Institution: King's College London (KCL)

Unit of Assessment: 9 (Physics)

Title of case study: Sharing and nurturing public excitement in science with the discovery of the Higgs boson

1. Summary of the impact (indicative maximum 100 words)

The discovery of the Higgs boson at the Large Hadron Collider (LHC) has been one of the biggest science stories in recent years. John Ellis of the KCL Physics Department has significantly enhanced the impact of this scientific breakthrough by engaging the general public around the world with the landmark scientific developments. Based on his original research on the Higgs boson and other aspects of LHC physics, and drawing on work of his colleagues, Ellis has given 76 outreach talks since April 2011 in the UK and in 24 other countries. He has participated in five cultural festivals, given a Youtube presentation with over 500,000 views, made many BBC appearances and given expert analysis and interviews to UK and international print and broadcast media. The reach of the impact is truly global with an audience estimated in the millions.

2. Underpinning research (indicative maximum 500 words)

The LHC has opened a new chapter in the scientific exploration of the fundamental laws of Nature and thereby the understanding of the processes that governed the early history of the Universe. The highlight of the first LHC running period has been the discovery of a new particle that is generally thought to be the Higgs boson. This discovery provides experimental evidence for the origin of particle masses, which govern diverse phenomena such as the sizes of atoms and the relative weakness of radioactive processes.

John Ellis has long been a world leader in the search for new particle physics and the interpretation of new experimental data. In particular, he was a pioneer in the search for the Higgs boson and a leading formative influence on the LHC experimental programme at CERN. As a result, he was uniquely placed to play a leading international role in the analysis of LHC data when they started emerging in 2011, and he and his research team have led predictions concerning the existence and properties of the Higgs boson, as well as the interpretation of the new particle discovered at the LHC. Even before the discovery of the Higgs boson, he was at the forefront of efforts to predict its mass and other properties. Once signals of a Higgs-like particle started appearing in the LHC data, he immediately analysed its key properties, publishing several important and original papers determining its couplings to other particles and its spin (intrinsic angular momentum).

Professor Ellis was appointed Clerk Maxwell Professor of Theoretical Physics at King's College London from 1st August 2010. Since then, his research has included an analysis of the way this new particle couples to other particles, demonstrating the predicted connection with particle masses, and the proposal of methods to determine the spin of this new particle, one of which has been used to provide the first experimental evidence that it has spin zero, as predicted. This research was carried out between the Autumn of 2011 and the Spring of 2013, with key publications appearing in February 2012, April 2012, July 2012, August 2012, October 2012, November 2012, February and March 2013. Some of the high-impact research papers listed were written by John Ellis and Tevong You (PhD student who started working at King's in September 2012, under Professor Ellis' supervision), without external collaborators. Some of the research was done in collaboration with theoretical physicists from York University in Canada and Sejong University in Korea. Other related research papers not listed were written in collaboration with experimental physicists from Imperial College and CERN, and theoretical physicists from the University of Minnesota in the US and elsewhere. In each case, John Ellis led the respective collaboration.

3. References to the research (indicative maximum of six references)

[1]* J. Ellis and D. S. Hwang. *Does the 'Higgs' have Spin Zero?* JHEP 1209 (2012) 071 [arXiv:1202.6660 [hep-ph]]. DOI: 10.1007/JHEP09(2012)071

[2]* J. Ellis and T. You. *Global Analysis of Experimental Constraints on a Possible Higgs-Like Particle with Mass 125 GeV*. JHEP 1206 (2012) 140 [arXiv:1204.0464 [hep-ph]]. DOI: 10.1007/JHEP06(2012)140

[3]* J. Ellis and T. You. *Global Analysis of the Higgs Candidate with Mass.* 125 GeV. JHEP 1209 (2012) 123 [arXiv:1207.1693 [hep-ph]]. DOI: 10.1007/JHEP09(2012)123

[4] J. Ellis, D. S. Hwang, V. Sanz and T. You. *A Fast Track towards the 'Higgs' Spin and Parity.* JHEP 1211 (2012) 134 [arXiv:1208.6002 [hep-ph]]. DOI: 10.1007/JHEP11(2012)134

[5] J. Ellis, R. Fok, D. S. Hwang, V. Sanz and T. You. *Distinguishing 'Higgs' Spin Hypotheses using gamma gamma and WW* Decays*. Eur. Phys. J. C73 (2013) 2488 [arXiv:1210.5229 [hep-ph]]. DOI: 10.1140/epjc/s10052-013-2488-5

[6] J. Ellis, V. Sanz and T. You. *Prima Facie Evidence against Spin-Two Higgs Impostors*. Phys.Lett. B726 (2013) 244-250 [arXiv:1211.3068 [hep-ph]]. DOI: 10.1016/j.physletb.2013.08.007

*** Publications that best indicate the quality of the underpinning research**

4. Details of the impact (indicative maximum 750 words)

In view of the world leading recognition of his expertise in particle physics, and his active and ongoing research in collider phenomenology and the properties of the Higgs boson in particular, John Ellis has received numerous requests for interviews from print and broadcast media and invitations to deliver public lectures. He is widely recognized as an authoritative and clear interpreter of this new discovery by students, the general public and the media in the UK and elsewhere, and he has played a significant role in conveying to the public around the world the excitement of the new science, of which his own research has formed an important part. In his public presentations Ellis regularly highlights his latest research findings, notably those on the properties of the recently-discovered Higgs boson, including its spin, couplings and interpretation within theories such as supersymmetry.

