

# Particle Accelerator Fits on a Chip

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*The first full characterization measurement of an accelerator beam in six dimensions will advance the understanding and performance of current and planned accelerators around the world. [11]*

*Researchers have found a way to accelerate antimatter in a 1000x smaller space than current accelerators, boosting the science of exotic particles. [10]*

*THREE WEEKS AGO, upon sifting through the aftermath of their protonsmashing experiments, physicists working at the Large Hadron Collider reported an unusual bump in their signal: the signature of two photons simultaneously hitting a detector. Physicists identify particles by reading these signatures, which result from the decay of larger, unstable particles that form during high-energy collisions. It's how they discovered the Higgs boson back in 2012. But this time, they had no idea where the photons came from. [9]*

*In 2012, a proposed observation of the Higgs boson was reported at the Large Hadron Collider in CERN. The observation has puzzled the physics community, as the mass of the observed particle, 125 GeV, looks lighter than the expected energy scale, about 1 TeV. [8]*

*'In the new run, because of the highest-ever energies available at the LHC, we might finally create dark matter in the laboratory,' says Daniela. 'If dark matter is the lightest SUSY particle than we might discover many other SUSY particles, since SUSY predicts that every Standard Model particle has a SUSY counterpart.' [7]*

*The problem is that there are several things the Standard Model is unable to explain, for example the dark matter that makes up a large part of the universe. Many particle physicists are therefore working on the development of new, more comprehensive models. [6]*

*They might seem quite different, but both the Higgs boson and dark matter particles may have some similarities. The Higgs boson is thought to be the particle that gives matter its mass. And in the same vein, dark matter is thought to account for much of the 'missing mass' in galaxies in the universe. It may be that these mass-giving particles have more in common than was thought. [5]*

*The magnetic induction creates a negative electric field, causing an electromagnetic inertia responsible for the relativistic mass change; it is the mysterious Higgs Field giving mass to the particles. The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate by the diffraction patterns. The accelerating charges explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Relativistic Quantum Theories. The self maintained electric potential of the accelerating charges equivalent with the General Relativity space-time curvature, and since it is true on the quantum level also, gives the base of the Quantum Gravity.*

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## Preface

### Popular questions about the Higgs Field:

- 1.) If the Higgs field is responsible for imbuing particles with mass, and mass is responsible for gravity, is it possible that the Higgs field will provide the missing link between general relativity and quantum mechanics i.e. could the Higgs field be the basis of a quantum theory of gravity?
- 2.) Can the theoretical Higgs Field be used as the “cause” of relativistic momentum or relativistic kinetic energy of a moving body?
- 3.) Does Einstein's General Relativity need to be adjusted for the Higgs field?
- 4.) Since the Higgs field gives most particles mass, and permeates all space, then GR needs the Higgs field to be a theory of space?
- 5.) So where GR is highly curved, the Higgs field is also curved? And does a highly curved Higgs field affect the way particles acquire mass? For that matter, a curved space-time would also curve electromagnetic field?

### How can we answer these questions?

There is an explanation of the magnetic effect caused by the electric current from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the electric wire. The charge distribution is lowering in the reference frame of the accelerating charges linearly:  $ds/dt = at$  (time coordinate), but in the reference frame of the current it is parabolic:  $s = a/2 t^2$  (geometric coordinate). The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron’s spin also, building the bridge between the Classical and Quantum Theories. [1]

One origin of the Quantum Physics is the Planck Distribution Law of the electromagnetic oscillators, giving equal intensity for 2 different wavelengths on any temperature. Any of these two wavelengths will give equal intensity diffraction patterns, building different asymmetric

constructions, for example proton - electron structures (atoms), molecules, etc. Since the particles are centers of diffraction patterns they also have particle – wave duality as the electromagnetic waves have. The Electroweak Interaction shows that the Weak Interaction is basically electromagnetic in nature. The arrow of time shows the entropy grows by changing the temperature dependent diffraction patterns of the electromagnetic oscillators. [2]

## Researchers build a particle accelerator that fits on a chip

On a hillside above Stanford University, the SLAC National Accelerator Laboratory operates a scientific instrument nearly 2 miles long. In this giant accelerator, a stream of electrons flows through a vacuum pipe, as bursts of microwave radiation nudge the particles ever-faster forward until their velocity approaches the speed of light, creating a powerful beam that scientists from around the world use to probe the atomic and molecular structures of inorganic and biological materials.

Now, for the first time, scientists at Stanford and SLAC have created a [silicon chip](#) that can accelerate electrons—albeit at a fraction of the velocity of that massive instrument—using an infrared laser to deliver, in less than a hair's width, the sort of energy boost that takes microwaves many feet.

Writing in the Jan. 3 issue of *Science*, a team led by electrical engineer Jelena Vuckovic explained how they carved a nanoscale channel out of silicon, sealed it in a vacuum and sent electrons through this cavity while pulses of infrared light—to which silicon is as transparent as glass is to visible light—were transmitted by the channel walls to speed the electrons along.

The accelerator-on-a-chip demonstrated in *Science* is just a prototype, but Vuckovic said its design and fabrication techniques can be scaled up to deliver particle beams accelerated enough to perform cutting-edge experiments in chemistry, materials science and biological discovery that don't require the power of a massive accelerator.

