1. INTRODUCTION

High-energy physics is the study of matter at extremely small distances. It tries to answer questions like "What is the world made of?" and "How is it put together?" Whereas ancient philosophers saw nature as made from basic elements like earth, air, fire, and water, high-energy physicists seek the smallest set of elementary particles with a few simple forces acting among them. The great variety of natural phenomena occurs, at least in this picture, because there are so many different ways to arrange such fundamental building blocks. By discovering what the elementary particles are—and how they interact with each other—physicists hope to account for this diversity.

At the beginning of the twentieth century, most physicists considered atoms to be the fundamental building blocks of nature. So miniscule are these bits of matter that a trillion trillion of them can fit easily inside a common thimble. But the atom itself was soon found to be composed of far tinier things: swarms of negatively charged electrons (denoted by the symbol e^-) gyrating about a central core called the *atomic nucleus*. If an atom were somehow blown up to the size of a football stadium, its nucleus would be no bigger than a common housefly buzzing around near the 50-yard line. Yet over 99 percent of an atom's mass is concentrated in its nucleus!

In the 1930's atomic nuclei were themselves found to be made of *protons* (denoted by p) and *neutrons* (denoted by n) stuck together in various combinations. A proton is almost 2,000 times heavier than an electron and has the opposite electric charge; the electrically neutral neutron is slightly heavier than the proton. As both are components of nuclei, they are often referred to as *nucleons*.

With the discovery of these two nucleons, matter seemed simple again. All the various types of atoms could be readily explained as different combinations of electrons, protons, and neutrons. But this simple picture of matter did not last long. Many other particles similar to the nucleons turned up during the late 1940's and early 1950's, clouding the picture tremendously.

During the past three decades, however, high-energy physicists have discovered that protons, neutrons, and a large group of heavy particles like them are not truly "elementary" as previously thought. These subatomic particles are instead composed of pairs and trios of unusual particles called *quarks*. Electrons and quarks are today thought to be the fundamental building blocks; both have no apparent size, as far as we can tell. For all we know, they may be truly elementary—in every sense of the word.

To study matter at small distances, scientists use energetic (high-speed) particles. From the way these particles rebound from an object, its structure can be determined. The higher the energy of the probes, the tinier the structural features that can be examined. Using visible light, made of elementary particles called *photons,* one can easily discern objects like human cells millionths of an inch across. Electron microscopes probe matter with beams of electrons accelerated through thousands of volts to uncover features hundreds of times smaller. The most powerful and sensitive electron microscopes today can even resolve individual atoms.

To probe *inside* the atom and discern its internal components and their structure, however, particles with far higher energies are required. They must be boosted to extremely high speed and shot *through* atoms. Any deflection of these probes indicates the presence of something inside.

In 1911, the British physicist Ernest Rutherford used streams of high-energy *alpha* particles (actually the nuclei of helium atoms, made of two protons and two neutrons) to peer inside gold atoms and discover the atomic nucleus. Produced by nuclear disintegrations, these alpha particles came shooting out violently. By aiming them at a gold foil and observing how they bounced off it, Rutherford and his assistants were able to conclude that a gold nucleus was very tiny indeed—about a trillionth of a centimeter (10^{-12} cm) across.