RHIC DATA CORRELATION METHODOLOGY*

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Abstract

A requirement for RHIC data plotting software and physics analysis is the correlation of data from all accelerator data gathering systems. Data correlation provides the capability for a user to request a plot of multiple data channels vs. time, and to make meaningful time-correlated data comparisons. The task of data correlation for RHIC requires careful consideration because data acquisition triggers are generated from various asynchronous sources including events from the RHIC Event Link, events from the two Beam Sync Links, and other unrelated clocks. In order to correlate data from asynchronous acquisition systems a common time reference is required. The RHIC data correlation methodology will allow all RHIC data to be converted to a common wall clock time, while still preserving native acquisition trigger information. A data correlation task force team, composed of the authors of this paper, has been formed to develop data correlation design details and provide guidelines for software developers. The overall data correlation methodology will be presented in this paper.

1 CONTROL SYSTEM ARCHITECTURE

The RHIC control system architecture consists of more than 100 VME based systems, each housing a front end computer (FEC) running the VxWorks operating system. The front end computers communicate to higher level workstations via an ethernet network. Software objects known as Accelerator Device Objects (ADO) [1] reside in the FEC and provide the interface between the local hardware and higher level workstations. Each ADO consists of a set of parameters where each parameter usually relates to a specific hardware operation, such as a configuration setting, a status value or a data set.

2 ACQUISITION TRIGGER SOURCES

Data acquired with synchronous or asynchronous trigger sources from ADOs on different FECs must be correlated for plotting and analysis at the workstation level.

Data acquisition systems for RHIC will typically be triggered using one of the following sources.

a) Events on the RHIC Event Link (REL).
b) Events on the Beam Sync Links (2).
c) Triggers unrelated to the links.

The REL [2] is a 10 MHz serial link distributed throughout the accelerator complex. Accelerator-specific event codes are transmitted on the REL. Systems throughout the RHIC complex monitor the REL and perform system-specific actions when selected event codes are detected. General purpose periodic events used for data acquisition are transmitted at the following rates: 720 Hz, 60 Hz, 10 Hz, 1 Hz and 0.25 Hz. Data acquisition systems that use these events for triggering include the Beam Loss Monitor System (BLM) [3] and the Magnet Power Supply system.

Two Beam Sync Links [4] are used for RHIC, one for each collider ring. They are referred to as blue and yellow. Each Beam Sync Link is a 14 MHz serial link and transmits event codes similar to the REL. The carrier is synchronized to the RF frequency to allow bucket-specific triggering. The Beam Sync Link events are primarily used to trigger beam instrumentation systems. One important event on each Beam Sync Link is the revolution tick event. This event is transmitted when bucket 1 passes a known location in the ring. Instrumentation systems that use the Beam Sync Link events for bucket-specific triggering include the Beam Position Monitors, the Ionization Profile Monitor [5] and the Wall Current Monitor.

3 RTDL DISTRIBUTED TIME

Another serial link used in RHIC is the Real Time Data Link (RTDL) [6]. The purpose of RTDL is to distribute basic accelerator data to every FEC throughout the complex. RTDL data is sent on every REL 720 Hz event.

Wall clock time will be distributed on RTDL. Two 24-bit RTDL frames will be used to transmit 32 bits representing the number of seconds since Jan 1, 1970 (standard UNIX time) and 10 bits representing the number of 720 Hz ticks within each second.

A time generator module is currently being developed to produce the wall clock time. This module will reside in the RTDL system. A 720 Hz clock input from the main magnet power supply system is used to generate the 720 Hz, 60 Hz, 10 Hz, 1 Hz and 0.25 Hz events. The hardware triggers the 0.25 Hz event on an even 4 second boundary (when the least two significant bits of the number of seconds change to 00).

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4 SYNC EVENT

The 0.25 Hz event code will be used as a synchronizing event (Sync Event) and is transmitted on the REL, the Blue Beam Sync Link, and the Yellow Beam Sync Link. Hardware modules use the Sync Event to perform such actions as resetting on-board timestamps, resetting scan counters, and copying data buffer pointers.

The period of time from one Sync Event to the next Sync Event is called a sync period.

5 TIME INFORMATION

The following time information has been defined to be associated with each data set. Not every item is necessarily delivered with each data set. Some items may be static and others may not be relevant for the specific data set. A data set may be an array of data, a single data value, an average, etc.

a) Time associated with the data set. This consists of 3 components - TimeType, Time, and Index. TimeType is used to identify the meaning of Time and Index, as shown in table 1. Additional TimeTypes will be added as necessary. Sync time is the time of the sync period associated with the data set. This is expressed as the number of seconds since Jan 1, 1970 and is always evenly divisible by 4.

Table 1 - TimeType definitions

Time Type	Time	Index
1	Sync time	Beam sync blue turn ticks since last Sync Event
2	Sync time	Beam sync yellow turn ticks since last Sync Event
3	Sync time	720 Hz ticks since last Sync
4	Sync time	60 Hz ticks since last Sync
5	Sync time	10 Hz ticks since last Sync
6	Sync time	1 Hz ticks since last Sync
7	Sync time	Febbunch events since last Sync (febbunch occurs when bunch is extracted from AGS to RHIC)
8	Sync time	Trigger number since last Sync
9	Wall clock time (sec since Jan 1, 1970)	0

b) Sample number associated with Time/Index. This is the element number in the data set that corresponds with Time/Index. This is typically used when the data set is an array, but may also be used to indicate that the time is associated with a specific element within an averaged data set.

c) Time offset relative to Time/Index. This is used to correct for known delay times. For example, an acquisition trigger may be configured to be a delay from a specified REL code. Time/Index indicates the time that the event occurred and time offset is the configured delay time.

d) Points per average. This is valid only when the data is an average of multiple samples.

e) Time between samples.

f) Selected bucket number.

g) Bandwidth/Resolution of data acquisition hardware.

h) Report frequency. This is the time interval at which data sets are sent to higher level workstations.

i) Wall clock time translation information. In some cases additional information is required to convert the Time/Index to wall clock time. For example, the febbunch event may occur multiple times within an AGS cycle but is not a continuous periodic event. When Index is the febbunch event number, data from the event monitor is used to apply a time in microseconds since the Sync Event, to the febbunch event number.

