STUDY OF SINGLE PARTICLE EXCITATIONS IN ^{153}Sm VIA ONE NEUTRON PICKUP*

A. Gollwitzer[a], N. Blasi[b], P.F. Bortignon[b], S. Deylitz[a], G. Graw[a], C. Hategan[c], R. Hertenberger[a], R. deLeo[d], S. Lucchini[b], S. Micheletti[b], M. Pignanelli[b], P. Schiemenz[a], and B.D. Valnion[a]

[a]Sektion Physik der Universität München, D-85748 Garching, Germany
[b]Dipartimento di Fisica dell'Universita' di Milano, I-20133 Milano, Italy
[c]Institute of Atomic Physics, Bukarest, Romania
[d]Universita'di Bari and Sezione INFN di Bari, Italy

(Received December 18, 1995)

Using the Munich Q3D spectrograph the ^{154}Sm($\vec{d}$,t), (d,t), (p,d), and (^{3}He,^{4}He) ^{153}Sm reactions have been measured at beam energies between 23 and 32 MeV. The high resolution of up to 4 keV FWHM especially in (p,d) is essential to achieve reliable energy calibration. All levels reported in the Nuclear Data Sheets [1] with the exception of high spin states ($J \geq 13/2$) are observed and at higher excitation energy (E_x >1MeV) many new levels could be identified. The analysis in the framework of the Nilsson model uses CCBA to include inelastic transfer amplitudes.

PACS numbers: 21.60.Cs, 24.10.Eq, 25.40.Gr, 25.45.Gh

1. Introduction

The investigation of the resolved distribution of single particle strength in a deformed nucleus like ^{153}Sm is of interest for a detailed comparison with modern nuclear structure calculations [2]. In the limit of one step processes the observed strength of one neutron pickup determines the Nilsson expansion coefficients and, thus, allows to study directly the wave function of Nilsson orbitals. Mixing of these states can be identified comparing

* Presented at the XXIV Mazurian Lakes School of Physics, Piaski, Poland, August 23– September 2, 1995.

measured Nilsson coefficients with model calculations. The main aim is to investigate modifications of Nilsson states due to RPA like excitations of the deformed core.

2. Experimental results and analysis

The one neutron pickup reactions ^{154}Sm($\vec{d}$,t), (d,t), (p,d), and (^{3}He,^{4}He) ^{153}Sm have been measured with three different beams and at beam energies ranging from 23 to 32 MeV. The reaction products from ^{154}Sm-targets of 99.2% enrichment and area densities from 20 to 200 μg/cm^2 were analysed in a Q3D-magnetic spectrograph equipped with a high resolution focal plane detector [3]. Parts of the spectra of these three different reactions are shown in Fig. 1. The high resolution of up to 4keV obtained in (p,d) FWHM is required to separate the dense spectra and to achieve a reliable energy calibration.

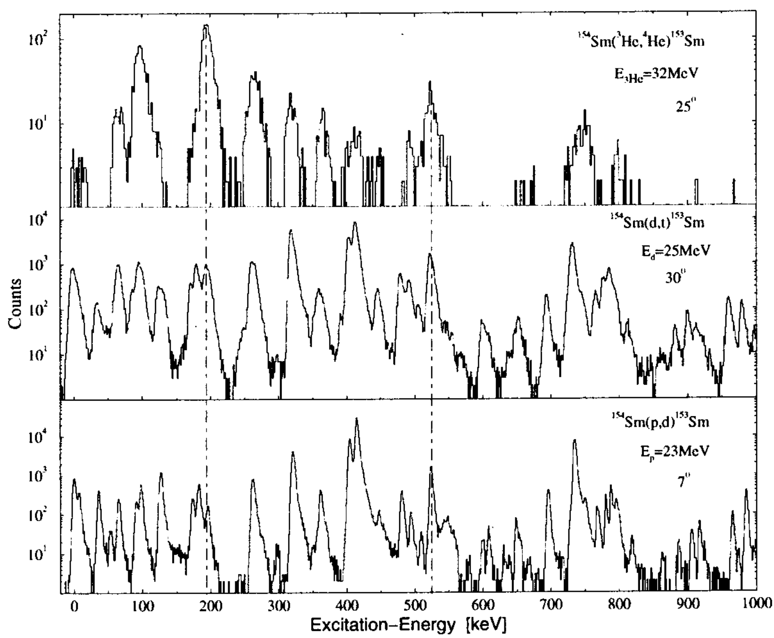

Fig. 1. Part of the energy calibrated spectra of one neutron pickup reactions to ^{153}Sm

So far, for about hundred angular distributions below 2MeV unique L-transfers have been assigned consistently in the (d,t) and (p,d), about 60% of them are new. Above 1MeV about twenty new levels mostly observed as $L = 2$ or $L = 3$ transfers can be reported.

The analysing power of the ^{154}Sm($\vec{d}$,t) is essential for reliable determination of I^π for a number of states. In Fig. 2 the three lowest band members of the 3/2[532] Nilsson band are shown. The theoretical calculations, which are done with the CCBA code CHUCK [4], reproduce here both the angular distribution and the analysing power (asymmetry) in a reasonable way with Nilsson coefficients near to the theoretical values.

