The Large Hadron Collider
What is the real legacy of the LHC?

Dr David Broadhurst, Department of Physics and Astronomy, Open University
The interesting question to my mind is whether it's really going to be the last such gargantuan particle accelerator on Earth, or whether there might another one.

Dr Bruce Kennedy, Rutherford Appleton Laboratory, UK.
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Dr Bruce Kennedy is particle physicist at the Rutherford Appleton Lab in the UK. He helped design of one of the LHC detectors and is soon to start working on its upgrade.

The SLHC simply stands for the Super LHC, which is an upgrade to the existing LHC. Now may seem rather previous to be planning upgrade even before the accelerator itself works, but because to develop large pieces of equipment takes a lot of design work and R and D, the process of thinking about upgrading the existing accelerating detectors has already begun.

The reason for doing it is that we expect LHC to produce as many questions as answers. So we hope for answers about things such as the Higgs, supersymmetry, but those answers may well not be complete. Often, when you discover something new, you then want investigate it further to really understand, if its a new particle, its properties, see how it decays, measure its mass, and other properties it will have. And often the machine you use to discover it wont be appropriate for making many, many of such particles to really study the properties.

So the point of the SLHC is that it wont be an upgrade in the energy, it will be an upgrade in the intensity of the beams. So that you'll have data produced at a much higher rate, you'll have many more collisions per second.

At ISIS, the accelerator at the Rutherford Appleton Laboratory, Dr Dan Faircloth manages the ion source. He is also part of a team planning the upgrade to the LHC beam.

I am actually working on making the ion source produce more particles in the first place, if we can produce more particles we can accelerate more particles into the ring, and then we can make more interactions, and then we can make more Higgs Bosons. And the upgrade is to produce a luminosity increase of ten times. So we will hopefully produce rather than one Higgs Boson an hour, we will produce 10 Higgs Bosons an hour

Theres several things that need to be put in place to be able to work at higher luminosities. One is the ion source, you've got to actually produce more particles to accelerate, the other is we're going to need more powerful focusing magnets to be able to actually focus this higher density beam to a smaller point and if you make the beam even denser you're likely to make more particles. And the final thing is in detectors, where the actual collisions take place, because we're increasing the brightness of the beam ten times, we're gonna be creating 10 times as many particles, and ten times as many particles means much higher radiation, much higher levels of bombardment on our detectors and so the detectors need to be made more robust.

For Dr Stephen Serjeant, senior lecturer in Astrophysics at the Open University, there are always risks involved when planning an upgrade.

We hope that by the time that this upgrade is happening questions like the discovery of the Higgs Boson will be done and dusted, we hope that'll be a closed chapter, the discovery will be a closed chapter. We will be able to study interactions with this Higgs Boson, we'll be able to find out a lot more about how it works. But this is the trouble with these very long range forecasts, it could be, I would say it's unlikely, but it could be that we find there is no Higgs Boson, for example, and we have to start completely rethinking what we're doing, so it's a risky thing to foresee a new facility and say it will make these discoveries 'cos we don't even know what our existing LHC is going to reveal in the next few years.

Dr Bruce Kennedy is hoping the SLHC will firm up the facts about supersymmetry.

If we find evidence of supersymmetry at the LHC, the SLHC will begin to tie that down because supersymmetry is a very large area of theory with a lot of adjustable parameters. You need a lot of data to start tying down what type you've got. You always want more data, you're usually limited by having not quite enough data to make quite precise enough measurements, so the more kind of data you have there, then the better off you are. But really, without running the LHC first and understanding the questions that come out of that, it's hard to say precisely what SLHC will produce. If we knew in advance then it wouldn't be worth doing it. It will be providing detailed answers to questions the LHC produces

Dr David Broadhurst of the Department of Physics and Astronomy at the Open University believes they may not find the results they're looking for until the LHC has been running for a number of years.

So suppose that there is new physics that just basically doesn't emerge until you put enough energy in it, it could be in five years' time that we have our most sensational result from the LHC. The machine is designed to have a lifetime of about ten years, that is a huge challenge because in this intense region of particle interactions there's an enormous amount of radioactive damage that can occur to very delicate equipment, but things have been radiation hardened, and the lifetime of the machine is to be measured, you know, in a decade or so. So I see a lot of future for the LHC over that time and the interesting question to my mind is whether it's really going to be the last such gargantuan particle accelerator on Earth, or whether there might another one.

A new international accelerator, called the Next Linear collider is one possibility.

If we do have an international facility, and after Large Hadron Collider it's most likely to be a world machine, and we have a name to it – we refer to it as the NLC – the Next Linear Collider. Now what's a linear collider? Well a linear collider is a long, straight tunnel, or two long, straight tunnels, rather than a circular one. The trouble is it costs an enormous amount of energy to provide the magnets that provide the force to keep the electrons moving in a circle. You can dispense with that if you have a long machine.

Dr Bruce Kennedy
They would need to be very large, these machines, perhaps 20-30km in length, just in a straight line rather than in a circle. They would accelerate beams of electrons and positrons to a sufficiently high energy, so you could basically churn out Higgs particles in very large numbers, and that would then enable you to do very precise measurements on their properties. So, if it proved to be possible in decades to come to build an accelerator like that, that would be a very exciting prospect.

Even more speculative, and this is almost in the realms of, not quite fantasy, but certainly not solid planning, would be to build a muon collider. The disadvantage of muons as beam particle is that they only live for about a microsecond. But, there are some very interesting ideas on how you could make muons and accelerate them very rapidly before they manage to decay. And, of course, once you've accelerated them you get the benefit of time dilation, you know relativity theory, so you could stretch out their microsecond of life to accelerate them to higher energies, and again you can make a collider out of these which would have many advantages and would be a very good way to produce a something called a Higgs factory, *which is basically an accelerator that makes Higgs particles by the hundred and the thousand, so you can make very precise measurements.*

Now before we even discover the Higgs, it's perhaps premature to be thinking 20-30 years down the line in doing that kind of thing, but these projects have such a large lead time in finding right site and being able to afford to construct them, that people need to start thinking about this and are already talking, at least, about this kind of project.