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ARC STUDY OF ^{185}W AND A TEST OF SUPERSYMMETRY IN THE DEFORMED REGION

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ABSTRACT

An ARC study of ^{185}W has been performed in order to identify the complete set of $1/2^-$, $3/2^-$ levels below 1.5 MeV. The results have been compared to the Nilsson model and also to the SU(3) limit of the U(6/12) boson-fermion symmetry. Consideration of the level scheme of ^{184}W tests the evidence for supersymmetry in the tungsten nuclei.

1. INTRODUCTION

Previous attempts[1] to test supersymmetry in nuclei have concentrated on the platinum region, but it is a logical step to try and extend this description to another region of nuclei. ^{185}W can be considered as an odd particle coupled to a rotational core and is therefore an ideal testing ground for both the Nilsson model and the SU(3) limit of the U(6/12) symmetry. Another contribution[2] to this conference has shown that a direct comparison can be drawn between states predicted by the two models; but until a complete level scheme is empirically determined, it is not possible to make a definitive comparison with experiment. To alleviate this difficulty an Average Resonance Capture (ARC) study of ^{185}W has been undertaken which guarantees the population of a complete set of $1/2^-$, $3/2^-$ levels up to an excitation energy of 1.5 MeV.

2. EXPERIMENT

The ARC technique uses the neutron capture reaction employing beams of neutrons with energies centered at 2 keV and 24 keV and FWHM ≈850 eV and ≈1.9 keV. The finite energy width of the neutron beam and the level spacing of resonances above the binding energy in ^{185}W enables capture to occur into several resonances. This results in a reduction in the fluctuations in primary intensities normally associated with single resonance capture, so that the intensities of, for instance, E1 primaries will, after correction for an E^5_γ dependence, fall in a band whose mean and width can be determined via a Monte Carlo calculation. A further consequence of this averaging process is thus a guarantee that all states with appropriate J^π values will be populated up to an empirical sensitivity limit.

The capture states in ^{185}W are $1/2^+$, which can decay by E1 transitions to $1/2^-$, $3/2^-$ states or by M1 transitions, which will be a factor of six weaker, to $1/2^+$, $3/2^+$ states. The results for the 2 keV experiment are shown in the top of Fig. 1 as a plot of reduced intensity against excitation energy. The solid line represents the Monte Carlo calculated $\pm 1\sigma$ limits for $1/2^-$, $3/2^-$ states. The dotted line represents the upper limit of 2σ for $1/2^+$, $3/2^+$ states. The bottom of the figure shows the ratio of 2 and 24 keV reduced intensities. The 24 keV beam contains a greater proportion of p-wave neutrons and therefore this ratio serves as an indication of the parity of the states. States which satisfy the criterion of being

