CERN Data Tsunami

The upgrade dramatically increased the number of events per second that ALICE can sample and read out. [12]

Together, these developments mark a new approach to open and reproducible research at the LHC. The ATLAS Collaboration will continue to focus on creating rich, preservable open access tools—such as the open likelihoods—and looks forward to the compelling new insights they create. [11]

The Higgs boson was discovered in 2012 by the ATLAS and CMS Experiments at CERN, but its coupling to other particles remains a puzzle. [10]

Higgs boson decaying into bottom quarks. Now, scientists are tackling its relationship with the top quark. [9]

Usha Mallik and her team used a grant from the U.S. Department of Energy to help build a sub-detector at the Large Hadron Collider, the world's largest and most powerful particle accelerator, located in Switzerland. They're running experiments on the sub-detector to search for a pair of bottom quarks— subatomic yin-and-yang particles that should be produced about 60 percent of the time a Higgs boson decays. [8]

A new way of measuring how the Higgs boson couples to other fundamental particles has been proposed by physicists in France, Israel and the US. Their technique would involve comparing the spectra of several different isotopes of the same atom to see how the Higgs force between the atom's electrons and its nucleus affects the atomic energy levels. [7]

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. The diffraction patterns and the locality of the self-maintaining electromagnetic potential explains also the Quantum Entanglement, giving it as a natural part of the relativistic quantum theory.

Contents

Author: George Rajna

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]

Major upgrades of particle detectors and electronics prepare CERN experiment to stream a data tsunami

For a gargantuan nuclear physics experiment that will generate big data at unprecedented rates—called A Large Ion Collider Experiment, or ALICE—the University of Tennessee has worked with the Department of Energy's Oak Ridge National Laboratory to lead a group of U.S. nuclear physicists from a suite of institutions in the design, development, mass production and delivery of a significant upgrade of novel particle detectors and state-of-the art electronics, with parts built all over the world and now undergoing installation at CERN's Large Hadron Collider (LHC).

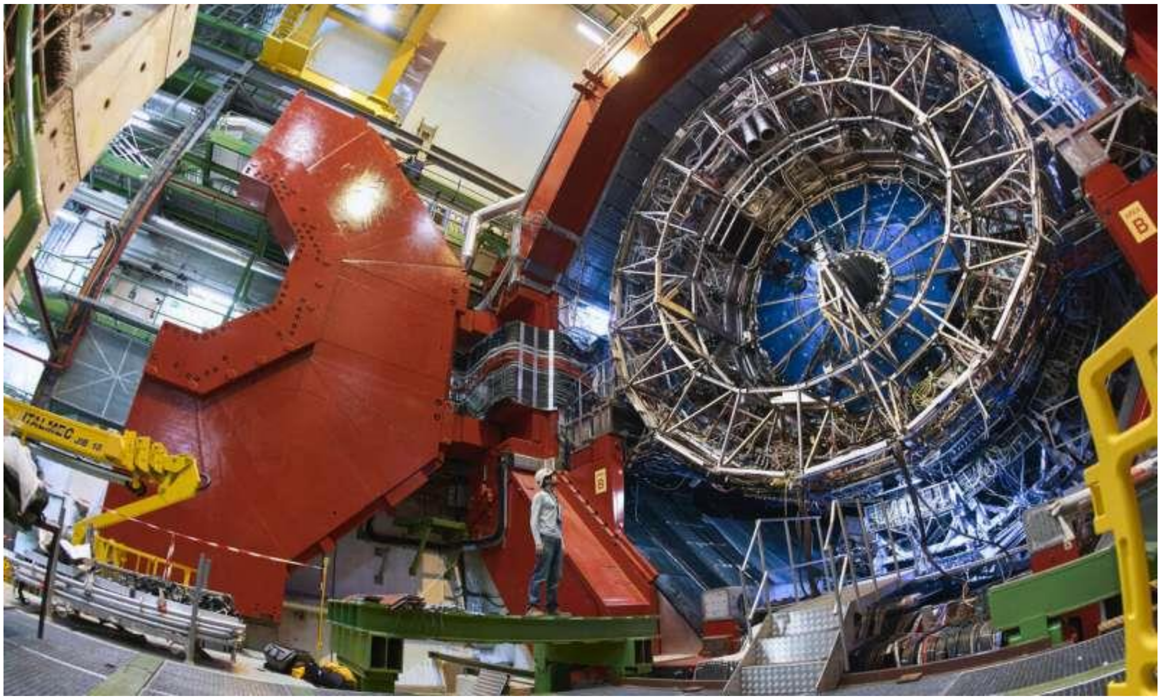
"This upgrade brings entirely new capabilities to the ALICE experiment," said Thomas M. Cormier, project director of the ALICE Barrel Tracking Upgrade (BTU), which includes an electronics overhaul that is among the biggest ever undertaken by DOE's Office of Nuclear Physics.

