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MASTER

PROGRESS REPORT

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HIGH RESOLUTION POSITRON Q-VALUE MEASUREMENTS
AND NUCLEAR STRUCTURE STUDIES FAR FROM
THE STABILITY LINE

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ABSTRACT

This document represents a progress report and renewal proposal for the contract DEAS 09 79 ER10434 between the USD0E and USC. During the time from 1 July 1979 and 1 Mar 1980, the large 35% intrinsic Ge detector was purchased and tested, and the new hyperpure Ge detector for positron end-point-energy measurements was designed and fabricated by ORTEC. It was delivered just prior to January 1, 1980. Measurements using this special equipment will begin in January 1980. During this period, a new effort in the measurement of short nuclear lifetimes was completed and nuclear structure measurements of ^{205}Rn and ^{208}Rn were completed. The results of these efforts are described in the text. A search for the Post Doctoral Research Associate was started last summer and the position will be filled on or about 1 Mar 1980. The first experiments to measure positron end-point-energies were proposed to the ORIC scheduling committee and measurements will begin in March 1980. Theoretical efforts have begun in attempting to accurately describe the interference of annihilation radiation with positron end-point-energy measurements.

Nuclear Structure and Spectroscopic Studies at UNISOR

F.T. Avignone, III

Introduction

The forefront of experimental nuclear spectroscopy and nuclear structure lies in the study of the properties of nuclear levels, the electromagnetic transitions between levels and the decay by α , β , or proton emission, of nuclei far from the line of β -stability. This is most efficiently pursued by use of an isotope separator on-line to a nuclear reactor (to study neutron-rich nuclides) or on-line to a particle or a heavy ion accelerator (for the study of neutron-deficient nuclides).

UNISOR is an organization of twelve universities, Oak Ridge Associated Universities, and the Oak Ridge National Laboratory and stands for "UNIVERSITIES' ISOTOPE SEPARATOR at OAK RIDGE." Professor Avignone was one of its founders and developers, has served as Chairman of the Scientific Programs Committee, Vice Chairman of its Executive Committee and two years as Chairman of the UNISOR Executive Committee. The facility consists of a 90° isotope separator, on-line to the Oak Ridge Isochronous Cyclotron which is soon to be upgraded with the Hollifield-Heavy-Ion, Van de Graaff injector. The injector facility will be on-line during the early months of 1980. The University of South Carolina, and the other participating universities, each contribute \$6000 annually towards the operating budget of UNISOR. The USDOE funds the remainder of the operating budget (approximately \$150,000) and approximately \$40,000 per year in capital equipment improvements. There are three permanent staff members at UNISOR who work continuously on the development, operation, and maintenance of one of the most modern and versatile nuclear structure laboratories in the world.

Professor Avignone has joined the staff during part of three summers and has participated in many ways in the development of the project's capabilities as well as in nuclear structure studies performed there.

Recent UNISOR Research Involving the USC Group

Recent research involving Professor Avignone's group at UNISOR has included many topics, most notably the discovery of new isomers in ^{185}Tl and ^{187}Tl and the departure of the $9/2$ - intruder state at ^{187}Tl .¹ These studies were carried out with the separated $A=185$ and 187 mass chains, following the heavy ion reactions: $^{14}\text{N}(^{180}\text{W},9n)^{185}\text{Tl}$ and $^{14}\text{N}(^{182}\text{W},9n)^{187}\text{Tl}$. In other studies the USC group has participated in, the coexistence of spherical and deformed bands in ^{186}Hg and ^{186}Tl were discovered.² This study was carried out on the isotopically separated $A=186$ mass chain, following the reactions $^{181}\text{Ta}(^{16}\text{O},11n)^{186}\text{Tl}$ and $^{182}\text{W}(^{14}\text{N},10n)^{186}\text{Tl}$, respectively. They have also been intensively involved with instrumentation³ and project development⁴ as well as in more routine spectroscopic measurements.⁵

Professor Avignone and Dr. T.A. Girard, a recent USC Ph.D. graduate, recently developed a new method for measuring the end-point energies of β^+ branches in short lived isotopes by use of a planar, hyperpure-Germanium charged particle detector, surrounded by a large $\text{NaI}(\text{Tl})$, two-region annihilation radiation detector.⁶ This spectrometer is presently being upgraded to achieve higher efficiency. There is also a theoretical study underway to determine if the interference of the spectral measurements by annihilation radiations can be accurately corrected for by a Monte Carlo computational technique which would eliminate the need for the $\text{NaI}(\text{Tl})$ annulus and increase the efficiency drastically.

