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INTRODUCTION

The tandem Van de Graaff has been in its second year of operation. Concentration on the use of heavy-ion beams for atomic and nuclear physics has continued. The PDP-15/30 computer has been installed and brought into operation during the present year.

PRINCIPAL INVESTIGATOR

The principal investigator, Robert B. Leachman, has devoted 40 percent of his time to the project during the academic year and will continue to devote 40 percent of his time to the project during the remainder of the current term. During the summer months of 1971, he received no pay assignable to the project, but remained as Principal Investigator.

ON-LINE COMPUTER

G. G. Seaman, J. C. Legg, and G. W. Hartnell

The computer system described in the proposal submitted to the AEC in March, 1970 was modified during the fall of 1970 and approved. Purchase was made of a PDP-15/30 computer manufactured by Digital Equipment Corporation in compliance with State procedures. The computer was delivered in July, 1971.

The PDP-15/30 consists of a central processing unit with automatic priority interrupt, 28 k of memory, two teletypes, a line printer, a storage oscilloscope, five DEC tape units (not IBM compatible), an incremental plotter,

and an interface with two analog-to-digital converters. The software allows time-sharing between a protected "foreground" user for data acquisition and a "background" user for program preparation and data analysis.

The data acquisition software was delivered in August, 1971, and has been used since that time. Several modifications were made here to more efficiently use the computer. The programs as delivered did not use the memory area from 24k to 28k. This core area was recovered as a data region. The two-parameter data acquisition program was not matched properly to the analog-to-digital converters supplied, and this was corrected.

Digital interfacing has been designed to allow computer access from an existing analog-to-digital converter system with magnetic tape storage, from scalars, and from readout of analog devices and position indicators. The existing analog-to-digital converter system interface has been completed and allows data taken earlier and stored on magnetic tape to be transferred to the computer for analysis.

APPLIED PHYSICS PROGRESS

Detection of Heavy Trace Elements in Biological Samples G. G. Seaman, M. O. Volckmann, and C. L. Cocke

Initial studies of detecting very heavy trace elements, such as lead and mercury, in flour samples by detection of back-scattered oxygen ions were unable to resolve the masses of lead and mercury separately. In order to make this separation, a thin Ge(Li) detector with about 1.5-keV resolution for 122-keV gamma rays has been used to measure the characteristic X-rays from lead and mercury produced with proton and heavy-ion bombardment.

The dominant problem is in reducing the background in the region of 70 to 80 keV where the K X-rays would appear. The detector is large enough to detect 511-keV gamma rays with reasonably large efficiency, and the Compton electron distribution from these gamma rays is the chief source of background. Accordingly, the amount of β^+ activity must be kept to a minimum. In the thick samples studied thus far, the production of ^{13}N by proton capture by the carbon nuclei is the primary source of β^+ with proton beams. With a heavy-ion beam such as carbon, the reactions with carbon and oxygen nuclei yield several nuclei which are β^+ emitters.

Because of the β^+ rays background problem, the analysis of lead and mercury content in thick targets is limited to about 1 part in 10^4 . It is hoped that by using targets thin to the proton beam this sensitivity can be improved.

ATOMIC PHYSICS PROGRESS

During the year 1971, the Atomic Collision program under the direction of J. R. Macdonald has encompassed the completion of several experimental projects begun in 1970 or earlier and the initiation of projects that will continue into 1972. Contributions to the program have been made by S. M. Ferguson, L. D. Ellsworth, Tang Chiao, S. A. Savoy, and Loren Winters.

Equilibrium Charges of Ions

The measurement of equilibrium charge distributions of heavy ions of carbon, nitrogen, fluorine and chlorine emerging from carbon foils with energies from 0.3 to 2.5 MeV/amu has been completed. This work has comprised the M.S. Thesis of S. A. Savoy. The results have been prepared for submission to Physical Review A in November 1971.

Charge Exchange Cross Sections for Heavy Ions

The experiments to measure charge exchange cross sections in single collisions of heavy ions with gases have been further developed in the past year. Using off-line data analysis, complete sets of cross sections have been obtained for fluorine ions passing through thin nitrogen targets at energies from 5 to 54 MeV. These results have been submitted to Physical Review A in September 1971. Theoretical analysis of the multiple electron capture cross sections measured for fluorine ions has progressed and results have been published in the Proceedings of the Seventh International Conference on the Physics of Electron and Atomic Collisions, (ICPEAC), Amsterdam, p.519, 1971. This analysis is continuing and prompted the initiation of measurements of the multiple electron capture cross sections of fluorine ions in argon and krypton in order to investigate the importance of the binding energy of the captured electron on the energy dependence of the capture cross section. These experiments will be completed in the next six months.

