Institution: University of Liverpool

Unit of Assessment: 9 – Physics

Title of case study: Particle Physics Outreach

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

Professor Tara Shears is one of the most recognizable faces in particle physics (PP). Her work on the matter-antimatter experiment Large Hadron Collider b (LHCb) has reached a huge audience. As an expert on PP and the Large Hadron Collider (LHC), she is a point of contact for the media. She is regularly interviewed in print, and on radio and television, has appeared at Science Festivals, debated and talked at learned institutions and starred in outreach videos. As one of the most influential nationally known particle physicists, she is an excellent female role model for thousands of aspiring young physicists. At a conservative estimate, her broadcast and print work has reached over a million and her personal appearances over four thousand people.

2. Underpinning research (indicative maximum 500 words)

The outreach programme described here communicates LHC science, latest results, and their relevance and importance to a broad audience.

The LHC started operation in 2008 and is the most powerful PP facility ever constructed. Based at CERN, the European centre for PP, its data revealed the existence of the Higgs Boson, and allowed investigation of matter and antimatter differences ("CP violation"), Dark Matter and other phenomena that cannot be explained by our current understanding of PP, the Standard Model (SM). Each of these topics is of outstanding importance to our knowledge of fundamental physics. Four main experiments are based at the LHC; ATLAS, CMS, LHCb and ALICE. The Liverpool PP group are and have been members of the 600-strong LHCb and 3000-strong ATLAS collaborations during the REF qualifying period.

Tara Shears created and led the SM Electroweak Physics Group on the LHCb experiment (2008-2012), where she convenes the physics working group covering Quantum Chromodynamics, Electroweak and Beyond the SM analyses (2012-2013). She is a convenor of the LHC Electroweak Working Group that spans all LHC experimental and theoretical physicists (2011 onwards). She leads the Liverpool LHCb group (2012 onwards). The group has research interests spanning both SM (Shears) and CP violation physics (Hutchcroft). The group constructed, commissioned and maintains the VELO particle detector (Bowcock) which provides the data necessary to perform all LHCb physics analyses. Notably, these include the first measurements of CP violation in the charm (2012), and B_s meson sectors (2013), and the first constraints on new physics made by observing rare B decays (2012, 2013), which have all been extensively reported in the media.

Prior to joining LHCb in 2004, Tara studied the strong force and searched for new physics on the Fermilab CDF experiment (2000 onwards) and worked on the ATLAS experiment (2000-2004). Her work on ATLAS provided the first electron, muon and photon trigger algorithms. These are used to amass the data samples needed to discover and study the Higgs Boson, perform SM tests and to search for new physics. The Liverpool PP group has a strong involvement in ATLAS. The group assembled one semiconductor particle detector endcap (Allport), and members play leading roles in the revolutionary and widely publicised Higgs discovery (2012 - Mehta, Vossebeld), SM tests (Klein M, Klein U, Kretzschmar) and Dark Matter searches (D'Onofrio, Burdin, King, Maxfield).

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

Peer reviewed academic references (4 of approx. 800 published LHC experimental papers):

1. R. Aaj et al, LHCb Collaboration , "Inclusive W and Z production in the forward region at sqrt(s)=7 TeV", JHEP 1206 (2012) 058. **DOI:** 10.1007/JHEP06(2012)058
2. R. Aaj et al, LHCb Collaboration, "Strong constraints on the rare decays $Bs\to\mu+\mu-$ and $B0\to\mu+\mu-$ "Phys.Rev.Lett. 108 (2012) 231801. **DOI:** 10.1103/PhysRevLett.108.231801
3. R. Aaj et al, LHCb Collaboration, "Evidence for CP violation in time-integrated $D0\to h-h+$ decay rates", Phys.Rev.Lett. 108 (2012) 111602. **DOI:** 10.1103/PhysRevLett.108.129903,

10.1103/PhysRevLett.108.111602
4. G. Aad et al, ATLAS Collaboration "Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC", Phys.Lett. B716 (2012) 1. **DOI:** 10.1016/j.physletb.2012.08.020

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1. The University of Liverpool, Department of Physics Particle Physics Rolling Grant, STFC, ST/F007469/1, (10/08 -9/12), £5,357,268, PI P Allport.
2. Department of Physics Particle Physics Research Grant, STFC, (10/12 – 9/16), £8,935,336, PI T Bowcock.

Prizes:
1. Fundamental Physics prize 2012
2. EPS Edison Volta prize (2012)
3. Time "Particle of the Year" (2012)
4. Time runner-up "Person of the Year" (2012)
5. Prince of Asturias award to CERN (2013)
6. EPS High Energy and Particle Physics Prize (2013).

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

Over a million people worldwide in many audience sectors have been reached by UoL outreach. The programme communicates LHC physics, of which ~10% has direct input from UoL; that which is solely reliant on UoL is highlighted in bold type.

Schoolchildren and teachers: PP forms part of the 'A'-level syllabus. Tara has delivered talks in schools, masterclasses, and for institutions (Institute of Physics (IoP), Royal Institution (RI), Science Learning Centres) to ~1000 pupils and teachers (2008 onwards). With an STFC award (ST/F500456/1, 2008), she hosted and co-wrote five PP films, distributed to schools in 2008 via IoP School's lecture DVD, which are used as teaching aids in the UK/Ireland. Success, quality and sustainability is evidenced by: film interviews for Pearson to supplement their A-level physics materials (2009); membership of the Pearson Physics Expert Panel to review the A-level syllabus (2012, 2013); invitations to address 6th formers (RI 2010, 2013, IoP); an STFC film shortlisted for the International Science Film Prize (2008); films listed on the STFC education website.

