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ORNL
FOREIGN TRIP REPORT

ORNL/FTR-3479

DATE: November 17, 1989

SUBJECT: Report of Foreign Travel of Noah R. Johnson, Cyrus Baktash, and I-Yang Lee, Research Staff Members, Physics Division

TO: Alvin W. Trivelpiece

FROM: Noah R. Johnson, Cyrus Baktash, and I-Yang Lee

PURPOSE

To present invited talks (each traveler spoke about research carried out by the ORNL Nuclear Structure Group) at the symposium on "The Nucleus at High Spin"; also to plan future research directions to be pursued in the era of new spectroscopy available with large gamma-ray detection systems such as GAMMASPHERE.

To visit the Tandem Accelerator Laboratory of the Niels Bohr Institute, in Roskilde, to discuss new nuclear structure instrumentation, especially with respect to ideas that may be useful in the construction of GAMMASPHERE.

SITES VISITED

10/19-27/89	Symposium on "The Nucleus at High Spin" Niels Bohr Institute Copenhagen, Denmark	Bent Herskind Ben Mottelson Gudrun Hagemann
10/25/89	Tandem Accelerator Lab Niels Bohr Institute Roskilde, Denmark	Geirr Sletten Bent Herskind Jan Borggren

ABSTRACT

The travelers attended the symposium of the workshop on "Nuclear Structure in the Era of New Spectroscopy, Part B: The Nucleus at High Spin," that was held at the Niels Bohr Institute (NBI) in Copenhagen, Denmark. They gave a total of five presentations that covered various aspects of the

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nuclear spectroscopy research at ORNL. In addition, one of the travelers (C.B.) attended the first week of "Part C: Nuclear Physics with Large Arrays," of the same workshop, where he discussed the heavy-ion transfer work at the HHIRF. The travelers visited the Tandem Accelerator Laboratory of the Niels Bohr Institute at Roskilde, Denmark, where they discussed plans for new instrumentation developments and research activities of mutual interest.

Symposium on "The Nucleus at High Spin"
The Niels Bohr Institute, Copenhagen, Denmark
October 19-27, 1989

This symposium was part of a workshop which was the second of three workshops sponsored by the Niels Bohr Institute and NORDITA, with support from Danish private foundations. The three one-month-long workshops were on: 1) data acquisition and correlation analysis, 2) the nucleus at high spin, and 3) nuclear physics with large arrays, respectively. These workshops were motivated by the new generation of 4π gamma-ray detectors, GAMMASPHERE and EUROBall. Each workshop consisted of three weeks of lectures and work group discussions, and at the end of each workshop a week-long symposium was arranged to present reports from the the study groups and from recent results by others in the field.

Each of the first five days of the symposium was devoted to one of the five topics that were covered in the study groups: Nuclear Models, Exotic Nuclear Shapes, Nuclear Dynamics, Complete Spectroscopy, and Warm Nuclei. Included in the daily schedules were sessions that focused on the "open problems" that merit future experimental and theoretical studies. Conclusions about the above topics, as well as some general remarks about the workshop, were given in the last day of the symposium.

The diversity of the nuclear structure research activity at ORNL was well reflected in the contributions that the ORNL staff members made to many of the topics discussed at the symposium. Apart from the contributions of J. D. Garrett as the coordinator of the "Complete Spectroscopy" study group, the following presentations were made by the ORNL staff members in attendance: discrete-state lifetime measurements (N.R.J.), continuum lifetime measurements (I.Y.L.), shape evolution of warm nuclei (C.B.), particle-gamma coincidence spectroscopy (C.B.), progress report on GAMMASPHERE (I.Y.L.), and global B(E2) systematics (S. Raman).