The availability of the PDP-15 computer for on-line analysis has permitted charge exchange cross sections to be extracted from the experimental data with considerably greater accuracy than has previously been possible. The ability to insist on stringent conditions for the resolution of different charge states and peak-to-valley ratios by instantaneous data reduction has resulted in the use of much thinner target conditions than have ever been used in these experiments before. Hence, smaller corrections need be made for multiple collision events.

Using the on-line computer, cross sections have been determined for electron capture and loss by fluorine ions in argon gas at energies from 4 to 54 MeV. The analysis technique and these experimental results are being prepared for submission to Physical Review A in December 1971.

Electron Capture by Protons

In addition to the charge exchange measurements with heavy ions, electron capture cross sections by protons in various gases have been determined experimentally at energies from 1 to 12 MeV. In this work, W. W. Eidson of the University of Missouri at St. Louis has been a collaborator with the group at K.S.U. Preliminary results of these experiments have been published in the Proceedings of the Seventh ICPEAC Conference, Amsterdam, p.516, 1971. More complete results and a detailed comparison with theoretical predictions are being prepared for submission to Physical Review Letters in December, 1971.

Production of Inner Shell Vacancies

Following theoretical analysis that suggests that electron capture occurs from inner atomic shells, an experimental program has been initiated to investigate the formation of inner shell vacancies in single collisions in gas targets. Analysis of x-ray production by protons on Ne, Ar, and Kr has begun using a Si(Li) detector with a resolution of 190eV. Preliminary results have permitted x-ray production cross sections to be determined at gas pressures less than 4 microns, the pressure at which reabsorption phenomena become apparent. Preliminary results of these experiments will be presented at the San Francisco meeting of the A.P.S. in February 1972. These experiments will continue in 1972 and will be extended to excitation by representative heavy ions.

Gas Fluorescence

Experiments have begun to investigate the gas fluorescence of helium excited by protons and heavy ions at energies greater than 1 MeV/amu. This work is being carried on in collaboration with C. L. Cocke of the Department of Physics, K.S.U. Initial analysis has been made of the fluorescence spectrum,

and detailed examination is under way of the collisional excitation and de-excitation of several spectral lines. The collision processes for these states are not clear, but different mechanisms are apparent because of the radically different dependence of de-excitation upon gas pressure. This work will continue in 1972.

Ion Source Developments

Because of the work being done with heavy ions on this accelerator, development is continuing in ion source technology. Stable beams of a variety of ions are now reliably obtained from the Diode Ion Source. A progress report on our first 18 months of operation with this source was published in the Proceedings of the Ion Source Symposium, Brookhaven National Laboratory, p. 285, 1971. However, attempts to accelerate lithium, boron, and phosphorus, as well as noble gas ions, have been unsuccessful from this source. As a result, a new ion source is being constructed at K.S.U. A Sidenius Hollow Cathode Positive Source to be used either with alkali exchange or to produce negative recoil ions has been designed by J. R. Macdonald and partially constructed in the K.S.U. machine shop. The development of this source will continue in 1972, with injection into the Tandem expected before June 1972.

In connection with the development of charge exchange ion sources and the injection of neutral noble gas ions into the Tandem Van de Graaff, experiments have been conducted to determine the multiple scattering angles associated with charge exchange. Assistance on these experiments has been provided by Miss Jacqueline Spears. At present, measurements have been made of the angular spread of helium and argon atoms emerging from thin foils at energies from 60 to 130 keV. Analysis of this work is not yet complete, but it is apparent that additional measurements are needed to determine

optional beam handling conditions. In 1972, this work will continue with modifications to permit determination of multiple scattering angles in gas exchange canals.

Atomic Physics Studies with the Mössbauer Process
T. A. Tumolillo

Preparations continue for doing coulomb excitation Mössbauer experiments with the dewar arrangement built on a beam line of the tandem Van de Graaff. This dewar is designed for liquid helium temperatures. Until recently, difficulties have been encountered in obtaining a sufficiently stable and large beam of oxygen ions at the necessary energy for the experiments.

