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HERBERT L. ANDERSON

1914—1988

A Biographical Memoir by

HAROLD M. AGNEW

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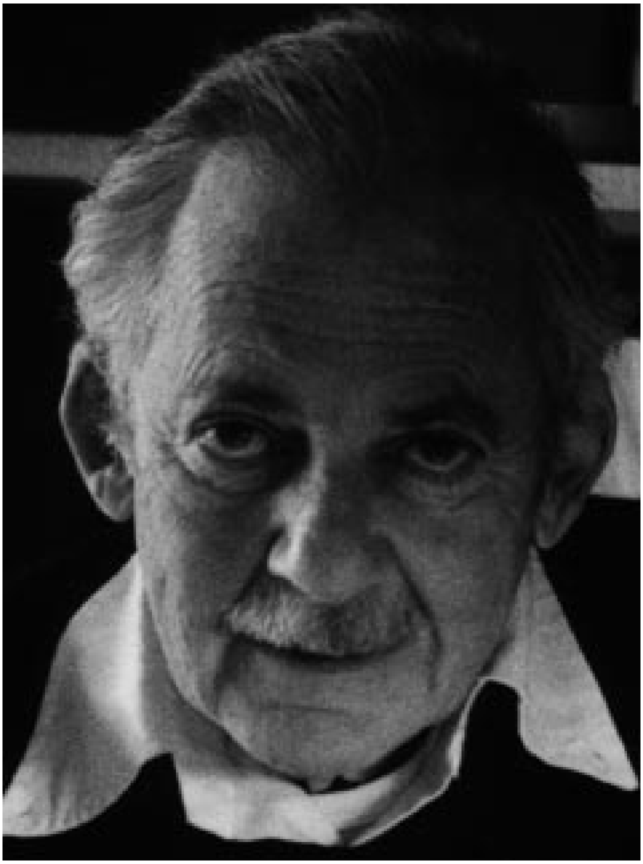

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Herbert L. Anderson

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May 24, 1914–July 16, 1988

BY HAROLD M. AGNEW

HERBERT L. ANDERSON WAS born in New York City on May 24, 1914, and died in Los Alamos on July 16, 1988, after an almost forty-year battle with berylliosis. Anderson attended New York City public schools and entered Columbia University in 1931. He received an A.B. degree in 1935, a B.S. in electrical engineering in 1936, and a Ph.D. in physics in 1940.

As a high school student Anderson was fascinated with radios and it was this interest in early electronics that led him to electrical engineering and eventually to his distinguished career in physics. He was Enrico Fermi's first collaborator in the United States.

While Anderson was completing his degree in electrical engineering John Dunning, professor of physics at Columbia, decided to build a cyclotron. At the urging of Professor Dana Mitchell, Dunning offered Anderson a job as a teaching assistant while he worked toward his Ph.D., with the proviso that he was also to assist in the design and construction of the cyclotron. As an undergraduate, Anderson made two major contributions to the design and construction of the Columbia cyclotron. The first was the design of a high frequency filament supply to replace the direct current version then in common use. This concept allowed for a much longer filament life in the high magnetic field to which the filament was exposed. However, his most important contribution and the one of which he was most proud was the result of his belief that the high frequency system would be much more efficient if the dees were fed with a pair of concentric lines instead of the usual ordinary induction system. Dunning accepted this innovation, and it became a common feature of all future cyclotron designs. Assisting Anderson in construction of the cyclotron were Eugene Booth, Norris Glascoe, Hugh Glassford, and, of course, John Dunning. In late 1938 in anticipation of doing experiments with the cyclotron Anderson built an ionization chamber and a linear amplifier.

In late 1938 and early 1939 the experiments of Otto Hahn and Fritz Strassmann had been correctly interpreted by Lise Meitner, who, with her nephew Otto Frisch, was at Bohr's institute in Copenhagen, having fled there to escape Nazi Germany. At that time Fermi had been awarded the Nobel Prize (for his work on nuclear processes induced by slow neutrons) and he and his family were in Sweden for the ceremonies. After acceptance of the prize Fermi and family went on to Columbia rather than return to fascism in Italy.

