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Where's my Higgs?

LHC physicist Joe Lykken speaks.

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Joe Lykken.

On December 13, CERN will release the results of a new data analysis in the search for the Higgs boson at the Large Hadron Collider. On December 7, I spoke on the phone with Joe Lykken, a Fermilab staff theoretical physicist. Lykken is a member of the CMS collaboration, one of the two largest experiments at the LHC (the other one being ATLAS). The following is a lightly edited, partial transcript of that conversation.

Do you have high expectations for next week?
It will be an interesting meeting. It will be the first time that there's really enough data you can have an argument about it. Whatever happens eventually with the Higgs I think we'll look back on this meeting and say this was the beginning of something. There is enough data and enough different searches that you can get your hands dirty.

Have you been following the rumors about the announcement?
I am a member of the CMS collaboration, so it's only the ATLAS rumors that I follow. In CMS I actually know what's happening. The thing I know for sure is that [CERN Director General] Rolf-Dieter Heuer, who must know the results of both experiments, says that on December 13 we will not have a discovery and we will not have an exclusion.

Readers may be confused because of all the rumors and speculation, and it is not clear to outsiders how to interpret the expected announcement. What does it mean if both experiments have seen a signal of around "three sigmas," short of the five sigmas that are considered solid enough to officially claim a discovery?
There's an important point there. We built the LHC and it cost a lot of money, and part of that is because we don't want to just say, maybe there's a Higgs boson, and maybe its mass is this. This machine was built to give a completely definitive answer about the Higgs boson. And it's just a question of time in order to do that. The machine works, the detectors work, we have all the people doing what they need to do. So we will have a definitive answer about the Higgs. It's just a question of when it will happen. We know [a five-sigma announcement] is not going to be next week because Rolf-Dieter Heuer said it won't be. But we know we can do it. And it's not going to be a maybe-yes-maybe-no kind of answer.

What makes it so hard to find a new particle such as the Higgs boson?
What's really important about these data is that there are other processes that produce signals that look like Higgs bosons. So for example we look for Higgs bosons that decay into two photons. Well, there's other things in the Standard Model [of particle physics] that produce two photons. So the reason why we don't know whether there's a Higgs yet has mostly to do with the fact that Higgs-boson decays look like other kinds of physics. So it's not just a question of statistics: it's understanding the other things that look like Higgs bosons. And that's the place where we are now. It's not about, "what if we had one more data point?" It's much more complicated and it's much more physics-driven than that.

The issue is that detectors don't see a particle like the Higgs directly, correct? All they can see is the decay products of it.
Yes, and there's never going to be one single event where you say, "aha! I know with 100 percent certainty that it's a Higgs boson." That's never going to happen.

Some physicists, both in the LHC and outside, have manifested disappointment that the LHC has not made major discoveries yet, and in particular that it has not found evidence of supersymmetry, the extension of the Standard Model

in which every particle has a heavier twin called its superpartner.

I'm old enough to remember when they turned on the energy upgrade of [the LHC's predecessor, CERN's Large Electron-Positron collider] experiment in the 1990s. Everybody said, "they're going to discover supersymmetry as soon as the machine is turned on." And then of course they didn't, and everybody was disappointed. This is just a function of human nature: when you turn on a machine of course what you're hoping is that things will jump at you. You have to be in it for the long haul. If it takes ten years, it takes ten years.

But were you expecting that the LHC would have discovered supersymmetry by now?

I was not expecting gluinos and squarks [the superpartners of gluons and quarks] to be lighter than a TeV [one trillion electronvolts, or about 1,000 as massive as a hydrogen atom], which is more or less what the energy limits are now. That was just because of my prejudice that we already knew indirectly that some of supersymmetry was at least was a little bit heavy. Although people are disappointed, I don't think it's inconsistent with what everybody was saying before the LHC turned on.

What do you think are the prospects for the LHC finding supersymmetry?

The most likely thing with supersymmetry is we will see something either this coming year or the first year of energy upgrade. It just depends on how heavy things are and how difficult it is to see them. If that doesn't happen then I think you should start to rethink what you're doing. The trouble with supersymmetry is—sort of like string theory—that there's a thousand different ways to dice it and slice it. And maybe we're just not wrapping our minds around the problem correctly.