The first experiment being undertaken is the observation of the Mössbauer effect of the 75-keV level in ^{171}Yb following coulomb excitation with ^{16}O ions. The target is a metal foil enriched in ^{171}Yb (purchased from ORNL) which will provide a Mössbauer source free of hyperfine interactions. It will be used to study the hyperfine interactions in the oxide and chloride compounds of ytterbium.

Mössbauer Effect experiments on the 37-keV level in ^{121}Sb have been in progress for several months in collaboration with Dr. R. Pruitt of Fort Hays Kansas State College, who worked in our laboratory during the summer of 1971 while holding a Consortium for the Advancement of Physics Education fellowship. Under investigation are a large number of the intermetallic compounds of antimony, especially the ferromagnetic compounds MnSb , FeSb , CoSb , and NiSb . Mössbauer spectra have also been measured for many of the rare earth

compounds RSb (R=Rare Earth). Plans are to study the isomer shifts in the Group IV antimonides GeSb, SnSb, and PbSb.

Quite recently experiments to measure the Mössbauer spectra of iron implanted in aluminum oxide have been initiated. The iron is implanted using our small 150-keV accelerator. The Mössbauer spectrum has been obtained by observing backscattered conversion electrons in a proportional counter filled with a helium-methane mixture. This work is being done in collaboration with Professor R. D. Dragsdorf and associates in the Physics Department.

Perturbed Angular Correlations J. S. Eck and D. S. Gale

During the past year, a rather unique angular correlation chamber was designed, constructed and installed at the tandem accelerator.¹ This chamber will allow the measurement of particle- γ and γ - γ correlations. The first study to be undertaken will be the measurement of the hyperfine fields at the ^{57}Fe nucleus recoil implanted in Fe foils by the reaction $^{16}\text{O} + ^{57}\text{Fe} \rightarrow ^{16}\text{O} (180^\circ) + ^{57}\text{Fe}^*$. Similar studies of the hyperfine fields of recoil ^{57}Fe using Mössbauer techniques² were limited by the 100-ns lifetime of the Mössbauer 14.4-keV state in ^{57}Fe . It is hoped to overcome this limitation by using perturbed angular correlation techniques on the higher excited states of shorter lifetime in ^{57}Fe and other nuclei.

¹ E. J. Feldl and J. S. Eck, Nucl. Inst. & Methods, 95, 233 (1971).

² E. T. Ritter, P. W. Keaton, Jr., Y. K. Lee, R. R. Stevens, Jr., and J. C. Walker, Phys. Rev. 154, 287 (1967).

NUCLEAR PHYSICS PROGRESS

Isomer and Prompt Fission of ^{242}Am
R. B. Leachman and G. Griffith

Extensive data analyses have now been completed on our existing data of prompt and isomer fission of ^{242}Am . These data were of energies of fragment pairs, which provide complete information on the fission modes.

Detailed applications of instrumental and inherent resolutions were made for each case in an effort to determine whether small differences exist between modes of prompt and isomer fission of this compound nucleus. No differences outside of statistical incertainties could be detected.

Fission Isomers with Multiple Lifetimes
N. Vilcov, R. B. Leachman, G. Griffith, and C. W. Woods

Evidence of decay from various states exists for fission isomers in the form of a multiple-component decay curve. The fission isomer used in the present study was $^{237}\text{Pu}^m$ produced by the reaction $^{237}\text{Np}(d,2n)^{237}\text{Pu}^m$. The isomer lifetimes are 120 ns and 900 ns. The experimental arrangement involved a chopped beam of deuterons from the tandem, recoil of isomer nuclei from the target, and a ring detector of fission fragments.

Relative yields of the two lifetimes were made for 9-, 10-, 11-, and 12-MeV deuterons. The ratio of the yields did not show any clear trend with incident energy, which is consistent with other recent measurements.^{3,4}

The yield of the isomeric fissions of $^{239}\text{Pu}^m$ from the $^{239}\text{Pu}(d,pn)^{239}\text{Pu}^m$ reaction was found to be too small for similar measurements of the 500-ns and 8- μ sec isomers from this nucleus.

³ P. A. Russo, R. Vandenbosch, M. Mehta, J. R. Tesmer, and K. L. Wolf, Phys. Rev. C3, 1595 (1971).

⁴ S. L. Bacharach, J. K. Temperley, and J. A. Morrissey, Bul. Am. Phys. Soc. 16, 56 (1971).

