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RESEARCH PROGRAM IN NUCLEAR AND SOLID STATE PHYSICS

VIRGINIA STATE COLLEGE

PETERSBURG, VIRGINIA

SUPPORTED BY NASA GRANT NGR 47-014-006



SEMI-ANNUAL REPORT

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CAREY E. STRONACH

PROJECT DIRECTOR

FEBRUARY 28, 1973

RESEARCH PROGRAM IN NUCLEAR AND SOLID STATE PHYSICS

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The first six months of this research project have been most successful and the prospects for the remaining half year are quite good.

This program began on September 1, 1972, but the research projects were actually started the previous academic year while the project director was a National Science Foundation Science Faculty Fellow at the College of William and Mary, and on leave from Virginia State College.

His research advisor, William J. Kossler, and co-workers Herbert O. Funsten, Neil Heiman, and Mary Grayson Foy are working on these projects although, of course, they receive no financial support from NGR 47-014-006. This collaboration between Virginia State and William and Mary is working very well, enabling the combined research group to do far more than either could alone.

The services of two V.S.C. physics students were obtained at the beginning of the fall semester and they have continued to work most successfully. They are Leroy S. Jackson, a senior physics major from Beaufort, South Carolina, and James M.C. Lin, a graduate student from Taipei, Taiwan, The Republic of China. Lin plans to write his master's thesis on one of the problems being studied under this program, and will fill the full-time assistantship position funded by the grant this summer.

PION - NUCLEUS INTERACTIONS

This project studies the spectra of prompt gamma rays emitted following nuclear pion absorption. Examination of the spectra shows which states of which daughter nuclei are excited and the branching ratios for these states. Measurement of the Doppler broadening, if any, of the spectral lines gives the recoil momentum distribution of the particular daughter nuclei.

The 600 mev. synchrocyclotron at the Space-Radiation Effects Laboratory in Newport News, Virginia serves as the source of pions. An absorption event is recorded by the passage of a pion through three scintillation paddles in front of the target with no subsequent signal in the fourth paddle behind the target (see figure 1). This is called a 1234. Gamma rays are detected by a Ge(Li) detector placed adjacent to the target just outside the beam path. The Ge(Li) and its auxiliary equipment are shown in figure 2, the apparatus being assembled in figure 3, and the assembled apparatus in figure 4.

The electronic processing equipment is shown in figure 5, and a schematic is given in figure 6. The requisite AND signals from the coincidence of pulses 1, 2, and 3, and the anticoincidence of 4 produce the 1234 pulses which feed into the start input of a time-to-amplitude converter (TAC). The stop input to this TAC consists of pulses from the Ge(Li) which have been amplified, shaped, and put into standard logic form by a timing filter amplifier (TFA) and a constant fraction discriminator (CFD). (The CFD was purchased through this grant and has brought about a spectacular improvement in the timing resolution of this experiment.) The output from the TAC is analyzed by a multichannel analyzer and two regions are selected by two timing single channel analyzers

