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**The Surprising Truth About the Higgs Boson "Discovery" at CERN**

Překvapivá pravda o „objevu“ Higgsova bosonu v CERNu

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SUMMARY

In 2012, the Higgs boson (the God Particle) was discovered. It's responsible for giving mass to fundamental particles. But the scientists never measured the particle. So how can scientists claim a discovery without ever having seen or measured it? What is a measurement anyway? The Standard Model shows that all fundamental particles that we know of are an excitation in their own field. Since the Higgs particle has a mass of 125 GeV, you must add 125 GeV worth of energy in the Higgs Field to form a Higgs particle. This is a very high energy level, equivalent to the rest mass of about 244,000 electrons. Making a Higgs is not easy because heavy particles are not stable. They decay to lower mass particles, because the universe intrinsically favors lower mass/energy particles over higher mass particles. The Higgs particle being heavy is unstable and tends to decay into lighter particles. But mass is only part of the energy of the particle. The combination of rest mass and kinetic energy of ligher particles can add up to the mass of a heavy particle like the Higgs. This is the principle behind particle accelerators like the Large Hadron Collider at CERN in Geneva. The LHC actually accelerates protons to do this because it's a bit easier than electrona since a proton is much heavier at around 1 GeV, so it needs less kinetic energy to create the Higgs particle. How do you detect the Higgs once it is made? You cannot detect it directly for two reasons. First, two protons collide with the same energy, but in opposite directions. The combined momentum is roughly zero. This means that the created Higgs boson will be roughly stationary in the particle beam. It's difficult to detect something that doesn't move because the detectors only picks up particles that fly away from the collision. Secondly, Its lifetime is incredibly short. It decays almost instantly. Thirdly, the Higgs is not a charged particle. Since we generally rely on some electromagnetic interaction to physically detect a particle, it's not clear how you would detect it even if it could reach the detector. If all that is true, what did we actually "discover" if no one ever measured a Higgs? You don't need to measure it to know that it's there. Essentially, if you smash two protons together and get an event where the sum of the decay products adds up to the mass of the Higgs, then we can reasonably conclude that the event likely created a Higgs particle. But you might ask, what if the event created random interactions which just happened to yield a decay products equal to the Higgs mass? Yes, that could happen. But if you have many multiple measurements over a long period of time, then you can eliminate the possibility of just random interactions. And in the case of the 2012 announcement, this spike achieved 5 sigma significance, which is the gold standard in particle physics, for determining that a new particle was detected. It is thus as statistically significant discovery. And it turns out that in there are many other particles, that we also never actually directly measure, because of similar limitations. For example, the quarks and gluons that make up protons and neutrons, cannot because of the nature of the strong force, ever be directly detected. Yet, scientists still claim we discovered them. They can make this claim because the procedure of their discovery is similar to that of the Higgs. How is the Higgs Boson produced? The most prominent process used at the Large hadron collider is the gluon fusion process. First, two high energy gluons can be produced by smashing two high energy protons. These can, in some cases, turn into top quarks, and fuse together via a triangle loop. This loop represents top quark, and anti-top quark creation and annihilation. The energy of this annihilation can create a Higgs boson. #HiggsBoson #LHC This Higgs particle of course, as I stated earlier, almost instantly decays. So, what does it decay into? The Higgs decays to form very heavy bottom/anti-bottom quarks, which annihilates into two high energy photons. And the energy of these photons adds up to the mass of the Higgs. The photons is what we actually detect. →

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**The surprising truth about the "discovery" of the Higgs boson at CERN**.

