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FOREIGN TRIP REPORT

ORNL/FTR-3466

DATE: November 8, 1989

SUBJECT: Report of Foreign Travel of Jerry D. Garrett, Research Staff Member, Physics Division

TO: Alvin W. Trivelpiece

FROM: Jerry D. Garrett

PURPOSE

To attend, lecture, and serve as study group chairman at the Workshop on Nuclear Structure in the Era of New Spectroscopy, Part B: The Nucleus at High Spin, and to visit the Tandem Accelerator Laboratory to discuss new nuclear structure instrumentation at the Niels Bohr Institute, Copenhagen, Denmark.

SITES VISITED

10/4-24 & 26-27/89	The Niels Bohr Institute Copenhagen, Denmark
10/25/89	Tandem Accelerator Laboratory The Niels Bohr Institute Roskilde, Denmark

ABSTRACT

The traveler lectured on "New Ways to Look at Old (and New) Data" and served as a study group chairman at the four-week-long Workshop on Nuclear Structure in the Era of New Spectroscopy, Part B: The Nucleus at High Spin, held at the Niels Bohr Institute, October 2-27, 1989. He also visited the Tandem Accelerator Laboratory of the Niels Bohr Institute and, during the workshop, discussed plans for new nuclear structure instrumentation with various European colleagues.

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Workshop on Nuclear Structure in the Era of New Spectroscopy
Part B: The Nucleus at High Spin
The Niels Bohr Institute, Copenhagen, Denmark
October 2-27, 1989

A three-month series of workshops was held this autumn at the Niels Bohr Institute on the subject of Nuclear Structure in the Era of New Spectroscopy. This series is an outgrowth of the plans both in Europe and the United States to construct a new generation of high-resolution, low-background, large solid-angle arrays of gamma-ray detectors, such as the GAMMASPHERE and the EUROBall. Part A (September) concentrated on technical considerations associated with data acquisition and analysis; Part B (October) on high spin studies, the driving force for the construction of these instruments; and Part C (November) on other physics problems that such instruments can address. This series of meetings was organized by the Danish Nuclear Structure Physicists as a part of their contribution to the EUROBall effort, both because of the tradition of workshops and symposia at the Niels Bohr Institute bringing together experimentalists and theorists and because it is easier to obtain funding for this activity in Denmark than for capital equipment. The workshops also were sponsored by the Nordic Institute for Theoretical Atomic Physics (NORDITA) as a part of a revised program of studies recommended by an evaluation earlier this year by a group headed by J. R. Schreiffer. Thus, we can expect to see more such in-depth studies of this type in Copenhagen.

The structure of the program was three-hour lectures on Monday, Wednesday, and Friday mornings. In the afternoon of these days and on Tuesdays and Thursdays, the participants attended study groups (Nuclear Models, Exotic Nuclear Shapes, Nuclear Dynamics, Complete Spectroscopy, and Warm Nuclei). Orginally, it was planned to conduct these study groups in parallel; however, the overlap of interest was so great that, for the most part, they were organized in series. Each group met an average of four two-hour sessions so, though the discussion was informal, it was intense. Actually, the traveler felt that more time for private discussion would have been preferable. At the end of the workshop a

five-day symposium was held, October 19-24 (Sunday, October 22, being free). In the symposium, attended by about 100, a report was given from each of the five study groups as well as talks from selected participants. Since several of my colleagues (I-Yang Lee, Cyrus Baktash, and Noah Johnson) will report on the symposium, this report will concentrate on the workshop.

The traveler's formal participation was a lecture entitled "New Ways to Look at Old (and New) Data," on October 4; chairing of the study group on Complete Spectroscopy on October 6, 10, 13 and 17; a report of this study group to the symposium on October 23, and a short summary of the work of this study group during the closing day, October 27. Three topics were included in the traveler's lecture: (i) the use of constant N contour plots in λ_n and ω to study nuclear correlations, the distribution of single-particle levels, and "diabolic points"; (ii) empirical estimates of residual proton-neutron interactions; and (iii) a preliminary nearest-neighbor analysis (order vs. chaos) at high spin. The traveler also made short presentations in the other study groups on discrepancies between measured and predicted transition rates at high spin, the empirical evidence for "diabolic points," and why more nuclei are prolate than oblate.

