NUCLEAR STRUCTURE RESEARCH

Progress Report for the Period
August 1, 1990 – July 31, 1993

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I. ABSTRACT

The Clark University research program in nuclear structure is a collaborative effort involving Clark University personnel, staff members from Brookhaven National Laboratory and an active participation of scientists from the U.S. and other nations. The TRISTAN on-line isotope separator and the capture γ -ray facility at the High Flux Beam Reactor are the primary experimental foci of the program which has four principal research themes, three involving nuclear structure physics and one directed towards astrophysics. These themes are: (1) the manifestation of the proton-neutron interaction in the evolution of nuclear structure and its relation to collectivity, (2) the appearance and the role of symmetries and supersymmetries in nuclei, (3) the study of new regions of magic nuclei, and (4) the characterization of nuclei important in r-process stellar nucleosynthesis.

The activities involving Clark personnel during the operating period of Grant No. DE-FG02-88ER40417, August 1, 1990 – July 31, 1993, are summarized below.

II. NUCLEAR STRUCTURE RESEARCH

A. Introduction

The Clark University nuclear structure research group has been actively involved in research at the High Flux Beam Reactor, Brookhaven National Laboratory, since 1980 when the TRISTAN on-line isotope separator was installed at BNL. During the period 1980-86 TRISTAN operated as a facility which provided beam time and support services to independent user groups. Since then the format has evolved into a collaborative effort involving personnel from Brookhaven National Laboratory, Clark University, and other institutions both in the U.S. and from abroad. The scope of our initiatives has broadened to include the tailored beam facility at BNL and joint projects with scientists at other facilities, most notably the Institute Laue-Langevin, Grenoble, France.

From the scientific perspective the major impact of the collaborative program has been the focussing of effort on several research themes deemed to have critical interest by the group. Currently, four themes have been identified for concerted study: (1) the crucial effects of the proton-neutron interaction on the evolution of nuclear structure and its relation to collectivity, (2) the appearance and role of symmetries and supersymmetries in nuclei, (3) the study of new regions of magic nuclei, and (4) the characterization of nuclei far-from-stability of significance to r-process nucleosynthesis. The focussing of the research effort on these four themes is evident in the progress reported herein and in recent publications involving Clark personnel.

Experimental progress in recent years has been hampered by unforeseen extended shutdowns of the HFBR for safety evaluations and repair. These shutdowns, which were in effect from April, 1989 to July, 1991 and from November, 1992 to June 1993, resulted in a redirection of effort to studies of the systematics of the p-n interaction and evolution of collective behavior in nuclei. At the same time the shutdowns provided an opportunity to develop and test new experimental systems such as a barium fluoride detector array for angular correlation and g-factor

measurements and a fast electronic scintillation counting unit (FEST) for short lifetime measurements. In addition, plans were developed and implemented for joint initiatives at the Institute Laue-Langevin. Now that the HFBR has resumed regular operation, we are again pursuing a vigorous program at TRISTAN and the tailored beam, capture γ -ray facility.

In preparation for the advent of a first generation radioactive beam facility at Oak Ridge National Laboratory, planning is underway for a transportable coulomb excitation system that will be used to study the excitation of low lying states of radioactive beam nuclei.

These projects and other progress are described in more detail below.

B. Publications

During the period, August 1, 1990 – July 31, 1993, covered by this report, a number of projects were completed and submitted for publication. The following list includes papers published, accepted for publication, or under review at the present time.

1. Letters

Shell Structure in Empirical p-n Interactions: Comparison with Nilsson and Shell Model Calculations

W.-T. Chou, J.-Y. Zhang, R.F. Casten, and D.S. Brenner
Phys. Lett. **B255**, 487-492 (1991).

Identical Bands and the Varieties of Rotational Behavior

J.-Y. Zhang, R.F. Casten, W.-T. Chou, D.S. Brenner, N.V. Zamfir, and P. von Brentano
Phys. Rev. Lett. **69**, 1160-1162 (1992).

