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BOYCE DAWKINS McDANIEL
1917–2002

A Biographical Memoir by

ALBERT SILVERMAN AND PETER STEIN

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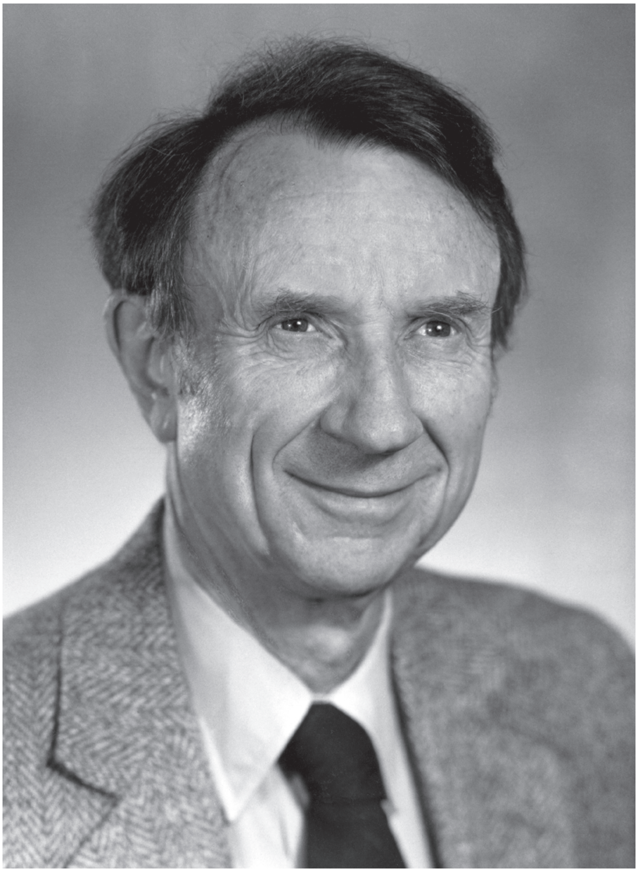

Boyce D McDaniel

BOYCE DAWKINS McDANIEL

June 11, 1917–May 8, 2002

BY ALBERT SILVERMAN AND PETER STEIN

BOYCE DAWKINS ("MAC") McDaniel died from cardiac arrest unexpectedly and quickly on May 8, 2002, at his home at Kendal of Ithaca in Ithaca, New York. For more than half a century Mac played a leading role in the birth, development, and mature phases of accelerators and experimental particle physics. Throughout his career his time, often on a daily basis, was seamlessly divided between administration, accelerator physics, instrumentation, and particle physics.

Mac was born on July 11, 1917, in Brevard, North Carolina, the youngest of the three children of Allen and Grace McDaniel. He completed high school in Chesterville, Ohio, in 1933 and graduated from Ohio Wesleyan University in 1938. In 1940 he received his M.A. degree under Eugene Crittenden at what is now Case Western Reserve University, and immediately entered a Ph.D. program at Cornell University. As a graduate student of Robert Bacher from 1940 to 1943, he built a multichannel high-resolution time-of-flight energy spectrometer and used it to carry out precision measurements of the energy levels of indium for his thesis (1946).

Following the completion of his Ph.D. he accepted a postdoctoral position at MIT to learn the rapidly evolving field of fast electronics to apply it to particle physics research.

After only a few months in Cambridge, Mac was recruited by phone to join a secret government project at an undisclosed location. Without any knowledge of its nature and location Mac abruptly pulled up stakes and joined the Manhattan Project in Los Alamos. A pressing need for accurate measurements of neutron cross-sections had arisen. Mac brought the neutron spectrometer he had used for his Ph.D. thesis at Cornell to Los Alamos, where he led a research team that discovered and made accurate measurements of fission induced by resonance absorption of epithermal neutrons in uranium and plutonium. This data made an important contribution to the design of the first nuclear bombs. He subsequently was transferred to a group set up to assemble the bomb, and played a key role in the test of the first plutonium bomb at Alamogordo. Mac had constructed a portable neutron counter to monitor the activity of the plutonium core of the bomb. Every four hours before the test he climbed an open steel ladder to make the measurement. Val Fitch, also at the test site, has written the following account of Mac's role.

