# DATA ACQUISITION SYSTEM FOR NORDBALL

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Abstract

A modular data aqcuisition system based on parallel data read-out and processing and utilizing several MC68xxx based CPU's and VME-buses is described. It has been designed for a joint Nordic Nuclear physics (heavy-ion) $4\pi$ multidetector system - Nordball, but is easily applicable for other systems. Readout and preprocessing system has been implemented and full processing system is under construction.

## 1. Introduction

The rapid development in the experimental facilities during last few years and even more complex systems available in the future have created greater demands on data aqcuisition systems of a nuclear physics laboratories. Especially multicoincidence and multiparameter experiments used in nuclear physics research can only be matched with a multiprocessor data aqcuisition and processing system. The joint Nordic multidetector system (NORDBALL) requires an efficient data aqcuisition system, but also experiments with other equipments are becoming more complex. An efficient system designed for such a detector arrangement with tens of parameters can also easily be adapted for smaller scale experiments and used in smaller laboratories.

The basic concept of the NORDBALL project is that many different types of detectors needed for the experimental program are designed with the restrictions given by the modular NORDBALL frame.

The basic structure gives room for 20 large BGO shielded Ge-detectors placed in the hexagons and 12 smaller detectors placed in the pentagons.

It is planned that at least one frame is installed in connection with each accelerator in the Nordic countries. Many groups are taking part in the design of special equipment for their own primary use, which then becomes available to other users too. The following detector systems are considerd at the moment.

1. Anticompton spectrometers
2. Calorimeter for sum energy and gamma multiplicity and with time of flight (TOF) discriminations against neutrons

3. Beta-spectrometers of the orange type
4. Neutron TOF detectors
5. Particle telescopes
6. Recoil detectors
7. Position sensitive detectors doe Coulomb excitation experiments
8. A plunger facility for lifetime measurements
9. A catcher facility for experiments with delayed radiation

A typical example of the NORDBALL equipped with 20 anticompton spectrometers and a $BaF_2$ calorimeter for high spin spectroscopy is shown in fig. 1.