Fission Modes from Proton-Induced Thorium Fission
R. B. Leachman, C. Rudy, and C. W. Woods

Coincident recording of the energies of the fragment pairs has been done for proton - induced fission of ^{232}Th . In the multiple dimensional display of fission modes, a small symmetrical fission peak in the mass yield is seen in addition to the dominant asymmetric peaks.⁵ Further study is underway.

Spin-Flip Probability for $^{13}\text{C} + ^{24}\text{Mg}$ Scattering
J. S. Eck, D. S. Gale, and G. G. Seaman

In the analysis of heavy-ion scattering experiments, it is assumed ad hoc that the spin-orbit interaction is negligible. The polarization measured in a scattering experiment is roughly proportional to $V_{\text{so}}/V_{\text{cent}}$, where V_{so} is the spin-orbit potential and V_{cent} is the real central potential. For example, the spin-orbit potential for proton-nucleus scattering is about 6 MeV and the real potential is ~ 50 MeV, while for $\text{He}^3 + \text{nucleus}$ scattering the spin-orbit potential is 2 MeV and the real potential is ~ 150 MeV. It is, therefore, expected that the polarization for $\text{He}^3 + \text{nucleus}$ scattering is approximately 1/9 that of proton + nucleus scattering. This is observed to be the case. Unlike the lighter particles such as p, d, He^3 and α the real central potential for heavy ion scattering does not increase in proportion to n where n is the number of nucleons in the projectile, but rather is of the order of ~ 50 MeV. It can be estimated on the basis of the crude folding model for calculating spin-orbit potentials that the

⁵ R. L. Ferguson, F. Plasil, H. W. Schmitt, ORNL 4513, 1969, p. 79

spin-orbit potential for C^{13} + nucleus scattering is ~ 5 MeV and, therefore, it is conceivable that the polarization observed in C^{13} + nucleus scattering might be about 1/12 that observed for p + nucleus scattering.

An attempt is being made in this laboratory to measure the spin-flip probability for inelastic scattering of $^{13}C + ^{24}Mg$ to the 1.36-MeV state of ^{24}Mg . A special chamber has been constructed and installed at the accelerator. Preliminary γ -ray excitation experiments have shown that the excitation of the 1.36-MeV state in ^{24}Mg by 24-to 27-MeV ^{13}C projectiles is considerable. These preliminary estimates of feasibility are very encouraging, and it is expected that the experiment will be completed during the coming year.

Nuclear Deformation of ^{28}Si from ^{16}O Scattering
J. S. Eck and D. S. Gale

Elastic and inelastic scattering angular distributions have been measured for $^{16}O + ^{28}Si$ in the energy range from 32- to 36-MeV bombarding energy of ^{16}O in order to determine the deformation of ^{28}Si . The preliminary results indicate that the deformation parameter $\beta_2 \approx -.25$ (i.e., Si^{28} has a strong prolate deformation). The angular distributions for the elastic and inelastic scattering exhibit strong nuclear-coulomb interference and this fact makes the fitting of the cross-sections a sensitive determination of β_2 . Although this technique requires introducing a nuclear model (i.e., the optical model) it has been shown that the deformation parameter β_2 is very insensitive to the particular model parameters used to fit the data.

Optical Model Potential Variation from Proton Scattering near the Coulomb Barrier
J. S. Eck

Recent studies of (p,n) cross sections on the Sn isotopes have indicated that the real part of the optical model potential varies strongly with energy

near the coulomb barrier.⁶ In order to more directly determine this energy variation, elastic angular distributions of $p + {}^{197}\text{Au}$ and $p + {}^{208}\text{Pb}$ were measured between 9 and 12 MeV. The previous energy variation observed for the Sn isotopes was substantiated by these measurements. It has been further shown that, by including antisymmetrization in a Fermi gas model calculation of the optical potential, the observed energy variation of the optical model potential is obtained. An interesting development found in this work was that by including a surface isospin term in the real potential of the form $4.0 \left[\frac{(N-Z)}{A} \right] 4a \frac{dv}{RdR}$ as compared to previous results⁷ where the isospin term was six times as strong, much better fits to the data could be obtained. The inclusion of this term accounts for the large neutron excess found on the surface of nuclei in the $A \approx 200$ region. The results obtained for the N and Z dependence of the various terms in the real optical potential were compared to the predictions of the semi-empirical mass formulas and agreement within 5 percent was obtained.

