Don't panic about the missing Higgs – for now

- 18:00 28 August 2011 by **Lisa Grossman**
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Online quiz: "Will the LHC discover the Higgs boson?"

The world's most-wanted particle continues to elude the world's most powerful particle accelerator. A sign that the elusive Higgs boson doesn't exist? Not so fast. For now, there are good reasons to assume the Higgs is just hiding.

"It's never too early to think about it, but it is too early to worry," says Nobel prize-winner Frank Wilczek of the Massachusetts Institute of Technology.

The still-hypothetical Higgs boson is thought to endow all other particles with mass. Confirming its existence would complete the standard model of physics, the leading theory for how particles and forces interact. Finding the Higgs and pinning down its mass, or ruling out its existence and paving the way for new models, is one of the goals of the Large Hadron Collider at CERN near Geneva, Switzerland.

Since it started smashing protons together in 2009, the LHC has steadily collected data that help rule out various masses for the Higgs from a range of possibilities allowed by the standard model. Combined with earlier results from other accelerators, the latest LHC limits, announced on 22 August at the Lepton-Photon conference in Mumbai, India, mean the Higgs is now restricted to having a mass of between 115 and 145 gigaelectronvolts (GeV), or 122 to 154 times the mass of a proton (mass and energy can be treated interchangeably for particles).

Low-hanging fruit

This means that about 90 per cent of the possible masses for the Higgs are now ruled out, says CERN spokesman James Gillies.

And that has sparked speculation that the Higgs might not exist at all. If this turns out to be true – and it's certainly a possibility – it would leave room for exotic theories involving an extra force of nature. Indeed, some are banking on this. "I don't pay close attention to it, because I don't think it's going to show up anyway," says Ken Lane of Boston University.

It is still too soon to assume the universe is Higgs-less, however. Take the small mass range that's now left. It is at the low end of potential masses and so is the most difficult for the LHC to explore. A heavier Higgs would leave clearer tracks in the detector, but the lighter it is, the harder it would be to tell a true signal from other particles that produce similar tracks.

"In the low mass range, disentangling signals from noise is a more painstaking process, and needs more data," Gillies says. In other words, rather than sounding a death knell for the Higgs, the latest limits could merely signal that we have sorted through the low-hanging fruit.

Strict supersymmetry

Some Higgs hunters are actually relieved that it hasn't shown up yet as they never expected the particle to be heavier than 145 GeV. That's because, as the Higgs gives mass to the known particles, these particles can put limits on the Higgs's mass. Earlier experiments at accelerators like the Tevatron, the Large Electron Positron Collider and the Stanford Linear Collider suggest that the Higgs should be slightly heavier than the W and Z bosons, at between 120 and 130 GeV.

An extension of the standard model called supersymmetry makes an even stronger case for a light Higgs. Theoretically, the standard model allows the Higgs to weigh almost anything. But supersymmetry, which calls for twice as many particles as the standard model, has stricter rules. This theory directly links the Higgs mass to the W and Z boson masses, plus offers some quantum corrections that bump it up to about 130 GeV.

"In a sense, these [latest] results from the LHC are not surprising," Wilczek says. "It would have been very embarrassing for supersymmetry and the properties of the particles we know about if the Higgs had been discovered in the range of masses that have [now] been explored."

There's another explanation for the Higgs's absence: it decays into particles we don't know how to detect, such as dark matter or as yet unknown particles. In that case, the only way to detect the Higgs would be by looking for tiny amounts of missing energy.