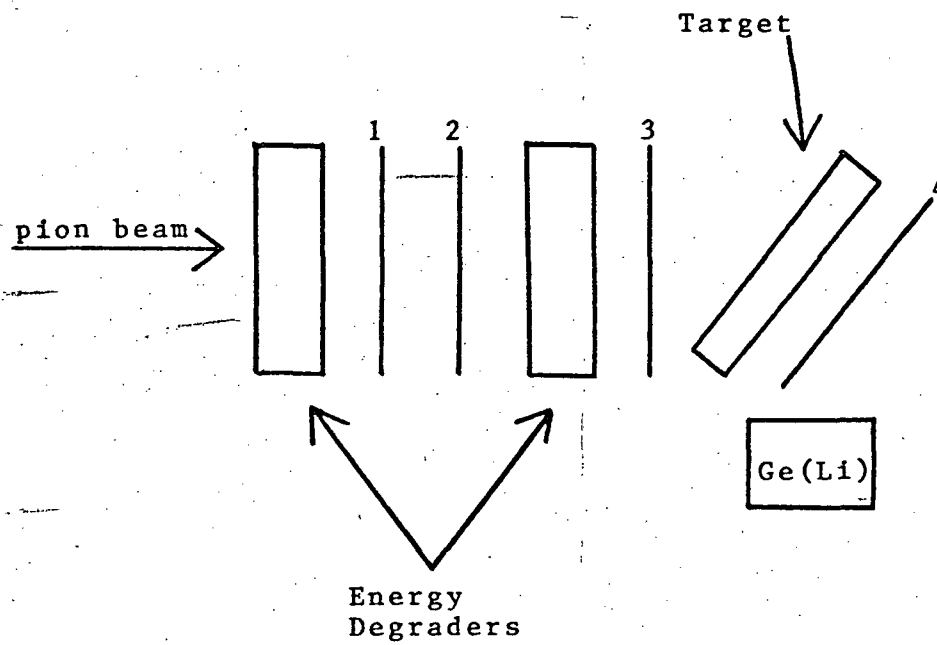


FIGURE 1. Schematic of Pion Absorption Apparatus

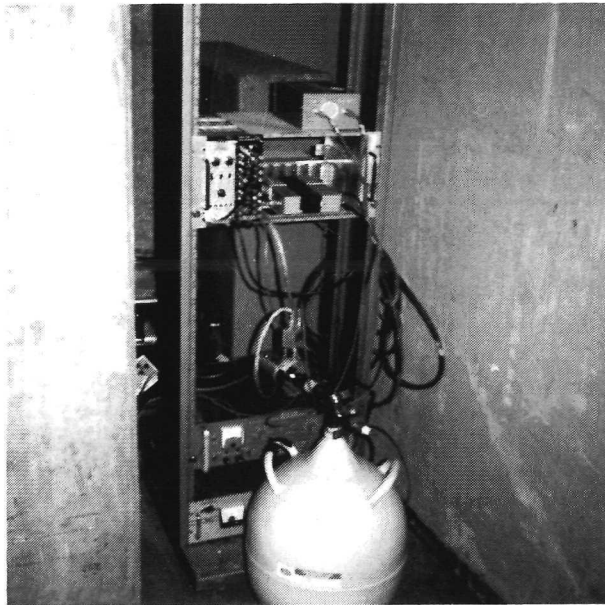


FIGURE 2. Ge(Li) Detector and its Auxiliary Apparatus

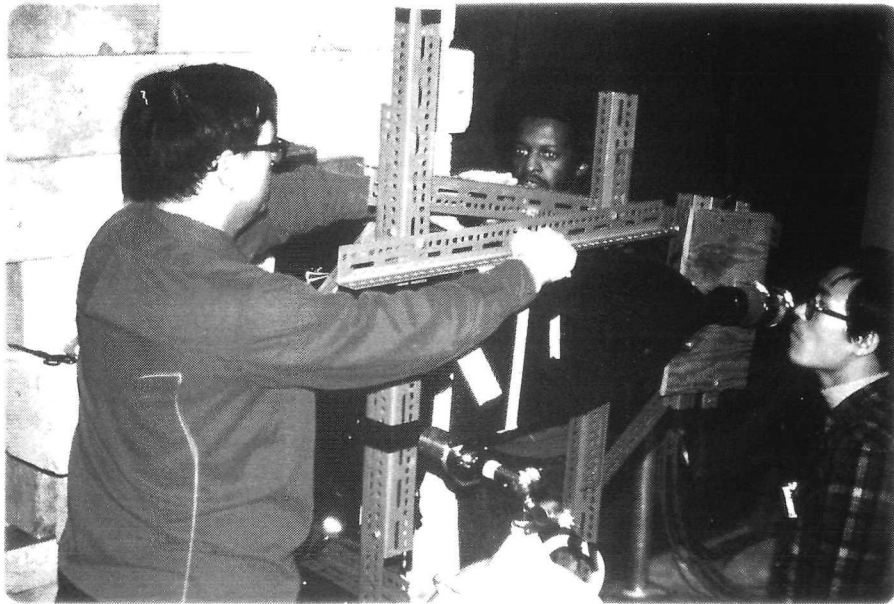


FIGURE 3. Pion Absorption Experiment Being Assembled

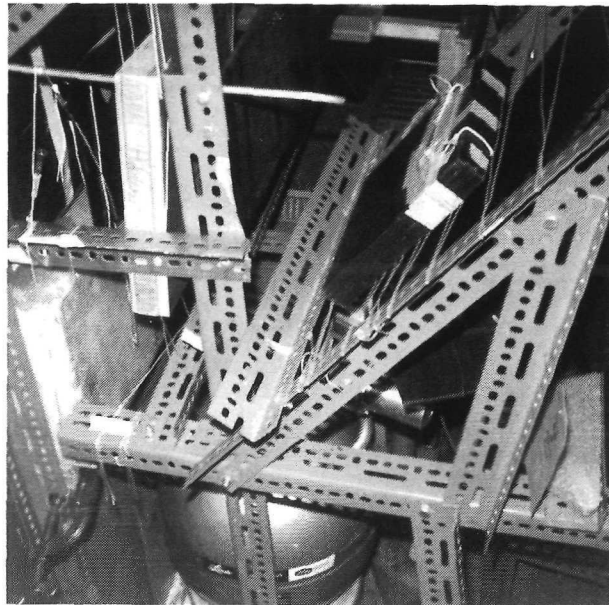


FIGURE 4. Pion Absorption Experiment Apparatus

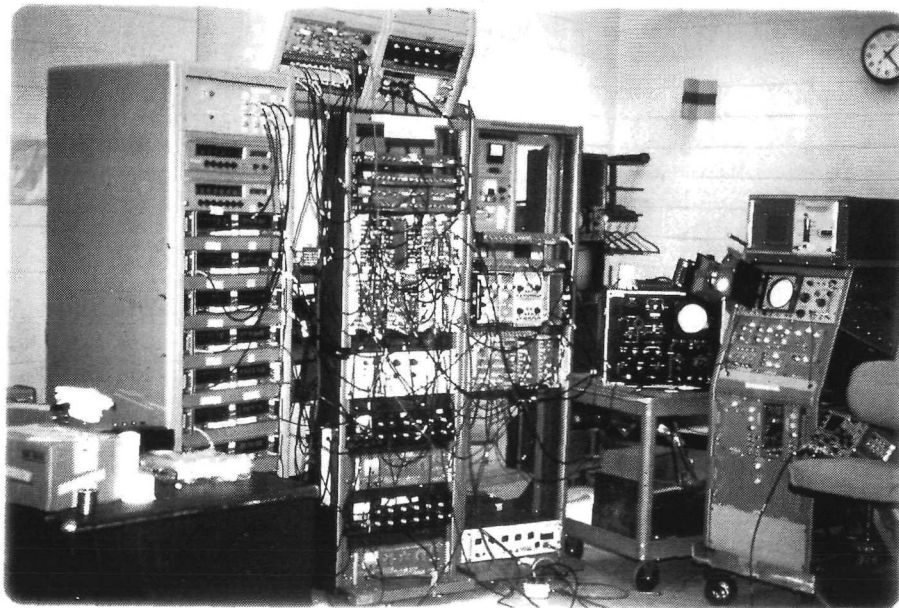
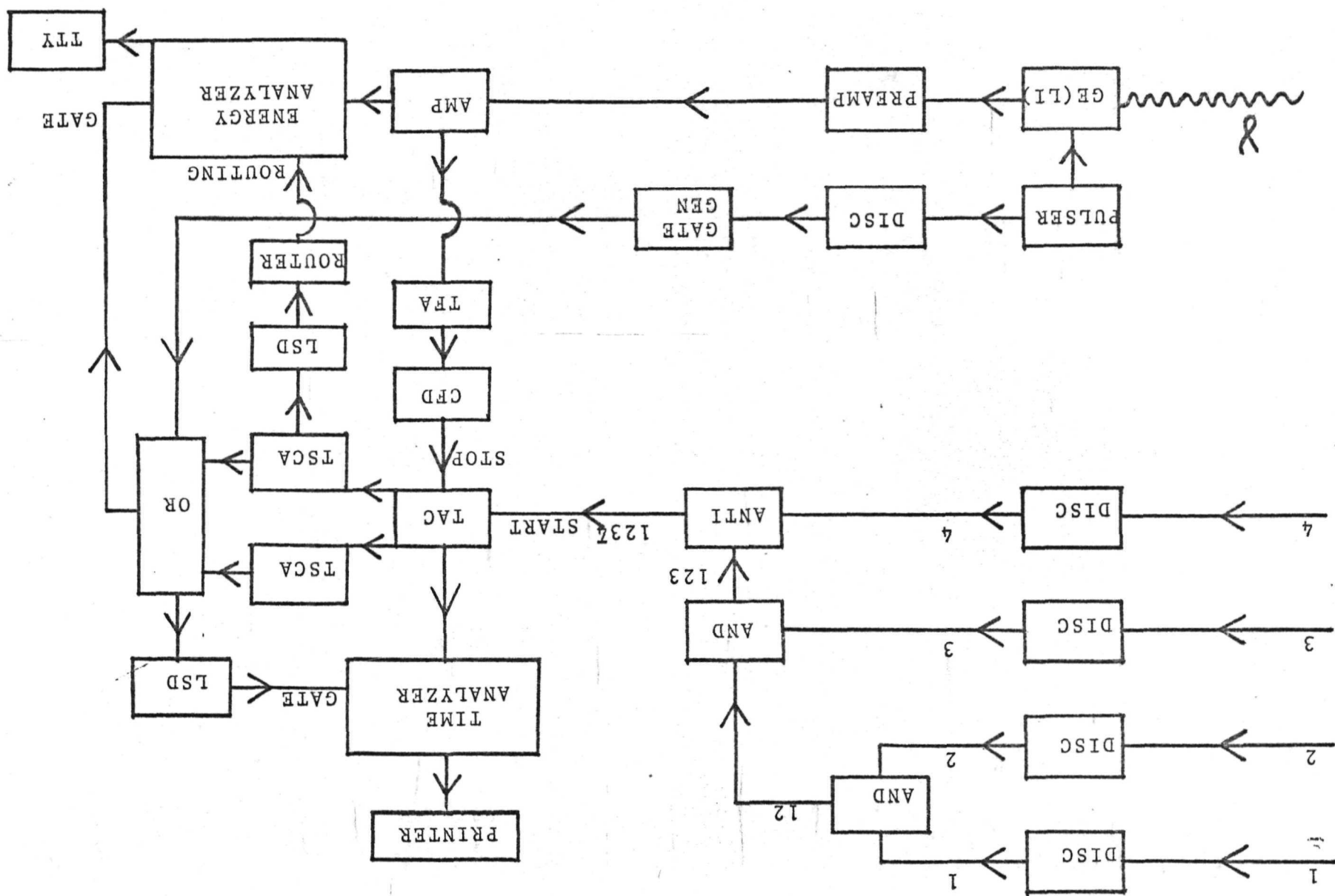


FIGURE 5. Electronics for Pion Absorption Experiment

FIGURE 6. Schematic of Pion Absorption Electronics



(TSCA's). These regions are called on-time and off-time and refer, respectively, to the time period when the largest number of gamma rays are detected and to a period before that (see figure 7). Signals referring to the on-time and off-time regions are used to route the respective energy signals from the Ge(Li) into the two halves of the energy multichannel analyzer (2048 channels to each). These spectra are accumulated and printed out on a teletype (TTY). A pulser signal is introduced into the system at the Ge(Li) for digital stabilization of the gain.

At the inception of this grant the project director was in the midst of an experiment studying negative pion absorption on ^{12}C . Analysis to date shows that the 717 kev ($J^{\text{PT}}=1^+,0$) and 2154 kev ($J^{\text{PT}}=1^+,0$) states of ^{10}B were excited, but the 1740 kev ($J^{\text{PT}}=0^+,1$) state of ^{10}B was not. No lines corresponding to nuclei other than ^{10}B were observed. Analysis and interpretation of these data are continuing.

An experiment studying negative pion absorption on ^{32}S was conducted in October, 1972. The results are summarized in Appendix I. Further analysis and interpretation are in process and will be discussed in a talk to be given at the Washington, D.C. meeting of the American Physical Society in April, 1973.

Negative pion absorption on ^{14}N was studied in an experiment conducted in January, 1973. The target was lithium amide (LiNH_2) powder purchased through this grant. The results of this experiment are described in Appendix I also, and will be discussed in the talk at the Washington APS meeting.

Positive pion absorption on ^{16}O was studied in a run conducted in February, 1973. The extremely low count rate for positive pions

