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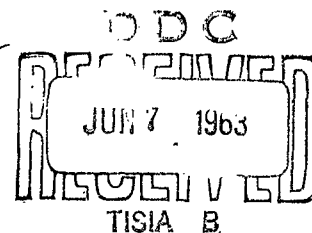
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Final Report on Contract N6/onr-25116 to Office of Naval Research

This contract between the Office of Naval Research and Stanford University was in effect from June 1948 to December 1962, and in this period of almost 15 years a number of important scientific and technical advances were made. This report is a brief summary of some of the more important advances. During part of the duration of the contract the financing was carried under a joint program, with the Atomic Energy Commission and the Air Force contributing support. This report will not include the details of these arrangements.

In the five-year period from June 1948 to June 1953, the work was mainly concerned with the design, development, and construction of a linear electron accelerator with the aim of producing a 1 BeV electron beam. The accelerator principle was the idea of Professor W. W. Hansen, and initially the contract was under his direction. An organization named the Microwave Laboratory was set up to carry out the work. The Laboratory work began in the Physics corner of the University Main Quadrangle, but in early 1949 a building to house the large accelerator was completed and almost all the contract work was transferred to the new building. Professor Hansen died in May 1949 and Professor E. L. Ginzton was appointed Laboratory director.

During this early period, most of the important advances and developments carried out under the contract were aimed toward the construction of the large linac. The following is a partial listing of advances:

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- 1 - Elaboration of the theory of the microwave linear electron accelerator.
- 2 - Investigation of wave-guide structures to determine which are most suitable for electron acceleration.
- 3 - Development of microwave measuring techniques for testing accelerator components.
- 4 - Demonstration of the accelerator principle by the magnetron powered, MkI, 6 MeV accelerator.
- 5 - Design, development and construction of the high-powered klystron amplifier without which the multi-BeV linear electron accelerator would be impossible.
- 6 - Design, development, and construction of the pulsers for the high-power klystrons.
- 7 - Development and construction of components for a 1 BeV accelerator.
- 8 - Operation of the prototype accelerator, Mk II, using a high power klystron.
- 9 - Construction of the Mk III accelerator.

During the early period there was also important work not directly related to accelerator construction. This included:

- 1 - Planning of experiments to be done with the high-energy electrons from the accelerator.
- 2 - Investigation of scintillating materials and the development of detection systems for use in experiments with high-energy electrons.
- 3 - Development of a means of generating millimeter electromagnetic waves from the interaction of electrons with periodic structures (undulator principle).
- 4 - Development of electron beam bending, analyzing and focusing devices.

By 1953 the Mk III accelerator was operating in a routine manner, and a full scale program of experiments was under way. At this time, it became clear that the program of high-energy physics was not directly related to the microwave tube research and development program that had grown out of the development of the high-power klystrons. In June 1953 what had been called the Microwave Laboratory was divided into two parts, the High-Energy Physics Laboratory and the Microwave Laboratory. The High-Energy Physics Laboratory was concerned with operation of the Mk II and Mk III accelerators for investigation of atomic nuclei and elementary particles. This work continued to be supported by contract N6/onr-25116, and the building formerly called the Microwave Laboratory was renamed the High-Energy Physics Laboratory. Professor W. K. H. Panofsky was appointed Director of H.E.P.L.. The Microwave Laboratory continued under the direction of Professor E. L. Ginzton. The Microwave Laboratory carried on a number of activities in a new building adjacent to the High-Energy Physics Laboratory, but none of these activities received direct support from contract N6/onr-25116. The two laboratories shared some administrative and shop facilities, and the combined facility was named the W. W. Hansen Laboratories of Physics.

By the end of November 1953, the accelerator had 21 ten-foot sections in place, but there were not yet enough reliably operating klystrons to power the entire machine. The maximum electron energy up to that time was 400 MeV obtained with 14 klystrons operating.

By the end of 1953 Professor R. Hofstadter and his collaborators had begun their investigation of nuclear structure by means of electron scattering. They had already demonstrated that the root mean square charge radii of heavy nuclei were considerably smaller than the previously accepted

values. A 36" spectrometer which made it possible to extend these experiments was under construction with costs paid by the contract.

A program of the study of the photoproduction of mesons was instituted by Professor Panofsky and results, for the relative numbers of π^- to π^+ mesons were obtained for a number of elements.

At this time the Mk II accelerator was operating at about 35 MeV, and an experimental program of investigating the "giant" photonuclear resonance was under way. This program continued actively for the entire duration of the contract.

By December 1955, the accelerator was operating routinely with a full complement of 21 klystrons to yield an energy of about 600 MeV. The 36" spectrometer was in operation and it had been used in a number of electron scattering studies. The analysis of the scattering from the proton and the deuteron had revealed that the Dirac form factors for the proton and the Pauli form factors for the proton and neutron anomalous moments corresponded to distributed structures with a rms radii of about 0.7×10^{-13} cm. Small differences in these three form factors were being investigated in detail. The neutron's Dirac form factor was always found to be about zero, but the uncertainty in this result was rather large. Inelastic electron scattering from complex nuclei was shown to be an effective means of investigating excited states of nuclei and a number of such investigations were made. The program of studying the production and properties of π -mesons was continued. Polarized X-ray beams produced in electron bremsstrahlung were used in some of these studies. The direct photo-production of μ -meson pairs was observed for the first time and the cross section of the process was within experimental error equal to the prediction of the Dirac theory. This provided additional support for the

idea that the meson is in all respects a heavy electron. An accurate measurement of the momentum spectrum of the electrons from the decay of stopped μ -mesons was made. The result differed slightly from the predictions of the two component neutrino theory, and therefore prompted a number of theoretical investigations and refinements.

