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Short note

Maximum spin aligned states in $^{98}_{47}Ag_{51}$

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Abstract. New excited states have been observed in the neutron deficient isotope ^{98}Ag following the ^{58}Ni+^{50}Cr→ ^{108}Te* heavy–ion reaction. One of these states may be interpreted as a maximum spin aligned state of the $\pi g_{9/2}{}^{-3}$ $\nu g_{7/2}$ configuration. Other possible interpretations within the nuclear shell model are discussed as well.

PACS. 23.20.Lv Gamma transitions and level energies – 21.60.Cs Shell model – 27.60+j $90 \leq A \leq 149$

This study is concerned with two topics regarding the structure of the isotope ^{98}Ag. The first one is to experimentally verify the spins assigned to some of the excited states in ^{98}Ag in a recent in–beam study where six excited states were reported [1]. The second is to try to extend the level structure of this isotope into the $\nu g_{7/2}$ and/or the $\nu h_{11/2}$ configuration spaces. The following discussion of calculated energies and branching ratios relies on the presentation of this subject in ref [1]. Excited states in the nucleus ^{98}Ag have also been observed in the β^+/EC–decay of ^{98}Cd [2,3]. In the present study we report on the observation of an additional four excited states in ^{98}Ag following the ^{50}Cr(^{58}Ni,2α1p1n)^{98}Ag reaction at 261 MeV in an experiment carried out at the NORDBALL Ge–detector array [4] at the Niels Bohr Institute, Denmark. The coincidence relations allowed for six new transitions to be placed in the level scheme (see Table 1 and Fig. 1). Four additional γ rays of energy 489 keV, 677 keV, 1932 keV and 2489 keV appear to belong to ^{98}Ag but their positions in the level scheme cannot be firmly established. The charged particles and neutrons emitted by the produced compound nuclei were detected in coincidence with the emitted γ rays by employing a set of silicon detectors and a neutron multiplicity filter. The information gained from these two ancillary detector systems was used to select specific exit channels for the analysis of the γ-ray spectra (see Fig. 2). The multipole order of the emitted γ–rays was deduced from the ratio between the intensities in two non-equivalent angles with respect to the beam axis (79°,101° and 143°). In the analysis it is assumed that stretched dipoles and quadrupoles dominate the de–excitation through the main cascade [5].

In the ground state of ^{98}Ag, the three proton holes reside, with large probability, in the $g_{9/2}$ shell and the odd neutron occupies the $d_{5/2}$ orbital. In the previous heavy–ion study the spins of the levels up to the first 11^+ state at 2151 keV (see Fig. 1) were tentatively assigned on the basis of theoretical arguments and by comparison to relevant neighbouring isotopes. No spin assignments were, however, made for the 2560 keV and 2713 keV levels. The present study shows that the 409 keV and 153 keV transi-

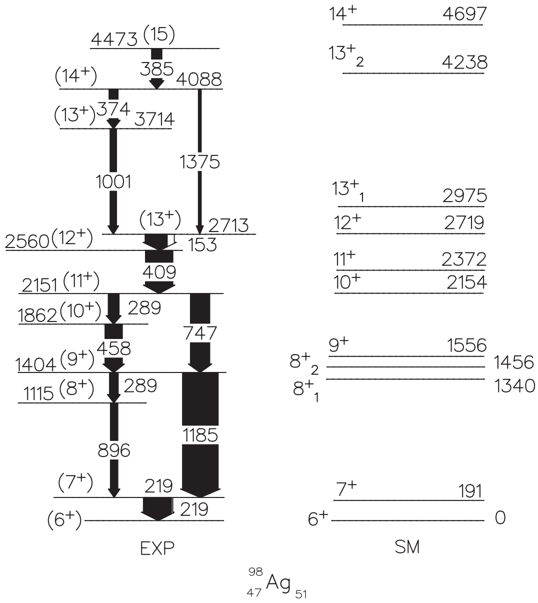

Fig. 1. Proposed extended level scheme of ^{98}Ag. Calculation to the right

Table 1. Energies, intensities and tentative spin assignments of transitions in ^{98}Ag. R $= I_\gamma(143°)/(I_\gamma(79°) + I_\gamma(101°))$. R≈0.8 for stretched dipoles and R≈1.6 for stretched quadrupoles and non-stretched dipoles

E_γ(keV)	I_γ
153	756(51)
219	877(61)
289[1]*	560(50)
	190(60)
374*	367(29)
385*	371(29)
409	948(64)
458	461(37)
747	538(46)
896*	264(32)
1001*	404(42)
1185	1000
1375*	168(25)

[1] R of doublet
* new

tions have stretched dipole character. Assuming that the observed de-excitation occurs at or close to the yrast line it may be concluded that the 2713 keV state has a spin and parity of 13^+. This state can to a large extent be seen as the maximum spin aligned state of the ground state configuration with the neutron in the $d_{5/2}$ orbital. Furthermore, all transitions known from the previous heavy–ion study have intensity ratios that support the previous spin assignments. The reader should note that the E2 cross–over transition between the 13^+ and 11^+ states remains unobserved.