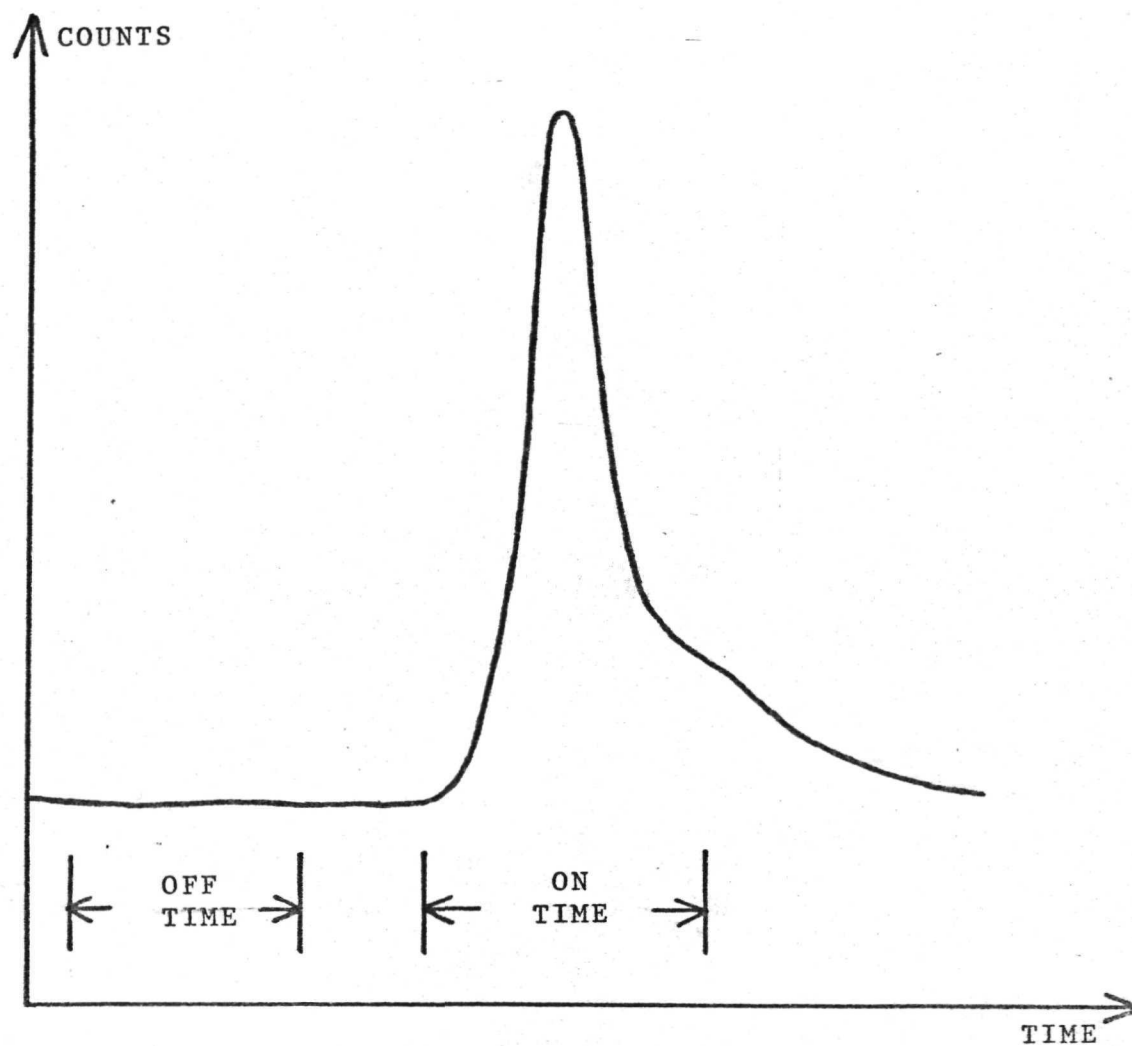


FIGURE 7. Typical Timing Spectrum from Pion Absorption Experiments

from the parasite channel at SREL caused the resulting data to have such poor statistics that it is worthless in terms of nuclear physics analysis. However, it definitely proved the feasibility of positive pion absorption experiments, and the group will definitely perform such experiments in the future at the Nevis synchrocyclotron or the Los Alamos Meson Physics Facility (LAMPF), where positive pion fluxes are many orders of magnitude larger than at SREL.

A negative pion absorption experiment, probably on ^{40}Ca , is tentatively set for late March at SREL, and a run at LAMPF is possible this summer.

MUON PRECESSION IN SOLIDS

This project utilizes the unique properties of muons to study the magnetic properties of solids. As a result of the innate helicity of neutrinos, muons created by the decay of pions likewise have unique helicity in their own rest frames. By proper choice of bending magnet currents backward decay positive muons can be channeled into our apparatus (see figure 8) at SREL. As in the pion experiment a logical $123\bar{4}$ signal indicates the stopping of a muon in the target, the target being in a uniform magnetic field produced by either a Helmholtz coil or an iron core electromagnet. A heating coil which serves to vary its temperature surrounds the target and this system is wrapped in asbestos insulation. The nickel target is shown in figure 9, and the assembly of the insulation layer is displayed in figure 10. Figures 11 through 15 show various views of the complete apparatus.

The $123\bar{4}$ signals go to the start input of a TAC (see figure 16) and signals from a fifth paddle (or, alternatively, paddle 4) go to

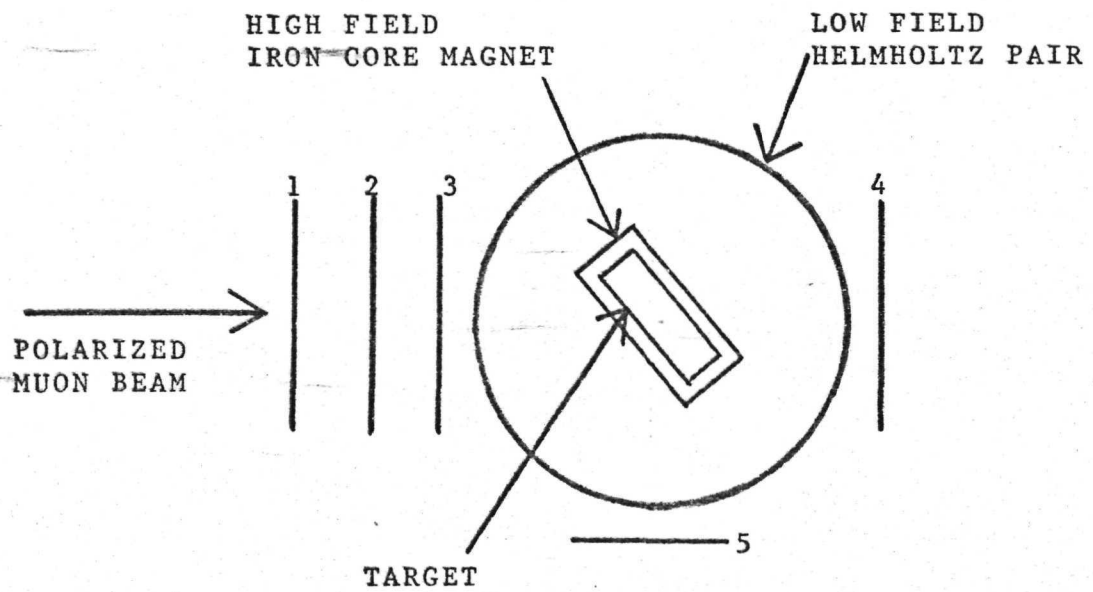


FIGURE 8. Schematic of Muon Precession Apparatus

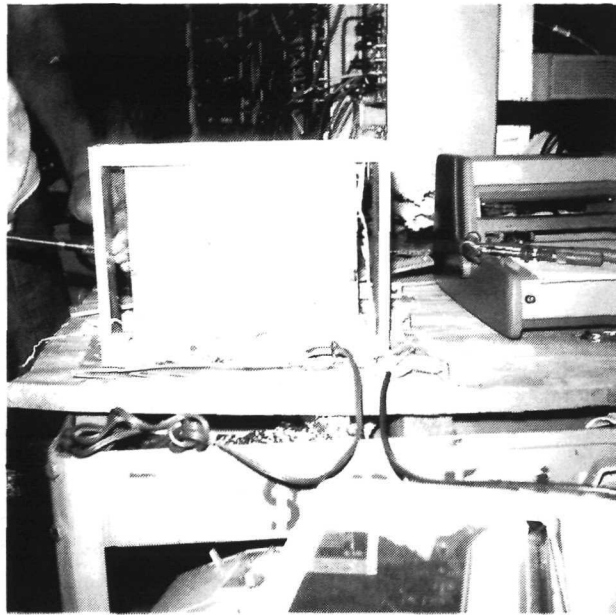


FIGURE 9. The Nickel Target. Note Heating Coil.