By December 1957, a ninety-foot extension of the Mark III accelerator was under construction. The scope and accuracy of electron scattering studies of the proton and other nuclei had been increased. The finite extent of the neutron magnetic moment distribution was verified by study of the direct production of positive pions from electrons bombarding protons.

The ninety-foot extension of Mark III was completed by July 1960 and from this time on routine operation at energies of 900 MeV was possible. One BeV was obtainable if all klystrons were effective and well processed. A 72-inch spectrometer had been constructed to permit analysis of scattered electrons with momenta up to 1 BeV/c. These improvements permitted detailed studies of the nucleon form factors with the result that the proton Dirac and Pauli form factors were found to be much different at very high momentum transfers. A high point in the electron scattering program was the awarding of the 1961 Nobel prize in physics to Professor Hofstadter "for his pioneering studies of electron scattering in atomic nuclei, and for his thereby achieved discoveries concerning the structure of the nucleons".

An experiment to study the limits of quantum electrodynamics by means of colliding beams of 500 MeV electrons was begun in January 1959, as a joint project of Princeton and Stanford University. Funds for the

support of this project were supplied through contract N6/onr-25116.

This experiment required the construction of a number of major items of equipment and it was not until March 1962 that electrons were successfully injected into the storage rings and captured into stable orbits by the R.F. cavities. At that time the vacuum chamber had not been baked and the beam lifetime was limited by the gas pressure to 5 seconds.

By autumn 1962 the vacuum chamber had been baked and lifetimes of up to two hours were observed.

At the termination of the contract in December 1962, the research activities were continuing unabated. A new target area made possible with funds provided by the contract was nearly completed. The electron scattering program was being extended in accuracy and plans were under way to increase the accelerator energy to 1.5 BeV so that a higher range of momentum transfers could be investigated. A program of positron scattering on nuclei was in process, and an experiment to compare the scattering of positrons from the proton with electrons from the proton showed a significant difference which was unexpected according to the present theoretical ideas. The program of investigating mesons and their production was still active. This program also would benefit from a higher energy electron beam because the present energy is not comfortably above the threshold for the associated photoproductions of K's and Λ 's from the proton. Several difficulties are associated with colliding beam experiments but it is believed that none of these will prevent the proposed test of quantum electrodynamics by e - e scattering.

All of these experiments will be continued and others now unforeseen will be carried out under the new contract, N-onr 225 (67).

A list of the reports and publications describing works performed under contract N6/onr-25116 is given in Appendix A.

A list of students who received M.S. degrees or Ph.D. degrees for work supported by the contract is given in Appendix B. The Department of Physics at Stanford no longer requires a thesis for the M.S. degree, and it would have been difficult to find out in exact detail how the contract contributed to the M.S. degree in each case. In Appendix B we have simply listed those students who were research assistants paid by the contract at the time they received their M.S. degree.

W. C. Barber

W. C. Barber
Director
High-Energy Physics Laboratory

WCB/eh
April, 1963

APPENDIX A.

List of Reports and Publications Describing Work Performed Under Contract N6/onr-25116

<u>M. L. No.</u>	<u>Author and Report</u>	<u>Contract</u>
80	W. W. Hansen, "X-Ray Protection", Technical Report, August 1948.	N6-onr-25116
86	Staff, "Linear Electron Accelerator Project", Progress Report No. 1, December 1948.	N6-onr-25116
90	Staff, "Linear Electron Accelerator Project", Status Report No. 2, September 1949.	N6-onr-25116
95	Staff, "Development of High Power Pulsed Klystrons" Special Report No. 1, June 1949.	N6-onr-25116
102	L. I. Schiff, "Survey of Possible Experiments with Linear Electron Accelerators", Technical Report, November 1949.	N6-onr-25116
103	E. L. Ginzton, "Conference on High-Power Pulsed Microwave Generators and Related High-Power Devices", Technical Report (CONFIDENTIAL), January 1950.	N6-onr-25116
107	Staff, "Shielding Plan for the Stanford Linear Accelerator", Technical Report, February 1950.	N6-onr-25116
109	Staff, "Linear Electron Accelerator Project", Status Report No. 3, November 1949.	N6-onr-25116
112	Staff, "Linear Electron Accelerator Project", Status Report No. 4, February, 1950.	N6-onr-25116
114	R. F. Post and N.S. Shiren, "Performance of Pulsed Photo-Multiplier Scintillation Counters", February 1950.	N6-onr-25116
	<u>Also published in Phys. Rev. 78, No. 1, 81, (April 1950)</u>	
115	R. F. Post and N. S. Shiren, "Decay Time of Stilbene Scintillations as a Function of Temperature", February 1950.	N6-onr-25116