> Titterton and I were at the test site to make measurements on the simultaneity of detonation of the 32 lenses, and so I knew about climbing that ladder to the top of the tower. I can testify, personally, that climbing up an open ladder to the top of the tower was a highly intimidating experience, and Mac was doing it every four hours, day and night. He was not one to pass a job like that to someone else.
>
> Mac's last measurement was made at 2:00 o'clock on the morning that the bomb was exploded at 5:30. It so happened that at that time a thunder and lightning storm was passing through the area. There was Mac alone, cozying up to that gadget at the top of the tower to measure its neutron activity, while lightning was playing around the area in the spectacular fashion common in the desert. I will let your own imagination play on what he may have been thinking.

After the war, Mac returned to Cornell and took charge of the 2 MeV proton cyclotron built by M. Stanley Livingston before the war. It was one of the earliest and lowest-energy cyclotrons ever built, but Mac and his students did a lot of good nuclear physics with it. One experiment in particular deserves mention. A good way to study nuclear structure is to measure the energy of gamma rays emitted by excited nuclei. To carry out these measurements it was necessary to measure gamma-ray energies more accurately than was possible with existing detectors. In characteristic style he, together with his student Robert Walker, invented the pair spectrometer, which for many years was the best available instrument for measuring gamma-ray energies (1948). Mac was much admired by his students. Bob Walker described him as the perfect thesis advisor, allowing the student great independence but always there when needed.

Under the leadership of Bob Bacher and Hans Bethe the Cornell Laboratory of Nuclear Studies was established in1946, with Bob Bacher as the director. Bacher left in 1947 to become a member of the Atomic Energy Commission, and was succeeded by Robert Rathbun ("Bob") Wilson. Mac was one of the charter members of the laboratory and continued to work there for the rest of his life. He was the associate director under Wilson from 1960 to 1967, and was appointed director of the laboratory in 1967 when Wilson left Cornell to build Fermilab; he continued as director until his retirement in 1985. The authors of this memoir are members of the laboratory (A.S. since 1950 and P.S. since 1956).

Under Wilson's leadership, from 1947 to 1967 the laboratory built four electron synchrotrons, from 300 MeV to 10 GeV. The research at all these machines focused on two subjects: quantum electrodynamics (QED), which describes the electrical forces between elementary particles, and quantum chromodynamics (QCD), which describes the strong force between elementary particles. The drive for ever-higher energies was motivated by the desire to test QED at smaller distances and to extend the study of QCD to more massive hadrons.

To keep an active experimental program each accelerator was kept in service until its successor was built and ready for testing. It was a very ambitious program, with lots of technical problems, a perfect match for Mac's extraordinary abilities, and he played a leading role in its success.

The first accelerator, started in 1946, was a 300 MeV electron synchrotron, one of four such machines started at that time (1949). Dale Corson, also one of the laboratory charter members, tells of a bad moment in the construction of this machine. The magnet coil was wound incorrectly, a fatal flaw. To get it repaired by the manufacturer could take months. Mac made a toy model of the coil, studied it carefully for an evening, and discovered an ingenious but simple way to repair it, which he did in about a day, and defused the crisis.

The accelerator was completed in 1949. Among the early experimental results were precise measurements of the electromagnetic interaction of high-energy gamma rays with nuclei, confirming an important theoretical calculation of Bethe and Heitler, an elegant measurement by Dale Corson of the rate of synchrotron radiation, resolving a theoretical controversy on the subject, an influential measurement by Hartman and Tomboulian of the spectrum of synchrotron radiation, and, most importantly, many measurements of the properties of the pi meson, thought at the time to be responsible for the nuclear force. The discovery in the next few years of several other particles heavier than the pion, all of which appeared to play a role in the nuclear force, showed that the story was more complicated than expected and fueled the desire for higher-energy experiments to explore and clarify the situation.

In 1953 Bob Wilson asked the Office of Naval Research (ONR) for money to build a 1 GeV electron accelerator, which he described in these words.

> The laboratory has indulged itself in some high adventure. A new synchrotron has been designed which is to give over a billion volts of energy. The design is highly controversial in that it is exceedingly small and cheap for what it will do, hence there is considerable risk that it may not work at all. On the other hand, if we are successful, we shall have the largest electron accelerator in the world and new areas of research will be open to us.

