AN INTRODUCTION TO ELEMENTARY PARTICLES: THE OPEN UNIVERSITY APPROACH

F. Stannard

To cite this version:


HAL Id: jpa-00215242
https://hal.archives-ouvertes.fr/jpa-00215242
Submitted on 1 Jan 1973

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
AN INTRODUCTION TO ELEMENTARY PARTICLES: THE OPEN UNIVERSITY APPROACH

F.R. STANNARD
The Open University, United Kingdom

All science students at the Open University, whether their prime interests lie in biology, physics, chemistry or the earth sciences, must begin their studies by taking the first year Foundation Course in Science. In addition, many non-science students take the course (about 30% of the enrolment). In common with the other Open University first year courses it has to be open to all potential students whether or not they have any previous qualifications: it has to be open to those with no previous scientific training as well as those who are already graduates of other universities. The course has therefore to serve a student population with a wide variety of interests and abilities.

Perhaps one of the more controversial decisions we made when designing the course was the decision to include an introduction to elementary particles. As you will readily appreciate, concern was expressed regarding both the conceptual difficulty involved and also the difficulty of making such a subject relevant to the experience of students, 80% of whom would not even regard themselves as particularly interested in physics.

In the event, I am happy to be able to report, especially to a gathering such as this, that our decision has been fully vindicated. Surveys of the 10,000 students who have so far studied the course, reveal that the introduction to elementary particles was regarded as being the most interesting and stimulating feature of their entire first year studies. It even proved to be more interesting than the biological subjects of natural selection and the role of DNA in genetics (this despite the fact that more students declare an intention to specialize in biology than any other science discipline) and it also out-ranked the popular Earth Sciences subjects of plate tectonics and sea-floor spreading.

Although students need know very little science in order to embark on the course, I certainly would not wish to give the impression that our introduction to elementary particles would be suitable in its present form for presentation to the general public. The subject is dealt with towards the end of the course and only after the students have had a chance to come to grips with some of the ideas of special relativity and quantum theory. Nevertheless I think anyone interested in popularizing the subject for the general public might find it advantageous to study certain aspects of our approach - in particular the general philosophy we adopted.

Before describing this, however, I ought briefly to describe the Open University in general for the benefit of those who are unfamiliar with our teaching methods.

Students of the Open University study part-time in their homes. Most are mature students over the age of 21 years and in full-time employment. The main form of teaching is through correspondence, the students receiving books through the post written by central academic staff, like myself.

Integrated with the written material are television and radio programmes broadcast by the BBC over the national networks, many programmes being transmitted at prime viewing and listening times in the evening and at weekends. Students are supplied with kits of equipment for performing experiments in their homes. The first year science kit includes, for example, a microscope, a photoelectric colourimeter, 60 test-tubes, chemicals, a stop-watch etc. At second level the kits become more sophisticated - for instance, all 1500 students of a second level electronics course receive on loan their own oscilloscope, oscillator, stabilized power supply and multi-range meter. Students are assigned to local study centres where they receive face-to-face tuition. Three hundred of these centres have been established throughout the country and about half...
are equipped with computer terminals to allow students to learn and practice computer programming. All science students attend summer schools for intensive periods of laboratory work. These are held on the premises of conventional universities during their long vacations. Assessment of the students' work is carried out continuously over the year and at end-of-year examinations.

Having described our general teaching methods, let me now tell you how we have employed them across an introduction to elementary particles.

The main core of the teaching is carried by the written text. Here we begin by explaining that in order to study elementary particles they have first to be created. Through Einstein's equation \( E = mc^2 \), it becomes clear that we need a source of high energy particles. The simplest procedure for accelerating particles is to use a high voltage drop but this brings us up against the problem of insulation breakdown. The use of cavities in a linear accelerator gets round that problem but brings us up against a financial problem - how many miles of accelerator can you buy? This problem is countered in its turn by the synchrotron principle whereby the same cavities are used many times. But eventually the financial problem hits us a second time in terms of the maximum diameter of the synchrotron ring we can afford. How much money is it reasonable to spend on an accelerator? The students are taxpayers, so this is no academic question - it is a question we return to later.

The newly created particles are separated by electric and magnetic fields. The problem now is how to detect them. We concentrate on a description of the bubble chamber. We cannot, of course, send our students a bubble chamber in their home kit but we can at least get them to study bubble formation. First they heat test-tubes and note that the bubbles start growing from certain preferred points on the side of the tube - the bubbles need a centre upon which to grow. We then have them heat water in a tube and subsequently seal the mouth of the tube with a rubber bung. On placing the tube under a cold water tap, the air in the tube cools, so lowering the pressure and the hot water starts to boil. This illustrates the idea that a reduction of pressure leads to superheating (it is also rather fascinating in its own right to see cold water being used to boil hot water!)