FIGURE 10. Assembly of Insulation to Target

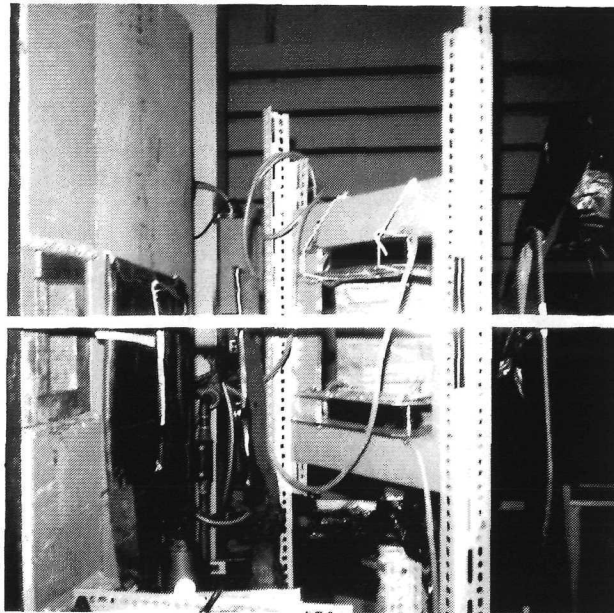


FIGURE 11A. Side View of Muon Precession Apparatus

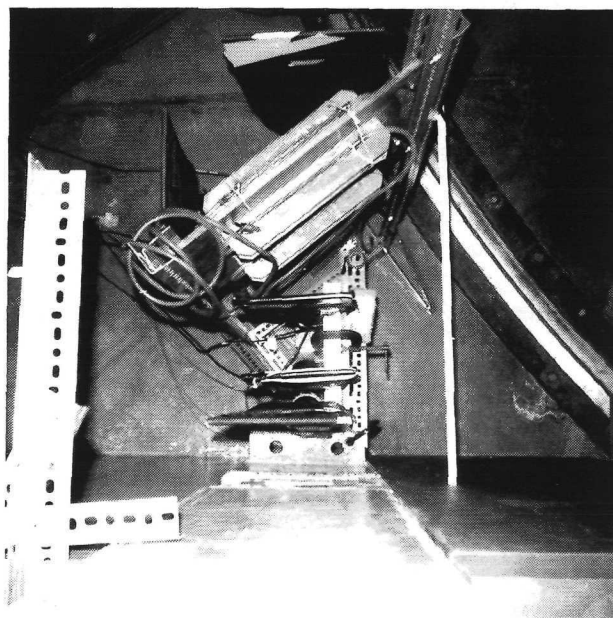


FIGURE 11B. Top View of Muon Precession Apparatus

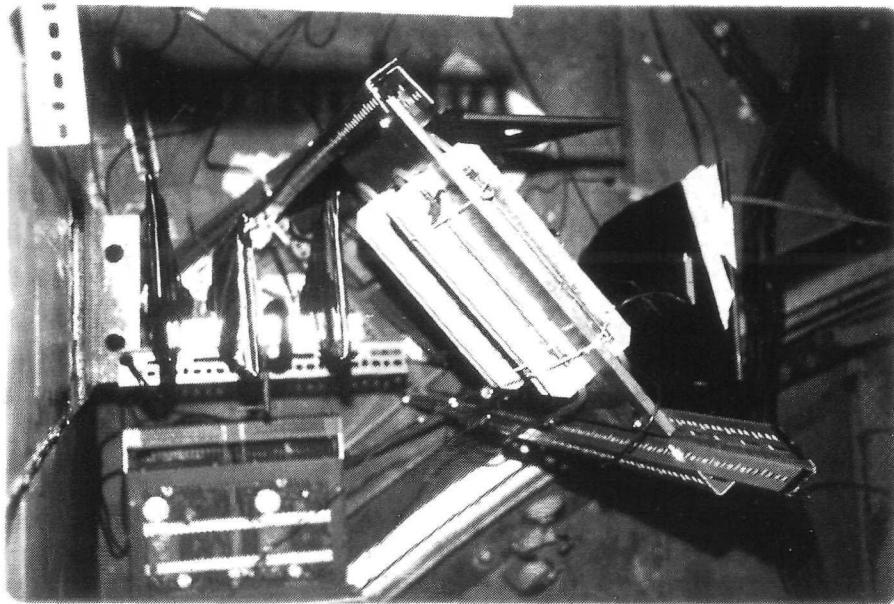


FIGURE 12. Top View of Muon Precession Apparatus

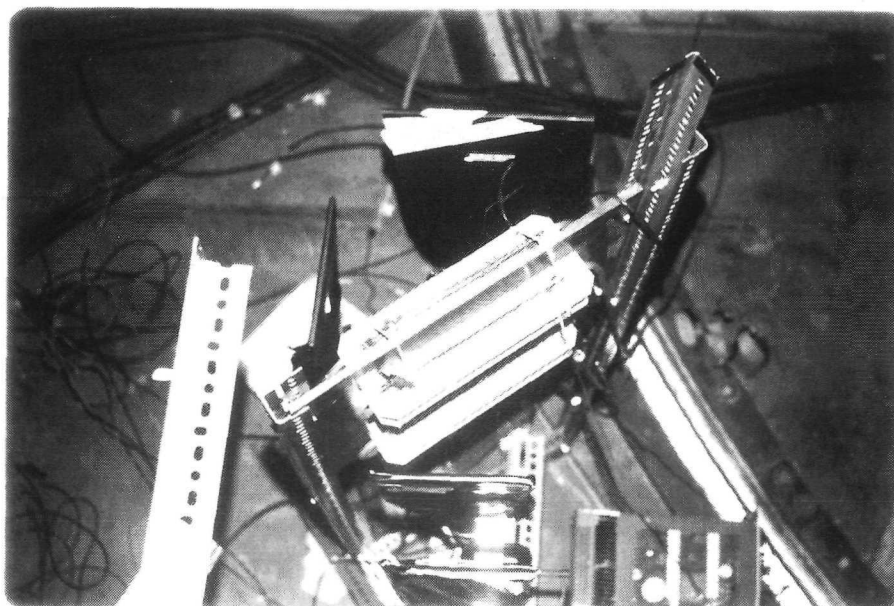


FIGURE 13. Top View of Muon Precession Apparatus

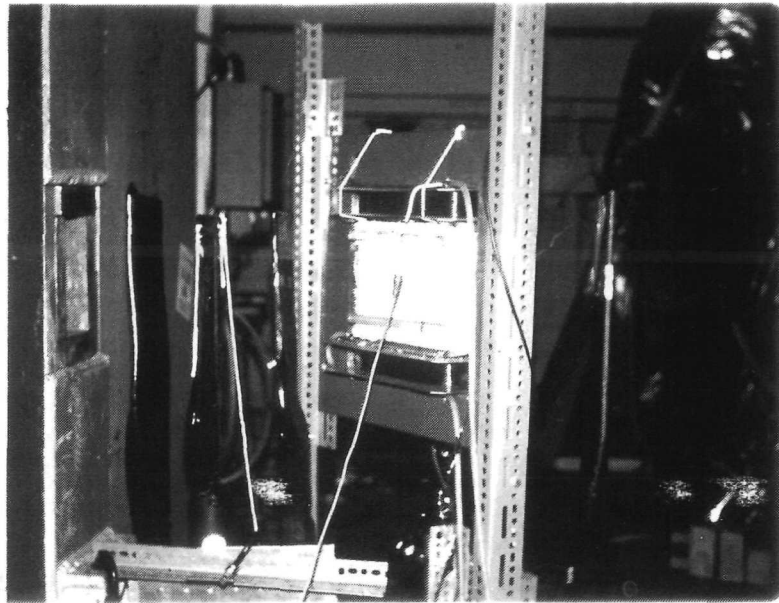


FIGURE 14. Side View of Muon Precession Apparatus

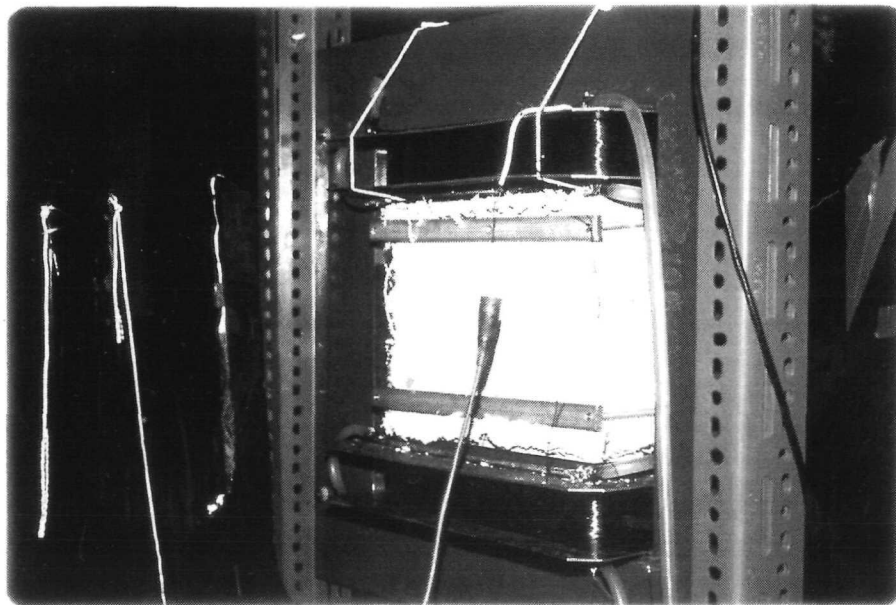


FIGURE 15. Closeup of Target and Iron Core Magnet

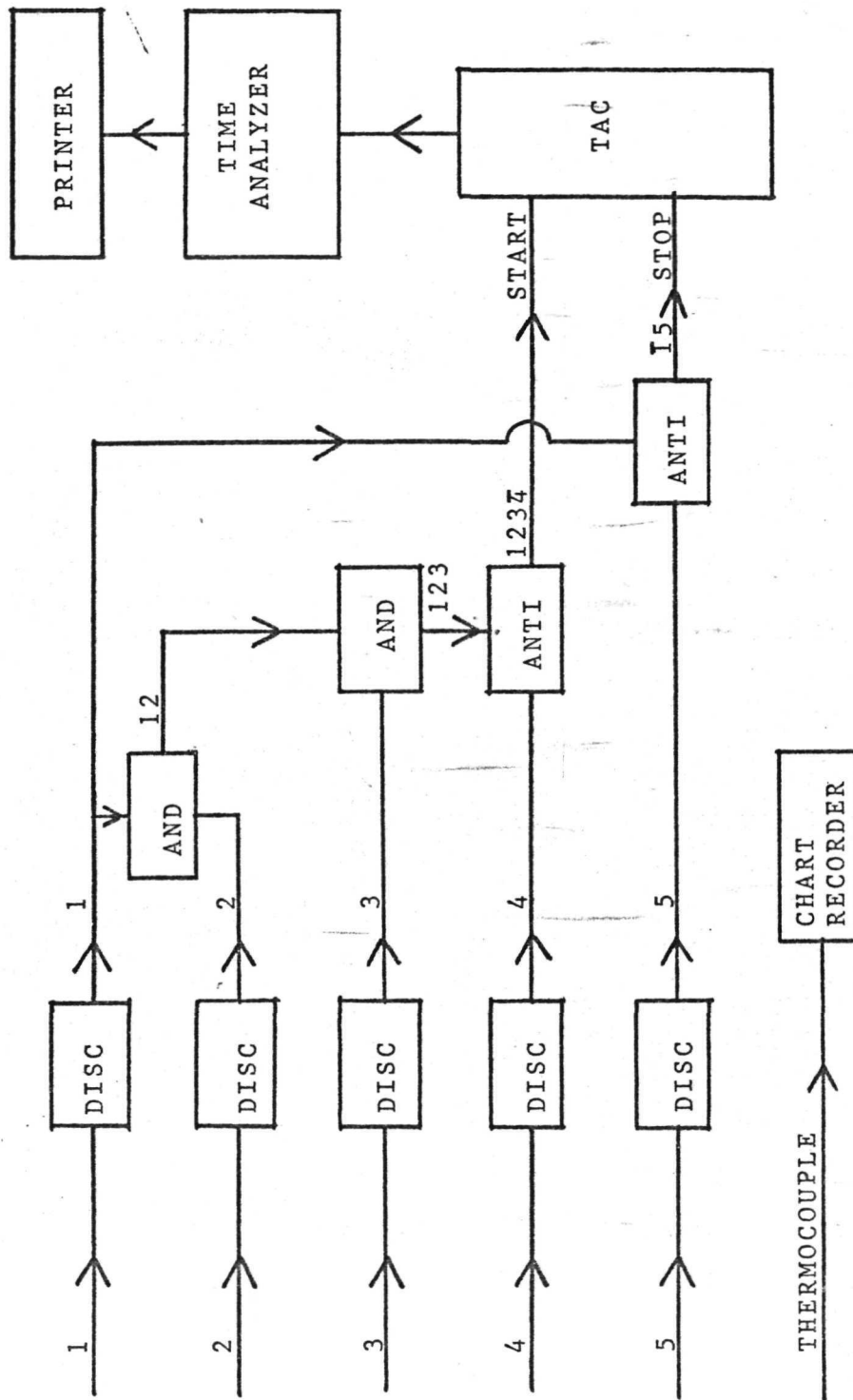


FIGURE 16. Schematic of Muon Precession Electronics

the stop input. This fifth paddle serves to detect positrons from positive muon decays and the time spectrum from the TAC is analyzed by a multichannel analyzer. Figure 17 shows the project director adjusting this analyzer.

