People Science & Policy

Formative Evaluation of the Large Hadron Collider Communication Project

Report prepared for

Particle Physics and Astronomy Research Council

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Background

PPARC wants to use the opportunity provided by the Large Hadron Collider (LHC) project to engage the public with particle physics. It is developing a four-year programme with the twin aims of increasing public knowledge of, and support for, particle physics and inspiring young people to choose physics courses at 16 and subsequent decision points. The principal messages that PPARC wishes to communicate about the LHC project are:

1 This facility – one of the biggest in the history of science – seeks to shed light on some of the most fundamental questions in science
2 It is an exciting international venture that involves thousands of people from dozens of countries collaborating harmoniously; the UK has a leading role
3 There are valuable technological spin-offs from this type of work
4 Scientists want the public to share the excitement of this project
5 All young people, whatever their background can be part of scientific activities
6 British industry benefits considerably from this project
7 The project will tell us fundamental things about the way the universe works at a reasonable cost

The three main target audiences for the programme are the public, policy makers and opinion formers, and students aged 14-18. PPARC intends the strategy to make a national impact with these three groups and intends the legacy to be:

- greater awareness in the media of the excitement of particle physics
- a higher level of skill among particle physicists in dealing with the media
- increased awareness in UK industry of the commercial opportunities at CERN
- substantially increased political support for particle physics.

The proposed communication programme includes TV and radio coverage, a national schools programme, a national touring exhibition, public events across the UK, receptions for VIPs and opinion formers, updating meetings for journalists and a continually updated website.

PSP was commissioned to undertake formative evaluation with adults, teachers and young people to inform the development of the communication strategy. Reported here is qualitative research based on focus groups and in depth interviews.

The Public

Openness

There was strong support for openness. Participants felt that as this is taxpayers' money they have a right to know about the work. The need to communicate that the work is being done, before there are significant findings, was spontaneously emphasised. Communicating the rationale for the experiments is also important to engender understanding.

Recommendation: On-going communications about the development, as well as the outcomes, of the LHC project should be a priority, in order to demonstrate the 'open' nature of the LHC project.

Recommendation: All communication activity must emphasise the rationale for the experiments.

Physics

Physics is seen in the context of school and remembered as a difficult and abstract subject for people who are 'really clever'. Men tend to be more interested than women. As the discussions progressed participants tended to become more interested, the difficulty in real life is to attract the public's attention in the first place.

Recommendation: Avoid using the words 'physics' and 'particle physics' in titles or early in communications.

Topics of interest

The main topics of interest were the Big Bang and the origins of the universe. The term 'Big Bang' was familiar to all participants.

"I think it's fantastic. Why wouldn't we want to know where we've come from and why we're here?" Older C2DE Woman

In general participants did not know what antimatter or dark matter are (although they may have heard the terms) and they assumed that scientists already knew about matter, mass and how gravity works.

Recommendation: General communications should focus on the 'origins of the universe' and what happened immediately after the Big Bang as points for initially engaging the public.

Research

There is support for blue skies research and participants recognised that it is not always possible to predict benefits. However, there is usually some utilitarian drive behind support. OST/Wellcome Trust (2000) research supports this link between utility and interest.

Recommendation: Communications should, where possible, highlight the potential utility of the project. This may be done by referring to past spin-offs.

Spin-offs

Medical spin-offs and others that will directly affect people were seen to be the outputs most relevant to the public. Interest in other spin-offs is more specific. For example, participants struggled to see how the GRID would be useful to them personally, although they did voice concerns about security when sharing computing power.

Recommendation: When highlighting utility, communications should refer to past medical spin-offs.
Recommendation: Communications about other spin-offs should be targeted at specialist media or explicitly set out how 'ordinary' people will be affected.

Concerns

There was a fear of the unknown and of the term 'nuclear'. A few participants were concerned about the safety of the experiments. The phrase 'recreating the Big Bang' caused

some concern and led to some confusion with recreating the conditions immediately after the Big Bang. There was also some concern about the potential for the development of weapons and environmental damage. Mention was also made of possible terrorist attacks.

The tunnel being underground aroused suspicion and some felt that research generally is a rather secretive endeavour. Some participants also commented that that the way in which science is controlled and used is 'intimidating'. Some participants suggested that those with religious beliefs may be offended by work on the origins of the Universe.

Recommendation: Communications should emphasise that similar work has been done safely before and how this informs current risk assessments.
Recommendation: Communications should avoid the ambiguous phrase 'recreating the Big Bang'.
Recommendation: Communications must take into account that not everyone interested in science is unreservedly pro-science.

CERN and the LHC

Few participants were aware of CERN but even those who were did not necessarily know about the technological spin-offs. The UK was presented as a partner in an international collaboration and participants expected that the UK would be involved in such an endeavour.

Recommendation: Communications should include in notes to editors some background on CERN and the UK's involvement.

Funding

Initially the UK's £48 million per year contribution seemed like a lot of money to most participants, but put in context it did not. There is an opportunity cost issue for some on how else the money might be spent and for some this is an ethical question.

Recommendation: Communications should include information on the funding and examples of how this compares to other public sector spending in notes to editors.

Communication

Hargreaves, Lewis and Speers (2003) found that the media can be used to get the main themes of scientific topics across, but communicating any detail is unlikely. However, we found evidence that documentaries will be watched if marketed/trailed appropriately and this provides an opportunity to explore topics in more depth. Participants expected that a range of media will be used and emphasised that headlines, pictures and human interest capture attention.

Recommendation: The development of documentaries is an important means of communication and should be pursued.
Recommendation: Communications must tell real stories, include photos and feature real scientists.

Teachers

Views on physics students

Physics was seen as a male subject, using a male lexicon that is off-putting to many women and reinforces stereotypes. Teachers said that physics tends to attract those who like to think rather than be active. Some teachers had examples of how non-stereotypical groups could be drawn-in to physics but emphasised that this is difficult.

CERN

Not all teachers were familiar with CERN; those who taught A level were more likely to be aware of it.

Recommendation: PPARC will need to provide teachers with background information on CERN, as part of the resources it produces on the LHC project.

A Level

Particle physics is covered in the English AS and A2 curricula but not all teachers, even those with physics degrees, have expertise in particle physics. Relevant and current material would be welcome, including results data from the LHC experiments.

Teachers said that many students study physics at A level as a means to an end rather than because they have a specific interest in the subject. They suggested that the topics covered by the A level curricula could be modified to make the course more engaging.

Recommendation: PPARC should work with the exam boards on syllabus coverage and to identify ways to make LHC resources preferred materials for examples/case studies.

GCSE

The Big Bang is briefly covered at GCSE and is interesting to students.

Recommendation: The LHC project and experiments can be used as extension activities for more able/gifted and talented students, or for summer school activities.

It is important, but difficult, for teachers to be able to explain to students 'how scientists know about the origins of the universe'.

Recommendation: LHC could provide a useful case study for the 'how science works' element of the new curriculum.

Teaching support

Teachers are quite individual in their likes and dislikes but we were able to deduce some general guidelines for LHC school materials. Peer recommendation is a very important dissemination mechanism.

Recommendation: Materials and promotions must make clear where and how they fit within the curriculum.
Recommendation: Materials for students must be available in class sets.
Recommendation: Revision aids and self-learning can be supported by quiz formats.

Recommendation: Posters are valued but should not include too much information, be readable from a distance and be targeted appropriately. Importantly, both design and content must match the target age group.
Recommendation: The development of materials must include research, using prototypes, with teachers to ensure that format, design/style and content are all appropriate.
Recommendation: PPARC should identify trusted organisations to help market materials and identify how materials can be introduced to teachers who will then act as 'champions' for resources.

Increasingly teachers are searching the internet for material and welcome multimedia approaches but text books and worksheets remain important.

Recommendation: Web-based resources must include materials and images that teachers can manipulate themselves.

The Attoworld theatrical production was felt to be more suitable for less able students. The more able, who are likely to continue with physics, are better served by a demonstration lecture, especially if it is presented by a working scientist.

Recommendation: PPARC should not pursue Attoworld. A demonstration lecture around the LHC project should be developed for in-school delivery and used as a means to provide students with access to real scientists.

Careers

Teachers admitted that they were generally poorly informed about the options available to those who study physics at university and said that they would welcome more support.

Recommendation: PPARC should produce careers material targeted at physics teachers (rather than at careers teachers) for introduction in physics lessons. The LHC project provides a platform for this.

Role models and scientists

Teachers were very keen on being able to access scientist role models via hard copy or Web-based resources, and especially in person, and said that it is important for students to see 'people like them' portrayed. PPARC has an important role to play in encouraging particle physicists to take on this role.

Recommendation: PPARC should encourage scientists to join the Science and Engineering Ambassadors (SEAs) and the Researchers in Residence (RinR) schemes.
Recommendation: PPARC should developing a kit or pack, possibly based on the demonstration lecture, which can be used by particle physicists to assist them in presentations/demonstrations at schools.

CPD

There was some interest from teachers in learning more about the LHC work for their own CPD but further research is needed on whether there is sufficient demand for a CPD course.

Reaching teachers

Websites and the post are the best way to reach teachers. Individual schools have bottlenecks in their communications but in the absence of full lists of physics teachers, targeting the Head of Science (ideally with their name) is the most effective channel.

Recommendation: There should be an easily found website that targets teachers (and students) with appropriate LHC information and resources, plus direct marketing of free materials to Heads of Physics or Heads of Science.

Students

Physics

Students' views of physics mirrored those of adults. They highlighted that the experiments are less exciting than in other sciences and that they needed something to stimulate their interest at Key Stage 4. Many questioned the relevance of physics and we found that teachers were challenged in addressing this.

Recommendation: The LHC project should be used to show students that physics is not just about learning facts but that there is still a lot to discover about our Universe.

Careers

The students found the timescales involved in research off-putting when considering careers. They sought careers where they could make an immediate impact. *'...waiting for years and years and doing repeated tests isn't my idea of a job'.*

Some young people had very low aspirations and could not believe that research jobs were within their reach.

Funding

Students were more concerned than adults about the LHC being a waste of money.

Recommendation: The LHC project could be used as a case study in debates about spending priorities in the context of the 'science and society' or 'citizenship' elements of the curriculum.

Communication

Young people saw science centres as interesting but educational and they would be unlikely to visit them outside of an educational or family trip. Some of the older students said that there is nothing in these venues for their age group.

Recommendation: Any investment in science centres should be targeted at school and family groups, bearing in mind that it is the 'origins of the universe' that will draw in parents and possibly young adults.

Methodology

Eight focus groups were held with a cross-section of the public (a total of 63 adults). All had expressed an interest in science but some were concerned about scientific developments. 30 teachers were interviewed either individually or in pairs. All taught physics at either GCSE or A level. Four focus groups with students aged 14 to 18 interested in science were conducted. Fieldwork took place in August and September 2006.

1 Introduction

1.1 Background

The Particle Physics and Astronomy Research Council (PPARC) is the UK's strategic science investment agency in four broad areas - particle physics, astronomy, cosmology and space science, and, while Government funded, operates independently of Government in allocating funding. It funds research, education and public engagement with science in the aforementioned areas. It has five objectives, four relate to maintaining and enhancing the UK's position in its areas of science, the fifth is to *"engage the interest and support of the general public in the PPARC science programme and in scientific research in general"*. It seeks to achieve this through the Science and Society programme, which aims to *"inform and inspire audiences by capitalising on the excitement of new developments and discoveries in current astronomy, space and particle physics"*. It is within this framework that PPARC is seeking to share the excitement, and findings, of the research that will result from its investment in the Large Hadron Collider (LHC) at CERN.

PPARC is developing a medium term communications programme for the LHC project over the next four years and commissioned PSP to conduct a formative evaluation with two key audiences: members of the general public who are interested in science; and students and their teachers.

1.2 Evaluation objectives

The objectives for this formative evaluation were to:

- understand the existing level of knowledge and understanding of both particle physics and the basic scientific questions that are driving the LHC project amongst the target audiences;
- assess the awareness of CERN and the LHC among the target audiences;
- understand which of the questions that will be addressed by the LHC project are of interest to the target audiences; and
- understand the most effective way to communicate to the target audiences about the LHC and the findings it generates.

For teachers there were the additional objectives of assessing:

- whether teachers would want to cover the facility and its outputs in their lessons;
- at which age groups/key stages (if any) they would seek to introduce students to the LHC project; and
- how closely would they seek to link to the curriculum and what type of materials/content would they need to support them in including the LHC project in lessons.

For young people there was the additional objective of:

- understanding how to engage them outside the classroom.

1.3 Methodology

The project comprised:

- a review of existing UK research on the general public's knowledge of, and interest in, particle physics (see appendix 1);
- eight focus groups with members of the general public who are interested in science;
- seventeen depth interviews (13 paired and 4 single) with a total of 31 science teachers; and
- four focus groups with young people.