ALICE's 1,917 participants from 177 institutes and 40 nations are united in trying to better understand the nature of matter at extreme temperature and density. To that end, the LHC creates a succession of "little bangs"—samples of matter at energy densities not seen in the universe since microseconds after the Big Bang. ALICE's detectors identify the high-energy particles and track their trajectories, interactions and decays that produce lower-energy daughter particles, daughters of daughters, and so on. The upgrades enable ALICE to more efficiently track particles at high rates, digitize their weak analog electronic signals continuously and stream the tsunami of readout data to high-performance computing (HPC) centers around the world for analysis.

"Revising the instrumentation lets us expand the window of the science that ALICE can look at," said Cormier, who is a physicist at ORNL and professor at the University of Tennessee at Knoxville. "A lot of things are waiting out there to be discovered if we just have the sensitivity to see them." Combined with upgrades to the LHC accelerator, the BTU will increase sensitivity tenfold, enabling greater differentiation of the underlying science.

Completed ahead of schedule and under budget, the project relied on participants from DOE's Oak Ridge (ORNL) and Lawrence Berkeley (LBNL) National Laboratories and seven universities: California at Berkeley, Creighton, Houston, Tennessee at Knoxville (UTK), Texas at Austin (UT Austin), Wayne State and Yale.

The upgrade effort began in April 2015 and ended in November 2019, delivering a suite of advanced detectors and electronics to CERN. Researchers anticipate the completion of installations this spring.



ALICE’s magnet doors open to provide access to detectors undergoing upgrades. Credit: Julien Marius Ordan/CERN

Considering the scale, this is no easy feat. Sited underground at the Franco-Swiss border, ALICE is heavier than the Eiffel Tower. A 52-foot-tall magnet is its front door. Behind it, nuclear physicists have rolled out one of the world's biggest barrel instruments, housing many detectors arranged in concentric cylinders. LHC's beam line runs through its center axis.

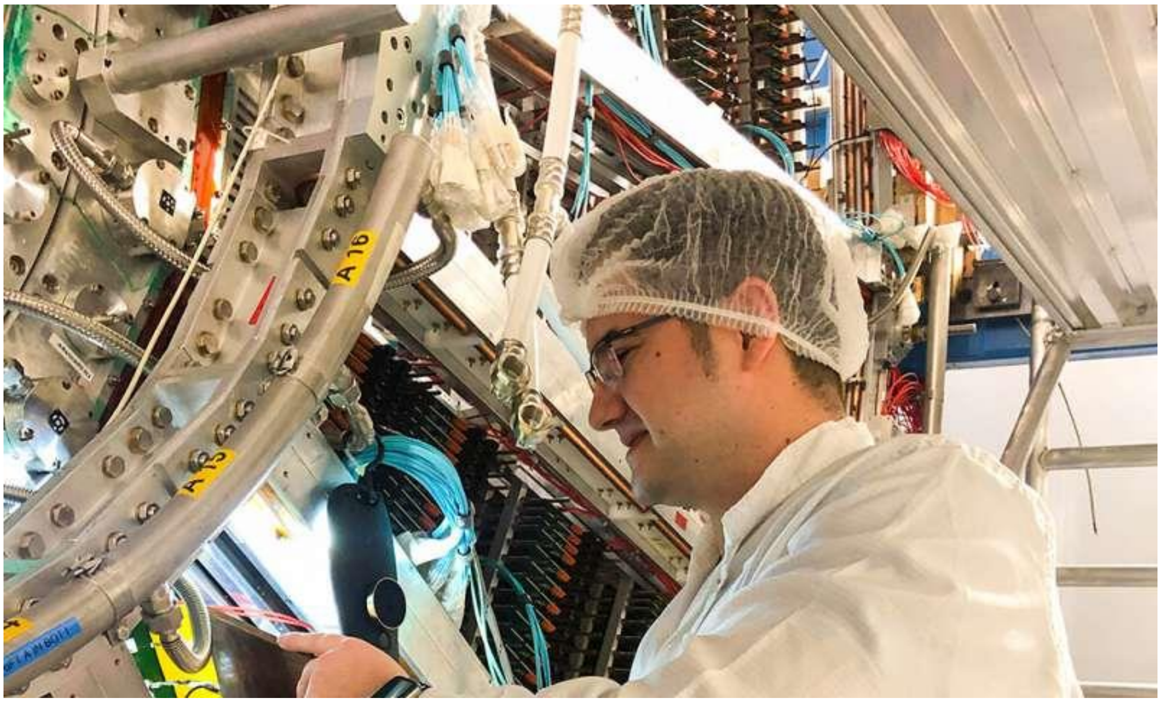
Significant effort went into improving two ALICE detector systems. One is the Time Projection Chamber (TPC), a gas-filled cylindrical apparatus the size of a shuttle bus. As charged particles speed through the gas, a magnetic field bends their paths, creating curved trajectories that reveal their momenta and masses and, in turn, their identities. Each endcap of the TPC cylinder is covered with two concentric rings of novel inner and outer readout chambers that receive the ionization charge and amplify it using an innovative four-layer system of micro-pattern perforated Gaseous Electron Multiplier foils. A system of nearly a half million, millimeter-scale pads spreads across the ends of the TPC cylinder to collect the amplified charge and create an electronic image of the charged particle tracks.

