Time-stamping system for nuclear physics experiments at RIKEN RIBF†

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At the RIKEN RIBF, a new time-stamping system has been developed for nuclear physics experiments. The time-stamping function is implemented in a logic unit for programmable operation (LUPO)[1]. One of the remarkable features is that it can attach the time-stamp information to an existing CAMAC/VME based DAQ system in RIBF[2]. The timing resolution of the time-stamping system is 10 ns, which is sufficient to find the event correlation between separated DAQ systems. This specification enables us to merge obtained data separately on an event-by-event basis after the measurement.

The proposed time-stamping system was installed at RIKEN RIBF for use in β-decay experiments[3–6]. In these experiments, a beam line detector set, a silicon detector array, and a germanium detector array were used. Since the triggers for these detectors are independent of each other, three separate DAQ systems were used. In this report, the results for the DAQ systems for the beam line detector set (BeamDAQ) and the silicon detector array (SiDAQ) are described. The beam line detector set is triggered by RI-beams, i.e., beam events. The silicon detector array is triggered by both implanted isotopes and β rays, i.e., beam events and β-decay events. For the silicon detector array, when both SiDAQ and BeamDAQ are triggered at the same time, the event can be identified as a beam event. On the other hand, if SiDAQ is triggered but BeamDAQ is not, the event is a β-decay event. In order to determine the relationship between the number of actually generated physics events and the number of events accepted by separate DAQ systems, the combined live time was investigated. An additional DAQ system named full-event monitor was installed to acquire the time stamps of all generated triggers. By using LUPO, trigger time stamps for each DAQ system are recorded without loss. BeamDAQ and SiDAQ store detector data together with the time stamps of accepted triggers. In contrast, the full-event monitor only accumulates time-stamp values of triggers generated for BeamDAQ and SiDAQ. The combined live times for beam events and β-decay events in the silicon detector array are determined as the ratio of the number of events identified using BeamDAQ and SiDAQ and the number of triggers recorded by the full-event monitor. Table 1 lists the measured and estimated combined live times for beam and β-decay events in the silicon detector array. The real event-occurrence rate (R) is unknown if the full-event monitor is not present. However, it is possible to estimate it by comparing the observed and simulated DAQ acceptance rates (R_{acc}) when a trigger is accepted by both BeamDAQ and SiDAQ. Monte Carlo simulation was performed in order to estimate DAQ acceptance rates from a DAQ transaction time, which can be obtained using the scaler circuit in the experiment. The transaction times of BeamDAQ and SiDAQ were 210 and 108 μs, respectively. From the results of the Monte Carlo simulation, the assumed beam-event and β-decay event rates (R) are calculated to fit the observed DAQ acceptance rate (R_{acc} = 82.2 events/s). These results indicate that for beam and β-decay events, the accuracy of the Monte Carlo simulation was good. Within this simulation, the systematic error in the simulated event rates was 0.2%.

Table 1. Event rates and combined live times for beam and β decay events in the silicon detector array.

Beam events	R (events/s)	P_L (%)
Measured	87.5	94.0
Estimated	87.3	94.0
β decay events	**R (events/s)**	**P_L (%)**
Measured	368	95.3
Estimated	369	95.3

In summary, a time-stamping system has been introduced in the RIKEN RIBF. This system is particularly useful for β-decay experiments. Although the combined live time for separate DAQ systems is not straightforward to determine, it can be measured by installing a full-event monitor. It was found that Monte Carlo simulations can estimate the true event rate with a high degree of accuracy.

References
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