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Journeying to the Heart of the Matter

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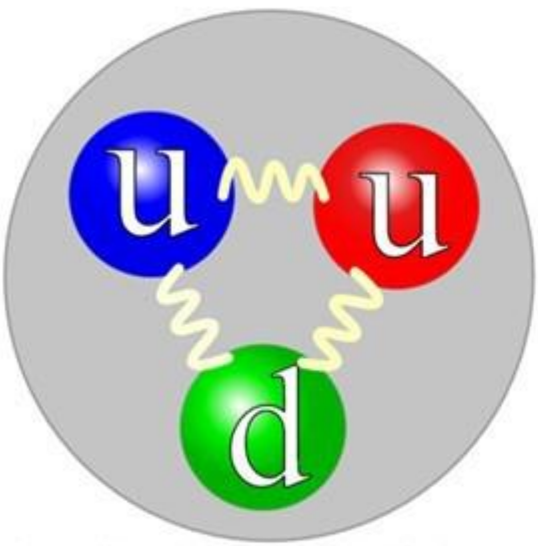
On December 5th, 2016 Dr. Douglas Higinbotham, a staff scientist from Thomas Jefferson National Accelerator Facility, took us on a journey to discover the building blocks of matter: quarks. This path began 3000 years ago when Aristotle believed earth, air, wind, fire, and æther to be the building blocks of matter. This initial model was revised many times, leading to the late 1800's formulation of the periodic table of the elements. In this table each element was considered to be one building block. However, as Dr. Higinbotham mentioned, the model was too complex, going from 5 to over 100 individual pieces. The model was then simplified to 3 building blocks – protons, neutrons, and electrons. The model gained complexity again with the quantum mechanical table of the elements – a simplification of the periodic table of elements based on the arrangement of electrons – and the Chart of Nuclides, an inclusive arrangement of elements with a varying number of neutrons. Scientists again wanted a simpler model and realized neutrons and protons were made of smaller particles. These subatomic particles were called quarks and held together by a glue-like particle called the gluon. Quarks come in flavors (pairs) of up and down, strange and charm, and top and bottom. Using only up quarks, down quarks, and electrons, the entire periodic table of the elements can be reconstructed. This model, called the Standard Model, was supported with the detection of the Higgs Boson, a predicted particle, at CERN (European Organization for Nuclear Research).



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One mission of Jefferson Lab is understanding how to create quarks and gluons from protons and neutrons, and vice versa. Dr. Higinbotham introduced how particle physicists detect these particles. Similar to how X-rays work, we can "see" the charged particles in devices such as a cloud chamber by looking at the paths it travels. The scientists use linear accelerators, aka atom smashers, to create quarks and gluons by breaking apart neutrons and protons. A beam of electrons is created and then accelerated around a "race track" using magnets. The resultant electron beam is 12 GeV, which is over one trillion times the voltage you can get from a wall socket, and requires massive amounts of engineering to create. The electron beam is directed into the experimental setup and “breaks” apart the protons and neutrons. The particles created by the collision are tracked and identified using mathematical models that take data from particle detectors, such as Cherenkov detectors.

Dr. Higinbotham illustrated the importance of researching the behavior of protons and neutrons when an experiment resulted in astrophysicists changing their picture of a neutron star. Not only is particle physics relevant to other sciences, but it also has applications in MRI imaging, proton therapy for cancer patients, and homeland security. The most important implication of this research is that scientists now realize the building blocks of matter to are quarks, gluons, and electrons.

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