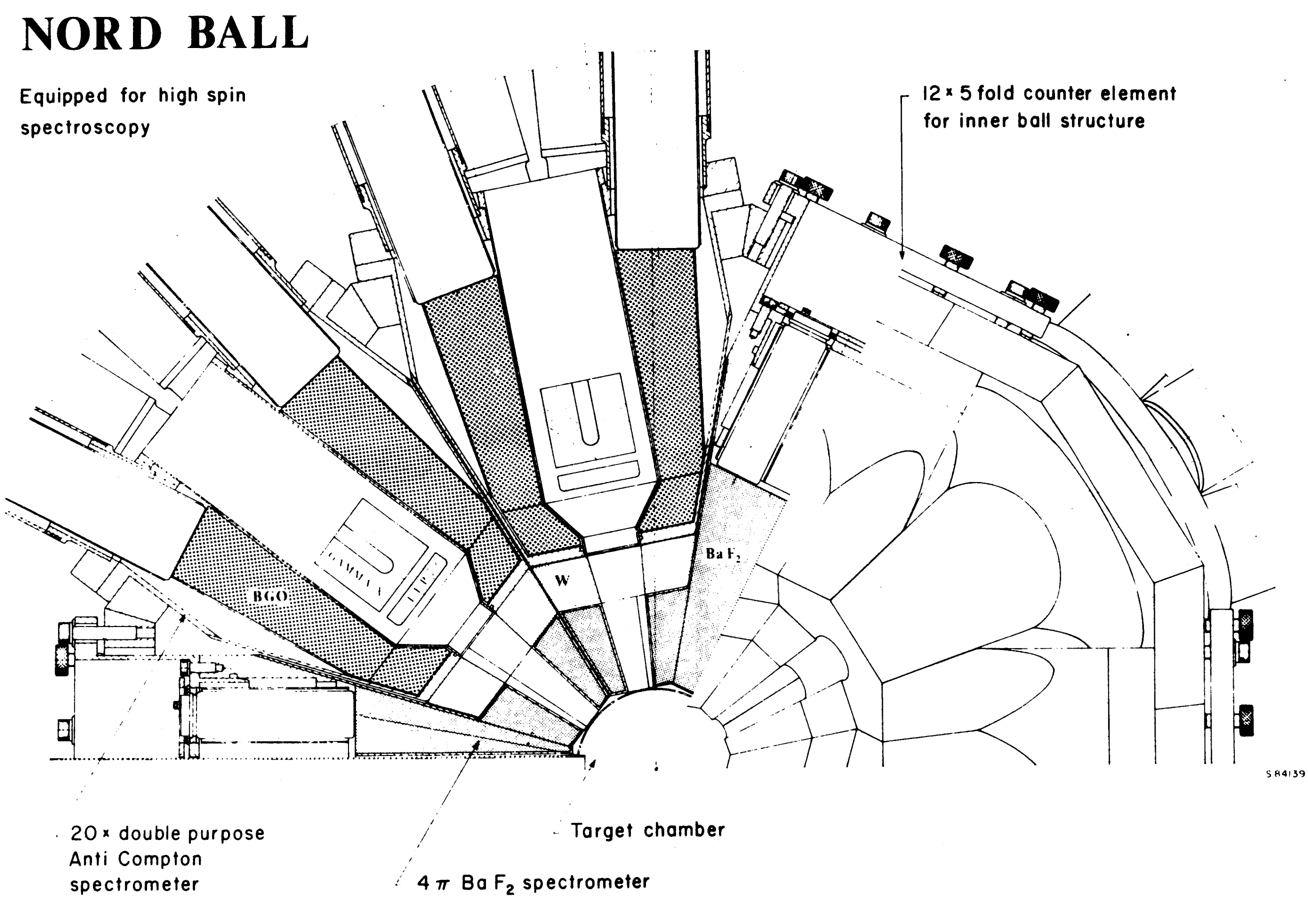


Fig. 1. A cut through the Nordball equipped with detectors for a typical high spin experiment. The set up includes 20 Anti-Compton spectrometers and a $4\pi$ $BaF_2$ calorimeter around the center.

The most important detector, the basic element in NORDBALL detector system is the anticompton spectrometer.

The design is compact and easy to "pack" around the target to obtain optimum solid angle for each detector. The triple coincidence rate is proportional to the 6th power of the distance to the target. A good response function with a high peak/total ratio is also very important such that the remaining background can easily be removed by simple unfolding procedures. It may then become feasible to unfold 3- and maybe 4-dimensional matrix spectra without erroneous "blowup".

The main use of the data acquisition system for NORDBALL is to collect data from the experiment and to store it for final data analysis. However, also on-line sorting is essential due to large amount of events. The data acquisition system has been designed

1) to collect event-by-event data up to 500 kB/s rate without considerable dead time.
2) to preprocess events according to users criteria(by calibrating, gating etc.)
3) to sort or presort some type of events on-line into computer memory or to disk
4) to store unsorted events (or all events if so desired) on tape or disk
5) to monitor some critical parameters during the experiment.

In order to fullfil these requirements a modular VME-based system have been designed. The whole data acquisition system is modular both in hardware and in software design. It is constructed in two steps and thus there will be two generations of the system. It has also been designed so that it can be used at different size of Nordic laboratories together with the NORDBALL or for some other experiments.

## 2. First generation

In the first generation, which has been constructed, the data collection and preprocessing is implemented on a multiprocessor VME-system. At this point the on-line sorting and storage of the event-by-event data is done by a host computer which has disk and tape units. The existing laboratory computers in each laboratory (PDP, VAX) are used as the host computer. A schematic diagram of a hardware setup of the first generation data acquisition system with one VME-crate and a VAX host computer is shown in Fig. 2. As seen from the figure the system can logically and physically be divided into three separate parts: the LAB-system, the VME-system and the host computer.