Coulomb Excitation of ${}^{93}\text{Nb}$
M. Kregar and G. G. Seaman

Thick targets of natural Nb metal were bombarded with oxygen ions in the range of 25 to 42 MeV. The gamma rays observed were assigned to the decay of five excited states. These states can be described as members of the multiplet formed by coupling a $g_{9/2}$ proton to the ${}^{92}\text{Zr}$ core. Energy levels and $B(E2)$ values were measured. Gamma ray yields were measured as a function of energy to insure that the excitation process was pure single Coulomb excitation. Above 38 MeV, the yield deviated from that predicted by Coulomb excitation, presumably because nuclear interactions were taking place.

⁶ C. H. Johnson and R. L. Kernell, Phys. Rev. C2, 639 (1970).

⁷ F. D. Becchetti, Jr., and G. W. Greenlees, Phys. Rev. 182, 1190 (1969).

The spins of two of the levels of the multiplet are not well known. However, on the basis of the weak coupling model, the measured $B(E2)$ values were used to suggest an appropriate spin sequence.

This work has been accepted for publication in Nuclear Physics.

Search for Transfer Reactions with ^{16}O Ions by Observation of Gamma Rays from Residual Nuclei

M. Kregar and G. G. Seaman

Thick targets of aluminum were bombarded with oxygen ions in the range 20 to 40 MeV. The gamma radiation produced was observed in a Ge(Li) detector. Single neutron or proton transfer reactions would result in the nuclei ^{26}Al , ^{28}Si , ^{26}Mg and ^{28}Si . However, no gamma rays from these nuclei were observed.

All gamma rays detected, approximately 30 strong peaks in the range 100 keV to 4 MeV, could be assigned to transitions in final nuclei resulting from one- or two-particle emission from the compound nucleus ^{43}Sc . For example, the reactions $^{16}\text{O} + ^{27}\text{Al}$ going to $\alpha + n + ^{38}\text{K}$, $\alpha + p + ^{38}\text{Cl}$, $p + p + ^{41}\text{K}$, and $p + ^{42}\text{Sc}$ are observed. These compound nucleus reactions are sufficiently intense to mask any weak gamma radiation, which indicates that the transfer reactions sought are either very weak or that all transfer go to ground states of the final nuclei.

Neutron Transfer Reactions Induced by ^{13}C Beams
G. G. Seaman and R. F. Keller

The ^{13}C beam was used to study neutron transfer reactions to ground states by activation of targets with suitable half-lives for beta decay. The initial work has been carried out on ^{19}F . Excitation functions have been measured for the yield of ^{20}F in thick targets of SbF_3 at ^{13}C energies of 10 to 27 MeV. The measurements were made by activating the target at constant beam intensity for about 7 half-lives (the half-life of ^{20}F is 11.4 seconds), then turning the beam off and counting the 1.63-MeV gamma rays in ^{20}Ne from

the ^{20}F decay. The beam is cycled until adequate statistics are obtained. The gamma rays are detected by a Ge(Li) detector located near the target.

Gamma ray spectra obtained while the beam is on indicate that some neutrons are transferred to the first excited state of ^{20}F . Analysis of the data is in progress. The analysis seeks to determine the validity of the semi-classical model of Breit and Ebel⁸ and the DWBA formalism of Buttle and Goldfarb⁹, with special attention given to the dependence upon the binding energy of neutron.

Lifetimes of Excited States in ^{39}K

R. M. Tapphorn, M. Kregar and G. G. Seaman

This work was completed during 1970. It was submitted for publication in 1971 and appeared as an article in Phys. Rev. C3, 2232 (1971).

Gamma Rays Resulting from $^{12}\text{C} + ^{13}\text{C}$ Reactions

S. Apostolescu and J. C. Legg

In the process of investigating ^{13}C -induced reactions, ^{12}C was found to be a ubiquitous target contaminant with a large reaction cross section. Therefore, a study of the reactions resulting from the bombardment of ^{12}C by ^{13}C was started.

Gamma ray spectra indicate that the strongest reactions leave residual excited nuclei of ^{21}Ne , ^{24}Na , and ^{24}Mg . Excitation curves in the region of the coulomb barrier show some resonance-like peaks. An angular correlation of the gamma rays on one of these resonances yields isotropic correlations

⁸ G. Breit and M. E. Ebel, Phys. Rev. 103, 679 (1956).