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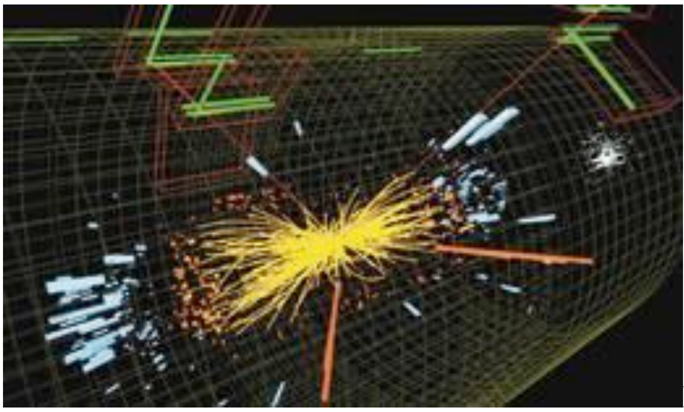
News

News

Hint of Higgs, but little more

No signs of exotic new physics have yet emerged from Europe's giant particle accelerator.

Geoff Brumfiel



Particle collisions at the Large Hadron Collider — including this smash-up observed by the Compact Muon Solenoid detector — are not yet giving physicists many surprises.CERN

GRENOBLE, FRANCE

When its experiments started in earnest earlier this year, many scientists hoped that the world's most powerful collider would turn up new particles, additional dimensions and perhaps even a small black hole or two. But beyond a handful of unusual events, the latest data from the Large

Hadron Collider (LHC) are frustratingly ordinary.

Based at CERN, Europe's premier high-energy physics lab near Geneva in Switzerland, the LHC accelerates protons to almost the speed of light before slamming them together to create new, heavier particles. For more than a decade, theorists have hoped that the LHC might be powerful enough to generate previously unseen phenomena that would shake the sturdy standard model of particle physics to its core.

But the latest findings from the machine couldn't raise even a tremor inside the main auditorium of the Alpexpo centre in Grenoble, where scientists gathered last week for the International Europhysics Conference on High Energy Physics. In one session, Helen Hayward, an experimental physicist at the University of Liverpool, UK, flashed her data from the LHC's ATLAS detector onto the screen, along with the standard model's predictions of the particles that should have emerged from the smash-up. Her observations matched the predictions so perfectly that many of the numbers were identical. "You can see that there's good agreement," she said, with a hint of disappointment. She wasn't alone: in talk after talk, analyses followed the standard model's predictions with unwavering fidelity.

There was one exception. On Friday afternoon, groups working on the two main detectors at the LHC presented evidence of a few extra particles corresponding to something new at energies around 140 giga-electronvolts (GeV). For now, physicists are only willing to call them "excess events", but if the signal grows stronger as data accumulates, then it could be a sign of the Higgs boson, a vital component of the mechanism that endows other particles with mass. Since the 1960s, scientists have believed that the Higgs, or something like it, is needed to explain why some particles are heavy and others have no mass at all. The Higgs would also be the key to combining the weak nuclear force — which governs some forms of nuclear decay — with the electro-magnetic force, into a single 'electroweak' force. This would see the carriers of the two forces — the W and Z bosons, and the photon, respectively — merge into a single entity at high energies.

“Supersymmetry is clearly on the ropes.”

But even the Higgs is technically part of the standard model. Instead of confirming the status quo, many physicists anticipated that the LHC might point them in new directions. In particular, theorists hoped the accelerator would turn up evidence supporting a theory called supersymmetry, dubbed SUSY, which postulates a shadowy world of heavy particles corresponding to familiar ones. These superparticles could explain dark matter, mysterious cosmic stuff that seems to interact with the visible world only through gravity. SUSY particles would also eliminate troublesome quantum fluctuations that appear in the standard model and threaten to make nonsense of calculations of the Higgs' mass.

Earlier findings had already cast doubt on SUSY (see Nature **471,** 13–14; 2011). Now data presented by Hayward and others suggest that superparticles predicted by the most common formulations of SUSY must be heavier than 1,000 GeV. The LHC will probe higher energies as it gathers more data, leaving a chance that it may yet find the superparticles. But even if it did, they would be much too heavy to quell the quantum fluctuations that the theory was originally designed to control. "Supersymmetry is clearly on the ropes," says Rob Roser, a physicist at Fermilab in Batavia, Illinois.

