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title
TECHNICAL PROGRESS REPORT

for the period October 1, 1973 to September 30, 1974,

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TANDEM ACCELERATOR

General Performance:

The overall tandem accelerator performance has improved during the past year but because of reduced budget and personnel we could not always operate the tandem on a 24-hour, 7-day week schedule. Because of less machine maintenance we have logged ~ almost as many net hours of tandem operation as last year, 6275 hours vs. 6470 hours.

Pelletron Chain:

The pelletron chain performance improved substantially. In part the improvement results from the new higher value column resistors which permit us to stay well below the maximum chain current. After 17,000 hours of operation we finally replaced a pelletron chain because wear in the joints was excessive.

Accelerating Tubes:

The new HETA design stainless steel accelerating tubes have not yet been installed because they were damaged in shipment and had to be returned for repair. We expect to install them some time this fall. Meanwhile the old inclined field tubes have performed well. The low energy tube has ~ 20,000 hours and conditions to > 6.5 MV on demand though recently it shows symptoms of excessive radiation characteristic of a bad glass section. The high energy tube with only half the number of hours had a bad section which had to be shorted out over a year ago (see last year's report). This tube also conditions to > 6.5 MV on demand.

Miscellaneous items:

During the past year the vacuum interlock and power facilities on the tandem have been standardized and upgraded to provide more reliable operation and protection. We hope further to reduce down time by the resultant easier diagnosis, repair and maintenance operations. These changes will be

increasingly important toward achieving the efficient (i.e. low overhead) operation necessary for a smaller staff and budget.

COMPUTER

As in previous years the DDP-124 continues to provide reliable and inexpensive on-line and off-line interactive data acquisition and processing for a wide range of experiments. Machine performance has been excellent but the printer and card reader (which were not replaced after the bombing) are beginning to show signs of old age. Mechanical and electrical maintenance of the printer consumed over two man-months of time. A fault in the printer buffer was bypassed with a modification of the software handler.

During the year an additional disc, acquired from a bankrupt computer company, was added to the system. The on-line teletype, long a source of trouble, was replaced with a CRT terminal of advanced design. Soon an additional 8K of core memory will be added. This new core is modular, inexpensive Datacraft type DC-38. The memory controller is designed to permit replacement of Honeywell memory units (we have had two failures in five years) with additional Datacraft modules.

Improvements to the operating system this year include implementation of FORTRAN processing of list-mode data accumulation and development of a systems generator which permits straightforward adaptation of the operating system to core limits and device availability. A large fraction of a new system which will incorporate user program overlaying and an environmental interaction processor has been written.

PROGRESS REPORTS OF THE RESEARCH GROUPS

Activities of the group of W. Haeberli

1. The tensor analyzing power in sub-Coulomb stripping reactions is expected to arise solely from the deuteron D-state. All three tensor an-

alyzing powers in $^{208}\text{Pb}(d,p)^{209}\text{Pb}$ at 9 MeV have been measured and analyzed by a DWBA calculation which includes the deuteron D-state. Excellent agreement is obtained, using only one adjustable parameter (asymptotic D- to S-ratio).

2. In cooperation with Quin's group the reactions $^{58}\text{Ni}(d,n)$ and $^{60}\text{Ni}(d,n)$ were studied with the pulsed polarized beam. The cross sections and analyzing powers are similar to the corresponding (d,p)-reactions and in reasonable agreement with DWBA theory.
3. Measurements on tensor analyzing powers in deuteron stripping reactions have continued. The effect of compound-nucleus contributions have been studied in an effort to explain discrepancies with DWBA theory.
4. Studies of the spin-dependence in deuteron-nucleus elastic scattering have continued. Comparison to predictions of the folding model suggest a much larger diffuseness of the spin-orbit term than had been assumed previously.
5. Two coupled-channel codes (JUPITER and CHUCK) were adapted for use on our 1110 computer and were modified to calculate polarization parameters. A program was written to calculate compound nucleus contributions to vector and tensor analyzing powers.
6. To provide absolute calibrations of proton polarization, points where the analyzing power is exactly 100% have been located in p- α and in p- ^{12}C scattering.
7. In a joint experiment with the Berkeley 88" cyclotron group, the deuteron vector analyzing power of $^{12}\text{C}(d,d)^{12}\text{C}$ was studied to provide a polarization standard for 20-30 MeV deuterons.
8. Apparatus to study the production of polarized negative ions by crossing beams of polarized hydrogen atoms and negative deuterium ions has been constructed in collaboration with Prof. Anderson.