Linearity of Nuclear Level Energies with the P-Factor

D.S. Brenner, R.F. Casten, W.-T. Chou, J.-Y. Zhang, K. Heyde, and N.V. Zamfir
Phys. Lett. **B293**, 282-286 (1992).

The Enigma of ^{114}Cd . A Classical Case of Ambiguities in Quantum Mechanical State Mixing

R.F. Casten, J. Jolie, H.G. Börner, D.S. Brenner, N.V. Zamfir, W.-T. Chou and A. Aprahamian
Phys. Lett. **B297**, 19-24 (1992).

Valence Correlation Schemes and New Signatures of Nuclear Structure: A Simple Global Phenomenology for $B(E2:2_1^+ \rightarrow 0_1^+)$ Values

R.F. Casten and N.V. Zamfir
Phys. Rev. Lett. **70**, 402-405 (1993).

A New Signature for Phase Transition Regions

N.V. Zamfir and R.F. Casten

Phys. Lett. **B305**, 317-321 (1993).Universal Anharmonic Vibrator Description of Nuclei and Critical Nuclear Phase Transitions

R.F. Casten, N.V. Zamfir, and D.S. Brenner

Phys. Rev. Lett. **71**, 227-230 (1993).Effective Valence Spaces and Collectivity in Neutron Deficient Dy-Pt Nuclei

W.-T. Chou, R.F. Casten, R.L. Gill, N.V. Zamfir, and D.S. Brenner

Mod. Phys. Lett. (in press).

F-Spin Purity of $2_1^\pm$ States in Even-Even Nuclei

A. Wolf, O. Scholten, and R.F. Casten

Phys. Lett. **B** (submitted).**2. Articles**Coexistence Features in the Spherical-Deformed $A \sim 100$ Transition Region: Picosecond Lifetime Measurements in ^{97}Sr , ^{97}Y and ^{97}Zr

M. Büscher, R.F. Casten, R.L. Gill, R. Schuhmann, J.A. Winger, H. Mach, M. Moszynski, and K. Sistemich

Phys. Rev. **C41**, 1115-1125 (1990).Structure of ^{76}Zn from ^{76}Cu Decay and Systematics for Neutron-Rich Zn Nuclei

J.A. Winger, J.C. Hill, F.K. Wohn, E.K. Warburton, R.L. Gill, A. Piotrowski, R.B. Schuhmann, and D.S. Brenner

Phys. Rev. **C42**, 954-960 (1990).Simplified Shell Model Calculations for Valence Mirror Nuclei

R.F. Casten, J. Yan, R. Wirowski, A. Gelberg, P. von Brentano, and D.S. Brenner

Nucl. Phys. **A514**, 252-272 (1990).Retardation of $B(E2; 0_1^\pm \rightarrow 2_1^\pm)$ Rates in $^{90-96}\text{Sr}$ and Strong Subshell Closure Effects in the $A \sim 100$ Region

H. Mach, F.K. Wohn, G. Molnár, K. Sistemich, J.C. Hill, M. Moszynski, R.L. Gill, W. Krips, and D.S. Brenner

Nucl. Phys. **A523**, 197-227 (1991).Spectroscopy of ^{214}Bi and Systematics of $^{210,212,214}\text{Pb}(0_1^+) \xrightarrow{\beta^-} ^{210,212,214}\text{Bi}(0_1^-)$

Z. Berant, R.B. Schuhmann, D.E. Alburger, W.-T. Chou, R.L. Gill, E.K. Warburton, and C. Wesselborg

Phys. Rev. **C34**, 1639-1655 (1991).Linkage Between β and γ Vibrational Excitations in Deformed Nuclei

W.-T. Chou, R.F. Casten, and P. von Brentano

Phys. Rev. **C45**, R9-R12 (1992).