SUSY's supporters say that lighter super-particles could still exist, despite the data, in some formulations of the theory. "I'd say SUSY has a mild hangover for the moment," says Ben Allanach, a theoretical physicist at the University of Cambridge, UK. But, he adds, when the LHC begins operating at its full energy of 14 teraelectronvolts — twice its current level — in a few years time, that hangover could turn into a "fatal migraine".

Others say that data collected during the next six months may be enough to cause serious headaches for theorists. By that point, physicists expect to have gathered enough data to either build up the Higgs signal or prove, once and for all, that the mass-giving boson doesn't exist.

With petabytes of data to be gathered over its 20-year lifetime, the collider could still turn up something entirely new. But many at the meeting admitted disappointment that nothing unusual has popped up inside the machine so far. "I think a lot of people thought there would be some low-hanging fruit," says Roser.

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Large Hadron Collider results excite scientists

By Paul Rincon Science reporter, BBC News, Grenoble

The Atlas experiment is one of two multi-purpose experiments at the LHC

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The Large Hadron Collider (LHC) has picked up tantalising fluctuations which might - or might not - be hints of the sought-after Higgs boson particle.

But scientists stress caution over these "excess events", because similar wrinkles have been detected before only to disappear after further analysis.

Either way, if the sub-atomic particle exists it is running out of places to hide, says the head of the European Organization for Nuclear Research (Cern), which runs the LHC.

He told BBC News the collider had now ruled out more of the "mass range" where the Higgs might be.

The new results are based on analyses of one inverse femtobarn of data, gathered as the vast machine smashes beams of protons together at close to light-speed.

Scientists from two different experiments (Atlas and CMS) based at the LHC are scouring the wreckage of these collisions.

One of their primary goals is to search for hints of the Higgs, which is the last missing piece in the Standard Model - the most widely accepted theory of particle physics.

Without the Higgs, physicists cannot explain why particles have mass. But despite the best efforts of scientists working on both sides of the Atlantic to detect it experimentally, the boson remains a theoretical sub-atomic particle.

Statistics of a 'discovery'

- Particle physics has an accepted definition for a "discovery": a five-sigma level of certainty
- The number of sigmas (or standard deviations) is a measure of how unlikely it is that an experimental result is simply down to chance rather than a real effect
- Similarly, tossing a coin and getting a number of heads in a row may just be chance, rather than a sign of a "loaded" coin
- The "three sigma" level represents about the same likelihood of tossing more than eight heads in a row
- Five sigma, on the other hand, would correspond to tossing more than 20 in a row
- A five-sigma result is highly unlikely to happen by chance, and thus an experimental result becomes an accepted discovery

Rolf-Dieter Heuer, director-general of Cern, said the amount of data gathered was a factor of 20 greater than had been amassed at the same time last year.

"With one inverse femtobarn, you cannot cover the entire mass region which is allowed for the Higgs boson," Professor Heuer told me.

"However, the experiments can now - unfortunately - exclude quite a large part of this allowed mass region."

Physicists think the Higgs will most probably be found in the low-mass region - between 114 GeV (gigaelectronvolts) and 140 GeV. While the gigaelectronvolt is a unit of energy, in particle physics, mass and energy can be interchanged because of Einstein's equivalence idea (E=MC2).

Professor Heuer said that searches at low masses had picked up small fluctuations "here and there", but that this was expected because physicists were analysing small numbers across a number of different "channels".

"The whole thing becomes more interesting the more data we collect," he explained.

News of the surplus of interesting events - seen by both the Atlas and CMS teams - were outlined at the European Physical Society's HEP 2011 conference here in Grenoble, France.

One candidate noted by the Atlas team occurs at the higher mass of 250 GeV and has reached the 2.8 sigma level of certainty. A three-sigma result means there is roughly a 1 in 1,000 chance that the result is attributable to some statistical quirk in the data.

Five sigma means there is about a one-in-one-million chance that the "bump" is just a fluke and is the level generally required for a formal discovery.

Another Atlas fluctuation occurs between 130 GeV and 150 GeV and is at the 2.5-sigma level.

