Other government agencies like the U.S. Office of Naval Research and the National Science Foundation built and operated accelerators and supported theoretical and experimental research. But the bulk of the funding for high-energy physics came from the AEC. This pattern has persisted to the present day, with the U.S. Department of Energy (DOE) now playing the role of principal (90 percent) investor.

Today, most high-energy physics experiments in the United States are carried out at four Laboratories—three built and operated by the DOE and one, the Cornell Energy Storage Ring at Cornell University in New York, built and operated by the National Science Foundation.

At the energies generated by these machines, physicists could produce not only particles of matter, but also particles of *antimatter* known as *antiparticles,* which have exactly the same mass as their counterparts but the opposite electric charge. The first antiparticle to be identified was the *positron* ($e^+$), or positive electron, discovered in 1932 in cosmic rays. In 1955, Berkeley scientists working on the Bevatron produced the first man-made *antiproton* ($\bar{p}$)—the antiparticle of the proton. Antiparticles effectively doubled the already burgeoning list of subatomic particles.

Physicists of the 1950's recognized yet another force operating on subatomic particles—an exceedingly feeble force called the *weak* force, responsible for phenomena like radioactive decay of atomic nuclei. The strong force holds nuclei together, while the weak force triggers their disintegration. It began to be identified as a completely different force during the 1930's, when the Italian physicist Enrico Fermi formulated an ad hoc theory that explained radioactive decay as due to the transformation of a neutron into a proton, electron, and a very light, possibly massless, neutral particle called the *antineutrino,* the antiparticle of still another massless particle, the *neutrino* ($\nu$).

In the late 1940's and early 1950's, other physicists realized that Fermi's theory could help explain the decays of pions, kaons, lambdas, and a host of other unstable subatomic particles. The weak force triggering these decays is far more feeble—many thousands of times—than the electromagnetic or strong forces. It acts only over extremely short distances smaller than the size of a nucleon. Thus a neutrino or antineutrino, which feels only the effects of the weak force and not the other two, can speed through millions of miles of matter without ever once being absorbed or deflected.

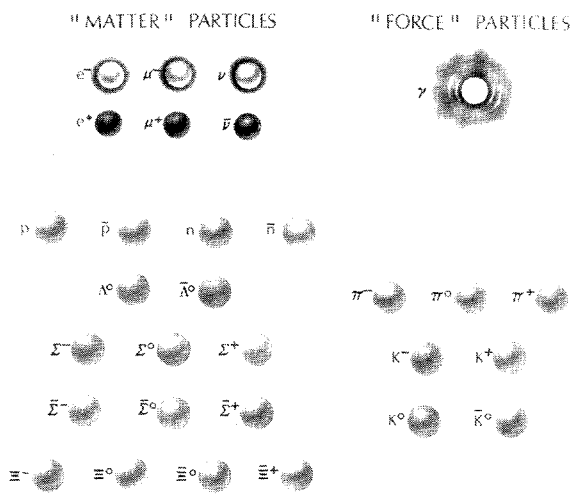


**Figure 3. The subatomic particles and antiparticles (with bar) identified by the mid-1950's.**

This, in brief, was the state of high-energy physics by the mid-1950's. The list of supposedly elementary particles had swollen to over 20 individual species—an untidy state of affairs. They interacted with one another through the agency of three very different forces. (The fourth force, gravity, plays no measurable role in elementary particle interactions.) Physicists had a completely satisfactory theory only for the electromagnetic force, while the strong force seemed hopelessly complicated. Out of this widespread confusion, however, emerged a number of truly remarkable discoveries that simplified matters tremendously during the next few decades. These great scientific advances, which are discussed in the next seven chapters, form the core of this booklet.

The knowledge obtained in high-energy physics has already begun to have a major impact upon other scientific fields like astrophysics, cosmology, and nuclear physics. Our understanding of the first moments of the universe, when matter was extremely energetic and packed together very densely, relies on the insights gained at particle accelerators over the past 30 years. And the technologies developed for high-energy physics are finding practical use in areas as diverse as medicine and materials science. Such wider applications of high-energy physics are the subject of the final two chapters.