One of the USC developmental contributions, was the installation of a modified, Gerholm magnetic solenoid spectrometer on-line to the tape collection

system of the UNISOR separator. Recently, a collaboration of Vanderbilt, USC, and UNISOR used this lens to measure the nuclear lifetime of the first 0^+ state in its decay to the 0^+ ground state of ^{186}Tl , to be less than 150 picoseconds.⁷ This is the first in a series of proposed measurements to determine the degree of validity of the nuclear models which predict these transitions to be between bands associated with two distinct stable equilibrium deformations of the nuclei in this region. The model of Dickman and Dietrich[†], for example, predicts lifetimes of approximately ten nanoseconds which is in clear disagreement with the recent measurements. We propose to continue the refinement of this technique and its application to other interesting cases in order to settle this important theoretical question and to stimulate theoretical treatments which will explain such short $0^+ \rightarrow 0^+$ electromagnetic decay lifetimes.

The feasibility study for the investigation of the structure of the levels of the even-even Radon isotopes $^{204,206,208}\text{Rn}$, has recently been completed at UNISOR by one of Professor Avignone's graduate students, Mr. B.G. Ritchie.⁸ The motivation of this investigation is the direct test of the recent (IBA), Independent Bozon Approximation Model proposed by Arima and Iachello.^{††} Mr. Ritchie is the recipient of an ORAU graduate fellowship for the two academic years (1977 - 1978) and (1978 - 1979), and is situated at the Oak Ridge National Laboratory which is the main reason for such rapid progress on this project.

Future Research Proposed by USC at UNISOR

The main thrust of the entire UNISOR effort has recently been in the investigation of nuclear structure details, as well as the systematics of nuclear structure, in the highly neutron deficient isotopes of Tl, Hg, Au, and Pt. Such studies are highly desirable in higher-Z as well as in lower-Z

[†] Z. Phys. 271, 417(1974)

^{††} Ann. Phys. 99, 253(1976)

regions. However, they have mainly been constrained by the state of the art of target-ion-source development, for the on-line separator, and by the energies as well as the variety of heavy ions available from the Oak Ridge Isochronous Cyclotron (ORIC).

The new, National Heavy Ion facility at ORIC, called the Hollifield Heavy Ion Laboratory, is scheduled to come on-line during 1980. It is a large vertical Van de Graaff accelerator which can accelerate a very wide variety of heavy ions and a much greater range of energies. The nuclear-evaporation model, which has successfully guided them in their past work, indicates that they will be able to reach far from nuclear stability, in almost any mass region chosen, with the variety of ions and energies afforded by the Van de Graaff injector into ORIC. Based on recent experience at UNISOR, it is safe to say that UNISOR research will be on the very forefront of nuclear structure research for more than a decade.

It is proposed to apply USC's recently developed hyperpure-Germanium spectrometer technique to measure the mass differences between successive nuclides connected by $\beta^\pm$ decay in every possible case. One of the fundamental quantities which sensitively tests the various nuclear interaction models are the nuclear binding energy systematics of a series of β^+ connected nuclides. Such measurements directly test semi-empirical mass formulae and their various theoretical postulates, as well as microscopic models based on some specific two-body interaction, for example, the Shell-Model, Projected-Hartree-Fock and Projected Hartree-Fock-Bogoliubov models. Further development of this technique would also be most useful in studies of neutron-rich nuclides following fission which will soon be under investigation at TRISTAN, at the Brookhaven National Laboratory.

It is further proposed that the more routine previous nuclear spectroscopic studies, including the measurement of short nuclear lifetimes in the range of hundreds of picoseconds to many nanoseconds, be extended to new regions of the nuclide chart as they become available at UNISOR via the new facility. These studies, as in the past, have shown to be powerful tests of nuclear models. The disagreement between our recent lifetime measurement of the first excited 0^+ state in ^{186}Tl as <100 picoseconds, will if supported by a number of similar cases, cast serious doubts on recently accepted models and stimulate new models which properly predict these transition strengths. The more routine assignments of energies, spins and parities, while not usually exciting in any single case, become highly important when they are known for a chain of isotopes, for example (Z,A) , $(Z,A-1)$, $(Z,A-2)$, etc. Such systematics directly test the simplest features of a nuclear model namely the ability to correctly predict energies, spins, and parities of levels. UNISOR measurements have always resulted in such connected studies rather than just isolated cases. This is one of the desirable features afforded by the separator.

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