Among the high points of the workshop was the realization that certain of the second superdeformed bands in neighboring isotopes and isotones have the same gamma-ray energies to within one to two parts in a thousand for the entire cascade. This was presented by Peter Twin (Liverpool) for an excited superdeformed band in ^{151}Tb compared to the yrast superdeformed band in ^{152}Dy. Similar relations exist for excited superdeformed bands in ^{153}Dy compared to ^{152}Dy and for superdeformed bands in the mercury isotopes. Such degeneracies surely are not accidental. After a weekend of work and thought, Witek Nazarewicz (Warsaw) showed that, in the pseudospin formalism, the decoupling parameter for the bands in the dysprosium region (which have K = 1/2) gives this approximate relation between the gamma rays. However, it still is not

completely understood why the moments of inertia are so constant (two parts in a thousand) in nuclei with different masses. Other interesting topics associated with superdeformed nuclei include: (i) A method developed by the Berkeley-Livermore group for fitting the transition energies in a superdeformed decay sequence to obtain some information about the spins of the superdeformed states. This seemed to give some information in the mercury cases, where the superdeformed band extends to lower spins. (ii) The second ridge in $E\gamma$ correlations plots for the superdeformed continuum appears to be too weak for all of the simulations. (iii) There also was a very nice detailed discussion of the variety of exotic shapes associated with the rotational sequences in light nuclei by Ingmar Ragnarsson (Lund). (iv) There also was a long discussion in the exotic shape study group about why most nuclei are prolate. Ben Mottelson (NORDITA) gave a detailed discussion of the different effects. Volume conservation imposed on the Nilsson scheme gives a preference for an oblate shape. The Strutinsky corrections, however, prefer prolate shapes. The traveler contributed to this discussion by showing how the spin-orbit and the ℓ-squared terms in the Nilsson model prefer prolate shapes.

There was considerable interest in the complete spectrum of interactions between levels having the *same* spin and parity. This topic extends from the question of, Can such interactions go to zero (the so-called "diabolic point") in a real nucleus? to the question of, What happens in the completely mixed ("chaotic") situation? The question of interactions approaching zero probes how adiabatic the process is. Fumihiko Sakata (Institute of Nuclear Studies, Tokyo), Kenishi Matsuyanagi (Kyoto), and Vladimir Zelevinsky (Novosibirsk) were very interested in the traveler's analysis showing experimental evidence for "diabolic points." How adiabatic can the nucleus be and still have such features? Daniel Bes (Buenos Aires) discussed the details of two-particle transfer from excited states near the "diabolic points" and their relation to the Berry phase. The traveler pointed out that it may be possible to experimentally circumscribe a "diabolic point" associated

with the excitation of a pair of quasiparticles at a band crossing in Coulomb excitation. Ikuko Hamamoto (Lund) discussed small interactions in terms of the particle-rotor model, showing that it is possible to understand the 2 keV separations observed by David Radford (Chalk River) in a very complete study of ^{157}Ho. The role of mixing between states and how that will limit discrete line spectroscopy as one proceeds further from the yrast configuration was a major topic of the complete spectroscopy study group that the traveler chaired. In the limit of strong mixing, "chaos," Ben Mottelson (NORDITA) discussed the question of what if some levels don't mix with other levels. The premise to a Grand Orthogonal Ensemble (GOE) is that all levels interact with all others, but we know in nuclear physics that we see giant resonances and strength functions of various processes at high excitation energies involving many levels, but that only spread over a limited range of energies.

Several nuclear theorists, e.g., Hubert Flocard (Orsay), Fritz Dönau (Rossendorf), and Dick Chasman (Argonne), are using the Generator Coordinate Method. These more sophisticated calculations have the advantage of not only including effects ignored in the more standard cranking calculations (e.g., fluctuations), but they also give wave functions that can be used to calculate transition probabilities in a more natural way. Such calculations are very important for our lifetime measurements. Kenishi Matsuyanagi (Kyoto) predicts from Random Phase Approximation (RPA) calculations that a giant octupole resonance should be found a few (1-3) MeV above the yrast configuration.

