Introduction and performance evaluation of a new data acquisition system for germanium detectors

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Isomer tagging is an essential technique for unambiguous particle identification (PID) in BigRIPS[1)] and is achieved by detecting characteristic γ rays emitted from known short-lived nuclear isomers. Currently, two clover-type high-purity germanium (Ge) detectors are used for this purpose. Data acquisition (DAQ) for Ge detectors has traditionally been performed with a CAMAC-based system. However, many CAMAC modules are aging and becoming difficult to maintain due to discontinued production. Further failure of the critical modules could interfere with the isomer tagging. Therefore, considering an alternative DAQ system has been an urgent issue recently.

Mesytec MDPP-16[2)] is a promising candidate for the new DAQ system. It is a VME-based, 16-channel digital pulse processor with a fast high-resolution time and amplitude digitizer. Input signals are first amplified, filtered, and then digitally reconstructed in a hardware component, followed by detailed analysis in a digital signal processing unit implemented in a field-programmable gate array (FPGA). Among several FPGA software modules available for the MDPP-16, the standard "SCP" module suits our purpose. It delivers timing and amplitude information for standard charge-integrating preamplifier signals with 16-bit (64k) resolution. It can replace all the conventional shaping amplifiers, peak-sensitive ADCs, timing filter amplifiers, constant fraction discriminators, and TDCs.

First, we examined the ADC and TDC performance of the MDPP-16 SCP. The integral non-linearity (INL) of ADC was less than 0.1%, while the differential non-linearity (DNL) of ADC was less than 4% over the 20%–90% range of full scale. The INL and DNL of TDC were less than 0.001% and 0.03%, respectively. Time slewing with respect to the pulse height was less than 0.4 ns. These performance values were comparable to or better than the current system.

Figure 1 shows a γ-ray spectrum of a ^{60}Co source measured with the MDPP-16 SCP by the Ge detector used in the actual isomer tagging.

FWHM resolution of the 1332-keV peak was typically 4.7 keV. This value was mainly due to the accumulation of radiation damage to the Ge crystals over the years and was the same as that measured with the current system.

The isomeric γ-ray measurement using the MDPP-16 SCP was performed during the BigRIPS tuning this autumn. Figure 2 shows an atomic number (Z) versus mass-to-charge ratio (A/Q) PID plot for a ^{52}Ca-centered radioactive isotope (RI) beam.

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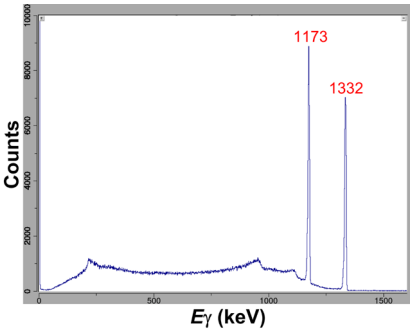

Fig. 1. γ-ray spectrum of a ^{60}Co source measured with the MDPP-16 SCP.

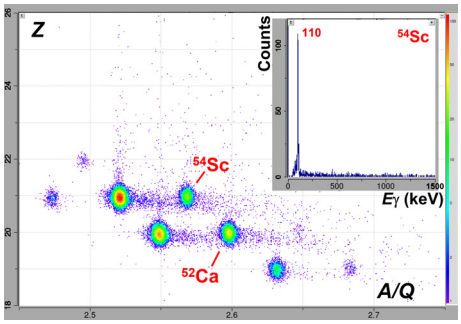

Fig. 2. Z versus A/Q PID plot of the ^{52}Ca-centered RI beam. Delayed γ-ray energy spectrum of the ^{54}Sc isomer is overlaid in the upper right corner.

The delayed γ-ray energy spectrum of the isomeric nucleus ^{54}Sc is overlaid in the upper right corner. The presence of a distinct 110-keV peak indicates that the MDPP-16 SCP can be used for isomer tagging.

Finally, we examined long-term stability, which is also important for practical operations. The energy calibration was stable within 0.5 keV over several days if no setting was changed. However, when we changed the settings, such as thresholds, the calibration was occasionally shifted from a few keV to a maximum of 10 keV. Based on oscilloscope observations, it is suspected that the baseline may shift when the settings are changed. A detailed investigation is in progress. While this issue must be resolved, the MDPP-16 SCP has the sufficient performance required for the new DAQ system of the Ge detectors. We plan to replace the current CAMAC-based system with the new system as soon as possible.

References

1) N. Fukuda *et al.*, Nucl. Instrum. Methods Phys. Res. B **317**, 323 (2013).
2) `https://www.mesytec.com/products/nuclear-physics/MDPP-16.html`.