Between April 2011 and July 2013, John Ellis gave 76 outreach talks to audiences including school pupils, university students and the lay public, in the UK as well as in 24 other countries. He has spoken at five cultural festivals in the UK, delivering, to another diverse and unique audience, insights into particle physics and cosmology, highlighting the Higgs boson.

In this period he has given 90 interviews to print and broadcast media in the UK and 26 other countries, reaching a total worldwide audience of many millions.

- These include interviews with the following print media: **Nature** (estimated readership 400,000; 9 million monthly page views), **Science magazine** (estimated print and online readership 1 million), **Physics World** (circulation 110,000), **New Scientist** (circulation 388,000), **The Times** (print circulation 400,000), **Sunday Times** (print circulation 939,000), **Guardian** (print circulation 196,000), **Daily Telegraph** (circulation 550,000), **Le Figaro** (print circulation 321,500; online 1.2 million), **Der Spiegel** (weekly circulation 1.1 million), **South China Morning Post** (readership 388,000), **Hindustan Times** (readership 3.8 million), **New York Times** (print and online circulation 1.8 million; No. 1 English language newspaper website in the world with nearly 60 million unique monthly visitors), **Washington Post** (circulation 475,000; nearly 20 million online readers in the US and 7.3 million international), **Wall Street Journal** (circulation 2.4 million, including print and online), **Los Angeles Times** (1.5 million daily print circulation, 1.8 million online), **Associated Press** (one of the largest news organizations in the world, primarily supplying news for US newspapers and broadcasters; according to AP, their news content is seen by half the world's population on any given day).
- BBC interviews include 7 television appearances (including **BBC2**'s **Newsnight**, average

audience 900,000, and **BBC News Channel**, average weekly audience ca. 9 million), and 6 on BBC national radio (including BBC Radio 4 and BBC World Service, average weekly listeners of 11 million and 1.7 million, respectively).

- He has also appeared on television programmes in 7 other countries including **Al Jazeera TV** (broadcast to more than 220 million households in more than 100 countries; the most watched news channel on YouTube, receiving 2.5 million views per month) and **China Central TV** (Main state TV news channel in China, available to over one billion viewers), and also **National Public Radio USA** (26 million listeners in the US and worldwide, a network of over 975 independent stations).
- One of his presentations on Youtube about the Higgs boson, published July 2012, has been viewed over 500,000 times and prompted over 2,600 online comments and over 4,000 'likes'.

Evidence of the impact that Professor Ellis' message has had on his audiences is provided by the frequent, *sustained* demand for his views from the media, particularly from global outlets. The public have shown a great thirst for information on, and interpretation of, this breakthrough story in science, and the print and broadcast media have recognised John's ability to satisfy it. The Science Editor for BBC Newsnight has commented that: "John Ellis is accessible, approachable and, above all, immensely capable of elucidating the most difficult concepts in physics, such as the hunt for the Higgs-Boson particle, with unhesitating clarity and engaging relevance for non-specialists. He's always among the first people I call when researching topics even remotely connected to his field." The science correspondent for National Public Radio in the USA (and previously from the Nature news team) has stated: "John Ellis is an exceptional science communicator ... he's been great at explaining complex ideas simply, which has made him a very helpful voice in my work for popular outlets."

In his position as a leading and active expert on LHC physics, and as a result of the impact of his public engagement activities, John Ellis has been in a position to influence government policy, not only in the UK but worldwide, by helping politicians to understand the importance of the science and capitalise on the public excitement surrounding it.

He was invited to speak at an event organized for the European Parliament in November 2012, and has had individual meetings with ministers from 7 other countries. In the UK he was invited to speak at a reception at Parliament in September 2012, a report on which was published in *Science in Parliament* (SIP). In the publication's editorial from the Chairman of the Parliamentary and Scientific Committee, John's skill at working to galvanise worldwide interest was highlighted: "(John) eloquently described the 'legacy' of the hadron collider and we would be missing an important opportunity if we didn't use it to help inspire the next generation."

As noted in the main SIP article on the event, "what was clear and gratifying to see from the MPs in attendance was the wider impact that the LHC was having on MPs and Peers, many of whom were being drawn to science for the first time because of it." John has also been asked by Rt Hon David Willetts MP, Minister for Universities and Science, to develop a proposal for co-operation with developing countries in physics research.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. A full list of media interviews and meetings with associated dates.
2. Youtube video explaining in lay terms the science behind the Higgs boson (500,000+ views): http://www.youtube.com/watch?v=QG8g5JW64BA
3. Science Editor, BBC Newsnight
4. Science correspondent, National Public Radio
5. *Science in Parliament*, the journal of the Parliamentary and Scientific Committee, volume 69, Autumn 2012.
6. Participants Handbook for the European Parliament Science and Technology Options Assessment (STOA) 2012 Annual Lectures.