To control the cost Wilson proposed to drastically reduce the space containing the beam. This space set the scale for the size of most of the components of the accelerator. The magnet gap, coil, iron, and power supply and the vacuum system were all reduced in size. The machine was smaller, the components easier to build, and the construction time shortened, all of which reduced the costs. One can get some feeling for how radical a change this was from the fact that the 300 MeV magnet weighed 80 tons and the 1 GeV magnet, with four times the radius, weighed only 20 tons.

There was, of course, a price to pay for all of these blessings. The smaller aperture complicated the acceleration and containment of the beam. One of the most serious problems was that the position of the beam could not be accurately measured without destroying it. Again Mac came to the rescue. He invented, or at any rate produced, an instrument to measure accurately the position of the beam throughout the acceleration cycle. This changed the tuning of the machine from an art to a science, and by 1957, with the machine running at about 750 MeV, experiments began. The higher energy paid off immediately. The first round of experiments revealed a new excited state of the nucleon at 1440 MeV.

Mac's wizardry was also seen in the experimental program. One of the important research programs was the study of the photoproduction of K mesons, one of nature's more interesting particles. The early work in this field was crude, largely because the efficiency for identifying the K mesons was very small. Mac designed and built an apparatus that identified K mesons with good efficiency and low background by accurate time-of-flight measurement (1963). Then, together with his students he carried out a series of precise measurements of K-meson photoproduction that are still among the best measurements in this field (1962, 1963).

Despite Wilson's warning, the 1 GeV synchrotron was a great success, reaching eventually 1.4 GeV, with good intensity and supporting an active research program. It was the first strong-focusing accelerator to accelerate a beam. The success of the 1 GeV machine and successive machines built by Wilson at Cornell and Fermilab had a great influence on accelerator design.

The next machine was originally conceived as a 3 GeV electron synchrotron to be built by an industrial firm with accelerator experience. The National Science Foundation (NSF) had approved the project, which was to cost $8 million. At some stage Mac concluded that the two 6 GeV electron synchrotrons operating at that time in Cambridge, Massachusetts, and Hamburg, Germany, would make the 3 GeV machine obsolete by the time we got it. He proposed building a 10 GeV accelerator, which would again give us the highest-energy electron synchrotron in the world. He estimated that the 10 GeV machine could be built in-house for about the cost of the proposed 3 GeV machine. Wilson enthusiastically embraced Mac's suggestion, called the NSF to return the money, and told them he would be proposing a 10 GeV accelerator for about the same cost.

In a daring move Bob and Mac proposed building two machines simultaneously; a quick upgrade of the 1 GeV machine to 2 GeV and a brand new 10 GeV machine in a new facility. Mac supervised the upgrade of the 1 GeV. After about a year spent in constructing such parts as the magnet (which was built in-house by Mac and one technician) and a new donut, the 1 GeV machine was turned off in January 1964. A little more than three months later, in April, the 2 GeV machine was ready. Less than a day after the beam was first injected, the accelerator reached full energy. Two GeV was a modest energy increase, but it opened important new physics possibilities. The 2 GeV synchrotron was active until the 10 GeV machine was finished.

The 10 GeV machine was also built in Wilson's "small is better" style. In fact, the magnet aperture was even smaller than that of the 1 GeV magnet. Helen Edwards, who had been a student of Mac's and was one of the key players in commissioning the 10 GeV machine, described Mac's role in the project in these words.

> Mac focused specifically on the magnet fabrication, the magnet string test, and seeing that everything got designed, built, and installed. Mac was superbly good at technical design and implementation (both mechanical and electrical). He had a remarkable knack for perceiving a problem, then with great determination, intense energy and speed, and no wasted effort, coming up with a solution. There was the problem; then there was the solution. It was awesome. If you couldn't solve something, well, Mac could.

Shortly after the 10 GeV project was funded, Wilson was appointed director of the National Accelerator Laboratory (now called Fermilab), a new laboratory to be built in Illinois, which immediately demanded much of Wilson's attention, and Mac took over most of the responsibility for building the 10 GeV machine. Mac was appointed director in 1967, when Wilson left to build Fermilab, and continued in that role until his retirement in 1985.