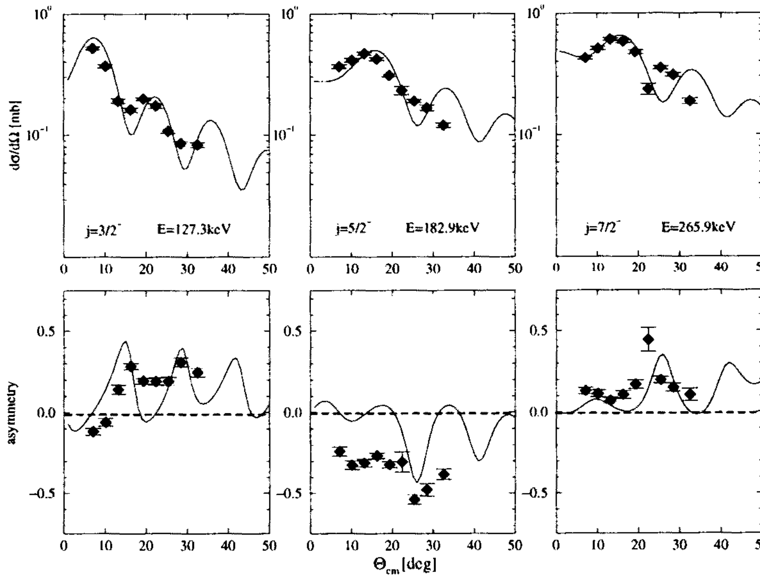

Fig. 2. Coupled channel calculations for the lowest 3/2[532] band members

In the forthcoming CCBA calculations the theoretical Nilsson coefficients [5] are modified to optimize the reproduction of the data. Moreover $\Delta N = 2$ (main shell) mixing, Coriolis mixing and pairing interaction has to be taken into account in the future [6]. Comparision of the different reactions with their different inelastic excitation strength will help to disentangle one step and two step processes.

With the exception of about six very small levels all observed states below 1MeV could be identified with respect to the I^π quantum number. Many of these assignments compared to [1] are new. Fig. 3 shows the positive and negative parity states.

Up to 1MeV fourteen negative parity states are seen. Two of them cannot be assigned to a known Nilsson band. One of them, the $I^\pi = (3/2)^-$ state at $E_x = 979$ keV, obviously is a new bandhead. For the positive parity states, the situation is even more complicated: Twenty one positive parity states are observed and only twelve can be assigned to Nilsson bands, at

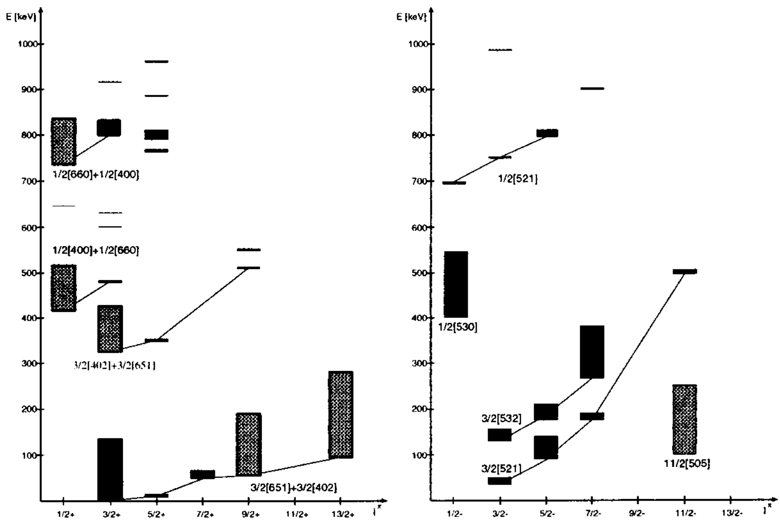

Fig. 3. Observed levels of identified positive parity states (left side) and negative parity states (right side) as function of angular momentum I^{π}. The size of the symbols corresponds to the measured transition strength (nonfilling means not accuratly scaled). Identified members of Nilsson bands are indicated.

least four new bandheads are identified. Theoretical Nilsson calculations based on single particle energies [5, 7, 8] predict four $I^{\pi} = (1/2)^{+}$, seven $I^{\pi} = (3/2)^{+}$, and nine $I^{\pi} = (5/2)^{+}$ states in a large energy range. We see, however, at the $E_x < 1$MeV already three $I^{\pi} = (1/2)^{+}$, six $I^{\pi} = (3/2)^{+}$, and five $I^{\pi} = (5/2)^{+}$ states. Between 1 and 2 MeV at least three more $L = 0$ and about ten $L = 2$ new transitions are identified. Thus, we have much more states than are predicted by the pure Nilsson model. Nilsson bands are discussed as observed, when bands with respect strength distributions in transition ("finger prints") are seen. It should be noted, that the observed excitation energies are much lower than the calculated values and partly three times compressed, a feature not really understood [10].

3. Conclusion

Even from this preliminary analysis it is obvious, that the Nilsson model does not account for the many states observed in ^{153}Sm. Other degrees of freedom like vibrations [9] of the deformed core have to be taken into account. Fragmentation of the transferred strength has to be studied in order to explain the large number of low L-transfers, which have been observed.

Work supported in Part by the DFG under IIC4-Gr 894/2.

REFERENCES

[1] *Nucl. Data Sheets*, Vol. 60, No. 2 (1990)
[2] Y.R. Shimizu, K. Matzuyanagi, *Prog. Theor. Phys.* **70**, No.1, July (1983).
[3] E. Zanotti *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A310**, 706 (1991).
[4] J. Comfort, P.D. Kunz, Input data for program CHUCK3, not published.
[5] P. Ring, program for calculating Nilsson Energies and Coefficients, private communication.
[6] M. Jaskola, Nukleonika, Vol.20, No. 10/75.
[7] J. Rekstad *et al.*, *Nucl. Phys.* **A320**, 239 (1979).
[8] J. Rekstad *et al.*, *Nucl. Phys.* **A298**, 122 (1978).
[9] A.K. Jain, R.K. Sheline *et al. Rev. Mod. Phys.* **62**, No.2, April (1990).
[10] I. Kanström, P.O. Tjöm, *Nucl. Phys.* **A179**, 305 (1972).