Identical Bands in Widely Dispersed Nuclei

R.F. Casten, N. V. Zamfir, P. von Brentano, and W.-T. Chou
Phys. Rev. **C45**, R1413-R1416 (1992).

Construction of Shell Model Interactions for $Z > 50$, $N > 82$ Nuclei: Predictions for $A = 133-134$ β -Decays

W.-T. Chou and E.K. Warburton
Phys. Rev. **C45**, 1720-1729 (1992).

Signature Splitting in Octupole Bands of Deformed Nuclei

W.-T. Chou, R.F. Casten, and N.V. Zamfir
Phys. Rev. **C45**, R2545-R2547 (1992).

A Study of High Spin States in the Transitional Nucleus ^{90}Mo

M.K. Kabadiyski, F. Cristancho, C.J. Gross, A. Jungclaus, K.P. Lieb, D. Rudolph, H. Grawe, J. Heese, K.-H. Maier, J. Eberth, S. Skoda, W.-T. Chou, and E.K. Warburton
Z. Phys. **A343**, 165-177 (1992).

F-Spin Multiplets of $O(6)$ -Like Nuclei

N.V. Zamfir, R.F. Casten, P. von Brentano, and W.-T. Chou
Phys. Rev. **C46**, R393-R396 (1992).

Average Resonance Capture Study of ^{126}Te

W.-T. Chou, R.F. Casten, and N.V. Zamfir
Phys. Rev. **C46**, 2283-2288 (1992).

Axial Asymmetry in Nearly Symmetric Deformed Nuclei

R.L. Gill, W.-T. Chou, and R.F. Casten
Nucl. Phys. **A542**, 32-42 (1992).

Level Lifetime Measurements and the Structure of Neutron-Rich ^{78}Ge

W.-T. Chou, D.S. Brenner, R.F. Casten, and R.L. Gill
Phys. Rev. **C47**, 157-162 (1993).

Gamow-Teller Beta-Decay Rates for $A \leq 18$ Nuclei

W.-T. Chou, E.K. Warburton, and B.A. Brown
Phys. Rev. **C47**, 163-177 (1993).

Signature Splitting in Octupole Bands of Vibrational and Deformed Nuclei

R.F. Casten, W.-T. Chou, and N.V. Zamfir
Nucl. Phys. **A555**, 563-584 (1993).

g-Factor of the $3/2^+$ 93.6 keV Level in ^{91}Sr

A. Wolf, R.L. Gill, D.S. Brenner, Z. Berant, R.B. Schuhmann, and N.V. Zamfir
Phys. Rev. **C** (in press).

The Relation of Collective Observables to Nuclear Shapes

J.-Y. Zhang, R.F. Casten, and N.V. Zamfir
Phys. Rev. **C** (submitted).

Performance of Conventional Fast Photomultipliers in an External Magnetic Field

A. Wolf, R.L. Gill, D. S. Brenner, Z. Berant, and R.B. Schuhmann
Nucl. Instr. Meth. (submitted).

Lifetimes and Electromagnetic Decay Properties of Negative-Parity States in $^{150,152,154}\text{Sm}$ from $(n,n'\gamma)$ Measurements

A. Jungklaus, T. Belgia, D.P. DiPrete, M. Villani, E.L. Johnson, E.M. Baum, C.A. McGrath, S.W. Yates, and N.V. Zamfir
Phys. Rev. C (submitted).

Octupole Fragmentation and $O(6)$ Symmetry in Even-A Pt Isotopes

N.V. Zamfir, P.D. Cottle, J.L. Johnson, and R.F. Casten
Phys. Rev. C (submitted).

3. Conference Proceedings

Configuration Sensitivity of Residual p-n Interactions

R.F. Casten, D.S. Brenner, C. Wesselborg, and J.-Y. Zhang
XII Workshop on Nuclear Physics, Iguazu Falls, Argentina, M.C. Cambiaggio, A.J. Kreiner and E. Ventura, eds. (World Scientific, Singapore, 1990), p. 310-313.

