


# Physics





# Physicists

from UCT's Department of Physics were among those celebrating when, after nearly five decades, billions of euros and millions of man-hours, the announcement was recently made that the long-postulated, but until then elusive, Higgs boson particle may finally have been observed. The discovery marks a significant milestone for world physics and UCT's Department of Physics, and draws attention to other groundbreaking work in the department.



# Solving the mysteries of the Universe

“We have a discovery,” Rolf Heuer, the director-general of Conseil Européen pour la Recherche Nucléaire (CERN), the world’s largest particle-physics laboratory, based in Geneva, Switzerland announced in early July. This vindicated considerable investment from governments, research organisations, universities and physicists around the world; and marked a long-awaited moment in physics.

After a 48-year search, a particle was observed by two of the particle detection experiments (ATLAS – A Toroidal LHC ApparatuS – and CMS – Compact Muon Solenoid) run at the Large Hadron Collider (LHC), the most powerful particle accelerator and one of the most complicated scientific instruments ever built. Each collaboration confirmed the formal discovery of a previously unknown particle, whose weight and behaviour was consistent with a Higgs boson.

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“This is the most exciting development in the last 30 years, since the Z and W subatomic particles were observed in the 1980s,” says Emeritus Professor Jean Cleymans, senior scholar at the UCT Department of Physics and director of the South Africa-CERN programme – a collaboration of seven South African universities and research laboratories participating in experiments at CERN.

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If this particle is not the Higgs boson it could open the door for exploration to a completely new level of understanding beyond the Standard Model. Either way, this is big,” says UCT physics lecturer, Dr Andrew Hamilton, speaking from CERN.

## Smashing atoms

The idea that the building blocks, out of which everything is made, are composed of smaller particles than had previously been supposed gained momentum in the latter part of the last century. The mechanism first proposed in the 1960s, which later became known as the Standard Model, explained how fundamental particles such as quarks, gluons, electrons, and photons interact to build the Universe we see around us; it explained the nature of matter, but one element remained missing.

Without the Higgs, the mathematics underlying all this simply would not add up.

“This discovery potentially completes the Standard Model of particle physics,” says Professor Cleymans. “If it is the Higgs, it is a defining moment in the history and future of physics – it’s textbook material.”

*“This is one more example that UCT is participating in world-leading research. We are actively and meaningfully contributing to the international scientific community.”*

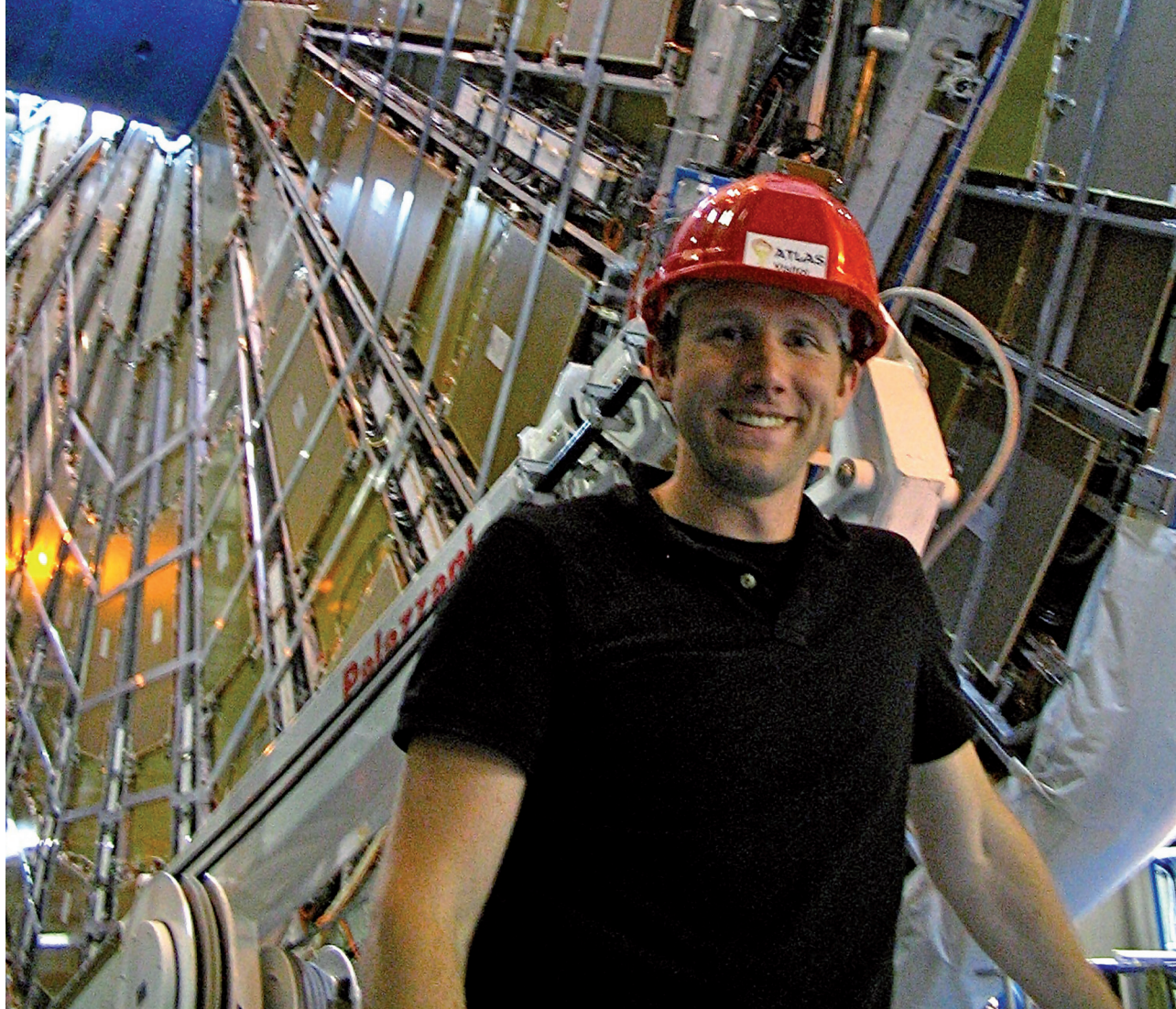
The LHC uses two beams of protons travelling at almost the speed of light, in opposite directions, in a superconducting evacuated beam line of 27km circumference. The two beams are magnetically manipulated to collide within a detector – producing around 800 trillion multifarious proton-proton collisions. The collisions provide individual data points that, collectively, show the presence of what is likely to be the Higgs boson.

