Institution: University College London (UCL)

Unit of Assessment: 9 – Physics

Title of case study: Stimulating public engagement with physics through the LHC and discovery of the Higgs boson

1. Summary of the impact

The switch-on of the Large Hadron Collider (LHC) and the discovery of a Higgs boson have stimulated interest in science and engineering, and in physics in particular, on a scale unprecedented by any other single experiment. Since 2008, UCL researchers have received a marked increase in requests for media appearances and written contributions, public talks and discussions. Many of these requests are directly related to the LHC work. While the evidence is not complete, it seems very likely that this has been a significant factor in the improved level of applications to study physics at levels from GCSE to undergraduate degree. In addition, public engagement with, and understanding of, the process of how science works has benefited.

2. Underpinning research

The ATLAS detector is one of the two general-purpose particle detectors at the CERN LHC, the largest physics experiment ever built. A major goal of ATLAS and the LHC was to understand electroweak symmetry breaking and the origin of mass; in the Standard Model the Higgs boson is responsible for these phenomena. The LHC began physics operation in late 2009, and on 4 July 2012 the ATLAS collaboration announced the discovery of a new particle, since shown to be a Higgs boson and consistent with the Standard Model [1].

The Higgs boson was discovered by measuring the results of proton-proton collisions at the LHC. Many particles are produced in these collisions, and identifying the evidence for a new particle, such as the Higgs boson, is a huge instrumental and analytical challenge. The High Energy Physics (HEP) group, part of UCL's Department of Physics and Astronomy, played a major role in this research.

HEP researchers were involved in constructing ATLAS's detectors [2]. They built electronics for the data acquisition and trigger systems; wrote simulation, trigger and visualisation code for the experiment; and worked on the mechanical engineering of the SemiConductor Tracker (an essential component of the detector), including cable layout and thermal properties. Other important contributions to the research by HEP included the measurement of several key Standard Model backgrounds (for example [3]) to the Higgs (as conveners of the ATLAS Standard Model group, several subgroups, and lead authors on papers); development of a new way of finding Higgs bosons using the boost and jet substructure [4], which has been implemented at the LHC [5]; work on jet calibration (leading the subgroup responsible); and work on aspects of the discovery analysis including simulation software and the Higgs to bottom quark decay channel.

Key UCL researchers: Jonathan Butterworth (Professor; ATLAS UK PI 2007-2009; ATLAS Standard Model Convener 2010-2012), Emily Nurse (Lecturer and RS URF; convener of soft QCD subgroup 2010), Mario Campanelli (Lecturer; jet subgroup convener 2011), Andrew Pilkington (RS URF; Soft QCD subgroup convener 2011), Gavin Hesketh (RS URF and Lecturer), Nikos Konstantinidis (Professor), Adam Davison (PDRA 2009-2013; jet calibration subgroup convener 2011-2013) and James Monk (PDRA 2007-2012).

3. References to the research

[1] Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, ATLAS Collaboration, *Phys. Lett. B*, 716, 1-29 (2012) doi:10/jb7

[2] The ATLAS experiment at the CERN Large Hadron Collider, ATLAS Collaboration, *JINST*, 3, S08003 (2008) doi:10/bz886x

[3] Measurement of the cross-section for b−jets produced in association with a Z boson at $s\sqrt{}=7$ TeV with the ATLAS detector, ATLAS Collaboration, *Phys. Lett. B*, 706, 295-313 (2012) doi:10/b6m7c5

[4] Jet substructure as a new Higgs search channel at the Large Hadron Collider, J. M. Butterworth, A. R. Davison, M. Rubin and G. P. Salam, *Phys. Rev. Lett.*, 100, 242001 (2008) doi:10/fj9qvg

[5] Search for the Standard Model Higgs boson produced in association with a vector boson and decaying to a *b*-quark pair with the ATLAS detector, ATLAS Collaboration, *Phys. Lett. B*, 718, 369-390 (2012) doi:10/n3v

References [1], [2] and [4] best indicate the quality of the underpinning research.

4. Details of the impact

The search for and discovery of the Higgs boson using the ATLAS detector have had a significant impact upon the public's interest and engagement in physics. This has been achieved through a variety of public engagement activities that UCL research helped underpin.