SUMMARY

In 2012, the Higgs boson (God particle) was discovered. It is responsible for giving matter to fundamental particles. First: it does not give "matter", but gives away mass, and second: if a boson gives up matter (some more, some less, some all, some nothing), then what happens to it?? Then an "immaterial boson" flies around the universe??...?? Where did the boson actually gain that mass? I have a different vision, radically different. Matter, i.e. all mass particles, are made by "curving the dimensions" of two physical quantities Length and Time. In the plasma immediately after the Big Bang, which is a **chaotic *package* of curved dimensions**,

(according to rules unknown to me), the 3+3 dimensions start to "pack" *into precise* formations: The Universe produces a "standard table of elementary particles", but by warping - packing the dimensions of quantities. ☐ https://www.hypothesis-of-universe.com/index.php?nav=ea ; However, scientists have never measured this particle. So how can scientists claim discovery without ever seeing or measuring it? What is measurement? The Standard Model shows that all elementary particles we know are excitations in their own field. Since the Higgs particle has a mass of 125 GeV, you have to|| add ? energy of 125 GeV in the Higgs field to create a Higgs particle. This is a very high energy level, equivalent to a rest mass of about 244,000 electrons. Creating a Higgs boson is not easy because heavy particles are not stable. They decay into particles with lower mass because the universe inherently favors particles, and who said that? Did the universe whisper this in some physicist's ear? And his friends then did an experiment to find out the essence? with lower mass/energy over particles with higher mass. The Higgs particle is heavy and tends to decay into lighter particles. But I heard that the Higgs particle's job is to fly around the Universe and give away its mass!! Or am I wrong? So when is mass given away and when does the HB "tend" to decay into lighter particles? However, mass is only part of the energy of a particle. The combination of the rest mass and kinetic energy of lighter particles can add up to the mass of a heavy particle, such as the Higgs boson. That's the principle of particle accelerators, I'll repeat the question: physicists at CERN work on the principle of????? like the Large Hadron Collider at CERN in Geneva. The LHC actually accelerates protons to achieve this, because it's a little easier than electrons, since a proton is much heavier, around 1 GeV, so it takes less kinetic energy to create a Higgs boson. How do you detect the Higgs boson once it's created? It can't be detected directly for two reasons.
**First**, two protons collide with the same energy but in opposite directions. The combined momentum is roughly zero. This means that the Higgs boson that is created will be roughly stationary in the particle beam. It is difficult to detect something that is not moving, because detectors only pick up particles that fly away from the collision.
**Second**, its lifetime is incredibly short. It decays almost instantly.
**Third**, the Higgs boson is not a charged particle. Since we generally rely on some electromagnetic interaction to physically detect a particle, it is not clear how you would detect it even if it could reach a detector. If all of this is true, what have we actually "discovered" when no one has ever measured the Higgs? You don't have to measure it to know it is there. Basically, if you smash two protons together and an event occurs where the sum of the decay products equals the Higgs mass, then we can reasonably assume that this event probably produced a Higgs particle. But you might ask, what if this event produced random interactions that happened to produce decay products equal to the Higgs mass? Yes, that could happen. But if you have a lot of measurements over a long period of time, then you can rule out the possibility of just random interactions. And in the case of the 2012 announcement, this increase reached 5 sigma significance, which is the gold standard in particle physics for determining that a new particle has been detected. So this is a statistically significant discovery. And it turns out that there are many other particles that we also never directly measure due to similar limitations. For example, the quarks and gluons that make up protons and neutrons can never be directly detected due to the nature of the strong interaction. Yet scientists still claim to have discovered them. They can claim this because the process of their discovery is similar to that of the Higgs boson. How is the Higgs boson created? The most important process used in the Large Hadron Collider is the process of gluon fusion. First, two

high-energy gluons can be created by the collision of two high-energy protons. These can in some cases turn into top quarks and merge together using a triangular loop. ?? This loop represents the creation and annihilation of a top quark and an antitop quark. ?? The energy of this annihilation can, may or may not… create the Higgs boson. #HiggsBoson #LHC Of course, as I have already mentioned, this Higgs particle decays almost immediately. So what does it decay into? The Higgs boson decays into very heavy "bottom/anti-bottom" quarks, which annihilate into two high-energy photons. The energy of these photons adds up to the mass of the Higgs boson. It is the photons in fact we detect.