The second detector system to receive an upgrade is a seven-layer Inner Tracking System. LBNL collaborated with UT Austin to develop its middle layers, which include a strong-but-lightweight carbon-fiber frame to support seven layers of staves holding 24,000 silicon-pixel sensors for high-precision particle tracking. Each pixel is 30 × 30 micrometers squared—finer than an average human hair. This detector will have a total of 12.5 billion pixels—making it the largest "digital camera" ever built.

Processing the biggest of data

The upgrade dramatically increased the number of events per second that ALICE can sample and read out. Kenneth Read, manager of BTU's electronics upgrade, led a huge undertaking in design, fabrication and assembly of electronics hardware. Read, an experimental nuclear physicist with expertise in high performance computing, holds joint appointments at ORNL and UTK.

Ultimately, Read's team delivered 3,276 circuit boards (plus 426 spares) for readout of the half a million TPC channels. The electronics upgrade makes it possible to digitize and distribute 5 million samples per second per channel.



ORNL electronics engineer Alex Rusu performs installation steps on the Time Projection Chamber in the clean room at the ALICE site. Credit: Oak Ridge National Laboratory, U.S. Dept. of Energy

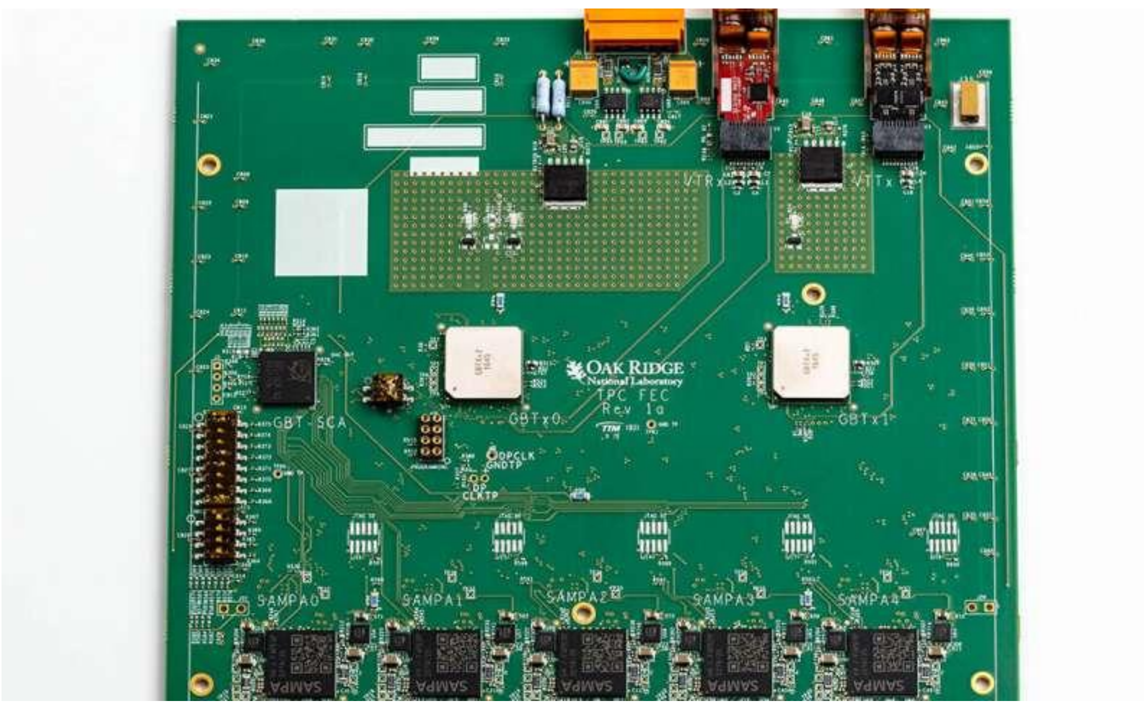
"Non-stop data output totaling 3 terabytes per second will flow from the Time Projection Chamber, 24/7, during data taking," Read explained. "Historically, many experiments have dealt with megabyte per second, or even gigabyte per second, data rates. Real-time processing of streaming scientific data at 3 terabytes per second is approaching unique in the world. This is a big data problem of immense proportions."