Two experiments of this type were performed in late 1972, one in late September and early October, the other in late November and early December. The results of these experiments are given briefly in Appendix II, and in more detail in Appendix III, the latter being a preprint of an article submitted to Physical Review Letters.

The next muon precession experiment is planned for late April and early May at SREL. Further experiments on this problem will probably be run during the next academic year, most likely at the Nevis synchrocyclotron operated by Columbia University at Irvington-on-Hudson, New York.

The results of the muon precession experiments performed upon ferromagnetic metals indicate that this technique may be most useful in studying the structure of alloys and in the effect of implanted ions upon metallic structures. For instance, suppose that muon precession analyses are performed upon a metal crystal both before and after hydrogen ion implantation. The comparison could shed some light upon problems relevant to materials to be used in aircraft and spacecraft construction, as well as terrestrial and sub-terrestrial applications.

PAPERS AND TALKS

Appendices I and II are abstracts of talks given or to be given at meetings of the American Physical Society. Appendix III is a preprint of a paper submitted to Physical Review Letters. A paper on



FIGURE 17. Project Director Adjusting Timing Analyzer

pion absorption experiments will probably be submitted to the Physical Review this summer. The project director has given a talk on these projects to the faculty of the School of Science and Technology at Virginia State College and has been invited to give a similar talk to the college Sigma Xi chapter. Student workers Jackson and Lin will, respectively, give talks on the pion and muon experiments at the Zone Four meeting of Sigma Pi Sigma to be held at VSC on April 6, and at the annual meeting of the Beta Kappa Chi national honorary science fraternity in Philadelphia on April 13.

Newspaper articles on this project have appeared in the Petersburg Progress-Index, the Norfolk Journal and Guide, and the Beaufort Gazette (see Appendices IV and V).

FUTURE PROSPECTS

Decisions already made indicate a very busy and, hopefully, productive coming six months. The pion runs at SREL in March and LAMPF this summer, plus the muon run at SREL in April and May will keep us busy producing and analyzing data. In addition, further analysis and interpretation is necessary for much of the data already accumulated. We plan to write an article for the Physical Review on the results of our pion experiments.

Beyond the next six months lie both problems and opportunities. The chief problem is the expected closing of SREL on June 30, 1973. The chief opportunity is the opening of new facilities, especially Nevis and LAMPF, in the very near future. The particle fluxes to be produced by these machines will multiply those from SREL by factors from 30 to 100, depending upon the beam mode being utilized. These new machines will multiply the quantity of data we can take

per given time interval by approximately these factors. They will also allow us to increase the level of sophistication of these experiments by tightening logical requirements upon our data.

The closing of SREL will, of course, mean the closing of the SREL instrument pool. Dr. James C. Davenport, VSC physics department chairman, has written the director of SREL requesting a grant or loan of any relevant surplus equipment from the pool.

One problem which has delayed us these past six months is the slow and obsolete method of data retrieval we have had to use. Data from the multichannel analyzers has been printed on a teletype and this has been hand punched on IBM cards for analysis. Each such printout requires about an hour taken from running time plus two man-days of work to punch it onto cards. The multiplication of data accumulation arising from running at Nevis and LAMPF next year will make the present method impossible. A system of data storage on and retrieval from magnetic tape controlled by a minicomputer will become a necessity.

Because of these developments the equipment request in our renewal proposal will be many times larger than that requested for the current year. However, it will be a one-time request and will permit us to perform high quality research in these areas for many years to come.

In closing I would like to express my appreciation to NASA for funding this program. It has been a wonderful opportunity and challenge for me and my students, and is, I believe, producing worthwhile new knowledge of the structure of matter in two diverse areas.

Respectfully submitted,

Carey E. Stronach

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Assistant Professor of Physics

Project Director

February 28, 1973

Abstract Submitted

For the Washington, D.C. Meeting of
The American Physical Society

23-26 April 1973

Physical Review
Analytic Subject Index
Number 53.4

Bulletin Subject Heading in
which Paper should be placed
Medium Energy Nuclear Reactions

Nuclear De-excitation Gamma Rays Following Negative Pion Capture on ^{32}S and ^{14}N .* C.E. STRONACH, Virginia State College, and W.J. KOSSLER and H.O. FUNSTEN, College of William and Mary--Negative pions from the SREL cyclotron were stopped in ^{32}S and LiNH_2 targets. Prompt gamma rays were observed with a Ge(Li) detector, and the spectra were analyzed, the strengths and widths of the nuclear de-excitation lines being measured. States excited in the ^{32}S experiment include the 678, 709, and 1455 keV states of ^{30}P , the 2232 keV state of ^{30}Si , the 1273 and 2032 keV states of ^{29}Si , and the 1779 keV state of ^{28}Si . The ^{14}N experiment excited the 4430 keV state of ^{12}C , which displayed considerable Doppler broadening. The analysis yields the recoil momentum distribution of the ^{12}C , which is approximately the same as that of ^{14}N formed by pion absorption on ^{16}O .¹

* Supported in part by NASA and NSF.

¹ W.J. Kossler, H.O. Funsten, B.A. MacDonald,
and W.F. Lankford, Phys. Rev. C4, 1551 (1971).

Submitted by

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Abstract Submitted
for the 1973 New York Meeting of the
American Physical Society
27 January - 1 February 1973

Physical Review
Analytic Subject Index
Number 49.6

Bulletin Subject Heading
in which Paper should be placed
Magnetism and Magnetic Materials

Precession of Positive Muons in Ferromagnetic Metals. M.L.G. FOY, NEIL HEIMAN, and W.J. KOSSLER, College of William and Mary, and C.E. STRONACH, Virginia State College--Polarized μ^+ were stopped in Fe and Ni. The angular distribution of the decay positrons precessed past detectors. The detection rates were fit to: $N(t) = N_0 e^{-\lambda t} [1 + P e^{-t/\tau} \cos(\omega t + \phi)] + B_{\text{gnd}}$. P is a measure of the polarization of the stopped μ^+ at the start of timing, τ is the depolarization time, and ω , the precession rate, is a measure of the field (B_μ) at the μ^+ site. In paramagnetic Ni ($T > \text{Curie Temperature } T_c$), we found $P = P_c$ (P_c is the polarization of μ^+ stopped in carbon for calibration), $B_\mu = B_{\text{ext}} = 50\text{G}$, and $\tau = 4\mu\text{sec}$. In ferromagnetic Ni ($T < T_c$), the parameters were measured as a function of T and B_{ext} ; e.g. at $T = 300^\circ\text{C}$ and $B_{\text{ext}} = 1100\text{G}$, $B_\mu = 620\text{G}$, $P/P_c = 1/3$, and $\tau = 1/4\mu\text{sec}$. Varying B_{ext} from 600G to 2200G did not strongly affect B_μ . The T dependence of B_μ can be approximated by a Brillouin function with a 1700G saturation field and $T_c = 610^\circ\text{K}$. P/P_c increased to 1/2 as T_c was approached and also increased with B_{ext} . τ remained constant at $1/4\mu\text{sec}$ from 190°C to 300°C but fell as T_c was approached. All oscillations seem to disappear below about 200°C , possibly associated with the change of easy axis of magnetization. For Fe at 270°C , we found $P/P_c = 0.1$, $B_\mu = 3510\text{G}$ and $\tau = 1/2\mu\text{sec}$.

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Precession of Positive Muons in Nickel and Iron

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Polarized μ^+ were stopped in Ni and Fe. The magnetic fields at the site of the muons, the initial polarization, and the depolarization time constant were obtained from 300°K to 700°K, i.e. through the Curie temperature of Ni. This experiment demonstrated that precession of muons stopped in ferromagnetic material can be observed and determined what the magnitude of the internal fields are: ~ 1500 G for Ni and 4000 G for Fe.

We implanted polarized positive muons in nickel and iron. The magnetic fields at the sites of the muons (B_μ) were measured by observing the precession of the angular distribution of the decay positrons. The same data yielded the initial polarization (P) of the stopped muons and the time constant (τ) of the slow depolarization. Data were collected as a function of temperature from room temperature to 700°K so that we observed the shift from the ferromagnetic to the paramagnetic state in nickel. This experiment demonstrated for the first time that the precession of muons stopped in ferromagnetic material can be observed and determined what the magnitude and direction of the internal fields are.