The first day of this symposium was on nuclear models and status reports on GAMMASPHERE and EUROBall. R. Bengtsson (Lund) presented the study group report on nuclear models. He compared the cranking model, the particle-plus-rotor model, and the interacting boson model. In comparing the cranking model with the particle-plus-rotor model, he pointed out the importance of a careful systematic study of all the parameters used in the models such as deformation parameters, pairing gap, position of the single particle levels, etc. Fitting a few parameters to the limited aspects of the experimental results can sometimes give misleading conclusions. As an example, he discussed the determination of Q_t values from lifetime data. A simple geometrical model can fit the data very well in the Pt-Pb region. However, the model underpredicts the Q_t values for the ground band of ^{158}Er. He concluded that it is important to understand both the weaknesses and strong points of every model so that the correct model is used to interpret the data.

T. Bengtsson (Lund) presented a critical review of the total Routhian surface (TRS) calculations. He first pointed out the advantages of the diabatic over the adiabatic calculation of the energy surface of a deformed nucleus. In the more involved diabatic calculation where the single particle levels are followed carefully through the band crossing, the yrast energy can be obtained for each spin value. However, to interpret the minimum in the TRS correctly, it is necessary to examine the dependence of the spin value on both the rotational frequency and the deformation. If the dependence is not stable (as in the case at a band crossing), the TRS results may be unreliable.

D. Bes (Buenos Aires) talked on a systematic treatment of axial and triaxial nuclei at high spin. Using a technique borrowed from the string theory, he added Fermion variables to a Hamiltonian for collective motion. This method looked promising for the study of nuclear rotation in three dimensions, and it also provides higher order corrections to the particle-plus-rotor model.

A. Ikeda (Tokyo Institute of Technology) gave a talk on the theoretical study of the signature inversion of odd-Z isotopes of Ho, Tm, and Lu with the particle-plus-rotor model plus gamma vibration. In order to reproduce the measured signature splitting and B(M1) values simultaneously, he found it necessary to include not only the gamma vibration, but also a value of the moment of inertia which has a larger value along the shorter axis. His calculation indicated that the gamma vibration, rather than the gamma deformation, is the main cause of signature splitting.

One of the travelers (I.Y.L.) gave a report on the recent development in the GAMMASPHERE effort. Results from simulation calculations for a cluster design were presented. Options for the innerball design were discussed. Plans for development of electronics and data acquisition system prototypes were also presented.

J. Eberth (Köln) reported on the Ge detector development program for EUROBall. He first pointed out that the unusually fast damage of the large volume Ge detectors at Strasbourg was due to the high temperature (105 K) of the Ge detector. This effect was studied by R. Pehl of LBL many years ago. However, his results were not widely appreciated. Operating the detector at lower (<95 K) temperature will increase the lifetime, but the energy resolution will be worse due to the increase in the electron trapping, which can be corrected electronically (ballistic deficit correction). In studies of radiation damage induced by 148-MeV protons, there has been found both a flux dependence and an operating temperature dependence for resolution deterioration in Ge detectors. Three prototype Ge detectors of different design have been ordered as part of the EUROBall R&D: 1) an encapsulated 23% detector from Intertechnique Enertec which has been temperature cycled five times without any ill effect. The encapsulation has the advantage of keeping the detector in a clean vacuum, which prevents the contamination of the detector surface. 2) a tapered cylindrical detector (6 cm dia., 7 cm long) ordered by Köln from Intertechnique. 3) an encapsulated hexagonal detector ordered by HMI from Ingenieurburo Jans. The goal of these efforts is to develop an encapsulated tapered hexagonal detector for the cluster design for EUROBall.

P. Twin (Liverpool) talked on the first phase of the EUROBall project. The design of the first phase of EUROBall, the EUROGam, consists of 70 individually shielded Ge detectors similar to those of the GAMMASPHERE. The shields are tapered inside to accommodate either tapered Ge detectors with maximum diameter of 8 cm or smaller untapered detectors. One prototype Ge detector has been ordered from ORTEC, and five sets of BGO shields are also on order, three form Engelhard (formerly Harshaw) and two from Crismatec. The United Kingdom and France have decided to build the phase I together, independent of the rest of the EUROBall collaboration. The justification is that both countries have money available at the present time to finish the EUROGam, but that money will not be available two years from now. On the other hand, funding from other countries is not available now. This device will be built in about two years. It will be sited at Darebury for the first year and move to Strasbourg for the following year. A four-year agreement is being negotiated between the UK and France, and this will contain details of funding, siting, beam time allocation, etc.