Science-inclined public: are targeted through talks at science festivals (Edinburgh 2010/2012; European Science Open Festival 2010/2012; British Science Festival (BSF) 2010/2012; Manchester 2012; **Hay 2013**; Cheltenham 2013), learned societies (**Royal Society** 2008/2010/**2011**[2]**;** Institution of Engineering and Technology (IET) 2009 [3]/2010; **Royal Irish Academy** (**RIA) 2009**/2012; **RI** 2011/**2013**; Gustavus Nobel Conference 2013), local societies and museums (IoP 2008, 2009; Science Museum 2009; University societies in Edinburgh 2008; Open University 2010; University College London 2010; Liverpool 2011; STFC 2012). The talks reached ~3000 in person, ~12,000 through lecture webcasts, ~100,000 through follow-up media coverage of the Edinburgh, IET, **RIA** and **BSF** events. Success and quality is evidenced by: invitations by science festivals and learned institutions, sell-out events (Edinburgh 2012, BSF 2012, Manchester 2012); requests to host and edit films for CERN on LHC (2008, >500,000 views), **LHCb** (2011, shortlisted for 2011 NHK Japan film prize festival, 2012 European Science TV and New Media festival; 37,000 views). The film work has led to speaking engagements at film awards ceremonies (EuroPAWS 2010), and an advisory position (RI video channel advisor, 2011 onwards). Sustainability is shown by appointments to enabling and advisory positions and by the high number of invitations to talk nationally, and now, internationally.

General public: are engaged through big-screen presentations of PP and media work. Tara devised a project to play the STFC films on all BBC UK Big Screens coinciding with the LHC-startup (2008). The footfall was ~20,000/screen, with an audience representative of the regional

gender/ethnicity/socio-economic composition. This resulted in follow-up local radio coverage. Millions worldwide are reached through media work: LHC-startup 2008 press/television; "Angels and Demons" release 2009 press/radio; LHC-startup 2010 press/radio; **UK CERN press media visit 2013**; Higgs news 2011/ 2012,/2013 press/radio/television; **Antimatter news 2010/, /2011, /2012, /2013 press/radio**; Neutrino news 2011 press/radio/television; **New physics news 2012, /2013 press/radio**. Quality is evidenced by repeat interviews with press (BBC news online, Guardian, Irish Times, Financial Times, Sunday Times), radio (BBC World Service/local radio/Radio 4, Drivetime (Ireland)), television (BBC news), anecdotal evidence, contributions to series/documentaries on radio and television. Sustainability is evidenced by the high number of requests for interview (Tara is a University, STFC and CERN press contact) and an increasing demand for **expert blog posts**.

Technology-inclined public: are targeted through new media and presentations. Tara has delivered LHC news briefs to: technology conferences Thinking Digital 2009; LIFT 2011; TEDxManchester 2012, ~700 reached in person, 8000 through web hosted talks; TEDxCERN 2013; web-hosted **video interviews for CERN, Google science fair and follow-up interviews** (18,000 hits), webcast lectures, short films, **CERN Google hangouts discussing latest research** (2013). Tara maintains her own Twitter account (2010 onwards) to tweet LHC events and answer PP queries. Success is demonstrated by web hits, and the positive comments posted by viewers. Impact is evidenced by links on YouTube, and by interviews being remixed for Symphony of Science ~730,000 views. Sustainability is demonstrated by: requests for talks; continual hit growth in web-based material; a rising Twitter follower count (>2000).

Arts, media and policy makers: Approximately 500 have been reached in person in discussion at: RFH (2011); Wellcome Trust (2012); **Guardian Open Weekend** (2012). Several thousand have been reached through arts-based radio exploring ideas from PP and elsewhere. Tara has worked with: artists through Collide@CERN (Michael Trainor 2013, Christoph Keller 2013); novelists (**Sara Maitland** 2012-2013, Lucia Cox 2013). Impact is shown by requests for: discussions on Radio 3 and Radio 4; novelist collaboration; participation in arts/science events. Following participation in the RS MP pairing scheme with Andrew Miller (2006), Tara has: briefed the Science and Technology Select Committee on CERN (2011); guided local MPs at CERN (Select Committee 2011, Esther McVey 2010). That this is useful is evidenced by follow-up work with Andrew Miller (ad hoc briefing). Sustainability and inspiration to others is evidenced by a UoL **PhD student** being awarded an internship with the Science and Technology Select Committee (2013).

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

1. The Guardian science correspondent has provided a statement to corroborate the quality, effectiveness, positive impact and inspirational nature of Tara's communication of her research to the press and general public.
2. The Head of the CERN Press Office has provided a statement to corroborate Tara's ability and reliability to communicate her research to a variety of non-expert audiences, and the high quality of her film work.
3. The Headteacher of Hardenhuish School has provided a statement to corroborate the quality of Tara's films as educational aids and their positive impact on A-level students.
4. The founder of Thinking Digital and TEDxManchester has provided a statement to corroborate Tara's inspirational presentation, ability to communicate to and positive impact on a non-expert audience.
5. The UK Communications and Innovation officer at STFC/CERN can be contacted to corroborate the high quality, reach and impact of Tara's interactions with the press, non-experts, and her ability to represent the research carried out at Liverpool to a wide variety of audiences.
6. Tara Shears's Films, distributed via YouTube, provide evidence of how PP research has been disseminated to reach wider audiences outside of academia .
7. BBC4 "The discovery machine" (2008), "Faster than the speed of light" (2011), BBC2 "Bang goes the theory" (2010), webchat to support episode 2 of Dara O'Briain's Science

Club (2012), National geographic “Naked Science: Big Bang” (2008), Discovery channel Canada “Antimatter” (2010), ORF forthcoming LHC documentary (2013) – all provide evidence of the distribution of PP research across a wide range of media to target a broad audience outside of academia.