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**(01)-** This video is brought to you by Brilliant. Click the link in the description to sign up for free and support this channel. You probably heard the big news in 2012. Titles like "Physicists find elusive particle seen as key to universe" or "God particle found". It was a big day in particle physics and one of the biggest scientific triumphs in decades. The last piece of the standard model was discovered, the Higgs boson, a unique particle responsible for giving fundamental particles their mass. With all the hoopla, you would assume the scientists must have seen or somehow measured the particle. But no such thing happened. It was never seen nor measured. What? How is that possible? Yes, it's true. But if scientists can declare the discovery of a particle without ever having seen or measured it, then we have to ask the question, what is a measurement anyway? In this video I will tell you the truth about particle discoveries and how we can't really see most the particles of the standard model, but we know they exist.

1:03

How can we be so sure? I'm going to explain that coming up right now… The chart that you are looking at represents the Standard Model of particle physics. It lists all the fundamental particles that we know of. Everything in the universe that we can see is made up of them. This chart along with all the equations representing how all these particles interact, represents the best theory we have about how the universe works. But here is a hard truth about these particles. We have never actually seen or measured most of them. The standard model is based on something called quantum field theory. According to this theory, a particle is nothing but an excitation, or a kind of wave in a quantum field that permeates all of spacetime. Each particle is an excitation or a quanta of energy in its own field.

2:02

So for example, an electron would be quanta of energy equal to 0.511 Mega Electron Volts, or MeV, the rest mass of an electron, in the electron field. Similarly, an Up Quark would be an excitation of 2.2 MeV in the Up Quark field. If you have a field and add a quanta of energy, you get a particle. If you add another quanta, you get a two particles in the field, and so on. Since the Higgs particle has a mass of 125 Giga Electron Volts, or GeV, you must add 125 GeV worth of energy in the Higgs Field to form a Higgs particle. Note that this a relatively very high energy level, equivalent to the rest mass of about 244,000 electrons. So, based on this you might logically conclude that all we need to do is add 125 GeV to the Higgs field, and boom, we can discover the Higgs particle, right?

3:02

In principle, yes. That's all you need to do. In practice this is not easy, because the Higgs particle is extremely heavy compared to other particle of the standard model. In fact, only the top quark is heavier at 173 GeV. The issue is that most heavy particles of the standard model are not stable, because they decay to lower mass particles. This is also the case for the Higgs particle. Why? Because everything in the universe is intrinsically lazy and wants to go to its minimum state of energy. I have a video on why the universe is this way, and how entropy plays a role up here, if you want to know the details. The upshot of this is that is, as I said, heavy particles will be unstable and tend to decay into lighter particles. So the rules of particle physics is pretty simple. If a particle can decay into something lighter, it will do so eventually. And the greater the mass difference, which is also the energy difference, the faster the particle will decay.

4:01

For example, the heavier cousin of the electron, the tau particle has a lifetime of around 2.9x10^-13 seconds. The slightly lighter cousin of the electron, the muon particle, has a lifetime of 2.2x10^-6 seconds. But the electron is stable simply because it’s the lightest of its type. There are some details to this that we are ignoring right now, but in short, there is no lighter particle which the electron can turn into, so it is stable. Now the issue is that since there are many particles of the standard model that are lighter than the Higgs particle, there are many energy paths that lead to more stable particles if you start out with the Higgs particle. Consider for example the electron. Its mass is almost 250,000 times less than the Higgs mass. In protons, which are stable, we have up and down quarks which have masses of around 2 and 5 MeV. This is 5 and 10 times heavier than the electron, but still nowhere close to the Higgs mass.

5:02

The other heavier quarks are all less stable, and are thus not readily available in the universe. And neutrinos are even lighter and almost never interact with any other particle, so they are completely hopeless to work with in this context. At this point you might think, how the heck can we ever even hope to make such a heavy particle as the Higgs, if the only stable things we

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**(01)–** This video is brought to you by Brilliant. Click the link in the caption to sign up for free and support this channel. You probably heard the big news in 2012. Headlines like “Physicists Discover Elusive Particle Seen as Key to the Universe” or “God Particle Found.” It was a big day in particle physics and one of the biggest scientific triumphs of the last decade. The final piece of the Standard Model, the Higgs boson, the unique particle responsible for giving fundamental particles their mass, had been discovered. With all the fuss, you would assume that scientists must have seen the particle or somehow measured it. But no such thing happened. It has never been seen or measured. What? How is that possible? Yes, it is true. But if scientists can claim to have discovered a particle without ever seeing or measuring it, then we have to ask ourselves what measurement is, really? In this video, I'm going to tell you the truth about particle discoveries and how we can't actually see most of the Standard Model particles, but we know they exist.