That data provides a snapshot of the quantum system known as the quark–gluon plasma—the matter of the very early universe first discovered at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and subsequently studied at both RHIC and the ALICE detector at the LHC. Such a plasma is produced here on Earth when a powerful collider, such as the LHC, accelerates heavy ions, each containing many protons and neutrons, and collides these heavy ions with so much energy that their protons and neutrons "melt" into their elementary building blocks—quarks and gluons—in a plasma more than 100,000 times hotter than our sun's core. This exploding "soup" of liberated quarks and gluons forms particles that decay into myriad other particles. The detector array identifies and maps them so nuclear scientists can reconstruct what happened and gain understanding of the collective phenomena.

Capturing that plethora of particle collision events required a team of institutes to develop a custom-tailored chip that could digitize and read out the biggest of data. Enter "SAMPA." At the heart of ALICE's massive electronics upgrade, this chip began as the Ph.D. thesis project of Hugo Hernandez, then at the University of Sao Paolo.

SAMPA chips and other electronic components were shipped to Zollner Electronics in Silicon Valley for assembly onto printed circuit boards fabricated by electronics manufacturing giant TTM Technologies. The team of ORNL Ph.D.-level electrical engineers making critical contributions throughout the electronics upgrade—lead designer Charles Britton with N. Dianne Bull Ezell, Lloyd Clonts, Bruce Warmack and Daniel Simpson—also developed a high-throughput station to test the boards right at the assembly factory. Whereas it traditionally took 1 hour to diagnose and debug a complex board, the ORNL team's automated process did it in a mere 6 minutes.

"It used to be, you'd order a thousand widgets, receive them at Oak Ridge and test them," Read reminisced. "You'd send the bad ones back to the factory and the good ones on to CERN." The ORNL test stations allowed the assembly factory to ship passing boards directly to CERN in small "just-in-time" batches for quicker installation than possible when waiting on large lots.



Circuit boards were customized with SAMPA chips (five black squares) and fast, radiation-tolerant optical transceivers (two components protruding at top right). Credit: Oak Ridge National Laboratory, U.S. Dept. of Energy

The researchers will calibrate the BTU using cosmic rays. Then, the upgraded equipment will be ready for the high-luminosity LHC Run-3, anticipated in 2021. Several runs of various collision data sets are planned—lead-on-lead, proton-on-lead and proton-on-proton—to illuminate emergent features of the quark-gluon plasma.

Even one year of collected raw data will be far too big to archive. The readout system winnows the streaming data to petabyte scale by processing it on the fly with hardware acceleration using field-programmable gate arrays and graphics processing units (GPUs)—considered a best practice. The reduced data is distributed over high-speed networks to HPC centers around the world, including ORNL's Compute and Data Environment for Science, for further processing. As experiments get larger, physicists build the case for also using centralized resources, such as the Oak Ridge Leadership Computing Facility's Summit supercomputer for GPU-accelerated data processing.

"Other large experiments at the LHC using different particle detectors—notably ATLAS and CMS—will confront some of the same data challenges as ALICE in 2027 and beyond," said ALICE researcher Constantin Loizides of ORNL. "The world-leading capabilities of the BTU electronics will likely benefit future physics experiments like the planned electron–ion collider, a top priority for U.S. nuclear physics." [12]

New open release from CERN streamlines interactions with theoretical physicists

What if you could test a new theory against data from the Large Hadron Collider (LHC)? Better yet, what if the expert knowledge needed to do this was captured in a convenient format? This tall order is now on its way from the ATLAS Collaboration at CERN, with the first open release of full analysis likelihoods from an LHC experiment.

"In particle physics, experimentalists develop a very rich summary of measurements, which account for all relevant scattering processes and every source of uncertainty, encapsulated into what we call *likelihoods*," explains Lukas Heinrich, CERN research fellow working for the ATLAS Experiment. "Likelihoods allow you to compute the probability that the data observed in a particular experiment match a specific model or theory. Effectively, it summarizes every aspect of a particular analysis, from the detector settings, event selection, expected signal and background processes, to uncertainties and theoretical models." Extraordinarily complex and critical to every analysis, likelihoods are one of the most valuable tools produced at the LHC experiments. Their public release will now enable phenomenologists around the world to explore ATLAS data in a whole new way.

The ATLAS open likelihoods are available on HEPData, an open-access repository for experimental particle physics data. The first open likelihoods released were for a search for supersymmetry in proton–proton collision events containing Higgs bosons, numerous jets of b-quarks and missing transverse momentum. "While ATLAS had published likelihood scans focused on the Higgs boson in 2013, those did not expose the full complexity of the measurements," says Kyle Cranmer, Professor at New York University. "We hope this first release—

which provides the full likelihoods in all their glory—will form a new communication bridge between theorists and experimentalists, enriching the discourse between the communities."

