Q&A following the event.

#	Question	Answer
1	At an appropriate stage will you be talking about axions and the recent experimental evidence in support?	We did talk about axions which were introduced in the mid-1970s to explain the nature of symmetry violation by the strong force. They are currently the subjects of considerable experimental search but with no definite evidence so far. They could be components of the missing mass - dark matter - of the universe.
2	Will it be possible to share your PowerPoint afterwards	Yes, I think will be posted on the alumni section of the Physics Department site.
3	Surely, it's the case that Rutherford wasn't surprised, he was testing his theory	As I said in answer he is supposed to have been as surprised as if a 15-inch shell fired at a piece of tissue paper had bounced back and hit him. Thomson’s plum pudding model of the atom suggest electrons embedded in an amorphous body - as opposed to the nuclear model discovered by Rutherford and explained by Bohr.
4	Where could we see Einstein’s 1916 manuscript?	In the Albert Einstein Archive in the Hebrew University in Jerusalem. (I think also online)
5	Hi, I cannot read well, is this manuscript of Einstein in German or English?	In German
6	Where does the Higgs fit in this system of classification?	It couples to all of the weak, electromagnetic and strongly interacting particles, so would be in the third column - but way off the top of the scale at c. 125,000 MeV!
7	Are we any closer to understanding why the electron (which is a lepton) has exactly the same magnitude of electrical charge as the proton (which consists of 3 quarks)?	I’d have to take more expert advice - but I think it may be a consequence of the so-called Grand Unified Theories which propose united multiplets of the quarks and the leptons.
8	Why do physicists sometimes state that the strong force is mediated by pions, and sometimes by gluons?	The former, pion exchange between baryons (e.g. protons), was Yukawa’s first model for the strong force. The latter is the picture of the more fundamental Quantum Chromodynamics which describes gluon exchange between quarks. As the proton consists of three quarks - and the pion, a quark -antiquark pair, Yukawa’s picture can be described in terms of QCD.

9	Do we know why there are 3 generations of quarks for the Standard model to work?	No definite answer as yet - but a recent talk I heard by John March-Russell seemed to suggest that modern string theory implies just the three families we observe.
10	What are particles such as electrons and quarks etc made of?	In traditional quantum field theories, they are simple point-like particles - so strictly speaking have no substance. In string theory, they are vibrating strings - but that rather begs the question of what the strings are made of. My own personal visualisation is of energetic points or filigrees of space-time?
11	If the story of physics at the start of the 20th century was one of unification and simplification, how should we seek to understand the proliferation of diversity and complexity? Is this a period of transition to a more fundamental picture?	At the start of the 20th century, physics had discovered the four forces of nature - and c 100 different types of atoms. Modern physics has achieved a reduction of this complexity to the components of the standard model… plus gravity!
12	Point-like nature of quarks? What is the current view of particle-wave duality for all particles?	A particle can be described by its wave function. In interaction this is localised as a particle. Without interaction the wave function is extended through space (but without interaction cannot be observed).
13	Is anti particle a physical entity? if so how long do they exist in nature?	Yes, an antiparticle is a real as a real particle. A positron is as fundamental as an electron. One fundamental problem for physics is to explain why the observable universe seems to consist mainly of matter. This may be a consequence of symmetry violating effects in the first instants of the Universe.
14	I've never studied group theory. Is it possible to say why it is so powerful in fundamental physics?	Group theory provides the mathematical description of symmetry which is one of the most fundamental approaches in physics. Dynamical symmetries lead to the famous conservation laws of momentum, energy etc. Internal symmetries. Describe the patterns formed by the quantum numbers of the particles such as electrical charge, strangeness, charm etc
15	Anonymous	
16	Could you go into more detail regarding the effects of magnetic monopoles seen in solid state physics?	I'm afraid not within the confines of this Q and A - but a simple search will throw up a variety of articles. I think a brief summary might be that the collective effects seen in solid state physics can lead to magnetic monopole effects - rather than actually finding a MM in a solid-state body.

