Princeton University

Honors Faculty Members Receiving Emeritus Status

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The biographical sketches were written by staff and colleagues in the departments of those honored.

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Kirk T. McDonald

Kirk McDonald was raised in Tucson, Arizona, where he graduated from the University of Arizona in 1966 in physics. Six years later, he received his Ph.D. from the California Institute of Technology in the field of high-energy particle physics, using the Caltech electron synchrotron with fellow graduate students. They effectively took over the facility when the senior professors focused their research on new larger accelerators at Brookhaven National Laboratory and Stanford University. He then went to CERN in Geneva, Switzerland, on a highly competitive CERN fellowship, measuring correlations of particles produced in the world's highest-energy collisions at the time, with the then-new Intersecting Storage Rings invented by Princeton physicist Gerry O'Neill.

Kirk returned to the United States in 1975, winning an honorific Enrico Fermi Fellowship at the University of Chicago. Only a few months after the discovery of the charmed quark at Brookhaven and Stanford, which had launched a frenzy of experimental and theoretical activity, this was an opportune time in particle physics. Kirk joined a three-month-old embryonic collaboration between Chicago and Princeton physicists to study the quark structure of hadrons at Fermilab, the world's highest-energy accelerator laboratory at the time. These experiments were based on an ambitious high-resolution particle detector using the huge magnet built after World War II by Fermi himself for the 485-MeV Chicago synchrocyclotron.

Kirk's creativity and drive were evident immediately, and soon he was offered a faculty position at Princeton, arriving as an assistant professor in 1976. In an era in which the promotion rate in physics was less than 25 percent, he was tenured four years later for his work on the so-called Drell-Yan process, by which high-mass muon pairs were used as probes to "x-ray" the protons and pion at short distances. Many of these results remain the best today.

During the early 1980s, the Standard Model of particle physics became well established, surviving all experimental tests and making the exciting prediction that a new field, the Higgs, was responsible for giving masses to otherwise massless fundamental constituents. However, finding the Higgs particle would require even more powerful particle colliders, so the U.S. particle physics community converged on the Superconducting Super Collider (SSC) in Texas. Kirk realized that the high energies available at the SSC would also make it possible to explore other profound questions. In collaboration with colleagues at the University of Pennsylvania and other institutions, he designed a specialized detector, named "BCD," to explore CP violation, the unexpected imbalance between matter and antimatter discovered in 1964 by Princeton physicists Val Fitch and James Cronin, for which they won the 1980 Nobel Prize in physics. After carrying out major research and development for the detector over several years, Kirk and his colleagues had their hopes dashed by the cancellation of the SSC in 1993.

Fortunately this effort was not in vain. It inspired experiments and innovative technology for Fermilab, Stanford, and the future CERN Large Hadron Collider. On the basis of his expertise in CP violation, Kirk was invited to be a founding member of the BaBar collaboration at the new Stanford Linear Accelerator Center (SLAC) B Factory electron-positron collider, serving on the BaBar executive board for several years and playing a leading role in the design and construction of the BaBar central tracking drift chamber, a major Princeton responsibility. In 2001, BaBar finally found a second manifestation of CP violation and followed up with additional effects that together led to the 2008 Nobel Prize for the theorists who had proposed a Standard Model explanation of CP violation in 1973.

Kirk is known as a rugged individualist with ideas that are "out of the box" and ahead of their time. With his brilliance, piercing insight, and straightforwardness, he was at times the *enfant terrible* of particle physics. Kirk is most famous for an ingenious experiment that he led during the hiatus between the SSC disaster and the onset of BaBar. With Adrian Melissinos of the University of Rochester and colleagues, Kirk proposed that colliding a high-brightness laser beam (a trillion watts for a trillionth of a second) with the 50-GeV SLAC electron beam would produce enough photons with sufficient energy to produce electron-positron pairs in subsequent collisions with the incident laser photons. When it was proposed to the leadership at SLAC, they thought it was a waste of time. Undaunted, the team forged ahead, and showed that, under extreme conditions, light could interact with light to produce matter. SLAC management then could not say enough about this great advance. While predicted theoretically some 60 years before, Kirk's experiment was a breakthrough in electromagnetism and particle physics. One of the primary reasons that we can see each other in a room is because light waves pass through each other and do not interact, but at high enough energies and brightness they can interact and produce matter at detectable rates because $E=mc^2$. As Malcolm Browne described it in *The New York Times*, they "goaded the empty vacuum into creating something out of nothing." The results were prominently reported in the popular press around the world.

Kirk has also had a long-term interest in the physics of neutrinos, elusive subatomic particles associated with radioactivity. Every second some 70 billion neutrinos from the sun pass through every square centimeter of us that faces the Sun, but they interact so rarely they are exceedingly difficult to detect. Unlocking their mysteries has led to numerous Nobel Prizes, including to former Princeton professor Arthur McDonald (no relation) in 2015. Most recently, Kirk has been involved in the Daya Bay Reactor Neutrino Experiment near Hong Kong, which in 2012 made the first significant measurement of one of the key and most elusive parameters that describes how the neutrino mass and type (or flavor) are related. The team was awarded a Breakthrough Prize in Fundamental Physics in 2016 for the research.

As in everything else, Kirk followed his own path in scholarship, with well over a hundred refereed research papers, and an astounding collection of about 1,200 pedagogical papers, research notes, technical notes, and conference proceedings, many of which are quite detailed and many others of which address fundamental problems in physics. In the department, he is well known for his extensive collection of worked problems, primarily in electromagnetism, and their solutions. It has often served as a source for the Ph.D. qualifying exam. In 2012, a paper was submitted to one of the leading physics journals, *Physical Review Letters*, that purported an incompatibility between special relativity and electromagnetic momentum conservation. Kirk quickly solved the paradox and rooted it in a long tradition of subtle problems and their solutions in electromagnetism. His graduate-level course on advanced electromagnetism was highly rated. We are not aware of anyone else who possesses such a deep knowledge of classical electromagnetism.

One of our colleagues summed up Kirk McDonald as follows: "To me, Kirk is a scholar of the old school — the kind who viewed it as their duty to tend with great love and rigor to a well-defined intellectual field. Such people make no apologies for the importance of getting things right even when no sexy headline is at issue and without their kind science would never have got off the ground. In his case, the field that I know of is classical E&M, although I have no doubt his style extends to all his intellectual interests. There is his intimidatingly encyclopedic website. But there is also the experience of walking into his office and having him happily drop everything to discuss a subtlety in an E&M problem, his eyes lighting up as he explains what some standard reference gets wrong. Few people exemplify the scholar's credo as well as he does — that knowledge is important for its own sake."