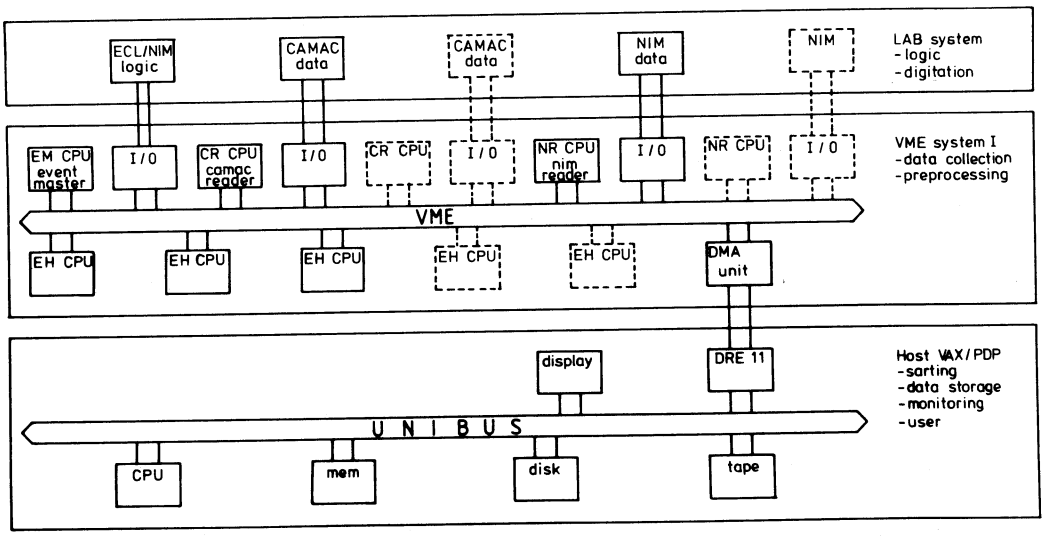


Fig. 2. A block diagram of the hardware of the first generation data acquisition system.

The LAB-system consists of the data digitation devices (ADC's, TDS's, etc.), their housing and interfacing. The system is designed so that different kind of laboratory equipment and data transfer connections can be used according to local and experimental requirements. Presently these include interfaces to NIM and ECL logic, CAMAC crates and direct interface of NIM ADC's to the VME-bus. Later connections for Fastbus, IEEE-488 bus etc. can be implemented. The system is designed to be fully modular so that any combination of the laboratory interfaces can be used.

The VME system I is a multiprocessor system based on one global VME-bus, which can also be distributed into several VMEbuses, several MC68000 (or MC68010) microprocessor cpu's and local buses. This system is used to manage and perform the event-by-event collection from the LAB-system using parallel readout, to perform event-by-event preprocessing (calibration, event recognition, gating, event formating etc.) and to pass the data to the host computer via a fast parallel I/O link. The use of several cpu's on the system enables parallel readout and preprocessing thus utilizing the full power of the VME-system to receive a fast data throughput.

The host VAX computer is used to enter the user control commands, to control the data acquisition, to sort events on-line and to store the sorted spectra into memory or on disk and to write the events on tape as desired. The fast parallel (16 bit) DMA link to the host computer for VAX and PDP computers is done with DRE11 or DR11W units.

The VME-system I used for data collection includes one cpu that will control the event-by-event data readout and preprocessing. Here this cpu is named EM (event master). It is a master cpu only in a logical (software) sense because each of the cpu's in the system will be the actual bus master whenever it will be using the bus. In addition to the general management of the data EM will handle the communications to the external event logic system. The direct interfacing of the NIM ADC's to the readout VME-bus are done with a 15-channel (16 bits/channel) input registers JYVME-I developed at University of Jyväskylä. The data from these interfaces are read with NIM reader cpus (NR). Depending on the actual number of NIM interfaces and data rate one or more NR cpu's can be used in the system.

Also several CAMAC crates can be interfaced to the VME system. Each crate will be connected using the CAMAC-crate controller developed at the University of Lund and one cpu, (CR). The data from each CAMAC crate and NIM interface are read by the corresponding reader cpu and passed to the system via the dual ported memory of the preprocessing or event handler cpu's (EH).