<u>M. L. No.</u>	<u>Author and Report</u>	<u>Contract</u>
115	Also published in Phys. Rev. <u>78</u> , No. 1, 80-81 (April 1950)	N6-onr-25116
116	Staff, "Linear Electron Accelerator Project", Status Report No. 5, May 1950.	N6-onr-25116
120	H. Motz, "Applications of the Radiation from Fast Electron Beams", Technical Report, July 1950.	N6-onr-25116
	Also published in J. Appl. Phys. <u>22</u> , No. 5, 527-535 (May 1951).	
127	Staff, "Linear Electron Accelerator Project", Status Report, August 1950.	N6-onr-25116
128	R. F. Post, "Decay Time and Efficiency of a Liquid Scintillator", Internal Memorandum, June 1950.	N6-onr-25116
	Also published in Phys. Rev. <u>79</u> , No. 4, 735 (August 1950).	
134	Staff, "Linear Electron Accelerator Project", Status Report, November 1950.	N6-onr-25116
137	Staff, "Linear Electron Accelerator Project", Status Report, February 1951.	N6-onr-25116
140	E. L. Chu, "The Theory of Linear Electron Accelerators", Technical Report and Dissertation, May 1951.	N6-onr-25116
141	G. E. Becker and D. A. Caswell, "Operation of a Six-MeV Linear Electron Accelerator", January 1951.	N6-onr-25116
	Also published in Rev. Sci. Instr. <u>22</u> , No. 6, 402-405 (June 1951).	
143	Staff, "Linear Electron Accelerator Project", Status Report, May 1951.	N6-onr-25116
144.	L. I. Schiff, "Nonlinear Meson Theory of Nuclear Forces. I: Neutral Scalar Mesons with Point-Contact Repulsion. II: Nonlinearity in the Meson-Nucleon Coupling", Technical Report, June 1951.	N6-onr-25116
	Also published in Phys. Rev. <u>84</u> , No. 1, 1-11 (October 1951).	
147	Staff, "Linear Electron Accelerator Project", Status Report, August 1951.	N6-onr-25116

<u>M. L. No.</u>	<u>Author and Report</u>	<u>Contract</u>
150a	W. C. Barber and R. H. Helm, "Evidence for K-Shell Ionization Accompanying the Alpha Decay of Po^{210} ", Technical Report, October 1951.	N6-onr-25116
151	Staff, "Linear Electron Accelerator Project", Status Report, November 1951.	N6-onr-25116
153	L. I. Schiff, "Radiative Correction to the Angular Distribution of Nuclear Recoils from Electron Scattering", Technical Report, December 1951.	N6-onr-25116
154	L. I. Schiff, "Neutral V Particle Decay and the Negative Proton", Technical Report, December 1951.	N6-onr-25116
158	Staff, "Linear Electron Accelerator Project", Status Report, February 1952.	N6-onr-25116
161	Staff, "Linear Electron Accelerator Project", Status Report, May 1952.	N6-onr-25116
165	S. D. Drell and E. M. Henley, "Pseudoscalar Mesons with Applications to Meson-Nucleon Scattering and Photoproduction", Technical Report, August 1952. <u>Also published in Phys. Rev. 88, No. 5, 1053-1064 (Dec. 1952).</u>	N6-onr-25116
169	Staff, "Linear Electron Accelerator Project", Status Report, August 1952.	N6-onr-25116
171a	H. Motz, W. Thon, and R. N. Whitehurst, "Experiments on Radiation by Fast Electron Beams", October 1952. <u>Also published in J. Appl. Phys. 24, No. 7, 826-833 (July 1953).</u>	N6-onr-25116
172	E. T. Jaynes, "The Concept and Measurement of Impedance Periodically Loaded Waveguides", April 1952. <u>Also published in J. Appl. Phys. 23, No. 10, 1077-1084 (October 1952).</u>	N6-onr-25116
173	P. A. Pearson, "Pulsers for the Stanford Linear Electron Accelerators", Technical Report November 1952.	N6-onr-25116

