The Search for Superdeformation in Odd-Odd Praseodymium-132

Volume I

By

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ABSTRACT

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Results are presented from a fusion-evaporation experiment, conducted at the Holifield Heavy Ion Research facility at Oak Ridge National Laboratory. The reaction ^{100}Mo(^{37}Cl,γ)^{137}Pr* was studied using a beam energy of 160 MeV from the Tandem van deGraaf generator. Approximately 250×10^{6} coincidence events with a three–fold or higher multiplicity in the 20 HPGe Compton Suppression Spectrometer γ-ray detector array were recorded for analysis. The objective of this work was to determine the rotational band structure of ^{132}Pr at high spin and to search for superdeformation in this nucleus. Superdeformed rotational bands (SD) have the properties of deformed prolate rotors (β= .35–.5) and appear to originate from highly deformed intruder orbitals such as the $i_{13/2}$ neutron orbital and have been attributed to quasiparticle alignments.

A double gating method was developed to better select the ^{132}Pr transitions. Events in coincidence with four major transitions (116, 130, 178, 283 keV) were scanned into a 2-D array; then selected energy gates were summed to represent each band. Spectra of interest were extracted from the 2D arrays and refined using a novel Fast Fourier Transform technique that we developed during the course of this work.

The coincidence spectra for ^{132}Pr, in general, confirm the three rotational bands

observed in a previous (low spin) study. The negative parity, prolate shaped $\pi h_{11/2} \otimes \nu g_{7/2}$ (band 1) and the triaxial $\pi h_{11/2} \otimes \nu h_{11/2}$ (band 2) have been extended by a few energy transitions. We have seen five additional energy transitions, extending the decay scheme of the doubly decoupled band based on a $\pi h_{11/2} \otimes \nu i_{13/2}$ orbital coupling.

Four regularly spaced, weakly populated rotational bands were observed in coincidence with low-lying transitions in the ground state structure of ^{132}Pr. The four bands have very similar rotational characteristics. The spacings of successive transitions is comparable to those observed in superdeformed bands in the region. Cranked Shell Model (CSM) and Total Routhian Surface (TRS) calculations using a Woods-Saxon potential suggest a small set of plausible structures.

Also, in the course of this work, we have developed an extremely sensitive search technique for superdeformed bands. Our initial objective was to construct a fast method that would locate the same peaks within a simple total projection of all the energies within the data set. The Segmented FFT technique works through a mathematical investigation of the peaks that are present in the total spectrum. Peaks will be located depending on the presence of their spectral harmonics. The important features of this technique are: 1) the extreme sensitivity allows SD bands to be located within a total energy projection spectrum, as well as a spectrum generated without background subtraction from the sum of energy gates on the band and 2) the method is extremely fast. Once the parameters and conditions have been optimized, the analysis is complete within minutes instead of weeks that other methods require. 3) The technique can be used to confirm the presence of a known SD band or to locate a potential SD band prior to setting gates on a data array. When using a template for a known band, the Segmented FFT routine can be a diagnostic tool that cannot be matched by any other search techniques.

A.M.D.G.

To Erick, Emily, and Zoe

with love

PREFACE

A most dramatic, historically important event occurred during the time of this research experiment. We drove to Oak Ridge, Tennessee for two weeks to do the experiment and on the way back we heard that the Berlin Wall was being torn down, making way for the most unprecedented strides in thinking that this Century has known. Minds were open and the stage was set for tremendous change: The people of the Soviet Union said no to communism. Israel and Palestine talked peace.... And, on a personal note, for me, freedom and scientific research were forever linked.

There are many people who deserve acknowledgment for this work. Foremost, for help during the experiment at HHIRF, Oak Ridge National Lab, and for advice about the analysis, I would like to express my gratitude to: Professor William C. McHarris, Reg Ronningen, Aracelys Rios, Wade Olivier (NSCL), Rahmat Aryaeinejad (EG & G Idaho), the Oak Ridge Nuclear Structure Group: Francis McGowan, Jim McNeil, I.Yang Lee, Mark Whitley, Shi Yong, Noah Johnson, Cyrus Backtash, J.D. Garrett, the Tandem Operators who provided days of a 160.00 MeV, $^{37}Cl^{+7}$ beam, and Franda Irving and the people who coordinate the Holifield Joint Institute for Heavy Ion Research facility that provided accommodations for the stay at Oak Ridge.