Professor Dave Charlton, who works on the Atlas experiment at the LHC, called the excess of events "intriguing".

But the particle physicist from the University of Birmingham, UK, told BBC News these "could go up to three sigma, or they could disappear".

HEP 2011 runs until 29 July in Grenoble.

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News

Collider sees tantalizing hint of Higgs

Excess events suggest LHC is homing in on elusive particle.

Geoff Brumfiel

Researchers at the Large Hadron Collider say they could confirm the existence of the Higgs boson within a matter of months.Claudia Marcelloni/CERN

For now, physicists are only willing to call them 'excess events', but fresh data from two experiments at the Large Hadron Collider (LHC) are hinting at something unusual — and it could be the most sought-after particle in all of physics.

Both ATLAS and the Compact Muon Solenoid (CMS) experiments are seeing an unusual surplus of events in a rough mass range of 130–150 gigaelectronvolts (energy and mass are used interchangeably in particle physics). The data are far from conclusive, but physicists believe this could be the first indication of the Higgs particle, believed to be responsible for the masses of other particles. The results were presented this afternoon at the Europhysics Conference on High Energy Physics in Grenoble, France.

Physicists familiar with the experiments urge caution. The new data are a long way from a discovery, says Matthew Strassler, a theoretical physicist at Rutgers University in New Jersey. "I would call it tantalizing."

The hunt for Higgs

Since its prediction in 1964, the Higgs has been the most wanted particle in all of physics. The particle is part of the mechanism that endows all other particles with mass. The standard model of particle physics, which has been verified to astonishing accuracy, also requires a Higgs (or something like it) to unify the weak nuclear force, which regulates nuclear decays, and the electromagnetic force, which governs electricity, magnetism and light.

To track down the Higgs, high-energy physicists have built the LHC — a 27-kilometre ring housed at CERN, the European particle-physics laboratory near Geneva, that accelerates protons to near the speed of light and then smashes them together. The collisions can briefly create heavier particles. Those heavier particles then decay into a cascade of lighter particles that are picked up by building-sized detectors.

The two largest detectors, ATLAS and CMS, are now reporting excess numbers of lighter particles in the range of 130–150 GeV. That is smack in the middle of the range in which some physicists believe the Higgs particle might exist.

The statistics are far from conclusive, and the signal could yet disappear. "We really need to be very prudent; we really need to be systematic," says Guido Tonelli, the spokesperson for the CMS experiment. In the coming months, Tonelli says that CMS will focus its efforts on probing the unusual bump.

"I think that we have to be extremely careful," agrees Fabiola Gianotti, spokesperson for the ATLAS detector. Gianotti says that these low-energy excesses, and a few others seen at higher energies, could yet disappear when more data are collected.

Much of the increase seems to be in the decay of particles called W bosons. W bosons help to moderate the weak nuclear force, and theory predicts that the Higgs can sometimes decay into a pair of Ws. Both experiments have seen an unusually large number of W pairs. But they do not have enough events to confirm the excess as a signal. What's more, the way W particles themselves decay means that they cannot give a precise value of the Higgs' mass.

Even if the excess is a real signal, it could be down to a theoretical miscalculation, says Strassler. Predicting the precise quantities in which W bosons decay can be tricky, and the standard model may simply need an adjustment to explain the excess.

The picture will change rapidly in the coming months. At present, the LHC is "going gangbusters", says Vivek Sharma, a researcher at the University of California, San Diego, who is heading the Higgs search at the CMS. ATLAS and the CMS will combine their results at next month's Lepton Photon meeting in Mumbai. Additional data this autumn and winter should either confirm the excess as a real signal or show once and for all that a Higgs, at reasonably low masses, doesn't exist.

"I'm excited," Tonelli says. "We have been working in this field for 20 years and now in a matter of months we'll know the answer."