The 10 GeV machine was approved in 1964. Research began at 7 GeV in 1967 and reached design energy, 10 GeV, in 1968. Though Mac did not continue active participation in any research project, he paid close attention to the experimental program and was consulted frequently. Helen Edwards was not the only one who knew that when you were stuck on a problem, Mac was the one to go to.

Many individual experimental physicists visited Cornell, particularly from Italian laboratories with whom Cornell had a lively exchange program; however there were no "user groups" that worked at the lab. This changed with the 10 GeV accelerator. Harvard, Rochester, MIT, Syracuse, and a group from DESY, the German laboratory in Hamburg, had groups working at Cornell and made up a substantial part of the experimental program. Mac welcomed their participation and made no distinction between them and the in-house groups. Harvard, Rochester, and Syracuse have been part of CLEO (an experiment at the Cornell Collider) since its beginning in 1976.

In 1972 Wilson prevailed on Mac to take a leave of absence from Cornell to assist in commissioning the 400 GeV proton synchrotron. The project was experiencing serious problems with accelerating useable beams beyond 20 GeV, and frequent component failure resulted in intermittent operation. Mac threw himself into the work with his usual enthusiasm. When he left eight months later, the beam had been accelerated to 300 GeV, and the beam intensity had increased by a factor of one thousand, to 3×10^{12} protons per pulse.

Ned Goldwasser, associate director of Fermilab, speaking of Mac said, "Shortly after his arrival on his first visit he 'disappeared' into the main ring tunnel and was rarely seen above ground. He soon became the acknowledged leader of all the main ring crew. That happened, not by pushing on his part, but simply by his setting an example of clear thinking and hard work." Speaking of Mac's contribution, Bob Wilson said, "This bravura performance demonstrated Mac's skill for leadership as well as his celebrated sixth sense for finding sources of trouble and fixing them."

Mac's work at Fermilab became known to and admired by a worldwide audience. From that time on he was recognized internationally as a leading figure in high-energy physics. His advice was highly valued, resulting in his service on many high-level scientific advisory committees in particle physics, astronomy, synchrotron radiation, and cosmic rays.

In the early 1970s the laboratory, under Mac's leadership, began a search for its next project. Mac, Maury Tigner, and others were enthusiastic about an electron-positron colliding beam facility, but some questioned its utility for physics beyond testing the validity of QED. The discovery of the psi meson at Stanford, in November 1974, decisively removed any such doubts. At about the same time, Maury Tigner invented a very clever scheme to use the synchrotron as an efficient injector for a collider. At that stage the collider looked very attractive, and in May 1975 Mac submitted a proposal to the NSF to "convert" the 10 GeV synchrotron to an 8 GeV (16 GeV center-of-mass energy) electron-positron collider using the synchrotron as an injector and adding a storage ring in the same tunnel (1975). Since the only major components that had to be built were the storage ring and the RF system, the cost was low and the construction time short. The proposal was initially rejected, but Mac rallied the support of the high-energy community, and in 1977 the NSF approved the project.

Mac threw himself into the construction and by October 1979, just two years after the proposal was approved, the two experiments, CLEO and CUSB, were taking data (1979). The rich trove of 25 years of b-quark physics that followed was the ultimate reward for the daring, innovative, and low-cost style of physics practiced by Mac, Bob, and their Cornell colleagues.

After his retirement in 1985, Mac remained active and played an important role in both the Cornell electron storage ring and CLEO. In addition, he served on many advisory and visiting committees for the NSF and the U.S. Department of Energy. He was a trustee of the Associated Universities (1963-1975) and Universities Research association (1971-1977); a member of Department of Energy's High Energy Physics Advisory Panel (1975-1978); and a member of the Superconducting Supercollider Board of Overseers (1984-1991), which he chaired part of this period. He was elected to the National Academy of Sciences in 1981. His modesty, integrity, and sound judgment, and his passion for life, physics, and making things work were widely recognized and admired by the scientific community.

SOME OF THE TEXT of this memoir was taken, with some changes, from an obituary that we wrote for *Physics Today* (February 2003, p. 73). The text quoted from Bob Wilson was taken from a yearly report to the Office of Naval Research on June 15, 1953, and the texts of Val Fitch, Helen Edwards, and Ned Goldwasser from a memorial service for Mac at Cornell University on September 21, 2003.

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