6 EVENT MONITOR

A VME based event monitor module is used for each event link to provide a timestamp for selected event codes. The delivered data set is time, and is specified as the number of microseconds since the last Sync Event.

The event monitors provide information that is critical to applying a common wall clock time to all data. The Sync Event is transmitted on all three links at the same time (to within 12 microseconds). The microsecond timestamp counter for all event monitors is derived from the REL 10 MHz carrier to guarantee synchronous counting. Event timestamps are converted to a common wall clock time, thereby correlating data to within one RHIC revolution (approximately 12 microseconds).

The time information as described above will be provided with each event monitor data set. Time offset, points per average, time between samples, bucket selection, bandwidth/resolution, and wall clock translation information are not used for event monitor data.

7 ASSOCIATING TIME INFORMATION WITH DATA

Associating time information with a particular data set requires careful consideration. In order to provide ADO design flexibility, a data correlation design goal was to allow time information to reside in the same ADO as the data source or in an ADO different from the data source. Systems may be designed to correlate one set of time information to many data sets. The multiple association works as long as the order of data delivery can be guaranteed. For the RHIC control system, the order of data delivery can be guaranteed only for data sent from a single FEC. Therefore, for RHIC, the time information that changes on each data update must reside in the same FEC as the data source.

One option currently under consideration is to provide a database to associate time information items with each data ADO parameter. The database entry for each time information item may be the name of an ADO parameter or a static value. A static value may be used, for example

Table 2 - Example ADO parameter definitions

FEC name	ADO name	Parameter name	Description
BlmFec	BlmDataAdo1	dataArray1Hz	Array of 720 samples, delivered each second. This is data for 1 BLM channel.
BlmFec	BlmTimeAdo	syncTime1Hz	Sync time, delivered each second. Same for all 64 channels in same FEC.
BlmFec	BlmTimeAdo	index1Hz	Number of 720 Hz ticks since sync corresponding with first array element.
EvMonFec	EvMon720HzAdo	dataArray1Hz	Array of 720 times, delivered each second. This is time for each 720Hz event.
EvMonFec	EvMon720HzAdo	syncTime1Hz	Sync time, delivered each second.
EvMonFec	EvMon720HzAdo	index1Hz	Number of 720 Hz ticks since sync corresponding with first array element.

Table 3 - Example time information database entries

Database field	Loss Monitor channel ADO, parameter: BlmDataAdo1, dataArray1Hz	Event Monitor ADO , parameter: EvMon720Hz, dataArray1Hz
TimeType	3 (Sync time, 720 Hz ticks since Sync)	3 (Sync time, 720 Hz ticks since Sync)
Sync time ADO name, parameter name	BlmDataAdo1, syncTime1Hz	EvMon720HzAdo, syncTime1Hz
Index ADO name, parameter name	BlmDataAdo1, index1Hz	EvMon720HzAdo, index1Hz
Sample number assoc. with Time/Index	1	1
Time offset relative to Time/Index	0	Unused
Points per average	Unused	Unused
Time between samples	1389 microseconds (720 Hz)	Unused
Bucket selection	Unused	Unused
Report frequency	1 second	1 second
Wall clock time ADO name, parameter name	EvMon720HzAdo, dataArray1Hz	Unused

when the sample number associated with Time/Index is a constant.

The wall clock translation information item will typically point to a data source ADO parameter that resides in an ADO on a different front end computer. This will usually be an event monitor ADO, which returns time for selected event codes.

8 EXAMPLE

As an example, the process of applying wall clock time to an array of BLM channel data will be described. The BLM system acquires data on every REL 720 Hz event. For this example an array of 720 samples is delivered each second to higher level software.

Data from all the ADO parameters defined in table 2 are delivered once each second. The other time information shown in table 3 is not sent every second since it is static and can be retrieved directly from the database.

The correlation between dataArray1Hz, syncTime1Hz, and index1Hz delivered from the same FEC is accomplished simply by knowing the order of delivery.

syncTime1Hz and index1Hz are used to correlate the data array (BlmDataAdo1, dataArray1Hz) with the time array (Evmon720HzAdo, dataArray1Hz) to determine a wall clock time to the microsecond for each data sample.

Every system acquiring data on the REL 720 Hz event will use time data from EvMon720HzAdo. This guarantees that the microsecond timestamp for all data acquired on a given 720 Hz event will have the exact same timestamp to the microsecond.

Systems acquiring data using events from the Beam Sync Links will use the same mechanism as described above to apply a wall clock timestamp. Once a wall clock timestamp has been applied, all data can be correlated.

Note that Sync Time and Index provide enough information to correlate data when acquisition triggers are on the same event. In these cases converting to wall clock time may not be necessary.

9 IMPLEMENTATION STATUS

Some software systems in RHIC are beginning to use data correlation mechanisms similar to the methodology described in this paper. However, significant implementation standards still need to be defined, and software development for data correlation will be continuing for many months.

10 REFERENCES

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