1:03

How can we be so sure? I'll explain that to you now... The chart you're looking at is the Standard Model of particle physics. It lists all the fundamental particles that we know. Everything in the universe we see is made up of them. This chart, along with all the equations that show how all of these particles interact, represents **the best theory we have** about how the universe works. But here's the hard truth about these particles. We've never seen or measured most of them. The Standard Model is based on something called quantum field

theory. **According to this theory** a particle is nothing more than an excitation or a kind of wave in a quantum field that permeates all of space-time.Each particle is an excitation (or quantum of energy) **in its own field.**
2:02
For example, an electron would be an energy quantum equal to 0.511 megaelectronvolts, or MeV, the rest mass of an electron, in an electron field. Similarly, an Up quark would be an excitation of 2.2 MeV in an Up quark field. . If you have a field and you add a quantum of energy, you get a particle. If you add another quantum, you get two particles in the field and so on. Because the Higgs particle has a mass of 125 gigaelectronvolts or GeV, you have to add 125 GeV energy to the Higgs field 0 GeV, so 0GeV + 125GeV = Higgs particle, right? And where do you go for the Higgs field? To the dairy? And when I already have the field (Higgs) to whom do I give the 125 GeV energy?, who will take it?, and when I already have the H-field on the counter in the dairy, I give it the 125 GeV energy (how?..how and with what does the field take it?), and…and when the H-field has taken the 125 GeV energy, how does it, excuse me, create (I get) a particle? to create the Higgs particle.
Note that this is a relatively very high energy level, equivalent to a rest mass of approximately 244,000 electrons. Based on this, you could logically conclude that all you need to do is add 125 GeV to the Higgs field and boom, we can discover the Higgs particle, right? Yeah, that's exactly how I did it... except that you "took" the H-field from the counter at the dairy, and I didn't, I don't know where the field is flying around me...
3:02
In principle, yes. That's all you have to do. In practice, it's not easy, because the Higgs particle is extremely heavy compared to other particles of the standard model. And how did you get it? By adding 125GeV to the Higgs field?? You don't even have a field and the energy you produce (by colliding two protons) you don't know how to transfer to the non-existent H-field. Who will take it from that field? And how does the H-boson hatch from this "cocoon" = energy of 125 GeV?? In fact, only the top quark with 173 GeV is heavier. The problem is that most heavy particles of the standard model are not stable, because they decay into particles with lower mass. And why do they spontaneously decay? This also applies to the Higgs particle. Why? Because everything in the universe is inherently lazy and wants to reach its minimum energy state. It's not laziness, it's a "higher order" to unwrap itself. The Big Bang simply cannot remain "in its original state of creation" (due to the Principle of alternating symmetries with asymmetries) and...and everything that unwraps itself loses mass. And vice versa: everything that changes to a more complex curvature of dimensions, by a jump (an act against entropy), is more massive and complex. I have a video about why the universe is like this and what role entropy plays, if you want to know the details. The consequence of this is, as I said, that heavy particles will be unstable and will tend to decay **!!** into lighter particles. So the rules of particle physics are pretty simple. If a particle can decay into something lighter, it will eventually. O.K. But this decay is preceded by "matter production" by fusion or combining simple packages into more complex ones, or otherwise, as you already know from classical physics. You just don't know that this happens using the dimensions of two quantities. And the greater the mass difference, which is also the energy difference, the faster the particle decays.
4:01
For example, the electron's heavier cousin, the **tau particle, has a** lifetime of about $2.9 \times 10^{-13}$ seconds. The electron's slightly lighter cousin, the **muon particle, has a** lifetime of $2.2 \times 10^{-6}$

