Institution: The University of Manchester

Unit of Assessment: UoA9 Physics

Title of case study: Public & Media Impacts Arising from Particle Physics Research at Manchester.

1. Summary of the impact

Research in particle physics at Manchester has impacted on the public understanding and appreciation of science around the world by underpinning the hugely successful media impact of Professor Brian Cox, which in turn has had a strong influence on societal views of science. Audiences in their millions have been reached, especially through Cox's work on television and, with Forshaw, the writing of several best-selling books. These efforts have helped people to understand, appreciate and enjoy science, and have inspired young people to study science at school and university, contributing to a 52% rise in applications to study physics at university.

2. Underpinning research

The impact is underpinned by particle physics research at Manchester published since 1995, focusing particularly on the collaboration between Brian Cox and Jeff Forshaw and the leading role played by the UoA (including Cox) in the ATLAS experiment at the Large Hadron Collider (LHC).

Key researchers involved since 1st January 1993 (with dates of appointment) include:

Brian Cox (PPARC-PDF 98-01, PPARC-AF 01-05, RS-URF 05-); Jeff Forshaw (staff 95-); Cinzia DaVia (staff 07-), Ian Duerdoth (staff -07); Mike Ibbotson (staff -05); Fred Loebinger (staff throughout); Robin Marshall (staff -07); Alexander Oh (RS-URF 09-); Christian Schwanenberger (roles with dates); Stefan Soldner-Rembold (staff 03-); Steve Watts (staff 07-); Thorsten Wengler (UoM roles with dates; ATLAS Run Coordinator 2008-9, Trigger Coordinator 2009-10); Terry Wyatt (staff throughout); Un-Ki Yang (staff -13). In addition, the ATLAS group has trained 42 PhDs and has employed 15 postdocs.

Representative research contributions:

- The Cox-Forshaw collaboration was critical in developing models and an event generator for diffractive processes [4], which contributed to ideas for Higgs boson searches based on central exclusive production [1].
- Cox later led the FP420 R&D Project [2] aimed at designing a detector system to measure central exclusive Higgs boson production at the LHC. This project has informed the design of the forward physics upgrade (AFP) to the ATLAS detector.

The Manchester group, including Cox, have played important roles in:

- Development and operation of the ATLAS Semiconductor Tracker (SCT) and a leading role in the conception, development and operation of the High Level Trigger system (HLT) – key components of the ATLAS Detector [3] and critical to the discovery of the Higgs boson candidate [5].
- Scientific output from ATLAS, for example, in methods for calibrating and determining the uncertainty in the energy scale for hadronic "jets" [6], exploited in [5] in order to optimize the significance of the Higgs boson discovery.

3. References to the research

The research has been published in leading academic journals, and is well cited. Citations are taken from the INSPIRE database (inspirehep.net) on 18 November 2013.

Key references

[1] B.E. Cox, J.R. Forshaw, B. Heinemann *Double diffractive higgs and di-photon production at the Tevatron and LHC* Physics Letters B 540 (2002) 263-268. DOI: 10.1016/S0370-2693(02)02144-5 [48 citations.]

[2] M.G. Albrow et al.*The FP420 R and D Project: Higgs and New Physics with forward protons at the LHC, Journal of Instrumentation 4 (2009)* T10001. DOI: 10.1088/1748-0221/4/10/T10001 [167 citations]

[3] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider,* JINST 3

(2008) S08003. DOI:10.1088/1748-0221/3/08/S08003 [2120 citations.]

Supporting references

[4] B.E. Cox and J.R. Forshaw, *POMWIG: Herwig for diffractive interactions*, Computer Physics Communications 144 (2002) 104-110. DOI:10.1016/S0010-4655(01)00467-2 [82 citations.]

[5] ATLAS Collaboration, Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, Physics Letters B716 (2012) 1. DOI: 10.1016/j.physletb.2012.08.020 [1897 citations.]

[6] ATLAS Collaboration, Jet energy measurement with the ATLAS detector in proton-proton collisions at √s = 7 TeV, European Physical Journal C73 (2013) 2304. DOI: 10.1140/epjc/s10052-013-2304-2 [336 citations.]

4. Details of the impact

Brian Cox's success in communicating science to a broad audience is underpinned by his credentials as a leading researcher, and by the research of the particle physics group in Manchester. He set out to convey the excitement of particle-physics research, through the broadcast media, contributing significantly to public interest in, and understanding of, the search for the Higgs boson, and has gone on to popularise many other areas of science. His deep understanding of much of the material he presents makes him an authoritative voice, and his specific expertise in particle physics regularly informs his media work. With Jeff Forshaw, his writing on popular science books adds to the reach of the impact.