F. Beck (Strasbourg) expanded on the EUROGam discussion of Twin. He discussed a prototyping effort for stacked planar detectors, each of 7 cm diameter and 2 cm thickness. He commented on the importance of establishing a standard for computer software, on the progress in the Vivitron project, and on the two to three year time scale for the EUROGam project.

The second day's program was on superdeformation. Recently, it has been the subject of intensive experimental study. Many new results were presented in the symposium, and most of them involved the observation of multiple excited superdeformed bands in a nucleus. The most striking result is that in some of the excited superdeformed bands the γ-ray transition energies are almost identical to those of the yrast superdeformed band of a neighboring nucleus. There was much discussion on the interpretation of these observations. On one extreme it was argued that the likeness is from a fundamental symmetry yet to be identified, and on the other extreme it was proposed that accidental cancellation of several effects is the reason.

I. Ragnarsson (Lund) discussed the superdeformed state in light nuclei. He pointed out the advantages of studying superdeformation in light nuclei: 1) few orbitals are involved; 2) large rotational frequencies are involved and, therefore, shape changes happen at lower spin; and 3) experimental results can be compared to shell model calculations. He presented predictions of nuclear shapes for ^{11}B and ^{11}Be and pointed out that the large interaction radius measured for ^{11}Be is consistent with the calculation. He also pointed out that the superdeformed states in ^{16}O have the characteristics of α-clusters.

M. Riley (Liverpool) presented the results on the observation of three superdeformed bands in ^{194}Hg. The experiment was carried out at Daresbury using the $^{48}Ca+^{150}Nd$ reaction, and 80 x 10^6 events were collected. Two of the bands are signature partners. The moments of inertia show a smooth increase with increasing spin similar to superdeformed bands in other Hg isotopes. He suggested the increased alignment of $j_{15/2}$ neutron and $i_{13/2}$ proton, together with weak pairing, as the reasons for the effect.

S. Åberg (Lund) discussed the theoretical interpretation of the moment of inertia of the superdeformed bands in Gd isotopes with mass numbers 146, 148, 149, and 150. Except for ^{146}Gd, which shows an increasing moment of inertia with increasing rotational frequency, the other nuclei show decreasing moments of inertia with increasing rotational frequency. Theoretical calculations indicate that the increase is due to a neutron band crossing of the $j_{15/2}$ orbital with the $g_{9/2}$ orbital.

P. Fallon (Liverpool) presented experimental results from Daresbury on the excited superdeformed band in ^{151}Tb, ^{150}Gd, and ^{153}Dy. In ^{151}Tb and ^{150}Gd the observed γ-ray transitions from excited superdeformed bands have energies very close to the yrast superdeformed band in ^{152}Dy. The maximum deviation of all the transition energies is 3 keV, while the average deviation is about 1 keV. Such a close relation in energies for many states in rotational bands has not been observed before in nuclear physics. Even more interesting is the observation that the even-even and even-odd nuclei show the same behavior. He pointed out that the pseudo spin symmetry, as proposed by Bohr et al. in 1982, may be the cause of the effect; however, no quantitative calculation has been carried out to reproduce such a close agreement in energy. Another interesting observation is that the excited superdeformed band in ^{151}Tb decays out of the band at a lower rotational frequency than does the ground superdeformed band. It is opposite to what one might expect from a simple barrier penetration picture. The implication is that there must be a difference in the structure of these bands.

R. Janssens (ANL) presented results on superdeformed states in ^{190,191,192}Hg. In addition to the γ-spectroscopy measurements, lifetime studies of ^{192}Hg were also done. The lifetime results gave a constant quadrupole moment in the band. Thus, the deformation is constant in the band, and the increase of the moment of inertia is likely due to alignment and pairing effects.