Frisch contacted Bohr who was leaving for America and told him of his and Meitner's concept of the implications of the experiments by Hahn and Strassmann. Consequently, when Bohr arrived in New York he immediately contacted Fermi. Fortunately for Anderson he couldn't find Fermi, but he did find Anderson and proceeded to tell him about nuclear fission of uranium. Bohr left, and Anderson searched for Fermi and found him at work in his office (Bohr hadn't looked there). Anderson proceeded to explain his conversation with Bohr, but Fermi, according to Anderson, immediately took over and explained fission to Anderson. Anderson seized the opportunity to point out to Fermi, who had arrived only ten days earlier, that he, Anderson, had equipment to do experiments ready to go, needed a sponsor for his thesis, and in effect made Fermi "an offer he couldn't refuse." Using his equipment, Anderson on January 25, 1939, became the first person in the United States to demonstrate the large energy release in the fission of uranium. His crucially important Ph.D. thesis, "Resonance capture of neutrons by uranium," finished in 1941, was not published for reasons of national security until ten years later.

Thus began a most rewarding relationship between these two physicists that lasted until Fermi's death in 1954. In anticipation of the importance of the discovery of the fission process Fermi and Anderson conducted a series of experiments at Columbia on the fissioning of uranium, slowing down of neutrons in graphite, absorption and reflection of slow neutrons by numerous relevant materials, and preliminary experiments involving a lattice of uranium in graphite.

When the Metallurgical Laboratory was started at the University of Chicago in February 1942 Anderson and Fermi along with Wally Zinn from Columbia became the leaders in the construction of the first man-made nuclear chain reaction, accomplished in the racquet court under Stagg Field. The experiment, known as CP-1, went critical the afternoon of December 2, 1942. Following CP-1 Anderson led the construction of CP-2 at the Argonne site in 1943 and was a key consultant for Dupont in the construction of the Hanford reactors, which produced the first plutonium for the U.S. nuclear arsenal.

Anderson left Chicago for Los Alamos in 1944 and participated in determining the critical mass of ^{235}U using the Omega reactor. When it was decided to test the first nuclear device on July 16, 1945, Anderson and his radiochemist colleagues devised methods for determining the yield of the device by collecting fission products from the crater under the tower on which the device had been detonated. Subsequently, this technique was perfected and used to analyze air samples containing radioactive debris from U.S. and foreign tests.

After the war Fermi and Anderson returned to the University of Chicago where they established the Institute for Nuclear Studies. Anderson became successively assistant professor of physics (1946-47), associate professor (1947-50), professor (1950-77), and distinguished service professor (1977-82). He served as director of the Enrico Fermi Institute from 1958 to 1962. He was appointed a Guggenheim fellow (1955-57) and a Fulbright lecturer in Italy (1956-57). He was elected to the National Academy of Sciences in 1960, to the American Academy of Arts and Sciences in 1978, and was accorded the Enrico Fermi Award for 1982.

At Chicago in 1946 he and Aaron Novick constructed the first plant for extracting tritium and He^3 from material irradiated at the Hanford reactors. Using a novel form of radio frequency bridge for detecting the nuclear magnetic resonance, he made the first precision measurements of the nuclear magnetic moments of these nuclei. Tritium eventually became a key ingredient in all modern nuclear warheads.

At the University of Chicago, Fermi was approached by Urner Lidell of the Office of Naval Research who said to him, “Look Fermi, isn’t there something you would like to do? I’d like to get you the money for it.” After discussions between Edward Teller, who urged the construction of a large computer, and Anderson, who volunteered to build whatever was decided, Fermi elected to build a cyclotron. Pi mesons had just been discovered and it was decided to build a 450 MeV synchrocyclotron. Work started in 1947. Anderson with John Marshall successfully completed the construction in 1951. The magnet coils were unique because they were cooled by circulating water through the interior of the actual copper windings. Initially it was believed that their accelerator was the most powerful in the world at that time. However, it was subsequently determined that a somewhat higher energy machine had been completed in Russia in 1949.