Spreading the excitement of particle physics

2008 saw the iTunes release of the final 4 in a series of 12 CERN-LHC podcasts funded by the STFC in which "*Dr Brian Cox invites a series of unlikely guests around the biggest experiment in the history of the universe*" which have become popular downloads [A]. Shortly after these, Cox was interviewed on the BBC Horizon programme "The 6 Billion Dollar Experiment" whilst he was working at CERN. As a result of that initial appearance, Andrew Cohen (current Head of Science at the BBC) invited Cox to present "The Big Bang Machine" for BBC4. In this 1 hour show, first broadcast on 4 September 2008, "*Brian Cox visits Geneva to take a look around CERN's Large Hadron Collider before this vast, 27km long, machine is sealed off and a simulation experiment begins to try and create the conditions that existed just a billionth of a second after the Big Bang*" [B]. This programme was repeated 3 times after initial broadcast (Sept 2008, Jan 2009, Aug 2011) and was seen by a total of over a million viewers of which nearly 40% were female – unusual for a programme about physics – with a broad range of ages (16% 4-15, 43% 16-34 and 33% 55+) [C].

Taking science broadcasting to a new level

Building on his background in particle physics, the success of "Big Bang Machine" led rapidly to three further Horizon programmes: "What on Earth is wrong with gravity?", "What time is it?" and "Can we make a star on Earth?". The success of these programmes was the trigger for the "Wonders of the Solar System" five-programme mini-series. Audience figures for the series were extremely high and persistent, averaging over 3 million per programme, and regularly featuring in the top 3 BBC2 programmes of the week [C]. Wonders of the Solar System won a Peabody Award in the USA for excellence in documentary film making. In 2011 Cox won "Best Presenter" at the Royal Television Society awards for Wonders of the Solar System and at the Broadcasting Press Guild Awards he won the award for best performer in a non-acting role, while Wonders of the Solar System was named best documentary series.

The two further five programme series: "Wonders of the Universe" and "Wonders of Life" succeeded in building on that initial success, with audiences for Wonders of the Universe programmes averaging well over 3 million, and ranked in the top two BBC2 programmes, and Wonders of Life averaging around 2.5 million. The "Wonders" programmes have also been broadcast internationally [USA August 2010, Australia March 2011, New Zealand April 2011, Netherlands April 2011]. The impact of the three "Wonders" series on viewers is also evidenced by associated book and DVD sales (165k DVD/BluRay were sold for the first two Wonders series as of end of May 2012 [D] and the three "Wonders" books, co-written with Andrew Cohen, head of science at the BBC and published by Harper Collins, have sold more than 600,000 copies worldwide to date. The associated app and e-books have sold over 303,000 copies to date [E]).

The impact of these programmes on the broadcasting media, and the BBC in particular, is clear from repeat showings, re-commissioning and associated invitations for Cox to appear on other shows, including several appearances on The Jonathan Ross Show, The One Show, The Sky at Night, QI, Blue Peter, BBC Radio 5 Live and The Today Programme. Cox has a regular science slot on BBC6 Music's Shaun Keaveny Breakfast Show and has made many other one-off appearances on other TV and radio programmes. In 2009, Cox became co-host (with comedian Robin Ince) of the BBC Radio 4 series "The Infinite Monkey Cage". The show won a Gold Award in the 2011 Sony Radio Awards and continues to be broadcast: the 8th series was broadcast in 2013. Cox is also the co-host (with comedian Dara O'Briain) of the annual "Stargazing Live" event broadcast on BBC2 in 2011, 2012 and 2013. After the most recent of these, amazon.co.uk announced a 500% increase in telescope sales [F].

Cox also has a long-standing collaboration with Professor Jeff Forshaw. Together they have written two best-selling popular science books, "Why does E=mc2?" (da Capo) and "The Quantum Universe" (Penguin), which have sold 434k copies to the end of 2012 [G]. These books have been translated into several languages and the figures quoted here are only for USA/Canada and UK sales. They have been commissioned to write a further book for Penguin, to be published in 2014. Forshaw has also written several articles in the national press related to LHC physics [H]. He appeared on "BBC Breakfast" in July 2012 to talk about the discovery of the Higgs boson and, in January 2012, he was on the BBC Radio 4 "Today" programme to discuss the Higgs boson with CERN Director General Rolf-Dieter Heuer.