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Higgs boson 'hints' also seen by US lab

By Paul Rincon Science reporter, BBC News, Grenoble

The Tevatron might also be seeing hints of the elusive particle

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A US particle machine has seen possible hints of the Higgs boson, it has emerged, after reports this week of similar glimpses at Europe's Large Hadron Collider (LHC) laboratory.

The Higgs boson sub-atomic particle is a missing cornerstone in the accepted theory of particle physics.

Researchers have been analysing data from the Tevatron machine near Chicago.

The hints seen at the Tevatron are weaker than those reported at the LHC, but occur in the same "search region".

Physicists have cautioned that these possible hints could disappear after further analysis.

But researchers also say when the US and European results are taken together, they start to paint an "intriguing" picture.

The results are being presented and discussed at the Europhysics conference in Grenoble, France.

"There might be some picture emerging from the fog"
Professor Stefan Soldner-Rembold DZero spokesperson
The Tevatron and LHC machines work on similar basic principles, accelerating beams of particles to high energies around a tunnel before smashing them together.

These collisions can generate new particles which can then be picked up by detectors built at the points where particle beams cross over.

The LHC, which is housed in a 27km-long circular tunnel below the French-Swiss border, has two detectors looking for the Higgs: Atlas and CMS. Each is staffed by a different team of scientists.

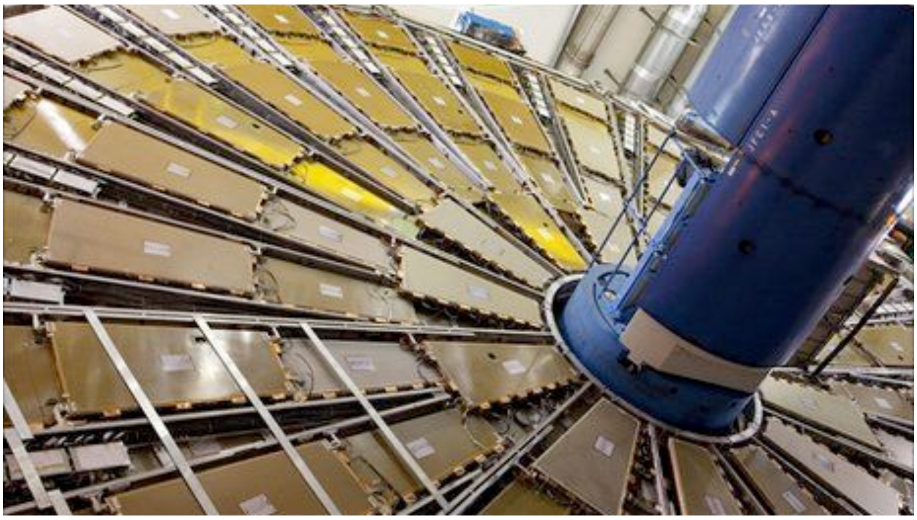
The Tevatron has a comparable arrangement, with two detectors called DZero and CDF.

Just a quirk?
On Friday, the Atlas and CMS teams reported finding what physicists call an "excess" of interesting particle events at a mass of between 140 and 145 gigaelectronvolts (GeV).

The excess seen by the Atlas team has reached a 2.8 sigma level of certainty. A three-sigma result means there is roughly a one in 1,000 chance that the result is attributable to some statistical quirk in the data.

Now, the US DZero and CDF experiments have also seen hints of something at about 140GeV.

Professor Stefan Soldner-Rembold, spokesperson for the DZero detector team, told BBC News: "There are some intriguing things going on around a mass of 140GeV.


The Atlas experiment is one of two multi-purpose experiments at the LHC
Professor Soldner-Rembold, from the University of Manchester in the UK, added: "There might be some picture emerging from the fog."

The Tevatron is also seeing the same type of interesting particle events as the LHC. In these events, one elementary particle "decays", or transforms, into another with a smaller mass.

The interesting fluctuations seen at the Tevatron and the LHC are dominated by what might be the Higgs decaying into a pair of "W boson" particles.