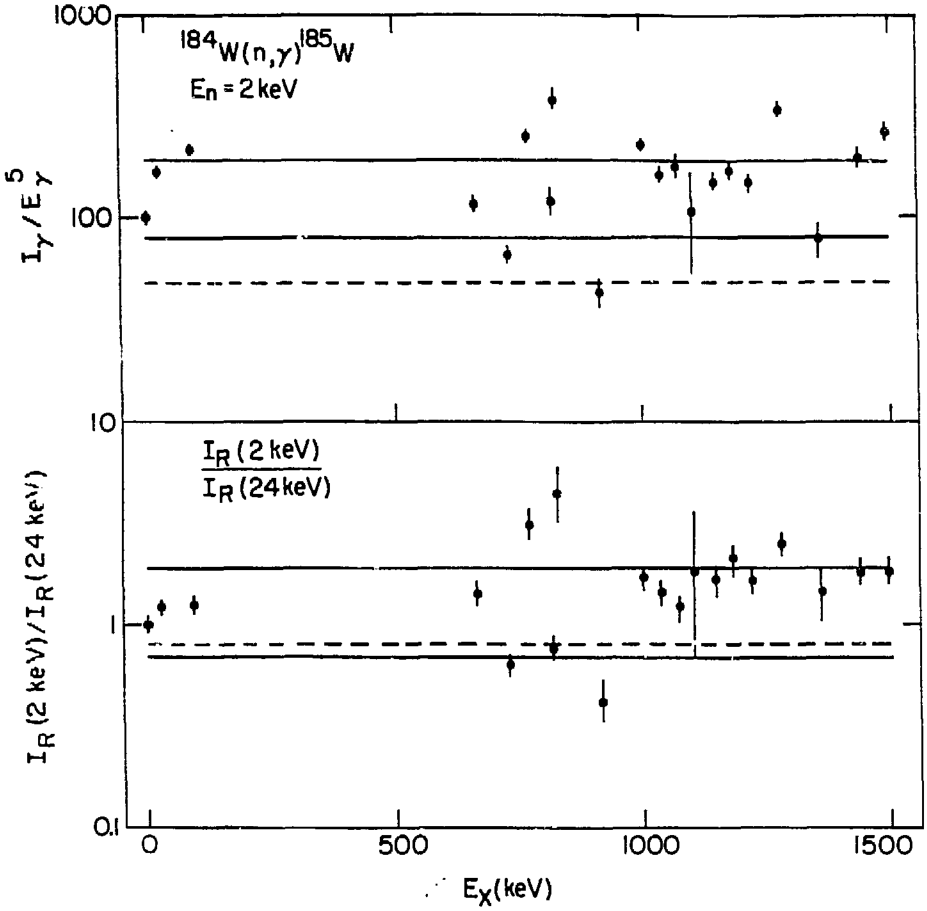

Fig. 1. Reduced intensities for the 2 keV experiment and ratio for 2 and 24 keV plotted against excitation energy.

outside 2σ of the predictions for a positive parity state have been assigned $1/2^-$, $3/2^-$ and are listed up to the $1/2^-[521]$ bandhead in Table 1 along with previous Nilsson assignments.[3]

Table 1. $1/2^-$, $3/2^-$ states seen in ARC measurement

E_x(keV)	Nilsson Assignment	$(\lambda,\mu)_{B+F}$	Q-reduced cross section at 90° (μb/sr)	
			(d,p)	(d,t)
-0.1(4)	$3/2^-[512]$	(2N,1)	5	<1
23.7(4)	$1/2^-[510]$	(2N,1)	4	2.7
93.3(3)	$3/2^-[510]$	(2N,1)	357	308
663.0(4)		(2N-2,2)	54	11
729.7(5)		(2N-2,2)	95	45
768.0(3)				
823.2(6)				
827.4(4)		(2N-2,2)	10	1.3
1005.6(4)	$1/2^-[521]$	(2N+2,0)	<62	<386

3. DISCUSSION

The tungsten nuclei lie near the end of the 82-126 neutron shell where the shell model orbits are the $2p_{1/2}$, $2p_{3/2}$ and $1f_{5/2}$, the same spin values as in the U(6/12) boson-fermion symmetry. ^{186}W is not an ideal SU(3) nucleus, but as an initial approximation it is feasible to consider ^{185}W in terms of the SU(3) limit of the U(6/12) symmetry. Another contribution[2] discusses two possible decompositions of this group chain and shows that in order to explain the empirical data it is necessary to use the eigenvalue expression:

$$E = A\{N_1(N_1+5)+N_2(N_2+3)\} + B(\lambda^2+\mu^2+\lambda\mu+3(\lambda+\mu)) \\ + (C-0.75B)L(L+L) + DJ(J+1). \tag{1}$$

where $[N_1,N_2]$, (λ,μ), L, and J are the quantum numbers of the Casimir operators of $U^{B+F}(6)$, $SU^{B+F}(3)$, $O^{B+F}(3)$, and Spin(3). Figure 2 shows the result of fitting Eq. (1) to the level scheme of ^{185}W.

Consideration[2] of the single particle structure of the wavefunctions produced by the boson-fermion symmetry shows that a correspondence can be made between the low-lying representations and the bands built on the 1/2[510], 3/2[512] and 1/2[521] Nilsson model orbits. The recent experiment reveals 5 additional states in the energy range 600-800 keV which have J^π assignments of $1/2^-$,$3/2^-$. Previously only three of the states were known but the ARC experiment ensures that the complete set is now identified. The existence of these

