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DATA ACQUISITION FOR THE HILI DETECTOR

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Abstract

A large acceptance, multi-segmented detector system capable of the simultaneous detection of heavy and light ions has been constructed. The heavy ions are detected with a segmented gas ionization chamber and a multiwire proportional counter while the light ions are detected with a 192 element plastic phoswich hodoscope. Processing the large number of signals is accomplished through a combination of CAMAC and FASTBUS modules and preprocessors, and a Host minicomputer. Details of the data acquisition system and the reasons for adopting a dual standards system are discussed. In addition, a technique for processing signals from an individual hodoscope detector is presented.

Introduction

A large acceptance detector capable of detecting multiple heavy ions in coincidence with multiple light ions has been constructed at the Holified Heavy Ion Research Facility (HHIRF). An exploded view of the Heavy Ion Light Ion (HILI) detector with its three major subsystems is shown in figure 1. We present, herein, its signal processing scheme and data acquisition system. In addition, we will also discuss the event rate capabilities of the detector.

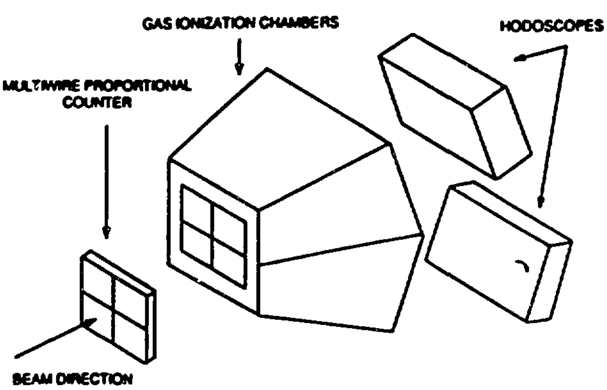

Figure 1. An exploded view of the HILI detector.

The HILI detector

The HILI detector is made up of three major components. They are (1) a four quadrant multiwire proportional counter which is operated at low gas pressures, (2) two segmented gas ionization chambers, and (3) two 96 element scintillation hodoscopes. The multiwire proportional counter (MWPC) provides a fast timing signal which can be used as the primary event trigger. Using delay line chips, it can also measure the horizontal position of the heavy ions that traverse it.[1] Located directly behind the multiwire proportional counter are the upper and lower halves of the gas ionization chambers. The first two components of the detector system are used primarily to detect and identify heavy fragments. Each half is divided into two quadrants with each quadrant having multiple electrodes that measure the energy loss of the incident heavy ions. Besides the energy signals, a vertical drift time is also derived from the fast start in the multiwire proportional counter and from one of the anode signals in each quadrant of the ionization chamber. This signal together with the horizontal position signal obtained from the multiwire proportional counter determines the x and y position of the heavy ion. The upper and lower ionization chambers are isolated from each other and can be operated at different gas pressures. They can therefore, be configured to detect different ranges of Z. The hodoscopes are mounted behind the gas ionization chambers. Each hodoscope is made up of 96 plastic "phoswich"[2] detectors and it is designed primarily to detect light ions (n,p,α), although we have successfully identified energetic light heavy ions up to Z = 8.

The signal processing scheme used for one quadrant of the detector system is shown in figure 2. It is, for the most part, quite straightforward. However, the scheme used to process signals from an individual hodoscope element bears mention and will be described in detail below. One feature that has not been mentioned is the alternative trigger shown in the diagram which is derived from the OR of the hodoscope discriminators. Presently, the detector may be triggered in one of three ways — (1) by the multiwire proportional counter, (2) by the hodoscope, or (3) by a logical combination of both triggers.

The entrance window of the HILI detector spans ±20° in the horizontal plane and ±16° vertically. When it is positioned at 0°, the detector is particularly suited to the study of inverse kinematic reactions where the forward focus of the reaction products increases its effective solid angle. With its high degree of hodoscope segmentation, the detector can be used to study correlations between emitted light particles, and these correlated events can further be characterized by the heavy fragments detected in the gas ionization chambers. One half of the full complement of detectors has already been implemented, and has been used to study energy and angular momentum distributions in heavy fragments produced by the close collisions between a 950 MeV ^{58}Ni beam and a ^{12}C target.

