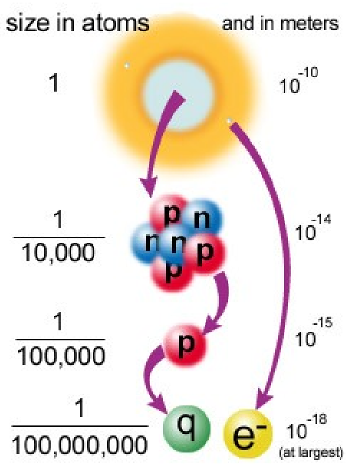
Vol.6, No. 111 UIC TODAY *April 4-5, 2002*

Search for the Smallest Constituents of Matter

From the time humans began to ask questions about themselves and their world, they have wondered what the world is made of and how it behaves. Over and over, in different times and with different methods, people have tried to answer the questions, "What is the smallest possible piece of matter? What are the fundamental forces of nature?" From the time of the ancient Greeks, with their designation of the elements Earth, Air, Fire, and Water, this ongoing quest has yielded extraordinary advances in knowledge that make our universe more understandable. Today, the fundamental science of high-energy or particle physics continues to pursue answers to these most ancient, and most modern, of questions.

In the 19th century it was understood that everyday objects are made of molecules, then that these molecules are composed of *atoms* (from a Greek word meaning "indivisible"). The atoms were later discovered to consist of a nucleus orbited by electrons, and by the 1930's it was found that the nucleus is made up of particles called protons and neutrons. In the late 1960's a series of experiments at the Stanford Linear Accelerator Center in California demonstrated that these protons and neutrons are themselves made of smaller constituents, which were named *"quarks"* (a quirky name perhaps in tune with the spirit of the sixties). Over the last three decades physicists developed a theory which describes all matter and forces in the universe (except gravity) called the *Standard Model*. In the Standard Model, all matter is composed of either quarks (protons and neutrons for example) or leptons (electron being a type of lepton). In this theory, the quarks and leptons are assumed to be fundamental objects, that is, there are no smaller constituents inside them.



Physicists at UIC and from around the world working at the world's highest-energy particle accelerator, the Tevatron collider at Fermilab (in Batavia, Illinois), study the results of extremely hard collisions between protons and their antimatter counterparts, antiprotons. Much like hitting a watch with a sledge hammer, sometimes the debris from these collisions can give us a lot of insight into the structure and workings of the proton and other forms of matter. In these high-energy collisions, one of the quarks inside the proton collides with one of the quarks inside the antiproton; if the collision is violent enough, a whole shower of particles is produced from the energy of the collision. Particle physicists use large and complex arrays of instrumentation called *detectors* to measure the energy and position of these outgoing particles.

By studying correlations of the outgoing particles and the frequency of such rare violent collisions, UIC physicists and their colleagues at the DZERO experiment at Fermilab observe that the quarks and electrons are behaving like mathematical points – entities with no size at all, and not composed of any smaller building blocks. Given the precision of our measurements, we can be sure that quarks and electrons are smaller than one twenty thousandth of a trillionth of a centimeter, or 5×10^{-17} cm. This is about ten thousand times smaller than the size of a proton! These results are the world's best test of the point-like nature of quarks and electrons and are in fact the best measurement of these smallest known objects. Last year the two experiments at Fermilab (CDF and DZERO) started taking data with improved detectors, hoping to unveil the secrets of matter at even smaller scales. Stay tuned for more exciting news from the Laboratory near you…

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