The search for new physics will benefit significantly from open likelihoods. "If you're a theorist developing a new idea, your first question is likely: "Is my model already excluded by experiments at the LHC?'" says Giordon Stark, postdoctoral scholar at SCIPP, UC Santa Cruz. "Until now, there was no easy way to answer this." Most LHC searches focus on certain benchmark models, giving a detailed analysis of the data to make a statement on whether or not the Standard Model holds in the considered processes and, if so, which model parameters are still allowed and which are excluded by the data. But, of course, any search analysis is sensitive to numerous new physics scenarios.

Using publicly released likelihoods, theorists will now be able to alter the original hypothesis studied by ATLAS. While such results may not reach the accuracy of the original result—given the missing step of simulating the putative processes in the ATLAS detector—they will give theorists a quick assessment of the potential of their new theory.

Providing the tools for open analysis

But why do you need likelihoods to understand ATLAS data? Like many public scientific datasets, data from LHC experiments can be impenetrable without domain-specific knowledge. Before it can begin to make sense, one needs to account for a vast set of detector and software parameters, as well as complex theoretical modeling.

"Instead, the ATLAS Collaboration has focussed on open data resources," says Matthew Feickert, postdoctoral research associate at the University of Illinois at Urbana-Champaign. "It is our responsibility to minimize the complexity that stands between theorists and the relevant ATLAS information. There are many valuable questions that theorists outside of the ATLAS experiment can help us answer, and we need to give them the best tools to do so."

Since the early days of the LHC, there has been strong consensus between the experimental and theoretical physics communities that this could best be done by publicly releasing analysis likelihoods. The formats that have been developed internally by the experiments to share likelihoods are not well suited for publishing or easy use by the theoretical community. "Recently, we rewrote the software for likelihoods to take advantage of machine learning frameworks, and realized it also offered the opportunity to address the publishing problem." explains Heinrich. "We also ensured that we chose human and machine-readable formats with ubiquitous, long-term support. That way, even as technologies and software evolve, the likelihoods will still be usable."

Ensuring the future of open physics

"We plan to make the open release of likelihoods a regular part of our publication process, and have already made them available from a search for the direct production of tau slepton pairs," says Laura Jeanty, ATLAS Supersymmetry working group convenor. "Over the coming months, we aim to collect feedback from theorists outside the collaboration to best understand how they are using this new resource to further refine future releases."

The public release of full likelihoods will also bring with it significant benefits for experimentalists. "Likelihoods are an essential ingredient for combining analyses from different experiments," says Stark, who organizes the statistical combinations of ATLAS supersymmetry results. "As their open release becomes more common place, I look forward to seeing larger-scale statistical combinations."

In parallel, the ATLAS Supersymmetry and Exotics working groups have also established a new approach to analysis preservation. "These are parts of our efforts to 'future-proof' ATLAS results," explains Federico Meloni, ATLAS Supersymmetry working group convenor. "As theorists develop new ideas, ATLAS data may need to be re-examined. As such, we are now archiving the software and analysis tools used in the result prior to its publication. This will ease future reinterpretations of the data, years down the line." When these archived analysis pipelines are paired with published likelihoods, physicists will be equipped with a transformative capability: the ability to test a new theory against the data in an automated fashion.

Together, these developments mark a new approach to open and reproducible research at the LHC. The ATLAS Collaboration will continue to focus on creating rich, preservable open access tools—such as the open likelihoods—and looks forward to the compelling new insights they create. [11]

ATLAS Experiment adds more pieces to the Higgs boson puzzle

The Higgs boson was discovered in 2012 by the ATLAS and CMS Experiments at CERN, but its coupling to other particles remains a puzzle.

Fortunately, the LHC provides many windows into measuring Higgs boson couplings. There are four main ways to produce the Higgs boson: through the fusion of two gluon particles (gluon-fusion, or ggF), through the fusion of weak vector bosons (VBF), or in association with a W or Z boson (VH), or one or more top quarks (ttH+tH). There are also five main channels in which Higgs bosons can decay: into pairs of photons, W or Z bosons, tau leptons or b quarks. Each of these processes brings unique insights into the Higgs boson properties.

Thanks to the unprecedented quantities of Higgs bosons produced at the LHC, all of the above production and decay modes have now been observed. In a new result presented by the ATLAS Collaboration, using data collected through 2017, the measurements for each of these processes have reached the significance threshold of five standard deviations, beyond which their existence is considered established.

The Higgs boson yields for most of the combinations of production and decay have been measured (see figure) and have been found to agree with Standard Model predictions. The measurement of the cross sections for each production mode in proton–proton collisions at 13 TeV, assuming the decays occur as predicted by the Standard Model, are the most precise ones obtained to date.