"The largest accelerators are like powerful telescopes. There are only a few in the world and scientists must come to places like SLAC to use them," Vuckovic said. "We want to miniaturize accelerator technology in a way that makes it a more accessible research tool."

Team members liken their approach to the way that computing evolved from the mainframe to the smaller but still useful PC. Accelerator-on-a-chip technology could also lead to new cancer radiation therapies, said physicist Robert Byer, a co-author of the *Science* paper. Again, it's a matter of size. Today, medical X-ray machines fill a room and deliver a beam of radiation that's tough to focus on tumors, requiring patients to wear lead shields to minimize collateral damage.

"In this paper we begin to show how it might be possible to deliver electron beam radiation directly to a tumor, leaving healthy tissue unaffected," said Byer, who leads the Accelerator on a Chip International Program, or ACHIP, a broader effort of which this current research is a part.

## Inverse design

In their paper, Vuckovic and graduate student Neil Sapiro, the first author, explain how the team built a chip that fires pulses of infrared light through silicon to hit electrons at just the right moment, and just the right angle, to move them forward just a bit faster than before.

To accomplish this, they turned the design process upside down. In a traditional accelerator, like the one at SLAC, engineers generally draft a basic design, then run simulations to physically arrange the microwave bursts to deliver the greatest possible acceleration. But microwaves measure 4 inches from peak to trough, while infrared light has a wavelength one-tenth the width of a human hair. That difference explains why infrared light can accelerate electrons in such short distances compared to microwaves. But this also means that the chip's physical features must be 100,000 times smaller than the copper structures in a traditional accelerator. This demands a new approach to engineering based on silicon integrated photonics and lithography.

Vuckovic's team solved the problem using inverse design algorithms that her lab has developed. These algorithms allowed the researchers to work backward, by specifying how much light energy they wanted the chip to deliver, and tasking the software with suggesting how to build the right nanoscale structures required to bring the photons into proper contact with the flow of electrons.

"Sometimes, inverse designs can produce solutions that a human engineer might not have thought of," said R. Joel England, a SLAC staff scientist and co-author on the *Science* paper.

The design algorithm came up with a chip layout that seems almost otherworldly. Imagine nanoscale mesas, separated by a channel, etched out of silicon. Electrons flowing through the channel run a gantlet of silicon wires, poking through the canyon wall at strategic locations. Each time the laser pulses—which it does 100,000 times a second—a burst of photons hits a bunch of electrons, accelerating them forward. All of this occurs in less than a hair's width, on the surface of a vacuum-sealed silicon chip, made by team members at Stanford.

The researchers want to accelerate electrons to 94 percent of the speed of light, or 1 million electron volts (1MeV), to create a particle flow powerful enough for research or medical purposes. This prototype chip provides only a single stage of acceleration, and the electron flow would have to pass through around 1,000 of these stages to achieve 1MeV. But that's not as daunting as it may seem, said Vuckovic, because this prototype accelerator-on-a-chip is a fully integrated circuit. That means all of the critical functions needed to create acceleration are built right into the chip, and increasing its capabilities should be reasonably straightforward.

The researchers plan to pack a thousand stages of acceleration into roughly an inch of chip space by the end of 2020 to reach their 1MeV target. Although that would be an important milestone, such a device would still pale in power alongside the capabilities of the SLAC research accelerator, which can generate energy levels 30,000 times greater than 1MeV. But Byer believes that, just as transistors eventually replaced vacuum tubes in electronics, light-based devices will one day challenge the capabilities of microwave-driven accelerators.

Meanwhile, in anticipation of developing a 1MeV accelerator on a chip, electrical engineer Olav Solgaard, a co-author on the paper, has already begun work on a possible cancer-fighting application. Today, highly energized electrons aren't used for radiation therapy because they would

burn the skin. Solgaard is working on a way to channel high-energy electrons from a chip-sized accelerator through a catheter-like vacuum tube that could be inserted below the skin, right alongside a tumor, using the particle beam to administer radiation therapy surgically.

"We can derive medical benefits from the miniaturization of [accelerator](#) technology in addition to the research applications," Solgaard said. [12]

## **Team makes first particle accelerator beam measurement in six dimensions**

The first full characterization measurement of an accelerator beam in six dimensions will advance the understanding and performance of current and planned accelerators around the world.

A team of researchers led by the University of Tennessee, Knoxville conducted the measurement in a beam test facility at the Department of Energy's Oak Ridge National Laboratory using a replica of the Spallation Neutron Source's [linear accelerator](#), or linac. The details are published in the journal *Physical Review Letters*.

"Our goal is to better understand the physics of the beam so that we can improve how accelerators operate," said Sarah Cousineau, group leader in ORNL's Research Accelerator Division and UT joint faculty professor. "Part of that is related to being able to fully characterize or measure a beam in 6D space—and that's something that, until now, has never been done."

Six-dimensional space is like 3-D space but includes three additional coordinates on the x, y, and z axes to track motion or velocity.

"Right away we saw the beam has this complex structure in 6D space that you can't see below 5D—layers and layers of complexities that can't be detangled," Cousineau said. "The measurement also revealed the beam structure is directly related to the beam's intensity, which gets more complex as the intensity increases."