<u>M. L. No.</u>	<u>Author and Report</u>	<u>Contract</u>
175	R. F. Post, "Performance of Pulsed Photo-multipliers", January 1952 <u>Also presented at the Scintillation Counter Symposium, Washington, D.C., January 30, 1962.</u> <u>Also published in Nucleonics 10, No. 5, 46-50 (May 1952).</u>	N6-onr-25116
176	R. F. Post, "Resolving Time of Scintillation Counters", January 1952. <u>Also presented at the Scintillation Counter Symposium, Washington D.C., January 30, 1952.</u> <u>Also published in Nucleonics 10, No. 6, 56-58 (June 1952).</u>	N6-onr-25116
177	W. Van Sciver and R. Hofstadter, "Scintillations in Thallium-Activated CaI_2 and CsI ", October 1951. <u>Also published in Phys. Rev. 84, No. 5, 1062-1063 (December 1951).</u>	N6-onr-25116
178	R. F. Post and L. I. Schiff, "Statistical Limitations on the Resolving Time of a Scintillation Counter". <u>Also published in Phys. Rev. 80, No. 3, 1113 (December 1950).</u>	N6-onr-25116
179	W. Van Sciver and R. Hofstadter, "Gamma- and Alpha-Produced Scintillations in Cesium Fluoride" June 1952. <u>Also published in Phys. Rev. 87, No. 3, 522 (August 1952).</u>	N6-onr-25116
180	W. K. H. Panofsky and D. Reagan, "The Reaction $\text{N}^{14}(\nu, 2n) \text{N}^{12}$ ", June 1952. <u>Also published in Phys. Rev. 87, No. 3, 543 (August 1952).</u>	N6-onr-25116
181	W. C. Barber, G. E. Becker, E. L. Chu, "Electron-Electron Scattering at 6.1 MeV", June 1952. <u>Also published in Phys. Rev. 89, No. 5, 950-957 (March 1953).</u>	N6-onr-25116
182	A. Hudson and R. Hofstadter, "Energy Loss of Cosmic-Ray μ -Mesons in Sodium Iodide Crystals", June 1952. <u>Also published in Phys. Rev. 88, No. 3, 589-596 (November 1952).</u>	N6-onr-25116

<u>M. L. No.</u>	<u>Author and Report</u>	<u>Contract</u>
183	A. Kantz and R. Hofstadter, "Electron-Induced Showers in Copper", September 1952. <u>Also published in Phys. Rev. 89</u> , No. 3, 607-617 (February 1953).	N6-onr-25116
185	R. B. Neal, "A High Energy Linear Electron Accelerator", Technical Report and Dissertation, February 1953.	N6-onr-25116
186	Staff, "Linear Electron Accelerator Project", Status Report, December 1952.	N6-onr-25116
191	Staff, "Linear Electron Accelerator Project", Status Report, March 1953.	N6-onr-25116
194	S. D. Drell, "Recoil Correction to Bremsstrahlung Cross Section", May 1952. <u>Also published in Phys. Rev. 87</u> , No. 5 753-755 (September 1952).	N6-onr-25116
195	L. I. Schiff, "Radiative Correction to the Angular Distribution of Nuclear Recoils from Electron Scattering", reprint of M.L. Report No. 153, Phys. Rev. <u>87</u> , No. 5, 750-752 (Sept. 1952)	N6-onr-25116
199	Staff, "Linear Electron Accelerator Project", Status Report, June 1953.	N6-onr-25116
202	J. A. McIntyre, R. L. Kyhl, W.K.H. Panofsky "External Magnetic Focusing Devices for the Mark III Accelerator", Technical Report, July 1953.	N6-onr-25116
206	H. Motz and L.I. Schiff, "Cerenkov Radiation in a Dispersive Medium", October 1952. <u>Also published in Am. J. of Physics 21</u> , No. 4, 258-259 (April 1953).	N6-onr-25116
207	R. D. Lawson and S. D. Drell, "Double Meson Photoproduction", February 1953. <u>Also published in Phys. Rev. 90</u> , No. 2, 326-327 (April 1953).	N6-onr-25116
208	W.K.H. Panofsky and J.A. McIntyre, "Achromatic Beam Translation Systems for Use with the Linear Accelerator", February 1953. <u>Also published in Rev. Sci. Instr. 25</u> , 287 (July 1953).	N6-onr-25116

<u>M. L. No.</u>	<u>Author and Report</u>	<u>Contract</u>
213	W. C. Barber, "Foil Uniformity Measurement by Alpha-Particle Transmission", December 1952. <u>Also published in Rev. Sci. Instr.</u> <u>24</u> , No. 6, 469-470 (June 1953).	N6-onr-25116
258	M. Chodorow, E.L. Ginzton, W. W. Hansen, R.L. Kyhl, R.B. Neal, W.K.H. Panofsky, and Staff, "Stanford High-Energy Linear Electron Accelerator", Technical Report, December 1954. <u>Also published in Rev. Sci. Instr.</u> <u>26</u> , No. 2, 134-204 (February 1955).	N6-onr-25116
375	R. B. Neal and W.K.H. Panofsky, "The Stanford Mark III Linear Accelerator and Speculations Concerning the Multi-BeV Applications of Electron Linear Accelerators", Technical Report, 1956. <u>Also published in Volume 1 of CERN Symposium</u> (1956).	AT(04-3)-21 PA-1 and N6-onr-25116
420	K.B. Mallory, "On the Measurement of Shunt Impedance of a Cavity", paper, August, 1957. <u>Also published in J. Appl. Phys.</u> <u>24</u> , 790-793 (May 1958).	N6-onr-25116
<u>H.E.P.L. No.</u>		
1	Staff, "Status Report" Period June 1 - Aug. 31 1953.	N6-onr-25116
2	R. Hofstadter, H.R. Fechter, J.A. McIntyre, "High-Energy Electron Scattering and Nuclear Structure Determinations", September 1953 <u>Also published in Phys. Rev.</u> <u>92</u> , 978 (1953).	N6-onr-25116
3	D.D. Reagan, "The Reaction $C^{12}(\gamma, 3p)Li^9$ " November 1953 <u>Also published in the Phys. Rev.</u> <u>92</u> , No. 3, 651 (1953).	N6-onr-25116
4	Richard Wilson, "A Formula for Thick Target Bremsstrahlung", March 1953 <u>Also published in the Proc. Phys. Soc. (London)</u> <u>A66</u> , 638 (1953).	N6-onr-25116
5	Richard Wilson, "Analysis of Photonuclear Reactions", March 1953. <u>Also published in the Proc. Phys. Soc. (London)</u> <u>A66</u> , 645 (1953).	N6-onr-25116