Comment on Collective Models and the p-n Interaction

R.F. Casten, D.S. Brenner, and P. von Brentano
Alaga Memorial Volume, Fizika 22, 145-151 (1990).

Empirical Estimates of the Proton-Neutron Interaction and Diabolical Points

J.-Y. Zhang, J.D. Garrett, R.F. Casten, D.S. Brenner, C. Wesselborg, C.-H. Yu, and M. Carpenter

International Conference on Nuclear Structure in the Nineties, Oak Ridge, Nucl. Phys. A520, 251-258 (1990).

Global Trends and Structural Consequences of the Proton-Neutron Interaction

D.S. Brenner, R.F. Casten, C. Wesselborg, D.D. Warner, and J.-Y. Zhang
ACS Symposium on Exotic Nuclear Spectroscopy, W.C. McHarris, ed. (Plenum, New York), p. 511-522 (1990).

E2 and M1 Strengths and Strong Sub-Shell Closure Effects in Neutron-Rich $A \sim 100$ Nuclei

F.K. Wohn, H. Mach, G. Molnar, K. Sistemich, J.C. Hill, M. Moszynski, R.L. Gill, W. Krips, D.S. Brenner, and R.F. Casten

International Symposium on Capture Gamma-Ray Spectroscopy and Related Topics (7th; 1990; Pacific Grove, CA), AIP Conference Proceedings 238, R.W. Hoff, ed., American Institute of Physics, New York (1991) p. 418-420.

Is Nuclear Structure Really So Simple? (The P-Factor Revisited)

D.S. Brenner, R.F. Casten, W.-T. Chou, J.-Y. Zhang, N.V. Zamfir, and K. Heyde
Proceedings of the 6th International Conference on Nuclei Far From Stability and the 9th International Conference on Atomic Masses and Fundamental Constants
Bernkastel-Kues, Germany, July (1992), Inst. Phys. Conf. Ser. No. 132, Section 5, IOP Publishing Ltd., (1993) p. 615-617.

Phenomenological Correlations in Nuclear Structure: An Opportunity for Nuclear Astrophysics and a Challenge to Theory

R.F. Casten and N.V. Zamfir

First Symposium on Nuclear Physics in the Universe, Oak Ridge National Laboratory, Oak Ridge, TN, September (1992) in press.

A New Simple Global Phenomenology of Nuclear Shape Transition

R.F. Casten, N.V. Zamfir, and D.S. Brenner

Third International Conference on Radioactive Nuclear Beams, East Lansing, MI, May (1993) in press.Predicting Properties of Exotic Collective Nuclei Using Valence Nucleon Correlation Schemes

D.S. Brenner

Third International Conference on Radioactive Nuclear Beams, East Lansing, MI, May (1993) in press.New Signatures for Phase/Shape Transitional Regions

N.V. Zamfir, R.F. Casten, J.-Y. Zhang, and D.S. Brenner

International Symposium on Capture Gamma-Ray Spectroscopy and Related Topics, (8th; 1993; Fribourg, Switzerland) in press.Correlations in Nuclear Observables: Towards a Universal Synthesis of Structural Evolution

R.F. Casten, N.V. Zamfir, and D.S. Brenner

International Symposium on Capture Gamma-Ray Spectroscopy and Related Topics, (8th; 1993; Fribourg, Switzerland) in press.**C. Professional Activities**

In addition to formal publication, the results of our work have been presented orally, as posters and in abstracted form at professional meetings.