"Phoswich" Signal Processing

Each "Phoswich" detector is made up of a 0.5 mm thick "fast" (decay time ~3 ns) plastic scintillator,

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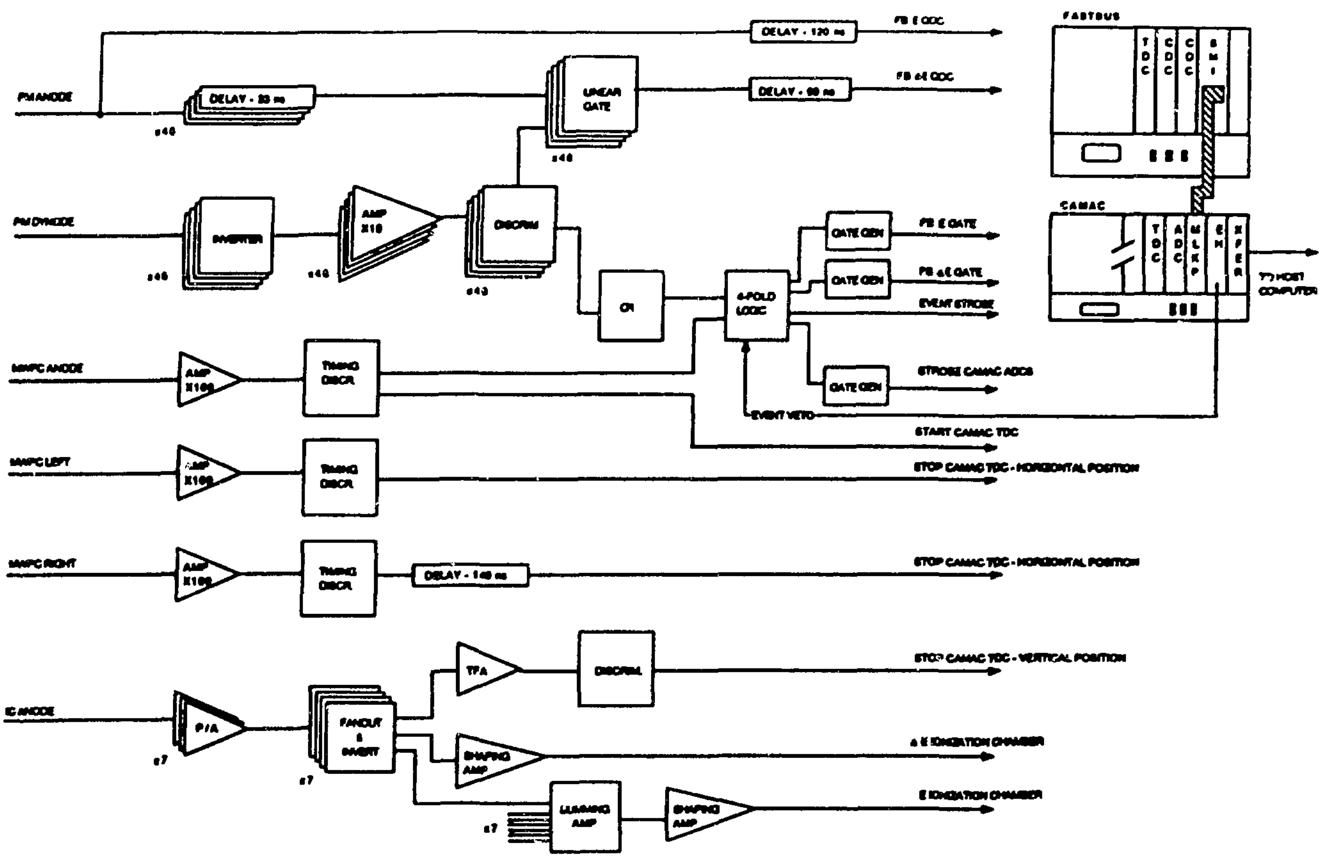

FIGURE 2. Block diagram of the signal processing electronics for one quadrant of the HILI detector. Also, shown is the data acquisition system.