Physicists have also begun to explore the Higgs boson puzzle in a new way. In the latest analyses, instead of counting Higgs bosons inclusively in the major production and decay modes, ATLAS physicists have measured Higgs boson topologies separately for smaller regions of phase-space:

different ranges of Higgs boson transverse momentum, numbers of associated jets, and numbers and kinematic properties of associated weak bosons and top quarks. Using these smaller puzzle pieces, called "simplified template cross sections" (STXS), allows physicists to better separate the measurement process from the interpretation in terms of theoretical properties. Ultimately, it provides a finer-grained picture of Higgs boson couplings at the LHC and more stringent tests of the Standard Model.

Among the STXS regions considered in the analysis, some have already been measured with good precision at the LHC, but no deviation from the Standard Model has been observed so far. These measurements allow physicists to further enhance the sensitivity on the coupling properties of the Higgs boson to the other elementary particles. Further, they have set constraints on new physics theories – such as the "two-Higgs doublet model", which introduces additional Higgs bosons, and the hMSSM supersymmetric model – which are more stringent than those reported previously by ATLAS.

These measurements will continue to improve as more data from Run 2 and beyond are included, providing a yet-finer picture of the properties of the Higgs boson. [10]

Who gets their mass from the Higgs?

The Higgs field is like an endless ocean through which all matter swims. Some particles are like sponges and sop up mass as they lumber along, while others are as sprightly as tiny minnows and dart right through.

The Higgs theory is a beautifully simple explanation as to why some particles are massive while others are not. But not all predictions of the Higgs theory have been experimentally tested yet. That's why scientists on the CMS experiment at the Large Hadron Collider are putting the Higgs boson under a microscope and trying to determine how it fits into the delicate ecosystem of particles.

"We know that the Higgs interacts with massive force-carrying particles, like the W boson, because that's how we originally discovered it," said scientist Patty McBride from the U.S. Department of Energy's Fermi National Accelerator Laboratory, which supports the research of hundreds of U.S. scientists on the CMS experiment. "Now we're trying to understand its relationship with fermions."

Fermions are particles that click together to form the invisible scaffolding inside atoms. Bosons, on the other hand, are the physical manifestation of forces and perform tasks such as gluing fermions together.

In June 2014, scientists on the CMS experiment published a paper in *Nature* showing that the Higgs boson has a relationship with fermions by measuring the rate at which it decays into tau leptons, a heavier cousin of the electron. Later, both the CMS and ATLAS experiments found evidence of the Higgs boson decaying into bottom quarks. Now, scientists are tackling its relationship with the top quark.

"The relationship between the Higgs and the top quark is particularly interesting because the top quark is the most massive particle ever discovered," McBride said. "As the 'giver of mass,' the Higgs boson should be enormously fond of the top quark."

Because the top quark is much more massive than the Higgs boson, it's impossible for a Higgs boson to decay into a pair of top quarks. Luckily, there is another way to measure how strongly the Higgs boson couples to top quarks: looking for the rare case of simultaneous production of top quarks and a Higgs boson.

"Higgs boson production is rare – but Higgs production with top quarks is rarest of them all, amounting to only about 1 percent of the Higgs boson events produced at the LHC," said Chris Neu, a physicist at the University of Virginia who worked on this analysis.

In a paper published today in the journal *Physical Review Letters*, scientists on the CMS experiment report observing a statistically significant abundance of events in which the Higgs boson is produced in association with two top quarks. The CMS result for this rare Standard Model process with a significance of 5.2 sigma constitutes the first observation that exceeds the 5 sigma threshold physicists require. The ATLAS experiment has also submitted a paper on the same phenomenon for publication.

To get these results, the CMS experiment looked for Higgs bosons based on the numerous possible signatures it can leave behind in the detector.

"A top quark decays almost exclusively into a bottom quark and a W boson," Neu said. "The Higgs boson, on the other hand, has a rich spectrum of decay modes, including decays to pairs of bottom quarks, W bosons, tau leptons, photons and several others. This leads to a wide variety of signatures in events with two top quarks and a Higgs boson. We pursued each of these and combined the results to produce our final analysis."

Exploring the Higgs boson's relationship with the top quark further could also be a possible window to new physics, according to Fermilab Deputy Director Joe Lykken.

"Pinning down this coupling will tell us a lot about the behavior of the Higgs and how it might also interact with other particles we haven't discovered, like dark matter," Lykken said. "Deeply understanding how the Higgs interacts with known particles could help lead us to physics beyond the Standard Model." [9]

A quark like no other: Searching for 'bottom quark'

A University of Iowa physicist is at the forefront of the search for a missing particle that could prove whether the Higgs boson—believed to give mass to all matter—exists.

Usha Mallik and her team used a grant from the U.S. Department of Energy to help build a subdetector at the Large Hadron Collider, the world's largest and most powerful particle accelerator, located in Switzerland. They're running experiments on the sub-detector to search for a pair of bottom quarks—subatomic yin-and-yang particles that should be produced about 60 percent of the time a Higgs boson decays.

