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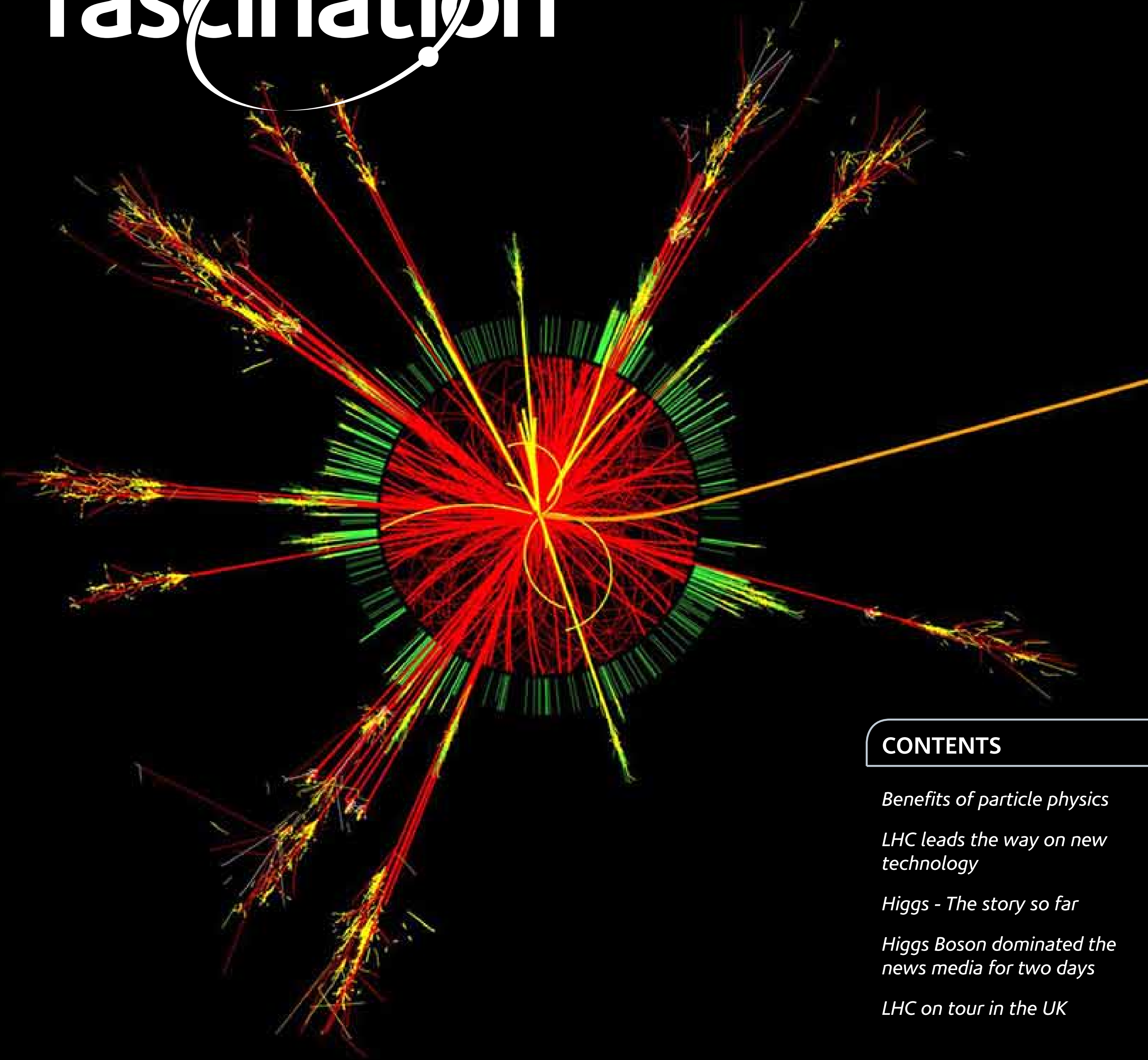
Cover image: A proton collision at the ATLAS experiment which produced a microscopic-black-hole. Credit: CERN

ISSUE 11
News from the Science and Technology Facilities Council

Particle physics special

Exploring & Understanding Science

fascination



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Science & Technology Facilities Council

Using the very large to look for the extremely small

How did the Universe begin? What are we made of? Why does matter behave the way it does? These are questions that particle physics can answer. Particle physics is an ideal showcase for STFC's work – a subject where the research, the resultant innovation and the inspirational value of the science are all world class. It represents amazing value for the amount of added benefit we get from what is at heart a fundamental science project. With the recent breakthrough discovery of a Higgs-like particle, this edition is focussing on particle physics and why it matters to the UK.

The benefits of particle physics to you and everyone you know

The tracker is inserted into the centre of the CMS detector. (Credit: CERN)

On Wednesday 4 July, researchers at CERN in Geneva announced the latest results from the world's largest scientific experiment – the Large Hadron Collider (LHC), and the search for the elusive Higgs Boson. This event generated global media coverage and huge public interest. However, this public interest was not just because an interesting piece of 'blue-sky' research had a new finding to report, but because the work of the team at CERN has already led to spin outs, that directly impact on our lives and the people around us.

These spin outs contribute to and improve our lives every day – from the World Wide Web to touch screen technology, from curing cancers to cloud computing.

Particle physics is curiosity-driven research into the fundamental constituents of matter and the forces of nature. It looks to answer questions we currently have about the nature of matter, the so called known unknowns, and in the process uncover new questions we have yet to answer.

It's a compellingly difficult search that pushes our understanding of matter beyond the limits of what was previously possible. But the search is expensive, times are tough and costs need to be justified, so the secondary benefits from the research are often just as important.