More results on superdeformation in ^{192,194}Hg isotopes were presented by M. A. Deleplanque of LBL. Three superdeformed bands were observed in ^{194}Hg. Since the decay pathways of most superdeformed states to the normal deformed states are not established, it has not been possible to determine their spin with accuracy better than $2\hbar$. However, by fitting the Harris formula to the γ-ray cascade energy, they were able to determine the spin of the states with accuracy better than $1\hbar$. Transitions in one of the superdeformed bands in ^{194}Hg have the same energies as those from the ^{191}Hg yrast superdeformed band. This band has odd spin and an alignment of $1\hbar$ compared to the ^{191}Hg yrast superdeformed band. Again, pseudospin coupling was invoked to explain the result.

R. Chasman (ANL) discussed theoretical aspects of superdeformation in the A=190 region. He pointed out that currently the accuracy of shell model calculations with Strutinsky corrections is about 0.5-0.8 MeV in predicting the excitation energy and the barrier height of superdeformed minima. He pointed out that possible improvements of the calculations may be achieved by using a density-dependent pairing force and more accurate Woods-Saxon parameters based on experimental results. He also discussed the decay of superdeformed states based on the HFBCS model and the horizontal expansion method.

J. Nyberg (NBI) presented results on well-deformed bands in the $A \sim 130$ region. These bands have been observed in several La, Ce, Nd, and Sm isotopes. In ^{131}Ce, the drop-off in the intensity at high spin is faster for the oxygen-induced reaction than for the sulfur-induced reaction. However, in ^{135}Nd, there is no difference between the two reactions.

J. Blons (Saclay) presented interesting results on the spectroscopy in the third minimum (hyperdeformation) in Th isotopes. The experiments were carried out using neutron capture fission reactions (n,f) and the (d,pf) reaction, and the levels in the third minimum were identified as fine structure in the resonance. From the peak structure in cross section and the anisotopy of the fission fragment, two rotational bands with opposite parities were identified. The moment of inertia has a value of about 250 $\hbar$ MeV^{-1}, which corresponds to a deformation parameter $\varepsilon_2 = 0.9$ and an axis ratio of 3:1.

D. Ward (Chalk River) gave a talk on the use of particle-γ coincidence to enhance the population of superdeformed bands. This is an initial step toward using this technique in the study of hyperdeformed states. Two reactions which populate known superdeformed states were utilized: ^{105}Pd(^{32}S,2p2n)^{133}Nd and ^{120}Sn(^{37}Cl,p4n)^{152}Dy. However, no enhancement in the population of the superdeformed state was observed from the p-γ coincidence measurement.

On the third day of the conference, Wietek Nazarewicz, the coordinator of the study group on Nuclear Dynamics, gave a very interesting presentation on a sophisticated approach to the mapping of the dynamic aspects of the nuclear collectivity. The method is one that provides the overlap matrix elements in a rotational band by a solution of the Hill-Wheeler equation. The generator coordinate method is employed in obtaining the wave functions, with deformation parameters from Total Routhian Surface calculations serving as initial input. Next, the integral in the Hill-Wheeler equation is replaced by a summation over a two-dimensional grid (in β_2 and ω). The eigenfunctions obtained lead to a more reliable tracing of the nuclear collectivity as a function of rotational frequency than is normally obtained in the cranked Hartree-Fock-Bogoliubov approach. We recently compared these two types of calculations with some of our lifetime results on collectivity of high-spin states in ^{172}Os and found improved agreement between experiment and theory when the overlap-matrix element approach was utilized.

Measurements of static electromagnetic transition moments (g-factors) of states beyond the backbend in an yrast sequence enables one to quantify the type of quasiparticles that have participated in the rotation-alignment process. The difficulties encountered in such experiments have led to little success in past attempts in this area. However, H. Hübel from the University of Bonn, reported on an apparently successful measurement of the g-factor of the 36^+ state in ^{154}Dy. Data analyses of this experiment, done by the "transient field method," had not been completed.