The preprocessing of the event-by-event data is done using several parallel cpu's connected to the VMEbus and having dual ported memory for data transfer. These cpu's are called event handlers, EH's. The data processing is done by the cpu's using a local bus without disturbing the VME-bus and then passed forward, in block mode using, the fast DMA link.

## 2.1. Event collection

The external ECL logic is used to create an event signal (trigger) and to interrupt the event master (EM) externally. It also provides a master event pattern and other information about the event for EM cpu. Once interrupted EM cpu will create an external busy to block further events during the readout and make up the reader cpu's to start the parallel readout. The event master cpu (EM) selects a free event handler cpu ( EH), during data digitation and instructs the reader cpu's to press data that cpu.

After the readout is finished and the data is stored into the dual ported memory of the EH cpu each reader cpu informs EM cpu and get ready for the next event. At this point the data has been transferred from the LAB-system into the VME-system and thus EM cpu clears the data registers (JYVME-I, CAMAC TDC's, ADC's and IR's, etc.) externally and then allows new events by releasing the busy signal. It should be noted that using this readout system the parameters are transferred parallel and thus effective transfer rate of several megabytes per second can be reached.

After releasing the LAB-system for the next event, CPU EM will interrupt the processing (EH) cpu locate a new free event handler and wait for the next event.

## 2.2. Preprocessing

The preprocessing cpu's manipulate the event-by-event data according to user's definitions. At the preprocessing system parameters can be selected, new parameters can be defined, whole events or individual parameters can be gated, some parameters can be calibrated etc. The preprocessing cpu's process the events using local bus without disturbing the VME bus and place the events into a buffer in dual parted memory. Whenever the output buffer is filled the cpu initiates a DMA transfer from dual ported memory into the host computer using the VME bus, and DRE11 link. The number of the preprocessing cpu's required depends on the event data rate and it can vary from experiment to another. The system is designed to use one to eight preprocessing cpu's without any changes. Typically one to three cpu's are enough. Since the event handler cpu all do the same event formating handling separate events they are independent of each other and the number of them can vary from experimental to another.

## 2.3. Host computer

The maximum data collection speed is received if each laboratory interface used in the experiment is controlled with its own reader cpu. However, one cpu can manage several interfaces and in an experiment with low counting rates the event master (EM)can do also the readout. Futhermore the addition of different readout channels (ex Fastbus) are relatively easily incorporated to the system of this modular design.

The software for the data collection system is written so that it is adaptable for systems of different sizes from a small system with one cpu up to a multiparameter experimental setup. The data rate received with DRE11 can be easily obtained with the VME system described above. Actually the processing load of the host computer can be decreased by adding more preprocessing power to the system and implementing maximum amount of processing into this step of the data acquisition. The on-line sorting of the events and writing of event-by-event data on tape will be done by the host computer.

In addition to the parallel DRE11 connection between the VME system and the host computer a serial RS232C connection is used for the user control of the experiment. The definitions and the control of the experiment is done by using a control program in the host computer. The same control program is used in the host computer to define the form of data storage. At the first generation the existing tape and disk units are used in the host computer. Eventually a new on-line sorting system will be developed for the host VAX computers to create spectra on disk. However, since the readout from DRE11 is formally equivalent for reading data from event tapes any existing off-line sorting system can be easily modified to be a temporary on-line sorting system. The existing on-line sorting system at PDP11/44 in Jyväskylä has been modified for the new VME based data acquisition system and the modification of the on-line sorting system on VAX 11/780 at Niels Bohr Institute (Risø, Denmark) is under way. An experimental version of the first generation of the data acquisition system has been developed at JYFL during the spring 1985 and is used for experiemnts at Jyväskylä Cyclotron Laboratory. The system will be implemented using a VAX host computer during the and fall 1985. A small version of the Nordball will be operational early 1986 at Risø.