More than 20 research groups and many hundreds of engineers, physicists and other researchers across the UK helped prepare for the LHC and are now involved in the scientific research programmes there.

A number of spin out technologies have come from scientists' work in preparing for the LHC and many new applications are anticipated in coming years – hardly surprising since the last major experiment at CERN resulted in the creation of the World Wide Web. The British engineer and computer scientist, Sir Tim Berners-Lee (whose work was celebrated recently at the London 2012 Opening Ceremony) designed the Web to make it easier for scientists in different locations to work together. Now it is the basis of an online economy that was worth £121 billion in the UK alone in 2010.

The first touch screens were developed at CERN to simplify their particle accelerator control system; today's smart phones and tablet computers, markets which combined have a global value in excess of $180 billion, wouldn't work without touch screens.

Particle accelerators need superconducting magnets to operate and were the first places where mass-produced superconducting magnets were installed. These magnets are now used in MRI scanners, which can image the internal structures of the body and diagnose illness - a market valued at $5 billion each year.

The next leap in connecting computers is 'cloud' computing and the Grid. Particle physics experiments make huge demands on computing resources. The concept of 'cloud' computing – remotely accessible services stored on 'farms' of computers –

was pioneered to share and analyse data from particle physics experiments; it now underpins services such as those offered by Amazon and Google. The internet and World Wide Web let us share information easily but this new technique goes a step further by letting people share things other than files and facts, such as processing power and data storage space.

On a purely economic level the UK involvement at CERN has enabled UK companies to bid for a wide range of lucrative high-tech and construction contracts. In addition UK scientists, with funding from STFC, have contributed vital hardware, computing and expertise to the LHC. This benefits both the economy and the UK's science base and more importantly has pushed the boundaries of what these engineers, designers and researchers have been able to achieve.

UK industry won £19 million worth of contracts a year from CERN during the construction of the LHC and UK industry continues to win, on average, around £15m every year in contracts from CERN. UK IT companies Viglen and Broadberry have won multi million pound contracts to provide part of the required processing power needed to analyse data from the LHC, and the company Concrete Repairs Ltd recently won a contract for the renovation of buildings at CERN.

Research undertaken at the LHC is also expected to have wider benefits for society potentially leading to new cancer therapies, types of medical and industrial imaging, and manufacturing processes.

The micro-electronic technology developed at CERN has found its way into the chips in your phone, making them and your phone smaller and more durable than ever before.

Meanwhile particle detectors, based on those at CERN, are used to monitor nuclear reactor cores to check both for safe operation and, in some installations, to see whether weapons-grade enriched with uranium or plutonium are present Also to screen materials at airports and other national points of entry to check whether radioactive materials are being transported.

The complex accelerators used for particle physics research led directly to the development of synchrotron light sources, which have now become an essential tool for modern science. By revealing the 3D structure of materials, including biological materials, at an atomic and molecular level in unprecedented detail, synchrotron light has led to improvements in the food you eat, the shampoo you use, the clothes you wear and the fuel in your car - amongst other things.

Finally, particle physics is an inspirational subject that attracts many young people to study physics at undergraduate and PhD level. These skilled, highly numerate people are becoming the entrepreneurs and leaders in the knowledge economy and will also produce the next generation of researchers working at CERN.

How did you **become a particle physicist** working on the discovery of the Higgs?

With the recent excitement surrounding the Higgs Boson announcement and the work of the LHC, particle physics is a hot topic and aims to inspire a new generation of physicists.

"The idea of trying to understand how the Universe works sounded very exciting to me so I told myself that that was what I was going to do!" explains Dan Tovey, Professor of Particle Physics at the University of Sheffield who currently works on the ATLAS Experiment (A Toroidal LHC Apparatus), one of seven particle detector experiments at the LHC. "I studied hard and after graduating went to work for my PhD on experiments searching for dark matter.... A few years later I moved across onto ATLAS and the LHC, where I've worked ever since."

Sarah Baker, a PhD student at University College London was also inspired by physics at a young age: "I really wanted to be [a physicist] but it just looked impossible...you look at these big equations and think how do people understand this?" Sarah currently works on the Higgs and future research at the LHC and explains how: "It's just a slow progression of learning...It takes a while but when you are working in the field it's one of the best places to work in the world."

Adam Davidson, a Research Associate at University College London, explains how research as part of his masters degree inspired him: "I found the research to be a big contrast [to lectures] and really enjoyed the project. That motivated me to apply for PhD places in high energy physics." He currently works on the ATLAS experiment at CERN aiming to investigate the theories behind the Standard Model of the Universe.

Jasper Kirkby, Head leader of the cloud experiment, insider the chamber. (Credit: CERN)

Installing the new Quench Protection System, January 2010. (Credit: CERN)

LHC leads the way on new technology

Computing, health and business all benefit

Fundamental high energy physics might seem far removed from our everyday lives, but as this edition of Fascination highlights, the research has led to a number of world changing innovations. Most recently, the LHC, and particularly the technologies and expertise gained through its development, are creating a new era in technological innovation, resulting in the creation of a wealth of industrial collaborations, spin out companies, licenses and patent, benefitting industry, the economy and society.

One such innovation has the potential to cure age-related macular degeneration (AMD), the most common form of blindness in the elderly that affects one in 500 people aged between 55 and 64. An extremely high pixel chip, the Medipix chip, was originally developed for use at the collision points at the LHC's massive detectors. The Universities of Glasgow and Strathclyde are now using this chip to develop an artificial retina, a thin silicon device that will be simpler to implant and operate than any other device currently in use. This is just one use for this kind of chip, which has also been licensed for use at the Diamond Light Source, and also to Oxford Instruments Ltd as part of a collaborative project that is using the chip to develop a more efficient, radiation tolerant sensor, that can not only keep up with the rigorous demands of the LHC, but can also be used in other areas, such as medical imaging.