One of the travelers (N.R.J.) presented a talk on the collective properties of light-mass tungsten and osmium nuclei. Work in this region by the ORNL group was prompted by earlier predictions of cranking theories which indicated that the collectivity of yrast states in the spin range of $I = 12^+ - 20^+$ should not suffer appreciable reduction as had been found for several ytterbium nuclei near $N = 90$. Lifetime measurements performed at ORNL, indeed, show a rather constant collective behavior for states from 2^+ through 20^+ in ^{170}W, ^{172}W, and ^{172}Os. Refined cranked Hartree-Fock-Bogoliubov and overlap matrix element calculations carried out in these studies indicate some evolving changes in the deformation parameters (β_2 and γ) in each case, but these turn out to be compensating effects which give a reasonable accounting for the trend of collective behavior observed in the experimental data.

A report on new microscopic calculations of octupole deformations in heavy nuclei was presented by J. Egido from Madrid. He utilized three schemes in his work: 1) one he called the "mean field approach"; 2) the second he referred to as "beyond the mean field approach," in which he accounted for quantum correlations; and 3) finally, an approach involving the microscopic projection of good quantum numbers. In the latter approach he projected out the positive and negative parity sequences and examined the energy minima for these. His criterion for a permanent octupole deformation was based on a small energy splitting for these opposite parity sequences. If the splitting were large, he assumed this represented a γ-soft nucleus. He was also able to calculate B(E1) and B(E3) values in his treatment.

A report of the "Complete Spectroscopy" study group was given on the fourth day of the symposium by J. D. Garrett, the coordinator of the group. For a detailed account of the activities reported by J. D. Garrett, please consult ORNL/FTR-3466. A few highlights of the topics covered by the contributors are given below.

The question of shape coexistence was addressed by S. L. Tabor (Florida State University) and D. Fossan (SUNY, Stony Brook), who presented examples of shape transition and coexistence in the mass A=80 and A=130 regions, respectively. S. Tabor emphasized the rich variety of shapes that have been observed in the A=80 region, and the fact that some of the largest deformations at moderate spins have been observed in these nuclei. D. Fossan pointed out that the A=130 nuclei have gamma-soft cores which are easily polarized by the valence high-j orbitals. He presented an extensive set of data on the systematics of the $\pi(h_{11/2}) \otimes \nu(h_{11/2})^2$ bands in the odd-Z nuclei that may be interpreted as oblate structures.

David Ward (Chalk River) presented an extensive set of data on the band structures (13 bands) in ^{126}Ba. He emphasized the importance of the multiplicity/total-pulse-height gating for channel selection and the advantages of computer-aided coincidence-data analysis for building complex level schemes that incorporate transition intensities down to the 0.1% level.

The balance of the contributed talks included presentations by S. Raman (ORNL) on the subject of the global systematics of the B(E2) transition, C. H. Wu (University of Tennessee) who spoke about the DSAM lifetime measurements in ^{157}Ho, and L. L. Riedinger (University of Tennessee) who discussed the systematics of the crossing frequencies of the proton $h_{9/2}$ and $i_{13/2}$ orbitals in the Re and Ir nuclei. The lifetime measurements in ^{157}Ho show significant reductions of the Q_t values compared to its even-even neighbors.

In the last session of the day, A. Holm and B. Herskind gave a short report of the first workshop in September, on data acquisition and data analysis. A detailed account of this workshop is given in the Foreign Trip Reports of R. L. Varner (ORNL/FTR-3405) and D. C. Hensley (ORNL/FTR-3408).

K. Schiffer (Canberra) opened the fifth day of the symposium with a short report of the work by the study group on "Warm Nuclei." By their very nature, gamma-ray studies of warm and hot nuclei involve continuum γ-ray spectroscopy techniques. F. Stephens (LBL) posed the question of how many pathways are involved in the deexcitation of the excited states. He then sketched a method by which the number of pathways may be estimated. However, in the subsequent discussions that ensued, a consensus emerged that this method does not provide a unique answer.