After the experiment, the actual day-to-day work was replete with tedium and trial-and-error repetition of the analyses until the results looked right. The data tapes were spinning so often that one of the post-docs suggested that the computer be renamed 'Hampton'. I found a source of consolation and inspiration in the following anonymous poem entitled 'dream big' that was published in *The State News* circa 1991. It was the lead-in to a computer advertisement section called 'The big paper about ideas, college and Macintosh' and was helpful on many more than one occasion.

If there were ever a time to dare,
to make a difference,
to embark on something worth doing,
it is now.
Not for any grand cause, necessarily —
but for something that tugs at your heart,
something that's your aspiration,
something that's your dream.
You owe it to yourself
to make your days here count.
Have fun.
Dig deep.
Stretch.
Dream big.
Know, though, that things worth doing
seldom come easy.
There will be good days.
And there will be bad days.
There will be times when you want to turn around,
pack it up,
and call it quits.
Those times tell you
that you are pushing yourself,
that you are not afraid to learn by trying.
Persist.
Because with an idea,
determination,
and the right tools,
you can do great things.
Let your instincts,
your intellect,
and your heart
guide you.
Trust.
Believe in the incredible power of the human mind.
Of doing something that makes a difference.
Of working hard.
Of laughing and hoping.
Of lazy afternoons.
Of lasting friends.
Of all the things that will cross your path this year.
The start of something new
brings the hope of something great.
Anything is possible.
And you will pass this way only once.
Do it right.

For help during those long, seemingly countless days of spinning tapes and generating data arrays, thanks go to: Bill Milner from the Oak Ridge computer group; the NSCL computer group: Richard Au, Ron Fox, Barbara Pollack, Lisa Besko, Lori and Cindi Ramon and Bill Paddock. We would like to express our appreciation to Karl Hauschild (LBNL) and the authors of Ref. [hau95] who provided the ^{133}Ce SD data to help with the development of the SD search technique. Also, we acknowledge those who sent data to test out our FFT signal enhancement techniques: Nada Jevtic (SRI), Thomas Semkow (Albany), Arlyn Antolak (Sandia), and K. Hauschild.

We would like to thank Henry Blosser, Sam Austin, and Konrad Gelbke, directors of the National Superconducting Cyclotron Lab for the extended use of the facilities. Also, we would like to acknowledge the aid of the guidance committee: Professors Katherine Hunt, John McCracken , William Reusch, Victoria McGuffin, and the late Professor Carl Brubacker from the Chemistry Department, and Professors Aaron Galonsky from NSCL and the Physics/Astronomy Department and Jerry Nolen now Director of the ATLAS facility at Argonne. All of those who have been in the McHarris group, in one capacity or another, deserve acknowledgment: Wen-Tsae Chou, Wade Olivier for the tremendous help with the program development for the FFT search technique and the shell model calculations, Aracelys Rios, Yves Dardenne, Bin Lian for help with the initial FFT program, Tony Hsieh, and Nancy Davis; for help in various phases of the data analysis: Jill E. Johnson, Jeff Wesley, Ron Brown, and Christopher P. Maloney, MSU chemistry students completing their undergraduate degrees.

I would also like to bid adieu to those that I have shared office space with: Hong Ming Xu, Wen-Guang Gong, Cornelius Williams, Wen-Chien Hsi, James Dinius, Afshin Azhari, Ray Min-Jui Huang, and Omar Bjarki. To Rilla, the other Dr. McHarris, I say thanks for help with the figures, for the many discussions, — for everything. To my family, without whose generous emotional and financial help this work would not

have been possible, I give my deepest gratitude. To Professor William C. McHarris, someone wise once said that good teachers show their student the way but great teachers allow the student to look through their eyes and listen with their ears, to discover it for themselves. For encouraging the discovery process, I truely thank you.

Okemos

March, 1994

revised

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C.V.H.

Contents

List of Tables

List of Figures