Full details of the methodology are set out in Appendix 2.

1.4 The report

Section 2 of the report details the findings of the focus groups with adults interested in science. Sections 3 and 4 highlight the findings from discussions with teachers and students. Recommendations are made in chapter 5 on the basis of the conclusions drawn in sections 2-4. The appendices provide more detailed information on the literature review and the methodology and associated materials.

2 Adults

2.1 Introduction

The main purpose of the work with adults was to identify features of the LHC project that might attract the interest of members of the public and thus provide a foundation for PPARC's communication strategy. It is important to recognise that people's underlying attitudes to science will affect their sensitivity to science stories and the degree to which they engage with those that they notice.

2.1.1 Public attitudes to science

In general, the public is interested in and has a positive attitude towards science. A major study found that three-quarters of the British public are '*amazed*' by the achievements of science (OST/Wellcome Trust 2000). The basic findings of this survey in 2000 were confirmed by a follow-up study that explored many of the same issues (MORI 2005); in particular that overall, public opinion of science is positive.

This positive view is largely due to the perceived direct benefits of science and engineering, which make lives '*healthier, easier and more comfortable*'. However, views are not totally driven by the need for science to be productive. In 2000, 72% of the public agreed that "*even if it brings no immediate benefits, scientific research which advances the frontiers of knowledge is necessary and should be supported by the Government*" (OST/Wellcome Trust 2000).

Interest in science and attitudes to science are affected by age, level of education and gender. Generally, as familiarity increases interest increases but attitudes to science are, in reality, more complex than this. The OST and Wellcome Trust (2000) concluded that the public can be divided into different groups dependent on their attitudes to science; these groups have distinct profiles and are summarised below.

1. *Confident believers* (17% of the sample): are supportive of science because they appreciate the benefits and have confidence in society and the political system to control developments. They are up-market and well-educated.
2. *Technophiles* (20%): are less trusting of regulatory system but more confidence in scientists. They are up-market, well-educated and have the highest level of science qualifications.
3. *Supporters* (17%): are trusting of the regulatory system, but younger than confident believers. They have higher than average qualifications but lower than the technophiles, and their social class is broadly similar to society as a whole.
4. *Concerned* (13%): are concerned about personal and societal ability to cope with changes. They are the most likely group to be female and have the greatest scepticism of authority.
5. *Not sure* (17%): neither agree nor disagree with many statements, they do not identify benefits delivered by science. They are poorly educated and more likely than the other groups to be under 35 with below-average incomes.
6. *Not for me* (15%): are personally uninterested but think science is important. They are poorly educated but more to be likely over 65.

The first four of these groups i.e. two thirds of the population are all 'interested' in science and our recruitment strategy used this segmentation to ensure that we included the full range of interested groups.

Many of the focus group participants felt that there ought to be some utility to any research. Even those who could see the value in funding blue skies research justified this with the assumption that it might lead to something useful in the future. One participant also suggested that:

> *"People are getting more interested in science now."*
> Older C2DE Woman

2.1.2 The participants

In total 63 adults took part in the focus groups recruited to the age, gender and social grade criteria as set out in the table below; people with no interest in science were excluded from the project. We also gave participants a short attitudinal questionnaire to complete while they were waiting for the focus groups to begin (see appendix 5) and ran a small cluster analysis on the results. We found two attitudinal groups within the focus group participants and these were distributed as below.

Region	**Male**	**Attitudinal group**	
		Number in group positive about science*	**Number in group concerned about science**
South East	ABC1 aged 20 to 39	4	4
South West	C2DE aged 40+	6	2
Midlands	C2DE aged 20 to 39	5	4
North West	ABC1 aged 40+	9	0
	Female		
South East	C2D aged 40+	8	0
South West	ABC1 aged 20 to 39	5	3
Midlands	ABC aged 40+	2	5
North West	C2DE aged 20 to 39	1	5
	Total	**40**	**23**

**Those positive about science were a mix of confident believers, supporters and technophiles (see section 2.1.1).*

2.2 Perceptions of physics

In common with other projects PSP has undertaken on the public's perceptions of science, we found that 'top of mind' references to physics hark back to school science lessons. Quick brainstorming sessions on 'physics' revealed that participants thought of *'maths', 'formulae', 'laws', 'gravity', 'magnetics', 'atoms', circuits', 'lasers', 'forces', 'engines', 'electricity*' and other curriculum topics. Reflecting back on school days, participants felt that:

> *"...experiments* [at school] *"weren't as good* [as in other sciences]*…not as good as mixing proper chemicals together and causing explosions or cutting up a heart."*

Younger ABC1 Woman

There was also a perception that physics is *'hard'* and *'abstract'*.

> *"It's more to do with how things work and why things work…inanimate objects'*.
> Younger ABC1 woman

And the perception of difficulty could impact on interest in the subject:

> *"I think that when people aren't interested it's sometimes because they don't understand things."*
> Younger ABC1 Woman

It also leads to the belief that people who are good at physics must be *"really clever"*.

For many people physics conjures up images of atomic bombs and nuclear power and for some this raises ethical issues.

> [What is physics?] *"Chemicals and Bombs."*
> Older C2DE Woman

Nonetheless, there was also recognition, particularly amongst the men, that physics is important and some regretted that they had not paid more attention to the subject in school.

> *"You don't realise how important physics is at school."*
> Older C2DE man

> *"Everywhere you look physics is the basis for a lot of subjects."*
> Older C2DE man

Indeed, during the course of the discussions many participants became increasingly interested.

> *"I'm partially changing my opinion of physics. It seems that the higher up you get the more interesting the work is."*
> Younger ABC1 Woman

> *"I wasn't interested …now I'm very interested."*
> Younger ABC1 Woman

Some parents found their interest had been stimulated when helping their children with homework and this served to highlight their regret that they had not spent more time on the subject at school.

> *"Supporting children…answering their questions."*
> Older C2DE Man

There were also a few men who were interested in astronomy and one who mentioned a home telescope and another who was very knowledgeable on CERN and the work done there; this was purely as a hobby.

Previous research of visitors to museums, science centres and visitor centres has been conducted on behalf of PPARC (Creative Research 1999). Specifically, respondents in that research were found to be more familiar with concepts relating to astronomy than with those relating to particle physics. Interest in concepts was closely correlated with familiarity. Creative Research highlighted differences between levels of familiarity for all concepts in relation to gender, age, level of educational attainment. Gender differences were most striking with men significantly more familiar with, and more interested in, particle physics concepts than women.

2.3 Perceptions of the work of CERN and LHC

2.3.1 Awareness

Across the eight groups about a dozen or so individuals were aware of CERN and the work that is done there but as we expected, the majority were unfamiliar with the organisation. Even amongst those who had heard of CERN there was little awareness of the industrial and medical spin-offs from the work or that the World-Wide Web had been invented there.

Surprisingly, a few people remembered seeing very recent publicity about the LHC although they did not know the name, merely remembering about tunnels. PSP was aware that there had been some earlier coverage of the LHC and clearly some of this had caught the attention of some people.

2.3.2 Misconceptions and trust

The full name of CERN – the European Organization for Nuclear Research – evokes images of research into nuclear power and nuclear bombs in the minds of many. This needs to be born in mind in any publicity material and it is interesting that CERN's website already takes this on board by not providing the full name, it calls itself "The World's Largest Particle Physics Laboratory". The term '*particle physics*' however, was somewhat daunting for participants.

The fact that the LHC is underground aroused suspicion in the minds of some participants. It implies to some that the project is secretive and hidden. Communications might want to address the rationale for this.

There is a general fear of the unknown among the public with regard to scientific developments (MORI 2005). Opinions about science are not only affected by demographics and level of scientific knowledge but also by perceived level of risk. It has been found that scientists working for industry and the government were least trusted when compared with other funding bodies. Furthermore, although the population as a whole is generally amazed by scientific achievements, it is ambiguous about the benefits of science being greater than any harmful effects (OST/Wellcome Trust 2000).

2.3.3 UK involvement

The moderators provided background information on CERN, including that Britain is a founder member. There was widespread support for our involvement and an expectation that Britain would be involved in such a high quality scientific endeavour.

> *"Why should we be left behind?"*
> Older C2DE Woman

> *"We don't want to be left vulnerable."*
> Older C2DE Woman

It was also expected that the UK should be involved *"with our history of research"* and given that it is a European project.

> *"We're part of Europe."*
> Older ABC1 Man

There was also a perception that:

> *"...it's good for countries to share information because you don't feel as if something's being hidden."*
> Older C2DE Woman

However, for some participants, the desirability of our involvement depends on whether the discoveries would be freely available or only accessible to those who paid.

> *"...depends on what they do with the knowledge they get. Are they going to sell it or are they going to give it free of charge?"*
> Younger ABC1 woman

2.3.4 Funding

A review of the literature illustrated that there is some concern that the funding of science has become too commercialised and support for more public control over science has been expressed (Poortinga & Pidgeon 2003).

Reactions to the funding of the LHC project were mixed, although the initial thought was that such work costs billions of pounds. However, even £48 million per year for the UK was thought initially by most participants to be a large amount.

> *"It's a lot of taxpayers' money isn't it?"*
> Older C2DE Man

A few realised that in the context of Government spending, £48 million per annum is a *"drop in the ocean"* and possibly good value for money. This was especially true when it was put into context as about £1 per UK adult per year.

> *"I'm surprised it's that little money."*
> Younger C2DE Man

After debating the costs, it was generally agreed that those taking part would pay £1 per year for this research, some had volunteered to contribute significantly more per head before they had been informed of the level of funding.

However, there was also the concept that it is a risky venture and that the money might be wasted; that *"you might never see any benefit"*.

For some there was a sense that if it is taxpayers money that is funding these experiments, then the general public has a right to know about the findings:

> *"I think we should invest…I think we should know what they find."*
> Older C2DE Woman

A few people continued to question the value of the work, however, 'interesting' the findings.

> *"It's a lot of money to answer one question."*
> Older C2DE Man

> *"If it's a lot of physicists trying to prove their theories then no, but if they're trying to improve the world in a better way then yes. It comes down to ethics, could the money be spent in better ways?"*
> Older ABC1 Man

> *"There's lots of things I like doing but I don't ask for taxpayers money to do it."*
> Younger ABC1 woman

Questions were asked about how contribution levels are agreed and participants wanted to ensure that the UK was paying a fair contribution compared to other countries. There was a hope that contribution levels were related to relative ability to pay amongst members.

> *"Contributions should be fair and based on* [the] *economy of each member state."*
> Older C2DE Woman

Research has shown that people generally want to know the rationale behind scientific research, for example, the reasons why researchers want to do whole animal cloning (OST/Wellcome Trust 2000). A few participants were somewhat disheartened because the decision has been made to fund and run the LHC project and whatever they said would have no effect on that.

The public also wants to learn about scientific developments *during* the research stage rather than hearing about them in the mass media after the research has been conducted (MORI 2005). This is something that an ongoing communications strategy can provide, by setting out what is to be done, and why at key points in the commissioning and switch on phases before starting to disseminate results as they emerge.

2.3.5 Support for LHC experiments

Typically, following an explanation of the LHC experiments there was a stunned silence, but participants became more interested as they learnt more.

There was support for the proposed experiments. As one participant said:

> *"I think it's fantastic. Why wouldn't we want to know where we've come from and why we're here?*
> Older C2DE Woman

> *"It's one of those questions* [origins of the universe] *that needs to be answered."*
> Younger C2DE Woman

> *"It's everything…it's the big question."*
> Younger C2DE Woman

> *"People have wondered about it for such a long time, if you can finally get the answer for it I think quite a lot of people would actually be interested in it."*
> Younger C2DE Woman

On the other hand there were those who thought:

> *"The Big Bang theory, why would I want to know about that?"*
> Older C2DE woman

Some had apparently contradictory perspectives.

> *"I'm not sure how much I want to learn about them though* [after professing interest]*."*
> Younger C2DE Woman

> *"I may think it was a waste of money but it would still interest me."*
> Older ABC1 Man

Such contradictions bubbled under many of the conversations with people oscillating between positive support and concern, the belief that they had the right to "*know*" and the fear that they "*would not understand*" and professing interest whilst recognising potential apathy.

Interestingly there was also some fascination in the machinery itself:

> *"It's amazing that there's actually a machine that can record that…that they can actually capture that moment in an experiment* [the moment just after the Big Bang].
> Older C2DE Woman

> *"…a machine as big as that is impressive…"*
> Older ABC1 Woman

There was support for the idea of conducting research purely in the pursuit of knowledge.

"If you had to justify every single project, if you were a scientist, justify everything you ever did and show tangible benefits and products and improvements before you got the funding to do these things, half the science in the world would never get done."
Older ABC1 Man

"Anything that you're asking questions about you've got to go ahead with."
Older ABC1 Man

"If nobody ever asked the question it would be a dull world."
Older ABC1 Man

"I think it's difficult to go against it really because so many things have come from it, and these things have helped us."
Older C2DE Man

"Things have been discovered by accident…"
Younger ABC1 Woman

Others were concerned about the drive to continually undertake more scientific research and questioned whether this research was justifiable.

