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The dawn of a new era of discovery?

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On Wednesday September 10th 2008, physicists and engineers at the CERN laboratory which straddles the Swiss-French border near Geneva began the commissioning of the Large Hadron Collider (the LHC) with beam, and the four LHC experiments (ATLAS, CMS, LCHb and ALICE) saw their first interactions, albeit between the contra-rotating beams of protons and the tiny amounts of residual gas in the beam pipe. Remarkably, these first steps in the ambitious physics programme were taken in the full glare of the media spotlight, which was no doubt excited by the speculation that these first collisions might produce a black hole and destroy the Universe as we know it, or at least the part of it that is near and dear to us.

I cannot remember a recent time when there was so much public interest in a story about fundamental science. I was recently at a party where the imminent start-up of the LHC was one of the main topics of the before and after dinner conversation. Related science stories have been reported — for example, the search for dark matter deep underground in the Boulby potash mine in North Yorkshire, which would complement the discovery of (say) Supersymmetry at the LHC and advance enormously our understanding of the origins of the Universe today.

So, what is the true story? In fact, it is even more remarkable than the media hype suggests. The Standard Model of particles and their interactions (excluding for now gravity) is one of the towering intellectual achievements of the 20th century. But it is incomplete.

Firstly, in order to explain why particles have mass, some extra ingredient is required, and the most elegant proposal is the Higgs mechanism (also discovered by Brout and Englert, and Kibble); as Higgs pointed out, the spontaneous symmetry breaking that gives mass to, for example, the W and Z vector bosons leaves a tell-tale signature in the existence of at least one fundamental scalar particle — the Higgs boson — with properties different from any currently known particle.

The task of the LHC is to discover the Higgs (if it has not already been glimpsed by the Tevatron) but more importantly to establish that it is the Higgs particle — namely, that it couples to mass and behaves as expected.

Secondly, the Standard Model is incomplete in a different way — although it describes all of the currently available data with remarkable precision, there are many unexplained features, such as why are there three generations of particles, why do they have such a striking pattern of masses, are the strong and electroweak interactions different manifestations of a more fundamental force, how do neutrinos obtain their mass, and how does gravity fit in to the picture. New physics, like Supersymmetry, is required to provide the answers to these questions.

Thirdly, there is the unexpected. We are confident that the Standard Model as it is today is the appropriate description of the fundamental interactions at the electroweak scale (energies of order the mass of the W and Z), but we know that it is only a low-energy approximation of a more complete theory, just as Newtonian mechanics is the appropriate low-velocity approximation to special relativity. The "unexpected" could be one of the many speculations about new physics (for example, the existence of extra space dimensions) or it could be something completely unexpected which (by definition) is difficult to predict in advance.

Exploring the TeV scale will take time. The conventional physics expectations (the Standard Model) have to be verified and understood — otherwise, how is the unexpected to be recognised? When the unexpected is at last revealed it will undoubtedly take time to understand its true nature. In the short term, Nature will have become more complicated, but this will disguise a deeper simplicity, which will require new insights and more data to reveal. This is the role, and the challenge, of the LHC.

The LHC machine has been built as a global collaboration, led by and from CERN. The four large experiments have also been built as global collaborations. We at *PMC Physics A* welcome the commitment by CERN and by the experiments to make the results freely available through publication in open access journals. The media coverage of the start-up of LHC demonstrates that there is interest in the general public in fundamental science, and in the structure and origins of our Universe. We should ensure that those who wish can see the results directly for themselves, and not only as viewed through the prism of the media.