Could the lightest superpartner be as heavy as 1 TeV?

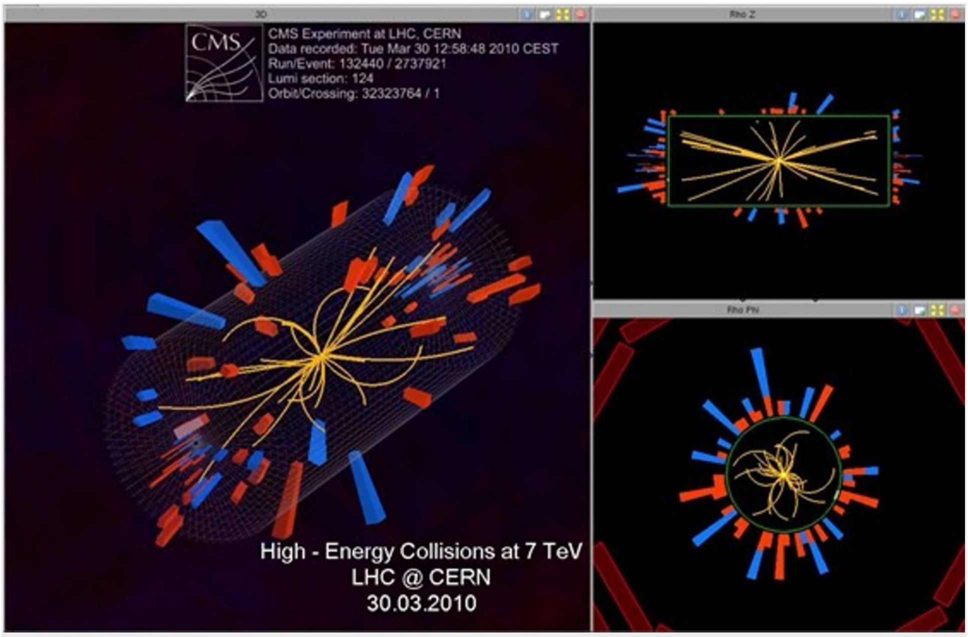
It could be. Now, you have to start worrying about dark matter once you make it that heavy. But the connection between supersymmetry and dark matter is tricky–it involves extra assumptions. The whole idea that you can even connect supersymmetry and dark matter is incredibly ambitious. Dark matter supposedly came from the big bang. The idea that you're going to find something in the collider and say aha, it solved all those problems, it's very ambitious.

The type of particles that physicists think make up dark matter, called weakly interacting massive particles, or WIMPS, may or may not be part of supersymmetry, but whatever they are, they are supposed to be relatively light, correct?

Yes. The problem is that at the LHC so far we've looked for WIMPS only in decays of other particles. Now, starting in 2012, we want to look for direct production of these WIMPS. The trouble with that is that these are weakly interacting massive particles. Weakly interacting means that they are hard to make from collisions of other particles. So far we haven't had enough data to even think about a serious search like that.

But if WIMPS exist at 200 GeV or so, wouldn't they already show up as missing mass in the existing data?

Yes–it's just a question of pulling them out of the background. We would have already made some dark matter particles. Just like if the Higgs is at 125 GeV, that means that the Tevatron [Fermilab's particle accelerator, which was shut down this fall] already made quite a few of them, it's just that we were not able to pull them definitively out of the Tevatron data. We could be in the same situation now with dark matter, that there's already some dark matter particles but we're not able to distinguish them yet. For example, [collisions inside the CMS detector] produce a lot of neutrinos: neutrinos are invisible as well. How do you tell the difference between a neutrino that's invisible and a dark matter particle that's invisible? That's a tricky issue.



CERN

A computer reconstruction of one of the first high-energy proton-proton collisions recorded at the CMS detector, on March 30, 2010.

But do you think it’s likely that supersymmetry will be found at the LHC in the end?
Saying it’s likely is not a scientific statement. You can’t assign a probability to new physics happening. But if you asked me how would I bet my own money, I would bet my own money that either [2012] or the first year of the energy upgrade [when the LHC's energy is supposed to nearly double, bringing it close to its original design specs] is a prime time to find supersymmetry. And I think if you had asked me three years ago I would have said the same thing.