"The only thing I have doubts about is the reasoning behind the need to get down to that level, is this not science for science's sake?"
Older ABC1 Man

There was also some debate as to whether there will ever come a time when we cannot learn anymore.

"You can't suddenly stop learning and say we've learnt enough in that direction and everything stops … to get where we are now it's always been because we've taken one more step."
Older ABC1 Man

Scepticism about the value of the experiments was mainly related to the opportunity cost of using public money in this way rather than for other purposes, given the rationale for the experiments and the likely 'useful' outputs.

"There's a lot more things that people could be looking at, curing cancer, AIDS…"
Younger C2DE Man

"It doesn't sit easily when there are so many other things that need sorting out…"
Older ABC1 Woman

"What point it there to knowing how the world evolved…we're in the here and now and I'm more concerned about the future than the past."
Younger ABC1 Woman

2.3.6 Safety

A few participants raised the question of whether or not the experiment would be safe, largely stimulated by concerns about the term 'nuclear' and the release of energy, explosions, bomb-making and the potential for environmental damage.

> *"It doesn't sound like a good idea to me…I can see something going wrong…a big explosion."*
> Younger C2DE Man

> *"…sounds worrying to me…"*
> Younger C2DE Man

Another area of safety concern was the possible negative health effects of the experiment on those working at CERN.

> *"It doesn't sound too healthy…Possible side effects?...Are the scientists working in the tunnel?"*
> Younger C2DE Men

The question was also raised as to whether it might be a target for terrorists – this was probably because of the 'nuclear' link.

There was also concern about the regulation of scientists and the results of the experiments.

> *"Knowledge is power, this is potentially dangerous…I think a lot of evil goes on with scientists, it's not for the greater good, but just them experimenting, not really bothering about man kind and the planet, this negativity gets into the papers and because of what's happened in the past e.g. during War."*
> Older ABC1 Woman

There was some reassurance, however, for those who thought there might be dangers in that similar work had been done before.

2.4 Subjects of interest

We gave participants two sets of shuffle cards (see appendix 6) and asked participants to rank them in order of interest. The first set of cards was on scientific topics that the LHC experiments aim to address; the second set was on spin-offs from building the accelerators and detectors.

Despite the instructions to rank topics by interest, participants had a variety of rationales behind their ranking, including utility and helping people, job generation, personal interest and because the funding comes from public taxes. Many also discussed the worthiness of the questions being answered and potential and actual spin-offs when deciding on what was interesting.

> *"In reality people don't care, unless it's a direct benefit."*
> Younger ABC1 Woman

"It's not a case of not being interesting it's a case of we don't know what it is."
Older ABC1 Woman

Some said interest in topics would "*depend on what you believed in*". However, one participant thought that we need to understand simple things, such as violence and crime before we look into more complicated things.

As with their perspectives on physics, with some participants if they have not heard of a topic or do not know what it is, they tend to be less interested in it. On the other hand, others were attracted to press articles about topics that were new to them. So, interest seemed to be affected by knowledge in contrasting ways.

"I'm not very fussed about what matter is, I've never known about it so I'm not too bothered about knowing about it now…"
Younger C2DE Woman

"I don't really know anything about it [matter]...[that makes it] *interesting because knowledge is good."*
Younger C2DE Woman

Often, people used 'importance' as a way of measuring the interest in a topic. Previous work (OST/Wellcome Trust 2000) showed a strong correlation between the degree of interest in an aspect of science and the perceived benefits that it delivered.

Some participants highlighted the unknown potential that may result from the experiments. Some saw this positively, others negatively; this seemed to affect their level of interest.

"The possibilities are limitless."
Younger C2DE Man

"From knowledge you get advances and possible applications, if don't know how it works, never realise potential."
Younger C2DE Man

Some were suspicious of the reasons for highlighting what seemed to be only positive benefits of the project.

"These are all totally positive things…are they trying to justify the £48 million."
Older ABC1 Woman

Others raised the idea that just because something was interesting doesn't mean that they agreed that money should be put into it.

"Being interested in something doesn't mean to say that you should put money in and invest in it."
Younger ABC1Woman

One group thought that all the cards are interesting but "*nothing to write home about*" suggesting that the spin-offs were the most interesting aspects. Another person saw the information on the spin-off cards as the way to communicate the project with the public.

> *"This is the sort of thing you've got to publish to keep it going, to tell the public that this project is useful."*
> Older C2DE Man

It should be remembered that the levels of interest discussed above and below are from groups of people who have been selected because they are interested in science, so are likely to be more positive than the public in general.

2.4.1 Scientific topics

The Big Bang/origins of the universe

The overwhelming topic that captured people's imagination is the idea that this work could throw light on the origins of the universe.

> *I think it's important to understand what's happened and what you've got now to enable you to understand the future.* [that's why she's interested in the Big Bang]
> Younger ABC1 Woman

The Big Bang theory was recognised by all the participants and the idea of knowing more about it intrigued almost, but not quite, all of them.

> *"The Big Bang theory, why would I want to know about that?"*
> Older C2DE Woman

Although there was no one in any of the groups who claimed to believe in creationism or to be hold particularly strong religious views, there was an awareness that for some members of the wider community the findings could be controversial.

> *"It's dependent on people's beliefs, some don't believe that the Big Bang happened. Some people think you're here and you die, that's it. I think there might be a lot of controversy about it."*
> Younger C2DE Woman

> *"Some people believe that God made the planet and that's it, so a lot of people won't be comfortable with* [these experiments]."
> Younger C2DE Woman

In other groups there was concern that those with a religious belief might be offended by the whole concept.

> *"People are funny about religion and creation."*
> Younger C2DE Woman

There was also a view from some participants that they thought this could never be known, *"after all, nobody was there at the time",* while some assumed that it was known already.

Questions Einstein couldn't answer

There were a variety of responses to this. Some felt that these were old questions and irrelevant, others that we have much better equipment so answering these questions would be much easier today, and yet another group thought that they must be 'hard' questions if Einstein had not been able to answer them.

Some participants identified this as a good 'hook' by which to draw in the public as most people have heard of Einstein. It was suggested that:

> *"People can understand and relate to Einstein, albeit at different levels."*
> Older ABC1 Man

Some thought that Einstein and his work could be used to draw parallels with modern science

> *"I'm sure you could identify a number of long term benefits that have arisen from Einstein's work."*
> Older ABC1 Men

> *"I'm sure he would have trouble getting funding too."*
> Older ABC1 Men

Biggest experiment ever

This generated some interest among a few participants and for those who found this engaging this impacted on all the other topics. For one younger woman this was the main 'hook'.

Anti-matter and dark matter

In general participants did not know what antimatter is, therefore the question in which they were interested was not *"Where is antimatter?"* as on the shuffle card, but: *"What is antimatter?"* Any communication about the LHC experiments that features antimatter must include an explanation of what it is. Similarly the great majority of participants did not know what dark matter is. Once they did, it was of some interest to some people. Any communication about the LHC experiments that features *"dark matter"* must, as with antimatter, include an explanation of what it is and why its existence or absence matters.

Why does matter have mass?

Most participants thought that this was already known. There was also a view that they had lived long enough without knowing about matter (and indeed the other topics) that the knowledge was not relevant to their lives.

How gravity works

Again, most participants thought that this was already known and there was a general surprise at how much is not yet known.

Fundamental laws of nature

While this topic was of interest it was too broad and general for enthusiastic engagement and was overshadowed by the origins of the universe topic.

2.4.2 Applications and spin-offs

Research suggests that the biggest barrier to a greater understanding of science by the public is lack of appreciation about how scientific developments affect them personally or society in general (NESTA 2005). This lack of appreciation about how science affects them is more apparent in the physical sciences than in any of the other sciences.

Research has shown that the utility of science and its benefits are recognised as key in gaining public support and interest. For many, if not most of the focus group participants, utility was very important. Even those who supported blue skies research tended to expect there to be some long term payback from the initial investment. There was also a feeling that in general the public is mainly interested in research that will benefit them, even if they can see a wider usefulness.

While we focussed on the topics set out below, concerns were raised that the results might be used to develop new weapons.

> *"Is there any guarantee that the research that they develop won't be used to make a new weapon?"*
> Older C2DE Man

> *"The ethics get pushed aside at times where fast development is needed, for example in times of war."*
> Older ABC1 Man

Medical applications

Medical applications are always interesting to members of the public and these participants were no different.

Engineering advances

Engineering advances were thought worthwhile but did not engender strong interest.

The Grid

The moderators went to some lengths to explain the Grid and although one or two of the participants had heard of the Grid, most struggled to see how it would be of use to them personally. They could not envisage wanting to do anything that would require the Grid. It was seen as something very specialised, although some felt that if it existed there should be the option to use it.

Moreover, some felt that they might not want to use the Grid because of security issues. They felt that linking computers together had security implications that should be addressed now, rather than once *"something"* had happened. Governments were thought to have a responsibility to police a publicly accessible Grid.

Computers and the Internet

Progress in computing was taken for granted and aroused little interest specifically.

UK involvement in international science and leading the USA in science

For many participants this was not an issue. It was expected that the UK would be involved in large international projects and being better than other countries was of no

consequence and did not matter. However, for a few, being *"better"* than other countries, especially the USA, did hold some appeal. One or two participants felt that the US always seemed to be bigger and better and it was nice for the UK to be in the lead for a change.

Opportunities for UK business and UK scientists

These topics probably have interest for only a specialist market. In general this was seen as irrelevant to the participants who took part in this study, although some thought that job generation and economic prospects would be interesting.

Careers in science and engineering for young people

In general, the LHC experiment was felt to be a good thing if it created employment opportunities.

2.4.3 Headlines

We asked participants to use what they now knew about the LHC to write headlines that they thought would capture other people's imaginations. The headlines could have a positive, neutral or negative slant, but the key was that they should attract attention, thus providing an additional insight into what the participants found to be most interesting

A few examples are highlighted below (a fuller list can be found in appendix 8):

- Big Bang in Swiss Alps
- How it all began
- The Big Bang! Did it really happen?
- Biggest Crash in the world due this Monday!
- Big Bang Exposed
- Einstein's Missing Tool Kit
- 27 Miles of Tunnel –only two vehicles and they still crash!
- A Science Orgy – The Big Bang Revealed
- A "Tunnel vision" of the Future

2.5 Reaching people

One participant referred to one of the concerns that has been voiced over other scientific announcements, namely that the ground needs to be prepared for major announcements.

> *"If you don't get people excited in it…when results are announced people won't care because they haven't been involved."*
> Younger ABC1 Woman

Research has shown that controversies of the GM food kind are more likely to emerge where the public believes there is a lack of knowledge. People generally make judgements by relying on the judgement of trusted others (individuals and organisations), but take it for granted that information provided by institutions will tend to be framed to that institutions advantage. It is argued that it is important to establish connections between science, policy and the general interests of the public (Hargreaves, Lewis & Speers 2003). Similar concern was highlighted by one participant in this research.

> *"I think the general public are very, very frightened because every time they get given a new product, there is always a scare attached to it. It's like here you go guys, have a mobile phone, oh by the way, the radiation can give you a brain tumour. And it happens so many times that when they release something, there's a scare attached to it."*
> Younger C2DE Man

Importantly:

> *"They'll want to know the benefits."*
> Younger C2DE Man

Participants advised us that key to attracting attention would be to highlight:

- What has already been achieved by this type of work
- Why the work is being done, rather than how it is being done
- Medical advances
- Engineering advances
- Include photos and keep it simple and have experts available who can communicate clearly with the public.
- Be positive

These findings partly map with the three main 'hooks' identified as ways of engaging interested adults in science (PSP for CCLRC 2004), which were:

- the quality of UK science;
- new investments in UK science; and
- understanding how things work.

However, in that work substantial UK-based facilities were discussed with local residents boosting the sense of 'civic pride'. The likely interpretation by respondents of the phrase "*new investments in UK science*" in that survey could have been investments based in the UK. For PPARC, we presented the LHC work as the UK being part of an international collaboration, this and the overseas location, may have affected the perception of the importance of the UK role.

One participant suggested that newspaper articles might start from the inventions and benefits and work back towards how the machinery came into being. One group felt that the whole endeavour might be more interesting to those who read *"broadsheets rather than the Sun"*.

> *"It's just so minute, it's hard to comprehend."*
> Older C2DE Woman

> *"I don't know how you're going to publicise this because to me it's just… particles and getting them to spin around and collide…"*
> Younger C2DE Man

Hargreaves, Lewis & Speers (2003) found that what and how people learn from the media indicates that 'the details or subtleties of media coverage are…much less important than the general themes of that coverage, in which certain ideas are repeated and associated with one another'. They concluded that 'while this does mean some information is communicated effectively to most people, it can result in widespread misunderstanding – even if the reporting is generally accurate'. Therefore, the media can be used to get the main themes across but is unlikely to reach the public with any details. The challenge remains as to whether this overall view provides enough information to allow the public to develop a greater understanding and perhaps allay any concerns they have.