That the muon can be a fundamentally important tool for condensed matter physics has recently begun to be recognized.⁽¹⁾ The work of Schenck, Crowe, and collaborators^(2,3) has shown that the implanted positive muon behaves very much like a hydrogen nucleus, and that muon studies can provide information about lattice structure and chemical reactions. The present letter provides new evidence of the usefulness of implanted muons for the study of metals and hyperfine fields. The behavior of hydrogen in metals is of intrinsic interest as one of the simplest alloy problems.⁽⁴⁾ It is also a problem of considerable technological importance.⁽⁵⁾ The behavior of the hydrogen like positive muons in ferromagnetic metals is of additional interest because of the interactions with the magnetic medium. Implanted muons cause minimal radiation damage, occur in infinitesimal concentration, leave no residual contamination, have no nuclear or quadrupole interactions, and do not possess a complicated ion core. Consequently the use of implanted muons can not only yield fundamental solid state information, but also contribute to the understanding of radioactive ion implantation⁽⁶⁾, particularly in the case of

ferromagnetic targets. (7)

The positive muon is also an excellent probe from the standpoint of experimental simplicity. High count rates are available with polarization approaching 100%. The muon mean life (2.2 μ sec) is long enough for easy timing and short enough for high count rates. The decay positrons are easily detected and the angular distributions of these positrons is highly anisotropic. The muon's magnetic moment has been determined to a few parts per million allowing high precision measurement of B_{μ} .

We implanted positive muons from the Space Radiation Effects Laboratory synchrocyclotron in targets of nickel and iron. The targets could be heated and the temperature monitored. The external magnetic field for ferromagnetic targets was supplied by an iron core electromagnet. A large Helmholtz pair supplied the field for paramagnetic measurements.

Scintillators 1, 2, 3 were in front of the sample, 4 behind and 5 at 90° . A stopped muon signal, defined as a 1234, was used to start a time to amplitude converter (TAC). A decay positron detection signal (either a 41 or a 51) stopped the TAC. The output of the TAC was fed to a pulse height analyzer to obtain a plot of count rate vs time.

Fig. 1 provides examples of data for paramagnetic nickel (at 670°K) and ferromagnetic nickel (at 551°K). Note that the time scales differ by about a factor of 10. The data were fit to the function:

$$N(t) = N_0 \exp(-\lambda t) [1 + Pa \exp(-t/\tau) \cos(\omega t + \phi)] + B_{\text{gnd}}$$

where N_0 is for normalization, λ is the muon decay rate, P is a measure of the initial polarization, a is the positron anisotropy, τ is the depolarization time constant, ω is the angular precession frequency, ϕ is the initial phase angle, and B_{gnd} is the background. The solid lines in Fig. 1

are the fitted function.

Paramagnetic nickel results: In this region $B_\mu \sim B_{\text{external}}$, the externally applied field. The paramagnetic Knight shift was small and significant variation of B_μ with temperature was not detected. The initial polarization P was equal to $0.8 P_c$, where P_c was the initial polarization observed in a carbon target of similar dimensions. Muons stopped in carbon are known to retain virtually 100% of their polarization.⁽⁸⁾ Therefore carbon is useful for calibration. The depolarization time constant τ was 4 μsec . The parameters B_μ , P , and τ did not vary significantly over the temperature range: 630°K to 705°K , ($T_c \sim 630^\circ\text{K}$). There was no evidence of muonium formation.

Ferromagnetic nickel results: In this region we were able to fit B_μ to a Brillouin function, see Fig. 2, with a saturation field of 1550 G. The circular data points were taken with a current of 1.5 A in the electromagnet. This corresponded to a field in the gap between the magnet and target of 1100 G at room temperature. Increasing the field to 2200 G or lowering the field to 500 G or even to zero had little effect on B_μ . In the runs with nickel below 385°K and in an external field of about 1100 G, we were not able to detect the precession of the angular distribution. On increasing the magnetic field to approximately 2200 G, we were able to observe the precession. The square data point in Fig. 2 was obtained at 2200 G. The internal field is in the same direction as the external field. This was determined by noting the relative phase of the data from the 4 and 5 detectors and also by noting that the initial phase for each detector was maintained during the transition from paramagnetic to ferromagnetic behavior.

Fig. 3 shows the behavior of P and τ . P/P_c is seen to increase

from about 20% at room temperature to near 40% as T_c is approached. We believe this is due to domain alignment. The solid line is a measure of domain alignment extracted by dividing the measured permeability by the magnetization and normalizing to P. We were unable to saturate the sample, but increasing the magnet current from 1.5 A to 3.0 A increased P only slightly, indicating that the initial polarization even at saturation may be less in ferromagnetic than in paramagnetic nickel.

τ was on the order of 0.25 μ sec and appeared to increase slightly with increasing temperature and to drop sharply as T_c was approached. The dashed line in Fig. 3 is intended only to illustrate this trend. Varying B_μ by changing temperature or varying the external field seemed to have little effect on τ , implying that the depolarization was not arising from field inhomogeneity.

Ferromagnetic iron results: In the temperature range from room temperature to 675°K, B_μ was observed to decrease from approximately 4100 G to 3700 G. P/P_c was about 10% and τ was on the order of 0.5 μ sec. It is interesting that the ratio of the field in Fe to that in Ni is not much different from the ratio of the magnetizations.

There is evidence that hydrogen atoms are implanted in the octahedral or body centered site in nickel.⁽⁹⁾ It is reasonable to assume that the muon stops in the same site although it may not be as well localized due to its smaller mass. It is interesting to compare B_μ for ferromagnetic nickel, 1550 G, to a number of possible contributions. Because of the site symmetry, the classical dipolar field due to the nickel ions is zero. Further due to sample geometry, the demagnetizing field is negligible. The hyperfine field at the muon in free muonium is on the order of 300,000 G. The Lorentz field $4\pi M/3$ for nickel is about 2800 G, nearly

double B_μ . The contributions to B_μ from core polarization and conduction electron polarization cannot be estimated using conventional techniques (10,11) because the muon does not possess a core in the usual sense and its interstitial location makes extrapolation of conduction electron polarization from previously existing data questionable. Nevertheless the major contribution to the internal field should arise from the Fermi contact interaction with the conduction electrons, provided the muon exists as a nonmagnetic impurity. Except for unusual circumstances hydrogen-like impurities in metals should be nonmagnetic and in fact the present result that B_μ follows the host magnetization confirms the non-magnetic character of the implanted muon. (12,13) Under these conditions, one can approximate the conduction electron contribution to B_μ by (14)

$$B_\mu^{CE} \approx (16\pi/3)\mu_B \delta\rho(0)$$

where $\delta\rho(0)$ is the net spin density at the muon. If we neglect other contributions, the observed B_μ of 1550 G implies a net spin density of approximately 0.5% of that of the free muon. If we include the Lorentz field, the spin density is of the same order but of opposite sign. The smallness of this number may well reflect a cancellation between the s and d contributions to $\delta\rho(0)$ at the interstitial site. In fact Friedel (4) shows that the electronic density attracted to an interstitial hydrogen nucleus is roughly similar to that of a hydrogen atom in vacuum, and he shows further that the screening in transition metal hosts is primarily by d electrons, although the s electron contribution is not negligible. It seems clear that the problem of calculating the field at the muon site lacks many of the obscuring complications associated with other implanted impurities and therefore provides a sensitive and intrinsically interesting test for the theory of internal fields.

The present experiment was performed with a parasite beam, necessitating large targets (20 x 20 x 1 cm). The experiment will be continued shortly using the prime muon beam. The improved beam will allow us to use much smaller targets. We can then obtain much more intense and homogeneous magnetic fields and a more uniform sample temperature. Such circumstances will permit more accurate measurements near T_c and in the paramagnetic region and will allow us to magnetically saturate our samples. From these improved data we should be able to observe critical behavior near T_c . Improved examination of the temperature dependence of τ should help determine the depolarization mechanism, and accurate measurement of the temperature dependence of the paramagnetic Knight shift should help determine the relative d and s electron contribution to screening charge. Finally by magnetically saturating our targets we can determine the true fast depolarization and examine the apparent shielding of the external field from the muon site.

