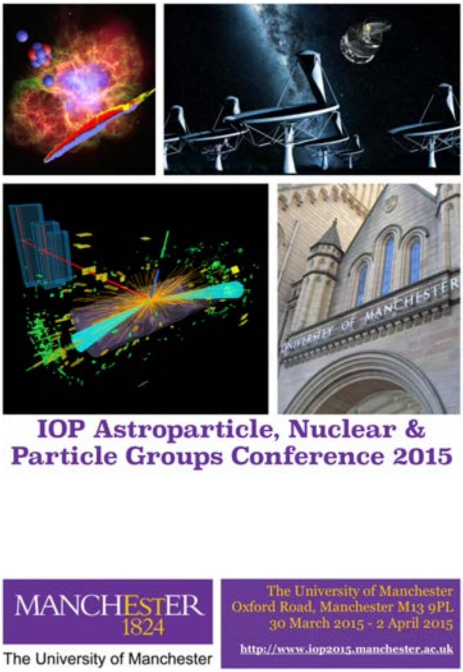
IOP Institute of Physics
High Energy Particle Physics Group

Newsletter
Issue 12

Happy New Year From The IoP HEPP Committee



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Student Conference Fund maximum Increased to £300

Meet the Committee

IoP HEPP group Chairperson's Report

In April, at the Annual Conference at Royal Holloway, I had the honour of being asked to be the next chair of the High Energy Particle Physics Committee. I have been on the committee since shortly after I arrived in the UK in 2004, having spent ten years based in the United States, and I have had the privilege of seeing three different committee chairs at work, Mike Green, Phil Allport and my predecessor, Mark Lancaster. Each one of these brought with them their own distinct style, and I believe that I have learnt enough from them all to carry on their excellent work, while also introducing something new of my own to the role.

In these ten years I have also learnt much about the way in which particle physics is carried out in the UK and Ireland, and I am proud to be part of this community and I look forward to working with my colleagues to help us pursue particle physics in all its forms.

We are experiencing some of the most exciting times in our field, where high-energy collider experiments have justified one of the most extraordinary predictions that has ever been made, the Higgs boson, while neutrino experiments continue to show us that the Standard Model is not complete and every new measurement points us towards new discoveries that are within our reach. As we continue to probe the predictions of the Standard Model, every precision measurement whose result is not 'unexpected' represents a triumph in its own right—something which is easily forgotten.

The IoP HEPP group spans many things; from the huge and extraordinary experiments at the LHC, to the smaller complementary experiments measuring the properties of particles to fantastic precision, and many in between, all of which have the potential to make revolutionary discoveries—it encompasses students, postdocs, researchers and academics, as well as retired physicists, educators and those who have a connection with our field in other ways. I am proud to be chair of a committee that serves all of these different aspects of our community, and I do hope that we can do our bit to help our field flourish through these times that are both exciting and challenging.

Whatever our individual involvement may be, I am certain we share a desire for the field of particle physics to be as vibrant as it can be, and each one of you can participate actively in our group in many ways; by suggesting a half-day meeting to be held on a favoured topic, or reaching out to the world at large with your knowledge through our outreach events, or by simply letting us know your thoughts on how things can be made better, and of course, through joining the committee itself to coordinate new initiatives. We can also help co-sponsor your events and fund postgraduate students as they present their research at international conferences. For any of these and more, please do not hesitate to contact me personally at Yoshi.Uchida@imperial.ac.uk and I would be happy to do my best to help.

Our Annual Conference in 2015 will be at Manchester University from 30th March until 2nd April, to be held jointly with the Astroparticle and Nuclear physics groups, where we will also hold our General Meeting. I very much look forward to seeing many of you there,

Dr. Yoshi Uchida

Particle fever returns to the Large Hadron Collider

By any measure, the first three years of collisions at the LHC were an historic success. In 2012 the ATLAS and CMS experiments dramatically observed a new form of fundamental matter, a Higgs boson, nearly fifty years after it was first proposed. But just as notable is what was not discovered. The source of dark matter remains elusive, perhaps awaiting the next significant increase in experimental sensitivity. With the LHC set to provide more than a 60% increase in collision energy next year, the anticipation is high for the next discovery, a discovery that would be even more dramatic than the last.

