Development of a high-speed digital data acquisition system for the ZD-MRTOF and β-decay experiments at F11

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A new project ZD-MRTOF has been launched to survey the masses of exotic nuclei using high-intensity radioactive isotope beams at RIBF.[1] Optimizing the degrader thickness online is essential to maximize the stopping efficiency of rare isotopes in the He gas cell during the experiment.[2] Here, we report the performance of the newly introduced data acquisition system designed for the ZD-MRTOF experiments using high-speed digitizers during the Spring campaign of the ZD-MRTOF in 2022, where identification of rare isotopes under the beam rate of about 10^4 cps has been confirmed with minimum event loss. The system is based on the CAEN VME digitizers equipped with Field Programmable Gate Arrays (FPGAs), where signals that exceed programmable thresholds are digitized and processed to extract amplitude and timing information.[3] The recorded signals are time-stamped and synchronized with the existing DAQ systems at RIBF thanks to the use of LUPO modules,[4] which distribute common 50 MHz clock signals to all digitizers.

Data acquisition is carried out using RCDAQ software.[5] To combine online data from different DDAQ subsystems for Zerodegree, ZD-MRTOF and β-decay setups, the ZeroMQ protocol[6] was implemented. The acquired data are distributed to data analysis computers on the network, where event reconstruction and time correlations are performed online or offline.

The performance of the DDAQ system under high rate conditions was tested using a cocktail beam of neutron-rich Fe-Ge isotopes during the ZD-MRTOF experiment NP2012-RIBF202. Signals from ZeroDegree spectrometer beamline detectors were readout using the CAEN V1730 digitizers running the DPP-PSD and DPP-PHA firmwares. Figure 1 demonstrates the improvement in deadtime using our DDAQ compared to the existing CAMAC DAQ system, where deadtime and event rate are evaluated based on a fit of the distribution of time intervals between subsequent events to a non-extended deadtime model.[7] A particle identification (PID) plot obtained using our DDAQ system is also shown. With the extracted event rate of 13.5 kHz, a dead time of $\approx$4 μs was obtained for our DDAQ system, compared to $\approx$377 μs for the CAMAC DAQ.

Our DDAQ system has also been successfully employed to readout the TOF signals of the ZD-MRTOF system, providing possibility to combine with the ZeroDegree spectrometer PID information to monitor online the absolute efficiency of the ZD-MRTOF setup. Figure 2 shows a TOF spectrum obtained with a ^{248}Cm fission source,[8] where the start signals of the mirror ejection and the stop signals of the fast ion impact detector (ETP 14DM572)[1] were recorded using a CAEN V1730 digitizer running the DPP-PSD firmware.

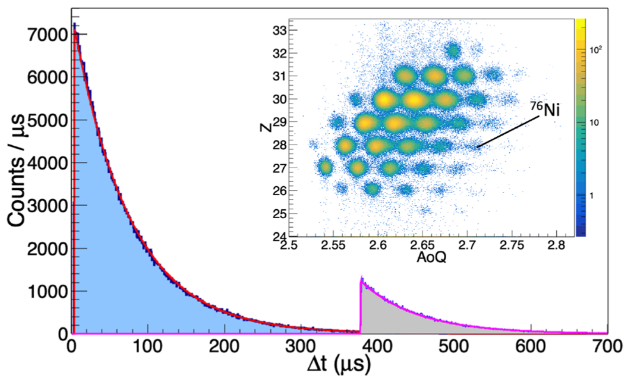

Fig. 1. Fitted distribution of the time interval between subsequent events (blue-filled) and a PID plot (inset) obtained with our DDAQ system compared to the distribution obtained with the BigRIPS CAMAC DAQ (gray-filled).

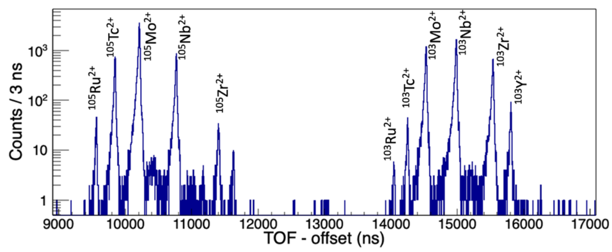

Fig. 2. TOF spectrum obtained with our DDAQ system.

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