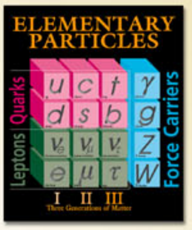
High Energy and Nuclear Physics

Understanding of Matter and the Physical Universe

The High Energy and Nuclear Physics (HENP) program mission is to advance our fundamental understanding of matter and the physical universe by supporting research in elementary particles and forces, nuclear matter, and the interactions of matter, energy, space, and time.

Historic Accomplishments

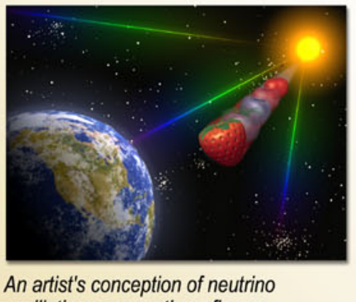


- **Discovery of a deeper level in the structure of matter**. Twelve fundamental constituents of matter—six quarks and six leptons—have been identified, nearly all of them discovered by American physicists using DOE Office of Science facilities.
- **Standard Model**. Our knowledge of particles and forces has been summarized in the Standard Model, which describes matter as made of quarks and leptons interacting through fields transmitted by bosons. The strong, weak, and eletromagnetic forces are included, but the gravitational force is not. A mechanism for the origin of mass, the Higgs field, is proposed by the Model, but has not yet been confirmed.
- **Nobel Prizes in Physics**. Since the Atomic Energy Commission was established in 1947, 17 Nobel Prizes have been awarded to 28 physicists supported by HENP.

Raymond Davis, Jr, retired Brookhaven National Laboratory scientist, shared the 2002 Nobel Prize for Physics "for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos."

Recent Scientific Achievements

- **Neutrino Discoveries**. Research at HENP neutrino detectors has determined that the mysterious elementary particle called the neutrino has mass and oscillates among three "flavors" as it travels through space. The 2002 Nobel Prize in physics recognized Ray Davis' discovery of solar neutrinos, and his findings motivated the search for neutrino oscillations.



An artist's conception of neutrino oscillations among three flavors.

- **Acceleration of Expanding Universe**. Observations of the motions of exploding stars (supernovae) have shown that the universe is not only expanding, but expanding at an accelerating rate. This surprising discovery suggests that some previously unknown form of energy is opposing the attractive force of gravity. Called "dark energy," it may be a property of space itself.
- **Little Big Bang**. Initial results from the Relativistic Heavy Ion Collider offer tantalizing indications that collisions of gold nuclei may have briefly created tiny samples of quark-gluon plasma like that which filled the universe when it was one millionth of a second old.

Major User Facilities

The Office of High Energy and Nuclear Physics supports a number of accelerator facilities at DOE national laboratories and American universities and is supporting construction of a new one in Europe.

Aerial view of Fermilab Accelerators, with the Main Injector in the foreground and the Tevatron at the back.

- **Tevatron,** operated by **Fermi National Accelerator Laboratory**, is a proton-antiproton collider that now offers the world's highest energy particle collisions.
- **B Factory,** operated by **Stanford Linear Accelerator Center**, is an electron-positron collider used for studies of heavy quarks.
- **Relativistic Heavy Ion Collider**, operated by Brookhaven National Laboratory, collides nuclei ranging from deuterons to gold and polarized protons.
- **Continuous Electron Beam Accelerator Facility**, operated by the Thomas Jefferson National Accelerator Facility, provides high intensity, polarized electron beams for a wide range of research in nuclear physics.
- **Large Hadron Collider**, a new proton and nucleus collider, is now under construction at CERN (European Organization for Nuclear Research) in Switzerland.
- **Holifield Radioactive Ion Beam Facility** at Oak Ridge National Laboratory, **Argonne Tandem Linac Accelerator System** at Argonne National Laboratory, and **88-inch Cyclotron** at Lawrence Berkeley National Laboratory provide stable and radioactive heavy ion beams for nuclear structure and nuclear astrophysics studies.
- **William H. Bates Linear Accelerator** at MIT provides intense polarized electron beams to a storage ring with a polarized gas jet target.

Non-Accelerator Experiments

- Three international underground neutrino detectors—**Solar Neutrino Observatory**, **SuperKamiokande**, and **KamLAND**—study neutrinos from the sun or from nuclear power reactors.
- The **Pierre Auger Observatory** in Argentina is a cosmic ray detector the size of Paris; the **Sloan Digital Sky Survey** is mapping 100 million celestial objects in one quarter of the sky; the **Gamma Ray Large Area Space Telescope** will be in earth orbit studying gamma rays from black holes and other sources; the **Alpha Magnetic Spectrometer** will be in earth orbit looking for antimatter and dark matter.

Science Workforce Development

The HENP program also supports the development of a highly skilled scientific and technical workforce.

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