1. Contributed Papers/Abstracts/PostersEmpirical Proton-neutron Interaction Energies and Nuclear Structure

D.S. Brenner, C. Wesselborg, R.F. Casten, D.D. Warner, and J.-Y. Zhang

8th International Conference on Atomic Masses and Fundamental Constants, Jerusalem, Israel, September 9-14, 1990 (cancelled, published abstract).B(E2) Strengths in $^{90-96}\text{Sr}$ and Strong Subshell Effects in Sr Nuclei

F.K. Wohn, J.C. Hill, H. Mach, K. Sistemich, G. Molnár, R.L. Gill, W. Krips, M. Moszynski, and D.S. Brenner

Bull. Am. Phys. Soc. **35**, 1649 (1990).Comparison of Experimental with Calculated p-n Interactions in Doubly Magic Regions

W.-T. Chou, J.-Y. Zhang, R.F. Casten, D.S. Brenner, and C. Wesselborg

Bull. Am Phys. Soc. **35**, 1656 (1990).Small B(E2; $0_1^+ \rightarrow 2_1^+$) Rates in $^{90-96}\text{Sr}$: Evidence for Subshell Closure Effects

H. Mach, F.K. Wohn, G. Molnar, K. Sistemich, J.C. Hill, M. Moszynski, R.L. Gill, W. Kripps, and D.S. Brenner

German Physical Society (DPG), March, 1991 (published abstract).

Linkage Between Properties of β and γ Bands in Deformed Nuclei

W.-T. Chou, R.F. Casten, and P. von Brentano
Bull. Am. Phys. Soc. **36**, 2143 (1991).

Signature Splitting in Octupole Bands of Transitional Nuclei

N.V. Zamfir, R.F. Casten, and W.-T. Chou
Bull. Am. Phys. Soc. **37**, 1289 (1992).

Linearity of Nuclear Energies with the P-Factor

D.S. Brenner, R.F. Casten, W.-T. Chou, J.-Y. Zhang, K. Heyde, and N.V. Zamfir
Bull. Am. Phys. Soc. **37**, 1321 (1992).

Universal Anharmonic Vibrator Description of Nuclei and Critical Phase Transition Behavior

D.S. Brenner, N.V. Zamfir, and R.F. Casten
Bull. Am. Phys. Soc. (in press).

2. Invited Talks**D.S. Brenner**The Structure of the Nucleus – A Tutorial from a Chemist

Bates College, January, 1991
SUNY Stony Brook, February, 1991
St. Lawrence University, April, 1991
SUNY Potsdam, April, 1991
NEACT (New England Association of Chemistry Teachers) Summer Conference, Rivier
College, August, 1991
St. Joseph's College, January, 1993

The Role of the p-n Interaction in Nuclear Structure

SUNY Stony Brook, February, 1991

Is Nuclear Structure Really So Simple? (The P-Factor Revisited)

Notre Dame University, March, 1992
Symposium on Nuclear Shapes, National Meeting of the American Chemical Society,
Washington, D.C., August, 1992
SUNY Stony Brook, November, 1992

W.-T. ChouExploiting the Simplicities of the IBA to Understand Nuclear Shapes and Excitations

Rutgers University, November, 1991

Valence Correlation Schemes in Nuclei

Michigan State University, April, 1992
Argonne National Laboratory, April, 1992

3. Education

Each summer since 1989 D.S. Brenner has presented a series of lectures on nuclear chemistry and physics to students in the BNL Summer School on Nuclear Chemistry. This program, which is designed to provide intense and rigorous training in nuclear and radiochemistry to students who are between their sophomore and junior years in college, is focussed on addressing the shortfall in trained personnel for applied and basic research in nuclear science and medicine. Primary funding for the Summer School is provided by DOE with ancillary support from the Division of Nuclear Chemistry and Technology of the American Chemical Society and from Brookhaven National Laboratory.

4. Professional Service

D.S. Brenner has served as a member of the Program Committee of the Division of Nuclear Chemistry and Technology of the American Chemical Society (1990-92) and as a member of the Division's Committee on Education and Training (1991-93). In addition, he served as Chairman of the Undergraduate Awards Committee (1991-93).

He also was the organizer of a Symposium on Recent Advances in Nuclear Structure Research for the American Chemical Society Meeting, Atlanta, April, 1991 (a 3.5-day symposium involving 39 speakers from 8 countries) and a Symposium in Honor of Thomas T. Sugihara for the Chicago ACS Meeting, August, 1993.