But the Tevatron results are currently at the one-sigma level of certainty - a lower level of statistical significance than those presented by the Atlas and CMS teams.

Five-sigma is the level of certainty generally required for a formal discovery. At this significance level there is about a one in 1,000,000 chance that a bump in the data is just a fluke.

However, says Professor Soldner-Rembold, the fact that teams working independently are now seeing similar phenomena point to an exciting possibility.

The existence of the Higgs boson was first proposed in the 1960s by Edinburgh University physicist Peter Higgs. The boson helps confer the property of mass on all other particles through their interaction with something called the Higgs field.

The efforts put into finding the boson relate to its status as the last missing piece in the the Standard Model - the most widely accepted theory of particle physics.

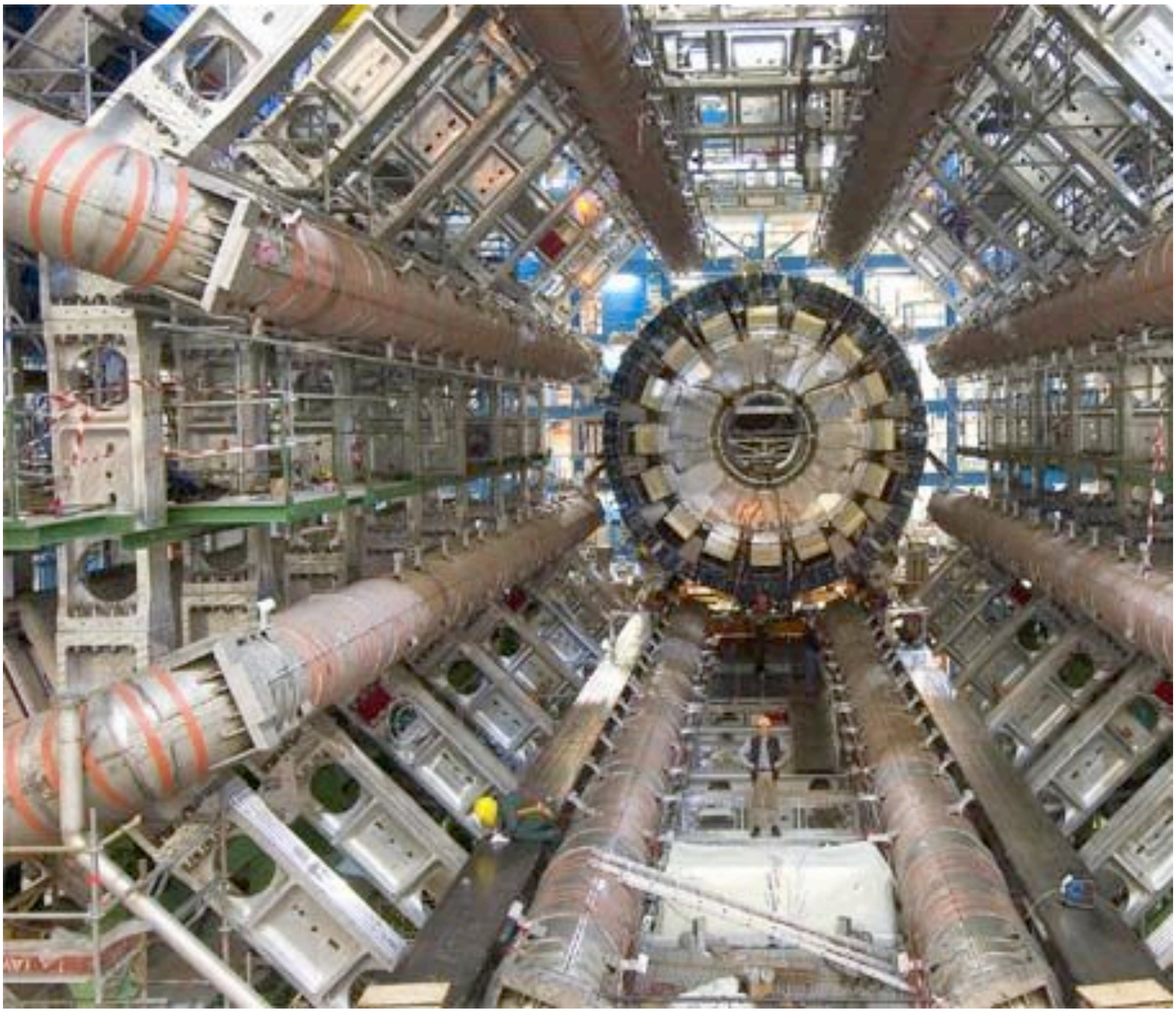
The Standard Model is a framework that explains how the known sub-atomic particles interact with each other. If the Higgs boson is not found, physicists would have to find some other mechanism to explain where particles get their mass.

