Special Report

What Is the Future for Particle Accelerators? & HCP 2011: Will it Deliver?

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Abstract

This year all physics eyes are on the Large Hadron Collider as it approaches its promised landmark discovery of the Higgs Boson (or maybe its undiscovery). At the same time some physicists are planning the future for the next generation of colliders. What will they be like? The answer depends in part on what the LHC finds. Nothing is likely to be built if there is no sign that it will do anything useful, but decisions are overdue and they have to make some choices soon. On the other hand, the rumour mill is once again turning its rusty wheels, and there are suggestions that an interesting result will be revealed at Hadron Collider Physics conference in Paris in the week of November 14, 2011.

Key Words: particle accelerator, future, LHC, HCP 2011.

November 6, 2011: What is the Future for Particle Accelerators?

This year all physics eyes are on the Large Hadron Collider as it approaches its promised landmark discovery of the Higgs Boson (or maybe its undiscovery). At the same time some physicists are planning the future for the next generation of colliders. What will they be like?

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Hadron colliders

Accelerators like the LHC that collide protons are at the leading edge of the Energy and Luminosity frontiers because they work with the heaviest stable particles that are available. The downside of colliding protons is that they produce messy showers of hadrons making it difficult to separate the signal from the noise. With the Tevatron and now the LHC, hadron colliders have been transformed into precision experiments using advanced detectors.

One technique is to capture and track nearly all the particles from the collisions making it possible to reconstruct the jets corresponding to interesting high energy particles such as bottom quarks created in the heart of the collision. Missing energy and momentum can also be calculated by subtracting the observed energy of all the particles from the original energy

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of the protons. This may correspond to neutrinos that cannot be detected or even to new stable uncharged particles that could be candidates for dark matter.

High luminosities have been achieved making it possible to scour the data for rare events and build up a picture of the interactions with high statistics. As luminosity increases further there can be many collision events at once making it difficult to reconstruct everything that happens. The LHC is now moving towards a new method of operation where it looks for rare events producing high energy electrons, muons and photons that escape from the heart of the collision giving precise information about new particles that decayed without producing jets or missing energy. In this way hadron colliders are getting a new lease of life that turns them into precision tools very different from how they have been seen in the past.

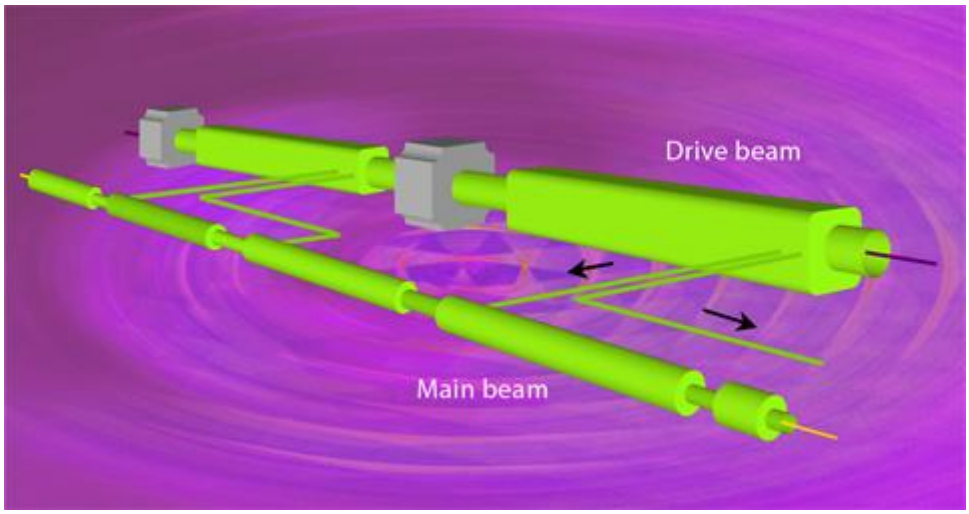
So what is the future of hadron colliders? The LHC will go on to increase its energy to the design limit of 14 TeV while pushing its luminosity even higher over the coming years. Its luminosity is currently limited by the capabilities of the injection chain and the cryogenics. These could undergo an upgrade to push luminosities ten times higher so that each year they collect 50 times as much data as they have in 2011. Beyond that a higher energy upgrade is being planned that could push its energy up to 33 TeV. The magnets used in the LHC main ring today are based on superconducting niobium-titanium coils to generate magnetic fields of 8.5 tesla. Newer magnets could be built using niobium-tin to push the field up to 20 Tesla to more than double the energy. If they could revive the tunnel of the abandoned SSC collider in Texas and use niobium-tin magnets it would be possible to build a 100 TeV collider, but the cost would be enormous. The high-energy upgrade for the LHC is not foreseen before 2030 and anything beyond that is very distant. Realistically we must look to other methods for earlier advances.