seconds. However, the electron is stable simply because it is the lightest of its kind. *with a rest mass of just* $9.109382 \times 10^{-31}$ *kg*, which is equivalent to 0.511 MeV. There are some details here that we are ignoring for now, but in short there is no lighter particle that the electron can change into, so it is stable. The problem is that since there are many Standard Model particles that are lighter than the Higgs particle, there are many energy paths that lead to more stable particles if you start with the Higgs particle. Take the electron, for example. Its mass is $9.1 . 10^{-31}$ kg is almost 250,000 times less than the mass of the Higgs boson. Or $25 . 10^{-26}$ kg. In protons, which are stable, we have up and down quarks, which have masses of about 2 and 5 MeV. That's 5 and 10 times heavier than an electron, but still nowhere near the mass of the Higgs boson.

5:02

The other heavier quarks are less stable and therefore not readily available in the universe. And neutrinos are even lighter and almost never interact with any other particle, so they are completely hopeless to work with in this context. At this point, you might be wondering how the hell we can ever hope to make a particle as heavy as the Higgs boson when the only stable things that...

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**(02)-** have to work with are particles thousands of times lighter? Well, here we are rescued by the mass-energy equivalence principle. Recall that mass is only part of the energy of the particle. So if you want to create a Higgs particle from electrons, you would need to give it a lot of momentum, or kinetic energy, such that you add the equivalent of about 250,000 times its rest mass, such that its total energy is 125 GeV. Now, this is not the full story. You can't just turn an electron into Higgs particle, but the general idea is that we

6:01

can form heavy particles from lighter particles by accelerating them and smashing them into each other and by combining potential energy from mass and kinetic energy from movement, so that we have enough energy to make something heavier. This is the principle behind particle accelerators like the Large Hadron Colliders at CERN in Geneva, the world's largest and most powerful collider. In principle, you could make the Higgs by smashing an electron and an anti-electron. But you'd have to pump a lot of energy to do this. The LHC actually accelerates protons, not electrons, to do this because it's a bit easier since a proton is much heavier at around 1 GeV, so it needs less kinetic energy to create the Higgs particle. But now, the question is how do you detect the Higgs once it is made? This is the tricky part, because you cannot detect the particle itself directly. There are two reasons for this. First, the protons collide with the same energy, but in opposite directions.

7:03

The combined momentum is roughly zero. This means that if you create a Higgs boson in the accelerator, it will be roughly stationary in the particle beam. It's difficult to detect something that doesn't move because the detectors only pick up particles that fly away from the collision. The detector is built around the beam. It cannot be built within the beam because the energy of the beam would destroy the detector. So anything formed within the beam is not really detected. Only things that fly away. Furthermore, because the Higgs is really heavy, it's not stable. Its lifetime is incredibly short at around 1.5x10^-22 seconds. So it decays effectively instantly. These two things make the Higgs boson practically impossible to detect. It should be no surprise then that we have never actually detected it. But on top of that, the Higgs is not a charged particle.