The explanations of particle acceleration, beam design, and particle detection given in the text are kept as clear and simple as possible. This we think is important. However, it would be misleading to allow the students to form the notion that the technology involved in high energy physics is trivial! The text is therefore complemented in this respect by the television programme. In this programme, Professor M.J. Pentz and myself take a tour around the accelerator complex and the 2 metre hydrogen bubble chamber at CERN. Starting from the proton source in the linac we trace the steps involved in the acceleration, production and separation of the particles. The design of the accelerator and bubble chamber are further explained by the use of models. Hopefully the students gain from the programme a proper respect for the technology involved, without being overwhelmed by its complexity.

Having learnt how particles are produced and detected, we are then able to tell the students something of their behaviour and properties. This is done in a rather novel way. Each student is supplied with a stereoviewer and a reel of three-dimensional bubble chamber photographs. A large part of the written text is then in the form of a commentary on what students see in the viewer as they work their way through the photographs.

The first picture is of a spiralling electron. This serves to introduce the idea of magnetic curvature and ionization loss. Subsequent pictures are progressively more complicated and the series culminates with examples of the associated production and interaction of strange particles. The idea of strangeness is introduced in order to explain the non-existence of certain reactions. The students are presented with lists of reactions, some involving particles new to them. From what they have already learnt from the photographs, they have to go on and make baryon number and strangeness assignments for these new particles and make predictions concerning their interactions. Through these simple exercises, the students learn that strangeness is no more mysterious than the more familiar electric charge - while it is true that in a sense we do not 'understand' either, both may be used as tools for ordering our observations.

The main home experiment for the week consists of
a measurement of the mass of the muon. The students receive bubble chamber prints of $\pi \rightarrow \mu \rightarrow$ electron decays at rest and a set of curvature templates. They measure the average projected momentum of the decay electron and through a geometrical correction, the average momentum in space. It is a good enough approximation to assume that the electrons on average receive a third of the energy associated with the rest-mass of the muon. In this way the students arrive at a value for the muon mass. This straightforward experiment was remarkably popular with the students. They liked the idea of actually measuring the mass of one of these tiny particles for themselves - and by such simple means.

The work on elementary particles ends with a broad introduction to the idea of the SU3 classification scheme. Presented with the general layout of an SU3 decuplet, the students are given the properties of 9 particles and are told to predict the properties of the tenth - the $\Omega^-$. The radio programme is devoted to the discovery of this particle. It is here that I can point to one of the fruitful outcomes of the close collaboration that exists between the Open University and the BBC. We were able to delve into the BBC archives and construct a programme that captures the atmosphere of that historic discovery. Gell-Mann and Ne'eman discuss how they came to propose the SU3 scheme. Samios describes the excitement he and his colleagues experienced when the first $\Omega^-$ was discovered. Finally, Feynman gives one of his inimitable inspirational pieces on how great it is to be a physicist at times such as these!

The comparison is drawn between the SU3 classification scheme and Mendeleef's Periodic Table. The latter pointed the way to the quantum theory of atomic structure: where will SU3 lead - to quarks? Having got the student under the skin of the high energy physicist, and having got him interested in knowing what the structure of the proton might be, we now return to the earlier problem - finance.

What is it worth to know the answers to questions such as these? How can one possibly decide whether or not one should build a 300 GeV accelerator? In the week following their study of elementary particles, the students have to weigh up the pros and cons of a decision to build an accelerator. For this purpose they are supplied with a 'decision-making kit'. This consists of recommendations from scientific advisory committees, a minority dissentient report, conflicting letters to Nature, extracts from governmental statements in Parliament, etc. The students are not asked to decide whether the governmental decision was the right one - what we ask is that they show that they can appreciate the various factors that must be taken into account in making such a decision.

As I said at the beginning, I do not wish to give the impression that this introduction to elementary particles can be used as it stands for direct communication to the general public. It cannot without sections being substantially re-written to introduce, for example, the notions of special relativity and quantum theory. Nevertheless, those who attempt to popularize high energy physics could perhaps learn from our experience and from our general philosophy.

What is that philosophy? Quite simply this - to take the 'mystique' out of the high energy physicist. Too often he is portrayed as some remote scientist thinking abstract thoughts, talking a language of his own, demanding vast sums of money for reasons that are too difficult to explain. By helping the students to learn through their own experience, and through making their own deductions, we hope to have gone some way towards breaking down the psychological barrier between them and the professional high energy physicist. Like the physicist, they too have been able to measure the mass of a particle, to make strangeness assignments, to make predictions. They too have come to realize that there simply is no easy formula for deciding at what level to support big science. This philosophy of getting the students to identify with the high energy physicist and his problems is one ingredient for success. The other is the general attractive appearance of Open University teaching materials - the text printed in two colours and written in a friendly informal style, the beautiful three-dimensional bubble chamber photographs, the impressive views of CERN in the TV programme, and the sheer enthusiasm of the high energy physicist manifest in the radio programme. High energy physics can be a very visual and evocative subject. It can and should be made accessible to a wider public.

All materials produced by the Open University are available for purchase. They can be bought as complete
courses or as separate items. Free catalogues and brochures describing the materials available and listing their prices may be obtained from:

The Marketing Director, Open University, Walton Hall, Milton Keynes, Bucks., England.

When writing, please specify the types of material of interest, for example, books, films of television programmes, tapes of radio programmes, and home experiment kits.