As previously mentioned, it is well documented that the World Wide Web was developed by Sir Tim Berners Lee at CERN, to meet the demands of its high energy physics experiments. Since then the development of the LHC has meant the creation of a whole new generation of information technology. The Grid was developed as a distributed computer system designed to handle the petabytes of data produced by the LHC - estimated to be enough to fill more than 20,000,000 million CDs annually. A number of business solution spin out companies have now evolved as a result of the Grid.

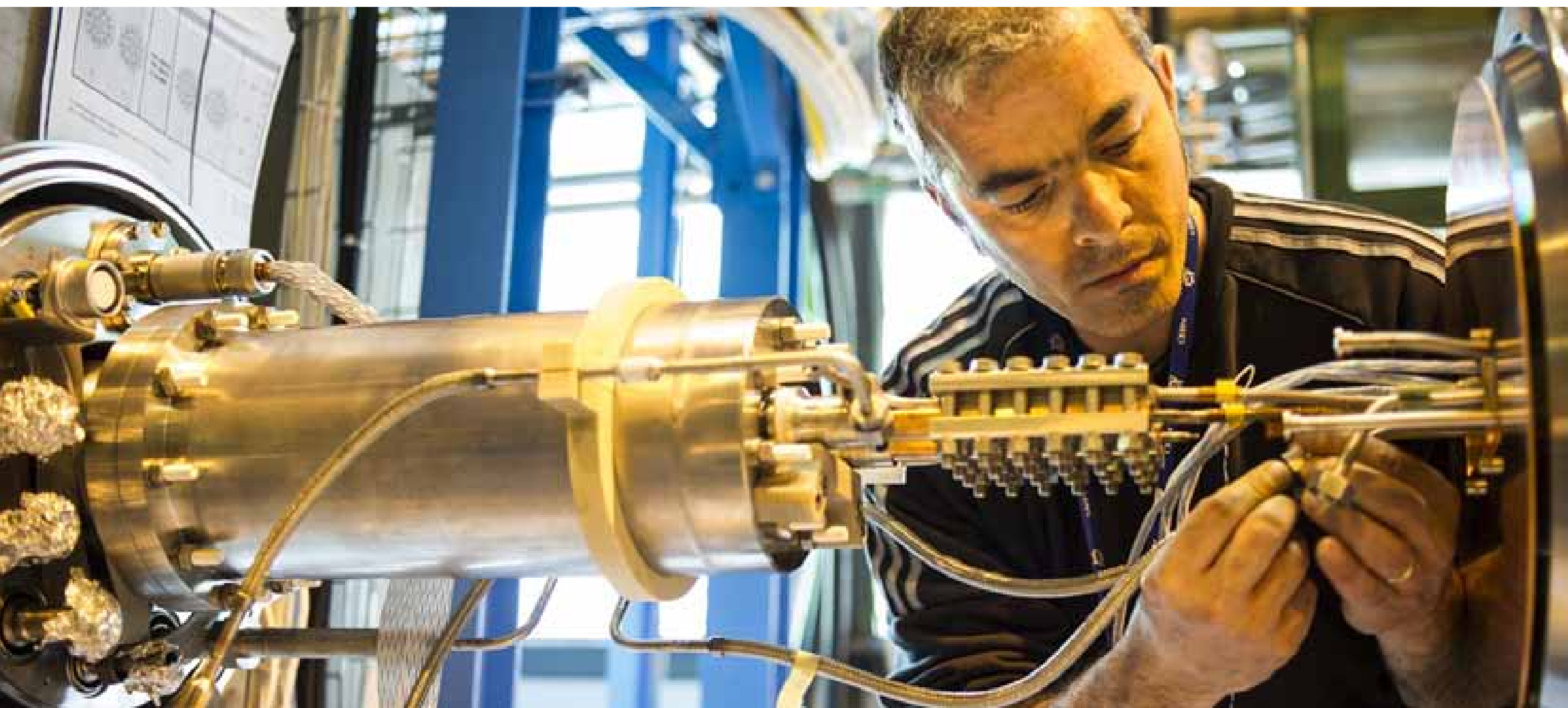
One of these spin outs, Constellation Technologies, is a developer of cloud computing solutions, particularly for the life science and pharmaceutical sectors. Using CERN's Grid technology, combined with STFC's expertise, Constellation Technologies makes supercomputing power available to small businesses, by providing software products and services to those that require complex data management and storage of large data sets at the lowest possible cost. This is particularly relevant to businesses in the life science sector, where genome science is a fast growing computer modelling area in which this powerful IT infrastructure is essential to support the significant investment going into personalised medicine. Since its creation, Constellation has already worked with major names, such as Microsoft and Viglen and has been nominated for a UK IT Industry Award.

Imense Ltd, a small University of Cambridge spin out, that could provide the next generation of web search engine, has benefitted hugely from the Grid, which it has used to develop a new way of searching for images on the on the web, without needing text descriptions that have been entered manually. Imense were able to test their software on millions of images using Grid technology, enabling them to gain essential funding to take their product forward.

Software information system, CRISTAL, is a distributed workflow management tool developed at CERN in association with the University of West England at Bristol, which was specifically written to support the production and assembly phases of the LHC's CMS detector. The CRISTAL information system provides a radically new process of implementing new business process systems and enables the tracking of product and process evolution across a project's life cycle. Now adapted for use in industry, CRISTAL technology has already spun out to French business process management firm, Agilium, which designs software to manage the lifecycle of business processes.