Films for schools and the general public: "Colliding Particles" is a series of 12 short films funded by the STFC and produced between 2008 and 2012. They are based in large part on reference [4] above, following the development of the new way of finding the Higgs boson, and showing how an experiment-theory collaboration works and how a result can get approved by a big collaboration such as ATLAS. The films, which also extensively feature the detector [2] and the Higgs discovery [1], were targeted at schools and the "how science works" curriculum. As of December 2012 they had been viewed approximately 100,000 times on YouTube and Vimeo, and many of these views would have been in classes with many students seeing a single view. The level of interest seems to have been sustained or increased, and the number of views was nearly 200,000 as of 31 July 2013. They are also available on a dedicated website (www.collidingparticles.com) along with teaching resources for each episode. The series has stimulated interest in physics amongst school children and the wider public, as evidenced by the following selected feedback [A]:

"*As a physics teacher, I've used [the films] quite a bit in my teaching at Dulwich College and several students appear to have been really quite taken with them - in fact at least 4 are pursuing physics and the films actively helped them make their decision.*"

"Great series, has inspired me to begin studying physics at the Open University."

"From a consummate layman, this sort of snapshot is v important for people like me, its good to get an insider's view of the reasons behind the investment and the possibilities that become reality for you boffins. Good work."

"The best film I've seen about science, full stop. As a scientist, I recommended it strongly to my non-scientist friends as the best way of understanding what science is really like. Thank you."

"Quality reality television which has something totally fascinating to say with grit, class and style - captivating and moreish. I'm sure these films inspired at least 3 of my students to apply for physics at university."

Online blog: Butterworth's "Life & Physics" blog began on Wordpress in December 2009, with a post explaining the physics of reference [4], and moved to The Guardian's website in August 2010. The blog regularly discusses UCL research, including the progress and implementation of the technique described in reference [4], and the key background measurements and calibrations. Butterworth posts approximately once a week, and the blog attracts a sustained average of about 50,000 unique visitors a month, with peaks of around 20,000 a day for key posts at key times. The Guardian's Editor in Chief said [B]:

"The discovery of the Higgs boson was a huge international news story with massive interest from readers. Prof Butterworth's insider take on the Higgs and his contributions on the field of particle physics in general have been integral to the Guardian's science coverage. And his blog has been very popular with our online audience."

The Guardian's Assistant National News Editor with special responsibility for science, environment and technology said [C]:

"The discovery of the Higgs boson was undoubtedly the most important pure science story of 2012 and biggest in terms of readership on the Guardian's website. This culminated in a rich suite of coverage around the discovery announcement in July last year – including a live blog (over 300k page impressions) and video (over 200k) that explains what the Higgs boson is in simple terms. […] And needless to say, the announcement dominated the front page of the newspaper.

"The Guardian's network of science blogs, of which Prof Butterworth's Life and Physics is one, have a very unusual status that is unique in Fleet Street. He and the other bloggers are able to publish directly to the Guardian's website without direct editorial intervention. He was selected for one of these coveted blogs because he is a great writer and an immensely authoritative figure in the field. We recognised when we set them up that this area of physics was going to be scientifically interesting as well as hugely newsworthy and wanted someone who could write from the inside on what the developments in the field really meant. Prof Butterworth's blogs have delivered that in spades including a personal take on the Higgs announcement itself. He has been integral to our coverage of this vitally important area of research."

Public discourse about science is stimulated by the blog, as evidenced by the frequent online discussions (dependent on topic) with some posts attracting more than 500 comments. A selection of feedback from readers demonstrates the significant impact that the blog is also having on public interest and understanding of physics [D]:

"Professor Butterworth's online outreach and engagement activities have had a profound impact on my career in science. As I was completing my STFC-funded PhD […] I often found myself wondering if juggling the research and the communication of the research was sustainable - even possible - in the long term. […] The picture painted [by the blog] was one that convinced me that perhaps a combination of physics, engagement, management -- and even a healthy work/life balance -- was possible […]."

