Spallation Neutron Source

Technical Note on Event Mode at SNS

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Before one can understand the use of event mode at SNS one must understand the historical method of data collection at spallation neutron sources. The standard method of collecting data is known as histogramming. The histogramming concept is depicted below in figure one. In any neutron frame (large gray cubes in figure one) there are many neutron events (small dark blue cubes), with each neutron frame being statistically very similar to other neutron frames. In order to improve the statistics of the experimental data, neutron events from different frames are typically summed together into time and space bins that may be less precise in space and time than the original neutron events. This process of adding neutron events from different neutron frames together is known as histogramming. After histogramming (middle of diagram), the data still retains the flavor of the neutron event, being labeled by spatial location and time values. The size of the bins in space and time being under the control of the user.

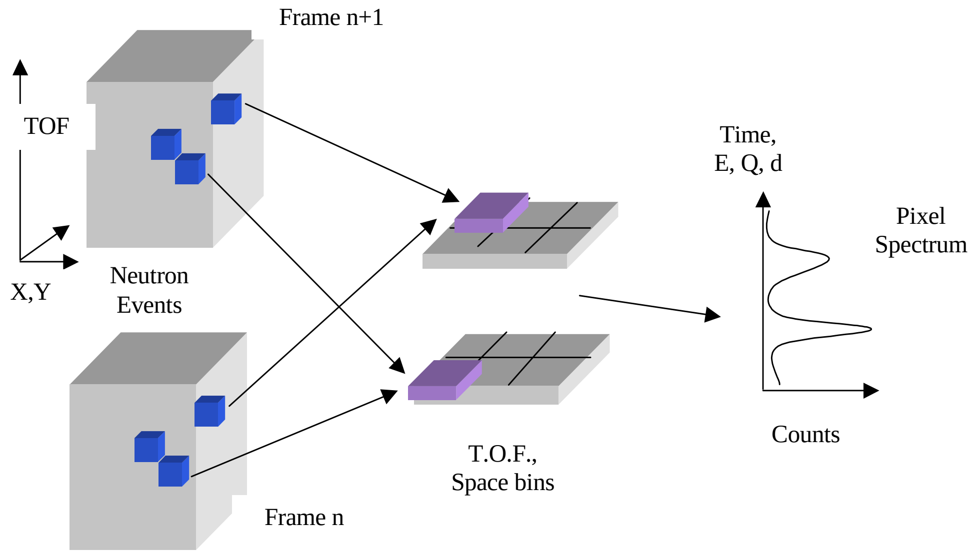


Figure One: Diagram depicting the process of histogramming. Neutron events from each neutron frame (left hand side of diagram) are summed together into time and space bins. (middle of diagram). The histogrammed data may be further processed into other variables of interest producing a spectrum (right hand side) that provides information about the sample.

These space and time histograms, where the original pulse information has been lost are generally referred to as pixel spectra and comprise the “raw data” that is permanently stored. These spectra may further be transformed into other variables such as energy or d-spacing, and may even be further summed together using time focusing forming one or more spectra of intensity versus a variable of interest. There are a variety of historical reasons for the reliance on histogramming for data collection. With the modern generation of pulsed sources, and current computer technology most of these reasons are no longer valid. In light of the fact that histogramming by its very nature is an information destroying process the need for an alternative method of data collection where the information from each pulse can be used to the greatest extent is obvious. This method at SNS is known as event mode.

Event mode data at SNS is neutron data that consists of the following information: detection position (spatial information), time of flight and pulse ID. One of the great strengths of the event mode technique is that if one synchronizes other external variables with the neutron pulse one can lower the system noise threshold by using standard statistical methods such as cross correlation.
Because of its importance every detector at SNS is required to output data in a standard event mode format. The data quantum is a neutron event which is an eight byte structure consisting of the uncorrected time of flight (four bytes) of the detected neutron, and the pixel ID (four bytes) it was detected in. This structure is shown in the table below.

Time Stamp [31:0]	Uncorrected time of flight
Position Index [31:0]	Pixel ID of detected neutron

Standard neutron event data generated by all detector electronics at the SNS

The data format is little endian. Using this standard data format for detector output greatly simplifies the development of the software that communicates with the detector. In addition, because no histogramming is done in the electronics, the electronics design is also simplified. Event data is collected by a set of computers known as the preprocessor cluster. The preprocessor cluster adds a correction to the time of flight and stores the events in an event array. To associate a pulse ID with a set of neutron events, a second data array is needed. This consists of two 64bit quad words, a pulse ID and an index.

Pulse ID [63:0]	Pulse ID from accelerator
Zero Based Starting Index [63:0]	Index of starting neutron event structure that was produced with the above pulse ID

Standard pointer array which associates a pulse ID with a set of event data.

The pulse ID is a number generated by the accelerator and transmitted via a UDP Ethernet packet to the preprocessor cluster. The index is the zero based starting index of neutrons produced by this pulse in the neutron event data array. For example if the first pulse created 1001 events and the second pulse created 1100 events, the pointer array would have entries