D.S. Brenner has reviewed manuscripts for Physical Review Letters, Physical Review C, and the Journal of Modern Physics E as well as research proposals for DOE and for the Scientific and Engineering Research Council of Canada. During 1992 he served on DOE performance review panels for the National Nuclear Data Center (BNL) and for the Lawrence Berkeley Laboratory - Isotopes Project (LBLIP)

D. Recent Initiatives

In this section we include brief reports of recent research which is still in progress or which has been submitted for publication, but has not yet appeared in the open literature.

1. g-Factor of the $3/2^+$ 93.6 keV Level in ^{91}Sr

(Clark/BNL/Negev/Bucharest-Magurele)

The g-factor of the first excited, $3/2^+$, 93.6 keV level of ^{91}Sr has been measured using a beam of separated fission products at the TRISTAN on-line isotope separator and the Time-Differential Perturbed Angular Correlation method. The fission products, which were deposited on an aluminized tape, were transported periodically to the center of a superconducting magnet (maximum field--6.3 Tesla). The time correlations of the decays were made using the newly constructed BaF_2 4-detector array since the lifetime of the 93.6 keV level (88.8 ns) was too short to permit accurate measurements with HpGe detectors. The BaF_2 detectors featured special magnetic shielding around the photomultiplier tubes which enabled proper operation in the fringe field of the magnet. Fig. 1 shows the measured lifetime of the 93.6 keV level and time differential perturbed angular correlation obtained with the BaF_2 array. The g-factor determined in this fashion

Fig. 1. (a) Sum of time spectra for the 93.6 keV transition in the 345.5 keV gate. The solid line is a fit to a lifetime plus background function, yielding $t_{1/2} = 94(5)$ nsec. (b) The time differential perturbed angular correlation for the 93.6 keV level and a functional fit to the data.

was $g(3/2^+) = -0.231(11)$. We calculated a value for this level using the simple core-excitation model of de Shalit [1] and obtained $g_{\text{calc}}(3/2^+) = -0.252(13)$ in agreement with experiment. Similar calculations for ^{95}Mo , ^{99}Ru , and ^{101}Ru , the only $N = 53-57$ isotones for which $g(3/2^+)$ is

Fig. 2. Energy and time resolution (FWHM) for five values of the external magnetic field. The values for zero field are shown for comparison.

known, also gave quite good agreement. The data display a definite N -dependence with the absolute value of the g -factor decreasing as more neutrons are added to the nucleus. This effect may be related to particle-hole excitations which are known [2] to considerably affect the magnetic moments, and become less effective as the shell fills because of the Pauli principle.

This work has been accepted for publication in Physical Review C.

- [1] A. de Shalit, Phys. Rev. **122**, 1530 (1961).
- [2] A. Arima and H. Horie, Prog. Theor. Phys. **12**, 623 (1954).

2. Performance of Conventional Fast Photomultipliers in an External Magnetic Field

(BNL/Clark/Negev)

The performance of fast XP2020Q photomultipliers in an external magnetic field was shown to be reasonably good up to average fringe fields of about 0.1 Tesla, when appropriate, commercially available, magnetic shielding is used. These photomultipliers, which are an essential part of our BaF₂ fast-timing detector array, must be operated in a quite high (~0.15T) fringe field environment of our superconducting solenoid positioned on the +45° beam line of the TRISTAN on-line isotope separator. Fortunately the special magnetic shielding (Philips S5632/AV) used around the detector/photomultiplier assemblies was shown to reduce the fringe field by a factor of about 10⁴. The characteristic energy and time resolutions of the BaF₂ system as a function of average external fringe field is shown in Fig. 2.

This work has been submitted to Nuclear Instruments and Methods for publication.