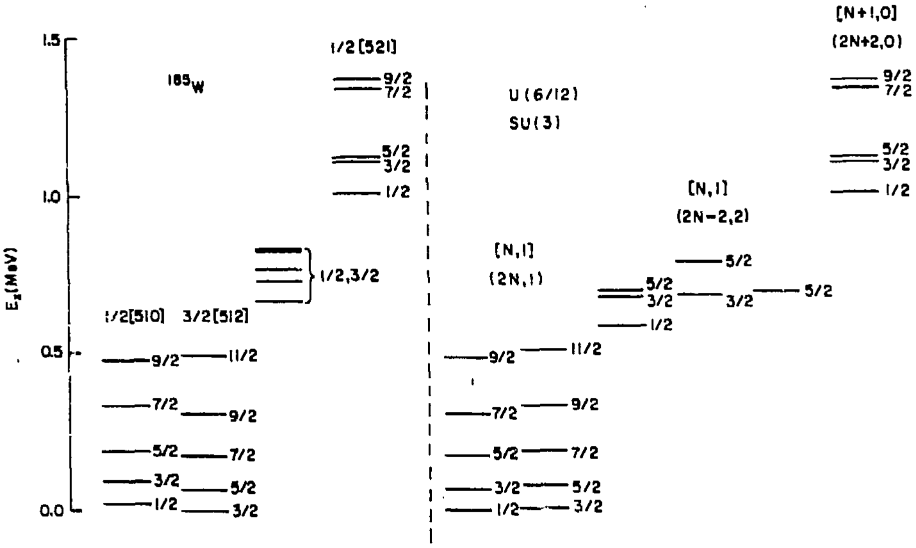

Fig. 2. A comparison of the empirical data for ^{185}W and the predictions of the SU(3) limit of the U(6/12) boson-fermion symmetry.

states poses a problem for both the Nilsson model and the boson-fermion symmetry. In the former, the energy and structure of all of the states cannot be accounted for by pure Nilsson orbits, so that some, if not all, must be ascribed to mixing with other degrees of freedom, such as vibrational modes. Thus they fall in the category of "fragmented" states. In the U(6/12) basis, this latter degree of freedom is automatically included, and it is possible to bring the (2N-2,2) representation into this region to account for 3 of the states. One possible explanation for the existence of the remaining two states can be given in terms of the 1/2[770] and 3/2[761] Nilsson orbits which are outside the symmetry scheme. At first glance this would introduce three more states, but since the 1/2 band has a large decoupling parameter (≈-8), there should be an energy gap of ≈350 keV between the 1/2 and 3/2 states of the 1/2[770] band with the 3/2 state being lower. Hence one solution is that the states are the 3/2[701] and the 3/2 state of the 1/2[770] band. Identification of states could be done by considering single particle transfer cross sections, but it has not yet been possible to deduce a conclusive form for the IBFA transfer operator in the deformed region. Therefore, a quantitative analysis cannot be performed. However, Table 1 also shows experimental cross sections for (d,p) and (d,t) reactions[3] and tentative assignments for the three (2N-2,2) states are suggested on the basis that in the absence of strong ΔN=2 mixing, the cross sections to the N=7 states will be negligible.

4. STATUS OF A SUPERSYMMETRY

If the $U^B(6) \times U^F(12)$ boson-fermion symmetry is to be thought of as stemming from the supersymmetric group U(6/12), then other nuclei in the same supersymmetry multiplet as ^{185}W, specifically ^{184}W, should be describable using the same values for parameters. In the even-even case, the parameter A of Eq. 2 does not affect excitation energies, so its value is not important. The total rotational parameter used to describe ^{185}W is given by the coefficients of the L(L+1) and J(J+1) terms and takes the value of 17.5 keV. This compares well with the 18.5 keV used in ^{184}W. However, the strength of the Q·Q interaction, given by the parameter B in Eq. 2 takes the value of 11.6 keV for ^{185}W, using the assumption that the 663 keV level is the $1/2^-(2N-2,2)$ state, but only 5.7 keV for ^{184}W. This presents a major problem for the supersymmetric description. An analogous situation in the 0(6) limit was rectified[4] by multiplying the whole Hamiltonian by a factor $(1+\alpha C_{2U6})$ where C_{2U6} represents the Casimir operator of the $U^{B+F}(6)$ group and α is an additional parameter. However, in the SU(3) limit, a similar treatment would, while separating the different representations, predict different moments of inertia for the analogues of the 1/2[510] and 3/2[512] bands as compared to the 1/2[521] band. If it were possible to adjust the multiplicative factor so that the moments of inertia remained constant, then this treatment might enable the use of the same value of B in the two neighboring nuclei.

CONCLUSION

The agreement between the values of parameters for ^{184}W and ^{185}W is encouraging but does not constitute a supersymmetry as such. One way to remedy this while maintaining the symmetry has been suggested but as yet a physical interpretation for such an approach is lacking. Another solution is simply that the strict SU(3) symmetry is broken. Such a conclusion would not be surprising in light of the fact, mentioned above, that the even-even nucleus does not show the exact properties of the pure SU(3) limit. Thus symmetry breaking mechanisms must be studied and their investigation could provide a valuable insight into the application of IBFA schemes in this region.

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