Previous attempts to fully characterize an accelerator beam fell victim to "the curse of dimensionality," in which measurements in low dimensions become exponentially more difficult in higher dimensions. Scientists have tried to circumvent the issue by adding three 2-D measurements together to create a quasi-6D representation. The UT-ORNL team notes that approach is incomplete as a measurement of the beam's initial conditions entering the accelerator, which determine beam behavior farther down the linac.

As part of efforts to boost the power output of SNS, ORNL physicists used the beam test facility to commission the new radio frequency quadrupole, the first accelerating element located at the linac's front-end assembly. With the infrastructure already in place, a research grant from the National Science Foundation to the University of Tennessee enabled outfitting the beam test facility with the state-of-the-art 6D measurement capability. Conducting 6D measurements in an accelerator has been limited by the need for multiple days of beam time, which can be a challenge for production accelerators.

"Because we have a replica of the linac's front-end assembly at the beam test facility, we don't have to worry about interrupting users' experiment cycles at SNS. That provides us with unfettered access to perform these time-consuming measurements, which is something we wouldn't have at other facilities," said lead author Brandon Cathey, a UT graduate student.

"This result shows the value of combining the freedom and ingenuity of NSF-funded academic research with facilities available through the broad national laboratory complex," said Vyacheslav Lukin, the NSF program officer who oversees the grant to the University of Tennessee. "There is no better way to introduce a new scientist—a graduate student—to the modern scientific enterprise than by allowing them to lead a first-of-a-kind research project at a facility that uniquely can dissect the particles that underpin what we know and understand about matter and energy."

The researchers' ultimate goal is to model the entire beam, including mitigating so-called beam halo, or beam loss—when particles travel to the outer extremes of the [beam](#) and are lost. The more immediate challenge, they say, will be finding software tools capable of analyzing the roughly 5 million data points the 6D measurement generated during the 35-hour period.

"When we proposed making a 6D measurement 15 years ago, the problems associated with the curse of dimensionality seemed insurmountable," said ORNL physicist and coauthor Alexander Aleksandrov. "Now that we've succeeded, we're sure we can improve the system to make faster, higher resolution measurements, adding an almost ubiquitous technique to the arsenal of [accelerator](#) physicists everywhere."

The PRL paper is titled "First Six Dimensional Phase Space Measurement of an Accelerator Beam." The paper's coauthors also include ORNL's Alexander Zhukov.

"This research is vital to our understanding if we're going to build accelerators capable of reaching hundreds of megawatts," Cousineau said. "We'll be studying this for the next decade, and SNS is better positioned to do this than any other facility in the world." [11]

## **Mini antimatter accelerator could rival the likes of the Large Hadron Collider**

Researchers have found a way to accelerate antimatter in a 1000x smaller space than current accelerators, boosting the science of exotic particles.

The new [method](#) could be used to probe more mysteries of [physics](#), like the properties of the Higgs boson and the nature of dark matter and dark energy, and provide more sensitive testing of aircraft and computer chips.

The method has been modelled using the properties of existing lasers, with experiments planned soon. If proven, the technology could allow many more labs around the world to conduct antimatter acceleration experiments.



Particle accelerators in facilities such as the Large Hadron Collider (LHC) in CERN and the Linac Coherent Light Source (LCLS) at Stanford University in the United States, speed up elementary particles like protons and electrons.

