Short note

New transitions in the $\beta$-decay of $^{36}$Ca

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Abstract. The $\beta$-decay of the $T_\beta = -2$ nucleus $^{36}$Ca was studied at the LISE3 magnetic spectrometer at GANIL. Two new proton-emitting states have been detected and the other nine known $\beta p$ and $\beta\gamma$ transitions have been remeasured with improved resolution. A simulation with the GEANT code has been applied to this experimental setup. A comparison with shell model calculations is given.

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During the past few years, improvements in experimental techniques have enabled the study of $\beta$-decay properties of very proton-rich nuclei [1]. Characterized by high energy release, these decays allow one to extract the Gamow-Teller (GT) strength for transitions to a large range of excitations energies in the daughter nucleus and thus to test the quality of model calculations.

Previous studies of high energy release $\beta$-decays of $^{37}$Ca [2–5] ($Q_{\beta C} = 11638(22)$ keV [6]) and $^{36}$Ca [5,7] ($Q_{\beta C} = 10985(40)$ keV [6]) revealed that the good agreement between experiment and shell-model calculations [8,9] did not extend to high excitation energies where much more strength was observed than calculated. It was stressed, however, that the size of this effect seems to depend strongly on the interaction applied in the theory [5,10].

This note reports on a new detailed study of the $\beta$-decay of $^{36}$Ca produced at the GANIL facility. The experiment was performed using the SISSI-ALPHA and LISE3 spectrometers [11–13]. A $^{36}$Ca secondary beam was produced by fragmentation reactions of a 95 AMeV $^{40}$Ca$^{20+}$ beam at an average intensity of $\sim 400$ enA impinging on a rotating 560 $\mu$m thick $^{58}$Ni target. The secondary beam purity was enhanced by a 550 $\mu$m thick wedge-shaped $^{9}$Be degrader at the intermediate focal point and by using the velocity filter at the exit of the LISE3 spectrometer. The 96% pure secondary $^{36}$Ca beam (12 atoms per s) was implanted into a 500 $\mu$m thick silicon detector; the main contaminant stopped in this detector was $^{40}$K (0.5 atoms per s). The implantation detector was positioned between two silicon counters of the same thickness for detecting $\beta$-rays ($\beta$-detectors). Two additional silicon counters, the first one with a thickness of 500 $\mu$m and the second one, position sensitive, with a thickness of 150 $\mu$m, were mounted upstream. These detectors provided the energy loss ($\Delta E$) and time-of-flight signals for identifying the isotopes transmitted to the final focus of the LISE3 spectrometer. Three large-volume (70%) germanium detectors with a total efficiency of 0.02 at 1.1 MeV for registering $\gamma$-rays were mounted close to the implantation detector.

The energy calibration has been performed by implanting the well-known $\beta$-delayed proton ($\beta p$) emitter $^{35}$Ca under similar conditions in an additional LISE3 setting, the proton separation energies of $^{37}$Ca and $^{36}$Ca being similar ($S_p = 1857.77$ (9) and $S_p = 1666(8)$ keV [14], respectively). Corrections were made for different

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implantation depths of $^{36}$Ca and $^{37}$Ca atoms ($\Delta \approx 100 \mu m$) by means of the well-known proton transition from the Isobaric Analogue State (IAS) [15]. The difference of the line shifts due to pulse-height defects of the recoil atoms ($^{35}$Ar, $^{36}$Ar) in the decay of $^{36}$Ca and $^{37}$Ca is negligible.

In the first setting (48516 atoms), the $^{36}$Ca implantation profile (FWHM $\sim 68 \mu m$) was positioned at a depth of about 142 $\mu m$. In a second setting (53891 atoms), the profile was shifted to 292 $\mu m$, i.e., nearer to the downstream $\beta$-counter, by removing the 150 $\mu m$ thick $\Delta E$ detector. Figure 1 shows the measured $^{36}$Ca $\beta p$ energy spectra: a) proton spectrum in coincidence with $\beta$ particles and b) under the condition of a small energy-loss of the coincident $\beta$-rays in the downstream $\beta$-detector ($\Delta E_\beta \leq 300$ keV).

Nine $\beta p$ transitions were extracted from the spectra shown in fig. 1. These lines have been assigned to single proton transitions between levels in $^{36}$K and $^{35}$Ar.

The relative intensities are deduced by integrating the full-energy peaks and applying a correction factor to account for protons for which the energy is only partially collected in the implantation detector. We have used GEANT [16] simulations to obtain the correction factor. The implantation depth profile deduced from the $^{36}$Ca energy-loss spectrum in the implantation detector has been taken into account. The number of identified and implanted $^{36}$Ca atoms was corrected for losses due to secondary reactions in the stopping process [17,18]. This correction factor was 1%. Absolute proton intensities are obtained by dividing the corrected number of protons by the number of $^{36}$Ca ions collected in the implantation detector.

Figure 2 (top) shows the experimental IAS region of the $^{36}$K proton spectrum and the simulated $\beta p$ IAS decay spectrum (dots). The GEANT simulations give results which are in good agreement with experimental data for the decay of the IAS. The simulated spectrum has been used as a background spectrum to determine the intensities of the small peaks in the tail of the IAS peak. Figure 2 (bottom) shows the background-subtracted spectrum. We can observe two new weak $\beta p$ transitions in the $^{36}$Ca decay (marked by a star).