Deuteron Evaporation and Proton Emission in the Upper fp Shell*

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An experimental campaign focusing on isospin-symmetry and proton emission in the upper fp shell was performed at Argonne National Laboratory (ANL) in 2020. The overarching goal was to perform in-beam high-resolution particle- and γ-ray coincidence spectroscopy along the $N = Z$ line beyond doubly-magic ^{56}Ni. The first experiment focused on ^{57}Cu. The second experiment studied isobaric analog states in mass $A = 61, 62$ nuclei, and in particular proton emission from low-lying states in ^{61}Ga [see Fig. 1(a)]. The third experiment explored isospin symmetry at the limits of nuclear binding via proton-γ spectroscopy of ^{65}As.

The focus of the campaign on in-beam proton spectroscopy called for a new approach in charged-particle detection. A complex setup comprising two CD-type double-sided Si-strip detectors (DSSDs), the Microball CsI(Tl) array, the Gammasphere array, the Neutron Shell liquid scintillator array, and the Fragment Mass Analyzer (FMA). The novel combination of CD-DSSDs (pixelation 2×2048) with Microball is shown in Figs. 1(b) and (c). It adds proton tracking capabilities and optimizes proton energy resolution while keeping high detection efficiency for evaporated charged particles.

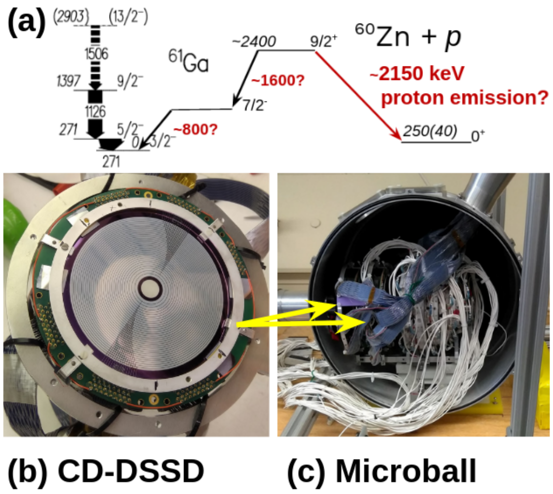

FIG. 1: (a) Suggested fast proton radioactivity from a hitherto unknown $g_{9/2}$ single-particle state in ^{61}Ga into the ground state of ^{60}Zn. Energies are in keV. (b) One of the two CD-DSSDs used for in-beam proton spectroscopy, particle tracking, and deuteron-proton discrimination. (c) Novel combination of the Microball CsI array and the CD-DSSDs inside the Gammasphere target chamber aiming at high-resolution in-beam particle-γ coincidence spectroscopy.

For the second experiment, excited states in ^{61}Ga were populated via the fusion-evaporation reaction ^{24}Mg(^{40}Ca, $p2n$)^{61}Ga. Results from an earlier study concerning this $T_z = -1/2$ nucleus suggest a proton-emitting $g_{9/2}$ single-particle state at $E_x \approx 2400$ keV as indicated in Fig. 1(a).

During the offline analysis it was realized that the setup is also capable of distinguishing evaporated deuterons from evaporated protons. In combination with Gammasphere, this opens up for an unprecedented study of – possibly preferential – production cross sections along the $N = Z$ line involving deuterons for a series of compound and residual nuclei: for instance, ^{24}Mg(^{40}Ca, $2pn$)^{61}Zn vs. ^{24}Mg(^{40}Ca, dp)^{61}Zn.

The analysis is ongoing. First results on deuteron evaporation and the search for proton emission from excited states in ^{61}Ga will be presented.

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