Some participants felt that they would not want a lot of detail.

> *"None of us are Einstein's in this room…the average person, there is only so much you can take on board."*
> Older C2DE Woman

> *"Would you want to know all the figures? Would you not be drowned by all this technology?"*
> Older C2DE Woman

On costs, it was felt that if it can be justified and put into context as £1 per adult per year in the UK, then there would be little complaint (see also section 2.3.4 on funding). Indeed, with a view to publicity, some participants felt that there was no need to explicitly publicise the cost:

> *"People are not that bothered* [about the cost] *if they can see something tangible at the end of it."*
> Younger C2DE Man

> *"People who are interested can read up on it."*
> Younger C2DE Man

> *"People know experiments cost money…Like with Dolly the sheep, no one asked how much it cost."*
> Younger C2DE Man

The advice from participants to PPARC for reaching people is:

> *"They can't miss out any type of medium...they've go to do TV...the papers...if it's such a big thing, then they've got to make sure it's radio, it's TV and it's journalism."*
> Older C2DE Woman

> *"Where people are looking incidentally anyway."*
> Younger C2DE Man

It was claimed that documentaries are very popular and certainly many were mentioned during the course of the discussions that suggest our participants are fairly keen

documentary watchers. Television and interactive TV were mentioned as main channels of communication and it was assumed that there would be information on the Web.

The adults saw the project as something young people need to learn about and they recommended that schools should be made aware of the research and that it should be incorporated in the curriculum in some way.

> *"Kids need to know about it because they are the decision-makers of the future."*
> Older ABC1 Man

> *"School would be a good place because children would be interested and they would be more likely to talk about it."*
> Older C2DE Man

> *"They could turn it into a whole project that would encompass schools as well."*
> Older C2DE Woman

Interestingly, the adults felt that children are more interested in the technology than in the science.

2.6 The need for openness

We asked participants whether they felt that some of the budget should be spent on communicating with the public or whether the scientists should *"just get on with the research"*. There was strong support for openness, even though many participants felt that most people would not understand the LHC experiments.

> *"It's good to be open…if problems arise then the general public will be aware of them."*
> Younger ABC1 Woman

> *"Part of that openness is to explain to the general public what they're doing and why."*
> Younger ABC1 Woman

> *"This sort of thing you've got to publish to keep it going, to tell the public that this project is useful."*
> Older ABC1 Man

However, there was a view that communication needed to be carefully considered.

> *"…need to communicate it in a way that people will understand…in an interesting and exciting way…"*
> Older ABC1 Man

> *"I wonder about whether it's worth having a campaign that is for everybody though, I just think that most people won't be interested… better directing a campaign towards science journals."*
> Younger ABC1 Woman

On the other hand, although a supporter of science and the work in general, another participant felt:

> *"I think there's a lot of these things we don't need access to…a lot of things we don't need to know…we don't need to know the decisions that the Government takes on our behalf all the time."*
> Older C2DE Woman

And there was some feeling that:

> *"It's more important to do science and make discoveries, than it is to make people understand why you've done it."*
> Younger C2DE Man

There was some awareness that results would be published in scientific journals but this was not universal and some participants thought that research was generally a rather secretive endeavour. Indeed there was some suspicion as to why CERN wanted to, or needed to, publicise its work. A downside to being more open is that some participants assumed that there is more being done that remains hidden.

> *"Maybe there's stuff you can't share. Maybe we're on the verge of something bigger."*
> Older C2DE Woman

> *"How much more is going on on other projects?"*
> Older C2DE Man

Research has shown that one-way information provision is not thought of as adequate for addressing public concerns likely to emerge in relation to new technologies (Grove-White, Macnaughton & Wynne 2000). Yet generally participants felt that:

> *"Communication is very ameliorating, it stops any fears and conspiracy theories."*
> Older ABC1 Man

However, there were several participants who expressed concern over whether *"scientists really know what they are doing"* or whether things are being covered up and information controlled. There was a feeling that "*people want science but are intimidated by the way in which it is used and controlled"*. At the extreme one participant believed that *"there is a lot of evil that goes on with science"*.

2.7 Conclusions

2.7.1 Topics of interest

The overarching topic of interest is the Big Bang and the origins of the universe; this is also supported by previous research. Beyond that there is a mixed response with some being more interested in the science and others more interested in practical spin-offs but there is no clear age, class or gender division.

Our participants were recruited to be interested in science but not all of those who are interested in science are necessarily staunchly pro-science. As *"Science and the Public"* showed, some of those who are interested in science are also concerned about the governance of science. In our sample we found just over a third could be classified as 'Concerned'. Any communication targeted at those interested in science must take account of those who are more concerned within the broad audience. The 'Concerneds' antipathy centred around the opportunity cost of using the money to fund the LHC rather than using the money to cure diseases (especially cancer), alleviate poverty or generally improve life in the UK.

Some participants claimed that they intended to find out more about CERN and the work that goes on there after the session.

2.7.2 Methods and content of communication

All media were mentioned as channels of communication. There is, however, great potential for a general interest documentary, especially if there are visuals of the machinery with simulations of the protons colliding and UK scientists who can be interviewed. Reference might also be made to the business and career opportunities that are available on the project.

More targeted communications would include targeting stories of spin-offs, job creation and economic activity at specialist magazines. Similarly, the Grid and computing advances are only of interest to specialists. The wider public take computing for granted and see no personal usefulness for the Grid.

Openness was greatly valued and focused publicity for the LHC experiments should be used as a way to raise awareness of the new 'Large Facilities Council' and to engender trust in its operation. Any communication needs some underlying reassurance about the safety of the experiments with an explanation of why there is no danger. PPARC cannot rely on the public taking this on trust.

2.7.3 Perceptions of physics

For the general public words like 'physics', 'particle' and 'nuclear' are turn-offs. They think this is difficult and (therefore) boring and too much like school. Understanding of antimatter and dark matter is very limited and most participants assumed that 'we' already know about mass and understand how gravity works.

2.7.4 UK's role and funding

Highlighting the UK's role is not a negative, although it only positively attracts some individuals. It seems unlikely that the UK's funding needs to be actively publicised by PPARC but there should be a strategy prepared to deal with criticism. This strategy should include reference to the scale of the funding (£1 per adult per year) and the resultant spin-offs, particularly in the medical sector, highlighting direct health benefits.

3 Teachers

3.1 Introduction

The teachers who took part in this project taught in a variety of schools, although these were mostly in the state sector. They were teaching students of varying ability throughout secondary school. Some teachers were physics specialists, but many were not. Despite the variety of individual experience, there were a number of issues that emerged almost regardless of teacher background, these included:

- LHC relevance to curricula
- Teaching materials
- Format of support/materials
- Student's attitudes to physics
- Inspiring students
- Inspiring teachers

The variations between teachers that may have been influenced by their experience and background tended to be in the nuances around the core issue.

One factor that differentiated teachers was that those who were teaching A-level Physics tended to be more familiar not only with particle physics but also with CERN and in some instances the LHC. We have therefore noted whether or not someone was teaching physics at A-level in the attributions of quotes.

3.2 LHC Relevance to curricula

At PPARC's request, all the teachers who took part in this project were based in England. The references to different educational stages therefore refer to the progression of students in England.

3.2.1 AS and A2

A-level was highlighted as the stage where the work of CERN in general and the LHC in particular was of most direct relevance. Teachers referred to "*particle physics*" elements of the syllabus and some said that they had referred to CERN or used the CERN website. A few were also aware of the potential to arrange visits to CERN; one teacher was aware that pupils from their school had previously visited CERN. Another teacher highlighted the possibility of fitting in a visit to CERN alongside a skiing trip.

> *"Does come into the curriculum at A-level…would like to talk about it then."*
> Teacher (A-level)

> *"Colliders are part of the A-level course."*
> Teacher (A-level)

> *"Particle physics…is only really at A-level."*
> Teacher (A-level)

Some teachers thought that emerging data from CERN could be useful for A-level students.

> *"*[emerging data] *too advanced for GCSE, useful in A-level."*
> Teacher (not currently teaching A-level)

One A-level teacher mentioned that particle physics appeared to be quite a popular topic at A-level and hypothesised that this was due to its novelty compared to some other topics. Others referred to the interest provoked by science fiction.

> *"Physics is perceived as being about rules, which is off-putting, the particle stuff is more exciting and interesting, which puts physics on another level."*
> Teacher (A-level)

> *"At A-level there is more interest in particle physics because it links in with science fiction such as Star Trek."*
> Teacher (A-level)

For A-level science a key issue for teachers was the relevance of any material to the individual curriculum being taught. It is important to remember that there are different exam boards and that at A-level there are different specifications including different options.

3.2.2 GCSE

In terms of standard physics curriculum content, few teachers saw much opportunity to include the work of the LHC.

> *"There isn't really room in the curriculum for something like that."*
> Teacher (not A-level)

> *"Not really, you mention the Big Bang but then you have to move on before you go into detail."*
> Teacher (A-level)

Others believed that the LHC could be mentioned when the Big Bang is covered at GCSE. Some thought the LHC could be used to inspire more gifted students; one suggested setting a research project for students on the topic.

The Association for Science Education (2006) argue that science education should be designed to encourage the curiosity of young people about the natural world around them, and help them acquire a broad appreciation of the important ideas and explanatory frameworks of science and how scientific enquiry works. Science is also often seen as interesting when it stimulates a sense of awe and wonder (KCL 2000). A number of teachers in the current study mentioned that the real-life example of the LHC in relation to "*how science works*" could be useful. In this context high profile, blue sky research could provide an engaging case study about international co-operation and exploring the unknown that could also open up debates about prioritisation of spending leading into discussions about science in society.

"I know my triple science group would be really interested in it, even though it doesn't have an aim…they find it very interesting to see what's going on in modern day research…my double science kids might struggle."
Teacher (not currently teaching A-level)

"It might be an interesting way to involve the lower sets in the fact that not everything in science has to be for a reason…if it was simplified enough I would be quite interested in talking to all my pupils about it…because it shows the scientific process."
Teacher (not A-level)

"This thing about CERN could start to have a bigger part…I can see it coming into GCSE."
Teacher (A-level)

The LHC was also highlighted as a possible route for explaining how we know things about the origins of the universe to children in a way that they can understand.

"It's a very good resource [PPARC poster]*...You do struggle, it is quite difficult to explain the scientific theory for the Big Bang…especially with kids who want to know how scientists know these things and whether religion is right about these things…it's difficult to cover all the arguments."*
Teacher (A-level)

There were occasional references to the way that data might be used to help hone other skills

"If there was data we could use that to improve their graphical skill…presenting information as charts."
Teacher (not A-level)

A number of teachers suggested that the LHC and CERN could be used to provide extension materials to stretch and/or inspire students. Some highlighted a fall-off in interest at Key Stage 4.

"*At GCSE they are too often spoon-fed*"
Teacher (A-level)

"*Textbooks are not substantial enough for talented children.*"
Teacher (A-level)

"*Fantastic for enrichment activities.*"
Teacher (A-level)

"*Kids love science at KS3, they adore it…as soon as they hit KS4 there's a sudden turn round…less practical work and more in detail and they start to drift off.*"
Teacher (not A-level)

3.2.3 Key stage 3

None of the teachers interviewed saw curriculum links at Key Stage 3. However, a number believed that large-scale fundamental science, and especially the scientists doing it, could be used to inspire students at this age and thus influence later subject choices. Section 3.4 picks up on the theme of inspiring students.

The Researchers in Residence scheme places PhD students into secondary school science departments for placements of four working days. The biosciences element of this scheme was evaluated during 1998-1999 (Woodfield, Ritchie & Clayden 1999). Overall it 'was perceived as highly effective by participant pupils, teachers and researchers saw it as a powerful mechanism for introducing real world science to the classroom and as an effective method of promoting science and higher education amongst pupils'.

3.2.4 Curriculum development

Some teachers suggested that PPARC should seek to become actively involved in the development of curricula. The purpose of such involvement would be to ensure that science curricula reflect contemporary science and the issues at the forefront of current research. At a practical level, it may be that this is an issue that could be taken forward by RCUK on behalf of all the scientific disciplines.

3.3 Teaching materials

What became clear from this research is that there is no specific material that can be used as a 'magic bullet'. The usefulness of different types of materials vary between teachers, but there do seem to be some features that will make it more likely that a teacher will consider or use a given resource. The key features are:

- peer recommendation;
- trusted supplier;
- fitness for purpose/relevance;
- ease of use;
- access;
- format; and
- cost.