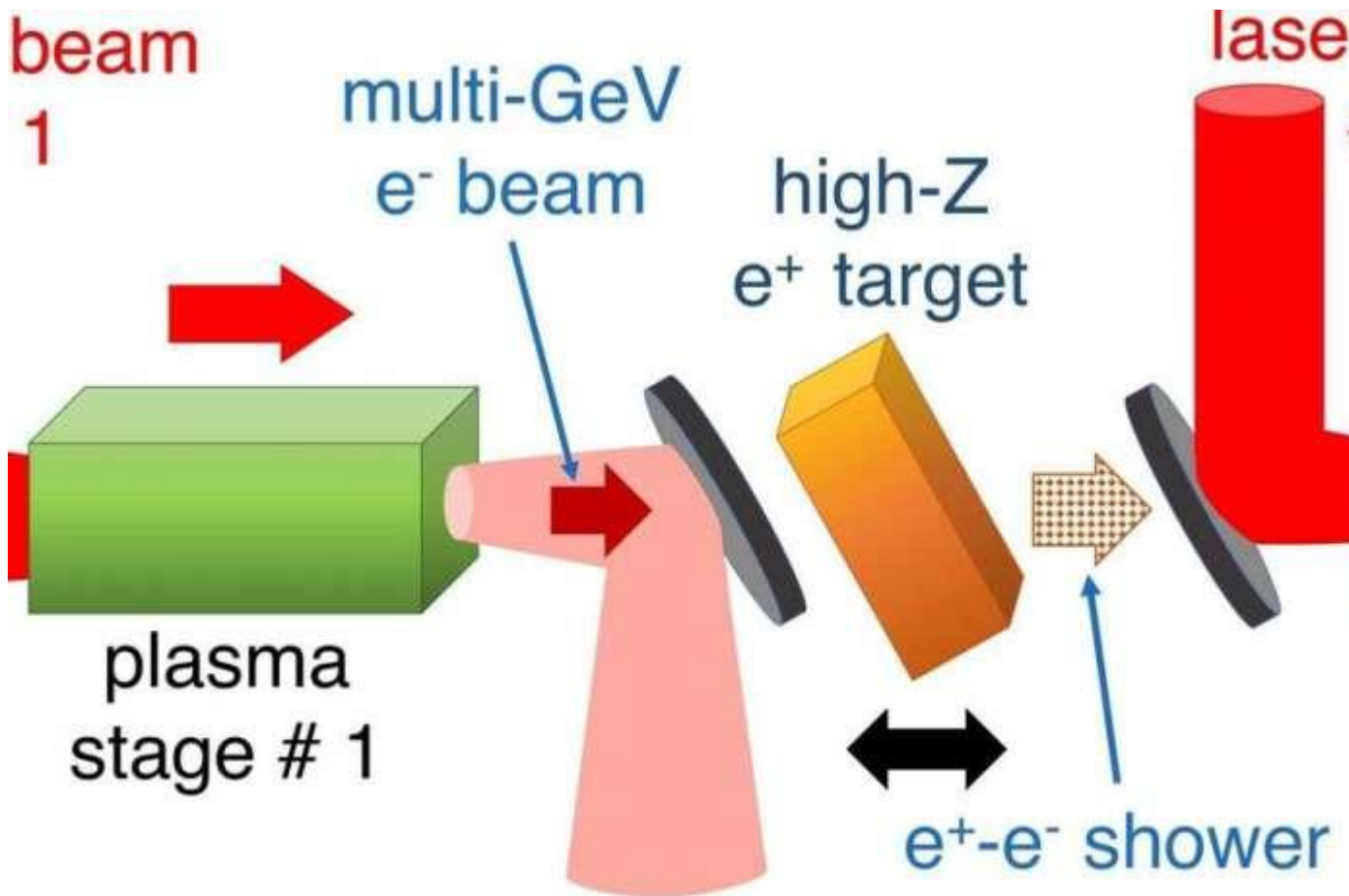
These accelerated particles can be smashed together, as in the LHC, to produce particles that are more elementary, like the Higgs boson, which gives all other particles mass.

They can also be used to generate X-ray laser light, such as in the LCLS, which is used to image extremely fast and small process, like photosynthesis.

However, to get to these high speeds, the accelerators need to use equipment that is at least two kilometres long. Previously, researchers at Imperial College London had invented a system that could accelerate electrons using equipment only meters long.

Now a researcher at Imperial has invented a method of accelerating the antimatter version of electrons—called positrons—in a system that would be just centimetres long.

The accelerator would require a type of laser system that currently covers around 25 square metres, but that is already present in many physics labs. Dr. Aakash Sahai, from the Department of Physics at Imperial reported his method today in the *Physical Review Journal for Accelerators and Beams*.





Credit: Imperial College London

He said: "With this new accelerator method, we could drastically reduce the size and the cost of antimatter acceleration. What is now only possible by using large physics facilities at tens of million-dollar costs could soon be possible in ordinary physics labs."

"The technologies used in facilities like the Large Hadron Collider or the Linac Coherent Light Source have not undergone significant advances since their invention in the 1950s. They are expensive to run, and it may be that we will soon have all we can get out of them.

"A new generation of compact, energetic and cheap accelerators of elusive particles would allow us to probe new physics—and allow many more labs worldwide to join the effort."

### Creating 'Higgs factories' and testing aircraft

While the method is currently undergoing experimental validation, Dr. Sahai is confident it will be possible to produce a working prototype within a couple of years, based on the Department's previous experience creating electron beams using a similar method.

The method uses lasers and plasma—a gas of charged particles—to produce, concentrate positrons and accelerate them to create a beam. This centimetre-scale accelerator could use existing lasers to accelerate positron beams with tens of millions of particles to the same energy as reached over two kilometres at the Stanford accelerator.

Colliding electron and positron beams could have implications in fundamental physics. For example, they could create a higher rate of Higgs bosons than the LHC can, allowing physicists to better study its properties. They could also be used to look for new [particles](#) thought to exist in a theory called 'supersymmetry', which would fill in some gaps in the Standard Model of particle physics.

The positron beams would also have practical applications. Currently, when checking for faults and fracture risks in materials such as aircraft bodies, engine blades and computer chips, x-rays or electron beams are used. Positrons interact in a different way with these materials than x-rays and electrons, providing another dimension to the quality control process.

Dr. Sahai added: "It is particularly gratifying to do this work at Imperial, where our lab's namesake—Professor Patrick Blackett—won a Nobel Prize for his invention of methods to track [exotic particles](#) like antimatter. Professor Abdus Salam, another Imperial academic, also won a Nobel Prize for the validation of his theory of weak force made possible only using a pre-LHC positron-electron collider machine at CERN. It's wonderful to attempt to carry on this legacy." [10]

### Mysterious LHC Photons Have Physicists Searching for Answers

If—and at this point, it's a big, fat if—this bump is real and not a statistical anomaly, it is a gamechanger for physicists' understanding of the universe. The signature can't be explained by the Standard Model, the current rulebook for how all particles behave and interact. That could mean entirely new physics—though what kind, researchers don't yet know.

“We were like, ‘Whoa, what is that?’” says Adam Martin, a physicist at the University of Notre Dame who recently submitted a paper theorizing about the bump to arXiv, the online, pre-peer review science repository. “What if it’s a new particle? What if it’s two?”

