Fermilab: Scientific Citizenship by Example

FEATURE

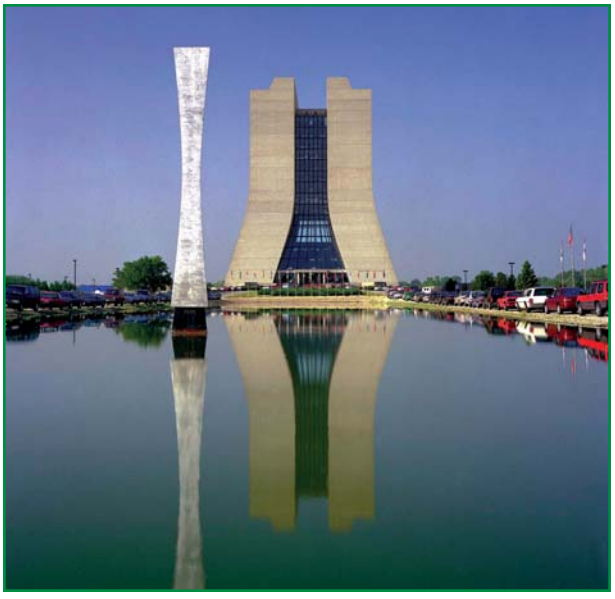
by Dwight E. Neuenschwander

In 1965, the Joint Congressional Committee on Atomic Energy urged the construction of a machine that would accelerate protons to unprecedented high energy. In the collisions of those protons, matter could be studied at the sub-nuclear scale. Robert R. Wilson became the first director of the National Accelerator Laboratory (NAL). Wilson had headed the Manhattan Project's Experimental Physics Division at Los Alamos during WWII. In 1947, at Cornell University, he designed the accelerators that led to the electron-positron storage ring, a facility now called the Wilson Synchrotron Laboratory. Construction of the NAL began in 1967. That year also saw the laboratory's first proton beam. Its 750 keV accelerator eventually became the first in a sequence of accelerators, where one injects its beam of protons into the next, boosting the beam to higher energy in steps, culminating in the four-mile-circumference ring. That ring today serves as the Main Injector Ring to another ring, a 2 TeV proton-antiproton colliding beam machine called the Tevatron.

An institution projects the values of the people who create and maintain it. The 2008 Sigma Pi Sigma Congress will be held at Fermilab. This was an inspired choice, a statement of values in a celebration of physics. Science and human values cannot be decoupled.[1] At Fermilab they are purposely mixed, mutually enriched, and find expression beyond science itself.

On May 11, 1974, the Laboratory's name was expanded to the Fermi National Accelerator Laboratory, in honor of Enrico Fermi (1901-1954). Fermi's life and career exemplify the mission and values of Fermilab. In 1926, Fermi used the new quantum statistics to describe the "degenerate electron gas"; he proposed a theory of beta decay in 1933 that included the postulate of the "little neutral one," or neutrino. Out of this theory there ultimately grew the theory of the weak interaction mediated by massive W and Z gauge bosons, and from there came the Standard Model of elementary particles and their interactions. After the neutron was discovered by Chadwick in 1932, Fermi's group in Rome began bombarding heavy elements with neutrons to study the possibility of trans-uranium elements. Such work, soon taken up by others, led to the discovery of nuclear fission in late 1938, in Berlin. By then Fermi had become a refugee from Facism, leaving Italy with his family, via Stockholm and the Nobel Prize, to Columbia University, ultimately to land at the University of Chicago. There Fermi led the creation of the first self-sustained fission chain reaction on December 2, 1942. Fermilab sits about an hour's drive from the Henry Moore sculpture that commemorates Fermi's 1942 accomplishment.

Fermilab consumes enough electrical power to run a small city. But it manufactures no marketable products, mines no ore, offers no defense against nuclear attack. Much of the energy it consumes gets concentrated into two small colliding beam interaction regions, surrounded by their colossal particle detectors networked to vast banks of computers. What FNAL *does* produce are bizarre states of matter, some of the more esoteric of which survive some 10^{-20} s. What is mined at FNAL is new knowledge from the flood of raw data, whose analysis has motivated the development of the most sophisticated computer systems on the planet. Discoveries to come out of Fermilab over the years include the top quark (1995) and the bottom quark (1977); precision measurements of the masses of the top quark, the W gauge boson mass, and the lifetime of the charmed quark; direct observation of CP violation in kaon decay (1999); first direct evidence for the tau neutrino (2000); probing proton and neutron structure by scattering neutrino beams.



Fermilab's distinctive Wilson Hall houses many Fermilab staff and offers a great view of the laboratory grounds.

Photo courtesy of Fermilab.

A high-energy particle accelerator is kind of microscope. The observable detail is limited by the wavelength of the imaging radiation. The size of a proton is about 10^{-15} m, so to "see" an object this size one needs a wavelength smaller than this value. According to quantum theory, a particle moving with momentum p corresponds to a harmonic wave of wavelength λ, where $p = h/\lambda$, with h denoting Planck's constant. Moving at essentially the speed of light c, a particle's energy E and momentum are related by $E \approx pc$. Therefore, to image something at the proton scale requires energy no less than $E = hc/\lambda \sim 1$ GeV, one billion electron volts. To probe a thousand times smaller takes a thousand times more energy, about 1 TeV, or trillion electron volts: the Tevatron. When a 1 TeV proton collides with a 1 TeV antiproton, diverse states of matter may emerge with various probabilities from the debris. Fermilab's Tevatron offers a window inside matter at the sub-proton scale.