PPARC has previously commissioned work that reviewed its school material. Creative Research (2000a) found that there were mixed levels of awareness of PPARC amongst teachers. Creative Research (2000a) concluded that most of PPARC's material was 'not accessible to the most able students and is sometimes over the heads of some teachers'. A number of key issues were highlighted with regard to the PPARC material, they were:

- the lack of relevance (to the curriculum);
- the high level of difficulty and detail; and
- a lack of clarity with regard to the target audience.

All issues that the teachers taking part in the current interviews highlight as critical.

Overall, research suggests that the main factor determining attitudes towards school science is the quality of the educational experience provided by the teacher (Osborne *et al* 2003). Pupils express definite views on teaching methods, with a dislike for writing and an enthusiasm for practical work, especially where they have some real input into the design and interpretation (Association for Science Education 2006).Various groups of pupils respond differently to different teaching styles. Previous research has shown that there are, in general, positive attitudes to:

- varied teaching and learning activities;
- high level of involvement in class; and
- positive teacher-pupil relationships and support.

3.3.1 Peer recommendation

A recurring theme when we asked teachers what had influenced them to first consider using a particular resource or material was peer recommendation.

> *"*[I find something by] *someone shoving it in my face."*
> Teacher (A-level)

Many of the teachers described being inundated or overloaded with flyers and introductions to new materials.

> *I'm head of science and I get tonnes of fliers and normally I take it from my pigeon hole to where the recycling bin is and then just go through it and just recycle 90% of what I receive But I am discriminating, I do pick out the ones I like.*
> Teacher (A-level)

While the teachers said that they tried to work through this material and make judgements on its potential value, the existence of a peer recommendation (either good or bad) was a powerful influence on whether or not to explore further the potential for using a given product. Shared information makes the discovery of new resources sometimes appear to be serendipitous.

> "*A lot of what you find seems accidental.*"
> Teacher (A-level)

One teacher suggested that peer recommendation was so important that PPARC should actively recruit teachers to act as champions.

> "*Recruit some enthusiastic teachers that are going to sell this for you, there's nothing like hearing it from a teacher…who can sell it for you in schools.*"
> Teacher (not A-level)

In addition, one teacher suggested that PPARC should have a teacher who works for them in an advisory capacity with regard to the production of materials.

3.3.2 Trusted supplier

As well as peer recommendation, a factor that helps teachers decide whether or not to give materials a second glance is their view of the supplier. The view is informed both by peer

recommendation and personal experience. For a number of teachers, especially those teaching A-level, PPARC was a recognised and trusted name that would help unsolicited materials to get through a teacher's initial sift.

> *"I don't think their stuff* [PPARC's] *goes straight in the bin"*
> Teacher (A-level)

However, by no means were all of the teachers aware of PPARC and its work for schools and teachers. Clearly for these teachers, the PPARC name alone will not be enough to provoke interest in the materials.

3.3.3 Fitness for purpose/relevance

Peer recommendation and the profile of a trusted supplier will get materials onto a teacher's shortlist, but the critical factor as to whether they will be used is whether they are fit for purpose. There are a range of potential purposes ranging from direct teaching aids, through inspirational material to decorative background. It is vital that the purpose and the target age range/key stage are apparent to teachers if they are to use materials.

We reviewed the "Support for Schools and Colleges" section of the PPARC website and only a few of the descriptions of materials relating to particle physics mention supporting the curriculum. None have explicit references detailing how the materials will support teachers.

If material is to be used as a teaching aid, it has to be very clear what elements of the relevant curriculum it is addressing.

> *"You would have to fit it with what we are trying to teach them."*
> Teacher (A-level)

> "*You can't write off a week's lessons so you can look at CERN because it's inspiring. It's got to be something that is related to the syllabus.*"
> Teacher (A-level)

Some teaching aids can be for teachers to aid the teacher's own understanding so that they can teach more effectively. For non-physics specialists formats such as books and teaching guides are useful, for those with a stronger basic grasp of physics the important thing is material that can add to their core knowledge (of both the subject and the curriculum).

> *"Snippets of info can be rolled into teaching."*
> Teacher (not currently teaching A-level)

On the other hand, some material can be used directly by students in an investigative mode. If material is to be used directly by students then it needs to be in a format that can be easily handled, stored and available in sufficient numbers for full classes to have access. One teacher explained how the small version of PPARC posters had been laminated to provide a hard-wearing resource that was small enough to be stored in whole class quantities.

> "*worksheets are helpful if they are photocopiable otherwise it's a waste of time.*"
> Teacher (not A-level)

3.3.4 Ease of use

We encountered two different perspectives. One perspective was that the less a teacher needed to adapt a particular resource, the more likely it was to be useful. The opposite perspective was expressed occasionally that some teachers were happy to take materials that they thought were useful and shape them to their own needs.

> "*Any resource that someone gives me, I will use, it just makes my life easier …it must be relevant and tie in with syllabus.*"
> Teacher (not A-level)

> "[I] t*ry to build worksheet and use as a resource…found it difficult to get pupils to engage with the materials on their* [own]."
> Teacher (A-level)

This project is not intended to be quantitative, so from the interivews, we cannot draw conclusions about the relative prevalence of these two views. However, in our other work with teachers and the suppliers of external resources, we would suggest that for a large number of teachers it is important that they can quickly and easily see how a resource will provide direct help. After they have used it and have become comfortable with the material they are more willing to stretch and adapt the resource.

With regard to ease of use it is again important to recognise that different specifications exist for different A-level boards and that for some teachers it will be important that materials are relevant to a particular specification.

> "*Some of the things that are produced are generic, so they are covering several syllabuses at once which means that much of it is not useful for my students.*"
> Teacher (A-level)

3.3.5 Access

Teachers access support material in two ways, either they proactively look for it, or they are more passive recipients. Increasingly, proactive searching means using the Internet. A few teachers were aware of PPARC's web site, but many were not.

> "*If PPARC had a website of their own through which you could access KS3, KS4, A level friendly resources; that is the best way to go.*"
> Teacher (not A-level)

Teachers rely on familiarity to guide their searching.

> "*It's getting their* [PPARC] *name known, I always go to NASA because I know the name.*"
> Teacher (not currently teaching A-level)

While others highlighted that only a finite amount of effort can go into searching.

> "*PPARC needs to be pulled out first when you 'Google' the topic, there is a limit to how many websites you can look at.*"
> Teacher (not currently teaching A-level)

Another source of materials that teachers use in a proactive fashion is the annual Association for Science Education (ASE) meeting. Some of the teachers who had previously come across PPARC's materials had found them at the ASE.

> "*Pick them all up at ASE conference.*"
> Teacher (A-level)

> "*They're on my wall…got them at a science conference* [ASE]."
> Teacher (not currently teaching A-level)

An important source is still material that arrives at schools via mailshots. Teachers recognised the difficulty of targeting mail effectively but emphasised that mail has a much greater chance of attracting attention if it is addressed to an individual and not to the post. So "Dr Smith, Head of Science" is better than just "The Head of Science".

Teachers also recognised the internal barriers within school, such as bottlenecks when all science information is forwarded to the head of science.

> *Head of science is a biologist so she may 'bin' stuff she's not interested in.*
> Teacher (A-level)

For some, if material came via the Head of Science, this meant that the peer recommendation and trusted supplier factors had already been addressed.

> "*Come through from head of department.*"
> Teacher (not A-level)

> "*Most of my stuff I got from my head of department.*"
> Teacher (A-level)

However, for most the head of department only had time to divide material into the relevant topics for the subject heads to sift through.

There were also occasional references to different sources of support. Some teachers suggested that PPARC should seek to work with exam boards.

> "*Good for them to get involved with the exam board to spice up the modules.*"
> Teacher (not A-level)

This approach would ensure association with trusted suppliers and mean that PPARC's materials could be presented as immediately relevant.

A couple of teachers picked up on PPARC's funding of university-based research in the UK and suggested that they use relationships with Higher Education Institutes to build

links to schools and teachers. In particular, reference was made to schemes to broaden access to university education.

> "*A lot of stuff comes through Aim Higher, are they doing it with them?*"
> Teacher (A-level)

3.3.6 Cost

Even though many of the examples of good products that teachers brought with them had been bought, a few mentioned that the word "*free*" is a good way of attracting interest. The product then has to meet the criteria set out above for relevance and usability, but free will attract attention and get some material past the first cull.

3.4 Format of support/materials

We explored teachers' preferred formats for support materials. Those listed below were the ones that emerged most frequently and are probably therefore most suited for large-scale production. However, there were other formats referred to such as small kits, hands-on materials, worksheets and text books that are very important to some teachers. Some teachers mentioned 'Focus' magazine as being particularly useful and more user friendly than 'New Scientist'.

Our findings are supported by Creative Research (2000b) who reported that teachers are open to, and want to use, various materials for classroom activities and to extend brighter students. PPARC material, however, was being used for only a small percentage of these activities; Creative Research reported that three quarters of teachers who had requested teacher's packs (from PPARC) were not using them. It was thought that a range of formats for resources should be offered.

3.4.1 Revision aids

One of the most popular teaching materials were revision aids. A number of teachers mentioned "Blockbusters" others suggested word searches and crosswords.

> *"The competitions make the kids think about answers which are given in earlier years, which is what revision is all about."*
> Teacher (not A-level)

> "*Sometimes the simplest activities are the most effective, for example crosswords… that every single child can enjoy doing.*"
> Teacher (A-level)

If PPARC were to work with teachers and/or examination boards, it should be relatively easy to ensure that materials like these could both draw on PPARC/LHC science and cover critical curriculum requirements.

3.4.2 Multimedia

In the section on access we explained the importance of the Internet to teachers when they are proactively looking for materials. Teachers do not simply order materials, whether in paper copy or in multi-media formats, they also directly download material, as many find moving images and interactive options attractive resources. It is important that materials

can be manipulated, one teacher said that he would not look twice at something in a PDF format as this reduced its flexibility too much.

> "*Another advantage of the internet is that it allows you to use graphics and animations…*[students] *appreciate moving images and often learn a lot more than they would from a teacher talking or by simply reading lots of text.*"
> Teacher (not A-level)

A number of teachers referred to the increasing importance of the interactive whiteboard.

> "[the smart board] *can't live without it.*"
> Teacher (A-level)

Others highlighted the useful nature of video material for breaking up topics and lessons and providing additional stimulus.

> "*I welcome good videos…students seem to love* [them] *they also learn and make notes from the videos.*"
> Teacher (not A-level)

> "*We use DVDs a lot, they are very useful.*"
> Teacher (not A-level)

Some teachers brought laptops with them to the interview in response to the request that they bring materials that they already use in class. The high regard for interactive multi-media material suggests that simulations of the LHC, and video material of the work at CERN, and its scientists, could be useful. We will return to the importance of highlighting the contributions of real people in the section on inspiring students.

3.4.3 Posters

In the conversations with teachers we introduced some of PPARC's existing materials and sought teachers' comments. The particle physics posters sparked a good deal of comment. Initial responses were positive as the posters were seen as bright, colourful and eye-catching. Some teachers use them in corridors where students wait outside classrooms as well as in the classroom itself.

> "*Something like that* [Big Bang poster] *on the wall would be immensely helpful.*"
> Teacher (A-level)

> "*I tend to have a lot of posters on the wall…and refer to them occasionally…if I was to use* [a PPARC poster] *I would…give it to a group of students to… summarise.*"
> Teacher (not A-level)

> "*We don't have enough of this sort of stuff* [posters etc.] *within school.*"
> Teacher (A-level)

Other teachers used the posters as worksheets or to help teach classes by way of comprehensions, quizzes and tests; some also use them as research tools for their pupils.

One of the strengths of the posters we showed was the diversity of the scientists featured, with both women and ethnic minority groups featured prominently.

However, teachers often became more critical as they looked at the posters in more detail. Some teachers accepted that posters tend to act as wallpaper rather then being used by students.

> *"They see them* [posters] *but they don't go up to them and read them…you have to make a point of pointing it out to them."*
> Teacher (not A-level)

> "*It's* [PPARC poster] *not something you can use from afar.*"
> Teacher (A-level)

There were also criticisms of the designs and their lack of clarity.

> "*Kids probably don't read them…there's a lot going on in them*"
> Teacher (A-level)

> "*Some of them* [PPARC posters] *are a little bit cluttered.*"
> Teacher (not currently teaching A-level)

> *"Some are quite busy…lots of the information can be ignored."*
> Teacher (not currently teaching A-level)

> *"The large amount of information on the sheets means that a lot of kids will lose interest. The poster will attract kids if they are interested in physics to start with but kids who are not interested in physics are unlikely to be made more interest by the posters as there are simply too many facts on them."*
> Teacher (A-level)

> *"The colour and the layout is very much key stage three and yet the content is another level altogether so on the one hand you've got something attractive to a certain audience and then* [the content's] *aimed really at the top level GCSE type kids the kids* [who] *are going to go onto work in physics particularly…"*
> Teacher (A-level)

Finally some teachers were disappointed that the associated activities are on the back of the poster.