The physicists’ excitement comes with a heavy dose of pragmatism. No one is claiming that the bump is a new particle yet because the data simply isn’t good enough. “I can’t tell you if this bump is going to break the books or just fade away,” says Don Lincoln, a physicist at Fermilab who works with CMS, a group that detected the bump. Their measurement had a one in 10 chance of being a statistical fluke.

Those odds are no cause for fanfare, but CMS isn’t the only team that measured the bump; another, Atlas, saw it too. Atlas’s measurement had a one in 100 chance of being an anomaly—also not great, considering that the gold standard for a particle physics discovery is one in 3.5 million. But taken together, the two results were enough to get the field excited.

To improve those odds, physicists will attempt to confirm the signal during the LHC’s next batch of collisions this upcoming April. But in the meantime, the theoreticians are cranking out explanations. If the bump is real, what could it be?

### Competing Theories

One possibility is that the photons come from a graviton, a theorized particle that carries gravitational force the same way that photons carry electromagnetic force.

The current understanding is that gravitons should be massless, but this graviton would have mass— and because it has mass, it could indicate the existence of smaller dimensions invisible to everyday life.

Another possibility—one that Martin’s paper develops—is that the photons indicate a heavy cousin of the Higgs boson. Many theories currently predict the existence of multiple Higgs bosons, but experiments have only revealed the one that nabbed the 2013 Nobel Prize in physics. The existence of certain Higgs bosons would support some theories of supersymmetry, an attractive hypothetical genre that could shed light on physics’ big questions. Some supersymmetry theories could explain why the Higgs boson exists, or identify the source of dark matter in the rotation of galaxies.

Less likely, says Lincoln, is that the bump could come from a heavier particle that physicists have never seen before. Experimenters measured the bump after the LHC’s highest-energy collisions yet, which means that they can produce those heavier particles.

But physicists aren’t battling over these conflicting theories. It’s more of a team effort, with each theorist presenting a potential piece of the puzzle. “It’s not that theorists might think some theories are bad,” Martin says. It’s simply the name of the game, he says, to dig as many rabbit holes as possible to explain the physics.

And now they’re burrowing down pathways that are consistent with the new measurement.

Martin says that some half dozen times during his career, he’s worked to develop a theory around an exciting new experimental measurement—only for the measurement to evaporate into mythological artifact of statistical randomness. Or vice versa.

"I used to work on theories that had no Higgs boson," Martin says. "Too bad for me." So the physicists proceed with cautious excitement. [9]

## **Recent study predicts that Higgs particles are much heavier than earlier observation**

Researchers at Aalto University in Finland now propose that there is more than one Higgs boson, and they are much heavier than the 2012 observation. The results were recently published in Nature Communications.

"Our recent ultra-low temperature experiments on superfluid helium ( $^3\text{He}$ ) suggest an explanation why the Higgs boson observed at CERN appears to be too light.

By using the superfluid helium analogy, we have predicted that there should be other Higgs bosons, which are much heavier (about 1 TeV) than previously observed," says Professor (emeritus) Grigory E. Volovik.

Prof. Volovik holds a position in the Low Temperature Laboratory at Aalto University and in Landau Institute, Moscow. He has received the international Simon Prize in 2004 for distinguished work in theoretical low temperature physics, and the Lars Onsager Prize in 2014 for outstanding research in theoretical statistical physics.

At the same time, the new CERN experiments have shown evidence of the second Higgs in just the suggested region (at 0.75 TeV). This evidence has immediately been commented and discussed in a large number of papers submitted to arXiv, an e-print service widely utilised by the physics community to distribute manuscripts of their unpublished work. [8]

## **Exploring the Higgs boson's dark side**

Last month, after two years of preparation, the LHC began smashing its proton beams together at 13 Trillion electron Volts (TeV), close to double the energy achieved during its first run.

'We do not know what we will find next and that makes the new run even more exciting,' Daniela Bortoletto of Oxford University's Department of Physics, a member of the team running the LHC's ATLAS experiment, tells me. 'We hope to finally find some cracks in the Standard Model as there are many questions about our universe that it does not answer.'

One of the big questions concerns dark matter, the invisible 'stuff' that astrophysicists estimate makes up over 80% of the mass of the Universe. As yet nobody has identified particles of dark matter although physicists think it could be the lightest supersymmetric (SUSY) particle.

'In the new run, because of the highest-ever energies available at the LHC, we might finally create dark matter in the laboratory,' says Daniela. 'If dark matter is the lightest SUSY particle than we might discover many other SUSY particles, since SUSY predicts that every Standard Model particle has a SUSY counterpart.'

Then there's the puzzle of antimatter: in the early Universe matter and antimatter were created in equal quantities but now matter dominates the Universe.

'We still do not know what caused the emergence of this asymmetry,' Daniela explains. 'We have finally discovered the Higgs boson: this special particle, a particle that does not carry any spin, might decay to dark matter particles and may even explain why the Universe is matter dominated.'

Discovering the Higgs boson was a huge achievement but now the race is on to understand it: a prospect that Daniela is particularly excited about.