3. New Signatures for Phase/Shape Transitional Regions

(BNL/Clark/Bucharest-Magurele/Tennessee/Lanzhou)

An analysis of yrast energies in collective even-even nuclei shows that the data are highly correlated along a single curve as shown in Fig. 3 where the 2₁⁺ and 4₁⁺ energies for all “collective” nuclei, i.e., those with $R_{4/2} \equiv E(4_1+)/E(2_1+) > 2.05$ are plotted. All non-rotational nuclei ($R_{4/2} < 3.15$), which include spherical, γ -soft, and transitional nuclei, can be described by a simple anharmonic vibrator equation with nearly constant anharmonicity, which is independent of the internal phonon structure:

$$E(4_1^+) = 2.02(2)E(2_1^+) + \epsilon_4 \quad [1]$$

where $\epsilon_4 = 156(10)$ keV. The transition from anharmonic vibrator to rotor can be represented by a modification of ϵ_4 so that the derivative $dE(4_1^+)/dE(2_1^+)$ behaves as a critical phase transition:

$$dE(4_1^+)/dE(2_1^+) = 2 + \alpha[E_C - E(2_1^+)]^\lambda \quad [2]$$

where $E_C = 155$ keV, $\lambda = 0.39$ and $\alpha = 0.19$ keV $^{-\lambda}$ for $Z = 38-82$ and $E(2_1^+) < E_C$. This equation is exactly the expression for a critical phase transition in condensed matter systems, where E_C is the critical point, λ is the so-called critical exponent, and where $dE(4_1^+)/dE(2_1^+) - 2$ is a nuclear order parameter. Thus we see that the structural transition in nuclei is from an anharmonic vibrator with nearly constant anharmonicity to a rotor and that this transition takes place over a very narrow range of $E(2_1^+)$ [see the inset of Fig. 3].

Fig. 3. Plot of $E(4_1^+)$ and $E(2_1^+)$. The harmonic vibrator ($R_{4/2} = 2.00$) and rotor ($R_{4/2} = 3.33$) limits and a linear least-squares fit for nuclei with $R_{4/2} < 3.15$ (eq. [1]) are shown. Inset: the derivative $dE(4_1^+)/dE(2_1^+)$ against $E(2_1^+)$ (eq. [2]).

Another correlation that reveals structure in a unique way is that of $B(E2; 2_1^+ \rightarrow 0_1^+)$ values with $R_{4/2}$ as shown in Fig. 4. Here we see that both experimental data and schematic IBA-1 calculations show that there are two distinct tracks which mark the transitions from A~150 spherical vibrators to the symmetric rotor region [$U(5) \leftrightarrow SU(3)$, the upper track] and from γ -soft

Fig. 4. Experimental plot of $B(E2; 2_1^+ \rightarrow 0_1^+)$ vs. $R_{4/2}$ compared with schematic IBA-1 calculations (solid line) for the shape transitional trajectories $U(5) \leftrightarrow SU(3)$, $O(6) \leftrightarrow SU(3)$, and $U(5) \leftrightarrow O(6)$.

to symmetric rotors [$O(6) \leftrightarrow SU(3)$, the lower track]. Also shown is the $U(5) \leftrightarrow O(6)$ path which is not well defined by experimental data.

The remarkable result is that the measurement of a very few observables can serve to characterize the structure of a new nucleus, for example, one that might become available in a first generation radioactive beam facility. Simple measurements of $E(2_1^+)$, $E(4_1^+)$, and $B(E2; 2_1^+ \rightarrow 0_1^+)$ for one or two nuclei in a region can serve to define the structure and to locate a transitional nucleus within or along the legs of the symmetry triangle.

Aspects of this work have been published or are pending publication in conference proceedings.

4. F-Spin Purity of 2_1^+ States in Even-Even Nuclei

(BNL/Clark/Negev/Groningen)

A procedure has been developed by which the upper limits of F-spin purity of 2_1^+ states in even-even nuclei can be estimated by an analysis based on the experimental g-factors of these states and on IBA-2 calculations. The procedure was applied to 17 nuclei with $46 < Z < 78$. We find that $F < F_{\max}$ admixtures of up to 15% are not uncommon. A systematic behavior with respect to Z was observed. In the present approach, at least part of the deviations of the boson g-factors, g_π and g_ν , from their "bare" values of 1 and 0, which have been known empirically for some time, can be interpreted in terms of F-spin admixtures.