17	What is so special about Higgs boson, which was predicted by Boes and Einstein long before its discovery, that it is called GOD PARTICLE?	In fact, the Higgs boson was predicted by Peter Higgs and co-workers. (Boson simply refers to any particle with zero or integer spin in units of Planck's constant). It was given that nickname as it is the particle which gives mass to all the others.
18	When one neutrino turns into another type do we know if it is a process of annilation of one and the creation of the other or is it some internal change within the neutrino?	It's not annihilation then creation, it's a process of oscillation between types.
19	Are Gravitons still thought to exist.	Yes. For the force to be always attractive and long range, they must be spin2 and massless. An attraction of string theory is that they emerge naturally from the maths
20	What will be the next milestone event/discovery at the LHC?	Well, the most anticipated milestone would be the detection of a supersymmetric particle like the higgsino. Intense searches are underway. Another milestone would be the identification of axions? Best of all would be something totally unexpected.
21	Was there a slight time delay in the arrival of gravitational waves at the two detectors? Can this be used to suggest a direction?	It really takes three such to triangulate and a third Vigo in Italy has done just that in locating the approximate position of subsequent events. Also look up multi-multi-messenger astronomy which looks for gamma rays and neutrons emerging along with gravitational waves in neutron stars and supernova events.
22	How could the dark matter candidate WIMP fit into (if at all) the standard model?	It would be additional to the current standard model. Rather like axions were added to cure a specific problem - if they exist !!
23	Dark Matter?	Could be a mix of black holes, axions, supersymmetric particles etc. No one candidate seems able to account for all 20% that is missing.
24	How, if at all, do gravitons fit with the Standard Model?	They do not. The search for a quantum theory of gravity compatible with the SM is the greatest challenge facing theorist - as it has been for the last 50 Years.
25	Do you think there is a 4th type of neutrino ('sterile')? Could it be a candidate for dark matter? I believe that these neutrinos do not experience the weak force, only gravity.	I think the current view is that they would not be massive enough to account for all of dark matter.

26	Thank you so much for doing this lecture. Really interesting. -	Really very welcome - I enjoyed preparing it. The book has far more explanation and diagrams / pictures of all the material covered !!
27	More on "Wider World," please, if possible/relevant? Thank you!	What a good question!! I had two thoughts in mind!! First is that physicists have been able to construct the most enormous and enormously complicated pieces of apparatus - generally on time and on budget. So, the rest of the world should be able to learn from this. Secondly the physics itself shows us what a tiny part of the Universe we are - even if bright and promising - but also only recent - hopefully not temporary! Appreciation of this might persuade humans to moderate previous destructive behaviour.
28	In your opinion, why is string theory still so attractive to theoreticians?	It seems to be a very appealing mathematics. Jo Conlon of Oxford has called it Physical mathematics
29	Anonymous	
30	How does entanglement fit into this picture?	Currently, it doesn't - being one of the great unexplained puzzles (paradoxes) of quantum theory. Progress on this topic will be a historic step forward. Very much work in progress.
31	If neutrinos now have mass, however small, can you stop them moving? And what would they look like!	I think not. As they experience only the weak nuclear force - then it will be next to impossible to isolate them - as we can with an atom.
32	Any views on the existence, or not, of gravitons, and hence, at some point, a Grand Unified Theory?	
33	We talked about invariance in the 70s is the term symmetry a renaming?	Basically yes. For example, variance under mirror reflection / charge conjugation / time reversal leads to the PCT symmetry which is one of the most fundamental of physics principles.
34	You have said there are 3 families of particles; would the postulated particles of gravitons (from quantum gravity theory) and inflations (from the theory of inflation) fit into one of these families?	
35	Would you care to bet which of your prospective milestones might start to address the problem of 'dark matter'?	I think it's likely to be a mixture of several candidates as per answer to Q 23

36	You mentioned some candidates for dark matter. Is there any way that dark energy might be explained by the models?	Dark energy is the mysterious cosmological constant proposed by Einstein to explain the expanding universe. Recent controversy over whether the Universe is actually expanding may signal need for a rethink of this idea.
37	Hi, thanks for the nice talk. I would like to ask two questions. The first one is: who named it 'standard model', it seems pretty special to me, also the name of all the particles in the standard model are quite fancy, who decided on that? The second one is if there is any undergoing experiment aiming at proving the existence of gravitons.	The naming of particles and models / theories in particle physics is hilariously random. Ideas get proposed and then generally accepted over time. E.g. The bottom quark almost became the beauty quark. Pauli coined the neutrino little neutral one all by himself!). Well gravitational waves are the macroscopic evidence for mass behaviour of gravitons. Thanks
38	James is your book available only in English?	Yes, fourth edition only in English so far !!
39	Thanks.	Very welcome