In fact, I think you did say that when we talked five years ago. If, let’s say a year from now, it’s confirmed that the Higgs exists and that its mass is 125 GeV, would that tell us something about supersymmetry?
As I’ve been telling people for quite a while now, the fact that the remaining mass range that’s allowed for the Higgs boson is between 115 GeV and 140 GeV—for supersymmetry it’s at least very interesting that the currently allowed range is exactly the range where supersymmetry says it should be.

So it would be consistent with supersymmetry?
Yes. Furthermore, once you’ve found any real discovery of the Higgs, the question would be, is it really a Standard Model Higgs, or does it have slight differences? The supersymmetry Higgs is at least a little bit different from the Standard Model variety. Can we see those differences? That will be the next big challenge.

Gordon Kane and his collaborators posted a paper on the arXiv this week that claims to predict that the mass of the Higgs is 125 GeV based on string theory. If the rumors pan out and the Higgs’s mass does turn out to have that value, would you call this a success of string theory?
I would say it would be an example of a successful connection between string theory and experiment. The trouble is, for all we know, there might be 10,000 other ways of starting with string theory and getting the same Higgs mass, and [all those versions of string theory] may differ in other respects. This is just a problem of string theory having too many solutions. But having any successful solution that gets you from string theory to a real measurement–that’s a big step forward.

But if a theory can make all sorts of different assumptions and all sorts of different predictions, then no matter what the experiments find, people can always claim that the theory was right.
Yes, so this is how you get to the multiverse. You can say, yes, I can predict our universe but I can also predict 10^500 variations of our universe–and some of those differ from our universe only in the value of the Higgs mass, let’s say. Therefore in that sense you’re never going to predict a Higgs mass. If there really is a multiverse then there is no solution to that problem. You have to figure out which of those universes you live in. It’s not that you’re going to predict which of those universes you live in.

Traditionally, particle physics experiments have been done by experimental physicists, and theorists were outsiders. But ATLAS and CMS include theorists such as you. How has your experience been, being part of an experimental collaboration?
It's been a real learning experience for me. It's a different culture, first of all. It's extremely competitive, in different ways than we are in the theory community. Experimentalists are much nicer to each other. Typically, if I write a theory paper and I give a theory talk, at least one theorist will jump up and say, "that's completely wrong, and I can show you exactly why."

That sounds very familiar—it sounds similar to mathematicians' culture, which is where I come from.
But with experimental physicists you present your results and you have a polite discussion, where people make very polite suggestions. But at the end of the day we have to make sure that our results are absolutely correct before we release them to the world. The public is trusting us to do a very good analysis. Somehow this polite dance that goes on over seemingly endless meetings gets you to very solid results at the end. I'm learning to be polite in my old age.

Do people think it's a good idea to have theorists in the collaborations?
I think it wouldn't be good to have too many theorists because theorists are very undisciplined and we don't really fit in too well in the way things are done. It's good to have a handful of theorists as a resource, but If we had 100 theorists it would just add to the noise. I think both experiments have in the order of five, and that's about the right number. Furthermore, it has to be people that are willing to make a very strong commitment. Just to figure out how to run CMS software took me a year. Everything is done with incredibly sophisticated computers.

Are physicists excited in the run-up to next week?
Even though we're not going to get any conclusive word from this December 13 meeting, people of course are thinking more about Higgs physics and hypothetical scenarios. There's a lot of that kind of excitement. Obviously, even though we're not going to get the final word this year, the Higgs is going to be at the top of our agenda for the foreseeable future now. Finally!

So no more distractions with superluminal neutrinos?
Let's see what the [MINOS neutrino] experiment at Fermilab says—they are going to check that result. If they confirm it, then I'll start to actually believe it. That will be trouble. You can come up with explanations but to really work out all the ramifications of something like changing special relativity, that's probably for the next generation to figure out.

Any further comments to conclude?
I am extremely happy with the way the LHC has progressed. It has been a complicated effort, with thousands of technological and scientific challenges. This is my generation's Manhattan Project. The dedication of these people is paying off on a really rapid time scale.

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