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6	K.L. Brown, R. Wilson, "Electrodisintegration of Cu^{63} , Zn^{64} , Ag^{109} , and Ta^{181} ", Feb. 1954 Also published in the Phys. Rev. <u>93</u> No. 3, 443 (1954)	N6-onr-25116
8	Berman and Staff, "Status Report" Period: Sept. 1 - Nov. 30, 1953.	N6-onr-25116
9	R. Hofstadter and A.D. Kantz, "The Application of Large Scintillators and Cerenkov Counters to the Measurement of High Energies", March 1954. Also published in the Nucleonics <u>12</u> , No. 3, 36 (1954).	N6-onr-25116
10	W.K.H. Panofsky and J.A. McIntyre, "Achromatic Beam Translation Systems for Use with Linear Accelerators", May 1954. Also published in the Rev. Sci. Instr. <u>25</u> , No. 3, 287 (1954).	N6-onr-25116
11	R. Post, N. Shiren and K. Brown, "The Stanford Mark II Linear Accelerator", Technical Report May 1954.	N6-onr-25116
13	R. Post and N. Shiren, "The Stanford Mark II Linear Accelerator", February 1955. Also published in the Rev. Sci. Instr. <u>26</u> , 205 (1955).	N6-onr-25116
14	Berman and Staff, "Status Report" Period: Dec. 1 1953 - February 28, 1954.	N6-onr-25116
15	J.A. McIntyre, B. Hahn and R. Hofstadter, "Inelastic Scattering of 190 MeV Electrons in Beryllium", May 1954. Also published in the Phys. Rev. <u>94</u> , 1084 (1954).	N6-onr-25116
16	R. Hofstadter, B. Hahn, J.A. McIntyre, A. Knudsen, "High-Energy Electron Scattering and Nuclear Structure Determination, II", July 1954. Also published in the Phys. Rev. <u>95</u> , 512 (1954).	N6-onr-25116
17	A. Kantz, "Electron-Induced Showers", Technical Report (Thesis), May 1954.	N6-onr-25116
19	Reagan and Staff, "Status Report" Period: March 1 - May 31, 1954.	N6-onr-25116

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20	A. Berman, "Photonuclear Reactions" May 1954.	N6-onr-25116
	<u>Also</u> published in the Am. Journal of Phys. <u>22</u> , 227-290 (1954)	
21	G. Tautfest, H. Fechter, "Secondary Electron Yield from Al by High-Energy Primary Electrons" October 1954	N6-onr-25116
	<u>Also</u> published in the Phys. Rev. <u>96</u> , 35 (1954)	
22	A. Berman, K. Brown, "Absolute Cross Section vs Energy of the Cu ⁶³ (γ ,n) and (γ ,2n) Re- actions", October 1954.	N6-onr-25116
	<u>Also</u> published in the Phys. Rev. <u>96</u> , No.1,83, (1954).	
23	G. Tautfest, H. Fechter, "A Non-Saturable High-Energy Beam Monitor", February 1955.	N6-onr-25116
	<u>Also</u> published in the Rev. Sci. Instr. <u>26</u> , No. 2, 229 (1955).	
25	Reagan and Staff, "Status Report" Period: June 1 - Aug. 31, 1954.	N6-onr-25116
26	W. Van Sciver, R. Hofstadter, "Scintillation and Luminescence in Unactivated NaI.", Feb. 1955.	N6-onr-25116
	<u>Also</u> published in the Phys. Rev. <u>97</u> , No.4, 1181 (1955).	
28	W.C. Barber, "Specific Ionization of High Energy Electrons", February 1955.	N6-onr-25116
	<u>Also</u> published in the Phys. Rev. <u>97</u> , No.4,1071 (1955).	
29	W.C. Barber, W.D. George, D.D. Reagan, "Absolute Cross Section for the Reaction Cl ³⁵ (γ ,n)Cl ³⁶ ". May 1955.	N6-onr-25116
	<u>Also</u> published in the Phys. Rev. <u>98</u> No.1,73 (1955).	
30	M. Chodorow, E.L. Ginzton, W.W. Hansen, R.L. Kyhl, R.B. Neal, W.K.H. Panofsky and Staff, "The Stanford High-Energy Linear Electron Accelerator (Mark III)", February 1955.	N6-onr-25116
	<u>Also</u> published in the Rev. Sci. Instr. <u>26</u> No.2, 134 (1955).	