backed by a 10 cm thick "slow" (decay time ~300 ns) plastic scintillator. The scintillators are optically coupled to a single photomultiplier. Particle identification is accomplished by integrating the fast component of the combined light signal which gives the energy loss (ΔE) in the 0.5 mm plastic, and by integrating the total light signal which gives the total energy deposited in the detector. The integration is done by feeding the photomultiplier's anode current into a pair of LeCroy 1885 charge integrating QDCs. An independent event pulse, typically the primary event trigger obtained from the multiwire proportional counter, is used to provide the integration gate. The gate widths are 1 μs for the EQDC and 100 ns for the ΔEQDC, and are both sufficiently wide to accomodate the expected flight time differences of the light ions. In the case of the total energy signals, the anode current is fed directly into the QDC. Since its gate width is large, differences in the flight times of the ions have little effect on the integrated value of E. On the other hand, the fast component of the light signals is only about 8-12 ns wide, which means that the expected variations in the flight times (~±10 ns) will affect the derived value of ΔE. This problem is solved by using a linear gate module. The current signals is "clipped' by a linear gate, a Phillips 7145, before it is analyzed by the ΔEQDC. The clipping gate which is about 40 ns wide, is obtained from the discriminator output of the signal itself. Therefore, it is fixed in time with respect to the signal and is independent of the arrival time of the light ion at the hodoscope. This "self-gating" technique permits a longer integration gate to be applied to the QDC while avoiding erroneous ΔE values.

Figure 3 shows this signal processing scheme. The input to the discriminator is derived from a dynode signal. Because it is positive and has a small amplitude, it is inverted and amplified before it is input into the discriminator. The signal is passed through a high pass filter to remove any offsets produced by the linear gate module as well as to filter out possible low frequency (line) noise before it is integrated by the QDC. Since the maximum counting rate is each hodoscope element is not expected to exceed a few kHz, the signal quality is not affected.

