This paper will give a general overview of the current thoughts on the building blocks of atoms through the scope of the Standard Model. There will be an abridged explanation of the interactions that these elementary particles share with one-another. A qualitative description of the standard model of particle physics will be given without quantitative analysis. Special interest paid to the D0 detector's role in current research.

Democritus, a fifth century B.C. philosopher, is credited with being the first person to attempt to name the smallest particles of matter. He called them *atomos* or atoms. He believed that these particles were the foundation upon which all objects were built. It was not until the late nineteenth and early twentieth centuries that scientists became aware that atoms were divisible. The electron was understood to orbit a central nucleus. This nucleus, though only a tiny fraction of an atom=s volume, held almost all of its mass. The nucleus was composed of two types of particles, but it would later be learned that these too could be divided into more basic particles. Today, the question in modern elementary particle physics is what exactly are the absolute smallest particles of matter and how do they interact with each other to form our macroscopic world. The Standard Model, which is a comprehensive theory that combines the current knowledge of strong interactions and the unified theory of electroweak interactions is an attempt to answer this and other questions.

Since Democritus, there has been a great deal of information gleaned from theoretical work and experimental data. The twentieth century saw the greatest advancement in the search for truly fundamental particles. Atoms were discovered to be comprised of negatively charged electrons orbiting a central nucleus of positively charged protons and neutral neutrons. During the nineteen thirties, these three particles were thought to be the smallest parts of matter, but this view would not last for long.

The next breakthrough came with the understanding that there are two basic types of particles: hadrons and leptons. While hadrons are influenced by the strong nuclear force, leptons are not. Hadrons are particles like the proton and neutron that are bound together by the strong force. There are many types of hadrons but only a few leptons. An electron is an example of a lepton[1].

Today, the theory has evolved to include six types of quarks. These quarks only exist in hadrons, because they must be held by the strong force. For this reason, it has not been possible to isolate them and directly measure their masses. Quarks are divided into three generations. The first generation is comprised of the up and down quarks; their charges are +2/3 and -1/3 respectively. The second generation holds the charmed and strange quarks with charges +2/3 and -1/3. And the third generation is made up of top and bottom quarks with charges +2/3 and -1/3. Matter is made up of quarks from the first generation. Generations two and three are only present at very high energies and, as such, are unstable and quickly decay into members of lower order generations[4]. From this it is clear that the proton is made up of two up quarks and one down quark. By adding the charges of these quarks together, the proton=s charge is +1. The same process for the neutron, shows that one up quark and two down quarks are needed to satisfy the neutron=s neutral charge.

Similarly, there are three generations of leptons. The first generation is comprised of the electron and the e-neutrino. The second generation is made up of the mu and mu-neutrino. The third generation holds the tau and tau-neutrino. The electron, mu and tau all have a charge of -1 while the three types of neutrinos carry no charge.

These fundamental particlesBleptons and quarksBall have spin 2. This spin property is important; because it allows physicists to further catagorize objects. Particles with integral spin are bosons and particles with 2 integral spin are named fermions. All leptons and quarks are then categorized as fermions. Bosons are mediating particles, such as photons, and certain combinations of fermions[4].

It is necessary to note that all of the above particles have a corresponding antiparticle. An antiparticle has almost identical characteristics to its mirror particle but with an opposite charge. A positron and an electron, for example, have opposite charges but are otherwise nearly undistinguishable by any other feature. Antimatter is very rare in the universe; as anytime that it comes in contact with matter, the two completely annihilate into pure energy.

There remain many unanswered questions and inconsistencies that keep the current working model incomplete. There is no explanation as to why matter should break into quarks and leptons, nor is it known why there are only six quarks and six leptons. There is also the unsolved question of why the universe is filled with matter while there is relatively no antimatter. Further, even with the current understanding of the different types of forces that act on particles, the question of the root of mass is still unanswered by the Standard Model.

Four types of forces are recognized as acting on particles. These are the strong, electromagnetic, weak and gravitational forces. The strong force binds quarks together to form neutrons and protons and similar particles. The electromagnetic force pulls oppositely charged particles together, such as electrons and protons. The weak force allows larger particles to decay into smaller particles. The gravitational force does not act on elementary particles to any noticeable effect but instead moves objects at a macroscopic level.

Each of these forces has a particle that mediates it. The strong force is mediated by gluons that bind quarks together to form protons, mesons and neutrons. The electromagnetic and weak interactions use leptons in their interchanges. The electromagnetic force is mediated by photons while the weak force is mediated by W and Z bosons. The Standard Model does not fully explain why photons have no mass and W and Z bosons do[2]. This difference is noticeable at low energies, but disappears as energies reach higher and higher levels, thereby effectively nullifying the mass problem. This discrepancy has a theoretical answer in the Higgs boson.

The Higgs boson was proposed by Peter Higgs to explain where fundamental mass originates. His explanation was that a field permeated all space. As a particle passed through the field, it might interact with it. The more that the particle interacted with the field the greater its apparent mass. And just as the electromagnetic field is associated with the photon, so the Higgs boson is associated with the Higgs field. This particle has not been found, but is theorized. If it is found not to exist, then there will be a serious flaw in the Standard Model that will require some new ideas. Experiments at CERN and Fermilab have so far failed to find the Higgs boson, but with recent modification made to the D-Zero project at Fermilab=s collider, there is hope that the discovery will come soon.

The difficulties finding the Higgs boson stem from the extreme energies needed to break apart the accelerated particles. It is theorized that two quarks having a minimum of 1 TeV (one trillion electron volts) of energy must strike each other. This would require about 40 TeV of energy within the volume of a proton.[2] To obtain these high energies, particles are accelerated using extremely complex mechanisms that attempt to sort through the aftermath of a collision occurring between two particles at relativistic speeds. This is accomplished by setting detectors to recognize the expected behaviors of many different particles. If any particles are seen exhibiting these behaviors, then the detector registers the signature as being from the prescribed particle.

While current research appears to support the Standard Model, there are a few problems that need to be addressed. The model is only accurate up to the electroweak symmetry breaking scale--245GeV(245 billion electron volts); it is wholly invalid for energies outside the Planck scaleB >10^19GeVBwhere gravitational effects cannot be ignored. There is also a problem with the Standard Model treating neutrinos as massless, because recent experiments suggest that this may not be the case. Another question that remains unanswered is the inability to independently calculate all of the parameters of the Standard Model, such as, particle masses. Even with these short comings, most physicists agree that this is currently the most comprehensive model to describe the foundations of matter and its subatomic interactions. The future promises new discoveries and better explanations as experimental techniques are refined, new technologies are unveiled and theoretical work continues.

The cutting edge of this field now lies at the D0 detector at Fermi National Laboratory's proton/anti-proton collider. The necessary energies are produced by accelerating the particles around a 4 mile circumference ring to 99.9999% of the speed of light. When the particles collide there is an enormous amount of data produced. D0 is the detector that sorts through this data and tries to output all relevant information for scientists to inspect. The detector itself is 4 stories tall and weighs over 10 million pounds. All of the data requires that there be 800,000 path ways to collect it from, though only 400,000 are used during any one event.

Democritus= *atomos* were the beginning of the search for the fundamental building blocks of matter. Through the twentieth century, the model of matter=s foundations has continued to grow in its sophistication and scope. It was not until the late nineteenth and early twentieth century that scientists became aware that atoms were divisible. The electron was understood to orbit a central nucleus. Today=s questions in modern elementary particle physics are partially answered by the Standard Model. Though it is not perfect, it continues to prove its worth through experimental confirmation and to evolve into a more and more comprehensive and applicable model.

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