One of the travelers (C.B.) presented a talk on the "Complete Spectroscopy in the Continuum Regime," in which he illustrated the power of 4π detectors in providing detailed information about the structural changes that nuclei undergo as their spin or temperature is increased. The traveler also sketched a new technique, based on ordering the emitted γ rays according to their energies, that holds the promise for extracting information on the evolution of such parameters as the rotational damping width and dynamical moment of inertia with spin and temperature.

Another presentation by one of the travelers (I.Y.L.) addressed the question of lifetime measurements in the continumm. In one recent study of the lifetimes of the transitions comprising the ridge structure in ^{170}Hf, we have observed an increase in the collectivity of the highest-energy γ rays.

K. Matsuyanagi (Kyoto) presented preliminary results from a cranking-plus RPA calculation of giant resonances built on the super-deformed states. He suggests that giant octupole vibrations are likely to appear only a few MeV above the superdeformed yrast structures.

B. Herskind (NBI) discussed various ways of examining triple γ-coincidence data for the quantitative study of the rotational damping width. Specifically, by comparing double- and triple-correlation data, he inferred a value of 185 keV for the damping width in ^{168}Yb.

In the session discussing "open problems in Warm Nuclei," one of the travelers (C.B.) presented our very recent results on proton-emission in the ^{52}Cr(^{34}S,2p2n)^{82}Sr reaction. When gated by discrete γ rays belonging to different bands in the ^{82}Sr nucleus, the proton spectra show significant shifts that demonstrate their sensitivity to the underlying nuclear structure.

In the final session of the day, B. Mottelson (NORDITA) discussed several issues. In particular, he commented that the predictions for the motional narrowing do not necessarily imply a reduction of the damping width at high excitation energies. Rather, it only implies that the change in the damping width is expected to be smaller than the rise expected on the basis of the Thomas-Fermi model. He also expressed surprise at the astonishing similarity between the γ-ray energies belonging to the superdeformed bands of the neighboring isotones. The interpretation of these bands within the pseudospin framework cannot account for the rigidity of the cores. He also pointed out that transitions between the gamma and beta vibrational bands provide a discriminating clue between the IBA and geometrical models.

The last day of the symposium was devoted to conclusions presented by the coordinators of the study groups, and "impressions" given by F. Stephens and P. Von Brentano. It was clear that the most-discussed and frequently mentioned topic was the observation of the excited superdeformed bands in many nuclei, and the unexpected (and yet unexplained) constancy of their $J^{(2)}$ moments of inertia relative to their neighbors'. In the words of M. Riley, "This symposium will mark the birth of true spectroscopy of superdeformed bands."

Workshop on Nuclear Structure in the Era of New Spectroscopy
Part C: Nuclear Physics With Large Arrays
The Niels Bohr Institute, Copenhagen, Denmark
October 30-November 3, 1989

This was the third and last workshop in this series. C. Baktash participated in the first week of the workshop and presented an overview of the heavy-ion transfer program (techniques and results) conducted at the HHIRF facility (ORNL) by the University of Tennessee researchers in collaboration with researchers from ORNL and the University of Rochester.

The format of the workshop followed the pattern of the earlier ones: Morning lectures on Monday, Wednesday, and Friday were followed by study groups in the afternoons and on Tuesdays and Thursdays on the following topics: Collective Excitations, Chaos, Reactions, Symmetry and Dynamics, and Far from Stability. Since J. R. Beene of ORNL participated in this workshop as one of the lecturers and will give a more thorough coverage of the workshop in his report, this section will only cover highlights of a few selected topics.

The lecturers for the first week were A. Winther (Theoretical Heavy-ion Reactions), D. Schwalm (Experimental Reactions), J. R. Beene (Collective Excitations), B. Mottelson and V. Zelevinsky (Chaos), P. Gregers Hansen (Far from Stability), and V. Zelevinsky (Symmetries). In this first week, most of the lectures were of a review nature.

