ENGAGING SCHOOLS AND THE PUBLIC WITH ACCELERATOR PHYSICS*

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Abstract

Accelerator physics is often viewed as a difficult subject to communicate to schools and the public. The *Accelerate!* project, initiated in the UK in 2008, engages audiences with accelerator physics through a 45-minute live, interactive demonstration show, using basic physics demonstrations to explain the science of particle accelerators and what they are used for. Feedback has been overwhelmingly positive from all areas and demand for the show is very high, with over 3000 students involved in the first year of running. The program is also contributing to the science communication skills of physics graduate students. I discuss how to portray basic accelerator concepts through easy to access demonstrations and initial results of audience evaluation of the show.

INTRODUCTION

A 2006 report on public engagement for the LHC in the UK [1] highlighted the need for a demonstration lecture about accelerator and particle physics given by real scientists. In addition, it was felt that an outreach program focused specifically on accelerator physics, rather than particle physics, would both complement LHC outreach initiatives and enhance public awareness of the other applications of particle accelerators. In answer to this, *Accelerate!* was conceived by Suzie Sheehy (Univ. Oxford) and Emmanuel Tsesmelis (CERN) in June 2008. The project has four main aims:

1. To provide a novel method of engaging students, teachers and the public with current particle and accelerator physics research, and to enhance understanding of basic physics concepts through exciting, relevant examples and applications.
2. To change preconceived ideas about science, particularly physics, and ignite curiosity about science and technology. Overall, audience members should leave with the impression that science is fun, relevant and exciting. In addition, by providing current university students as role models, it is hoped the audience will also leave with a positive view of further study in science, or a career in science.
3. To provide young physicists at the undergraduate and graduate level with a unique opportunity to develop science communication skills.
4. To provide an example, and thus promote, collaboration in science outreach and public engagement between major research labs, universities, schools and the public.

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DEMONSTRATIONS

The 45-minute long science show is based around a set of demonstrations which should be accessible in most universities or major laboratories. The full list of demonstrations is given in Table 1, with a few in-depth explanations for those wishing to present the show themselves.

Exploding hydrogen balloon A common question from school students is where physicists 'get' the protons from to accelerate in the LHC. We explain that the process starts from a bottle of hydrogen gas. The hydrogen gas is injected into a metal cylinder, then surrounded with an electrical field to break down the gas into its constituent protons and electrons. All we then need to do is apply a very high voltage, separating out the protons. It is important to mention some of the properties of hydrogen gas which make it dangerous to work with, particularly that it is highly combustible.

When a flame or spark is applied, it will react rapidly with oxygen to form water and produce heat, as in $2H_2(G) + O_2(G) \rightarrow 2H_2O + \text{heat}$. The reaction is so fast it creates an explosion. We explain that the same reaction using liquid oxygen and liquid helium is used in the space industry to produce enough thrust to lift rockets up into space.

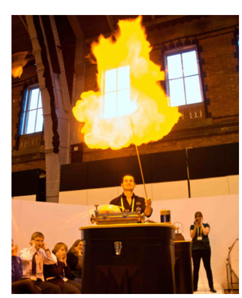

Figure 1: Exploding hydrogen balloon demonstration at the Big Bang Fair, 2010.

Van de Graff generator A Van de Graff generator with a 22 cm diameter dome can generate voltages (in practise) up to around 100 kV, producing sparks between 3 and 6 cm in length. We demonstrate the build up of charge produced using static electricity, explain electrical repulsion