Evidence of these bottom quarks would confirm the existence of the Higgs boson, sometimes referred to as the "God particle." The Higgs' apparent discovery in 2012 seemed to support the Standard Model, the prevailing theory in physics about how the laws governing the universe work.

But since that find, there's been a hitch: The bottom quarks expected to arise from a Higgs boson's decay have yet to be seen, and scientists need that to happen to know for sure the Higgs, in fact, exists.

"Until we're sure whether it's a Standard Model Higgs or an imposter mixed with another kind of Higgs, we are desperate to learn what is beyond the Standard Model. The Higgs is our window beyond the Standard Model," Mallik says.

Still, the quest remains complicated: A Higgs boson is created about once in 10 trillion tries. Moreover, Higgs bosons decay into other particles almost instantly after they are produced, which makes detecting and defining their decaying constituents—such as the bottom quarks—even more challenging.

Mallik and her team hope to observe bottom quarks by following the post-collision clutter that arises from the decay of the Higgs or other new heavy particles similar to it.

"It's basically identifying, picking that needle in the haystack while not getting fooled by something else," says Mallik, who spent the past academic year at ATLAS, one of four particle detectors at the Large Hadron Collider. "That is the challenge."

Mallik, three postdoctoral researchers, a graduate student, and a software engineer from the UI have all been at ATLAS sifting through the voluminous data produced by the collisions. Their work is funded through the High Energy Physics program, part of the U.S. Department of Energy's Office of Science.

Anindya Ghosh, a first-year UI graduate student from India joined Mallik's group in 2015 after hearing her speak the year before at the Indian Institute of Technology in Madras, India. Ghosh worked with the ATLAS experiments over most of last summer.

He calls it "a fantastic place" to be, with hundreds of scientists, students, and teachers joined in the same quest.

"It's a really great opportunity for a new student like me to learn from the experts," Ghosh says.

The attempt to understand the underpinnings of the universe—and human existence—has always fascinated Mallik.

"It's always interested me," she says. "How did we come into being? What led to our universe? It's a fundamental question in many forms." [8]

Physicists plan to seek Higgs force in atomic spectra

A new way of measuring how the Higgs boson couples to other fundamental particles has been proposed by physicists in France, Israel and the US. Their technique would involve comparing the spectra of several different isotopes of the same atom to see how the Higgs force between the atom's electrons and its nucleus affects the atomic energy levels.

The effect of the Higgs force is tiny, but the researchers say the test would involve technologies that already exist and that some of the required measurements have already been made. The measurement would provide important information about how the Higgs couples to electrons and quarks, and would complement data gleaned from collisions using the Large Hadron Collider (LHC) at CERN.

Important mysteries

After discovering the Higgs boson at the LHC in 2012, particle physicists now want to understand how it couples to matter such as electrons and quarks. Any deviations in these couplings from the Standard Model of particle physics could reveal whether the Higgs mechanism is responsible for the masses of charged fermions, including the electron. A new way of measuring these deviations has been proposed by Cédric Delaunay of the CNRS, France, Roee Ozeri and Gilad Perez of the Weizmann Institute of Science in Israel and Yotam Soreq of the Massachusetts Institute of Technology in the US.

According to the Standard Model, the Higgs coupling creates an attractive force between the electron and the nucleus. This force decays rapidly with distance from the nucleus, which means it will have a much greater effect on electrons in S orbitals (which overlap the nucleus) than on electrons in P, D or F orbitals (which do not). The energies of photons emitted when an electron moves from a P, D or F orbital to an S orbital would therefore be greater than if the Higgs force were not present.

One way of looking for this difference would be to use different isotopes of the same nucleus. As the isotopes would have different numbers of neutrons, the Higgs force should be greater for those isotopes with more neutrons. That would lead to a difference in energy between the same atomic transition in different isotopes – the Higgs shift.

Linear thinking

The problem is that there are other isotopic differences in atomic spectra that are much larger than those related to the Higgs force. The mass shift (MS) is related to the effect of the different masses of isotopic nuclei and the field shift (FS) to the different charge distributions found in different isotopes. While the MS and FS are fiendishly hard to calculate, there is a well-known linear relationship that links the FS and MS parameters to the observed shifts.

The team's idea is to measure the shifts of two different transitions in four isotopes of the same atom and display the data on a "King plot". If there is no Higgs coupling, the data will be represented by a straight line. But if there is a Higgs coupling – and it is described by the Standard Model – there will be a tiny deviation from a straight line. It is likely that this deviation will be too small to measure, but if the Higgs coupling is much larger than predicted by the Standard Model, the researchers say it should be measureable using state-of-the-art atomic spectroscopy.

Delaunay and Soreq told physicsworld.com that such a measurement could provide important information to particle physicists who are trying to understand how the Higgs couples to quarks and electrons – something that will be difficult to extract from LHC collision data. "The method we propose is an example – the first one as far as we know – of how table-top experiments may give us complementary information," they explain. "This is important to better understand the origin of the mass of the building blocks of matter – is it the Higgs mechanism, or other, unknown sources?"

