C. MARCELLONI/CERN

Josef Kristofoletti's massive mural of the ATLAS particle detector adorns a building at CERN.

PARTICLE PHYSICS

# Going massive

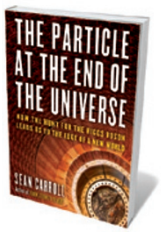
**Jonathan Butterworth** enjoys the latest chronicle of the hunt for the 'most wanted' particle.

The discovery of a Higgs boson, announced on 4 July, was both a long time coming and unexpectedly quick. A long time, considering that the first theoretical papers suggesting how hidden symmetries might have a role in the origin of mass were published in 1964. Quick, because most of us working on the experimental search did not expect to get the answer until the end of this year.

So it is not surprising that Caltech physicist Sean Carroll's *The Particle at the End of the Universe* should emerge soon after the big discovery at CERN, Europe's high-energy physics facility near Geneva in Switzerland. The particle-physics coup is a massive (no pun intended) step forward in our understanding of the underlying physical laws of the Universe, and Carroll seizes the chance to give a wide-ranging discussion of particle physics, how the experiments are carried out and the significance of the discovery itself.

The result is much heavier on the science than, say, Ian Sample's *Massive: The Hunt for the God Particle* (Virgin, 2010), which focuses more on the history and context of the search for the Higgs. Both are excellent, and complementary.

Most of Carroll's book could have been — and probably was — written months or even years ago. Like the Large Hadron Collider (LHC) with which the discovery was made, it was a risk-free investment of time. Had a Higgs not shown up, the theoretical edifice that had clicked into place since the publication of the key papers (by, depending on your taste in assignment of credit, Yoichiro Nambu, Philip Anderson, Robert Brout, François Englert, Peter Higgs, Carl Hagen, Gerald Guralnik, Tom Kibble and Gerard t'Hooft, among many others) would have been revealed as a facade. The experimental answer was always going to be definitive, and the moment would have been right to produce this book either way.




**The Particle at the End of the Universe: How the Hunt for the Higgs Boson Leads Us to the Edge of a New World**
SEAN CARROLL
*Dutton: 2012. 352 pp. $27.95, £16.99*

Carroll has an unintimidating style, but as befits a first-rate particle cosmologist, he presents the real information with little blurring and without a blizzard of maths. He starts with the latest news — the 4 July seminars and the accompanying excitement — then gives an accurate primer on the standard model of particle physics. He enumerates the forces and particles, and discusses the role of quantum fields and symmetries, as well as the accelerators and detectors that provide the evidence to keep the crazy concepts rooted in reality. Towards the end of the book, Carroll touches on the discovery's impact.

I could have done without the *Winnie the Pooh*-style subtitles to each chapter, such as "In which we suggest that everything in the universe is made out of fields". But this is a minor flaw and, elsewhere, he discusses the issues and events with passion and clarity.

An example is the moment, nine days after the LHC was switched on in 2008, when one-eighth of it suffered a catastrophic leak of liquid helium. Or, as Carroll accurately puts it, "it exploded". The disappointment, the challenges of explaining the event to the public and of dealing with the alleged risks of turning on the machine — 'Black holes will eat you!' — are beautifully done.

Carroll gives a sense of the intensity (and the international nature) of the effort of building and running the LHC. I was not surprised by his report that 1 in 16 of the passengers passing through Geneva airport are in some way associated with CERN. I have frequently been one of them. And that is just the tip of an iceberg of teleconferences, e-mails, night shifts and a general shortage of sleep.

The book finishes with a compelling discussion of the new discovery as a possible gateway to understanding the many open issues in particle physics and cosmology. Why is there more matter than antimatter? What are dark energy and dark matter? And are supersymmetry and strings anything more than nice ideas? As a fundamentally novel kind of object and evidence of a new quantum field permeating the Universe, a Higgs boson (whether exactly the standard model Higgs boson or not) may well be the key to more doors in these directions.

Carroll is an experienced advocate for engagement between the scientific community and the general public who, as taxpayers, fund much of the process of discovery. He also acknowledges the distinct possibility that the Higgs boson may never lead directly to applications, while covering the value of new knowledge for its own sake and the benefits of the spin-off technologies developed in the search. On this long journey — which is far from over yet — Carroll is an eloquent and able guide. ■

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