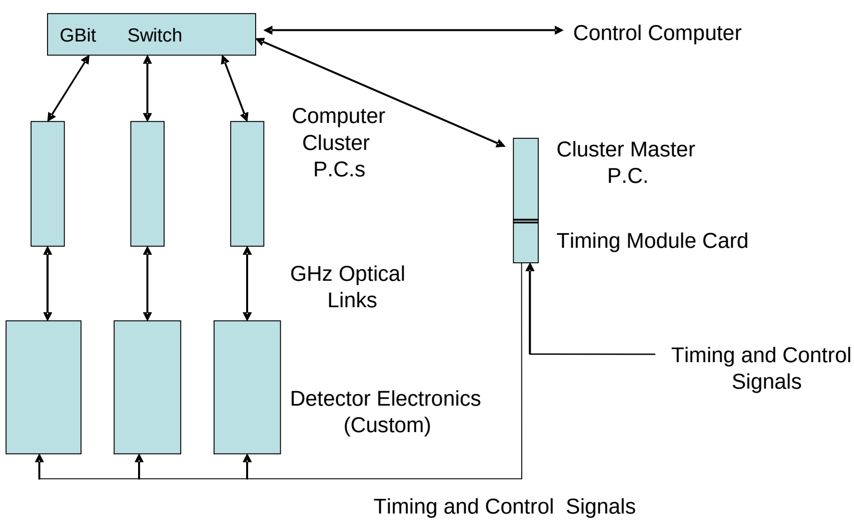
1,0 : 2,1001: 3:2101: ….. etc.

If one is interested in the neutron events generated by the second pulse, one would read the event array starting at index 1001 and read in structures up to index 2100. Using these two data arrays one can uniquely identify what pulse any neutron was produced from. Equally of interest when operating in event mode is the collection of other data that may be synchronized with the production of neutrons. For example the exact phase of choppers or a set of correlated strain measurements may be of interest. In both cases cross correlation of the external data with the neutron pulse may provide additional information that the averaging process of histogramming hides. One of the computers in the preprocessor known as the preprocessor master is where external information other than neutron events are associated with a pulse ID. The term “master” is somewhat of a misnomer since there may be additional computers that associate a pulse ID with external signal measurements. The chief responsibility of the preprocessor master is to store the pulse by pulse phase information from each chopper and to associate the data with a pulse ID. This process also produces a set of two data arrays. One array contains the chopper phase information, while the other contains the pulse ID and index pointer. It should be noted that any external data collected in such a manner (pulse by pulse) will consist of two data arrays, one array containing the data and a second that associates the data with a pulse ID.

Although event mode data collection has been given a central role at the SNS, histogramming must still be supported. One obvious need is for real time feedback of detector performance, typically done with a 2D view of total counts in each detector pixel. Such a histogram allows the experimenter to immediately assess, among other things, whether the detectors are operating correctly. Additionally, event mode may not be of use for some experiments. Histogramming of the event data in each of these histograms is handled by a different computer and in the standard SNS configuration these computers are not part of the preprocessor cluster. In the former case, the histogramming is preformed on a computer known as the control computer, while in the latter case histogramming is handled by an application running on a computer known as the data/file server. In both cases the histogramming is accomplished by the use of lookup tables so the speed at which the event mode array can be transformed to a histogrammed array is limited by computer memory access speed rather than CPU speed. It is estimated from benchmarking done in 2002 that a server class computer will allow the histogramming of 2 to 3 million events per second. Because the preprocessor only stores data in event mode, if an instrument scientist decides upon a different rebinning size or method then he will be able to accomplish this any time prior to the final formation of the histogrammed file. The point of finality is reached when a save data command is issued by the control computer. The distributed architecture creates a very flexible system in that information is not lost until the last possible moment, and that determination is always in the hands of the instrument scientist rather than in the hands of hardware.

Because histogramming is done on a different computer[1] than the one that collects the event mode data, the method of transfer of the event data is important to understand. Data is transferred using UDP on a predefined set of sockets. Event data transfer is currently allocated a 7millisecond time slice during each pulse. For the standard Gbit Ethernet link, this puts an upper limit of about .7Megabytes of data or about 85,000 events per pulse to be transferred to both the control computer and data/file server. Current Gbit communications hardware thus places an upper transfer limit of about 2.5million events/second. Instruments requiring larger data moves (such as single crystal) will need to upgrade to 10Gbit.standard links, or to use a technique known has random data interweaving which provides a statistical correct subset of the event data. Figure two below depicts the physical arrangement of the computer network.

One additional system needed to implement event mode at the SNS is a method to transmit the accelerator pulse ID in "soft" real time.[2] The soft real time subsystem at SNS consists of an embedded time circuit (ETC) card developed by accelerator systems, a P.C., an ETC driver developed by instrument systems, and a high thread priority system application also written by instrument systems. This combination of hardware and software transmits in soft real time the pulse I.D. along with a small amount of other accelerator data to the preprocessor cluster via a broadcast UDP protocol. This packet transfer is allocated a 1millisecond time slice during each pulse. Benchmarking has shown that such a time slice is adequate for the guaranteed delivery of the small data set size being transmitted. By using preemptive interrupts offered by the Windows operating system, sequencing of the delivery of the pulse ID with other events, such as data collection and delivery can be accomplished.



[1] Because communications is done using standard socket methods the preprocessor and control computer applications can be run on the same computer. This may make sense in a low count rate instrument. The IP information is contained in a set of XML configuration files which allows the communication link to be easily changed.
[2] Soft real time at SNS means guaranteed delivery of data taking no longer than a millisecond.

Figure two showing the physical arrangement of the preprocessor computer cluster and the control computer. Not shown is the data file/server link which resides on the same subnet. This subnet is separate from the slow-controls subnet of which the control computer is also a member. The detector electronics is sectioned into one or more parts depending upon the expected event rate. Each detector subsection is linked via a high speed 2.1GHz optical link to a computer of the preprocessor cluster. The cluster master handles real time signals that are not detector associated, such as chopper phasing. The preprocessor cluster communicates with each other, the control computer and data file server via standard Gbit Ethernet links.

In summary we believe that event mode will become the standard method of neutron data collection at SNS and will provide an additional as yet unexplored method of analyzing