Is the future linear?

The latest linear accelerator built to date is SLAC at Stanford with a centre of mass energy of 90 GeV. As hadron colliders reach their physical limits physicists are returning to the linear

design for the next generation of colliders. When accelerating in a straight line there is no advantage in using heavy particles so linear colliders work equally well with electrons and positrons which give much cleaner collisions.

The most advanced proposal is the International Linear Collider which would provide centre of mass energies of at least 500 GeV with 1 TeV also possible. The aim of the ILC would be to study the Higgs boson and top quark with very high precision measurements of their mass, width and other parameters. This may seem like an unambitious goal but if the LHC finds nothing beyond the standard model in the data collected in 2011 this could be the best option. the standard model makes very precise predictions about the quantities that a linear collider could measure. If these can be checked, any deviations could give clues to the existence of new particles at higher energies. Such precision measurements have already been useful in predicting where the mass of the Higgs Boson lies, but once all the parameters of the standard model can be measured the technique will really come into its own. Finding solid evidence for deviations from the standard model would be the requirement to choose and justify the construction of the next collider at the energy frontier.



But there is an alternative. A new innovative design for a compact linear collider (CLIC) is being studied at CERN and it could push the energy of linear colliders up to 3 TeV or even 5 TeV. The principle behind CLIC is to use a high intensity drive beam of electrons at lower energy to accelerate another lower intensity beam of electrons too much higher energy. Just think of how a simple transformer can be used to convert a high current low voltage source of electricity into a low current high voltage source. CLIC does a similar trick but the coils of wire in the transformer are replaced by resonant cavities. It is a beautiful idea, but is it worth doing?

The answer depends on whether there is anything to be found in the extended energy range. This is being explored by the LHC and so far nothing new has been seen with any level of certainty. There is still plenty of room for discovery but decisions must be made soon so the data collected in 2011 will be what any decision has to be based on.

It is going to be a hard choice. For me it would be swung towards CLIC if it could be the start of a design that could lead to even higher energies. Could the same trick be used a second

time to provide even higher energies, or is it limited by the amount of power needed to run it? Do other designs have better prospects, such as a muon collider? Big money and decades of development are at stake so let's hope that the right decision is made based on physics rather than politics.

Perhaps it is worth a poll. If it was a straight choice, which of these would you prefer to see international funds spent on?

Which Collider?

33 TeV high energy LHC **28.03%** (44 votes)

1 TeV ILC **8.92%** (14 votes)

3 TeV CLIC **22.93%** (36 votes)

Muon Collider **14.65%** (23 votes)

Something else **6.37%** (10 votes)

Nothing yet **19.11%** (30 votes)

Total Votes: **157**

November 10, 2011: HCP 2011: Will It Deliver?

The rumour mill is once again turning its rusty wheels, and there are suggestions that an interesting result will be revealed at Hadron Collider Physics conference in Paris next week. More on that in a minute.

You may think that things have been quietly lately but there have been a lot of workshops going. They have not been reported much but of course us bloggers have been trawling the slides for anything new and exciting. In case you want to search for anything we might have missed here is a convenient list of links:

- A First Glimpse of the Terascale, Brookhaven, 19th October
- Implications of LHC results for TeV-scale physics, CERN 31st October
- Journee de l'Irfu sur la physics du Higgs, Paris 2 November
- US LHC Users Organisation Annual Meeting, Argonne 3 November
- NeXT Meeting, QMU London, 9 November

One thing that turned up was an update to the Higgs -> WW analysis for ATLAS upgrading it from 1.7/fb to 2/fb, The effect is not terribly exciting, nothing has changed.
So now we are waiting for the HCP conference but not much is expected, or is it? The full schedule of talks can be found here. If this is to believed even the new update for H -> WW will not be shown. The only thing certainly new is the ATLAS+CMS combination of data shown at Lepton Photon nearly three months ago.

But then an organizer speaks of a last-minute talk being added and a comment over at NEW says "…or maybe something else violates CP at 3.5 sigma level." So do we have a new rumour about – perhaps – a result from LHCb, or is someone just hyping the conference?
Apart from that the next big question is when will the next wave of Higgs results be revealed? They must have done more analysis at 2/fb, yet we have not had anything beyond 1/fb for the crucial diphoton search from ATLAS. I am sure they must have also looked at plots using 3/fb to 4/fb but nothing has been said, except a few vague rumours that I don't find convincing.

Now they will be preparing the 5/fb plots that should be ready for approval in December. We may see them soon after but if the results are really so inconclusive we may have to wait for the 5/fb ATLAS+CMS combination. That means there may be nothing ready to show until Moriond in March, unless…

References

1. http://blog.vixra.org/2011/11/06/what-is-the-future-for-particle-accelerators/

2. http://blog.vixra.org/2011/11/10/hcp-2011-will-it-deliver/