8:00
And since we generally rely on some electromagnetic interaction to physically detect a particle, it's not clear exactly how you would detect it even if it could reach the detector. If all that is true, you have to ask the question then, what's all the fuss about regarding its so called "discovery" of the Higgs? As it turns out, you don't need to measure it to know that it's there. Think of the dinosaurs. We don't see them today, yet by looking at fossils, we can learn a lot about them. And we can certainly conclude that they once existed. We can do something similar with the Higgs, by looking at its decay products. The idea is something like this: if you smash two protons together and get an event where the sum of the decay products adds up to the mass of the Higgs, then we can reasonably conclude that the event likely created a Higgs particle. But you might ask, what if the event created random interactions which just happened to yield a decay products equal to the Higgs mass. Yes, that could happen.
9:00
And this is called background noise. But the trick is, that if you many multiple measurements over a long period of time, then you can eliminate the possibility of just random interactions that just happen to add up to the same mass. And in this case, you can make a reasonable conclusion that the consistent signal you are detecting, in the form of an unexplainable spike, represents in fact, the mass of the Higgs particle, and is not just random noise.. And in the case of the 2012 announcement, this spike achieved 5 sigma significance, which is the gold standard in particle physics, for determining that a new particle was detected. So the guys working at the LHC declared the discovery of the Higgs boson not because they had actually measured the Higgs particle itself, but because they measured events that could only make sense if the Higgs particle had been there. It is thus as statistically significant discovery. And given that it is 5 sigma, the chance of this being just a statistical fluke is 1 in
10:05
3.5 million, which is pretty low. Today in fact the measurement has achieved a higher than 6 sigma significance and so there is no longer any doubt that the particle is there. And it turns out that in there are many other particles, that we also never actually directly measures,
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**(02)-** What do we have to deal with, are particles a thousand times lighter? This is where the principle of mass-energy equivalence comes to the rescue. Let's remember that mass is only part of the energy of a particle. If you want to create a Higgs particle from electrons, you would have to give it a lot of momentum, or kinetic energy, to add the equivalent of about 250,000 times its rest mass, so its total energy is 125 GeV. But that's not the whole story. You can't just turn an electron into a Higgs particle, but the general idea is that
6:01
we can create heavy particles from lighter particles by accelerating them and colliding them with each other and combining the potential energy from mass and the kinetic energy from motion, so we have enough energy to create something heavier. □ **That's the principle** that particle accelerators like the Large Hadron Collider at CERN in Geneva, the largest and most powerful accelerator in the world, are based on. **In principle, you could create the Higgs boson by colliding** an electron and an antielectron. But you'd have to pump a lot of energy to do that. The LHC actually accelerates protons, not electrons, to do that, because it's a little easier, because the proton is much heavier, around 1 GeV, so it takes less kinetic energy to create the Higgs particle. The question now is, how do we detect the Higgs boson once it's

created? But why do we want the Higgs boson? Apparently, as I understand from the above, this boson has been flying around the world since the VT itself, giving mass to elementary particles. (I emphasize: =**mass**= not =**matter**=.) That's the tricky part, because the particle itself can't be detected directly. There are two reasons for this. First, protons collide with the same energy, but in opposite directions.
7:03
The combined momentum is roughly zero. In a collision, that... That means if you create a Higgs boson in an accelerator, it will be roughly stationary in the particle beam. It's difficult to detect something that's not moving, because detectors only pick up particles that fly away from the collision. The detector is built ||around the beam||. You can't build it into the beam, because the energy of the beam would destroy the detector. So anything that's created inside the beam isn't actually detected. Only the stuff that flies away. Plus, because the Higgs boson is really heavy, it's not stable. Its lifespan is incredibly short, approximately 1.5x10^-22 seconds.
Repeat: **tau particle, has** a lifetime about 2.9x10^-13 seconds. The electron's slightly lighter cousin, the **muon particle, has** a lifetime of 2.2x10^-6 seconds. So it decays virtually instantly. These two factors make the Higgs boson virtually undetectable. So it should come as no surprise that we've never detected it before. Moreover, the Higgs is not a charged particle.
8:00
And since we generally rely on some electromagnetic interaction to physically detect the particle, it's not clear how you would detect it even if it did make it to a detector. If all of this is true, we have to ask why there's so much fuss about the so-called "discovery" of the Higgs? Well, well, well, and here we are at the heart of the matter. It turns out that you don't have to measure it to know it's there. Think of dinosaurs. We can't see them today, but we can learn a lot about them by looking at fossils. And we can safely conclude that they once existed. We can do something similar with the Higgs boson by looking at its decay products. The idea is roughly this: if you collide two protons and there's an event where the sum of the decay products is equal to the mass of the Higgs boson, then we can reasonably conclude that this event probably created a Higgs particle and then it decayed. But you might be wondering, what if this event created random interactions that happened to give a decay product equal to the mass of the Higgs boson? Yes, that can happen.
9:00
And that's called background noise. The trick is that if you take a lot of measurements over a long period of time, you can eliminate the possibility of random interactions that just happen to converge on the same mass. And in this case, you can reasonably conclude that the consistent signal that you're detecting, in the form of an unexplained spike, is actually the mass of the Higgs boson, and it's not just random noise. And in the case of the 2012 announcement, that spike reached a significance of 5 sigma, which is the gold standard in particle physics for determining that a new particle has been detected. So the people working at the LHC announced the discovery of the Higgs boson not because they actually measured the Higgs boson itself, but because they measured events that would only make sense if the Higgs boson were there. **!!** So this is a statistically significant discovery. And given that it's 5 sigma, the chance that it's just a statistical fluke is 1 in 3.5 million, which is pretty small. Today, in fact, the measurement has reached a significance of more than 6 sigma, so there's

no longer any doubt that the particle is there. And it turns out that there are many other particles that we also never directly measure,