> "*It's on one side…Oh that's lovely…could go on wall…then I'll miss all information on one side.*"
> Teacher (A-level)

Posters clearly have a role to play both in the classroom and outside, but careful consideration needs to be given to the design and content, bearing in mind the earlier sections of this report covering relevance and ease of use.

3.4.4 Attoworld

We were asked to explore teachers' reactions to a proposal for a multi-media show involving scientists and actors, with the working title "Attoworld". The proposal attracted mixed responses.

Some teachers were very enthusiastic.

> "[Can I] *book it now, what date?*"
> Teacher (A-level)

> "*I'm a great fan of anything that's a bit different…it makes it more fun to teach.*"
> Teacher (A-level)

> "*If you can get the whole year group involved that's great.*"
> Teacher (not currently teaching A-level)

Some were less enthusiastic about the idea of actors and had clearly had bad experiences. These teachers were more interested in high quality demonstration lectures and providing their students with contact with working scientists.

> "*If you could get people coming in and talking to the kids that would be great.*"
> Teacher (not A-level)

> "*We've had to* [invite working scientists to talk to children] *just to increase recruitment…they sell the subject really well, there's nothing like people that are at the forefront.*"
> Teacher (not A-level)

> "*Sometimes it's more interesting to see what the real people* [real scientists] *are doing."*
> Teacher (not A-level)

Teachers also wanted to know whether they would have to pay for the show; some teachers indicated that their schools were more willing and able to pay than others.

Logistically, regardless of format most of the teachers would prefer a show/lecture that goes out to them.

> "*Come to the school as it reduces hassle.*"
> Teacher (not A-level)

> "*Having to travel causes aggravation as well as extra travel costs and you need more staff.*"
> Teacher (A-level)

Finally, again regardless of format, a show/lecture has to be of very high quality and provide a memorable experience that the school/teacher could not offer in the context of normal teaching. Some teachers highlighted that their students were sophisticated users of

different media and could tell things that were low quality or as one teacher put it "*fake*". One teacher suggested that piloting the event might help overcome such problems.

> "*Unfortunately kids need things these days which are all singing all dancing, flashing lights, loud music.*"
> Teacher (A-level)

> "*...need right lecturer and special effects.*"
> Teacher (A-level)

> *"There is a danger of pitching it incorrectly."*
> Teacher (A-level)

In one interview a pair of teachers explained that students' expectations of production values were set by television. This led to the suggestion of approaching the makers of the "Brainiac" programme to see whether it would be possible to do a CERN special.

3.5 Student's attitudes to Physics

Part of the discussions involved exploring what teachers thought of their students' attitudes towards physics so that we could compare these with what students themselves said. Many of the teachers highlighted that there were certain stereotypes associated with physics; that it is hard, it is not practical and that it is not relevant. This resonates with the review of existing research. Bennett (2003) summarised the key research findings on pupil's attitudes to science:

- School science is a hard subject.
- Science and school science is not relevant to everyday life and not relevant to most people.
- Pupils see science as causing environmental and social problems.
- School science is more attractive to males than females.
- Interest in science declines while in secondary school.
- Pupils are more negative about the physical sciences than the biological sciences.
- Pupils are more negative towards school science than to science more generally (or more precisely, the technological spin-offs).'

Teachers' comments re-affirmed much of this.

> "*I think the problem is that it is considered hard…there is an instinctive barrier there already.*"
> Teacher (A-level)

> "*You have to be a certain calibre of student to study physics.*"
> Teacher (not A-level)

> "*They need to imagine concepts* [with physics]*...I think they find that really hard.*"
> Teacher (not A-level)

> "*It's the swot, it's the anorak, it's the one that likes thinking about things rather than necessarily doing things.*"

Teacher (A-level)

"*A lot of students…feel that everything is abstract…there's no real people behind the work that's being done.*"
Teacher (not A-level)

3.5.1 Gender

Teachers highlighted that physics is seen as a male subject. Many teachers provided evidence that this is the case by referring to student numbers or achievement.

"*Boys particularly head towards physics. It's still uncommon to have anything like 20% girls taking physics in my school, despite all our efforts.*"
Teacher (A-level)

"*The top 10% is predominantly boys.*"
Teacher (not A-level)

The language used by the teachers, both male and female, often reinforced stereotypes.

"*Particle accelerators smashing atoms, they're words that boys associate with more than girls, the lads like to talk about things being smashed apart and breaking atoms.*"
Teacher (not A-level)

"*It takes a very determined type of female to go into this field.*"
Teacher (not A-level)

"*You get very few proper nerdy females. Even the ones who are properly keen on physics, they generally have lots of other interests. Whereas when you have a proper nerdy boy they actually don't do anything other than physics.*"
Teacher (A-level)

Some teachers did report that they had found it possible to break down these stereotypes, they referred to role models and steady progression.

"I [female teacher] *used to teach in a mixed school in a mining area in Yorkshire…by the time I left after nine years we had as many girls doing physics and engineering A levels as boys…can be done…if you provide a role model."*
Teacher (not A-level)

"*Starting* [at the school] *seven years ago teaching physics there and I had one girl in a set of 14 and it's…risen year by year by one only though…now out of 24 there are seven or eight* [girls]."
Teacher (A-level)

One issue that some teachers raised with regard to gender was the lack of information about careers options. They highlighted that many able girls wanted to go into professions where they work with people and that their families saw as respectable, for example medicine and law.

> "*It's not that the girls are being pressurised to go into those careers, it's that they don't know that any others exist.*"
> Teacher (A-level)

The gender differences reported by teachers are backed up by other work.

A review of the literature found that although girls out perform boys at GCSE in science their attitudes to school science, particularly physical science, are significantly more negative than that of boys (Osborne *et al* 1997). Girls also tend to choose A levels that they enjoy whereas boys are more likely to relate their choice to potential career choices. In 2004/2005 male to female ratios for the science subjects at A level in England were:

- Physics: 3.7 boys to 1 girl.
- Chemistry: approximately equal.
- Biology: 1 boy to 1.4 girls (DfES 2004/05).

3.5.2 Ethnicity

As well as exploring possible gender issues we explicitly asked teachers whether they had encountered different attitudes to physics amongst different ethnic groups. A number of teachers were unable to express views on ethnicity; this could be because they had limited experience on which to make a general view or possibly because they were uncomfortable discussing a potentially contentious topic. Two different issues were raised which hinge on socio-demographics as well as ethnicity. The first was that amongst some ethnic minority communities (Asian, including Oriental) science has a high reputation, albeit often as a passport to something else.

> "*A lot of them* [Asian boys] *say that being a good scientist will make you a good doctor. They are doing physics because they are going to be doctors.*"
> Teacher (A-level)

> *"A lot of Asian boys and girls want to work in the city and are told that economics and physics go together well."*
> Teacher (A-level)

> *"Koreans tend to prefer science."*
> Teacher (not A-level)

The other experience was with more recent immigrants, where more fundamental barriers to education such as language, were exacerbated in the context of the sciences.

> "*...high immigrant population…minority groups are non-English speakers, so complex scientific language is difficult for them to access.*"
> Teacher (not A-level)

As some of our conversations with students show in chapter 4, individual perceptions of what students believe they can achieve are important. In this context, teachers suggested that role models are important. A number highlighted the importance of including real

scientists from (all) ethnic minorities on materials such as posters, to highlight to students that people like them could take advantage of opportunities.

> "*…need to reduce stereotypes*"
> Teacher (not A-level)

> "[we are an] *ethnically diverse school…traditionally it has been a bit of a struggle*"
> Teacher (not A-level)

> "*If you have male/female/black/white* [that] *will be good.*"
> Teacher (not A-level)

One teacher from a minority ethnic group sounded an important word of warning when putting together role model material, which is the importance of reflecting diversity of cultural background not just visible racial characteristics. For example black British students from Caribbean and African backgrounds will require role models from their own cultures, not simply 'Black' ones.

> *"There are a couple of kids I teach who would definitely pick up on it."*
> Teacher (not A-level)

3.6 Inspiring students

The need for material to be relevant to the curriculum provides limited scope for PPARC to highlight the work of the LHC in support of core science teaching. However, many teachers felt that the LHC and especially the scientists working on the experiments could play an important role in inspiring and enthusing students. Four different areas were raised:

- careers in science and engineering;
- role models;
- science (physics) as a dynamic evolving subject; and
- summer schools.

3.6.1 Careers in science and engineering

Many teachers highlighted the need for careers information that explained how physics (and science more widely) could lead to a variety of career options. Some talked of the value of being able to drop examples of real career situations into lessons. Others spoke about students' need for information about career options and the impact that their choice of studies has on these options. Some teachers were not sure themselves of the options available and would welcome materials that can help them to support students in this way.

> "*One of the things I get all the time off kids is 'why am I doing science, I don't want to do science 'cause I don't want to be a scientist', they don't realise that if you go on and get qualifications you don't have to be a scientist, you can be an engineer.*"
> Teacher (not A-level)

"*Unless they want to be a scientist then they don't see physics and maths as particularly useful to them.*"
Teacher (A-level)

"*Even as a teacher I don't have a great understanding of where physics can take students…any information in respect to that would be welcome.*"
Teacher (A-level)

The review of existing research highlights that pupils tend to value science education for career aspirations rather than as a subject of intrinsic value. Perhaps because of the limited appreciation of career opportunities that we have found, there is little recognition of the value of a generic science qualification as there is for the value of mathematics or English qualification (KCL, 2000)

3.6.2 Role models

In earlier sections we have already highlighted the importance of role models in helping to break down stereotypes and alluded to the power of working scientists coming into schools. Creative Research (2000b) reported that many teachers expressed an interest in having school visits from PPARC scientists. It was thought that such visits would provide inspiration for students through meeting real scientists who carry out real research. Comments from teachers in our recent interviews re-iterate the belief that such visits are vital in highlighting that studying physics leads to real career opportunities for these individuals.

"*Show that it is an ordinary but exciting job.*"
Teacher (not A-level)

"*Anything where you see young people who are scientists (not weirdos with funny haircuts)*"
Teacher (not A-level)

"*Every time that somebody's come in from outside and talked to them they just go away with this feeling of... 'I am really turned on by that'.*"
Teacher (A-level)

Creative Research (2000b) reported that lack of scientists available to visit schools might be a factor, a concern still shared by teachers.

"*Paucity of real scientists to share what they're doing with school kids.*"
Teacher (not A-level)

However, Researchers in Residence continues to be supported by the Research Councils and since 2002, the Science and Engineering Ambassadors scheme has been established.

As well as showcasing the normality of physics, many teachers believe that working scientists can bring the curriculum to life and generate additional interest.

"*We have brought scientists into school recently; they seem to have been appreciated. It gives a great insight into what the experiment in the textbook is really about.*"
Teacher (not currently teaching A-level)

"*Anything which brings out science with reference to the outside world is great.*"
Teacher (not currently teaching A-level)

"*Whatever aspect of science it's really important for students to know where the theory they're learning is in operation…that it's current.*"
Teacher (not currently teaching A-level)

"So busy trying to teach syllabus that you can't do all the fun things…this is what inspires children"
Teacher (not A-level)

Students' views of science-based careers may well be based more on their experience of school laboratories than any appreciation of what jobs really entail. Braund & Reiss's (2004) review of research assessing the impact on students of visiting industrial sites has shown that students are left with a more accurate awareness of that industry. Secondary school pupils, for example, appeared to be more motivated, have more confidence, understand more clearly the relevance of school science and had an insight into career opportunities. In this context an earlier report concluding that there is a need for role models that are not only academic but also from other science-related careers (Osborne *et al* 1997) remains relevant.

Some teachers recognised that physics teachers themselves may not have helped with overcoming stereotypes as the conversation below shows.

"*Historically it was taught by some very strange people.*"
Teacher (A-level)

"*All my physics teachers at my school were odd.*"
Teacher (A-level)

"*Perhaps we are odd as well?*"
Teacher (A-level)

3.6.3 Science (physics) as a dynamic evolving subject

In particular teachers wanted students to realise that physics is not a completed set of rules:

"*If you give them* [students] *a piece of investigative work they get really involved in it…this* [LHC] *will show them that there are still things left to be discovered.*"
Teacher (not currently teaching A-level)

"*To be a good physicist you have to have an inquiring mind and know that there are still questions out there.*"
Teacher (A-level)

> "*If you are getting kids asking you questions then that is half the battle isn't it?*"
> Teacher (A-level)

And that if there are questions remaining people are needed to answer them. Teachers were keen to show to students that they could be those people. However, as the section about careers shows, teachers need support to be able to do this and recognise that school science does not necessarily help.

