Decay properties of ^{68,69,70}Mn[†]

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In recent years the evolution of magic numbers moving away from the valley of stability has been a hot topic both from experimental and theoretical points of view. In this context, one region in the chart of nuclides that is attracting particular attention lies around ^{78}Ni: this is a key region to study the path toward the N=50 shell closure and its implications on the astrophysical r-process. In particular, the study of the evolution of excited states for the Cr, Fe, Zn, Ge isotopes provides a stringent test for shell model calculations leading to N=50.

The experiment described here was performed at RIKEN in May 2013, as part of the EURICA campaign at the Radioactive-Isotope Beam Factory (RIBF) facility . The nuclear species were produced by means of in-flight fission of a ^{238}U beam at a bombarding energy of 345 MeV/nucleon. The experiment collected data for an equivalent time of 3 days with an average primary beam intensity of 10 pnA. The resulting fragments were transported and separated in the BigRIPS separator and Zero-Degree spectrometer down to the final focal plane. They were implanted in the 5 silicon detectors of the WAS3ABi array[1)] which was surrounded by the EURICA spectrometer[2)] coupled to 18 small volume $LaBr_3$(Ce) scintillator detectors, for fast-timing measurements[3)]. The yields for the mother nuclei, after implantation, were: 6700 ^{68}Mn ions, 4300 ^{69}Mn ions and 400 ^{70}Mn ions.

The experimental data confirm the β-decay spectrum of ^{68}Mn reported previously in Ref.[4)] even if we see different relative population of the transitions at 1250 keV and 1514 keV. In addition, γ-ray energies for the decay of ^{69}Fe and ^{70}Fe are extracted for the first time. For the odd isotope, the limited statistics do not allow the extraction of $\gamma-\gamma$ coincidences. Its decay spectrum shows a substantial contribution from the β-delayed neutron channel, which preferentially seems to populate specific low-J states. By systematics and supported by recent shell-model calculations, we assign the γ rays seen in the spectrum of ^{70}Fe to the depopulation of the 2_1^+ and 4_1^+ levels.

The proposed level schemes following the β decay of even-mass isotopes are shown in Fig. 1. The comparison of the decay patterns of ^{68}Mn $\rightarrow$ ^{68}Fe and ^{70}Mn $\rightarrow$ ^{70}Fe shows a sudden change: in the case of ^{70}Mn $\rightarrow$ ^{70}Fe, the feeding seems to preferably go to the proposed 4^+ state, while the 2^+ state is mainly fed by internal decay coming from the higher-lying states. The sudden change of the spin population in the daughter nuclei indicates different spin of the ground state of the mother nuclei.

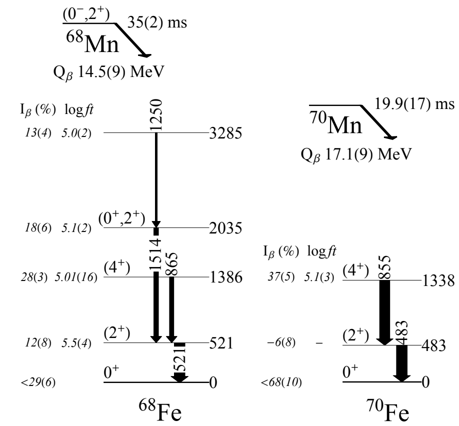

Fig. 1. Partial level schemes following the β decays ^{68}Mn $\rightarrow$ ^{68}Fe (left) and ^{70}Mn $\rightarrow$ ^{70}Fe (right).

The experimental results have been compared to a shell-model calculation performed with the CD-Bonn NN potential in the V_{low-k} approach[5)] extended to ^{68,70}Fe isotopes. It is found that the experimental $R_{4/2}$ ratio is properly reproduced by the calculations only with the inclusion of the $1d_{5/2}$ neutron orbital in the valence space. This is interpreted, as for Cr isotopes, in terms of the interplay between the quadrupole correlations of the $\nu 1d_{5/2}$ and $\nu 0g_{9/2}$ orbitals and the monopole component of the $\pi 0f_{7/2}$ - $\nu 0f_{5/2}$ interaction, thus driving the deformation in the neutron-rich Cr-Fe region. Since the maximum of quadrupole deformation has not been reached yet, investigating heavier Fe isotopes is of foremost interest to assess the robustness of the N=50 shell closure below ^{78}Ni.

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