⁹ P. J. A. Buttle and L. J. B. Goldfarb, Nucl. Phys. 78, 409 (1966).

for all of the reaction gamma rays. This would suggest an isolated compound nuclear resonance in ^{25}Mg with spin 1/2 is being excited; however, the excitation curves do not support the idea of an isolated resonance.

A particle-gamma correlation was measured at a center-of-mass energy of approximately 12.5 MeV. This correlation was obtained with an annular particle detector in coincidence with a 3" x 3" NaI(Tl) detector. Analysis of these results for the observed ^{21}Ne states at 1.75, 2.89, and 3.66 MeV are in agreement with previous results.¹⁰

It is planned to extend these measurements to higher excitations by using a particle detector at 0° . This detector will have a gold foil ($\sim 25 \text{ mg/cm}^2$) placed in front of it to differentially absorb the beam projectiles. Using this technique, states in ^{21}Ne at excitations up to 12 MeV should be observed.

$^{62}\text{Ni}(p,p)^{62}\text{Ni}$ and $^{62}\text{Ni}(p,\gamma)^{63}\text{Cu}$
J. C. Legg and J. W. Gray

The $^{62}\text{Ni}(p,\gamma)^{63}\text{Cu}$ excitation curve has been found to exhibit many more resonances than the elastic scattering excitation curves between 2.3 and 3 MeV bombarding energy. In the course of studying the elastic scattering of protons from ^{62}Ni some effort was spent in investigating discrepancies between our results and those of Browne, *et al.*¹¹ In the course of this work the overall energy spread including target thickness was reduced below 1 keV FWHM.

¹⁰ A. J. Howard, J. P. Allen, D. A. Bromley, J. W. Olness, and E. K. Warburton, Phys. Rev. 157, 1022 (1967) and J. G. Pronko, C. Rolfs, and H. J. Maier, Nucl. Phys. A94, 561 (1967).

A program was written and, after some initial errors, thoroughly tested for the analysis of spin 1/2 on spin zero elastic scattering resonances. Our results were found to be consistent with a 40 ± 20 eV $p_{1/2}$ resonance at 2.7986 MeV, a 145 eV $s_{1/2}$ resonance at 2.799 MeV, and a 110 eV $s_{1/2}$ resonance at 2.806 MeV.

Unfortunately, the width of the p-wave resonance is considerably less than our preliminary results suggested,¹² so that the observation of this p-wave resonance does not alter significantly the conclusion of Browne, *et al.*¹¹

$^{16}_0(p,p'\gamma)^{16}_0$
J.C. Legg, D. Abraham, and J. W. Gray

Analysis was completed and a paper submitted for publication on the angular correlation of gamma rays emitted following inelastic proton scattering from $^{16}_0$. Perhaps the most noteworthy result is that the 6.85-MeV resonance observed in the inelastic gamma rays has an angular correlation consistent with a resonance spin of 5/2. Analysis of the elastic scattering of protons from oxygen by Salisbury and Richards¹³ assigns the resonance observed at 6.83 MeV in this reaction to be 3/2-. Additional experiments are needed to determine whether the elastic and inelastic scattering resonances are the same resonance or two different resonances.

¹¹ J. C. Browne, H. W. Newson, E. G. Bilpuch, and G. E. Mitchell, Nucl. Phys. A153, 481(1970).

¹² J. W. Gray and J. C. Legg, Bull. Amer. Phys. Soc. 16, 1174 (1971).

¹³ S. R. Salisbury and H. T. Richards, Phys. Rev. 126, 2147 (1962).

ACCELERATOR DIAGNOSTICS

Bremsstrahlung Location of Bad Tube Sections

J. C. Legg, J. W. Gray, and G. Hartnell

A search for a bad section of the accelerating tube led us to attempt to locate this bad section by measuring the bremsstrahlung energy spectrum while the high energy tube was breaking down under voltage. The bremsstrahlung energy spectrum was measured with a 3" x 3" NaI(Tl) detector and the end point of this spectrum was easily determined.

The location of the bad tube section was calculated by assuming that the end point energy of the bremsstrahlung spectrum corresponded to eV , where V is the voltage between the dome and the bad tube section. The calculations suggested that the bad section was located 120 ± 3 sections away from the terminal. Visual inspection later found burned tube sections centered on section 122. Shorting of these sections removed the voltage limitation on the accelerator.

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