<u>H.E.P.L. No.</u>	<u>Author and Report</u>	<u>Contract</u>
31	W.K.H. Panofsky, C.M. Newton, G.B. Yodh, "Pion Production by Electrons", May 1955. <u>Also published in the Phys. Rev. 98, No.3,751 (1955).</u>	N6-onr-25116
32	K. Crowe, R. Helm, G. Tautfest, "Preliminary Data on the Measurement of the μ^+ - β^+ Decay Spectrum", August 1955. <u>Also published in the Phys. Rev. 99, No.3,872, (1955).</u>	N6-onr-25116
33	R. Carlile, "The Quadrupole Magnet as a Focusing Device", February 1957 (Technical Report)	N6-onr-25116
34	J.A. Narud, "Theory of Nonlinear Feedback Systems having a Multiple Number of First- order Operating Points and its Application to Millimicrosecond Counting Techniques", May 1955, (Technical Report).	N6-onr-25116
35	D. D. Reagan, "Photonuclear Yields in N ¹⁷ " February 1955 (Technical Report).	N6-onr-25116
36	Staff, "Status Report" Period: Sept 1 - Nov. 30, 1954.	N6-onr-25116
37	J. McIntyre, R. Hofstadter, "Scattering of 192-MeV Electrons from the Deuteron", Feb. 1955. (Technical Report).	N6-onr-25116
38	W. Van Sciver, "Scintillation Phenomena in NaI and CsBr", May 1955 (Technical Report)	N6-onr-25116
39	J. Narud, "Theory of Nonlinear Feedback Systems having a Multiple Number of First- order Operating Points", September 1956..	N6-onr-25116
41	R.H. Helm, "Inelastic and Elastic Scatter- ing of 187 MeV Electrons from selected Even-Even Nuclei", February 1956 (Technical Report). <u>Also published in the Phys. Rev. 104 No.5, 1466-1475 (1956).</u>	N6-onr-25116
42	R. Hofstadter, J. McAllister, "Electron Scattering from the Proton", April 1955. <u>Also published in the Phys. Rev. 98, No.1,217 (1955).</u>	N6-onr-25116

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201	G. Burleson, "Inelastic Electron Scattering from He ⁴ ", Sept. 1960. <u>Also published in the Phys. Rev.</u> <u>121</u> , No. 2, 624 (1961).	N6-onr-25116
202	H. DeStaebler, W.K.H. Panofsky, L. Becker, "Bremsstrahlung Intensities from Hydrogen", May 1960.	N6-onr-25116
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	<u>Also published in the Phys. Rev. 121</u> , No. 1, 283 (1961).	
207	H. Kendall, "Virtual Photon Spectrum", June 1960. An Internal Memorandum.	N6-onr-25116
208	J.A. Poirier, D.M. Bernstein, J. Pine, "An Erratum for HEPL-174", June 1960	N6-onr-25116
209	R. Hofstadter, "Principle Methods of Measuring Nuclear Size", Sept. 1960.	N6-onr-25116
210	W.C. Barber, "Photonuclear Research at Stanford University", August 1960. For Karlsruhe Conf.	N6-onr-25116
211	L. Hand, "Electron Proton Scattering at 900 MeV and 135 ⁰ ", August 1960.	N6-onr-25116
	<u>Also published in the Phys. Rev. Letters 5</u> , No. 4, 168 (1960).	
212	Staff, "Status Report", Period: March 1. - July 31, 1960.	N6-onr-25116
213	P. B. Phillips, "A Microwave Separator for High Energy Particle Beams", August 1960.	N6-onr-25116
214	F. Bumiller, M. Croissiaux, R. Hofstadter, "Electron Scattering from the Proton", Sept. 1960.	N6-onr-25116
	<u>Also published in the Phys. Rev. Letters, 5</u> , No. 6 261 (1960).	
215	R. Hofstadter, F. Bumiller, M. Croissiaux, "Splitting of the Proton Form Factors and Diffraction in the Proton", Sept. 1960.	N6-onr-25116
	<u>Also published in the Phys. Rev. Letters 5</u> , No. 6, 263 (1960).	