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**(03)-** because of similar limitations. For example, the quarks and gluons that make up protons and neutrons, cannot because of the nature of the strong force, ever be directly detected. Yet, scientists still claim we discovered them. They can make this claim because the procedure of their discovery is similar to that of the Higgs. We smash things together and end up with a result, and from looking at the decay products of the process, we declare that it statistically only makes sense if these particles where in fact present as part of the process we measured. This next part of the video is going to be the most interesting part to some of you,
11:00
who love details. I am going to talk about exactly how the Higgs particle was created at the LHC and how it was detected. But before I do that, if you guys want to learn this material in greater depth than ever before, hop on over to Brilliant.org our sponsor. They have two of the best fundamental courses on quantum mechanics I have come across. I would start with the course, "Quantum Objects," which begins by explaining how quantum mechanics is fundamentally different than classical mechanics, and why it's necessary. And over the course of 18 fascinating lessons, it ends with explaining what I think is the most important equation to really understanding quantum mechanics, and that is the Schrodinger equation. The second course was developed with the help of my friend and fellow Youtuber, Sabine Hossenfelder. It gets into explaining some of the more confusing elements of quantum mechanics including superpositions, entanglement, and Bell's theorem. The best part of Brilliant courses is that they make it fun to learn by using graphics, interactive quizzes and simulations. This kind of hands-on interactive learning is, in my opinion, the best way to learn new
12:04
things and retain the information long term. Brilliant has a special offer for Arvin Ash viewers right now - Go to brilliant.org/ArvinAsh to get started for free for a full 30 days! And the first 200 people will get 20% off their subscription. I encourage you to give it a try. I think you're going to like it a lot. Visit the link in my description for more details. Now, back to our program. While there are several ways it can be made, the most prominent process used at the Large hadron collider is the so-called gluon fusion process. What happens is that in some high energy proton-proton collisions, two high energy gluons can be produced. These can, in some cases, due to strong force interactions, turn into top quarks, and fuse together via a triangle loop. This loop represents top quark, and anti-top quark creation and annihilation. The energy of this annihilation can create a Higgs boson.
13:01
In general, when particles decay, they tend to decay into the next highest mass particle. Because the top quark has the highest mass of all elementary particles, its annihilation is most likely to result in a Higgs boson which has the second highest mass of all the elementary particles. This Higgs particle of course, as I stated earlier, almost instantly decays. So, what does it decay into? A very interesting fact about the Higgs decay that led to its initial discovery is that it came from the detection of photons. Now this might seem really confusing to you, because I said earlier that the Higgs doesn't interact directly with massless particles like photons. The key word there is "directly." The Higgs decays to form very heavy bottom/anti-bottom quarks, which are strongly coupled with the Higgs. And these quarks do