To prepare for the expected collisions, LHC physicists are poring over the wealth of information provided by the existing data. The newly observed particle appears to have one of the key features of a Higgs boson: it interacts with other particles with a strength proportional to their masses (see Fig 1). The boson has been unambiguously observed in its decays to W bosons, Z bosons, and photons, and each experiment has demonstrated strong evidence for its decay to tau leptons. The measurements of the rates for Higgs boson production and decay to these particles have a precision of 20-40% (see Fig 2),

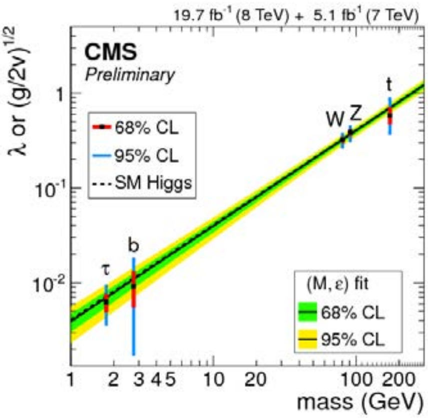


Figure 1: The inferred coupling of Standard Model particles to the Higgs boson as a function of each particle's mass, based on measurements of Higgs boson production and decay rates with the CMS experiment [CMS-PAS-HIG-14-009 (https://cds.cern.ch/record/1728249)].

impressive accuracy for a newly observed particle with challenging decay signatures. LHC physicists aim to improve the accuracy of these measurements by factors of 2-3 in the next three years of collisions. The collisions will also allow for the first observation of interactions between the Higgs boson and top quarks, and between the Higgs boson and bottom quarks. If there are other Higgs bosons contributing to the masses of any of the Standard Model particles, deviations could be observed in the predicted rates of Higgs boson production and decay.

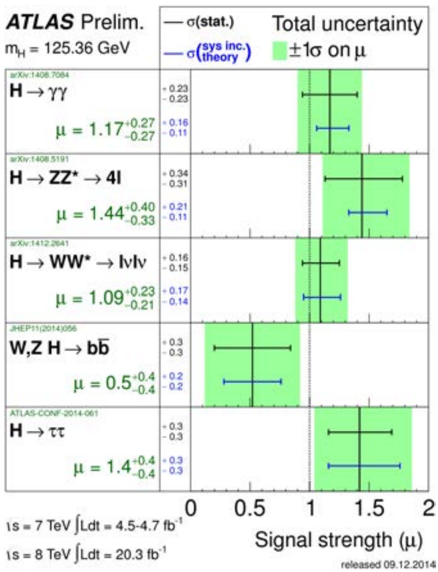


Figure 2: The measurements of several Higgs boson production and decay rates with the ATLAS experiment, relative to the Standard Model predictions [https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/HIGGS]

Now that a Higgs-like boson has been observed, one of the long-term goals is the observation of its self-couplings. These self-couplings are required by the Higgs mechanism; the particle can not be called a Higgs boson without them. While it will take the lifetime of the LHC to measure the self-couplings with any precision, the experiments are already constraining their values using the existing data. A non-zero value of the self-coupling could be demonstrated with the data to be collected over the next three years.

Another important property of the Higgs boson is its mass. Prior to the Higgs boson discovery, the self-consistency of the Standard Model required its mass to be less than about 150 GeV. The ATLAS and CMS experiments have measured the new boson's mass to be about 125 GeV, consistent with this prediction and with the prediction of a range of models that include an as-yet unobserved supersymmetry relating fermions to bosons. The mass can also be used to fix the form of the Higgs potential and determine the stability of the vacuum under quantum corrections. If one assumes that there are no unobserved particles affecting the Higgs potential, the vacuum appears to be meta-stable but with a lifetime that is considerably longer than the age of the universe, and with the possibility that gravitational interactions could stabilize the vacuum.

While the vacuum may be stable without new interactions below the Planck scale, quantum corrections to the Higgs boson mass suggest that such interactions should appear at the TeV scale. Top-quark loops in the Higgs boson propagator contribute to the boson's mass, and should drive it to large values without the presence of new interactions at this scale. In the absence of such interactions there must be a fine-tuned cancellation between the top-quark loop and high-scale contributions to the Higgs boson mass. If the high scale is taken to be the Planck scale, the cancellation in the Lagrangian mass-square parameter must be a part in 10^{34} .

The seemingly low value of the Higgs boson mass in the face of quantum corrections is a curious mystery. A more concrete deficiency of the Standard Model is its failure to account for the observed dark matter in the universe. Here again the

LHC is primed for discovery: if the source of dark matter is a particle with natural weak couplings, it should be observable at the LHC. Supersymmetry predicts a particle with such couplings, and is made more appealing by its ability to also explain the low value of the Higgs boson mass: supersymmetric quantum corrections approximately cancel those due to Standard Model particles. One of the surprises of the first three years of LHC data was the absence of any evidence for supersymmetry. With the additional energy in next year's collisions, this evidence could be just around the corner.