In his introductory lecture on chaos, B. Mottelson defined ordered systems being associated with presence of good quantum numbers, and hence selection rules. Chaos, then, is defined as opposite of order. He analyzed radiative neutron capture data on ^{167}Er that leads to ^{168}Er to check if K remains a good quantum number at low spins and nearly 8 MeV of excitation energy. His simple analysis indicated that the data are best reproduced if one assumed one K value, implying that the K-selection rule is ineffective at these energies. Thus, the system is chaotic.

V. Zelevinsky (Novosibirsk) discussed empirical evidence for the presence of a new dynamical symmetry in soft, nearly spherical nuclei. These are transitional nuclei that bridge the deformed and magic nuclei. Some examples include ^{68}Ge, ^{72}Se, ^{98}Ru, ^{102}Cd, ^{132}Xe, ^{148}Sm, ^{154}Dy, and ^{218}Ra. Remarkably, he can get a very good fit to the energy spectra of these nuclei using an approximate O(5) symmetry formalism that incorporates only one parameter. The resulting fits are superior to those using VMI, and IBA fits that employ three parameters. He attributed the success of the model to the fact that his model includes the contributions of both particle-particle and particle-hole excitations.

In his review of the "Far from Stability," P. Gregers Hansen (CERN) discussed data from CERN and LBL, with emphasis on the very neutron-rich nuclei such as ^{8}He, ^{11}Li and ^{14}Be, and ^{17}B. He suggested an interpretation of, e.g., ^{11}Li in terms of a dineutron orbiting around a ^{9}Li core. Observed ^{11}Li and ^{9}Li radii and binding energies are explained by this model. Also in agreement with the model are the calculated Coulomb dissociation cross sections. He also discussed their "Pandemonium" model nucleus and sounded a note of caution for reading too much into observed structures in the spectra. His advice was that one needs to carry out some autocorrelation analysis on the data before attaching significance to these peak-like structures in the spectra.

Visit to Niels Bohr Institute, Risø
October 25, 1989 (N.R.J.)

A visit to NBI-Risø revealed that much progress has been made during the past year, both on the linac booster for their 9.5-MV tandem and on the NORDBall, which consists of an array of 20 Compton-suppressed Ge detectors. Each of the two room-temperature linac cavities provides a 3.5-MV boost, so that they can accelerate beams with $A \sim 50$ above the Coulomb barrier of medium weight targets. For example, they can accelerate a beam of $(^{50}Ti)^{15+}$ ions to 225 MeV. They expressed great delight with the beam quality, from the beginning of their operation, of the linac. The beam is well defined with a diameter of less than 4 mm.

Up to 10 of the array of 20 BGO-Compton-suppressed Ge detectors in the Nordball can be replaced by neutron detectors composed of Nuclear Enterprise scintillators. An inner ball of 60 BaF_2 detectors is nearly complete. This will provide excellent selection in total energy and γ-ray multiplicity. The 13-cm-long BaF_2 detectors are cleverly designed so that they just cover the faces of the BGO units and, therefore, prevent γ rays from direct hits in the BGO, thus eliminating the problem of false Compton rejection.

During the past several months, much data has been taken with the Nordball in both high-spin spectroscopy and lifetime measurements. They are now having some of the problems common to all Compton-suppressed Ge arrays. After having experienced appreciable neutron damage to the Ge detectors, they began the recovery process using a two-port recovery system much like that used at ORNL. Although they have rather poor statistics, it appears that about 25% of the detectors do not recover in the "pump and bake" procedure and must be returned to the vendor for a more extensive treatment process. This is about the same percentage of failed recovery experienced at ORNL and other laboratories. They are particularly interested in determining if the so-called "pop-top" detectors suffer radiation damage from neutrons more rapidly than do those where the Ge diode is directly attached to the cooling arm. The pop-top detectors (they have five of these) are detachable from the cryostat and, thus, offer much convenience, especially if the detector must be returned to the factory. However, because of loss in conduction, these detectors operate at about 105 K, which is about 10° higher than for the single-unit-constructed Ge detector - cryostat system. (Measurements by Pehl et al. have shown that Ge detectors operated at ~ 105 K show an accelerated rate of damage by neutrons.) Geirr Sletten at NBI has agreed to supply us with their data from these studies.