Table 1: Demonstrations with Relevant Accelerator Physics Concepts

Demonstration	Concepts
Cathode ray tube television	Components of a particle accelerator, how a TV works, thermionic emission of photons
Interactive map of UK accelerators	Relevance to everyday life, accelerators for medical and industrial applications.
Exploding hydrogen balloon	Stripping hydrogen to get protons, safety when working with H_2.
Van de Graff generator	Generating large electric fields, electric attraction/repulsion, electrostatic accelerators.
Giant beach ball wave	EM waves, RF acceleration.
Plasma ball and fluororescent tubes	RF acceleration, oscillating voltages and EM waves.
CLIC RF cavity	RF acceleration, wavelength.
Electron tube and Helmholtz coils	Electromagnets, Lorentz force, bending and focusing.
Melting wire with current	Electrical resistance, limitations of normal conducting electromagnets.
Liquid nitrogen	Cryogenics, materials at extreme temperatures, safety.
Levitating $YBa_2Cu_3O_7$ (YBCO) superconductor and bed of neodymium magnets	Superconducting magnets to reach higher magnetic fields.
Colliding giant beach balls	Benefit of particle collider over fixed target experiment, difficulty of control to collide beams.
Cloud chamber	Detection, observing the unseen, subatomic particles.

by making a volunteer's hair stand on end and the presenter then creates sparks to estimate the voltage on the dome. We explain that the belt mechanism used to generate the voltage was used in early electrostatic accelerators. The high voltage terminals in these accelerators are used to attract or repel charged particles, giving them energy and making them accelerate. Unfortunately, the absolute limit of the Van de Graff style accelerator is around 30 MV, so a different method needs to be used to reach higher energies.

Giant beach ball wave This demonstration is entirely original to the *Accelerate!* project and was created in order to get the entire audience interacting with the show. Before the show starts we ask the audience to practise doing a 'mexican wave', which is only explained when we get to this demonstration. The audience is tasked with making their own 'electromagnetic wave' in order to accelerate our giant protons (beach balls). As the audience makes the wave across the theatre, the idea is that the balls 'ride' the wave across, being accelerated in the process. This is an analogy for charged particles being accelerated by an RF wave in an accelerating cavity. Of course, it is never perfect, but usually results in a lot of fun had by the audience - remember, sometimes audience enjoyment is more important than having the exact physics explanation!

Plasma ball and fluorescent tubes The part of the plasma ball of interest to us is the rapidly alternating voltage at the centre of the ball. It oscillates at around 30 MHz, generating an electromagnetic wave which spreads out in all directions. This wave then enters the fluorescent tube which lights up when it is brought near the ball. Importantly, the tube doesn't need to be touching the ball to light up. This fact disproves a number of common explanations. A good explanation for this is that the particles inside the tube are accelerated by the EM wave coming from the

Figure 2: Beach ball wave demonstration in action with an audience of 400 students.

plasma ball, and they then hit the edge of the tube causing the phosphor to fluoresce, producing visible light. This explanation can be backed up by producing sparks with the Van de Graff generator while the fluorescent tube is being held nearby - the tube will light up with each spark.

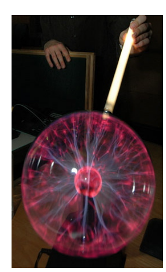

Figure 3: Using a plasma ball to light up a fluorescent tube, demonstrating how an RF cavity accelerates particles.

EVALUATION

To date there have been 32 school shows for students between the ages of 11 and 18, 3 public shows and 3 shows exclusively for teachers. The show has toured the UK and been invited to major science festivals and events. Total audience numbers as of February 2010 are 3543, with a projected total to the end the project in October 2010 of close to 5000.

Each audience member is asked to complete a questionnaire after they have seen the show. For students, these questions are: Did you have fun during the show? Do you feel you understood the science? Do you think this is a good way of learning about physics? How interested were you in physics before you saw the show? Are you more interested in physics now you've seen the show?

Of the student respondents, 92.2% said the show was fun, 91.4% viewed the presenters as role models and 89.4% who said they werent interested in physics were more interested after having watched the show. Graphs of the audience responses to each question are shown in Fig. 4.