'This particle is truly fascinating,' she says. 'Spin explains the behaviour of elementary particles: matter particles like the electron have spin  $1/2$  while force particles

like the photon, which is responsible for the electromagnetic interaction, have spin 1. Spin  $1/2$  particles obey the Pauli principle that forbids electrons to be in the same quantum state.

'The Higgs is the first spin 0 particle, or as particle physicists would say the first 'scalar particle' we've found, so the Higgs is neither matter nor force.'

Because of its nature the Higgs could have an impact on cosmic inflation and the energy of a vacuum as well as explaining the mass of elementary particles.

Daniela tells me: 'Because of the Higgs the electron has mass, atoms can be formed, and we exist. But why do elementary particles have such different masses?

The data of run 2 will enable us to study, with higher precision, the decays of the Higgs boson and directly measure the coupling of the Higgs to quarks. It will also enable us to search for other particles similar to the Higgs and determine if the Higgs decays to dark matter.'

Daniela is one of 13 academics at Oxford working on ATLAS supported by a team of postdoctoral fellows, postgraduate students and engineering, technical, and computing teams. The Oxford group plays a lead role in operating the Semiconductor Tracker (SCT), most of which was assembled in an Oxford lab. This provides information on the trajectories of the particles produced when the LHC's beams collide, which was crucial to the discovery of the Higgs boson.

Whilst the next few years will see the Oxford group busy with research that exploits the LHC's new high-energy run, the team are also looking ahead to 2025 when the intensity or 'luminosity' of the beams will be increased.

The LHC is filled with 1,380 bunches of protons each containing almost a billion protons and colliding 40 million times per second. This means that every time two bunches of protons cross they generate not one collision but many, an effect called 'pile-up'.

'After this luminosity upgrade the LHC will operate at collision rates five to ten times higher than it does at present,' Daniela explains. 'In run 1 of the LHC we had a maximum of 37 pile-up collisions per crossing but with the upgrade to the High Luminosity LHC, or 'HL-LHC', this will increase to an average of 140 pile-up events in each bunch crossing.'

With the HL-LHC generating many more collisions, the international Oxford-led team are designing and prototyping parts of a new semiconductor tracker that will be needed to help reconstruct particles from the complex web of decay trails they leave inside the machine.

As the LHC ramps up both its energy and luminosity it promises to give scientists working on experiments such as ATLAS answers to some of the biggest questions in physics. One thing is certain: this new physics will also lead to a whole set of new questions about the matter that makes up us and the Universe around us. [7]

## **The Higgs particle can disintegrate into particles of dark matter, according to new model**

The problem is that there are several things the Standard Model is unable to explain, for example the dark matter that makes up a large part of the universe. Many particle physicists are therefore working on the development of new, more comprehensive models.

One of them is Christoffer Petersson, who carries out research in theoretical particle physics at Chalmers University of Technology in Sweden and the Université Libre in Belgium. Together with two research colleagues he has proposed a particle model based on what is known as supersymmetry.

This model contains more elementary particles than the Standard Model, including dark matter particles. In addition, the model gives the Higgs particle different properties than the Standard Model predicts. The model proposes that the Higgs particle can disintegrate into a photon (a particle of light) and particles of dark matter. However, these properties are quite difficult to discover – you have to look for them specifically to have a chance of finding them.

But Christoffer Petersson is fortunate – his model has met with a response at CERN. Two independent experimental stations – Atlas and CMS – at the Large Hadron Collider are now looking for the very properties of the Higgs particle his model predicts. If the properties are there, it is a clear indication that the model fits.

“It’s a dream for a theorist in particle physics. LHC is the only place where the model can be tested. It’s even nicer that two independent experiments are going to do it,” says Christoffer Petersson.

In the first studies the volume of data was unfortunately too small for it to be possible to either confirm or reject Petersson’s model.

A Higgs particle has been created in an LHC detector and has then disintegrated into four muons (the four red lines). According to Christoffer Petersson’s model the Higgs particle can also disintegrate into a photon and particles of dark matter. Picture: CERN

A Higgs particle has been created in an LHC detector and has then disintegrated into four muons (the four red lines). According to Christoffer Petersson’s model the Higgs particle can also disintegrate into a photon and particles of dark matter.