An interesting new type of experimental effort involving the study of "metallic clusters" is underway at Risø by J. Borggreen, J. Pederson, S. Bjørnholm, and collaborators. The apparatus constructed for producing alkali metal clusters does so by expansion of pressurized sodium vapor from an oven, through a fine nozzle, and into low-pressure argon cooling gas. The jet of sodium metal clusters produced is then ionized and mass analyzed in a mass spectrometer.

These metallic clusters are small aggregates of atoms and molecules of sodium, and are described as a state of matter intermediate between a dilute gas and condensed matter. Interestingly, these clusters are reported to behave much like nuclei in that they are dominated to a large extent by the fermion nature of their constituents. Also, just as for nuclei, the metallic clusters are expected to reveal an interplay between independent particle motion and collective motion. From a Woods-Saxon type of calculation, the energy of the valence electrons of these clusters is obtained. A plot of this energy versus the number of sodium atoms per cluster shows a distinct shell effect in its oscillatory pattern of behavior.

In recent conversations with Ben Mottelson, he has expressed his considerable interest in this work. He says he would like to talk about this topic on his visit to Oak Ridge in April 1990, either in his talk at the conference on "Nuclear Structure in the Nineties" or at a special Laboratory-wide seminar the week preceding our conference.

Visit to Niels Bohr Institute, Risø
October 26, 1989 (C.B.)

One of the travelers (C.B.) visited the Tandem Accelerator Laboratory at Risø, and discussed the progress of a collaborative project with J. J. Gaardhoje and B. Herskind. The NBI group visited ORNL in the summer of 1987 to perform an experiment to search for the giant resonances built on the superdeformed states in ^{152}Dy. During the current visit, it became apparent that both groups share interest in a follow-up of these experiments. A closer collaboration, possibly in the form of an exchange program, will be mutually beneficial. First, both groups have recently acquired large BaF_2 detection systems that can efficiently detect high-energy γ rays with good energy resolution. Secondly, while the Tandem Accelerator at Riso is rather restrictive in terms of the beam species and energies that it can deliver (190-220 MeV beams of ions of mass $A \approx 50$), it can provide ample beam time for the giant resonance studies. This is due to the fact that while the Ge detectors of the NORDBall are being recovered from their neutron-radiation damage (typically after 2-3 weeks of beam time), the tandem beam may be used sometimes up to several weeks for the beam-intensive studies of the giant resonances built on the excited states. In contrast, the ORNL facility can provide a wide range of beam species and energies, albeit with limited time (typically less than a week). Bent Herskind expressed interest in a month-long visit to ORNL next April.

APPENDICES

A. Itinerary

October 17-18, 1989	Travel from Oak Ridge to Copenhagen, Denmark	
October 19-24	Symposium on "The Nucleus at High Spin," Niels Bohr Institute, Copenhagen, Denmark	
October 25	Tandem Accelerator Laboratory Niels Bohr Institute Roskilde, Denmark	(NRJ)
October 25	Travel from Copenhagen to Oak Ridge	(IYL)
October 26	Tandem Accelerator Laboratory Niels Bohr Institute Roskilde, Denmark	(CB)
October 27	Workshop Summary Niels Bohr Institute Copenhagen, Denmark	(NRJ&CB)
October 28	Travel from Copenhagen to Oak Ridge	(NRJ)
October 30- November 3	Workshop on "Nuclear Physics With Large Arrays," Niels Bohr Institute, Copenhagen, Denmark	(CB)
November 4	Travel from Copenhagen to Oak Ridge	(CB)

B. Persons Contacted

Symposium on "The Nucleus at High Spin"
  Bent Herskind, Ben Mottelson, Gudrun Hagemann

Tandem Accelerator Laboratory (NRJ)
Niels Bohr Institute at Roskilde
  Bent Herskind, Geirr Sletten, Jan Borggren

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