A paper describing these results has been submitted for publication in Physics Letters B.

5. Octupole Fragmentation and O(6) Symmetry in Even-A Pt

(BNL/Clark/Bucharest-Magurele/Florida State)

The systematic behavior of the fragmentation of the low energy octupole state over a wide range of mass regions has been well reproduced using a $U(5) \leftrightarrow SU(3)$ transition in the context of the Interacting Boson Approximation. However, the octupole fragmentation in the even-A Pt isotopes deviates strongly from both the systematic behavior of other nuclei and from the $U(5) \leftrightarrow SU(3)$ calculations. This anomalous behavior can be explained in terms of the O(6) nature of the stable Pt isotopes. From this we conclude that the anomalously large fragmentation of the low energy octupole state is a signature of nuclei conforming to the O(6) dynamical symmetry.

This work has been submitted for publication.

6. Predicting Properties of Exotic Collective Nuclei Using Valence Nucleon Correlation Schemes

(Clark)

Simple parameterizations of collective behavior in nuclei, in terms of the pairwise interactions

of valence nucleons with partners of the same and opposite type, have been remarkably successful in providing a physically intuitive framework for understanding the development of collectivity in medium and heavy nuclei. Properties such as $E(2_1^+)$, $E(4_1^+)/E(2_1^+)$, $B(E2; 2_1^+ \rightarrow 0_1^+)$ and masses have been shown to vary smoothly, and sometime linearly, when plotted against the valence nucleon product $N_p N_n$ or a related quantity, the P-factor, $P = N_p N_n / (N_p + N_n)$, where the quantities N_p and N_n are the number of valence protons and valence neutrons, respectively, counted from the nearest shell or subshell closure.

Fig. 5. A portion of the chart of the nuclides highlighting the traditional r-process path. The regions A, B, and C are quadrants of regions bounded by major proton and neutron shells where predictions of collective properties have been made. New nuclei accessible at the proposed IsoSpin Laboratory lie within the hatched region.

These simple prescriptions also provide bases for predicting the properties of unknown nuclei since $N_p N_n$ and P are symmetric about mid-shell along isotopic and isotonic chains. Thus properties of nuclei very far from stability will in many instances have $N_p N_n$ or P values which fall

along curves determined by known nuclei much closer to stability. If the assumption is made that known strong shell closures project unchanged into regions far removed from the line of stability, then predictions of collective properties can be made.

Using these methods we have predicted $E(2_1^+)$ and $B(E2; 0_1^+ \rightarrow 2_1^+)$ values for medium and heavy neutron-rich nuclides in selected regions as shown in Fig. 5. In some instances tests of these predictions will be feasible at developing or planned radioactive nuclear beam facilities. In the interim such predictions may find application in calculations of r-process nucleosynthesis.

This paper is in press.

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D.S. Brenner is principal investigator for this project. R.B. Schuhmann received support from this project for a two-year period. He completed his work at the TRISTAN facility during the Fall, 1990, and left us to join the Physical Review where he now holds a position as Assistant Editor for Physical Review Letters. W.-T. Chou, who worked jointly for our grant and for BNL under DOE Contract DE-AC02-76CH00016, joined the National Tsing Hua University, Taiwan, as Associate Professor of Nuclear Science in September, 1992. N.V. Zamfir, a visiting scholar from the Institute of Atomic Physics, Bucharest-Magurele, Romania, received joint support from BNL and Clark University. He will continue to work on projects of mutual interest in 1993-94.

A. Wolf, a distinguished research physicist from the Negev Research Centre, Israel, will complete a very productive year in August, 1993.

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