When accelerators called *synchrocyclotrons* capable of generating energies in the hundreds of MeV were built in the late 1940's and early 1950's, physicists could finally create subatomic particles known as pions (pronounced "pie-ons" and denoted by the Greek letter π) from little more than pure energy. Depending on their electric charge, which can be positive (π^+), negative, (π^-) or neutral (π^0), pions have masses of 135 or 140 MeV—or about one-seventh the mass of the proton. Predicted in 1935 by the Japanese physicist Hideki Yukawa, these particles were discovered in cosmic rays just after World War II. Beams of pions were soon being produced at particle accelerators around the globe.

Yukawa originally proposed pions as a way to explain the *strong* force thought to be binding nucleons within atomic nuclei. Something had to be holding them together. If not, the natural repulsion of the positive charges on the protons inside a nucleus would force them violently apart, causing it to explode. The stable matter we observe all around us would be absolutely impossible under such conditions. But pions are known to flit between the nucleons, "carrying" the effects of strong force from one to the other, binding them together tightly.

Unlike electrons, protons, and neutrons, which are the constituents of normal matter, pions have a fleeting existence. Outside of a nucleus, they survive only several billionths of a second before disintegrating into other subatomic particles. The former are relatively stable examples of *matter particles,* while the latter are among the *force particles* that carry forces from one matter particle to another.

Another force-carrying particle is the common photon, which (in its many guises) carries the effects of the electromagnetic force (electricity and magnetism) between charged particles. Photons stream away from an electric light bulb because the atoms and electrons in its filament are extremely agitated; these photons then disturb atoms in our retinas, and our brains form images based on the information transmitted. Whenever we "jiggle" electrons, which is what happens in a radio transmitter, they emit photons that carry electromagnetic force to other electrons in a receiving antenna and cause them to jiggle in turn.

This division of the particle kingdom into matter particles and force particles is very deep and powerful. The task of high-energy physicists thus becomes one of identifying and studying the fundamental building blocks of matter and the particles that carry the forces between them.

By the late 1940's, physicists had an excellent theory called *quantum electrodynamics,* or QED, that described the behavior of the photon—the carrier of the electromagnetic force. A marriage of quantum mechanics and Einstein's theory of special relativity, QED makes predictions accurate to parts per *billion.* (Quantum mechanics is the mathematical framework physicists use to describe molecules, atoms, and smaller particles.) Many theorists hoped that a theory similar to QED would also be found to describe the behavior of the pions carrying the strong force.

Nature, unfortunately, failed to cooperate. Other particles feeling the strong force besides nucleons and pions kept turning up in cosmic rays. The *kaon* (pronounced "kay-on" and denoted by K) weighed in at 495 MeV, while the lambda (Λ), at 1,115 MeV, is even heavier than the neutron. More massive yet were the *sigma* (denoted by Σ)and *xi* ("ks-eye" denoted by Ξ) particles, which were discovered in the 1950's.

What were all these odd new particles? Who needed them, anyway? Physicists began to despair of ever incorporating this unruly menagerie within a simple, powerful theory like quantum electrodynamics.

To help study all these new particles and their interactions, physicists of the 1950's began building powerful new particle accelerators able to speed protons and electrons to billions of electron volts. In 1952, the 3 GeV Cosmotron began operations at Brookhaven National Laboratory on Long Island. Three years later, Berkeley scientists completed their own machine, the Bevatron, able to accelerate protons to 6 GeV. At Stanford a series of linear accelerators was built during the decade, culminating in the Mark III, which could generate electron energies up to 1 GeV.

While cyclotrons and the other small accelerators were often built with private funds, these big new machines required funding in millions of dollars. More often than not, it was the Atomic Energy Commission (AEC) that met the need. A pattern arose in which this government agency paid for the construction of a particle accelerator and all its supporting equipment—as well as the salaries and expenses of the staff. Physicists from universities who did their research at these machines were often supported by the AEC, too.