As the world's largest scientific instrument, the LHC is no doubt leading the way in new technologies and expertise that are transferable to industry, and is likely to do so for the foreseeable future.

Connecting up the Fast Cycled Superconducting Magnet. (Credit: CERN)



How the Higgs Boson announcement dominated the news media for three days in July

The discovery of a Higgs-like particle was always going to be a big science story, but the announcement at CERN on 4 July transcended the science media and became a lead story in the national and international press.

Broadcast media broke the story first, with many carrying it live from CERN or London. Over 12 million people watched coverage of the Higgs announcement on television, with BBC and ITV producing a series of bulletins live from the CERN and London media events, and making it a key story in their news as well as on Channel 4, Newsround (CBBC) and Newsnight.

Over 14 million people heard the announcement through local and national radio. The BBC broadcast two segments on Radio 4's Today programme and BBC Radio 5 Live reported on the Higgs throughout the day.

The extensive coverage on 5 July included the front cover of the 'I', The Independent, The Guardian, The Times, The Wall Street Journal and the Financial Times. Over the next three days nearly 1500 articles were published in daily, weekly and monthly newspapers and magazines and from 5 to 20 July almost 4,500 articles were printed globally which mentioned the Higgs Boson.

However, social media was perhaps the most active, with the Higgs Boson mentioned every 1.1 seconds at the peak of the excitement. Throughout 4 July Higgs-related themes made up 8 of the 10 trending topics and globally there were over 7.5 million Twitter mentions. But social media extends beyond Twitter - in the first two weeks 2,010 Higgs-related videos were uploaded to YouTube. The Top 20 of these have been viewed by over 3.8 million people.

The STFC Communications team briefed hundreds of journalists about the story by phone, in emails and in person at the London media event as well as arranging interviews for them with particle physics experts. 82 experts, from PhD students to Professors were available to talk to the media, and 19 of those spoke to over 160 media outlets on 4 and 5 July. STFC Chief Executive John Womersley was quoted in over 80 news articles and broadcasts.

Higgs – the story so far

At the LHC, physicists have discovered a particle consistent with the Higgs boson. But where did it all begin?

Three groups of physicists simultaneously proposed theories similar to the Higgs mechanism in 1964. Over the next five decades, scientists searched for the Higgs boson. From 1987 to 2000 the Large Electron-Positron Collider (LEP) at CERN ran experiments that set a region in which future endeavours would focus. LEP was closed in 2000 to allow for the construction of the Large Hadron Collider (LHC), which became fully operational in 2010. During this period, Fermilab's Tevatron, another hadron collider, worked to focus the hunt for the Higgs further. After studying data from both accelerators, in December 2011 the search was focused at 125GeV.

On 2 July Tevatron announced that the Higgs would probably be found between 125-126GeV, but they only had 2.9 sigma confidence levels. The accepted level for a 'discovery' is five sigma (a probability of one in a 3.5 million that the discovery occurred by chance).

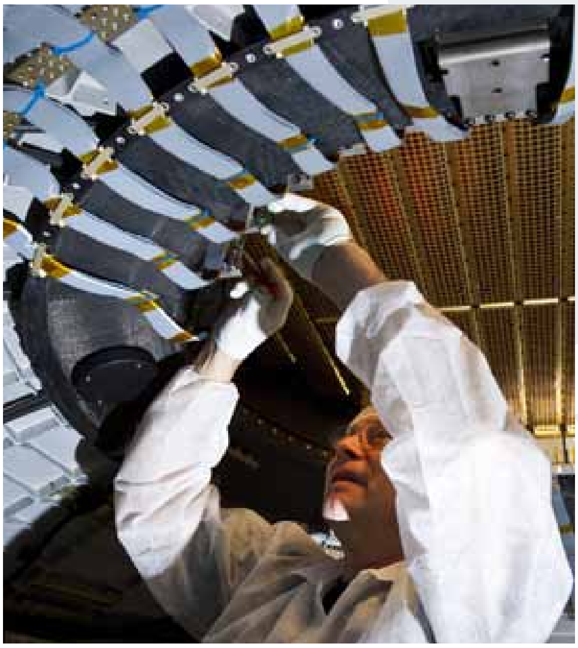
Two days later CERN reached five sigma and cautiously announced the discovery of a 'Higgs-like particle'. Further analysis of the data collected since then continues to increase confidence in the finding.

STFC is the UK's sponsor of particle physics – coordinating the UK particle physics and particle astrophysics programmes and is involved in many high energy physics experiments at different research institutes around the world, such as CERN, MICE (Muon Ionisation Cooling Experiment) , MINOS (Main Injector Neutrino Oscillation Search) and nEDM (Neutron Electric Dipole Moment). Many large facilities (synchrotrons and neutrons) rely on techniques discovered in particle physics.

Particle physics has an accepted definition for a discovery: a 'five-sigma' (or five standard-deviation) level of certainty. The number of sigmas measures how unlikely it is to get a certain experimental result as a matter of chance rather than due to a real effect.

- Similarly, tossing a coin and getting a number of heads in a row may just be chance, rather than a sign of a 'loaded' coin
- The 'three sigma' level represents about the same likelihood of tossing a coin more than eight heads in a row.
- Five sigma, on the other hand, would correspond to tossing more than 20 in a row.

Dedicated to explaining our complicated Universe, particle physics is looking to answer questions about the most basic building blocks of life (and everything else). This field of physics investigates the nature of matter, and in particular the properties and behaviour of the elementary particles, of which matter is composed.