Measurements of the Higgs boson and searches for dark matter and supersymmetry are just a taste of the broad array of the ongoing measurements and searches at the LHC. Next year's collisions will explore completely new territory, promising a return of “particle fever” to the LHC.

Dr. Chris Hays

Recent highlights and future plans of the LHCb experiment

The LHCb experiment is a dedicated flavour-physics laboratory at the LHC. Since 2010 it has successfully recorded huge samples of b and c hadron decays that provide fertile ground to further our understanding of CP violation, the mechanism of the strong interaction and the search for very rare heavy-flavour decay processes. With each precision measurement LHCb can test the Standard Model (SM) to a new level, looking for the first signs of new physics effects that could open up new avenues of discovery. Analysis of the Run-1 dataset, collected in 2011–2012, has led to over 220 published papers with many more in preparation.

The LHCb collaboration has recently published the most precise measurement of the CP-violating phase phi_s and B^0_s meson lifetimes using B^0_s -> $J/\psi\ \varphi_s$ decays. In the SM φ_s predicted to be very small with almost no theoretical uncertainty. New physics contributions in B^0_s-mixing diagrams could substantially increase φ_s and the measurement is therefore a very sensitive probe for physics beyond the SM. The published results are in good agreement with SM predictions and significantly constrain possible new physics models such as supersymmetry.

One of the main objectives of the LHCb experiment is to search for and study the decays of B mesons that are controlled by quantum processes involving particle loops. These loops typically mean that the decays are very rare (e.g. 1 decay for every 300 million B mesons produced) and so are challenging to detect but this also makes them very sensitive to the effects that particles from beyond-the-SM theories could have in these loops. The benchmark $B^0_s \to \mu^+ \mu^-$ mode has recently been observed by LHCb and the CMS collaboration (another experiment at the LHC), with a measured decay rate that is consistent with the SM prediction. Another rare decay is $B^0 \to K^* \mu^+ \mu^-$, the analysis of which allows many theoretically clean observables to be measured. LHCb has published results (using only the 2011 dataset) that are generally in good agreement with SM predictions, except for the variable called P5', which is showing a discrepancy from the SM prediction in a single bin of the di-muon invariant mass by 3.7 sigma. LHCb is currently preparing the analysis of its full Run-1 dataset for $B^0 \to K^* \mu^+ \mu^-$ and is certainly something to pay attention to in the future!

Our understanding of the strong interaction that binds quarks into hadrons has been advanced through the exciting discovery of two new particles: the χ $b^{'-}$ and χi b^{*-} baryons. These are composed of one b quark, one s quark and one d quark and have long been predicted to exist but had never previously been observed. By precisely measuring properties such as the mass and widths of these baryons it is possible to make stringent tests of theorists predictions using QCD. In addition, LHCb has confirmed the existence of the $Z(4430)^-$ charmonium state, measured its quantum numbers and demonstrated that it indeed behaves like a particle. Together, these measurements confirm the exotic nature of this state, which is believed to be composed of four quarks or a combination of two quarks and two anti-quarks, unlike anything other hadron previously studied.

The second proton-proton run of the LHC will start in mid-2015, operating with 25 ns collisions at a centre-of-mass energy of 13 TeV until the end of 2018. The LHCb detector will collect data at an instantaneous luminosity of $4x10^{32}$ $cm^{-2}s^{-1}$, a factor two above the design, allowing an additional 6 fb^{-1} of pp collision data to be recorded, effectively tripling the total dataset available. In the period between Run-1 and Run-2 the LHCb collaboration have been very active in preparing the detector subsystems and computing infrastructure so that it is fully operational for the first collisions in 2015. Run-2 will provide LHCb physicists the chance to build upon their impressive programme of flavour physics measurements, which will allow them to look for the effects of new physics in quantum loops at unprecedented precision.

Dr. Greig Cowan

IoP Half Day Meetings 2014

A half day meeting on "**Vector Boson Fusion**" (VBF) was held at the University of Warwick in June. It was well attended by a good mix of experimentalists (ATLAS and CMS) and theorists. The program included reviews of recent experimental evidence for the VBF process in Higgs and W/Z boson production and a discussion of future experimental measurements using VBF to probe, for example, the CP properties of the Higgs boson. The theory status was reviewed and the talks on the state of the art of QCD calculations and higher order Higgs process simulations led to spirited discussions. Effective Field Theory (EFT) is likely to be the language of future Higgs boson measurements at the LHC and we were led through this in a thought-provoking talk. The outcome was a clear view of the future experimental methods using VBF and the future language in which measurements should be couched, namely EFT.