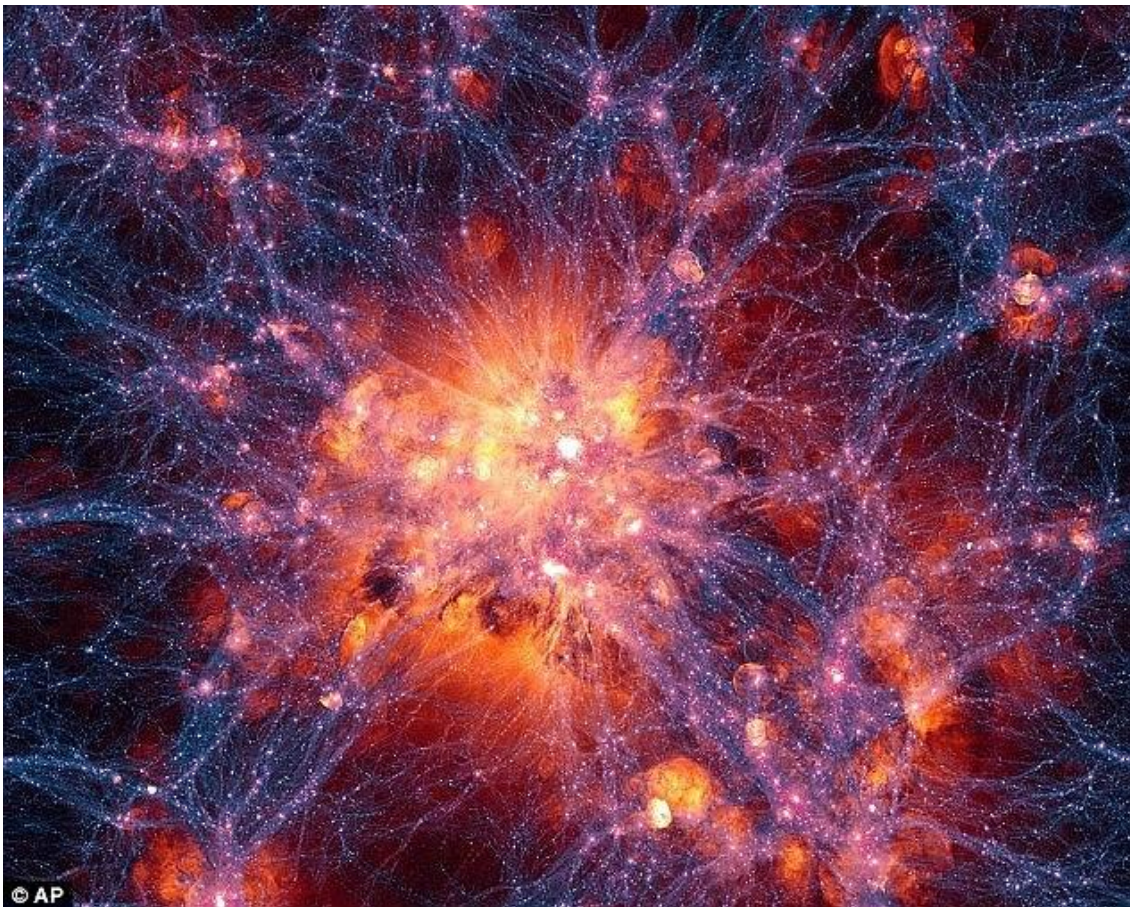
“But we are already in full swing with new analyses in which we are testing his model in other ways and with more data. We congratulate Christoffer Petersson for having done an important job,” says Zeynep Demiragli at the CMS experiment at CERN.

After being closed down for a time for an upgrade, LHC will start up again in the spring of 2015. With higher energies in the accelerator, the experiments will finally gather sufficient data to evaluate

Petersson’s model properly. He is on tenterhooks awaiting the results. [6]

### **Will the Large Hadron Collider find dark matter?**

Atom smasher could soon solve one the universe's greatest mysteries, claims scientist. Dr Monica Dunford worked at Cern in Switzerland up until 2013. She was directly involved in the detection of the Higgs boson in 2012. Speaking to Mail Online she said of the time leading up to its discovery: 'I don't think there will be another time like that in my career for sure'. But she said that the Large Hadron Collider could find dark matter. And if it did it would be a 'bigger discovery' than the Higgs boson. In March 2015 the LHC will be restarted at double its previous power.



‘One of the things I’m most interested in is creating and discovering dark matter,’ Dr Dunford said. ‘We know from measurements of cosmology that 25 per cent of the universe is dark matter and we have absolutely no idea what that is.’ An illustration of dark matter in the universe is shown.

When physicists study the dynamics of galaxies and the movement of stars, they are confronted with a mystery.

If they only take visible matter into account, their equations simply don't add up: the elements that can be observed are not sufficient to explain the rotation of objects and the existing gravitational forces. There is something missing.

From this they deduced that there must be an invisible kind of matter that does not interact with light, but does, as a whole, interact by means of the gravitational force. Called 'dark matter', this substance appears to make up at least 80 per cent of the universe. Finding the Higgs boson was one of the primary goals of the LHC - but perhaps the LHC's most important moment is yet to come.

'One of the things I'm most interested in is creating and discovering dark matter,' Dr Dunford said. We know from measurements of cosmology that 25 per cent of the universe is dark matter and we have absolutely no idea what that is. For comparison, what we do know, electrons and protons, only count for four per cent. You have this huge chunk of a pie and no idea what it consists of.

One thing we could possibly produce would be a dark matter candidate via its decay products. Being able to produce it at the LHC would be a huge connection between our astronomical measurements and what we can produce in the laboratory. [5]

## **The Classical Relativistic effect**

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field.

In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion. [1]

## **The Relativistic Quantum Mechanics**

The same thing happens on the atomic scale giving a dp impulse difference and a dx way difference between the different part of the not point like particles.

Commonly accepted idea that the relativistic effect on the particle physics it is the fermions' spin - another unresolved problem in the classical concepts. If the electric charges can move only with accelerated motions in the self maintaining electromagnetic field, once upon a time they would reach the velocity of the electromagnetic field. The resolution of this problem is the spinning particle, constantly accelerating and not reaching the velocity of light because the acceleration is radial.



## The Heisenberg Uncertainty Relation

I think that we have a simple bridge between the classical and quantum mechanics by understanding the Heisenberg Uncertainty Relations. It makes clear that the particles are not point like but have a  $dx$  and  $dp$  uncertainty.