## Why particles matter

In particle physics, elementary particles give rise to the world around us. The existence of the Higgs boson and the associated Higgs field is the simplest of several theories explaining why elementary particles have mass. Without the Higgs boson, which is named after British theoretical physicist Peter Higgs (who, at 83, was present at the announcement in Geneva), no elementary particle would have mass. And without this mass, there would be no stars, no planets, and no atoms. No us, no matter.

What does it mean for the average Joe? In a theoretical sense, the discovery contributes to the understanding





*Dr Andrew Hamilton, of the UCT Department of Physics, inside the ATLAS detector at CERN in Geneva.*

of matter; and in a practical sense the particle detector software has a multitude of commercial purposes. For example, one company intended to use software coming out of CERN's third major experiment: A Large Ion Collider Experiment (ALICE) programme, to detect smuggled diamonds in the human body, but ended up using it in a low-dose full-body scanner instead.

"Other spin-offs from the LHC and related technologies are improved superconducting magnets (that lead to better medical imaging devices such as MRIs) and the Internet as we know it," says UCT physics lecturer Dr Will Horowitz. (It was at CERN that physicists invented the World Wide Web.) But, it will probably be years and decades before we realise the full potential of this find.

## UCT's pioneering physicists

The particle discovery was a global effort and a global victory. The ATLAS Experiment alone includes over 3 000 collaborators from 38 countries, including South Africa. UCT physicists also participate in the experiments of the ALICE programme, which uses heavy ion collisions to search for a new state of matter, known as the quark-gluon-plasma.

*"Physics has no local geographical niche to appeal to, such as the southern sky. Physics is truly universal, and to be recognised as excellent, we need to play on the international stage. Being in on big science is good for many reasons. Not least of all attracting excellent students."*

Dr Hamilton has worked directly on the Higgs search as a member of the ATLAS collaboration: "I built part of the trigger system, which is the part of the experiment that chooses which proton collisions will be saved for analysis and which will be thrown away. In ATLAS, we have approximately 40 million events per second, if we were to record every one, we would need to write about three petabytes of data per second (a petabyte is one million gigabytes). This is clearly not possible, so the trigger system selects about 500 events per second that are interesting for analysis."

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# Research groupings associated with this theme

## ■ Centre for Theoretical and Mathematical Physics

The Centre for Theoretical and Mathematical Physics (CTMP) is an inter-departmental research unit devoted to the promotion of inter-disciplinary research in these areas. CTMP is part of the National Institute of Theoretical Physics. CTMP has twelve local members from the departments of Astronomy, Mathematics and Applied Mathematics, and Physics. It also has five international members who visit the centre on a regular basis. Postgraduate students doing theses on related research fields are admitted to CTMP for the duration of their studies. An international advisory board of seven internationally acclaimed scientists was appointed in 2006.

*Director:* Professor I. Barashenkov *E-mail:* Igor.Barashenkov@uct.ac.za *Web:* <http://www.uct.ac.za/faculties/science/research/astrophysics/>

## ■ UCT-CERN Research Centre

The UCT-CERN Research Centre was established in 2003 out of a confluence of certain research programmes within the Department of Physics. As implied by the name of the centre, there is extensive collaboration with CERN, the European Centre for Particle Physics, which is one of the most prestigious research laboratories in the world. In particular, the UCT-CERN Research Centre has close collaboration with the next-generation ultra-relativistic heavy-ion experiment at CERN's Large Hadron Collider (LHC), named ALICE (A Large Ion Collider Experiment).