Paul.Rincon-INTERNET@bbc.co.uk

Has the LHC found a hint of the Higgs

boson?

22:49 22 April 2011
Physics & Math
David Shiga, reporter



(Image: ATLAS Experiment © 2011 CERN)

Physics blogs are alive with chatter about a possible sign of the Higgs boson – or perhaps an entirely unexpected particle – in data from the Large Hadron Collider near Geneva, Switzerland. But the claim has not gone through the experiment's vetting process and could easily turn out to be wrong, physicists say.

The LHC, which smashes beams of protons together, was built largely in the hope of netting the first observational evidence of the Higgs, which is thought to endow other particles with mass. The Higgs is the last undiscovered particle in the standard model of particle physics, which for three decades has reigned supreme in explaining how particles and forces interact.

The latest rumours of its possible sighting come from an abstract that was posted by an anonymous commenter on mathematician Peter Woit's blog on Thursday.

The abstract appears to be part of a longer paper written by four physicists involved with the LHC's ATLAS detector, though the full paper has not been posted publicly yet.

The authors of the abstract say ATLAS data shows more photon pairs than expected with an energy of 115 GeV.

That number is interesting because many physicists think the Higgs boson is likely to have a mass of around 115 GeV – at least if supersymmetry, a popular theory that wraps up some of the standard model's loose ends, is correct. (Physicists often use energy units when describing particle masses, since they are related according to Einstein's formula $E=mc^2$.)

The Higgs should occasionally decay into a pair of photons, which would produce a bump in the photon-pair energy distribution. But if the Higgs has the properties predicted by the standard model, that bump should be much too small to see. The bump claimed in the abstract is 30 times bigger than the expected value.

The Résonaances blog by physicist Adam Falkowski has a good rundown of the possible explanations for the signal. Physicist bloggers Tommaso Dorigo and Lubos Motl have interesting discussions too.

The consensus seems to be that the paper itself is real rather than some sort of hoax, but the result may well turn out to be wrong.

However, it could be that the Higgs just behaves differently than expected. Physicists have dreamed up many ways to extend the standard model that would modify the properties of the Higgs. Some of these would boost the size of the photon-pair bump, though making it big enough still seems to be a stretch.

Or the bump could be from some unexpected new particle rather than the Higgs.

But perhaps the most likely explanation is that the bump is a mistake. Particle collisions are messy and it takes a lot of careful analysis to separate anomalies from mundane background events. An error somewhere along the way could make a bump appear that isn't really there.

It is worth noting that the claim is at a very early stage. Apparently the paper has not been reviewed or endorsed yet by the ATLAS collaboration, an organisation of hundreds of physicists that runs the detector.

By comparison, the 145 GeV bump seen recently in a different kind of measurement at Fermilab's Tevatron collider in Batavia, Illinois, had the backing of the collaboration that runs the CDF experiment the result was based on.

Even if the 115 GeV bump goes away, chances are good that the LHC will have more interesting results soon. CERN reports today that the LHC has broken the record for the world's most intense beams of colliding particles, snatching the title from the Tevatron. The LHC had already broken the record for collision energy, but now it has the highest rate of particle collisions per second as well, which should speed up new discoveries.