Anderson's first research with the cyclotron, in collaboration with Fermi, Nagle, and others, had to do with the scattering of pions and protons. This work established the nature of the pion-proton interaction and made evident the fundamental role played by pions in accounting for the nuclear force. This work was climaxed by the discovery of the N*(1236), which turned out to be the first of a series of excited states of the nucleon.

Anderson's further work at the cyclotron dealt with rare modes of the π and μ decay. This helped establish the form of the weak interaction. His study of μ capture and μ mesic atoms turned out to be a very fruitful field of research, which he pursued with his students and a group of Canadian physicists for more than ten years. These experiments gave highly precise measurements of the size and shape of the distribution of electric charge in nuclei. They also provided a searching experimental test of vacuum polarization and the theory of quantum electrodynamics as it applied to muonic atoms.

When the Argonne 12-GeV ZGS accelerator was completed Anderson turned his attention to physics at higher energy. He developed a system for automatic readout of spark chambers using TV vidicon cameras; this was used on a number of studies of boson production in pp collisions done with students and a group of Canadian collaborators. Then came a study of the reaction $pp \rightarrow d\pi^+$ at the Bevatron, using specially designed decision-making, proportional-wire chambers in the spectrometer arms.

In 1971 Anderson collaborated with physicists from Chicago, Harvard, Illinois, and the University of Oxford to carry out a series of experiments on the deep inelastic scattering of muons in hydrogen and deuterium. The work was done at Fermi's lab where a new accelerator made available muon beams of energy up to 219 GeV. For this experiment the magnet from the recommissioned University of Chicago cyclotron was moved from the University of Chicago campus to Fermi's lab. The experiment showed a breakdown of scaling in the manner predicted by quantum chromodynamics. It gave strong evidence for the model that colored quarks and vector gluons were constituent parts of the nucleon.

In 1978, when the question of lepton conservation was revived as an important issue for elementary particle research, Anderson went to Los Alamos to search for the process with a collaboration from Stanford, Los Alamos, and Chicago. The null result found set a new upper limit in the branching ratio at $2x10^{-10}$.

From the early fifties until his death Anderson carried on his strenuous activities while fighting the debilitating effects of berylliosis, incurred while preparing radium beryllium sources. In the spring of 1942 Anderson and I made the first compressed radium beryllium source. The powdered beryllium was prepared by filing on a block of beryllium. The die and press for making the source were designed by Anderson, and we flew to New York City with them. We prepared the source by pouring a solution of radium chloride on the beryllium powder, evaporating the mixture on a hot plate, pouring the dried powder into the die, pressing the mixture to form a pellet which was hand soldered into a brass capsule. The source was then wrapped in tissue, inserted into a small mayonnaise jar, and placed in a briefcase. We then boarded a plane and placed the briefcase under our seat and returned to Chicago. On our return the tissue was taken from the mayonnaise jar and tested with a Geiger counter to check that the source was properly sealed and no radon was leaking from the source. The rationale for making pressed sources was to make them physically smaller and even more important stabilize their neutron output. Previously made, loosely packed sources had the disadvantage that the neutron yield could vary because of variations in the mixing of the powdered beryllium and radium salt.

In addition to his work in Italy and Brazil, Anderson intermittently spent time at Los Alamos, and finally in 1978 he returned to Los Alamos as a fellow and was a senior fellow until his death in 1988, on the same day as the Trinity atomic test in 1945. At Los Alamos he initially concentrated his research at the Los Alamos Meson Facility, where he initiated, in collaboration with Darragh Nagle, a program of research that included studies of rare and normal muon decays. At the end of his career he collaborated with biologist Theodore Puck in developing automatic instrumentation to analyze the proteins made by living cells. The proteins were separated by two-dimensional electrophoresis. For this he designed a protein analyzer to measure the separated proteins by direct β-ray counting. In addition to his research at the University of Chicago he sponsored many graduate students who went on to successful careers in physics.

Those who were privileged to know and work with Anderson remember him as a physicist's physicist. He was an innovator, a tireless searcher for new knowledge, an inspiring teacher, and one to whom his colleagues owe a debt of gratitude.