"Intriguing new application"

"Qualitatively, their arguments make sense," says Andrei Derevianko of the University of Nevada, Reno. "However, detailed atomic-structure analysis is needed – and they are clearly aware of this need – to make sure that the effect is indeed as large as they claim."

Marianna Safronova of the University of Delaware also thinks that the proposal could be viable, but points out that a successful experiment would have to accurately separate the effects of the weak interaction. She also agrees with the team's conclusion that ytterbium isotopes would be a good place to look for the effect, buts adds that calcium may be another viable candidate. Dmitry Budker, an experimental physicist at the University of California, Berkeley, told physicsworld.com that he plans to collaborate with the team to try to make the measurements. "It is not yet clear what specific atomic system – which atoms and/or ions – will be best for this, and so it is also not clear where the experiments will be done. I see an exciting possibility of potentially doing these tests in a range of systems and at different laboratories and facilities." [7]

Quantum entanglement

Measurements of physical properties such as position, momentum, spin, polarization, etc. performed on entangled particles are found to be appropriately correlated. For example, if a pair of particles is generated in such a way that their total spin is known to be zero, and one particle is found to have clockwise spin on a certain axis, then the spin of the other particle, measured on the same axis, will be found to be counterclockwise. Because of the nature of quantum measurement, however, this behavior gives rise to effects that can appear paradoxical: any measurement of a property of a particle can be seen as acting on that particle (e.g. by collapsing a number of superimposed states); and in the case of entangled particles, such action must be on the entangled system as a whole. It thus appears that one particle of an entangled pair "knows" what measurement has been performed on the other, and with what outcome, even though there is no known means for such information to be communicated between the particles, which at the time of measurement may be separated by arbitrarily large distances. [6]

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 $E = hv$ and $E = mc^2$, $m = hv /c^2$ that is the m depends only on the v 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_o 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=RIg1Vh7uPyw . 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 Bing 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 rate Mp=1840 Me. 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

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.

The accelerated charges self-maintaining potential shows the locality of the relativity, working on the quantum level also. [1]
The Secret of Quantum Entanglement that the particles are diffraction patterns of the electromagnetic waves and this way their quantum states every time is the result of the quantum state of the intermediate electromagnetic waves. [2]

References

[1] The Magnetic field of the Electric current and the Magnetic induction

Author: George Rajna

Publication date: 15/09/2013 Website: Academia.edu

http://academia.edu/3833335/The_Magnetic_field_of_the_Electric_curre

nt

Last accessed: 28/02/2014

[2] 3 Dimensional String Theory

Author: George Rajna

Publication date: 13/06/2013 Website: Academia.edu

http://academia.edu/3834454/3_Dimensional_String_Theor

y

Last accessed: 28/02/2014

[3] Graviton Production By Two Photon and Electron-Photon Processes In Kaluza-Klein Theories With Large Extra Dimensions

Authors: David Atwood, Shaouly Bar-Shalom, Amarjit Soni

Journal reference: Phys.Rev. D61 (2000) 116011

Publication date: 21/09/1999 Website: Arxiv.org

http://arxiv.org/abs/hep-ph/9909392

Last accessed: 28/02/2014

[4] Explaining the Higgs – Interview with Lisa Randall, Professor of Science in Harvard's Department of Physics

By Sarah Sweeney, Harvard Staff Writer

Publication date: 13/01/2014 Website: Harvard Gazette

http://news.harvard.edu/gazette/story/2014/01/explaining-the-

higgs/

Last accessed: 28/02/2014 [5] Quantum

Entanglement

http://en.wikipedia.org/wiki/Quantum_entanglemen

t

[6] Space-based experiment could test gravity's effects on quantum entanglement http://phys.org/news/2014-05-space-based-gravity-effects-quantum-entanglement.html

[7] Physicists plan to seek Higgs force in atomic spectra

http://physicsworld.com/cws/article/news/2016/feb/09/physicists-plan-to-seek-higgs-force-inatomic-spectra

[8] A quark like no other: Searching for 'bottom quark' https://phys.org/news/2017-01-quark-

bottom.html

[9] Who gets their mass from the Higgs?

https://phys.org/news/2018-06-mass-higgs.html

[10] ATLAS Experiment adds more pieces to the Higgs boson puzzle

https://phys.org/news/2019-05-atlas-pieces-higgs-boson-puzzle.html

[11] New open release from CERN streamlines interactions with theoretical physicists

https://phys.org/news/2019-12-cern-interactions-theoretical-physicists.html

[12] Major upgrades of particle detectors and electronics prepare CERN experiment to stream a data tsunami

https://phys.org/news/2020-04-major-particle-detectors-electronics-cern.html