> *"The cutting edge of research is what we should be teaching, especially at A level because you want to inspire people to go on and do science…the cutting edge is where you want to be."*
> Teacher (A-level)

3.6.4 Summer schools

One teacher mentioned the growth of summer schools and highlighted this as an opportunity for PPARC. As summer schools do not operate under curriculum constraints there is the capacity to branch out and work on topics simply for the sake of interest and it was suggested that particle physics might provide such a topic.

> "*A summer school pack would be great…so difficult to get it organised…lesson plans* [would be] *so much more helpful.*"
> Teacher (not A-level)

It was clear that despite teachers' concerns over stereotypes in physics, perceptions of difficulty and curriculum constraints, many see cutting edge physics and the scientists doing this work as a way of broadening students' horizons.

3.7 Inspiring teachers

Much of the focus of the conversations with teachers was on students. However, we did also explore possible support for teachers. Some raised the importance of continuing professional development (CPD). With the shortage of specialist physics teachers, it is no surprise that teachers currently teaching physics who do not have a background in physics want support.

Smithers & Robinson (2005) conducted a survey of the state of physics education in England and Wales for 14-18 year olds. This survey showed that less than four in ten teachers who teach physics to 14-18 year olds had physics as their main subject of qualification. While non-specialists can provide a high standard of teaching, they are unlikely to have the subject knowledge or confidence to enable them to bring exciting contemporary physics into the classroom (PPARC 2006).

It is also important to bear in mind that even those with specialist knowledge will still require support.

> "*Because the syllabus is so broad we haven't got the expertise to be experts in particle physics*"
> Teacher (A-level)

Views were mixed on how easy or difficult it is for teachers to take part in CPD activities. From this qualitative exercise it seems that this is driven largely by school culture. Some teachers spoke of the ease of being released for "*courses*", for others it was more problematic. As well as the cost of courses, time away from the class meant the need for cover, which would entail additional cost and often not be specialist. The lack of good quality cover led at least a couple of teachers to refer to their feelings of guilt if they interrupted the continuity of their students' study to improve their own knowledge or skills.

Teachers tended to think that suppliers of CPD, and other support, had little understanding of working practices in schools.

> "*People outside don't know when the bottlenecks come.*"
> Teacher (A-level)

In the interviews it was clear that there were not defined periods when all schools/teachers would be covering the same topics or face the same pressures. However, one window of opportunity that was widely recognised was the summer term, when teaching loads are lower and preparation is being undertaken for the following year.

> "*When that planning comes in for next year…have little bit more time.*"
> Teacher (A-level)

3.8 Conclusions

3.8.1 Science curricula

Particle physics does not really come into its own as a topic until A-level physics, so curriculum support material is probably best targeted at AS and A2 level. That said there are aspects of GCSE science, where targeted materials could be useful, these include using the LHC to help explain 'how science works' as well as using it as a specific example in physics.

3.8.2 Teaching materials

Teachers report that there is an over-abundance of teaching materials, but there are key things that will get new materials noticed, of which one of the most important is peer referral. Relevance and usability are also critical. Clarity and simplicity are important and although the eye-catching nature of some of PPARC's existing material is appreciated, teachers highlighted some design flaws in existing materials.

This project has provided an overview of teachers' requirements, but if PPARC intends to develop materials based on the LHC, the development process should include detailed formative research on style, content and format, using real test materials. As well as ensuring that materials are as well targeted as possible, the testing process could also be used as a marketing tool, by enlisting teachers in the research process who then go on to champion the materials.

3.8.3 Format of support/materials

As students become ever more sophisticated media users, teachers and the providers of curriculum support need to keep up. Multi-media materials are much appreciated, but so

are simpler tools, especially ones that can be distributed to whole classes. Revision aids and quizzes appear to be formats that are well received.

The "Attoworld" suggestion received a mixed response and it may be that a better option is an investment in demonstration lectures. Teachers want working scientists to talk about their own work because they know it well and can present it more creatively and also show that what is learnt in school can be built upon and used for future careers.

3.8.4 Student attitudes

Stereotypes are persistent. Students perceive physics as difficult, irrelevant and male. Some teachers confess that in isolation they cannot address these stereotypes and find role models, in print, but especially in person, helpful in this regard.

3.8.5 Inspiring students

Despite the limited extent of particle physics in science curricula, many teachers thought that there was a potential role for the LHC project to inspire students. The LHC demonstrates that science is not a book of facts to be learnt, but a dynamic process employing real people, who are attempting to push forward human knowledge. This was regarded as extremely useful for inspiring students. Again role models, especially in person were often mentioned by teachers as providing an important extra perspective for their students.

3.8.6 Inspiring teachers

We found some demand for support specifically for teachers themselves (CPD), as opposed to helping them to support students. Some were interested in updating their knowledge and some had found that CPD and training courses could re-invigorate their teaching. The new network of Science Learning Centres provides an opportunity to pilot support for teachers in one (or more) locations. The impression we received was that teachers will be most interested in provision that has a fairly direct benefit to the students rather than to themselves and that the best time of year for this provision to be available is the summer term.

4 Students

4.1 Introduction

The importance of the need for young people to have a basic understanding of science is almost universally recognised amongst most policy makers. Additionally, the lack of students choosing to study science in post compulsory education in the UK has a clear potential impact on the ability of Research Councils to carry out world-leading scientific research (RCUK 2006). In particular, while the number of students taking biology post-16 has increased significantly over the last 20 years, the number taking chemistry has remained the same, and the numbers for physics have decreased significantly (DfES 2006). In isolation the LHC is not going to change this situation, but it does offer a topical way of stimulating interest in physics.

Our proposal for this element of the work was based around a belief that a relatively complete picture of young people's likely attitudes to particle physics and the LHC could be assembled from existing work. We augmented the review of relevant literature with four focus groups constituted as follows.

Region	Male	Female
South East	17-19 (6th form)	-
South West	-	14-16 (years 10 and 11/KS4)
Midlands	-	17-19 (6th form)
North West	14-16 (years 10 and 11/KS4)	-

4.2 Perspectives on school science

4.2.1 Utility of science

Previous research has shown that school students tend to value science education for career aspirations rather than as a subject of intrinsic value (Osborne *et al* 2003). It has also been reported that there is little recognition of the value of a generic science qualification unlike mathematics and English (KCL 2000). However, we saw some evidence that the sciences were in fact regarded as part of the fundamental package.

> "*You can't get anywhere without science or maths really can you?*"
> Girl KS4

> "*I chose the subjects because they had a mix of the basics.*"
> Girl A-level studying physics

There was nevertheless a widespread utilitarian attitude towards the study of specific topics amongst the young people in the focus groups. Although many were unsure of their career destinations, they were largely thinking about school subjects in terms of their potential usefulness.

> "[You choose] *what's going to be useful and if you like it.*"
> Boy KS4

4.2.2 Relevance of science

Previous research has shown that students view school science differently from general 'science in society'. This is because they tend to view science in school as more theoretical and link science outside school with technological spin-offs such as television and mobile phones (Bennett 2003). In the focus groups we did see evidence of a perceived lack of relevance of school science.

> "*Most of the stuff we have been taught in science, no-one would need it.*"
> Girl A-level

Yet there was a sense that school science could be more interesting if its relevance was drawn out.

> "*…doing physics, it's nice to see how it links to the real world.*"
> Boy A-level studying physics

> "*If it's happening now then it is more interesting than something that was happening ten years ago.*"
> Girl A-level

In addition some students recognised that their views were formed quite early and stimulating their interest in subjects required something out of the ordinary to happen early in their school life. Introducing contemporary science before the sixth form might have this effect for some.

> "*Maybe year 10 or 11 where you start the physics syllabus it should be introduced…you immediately spark an interest in the physical side and people think 'Wow that sounds really interesting, maybe that's something* [I'll do] *when I'm older'.*"
> Boy A-level studying physics

The teachers' belief that bringing working scientists and engineers into schools would help their students to construct a picture of the wider relevance of scientific study and thereby enthuse them, does therefore accord with the views of some students. In a couple of the student groups, they spoke of memorable experiences related to people coming into the school. Monk & Osborne (2000) have found that science subject choice by A level students can be positively influenced by extra curricular activities.

4.2.3 Physics

Physics as a subject did not generally provoke a very positive response from the students.

Amongst the group of KS4 boys the consensus was that physics was not a popular subject, even though a couple had plans to go on and study the subject at AS/A-level. The prevalence of written work and the lack of interesting practicals were raised as reasons for the subject's lack of popularity.

> "*Practicals and experiments* [are the good things about science]."
> Boy KS4

The KS4 girls also highlighted the role of practicals. They felt that physics contained less practical work and that the scope was limited. One student referred to a single set of apparatus that seemed to be used for most experiments.

> "*You don't get to do as many practicals in physics as you do in chemistry.*"
> Girl KS4

> "*Physics experiments are boring.*"
> Girl KS4

The positive impact of practical work was also cited in both of the A-level groups.

> "*I quite enjoy experimenting with things…when I do get it right I get a lot more enjoyment…than reading in a paper about someone else getting it right.*"
> Boy A-level

Teachers also recognised that practical work is being curtailed, one suggested that this is due to the requirements to structure lessons to specific formats that achieve specific learning outcomes. These don't allow an entire lesson to be spent on one practical.

> "*The idea about the lesson being around the big practical is gone because pupils are not learning enough in the practical lessons.*"
> Teacher A-level

Other research has also shown that pupils express definite views on teaching methods, with a dislike for writing and an enthusiasm for practical work, especially where they have some real input into the design and interpretation (Association for Science Education 2006).

The apparent lack of relevance of physics was raised by some of the A-level boys.

> "*Not the greatest fan of physics…I like the factual side like how the body works.*"
> Boy A-level

> "*I prefer learning about the more logical things, the things that are definite, the things that we know happened…sometimes the other things can be interesting but for me it's not as easy to learn about.*"
> Boy A-level

However, amongst the A-level boys, as the discussion progressed, different views started to emerge, with some students saying that they had not realised the breadth of the subject.

> "*Physics is everywhere."*
> Boy A-level, studying physics

> *"I suppose physics is the way of doing pretty much everything."*
> Boy A-level

> "*It's just so interesting, it's like they say if you drop a house and a hammock from the same height with no other forces acting on them…they'll fall at the same rate and yet you can't see it happening can you?...but it does actually work out right.*"
> Boy A-level, studying physics

Maths and physics were seen by a number of students as closely linked, "*equations*" were mentioned by a number. In the group of A-level girls there was an interesting discussion between two girls one of whom had chosen to study physics because her maths was weak and hoped that it would help, the other was strong at maths and therefore believed that physics would be a relatively easy option for her. This relationship was also recognised by the younger girls, but not necessarily in a positive sense.

> "*Physics is maths by another name.*"
> Girl KS4

Although another girl in this group said that this relationship made physics easy "*if you understand what you are doing*".

The overall impression from the students was that physics was less popular than the biological sciences, which accords with the uptake of the subjects post 16 described above and previous work by Cambell Keegan Ltd (2000) and Bennett (2003).

4.2.4 Teaching

Research has shown that teachers' expertise in physics as measured by qualification is the second most powerful predictor of pupil achievement in GCSE and A level physics after pupil ability (Smithers & Robinson 2005). It is beyond the scope of this project to consider how those with higher physics qualifications can be attracted into teaching. However, other research (Osborne *et al* 1997) highlighted that alongside the perceived difficulty of science, the quality of teaching was a major factor influencing students' subject choice for A-level. Monk & Osborne (2000) also found that the nature of in-class activities was a factor which affected science subject choice by A-level.

So, research suggests that the main factor determining attitudes towards school science is the quality of the educational experience provided by the teacher (Osborne *et al* 2003). Therefore, as far as students are concerned anything that helps teachers to deliver more exciting, and relevant, lessons is likely to have a positive effect. Given the undercurrent of "*guilt*" amongst some teachers about taking time away from the classroom for CPD, the desire of students for more engaging teaching might be a useful argument in promoting CPD as well as the use of external stimuli. Some highlighted the weakness of teachers.

> "*…tell you to copy from a book, they don't explain it, they just say 'copy the page'.*"
> Boy KS4

On the other hand, where excitement and enthusiasm accompanied teaching, then students confirmed that they expect learning to be more effective.

"*If you do something you're interested in then you're more likely to get better grades.*"
Girl KS4

"*If you can see it and like understand and be told with a bit of passion it's better and it sticks in your mind.*"
Boy A-level

4.3 Science outside of school

In the focus groups, science was largely, but not completely, seen as a school-based activity. It is not generally something done in leisure time or "*with your mates*".

"*In my free time I don't want to go back to learning.*"
Girl A-level

"*The only time I would read outside of the subject would be if I needed it to get into university.*"
Girl A-level

"*Sometimes you think outside of what they are teaching you if it relates to your world outside of the classroom. Otherwise it's just when you are at school really.*"
Boy KS4

Most of the focus groups were run in cities with a science centre. Many of the students had visited science centres either with school or their parents. The experiences were seen as positive, the science centres had facilities that were not available at school and the ability to explore for themselves was attractive to some students.

