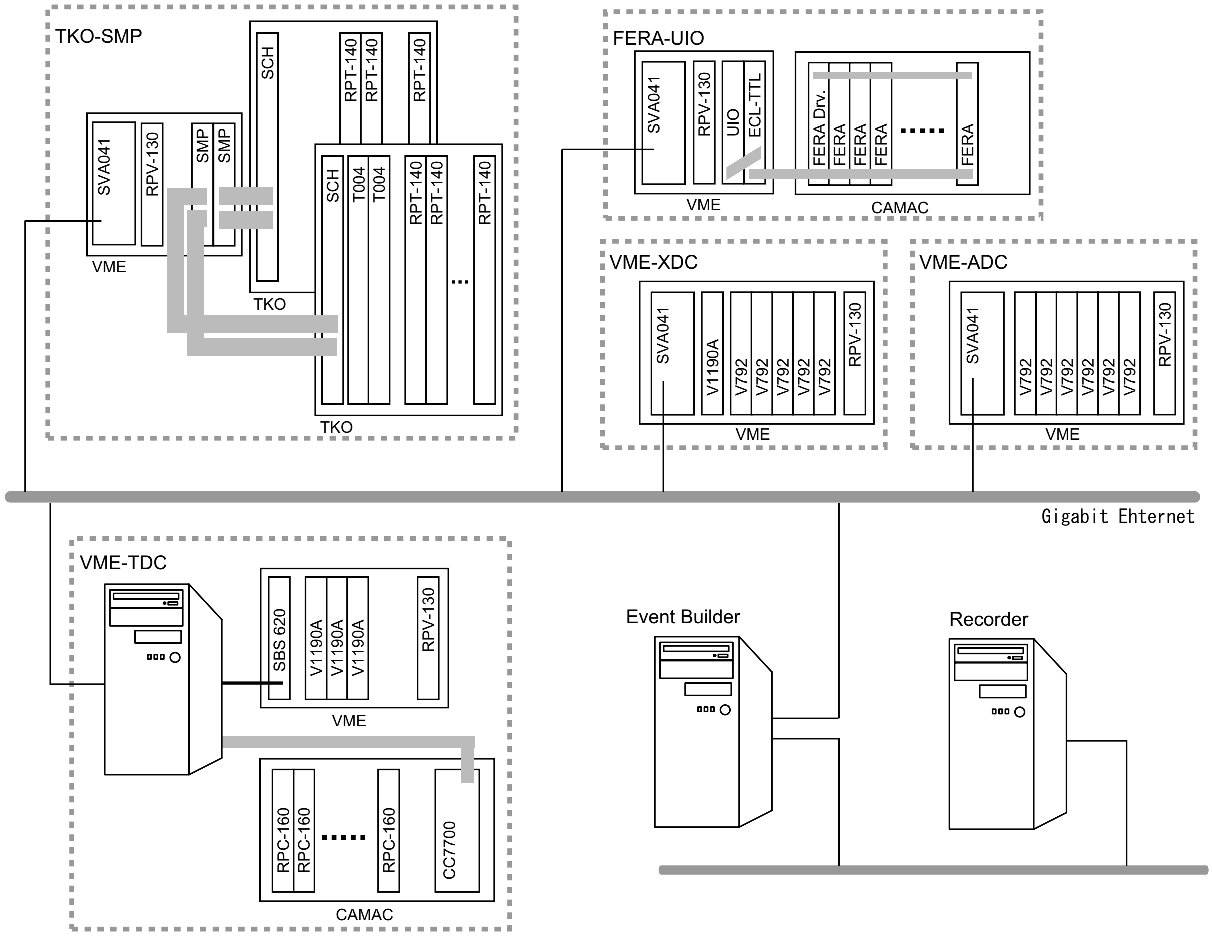


Fig.2. The DAQ subsystem configuration of the FOREST experiment. The number of collectors is 5. The computers in which the collector and event builder processes work are connected to a private gigabit Ethernet network.

LeCroy 4301 FERA driver in the CAMAC system through a FERA bus and temporally stored in a universal I/O (UIO) module [6] in a VME system. The UIO has two data buffers and each buffer is switched to the other every 20 events. After receiving a buffer change request signal, the UIO-FERA collector asks UIO to switch a recording buffer to the other one, and releases an event veto signal. The data sorted in one buffer of UIO are transferred every 20 events to the FERA-UIO collector which works on a SVA041 in the VME system, while the every-event data fragments from FERA are stored in the other one. The collector slices the data stream from UIO into 20 event fragments and sends an output stream in the order of event sequential number.