The AMS experiment is prepared for a new magnet to be installed. (Credit CERN)

The LHC is the most powerful particle accelerator ever built. Based at CERN, the European particle physics laboratory near Geneva in Switzerland, it is one of the world's largest laboratories and is dedicated to the pursuit of fundamental science. The LHC lets scientists reproduce the conditions that existed within a billionth of a second after the Big Bang. This is the moment, around 14billion years ago, when the Universe is believed to have started with an explosion of energy and matter. During this first moment of time the particles and forces that shaped out Universe came into existence. Scientists recreate these conditions by accelerating two beams of high-energy protons or lead ions inside the LHC's 27 km circular tunnel, which crosses the French-Swiss border 100m below the ground. The beams travel in opposite directions at close to the speed of light.

A huge international project exploring the boundaries of our knowledge and theories about the world we live in. The LHC experiments will help us understand the origins and evolution of our Universe and possibly reshape how we think about the physical world.

Shortly after the Big Bang, it is thought that many particles had no mass, but became heavy later on due to what we refer to as the Higgs field. Any particles that interact with this field are given mass. The Higgs Boson is the signature particle of the field. Named after Peter Higgs, a University of Edinburgh physicist who came up with the theory of its existence, the Higgs Boson is crucial to understanding the origin of mass.

Through STFC's subscription, the UK is one of the biggest investors in CERN and through its membership UK companies can bid for lucrative high-tech contracts. In addition UK scientists, with funding from STFC, have contributed vital hardware, computing and expertise to the LHC.

The current UK share of the CERN budget is 14.6%, £95 million a year.

24:hours around the announcement

"Everyone always jokes that the British are obsessed with queuing. However on Tuesday 3 July, the night before the CERN seminar to announce the latest results on searches for the Higgs Boson at ATLAS and CMS, the two multipurpose experiments at the LHC, we certainly weren't the only ones...

The seminar was due to start at 9.00am the following morning, but by 11.30pm there were already about 30 people assembled, and we worked out that to be in the front 150 (the number of free seats in the seminar room) you would have had to join the queue by 5am. So why did we bother? There are certainly much more comfortable ways to spend the night than the floor outside the CERN auditorium, and obviously there was a chance you could just get up very early the next morning and make it in. However instead a group of us decided to camp out, just to make sure we got a space in the room. We all knew the discovery of the Higgs Boson would probably be the biggest discovery in particle physics of this generation. And we were all expecting the announcement- I think that was the best part of it. There had been a general air of anticipation for days.

There was a reasonable sized group of researchers from the UK who camped out together ahead of the seminar. There was a really good atmosphere amongst those queuing- some people watched films or played cards, admittedly some people slept, but by about 5am there were enough people in the area outside the Auditorium to make sleeping pretty much impossible. By 7am the security staff were outside the door waiting to start letting people in and, it's safe to say, the atmosphere was more like that before a football match than a physics seminar. Everyone was on their feet waiting to get in, and there were various film crews and photographers around the place.

At 7.30am we were let in and took our seats, and then it was just a matter of waiting for the talks to begin. The front rows of the auditorium had been reserved for invited guests, and right before it started, when Peter Higgs arrived to take his seat, there was a great cheer from the crowd. It was quite bizarre being in the room, knowing that it was being webcast not only to many conference rooms in CERN where people had assembled to watch the talks, but also across to the ICHEP conference in Melbourne, and to anyone else who was watching at home. The room was packed, with people of many different nationalities and stages in their career. In age it went from the CERN summer students right up to researchers who had been in the field since the Higgs Boson was first postulated.

The CMS and ATLAS spokespeople gave their presentations in turn, and it was a funny mix of complete silence as everyone tried to take in the results, and loud applause whenever a key result was announced. I think the Director General of CERN, Rolf-Dieter Heuer, summarised it pretty well at the end with "As a layman, I would now say I think we have it." It was good to hear live the reaction of the theorists to the news - four of the six theorists who first predicted the existence of the Higg's Boson were in the room, and were clearly delighted with the announcements.

Even now, there is still a bit of a buzz about the place. It's been great to be out here in what I think is undoubtedly going to be a historical year for particle physics, and I guess we just have to see what else there is to come..." Sarah Williams.

Particle physicists queued overnight to get a seat for the announcement at CERN. (Credit: Sarah Williams, University of Cambridge)

Large Hadron Collider on tour in the UK

The 'Large Hadron Collider on Tour' is a travelling exhibition showcasing the LHC to highlight the UK's role as a world leader in research and innovation.

Visitors enjoying the model of the LHC tunnel.

The Spinning Ball accelerator shows how the LHC accelerates particles using magnets.

Visitors can get hands-on with a number of interactive exhibits, which create a feel for what it's like to be a particle physicist working on this international scientific exploration. Visitors also have the opportunity to meet some of the UK's top LHC researchers and physics students, who are working at the LHC and who will be on hand to answer questions and inspire the next generation of scientists.

- Spinning ball particle accelerator – Demonstrating how the 1,600 superconducting magnets that are inside the LHC can control and accelerate a subatomic particle.
- Cosmic ray detector - This year sees the centenary celebrations of the discovery of cosmic rays. Thousands of these subatomic particles pass through our bodies everyday without us even noticing. The detector allows visitors to see when one passes through the equipment.

It has already visited six venues around the UK ranging from Central Hall in Westminster to the Jodrell Bank music festival. The exhibition is being run by STFC with the help of UK PhD and post doc particle physics students who have worked at or with CERN on an experiment on the LHC.

Upcoming tour dates for 2012 include:
30 September - Daresbury Science Festival
28 November - 2 December - Senedd Building, Welsh Assembly, Cardiff

Getting hands on with science – a visitor discovers how a magnet affects a TV picture.