Finally, it is always interesting to attend lectures by Ben Mottelson (NORDITA). This time Ben chose five topics to mention: (i) The independent-particle model and, in particular, the determination of the absolute occupation of single-particle configurations from electron measurements. (ii) Deformations emphasizing the possibility of new symmetries and phase transitions, e.g., the pair phase transition and the melting of shell structure. (iii) Radical truncation schemes, e.g., the IBA and other bosonic models. They identify a significant degree of

freedom, but the truncation imposed by the artificial limitation of only $L < 2$ bosons limits the model to low spin. (iv) Statistical approaches asking for such quantities as the single-particle level density along the yrast line. Do you need an effective mass to explain the level density at high spin like you do a high temperature? This is a question that the traveler may be able to address using the Oak Ridge high spin data base. (v) Chaos. What are the experimental features associated with the fact that the GOE assumption that all levels mix with all others is not valid in nuclei? Ben also gave a general review of chaos in nuclear physics. Chaos will be a major topic of the November Workshop.

Visit to Tandem Accelerator Laboratory Niels Bohr Institute, Roskilde, Denmark October 25

During my stay in Copenhagen I also visited the Tandem Accelerator Laboratory at the Niels Bohr Institute. The booster is now operating — A = 40-50 beams have been accelerated to about 6 MeV/A and used in experiments. Jens Jorgen Gaardhøje's array of barium fluoride crystals for high energy gamma rays, HECTOR, is in operation as is the NORDBall (an array of 20 Compton-suppressed germanium detectors). However, the "pop top" design of the germanium detectors in the NORDBall is very quickly damaged by neutrons, probably because the detectors operate at too high a temperature. The staff is trying to determine how to modify these detectors to solve this problem. I also saw the apparatus for producing and accelerating small sodium clusters (a few hundred atoms) that is now operating in this laboratory. Sven Bjørnholm and Jorgen Pederson are the main people associated with this program.

European Collaborations on Nuclear Structure Instrumentation

The British and French nuclear structure physicists now have sufficient funds to proceed with GAMIC (called EUROGAM when it was to be a European project), an array of 70 Compton-suppressed detectors. It will be constructed at the Nuclear Structure Facility in Daresbury and operate

there for a year (or until the VIVITRON operates) and then move to the VIVITRON in Strasbourg. This device should be in operation in two years. The fact that the British and French have decided to build GAMIC alone has disappointed some of the nuclear structure communities in other European countries. Apparently this decision was based on wanting to keep the array in England and France as much as possible. Previously EUROGAM was to be constructed in Daresbury and remain there for about a year, then move to the VIVITRON for about a year, and finally to SIS in Darmstadt, where it was hoped that it could be upgraded to an array of 70 cluster detectors, EUROBall. It seems that the British and French communities are saying that they are just as happy with GAMIC if it can stay within their own countries. Of course, they invite use from abroad.

This development leaves the other European countries with a decision of what to do with the plans for the final EUROBall array of 70 clusters of seven detectors. For the short term, the Scandinavians and their Dutch, Italian, and Japanese collaborators will continue to upgrade the NORDBall located at Risø. They plan to add ten large, about 70 percent, germanium detectors in the the ten pentagons of the NORDBall array. The surrounding 20 Compton suppression shields will give some suppression for these large detectors. This will give two versions of the NORDBall, one with the ten large detectors plus the 20 Compton-suppressed detectors, and one with 20 suppressed detectors and an inner barium fluoride ball for total energy and multiplicity information. Several ancillary items also have been developed or are planned: a forward hemisphere of neutron detectors and a very small array of ten light particle detectors covering about 80 percent of 4π are available. Soon a mini-orange spectrometer will be permanently installed surrounding the beam entrance, and parallel-plate avalanche detectors are planned for heavy-particle detection. Likewise, the Germans will probably continue to improve the OSIRIS array which moves between Berlin and Cologne. Since the Europeans other than the British and the French are no longer tied to a collaboration, at least for EUROGAM, they are very interested in using the GAMMASPHERE. It should be a somewhat better instrument than GAMIC.