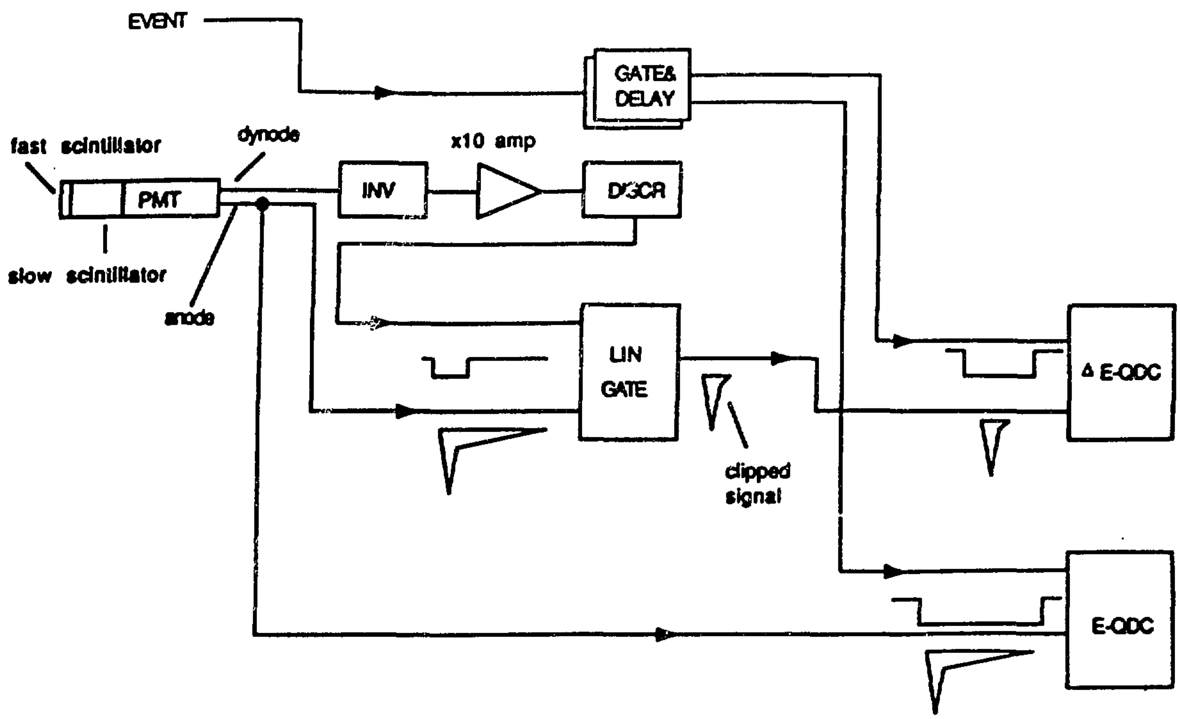

Fig. 3 The block diagram shows the signal processing scheme for a single 'phoswich' detector.

<u>Why a dual standards acquisition system?</u>

The data acquisition task on the HILI detector is shared by CAMAC and FASTBUS components. Signals from the heavy ion detector, that is, the multiwire proportional counter and the gas ionization chamber, are converted by the CAMAC component, while the light ion signals from the hodoscopes are processed by the FASTBUS component. The reasons for adopting a dual standards data acquisition system may be enumerated as follows:

1. Integration of the HILI's front-end data acquisition system into the HHIRF data acquisition environment.
2. The division into CAMAC and FASTBUS components addresses the requirements imposed by the typical event profile.
3. Cost of the acquisition electronics per detector unit.

Data acquisition at the Holifield facility is built around the Event Handler,[3] a CAMAC based programmable front-end processor, and the Concurrent 3220 minicomputers. There exists extensive software for data processing and analysis for this system. It was therefore, the logical choice to utilize the Event Handler for the overall control of the HILI's data acquisition system and for transferring data to the host minicomputer. Furthermore, the data acquisition code for the Event Handler is written in an assembly language developed at HHIRF.[4] It is therefore, a simple matter to adapt the code to specific needs of the experiment.

The choice of the front-end acquisition system depends on the event profile which should typically consist of 1 to 2 heavy ions and several light ions. The number of light ions produced are not expected to exceed 10 per event. In the case of such sparse data events, the FASTBUS system is the natural choice given its fast data transfer rate across the FASTBUS segment and the ability of the LeCroy 1821 programmable Segment Manager/Interface to delete empty channels from the data stream. On the other hand, the few signals that come from the multiwire proportional counter and the gas ionization chambers can be adequately analyzed by the lower density CAMAC modules. There are also a larger variety of commercially available CAMAC modules which lend greater flexibility in designing the data acquisition system for specific needs. For example, we have incorporated a second level software trigger which selectively accepts or rejects events. Because of its large acceptance, the HILI detector will "see" a large number of quasielastic events. These can be scaled down or rejected by converting a select number of parameters with fast discrete ADCs. Specifically, the ΔE and E values for each quadrant of the gas ionization chambers are converted and tested against a window drawn around the quasielastics in a $\Delta E - E$ map. Based on the outcome, the decision to accept or reject the event can be made in less than 25 μs.

One must also consider the resulting cost of electronics for a detector system. Since the multiwire proportional counter and the gas ionization chambers produce only a small number of signals (there are presently 30 parameters derived from the heavy ion detectors), CAMAC modules offer a cost effective solution. On the other hand, it is cheaper to use the high density FASTBUS modules to process the 288 signals from each hodoscope.

Integrating CAMAC and FASTBUS

The problems of integrating CAMAC and FASTBUS based components into a working data acquisition system arise from the simple facts that: (1) the signals standards are different, (2) CAMAC is a synchronous standard while FASTBUS operates asynchronously, and (3) the instruction cycles of the Event Handler and the LeCroy Segment Manager operate at different speeds. The first problem is treated simply with a signal conversion unit. The other two problems are solved by developing a simple handshake procedure between the two front-end processors which will be outlined below.