An 8^+ state is according to calculations predicted to be fed from the 9^+ state at 1404 keV. In the present experiment we have found a side branch that proceeds via two γ–rays at 289 keV and 896 keV. The branching through the new cascade is measured to be 0.19 ± 0.06 of the main $9^+ \rightarrow 7^+$ branch. The main de–excitation of this new level goes to the 7^+ state suggesting that the observed level corresponds to the second calculated 8^+ state. Three new states have been observed above the 2713 keV level. The 374 keV and 385 keV transitions both have angular distribution ratios that correspond to a stretched dipole. The ratio for the 1001 keV γ–ray is less conclusive. An interpretation of the 1001 keV γ–ray as a non–stretched dipole turns out to be the most attractive solution taking theoretical arguments into account. This would infer that the 3714 keV and 4088 keV levels have spins and parities of 13^+ and 14^+, respectively. The only way to obtain a new state with a spin of $13\hbar$ or more without invoking the $\nu h_{11/2}$ orbital or exciting the core is to align the spins of the three proton holes in the $g_{9/2}$ orbital and the spin of a $g_{7/2}$ neutron. This gives an yrast state with spin and parity 14^+ and a non–yrast 13^+ state. An energy gap of 1 MeV between the $d_{5/2}$ and $g_{7/2}$ 13^+ neutron states is reasonable taking into account the strongly repulsive character of the interaction between the $g_{9/2}$ proton hole and the $g_{7/2}$ neutron particle. The state at 4473 keV would in this interpretation have a spin of $15\hbar$. There is a possibility that this state has positive parity since a 15^+ state can be obtained by exciting a neutron in the $g_{9/2}$ shell across the gap. The strongly attractive interaction between the aligned $g_{9/2}$ proton and neutron holes may bring down the core excited 15^+ state close to the suggested 14^+ level at 4088 keV. A further argument for such a state at this energy is the gain in pairing energy obtained by forming a 0^+ pair with the two neutron particles. No calculation has, to the knowledge of the authors, so far been carried out to predict the energy of such a state in ^{98}Ag. We emphasize that the experimental data allow for alternative interpretations. It can not be excluded that the states above 2713 keV carry one unit of spin more than suggested by the above interpretation. A neutron configuration space restricted to the $d_{5/2}$, $g_{7/2}$ and $h_{11/2}$ orbitals naturally imply that states built on the $h_{11/2}$ orbital are yrast above $14\hbar$. Nevertheless, calculations predict that below $15\hbar$ the $\nu h_{11/2}$ states are non–yrast. The same prediction is made for states built on the $\pi p_{1/2}{}^{-1}$ orbital that can give a maximum spin of $12\hbar$ if combined with the $\nu g_{7/2}$ orbital. The fact that no transitions have been observed from the 3714 keV, 4088 keV and 4473 keV levels to states below the level at 2713 keV indicates that the suggested interpretation of the 3714 keV and 4088 keV levels as positive parity yrast states is the most plausible. The decay of the proposed 15^+ level at 4473 naturally proceeds by an M1 transition $\nu g_{7/2} \rightarrow \nu g_{9/2}$ to the 14^+ level at 4088 keV. Another interesting piece of information derives from the anomalous intensity ratio between the 374 keV and 1375 keV transitions depopulating the 4088 keV level. The 1375 keV transition has a reduced intensity that makes it 100 times weaker than the 374 keV transition, assuming both are M1 transitions. It is well known that an

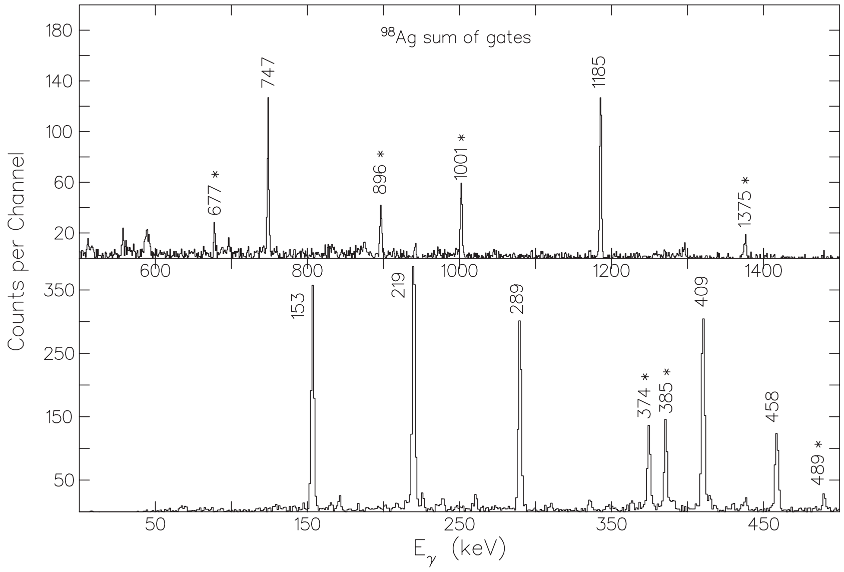

Fig. 2. Sum of gates on transitions in ^{98}Ag. * = new transition

l–forbidden M1 transition proceeds mainly via core polarization and exchange currents, which two contributions to the M1 amplitude generally have opposite signs [6]. A large hindrance factor could also explain why the similarly l–forbidden transition from the 3714 keV level to the 12^+ state at 2560 keV is not observed. A configuration mixing between the two 13^+ states may explain why the non-stretched M1 is favoured.

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