Activities of the group of P.A. Quin

Nuclear Structure Studies:

1. In cooperation with Professor Haeberli's group the $^{48}\text{Cu}(^{12}\text{C}, 3n \gamma\gamma \dots)^{57}\text{Fe}$ reaction has been used to populate states in ^{57}Fe and to search for the existence of high-spin, high-excitation rotational bands. Some new transitions to low-lying bands have been observed and complete analysis of γ - γ coincidence data is underway.
2. Our study of $(\vec{d}, \alpha)$ reactions continues. We now have measurements on ^{58}Ni and ^{90}Zr targets including excitation functions from which we can determine those transitions which proceed by a direct reaction. The two-nucleon transfer code DWUCK II is being used to analyze our results. We find considerable sensitivity to the α -particle potential and only slight sensitivity to the two-nucleon j-j coupling configuration.
3. Our study of single particle transitions on even-A 2s1d shell nuclei has been concluded with measurements of the $^{22}\text{Ne}(\vec{d}, p)^{23}\text{Ne}$ reaction. A total of five new spin assignments were made to levels in ^{23}Ne .

Neutron Studies:

1. We have made precision measurements of the $^6\text{Li}(n, \alpha t)$ total cross section for neutron energies between 3 and 10 MeV. Our results are in general agreement with the Pendlebury evaluation but do not agree with the most recent measurements. We are presently attempting to extract angular distributions and the $^6\text{Li}(n, \alpha n)$ cross sections from our data.
2. We have measured the $^{23}\text{Na}(n, p)^{23}\text{Ne}$ and $^{23}\text{Na}(n, \alpha)^{20}\text{F}$ cross sections for 7 to 10 MeV neutron energy.
3. A precise measurement of the $^4\text{He}(n, ^4\text{He})n$ differential cross section near 7 MeV neutron energy is underway. Earlier measurements are not compatible with the LASL five-nucleon R-matrix calculations.

4. The $^{12}\text{C}(\vec{d},n)^{13}\text{N}$ and $^{12}\text{C}(\vec{d},\vec{n})^{13}\text{N}$ reactions are being studied in the 5 to 10 MeV deuteron range where considerable resonance structure has been observed. Forward angle cross sections and vector analyzing powers have been measured.
5. The $^2\text{H}(\vec{p},n)2p$ reaction has been measured in collaboration with the University of Washington in Seattle. Analysis of the data has just begun, but over part of the angular range the analyzing power is as large as 0.05. The Amado model predicts an analyzing power of zero.

Activities of the group of H.T. Richards

1. The $^{14}\text{N}(\alpha,\alpha_1)^{14}\text{N}(T=1)$ study has almost been completed. We now have extensive differential cross section measurements (11 to 16 angles) in 20 to 30 keV steps between $7.6 < E_\alpha < 16.9$ MeV and have parametrized these data in terms of 151 isospin-mixed states of ^{18}F . The parametrization fixes the J^π , E_R , Γ , $|S(E_R)|$ and the phase information for these states. When the ^{18}F excitation energies overlap our earlier $^{16}\text{O}(d,\alpha_1)^{14}\text{N}(T=1)$ study, many agreements on ^{18}F state parameters occur. A number of the states are analogues to ^{18}O states seen via $^{14}\text{C}+\alpha$ scattering, though in some cases the analogue strength seems divided among a cluster of nearby ^{18}F levels.

The analysis of the data involved dealing with the complex zeros of the scattering amplitudes. Certain regularities in the trajectories of these complex zeros as a function of energy appear. In particular for the "physical" solution, (in contrast to the other ambiguous solutions), the position of all complex zero tend to rotate in the same sense in the complex plane as the energy increases. A computer simulation where the resonances were arbitrary showed the same characteristics.