SUMMARY

The *Accelerate!* project has engaged both the general public and school audiences in the UK with particle and accelerator physics since December 2008. Importantly, it has also enhanced the science communication skills of around 20 Oxford Physics graduate and undergraduate students. The ability of the presenter to engage the audience is widely held to be the single most important factor in the audiences enjoyment and educational experience of science shows. Despite many scientists best efforts, if presented poorly, a science demonstration has the potential to confuse as much as it could inform [2]. The training of high quality presenters is thus an integral part of the success of this project.

The project is ongoing at this stage until October 2010, and it is hoped that it will continue in some form when the current organisers move on to new projects. At the very least it will leave a comprehensive set of demonstrations and ideas for future outreach in accelerator physics. Undertaking this project has allowed us to provide an example of a collaborative outreach project between a university and research institution, which we hope will provide the motivation for future collaborations of this kind.

Further information, full powerpoint slides for use during the show and a script are available upon request from the author. A full risk assessment should be carried out before performing the demonstrations.

REFERENCES

[1] "Strategy for engaging the UK public with the Large Hadron Collider programme" (contact STFC for 2006 version) http://www.lhc.ac.uk/resources/, (2008).

[2] W. Sadler, Evaluating the short and long-term impact of an interactive science show, Open University (T3682095), 2004.

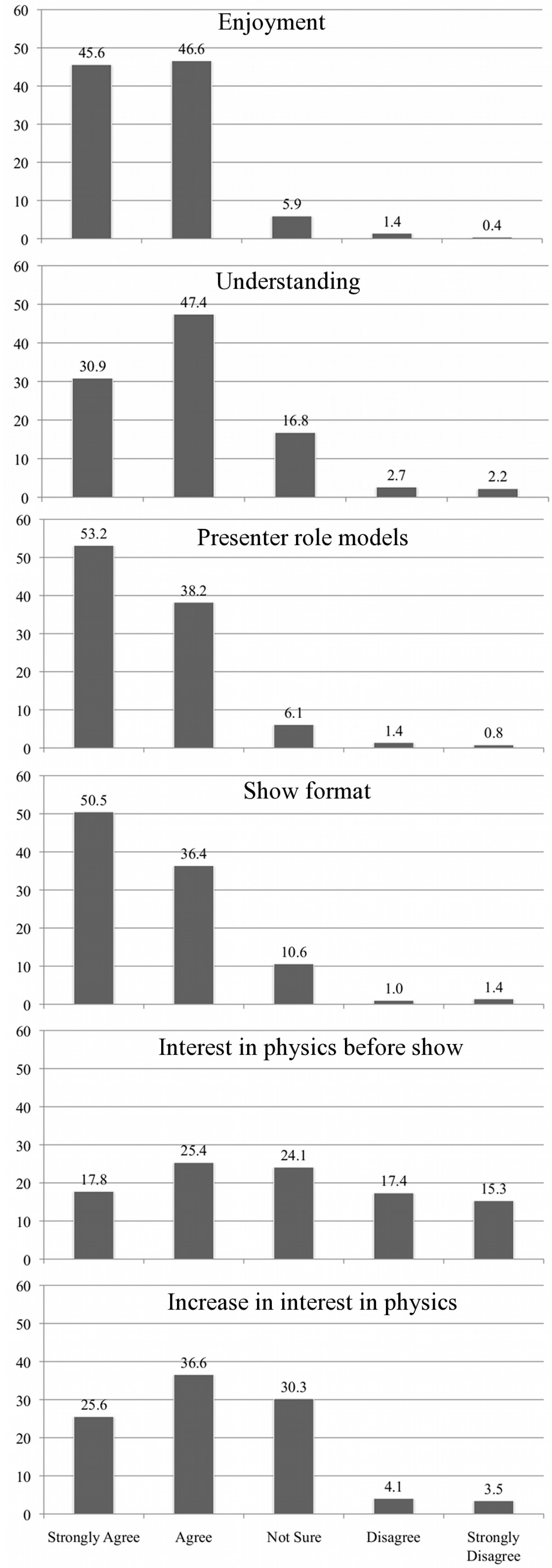

Figure 4: Audience responses to evaluation questionnaires.