

with the background plasma, energetic ions injected into confined plasma could significantly increase the number of fusion reactions at a given temperature.

Harold directed PPPL from 1981 to 1990. He supervised the completion of and early experiments on TFTR, the largest American enterprise in controlled nuclear fusion to date. As director, he was intensely engaged both in the TFTR discoveries and in the imagining of different approaches to confining plasma. In 1994, TFTR produced for one-third of a second a record 11 megawatts of fusion power in plasma of deuterium and tritium, and thereby demonstrated the promise of future fusion reactors.

Harold received numerous awards, including the E. O. Lawrence Award from the US Atomic Energy Commission in 1974, the American Physical Society's James Clerk Maxwell Prize for Plasma Physics in 1983, and the Delmer S. Fahrney Medal from the Franklin Institute in 1992. He was a fellow of the American Academy of Arts and Sciences and a member of the National Academy of Sciences.

Harold's charge to himself and to his colleagues was to take on only the lofty goals worthy of precious time, or as Harold put it, "not to take in laundry." For his colleagues, Harold was a true inspiration: He embodied leadership, purpose, personal integrity, brilliant wit, refreshing humor, and monumental accomplishment.

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Vernon Willard Hughes

Vernon Willard Hughes, Sterling Professor Emeritus and Senior Research Associate at Yale University, died 25 March 2003 in New Haven, Connecticut, from medical complications following an operation for an aneurysm. Hughes began research in physics in 1942 at the MIT Radiation Laboratory. During his terminal stay in the hospital, he wrote recommendation letters for a postdoc who worked with him. Thus Hughes worked at physics research—largely at the cutting edge of atomic, nuclear,

and particle physics—for 61 years.

Hughes was born in Kankakee, Illinois, on 28 May 1921. After his father died when he was three, Hughes was raised in New York City by his mother, a librarian at Teachers College of Columbia University. Having entered Columbia as a pre-law student with the intention, he wrote, "of doing good things for the world," he found mathematics and physics more interesting than law. After completing a heavy academic schedule in only three years and winning the Van Buren Math Prize, Hughes graduated from Columbia as a physics major and enrolled as a graduate student at Caltech in 1941. He received his MSc in 1942.

With the nation at war, Hughes worked on radar at the MIT Radiation Laboratory. After the war, he began research at Columbia, under I. I. Rabi, on nuclear electric quadrupole moments and received his PhD in 1950. Following two years as a postdoc at Columbia and two years at the University of Pennsylvania, Hughes came to Yale in 1954.

Although much of Hughes's work was on the properties of atoms, he regarded atoms primarily as laboratories for studies of the fundamentals of electromagnetism. Thus he concentrated on the helium atom, on positronium, and then—arguably his unique contribution to physics—on muonium, the muon–electron atom that, in 1960, he was the first to identify. His next 40 years of experimentation on that atom verified to high precision that the muon is indeed a "heavy electron," gave us new avenues into the experimental study of quantum electrodynamics, and created a tool to probe the highest energy scales of elementary particle physics.

Hughes's deep interest in fundamentals was manifest in his 1957 and 1988 measurements, in which he established limits of the electron–proton charge difference, and his 1960 measurements that limited the anisotropy of the inertial mass of a proton moving in the lithium nucleus. From Mach's principle, that observation established the isotropy of the universe to better than one part in 10^{22} .

In 1958 at Yale, Hughes initiated a design study of a proton linear accelerator "meson factory" to produce meson and muon fluxes a thousand times greater than those available at the time. Beginning in the mid-1960s, he began working on muonium physics at Los Alamos using the Los Alamos Meson Physics Facility accelerator that was based partially on the Yale design. His summers at LAMPF led to his long-time friendship with

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Vernon Willard Hughes

the local San Ildefonso Indians and a special appreciation of their remarkable pottery and sand paintings. With his first wife, Inge, and, after her death, with his second wife, Miriam, Hughes amassed an art collection that gave their home in New Haven some of the ambience of a charming museum set.

Hughes was also an originator of the use of polarized electrons in high-energy accelerators: In 1963, he led a group that developed the first polarized source for SLAC. That vision led to the observation of parity nonconservation in electron–nucleon scattering and to measurements of the deep inelastic scattering of polarized electrons by nucleons. The control of the spin of the incident electrons on polarized nucleon targets allowed measurements of the proton's spin-dependent structure; those measurements demonstrated inadequacies in the understanding of the relationship between the nature of the proton's constituents and its spin. Some 10 years after Hughes's work at SLAC was terminated, his son, Emlyn Hughes, led a program that extended the measurements of polarized-electron scattering by polarized nucleons.

In the last two decades of his life, Hughes took leading roles in three major programs. He conceived of and led an experiment to measure the anomalous magnetic moment of the muon $g - 2$ to an accuracy of better than 1 ppm. That effort placed severe constraints on the extensions of the standard particle physics model. He continued his work on nucleon spin constituents as the spokesman for the

Spin Muon Collaboration at CERN, and he directed an extensive program of muonium physics at LAMPF until it closed in 1996.

Although Hughes preferred to direct his administrative talents to his varied experimental programs, he kept in sight his early goal “of doing good things for the world.” He accepted the position of chairman of the Yale physics department during the critical years 1960–66, when Yale was undergoing a transformation into a modern research university. He also worked sedulously, from 1962 until his death, as a trustee of Associated Universities Inc, which operated Brookhaven National Laboratory and the National Radio Astronomy Laboratory.

Hughes was elected to the National Academy of Sciences in 1967. In 1978, he was awarded the American Physical Society's Davisson–Germer Prize in Atomic Physics and, in 1990, the society's Tom W. Bonner Prize in Nuclear Physics.

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Henri Arthur Levy

Henri Arthur Levy, a pioneer in neutron crystallography at Oak Ridge National Laboratory (ORNL), died of congestive heart failure on 25 March 2003 at his home in Oak Ridge, Tennessee.

Henri (who pronounced his name “Henry”) was born in Oxnard, California, on 12 September 1913. He attended Caltech, where he received his BA in chemistry in 1935 and his PhD in physical chemistry in 1938. His thesis included a section on second-order polarization energies in atoms, a theoretical topic proposed by Linus Pauling. Another section described electron diffraction studies done in cooperation with Lawrence Brockway. After receiving his degree, Henri stayed on at Caltech to work on x-ray crystallography.

In 1943, Henri joined Clinton Laboratories, the predecessor to ORNL, where he became an expert in the new field of radiochemistry. He extracted radioactive lanthanum from fission products to produce an intense radiation source needed at Los Alamos for testing the implosion bomb during World War II. That work formed the basis of articles he subsequently published on designing laboratories to handle radioactive materials.

As the war work wound down, Ernest Wollan and Clifford Shull began using a neutron beam from