Strong coupling in ^{65,67}Mn

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Abstract. Excited states in ^{63,65,67}Mn were studied via in-beam γ-ray spectroscopy following knockout reactions from ^{68}Fe. Similar level schemes, consisting of the $11/2^-$, $9/2^-$, $7/2^-$ and $5/2^-_{g.s.}$ level sequence, connected by $I \rightarrow I-1$ transitions, were established. Their level structures show features consistent with strongly-coupled rotational bands with $K = 5/2$.

1 Introduction

At the $N = 40$ harmonic oscillator shell closure, ^{68}Ni has the appearance of being doubly magic based on the high 2^+_1 energy and a low transition probability. However, well deformed low-lying states with considerable particle-hole excitation strength across the $N = 40$ gap have been observed and/or predicted in the nuclei around ^{68}Ni, described as a new "island of inversion" [1]. Lying in between Cr and Fe, Mn isotopes are expected to be well deformed around $N = 40$, so it is very intriguing and challenging to reveal the coupling mode in these odd-mass Mn isotopes.

2 Experiment and Results

The experiment was performed at the Radioactive Isotope Beam Factory (RIBF). A 15 pnA ^{238}U primary beam, accelerated to 345 MeV/u, was impinged on a 3-mm-thick ^{9}Be primary target for the production of secondary radioactive isotope beam at the entrance of the BigRIPS separator. The isotopes of interest were selected and separated from the secondary beams, and then impinged on a 102(1)-mm-thick liquid hydrogen (LH_2) secondary target. The secondary reaction residues were produced via proton-induced knockout reactions. The particle identification before and after the LH_2 target was performed in the BigRIPS and ZeroDegree spectrometer. The Time-Projection Chamber (TPC) of the MINOS device surrounding the LH_2 target was used to reconstruct the vertex of the knockout reactions. The γ rays emitted in-flight were measured by the DALI2 γ-ray spectrometer surrouding the MINOS device.

In the present work, excited states of ^{63,65,67}Mn were populated by the fragmentation of ^{68}Fe via the ^{68}Fe$(p, 2pxn)^{67-x}$Mn reaction channels, with $x = 4$, 2 and 0, respectively. The Doppler-corrected γ-ray spectra are displayed in figure 1. The γ-transition energies, relative intensities after efficiency calibration, and the tentative spin-parity assignments of the initial and final states are summarized in table 1. The spin-parity assignments were made following the systematics of low-lying levels in the lighter odd-mass Mn isotopes.

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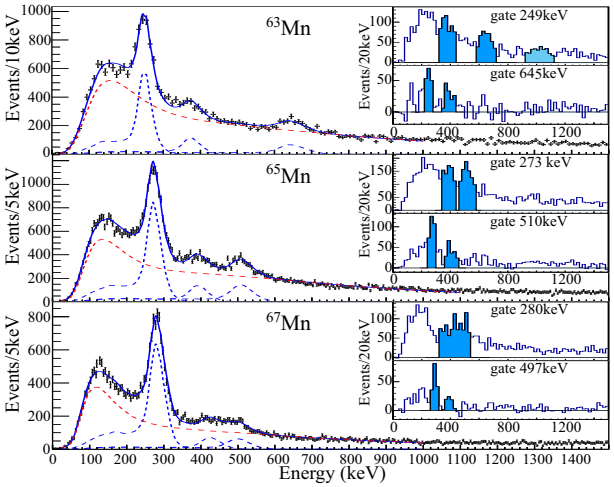

Figure 1. (Color online) Doppler-corrected γ-ray spectra of ^{63,65,67}Mn detected by DALI2, and the background subtracted γ-γ coincidence spectra labeled with the gating transitions are displayed in the insets.

Table 1. The γ-transition energies (E_γ), relative intensities after efficiency calibration (I_γ) observed in ^{63,65,67}Mn, and the tentative spin-parity assignments of the initial and final states.

	^{63}Mn		^{65}Mn		^{67}Mn	
$J_i^\pi \rightarrow J_f^\pi$	E_γ (keV)	I_γ	E_γ (keV)	I_γ	E_γ (keV)	I_γ
$(7/2^-) \rightarrow 5/2^-_{g.s.}$	249(5)	100(4)	273(5)	100(2)	280(5)	100(2)
$(9/2^-) \rightarrow (7/2^-)$	645(6)	20(2)	510(6)	22(1)	497(7)	13(1)
$(11/2^-) \rightarrow (9/2^-)$	376(7)	20(2)	394(6)	16(1)	427(8)	11(1)

3 Summary

In summary, we studied the spectroscopy of ^{63,65,67}Mn. Very similar level schemes with $11/2^- \rightarrow 9/2^- \rightarrow 7/2^- \rightarrow 5/2^-_{g.s.}$ transition cascades were proposed. With the excitation energies following the $I(I+1)$ law and the decay pattern dominated by $\Delta I = 1$ transitions, the first cases of strongly-coupled rotational bands in the $N = 40$ "island of inversion" have been identified in ^{65,67}Mn.

4 Acknowledgement

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