Identification of the Proton $2p_{1/2} \rightarrow 2p_{3/2}$ M1 Spin-Flip Transition in ^{87}Rb*

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M1 transitions between two spin-orbit partner orbitals with $j_> = l + 1/2$ and $j_< = l - 1/2$, so-called spin-flip transitions, with transition rates on the order of $B(M1) \approx 1\mu_N^2$ represent some of the strongest M1 transition rates observed in nuclei. In the semi-magic N=50 nucleus ^{87}Rb, the nuclear properties are governed by the proton $1f_{5/2}$, $2p_{3/2}$ and $2p_{1/2}$ orbitals. The Fermi surface is located between the $2p_{3/2}$ and $2p_{1/2}$ orbitals, which is reflected in the $J^\pi = 3/2^-$ ground state of ^{87}Rb. Shell model calculations indicate that the second excited state of ^{87}Rb at 845.4 keV is dominated by the $2p_{1/2}$ orbital and thus is the spin-orbit partner of the $2p_{3/2}$-dominated ground state [1]. The experimental proof for this assumption is still pending, since the spin of the 845.4-keV state could so far not unambiguously be determined although the orbital quantum number $l = 1$ of this state is already known from $(^3\mathrm{He}, d)$ [2] and $(d,^3\mathrm{He})$ measurements [3, 4]. Since the transition strength for the 845-keV M1 transition to the ground state of ^{87}Rb is already known to be sufficiently large [1], a determination of the spin of the 845-keV state will decide whether the respective transition really is the dominant part of the proton $2p_{1/2} \rightarrow 2p_{3/2}$ spin-flip transition.

This spin assignment was achieved [5] by measuring the lifetime of the 845-keV state and comparing the resulting transition strength for the deexcitation, $B(M1)\downarrow$, to the transition strength for the excitation of this state, $B(M1)\uparrow$, which is known from a (γ, γ') measurement [1]:

$$J_2 = \frac{1}{2}\left[(2J_1 + 1)\frac{B(M1)\uparrow}{B(M1)\downarrow} - 1\right] = 0.56(19) \qquad (1)$$

Here, J_2 denotes the spin quantum number of the excited 845-keV state and $J_1 = \frac{3}{2}$ the spin of the groundstate of ^{87}Rb. The level lifetime of the 845-keV state was measured using the Doppler-shift attenuation method (DSAM) after the proton-transfer reaction ^{12}C(^{86}Kr,^{11}B)^{87}Rb, which was observed in experiment U246 performed at the X7 experimental station at GSI in Oktober 2011. In this experiment, an isotopically pure beam of ^{86}Kr with an energy of 2.85 MeV/u provided by the UNILAC accelerator impinged on a multi-layered target consisting of 0.33 mg/cm^2 ^{nat}C followed ^{nat}Gd, ^{nat}Ta and ^{nat}Cu. The original aim of the experiment was to populate low-lying states in ^{86}Kr and ^{90}Sr by Coulomb excitation and an α-transfer reaction, respectively, for the measurement of g-factors by the transient field technique. However, also deexcitation γ-rays from the excited ^{87}Rb nuclei were detected in coincidence with the target-like reaction recoils by four EUROBALL cluster HPGe detectors. The γ-events were sorted into 6 groups of identical polar angle of γ-ray detection with respect to the beam axis. A fit of calculated lineshapes to the experimentally observed spectra was performed using the computer code APCAD [6]. A mean lifetime of $\tau = 146(\pm 10)_{stat}(^{+8}_{-12})_{sys}$ fs for the 845-keV state could be extracted from the data, where the systematic error stems from uncertainties of the ion stopping powers that were assumed in the analysis process. The corresponding M1 transition strength for the deexcitation is $B(M1)\downarrow = 0.644^{+0.075}_{-0.053}\mu_N^2 = 0.36^{+0.04}_{-0.03}\ W.u.$ With this information, the spin of the excited state at 845 keV could be pinned down to be $\frac{1}{2}$ (see Fig. 1), comfirming the dominant proton $2p_{1/2} \rightarrow 2p_{3/2}$ M1 spin-flip character of the 845-keV transition.

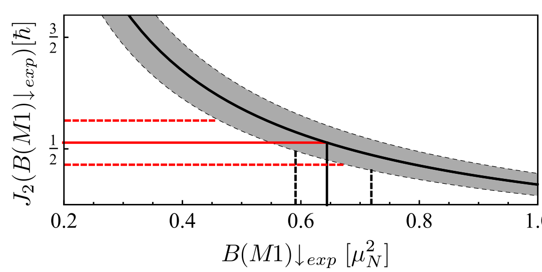

Figure 1: Determination of the spin of the 845-keV state of ^{87}Rb using eq. 1, the value of $B(M1)\uparrow$ determined in a (γ, γ') experiment [1] and the value of $B(M1)\downarrow$ determined in this work. The gray band depicts the functional dependance of the derived spin from the measured value of $B(M1)\downarrow$, accounting for the experimental uncertainties of $B(M1)\uparrow$. The horizontal lines mark the spin of the 845 keV state of ^{87}Rb resulting from the value of $B(M1)\downarrow$ measured in this work (vertical lines).

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* This work was supported by the BMBF under grant 05P12RDFN8, by the German-Bulgarian exchange program under Grant Nos. PPP 50751591 and DNTS/01/2/2011 and resources of the European gammapool.