For the longer term, the Europeans plan to continue development of the cluster detectors. The Germans, Dutch, and Danes all plan to buy a prototype. When such detectors work, they will be added to the existing arrays. Plans also seem to be forming for an array of probably 30 to 40 cluster detectors for SIS at Darmstadt. These would be used in several different configurations, e.g., a 4π array, a backward-hemisphere array with the forward hemisphere left for particle and/or high-energy gamma-ray detectors, and a smaller solid-angle array at very backward angles to reduce Doppler broadening for relativistic Coulomb excitation. Such a proposal would probably be made as a European project, with a large fraction of the funding from the Germans.

It was a very interesting time to be in Copenhagen and among several friends from Eastern Europe. All our Eastern European colleagues are very excited, with the political events which seem to occur daily there. In fact, the ex-East German First Secretary Erich Honecker was supposed to visit the Niels Bohr Institute as a part of a state visit to Denmark during the last week of the workshop. Of course, he did not, because by that time he had been forced to resign, and his replacement was too busy trying to decide what changes to make to even contemplate such a visit. An interesting aside to this visit was that the Danish Foreign Ministry was planning to request that Stefan Frauendorf, a theoretical nuclear physicist who had spent considerable time at the Niels Bohr Institute and also a year at the University of Tennessee, be released from prison as a show of good will at the time of this trip. Stefan now has been imprisoned in his native East Germany for five years of an 11-year sentence for alleged spying for West Germany. Since Honecker's visit was cancelled, the traveler does not know whether the Danish Foreign Ministry will proceed with these plans. A group of nuclear structure physicists is preparing a petition to the new East German government requesting Stefan Frauendorf's release on humanitarian grounds.

APPENDIX A

Itinerary

October 2-3, 1989	Travel from Oak Ridge to Copenhagen, Denmark
October 4-18	High-Spin Workshop Niels Bohr Institute Copenhagen, Denmark
October 19-24	High-Spin Symposium Niels Bohr Institute Copenhagen, Denmark
October 25	Tandem Accelerator Laboratory Niels Bohr Institute Risø, Roskilde, Denmark
October 26-27	High-Spin Workshop Summary Niels Bohr Institute Copenhagen, Denmark
October 28	Travel from Copenhagen to Oak Ridge

1. David B. Waller, Assistant Secretary for International Affairs and Energy Emergencies (IE-1), DOE, Washington
2. Wilmot N. Hess, Associate Director for High Energy and Nuclear Physics, Office of Energy Research, DOE, Washington
3. D. L. Hendrie, Director of Nuclear Physics, Office of High Energy and Nuclear Physics, Office of Energy Research, DOE, Washington
4. Elizabeth Q. Ten Eyck, Director, Division of Safeguards and Security, DOE, Washington
5. A. Bryan Siebert, Director, Office of Clssification and Technology Policy (DP-323.2), DOE, Washington
6. R. L. Egli, Assistant Manager, Energy Research and Development, DOE/ORO
7. D. J. Cook, Director, Safeguards and Security Division, DOE/ORO
8-9. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831
10-12. J. D. Garrett
13. B. R. Appleton
14. Y. A. Akovali
15. C. Baktash
16. J. B. Ball
17. J. R. Beene
18. F. E. Bertrand
19. H. K. Carter
20. E. E. Gross
21. M. W. Guidry
22. M. L. Halbert
23. J. H. Hamilton
24. D. J. Horen
25. J. W. Johnson
26. N. R. Johnson
27. C. M. Jones
28. I. Y. Lee
29. F. K. McGowan
30. J. B. McGrory
31. J. H. McNeill
32. W. T. Milner
33. S. Pilotte
34. F. Plasil
35. L. L. Riedinger
36. R. L. Robinson
37 G. R. Satchler
38. D. Shapira
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41. A. W. Trivelpiece
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