# Rutherford’s Gold Foil Experiment

Rutherford's Gold Foil Experiment proved the existence of a small massive center to atoms, which would later be known as the nucleus of an atom. Ernest Rutherford was born in 1871 in Brightwater, New Zealand. After graduating from the University of New Zealand, Rutherford researched at both Canterbury University and McGill University, which are located in the United Kingdom and Canada respectively. At both universities he studied radioactivity and radiation. He eventually was offered the Langworthy Professor of Physics position at the University of Manchester. At the University of Manchester, Rutherford aided Professor Hans Geiger in creating the Geiger Counter. This device detects alpha particles. Geiger and Rutherford had previously revealed in 1908 that the alpha particles were helium ions, as both had the same atomic light spectrum (emission spectrum). With tensions high in Europe on the verge of WWI, and many German scientists working on x-ray and radiation research, pressure was put on English scientists to match these with new discoveries. After determining the identity of the alpha particles, Rutherford, Geiger, and Geiger's graduate student Ernest Marsden decided to test how alpha particles interacted with other elements. They tested this by shooting alpha particles at a thin gold foil.

Ernest Rutherford hypothesized that an atom's mass was uniformly spread out in its shape. In the Gold Foil Experiment he shot alpha particles at a thin sheet of gold; he thought the particles would travel right through the sheet, rather like a bullet traveling through a sand bag. However, he found that a minute percentage of alpha particles ricocheted backwards. This led him to conclude that most of the mass of an atom was centered in the positive nucleus, while only a small amount of mass surrounded this positive ball.

Ernest Rutherford, Hans Geiger and Ernest Marsden carried out their Gold Foil Experiment to observe the effect of alpha particles on matter. Rutherford devised a way to record the location of the alpha particles by surrounding the bombarded object with a sheet coated in ZnS, which would emit of flash of light when hit with an alpha particle. Through previous experiments of shooting alpha particles, Rutherford knew they had considerable mass and speed. He then hypothesized that these particles would penetrate a thin metal foil, although they may scatter slightly because of the charge in the metal atom's subatomic particles. After shooting alpha particles through the thin sheet of gold, Geiger, Marsden and Rutherford discovered that a small proportion of the molecules were scattered at larger than 90° angles. This caused them to conclude that there was a small fraction of the total volume of the atom that held most of the mass of the atom.

Works Cited

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# The Large Hadron Collider

Our understanding of the Universe is about to change...

The Large Hadron Collider (LHC) is a gigantic scientific instrument near Geneva, where it spans the border between Switzerland and France about 100m underground. It is a particle accelerator used by physicists to study the smallest known particles – the fundamental building blocks of all things. It will revolutionise our understanding, from the minuscule world deep within atoms to the vastness of the Universe.

Two beams of subatomic particles called "hadrons" – either protons or lead ions – travel in opposite directions inside the circular accelerator, gaining energy with every lap. Physicists use the LHC to recreate the conditions just after the Big Bang, by colliding the two beams head-on at very high energy. Teams of physicists from around the world then analyse the particles created in the collisions using special detectors in a number of experiments dedicated to the LHC.

There are many theories as to what will result from these collisions. For decades, the Standard Model of particle physics has served physicists well as a means of understanding the fundamental laws of Nature, but it does not tell the whole story. Only experimental data using the high energies reached by the LHC can push knowledge forward, challenging those who seek confirmation of established knowledge, and those who dare to dream beyond the paradigm.

# How the LHC works

The LHC, the world’s largest and most powerful particle accelerator, is the latest addition to CERN’s accelerator complex. It mainly consists of a 27-kilometre ring of superconducting magnets with a number of accelerating structures to boost the energy of the particles along the way.

Inside the accelerator, two beams of particles travel at close to the speed of light with very high energies before colliding with one another. The beams travel in opposite directions in separate beam pipes – two tubes kept at ultrahigh vacuum. They are guided around the accelerator ring by a strong magnetic field, achieved using superconducting electromagnets. These are built from coils of special electric cable that operates in a superconducting state, efficiently conducting electricity without resistance or loss of energy. This requires chilling the magnets to about ‑271°C – a temperature colder than outer space. For this reason, much of the accelerator is connected to a distribution system of liquid helium, which cools the magnets, as well as to other supply services.

Thousands of magnets of different varieties and sizes are used to direct the beams around the accelerator. These include 1232 dipole magnets of 15m length which are used to bend the beams, and 392 quadrupole magnets, each 5–7m long, to focus the beams. Just prior to collision, another type of magnet is used to "squeeze" the particles closer together to increase the chances of collisions. The particles are so tiny that the task of making them collide is akin to firing needles from two positions 10km apart with such precision that they meet halfway!

The CERN Control CentreAll the controls for the accelerator, its services and technical infrastructure are housed under one roof at the CERN Control Centre. From here, the beams inside the LHC are made to collide at four locations around the accelerator ring, corresponding to the positions of the particle detectors.

Physicists Detect New Heavy Particle



A proton-proton collision event in the CMS experiment producing two high-energy photons (red towers). This is what would be expected from the decay of a Higgs boson but it is also consistent with other, more common physics processes.

Image credit: CERN

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Signature resembles long-sought 'Higgs boson.'

