Foundation

Have we found the Higgs boson?

I'm a Scientist Get me out of here

The Large Hadron Collider (LHC) at CERN, one of the world's biggest international projects, regularly hits the headlines for its new discoveries. One particle they are looking for is the Higgs boson, but with so much data to collect, how will we know when they find it?

The Large Hadron Collider

It's hard work to split atoms up into smaller particles. Subatomic physics experiments are like crashing two cars together so fast that they break apart, then looking at the pieces.

What's surprising about the LHC isn't the energy involved, which is currently at 7TeV when protons collide. This is about 2 millionths of a joule, a lot smaller than you might expect (1TeV is about the kinetic energy of a flying mosquito). What makes it special is that the energy is concentrated into a space much smaller than the size of an atom.

The Standard Model predicts the existence of the **Higgs Field** and special particles called **Higgs bosons**. It is one of the best ways to explain how particles have mass. If it does exist, physicists predict that the LHC will produce Higgs bosons which will then break down to particles which can be observed by very sensitive detectors. The results will tell us how accurate the Standard Model is.

Loaded Dice?

Imagine you are given a die and told it might be loaded so that one side comes up more often than the others. It's hard to be sure if you're only allowed to roll it ten or twenty times; it wouldn't be surprising to roll a six several times in a row.

This pattern might be chance – or it might be because the die is unfair. As you roll it more and more, keeping track of the totals, initial patterns may be confirmed or contradicted. In theory, we can never be sure it is a balanced or loaded die, even with a clear pattern after 1000 trials; but the more often we roll the die the more confidence we can have in our conclusion.

Statistical Significance

With many thousands of collisions, some observations are repeated more than others. Some of these results can be identified as known particles. Others may be combinations of ones we know about, or entirely new ones. The more results that can be collected, the more confident scientists can be about the pattern. Early 'patterns' may turn out to be unrepeated flukes.

The accepted level for a scientific discovery in particle physics is called a 'five-sigma' result. This is a measure of how far a result is from what would be expected by chance, rather than an actual new particle being observed. A five-sigma result is equivalent to getting twenty heads in a row when tossing a coin – it is much more likely to be because of a real physical effect than just chance.

What makes it harder to be sure is that Higgs bosons are only produced very rarely. To be sure that particles seen are not just chance combinations, but are something new, we look for results that are **statistically significant.** There are several ways we can make the 'signal' of an actual event stand out more from the 'noise' of all the other particles produced during collisions.

1. Doing more experiments means that if they exist, more Higgs Bosons will have been produced in total.
2. Using very sensitive detectors, completely surrounding the collision, reduces the chance of us missing any particles.
3. Measuring very precisely means a clearer signal (Three particles between 155 and 156GeV stand out a lot more on a frequency chart than three somewhere between 150 and 160GeV).
4. Some regions are easier to examine because there is less 'background noise' - fewer particles to confuse the detectors.

Scientists say that the early results were always subject to change as they continued the experiment. A final result should be available before the end of 2012.

Science & Technology Facilities Council

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BBC news article

Higgs boson range narrows at European collider

Scientists at the Large Hadron Collider say a signal that suggested they might have seen "hints" of the long-sought Higgs boson particle has weakened.

Last month, scientists reported at the Europhysics meeting in Grenoble, France, that the collisions were throwing up some intriguing results.

The data presented at the meeting showed what physicists described as "excess events" across the search area - or mass region - where the Higgs has been predicted to be found. The most significant of these was a surplus of unusual particle events at a mass of 140-145 gigaelectronvolts (GeV).

New results to be presented this week at a conference in India all but eliminate the mid-range where the Higgs - if it exists - might be found. The ranges left after these results suggest that the Higgs is either quite a light particle, below about 145 GeV, or a heavy one, above 466 GeV. It is much more difficult to detect new particles in these ranges, however.

"These are exciting times for particle physics," said Sergio Bertolucci, the research director at the European Organization for Nuclear Research (Cern), which runs the LHC. "Discoveries are almost assured within the next 12 months. If the Higgs exists, the LHC experiments will soon find it. If it does not, its absence will point the way to new physics."

bbc.co.uk/news 22nd August 2011

One important thing to remember is that to the scientists a **negative result** is not a failure. Being 95% sure that Higgs bosons do not have a mass within a certain range lets scientists concentrate on other possibilities. This is like rescue teams searching open areas of a park quickly and not finding a missing person - it lets them focus on other areas like dense woodland.

LHC Facts

1. **The total cost of the LHC is around €4 billion.**
2. **The tunnels form an approximate circle with a circumference of 26.659km.**
3. **It operates at -271.3 °C, cooled by liquid nitrogen and superfluid helium.**
4. **Protons travel around the ring 11245 times per second.**

Questions

Get into pairs. Look at the BBC news article and answer these questions:

Q1 Discuss the earlier and later results mentioned in the news article with your partner. Should this be a surprise?

Q2 A new film is reviewed based on rehearsal clips of a few scenes, released on the internet. How is this similar to news reports on early LHC experiments?

Q3 Why does Sergio Bertolucci not seem disappointed by the thought of not finding the Higgs boson?