All this has cost hundreds of millions of dollars and occupies daily the talents of some 2,300 physicists. Why should society care

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The bison at Fermilab.

Photo courtesy of Fermilab.

about such questions not directly related to survival, or activities not directly linked to the production of immediate wealth? Similar questions could be put to those who build art galleries, concert halls, racetracks, or cathedrals. We are insatiably curious. We like to push the limits of what we can know and do. Such quests are guided by values that transcend sheer survival or the quarterly financial report.

In 1969, Robert Wilson was called to testify before the Congressional Joint Committee on Atomic Energy. Senator John Pastore demanded to know how this new multi-million dollar accelerator would improve the security of the nation. Wilson gave the Senator a gold-standard answer:

"It has only to do with the respect with which we regard one another, the dignity of men, our love of culture. It has do to with: Are we good painters, good sculptors, good poets? I mean all the things we really venerate in our country and are patriotic about. It has nothing to do with defending our country except to make it worth defending."[2]

Fermilab is a monument to all that can be right in the human species. Robert Wilson set the tone. He was an artist and a physicist. Several Robert Wilson sculptures grace the Fermilab campus, including the arch, "Broken Symmetry," under which you drive when you enter. The main office and conference building, designed by Wilson and modeled on Beauveais Cathedral, is today called Wilson Hall (see fig. 1).[3] Wilson was struck by the analogies between medieval cathedrals and modern particle accelerators: both are collective enterprises that required the best work of extended communities; both push the technologies of their day to their limits; both are expressions of mankind's yearning for a life of meaning and awareness and appreciation. Inside the vast atrium of Wilson Hall one finds proudly displayed numerous works of art by local artists, announcements of cultural events hosted there, and the work of school children.

The theme of the 2008 Sigma Pi Sigma Congress is "Scientific Citizenship: Connecting Physics and Society." As it probes microscopic nature, Fermilab has also from its very beginning practiced authentic stewardship towards its surroundings. When you first enter the Laboratory, you do not see the industrial flotsam. You will see sculptures, trees, open space, reflecting pools, and the herd of American bison that live in a pasture near the Feynman Computing Center. The bison are now part of Fermilab.

Fermilab has been a responsible neighbor and citizen. The Laboratory's website includes a link for nearby residents to share any concerns they have. The Laboratory uses its facilities to offer cancer therapy. Fermilab has always maintained an active emphasis on public and K-12 education, whose most visible centerpiece today is the Lederman Science Center next to Wilson Hall, that works closely with area schools.

From its beginning, Fermilab has operated with concern for human welfare as its fundamental value. The Laboratory announced in 1968 that it would operate only within a policy of basic human rights. As a segue into our Congress theme of "Scientific Citizenship," we quote at length from the Fermilab policy, which is distinguished by a personal rather than a bureaucratic tone:[4]

It will be the policy of the National Accelerator Laboratory to seek the achievement of its scientific goals within a framework of equal employment opportunity and of a deep appreciation to the fundamental tenets of human rights and dignity.

We have seen the creation of NAL near Chicago in a year of social tension and urban unrest, and we have observed the destiny of our Laboratory to be linked to the long history of neglect of the problems of minority groups. We intend that the formation of the Laboratory shall be a positive force in the progress toward open housing in the vicinity of the Laboratory site. We intend that it shall also make a real contribution toward providing employment opportunities for minority groups. For this, the principle of equal opportunity is not enough. Special opportunity must be provided to the educationally deprived if they are to be able to exploit their inherent potential to contribute to, and to benefit from, the development of our Laboratory. This is a matter of personal conviction as well as of practical necessity...

Prejudice has no place in the pursuit of knowledge...The [NAL] is in a position to attract to its program some of the greatest physicists, not only of this country but of other nations as well. Thus the Laboratory will be, in a very real sense, one of the windows through which the United States will be viewed by the rest of the world...It is essential that the Laboratory provide an environment in which both its staff and its visitors can live and work with pride and dignity.

In any conflict between technical expediency and human rights, we shall stand firmly on the side of human rights. This stand is taken because of, rather than in spite of, a dedication to science. However, such a conflict should never arise. Our support of the rights of members of minority groups in our Laboratory and in its environs is inextricably intertwined with our goal of creating a new center of technical and scientific excellence. The latter cannot be achieved unless we are successful in the former.
— Robert Rathbun Wilson, Director;
Edwin L. Goldwasser, Deputy Director; March 15, 1968

A more appropriate setting for a conference on "Scientific Citizenship: Connecting Physics and Society" could hardly be imagined than Fermilab. See you there in November!
— Editor

References

[1] J. Bronowski, *Science and Human Values* (Harper, 1956, 1965).
[2] Obituary by R. Segelken of R. R. Wilson, placed on Cornell University's website, at http://www.news.cornell.edu/chronicle/00/1020.00/Wilson_obit.html.
[3] Discussed by Timothy Ferris in his video, "The Creation of the Universe" (1985). See also "Cathedrals and Accelerators," *Radiations* (Fall 1998), pp. 6-7.
[4] FNAL website, http://www.fnal.gov/pub/

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