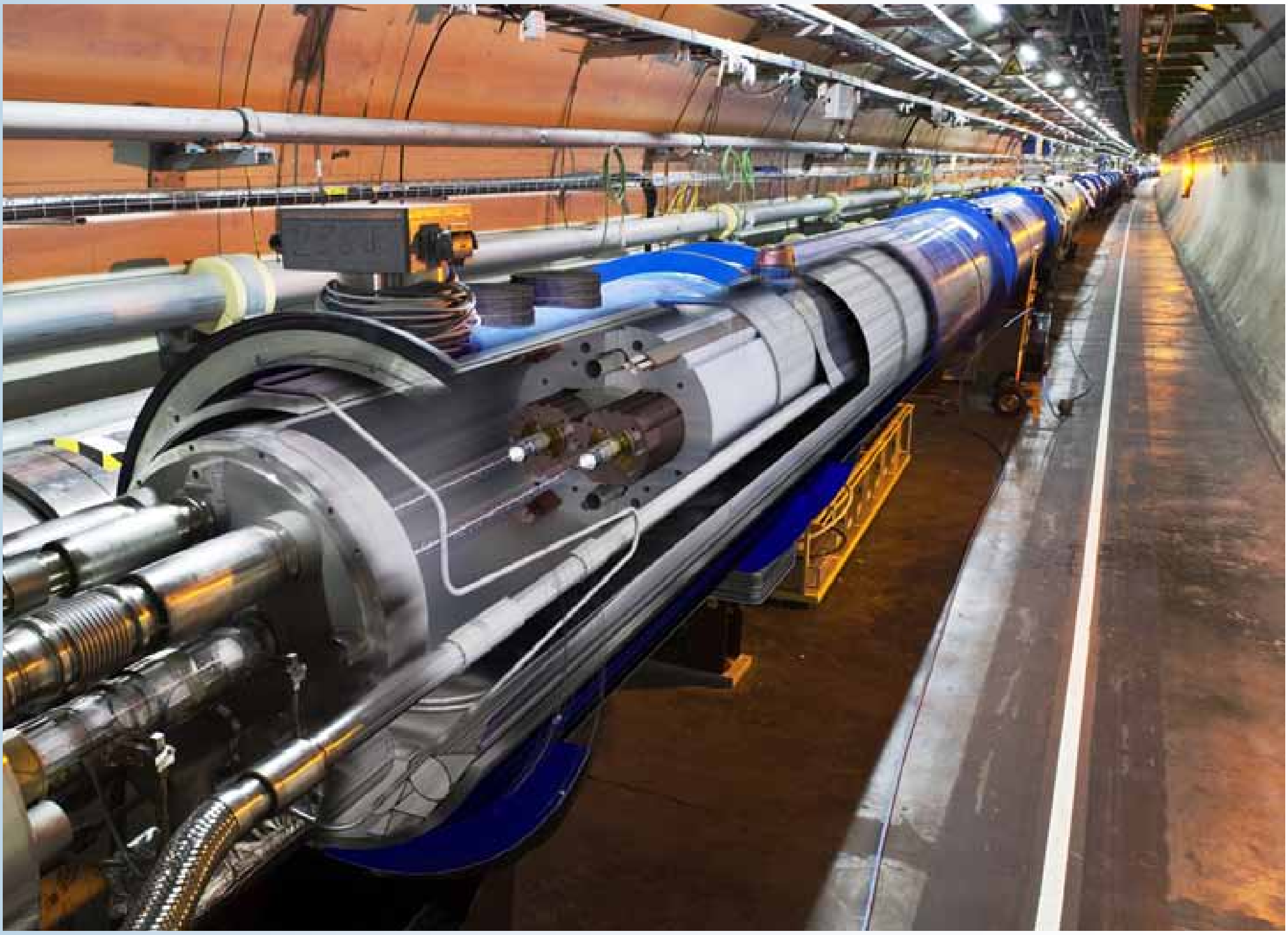
After the Higgs, **what next?**

In August the ALICE team, based at the LHC, reported that they are closer than ever to unravelling the properties of the primordial state of the Universe: the quark–gluon plasma. Their latest research findings have looked at the more refined characterisations of the densest and hottest matter ever studied in the laboratory – 100,000 times hotter than the interior of the Sun and denser than a neutron star. The team, whose experiments use heavy ions at CERN's LHC, have made new measurements of the kind of matter that probably existed in the first instants of the Universe.

The experiment has also observed indications of a thermalisation phenomenon, which involves the recombination of charm and anticharm quarks to form 'charmonium'. These studies will contribute significantly to our understanding of the early Universe.

1 fb-1 of luminosity has been delivered to LHCb this year.

The LHC beauty (LHCb) is an experiment at CERN set up to explore what happened after the Big Bang that allowed matter to survive and build the Universe we inhabit today. The experiment is investigating the slight differences between matter and antimatter by studying a type of particle called the 'beauty quark', or 'b quark'. The latest results announced in August show that over 1 fb-1 of luminosity has been delivered to LHCb this year. This great achievement will allow the team at CERN to push further our knowledge of the Standard Model.



A 3D view of the LHC machine. (Credit: CERN)

Imagine a camera so sensitive that it could see a candle on one of Jupiter's moons. Impossible? Not anymore

The MIRI instrument was assembled and tested at STFC's RAL Space.

MIRI (Mid InfraRed Instrument) is the first of four instruments to be constructed for the James Webb Space Telescope (JWST). The JWST will end up in orbit four times further away from Earth than the Moon, around 1.5 million km away, in order to study other galaxies and the solar systems within them. MIRI will contribute to the mission by allowing astronomers to study the formation of planets around stars, and could even lead to the discovery of other habitable planets. MIRI is designed to observe light at a longer wavelength than the other instruments commissioned for the telescope, making new areas of research available.

