Digital Pulse Processing and Data Acquisition for Gamma-ray Spectroscopy: Perspectives, Developments and Applications

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Introduction

The advent of digitizer based pulse processing and data acquisition (DAQ) systems has ushered an era of improved experimental setups in the domain of nuclear spectroscopy. These facilities are characterized by increased event rates from state-of-the-art large detector arrays used in the contemporary spectroscopic endeavours and the digital hardware used therewith, with its superior throughput, befits the purpose. Such vantage is owing to the development of fast recursive algorithms that are applied on the digitized detector output pulse for extracting the information of interest, therefrom. The acquired data is typically constituted with the energy and the timing of the detection, apart from the identity of the respective detector element. These parameters are used to construct the level structure of nuclei being investigated following a meticulous processing of the acquired data and its detailed analysis. The maiden instance of using digital signal processing for large detector arrays in the country was realized at the previous (2009-13) campaign of the Indian National Gamma Array (INGA) hosted in TIFR, Mumbai [1]. Subsequent to this first stride there have been efforts to further implement the digital hardware and pulse processing algorithms in the gamma-ray spectroscopy measurements with multi-detector arrays such as INGA. The current presentation aims in elaborating on one such development [2] carried out by the UGC-DAE CSR, Kolkata Centre and being used in the present campaign of the INGA facility at VECC, Kolkata.

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Trigger Logic, Hardware and Data Processing

Consequent to the fast processing characteristics and superior throughput of the digital signal processing methodology, it is alluring to use the digitizer based acquisition systems in the so called triggerless mode. Herein all the detector parameters in the setup are acquired indiscriminately in the measurements. The events of interest are selected offline during the data reduction and the analysis exercise through application of varied criteria pertaining to the data parameters. While this facilitates much flexibility to the usage, it might be more appropriate for setups consisting of different types of detectors wherein the condition for acquisition might not be optimized a priori. However, for gamma-ray detector arrays, without any ancilliary devices, such triggerless acquisition would typically imply recording of the Compton events from the Anti Compton Shields (ACS), as well. The latter being fast and efficient detectors, this mode of acquisition would manifold the event load on the system and increase the probability of loosing the valid ones. Generally the triggerless acquisition results in an increased data volume most of which is unusable. Apart from the inconvenience of increased memory consumption, such data also requires larger processing time without producing any gain in the desired statistics. A digitizer based pulse processing and data acquisition system [2] has been conceptualized at UGC-DAE CSR, Kolkata Centre, for use in the gamma-ray detector arrays consisting of Compton suppressed Clover detectors, such as INGA. The system has been designed to operate under a trigger based on (user chosen) multiplicity of Compton suppressed detectors. The trigger has been implemented in the firmware by XIA LLC (USA) and executed through a hardware principally consisting of 16-channels PIXIE modules, with 12-bit 250 MHz digitizers, housed in PXI crate and controlled through PXI-PCI8366 controller that communicates with the host computer via a fibre optic cable. The PIXIE modules accept preamplifier signals from the Clover and the corresponding ACS for pulse processing and acquisition. Each 16-channel module can support three Compton suppressed Clover detectors. The pulse processing methodology in this digital system is similar to that practised in analog domain for Compton suppressed gamma-ray detector arrays. The input pulses are digitized and subjected to trapezoidal filter for extracting the energy information and generating the fast trigger. The latter is used for timing correlations between the detector elements, probe for Compton suppression and calculate multiplicity for event validation. Event-by-event information, for valid events, are recorded in time stamped list mode data for subsequent use. Data acquired in the presence of trigger based on multiplicity of Compton suppressed detectors typically consist of usable events for spectroscopic applications. For each channel of the digital daq, that has recorded a valid detection in an event, the list mode data file records four 32-bit words principally encoding time stamp (48-bit), CFD (16-bit), energy (16-bit), detector ID (6-bit) and pileup (1-bit) information. A set of programs, called IUCPIX [2], have been developed, by UGC-DAE CSR, Kolkata Centre, for data reduction and analysis of the processed data is carried out using standard softwares. The IUCPIX package has programs for simplifying the data format, time sequencing the data from individual digitizer module, time sequencing data from multiple modules and finally sort the data into spectra and γ-γ matrices for analysis and output files for constructing γ-γ-γ cube.

Use of Digital DAQ in INGA

The digital pulse processing and DAQ system of UGC-DAE CSR, Kolkata Centre, is being used with the current INGA campaign, in progress, at VECC, Kolkata. Around 20 experiments have been carried out using the system and address diverse structural phenomena across the nuclear chart. Some of the interesting results from these measurements, carried out with alpha and proton beams from the Room Temperature Cyclotron at VECC, are being presented in this Symposium by our Group and Collaborators (supported by INGA based CRS Projects of UGC-DAE CSR, Kolkata Centre). Very significantly, the merit of Compton suppressed multiplicity validation applied on the digital DAQ is manifested in the preservation of the coincidence event rates even in the presence of an 1-fold trigger (singles) condition. Since the Compton events are necessarily undesired in gamma-ray spectroscopy experiments, this multiplicity-1 trigger, extracted from a Compton suppressed detector, tantamounts to acquiring data in a triggerless condition. This is at stark variance with acquisition in the analog domain where such sustained coincidence rates in singles trigger condition is an impossibility. The features of the digital system and the associated developments shall be elaborated in the Symposium.

The Nuclear Physics Group at the UGC-DAE CSR, associated with the development of the digital daq, has members, Dr. A. K. Sinha, Dr. S. S. Ghugre, Dr. R. Raut, Mr. S. Das, Mr. S. Samanta, Mr. S. Chatterjee and Mr. K. Basu. Dr. H. Tan of XIA LLC (USA) has led the fabrication of the daq system at the manufacturing end. Help received from the INGA collaboration is acknowledged. The support of the staff members associated with cyclotron operation, the target laboratory and the health physics unit at VECC, during the experiments, is deeply appreciated.

References

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