## The General Relativity - Electromagnetic inertia and mass

### Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

### Relativistic change of mass

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

### The frequency dependence of mass

Since  $E = h\nu$  and  $E = mc^2$ ,  $m = h\nu/c^2$  that is the  $m$  depends only on the  $\nu$  frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the  $m_0$  inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation. [2]

### Electron – Proton mass rate

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. In the maximum intensity no diffraction patterns with equal intensity that is no fermions only bosons. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter. The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force.

In Quantum Field Theory (QFT), particles are described by excitations of a quantum field that satisfies the appropriate quantum mechanical field equations.

The excitations of the quantum field mean diffraction patterns in my theory. [2]

## Higgs Field

The Higgs mechanism is a result of something called a field that extends throughout space, even where no particles are present. This notion is probably most familiar to you from a magnetic field. You feel a force between a magnet and your refrigerator even when “nothing” is there. A field can fill “empty” space. The Higgs field extends throughout space. Elementary particles acquire their masses by interacting with this field. It is kind of like space is charged and particles get mass through their interactions with this charge.

The Higgs boson is not directly responsible for mass. The Higgs field is. The boson is a particle that tells us our understanding of this mechanism is correct. It also is a big clue as to where that field came from in the first place. Its discovery tells us that what we expected to be true was indeed correct, and it gives us clues as to what else might underlie the Standard Model. [4]

## The Higgs boson

By March 2013, the particle had been proven to behave, interact and decay in many of the expected ways predicted by the Standard Model, and was also tentatively confirmed to have + parity and zero spin, two fundamental criteria of a Higgs boson, making it also the first known scalar particle to be discovered in nature, although a number of other properties were not fully proven and some partial results do not yet precisely match those expected; in some cases data is also still awaited or being analyzed.

In my opinion, the best explanation of the Higgs mechanism for a lay audience is the one invented by David Miller. You can find it here: <http://www.strings.ph.qmul.ac.uk/~jmc/epp/higgs3.html> . The field must come first. The boson is an excitation of the field. So no field, no excitation. On the other hand in quantum field theory it is difficult to separate the field and the excitations. The Higgs field is what gives particles their mass.

There is a video that gives an idea as to the Higgs field and the boson. It is here: <http://www.youtube.com/watch?v=Rlg1Vh7uPyw> . Note that this analogy isn't as good as the Miller one, but as is usually the case, if you look at all the analogies you'll get the best understanding of the situation.

## What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain indirect indicators.

## The Weak Interaction

Since the Higgs boson is necessary to the W and Z bosons, the dipole change of the Weak interaction and the change in the magnetic effect caused gravitation must be conducted. The Wien

law is also important to explain the Weak interaction, since it describes the  $T_{\max}$  change and the diffraction patterns change. [2]

## Higgs mechanism

The magnetic induction creates a negative electric field, causing an electromagnetic inertia. Probably it is the mysterious Higgs field giving mass to the charged particles? We can think about the photon as an electron-positron pair, they have mass. The neutral particles are built from negative and positive charges, for example the neutron, decaying to proton and electron. The wave – particle duality makes sure that the particles are oscillating and creating magnetic induction as an inertial mass, explaining also the relativistic mass change. Higher frequency creates stronger magnetic induction, smaller frequency results lesser magnetic induction. It seems to me that the magnetic induction is the secret of the Higgs field.

In particle physics, the Higgs mechanism is a kind of mass generation mechanism, a process that gives mass to elementary particles. According to this theory, particles gain mass by interacting with the Higgs field that permeates all space. More precisely, the Higgs mechanism endows gauge bosons in a gauge theory with mass through absorption of Nambu–Goldstone bosons arising in spontaneous symmetry breaking.

The simplest implementation of the mechanism adds an extra Higgs field to the gauge theory. The spontaneous symmetry breaking of the underlying local symmetry triggers conversion of components of this Higgs field to Goldstone bosons which interact with (at least some of) the other fields in the theory, so as to produce mass terms for (at least some of) the gauge bosons. This mechanism may also leave behind elementary scalar (spin-0) particles, known as Higgs bosons.

In the Standard Model, the phrase "Higgs mechanism" refers specifically to the generation of masses for the  $W^\pm$ , and Z weak gauge bosons through electroweak symmetry breaking. The Large Hadron Collider at CERN announced results consistent with the Higgs particle on July 4, 2012 but stressed that further testing is needed to confirm the Standard Model.

## Gravity from the point of view of quantum physics

### The Gravitational force

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Big Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass ratio  $M_p=1840 m_e$ . In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass.

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

## The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

## Conclusions

“If the model is found to fit, it would completely change our understanding of the fundamental building blocks of nature. If not, just the fact that they are willing to test my model at CERN is great,” he says. [6]

On whether it would be the LHC’s most important discovery to date, she said: ‘Personally yes. It would be a bigger discovery than the Higgs boson. ‘For the Higgs we had a very good concrete theoretical prediction; for dark matter we really have no idea what it would be.’

She added: 'There is no particle that we know of today that can explain dark matter, let alone what dark energy might be. So if we could directly produce dark matter particles at the LHC this would be a huge step forward in our understanding of the composition of the universe!' [5]

The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together.

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