MIRI was built collaboratively between Britain and Europe, and utilised some of the best world class facilities the UK has to offer; both the assembly of MIRI and the mechanical and thermal testing were carried out at STFC's RAL Space.

It took 10 years of work by 200 dedicated engineers, but MIRI has finally been completed, and was handed over to NASA on 9 May. MIRI was transported to the Goddard Space Flight Center in a container specially designed to keep it at a regular temperature, and to protect it from moisture. It arrived at NASA Goddard on 30 May, where it will be integrated with the rest of the telescope ready for launch in 2018.

Gravity sensors

Gravity sensors adapted from satellites can find new oil and gas fields thanks to collaboration between STFC's Rutherford Appleton Laboratory and scientists from the University of Aberdeen.

The sensor attaches to Remotely Operated Vehicles (ROVs) which works deep under the waves, and measures variations in gravity and density on the sea bed which might indicate the presence of natural gas or oil. The technology is called a 'cold atom trap' and involves cooling rubidium atoms to close to absolute zero until they behave a bit like a laser beam. Their movement is affected by gravity and can be measured more accurately than traditional lasers, and their ability to be attached to ROVs and taken to the seabed, allows them to be much more precise than traditional gravity sensors. This aptitude for detecting oil could prolong the life of the North Sea reserves and increase the quantity of oil able to be extracted world-wide.

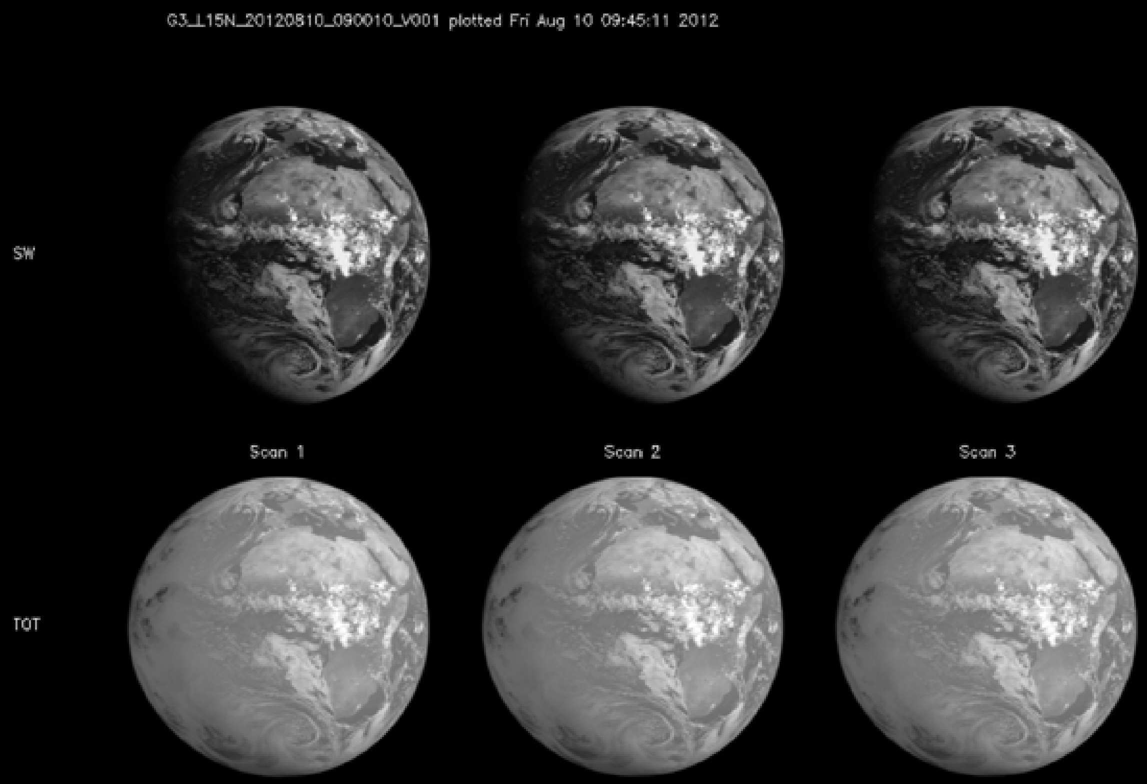
Dr Charles Wang, who is leading the project, told Fascination about how he had worked with STFC -

"The STFC Centre for Fundamental Physics has provided support for me to collaborate with Professor Bob Bingham, Dr Martin Caldwell and other colleagues at RAL in the past few years on a range of research topics in theoretical and experimental physics. In particular we have been collaborating on quantum sensing techniques using ultra cold atoms that could test theories of quantum gravity."

Quantum gravity tries to unify theories of quantum mechanics and general relativity. Dr Wang went on to describe how his partnership with RAL stimulated 'new ideas' and access to its facilities took his research forward 'widening its impact on academic and industrial sectors.'

The prototype trials of the subsea gravity sensors will take place in a couple of months and Dr Wang hopes that the technology can begin to be used industrially over the next few years.

Severe weather supercomputers and satellites help protect us



The image shows calibrated radiances produced by RAL Space for the shortwave (SW) channel which measures reflected sunlight and its total channel sensitive to all outgoing energy from thermal emissions by the Earth and reflected sunlight. These observations allow reflected shortwave and emitted long-wave fluxes to be calculated that are then used by scientists for studying climate. (Credit: EUMETSAT)

Severe weather can have a huge impact on our lives, affecting everything from transport to agriculture, costing the economy millions of pounds per day of disruption. STFC, together with the Met Office and the Natural Environment Research Council (NERC), have joined together to design and build a next-generation weather forecasting model, to help prevent bad weather having such damaging results.