The **Dark Matter at the Large Hadron Collider** (DM@LHC) meeting held in Oxford in September saw the launch of a new international workshop series dedicated to the search for Dark Matter at the LHC. The workshop featured many new experimental results from the LHC, ideas for improving the searches and also discussion of the limitations of the current theoretical interpretations. The IoP-sponsored Half-Day Meeting within the workshop (on

September 27) brought together an international panel of experts with a focused and ambitious goal; to create a "simplified model" structure for Dark Matter interpretation that will allow a detailed and fair comparison between the different channels, and also comparison with direct-detection searches for Dark Matter. More than 60 participants joined the Half-Day Meeting, which spawned a working group that has grown to well over 100 people engaged in writing up the conclusions of the workshop. The plans for Dark Matter simplified model generation for use by CMS and ATLAS are now well underway, and should be ready for the new data in 2015.

All of our half-day meetings are intended to be accessible for a general particle-physics audience, not just for people working in a specific area. Please support the IoP HEPP group and your colleagues who organise these events by attending as many of our upcoming meetings as you can.

More information can be found at
http://www.iop.org/activity/groups/subject/hepp/calendar/index.html

IoP Particle Accelerator and Beams Newsletter

Our friends of the IoP PAB group also have a newsletter which may be of interest and you can be viewed through the following link.

http://www.iop.org/activity/groups/subject/pab/news/page_40592.html

IoP HEPP Prizes 2014

Group Prize:

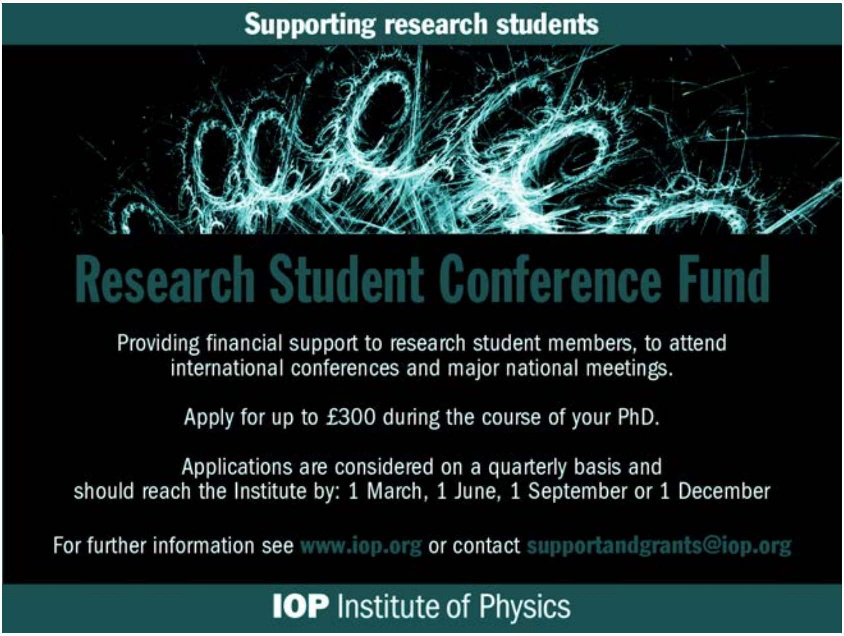
Justin Evans – For his contributions to world-leading neutrino oscillation measurements at MINOS.

Poster Prize:

Emily Grace – Liquid Argon Neutrino Detectors

Science in Society Prize:

Tom Whyntie – For his work in establishing the nationwide CERN@school programme that has brought CERN technology into the classroom.



Meet the Committee

Yoshi Uchida (Imperial): chair

Melissa Uchida (Imperial): newsletter & PAB group liaison

Sinead Farrington (Warwick): treasurer/secretary

Thomas Bird (Manchester): student experimental rep.

Franz Muheim (Edinburgh)

Alexandra Wilcock (Durham): theory student representative

Celine Boehm (Durham)

Mrinal Dasgupta (Manchester)

We have ex-officio/cross members to provide links with other IoP and STFC groups:

Neville Hollingworth, **Penny Woodman** (STFC Science and Society)
Paul Newman (STFC PPAP)
Peter Williams (Particle Beams and Accelerators group)

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