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227	Staff, "Status Report" Period: Nov. 1, 1960 - Jan. 31, 1961.	N6-onr-25116
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229	R. Alvarez, "Burroughs 220 Program for Thick Radiation Bremsstrahlung", June 1961. An Internal Memorandum.	N6-onr-25116
230	L. Hand, C. Schaerf, "Pion Photoproduction of Backward Angles near the Second Nuclear-Pion Resonance", Feb. 1961.	N6-onr-25116
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232	R. Hofstadter, C. de Vries, "Dirac and Pauli Form Factors of the Neutron", March 1961.	N6-onr-25116
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233	R. Hofstadter, R. Herman, "The Electric and Magnetic Structure of the Proton and Neutron", March 1961.	N6-onr-25116
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234	R. Hofstadter, F. Bumiller, M. Croissiaux, "Splitting of the Proton Form Factors and Diffraction in the Proton", Revised Version of HEPL-215. Rochester Proc. 1960.	N6-onr-25116
235	E.B. Dally, "Electron-Electron Scattering at 500 MeV", March 1961.	N6-onr-25116
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238	W.K.H. Panofsky, "Progress Report on E.E. Colliding Beams Experiment", May 1961. Rochester Proc.	N6-onr-25116
239	Staff, "Status Report", Period: Feb. 1 - April 30, 1961.	N6-onr-25116
240	W.C. Barber, G.A. Peterson, "Inelastic Electron Scattering from the Deuteron", June 1961. Ruthford Jubilee Conference.	N6-onr-25116
241	Staff, "Status Report", Period: May 1 - July 31, 1961.	N6-onr-25116
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244	A. Saxena, "High-Energy Interference Effect of Bremsstrahlung Producing in a Single Crystal of Silicon", Sept. 1961.	N6-onr-25116
245	<u>Also</u> published in the Phys. Rev. <u>125</u> , No. 5, 1720 (1961).	
245	B. Richter, "Suggestion for a L-Bev/C Spectrometer", August 1961. An Internal Memorandum.	N6-onr-25116
246	W.R. Dodge, "Photoprotons from Oxygen Fluorine, Neon and Other Light Elements", October 1961. A Technical Report.	N6-onr-25116
248	C. de Vries, R. Hofstadter, R. Herman, S. Krasnor, "Recent Results on the Neutron and on the Structure of Nucleons", Sept. 1961.	N6-onr-25116
249	D. Yount, J. Pine, "Production of Positrons with the Stanford Mark III Accelerator", Sept. 1962.	N6-onr-25116
	<u>Also</u> published in the Nucl. Inst. and Methods, <u>15</u> (1962) 40-50.	
250	M. Bazin, C. Schaerf, "Absolute Calibrations of the Triple Focussing Spectrometer (MBM)." Nov. 1961. An Internal Memorandum.	N6-onr-25116
251	Staff, "Status Report", Period: August 1 - October 31, 1961.	N6-onr-25116

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254	Staff, "Status Report", Period: Nov. 1 - Jan. 31, 1962.	N6-onr-25116
255	W.C. Barber, W.R. Dodge, "Photoprotons from Oxygen, Fluorine, Neon, and Other Light Elements", March 1962. <u>Also published in the Phys. Rev., 127, No. 5, 1746 (1962).</u>	N6-onr-25116
256	R.C. Smith, R.F. Mozley, "Positive Pion Production by Polarized X-Rays Between 227 and 373 MeV", Dec. 1962.	N6-onr-25116
257	F. Bumiller, "A Precision Rotating Coil Flux-meter", March 1962. An Internal Memorandum.	N6-onr-25116
258	C. de Vries, R. Hofstadter, R. Herman, "Neutron Form Factors and Nucleon Structure", May 1962. <u>Also published in the Phys. Rev. Letters, 8, 9, 381 (1962).</u>	N6-onr-25116
259	Staff, "Status Report", Period: Feb. 1 - April 30, 1962.	N6-onr-25116
260	G.A. Peterson, W.C. Barber, "Deuteron Magnetic Dipole Disintegration by 180° Electron Scattering", May 1962. <u>Also published in the Phys. Rev. 128, No. 2, 812 (1962).</u>	N6-onr-25116
261	H. Kendall, I. Talmi, "Inelastic Electron Scattering from V^{51} ", July 1962. <u>Also published in the Phys. Rev. 128, No. 2, 792 (1962).</u>	N6-onr-25116
262	P.B. Wilson, "Investigation of the Q of a Superconducting Microwave Cavity", July 1962. Paper delivered at CERN.	N6-onr-25116
263	J. Pine, D. Yount, "Scattering of High-Energy Positron from Proton", Nov. 1962. <u>Also published in the Phys. Rev. 128, No. 4, 1842 (1962).</u>	N6-onr-25116

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266	A. Browman, J. Pine, "Annihilation in Flight of 200 and 800 MeV Positrons", July 1962.	N6-onr-25116
267	W.C. Barber, "Inelastic Electron Scattering", July 1962. <u>Also published in the Annual Rev. of Nuclear Sci.</u> <u>12</u> , 1962	N6-onr-25116
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270	B. Richter, "Low-Mass Anomaly in Photoproduction of Pion Pairs", July 1962. <u>Also published in the Phys. Rev. Letters</u> <u>9</u> , No. 5 217 (1962).	N6-onr-25116
271	R. Hofstadter, "New Results on the Electromagnetic Form Factors of Nucleons", July 1962. Invited paper given at the Conf. on High-Energy Physics, CERN-62.	N6-onr-25116
272	J. Goldemberg, J.D. Walecka, R.H. Pratt, "Magnetic Electron Scattering", Aug. 1962.	N6-onr-25116
273	H. Kendall, R.M. Friedman, "Determination of the Deuteron Form Factor from Coherent π^0 Photoproduction", Oct. 1962. <u>Also published in the Phys. Rev.</u> <u>129</u> , No. 6, 2802 (1963).	N6-onr-25116
274	Staff, "Status Report", Period: May 31, - July 31, 1962.	N6-onr-25116
275	L.N. Hand, "An Experiment Investigation of Pion Electroproduction", August 1962. <u>Also published in the Phys. Rev.</u> <u>129</u> , No. 4, 1834 (1963).	N6-onr-25116