REFERENCES

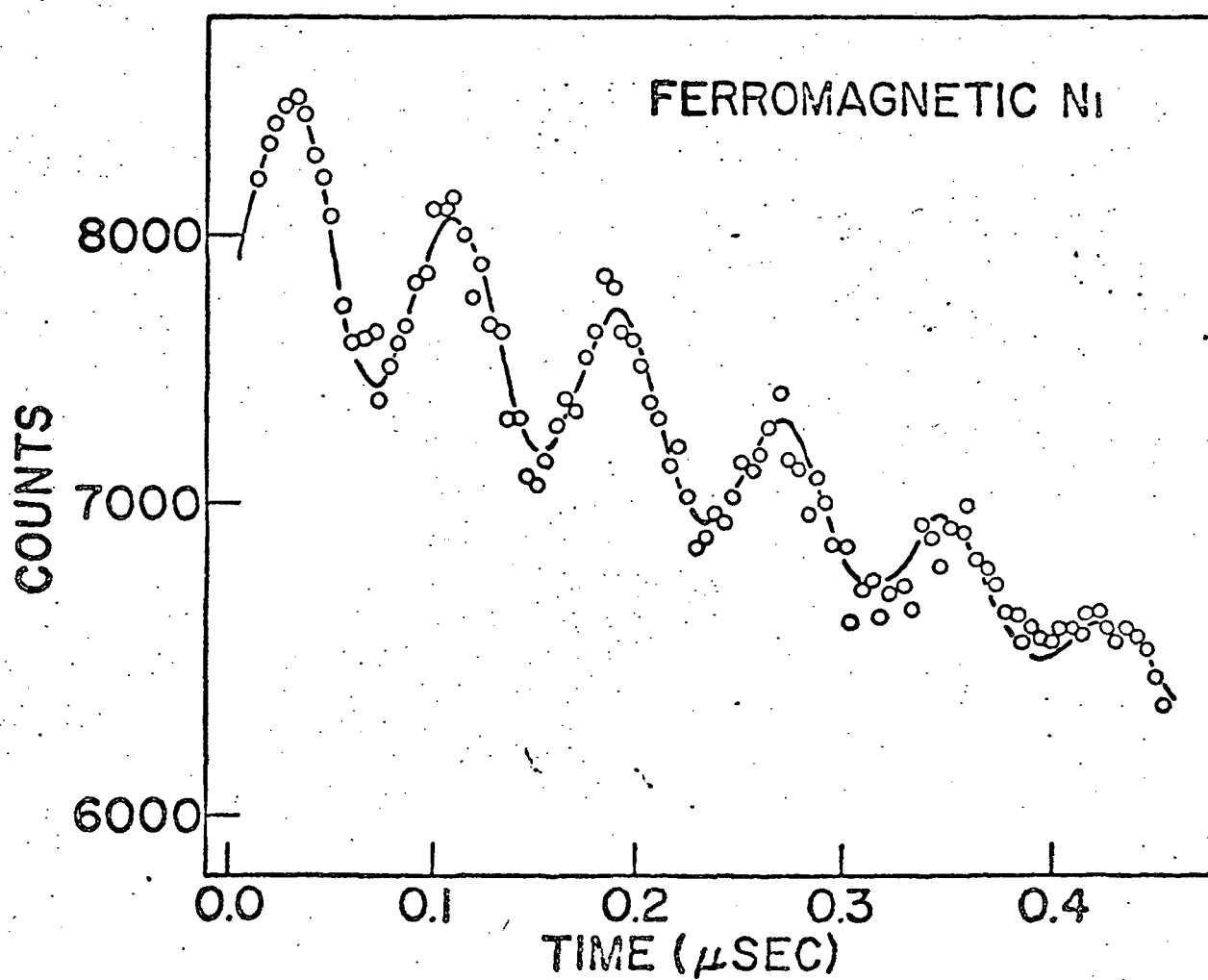
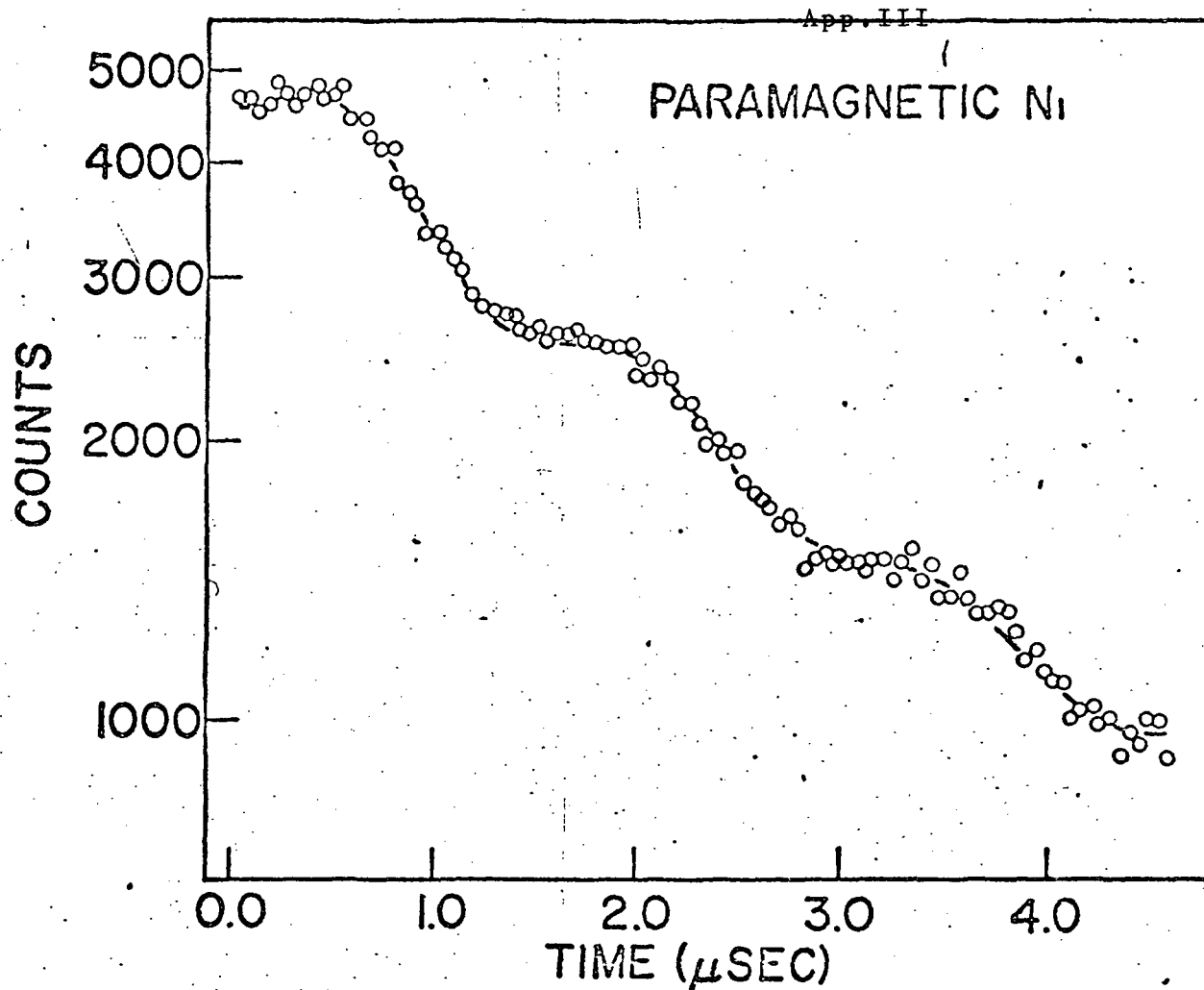
- 1) Meeting on Muons in Solid, Schweizerisches Institut für Nuklearforschung (SIN Zurich (1971).
- 2) A. Schenck and K. M. Crowe Phys. Rev. Letters 26, 57 (1971).
- 3) J. H. Brewer, K. M. Crowe, R. F. Johnson, A. Schenck and R. W. Williams, Phys. Rev. Letters 27, 297 (1971).
- 4) J. Friedel, Berichte der Bunsen-Gesellschaft 76, 828 (1972).
- 5) Proceedings of the International Conference on Hydrogen in Metals, Jülich, (1972).
- 6) Hyperfine Structure and Nuclear Radiations, E. Matthias and D. A. Shirley ed., North Holland Publishing Co., Amsterdam (1968), Chaps. VI and VIII.
- 7) B. Herskind, R. R. Borchers, J. D. Bronson, D. E. Murnick, L. Grodzins, and R. Kalish, in Hyperfine Structure and Nuclear Radiation, E. Matthias and D. A. Shirley ed., North Holland Publishing Co., Amsterdam (1968), p. 735.
- 8) R. A. Swanson, Phys. Rev. 112, 580 (1958).
- 9) Franz Brötzen, private communication.
- 10) R. E. Watson and A. J. Freeman, Phys. Rev. 123, 2027 (1961).
- 11) D. A. Shirley and G. A. Westenbarger, Phys. Rev. 138A, 170 (1964)
- 12) V. Jaccarino, L. R. Walker, and G. K. Wertheim, Phys. Rev. Letters 13, 752 (1964).
- 13) I. A. Campbell, J. Physic C 3 2151 (1970).
- 14) E. Daniel and J. Friedel, J. Phys. Chem. Solids, 24, 1601 (1963).