For several sets of resonances, there are marked correlations between the

complex amplitudes of nearby ^{18}F states. These correlations are of the type reported earlier by us for the $^{16}\text{O}(d, \alpha_1)^{14}\text{N}(T=1)$ data and interpreted by Friedman in terms of bridge states and intermediate structure [Phys. Rev. Lett. 30, 394 (1973)]. This work constituted the Ph.D. thesis of Lily Chen. One of Friedman's theory students is looking into the intermediate structure questions in more detail.

2. The $^{14}\text{N}(\alpha, \gamma)^{18}\text{F}$ data taking has been completed together with excitation functions for $^{14}\text{N}(\alpha, p_i)^{17}\text{O}$ and $^{14}\text{N}(\alpha, \alpha_0)$. The data now are undergoing analysis; there is a suggestion of intermediate structure in the (α, p_1) channel data. Prof. T. Piza of the University of Sao Paulo, Brasil, is helping L.C. Boueres with the analysis.

3. Most of the data on the $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$ (together with some relevant $^{16}\text{O}(\alpha, \alpha_0)^{16}\text{O}$ cross sections) are now in hand and the analysis is underway.

4. The unnatural parity states of ^{18}F : The reaction $^{16}\text{O}(d, \alpha_2)^{14}\text{N}(4.193 \text{ MeV})$ leaves ^{14}N in an 0^- state. Hence only unnatural parity states of the compound nucleus can contribute. We have studied this reaction over the excitation range $(12.8 < E_x(^{18}\text{F}) < 13.8)$. Detector limitations fixed the lower energy range and complications in the analysis (high partial waves) determined the upper limit. To achieve an unambiguous S matrix analysis we also needed cross section measurements for vector and tensor polarized deuterons. These have also been taken though in coarser energy steps since the polarized beams are small compared to the unpolarized. Preliminary results on the analysis indicate that we can none-the-less achieve a unique parametrization of the differential cross sections in terms of the unnatural parity states of ^{18}F .

5. Double Spin and Isospin Flip Scattering: $(^{14}\text{N} + ^{14}\text{N} \rightarrow ^{14}\text{N}(2.31) + ^{14}\text{N}(2.31))$. Although considerable effort was spent on this project, the cross sections are so low that with our reduced personnel, this project had to be abandoned.

6. Heavy Ion Reactions: $^{14}\text{N}(^{10}\text{B}, ^{10}\text{B})^{14}\text{N}$. The elastic scattering data has been partially analyzed, but this project too has suffered from lack of personnel.

7. Ion Source Developments: The continuously displayed emittance measuring system described in last year's report has been improved and used as a valuable diagnostic tool in our ion source program. We quickly found that our He^- source had relatively poor emittance compared to our H^- , D^- , and heavy ion sources. In fact it was comparable to the tandem acceptance. This result is consistent with the poor transmission of helium beams which we sometime experience. We traced the poor emittance to the RF source of He^+ ions (before the cesium charge exchange cell). We currently are testing a locally designed PIG source with axial extraction of the He^+ which source has considerably better emittance and total current than the RF source.

We also note that our sputter PIG source described in last year's report has much better emittance than the U.N.I.S. source (which employs sputtering by a Cs^+ beam from a surface ionization source), and in the commercial version is widely used though some tandems do report poor transmission through the machine.

Collaborations with Nuclear Engineering and Medical Physics: An ultra high vacuum target chamber (built chiefly by Nuclear Engineering) has now been installed on the Tandem for simulation of fast neutron damage in reactors. Our sputter PIG source provides the heavy negative ions which after acceleration bombard the samples in the target chamber. The rest of the program involves entirely nuclear engineering funds and personnel. The medical physics collaboration has involved only machine time as our contribution. An on-line chemical processing station is located in the tandem vault and many capillary tubes carry the short lived isotopes through the University heating tunnel to the medical laboratories some 400 meters away.

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A Sputter PIG Source (SPIGS) for Negative Ions

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