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277	G.A. Peterson, "Magnetic Form Factors by 180° Electron Scattering", Sept. 1962. Also published in the Phys. Rev. <u>2</u> , No. 3, 162 (1962).	N6-onr-25116
278	J. Goldemberg, J. Pine, D. Yount, "Scattering of 300 MeV Positrons from Cobalt and Bismuth", Sept. 1962.	N6-onr-25116
279	R. Simonds, B. Richter, "Mylar Windows for High Pressure Gas Counters", Sept. 1962.	N6-onr-25116
280	J. Goldemberg, Y. Torizuka, W.C. Barber, "Excitation of the Electric Dipole "Giant Resonance" by Inelastic Electron Scattering at 180° ", Oct. 1962.	N6-onr-25116
281	D.J. Drickey, L. N. Hand, "Precise Neutron and Proton Form Factors", Nov. 1962. Also published in the Phys. Rev. Letters <u>9</u> , No. 12, 521 (1962).	N6-onr-25116
282	H. Kendall, J. Oeser, "Inelastic Electron Scattering Studies", October 1962.	N6-onr-25116
283	H. Crannell, H. Collard, "Relative Efficiency Corrections for a "Y" Channel Ladder", Jan. 1963. An Internal Memorandum.	N6-onr-25116
284	Staff, "Status Report", Period: Aug. 1 - Oct. 31, 1962.	N6-onr-25116
285	R. Hofstadter, H. Collard, "The Structure of the He^3 Nucleus", Jan. 1963.	N6-onr-25116
286	Staff, "Status Report", Period: Nov. 1, 1962 - Jan. 31, 1963.	N6-onr-25116
287	R.D. Edge and G.A. Peterson, "Nuclear Excitation by 180° Electron Scattering", July 1962. Also published in the Phys. Rev. <u>128</u> , No. 6, 2750 (1962).	N6-onr-25116

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289	H. Fischer, C. Schaerf, T. Woodard, "An Inexpensive 300 MeV/c Spectrometer with a Solid Angle of 0.017 Ster., A Momentum Acceptance of 20% and Momentum Resolution of 1%", March 1963. An Internal Memorandum.	N6-onr-25116
290	D.M. Ritson, "Coherent Vertical Machine Instabilities", January 1963. An Internal Memorandum.	N6-onr-25116
291	B. Gittelman, D.M. Ritson, "Spillout Rate of Electrons in Storage Rings Due to Electron-Electron Scattering Within the Stored Bunch", April 1963. An Internal Memorandum.	N6-onr-25116

APPENDIX B

List of Students Who Received M.S. Degrees While Employed As Research Assistants and Students Who Received Ph.D. Degrees For Research Work Supported by Contract N6-onr-25116

<u>YEAR</u>	<u>M. S.</u>	<u>Ph.D.</u>
1963		Bazin, Maurice J. Dahl, Harvey A. Drickey, Darrell J.
1962	Rapier, Jerry L. Suelzle, Larry R. Swanson, Stanley M.	Bulos, Fatin Y. Dodge, William R. Hand, Louis N. Peterson, Gerald A. Taylor, Richard E.
1961	Aitken, Donald W. Creveling, Jr., Louis Haissinsky, Jacques Janssens, Thomas J.	Burleson, George R. Dally, Edgar B. McAllister, Robert W. Phillips, Peter R. Yearian, Mason R.
1960	Cutler, Leonard S. Drickey, Darrell J. Jabbur, Ramzi J. Kuglin, Charles D. Schwartz, Bernard	Ohlsen, Gerald G. Sobottka, Stanley E.
1959	Erickson, Edward F. Sanders, Timothy D. Young, David E.	Bernstein, David M. Blankenbecler, Richard Lazarus, Alan J. Poirier, John A.

<u>YEAR</u>	<u>M. S.</u>	<u>Ph.D.</u>
1958	Hadjiannou, Fokion T. Kerr, Nancy A.	Whitehurst, Robert N. Wilson, Perry B.
1957	Burleson, George R. George, Wayland D. Hudson, Richard H. Sobottka, Stanley E.	Friedman, Richard M. Hudson, Alvin M. Newton, Carol M. Tautfest, George W.
1956		Chambers, Edward E. Fregeau, Jerome H. Hagerman, Donald C. Helm, Richard H. Masek, George E. Shiren, Norman S.
1955	Poirier, John A.	Mallory, Kenneth B. Reagan, Daryl D. Van Sciver, Wesley, J. Narud, Jan A.
1954	Friedman, Richard M.	Berman, Arthur I. Fechter, Harry R. Kantz, Asher D.
1953		Brown, Karl L. Neal, Richard B.
1952		Neilsen, Ivan R.
1951	Caswell, Dwight A. Fechter, Harry R. Masek, George E.	Carter, David Chu, En-lung Post, Richard F.

<u>YEAR</u>	<u>M. S.</u>	<u>Ph.D.</u>
1950	Baskins, Lowell L. Cranston, Jr., Frederick P. Helm, Richard H.	
1949	Brown, Karl L Reagan, Daryl D.	Kennedy, William R.