interact with photons because they are electrically charged. So what you get as a result, is a Bottom/anti-Bottom loop which annihilates into two high energy
14:04
photons. And the energy of these photons adds up to the mass of the Higgs. The photon is what we actually detect, not the HIggs. I might make it sound simple, but this is actually a rather rare event. But because the signal is very clean it is easy to detect, and was the way the Higgs was first discovered. Today, it has been found via many decay processes precisely as the standard model predicts. Now, you might say, wait a minute, this is all bullshit, we need to see a particle to conclude that it actually exists. To this, I can't completely disagree with you. But I think you should keep in mind that physics is does not guarantee the truth, but only the most reasonable explanation for the observations we make. The hard truth is that evidence for the nature of reality is really nothing more than a statistically
15:03
significant result. If you learned something, leave a like and a comment.
15:08
I will see you in the next video my friend.
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**(03)-** because of similar limitations. For example, the quarks and gluons that make up protons and neutrons can never be directly detected because of the nature of the strong interaction. Yet scientists still claim to have discovered them. They can claim this because the process of their discovery is similar to that of the Higgs boson. We smash things together and get a result, and based on looking at the decay products of the process, we declare that it only makes statistical sense if these particles were actually present as part of the process that we measured. This next part of the video will be the most interesting for some of you who love details.
11:00
a.m I'm going to talk about exactly how the Higgs boson was created at the LHC and how it was detected. More interesting and necessary will want to know what we need the H-particle for? You say because the H-particle gives mass to all the other particles. This could be nonsense, a hoax, just a fabrication that we need "for something" and have "nothing" to explain the given reality. But before I do, if you want to learn this material more deeply than ever before, visit Brilliant.org, our sponsor. They have two of the best introductory courses on quantum mechanics I've come across. I'd start with "Quantum Objects," which begins by explaining how quantum mechanics is fundamentally different from classical mechanics and why it's necessary. And over the course of 18 fascinating lessons, it ends by explaining what I consider to be the most important equation for truly understanding quantum mechanics, which is the Schrodinger equation. The second course was developed with the help of my friend and fellow YouTuber, Sabine Hossenfelder. It explains some of the confusing elements of quantum mechanics, including superposition, entanglement, and Bell's theorem. The best thing about Brilliant's courses is that the graphics, interactive quizzes, and simulations make learning fun. This kind of hands-on interactive learning is, in my opinion, the best way to learn new things and retain information in your head for the long term. Brilliant is having a special offer right now for Arvin Ash viewers – go to brilliant.org/ArvinAsh and get started for free for 30 days! And the first 200 people will get 20% off their subscription. I recommend you give it a try. I think you'll love it. For more information, visit the link in my description. Now back to our program. While there are several ways to do this, the most

prominent process used at the Large Hadron Collider is the so-called gluon fusion process. In some high-energy proton-proton collisions, two high-energy gluons can be created. So theoretically they "can", that is, "on paper". In some cases ||can|| as a result of strong force interactions transform into top quarks and merge together via a triangular loop. All this is just abstract on paper… This loop represents the creation and annihilation of a top quark and an antitop quark. The energy of this annihilation **can**, physicists are still in the abstract… create the Higgs boson.
13:01
In general, when particles decay, they tend to decay into the particle with the second-highest mass. Well, let's just say... Since the top quark has the highest mass of all elementary particles, its **annihilation** will most likely **lead to the formation of the Higgs boson**, ?? which has the second-highest mass of all elementary particles. Of course, this Higgs particle decays almost instantly, as I mentioned earlier. So what does it decay into? A very interesting fact about the Higgs decay that led to its original discovery is that it was created by the detection of photons. This may seem very confusing to you, because I said earlier that Higgs does not interact directly with non-massive particles like photons. The key word is "directly". The Higgs decays to form very heavy "bottom/anti-bottom" quarks, which are strongly bound to the Higgs. And these quarks interact with photons because they are electrically charged. So the result is a bottom/anti-bottom loop that annihilates into two high-energy photons.
14:04
And the energy of these photons adds up to the mass of the Higgs. We are actually detecting a photon, not a Higgs boson. It may sound simple, but it is actually quite a rare phenomenon. But because the signal is very clean, it is easy to detect, and that is how the Higgs was first discovered. Today it was discovered through many decay processes, exactly as the Standard Model predicts. You might say, wait a minute, this is all nonsense, we need to see the particle to conclude that it actually exists. I can't disagree with you completely. But I think you should keep in mind that **physics does not guarantee the truth, only the most reasonable explanation**, that is an amazing theorem, so at this point HDV is already on solid ground… because it has the **most reasonable** explanation for the creation of matter, the observations that we are making. The hard truth is that evidence for the nature of reality is really nothing more than a statistically
15:03
significant result. If you learned something, leave a like and a comment.
15:08 See you in the next video, my friend.
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