*Director:* Professor J.W.A. Cleymans *E-mail:* Jean.Cleymans@uct.ac.za *Web:* <http://hep.phy.uct.ac.za/>

## ■ NanoSciences Innovation Centre

The Nanosciences Innovation Centre, located in the Department of Physics and established in 2010, aims to form a bridge between the nanotechnology innovation chain (basic research and technological innovation), and human capacity development. The centre's scientific focus was initially based on existing activities in nanoscale physics and nanostructured materials. These include the development of advanced nanomaterials characterisation techniques, as well as the development of two technology platforms: printed nanoparticulate silicon electronics and metallic matrix nanocomposites. The centre's primary function is to serve as an African hub for nanoscience research and postgraduate education, with an orientation towards renewable energy and sustainable development.

*Director:* Associate professors D.T. Britton and M. Härting *E-mail:* David.Britton@uct.ac.za and Margit.Harting@uct.ac.za *Web:* <http://www.phy.uct.ac.za/nano/development.html>

contributing to the international scientific community," says Dr Hamilton.

The South African effort was partly funded by the South African Department of Science and Technology, which provided around R10,6 million. This funding was distributed by the National Research Foundation over three years.

## Other innovations of the UCT Department of Physics

Recently appointed head of the Department of Physics, Professor Andy Buffler, says that there is no doubt that UCT's participation in these global projects is essential for the reputation of the university. "Physics has no local geographical niche to appeal to, such as the southern

sky. Physics is truly universal, and to be recognised as excellent, we need to play on the international stage. Being in on big science is good for many reasons. Not least of all attracting excellent students," he says.

Professor Buffler has a vision to build on these achievements and bring the department to new heights. "We have to maximise what we have, to be where we want to be," he says. "We will have made nine new appointments in a staff of 14, over five years. This means a lot of fresh energy and many new ideas and big plans that will inform the direction of the department going forward, research and teaching wise."

But it's not only 'big science' that is innovating in the department. "We are looking at nature on every scale, from the smallest particles (such as in the Higgs search); to





*UCT NanoSciences Innovation Centre's Associate Professor Margit Härting (right) and students Ulrich Mannl, Batsirai Magunje, and Stanley Walton show off a newly printed tiger design large area temperature sensor, produced in collaboration with Austin-based company Novacentrix, using their unique copper ink and processing methods. The design is the first step towards replacing expensive – and ecologically questionable – silver inks. For this and other innovations, Associate Professor Härting and colleague Associate Professor David Britton of the Department of Physics won the 2011 Printed Electronics USA Best in Show Award.*

nuclear physics; to nanoscience (using groups of atoms); to the flow and movement of matter (macro material) in applied physics. The department is also mindful of the exciting prospects for research provided by the building of the Square Kilometre Array telescope, which should bring groups in physics, applied mathematics, and astronomy closer together," says Professor Buffler.

The theoretical physicists in the department are working at the international cutting edge of the development of theories aimed at determining the properties of the matter created microseconds after the Big Bang, and recreated on Earth in accelerators such as the LHC at CERN.

Nuclear physics research in the department uses the world-class facilities of iThemba LABS (national laboratory), where there is a 200 MeV cyclotron providing beams for fundamental, applied, and medical research. For example, the AFRODITE array of high purity germanium gamma ray detectors is used to study the structure of nuclei in high spin states. iThemba LABS has plans for significant growth, most notably through the introduction of a second cyclotron that will deliver radioactive beams for research.

Solid state research also takes place at iThemba LABS, as well as within the NanoSciences Innovation Centre in the department, whose work on printed electronics, for example, has tremendous commercial potential in many contexts including food and pharmaceutical packaging, retail, transport and logistics, aerospace and automotive engineering, health care, marketing, and advertising.

There is also very high profile work on the development of models of flow within systems that are important in

industry, such as the use of tumbling mills in the minerals industry in South Africa. The work relies on theoretical and computational modelling, and measurements using Positron Emission Tomography (PET) scanners adapted for Positron Emission Particle Tracking, for which a dedicated laboratory was recently established by the department at iThemba LABS.

Finally, research in the department focuses on physics education at university level. These activities often feed back into curriculum development in the department, to the benefit of both students and lecturers. "The department believes strongly in being research-led in its teaching, by allowing courses to be flavoured by the research in the department and be improved by influences from research into teaching and learning," says Professor Buffler.

All these fields of discovery feed into a larger scientific body of knowledge contributing to discoveries such as the Higgs boson – which is also known as the 'God particle'; so-called in the popular press because of its possible role in producing a fundamental property of elementary particles. The Higgs is crucial to our understanding of the structure of matter. It is to physics what DNA is to life. Perhaps a more apt appellation would be the 'Champagne bottle particle' (apparently the bottom of the bottle is in the shape of the Higgs potential).

This, and other research emanating from physics at UCT, has the potential to change our understanding of the world. The laws of physics are eternal and universal; with science's constant search for the truth, elucidating them is one of the triumphs of mankind.