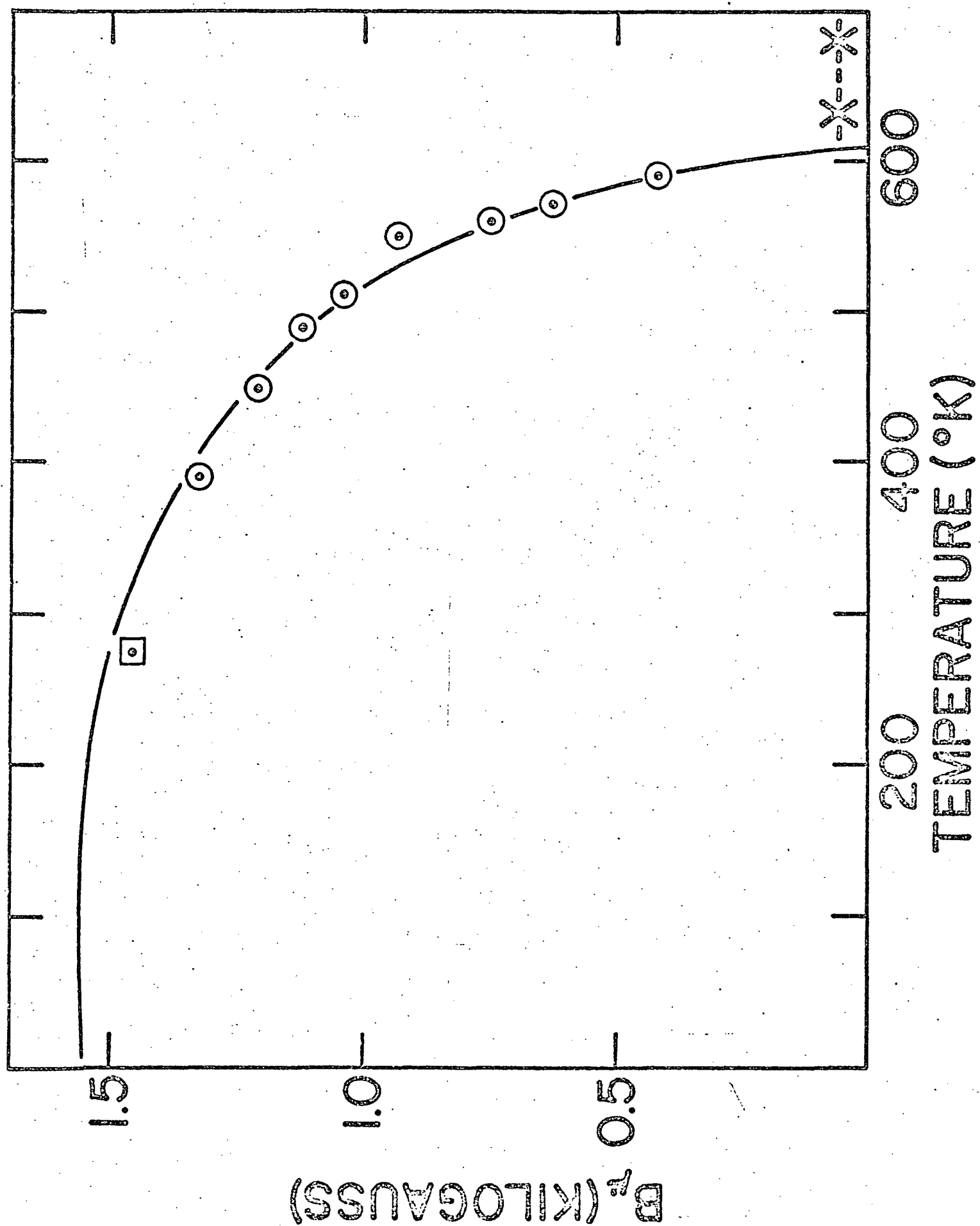
Figure Captions

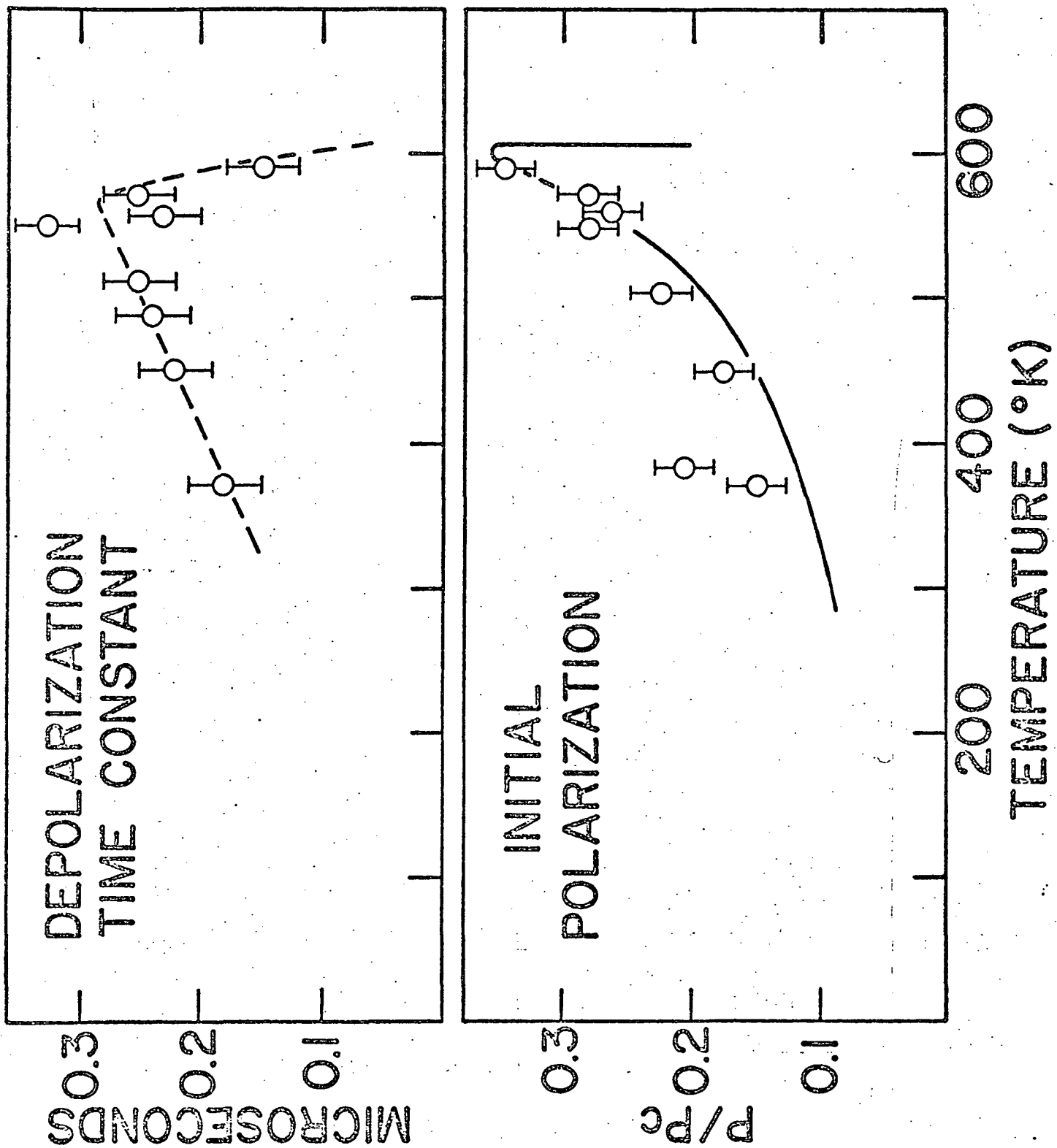
Fig. 1. Data for paramagnetic nickel at about 670°K and ferromagnetic nickel at 551°K. Note that time scales differ by a factor of 10.

Fig. 2. B_{μ} as a function of temperature. Circular data points were obtained with 1.5 amperes in the electromagnet. The square data point was taken at room temperature with 3.0 amperes.

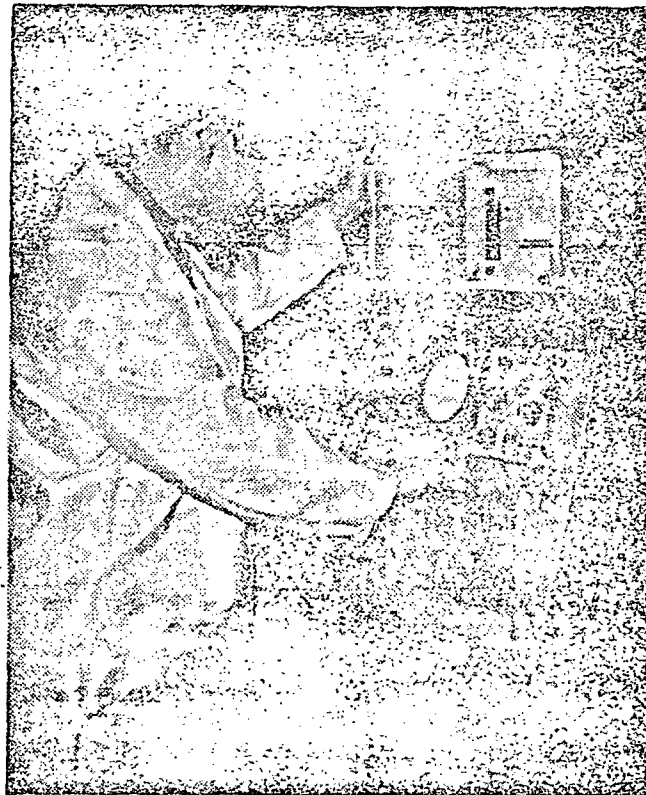
Fig. 3. Initial polarization P and depolarization time constant τ as functions of temperature. The solid line is a measure of domain alignment: the measured sample permeability divided by B_{μ} . The dashed line is only to guide the eye.







14 The Progress-Index, Petersburg, Va., Wednesday, January 3, 1973



VSC Photo

Stronach Adjusts Time Analyzer In NASA Project

VSC Physicists Conduct NASA Research Projects

PETERSBURG — Three physicists at Virginia State College are conducting two research projects at the NASA Space Radiation Effects Laboratory in Newport News.

They are Carey E. Stronach, assistant professor of physics, Leroy Jackson, a senior physics major from Beaufort, S. C. and James M. C. Lin, a graduate student in physics from Taipei, Taiwan, the Republic of China.

Their first project uses muons to probe the magnetic properties of solid crystals in an unusual way. Positrons produced by decay of muons are immediately detected and their emissions plotted as a function of time. An analysis of this time plot tells how fast the muons were rotating and how the crystals magnetized.

The other experiment uses

pions which are absorbed by nuclei. The gamma rays emitted in the ensuing nuclear reactions are analyzed to give out information about nuclear structure.

The first experiment has already produced new knowledge of the magnetic structure of nickel. Both projects were performed at NASA on a 600-million volt synchrocyclotron which produces beams of pions and muons. The two research projects are being supported by a financial grant from NASA awarded to the physics department at Virginia State College.

Stronach and three other physicists from the College of William and Mary will present the findings on the first research project to the American Physical Society, meeting in their annual session in New York City later this month.

JOURNAL AND GUIDE

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Nickel Target Precision Experiment

Leroy Jackson (left), from Beaufort, S. C. and James M. C. Lin, from Taipei, Taiwan, the Republic of China, both students at Virginia State College, prepare the nickel target for a muon precision experiment as part of a research project.

The project is being conducted by them under the supervision of their VSC physics professor, Carey E. Stronach, at the NASA Space Radiation Effects Laboratory in Newport News, Va. (VSC Photo by Stronach)