The model will exploit advanced computers known as supercomputers- ultra-fast computers that run thousands of times faster than an average computer. The computers contain millions of processors, meaning they are capable of running up to a million trillion calculations per second. Supercomputers will make weather and climate prediction much more accurate, allowing us to plan and therefore live more easily with bouts of severe weather.

The project will be one of the first to benefit from STFC's Hartree Centre, a future software research facility based at Daresbury Laboratory in Cheshire. The IBM Blue Gene/Q at Daresbury, named Blue Joule, has been ranked number one in the UK, and number 13 in the world, in this year's Top 500 list of supercomputers.

Eyes above

In addition to harnessing the power of supercomputers, satellites are still being used to help predict the weather. The latest addition to the fleet of 'eyes in the sky' is an instrument to take the Earth's temperature. Meteosat Second Generation 3 (MSG 3) was launched from Europe's Spaceport in Kourou, French Guiana on 5 July. On board is the 200th RAL space instrument to be launched, the Geostationary Earth Radiation Budget (GERB) instrument.

GERB measures how the Earth heats and cools by making high accuracy measurements of the solar radiation absorbed, and the infrared energy emitted. It provides measurements every 15 minutes allowing scientists to study events and features such as convective cloud, frontal systems and aerosol variability from dust storms or volcanoes. It is the first instrument providing dedicated measurements of the Earth radiation budget from geostationary orbit and will provide data for use by meteorologists and climate scientists worldwide.

Graphene -
Re-knits its own holes

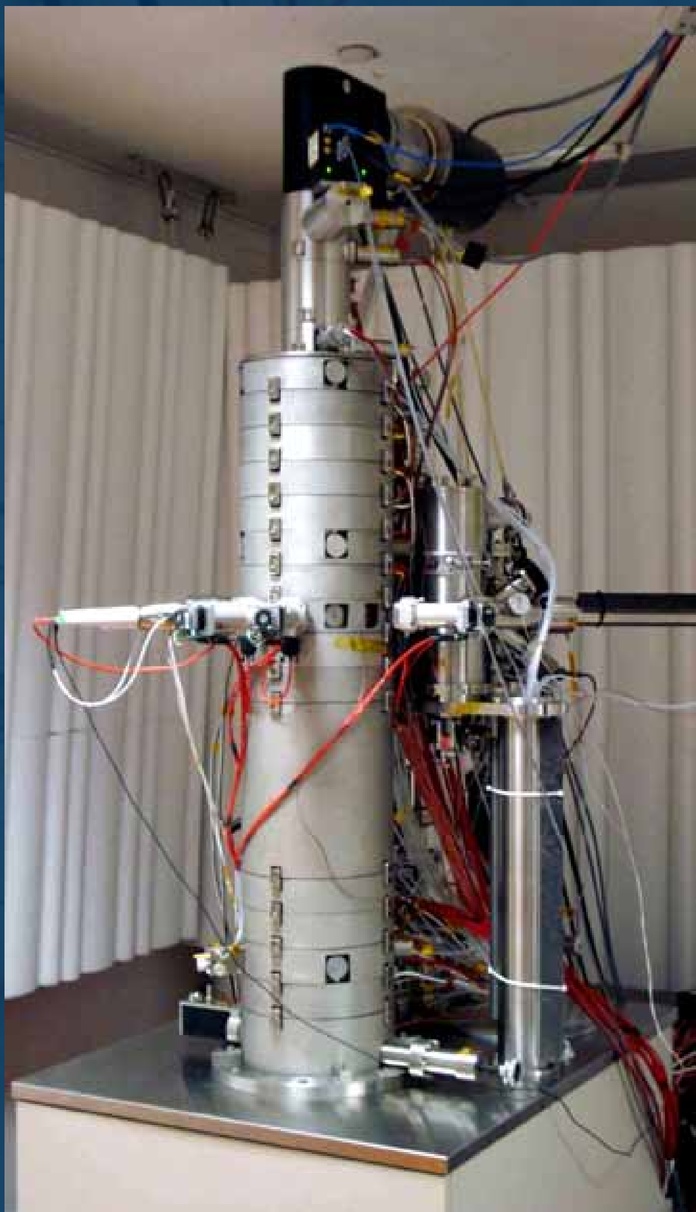
Scientists at the University of Manchester and the SuperSTEM facility at STFC's Daresbury Laboratory have discovered that the 'miracle material', graphene, can undergo a self repairing process to mend holes. Graphene, which is made of sheets of carbon just one atom thick, has a wide range of potential applications from electronics to medicine.

The researchers were using a powerful electron microscope at SuperSTEM, which allows scientists to study the properties of materials one atom at a time. They recently demonstrated that metals can initiate the formation of holes in the graphene sheet, which could be hugely detrimental to the properties of any graphene-based device.

Surprise results then showed that some of the holes that had been created during this process were actually mending themselves spontaneously using nearby loose carbon atoms to re-knit the graphene structure.

The team were originally looking at how metals interact with graphene, which is essential if it is to be used in electronic devices of the future.

Dr Quentin Ramasse, Scientific Director at SuperSTEM said: "This was a very exciting and unexpected result. The fact that graphene can heal itself under the right conditions may be the difference between a working device and a proof of concept without any real application. This adds a lot of flexibility to our nanotechnology toolbox and could pave the way to future technological applications".



SuperSTEM2, there are only six of these exceptionally sensitive instruments worldwide. (Credit: SuperSTEM Consortium)

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