At the time of his death Anderson's survivors included his wife Mary Elizabeth Anderson of Jacona, New Mexico; Jean Clough Anderson, his first wife, and their sons Dana Zachary Anderson of Boulder, Colorado; Kelly Pierce Anderson of Salt Lake City, Utah; Clifton Leon Anderson of Sunnyvale, California; stepdaughter Faith A. Campbell of Sonoma, California; and one grandchild.

SELECTED BIBLIOGRAPHY

1938

With J. R. Dunning. High frequency systems for the cyclotron. *Phys. Rev.* 53:334.

1939

With E. T. Booth, J. R. Dunning, E. Fermi, G. N. Glascoe, and F. G. Slack. Fission of uranium. *Phys. Rev.* 55:511.

With E. Fermi and H. B. Hanstein. Production of neutrons in uranium bombarded by neutrons. *Phys. Rev.* 55:797.

With E. Fermi and L. Szilard. Neutron production and absorption in uranium. *Phys. Rev.* 56:284.

1940

Resonance capture of neutrons by uranium. *Phys. Rev.* 57:566.

1942

With H. M. Agnew and W. H. Burgus. Measurements of neutron absorption of impurities in uranium. Report C-218. Metallurgical Laboratory, University of Chicago.

1943

With others. Experimental production of a divergent chain reaction. Report CP-413. Metallurgical Laboratory, University of Chicago.

1945

With D. Nagle, J. Tabin, and G. L. Weil. 100 ton test: Radioactivity measurements after one month. Report LA-282A, Los Alamos Scientific Laboratory.

With A. Novick and G. L. Weil. Proposal for the production of tritium using the Hanford pile. Report N-2240. Metallurgical Laboratory, University of Chicago.

1946

With E. Fermi and L. Harshall. Production of low energy neutrons by filtering through graphite. *Phys. Rev.* 70:815.

1947

With E. Fermi, A. Wattenberg, G. L. Weil, and W. H. Zinn. Method for measuring neutron-absorption cross sections by the effect on the reactivity of a chain-reacting pile. *Phys. Rev.* 72:16.

1949

With H. M. Agnew. A double magnetic lens nuclear spectrometer. *Rev. Sci. Instrum.* 20:869.

1950

Resonance capture of neutrons by uranium. *Phys. Rev.* 80:499.

1951

With J. Marshall. The University of Chicago synchrocyclotron. *Phys. Rev.* 83:232.

1952

With others. Experimental production of a divergent chain reaction. *Am. J. Phys.* 20:536.

With E. Fermi, E. A. Long, and D. E. Nagle. Total cross sections of positive pions in hydron. *Phys. Rev.* 85:936.

With E. Fermi, D. E. Nagle, and G. B. Yooh. Angular distribution of pions scattered by hydrogen. *Phys. Rev.* 86:793.

With J. Marshall, L. Korrblith, R. H. Miller, and L. Schwarcz. Synchrocyclotron for 450 MeV protons. *Rev. Sci. Instrum.* 23:707.

With others. Experimental production of a divergent chain reaction. *Am. J. Phys.* 20:536.

1953

With E. Fermi, R. Martin, and D. E. Nagle. Angular distribution of pions scattered by hydrogen. *Phys. Rev.* 91:155.

1963

With C. S. Johnson and E. P. Hincks. μ-mesonic X-ray energies and nuclear radii for fourteen elements from Z = 12 to 50. *Phys. Rev.* 130:2468-80.

1967

With others. μ-atomic Lyman and Balmer series Ti, TiO_2 and Mn. *Phys. Rev. Lett.* 18:1179.

1968

With others. Forward differential cross sections for the reaction p + p$\rightarrow\pi^+$ in the range 3.4 to 12.2 GeV/c*. *Phys. Rev. Lett.* 21:853.

1969

With C. K. Hargrove, E. P. Hincks, J. D. McAndrew, R. J. McKee, R. D. Barton, and D. Kessler. Precise measurement of the muonic X-rays in the lead isotopes. *Phys. Rev.* 187:1565.

1977

With others. Measurement of the proton structure function from muon scattering. *Phys. Rev. Lett.* 38:1450.

1979

With others. Upper limit for the decay of $\mu^+\rightarrow e^+\Upsilon$. *Phys. Rev. Lett.* 42:556.