In-beam Spectroscopy of ^{231}Pa ◇

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Coulex calculations were continued to obtain a set of electromagnetic matrix elements describing ^{231}Pa a nucleus located near the boundary of octupole correlations.

Coulomb-excitation data was collected by particle-$\gamma\gamma$-coincidences using ^{32}S(148MeV) and ^{58}Ni(255,260,261MeV) projectiles backscattered from a 105$\,\mu$g/cm^2 radioactive ^{231}Pa oxide target on a 15$\,\mu$g/cm^2 carbon backing into either a segmented PSD-silicon detector or a multi-PIN-diode detector array and the readout of 20 Compton-suppressed germanium detectors of NORDBALL.

A level scheme was constructed from the data [1]. From this scheme 47 levels of 1/2[530], 3/2[651] and 1/2[400] bands are included in a Coulex calculation with a total of 672 E1,E2,E3,E4 and M1 matrix elements.

By the computer code GASPAN [2] about 2500 energy and efficiency calibrated yields were obtained. Using the symmetry of the NORDBALL-particle detector system and eliminating erroneous fits, e.g. in doublets with strong and weak partners, reduces the data to about 600 yields in 4×4 virtual detectors.

The computer code GOSIA [3] enlarged for the complex analysis, simultaneously fits the matrix elements to the yields. Since available computer power does not allow a optimization by the "annealing method" the code uses a gradient approach. Thus the problem is to determine a starting point from a set of parameters near the global minimum to avoid being trapped in local minima of the 672 dimensional hypersurface.

The influence of numerous weak side-band transitions gives rise to drastic changes in the measured intensities. Models were therefore introduced whose parameters could be adjusted to find a suitable starting point (see Fig.1). Since the experimental yields fix individual matrix elements to varying ranges and since correlation strengths differ within the parameter space, a fully model-independent fit in 672 dimensions leads to non-physical solutions especially for poorly determined matrix elements.

By coupling the matrix elements by a model [4] the number of degrees of freedom can be reduced. The $K=1/2$ bands involved lead to a parametrization with at least two parameters for one set of coupled matrix elements in E1, M1 transitions. The code however varies only one-parametrical coupled subsets. This restriction can be overcome by iterative minimizations on a subset with released matrix elements and by afterwards restoring the matrix elements to the fitted model values.

Deviations from the model assumptions are expected because of coriolis coupling. The sign of these deviations can be reproduced in particle-plus-phonon model calculations. Additionally a configuration change is introduced in the g.s.-band accounted for by splitting it into two virtual bands.

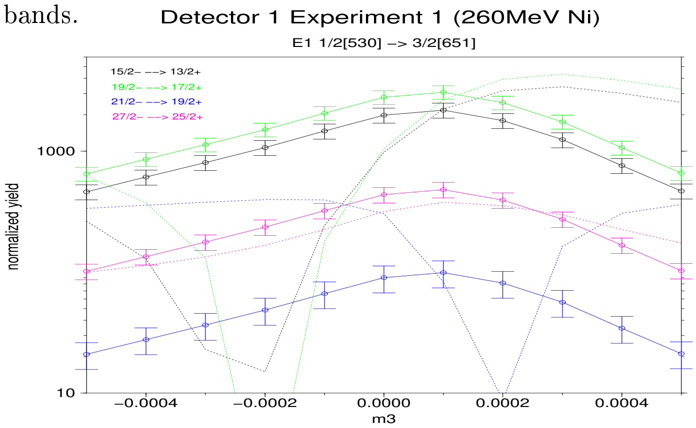

Fig. 1: Experimental E1 transitions feeding the 3/2[651] side band from the 1/2[530] g.s.-band with their errors (solid lines) are compared to calculated yields varying m_3 in the Mikhailov formula (dotted lines) $<K_f I_f||E1||K_i I_i> = \sqrt{2I_i+1}\ <I_i\, K_f{-}1\, 1\, 1|I_f K_f>\ (m_1 + m_2(I_f(I_i+1) - I_f(I_i+1)) + m_3(-1)^{I_{i|f}+0.5}(I_{i|f}+0.5)\delta(K_{i|f},0.5))$.

The quality of the obtained minima can be checked by using different starting points and comparing the values obtained from the best fit to relations given by the rules of tensor algebra.

In the minimization procedure the χ^2 statistics is normalized to the number of yields, because the number of uncorrelated degrees of freedom is not known. In the error analysis the code approximates the maximum error limits by taking into account correlated errors.

Up to now the averaged quadrupole moment Q_2 from the analysis is determined to be 2.8eb in agreement with 2.70(9)eb [5] from β-decay lifetime using the same conversion coefficients and 2.71(9)eb calculated from the spectroscopic quadrupole moment. Results from Coulomb excitation by particle spectroscopy with light ions and γ-spectroscopy yielded 2.9(1)eb [6,7].

A final analysis, especially of the errors, is in progress.

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