Mixed-symmetry octupole and hexadecapole excitations in N=52 isotones

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Abstract. In addition to the well-established quadrupole mixed-symmetry states, octupole and hexadecapole excitations with mixed-symmetry character have been recently proposed for the N=52 isotones 92 Zr and 94 Mo. We performed two inelastic proton-scattering experiments to study this kind of excitations in the heaviest stable N=52 isotone 96 Ru. From the combined experimental data of both experiments absolute transition strengths were extracted.

1 Introduction

Isovector excitations of valence-shell nucleons are usually denoted as mixed-symmetry states (MSS) [1]. They are predicted in the proton-neutron version of the Interacting Boson Model (IBM-2) [2-4] and can be distinguished from fully-symmetric states (FSS) by their F-spin quantum number [5]. As an experimental signature for MSS, the IBM-2 predicts strong M1 transitions to their symmetric counterparts with transition matrix elements in the order of 1 μ_N . The collective structure of low-lying states in near-spherical, vibrational nuclei is dominated by the quadrupole degree of freedom. By now, mixed-symmetry quadrupole excitations in vibrational nuclei are well established as collective features near closed shells [6]. In addition to the quadrupole degree of freedom, mixedsymmetry excitations of octupole and hexadecapole character have been proposed in the N = 52 isotones 92 Zr and ⁹⁴Mo [7–9]. The identification is based on remarkably strong M1 transitions between the lowest-lying 3⁻ and 4^+ states. Recently, the strong M1 transition between the lowest-lying 4+ states in 94Mo was successfully described by including g-boson excitations in IBM-2 calculations [9], suggesting FS and MS one-phonon hexadecapole admixtures in the 4_1^+ and 4_2^+ states, respectively. It

is the purpose of the present work to study possible mixed-symmetry octupole and hexadecapole states in the heaviest stable N = 52 isotone 96 Ru.

2 Experiments

The determination of absolute transition strengths requires the measurement of spins and parities of excited states, γ -decay branching ratios, multipole mixing ratios, and nuclear level lifetimes. For this purpose, two inelastic proton-scattering experiments were performed. In a first experiment, performed at the Wright Nuclear Structure Laboratory (WNSL) at Yale University, USA, a proton beam with an energy of $E_p = 8.4$ MeV impinged on a 106 μ g/cm² enriched ⁹⁶Ru target, supported by a ¹²C backing with a thickness of $14 \mu g/cm^2$. The scattered protons were detected in coincidence with de-exciting γ rays using five silicon particle detectors and eight BGOshielded Clover-type HPGe detectors, respectively. From the acquired $p\gamma$ coincidence data γ -decay branching ratios were extracted, while the additionally acquired $\gamma\gamma$ coincidence data were used to determine spins and multipole mixing ratios by means of a $\gamma\gamma$ angular correlation analysis.

In order to extract nuclear level lifetimes in the fs range, we performed a second proton scattering experiment at the Institute for Nuclear Physics at the Univer-

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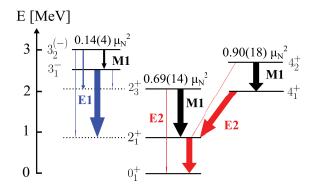


Figure 1. (Color online) Excerpt of the experimental level scheme of 96 Ru. M1, E1, and E2 transitions are indicated with black, blue, and red arrows, respectively. The width of the arrows is proportional to the γ -decay branching ratios. Along with the $2^+_{ms} (\equiv 2^+_3) \rightarrow 2^+_1$ transition [13], M1 transitions with sizeable strengths were observed between the lowest-lying 3^- and 4^+ states.

sity of Cologne, Germany. The same target as used for the experiment at WNSL was bombarded with a beam of 7.0 MeV protons. The scattered protons were detected with the new particle detector array SONIC embedded within the γ -spectrometer HORUS to allow for a coincident detection of scattered protons and de-exciting γ -rays. Nuclear level lifetimes were extracted by means of the Doppler-shift attenuation method (DSAM) [10] from the $p\gamma$ coincidence data. Since the initial direction and velocity of the recoil nucleus, as well as its excitation energy can be extracted from the energy of the scattered proton, the $p\gamma$ coincidence yields several advantages for the DSAM measurement [11]:

- The angle θ_{γ} between the direction of the γ -ray emission and the direction of motion of the recoil nucleus can be extracted on an event-by-event basis.
- Feeding from higher-lying states is eliminated by gating on the excitation energy.
- Peak centroids can be extracted from proton-gated γ -ray spectra, yielding an increased peak-to-background ratio.

The slowing-down process of the ⁹⁶Ru recoil nuclei in the target and stopper materials was modeled by means of the Monte-Carlo simulation program DSTOP96 [12]. A comparison of the calculated Doppler-shift attenuation factor with the experimentally determined value finally yields the nuclear level lifetime.

3 Experimental results

From the combined experimental data of both experiments absolute transition strengths were calculated. The results concerning one-phonon mixed-symmetry states in $^{96}{\rm Ru}$ are shown in Figure 1, pointing out M1 transitions with sizeable strengths of 0.14(4) μ_N^2 and 0.90(18) μ_N^2 between the low-lying 3 $^-$ and 4 $^+$ states, respectively. Based on

their absolute M1 transition strengths, the $3_2^{(-)}$ state at $E_x = 3077$ keV and the 4_2^+ state at $E_x = 2462$ keV are likely candidates to show mixed-symmetry one-phonon octupole and hexadecapole contributions, respectively.

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