Influencing public debate on science

Cox's impact on public debate is further illustrated by the following example. In November 2010, Cox delivered the Royal Television Society's "Huw Wheldon Lecture" entitled "Science: A Challenge To TV Orthodoxy" (broadcast on BBC2). This lecture was explicitly mentioned in the 2nd report of Session 2010-2012 of the House of Lords Select Committee on Communications, "The governance and regulation of the BBC", to which Cox gave evidence in May 2011, and also in Professor Steve Jones' report in the "BBC Trust Review of Impartiality and Accuracy of the BBC's Coverage of Science" (July 2011).

Cox's impact on the public understanding of science has been recognised by several major awards. In 2010 he was awarded an OBE for his services to science. He was awarded prizes in science communication from the Institute of Physics (2010 Kelvin Medal "For communicating the appeal and excitement of physics to the general public through the broadcast media") and the Royal Society (2012 Faraday Prize "For his excellent work in science communication"). His extraordinary impact on popular culture is also indicated by the fact that, in 2011, he was ranked the 11th most influential man in Britain according to GQ Magazine. Forshaw was also awarded the 2013 Kelvin Medal of the Institute of Physics "for his wide-reaching work aimed at helping the general public understand complex ideas in physics".

Impact on recruitment of young people to science

Brian Cox's impact in helping popularize science in general and physics in particular has led to what is now termed "The Brian Cox Effect" by the media. Examples include: "Brian Cox Effect leads to surge in demand for physics, Daily Telegraph, 11 January 2013; "The Brian Cox effect is a star turn", Daily Telegraph, 6 September 2011; "Making science sexy: The Brian Cox effect", BBC Radio 5 Live (Tony Livesey), 8 March 2011; and "A-levels boom in maths and science credited to Brian Cox effect", The Guardian, 18 August 2011, in which Ziggy Liaquat (managing director of Edexcel) said of the increasing presence of science and maths in popular culture: "It could be the Brian Cox effect. It could be as simple as that." These claims are made in part because of a large increase in the numbers of students studying physics over the past few years. For example, according to UCAS [H], the number of applications ("choices") to universities to study physics has increased year-on-year from 17.0k in 2008 to 25.9k in 2012 (a 52% increase), which is a more rapid rise than in the other sciences (mathematics (+19%), chemistry (+27%) and biology (+35%)). It is hard to quantify the extent of Cox's contributions to these increases, but the abundant media coverage and statements like the one above from Liaquat and the following quote from Professor Sir Peter Knight (President of the Institute of Physics), do indicate that the widespread perception is of a very significant effect [J]:

"*Year-on-year we are seeing increases in the number of students choosing to sit physics A-level.*

As physics has enjoyed popular rejuvenation - thanks, in no small part, to the 'Brian Cox effect' and the excitement surrounding the Large Hadron Collider…The incremental increases each year have led to a significant long-term trend. Over the last five years, the number of A-level exams taken across all subjects has risen 7.7% but the growth in the number entering for physics is far stronger - a 19.6% increase over the last five years. Students across the country are hearing the cry for more scientists and rising to the challenge!"

5. Sources to corroborate the impact

[A] *Information on iTunes videos:* https://itunes.apple.com/gb/podcast/cern-large-hadron-collider/id251294167.

[B] *Information on Big Bang Machine broadcasts:* www.bbc.co.uk/programmes/b00dccnr.

[C] *Viewing figures:* BBC Audience Consolidated Figures Portal, statistics quoted were obtained from Vicky Edgar (PA to BBC Head of Science). Figures for Wonders of Life from the Broadcasters Audience Research Board (BARB: www.barb.co.uk).

[D] *Wonders DVD, BluRay. book sales:* Sales figures.

[E] *Wonders book/app/e-book sales:* Sales figures.

[F] *Telescope sales:* "The Cox Effect: Amazon reports 500% increase in telescope sales following astronomer's Stargazing TV show", Daily Mail (9 January 2012) and "Britons reach for telescopes as BBC and Brian Cox spark interest in astronomy", The Observer (21 January 2012).

[G] *Book sales:* Sales figures.

[H] *Press articles related to LHC physics:* The Observer (11 Dec 2011 "Higgs boson to be unveiled (possibly)"); The Observer (17 June 2012 "Why the Higgs particle hunt was always going to be a waiting game"); The Guardian (4 July 2012, "How the Higgs boson explains our universe"); The Observer (5 August 2012, "The beauty of the Higgs boson"); The Observer (9 Dec 2012, Supersymmetry: is it really too good not to be true?).

[I] *UCAS application statistics:* www.ucas.com/data-analysis/data-resources/data-tables/subject/. See the tables for "Applications (choices), acceptances and ratios by subject group" for 2008 and 2012.

[J] *Link to undergraduate applications:* Quoted in the August 2011 edition of National STEM Centre news: www.nationalstemcentre.org.uk/news/physics-a-level-entrants-rise-dramatically