"*Alright, you can look around and touch stuff without a guide.*"
Boy KS4

One concern that was raised by the A-level boys was that there was limited material for people of "*our age*", with provision targeted more at younger children. Few of the students saw science centres as places that they would visit of their own volition or with friends, they placed the centres in an educative framework associated with schools or worthy places, to which parents take you. Two boys, however, mentioned with enthusiasm events which they had attended. One had been to a physics convention in New York and another talked about an earthquake simulation that they had been to at the Natural History Museum.

It does not appear likely that using communications mechanisms based wholly outside of the school environment will raise the profile of the LHC with young people. Science centres may have a role to play, but the marketing will need to be aimed primarily at schools.

4.4 Careers

As might be expected, the A-level students had clearer pictures of their likely career paths than the younger students. Few saw themselves going into science-related careers. Many

of those who did, believed that they would be heading towards the biological sciences, with a couple mentioning engineering.

4.4.1 Perceptions of careers in science

In an evaluation of Einstein Year (Malek & Stylianidou 2006) 11 to14 year old students were asked about their attitudes towards science and scientists. The survey revealed generally positive attitudes towards scientists. However, the students surveyed during that evaluation seemed to be deterred from being scientists by their strongly held opinions that scientists worked long hours, with repetitive work and strict guidelines. A similar pattern emerged in the focus groups, where the students saw this lifestyle as the norm for scientists, acceptable for some people, but probably not for them.

> "*Interesting, but I'll read about it in the paper when they find out what it is… waiting for years and years and doing repeated tests isn't my idea of a job.*"
> Boy A-level

> "*It's one of those projects that you'd have to dedicate your entire time…you have to have a proper concentration…interest…there's other things that my personal goals are set towards…if someone else is gonna do that, fair enough…I wouldn't want to put all my time and life into it.*"
> Boy A-level

> "*I think it's interesting but I wouldn't want to do it as a job.*"
> Girl A-level

> "*Having one question and spending thirty years of your life and not finding the answer would drive me mad.*"
> Girl A-level

> "*I'm sure there are people around the world who do* [want to put their time and life into CERN]."
> Boy A-level studying physics

Other work has shown that these perceptions of a career that is 'not for me' extend into other areas allied to physics. Although engineering is recognised by young people as important and necessary for day-to-day life, only a limited proportion (mainly boys) feel it is a future career for them (MORI 1998).

4.4.2 Influences

Other than school, Munro & Elson (2000) found that the following factors seem to have a significant influence on children's interest in science and science careers:

- parents and family;
- image of science subjects;
- image of jobs in science and engineering;
- gender; and
- the media.

One conversation amongst the A-level boys showed recognition of stereotypes and an appreciation that the stereotypes presented to them may not represent the whole picture.

> "*Stereotypical research scientist…spends his whole time eating fast food and standing in a lab.*"
> Boy A-level

> "M*aybe that's what TV's put in our head.*"
> Boy A-level studying physics

> "*…someone needs to change that opinion.*"
> Boy A-level

4.4.3 Impact and reward

Hardly any of the young people in the focus groups highlighted material rewards as reasons for following particular career options. Enjoyment and aptitude were the strongest factors, as for the choice of subjects studied.

However there were also references to helping people and making a personal mark.

> "*Figuring out cures for cancer and, like medical things, is more rewarding.*"
> Girl KS4

> "*I want a job that has a personal impact* [and in which she can see the immediate results]."
> Girl A-level

As the conversations about funding in the following section make clear, most of the young people believed that the biological sciences (particularly the medical sciences) rather than the physical ones were the places where critical advances would be made. However, the LHC and associated experiments led some students to believe that there was a role for their contemporaries to make lasting contributions.

> "*It's gonna be our generation that builds on that.*"
> Boy A-level studying physics

4.4.4 Knowledge of career paths

Aside from the negative perceptions of scientific careers, another barrier is the lack of understanding of ways into science-based careers.

> "*It's a bit extreme for me…I don't know what degree…training I'd have to do.*"
> Boy A-level studying physics

There was a widely held assumption that careers in science are only for the very "*smart*" or "*clever*", with many of the students in the focus groups believing that they did not have these attributes.

4.5 Other ways to use the money

The young people across all the focus groups were much less willing than the adults to accept that the proposed investment was worthwhile.

> "*The money could probably save a lot of lives in the third world.*"
> Girl KS4

> "*I know it's cool, right, but is it relevant?*"
> Girl KS4

> "*Not really worth it, most people don't want to find out…it's not important to them.*"
> Boy KS4

> "*It's a lot of money to be spent on finding out that the Big Bang did happen.*"
> Girl A-level

> "*It should be spent on better things.*" [Examples included] "*curing cancer*"
> Girl A-level

> "*saving lives*"
> Girl A-level

> "*making sure that there are jobs*"
> Girl A-level

> "*It's not so much fundamental to the country as other things are…this could happen, but the NHS needs to happen.*"
> Boy A-level

> "*It does have a lot of practical benefits but they're not…a necessity to people… right now.*"
> Boy A-level

4.6 "Hooks" to interest students

As part of the Einstein Year evaluation (Malek & Stylianidou 2006), young people were asked to indicate their level of interest in a range of topics. Three of these related, at least to some degree, to particle physics; two of these statements elicited more than average interest:

- How a nuclear plant functions (less than average interest).
- How x-rays, ultrasound etc are used in medicine (slightly more than average interest).
- The origin of stars, planets and the universe (more than average interest).

In addition, science is often seen as interesting when it stimulates a sense of awe and wonder (KCL 2000). Taken together, this previous research suggests that both the scientific output of the LHC and the likely spin-out benefits of the engineering associated with the construction of the collider and the detectors might have the capacity to interest

young people. The focus groups imply that this could be the case, but that it is most likely that students will be engaged if the LHC can play a role in augmenting their experience of science in school.

Other work has argued that as attitudes are enduring while knowledge often has a transient quality, science education should be designed to develop the curiosity of young people about the natural world around them (Association for Science Education 2006). The findings from the focus groups support the suggestion that stimulating curiosity is a possible hook.

4.6.1 Shuffle cards

We used shuffle cards to help students to rank outputs (scientific findings) and outcomes (applications arising from the engineering of the LHC) according to whether they were interesting. Largely the rankings reflected two things, utility and familiarity. So medical and engineering applications, 'the Big Bang' and 'origins of the universe' were often the first choice as topics that are interesting.

However, some of the shuffle cards had unfamiliar terms such as 'dark matter' on them and occasionally attitudes to unfamiliar topics changed after a brief explanation,

> "*...we didn't know anything and then you told us a little it intrigued us.*"
> Girl A-level

> "*This makes it more interesting, more of a mystery.*"
> Boy KS4

although this did not apply to everyone.

> "*I know enough about the planet and don't need to know more because it'll just confuse my brain.*"
> Boy KS4

4.6.2

We asked students at the end of the groups to use what they now knew about the LHC to write headlines that they thought would capture other people's imaginations. The headlines could have a positive, neutral or negative slant, but the key was that they should attract attention. Suggestions included:

- For £1 you can recreate the universe.
- Einstein's unanswered questions- answered
- How it REALLY all began
- £48 million a year – do you know, does it matter?
- Big bang returns
- Bangers and smash
- Biggest experiment ever – is it important, will you pay?
- Origins of the universe explained

These suggestions highlight the students' focus on the big questions and the cost. These twin factors suggest that some of the teachers' suggestions regarding material to support debates might well capture students' interest.

4.7 Conclusions

4.7.1 Perceptions of the LHC

The focus group discussions with young people reflected many of the findings of previous work. Science is seen as something relatively abstract that happens in school. We saw little evidence that students, save for those who are already very interested, will be engaged by the LHC outside of the school context. But, the LHC could be something that could highlight the relevance of school science with careers and life outside school.

The students were far more concerned about the LHC as a potential waste of money than the adults and this, allied to their interest in the potential to address the big questions 'the Big Bang' and 'origins of the universe', suggests that materials to support debates about the role and process of science might be well received.

4.7.2 Perceptions of physics and its teaching

Physics is seen by many students as mathematical, difficult and not especially relevant. The quality of teaching is also very important in shaping perspectives, so anything that PPARC can do to support teachers and add variety and interest to the classroom experience will have a positive effect on students' perception of the subject.

Students are quite utilitarian in their choice of subjects, generally picking subjects that will help them into careers and that they enjoy (and are good at it). Careers in the physical sciences are not seen as attractive options. The potential role of physics as a utilitarian option post 16 is not widely recognised. However, there is some realisation that career judgements are being made on limited information.

5 Conclusions and Recommendations

Our findings illustrate that the overarching topics of interest to members of the public who are interested in science are the Big Bang and the origins of the universe. All types of media were mentioned as channels of communication that could be used to promote the LHC project, but there was a particular emphasis on the power of television.

With regard to teachers and students, particle physics is largely an A-level subject. Therefore, curriculum support would be best targeted at this level. There are a number of key factors that will get teaching materials noticed and used, these are:

- peer recommendation;
- trusted supplier;
- fitness for purpose/relevance;
- ease of use;
- access;
- format; and
- cost.

In the wider school context there is potential for the LHC to support teaching on 'how science works' and to inspire a wider age range of students as part of their school learning experience. Discussions with the students emphasised that the LHC is likely to be most effective if used to engage with students within the context of school.

On the basis of these conclusions we make the following recommendations:

5.1 Teachers

5.1.1 PPARC should not pursue the Attoworld proposal

Although some teachers were enthusiastic about the prospect of a show, many were sceptical. Regardless of positive or negative attitudes to the idea of a show, there was essentially unanimity that any such show needed to be of extremely high quality. The budget suggested to us does not seem appropriate to achieve the quality of product expected.

5.1.2 PPARC should consider the development of a demonstration lecture

For many teachers a demonstration lecture was a better option than a show. One of the great strengths that teachers saw in a demonstration lecture was having working scientists in contact with students. This would enable the students to ask wider questions about science, its study and career options of people who had a wider real-life perspective.

PPARC could support the development of a core lecture and train a small cadre of particle physicists to deliver it. The development of this lecture should be informed by ongoing consultation with both researchers and teachers. This will help to ensure confident and properly supported scientists delivering material that adds value to the work done by teachers.

5.1.3 PPARC should use the LHC as a means of providing students with access to 'real scientists'.

For many teachers this was a fundamental additional resource that PPARC could provide that would augment what they could offer students. However, the Royal Society survey of factors affecting science communication by research scientists and engineers (Royal Society 2006) highlights that many researchers do not feel equipped to talk to non-specialist audiences. Encouraging particle physicists to join the Researchers in Residence scheme and to sign up as Science and Engineering Ambassadors is one action that can build on PPARC and other public sector investments.

Additionally, PPARC should consider developing a kit or pack, possibly based on the demonstration lecture, which can be used by particle physicists to assist them in presentations/demonstrations at schools. The development of both the content and nature of this kit/pack should be informed by ongoing consultation with both researchers and teachers. This will help to ensure confident and properly supported scientists delivering material that adds value to the work done by teachers.

5.1.4 PPARC should develop/sponsor teaching materials

Despite the plethora of existing teaching materials there is an ongoing demand for good materials, especially those that help with more difficult topics. In particular PPARC should consider interactive multimedia resources and revision aids such as quizzes.

Detailed research, with both examination boards and teachers, should be used to ensure that the proposed content and nature of any materials is appropriate.

For A-level it is important to ensure that the material meets the many curriculum requirements. Below A-level, materials could be used to inspire students by way of extra curricular activities and for explaining 'how science works' and setting out the process of science. Debate materials could be developed that cover a number of issues. One might be the relative merits of investing public money in different ways. Another might be the difference between a scientific perspective based on evidence and other world views based on belief.

5.2 General public

5.2.1 PPARC should focus its public communication work

The primary hooks are the Big Bang and the origins of the universe as identified by people who were recruited to be interested in science. These should underpin all communication activity for the general public in relation to the LHC project.

These hooks should be supported by reference to the benefits (potential or otherwise) that the research and the associated engineering will yield. For general communications, medical applications are likely to be especially powerful. Other applications can be highlighted in communications to different audiences, for example communications highlighting IT applications could be sent to the IT press.

Communication material should include material that addresses concerns related to the safety and ethics of the LHC project. It is also important to provide information that puts

the research costs into context. However, both of these issues are more "notes for editors" than headline material.

5.2.2 PPARC should explore televisual opportunities

In addition to standard press work, PPARC should invest time in trying to stimulate the production of television documentaries. It is unlikely that PPARC would be able to fund this work, but could facilitate access to facilities and people that might provide documentary makers with material that would enthuse them and commissioning editors. For "docu-drama" PPARC could build on its existing links with PAWS to promote the stories behind the LHC.