"I think [your blog] is one of the most influential blogs in particle physics, including also the discussion of wider issues like science funding etc. It is a very nice mixture of scientific facts and personal insights, and as such it appeals to both a wider audience and to professionals. Personally, I have to say that your blog is one of the very few I actually read, and it not only provided stimulating thoughts, but has also informed me of recent scientific results."

"It is the best physics blog and I read every article with great attention. It makes having the internet worthwhile and it makes the readers feel like they're a part of the biggest experiment of the age."

"I had decided some time ago that I was going to try to learn physics properly, and had made a small start on it around the time the LHC kicked off its proton-bothering in anger. But since then, having been able to follow its progress (along with other science news), as written by a real, day-to-day working scientist […] has really spurred me on. In short, your blog has fuelled my enthusiasm for the subject […]."

TV programme: BBC's programme Horizon: The Hunt for Higgs, based on references [1] and [2] above and specifically featuring UCL's Butterworth and Davison, attracted around 1.43 million viewers with an audience appreciation score of 85%, significantly above the average of 82% (source: BBC, Programme Producer [E]) on its first broadcast on BBC Two (Jan 2012) and has subsequently been repeated several times. AA Gill in the Sunday Times reviewed the show, describing it as the "top show of the week" [F]. The programme was shortlisted for the EuroPAWS

best Science in TV Documentaries Award 2012 [G].

Public events: About 15,000 people attended five shows (Nine Lessons and Carols for Godless People, 2011 and 2012; End of the World Show, 2012; Science Showoff, 2013; and Feynman Birthday, 2013) at which Butterworth and others discussed the Higgs [1, 2]. The End of the World Show had an audience of about 3,500 and a ticket price of £25-40.

Butterworth also contributed to two events held at Latitude Festival in 2012 about the discovery of the Higgs boson, based on the research in references [1] and [2] above. These were an Infinite Monkey Cage event and an hour discussion on the Higgs boson in the Literary Tent, and were attended by about 8,000 people in total.

Schools talks: Members of the UCL HEP group also deliver many talks in schools, underpinned by their particle physics research. At least 14 Higgs-related talks have been given since January 2008, reaching between 20 and 250 students at a time (approximately 1,000 students in total). An example of feedback (from the Head of Physics at Highlands School, a state-funded comprehensive in Enfield, London) [H]:

"We are very much missing James Monk's contribution to our physics students (incidentally we had 12 AS students when you visited us, now we have 40). They are about to start particle physics and it would be great if one of your team could find the time to come and talk about what is happening in your research. This type of talk has a huge impact in terms of connecting students with the subject."

While aspects of the impact clearly focus on UCL contributions, the huge collaborative effort of ATLAS, the LHC and CERN, which involves many other UK institutions, was obviously vital and these other institutions share in the credit for the impact generated.

5. Sources to corroborate the impact

[A] The feedback is contained in the Colliding Particles Project Final Report and Evaluation, which is available on request. It provides corroboration that the films have stimulated public interest and inspired school children to study physics.

[B] Supporting statement from the Editor in Chief of The Guardian – corroborates the impact of the Life & Physics blog on The Guardian and its readers. Available on request.

[C] Supporting statement from the Assistant National News Editor at The Guardian – corroborates the impact of the Life & Physics blog on The Guardian and its readers. Available on request.

[D] For corroboration of the stimulation of public discourse and the number of comments on blog posts, see the Life & Physics blog website: http://www.guardian.co.uk/science/life-and-physics. Some of the quoted comments can be found under the post dated 23 Feb 2013; others were received by email (compilation available on request).

[E] Supporting statement from Programme Producer at the BBC – corroborates viewing figures and audience appreciation score for the programme Horizon: The Hunt for Higgs. Available on request.

[F] Review by AA Gill http://www.thesundaytimes.co.uk/sto/culture/film_and_tv/tv/article854700.ece where Horizon: The Hunt for Higgs is described as the top show of the week.

[G] Corroboration that Horizon: The Hunt for Higgs was shortlisted for the EuroPAWS best Science in TV Documentaries Award 2012 can be found at http://europaws.org/archive/awards-2012/.

[H] Supporting statement from the Head of Physics at Highlands School in Enfield, London – corroborates that particle physics talks delivered by the HEP group impact upon students. Available on request.