The ADC data are read without pedestal suppressions; the dead time of every event is about 120 $\mu$sec. This is mainly caused by the bus communication speed between UIO and FERA.

- **VME-TDC collector**

  The timing signals from the BG detector are measured with CAEN V1190A 128 Ch Multihit TDC modules in a VME system. The digitized data are transferred to a personal computer (PC) in

Table 1. The number of channels connected to the front-end electronics of each collector. The list is classified by the FOREST detector assembly. The last line shows the average dead time of each collector. The TDC modules used are REPIC RPT-140 and CAEN V1190A. The ADC modules used are LeCroy FERA and CAEN V792. The REPIC RPC-160 is a scaler module.

| | TKO-SMP | FERA-UIO | VME-TDC | | VME-XDC | | VME-ADC |
|---|---|---|---|---|---|---|---|
| | RPT-140 | FERA | V1190A | RPC-160 | V1190A | V792 | V792 |
| STB-Tagger II | 116 | — | — | 116 | — | — | — |
| SCISSORS III | 192 | — | — | 10 | — | — | 192 |
| Backward Gamma | — | 252 | 252 | — | — | — | — |
| Rafflesia II | — | — | 48 | — | 14 | 62 | — |
| Plastic scintillators | — | — | — | — | 90 | 90 | — |
| Others | — | 3 | 4 | 12 | 1 | — | — |
| Total | 308 | 255 | 304 | 138 | 105 | 152 | 192 |
| Dead time ($\mu$sec) | 110 | 120 | <50 | — | <40 | | <40 |

sequential mode via a SBS Technologies (Bit3) PCI-VME interface 620. Since the data buffer of V1190A is a First-In First-Out (FIFO) structure, it is possible to read out the data stored in the FIFO buffer while the other data taking process, conversion and setting the data to the FIFO buffer, is being treated. The dead time is less than 50 $\mu$sec and negligibly small.

The VME-TDC collector also handles REPIC RPC-160 scaler modules in a CAMAC system via a TOYO Corporation CAMAC controller CC7700. The scaler data are collected every spill off.

- **VME-XDC collector**

  The VME-XDC collector consists of a CAEN V1190A module and CAEN V792 32 Ch QDC modules. The deposited energy and the timing signals from plastic scintillator detectors in front of the EM calorimeters [2] are digitized by these VME modules. The data are gathered in sequential mode by a SVA041 in a VME system. Since the data buffer of V1190A and V792 are FIFO, the dead time is less than 40 $\mu$sec and negligibly small.

- **VME-ADC collector**

  The energy from each crystal of SCISSORS III is digitized by a CAEN V792. The data are collected by a SVA041 single board computer in a VME system. Since the data buffer of V792 has a FIFO structure. the dead time is less than 40 $\mu$sec and negligibly small.

The number of channels connected to the front-end electronics of each collector are summarized in the Table 1. The average dead time of each collector is also listed.

## §3. Beam Test

A performance study using a $\gamma$-beam was carried out in June and July 2008. The trigger condition for the DAQ system was more than one cluster hit measured by FOREST and at least one hit measured in STB-Tagger II [7, 8]. The typical data size was 2 kB/event with a liquid hydrogen target with a thickness of 40 mm. All the ADC data were read out without pedestal suppressions. The DAQ dead time was about 120 $\mu$sec. This is mainly caused by the FERA-UIO and TKO-SMP collector processes, and the dead times of the other collectors were negligiblly small. The DAQ efficiencies were about 88 % and 76 % for 1 kHz and 2 kHz trigger rate, respectively.

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## References

[1] T. Ishikawa *et al.*: Research Report of LNS, Tohoku University **39** (2006) 35.
[2] T. Ishikawa *et al.*: in this Research Report of LNS, **41** (2008) 7 .
[3] ISO/IEC 14882:2003
[4] T. Ishikawa *et al.*: Research Report of LNS, Tohoku University **40** (2007) 23.
[5] T. Ishikawa *et al.*: Research Report of LNS, Tohoku University **40** (2007) 19.
[6] Y. Sugaya and M. Nomachi: Nucl. Instrum. and Meth. **A437** (1999) 68.
[7] T. Nakabayashi *et al.*: Research Report of LNS, Tohoku University **37** (2004) 17.
[8] T. Ishikawa *et al.*, in this Research Report of LNS, **41** (2008) 1.