Nuclear Structure Studies of Exotic Nuclei

Progress Report

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This report concerns the current status of the project "Nuclear Structure Studies of Exotic Nuclei". Discussed in this report are experiments performed during the current year, status of data analysis, plans and proposals for future experiments, conferences attended, equipment purchases related to the project, and use of graduate and undergraduate students.

Experimental Research Performed

An experiment was performed in August of 1996 at the National Superconducting Cyclotron Laboratory (NSCL) of Michigan State University. Although it occurred prior to the official starting date of the grant, it represents the first of many planned experiments which are a part of the whole research project. The experiment involved the use of a radioactive ion beam to study nuclear structure through β -delayed γ -ray emission. In the experiment, a ^{48}Ca beam at 70 MeV/u was fragmented to produce nuclei in the region near ^{40}P . The resulting fragments were isolated using the A1200 and sent to an end station where they were embedded in a target wheel. The stopped radioactive sources were viewed by two large Ge detectors. The system (detector mounts and target wheel apparatus) was designed at Mississippi State and fabricated by Michigan State, and is planned for use in future experiments by several groups. Data were obtained for the decays of ^{40}P , ^{42}S , and $^{42,43}\text{Cl}$. This represents the first measurement of this type for each of these nuclei. The experiment also proved the effectiveness of using the NSCL facilities for high resolution γ -ray studies of exotic nuclei. Of particular interest in this study is a determination of the structure of low-lying states in the daughter nuclei. Results will be used to help clarify results from a Coulomb excitation measurement at the NSCL which showed evidence of moderate deformation for sulphur nuclei near $N=28$. Analysis of the data is on-going.

A second experiment was performed in January of 1997. It involved a collaboration with which I became involved several years ago. The principal investigators on the project are Dr. Alex Szanto de Toledo of the Instituto de Fisica at the Universidade de Sao Paulo and Dr. Gary Crawley at the NSCL. The experiment was a measurement of the total reaction cross sections for exotic nuclei in the neutron-rich f-p shell region. In this experiment the energy dependency of the cross sections was measured. The results will be compared to those of an earlier measurement at lower energies. The technique used is quite efficient for global studies since it allows the simultaneous measurement of a large number of nuclei. The analysis of the data from this experiment is being carried out at the Universidade de Sao Paulo.

Planned Experiments

Several future experiments are currently in the planning stages. Two of these experiments have been awarded beam time at the NSCL. The first, " β -decay Studies Toward ^{78}Ni " with Dr. Paul Mantica as spokesman, has been given 84 hours of beam time for preliminary studies. The second, "Nuclear Structure in the Heavy S, Cl, and Ar Region" for which I am the spokesman, has been given 132 hours of beam time to continue the measurements begun with the previously mentioned experiment. Both of these experiments will use the system designed at Mississippi State and should lead to further experiments. Neither of these experiments is currently scheduled due to a large backlog of approved

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experiments at the NSCL. It is hoped that both can be scheduled during the Fall or Spring terms of the coming year. In addition, discussions continue on possible proposals for the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) as well as for new types of experiments at the NSCL. Of particular interest is the possibility of doing time-of-flight mass measurements at the NSCL using a timing detector which has recently become available. Proposals for these experiments will probably be made in the near future.

Conferences

My research work has and will allow me to be involved with several scientific meetings. I was able to attend the dedication ceremonies for the HRIBF in December 1996. Included with this was an opportunity to strengthen ties to the UNIRIB Consortium which will hopefully lead to future experiments at the HRIBF. I will be attending the Sixth International Conference on Nucleus-Nucleus Collisions in June 1997. I have also been invited to give talks at the NSCL Users' Workshop on Future Experiments and Detectors for Nuclear Structure Studies and Astrophysics at the Upgraded NSCL to be held in August 1997 and at the International Conference on Fission and Properties of Neutron-Rich Nuclei to be held in November 1997.

Equipment Purchases

Several equipment purchases were made during the current year. These were all made to update and improve the computer facilities we have in the Nuclear Physics Group at Mississippi State. Primary among these has been the purchase of a Digital AlphaStation 233. The total cost of the system exceeded my budget, but additional funds were secured from Mississippi State to make the purchase possible. This computer system should allow for a more coordinated use of computer programs, primarily data analysis software, between Mississippi State and the national laboratories. This will hopefully assist in data analysis and program development. This system also provides a more useful avenue for upgrading should there be a shift in operating systems at the national laboratories. This is not true of the Sun workstations which we have been using.