3. The second generation

The second generation will include all the parts of the first generation and a second VME-system will be added and the on-line data sorting will be done by this VME system II. A schematic diagram of the second generation data acquisition system is shown in fig. 3. The host computer will still control the system (user communication program). The VME system II will be based on full 32 bit address and data space and at least at some parts use MC68020 based CPU's. The data sorting will be done by several cpu's (DS) which are controlled by one data master CPU (DM), (parallel processing).

The sequence of the data sorting at this stage will be done much the same way as the event preprocessing is done in the data collection at VME system I. Here, however, the master CPU will receive blocks from the VME system I via the crate interconnect units and the processing cpu's (DS) will sort the events one block at a time. The master cpu (DM) will distribute the blocks for the slave cpu's se-

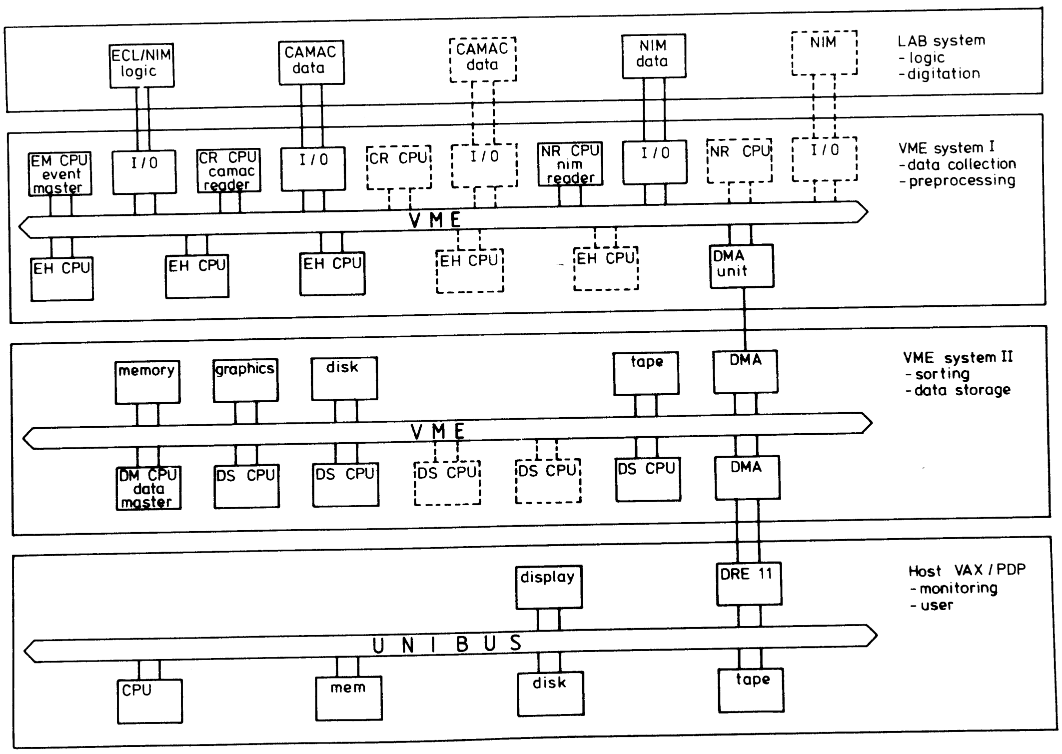


Fig. 3. A block diagram of the hardware of the second generation data acquisition system.

quentially. Also here the amount of the cpu's depend on the amount of computing power required. Since all the slave cpu's are performing the same functions doubling of the number of cpu's will double also the computing power.

Because of the large address space (4GB) even big matrices can be created in memory. In Nordball experiments at least one $E\gamma$ vs $E\gamma$ spectrum can be created into the memory. In addition to the on-line sorting a graphics system for on-line data display in the VME-bus system will be developed. The development of the VME system II have been started in fall -85 and it will be finished during the spring -86.

The VME system II will also be made modular in both hardware and software so that it can be implemented with different amount of cpu's according to the experimental and laboratory requirements. It will also be designed so that it can be used for off-line data analysis (data playback) to sort the stored events. At this mode the events will be fed from the host computer via DRE11 system or read from a storage unit directly connected to the VME system II.

Acknowledgement

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