As we have mentioned, the Event Handler retains overall control of the data acquisition process. Although the LeCroy Segment Manager is the functional master of the FASTBUS crate, it is in effect, a slave module to the Event Handler. The Event Handler reads data from both the CAMAC and FASTBUS modules. It retrieves data from the FASTBUS modules by instructing the Segment Manager to read them. Communication and data transfer between the Event Handler and the Segment Manager is facilitated through an interface module that resides on the CAMAC crate. The interface module, called the memory lookup unit, was built by one of us (JWM). It contains CAMAC subaddress registers that corresponds to the internal HOST I/O registers that reside on the Segment Manager, and is physically connected to the front-panel of the Segment Manager by a 34 pin ribbon cable. Parameters are passed to and from the Segment Manager by simply issuing NAFs to the appropriate subaddress registers on the lookup unit. In addition, the memory lookup unit converts the geographical address (GA) field of the 32-bit FASTBUS word into a parameter tag suitable for the HOST computer's data acquisition system. By placing the parameter tag in the data stream, one may within the HHIRF's data acquisition environment, implement on-line histogramming and monitoring tasks.

When an event is accepted, the Event Handler first reads the fast ADCs. It checks the ΔE and E values against the "scale-down" window and decides whether to proceed with a complete readout or to issue a fast clear. It is decides to accept the event, it then reads out the remaining CAMAC modules. It also sets an event inhibit which blocks out any subsequent event triggers. When the CAMAC readout is completed, it strobes the Segment Manager which in turn reads out the FASTBUS modules. The FASTBUS data undergo pedestal substraction and zero compression before they are packed into the Segment Manager's internal memory. At this point, the Segment Manager issues a "readout complete" (RDOC) strobe to the Event Handler and resets the FASTBUS modules to their data acquisition mode. The Event Handler then clears the CAMAC modules and begins to retrieve data from the Segment Manager. The event inhibit is not reset until all the data is read out. It can in principle be cleared at an earlier point, that is, after the Segment Manager has completed its readout, but this has not yet been implemented.

The Segment Manager's program is in machine code and was designed mainly for speed. It contains only the necessary instructions for performing the appropriate protocols and the READ functions, which presently, are implemented via random data cycles. A rudimentary error traceback feature was also included which inserts error codes into the data stream without interrupting the data acquisition process.

Event Rates

It takes approximately 200 μs to readout the CAMAC modules. The Event Handler then waits for an additional 200 μs for the FASTBUS QDCs to complete their conversion cycle before requesting the Segment Manager to proceed with it readout. The conversion time for the LeCroy 1885 QDC is about 400 μs while the readout time, using random read cycles is about 45 μs for all 96 channels per module. The amount of time required to transfer data from the Segment Manager to the Event Handler depends on the number of data words. Theoretically, it can range anywhere form zero to 288 words. If we assume it takes about 2 μs for a CAMAC read operation, the total processing time per event will range from about 500 to 1000 μs, that is, the data acquisition system can sustain an event rate of 1 to 2 kHz with minimal dead time.

During the experimental runs, we tested the event rate capability of the HILI's acquisition system under different triggering modes. When it was triggered by the hodoscope, we obtained an average processing time of about 630 μs per event. With a trigger provided by the OR of the multiwire proportional counter and the hodoscope, followed by the "quasielastic reject" gate, the average processing time per event was about 160 μs. Although the latter figure depends much more on the reaction, it does indicate that under "normal" running conditions, the data acquisition will be able to sustain an event rate of 1 to 5 kHz without too much difficulty.

One benefit of dividing the acquisition task between CAMAC and FASTBUS components is the almost no additional time penalties will be incurred when the second half of the detector is implemented. Reading out the two heavy ion detectors will require 400 μs, thus eliminating the present wait time. Any additional time imposed by the second half will come solely from the transfer of data from the Segment Manager to the Even Handler, and this depend on the reaction event.

Conclusion

We have presented an outline of the signal processing and data acquisition schemes for the HILI detector. Specifically, a "self-gating" method that is independent of light ion flight time differences was developed to process signals from a phoswich detector. In addition, reasons for adopting a dual standards data acquisition system and some details on integrating the two standards were presented. Results form the first experimental runs with the detector showed that the data acquisition system can sustain, at worst, an event rate of 1 kHz with almost no dead time. However, under "normal" running conditions, we expect the detector system to be able to process about 5000 events per second.

Acknowledgement

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