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By: Virat Markandeya, ISNS Contributor

(ISNS) -- Scientists from two experiments at the Large Hadron Collider in Europe confirmed the existence of a new heavy particle, likely to be the long-sought Higgs boson, thanks to troves of particle-collision data that yielded discovery-level certainty upon analysis. The results, announced at a major particle physics conference in Melbourne, Australia, mark the culmination of a search for a heavy particle believed to give mass to elementary particles such as electrons and quarks.

RELATED: Higgs Boson Could Help Explain How We Exist [Video]

The announcements represent the current high-water mark for the $7-billion LHC particle accelerator at the Franco-Swiss border, which smashes together subatomic particles known as protons at super-high energies to recreate conditions thought to exist fractions of a second after the Big Bang.

"To me it's really an incredible thing that it's happened in my lifetime," said Peter Higgs, the British theorist after whom the particle is named, who was present at the conference and at times appeared choked with emotion. The ideas were in the air when Higgs had written a brief 2-page paper in 1964 that led to the moniker "Higgs boson." The Higgs has been the last undiscovered particle predicted by the Standard Model, the bedrock theory of known subatomic particles and the forces that govern them, and it also holds the promise of revealing new physics phenomena.

It was vindication for a generation of scientists. "Tears came in my eyes when the five-sigma number came up," said Brookhaven National Laboratory's Howard Gordon, who is the U.S. deputy operations program manager for the ATLAS experiment at the LHC. The U.S. contingent of ATLAS, hosted by Brookhaven and consisting of over 700 people from 44 institutions, helped to build many of its key detectors and handles about 20 percent of the worldwide computing effort involved in simulation and analysis of its data.

The two experiments, CMS and ATLAS, analyzed particle decay data from approximately 500 trillion particle collisions. Joe Incandela, spokesperson for the CMS experiment, said that if you imagine each collision as a grain of sand, you'd have enough sand to fill an Olympic swimming pool. However, Higgs-related collisions are so rare that the grains of sand would only cover the tip of a finger, he said.

At the ICHEP2012 conference earlier this morning, both groups reported "bumps" in their collision data indicating the presence of a particle with mass measured at around 125 -126 billion electron volts, abbreviated as GeV. This is over a hundred times heavier than the proton, which is the core of the basic hydrogen atom, and is only about 1 GeV.

Each LHC experiment confirmed these results to about five sigmas of certainty, indicating that there is less than a one in a million probability that these were chance results resulting from something other than the presence of a new particle.

"We have a new particle consistent with a Higgs boson," said Rolf-Dieter Heuer, Director-General of CERN.

The new particle was detected by the sprays of particles into which it decays. The Standard Model predicts that the Higgs can decay into pairs of about half a dozen types of particles, but other, more ordinary matter can also make similar decays. So experimental physicists must tally up the number of events in each of the ways a Higgs particle can decay and look for unexpected excesses in these decay events. At a very basic level, it is like rolling a die again and again to figure out if it is loaded.

The CMS experiment studied five decay channels of which two, where the decay is into a pair of photons or particles known as Z bosons, are the most important because they allow for more precise measurements of the Higgs' mass. The combined significance of the signal for all five was 4.9 sigma.

The ATLAS experiment studied two main channels where the Higgs-like particle decays, into two photons or four leptons, a category of particles such as electrons and muons. It found a signature at around 126 GeV at a 5 sigma significance, combining the data from the two kinds of events.

"It is very, very nice for the Standard Model Higgs boson to be at that mass," said ATLAS spokesperson Fabiola Gianotti, because LHC is well suited to studying particles at that mass. "So thanks, nature," she added.

These results follow earlier LHC data and the Monday announcement from the Fermi National Accelerator Laboratory in Illinois of evidence, extracted from the less powerful and now-retired Tevatron accelerator, for the particle at a level of three sigma.

The Higgs mechanism answers the fundamental question of why most of elementary particles have masses. Without the Higgs, everything from stars to atoms would not exist. It was the last remaining piece of the Standard Model. Elementary particles, such as electrons and quarks, interact with the Higgs field and their interaction creates their mass.

Today's results represent a "marvelous achievement, the cornerstone of 400 years of efforts to explain what we observe in the universe," said Gordon Kane, a University of Michigan theoretical physicist who did not work on the experiment. The data, he said, suggest a particle that's remarkably close to the Higgs predicted by the Standard Model. Time will tell, he said, as to whether the small discrepancies that currently exist between the data and the predictions of the Standard Model are experimental errors or if they point to new physics beyond the Standard Model. If confirmed, even small deviations from the Standard Model could lead the way to new physics, and could be consistent with the predictions of major extensions to the Standard Model such as string theory.

The latest tranche represents merely a third of the data that ATLAS is expected to obtain in 2012. The current results are expected to be published by the end of July. "There's more to come…Please, in particular theorists, be patient. There is a long path to go," ATLAS spokesperson Gianotti jestfully chided the scientific audience.

The results came in the last runs of the experiments which ended about two weeks ago. The announcements were met by standing ovations and a surprisingly low number of questions at the end of the scientific presentations.

More questions flowed from layperson reporters at a post-seminar news conference. One reporter asked whether the results have any relevance to him, being that he's made up of elementary particles.

"I think it has a lot of relevance to you," said Heuer, the CERN Director-General of CERN, "because if that [Higgs field] would not exist, then you would not exist."

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