Student Research Activities

I am currently directing the research of two graduate students who are seeking masters degrees. Jerry Middleton is in the process of finishing a thesis involving work with Dr. Gerald Alton at ORNL to develop more efficient ion sources for the HRIBF. His primary work has been at ORNL while his degree will be conferred by Mississippi State. Hatim Yousef will begin working on a research project in the near future. His work will concentrate on analysis of the β -decay data from the NSCL and preparation for the future experiments. I hope to attract additional graduate students into the program in the coming year now that the University has made an additional commitment in helping us attract new graduate students. Another important aspect of the research program has been the inclusion of undergraduate students to work on data analysis, computer system management, and some aspects of experiment design. Their work in these areas are quite satisfactory even though they often do not totally understand the concepts involved in the research. I also hope to bring additional undergraduate students into the program in the coming years.

Conclusion

The basic goals of the research project remain unchanged from those described in the original proposal. Experiments at the HRIBF have not started at this time as hoped, however I feel confident that this portion of the project will develop more completely over the next year. The research work at the NSCL is progressing as hoped. A total of approximately \$2.5k in unexpended funds are expected at the end of the current budget period. This is primarily due to the delay in performance of the new NSCL experiment where purchase of ^{48}Ca would be necessary. These funds will be used in the next budget period to allow use of additional undergraduate students.

The research project is progressing well, although not as quickly as I had originally hoped. Concentrated work over the coming summer should help me in making significant progress on data analysis, publication of papers, and design of future experiments.

Nuclear Structure Studies of Exotic Nuclei

Project Plan and Budget for FY98

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Experimental Research

Two experiments have been given beam time at the NSCL and will be scheduled at the earliest possible date. Both involve the β decay of parent nuclei produced through projectile fragmentation and use the detector system designed at Mississippi State. These experiments will be scheduled consecutively to optimize setup and calibration time. The first experiment will focus on the low-lying states in ^{42}S but will also provide information on states in other nearby nuclei. This experiment will again use the fragmentation of a ^{48}Ca beam and will probably push the detection limits for our system. Additional experiments in this series may be proposed to study the states in the adjacent odd-A sulphur isotopes but continuation of the measurements out to ^{44}S will need to wait for the completion of the NSCL upgrade. The second experiment will involve initial studies of states in heavy nickel isotopes. The purpose of this experiment is to determine the feasibility for additional studies. It is hoped that these experiments can be scheduled during the Fall or Spring terms. Additional experiments will be proposed during the year, but scheduling of these experiments will depend on approval of the appropriate PAC and the availability of beam time. Specifically, I hope to submit a proposal to the next NSCL PAC to make time-of-flight mass measurements of neutron-rich nuclei produced in the fragmentation of a beam between ^{48}Ca and ^{86}Kr . The specific beam to be used will depend on prospects for obtaining the greatest amount of information as compared to the probability of success. This experiment will use both the A1200 and the S800 to provide a long flight path and a high resolution measurement of the beam rigidity.

Data Analysis, Publications, and Invited Talks

Analysis of the data from the August 1996 NSCL experiment will continue. It is expected that this analysis should lead to the publication of several journal articles as well as conference proceedings. I have already been invited to give a talk on these results at the International Conference on Fission and Properties of Neutron-Rich Nuclei to be held in November 1997.

Budget

Attached is a revised budget for the second year of the project. The request is for \$37k and only reflects minor changes from the original submission. In salaries and wages, two months in summer salary are requested for the principal investigator and 400 hours at \$5.50 per hour are requested for support of undergraduate students. The equipment request has been reduced to \$4.5k to offset necessary increases in other areas. With these funds I hope to purchase a PC for use as a stand alone system as well as for a terminal to connect to the Sun and DEC workstations. In terms of relative cost this seems to be the most efficient use of funds. I also request funds to purchase equipment related to detector development. Although the decrease in equipment is not desirable, it will still be possible to purchase a number of smaller items related to detector development using other funds. There is a small increase in travel funds in expectation of increases in the opportunities to be involved in experiments. These funds will be supplemented by a small amount of unexpended funds from the first year.

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